

A Novel IP-Centric Approach to LEO Communications

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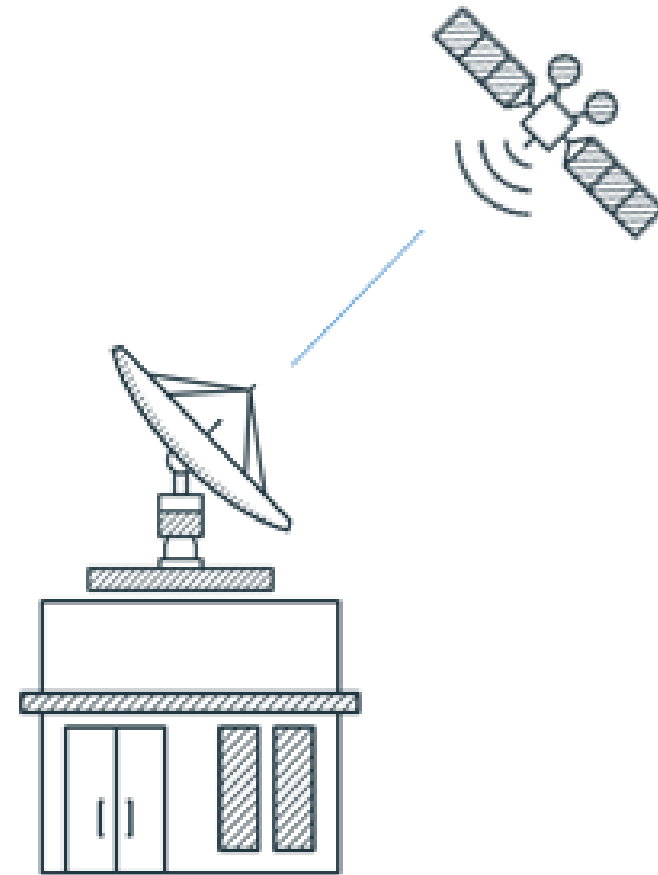
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VIASAT PROPRIETARY

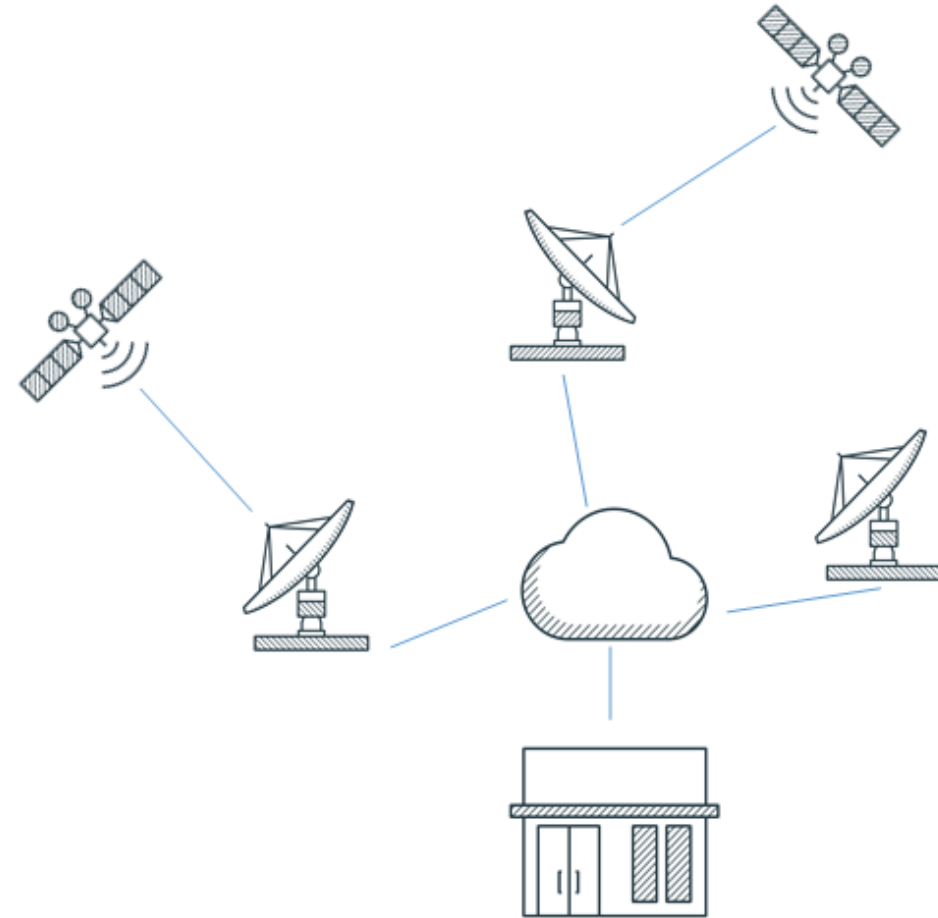
Single Spacecraft, Single Ground Station

- > Approached by a Customer (SSTL) who provides traditional single ground segments for single satellite operations
- > Typical components
 - Mission Operations Center (MOC) including command/telemetry processing and crypto
 - Ground Station including a modem and antenna
 - Satellite
- > Interested in providing additional capability in terms of reach and flexibility

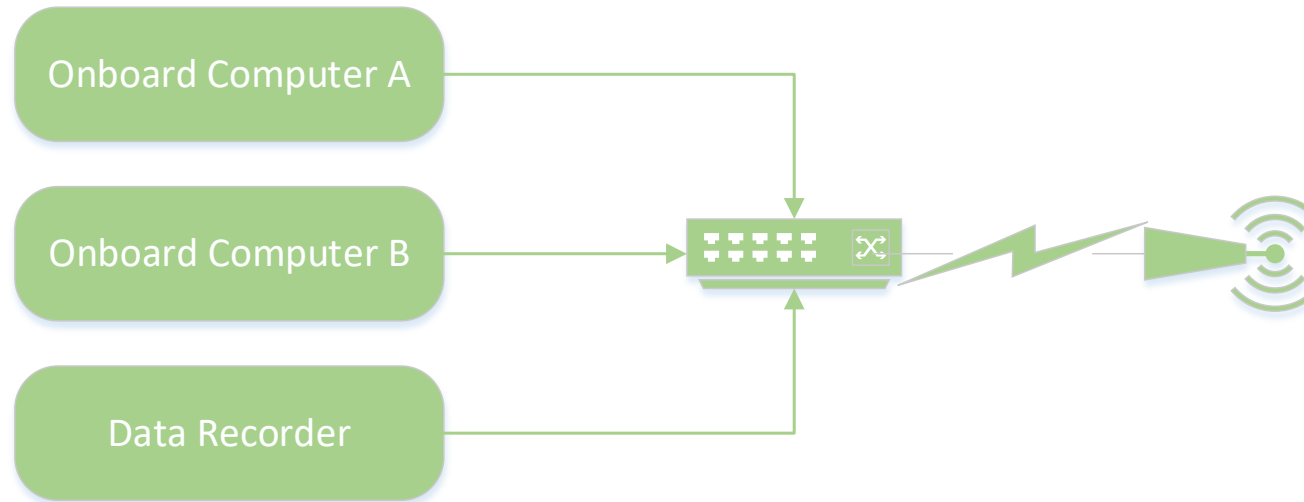


Multi-Satellite, Multi-Ground Station

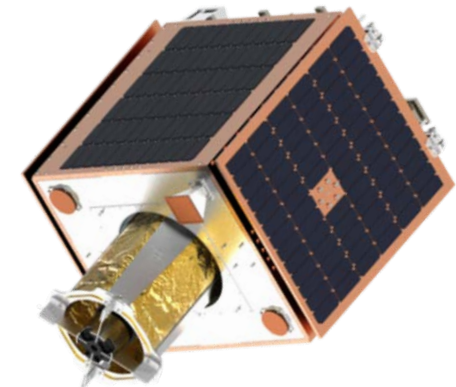
- > Obviously better!
- > Enhance the flexibility and availability of ground stations contacts around the world
- > Enable large constellation missions with multiple satellites and ground stations



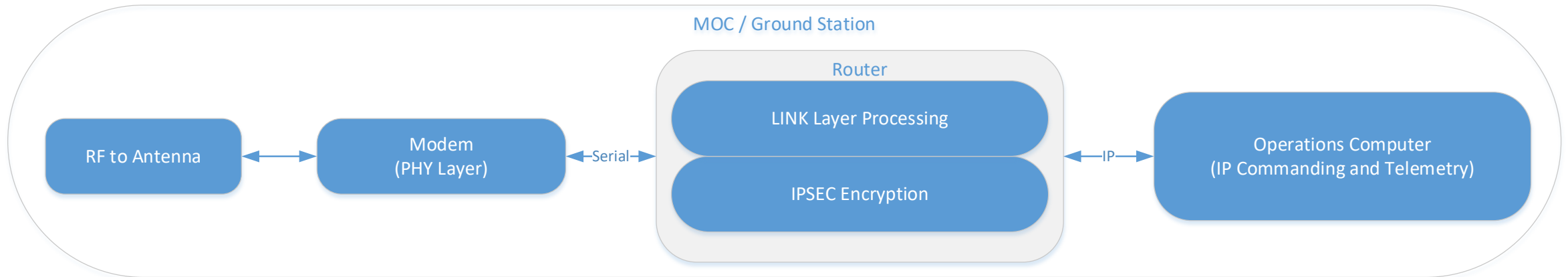
Spacecraft Architecture



- > Unique spacecraft architecture
 - Every component has a unique IP
 - Spacecraft includes switching functionality
 - All traffic multiplexed on a single channel



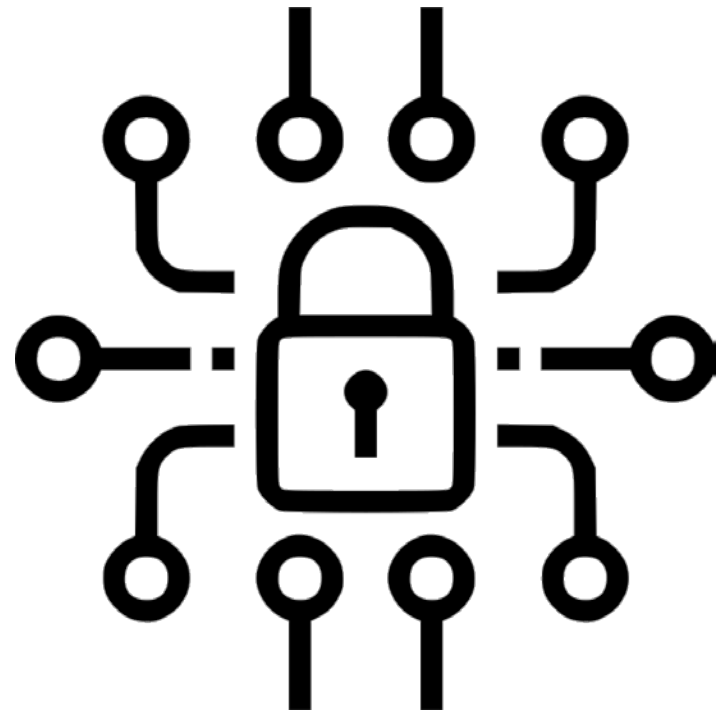
Existing System



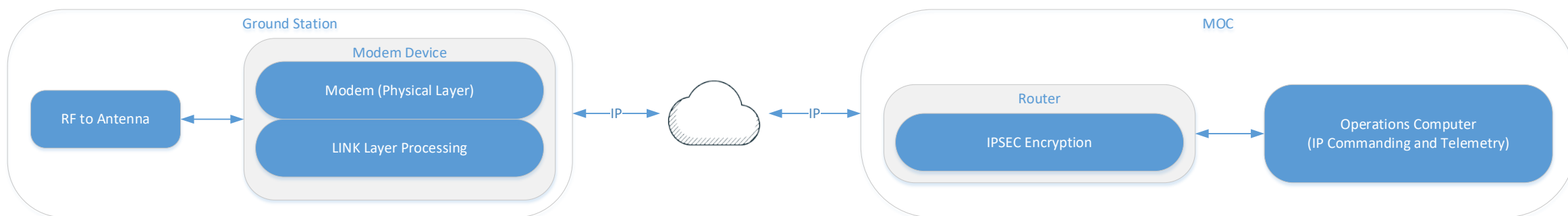
- > Mission Operators Center (MOC) is co-located with ground station
- > Commercial router is used for both encryption and link layer processing
 - Serial is used for outbound interface (tightly coupled)
 - Creates a potential interface problem for multi-station systems

Security Considerations

- > Hard requirement to maintain the same security profile as the single site design
- > System utilizes standard IPSEC encryption
- > Decision: encryption appliance should remain at the Mission Control Center (MOC)
 - Avoids physical compromises at remote ground stations
 - Avoids the need for key exchange mechanisms
 - Bonus: only a single encryption device is needed



Redesigned System



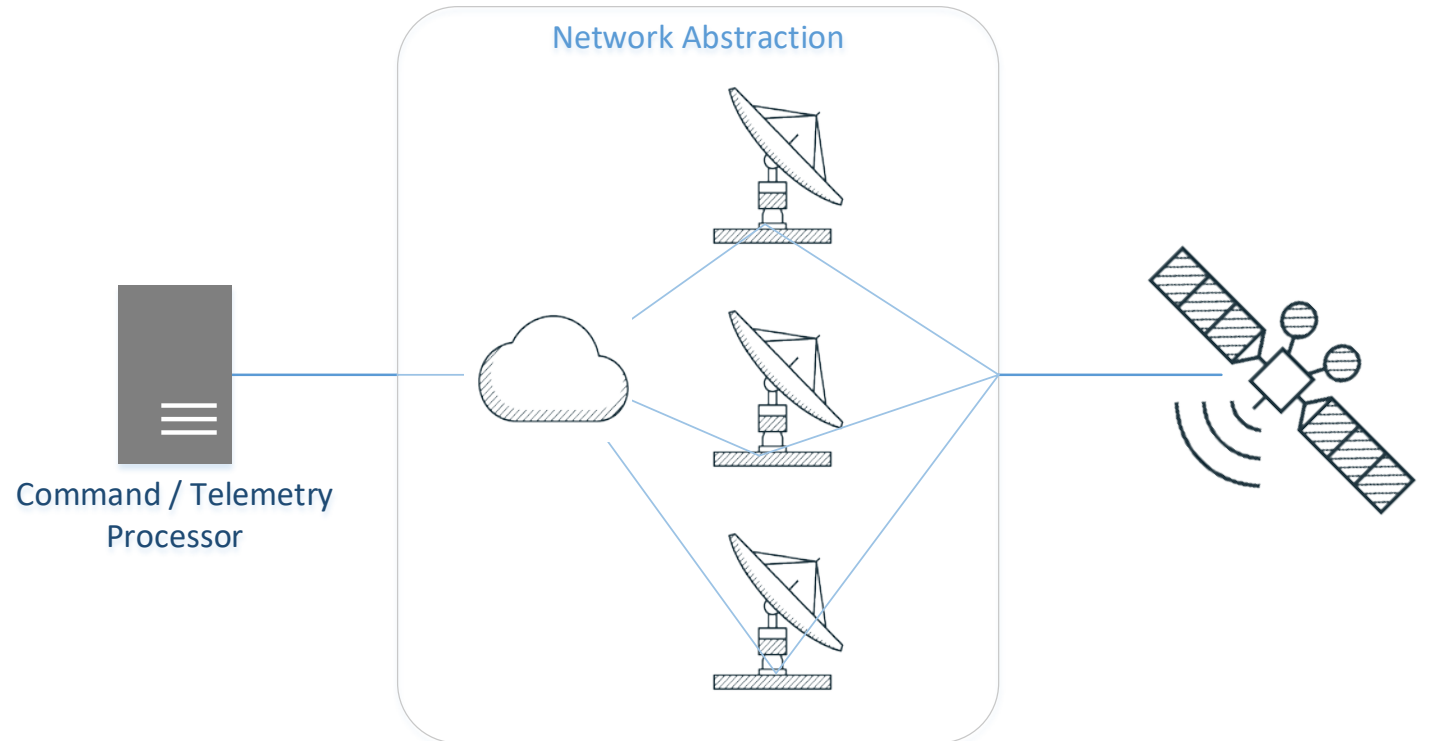
> Key design points

- Encryption device remains at the MOC
- Link layer processing is combined with modem
- Convenient IP interface is exposed, allowing a WAN to be inserted in-between

> Alternative design with digitized RF was evaluated but was not chosen due to WAN-use efficiency

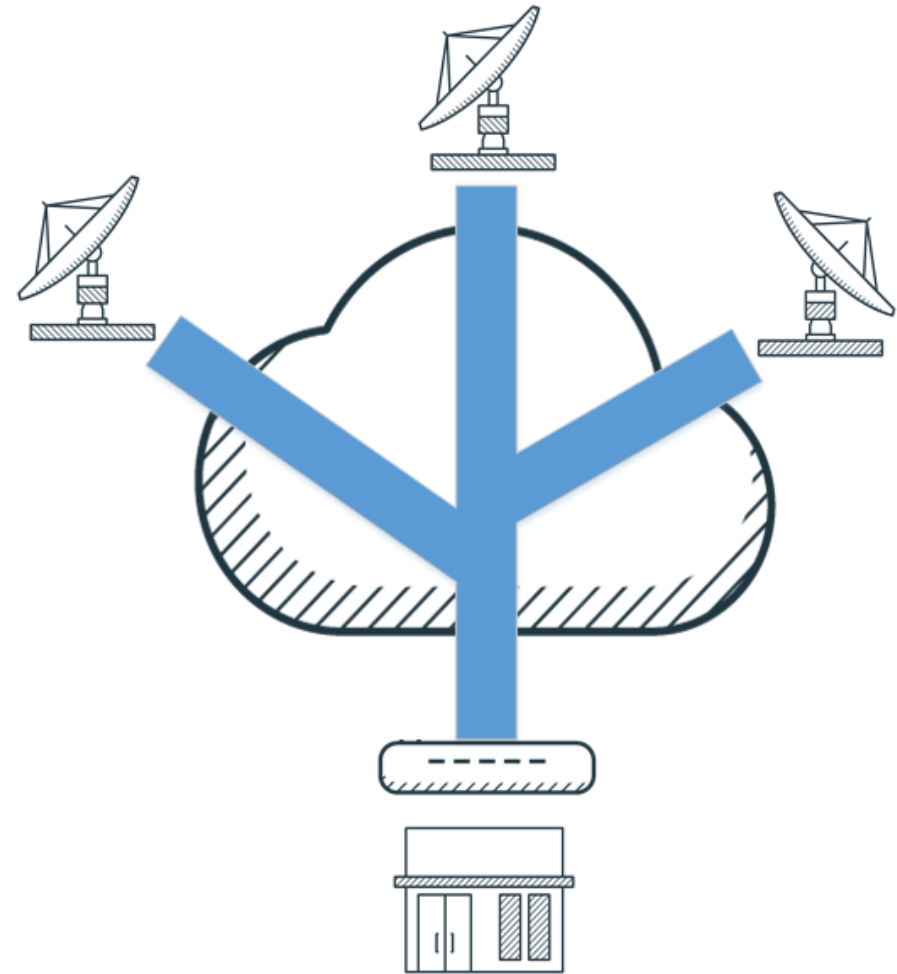
Network Topology

- > Basically a set of IP endpoints on the spacecraft that communicate with the MOC
 - So who talks to the ground equipment?
 - Total ground station abstraction
- > Interesting design!
 - So who talks to the ground equipment?
 - Total ground station abstraction
- > MOC to Spacecraft connection is independent of the network implementation

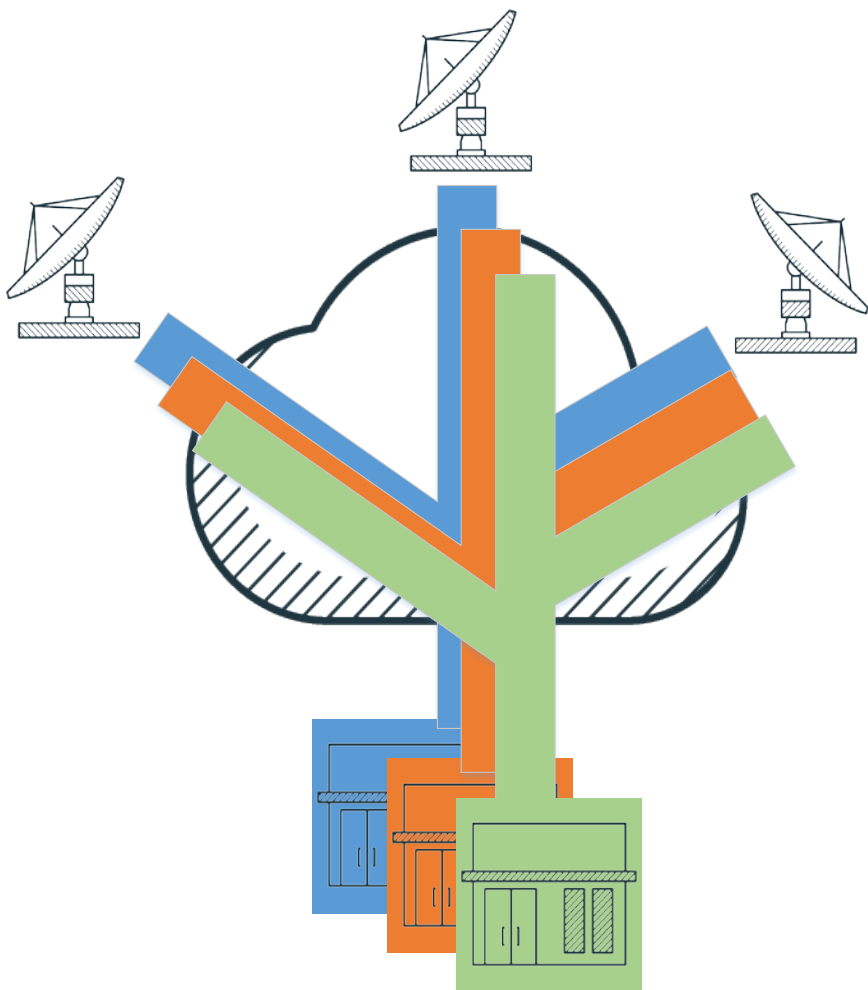


Another Twist

- > Current spacecraft operate with IPs in the 192.168.1.0/23 subnet.
 - This is a private subnet
 - Not usable over the Internet
- > Solution: Multi-point GRE tunnel (mGRE)
 - Encapsulates an IP packet in an IP packet
 - Multi-point capability allows multiple sites
 - Standard protocol
 - Lightweight, low overhead
- > Allows for use of any IP ranges = future proof



Enabling a Multi-Customer Approach



- > Multi-user support
 - Not originally in the scope of the design
 - Arose naturally out of the chosen technologies
- > New GRE tunnel per user
 - Separate MOC (including crypto)
 - Shared ground stations resources
 - Routing / network isolation
- > Useful for future extensibility

Commanding and Telemetry

- › Significant difference between commanding and telemetry in a multi-station network
 - Telemetry: Many stations to a single MOC
 - Commanding: Single MOC to many stations

- › When the MOC sends a command packet, how does it make it to the proper satellite?
 - Needs to go through the correct ground station
 - The “correct” ground station changes over time, correlating to the actual satellite pass – dynamic!

- › Solution: Make the ground station a router
 - Ground station advertises itself as the next hop for the satellite during the pass
 - Propagate the route using OSPF (open shortest path first) down to the MOC

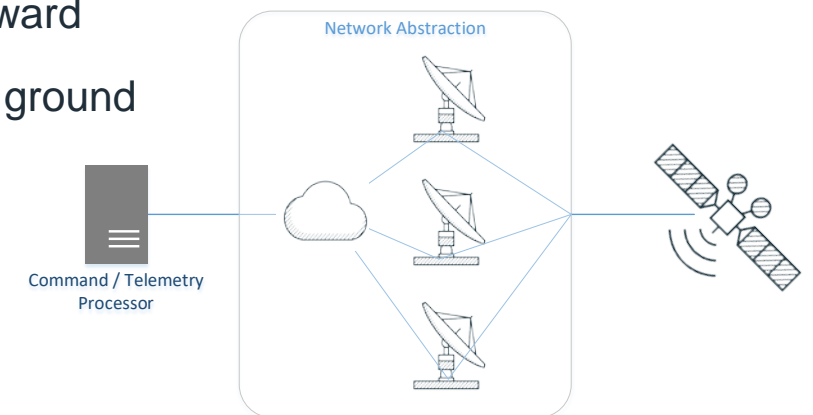
Testing and Verification



- > Full system testing was performed using a variety of spacecraft currently on orbit
 - Carbonite series
 - DMC-2/-3 series
- > Commanding and telemetry was performed
 - Command and telemetry over WAN
 - Multi-site routing of command packets during a pass
 - Encryption/decryption at MOC
- > Success!

Implications

- > Mission Operations Center (MOC) and Spacecraft are effectively “talking” directly to each other
 - Ground stations are fully abstracted from the process
 - Multiple antennas, equipment redundancy, and other ground station implementations are hidden
 - There are no ground station “protocols” as typically implemented on modems, such as SLE
- > Commercial, widely utilized protocols that build on IP can be utilized with no changes on the ground
 - Ground stations are basically routers
 - Adding new ground stations and even ground stations networks is straightforward
 - Adding more satellites and constellations is completely independent from the ground
 - Different IP-based security can be implemented easily



Final Thoughts & Future Efforts

- > Extensible architecture
 - Easily add additional ground stations and satellites with little effort
 - Networking routing hides all implementation details from end users
- > IP centric approach provides a solid foundation for new features
 - Upgrades to more secure IP-based encryptors, potentially even Type-1
 - Enables dynamic routing and configurations
 - Troubleshooting and testing with COTS tools – wireshark your satellite!
- > Future testing with increased redundancy protocols in underlying network



Thank you!

Special thanks to Surrey Satellite