CLEO

Cisco router in Low Earth Orbit

IPv6 and IPsec on a satellite in space

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Surrey Satellite Technology Ltd (SSTL)
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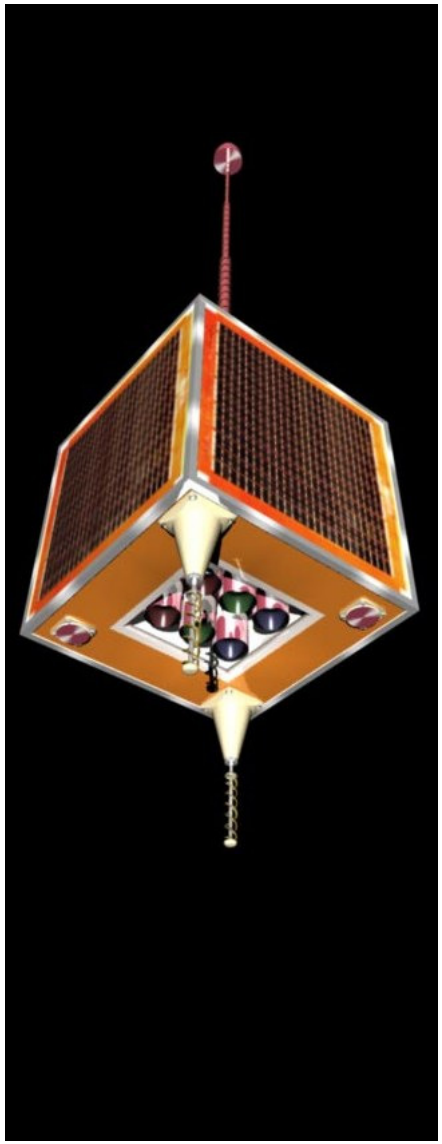
Executive summary

- 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 works for satellite and payload communication and control.
- IP internetworking of satellite and router tested and validated by international collaboration and demonstration at Vandenberg Air Force Base, June 2004.
- IPv6 and IPsec tested in orbit using Cisco router, 2007.
- Cisco router has worked in orbit for four years.



Overview

- The Disaster Monitoring Constellation
- Steps in extending the Internet into space
- CLEO – Cisco's mobile access router
- The existing network environment for the DMC
- CLEO IPv6 and IPsec testing

Images shared by other organisations are used with thanks.

Disaster Monitoring Constellation (DMC)

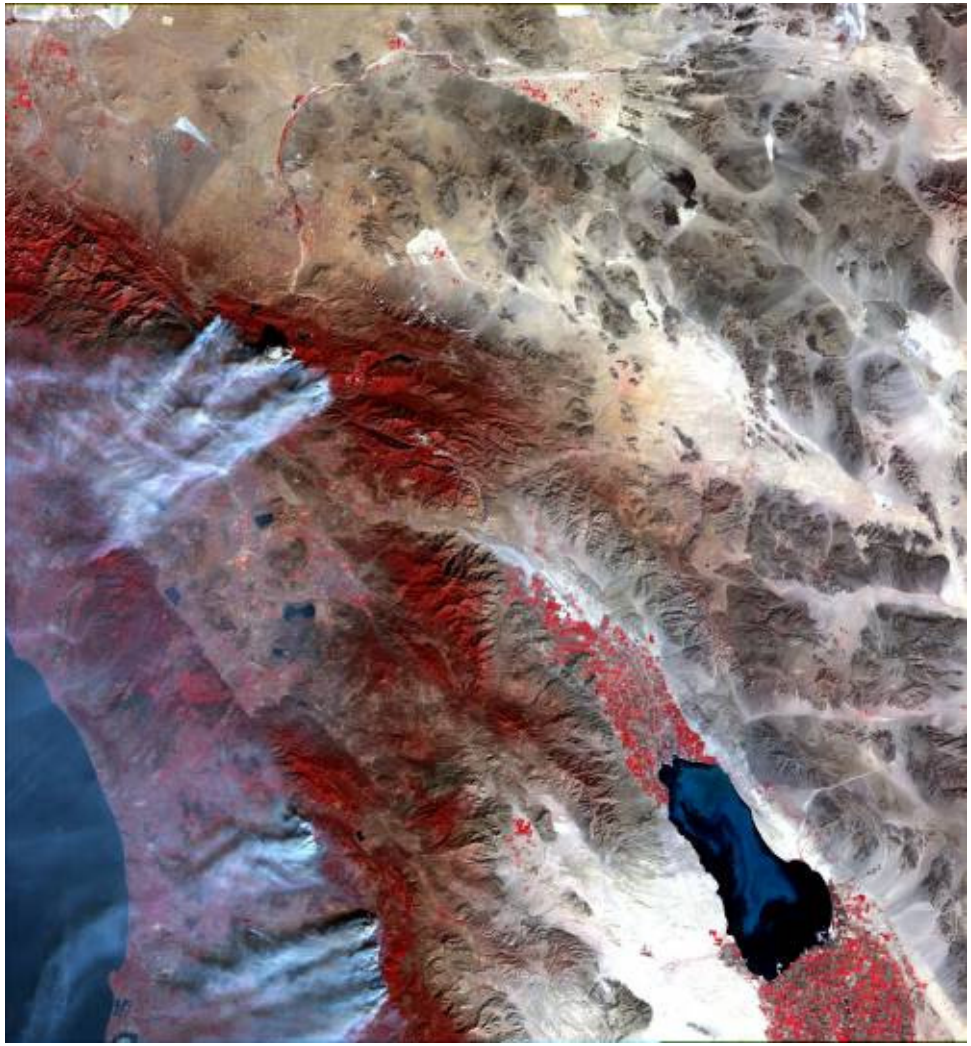
www.dmcii.com

Surrey Satellite Technology Ltd (SSTL) build 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, United Kingdom, and China.

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



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

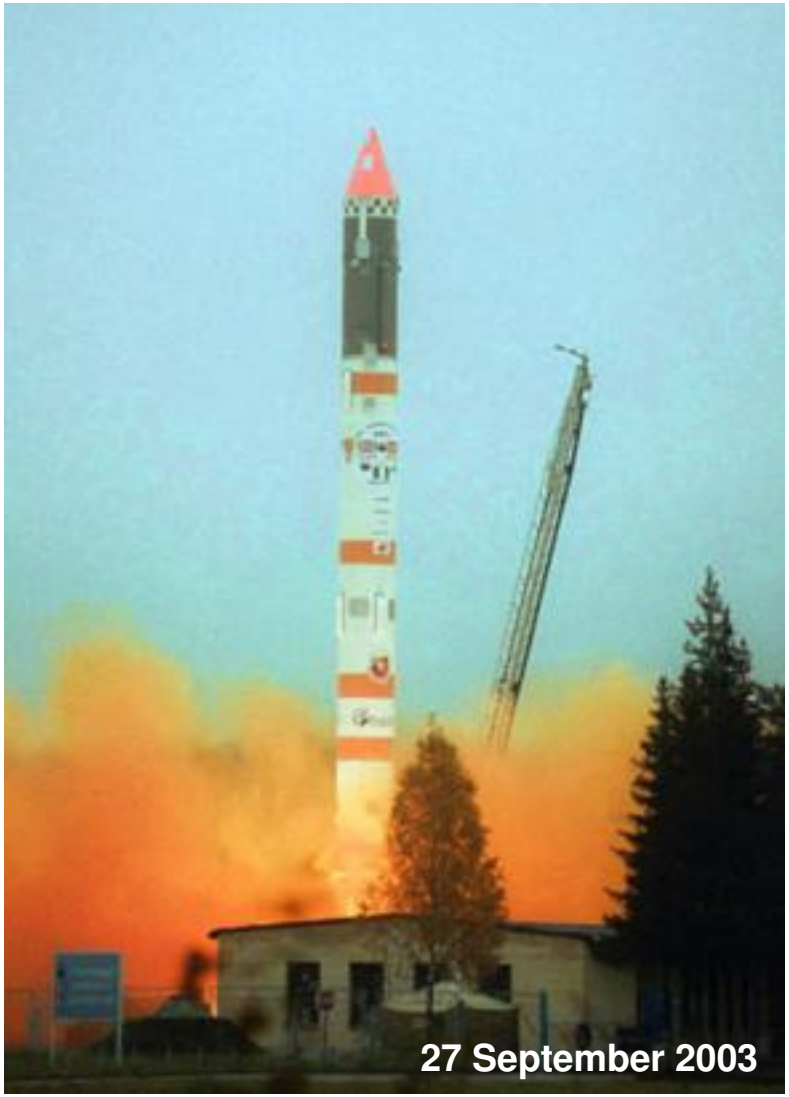
DMC satellite constellation launches

Five satellites launched so far. Similar base designs and subsystems, with custom modifications for each country.

Satellites launched from Plesetsk in Siberia on affordable shared Russian Kosmos-3M launches:
November 2002: AlSAT-1 (Algeria)
September 2003: UK-DMC, NigeriaSAT-1 and BilSat (Turkey)
October 2005: Beijing-1 (China)

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

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



DMC can image anywhere on Earth

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

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

www.dmcii.com

DMC in use: after Hurricane Katrina, 2005

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

Small part of an image taken by the Nigerian DMC satellite 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 – all IPv4.

Extending the Internet into space

- NASA JPL gives DERA's STRV-1b an IPv4 address (1996).
- NASA Goddard flies IPv4 stack on SSTL's UoSAT-12* (2000). This encourages SSTL to adopt IPv4.
- Cabletron router on Russian module of ISS. NASA uses IPv4 in shuttle experiments, e.g. VoIP with Cisco SoftPhone tested from *Atlantis* (Feb 2001). These culminated in CANDOS,* tested onboard *Columbia* (Jan 2003).
- NASA gets SpaceDev to launch CHIPSat (Jan 2003).
- SSTL adopts IP with DMC (AISAT-1 launched Nov 2002, UK-DMC et al. Sep 2003, Beijing-1 Oct 2005). Cisco and SSTL fit CLEO mobile access router on UK-DMC satellite, alongside imaging payloads. CLEO used to test IPv6 and IPSec.
- MidSTAR-1* and SSTL's CFESat launch (March 2007).

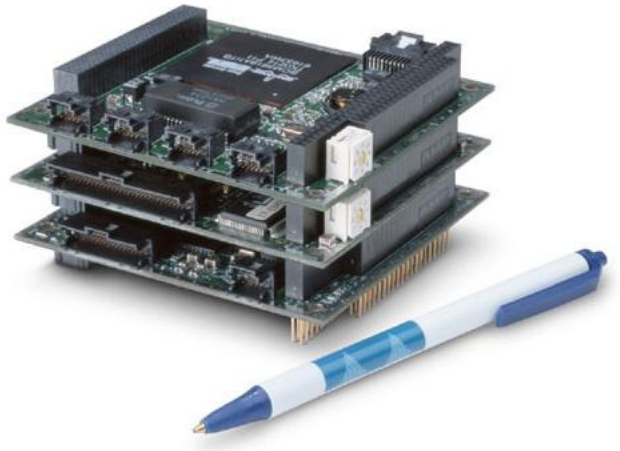
*Keith Hogie's team at NASA Goddard was instrumental in use of IP in these projects.

What is the CLEO router?

A Cisco 3251 Mobile Access Router (MAR). The MAR is a commercial off-the-shelf (COTS) product family – 3251 and 3220 series. Runs Cisco's IOS (Internetwork Operating System) router code – version 12.2(11)YQ.

The 3251 MAR features:

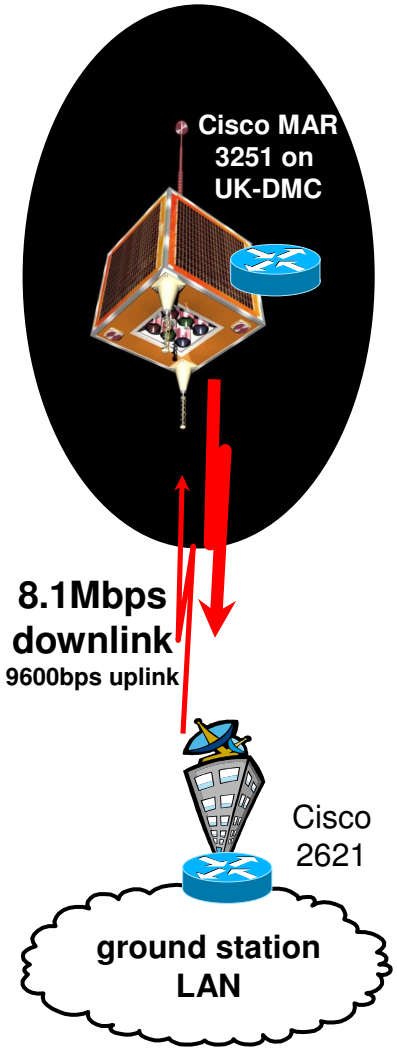
- 210MHz Motorola processor.
- Built-in 100Mbps Ethernet.
- PC/104-Plus interfaces and form factor.
- Additional stackable 90mm x 96mm cards (serial, Ethernet, power supply, WiFi, etc.)



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

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.

Existing network environment for 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 8.1Mbps 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 an integral part of SSTL's corporate IP network.

IPv6 and IPsec testing with CLEO

IPv6 and IPsec are now being tested onboard CLEO.
First to test IPv6 onboard a satellite, 29 March 2007.

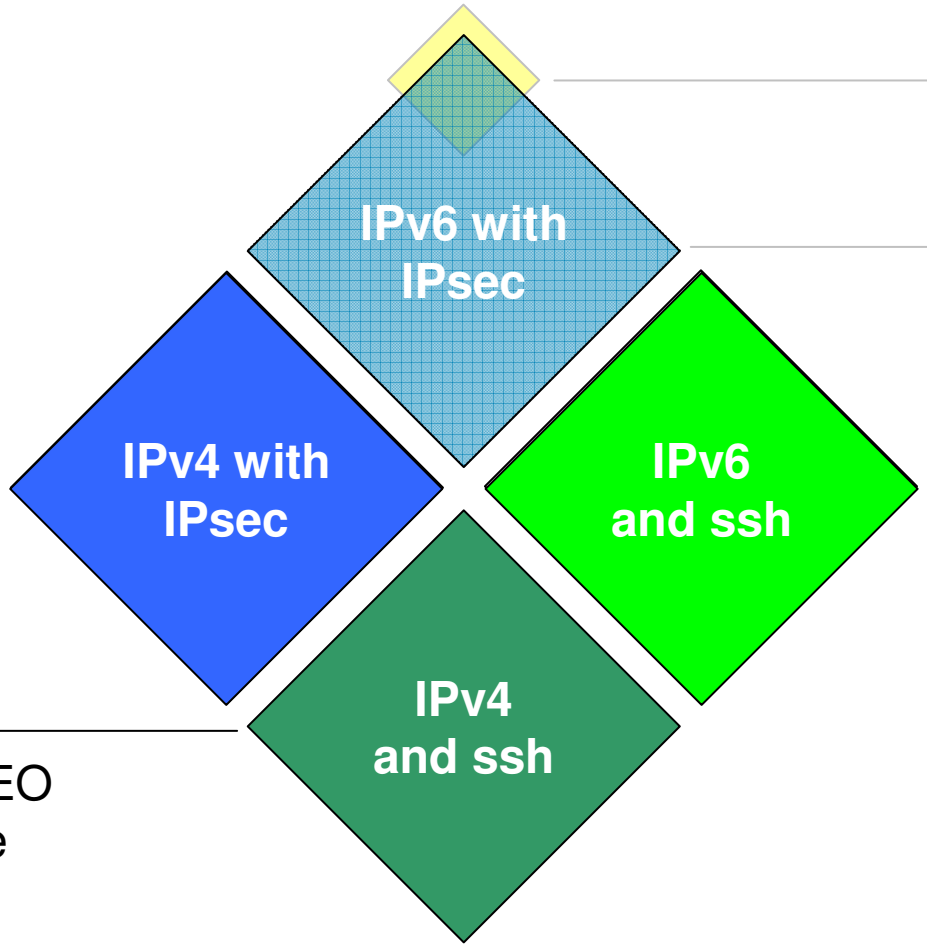
IPv6 – CLEO, ground Cisco routers and PIX firewalls are IPv6-capable, although SSTL and UK-DMC payloads rely only on IPv4.

IPsec – CLEO and ground station routers can use this to secure unencrypted ground-space link by tunnelling IP traffic through the router. (*ssh* to CLEO and a passworded web interface were configured in 2004.)

Separate frame-relay/HDLC subinterfaces are used to the satellite:
- unencrypted IPv4 and IPv6.
- IPv4 encrypted with IPv4 IPsec, able to carry IPv6 in a 6-to-4 tunnel. (IPv6 IPsec is in a more recent code release, and was not flown.)

Set up a number of test scenarios. (Could also use SNMP and MIBs to show that a satellite payload can be managed just as you would manage a terrestrial network asset.)

How far can we take CLEO demonstration?
IPv6 and IPsec are now being tested in orbit



Future
IPv6+HAIPE, other security methods

Future
IPv6+IPsec together (post-CLEO)

2007
IPv4+IPsec is tested to CLEO

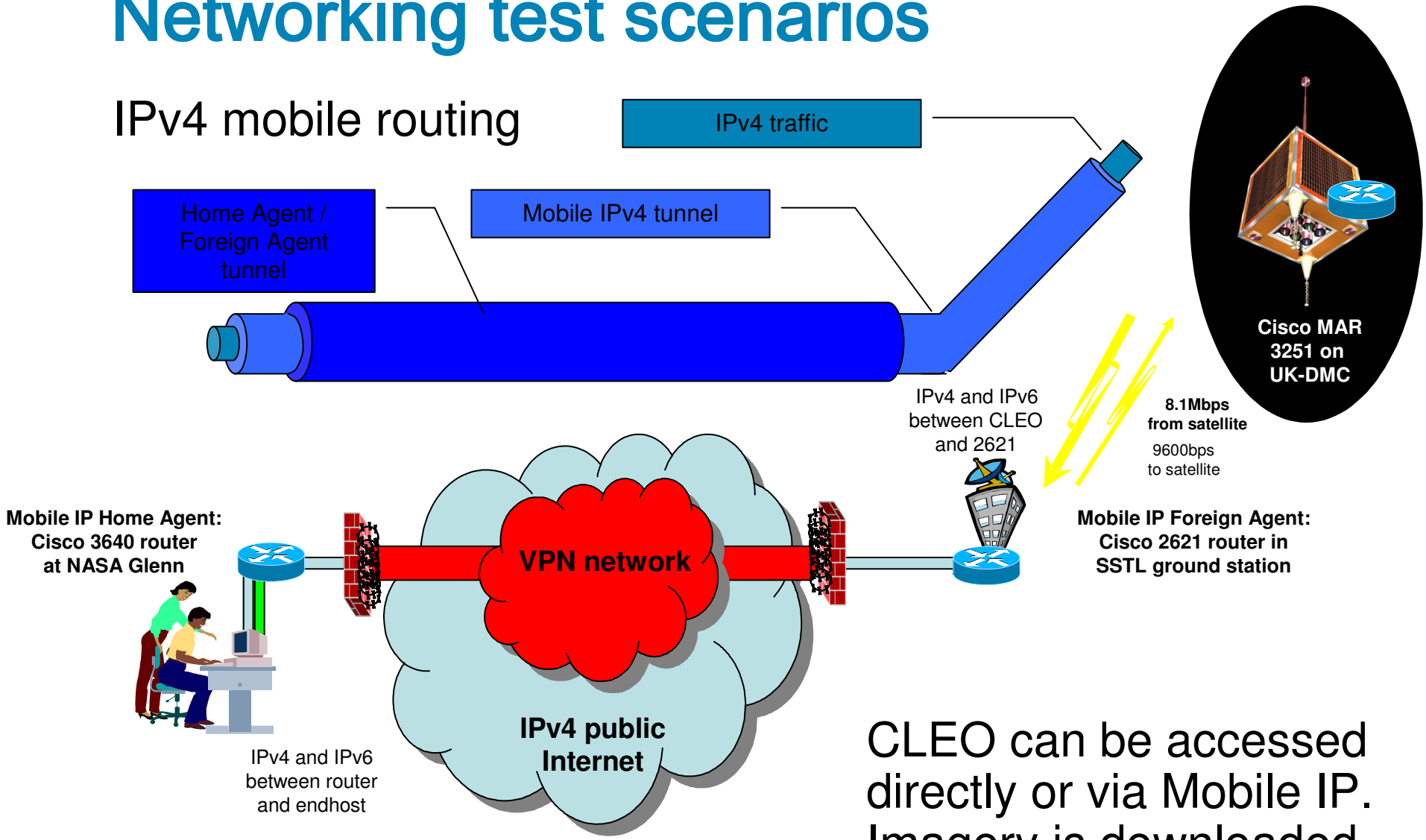
2007
IPv6 is tested to CLEO

2004
VMOC tested CLEO with IPv4 in space

CLEO, the Cisco router in Low Earth Orbit, is able to show three of these steps.

Networking test scenarios

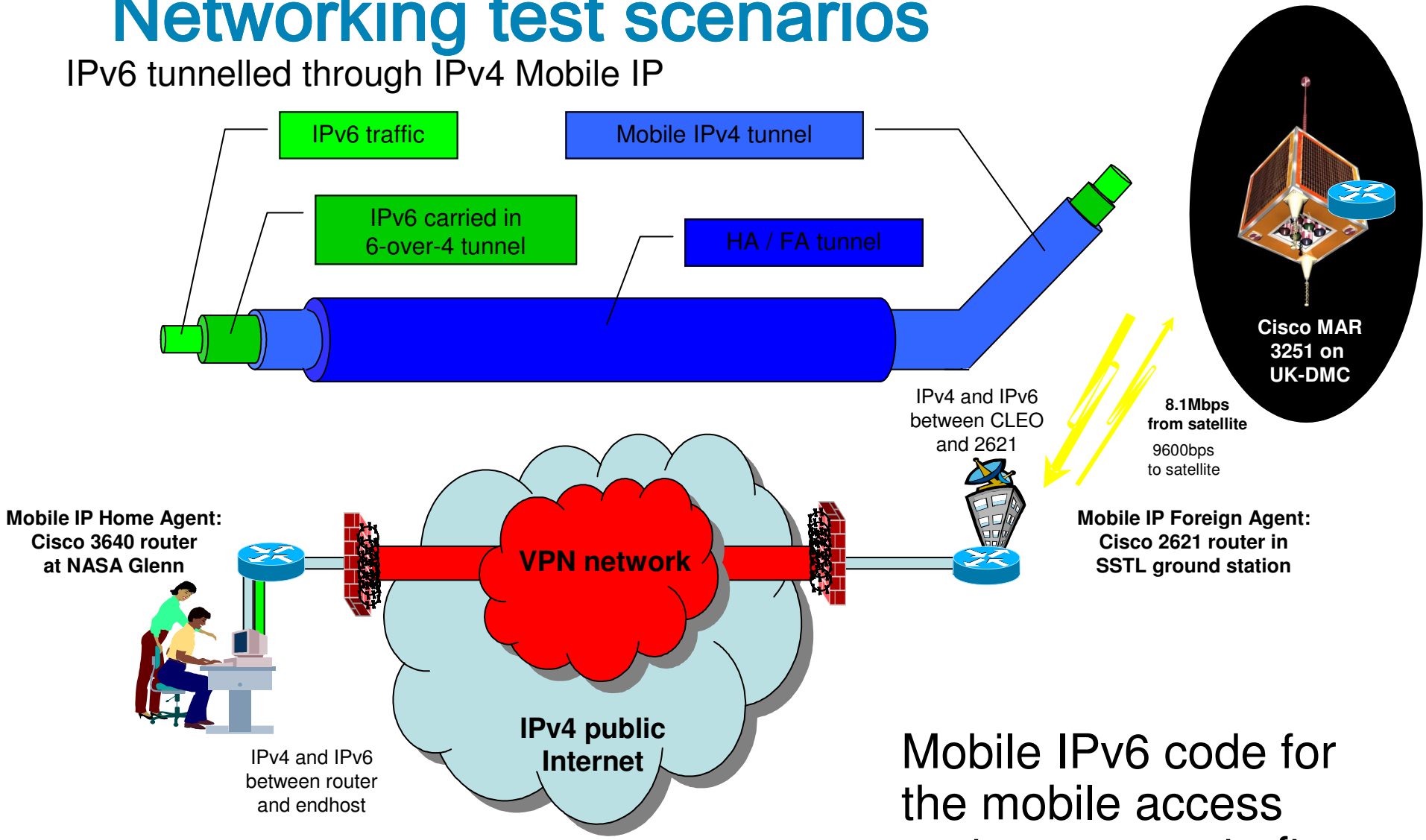
IPv4 mobile routing



CLEO can be accessed directly or via Mobile IP. Imagery is downloaded directly.

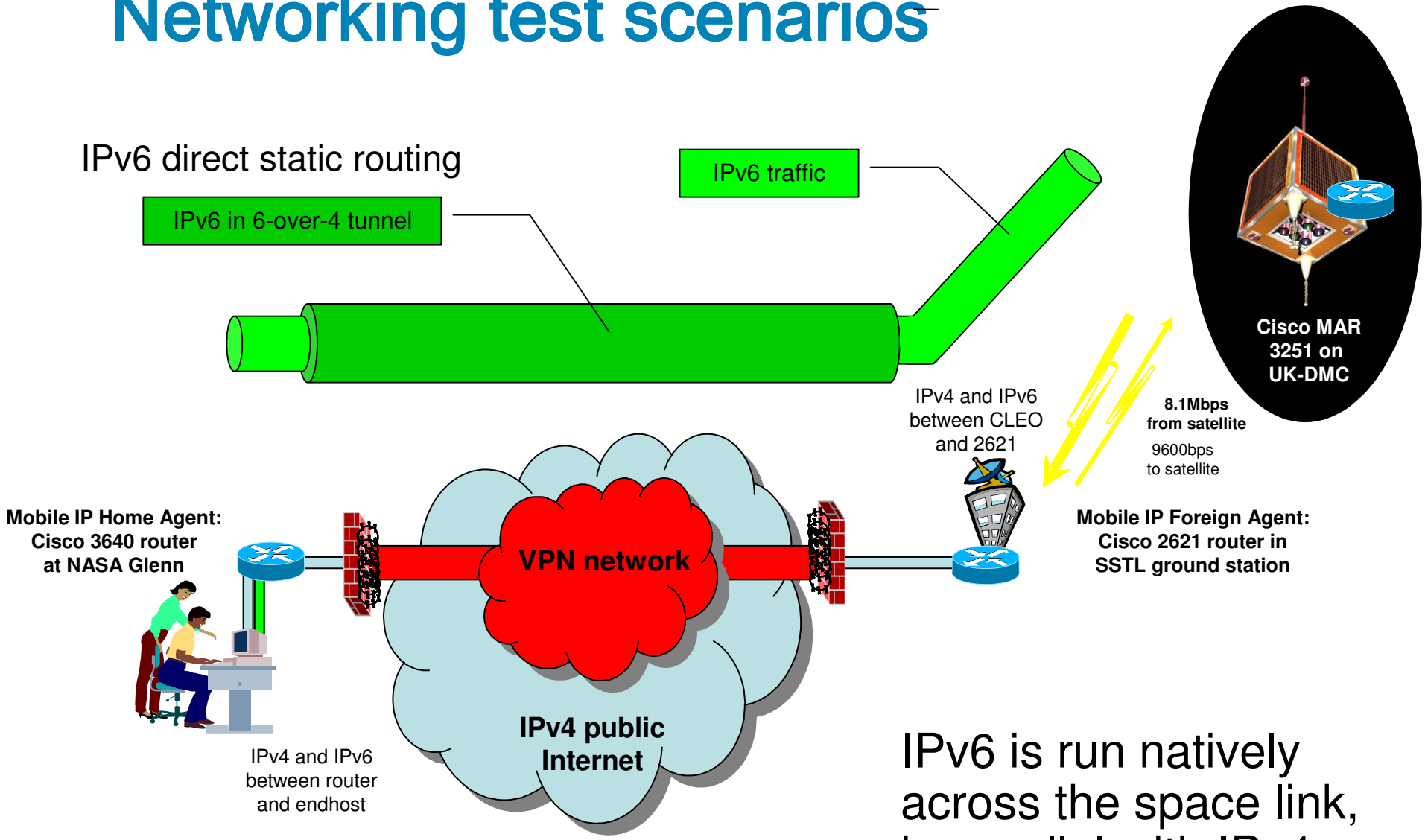
Networking test scenarios

IPv6 tunnelled through IPv4 Mobile IP



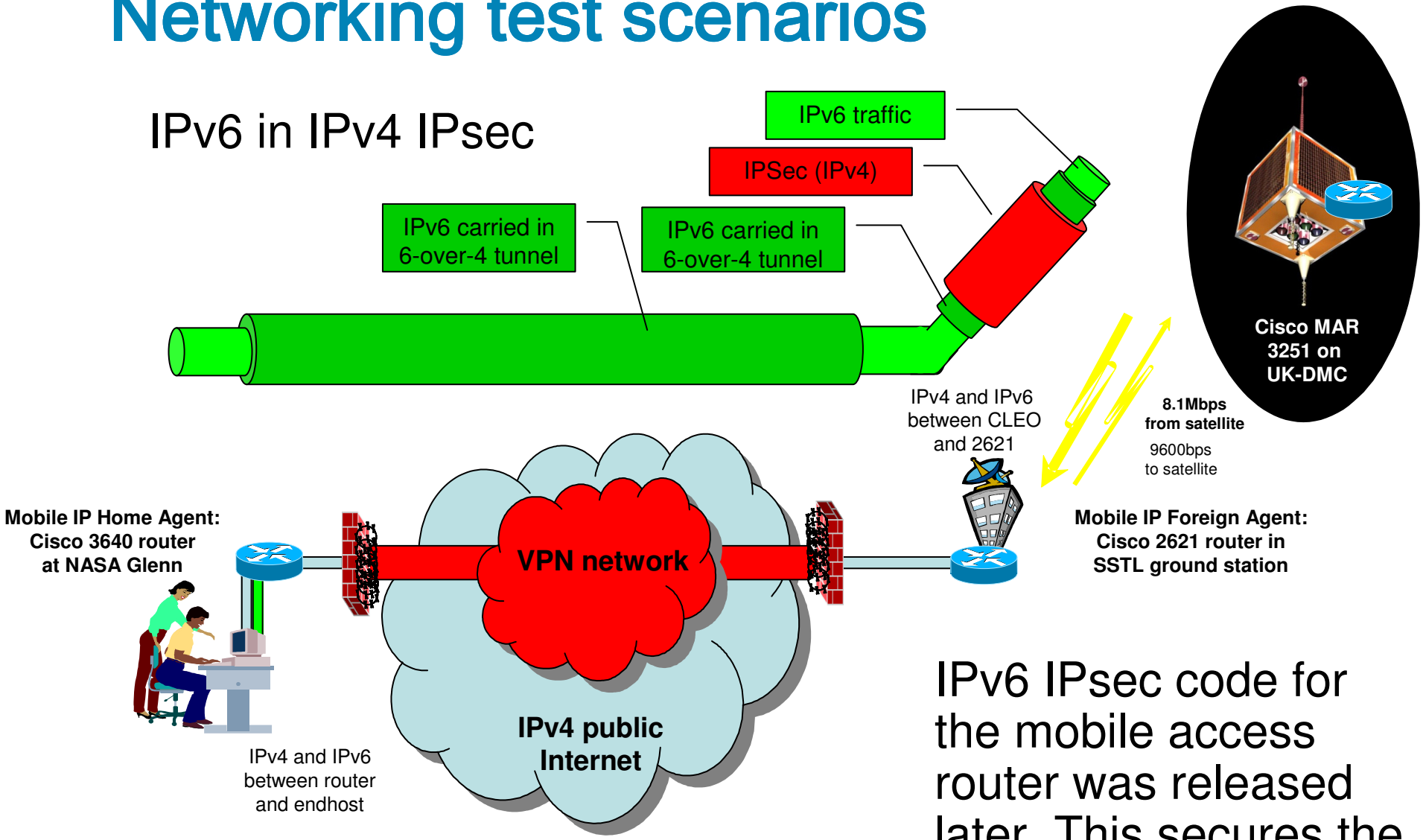
Mobile IPv6 code for the mobile access router came out after launch.

Networking test scenarios



IPv6 is run natively across the space link, in parallel with IPv4.

Networking test scenarios



IPv6 IPsec code for the mobile access router was released later. This secures the space link.

Why move satellites and infrastructure to IPv6?

- Because the US DoD says IPv6 is mandatory.
- NASA's Constellation project moving to IPv6.
- Available IPv4 address space is running out
  - will be depleted by 2010-2012.
- IPv6 advantages:
  - addressing improved, routing tables smaller/simpler.
  - NAT not (yet!) needed to integrate legacy networks.
  - IPsec is an integral part of IPv6, not an afterthought.
  - link-local addressing eases ad-hoc connectivity and dynamic routing for MANET.
  - Mobile IP becomes less messy.
  - Diffserv and per-flow stuff becomes easier to do.
  - Lots of little advantages, which all add together.

Limits to use of CLEO

As a secondary experimental payload, CLEO spends most of its time turned off. CLEO is only active when tested during passes over ground stations, or when used to transfer data between SSDRs.

The mobile router is a commercial product, not a space instrument. CLEO does not contain any special instrumentation for the space environment. CLEO does not measure cumulative radiation dosage.

SSTL does have some additional thermal and power draw instrumentation around the CLEO assembly motherboard.

Available satellite power is a constraint – CLEO is powered up for around ten minutes at a time during a daytime sunlit pass to communicate with ground station using high-speed 8.1Mbps downlink. CLEO needs ~10W. High-speed downlink needs ~10W. UK-DMC power budget is only ~30W.

Onboard software will not be upgraded – no plans to *ever* upload 6MB router IOS software over many passes via 9600bps uplink.

Status of CLEO

CLEO remains operational. IPv6 and IPsec are currently being tested. Collaboration between SSTL, NASA and Cisco is now leading to delay-tolerant networking work.

As a secondary experimental payload, use 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 save power.

CLEO has spent four years in orbit. Testing of CLEO has been carried out for over two years. CLEO has been powered up for use on more than ninety occasions.

further information:

http://www.cisco.com/go/space

http://www.ee.surrey.ac.uk/Personal/L.Wood/cleo/

Questions?

thankyou