

IAC-02-P.3.02

AMATEUR RADIO ON THE INTERNATIONAL SPACE STATION (ARISS) – THE FIRST EDUCATIONAL OUTREACH PROGRAM ON ISS

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ABSTRACT

Amateur Radio on the International Space Station (ARISS) represents the first educational outreach program that is flying on the International Space Station (ISS). The astronauts and cosmonauts will work hard on the International Space Station, but they plan to take some time off for educational activities with schools. The National Aeronautics and Space Administration's (NASA's) Education Division is a major supporter and sponsor of this student outreach activity on the ISS. This meets NASA's educational mission objective: "To inspire the next generation of explorers...as only NASA can." The amateur radio community is helping to enrich the experience of those visiting and living on the station as well as the students on Earth. Through ARISS sponsored hardware and activities, students on Earth

get a first-hand feel of what it is like to live and work in space. This paper will discuss the educational outreach accomplishments of ARISS, the school contact process, the ARISS international cooperation and volunteers, and ISS Ham radio plans for the future.

HISTORY OF AMATEUR RADIO IN SPACE

Amateur radio has had a significant human presence in space starting with a flight on-board the space shuttle Columbia on the STS-9 mission late in 1983. At that time, astronaut Owen Garriott provided an unprecedented level of excitement in the amateur radio community by talking to ham radio operators on the ground using a 2-meter FM transceiver. These modest beginnings 19 years ago have led to a significant, nearly continuous presence of ham radio in human-tended space vehicles today.

In the U.S. the human spaceflight amateur radio activities are sponsored by the American Radio Relay League (ARRL), the

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Radio Amateur Satellite Corporation (AMSAT), and NASA. Several international amateur radio organizations have worked with the U.S. team for nearly two decades to maintain a constant amateur radio presence in space. Members of the international consortium of amateur radio teams include:

Germany – The amateur radio (called SAFEX) team successfully operated amateur radio hardware on two shuttle missions and on the space station *Mir*.

Russia -- Since 1987, Russia operated amateur radio hardware on the space station *Mir*. The current ISS amateur radio hardware is located in the Russian Segment of the ISS.

United States-- Since 1983, the Space/Shuttle Amateur Radio EXperiment (SAREX) team successfully flew amateur radio hardware on 25 shuttle missions & supported astronaut amateur radio operations on the Russian space station *Mir*.

This combined team pioneered several new and exciting communications capabilities on U.S. and Russian-based human spaceflight vehicles. Some of the accomplishments include:

- The first human tended amateur radio in space (1983)
- The first communications between astronauts and people outside official NASA channels (1983)
- The first pictures uplinked and downlinked to Shuttle (1985)
- The first astronaut-student interviews (1990)
- The first computer-to-computer e-mails from the Shuttle (1990)
- The first television uplink to the Shuttle (1991)
- The first backup communications during a NASA satellite (TDRSS) outage (1992)

ARISS—THE INTERNATIONAL SPACE STATION CONNECTION

More than 40 space flight missions over five years will be required to assemble the ISS. The astronauts and cosmonauts will work hard on these missions, but have committed some of their free time to talk with schools. ARISS represents the first Educational Outreach program that is flying on ISS. In the U.S., NASA's Education Division and Office of Space Flight are the primary supporters and sponsors of this student outreach activity on the International Space Station. This meets NASA's educational mission objective: "To inspire the next generation of explorers...as only NASA can."

As the International Space Station takes its place in the heavens, the amateur radio community is doing its part by helping to enrich the experience of those visiting and living on the station as well as the students on Earth. Through ARISS activities, students on Earth have a once in a lifetime opportunity—to talk to the crew on-board ISS. Using amateur radio equipment set up in their school, students get a first-hand feel of what it is like to live and work in space. Each school gets a 10-minute question and answer interview with the on-orbit crew using a ground station located in their classroom or through a remote ground station. Through ARISS, students learn about orbit dynamics, wave transmission, radio communications, and working with the press. Since its inception, thousands of students and their families have participated in an ARISS event.

ARISS—A program and an international team

The first organizing meeting was held in August 1996 to leverage successful, independent, international amateur radio teams to develop an amateur radio station plan for ISS. The NASA Education Division required the amateur community to commit to the development and operation of a single,

coordinated amateur radio system on ISS. The ARISS team was formed consisting of nine international partners—Belgium, Canada, France, Germany, Italy, Netherlands, Japan, Russia and United States. A joint agreement was signed committing to the development and operations of a single, coordinated amateur radio system for ISS. International ARISS meetings are held about twice per year. To date these have been in Canada, England, the Netherlands, and the United States. The team also has executive-level teleconferences once a month and numerous committee teleconferences throughout the month.

ARISS Objectives

The primary goals of the ARISS program are fourfold. These include:

1. Educational outreach Through school contacts, ten or more students at each school ask the orbiting ISS crews questions and hundreds of students and family members participate. The nature of these contacts embodies the primary goal of the ARISS program -- to excite students' interest in science, mathematics, technology and amateur radio.
2. Crew psychological factors Contacts are scheduled with the astronauts' friends and families. Random contacts with the amateur radio public provide a unique opportunity for casual conversations with non-project related individuals. These boost the crew's morale by reducing the sense of isolation. This gives the crews more freedom in talking with family and friends.
3. ISS-based Communications Experimentation ISS provides a testbed for development of new communications techniques which can be used to develop new educational projects.



Merivale Public School child¹ reading her question to Commander William Shepherd, Expedition 1

4. International Good Will Astronaut contacts to schools and the amateur community fosters international good will. Joint hardware development provides a forum to enable international technical partnerships.

Volunteerism

Community involvement and volunteers are critical to the success of this program. Taking on a volunteer project that must meet the stringent requirements of a human spaceflight mission is a monumental task, to say the least. Literally hundreds of volunteers from numerous organizations worldwide have helped to make ARISS the outstanding success that it has become. The success of ARISS is, and will continue to be, predicated on the dedication and sacrifices made by those that have a desire to share amateur radio and the human spaceflight program with students and the general public.

¹ Photo © 2001 Michelle Rickard, courtesy of [Nepean This Week](#), Ontario, Canada

Current ARISS On-Board Hardware

The ARISS team has developed various hardware elements for the ISS amateur radio station. These hardware elements have flown to ISS on three Shuttle flights and one Progress flight. The initial educational outreach system consists of an FM radio system attached to some externally mounted antennas. The radio system is located in the Functional Cargo Block, named Zarya. This system supports FM voice operations and packet radio (computer-to-computer radio link) capabilities. Packet radio has several capabilities including an Instant Messaging-type system and a Bulletin Board System that allows radio amateurs to store and forward messages and allows the orbiting crew to send e-mail to all hams or to individuals.

SCHOOL CONTACTS

School Contact Process

Individual schools submit an application to the ARISS program to hold a ten minute interview with a crew member on the International Space Station (ISS). After initial screening, these applications are processed on a first-come-first-served basis. An ARISS internationally based school committee reviews and prioritizes all applications for incorporation into the flight queue. The school group committee then forwards all completed applications with their priorities to the ARISS international operations team. This team assigns an operations mentor to each school. The schools have several months to prepare for their contacts. The operations team recruits volunteer amateur radio operators that are cognizant in amateur radio satellite operations and are near the school to support the local school group contact. A school may have its own radio club or station, but it is not required. The local amateur radio volunteers support the school with the technical know-

how to make the ARISS contact successful. They also provide the required antennas, radios, computers and software to establish an effective ground station at the school.

The classroom teacher needs on the order of six months to plan and prepare the school for the 10-minute amateur radio interview. Actually, the contact is just the pinnacle of a substantial educational program that centers around amateur radio in space. Grades K-12 are encouraged to participate. However, other educational institutions, including colleges and museums, may also participate.

Contacts are available year round, but depend on the work schedule of the crews on the ISS. The operations team attempts to schedule one to two contacts per week. During weeks involving extravehicular activity (EVA) or visiting Soyuz or Shuttle crews, the ISS crew is usually not available for school contacts.

The operations mentor works closely with the local amateur radio volunteers and the school teacher to ensure they are prepared for the contact. This includes the preparation of the questions to be asked. Since the operations mentor has performed numerous ARISS contacts, the mentor knows many tips to maximize the success of the contact. One important decision that is made early on is whether the contact will be made through a radio station that is installed at the school (a direct contact) or through a remote ground station (a telebridge contact).

Approximately 4-6 weeks prior to the ARISS event, several contact opportunities are generated by the operations team. This information is shared with the school group to arrive at a prioritization of contact times. These priorities, as well as specific information about the school and the questions to be asked by the students is forwarded to the ISS mission control team. These contact opportunities usually fall within a specific week for that particular school.

Approximately one week prior to the event, the ISS mission control team provides the rise and set time for the event and the crew member that will participate in the event.

During contact day, the operations mentor and the school team are in constant communication, sharing and confirming orbital data, synchronizing timing, sharing information on contact success and compiling metrics from the contact.

Once the contact is complete, the school is asked to fill out a NASA educational survey form called EDCATS. This helps NASA compile its own statistics on the educational benefit of this and other programs.

Direct Contact Ground Station Requirements

The mentors that have supported the Shuttle, Mir and Space Station programs have spent years developing and honing the optimal amateur radio station configuration to be installed at the school. This station will ensure a solid, 10 minute horizon-to-horizon contact for the school. Specifically, the station should include:

- A 2-meter FM radio system with the ability to memorize multiple odd split pairs of frequencies
- Output power at least 75 to 100 watts
- A receive pre-amplifier
- OSCAR style circular polarized crossed yagi antenna,
- Azimuth/elevation rotation control of the antenna system
- Computer with current satellite tracking software.
- Battery backup power supply
- A redundant radio system that supports 75-100 watts of power output. This should be attached to a simple, vertical antenna

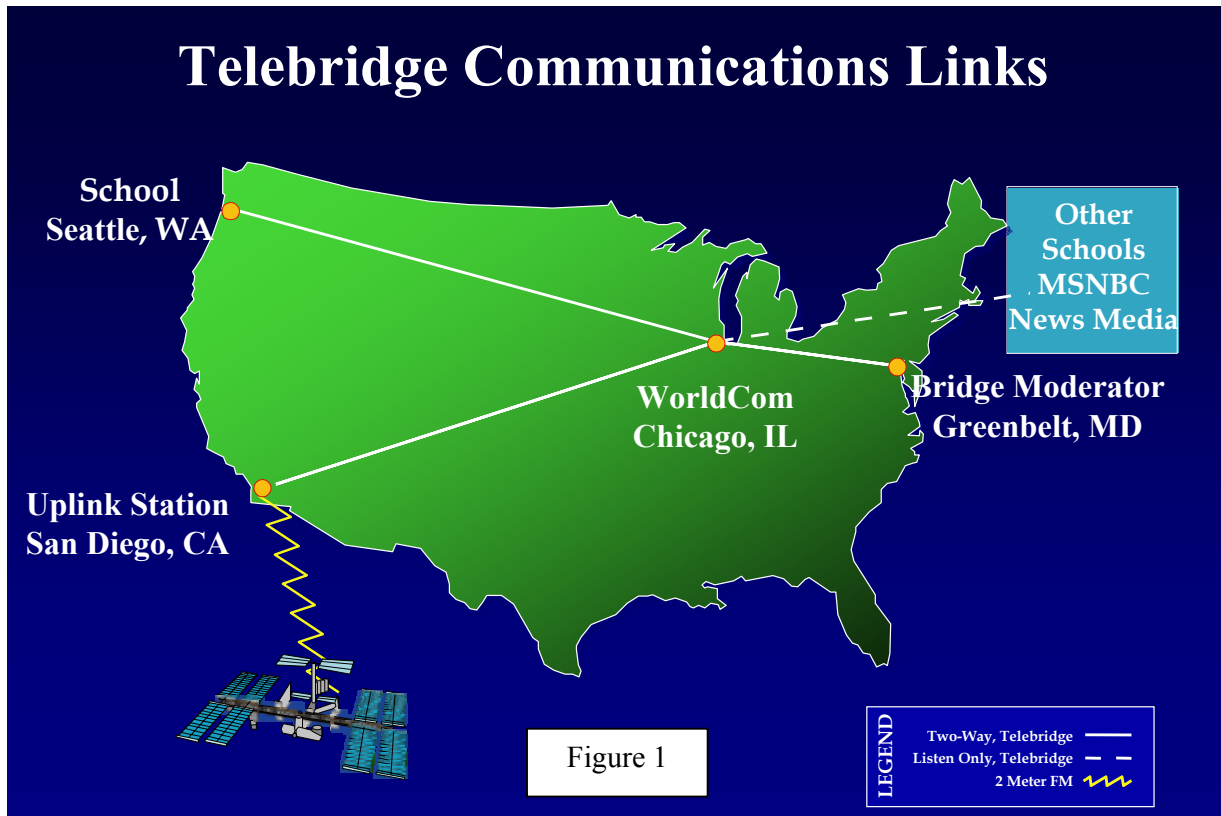
The redundant radio system and the backup power supply are included to minimize the

effects of “Murphy’s Law” where things can and will go wrong at the worst possible time.

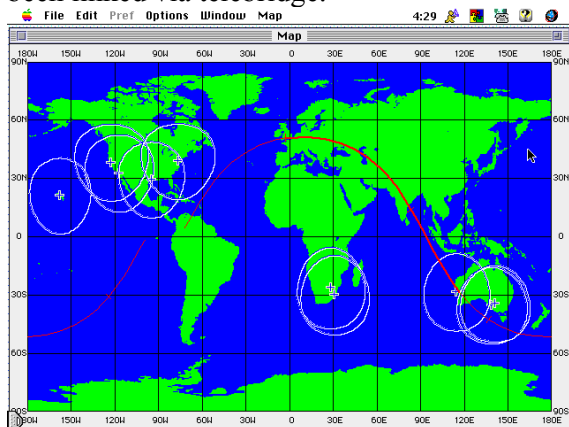
Worldwide Telebridge Facilities

The telebridge system is used when direct ISS communications is impractical, either due to visibility or timing constraints, (e.g. low elevation passes at school location, late night passes), national rules on unlicensed persons using an amateur radio, or technical concerns at the school. The telebridge system consists of an international network of ISS ground station volunteers that can be linked to school groups using a telephone conferencing system. See figures 1 and 2. This system is similar to NASA's system of tracking stations which were used extensively during the 1960's, 1970's and early 1980's to track human space flights. One school is interactively linked to the bridge with one ground station for the entire 10 minute pass. However, several school groups can be interactively connected to the bridge with several ground stations providing a direct link to the ISS for periods of up to 20 minutes. The school groups usually talk to the astronauts through a local radio system which is patched to the telebridge. If this is not practical, a speaker phone can be used; however this is not encouraged since it is not in the spirit of an amateur radio activity.

Figure 1 depicts the telebridge communications links for a hypothetical school group in Seattle, Washington. As shown, the primary bridging service is graciously donated by Worldcom. During the contact, an ARISS bridge coordinator is on-line with the technical staff at Worldcom to ensure that the voice levels are appropriate and that the bridge is working well. Other groups tied into the bridge as listen-only participants include MSNBC, specific press sites that coordinate with the team prior to the



contact, and other schools interested in witnessing the event. Figure 2 illustrates the specific ground stations around the world that support this activity. ARISS telebridge ground stations are located in Australia, South Africa, California, Hawaii, Maryland, and Texas. To date, over 30 ARISS schools have been linked via telebridge.



Telebridge Network
Figure 2

Application Information

Applications are available at:
www.arll.org/ARISS/ariss-ap.html
 Applications are accepted continually, but because of worldwide interest, there is a one to two year waiting list for ISS contacts. The program's official website is at:
ariss.gsfc.nasa.gov

ON-ORBIT OPERATIONS METRICS

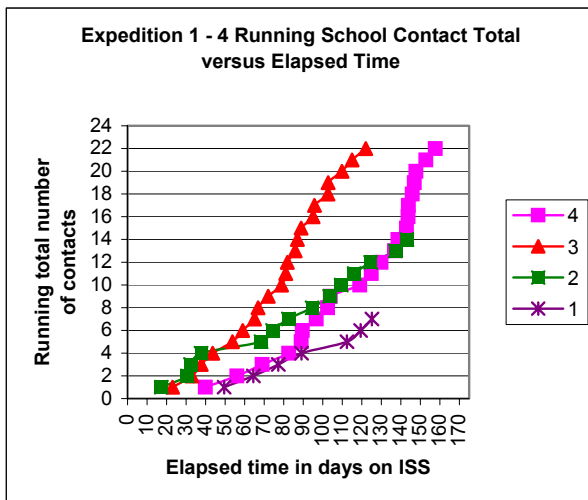
To date, over 70 school contacts have been performed through ARISS. These include contacts in thirteen countries and over 26 states in the U.S. Table 1 illustrates the specific number of contacts performed by each expedition crew and by the Soyuz Taxis crew members. As shown, Frank Culbertson performed the highest number of ARISS school group contacts. He averaged approximately 1.2 schools per week during his stay on ISS.

Crew Expedition	School Contacts
1	7
2	14
3	22
4	17
5	10
Tourists/Taxi Flights	5

School Contact Metrics
Table 1

Other educational events that the crew supported included contacts during the 2001 and 2002 amateur radio field day by Expeditions 2 and 5 respectively and the Boy Scout Jamboree-on-the-Air in 2001 by Expedition 3 Commander Frank Culbertson.

The following graph illustrates the consistent participation in school contacts by the ISS crews.



Early in the ISS Expeditions, the crew relied almost exclusively on the ISS Ham radio system for friends and family contacts. For example, up to 5 friends and family members were contacted per week by the Expedition 1 crew. With the introduction of the IP Phone on ISS, the U.S. friends and family contacts have curtailed but the Russian friends and



Frank Culbertson at the ARISS Station during Jamboree on the Air

family contacts continue. In addition, the use of the equipment for general, worldwide communications have increased, particularly with commander Valery Korzun on Expedition 5.

The ISS Ham radio system also supports packet (computer-to-computer radio link) capabilities. Packet radio has several capabilities including an Instant Messaging-type system and a Bulletin Board System that allows radio amateurs to store and forward messages and allows the orbiting crew to send e-mail to all hams or to individuals. The Instant Messaging capabilities have been operational since April 2001 on Expedition 2. Valery Korzun from Expedition 5 enabled the Bulletin Board System in February 2002. Since that time, hundreds of e-mail messages have been sent by the ISS crew and forwarded between radio amateurs on the ground.

International Outreach

Thirteen countries have had school contacts to date--Australia, Belgium, Canada, Finland, France, Germany, Italy, Israel, Japan, Russia, South Africa, United Kingdom, and the United States. Some of the more exciting international contacts are described below:

Japan -- A school contact was organized for a Saturday morning that had the entire school and community involved.

During this contact, the astronaut's answers were simultaneously translated into Japanese and projected on a screen in the auditorium. All the Japan television stations attended this historic event and either broadcast the contact live or replayed it on the evening news.

Newfoundland, Canada -- A special request was made by the Canadian Space Agency to support a school contact at Signal Hill, Newfoundland to commemorate the 100th Anniversary celebration of the first Marconi radio transmission.

South Africa – Space tourist Mark Shuttleworth conducted four school contacts during his stay on ISS. These contacts were transmitted over national television and retransmitted to 38 countries in the continent of Africa.

Estimated Outreach

NASA maintains an educational database, called EDCATS, to track the success of all the ARISS school contacts. With over 70 schools contact since its inception in late 2000, over 15,000 school children have participated in an ARISS event. In addition to classroom activities, the ARISS program requires that each school involve the local community. The teachers are encouraged to include in their planning and lessons, interactions with their local media. All of the 70+ schools have had local, state, and/or national news coverage reaching a minimum of another 12 million people worldwide. At least one-third of all school contacts are broadcast live on the Internet via MSNBC.com. Several school contacts are archived on the Internet by MSNBC and others. Clearly, ARISS is *inspiring the next generation of space explorers*.

IMAX “Space Station 3D” and ARISS

ARISS successfully supported the IMAX team in their production of the first film

documenting the construction of the ISS. The IMAX “Space Station 3D” film includes two scenes with students on the radio talking to the crew. As of late June 2002, the "Space Station 3D" film is showing in 104 IMAX theatres in approximately 26 US cities and nine countries. Twenty-four more theatres in seven additional countries will open later in 2002 and in 2003. Countries initially showing in 2002 included Australia, Canada, Denmark, England, Germany, Japan, Norway, Sweden, and the USA. Upcoming countries include Ireland, Kuwait, Netherlands, New Zealand, South Africa, Taiwan, and Thailand. There are currently 226 IMAX theatres in 30 countries worldwide; additional theatres may decide to show the film over the next few years.

SCHOOL CONTACTS—A ONCE IN A LIFETIME EVENT

The radio contact is the culmination of a long series of classroom projects, space science and engineering activities, community involvement, and public relations that produce a spirit of teamwork. There is a sense of accomplishment that results from the school and the students setting up and conducting the ISS Ham contact themselves. The students better understand how NASA and the other international space agencies conduct science on ISS. The unique, hands-on nature of the amateur radio contact provides the incentive to learn about orbital mechanics, space flight, and radio operations. This is the “best educational outreach program at NASA,” says one of our NASA Headquarters sponsors. In addition, the ISS Ham educational activities support the National Education Standards in Math, Science & Technology.

A coordinating teacher said, "To see the kids' eyes light up, it was worth everything we've done to see that. This is something they will remember for the rest of their lives."

THE FUTURE

The ARISS team will be expanding the program with new communications capabilities such as television, image e-mails sent automatically to schools and other communications projects. This past year, the team has installed 4 antenna systems on the outside of the Russian Service Module. These antenna systems will support future operations within this module. Additional hardware systems to exploit these antennas are currently under development. These systems will allow the crew to support multiple activities at the same time (e.g. voice, e-mail, and television) with higher power radio systems. This will enable a more comprehensive school contact event.

Each school contact performed allows additional schools to network into the

program. New lesson plans are under development and additional material will be available for the schools and for the general public on the ARISS web pages.

CONCLUSIONS

The ARISS program represents the first Educational Outreach Payload on-board the ISS. The ISS ham radio activity is one of the most exciting and stimulating educational outreach programs in space, providing students a once in a lifetime opportunity to talk to a crew member on-board ISS and learn what it is like to live and work on ISS. In less than two years, this program has enabled tens of thousands of students to participate and learn about science, technology, and amateur radio. Through ARISS, the space agencies and amateur radio community is inspiring the next generation of space explorers.

Comments about ARISS from the NASA EDCATS Educational Database:

"I believe strongly in ARISS as an educational tool- I cannot express briefly the impact it made on our entire student body!"

... a classroom teacher.

"My future contacts are waiting, some of the schools on my list see this project as the best way to turn children on to science and technology - they are right !!"

...an educational administrator.