EXECUTIVE SUMMARY
Secure, Network-Centric Operations of a Space-Based Asset: Cisco Router in Low-Earth Orbit (CLEO) and Virtual Mission Operations Center (VMOC)

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Executive Summary

This report documents the detailed communication network design and operations that resulted in a demonstration of the Office of the Secretary of Defense (OSD) space-based network-centric operations concepts and major elements of the National Reconnaissance Organization (NRO) Transformational Communication Architecture (TCA), using technology based around the Internet Protocol (IP). This report also illustrates that the broad functional intent of the Consultative Committee for Space Data Systems (CCSDS) Space Link Extension (SLE) was met. A key element of this demonstration was the ability to securely use networks and infrastructure owned and/or controlled by various parties.

On 27 September 2003, a Cisco Internet router (Cisco Systems, Inc., San Jose, CA) was launched into low Earth orbit onboard the UK–DMC disaster-monitoring satellite built by Surrey Satellite Technology Limited (SSTL, Guildford, UK). This router has since been successfully tested and demonstrated by an international government and private sector collaboration, showing how IP can be used to communicate with satellite payloads in space.

In June 2004, after lying dormant while the satellite's primary payloads were used, the router successfully completed a number of tests that demonstrate the effectiveness of IP communication to satellites.

While the satellite's primary purpose is to provide images of the environment on Earth, its onboard router is the focal point of a secondary payload, an experiment that involves a wide range of organizations, including Cisco Systems, SSTL, the U.S. National Aeronautics and Space Administration (NASA), the U.S. Air Force, the U.S. Army, General Dynamics Advanced Information Systems (Arlington, VA), Universal Space Network, Inc. (Horsham, PA), Western DataCom (Westlake, OH), and others. The router was used as the IP-compliant, space-based asset for the OSD Rapid Acquisition Net Centricity "virtual mission operations center" demonstration (VMOC, discussed in section 2.0 "Background"). This initiative was executed as a collaborative experiment between the Air Force, the Army, and NASA Glenn Research Center (GRC) in Cleveland, Ohio. Nautilus Horizon, IP-based software by General Dynamics, was used to acquire satellite telemetry, request images from SSTL's satellite dynamically, and perform real-time access to on-orbit satellite equipment (the Cisco router).

The Army and Air Force Battle Labs provided support and performed the overall metrics collection and evaluation as part of the OSD-sponsored VMOC effort. See

- Unruh, Nicholas D.: Virtual Mission Operations Center (VMOC) After Initiative Report. Air Force Space Battlelab, 2004. Available from the Department of Defense.
- Unruh, Nicholas D.: Opportunity Analysis for Virtual Mission Operations Center Web-Based Interface (VMOC WBi). Department of the Navy Business Innovation Team and Air Force Space Battlelab/Army Space and Missile Defense Battle Lab, 2004. Available from the Department of Defense.
- Schmitt, C.: VMOC Metrics Collection Data Report. Prepared for Contract DASG62–01–D–0003, 2004.
- Schmitt, C.L.; Groves, S.R.; and Tomasino, T.: Net-centric C2 in Near and Far Space. Proceedings of the 24th Army Science Conference, Orlando, Florida, 2004.
- Conner, B.P., et al.: Bringing Space Capabilities to the Warfighter: Virtual Mission Operations Center (VMOC). Proceedings of the 18th Annual AIAA/USU Small Satellite Conference, VMOC Paper SSC0–II–7, 2004.

The VMOC experiments occurred at Vandenberg Air Force Base in California from June 1 to 13, 2004, and ended with a three-day demonstration there on June 14, 15, and 16. The users at the remote battlefield operations center at Vandenberg requested images of specific areas of the Earth, which were taken by the satellite and delivered from SSTL using standard IP. The General Dynamics VMOC

application relied on mobile routing to communicate across the Internet via NASA GRC to SSTL's ground station and up to the Cisco router onboard the satellite. The VMOC application also monitored the health of the satellite using satellite telemetry information delivered over IP.

This VMOC demonstration serves as a blueprint for space-based network-centric operations and the Transformational Communication Architecture; VMOC is also intended for use with the TacSat-1 and TacSat-2 satellites. In addition, the interfaces developed to allow various organizations to share infrastructure (space and ground assets) meet all the functional requirements of the Consultative Committee for Space Data Systems (CCSDS) Space Link Extension (SLE), without relying upon the CCSDS protocol suite.

Cisco Systems' Global Defense, Space and Security group acted as a catalyst in bringing organizations in the defense, civil, and commercial worlds together to test and demonstrate its space-based router. NASA Glenn provided secure mobile networking expertise, was the network system integrator, and performed all preliminary tests leading to the successful router testing and VMOC experiments and demonstration. General Dynamics used Internal Research and Development funds to produce their VMOC software, Nautilus Horizon. Integral Systems, Inc. (Lanham, MD) also ran comparative testing of a pared-down VMOC in parallel with the General Dynamics VMOC.

Up until now, the space community has traditionally used purpose-built hardware. These tests represent a first demonstration of a generic commercial network device—a Cisco IP router—onboard a satellite in space. IP-based technologies and hardware can bring a number of benefits to satellite communications, including:

(1) Reducing the development/design time of satellite communication systems (both space- and ground-based)
(2) Increasing networking capabilities, thereby helping to enable secured remote access to cost-effective unmanned ground stations
(3) Improving satellites' ability to interoperate with ground stations and air and space systems by making satellites active nodes on the Internet.

NASA expects to save at least 25 percent of the cost of future spacecraft development by implementing architecture similar to the one tested with the VMOC. See

- Guo, G.: TRW: NASA Rapid II IP-Based Spacecraft Accommodation Study Final Report, 2000. Available from Phil Paulsen, NASA Glenn Research Center.
- Jackson, C.: SSTL: IP Accommodation Study Final Presentation, 2000. Available from Phil Paulsen, NASA Glenn Research Center.
- Laizbin, J.: Spectrum Astro: IP-Based Spacecraft Accommodation Study Final Presentation, 2000. Available from Phil Paulsen, NASA Glenn Research Center.
- Runge, H.: Orbital: Final Briefing IP-Based Spacecraft Accommodation Study, 2000. Available from Phil Paulsen, NASA Glenn Research Center.

The goal is to develop satellite systems that are as easy to integrate as networked printers, rather than to follow the difficult and different network paths encountered with today's non-IP-compliant systems. As the space and ground infrastructures merge, it becomes increasingly important that there is a common frame of reference—IP—to help enable end-to-end quality of service and a common framework for management. NASA also expects significant operations improvements with the full-scale adoption of IP, such as rapid adaptation to change, improved interoperability, and end-to-end security (where required).