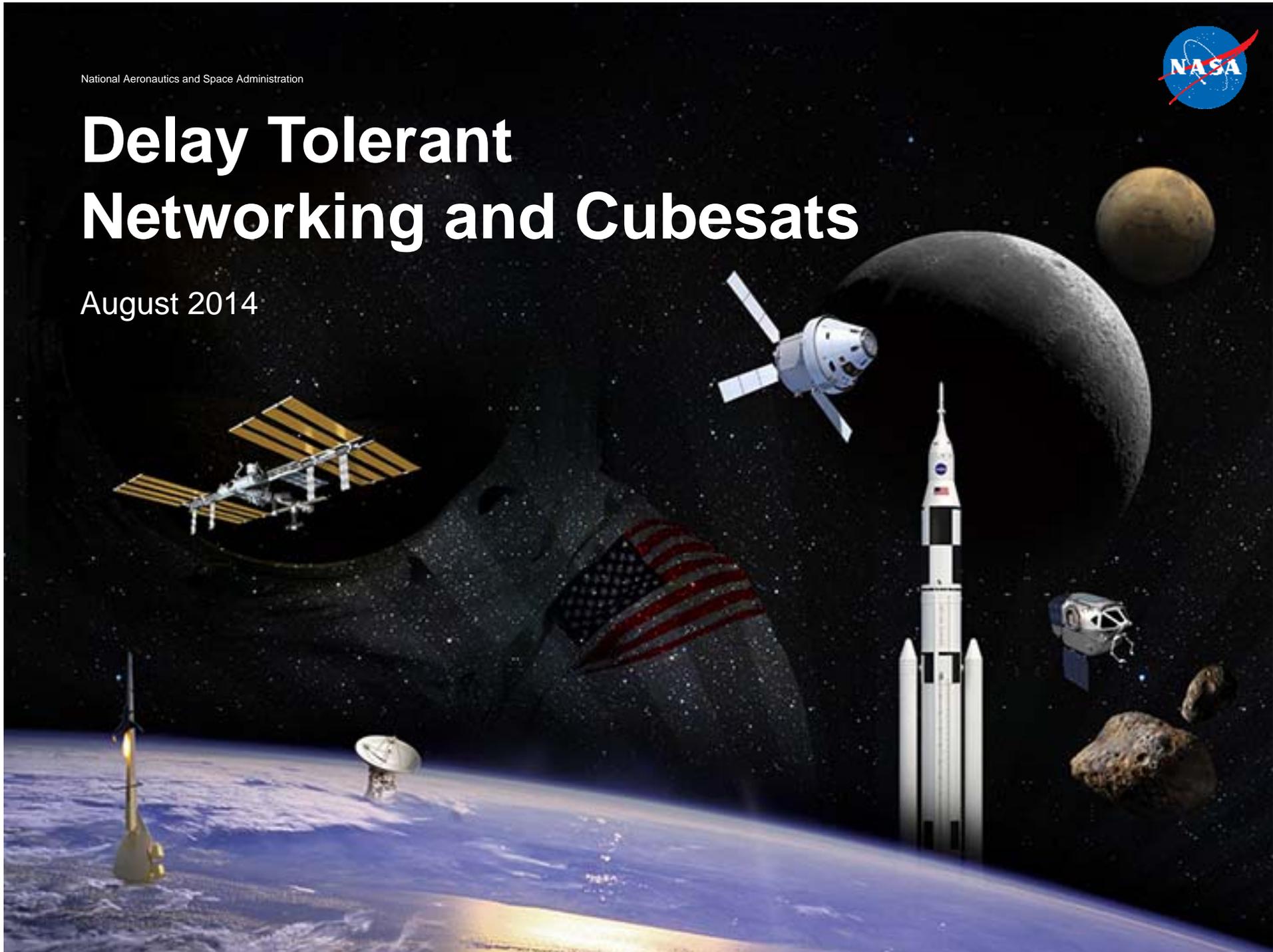


National Aeronautics and Space Administration



# Delay Tolerant Networking and Cubesats

August 2014



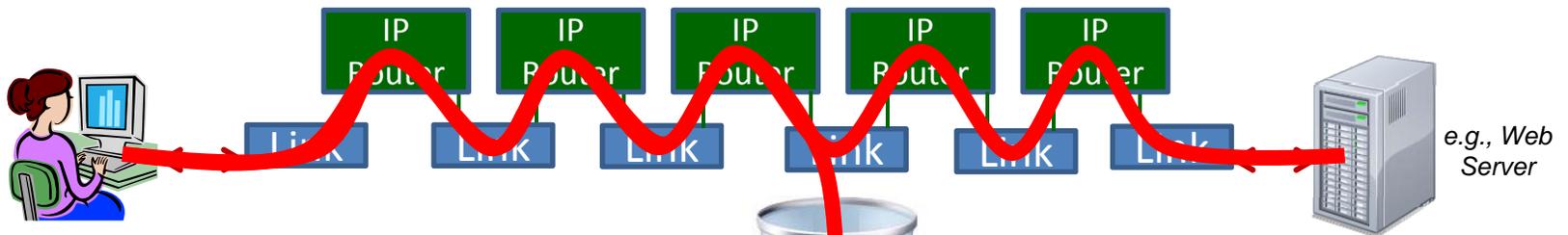


# Introduction to Delay Tolerant Networking

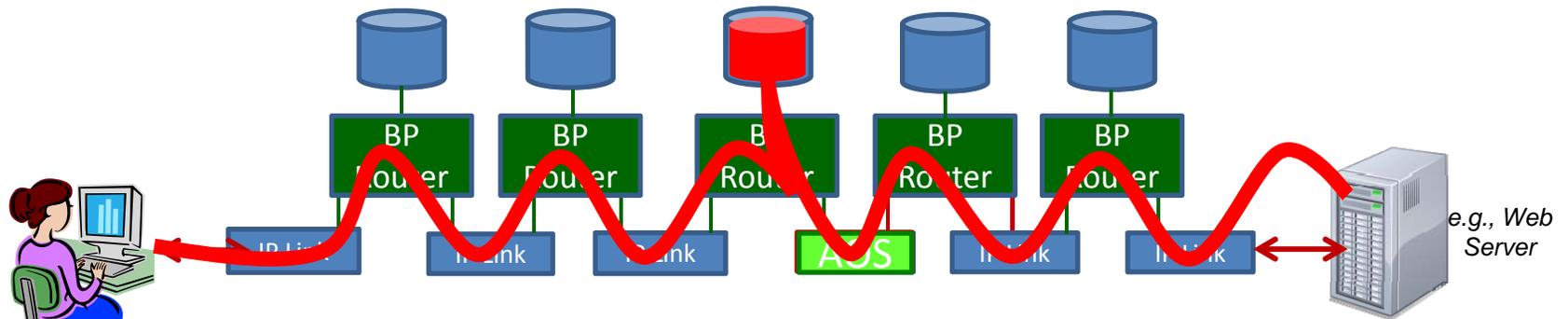
# What is DTN?



- DTN is a suite of protocols. It extends the terrestrial Internet to form a “Solar System Internet”
- The terrestrial Internet works by connecting multiple individual **links** into an end-end path using Internet Protocol (**IP**) routers. The end-end path is always available, delays are short (a few milliseconds) and error rates are very low. The animation below demonstrates a terrestrial Internet.



- The “IP” of the Solar System Internet is the Bundle Protocol (**BP**).
- The Solar System Internet works by connecting multiple Bundle Protocol (**BP**) routers. A hop may use IP or any other protocol. The end-end path is rarely available owing to disruptions and outages of individual links, delays are potentially very long as a consequence of Solar System geometry (minutes to days) and error rates are often high.
  - The BP routers work in a store-and-forward mode where data are held until the next hop becomes available.
  - BP often uses “Custody Transfer” to improve network efficiency – a BP router accepts custody of incoming Bundles, thus allowing the previous hop to clear its buffers.
- The Bundle Protocol therefore forms an *Overlay Network*. It can run over IP where IP is available, or it can run directly across individual links. The animation below demonstrates an IP network with the bundle protocol overlaid.



# Comparison of Packet Delivery in Different Networks



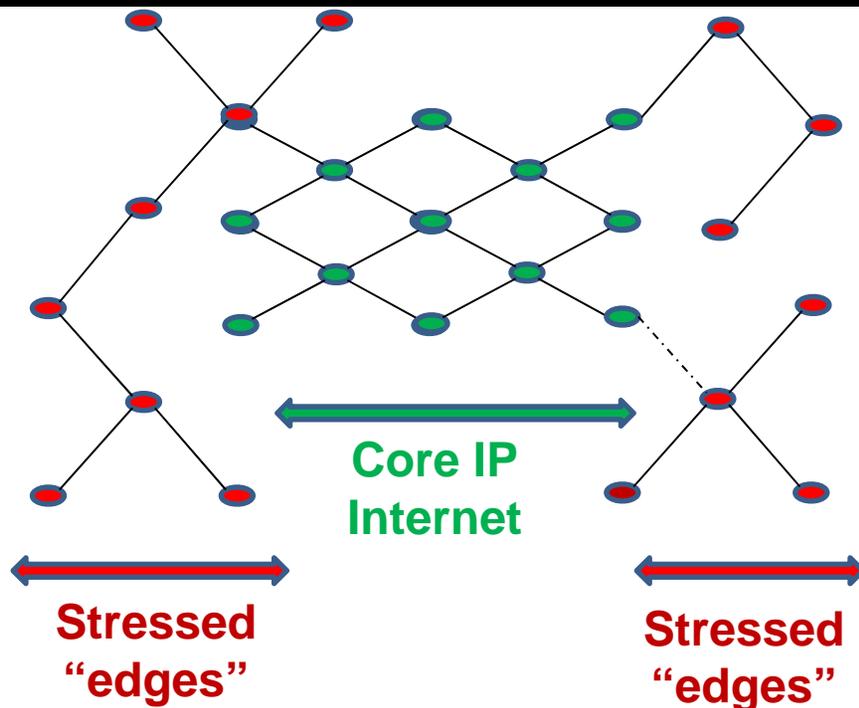
- This video demonstrates how a network with DTN overlaid can improve transmission of the packets.
- The video shows the difference between TCP/IP, UDP/IP and Bundle Protocol (BP).

## A Simplified Introduction to Disruption-Tolerant Networking



Jet Propulsion Laboratory  
California Institute of Technology

# Why is DTN important?



- DTN is a game-changing internetworking technology that allows the reach of the *IP-based Internet* to reach out into the *highly stressed* communications environments at its edges:

- Public emergency networks
- Tactical military
- Mining, nuclear plants
- Remote area communications
- Space missions

Multiple-use  
Technology

- DTN development started in NASA in 1998 in response to a DARPA initiative to develop an “Interplanetary Internet”. Since the mid-2000s worldwide DTN development has been led by NASA and is approximately 50% complete. Basic open source DTN core protocols are getting close to reaching international standards, but the ancillary protocols required to operate a network (routing, network management, security, key management, etc.) need further development and testing
- NASA has a “Core Team” of experts across the Centers who have led DTN development for the past decade, plus “DTN Advocates” at the Centers who assist with pickup of DTN by spaceflight missions and external organizations. *NASA is the world leader in DTN.*

# DTN Technical Features



- Interoperability and Reuse
  - A standardized open-source\* DTN protocol suite enables interoperability of multi-organization communication assets and also allows re-use of the same communication stack for future projects. Interoperability with NASA's partner agencies greatly expands the opportunities for new, collaborative missions to emerge.
- Improved Operations and Situational Awareness
  - The DTN store-and-forward mechanism along with automatic retransmission provides more insight into events during communication outages and significantly reduce the need for manually commanded communications operations by automating communication in the context of the contact schedule.
- Space Link Efficiency, Utilization and Robustness
  - DTN enables more reliable and efficient data transmissions resulting in more usable bandwidth. DTN also improves link reliability by having multiple network paths and assets for potential communication hops.
- Security
  - The DTN Bundle Security Protocol allows for authentication and encryption, even on links where not previously used.
- Quality of Service
  - The DTN protocol suite allows for many priority levels to be set for different data types, ensuring that the most important data is received ahead of less important data.

❖ [http://sourceforge.net/projects/dtn/?\\_test=b](http://sourceforge.net/projects/dtn/?_test=b)

❖ <http://sourceforge.net/projects/ion-dtn/>

# DTN is a Suite of Protocols



- Licklider Transmission Protocol (LTP)
  - Provides retransmission-based reliability over links characterized by extremely long message round-trip times and/or frequent interruptions in connectivity
- Contact Graph Routing (CGR)
  - Enables dynamic selection of data transmission routes in a space network based on DTN. This dynamic responsiveness in route computation should be significantly more effective and less expensive than static routing, increasing total data return while at the same time reducing mission operations cost and risk
- Compressed Bundle Header Encoding (CBHE)
  - Developed to improve DTN transmission efficiency by further reducing the number of bytes used by convergence-layer adapters to represent EIDs in the primary blocks of bundles
- Extended Class of Service (ECOS)
  - Extends the class of service definitions to allow for a more granular approach
- Bundle Security Protocol (BSP)
  - Provides the mechanisms to authenticate the source as well as protect the integrity and confidentiality of the data



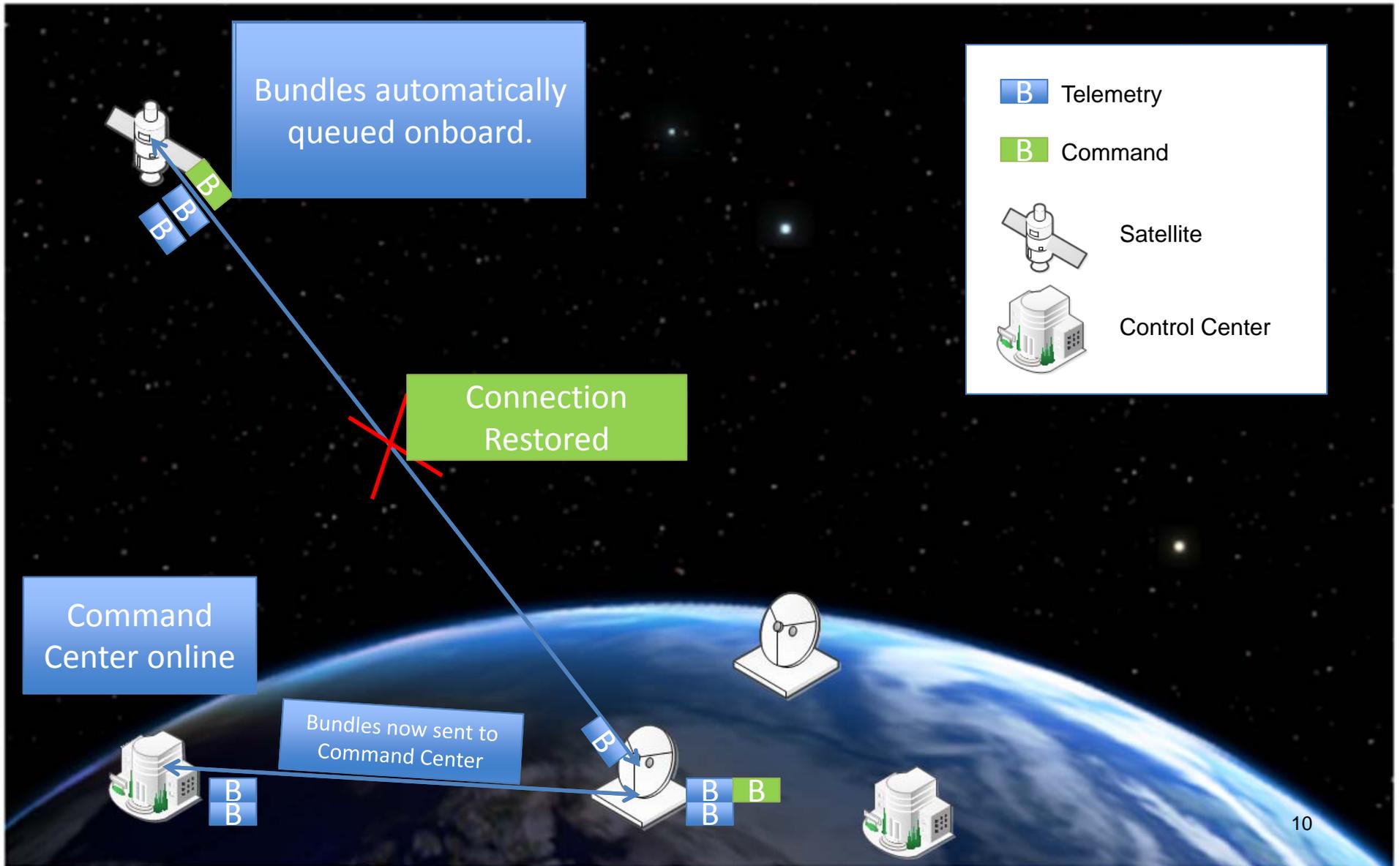
## Example Operations Scenario

# Problem



- Future space missions will include features that cannot be accommodated by today's link layer based communications
  - Multiple spacecraft
  - Intermittent connectivity and long light-time delays
  - Data flow across multiple hops and potential paths
  - Spacecraft that need to communicate without Earth in the loop (e.g., a lander and orbiter)
- This complex topology will require a network layer in the space communications protocol stack to provide reliable routing and forwarding of data
- TCP/IP cannot support this type of network because it requires a point to point path and low latencies at all times to work. Delay/Disruption Tolerant Networking is the effort to solve this problem.

# Operations Scenario



# Scenario Analysis

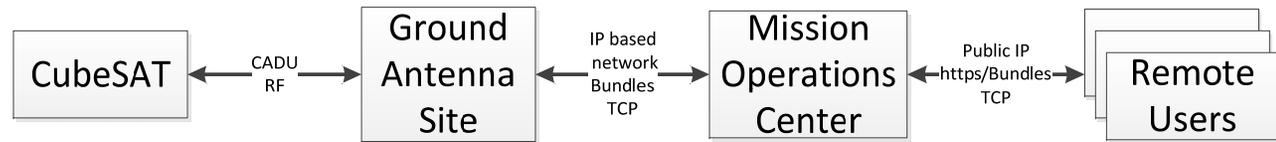


- What made this different for operations?
- Satellite operations can be performed in a “light’s out” mode
  - The operator did not have to command the data downlink it was automatic using the onboard system with contact graph routing
    - Can be used to completely automate passes especially overnight and through weekends
  - The operator did not command data retransmits. LTP and BP with custody transfer requested missing data
  - The operator did not have to be online. The operator used the DTN command queue to have them automatically sent
  - Allows operators to support multiple vehicles easier



## Example End-to-End Implementations

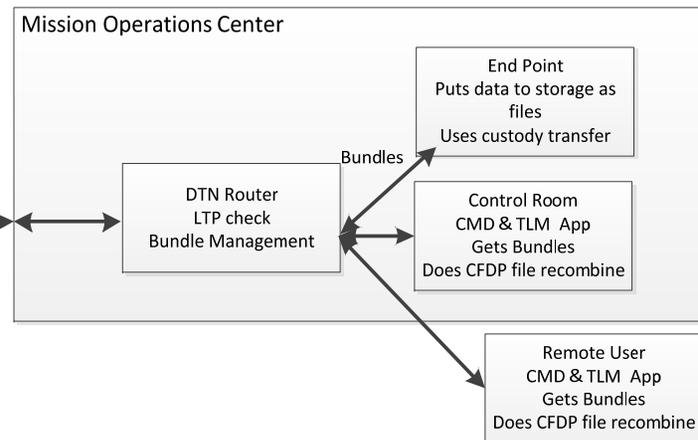
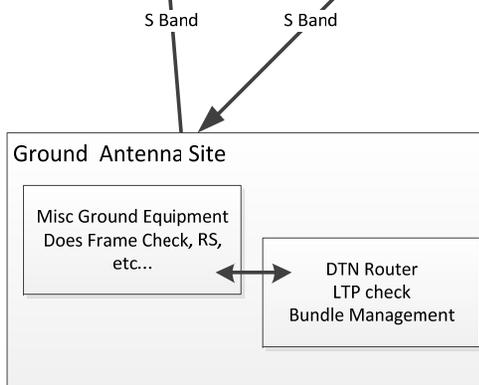
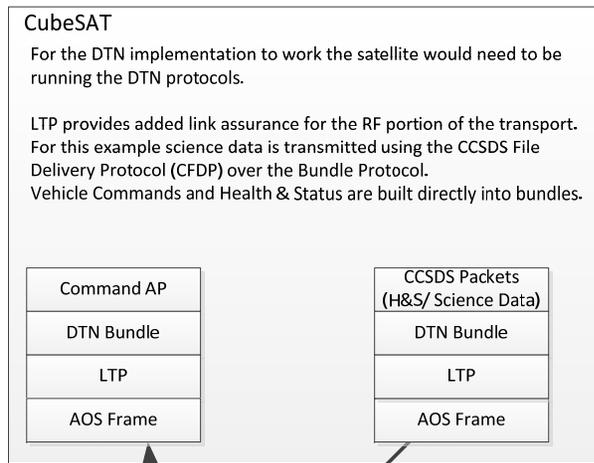
# Example Implementation (Combined Science Downlink)



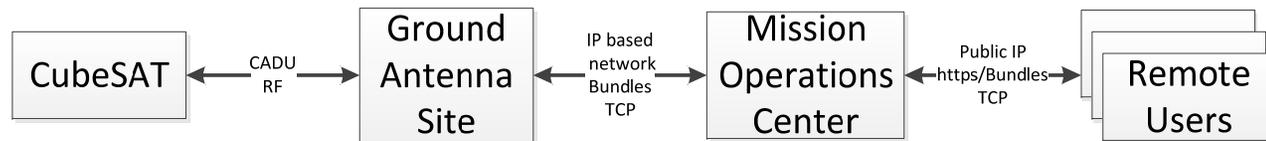
Ground Antenna Site provides a first level check of the frames to insure delivery to the ground. It also provides the broker between the Mission Operations Center and the CubeSAT.

Receives the bundles from the antenna site and extracts the satellite health and status for operations team. Distributes payload and other data to remotes. Sends the command packets to the antenna site for uplink.

Receives the data for analysis. Commands can be built and sent to MOC for uplink to satellite. Bundles as well as other methods of delivery (such as an operations support portal) can be used for mission analysis and support.



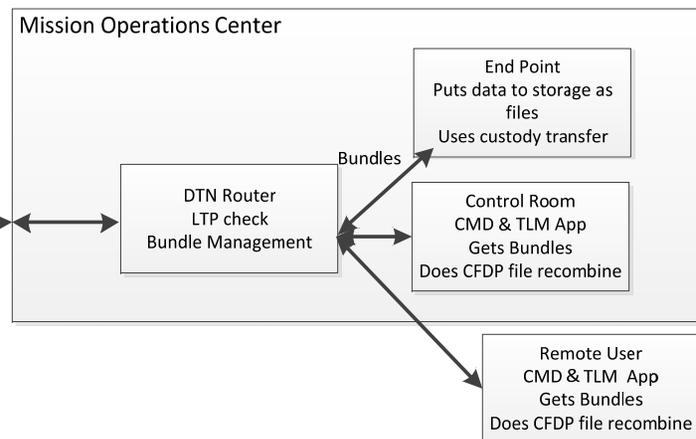
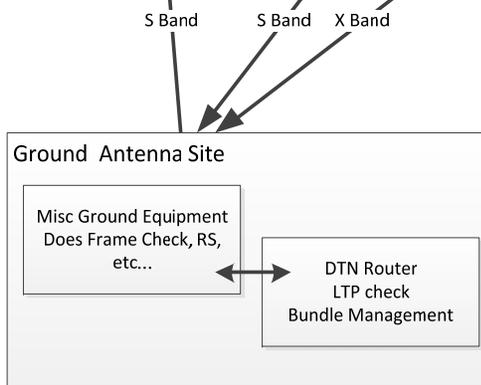
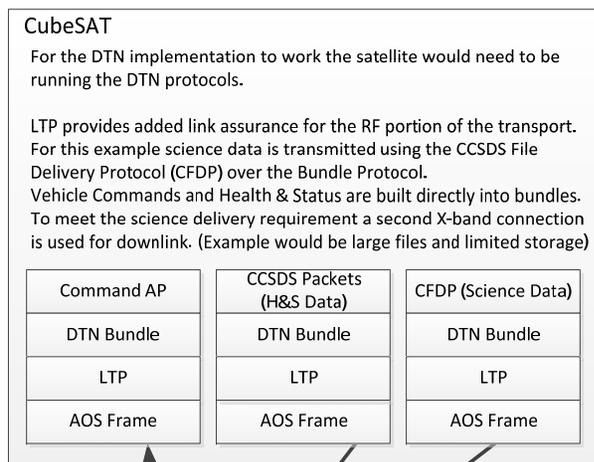
# Example Implementation (Separate Science Downlink)



Ground Antenna Site provides a first level check of the frames to insure delivery to the ground. It also provides the broker between the Mission Operations Center and the CubeSAT.

Receives the bundles from the antenna site and extracts the satellite health and status for operations team. Distributes payload and other data to remotes. Sends the command packets to the antenna site for uplink.

Receives the data for analysis. Commands can be built and sent to MOC for uplink to satellite. Bundles as well as other methods of delivery (such as an operations support portal) can be used for mission analysis and support.





## References

# References



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- [4] Burleigh,S.;; “Compressed Bundle Header Encoding”,draft-irtf-dtnrg-cbhe-09,  
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# References



- [5] CCSDS DTN Working Group;, “Summary of Solar System Internet (SSI) Operations Concept”, May 2010

# Acronyms and Abbreviations



AMS	Asynchronous Message Service
BP	Bundle Protocol
BSP	Bundle Security Protocol
CBHE	Compressed Bundle Header Encoding
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CGBA	Commercial Generic Bioprocessing Apparatus
CGR	Contact Graph Routing
CU	University of Colorado Boulder
DARN	DTN Academic Research Network
DEN	DTN Engineering Network
DRTS	Data Relay and Tracking Satellite
DSN	Deep Space Network
DTN	Delay (Disruption) Tolerant Networking
ECOS	Extended Class of Service
EO-1	Earth Observing Satellite - 1
EPOXI	Extrasolar Planet Observation and Characterization Deep Impact Extended Investigation
ESOC	European Space Operations Center
HOSC	Huntsville Operations Support Center
IOAG	Internet Operations Advisory Group
ISS	International Space Station
LTP	Licklider Transmission Protocol
MCC	Mission Control Center
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
SCaN	Space Communications and Navigation
SISG	Space Internetworking Strategy Group
SSI	Solar System Internet
TCP/IP	Transmission Control Protocol/ Internet Protocol
TDRS	Tracking and Data Relay Satellite
TKSC	Tsukuba Space Center
WG	Working Group