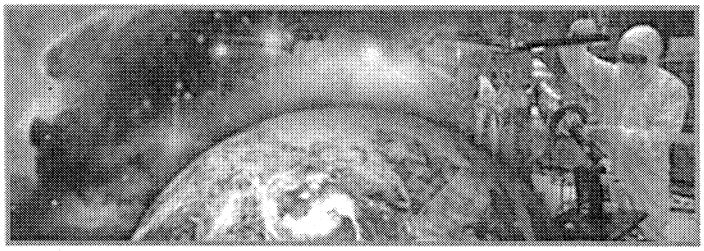
NRO

Friday
Speaker
Series



Advancing NASA's Satellite Control Capabilities

- more than just better technology -

February 22, 2008

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Software Engineering Division

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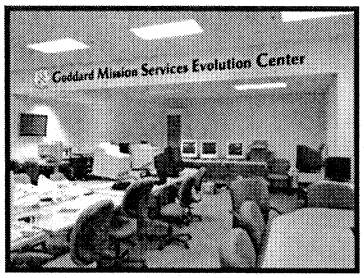
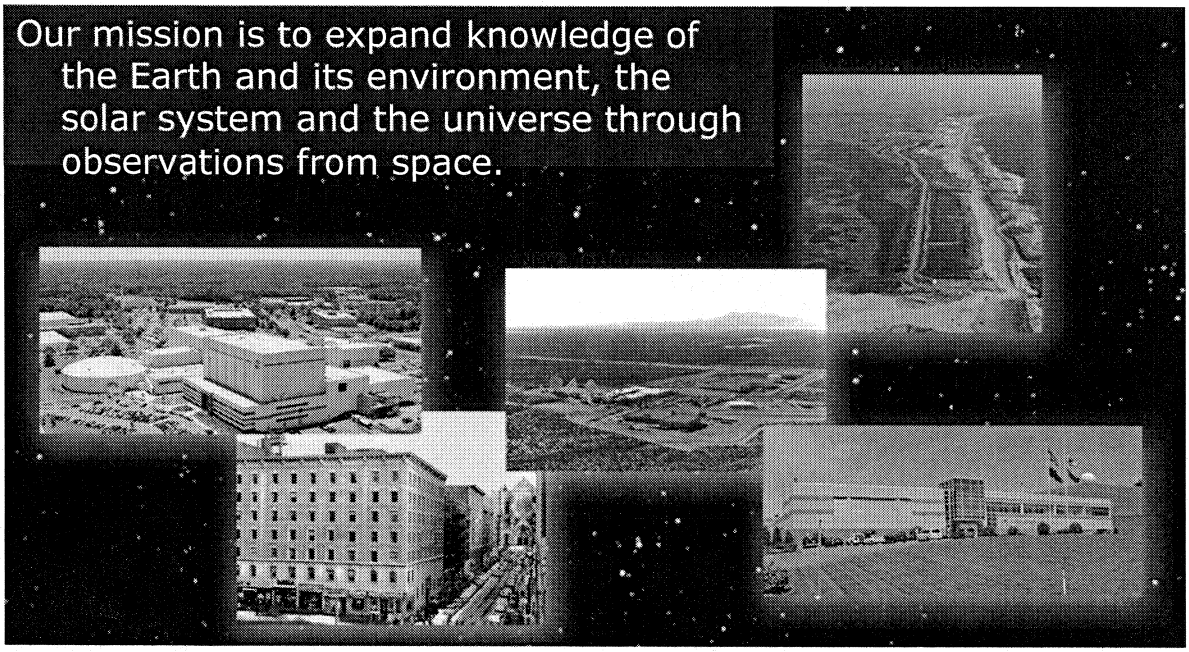


Purpose

To provide a quick overview of NASA's Goddard Space Flight Center and our approach to coordinating the ground system resources and development activities across many different missions.

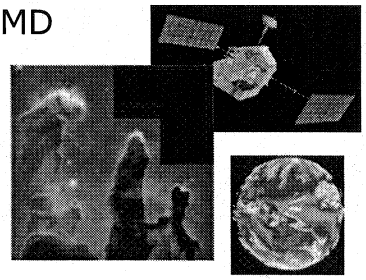
It has taken both organizational and technical changes to make improvements over the past five years.

Five GSFC Facilities



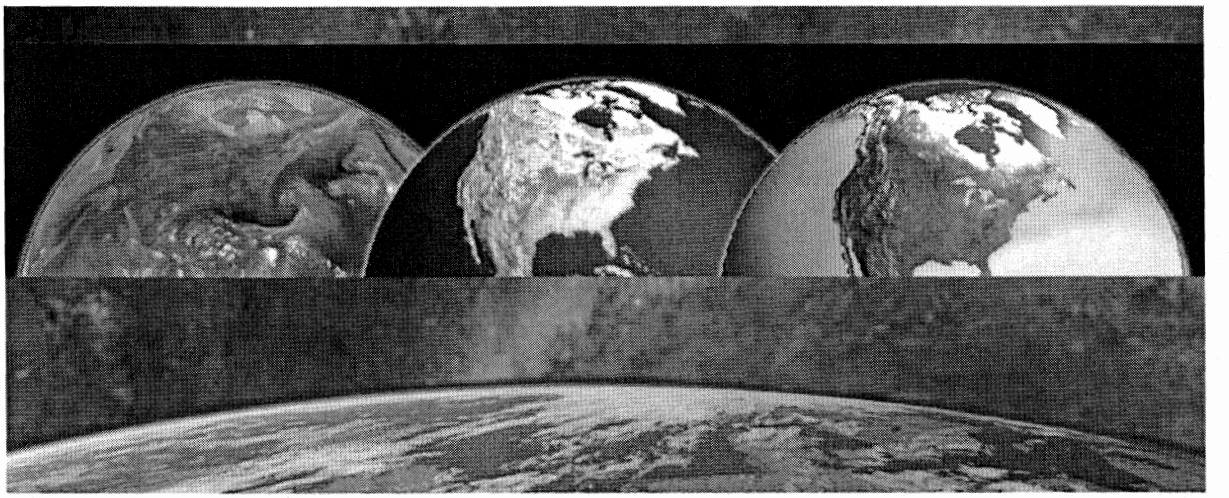
NASA/GSFC Mission Background

- NASA/GSFC manages over 30 spacecraft
  - ½ at the NASA campus in Greenbelt, MD
  - ½ at Universities around the country



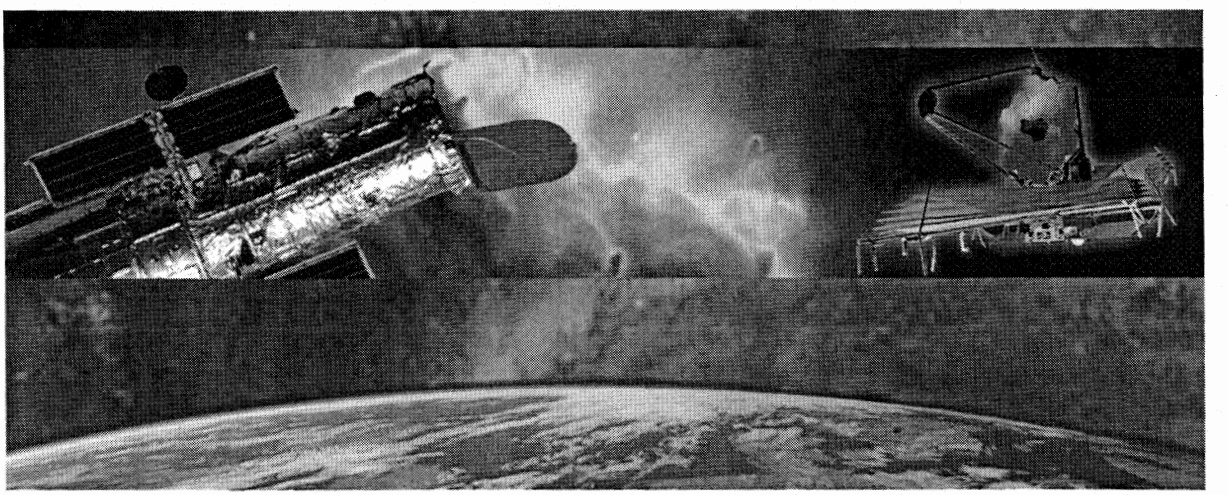
- Typical characteristics . . .
  - Scientific missions in low-earth orbit
  - Telemetry rates of <100Kbps; up to 150 Mbps for science recorder dumps (Most have had 24/7 operations
  - Mission durations of 3 months to 20+ years
  - Each has its own control center, separate ops team
  - Satellite control centers are typically separate from science processing facilities

Did You Know That NASA's Goddard Space Flight Center:



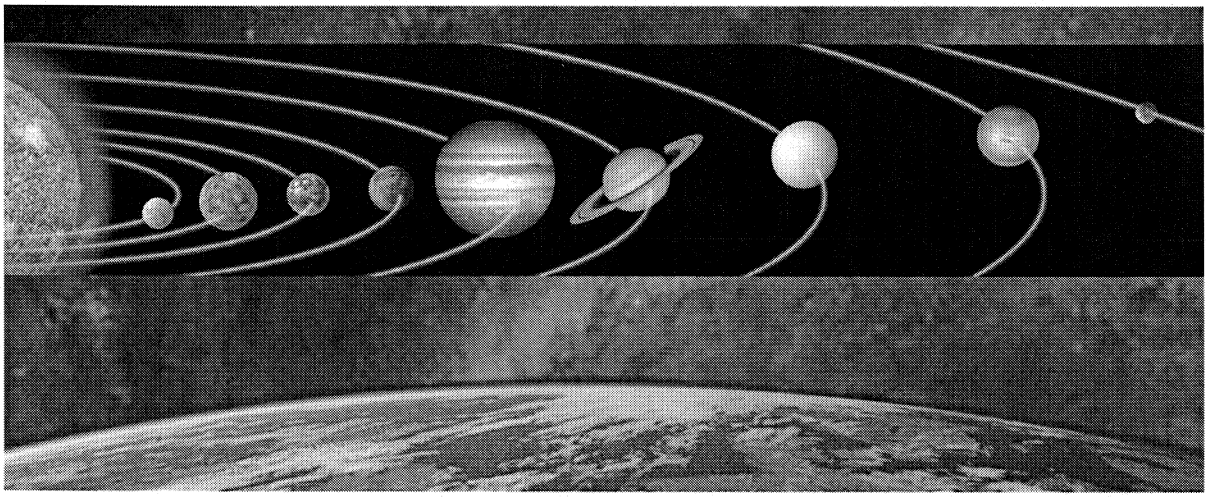
is home to the Nation's largest organization of earth scientists?

Did You Know That NASA's Goddard Space Flight Center:



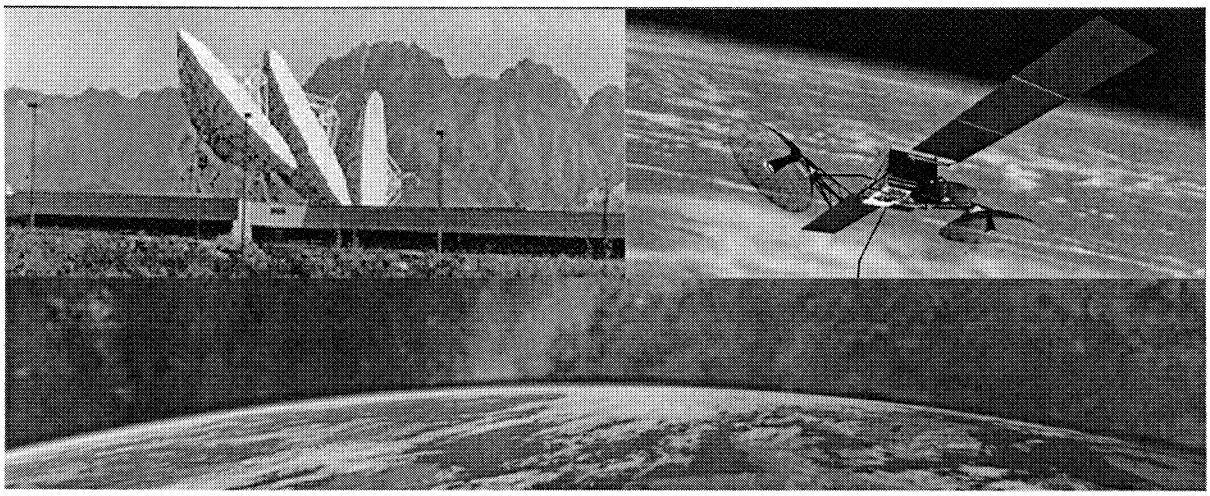
operates the Hubble Space Telescope and is developing its successor, the James Webb Space Telescope?

Did You Know That NASA's Goddard Space Flight Center:



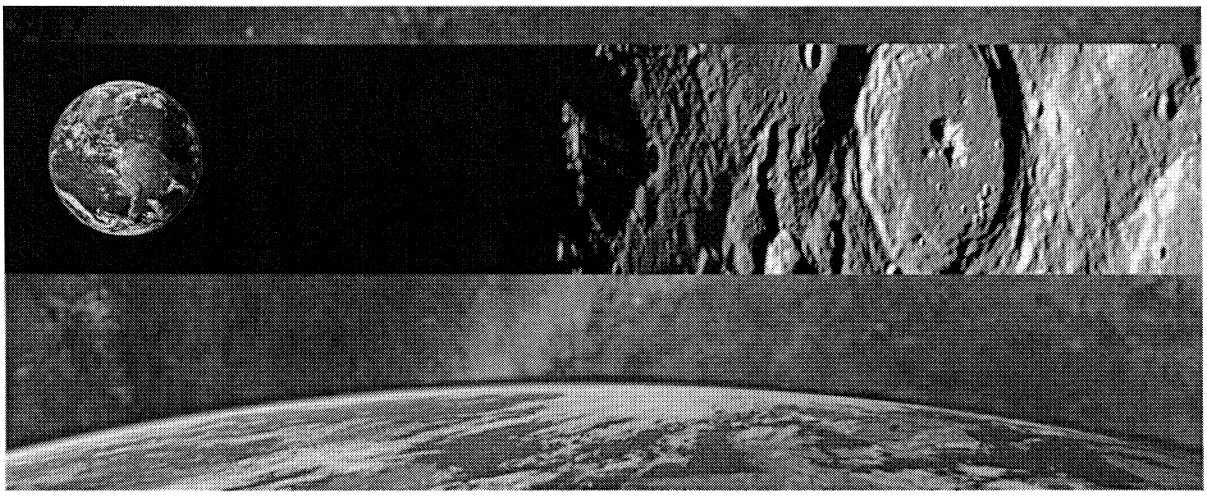
has built instruments on satellites to study every planet in our solar system?

Did You Know That NASA's Goddard Space Flight Center:



builds and operates the communication and navigation systems that serve our Nation's astronauts and is leading the development of future communications and navigation systems to enable human exploration of the Moon and Mars?

Did You Know That NASA's Goddard Space Flight Center:



is building the Lunar Reconnaissance Orbiter, the first robotic flight mission devoted to the vision for space exploration?

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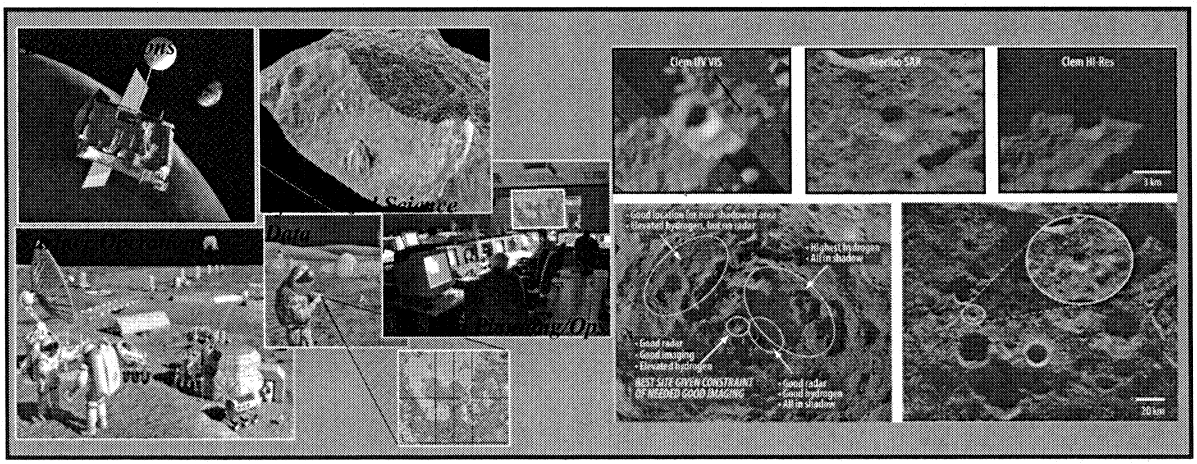
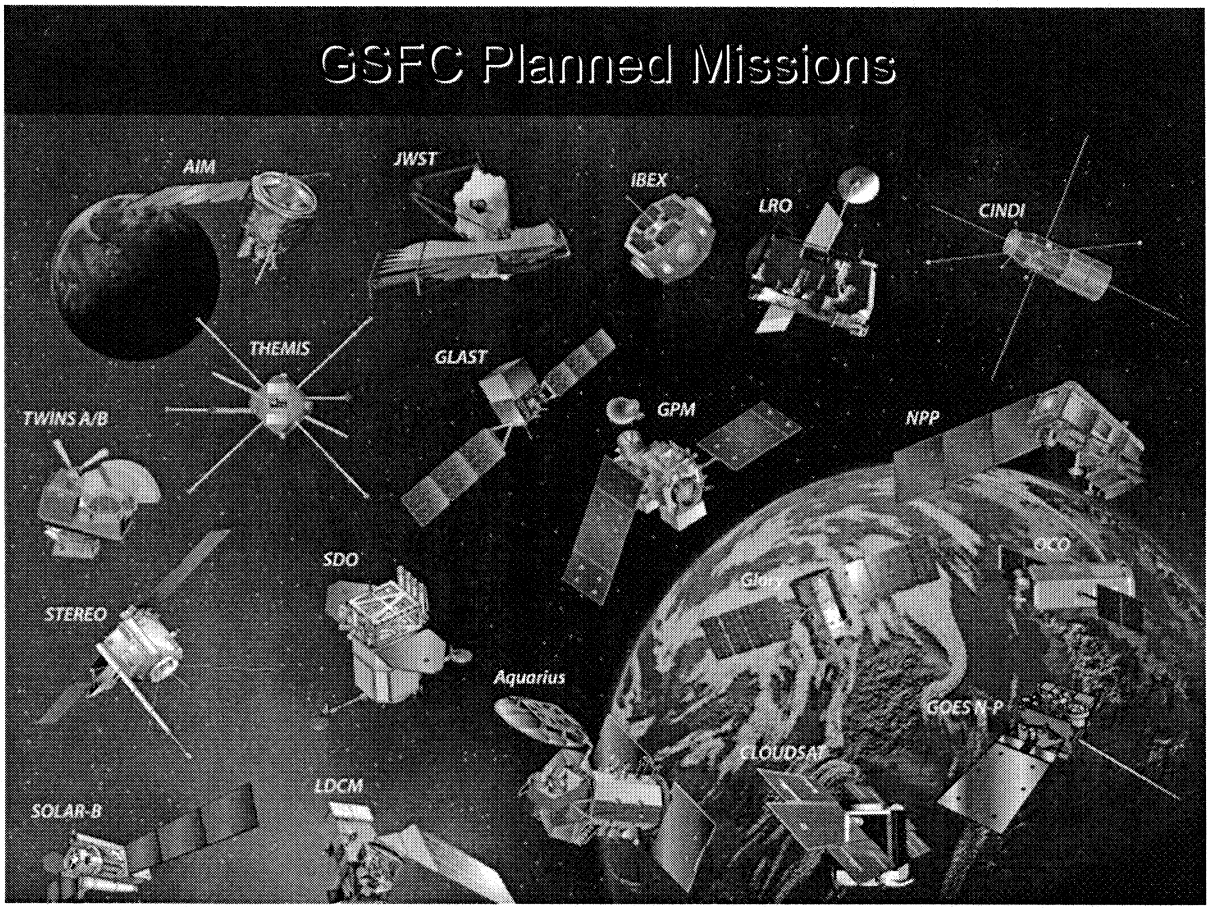
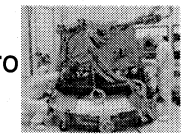


is developing the Integrated Lunar Information Architecture Decision Support (ILIADS) system to provide detailed topography, illumination, temperature and hazard data from many sources to lunar outpost mission planners?

GSFC Orbiting Missions
ERBS
WMAP
XMM
ASTRO-E2
Cluster
SOHO
POLAR
LAGEOS 1, 2
WIND
New Horizons
RHESSI
HST
INTEGRAL
SWAS
ACE
AURA
WIRE
HETE-2
IMAGE
CHIPS
Swift
LANDSAT-7
MESSENGER
STS
UARS
TIMED
GALEX
CALIPSO
AQUA
GRACE
SORCE
TRMM
SAMPEX
GOES-M
TOMS
RXTE
GEOTAIL
EO-1
FAST
TRACE
ICESAT
TERRA
TDRSS
CONTOUR
JASON


GSFC Planned Missions
AIM
JWST
IBEX
LRO
CINDI
THEMIS
GLAST
TWINS A/B
GPM
NPP
SDO
OCO
STEREO
Aquarius
GOES N-P
CLOUDSAT
LDCM
SOLAR-B

The "Old Way" Mission Development Approach



- Each mission on its own
  - The missions hold their own budgets (spacecraft thro
  - Objective is to meet its own objectives
  - Missions use NASA or outside development teams
  - No formal obligation to benefit the Center, the Agency or other missions
- Non-Mission funding provided to the engineering "stovepipe" organizations to advance their systems
- Some changes since the late 1990's didn't help
  - Overall cost and schedule pressures increased
  - Technology advancement funds nearly eliminated
  - Nearly all funding moved to the Projects/missions
- Bottom Line – Little or no ground system investment, advancement or strategic direction

Issues with the Traditional Mission Approach

- Innovation is Slowed
- Maintenance and Operations Costs are High
- Efforts are Duplicated, Each done "just a little Different"
- Every Interface is a Special Case

Moving to a New Approach . . .

Changes were started in 2001 to address concerns . . .

- The Goddard Mission Services Evolution Center (GMSEC) was established as a mission and domain cross-cutting organization
  - Thought of as a technical initiative to create a new standard ground system for many missions
  - The reality was that business reengineering and mindset were just as important
- Funding paths were changed
  - GMSEC would provide some funding to the technology teams as long as their work was helping to meet the larger strategic goals.
  - Missions would still have bulk of funds and responsibility, but they now had a single interface to help with command and control needs.

GMSEC Overview

NASA GSFC's "GMSEC" Reference Architecture supports the simplified integration of heritage, new and COTS ground system products while enabling increased automation and new operations concepts.

GMSEC Background and Introduction

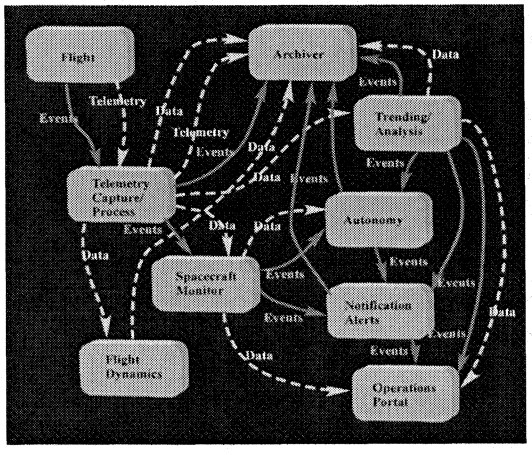
GMSEC was established in 2001 to coordinate ground and flight data systems development and services at GSFC

- Goals
  1. Simplify development, integration and testing
  2. Facilitate technology infusion over time
  3. Support evolving development and operational concepts
  4. Allow for mix of heritage, COTS and new components while avoiding vendor lock-in

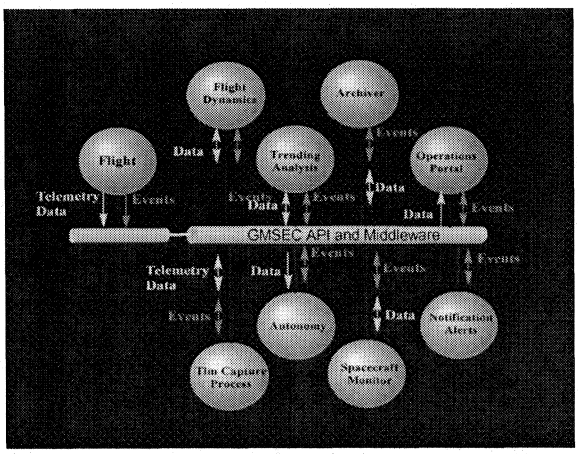
- Concepts
  1. Standardize interfaces – not components
  2. Provide a middleware infrastructure
  3. Allow users to choose – GMSEC doesn't decide which components are best or dictate which components a mission must use. It's the mission/user's choice!

GMSEC Publish/Subscribe Communications

Traditional Design
Socket Connections

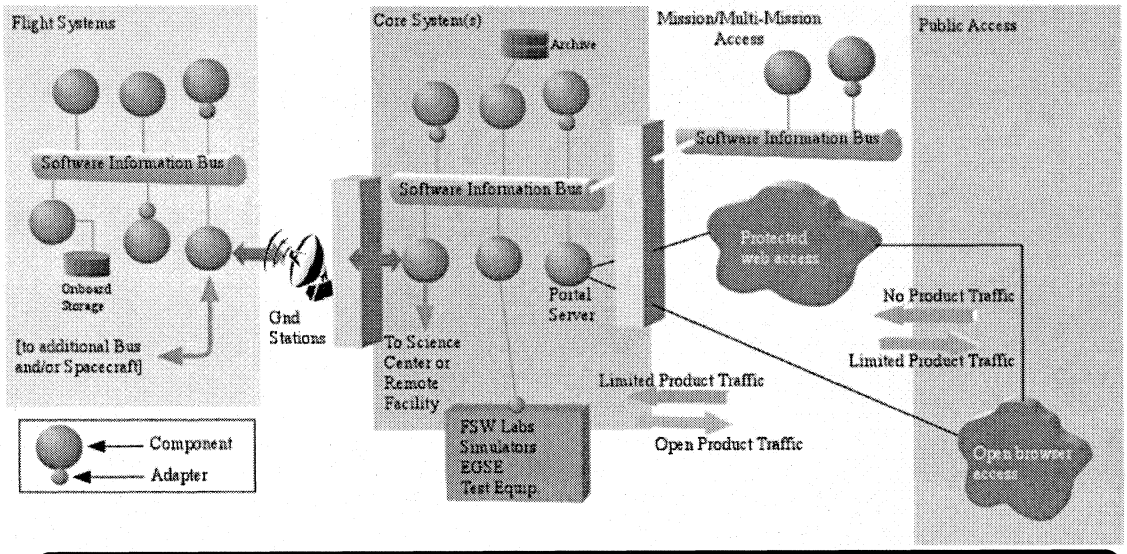


GMSEC Architected
Middleware Connections



Middleware-based architecture reduces interface complexity and simplifies integration.

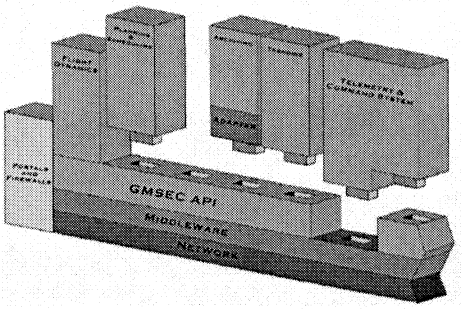
GMSEC Architecture Extends from Flight to Ground



API for middleware isolation, message standards and publish/subscribe communications facilitate end-to-end 'plug-and-play'.

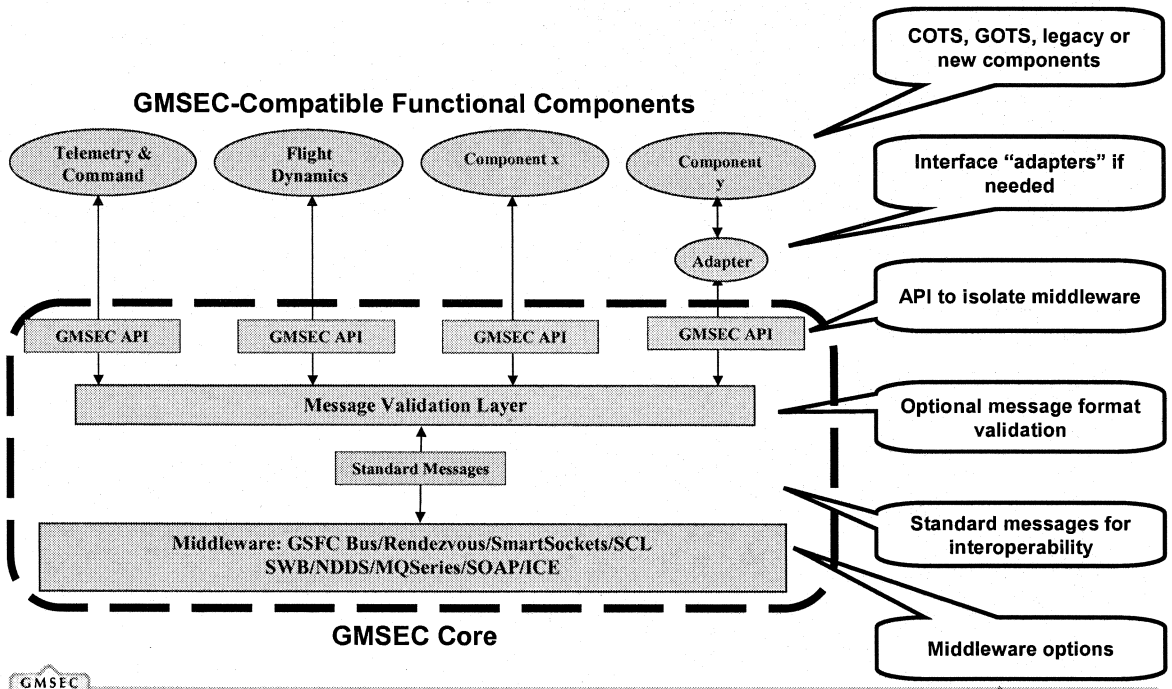
Plug-and-Play Concept

By creating a "framework", individual applications can be easily integrated into an existing system without regard to many underlying implementation details.



Components	Telemetry & Command	Automation	Flight Dynamics		
	Planning	Monitoring	Archive & Assessment	Simulators	
GMSEC Messages	Telemetry Frame	Log	Directive Request	Directive Reply	
	Scheduling	Mnemonic Value	Comp. to Comp. Transfer		
GMSEC API	GMSEC Applications Programming Interface C, C++, Java, Perl, *Python, Delphi*				
Middleware	*Rendezvous*	TIBCO SmartSockets	GSFC Bus	*ICE*	*SCL SWB*
Operating Systems	Windows	Linux	HP-UX	Solaris	Mac OS X

GMSEC Message Bus Architecture



GMSEC Yearly Progress

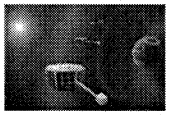
- FY02 Architecture definition (paper studies)
- FY03 Lab Created
  - -- Proof of concept prototypes
- FY04 Development of operational tools
- FY05 First operational missions
  - -- Labs established at other Centers
  - -- Exploration Initiative moves towards GMSEC concepts
- FY06 Expanded operational use
  - -- Formal CM, maintenance of mature components
  - -- Exploration prototyping across Centers
- FY07 Customer-Driven Support and Enhancement
  - -- Multiple customers set priorities
  - -- Lab used to prototype security changes
  - -- More formal software processes
- FY08 Spinoffs to other organizations
  - -- GSFC's Flight Dynamics Facility
  - -- Sharing agreements with other NASA Centers
  - -- Consideration by other government space organizations

GMSEC Operational Status

- First Three Operational GMSEC Implementations
  - Tropical Rainfall Measuring Mission (TRMM) – since Fall 2005
    - Reduced operations cost by 50%
    - Pathfinder for Terra, Aqua, Aura automation (2007-2009)

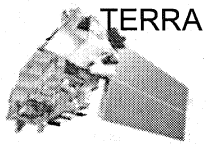
  - Multi-Mission Operation Center (MMOC) missions – SWAS, WIRE, TRACE, SAMPEX
    - Conducted a successful continual lights-out operation
    - Pathfinder for low-cost fleet operations
    - Concepts being extended to other small missions

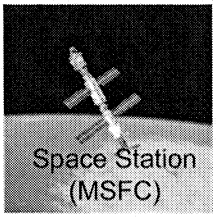
  - ST-5 Three-Satellite Constellation - Launched March 2006
    - Technology demonstration with subsystem modeling and closed-loop automation
    - Conducted successful lights-out operations

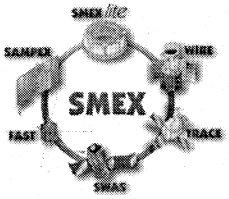


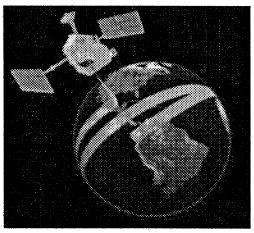
- **Systems in Development**
  - Working with 6 future missions
  - Working with other GSFC labs, other NASA Centers, Constellation Program, others.

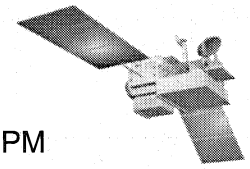
GMSEC Team Provides Support and Consultation to Many Missions

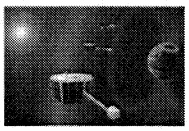


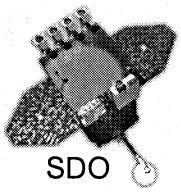


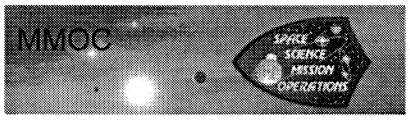


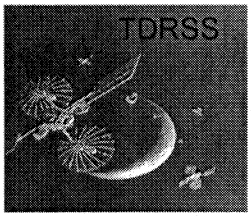




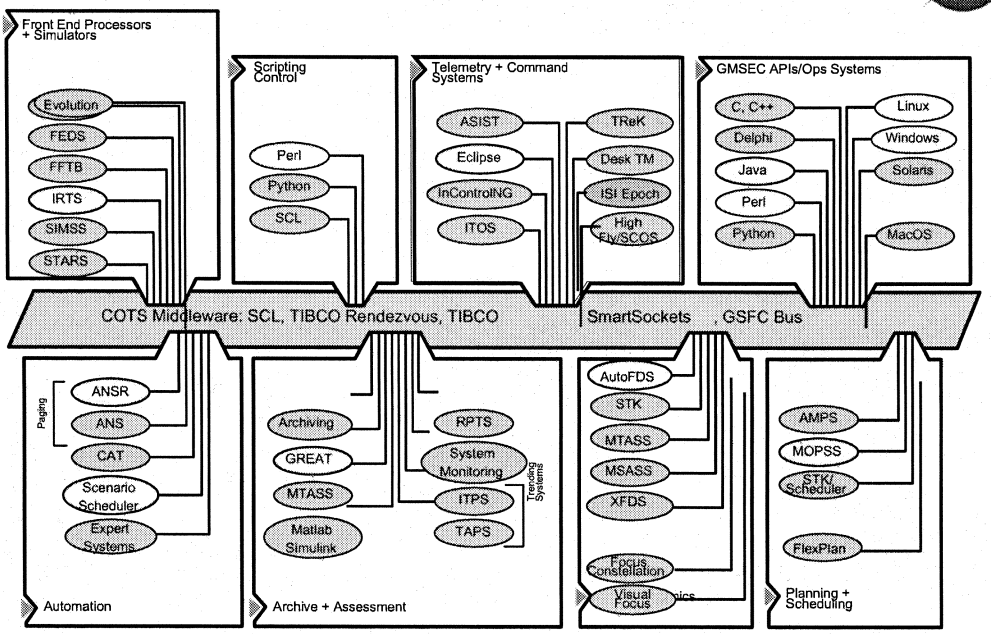








GMSEC Component Catalog



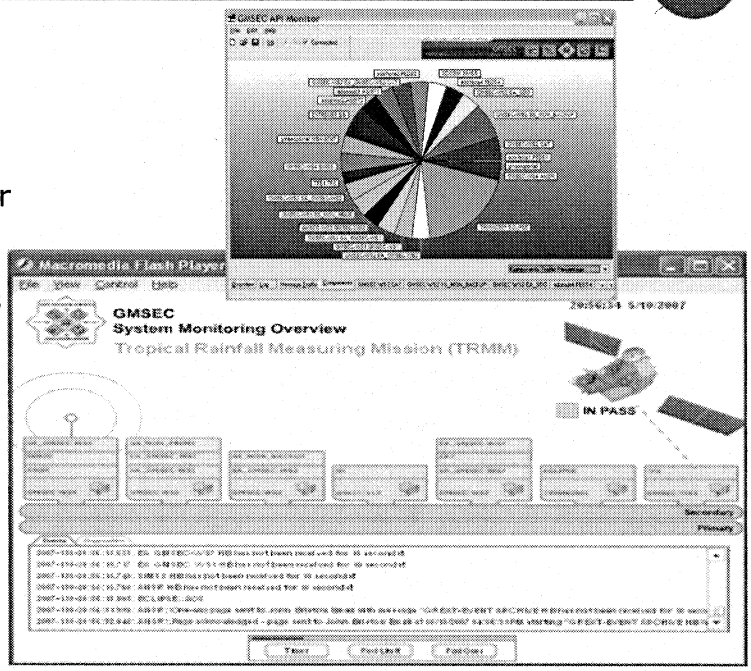
Choices are available for many subsystems. [acronyms not important]

Innovation "Spinoff" - Automation

- Architecture enables new approach for automation
- Simple "standards" for components
  1. Follow functional interfaces (use API & standard messages)
  2. Publish keep-alive and status messages
  3. Accept control directives over the bus
- New tools can cross domain boundaries
  - Can "listen" for status from all components → **situational awareness**
  - Can direct actions of components → **system-wide control**
  - Recognize status and respond → **event-driven automation**
    - "Criteria-Action Tool" provides situational awareness rules and actions
    - Complex temporal and cross-domain rules/actions defined by MOC Team

Tool Development is Simplified

- Support tools are easy to develop
- May not require any integration with other components
- Simply monitor messages on the bus
- Examples
  - Performance tool
  - Configuration display
  - Message replay



Observed GMSEC Benefits

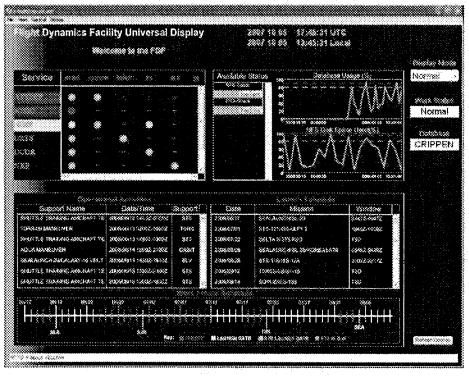
1. Significant reduction in integration time
2. Components added/upgraded without impacting existing system
3. Ideal for using multiple small distributed development teams and vendors
4. New concepts emerging for small independent components that integrate with the bus and provide immediate benefits
5. Missions more willing to adopt the approach if "old favorite" components can still be used
6. Some vendors see message compliance as a way to enter what had appeared to be a closed marketplace
7. Standard message approach provides collaboration possibilities with other organizations
8. Automation for cost and risk reduction is the #1 selling point

GMSEC Reference Architecture

Applications & Future Directions

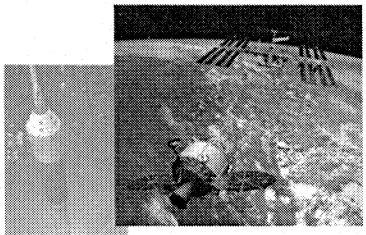
Flight Dynamics Facility Re-engineering

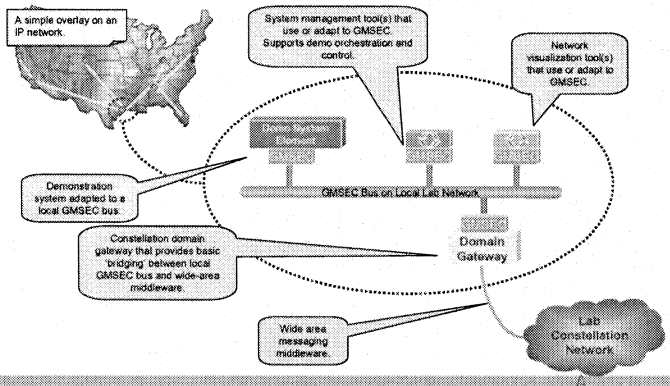
- GSFC Flight Dynamics Facility is being re-engineered using a GMSEC architecture
- FDF provides services to missions across NASA



NASA-Wide Exploration Initiative

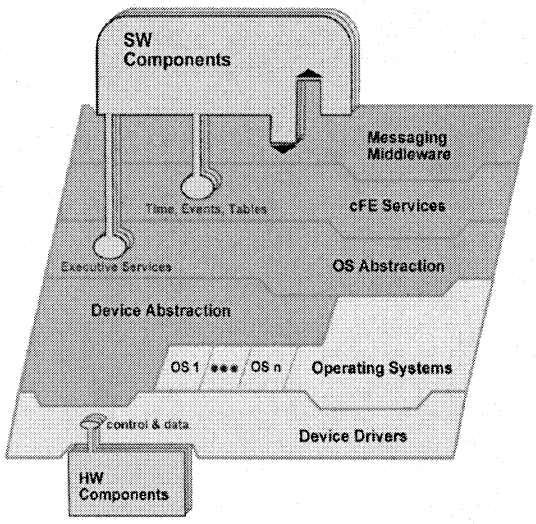
- The GMSEC team participates in Exploration communications, command, control and information working groups (develop vision, requirements, prototypes)
- GSFC has lead role for defining Exploration framework
- Labs across NASA have been tied together with GMSEC framework





GSFC's Flight Software Framework

- Plug & Play software and hardware interfaces
- Small footprint ~250kBytes
- Advanced message handling with network services
- Multiple target processors and operation systems already available



Core Flight Executive (cFE)

Other Potential Applications

- May be used to develop broader GSFC framework to link control centers with solar weather or security centers
- NASA's Jet Propulsion Lab (JPL) using many GMSEC ideas to enable sharing of software across the NASA Centers
- Topic of study at other government space organizations

Future Directions for GMSEC

1. Expanded security layer
2. System-of-System bridging
3. Move towards more of a Service Oriented Architecture
4. Increased situational awareness and data mining capabilities
5. Internet protocol for telemetry and command links
6. More flight-ground interaction
7. Increase in joint efforts with other organizations

GMSEC Business Aspects

Business Discussion Topics (1 of 2)

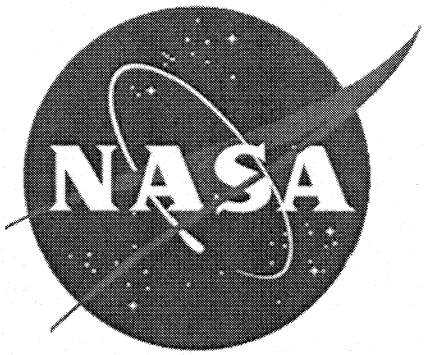
- GMSEC is more than a technical reference architecture
  - It has become a product "store front" for the missions
  - It works across all missions to set strategic directions
  - The team can provide critique at reviews
  - The team works with industry on new directions
  - It has created a GSFC point-of-contact across NASA for working on similar issues
  - It helps move the entire industry's "state of the practice"
  - It has worked to insert progressive wording into Acquisition Opportunity notices and RFPs (GMSEC references are now included in the RFPs)
- GMSEC has reinforced the idea that our entire organization must be customer-focused

Business Discussion Topics (2 of 2)

- Working with Missions
  - We must provide value
  - We can't dictate technical decisions
  - We must understand the services and products we provide
  - Remember: New missions don't want to be first with anything new
- Working with Stovepipe Development Organizations
  - We still want the development orgs to be the experts in their field
  - We still want them to own their domain area and software and to interact with customers
  - We want to help set the larger strategic direction and ensure that all the stovepipes can be part of the larger interoperable vision
  - GMSEC can now bring new work to the development teams and can provide funding for efforts with multi-mission benefit

Final Notes

- Having a common reference architecture and framework . . .
  - Is central enabler of our new long-term strategic direction
  - Has increased interaction and cooperation across development "stovepipes"
  - Has increased our involvement with industry and other NASA Centers
  - Has proven technically very successful
- Missions now look to the GMSEC team to coordinate long-range needs, advance new ideas and enable new operations concepts
- GMSEC only works because of the organization's business practices developed to complement the technical approach.



"The other U.S. Space Organization"

Additional Information

Additional Information

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General, high level, copies of component fact sheets

GMSEC Developers Website: must request access information
System documentation, developers toolkit, APIs, middleware, etc.

Acronyms List

API	Application Programming Interface	AMPS	Automated Mission Planning & Scheduling
COTS	Commercial Off The Shelf	ANS	Alert Notification System
CSTL	Building 25 Lab	ANSR	Alert Notification System Router
Cx	Constellation	ASIST	Advanced Spacecraft Integration and System Test
CxP	Constellation Program	AutoFDS	Autonomous Flight Dynamics System
GLAST	Gamma-ray Large Area Space Telescope	CAT	Criteria Action Table
GMSEC	Goddard Mission Services Evolution Center	EGSE	Electronic Ground Support Equipment
GOTS	Government Off The Shelf	FEDS	Front End Data System
GPM	Global Precipitation Measurement	FDF	Flight Dynamics Facility
GSFC	Goddard Space Flight Center	FFTB	Formation Flying Test Bed
ICS SWB	Interface & Control Systems Software Bus	FSW	Flight Software
ISI	Integral Systems Inc.	GDS	Goddard Dynamic Simulator
JPL	Jet Propulsion Laboratory	GREAT	GMSEC Reusable Event Analyzer Toolkit
JHU/APL	Johns Hopkins University/Applied Physics Lab	IRTS	ISTP Real-time Software Front End
JSC	Johnson Space Center	ITOS	Integrated Test and Operations System
JWST	James Webb Space Telescope	ITPS	Integrated Trending and Plotting System
KSC	Kennedy Space Center	MOPSS	Mission Operations Planning and Scheduling System
LRO	Lunar Reconnaissance Orbiter	MSASS	Multi-Mission Spin Axis Stabilized
MMS	Magnetospheric MultiScale Mission	MTASS	Multi-Mission Three-Axis Stabilized Spacecraft
MOU	Memorandum of Understanding	SIMSS	Scalable Integrated Multi-Mission Simulation Suite
MSFC	Marshall Space Flight Center	STARS	Spacecraft Trajectory and Attitude Real-Time Simulator
ORR	Operational Readiness Review	STK	Analytical Graphics Satellite Toolkit
SAMPEX	Solar Anomalous and Magnetospheric Particle Explorer	SERS	Spacecraft Emergency Response System
SMEX	Small Explorer	TAPS	Trending, Analysis, and Plotting System
SOAP	Simple Object Access Protocol		
ST-5	Space Technology 5		
SWAS	Submillimeter Wave Astronomy Satellite		
TRACE	Transition Region and Coronal Explorer		
TRMM	Tropical Rainforest Measuring Mission		
WFF	Wallops Flight Facility		
WIRE	Wide-Field Infrared Explorer		