



International Telecommunication Union

NASA's IP-over-Satellite Technology Development

Andrew Z. Downen

Data Standards Program Office Mgr., NASA

Robert C. Durst

The MITRE Corporation

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Topics

- o Briefing purpose
- o Motivation
- o Activities
- o Results
- o Issues
- o Conclusions



Briefing Purpose

- o To review NASA's development activities related to the use of Internet technologies...
 - For communication with a spacecraft (Mission Operations)
 - For communication via a spacecraft (SATCOM)



Background and Motivation

- Motivation for Internet communication *with* a spacecraft
 - Hypothesis 1: Internet/Intranet interfaces to spacecraft will simplify spacecraft bus and payload development and test
 - Hypothesis 2: Internet/Intranet access to spacecraft will reduce operations costs
 - Hypothesis 3: Internet/Intranet access to spacecraft will improve the quality, quantity, and timeliness of science data



Background and Motivation (Cont.)

- o Motivation for Internet communication *via* spacecraft
 - Satellite communications to remote regions
 - Exploitation of broadcast technology

NASA has been working to establish and optimize Internet communication *with* spacecraft and *via* spacecraft since 1992

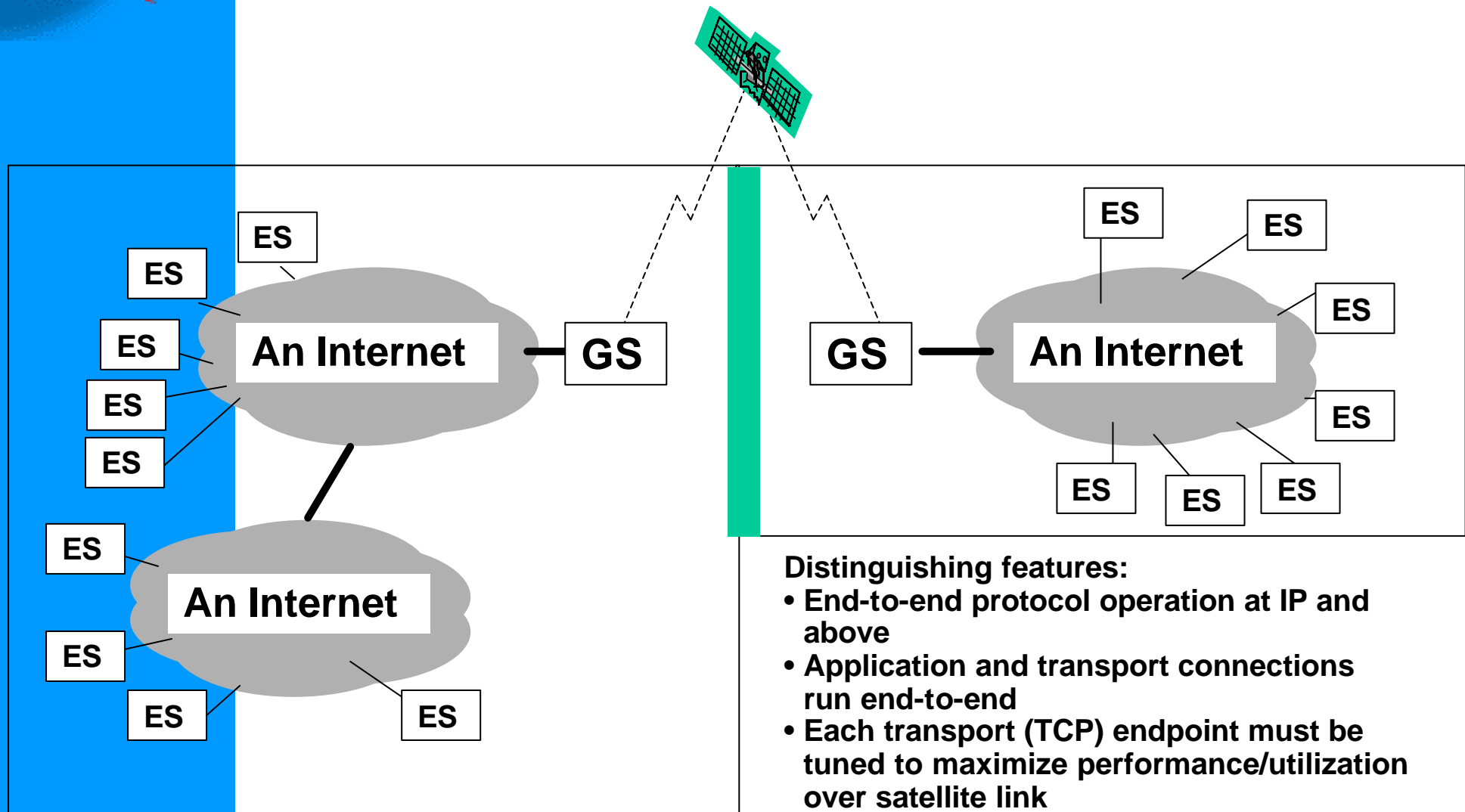


Activities

- o Architectural alternatives
- o Protocol development and tuning
- o Commercial product development
- o Commercial product integration
- o Operations concept development
- o Testing / Demonstrations



Architectural Alternative: End-to-End Architecture



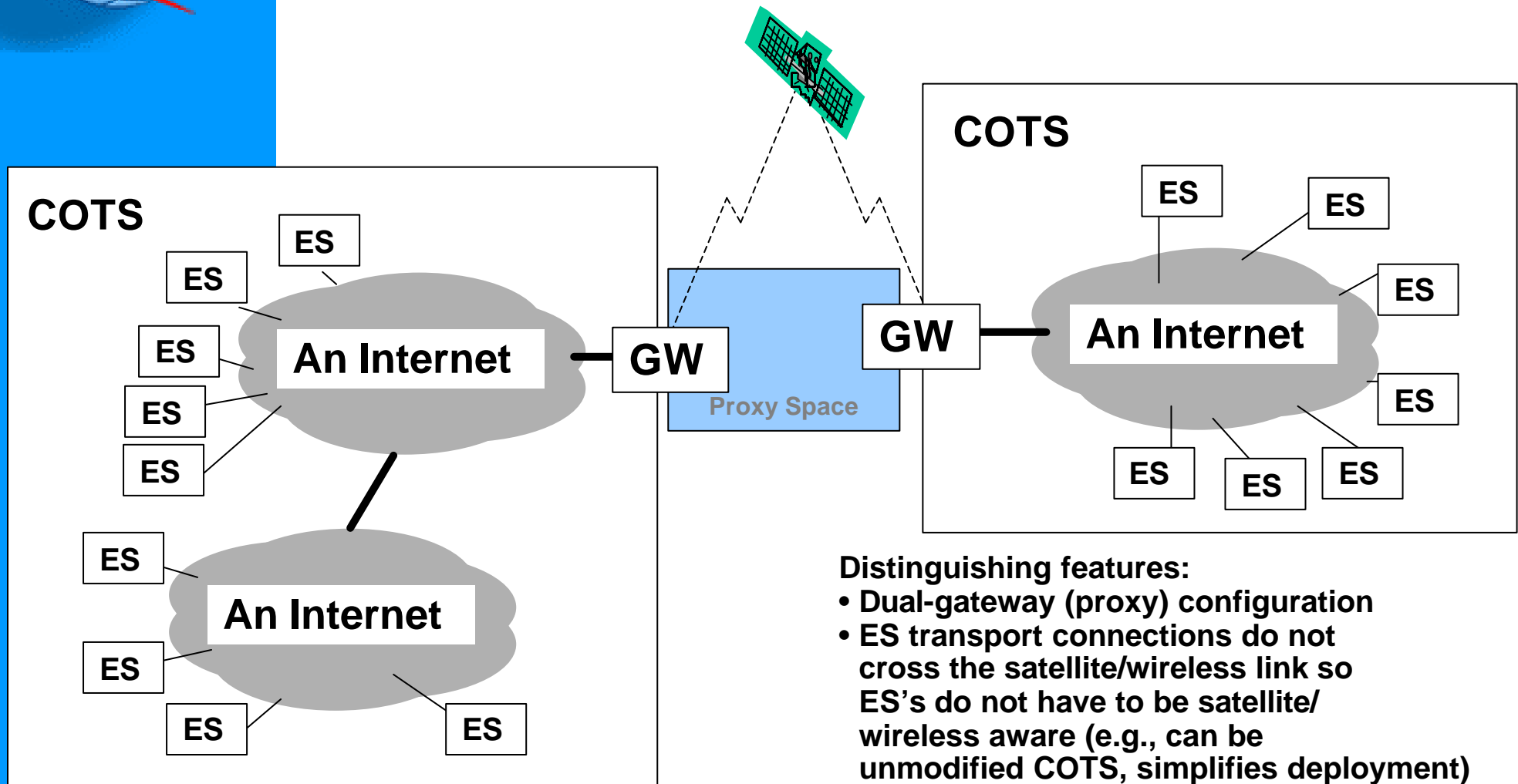
ES = End System
GS = Ground Station

Distinguishing features:

- End-to-end protocol operation at IP and above
- Application and transport connections run end-to-end
- Each transport (TCP) endpoint must be tuned to maximize performance/utilization over satellite link
- Tunings for satellite link may be inappropriate for terrestrial links



Architectural Alternative: Proxy-Based Architecture



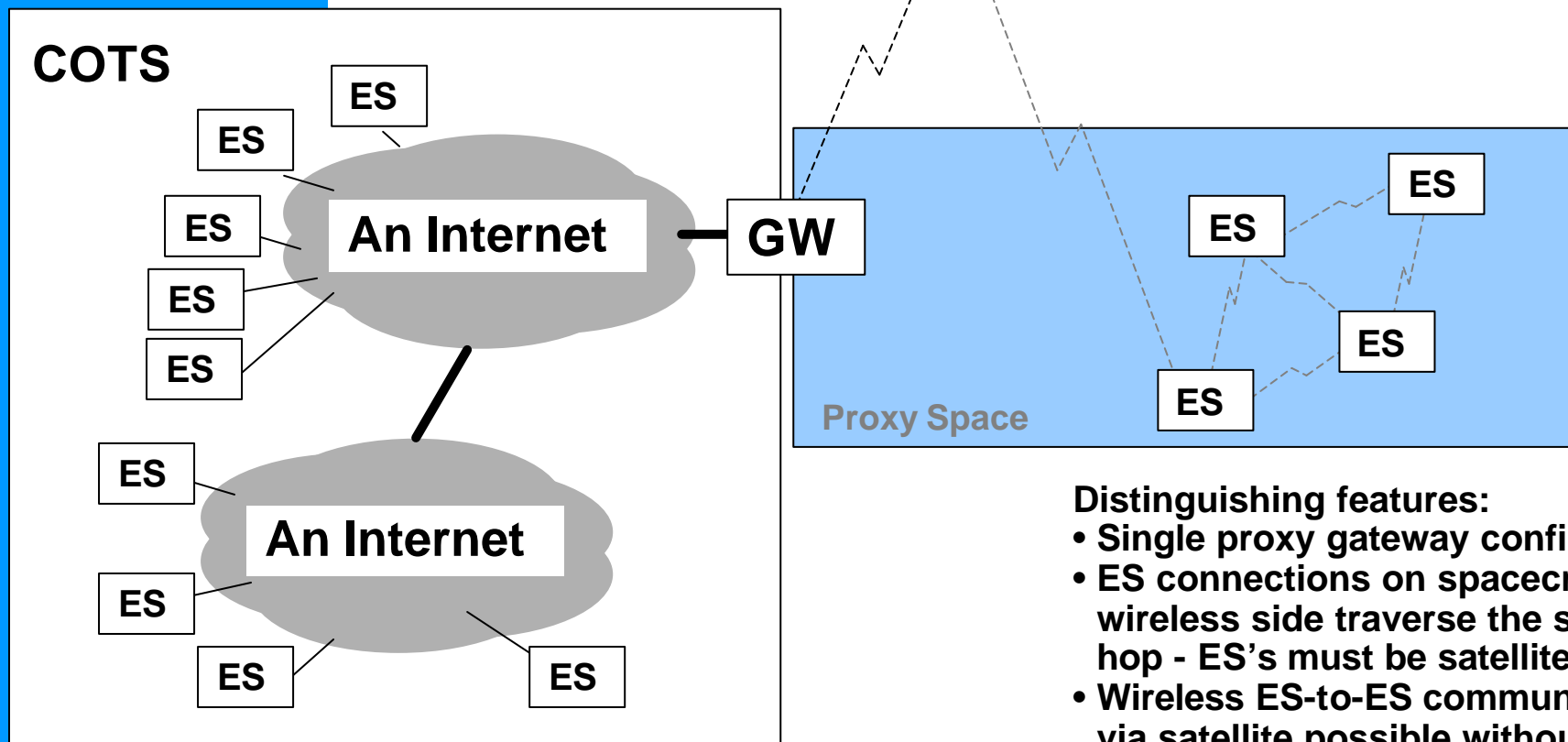
ES = End System
GW = Transport Layer Gateway (Proxy)

Distinguishing features:

- Dual-gateway (proxy) configuration
- ES transport connections do not cross the satellite/wireless link so ES's do not have to be satellite/wireless aware (e.g., can be unmodified COTS, simplifies deployment)
- Application layer connections run end-to-end
- Security above transport or via trusted gateways



Architectural Alternative: Hybrid Proxy Architecture



ES = End System
GW = Transport Layer Gateway (Proxy)

Distinguishing features:

- Single proxy gateway configuration
- ES connections on spacecraft/
wireless side traverse the satellite
hop - ES's must be satellite aware
- Wireless ES-to-ES communication
via satellite possible without GW's
- Suitable for constellations or onboard
use



Activities: Protocol Development and Tuning

- SCPS
 - FTP and TCP extensions
 - Security and network layer protocol definitions
 - Performance enhancing proxies
- ACTS
 - TCP tuning for end-to-end operation over high speed satellite channels
- Quality of Service
 - Integrated Services to SC (RSVP extensions for TCP proxy gateways)



Activities: Commercial Product Development Support

- SCPS Reference Implementation
 - End-system configuration
 - TCP Performance Enhancing Proxy (PEP) configuration
- CISCO Mobile Router
 - Enhancement to CISCO's Mobile IP software in a variety of their routers
- Consultative Committee for Space Data Systems (CCSDS) Device Driver for Linux
 - CCSDS TC/TM over Ethernet / serial



Activities: COTS/GOTS Product Integration

- Custom IP Router-to-Satellite Modem interface box (Ground-Station Router Interface Device)
 - Performs custom (not standard CCSDS/ISO) Reed-Solomon encoding/decoding of HDLC-framed space link traffic
- Linux PC/RS-422 to ITT/AES Low Power Transceiver (IP over HDLC)
 - Onboard analog of above, to be flown as part of CANDOS experiment on STS-107
- Internet Key Exchange (IKE) integrated with SCPS TCP Performance Enhancing Proxies



Activities: Operations Concept Development

- “FlatSAT” activities defined notional operations concepts for Internet interaction with spacecraft
 - Instrument to Command and Data Handling Subsystem
 - Onboard storage to ground (telemetry)
 - Mission Operations Center to Command and Data Handling
 - Instrument commanding
 - Spacecraft initiated communication



Activities: Testing and Demonstrations

- o SATCOM Testing
 - ACTS OC-12 (622 Mbps) satellite testbed for testing and tuning of high-speed Internet-over-satellite products
 - SCPS SATCOM testing on M22 hosted by USAF Space and Missile Systems Command and over ACTS hosted by US Air Force Research Lab



Results to date

- o Standards
 - ISO/CCSDS Space Link Extension service allows replacement of NASCOM custom 4800-bit block network with standard TCP/IP-based networks (underway)
 - ISO/CCSDS/MIL standards for SCPS protocols and enhancements
 - IETF Best Common Practice on TCP tuning (RFC 2488 / BCP 28)



Issues

- Benefits of Internet spacecraft operation over current practices need to be demonstrated/quantified
 - Reliance on automation *may* significantly reduce operations costs and increase flexibility
 - “Lights-out” control centers
 - Elimination of level zero processing



Issues (Cont.)

- Cost saving resulting from change must offset ROI of incumbent approach with acceptable risk
 - Is a below-IP hardware commanding capability (still) required? Not present on CHIPSAT; present with IP over CCSDS TC/TM
- Acceptance will require/cause cultural change
- Operations concepts and architecture for end-to-end Internet-based mission operations have not been well-articulated or agreed to by the mission operations community



Observations

- For communication *with* a satellite, to some extent, a technology looking for a need
 - Consistent with NASA Code-Y Strategy to shift from “technology derived from missions to missions enabled by technology”



Observations (Cont.)

- o NASA's IP-in-space efforts have produced significant spin-off products
 - Benefit to SATCOM and mobile/wireless industries
 - Continued work with similar environments (SATCOM/mobile/wireless) can produce mature technologies for use when need arises



Conclusions

- For communicating *with* a satellite, NASA has technology waiting for mission requirements and operations culture to evolve

- For communicating *via* a satellite, NASA's technology contribution has been considerable
 - Is there a way for NASA's mainstream missions to benefit?



Conclusions (Cont.)

- o Feedback requested: Is continued near-term investment in these technologies beneficial?
 - Should NASA continue to spend its research money here?



Support Slides



Activities: Protocol Development and Tuning (Cont.)

- Mobile IP Extensions
 - Registration acceleration (Ground station registers on behalf of all spacecraft endpoints)
 - Mobile router -- Mobile IP registration of a subnet router
- Quality of Service
 - Integrated Services to Spacecraft (RSVP extensions for TCP proxy gateways)



Activities: Testing and Demonstrations (Cont.)

- o STRV 1b
 - FTP/TCP/SCPS-TP testing on UK Defence Research Agency Satellite
- o Mobile Router
 - Field trial of mobile router using US Coast Guard ship, 802.11 and commercial satellite service



Activities: Testing and Demonstrations (Cont.)

- UoSAT-12
 - Internet stack testing on Surrey Satellite, including NTP, FTP, UDP, multicast file transfer (MDP)
- CANDOS
 - Shuttle payload to test Mobile IP to SC



Results to date (Cont.)

- Products
 - Refinements to commercial Internet implementations for satellite paths resulting from ACTS testing
 - Open standard SCPS protocols and proxies
 - Proprietary CISCO Mobile Router
 - SkipWare and XipLink
- Interstellar Plasma Spectrometer mission (launch Dec 02)



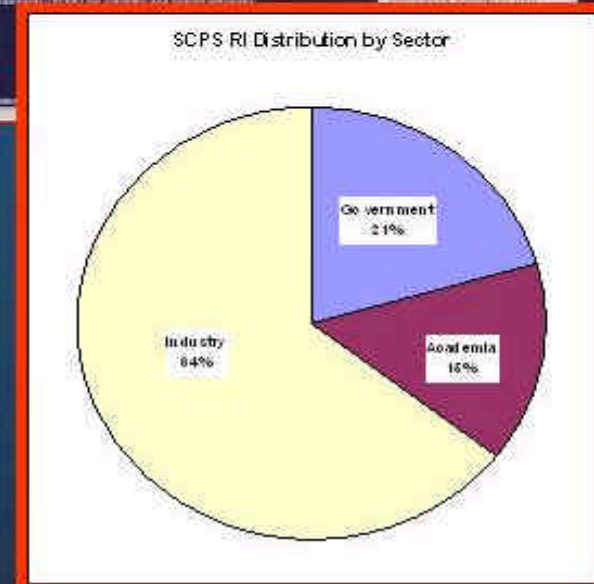
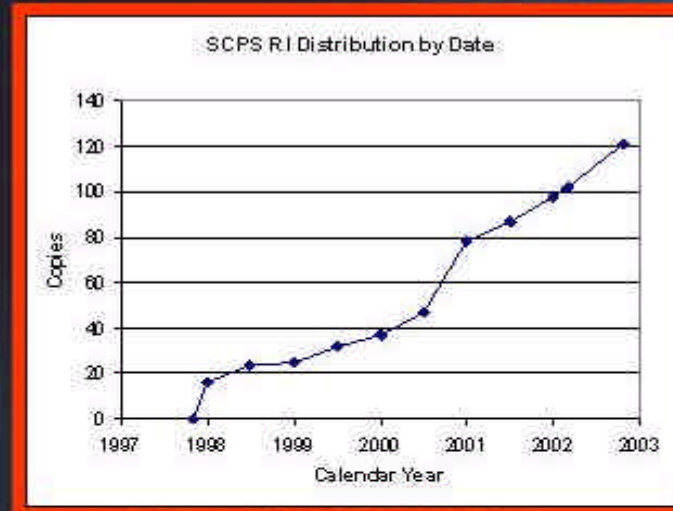
Results to date (Cont.)

- Mission(s)
 - CHIPS/CHIPSat mission -- Internet-only spacecraft bus built by SpaceDev for UC-Berkeley Cosmic Hot



Results to date (Cont.)

SCPS Reference Software





Results to date (Cont.)

A large graphic titled 'CCSDS: The Fleet' showing a vast number of satellites and spacecraft orbiting Earth. The CCSDS logo is prominently displayed in the center. Text in the center reads: '245 Missions now using CCSDS Space Link Protocols' and 'http://ccsds.gst.com/implementations'. There are two inset boxes: one in the top right labeled 'Space Domain' listing 'Spacecraft Platforms', 'On-Board Systems', and 'Space Qualified ASICs'; and one in the bottom left labeled 'Ground Domain' listing 'Commercial Ground Networks' and 'Command & Telemetry Data Processing'. The background shows a detailed view of Earth from space with various satellite constellations and individual spacecraft labeled with names like 'GPS-1', 'GPS-2', 'GPS-3', 'GPS-4', 'GPS-5', 'GPS-6', 'GPS-7', 'GPS-8', 'GPS-9', 'GPS-10', 'GPS-11', 'GPS-12', 'GPS-13', 'GPS-14', 'GPS-15', 'GPS-16', 'GPS-17', 'GPS-18', 'GPS-19', 'GPS-20', 'GPS-21', 'GPS-22', 'GPS-23', 'GPS-24', 'GPS-25', 'GPS-26', 'GPS-27', 'GPS-28', 'GPS-29', 'GPS-30', 'GPS-31', 'GPS-32', 'GPS-33', 'GPS-34', 'GPS-35', 'GPS-36', 'GPS-37', 'GPS-38', 'GPS-39', 'GPS-40', 'GPS-41', 'GPS-42', 'GPS-43', 'GPS-44', 'GPS-45', 'GPS-46', 'GPS-47', 'GPS-48', 'GPS-49', 'GPS-50', 'GPS-51', 'GPS-52', 'GPS-53', 'GPS-54', 'GPS-55', 'GPS-56', 'GPS-57', 'GPS-58', 'GPS-59', 'GPS-60', 'GPS-61', 'GPS-62', 'GPS-63', 'GPS-64', 'GPS-65', 'GPS-66', 'GPS-67', 'GPS-68', 'GPS-69', 'GPS-70', 'GPS-71', 'GPS-72', 'GPS-73', 'GPS-74', 'GPS-75', 'GPS-76', 'GPS-77', 'GPS-78', 'GPS-79', 'GPS-80', 'GPS-81', 'GPS-82', 'GPS-83', 'GPS-84', 'GPS-85', 'GPS-86', 'GPS-87', 'GPS-88', 'GPS-89', 'GPS-90', 'GPS-91', 'GPS-92', 'GPS-93', 'GPS-94', 'GPS-95', 'GPS-96', 'GPS-97', 'GPS-98', 'GPS-99', 'GPS-100', 'GPS-101', 'GPS-102', 'GPS-103', 'GPS-104', 'GPS-105', 'GPS-106', 'GPS-107', 'GPS-108', 'GPS-109', 'GPS-110', 'GPS-111', 'GPS-112', 'GPS-113', 'GPS-114', 'GPS-115', 'GPS-116', 'GPS-117', 'GPS-118', 'GPS-119', 'GPS-120', 'GPS-121', 'GPS-122', 'GPS-123', 'GPS-124', 'GPS-125', 'GPS-126', 'GPS-127', 'GPS-128', 'GPS-129', 'GPS-130', 'GPS-131', 'GPS-132', 'GPS-133', 'GPS-134', 'GPS-135', 'GPS-136', 'GPS-137', 'GPS-138', 'GPS-139', 'GPS-140', 'GPS-141', 'GPS-142', 'GPS-143', 'GPS-144', 'GPS-145', 'GPS-146', 'GPS-147', 'GPS-148', 'GPS-149', 'GPS-150', 'GPS-151', 'GPS-152', 'GPS-153', 'GPS-154', 'GPS-155', 'GPS-156', 'GPS-157', 'GPS-158', 'GPS-159', 'GPS-160', 'GPS-161', 'GPS-162', 'GPS-163', 'GPS-164', 'GPS-165', 'GPS-166', 'GPS-167', 'GPS-168', 'GPS-169', 'GPS-170', 'GPS-171', 'GPS-172', 'GPS-173', 'GPS-174', 'GPS-175', 'GPS-176', 'GPS-177', 'GPS-178', 'GPS-179', 'GPS-180', 'GPS-181', 'GPS-182', 'GPS-183', 'GPS-184', 'GPS-185', 'GPS-186', 'GPS-187', 'GPS-188', 'GPS-189', 'GPS-190', 'GPS-191', 'GPS-192', 'GPS-193', 'GPS-194', 'GPS-195', 'GPS-196', 'GPS-197', 'GPS-198', 'GPS-199', 'GPS-200', 'GPS-201', 'GPS-202', 'GPS-203', 'GPS-204', 'GPS-205', 'GPS-206', 'GPS-207', 'GPS-208', 'GPS-209', 'GPS-210', 'GPS-211', 'GPS-212', 'GPS-213', 'GPS-214', 'GPS-215', 'GPS-216', 'GPS-217', 'GPS-218', 'GPS-219', 'GPS-220', 'GPS-221', 'GPS-222', 'GPS-223', 'GPS-224', 'GPS-225', 'GPS-226', 'GPS-227', 'GPS-228', 'GPS-229', 'GPS-230', 'GPS-231', 'GPS-232', 'GPS-233', 'GPS-234', 'GPS-235', 'GPS-236', 'GPS-237', 'GPS-238', 'GPS-239', 'GPS-240', 'GPS-241', 'GPS-242', 'GPS-243', 'GPS-244', 'GPS-245'.

CCSDS:
The Fleet

CCSDS
Consultative Committee for Space Data Systems

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Space Domain
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