Novel Ground Communication for GEO Servicing Missions

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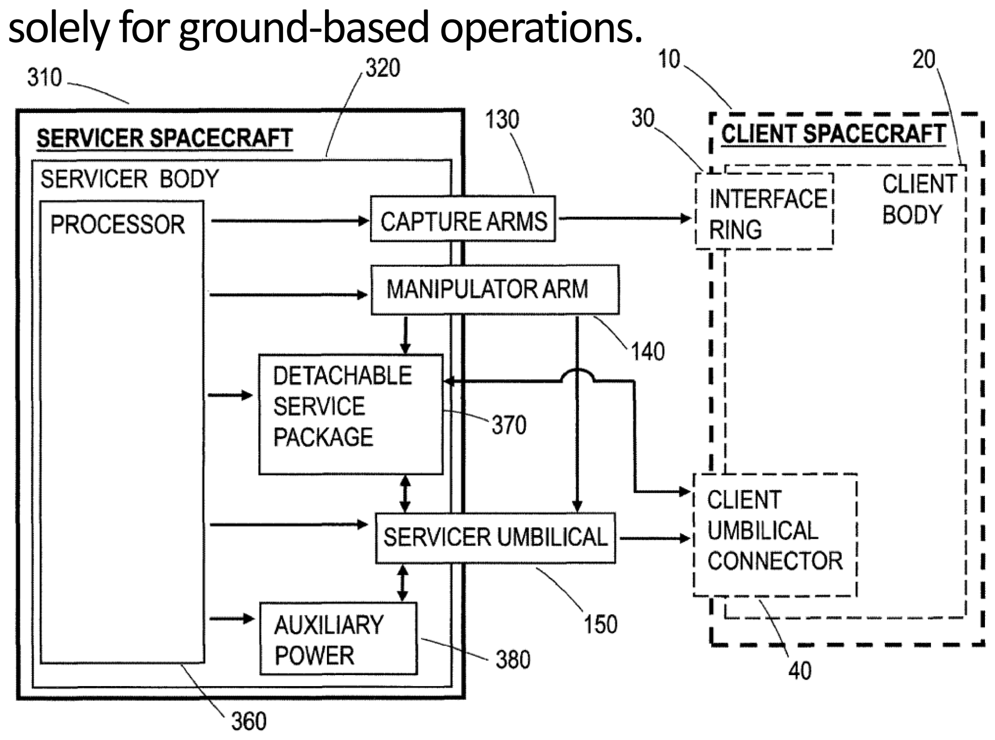
Abstract

As geostationary orbit (GEO) rendezvous proximity operations (RPO) missions are being launched as a means to provide life-extension services to active GEO satellites, new novel approaches to ground communication architecture have potential to simplify servicer design, reduce RF interference, and reduce overall mission operation costs. One such approach discussed here involves the servicer vehicle utilizing the client vehicle's active antenna and data stream during combined-stack operations versus maintaining a distinct communication stream with a separate ground station. The proposed method to accomplish this is to provide a physical umbilical connection during docking operations, allowing the servicer vehicle to provide power and transfer data to the client vehicle. Data that is unique to the servicer is isolated after reaching the client's ground station and transmitted to the servicer operations center. Challenges to this solution are explored, mainly including fault detection, isolation, and recovery (FDIR) concerns related to sustaining client operations with adequate security and minimal degradation, as well as protecting servicer vehicle functionality in the interest of servicing multiple clients per mission. Mitigations to these challenges include selection criteria for potential client vehicles, using intersatellite optical links, redundant umbilical hardware, and redundant communication system considerations.

Design Considerations

Umbilical Connector

Current GEO servicing missions do not include an electrical interface between servicer and client. In order to enable a shared communication stream, the servicer vehicle must include a manipulator arm to maneuver a physical connector between the servicer and a client spacecraft's umbilical connector conventionally used solely for ground-based operations.



Telemetry Packetization

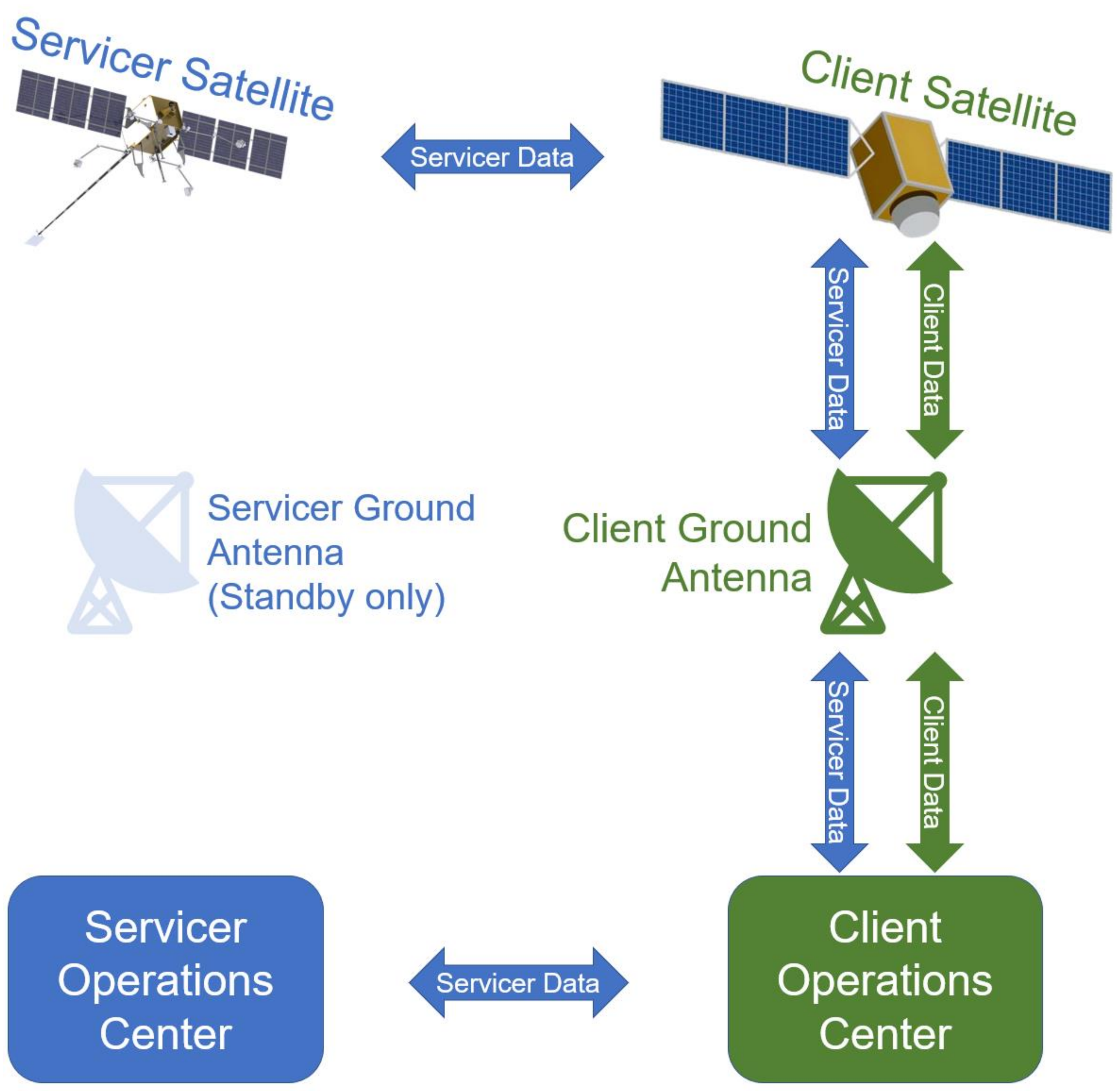
Servicer telemetry and commands utilize CCSDS space packet protocol. Unique Application IDs are implemented to differentiate data between client and servicer.

Client Selection Criteria

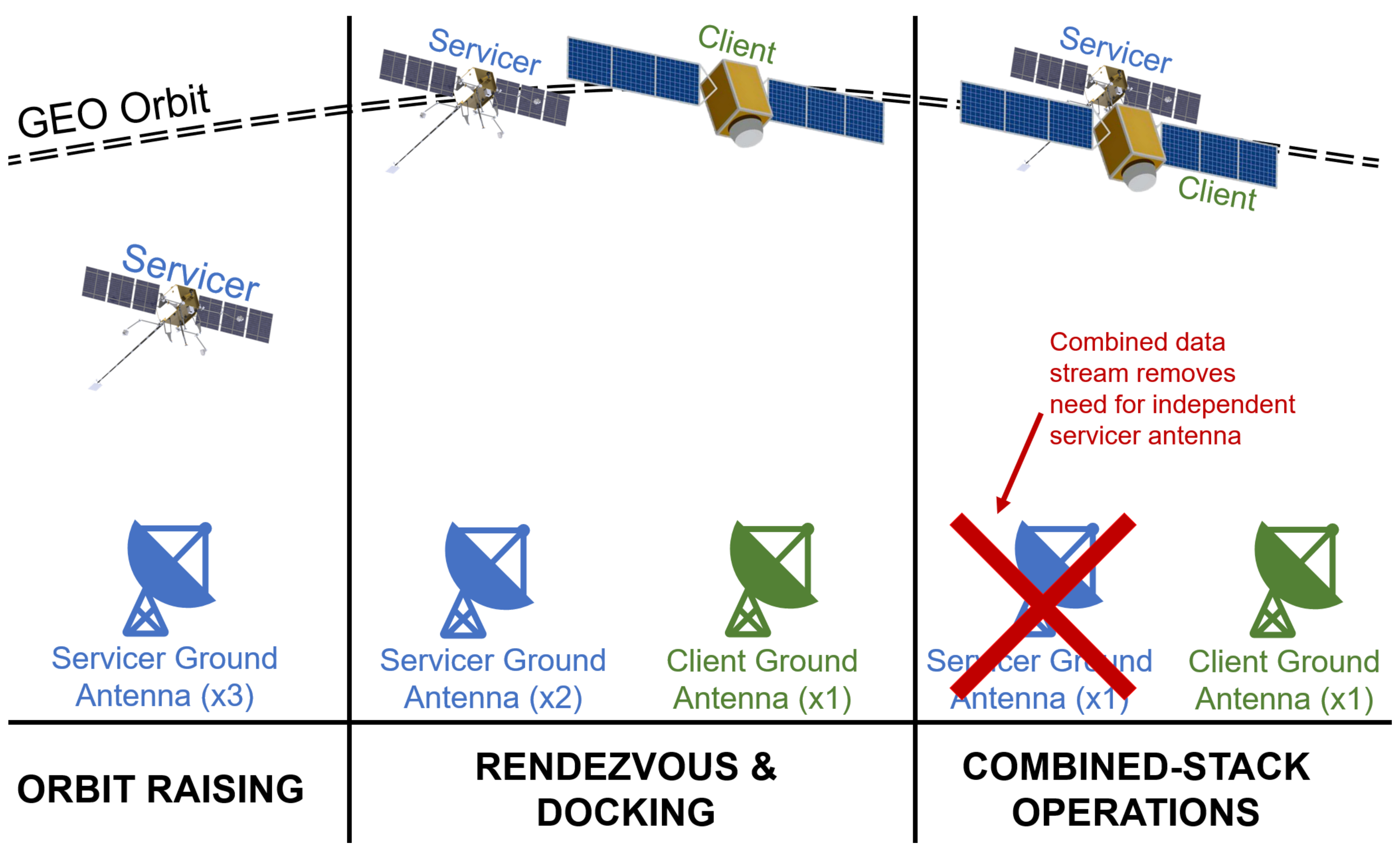
1. Location of umbilical connector port
   - Connector design must be standard.
   - Connector must be in proximity to the Launch Adapter Ring.
   - Connector must be located such that the servicer manipulator arm's motion is not restricted by the client vehicle.
2. Existing client communication protocol
   - The client must have the ability to authorize a new source of data and forward it to/from the servicer.
3. Client link margin
   - The client's link budget must have adequate margin to accommodate the servicer's required uplink and downlink data rates in addition to its own.
4. Client data throughput
   - The client's data architecture must possess sufficient margin for the servicer's data stream.
5. Client service availability
   - Client must be willing to lose service availability for a short period during umbilical interface procedures.
6. Electrical charge differences
   - Client (in addition to the servicer) must have the ability to mitigate electrical charge differences when interfacing its umbilical connection.

Concept of Operations

1. The GEO servicer vehicle performs nominal docking procedures per current mission designs.
2. After docking procedures are complete, the servicer establishes an umbilical power and data connection with the client. The location of the client's umbilical connector and interface procedures are established prior to the mission as part of a client feasibility analysis.
3. Servicer telemetry is encrypted, then passed to the client.
4. The client downlinks both its own telemetry as well as the servicer's telemetry to the client's existing operations center.
5. Encrypted servicer telemetry is identified and forwarded to the servicer's operation center.
6. File and command uploads to the servicer follows the same process in reverse.



A typical combined-stack servicing period is five years. Current mission designs utilize a dedicated ground antenna to communicate with the servicer vehicle over this period. By removing the necessity for a second active antenna in close proximity to a client's antenna, issues with RF interference are generally mitigated. Utilizing the client's existing ground communications also negates the need for an active dedicated servicer ground antenna, simultaneously eliminating associated costs. Operation of a dedicated antenna varies in cost, typically between $15k and $50k per month. Over five years, negating the need for this dedicated antenna results in a cost savings between $900k and $3m over the length of service.



Fault Detection, Isolation, Recovery

On-Board FDIR

Existing FDIR architecture for the client vehicle is largely unchanged at a spacecraft level. By design, client software updates to provide additional fault resolution are not required.

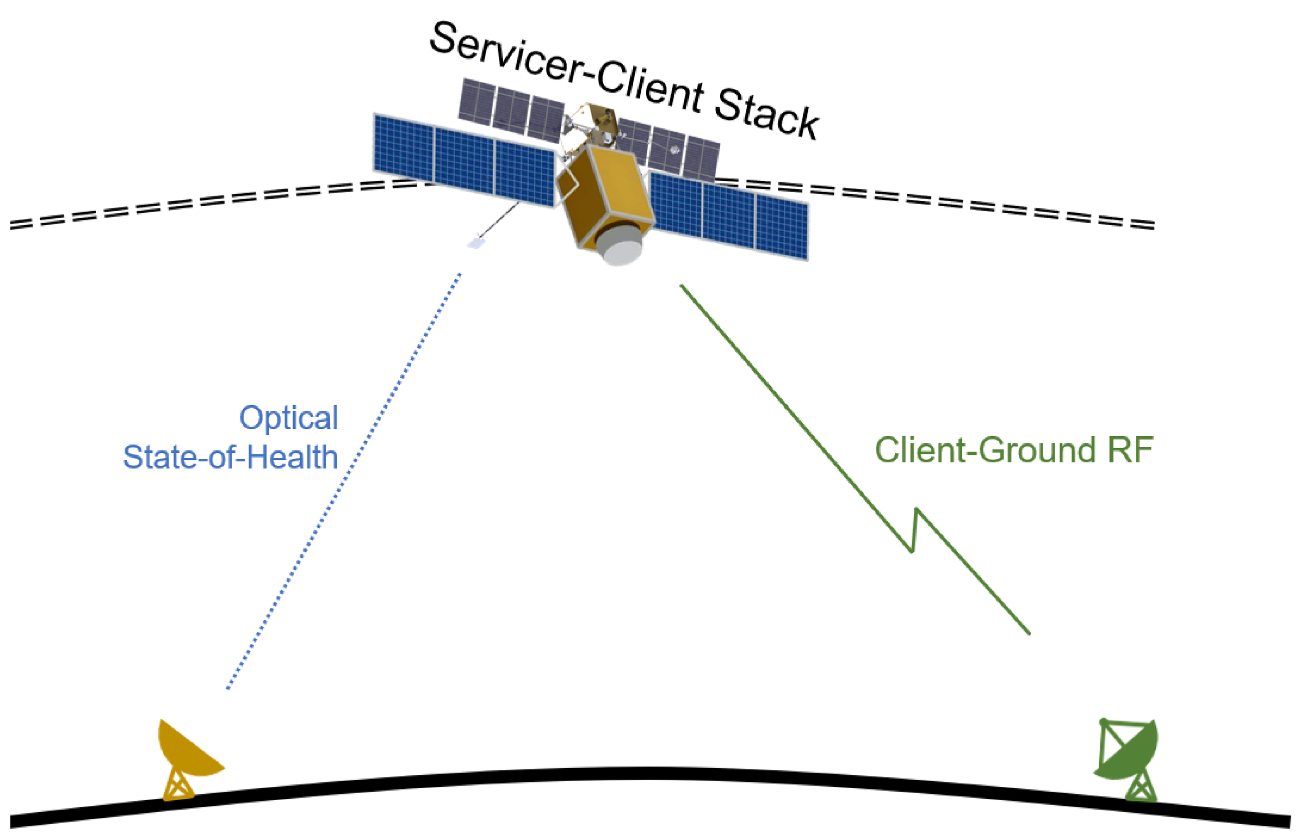
Servicer communication and data handling FDIR is also generally unchanged with communications traveling through the client, as the only difference in fault conditions is a different source/destination for servicer data.

Ground-Based FDIR

In order to diagnose and mitigate communications faults on the ground, an optical link from the servicer to an independent optical ground station can be utilized. In the interest of maintaining cost effectivity, this optical solution seeks to minimize specifications such as power and data throughput. As such, this connection is unidirectional between the servicer and ground and is limited to critical state-of-health data.

This redundant servicer health data provides key insight towards the cause of communication failures. A loss of RF telemetry on its own often provides minimal information to diagnose the loss of communication, but the addition of optical health data may enable operators to determine the failure's root cause. If both optical and RF telemetry are lost, this indicates a level of fault severity that would not otherwise be known.

Upon a loss of servicer communication, the servicer's antenna used for docking procedures provides redundant communication with a standby ground antenna.



Discussion

There are many alternative mission solutions to those discussed here that warrant further examination. The FDIR solution introduced uses direct-to-ground optical communication, while there may be some technical benefit and cost savings in an optical communications link to satellites in MEO or LEO as a health data redundancy. The solution discussed here generally assumes that the servicer is static in a GEO slot, but additional considerations would be required for a servicer providing inclination reduction or client relocation.

Future Work

1. Explore other servicing applications provided by an umbilical connection, such as a planned client software update via servicer or detachable service package.
2. Explore the possibility of providing redundant client communications through the servicer vehicle, i.e. reversing the communication flow discussed here.