



SBIR INVESTMENTS

in SOFTWARE DEFINED RADIO TECHNOLOGY

2005 to 2012



SPACE COMMUNICATIONS AND NAVIGATION



Cover photo: SCan testbed under GRC thermal vacuum testing.

FOREWORD



NASA's mission to pave the future of space exploration through innovations in science and technology is reflected in a balanced technology development and maturation program supported by all NASA Mission Directorates. Stimulating technology innovation through Small Business Innovation Research (SBIR)/Small business Technology Transfer (STTR) Programs, NASA has empowered U.S. small businesses to make significant contributions to the future of space exploration.

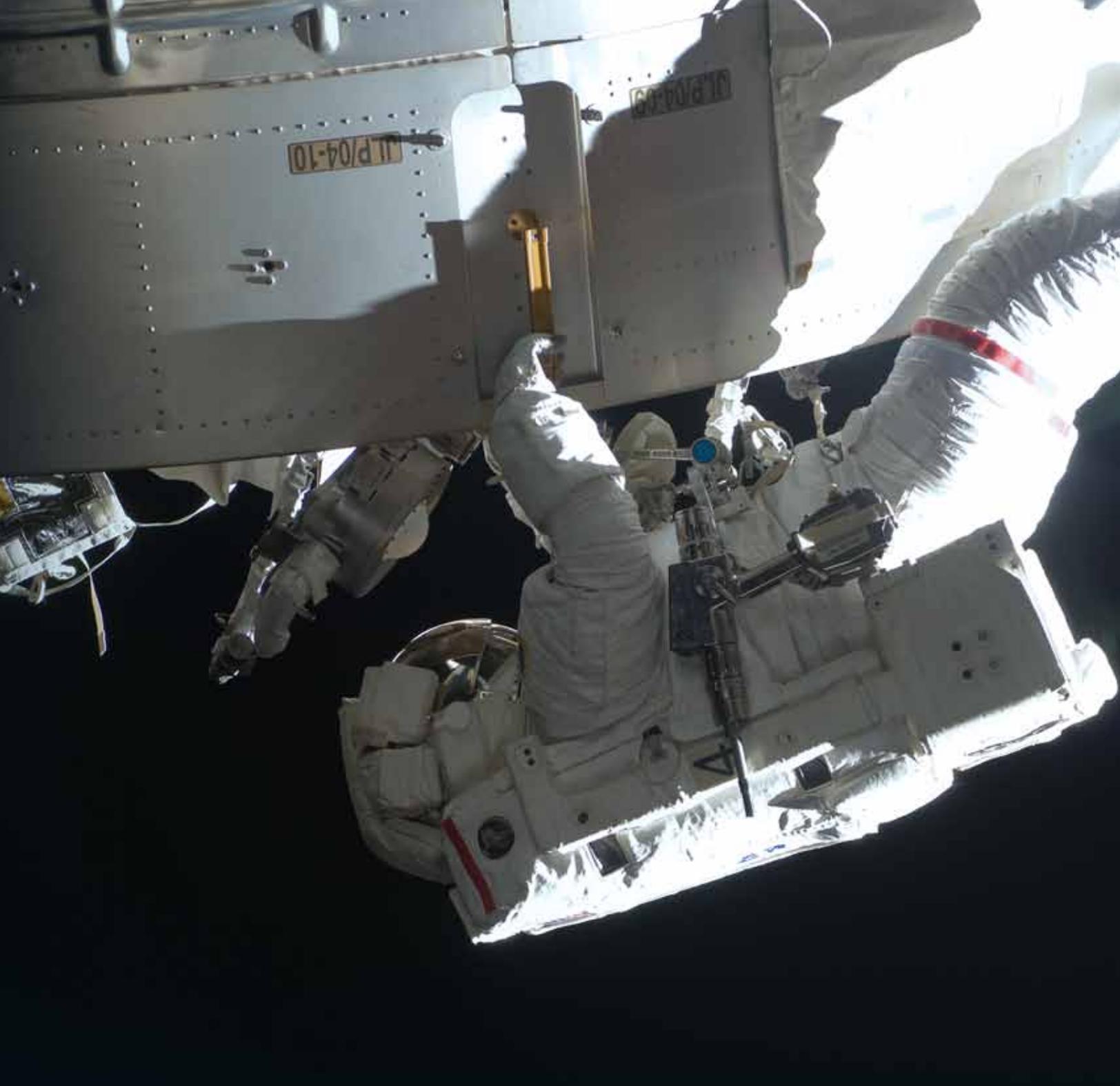
This technology investment portfolio highlights SBIR Phase I and Phase II investments in software defined radio (SDR) technology development for the Space Operations Mission Directorate (SOMD)/Human Exploration and Operations Mission Directorate (HEOMD) from 2005 to 2012. This report summarizes technology challenges addressed and advances made by the SBIR community in SDR technology. The goal of this document is to encourage program and project managers, stakeholders and prime contractors to take advantage of these technology advancements to leverage their own efforts and to help facilitate infusion of technology advancements into future NASA projects. A description of NASA's SBIR Program can be found at www.sbir.nasa.gov.



SMALL BUSINESS
INNOVATION RESEARCH



The Small Business Innovation Research (SBIR) Program provides opportunities for small, high technology companies to participate in Government sponsored research and development efforts in key technology areas of interest to NASA. The SBIR Program provides significant sources of seed funding to foster technology innovation. The SBIR Phase I contracts are awarded for 6 months with funding up to \$125,000; Phase II contracts are awarded for 24 months with funding up to \$750,000.



HUMAN EXPLORATION

A person wearing a space helmet is looking out of a window, with bright light visible outside. The person's face is partially obscured by the helmet's visor.

The Human Exploration and Operations Mission Directorate (HEOMD) is chartered with the development of core transportation elements, key systems, and enabling technologies required for beyond-low Earth orbit (LEO) human exploration that will provide the foundation for the next half-century of American leadership in space exploration.

This new space exploration era starts with increasingly challenging test missions in cislunar space, including flights to the Lagrange points, followed by human missions to near-Earth asteroids (NEAs), moon, the moons of Mars, and Mars as part of a sustained journey of exploration in the inner solar system. HEOMD was formed in 2011 by combining the Space Operations Mission Directorate (SOMD) and the Exploration Systems Mission Directorate (ESMD) to optimize the elements, systems, and technologies of the precursor Directorates to the maximum extent possible.

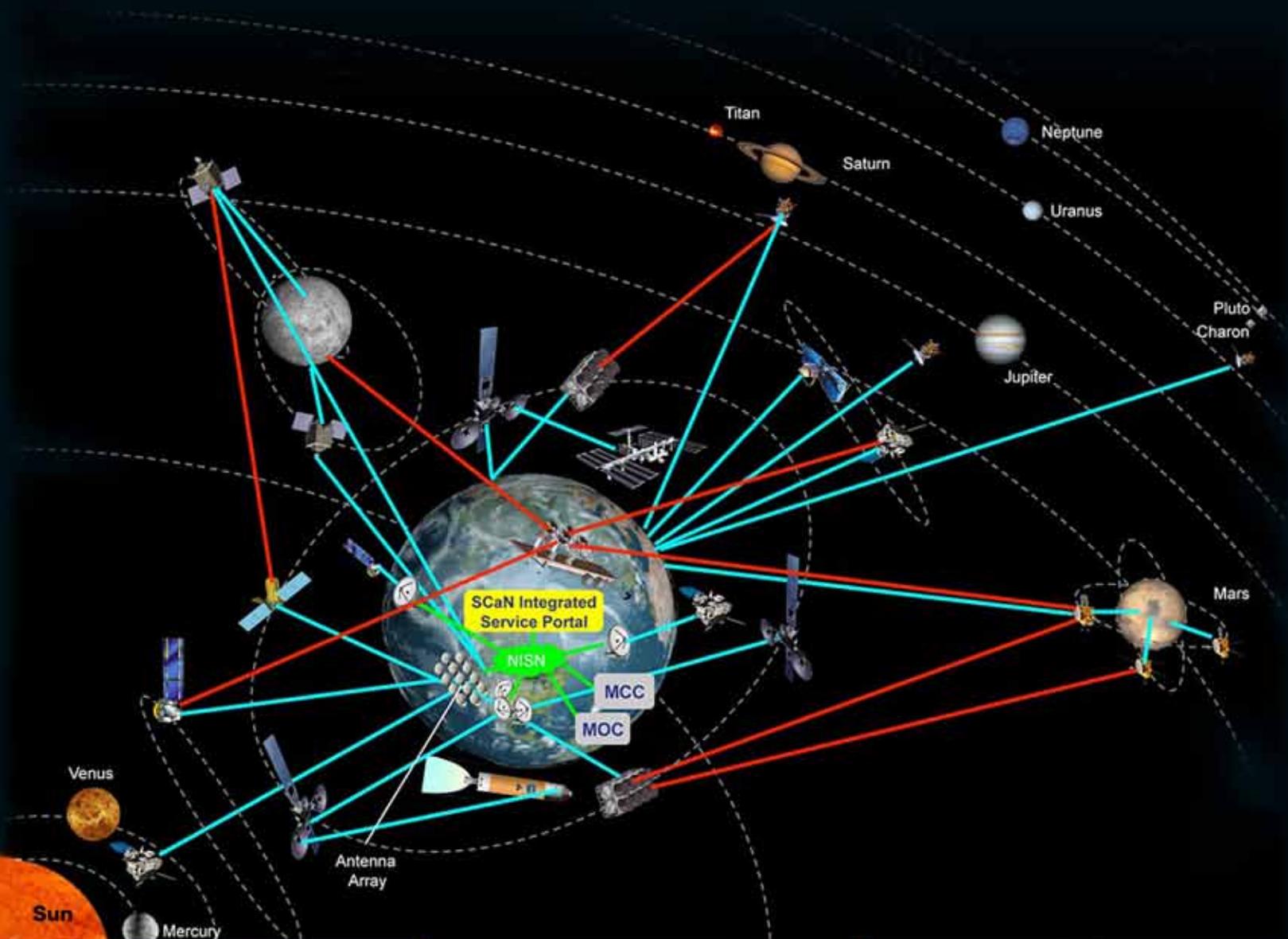
HEOMD mission goals include: key technology developments in Space Communications and Navigation, Space Transportation, Human Research and Health Maintenance, Radiation Protection, Life Support and Habitation, High Efficiency Space Power Systems, and Ground Processing/ISS Utilization.

HEOMD looks forward to incorporating SBIR developed technologies into current and future systems to contribute to the expansion of humanity across the solar system while providing continued cost effective space access and operations for its customers, with a high standard of safety, reliability, and affordability.

AND OPERATIONS MISSION DIRECTORATE

SCaN: KEEPING THE

SCaN NOTIONAL INTEGRATED NETWORK ARCHITECTURE



Microwave Links

Optical Links

NISN

UNIVERSE CONNECTED

PROGRAM AND TECHNOLOGY DEVELOPMENT OVERVIEW

The Space Communications and Navigation Program (SCaN) resides within HEOMD and is responsible for the development of technologies and capabilities to support all current and future NASA missions. The SCaN Program provides the communication, navigation and mission science data transfer services that are vital to the successful operation of NASA space flight missions. To accomplish this, SCaN operates three networks: the Deep Space Network (DSN), the Near Earth Network (NEN), and the Space Network (SN). Combined together, the services and network assets provide capabilities which enable space exploration for over 100 NASA and non-NASA missions. SCaN also provides scheduling services to new missions through Network Integration Management Office (NIMO) and Deep Space Network Commitment Office (DSNO).

To accomplish the above, the SCaN Program's vision is to build and maintain a scalable, integrated, mission support infrastructure that can evolve to accommodate new and changing technologies, while providing comprehensive, robust, cost effective, and exponentially higher data rate services to enable NASA's science and exploration missions. Today NASA communication and navigation capabilities using Radio Frequency technology can support spacecraft to the fringes of the solar system and beyond. The anticipated new missions for science and exploration of the universe are expected to challenge the current data rates of 300 Mbps in LEO and of 6 Mbps at Mars to rise significantly. The SCaN Program aims to

- Develop a SCaN infrastructure capable of meeting both robotic and human exploration mission needs.
- Evolve infrastructure to provide the highest data rates feasible.
- Develop internationally interoperable data communications protocols for space missions.
- Offer communications and navigation infrastructure for lunar and Mars surfaces.
- Offer communications and navigation services to enable lunar and Mars human missions.

SCaN technology development interests include optical communications, advanced antenna technology and Earth stations, cognitive networks, access links, reprogrammable communications systems, spacecraft positioning, navigation, and timing (PNT), and communications in support of launch services. Innovative solutions to operational issues are needed in all of the areas. Emphasis is placed on size, weight and power improvements. All SBIR technologies developed under SCaN Topic area are aligned with the SCaN Program technical directions.

This document catalogs SCaN SBIR investments in **Software Defined Radio Technology** development from 2005 to 2012.

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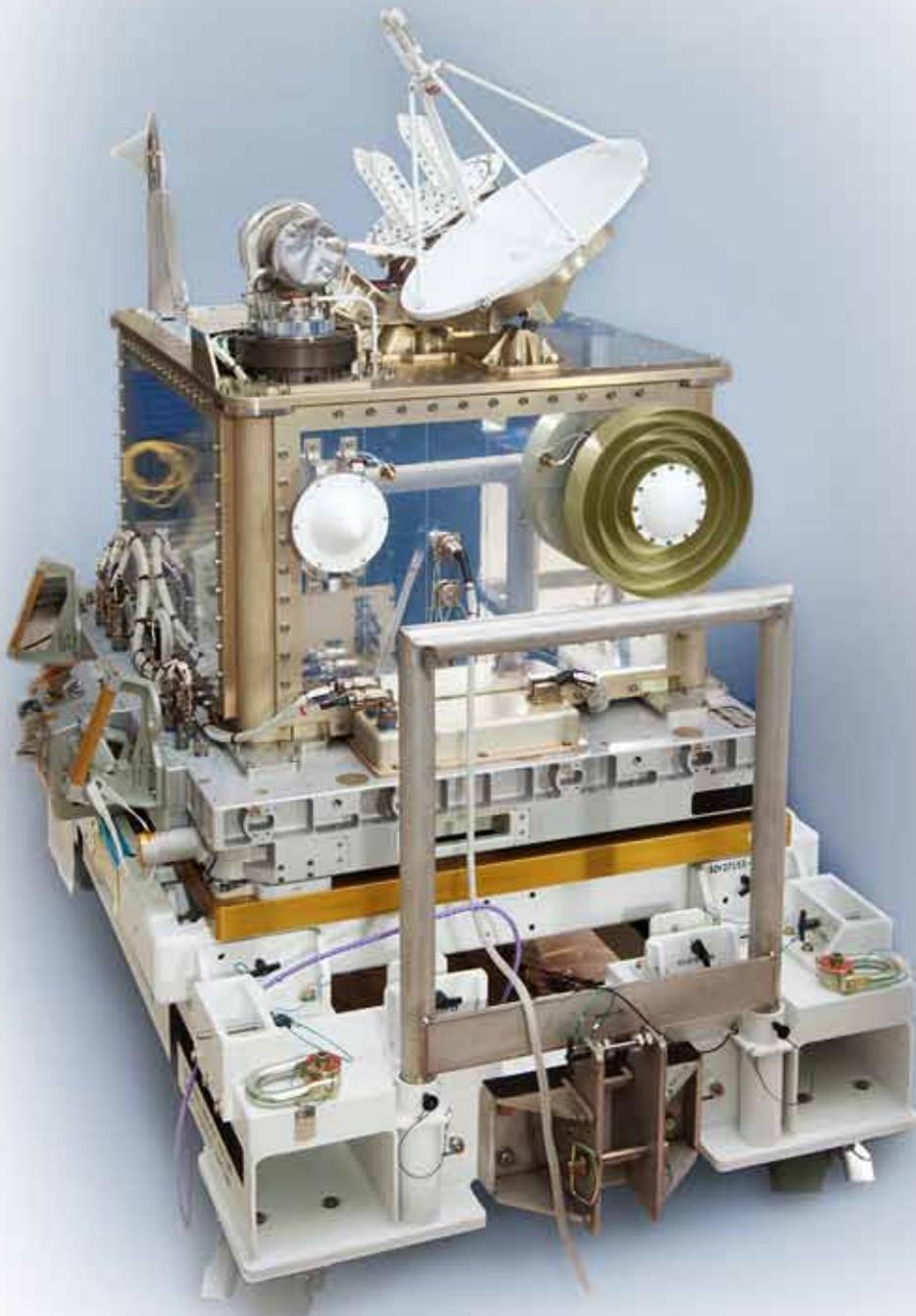
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SOFTWARE DEFINED RADIO TECHNOLOGY



NASA seeks novel approaches in reconfigurable, reprogrammable communication systems to enable the vision of Space, Exploration, Science and Aeronautical Systems. Exploration of Martian and lunar environments will demand harsh space environment compatible, flexible, adaptable electronic hardware to assure survivability for long-haul missions. NASA missions can have vastly different transceiver demands (e.g. 1's to 10's Mbps at UHF and S-bands, up to 10's to 1000's Mbps at X, and Ka-bands) and available resources, depending on operating spacecraft environments. Deep space missions are often power constrained, operate over large distances, subsequently, offer lower data rates when compared to near-Earth or near-planetary missions. These demands are known prior to launch; therefore, scalability features can maximize transceiver efficiency while minimizing resource consumption. Larger vehicles platforms, or relay spacecrafts may provide more resources but are also expected to perform complex functions or support multiple and simultaneous communication links to a diverse set of assets.

Goals to achieve flexible, reconfigurable communications while minimizing cost and on-board resources require reconfigurable transceivers and component technologies. Topics of interest include: development of software-defined radios (SDR) or subsystems that demonstrate reconfigurability, flexibility, reduced power consumption in digital signal processing systems, increased performance and bandwidth, reduced software qualification cost, and error detection and mitigation technologies. Complex reconfigurable systems will provide multiple channel and multiple and simultaneous waveforms. Specific interest areas are as follows:

- Advancements in bandwidth capacity, lower resource consumption, adherence to standard and open hardware and software interfaces. Techniques should include fault tolerant, reliable software execution, reprogrammable digital signal processing devices.
- Reconfigurable software and firmware that provide access control, authentication, and data integrity checks of the reconfiguration process, allows simultaneous operation and upload new waveforms or functions.
- Automated reconfiguration, allowing automated restore capability that ensures reverting back to a baseline configuration, thereby avoiding permanent communications loss due to an errant process or logic upset.
- Dynamic or distributed on-board processing architectures, for example, demonstrate technologies to enable a common processing system for communications, science, and EVA health monitoring.
- Adaptive modulation and waveform recognition techniques to enable transceivers to exchange waveforms with other assets automatically or through ground control
- Low overhead, low complexity hardware and software architectures to enable design reuse (e.g., software portability) to demonstrate cost or time savings. Emphasis is on the application of open standard architectures to facilitate interoperability among different vendors and to minimize operational impact of upgrading components
- Software tool chain methodologies that enable software modeling, code reuse, and advanced code optimization for digital signal processing systems
- Novel approaches sought to mitigate single event effects, hence, to improve reliability. The use of reconfigurable logic devices in SDR is expected to increase in the future to provide on-orbit flexibility for waveforms and applications. As the densities of these devices continue to increase and sizes decrease, the susceptibility to single event electronic effects also increases. Techniques and implementation schemes to provide a core capability within the SDR in the event of a disruption of the primary waveform or system hardware. Communication loss should be detected and core capability ("gold" waveform code) be automatically executed to provide access and restore operation.
- Innovative solutions sought to reduce power and mass in SDR implementation. Solutions must enable hardware scalability among different mission classes (e.g., low-rate, deep space to moderate or high-rate near planetary, or relay spacecraft) and should promote modularity and common, open interfaces
- Advancements sought in A/D or D/A converters to increase sampling speed and resolution, novel techniques to increase memory densities, advancements in processing and reconfigurable logic technology, while reducing power consumption.
- Innovative solution in harsh environment scenario, for example, in EVA radio, to address reconfigurable technology

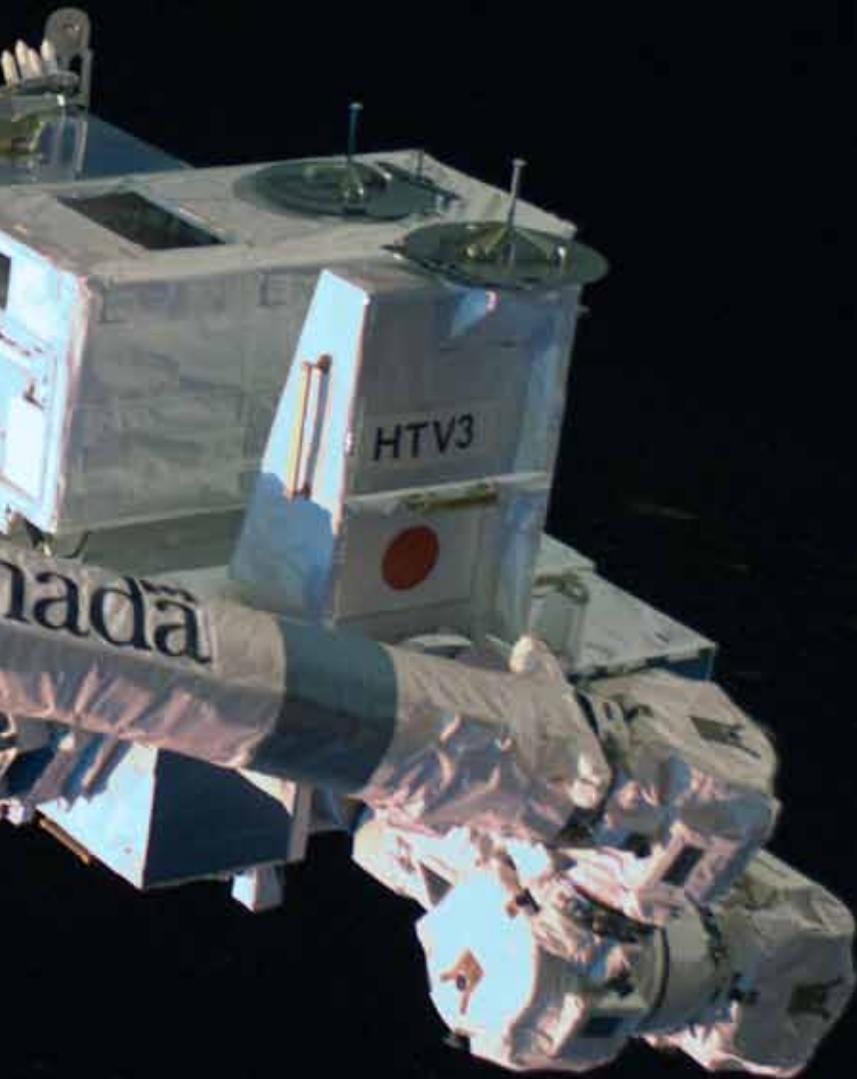
Phase I deliverables are based on research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and a path towards a hardware or software demonstration. Bench- or lab-level demonstrations are desirable.

Phase II deliverables emphasize development and demonstration of the technology under simulated flight conditions. The effort should outline a path towards a spaceworthy system. The SBIR contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II period.



SOFTWARE DEFINED RADIO TECHNOLOGY SBIR PHASE I AWARDS

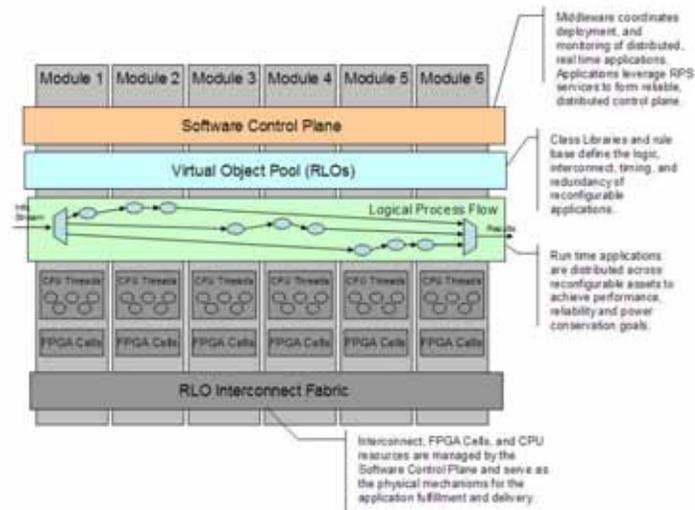
2005 TO 2012



RECONFIGURABLE COMPUTING FOR DYNAMICALLY REPROGRAMMABLE COMMUNICATIONS

WW Technology Group

2005 Phase I
01.06-7536



Identification and Significance of Innovation

- Integrates WWTG Reliable Technologies into a Reconfigurable Environment
- Extends adaptive capabilities into the domain of RC application space
- Establishes a foundation for software defined radios that incorporates adaptive processing, reconfigurable functionality, and SEE tolerance

Technical Objectives

- Establish foundational architecture from which RC and WWTG software middleware resources support software radios
- Demonstrate feasibility of methodology and approach
- Specify the functionality of RLOs in the software radio environment
- Create a functional design for RLO-based prototype
- Specify middleware support for dynamically reprogrammable communications
- Demonstrate feasibility with a proof of concept.

NASA Applications

- Leonardo
- Constellation X
- GMSEC
- Stellar Imager
- Leonardo

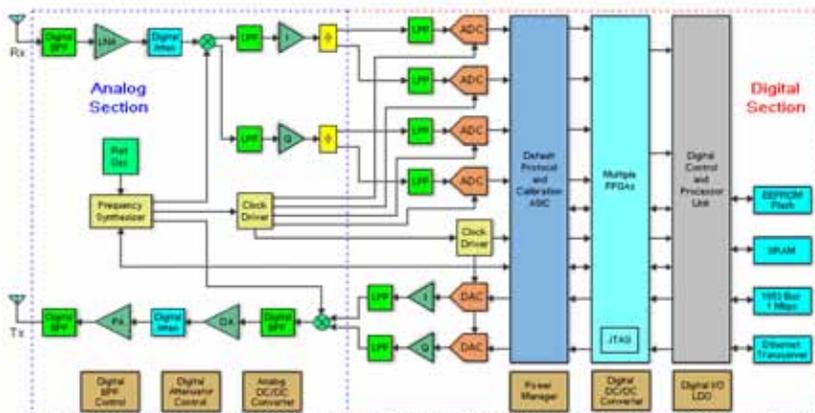
Non-NASA Applications

- Avionics—Integrated avionics systems
- Security—Buildings, borders, and MIL sensor webs

RECONFIGURABLE/REPROGRAMMABLE COMMUNICATION SYSTEMS

Hittite Microwave Corporation

2005 Phase I
01.06-7678



RRT Receiver Design Architecture

Technical Objectives

- Design a Receiver section having integration of X-band and K-band downconverters with an 8-bit 1 Gbps dual ADC as well as two 12-bit 250 MHz ADC boards.
- Conduct electrical performance characterization of Receiver by acquiring I/Q and complex test and measurement data sets.
- Measurement results show 504 Mps of instantaneous digital bandwidth is achievable to a precision of ≥ 10 effective bits by combining up to four 12-bit 300 Mps ADCs with a time-interleaving approach, and by applying linear, nonlinear and Error Vector Magnitude calibration techniques.

NASA Applications

- NASA Space Science Missions and Communications from outer planets to NASA terrestrial facilities and/or earth orbits.

Non-NASA Applications

- High data throughput applications where ease and cost of transporting large apertures is of prime importance such as natural or man-made disasters or combat theaters, plus industrial/commercial applications for high-performance digital communication systems.

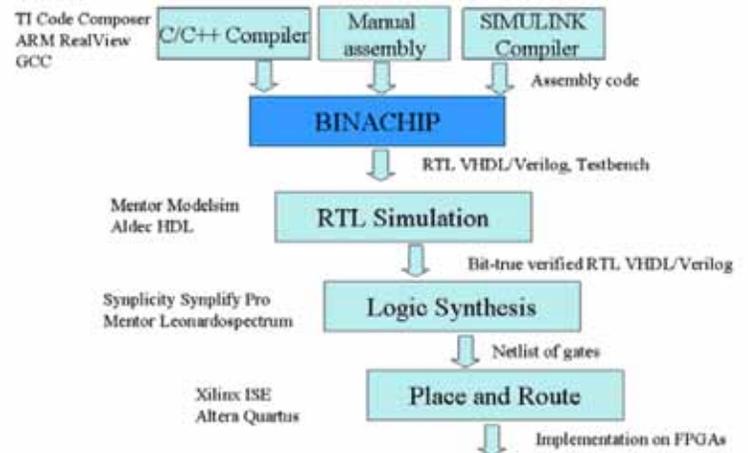
Identification and Significance of Innovation

- Develop high data rate Reconfigurable/Reprogrammable Transceiver (RRT) systems with sufficient bandwidth to support the digital rates planned for lunar and Mars mission data requirements. NASA/GRC has mandated a transmission and reception data rate of ≥ 500 Mbps for future space mission communication applications.
- A miniaturized modular RRT module allows easy conversion to other prescribed NASA frequency bands and new analog or digital updates/upgrades with integrated frequency selection, scalable digital bandwidth and digital bit precision.

A HARDWARE/SOFTWARE DESIGN ENVIRONMENT FOR RECONFIGURABLE COMMUNICATION SYSTEMS

BINACHIP, Inc.

2005 Phase I
01.06-9806



Identification and Significance of Innovation

- Space exploration will require advancements in communication systems to maintain flexibility and adaptability to changing needs and requirements
- Develop automated techniques to take software implementations of reconfigurable communication applications and map them to FPGAs and SOCs
- Reduce design times from months to days

Technical Objectives

- Study techniques for automatic translation of software implementations to RTL VHDL for mapping to FPGAs on reconfigurable hardware
- Investigate techniques for hardware/software co-design for reconfigurable hardware
- Apply techniques to Software Defined Radio (SDR)
- Task A—Translation of software to RTL VHDL
- Task B—Hardware/software co-design
- Demonstrate prototype compiler on SDR to Xilinx Virtex II Pro SOC and DINI Board

NASA Applications

- Software defined radio, communication systems

Non-NASA Applications

- Embedded systems software for PDAs, cellphones, electronic design automation for networking, communications, digital signal processing

REPROGRAMMABLE RADIATION TOLERANT SECURE NETWORK ACCESS MODULE

Aeronix, Inc.

2006 Phase I
01.05-8295

Graphic unavailable

Technical Objectives

- Develop a scalable space based cryptographic architecture which supports
 - NASA networking requirements for space, lunar, and planetary exploration mission
 - NASA requirements associated with the most recent version of the NSA High Assurance Internet Protocol Interoperability Specification (HAIPIS)
 - Reprogrammability and has the capacity to support future algorithms, operating modes, and network protocols
 - Maximizes use of COTS radiation tolerant FPGA technology while minimizing dependence on custom designed ASICs

NASA and Non-NASA Applications

- NASA TT&C Reprogrammable HAIPES compliant IP encryptor for ground to satellite communications
- Low Power Reprogrammable IP encryptor for manned and unmanned lunar and planetary exploration
- Orbital Relay encryptor for lunar to ground transmissions
- DoD TT&C encryptor
- High speed encryptor for applications such as TSAT
- Radiation Tolerant encryptor for homeland security and nuclear applications

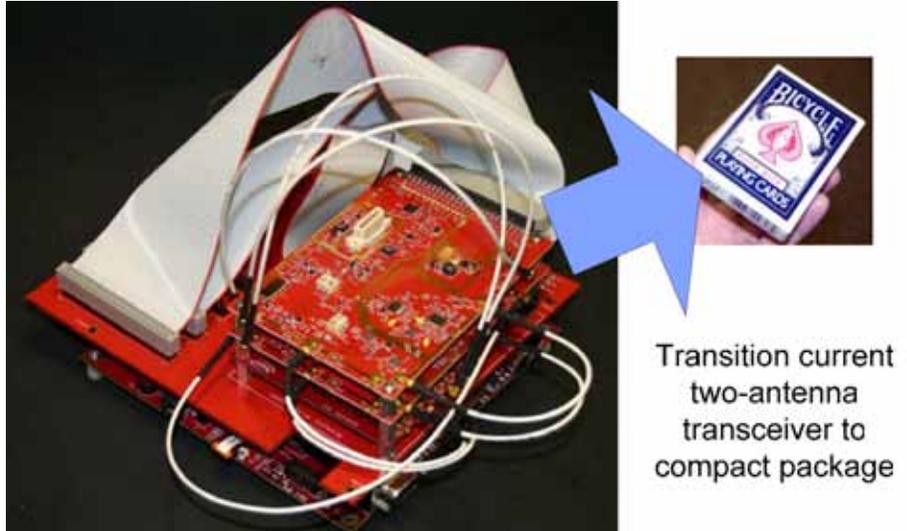
Identification and Significance of Innovation

- NASA's exploration of planetary surfaces will require a communication architecture that supports operational capabilities in which assets can communicate seamlessly and securely to coordinate exploration as well as communicate back to Earth
- Solutions are needed which are conformant to the most recent version of the HAIPIS, support reprogrammability, and employ COTS FPGA technology to support upgrade of new capabilities
- The innovation of this proposed solution is the development of an unclassified IP based network encryptor that is compatible with commercially available ground based HAIPES equipment operating with Suite B algorithms and the ability to operate in the presence of failures caused by the harsh environment of space

MULTI-MISSION MICRO μ SDR

Toyon Research Corporation

2006 Phase I
01.05-9020



Identification and Significance of Innovation

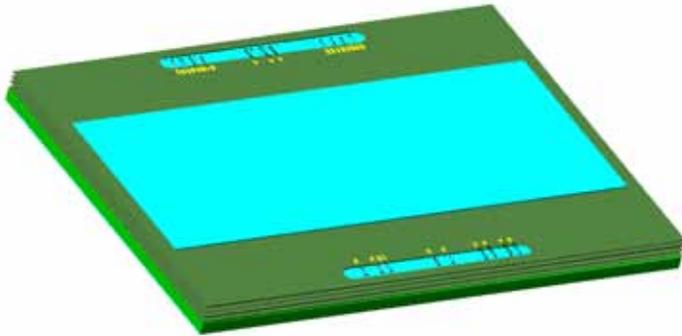
- The proliferation of space and terrestrial vehicles for space exploration calls for post flight reconfiguration in support of multiple waveforms as well as to enable architecture updates
- The vision for μ SDR is to meet varying mission needs in a low power and compact package by leveraging the state-of-the-art in hardware and software design
- Computationally tractable algorithms
- FPGA behavioral design tools to provide logic reuse and reduce development time
- Highly integrated ICs to maximize flexibility
- Standards-based IO, such as Ethernet, to provide compatibility

Technical Objectives

- High data rate that can scale to multiple Mbps
- Radiation tolerant devices suitable for space applications
- Open-standard data interfaces to ease integration to NASA programs
- Low part count to minimize size and ease qualification
- Identify vehicle application
- Candidate waveform selection
- Develop system architecture
- Baseband signal processing algorithms
- Develop hardware design

NASA and Non-NASA Applications

- Micro-satellites
- Autonomous ground vehicles
- Ground links
- Relatively low volume custom radio design for a variety of user specific applications in the DoD, emergency response, homeland security, and commercial sectors



Technical Objectives

- Celis Semiconductor had previously manufactured one wafer of die at Fujitsu, and performed confidence testing on several die. NxGen performed a 'blind' build of enough packaged parts to successfully support the radiation test series. For Phase II, Celis will support another spin of the FRAM design, NxGenElectronics will support radiation re-testing of the re-designed silicon and compare the results to modeling data. NxGen would then build a number of 2 & 4 high stacks to perform environmental tests and a reliability demonstration

NASA and Non-NASA Applications

- Shuttle, space station, earth sensing missions and deep space probes. Missions which will benefit are Mars Surveyor, solar system exploration e.g. (Titan, EuropaLanders, Comet Nucleus Return, New Discovery Program, and Living with a Star).
- Commercial applications include space platforms, both GEO and LEO such as the Boeing Space HS-601 and Lockheed A2100.
- Telecommunication satellites and sensing applications (NOAA) require this memory to store critical data and support on board data processing.
- Terrestrial applications include nuclear power plants and research accelerators (Fermi Lab).

Identification and Significance of Innovation

- In Phase I NEI assembled FRAM modules from die fabricated from the previous Phase II SBIR. The modules were subjected to TID and SEU testing to characterize the FRAM radiation tolerance. The first pass results were remarkably successful. This Phase II includes re-design of the mask sets and re-testing. Then 2 & 8 high stack designs will be completed and a complete environmental and life tests conducted. The result should be a low cost 2-16 Mb product offering based on a commercial foundry with 2 MradTID and high SEU tolerance.

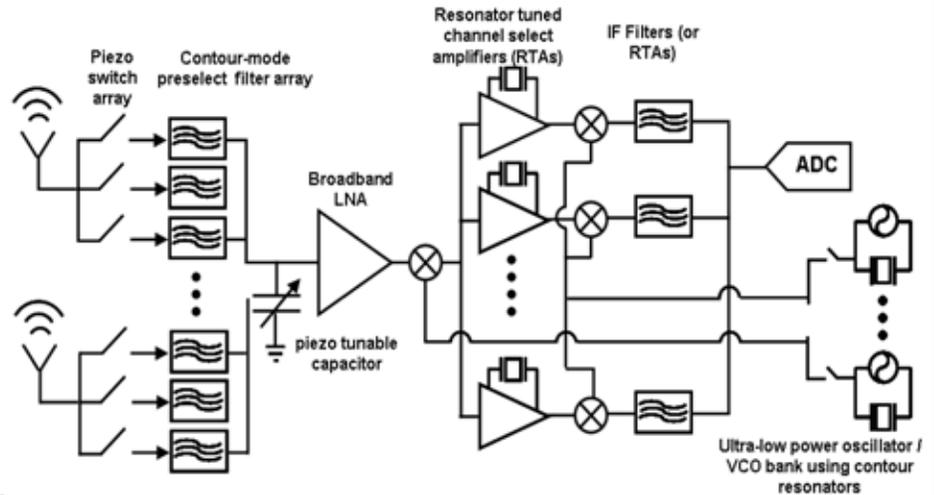
Expected TRL range at the end of contract

- 8

LOW POWER, SMALL FORM FACTOR, HIGH PERFORMANCE EVA RADIO EMPLOYING MICROMACHINED CONTOUR MODE PIEZOELECTRIC RESONATORS AND FILTERS

Harmonic Devices, Inc.

2006 Phase I
01.06-9177



Identification and Significance of Innovation

EVA radio based on the co-design of transceiver with high-Q micromachined RF components

- Drastically reduced power/volume/weight
- Reduced linearity requirement
- High performance reconfigurable, frequency agile, fault tolerant architecture
- Single-chip, high-Q micro-machined piezo RF components
 - Resonators/filters
 - 10 MHz to multi GHz
 - Switches
 - Tunable caps

Technical Objectives

Generate EVA radio circuits leveraging high-Q micro-machined contour components for Phase II STRS compliant implementation

- Co-design transceiver blocks with high-Q components
- Develop high-Q component-based architecture topologies
- Resonator/filter/tunable cap design and optimization for RFIC co-design
- Highly-scalable miniaturized frequency control solutions based on proprietary contour mode resonators spanning 10 MHz to multi-GHz on same piece of Si

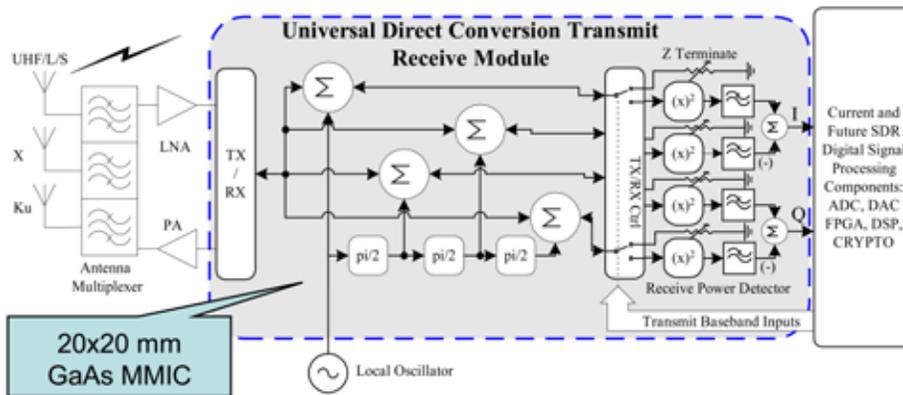
NASA Applications and Non-NASA Applications

- NASA EVA STRS radio systems
- Harsh environment (rad hard) operation
- Spacecraft and planetary surface vehicles
- Handheld military radios
- Cell phones/pagers, Wi-Fi, UWB
- Wideband direct waveform synthesis
- Ultra-low-power distributed sensor networks
- Tuned amps with micromachined high-Q components
- Interoperable first responder radios (police, fire, hazmat, Homeland Security, medical personnel)

LOW POWER UNIVERSAL DIRECT CONVERSION TRANSMIT AND RECEIVE (UTR) RF MODULE FOR SOFTWARE DEFINED RADIOS

Space Micro, Inc.

2007 Phase I
01.05-8647



Technical Objectives

- Flow down system to hardware specification for UTR module identifying specific system(s) targeted (ie EVA, deep space, comms, radar, UWB, other)
- Detail UTR design (block diagram, schematics), analysis (system parametrics) and simulation. Show UTR module capabilities for modular SDR applications
- Iterate UTR and identify manufacturing path, including projected size, weight and performance (SWAP). Validates components, space application and capabilities
- Leveraging UTR system and components, explore additional applications in areas such as RF power amplification. Design and analyze, define Phase II applicability
- Finalize UTR hardware specification: identification of all required manufacturing, calibration and practical manufacturing steps to provide Phase II hardware and demo
- Final report and identification of other commercial applications of UTR or derived UTR for military, public safety, homeland defense, commercial wireless markets

NASA and Non-NASA Applications

- In flight reconfigurable SDR agnostic RF front end for current and future RF communications and radar—CEV, EVA, SDST, SGLS, STDN, TDRSS, lunar, point to point, networked, surface/harsh environment etc.
- DOD software defined radio (eg JTRS, AMF, etc): terrestrial, airborne, naval. Electronic Warfare, C4ISR capabilities due to universal wideband capabilities.
- Wideband operation and low power are ideal for cognitive and mobile adaptive ad hoc networked (MANET) communications (802.xx) as well as traditional commercial wireless (GSM/EDGE, CDMA, UMTS-WCDMA)

Identification and Significance of Innovation

- Novel universal transmit and receive RF module with exceptional center frequency (UHF~35+GHz), bandwidth (Hz to >500 MHz), scales to >100 GHz
- Receive requires no DC input power; very low parts count; “DAC-less” wideband arbitrary direct to RF transmit modulator; direct digital wideband RF power amp
- Practical manufacture with existing and future technologies (GaAs, SiGe, GaN, MEMS, Ferroelectrics); tunable left handed meta-materials for best size reduction
- Easily integrated with available software defined radio (SDR) components; addresses NASA reconfigurable, modular multi-mission flexibility (narrow and wideband comms, radar) with one open architecture RF hardware component

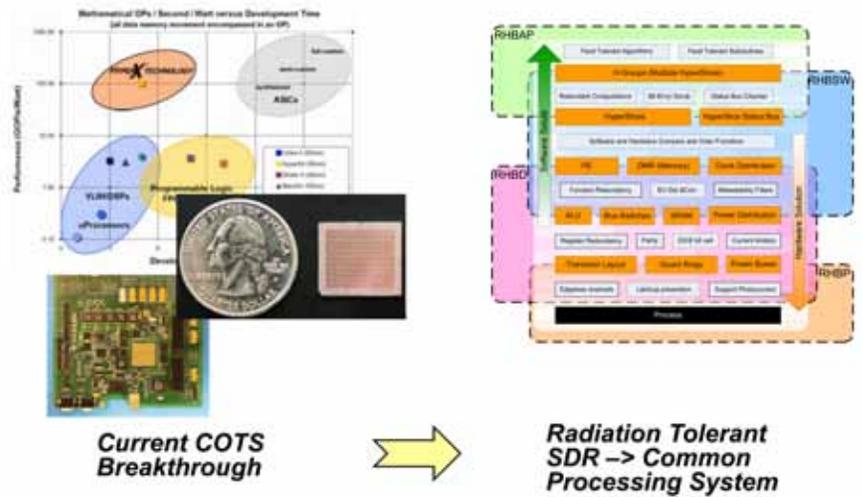
Expected TRL range at the end of contract

- 5-6

SOFTWARE DEFINED COMMON PROCESSING SYSTEM (SDCPS)

Coherent Logix, Inc.

2007 Phase I
01.05-8732



Identification and Significance of Innovation

- Enabling software defined systems
- Extremely-high performance
- Ultra-low power
- Unified software development environment
- Revolutionary reconfigurable processor
- Creation of SDR common processing system

Expected TRL range at the end of contract

- 8-9

Technical Objectives

Phase 1

- Define hardware and software SDR development system requirements
- Determine radiation tolerant processor requirements
- Conceptually define full SDR development kit (HW/SW co-development and hardware modules)

Phases 2 and 3

- Design, development, and productization of SDCPS platform

NASA Applications and Non-NASA Applications

- Exploration, science, and space operations systems
- High-reliability command, control, and safety systems (e.g. automotive, avionics, medical)



One of the low power small form factor SDRs currently produced by Lexycom Technologies (shown model number Tiamis-800L)

Technical Objectives

The main goal of this proposal is to design a suitable SDR transceiver to be used in a lunar environment.

- Analyze the required network functions and design suitable network algorithms
- Conduct the simulation of network performance and analyze the effectiveness of the selected network algorithms
- Design the radio transceiver's architecture and determine the functional requirements for its subsections
- Conduct the sensitivity analysis of the proposed network
- Determine the suggested modes of EVA SDR's operation to address different propagation and interference conditions
- Design and analyze the required cognitive middleware algorithms
- Draw conclusions, summarize the results

NASA Applications

- Incrementally expandable, software defined radio ad-hoc communications system that will provide the building blocks for all future planetary and navigation communication demands

Non-NASA Applications

- DOD training and field activities, first responder communication and navigation systems, mining and geological activities

Identification and Significance of Innovation

- With lunar and planetary becoming more and more common, the need for a highly reliable, reconfigurable communication system is paramount. Lexycom proposes a design of a state-of-the-art EVA software defined radio (SDR) that would be a part of an advanced, incrementally expandable ad hoc wireless network.
- For improved reliability and to assure stand-alone functionality, the network would support a real-time 3D location using mobile-assisted navigation and utilizing TOA/TDOA methods.

Expected TRL range at the end of contract

- 3-4

LOW PHASE NOISE UNIVERSAL MICROWAVE OSCILLATOR FOR ANALOG AND DIGITAL DEVICES

VIDA Products

2008 Phase I
01.03-9012

Graphic unavailable

Identification and Significance of Innovation

- Efficient uncompromising microwave signal generation using YIG resonators without the prior drawbacks of power inefficiency, large size and weight, poor yield and reliability, and high cost. Achieved by bringing the YIG oscillator into the latest integrated circuit technology enabled by VIDA products recent developments.

Expected TRL range at the end of contract

- 2-3

Technical Objectives

- Preliminary design and simulation of a SiGe differential YIG tuned ring oscillator, which simultaneously achieves operation up to 25 GHz with the lowest possible phase noise and time jitter
- Preliminary design and simulation of a 25 GHz pre-scaler for existing PFD/CP/PLL
- Preliminary design and simulation of the components of a magnetic field stabilization loop to eliminate all mechanical shock and vibration effects
- Design an ultra miniature permanent magnet together with an electromagnet coil housing using the latest magnetic materials technology
- Test Q improvement techniques to raise the oscillator's Q factor from 1,000 (Typical Oscillator) to over 10,000

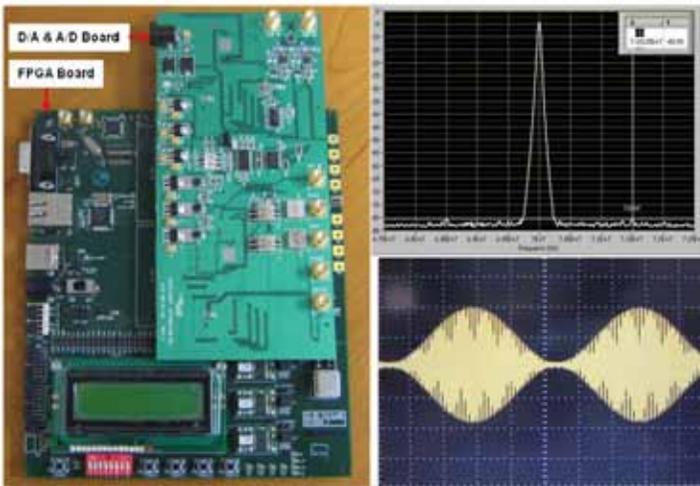
NASA and Non-NASA Applications

- Cognitive and software configured wireless communications
- Low cost precision radar and ranging systems
- Sensors using ADC with greatly improved resolution
- Portable test equipment with lab performance capabilities
- Affordable broadband communication wireless links
- Space qualified frequency sources with laboratory performance
- Ground stations data rate improvements with reduced signal strength
- Reduce personal microwave energy exposure with current capabilities

RECONFIGURABLE, COGNITIVE SOFTWARE DEFINED RADIO

Intelligent Automation, Inc.

2008 Phase I
01.03-9360



Technical Objectives

- Generate justified system designs and engineering guidelines. This will be accomplished by arranging kickoff meetings with the NASA technical personnel
- Demonstrate transmit waveform diversity and implementation of several candidate digital receiver architectures
- Demonstrate flexible user control and on the fly radio reconfiguration capabilities
- Implementation of cognitive capabilities in the software radio. We visualize adaptive modulation and AMR to be of general interest in the software radio community. Hence we will explore these areas and demonstrate these capabilities in the proposed software radio

NASA and Non-NASA Applications

- Arbitrary wideband waveform synthesizer
- Reconfigurable radar transceiver with multi-mode capabilities
- Cognitive radios
- Configurable telemetry and ranging radios
- Lab based software radio test-bed
- Extra Vehicular (EVA) radios for space applications

Identification and Significance of Innovation

Intelligent Automation Inc, (IAI) is currently developing a software defined radio (SDR) platform that can adaptively switch between different modes of operation for communication, by modifying both transmit waveforms and receive signal-processing tasks on the fly. High-speed analog-to-digital and digital-to-analog converters along with modern FPGAs and fast digital signal processors allow for maximum flexibility in digital radio design. The proposed software reconfigurable radio implementation technique and the system design will leverage IAI's vast experience in SDR, RF hardware design, signal processing and system level firmware design. Key innovations of the proposed effort are

- Reconfigurable digital transceiver/ waveform synthesizer design using high speed FPGA
- Multi-mode radio functionality and scalable architecture.
- Soft-processor based controller and flexible user control to enable on the fly radio configuration.
- Cognitive capabilities like Adaptive modulation and Automatic Modulation Recognition (AMR)
- Complex modulation and bandwidth efficient waveform implementation capability

Expected TRL range at the end of contract

- 6

MULTI-CLUSTER NETWORK ON A CHIP RECONFIGURABLE RADIATION HARDENED RADIO

Microelectronics Research Development Corporation (2008)

2008 Phase I
01.03-9430

Graphic unavailable

Identification and Significance of Innovation

- To support a wide range of throughputs over adverse conditions requires reconfigurable baseband processor radio communications systems, trading off long range or lower power versus throughput. Some communications require adaptation in the presence of jammers or noise. Communication systems based on MIMO OFDM can be reconfigured to meet a wide variety of requirements for range and throughput. OFDM in particular has proven to be a robust system in the presence of multi-path fading, Doppler shift due to vehicle motion or variations in the multipath channel. With MIMO OFDM, the system can be trained to support multiple Modulation Coding Schemes (MCS) that tradeoff throughput for range and enhanced diversity. The proposed Network on a Chip with clusters of 2D Grids of networked primitive agents addresses the task of supporting a wide variety of MIMO OFDM configurations. By shutting down primitive agents and their routes, the system can scale down power and throughput. In addition, damaged agents can be identified and isolated. Agents are targeted for SEU immunity and the switching fabric and routing links are radiation hardened by design so that the reconfigurable radio can meet the challenges of space born operation.

Expected TRL range at the end of contract

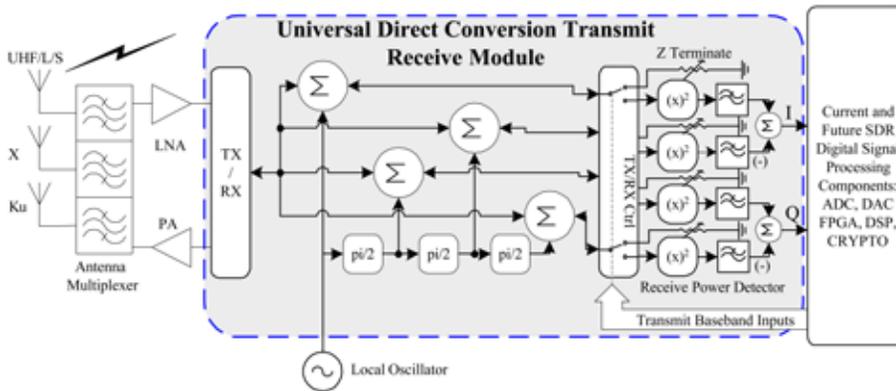
- 3-4

Technical Objectives

- Phase I objective is to architect, model and simulate the multi-cluster Network on a Chip (NoC) in RTL with SystemC to demonstrate digital signal processing flow requirements for 1 Gbps radio communication based on MIMO OFDM modulation. The NoC microarchitecture will be developed based on multiple clusters: (1) down conversion and FIR filtering, (2) implementation of AGC, packet detection, and variable length FFTs, (3) CORDIC cluster which implement the MIMO equalizer. The MIMO equalizer, SVD beamforming and space time coding will be developed and simulated in SystemC (RTL). The reconfigurability of the NoC based Radio will be verified using SystemC at the RTL level.
- The work plan includes mapping a 4x4 MIMO OFDM to a cluster of 2D Grids of networked agents, verifying the mapping through modeling and the simulation of the architecture in SystemC. In addition, the work plan includes tasks to simulate reconfiguring of the radio to support high throughput and to switch to high diversity for long range and lower throughput for power savings. The work plan includes modeling the impact of SEU and SET on the reconfigurable radio and the immunity gained by radiation hardening of agents with associated tradeoffs in chip speed and area. Finally, the high speed links will be modeled in Spice for the IBM 90nm processes to assess power and area requirements of the switch fabric.

NASA and Non-NASA Applications

- The key algorithm mapped to the architecture is 4x4 and 4x5 MIMO OFDM systems. The system can handle high throughput, can scale down power, and can serve the needs of base stations for the lander and meet the low power and range requirement for rovers. The reconfigurable NoC based radio has a huge commercial application and will directly compete with successful array-based reconfigurable radios in the MIMO-OFDM base station market.



Technical Objectives

- Flow down system to hardware specification for UTR module identifying specific system(s) targeted (EVA, deep space comm., radar, UWB etc.)
- UTR design (block diagram, schematics), analysis (system parametrics) and simulation. UTR module capabilities for modular SDR applications

Milestone #1—Preliminary UTR capability report

- Iterate UTR and identify manufacturing path, including projected size, weight and performance (SWAP). Validates components, space application and capabilities
- Leveraging UTR system and components, explore additional applications in areas such as RF power amplification. Design and analyze, define Phase II applicability
- Finalize UTR hardware specification: identify manufacturing, calibration, manufacturing steps for phase II hardware demonstration

Milestone #2—UTR module Phase II projected capability report

- Final report and identifying commercial applications of UTR for military, public safety, homeland defense, commercial wireless markets

NASA Applications and Non-NASA Applications

- In flight reconfigurable SDR agnostic RF front end for current and future
- RF communications and radar - EVA, SDST, SGLS, STDN, TDRSS, lunar, point to point, networked, surface/harsh environment etc.
- DOD software defined radio (JTRS, AMF): terrestrial, airborne, naval.
- Electronic Warfare, C4ISR capabilities.
- Ideal for cognitive and mobile adaptive ad hoc networked (MANET) communications (802.xx) as well as traditional commercial wireless (GSM/EDGE, CDMA, UMTS-WCDMA)

Identification and Significance of Innovation

- Novel universal transmit and receive RF module with exceptional center frequency (UHF ~35+GHz), bandwidth (Hz to >500 MHz), scales to >150 GHz
- Receive requires no DC input power; very low parts count; “DAC-less” wideband arbitrary direct to RF transmit modulator; direct digital wideband RF power amp.
- Practical manufacture with existing and future technologies (GaAs, SiGe, GaN, MEM’s, Ferroelectrics); tunable left handed meta-materials for best size reduction
- Easily integrated with available software defined radio (SDR) components; addresses NASA reconfigurable, modular multi-mission flexibility (narrow and wideband comms, radar) with one open architecture RF hardware component

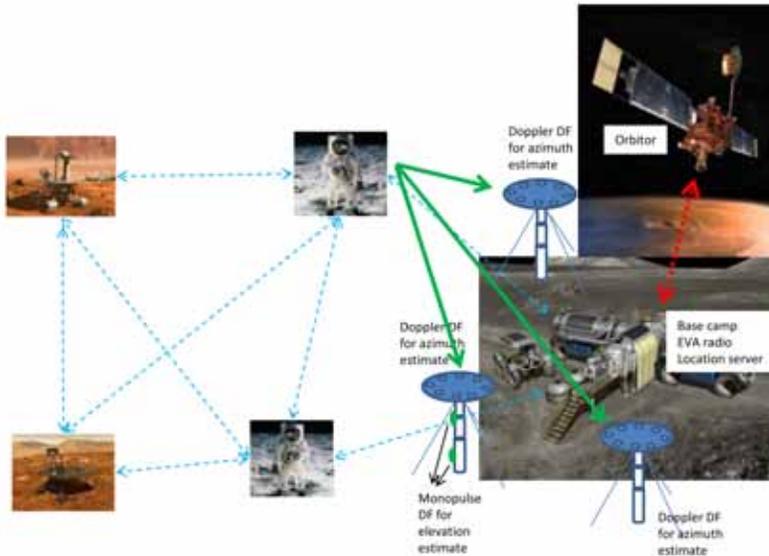
Expected TRL range at the end of contract

- 5-6

RECONFIGURABLE EVA RADIO WITH BUILT-IN NAVIGATION CAPABILITY

Intelligent Automation, Inc.

2008 Phase I
01.04-8899



Technical Objectives

- Generate an overall system design
- Design the EVA radio
- Design the MEMS tunable filter
- Develop the 3D navigation function
- Develop middleware for link adaptation
- Evaluate the performance using simulation and sensitivity analysis
- Estimate the power consumption, mass, size, and reliability

NASA Applications

- Communications between rovers and spacecraft
- Astronaut EVA communications
- Space port communications and asset tracking

Non-NASA Applications

- Warfighter/firefighter situation awareness system
- Autonomous navigation of unmanned vehicles

Identification and Significance of Innovation

- A power-efficient miniaturized reconfigurable EVA radio system with built-in 3D navigation capability is proposed. It uses the evanescent mode cavities RF MEMS tunable filter and software defined radio technologies to achieve extreme miniaturization, power saving, and reconfigurability.

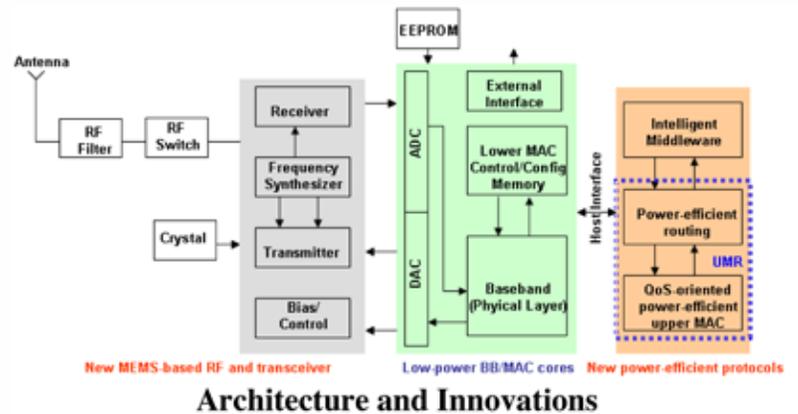
Expected TRL range at the end of contract

- 3-5

RECONFIGURABLE ULTRA-LOW POWER MINIATURIZED EVA RADIO

Teranovi Technologies

2008 Phase I
01.04-9638



Identification and Significance of Innovation

- A comprehensive design architecture that can achieve ultra-low power miniaturized EVA radio is proposed. Under this architecture, new MEMS-based technologies are employed to dramatically reduce the power consumption of RF front end and transceiver. By exploiting commercial wireless technologies in baseband and medium access control (MAC) modules, the EVA radio is also conformant to standard commercial wireless networks. Power consumption in baseband and MAC modules is minimized by selecting the most power-efficient design among commercial products. To further minimize power consumption during communications, power-efficient protocols across different layers are proposed. Such protocols are QoS-oriented and can support self-discovery, self-configuration, and self-healing of ad hoc networks formed by EVA radios.

Expected TRL range at the end of contract

- 3-4

Technical Objectives

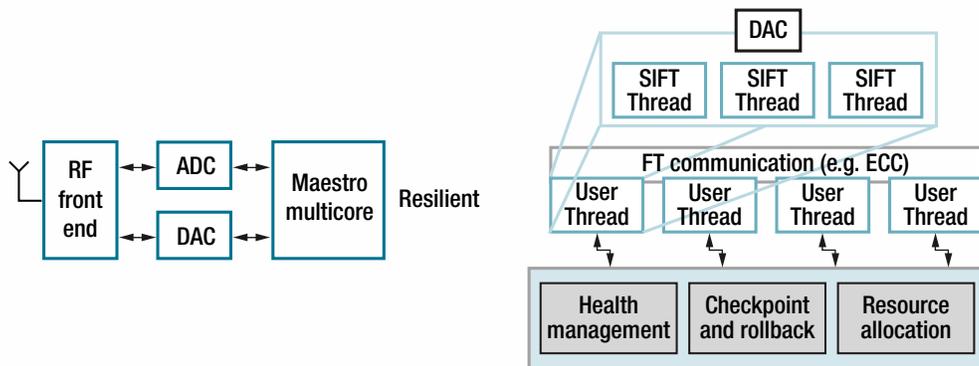
- Design the modular architecture of the EVA radio: designing the hardware/software architecture of the entire radio, studying the interface between transceiver and baseband, and investigating interactions between HAL/driver and hardware modules.
- Design RF front end and transceiver: designing an miniaturized ultra-low power RF front and transceiver covering the entire 2.4-2.483 GHz band of interest based on MEMS technologies; system-level simulation; performance impact by factors (e.g., radiation) in lunar environment.
- Select baseband and MAC modules: compare and determine the most power-efficient BB/MAC cores.
- Design protocols for performance optimization of EVA radios: a power-efficient UMR protocol with QoS support; power-efficient middleware.
- Develop location tracking algorithm: a distributed location tracking scheme only based on communications among EVA radios.

NASA Applications

- EVA radios can be used in lunar exploration. The same technologies can be adapted to the explorations of other stars like Mars. EVA radios can be used for other deep-space networks.

Non-NASA Applications

- DoD applications such as battlefield communications and networking.
- The most promising application area will be IEEE 802.11 radios and networks, as today IEEE 802.11 radio consumes too much power, a huge obstacle to integrating IEEE 802.11 radios into battery-powered devices such as cell phones, PDAs, laptops, palm PCs. Power-efficient radios and protocols are critical to wireless sensor networks. They can also find potential applications in vehicular networks, disaster-response networks, under-water networks seeking ultra-low power radios and power-efficient protocols.



Technical Objectives

- Prototype of a fault-tolerant multi-core radio system, Resilient
 - Prevention—on-chip software hardwalls, scrubbing, health monitoring
 - Detection—spatial, temporal, and spatial-temporal modulo redundancy
 - Correction—waveform- and system-level checkpointing and rollback
- Evaluation of Resilient’s fault tolerance
- Establishment of improvement objectives for Resilient for Phases II and III

NASA Applications

- Space-bound SDR (e.g. CoNNeCT)

Non-NASA Applications

- Military (e.g. JTRS), first responders, smart phones, femtocells, automobiles

Identification and Significance of Innovation

- Programmability
- Portability
- Fault tolerance
- Size, weight, power reduction

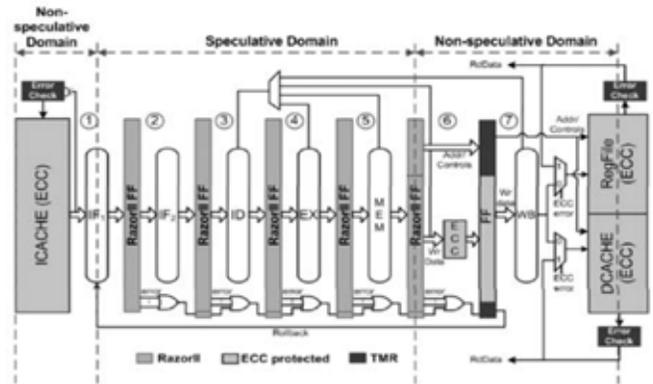
Expected TRL range at the end of contract

- 3-5

RECONFIGURABLE VLIW PROCESSOR FOR SOFTWARE DEFINED RADIO

Aries Design Automation, LLC

2009 Phase I
01.03-8382



Pipelined processor with the RazorII mechanism. Since the RazorII flip-flops (FFs) in each pipeline stage are Ored together, this scheme will detect any number of Single Event Upsets in a pipeline stage.

Identification and Significance of Innovation

- Future NASA missions depend on radiation-hardened, and power-efficient microprocessors that will be custom-tailored for space applications, and can execute legacy Power PC 750 binary code. We will implement and formally verify a reconfigurable VLIW processor optimized for Software Defined Radio (SDR) applications. The processor will implement RazorII, a microarchitectural mechanism that allows a microprocessor to self-monitor, self-analyze, and self-heal after timing errors, regardless of their cause—radiation, aging of the chip, or variations in the voltage, frequency, temperature, or manufacturing process.

Expected TRL range at the end of contract

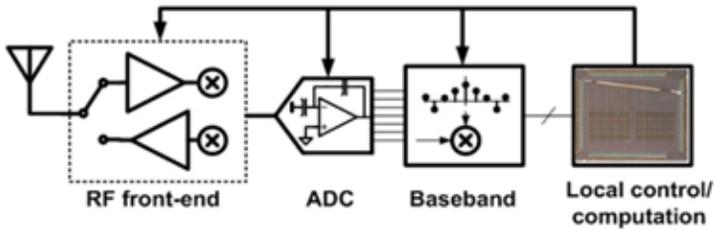
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Technical Objectives

- Design and formally verify for both safety and liveness a VLIW processor with the RazorII mechanism, with VLIW instructions consisting of predicated RISC instructions from the Power PC 750 Instruction Set Architecture (ISA)
- Design and formally verify reconfigurable functional units and corresponding new instructions to accelerate SDR applications and formally verify the binary-code compatibility of the new VLIW processor with the Power PC 750 ISA
- Compile SDR applications to the VLIW ISA
- Run simulations to measure the performance and power consumption of the VLIW processor

NASA Applications and Non-NASA Applications

- The project will result in technology to very quickly design and formally verify radiation-hardened and reconfigurable VLIW processors that are binary-code compatible with any legacy ISA that has a formal definition of its instruction semantics. It will be possible to add new instructions and reconfigurable functional units.



High-level EVA platform sub-units.

Technical Objectives

- System requirements specification and trade-space
- Determine additional requirements
- Characterize reconfigurable RF front-end
- EVA platform radio architecture development
- System controller architecture development
- RTL level design and demonstration of controller central processing unit

NASA Applications

- EVAs and future Lunar and Mars EVAs

Non-NASA Applications

- Mobile phone technology for significantly increased operation on a single battery charge
- DOD for lightweight radios (special ops) and unattended ground sensor power management

Identification and Significance of Innovation

- The objective of this proposed program is to develop a small, lightweight and very power-efficient mobile radio for use on the lunar surface—that will reduce power consumption by 90%. Bennett Aerospace, LLC of the Research Triangle Park area of North Carolina has teamed with Princeton University and Arizona State University. We will focus on the active and adaptive control of the power management system.

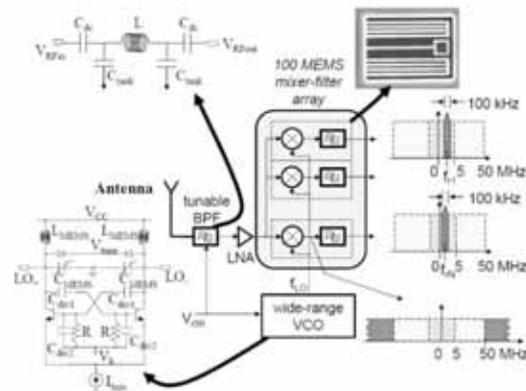
Expected TRL range at the end of contract

- 2-3

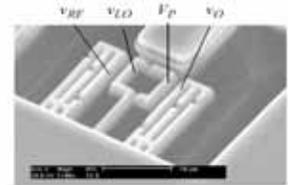
RF FRONT END BASED ON MEMS COMPONENTS FOR MINIATURIZED DIGITAL EVA RADIO

AlphaSense, Inc.

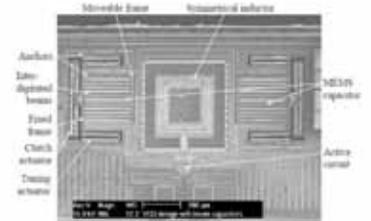
2009 Phase I
01.04-9344



Schematic of the RF front end architecture based on MEMS components



SEM image of RF MEMS mixer-filter



MEMS VCO

Identification and Significance of Innovation

- RF front end based on MEMS components for miniaturized digital EVA radio is proposed
- Key innovations of our approach include
 - Use of a novel parallel receiver front end architecture based on MEMS components
 - Novel design of a high Q mixer-filter and voltage controlled oscillator (VCO) using CMOS fabrication technique
 - Consequently, the proposed EVA radio has advantages including small size, light-weight, low power consumption, high sensitivity and frequency selectivity, good device reliability, easy device fabrication, and low manufacturing cost

Expected TRL range at the end of contract

- 4

Technical Objectives

- Prove the feasibility of using MEMS component to implement a miniature radio for EVA applications
- Optimize the designs for the MEMS mixer-filter, band pass filter, and VCO to operate in the S- band
- Optimize the MEMS device fabrication process
- Identify optimum components for the Phase II radio prototype construction and testing

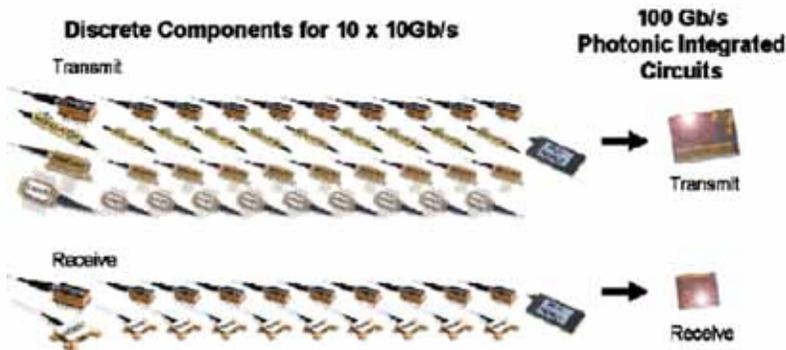
NASA Applications

- Used in EVA radios for space exploration. The significantly reduced form factor and power requirements along with the increased selectivity and performance of the MEMS-based EVA radio allows long duration human exploration while simultaneously increasing communication reliability and crew safety.

Non-NASA Applications

- Wireless and mobile radio communications. For example, it can be used by first responders to enhance interoperability among police, firefighters, HazMat, homeland security and medical personnel. It can also be used by military personnel for the soldier-centric secure communications and mode switchable on-the-fly communications
- The miniature MEMS RF front end components can also find commercial applications in cell phones, pagers, Wi-Fi/Bluetooth/UWB radio integration.

DEVELOPMENT OF A NOVEL, ULTRA-LOW SWAP, RAD-TOLERANT, MULTI-CHANNEL, REPROGRAMMABLE PHOTONIC INTEGRATED CIRCUIT OPTICAL TRANSCEIVER MODULE



Space Photonics, Inc.

2010 Phase I
01.02-8255

The RAD-tolerant, space-worthy, high speed optical communications PIC TRX's being developed by Space Photonics, Inc. provide a variety of enabling space communications options that are in-line with NASA's SCaN Internet Architecture Program goals.

Technical Objectives

- Identify and secure RAD tolerant COTs devices and packaging materials capable of facilitating the custom integration of the PIC device to create an ultra-low SWAP, RAD tolerant, multi-channel, high speed (up to 10 Gbps per channel) reprogrammable optical networking TRX module that will ultimately benefit NASA's SCaN Internet Architecture Program
- Prepare the devices as proposed and demonstrate the benefits to the NASA SCaN Program –namely: interconnect complexity reduction, significant SWAP reduction (> 2X size reduction from 6U to 3U, > 2X power dissipation reduction from ~1 W to 0.4 mW per optical TRX channel, and > 2X weight reduction from ~1 oz. to 0.4 oz. per optical TRX channel; and improved single channel data rates, flexibility, and scalability from 1 Gbps up to 10 Gbps

NASA and Non-NASA Applications

- Our products specifically target onboard data handling needs of NASA, DoD, and the Intelligence Community's satellite remote sensing applications. Our multi-protocol intelligent networking systems target both NASA's SCaN Internet Architecture and DOD's Transformational Communications Architecture (TCA)
- Other applications will include the utilization of some of SPI's optoelectronics components in harsh environment fiber to the 'x' applications, such as FTTH, FTTC, FTTD, etc.

Identification and Significance of Innovation

- Special purpose data processing: reconfigurable, reprogrammable, and multi-protocol compatible optical communications hardware
- Ultra-low SWAP electronics for intra-system data transfer and subsystem data transfer
- Extreme reduction in package size and component count for up to 10 Gbps x 10 channel optical switching, routing, networking, etc.
- Fully supports the NASA SCaN Internet Architecture Program
- Proven materials, fabrication and packaging processes will be utilized, many of which are based on NASA's EEE-INST-002, MIL-PRF-38534E, MIL-STD-883F, and parts/materials from the NPSL –SPI has full capability to qualify based on standards above

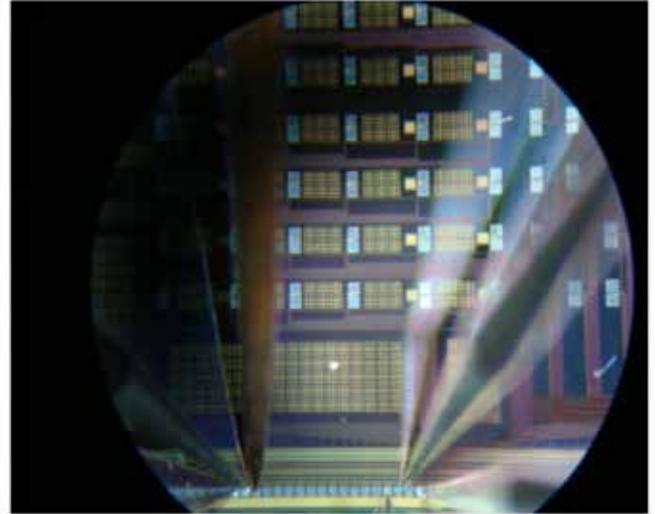
Expected TRL range at the end of contract

- 1-4

RADIATION HARD ELECTRONICS FOR ADVANCED COMMUNICATION SYSTEMS

ICs, LLC

2010 Phase I
01.02-9491



Identification and Significance of Innovation

- Sub 100 nm electronics are essential for advanced communication systems
- Legacy SEU tolerant electronics ineffective for sub 100 nm electronics
- A new radiation hard solution is needed for sub 100 nm electronics
- A new fault tolerant , high speed , configurable/reprogrammable electronic communication system solution is proposed that will provide the foundation for sub 100 nm electronics

Expected TRL range at the end of contract

- 1-3

Technical Objectives

- Design SEU tolerant logic for self recovering memory cell
- Design logic cells for Self Recovery Logic (SRL)
- Identify paradigm for SRL system
- Compare SRL hardware solutions with full TMR
- Perform layout of SRL for fabrication

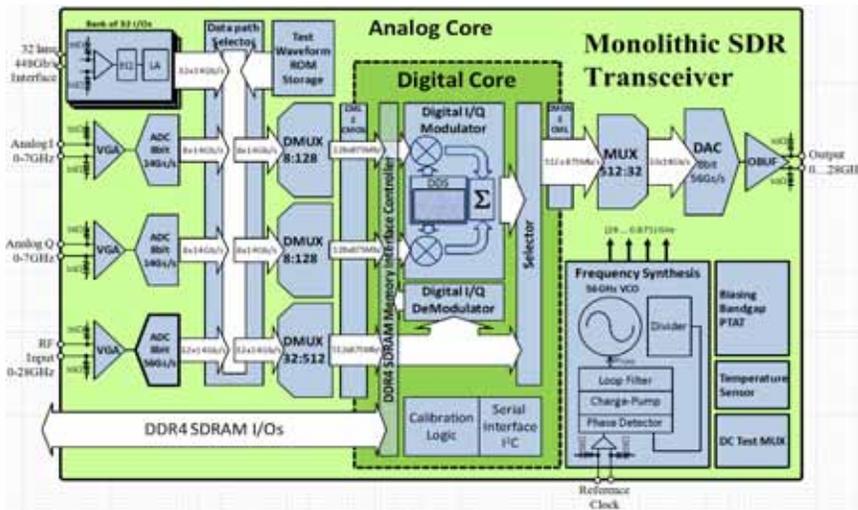
NASA and Non-NASA Applications

- Sub 100 nm electronic foundation for SEU tolerant electronics
- Electronic base for reconfigurable communication systems
- Single chip communication systems for NASA and DoD
- SEU tolerance solution for real time control systems using sub 100 nm commercial electronics

RECONFIGURABLE/REPROGRAMMABLE COMMUNICATIONS SYSTEMS

Pacific Microchip Corporation

2011 Phase I
01.02-8652



Technical Objectives

- To provide the architecture, schematics, in silico validation and a hardware proof of the concept of a low power SDR transceiver. To get the design ready for monolithic implementation in Phase II. The proposed SDR transceiver will satisfy NASA's requirements for low power consumption and functionality and be ready for commercialization in Phase III.
 - Block level design
 - Circuit level design and verification
 - Design validation in silico
 - Project report

NASA Applications

- Low power reconfigurable SDR transmitters and receivers featuring power optimization capability depending on the required data rate at high modulation frequencies have great potential in current and future NASA missions. Besides its application for CONNECT experiment installed on ISS, the proposed all-digital SDR transceiver is directly applicable to systems seeking autonomous operation such as deep space communication radios. Another application for the proposed SDR is NASA's OIB mission.

Non-NASA Applications

- The proposed wideband SDR transceiver and its building blocks will be targeting applications which require high speed capture, digitization, and synthesis of wideband signals. Commercial applications include wireless (WiMAX, 3G, 4G) and fiber optic communication (40G and 100G Ethernet). Military applications include high speed, secure communication systems and millimeter-resolution radars.

Identification and Significance of Innovation

- NASA developed Space Telecommunications Radio System (STRS) standard defines an architecture enabling interoperability of Software Defined Radio (SDR) components. Our proposed solution is a STRS compliant monolithic, low-power, multifunctional 56GS/s Direct Digital Modulation/Demodulation (DDM) SDR transceiver. The transceiver will utilize novel D/A and A/D converters and an all-digital implementation of frequency up- and down-conversion, I/Q modulation and demodulation. The innovation offers a highly reconfigurable low power SDR solution within STRS.

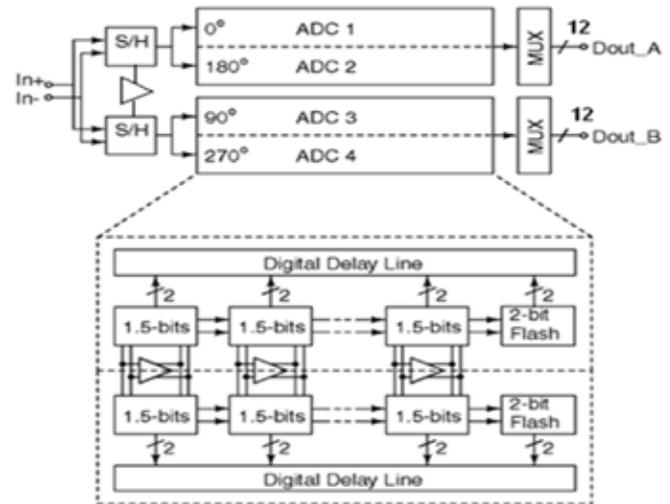
Expected TRL range at the end of contract

- 1-3

HIGH PERFORMANCE ADC FOR RECONFIGURABLE/REPROGRAMMABLE COMMUNICATION SYSTEMS

Ridgetop Group, Inc.

2011 Phase I
01.02-9553



Identification and Significance of Innovation

- Ridgetop proposes to design a novel, low-power, time-interleaved pipeline ADC that will have 2 bits higher effective number of bits (ENOB = 11.0 bits) than the best commercially available radiation-tolerant 1 GS/s ADCs (ENOB = 9.0 bits). In addition, the ADC will consume 50% less power than the competitors'. The ADC will have four configurable pipeline channels and three programmable operation modes:
 - 12-b, 2 GS/s, 1 W
 - 13-b, 500 MS/s, 750 mW
 - 12-b, 500 MS/s, 250 mW
- The ADC will be designed in the IBM 8HP SiGe 130 nm process, which is inherently tolerant to extreme levels of radiation. In addition, RHBD techniques will be used to guarantee tolerance to 5 Mrads of TID and sufficient hardness against single-event effects (SEEs). The operating temperature range will be –55 to 125 °C
- Due to its programmability, high performance, low power, and very high radiation tolerance, the ADC will be suitable to support reconfigurable transceiver technology for space missions.

Expected TRL range at the end of contract

- 2-4

Technical Objectives

- Design and simulate SiGe op-amps used in the sample-and-hold (S/H) circuits and in the first two pipeline stages
- Design and simulate CMOS operational amplifiers (op-amps) used in the remaining pipeline stages
- Design and simulate a CMOS comparator (can be simple, low-power design due to applied redundant signed digit (RSD) digital error correction)
- Design 1.5-bit flash stage and pipeline stages with calibrated MDACs (multiplying digital-to-analog converters)
- Design timing circuitry and perform clock jitter analysis
- Integrate and simulate the two MDAC stages
- Apply RHBD techniques and perform radiation effect simulations.

NASA Applications

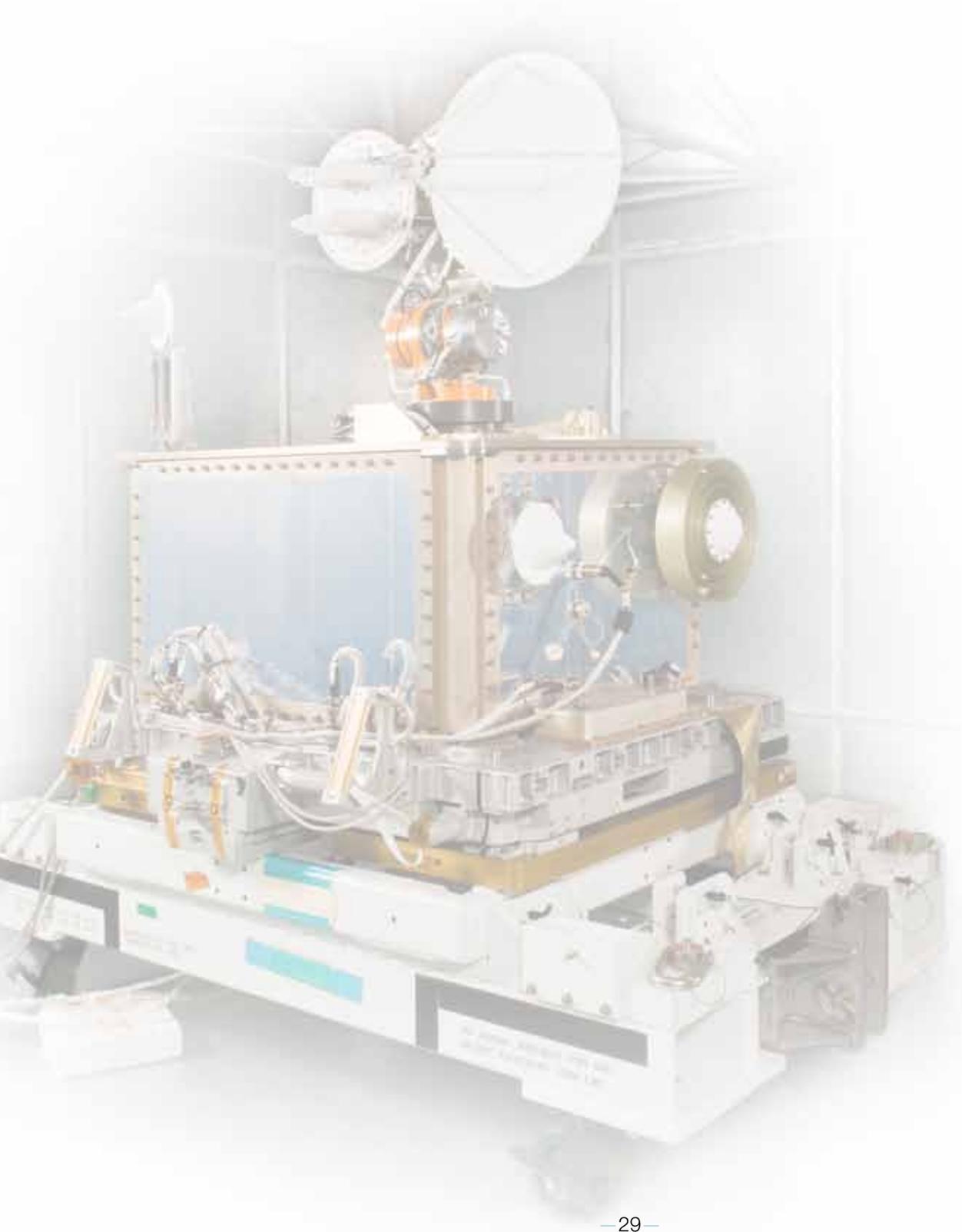
- NASA applications include: communication systems, radar, imaging, detectors, space radio astronomy, UAVSAR and Europa programs

Non-NASA Applications

- Military satellite communications
- Space-based, synthetic aperture, and digital beam-forming (DBF) radars
- Wide-band satellite receivers and wireless RF infrastructures
- Wireless LAN
- Data acquisition systems
- Software-defined radio
- Power amplifier linearization
- Signal intelligence and jamming

SOFTWARE DEFINED RADIO TECHNOLOGY SBIR PHASE II AWARDS

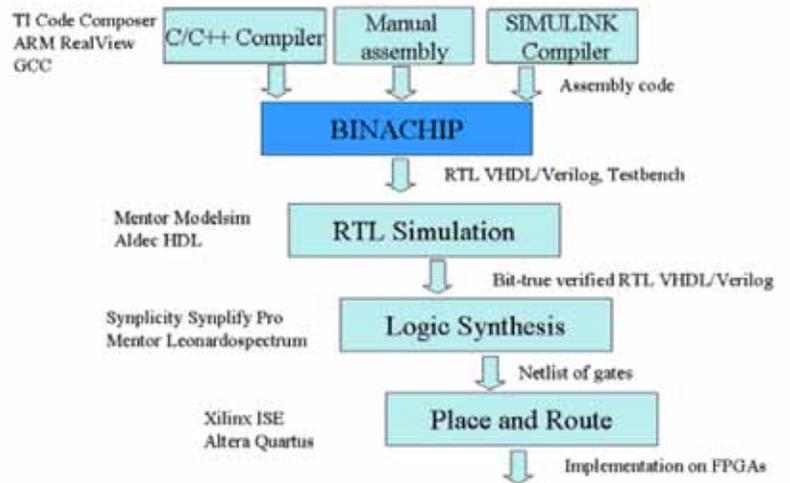
2005 TO 2012



A HARDWARE/SOFTWARE DESIGN ENVIRONMENT FOR RECONFIGURABLE COMMUNICATION SYSTEMS

BINACHIP, Inc.

2005 Phase II
01.06-9806



Identification and Significance of Innovation

- Space Exploration will require advancements in communication systems to maintain flexibility and adaptability to changing needs and requirements
- Develop automated techniques to take software implementations of reconfigurable communication applications and map them to FPGAs and SOCs
- Reduce design times from months to days

Technical Objectives

- Study techniques for automatic translation of software implementations to RTL VHDL for mapping to FPGAs on reconfigurable hardware
- Investigate techniques for hardware/software co-design for reconfigurable hardware
- Apply techniques to Software Defined Radio (SDR)
- Task A—Translation of software to RTL VHDL
- Task B—Low power design
- Task C—System level verification
- Task D—Demonstration on large NASA applications

NASA Applications

- Software defined radio, communication systems

Non-NASA Applications

- Embedded systems software for PDAs, cellphones, electronic design automation for networking, communications, digital signal processing



Technical Objectives

- Design and manufacture radiation-tolerant digital solution leveraging Xilinx QPro-R Virtex-II FPGA
 - Waveform support as well as standards-based data connectivity, such as Ethernet
- Develop second-generation RF solution and standards compliant waveform
 - Highly-integrated, direct-conversion RF front end
 - Baseline implementation of IEEE 802.16

NASA Applications and Non-NASA Applications

- Micro-satellites
- Autonomous ground vehicles
- Ground links
- Relatively low volume custom radio design for a variety of user specific applications in the DoD, emergency response, homeland security, and commercial sectors

Identification and Significance of Innovation

The proliferation of satellites and terrestrial vehicles for space exploration calls for post flight reconfiguration. Such capability supports multiple waveforms as well as system updates.

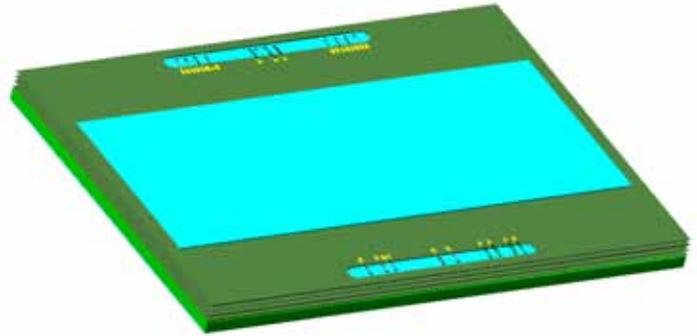
The vision for μ SDR is to meet varying mission needs in a low-power and compact package by leveraging the state-of-the-art in hardware and software design.

- Complete System-on-a-Chip (SoC) solution
 - Field programmable gate array (FPGA) provides hardware logic for implementing waveform physical layer and bus interfaces
 - Soft Microblaze processor implements data link and higher application layer support

STACKABLE RADIATION HARDENED FRAM

NxGen Electronics, Inc.

2006 Phase II
01.05-9630



Identification and Significance of Innovation

In Phase I NEI assembled FRAM modules from die fabricated from the previous Phase II SBIR. The modules were subjected to TID and SEU testing to characterize the FRAM radiation tolerance. The first pass results were remarkably successful.

This Phase II includes redesign of the mask sets and re-testing. Then 2 & 8 high stack designs will be completed and a complete environmental and life tests conducted. The result should be a low cost 2-16 Mb product offering based on a commercial foundry with 2 MradTID and high SEU tolerance.

Expected TRL range at the end of contract

- 8

Technical Objectives

- Celis Semiconductor had previously manufactured one wafer of die at Fujitsu, and performed confidence testing on several die. NxGen performed a 'blind' build of enough packaged parts to successfully support the radiation test series. For Phase II, Celis will support another spin of the FRAM design, NxGen Electronics will support radiation re-testing of the redesigned silicon and compare the results to modeling data. NxGen would then build a number of 2 & 4 high stacks to perform environmental tests and a reliability demonstration

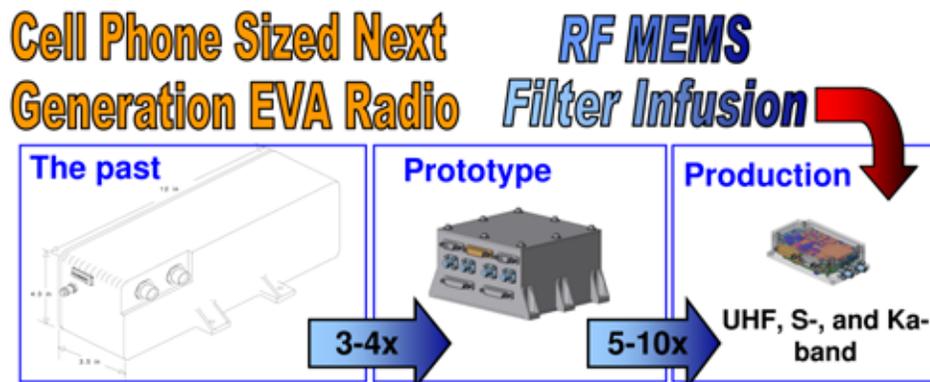
NASA and Non-NASA Applications

- Shuttle, space station, earth sensing missions and deep space probes. Missions which will benefit are Mars Surveyor, solar system exploration e.g. (Titan, Europa landers, Comet Nucleus Return, New Discovery Program, and Living with a Star).
- Commercial applications include space platforms, both GEO and LEO such as the Boeing Space HS-601 and Lockheed A2100.
- Telecommunication satellites and sensing applications (NOAA) require this memory to store critical data and support on board data processing.
- Terrestrial applications include nuclear power plants and research accelerators (Fermi Lab).

MINIATURIZED UHF, S-, AND KA-BAND RF MEMS FILTERS FOR SMALL FORM FACTOR, HIGH PERFORMANCE EVA RADIO

Harmonics Devices, Inc.

2006 Phase II
01.06-9177



Technical Objectives

- Develop representative UHF, S-band, and Ka-band filter prototypes that can be delivered to NASA for testing and sampled to commercial customers.
 - Resonator and materials optimization
 - Simulation and design software tools
 - UHF, S-band, and Ka-band filter fabrication and characterization
 - Statistical process control for high yield manufacturing
 - Trimming
 - Package and qualify components

NASA and Non-NASA Applications

- NASA EVA radio systems
- Harsh environment operation
- Spacecraft and planetary surface communication networks
- Cellphones/pagers, Wi-Fi, UWB (multi billion dollar market)
- Ultra-low-power distributed sensor networks
- Interoperable first responder radios (police, fire, hazmat, Homeland Security, medical personnel)

Identification and Significance of Innovation

RF MEMS filters are a key enabler for next generation EVA radio

- Miniaturized UHF, S-band and Ka-band MEMS filters drastically reduced volume and weight (up to 54 mm² per filter set)
- Enables high performance reconfigurable, frequency agile, fault tolerant architecture
- Single-chip, high-Q micro-machined piezo RF components for UHF and S-band
- 3D MEMS coaxial Ka-band interdigital technology

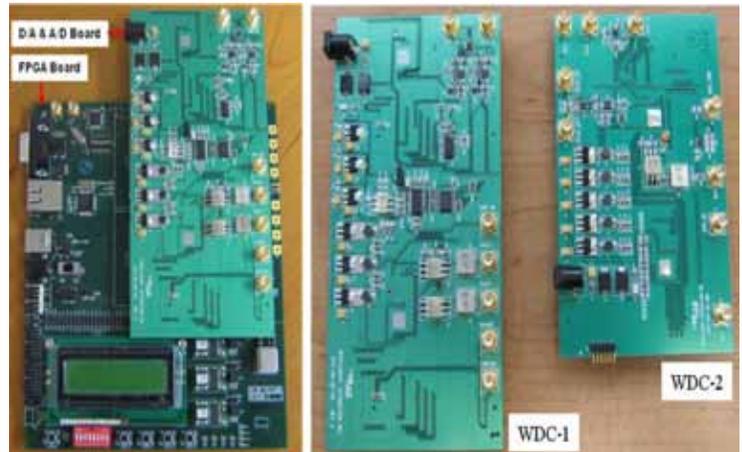
Expected TRL range at the end of contract

- 5

RECONFIGURABLE, COGNITIVE SOFTWARE DEFINED RADIO

Intelligent Automation, Inc.

2008 Phase II
01.03-9360



Wideband Data Converter (WDC)

Identification and Significance of Innovation

IAI is developing Software Defined Radio platforms that can adaptively switch between different modes of operation for communication; by modifying both transmit waveforms and receiver signal-processing tasks on the fly. Our innovation focuses on implementing maximum transceiver functionalities digital reconfigurable devices (FPGA), and minimizing the number of analog components. Our SDR designs are based on COTS components and are modular which makes it easier to upgrade smaller design units with state-of-the-art development instead of re-designing the entire SDR platform. The proposed innovations are:

- STRS implementation on COTS SDR platforms to realize NASA objectives and the benefits of an open architecture standard.
- Integration of cognitive capabilities (with focus on STRS compliant implementation) with the Phase I developed SDR. This would include adaptive modulation and coding, automatic modulation recognition and Spectrum Sensing.
- Reconfigurable digital transceiver design using high-speed FPGAs. This would enable multi-mode operation and scalable architecture for SDRs.

Expected TRL range at the end of contract

- 6

Technical Objectives

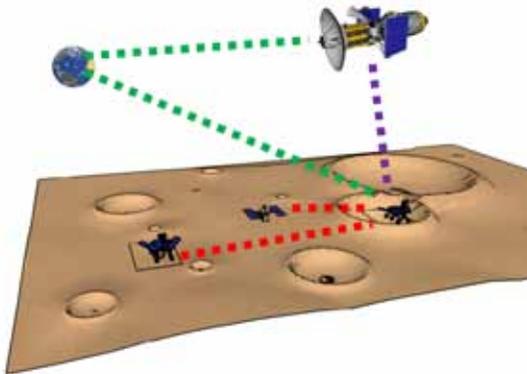
- Implement STRS on COTS or custom designed SDR platform. IAI will work closely with GDAIS in defining requirements for a COTS platform suitable for STRS implementation and implement a test waveform.
- Waveform definitions for NASA CoNNeCT program will be studied and requirements for AMC in these waveforms will be identified. A prototype transmitter system with desired AMC capabilities will be designed and demonstrated.
- AMR algorithms developed in Phase I will be modified to support modulation types identified under the earlier objective. The AMR algorithms will be simulated for performance analysis, and partitioned into fixed point hardware and software domain, depending on the implementation complexity. The modified AMR will be implemented on the prototype SDR platform
- Demonstrate joint operation of AMC, AMR (in a controlled environment) running on SDRs configured as dedicated transmitter and receiver.
- Implementation of advanced SDR features of interest to the NASA CoNNeCT program and identify path to space qualification.

NASA Applications

- Cognitive capabilities for NASA STRS like AMC, AMR and Spectral sensing
- Reconfigurable communication radios for EVA and space missions

Non-NASA Applications

- Cognitive Radios for DoD applications
- High bandwidth, plug-and-play waveform synthesizer
- Real-time digital processors
- UAV based applications, including UAV based communications and radar applications



Technical Objectives

- Ultra-flexible baseband processing on rad-hard multicore
- Programmable rad-hard multicore network stack
- STRS compliance for multicore-based architecture
- Support for non-communications applications
- Radiation tolerance and ruggedization for space application

NASA and Non-NASA Applications

- Ultra-flexible rad-hard communications for NASA and DoD missions
- Rad-hard communications for commercial satellites
- Rad-hard data processing for satellite-based surveillance (e.g. NRO)
- Easy-to-program research platform for communications R&D
- Rad-hard computing for nuclear application

Identification and Significance of Innovation

- Multicore rad-hard Maestro processor
 - 90 nm, 49 cores, beats competition by 100x
- STRS compliance for interoperability with other space radio components
- Multi-mode operation
 - Transition between waveforms in nanoseconds
- Future-proof comm systems
 - Patch software, not hardware, as missions evolve
- Over-the-air reconfiguration
 - Upload new software over-the-air
- Easy-to-program research platform
 - Program in C/C++ for low cost prototyping
- SWaP reduction
 - Support multiple applications, eliminating other processing boards

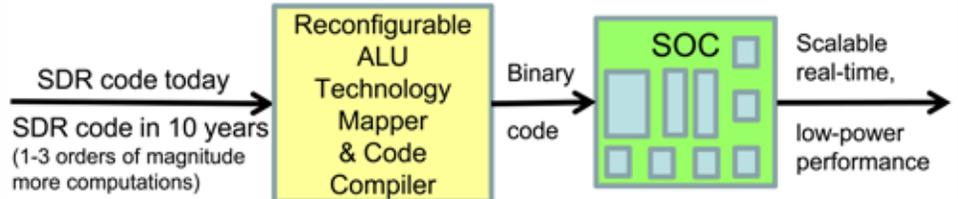
Expected TRL range at the end of contract

- 4-6

RECONFIGURABLE VLIW PROCESSOR FOR SOFTWARE DEFINED RADIO

Aries Design Automation, LLC

2009 Phase II
01.03-8382



Identification and Significance of Innovation

- Future NASA missions depend on radiation-hardened, and power-efficient Systems on a Chip (SOCs) that will consist of a range of processor cores that are custom-tailored for space applications, and can execute legacy PowerPC 750 binary code. We will implement and formally verify such SOC's optimized for Software Defined Radio (SDR) applications. The processor cores will implement RazorII, a microarchitectural mechanism that allows them to self-monitor, self-analyze, and self-heal after timing errors, regardless of their cause—radiation, aging of the chip, or variations in the voltage, frequency, temperature, or manufacturing process.
- New generations of SDR protocols require 1–3 orders of magnitude increase in computations with almost unchanged power-consumption; such constraints cannot be met by conventional CPUs, but only by flexible and scalable architectures such as specialized SOC's with reconfigurable functional units.

Expected TRL range at the end of contract

- 6

Technical Objectives

- Design and formally verify for both safety and liveness a range of different single-issue pipelined, dual-issue superscalar, and VLIW processor cores, having hardware support for multithreading and the RazorII mechanism, executing the instructions from the PowerPC 750 Instruction Set Architecture (ISA) to guarantee correct execution of legacy binary code from current space missions, and implementing new instructions that use reconfigurable functional units to accelerate SDR algorithms;
- Design and formally verify a range of different SOC's consisting of such processor cores;
- Perform SAT-based technology mapping, placement, and routing of complex SDR operations to the reconfigurable functional units;
- Compile SDR applications to the ISAs supported by the cores;
- Run hardware-software co-simulations to measure the performance and power consumption of the SOC's, and select an optimal design.

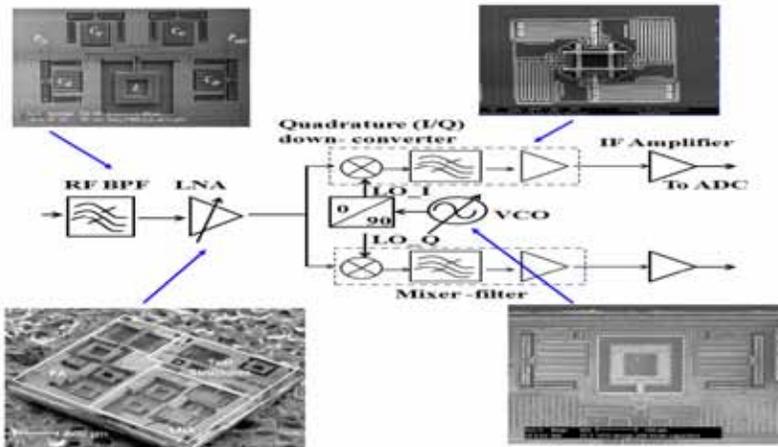
NASA and Non-NASA Applications

- The project will result in a design environment that will allow a user to very quickly implement and formally verify a System on a Chip (SOC) consisting of heterogeneous processor cores that are radiation-hardened, reconfigurable, and binary-code compatible with any legacy ISA that has a formal definition of its instruction semantics. It will be possible to add new instructions that use reconfigurable functional units to accelerate specific applications, such as SDR, as well as to formally verify properties of the resulting binary code.

RF FRONT END BASED ON MEMS COMPONENTS FOR MINIATURIZED DIGITAL EVA RADIO

AlphaSense, Inc.

2009 Phase II
01.04-9344



The receiver RF front end based on a low-IF architecture and its CMOS-MEMS implementation.

Technical Objectives

- Further enhance the conversion gain and noise figure characteristics of the MEMS mixer-filters;
- Develop a high quality quadrature generator with a high image rejection to improve the receiver performance;
- Implement adaptive beam steering to minimize multi-path loss, and to mitigate co-channel interference;
- Prototype a fully integrated S band receiver front end based on a radio-on-a-chip solution, and characterize its performance for voice, data, telemetry and high definition video applications .

NASA Applications

- Used in EVA radios for space exploration. The significantly reduced form factor and power requirements along with the increased selectivity and enhanced functionality of the MEMS-based EVA radio allows long duration human exploration while simultaneously increasing communication reliability and crew safety.

Non-NASA Applications

- Wireless and mobile radio communications. For example, it can be used by first responders to enhance interoperability among police, firefighters, HazMat, homeland security and medical personnel. It can also be used by the military personnel for the soldier-centric secure communications and mode switchable on-the-fly communications.
- The miniature MEMS RF front end components can also find commercial applications in cell phones, pagers, Wi-Fi/Bluetooth/UWB radio integration

Identification and Significance of Innovation

- A small form factor, low power consumption and high performance S band EVA radio receiver front end based on fully integrated CMOS-MEMS components;
- An optimized low-IF architecture allows the implementation of a high performance receiver with a small device count;
- A novel design of a high Q mixer-filter for RF mixing, IF filtering and amplification, which further reduces the form factor, device count and power consumption of the whole receiver.

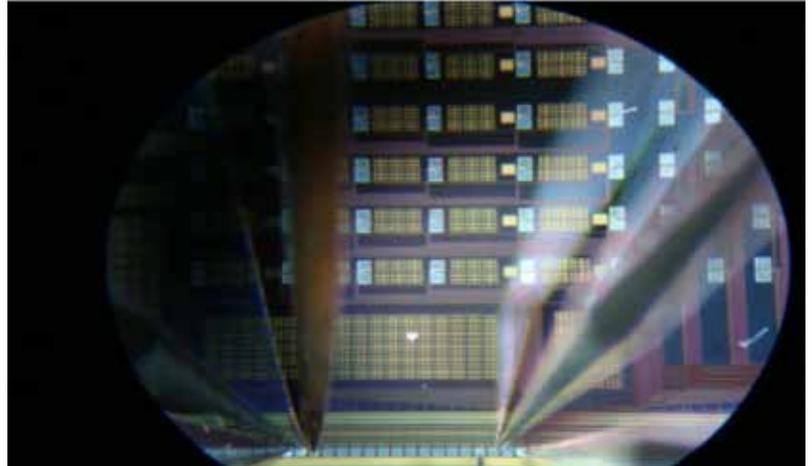
Expected TRL range at the end of contract

- 6-7

RADIATION HARD ELECTRONICS FOR ADVANCED COMMUNICATION SYSTEMS

ICs, LLC

2010 Phase II
01.02-9491



Identification and Significance of Innovation

- Self Restoring Logic (SRL)
- Sub 100 nm electronics critical for advanced communication systems
- Legacy SEU tolerant electronics ineffective for sub 100 nm electronics
- New radiation hard solution found for sub 100 electronics
- Truly fault tolerant high speed electronic solution is proposed that provides the foundation for sub 100 nm electronics
- A reconfigurable/reprogrammable communication system proposed.
- Replace Triple Modular Redundancy technology

Expected TRL range at the end of contract

- 2-5

Technical Objectives

- Design SRL synthesis library for use with commercial CAD tools
- Traditional latches, logic and arithmetic elements
- Low Voltage Digital Switching (LVDS) module
- On-chip Random Access Memory cells
- Serial-to-parallel and Parallel-to-Serial Converters
- Design, fabricate SRL test chip for high speed performance and radiation testing
- Test chip consists of:
 - SRL latches to conclusively prove high speed operation
 - Add control legacy RHBD cells
 - Non-redundant storage elements
 - LVDS circuit
 - Memory cells

NASA Applications

- Sub100 nm electronic foundation for SEU tolerant electronics
- Electronic base for reconfigurable communication systems
- Single chip communication systems for NASA and DoD
- Radiation hard electronics basis for NASA circuits

Non-NASA Applications

- Reprogrammable/reconfigurable communication systems with fault tolerant electronics has direct applications in Defense systems.
- In the past, every custom high performance ICs processor designed for NASA has been eventually incorporated into defense systems.



COMPANY NAMES

Aeronix, Inc., Melbourne, FL	7
AlphaSense, Inc., Newark, DE	24, 37
Aries Design Automation, LLC, Chicago, IL	22, 36
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WW Technology Group, Ellicott City, MD	4

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