## WIFI

- PalmH / TicketBreedProfession


# Lecture One

## Course Overview &

## Intro to Space

# Meet the instructors!

# Jacob Oakley

# Michael Butler






Current Job: Principal Engineer, Cybersecurity and Advanced Platforms Subdivision (CAPS), at The Aerospace Corporation

- Developing cyber labs for training, perform penetration testing & vulnerability assessments {Ethical Hacking!}
- Performing cybersecurity research on ground systems and spacecraft systems to better position the federal government with respect to protection of our critical space infrastructure.

FINAL FRONTIER SECURITY

**2005** — B.S. Electrical Engineering West Virginia University

**2009** — Lockheed Martin Supporting National Geospatial Intelligence Agency

NASA's Independent Verification and Validation Program

Working for Small Business in West Virginia doing Spacecraft and Ground Simulation/Emulation

**2013** — Transitioned to NASA Government Employee GS-13

Began "Hacking" Space Systems

**2018** — Left the Government as GS-15 to become Chief Technology Officer (CTO) for small business in West Virginia

- Supported NASA part-time as contractor

**2019** — Left Job as CTO to join Aerospace Corporation Federally Funded and Development Center

**2024**

## Pen-tested / "Ethically Hacked" Space Systems 2013-2024

- Mars' Rovers (MER & MSL) & Deep Space Network (DSN) at JPL
- Hubble Space Telescope (HST) at GSFC
- Closed IONet (CIONet) within NASCOM at GSFC
- Space Network (SN) at the White Sands Complex (WSC)
- KSC Ground Systems Development and Operations (GSDO) Kennedy Ground Control
- System (KGCS) and Launch Control System (LCS)
- James Web Space Telescope (JWST) Ground System at the Space Telescope Science Institute (STScI) in Baltimore
- Huntsville Operations Support Center (HOSC) at Marshall Space Flight Center
- Near Earth Network (NEN) at Wallops Flight Facility
- ISS Mission Control Center (MCC) at Johnson Space Center
- Wind tunnels at Glenn Research Center
- Hypersonic Environment at Langley Research Center
- NOAA's Joint Polar Satellite System (JPSS)

***NASA's Exceptional Service Medal (2019) for "groundbreaking" cyber work***

## 2019-2024

- DefCON Presentations:
  - DEF CON 2020: Exploiting Spacecraft
  - DEF CON 2021: Unboxing the Spacecraft Software BlackBox Hunting for Vulnerabilities
  - DEF CON 2022: Hunting for Spacecraft Zero Days using Digital Twins
  - DEF CON 2023: Building Space Attack Chains using SPARTA
- Papers/Articles:
  - 2019: Defending Spacecraft in the Cyber Domain
  - 2020: Establishing Space Cybersecurity Policy, Standards, & Risk Management Practices
  - 2021: Cybersecurity Protections for Spacecraft: A Threat Based Approach
  - 2021: Translating Space Cybersecurity Policy into Actionable Guidance for Space Vehicles
  - 2022: Protecting Space Systems from Cyber Attack
  - 2024: Space Segment Cybersecurity Profile for NSS
- July 2022 Congressional Testimony:
  - Video: https://science.house.gov/hearings?ID=996438A6-A93E-4469-8618-C1B59BC5A964
  - Written Testimony: https://republicans-science.house.gov/_cache/files/2/9/29fff6d3-0176-48bd-9c04-00390b826aed/A8F54300A11D55BEA5AF2CE305C015BA.2022-07-28-bailey-testimony.pdf
- SPARTA Launched
  - https://sparta.aerospace.org

SPARTA — SPACE ATTACK RESEARCH & TACTIC ANALYSIS

# Class Day 1

- 0900 – 1000 Lecture 1: Lecture 1: 60m Intro to course & Understanding the attack surface
- 1000 – 1030 Lab 1: 30m NOS3 and ground control system operations
- 1030 - Break: 15m
- 1045 – 1130 Lab 1: 45m NOS3 and ground control system operations continued
- 1130-1230 Lecture 2: 60m Adversarial Perspective
- 1230-1345 Lunch
- 1400-1500 – Lab 2: 1hr insider threat, malicious tasks
- 1500 - 1600 – Lab 3: 1hr Exploiting ground to space without using ground SW (garak command sende
- 1600-1615 Coffee Break
- 1615 – 1700 Lab 4: 45m IOCs and cleaning up after yourself
- 1700 – 1800 FFA

# Space

# Purpose

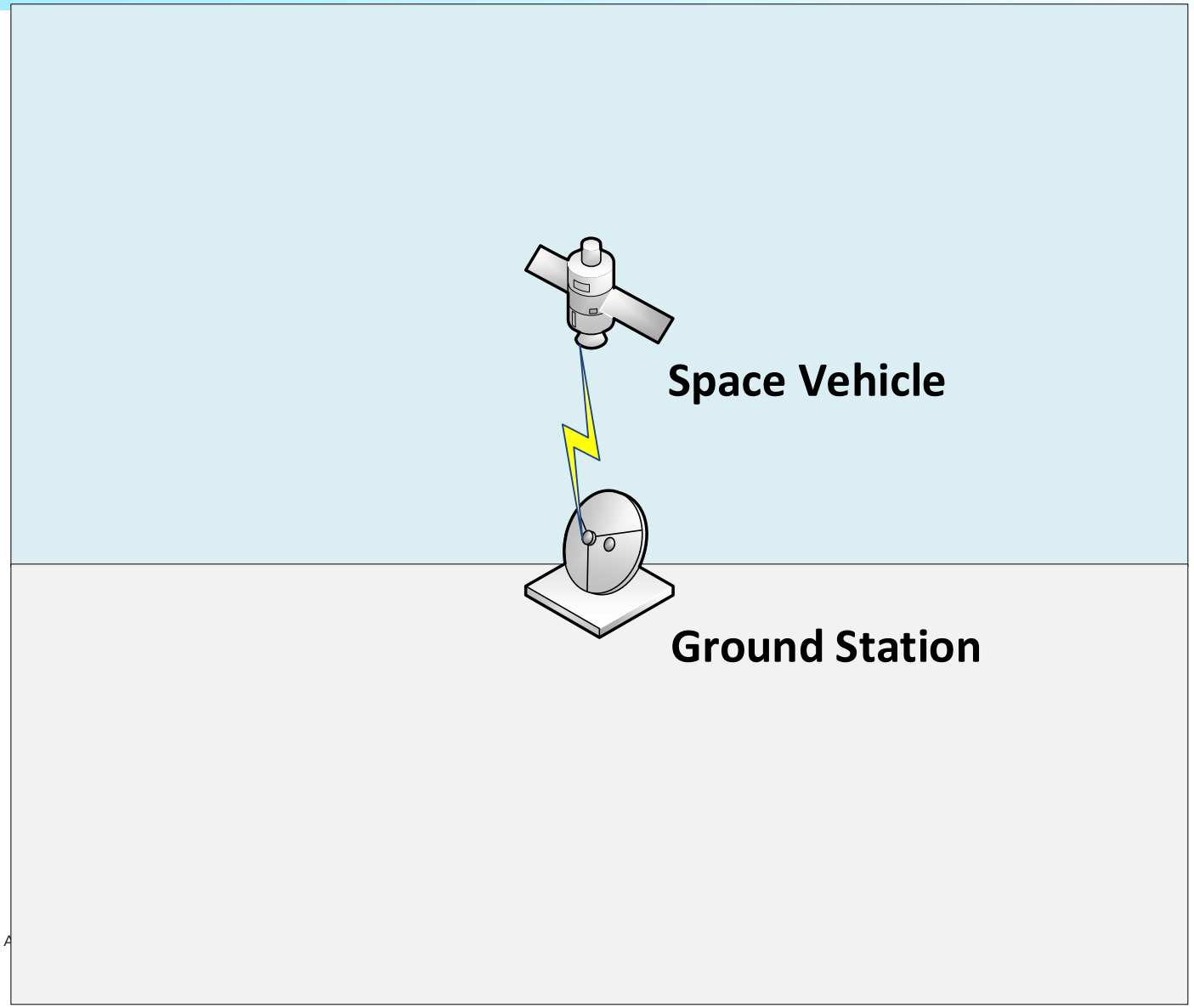
- Space Systems have unique constraints, challenges, technologies, missions and CONOPS
- These aspects dictate adversary tradecraft
- Understanding how malicious actors will operate within these systems is key to figuring out how to stop them

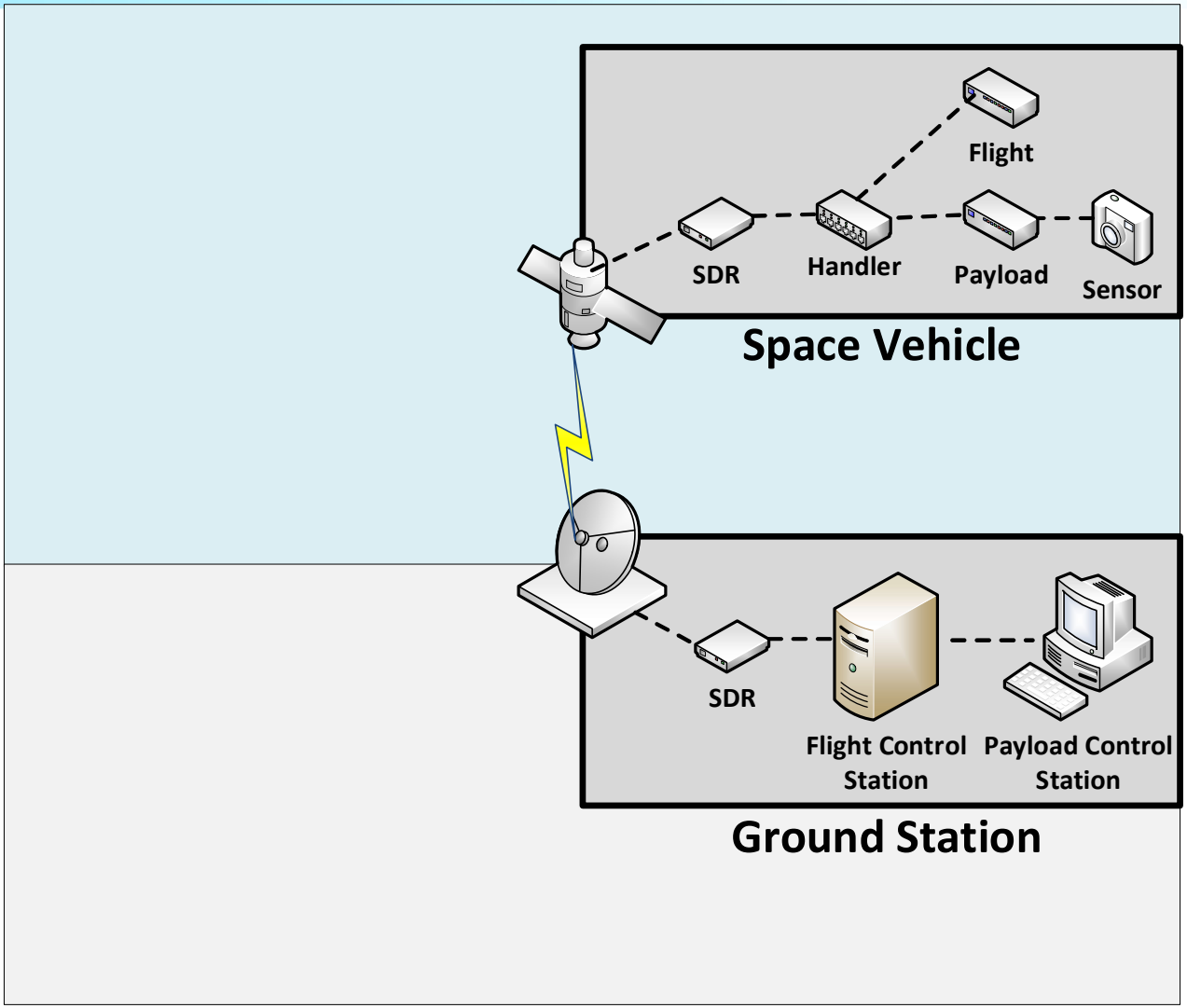
# So What?

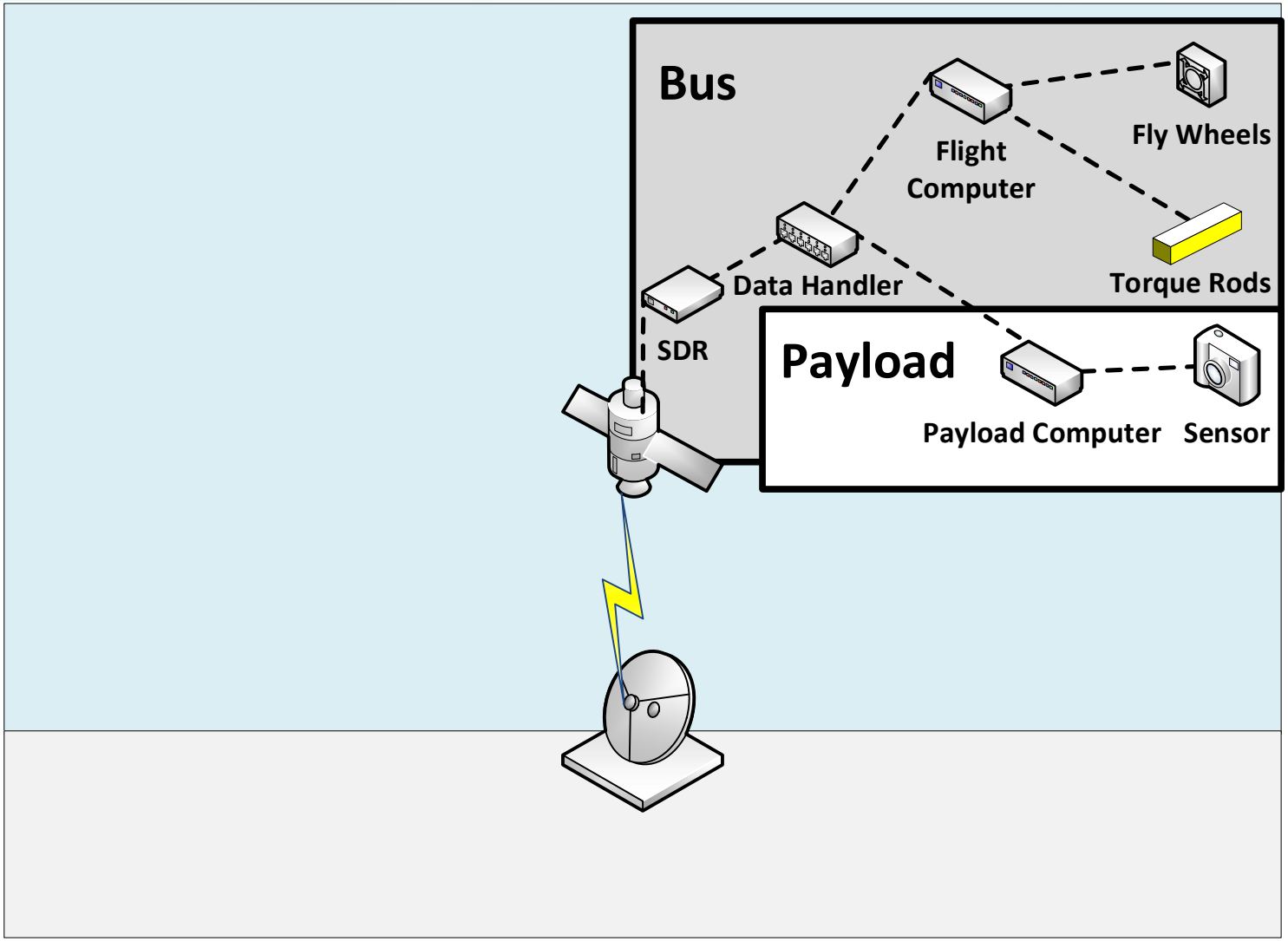
- Very limited international communication
- No weather forecasting
- No PNT
  - Flights grounded, ships lost at sea, inability for most people to navigate
- No time
  - Encryption
  - Financial transactions
  - Network protocol failures
- A bit hyperbolic, but illustrative of how important space has become

# Key Terms & Definitions

- SDR: Software defined radio capable of reprogramming RF communications characteristics
- Modem: modulates and demodulates RF signals
- Telemetry (TLM): Data from a spacecraft is telemetry, engineering (housekeeping) or science data
- Command / Task: request made to the satellite or payload to do or report something
- ADCS: Attitude determination and control system turns commands into execution
- Flight software: suite of SW and framework running on the flight computer (ADCS + comms, data management, storage etc)
- Satellite Bus: components responsible for flight
- Payload: components responsible for mission
- Software Bus: pub-sub mechanism for flight computer and ADCS to communicate to things like propulsion, PNT receiver, star tracker, sun sensor, solar panels battery etc.





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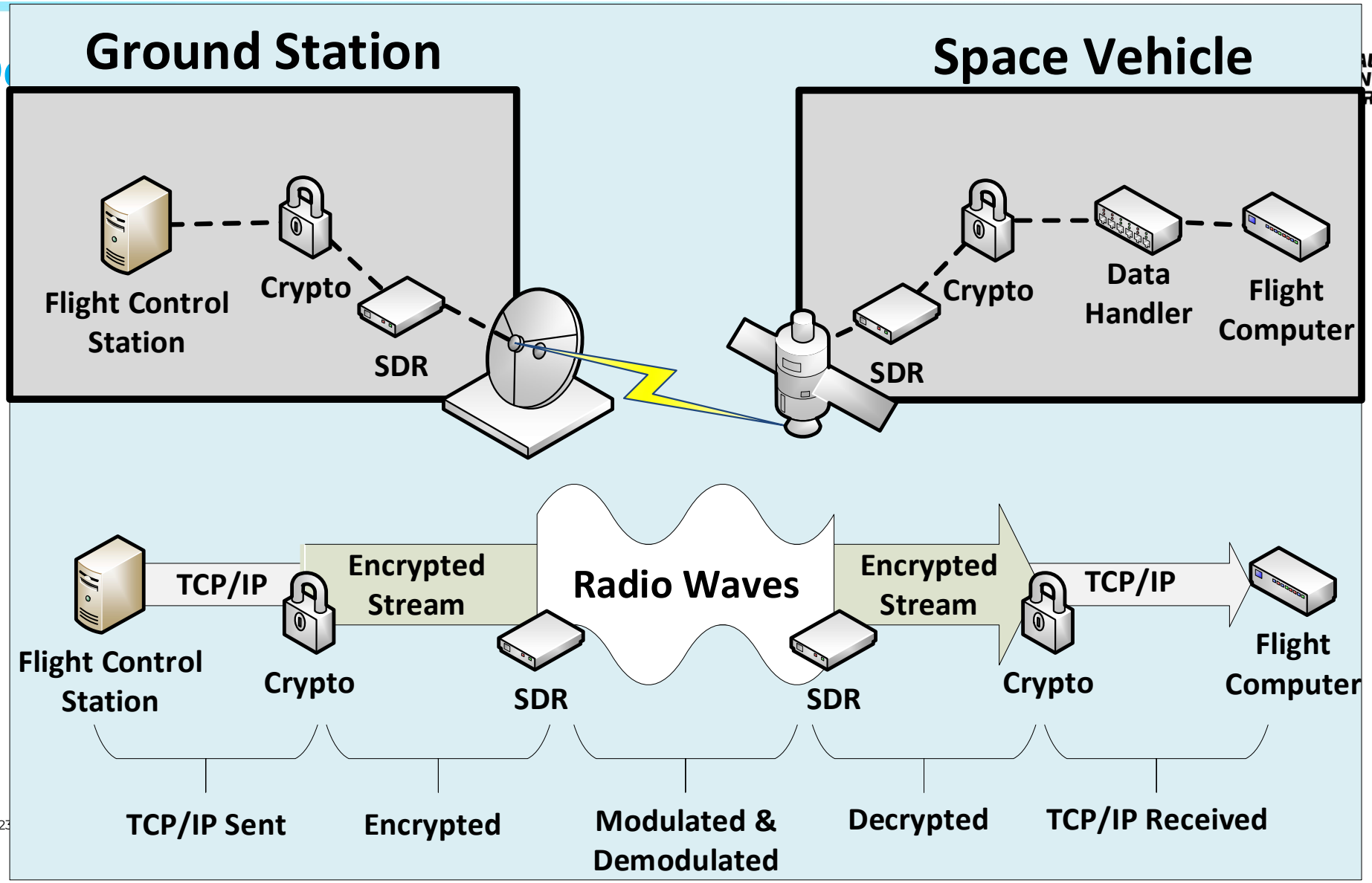
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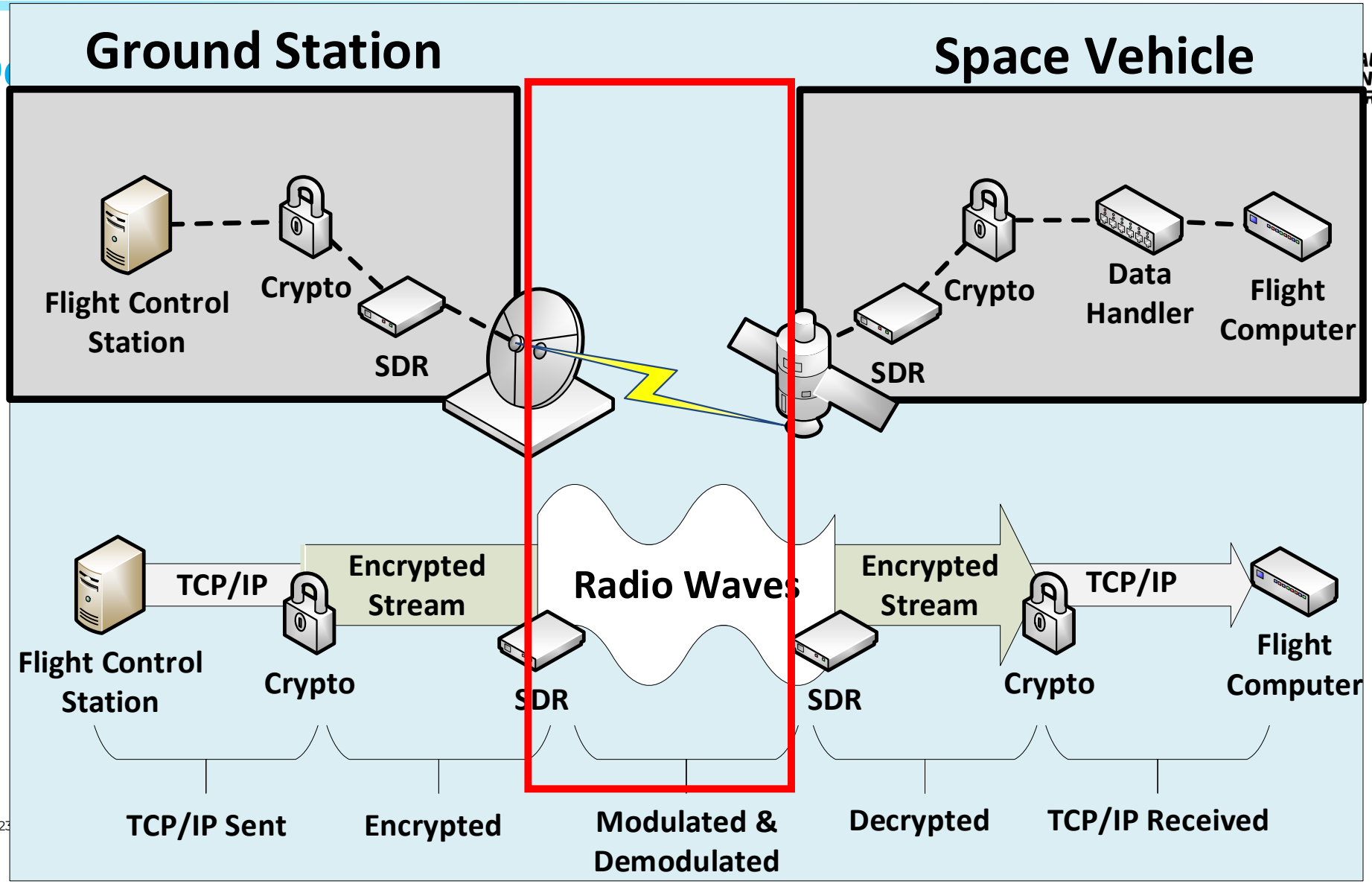
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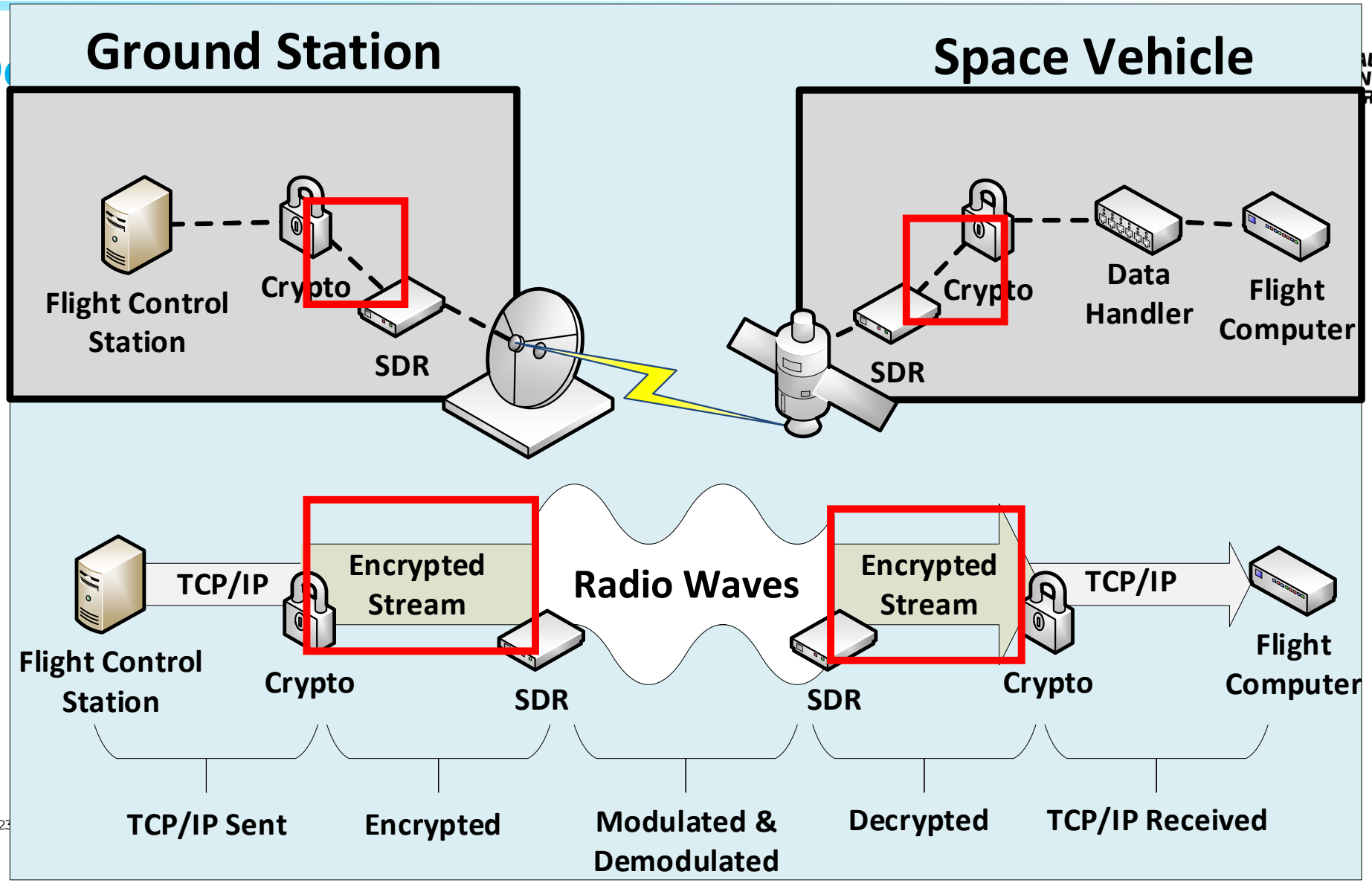
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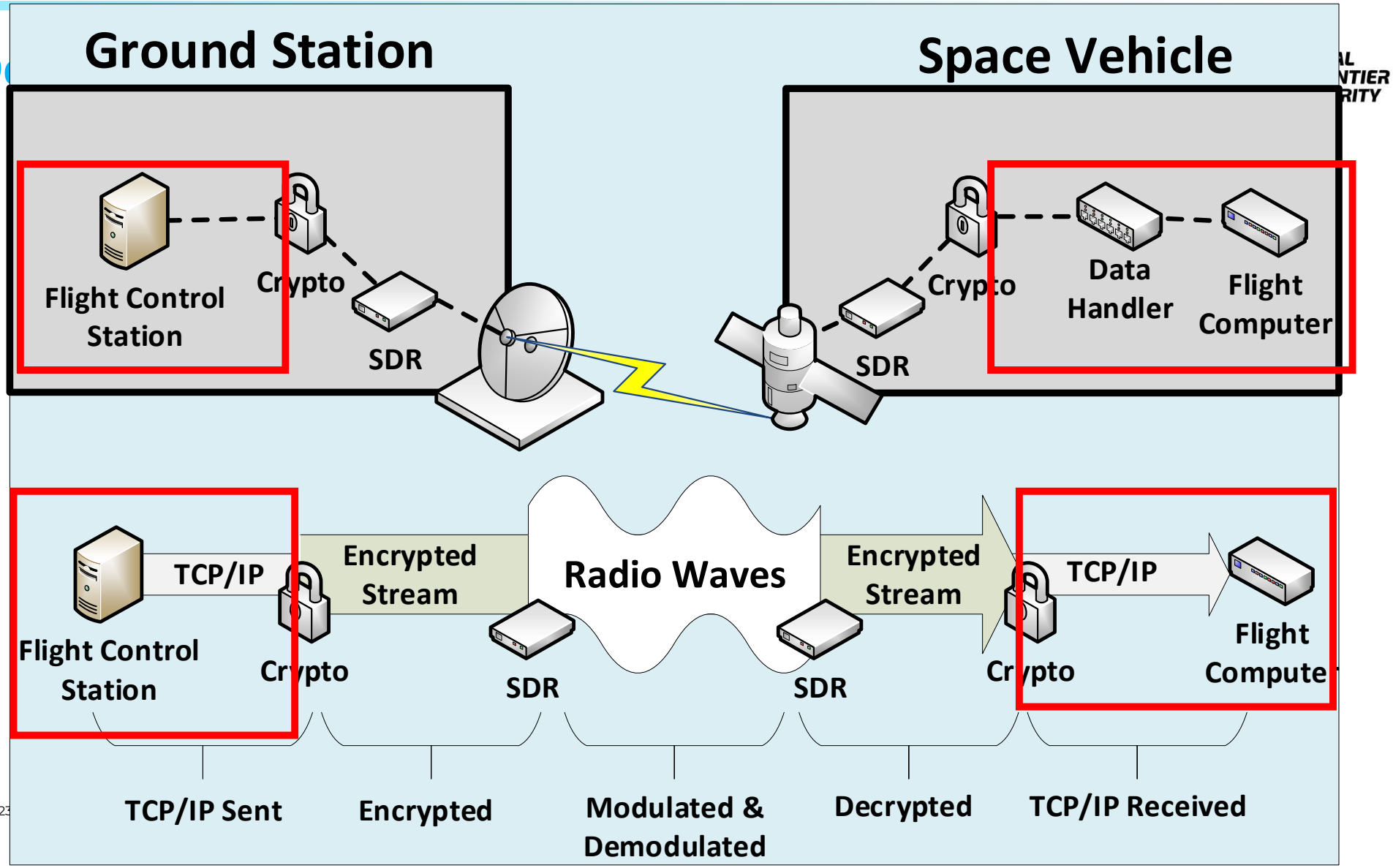
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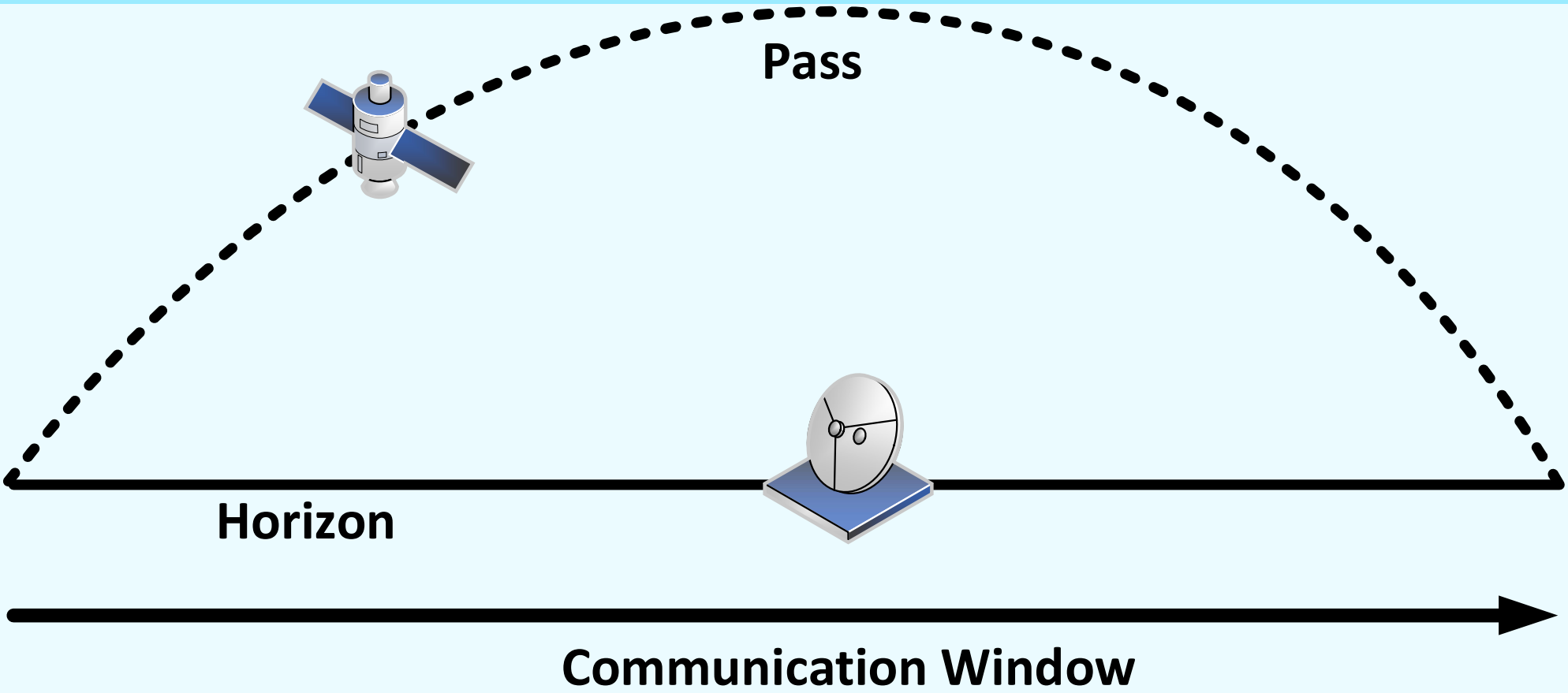


# Ground Station Functions

- Antennae movement
- Communication
- Tasking
  - Flight
  - Payload
- Dissemination

# Space Vehicle Functions

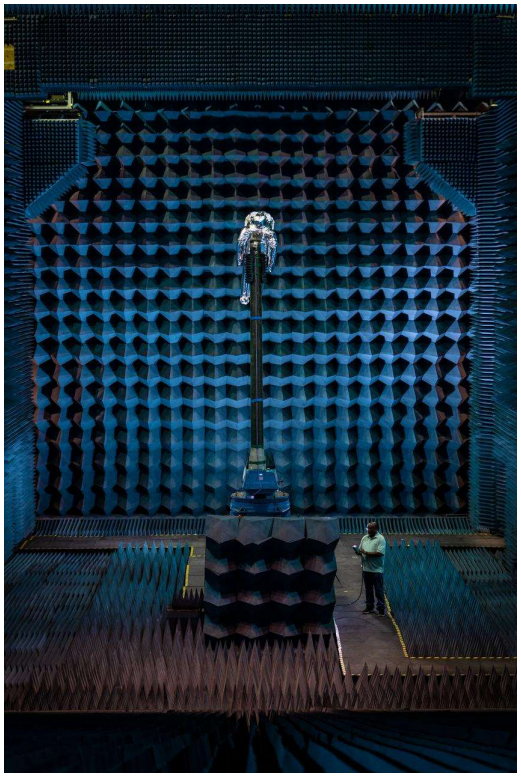
- Bus
  - Power
    - Generate, Store, Moderate
  - PNT
    - GPS, Star Tracker, Sun Sensor
  - Flight:
    - Propulsion & Attitude adjustment
  - Communication
- Payload
  - Tasking
  - Data storage and off load

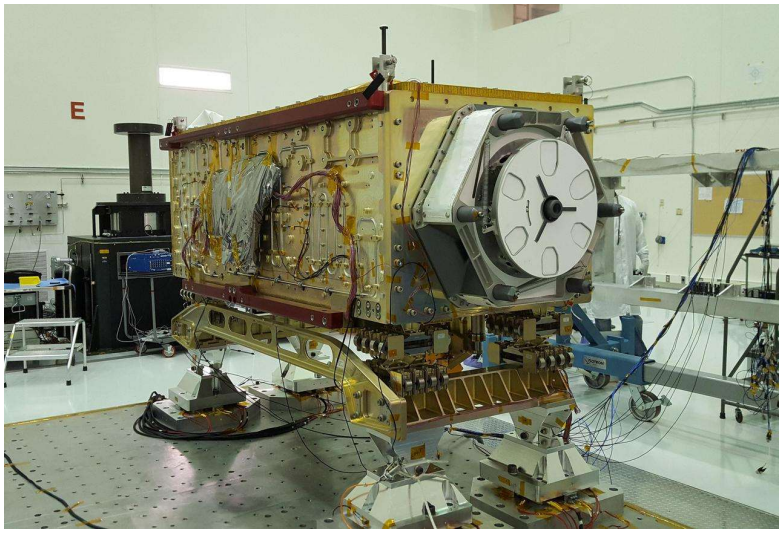
# Environmental Challenges

- Radiation
  - Single events
  - Accumulation
- Temperature extremes
- Vacuum
- Space objects
  - Junk
  - Others
- Vibration

# Operational Challenges

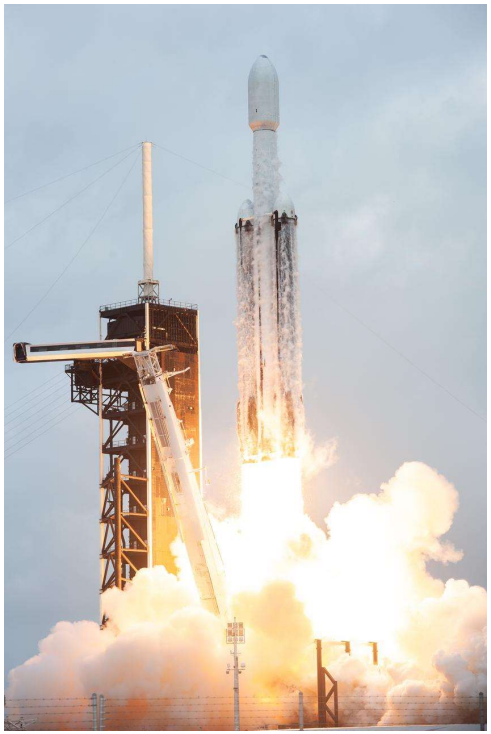
- Testing

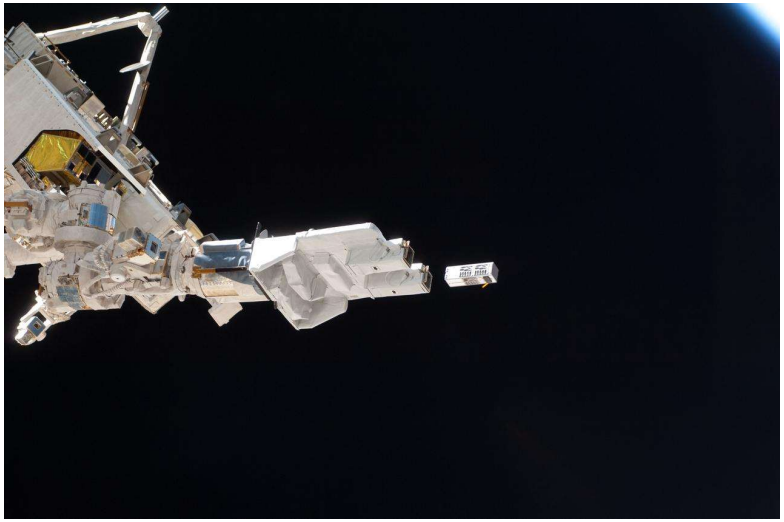




# Operational Challenges

- Launch
- Deployment
- Stabilization
  - De-tumble
  - Orbit





# Operational Challenges

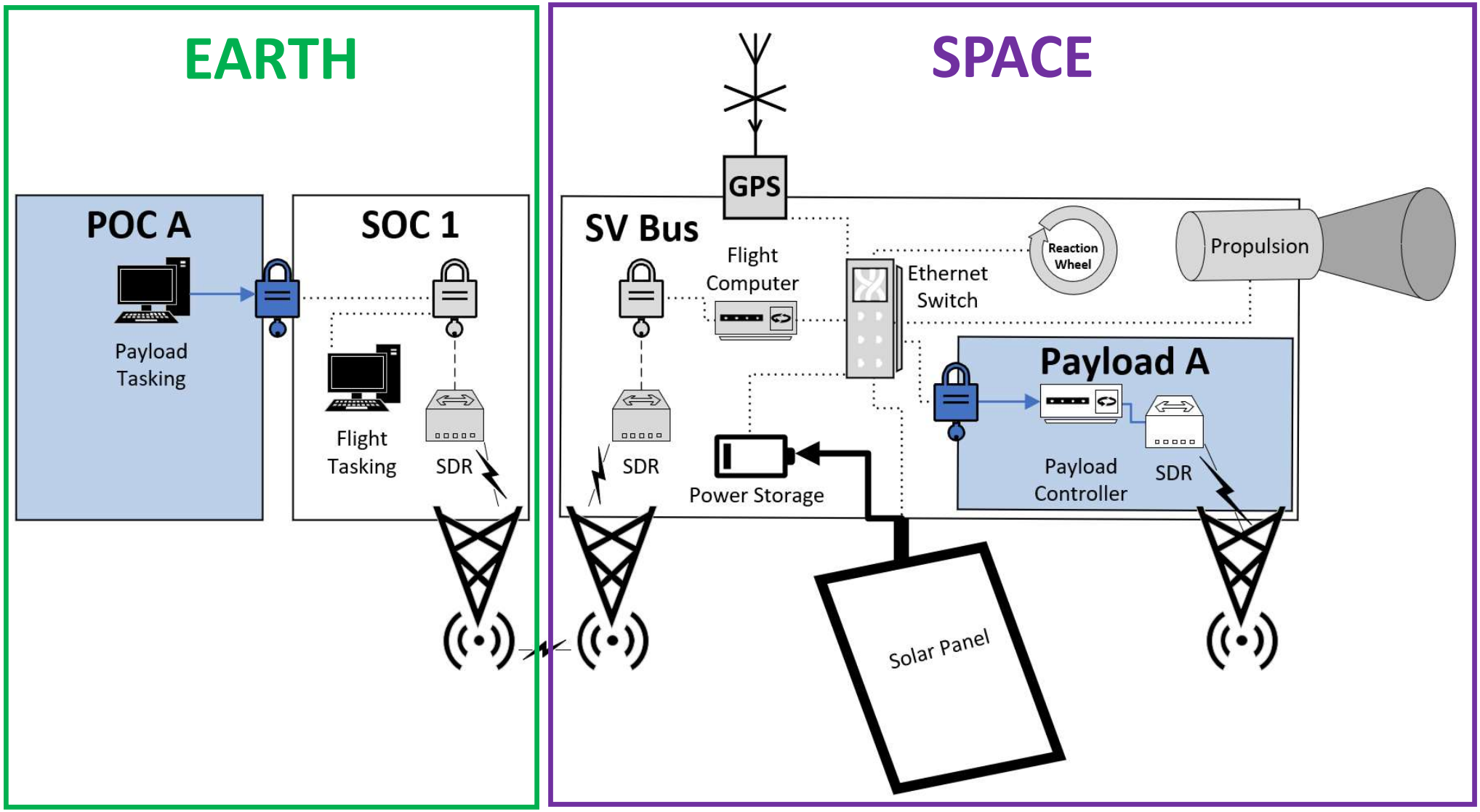
- Power
- Emanations interference (self inflicted and otherwise)
- De-Orbit

# Safeguards


- Back-ups
- Gold images
- Watchdogs
- Fall-back communications / encryption settings
- Resource limiters

***These are redundancy focused***

# What’s in the Box?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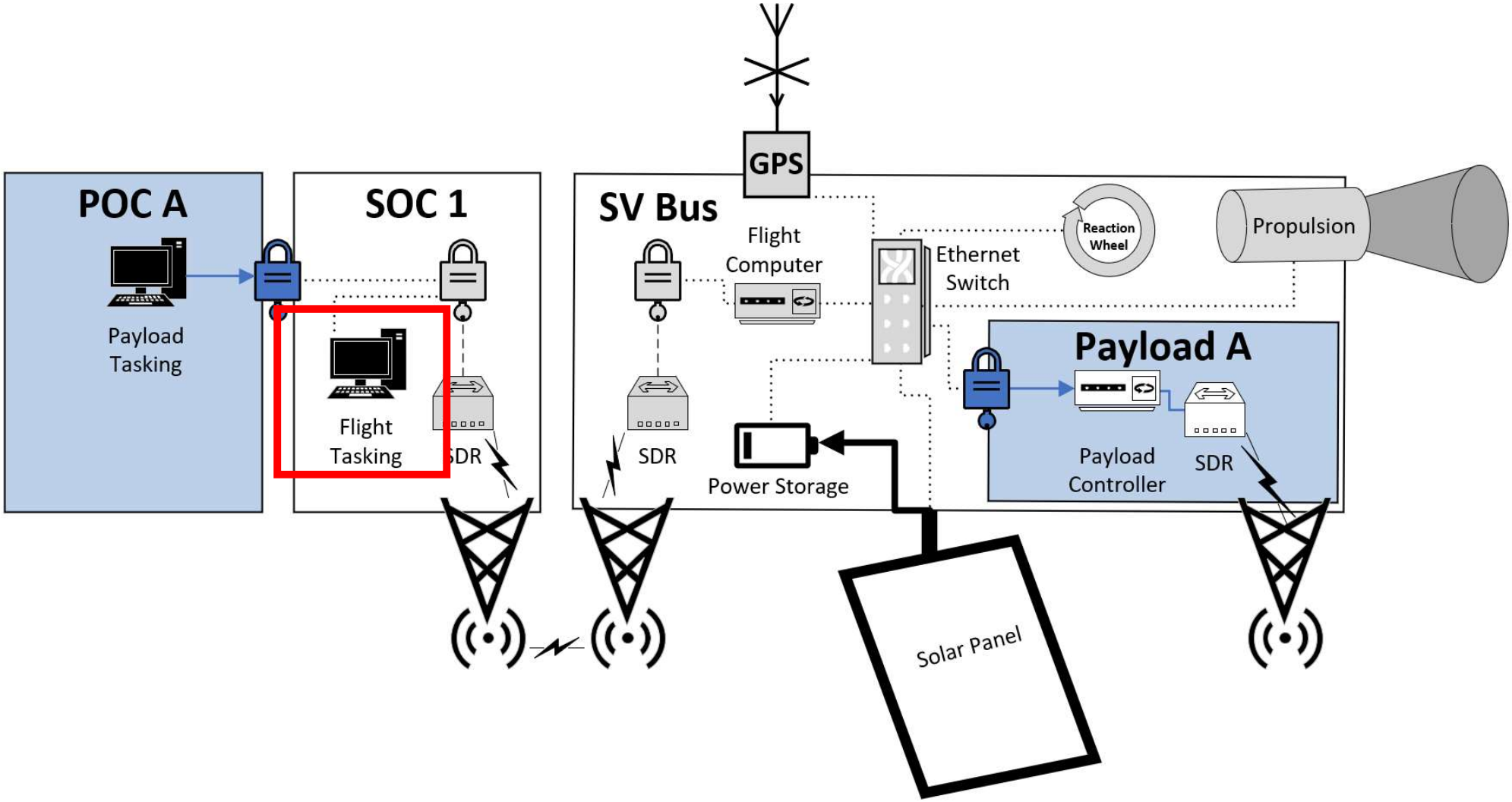
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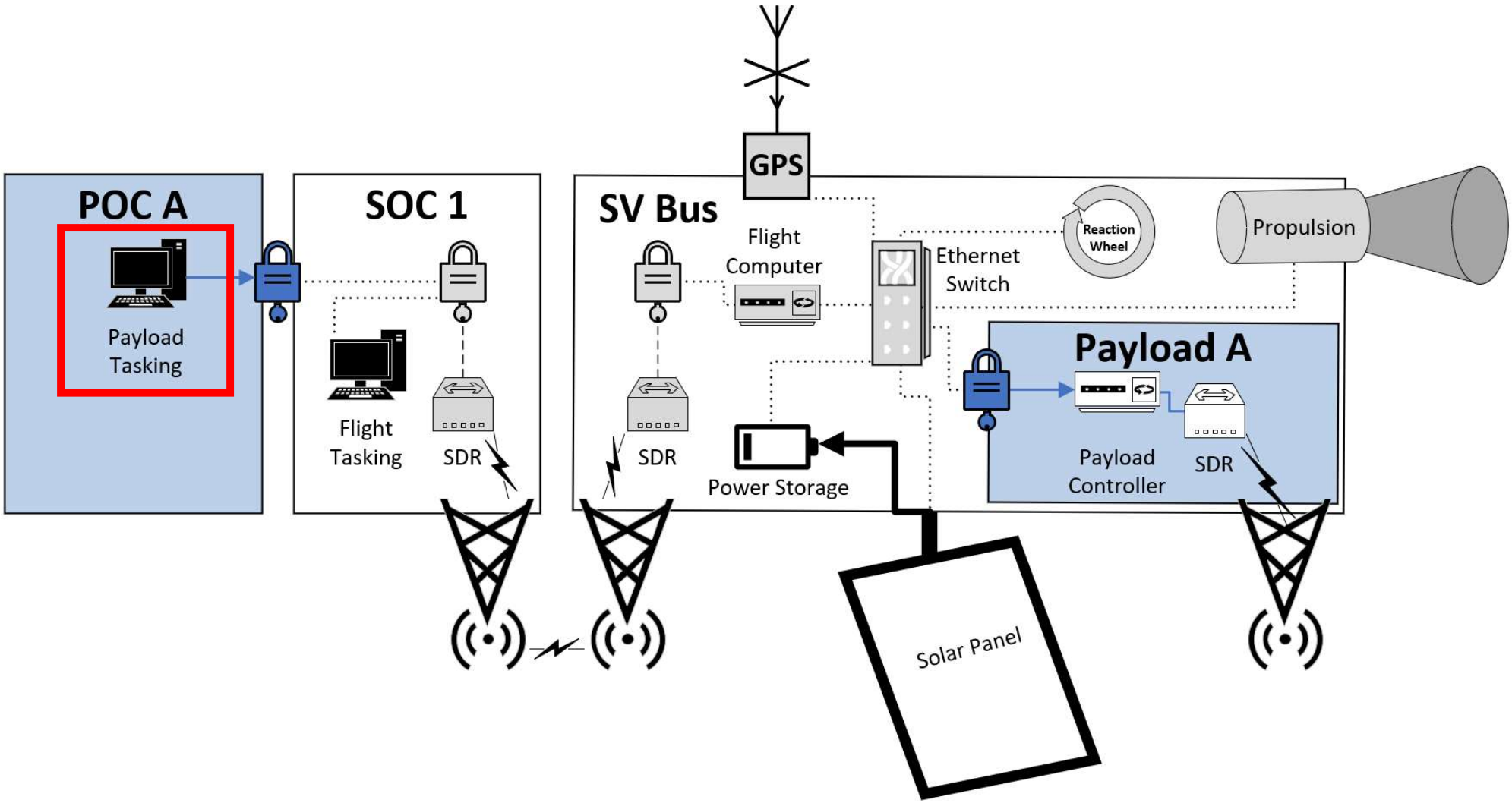
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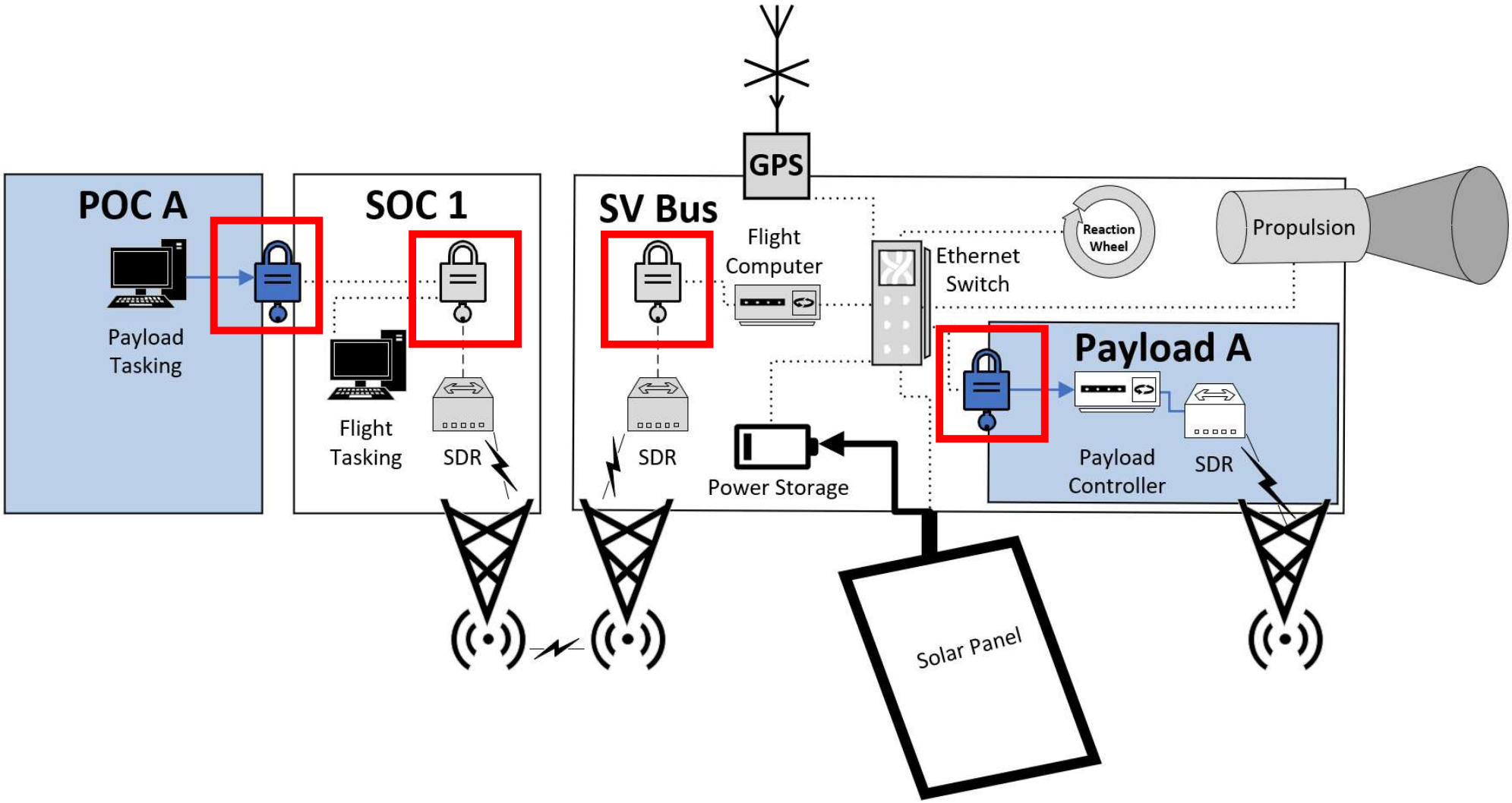
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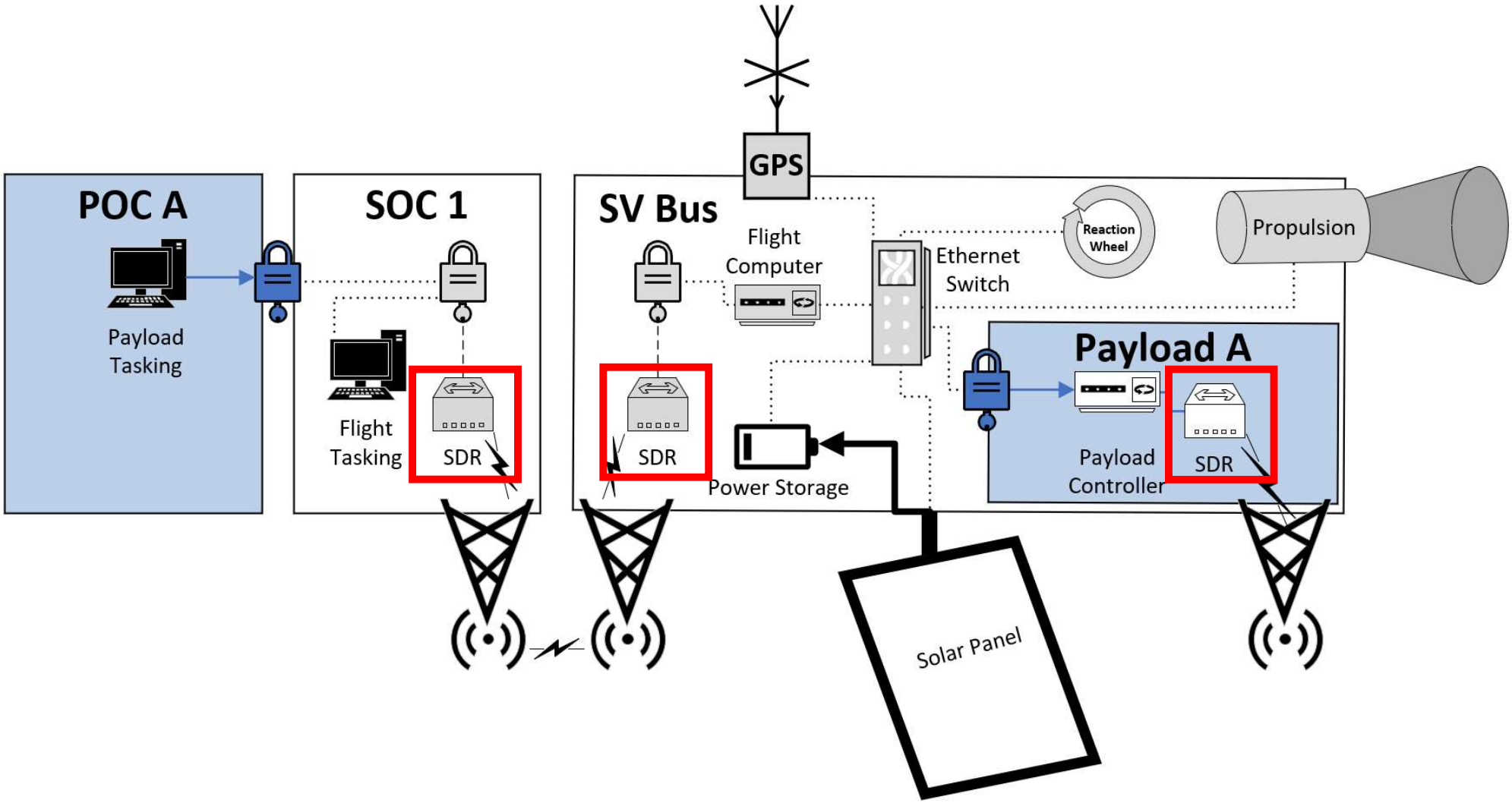
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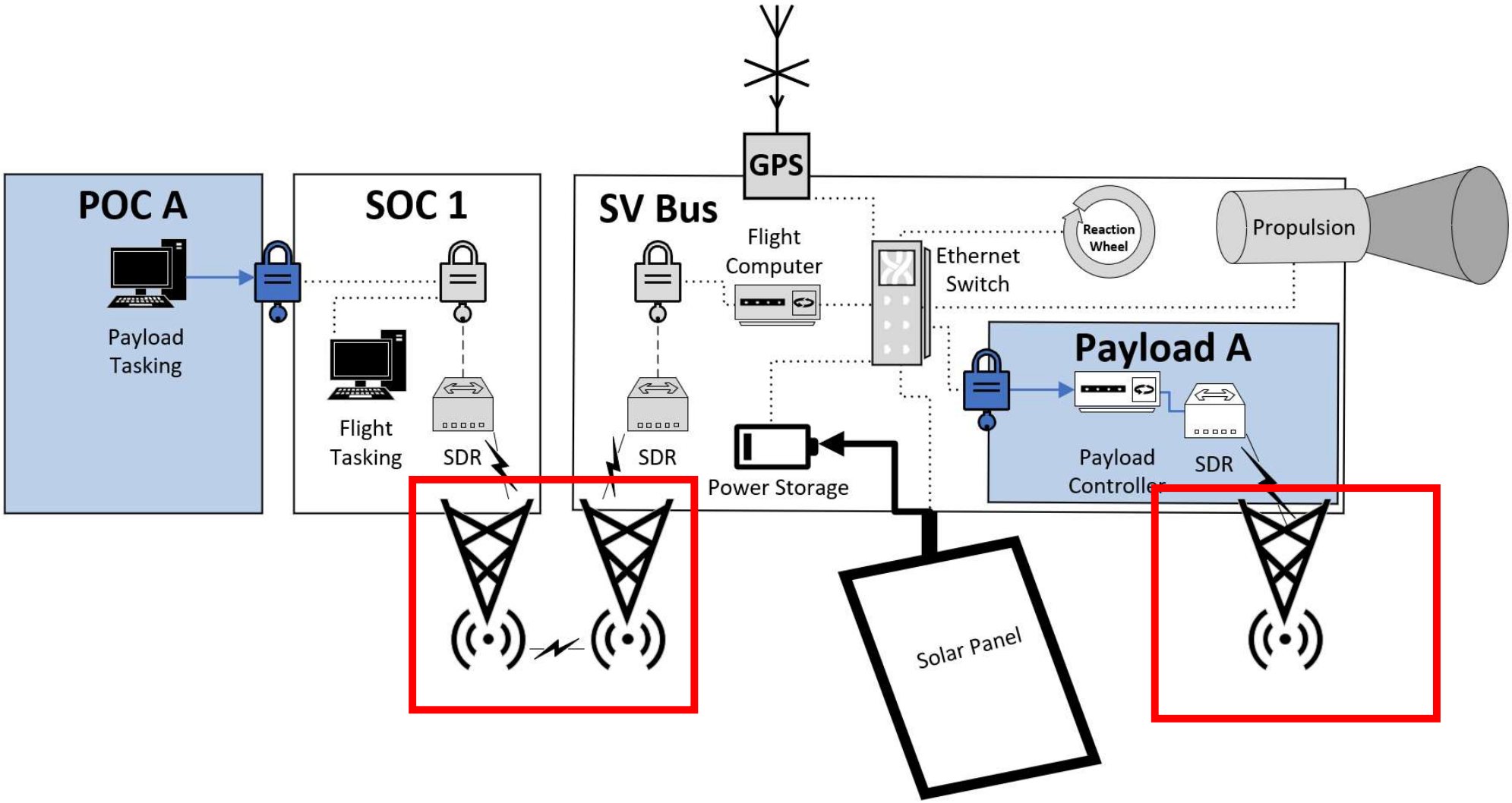
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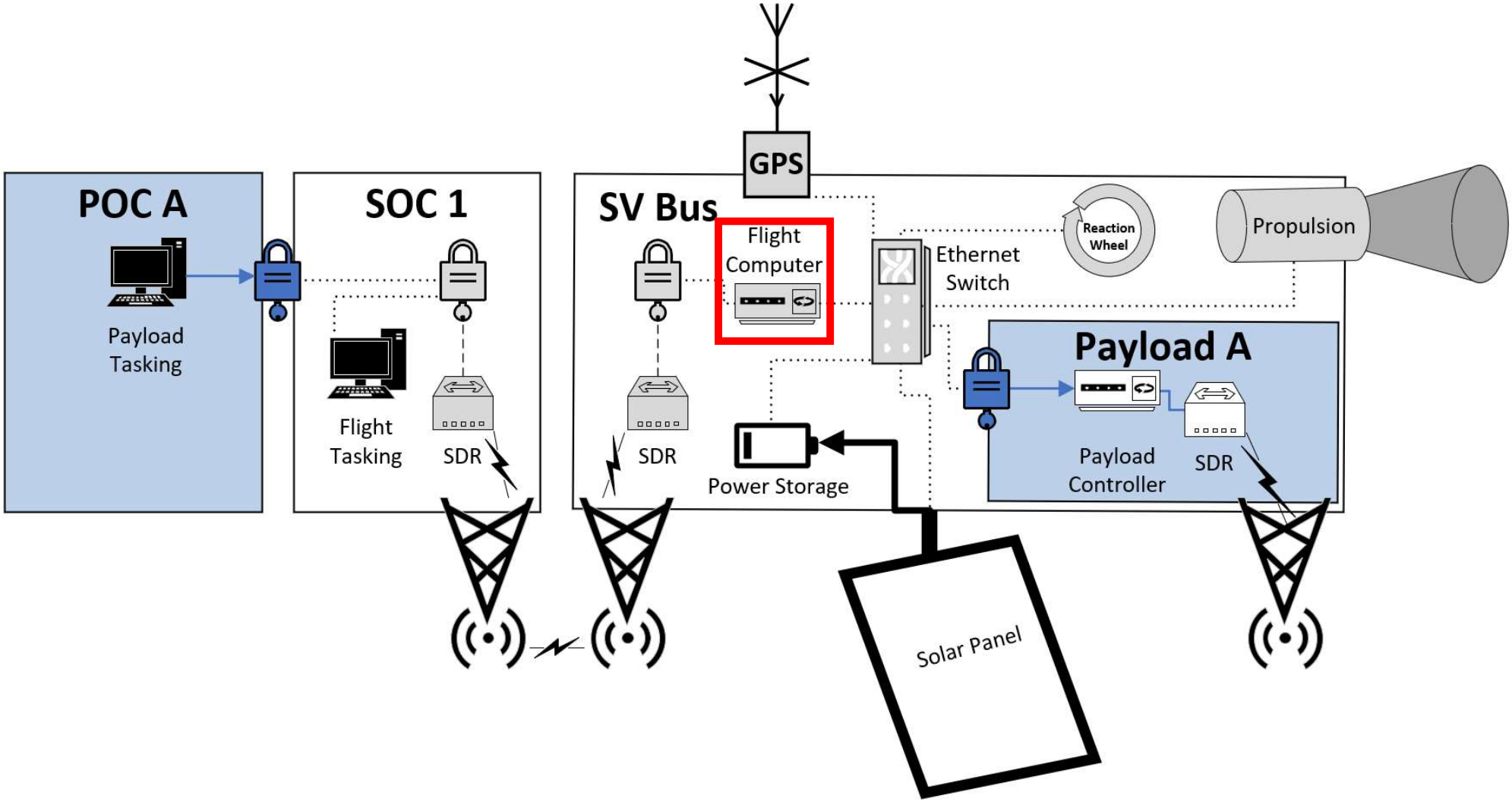
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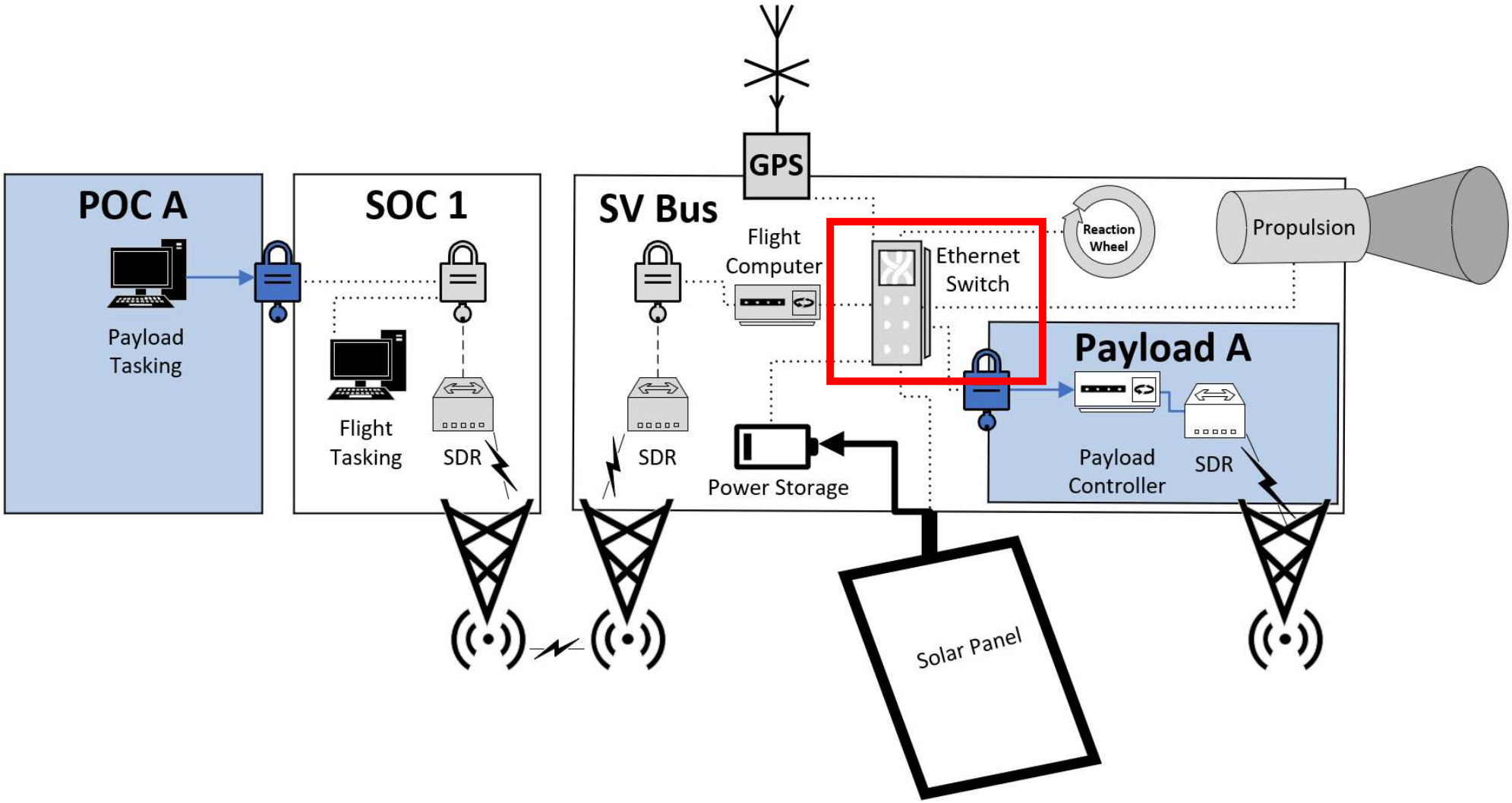
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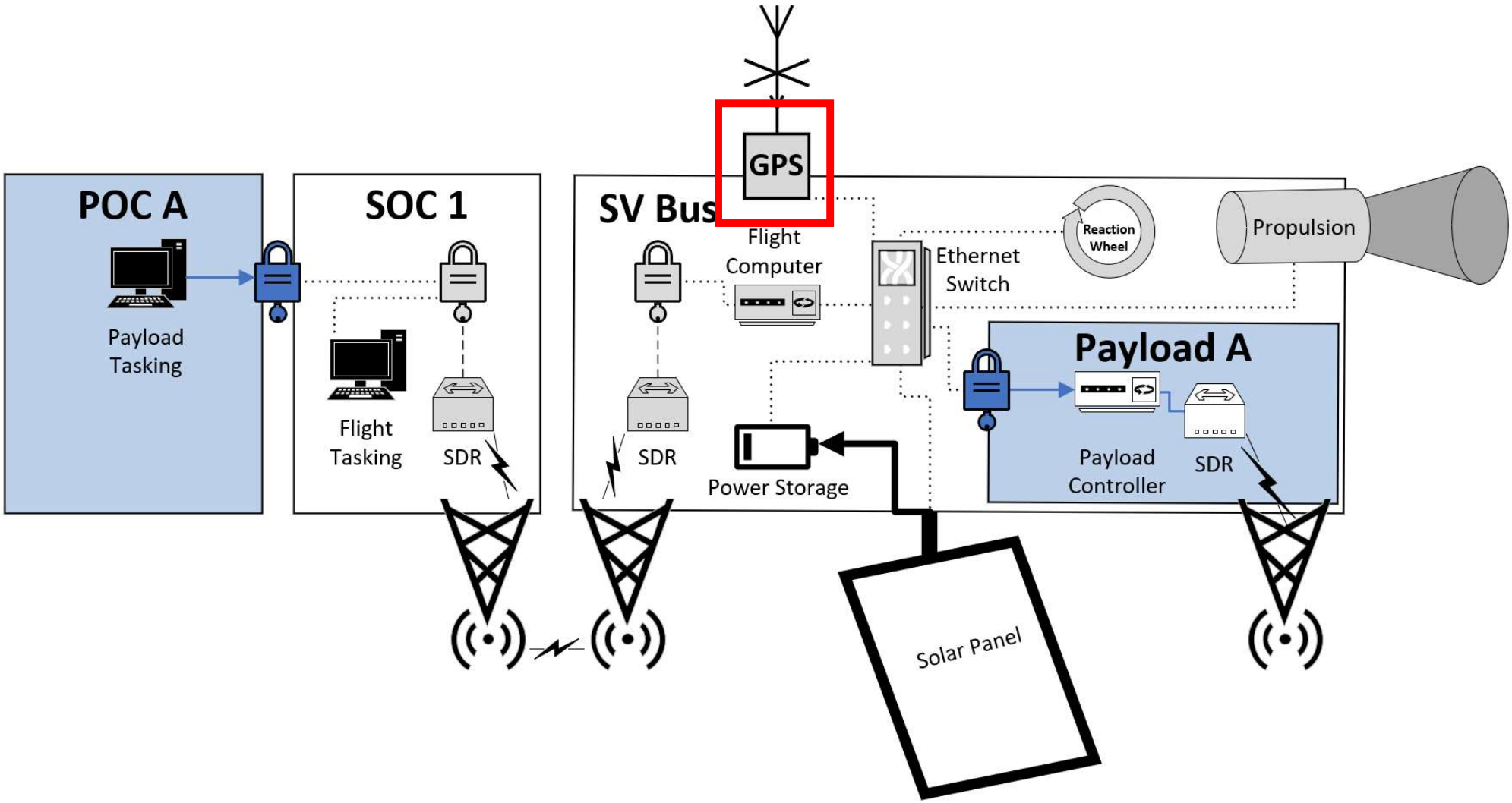
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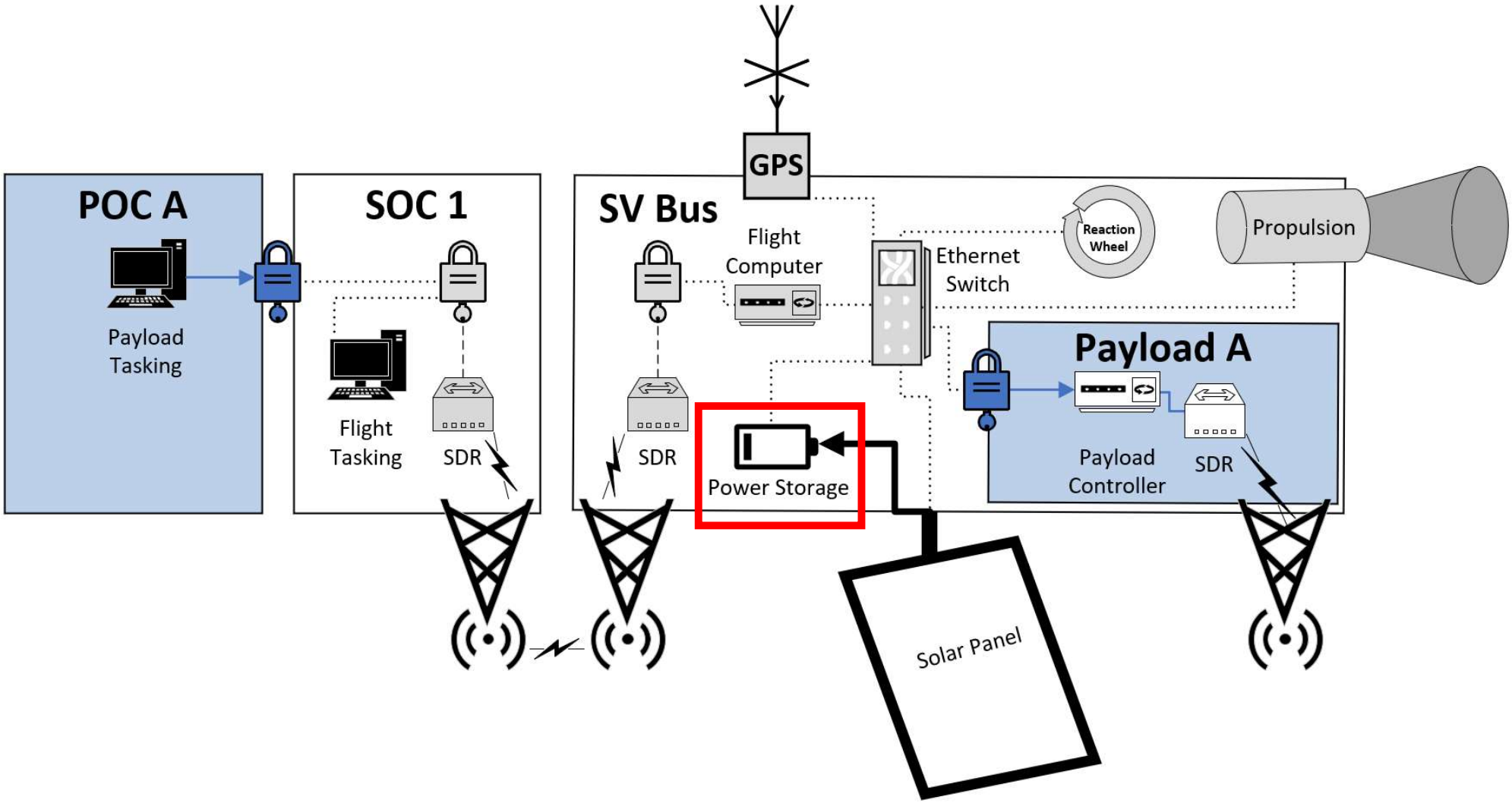
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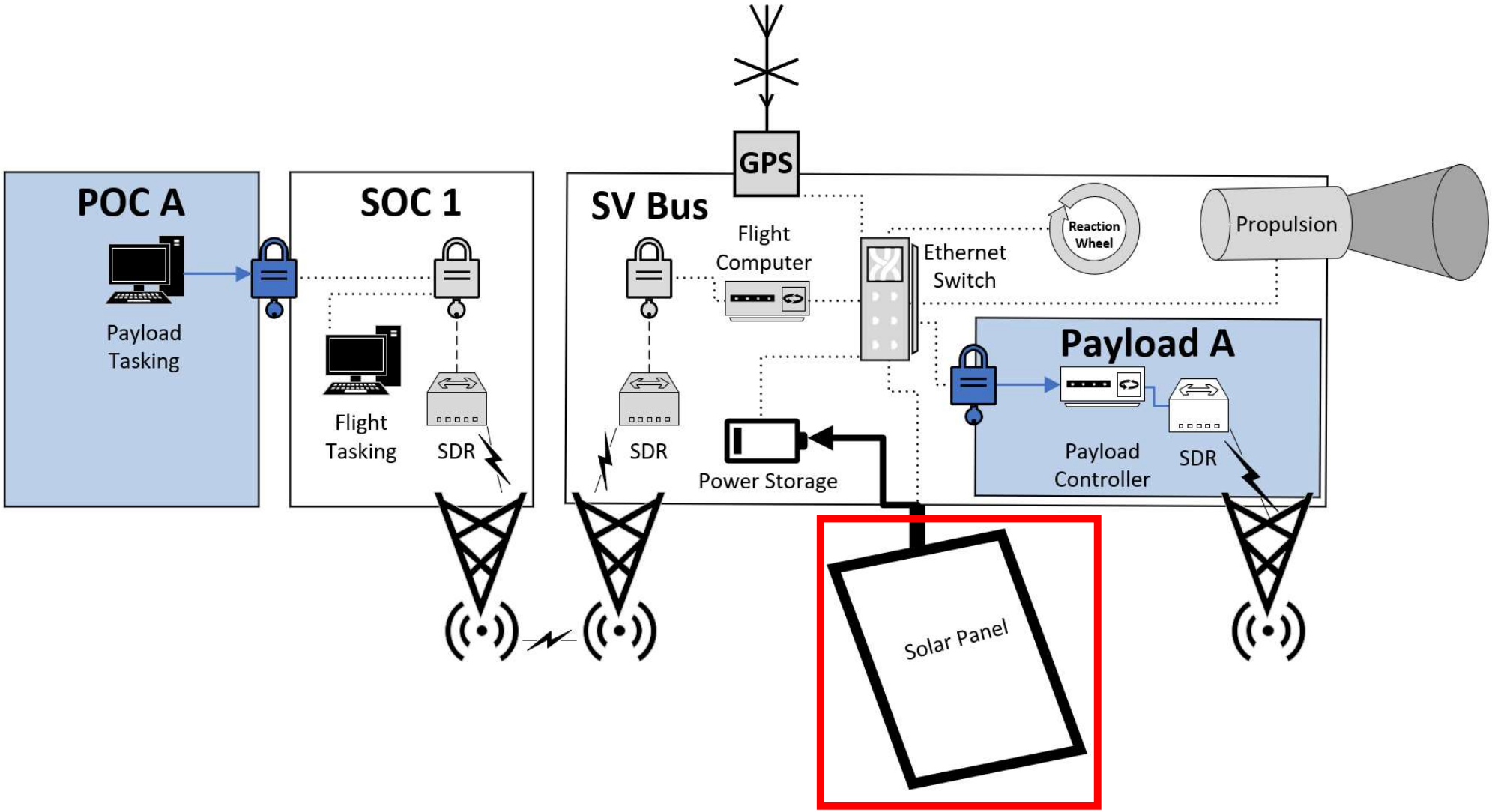
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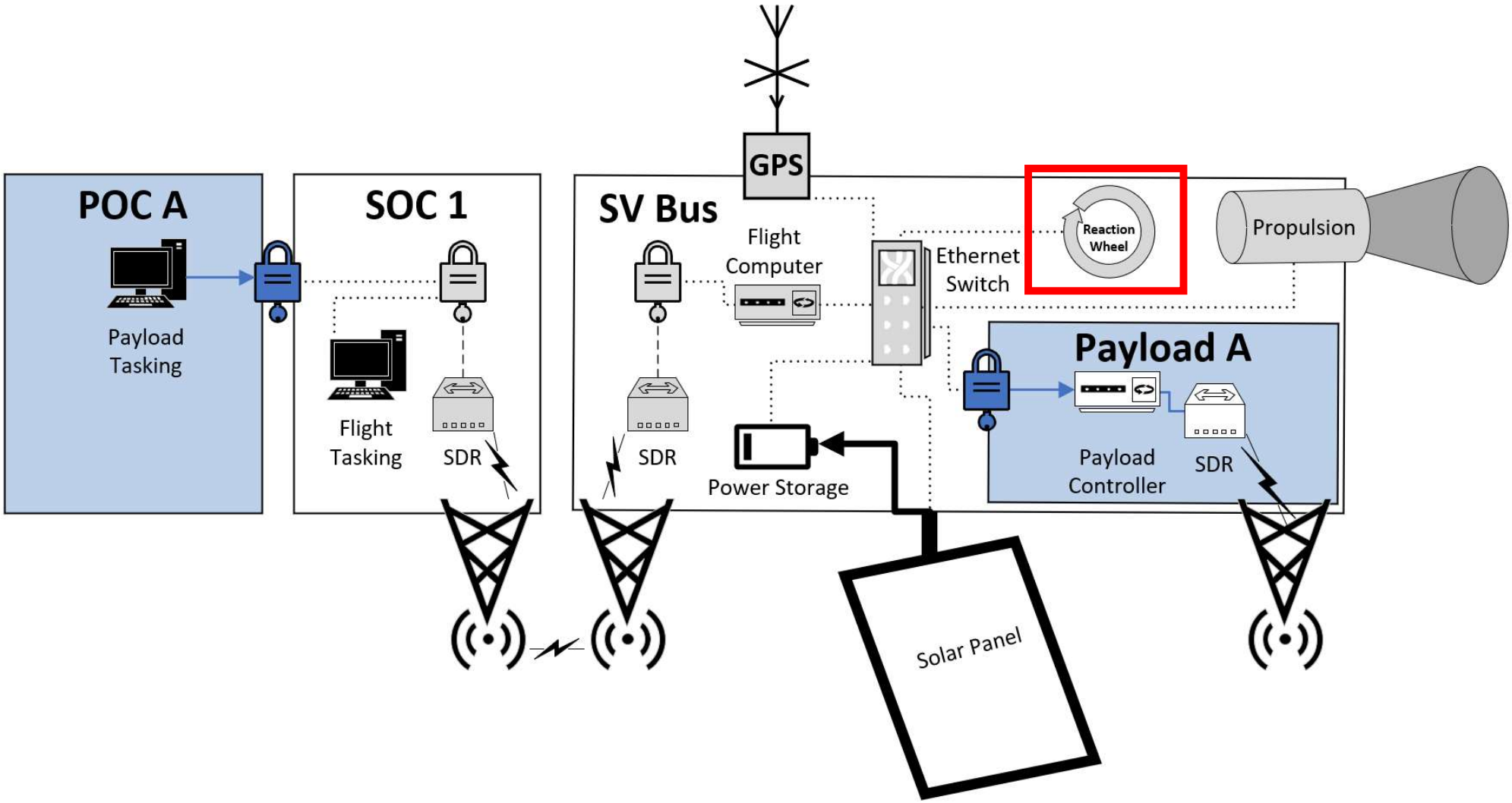
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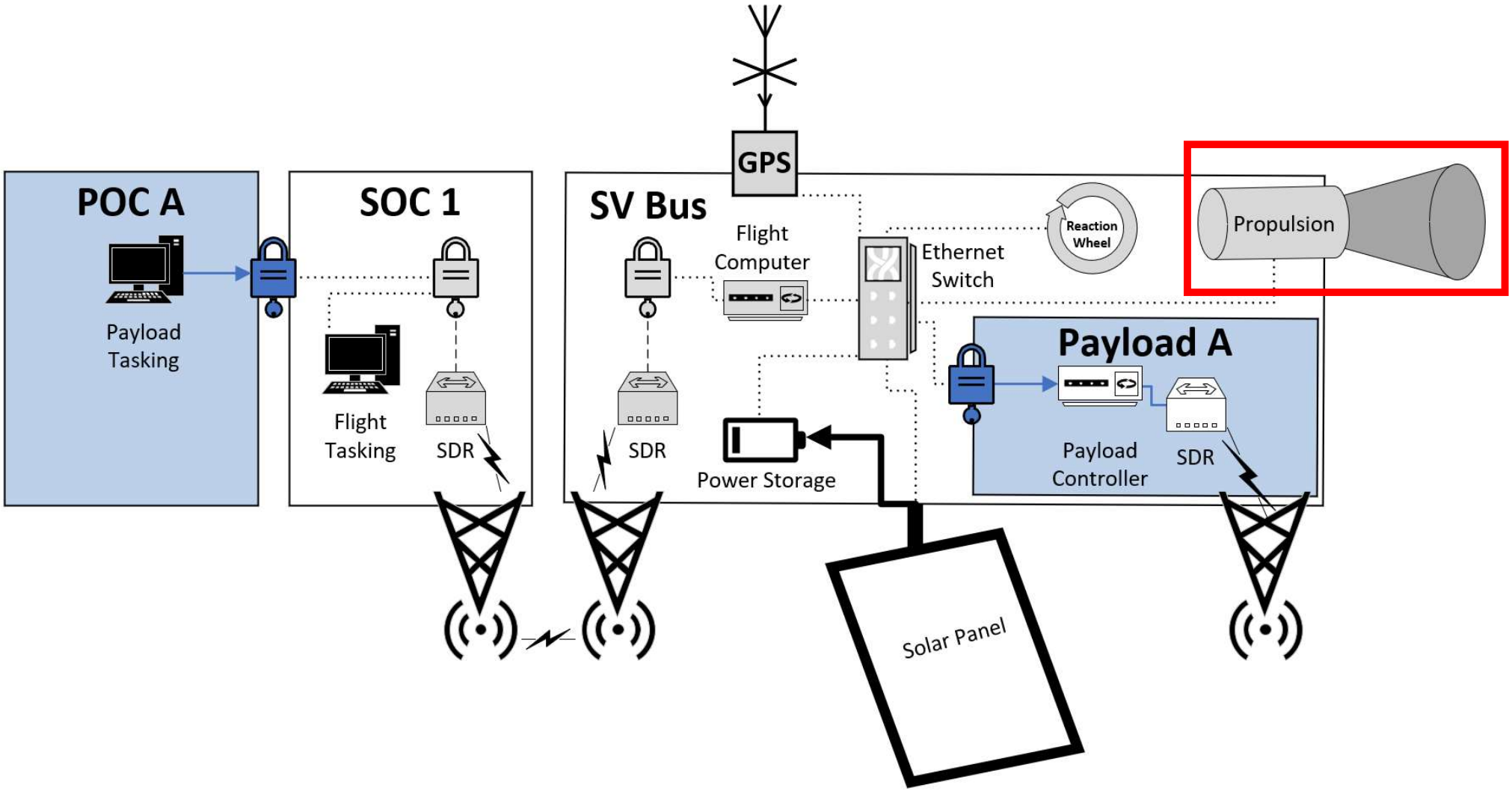
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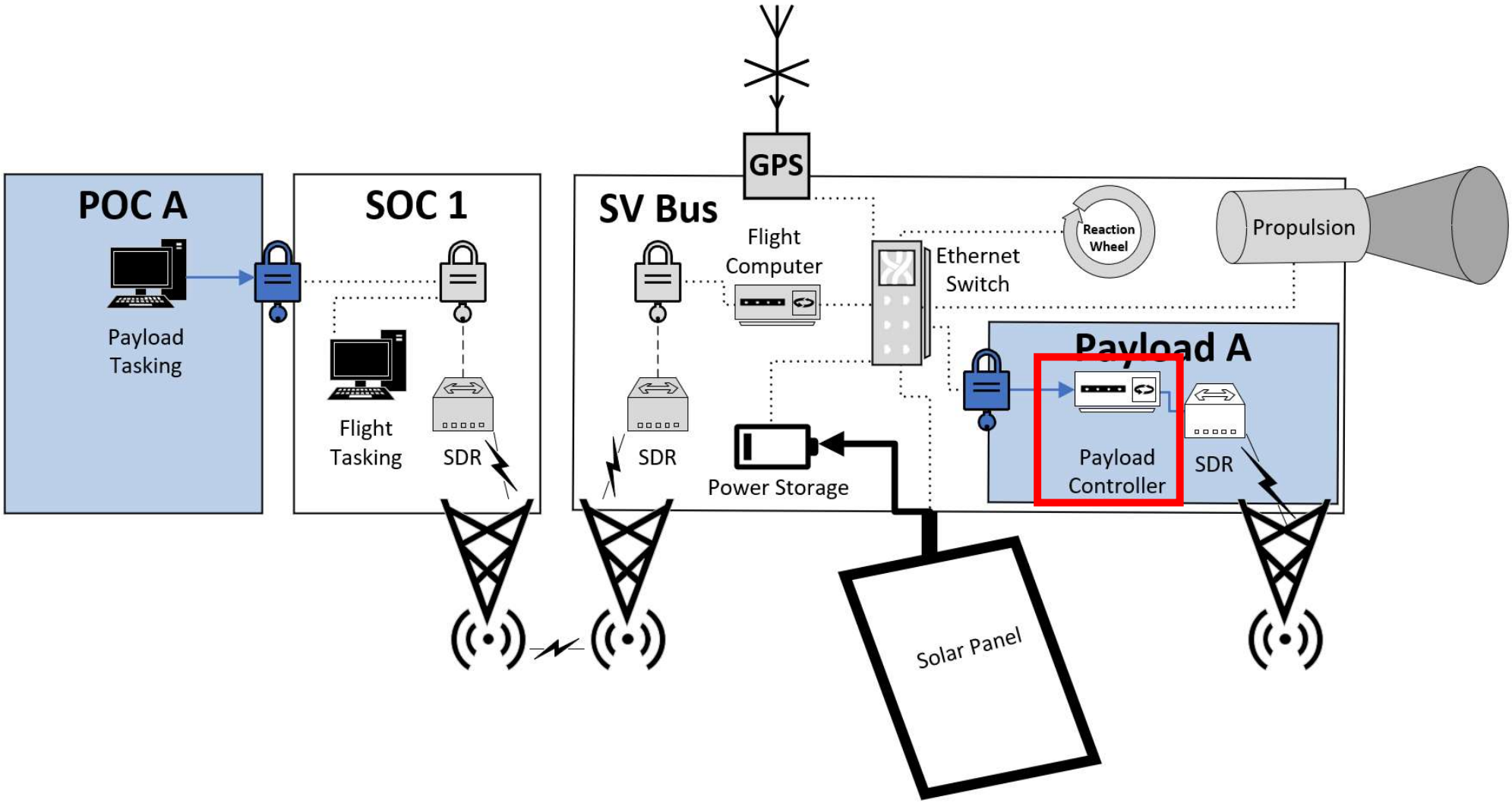
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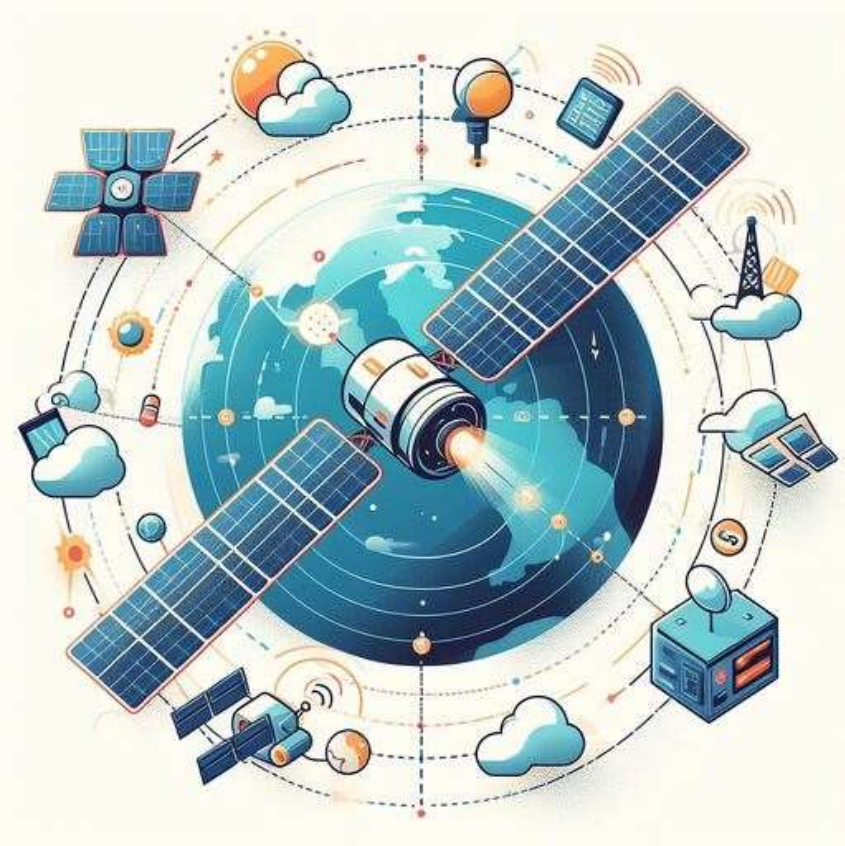
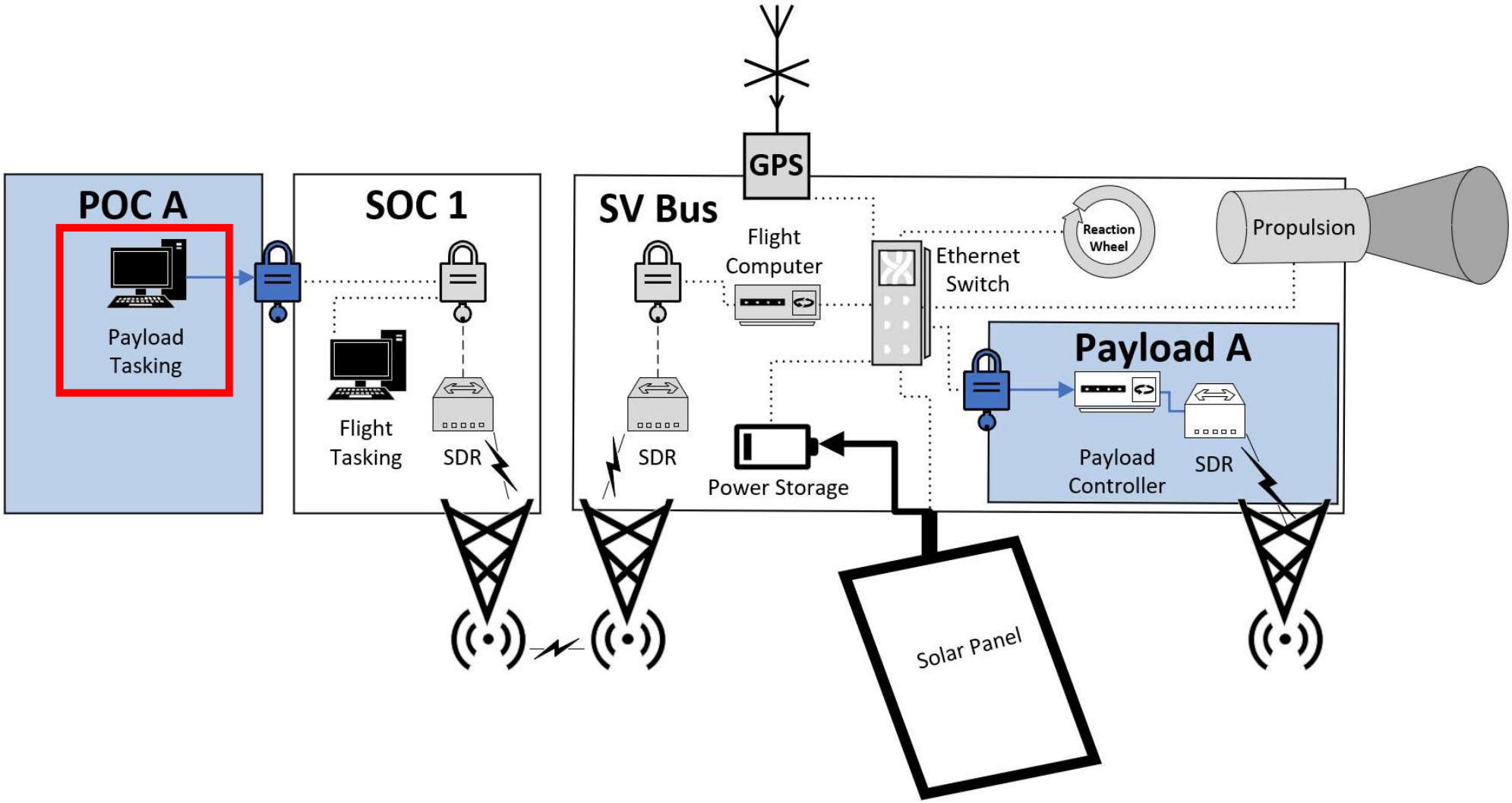
# Components

- Logic Bearing
  - SDRS
  - Flight computer
  - Encryption devices
- ‘Dumb’
  - Reaction Wheels
  - Propulsion
  - Antennae
  - Solar panels

# CONOPS

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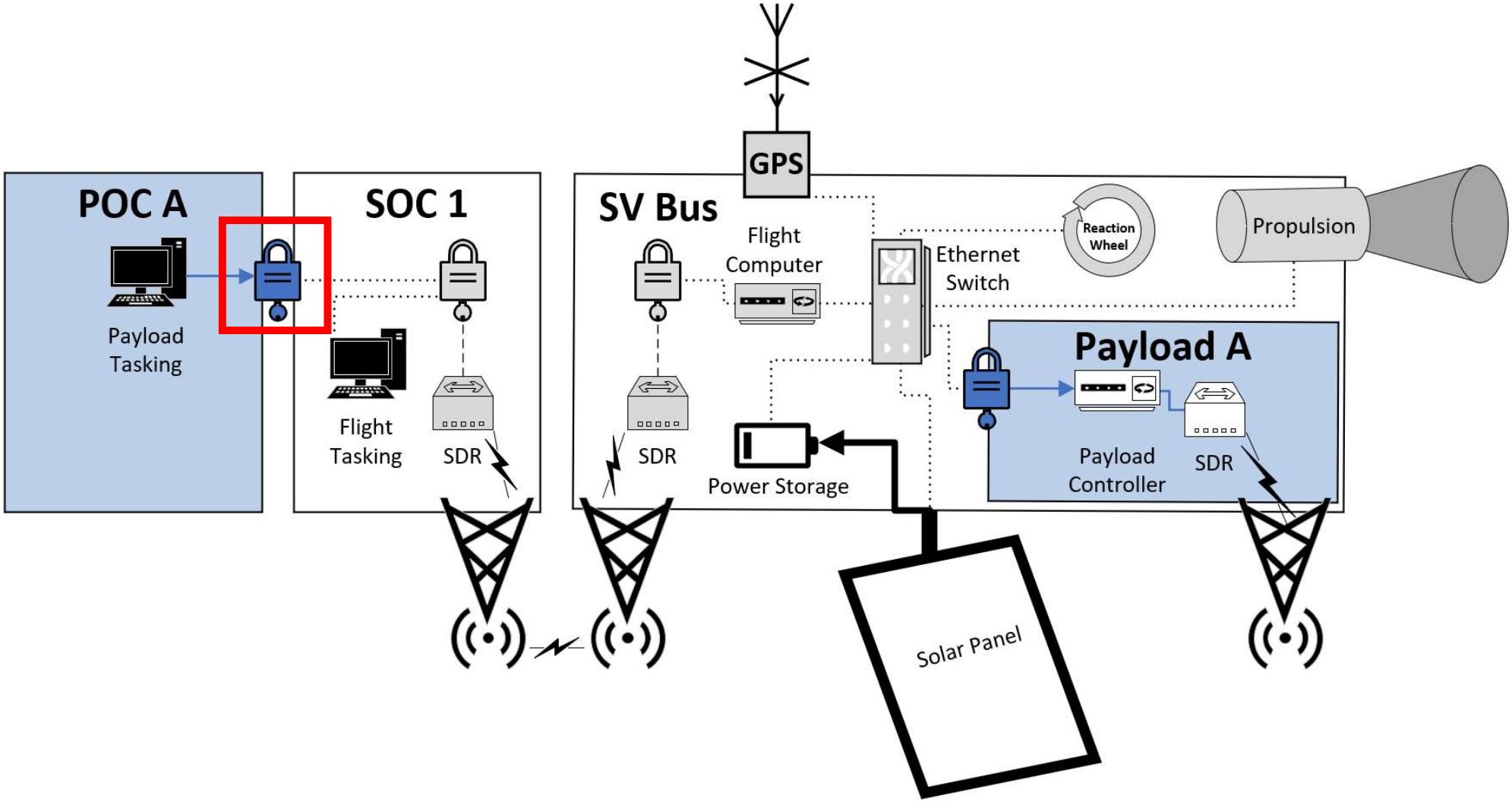
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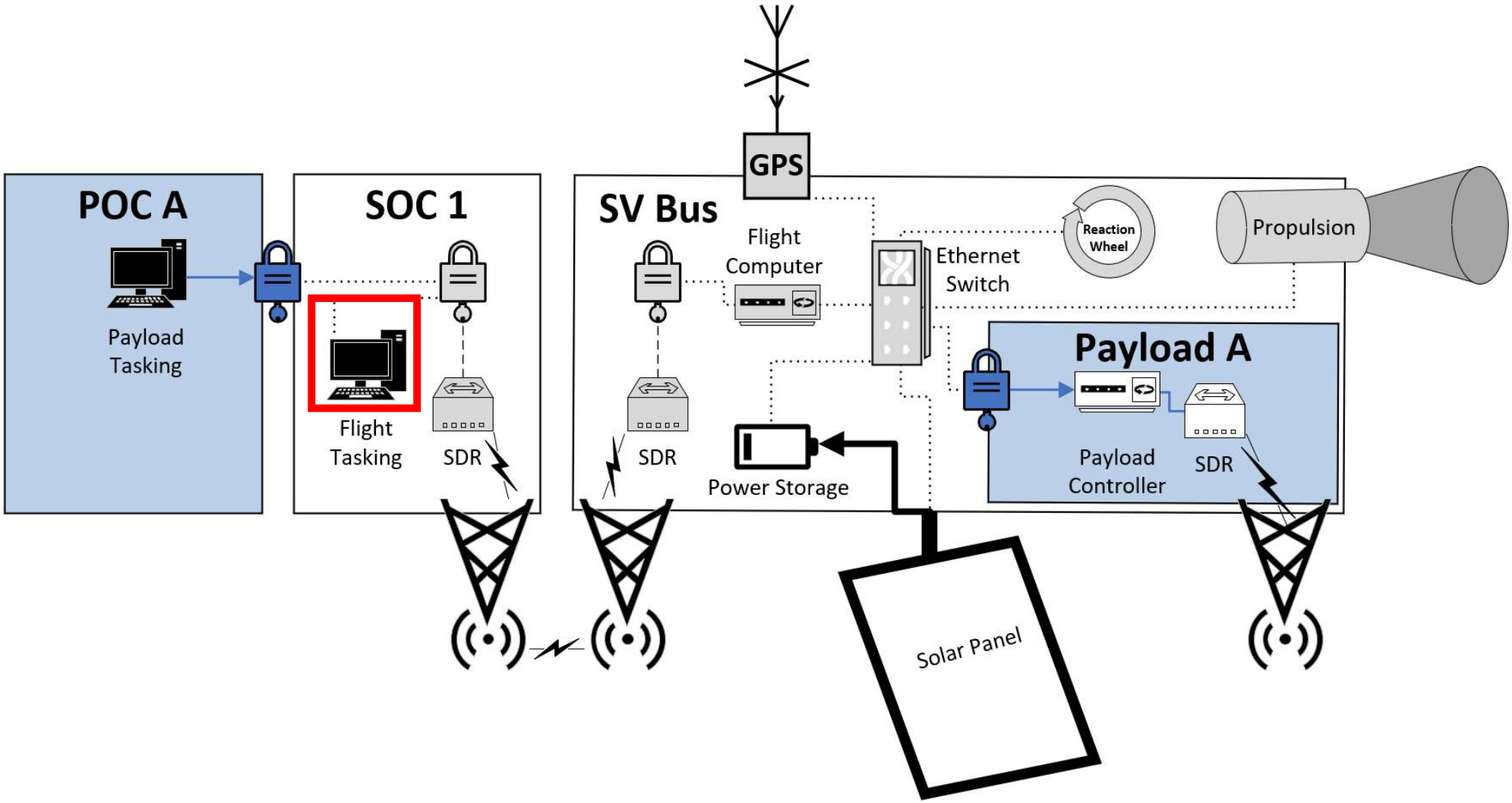
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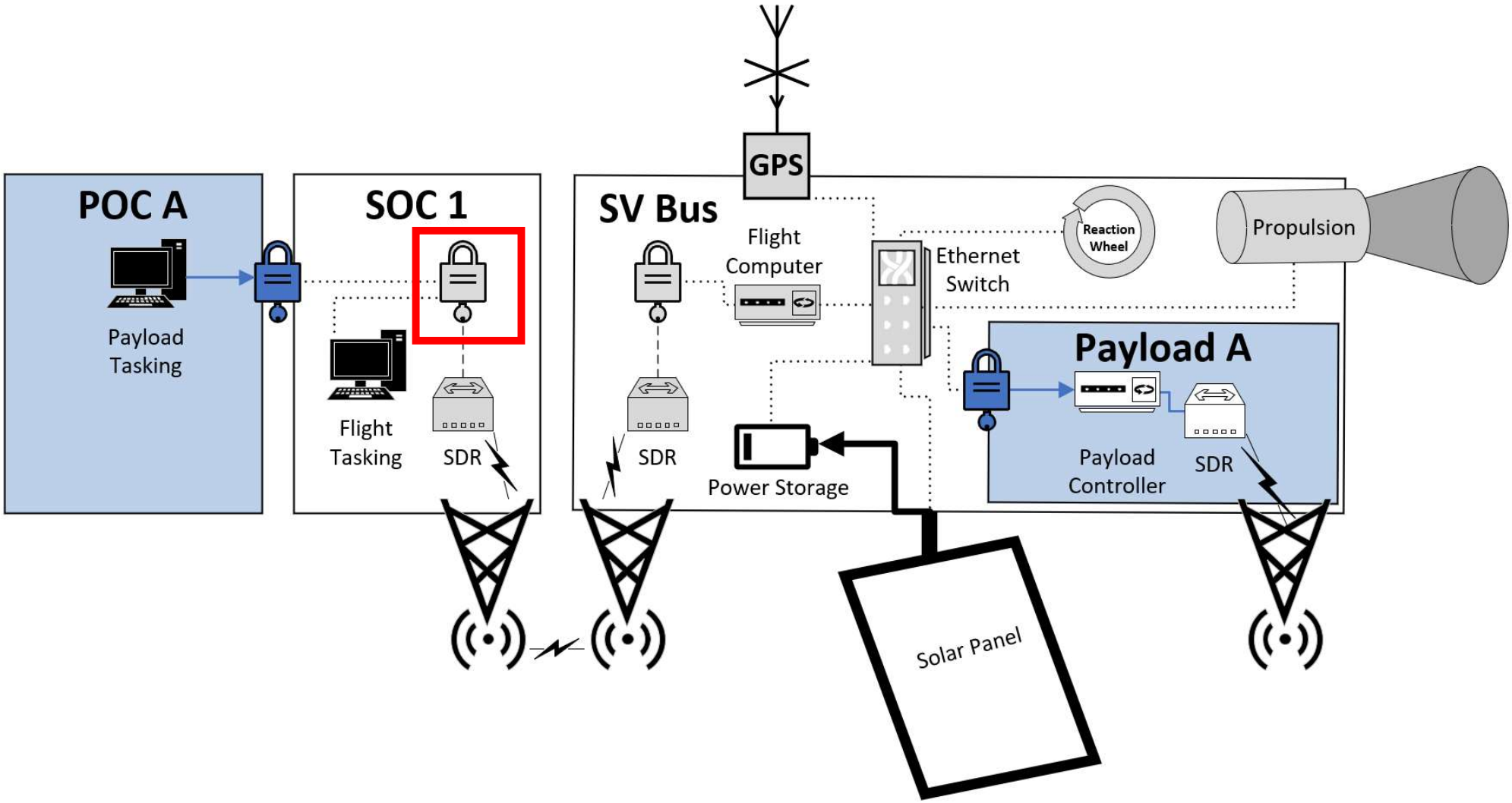
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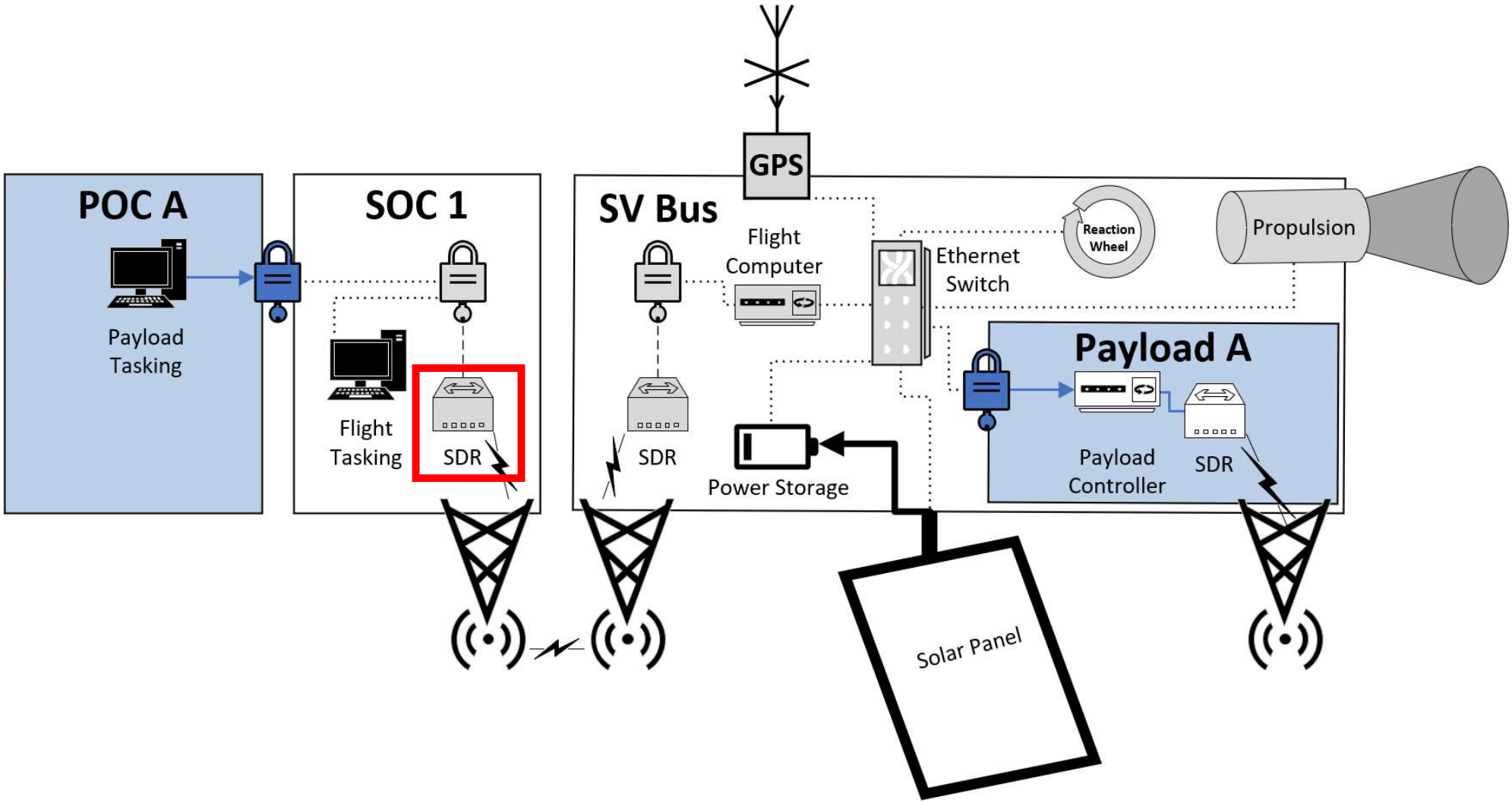
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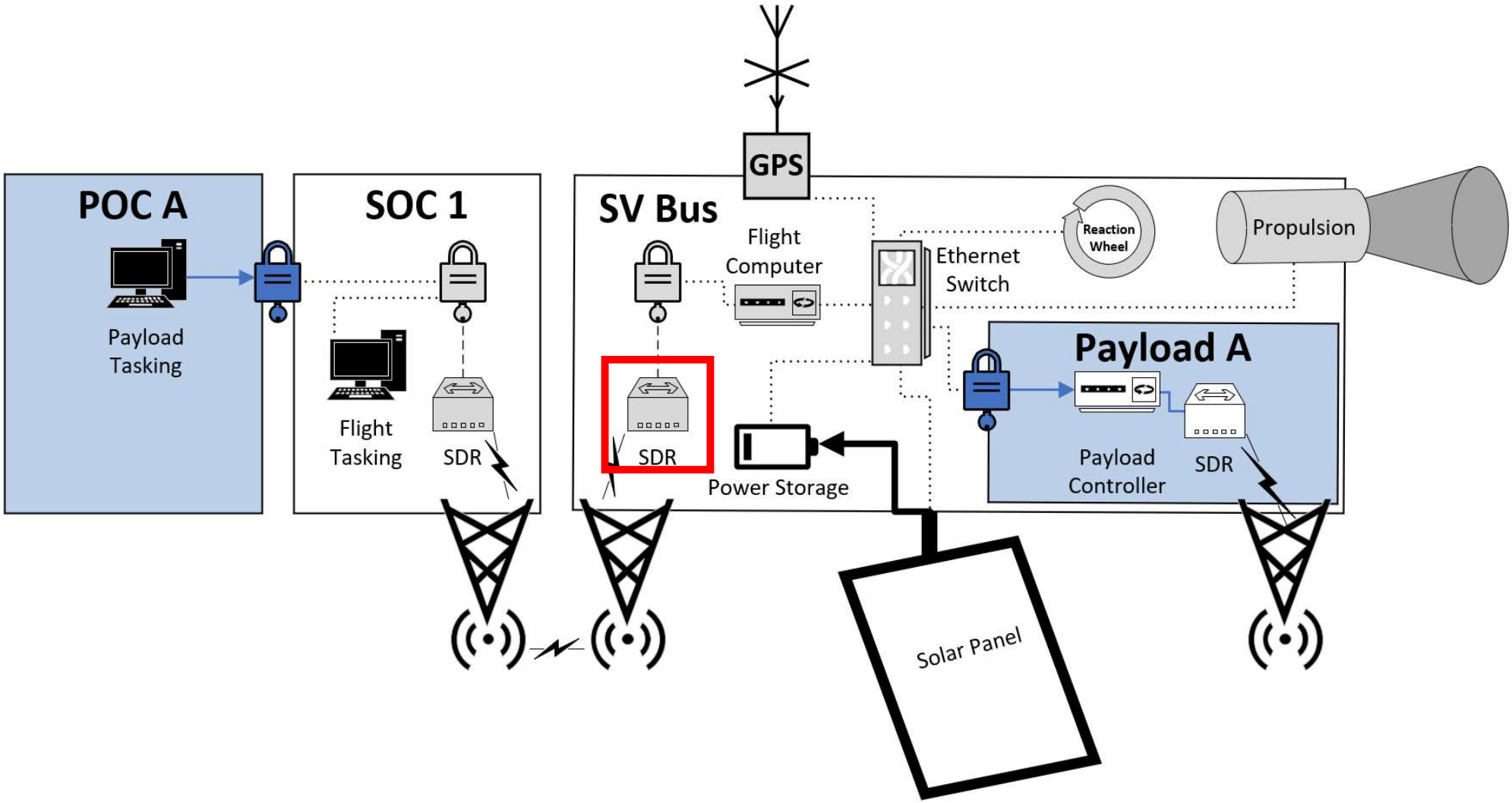
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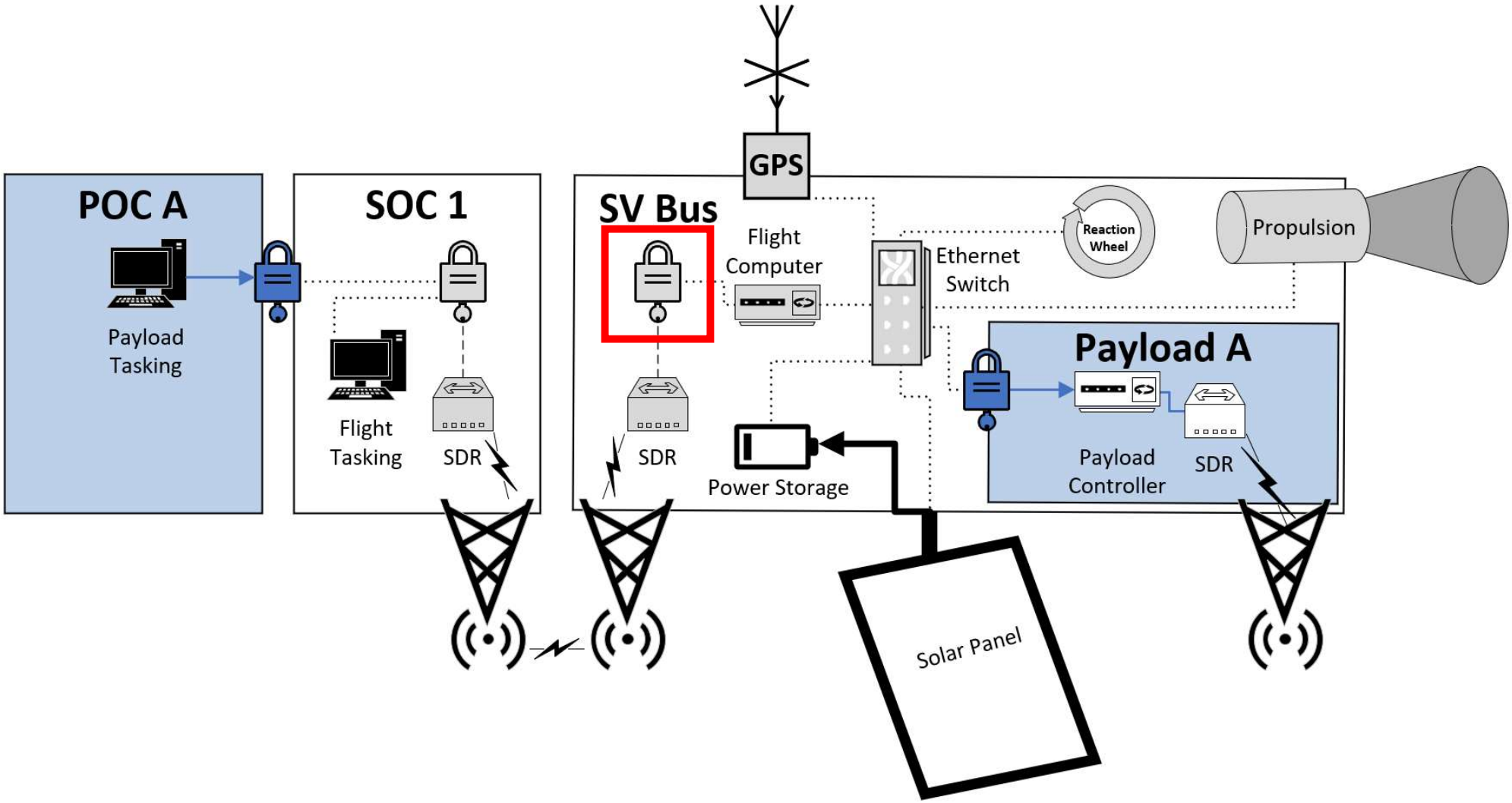
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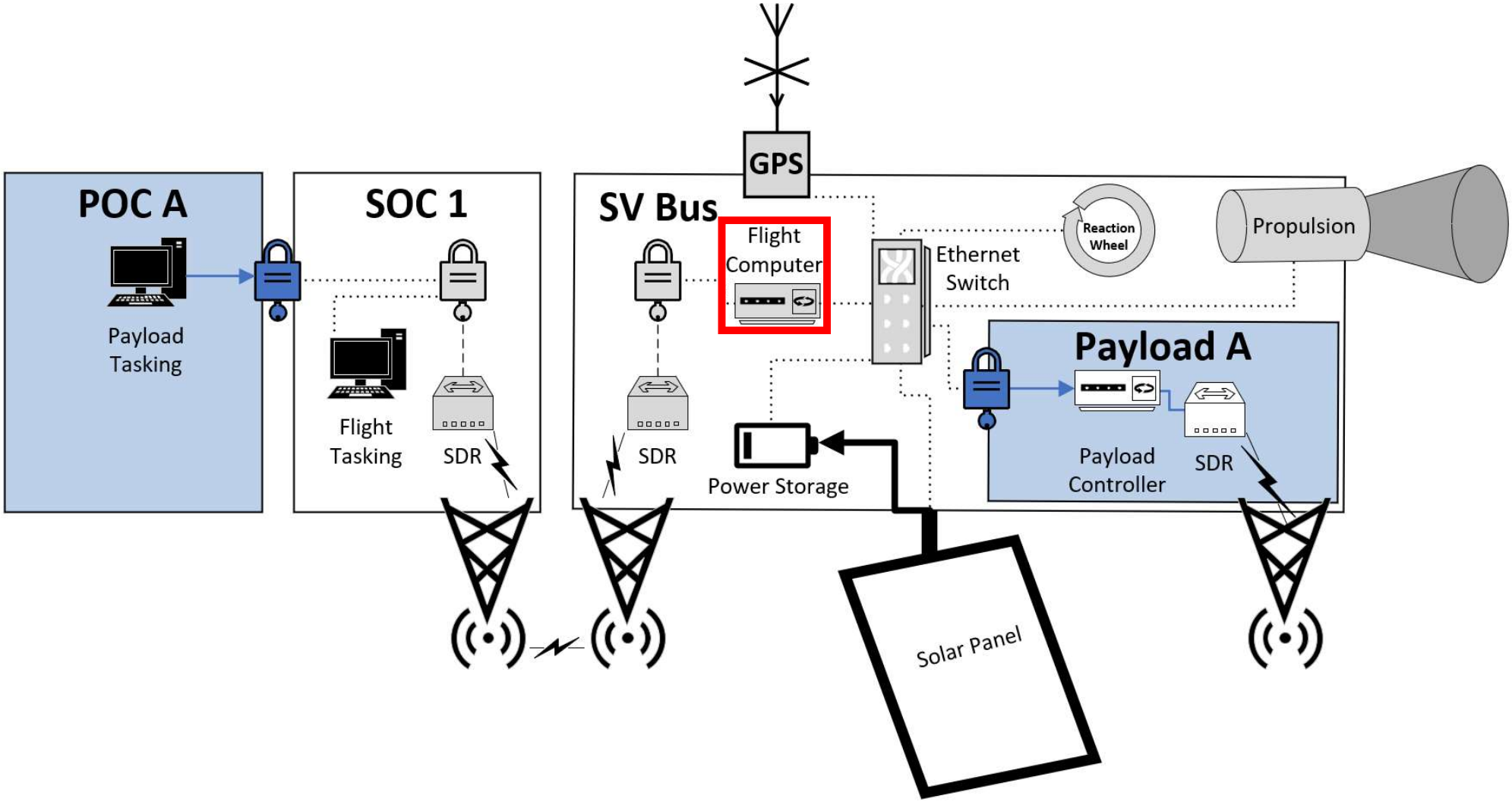
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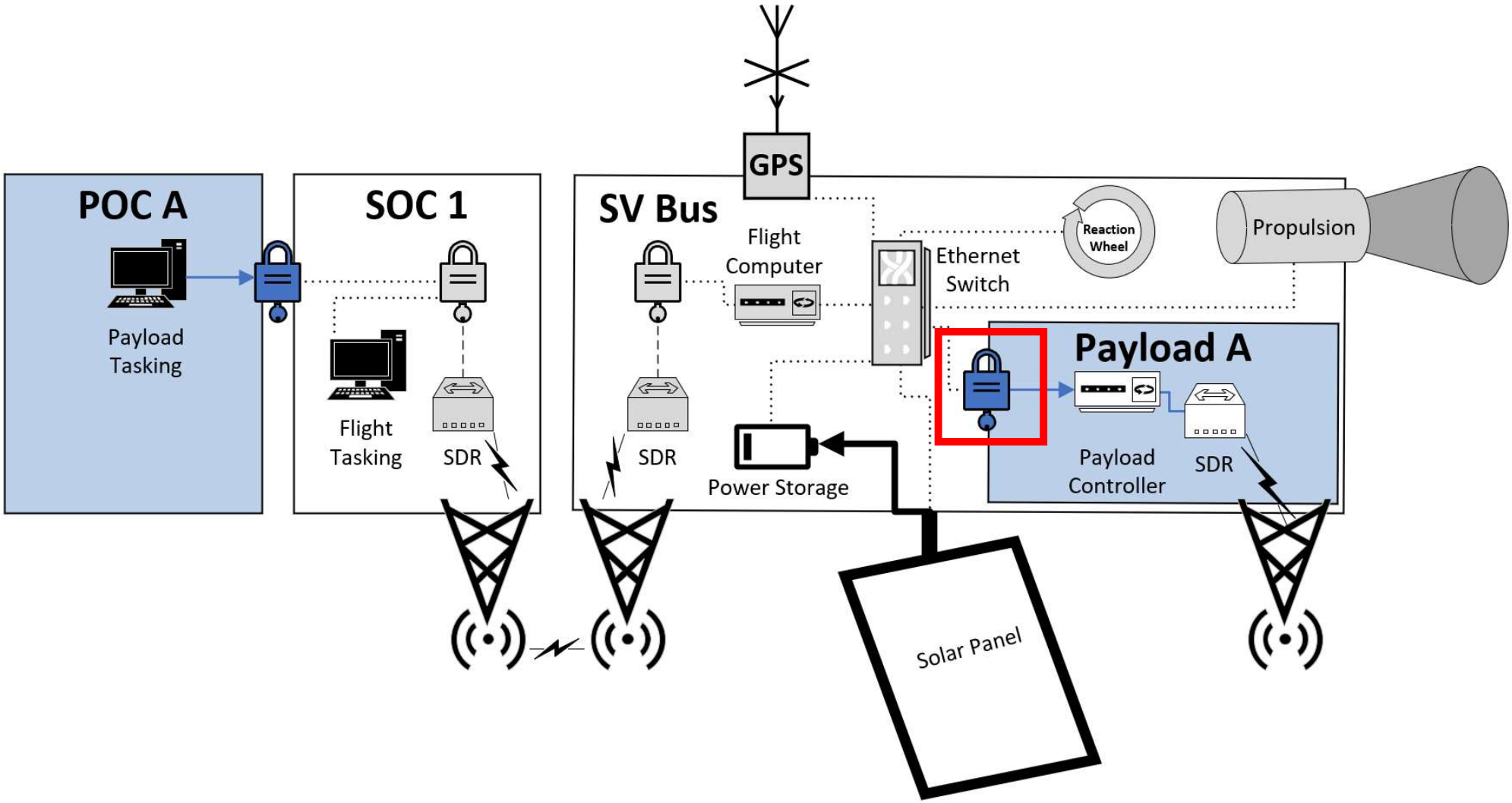
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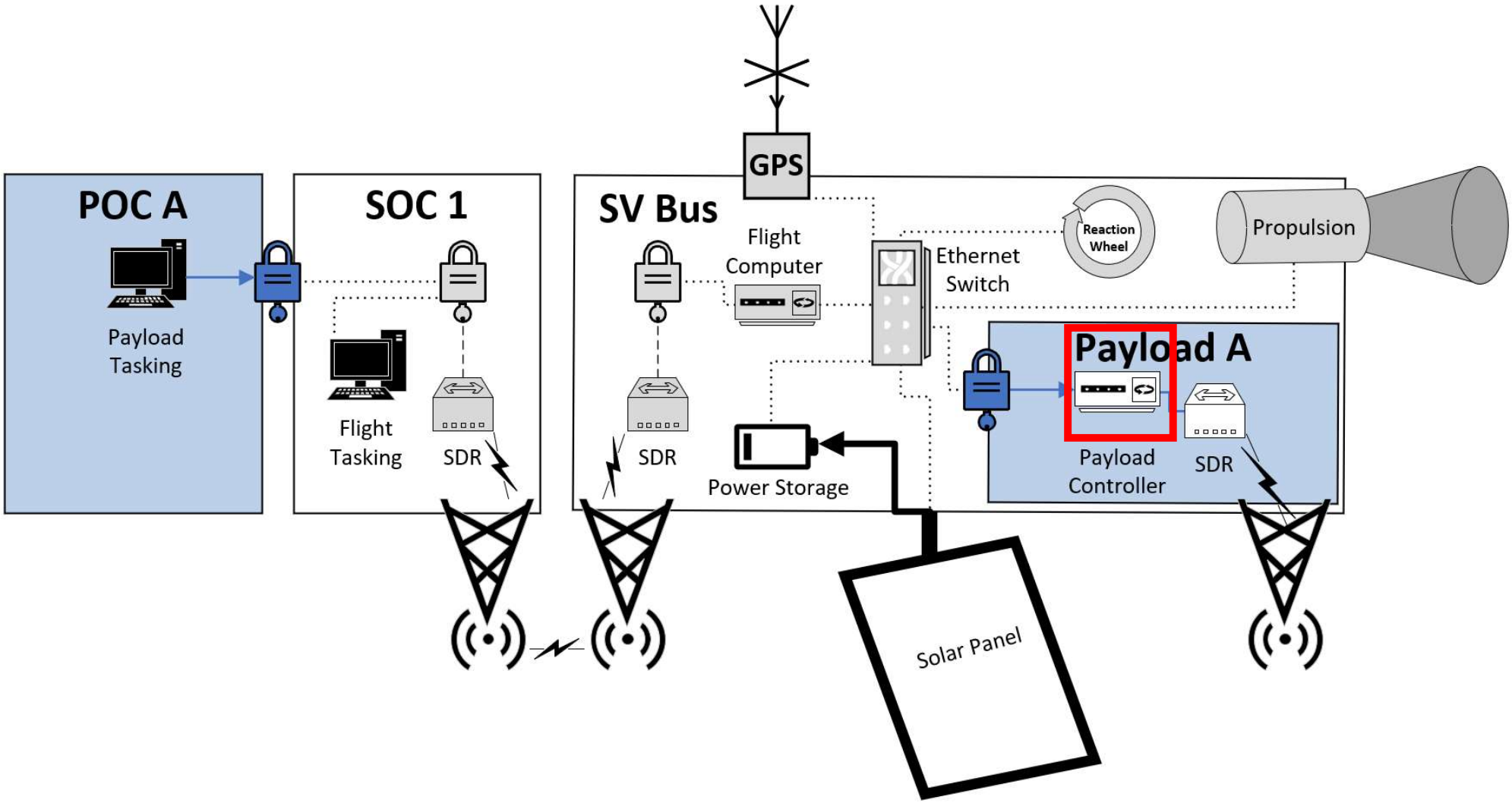
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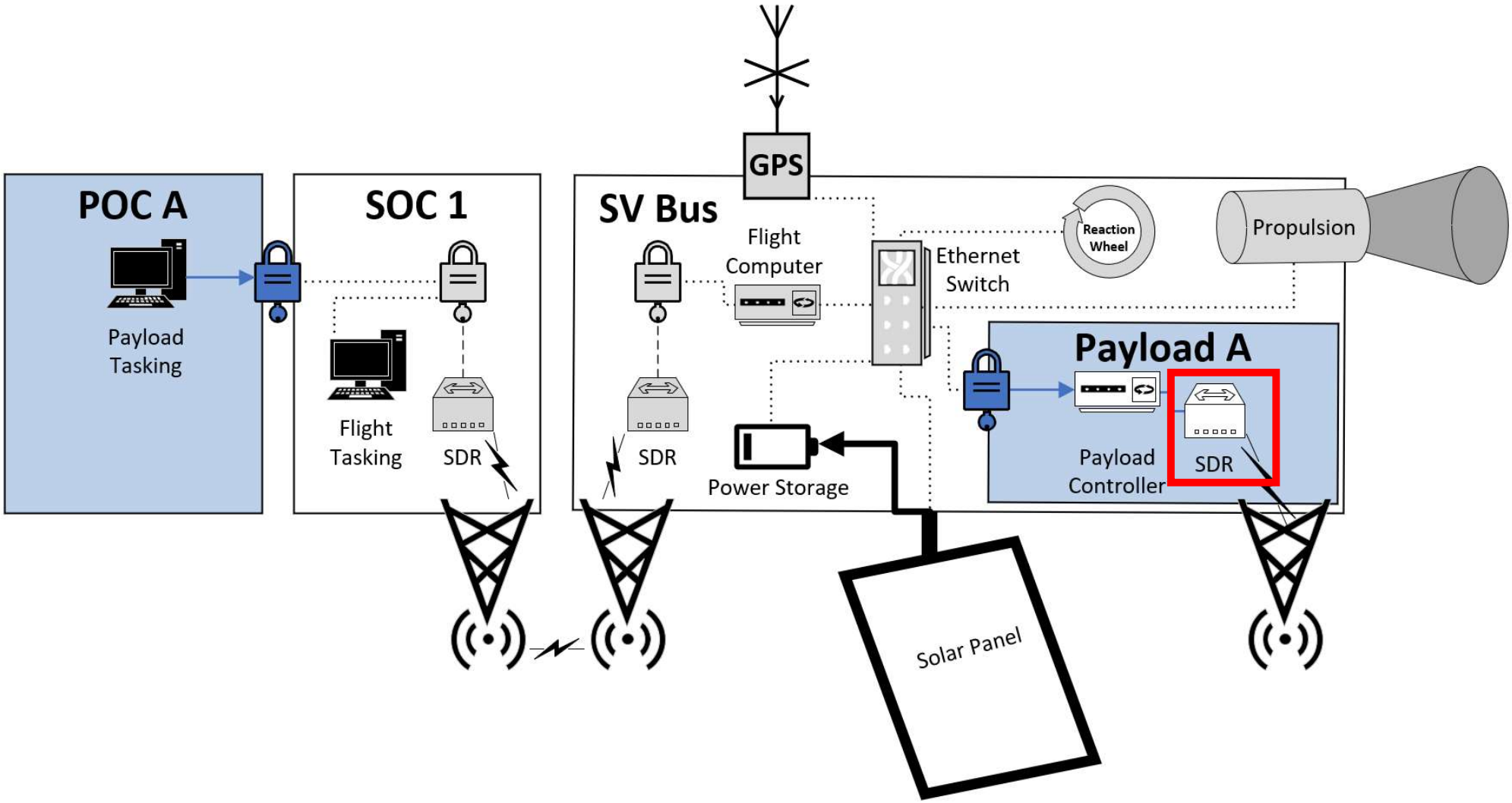
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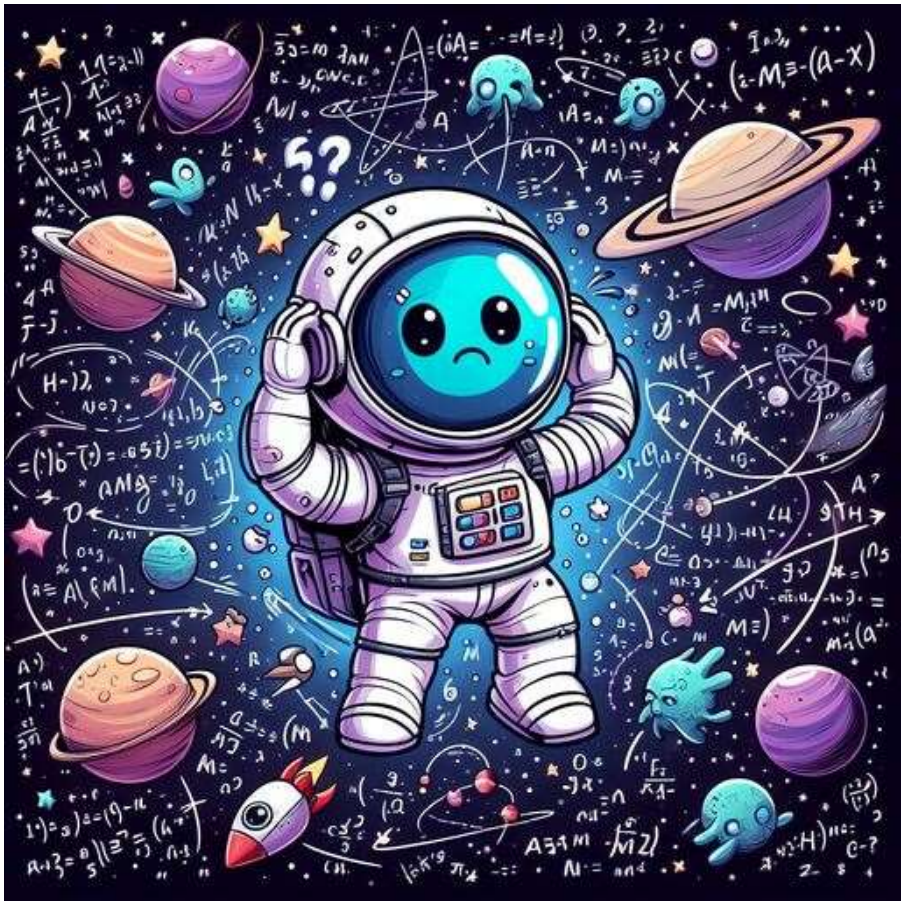
# Space Is Like…Really Hard…



# Hayabusa

- May 9th, 2003, Japan launches the satellite that will eventually be renamed to Hayabusa with the intention of sampling surface material from a small asteroid and bringing it back to Earth. Something that had never been done before.

# Hayabusa

- In late 2003, a large solar flare significantly damaged its solar panels, delaying its intended 2005 arrival at the asteroid by several months.

# Hayabusa

- In July 2005 one of three reaction wheels (the x-axis controller) used to adjust the satellite's attitude, fails.
- In October 2005 another reaction wheel fails (the y-axis controller), forcing it to use the one remaining reaction wheel and some of its thrust to fly and steer.

# Hayabusa

- On November 12, 2005, the satellite's small lander vehicle was launched at an incorrect altitude and flew off into space.
- November 19, 2005, the satellite itself tried at landing on the asteroid, but bounced and lost contact. Eventually contact was restored and it left the asteroid surface after 30 minutes.

# Hayabusa

- November 25, 2005, the satellite made its second landing, attempting to fire its two sampling bullets, which both failed.
- December 2005, a thruster leak alters the direction of the antennae and connection is lost for three months.
- Use of Backup antenna results in 1000x slower communications, protocol re-engineering made bandwidth usable

# Hayabusa

- Hayabusa limped back to Earth with:
  - 10-100x slower communications due to damaged primary antenna
  - No chemical fuel
  - A small portion of its solar panels powering a limited thrust ion thruster,
  - Only 1 out of 3 reaction wheels still functioning
  - 4 of the 11 batteries on board not functioning.