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AMSAT has begun the design and development of a new form of Amateur Satellite. The PACSAT series of satellite systems has as a design goal total global access by all hams to a store-and-forward packet radio message handler.

Introduction

AMSAT is proposing the design and prototyping of a satellite-based experiment for advanced digital packet satellite communications experiments. This system, called PACSAT, will use internationally-allocated Amateur Radio Service frequencies. The PACSAT system will connect a grid of ground-based amateur radio local area networks in the United States and many other countries via a common store-and-forward packet repeater operating in the Amateur Satellite Service.

This paper details the reasons behind such a satellite. Following the design concepts, a description of the entire system is given, and a list of technical parameters for each of the defined subsystems is shown. The current outline of tasks and scheduling follows, with a description of the efforts of groups already engaged in the initial design effort.

The PACSAT Concept

The Amateur Radio communities in the United States and other countries are currently experimenting with digital networks on radio channels. These networks are using techniques already in place on the national telecommunication networks known collectively as packet networking.

Packet radio systems have a set of benefits unusual in present amateur radio systems. Large numbers of stations may share a common frequency, and use multiple access packet techniques to multiplex several sets of users in the time domain; very high spectrum utilization is accomplished by keeping all of these users on the same channel. A second benefit of the single shared channel is the ability to find all other users of the packet radio system. No searching of a wide band of frequencies is required; connectivity is maximized. The need of multiple access techniques to detect successful transmissions yields a third benefit that of reliable transmissions. Any message that arrives at destination has had its data integrity checked. This inherent reliability may well open a series of possibilities for improving emergency traffic handling, one of amateur radio s most important aspects.

As experiments continue on ground-::;;," packet radio local area networks, a new of satellite is being considered to handle linking of both individual ground stations and local area networks. The PACket radio SATellite (PACSAT) system is designed to provide a store-and-forward digital repeater which is available to all groups around the world for fully global network coverage. The satellite provides this coverage by occupying a low-earth orbit (LEO), which has several benefits. The close proximity of passage, relative to geo-synchronous satellite, allows easy access, with good link margins ". There are thousands of amateur radio earth stations that are already configured to operate on this class of satellite. Additionally, proper choice of orbital parameters allows a sun-synchronous orbit, where passage of the satellite occurs at the same times each day, providing an easy means of scheduling transmissions. This orbit then provides both 100% global coverage and very fair access, and creates a powerful new use of a well-known class of amateur satellite.

There are several purposes for providing such a system in the Amateur Satellite Service. PACSAT will provide a wide-availability vehicle for advanced experimentation, and a prototype system for a new class of satellite service involving reliable transmission of data to remote sites and isolated users regardless of location. Several internationally-based organizations have expressed interest in just such capabilitiies, and this gives AMSAT the oppurtunity of spear-heading a potentially major new push in low-cost satellite systems, much in consonance with the F.C.C. Charter for the Amateur Radio Service as a "proving-grounds" for new technology. The Volunteers in Technical Assistance (VITA), a non-profit firm dedicated to advancing the level of technilogical expertise of less-developed countries, is actively pursuing the coordination of such vanguard activities, and is working directly with AMSAT on the PACSAT development.

Other benefits result from the use of digital techniques. Considerable improvements may be made to emergency communications, as reliable, high availability links compatible with global mobile and portable radio service requirements are provided. Additionally, a spin-off benefit for AMSAT itself is the attracting of the new, computer-aware members of the Amateur community into the Amateur Satellite Service.

A possible third set of benefits may be spun off the PACSAT system indirectly; the opportunity exists for designing new types of low-cost satellite launching and propulsion systems as a part of this next generation of Amateur spacecraft.

Such a system would provide a number of functions. In addition to the primary use as a world-wide store-and-forward link, or "flying mailbox", the PACSAT experiment could provide real-time regional linking (standard LEO amateur mode). As mentioned, both local network concentrators (gateways) and individual users could access the satellite. Finally, the system would provide the mechanism for advanced testing of network systems concepts, hardware, software and protocols to be used by packet radio networks in the future.

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PACSAT System Description

PACSAT is an extraordinarily complicated system, rather similar in complexity to the Phase III spacecrafts. In addition to a.11 of the required satellite support subsystems on board the spacecraft, there are two experimental packages, each consisting of multiple uplink channels, common downlink channels, and modems, coder/decoder link-access devices and control microprocessors with interfaces to a common satellite message processing unit (system control unit, or SCU). As if that isn't bad enough, the rigid packet environment demands structured ground stations with all of the familiar hardware (less the directional antennas, as we shall see), and perhaps several micropressors for handling both the data stream and the automatic station control functions. The age of the microprocessor is upon Amateur Radio.

To ease the burden of trying to understand the whole system, PACSAT can be broken up into subsections, each with well-defined interfaces to other sections. A description of each section or interface follows. Please note that, although the conceptual design has been finished, many design groups are hard at work coming up with the specifications for their parts of the overall system, so that nothing below can be consrued to be the "final word".

Spacecraft

As mentioned, the orbit of PACSAT would be sun-synchronous, that is, appearing at the same time each day. UoSAT/OSCAR 9 has this type of orbit, and displays this property. Additionally, such an orbit guarantees at least two passes per day will be seen by ALL corners of the Earth.

The PACSAT satellite system may be broken into the spacecraft itself, and the experimental packages. The interfaces are defined to be spacecraft/ experiment and spacecraft/ground station.

Two options are available for placing PACSAT experiments into space. The possibility of riding the packages inside of a spacecraft built primarilly for other purposes exists, and allows the PACSAT design team to avoid the additional complexity of designing and building all of the required subsystems. AMSAT has looked in particular at the future launch opportunities available on the Conestoga-series of launch vehicles to be provided as a commercial venture by Space Systems of America, Incorporated. SSI will be launching payloads directly into low-earth orbit, providing a mechanism for direct injection of PACSAT into its final orbit without requiring on-board propulsion systems in the satellite.

A second opportunity is more in line with AMSAT's traditional method of designing the satellite "from the ground up", and will likely provide many more opportunities for future launches. The Space Transportation System (Space Shuttle) has the option of carrying into space sets of three "Get-Away Special" canisters, or GAS cans. Although these cans have traditionally been reserved for inexpensive access for experimenters who did not require throwing their experiments into space, recent discussions with NASA have shown promise for using such a can as a launch opportunity. A satellite would be placed inside the can, with a mechanism in place to allow the Shuttle crew to remotely open the lid and push the spacecraft into the void (hopefully after opening the Shuttle bay doors).

This new opportunity has two tremendously useful aspects: GAS can opportunities are CHEAP ($10 000) and potentially plentiful. The drawbacks are the requirements of building such spacecraft as would be required to fit into the can, and providing a propulsion mechanism for altering the very low orbit into which the Shuttle would place the unit, so that a final, more stable orbit would be available. As it happens, there are active international AMSAT groups that are very excited with the possibility of providing both spacecraft and propulsion.

The University of Surrey spacecraft design team (UoSAT) has expressed an interest in continuing their advanced low-cost spacecraft design and construction projects, and view PACSAT as an excellent opportunity for using their integration expertise, and for providing a vehicle to carry other experiments of interest to their group.

The AMSAT/DL team at the University at Marburg, West Germany, has been discussing the possibility of providing an innovative spacecraft engine which would be ideal for such a craft as PACSAT - a steam engine, not unlike those first designed by Hero in ancient Greece. The mechanism for generating steam in space is not difficult, and impinging sunlight on external water tanks could provide a large part of the energy required to heat the water. Heating coils electrically powered in the area of the super-heated steam nozzles would finish the heating job. Although this concept seems a little far-fetched at first, calculations prove the amount of water required to alter the orbit of PACSAT is quite modest. Further, the ever-present problem of safety to the Shuttle crew is very much reduced by having spacecraft with extremely non-volatile fuels such as water! Gradual pushes from the steam nozzles at opposites sides of the orbit will nudge PACSAT into its final orbit, and residual water could be used to further occasionally alter the orbit to keep it in a sun-synchronous plane.

PACSAT Communications Experiment Package

Each of two packages will contain a set of uplink and downlink channels with associated analog and digital hardware. Current designs are targetted for typically four uplink channels, each dynamically configurable with respect to data rate. One high-speed downlink channel will be used to support the uplinks, and to provide control over the smart ground stations. For an excellent review of the design effort for the modulation techniques and access modes of these channels, see the paper "Modulation and Access Techniques for PACSAT" by Phil Karn, which is included in these proceedings.

Supporting these communications channels will be a series of filters, oscillators and amplifiers, along with microprocssors and buffer memory for channel control and support of link access protocols. These processors, with perhaps one or two channels per processor, will allow the demodulators chosen to be both adaptive in data rate and frequency agile.

The set of packages will have a common system controller and main memory unit (RAMUNIT). The software to support the higher-level protocols and application programs to be resident in the SCU will be loadable from the ground, a technique now common in the Amateur Satellite Service. A memory package in the megabyte range is being investigated.

Spacecraft/Experiment Interface

The spacecraft will provide the envvironment for PACSAT, including power, antennas and shielding from the extremes of space. A separate pocessor will handle the spacecraft's housekeeping functions, and separate communications channels will be available for satellite command. Standard interfaces will define nd stations will be fairly complicated, requiring smart controllers to handle the re uirements of frequency agility in the transmitters, and of linking, networking and presentation control.

To allow users to ease into packet radio satellites, a gradual upgrade path is to be provided for PACSAT use. A required piece of equipment will be the modem, which will include a modulator, demodulator and pass-through path for transmitter push-to-talk and frequency control. This modem will be capable of operating as a stand-alone modem attached to one of the current types of packet radio terminal node controllers (TNC).

Operation of the TNC and modem pair with a standard set of 440-MHz transmitter and L-meter receiver will allow operation at 1200 bauds. Higher speed operation will require a separate rf deck, with direct access to IF strips. Speeds of up to 9600 bauds are planned.

A final touch would be a custom TN, specifically designed for this system, and allowing direct interface to other TNCs for ground-based internetwork linking.

It should also be noted that conservative link margin calculations have shown that, with modest transmitter power on board the spacecraft and standard powere available to ground stations (around 25 watts,), the requirement for having directional antennas is not necessary. Simple gain verticals like 5/8th whips on 440 and 2 will probably be quite adaquate, especially at lower baud rates like 1200 bauds.

Spacecraft/Ground Station Interface

The PACSAT Project intends to use omnidirectional antennas on two of the most popular vhf/uhf bands, in a mode which will be familiar to Phase III users. Uplinks will be available at around 435 MHz, and choice of the proper channel will be made by the ground station controller, following the command requests of the satellite. The common downlink will appear at the edge of the Amateur Satellite allocations, probably around 145.806 MHz for one package and 145.994 MHz for the other.

The modulation technique, synchronization requirements, encoding mode and related parameters are to be determined, based on experiments to be performed by two different design teams this spring. It is assumed that either differentially-encoded phase-shift keying or minimum shift keying at rates in the 1200 to 9600 baud range, perhaps adaptively availble, are the most likely candidates.

The link-level access protocols, that is, the addressing and error detection schemes are planned to be corpatible with the AX.25 Amateur packet radio protocol standard. This protocol has already been implemented by several groups, and is a de facto AMSAT standard for all currently-planned packet satellite efforts.

The network protocol will probably support AX.25 network-level protocol, and perhaps also less corplicated (and less reliable) "datagram-type" protocols as well.

The memory interface between ground stations and the on board RAMUNIT will be little more than a virtual disk drive. with a very noisy connecting link. On top of this protocol will lie an applications program which will provide a number of message and file services. Experimenters will be provided with lower-level accesses to the system where such access does not significantly disrupt normal use of the system.

PACSAT Project Status

The final conceptual review meeting was held in February 1983, and several of the design groups attended, including representatives from both VITA and the University of Surrey. Many of the more sophisticated concepts were thrown away to provide an easier target for scheduling. There will be a set of subsystem design meetings at this conference, and further meetings to be held later this spring. Negotiations are currently underway with the candidate launch agencies and design support groups.

System design is likely to be completed early this summer, with deliverable items to be integrated and tested this fall. Following critical design review meetings, spacecraft-ready subsystems will be prepared and shipped to the integrating agancy by next spring. Such a schedule would allow AMSAT to take advantage of possible launch opportunities as early as late 1984. Slippages will be inevitable however, and more realistic times will in general coincide with the more likely target launch dates, early 1985 to 1986.

The project now has the support of twelve differennt design groups from four different countries, but is still in need of qualified hardware and software designers to help review all aspects of the current design, and provide needed manpower with several of the more important subsystems. PACSAT is an all-volunteer effort, and will require careful evaluation by the general user community during its initial phases to confirm design parameters and provide guidance in the utility of the various modes. It is hoped that this "system will not only provide many services which are forecast for the digital fututre of ham radio, but also create a whole new set of users and uses vet to be imagined.