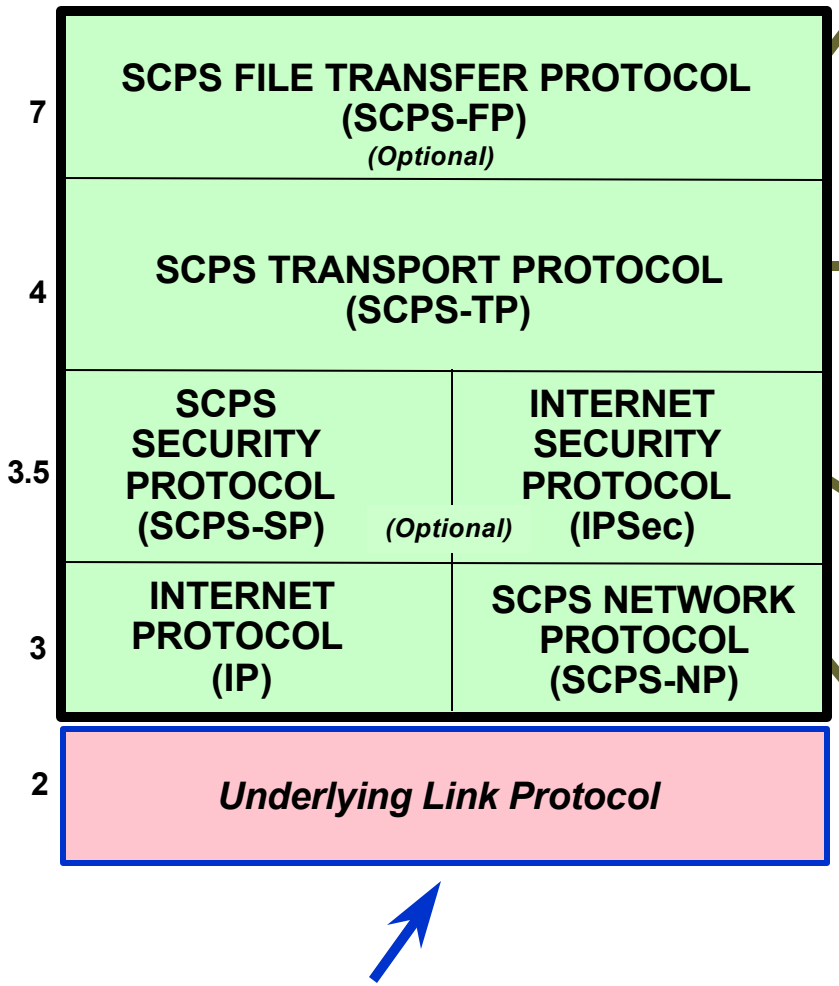
Space Communications Protocol Standards -- Capabilities and Software

Robert C. Durst
The MITRE Corporation

22 February 2001

MITRE

SCPS Capabilities



FTP +/-

- Record read & record update;
- File & record Integrity;
- Automatic restart;
- User suspend/resume;
- Suppress ASCII reply codes.

TCP/UDP+/-

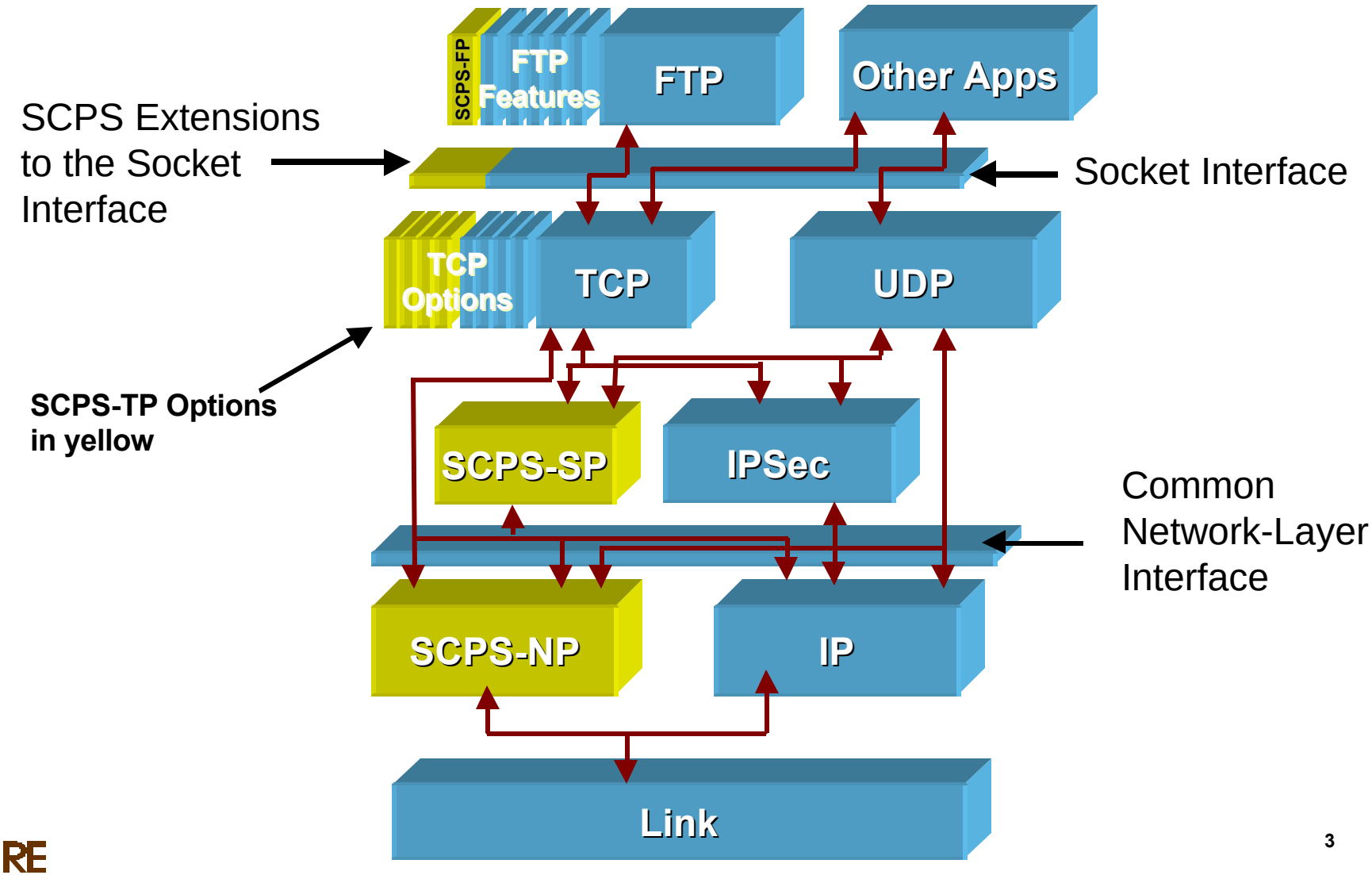
- Congestion control appropriate for mixed-loss environments (congestion, corruption, outage);
- Selective negative acknowledgment;
- Robust header compression;
- RFC 1323 window scaling;
- Partial Reliability service (BETS);
- Delimitation of record boundaries;
- RFC 1323 timestamps for high rate sequencing, delay measurement.

- Authentication: guarantee of the identity of a source;
- Access Control: prevention of unauthorized access;
- Integrity: protection against modification;
- Confidentiality: protection from disclosure.

- Provide both connectionless and managed-connection routing;
- Support precedence (priority) based handling;
- Offer multiple routing options;
- Signal errors to the layer above;
- Support packet lifetime control;
- Scalable - tailor capability to need, e.g., high communications efficiency in constrained bandwidth conditions.

SCPS sits on top of existing link capabilities, and augments them

SCPS Protocols -- Layering Options



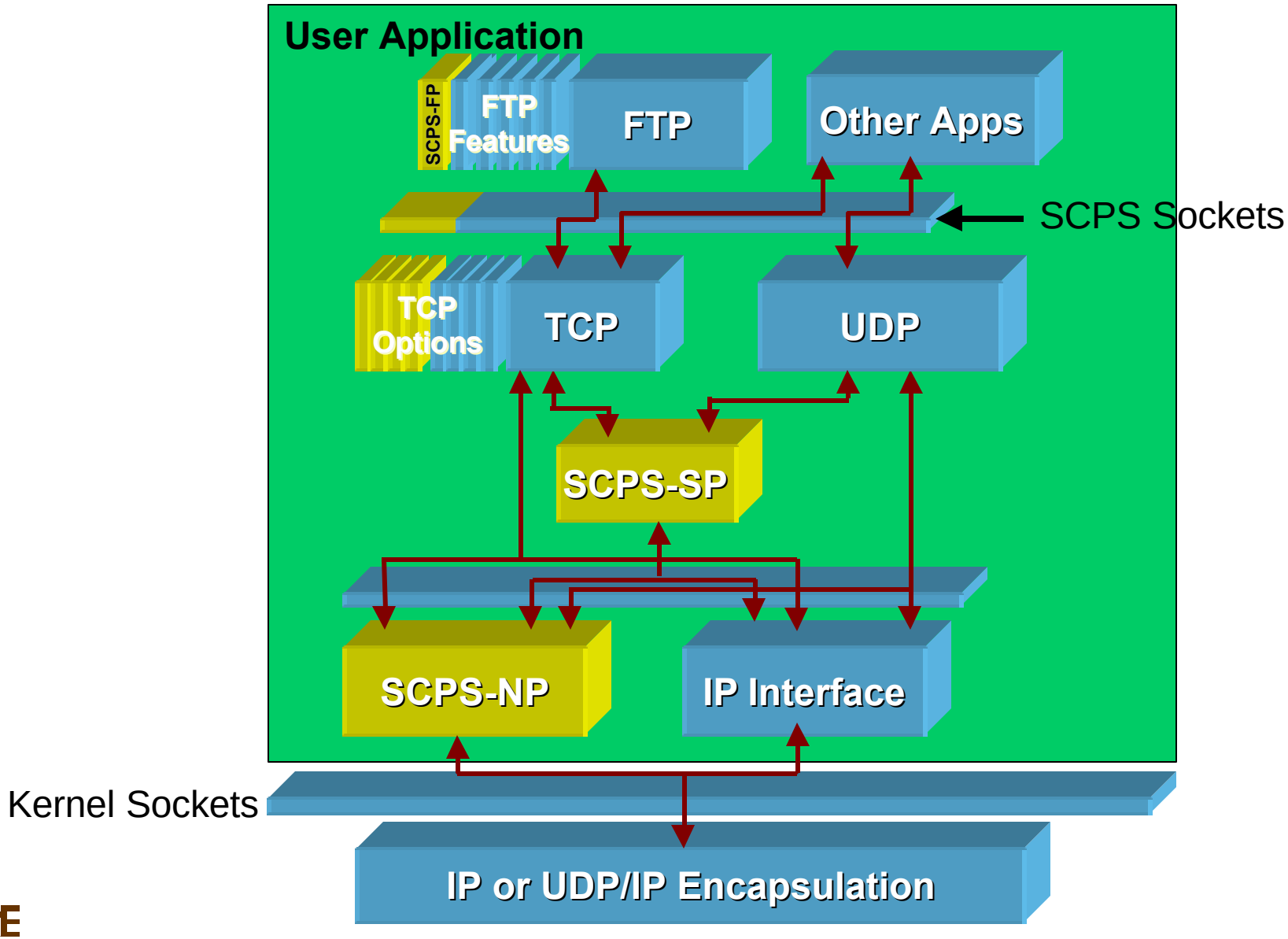
SCPS Reference Implementation

- The SCPS protocols have been implemented as an application that runs on most Unix platforms
  - Software is freely available to all interests (no longer export controlled)
  - Copies distributed to commercial, academic, and government organizations
- Commercialization activities
  - Avtec Systems - commercial SCPS satellite ground systems and SCPS transport layer gateway
  - Major Spacecraft Bus Contractor “1” - building VxWorks-based version of SCPS protocols for spacecraft on-board OS
  - Major Aerospace Contractor “2” - Building VxWorks-based stack for military use
  - Major Aerospace Contractor “3” - testing SCPS Gateway for commercial UHF SATCOM

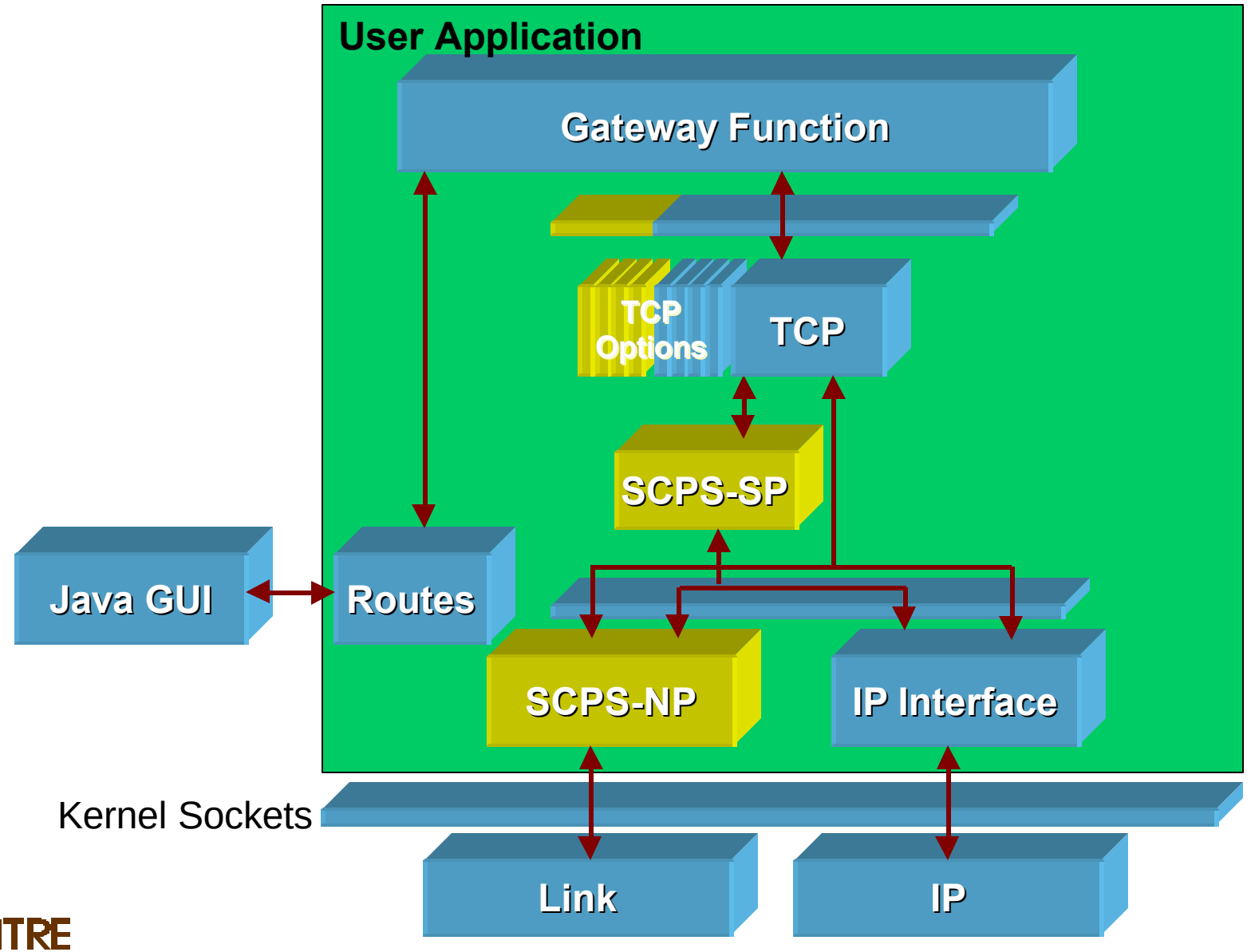
Reference Implementation - Capabilities

- End-system configuration
  - Application-space implementation: primarily an evaluation tool
  - Implementations of the FP, TP, SP, NP (and interface to IP)
  - Simple test applications
  - Configuration scripts to set various host and configuration defaults
  - Portable across most UNIX systems
- Protocol-translating transport-layer gateway configuration
  - TCP-to-TP conversion
  - UDP pass through (with rate control)
  - Optional use of SP
  - Either IP or IP-to-NP conversion
  - FreeBSD or Linux (with Divert sockets)
  - Java Graphical User Interface to configure gateway rules

SCPS Reference Implementation Options: End System Configuration



SCPS Reference Implementation Options: Transport Layer Gateway Configuration



SCPS Reference Implementation Distribution

- Unrestricted distribution as of July 2000
  - 13 non-US requesters to date
- 79 total copies of the SCPS Reference Implementation distributed (does not include updates) as of 8 Jan 2001
  - Industry: 46
  - Academia: 10
  - Government: 23

Contact Information:

Robert C. Durst
The MITRE Corporation
durst@mitre.org
+1 703 883-7535 voice
+1 703 883-7142 fax

Backup Information: SCPS Overview

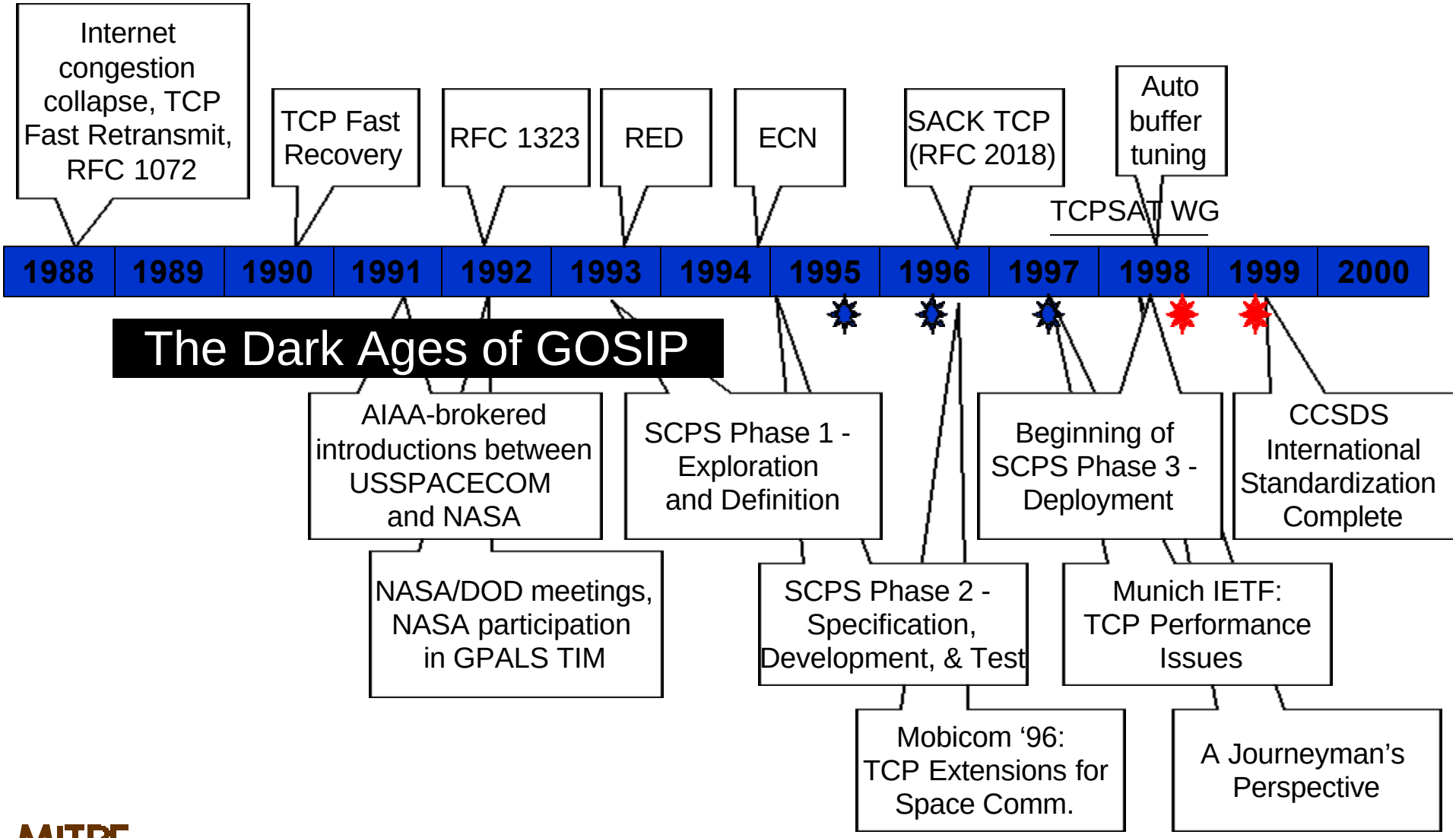
Robert C. Durst
The MITRE Corporation
durst@mitre.org
+1 703 883-7535 voice
+1 703 883-7142 fax

MITRE

Agenda

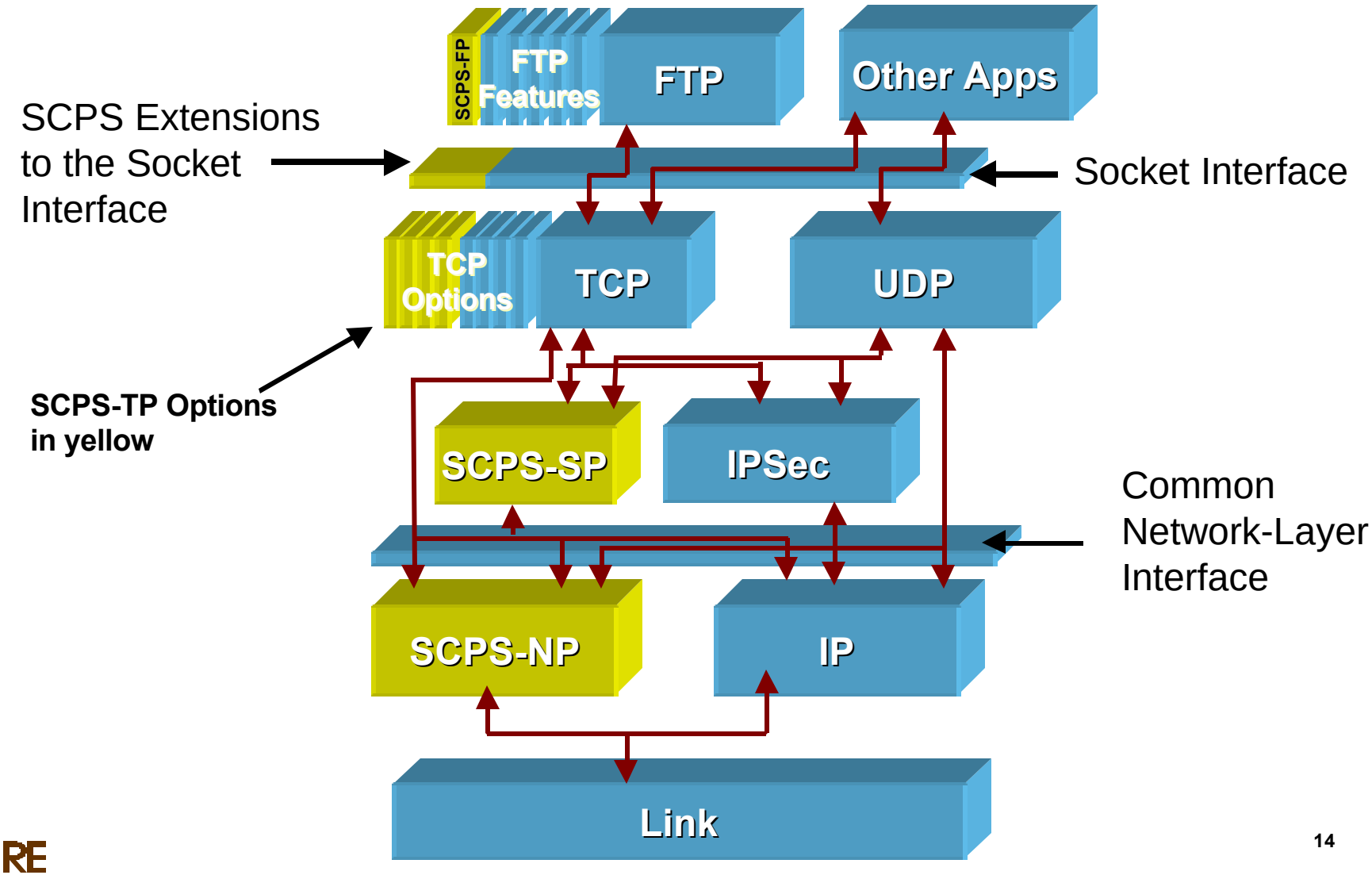
- SCPS Capabilities and Layers
  - Layering options and key protocol relationships
  - Capabilities by layer
- SCPS Software
  - Reference Implementation
  - Independent implementations
  - Testing

SCPS Development Timeline

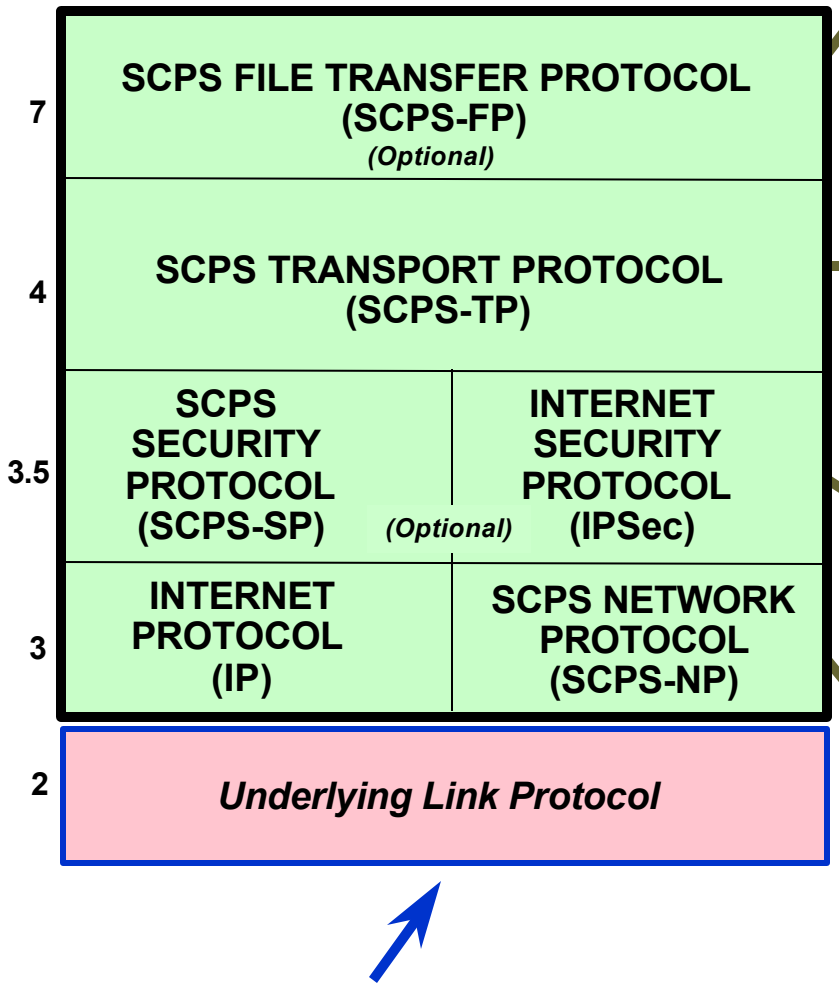


SCPS Capabilities and Layers

SCPS Protocols -- Layering Options



SCPS Capabilities



FTP +/-

- Record read & record update;
- File & record Integrity;
- Automatic restart;
- User suspend/resume;
- Suppress ASCII reply codes.

TCP/UDP+/-

- Congestion control appropriate for mixed-loss environments (congestion, corruption, outage);
- Selective negative acknowledgment;
- Robust header compression;
- RFC 1323 window scaling;
- Partial Reliability service (BETS);
- Delimitation of record boundaries;
- RFC 1323 timestamps for high rate sequencing, delay measurement.

- Authentication: guarantee of the identity of a source;
- Access Control: prevention of unauthorized access;
- Integrity: protection against modification;
- Confidentiality: protection from disclosure.

- Provide both connectionless and managed-connection routing;
- Support precedence (priority) based handling;
- Offer multiple routing options;
- Signal errors to the layer above;
- Support packet lifetime control;
- Scalable - tailor capability to need, e.g., high communications efficiency in constrained bandwidth conditions.

SCPS sits on top of existing link capabilities, and augments them

SCPS Network Protocol: Key Features

- 4-octet minimum header size, increases only to support required options (on per-packet basis)
- Addressing - Transport interface is via *IP Addresses*
  - Available translations for bandwidth efficiency:
    - "Flow ID" style (1 byte)
    - Short source and destination (1 byte each)
  - If translation not defined, regular addresses shipped
- Precedence - 16 levels (independent of IP TOS field)
- Routing - different routing treatments selectable per packet (e.g., standard, flood)
- IP TOS Field supported
- Enhanced network control functions

Important Differences Between SCPS-NP and IP

- SCPS-NP has 8191-byte packet size limit and no fragmentation
- SCPS-NP has max of 16 upper-layer protocols identifiable
- SCPS-NP has 16 levels of precedence, independent of TOS field
- SCPS-NP's version of ICMP (SCMP) supports explicit signaling of congestion, corruption, and link outage (requires information from link layer)

SCPS Security Protocol

- Resides above SCPS-NP or IP

- Developed under NSA sponsorship by SPARTA
  - Originally conceived for Brilliant Eyes/Brilliant Pebbles
  - Major design driver was reduction in header overhead - ruled out use of existing Internet protocols such as IPSec

Security Protocol Capabilities Comparison

Capability	SCPS SP	IP SEC	Remarks
• Confidentiality	•	•	
• Integrity	•	•	
• Authentication	•	•	
• Access Control	•	•	
• Replay Protection		•	SP uses transport sequence numbers
• Multiple security associations per address pair		•	Omitted for bit-efficiency

SCPS Transport Protocol

- SCPS-TP is TCP, with extensions, and UDP
  - TCP extensions developed to improve performance in tetherless environments
  - Additional services defined to support enhanced operations modes
  - Fully interoperable with existing TCPs - enhanced capabilities signaled by TCP options on connection establishment
- SCPS extensions developed for spacecraft communication
  - Equally applicable to SATCOM, low bandwidth, and/or error-prone environments
  - Rate control capability applicable in bandwidth-reserved environments (e.g. integrated services)

SCPS-TP Enhancements to TCP

- Congestion control alternatives:
  - "Standard" TCP (RFC 2001)
  - Adaptations of TCP-"Vegas" congestion avoidance
  - Rate control (with or without other congestion control)
- Selective Negative ACK
- Explicit corruption and link outage responses
- Loss-tolerant header compression
- Partial reliability service
- Record boundary marking

Major SCPS-TP Enhancements to TCP

- Congestion control alternatives:
  - Standard TCP (RFC 2001)
  - TCP-Vegas
    - Avoids congestion loss by measuring queuing
  - Rate control
    - Available in combination with RFC 2001 or Vegas
    - Can be used solo -- ideal for layering over Dynamic QOS RSVP enhancements (ongoing research) or between SCPS gateways over dedicated capacity link

Major SCPS-TP Enhancements to TCP (Continued)

- Error recovery modifications
  - Selective NACK defined
    - More bandwidth-efficient than SACK
    - Doesn't require 3 duplicate ACKs to invoke retransmission
  - Explicit corruption and link outage responses defined
    - Corruption response doesn't reduce transmission rate
    - Link outage response invokes zero-window probe (persist)
    - Coupled to network-layer signals
  - Can configure TCP-Vegas congestion control to not assume loss is a signal of congestion
    - Uses queueing and explicit congestion notification as indications of congestion

Major SCPS-TP Enhancements to TCP (Continued)

- Additional enhancements
  - Loss-tolerant header compression
    - Operates end-to-end - integrated with TCP state machine - multi-hop does not require decompression/recompression
    - Does not lose synchronization when packets are lost
  - Record boundary marking
    - Adds an option to delimit the end of a record, preserved appropriately across segmentation and reassembly
  - Partial Reliability Service
    - In-sequence, correct, possibly incomplete
    - Sender controls retransmission attempts, just “moves on” if retransmission count exceeded

SCPS-File Protocol

- Standard FTP with enhancements
  - Record Read
  - Record Update
  - Autorestart
  - Manual Interrupt
  - Suppression of Reply Text

SCPS Software

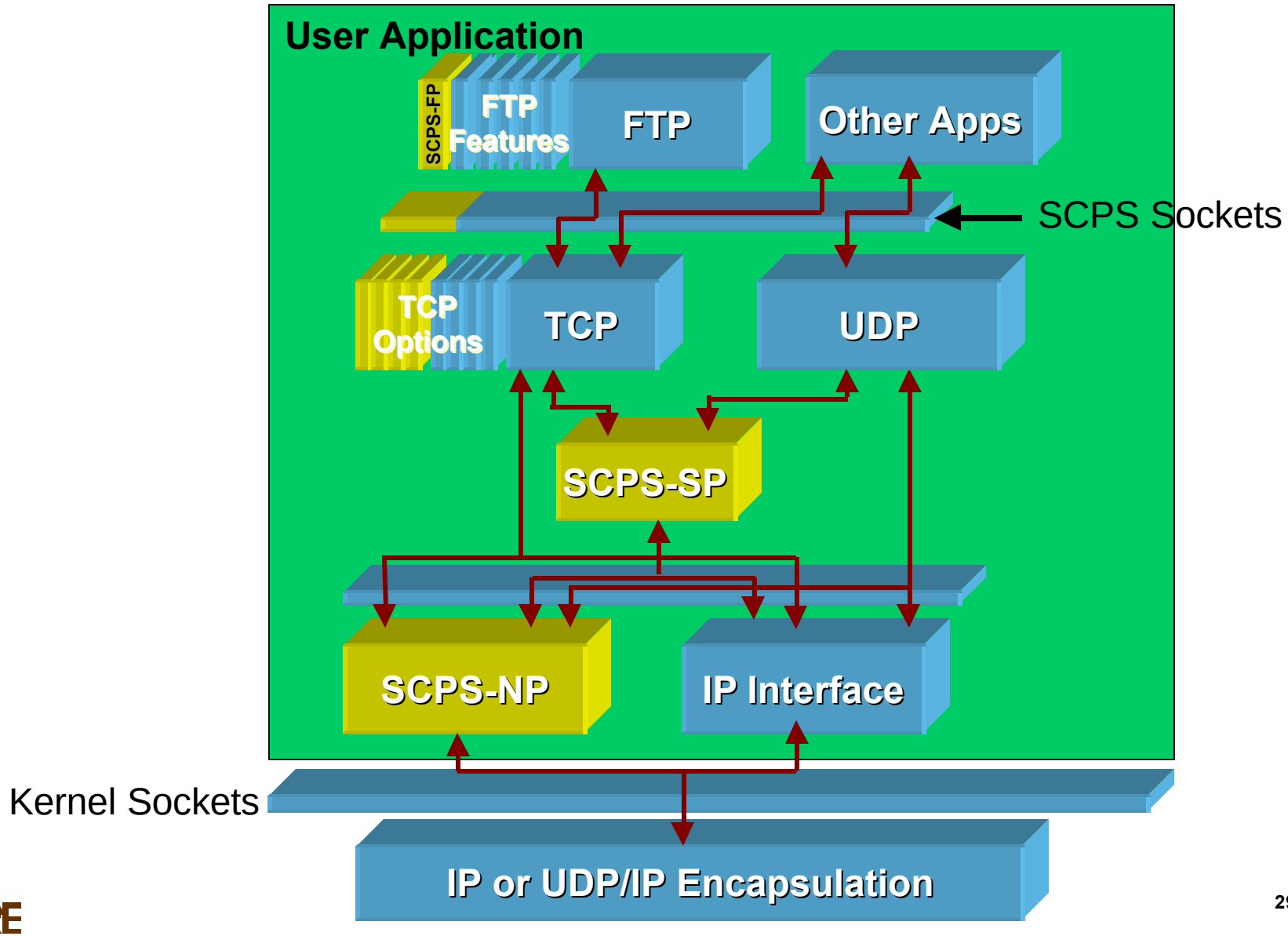
SCPS Reference Implementation

- The SCPS protocols have been implemented as an application that runs on most Unix platforms
  - Software is freely available to all interests (no longer export controlled)
  - Copies distributed to commercial, academic, and government organizations
- Commercialization activities
  - Avtec Systems - commercial SCPS satellite ground systems and SCPS transport layer gateway
  - Major Spacecraft Bus Contractor “1” - building VxWorks-based version of SCPS protocols for spacecraft on-board OS
  - Major Aerospace Contractor “2” - Building VxWorks-based stack for military use
  - Major Aerospace Contractor “3” - testing SCPS Gateway for commercial UHF SATCOM

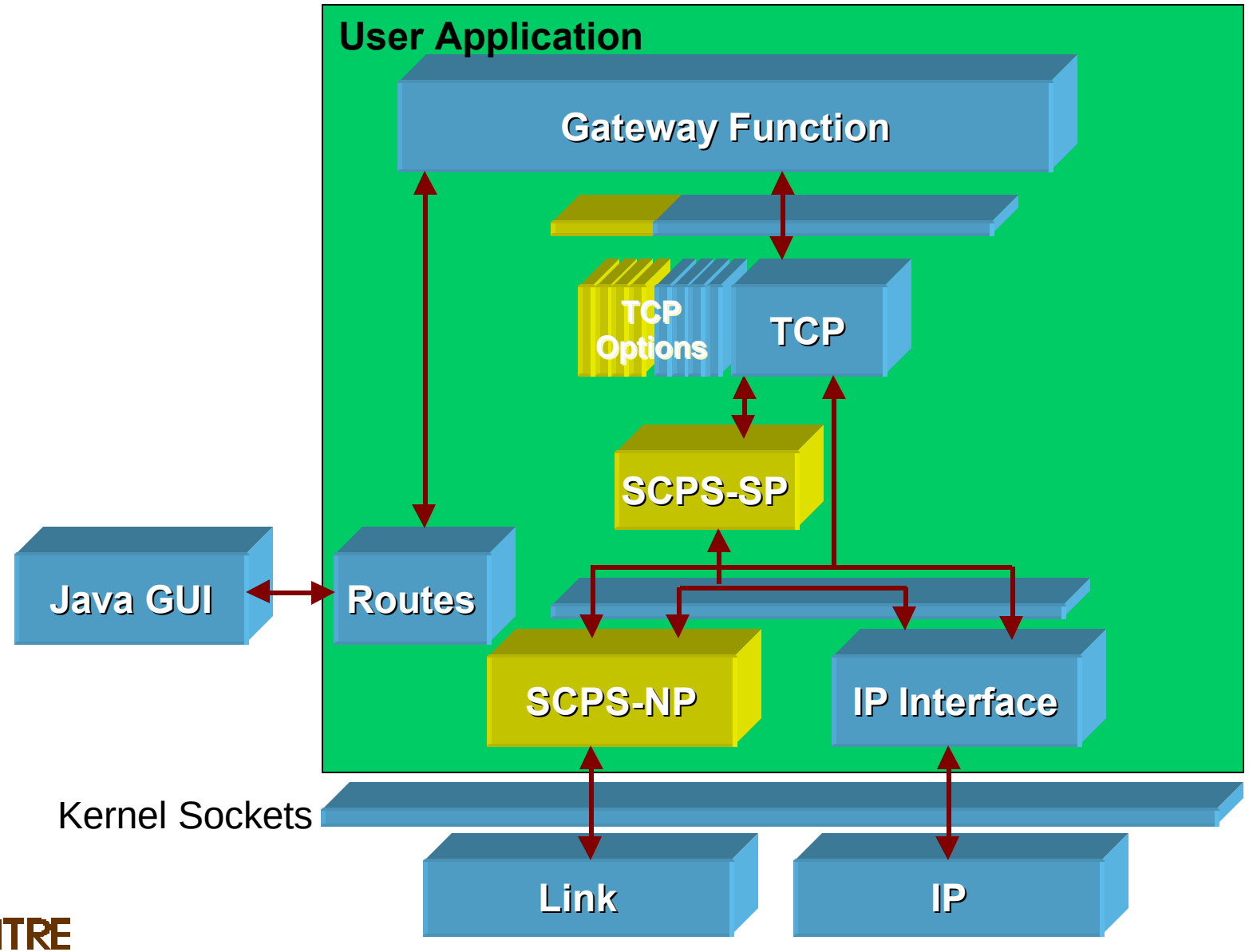
Reference Implementation - Capabilities

- End-system configuration
  - Application-space implementation: primarily an evaluation tool
  - Implementations of the FP, TP, SP, NP (and interface to IP)
  - Simple test applications
  - Configuration scripts to set various host and configuration defaults
  - Portable across most UNIX systems
- Protocol-translating transport-layer gateway configuration
  - TCP-to-TP conversion
  - UDP pass through (with rate control)
  - Optional use of SP
  - Either IP or IP-to-NP conversion
  - FreeBSD or Linux (with Divert sockets)
  - Java Graphical User Interface to configure gateway rules

SCPS Reference Implementation Options: End System Configuration



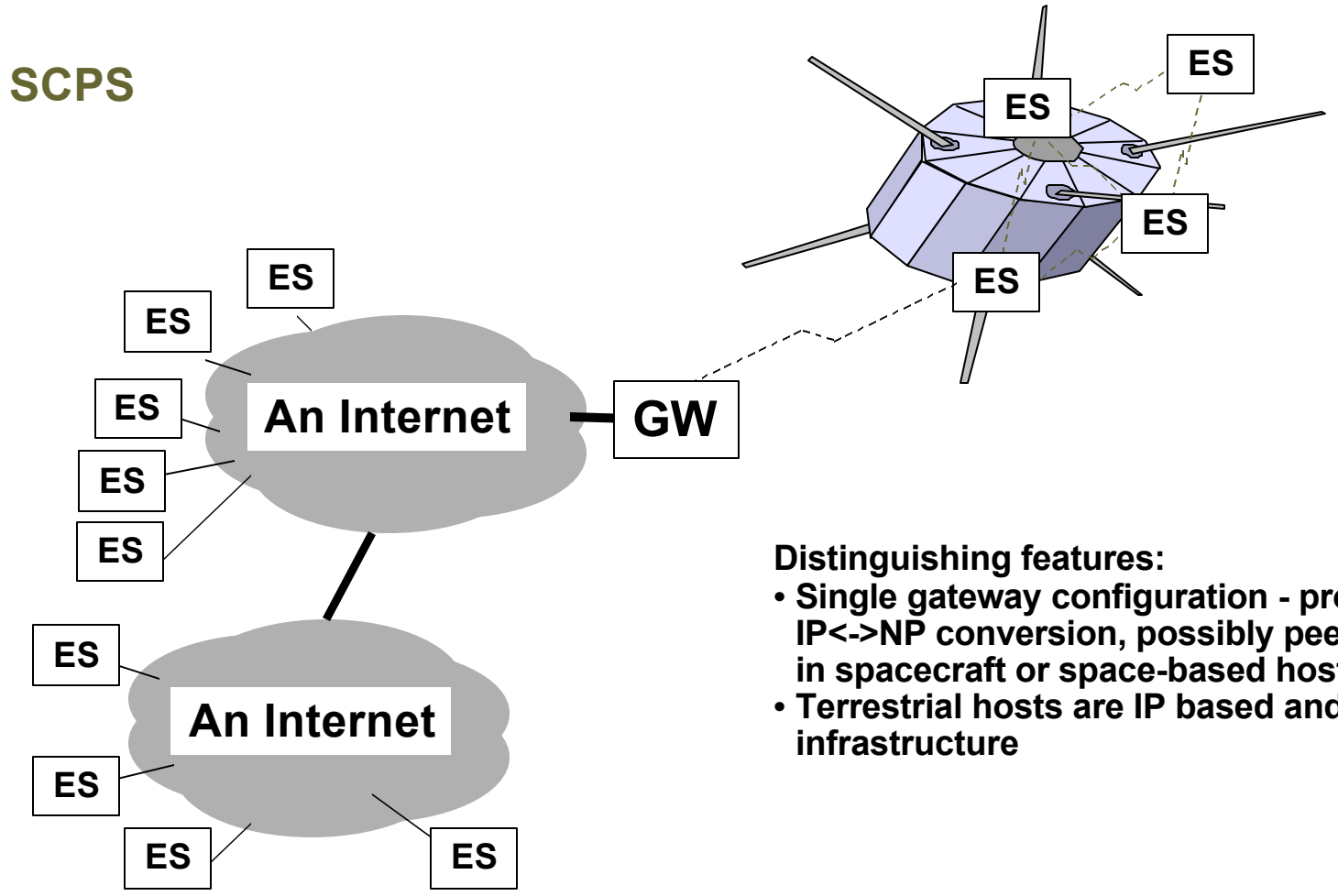
SCPS Reference Implementation Options: Transport Layer Gateway Configuration



SCPS Reference Implementation Distribution

- Unrestricted distribution as of July 2000
  - 13 non-US requesters to date
- 79 total copies of the SCPS Reference Implementation distributed (does not include updates) as of 8 Jan 2001
  - Industry: 46
  - Academia: 10
  - Government: 23

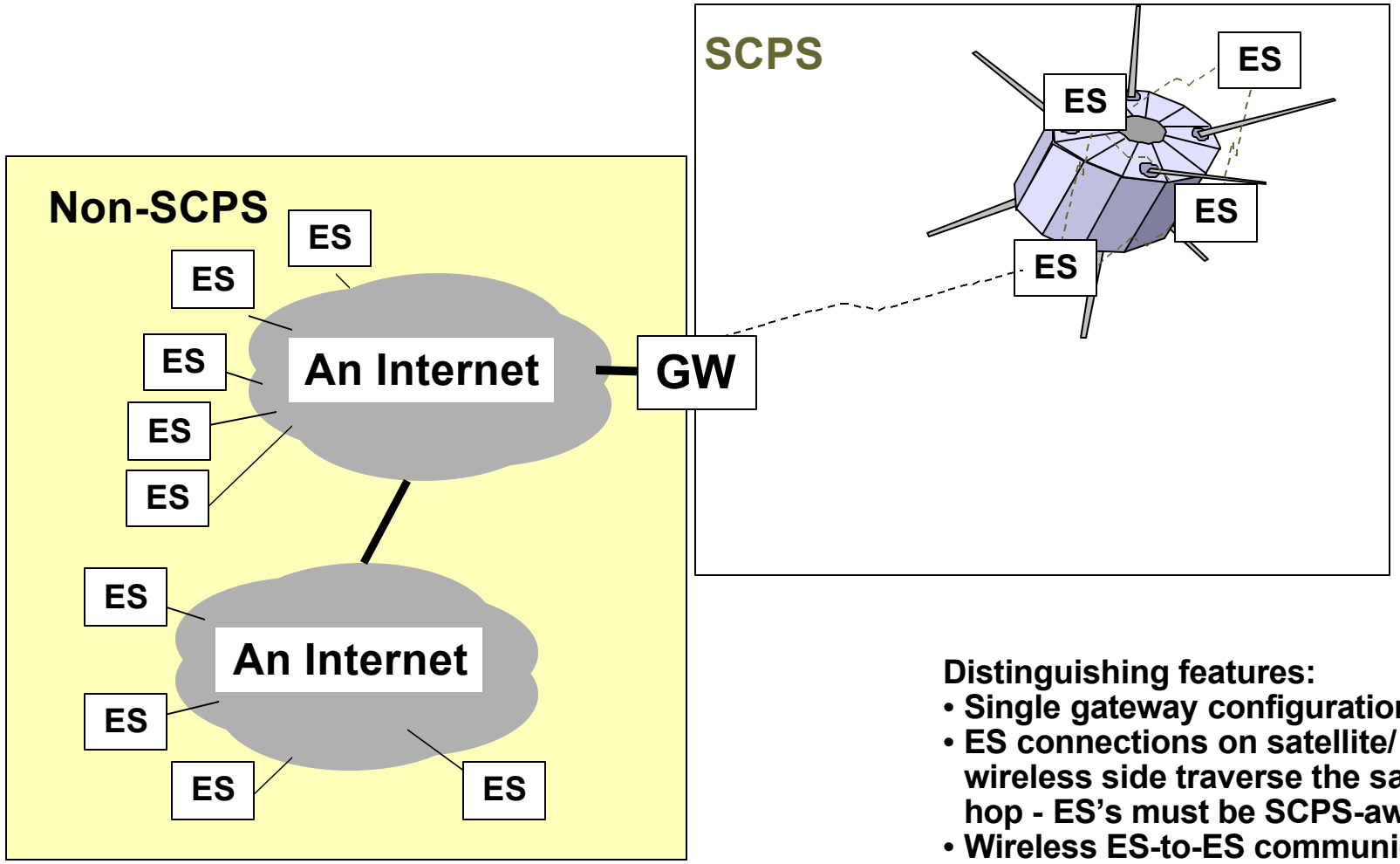
Deployment Alternative: End-to-End SCPS Transport Modifications



Distinguishing features:

- **Single gateway configuration - provides IP<->NP conversion, possibly peer gateway in spacecraft or space-based hosts use NP**
- **Terrestrial hosts are IP based and use IP infrastructure**

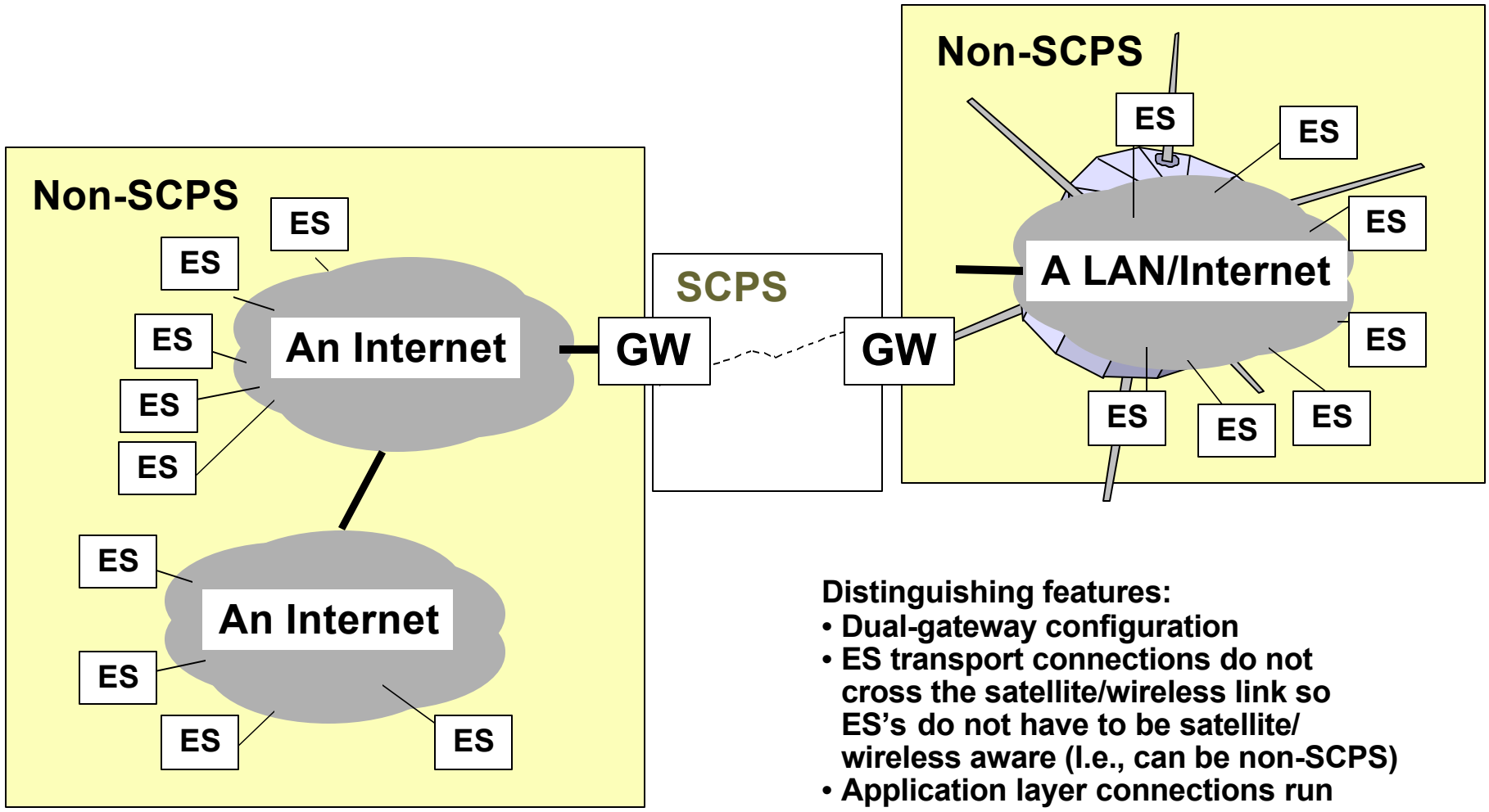
Deployment Alternative: Single Transport-Layer Gateway



Distinguishing features:

- **Single gateway configuration**
- **ES connections on satellite/ wireless side traverse the satellite hop - ES's must be SCPS-aware**
- **Wireless ES-to-ES communication using SCPS possible without GW's**

Deployment Alternative: Dual Transport-Layer Gateways



Distinguishing features:

- Dual-gateway configuration
- ES transport connections do not cross the satellite/wireless link so ES's do not have to be satellite/ wireless aware (I.e., can be non-SCPS)
- Application layer connections run end-to-end

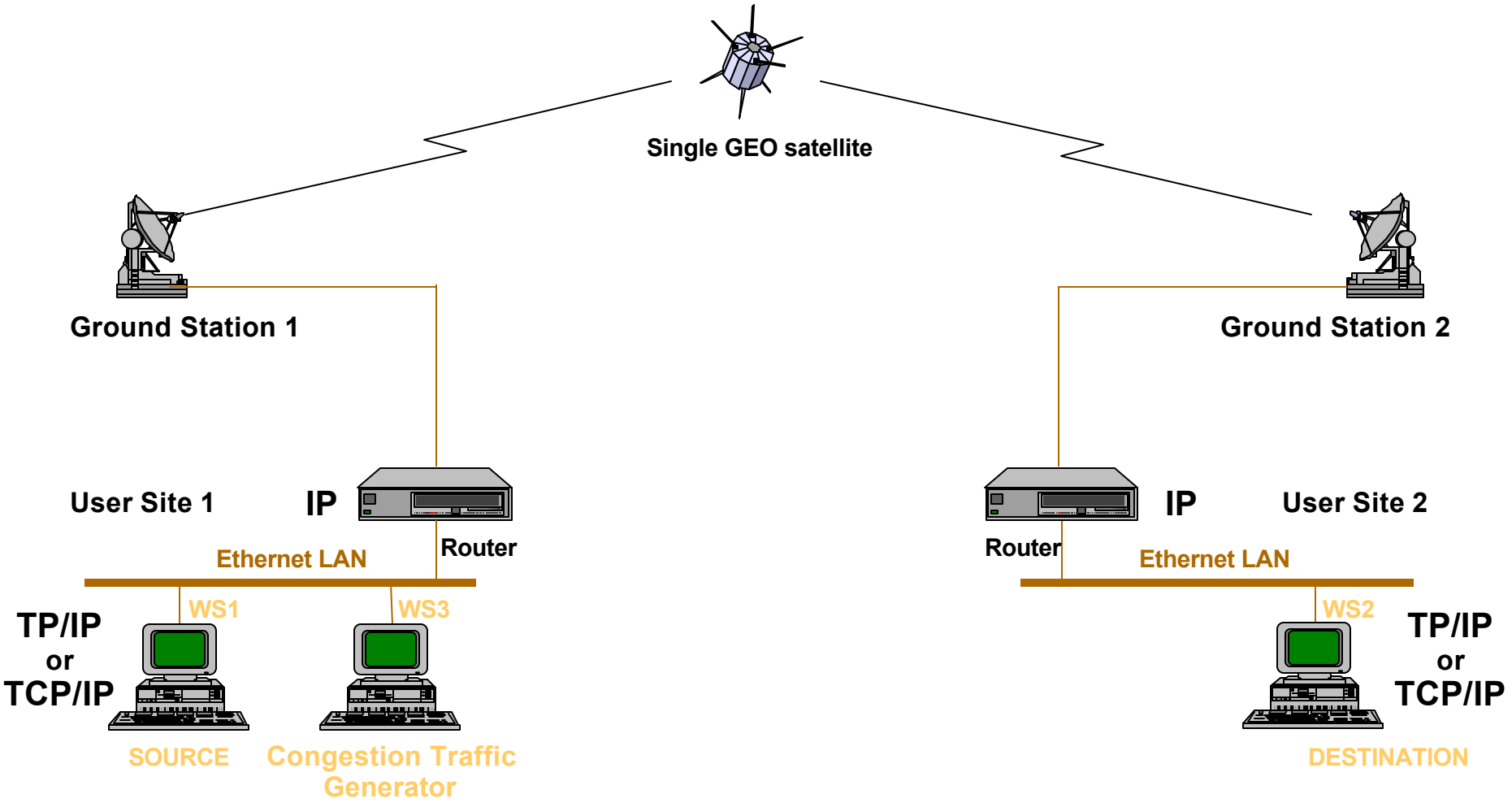
Transport Layer Gateways - Discussion

- Applications run end-to-end
  - Consistent with "End-to-End Argument" - the application process is the true endpoint, not the box
  - Even with TCP, applications *still* responsible for assurance of delivery - socket close/shutdown semantics
- Gateway advantages
  - "Impedance matching" - transport and network protocol features and assumptions suited to the environment
  - Control loop isolation, appropriate default assumptions
  - Doesn't require host modifications - "stock" TCP/IP in hosts can still derive benefits of enhanced TCP
- Issues
  - IPSec interaction: transparent gateways vs. security associations
  - End-to-end security at application layer

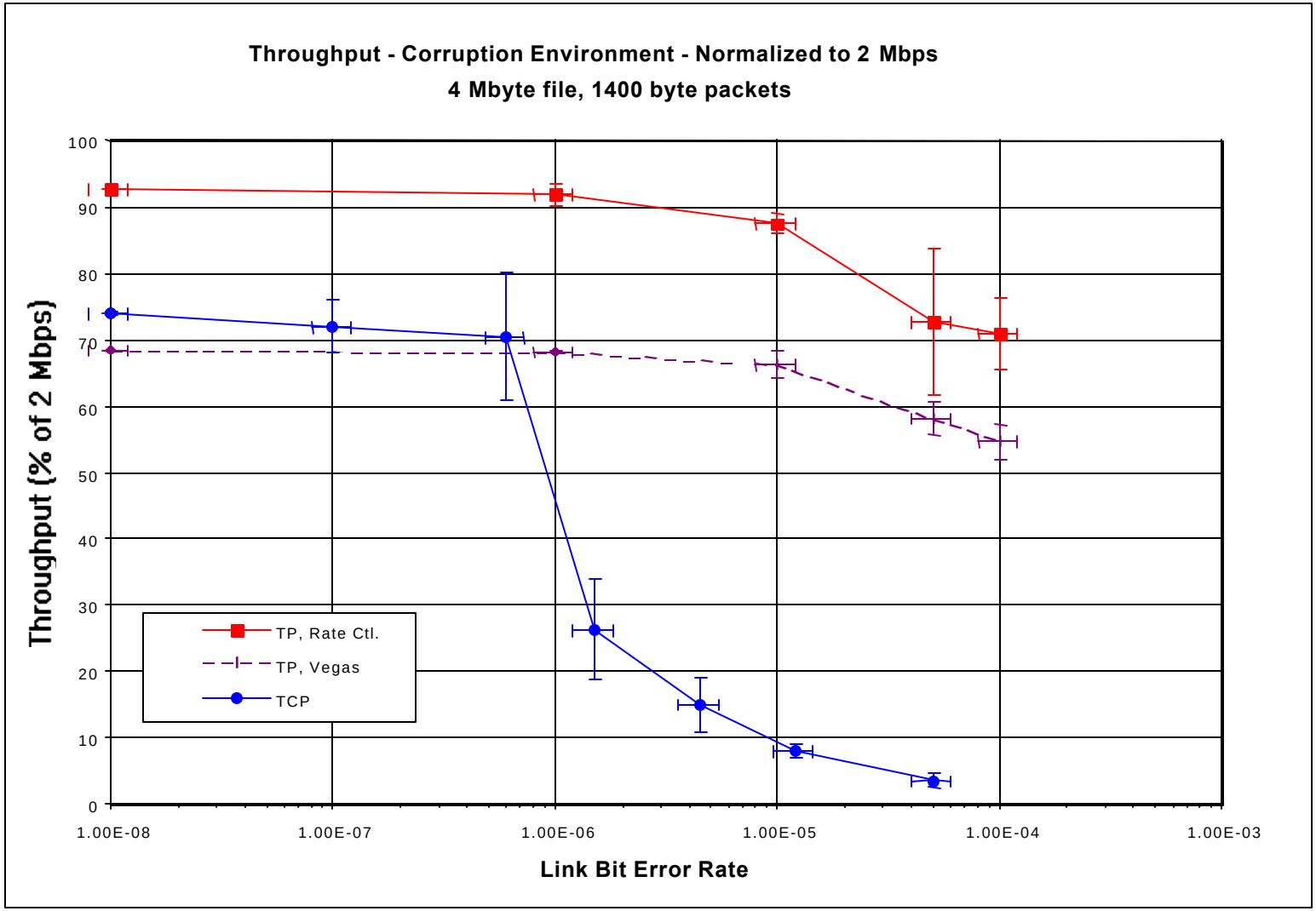
Test and Implementation Experience: Developer Testing

- Three major test reports available via SCPS web page (http://www.scps.org)
  - "Bent-pipe"
  - STRV 1B
  - ACTS
- Innumerable lab tests to examine specific issues
- Upcoming: STRV 1D Test
  - 4Q2000 - 1Q2001
  - NP and IP over CCSDS Link
  - SCPS Gateway in control center
  - VPN via IPSEC from control center to Internet-based users
  - Follow-on testing using commercial ground system provider and commercial ground equipment (including SCPS Gateway)
  - Testing at least delayed due to spacecraft problems

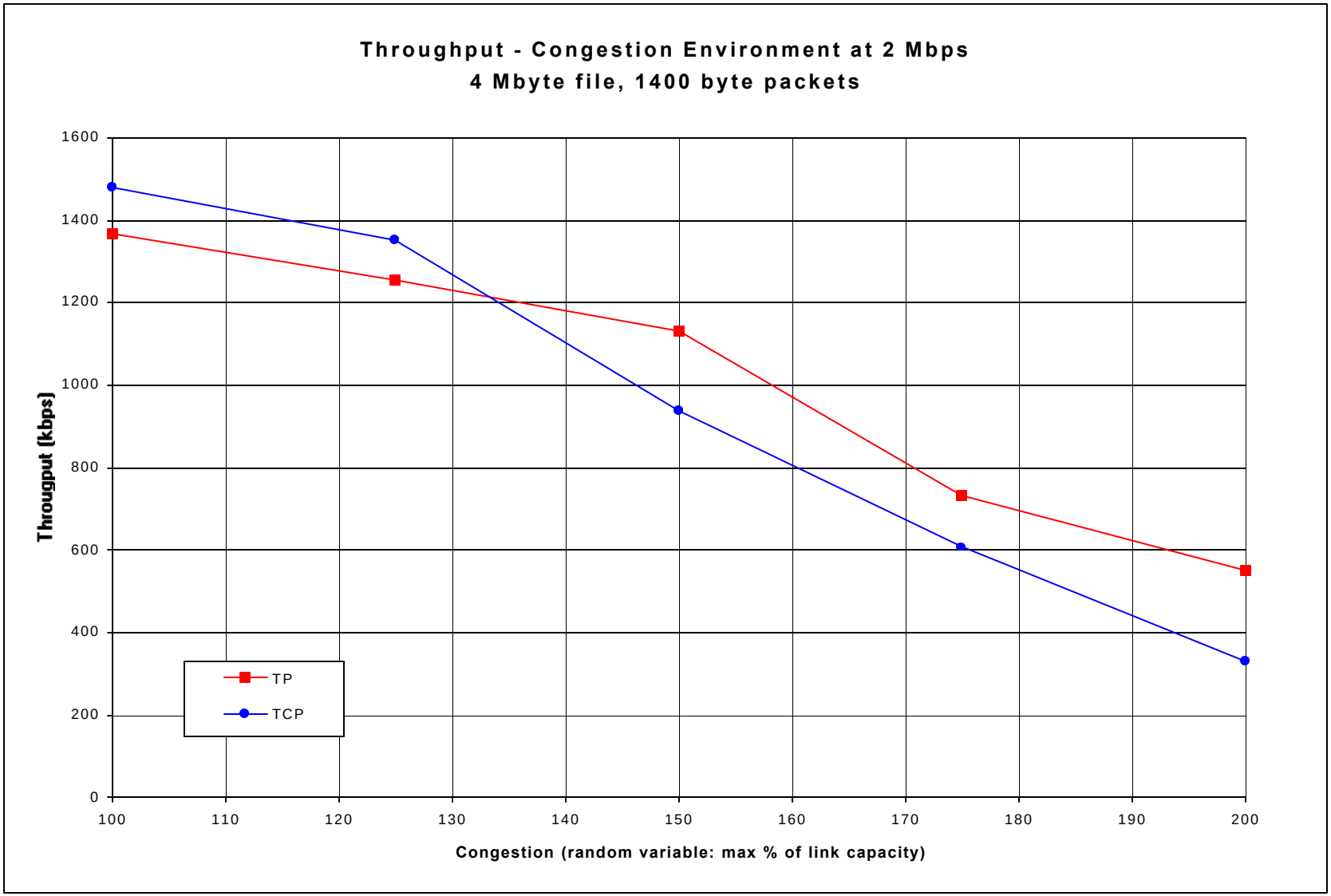
ACTS Satellite Test Configuration



Selected Results: 2Mbps Corruption Test - Throughput



Selected Results: 2Mbps Congestion Test - Throughput



Test and Implementation Experience: Independent Testing

- Avtec Systems - Commercial CCSDS equipment supplier
  - Port of SCPS Reference Implementation over ACTS satellite -- Test results in AIAA paper: http://www.avtec.com/sgs/pubs/pdf/AIAA_Paper.pdf
- New Mexico State University
  - Built hardware link simulator
  - Tested SCPS enhancements versus TCP over simulator
    - Results taken with important SCPS features disabled -- didn't see differences from TCP
    - They are currently rerunning their test suite with SCPS features enabled -- initial results consistent with our lab testing
- Joint Expeditionary Force Experiment 2000 (JEFX 2000)
  - Joint US services test
  - SCPS Gateways with SATCOM and military tactical radios from C130 to ground

Independent Implementations

- Avtec Systems
  - Implemented Windows-NT based in-kernel port
  - End system and gateway products in development
  - Avtec SCPS Gateway to be used in STRV-1D follow-on
- Xiphos Technologies
  - Canadian company
  - Developed hardware implementation of SCPS-NP for spacecraft onboard use
  - Currently developing independent implementation of SCPS-TP
- Global Sciences and Technology
  - Currently developing Linux kernel implementation
  - Lead on VxWorks “kernel” implementation for STRV-1D

Contact Information:

Robert C. Durst
The MITRE Corporation
durst@mitre.org
+1 703 883-7535 voice
+1 703 883-7142 fax