CLEO and

enabling the warfighter to task space payloads

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CLEO and VMOC – meeting needs of participants

**Commercial**
Cisco Systems
Show that a commercial COTS Internet router can work in space.

**Civil**
NASA Glenn
Demonstrate utility of IP and mobile routing for satellite TT&C.

**Military**
Air Force Space Battlelab
Test the Virtual Mission Operations Center in the field and task space asset.

CLEO: Cisco router in Low Earth Orbit placed on UK-DMC satellite by SSTL

Cisco gets its router launched as secondary experimental payload.

NASA Glenn uses router in space to test mobile routing for satellites.

VMOC is tested across Internet from Vandenberg with CLEO & UK-DMC.

CLEO router works in space. VMOC works with space asset. Mission success!
Summary

- UK-DMC satellite launched into low Earth orbit from Siberia with CLEO Cisco router onboard, September 2003.
- IP internetworking of satellite and router tested and validated by international collaboration and demonstration of Virtual Mission Operations Center (VMOC) at Vandenberg Air Force Base, June 2004.
- Internet Protocol works for satellite and payload communication and control. Cisco CLEO router works in orbit.
- Virtual Mission Operation Center enables the warfighter in the field to task space assets, using secure IP infrastructure.
Overview

- Disaster Monitoring Constellation (DMC)
- The IP network environment of the DMC
- Cisco CLEO router and satellite integration
- Virtual Mission Operations Center (VMOC)
- Vandenberg VMOC demonstration
- Awards won by the VMOC demonstration
- Current status and future plans

Images shared by various organisations are used with thanks.
Disaster Monitoring Constellation (DMC)

Surrey Satellite Technology Ltd (SSTL) built and help operate an international constellation of small sensor satellites.

The satellites share a sun-synchronous orbital plane for rapid daily large-area imaging (640km swath width with 32m resolution). Can observe effects of natural disasters.

Government co-operation: Algeria, Nigeria, Turkey, UK, China. Expected 5-year lifespan.

Each government finances a ground station in its country and a satellite. Ground stations are networked together using IP.

fires in California, 28 Oct 2003 (UK-DMC)

www.dmcii.com
DMC put to use: after Hurricane Katrina, 2005

In this false-color image, dry land is red. Flooded and damaged land is shown as brown.

Image taken by a DMC satellite (NigeriaSat-1) on Friday 2 September, for the US Geological Survey.

DMC is working as part of the United Nations International Charter for Space and Major Disasters.

Imagery delivered by using Internet Protocol.

www.dmcii.com
Existing IP network environment of the DMC

Satellite: each DMC satellite has multiple onboard computers. For housekeeping (the On Board Computer, OBC), for image capture and packetised transmission (the Solid State Data Recorders, SSDRs), for redundancy and survival. Interconnected by IP over 8.1Mbps serial links for data and slower CANbus for backup control; really a custom-built LAN.

CLEO: Cisco router was able to fit into UK-DMC satellite’s onboard network by connecting to OBC and SSDRs using common serial interfaces.

Ground: SSTL’s design for its ground station LANs uses IP. Satellites communicate with PCs on LAN via S-band radio space-ground link. IP over 8.1 Mbps serial stream from downlink commercial modem goes into a rack-mounted Cisco 2621 router, which forwards IP packets onto the LAN. SSTL’s ground station LAN is connected to and part of SSTL’s corporate IP network.
What is the CLEO router?

A Cisco 3251 Mobile Access Router (MAR). The MAR is a commercial off-the-shelf (COTS) product family.

The CLEO MAR is an experimental secondary payload on the UK-DMC satellite.

The 3251 MAR features:
• 210MHz Motorola processor.
• Built-in 100Mbps Ethernet.
• PC/104-Plus interfaces and form factor.
• Additional stackable 90mm x 96mm cards (serial, Ethernet, power supply, WiFi, etc.)

Local environment and high-speed downlink used by UK-DMC satellite dictate use of serial interface card to connect with existing 8.1Mbps serial links used onboard.
Alterations to CLEO router for launch and space

No radiation hardening; low orbit environment is relatively benign. 
No unique hardware design or software work done by Cisco.
Minor physical modifications made to router and serial card.
• Flow-soldered with lead-based solder to avoid ‘tin whiskers’.
• Flat heatsink added to main processor to take heat to chassis.
• To avoid leakage in vacuum, wet electrolytic capacitors with pressure vents replaced with dry.
• Unused components removed, including plastic sockets and clock battery. Time set with NTP. Directly soldered wires are more robust for vibration/thermal cycling.
CLEO integration 1 – the router assembly

MAR processor card and serial card wired to ‘motherboard’ designed by SSTL.

‘Motherboard’ provides physical mounting, power, serial connections and serial/CANbus interface for access to router console port.

Router console port was used to ‘bootstrap’ router configuration in orbit from nothing. After basic networking was configured during passes, telnet and ssh were then used.
CLEO integration 2 – payload tray to satellite

SSTL’s satellites are modular stacks of identical aluminium trays, screwed together. Aluminium provides grounding, heat conduction, and structural rigidity. Satellites are built rapidly, using COTS parts, in under 18 months.
Virtual Mission Operations Center (VMOC)

Software developed by General Dynamics intended to task satellites and provide imagery via a simple GUI interface for military users. VMOC was rated second out of 120 projects in importance by the US Office of the Secretary of Defense, Rapid Acquisition Incentive - Network Centric (RAI-NC) program. So became one of four pilots receiving advance funding. VMOC intended for use with TacSat-1, planned for launch in 2005, and later TacSat-2. UK-DMC provides an early opportunity to test VMOC.

VMOC requests images of ground from SSTL mission planning system for DMC satellites. Images are taken for VMOC by UK-DMC only. VMOC monitors UK-DMC satellite telemetry and accesses CLEO router. VMOC is simply a secure IP-based application for satellites, using an available IP-based satellite infrastructure!
VMOC demo, Vandenberg Air Force Base

May-June 2004, VMOC, image request and access to onboard payload (router) were tested by coalition of partners ‘in the field’ in tent and Humvee at Vandenberg Air Force Base in California.

Tested:
- requesting sensor data (imagery) from the UK-DMC satellite.
- use of IP for field operations.
- tasking a satellite payload (the CLEO router, accessed using mobile networking).
- failover between multiple VMOCs.

Testing and demonstration were successful. Cisco’s CLEO router in orbit shown to work by third parties while testing a larger integrated ‘system of systems’.
VMOC demonstration network topology

- **UK-DMC satellite**
  - CLEO onboard mobile access router
  - 8.1Mbps downlink
  - 9600bps uplink

- **low-rate UK-DMC passes over secondary ground stations receiving telemetry (Alaska, Colorado Springs)**

- **other satellite telemetry to VMOC**

- **‘battlefield operations’ (tent and Humvee, Vandenberg AFB)**

- **secure Virtual Private Network tunnels (VPNs) between VMOC partners**

- **primary VMOC-1 Air Force Battle Labs (CERES)**

- **‘shadow’ backup VMOC-2 (NASA Glenn)**

- **mobile routing Home Agent (NASA Glenn)**

- **mobile router appears to reside on Home Agent’s network at NASA Glenn**

- **Internet**
VMOC/CLEO demonstrated in action

5 November 2004, VMOC and imaging request operations were demonstrated at Air Force Space Command Headquarters in Colorado Springs to Gen. Lance Lord.

18 November 2004, to Air Force Space Command during its Commanders' Conference in Los Angeles.

2 December 2004, to the leadership of the Air Staff and Joint Staff in the Washington, DC area.

10 May 2005, CLEO and VMOC were demonstrated at AFEI Net-Centric Operations Conference.
Demonstration involved many organisations
Acknowledgement of success of CLEO and VMOC

- NASA Glenn – Computerworld Heroes finalists
- Internal awards within Air Force, NASA and General Dynamics
- Internal awards for project management
Current status of the CLEO router in space

CLEO remains operational. As a secondary experimental payload, testing of CLEO is on a best-effort basis, balanced against the other demands on the UK-DMC satellite.

When not being tested, CLEO is simply switched off to conserve energy.

CLEO has spent two years in orbit. Testing of CLEO has been done for over a year.
Next steps beyond CLEO

Cisco Systems has prototyped and evaluated IOS software running on a radiation-hardened PowerPC processor. Dave Buster will speak Thursday morning, here at MILCOM 2005:

Towards IP for space based communications systems;
A Cisco Systems Assessment of a Single Board Router

Next steps for VMOC

VMOC is being enhanced to increase its API functionality. VMOC will be used in the SAFE (Space Apportionment For Effect) demonstration.
Testing CLEO with VMOC validates VMOC. Testing VMOC with CLEO validates CLEO.

Questions?
thankyou