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Paper Session III-B - Overview of the Orbiting Radio Communications Asset (ORCA) Mission

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Abstract

The Orbiting Radio Communications Asset (ORCA) mission is a commercial mission being designed, built and conducted by the Iowa Space Grant Consortium, supported by Rockwell Collins, and Space Industries. The mission will utilize advanced technology digital radio equipment provided by Rockwell to survey the low-earth orbit radio spectrum. This survey is of interest to both the commercial communications industry and to the scientific radio astronomy community. In addition to the survey, the spacecraft will provide an on-orbit transmit and receive test platform for advanced communications technologies that can be fully reprogrammed from the control station. A significant feature of the ORCA mission is the intimate involvement of students from Drake University, the University of Iowa, the University of Northern Iowa, and Iowa State University. These students will be involved in all aspects of the mission design, development, and staff the operations center after the initial mission.

Mission Overview

The ORCA mission will place a small satellite in a high inclination low Earth orbit that will cover the majority of populated regions of the earth and provide at least one year of on-orbit operations. The spacecraft will be the first in a new line of high technology small satellites developed by Space Industries. It will host a variety of payloads for commercial and scientific research. The principle payload is a digitally programmable radio transceiver developed by Rockwell Collins. This payload will allow commercial users to test and validate various communication schemes including modulation waveforms, transmit power levels, and to study the effect of various atmospheric properties on radio transmissions. This payload will also allow background noise measurements to be taken over a wide spectrum of radio frequencies. Additional scientific payloads will study the properties of the ionosphere that effect radio communications and provide a means of study lightning by observing the interaction of lightning with the ionosphere.

It is intended to launch the mission as a secondary payload. The current conceptual design is compatible with the Pegasus or Taurus launch vehicles but minor refinements would allow the spacecraft to be launched by the Ariane or Delta launch vehicles.

The mission preliminary design is scheduled to begin in late summer 1998 with a launch planned for in summer 2000. Funding for the ORCA mission is currently being sought from interested members of the communications industry as well as venture investment for the development of a new line of high technology small spacecraft. Funding for the scientific aspects of the mission are also being sought from government sources.

Payload Description

The unique payload design comprises the heart of the ORCA mission equipment. A dual suite of digitally programmable communications equipment supports a wide variety of scientific experiments: communications technology, sounding, radio astronomy, noise measurement, etc. Each 6U VME-packaged element of the payload is RS-422 controlled from the payload CPU, and power-managed by the bus CPU. Experimental commands and data return are provided by the S-band TT&C link from mission control.

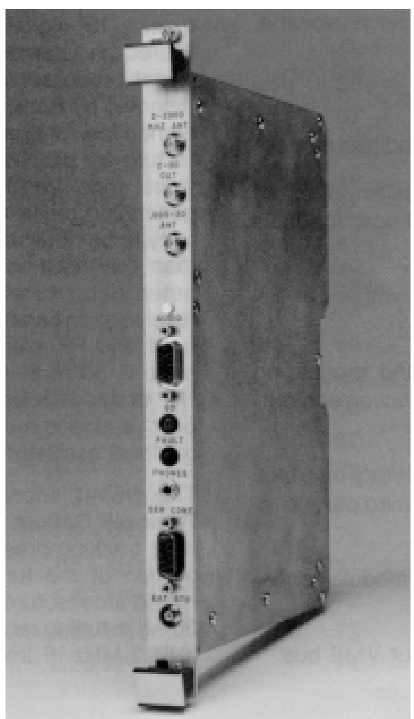

Figure 1. Rockwell Collins 95V-1 Receiver

The communications portion of the ORCA payload consists of dual transceivers matrix switched to one of three antennas. Dual GPS receivers provide precision location, time and frequency reference. The science portion of the payload includes a dedicated low frequency (<10 kHz) receiver and a particle detector.

The antenna array consists of two deployed wideband log periodic antennas, tentatively spanning 100 to 2500 MHz. The 20 meter long dipole is used for frequencies below 100 MHz, with transmit capability down to approximately 2 MHz. All three antennas are suitable for transmit and receive. Crosspoint matrix switching is provided by an RS-422 controlled latching relay matrix assembly.

The transceivers are modified versions of Rockwell Collins' latest direct conversion receiver (DCR) 95V-1 design. The transceiver tunes in 1 Hertz increments, contains 251 FIR bandpass filters, has a fully reprogrammable (via uplink) triple DSP processor section, and incorporates a tracking front end preselector to minimize the risk of overload from terrestrial signals. Transmit waveforms are generated from the 95V-1's synthesizer and a Rockwell Collins wideband vector modulator integrated circuit. The vector modulator allows synthesizing virtually any on-channel waveform from quadrature DSP words.

The power amplifiers are 10 watt (average) solid-state wideband designs, capable of operating into the broadband antenna VSWR. Higher peak and burst powers are possible, limited by the bus power source. A passive matching network flattens the long dipole impedance to maximize power transfer. Solid-state transmit/receive (T/R) switches rapidly switch the antenna between receive and transmit for time-critical sounding experiments.

Dual-redundant Rockwell Collins GPS receivers with patch antennas provide precision location, time and frequency reference for all experiments. Output is provided via RS-422 bus to the payload CPU.

Two dedicated science experiments are included in the payload in addition to the programmable communications equipment. Designed and built by the University of Iowa Physics Department, the low frequency receiver and the particle detector may be operated concurrently with many of the communications modes (limited by bus power availability) and in "off-times" for the communications equipment. The low frequency receiver uses a magnetic pickup to sense signals below 10 kHz, and amplifies them to a level suitable for digitization by the CPU's high speed audio frequency digitizer. Location and time references are merged into the data files prior to compression and transmission to the ground. The particle detector provides counts of ions and protons from two separate sensors, and likewise produces time/location-stamped data files for return to the ground. Both are based on the University of Iowa's long series of successful spacecraft instrument designs.

Other unique features of the ORCA payload include:

- Post-processing by the payload CPU, with uplinked software
- FFT post-processing within the 95V-1 receivers and the payload CPU
- Repeater and store-and-forward modes for any waveform
- Dual receiver and dual transmitter operational modes
- Employment of the ORCA transmitters as high speed downlinks
- Reliable, off-the-shelf commercial equipment with special hardening
- Common RS-422 interfaces provide modular design

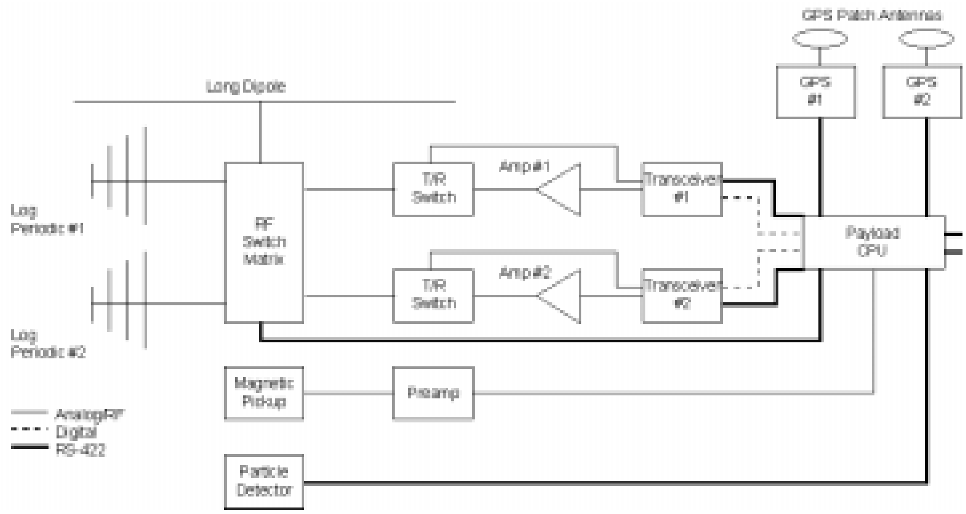

Figure 2. ORCA Payload Block Diagram

Spacecraft Description

The ORCA spacecraft has overall fundamental dimensions of 28 inches by 28 inches by 32 inches. The central body contains the spacecraft electronics and other hardware, payload electronics and provides attachment locations for the primary antennas and should encompass them within the volume. Solar arrays are attached and will deploy to a fixed configuration once on-orbit. This configuration will provide approximately 90 W total continuous power, of which approximately 15 W will be continuously available to the payload with additional power being available by duty cycle management. Total spacecraft weight is 190 lbs.

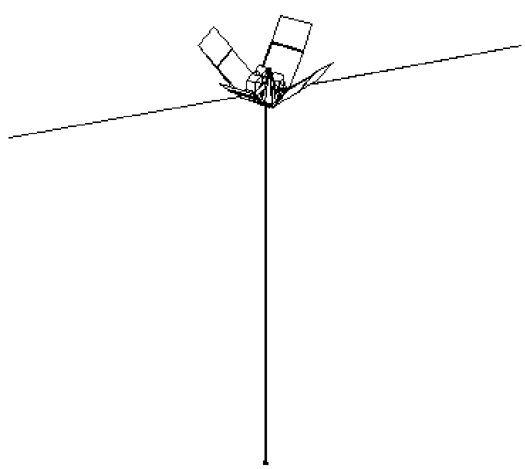

Figure 3. ORCA Spacecraft (Conceptual)

The spacecraft provides simple attitude control via gravity-gradient stabilization and magnetic torq rods. This will provide Earth pointing to within 10° at very low cost. Spacecraft attitude will be measured with a space qualified 3-axis magnetometer. This system provides fundamental earth-pointing orientation at very low cost and with limited requirements for on-board computing and few operational requirements.

Power is generated by silicon solar arrays that are deployed to a fixed angle with respect to the spacecraft body. This provides better thermal management and allows the array area to be increased by the addition of “extensions” that increase the length of the array with respect to body mounted arrays. The deployment also allows the primary antenna to be mounted in a more compact configuration while still allowing a clear field of view once on-orbit. Again, silicon provides power generation at a low cost and the simple deployment allows increased power generation without the use of costly and complex solar tracking systems. Power storage will be based on commercial Ni-Cd cells. Many other programs and spacecraft have successfully documented the use of commercial batteries.

Spacecraft communication with the ground is provided by a space-qualified system. A largely off-the-shelf system was selected utilizing transmitters, receivers, bit synchronizer, and tone decoder all from the same vendor. Space qualified antennas were also selected to provide hemispherical coverage for the critical command link. A custom based interface circuit will be required to provide interface to the spacecraft computer.

On-board processing will be provided by a commercial single-board computer operating in a PCI backplane. The selected computer is based on the PowerPC 603 which is currently undergoing radiation hardness evaluation. The PCI backplane will support twelve serial data and command interfaces to other devices on-board the spacecraft as well as acquiring engineering telemetry. VxWorks will be used as the real-time operation system and has space flight heritage from the Mars Pathfinder lander. This provides a robust, highly flexible, and well supported development environment for the flight code that will be developed in C.

Spacecraft structure will be a straightforward design that centers on an electronics enclosure that provides 6U and 3U slots for most spacecraft electronic equipment as well as the payloads. The structure provides for attachment of other equipment in a simple shelf arrangement. Aluminum construction is planed to provide for simplicity of manufacture, integration, and thermal management.

The spacecraft can be configured to be accommodated by a number of launch vehicles, but is currently configured for secondary launch on a Pegasus or Taurus launch vehicle.

Student Involvement

The Iowa Space Grant Consortium (ISGC) is part of the NASA Space Grant College and Fellowship program. Now in its ninth year, the ISGC has worked hard to build a genuine “team spirit” among its fifteen academic, industrial and outreach affiliates. Some of the ISGC projects cut across the academic lines to build strong research collaborations. One such project was the Iowa Joint Experiment in Microgravity Solidification (IJEMS). This student-built science experiment flew onboard the space shuttle in September 1995. Students from the University of Iowa and Iowa State University worked with faculty researchers from both schools and the US Department of Energy’s Ames Laboratory to complete the project.

With the IJEMS project successfully completed, the ISGC has taken on a more ambitious new project with ORCA. In this case, the ISGC is serving as the prime contractor to coordinate the design, build, test, launch, and operation of the satellite. Rockwell Collins (an ISGC industrial affiliate) recognized the need for an orbiting radio laboratory. They also have the contacts in the industry to use and raise funds for the spacecraft. Through the ISGC, they have become familiar with Space Industries (another ISGC industrial affiliate) and their interests and capabilities. Space Industries is beginning a new line of spacecraft and ORCA will serve as an ideal first mission. Both industrial affiliates have used ISGC students in the past through various scholarship and fellowship programs. As the ORCA project proceeds, students from all four ISGC academic institutions will be able to compete for positions on the ORCA team at Space Industries in Houston.

In addition to the student support at Space Industries during the design, build, and test phases, the operations phase will also utilize ISGC students. The concept involves development of an S-band ground station in Iowa where students will support ORCA spacecraft operations. This capability will be made available to other spacecraft operators as a supplemental ground station. The intent is to build a self-sustaining program for students to learn first-hand about spacecraft systems and operations by actually doing the work.

Several science objectives are part of the ORCA mission as well. Science in the areas of radio astronomy, plasma waves and particle detection provide opportunities for students. The principle investigators involve two of the four ISGC academic institutions. However, students from all four universities will have the opportunity to be involved in the design and development of spacecraft instrumentation as well as data analysis.

This hands-on experience will prove beneficial for the students involved in the ORCA project. Experience with the IJEMS project demonstrated that these students will be strong candidates for employment after graduation. Their success in the work of the project will help to maintain strength in the ISGC industrial team and provide valuable support for continuing future student opportunities at these companies.

Status Summary

The conceptual mission definition was completed by Space Industries in January 1998. Further work to refine the ORCA mission is on-going by the partners. The Iowa Space Grant Consortium is working to define the scientific research goals and the student involvement in the program, as well as securing a launch. Rockwell is working to refine the payload and solicit support from other members of the communication industry. Space Industries continues to refine the spacecraft and mission components as part of its ongoing development effort for small satellites.