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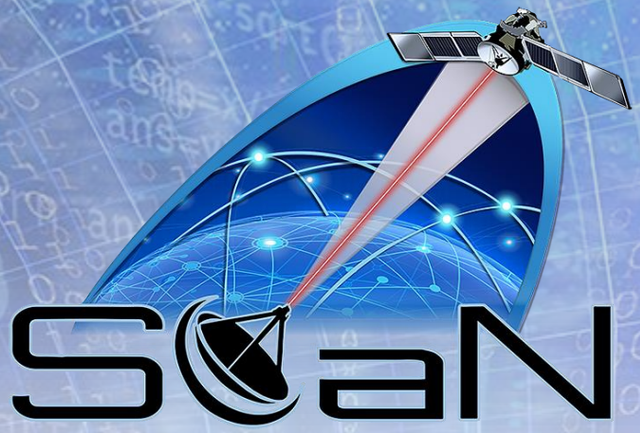

Next Steps: Laying the Groundwork for Bundle Protocol v7

Rowan Parker

Goddard Space Flight Center

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Introduction

Rowan Parker

B.S. Applied Mathematics & Software Engineering

Oregon Institute of Technology

Graduation June 2022

Mentor: Jonathan Wilmot
Senior Software Engineer for Flight Systems
NASA Goddard Space Flight Center

Oregon TECH
Oregon Institute of Technology

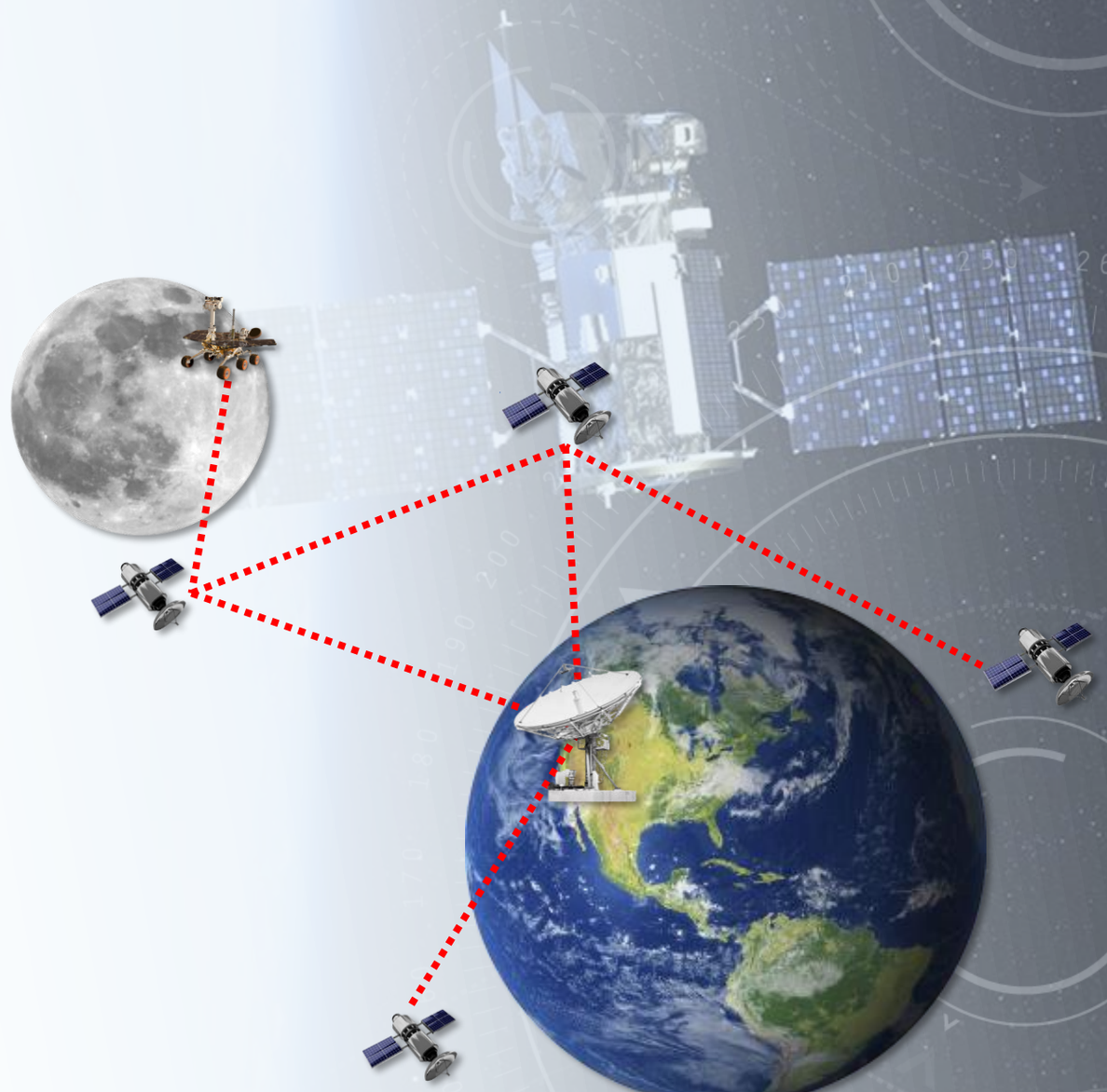
SCaN Intern Project

NASA
Goddard
SPACE FLIGHT CENTER

Background: DTN & BP

- **Delay/Disruption Tolerant Network (DTN)**
  - It's like terrestrial internet – but for space!
  - Multi-hop transmission
  - Uses store-and-forward mechanisms
  - Takes advantage of scheduled, predicted, and opportunistic connectivity
  - Chops data into smaller pieces for transport

- **Bundle Protocol (BP)**
  - Defines how data is sliced up
  - Defines disassembly and reassembly
  - Uses late binding of next hop connection



Background: Applications

- **Netflix on Mars**
- **Spotify on the Moon**
- **LunaNet**
  - **Networking, positioning, navigation, timing, and science services – on the Moon!**
- **Areas on Earth where connectivity may be inconsistent**
  - **At the poles**
  - **Out in the boonies**

Artist's concept of LunaNet being used by astronauts.
Credit: Reese Patillo, 2018 SIP intern

Background: PACE, Lunar IceCube, ISS

- **PACE**
  - Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)
  - NASA Earth-observing satellite mission that will provide unprecedented insight into the ocean and atmosphere
  - Flying a full implementation of BP

- **Lunar IceCube**
  - NASA/Morehead State University collaboration
  - CubeSat that will study ice on the Moon
  - Artemis I mission
  - Flying a full implementation of BP

- **ISS**
  - DTN testbed
  - Provided valuable data

Visualization of PACE in Orbit. *Credit: NASA*

Artist's rendition of Lunar IceCube in lunar orbit.
Credit: Morehead State University, NASA

Overview

- **Primary: Systems Engineering for Bundle Protocol v7**
  - Used lessons learned from missions flying BPv6
  - Investigated extensions of the protocol
  - Standardized terms and MIB parameters
  - Increased technology readiness of the DTN architecture
- **Secondary: “DTN Quick Reference”**
  - List of acronyms and mid-level concepts defined for easy reference
  - Help get interns (and new folks) up and running faster
  - Written from a fellow DTN intern perspective

Methodology

- **Initial Goals**
  - Understand how the DTN architecture works
  - Understand the difference between BPv6 and BPv7
  - Understand how BPv6 is implemented for PACE
  - Identify opportunities for standardization and extension

- **General Approach**
  - Reviewed literature
  - Met with subject matter experts and other engineers
  - Participated in weekly working group sessions
  - Lots of critical thinking and connecting the dots

Results

- **Use Case & Requirements Document**
  - Useful for aiding in the transition from BPv6 to BPv7
  - Helpful for managing engineering resources
  - Gained skills in systems engineering

- **BPv7 Dictionary of Terms**
  - Created named controls and parameters (MIB)
  - Suggested new terms to add clarification to BP bundle components
  - Useful for aiding in the standardization of terms across BP versions

- **DTN Quick Reference Document**
  - Living document
  - Help new people get oriented
  - Solidified DTN topics for me

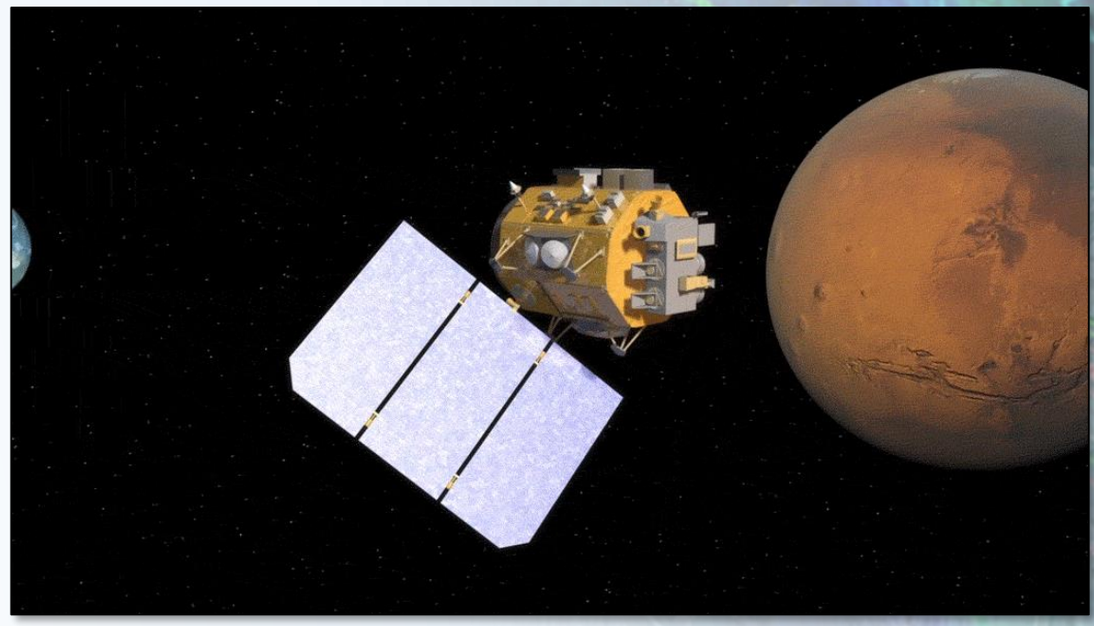
	Term		Data Type	Description	Behavior Notes	Location
2	**version**		unsigned integer	Identifies the version of the bundle protocol that constructed this block.		Primary Block
3	control flags	**isFragment**	boolean	Control flag that signals a bundle is or is not a fragment.		Primary Block
4	control flags	**isAdminRecord**	boolean	Control flag that signals that the payload block of a bundle is an adminstrative record.	If the bundle processing control flags indicate that the bundle's application data unit is an administrative record, then all status report request flag values MUST be zero.	Primary Block
5	control flags	**mustNotFragment**	boolean	Control flag that signals the bundle must never be fragemented.	If the bundle's source node is omitted, mustNotFragment flag value must be one and all status report request flag values must be zero.	Primary Block
6	control flags	**acknowledgementRequested**	boolean	Acknowledgment by the user application is requested.		Primary Block
7	control flags	**statusTimeRequested**	boolean	Status time is requested in all status reports.		Primary Block
8	status report flags	**receptionReportRequested**	boolean	Status report flag that signals a request for a report of bundle reception.		Primary Block
9	status report flags	**forwardingReportRequested**	boolean	Status report flag that signals a request for a report of bundle forwarding.		Primary Block
10	status report flags	**deliveryReportRequested**	boolean	Status report flag that signals a request for a report of bundle delivery.		Primary Block
11	status report flags	**deletionReportRequested**	boolean	Status report flag that signals a request for a report of bundle deletion.		Primary Block
12	**crcType**		unsigned integer	Type code the indicates "no CRC is present," "a standard X-25 CRC-16 is present," or "a standard CRC32C (Castagnoli) CRC-32 is present."		Primary Block
13	**crc**		byte string	When not omitted, the CRC SHALL be represented as a byte string of two bytes or of four bytes; in each case the sequence of bytes SHALL constitute an unsigned integer value (of 16 or 32 bits, respectively) in network byte order.	Shall be omitted from a block if and only if the block's **crcType** code is zero.	Primary Block
14	**destinationEID**		unsigned integer	Identifies the bundle endpoint that is the bundle's destination, i.e., the endpoint that contains the node(s) at which the bundle is to be delivered.		Primary Block
15	**sourceID**		unsigned integer	Identifies the bundle node at which the bundle was initially transmitted	May be the null endpoint ID in the event that the bundle's source chooses to remain anonymous	Primary Block
16	**reportEID**		unsigned integer	Identifies the bundle endpoint to which status reports pertaining to the		Primary Block
17	**creationTimestamp**					Primary Block

DTN Acronyms

BPSec	Bundle Protocol Security
CBHE	Compressed Bundle Header Encoding
CBOR	Concise Binary Object Representation
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
cFS	Core Flight System
CLA	Convergence Layer Adapter
CORE	Common Open Research Emulator
CSTL	Communications, Standards, and Technology Lab
CTEB	Custody Transfer Enhancement Block
DACS	DTN Aggregate Custody Signal
DEN	DTN Experimental Network.
DNS	Domain Name System
DOT	Dictionary of Terms
DSN	Deep Space Network
DTN	Delay/Disruption Tolerant Networking
DTNME	DTN Marshall Edition. MSFC's DTN implementation
DTN2	Reference implementation of the DTN
DTPC	Delay-Tolerant Payload Conditioning

Next Steps

- **Present DoT to CCSDS for review**
  - Consultative Committee for Space Data System
  - An international community, created by space agencies to develop standards for space data & information systems
  - Stamp of approval = adoption into standard
- **Upcoming LCRD tests**
  - Laser Communication Relay Demonstration
  - Demo of DTN network services using optical communication
- **LunaNet & Solar System Internet**
  - Increasing reliability and decreasing latency of data delivery
  - Expanding manned and unmanned space exploration opportunities



Conceptual animation depicting a satellite using lasers to relay data from Mars to Earth.
Credit: NASA Goddard Space Flight Center

SCaN Internship Program

- **Space Communications and Navigation (SCaN) oversees NASA's major networks, ensuring communications with science and exploration missions of all kinds and enabling new discoveries.**

- **SCaN also develops innovations that enhance the communications services and navigation capabilities of the agency.**

- **SIP provides additional programming and resources to supplement the standard NASA internship experience**
  - **Face time with NASA leadership**
  - **Skill building workshops**
  - **Professional development resources**
  - **Social and team building activities**

Questions

- **Thank you…**
  - **Jonathan Wilmot**
  - **Carla Matusow**
  - **Larry Barrett & Simon Singh**
  - **Jimmy Acevedo & SCaN Internship Program**
  - **Catherine Lanier & Oregon Space Grant Consortium**

Acronyms

BP	Bundle Protocol
CCSDS	Consultative Committee for Space Data System
DTN	Delay/Disruption Tolerant Networking
ISS	International Space Station
LCRD	Lase Communication Relay Demonstration
MIB	Management Information Base
PACE	Plankton, Aerosol, Cloud, ocean Ecosystem
SCaN	Space Communications and Navigation
SIP	SCaN Intern Project
SSI	Solar System Internet