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AMSAT

RADIO AMATEUR SATELLITE CORPORATION

PROCEEDINGS OF THE

AMSAT-NA

SIXTH SPACE SYMPOSIUM AND ANNUAL MEETING

NOVEMBER 11-13

1988

Proceedings of

AMSAT-NA Sixth Space Symposium and Annual Meeting

November 11-13, 1988
Atlanta, Georgia

Published by the
American Radio Relay League
225 Main Street
Newington, CT 06111

Papers courtesy
AMSAT
PO Box 27
Washington, DC 20044

Printed in USA

$12.00 in USA

ISBN: 0-87259-218-9

First Edition

AMSAT-NA Sixth Space Symposium

Held in conjuction with the 1988 Annual Meeting in Atlanta, Georgia
November 11-13, 1988

Co-sponored by the Atlanta Radio Club, Al Smarr, W4BTZ, President

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Sandy Donahue, WA4ABY
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Ken Wilhoit, W4OCW
Al Zoller, K6OTE

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Polar Bridge Skitrek Wrapup

Three months across the ice with Amateur Radio — a success!

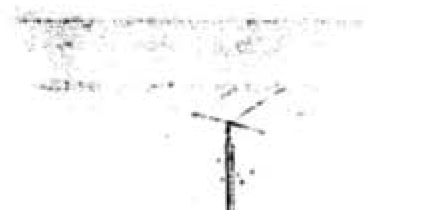
By David Adams, VE3HBF
R. R. 1
Sutton West, ON L0E 1R0

This year, thirteen skiers made polar history by skiing without motorized transport, dogs or sleds from the Soviet Union to Canada by way of the North Pole, a distance of some 1750 km. The four Canadian and nine Soviet skiers reached Ward Hunt Island at 1035 on the morning of June 1, ninety days after setting out from Cape Arktichesky in the Severnaya Zemla Archipelago on March 3. They stepped ashore in line abreast so that no one could claim to be first, symbolizing the teamwork and cooperation that made this unique event successful.

This splendid feat, the Polar Bridge Skitrek Expedition, was supported by an Amateur Radio communications network that also made history. Never before had this kind of international expedition relied solely on Amateur Radio for all its communications needs.

Coordinators of the Amateur Radio effort were Tom Atkins, VE3CDM, President of the Canadian Radio Relay League, and Leonid Labutin, UA3CR, a veteran of several previous Soviet polar expeditions. Leonid approached Tom in March 1987, asking for the support of Canadian amateurs. The basis for cooperation would be a unique reciprocal operating and third-party traffic agreement between the two countries, the first such agreement ever for the USSR, allowing Soviet and Canadian amateurs to operate from each other's countries, and to handle messages between them, without restrictions, through base stations in the Arctic.

Chief Operator Barry Garratt, VE3CDX, recruited the team of Canadian operators that would man the Canadian base station at Resolute Bay, CI8C. Both Tom, VE3CDM, and Barry went to Moscow to make final arrangements with Leonid and the Soviet amateurs. While visiting UK3KP, the club station of *Komsomolskaya Pravda* (a Soviet youth newspaper), Tom and Barry became the first Canadians amateurs to operate from the USSR under the newly signed reciprocal agreement. Soon after, Rick Burke, VO1SA joined Leonid at EX0CR, the main Soviet base station at Sredniy Island, some 200 km south of Cape Artichesky, the point from which the skiers started their trek. Rick's own call, VO1SA/UA0, was often heard S9 by scores of Canadians and others monitoring further to the south, as he passed traffic to Resolute Bay, Toronto and Ottawa.



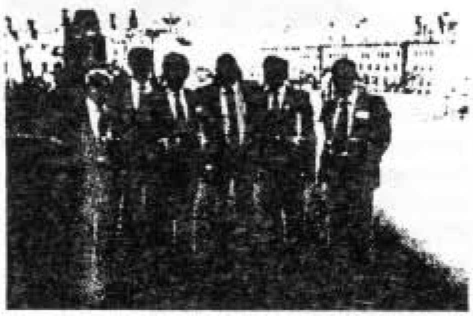
Top right: Leonid Labutin, UA3CR, Soviet coordinator for Skitrek communications, meets a real Canadian on the steps of the Parliament Buildings, Ottawa. Above: C18C at Resolute Bay, NT. Yes, it's a tiny building. Those squares painted on the side measure only 4' by 4'. *(VE3CDM photos)*

In Ottawa, Ron Bellville, VE3AUM, was the expedition's tireless anchorman, passing messages to and from Expedition Manager Peter Baird and between the skiers and their families, and dealing with the government and the media. In Toronto, it was Tom, VE3CDM, who was besieged with phone calls and visits from the media as he effectively dealt with problems of logistics, movement of equipment and operators, and a score of other matters as new situations arose.

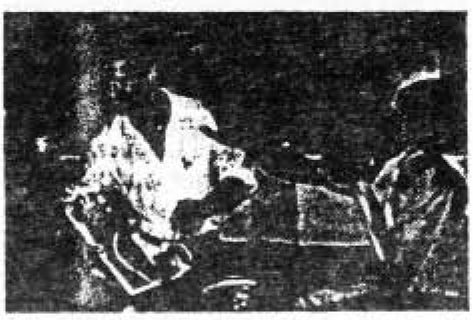
ICOM supplied a full range equipment: HF and VHF transceivers and amplifiers for the base stations, 2-metre FM handheld transceivers and a VHF-AM transceiver that would permit communication with the aircraft bringing supplies for the skiers. The base station equipment, in the hands of Barry, VE3CDX, and his team of experienced operators, provided contacts between the skiers (known as the "moving group"), and their families, their support groups and suppliers, and the worldwide Amateur Radio community. Never before did an expedition like this have communications that functioned so smoothly around the clock, or did more to keep up the morale of its participants through every kind of hardship. Much credit must go to the Soviet operators, most of whom had worked together for many years in the remote and harsh climate of the polar regions, and to the Canadians whose experience and teamwork resulted in plaudits from radio amateurs around the world.

Besides the ICOM equipment, the moving group carried a Soviet-designed miniature transceiver operating on crystal-controlled frequencies in the 20, 40 and 80-metre bands, and a dipole antenna that could be raised on a mast made of 3-4 ski poles connected end to end. All of this was developed over years of Arctic travel and experimentation.

Garth Hamilton, VE3HO, who operated CI8C during the critical first two weeks of the expedition, later became the principal backup for Tom, VE3CDM. Garth maintained a constant watch on expedition frequencies and forwarded messages and technical advice. Olle Ekblom, SM0KV, and his Swedish collegues also maintained a daily watch throughout the Skitrek, recorded daily satellite position reports, checked in daily with CI8C, and kept an eye on Soviet radio and television reports. Active support also came from AMSAT, through President Vern Riportella, WA2LQQ, Richard Ensign, N8IWJ,



Some of the Skitrek communications group on their visit to Ottawa: (l-r) David Adams, VE3HBF, Stan White, VE3FFD, Tom Atkins, VE3CDM, Ron Belleville, VE3AUM, Leonid Labutin, UA3CR, and Tony Fegan, VE3QF. *(VE3CDM photo)*



Skiers Dr Max Buxton (left) and Dr Dmitri Shparo, UA3AJH, demonstrate the Soviet-built 10-watt transceiver used by the "moving party" during the Polar Bridge Skitrek expedition. *(VE3AND photo)*

QSL cards for CI8C were provided courtesy of Fred Hammond, VE3HC, and the Hammond Manufacturing Co of Gulelph, Ontario. QSL Manager David Adams, VE3HBF, has sent many thousands of these cards to amateurs all over the world, to confirm contact with Skitrek's Canadian base station at Resolute Bay.

and AMSAT Director John Henry, VE2VQ.

Once the skiers approached the North Pole, "mission control" shifted from Sredniy Island to the base station at Soviet Ice Island NP28, then located only 20-30 km from the pole. Here, Barry, VE3CDX, joined Piotr, operator of 4K0DC, and used his personal Soviet call sign, 4K0DX, for a month of intensive traffic handling.

On April 26, when the skiers arrived at the North Pole, they were greeted by a gathering of almost 200 Soviet and Canadian officials and media people. Barry was up to his ears in official and unofficial duties and was delighted when Mike, G0/PA0BHF, the UoSAT technician from the University of Surrey, UK, offered to assist by operating CI8UA and giving scores of amateurs their first ever QSO with the North Pole. Mike had been flown in with the Soviet group, in recognition of his key role in operating the UoSAT OSCAR 11 digitalker that gave the skiers their daily position reports.

Now, CI8C at Resolute Bay became the communications hub. Just before Barry, VE3CDX, left for Resolute, he had a chance to experience a danger that the Soviet team on NP28 faced daily. The ice island split apart, breaking the runway for supply aircraft in two and sending Barry's camera, some supplies and some valuable ICOM equipment to the bottom of the Arctic Ocean.

Canadian Participants in the USSR- Canada Polar Bridge Skitrek Expedition:

Expedition Manager: Peter Baird
The Skiers: Dr Max Buxton, 32, Calabogie, ON; Rev Laurie Dexter, 43, Fort Smith, NT; Chris Holloway, 31, Old Chelsea, PQ; and Richard Weber, 29, Kingsmere, PQ
Canadian Communications Coordinator: Tom Atkins, VE3CDM/VE8UA
Chief Operator: Barry Garratt, VE3CDX/VE8CDX/4K0DX
Ottawa Communications: Ron Bellville, VE3AUM
The Operating Team: Joe Adams, VE3CPU; Rick Burke, VO1SA; Garth Hamilton, VE3HO; Garry Hammond, VE3XN; Bill Hardie, VE3EFX; Larry Horlick, VE8HL; John Hutchinson, VE3CKF; Terry Keim, VE8TF; Dennis Laliberty, VE3MFP; Garry Letford, VE3COP; Andy McLellan, VE1ASJ; Wally Mansz, VE7HQ; Dale Sackfie, VE3LVW; Staley White, VE3FKD; Don Whitty, VO1QF; Glen Wyant, VE3ICR; and Rolf Ziemann, VE8RZ
Publicity and Information: Al d'Eon, VE3AND
AMSAT Liaison: John Henry, VE2VQ
Packet Radio: Tony Fegan, VE3QF
CI8C QSL Manager: David Adams, VE3HBF
Canadian Base Station CI8C: Resolute Bay, NT, courtesy Transport Canada and VE8MB (Ron Lupack, VE8AZ, operator)

Media coverage of the Skitrek expedition was considerable. The job of keeping everyone informed was handled by Al d"Eon, VE3AND. Al issued regular news releases and made direct contact with key media people. Interviews with an Amateur Radio flavour appeared on *The Journal*, *Midday* and other television programs across the country. Newspapers carried feature articles and radio stations carried frequent reports. Amateur Radio publications around the world, including *QST*, gave prominent coverage to what was clearly recognized as a major milestone in Amateur Radio communications.

Throughout Skitrek, Tony Fegan, VE3QF, provided the Amateur Radio community with OSCAR 11 orbital data and advice for would-be monitors. Any radio amateur with a 2-metre handheld could hear the digitalker on board OSCAR 11 by listening at appropriate times on 145.825 MHz. Many amateurs who were teachers made a strong effort to involve their students in monitoring and charting the progress of the skiers across the Arctic. The Ontario Science Centre in Toronto (an educational facility where, for students of any age, science becomes fun) mounted a display that included a large map, recordings of the digitalker and a special on-the-air message from CI8C.

Following the completion of expedition, both the Government of Canada and the Soviet ambassador in Ottawa gave official receptions. Energy Minister Marcel Masse presented the Skitrek team to the House of Commons in session. All the Soviet radio amateurs who had provided communications for Skitrek were flown to Canada courtesy of Macdonalds Restaurants, a major sponsor of the expedition. During a four-day stay in Toronto, the entire Soviet team, with Dr Max Buxton representing the four Canadian skiers, took part in a program at the Ontario Science Centre, demonstrating equipment used during Skitrek: skis mounted in a circle like a "rib cage" over which the tent was slipped, and ski poles that could be joined to serve as a support for a dipole antenna.

Questioned in Ottawa about "What next?", the expedition's leader Dmitri Shparo, UA3AJH, hinted at the possibility of an Antarctic expedition. Now that the USSR-Canada Skitrek had laid the foundation for closer cooperation between these two countries, it might be possible for the USSR to achieve something similar with the United States. Hopes were also expressed that members of the Canadian communications team might visit Moscow in the near future.

The Vancouver Sun, Monday, April 4, 1988 ★★★

Radio provides lifeline for polar expedition

By LARRY EMRICK

Tom Atkins of Toronto is one of a small army of volunteers channelling professional expertise and enthusiasm into the support role that keeps the joint Canadian and Soviet Polar Bridge Expedition safe, supplied, and on route.

Atkins, 62, is an amateur radio enthusiast who is the expedition's Canadian communications coordinator. It was Atkins, as president of the Canadian Radio Relay League, who received the request from the U.S.S.R. to provide the Canadian communications network for the expedition.

"It's almost turned into a full-time iob for me," the semi-retired business consultant said in an interview rom Toronto.

"The thing that is exciting is that his is a Canadian project. We're up o our armpits in it and it makes you eel great to be a part of it. This is ne of the last great physical chalenges to man. It is a very difficult nd dangerous mission."

The role of Atkins and his 40 amaeur radio volunteers has been more han merely setting up and mainaining the radio links.

While the skiers push back the rontier of Canadian-Soviet cooperation on the ice, Atkins and his radio als have helped blaze a new trail in nternational communications liplomacy.

"In order for my people to operate n the Soviet Union and vice-versa, e signed a reciprocal agreement. 'he Soviets have never involved hemselves with this kind of thing. t's the first time that anyone in the Vest has been able to finalize this ind of agreement."

Communication is accomplished vith the help of SARSAT/COSPAS, Canadian-Soviet search and escue satellite that can locate a plane down in northern B.C. or Ontario as easily as it can find the trekkers on the Arctic Ocean.

> **"The thing that is exciting is that this is a Canadian project. We're up to our armpits in it and it makes you feel great to be a part of it."**
>
> **— Tom Atkins**

The expedition carries three radio transmitters that send a signal to the SARSAT satellite. SARSAT passes the signal to ground stations at Trenton, Ont., an air base in the U.S., and one in the Soviet Union. Then it is sent by radio teletype to an amateur satellite control station at the University of Surrey at Guildford, England.

The university station's satellite, called OSCAR 11, was funded by amateur radio operators around the world to carry their signals. One of OSCAR's daily jobs is to turn the data from the expedition's SARSAT beacon into a digitized computer "voice" and beam the voice back to earth where it is picked up on pocket-sized receivers carried by the skiers.

The time of the transmission varies but for radio fans with the time to listen — or the luck to find it — Atkins said it is broadcast on 148.825 megahertz FM.

For regular communications the expedition uses a custom-built, Soviet-made 10-watt, sideband transceiver transmitting on 80, 40 and 20-metre amateur bands, Atkins said.

Sophisticated though it is, its operation remains simple.

When they stop for the night the wire aerial is strung from the skiers' interconnected ski poles.

In an emergency it could save a life but it's also the means by which the expedition sends its shopping list for supply drops of food and equipment.

It also is possible to patch a call through regular phone lines to enable the trekkers to call home.

"It's a great morale thing," said Atkins. "It's possible for one of the Canadians to come on the phone and talk to his wife in Ottawa."

Not all of the messages have been of such a happy nature. After the expedition set out Laurie Dexter's father died and the message had to be relayed to him.

There are three main control bases for the expedition — on Sridny Island on the northern tip of the Severnayay Zemlya Archipelago in the northern U.S.S.R; at North Pole 28, a permanent Soviet base on the Arctic ice about 110 kilometres from the pole; and at Resolute on Cornwallis Island in the Northwest Territories. There also are control stations in Ottawa and Moscow.

Rick Burke, chief air traffic controller at St. John's, Nfld., and one of Atkins' band of volunteers has an unprecedented role in the communications setup.

He has been at the Sridny Island station, on a Soviet air base, for a month.

"The presence of a Canadian there is unprecedented because to my knowledge no one from the West has ever been there," Atkins said.

When the expedition nears the North Pole, control will pass to North Pole 28, where Barry Garratt, chief engineer at Hamilton's Channel 11 television station will handle communications with his Soviet counterpart.

Garratt, 42, was due to leave home today and be on the ice station in about two weeks.

AMSAT's MICROSAT/PACSAT PROGRAM

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ABSTRACT

In 1989 AMSAT-NA plans to launch the first of a series of low-earth orbit (LEO) satellites dedicated to serving digital store-and-forward message handling. These satellites are quite small cubes, approximately 230 cm (9 inches) on a side weighing less than 10 kg; this small size has led to our calling the project MICROSAT. Despite the small size, the satellites are crammed with state-of-the-art electronics. This paper will review the development program leading to this design and some of the technical details as well as describing how the terrestrial user will make use of the resource. We are planning on the launch of 4 satellites using MICROSAT technology into LEO in early 1989, and several more launches over the next 2 years.

A BIT OF HISTORY

In October 1981, the ARRL, AMRAD and AMSAT jointly hosted the first Networking Conference when packet radio was in its earliest period of development. Doug Lockhart (VE7APU) and the VADCG group had put the first TNCs into our hands. Hank Magnuski (KA6M) and the PPRS had the first digipeater on the air. In the D.C. area a few of us (W4MIB, WB4JFI, K8MMO, W3IWI, KE3Z) were on the air making funny sounds. The seed was planted!

On a warm sunny afternoon the following spring, at the AMSAT lab at NASA Goddard, I took Jan King (W3GEY) aside and told him of an idea I had. At the time we were building the AO-1Ø satellite which was to provide global scale communications from its vantage point in high earth orbit (HEO). My idea was to provide similar communications coverage from LEO using digital store-and-forward techniques, albeit not in real time. The basic idea was for the sender to uplink a message to the LEO satellite; then at a later time when it was in view of the recipient, it would be forwarded to him automatically.

After some more design work, I enlisted the aid of Den Connors (KD2S) who was then spearheading the effort in Tucson which became known as TAPR. Den and I started beating the bushes for support for the program. When the ideas became known to AMSAT, some of the old timers accused us of having lost our minds with statements like "There aren't more than a couple of hundred people on packet. Packet radio will never amount to anything. etcetera etcetera". By the fall of 1982 we were starting to see some ground-swell of support, so Den and I scheduled a special meeting (to be held in conjunction with AMSAT's annual meeting) which was to get inputs from packeteers in several groups on the PACSAT concept. The second purpose was to try to see if we couldn't come up with a national protocol standard; the result was the adoption of AX.25 (for which some people STILL blame me!).

Soon thereafter we found a potential sponsor who needed PACSAT support to aid in disseminating information on technologies appropriate to developing countries and thus was formed a tie between AMSAT and the Volunteers in Technical Assistance (VITA) and Gary Garriot (WA9FMQ). The VITA PACSAT project enlisted the assistance of Harold Price (NK6K), Larry Kayser (VE3QB/WA3ZIA, now VE3PAZ) and a number of others. The VITA/PACSAT team decided to test their messaging concepts on a UoSAT spacecraft resulting in UO-11's Digital Communications Experiment (DCE). The partnership between VITA and the UoSAT group has continued, and the UoSAT-D spacecraft (to be flown at the same time as our Microsats) is the culmination of that effort.

In the meantime I told the Miki Nakayama (JR1SWB) and Harry Yoneda (JA1ANG) of JAMSAT of our design concepts. The JAMSAT/JARL team were able to implement many of these ideas in the mode "JD" hardware on the Japanese JAS-1 (JO-12) satellite. They also developed state-of-the-art reproducable 1200 BPS PSK demodulator designs which have become important for future spacecraft designs. Unfortunately the negative power budget on JO-12 has limited the utility of an otherwise excellent spacecraft.

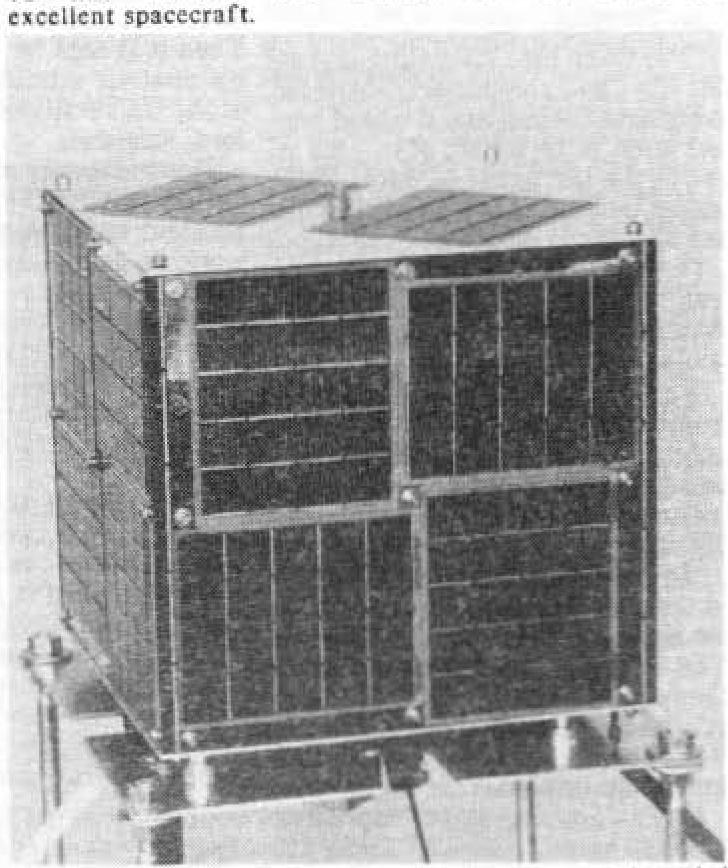

Figure 1. A photograph of the structural model of the MICROSAT satellite.

For the next couple of years any idea of our building a PACSAT in the USA languished. First we were busy building the AO-13 satellite in consort with AMSAT-DL. The American dependence on the Space Shuttle and the lack of suitable launches on which we could hitchhike made opportunities few and far between. We looked at low-thrust motors using water or Freon propellants to lift us to a suitable LEO if we used the Shuttle's GASCANs. Two groups flew small satellites ejected from GASCANs on the shuttle; one was NUSAT, built by a of students and faculty at Weber State College in Ogden, Utah. Then with the loss of the Challenger, even those hopes for our building a PACSAT were dashed.

THE BIRTH OF MICROSAT

The scene now shifts to November, 1987 in a hotel room in Detroit after the banquet at AMSAT's annual meeting. Jan King, Bob McGwier (N4HY), Phil Karn (KA9Q) and I are sitting around at 1AM. Jan starts telling us of a concept that he and Gordon Hardman (KE3D) have been thinking about. It involves a very small, simple satellite, a 9" cube. He describes how five 8" x 8" x 1.6" module "trays" would be stacked to make up the inner frame of a satellite. Then on the small 9" x 9" solar panels would make up the outside skin. He told us that he believed he had several different potential launches that could carry several of these cubes to LEO and asked us what we could do with the limited space. By 3 AM we had a conceptual design, we had done link margin calculations, we had selected a candidate CPU, and we had estimated size, weight and power requirements for each of the modules. The adrenalin flowing in our veins was at an all-time high!

By early December we had refined the basic design. Dick Jansson (WD4FAB) had done a complete mechanical design. We held a preliminary design review at the AMSAT office and decided we were GO!

While all this was going on, contacts were made with Junior DeCastro (PY2BJO) of the Brazilian BRAMSAT group, Arturo Carou (LU1AHC) of AMSAT-LU and with the NUSAT group at Weber State. Each agreed to join the team and we settled on building four satellites: The AMSAT-NA and AMSAT-LU satellites would be classical PACSATs. The Weber State satellite would be a PACSAT augmented by a TV camera which would send down pictures encoded in normal AX.25 packet frames. The Brazilian satellite would be the DOVE (Digital Orbiting Voice Experiment) which would "talk" voice bulletins which could be copied on a normal HT.

PACSAT AND ALOHA

First we need to review a little packet radio theory. Let us assume that the satellite operates with its transmitter and receiver on different bands so that the communications links are full-duplex. Let us also assume that there are many users, each with similar capabilities, who are spread out over the entire spacecraft "footprint". Let us further assume that traffic is balanced -- whatever goes up to the spacecraft equals what comes down, so the uplink and downlink channel capacity needs to be balanced.

Since the ground-based users are spread out, the cannot hear each other. Each will transmit at random in the hopes that his packets make it thru. This is the classic ALOHA network configuration with "hidden terminals". It can be shown that collisions on the uplink channel will statistically reduce the channel capacity so that only (1/2e) = 18.4% of the packets make it thru. Thus, the downlink (on which there are no collisions) can support about 5 times as much traffic as can a single, collision-limited uplink.

There are two ways out of this dilemma. First, the uplink users could use a data rate about 5 times the downlink; this approach was taken by the AMSAT-DL designers of AO-13's RUDAK experiment where a 2400 bit per second (BPS) uplink is balanced against a 400 BPS downlink.

The second approach is to have multiple, separate uplink receivers. The FO-12 satellite has four 1200 BPS uplink channels balancing one 1200 BPS downlink.

MODEMS AND RADIOS FOR PACSAT

For our PACSATs, we have allowed for both solutions to the ALOHA limit. Like FO-12, there are to be four user uplink channels; however each of which can be commanded to support 1200, 2400, 4800 and possibly 9600 BPS uplinks. The downlink transmitter will start its life at 1200 BPS, but higher rates should be possible.

Our design was heavily influenced by a decision we made early on: we would only use standards which were supported and available "off the shelf". Thus when our PACSAT comes to life, the ground user can use the identical hardware he uses for FO-12 today. The user's uplink will be at 1200 BPS, Manchester-encoded FSK and the downlink will be 1200 BPS binary PSK. These standards are supported by the TAPR and G3RUH modems, by the myriad FO-12 modems available on Akihabara in Japan, and by the DSP modems that N4HY and I have been working on.

These "mo" modulator in these modems plugs into the mike jack on a stock 2M FM radio, which we assume can be tuned in 5 kHz steps. The satellite link margins should be such that 10-25 watts into an omnidirectional antenna should be adequate (providing everyone runs similar power).

The "dem" demodulator plugs into an SSB-capable 70 cm receiver or all-mode transceiver, which needs to be tunable in 100 Hz (or preferably finer) steps. The PSK downlink should be "Q5" even with an omnidirectional antenna, providing the local noise level is low.

The spacecraft's receiver has 15 kHz wide channels, regardless of the bit rate programmed at the spacecraft. The 1200 BPS data rate combined with an FM deviation of < 3 kHz, plus doppler shift, plus 5 kHz steps on a typical FM radio just fit the 15 kHz bandwidth. At some later date we will begin enabling selected uplink receiver channels for higher data rates (like 4800 BPS), but the user will now have to pre-steer the doppler and set his frequency more accurately than 5 kHz. Also most stock FM radios will not pass the 4800 BPS data rates without significant modifications.

ONBOARD PACSAT

Let us now discuss some of the features of the satellite's architecture. The electronics is divided into modules, with the space inside each module being about 7.8" x 6.5" x 1.5". The mechanical layout has five of these modules stacked atop each other as shown in Figure 2, which we will describe from top to bottom.

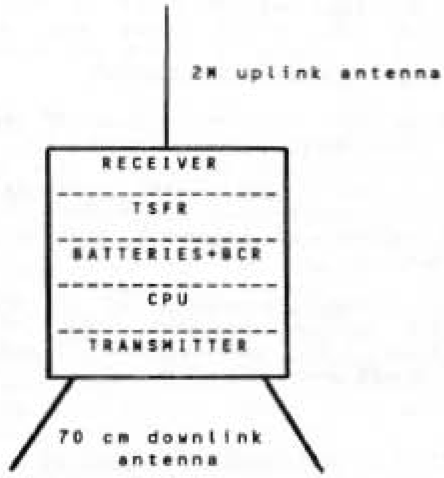

Figure 2. PACSAT LAYOUT

RECEIVER

The core of the receiver is the Motorola MC3362 single-chip FM receiver, couple with a stock NDK crystal filter with 15 kHz bandwidth centered at 10.7 MHz. The filter has very good skirts, with 80-90 dB ultimate rejection. The input to the 3362 is an IF in the 40-50 MHz range. The 1st LO in the 3362 is crystal controlled to mix to 10.7 MHz. Following the filter, the 3362's second mixer is driven from a crystal controlled 8.9 MHz 2nd LO to produce a final IF of 1.8 MHz selected for best linearity of the MC3362's FM detector (discriminator).

The MC3362's FM detector drives two matched data filters, each of which uses one section of a TLC274 CMOS op amp; the 2-pole Butterworth filters are optimized for 1200 and 4800 BPS data rates. A CD4066 analog switch selects the output of one of the two filters to drive the data clipper section of the 3362. The appropriate filter is selected by the CPU.

In addition, one section of the TLC274 produces an analog signal in the Ø-2.5v range corresponding to the user's frequency (the "disc meter") and another produces a Ø-2.5v analog signal corresponding to the user's signal strength (the "S meter").

All this circuitry takes up 1.5" x 3" on the receiver's circuit board and draws under 20 mW (< 4 ma at 5V). This circuit is replicated five times to provide the 4 user uplink channels plus a command/control channel.

The design of this portion of the receiver was done by W3IWI with invaluable inputs from Eric Gustavson (N7CL).

In front of this bank of five FM IF strips is a fairly conventional GaAsFET preamp with a noise figure < 1 dB. A narrow-band 3-stage helical filter provides selectivity between the GaAsFET preamp and a dual-gate MOSFET mixer which is driven by a crystal-controlled LO at about 100 MHz. The output of the MOSFET (at 40-50 MHz) drives five emitter followers to provide isolation between the five FM IF stages. The design of these stages was done by Jim Vogler (WA7CJO) and W3IWI.

The total power consumption for the entire receiver is about 150 mW.

[As a side note -- the receiver modules designed for PACSAT have been made easily reproducable, with very few "twiddles". All components, including the coils and helical filter are off-the-shelf items purchasable from sources like Digi-Key. It is anticipated that TAPR and/or AMSAT will make single-channel receiver kits available for use in dedicated packet link applications if there is enough interest].

TSFR

For PACSAT, this is a dummy module. TSFR means "this space for rent", and is reserved for future expansion.

POWER SYSTEM

The Battery Charge Regulator (BCR) module contains the NiCd battery pack, the charger that conditions solar panel power to charge the batteries, and the switching regulators that produce the +5 and +10 v power needed by each module. The BCR and regulator design was done by Jon Bloom (KE3Z) with help from Gordon Hardman (KE3D).

The solar panels make use of high-efficiency silicon cells with back-surface reflectors (BSR). BSR technology is new, but it allows for much higher efficiency; if a photon does not produce electricity as it passes thru the silicon on its way in, the reflector allows a second chance to "grab" it. The solar panel electrical and mechanical design was done by Jan King (W3GEY) and Dick Jansson (WD4FAB), and the solar panels are being produced under contract by Solarex.

The price of space qualified NiCd batteries has become prohibitive, so new, low cost approaches have been adopted. Larry Kayser (VE3PAZ) and his group in Ottawa proved with UO-11 that if good, commercial grade batteries were purchased, they could be flight qualified. The qualification procedure involves extensive cycling to characterize the charge-discharge curve and temperature performance, X-raying the batteries to look for internal structural flaws, then selecting only the best cells, and then finally potting the batteries.

While the solar panels produce about 14 watts, when averaged over a whole orbit (some time is spent in eclipse), and after losses in power conditioning about 7-10 watts is available.

CPU

In many ways the flight computer is the key to PACSAT. At the time we were selecting the CPU, the SANDPAC group in San Diego were finishing the first pre-production run of the new PS186 network switch. Based on their experience, we selected a similar architecture. The flight CPU is based on the NEC CMOS V-40 CPU (quite similar to an 80C188). The flight CPU includes EDAC (Error Detection and Correction) memory for storage of critical software, plus bank-switched memory for data storage (i.e. "RAM Disk"). We hope to fly upwards of 10 Mbytes on each PACSAT (limited only by available space and the price of memory chips). The CPU, when running hard draws about 2 watts of power.

A companion paper by Lyle Johnson (WA7GXD) and Chuck Green (NØADI) describes the CPU's architecture in much more detail. A paper by Bob McGwier (N4HY) and Harold Price (NK6K) describes the multi-tasking software. Jim DeArras (WA4ONG) is converting Lyle and Chuck's wire-wrapped prototype to multi-layer circuit board. The ROM-based bootloader to allow recovery from disasters has been written by Hugh Pett (VE3FLL) whose code had previously saved the day on UoSAT.

TRANSMITTER

At the time of this writing, the transmitter is still in the design phase, so some of these parameters may change. The transmitter will be BPSK modulated, and will have its power output changeable by ground command. The current plans are for two power levels, about 1.5 or 4 watts. The transmitter starts out with a crystal oscillator at 109 MHz, and is followed by two doublers to 436 MHz. This design is being done by Stan Sjol (WØKD). Gordon Hardman (KE3Z) is working on a power amplifier using a Motorola MRF750 driver and a MRF752 output stage. The collector voltage on the driver stage will be command selected to be either the +5 or +10v bus to provide power agility. This collector voltage may be amplitude modulated to provide some time-domain shaping to minimize the transmitted bandwidth. Transmitter development is also being done in Canada by Bob Pepper (VE2AO).

GLUE

The myriad mechanical details were all sorted out before we cut a single piece of metal by Dick Janssen (WD4FAB); Dick made extensive use of modern CAD techniques and all drawings were done with AutoCAD (see Figure 3). In Boulder, Jeff Zerr has been shepherding the detailed mechanical layout and find what pieces don't fit. A "show and tell" model was built by ???? with help from Dick Daniels, and a mechanical mockup for vibration testing has been built by Jeff Zerr.

When we began developing the Microsat concept, we took a look at problems that had been major hassles on earlier satellites. High on the list were problems in building a wiring harness and testing individual modules. We also wanted a design that allowed a "cookie cutter" approach to manufacturing since we anticipate a number of launches in the next few years. We came to the conclusion that we needed to develop a bus-like wiring approach with all modules having similar interfaces, and we needed to minimize the number of wires. I took on the task of solving this problem and defining the electrical "glue" that holds the system together.

After exploring a number of options, the design we adopted was to use hi-rel DB25 25-pin connectors on each module and use a 25-wire bus made like a flexible printed circuit. Of the 25 wires, about 40% are used for power distribution, about 40% to carry packet data from the receiver to the CPU and from the CPU to the transmitter, and the final 5 wires are used to let the CPU control functions in the individual modules and for analog telemetry.

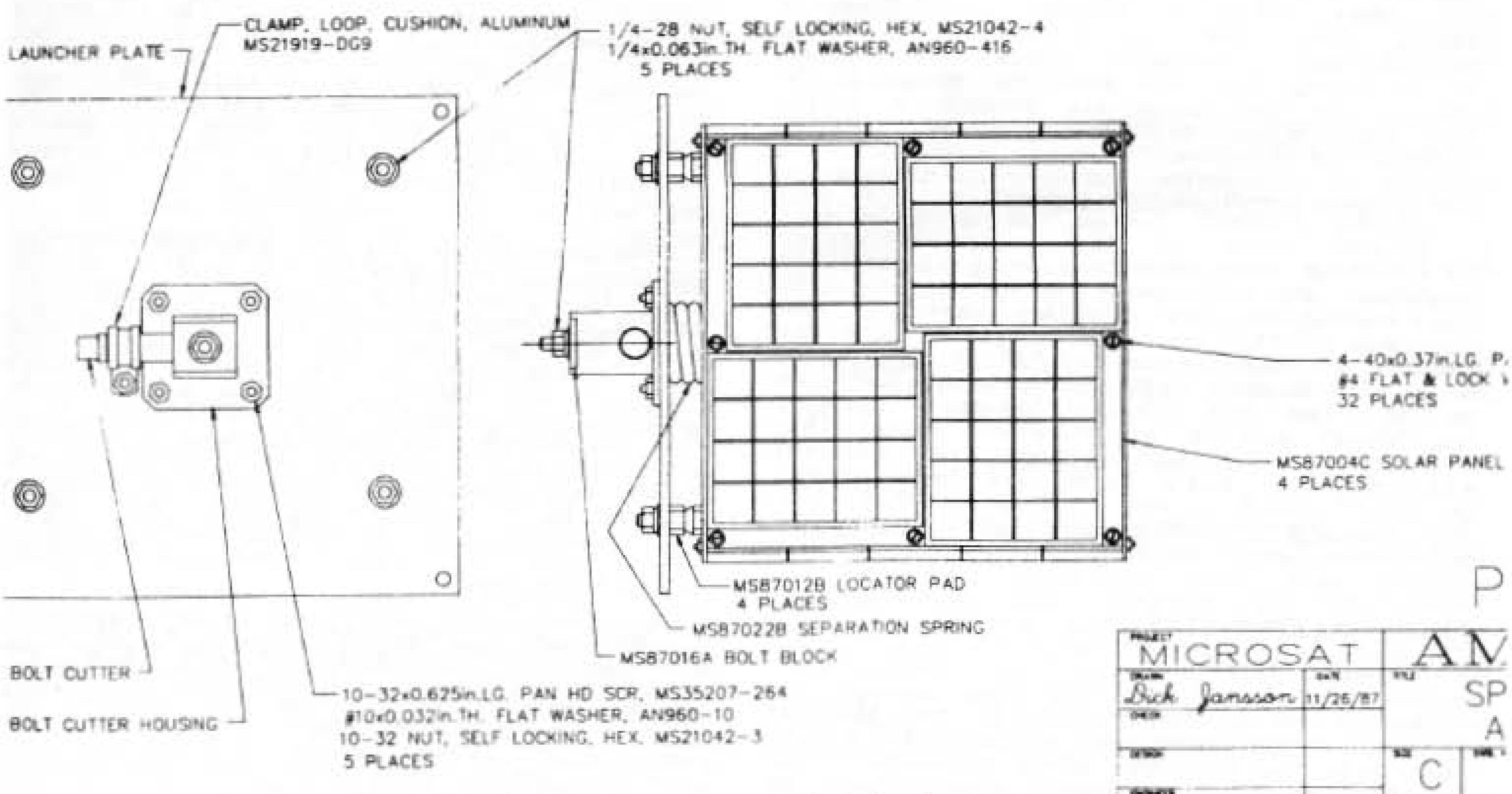

Figure 3. Part of one of WD4FAB's drawings showing MICROSAT assembly details.

AART

In order to squeeze all these command, control and telemetry functions into only five wires, we have built a very small (7 inches long!) LAN with the CPU acting as the network master node and each module being a slave node. Data communications from CPU to module consist of two byte packets; the first byte (with the MSB=1) addresses up to 128 slaves, and the second byte (with MSB=Ø) is a 7-bit received data field to be passed to the module (RXD). On receipt of a valid address, the module automatically sends back two 8-bit bytes (TXD) of data on another wire. All data is sent with normal asynchronous protocols.

On the CPU side, this async data is generated and received by the UART built into the V40 chip. The protocol is easily simulated on a PC, so testing each module does not require a complete working spacecraft.

In each module, we use a clever IC: the Motorola MC14469F Addressable Asynchronous Receiver/Transmitter (AART). The 14469 is a 44-pin surface mount part (also available as a 40-pin conventional DIP) which implements the protocol just described with very few external parts. It has separate pins for the 7 address bits, the 7 RXD bits and the 16 TXD bits.

The 7 RXD bits are used for a number of functions. The MSB of this word is used to select analog vs. digital functions, with the control data specified by the remaining 6 bits. For digital functions, the 6 bits are treated as two 3-bit nibbles which constitute the address and data for three CD4099 addressable latches, resulting in 24 bits of digital data being available for control functions in the module.

When the MSB selects analog functions, the 6 bits are taken as addresses for CD4052 CMOS analog multiplexer chips which decode 6 discrete analog telemetry samples plus four thermistors. When a module is selected in analog mode, the selected analog signal is switched onto two wires (signal plus return) in the 25-wire bus, and when the module is de-selected the two wires are floated. A single, fast 8-bit Ø-2.5v A/D converter in the CPU handles all spacecraft analog telemetry. Each module is responsible for pre-conditioning its analog signals to fit the 0-2.5v range.

All these parts, including some op amps to condition the thermistor signals, plus the DB25 spacecraft bus interface connector and tie-points for all signals needed in the modules are fitted onto a 7.8" x 1.5" board which is mounted against one wall of the module frame. The interface boards in each of the "slave" modules are identical except that the AART chip is strapped to different addresses. This small board has been dubbed the AART board. It was designed by W3IWI and Bob Stricklin (N5BRG). Each board requires 5 mW of power (about 1 ma at 5v).

THE OTHER MICROSATS

DOVE

So far we have described the two Microsat PACSATs: those sponsored by AMSAT-NA and AMSAT-LU. The BRAMSAT DOVE spacecraft is still in the final design phases, but it will be built from many of the same pieces and will have the same general mechanical layout. DOVE will transmit its digitized voice signals in the 2M band with conventional FM modulation. Rather than designing a different receiver system, we have decided to have the command uplinks also on 2M; the DOVE transmitter will turn itself off every few minutes to listen for commands. Only the transmitter module is different for DOVE. As of the time of this writing we are planning to use differentially-encoded voice synthesis (e.g. "delta modulation") with up to 4-bit encoding of the differential data. Preliminary design on the speech synthesizer has been done by Bob McGwier (N4Y) and W3IWI and is being simulated using our DSP hardware.

NUSAT

The Weber State NUSAT MICROSAT is different mechanically from the PACSATs, shown in Figure 4.

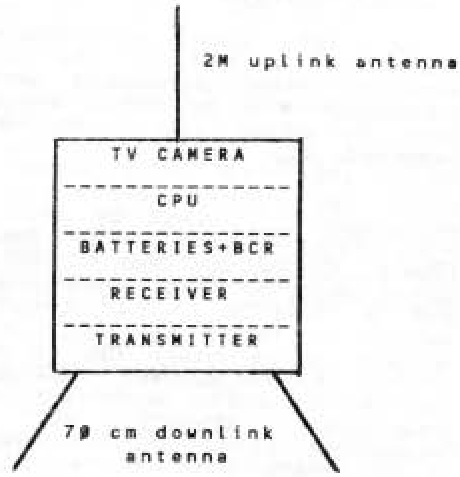

Figure 4. NUSAT LAYOUT

The major difference is that NUSAT has a CCD TV camera in the top module. The TV camera is connected to a high-speed multi-channel "flash" A/D converter which can digitize incoming video signals at 10 MHz sample rate. Its data is stored in memory which can also be accessed by the CPU. The Weber TV camera module and CPU were placed in adjacent modules so that the memory could be easily dual-ported.

The sample rate for the A/D converter and the input signal source can be selected by the CPU. The primary signal source is a CCD TV camera equipped with an electromechanical iris built into its lens. The iris's aperture can also be controlled by the CPU. The camera's field of view allows a 350 km square to be imaged from the satellite's 800 km high orbit.
The camera assembly occupies about 1/4 of the space in the module. It is planned to use video data compression techniques to minimize the downlink data requirements; Weber State and AMSAT-NA plan to have software to support these advanced video techniques available around launch time.

Weber State also plans to try a 1269 MHz video uplink. Video data from this uplink will be digitized by the "flash" A/D converter and loaded into the dual ported memory, just like data from the CCD camera. It is also hoped that the TV camera can be used as an visible and IR spectrometer covering the 400 to 2000 micrometer wavelength band.

The other NUSAT modules are nearly identical to the PACSATs and NUSAT could be also turned into a PACSAT merely by loading different software.

The Weber State team consists of a number of students, staff and faculty members from the Center for Aerospace Technology (CAST) including Bob Twiggs, Bob Summers and Chris Williams.

THE FIRST MICROSAT LAUNCH

AMSAT-NA and the UoSAT group have worked with the European Space Agency and Ariannespace to develop a new launch capability for very small satellites. This will be first tested on the launch of the SPOT-2 Earth Resources Satellite in early 1989. On that flight there will be SIX small satellites -- our four Microsats and two somewhat larger UoSAT spacecraft. The orbit is nearly ideal -- sun synchronous at 800 km altitude, much like the Oscar-8 orbit. At mid-latitudes, passes will occur twice per day at predictable times around 10:30 A.M. and 10:30 P.M. local time.

USING THE MICROSAT SATELLITES

As we mentioned before, our PACSATs and Weber State's NUSAT use ordinary AX.25 packet protocols. To receive any of the three, you merely need to add a PSK demodulator to your 70 cm receiver. The uplink requirements are modest and the same as FO-12. At a later time, when transmitter technology permits and user loading dictates, some of the receiver channels will be reprogrammed to higher speeds. But initially, if you are able to use the FO-12 satellite, then you are all set.

The spacecraft software that you will see will be designed for message handling, and the code is being written by Bob McGwier (N4HY) with inputs from a number of us. The initial software will probably look very much like a W0RLI/WA7MBL BBS system, with a few enhancements. First of all, the prompt that the satellite will send to you will have two telemetry numbers in it -- these are your signal strength and discriminator meter readings. The discriminator meter should be invaluable in helping you center your signal in the receiver's passband and its use will become mandatory as we migrate to higher uplink speeds. The spacecraft software will support multiple, simultaneous users. There may be commands that allow you to request specific telemetry information from the satellite.

I anticipate that much of the utility of these satellites will be as an augmentation of the terrestrial HF long-haul message forwarding networks. If this proves to be true, then fully automated gateway stations will make heavy use of the satellite capabilities.

Therefore it is important that we design both the ground-based and flight software to work together smoothly. We have had ongoing discussions with the writers of BBS code (like W0RLI and WA7MBL) to make sure that both sides of the link will be ready on launch day. In these discussions we have been devising schemes so that the burden of maintaining routing information resides on the ground. New forwarding protocols in which the receiving station tells the sender what message addresses it can handle are being defined. It is likely that these will be coupled with heirarchial domain-oriented addressing schemes like are used by TCP/IP protocols. A user on the W3IWI BBS would have an address like W3XYZ@W3IWI.MD.USA and if I were operating as a gateway for the MD/VA/DE/PA/NJ area, I would be able to inform the spacecraft to send me any messages so addressed.

At the same time that "connected" mode activity is going on, the satellite will be sending UI "broadcast" (i.e. UNPROTO) frames with telemetry and bulletins of interest to all. On NUSAT, digitally encoded pictures of the earth will be sent as UI frames which will be reassembled by the user on the ground.

THE FUTURE

We have reason to believe that there are a number of launch opportunities to LEO for very small satellites. We have designed our Microsats to be easily reproducable. As new capabilities (perhaps 9600 or 19,200 BPS modems? Experiments to fit into the TSFR module?) are developed, we feel there will be opportunities to fly them.

We anticipate non-amateur uses of our technology. Initial discussions with scientists specializing in oceanography and seismology have shown that they have a need for low-cost data collection systems from remote locations. We anticipate a scheme for a commercial licensee to "sell" our technology in these markets. Just like royalties from TAPR's TNC2 project have provided resources for future development activities in packet radio, we hope that Microsat royalties will provide a similar legacy for advancing amateur satellite technology.

We also see that the Microsat technology provides a perfect way for fledgling space groups associated with other AMSAT organizations around the world and with universities to develop their own satellite programs. Don't be surprised to see Microsats being built by people from many nations.

The spacecraft operating software can be uploaded from the ground. As NK6K and N4HY discuss in their companion paper, the software we will be flying is the most complex ever attempted in the amateur satellite program. It probably will crash! We have designed in several safeguards to make this possible. With this flexibility, we also have the ability to try new things. Perhaps we will see new mail-handling protocols developed which use datagrams. Perhaps we will see a PACSAT programmed to be a TCP/IP FTP file server. As the old adage states:

IT'S ONLY SOFTWARE !

PARTING COMMENTS AND ACKNOWLEDGMENTS

The most important "glue" that holds a project like this together is the project manager. We are indeed fortunate to have Jan King (W3GEY), with his wealth of experience, his contacts in the aerospace industry, his mother-hen persistence in reminding us of the rigors of space, and his compulsive personality to make sure everything happens.

Jan's "glue" binds together a team of high-strung, emotional prima donnas who are equally compulsive. Many of the team members have

invested a lot of 3AM mornings working on this project! All the team members have had to wear very thick skins to withstand the FLAME ON! communications blasts some of us are prone to emit. Bob Mcgwier, Dick Jansson and Lyle Johnson all deserve special credit for service above and beyond the call of duty.

This project has significant players spread out all over North America, with major activities in NJ, MD, VA, FL, CO, UT, AZ, TX and CA. Unfortunately amateur radio communications are inadequate to keep such a dispersed team working together. We have relied heavily on commercial electronic communication channels, particularly AMSAT's network on GTE TeleMail and TAPR's channels on CompuServe, plus a lot of phone calls. Every few months we get a number of the people in one place and lock the door to make sure everyone REALLY understands what is happening.

We have made heavy use of various CAD tools during the development activities. Mechanical layout was done with AutoCAD. ORCAD was heavily used for developing schematics, wiring lists, parts lists and net lists. CAD PCB layout used Smartwork, ORCAD PCB and Tango. See Figure 5 for an axample of some of this use of CAD techniques.

We have done some experimentation using higher-level networking for technical communications to move CAD data using my TOMCAT FTP file server which has a SLIP port in addition to being on the "real" network.

There are two organizations not mentioned earlier that have contributed a lot to this project: TAPR and the ARRL. For many of the volunteers working on this project, the distinction between TAPR and AMSAT is fuzzy since they seem to wear two hats. In addition to the TAPRites working on this project, TAPR has made vital contributions of funds and hardware, without which we couldn't make it. Special thanks to Andy Freeborn (N0CCZ) for helping to make the TAPR/AMSAT interface smooth. At the ARRL labs in Newington, Paul Rinaldo and Jon Bloom have made many vital contributions.

From the AMSAT organization, two people deserve a lot of credit. Vern Riportella (WA2LQQ) was instrumental in arranging the AMSAT-LU and BRAMSAT participation in the project. Martha Saragovitz has acted as mother confessor, paid bills, handled meeting logistics and kept smiling thru it all, despite repeatedly crying out "Where's the money coming from?".

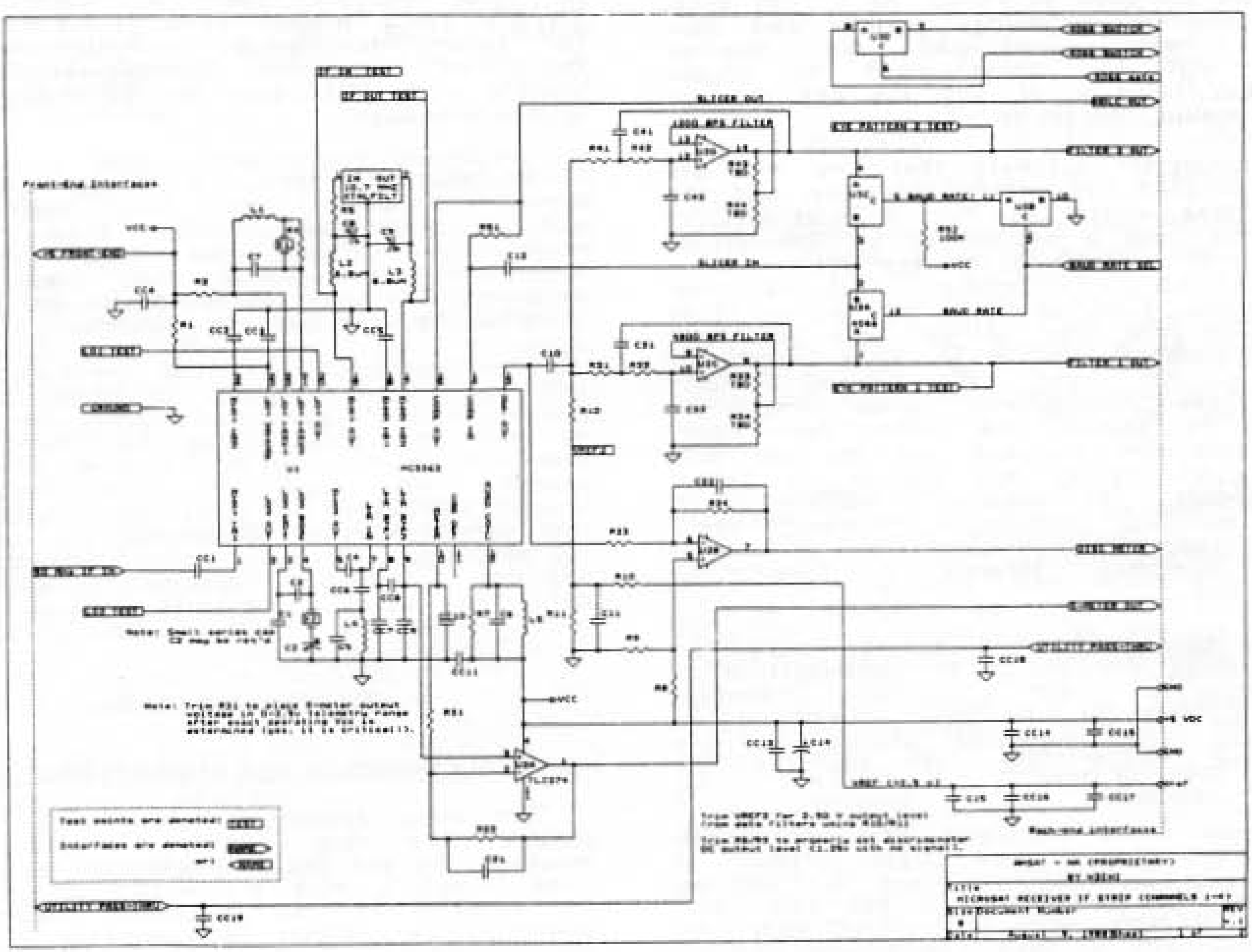

Figure 5. One of W3IWI's ORCAD schematics of the MICROSAT receiver IF strip.

The DSP Project Update

by

Dr. Thomas Clark, W3IWI and Dr. Robert McGwier, N4HY

1. Introduction

TAPR and AMSAT have signed a formal agreement which forms a joint project. The purpose is to bring the rapidly advancing technology and techniques of digital signal processing to bear on the communication needs of amateur radio. The AMSAT-TAPR digital signal processing project has made steady progress over the past year on both software and hardware. Lyle Johnson is leading the hardware effort in Tuscon and will report on that progress elsewhere in these proceedings. We will report on work that is ongoing to choose what the second generation DSP unit will look like.

The project has been very lucky to have several new people come along and offer valuable suggestions and in a few cases some new software. Motorola, Inc. and A.T.&T., Inc. have donated development systems, none of which we have running at the time this is being written but all within days of being handed to the project. The project has acquired the use of complete development system and software for the TMS320C25, T.I.'s current best that is available for OEM's 'over the counter.' That acquisition is a story that will amuse you and that will be covered. The TAPR-AMSAT project, whose current planning and future goals you will be told about here, believes strongly that we are leading amateur radio into new possibilities for special purpose communications modes being as easy as RTTY and packet and thus involving many more people in these areas of our fascinating hobby. Indeed in some cases, this could raise the involvement in many of these speciality modes significantly.

2. Software Developments

At the last networking conference, we reported on the spectrum analyzers and a modem for the reception of JAS-1 or FUJI OSCAR 12 and about ongoing software work at that time (1)(2). The work continues to emphasize modems and applications of fast fourier transforms which are at the heart of our spectrum analysis tools. All software efforts in the past year have been on either the DSP-10 boards the project acquired from Delanco Spry (3) or on the PC-clones in which they run. The FUJI Oscar 12 modem took on a new guise which has been very effective in demonstrating the functional versatility of DSP approaches to communications systems. We decided to add a BEL-202 modulator following the 1200 bps PSK demodulator. This enables one to copy the signals from JAS-1 with the DSP board and an unmodified tnc. We will be using this piece of software a great deal in the coming months after it has been modified to run on a dedicated DSP box the project will produce for the benefit of amateur radio. In the early part of next year, PACSAT 1,2, and 3 will be launched. PACSAT 3 will have a CCD camera on board as its primary mission. All of these satellites use PSK on the onboard transmitter at rates between 1200 bps and 4800 bps. The DSP software will support these satellites as the demodulators. The uplinks are Manchestered FSK with the rates as before. This is also easy to produce and will be part of the software work that will be available for distribution with the initial units.

N4HY also has working a Hilbert transform demodulator, of the type mentioned in last years proceedings, in DSP56001 'C' code and less optimal versions in TMS32010 code (due to smaller data space) which demodulate QPSK at rates up to 9600 BPS, BPSK to 4800 bps, coherent demod for GMSK to 4800 bps all with the same carrier and data extraction loop. The only change is the input of the minimum allowable phase transition during bauding. The data decision algorithms differ considerably from one type modem to the next but the same basic element is common to all these modems. In some cases, filter coefficients have to be changed (change a couple of dozen numbers in the data) to allow for different width spectra, etc. The common thread in the demodulation of phase modulated data signals is never more apparent than when the demodulators are written in software. The DSP56001 is fully capable of going faster than the numbers mention above, but these are the upper limits due to the TMS32010.

N4HY and KA9Q worked on DSP and PC software that does OSCAR 13 PSK telemetry modem functions and also does decode of the telemetry frames from the spacecraft. This was used to monitor tank pressures, battery voltages, and many other critical values relating to the health and welfare of the spacecraft during the critical engineering phase immediately following launch. The modem works well to small signal to noise ratios now but could use some more optimization of the parameters which control the phase locked loop which is at the heart of the system. Both the Oscar 12 and 13 modems are based on the Costas Loop demodulator (4). The work remaining to be done is the optimization of the numbers in the program which govern the dynamical behavior of the 'loop filter' which determines its response to various phase and frequency error it is trying to eliminate. This should allow the DSP modems to work down to smaller SNR in the case of Oscar 13. The dynamical behavior of the loop needs to be different in the case of high doppler and high SNR such as will be the case in the PACSAT's to be launched next year (5)(6)(7).

Two approaches to bel202 demodulators have been attempted. One is a PLL used as an FM demodulator and the other is a filter discriminator modem. The first attempts to track the frequency variation as the signalling changes from one tone to the other. The latter divides the passband into two parts by using a pair of filters. Bit decisions are based upon which filter shows a higher energy content. The former allows for much better data carrier detect to be built and the latter is easier to modify. It can't be too much longer that we will have to deal with these modems as the DSP box and better hardware modems come along to replace them. Nevertheless it is of at least academic interest to determine which of the approaches AFSK can be best done in an inexpensive DSP chip.

One of the most powerful tools that DSP allows us to make is a spectrum analyzer. This has wide applicability to many areas. W5SXD has given us a very nice EGA display for one of our early fast fourier transform routines. John Connor, WD0FHG has produced a useful DSPSCOPE utility for doing an audio oscilloscope function and it works nicely for examing waveforms. Franklin Antonio, N6NKF probably takes the prize for stirring up the troops as much as anyone. He wrote a routine, based upon the work of Burrus and Parks that runs in the PC along with the display routines. It did a creditable job of running at close to the same speed as one done by the authors of this paper and he uses the Delanco Spry board only for sampling. It is a smaller FFT but the display was autoselect EGA, CGA and could be mouse driven. Investigation by N4HY revealed that Burrus-Parks had the faster FFT's already done in TMS32010 code. They needed quite a bit of changing to run on the different architecture of the DSP-10 but they have allowed real valued signals to be done with one-half size complex FFT's saving time and storage. They are also much faster as they are radix four and radix 8 FFT's with three and two butterfly's respectively. Then a partial butterfly is needed to take the half size complex FFT and get the real signal FFT output from it. This gives us a much more serious tool for spectrum analysis of audio signals. (These are 'real' signals. Those that come out of your speaker are real valued signals). The code that runs on the PC is being optimized to run in hand coded assembler in critical areas where the speed bottleneck now exists. Linear and Power displays are now working along with a variety of other functions. This is a great deal faster than the old routines.

We are also studying in considerable detail, the optimal statistics to be used in weak signal detection problems. W3IWI did a detailed looked at the statistics of the signal returned from the moon. This study along with more recent input from Dick Goldstein of JPL, and Vince Poor (8) of University of Illinois also gave us some detailed input about this problem. With the recent success of I2KBD, DSP team member from Italy, in receiving his own echoes from the moon, we are again spurred on to applying this work to the task of truly QRP EME. This technique will not and should not be limited to QRP EME. It can and probably will perform much better along weak signal paths terrestially. It should give VHF-UHF types a tool that will allow QSO's using signals that were previously unusable. The coherence time should be much longer than those returned from the moon and the real power of the FFT will shine in these cases. In the early experiments done by the authors over a 150 mile path on 70 cm with satellite arrays were astounding to say the least. The power could not be turned low enough at N4HY for W3IWI to prevent detection on the screen using a crude display program. This can and should be revisited soon.

Another application of the FFT based spectrum analyzer has been occupying the thoughts of VE3JF, N6NKF, W3IWI, and N4HY. One of the great needs in packet radio and HF digital modes in general is a better modem for HF. The general idea is to send more than one tone at a time and encoding more than one bit of data during each baud or signal element. This will alleviate a large part of the damage HF propagation does to a digital signal. The multipath problem causes each signalling element to arrive from a random number of reflectors and all arriving at different times. This can cause destructive interference. If you signal at a slower rate, the likelihood of this multipath distortion causing you to make a decision error goes down considerably. If we encode 6 bits in each signal element and then transmit this at 50 signal elements per second (50 baud), we will be transmitting data at 300 bits per second. Several studies have been done which show that somewhere near 50 baud is nearly optimal for HF digital transmission in the 40 meter and 20 meter bands. This is one of the reasons AMTOR is so successful at getting the data through (along with its relentless retransmission). We need to spend a great deal more time developing this capability as it will be of great benefit to HF digital transmission modes.

N4HY has considered several specialty modes over the last year. The first to receive a concerted effort has been WEFAX-APT. This is the Automatic Picture Transmission from the NOAA weather satellites. For several years, many reference books (Taggart from 73 and ARRL Handbook) have claimed that a phase locked loop is not the best way to go in copying weather picture transmissions from the low earth orbitting weather satellites. The scheme used by both NOAA (USA) and Meteor (USSR) satellites is to encode the picture element at the current time as the amplitude of a pure tone. For the NOAA birds, this is very close to a 2400 Hz tone, sent into a wideband (70Khz) FM transmitter. When the amplitude is near minimum, the picture is black. When the amplitude is maximum the pixel is white. The same is true for the Soviet satellites with the exception that there is quite a variance in the frequency of the tone from one satellite to another. Most PLL's used in the demodulation of these satellite signals are first order PLL's with very narrow bandwidths in order that recovery of the signal may be done in noise. It would appear that most of them are tuned for the nominal frequency of 2400 Hz used by NOAA. When the Meteor satellites, with their low modulation index for black, are used with these 'mistuned' first order PLL's they do not function properly and the results are poor. Here is a strong case example for using DSP. Nothing had to be changed in the program to make it work PERFECTLY with the Meteor satellites except the frequency. Upon changing one number in the DSP program, the demodulator worked perfectly and the raw pictures one gets with the Meteor satellites are preferable to NOAA pictures since the dynamic range is smaller in the NOAA pictures. This may no longer be true after we begin working on image enhancement for these pictures. The conclusion is that the Meteor signals are phase continuous during the picture even when the modulation falls to small amplitude. A first order PLL will just receive a small error signal during this period and will not adjust the phase. If you have a small frequency error the PLL will just spin through these areas of low amplitude modulation and come out of them with small phase errors at most. This procedure yields several dB of signal to noise ratio improvement over the product detector approach used in so many WEFAX-APT demodulators.

3. Hardware donated, Future DSP projects

The major DSP chip manufacturers have both wittingly and unwittingly been of great aid to the DSP project. Motorola donated two DSP56001's, a boot ROM which includes a monitor, and bare boards for development purposes to our project. The DSP56001 executes 10.25 million operations per second and this number is an underestimate of its real capabilities. The reason is that like the T.I. chip we have been using, it does in parallel those things which make DSP very efficient on these chips. However, of all the second generation chips we have evaluated to date, this is clearly the most capable. Even without careful coding we should be able to run 19.2 kbps without much problem doing both FSK and PSK modems of several different varieties. Lyle Johnson, WA7GXD, and the authors have considered what should be the next step after the DSP-1, which is considered in these proceedings. We believe that we should have a very capable DSP board that will carry the DSP56001 at its heart, which will be available as a replacement card for the TMS32010 board in the DSP-1. Steve Sagerian, KA0YRE, is building the Motorola donated kits for the project. Serious coding will begin on this card once this construction is complete. Steve was also responsible for securing the donation for the project.

NN2Z, Dave Truly, has become well known to many tcp-ip enthusiasts as the current author and manager of the bm mailer program in KA9Q's, net.exe program. Recently, Dave was asked to join the DSP microprocessor support group at ATT. Shortly after joining this group, Dave began pushing the concept of this group donating some hardware and software to the DSP project. The group leader has decided to do exactly that. The DSP-32 development engine with the support software will be donated to the project. Dave is learning as much DSP as he can and will also be working on code for the DSP-32 with N4HY in support of our evaluating the DSP-32. We believe that this will be a useful product for the project to consider constructing.

Companies can sometimes even make unwitting contributions to our efforts. We don't turn them down just because they didn't intend for them to be of benefit! N4HY works at IDA/CRD in Princeton, NJ. He works in the area of signal detection and estimation. Also working there is Maureen Quirk, Ph. D. an engineer specializing in DSP and signals. They are partners on many technical projects. During the spring of this year, N4HY had to go to England for work at the time of the largest gathering of people specializing in signal and speech processing, the annual international meeting sponsored by the Acoustics, Speech, and Signal Processing section of the IEEE. Maureen decided to go to all vendors and gather as much information on DSP chips and the latest products for the benefit of N4HY. While doing this favor, she had a card from T.I. stamped at each vendor of a T.I. DSP chip product. Returning this card enabled her to participate in the drawing for the grand prize. She won. She got the ASDS from T.I. This is the complete software development PC plug in card for the TMS320C25. The memory chips alone, 128K of 25 nanosecond static memory, are pure gold even if they are silicon. She doesn't own a PC. Thinking that she would never use it, she started to give it back. Realizing that their would be death and destruction upon her return and her usual partner finding out about this curious circumstance, she decided in favor of life. The board now has a permanent home in the 386 machine residing at the QTH of N4HY. But of course, Maureen may use it ANY time she wants to!

We will be evaluating these DSP chips for the TAPR AMSAT DSP project and studying the best way to make use of all these resources. With all these development tools at our disposal, we will be able to give a fair evaluation to each of these chips and find the strength and weaknesses of each. This will be reported in the next Networking conference.

4. Future, Pie in the Sky, etc.

If the future of the DSP-1 is as bright as we believe it will be, one of the great benefits such an engine could provide would be as an educational tool. It would be an inexpensive approach to having several different DSP chips along with a host processor to interface with it available on an open architecture for programming. This is ideal for amateur radio experimentation and for educational purposes which are not easily seperable in this case. The current costs for one of these development engines for each of the DSP chips is several thousand dollars. For about the same cost one could have a less capable development system but be able to put many different chip/boards in it for evaluation and comparison. The obvious value to education does not need to be belabored further. This particular project has an audience that greatly exceeds amateur radio as some others have in the past. We are wiser than we have been in the past and are looking at this project as a means to do future projects. The interest in the outcome of this project is demonstrated by major companies donating hardware and software valued at several thousands of dollars. The applications are limited by people's imagination and time more than any other factors.

As evidence of growing interest, the IEEE ICASSP meeting for the coming year is in Glasgow, Scotland. This is the next meeting of the group where the TMS320C25 board was won. The authors of this paper have had accepted a paper on the DSP-1 and our project and we will represent our group at this conference next May.

5. People and Conclusions

The people in this project are what it is really about. The array of talents allied against the communications needs of amateur radio is very impressive. We need to thank Courtney, N5BF for beginning to try and give a responsive central location for information on DSP. Paul, KB5MU and Courtney have done a very nice job of producing a schematic of the Delanco board for the internal use of the project members. It has been invaluable aid in deciding what was done wrong and what was done right. John, WD0FHG deserves a great deal of thanks for his mailings of the DSP diskettes. TAPR is also mighty lucky to have Andy Freeborn, N0CCZ to be president. The value of his aid in managing the DSP project administratively cannot be overestimated. By next year, we should be here telling about all the neat stuff that runs on the DSP-1. We hope several of you will have it in your shack by conference time in 1989. For those who have despaired of progress, we hope that this DSP year in review has enlightened you. We also remind as often as we can, look at the people who are writing the papers on DSP and on PACSAT. The upcoming launch date early next year will not wait while DSP can, no matter how loathsome the prospect is. Whenever you write a report on a years activities in a group as diverse and widespread as this is, you inevitably leave some contribution out that should have been described. If we have made such a faux pas, it was inadvertent. For those of you with access to ARPANET, you may find the entire contents of the DSP mail distribution available in several diskette images. FTP to tomcat.gsfc.nasa.gov with user guest. The DSP diskette images are available in directories DSPX where x is the number of the DSP diskette image. ENJOY and thanks for your support and continued interest.

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TOWARD THE FUTURE IN THE AMATEUR SATELLITE PROGRAM
NEXT STEPS IN THE GROUND SEGMENT

01 October 88

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AMSAT Vice President for Technical Operations

ABSTRACT

As AMSAT leads amateur radio with new technologies and more frequency utilization via amateur satellites, it is necessary for the community of satellite users to make corresponding expansions and upgrades to their ground station facilities. This allows the amateur satellite program ground segment to more fully utilize the facilities available on our satellites and to expand the scope and amount of amateur operation carried via satellite.

This paper specifically overviews some of the rationale behind upgrades to mode L, phase shift keying modems for satellite based packet radio, computer aids in the shack, and the AMSAT Orbital Data Management system. The purpose is not particularly to tell 'how to' implement station improvements but to tell 'why' they are needed from a broader context.

THE PRESENT IN THE SPACE SEGMENT

The years 1988 and 1989 promise to be two of the most productive years in the amateur satellite program to date. With the launch of AMSAT-OSCAR 13, the dream of an amateur radio relay in a usefully high orbit has finally been achieved. The facilities aboard this bird offer ample room for experimentation and development and a foretaste of the Phase IV capabilities now on the horizon. With this new tool in place, it is now time to begin work toward phasing in a serious amount of public service and emergency communications preparedness via satellite.

A few months from now, AMSAT's first salvo of Microsats will be launched. Two of the four new satellites will be packet radio mailboxes, used both to enhance the packet mail forwarding system by contact with automated ground segment bulletin boards and by direct individual access. The other two Microsats will be receive-only for most users, one a digitalker, the other a camera which will downlink digitized pictures and telemetry via packet unproto frames.

The traditional OSCAR operators are hereby called upon to lead the way into this new era. This is an opportunity to be in on the ground level of some new and exciting facets of amateur radio and the ground swell of others.

WHAT DO WE HAVE TO DO?

Amateur radio enterprises at all levels are fraught with the perils of overzealous estimation and burnout. How many times have you planned a project for your shack that was a little (or a lot!) too big then find it difficult to get started, keep going, or get finished? The same thing happens with bigger projects undertaken by larger groups of hams. Sometimes, projects that succeed at all do so only after passing through many pairs of hands.

Slow but steady progress made in smaller steps is an effective way to maintain momentum among amateurs and groups for longer periods of time. In developing the AMSAT ground segment of satellite operators, there are many dreams and ideas of what can and should be done. Here are outlined some of the next steps to get from where we are now to where we want to be in the next decade.

WHY DO WE HAVE TO DO IT?

Satellite operators and satellite based or supported activities should share in all of the types of activities that comprise amateur radio and should lead in many of them. This includes DX, ragchewing, nets, emergency drills, weak signal work, public service events, digital, TV, special modes, and scientific research, to name just a few.

Why is this? Because amateur radio must remain state of the art. State of the art in the late 1980s implies greater coverage, better quality, and greater reliability than it did even ten or twenty years ago, just as it does among our commercial counterparts in communications and broadcasting. The amateur satellite program pushes and expands the envelope of amateur technologies, it does not merely occupy it.

The amateur satellites of the present and immediate future represent the beginning of a capability that can extend the ease of use and facility of local VHF repeaters and other solid communications support facilities to national and international scope. Satellites are no longer the domain only of experimenters, and the trend in that direction must continue if we are to expand our support base and continue to justify our use of frequencies, launches, and other precious resources.

SPECIFIC NEXT STEPS IN THE GROUND SEGMENT

In order to begin and maintain operational developments and events, members of the ground segment, that is, amateur operators with satellite stations, must start with certain minimum capabilities. Today this means CW and sideband capability for modes A, B, and J. Put another way, this means linear transceivers for two meters and seventy centimeters and a receiver for ten meters. Add FM reception on two meters for UoSAT downlinks, and the operator has some capability for each of the amateur satellites now functioning.

These units with appropriate antennas and accessories constitute a capability for people to talk with each other via satellite, the baseline satellite user configuration.

COMPUTERS

Ham shacks of the future without some kind of computer will be in the minority. Even today, it is difficult and inconvenient to do effective satellite work without electronic computing equipment. A station equipped for developmental or routine satellite work needs a computer of some kind.

The computer provides two basic functions for the satellite operator: satellite tracking ability and a data communications terminal.

A computer can do many other useful things too, some outside of direct utility for amateur radio. This paper, for example, was drafted and finished entirely on a computer. Many amateurs, because of their intrinsic interest in science, electronics, and logic, find computers interesting in themselves. It is, however, no more of a requirement to be interested in computers per se for them to be useful in satellite work than it is for the cook to be interested in the inner workings of a refrigerator in order to need one in the kitchen. The hardware and a few programs are the requirement, not necessarily initiation into the mystical cult of 'hackers.'

The computer needs one or two communications accessories, a modem for landline data handling and/or a terminal node controller (TNC) for packet radio. These along with 'communications software' will allow access to textual and tabular information of interest to amateurs, satellite operators in particular. The TNC is also the first building block toward the goal of doing digital communications with the satellites.

PHASE SHIFT KEYING

A standard TNC-2 comes with a built in 'radio modem,' it plugs right into the speaker and microphone jacks of a radio and then uses audio frequency shift keying (AFSK) either on FM or SSB to send data to other stations similarly equipped. Satellite builders have selected a different modulation technique for transmission from satellites, one that saves power on the satellite (always a paramount concern) by allowing better data recovery with less signal. This technique is called phase shift keying (PSK). Instead of sending different tones to represent different data, PSK changes the phase of the downlink carrier to represent the symbols of digital data.

PSK is, by the way, the way that ALL nominal communications (data and digitized voice) are transmitted to and from the Space Shuttle, both on S-Band ground station and via the TDRS system on Ku band. Use of the UHF AM transceivers is rare and is limited to special circumstances.

The signal to noise ratio difference between the level required for an acceptable bit error rate using AFSK on FM is about 4 dB greater than the level required for the same error rate using PSK. The decision to use PSK for digital satellite downlinks (from Oscars 10 and 13, FO-12, and the Microsats) was and is a sound and proper engineering judgement. The same advantage is realized on terresterial circuits. The implications are tantalizing but beyond the scope of this paper.

Unfortunately, the use of PSK also makes a step away from the popular modem techniques that allowed the use of unmodified FM transceivers in packet radio. The PSK demodulator is something to be added to the existing TNC and currently requires a sideband radio. The sideband radio should not be a problem for satellite operators with the minimum station outlined above, but is among the major obstacles standing in the way of prospective new satellite operators.

In terms of packet message forwarding, the Microsats will be to the HF Skipnet what the railroads were to the Pony Express: not the ultimate answer but a big step forward. In terms of direct access mail handling, they will improve geographic scope and delivery time significantly. Possibilities for meaningful public service and emergency communications using the packet satellites directly or indirectly will soon be available but can only be fully utilized if there is significant and coordinated support in the ground segment. Those of us who are already satellite operators have a head start and are called upon to lead the way in providing the facilities and organizing the services. The first step is for each operator to get that PSK modem on the air!

DIGITAL SIGNAL PROCESSING

Decisions concerning satellite digital modems, analog modes, and usage are not always made with the development of a large user base in mind, nor should they be. It can, however, be frustrating as a digital user to encounter the need for a new modem per satellite. We expect PSK modems to be standard equipment on future TNCs, particularly the 'all mode' varieties as PSK becomes more popular in satellite, HF, and VHF terresterial work.

A better solution for an amateur station today is to use digital signal processing (DSP). Basically, DSP uses computers and software to do what circuits and hardware do in ham shack assessories. Analog from a radio's audio or IF stages is 'sampled' rapidly and read into the computer as a series of numbers. The computer can process the numbers or generate other series of numbers to be converted back to analog to go out on the radio in ways and for uses limited only by the imagination.

Specialized filters, modems of virtually any type, spectrum analysis, or just plain digital recording of sounds are just software changes to a DSP system, and software is changed just by loading different programs.

In many instances, DSP based functions are superior to their analog hardware counterparts since they can be made 'dynamically adaptive' in software. This means that the program can monitor its conditions and alter itself to improve performance on a split second basis.

The thing that sells DSP to hams for their home shack is that this is THE truly multi mode box for digital and analog modes. You can buy equipment today that does CW, RTTY, weather FAX, Packet and Amtor, and you can buy SSB and CW filters for standard transceivers, but when a different mode is invented or standards or data rates change in the future, you're out of luck. With DSP, new modes, standards, or speeds are 'only software,' and much of that software will be publically available. You will be able to download it from a packet or telephone bulletin board, or from a Microsat, or acquire it on a diskette and you're all set. The possibilities for real operational flexibility and optimization are exciting.

Currently, a team of developers of DSP software is working on and testing programs to do many basic functions: test equipment, satellite digital and analog operations, extremely weak signal work, and modems. Much software has already been written and tested and it remains only to fit the routines into user friendly and automatic operation packages.

DSP hardware is now well within the amateur price range but is still a bit expensive for casual or appliance operators. Hardware is now under development by an AMSAT/TAPR team which will be priced competitively with other top line digital devices.

Again, as with computers, one need not be interested in or appreciate all the intracacies of DSP hardware and software to use DSP equipment in routine amateur operations. Indeed, one of the aims of the DSP development project is to provide experimenters with interesting work on the one hand while providing a very basic tool for routine, nominal operations on the other. If a shack computer compares to the kitchen refrigerator in utility, the DSP box compares to a microwave oven or dishwasher.

Very little is envisioned in the future of the amateur satellite ground segment that cannot be done with a station consisting of the current or some upcoming generation of the radios, computers, and DSP hardware available now!

ORBITAL DATA MANAGEMENT

A very practical step that is being taken to streamline the efforts required of the satellite user community is the development of AMSAT's Orbital Data Management system (ODM). Fundamentally, ODM provides a centralized point of collection and dissemenation for orbital data. Keplerian elements and other information are collected by AMSAT from government and other sources and are entered into a database using software that carefully appraises the data entered. Some but not all of the entry process is automated.

The central database is updated regularly (weekly) and the information is reformatted into standard tables and made available to operators in the form of widely distributed packet radio bulletins, downloadable BBS files, and printed matter.

End users are then provided with a utility to read the data from these bulletins or files (once captured from some digital source, packet BBS, landline BBS, satellite, diskette, or wherever) and update tracking program data files automatically. The format of the bulletins is being updated, end user utilities for popular tracking programs are being written and made available, and the specifications and procedures involved in end user auto updating are being established and documented.

For those that enter new element sets weekly, this service will free up a half hour to hour of time every week. For those who never update element sets in a tracking program, this provides an extremely easy method of obtaining up-to-date and accurate information regularly.

L BAND

The recent loss of part of our 220 MHz U. S. allocation is a shock and cause for concern to all amatuers. One of the first questions that arises is, "What can we do to secure our hold on other spectrum which may be threatened similarly in the future?" Among the many possible courses of action, one of the most effective is to fully occupy the amateur bands and publicize that occupancy as widely as possible. One of the most effective ways to publicize utilization of an amateur band on a nationwide and worldwide basis is to use some of it for a link to or from an amateur satellite, thus the decision to include L band uplinks on Oscars 10 and 13.

A move up in frequency like this is resisted by momentum in the user community, the momentum of a stationary mass. Nevertheless, it must be a priority for as many satellite operators as possible, including new ones, to make the move up and populate these bands. Satellites of the future will not even use frequencies below seventy centimeters. L band equipment will be among the minimum requirements to operate these satellites at all.

In a few more years the necessity of similarly moving up to S band en masse will be apparent. This is no time to fall behind.

Aside from spectrum preservation, there are other good reasons to expand upward. The one ten meter and two two meter satellite allocations are only 200 KHz each. Even if these allocations were exclusive for satellite use, which they are not, they would not support the type and level of communications required to really begin providing amateur services that need to be supported by satellites. The 145.8 to 146.0 MHz slot is particularly crowded and prone to intra-service interference, containing an uplink or downlink from every amateur satellite in operation today.

A PEEK AT THE FUTURE

AMSAT has many future plans for the amateur satellite ground segment. As a traditional satellite enthusiast, one or more of the small to moderate station enhancement steps listed in this paper help to prepare you for that future.

Improved packet forwarding, fast scan TV, "in house" AMSAT satellite tracking facilities (an extension of the Orbital Data Management system now under development), analog and digital repeater linking, communications access to the manned space station 'Freedom' via the "amateur TDRS," Phase IV, and more satellites on more bands and modes are just a few of the many bold dreams in the amateur satellite programs of the world today. Also, traffic and emergency nets, technical contests, state of the art experimentation, and vastly expanded opportunities in support of education are envisioned. We are called upon to prepare for and support these dreams by continuing to make incremental investments in time, money, and operating efforts.

For an active, growing program, it isnt too much to ask of the veterans to expand operations into one or two new bands per decade and to make upgrades to ground processing equipment, is it?

SATELLITE ORBITAL CHARACTERISTICS DURING THE PRE RE-ENTRY PHASE

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The orbital characteristics of Earth satellites, as defined by the Keplerian elements, undergo major changes during the days and weeks immediately preceeding final atmospheric re-entry. These changes are primarily due to the frictional drag of the atmosphere upon the satellite as it passes through each perigee. This drag is responsible for the so-called "satellite paradox" in that the "drag" actually causes the orbital velocity of satellite to increase rather than decrease. Analysis of the changes can yield a number of interesting characteristics of the upper atmosphere and, indeed, there are many studies currently underway by atmospheric scientists in this area. Changes in both the orbital inclination and the right ascension of the ascending node can be used to determine the meridional wind speeds near perigee. Additionally, changes in the argument of the perigee may be used to estimate the atmospheric oblateness. Orbital changes can also be introduced by the pressure of solar radiation and examples of this effect are given using data from the 1960-iota 1 and 1964-004A (Echo series) satellites. These changes in orbital characteristics may also be used to obtain estimates of satellite lifetimes using simple techniques developed by King-Hele. Complications in making such estimates, caused by the increased solar activity levels, are discussed. Examples are given using recent data from the Cosmos 1900 satellite. The orbit of this object underwent significant changes during the latter part of September during which period perigee distances fell by over three km per day.

FUJI-OSCAR 12 AND THE FUTURE JAPANESE SATELLITE PROJECT

The Japan Amateur Radio League

1. Introduction

Radio amateurs in Japan could have their satellite with many cooperation and assistance over the world. Satellite JAS-1, or FO-12 is now working and is utilized by radio amateurs in the world. This paper describes summary of behaviour and operation of FO-12 since it was launched.

2. Configuration of JAS-1

Figure 1 shows the external view of JAS-1 of a polyhedron with 26 faces, almost like a sphere, solar cells and antennas are on its surface. It weighs about 50 kg, which means higher density than usual satellites.

JARL planned and promoted JAS-1 project with many cooperation of radio amateurs and relating organizations. The radio transponders onboard JAS-1 were developed by the members of JAMSAT, with international cooperation, and NEC Corporation constructed the bus by contract. JAS-1 consists of two parts; the communication subsystem and the bus that includes power subsystem and works as a satellite. Table 1 and Figure 5 show characteristics and block diagramme of JAS-1.

3. Launch and orbit of JAS-1

NASDA developed a new launch vehicle H-I consisting of two stages of rocket, which is about 40 m long and 2.4 m in diameter and weighs 139 tons.

It is able to throw a satellite of 550 kg into a geostationary orbit. H-I vehicle has two stages of rocket, of which the first stage rocket succeeds to that of N-2 vehicle and the second one has an LE-5 engine developed by NASDA, which employs liquid hydrogen and liquid oxygen as its propellant. This time was the first test flight of H-I vehicle. The test flight of H-I is to verify its capability of rockets and to examine a basic experiment of launch of multi-payloads. Therefore, JAS-1 was launched with other mission payloads.

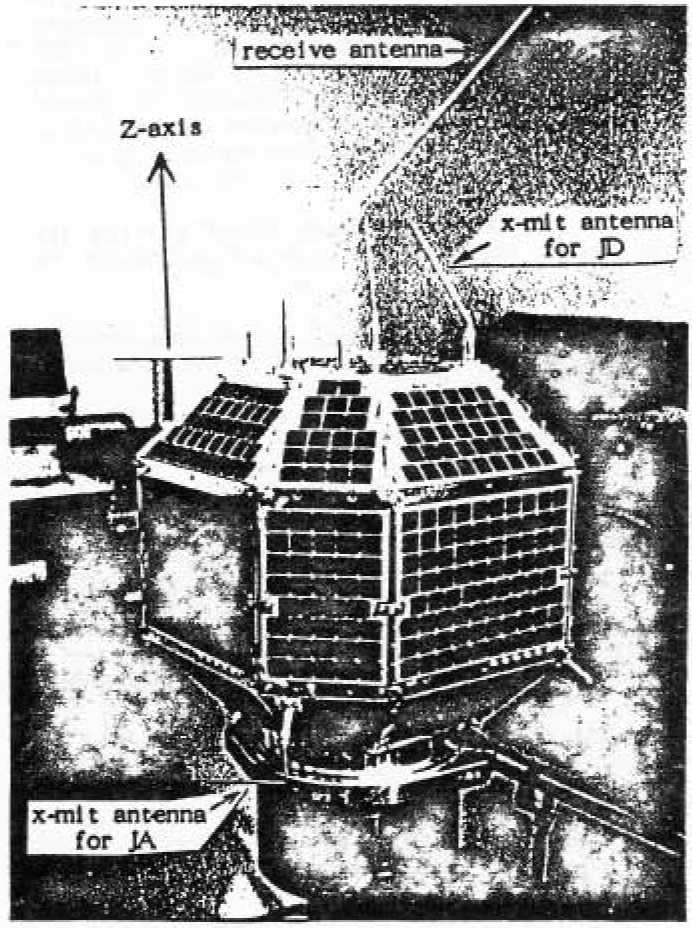


Figure 1.

At 2045, August 12th, 1986 UTC, H-I vehicle was launched successfully from Tanegashima Space Centre of NASDA, and the whole launch programme,

Table 1, Major specification of Fuji

unch and orbit

launch at	: August 12th, 1986 2045 UTC.
launch by	: H-I vehicle
launch from	: Tanegashima Space Centre of NASDA
orbit	: circular, altitude of 1500 km
period	: 116 min.
inclination	: 50 degrees
life	: 3 years expected

onstruction

weight	: 50 kg
shape	: polyhedron of 26 faces covered in solar cells
size	: 400 mm x 400 mm x 470 mm (height)
power generation	:8 watt at the beginning of life

Communication subsystem

Analog (JA) and digital (JD) communication in mode J.

Transponder

JA transponder (linear transponder)

input frequency	:145.9-146.0 MHz (bandwidth 100 kHz)
output frequency	:435.9-435.8 MHz (spectrum inverted)
required uplink elrp	: 100 W
elrp of transponder	: 2 W pep

JD transponder

input frequency	:4 channels of 145.85, 145.87, 145.89, 145.91 MHz
output frequency	:435.91 MHz
required uplink elrp	: 100 W
elrp of transponder	: 1 W rms
signal format	:1200 baud PSK, store and forward

Beacon and telemetry

JA beacon	:435.795 MHz, 100 mW, CW and PSK
JD telemetry	:435.910 MHz, 1W, PSK

including re-ignition of the second stage engine, was executed as scheduled.

About 62 minutes after the launch, JAS-1 was separated from the second stage, at the moment its switch was turned on, then transponder JTA started to operate and to transmit beacon signal including telemetry. The signal was received first by CEE of University of Chile, and twenty minutes later, it was heard in Europe and University of Surrey also received telemetry and reported data to JARL. From 2239Z, JARL could catch the signal from JAS-1 in Tokyo by themselves, on its first pass.

JAS-1 was named Fuji, after getting its orbit, and it may also be called Fuji-OSCAR 12 (FO-12).

NASDA provided for Fuji a very fine circular orbit as planned, and its latest orbital elements are shown in Table 2.

4. Performance of Fuji in orbit

Fuji has experienced both of eclipse maxima and minima since it was launched, and it is verified that temperature of the storage battery at the center of the satellite, does not exceed limited values of between 0 and 40 degree. Shading rate at the maximum eclipse becomes up to 31%, and 0% or no shade for some ten days at the minimum. Average output of the solar cell array was some 6W at the beginning of life.

Analog system JA

Transponder JTA in JA system started to operate at the moment of separation from the rocket, and has worked without any trouble.

Digital system JD

At the end of August 1986, transponder JTD in JD system was first activated. Strong PSK beacon was received, which showed only a series of flags of packet.

Then a programme for acquisition of telemetry data was loaded into the CPU of the JD system. This programme made telemetry transmission every two seconds, which was useful for many stations to exercise PSK signal reception and decoding, for several months. Next step was an operation of JD as a digipeater. After the preparation and verification of the programme on the ground, the first mailbox programme was loaded into FO-12, in June, 1987. Capacity of mail has increased up to 200 at present, from 50 at the beginning.

FO-12 has only one CPU, which cannot allow to load each programmes independently. All functions such as mailbox, telemetry and command processing, power system management and so on, are combined systematically. This work of construction of programmes required a large amount of time, because it was necessary to know in-orbit performance of the satellite for establishing parameters and procedure. Software group of JAMSAT made effort to realize mailbox.

Attitude of FO-12

JAS-1 was separated from the second stage rocket by pushing force of spring, at 2147, 12th. According to record of the received signal strength from the satellite, large variations of 4 times every minute were remarkable, indicating rotation of attitude.

Receiving antenna is a slanted quarter wave monopole on the top part of the satellite. Figure 2 shows one of the pattern of directivity of this antenna, with deep dips of about 25 dB.

Figure 3 shows a time-variation of received signal strength of the downlink, and Figure 4 is a decay curve of attitude variation for about one year. Small libration magnet attached to the inside of FO-12 cannot suppress these at t ude variation so quickly.

Variation of signal strength includes not only dip of antenna directivity but also polarization changes when received without changing polarization of receiving antenna on the ground.

JAS-1 is not a spin-stabilized satellite, and an axis of rotation is apt to move, because moments of inertia around three axes are similar to each other.

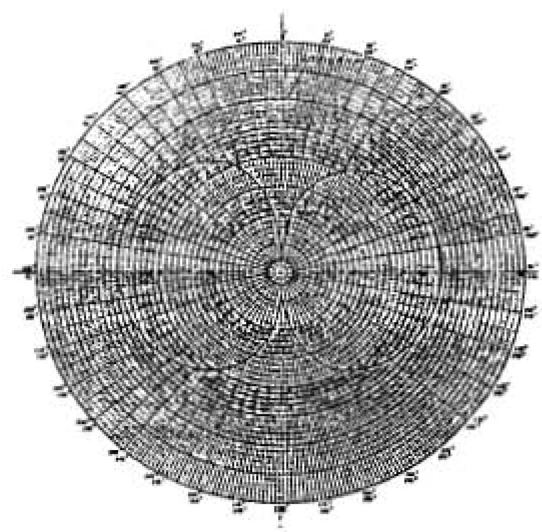


Figure 2.

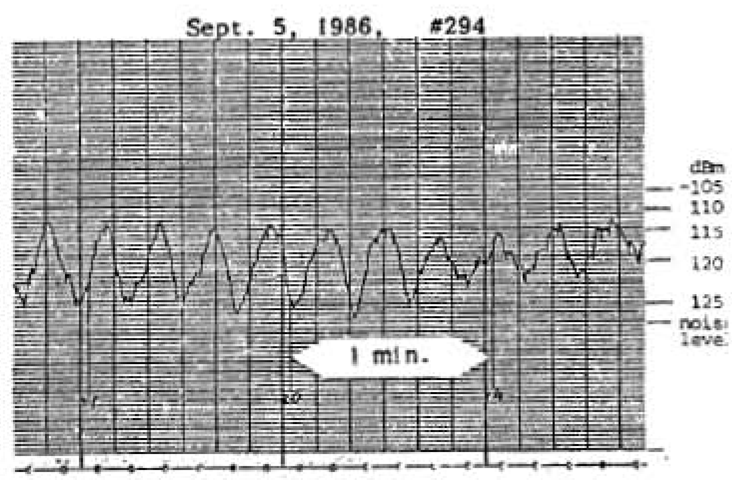


Figure 3.

Attitude of the satellite is estimated from telemetry data of solar sensor output signal of five solar panels. Solar sensor cell on one panel provides output signal bit of 1 for sunlit condition, and 0 for shade. Bit of 1 will occur when the sun illuminates the panel with even a very low incidence angle, that means this sensor has a very low angular resolution to the solar direction. Albedo, a reflected solar energy on the earth, makes these data more complicated situation. Therefore, it is difficult to determine its attitude toward the sun from the data. More improvement for the sensor is required.

Ineffective uplink

We have sometimes experienced commands and packets being not accepted by FO-12.

The reason why packets would not be accepted, may be considered as follows:

(1) Collision between packets

Ordinary collision of packets depress throughput down to less than 20 %, at pure ALOHA system that requires retry of transmission, when packets are crowded.

(2) Instantaneous increase of BER

Bit Error Rate of packet may increase when uplink signal encounters a dip of antenna pattern.

When FO-12 comes above Japan for instance, what does happen? Skies of Tokyo and Osaka are awfully congested in 2 metre band, and these energy will spread high above the sky. Consequently a part of these power will be received by FO-12 as undesired signal.

JA transmitter outputs 1 Watt for input level of -100 dBm. We sometimes recognize that JTA outputs around 0.5 W activating JTA in an instant, at the time of no scheduled operation. This means undesired input signal of -103 dBm or so.

An uplink from a typical earth station will provide an input power of around -100 dBm to the receiver. This gives enough Eb/No, a ratio of power per bit to spectral noise density, under the existence of natural Gaussian noise even at the worst directivity of receiving antenna, at which Bit Error Rate is less than 10^{-5}, that is required for packet.

If before-mentioned undesired signals exist, situation will change. Input power of -103 dBm of undesired signal makes Eb/No, decrease down to 29 and 20 dB for TCA and AOS/LOS, respectively, and this is still good enough for packet. For the worst directivity of antenna, however, 4 and -5 dB of Eb/No correspond to BERs more than 10^{-2}, much erroneous for packet. Around this direction, therefore, packets cannot be accepted.

(3) Scintillation

If there exist irregularity in ionosphere through which uplink signal propagates, packet signal can be affected to increase BER. These phenomena will spread over proper amount of area and hold for a while. Strong scintillation makes amplitude swing as large as ± 20 dB and more.

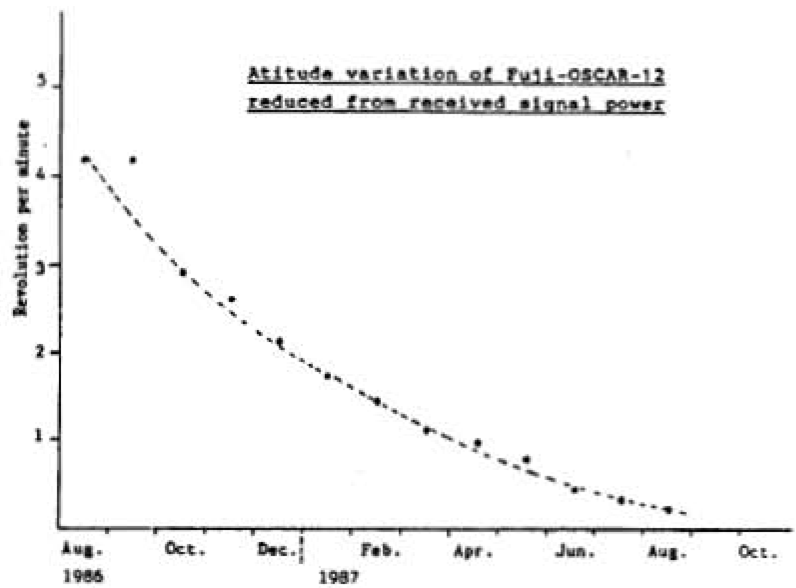


Figure 4.

Scintillation occurs more in 144 MHz band than 435MHz. But it is difficult to detect phenomena by link of FO-12.

Power Control Unit(PCU) and power condition

Power subsystem is controlled by PCU. Present setting of UVC (Under Voltage Controller) is at the lowest level, and full/trickle switching is at the highest level, to cope with decrease of capacity of battery, by widening its working range. For decrease of capacity of battery, it is said that reconditioning procedure may be effective. It is necessary to discharge battery deeper than 30% of the capacity, however,the system does not allow such an operation. It is better to have a simple and safe reconditioner.

The battery seems to be decreasing capacity gradually, that causes variation of charging mode according to output power of the solar array, which changes also due to the satellite attitude to the sun. At present, a full sunlit does not assure enough power.

Information of FO-12

At the beginning of mailbox open, information was distributed through W1AW by courtesy of ARRL and also through mail to each IARU Member Society, and RBBS of FO-12 was of course used. Owing to tight power condition, transponder cannot be operated continuously. Operating schedule is now distributed through magazines, OSCAR News and so on, including W1AW and FO-12 mailbox.

How many users are there on FO-12? It is easy to know number of space packeteers from the user's list in the mailbox. At present, it amounts around 200 stations, which may be of about 1% of all of packeteers.

We cannot estimate users of JA, but we think they are many, and also we are anxious for JA user P-3-C may be more attractive.

5. Future Satellite Project in Japan

JARL is now intending to launch another bird of JAS-1, a proto-flight model on the ground.

Considering the results of operation of FO-12 obtained so far, it is necessary to improve some parts. Mission subsystem will be kept unchanged, except transmitters. Improvement will be carried out mainly on following parts:

(1) power subsystem
(2) antenna subsystem
(3) solar sensor

Average power generation of FO-12 of 5 - 6 W at BOL decreased down to around 4 W, of which solar array consists of Silicon BSF cells. To increase power generation, solar cells are to be replaced by Gallium Arsenide cells and the outer panels of the bird are to be slightly enlarged to broaden surface on which solar cells are stuck. These will effect to increase 50 % of present power.

Orbit may be a polar one, but not circular, which will control power condition. Launch is not authorized yet.

Antennae are two sets of turnstile for uplink and downlink respectively. Downlink antenna for transmission is the same one as FO-12 in use, and is used commonly with both JA and JD. Receiving antenna has changed as a turnstile shaped circular around the skirt of the bird, of which a flat directivity may be expected. Downlink antenna may also show a better directivity by removing a slant monopole antenna.

Solar sensor should be improved to detect a direction of the sun more precisely as possible, within the limitation of telemetry items.

6. Conclusion

Outline of FO-12 in orbit and improvements of next bird is described. The next JAS-1b will be able to function as a standing mailbox, if power could be obtained as expected. More information will be announced, when details become concrete.

Table 2, Orbital elements
(provided by NASA)
date of issue :June 23, 1988

NASA element number:99	eccentricity :0.0011422
epoch :88162.57115930	argument of perigee:119.8763
inclination :50.0157	mean anomaly :240.3203
ascending node:0.6311	mean motion :12.44394851

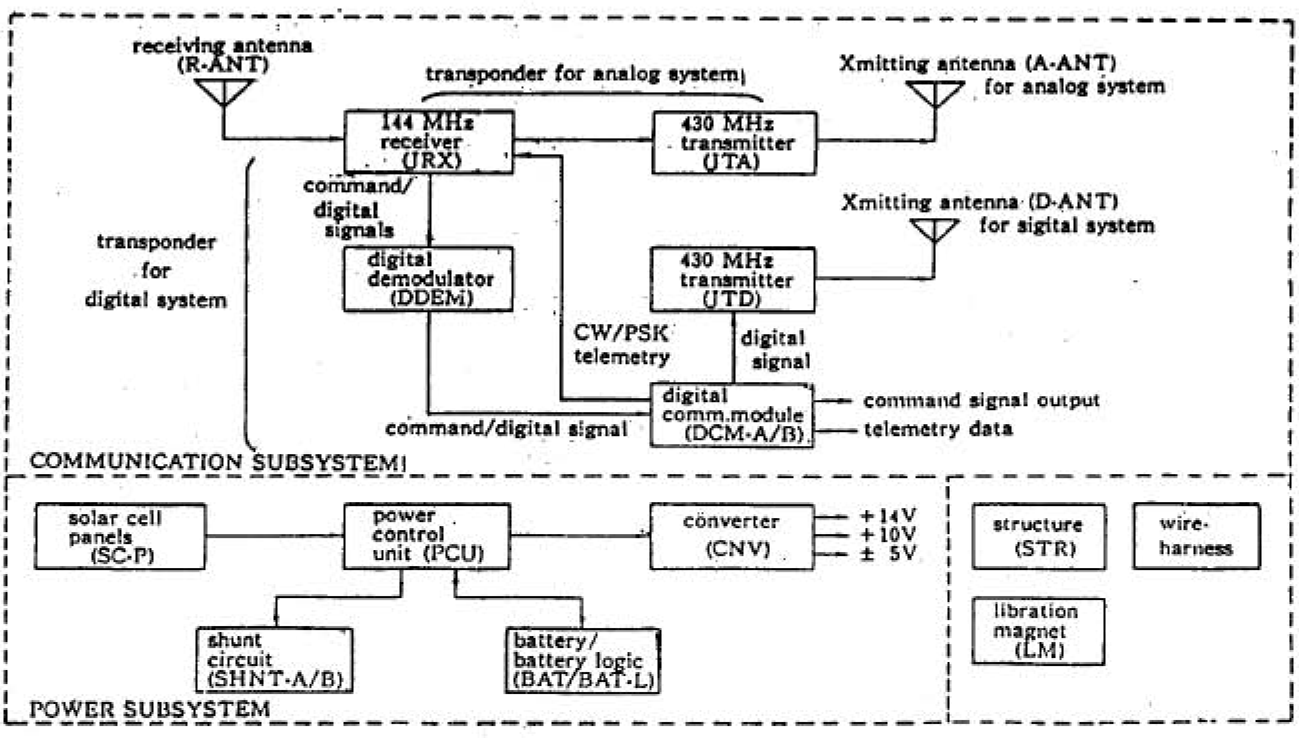


Figure 5.

The AMSAT Phase IV Project
A Mechanical Engineering Status Report

by Dick Jansson, WD4FAB
Project Administrator

INTRODUCTION

At this time a year ago, when we last met in Michigan in this august forum, you heard several reports on the preliminary efforts toward designing a viable Phase IV spacecraft. Since that time, we have made some very useful progress, not as much as had been hoped, but progress nevertheless. Some interfering elements entered our lives following last year's Space Symposium, such as doing the entire Mechanical Design of the Microsat satellite. The Microsat project will be reported in great detail by others and will not be further discussed at this instant.

Those interfering problems have not dampened our drive and desires for a really useful geostationary Amateur communications platform. In fact, the efforts on the Microsat program have sharpened our thinking and hardware knowledge of some of the non-mechanical aspects of Phase IV.

It is the purpose of this report to provide an update on the current status of Phase IV and give some idea about our plans for the coming year, including starting some of the hardware aspects of the program.

WHERE WE HAVE BEEN

When we last discussed Phase IV you saw some illustrations of an overall spacecraft, Fig. 1. We now understand, to a much higher degree of clarity, just how Phase IV would interface with an Ariane launch vehicle, Fig. 2. While seeming a bit cryptic, Fig. 2 shows us the locations in the launch vehicle that we can use, the areas that we have to avoid, and the stuff we have to get rid of before we are separated from the launcher.

It needs to be noted that most of this hardware has been previously flown. Such items as the "Separation 1920" is the identical separation section that was severed to expose Phase IIIC (now OSCAR 13) to space, prior to that satellite's final separation from the launch vehicle. In the case of Phase IIIC, however, the satellite was contained inside the 1920mm diameter cylinder, where on Phase IV that cylinder is a portion of the spacecraft.

Focusing on some of these large machined rings, which are inherent to the Ariane vehicle's prime load path, has caused some degree of consternation for our Team. These parts, Fig. 3, are large, complex, and quite expensive, certainly in the terms of component costs that we have become accustomed to seeing in AMSAT satellites. In the case of these flange rings, however, we have followed the Arianespace designs and cannot be too innovative, as we may never get accepted as a passenger on the launch vehicle, since a prime payload is supported by our rings. As we have had to slightly modify these rings for our own application, we understand, very well, how much is involved in their manufacture. The Lower Flange also has attachment points for the mounting of the skeleton of the Phase IV spacecraft.

When it is assembled as part of the Ariane "Adaptor", the conical structure which is the core of the Phase IV, the Lower Flange is quite a robust piece of hardware, and it can easily handle the loads of our spacecraft. Neither the cone nor the upper flange of the Adaptor are shown directly in the drawings to follow, as they have not been drawn in any detail as yet. The general space envelope for the cone is shown in phantom line.

We then place twelve "T" shaped vertical rails around the Adaptor, needed to support the Heat Pipe assemblies. These rails are supported by tubular struts bolted in place, Fig. 4. These struts will be made of carbon-fiber-epoxy composite with machined aluminum end fittings. Note that there are two type of struts, radial and diagonal. These strut supports should provide a very stiff, but light structure. While it appears that the tops of the T rails are just waving in the breeze, they really are captured by another piece of structure, as you will see presently.

The next element to be assembled on the Phase IV spacecraft is the mounting of the Heat Pipes, Fig. 5. These have changed somewhat in this last year, as we have been able to find a supplier who will construct the heat pipes in continuous loops, the design that we have needed for the Phase IV application. We have debated considerably in how to mount the Heat Pipes to a structure. The current implementations is a corner bracket that is riveted to the Heat Pipe in each of the twelve corners of each of the six Heat Pipes. We needed a cheap and easily reproduced bracket here and have now settled on one made from aluminum extrusions riveted together. Fig. 6 shows the Heat Pipes as they are installed onto the spacecraft structure. The Heat Pipes are mounted using a laminated shim pad at each corner so as to compensate for subassembly dimensional variations.

Just to take this verbal spacecraft assembly a bit further, let us add some more pieces. Fig. 7 shows one of the 72 the Solar Panels. While the panel substrate has not changed over this last year, the solar cells have changed. Our supplier of solar cells identified that using conventionally sized cells was costly, and that using rather large cells of 72.5 x 33.3 mm was the way to go. We had hoped for a complete series string of 72 solar cells on each panel, making wiring a bit simpler. Instead, the economics of covering over 50 square feet of Solar Panels shall be allowed to rule our wiring plans. Mounting these 72 Solar Panels onto the Heat Pipes will be a task that will not be quite as simple as it might seem, as each panel is mounted to its section of Heat Pipe with 20 #4 screws, a total of 1440 such screws for the entire spacecraft.

The final step of this mechanical assembly, as far as we will present at this time, is the mounting of the Top Plate, Fig. 8. This is a single twelve-sided piece of aluminum honeycomb material that is more than 6 ft. across and is bolted to both the Adaptor and to the tops of the twelve T rails in each corner, noted above.

We needed to get to this point in the assembly picture being presented here, as the Top Plate is one of the keys for our efforts for this next year. The Top Plate is the real heart of the Phase IV, as we will be mounting all of the electronic subassemblies, antennas, and many other parts to this plate. It can be seen that this single, removable structural component can be preassembled, wired and tested before it sees any of the remainder of the spacecraft, giving us great accessibility and freedom in our assembly and check-out operations. As can be seen, we have a fairly well detailed set of drawings on most of the major components of the Phase IV spacecraft. We even have manufacturable detail drawings on some of the more important smaller parts, quite an improvement on the design power curve from a year ago. Now let us discuss the next efforts.

WHERE WE ARE HEADED

One of the major happenings over the past year was the formation of an alliance between AMSAT-NA and Weber State College (WSC), of Ogden, UT. WSC has a program office that they call the Center for AeroSpace Technology (CAST), and this operation is very much different from those that you might have seen in almost any other academic institution. CAST is populated by both academic staff and by volunteers, and their objective is space-related projects, such as the NUSAT I that was launched into orbit from a Shuttle GAS cannister. CAST gets its labor force from the WSC requirement that each senior student complete a hands-on project that the student has applied him/herself at least 300 hours in their final year at WSC.

Weber State's CAST has proposed to perform a number of tasks on the Phase IV project for the academic year 1988-89. The focus of this effort centers on the Top Plate. While we are interested in learning the design and fabrication techniques to be used on that piece of honeycomb structural plate, we are even much more interested in seeing how all of the equipment that we want to fly on Phase IV will integrate onto the Top Plate. To this end CAST has proposed to:

a) Create a master system diagram for Phase IV, incorporating the efforts of the Phase IV Study Team and the desirable aspects of the Microsat project into a single definitive package.
b) Coordinate, examine and study the integration of various non-Amateur experiments onto the Phase IV bus.
c) Fabricate a complete scale = 1:1 Top Plate assembly with all equipment mounting points.
d) Model all of the system hardware and assemblies and define their mounting to the Top Plate.
e) Model the spacecraft major structure with low-cost mock-ups to study the interactions of the Top Plate, and its mounted equipment, with the remainder of the spacecraft.
f) Design and fabricate a low-cost tooling fixture for the Phase IV structural assembly.
g) Design assembly tooling for the struts. Fabricate sample struts and structurally test to verify mechanical properties.
h) Initiate a Finite-Element-Analytic structural model to follow the Phase IV design to insure structural adequacy.
i) Examine low-cost implementations of the Phase IV momentum control system.
j) Study the low-cost attitude sensor technologies needed for the mission.
k) Study and optimize propulsion systems for the mission.

While the above effort avoids getting directly into a major assembly effort and qualification tests of a full-fledged Phase IV structure, with its attendant costs, the program does very usefully address some very important subsystem integration topics. These tasks would need to be done at some time in the overall program, and it seems appropriate to tackle them now.

CONCLUSION

Phase IV represents a sizable project, both in terms of the final hardware assembly and in the total scope of the effort and its management. While Microsat may have seemed to have interfered in the progress of Phase IV, many of the key elements of systems that we will need for Phase IV will find their roots in the Microsat program. Microsat has not contributed anything, however, to the Phase IV mechanical engineering effort, as the two spacecraft are so vastly different in size and mission.

Managing a project the size of Microsat is very well within our direct experience in AMSAT. We need to learn how to change from the Microsat environment to one in which we are designing and managing a physically much larger device, such as Phase IV. Weber State's CAST brings to the program a facility and labor base that we could not readily find elsewhere in the AMSAT sphere of influence, certainly on this side of the Atlantic Ocean. We collectively need to work very carefully and thoroughly to bring the Phase IV in to being.

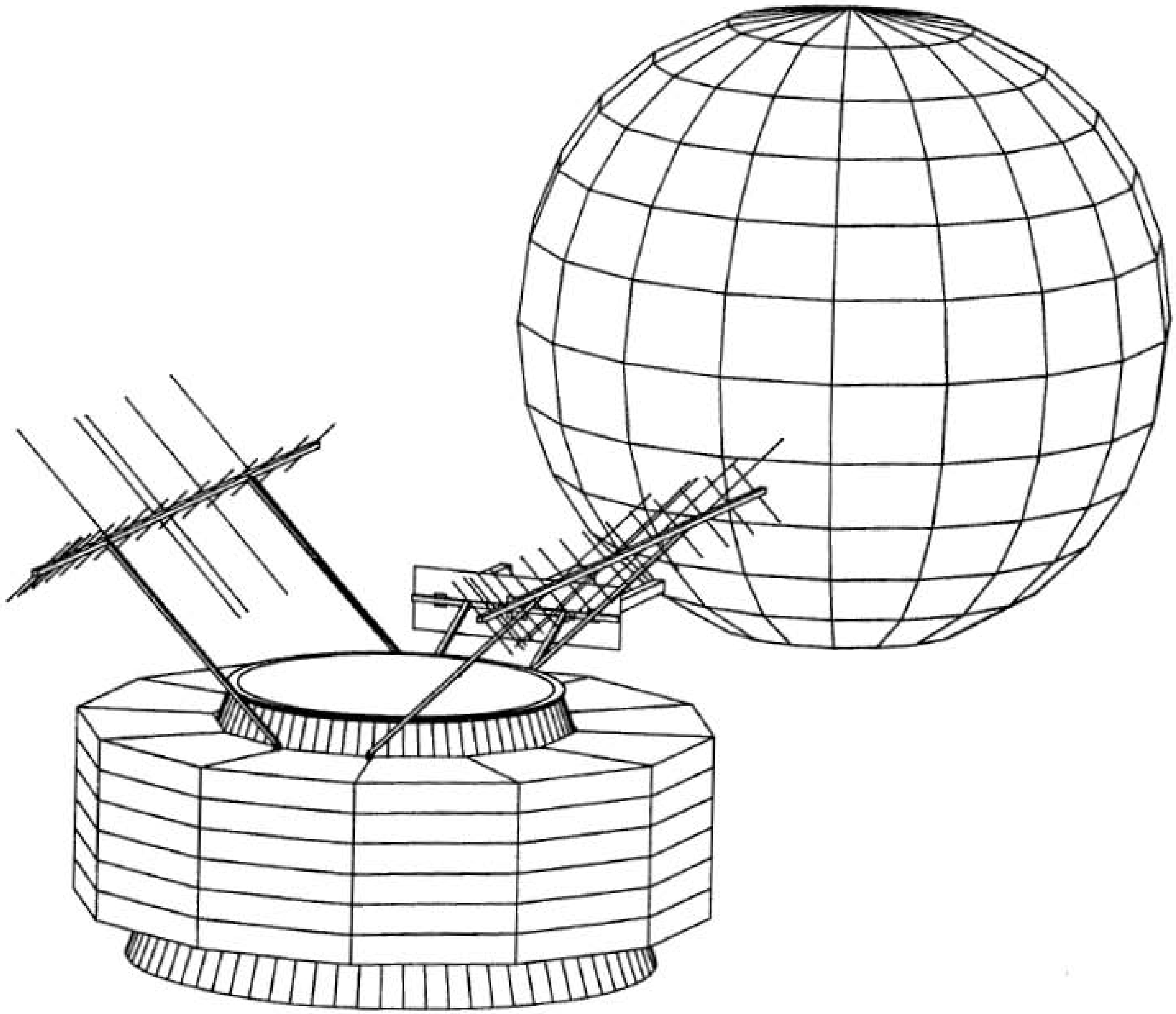


Fig. 1 - A computer's eye view of Phase IV in its geostationary orbit above the Earth.

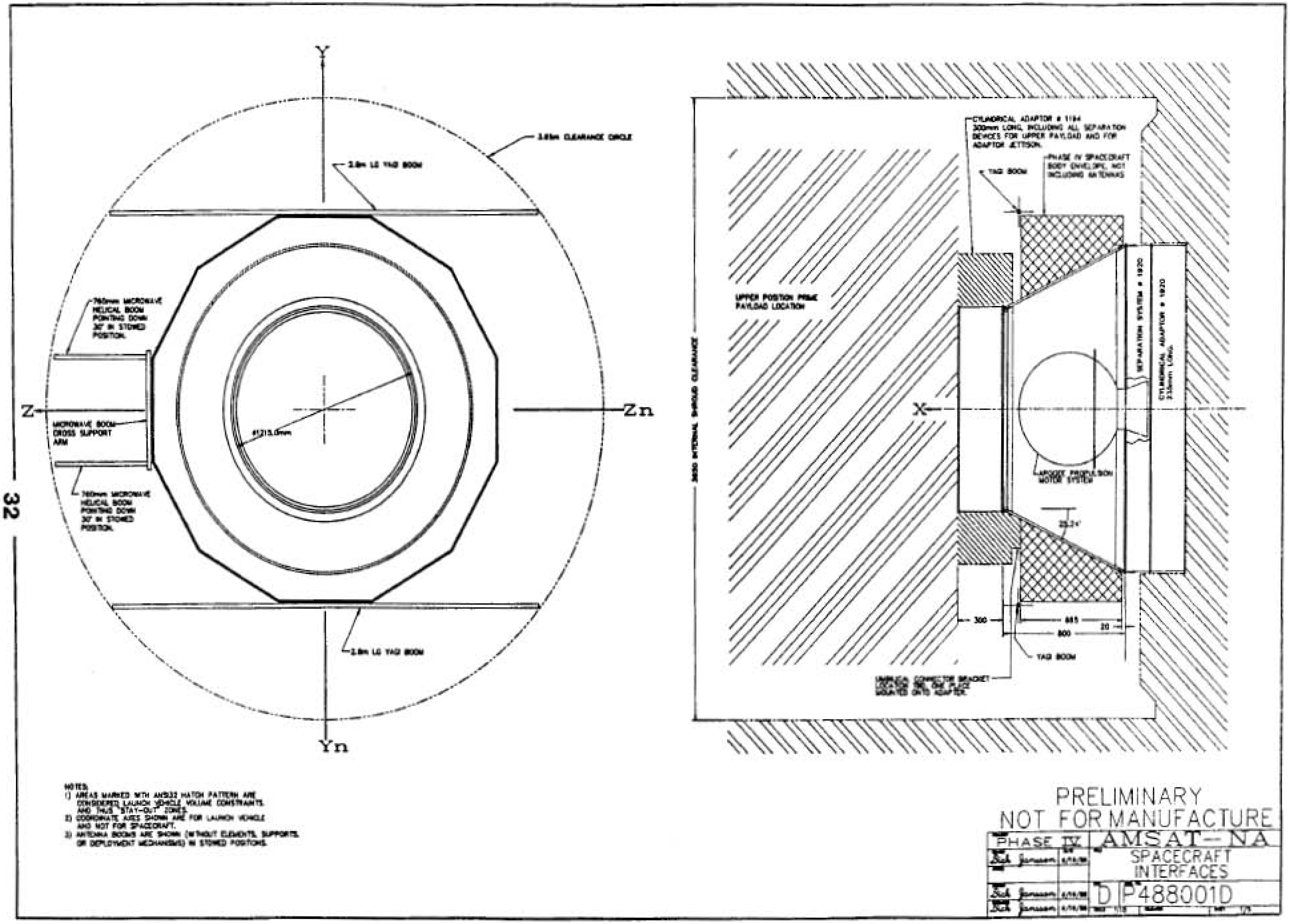


Fig. 2 - An interface study of Phase IV mounted in the Ariane 4 launch vehicle.

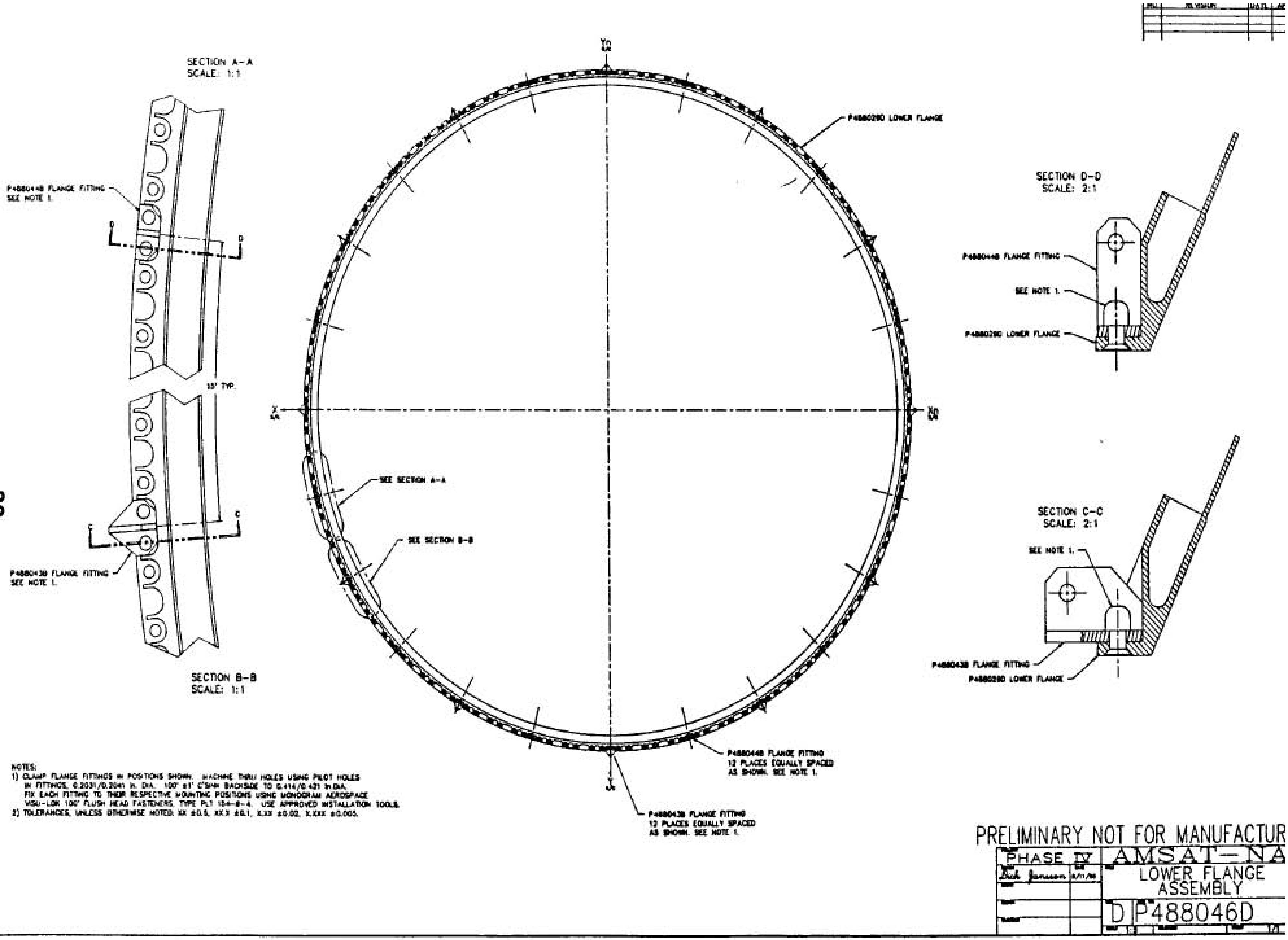


Fig. 3 - Lower Flange Assembly with the Phase IV attachment fittings.

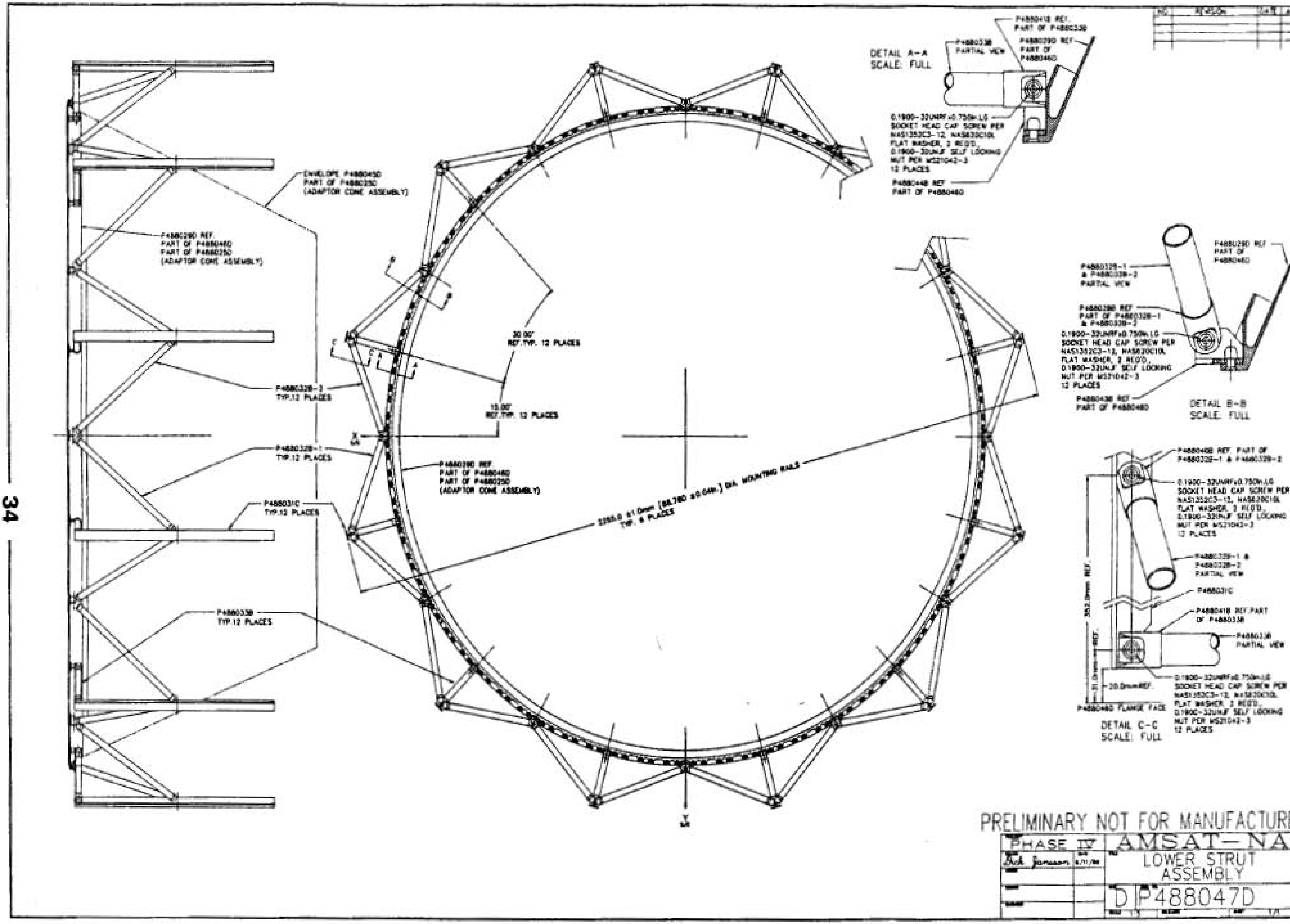
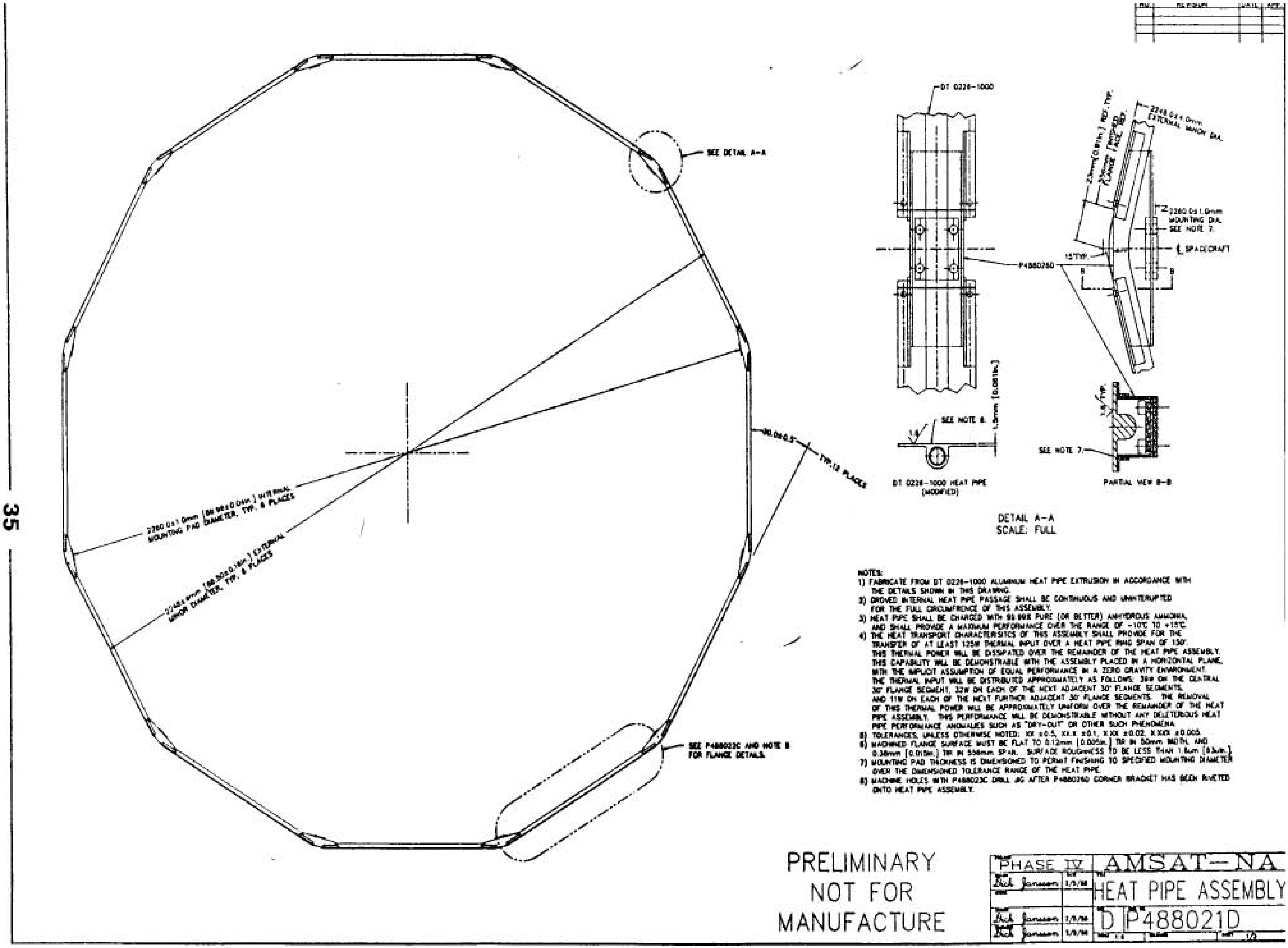


Fig. 4 - The Lower Flange starts to become a Phase IV with the 12 T rails and 36 struts installed.



SEE DETAIL A-A
SEE P488023C AND NOTE 8 FOR FLANGE DETAILS
TYP.12 PLACES
2260.0±1.0mm [88.98±0.04in.] INTERNAL MOUNTING PAD DIAMETER, TYP. 6 PLACES
2248±mm [88.50±0.16in.] EXTERNAL MINOR DIAMETER, TYP. 6 PLACES
DT 0228-1000
P488026D
SEE NOTE 8.
1.3mm [0.051in.]
DT 0228-1000 HEAT PIPE (MODIFIED)
2260.0±1.0mm MOUNTING DIA. SEE NOTE 7.
SPACECRAFT
15°TYP.
SEE NOTE 7.
PARTIAL VIEW B-B
DETAIL A-A
SCALE: FULL
NOTES:
1) FABRICATE FROM DT 0228-1000 ALUMINUM HEAT PIPE EXTRUSION IN ACCORDANCE WITH THE DETAILS SHOWN IN THIS DRAWING.
2) GROVED INTERNAL HEAT PIPE PASSAGE SHALL BE CONTINUOUS AND UNINTERUPTED FOR THE FULL CIRCUMFRENCE OF THIS ASSEMBLY.
3) HEAT PIPE SHALL BE CHARGED WITH 99.999% PURE (OR BETTER) ANHYDROUS AMMONIA, AND SHALL PROVIDE A MAXIMUM PERFORMANCE OVER THE RANGE OF -10°C TO +15°C.
4) THE HEAT TRANSPORT CHARACTERISTICS OF THIS ASSEMBLY SHALL PROVIDE FOR THE TRANSFER OF AT LEAST 125W THERMAL INPUT OVER A HEAT PIPE RING SPAN OF 150°. THIS THERMAL POWER WILL BE DISSIPATED OVER THE REMAINDER OF THE HEAT PIPE ASSEMBLY. THIS CAPABILITY WILL BE DEMONSTRABLE WITH THE ASSEMBLY PLACED IN A HORIZONTAL PLANE, WITH THE IMPLICIT ASSUMPTION OF EQUAL PERFORMANCE IN A ZERO GRAVITY ENVIRONMENT. THE THERMAL INPUT WILL BE DISTRIBUTED APPROXIMATELY AS FOLLOWS: 38W ON THE CENTRAL 30° FLANGE SEGMENT, 32W ON EACH OF THE NEXT ADJACENT 30° FLANGE SEGMENTS, AND 11W ON EACH OF THE NEXT FURTHER ADJACENT 30° FLANGE SEGMENTS. THE REMOVAL OF THIS THERMAL POWER WILL BE APPROXIMATELY UNIFORM OVER THE REMAINDER OF THE HEAT PIPE ASSEMBLY. THIS PERFORMANCE WILL BE DEMONSTRABLE WITHOUT ANY DELETERIOUS HEAT PIPE PERFORMANCE ANOMALIES SUCH AS "DRY-OUT" OR OTHER SUCH PHENOMENA.
5) TOLERANCES, UNLESS OTHERWISE NOTED: XX ±0.5, XX.X ±0.1, X.XX ±0.02, X.XXX ±0.005
6) MACHINED FLANGE SURFACE MUST BE FLAT TO 0.12mm [0.005in.] TIR IN 50mm WIDTH, AND 0.38mm [0.015in.] TIR IN 556mm SPAN. SURFACE ROUGHNESS TO BE LESS THAN 1.6um [63uin.]
7) MOUNTING PAD THICKNESS IS DIMENSIONED TO PERMIT FINISHING TO SPECIFIED MOUNTING DIAMETER OVER THE DIMENSIONED TOLERANCE RANGE OF THE HEAT PIPE.
8) MACHINE HOLES WITH P488023C DRILL JIG AFTER P488026D CORNER BRACKET HAS BEEN RIVETED ONTO HEAT PIPE ASSEMBLY.
PRELIMINARY
NOT FOR
MANUFACTURE
PHASE IV
AMSAT—NA
HEAT PIPE ASSEMBLY
D P488021D

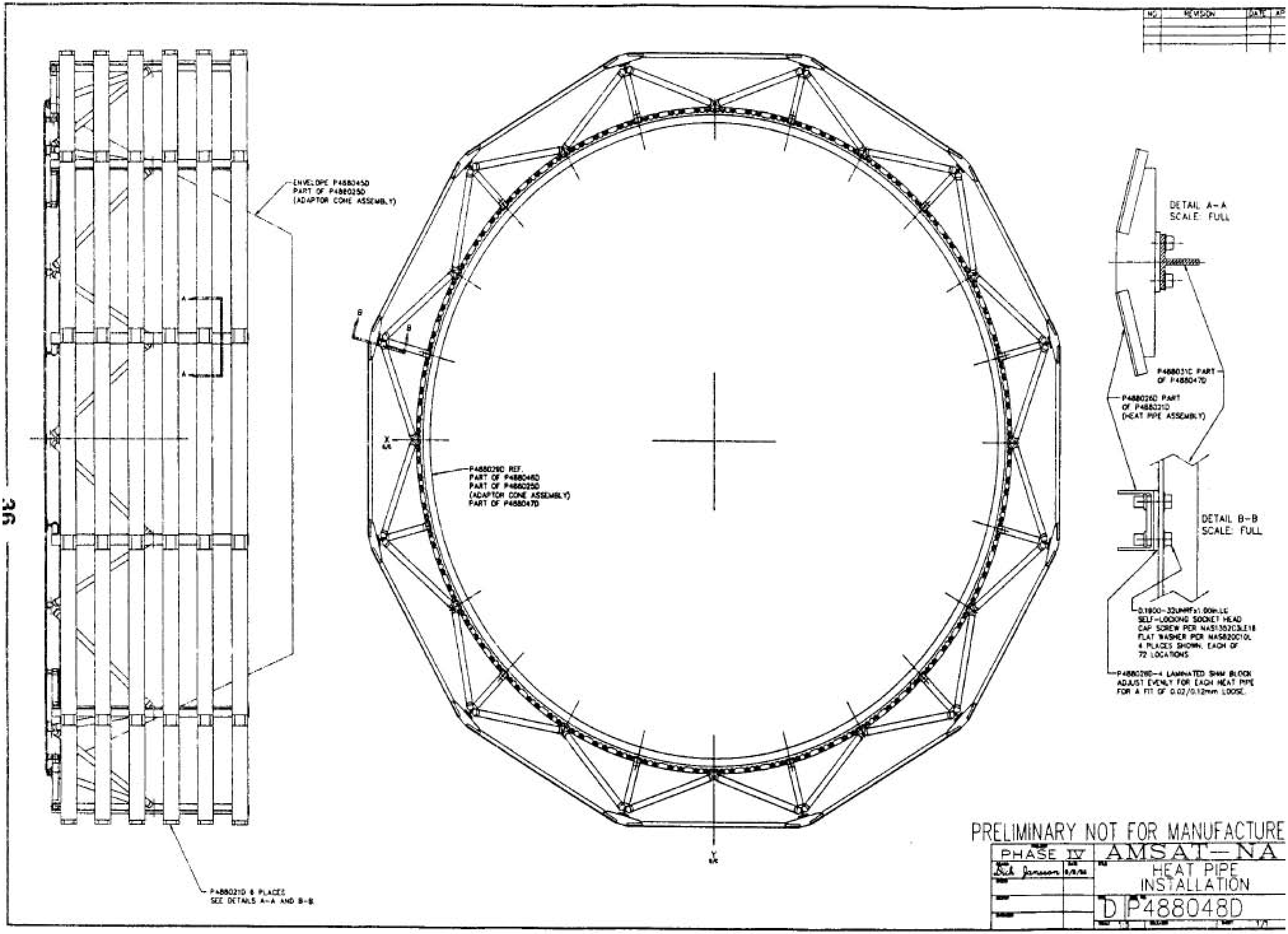
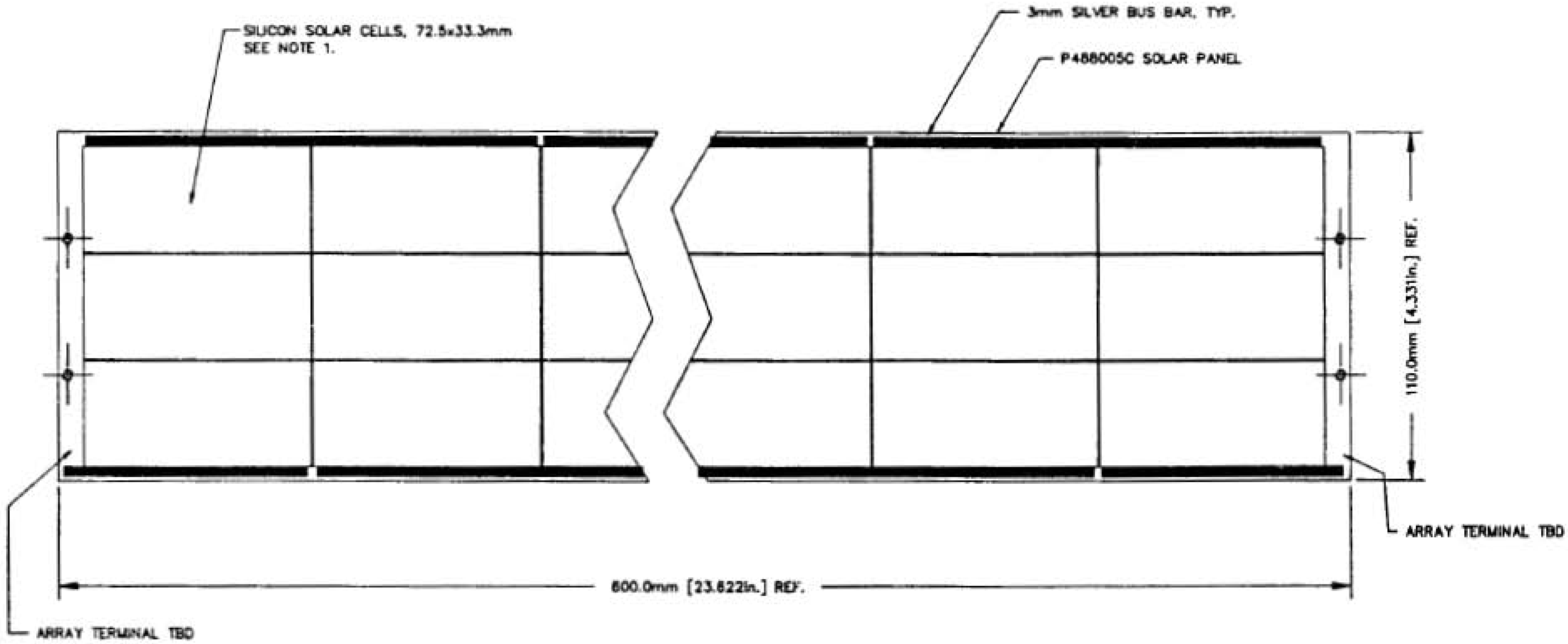


Fig. 6 - Six Heat pipes installed onto the Phase IV strut structure.



NOTES:
1) SOLAR CELL ARRAY COMPOSED OF 24 CELLS, 3 ROWS AND 8 COLUMNS, OF 72.5x33.3mm CELLS EACH. CELLS MOUNTED WITH TBD ADHESIVE ON 73.0x33.8mm CENTERS. SOLAR CELLS WILL BE PROTECTED WITH 0.006in.TH. A/R COATED QUARTZ COVER SLIDES, 72.5x33.3mm NOMINAL, MOUNTED WITH TBD ADHESIVE.
2) SOLAR PANEL WILL BE MOUNTED TO A PROTECTIVE BASE PLATE, SEE DWG.NO. TBD , FOR ALL OPERATIONS. SUBSEQUENT TO ASSEMBLY OF CELLS ONTO THE PANEL, CELLS WILL BE PROTECTED WITH COVER PLATE, P4880238, FOR HANDLING AND SHIPPING.

PRELIMINARY
NOT FOR
MANUFACTURE

PROJECT PHASE IV		AMSAT—NA	
DRAWN Dick Jansson	DATE 2/7/88	TITLE SOLAR PANEL ASSEMBLY	
CHECK			
DESIGN Dick Jansson	2/7/88	SIZE C	DWG. NO. P488018C
ENGINEER Dick Jansson	2/7/88	SCALE 1:2	RELEASED	SHEET 1/1

Fig. 7 - Phase IV Solar Panel assembly with the 24 large silicon solar cells suggested for this application.

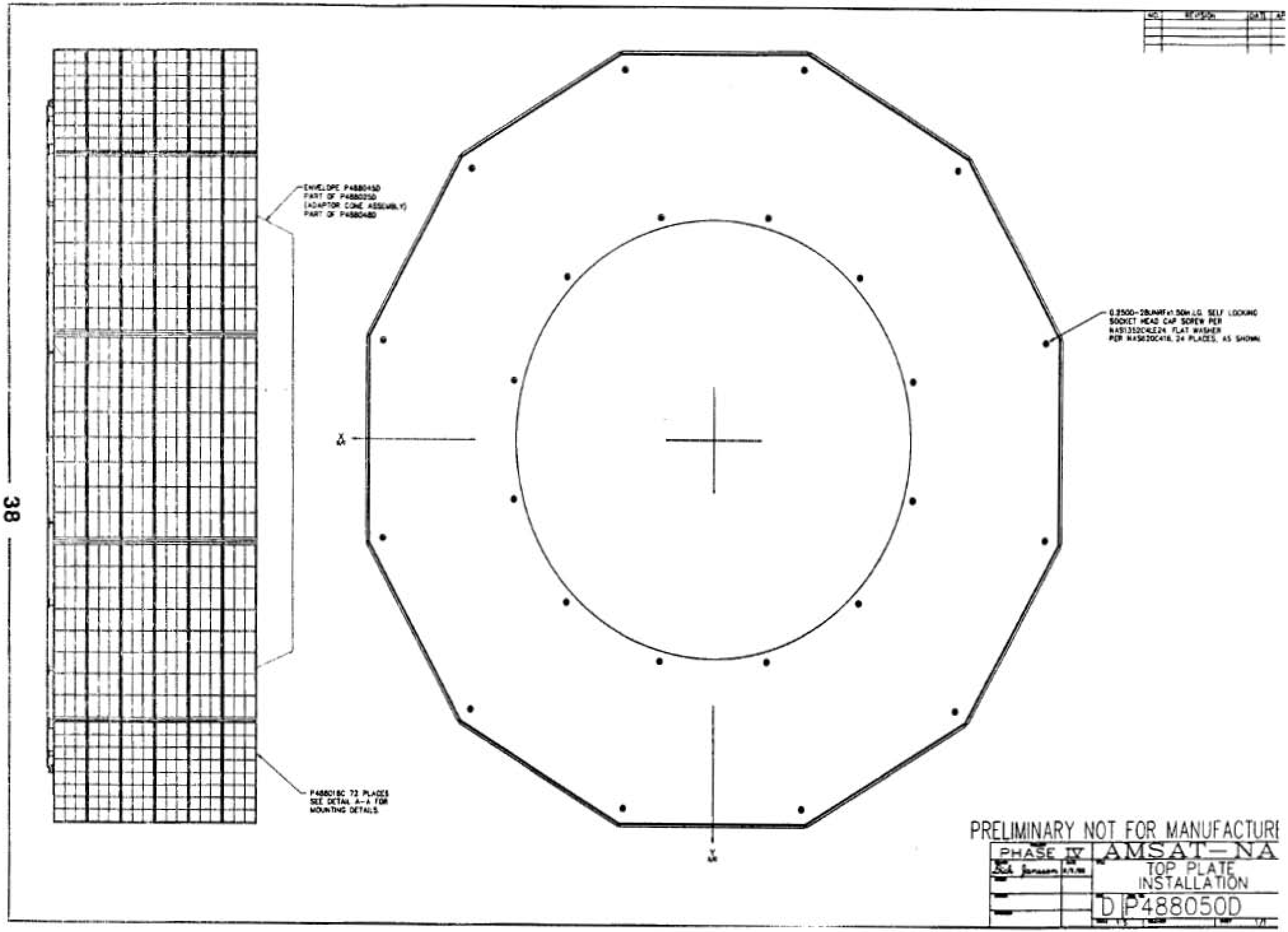


Fig. 8 - The Phase IV Top Plate mounted onto the structure.
This Top Plate will support nearly all of the electronic equipment and antennas.

THE AMSAT/TAPR DSP 1 PROJECT: HARDWARE DESIGN

by

Lyle V. Johnson, WA7GXD

BACKGROUND

A couple of years ago, Tom Clark, W3IWI and Bob McGwier, N4HY, began involving a number of Amateurs in applying digital signal processing (DSP) techniques to Amateur radio.

Recently, AMSAT and TAPR have combined forces to jointly develop and distribute DSP hardware and software for the Amateur community. Tom and Bob have written fairly extensively about the potential applications of DSP in the Amateur environment.

The first hardware fruits of this marriage is called DSP 1. This paper is intended to provide a design overview of the DSP 1 hardware configuration.

HARDWARE OVERVIEW

The DSP 1 is designed as a set of PC boards that can be configured to individual requirements. At a minimum, the system consists of a metal cabinet, an I/O board, a DSP board, a power supply board and a loader board. In place of the loader, a general purpose processor (GPP) board can be installed for greatly enhanced operation and flexibility. For all but the simplest applications the GPP will be required.

This breakdown of function to PC boards has the advantage of allowing upgrades at reasonable cost, providing flexibility for adoption of future standards or refinements in interfaces, and simpler troubleshooting. It has the disadvantage of increasing initial costs somewhat.

Cabinet

The system is designed around a Ten Tec B-series enclosure. This is an all metal, low profile box that can be shielded for RFI/EMI. The use of this enclosure increases costs over the type of case used by a TNC 2, but is less expensive than the "Gucci" cabinet used with the TNC 1.

I/O Board

The I/O board mounts on the back panel of the cabinet. All connections to the outside world are handled through this board. This allows internal interfaces to run at TTL levels for digital signals and -5V to +5V levels for analog signals. It also simplifies construction for the kit builder, eliminating wiring harnesses.

By standardizing all interface signal levels, future DSP and GPP boards may be developed to utilize improved technology without rendering DSP 1 obsolete. Future standards in radio and serial I/O interface levels can also be accommodated by replacing the I/O board rather than a far more expensive DSP or GPP board.

All connectors are well bypassed to ground for EMI/RFI. Radio interfacing (PTT, CW keying, microphone audio, speaker audio, up/down control, etc.) is handled here, along with level translation and filtering. Two radio ports are provided.

Serial I/O is handled at RS232 levels. Again, all level translation is handled on the I/O board.

A special TTL-level connector compatible with the modem disconnect arrangement used in TAPR TNCs and the TAPR PSK modem is also provided for those users who wish to use the DSP 1 as an external modem for an existing TAPR-compatible TNC.

Finally, power is routed into the DSP 1 through the I/O board for consistent filtering.

DSP Board

The initial DSP board is based on the Texas Instruments TMS320C15 processor. This is a first-generation DSP chip with some enhancements over the earlier TMS32010. It is run at a clock speed of 25 MHz, and has a full 4k words of high-speed static RAM for program memory.

An AD7569 eight-bit analog I/O port made by Analog Devices is used, and the board has provision for two such ports. Eight bits provide for over 40 dB of dynamic range, more than most radios provide at their audio outputs. More bits are useful for test equipment, but significantly increase the cost of the device.

Anti-alias filtering is generally required for any analog to digital converter. This filtering is provided in the case of the DSP 1 by a Gould S3528 programmable low pass filter. This filter provides a 7th order elliptic function with with stopband attenuation beyond the dynamic range of the 8-bit A/D converter. Placing its frequency cutoff under direct control of the DSP chip provides maximum flexibility for applications programmers.

A multiple channel programmable timer (82C54) is mapped in the TMS320C15 I/O space and may be used to generate interrupts and/or control the sample rate of the A/D and D/A. A phase shifter, designed by WB6HHV, allows the DSP chip to lock onto the external signal, allowing reduced sampling rates for a given signal after acquisition. This is a feature not normally found on DSP analog front ends, and should prove very useful in many applications.

Digital I/O is handled through CMOS eight-bit latches. This allows the DSP board to connect to a TNC and exchange TTL level data with the HDLC chip, thus acting as an external modem.

The 4k word memory has two access paths. An external device (loader or GPP) can suspend the DSP chip, access the 4k word area as an 8k byte area, and read or write to it. This is how the 32015 programs are loaded.

There is a series of single-bit latches provided to synchronize information exchange between the DSP and GPP boards for high-speed data transfers. Eight-bit latches are used to store the information bytes transferred in this manner.

Address mapping and general purpose logic functions are bundled into a reprogrammable logic device (Lattice GAL (r) or equivalent) to allow reconfiguration and reduction of parts count on this board.

CMOS parts are used exclusively for minimum power dissipation.

(A Look Ahead)

The next generation board (DSP 2) will have considerably more processing horsepower (Motorola DSP56001 or TMS320C25), memory and analog I/O resolution (12, 14 or 16 bits). It will probably contain FIFO buffers for all I/O. It will be designed to retrofit into the DSP 1 cabinet and utilize the GPP and other resources.

Power Supply Board

The power supply board provides regulated +5, -5, +10 to +12 and -10 to -12 volts from an unregulated +12 VDC nominal source. It utilizes switching techniques for efficiency, although the initial board may use simple charge pumps. There is nothing particularly unusual about this board.

Loader Board

The loader board is intended for low cost, modem-only applications. It allows the user to select from a number of programs stored in a single EPROM (4 programs in a 27C256, 8 in a 27C512). A press of a button halts the DSP board, loads the selected program into the DSP memory, then restarts the DSP engine. This board uses only a few standard CMOS logic functions and will be very inexpensive (excluding memory!).

GPP Board

The GPP board allows the DSP 1 system to become a highly flexible and very powerful communications tool for the Amateur.

The GPP is based on the NEC V40 integrated processor and 72001 serial I/O chip. This allows software to be developed and debugged on a standard IBM PC (r) or compatible system. This board features two serial channels running full duplex under DMA, allowing high speeds to be attained for use with such devices as the Heatherington 56 kbps modem.

Four (4) 32-pin bytewide sockets allow up to 1/2 megabyte of memory, with 64k bytes a typical minimum configuration. Battery-backed RAM and a CPU watchdog are included, along with a Centronics compatible parallel printer port.

CMOS logic and CMOS LSI are used exclusively in the GPP for reduced power consumption and high reliability. Programmable logic devices contribute to hardware design simplification.

Bytewide I/O ports to and from the GPP board allow high-speed data transfer with the DSP card. In addition, serial I/O supporting multiple protocols can be used to exchange data with the DSP section.

The net result is a truly flexible and powerful communications device. Narrow-shift RTTY (30 Hz shift for 60 WPM, for example), tracking filters, efficient HF packet, SSTV and FAX applications all become possible without compromised modem performance.

WHITHER SOFTWARE

The Dalanco-Spry Model 10 is being used by a number of Amateurs in the context of the overall DSP development project. This unit is a plug-in card for IBM PCs and compatibles. It allows development and testing of software for the TI 3201x processors. As such, it is an excellent development tool for the DSP 1.

There are a number of applications that have already been written and used by several Amateurs, including moonbounce work with OSCAR-class stations, weather satellite image decoders with software modems, PSK modulators and demodulators, etc.

In the case of DSP 1, the software is waiting on the hardware!

WRAP UP

The DSP 1 project represents a major effort by AMSAT and TAPR to provide the Amateur community with advanced, affordable technology to enhance digital communications. It provides a modular, flexible platform for experimentation and continuing development in this field.

As the technology represented by DSP 1 becomes commonplace in the ham shack, the need for new hardware to use new communications modes should become significantly reduced. For example, in order to use FUJI/OSCAR 12 or one of the new MicroSat-based PACSATs, one presently needs a PSK modem accessory for his TNC. Such a modem costs about $100 as a kit or $200 assembled. A DSP 1 should sell for less than the TNC and PSK modem combination, yet provide as much flexibility for the same specific application. It will also do numerous other things well, such as a multimode digital controller (like the AEA PK-232 or Kantronics KAM or MFJ-1278), or a special-purpose communications device (multi-level SSTV or WEFAX or weather satellite FAX decoder).

Digital signal processing techniques promise improved reliability in communications. The DSP 1 will help bring these techniques to Amateur radio.

MICROSAT PROJECT - FLIGHT CPU HARDWARE

by
Lyle V. Johnson, WA7GXD
and
Charles L. Green, N0ADI

ABSTRACT

AMSAT-NA is preparing a new class of satellite. Intended for low earth orbit (LEO), "MicroSat" will bring a new level of performance and flexibility to the satellite user community.

MicroSat embodies bold advances in low-cost satellite engineering. A new approach to satellite flight computer design was required to attain mission objectives: low power, low cost, small volume and mass, high performance, high reliability, flexibility, significant mass data storage capability and high speed I/O.

This paper focuses on the design of the flight computer hardware and outlines some of its capabilities.

INTRODUCTION

The first planned launch of the MicroSat series is scheduled in early 1989 aboard an ESA Ariane-4 rocket. A total of four (4) MicroSats are scheduled to be aboard: two (2) will be PACSAT missions [1], one (1) will be a speech synthesizer for educational use (DOVE) and one (1) will be a CCD camera experiment.

AMSAT, with support from TAPR, Weber State College (Utah), AMSAT-LU (Argentina) and BRAMSAT (Brazil), is designing and building these satellites on a fast-paced schedule. First proposed in late 1987, there will have been approximately one year elapsed time from concept to launch!

For the authors, it is reminiscent of the UoSAT/OSCAR-11 Digital Communications Experiment (DCE) schedule. The OSCAR 11 mission was proposed in late July, 1983, and delivered to NASA for launch in January, 1984 (and launched March 1, 1984)! [2]

The PACSAT mission spacecraft will have five 2m uplink channels and one 70 cm downlink channel. The modulation techniques will be fully compatible with FUJI/OSCAR-12 -- 1200 baud Manchester data fed to a standard 2m FM radio for the uplink and 1200 baud PSK data returned on the downlink. Eight (8) megabytes of message storage will be available on each PACSAT. Other data rates and modulation methods may also be experimented with via in-flight hardware reconfiguration.

GENERAL DESCRIPTION

A typical MicroSat occupies a cube about 9 inches on a side. The CPU module occupies a slice about 1-1/2 inches thick. The CPU power budget is only 1.5 watts.

The CPU module occupies two (2) PC boards and provides the following resources to the satellite:

- Six (6) serial I/O ports capable of multiple protocols.
- Six (6) channels of manchester decoding in the receive signal paths (five standard user and one special purpose).
- One (1) serial I/O port dedicated to telemetry gathering and control of the various spacecraft modules, experiments and systems.
- Six (6) DMA channels.
- 256k bytes of error detecting and correcting (EDAC) memory.
- Two (2) megabytes of RAM organized as four (4) 512k byte banks with dual-port access.
- Eight (8) megabytes of RAM organized as a serial-access pseudo-disk.
- One eight-bit A/D for analog signal measurement.
- Reference voltage for telemetry systems throughout the spacecraft.
- Eight (8) I/O ports mapped for external experiment support.
- Watchdog timer to automatically reset the CPU upon detection of a CPU crash.
- Ground control reset capability in case all else fails.

SPECIAL FEATURES

The CPU module utilizes CMOS logic and CMOS LSI chips throughout. It employs a true multitasking kernel and takes advantage of a reduced power wait state when the task scheduler allows. To reduce volume requirmeents, surface mount technology (SMT) ICs are used where available.

The microprocessor selected is the NEC 70208 (V40) CMOS integrated device. This IC contains a superset of the Intel 8088 microprocessor (including added instructions and reduced cycle times for a given clock speed) along with several peripheral functions. The on-chip peripherals include: clock generator; four (4) channel DMA controller (71071-compatible); UART (8251-compatible subset); three (3) sixteen-bit programmable timer/counters (8254-compatible); eight (8) input priority interrupt controller (8259-compatible); programmable wait-state generator and bus interface logic/drivers.

Additional DMA support is provided by a NEC 71071, a high-performance CMOS four (4) channel DMA controller. In conjunction with the V40 CPU, and allowing for the various modes and features used in the system, a total of six (6) usable DMA channels result.

Serial I/O (72001) chips are also from NEC. These devices are similar to the Zilog Z85C30 SCCs used in some Amateur packet applications, but provide a number of interesting benefits. The most important ones are (a) ability to interface to the V40 and 71071 with a reasonable amount of discrete logic glue and (b) independent programmable baud rate generators for each transmit and receive channel.

A Harris 2k byte CMOS fusible-link PROM is used for bootstrap memory. A smaller version of this same device was successfully employed for the same purpose in the UoSAT DCE.

EDAC

The EDAC memory posed an interesting challenge. This type of memory is necessary to store program code, vectors and certain data that cannot be allowed to become corrupted due to radiation effects.

The UoSAT DCE has 16k bytes of EDAC protected memory. The authors proposed a whopping 64k bytes of EDAC for MicroSat based on the availability of 64k by 1 CMOS memory chips. Surely, this should be enough memory for such a small satellite!

However, the software coders had other ideas and made it abundantly clear that at least 128k bytes of EDAC memory was needed and even more would be desirable.

The problem, as with most things in this roject, is that there just isn't much PC board area to cram ICs onto, and insufficient volume to easily stack more than three PC boards into. The EDAC memory utilizes twelve (12) memory chips to save enough information to recover from a one-bit error in each eight-bit byte.

Fortunately, 256k by 1 CMOS static RAMs became available in very limited quantities by June of 1988. The specifications for the chips were discouraging ... would apparently require a tremendous amount of power while operational. The price was only slightly more intimidating. Measurements, however, indicated power consumption would be manageable in this application. Successful operation of the wire wrap prototype running a program from the EDAC memory in early August of 1988 confirmed the earlier power consumption measurements.

Twelve Hitachi 6207 256k x 1 ICs are employed as the storage elements in the EDAC memory array, with a combination of 74AC and 74HC logic to provide buffering, syndrome encoding and decoding, and detected error logging. This memory occupies the lowest 1/4 megabyte of the V40 address space.

OTHER MEMORY

OSCAR 11's DCE demonstrated that conventional static CMOS bytewide RAMs would perform satisfactorily in low earth orbit [3]. Such memory requires software protection schemes to detect and errors in stored data. They are unsuited for program storage.

In the MicroSat CPU address space, the middle 1/2 megabyte is filled with such memory. A total of two (2) megabytes are located on the CPU main PC board, organized as four (4) banks of 1/2 megabyte each. Each bank is under control of the CPU and can be independently powered on or off, selected for access by the CPU or selected for access by an external experiment. This "dual porting" arrangement allows external devices (such as the Weber State CCD camera) to have high-speed access to memory for storage or retrieval of data as well as communication with the CPU. It also protects the CPU buses from any sort of malfunction by the external device.

Since the CPU controls the spacecraft as well as manages the experiments, CPU health is paramount to mission success. Hence, the dual port arrangement rather than allowing experiment access directly to the CPU's buses.

MASS STORAGE

It was determined that a total of two (2) megabytes of non-EDAC RAM is insufficient to support a PACSAT mission, especially when second-generation missions are flown with higher data rate radio channels. Speeds of 56 kilobits per second are envisioned in the near future for PACSATs and higher data rates soon thereafter. For this reason, additional memory is required.

On the other hand, many MicroSat missions may not require large amounts of memory, in which case the bank-switched two (2) megabytes will suffice. At a review meeting in Boulder, Colorado, in June of

988. WA4ONG suggested a serial-access mechanism be employed to allow a low-power, high capacity data storage device to be built on a separate PC board. This idea was adopted.

The mass storage board contains programmable address counters that may be written and read by the CPU. A 24-bit address bus is employed on the unit, allowing up to sixteen (16) megabytes of storage. Present chips limit this to 8 megabytes, but by mid-1989 it should be possible to build a 28-bit address bus unit (256 megabytes!) with at least 32 megabytes populated on the same size card!

The entire mass storage unit occupies eight (8) bytes of I/O space in the V40 address map. The address counter is auto-incremented following every memory read or write, so block move instructions may be employed to rapidly move chunks of data between mass storage and directly addressable CPU memory.

DMA

In order to provide capacity for high-speed data links, DMA techniques are employed in the CPU between the V40 and the 72001 serial I/O devices. Under DMA, the CPU has only to set up the DMA controller and serial I/O chip, then go on to other tasks. After the data is sent or received, the CPU will be interrupted. This greatly reduces the processing power needed to manage communications and allows for very rapid data link rates on multiple channels.

GENERAL LOGIC

Finally, it should be noted that programmable logic devices are not utilized in the CPU design. Currently available CMOS devices are either EPROM or EEPROM based (and thus susceptible to radiation damage) or too slow (Harris fusible link PALs). RAM based devices (Xilinx) are under investigation for future generations of MicroSats, but appear inappropriate for the present. Bipolar devices consume far too much power.

In order to achieve the required speeds with unknown capacitive loads, AC logic is generally employed. HC logic was used in the OSCAR-11 DCE and has performed well. AC logic will get its shakedown with the first MicroSats. The designers of the CPU think that the ground bounce spikes made famous by the designers of alternative pinout logic will not be a problem since such transients have plenty of time to subside at the relatively slow bus speed of the MicroSat CPU.

CONCLUSION

MicroSat provides a low cost spacecraft bus upon which various experiments may be flown. PACSATs will occupy two of the first four MicroSats. The MicroSat CPU is flexible and powerful, allowing significant growth in future mission capability without redesign.

It is the authors' hope that, with the successful launch of the first cluster of MicroSats, Amateur packet radio networking will take another giant step forward.

ACKNOWLEDGMENTS

The authors wish to thank the designers of the PS-186 [4] for many of the ideas employed in the MicroSat CPU. These are Mike Brock, Franklin Antonio and Tom Lafluer. Other ideas came from Tom CLark, Jan King, Bob McGwier, Harold Price and Skip Hansen.

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UNIFIED FILE MANAGEMENT SCHEME FOR MULTI-MICROSATS BY INTER-SATELLITE DATA LINK (ISDL)

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ABSTRACT

JAMSAT proposes a new scheme for better co-ordination of LEO store and forward communications satellites (PACSAT's). A satellite-to-satellite link between LEO satellites and Phase-3D (and/or Phase4) is to be employed. This system enables LEO PACSAT's to have a unified file system which gives PACSAT users a clear view of files in every PACSAT's. This leads to efficient use of users' time and effort. Employment of advanced coding technology will be essential to overcome tight satellite-to-satellite link budget. JAMSAT foresees MicroSats and a Phase3-D (and/or Phase4) satellite as a target to implement this approach.

BACKGROUND

The store-and-forward communications satellites, a.k.a. PACSAT, originally proposed by Dr. Tom Clark (W3IWI), are becoming a most popular ways of digital communications using satellites. JAS-1 (FO-12) as the initial satellite of this sort has proved the validity of its concept. AMSAT-NA recently proposed a very small and inexpensive satellite for the store-and-forward communication known as MicroSat. A number of similar satellites are supposed to be launched in a few years to come, which would lead to full-bloom of PACSAT concepts.

However, users may find inconveniences if several PACSAT's are in service independently: if one sends a message to his friend, the friend have to watch all MicroSats in order to find the very message. Moreover, he may not be assured if he could send a reply to the originator using a different MicroSat from which he got the message. The inconvenience in this case stems from the existence of satellite-dependent file systems, or lack of a unified file system for various MicroSats. Some sort of supervisory system will enhance the utility of MicroSats.

JAMSAT therefore proposes to make Phase3-D (or Phase4) satellite act as a 5T{{9dinator of file systems for MicroSats. This approa is chosen because of better visibility of MicroSats by a hig altitude satellites than by a dozens of terrestrial station (i.e. why NASA is launching TDRS satellites to abolish expensive-to-maintain terrestrial tracking stations.)

CONCEPT OF THE SYSTEM

A high altitude satellite with an onboard computer maintains a unified file managemet system for all the MicroSats in use. Th onboard computer is called a file system manager.

There is one file directory in the whole system. All MicroSat and the manager have the same copy. The directory contains no only originator and destinator, but also identification of a MicroSat which is in possesion of the content. Therefore, if on connects to a MicroSat, he can see a list of files stored i other MicroSats as well, which may include messages addressed t him.

The file system manager keeps the directory updated: when a fil is uploaded or deleted to/from a MicroSat, the directory (store in Phase3-D and/or Phase4) should reflect the change. A MicroSa is therefore obliged to notify the change to the file manager which enables the manager to relay it to all MicroSats in orde to update local directory copies in MicroSats.

Furthermore, an urget message could be relayed from a MicroSa (which originally received the message) to another MicroSa (which will be visible from the addressee in a minutes) throug the system manager. In this case, the manager works as a store-and-forward system connecting two MicroSats (super PACSAT!) Transfer of a message in this manner saves time which woul otherwise be spent only to wait for the very MicroSats in whic the message has been stored. The feasibility of this "supe PACSAT" service depends on (a) capacity of memory in the manage and (b) link capacity of inter-satellite links.

This satellite-to-satellite link may be used fo telecommand/telemetry system for MicroSats: the file syste manager monitors telemetry frames in MicroSat's downlink, an sends them to command stations via other MicroSats or directly By this service, command stations can grasp conditions o MicroSats in charge even when they are below horizon. This schem lessens the work load of telecommand stations which has merel been wasted to track satellites.

FEASIBILITY OF INTER SATELLITE DATA LINK (ISDL)

High quality inter-satellite data link is mandatory for this system. Nevertheless the large distance between MicroSats and Phase3-D (and/or Phase4) satellite makes the link budget very tight. Moreover we can not expect much output power nor high gain antenna for MicroSats.

The result of feasibility study on the link budget is shown below. No modification to the current MicroSat hardware design is assumed.

(1) MICROSAT -> PHASE3-D/PHASE4

1) Transmitted Power	35.0	dBm	
2) Transmitter Antenna Gain	0.0	dBi	
3) Space Loss	-176.1	dB	*
4) Receiver Antenna Gain	15.0	dBi	
5) Pointing Loss	-2.0	dB	
6) Polarization Loss	-3.0	dB	**
7) Noise Spectral Density	-173.8	dBm/Hz	***
C/N0	42.7	dBHz	
8) Data Rate	33.8	dBHz	****
Eb/N0	8.9	dB	
9) Required Eb/N0	5.4	dB	*****
Margin	3.5	dB	

* at 435 MHz, with 35000km range
** Assuming MICROSAT's antenna is linearly polarized
*** Receiver system temperature = 300 deg. K
**** 2400 bps
***** Viterbi Decoding, k=5, r=1/2

(2) PHASE3-D/PHASE4 -> MICROSAT

1) Transmitted Power	47.0	dBm	
2) Transmitter Antenna Gain	10.0	dBi	
3) Space Loss	-166.6	dB	*
4) Receiver Antenna Gain	0.0	dBi	
5) Pointing Loss	-1.0	dB	
6) Polarization Loss	-3.0	dB	**
7) Noise Spectral Density	-173.8	dBm/Hz	**
C/N0	60.2	dBHz	
8) Data Rate	36.8	dBHz	**
Eb/N0	23.4	dB	
9) Required Eb/N0	9.6	dB	***
Margin	13.8	dB	

* 145MHz, 35000km
** Same as (1)
*** With ideal BPSK demodulator

MicroSats is assumed to have mode J transmission/reception capability with 4800 bps modem, as is the case with planned initial two MicroSats, designed for usual PACSAT mission. In order to overcome large propagation loss, MicroSat should implement convolutional encoding (with r = 1/2 and k = 5) by software for decoding by Viterbi decoder to be installed in Phase3-D/Phase4. The effective data rate from MicroSat therefore becomes 2400 bps.

On the other hand, 4800 bps can be employed at full speed for the link from Phase3-D/Phase4 to MicroSats because of large Tx power available and less propagation loss at lower frequency. This link speed configuration (4800 bps for "downlink" and 2400 bps for "uplink") matches our scheme, for the planned file manager needs higher data link for trasnmission in order to broadcast one directory change to all MicroSats.

Conclusion

A system which integrates file systems distributed in MicroSats by using inter-satellite data link is proposed. Although the link budget is tight, the case study indicates this system is feasible without making a modification to current MicroSats design by employing coding transmission.

More studies are to be carried out, especially focusing on (1) implementation method of efficient decoder and demodulator, and (2) alternative cases which requires additional hardware on MicroSats.

THE MOUNT TOXAWAY NORTH CAROLINA
MICROWAVE BEACONS AND LINEAR TRANSLATOR

by Charles Osborne, WD4MBK

INTRODUCTION:

The following paper may at first seem a bit out of place in a satellite symposium, but closer inspection will reveal the beginings of a move in the southeastern US to more fully utilize our microwave bands. Someday perhaps we will be able to use small dishes to communicate thru an amateur geosynchronus satellite on the above 3.4 GHz bands.

This is the story of a beacon that eventually grew to encompase every amateur band from 432 MHz to 24 GHz. What's more it was retrofitted with linear translator capability on bands where to my knowledge, no other amateur translators or repeaters of any type exist. The idea is to show that operation on such bands is possible now, with amateur techniques and equipment. Why in a satellite Symposium ? The Beacon / Translator afterall resembles a ground based satellite.

PURPOSE:

The purposes of the beacon / translator are of course many fold. The main reason for its existance is of course to promote activity on the 3456, 5760, 10368, and 24192 MHz amateur bands. Propagation experimentation is the obvious other use for any beacon.

On some of these bands there is little if any chance of random contacts. The number of people on is very small and spread out, antennas are very sharp, RF power is quite low, the bands are very large, and absolute frequency accuracy is always in question. These all present very formidable obstacles to successful contacts. Just to have a test signal available 24 hours a day from a high mountain gives people something to work towards hearing. This eventually builds experience with both the stability of the equipment and the variablity of the paths on the band.

IMPLEMENTATION:

The K4MSK Mount Toxaway Beacon began as an idea for a 432 beacon following the 1985 September VHF contest. Even from our 4700' vantage point in EM85 we could hear only the WA4PGI beacon in Virginia. From my home station in Atlanta there were NO beacons to be heard on 432 and up. John, K4MSK, agreed to let me place a Beacon on his mountaintop at 4777'. We are fortunate that 2m and 220 were the highest bands he was interested in being active on, as the 432 and up beacons would make normal listening from the mountain all but impossible.

The Four Landers VHF Contest Group, of which I'm a member, already had a repeater on the mountain on 224.72 MHz, thus giving me a convenient control link.

At 115 miles out, my location near Atlanta Georgia is just beyond the radio horizon for the mountain. This further accentuates the signal strength changes from the beacon. However it makes it very difficult to go work on the beacon, since it becomes a whole day trip to go up and come back.

Over the winter of '85/'86 I had time to plan out many different beacon designs on paper and then build them up as modules. Everything fell in place with a system based on a 108.0177 MHz master reference crystal. This frequency was chosen because it allowed me to use a x4 multiplier to hit the tiny 432.070-432.080 beacon band on 70cm. This was the lowest band I had any plans to cover and the highest one the FCC had decided to legislate.

On the higher bands I felt any frequency within a reasonable tuning range of the calling frequencies would be fine. In fact, on 432 the close proximity to the calling frequency is a problem. The beacon , even running 800 mW to an omni antenna, is very loud. This causes AGC pumping and keyclicks when the band is open. Putting the 432 beacon band up 100 kHz or more higher in the band would help this situation tremendously.

In the final implementation I was able to get all the beacons within 4 MHz of the calling frequencies. This allows a 2meter transceiver to tune both the calling frequency and the beacons without having to have a special local oscillator built up just for beacon reception. 2meter transceivers are almost the world wide standard of microwave IFs.

Part of the pressure to put beacons on the other bands came from the local 1296 ops who were having a hard time making sure their equipment was working. Tom, W4VHH, who has been on 1296 for over a decade, offered to give me a tripler he had long since retired from 1296 use. This gave me a couple of watts on 1296 when driven by the 8 watts I was able to generate at 432. Gene, W4ODW, donated a big-wheel horizontally polarized omni antenna for 1296.

[Refer to the block diagrams at the end of the article. This will more clearly lead you thru the following verbal explainations.]

I realized that the 108.01775 MHz crystal would also lock a phase locked microwave source which I had for use as a 2160 MHz LO. This plus a 144 MHz drive signal modulated with the ID and 2304 would be operational as a beacon.

Next I found that by using a 20 dB coupler I could derive a low level sample of the 1296 output, mix it with the 2160 LO and get on 3456 MHz.

5760 MHz was next and also fell right out of the available modules already in the beacon. Since I had a 144 MHz driver all I needed was a 5616 MHz LO to mix with it to get the 5760 signal. Again the 108.0177 MHz reference xtal was used. I built up a distribution amplifier and power divider to split the 108 MHz reference signal to feed all the modules it was now being used by. I fabricated a x52 phase locked multiplier by modifying a x48 microwave source I already had.

For 10 and 24 GHz a slightly different approach was necessary. The 108 MHz would get me there, but not as an LO. The 108 MHz multiples fell close to the calling frequencies themselves. I elected to use the output from the 10 GHz source directly and drive an amplifier with it. The power to the amp would be keyed on and off, thus identifying the beacon in CW.

A sample of the 10 GHz beacon is then mixed with the output from a 13.8 GHz source. The resulting signal is near enough to the desired 24,192 MHz calling frequency.

903 MHz was brought up as kind of a ..."well you did all the other bands except this one..". So I used the 144 MHz identifier as a driver and mixed it with a 1047.916 MHz microwave source. This is the one band that I could not make lock to the 108.0177 MHz reference in some way or another. The reason for the high side LO was to match a bandplan published by the Southeastern Repeater Association. They have the Beacon frequencies above the translator outputs. Unfortunately this inverts the sidebands as well, making USB in on 3456 come out on 903 as LSB. This is a familiar situation faced by satellite users on some of the early OSCARs.

Portions of the beacon were placed into operation in June of 1986. It stayed on the air for about a year and a half until an intermittent failure in one of the microwave sources and a temperature related power supply problem caused me to pull it off the air in February '88 for the update to translator staus and a general tune-up.

The mountain is a very hazardous environment for anything human or electronic. The long AC power lines tend to build up tremendous surges during storms. The beacon is located in a small wooden building on the very peak of the mountain. This exposes it to 125 mph winds, 3" radial ice ,and subzero temperatures. The beacon building is guyed to the top of the mountain and well insulated. This allows the beacon and the other repeaters' own heat to moderate some of the extreme temperature variations. An ovenized reference crystal is still a necessity, particularly when multiplied as far as the beacon takes it. 500 Hz of drift at 108 MHz causes 125 kHz of wandering at 24 GHz !

THE TRANSLATOR IDEA:

Fall of '87 had brought me a few ideas to enhance the usefulness of the beacon. For one thing, I needed more information as to what was going on up on the mountain. The identifier was a cluge and begged for replacement. I saw an inexpensive repeater controller that finally provided the flexability I needed. It's made by a company called S-Comm in Denver. Their model 5K controller at $180 looked as if it packed a lot of features for the money.

By using its 3 inputs and 3 outputs plus some clever use of the COR lines. (that were supposed to come from a control receiver) I was able to allow programming of the microprocessor via touchtone pad remotely via the repeater.

Now that I had access to remote control, several features came to mind that would be very handy. On the microwave bands there was very little likelyhood of random contacts, so the difficulty in arranging SKEDs tends to discourage activity. I noted that by reversing the signal flow in the 3456 beacon section I could cause that part of the system to become a receive converter. Cheap TVRO LNAs give a low noise high gain front end for such a system.

The first IF in my design comes out on 1296 and thus has a good chance of being overloaded by leakage from the 1296 beacon. To prevent this I configured the 432 drive to the 1296 tripler could be interrupted. This cleared the 1296 spectrum so that an auxiliary input on 1296 could be summed in as well.

Both 1296 spectrums are downconverted to 2meters where amplification and heavy filtering could be more easily done. Using three two-section helical resonators distributed thru the gain stages I am able to bandlimit the downconverted pieces of 3456 and 1296 to only about 500 kHz worth of each band. So far this filtering appears adequate. If not, I have looped the 144 MHz signal on the back panel of the Translator chassis. This would allow me to downconvert to 10.7 MHz or 21.4 MHz if needed and use a xtal filter to precisely define the band. This segment would then be upconverted back to 144 with the same LO it was downconverted with cancelling any frequency error contribution.

Once the signal is at 2m, another possibility occurred to me. By using a xtal controlled 2m receiver I could pick a spot in the passband on which to listen for signals. A local hamfest netted me a vintage Kenwood TR-7400A that works well in this application. When the squelch opens, it triggers an input to the microprocessor. The processor then sends out a message saying "Signal heard on 1296.620 and/or 3456.97". This provides a rather clever way to find out if your signal is getting anywhere on these bands. The FM audio from the 2m receiver is fed into the repeater controller and decoded for any control tones. This gives me still another pair of control channels.

The repeater controller allows one other very useful feature. By remote programming of special command macros, I can cause special IDs to be sent, for instance, immediately following a power failure when the frequency accurracy may be a bit off. Or if one of the phase locked oscillators goes unlocked I can put out an occassional message saying that a particular band is off the air. Changes in antennas or EIRP could be folowed by similar messages to alert frequent listeners to the potential change in signal strength. Current frequencies for all the beacons can be entered as a part of the ID thus making the outdating of frequency tables due to crystal aging a thing of the past. This cuts down on the wasted time of listening for a beacon that is off frequency or off the air.

The 144 MHz signal passband is routed thru a variable attenuator and then combined with the 144 MHz identifier signal on 144.020. The beacon level is also variable. This allows independant level adjustment for the beacon and the translator passband. Eventually some form of passband AGC will be necessary, but for now I felt it was better to get the unit on the air and worry about the overload when it became a problem.

The 144 MHz passband/beacon spectrum chunk is then fed into the existing beacon system, upconverting the signals to 903, 2304, and 5760.

The Beacon Translator was placed on the air in May of '88 and proved very useful. Unfortunately, in July a near hit by lightning took it off the air. Luckily, the microprocessor and most of the key modules survived, so it will live again soon.

All the hardware fits in a 5.25 " high x 19" x 24" rack mount chassis and a 3.5" x19" x24" chassis. As the pictures accompanying this article show, it is one jam packed jig-saw puzzel of a microwave project.

The following is a table of the frequencies and EIRPs of the various beacon outputs as they are presently (Aug. '88) configured:

Band (MHz)	Beacon Mode,	frequency / EIRP
432	-A1 BCN only	432.0705 / 1 W omni K4NHN skeleton slot
903	-BCN/Translator output	903.900 / 4 W omni big-wheel
1296	-A1 BCN only	1296.211 / 2 W omni (off if RCV is on)
	-translator input	1296.000 - 1296.500 (switchable on/off)
2304	-BCN/Translator output	2304.370 / 1 W omni slot
3456	-Translator input	3456.350 - 3456.850 RCV only, southeast
5760	-BCN/Translator output	5760.930 / 1 W small horn aimed SSE.
10368	-A1 BCN only	10369.716/ 100 mW (under construction)
24192	-A1 BCN only	24195.976/ ?? (under construction)

CLEVER USES FOR THE BEACON/TRANSLATOR:

MASTER REFERENCES. My apparrent fixation on using as few xtals as possible has some hidden benefits to anyone who is close enough to hear several of the beacon output frequencies.

Example #1: Suppose you receive the 432 BCN on 432.0700 but on 1296 you hear it on 1296.200. Since the two are direct multiples of one another they will be x3 multiples by definition. If you are very clear in your understanding of how your particular 432 rig generates its offsets for the CW carrier proceed with trying to transmit, zero beat on top of the received 432 BCN. This will require a second 432 receiver or a friend close enough to hear both you and the beacon. Once you are exactly on top of the BCN carrier, look for your third harmonic on 1296. Retune the xtal in your 1152 MHz LO in the 1296 transverter until the beacon falls on exactly x3 of the 432 frequency. This will require an accurrate frequency reading on 432, probably from a good counter.

Since tuning in the beacon to exactly the same frequency tone each time is neccessary, I use a DVM that has an audio frequency counter built in. Using headphone jack audio I adjust the beat tone on CW to be 800 Hz on 432 and 1296. If all the carrier oscillators in both your 1296 system IF rig and the 432 rig are where they should be, this will result in the digital readouts now being exact on each band. Further tests using even higher bands of the beacon's outputs can give you even more reference points. This helps pinpoint which oscillators in your system are off frequency. It becomes like solving simultaneous equations.

One point to remember is that once you get above 903 MHz the sheer magnitude of the multiplication numbers used to derive your local oscillators will cause the stability of any crystals in your system to be very very critical. Rechecking over a period of days and weeks will likely reveal that un-ovenized crystals are to be avoided for use in converters at 2304 and up. [This gets into an area that is beyond the scope of this paper, crystal parameters. Stability over time and temperature as well as initial frequency accuracy all contribute to whether or not you'll be faced with annoying questions of what frequency you are operating on. The study of crystals is an involved subject, yet a worthwhile one to learn about.]

Example #2 Another trick is to use 5760 and 2304 to check the accuracy of the 5760 and 2304 local oscillators. Take the frequency of the beacon on 432.0705 and divide by 4. This gives the master xtal reference frequency at 108.01775 aprox. Multiply by 20 to get the current LO frequency (2160.35 approx.) for the 2304 beacon.

Multiply the reference xtal number by x52 to get the 5760 system LO (approx 5616 MHz). Both bands use the same 144.020 approximate crystal to get 2304 and 5760 outputs. Receive the beacon on each band (actually easier than you might think if you are within 125 miles of the mountain) and record the frequency you believe its on. Subtract the 5616 LO frequency and the 2160 LO frequencies from their respective bands. This back calculates to the 144.020 crystal frequency. If you don't get the same number, re-check your LOs.

Use the 1152 LO in your 1296 receive converter to (which was accurately set in the previous example) generate harmonics of the 1152 signal. Listen for them on your receivers at 2304.000 and 5760.000. If the signal is not heard on these frequencies, record the difference. This should help to find which LO is off frequency. Correct the LO frequency error and remeasure the 2304 and 5760 beacons. They should now be where predicted.

Again bear in mind that this use of the 1152 LO is based on the premise that the frequency accuracy of your 144 rig is set to within a few Hz. All these mathematical methods get more and more messy when any correction factors are used to compensate for crystals that can't be pulled onto the required frequency. Forcing crystals too far in frequency causes their temperature stability and cold start up properties to change. These methods are called " a transfer of standards". It's a little bit like zero beating a 10 MHz crystal in your own station to WWV. Within the limits of your ability to match the two, you have transferred the WWV frequency standard into your own equipment. The above methods work similarly, only by the time you get to the microwave bands the transfer of standards Hz errors can really add up if care is not taken.

PROPAGATION. Using the beacon as a standard eirp transmitter, day to day propagation variations become trackable. An added trick usable in my system is the use of the translator to see the paths on two bands at once.

By transmitting on 3456 MHz and listening to your own signal on 2304 you have access to more information than might be apparent at first. By comparing your return signal strength to the beacon strength on 2304 for several days you can get an idea how the path varies on 3456. The beacon strength itself shows the path variations on 2304. If you just listen to your own 2304 return signal over a period of time and ignor the fact that 2304 and 3456 propagation are both changing, you are clouding your data.

These tricks are a lot like comparing your downlink signal to the amplitude of the beacon on OSCAR-10 or 13. If you hear the OSCAR beacon very clearly but your own translated signal is weak, then the problem is your Uplink. If you hear the OSCAR beacon weakly , but your own translated signal is almost as loud as the beacon, then your receive system is what needs improvement. On my beacon / translator I refer to the path from user to the mountaintop as the "inbound" path. The mountaintop to the receive site is called the "outbound" path (earthbound equivalent of uplink and downlink).

THE IMPACT OF THE ARRL PROPOSED NEW BEACON PLAN:

In general I'm not too ruffled about the ARRL's new beacon plan. In fact, at least on 432, moving the beacons up a few hundred kilohertz would be good. That would allow us to run more power. My beacon runs 800 mW to a horizontal omni big-wheel antenna. At 115 miles out, in Atlanta, the signal never goes below the noise. When the band is open, my FT-767GX has trouble handling the 59+30 dB signal from the beacon while trying to receive a weak station 30 kHz away on 432.100. The problem is that the AGC pumps in time to the beacon. For that reason I purposefully left a fairly long dead time in the ID string so I could listen for other beacons and/or work people whenever the beacon was not transmitting.

Activity on 432 is still so low in the southeast that the 200 mile radius beacon coverage area only encompasses about 50 432 stations. With activity so low, the beacon becomes even more important because the band may be open and nobody is on to even work. The beacon solves this problem of finding signals at 3 AM also, for those of us known to be curious about propagation in the off prime time hours. So the higher the power the better. I'd love to be able to hear the WA4PGI beacon in Virginia more often than just during an opening.

Curt, WB2GGP, in Tampa Florida has an excellent 432 beacon on the air that solves the power versus overload problem nicely. He uses a PROM for his ID. Extra bits were available, so he controls an attenuator as the ID scrolls thru. The Beacon identifies at 50 watts, 5 watts, 500 milliwatts, and 50 milliwatts and then starts over again. It also tells you the power at each step in CW. If you normally only hear the 50 W signal and today you can hear the 50 mW signal just as well as the 50 W usually is, you know that the band is open 30 dB more than normal. Pretty clever I think.

The ARRL impact on my beacon would be to break up all the interdependancy on the one or two oscillators. Since they have (unwisely in my opinion) stopped 1296 beacons from being x3 triples of their 432 counterparts, any attempts at the frequency accuracy transferance games mentioned above will be impossible. Not that this is a prime consideration, it was just a nice added feature.

A lot of the microwave bands in my beacon would have to be locked to a 108.000000 MHz xtal now instead of the 108.01775 xtal. The beacons suggested on most of the bands are at .300-.400, so by simply changing the 144.020 oscillator to 144.350 for instance, most of the beacons would then fall on the band plan.

10 and 24 GHz fall directly on the calling frequencies of 10,368.000 and 24,192.000 MHz when the beacon is modified as mentioned to the ARRL plan. This is not desirable but is the best I'll likely be able to do. It's better to have some beacon, even if its not exactly in the perfect spot, than to not have any beacon at all.

All the whining and rhetoric about wanting the beacons close to the respective calling frequencies is just a holdover from the days of non-synthesized radios. Today if your digital readout says 144.0000 and your rig really is on that frequency, when you get to 147.550 there is little doubt that it really is 147.550. Synthesizers multiply by integers which gives them virtually perfect linearity, so long as their reference crystal is exactly where it should be. By checking one frequency, you are verifying the accuracy of the radio at all frequencies within its range so long as it doesn't switch to another reference crystal.

There are however a few games played in some of the cheaper implementations that use digital to analog converters to drive a VCO (my FT-767GX for instance is one of these I believe). These rigs are the ones that have little gaps and overlap zones when you tune across a CW signal. This is evidenced by the musical note not smoothly progressing, but rather having little unequal tone jumps, usually at repetative digital readout intervals of 5 or 10 kHz. This is caused by a cheap varactor diode causing a non-linear tuning curve in a VCO that is programmed to tune only perhaps 5 or 10 kHz before the synthesizer is incremented. If the VCO was linearized this method would be fine. In fact it would give lower phase noise than implementing 10 Hz steps in a synthesizer. Again the complaints are largely a holdover from the days of VFOs with non-linear response across a 500 kHz or 5 MHz range.

Complaints about wanting the beacons close to the calling frequency also don't make sense in view of the proliferation of radios with a large number of memories and multiple VFOs. These features allow jumping from the calling frequencies to the beacon and back in an instant.

I'll grant you, the changes proposed by the ARRL will not be incorporated into my beacon at K4MSK/BCN in the near future. With over 1000+ manhours expended in the development of the Beacon / Translator as it stands today, and a few hundred dollars out of pocket, I am trying to catch up on some of my own work around the house and my own station to insure domestic tranquility etc... before I start any major rework on something that is working out as planned.

Many of the beacon's subsystem parts are from my own station, thus taking me off a few of the bands until I can duplicate the items. It was worth it though. There's no use being first on a band if there's nobody to talk to. I felt the Beacon to be the the perfect gift to activity in the south as a necessary precursor to my own station's completion on 2304 and up. It seems to be working out well.

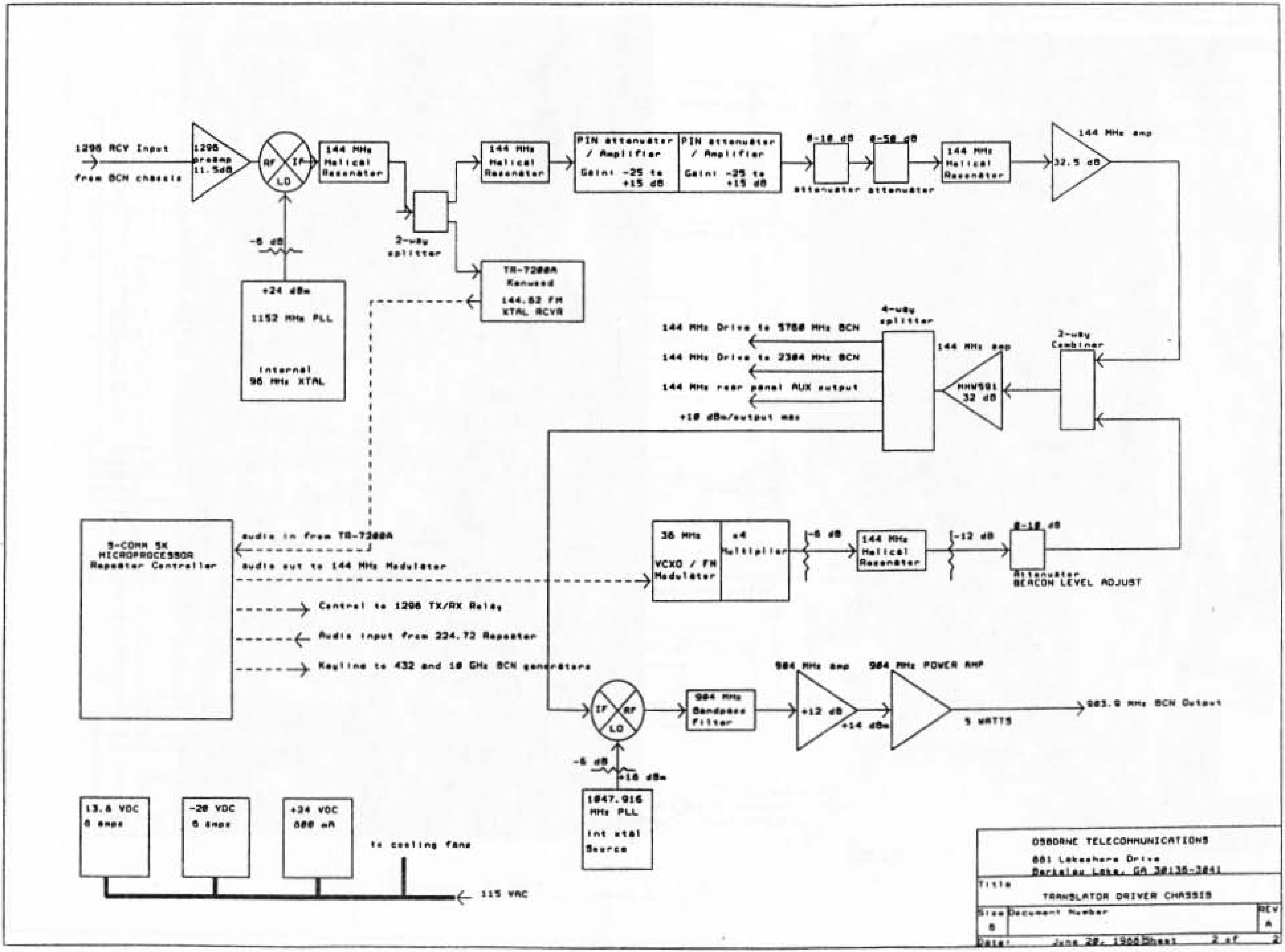
ACKNOWLEDGMENTS:

For donations of component assemblies, help in construction, testing on the air and on the mountain, these people helped make the Beacon / Translator possible:

W4VHH, W4ODW, K4MSK, The Scientific-Atlanta Amateur Radio Club WA4LOJ, K4KAZ, WB4EFZ, WS4F, K4NHN, WB4SLM, WW4T, W4ZPG, WQ4V, K4NEF, NC4W, and many more.

For Further Information and for Reception Reports send to:

Charles S. Osborne, WD4MBK, 881 Lakeshore Dr., Berkeley Lake, GA, 30136-3041. Phone: (404)242-7864 home, (404)925-6229 office.


1296 RCV Input
from BCN chassis
1296 preamp 11.5dB
RF
IF
LO
-6 dB
+24 dBm
1152 MHz PLL
internal 96 MHz XTAL
144 MHz Helical Resonator
2-way splitter
144 MHz Helical Resonator
TR-7200A Kenwood 144.82 FM XTAL RCVR
PIN attenuator / Amplifier Gain: -25 to +15 dB
PIN attenuator / Amplifier Gain: -25 to +15 dB
0-10 dB attenuator
0-50 dB attenuator
144 MHz Helical Resonator
144 MHz amp
32.5 dB
2-way Combiner
144 MHz amp
MWA501 32 dB
4-way splitter
144 MHz Drive to 5760 MHz BCN
144 MHz Drive to 2304 MHz BCN
144 MHz rear panel AUX output
+10 dBm/output max
S-COMM 5K MICROPROCESSOR Repeater Controller
audio in from TR-7200A
audio out to 144 MHz Modulator
Control to 1296 TX/RX Relay
Audio input from 224.72 Repeater
Keyline to 432 and 10 GHz BCN generators
36 MHz VCXO / FM Modulator
x4 Multiplier
-6 dB
144 MHz Helical Resonator
-12 dB
0-10 dB
Attenuator BEACON LEVEL ADJUST
IF
RF
LO
-6 dB
+10 dBm
1047.916 MHz PLL
Int xtal Source
904 MHz Bandpass Filter
904 MHz amp
+12 dB
+14 dBm
904 MHz POWER AMP
5 WATTS
903.9 MHz BCN Output
13.6 VDC 6 amps
-20 VDC 6 amps
+24 VDC 800 mA
to cooling fans
115 VAC
OSBORNE TELECOMMUNICATIONS
801 Lakeshore Drive
Berkeley Lake, GA 30136-3041
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June 20, 1988
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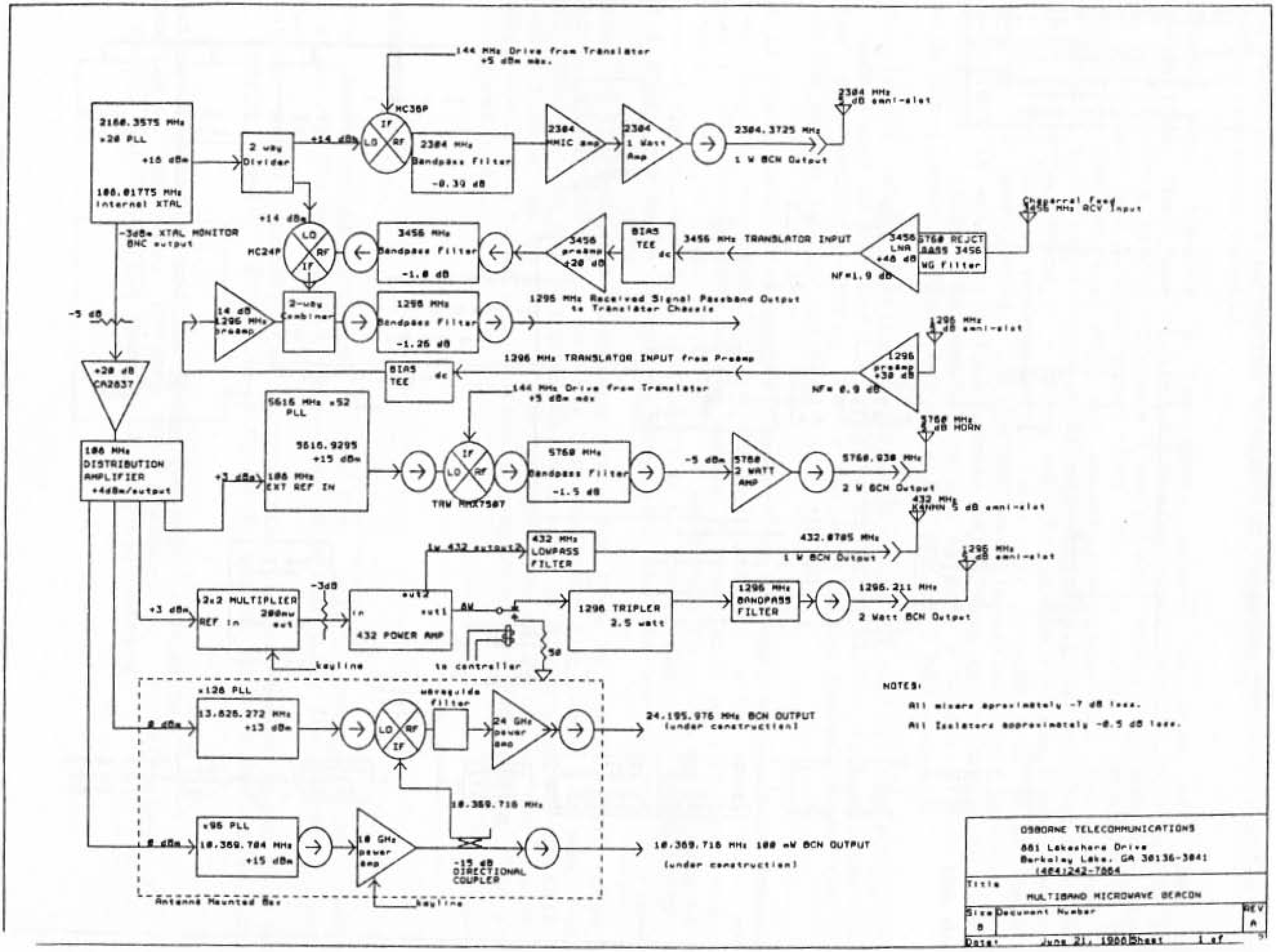
144 MHz Drive from Translator
+5 dBm max.
MC38P
IF
LO
RF
2160.3575 MHz
x20 PLL
+16 dBm
100.01775 MHz
Internal XTAL
2 way
Divider
+14 dBm
2304 MHz
Bandpass Filter
-0.30 dB
2304
MMIC amp
2304
1 Watt
Amp
2304.3725 MHz
1 W BCN Output
2304 MHz
5 dB omni-slot
-3dBm XTAL MONITOR
BNC output
+14 dBm
MC24P
3456 MHz
Bandpass Filter
-1.0 dB
3456
preamp
+20 dB
BIAS
TEE
dc
3456 MHz TRANSLATOR INPUT
3456
LNA
+40 dB
NF=1.9 dB
5760 REJCT
PASS 3456
WG Filter
Chaparral Feed
3456 MHz RCV Input
-5 dB
14 dB
1296 MHz
preamp
2-way
Combiner
1296 MHz
Bandpass Filter
-1.26 dB
1296 MHz Received Signal Passband Output
to Translator Chassis
1296 MHz
5 dB omni-slot
1296 MHz TRANSLATOR INPUT from Preamp
1296
preamp
+30 dB
NF= 0.9 dB
+20 dB
CA2837
108 MHz
DISTRIBUTION
AMPLIFIER
+4dBm/output
5616 MHz x52
PLL
5616.9295
+15 dBm
108 MHz
EXT REF IN
+3 dBm
144 MHz Drive from Translator
+5 dBm max
TRW MMX7507
5760 MHz
Bandpass Filter
-1.5 dB
-5 dBm
5760
2 WATT
AMP
5760.930 MHz
2 W BCN Output
5760 MHz
20 dB HORN
432 MHz
KANNN 5 dB omni-slot
1w 432 output2
432 MHz
LOWPASS
FILTER
432.0785 MHz
1 W BCN Output
1296 MHz
5 dB omni-slot
+3 dBm
12x2 MULTIPLIER
200mw
REF in
out
-3dB
in
out2
out1
432 POWER AMP
AW
keyline
to controller
50
1296 TRIPLER
2.5 watt
1296 MHz
BANDPASS
FILTER
1296.211 MHz
2 Watt BCN Output
x128 PLL
0 dBm
13.825.272 MHz
+13 dBm
waveguide
filter
24 GHz
power
amp
24.195.976 MHz BCN OUTPUT
(under construction)
10.369.716 MHz
x96 PLL
0 dBm
10.369.704 MHz
+15 dBm
10 GHz
power
amp
-15 dB
DIRECTIONAL
COUPLER
10.369.716 MHz 100 mW BCN OUTPUT
(under construction)
Antenna Mounted Box
keyline
NOTES:
All mixers approximately -7 dB loss.
All Isolators approximately -0.5 dB loss.
OSBORNE TELECOMMUNICATIONS
881 Lakeshore Drive
Berkeley Lake, GA 30136-3041
(404)242-7084
Title
MULTIBAND MICROWAVE BEACON
Size
B
Document Number
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Date:
June 21, 1988
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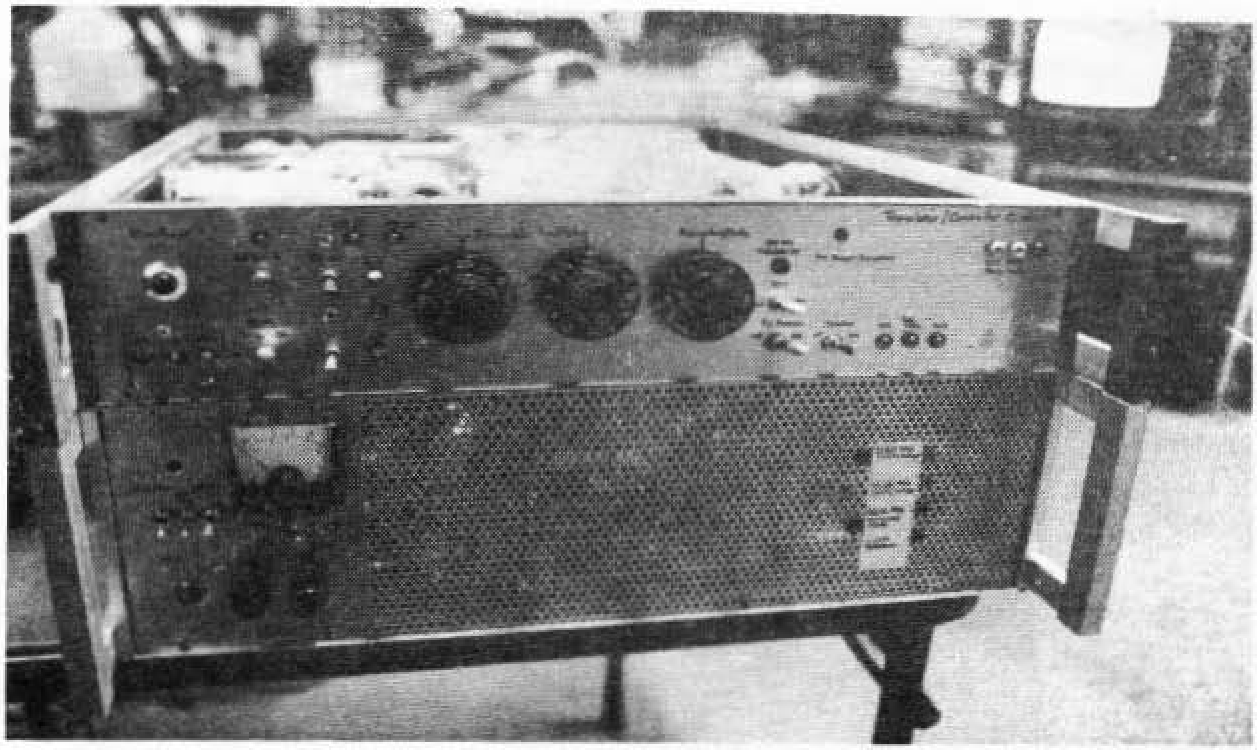
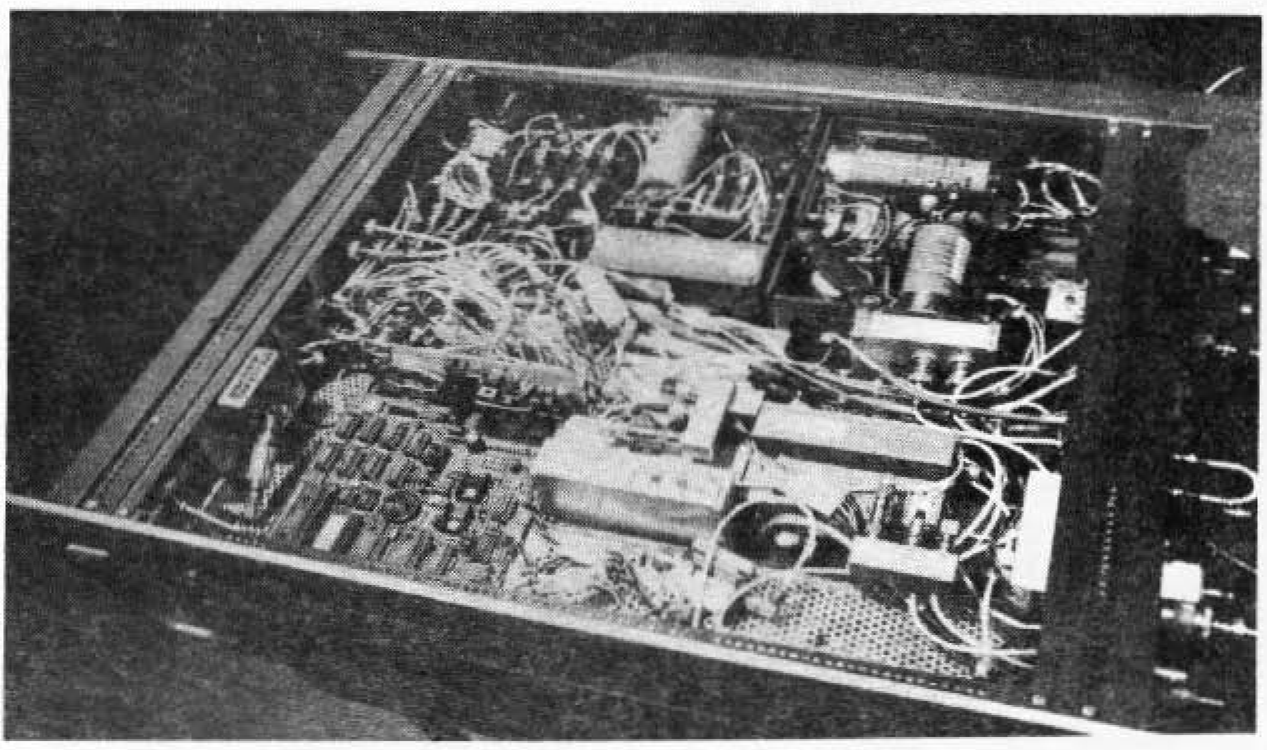
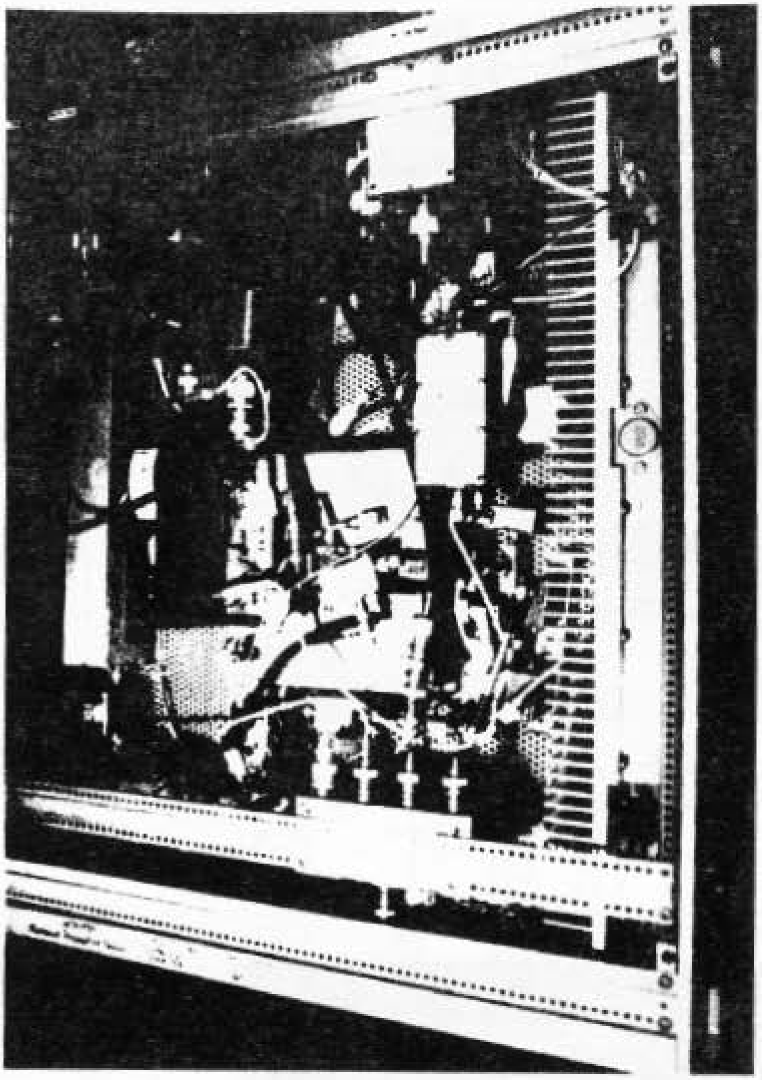


Front view of the Beacon (bottom 5-1/4" chassis)
and the controller/Translator (top 3-1/4" chassis).



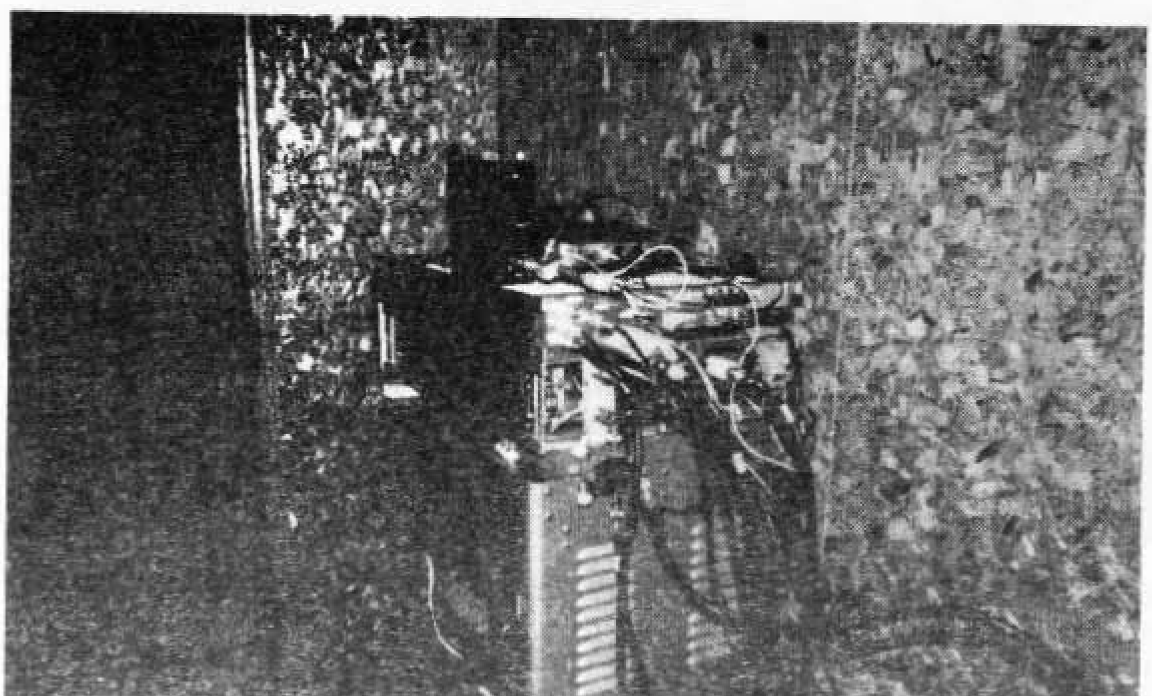
Interior view of the Controller/Translator chassis showing microprocessor, 1296 downconverter (lower right), 904 beacon transverter (lower center), 144 MHz Translator IF (center), and power supplies (top).

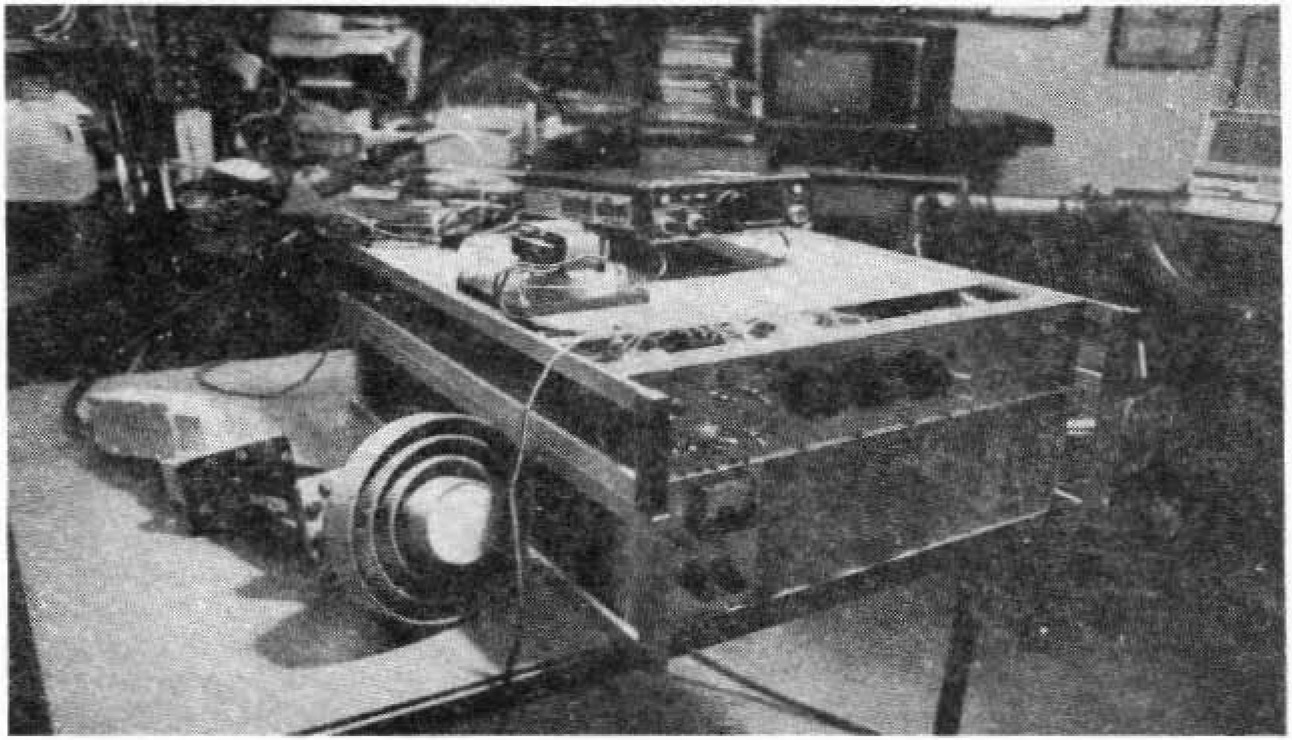


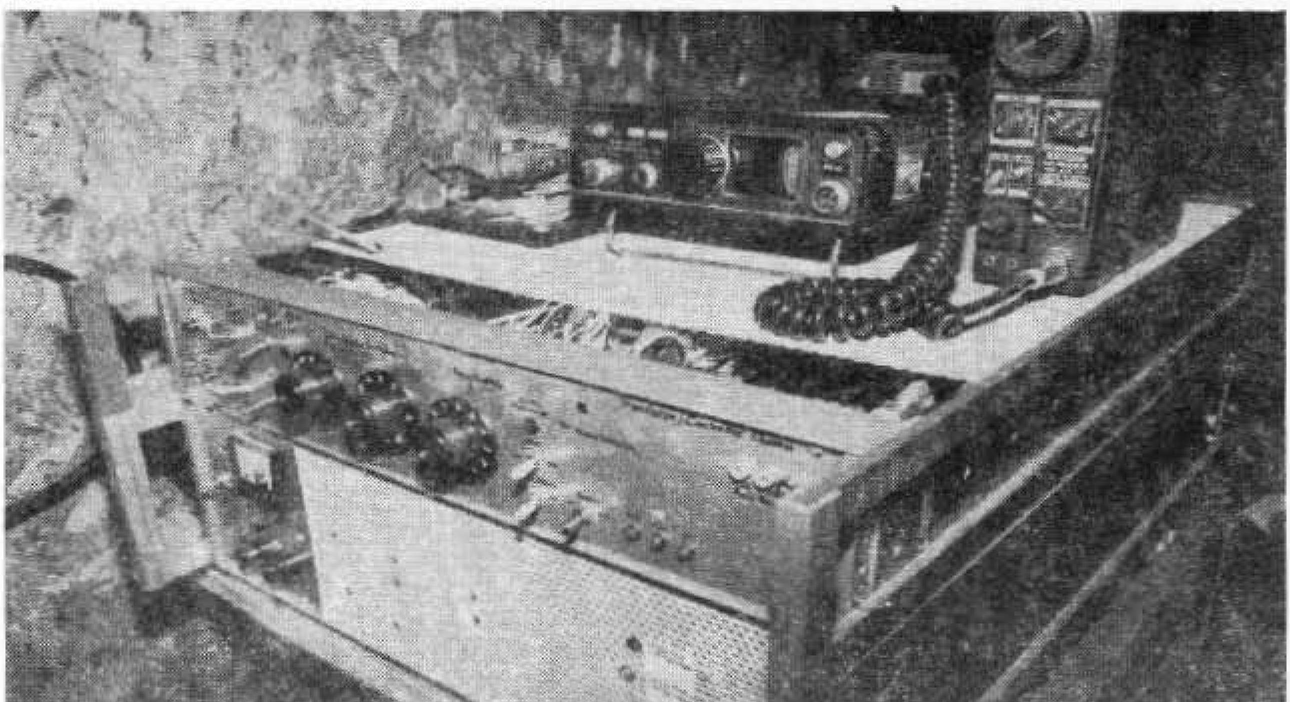
Interior view of the Beacon chassis.

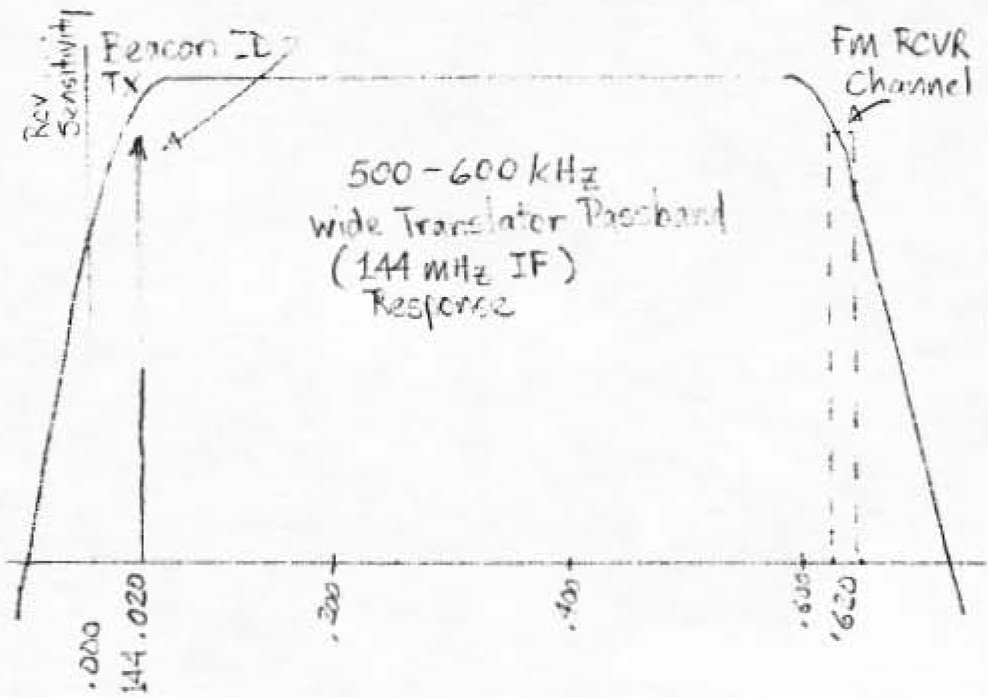
5760 Power Amp (right side)
2304 Power Amp (upper right)
X20 2160 PLL (center)
432 (left center)
1296 filter (left side)

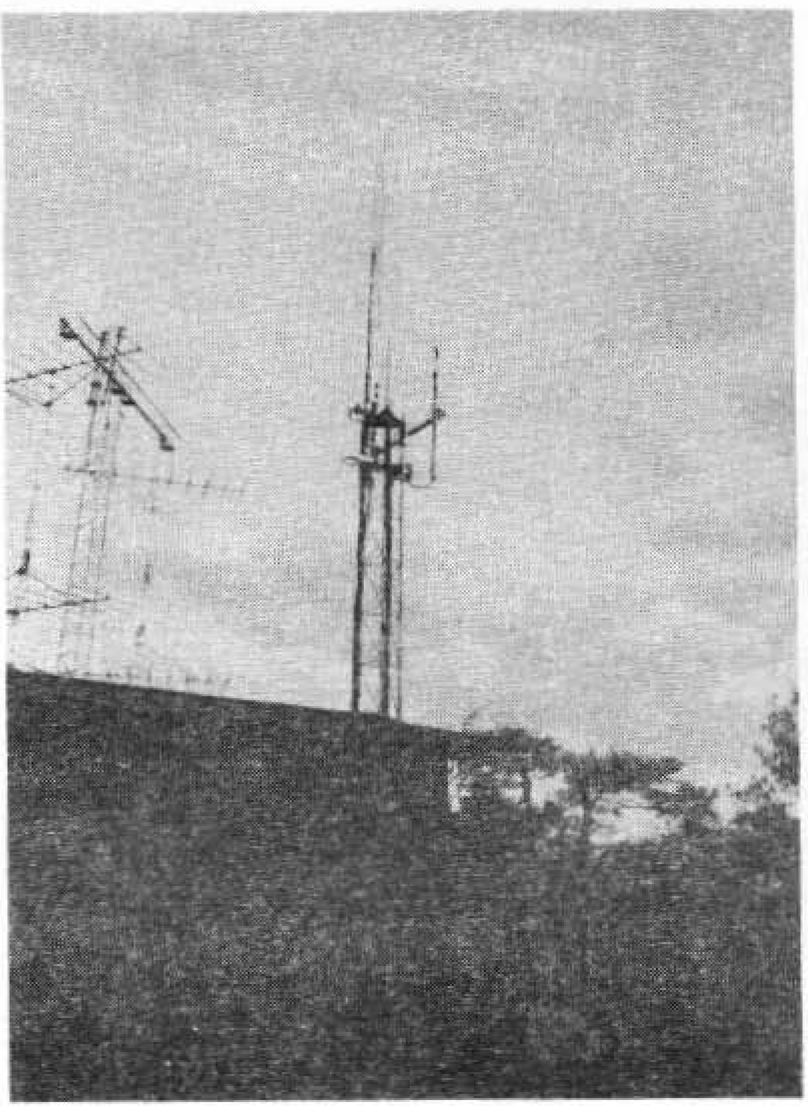
Rear view of the Beacon/Translater installed, showing six bands of antenna cabling converging on the unit.











Beacon/Translator Antennas at 4777 feet above mean sea leve Grid square is EM85md.

The RS 11 Ionospheric Experiment

by Mike Parker KT7D, Jeff Schoen,
and Dan Morrison KV7B

Total Electron Content (TEC) is a measure of the total number of electrons along a path through the ionosphere. It is important as a measure of the current state of the ionosphere, especially for understanding propagation effects between the ground and a satellite.

Radio waves passing through the ionosphere travel slower in regions of the ionosphere with a high density of electrons. One can determine the TEC by measuring the amount that the ionosphere delays a signal in excess of the free space propagation delay. Such an experiment was carried out in November and December 1987 using the RS 11 satellite. During this time the satellite operated almost exclusively in mode KA with uplink signals received on both 15 meters and 2 meters. In this mode the satellite adds the two signals and retransmits them at 10 meters. The experiment made use of the two uplink frequencies in determining TEC. Experimental techniques used, some of the analysis methods, and measurement results will be presented.

PACSAT SOFTWARE

by Harold Price NK6K and Robert McGwier N4HY

Abstract

The evolving structure of the Microsat system software is discussed. With a launch services agreement in hand, several "Pacsats" should be in orbit in 1989; they will have more memory and a more complex suite of system and application programs than any amateur spacecraft launched to date.

Background

"Pacsat", a dedicated packet radio satellite, is a concept that has been floating around in the amateur digital and space communities for more than six years. The basic concept is simple, using a low orbit satellite to "carry" messages from party to party rather than doing a real-time transfer though a high orbit satellite that both parties can see at the same time. Microsat is a specific AMSAT-NA satellite system that hosts a Pacsat mission.

A paper in these proceedings by Tom Clark gives an overview of the current Microsat design. Another paper by Lyle Johnson describes the hardware that supports the software described in this paper.

One of the large benefits of the amateur radio "Pacsat" concept has always been low cost. Not that hams are necessarily frugal, we'd spend it if we had it. If fact, it has been said that a ham will spare no expense in buying other parts to go with something he got for free. But we haven't got it, so we're forced to be smart. There are several cost reducing concepts in Microsat. One is small size. This reduces building costs (we're talking small, not miniaturized, which drives costs up). It also reduces launch costs, which are typically pegged to launch weight. Another cost reducer is dependence on off-the-shelf commercial grade parts. We're using extended temperature range parts, for the most part, but avoiding the much more expensive space rated parts. A combination of knowing the limitations, a fairly benign low orbit, and paying attention to the fine details of thermal control, allows us to get away less expensive electronics.

Another cost reducing element is the use of off-the-shelf software, and a low cost software development environment. As anyone who uses computers knows, a low cost software development environment has two components, the actual cost of the software itself, and the cost of the labor required to use the software to do something useful. With Microsat, a serendipitous turn of events has led to a development environment which should be both.

Off the Shelf

Microsat is a very low cost spacecraft. One reason is that it uses off-the-shelf parts and the simplest possible hardware design. The spacecraft itself is minimal, it is "stabilized" only by a bar magnet, which locks with the Earth's magnetic field and keeps the spacecraft from presenting the same face to the sun all the time. The interconnecting wiring harness is minimal, using a mere 25 wires and depending on serial bus controllers in each module to multiplex several control and sensor signals on a few wires. The CPU hardware uses standard commercial parts, such as a V40 CPU, closely related to the CPU found in IBM PCs, rather than some exotic, rad hard bit slicing wiz bang.

We'd also like the software to be off the shelf and straight-forward, able to take advantage of standard development tools and languages, and to use large blocks of existing protocol and bulletin board code.

With these goals in mind, Microsat will be the first amateur spacecraft to use an off-the-shelf high level language as its major implementation standard, Microsoft C. It will also use an off-the-shelf multi-tasking operating system from Quadron Service Corporation called qCF. It should be pointed out that the University of Surrey's UoSat-D, to be launched on the same mission, will also use some of the same software, so the distinction is a shared one.

Why C?

Why, in fact, a high level language? The purpose of the Microsat spacecraft is to support a 16 bit, 5 MHz computer with 10 Mb of memory. In addition to controlling the spacecraft, the computer will support one or more complex data communication protocols, a file system, memory error detection and correction, and data compression. It will compute its sub-satellite point (the point on the ground immediately below the satellite) so that it can switch the downlink transmitter to low power while over dead zones, or determine when to grab an image from the CCD camera. This will require floating point math. Last but not least, the software must be written in time to support a possible January 1989 launch. Doing all this in assembler would be a daunting task.

C, while not a perfect language, is at least ubiquitous. This means that many people write in it, including many hams. Microsoft C is well known, has copious documentation, has many debugging tools, and is easily available. While it has some bugs, they are well documented, and are in areas we are unlikely to use, such as graphics. It will generate code that is small enough to fit in the available space, and will run fast enough to support any modem technology we are likely to fly for some time to come.

For another advantage, implementations of the amateur radio packet protocols are available in C, including the KA9Q AX.25 and TCP/IP.

C is even nicer though when a support library of interface routines are available to support inter-task communication in a real-time system such as Microsat.

Why Multi-tasking?

Figure 1 shows a number of the tasks that the Microsat CPU will have to support, organized by major function. These tasks will be described in detail later. The chart is greatly simplified, as it leaves out such things as the software to manipulate the 10 Mb of memory, 2 Mb bank switched and 8 Mb as a randomly addressable serial buffer. Many non-related tasks must be carried on concurrently, such as searching the BBS message base for all messages to W1AW while monitoring battery voltage. Some things occur on demand, such as downloading a file, others happen based on time, such as including a telemetry frame in the downlink stream once every n seconds.

One way in which this can be done is to write each function as a subroutine to a single large program and link them all together. The main program would contain a table of subroutines to call when a timer it maintains expires. It would also contain what is commonly called a "commutator loop"; a set of subroutines representing major functions which are called in turn, each does some processing and returns to the main loop. A good example of this type of program is the TCP/IP package by Phil Karn, KA9Q, and others. FO-12 also uses a commutator loop.

Commutator loops have several disadvantages, however. The program is linked into one big unit, meaning that all parts of the program have to be aware of globals and subroutine names, even parts who's only point in common is that they are both called by the same main program. Because the program is one linked unit, individual parts can't be easily replaced or reloaded. While commutator-loop programs are effective in the right circumstances, in general the larger they get or the more disparate the parts, the harder they are to develop and maintain. KA9Q is also leaving the commutator behind for a home grown kernal for net.exe for reasons like those given here.

Another alternative to true multi-tasking is a multi-threaded FORTH. The Phase 3 satellites Oscar 10 and 13 use IPS, a FORTH-like system. Much has been said about FORTH and its applicability to real-time control programming, it was originally developed to control large telescopes. With FORTH you either love it or hate it, and most of the prospective programmers for the Microsat project were in the latter category. FORTH is not particularly optimized for things like AX.25 protocols and BBSes, and there are no existing amateur packet radio applications in this language. If FORTH were chosen, we'd be starting far down on the power curve.

A true multi-tasking system would have the following advantages:

1) All programs (tasks) could be written as separate entities. This eliminates global name and other problems, and makes it easier for several widely separated programming groups to contribute for the effort.

2) Since tasks are separate programs, they are easier to generate and test.

3) Tasks can be easily removed and reloaded.

4) The multi-tasking scheduler ensures that all tasks get a chance to use the CPU. More types of programming errors or failures are survivable, a glitch in one task will not necessarily halt processing in other tasks.

A true multi-tasking system seems more desirable, the problem is finding one for a particular hardware system. Fortunately, serendipity smiled on us. Early this year the generic Pacsat CPU design was upgraded from the 1984-style NSC800 Z-80 8 bit class to the 16 bit 8086 class. The serial communications chip was an 8030/8530 surrogate. It just so happens that someone with a long-time interest in PACSAT software (NK6K) was one of the founders of a company that has been marketing a real-time multi-tasking communication package for an 80186/8030 coprocessor card since 1986. One of the other founders, Wally Linstruth, WA6JPR was a charter member of the ARRL Digital Committee and was one of the first packet users in southern California. In short order, the company, Quadron Service Corporation, agreed to port its software to Microsat, and to give AMSAT free development software and no-cost license agreements for the use of the system on amateur radio spacecraft.

Attributes of the Quadron Multi-tasking system

1) Pre-emptive scheduler. This is a buzzword that means a task is given a certain amount of time to run, and is then placed at the end of a list of tasks waiting to run.

2) Sleep. Tasks can put themselves to sleep, meaning that they have nothing to do at the moment, and don't need to be scheduled on the CPU. Going to sleep is not something that a normal, single task program such as any standard PC-DOS program needs to do. Since there is only one task in such a system, if it has nothing to do it might as well loop. In a multi-tasking system, other tasks may have something to do, and it is more efficient if an idle task is simply not run rather than have it loop until it gets pre-empted. Tasks are automatically put to sleep if they start an operation that can't yet be completed, for example reading an input packet when one hasn't been recieved. The scheduler will start running the task again when input is available.

3) Timers. A sleeping task can also be awoken when a timer it has started goes off.

4) Inter-task messaging. Many of the tasks in Microsat will want to exchange data with other tasks, for example, the BBS will want to send data to the AX.25 output task. This is handled through a mechanism called streams.

A stream is like a little Local Area Network (LAN) connecting tasks together. A task opens to a stream which establishes a name on the "LAN". Other tasks can send messages to that name. Messages are queued. A sleeping task will wake up when a message is sent to it. For example, the AX.25 task sleeps until a task writes a message containing outbound data to it. The AX.25 task processes this data into an AX.25 frame and then writes that frame in a message to the HDLC Driver. The AX.25 handler is also awoken when the HDLC driver sends it a received

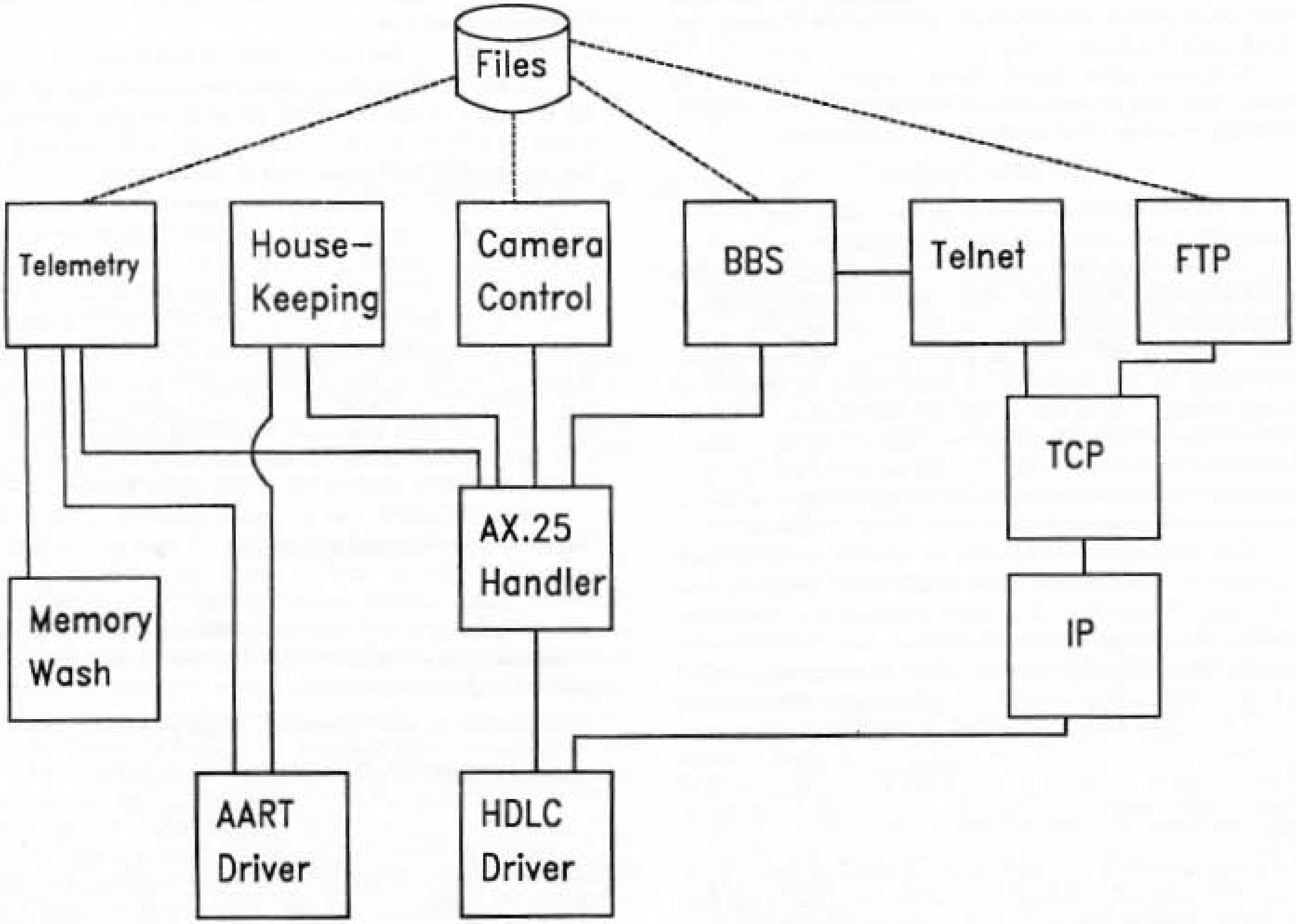


Figure 1. Possible Microsat Task Configuration

frame through a stream. Flow control limits may be set on streams, a task can be put to sleep if it writes too many messages; it is awoken when the target task reads the messages. This keeps one task from using all the buffers by flooding a second task with messages.

The inter-task messaging is implemented with calls similar to the standard C open, close, read, and write subroutines. Aside from using these calls to send data to other tasks, and the desire to find good places to go to sleep, writing a Microsat application program such as the BBS is pretty much like writing any other C program. Large portions of these programs can be tested on a regular IBM PC using Codeview, which should considerably speed development.

Specifics

Now that we've discussed some of the major design decisions, let's review the major tasks, as shown in figure one. Most of the fine details are still being worked out, the following discussions hit the high points.

Kernal

Not shown in figure one, the kernal supplies the basic multitasking services. It manages the hardware timers, sets up memory, loads and unloads tasks.

File Support

Not shown in figure one, the file support is implemented as a task. The low level C read and write subroutines in the standard C library are replaced by routines that format an I/O request and send it through a stream to the file support task. Acting much like an IBM PC ram disk driver, the file support task uses the 10 Mb of memory to emulate a disk. File support provides blocking and deblocking services as well as providing error correction for single bit errors (see the Mem Wash description).

BBS

This will be the most visible program to users on the ground. The major goal of the two PACSAT Microsats is to provide a bulletin board and file service. There will probably be two distinct interfaces. One will be an interface familiar to most packet users, the standard RLI/MBL BBS. This is for casual or occasional users who just want to see what's going on or forward an occasional message.

A second interface will be optimized for computer to computer transfers. While the RLI/MBL interface is currently used for this as well, Microsat will be in a different environment. The current auto-forwarding software is used a network where several hundred stations bang away at each other 24 hours a day, or at least several hours, HF conditions permitting. In the lower latitudes, a Microsat will be visible about 10 minutes at a time, four or five times a day. We'll want to take advantage of every second of that time. We won't want to wait while messages are sent one at a time, reprompting for each new message. We won't want to discard a long message just because the satellite went out of range before the last packet was sent. We'll probably want to block a large number of messages in a single file and send full speed, letting Microsat unblock them later. If a file is partially received, we'd like to be able to continue from the last byte received on the next pass.

The second access method could be used by a smaller number of backbone forwarding stations. The Microsats *will be* an experimental platform for testing various ways of simultaneously maximizing message throughput and maximizing the number of users who directly interact with the spacecraft. On the surface these items appear to be mutually exclusive.

AX.25 handler

If launch occurs as scheduled, the only protocol supported will be AX.25. The software will be a derivative of the KA9Q AX.25 code. It will support a large number of simultaneous connections through all of the uplink channels. When no frames are queued for the downlink, the AX.25 handler will send a message to the Telemetry task asking it to downlink a telemetry record. The telemetry task will also periodically send data based on a timer.

Sometime after launch, (time permitting before), we should also be able to test TCP/IP as an access method in addition to AX.25. AX.25 will at all times remain available.

HDLC driver

The HDLC driver passes frames between other tasks and the uplinks and downlink. The driver is non-trivial. The hardware design supplies several DMA channels, but even so there are more I/O channels than DMA, so the driver must do both DMA and straight interrupt driven I/O. To get the most out of the available processor power, and to enable later Microsat missions to use even higher baud rates, the HDLC driver is written in assembler code. Skip Hansen, WB6YMH, is a real wizard at this sort of thing, and will be porting the HDLC drivers he wrote for Quadron to the Microsat environment.

Although the HDLC driver will probably just be feeding the AX.25 handler at launch, it will later also be the front end for the IP module.

Housekeeping

For all these features to be usable, the spacecraft must be maintained in good operating condition. For example, if the battery voltage goes below a certain preset threshold, low power only should be allowed from the transmitter until recharge. Command stations must be able to talk to the algorithms that monitor optimal settings for power, solar panel operating points, and upload targets for these control algorithms. The command must also be able to manually intervene when the automatic algorithms don't do all that we have asked them to. It might be best to a only allow low power mode over sparesely populated areas on the globe unless a valid packet is heard. These and other spacecraft maintenance functions are handled by the housekeeping modules.

Telemetry

The Telemetry module periodically gathers telemetry data by using the AART driver to collect data from other modules. The data is both sent to the downlink as a UI frame for real-time monitoring, and is also stored in a virtual disk file in memory. The "whole orbit data" format, where the values for telemetry channels are store over several hours and are later downlinked has been proved popular with users by the UO-9 and UO-11 spacecraft. This data would be available in a file and could be downloaded by command stations and users.

The Telemetry module would be addressable via the AX.25 uplink by command stations for the purpose of modifying the interval used for dumping UI telemetry frames and for storing whole orbit data. When diagnosing a problem, the sample rate would be increased, as would the total memory to be dedicated to storing data. For example, the battery voltage can be sampled once every two milliseconds for a 24 hour period, and the data stored in 8 Mb of memory. It would, of course, take a long time to download that file.

Memory Wash

Some of the memory on the spacecraft is protected with hardware Error Detection and Correction (EDAC) circuitry. When an error is induced in memory by an energetic particle normally filtered out by the atmosphere, the EDAC will correct the error on a read and place the proper data on the bus. The corrected byte is not written back into memory automatically by the hardware. If an error is allowed to linger, there is a chance that a second bit in the same byte will get flipped. Since the hardware can only properly fix single bit errors, you'd like to fix all single bit errors before they become multi-bit. In a process called "washing memory", a task periodically runs through the EDAC memory, reading and writing every byte, causing the corrected byte to be written back into memory over a damaged one.

Most of the memory is not protected by hardware. The reason is economics, 12 bits are used to store each 8 bit byte in hardware protected memory. Hardware EDAC is used for memory that programs run out of, since a program byte in error will usually lead to no good. Software algorithms must be used to protect the remaining memory. This memory is used to store data files and messages. The ramdisk routines will use software EDAC to correct errors, but if a "disk sector" goes unread for too long, multiple bit errors may occur. To reduce this chance, the memory wash task periodically reads all "disk sectors" and writes them out.

The Memory Wash program responds to queries from the Telemetry task and reports the numbers of errors corrected and the current position in the wash cycle. This information then is incorporated into the standard telemetry frame.

AART Driver

This module reads AART commands from other tasks out of the message stream, and sends them to the AART serial control channel. If required, it uses the CPU boards A to D converter to read a data value and return it to the requesting task.

Camera Control

In the CAST Microsat, the primary mission is the CCD camera. In this spacecraft, the BBS will only be used for messages about stored images, and to store the images themselves. Weber State will write this application program.

IP and TCP

As an experiment, the TCP/IP suite of protocols will be ported to the Microsat CPU. This will allow processors such as FTP to be used in lieu of the BBS for file downloading.

FTP

File Transfer Protocol, part of the TCP/IP suite. It will have access to the various data files.

TELNET

The telnet protocol can be used in the TCP/IP suite to pass a stream of characters between a keyboard user and a program, and would thus serve as an alternate path to the BBS.

Implementation Schedule

The software group is aware of the tight schedule for the Spot 2 launch, and the need to balance the desire to do all of the above but be ready for testing in a few weeks. Therefore, we've separated tasks into several groups.

The highest priority group contains those things which must be present if anything useful is to be done with the spacecraft. This group includes the kernal, the HDLC driver, the AX.25 handler, the AART driver. To allow any reasonable development of the applications, these tasks must be present in their near-final form for testing and launch. This group also includes the bootstrap ROM code, which is being implemented by Hugh Pett in Canada, and is beyond the scope of this paper.

The next priority group are the applications which are required to run the spacecraft. Here, very simple temporary modules will do with the fancy ones coming later. The simple ones will be done ASAP; the fancier ones will be done before launch, time permitting. This group includes telemetry and housekeeping and memory wash. It also contains a very rudimentary BBS, with put-message, read-message, and list-message commands. The first BBS will also place its messages in linear memory, not in files.

Next are those things which are required before the final, fancy applications can be written. This is primarily the virtual ramdisk task. Finally comes the additional access methods such as TCP/IP.

Wrap up

This paper has discussed the current thinking in the area of Microsat operating software. Work to implement these plans is underway, some C code has already been run on the wire-wrap CPU prototype. Our choices of high level language, multi-tasking operating system, and implementation methodology have changed the project from impossible to merely difficult.

Acknowledgments

Thanks to Lyle Johnson WA7GXD for another fine hardware design, Chuck Green N0ADI for yeoman work at the wirewrap table; Skip Hansen WB6YMH for his work on the I/O drivers, Hugh Pett for the bootstrap loader; Martin Sweeting G3YJO and Jeff Ward G0/K8KA for past, present, and future collaboration on what a pacsat should do and how it ought to do it. Thanks to Jan King, W3GEY and Gordon Hardeman, KE3D, for stirring up this new project with the initial Microsat idea.

ABSTRACT

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Weber State College
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Weber State College is a public four-year baccalaureate degree granting college. It is located at the base of the beautiful Wasatch mountain range in Ogden, Utah. In 1989, Weber State College celebrates it's centennial year as an institution of higher education. In 1985, the Center for Aerospace Technology (CAST) at Weber State College became the first college to successfully launch a satellite from the space shuttle. NUSAT I was launched utilizing the shuttle's Getaway Special cannister.

This year Weber State's CAST has teamed up with AMSAT to build four small satellites called microsats because of their small size. Three of these, AMSAT North America's Pacsat, AMSAT Argentina's Pacsat and AMSAT Brazil's Project DOVE are covered elswhere. The Weber-Sat will carry experimental payloads to test several concepts. The primary payload on Weber-Sat will be a color CCD camera which can be activated on command and the video image digitized and stored into memory. There it can be compressed and transmitted to the ground as digital data. Once at the ground station the data can be un-compressed, enhanced and displayed on the computer monitor in shades of gray or generated as composite video and displayed in color. A software package which will allow amateur users to manipulate and display the downloaded pictures will be available through AMSAT. In conjunction with the CCD camera, there will be a 1289 MHZ receiver on board which will have the capability of receiving amplitude modulated television signals from the ground and providing composite video to the flash converter system. The flash converter can digitize the video and store it to be digitally transmitted to the ground later. It is estimated that with the amount of memory on board, eight to ten different pictures can be stored for later downloading.

Also on board will be a mass spectrometer system whose optical data can be stored digitally and also transmitted to the ground station for examination. The mass spectrometer experiment is in conjunction with the physics department at Weber State.

The college campus in Utah is also home to the AMSAT North American ground station. Located in one corner of the CAST office suite the futuristic console features the newest in satellite communications equipment. From the computer controlled azimuth and elevation rotors on the antenna system to the automated telemetry gathering and archiving, the station is the latest in state-of-the-art equipment.

AMSAT and CAST are planning future ventures in satellites such as the Microsat project where mechanical and manufacturing students can get involved in the engineering and fabrication of the structure and launch system and electronics students can get hands on experience in engineering, testing and building the electronic modules. The programs give the students a chance to be part of an engineering team and follow the projects from conception through operation. The goal of Weber State College is to provide the best possible education for the students as well as an enjoyable experience.

RADIO AMATEUR SATELLITE CORPORATION
(AMSAT)
6TH SPACE SYMPOSIUM
NOVEMBER 11-13, 1988
AIRPORT MARRIOTT HOTEL
COLLEGE PARK, GA

SPACE STATION AMATEUR RADIO STATION (SPACE STARS)

by

Edward F. Stluka, W4QAU

ABSTRACT

For the first time, planning for an Amateur Radio Station is being conducted during the preliminary design of a space facility system.

Earlier space Amateur Radio Stations have been realized, in the case of Spacelab, after Spacelab was operational and implementation was completed by selecting portable equipment, designing the antenna for available window space, at minimum cost to NASA.

Planning is under way, during the Space Station preliminary design, to include a Space Station Amateur Radio Station as an integral part of the Space Station design and not as an after thought. For the purposes of this paper, the Space Station Amateur Radio Station will be referred to as Space STARS. This paper describes the idea of including amateur radio clubs, schools and amateur radio enthusiasts to recommend their concepts and ideas for the Space STARS design and implementation.

BACKGROUND

The concept for operation of the first in-space Amateur Radio Station two-way, 2 meter voice communications, was demonstrated by Dr. Owen K. Garriott, W5LFL, on Spacelab-1, August 30-September 5, 1983.[1] During the July 29-August 6, 1985 Spacelab-2 flight, Dr. Tony England, W0ORE and Dr. John Bartoe, W4NYZ, demonstrated a more complex system, the first two-way Slow Scan Amateur TV (SSTV) in addition to the 2 meter two-way voice communications.[2] On October 30-November 6, 1985, the Germany and European Space Agency (ESA) Spacelab-D1, Astronauts Dr. Reinhard Furrer, DD6CF, and Dr. Ernst Messerschmidt, DG2KM, demonstrated the first Mode B, 70 cm up and 2 mtr down two-way communications. The D1 Amateur Radio Station demonstrated the use of a single 50 cm 1/4 wave VHF, 5/8 wave UHF 2 mtr -70 cm vertical whip antenna mounted on the outside of the Spacelab module wall, as shown in Figure 1.

A summary of the previously flown and near term planned amateur radio space operations is shown in Figure 2. It is evident that the sequence of increasingly more complex amateur radio space operations forms a solid base for the step to the Space STARS. Roy Neal, W6DUE, of NBC, Bernie Glassmeyer, W9KDR, American Radio Relay League (ARRL), former astronauts Dr. Owen Garriott, W5LFL, and Dr. Tony England, WOORE, and Dick Fenner, W5AVI and Lou Mc Fadin, W5DID of the Johnson Space Center (JSC) were instrumental in planning, coordinating and finalizing the approval for making the Spacelab amateur radio operations happen.

SPACE STARS PLANNING

Roy Neal, W6DUE, of NBC, is Chairman of the Shuttle Amateur Radio Experiment (SAREX) Working Group. John Blum,KE3Z, ARRL Senior Laboratory Engineer and the ARRL Headquarters Staff member for SAREX; Bill Tynan, W3XO, AMSAT Vice President for Manned Space Flight Projects and QST Contributing Editor; and Louis Mc Fadin, W5DID of the JSC are the Working Group members. This working group is now tasked with planning for the ASTRO-1 SAREX.

The next Amateur Radio Operations in space is planned for the Space Shuttle ASTRO-1 mission, with Dr. Ron Parise, WA4SIR operating 2 mtr two-way, SSTV two-way, up-link fast scan ATV and two-way packet radio as shown in Figure 3. Figure 4 is the two band window antenna planned for the ASTRO-1 Aft Flight Deck Window.

The SAREX Working Group is expected to be the nucleus of planners, designers and architects on the Space STARS. A Space STARS committee should be formed to support this core group. This committee should be charged with the planning and coordinating the activities, procedures, approvals for assuring that an amateur radio station system is installed on Space Station. A part of this effort must consider amateur radio astronauts availability, licensing details, including trusteeship, training, etc..

For long duration operations in space, astronauts require time for relaxation and free time activities. For the ham astronauts, communicating with school groups, clubs or the average ham around the world, with word or ATV descriptions of experiments, the environment in the work or living quarters of the space module/station and the view of the outside, has been exciting but short lived for Spacelab. Long duration space operations provides much more recreation time, where more school groups, clubs and the average ham would be involved. Space and earth sciences, including remote sensing benefits for student involvement, space experimentation and educational opportunities are extremely important for the competitive posture of present and future science and technology in the United States and the free world.

HAM INVOLVEMENT

Since hams, world wide, would have the opportunity to work the Space STARS, why not give them a chance to submit their ideas for consideration on the make-up of the Space STARS. The Space STARS equipment capabilities, operational modes, frequency bands, antenna locations, operational features and other qualities are in the definition stage. Safety, frequency compatibility, antenna configurations, interfaces and power limitations are other considerations.

APPROACH

The Space STARS Committee should inaugurate a project, in 1989, to receive proposals by the amateur radio clubs, school groups, and individual hams around the world. The proposals would be sent to both the ARRL and AMSAT for review, selection and negotiations with the Space STARS committee.

The proposal suspense date could be by the end of 1991 or defined by ARRL, AMSAT and the Space STARS committee. ARRL and AMSAT should define their individual guidelines and ground rules such as space operational modes with earth stations and satellite relay capabilities

Amateur radio clubs, school groups, and individual hams could be allowed to contribute funds or equipment (meeting appropriate specifications). This would make those contributing ideas, funds and/or equipment special members of the Space STARS, would provide incentives for developing improved communications and space experimentation and motivate amateur radio enthusiasts, student groups clubs and individuals to participate in space activities. The unique role of Space STARS may stimulate more astronauts to become hams and could have a similar incentive on the earth-bound individuals to becom hams.

Questions and resulting recommendations that could evolve out of the thought process of developing the requirements for the Space STARS

1. Should there be a Space STARS in each of the four pressurized modules? ESA and Japan will each have a laboratory module. USA will have two modules, one laboratory and one habitation. Each country has strong amateur radio activities as well as space launc facilities. The habitation module appears to be the best choice for a Space STARS, however, more than one module station may be justifiable. Canada is expected to provide a Mobile Servicing System. Their participation in the Space STARS should be encouraged.

2. If more than one Space STARS, for instance Space STARS-J (Japan), Space STARS-E (ESA), and Space STARS-U (USA) evolves as a reality, what operational constraints, on each module, would be required, i any.

3. If more than one Space STARS becomes a reality, what type of antenna farm should be proposed? Should there be a combination of certain antennas to be shared (selected) by each of the Space STAR and other antennas dedicated to each module? Low frequency bands could require long wire antennas. What bands should be shared or be dedicated, regarding antennas, if any?

4. Should each module have dedicated solar cell panels for power or should the Space STARS be allocated module power? Trade-off recommendations could evolve such as scheduling each modules operations, in sequence, to preclude inter-mod interference. Powe usage and other considerations would like wise benefit. Certain modules could be in a listening mode, at specified times.

5. What amateur radio bands, operational modes, features (for instance, Packet Radio bulletin boards) should the Space STARS contain? Since the Space Station is international, each country could conduct their own project, with their respective ARRL and AMSAT organizations and coordinate the results with the USA ARRL and AMSAT organizations. This approach would be much more involve and the schedule would be determined by the coordination approach and management process.

BENEFITS

Amateur radio has played a unique roll in communications research by individuals quest for diverse and un-proven techniques. Their creativity, dexterity and ability to construct and operate state of th art technology has been demonstrated by hams for decades. Radio and video communications and data transmission is the life line between earth and the space vehicles and ground to ground. Space science experiment projects, similar to the Get Away Special canisters on Spac Shuttle, but now with much longer experiment time on the Space Statior are expected to be common place. Will the experiment results be delayed until the experiment package is returned to earth, in 3 to 6 months? Amateur radio down-links would allow near real-time data transfer for experiment health, status and results, depending on the nature of the experiments.

SUMMARY CONCLUSIONS

This paper was written without knowing the details of planning by the Space STARS committee. Therefore, the approach presented represents one hams thought process, who would want the dream of ham space operations to continue and that Space ham radio research and technology contributions would likewise continue.

1. QST, August 1983, pages 50-51.
2. QST, October 1985, pages 47-49.

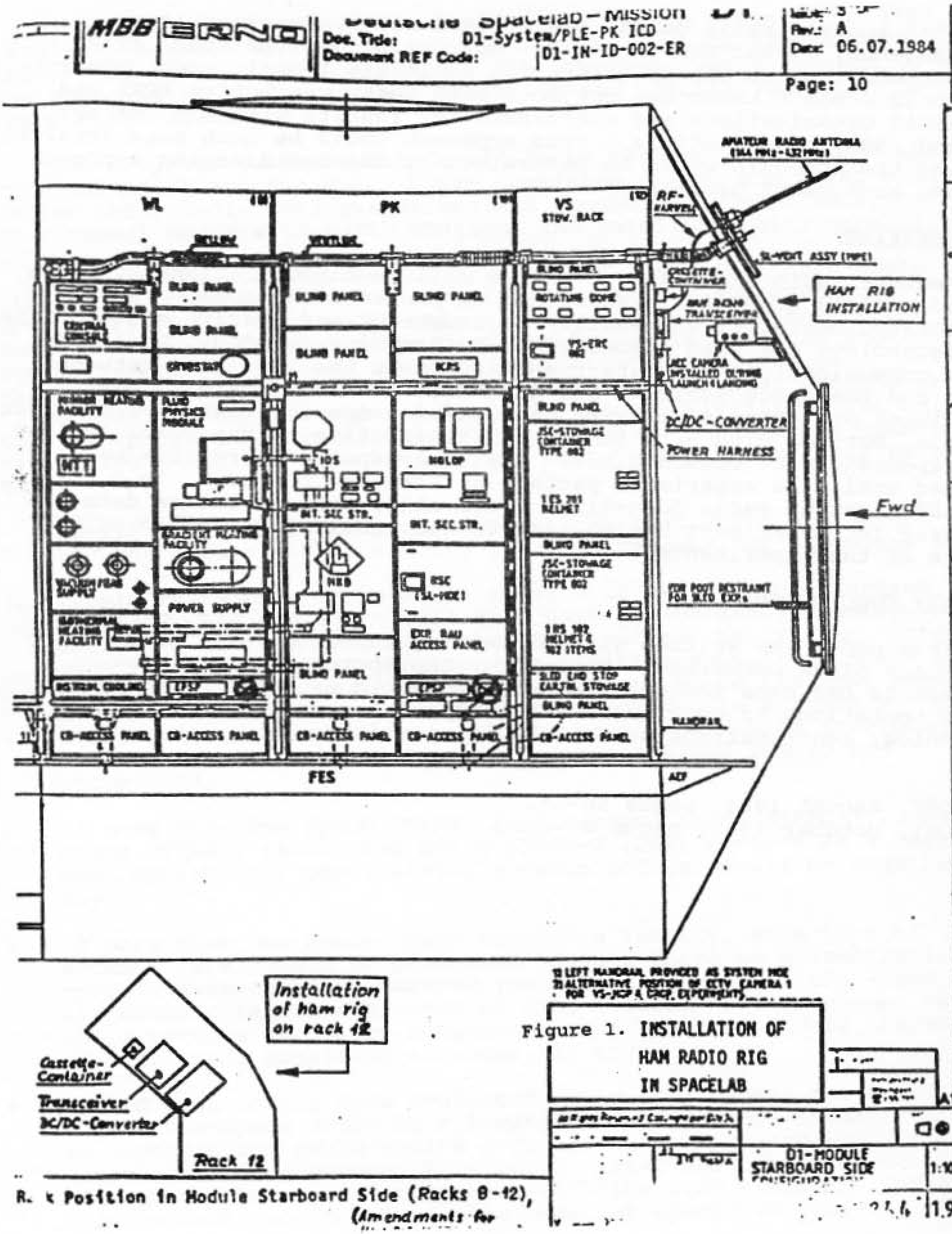

Figure 1. INSTALLATION OF HAM RADIO RIG IN SPACELAB

EVOLUTION OF THE SPACE SHUTTLE AMATEUR RADIO EXPERIMENT (SAREX)

SKYLAB SL-3 7/28 - 9/25, 1973	DR. OWEN K. GARRIOTT, W5LFL 1427hr 09mn 04sc	AMATEUR RADIO ON SKYLAB DISAPPROVED BY NASA
STS-9 COLUMBIA SPACELAB SL-1 11/28 - 12/3, 1983	DR. OWEN K. GARRIOTT, W5LFL 223hr 47mn 24sc (QST - AUG 1983, Pgs 50-51	AMATEUR RADIO (AMRAD) 2 MTR TWO WAY FIRST ASTRONAUT HAM "IN SPACE" OPERATIONS DEMONSTRATED SUCCESSFULLY.
STS-51F CHALLENGER SPACELAB SL-2 7/29 - 8/6, 1985	DR. TONY ENGLAND, W0ORE DR. JOHN-DAVID BARTOE, W4NYZ MISSION CMDR. GORDON FULLERTON, ONCE HELD WN7RQR, 190hr 45mn 26sc (QST - OCT 1985, Pgs 47-49)	SHUTTLE AMATEUR RADIO EXPERIMENT (SAREX) 2 MTR TWO WAY AND THE FIRST AMATEUR TV (ATV) SLOW SCAN UPLINK & DOWNLINK IMAGES DEMONSTRATED SUCCESSFULLY
STS-61A CHALLENGER SPACELAB D-1 10/30 - 11/6, 1985	DR. REINHARD FURRER, DD6CF DR. ERNST MESSERSCHMIDT, DG2KM DEUTSCHER ARC FEDERAL REPUBLIC OF GERMANY 168hr 44mn 51sc	GERMAN SPACELAB AR EXP., D-1 CALL: DP0SL 2 MTR DL (1 WATT), 70 CM UL BOSCH UHF/VHF TRANSCIEVER WITH BUILT IN MICRO-CASSETTE RECORDER; ANTENNA: WHIP, 50 cm 1/4 VHF, 5/8 UHF, MOUNTED ON THE OUTSIDE OF THE SPACELAB MODULE

***** PLANNED *****

EOM-1,-2,-3 NOW ATLAS-1	DR. OWEN K. GARRIOTT, W5LFL	SAREX-A COMPREHENSIVE PROPOSAL DROPPED AFTER CHALLENGER ACCIDENT
STS-35 COLUMBIA ASTRO-1 SCHEDULED: 11/89	DR. RON PARISE, WA4SIR (Next Astronaut Ham in space)	SAREX-II, 2 MTR TWO WAY + SLOW SCAN ATV TWO WAY FAST SCAN ATV UPLINK. (FIRST) PACKET RADIO (FIRST)

Figure 2

SAREX A

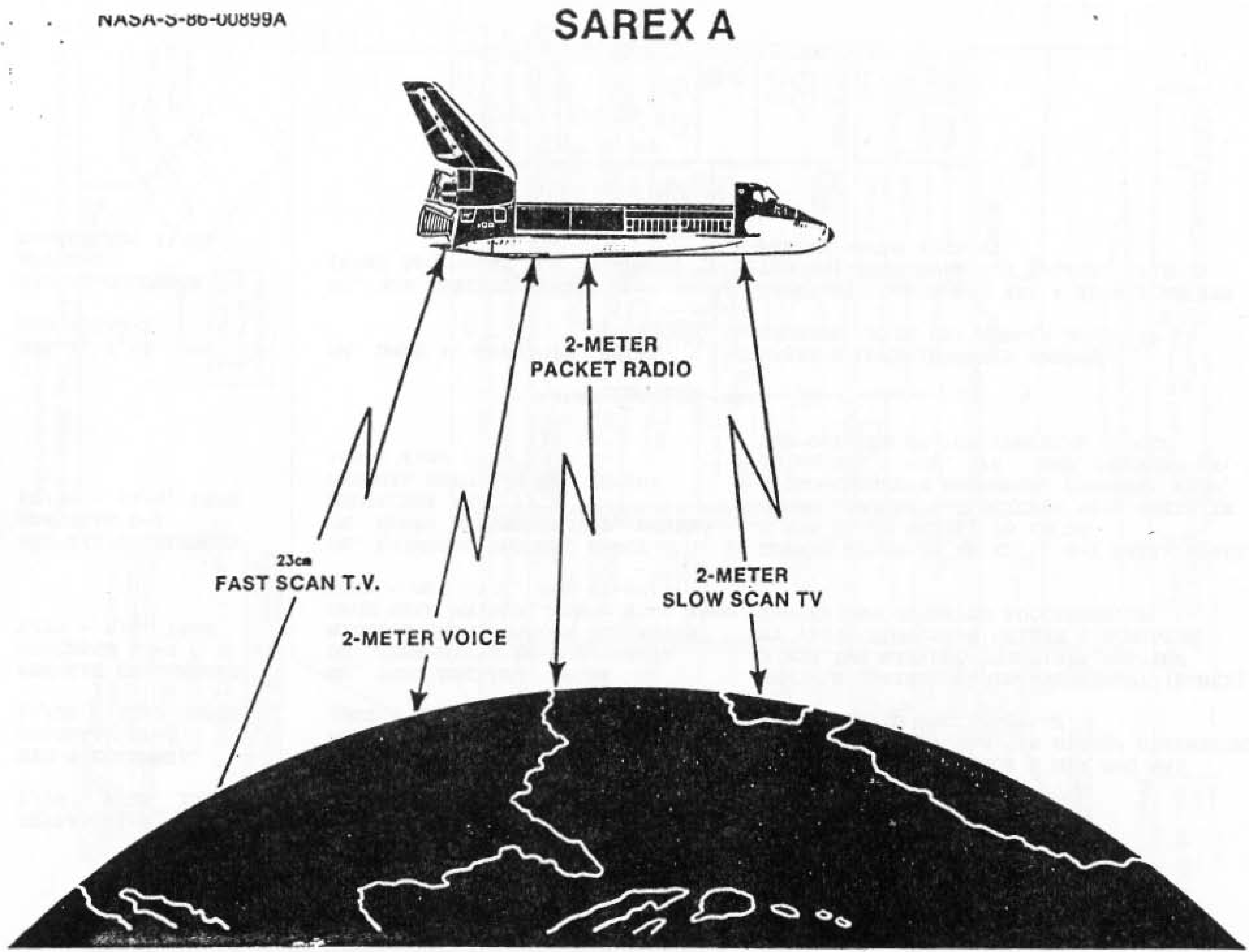

Figure 3

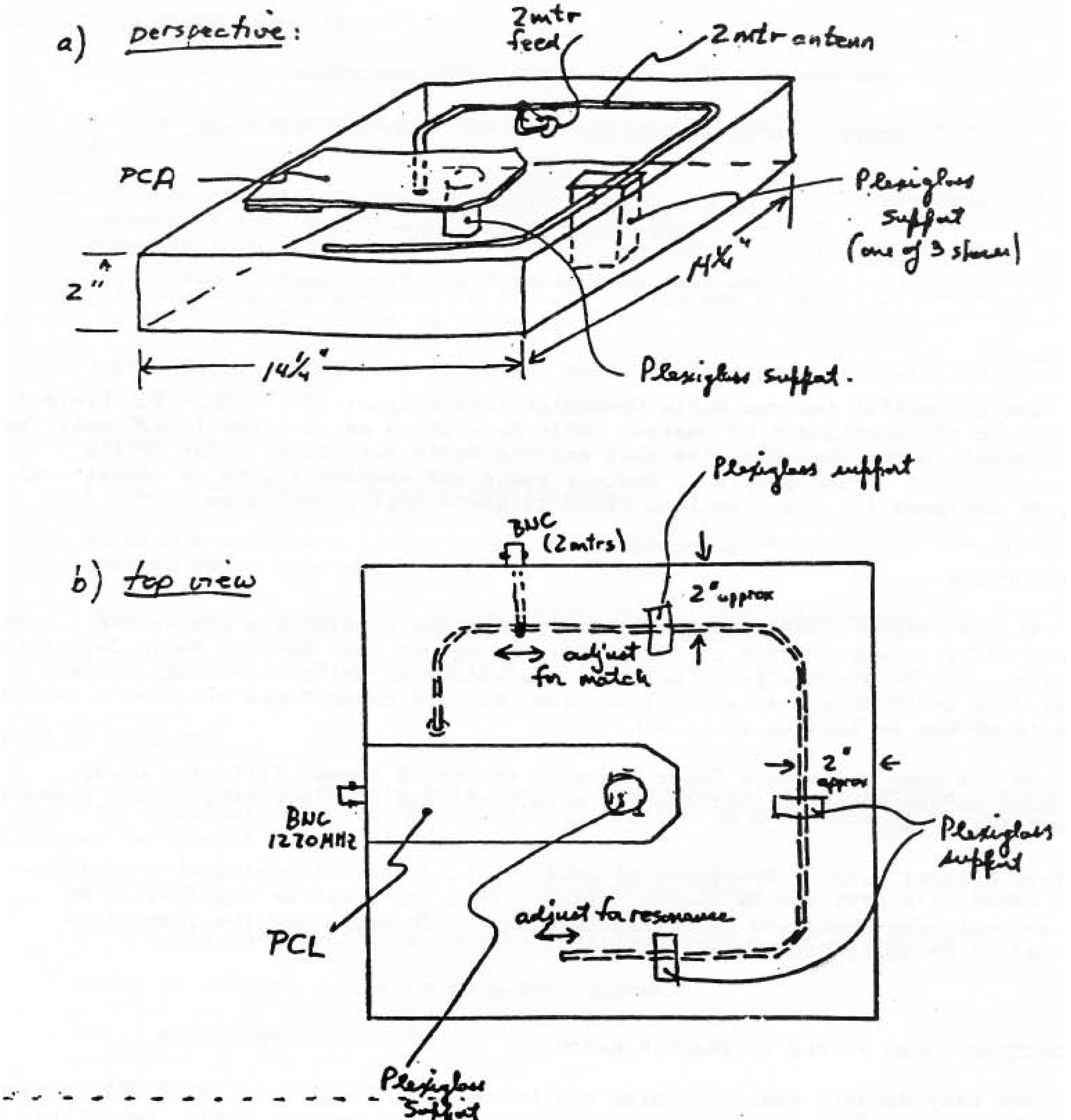

Figure 4

Cavity with 2mtr antenna and PCA.

drawing 2

AMATEUR RADIO SATELLITES - AN EDUCATIONAL EXPERIENCE.

Hans van de Groenendaal ZS6AKV
President of SA AMSAT

Director South African Amateur Radio Development Trust

SUMMARY

The successful Amateur Radio Communications support of the Ski-trek project focused on the usefulness of Amateur Radio Satellites as an educational tool. The paper examines the opportunities that Amateur Radio Satellites offer in the introduction of young people to Amateur Radio and concludes with an educational project designed for the Brazilian Peace Talker's digital voice encoder.

INTRODUCTION

At the recently held International Amateur Radio Satellite Conference, hosted by the RSGB, delegates from over 27 countries agreed that Amateur Radio Satellites could be used to attract young people . The sucessful Ski-trek schools project devised by AMSAT NA's E ducational Advisor ,Richard Ensign" was cited as a typical example of how to involve the youth.

At the same conference Geoff Perry of the world famous Kettering Group appealed to the satellite builders to keep producing and launching simple phase two type satellites.

Dr Carl Meinzer DJ4ZC , President of AMSAT DL told the International conference that OSCAR 13's RTTY and CW beacon bulletin facility could be employed in an educational programme, and Dr Martin Sweeting G3YJO explained the tremendous potentials of UOSAT OSCAR 9 and 11.

ATTRACTING YOUNG PEOPLE TO AMATEUR RADIO

For many decades radio captured the interest of people, but this all changed with the advent of the home computer. Fortunately for Amateur Radio, Satellites and Packet Radio came along and created new interest in the hobby.

Attracting young people through the educational route has already proved successful as we have learned from the various University of Surrey and ski-trek projects.

These projects should be used as guidelines for the creation of new eduacational projects.

ELEMENTS OF A SUCCESFUL PROJECT

The following elements are essential for a project to succeed:

- A detailed information kit should be available well ahead the start of a project.

- A Teachers' Guide should be available complete with tutorials covering all aspects of the project. Many Teachers will only tackle a project if they are supplied with the correct back-ground and tutorial material.

The information kit prepared by Richard Ensign was a major factor in the success of the Skitrek project in schools.

- Availability of low cost equipment such as receivers, decoders and recording equipment.

- Student work books

- A reward programme , e.g. a certificate

- Regular newsletters, radio talks and programming on Amplitude Modulation Amateur Radio Networks

- Inter-school contact via Amateur Radio Packet and Voice networks.

- Involvement of the local Amateur Radio Community in the project.

TYPES OF PROJECTS

A large number of projects have already been identified by various interest groups. The National Resources Centre for Satellites in Education at the University of Surrey has listed the following:

- Measurement of the changes in Earth magnetic field

- Monitoring satellite spin rate by measurement of solar derived power.

- Study of auroral radiation in polar regions

- Solar wind experiments

- Observation of orbital period

- Reception of synthesized speech such as digitalker and the proposed Bramsat Peace talker

- Study of climatology using weather satellite pictures.

These are just a few of the many opportunities that are available.

AMSAT RESOURCE CENTRES

To sucessfully expand the Satellites in Education concept Resource Centres need to be established in as many participating countries as possible. These centers should co-operate with each other and exchange ideas and material on an ongoing basis. By mutual agreeme nt each participating centre should develop material for an agreed project so that within a short space of time a number of programm es will become available on a world-wide basis.

As a starting point SA AMSAT has agreed with the University of Surrey to work on a number of projects. Jeff Ward has for some time now been involved in the National Resource Centre for Satellites in Education at the University of Surrey and has made valuable inpu ts to the concept.

To establish a world-wide network of these centres I propose that an International conference be arranged in conjunction with the U niversity of Surrey the day before the AMSAT UK Satellite Symposium i.e. 28th July, 1989. I believe that various AMSAT groups, The A RRL and the RSGB could make valuable contributions.

The suggestion that the conference be held in the UK stems from the experience that the UK is the crossroad of airtravel from many parts of the world.

BRAMSAT PEACE TALKER

PROJECT: "AMATEUR RADIO SATELLITE SAFARI" (ARSS)

OBJECTIVES:

- To Introduce Amateur Radio to a large number of school pupils
- To introduce the concepts of Space and Space Communication
- To provide interesting curricular and extra-curricular projects for use in schools, and youth groups such as Scouts,etc.

OUTLINE OF THE PROJECT:

For a 13 week period Peace talker will be programmed on a weekly basis and focus on a region or a particular country. This informati on is then used to complete a project work book. At the end of the project the Teacher in Charge awards a certificate of participation.

The first three weeks will be used to introduce the project with peacetalker providing additional tutorial material suchs as

- What is Amateur Radio
- The Amateur Radio Satellite Service
- AMSAT

Weeks 4 t0 13 will visit a different country each week starting with Brazil and including countries where AMSAT is most active: USA, Argentina, England, Germany, Japan, Australia, New Zealand, Southern Africa and others.

The information used in the project will include: Geography, Climatology, Agriculture, Industry, Amateur Radio activity etc.

During the 13 weeks a number of scientific projects will be included such as the observation of the orbit, determination of orbital period etc.

The success of this project will largely be determined by the comprehensiveness of the tutorial material and workbook.

This project could be repeated annually for some years or even be adapted for various language groups.

EQUIPMENT

Peace talker will be an ideal satellite for this as the ground station equipment required will be minimal. Dr Junior De Castro of Br amsat has already experimented with a low cost receiver costing in the region of $25.

CONCLUSION

The future of Amateur Radio is in Amateur Radio Satellites and in our youth. We can make a valuable contribution by getting the yout h involved and thus securing the future of our hobby.

PROJECT BACAR (BALLOON CARRYING AMATEUR RADIO)

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0.0 SYNOPSIS

At one time or another every Amateur Radio Satellite Enthusiast dreams about building a satellite, but usually because of the lack of any promise of a launch, the dream never materializes. OSCAR 7 and OSCAR 8, then UoSAT 1 fired the imagination of Dave Woodhall ZS6BNT and Project BACAR (Balloon Carrying Amateur Radio) was born.

The project offered challenges of design, development, construction and testing of satellite type equipment. Added to this, the excitement of launch, tracking and working through the transponder attracted many people to the project.

To date 25 BACAR projects have been undertaken. The paper reviews the various aspects of the project and focuses in detail on Mission 21.

1.0 INTRODUCTION

At one time or another every Amateur Radio Satellite Enthusiast dreams about building a satellite, but usually because of the lack of any promise of a launch, the dream never materializes.

OSCAR 7 and OSCAR 8, then UoSAT 1 fired the imagination of Dave Woodhall ZS6BNT and Project BACAR (Balloon Carrying Amateur Radio) was born.

Towards the end of 1981, one evening after a boring club meeting, a few of the members stopped off at a local pub for a beer. The group was discussing ways and means of creating more interest at meetings when Dave came up with the suggestion "Let's launch our own satellite". Stunned silence followed at first, but many beers later the date was set for the first launch of BACAR - Balloon Carrying Amateur Radio. It was to be in January 1982.

balloons must not touch
or Static May explode Hydrogen

At one of the first follow-up meetings the objectives were discussed and agreed upon. In broad terms the objectives of Project BACAR are:

- To experiment with radio equipment, electronics, test equipment and systems in a space-like environment.

- To provide a wide range of activities for as many radio amateurs as possible :

  1) Design, development, construction and testing
  2) Satellite type tracking
  3) Mapping
  4) Direction finding
  5) Telemetry encoding and decoding
  6) FUN

3.0 TECHNICAL COMMITTEES

A number of technical committees were set up to handle the various aspects of the project. Table 1 shows a diagrammatical representation of the Project BACAR structure today.

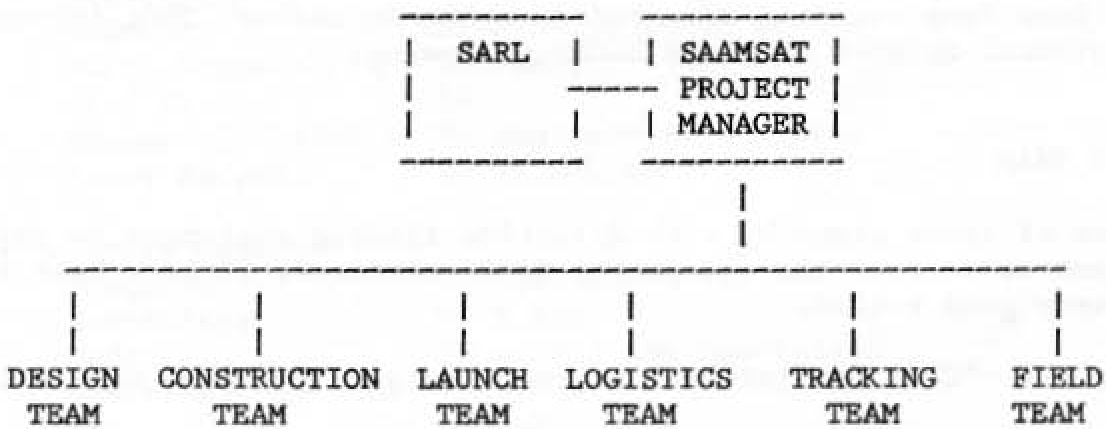


TABLE 1 -BACAR MANAGEMENT STRUCTURE

4.0 GETTING STARTED - MISSION ONE

BACAR Mission One has gone down in history as "The Coke special". It consisted of a beacon transmitter in a 2 litre plastic coke bottle. The beacon transmitted a tone which was varied under the control of a temperature sensor mounted on the outside of the bottle. The frequency of 145.550 MHz was chosen because of its popularity as a local simplex chat frequency which was, at the time, common in most crystallized transceivers. (Synthesized Transceivers were still new at the time).

From information received from the local Weather Bureau a temperature versus height above sea level was compiled.

4.1 LICENSING

An application to the Postmaster General for a special licence resulted in many queries. Armed with documentation about Amateur Radio Satellites licensed internationally, a visit to the PMG was arranged. The licence was granted under the call ZS6EXP.

4.2 AIR TRAFFIC CONTROL

We soon learned that special permission was necessary from the Department of Civil Aviation. Armed with more documents we returned to Pretoria. Permission was granted with the provision that permission for take off is requested from local ai traffic control before each launch.

4.3 LAUNCH INFORMATION NETWORK AND MISSION CONTROL

As one of the objectives was to involve as many radio amateurs as possible, a special launch information network was arranged. A commentator from the launch sit gives voice reports of the launch countdown and the launch itself. From there the commentary moves to the Mission Control Centre at the Johannesburg Amateur Radio Centre where the flight is recorded and mapped. Mission Control is set up to receive bearings from stations situated in a 100 Km radius. This information provides continual updates of where BACAR is moving.

4.4 TRACKING TEAM

A number of teams stand by with direction finding equipment to track BACAR on its decent and to recover the equipment. Of 25 missions, 22 have been recovered, which is a very good record.

Mission One -"Coke Special" was a great success. Everyone was enthused.

5.0 BACAR MISSION 21

Many interesting missions followed with varying degrees of success. For the purpose of this paper, Mission 21 will be reviewed in detail.

5.1 SPECIFICATIONS

- Linear transponder:

Uplink:	28.390 - 28.410 MHz
Downlink:	144.430 - 144.450 MHz
Frequency Stability:	+- 2 kHz
Mode:	Linear transponder with passband reversed
Sensitivity:	-90 dBm input delivers an output of 32 dBm (1.5W)
AGC range:	50 dB
Power Amplifier:	class AB
Power Budget	12v at 500 mA

- Command Receiver:

Mode:	Single tone
Input sensitivity:	-90 dBm
Input selectivity:	+- 5 kHz
Power:	5v

- Telemetry

Frequency:	145.800 MHz
Stability:	+- 2 kHz
Mode:	AFSK audio tones for FM
Power Output:	250 mW
Baud Rate:	50
Number of channels:	8, analogue 0v to +5v
Power Budget:	5v at 200 mA

- Recovery Beacon

Frequency:	145.500 MHz
Stability:	+- 2 kHz
Mode:	FM with 1 kHz modulation
Power:switched low:	1 mW
high:	350 mW
Power Budget:	12v self-contained, minimum lifetime 36 hours.

- Six metre Beacon

Frequency:	51.384 MHz
Mode:	CW on/off keying
Power:	4x3.3v Lithium batteries.

6.0 DESIGN AND CONSTRUCTION

A number of teams were assembled to construct the various sub-modules.

6.1 TECHNICAL CONSIDERATIONS

Path losses were calculated at an assumed height of 100 000 feet above sea level with look angles of between 0.5 and 45 degrees.

PATH DISTANCE (miles)	LOOK ANGLES (degrees)	LOSS AT 28MHz (dB)	LOSS AT 144MHz (dB)
600	0.5	122	135
500	0.6	121	134
400	0.7	118	132
300	0.9	115	130
200	1.4	112	126
100	2.8	106	121
50	5.7	106	114
25	11.0	95	108
10	26.5	86	101
5	45.0	83	96

Table 2 -Path loss vs Look angle

Taking the worst case of a station at a distance of 600 miles having an ERP of 100 W, the power at the input of the receiver would be -72 dBm. The return link would yield approximately 100 dBm at the distant receiver antenna. This is 2.2 microvolt, well within the capabilities of a normal VHF receiving set up. However in practice other losses such as polarization, angle radiation etc must be considered.

6.2 FREQUENCY SELECTION CONSIDERATIONS

With three transmitters in close proximity on the package, the possibility of interference is real. Given the selection of crystals available, one of the working groups used the computer software designed by G3DU and G4BXZ to calculate intermodulation products.

6.3 TARGET DATES

A number of target dates had to be met for a launch on the 19th October 1985. Needless to say there were last minute panics and modifications, but all was ready for launch on the due date.

Despite careful checking of all variables it was discovered that the 19th October was also the date of a local airshow. Fear of causing an accident BACAR Mission 21 was delayed till 16th November.

7.0 MISSION 21 A SUCCESS

BACAR Mission 21 was launched at 05h04 UTC and flew for two hours. The package travelled 130 km and achieved a rate of climb of 300 metres/minute. During its flight BACAR handled 456 contacts.

It is considered that this was one of the more successful flights to date. However no experiment can be without its problems, and the following points were noted on this mission:

1) The power supply voltage came down rapidly when at an altitude of 33 000 ft. This affected the telemetry. The battery problem started at launch when it started dropping from 15v nominal until it reached 10v. This value was maintained throughout the flight. The drop was most likely due to a faulty cell.

2) The telemetry transmitter antenna was horizontally polarized. Much fading was experienced contrary to previous flights were vertically polarized antennas were used.

3) The release mechanism failed and the package could not be released. This was a problem. With multi-balloon flights, not all the balloons burst at the same time which caused the package to hover.

4) Recovery was extremely difficult, but was successfully achieved by sunset.

8.0 GENERAL COMMENTS

Generally weather balloons are used which are filled with hydrogen. The use of hydrogen requires special precautions during filling. No one is allowed within one kilometre radius with any RF or fire source. The person filling the balloons wears a special asbestos suit and helmet. Fire fighting equipment is kept ready.

For a few missions large low pressure balloons were constructed, very much on the Zeppelin principle. However handling was difficult and well near impossible with even a slight breeze. The high altitude flight around the world dream was soon shattered!

Types of equipment flown to date:

- Mode A transponder
- Reverse Mode A transponder
- Mode B transponder
- Parrat Repeater (Voice store and forward system handling 20 seconds.)
- Various types of beacons and telemetry systems.

8.1 THE FUTURE

The next flight will carry a digipeater. Other systems to be used in BACAR missions include:

- SSTV System
- Mode L transponder
- Application experiments such as a small science projects by a high school science club, etc

Development never stops! The main development impetus is on improvement on weight and reduction in power consumption. Research into alternative power sources, like alkaline dry cell batteries, is also receiving high priority attention.

9.0 FUN

Fun is not an acronym; it is a plain old fashioned English word that takes preference in all BACAR project considerations. Each mission must have a large FUN component; it ensures continued interest and support from the Amateur Radio fraternity at large.

THE LAUNCH OF NOAA-H WEATHER SATELLITE: A MISSION PROFILE

Jeff Wallach, N5ITU

Chairman
Dallas Remote Imaging Group

The Dallas Remote Imaging Group has as it's primary mission the design, development, and evaluation of hardware/software systems that may be used to receive both low resolution (4 km.) Automatic Picture Transmission (APT) and high resolution (1 km.) High Resolution Picture Transmission (HRPT) imagery from the U.S. NOAA and Soviet Meteor series weather satellites. Another primary interest of the Dallas Remote Imaging Group (DRIG) is to assist local secondary school districts with setting up weather satellite groundstations to be used as an educational tool for the student's science and mathematics curriculum. Jeff Wallach, N5ITU, Chairman of DRIG was recently invited by N.A.S.A. and the Department of Commerce (NOAA/NESDIS) to attend the launch of NOAA-H polar orbiting weather satellite at Vandenberg Air Force Base. This presentation is an account of the launch sequence, orbit stabilization, and reception reports of imagery from NOAA-H. Videotapes of the launch and actual real-time imagery from the satellite received at the N5ITU groundstation will be presented.

INTRODUCTION

The Advanced TIROS-N (ATN) program is an extension of the older TIROS program, and significant upgrades to the onboard sensors have been initiated. The polar orbiting weather satellite program is a cooperative effort of the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), the United Kingdom, and France for providing day and night global environmental and associated data for operational purposes on a regular basis. The Soviet Union also operates a similar weather satellite program, the Meteor series of polar orbiting satellites. Elements of the Search and Rescue (SAR) system are provided by Canada and France. The U.S. Air Force provides launch support at Vandenberg Air Force Base, California. General Dynamics Convair (GDC) provides the Atlas launch vehicle.

The Advanced TIROS-N weather satellites provide scientists with the most comprehensive meteorological and environmental information since the start of the nation's space program. The TIROS-N/NOAA systems collect meteorological readings from several hundred data collection locations on land, in the air and at sea. It takes vertical measurements of the temperature and moisture distribution in the atmosphere. In addition, the satellites measure energy particles for solar research and radiation warning.

In addition to the normal complement of meteorological and climatological sensors, these advanced satellites are equipped with instrumentation for global search and rescue missions that local downed aircraft and ships in distress. ATN also carries instrumentation for ozone mapping and for monitoring the radiation gains and losses to and from the earth.

Of primary importance to the Dallas Remote Imaging Group, and other satellite imagery enthusiast around the world is the capability to receive weather observations, including visible and infrared pictures, real-time, from the direct readout capabilities of the spacecraft. It is these direct readout sensors for global weather imagery that will be the focus of this presentation.

MISSION SEQUENCE

NASA and NOAA held an educator's conference the evening prior to the launch, on September 23, 1988. Jeff Wallach of the Dallas Remote Imaging Group was invited to give a keynote address on the use of weather satellite groundstations in the educational environment. Over three hundred educators from around the country attended this conference. The use of amateur radio satellite communications, AMSAT, and requirements for building a weather satellite groundstation to receive real-time imagery were all discussed.

At 2:00 AM local time, all attendees boarded a bus for the launch site. The observation point was 3.2 miles from the Western Space and Missile Center at Vandenberg Air Force base. Visibility was minimal due to fog rolling in off the Pacific. The cloud ceiling was around four hundred feet. At 10:02 GMT, on September 24, 1988, NOAA-H was launched atop the twenty-five year old Atlas E booster into a perfect orbit. It was a beautiful nighttime launch that lit up the sky. Although there was only around eight seconds of visibility, it was truly spectacular to view. The videotape of the Atlas launch (to be presented) cannot convey the excitement and splendor of a nighttime launch from beautiful Southern California.

ATLAS LAUNCH VEHICLE

The spacecraft was launched by the Atlas E vehicle. This is a standard Atlas launch vehicle that consists of the E-series Atlas ballistic missile that has been refurbished and modified to a standard configuration for use as a launch vehicle for orbital missions. The vehicle stands 28.7 meters tall and is 3.05 meters in diameter. The fairing is 7.42 meters long and 2.13 meters in diameter. At liftoff, it carried 69 kiloliters of liquid oxygen and 43 kiloliters of RP-1 fuel, a highly refined kerosene.

ORBITAL PARAMETERS

The NOAA-H satellite (re-designated NOAA 11 following orbital insertion) is a three-axis stabilized spacecraft that was launched into a 870 km circular, near-polar orbit with an inclination angle of 98.86 degrees (retrograde) to the Equator. Total orbital period is approximately 102 minutes. The sunlight period will average 72 minutes and 30 minutes in the Earth shadow. Because the Earth rotates beneath the orbit 25.59 degree during each orbit, the satellite observes a different portion of the Earth's surface each orbit.

The nominal orbit is Sun-synchronous and precesses (rotates) eastward about the Earth's polar axis 0.986 degrees per day. This precession keeps the satellite in a constant position with reference to the Sun for consistent illumination throughout the year. NOAA-H was launched so that it always crosses the Equator at about 1:40 PM northbound and 1:40 AM southbound local solar time.

The circular orbit of NOAA-H permits uniform data acquisition by the satellite and efficient command control of the satellite by the NOAA Control Data Acquisition ground stations located at Fairbanks, Alaska and Wallops Island, Virginia.

Figure 1 represents schematically the orbital characteristics of NOAA-H (11).

Figure 2 shows the Launch-to-Orbit Injection sequence and the major launch events of the mission for the NOAA-11 spacecraft as provided by NASA, NOAA, and the U.S. Air Force.

NOAA-H INSTRUMENTATION

NOAA-H carries instrument systems that provide both direct readout (real time) and onboard recording (playback) of environmental data during day and night operations. The primary instruments carried by the NOAA-H spacecraft are as follows:

- o Advanced Very High Resolution Radiometer/2 (APT, HRPT)
- o High Resolution Infrared Radiation Sounder/2
- o Search and Rescue
- o Solar Backscatter Ultraviolet Spectral Radiometer
- o Microwave Sounding Unit

- o ARGOS Data Collection
- o Stratospheric Sound Unit

Figure 3 is a artist's conception of NOAA-H in earth orbit.

The Advanced Very High Resolution Radiometer/2 is the primary instrument amateurs are interested in to receive the weather satellite imagery. AVHRR is a radiation-detection instrument used to remotely determine cloud cover and the surface temperature. The scanning radiometer uses five detectors that collect different bands of radiation wavelengths. Measuring the same view, this array of diverse wavelengths, after processing, will permit multispectral analysis for more precisely defining meteorological, oceanographic, and hydrological parameters. One channel will monitor energy in visible band and another in the near-infrared portion of the electromagnetic spectrum to observe clouds, lakes, shorelines, snow, ice, and vegetation. The types of imagery the amateur can receive with very modest receiving and display systems are outstanding!

Figure 4 is an example of the HRPT imagery from NOAA-10 on May 9, 1987, Channel 2 InfraRed, at 12:57 GMT. The entire northeastern coast of the United States is clearly visible, along with small lakes, mountains, rivers, etc.

COMMUNICATIONS AND DATA HANDLING

NOAA-H has onboard a communications subsystem that uses ten separate transmission links to handle communications between the satellite and the ground stations. Table 5 summarizes the communications links.

Of primary interest for APT reception is the 137.62 Mhz wideband FM signal. The nominal IF frequency of the receiver should be about 50 khz. Although there are number of commercial receivers in the amateur marketplace that are designed specifically for weather satellite reception of the APT imagery, simple police scanners that cover the 137 Mhz band will do an adequate job.

For the HRPT high resolution imagery, receivers at 1698 MHZ and 1707 MHZ will be required.

WEATHER SATELLITE IMAGERY RECEPTION

The construction of a weather satellite groundstation, and reception of real-time imagery from the spacecraft was the topic of last year's presentation at the 1987 AMSAT Forum. However, let me provide a brief summary of how the amateur may get started in this fascinating hobby!

If you have a groundstation that is already configured for reception of telemetry from the OSCAR series of satellites, then you are more the 50% on your way to receiving weather satellite imagery. Essentially, what is required is a two meter band antenna, a good preamp, a receiver capable of 137 Mhz wideband FM modulation, with an IF frequency of around 50 Khz. To actually display the imagery, some type of hard copy facsimile machine, or a personal computer with appropriate demodulator and software is required. (Pictures of the groundstation and development lab at the N5ITU station will be presented during the forum).

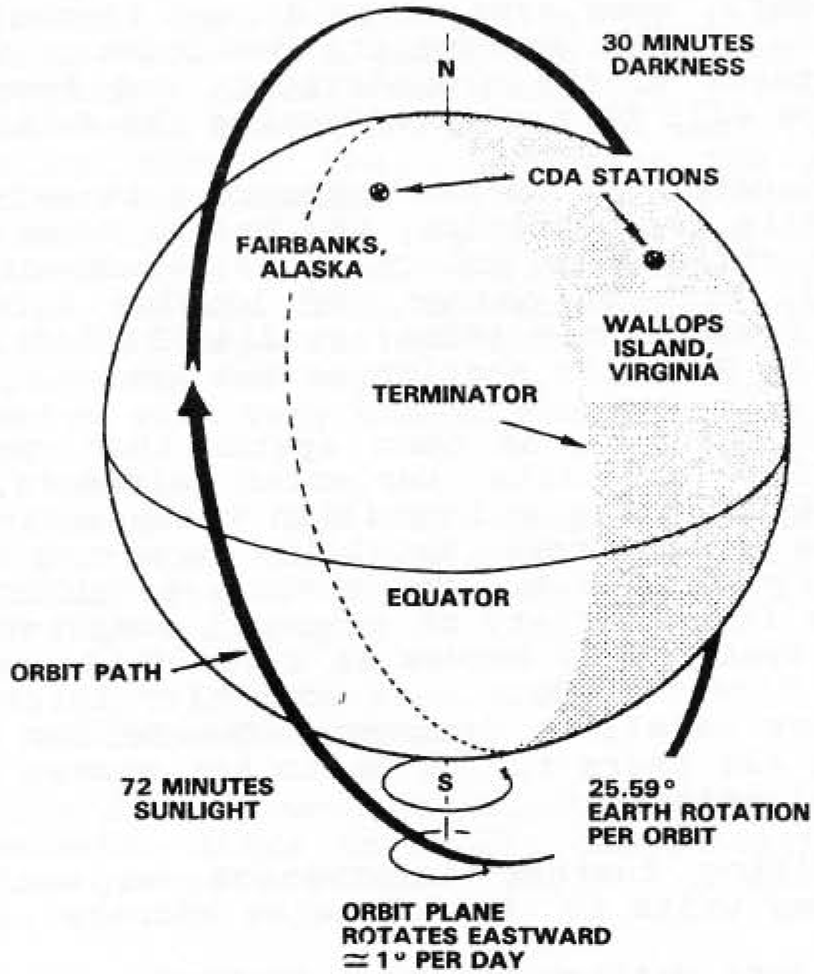
To assist educators and other amateurs interested in designing a weather satellite groundstation, the Dallas Remote Imaging Group has developed a three page primer on this subject. This primer may be obtained, free of charge, by logging into the Datalink Remote Bulletin Board system (RBBS) at 214-394-7438. It is listed as BULLET17 in the Bulletin section on the system.

The Datalink RBBS is an open system that carries the most current NASA/NORAD satellite keplerian elements, intelligence reports on Soviet military and civilian space activities, updates on NOAA weather satellites, satellite tracking programs, and real-time imagery from U.S. and Soviet satellites along with display programs for a variety of personal computers and graphics displays. This system also serves as a worldwide messaging system to keep the APT direct readout user community informed of current events in weather satellite imagery. The Dallas Remote Imaging Group encourages all users to log on to the system and use it for their educational enjoyment.

Users requiring further information on weather satellite groundstations may write to the following address:

Jeff Wallach, Ph.D. (N5ITU)
Chairman
Dallas Remote Imaging Group
PO BOX 118053
Carrollton, Texas 75011-8053
U.S.A.

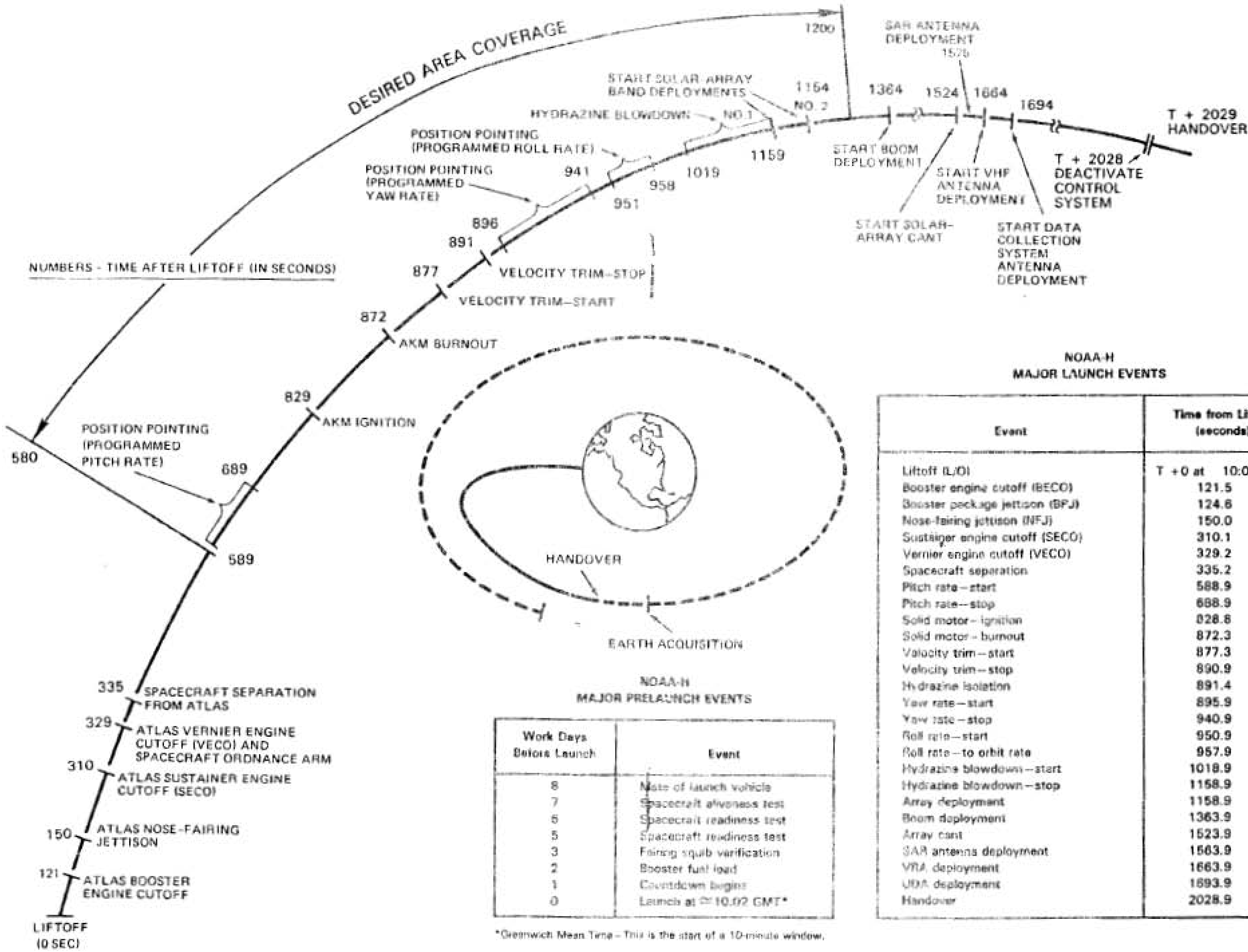
Voice phone 214-394-7325
Data phone 214-394-7438



ORBITAL CHARACTERISTICS
Apogee — 870 km (470 nmi) Perigee — 870 km (470 nmi) Minutes per orbit — 102.12 Degrees inclination — 98.86

NOAA-H Orbit

FIG. 1



NOAA-H
MAJOR PRELAUNCH EVENTS

Work Days Before Launch	Event
8	Mate of launch vehicle
7	Spacecraft aliveness test
6	Spacecraft readiness test
5	Spacecraft readiness test
3	Fairing squib verification
2	Booster fuel load
1	Countdown begins
0	Launch at ≈10:02 GMT*

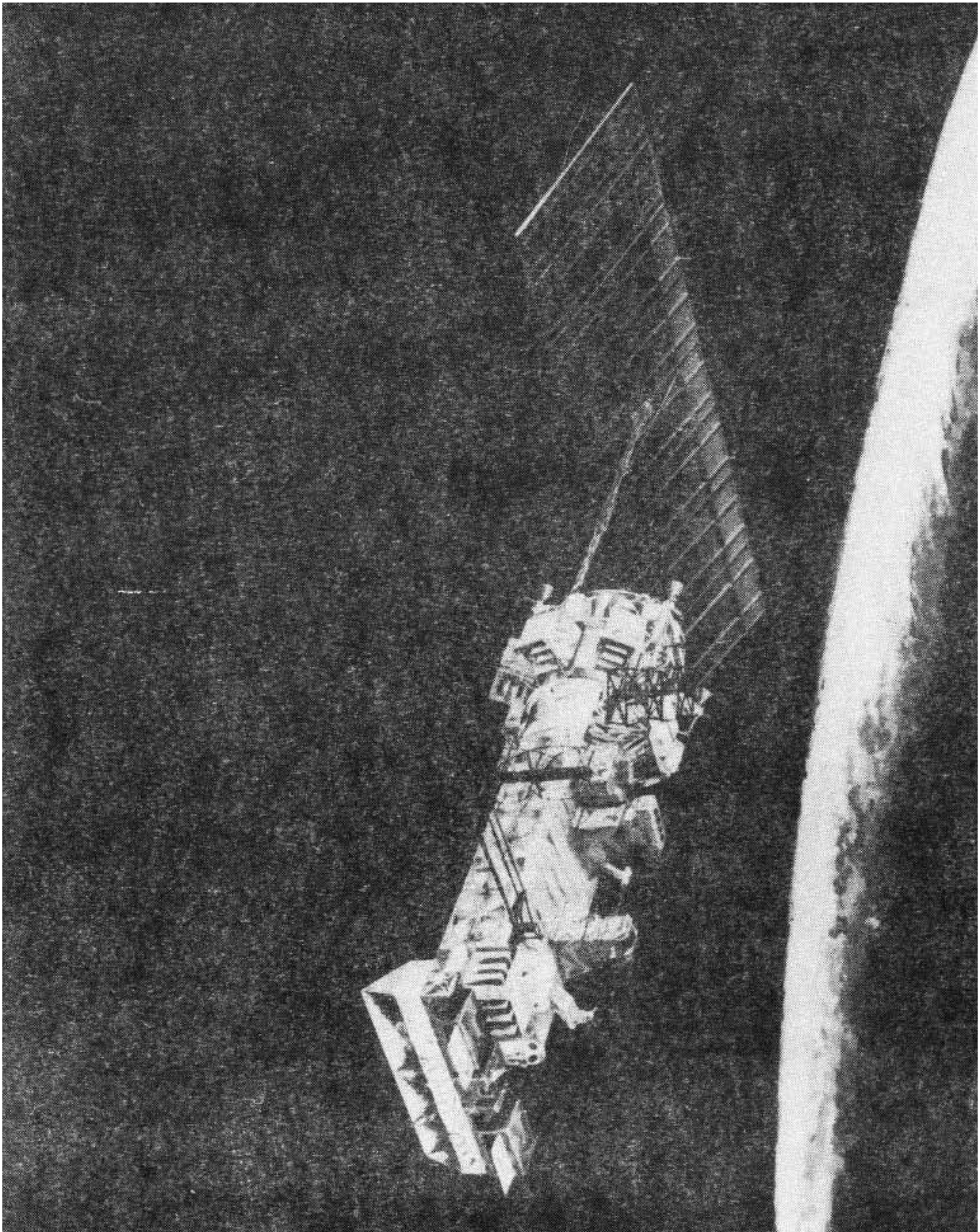
*Greenwich Mean Time – This is the start of a 10-minute window.

NOAA-H
MAJOR LAUNCH EVENTS

Event	Time from Liftoff (seconds)
Liftoff (L/O)	T +0 at 10:02 GMT
Booster engine cutoff (BECO)	121.5
Booster package jettison (BPJ)	124.6
Nose-fairing jettison (NFJ)	150.0
Sustainer engine cutoff (SECO)	310.1
Vernier engine cutoff (VECO)	329.2
Spacecraft separation	335.2
Pitch rate—start	588.9
Pitch rate—stop	688.9
Solid motor—ignition	828.8
Solid motor—burnout	872.3
Velocity trim—start	877.3
Velocity trim—stop	890.9
Hydrazine isolation	891.4
Yaw rate—start	895.9
Yaw rate—stop	940.9
Roll rate—start	950.9
Roll rate—to orbit rate	957.9
Hydrazine blowdown—start	1018.9
Hydrazine blowdown—stop	1158.9
Array deployment	1158.9
Boom deployment	1363.9
Array cant	1523.9
SAR antenna deployment	1563.9
VRA deployment	1663.9
UDA deployment	1693.9
Handover	2028.9

Launch-to-Orbit Injection Sequence

FIG. 2



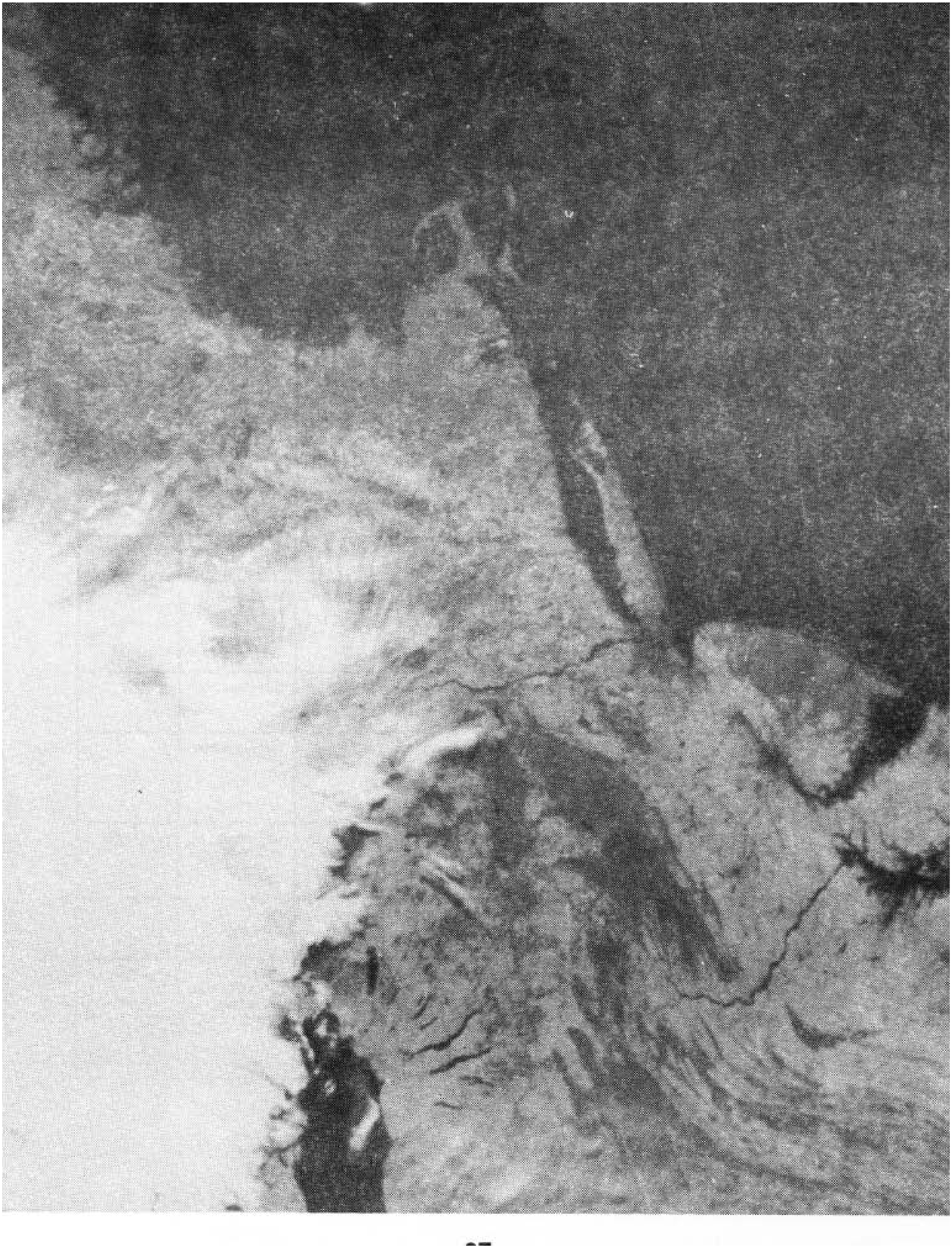


Table 5
Communications and Data Handling

Link	Carrier Frequency	Information Signal	Baseband Bit Rate	Modulation	Subcarrier Frequency
Command*	148.56 MHz	Digital commands	1 kbps	Ternary frequency-shift keyed (FSK/AM)	8, 10, and 12 kHz
Beacon	137.77 and 136.77 MHz	HIRS, SSU, MSU, SBUV/2 SEM, DCS data, spacecraft attitude data, time code, housekeeping telemetry, memory verification; all from TIP	8,320 bps	Split-phase phase-shift keyed PSK	
VHF real time	137.50 and 137.62 MHz	Medium-resolution video data from AVHRR	2 kHz	AM/FM	2.4 kHz
S-band real time	1,698 or 1,707 MHz	High-resolution AVHRR and TIP data	665.4 kbps	Split-phase PSK	
S-band playback	1,698, 1,702.5, or 1,707 MHz	High-resolution AVHRR data from MIRP, medium-resolution AVHRR data from MIRP; all TIP outputs	2.6616 Mbps	Randomized nonreturn-to-zero/PSK	
Data collection (uplink)	401.65 MHz	Earth-based platforms and balloons	400 bps	Split-phase PSK	
S-band playback to European ground station	1,698, 1,702.5, or 1,707 MHz	TIP data recovered from tape recorders	332.7 kbps	Split-phase PSK	
S-band contingency and launch	2,247.5 MHz	Boost during ascent and real-time TIP in orbit	Boost 16.64 kbps TIP in orbit 8.32 kbps	Split phase PCM/BPSK	1.024 MHz
SAR L-band downlink	1,544.5 MHz	Data transmission from SARR and SARP to ground LUT's	300 kHz (video)	PM 2 rad peak	
SAR uplinks	SARR 121.5 MHz 243 MHz 406.05 MHz SARP 406.025 MHz	From ground ELT/EPIRB's to spacecraft	(video) 25 kHz for 121.5 MHz 45 kHz for 243 MHz 400 bps for 406 MHz	AM for 121.5/243 MHz PM for 406 MHz	

*Uplink to the satellite

FIG. 5