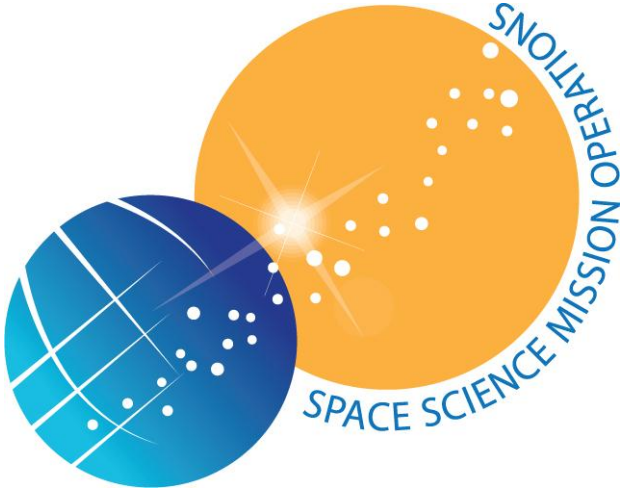
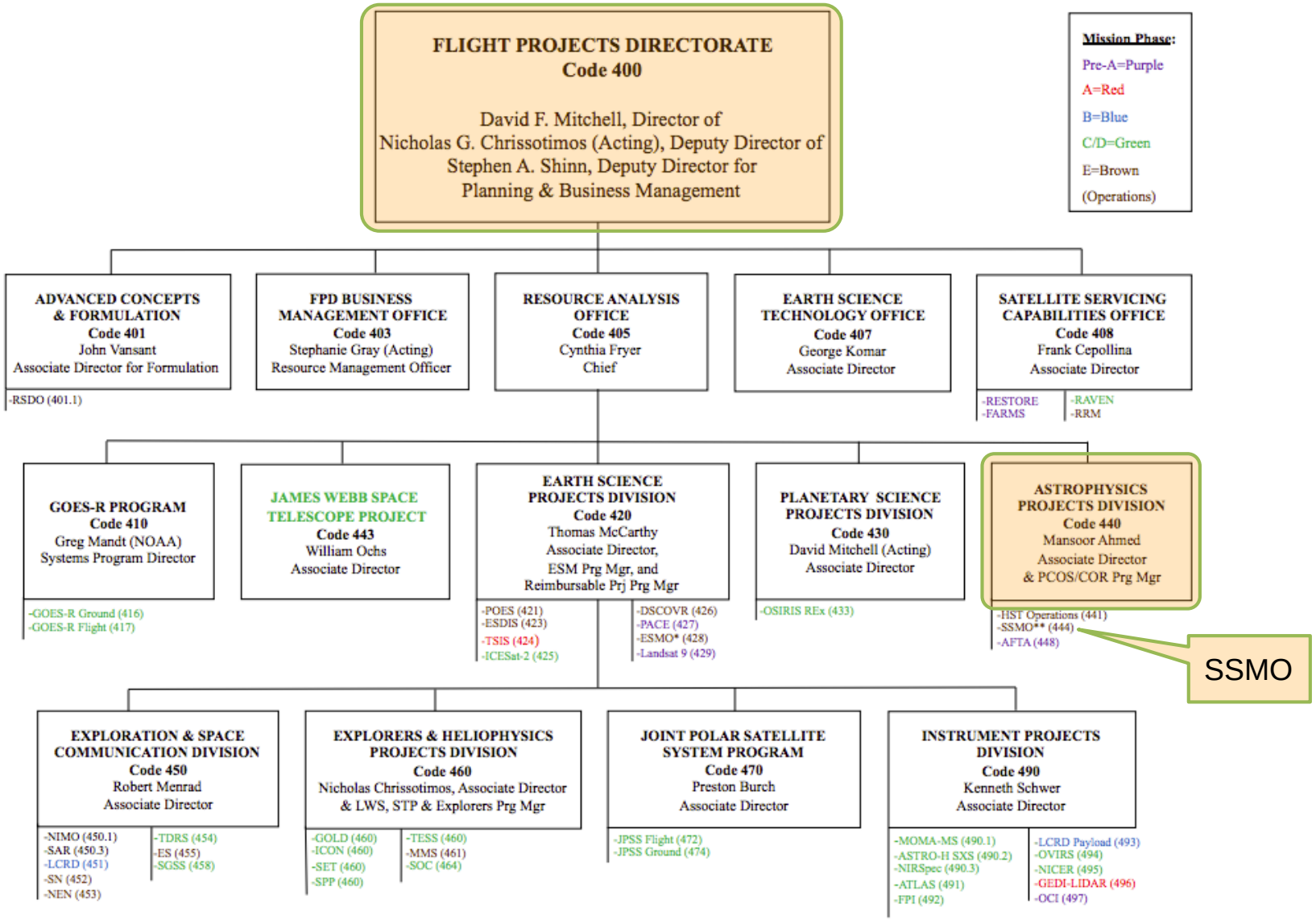
Technical Challenges and Opportunities of Centralizing Space Science Mission Operations (SSMO) at NASA Goddard Space Flight Center



Haisam Ido
Systems Engineer
haisam.ido@nasa.gov
NASA Goddard Space Flight Center - Space Science Mission Operations
Honeywell Technology Solutions Inc.

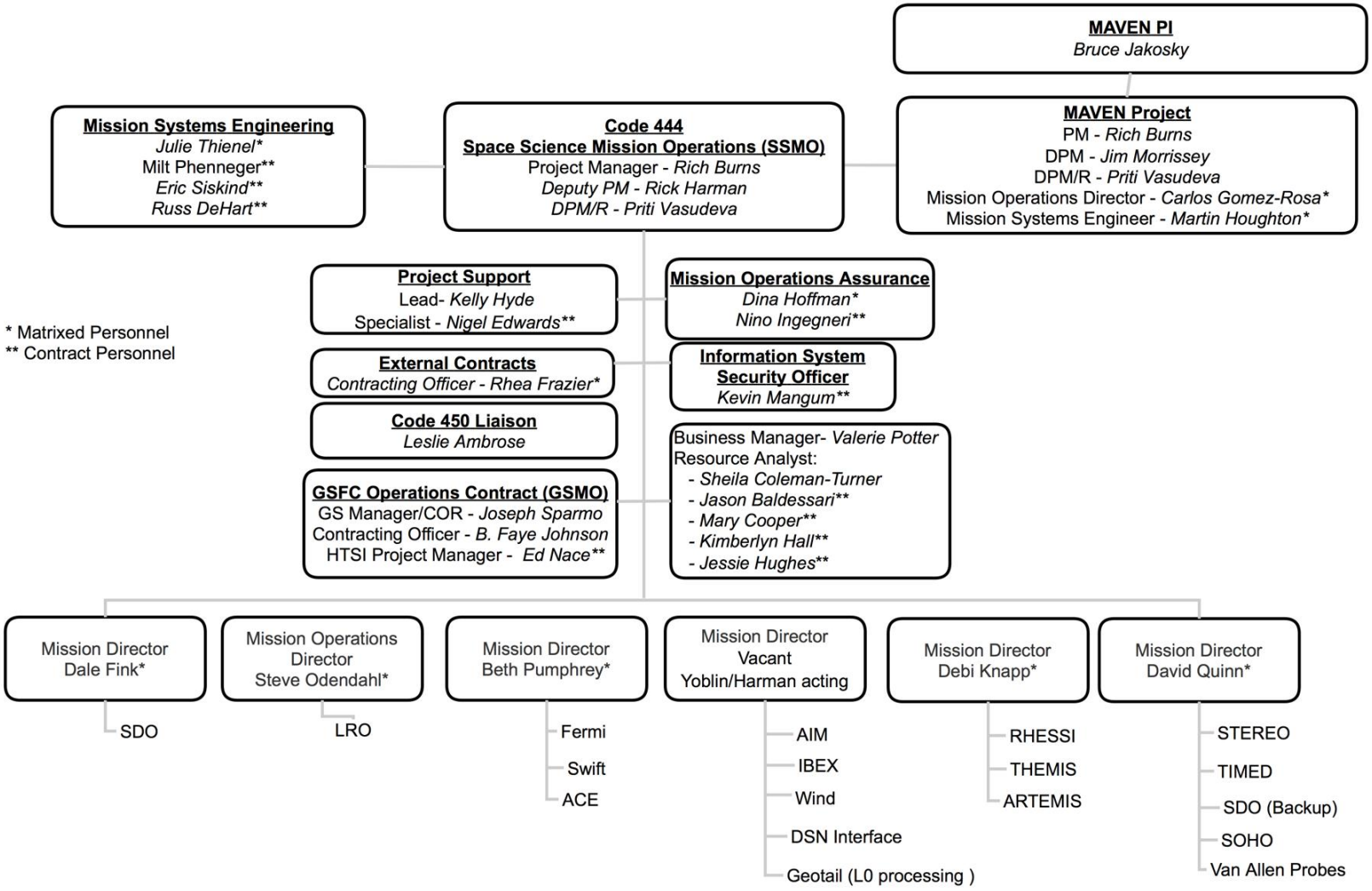
Rich Burns
Project Manager
rich.burns@nasa.gov
NASA Goddard Space Flight Center - Space Science Mission Operations

Where is Space Science Mission Operations (SSMO) ?



source: http://fpd.gsfc.nasa.gov/images/400orgchart.pdf

SSMO Organization



source: http://fpd.gsfc.nasa.gov/images/400orgchart.pdf

What is Space Science Mission Operations (SSMO)? (1/2)

- SSMO operates, manages, administers and processes science data for NASA space science missions for which GSFC is responsible

- SSMO is involved in the operations concept development, ground system development, integration and test, and operations readiness preparations for those missions it will manage in the operations phase.

- Spacecraft operations encompasses:
  - flight operations (planning, scheduling, real time operations, automation, monitoring, etc.)
  - instrument operations
  - spacecraft sustaining engineering
  - ground system sustaining engineering
  - anomaly management
  - risk management

What is Space Science Mission Operations (SSMO)? (2/2)

- SSMO currently manages the full mission operations for 18 space science missions
  - 7 are operated at GSFC
  - 11 are operated at control centers at industrial and university partners

- SSMO missions are diverse
  - heritage/launch date
  - orbit regime
  - bus type
  - mission profile
  - communication networks

SSMO Spacecraft in Operations

Mission	Launch Year	MOC Location	Science Type	# s/c	Orbit Regime	Catalog #
ACE	1997	GSFC	Heliophysics	1	L1	N/A
AIM	2007	LASP	Heliophysics	1	LEO	31304
ARTEMIS*	2007	UC Berkeley	Heliophysics	2	P1, lunar orbit; P2, Lunar Lagrange Point 1	30581, 30582
Fermi	2008	GSFC	Astrophysics	1	LEO	33053
IBEX	2008	Orbital	Heliophysics	1	HEO (T = 9 days)	33401
IRIS	2013	ARC	Heliophysics	1	LEO	
LRO	2009	GSFC	Planetary (Lunar)	1	Lunar Orbit	N/A
MAVEN	2013	LM - Denver	Planetary	1	Mars Orbit	N/A
MMS	2015	GSFC	Heliophysics	4	HEO	
Van Allen Probes (RBSP)	2012	APL	Heliophysics	2	HEO	38752, 38753
RHESSI	2002	UC Berkeley	Heliophysics	1	LEO	27370
SDO	2010	GSFC	Heliophysics	1	GEO	36395
SOHO**	1995	GSFC	Heliophysics	1	L1	n/a
STEREO	2006	APL	Heliophysics	2	Heliocentric	n/a
Swift	2004	Penn State	Astrophysics	1	LEO	28485
THEMIS	2007	UC Berkeley	Heliophysics	3	HEO	305880, 30584, 30585
TIMED	2001	APL	Heliophysics	1	LEO	26998
WIND	1994	GSFC	Heliophysics	1	L1	n/a

* ARTEMIS is a bifurcation of the THEMIS extended mission.
** SOHO is a cooperative program between ESA and NASA.

Why centralize operations?

- Generally GSFC builds and maintains a different operation center per mission
- Consider whether centralization would enhance efficiency
- What are the costs and benefits of centralization, consolidation and/or integration of a diverse set of operation centers, interfaces, services and processes
- There is no traditional or modern technical barriers to developing a centralized capability
- Operational efficiencies may be significantly enhanced with centralization and integration
- May require significant investments in infrastructure
- Existence proofs exist:
  - ACE, Wind, and TRACE (until decommissioning) were all operated from SSMO's Multi-Mission Operations Center (MMOC)
  - new centralization paradigms are enabled by modern technologies

SSMO Operations' Functions

1. **Telemetry, Tracking & Commanding (TT&C)**

2. **Data and Product Management**
   - Receiving
   - Archiving
   - Retrieving
   - Modeling
   - Trending
   - Visualizing
   - Distributing

3. **Flight Dynamics**
   - Maneuver planning, execution and reconstruction
   - Orbit Estimation + Control
   - Attitude Estimation + Control

4. **Subsystems Management**
   - Command and Data Handling (C&DH)
   - Guidance Navigation and Control (GN&C)
   - Instrument Subsystem
   - Payload Subsystem
   - Power Subsystem
   - Propulsion Subsystem
   - Thermal Subsystem

5. **Scheduling and Planning**
   - Instrument Activities
   - Maneuvers
   - Antenna Availability
   - AOS/LOS
   - Shadows
   - Sun/Moon Interference
   - Ranging

6. **Automation Management**
   Notification Management
   Logging Management
   Voice Management

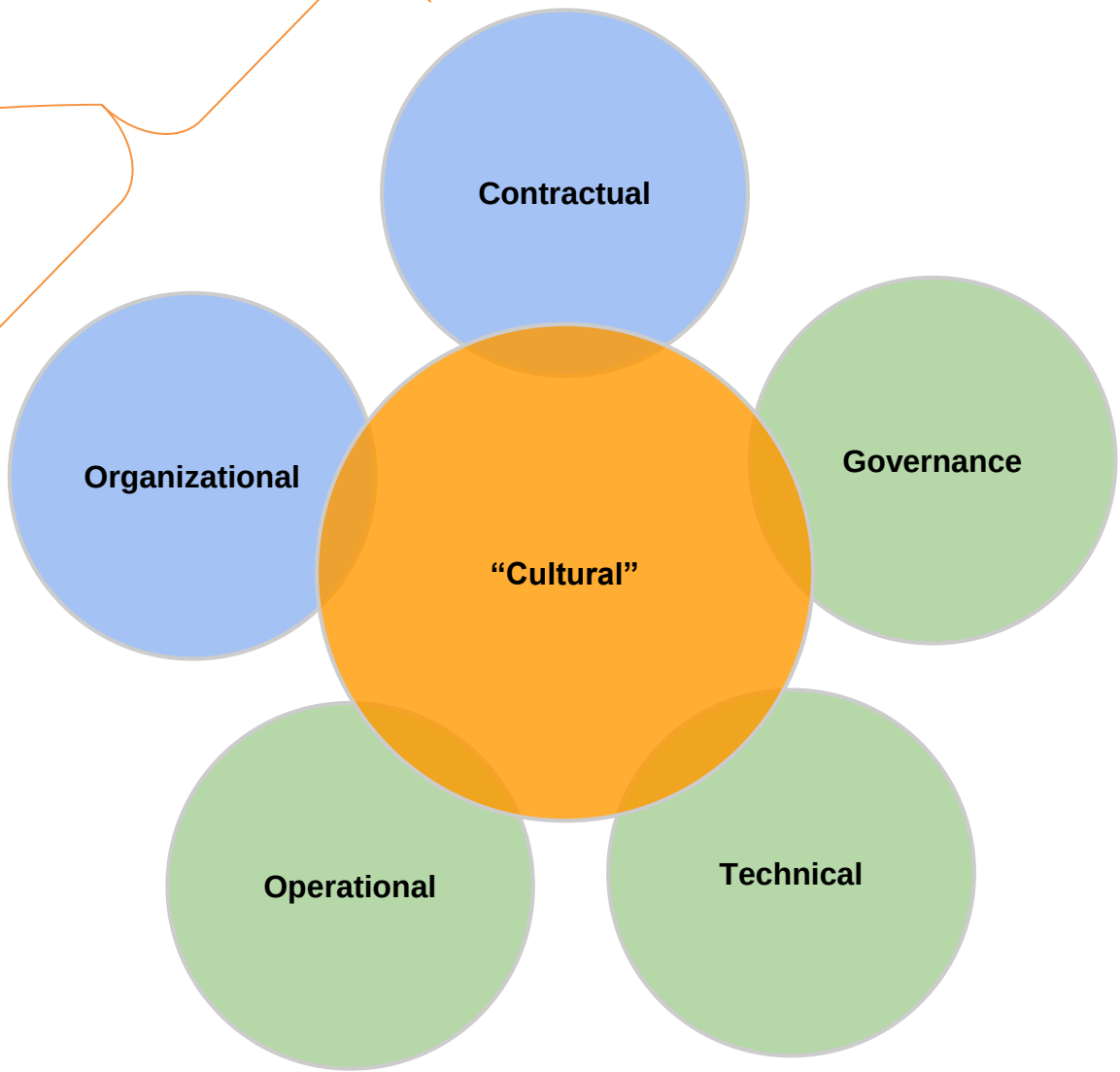
7. **Information Assurance/Information Security**

8. **Change and Configuration Management**
   - Documentation & Procedures
   - Spacecraft Configurations
   - Ground Segment Configurations
   - Software Configurations
   - Server Configurations

plus Continuity of Operations of all these functions

Challenges and Opportunities

not discussed in this presentation



Challenges in Centralizing Operations

- **Cultural**
  - The mode of one operations center per mission has been effectively utilized in the past, i.e. it is proven
  - Tendency to utilize heritage architectures, tools, methodologies
  - Are the benefits substantial enough to merit the investment/risk?
- **Governance**
  - Governance is generally tied to the Flight Project
  - Who governs a shared/centralized set of resources?
- **Operational**
  - Operations is performed independently of other spacecraft operations
  - Cross spacecraft and subsystems training is not common
- **Technical**
  - Although many operation centers leverage very similar software and hardware yet they tend to implement different architectures
  - Risk averse to newer methodologies and technologies
- **Programmatic**
  - Requires initial investment
  - What flight project is willing to "be first" (and assume cost/risk)?

Opportunities in Centralizing Operations

- **Cultural**
  - Familiarize staff with possible enhancements to current approaches and methodologies
  - Create a more diverse and engaging place of work
  - Create more opportunities for collaboration
- **Governance**
  - Must enable freedom of choice while influencing/incentivizing standardization
- **Operational**
  - Perform spacecraft operations, with all SSMO spacecraft in mind, e.g. scheduling, etc.
  - Train core staff across all spacecraft and subsystems
  - Normalize workflows and procedures
- **Technical**
  - Continue to leverage similar software and hardware and normalize architectures and configurations
  - Configure applications to be multi-tenant, when and where possible
  - Shared infrastructure and overhead functionality (e.g. IT Security)
- **Programmatic**
  - Establish compelling business case or discover that one does not exist
  - So what would centralized operations look like compared to current modes?

Current and Future Operations Environments

Current

Characteristics

- One mission in one center*
- Unique infrastructure
- Unique product formats
- Custom networking interfaces
- Custom workflows
- Custom procedures
- Custom security implementations
- Dedicated hardware and software
- Dedicated staff
- Localized lessons-learned

Consequences

- Increased cost
- Replication of effort
- Lower efficiency

Future**

Characteristics

- Multiple-missions in one center
- Shared infrastructure
- Shared product formats
- Shared networking interfaces
- Shared workflows
- Shared procedures
- Shared security implementations
- Shared hardware and software
- Shared core staff
- Shared lessons-learned

Consequences

- Reduction of costs in the long-term
- Reduction of effort in the long-term
- Improved efficiency in the long-term

*: ACE & WIND are together in one operations center

**: One possible path

Future Operations Environment** (continued)

1
- **Personnel Resources**
  - Shared Human Resources
  - Shared Skills
  - Shared Expertise

2
- **Project Management**
  - Shared Configuration Management
  - Shared Document Management System
  - Shared Documents
  - Shared Knowledge
  - Shared Lessons Learned
  - Shared Cost
  - Shared Procedures

3
- **Physical Facility**
  - Shared Floor space
  - Shared Rack space(s)
  - Shared Terminals
  - Shared Electrical power
  - Shared HVAC
  - Shared LANs & WANs
  - Shared Interface Testing

4
- **Broader Collaboration**
- **Shared Governance Body**

5
- **Shared Security**
- **Shared Risk**

6
- **Hardware & Computing**
  - Shared Computing
  - Shared Physical Machines
  - Shared Virtual Machines
  - Shared Cloud Services
  - Shared Memory Storage
  - Shared Storage

7
- **Software**
  - Simultaneous Multi-Execute without Interference (for Specific Functions)
  - Shared Provisioning System
  - Shared Version Control System
  - Shared Applications & Tools
  - Shared datastores and databases

8
- **Commonality & Integration**
  - Integrated Situational Awareness
  - Common User Experience (UX)
  - Common User Interfaces (UI)
  - Common Standards & Specifications
  - Common Workflows & Operating Procedures
  - Common Services & Interfaces
    - as a Service approach (aaS)
    - Web Services

**: One possible path

Technologies, Architectures and Goals To Consider (1/5)

- **Traditional Infrastructure Technologies**
  - Computing, Clustering, Redundancy, Storage, Networking

- **Contemporary Services**
  - Web services
  - Infrastructure as a Service (IaaS)
  - Platform as a Service (PaaS)
  - Software as a Service (SaaS)
  - Software Defined Networks (SDN)

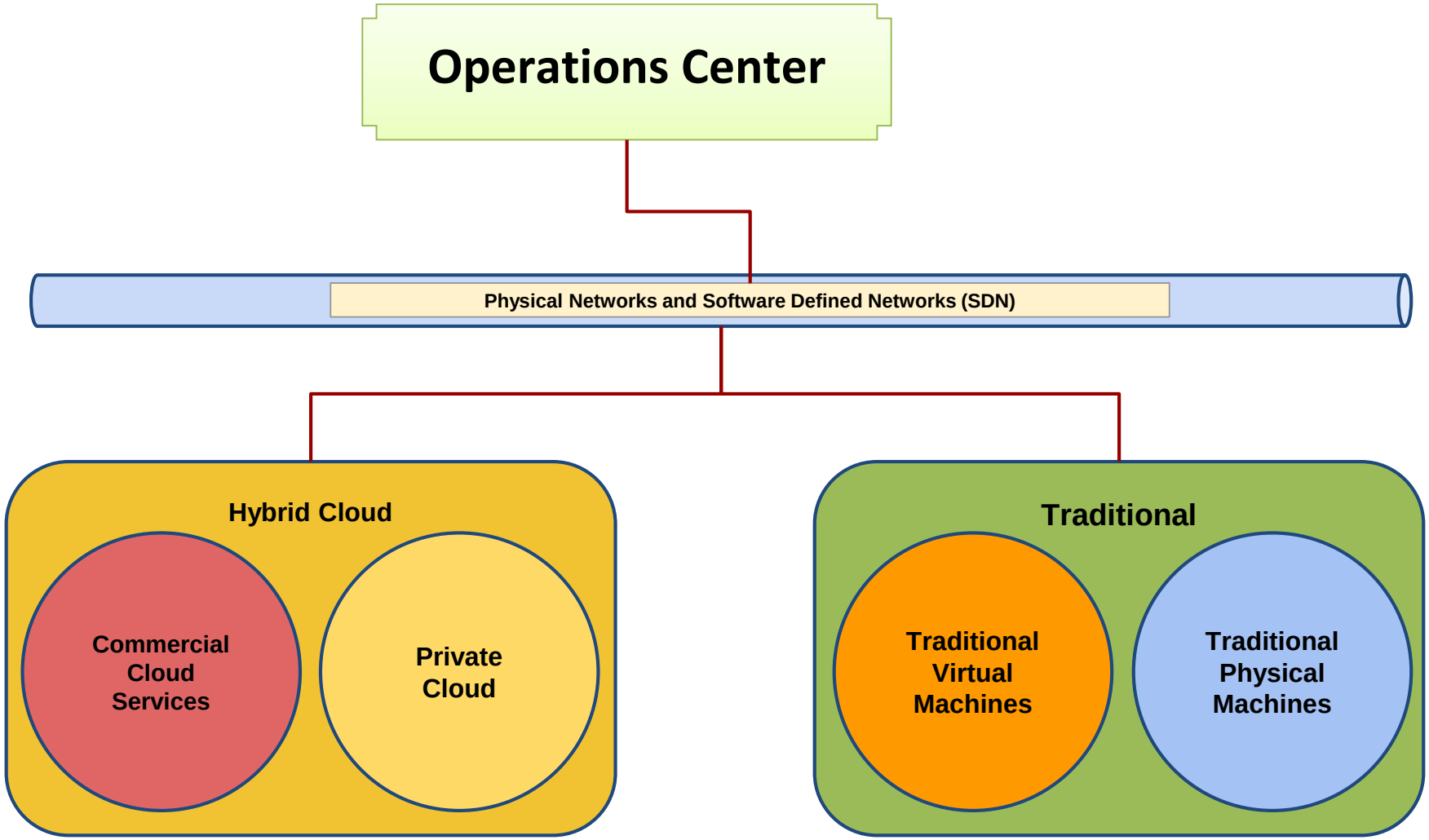
- **Derivable Services such as** Ground Segment as a Service (GSaaS)
  - TT&C as a Service (TTCaaS)
  - Mission Planning and Scheduling as a Service (MPSaaS)
  - Space Flight Dynamics as a Service (SFDaaS)
  - Database as a Service (DBaaS)
  - Data as a Service (DaaS)
  - Load Balancing as a Service (LBaaS)

Technologies, Architectures and Goals To Consider (2/3)

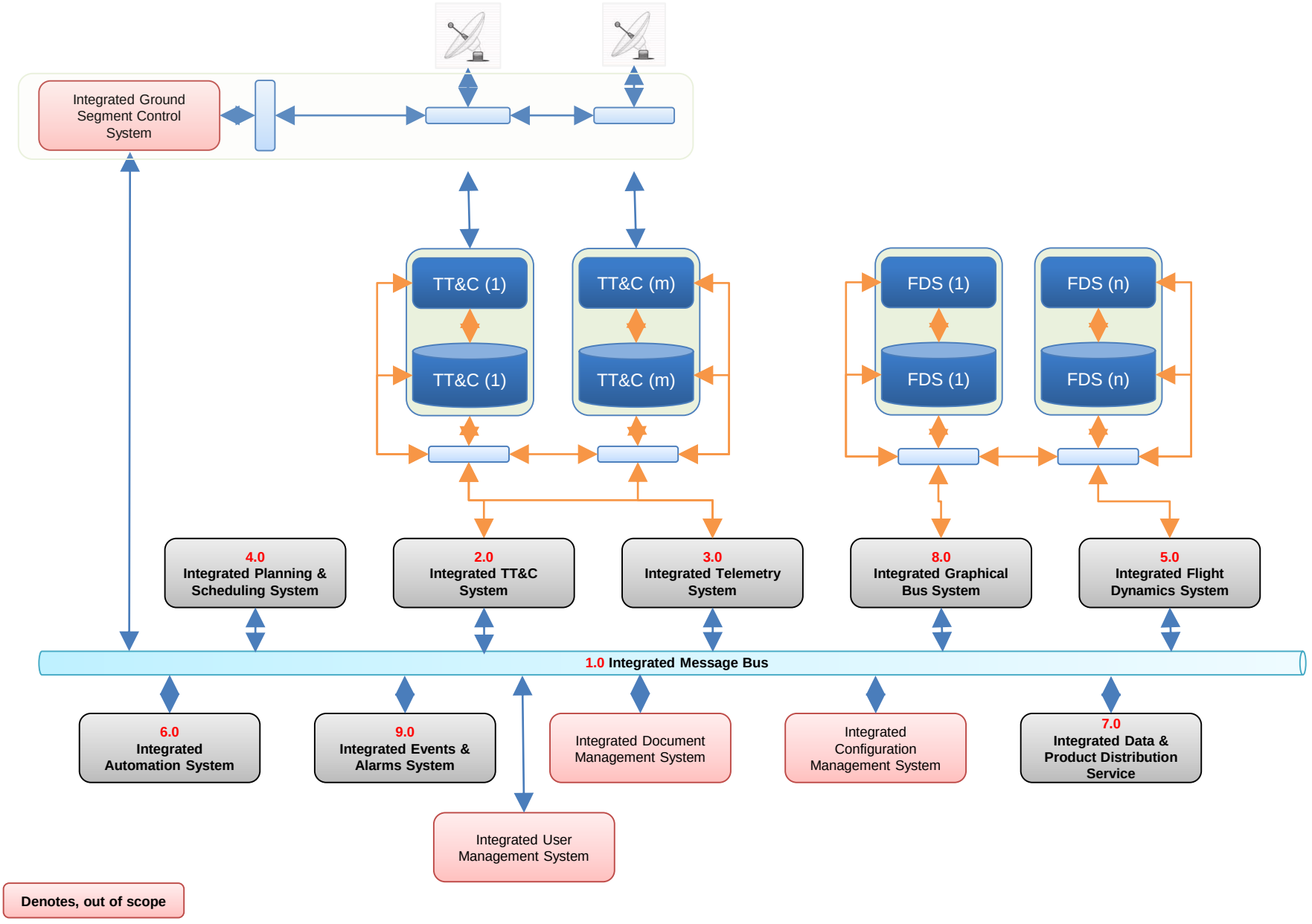
Architectural Goals

- Scalable
- Extensible
- Maintainable
- Based on open standards
- Based on an open architecture
- Can run on virtualized or physical machines
- Leverage physical machines, virtual machines and cloud services

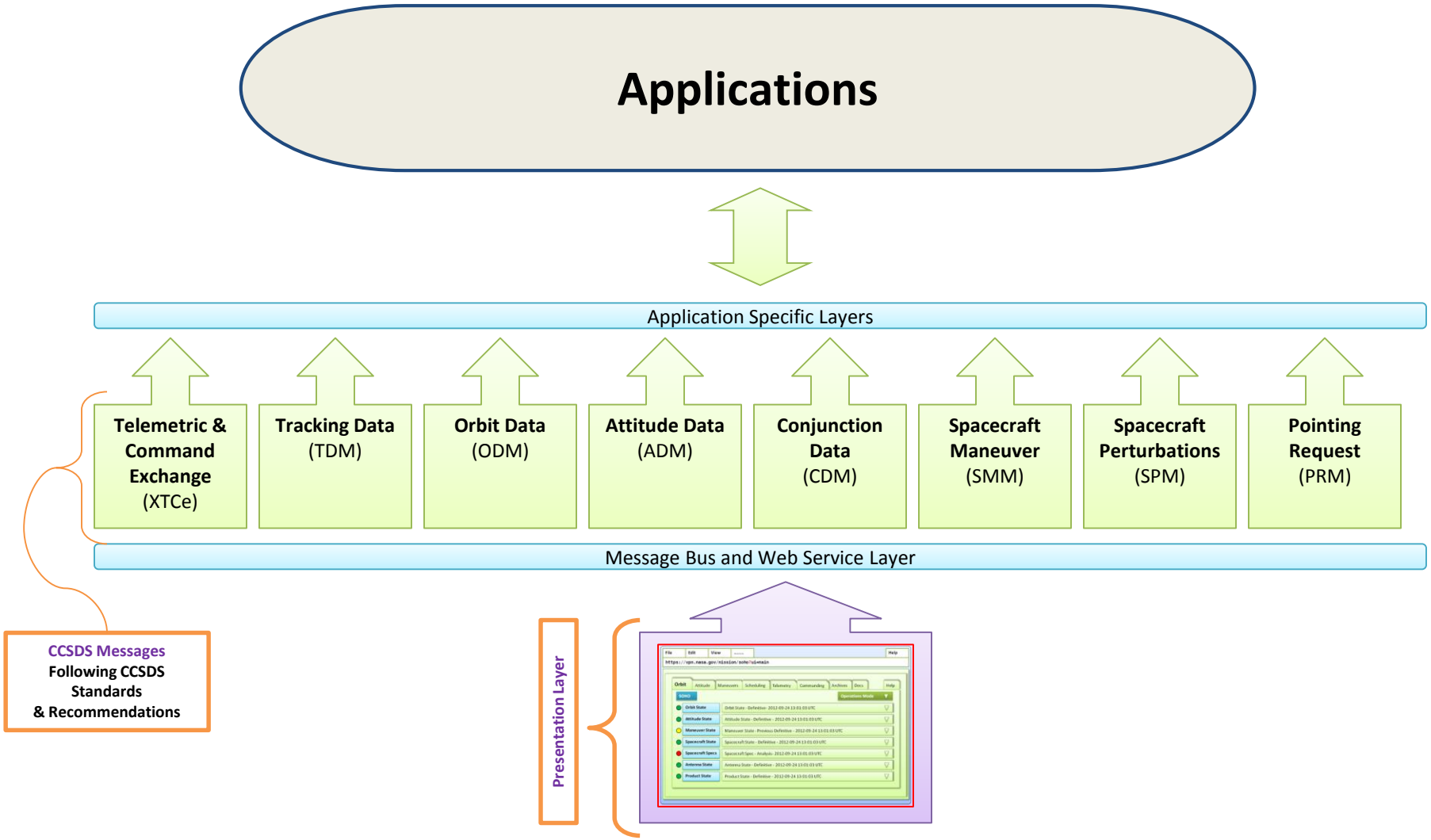
Technologies, Architectures and Goals To Consider (3/5)



Technologies, Architectures and Goals To Consider (4/5)



Technologies, Architectures and Goals To Consider (5/5)



Architectures, Standards & Specifications to leverage

Goddard Mission Services Evolution Center (GMSEC)

- GMSEC API
- GMSEC System Agent (SA)
- GMSEC Criteria Action Table (CAT)
- GMSEC Alert Notification System Router (ANSR)
- GMSEC Environment Diagnostic Tool (GEDAT)
- GMSEC Reusable Events Analysis Toolkit (GREAT)

CCSDS

- Mission Operations Services (MOS)
- Telemetric & Command Exchange (XTCe)
- Tracking Data Message (TDM)
- Orbit Data Message (ODM)
- Attitude Data Message (ADM)
- Conjunction Data Message (CDM)
- Spacecraft Maneuver Message (SMM)
- Spacecraft Perturbations Message (SPM)
- Pointing Request Message (PRM)

Notional Potential Approach

Provisioning & Orchestration of a New Ground Segment Infrastructure

File | Edit | View | ..... | Help

https://vpn.nasa.gov/mission/provisioning&spacecraft=NEW

Spacecraft ID	123098	Spacecraft Name	One	Security Level	FISMA Medium
Spacecraft Bus	Bus 12	Ops Center	MOC	Telemetry	CCSDS

TT&C System	ASSIST	ITOS		Data Trending	DAT		
Networks	DSN	NEN	SN	Data Distribution	DDS		
LANs	EBNet	IONet	RIONet	SEN			
FDS & ADCS	GMAT	GTDS	STK	Planning & Scheduling	MPS	MMS	

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Thank you!