National Aeronautics and Space Administration

Delay/Disruption Tolerant Networking

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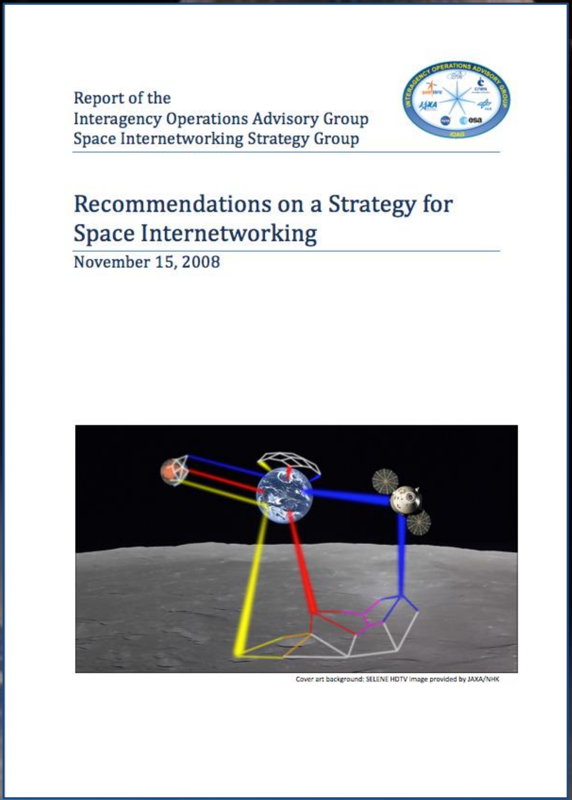
DELAY/DISRUPTION TOLERANT NETWORKING

Topics for Discussion

- The Solar System Internet
- Space Communication Evolution
- Delays in Perspective
- DTN Overview
- The Case for DTN
- DTN Visualization Example
- DTN Features
- Benefits of DTN
- DTN Standardization
- DTN Benefits on Earth
- DTN Resources
- Open Source DTN Implementations

The Solar System Internet

- Delay/Disruption Tolerant Networking (DTN) started at NASA in 1998 in response to an initiative to develop an “Interplanetary Internet”
- Since the mid-2000s worldwide DTN development has been led by NASA
- In 2010, the Interagency Operations Advisory Group (IOAG), consisting of NASA and major international partners, recommended a timely evolution toward a fully operational Solar System Internetwork (SSI), and includes DTN as a core service of the SSI

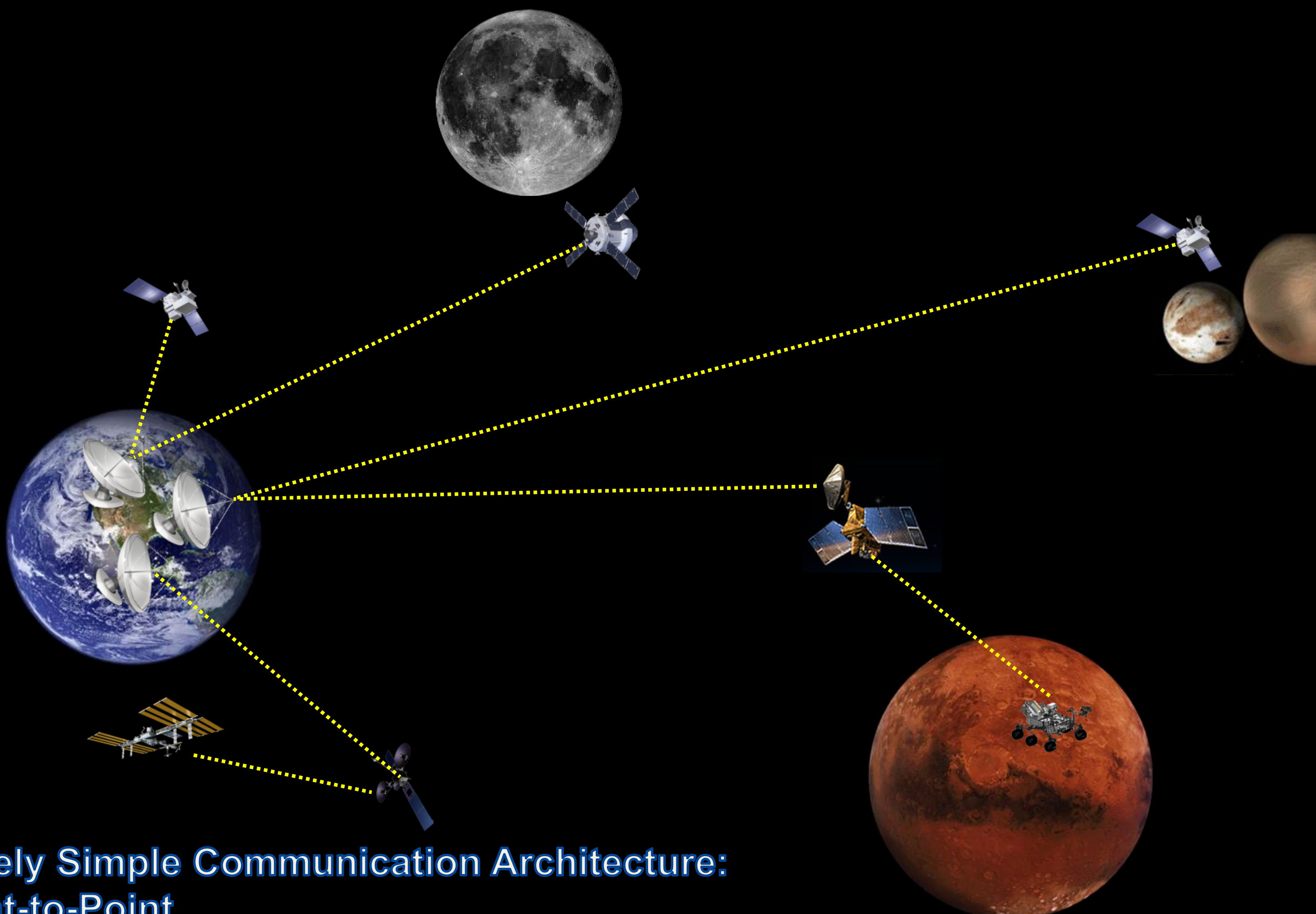

Report of the
Interagency Operations Advisory Group
Space Internetworking Strategy Group

Recommendations on a Strategy for Space Internetworking

November 15, 2008

Cover art background: SELENE HDTV image provided by JAXA/NHK

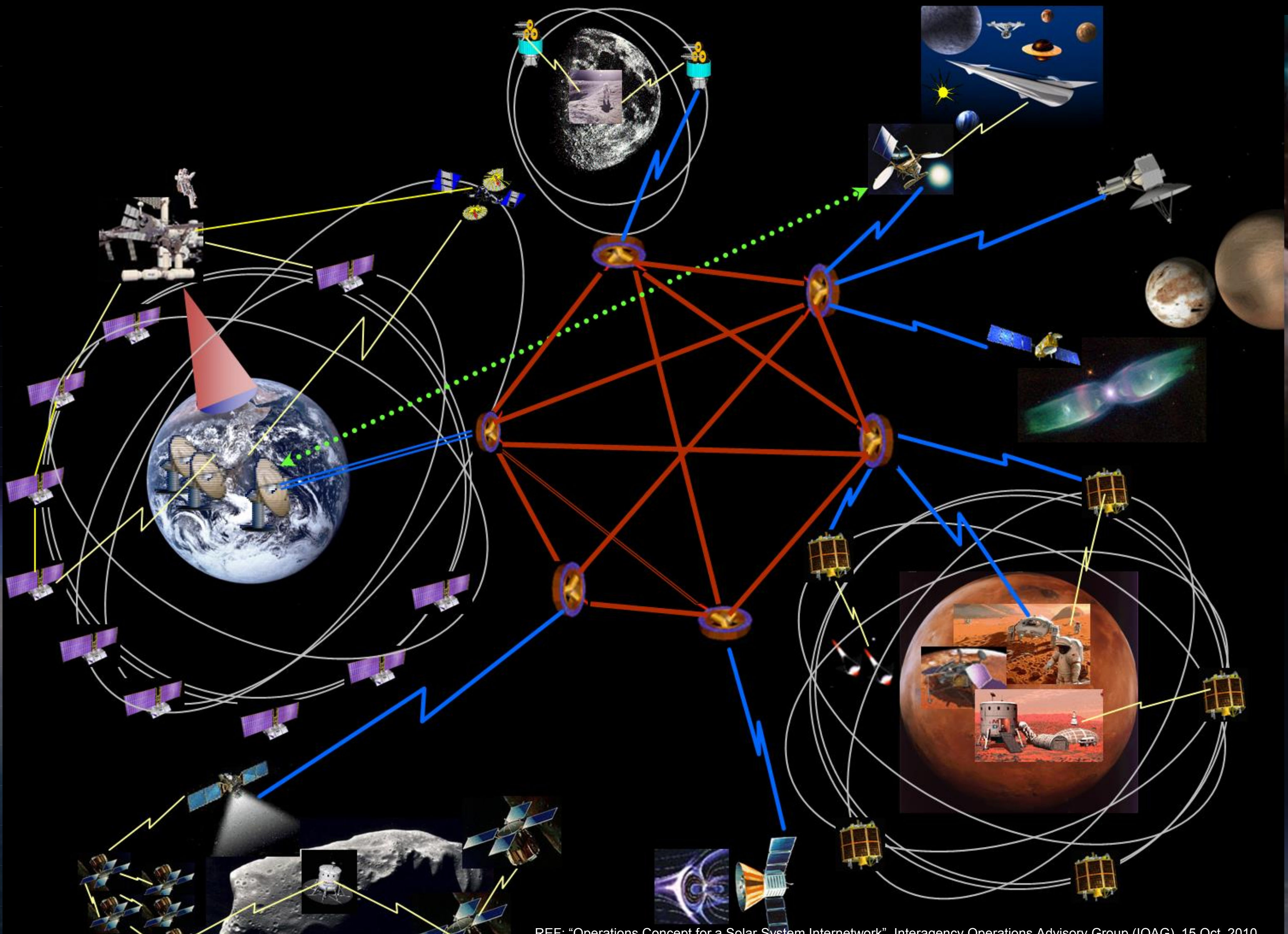
Traditional Space Communication



Relatively Simple Communication Architecture:

- Point-to-Point
- Single-hop Relay
- Well-served by traditional wireless comm

Solar System Internet



REF: “Operations Concept for a Solar System Internetwork”, Interagency Operations Advisory Group (IOAG), 15 Oct, 2010.
http://ipnsig.org/wp-content/uploads/2012/07/SISG-Operations-Concept-for-SSI-final-version.pdf

DTN
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Delays in Perspective

- Distance to ISS (through TDRS): ~71322 km
  - On-Way Light Time (OWLT) Delay: 0.24 s
- Distance to the Moon: ~384400 km
  - OWLT Delay: 1.28 s
- Minimum Distance to Mars: ~54.6 Million km
  - OWLT Delay: 182.13 sec or 3.04 min
- Average Distance to Mars: ~225 Million km
  - OWLT Delay: 750.52 sec or 12.51 min
- Farthest Distance to Mars: ~401 Million km
  - OWLT Delay: 1337.59 sec or 22.29 min

Notes:

- TCP requires a three-way handshake to establish a connection that consumes 1.5 round-trip times and has a 2 minute timeout.
- TCP also assumes continuous end-to-end connectivity.

DTN Overview

- The Delay/Disruption Tolerant Networking (DTN) protocol suite extends the terrestrial Internet capabilities into challenged communication environments where conventional Internet does not work. These challenges may be frequent disruptions, unidirectional/asymmetric links, long delays, and high error rates.

- DTN provides assured delivery of data using an automatic store-and-forward mechanism, while IP generally does not.

- DTN can run over an existing Internet Protocol (IP) suite or can operate as a full Internetworking protocol.

- DTN is being standardized by the Internet Engineering Task Force (IETF) and the Consultative Committee for Space Data Systems (CCSDS), with open international standards, supported by open-source software that can help users implement the new capabilities.

- The standardized DTN protocol suite is the foundation of the Solar System Internet.

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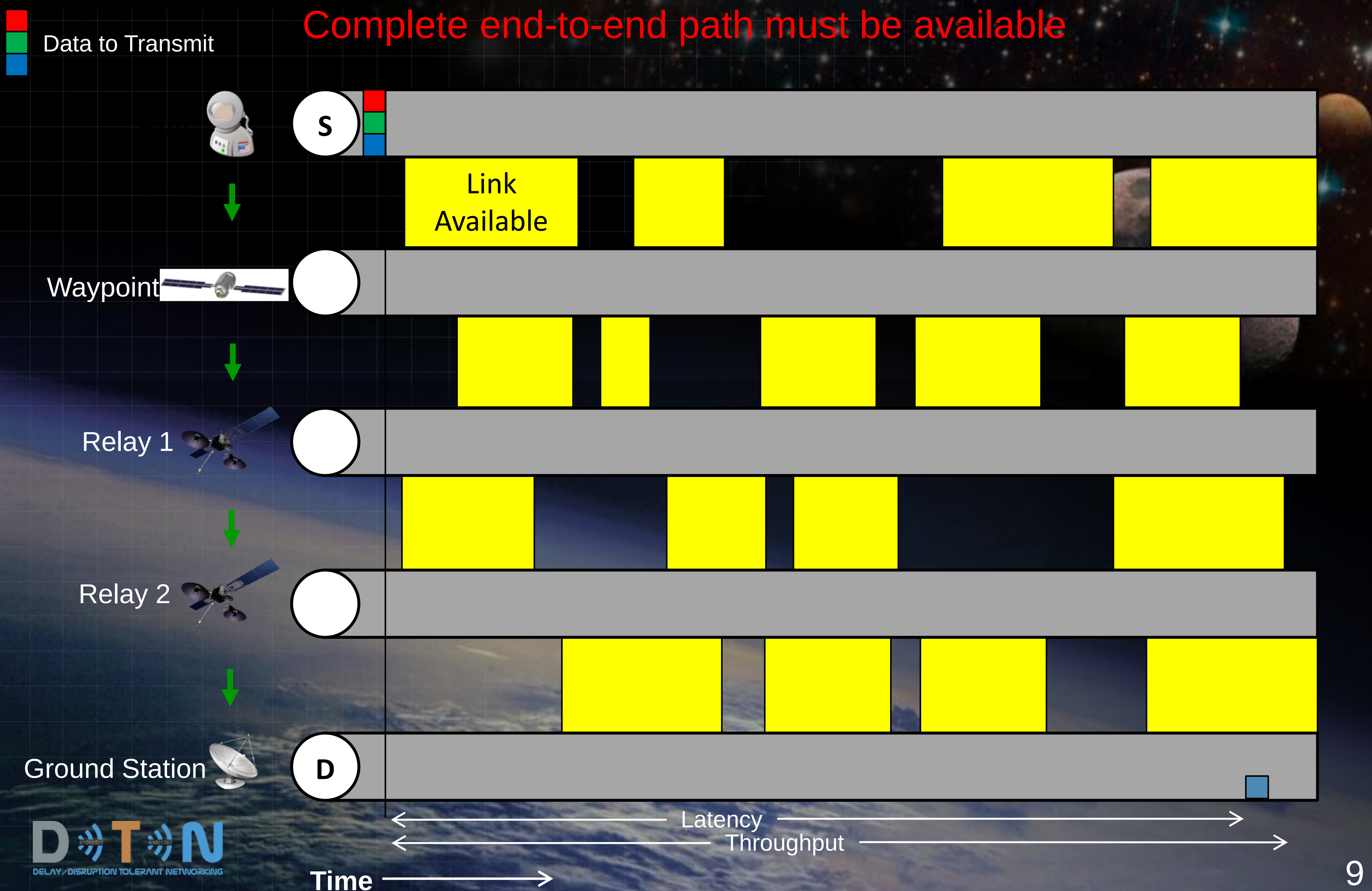
The Case for DTN

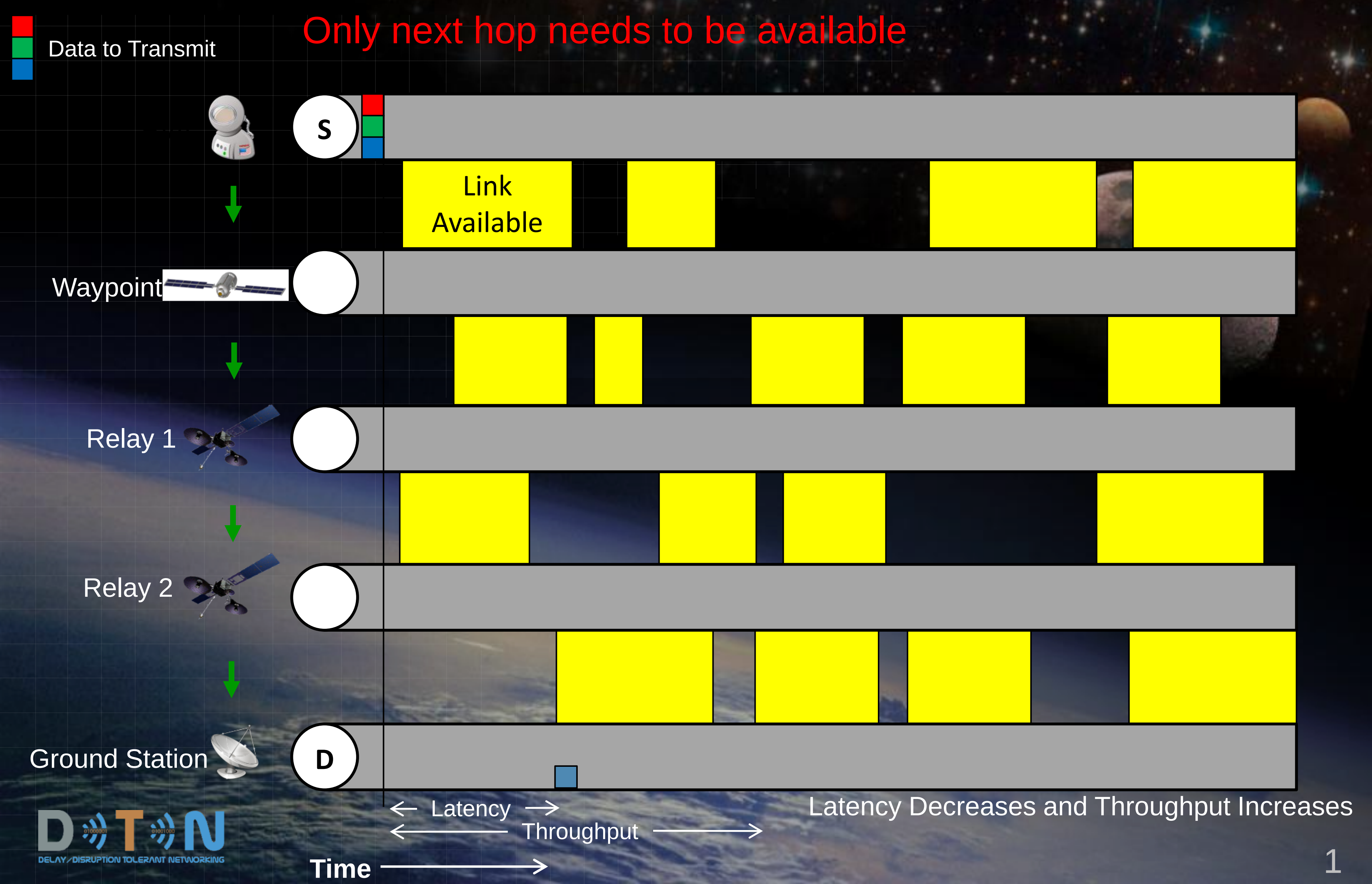
- The **Internet Protocol** is based on Five Key **Assumptions**
  - Networks are Richly Connected
  - Networks have Short Delays
  - Data Links are Symmetric and Bi-Directional
  - Links have Low Error Rates
  - Network Nodes are Trustworthy

- The Assumptions above are NOT VALID in the Space Environment
  - **Connections** can be blocked by orbital mechanics
  - **Delays** can be driven by very long distances
  - **Links** vary by spacecraft and ground station
  - **Error rates** can increase in this environment
  - **Security** is critical for reliable communications and control

Sample Multi-hop Scenario Using Traditional IP



Sample Multi-Hop Scenario Using DTN-Capable Nodes



DTN Features

The DTN protocol suite was designed for disrupted, mobile, airborne, and near-Earth and deep-space communications, featuring:

- An **internetworking layer** that functions efficiently in environments with time-disjoint and/or simplex links
- A **reliable data link layer** that improves efficiency of end-to-end delivery by leveraging local link information and tighter local control loops
- **Disruption-tolerant routing** services that can take advantage of scheduled and expected future connectivity, in addition to current connectivity, and that can interoperate with or without a terrestrial routing infrastructure
- **Quality of service** mechanisms to provide user control over the order in which traffic is served by the overlay internetworking layer and is independent of the underlying network segments
- **Security** features that protect the infrastructure from unauthorized traffic and provide standard end-to-end security capabilities (e.g. integrity, confidentiality) and 'over-the-air' key management
- A **network management** system to configure, monitor, and provide accounting for traffic passing through the system
- **International standards** (IETF & CCSDS)

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Benefits of DTN

- **Improved Operations and Situational Awareness:** The DTN store-and-forward mechanism along with automatic retransmission assures data delivery, provides more insight into events during communication outages and significantly reduces the need for ground-based scheduling.
- **Interoperability and Reuse:** A standardized DTN protocol suite enables interoperability of international and commercial partner communication assets, increases the availability of commercial hardware with DTN included, and allows NASA to use the same communication stack for future missions (LEO, NEO or Deep Space).
- **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 Protocol Security (BPSec) allows for integrity checks, authentication and encryption.
- **Quality of Service:** The DTN protocol suite allows for different priority levels to be set for different data types, ensuring that the most important data is received ahead of less important data.

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DTN Standardization

- The CCSDS DTN Working Group was established in 2008 and has since published several documents, including recommended standards of the core DTN protocols.
  - CCSDS 734.0-G-1 – Rationale, Scenarios, and Requirements for DTN in Space
  - CCSDS 730.1-G-1 – Solar System Internetworking Architecture Informational Report
  - CCSDS 734.2-B-1 (Approved 2015) – CCSDS Bundle Protocol Specification
  - CCSDS 734.1-B-1 (Approved 2015) – Licklider Transmission Protocol (LTP) for CCSDS
  - DTN Network Management Informational Report (Draft)
  - CCSDS Bundle Protocol Security Specification (Draft)
  - CCSDS Schedule-Aware Bundle Routing (Draft)

The Consultative Committee for Space Data Systems

- More recently, NASA helped establish the Internet Engineering Task Force (IETF) DTN Working Group, with the first active meeting at IETF 91 in November 2014.
  - Several documents have been published as internet drafts, including Bundle Protocol, Bundle Protocol Security, Asynchronous Management Architecture, Asynchronous Management Protocol, and Agent Application Data Models
  - https://datatracker.ietf.org/wg/dtn/documents/

DTN and Terrestrial Applications

- The SSI can be viewed as a very large (in both distances and numbers) internet of things that need to communicate
  - Orbiters, landers, probes, sensors, robots – many more “things” than humans
  - When the opportunity to communicate arises, DTN allows for automated, assured communications
  - With the increasing use of Space, we need more automation and less cognitive challenges for communicating
- The evolving terrestrial IoT doesn’t typically need immediate response and constant communication
  - Wearables, home automation, trending data, etc.
  - Some node storage is necessary for DTN, but is fairly cheap
- Other terrestrial use-cases could benefit from DTN
  - Sea-going vessels, outdoor explorers, wildlife research, etc.
- As the terrestrial IoT grows (in number and in geographic distribution), more infrastructure will be required to maintain all of the comm links
  - DTN is an alternative to the increased infrastructure
    - Automated, opportunistic, efficient use of existing links with assured delivery

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Resources

- NASA DTN Project Landing Page
  - https://www.nasa.gov/content/dtn
- Interplanetary Networking Special Interest Group
  - http://ipnsig.org
- DTN Tutorial
  - http://ipnsig.org/wp-content/uploads/2015/09/DTN_Tutorial_v3.2.pdf
- Internet Engineering Task Force DTN Working Group
  - https://datatracker.ietf.org/wg/dtn/documents/

DTN Implementations (open source)

- Interplanetary Overlay Network (ION)
  - https://sourceforge.net/projects/ion-dtn/
  - NASA developed DTN implementation
  - Includes BP and LTP, CFDP, BSS, AMS
  - Works on multiple operating systems
- DTN2
  - http://sourceforge.net/projects/dtn/
  - Includes an implementation of BP and BSP
  - Used at the NASA/MSFC HOSC for ISS Payloads Support
- Other Implementations:
  - IBR-DTN: http://www.ibr.cs.tu-bs.de/trac/ibr-dtn
    - Available on the Google Play store and as an OpenWRT package
  - JDTN: http://sourceforge.net/projects/jdtn/
    - Java implementation developed by Cisco
  - Postellation: http://postellation.viagenie.ca/

Thank you

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