

CLEO - Cisco router in Low Earth Orbit

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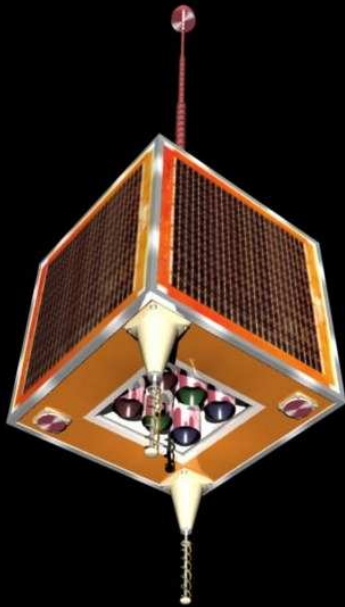
Overview

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- **The Disaster Monitoring Constellation (DMC)**
- **The existing network environment for the DMC**
- **Cisco router, modifications, satellite integration**
- **Work before and after launch**
- **Virtual Mission Operations Center**
- **Vandenberg demonstration**
- **Future plans**

Executive summary

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- **UK-DMC satellite, with Cisco router onboard, launched with other satellites into low Earth orbit, September 2003.**
- **UK-DMC and sister satellites are based around use of Internet Protocol (IP).**
- **IP internetworking of satellite and router tested and validated by international collaboration and demonstration at Vandenberg Air Force Base, June 2004.**
- **IP works for satellite and payload communication and control.**
- **Cisco router in orbit works.**

Disaster Monitoring Constellation (DMC)

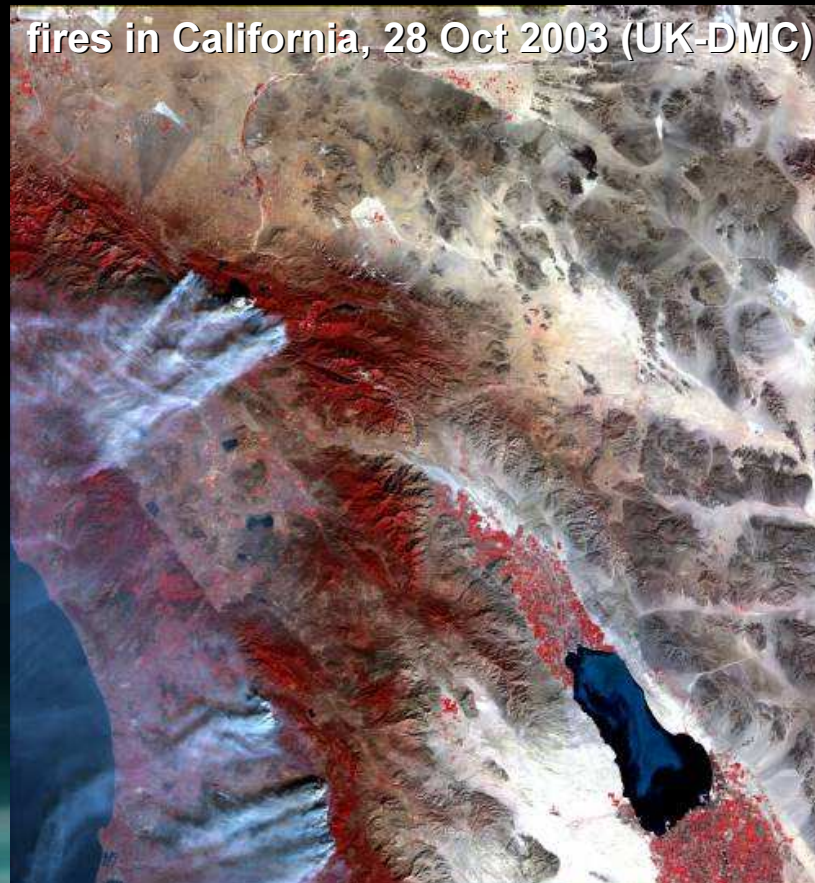
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Surrey Satellite Technology Ltd (SSTL) built and help operate an international constellation of small satellites.

The satellites share a sun-synchronous orbital plane for rapid daily large-area imaging (600km swath, 32m resolution). Observe effects of natural disasters.

Government co-operation: Algeria, Nigeria, Turkey, UK. Chinese contribution being built.

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



<http://www.dmcil.com/>

DMC can take images of anywhere on Earth

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Palm Island Resort, Dubai, 14 Dec 2003 (UK-DMC)



Three Gorges Dam, China, July 2004 (UK-DMC)

<http://www.dmcii.com/>

DMC satellite constellation launches

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Four satellites launched so far. Similar base designs, with modifications for each country.

Satellites launched from Plesetsk in Siberia on affordable shared Russian Kosmos-3M launches:

November 2002: AISAT-1 (Algeria)

September 2003: UK-DMC, NigeriaSAT-1 and BilSat (Turkey)

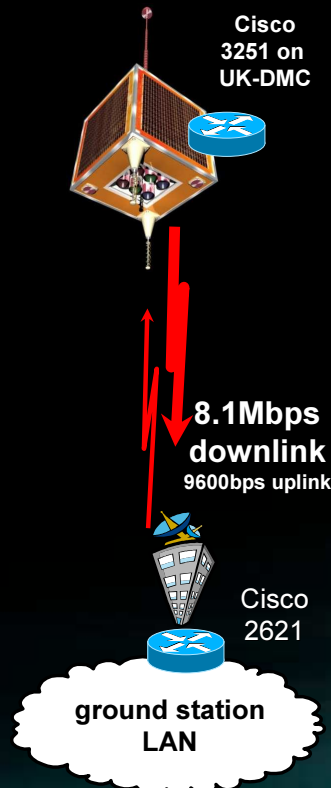
Satellites and ground stations in each country use IP to communicate. Earth images delivered to ground stations via UDP-based transfer.

SSTL migrated from AX.25, as used on previous missions. Use of IP makes a good fit with Cisco's IP router onboard UK-DMC satellite.



Existing network environment for the DMC

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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 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 goes into rack-mounted Cisco 2621 router, which forwards IP packets to ground-station LAN. SSTL's ground station LAN is connected to SSTL corporate IP network.

What is the CLEO router?

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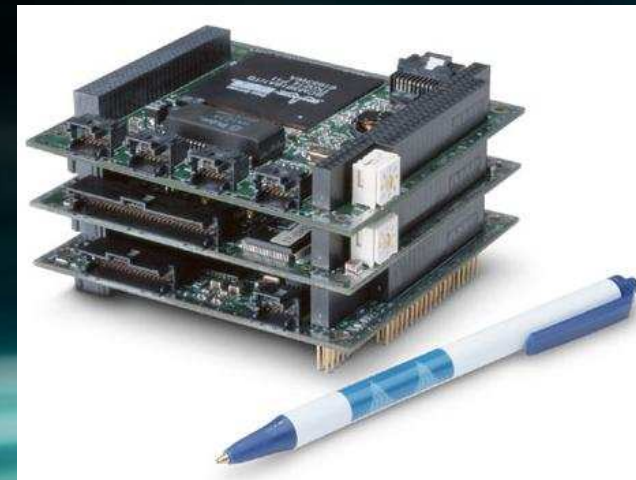
**A Cisco 3251 Mobile Access Router (MAR).
The MAR is a commercial off-the-shelf
(COTS) product family.**

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

MAR features:

- **200MHz Motorola processor.**
- **Built-in 100Mbps Ethernet.**
- **PC/104-Plus interfaces and form factor.**
- **Additional stackable 90 mm x 96 mm cards (serial, Ethernet, power supply, WiFi, etc.)**

**Local environment and high-speed downlink
onboard satellite dictate use of serial card to
connect with existing 8.1Mbps serial links.**



Previous tests of the mobile access router

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MAR previously tested for US Coast Guard by NASA Glenn Research Center onboard *Neah Bay* icebreaker in Great Lakes. Used mobile routing to roam seamlessly between wired network when docked and *Globalstar* satellite and long-range WiFi links when sailing.



CLEO modifications for launch and space

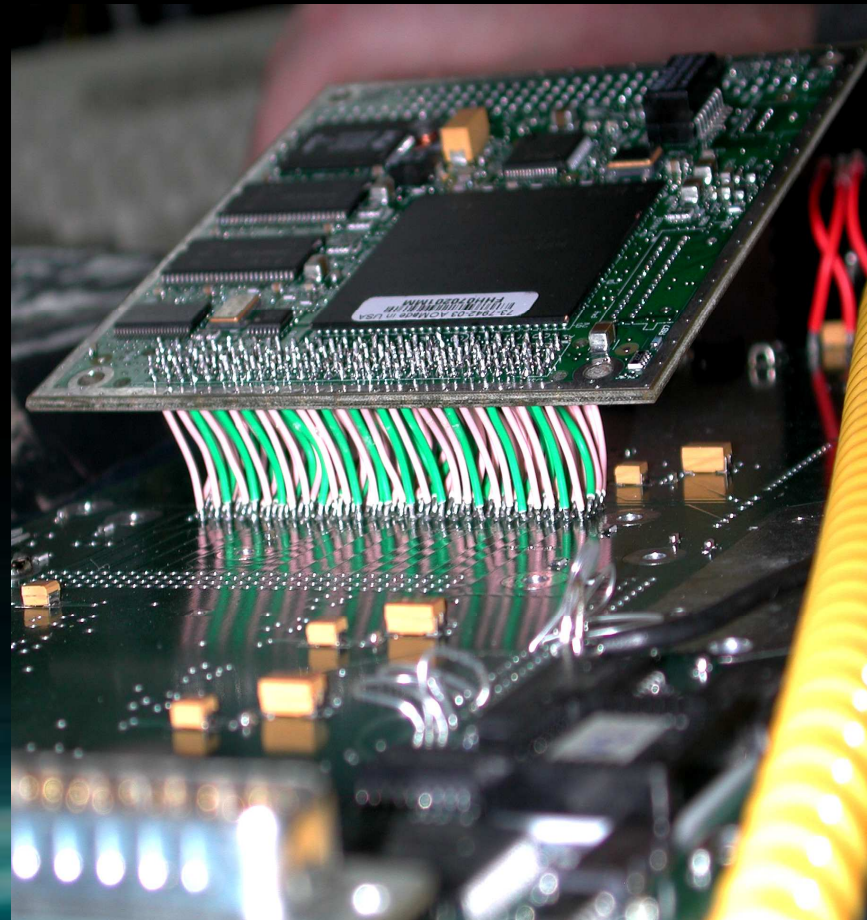
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No radiation hardening; low orbit environment is relatively benign.

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.**
- **Clock battery and sockets for connectors also removed. Direct soldered connections used for vibration/thermal survivability.**

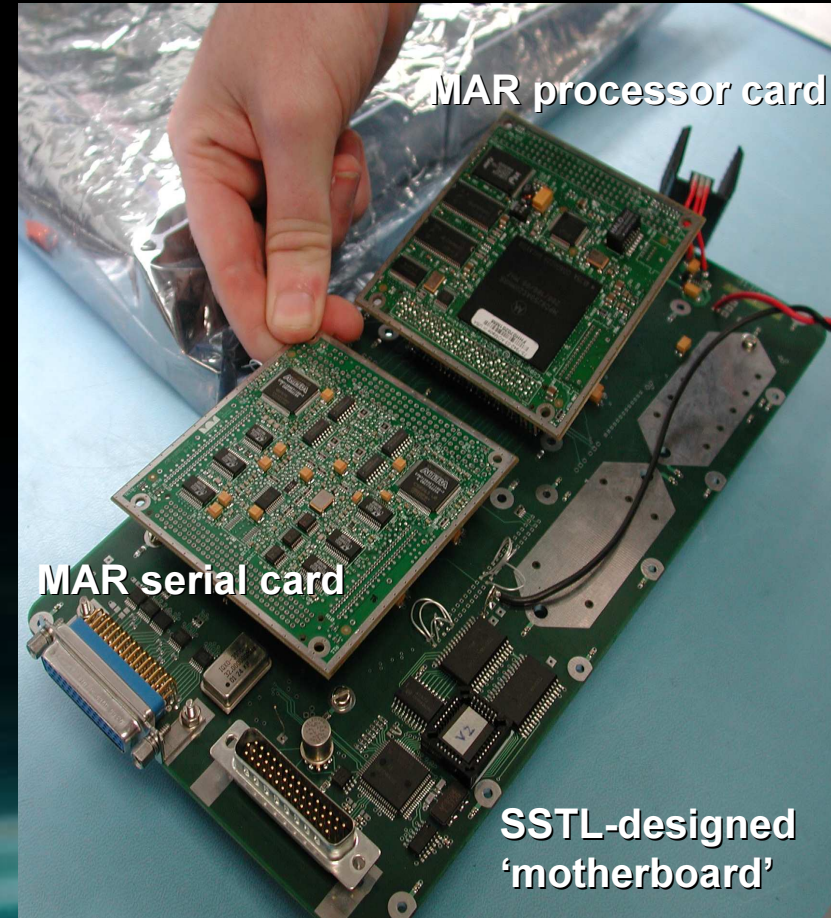


CLEO integration 1 – the router assembly

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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.

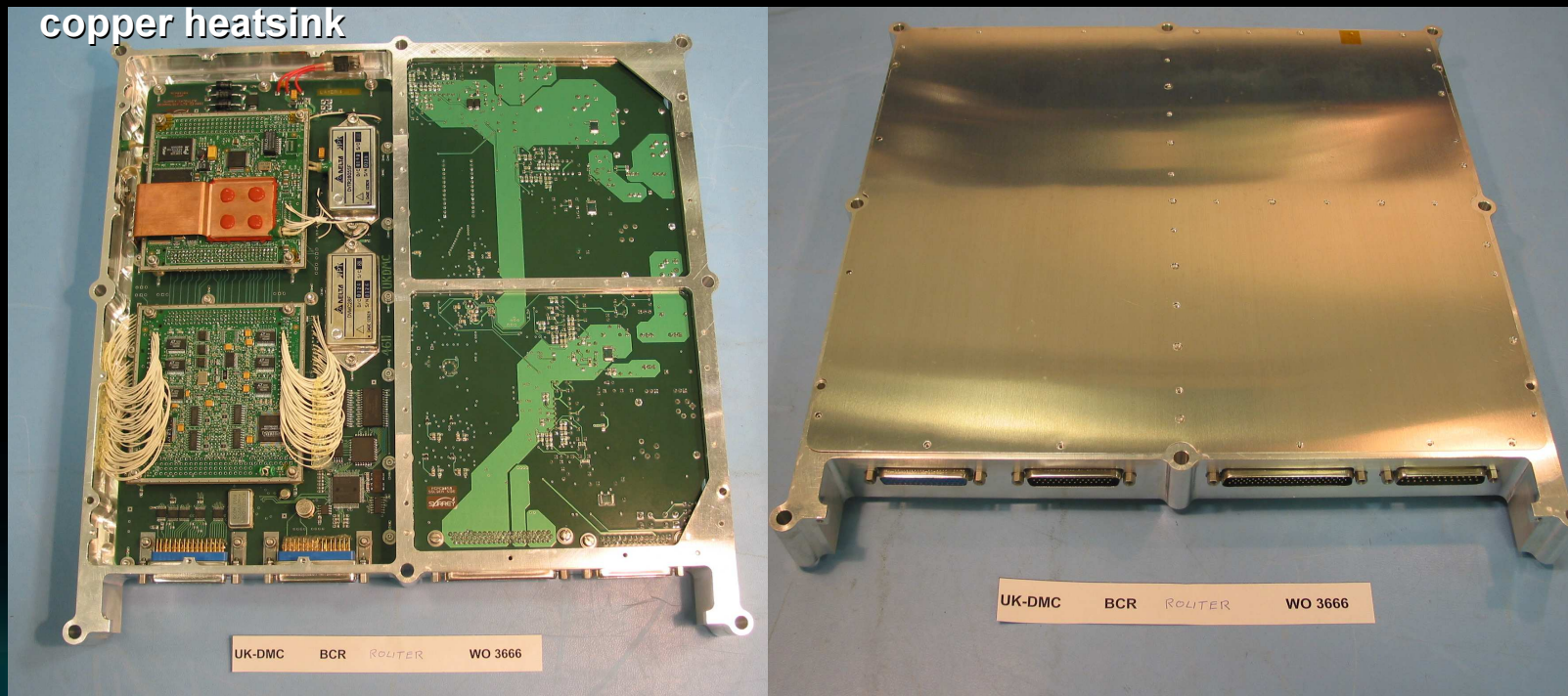


CLEO integration 2 – the payload tray

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SSTL's satellites are modular stacks of identical aluminium trays, screwed together. Aluminium provides grounding, heat conduction, and structural rigidity. Router card assembly takes up half of stackable tray.

copper heatsink



CLEO integration 3 – testing before launch

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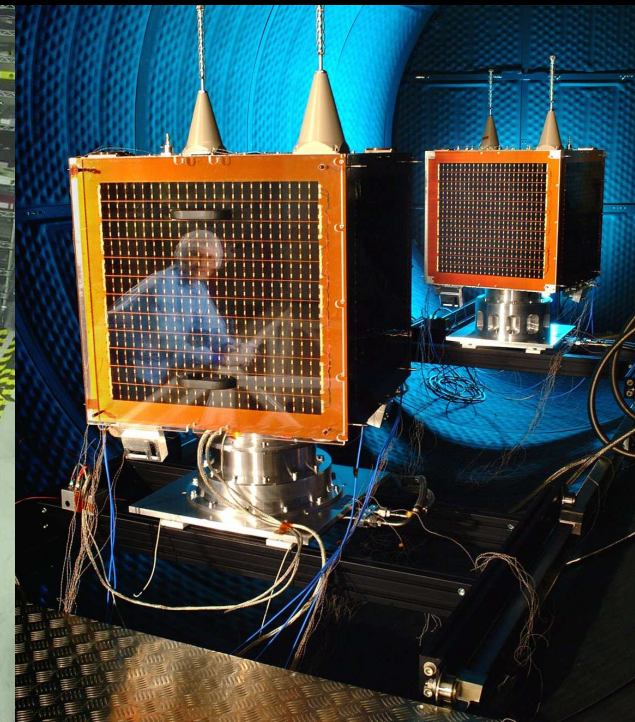
Satellite assembly, subsystems and router operated in partial vacuum of less than 1×10^{-5} torr (1×10^{-3} Pa), temperature range of -35°C up to $+60^{\circ}\text{C}$. Also vibration tested.



satellite assembly



in-house testing



vacuum chamber testing

Work after launch: ground-based testbed

NASA Glenn needed to gain familiarity with operating and configuring router with SSTL's onboard computers.

Ground-based testbed allows configuration changes to be tested on the ground at leisure before being made to CLEO during a ten-minute pass over a ground station.

Built rack-mount ground-based testbed ('flatsat') with SSSDR and engineering model of router, and networked it from NASA Glenn in Ohio.

Built testbed *after* launch!



VMOC demo, Vandenberg Air Force Base

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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:

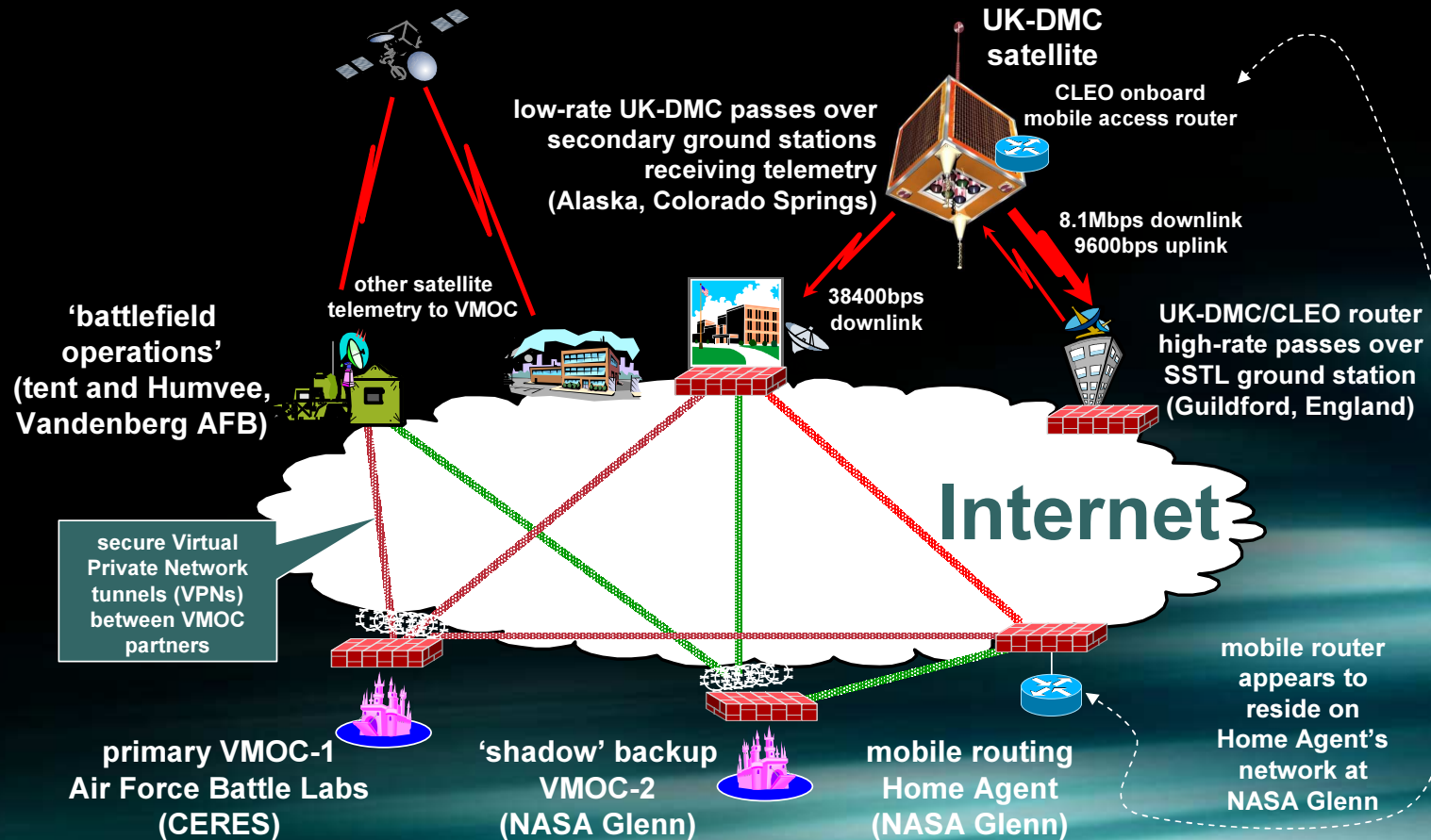
- requesting sensor data (imagery) from the UK-DMC satellite
- use of IP for field operations
- tasking a satellite payload (the CLEO router, accessed using mobile networking).
- failover between multiple VMOCs.

Testing and demonstration were successful. Cisco's CLEO router in orbit shown to work by third parties while testing a larger integrated system.



VMOC demonstration network topology

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Demonstration involved many organisations

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