Introduction

• Future manned missions present unique challenges:
  - Require interoperability among space agencies
  - Reduced budgets for operations and development

• Mission Operations identifies two benefits of interest:
  - Increase interoperability among space agencies
  - Reduced cost of mission-specific deployment

• Interoperability Prototype covers three main topics:
  - Validation of the Mission Operations Protocol
  - Integration of legacy systems in an SOA
  - Exploration of the Data Distribution Service
Motivation

- Common exchange format between NASA control centers is necessary
- Investigating ground-to-ground standardization
- Negotiation of data exchange format between control centers can be challenging.
Collaborate with the German Space Operations Center (DLR) to implement an interoperability prototype
- Prototype implements five MO services:
  ◦ Action Service
  ◦ Parameter Service
  ◦ Alert Service
  ◦ Directory Service
  ◦ Login Service (internal access control)

Identify additional capabilities for the services to meet human spaceflight operations concepts
Action, Alert and Parameter Service Architecture

JSC-OTF

- Service Application Layer C++
  - Core Services
    - Common Services
      - Common Object Model
        - Message Abstraction Layer
          - Binary Encoding
            - DDS Transport

DLR-GSOC

- Service Application Layer C++
  - Core Services
    - Common Services
      - Common Object Model
        - Message Abstraction Layer
          - Binary Encoding
            - DDS Transport
            - JMS Transport
Directory Service Architecture

JSC-OTF
- Service Application Layer: Java
  - Core Services
    - Common Services
    - Common Object Model
      - Message Abstraction Layer
        - XML
        - HTTP Transport
  - Language Mappings

DLR-GSOC
- Service Application Layer: C++
  - Core Services
    - Common Services
    - Common Object Model
      - Message Abstraction Layer
        - XML
        - JMS Transport
    - Transport Bridge
Encoding Specifications

- Encoding is currently mission implementation specific

- Developed a BNF like grammar to describe a binary encoding with emphasis on simplicity

- Developed an XML schema for encoding of the data structures necessary for the Directory Service
Bridging System Domains

- Use an “in care of” address to specify the routing information
  - otf-service-uri@otf-gateway-uri

- The Message Header URI contains the complete routing sequence similar to USENET addresses
In Care of Address Example

- DLR Action Service Consumer
- DLR Gateway
- OTF Gateway
- OTF Action Service Provider

**DLR Gateway**
- **URI to**
  - ddsbin:action-service@
  - jmsbin:otf-gateway@
  - jmsbin:dlr-gateway

- **URI from**
  - jmsbin:action-client@
  - ddsbin:otf-gateway@
  - jmsbin:dlr-gateway

**OTF Gateway**
- **URI to**
  - ddsbin:action-service@
  - jmsbin:otf-gateway@
  - jmsbin:dlr-gateway

- **URI from**
  - jmsbin:action-client@
  - ddsbin:otf-gateway@
  - jmsbin:dlr-gateway
Additional Capabilities

- Human spaceflight requirements for Action Service
- Significant departure from traditional unmanned environment:
  - Control a few number of resources with a large number of people
  - Consequences of sending the incorrect command are more serious when humans are aboard
  - Provides a distributed work environment to allow flight controllers and operators to collaborate
  - Maintain a dynamic and shared command repository
Integrating Legacy Systems

- Action Service interfaces with the ISS Command Server
  - Treated as just another client
  - Identified a set of eleven Station commands
- Parameter Service interfaces with the telemetry distribution system for ISS and the Space Shuttle
  - Identified a set of twenty corresponding ISS telemetry parameters
- Alert Service interfaces with the advisory service for ISS and the Space Shuttle.
Prototype Architecture

Spacecraft Simulator

MCC Systems

MCC Message Bus

JSC-OTF

Action Service
Parameter Service
Alert Service

Common Object Model
Message Abstraction Layer
Binary Encoding

DDS
HTTP

OTF Gateway
Message Abstraction Layer
XML / Binary Encoding

DDS
HTTP

JSC-OTF DMZ

OTF Gateway
Message Abstraction Layer
XML / Binary Encoding

XML Encoding

JSC-OTF DMZ

DLR-GSOC DMZ

DLR Gateway
Message Abstraction Layer
XML / Binary Encoding

XML Encoding

Directory Service

Common Object Model
Login Service

Common Object Model
Directory Service

Common Object Model
Directory Service
Bridging Control Centers

CC5 Gateway

Legacy Systems
Mission Operations

JSC Gateway
Mission Operations
Legacy Systems

CC2 Gateway

Legacy Systems
Mission Operations

CC3 Gateway

Legacy Systems
Mission Operations

CC5 Gateway

Mission Operations
Legacy Systems
Extend Prototype Bridge

- Prototype bridge solution requires knowledge of complete routing sequence
- Extend solution to accommodate an arbitrary number of gateways.
- Maintain only the next hop routing information in the URI
Bridge Publish Availability

1. publish(S, JSC-GW)
2. notify(S, S)
3. publish(S, JSC-GW)
4. addLink(S, JSC-GW)
5. notify(S, JSC-GW)
6. publish(S, CC2-GW)
Bridge Request / Reply

1. lookup(S, CC2-GW)

2. send[To=S, CC2-GW, From=C, C]

3. send[To=S, JSC-GW, From=C, CC2-GW]

4. send[To=S, S, From=C, JSC-GW]

5. send[To=C, JSC-GW, From=S, S]

6. send[To=C, CC2-GW, From=S, JSC-GW]

7. send[To=C, C, From=S, CC2-GW]
Data Distribution Service

• Prototype uses for bulk data transfer

• Plan to perform benchmark comparisons against legacy telemetry distribution system

• Investigate structured data messages
Transport Broker

REGISTER

REGISTER_ACK

PUBLISH__REGISTER

PUBLISH__REGISTER_ACK

*NOTIFY

*PUBLISH

PUBLISH__DEREGISTER

PUBLISH__REGISTER_ACK

DEREGISTER

DEREGISTER_ACK

Consumer

DDS Transport Broker

Provider
Conclusion

• Specifications are sufficiently robust to allow NASA missions to collaborate

• Specifications are not yet capable of replacing existing systems

• Encourage NASA space centers to participate in the working group and propose capabilities necessary for mission support
Thank You

• Questions