Radio Amateur Satellites: A Means for Relating the Advances in the Space Program to the Public

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ABSTRACT

Five amateur satellites in the Oscar series have been launched. They provide the radio amateur with an opportunity for a direct experience with space technology. Schools and educational organizations have used amateur satellites to aid in the instruction of space science. The planned Amsat-Oscar B spacecraft will involve an organized program to promote the educational utilization of Oscar satellites. In these ways sections of the general public receive personal contact with space technology.

INTRODUCTION

Ways for the general public to participate in the space program are very limited. This is due to the technical nature of the subject and because of the limited number of physical opportunities where an individual could have a direct encounter with space technology. Oscar, an acronym for Orbiting Satellite Carrying Amateur Radio, is a program which in a unique way is relating the advances of our space program to large segments of the general public.

The interest of radio amateurs in space phenomena is not new. In 1936 Grote Reber, a radio amateur built the first radio telescope and received radio noise of extraterrestrial origin¹. During the 1950s amateurs successfully employed meteor scatter communication and in 1953 two US amateurs, Ross Bateman and William Smith reflected the first amateur signals off the lunar surface at 144 MHz. Preceding the Launch of Sputnik 1, Radio, the journal of Soviet radio amateurs published information to aid amateurs in receiving the satellite's signals. Following the historic October 4, 1957 launch, amateurs the world over copied the 20 and 40 MHz transmissions. Hams provided some of the first orbital data to U.S. scientists and also aided later in measuring the orbits of the first U.S. satellites.

By 1960, interest in space technology was stimulated to the extent that a group of West Coast amateurs formed the Project Oscar Association². Its aim was to design and build satellites for use by radio amateurs. Membership was composed principally of amateurs professionally engaged as scientists and engineers in the field of space technology.

The initial task of the Oscar Association was the design and construction of a beacon satellite to transmit in a frequency band used by radio amateurs. The package which was developed operated on about 144.98 MHz with 100 milliwatts of power supplied by an 18 volt mercury battery. It transmitted the letters "HI" in international Morse code at a rate analogous to the internal temperature of the satellite. Oscar 1 was launched from Vandenberg Air Force Base on December 12, 1961 by the US Air Force as a piggyback payload, replacing balast on a Thor-Agena vehicle. The 10-pound satellite achieved a 268-mile orbit and transmitted for 277 revolutions.

Oscar 2, launched on June 2, 1962 was a package similar to the first amateur satellite. Additional batteries were added to increase operating life and the satellite was still transmitting as it re-entered the atmosphere on revolution 295.

The next two amateur satellites were communications packages. Oscar 3, which went into a 530 mile circular polar orbit on March 9, 1965 was a free-access frequency translator. It received a 50-kHz band centered at 144.1 MHz for retransmission at 145.95 MHz. This satellite also telemetered battery voltage and spacecraft temperature. The translator lifetime was more than two weeks. Oscar 4, the first amateur satellite launched by the Air Force from Cape Kennedy was also a translator -- this time from the 144 to 432 MHz band with a 10 kHz bandpass. The satellite was to be placed into a near-synchronous orbit. A failure in the Transtage of the Titan 3 C launch vehicle, however, left Oscar 4 in the elliptical synchronous transfer orbit where it functioned for at least several weeks.

In early 1969, Amsat, the Radio Amateur Satellite Corporation was organized by Washington DC area amateurs³. The organization now has a national...
and international membership and is affiliated with and receives financial support from the American Radio Relay League, the ham's national association. As its first project, Amsat undertook the launch preparation and testing of Australis-Oscar 5, a beacon satellite built by Project Australis, a group of amateurs who were students at Melbourne University in Australia. The satellite was launched as a secondary payload by NASA on the Tiros-M mission, January 23, 1970. AO-5 transmitted seven channels of telemetry in the 28-MHz and 144-MHz amateur bands. The package contained a Magnetic Attitude Stabilization System and was the first ham satellite to be ground controlled.

**AMATEUR PARTICIPATION**

Satellites in the Oscar series give a segment of the general public, the radio amateurs, a very personal and positive contact with space technology. The beacon satellites, Oscars 1 and 2 had as their primary mission, the introduction of amateurs to satellite technology. They first proved that amateurs could design and build their own spacecraft, and second, gave operators the opportunity to engage in satellite tracking from their own amateur stations. Response to these satellites was very encouraging. More than 5000 telemetry and tracking reports from 600 amateur stations were received for Oscar 1. The total for Oscar 2 was even greater, with 700 stations reporting.

Oscar 3 gave radio amateurs their first opportunity for actual communication via satellite. During the 247-orbit lifetime, almost 300 amateurs succeeded in transmitting signals which were repeated by the satellite. A total of 176 complete two-way contacts were reported by participants. Although Oscar 4 did not function as planned, it did make possible several more amateur satellite contacts.

The most recent ham satellite, Australis-Oscar 5 was significant in that it gave many amateurs a chance to study the trans-ionospheric propagation at 144 and 28 MHz. A detailed report on the findings was published in the October 1970 issue of QST. AO-5 also provided for a demonstration of the ability of the amateur service to exhibit ground control over a satellite's emissions. The 28 MHz beacon was regularly switched on and off to conserve battery power. Command capability is an important consideration for the operation of future Oscars as a means of preventing harmful interference to other services when utilizing shared frequency allocations.

The telemetry system on AO-5 is also noteworthy. Sensors on the spacecraft sampled the internal and external temperatures, along with battery voltage and current drain. Three optical sensors mounted on orthogonal axes were used to determine attitude from light reflected from the earth's disc. All of these data were telemetered using audio tones amplitude modulated on the beacon signals. Observers were able to decode the information by use of a calibrated audio oscillator or even a musical instrument. Once the frequency of the time-multiplexed tones was determined, reference to a graph permitted conversion to the actual parameters.

Through the propagation investigations and telemetry transmissions, amateurs were able to take part in a scientific-type of experiment. Analysis of the reports they provided indicate that an average data error of less than 10% can be expected from the amateur reports.

Oscar participation has come from a relatively small but very enthusiastic portion of the amateur community. The participating ground stations were operated both by individuals and groups of amateurs pooling their efforts. Many built Yagi and helical antennas and az-el mounts -- some even employed automatic tracking techniques. The result of this direct form of involvement is that amateurs gain a first-hand knowledge of the operation of a satellite link and of its utility.

Within amateur radio, interest in the Oscar program encompasses more than those who have directly participated. Through amateur journals, meetings and conventions, knowledge of the project and activities is brought before the entire group. Of particular interest is the first National Radio Amateur Satellite Conference held as a part of the ARRL National Convention in Boston during 1970 attended by hundreds of amateurs.

There are presently 265,000 licensed radio amateurs in the United States. They come from all walks of life, and range in age from 6 to nearly 100. With influx and attrition during the decade since the Oscar series began, there have been almost 1/2 million U.S. citizens involved with amateur radio. The total world-wide ham population is now over 500,000.

**INTERNATIONAL INTEREST**

Amateurs in more than 25 countries have taken part in each of the Oscar experiments. Interest has come from both industrialized and developing nations. Indeed, in some of the emerging countries, participation in the Oscar program may be the nation's first real encounter with space communications.

Indicating the non-political nature of amateur satellites, one operator, K. A. Kallemaa, UR2BU of Tartu, Estonia, USSR has participated in all of the Oscar missions. During the operation of Oscar 4,
another Soviet amateur, Valdas Simonis, UP2ON of Kaunas, Lithuania and Warren E. Butler, K2GUN of Scotch Plains, NJ established contact for the first direct USSR to US satellite-communication.

Oscar 5 was an especially noteworthy international venture having been constructed in Australia with space-qualification tests and launch arrangements handled in the US. Unlike earlier Oscars, the builders of this satellite had no previous experience in the construction of satellite hardware. An amateur space project now in preparation, called Amsat-Oscar B, involves the cooperative work of radio amateurs in Australia, Germany and the United States.

EDUCATIONAL INVOLVEMENT

The influence of the Oscar program extends beyond the amateur population through involvement of schools and educational institutions utilizing amateur satellite stations and the assistance of individual radio amateurs in the instruction of space science. With the Australis-Oscar 5 mission, an experimental education program was conducted at the Talcott Mountain Science Center, Avon, Connecticut. The program illustrates the value of an amateur satellite and ground station in a program of space science instruction. The Science Center is a regional facility serving the public and private schools in the surrounding area. Affiliated with it is the Talcott Mountain UHF Society, an amateur group interested in furthering the educational objectives of the Science Center through the use of amateur radio. Jointly, they undertook the project of utilizing the amateur station at the Science Center for space science instruction.

The primary objective of the Talcott program was to investigate how an amateur radio satellite ground station can be used by classroom teachers in areas normally outside the realm of laboratory involvement. The work done has relevance to the study of communications, astronomy, physics, mathematics, and meteorology. For example, using such a facility, students can verify the Doppler effect by noting the change in radio frequency of the received signals as the satellite passes overhead. The principles of orbital geometry can be discovered by plotting the satellite's course. The role of telemetry in the performance of spacecraft systems can also be demonstrated.

During the 46 days of the AO-5 experiment, the Talcott Mountain Science Center used the educational tool with over 300 students from fourth to twelfth grade levels. The primary levels benefited from demonstrations of the satellite ground station. Involvement of older students included actual operation by them of the equipment for first-hand investigations. In addition to the student involvement, adult participation took place with a NASA aerospace teacher workshop at the Science Center which happened to coincide with the AO-5 experiment.

Many problems were experimentally investigated by students using the amateur station with AO-5. The advantages of this approach over the traditional lecture/textbook methods lie principally in the area of motivation. The excitement created with students directly observing and operating a satellite tracking station does much to ensure a meaningful and lasting learning experience. Until now it has been unusual for students to have an opportunity for laboratory-type experiences in an area as esoteric as space science.

AMSAT-OSCAR B

Radio amateurs are now planning for their next satellite. Amsat-Oscar B (it will receive an appropriate numeral in the Oscar series upon launch) is to be a long-lifetime, solar-powered repeater satellite. A number of the spacecraft's sub-systems are now under construction. The final configuration is expected to include two or three repeaters, probably two telemetry systems, and a command system. The following is a description of the equipment:

The Wireless Institute of Australia's Project Australis is breadboarding a four-channel, channelized, hard-limiting fm repeater. It employs signal demodulation and remodulation with a 145.9 MHz up-link and a 432.35 MHz down-link. Power output is one watt per channel.

A group of amateurs in Marbach, West Germany have under construction a frequency translator with a 50-kHz bandwidth. Its input is 432.15 MHz and output is 145.95 MHz, with ten-watts output.

Amsat members in the US have breadboarded a linear repeater with a 145.95 MHz input and an output of two watts around 29.5 MHz. Like the German repeater, this one will handle any method of modulation permitted within its 50-kHz passband.

There are two major telemetry systems for housekeeping data. One has been developed by Project Australis and transmits directly in 850-Hz a.f.s.k. teletype format for print-out on a 60-wpm teleprinter. The other, designed by John Goode, W5CAY, transmits numbers directly in Morse Code. Another simple telemetry system is expected to be included to indicate the status of the various repeaters through use of audio.
NASA has agreed to undertake the launch of A-O-B as a secondary payload subject to identification of a suitable mission with adequate payload capacity. The orbit is expected to be similar to that of AO-5. A late 1971 or early 1972 launch is hoped for. Especially wide participation is expected from the amateur community since the satellite will provide a new band of frequencies for daily, long-distance amateur communications.

**FUTURE EDUCATION PLANS**

An exciting opportunity will be provided by the Amusat-Oscar B satellite for the implementation of a multi-faceted education and training program. It is anticipated that it can involve: 1. Elementary and secondary schools. 2. Colleges and universities. 3. Vocational and technical schools. 4. Adult groups. 5. Youth groups. 6. Educational institutions in developing nations.

The principal ingredient in the program is the small earth terminal useable with A-O-B. Use of the satellite will be made primarily as a motivational device and laboratory tool in space science and technology, earth science, social science and physics. The amateur satellite is superior in this application to other satellites available to small-terminal users in two important ways. First, among the entities listed above as program participants, there already exists a large number of amateur stations capable of serving as A-O-B ground stations with some additional equipment. And, second, in the communities where these entities are located, there are most likely qualified amateurs who could serve as resources for technical assistance.

The method of implementation for this program will be through an exemplary program at the Talcott Mountain Science Center. Activities will be organized so as to provide a model in terms of program organization for the groups of interest. The Science Center proposes to actually work with elementary and secondary schools, colleges and universities, vocational and technical schools, and adult and youth groups in the vicinity of Talcott Mountain, using the facilities at the Science Center. In addition, the Center and Amusat in cooperation with NASA will disseminate information about the program to like groups domestically and to educational institutions in developing nations. This activity will be carried out largely through mail consultation with educators. Additionally, the Science Center will undertake the sponsorship of teacher workshops aimed at familiarizing educators with the concepts, possibilities and techniques involved in utilizing A-O-B as an educational tool.

**REFERENCES**


**ILLUSTRATIONS**

Figure 1. Oscar 1.
Figure 2. Oscar participant Hans Lauber, HB9RG is a dentist in Zurich, Switzerland.
Figure 3. High school senior Clarke Greene operates WA1IOX, the ground station at the Talcott Mountain Science Center.
Figure 4. The internal structure of the Amusat-Oscar B satellite now under construction.
Figure 1  Oscar I

Figure 2  Oscar participant Hans Lauber, HB9RG, is a dentist in Zurich, Switzerland.
Figure 3 High school senior Clarke Greene operates WA1IOX, the ground station at the Talcott Mountain Science Center.

Figure 4 The internal structure of the Amsat–Oscar B satellite now under construction.