

A NEW GENERATION OF TELECOMMUNICATIONS FOR MARS: THE RECONFIGURABLE SOFTWARE RADIO, W. Horne¹ and J. Adams², ¹ITT Industries Advanced Engineering & Sciences Division, 1761 Business Center Dr., Reston, VA 20190, e-mail: william.horne@itt.com, ²Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, e-mail: jta@jpl.nasa.gov

Introduction: Telecommunications is a critical component for any mission at Mars as it is an enabling function that provides connectivity back to Earth and provides a means for conducting science. New developments in telecommunications, specifically in software-configurable radios, expand the possible approaches for science missions at Mars. These radios provide a flexible and re-configurable platform that can evolve with the mission and that provide an integrated approach to communications and science data processing.

Deep space telecommunication faces challenges not normally faced by terrestrial and near-earth communications. Radiation, thermal, highly constrained mass, volume, packaging and reliability all are significant issues. Additionally, once the spacecraft leaves earth, there is no way to go out and upgrade or replace radio components. The reconfigurable software radio is an effort to provide not only a product that is immediately usable in the harsh space environment but also to develop a radio that will stay current as the years pass and technologies evolve.

Software Radios & Science Approaches: The only product generated by current and near-future robotic explorations of Mars is data. This data, once collected by science instruments on the remote spacecraft, must be transferred to Earth in order to have value. While communications is often viewed as "infrastructure," it plays a key role in meeting science objectives especially for *in situ* analysis and global reconnaissance. Figure 1 illustrates some of the uses of telecommunications in Mars exploration. Software configurable radios provide capabilities to support science and related activities as well as enable mission and science approaches, including:

Data Networking & Sensor Webs. The exploration environment at Mars will continue to evolve from a single spacecraft visit every few years to an armada of landed and orbiting spacecraft, all with the need to communicate their data back to Earth. Orbiting telecommunications assets will provide this long-haul function. Multiple users, various levels of data criticality, and huge data volumes will cause congestion if networking standards are not applied early and firmly. The reconfigurable software radio performs protocols and routing to enable internetworking and on-board routing (e.g., TCP/IP, distributed processing on-board where instruments perform their own processing). This internetworking capability enables mission ap-

proaches that exploit interconnected but distributed instruments, often called sensor webs.

Equipment Flexibility. Traditionally, telecommunications equipment destined for deep-space have been hardware-specific devices with modifications to its functionality limited to changes in data rate or coding. This is true for current Mars missions. The flexibility of software-configurable radios allow for updating processing, protocols, and other activities (useful for cross-support of science missions). The reconfigurability enables mission approaches that evolve over time.

Auxiliary Science. Software-configurable radios can support cross-link capabilities for occultation studies including the capability to perform beamform-

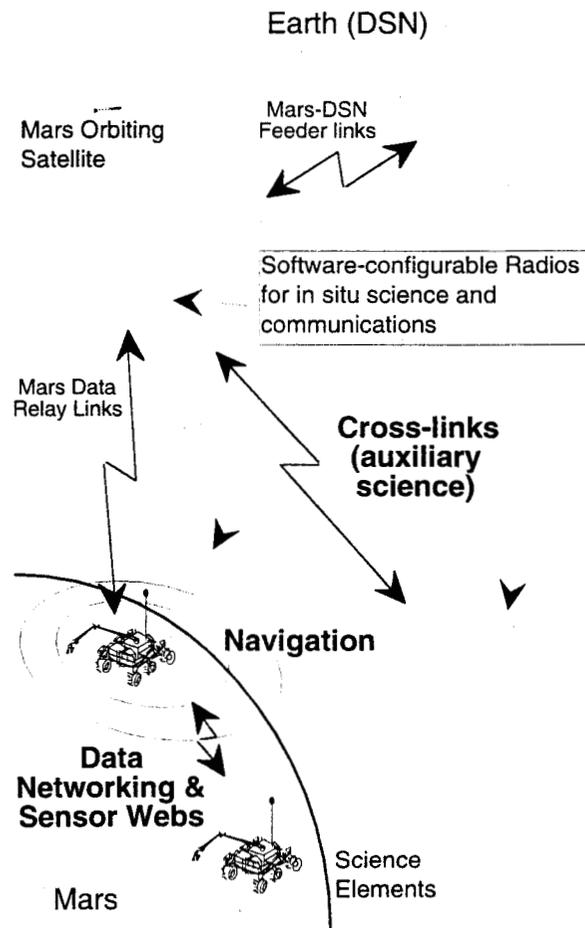


Figure 1. Software Radio Applications for Science

ing with a phased array antenna that can be used to assist in direction finding or tracking a spacecraft for closing cross-links. The digital nature of software radios enable a greater array of science measurements to be recorded from the received signals.

Navigation Utility. The users in the Martian environment not only need to move data but to know where they are so that the data has context. The software reconfigurable radio supports navigation and geolocation through better processing of Doppler, range, timing, and angle measurements.

Software Radio Overview: A software radio performs functions that are traditionally carried out solely in hardware, such as the generation of the transmitted radio signal and the detection and demodulation of the received radio signal, by using software residing in high-speed digital signal processors. Since these functions are carried out in software, the radio can be programmed to transmit and receive over a wide range of frequencies and to emulate virtually any desired transmission format. The operating parameters can be altered even after it is deployed by a simple software change. For example, a software radio could have the ability to transmit and receive using an existing protocol (e.g., CCSDS Return Telemetry) when launched, but it can

then be updated at a later date to handle a new protocol (e.g., CCSDS Proximity-1). The physical layer (e.g., PSK, FSK) processing can also be altered to support the needs of an evolving mission.

The key component of a software radio is an architecture that uses high speed digital signal processing to perform signal transmission and reception. The radio design also needs to achieve favorable size, weight, and power consumption characteristics necessary for the space environment. Figure 2 illustrates the basic architecture that is used in a software radio. The architecture features digital signal processing that can be implemented using different devices including Field-Programmable Gate Arrays (FPGAs), microprocessors, and digital signal processing chips.

Development Path: Software radios are becoming more and more widely used in industry and commerce, but additional work needs to be conducted to prepare these radios for the space environment. As mission approaches are identified for exploring Mars, the requirements for communications should be communicated to developers of software radios to ensure that the functionality needed are developed. Key issues that need to be developed for software radios include:

Radiation Tolerance. The digital signal devices used in software radios are susceptible to single-event-upsets (SEUs) and single-event latchup (SEL) in the presence of radiation. Methods to overcome these problems include radiation tolerant devices and architectures that use redundancy, but they are not fully developed for the space environment.

Power Consumption. The digital signal devices, especially microprocessors, used in software radios often require significant power, relative to available resources. Finding low-power approaches are required in the Mars environment.

Standard Approaches & Interfaces. The development of software radios is still quite new, so standards approaches are not yet defined. The evolution of software radios can be greatly enhanced with standard architectures and interfaces.

Summary: The reconfigurable software radio represents the logical evolution from hardware specific communications solutions. Software radios provide functionality that can be used to support new approaches to science missions at Mars, such as sensor webs. Scientists and planners should consider the future evolution of these flexible and powerful telecommunication devices when designing future missions to Mars.

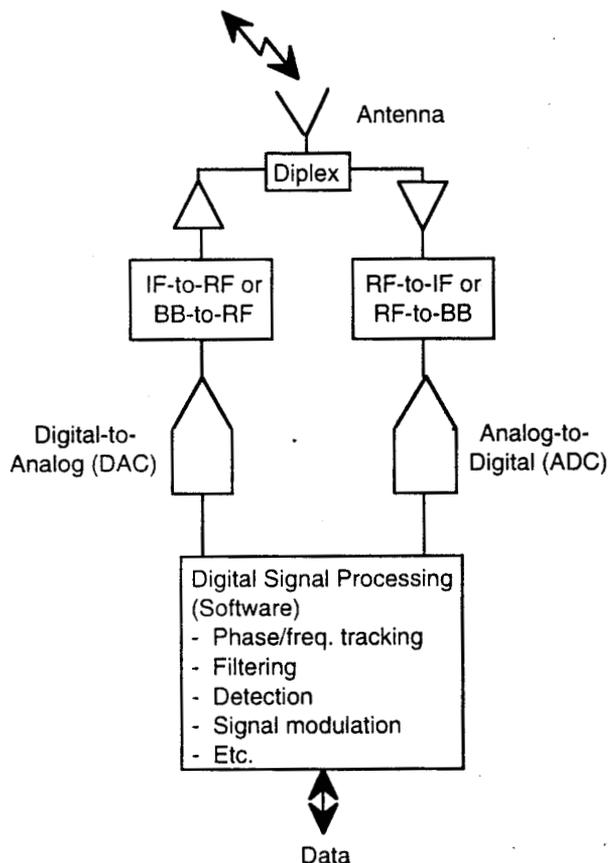


Figure 2. Fundamental Software Radio Architecture