GSAW 2016

The Earth Observing System (EOS) Ground System: Leveraging an Existing Operational Ground System Infrastructure to Support New Missions

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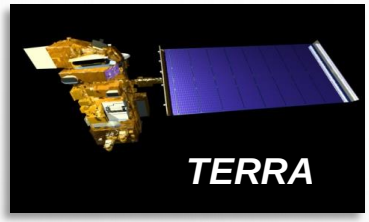
Terra Launch December 18, 1999

Outline

- High Level Mission and Ground System Overview
- Challenges
- Recent Ground System Enhancements
- Benefits to New Missions
- Conclusions

The Missions



Launched: 12/18/1999

- #2 Ranked Earth science mission *
- 6-year design life
- Mission extended through FY19
- Reliability estimates thru 2025
- Consumables through 2017/2020

Five Science Instruments

- 150Mbps data downlink
- Primary science data capture method is TDRSS (K-Band)
- Secondary science data capture method is Near Earth Network (NEN) (X-Band)
- 15Mbps real-time direct broadcast support for one of the five instruments (MODIS)

Launched: 05/04/2002

- #1 Ranked Earth science mission *
- 6-year design life
- Mission extended through FY19
- Reliability estimates thru 2022
- Consumables through 2021

Six Science Instruments

- Four still operational
- 150Mbps data downlink
- Science data capture method is Near Earth Network (NEN) (X-Band) exclusively
- 15Mbps real-time direct broadcast support for the four remaining instruments

Launched: 07/15/2004

- #3 Ranked Earth science mission *
- 6-year design life
- Mission extended through FY19
- Reliability estimates thru 2022
- Consumables through 2022+

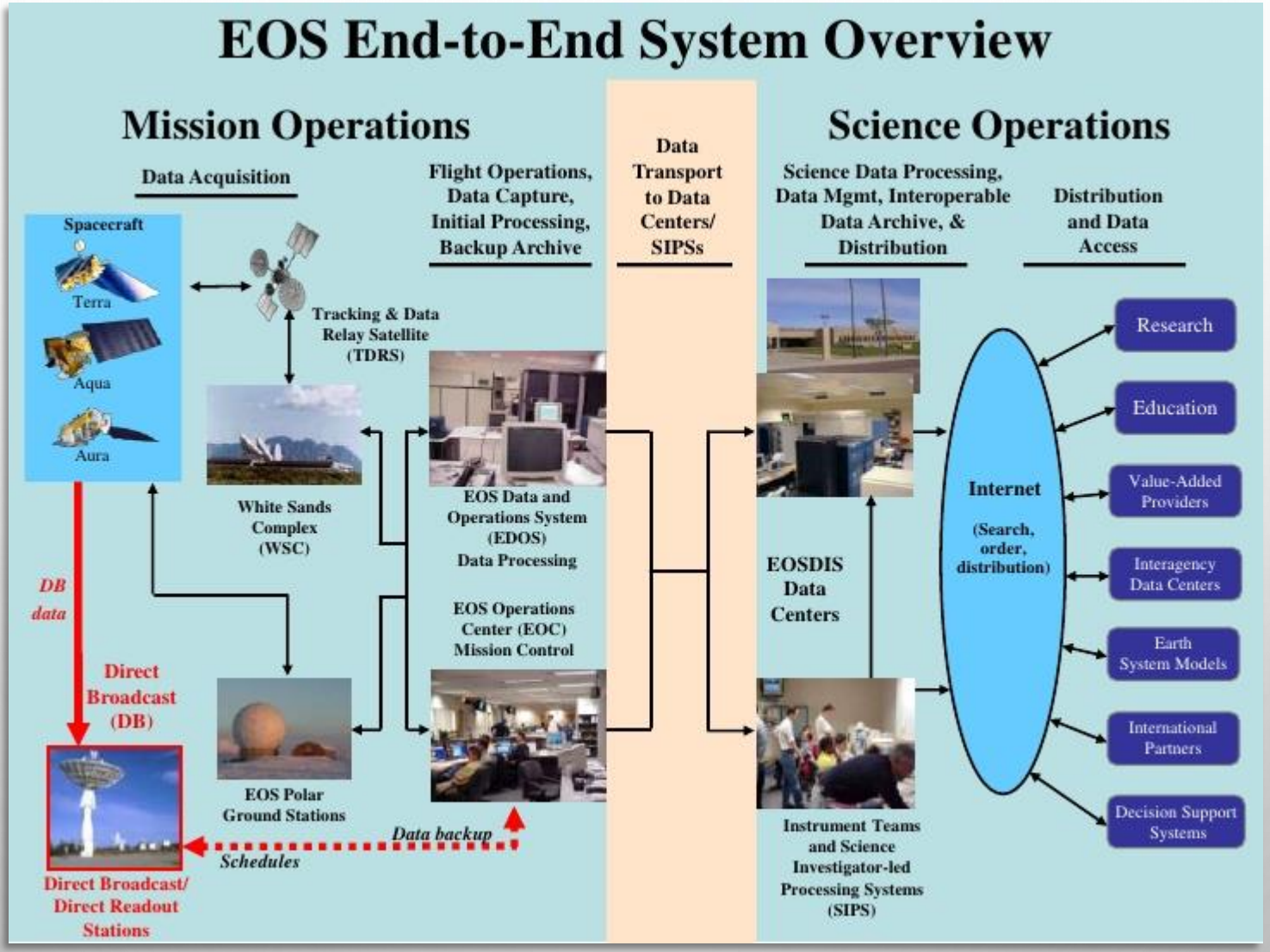
Four Science Instruments

- Three still operational
- 150Mbps data downlink
- Science data capture method is Near Earth Network (NEN) (X-Band) exclusively
- 15Mbps real-time direct broadcast support for one of the four instruments (OMI)

Ground system maintenance is critical for the continued operation of these high value and healthy NASA Earth Science Satellites

* Ranking based on 2015 NASA Earth Science Senior Review

The Big Picture



The Mission Operations System

Operational since 1999

There are currently three major system components that support all three missions:

Online – Telemetry and Commanding System

- Based on the ECLIPSE command and control software by Raytheon
- Telemetry Pages and Archiving
- Commanding and Procedure Execution
- Clock Correlation

earthobservatory.nasa.gov

MMS – Mission Management System

- Planning and Scheduling (PAS),
  - Activity and contact scheduling
- Command Management System (CMS),
  - Load generation
- Data Management System (DMS),
  - Spacecraft database and load management

ITPS – Integrated Trending and Plotting System

- Telemetry archiving for life of mission
- Archive playback
- Data transmission to end users
- Trending and Plotting

The Operation Networks

The Mission Operations System operates on one of three redundant local area networks at any given time

OPS – Operations LAN

SUP – Support LAN

- Redundant LANs located in the same building on GSFC campus
- Failover requires manual intervention, but can be done quickly (on the order of minutes)

BEOC – Backup EOS Operations Center LAN

- Backup LAN located in a different building on GSFC campus
- Not manned, FOT must relocate
  - For this reason, a full failover takes longer but T&C capabilities can be brought online quickly once personnel arrive
- Regular exercises ensure operational capability

With three LANs, one can be taken down for maintenance without losing redundancy, allowing software and hardware updates to be performed

The Challenges

Improve the reliability and flexibility of an aging ground system.

Enable more autonomous ground operations and simplify the integration of new missions.

System Software Updates

The primary EOS software systems (Online, MMS, ITPS) are in *ACTIVE* development. New releases may contain bug fixes, enhancements, or accommodate requirement changes

All proposed changes go through a multi-stage review board process before implementation and through operational deployment

Updates of operating systems, associated patches, and COTS tools are required to maintain our IT security posture

New Versions Deployed

System	2015	2016 (Planned)
Online	1	2
Supplemental Online COTS Bundles	3	2
MMS	2	1
ITPS	3	2

Frequent deployments maintain staff expertise in change management and updating systems. They also allow new technology and enhancements to be added incrementally with less risk to operations

Automation

An effort was started in 2012 to develop automation capabilities for the EOS ground system.

High-Level Automation Design Concept

For All Current and Future Missions
Provide a single communications infrastructure
Use R/T event messages to drive monitoring, alerting, & status
Provide a central event archive - Used for anomaly investigations
Use the T&C system for contact automation - No external directives to the T&C
Allow for control & extensibility by the FOT - Require little or no software developer involvement
Provide extensibility for new missions and offline tasks
Keep it as simple as possible

Baseline functions completed. Deployment of second phase of automation functions for spacecraft H&S monitoring scheduled for operational readiness review in Spring 2016

Leverages off the GMSEC framework developed at GSFC (https://gmsec.gsfc.nasa.gov/)

VM Migration

We are currently in the process of migrating EOS ground system components to a virtual machine infrastructure

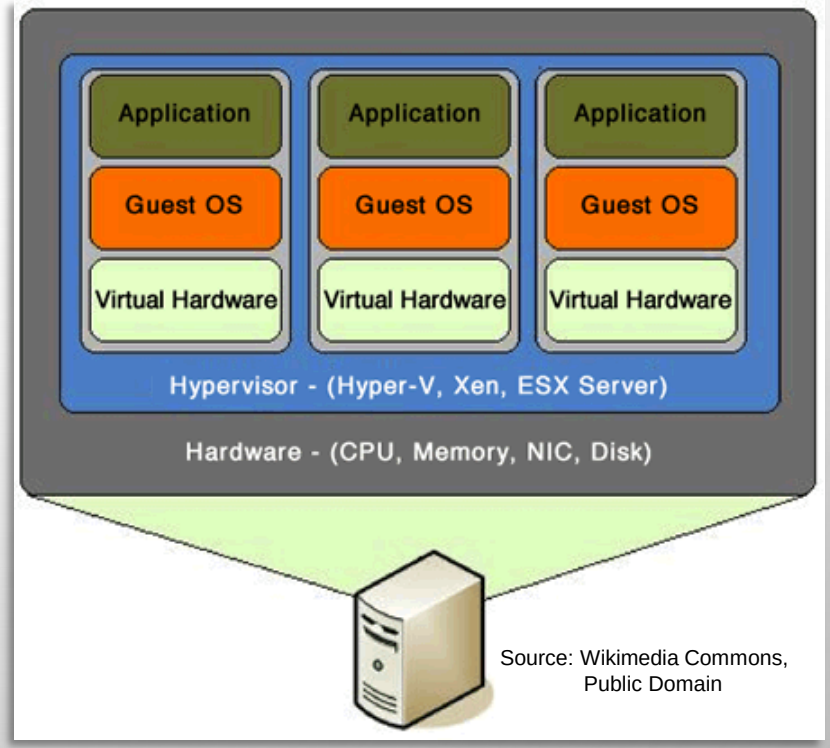
Allows consolidation of hardware which reduces system footprint, power requirements and administration effort

Ground system functions can be combined and deployed as a set of mission services instead of stand alone subsystems

New or unproven components can be better isolated from operational systems during development

Online and trending/analysis systems are operational in the VM environment

Mission Management System migration should be completed in 2016



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Network Upgrades

Network infrastructure upgrades are being performed to increase reliability, security and data capacity while reducing data capture and distribution latencies

Some of the highlights from 2015

- Network tech refreshes (replacement of switches, firewalls, console servers) at Wallops Island, White Sands, Svalbard Norway, and three sites in Alaska
- IP address reassignment of EDOS ground station equipment for increased security posture
- Access switch replacements for all three EOS LANs (OPS/SUP/BEOC)
- Implementation of redundant WDM (wave division multiplex) fiber links between Alaska ground stations

Some planned work for 2016

- Upgrades of the EOS backbone network (EBNet) peering design and data links from 10Gbps to 40Gbps
- Tech refresh of the EOS Data and Operations System (EDOS) Level Zero Processing Facility (LZPF) at GSFC

Benefits of EOS GS to a New Mission

Recently a study was performed to analyze the benefits a new Earth science mission would realize from using the existing EOS ground system infrastructure where possible

Several key advantages were identified:

- The ground system architecture is modern, kept current, and operationally proven
- Network architecture is fully deployed - only firewall rules are required to bring new mission systems online
- New systems would fall directly within the Earth Science Mission Operations (ESMO) IT Security Plan boundary. New hosts would be scanned and included in ESMO's host inventory. No need for an independent security plan.
- Configuration and Change management processes are established with Web based tools for change request tracking and approvals
- The VM based architecture allows deployment of new mission GS components in incremental phases that are isolated from existing EOS systems.
- A phased deployment approach combined with a mature operational infrastructure can simplify the transition to operations, lowering operations risk

Conclusions

NASA GSFC has demonstrated that an aggressive continual advancement approach to our flagship earth observing system mission operations center can be performed safely over a period of many years

Regular incremental updates involve less risk than large monolithic changes

- Staff maintain expertise in configuration management, updating, and verifying system operations
- System defects, new requirements, and security vulnerabilities can be prioritized and addressed more quickly
- New technologies can be incorporated in phases with less operational risk

New technologies now being infused will simplify the addition of new missions into the evolving multi-mission system

New missions can take advantage of established security plans, management processes and the high performance network infrastructure of a modern, operationally proven system

Questions?

Backup

Acronym List

BEOC	Back-up EOS Operations Center
COTS	Commercial Off The Shelf
CMS	Command Management System
DAAC	Distributed Active Archive Center
DAM	Debris Avoidance Maneuver
DB	Direct Broadcast
DMS	Data Management System
EBNet	EOS Backbone Network
EDOS	EOS Data and Operations System
EMOS	EOS Mission Operation System
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ESMO	Earth Science Mission Operations
FOT	Flight Operations Team
GMSEC	GSFC Mission Services Evolution Center
GS	Ground System
GSAW	Ground System Architectures Workshop
GSFC	Goddard Space Flight Center
H&S	Health and Safety
IT	Information Technology
ITPS	Integrated Trending and Plotting System
LAN	Local Area Network
LEO	Low Earth Orbit
LZPS	Level Zero Processing Facility
MMS	Mission Management System
NEN	Near Earth Network
OPS	Operations
PAS	Planning and Scheduling
R/T	Real-Time
SIPS	Science Investigator-led Processing Systems
SUP	Support
T&C	Telemetry and Commanding
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
VM	Virtual Machine
WDM	Wave Division Multiplexing
WSC	White Sands Complex

The Science Data System

The EOS Data and Operations System (EDOS) is a high-rate, multi-mission science data system that supports seven operational missions as well as the upcoming ICESat-2

Autonomously captures science data at remote ground stations

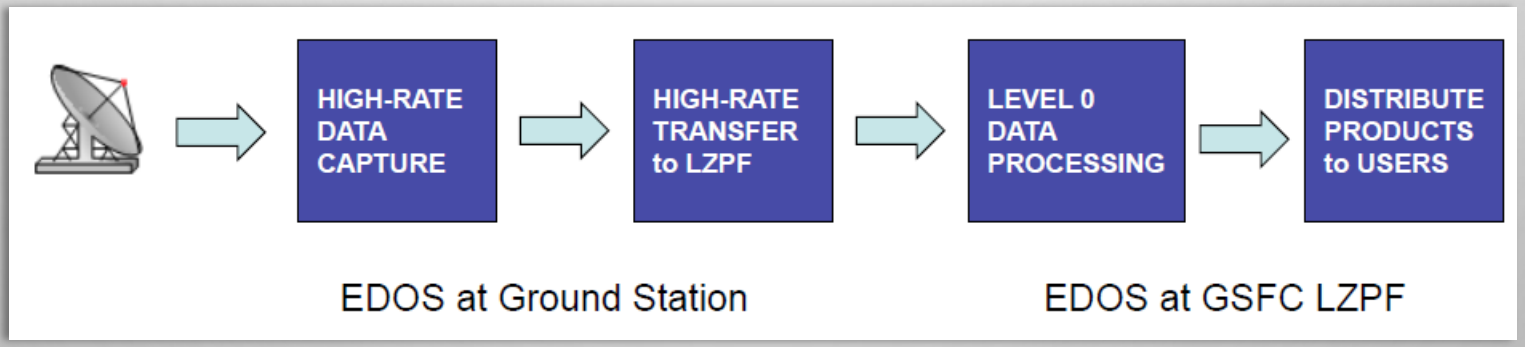
- EDOS capture systems are located at 6 sites serving 16 antennas
- Front-end processing includes demodulation, frame synchronization, and decoding, as needed

Transfers science data to GSFC over NASA's closed high-rate network or high-rate open (Internet) networks with increased bandwidth, where available

Performs initial level zero science data processing

Currently delivers more than 1/2 Terabyte of level-zero products worldwide (20 external customers) in a variety of formats and protocols on a daily basis

Can transfer data directly to level 1 science customers from station gateway via open (Internet) networks, where available



Benefits of EDOS to a New Mission

Benefits of using the existing EDOS infrastructure for science data capture and front-end processing:

- 24x7 operations support monitoring all station contacts and product deliveries for all missions and customers
- Additional EDOS capture systems can be easily added at existing (or new) ground stations worldwide as part of a modular, scalable architecture
- No schedule interface is required due to data-driven design assuring 24x7 data capture for any EDOS mission
- Existing integrated high-rate networks provide reduced product latencies
- Proven interface to EOSDIS Distributed Active Archive Centers for product distribution
- High-rate data delivery from remote site or centralized LZPF
- Additional spare capacity exists in existing system. More can be added!
- Reduced project risk by using existing EDOS infrastructure at a fraction of the cost of developing a new system

Data Processing Levels

EOSDIS data products are processed at various levels ranging from Level 0 to Level 4. Level 0 products are raw data at full instrument resolution. At higher levels, the data are converted into more useful parameters and formats. All EOS instruments must have Level 1 products. Most have products at Levels 2 and 3, and many have products at Level 4

Data Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed. (In most cases, the EOS Data and Operations System (EDOS) provides these data to the data centers as production data sets for processing by the Science Data Processing Segment (SDPS) or by a SIPS to produce higher-level products.)
Level 1A	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris) computed and appended but not applied to Level 0 data.
Level 1B	Level 1A data that have been processed to sensor units (not all instruments have Level 1B source data).
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data.
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).