

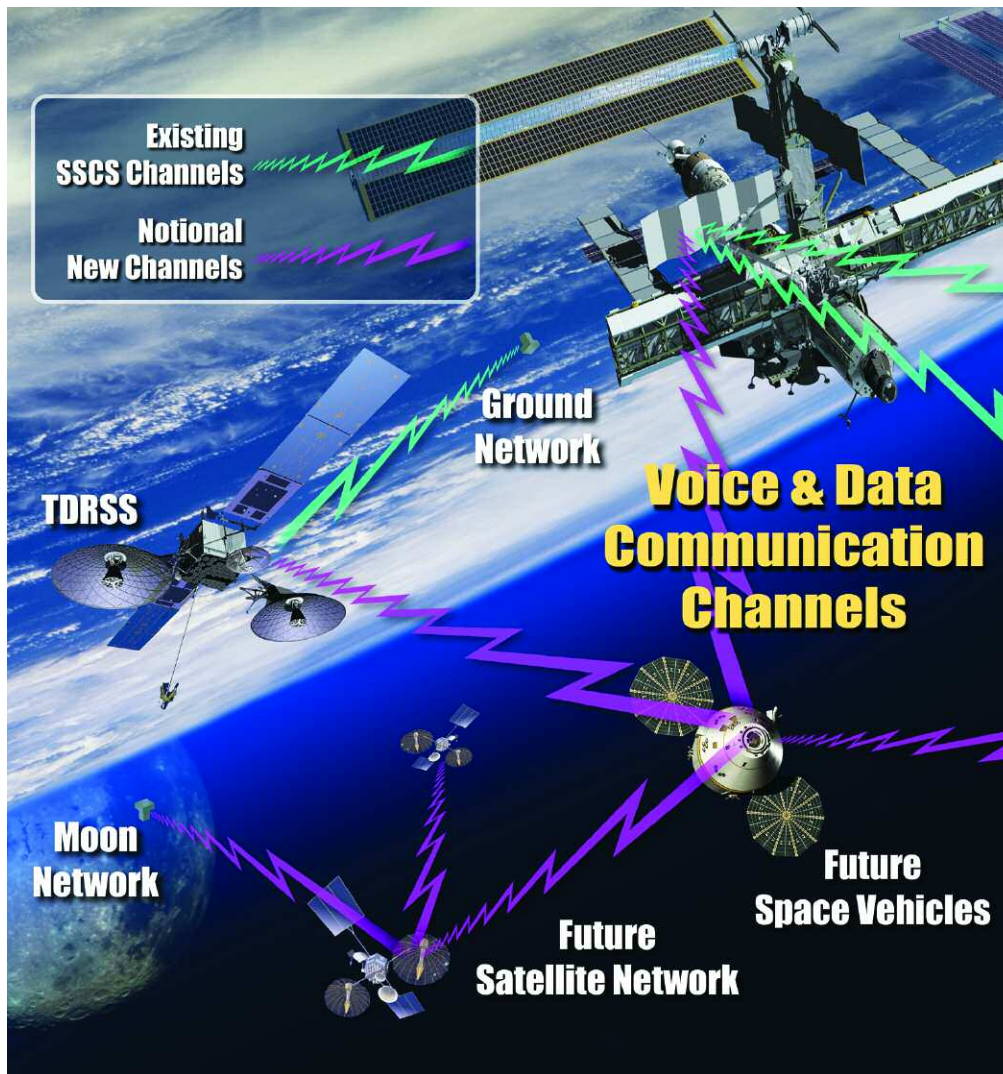
# Putting the Pieces Together

Software-defined radio technology is key piece of the network-based space communications puzzle

By Michael Moore, Ph.D., Jeremy Price and Ben Abbott, Ph.D.

**I**n January 2004, President George W. Bush outlined a new initiative for manned space exploration. The vision calls for the development of a Crew Exploration Vehicle (CEV). Initially, the CEV will serve as a replacement for the aging space shuttle and will assume the tasks previously performed by the shuttle, such as ferrying astronauts to and from the International Space Station. However, as its name implies, its true purpose is exploration. The CEV will return humans to the surface of the moon and eventually have a role in a manned mission to Mars.

With such a broad job description, the CEV must be designed with substantial flexibility in mind, especially in its communications system. In its travels, the CEV may be required to interact with many different communications systems, each with different waveforms and protocols. Because minimizing size, weight and power are paramount in space systems design, installing separate radios to cover each communications need is less desirable than building a reconfigurable communications system that can be adapted and re-purposed over the lifetime of the vehicle. Besides the CEV itself, supporting systems such as the extravehicular activity (EVA) suits worn by astronauts also could benefit from designed-in flexibility in their communications subsystems.



The need for flexibility is not limited to NASA, nor is the need for adaptability exclusive to radios using wireless communications channels. The military needs to be increasingly agile and responsive in launching its tactical satellite missions. To meet evolving needs while making the most of limited budgets, space communication assets must be designed to be operationally reconfigurable to meet as-yet-undefined needs. The speed at which threats evolve may necessitate designing and building a satellite even as details of its mission are being designed.

With these and other needs in view, scientists and engineers at Southwest Research Institute (SwRI) are evaluating and developing key technologies that will enable reconfigurable transceivers and flexible network architectures to be used for applications in space environments.

Reconfigurable communications technology could reduce the total size, weight and power of the overall com-

munications systems designed for the NASA Constellation program. Systems such as the CEV and the advanced EVA suit must have communications subsystems that can work with existing shuttle-era systems while also supporting future mission requirements. One solution is to create reconfigurable network equipment, such as radios, that can communicate with current systems and then be reconfigured to communicate with systems such as deep-space satellite relays and lunar and Martian surface habitats.

## The Reconfigurable Network Communications Puzzle

The traditionally separate areas of radio communications and network communications are melding together. All assets are now seen as network-enabled, and thus network-accessible, devices. Creating a seamless network that crosses vehicle boundaries and can be reconfigured to meet changes in the mission or battlespace requires solving



Each piece of the network communications “puzzle” addresses an aspect of the technical issues involved in developing an integrated network to support communications for space missions.

cross-disciplinary capabilities at SwRI help the Institute’s team address these challenges.

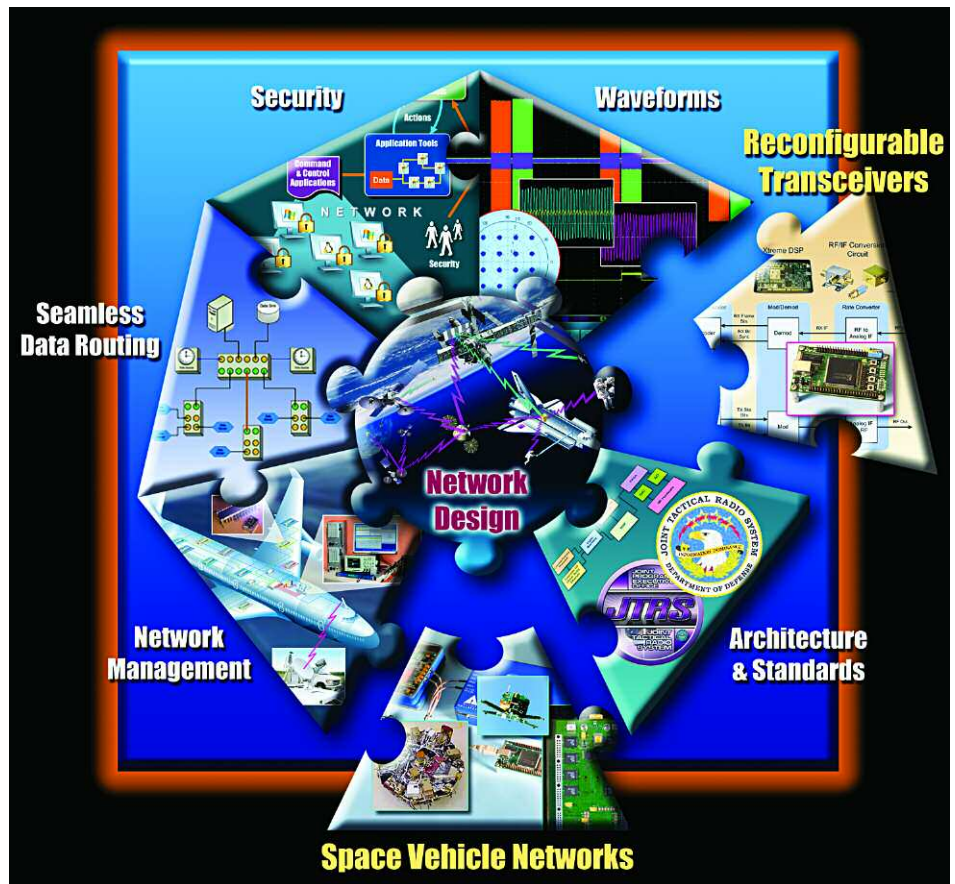
### Reconfigurable Transceivers

A transceiver sends and receives digital data that has been encoded in analog radio frequency signals. The method of encoding the digital data into analog signals is referred to as the radio waveform. Traditional, fixed transceivers can only operate with a single waveform. Transceivers that can be reconfigured, or updated with software and firmware to implement other waveforms, are more flexible because they can communicate with more than one radio system.

Enabling the transition from fixed to flexible, network-enabled transceivers is a key technology of software-defined radio (SDR).

### Software-defined Radio Technology

Traditional radios are built with mostly fixed analog electronics. With the transition to modern digital communications, digital electronics have become commonplace in radios. To support the high performance required to convert digital data to analog radio signals while keeping cost, size, weight and power requirements realistic, it had been necessary to implement the digital parts of these radios in fixed-capability components such as application-specific integrated circuits (ASIC). Modern digital



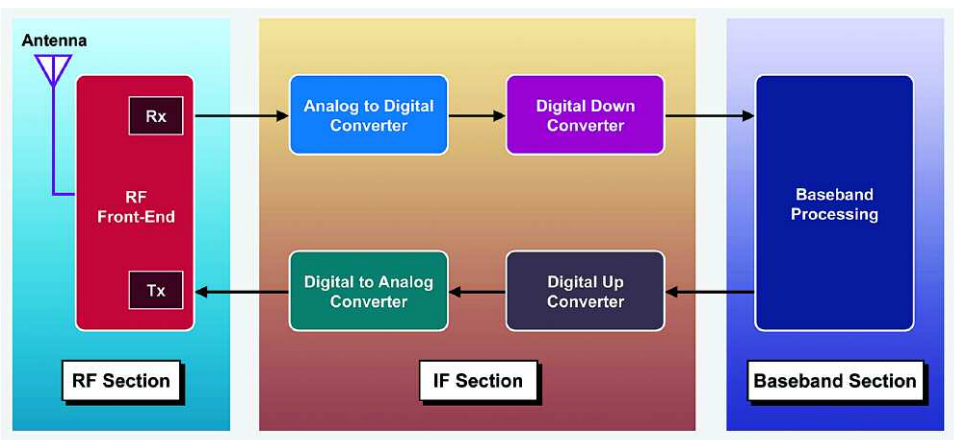
signal processing technologies, with higher processing capability per power consumed, have made it more reasonable to construct the digital sections of radios with programmable devices. These advances made possible the contemporary field of SDR. The benefit of SDR over fixed-capability digital electronics is that the waveform implementation—the implementation of the algorithm that converts between digital data and analog radio signals—can be independent of the hardware implementation.

SwRI engineers have performed internally funded research, as well as client-funded research on SDR projects, for a number of years. The SwRI SDR team

recently completed a project for NASA’s Johnson Space Center (JSC) to create a prototype SDR that interoperates with the existing space-to-space communications system (SSCS).

The project demonstrated the feasibility and effectiveness of SDR technologies for space applications by implementing an SDR that is interoperable with an existing space communications system, and that has a clear path to space-capable hardware. The SSCS was chosen for a prototype application because this waveform may be required on the new NASA crew exploration vehicle. The SSCS SDR prototype was implemented by a team of engineers from SwRI and JSC. The SwRI team implemented the user interface and the encoder/decoder and network controller components, and the JSC team implemented the mod/demod component with integration assistance

The schematic figure shows the logical breakdown of a digital radio. In software-defined radio (SDR), baseband processing is performed in firmware on an embedded digital computer.



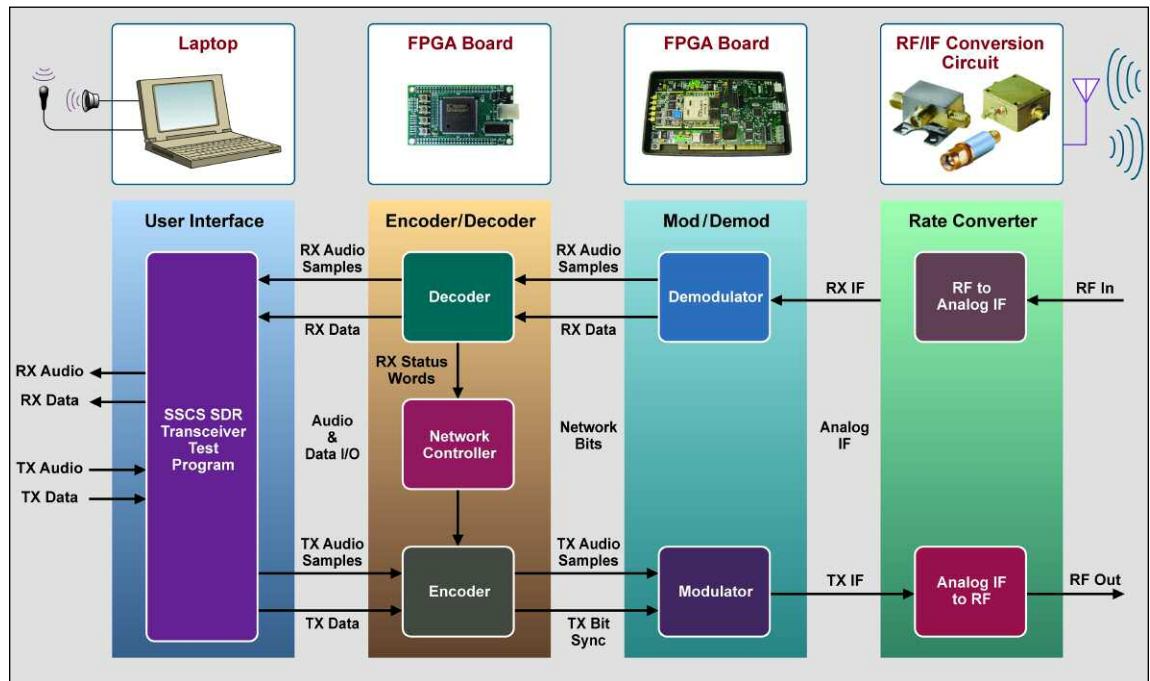
from the SwRI team. The SwRI and JSC teams worked together to integrate the rate conversion components and to integrate the SSCS SDR. The SSCS SDR has interperated with the existing SSCS space radios in a JSC laboratory and is an example of how SwRI and external teams can work together to build an integrated system.

Recently the SwRI SDR team began a new project to assist JSC in a trade study to evaluate SDR architectures that could be used to build a reconfigurable transceiver for the Lunar EVA suit. This project may have a bearing on the Constellation communications system design effort by NASA. SwRI researchers will evaluate the costs and benefits of various implementation approaches and assist in forming the design strategy for the EVA suit communications subsystem.

### Future Directions for SDR Research

NASA has initiated the SDR architecture team to evaluate the suitability of SDR technology for their manned and unmanned space flight missions and to develop a standard architecture for NASA space radios of the future. This team is defining the space telecommunications radio system (STRS) architecture, which standards bodies are evaluating as a potential standard architecture for space radios. The team is promoting a plan to move space-borne SDR in a flight-experimental phase by deploying an SDR testbed as a scientific payload on the International Space Station and potentially flying other reconfigurable radios on future shuttle flights to execute reconfigurable communications demonstrations in space. SwRI is a likely partner in this work if the plan is executed by NASA, and the waveform developed on the SSCS SDR project is a potential waveform for the space SDR demonstration project.

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Shown here is the component breakdown of the space-to-space communications system (SSCS) software-defined radio (SDR) prototype built during joint research between SwRI and NASA Johnson Space Center (JSC). Teams worked to integrate the demonstration and test its interoperability with the flight radios in the JSC SSCS laboratory.

### SpaceWire: Addressing another piece of the network communications puzzle

SwRI is working to extend protocol standards for SpaceWire, a low-power, high-speed networking technology for use on space vehicles. The SwRI team is working to integrate SpaceWire with traditional network applications and to support the development of a Plug-and-Play standard.

SwRI is developing some of the core components needed to provide SpaceWire with a foundation for supporting off-the-shelf network applications. An internally funded research project is exploring ways to implement a SpaceWire link-layer broadcast and address resolution protocol. Since broadcast is provided via Ethernet, many higher-level network protocols on the Internet make use of it. Broadcast provides a convenient way to distribute the same data across an entire network. The SwRI team has developed a simple, efficient protocol for broadcast across SpaceWire. The protocol was presented to the European Space Agency, the standards body for SpaceWire, early in 2007.

Standards to support rapid development of SpaceWire-networked spacecraft are another area of activity for the SwRI team. The U.S. Department of Defense is establishing initiatives for the Operationally Responsive Space program, a key goal of which is to develop low-cost, multi-mission spacecraft that can be deployed within a few days of a mission concept. The traditional process for development, assembly, integration, and testing must be streamlined to make this possible. SwRI engineers are participating in a working group to develop a Plug-and-Play standard. With Plug-and-Play, instruments, communications devices and other components are automatically detected and configured. The system would be ready for launch with little or no manual setup time required. In the near future, a satellite with Plug-and-Play design could be collecting images or providing communications within a few days of a major disaster or military conflict. Developing these standards will contribute to a more flexible and responsive environment for creating and deploying spacecraft applications.

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