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International Cooperation with Amateur Satellites

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Abstract:

AMSAT, The Radio Amateur Satellite Corporation, has launched over 30 amateur radio satellites. Most have been cooperative International projects. The first satellites from Argentina, Portugal, Korea, and other countries were amateur satellites, manufactured in cooperation with AMSAT chapters around the world. The Phase 3-D international satellite is a cooperative deal with 14 countries participating. This paper will discuss how the groups around the world decided to cooperate with each other, and lessons learned from the various projects. Examples of how international satellites have been used for education will also be included.

While countries around the world fight and compete with each other radio waves know no borders or boundaries. Since the 1930s hams - radio amateur operators - have been legally allowed to talk to fellow hams around the world. Many long distance friendships have developed among people who are likely to never meet in person. It's feasible to talk to people in all 50 states (and there are awards for doing so) but the real challenge is to try to talk to people in as many countries as possible. I was astonished to learn that you can legally use amateur radio to make contact with a station in Havana Cuba, which can then patch you in to the Cuban telephone system and permit you to talk to somebody in a country which you cannot legally contact directly!

The first international space communications via amateur radio frequencies was the world's very first satellite - Sputnik 1. The Soviets had released its transmitting frequencies (20.007 Mhz.) ahead of time. The frequency is fairly close to amateur radio bands, so within hours after launch hams were verifying the Soviet claims that they had launched the world's first artificial satellite. Five days after Sputnik 1's launch ham Roy Welch, W5SLL, was playing the audio recording at a state ham radio operator's meeting.

The first amateur satellite, OSCAR 1, was launched in place of ballast on the Discoverer 36 (Corona) launch vehicle on December 12, 1961. By today's standards it was incredibly crude - a couple of mercury batteries and a 145.0 Mhz. transmitter which broadcast "HI" in Morse code. The battery lasted 22 days -- and what a 22 days it was for hams around the world. Project OSCAR received reports from 570 amateur radio operators in 28 countries.

The reference section of this paper includes the Worldwide Web (WWW) site for one amateur's recordings of Sputnik 1, OSCAR 1, and other early satellites. The CD ROM of this year's "Space Congress" proceedings also includes those files.

The first direct satellite communications between the U.S. and the former Soviet Union was by amateurs - bouncing signals off of NASA's Echo balloon satellite.

International Satellites and Cooperative Efforts

The first four OSCAR satellites were all built in the United States, but hams in other countries weren't far behind. Students at the University of Melbourne, in Victoria Australia built their own 17.7 kg. satellite. Since the only countries who were launching payloads in to space were the U.S. and USSR they chose to ship their satellite to the United States for storage until a launch opportunity became available.

AMSAT, the Radio Amateur Satellite Corporation, was founded as a non-profit 501 (c)(3) organization in 1969 to find a launch opportunity for Australis-OSCAR and future amateur satellites. Many of AMSAT's founding members were located in the Washington, DC area and worked for NASA. A launch opportunity was obtained on a NASA Delta scheduled to launch the ITOS-1 (TIROS-M) weather satellite. Australis-OSCAR 5 was launched on January 23, 1970 from Vandenberg AFB in California. During its 46 days in operation the University of Melbourne compiled tracking reports from hundreds of stations in 27 countries.

Starting with OSCAR 6 many satellites became international cooperative projects, with subsystems built in different locations coming together for the final integration typically in the United States. U.S. hams had access to cleanrooms and other facilities necessary for the final integration and testing. Another advantage

to U.S. integration is a shorter journey to the launch site. AO-6 had subsystems from the United States, Australia, and Germany. AO-7 was built by a team of German, Canadian, Australian, and United States hams under the direction of AMSAT-NA. AO-8's components came from the United States, Canada, Germany, and Japan.

Dr. Martin Sweeting, G3YJO, at the University of Surrey in England wanted to start a small satellite program. He received assistance from AMSAT-NA and many of its technically oriented members. In particular Dr. Mario Acuna at the Goddard Spaceflight Center helped supply magnetometers which are used for spacecraft attitude control.

The first Surrey satellite, UoSAT 1 (University of Surrey satellite) was launched on October 6, 1981 by a Delta from Vandenberg with the Solar Mesosphere Explorer satellite.

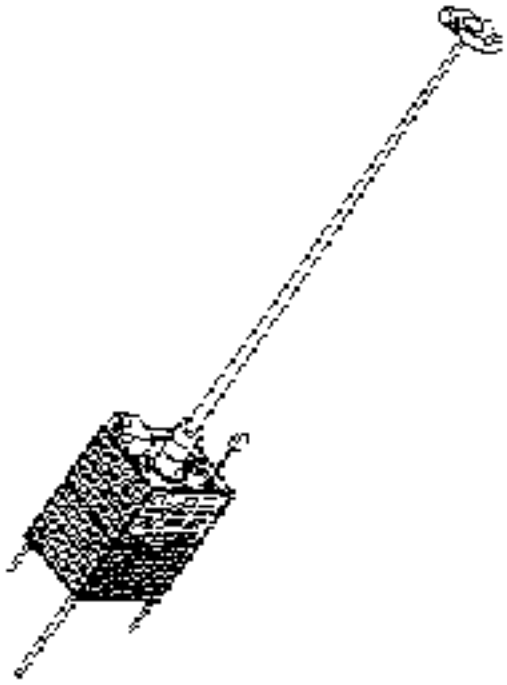
Since UoSAT 1 the University of Surrey has built over a dozen satellites for anybody who needs a relatively low cost experimental satellite. They are the acknowledged world leader in microsat construction. The 50 kg. UoSAT bus has been used for many applications, including packet communications, Earth resource monitoring, and military reconnaissance. But they haven't forgotten their roots, many satellites still include amateur transponders in addition to the satellite's primary functions.

UoSAT 2, a/k/a OSCAR 11 is still in operation, 12 years after its launch. It has amateur beacons and data from its housekeeping computer is monitored by hams around the globe.

The satellite building business eventually evolved in to the Surrey Satellite Technology Ltd. (SSTL). SSTL is now housed in its own building on the University campus, employs over 50 staff and has a budget of 5 million pounds each year.

AMSAT-NA is the North American chapter of AMSAT. There are many international AMSAT chapters around the world. AMSAT-DL (Deutchland) is the German chapter, the British chapter is "AMSAT-UK", the Japanese AMSAT group calls itself "JAMSAT", Brasil's chapter is "BRAMSAT", etc.

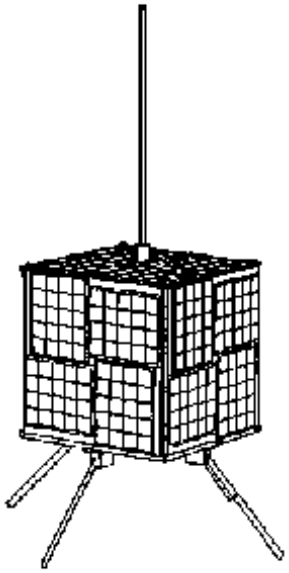
Only a few of these AMSAT chapters have the capabilities or resources to build their own satellites. In most cases the chapters exist to help introduce ham radio operators to satellites and provide information. But most of the chapters do help raise funds for international projects and many are involved in building subsystems for international satellite projects.



standard UoSAT microsat bus - AMSAT diagram

AMSAT chapters around the world - AMSAT diagram

1990 marked a significant step forward for international satellites. Argentina registered its first satellite with the UN. It was an amateur radio satellite, LUSat. Argentinean engineers and hams worked together with the AMSAT-NA chapter to build LUSat along with the other microsats. Many of the engineers who worked on the first Argentine scientific satellite, SAC-B, got their first taste of real spacecraft experience working on LUSat.



LUSat microsat - AMSAT diagram

Other countries which have launched amateur satellites before "real" satellites include Korea, Portugal, and the upcoming Sunsat which is being built in South Africa. In each case spacecraft engineers from those engineers have participated in the design and construction process.

German ham Dr. Karl Meinzer, DJ4ZC, wanted to develop a much more sophisticated satellite in a high altitude orbit. This included propulsion systems (solid or liquid propellant built-in upper stage), and much higher gain antennas. The Phase 3 project has been one of AMSAT's most ambitious international projects. Phase 3-A was launched on Ariane L02, the second test flight of the Ariane 1 launch vehicle. Two minutes after launch it was at the bottom of the Atlantic Ocean. *sigh* Phase 3-B and 3-C were more successful, and were renamed OSCAR 10 and OSCAR 13 when they reached orbit.

Russian amateur groups have built their own satellites, as independent spacecraft and also as piggyback transponders which fly on other spacecraft. Some of these have been international projects, most notably the RS-14 (AMSAT OSCAR 21) satellite which included a German experiment. As with the Western-built amateur satellites the Russian satellites are open for any ham in the world to use.

The Space Shuttle and Mir

SAREX, the Shuttle Amateur Radio Experiment, has always included international participation. STS-9 marked the first time amateur radio flew aboard the space shuttle. One of the hundreds of hams who got to talk to astronaut Owen Garriott W5FL was King Hussein of Jordan, JY1.

Hams around the world have successfully contacted the shuttle, including countries which you wouldn't expect to be ones where the public would follow the American space program closely, including Cuba and Iran!

The SAREX ground station network includes participating hams in South Africa, England, Australia, and Brazil. These stations are

normally used for school contacts and to permit the astronauts to call home and talk directly to their families, but are also available for use as emergency ground stations in case the shuttle loses communications through its normal network.

Most of the SAREX flights include school contacts in foreign countries. As a rule these contacts are in English, but there are some notable exceptions. Astronaut Charlie Precourt, KB5YSQ, has excellent language skills. While in the Air Force he was an exchange student with the French Air Force Academy, and during his first spaceflight he got to talk to students at the Air Force Academy in Colorado, and the French Air Force Academy in their native languages.

On the STS-60 shuttle flight Russian cosmonaut Sergei Krikalev, U5MIR, was scheduled to talk to students at a school in Moscow. Due to problems with the Wake Shield he had other duties, and the students agreed to try out their English skills and talk to pilot Ken Reightler instead.

Sergei Krikalev, U5MIR on Discovery STS-60 - NASA photo STS60-29-009

Other international mission specialists and payload specialists with ham radio licenses have included: Reinhard Furrer (Germany), Ernst Messerschmid (Germany), Wubbo Ockels (Netherlands), Dirk Frimout (Belgium), Mamoru Mohri (Japan), Hans Schlegel (Germany), Ulrich Walter (Germany), Vladimir Titov (Russia), Chris Hadfield (Canada), and Bob Thirsk (Canada).

It's important to note that not all international astronauts have obtained ham radio licenses or used SAREX, even the ones who have made educational contacts with schools. While the SAREX team asks every astronaut on a SAREX flight if they're interested, it's their choice whether or not they want to participate.

On STS-45 astronauts Dave Leestma, N5QWC, Kathy Sullivan, N5YYV, and Brian Duffy, N5WQW, successfully contacted hams on all six populated continents - plus Antarctica. Normally a "Worked All Continents" is an award which a ham radio operator has to spend much of his life to successfully complete, but the three STS-45 astronauts were able to do it during their week in space.

Belgian payload specialist Dirk Frimout, ON1AFD, was especially popular on the STS-45 mission. He reported that whenever he'd pick up the radio over Europe there would be literally hundreds of people calling at once, and whenever any of the other astronauts on that mission would use the radio over Europe - almost the first question would be could Dirk talk!

Mamoru Mohri, 7L2NJY, flew on STS-47 as the first Japanese scientist in space. He mentioned afterwards that the first Japanese he spoke from space was via amateur radio - trying to contact hams in Japan. He also got to talk to his

professor and students at the university he attended in Australia.

One of the biggest challenges for the SAREX community was to try for the first shuttle-to-Mir contact via amateur radio. Payload Specialist Ron Parise, WA4SIR, came up with the idea while training for the STS-35 ASTRO-1 mission. Once NASA headquarters was assured that it was quite legal for hams from the U.S. to talk to Russian hams it became an important 'event'. And when somebody realized that Apollo-Soyuz astronaut Vance Brand was the commander of STS-35 and the 15th anniversary of Apollo-Soyuz was that summer ...

Well, the shuttle flight delayed to December, and there wasn't any opportunity to attempt the contact. On the first opportunity the Soviet crew was busy with the docking of the replacement Soyuz spacecraft. The second opportunity was missed because incoming bad weather at Edwards Air Force Base and NASA's desire not to land Columbia in the dark at KSC resulted in the mission getting cut short.

Direct shuttle-Mir contacts were attempted on several SAREX flights, but unsuccessful due to timing problems and interference from others on the same frequency. Good coordination and a bit of luck resulted in a successful Shuttle-Mir contact on STS-56 in 1993.

Canadian astronaut Chris Hadfield earned the U.S. ham license KC5RNJ, and was granted a Canadian call sign shortly before his first spaceflight, STS-74. He surprised many hams by using the Canadian call VA3OOG. The Canadian Space Agency public relations department picked up on Chris's ham license and decided to set up a ham radio station at their headquarters in Quebec, with the intention of using it on future flights of Canadian astronauts to inform all of Canada about the mission's status. The STS-74 mission took place during one of the U.S. government's shutdowns, and non-critical events were curtailed. Consequently Canadian Prime Minister Chretien did not have the opportunity to talk to Chris in space. However, dozens of Canadian hams - and hundreds of hams around the world were able to talk to Chris and the rest of the STS-74 crew.

The STS-74 mission also marked an unique form of international cooperation among ham radio operators. It turned out that some of the manuals for Mir's ham radio equipment were never shipped to Mir. So astronaut Ken Cameron, KB5AWP, was given copies of the manuals which he personally carried to Mir, along with the other personal effects for the Mir crew.

Mir has had an amateur radio station since 1988. The first Russian hams in space were Vladimir Titov U1MIR, and Musa Manarov U2MIR. Musa was particularly popular with hams around the world because of his excellent English.

The initial Mir radio was just a simple handheld, but many pieces of additional hardware have been shipped to Mir during the past eight years. The cosmonauts mounted an external antenna during one of their spacewalks, and Mir now has an extremely sophisticated setup.

Short term international visitors to Mir from Austria, England, and France have used Mir's radio for token contacts with hams in their homelands. The long term international cosmonaut researchers representing ESA and the United States have been appreciative of the radio's capabilities.

Dr. Norm Thagard had not been officially approved to use Mir's ham equipment before launch, but his commander, Vladimir Dezhurov, told him that the Russian Federation has granted permission for anybody aboard Mir to use its ham radio setup. So Norm quickly became a

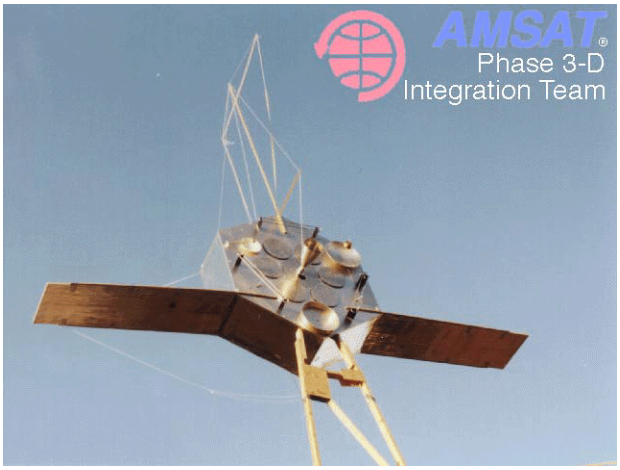
popular contact for hams around the world. Dr. Shannon Lucid was quite active on Mir's ham radio equipment, often using the radio to talk to her family and friends in Houston. John Blaha, KC5TZQ, was very enthusiastic about using the radio to just chat with hams, and also to keep up with sports scores, especially the World Series and Dallas Cowboys. John even got his commander, Valeri Korzun, interested in American football!

John Blaha, KC5TZQ, using Mir's amateur radio - NASA electronic photo S79E5150

All of the upcoming astronauts who will spend time on Mir have obtained ham licenses and will have the capability to talk to their family and friends, and hams around the world.

Current projects:

In 1991 hams in the United States and Germany agreed to pool their resources to build Phase 3-D, a much more sophisticated successor to AO-13. The spacecraft is currently undergoing integration in Orlando Florida in the Foreign Trade Zone at Orlando International Airport. Hams from fourteen countries are involved in the Phase 3-D project.



full size Phase 3-D mockup for antenna testing - AMSAT photo by KC4YER

The Foreign Trade Zone makes it practical to use components from around the world in an international effort of this magnitude. An FTZ works on the principle of 'added value'. While the U.S. government does not collect customs on the components coming in to the country, the local economy gets the benefits of the labor and other locally generated products and purchases. As long as the product (the satellite in this case) eventually leaves the United States it is exempt from customs duties.

Many different international educational organizations and individuals have been involved in the Phase 3-D effort. High school students in Canada built some of the precision machined components, undergraduate students at Weber State University in Utah built the spaceframe, and for several months two German graduate students lived in Florida and worked at the Lab full time. Their primary project was to build the spin-balance machine.

One question I'm constantly asked is why are we using an Ariane launch vehicle, even though we're based in Central Florida. The AMSAT Integration Lab's vicinity to the Kennedy Space Center is just a coincidence. U.S. hams agreed to handle the integration and testing portion of the project and for various reasons Central Florida was chosen as a suitable location. The AMSAT-DL (German) chapter was able to obtain a commitment for a launch opportunity from the European Space Agency. Other AMSAT organizations around the world have provided other locally generated resources and components for the Phase 3-D project. Eventually everything comes to Florida for integration in to the spacecraft. Once the spacecraft is completed and tested it will be shipped to French Guiana for the launch.

Other countries currently involved in amateur satellite building projects include South Africa, Taiwan, Chile, Finland, and Israel.

Future Projects:

Many AMSAT members are starting to think about what the next project should be after Phase 3-D is completed. Two major projects under consideration are a pair of

geosynchronous satellites and an amateur satellite to Mars.

For many decades hams have wanted to put their own satellite in to geosynchronous orbit. However, a single geosync satellite would have more problems associated with funding and participation than technology. If a single satellite was built for the Western hemisphere then other hams around the world are not likely to be interested in contributing to the project, either in terms of funds or resources. So a pair of satellites seems to be an absolute requirement, and that increases the project's cost.

Another project under serious consideration is an amateur mission to Mars. This would be funded from outside of the amateur radio community, but would involve many of the people and resources currently involved in building amateur satellites. The Phase 3-D satellite has enough propellant to make it from the Earth to Mars, and initial calculations have shown that it is possible for amateur stations to control satellites at Martian distances.

There is no doubt that, due to the magnitude of these proposed projects, both in terms of cost and technical capabilities, these will be international efforts.

SAREX and Mir amateur radio activities have proven the value of amateur radio aboard crewed spacecraft. The shuttle's amateur radio has been used for backup communications when NASA's communications network has had glitches, and many Mir cosmonauts have commented about how valuable it is to be able to just talk to people around the world. Initial plans have been made for the International Space Station's ham radio station.

Amateur Radio delegates from eight countries - Russia, Japan, Germany, Great Britain, Italy, Canada, France and the U.S. recently met at the Johnson Space Center for a planning meeting to discuss amateur radio activities aboard space station. The ARISS (Amateur Radio International Space Station) working group established initial plans for what kind of ham radio equipment might be suitable for space station.

ARISS logo - couresy of Matt Bordelon, KC5BTL

International Education on the Ground

International space educational activities are not just limited to satellite manufacturing, many schools and individuals use the existing amateur satellites for enhanced education. While few hams have the capabilities to design or build their own satellites, many participate directly in educational activities. By their nature most amateur satellite communications includes international participation.

1988 a Canadian-Soviet arctic expedition used UoSat to transmit their location and schoolchildren around the world followed the expedition's progress. The expedition had an Emergency Location Transmitter (ELT), a common VHF radio required in most aircraft and ships. Each night when the expedition rested they would turn on the ELT. Its signal would be

received by U.S. NOAA and Soviet Cosmos satellites, and the expedition's position was triangulated. The UoSAT-OSCAR 11 satellite has an off-the-shelf digital voice generator and the satellite's control operators programmed the digitalker to speak with the expedition's location. In addition, anybody else with the proper receiver could listen to the satellite's digitalker broadcasting the expedition's location. School groups in South Africa, Brazil, Siberia, Britain, the U.S., and Canada reported that they tracked the expedition's progress.

In 1994 Comet Shoemaker-Levy 9 smashed in to Jupiter. It was front page news in the United States, and the NASA WorldWide Web Internet sites set new records for folks who wanted to see the images. But while it was major news in the U.S., not all of the world got as much information. Bill Roth, N7RYW downloaded the images off the Internet and uplinked them to the KO-25 satellite. KO-25 is a British-built satellite, paid for by South Korea, and available for use by any ham in the world with the proper equipment and licenses. Bill got replies back from hams in Australia, New Zealand, Africa, and most of Europe who appreciated his efforts.

Many geography teachers give their students a fun assignment - obtain a stuffed animal and mail it with a notebook to a distant location. Each person who receives the animal is asked to write some details about themselves and the area where they live before sending it on to somebody else. Eventually the final recipient sends the animal back home - with a notebook filled with memories. The traveling animal can be handed from person-to-person, mailed, or in one particular case, tracked by satellite as it went around the world.

Ham radio operator Roy Welch's granddaughter was asked to mail a stuffed animal to a foreign country, and Roy decided it would be interesting to send the animal all of the way around the world, and to follow the animal's progress via packet satellites. "Scottie" was mailed from Missouri to Ireland, and then on to Morocco, Spain, Norway, Oman and three cities in Australia before returning to the United States. The only continents not visited were South America and Antarctica!

'Scottie' - photo by Roy Welch W0SL

In each location was a ham radio operator who exchanges correspondence with Roy via amateur packet radio satellites. So Roy was able to keep track of Scottie's progress as he made it from country to country. There are many gaps where Scottie apparently decided on his own to make sidetrips for long periods before ending up at his planned destination. At each stop the local ham operator would report back via the packet satellites that Scottie had arrived safely, and his activities while with his hosts.

When Scottie returned to Olathe, Kansas in April 1996 his knapsack was filled with coins, stamps, and other trinkets from his round the world journey. More importantly Rachel got a profound look at cultures in six different countries.

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