Remote Integration and Test Operations for Landsat 9

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Agenda

- Introduction and Overview
- Landsat Program
- Landsat 9 (L9) Observatory Integration and Test
- Test Support/Data Assessment – Hallway Ground System (HGS)
- Remote Network Access Approach
- Remote Test Operations and Lessons-Learned
- Remote Mission Operations and Launch Support
- Summary and Recommendation

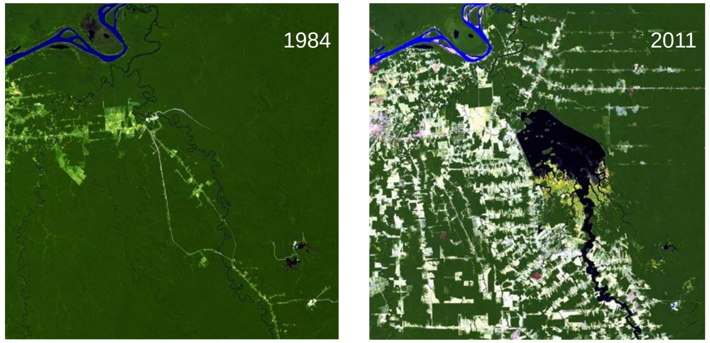
USGS

Landsat Program

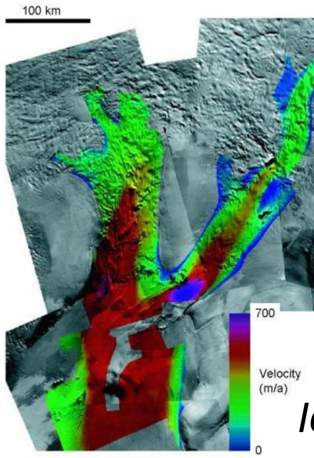
Landsat is our longest-lived series of land imaging satellites, providing a 50 year archive of natural and human-induced changes to the global landscape

Landsat provides multispectral imagery supporting key science and societal benefit areas:

- *Mapping Land Use & Change*
- *Forest Dynamics and Carbon*
- *Agriculture & Evapotranspiration*
- *Ecosystem Science (including coasts)*
- *Surface Water Quality*
- *Cryospheric Science*
- *Geology and Natural Resources*

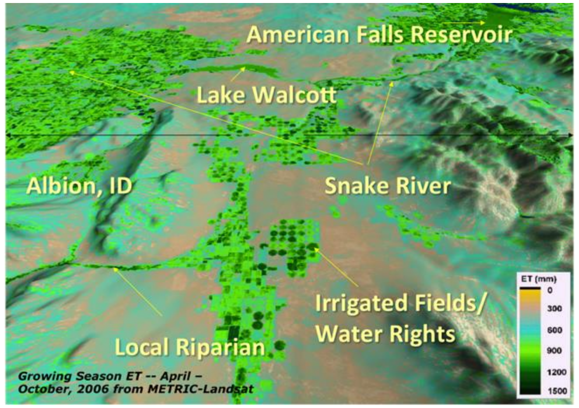


Forest Dynamics



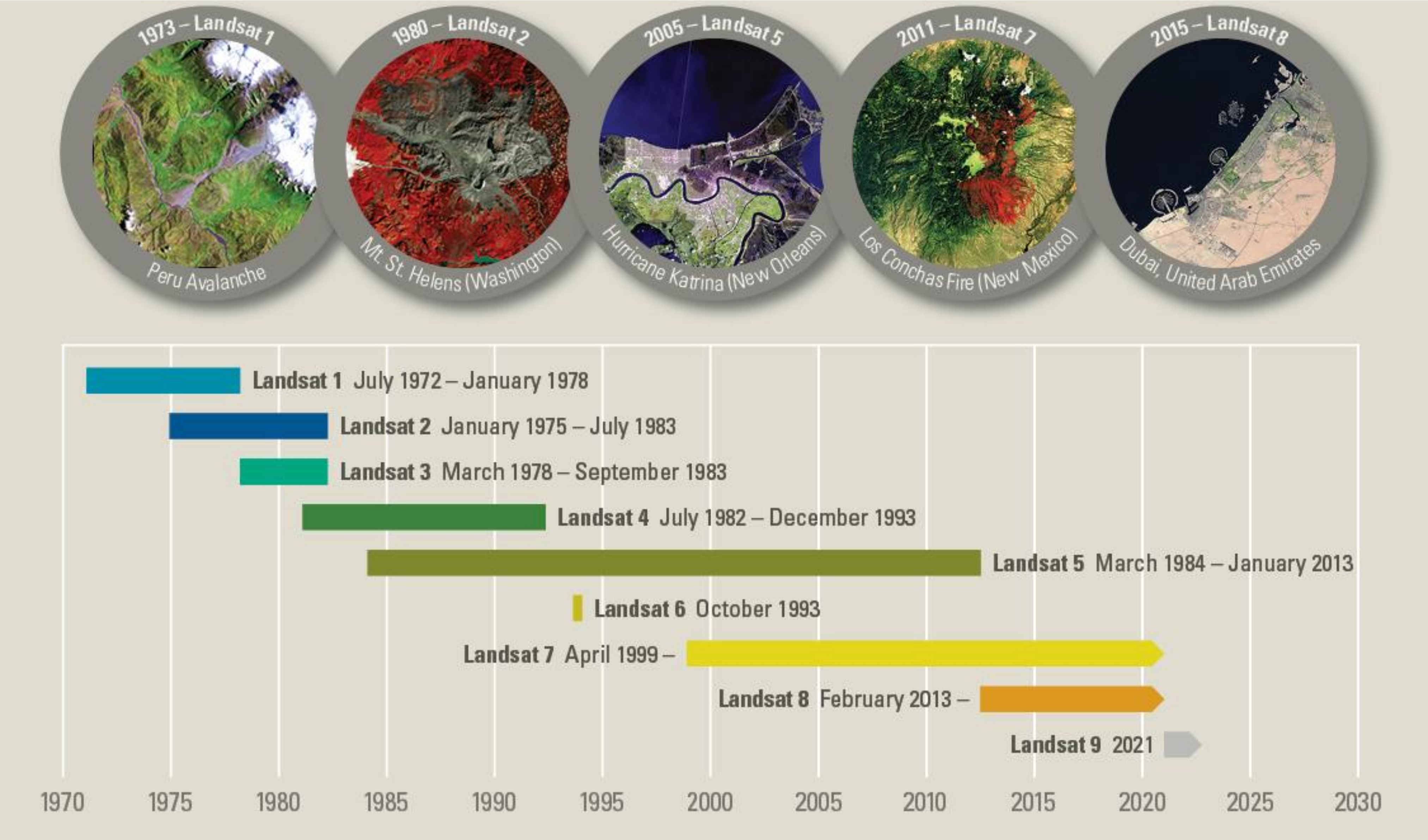
Ice Sheet Velocity

National Land Cover Dataset (NLCD)



Evapotranspiration & Crop Water Consumption

Landsat Program, cont.



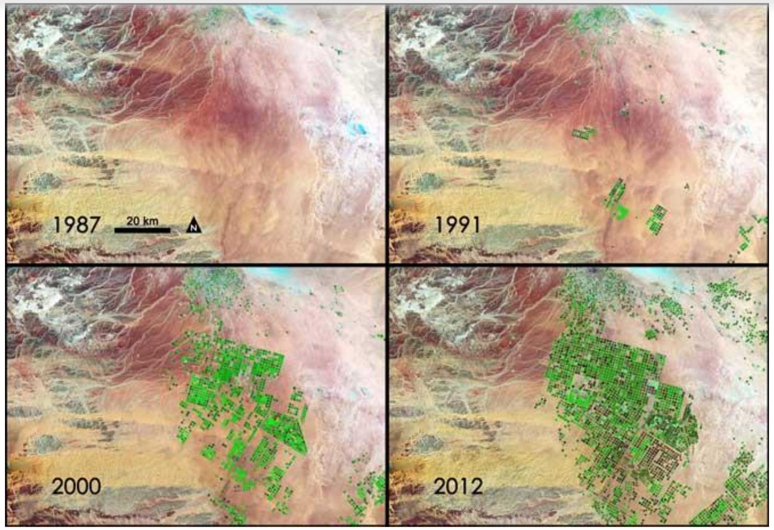
Landsat 9 (L9) Mission Description

Mission Objectives

- **Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics**
  - **Core Component of Sustainable Land Imaging Program**

Mission Team

- **NASA Goddard Space Flight Center (GSFC)**
- **USGS Earth Resources Observation & Science (EROS) Center**
- **NASA Kennedy Space Center (KSC)**



Increase in pivot irrigation in Saudi Arabia from 1987 to 2012 as recorded by Landsat. The increase in irrigated land correlates with declining groundwater levels measured from GRACE (courtesy M. Rodell, GSFC)

Mission Parameters

- **Single Satellite, Mission Category 1, Risk Class B**
  - 5-year design life after on-orbit checkout
  - At least 10 years of consumables
- **Sun-synchronous orbit, 705 km at equator, 98° inclination**
- **16-day global land revisit**
- **Partnership: NASA & United States Geological Survey (USGS)**
  - NASA: Flight segment, mission integration, launch & checkout
  - USGS: Ground system and operations
- **Launch: FY2021 (Targeting December 15, 2020), Category 3 Vehicle**

Instruments

- **Operational Land Imager 2 (Ball Aerospace)**
  - Reflective-band push-broom imager (15-30m res)
  - 9 spectral bands at 15 - 30m resolution
  - Retrieves data on surface properties, land cover, and vegetation condition
- **Thermal Infrared Sensor 2 (NASA GSFC)**
  - Thermal infrared (TIR) push-broom imager
  - 2 TIR bands at 100m resolution
  - Retrieves surface temperature, supporting agricultural and climate applications, including monitoring evapotranspiration

Spacecraft & Observatory I&T

- **Northrop Grumman Space**

Launch Services

- **United Launch Alliance (ULA) Atlas V 401**

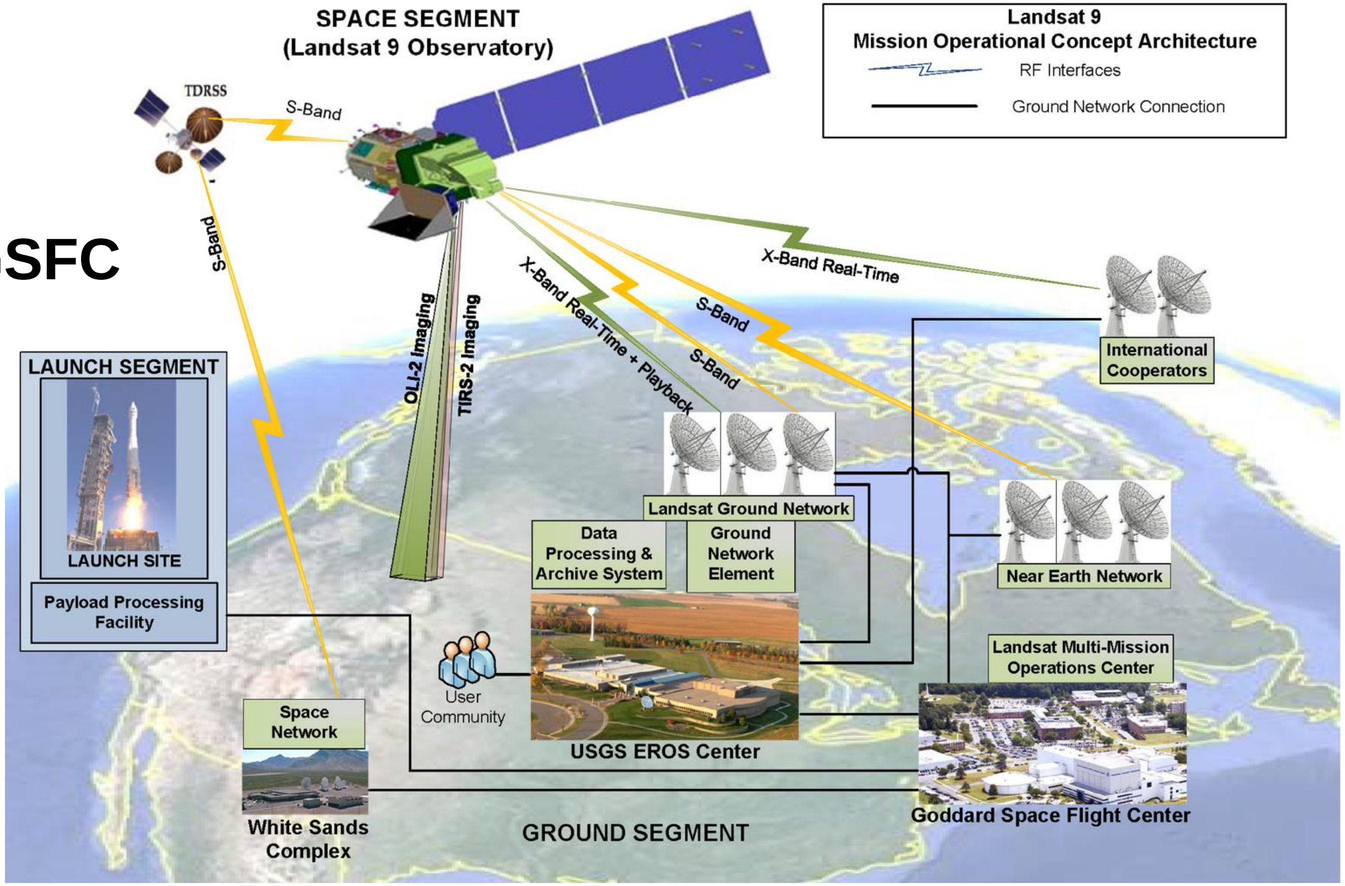
MOC and Mission Operations

- **General Dynamics Mission Systems (GDMS)**

USGS

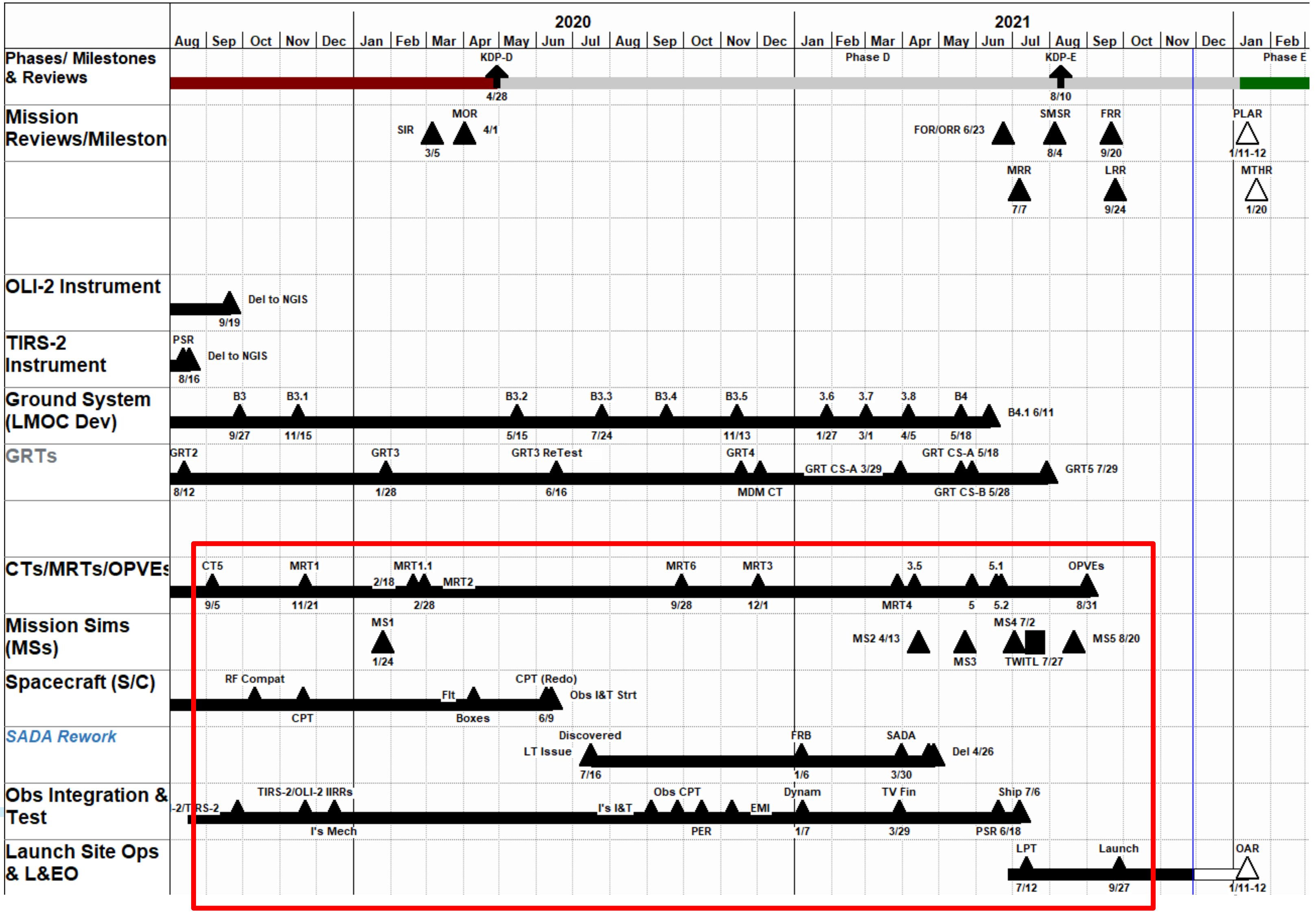
Landsat 9 Overview

- **Space Segment has Visible/NIR, SWIR and TIR Sensors at 30/100m Resolution**
  - X-Band image data D/L and S-Band T&C
  - NASA SN/NEN for launch/early-orbit and contingencies in operations
- **Ground System with LMOC at NASA/GSFC and Landsat Ground Network Stations**
  - Stations in Alice Springs Australia (GA), Gilmore Creek Alaska (NOAA), Sioux Falls SD (USGS), Neustrelitz Germany (DLR), Svalbard Norway (KSAT)
  - International Cooperators (ICs) that receive realtime downlinks
  - Processing and archive system (DPAS) at USGS/EROS in Sioux Falls, SD



L9 Integration and Test

- **Integrated Observatory Testing Started Fall 2019**
- **Normal Onsite Staffing Levels Until March 2020**
- **COVID Restrictions Imposed from March 2020 Until Launch in September 2021**
  - Ambient and Environmental Testing, Mission Readiness Testing, Launch Readiness
  - Limited Test Staff Onsite in Highbay with Remote Access for Remaining Participants



![USGS]

L9 Observatory Test Campaign Overview

- S- and X-Band RF Compatibility Testing
- Mission Readiness Testing (MRTs) with Mission Ops Center Interleaved with S/C Test Program
- Ambient Comprehensive Performance Test (CPT)
- Electromagnetic Interference (EMI) Testing
- Vibration and Acoustics (Dynamics) Testing
- Thermal/Vacuum (TVAC) Testing
- Pre-Ship Ambient CPT
- Launch Preparations (Aliveness Testing)

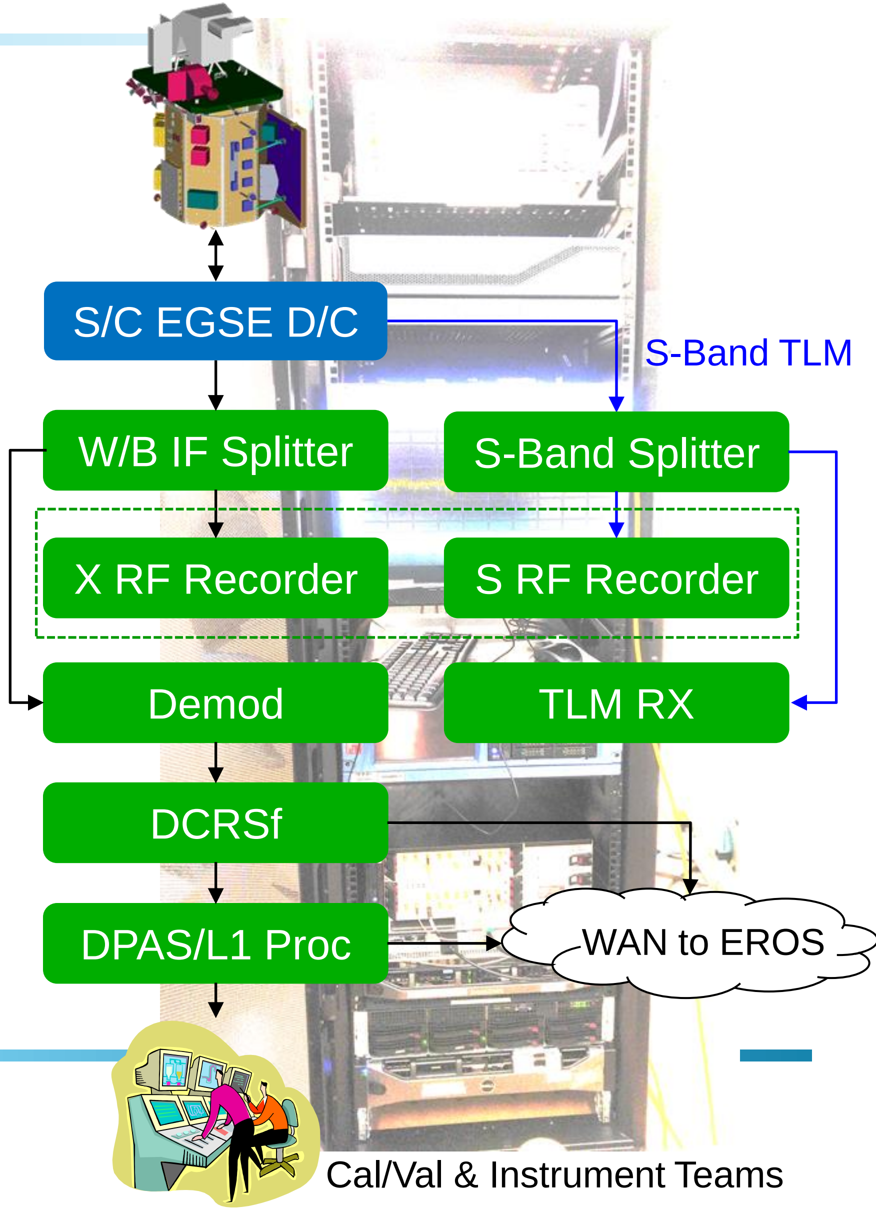
Hallway Ground System (HGS) Test Support

- HGS Provides Key Ground System Functionality for Test Support and Rapid Data Assessment at S/C Vendor Facility
- X-Band RF Wideband Interface to S/C
- Same Demodulators and Data Handling as Ground Stations
- Same L0/L1 Processing S/W as Ground System, Tailored for Near-Realtime Data Assessment
- Same Command and Telemetry Processor as Used in Ground Stations Connect to S/C Vendor RF Rack for MOC T&C Interface

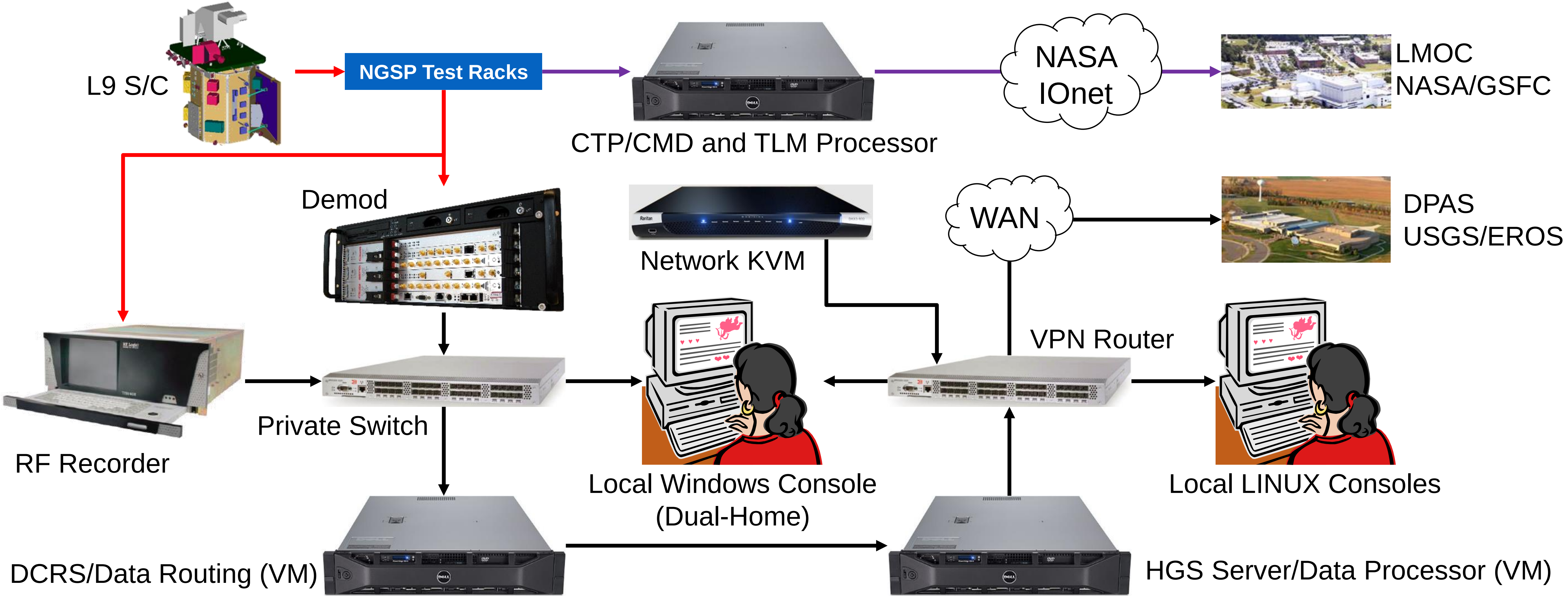
USGS

HGS Remote Network Access Approach

- **HGS Originally Implemented for Landsat 8 (L8) as Standalone System (No Network Connectivity) and External Hard Discs for Data Transfers**
- **Lesson Learned from L8: Implement WAN Connection for Data Transfers Between S/C Vendor Facility and USGS/EROS**
  - Internet-capable KVM also used for occasional remote access
- **VPN Used to Connect HGS Subnet to USGS/EROS LAN**
  - Driven by USGS IT security policies
  - Limited ability to share connection to people with USGS IT credentials/system access
  - Also constrained ability to connect to non-USGS systems (i.e. – NASA, S/C vendor, instrument vendor) for high-speed data transfers and test data access
  - External system connections limited to access points at USGS/EROS, even if non-USGS systems were physically collocated with HGS



L9 HGS Network Architecture



– Gigabit Ethernet and Network Connections for Data Transfers and Remote Access
– S- and X-Band RF Connections
– TLM and CMD WAN Connections

Initial Remote Access Experience

- **Access to Demod via KVM WAN Connection**
  - Very slow response for user interface, but adequate if just watching
  - Found that access was unacceptable to support troubleshooting where control of demod was required during testing
- **Migrated to Use of Windows Remote Desktop (RDP) Access to Demods Instead**
  - Much improved GUI response
  - Doesn’t run in browser window, so easier to use with other applications on a remote computer
- **CMD and TLM Processor (CTP) Access also via KVM**
  - Adequate for testing, but also had similar issues with response time once regular control of CTP was required
  - Replaced KVM access with X2Go LINUX RDP application, but different LINUX GUI environments prevented local console access
- **All Experience with HGS and Other Systems, Internet KVMs have been Barely Usable with Very Slow GUI Response Times**
  - Performance may be acceptable in a LAN environment
  - Performance may also be acceptable if using command-line interface

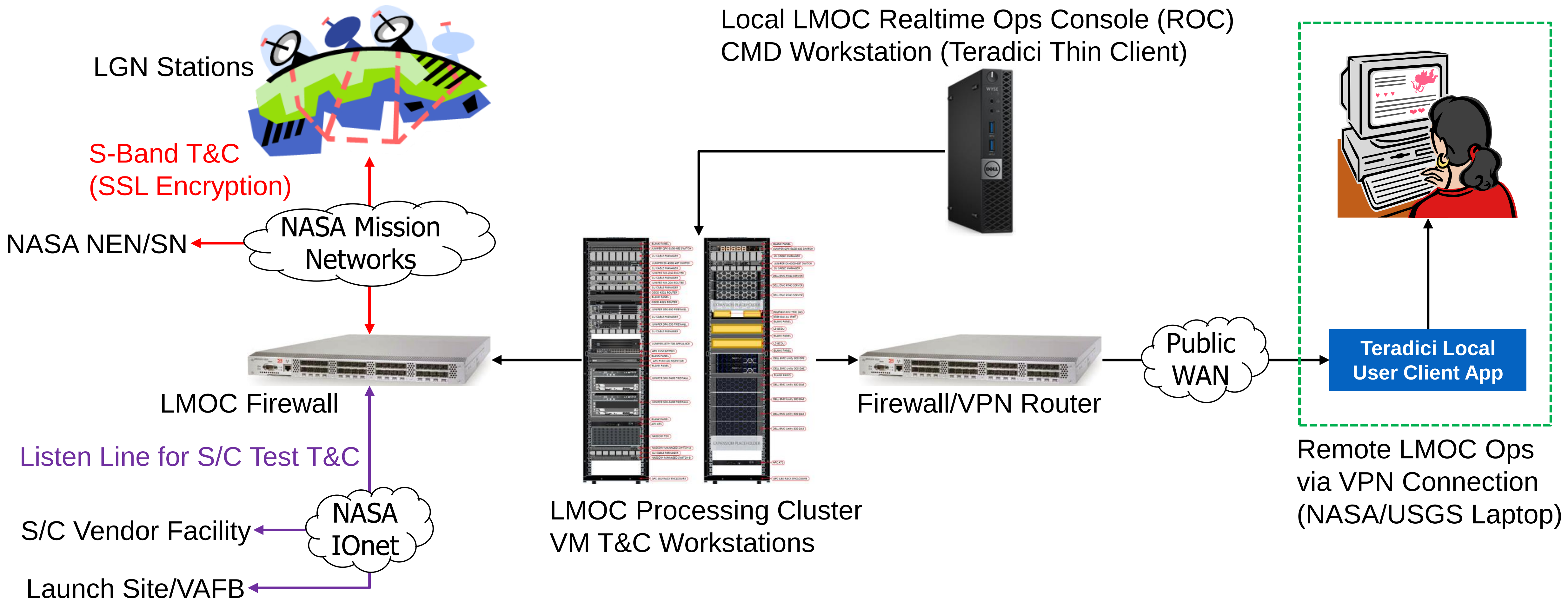
Sharing and Collaboration

- **WebEx and Microsoft Teams Used for Remote Collaboration Prior to COVID**
  - Continued to Use During Lockdown
  - Not much use of Zoom until the end, then primarily to present slides
- **Experience**
  - stopped use of video sharing due varying bandwidth issues and need to share equipment GUIs
  - Teams had best integrated IM capabilities – Good IM application and capability to use IM and view GUI at the same time, as well as integration with normal Teams application
  - Multiple sharing sessions possible using browser + application, as well as WebEx + Teams, but need to segment audio and watch mute status for windows
  - Teams file-sharing capabilities typically only work in local organization's group, though anyone in meeting can view shared GUI
  - Multiple monitors ideal to dedicate one to each share, but one big high-resolution monitor also worked

Remote Mission Operations

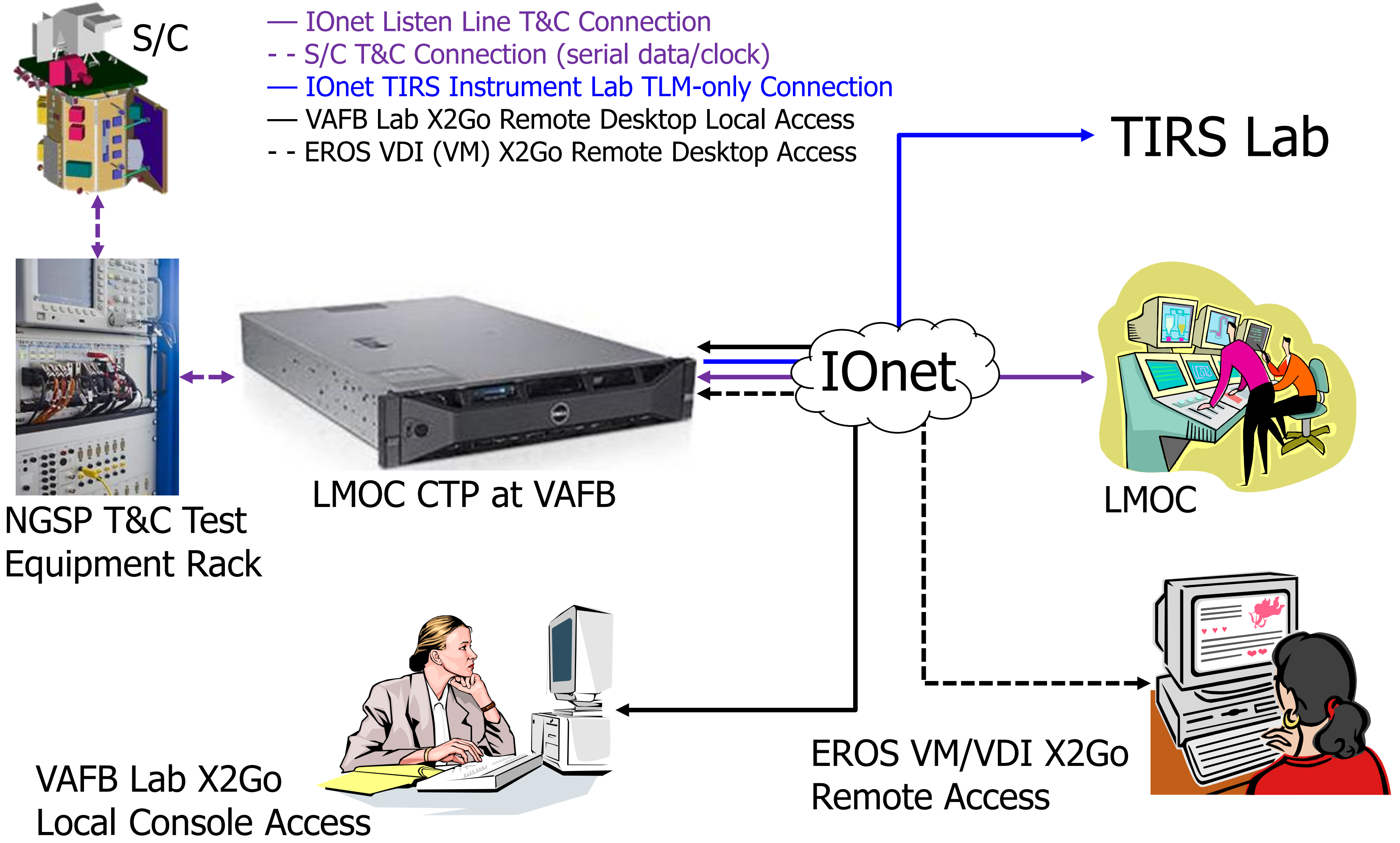
- **Landsat Multi-Satellite Mission Operations Center (LMOC) Access at NASA/GSFC also constrained by COVID Lockdowns**
- **LMOC Architecture Designed Using Teradici Thin Clients to Access TLM and CMD Workstations Running as Virtual Machines on Server Cluster**
  - Software-define network implementation
  - So, much easier to enable remote access through USGS or NASA VPNs
  - Implemented Teradici thin client (application) on user laptops to mimic physical thin client access
  - Laptops needed to have multiple monitors to mimic dual-screen LMOC interface
- **Slightly Relaxed IT Security Policies to Allow Remote Access for Testing, but Still Required Onsite Access in LMOC for S/C Commanding during Tests**

LMOC Architecture with Remote Access



Launch Support Operations

- **Similar Configuration as S/C Vendor Facility**
  - Different NASA IOnet subnet connectivity
- **Improved Remote Access Support by Setting up Local X2Go Access Using Intel NUC as Console**
- **Implemented X2Go with Desktop Sharing Mode to Allow GUI Access to Either Local Console or via Remote Access at the Same Time**



A Few Words on Staff Support and Burnout…

- **Work from Home Environment and Lockdown meant most People were always Logged In**
  - Project staff were extremely dedicated and engaged
- **Found that Many People Were Still Monitoring Test Operations Outside of their Normal Staff Shift Hours**
  - Opportunity for burnout when working long shifts and/of 24×7 test ops
  - Texting also gave impression people were always available
- **Needed to Make Conscious Effort to Make People Take Time Away for their Systems when not Working**
  - Also, no normal opportunities to take breaks due to lockdown situation

Recommendations

- **Remote Access/Control Recommendations**
  - Internet KVM not suitable for remote GUI operation over WAN connections
  - Windows and LINUX (X2Go) remote desktop (RDP) applications provide good GUI response over WAN connections
  - Systems need to be designed for use over low- to medium-bandwidth connections for remote access (i.e. – Teradici thin clients)
  - Need to be cognizant of IT security policies and constraints
- **Sharing and Collaboration Recommendations**
  - Teams was preferred due to better integrated IM capabilities
  - Multiple Teams sessions can be run using both client and browser applications
  - Need to be aware how local Teams server is set up to ensure proper sharing and access (need send out invitations, not just share a link)
  - WebEx and Teams can be run simultaneously to share multiple windows
  - WebEx allows more than one session to active at the same time

Summary

- **Through innovative use of remote access and sharing tools, L9 project maintained high level of productivity during work-from-home COVID lockdowns**
- **Productivity maybe even higher than pre-COVID work environment**
  - Need to be cognizant of potential for staff burnout due to continuous access
- **Sharing and collaboration tools provided greater access to view test systems and progress**
  - Was not even aware of unmet need to widely share test system access (pre-COVID, limited number of staff would work onsite and have access)
  - Will allow greater visibility for future missions