Space Communication Rates at Multi-Gbps (SCRAM)

Prepared for NASA's

Workshop on X-Ray Mission Architectural Concepts

December 15, 2011

Purpose of the Briefing

- Inform science community of the state-of-the-art in space communications to enable new and more capable astronomy missions

Outline

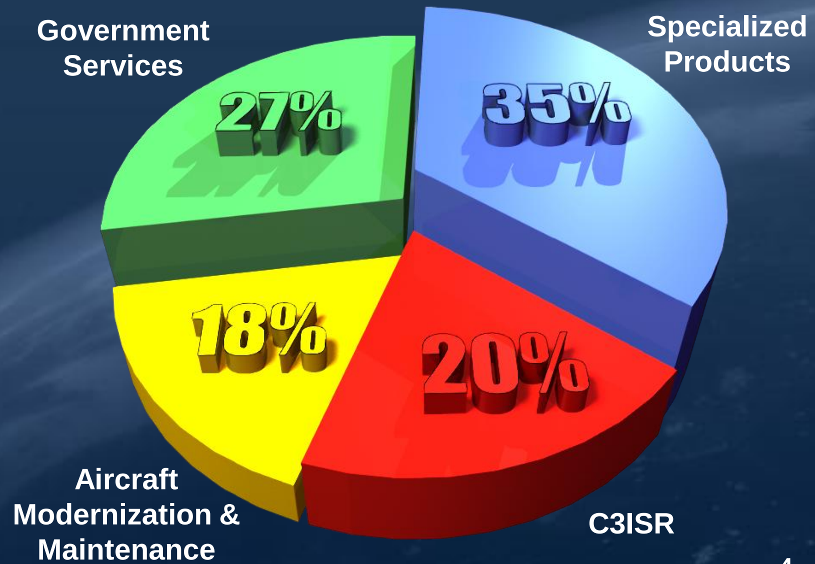
- L-3 Overview
- L-3 Experience in Space
- SCRAM Background
- SCRAM Benefits
- Enabling Technologies
- Key Performance and Technical Parameters
- Previous Demonstrations and Tests
- Technical Maturity
- Existing Space Hardware
- Contact Information

L-3 Communications Corporation

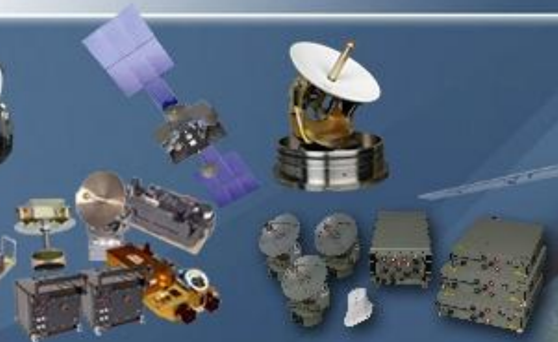
- **Hi-Tech Defense Systems & Products Supplier**
- **Prime Systems Integrator**
  - ISR Collection Platforms
  - Training & Simulation
  - Aircraft Modernization & Maintenance
- **Sub Systems Integrator/Supplier**
  - Digital Wireless Communication Networks
  - Shipboard Communication & Power Systems
  - SATCOM Terminals
  - Airport Security Systems
  - Missile & Munitions Fuzes
  - Telemetry & Instrumentation

Founded:	1997
2009 Annual Sales:	$15.6B
U.S. Defense Industry Rank:	# 6
Employees:	67,000

Business Sectors



Communication Systems Group



- Space Communications
- Telemetry and UGV Communications
- Integrated Communications
- ISR Communication Systems
- Information Assurance
- Tactical and Strategic SATCOM Terminals
- Sustainment Support and Services
- Fiber Optic Networks

L-3 Experience in Space

ORS – 2 (Operationally Responsive Space-2)
- Under development for 2013 delivery
- Space-qualified, Ka-band system operating at 600 Mbps

ORS – 1 (Operationally Responsive Space-1)
- Launched: June 2011
- Space-qualified, Ku-band system operating at 274 Mbps
- Designed to test and demonstrate the rapid development and qualification of militarily relevant spacecraft

TacSat-3
- Launched: May 2009
- Modified airborne communication system hardware, upgraded for space applications, under budget and ahead of schedule.
- TacSat-3 communications continues to operate today.

TacSat-2
- Launched: December 2006
- Modified airborne communication system hardware, upgraded for space
- TacSat-2 communications payload exceeded mission lifetime goal by a factor of 2.

DICE (Dynamic Ionosphere CubeSat Experiment)
- Launched: October 2011
- Delivered Cadet, a compact, low-power, high data rate transceiver designed for small satellite applications

ORS-1

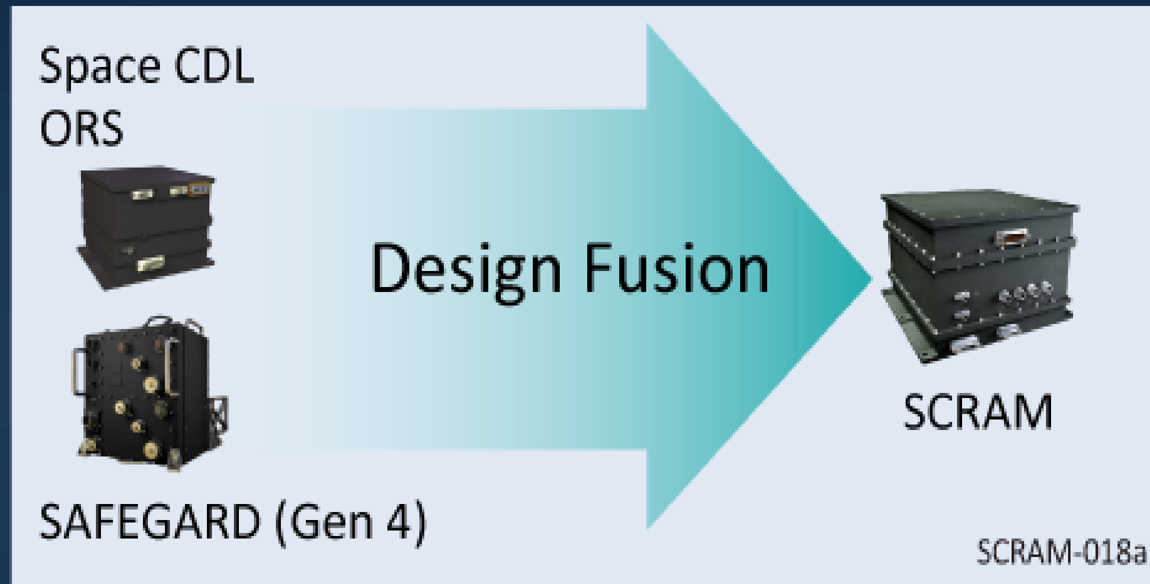
TacSat-3

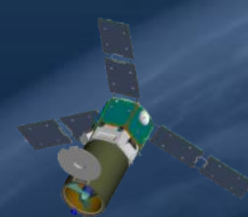
TacSat-2

DICE

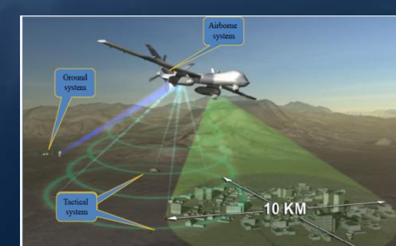
SCRAM Background

- Space transmitter leverages two existing TRL 5 (space) systems:
  - Space Common Data Link
    - Networking algorithms, C2 interfaces, space qualified parts, card layout, and mechanical design
  - SAFEGARD (AFRL)
    - Advanced digital firmware algorithms
- Ground terminal is the SAFEGARD hardware
  - Direct integration with ground system demonstrated in 2 hours
  - June 2012 flight demonstrations



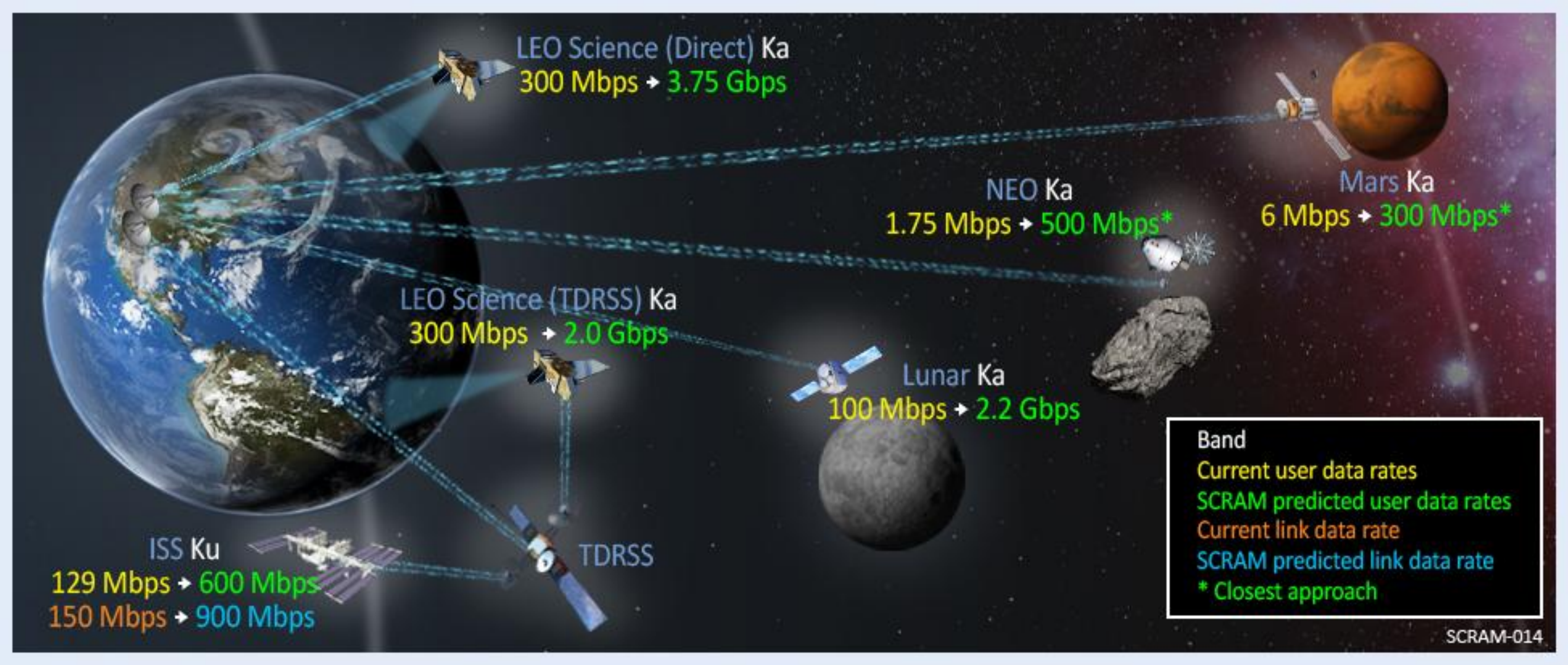


ORS-1



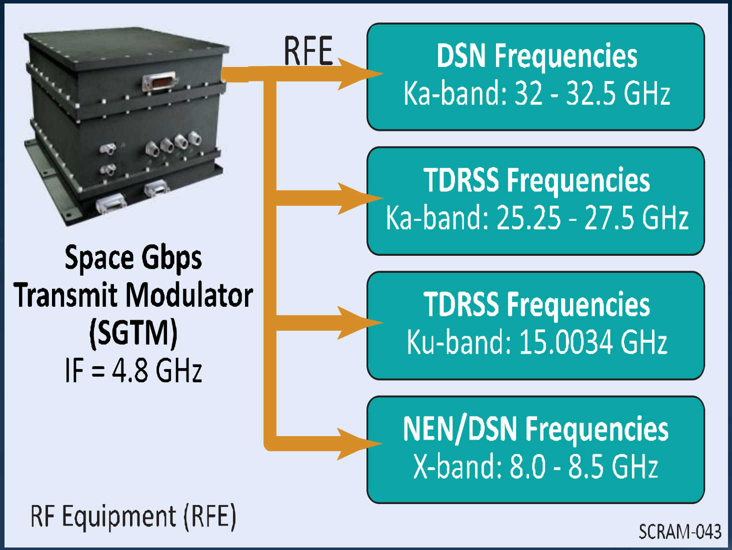
SAFEGARD

SCRAM Increases Communications Capabilities



Benefits

- High data rates
  - 2.0 – 3.4 Gbps over TDRSS
  - 3.75 Gbps LEO direct to ground
  - Multiple sensors
  - Enhanced sensors
- Enlarge mission design trade space
  - Reduce spacecraft antenna size
  - Reduce ground antenna size
  - Reduce overall system power
  - Reduce complexity
- Reduced costs
  - Reduce satellite contact time
  - Heritage programs share common development platforms and upgrades
  - Heritage programs provide solid financial base leveraging common component purchases and software development activities
- Flexibility for technology infusion
  - Reprogrammable digital core supports missions with long durations
  - Waveform Flexibility



SCRAM Frequency Flexibility:
SCRAM supports all NASA SCaN mission networks with minor changes to the system

No NASA mission should ever be limited by communication hardware again!

Expanding Trade Space Options

- L-3 enabling technologies support a variety of system configurations and parameters
- Spacecraft developers can select components that meet the mission goals and budgets without sacrificing performance
- Example Illustration:

Trade Parameters	S/C Antenna – 10 cm		S/C Antenna – 1 m	
	20 W PA	40 W PA	20 W PA	40 W PA
Ground antenna – 1 m	210 Mbps (QPSK)	420 Mbps (QPSK)	1280 Mbps (32APSK)	1470 Mbps (64APSK)
Ground antenna – 2 m	510 Mbps (QPSK)	660 Mbps (8PSK)	1540 Mbps (64APSK)	1800 Mbps (128QAM)

Notes:
S/C – Spacecraft
PA – Power Amplifier
Bandwidth was restricted to 300 MHz maximum

SCRAM expands the mission design trade space

L-3 Technologies Enable Multi-Gbps Rates

Higher Order Modulation

Method

– Leverage military/commercial investment in bandwidth efficient modulation schemes

Benefits

– L-3 algorithms are able to send more data in the same bandwidth

– Algorithm efficiency reduces implementation loss

Enables Gbps rates

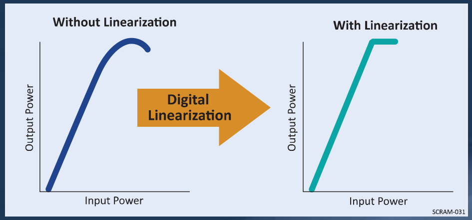
Amplifier Linearization

Method

– Operates closer to saturation without distortion

Benefit

– Linear transfer function increases system performance



Linearization fully exploits hardware capabilities for maximum performance

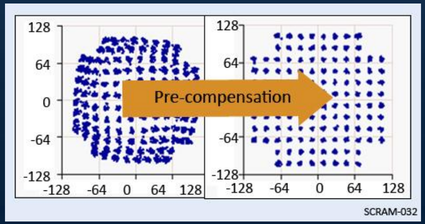
Pre-compensation

Method

– Adapts to the linear/nonlinear effects of the channel

Benefit

– Enhances system performance without prior knowledge of each element



Cleaner spectrum improves performance

Improves system performance by orders of magnitude for both new and legacy systems primarily through software algorithm techniques

Key Performance and Technical Parameters

Key Performance Parameters	Threshold Criteria	Goal
1. Reprogrammable	Perform updates during testing	N/A
2. Dial-a-rate from Mbps to Gbps	Vary data rates between 250 Mbps and 2.0 Gbps	3.0 Gbps
3. Digital Pre-compensation	Demonstrate with and without pre-compensation	N/A
4. Bandwidth efficient modulation	QPSK up to 32-APSK, FEC: 7/8, 9/10	64-APSK
5. Multiple frequency capability	Intermediate frequency output = 4.8 GHz	N/A

Key Technical Parameters	Threshold Criteria		Goal
1. Launch/flight environments	Shock Breakpoints 100 Hz, 100 g 1.3 kHz, 2500 g 10 kHz, 2500 g	Vibration: 18.5 Grms for 60 sec	Envelope GEO launch opportunities
2. Power	< 100 W		< 80 W
3. Weight	6 kg		5 kg
4. Dimensions	20 cm x 20 cm x 13 cm		18 cm x 18 cm x 12 cm
5. Mission Duration	7 years		15 years
6. Reliability (using MIL-HDBK-217F N2)	R(t) > 90%		R(t) > 95%

Tests From GSFC Thru TDRSS To WSC (April 2010)

TDRSS Ka-band test results

Company	Data Rate	Waveform
L-3	1.6 Gbps	8 PSK
L-3	2.0 Gbps	16 APSK
Other	1.0 Gbps	O-QPSK

L-3 demonstrated:

- With 8 PSK, 2dB improvement over alternative communications systems
- With 16 APSK, twice the previously demonstrated rate through TDRSS without any system modifications

Higher performance compared to other supplier algorithms and twice the previously-demonstrated maximum data rate over TDRSS

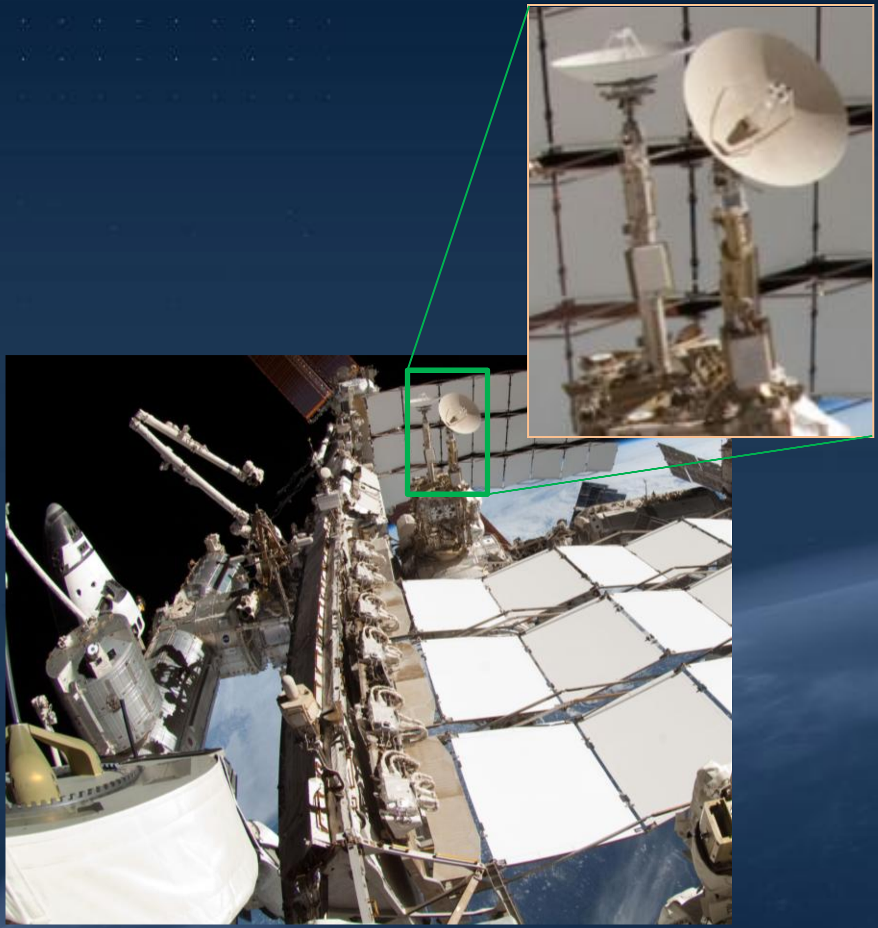
ISS Ku-Band Link Demonstration Results

Return Link Data Rates

Description	Information Bit Rate (Mbps)
Current ISS rate	129
ISS upgraded rate*	258
L-3 rate achieved	600

* ISS upgrade planned in 2012

- Conducted the demonstration at NASA JSC Electronic Systems Test Lab in May 2011
- Utilized a copy of the Ku-band RF hardware on orbit



Primary and backup ISS Ku-band antennas

Demonstrated return info rate 4 times the existing rate

TDRS Testing

- Completed testing of L-3 software algorithms at Boeing El Segundo facility with the TDRS-K testbed
  - July 25 – August 5, 2011
- Provided benchmarking of standard SNUG* waveforms against the TDRS-K hardware
  - Demonstrated error free communication at 3.4 Gbps using a DVB-S2** based waveform
  - Test report available upon request

* SNUG – *Space Network Users' Guide (SNUG)*, 450-SNUG, Rev. 9, NASA GSFC, August 2007
** DVB-S2 – Digital Video Broadcast – Satellite, 2nd generation

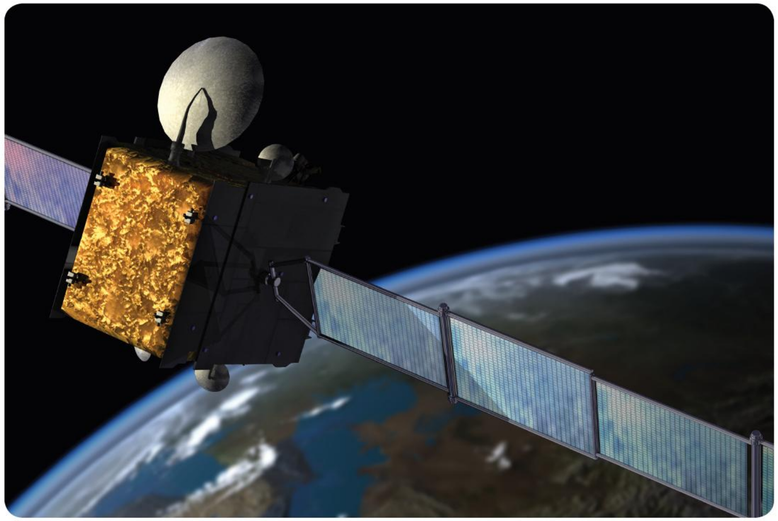
Path to Technical Maturity

- SCRAM technology already NASA TRL 5
- Demonstrations and testing
  - Multiple events completed with more planned
- Development funding 40% secured
  - Seeking remaining portion to complete development
- Multiple ride share opportunities identified

Space CDL

- Operational Space System with:
    - Transmitter
    - RF Equipment
    - Antenna
- 274 Mbps
- Currently transmitting sensor data

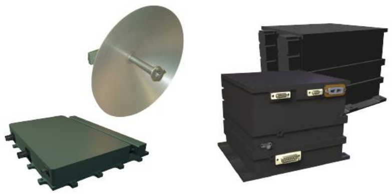
Space Common Data Link



The Space CDL system provides lightweight, wideband data link capability adaptable to a variety of space-based applications. It consists of separate transmitter and receiver modules that can be matched with a variety of antenna and power amplifier options based on mission requirements.

Key Features

- Rad Hard
- IP-Enabled
- Software programmable modem
- Extensive ground infrastructure
- Full-duplex or simplex available
- Embedded Type 1 encryption
- Compatible with typical LEO satellite requirements

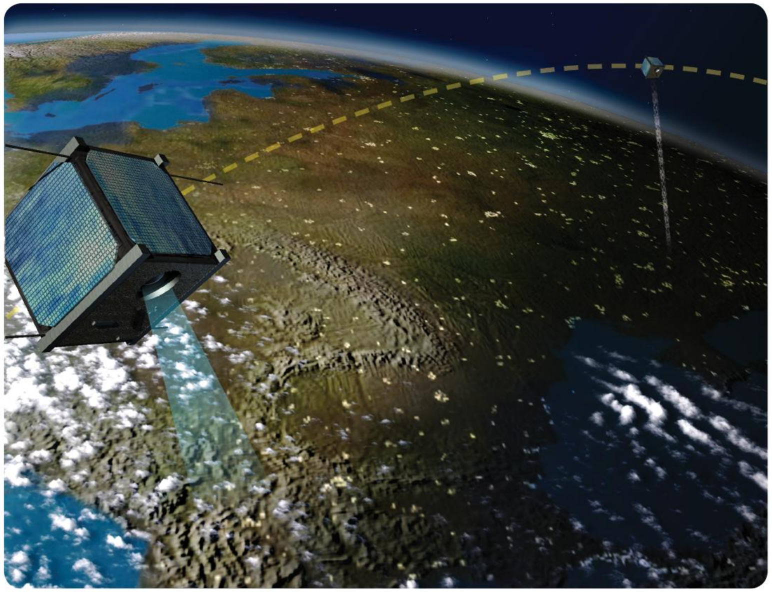


Communication Systems – West

Cadet

- Nanosat transceiver:
  - Simplex transmitter/receiver
  - Store and forward design
  - 4 Gbit internal storage
- 100 Mbps
- Operational on two 1.5U cubesat spacecraft

Cadet Nanosat Radio



The Cadet radio is a compact, low power, high data rate transceiver designed for small satellite applications. No larger than most cell phones, the Cadet makes use of software-defined radio technology, providing for exceptional mission agility.

Key Features

- Low power design for minimum satellite power consumption
- Up to 100 Mbps data rates, depending on configuration
- Implements the latest bandwidth-efficient modulation and FEC techniques
- "Store and Forward" architecture
- Scalable software-defined architecture
- Rapid customization time
- Extensible to air, ground, and maritime micro platforms

Communication Systems – West

Contact Information

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Thank you!