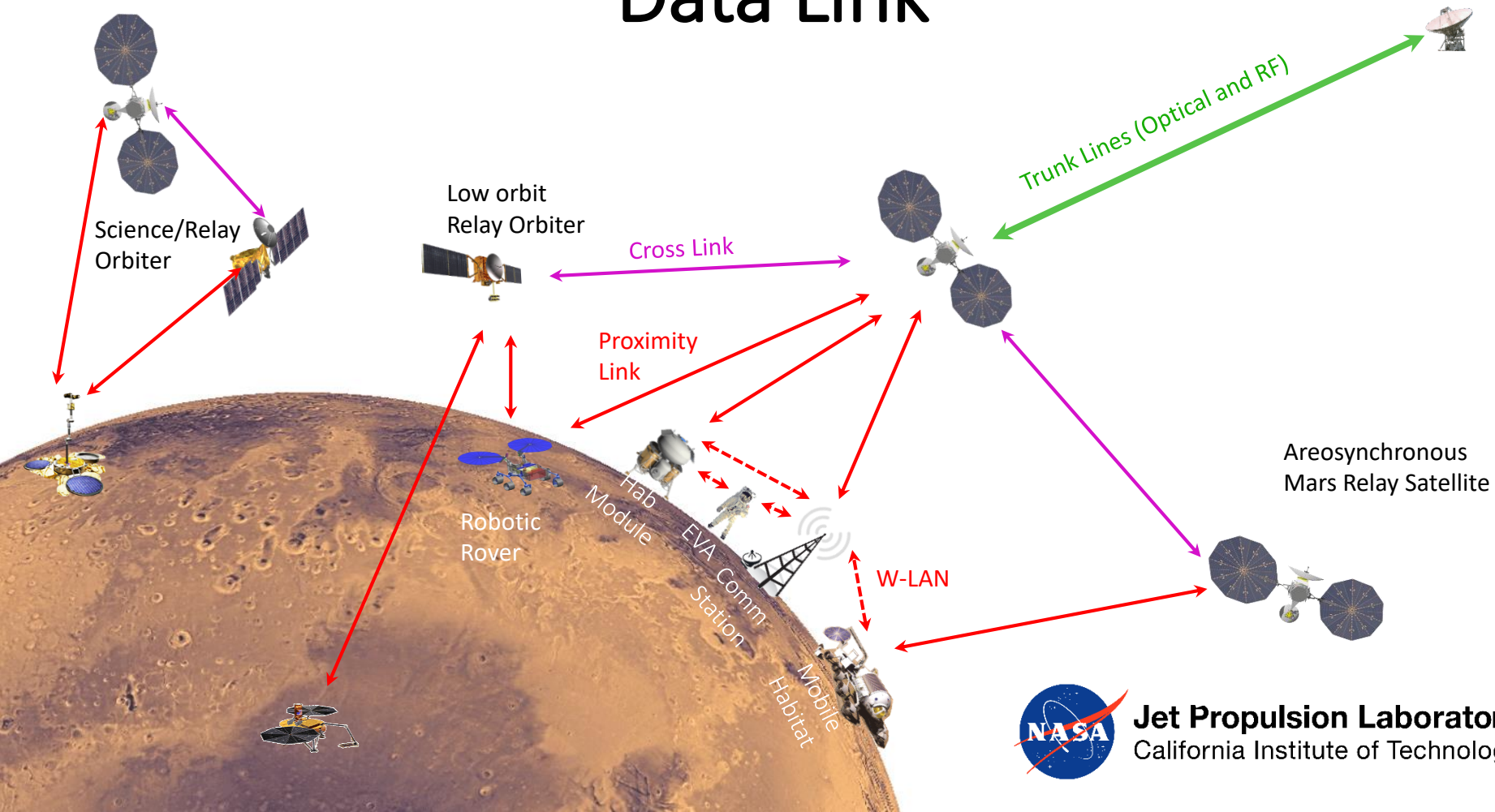
2018 Space Operations Conference Session CSIS-02

The Utilization Profiles of the CCSDS Unified Space Link Protocol (USLP) – Data Link



Jet Propulsion Laboratory
California Institute of Technology

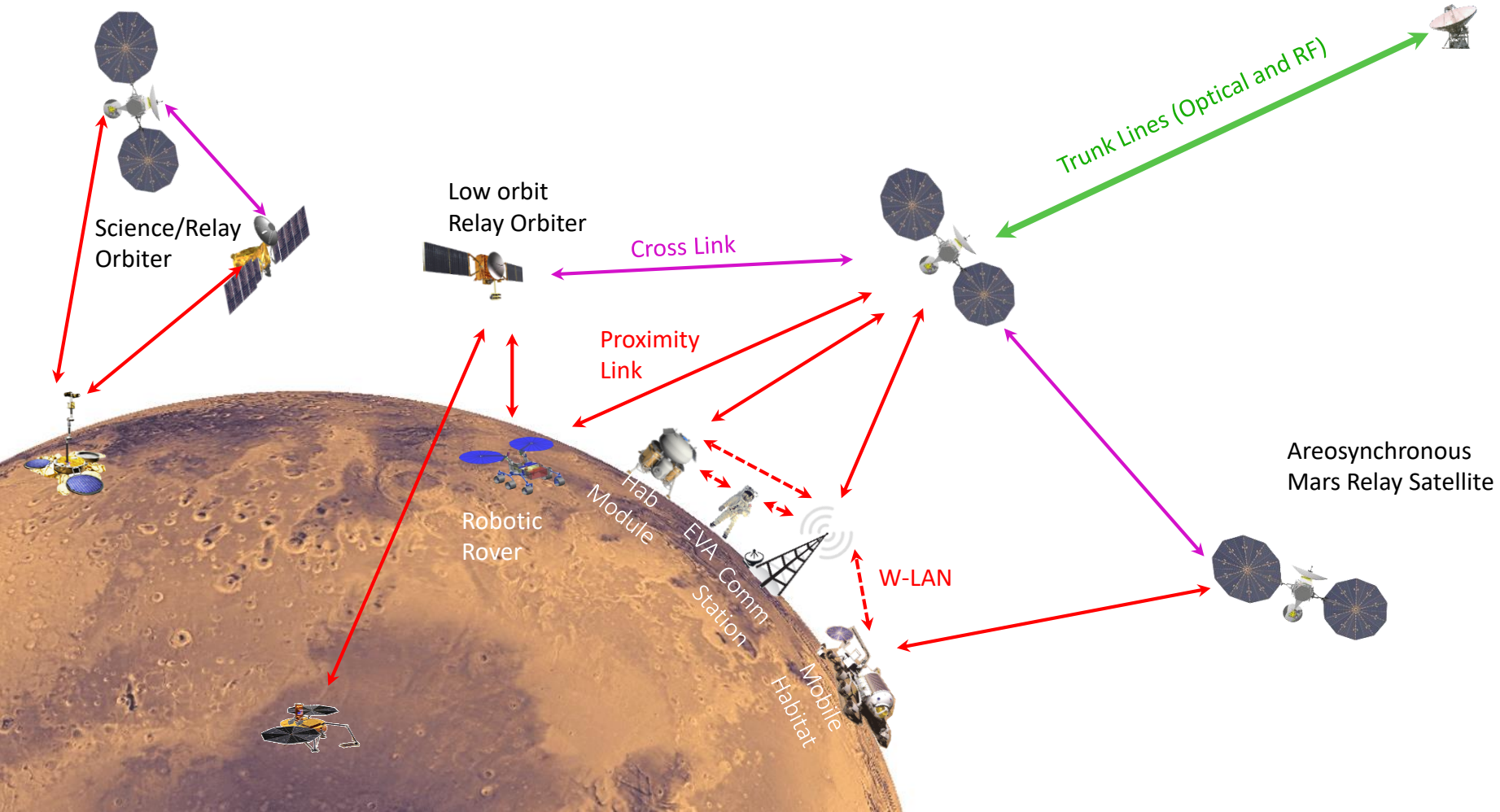
Agenda

- USLP Overview
- Protocol Layering
- How to Operate USLP over Coding & Synchronization Sublayer
- USLP Operational Modes
- Summary and Conclusions

Purpose

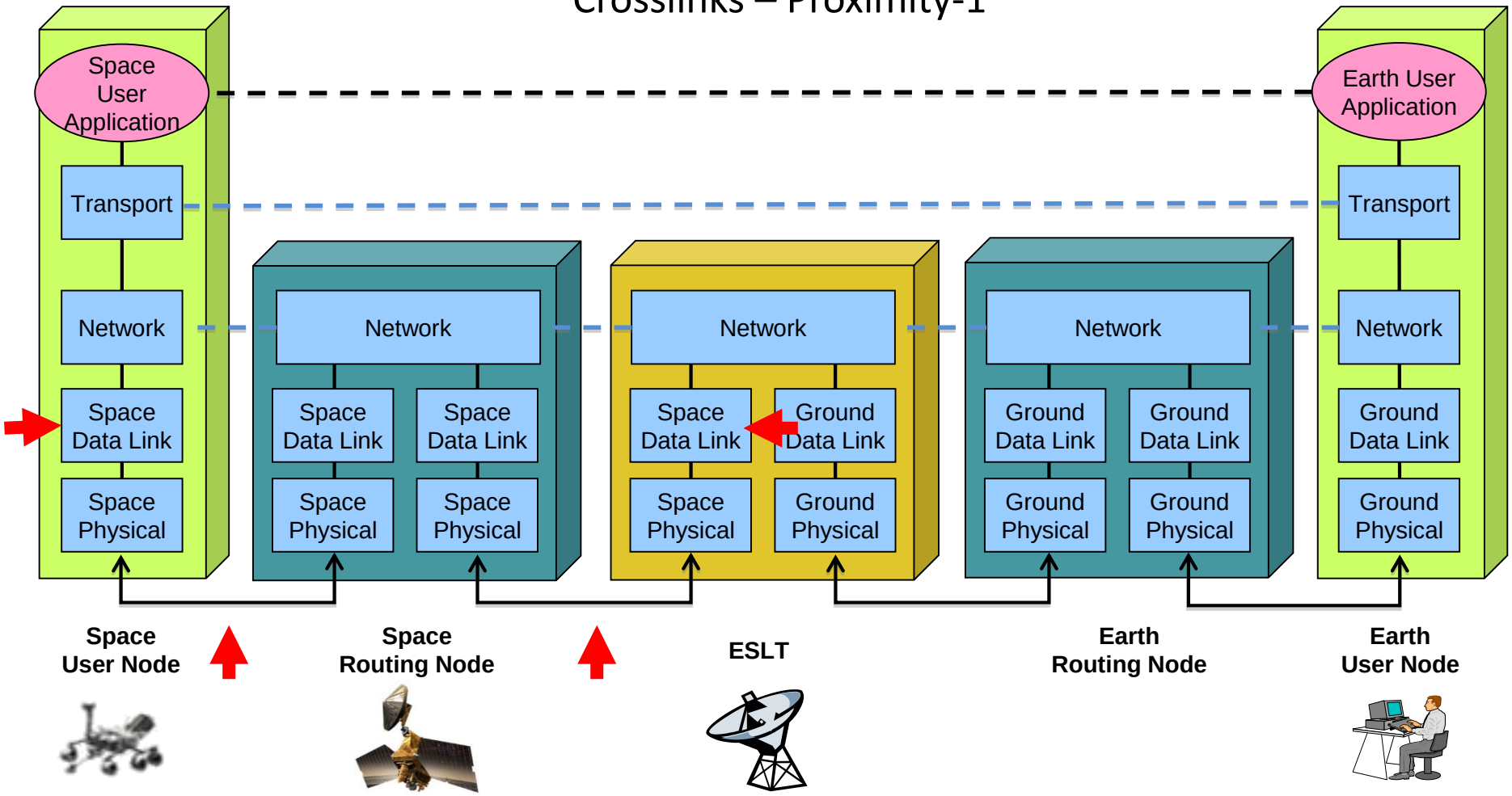
- The Unified Space Link Protocol (USLP) will be a CCSDS Recommended Standard at the Data Link Layer to be used over ***all*** space communications links: space-to-ground, ground-to-space, and space-to-space.
  - USLP is currently a mature Red-3 CCSDS specification
  - Blue Book expected before the end of 2018
- Over time, future missions will utilize one data link layer protocol instead of 4 (TM, TC, AOS, Proximity-1)

One Link Layer protocol for all Links



Current Space Protocol Layering

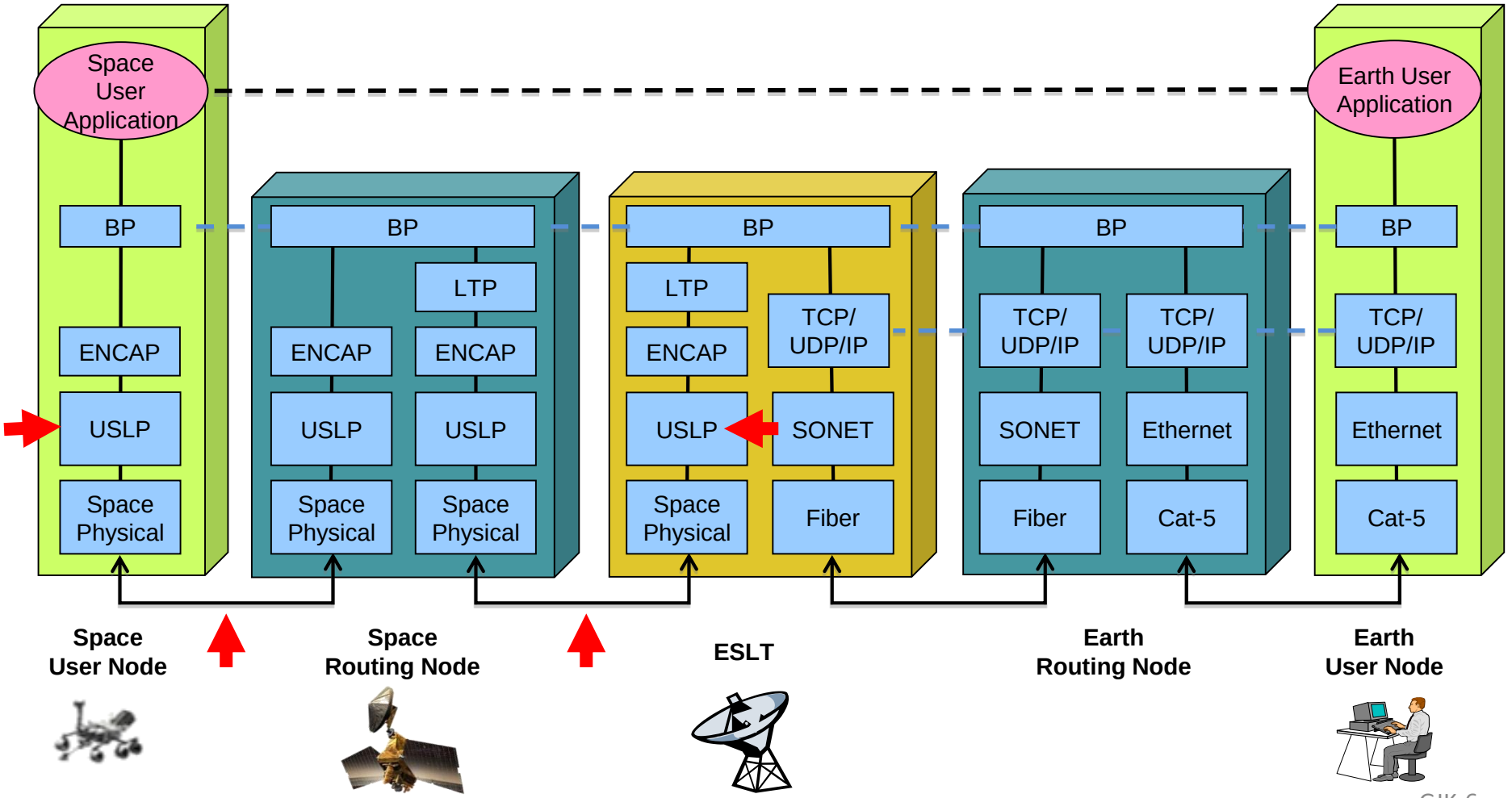
DFE - Telecommand (TC)
DTE - AOS or Telemetry (TM)
Crosslinks – Proximity-1



Acknowledgement: Peter Shames

Protocol Layering for *Future* based Space Comm

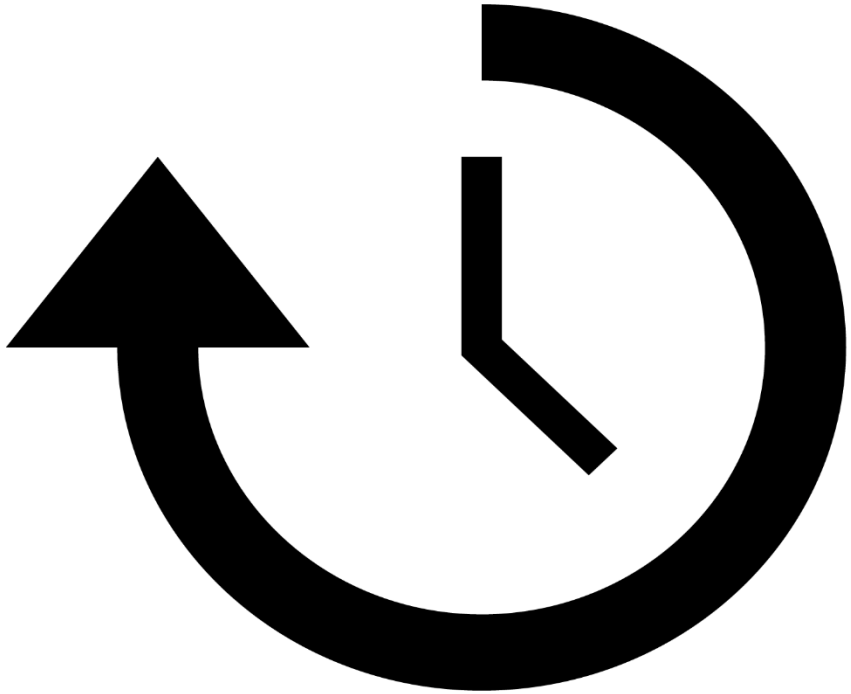
DFE, DTE, Crosslinks = USLP



Why use USLP?

- **Provides a single link protocol used by flight and ground across all manned and robotic space links**
- **Expands the number of Spacecraft CCSDS can identify to 64K**
- **Up to 32x greater transfer frame size (64K bytes)**
- **Modular frame counter (sizable up to 2**56 counts)**
- **Data Driven Protocol**
  - **Operational Control Field Flag**
  - **Shortened Primary Header Flag for Hardware Commands**
  - **Self-Identifying Payload**
- **Data can be segmented (TC-like or span multiple frames (AOS/TM)**
- **Variable length frames (fixed length is a subset)**
- **Supports decoupling of transfer frame length from codeblock size (data slicing)**
- **Similar in form, providing the same services, but not backward compatible with AOS, Prox-1, TC, TM**

USLP – Why now ?



- Glad you asked this question…

Evolving Space Communications Environment

- Development of very high rate Optical Communications
- Evolution of very small low cost space vehicles
- Utilization of Internetworking by Manned missions
- Adoption of Delay Tolerant Network (DTN) technology for relay data delivery, including selective retransmission and reliable link layer protocols.
- Flight technology to support high performance Forward Error Correcting Codes and Variable Code Modulation
- What's next?

Emerging Requirements on Link Layer

- Higher Data Rates put increased pressure on current implementations and operational data handling and routing
  - DSN today can provide up to 28 Mbps to Mars (bottleneck is tlm processing)
  - By arraying DSN can provide up to 120 Mbps (with bottleneck removed)
  - By 2025 DSN plans to provide 300 Mbps link to Mars
    - Using Current CCSDS Frame length (2 K max), generates 527 M frames in 1 hour
    - Using Max USLP frame length (64K max), 16 M frames generated in 1 hour
- Larger number of space vehicles requires more spacecraft identifiers
  - CCSDS is running out of the AOS 8-bit SCIDs
  - USLP provides 16 bit SCIDs
- Inclusion of uplink security (CCSDS SDLS or DSN/Bundle) will require new flight implementations
- Advances in technology provides the means to improve uplink performance using improved codes and FPGA devices.
  - Support reprogramming of Flight FPGAs systems (S/W Radios)
  - Increased control command size due to inclusion of security

Comparison of USLP to AOS and TC

Structural Aspects	USLP	AOS	TC
Maximum Frame Size (in Octets)	65,536	2048	1024
Frame Size Constraint	Variable/Signaled	Managed/Fixed	Variable/Signaled
MC-OCF Presence in VC	Signaled	Managed	Not Included
Control Data Flag Presence	Signaled in TFDF	Managed	Signaled
Insert Zone Size	Managed/Fixed	Managed/Fixed	Not Included
Frame Error Control Field	Managed/Optional	Managed/Fixed	Managed/Optional
Frame to Codeblock Alignment	Managed/Optional	Fixed Codeblock	Variable Codeblock
# Spacecraft Ids	65,536	256	1024
Sequence Counter Size	Variable (0->$7e^{16}$)	Fixed ($2.7e^{8}$)	256
Virtual Channels	64*	64	64
Segmentation (used when max size data unit exceeds frame size)	Signaled in TFDF	No (uses Spanning pkts)	Yes
Multiplexer Access Points (Subordinate VCs)	Signaled (16 MAPs)	No	64
Identifies Frame Contents	Signaled in TFDF	Managed by VC	Managed by VC

USLP Inherits Fundamental Transfer Frame Structure

USLP

Transfer Frame Header	Transfer Frame Insert Zone	Virtual Channel Security Header	Transfer Frame Data Field (**TFDF_SDU**)	Virtual Channel Security Trailer	Virtual Channel Operational Control Field	Transfer Frame Error Control Field
6-13 Octets Mandatory	Optional	Variable Optional	Variable Optional	Variable Optional	4 Octets Optional	Variable Optional

AOS

Transfer Frame Header	Transfer Frame Insert Zone	Virtual Channel Security Header	Transfer Frame Data Field (**TFDF_SDU**)	Virtual Channel Security Trailer	Virtual Channel Operational Control Field	Transfer Frame Error Control Field
6-8 Octets Mandatory	Optional Fixed	Variable Optional	Variable	Variable Optional	4 Octets Optional	2 Octets Optional

Frame

USLP

Version ID	Spacecraft ID	Destination or Source ID	Unspecified	Virtual Channel ID	Frame Length	Insert Zone Included Flag	FECF Size	OCF Flag	VC Counter Behavior Flag	VC Counter Length	VC Counter Value
3 bits	8 bits	1 bit	1 bit	6 Bits	16 Bits	1 bit	2 bits	1 bit	1 bit	3 bits	0-56 Bits

AOS

Version ID	Spacecraft ID	Virtual Channel ID	Frame Counter Value	Replay Flag	VC Frame Count Usage Flag	RSVD Spare	VC Frame Count Cycle	Frame Header Error Control (optional)
3 bits	13 bits	6 bits	24 bits	1 bit	1 bit	1 bit	4 bits	16 bits

Frame Header

USLP inherits From AOS

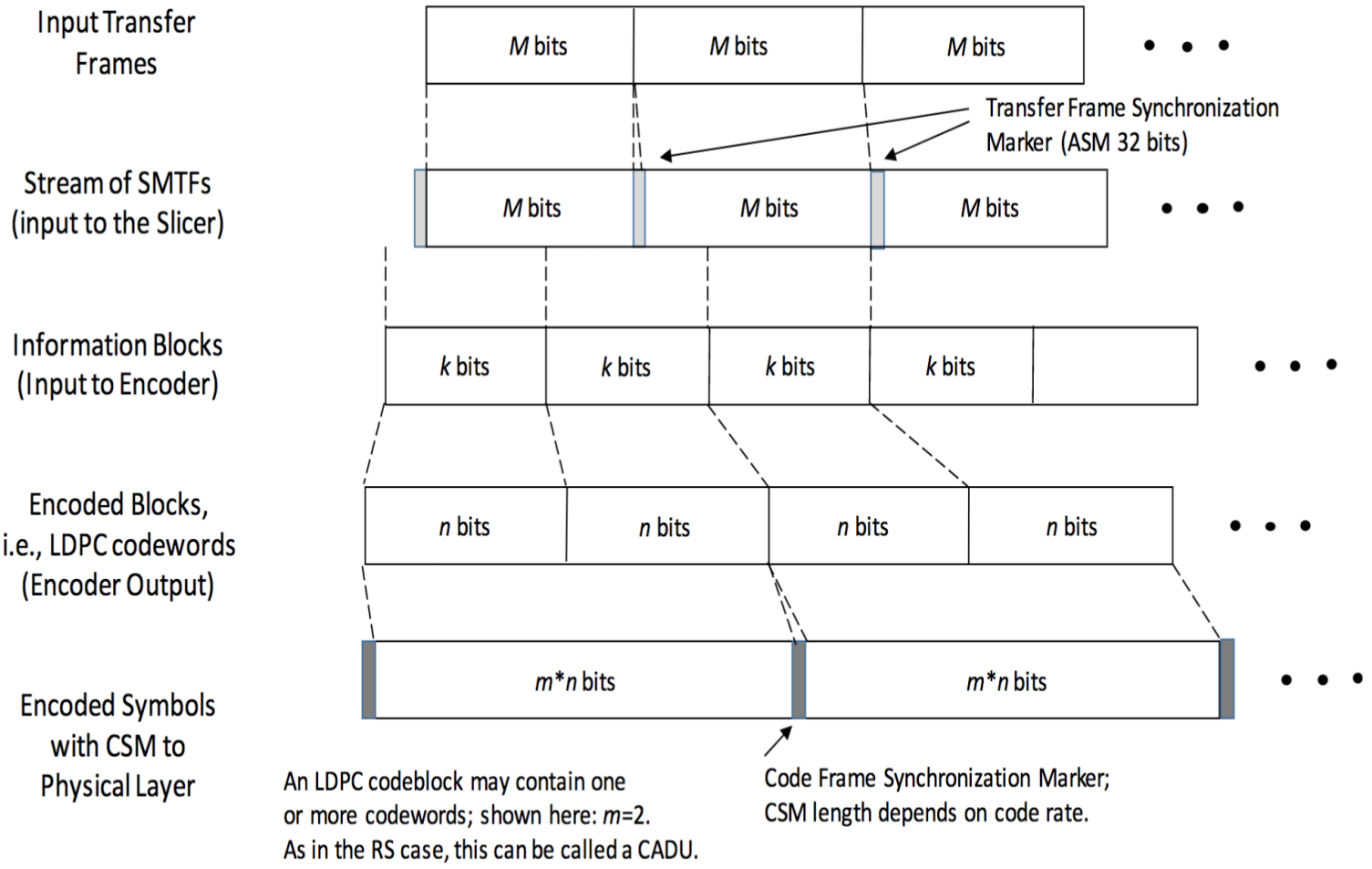
Transfer frame Data Field Header			**TFDF Data Zone**
VC Data Structure and Protocol fields Identifier		Optional (only required for Stream Data)	• CCSDS Space Packets • Internet Datagrams • DTN Bundles/Fragments • User Octets
Mandatory		Optional	
Construction Rules	Contained Protocol ID	• First Header Pointer For packets • Last valid octet for user defined data	
3 bits	5 bits	16 bits	Variable

Transfer Frame Data Field

USLP Operational Modes

- **Uncoded and Convolutional Coded**
  - Uncoded Examples: Engineering telemetry or Emergency mode
  - Convolutional: Mars Proximity Forward Link
- **Fixed Length Codeblocks**
  - Fixed Length Frames for telemetry production mode
  - Frames Aligned to Codeblock
  - Frames Unaligned to Codeblock (Data Slicing)
    - Rate ½ LDPC (2048,1024) code over the Proximity Link
    - Available now for LDPC family of codes over DTE links
    - Utilized for Variable Coding and Modulation (VCM)
- **Variable Length Frame Aligned to Variable Length Codeblock**
  - Commands are variable length messages
  - Telecommand uses this mode today BCH (64,56) code since 70s
  - New Short LDPC (128,64) and (512,256) codes improve performance over the current BCH in DED mode by 3.25 dB and 4.75 dB respectively

Slicing Transfer Frames into Fixed-Length Codeblocks



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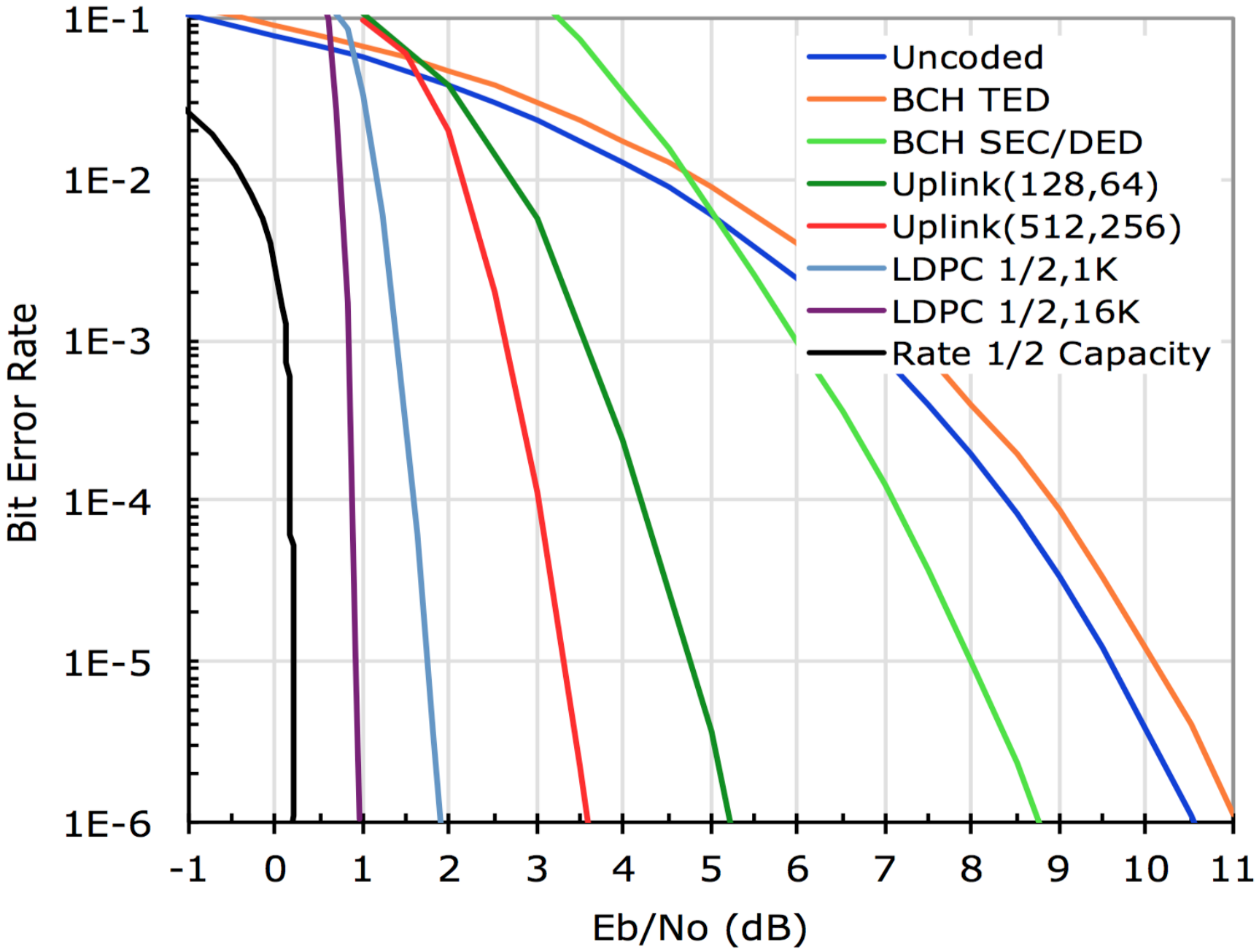
Backup


1E-1
1E-2
1E-3
1E-4
1E-5
1E-6
Bit Error Rate
-1
0
1
2
3
4
5
6
7
8
9
10
11
Eb/No (dB)
Uncoded
BCH TED
BCH SEC/DED
Uplink(128,64)
Uplink(512,256)
LDPC 1/2,1K
LDPC 1/2,16K
Rate 1/2 Capacity