Software Defined Radio Developments and Verification for Space Environment on NASA’s Communication Navigation, and Networking Testbed (CoNNeCT)

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AGENDA

• Updates and Progress on SCAN Testbed

• Call for Experiments

• Cognitive Applications

• Conclusion/Contacts
CoNNeCT / SCAN Testbed Overview

- The CoNNeCT Project will advance the Technology Readiness Level (TRL) of Space Communications for future NASA missions
  - Launch to the International Space Station (ISS) on JAXA H-II Transfer Vehicle (HTV-3) NET late June 2012
  - Utilizes a Flight Releasable Attachment Mechanism (FRAM)-based payload interface and is installed on the Expedite the Processing of Experiments to Space Station (ExPRESS) Logistics Carrier (ELC) at the ISS P3 location.
- CoNNeCT is a payload funded by the NASA Space Communications and Navigation (SCaN) Program
  - Partners include GSFC, JPL, Harris and GD; other NASA Centers provide key support: KSC, JSC, MSFC.
  - Flight System is the “SCAN Testbed” (Connect confusing term on orbit!)
- Scan Testbed is Class D and plans to operate for five years on ISS (minimum design life is two years).
  - Includes Ground System with a flight-like Ground Integration Unit (GIU) certified for S/W V&V
SCAN Testbed
Science & Technology Goals & Objectives

• **INVESTIGATE the APPLICATION of SDRS TO NASA MISSIONS**
  – Mission advantages and development/verification/operations aspects
  – On-Orbit Reconfiguration
  – More process intensive functions within the radio subsystem

• **SDR TECHNOLOGY DEVELOPMENT**
  – SDR Platforms to TRL-7
  – SDR platform hardware & waveform compliant to STRS, Foster Agency adoption
  – Understand/characterize space effects and SDR performance

• **VALIDATE FUTURE MISSION OPERATIONAL CAPABILITIES**
  – Capability representative of future missions
    • **Comm** data rate, performance, navigation/GPS, networking/routing
  – Understand SDR performance (reliability, SEE, telemetry, instrumentation)
  – Multiple and simultaneous RF Links (Ka-band, S-band, L-band/GPS)
  – Experimenter sw applications (On-board networking, DTN, routing, and security applications)
Flight System Overview

• Communication System
  – SDRs
    • 2 S-band SDRs (1 with GPS)
    • 1 Ka-band SDR
  – RF
    • Ka-band TWTA
    • S-band switch network
  – Antennas
    • 2 - low gain S-band antennas
    • 1 - L-band GPS antenna
    • Medium gain S-band and Ka-band antenna on antenna pointing subsystem
  – Antenna pointing system.
    • Two gimbals
    • Control electronics

• Flight Computer/Avionics

• Flight enclosure provides for thermal control/radiator surface.

Total mass ~746 lb
SCAN Testbed Flight System Configuration

Avionics Subsystem:
- Processor
- Storage
- Space wire
- STD-1553

SDR Subsystem:
- Harris SDR
- Ka-Rx
- LNA
- Ka-Tx
- GD SDR
- S-Rx
- LNA
- S-Tx
- HPA
- JPL SDR
- S-Rx
- LNA
- S-Tx
- HPA
- Space Wire
- Data
- Command/Telemetry
- MIL-STD-1553

RF Subsystem:
- Attenuator
- TWTA
- Isolator
- Diplexer

Antenna Subsystem:
- Ka HGA
- SN MGA
- GN LGA
- SNLGA
- GPS LGA
Software Defined Radios (SDRs) are the “Instruments” for Conducting Experiments

**JPL/L-3 CE**
- S-band SDR
  - 6 MHz wide channel
- L-band receive (GPS)
- Virtex II, Sparc Processor, RTEMs OS
- 10 Mbps Class
- STRS Compliant

**General Dynamics**
- S-band SDR
  - 6 MHz wide channel
- Virtex II, ColdFire Processor (60 MIPS), VxWorks OS, CRAM (Chalcogenide RAM) Memory
- 10 Mbps Class
- STRS Compliant

**Harris**
- Ka-band SDR
  - 225 MHz wide channel
- Virtex IV, PowerPC Proc, DSP (1 GFLOP), VxWorks OS
- >100 Mbps Class
- STRS Compliant
CoNNeCT Actual Schedule

- **Preliminary Design Review to ship in two years**
  - PDR – September 2009
  - CDR – April 2010

- **Completed all major Environmental and Testing**
  - Vibe: Jan 2011, TVAC: Mar 2011
  - EMI/EMC: June 2011

- **Completed all major Interface Testing**
  - ELC Power and C&DH
  - TDRSS Compatibility (Oct 2010 and Apr 2011)

- **Completed Closed Loop Antenna Pointing System (APS)**
  - Pointing and Tracking & Comm Performance Testing
  - July-Nov 2011

- **Final SW Verification & Functional Testing**
  - Dec 2011 - Jan 2012
Shipment, Launch, Checkout & Commissioning

- After testing was completed, the Flight system was packed up and sent to Japan
  - Air-ride truck to Chicago, Direct flight Chicago to Tokyo Narita Airport
  - Truck (air-ride) on barge from Narita Airport to Kagoshima Port
  - Truck on ferryboat from Kagoshima Port to Nishinoomote Port
  - Truck from Nishinoomote Port to TNSC
- A team of engineers completed the post-ship checkout before turnover, all was well!
- The payload will be integrated on the rocket next
- Launch is planned for June 26 2012
- Checkout scheduled for 7/18 to 8/28/2-12
- Commissioning scheduled for 8/28 to 10/17/2101
Experimenter Call
Call for Experiment Proposals

• After Commissioning is complete (10/17/12), the testbed will be available for experiments

• The CONNECT Project is planning to release an Announcement of Opportunity (AO) for experiments with the SCAN Test Bed. Develop/test applications and concepts—expect experiment call in mid 2012

• The call will go to NASA, industry, other government agencies, and academic partners

• These external experiments selected will complement experiments already selected from internal to NASA and through the SBIR process

• Goal is to develop a consistent and coordinated utilization of CoNNeCT / SCAN Testbed for the benefit of the Space Communication and Navigation (SCaN) Program, and NASA
What Experiments will be Solicited?

• Opportunities are to develop comm, navigation and networking technologies in the lab and demonstrate them in space based upon reconfigurable SDRs and STRS architecture

• **On-orbit** experiments will be solicited to:
  – Validate and advance the open architecture standard for SDRs among multiple SDRs in space environment
  – Advance communication, navigation and networking technologies to mitigate specific NASA mission risks and to enable future mission capabilities
    • Comm waveform development and operation in space
    • SDR-based mission concepts of operations
    • Networking experiments using avionics as router between SDR nodes
    • GPS-based navigation waveforms
Experimenter Access Points within CoNNeCT System

Experiment Interface
- Experiment Equipment

Ground System
- CONNECT Control Center

External Systems
- WSC Legacy Service
- WSC RTN-IF
- S-band DTE

ISS
- CONNECT Flight System
  - SDR
  - SDR
  - SDR

🌟 = Experiment Element (e.g. software, firmware, hw, component)

Experimenters have access to:
- Flight SDRs, Avionics, Ground SDR, various ground points
Cognitive Experiments
What is Unique about NASA’s Space SDRs and Cognitive Radio?

• NASA’s requirements for cognitive radio differ from the normal terrestrial radio requirements in that satellites move rapidly, encountering a wider range of atmospheric, solar, and cosmic effects, normally using higher frequency waveforms, and with longer distances and delays between radios.

• For NASA, cognitive radio is not just concerned with frequencies and bandwidth, but may also be concerned with such things as power management, antenna direction, temperature compensation, or even switching waveforms.

• There are applications where systems of radios pass information back and forth rather than just a single radio.

• Common cognitive radio architectures are desired over a large class of radios so that the knowledge base and lessons learned may be used on the next radio thereby saving money by not having to reinvent such a radio each time. NASA is looking at extending their STRS architecture for space SDRs and is an ideal base to extend into the cognitive realm.

State information to be kept for use by SCAN’s Context-Aware Routing Engine (CARE) decision-making program:

1) Link State Information
2) Application State Information
3) Spatial State Information
4) Environment State Information

• The STRS Architecture is for space software defined radios, cognitive experiments on the SCAN Testbed will help refine and update the STRS architecture for future applications

• The blocks may be broken down as needed considering the complexity of the SDR and the decision-making process.

Experiment Concept: Cognitive Radio and Networking

• Cognitive Radio = PHY Adaptation + Learning
  – SDR is an enabling technology for the realization of Mitola’s cognitive radio
  – Cognitive radios use a cognitive engine (neural net, genetic algorithm, etc.) to decide how the radio waveform should be configured based on knowledge learned from past decisions
  – Radio configuration parameters include things like transmit power, modulation scheme, frequency, coding rates, etc.
  – Goal is to hand over the waveform configuration responsibilities to the cognitive engine in the hopes that it will outperform human or rule-based adaptation mechanisms

• Cognitive Radio and CoNNeCT
  – The opportunity exists for the experimenter to develop a cognitive waveform for one or more of the CoNNeCT SDRs and a corresponding ground terminal
  – These waveforms/cognitive engines could potentially improve performance and lower costs by automating the optimization of the radio link between CoNNeCT and ground under various conditions that are difficult to model or predict, such as weather events, solar storms, and component degradation
Experiment Concept: Cognitive Radio and Networking

• Cognitive Networking = IP Route Adaptation + Learning
  – Similar to cognitive radio, cognitive networking applies the same concept to the networking layers of the OSI stack
  – Cognitive networks use a cognitive engine (neural net, genetic algorithm, etc.) to decide how information should be routed in a network and identify abnormal network use patterns such as a security breach
  – Data can be intelligently queued, stored, and throttled back based on the dynamics of the space network, where link availability is often intermittent and data rates uncertain

• Cognitive Networking and CoNNeCT
  – The opportunity exists for the experimenter to develop network protocols that implement cognition between various assets through CoNNeCT
  – Cognitive networking could work in conjunction with cognitive radio and delay-tolerant network technology to realize fully autonomous, intelligent, self-optimizing, and self-healing data paths between ground and space, and CoNNeCT gives us the opportunity to lower the risk of these concepts in space before operational use
SCAN Testbed is a technical and programmatic advancement of communications technology that will pave the way for future space communication architectures

- Launch scheduled for June 26, 2012
- Experiments Program planned after commissioning in late 2012, call for experiments will be announced this summer through NASA AO
- Experiments of cognitive nature are solicited
- The authors wish to acknowledge the extraordinary team that developed or contributed to the SCAN test bed
  - At the Glenn Research Center, the Jet Propulsion Lab, the Goddard Space Flight Center, the Johnson Space Center, the Kennedy Space Center, the Marshall Space Flight Center, NASA Headquarters
  - Our SDR partners, General Dynamics and Harris Corporation
  - SDR Forum/OMG supporters of the STRS architecture

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