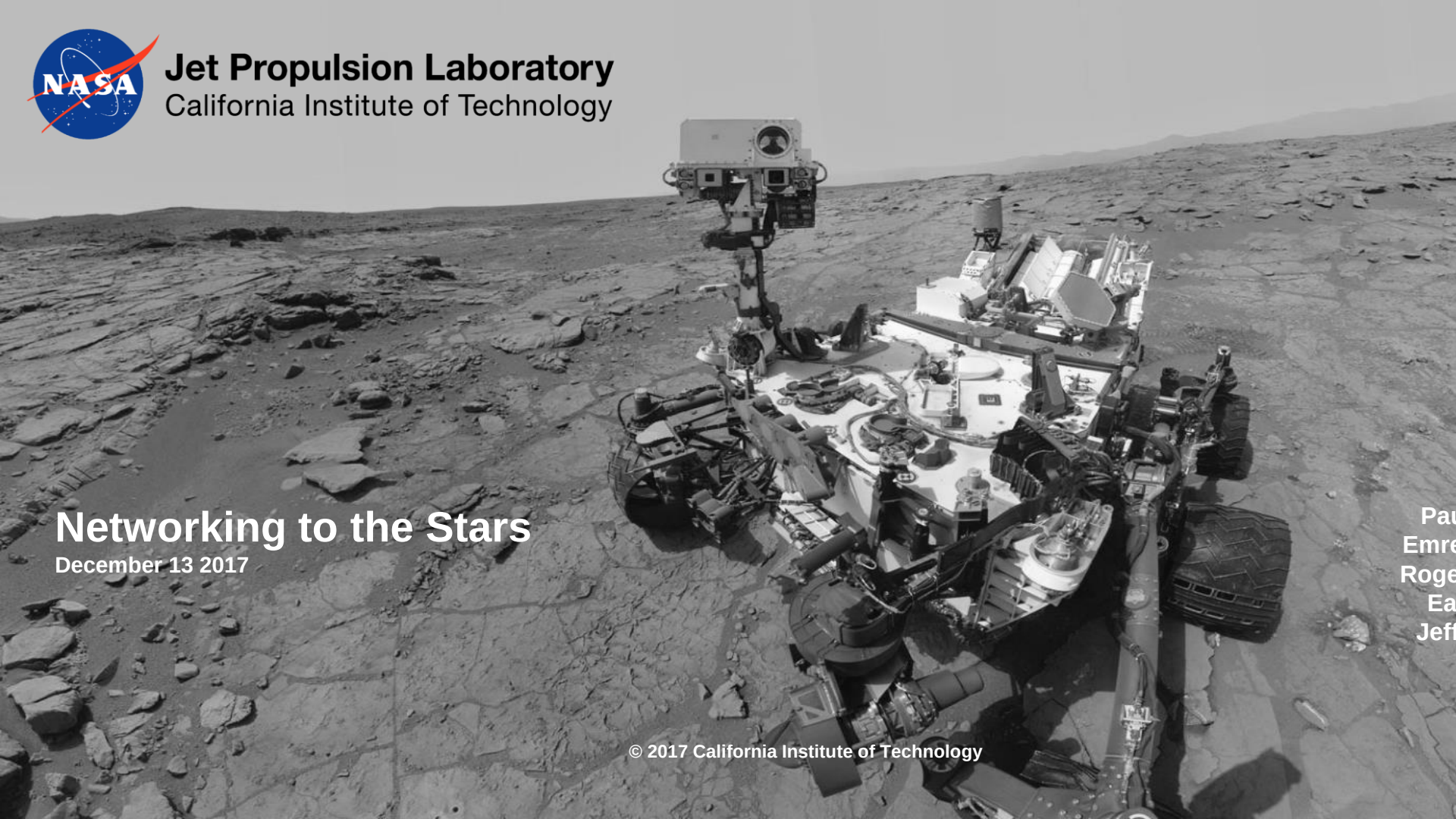


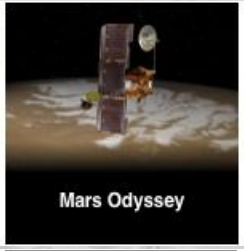
Jet Propulsion Laboratory
California Institute of Technology

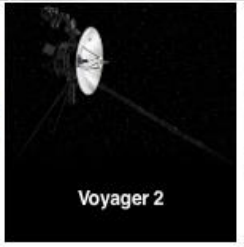
Networking to the Stars

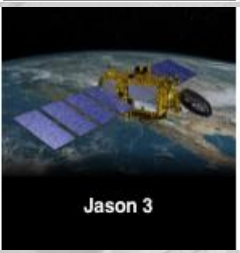
December 13 2017

Pau
Emre
Roge
Ea
Jeff

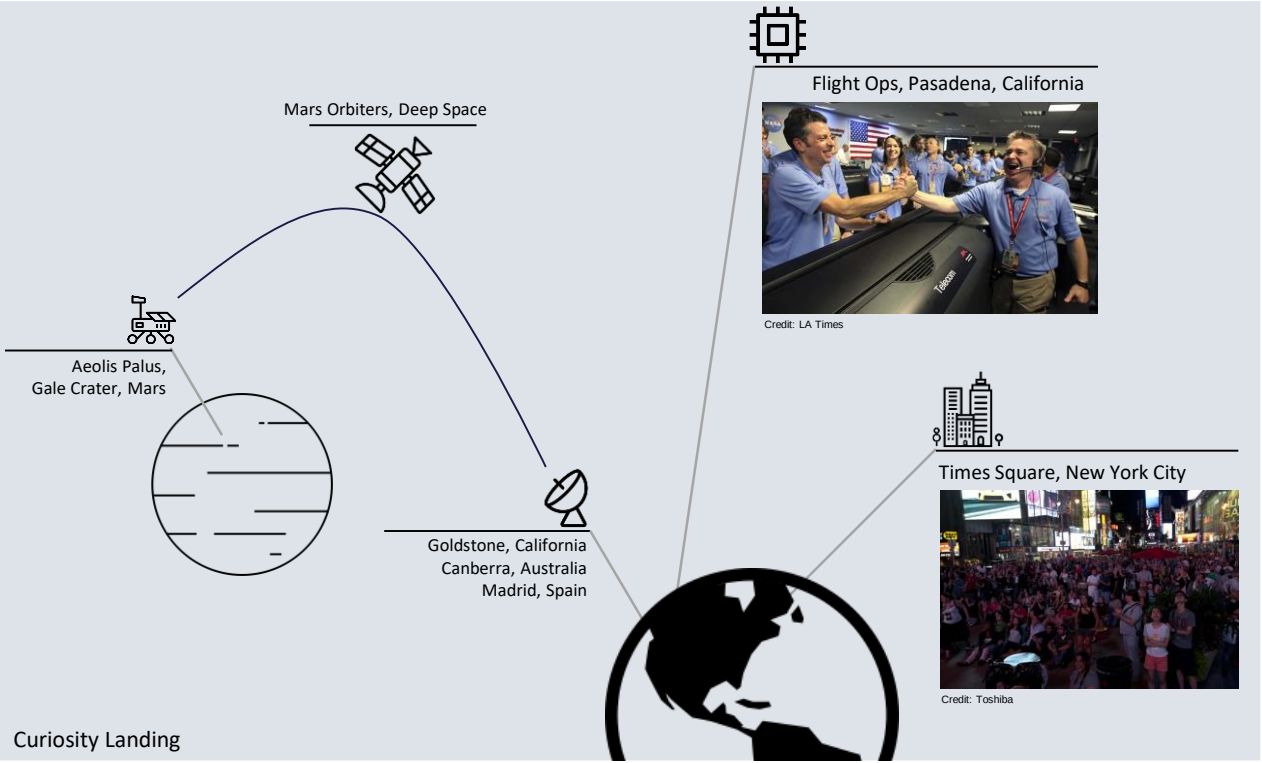
Who we are and our Missions



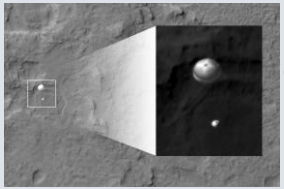




Networking is pervasive across all facets of every mission



Images from Mars

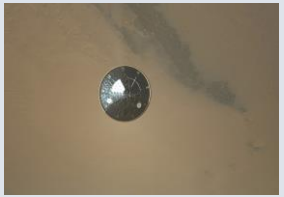


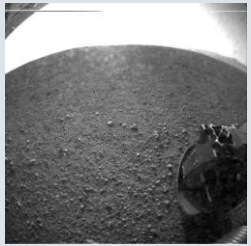
Curiosity and its parachute

Mars Reconnaissance Orbiter

Curiosity heat shield

MARDI Descent Camera





Curiosity - first images

Curiosity Hazcams

Deep Space Network (1/3)

Overview of the Deep Space Network

- Collection of antennas distributed 120 degrees apart that provides continuous coverage to robotic spacecrafts for command, tracking, and telemetry
- Composed of three Deep Space Communication Complexes (DSCC)
- Each DSCC consists of multiple 34 meter antennas and a single 70 meter antenna

DSN Locations

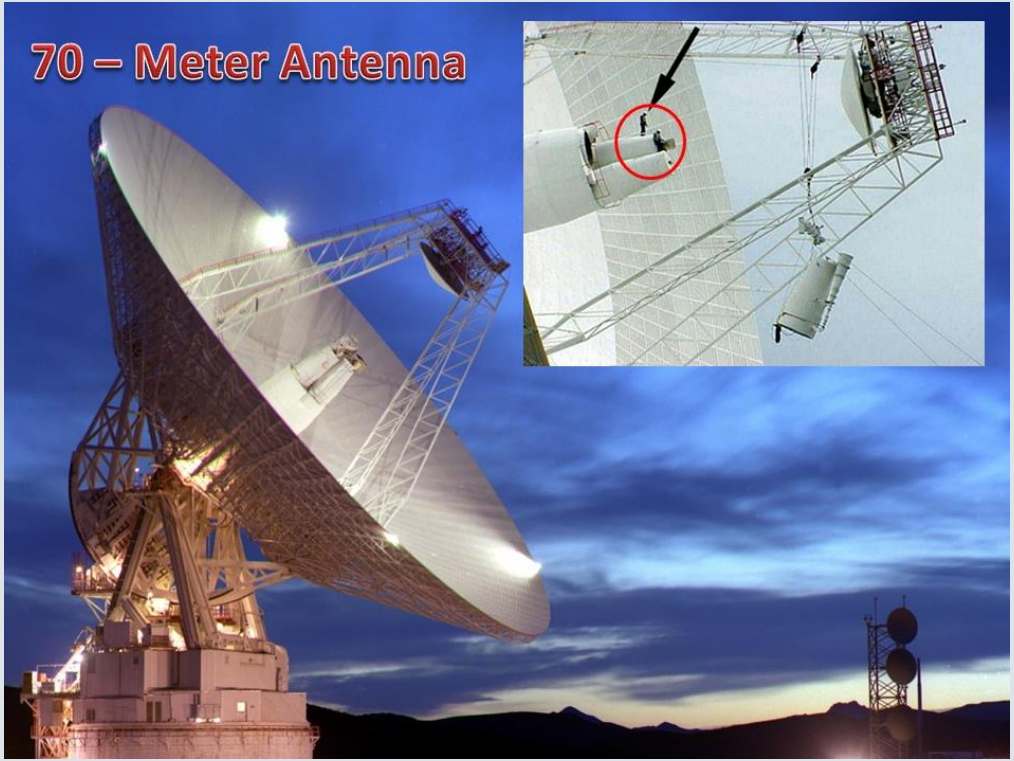
- Goldstone, California
- Madrid, Spain
- Canberra, Australia

Goldstone

Madrid

Canberra

Deep Space Network (2/3)



Form Factor*:

- Diameter: 70 Meter (230 Foot)
- Weight: 2.7M Kilograms
- Surface Area: 41,400 ft^2

70m antenna received Neil Armstrong's famous communiqué from Apollo 11:

"That's one small step for a man. One giant leap for mankind."

**https://deepspace.jpl.nasa.gov/about/DSN Complexes/70meter/#*

Deep Space Network (3/3)

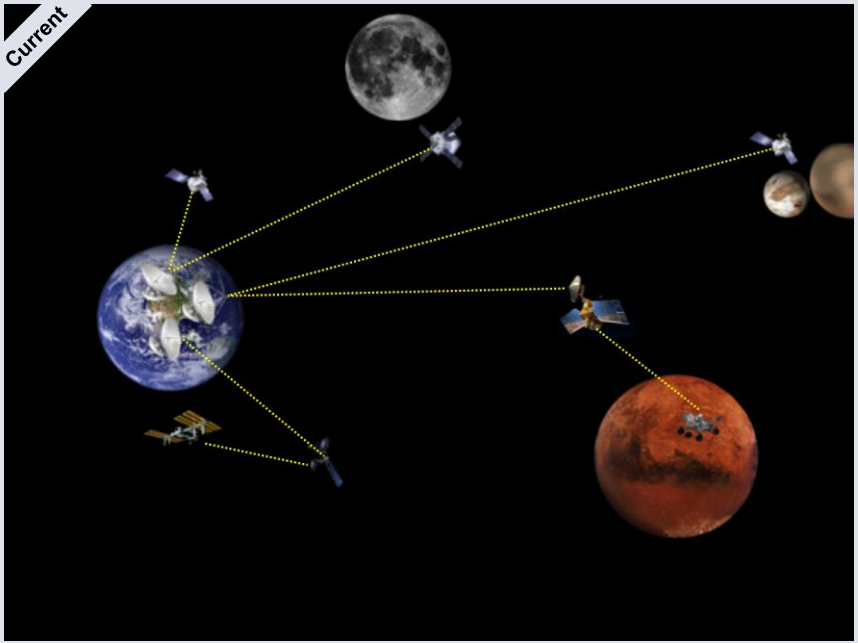
Canberra, Austraila

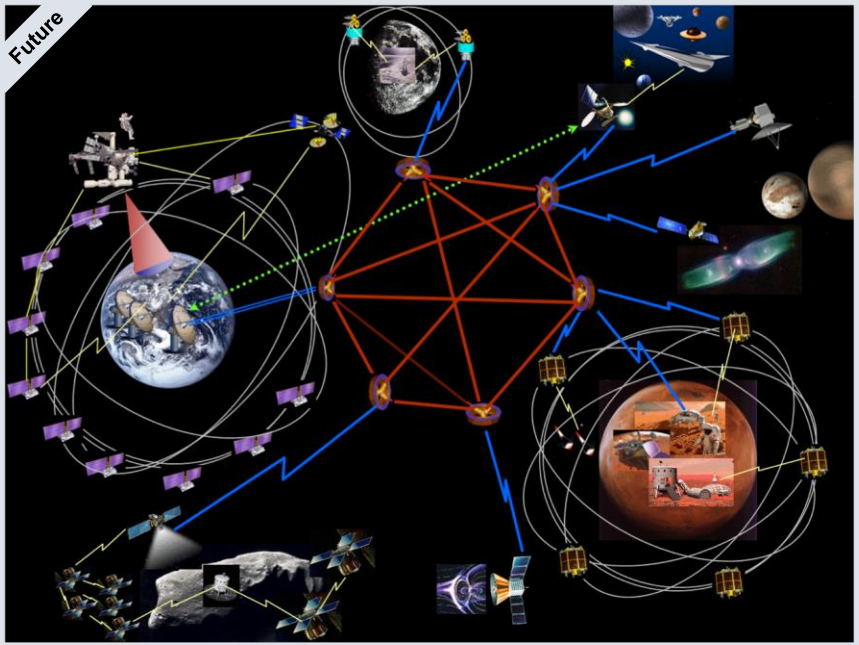
Sample of supported missions (JPL, NASA, and International)

Voyager 1

- Launched in 1977
- As of 12/5/17 it is 13,139,327,557 miles from earth
- 19:35:34 (hh:mm:ss) one way light time to earth
  (compare with 12.5 minutes on average from Mars)
- “The transmitter on each of the Voyagers is just strong enough to power an ordinary refrigerator light bulb. By the time those signals reach Earth, they're one-tenth of a billionth-trillionth of a watt.”
  - https://voyager.jpl.nasa.gov/news/details.php?article_id=50

Delay/Disruption Tolerant Networking (DTN)





*Source: https://www.nasa.gov/content/dtn

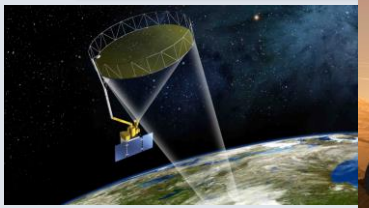
Mission Network (1/2)

Overview

- Sends and receives data with the DSN to communicate with the spacecraft
- Interfaces with our partners and other NASA centers and facilities
- Deliver that processed data to the Projects, Scientists, the Science Community and the Public

Current Missions

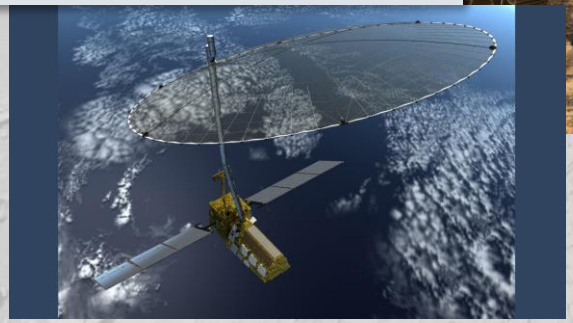
- JUNO, MER, MSL, and Voyager 1 the only human made device in interstellar space
- Link characteristics: over 19 hour one-way light time delay; downlink 160 bps (X-band), uplink 16 bps (S-band)



Mission Network (2/2)

Future Missions

- Both Deep Space Missions like Mars 2020 and Insight, as well as near Earth Missions such as SWOT and NISAR and many others we have a range of bandwidths needs, data volumes, and processing requirements.



Unique Challenges

- With dozens of amazing Mission customers. We have the and exciting missions like SWOT, NISAR, Insight, and Mars 2020 to name of few while support dozens of current missions.
- We support all our current missions while looking to integrate new technologies to enhance the environment with greater agility, open standards, and simplify operations. All while keep the 40 year old missions and the 6 month old mission running smoothly.

Architectural vision and principles

Guiding Design Principles

High Performance, Reliability, and Availability	Construct a high capacity 100GbE network with deterministic network performance; incorporates requisite measures that enable continuity of operations (high availability, disaster recovery)
Simplified Network Operations and Management	Develop a highly automated network management infrastructure that reduces service delivery timelines, and provides network operators with visibility into network health and status
Modulatory, Agility, and Scalability	Provide an extensible, flexible, distributed architecture that accommodates unique requirements for JPL users, while scaling linearly to meet future traffic loading requirements and being easily reproduced
Leverages Open Standards and BCPs	Maximize use of open standards, interfaces, and best/common practices; minimizes use of proprietary technologies
Secure, Hardened Infrastructure	Design an architecture where security is “baked in” to the design—one that incorporates measures for defense-in-depth (to include boundary protection as well as internal security controls)

Approach and design tenets for JPL's IT transformation

Formulate Concept

- Develop Guiding Principals
- Understand existing operational pain-points
- Solicit user requirements – Mission and Institutional users
- Evaluate industry trends and best/common practices
- Understand cybersecurity threat landscape
- Develop design

Build the Foundation

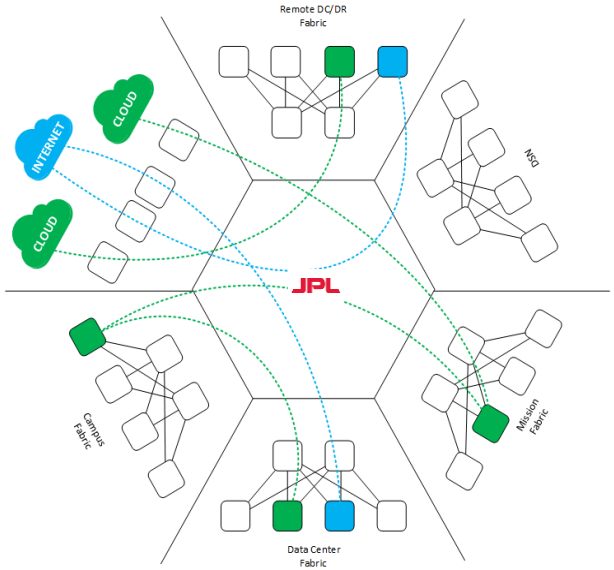
- 40/100 Gigabit Ethernet
- Universal Fabric Architecture (UFA)
- Spine-Leaf Topologies
- Virtualization Overlays
- Diverse connectivity to off-prem sites
- Data driven science networking (SciDMZ)
- Cyber monitoring infrastructure
- Automation/orchestration fundamentals

Virtualize, Auto-mize, and Optimize

- Software Defined Data Centers and Secure Networking
- Automation across campus, on-prem data centers, and cloud
- Network Functions Virtualization (NFV)
- Micro-segmentation and Zero Trust
- Infrastructure Availability Zones (AZs)
- IT Operations Analytics (ITOA)

Key Design Tenets

Build something truly amazing, not just another network

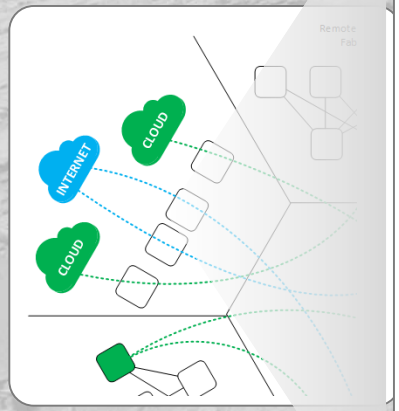


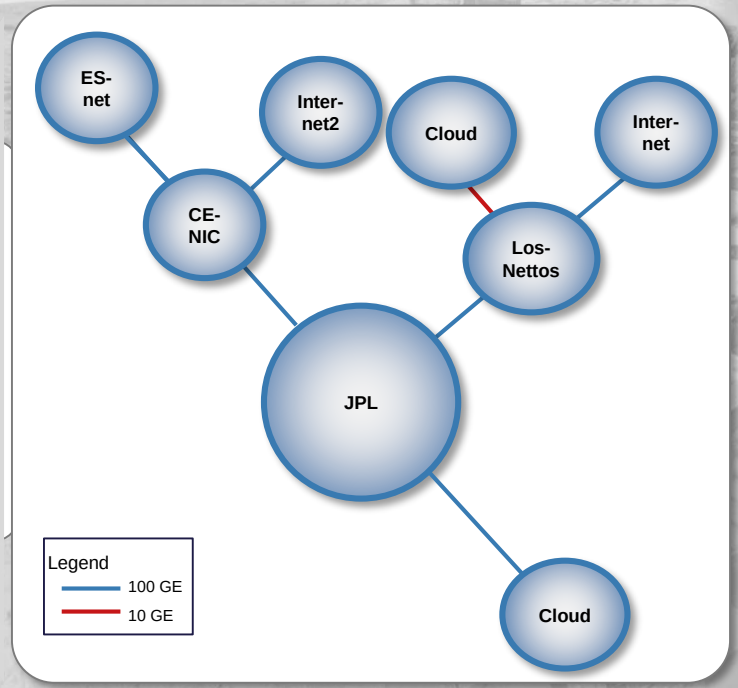
JPL's target reference Network Architecture – "The Honeycomb"

Internal Network Attributes

- **Universal Fabric Architecture**
  - Create an agile 100GbE IP Fabric reference architecture with build-to-print specifications for all future JPL networks utilizing BGP underlay and VXLAN/EVPN intelligent overlays
- **Campus IP Fabric Network**
  - Deploy agile 100GbE Spine/Leaf campus IP Fabric backbone network via the Universal Fabric Architecture with support for 40GbE user access switch interconnects
- **Data Center IP Fabric Network**
  - Deploy agile 40/100GbE Spine/Leaf data center networks via the Universal Fabric Architecture creating one logical local, remote or cloud based data center network
- **Mission IP Fabric Network**
  - Mission network core via Universal Fabric Architecture
- **Super Spine Network**
  - Create a 100Gb IP Fabric data center and campus Super Core interconnect to peer local and remote IP Fabric networks forming a single cohesive network controlled by the JPL zoning zero trust perimeter security architecture
- **Performance Monitoring with PerfSONAR**
  - Intra- and inter-domain network performance monitoring

Improving external connectivity, availability and agility



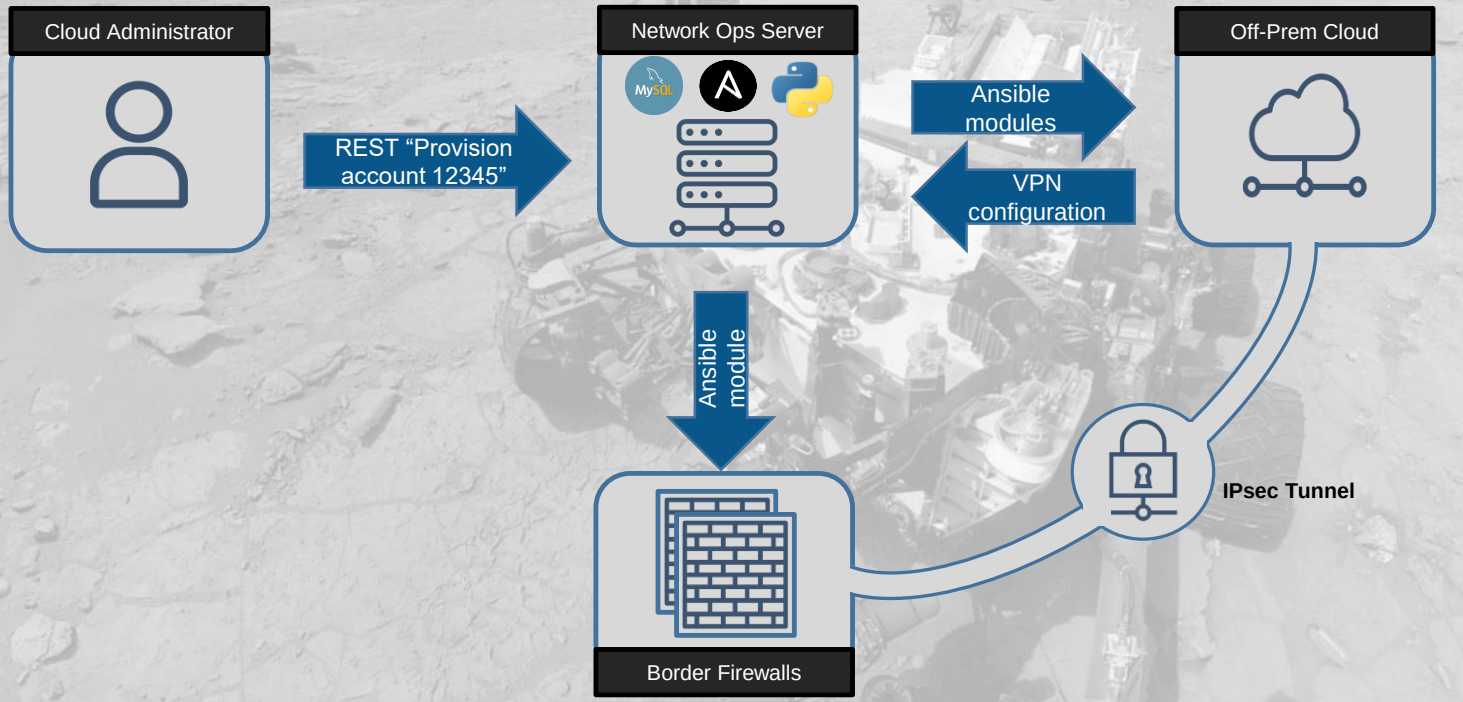


Target JPL External Connectivity Architecture

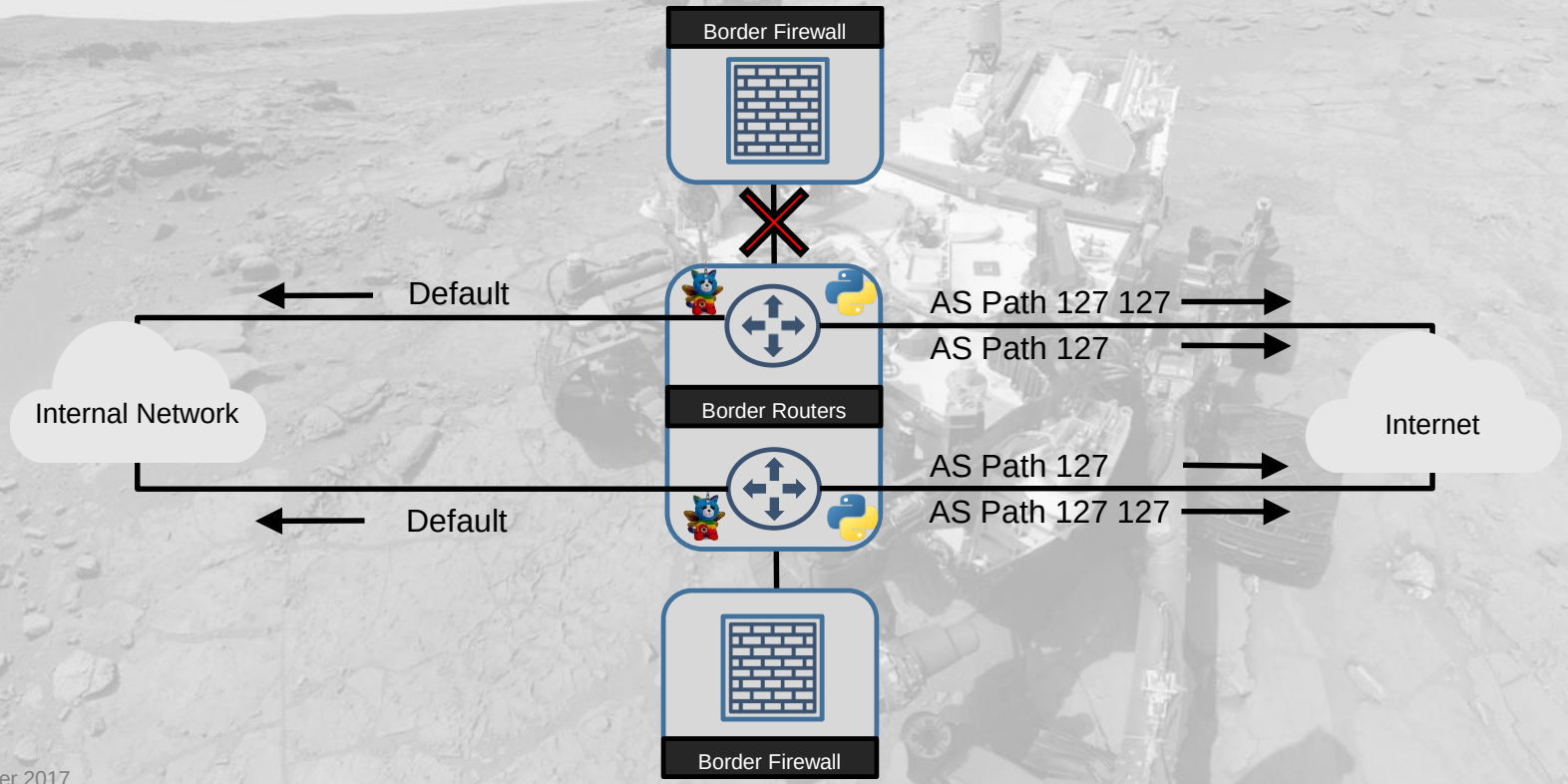
External Network Attributes

- **100Gb Border Routing Infrastructure**
  - 10Tbps border routers across isolated failure domains supporting Internet, Cloud and SciDMZ connectivity at multi 100GbE with SDN capabilities
- **High capacity, secure cloud connectivity**
  - 100Gbps connectivity to Cloud Providers
  - Large-Scale VPN (LSVPN) offers IPsec protection for traffic destined to the Cloud
- **Science DMZ**
  - Dedicated 10/100GbE ESnet based SciDMZ architecture providing easy to use science/mission data driven high-capacity networking
- **SD-WAN**
  - Network virtualization and automation use-cases across the WAN, such as dynamic WAN circuit provisioning

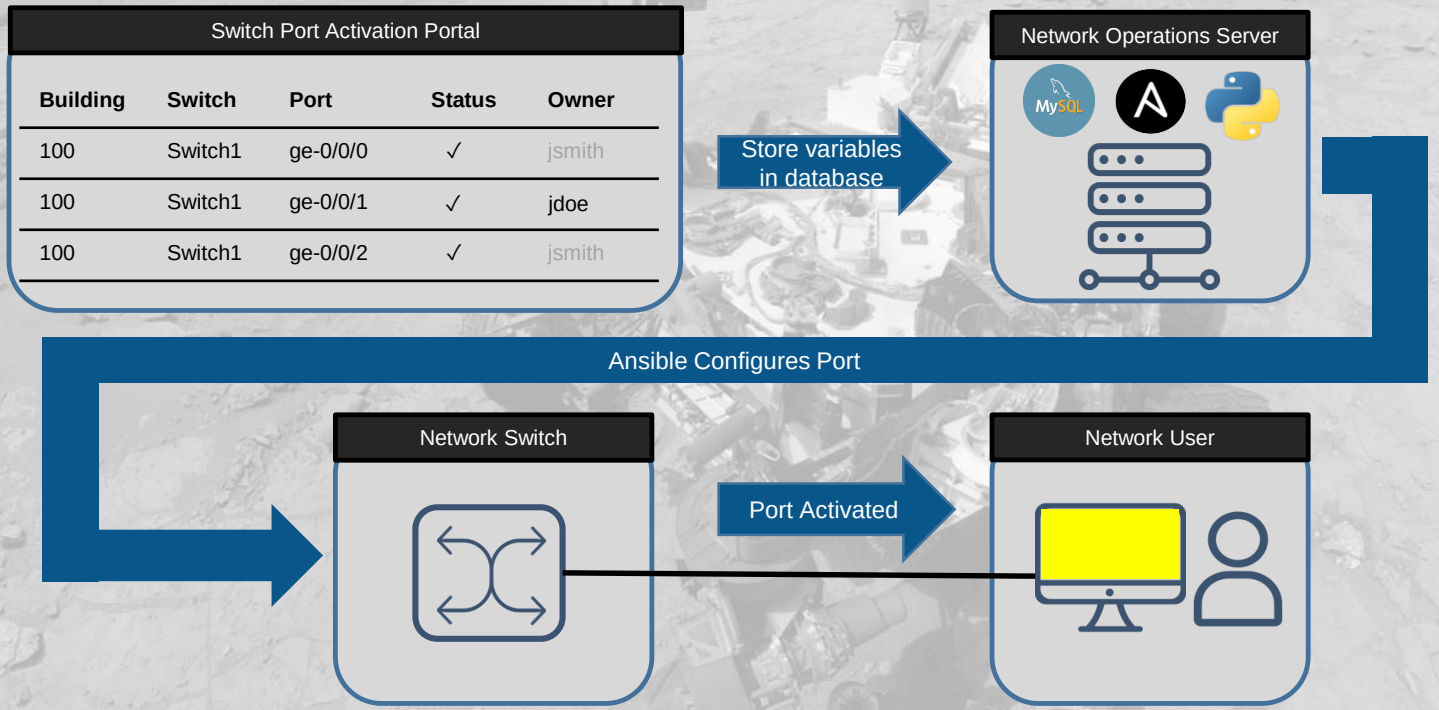
Automated provisioning of Cloud, and network protection mechanisms for traffic destined to/from the Cloud



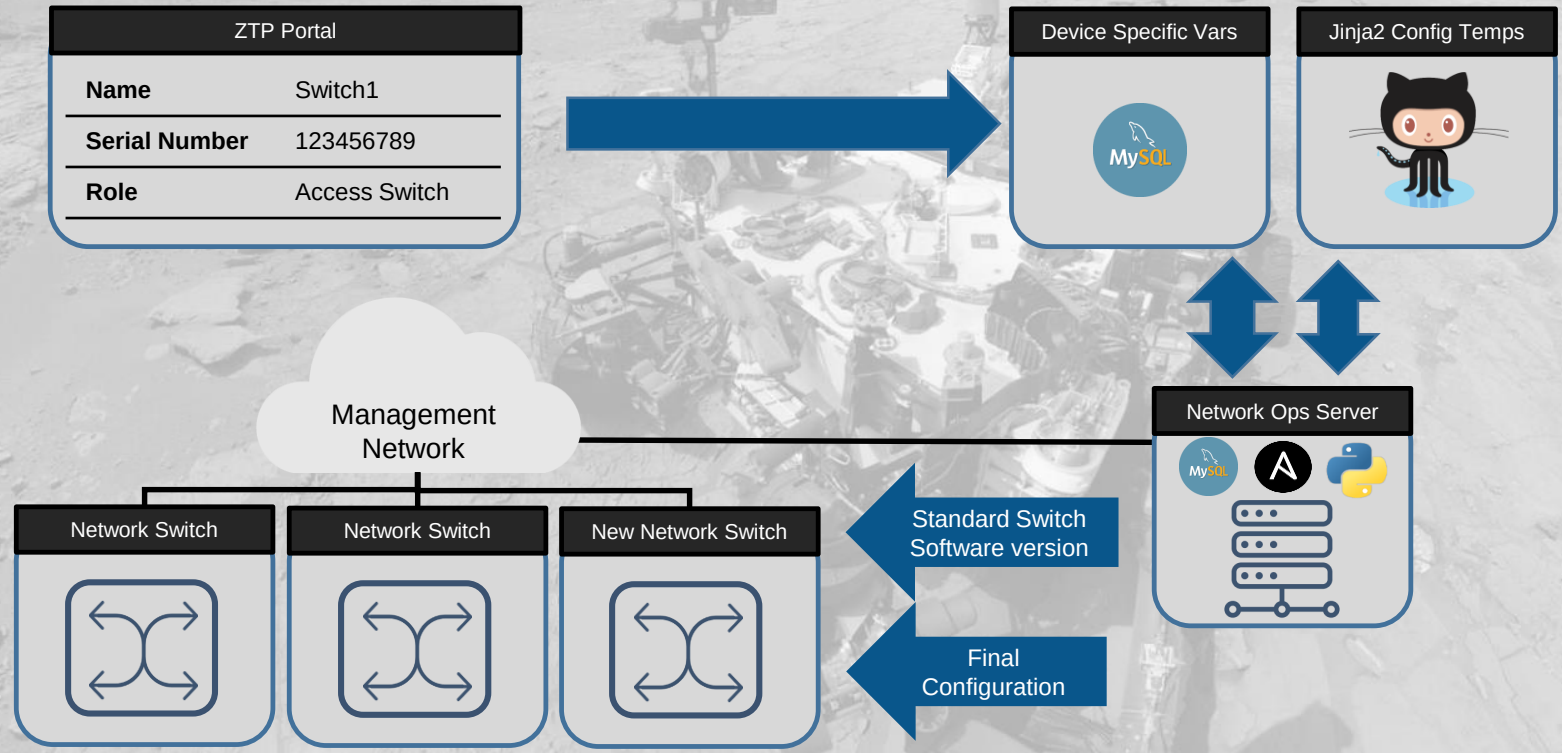
In addition, we currently use on-box scripts to dynamically influence inbound/outbound WAN traffic



One of our planned uses for Ansible is automation of port activation on network switches



Zero touch provisioning (ZTP) will automate deployment of switches across our Campus and Data Center Fabrics



Our vision is a cohesive network that is flexible to support the unique needs of future JPL missions

Virtualization and Automation

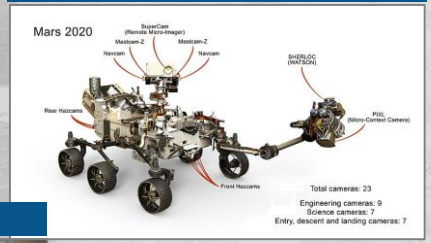
- **Software Defined Everything -- "putting intelligence in the network"**
  - Whitebox architectures and NFV
  - WAN (SD-WAN): External Dynamic Circuit Provisioning
  - Software Defined Data Center (SDDC): Hyper-converged data with fully automated platforms to enable IT-as-a-Service
  - Software Defined Secure Networking (SDSN): All elements of infrastructure participate in security policy enforcement; several use-cases under evaluation, to include: Automated Threat Response (e.g., Dynamic Host Quarantining) and Zoning

Optimization

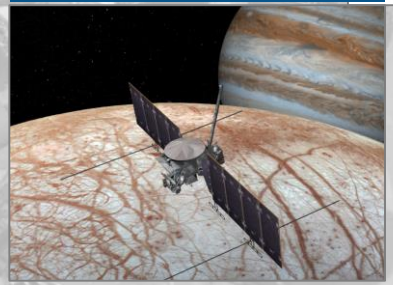
- **Efficient, orchestrated usage of compute, storage, and network resources**
  - Pooling resources regardless of location (on-prem, off-prem)
  - High capacity and resilient connectivity to off-prem (e.g., Cloud)
- **Enhanced network visibility and monitoring**
  - Baselining traffic profiles
  - Anomaly detection and resolution
  - Enhanced cybersecurity forensics

Insight

Mars 2020



Europa



Questions and Panel Discussion

MAHLI Image Mosaic, Sol 868 (January 14, 2015)
Credit: NASA/JPL-Caltech/MSSS/Jason Major

Unless otherwise noted all images taken from jpl.nasa.gov