

# A Multi-Center Space Data System Prototype Based on CCSDS Standards

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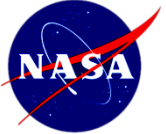
*CD231 – Mission Systems Strategic Projects*

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# Multi-Center Space Data System Rationale

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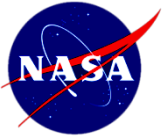


## Mission Operations Goals for the Multi-Center Space Data System prototype:

- To apply internationally standardized protocols to spacecraft command, telemetry, video, and file transfer in a realistic scenario where light-time delay becomes significant
  - Consultative Committee for Space Data Systems (CCSDS) standards:
    - Spacecraft Monitoring and Control (SM&C)
      - Provides a common data interface
      - Designed to be easily integrated into existing (legacy) applications
      - Provides architectural flexibility for locating applications anywhere
    - Asynchronous Message Service (AMS)
      - Provides publish / subscribe capability
      - Provides an efficient interface between SM&C and DTN
    - Delay / Disruption Tolerant Networking (DTN)
      - Licklider Transmission Protocol (LTP)
        - » Provides reliable space to ground data communication in high latency and high error rate scenarios
      - Bundle Protocol (BP)
        - » Provides reliable data communication in less stressful scenarios
  - To raise the Technical Readiness Level (TRL) of the SM&C / AMS / DTN protocol stack
  - To promote the acceptance and application of these standardized protocols, which will increase center-to-center interoperability and lower per-mission costs

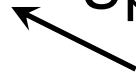


# Multi-Center JPL/MSFC/JSC Space Data System (SDS) Overview

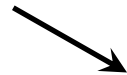


MPCV Flight-Like  
Hardware and Software  
iPAS Lab, JSC Bldg. 29

DTN / LTP  
Command  
Uplink



DTN / LTP  
Telemetry  
Downlink



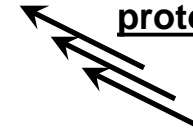
This SDS is a  
prototype for Deep  
Space Network  
automation based on  
CCSDS standards

Protocol Test Lab@JPL  
DSN Operations Center Sim  
Space-to-Ground Comm Link Sim  
4 sec. one way light time delay  
2% frame drop rate on downlink  
0.1% frame drop rate on uplink  
Available 24 / 7 / 365

This the only SDS prototype based end-to-end  
on this set of CCSDS international standards:

Spacecraft Monitor and Control  
Asynchronous Message Service  
Delay / Disruption Tolerant Networking  
Bundle Protocol  
Licklider Transmission Protocol

This SDS prototype is  
intended to raise the TRL of this  
protocol stack.



PTL@JPL



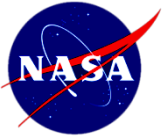
OTF@JSC Bldg. 30



HOSC@MSFC



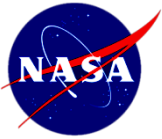
# Multi-Center Space Data System Detailed Design



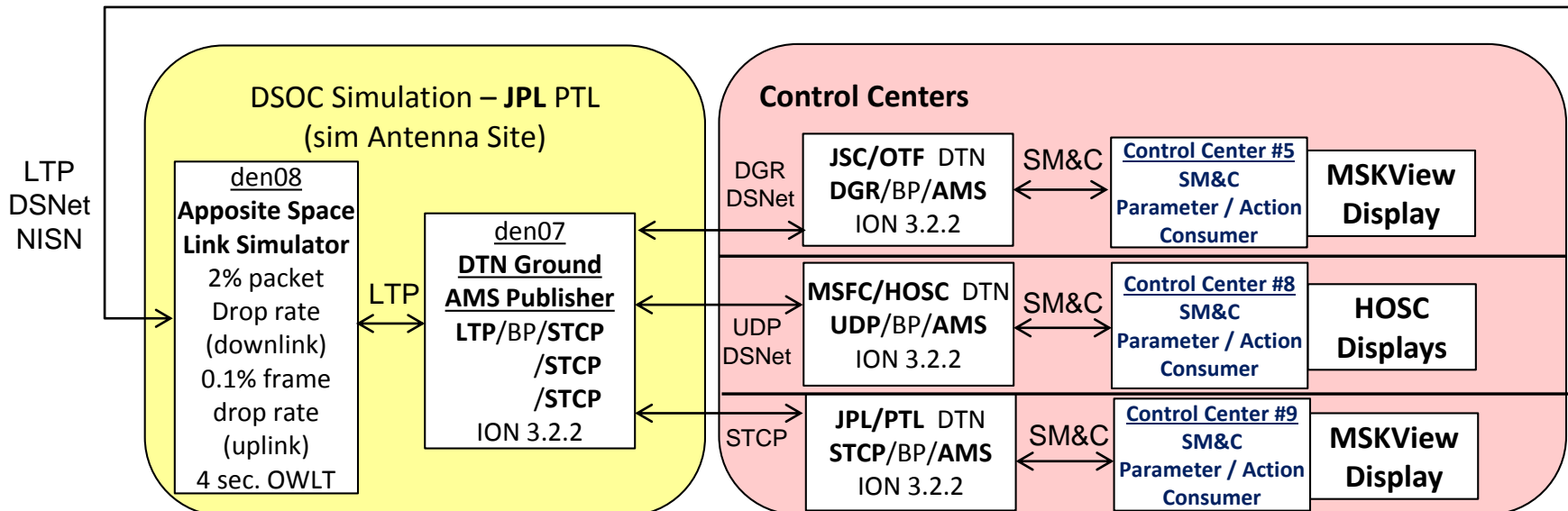
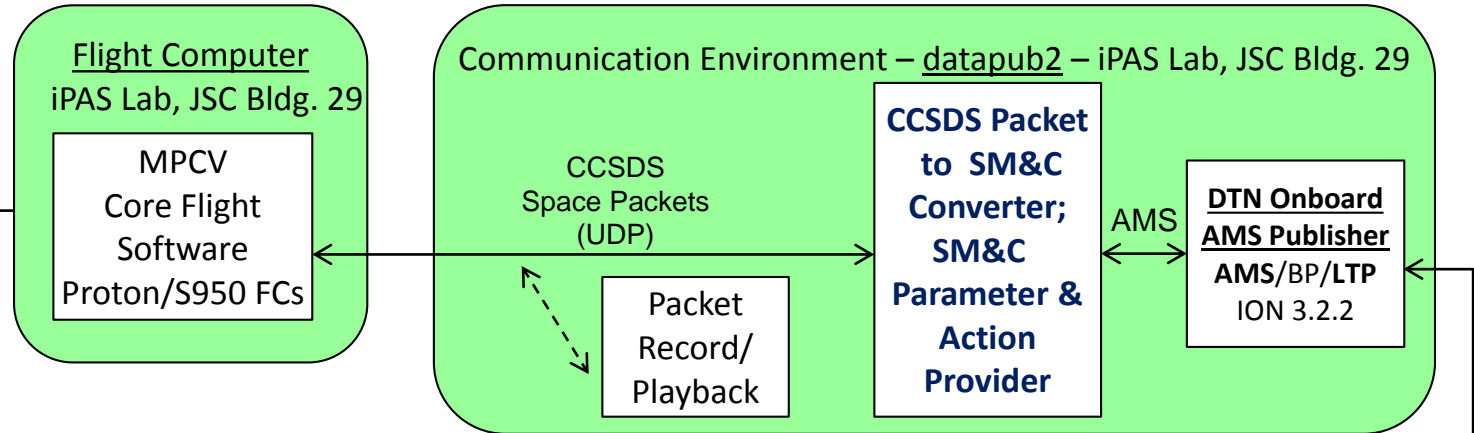
- In the integrated Power, Avionics, and Software (iPAS) lab at the Johnson Space Center (JSC):
  - Use flight like hardware and software to generate telemetry and process commands in the form of CCSDS Space Packets
  - In the onboard communications processor, convert these CCSDS Space Packets into Spacecraft Monitor and Control (SM&C) messages
  - Use the Asynchronous Message Service (AMS) and the Licklider Transmission Protocol (LTP) to transmit these SM&C messages to the simulated Deep Space Operations Center (DSOC), located at the Jet Propulsion Lab (JPL)
- In the DSOC at the Protocol Test Lab (PTL) at JPL:
  - Model the space-to-ground link
    - Apply one way light time delay
      - Currently at 4 seconds; it can be up to 30 minutes.
    - Apply 2% frame drop rate on the downlink; 0.1% frame drop rate on the uplink
  - Receive the SM&C / AMS messages over LTP
  - Distribute the SM&C / AMS messages to multiple simulated control centers located at JPL, JSC, and the Marshall Space Flight Center (MSFC)
- In the simulated control centers at the PTL at JPL, the Huntsville Operations Support Center (HOSC) at MSFC, and the Operations Technology Facility (OTF) at JSC:
  - SM&C applications are used to process the data.
  - At the HOSC, the legacy application “Display Dashboard” was easily fitted with the SM&C common interface.



# Multi-Center Space Data System Detailed Design

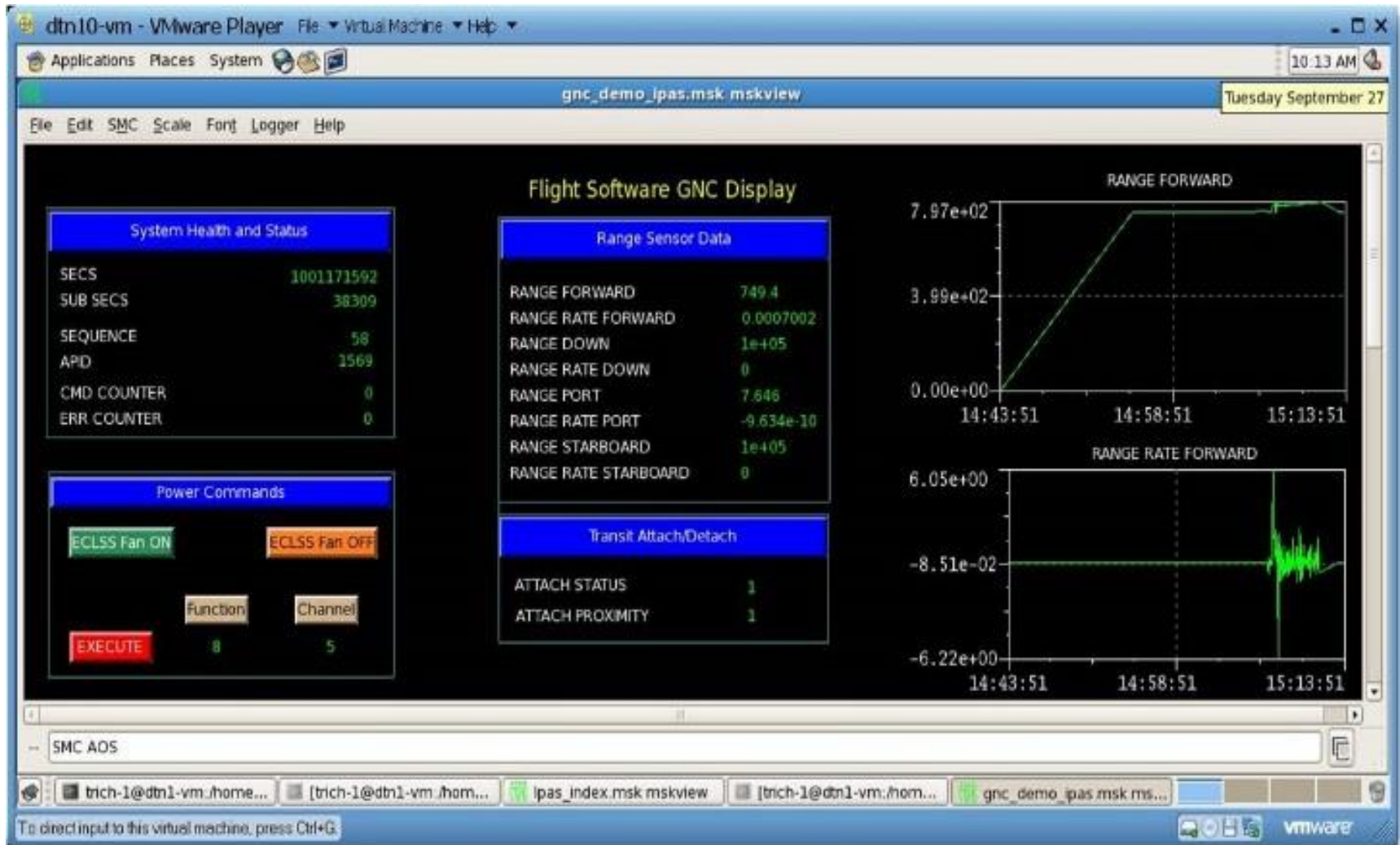
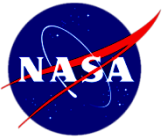


Onboard  
ECLSS Fan





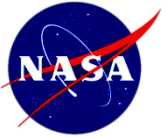
# MSKView Display Example







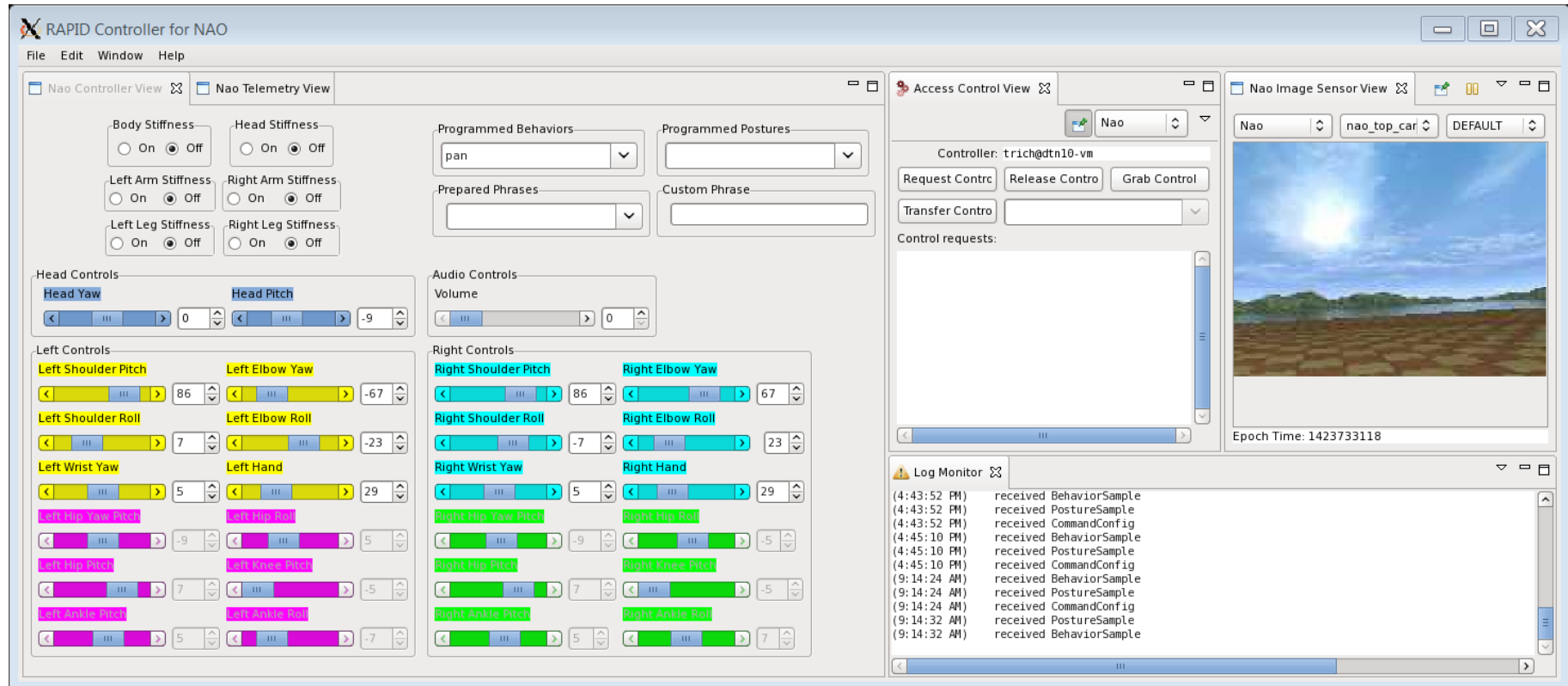
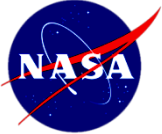
# Telerobotics Project Steps



- Add a Robotics API Delegate (RAPID) interface to the Multi-Center Space Data System
  - RAPID is designed to control multiple robots consistently and simultaneously.
  - RAPID is a candidate CCSDS standard.
- Integrate the Data Distribution Service (DDS) based RAPID with the SM&C based Multi-Center Space Data System
- Develop a RAPID based controller for the NAO telerobotic test article, a product of Aldebaran Robotics



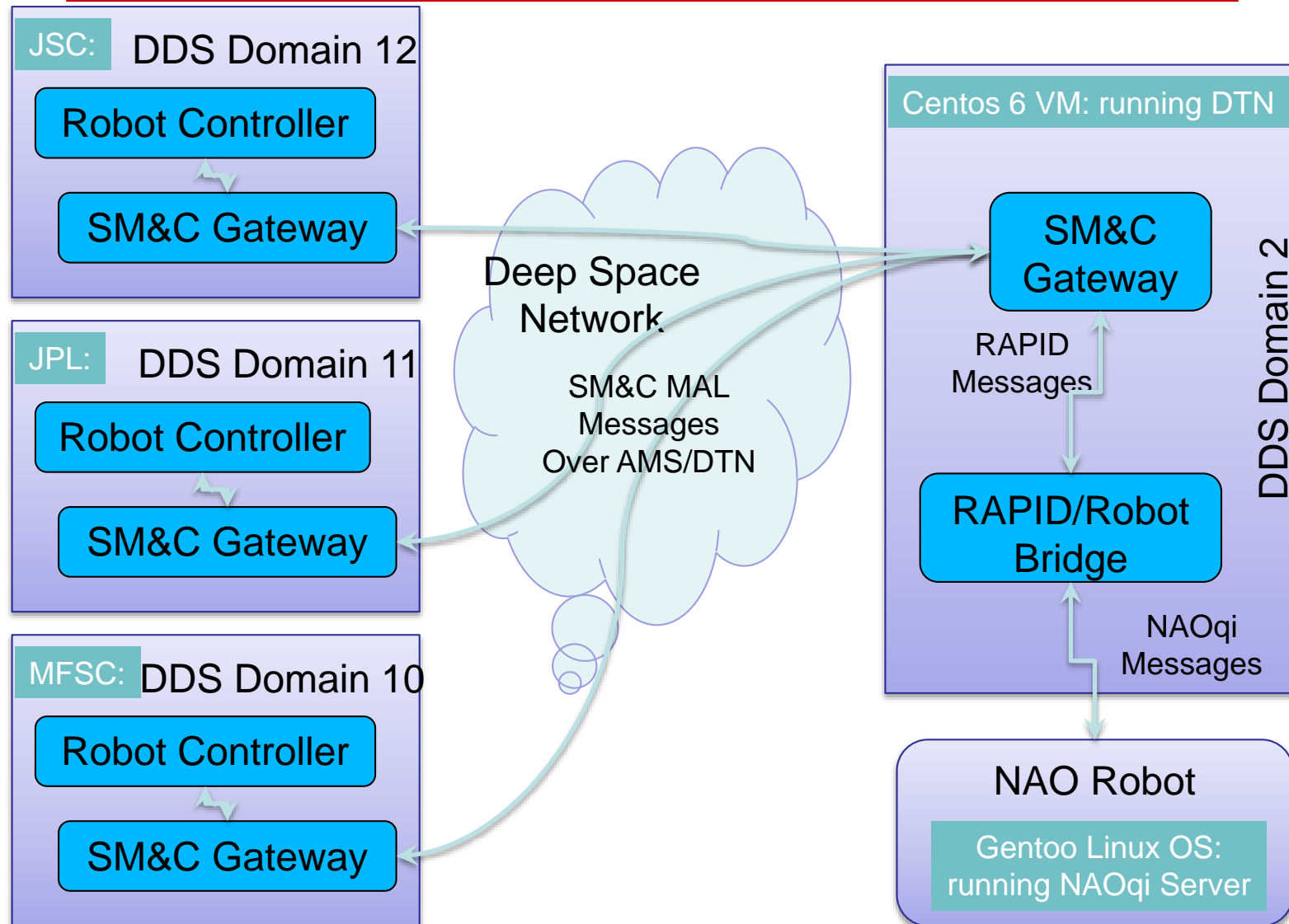
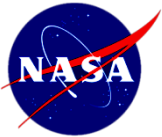
# RAPID Controller for the NAO Robot







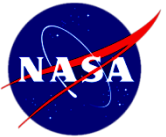
# NAO Multi-Control-Center Architecture





# Observations

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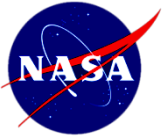


- This prototype is SM&C “end-to-end”, in that SM&C extends to the spacecraft.
  - Con: impacts onboard software complexity and resource utilization
  - Pro: offers architectural flexibility: The same SM&C applications can run both onboard and on the ground, saving development costs.
- There is an option to run SM&C on ground resources only.
  - Control centers can still benefit from interface commonality and center-to-center interoperability, which will lower per-mission costs.
- This Multi-Center Space Data System prototype has run continuously over the past two years.
  - Unplanned outages have become rare.
- The SM&C and DTN protocols have benefited from numerous prototypes and stress tests prior this prototype.
- This is the first prototype to add AMS to this protocol stack. Improvement suggestions have been noted.
- The Technical Readiness Level of this SM&C / AMS / DTN protocol stack will grow as AMS matures.



# Summary

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- This project has shown that space mission information can be distributed to multiple control centers using the CCSDS standard protocol stack SM&C, AMS, and DTN.
  - This increased interoperability will lower per-mission costs
- This project has shown that legacy applications at the control center endpoints can be easily integrated into this SM&C based infrastructure.
- Since SM&C, AMS, and DTN are CCSDS international standards, international interoperability can increase as well.



# Questions?

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