Multiple Views of Ground Data Systems

Based on Mars Reconnaissance Orbiter's GDS

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Abstract

This paper presents one JPL systems engineer's approach to describing a complex, multi-mission Ground Data System (GDS) using multiple, concurrent architectural views.

The Mars Reconnaissance Orbiter (MRO) Ground Data System is the integrated set of ground software, hardware, facilities and networks that supports multi-mission operations.

The use of multiple architectural views is a standard approach for specifying a system architecture and gaining its acceptance. Refer to "Architectural Blueprint – The 4+1 View Model of Software Architecture" by Philippe Kruchten [1]. In this reference, Mr. Kruchten makes the point that multiple views allow a presenter to address separately the concerns of the various "stakeholders": end-user, developers, system engineers, project managers, and others. Since the adaptation of a multi-mission GDS requires coordinated effort from many groups including hardware engineers, software engineers, network engineers, standards engineers, and their managers, the multiple view method of presenting the architecture was adopted and customized to address system architecture issues.

For the approach to be effective, the selection of which views to develop and present is based on the need to communicate to specific user groups. Philippe Kruchten selected the views presented in his article based on the needs of software architects. The presentation of MRO GDS addressed system architecture and a more diverse audience and hence a different set of views was required. For the views selected, there were no accepted notational standards in the industry. The following were the selected views: (1) *Geographic Site View* to communicate the scope of MRO GDS to all users, and defined the global communication needs; (2) *Layered CCSDS Communication Architecture View* to address end-to-end system engineers and CCSDS standard engineers; (3) *Architectures by Mission Phases View* defined the

chronology of system construction, and depicted the significant test bed effort addressing the needs of management and test engineers; (4) *Operations Processes versus Tools View* communicated the areas of change to the mission operation engineers; (5) *Decomposition into Configuration Items View* became a blueprint for development and configuration control engineers; (6) *Network Architecture View* presented a summary for the network engineers and hardware engineers; and (7) *Software Architecture View* defined the interconnection of software components and interfaces to the software engineers and interface designers.

These multiple views of MRO GDS were presented during the MRO Preliminary Design Review and mission scientists commented that for the first time they understood GDS. The multiple view approach to presenting system architecture has gained general acceptance. Future missions at JPL will use a similar approach for architecture design.

1. Overview of MRO and GDS

The objective of the Mars Reconnaissance Orbiter Project is to launch and operate a capable science, communications and reconnaissance spacecraft able to perform remote sensing of Mars surface and provide communications for future Mars missions. The Project includes the following five implementing systems: 1) orbiter system (OS), 2) launch system (LS), 3) the science and payload system (SPS), 4) the mission design and navigation system (MDNS) and 5) the Mission Operation System and Ground Data System (MOS/GDS). Each of these Project systems may have contractors, which are part of the Project.

This paper is concerned only with the GDS portion of the MRO Project.

The GDS is the integrated set of ground software, hardware, facilities and networks that support mission operations. Science processing elements that are required to support operations decisions are included, (e.g., targeting tools, engineering payload analysis tools). Operations teams and processes, and flight system and associated ground equipment are not considered part of GDS. GDS supports all phases of the mission including development, test, and operations. MRO GDS is based upon the Mission Management Office/Interplanetary Network Directorate multi-mission GDS, and incorporates significant inheritance from Mars Odyssey.

2. Challenges in Describing GDS

GDS is a very large multi-mission system which is adapted for every new mission. The system is complex and consists of over 4 million lines of source code. Adaptation is not a trivial undertaking from both size and complexity points of view. For MRO GDS it required 30 work years of effort and procurements of over one million (US) dollars. Other complications include: (a) the system is highly distributed and includes partners from several institutions, companies and countries; (b) large numbers of people from different disciplines contribute to the work and need to understand the GDS development effort.

3. Different Views

To address the above challenges the views detailed in this section were used.

3.1. Geographic Site Overview

This view (Figure 1) communicates the highly distributed nature of GDS and depicts MRO GDS Locations. The site labels are color-coded as follows: Yellow: MRO Management and Launch Sites; Gray: MRO Science Sites; Blue boxes are the different communication complexes around the world, owned by JPL. The intended audience was all users.

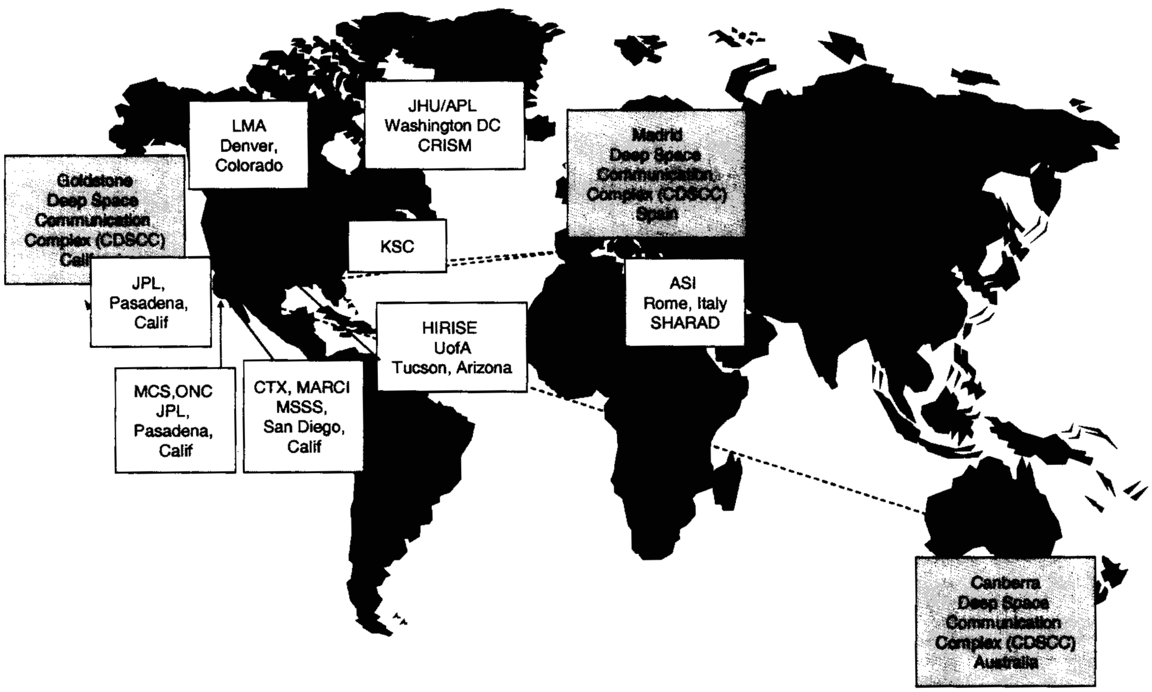

Figure 1. MRO GDS Geographic Overview

3.2. Operations Process View

These three diagrams (Figures 2, 3, and 4) show the relationship between operational processes and software components. Figure 2 shows the nominal operational process flow. Figure 3 depicts the software tools super-imposed on top of the processes. Figure 4 is the GDS subsystem decomposition, within which each color represents a different subsystem.

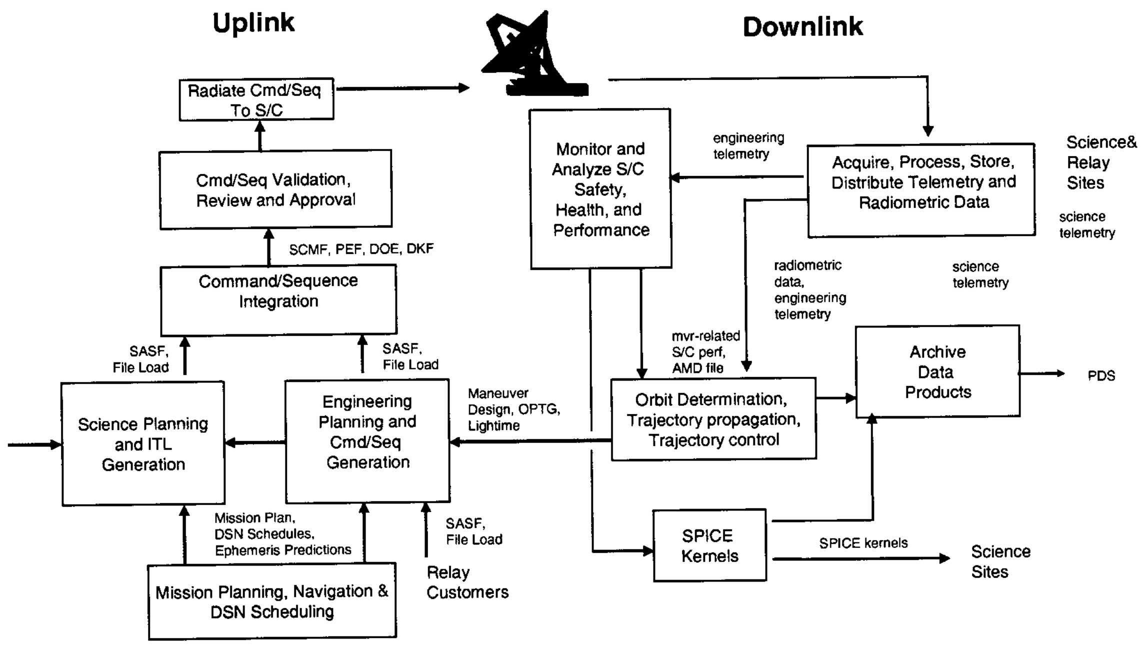

Figure 2: MOS/GDS Nominal Process Flow

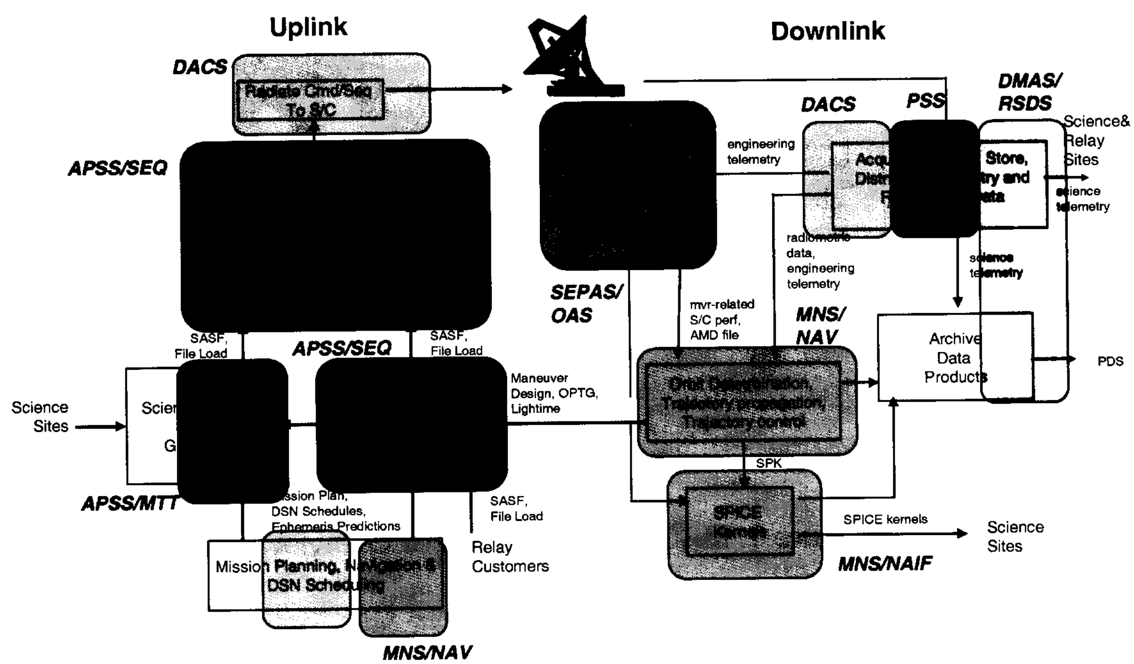

Figure 3: Software Tool Allocation to MOS/GDS Subsystems

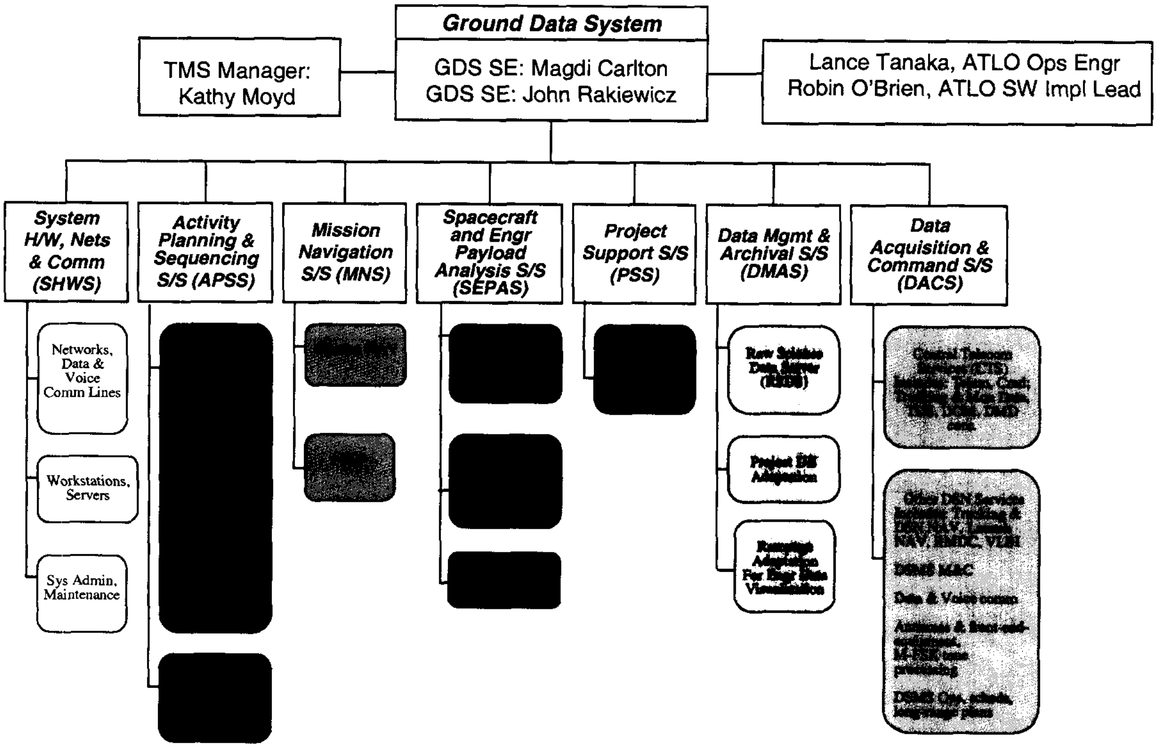

Figure 4: GDS Subsystems Composition

3.3. Architectures by Mission Phase: Pre-Launch, Launch, and Post Launch

The next three diagrams represent the phases of the mission and the components that support each. Figure 5 shows the Assembly, Test, and Launch Operations (ATLO) used during pre-launch. MRO GDS has a unique configuration during launch because GDS receives telemetry data from the launch vehicle. This is demonstrated in Figure 6, which depicts the GDS launch architecture. The third diagram, Figure 7, is the full post-launch GDS where purple represents multi-mission capabilities and green refers to MRO-specific functions. The intended audience is operations personnel, test and integration engineers, network engineers and software developers.

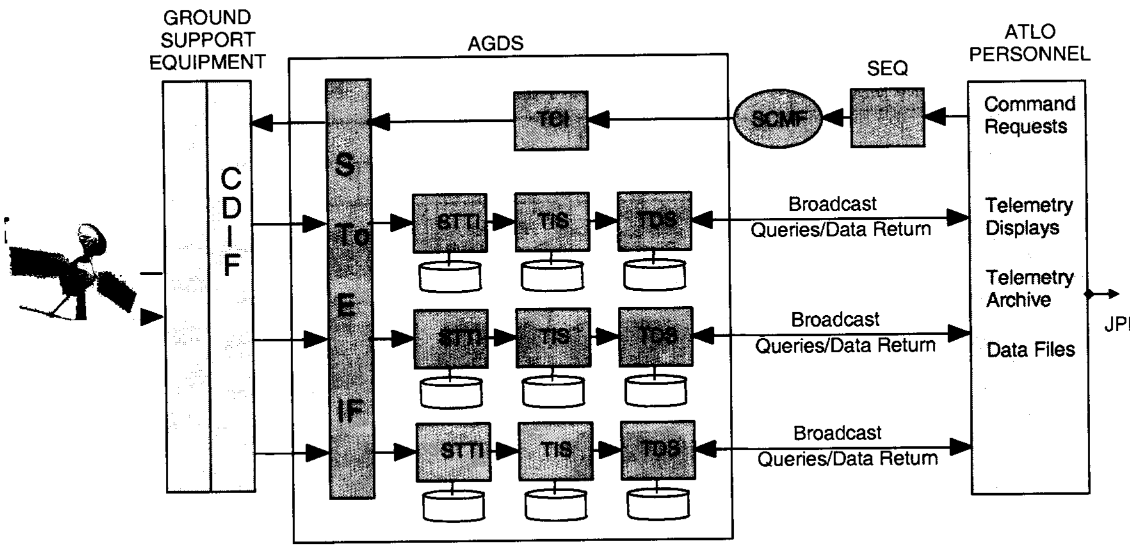

Figure 5: Pre-Launch Architecture

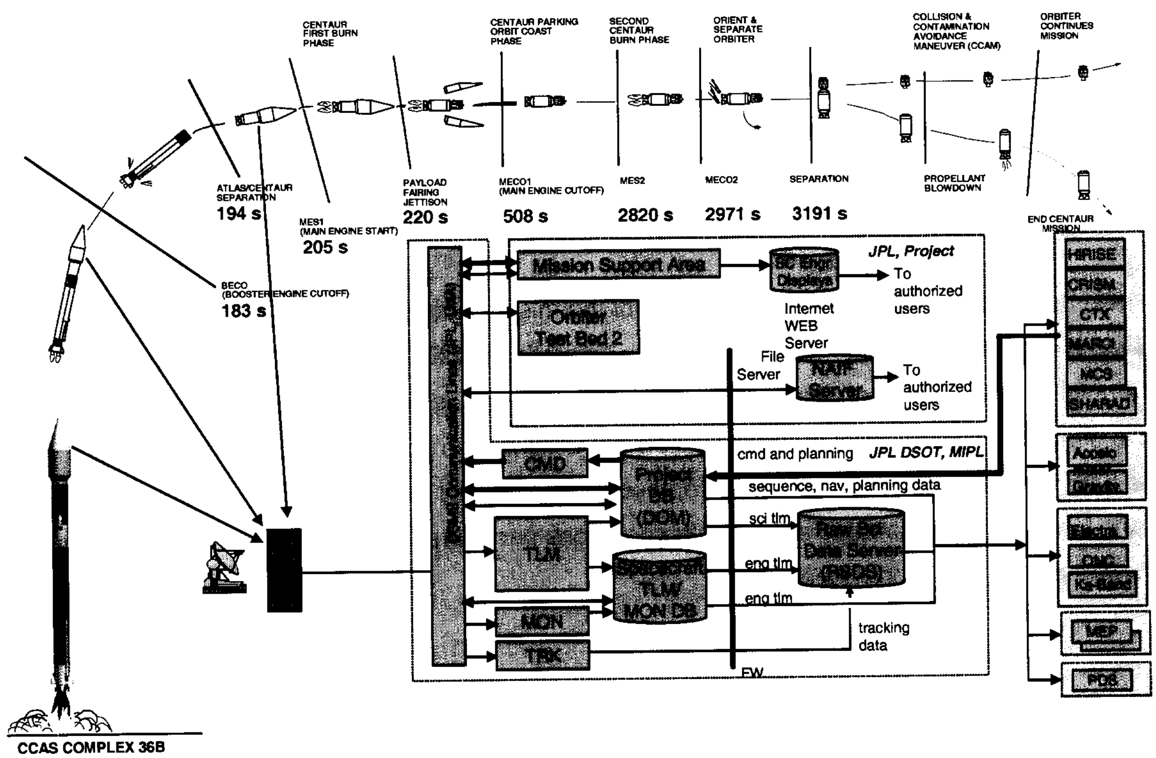

Figure 6: MRO GDS Launch Architecture

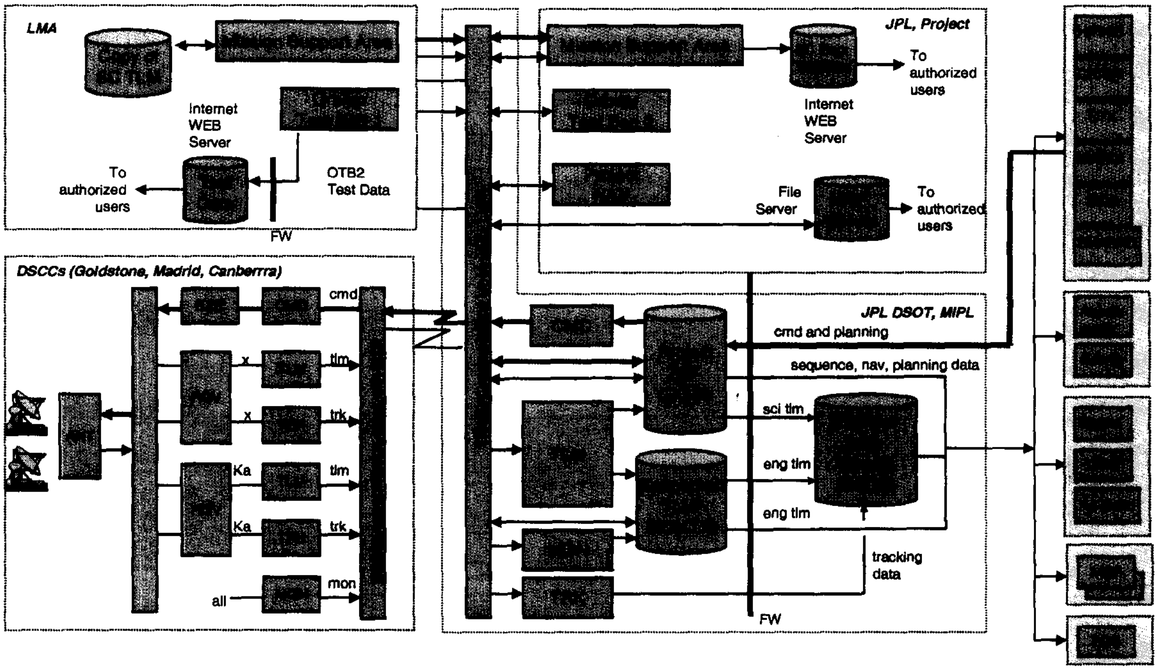

Figure 7: Post Launch Architecture

3.4. Software Architecture

The next diagram, Figure 8, shows the major GDS software components and the interfaces among them. Color-coding of the major software configuration items is the same as Figure 4. A black circle on a line refers to heritage from Mars Odyssey; a red hexagon on a line depicts a new interface. The second diagram, Figure 9, is a sample extracted from the interface dictionary. Data flow numbers from the first diagram are mapped to the names of the interface agreements. Red font refers to a new interface, black font is a heritage. Total number of software interface specifications is over 80. The intended audience for this view is the software engineers and test and integration engineers.

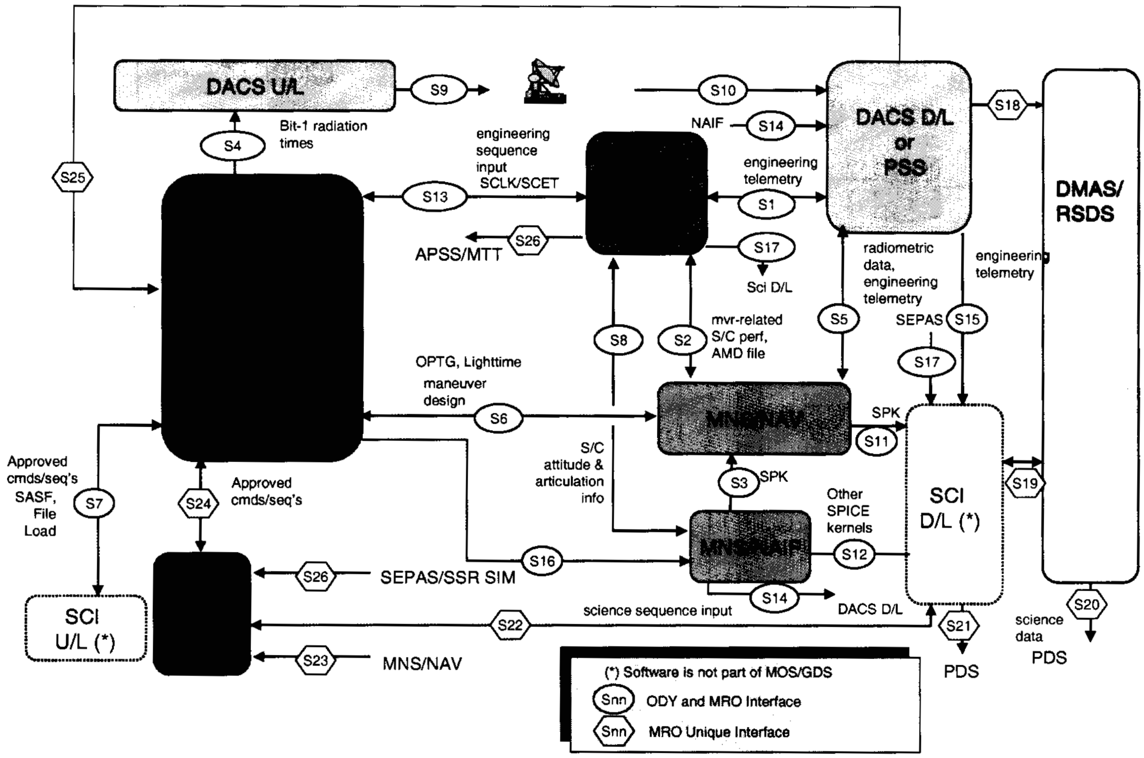

Figure 8: Software Architecture and Interfaces

Data Flow Number	Odyssey		MRO		SIS ID	Description	Acronym
	Producer	Consumer	Producer	Consumer			
S01	DAE	SOE	DACS D/L	SEPAS/OAS	DSN002	DSN Viewperiod File	VP
					SEQ009	Spacecraft Command Message File	SCMF
					TLM001	Expanded Channelized Data	ECDR
					TLM017	MRO TLM SFDUs	
S01	SOE	DAE	SEPAS/OAS	DACS D/L	MIS001	Spacecraft Clock Coefficient File	
					TLM003	Decommutation Map	
S02	NAE	SOE	MNS/NAV	SEPAS/OAS	NAF001	SPICE Ephemeris Kernel	SPK
					NAV001	Orbit Propagation and Timing Geometry File	OPTG
					NAV003	Light Time File	LTF
					NAV009	Maneuver Profile File	MPF
S02	SOE	NAE	SEPAS/OAS	MNS/NAV	NAV011	Maneuver Performance Data File	MPDF
					NAV013	Maneuver Implementation File	MIF
					NAV016	Small Forces Data File (for ODY)	
S03	NAE	AIE	MNS/NAV	MNS/NAIF	NAV004	Spacecraft Ephemeris File and Planetary Ephemeris File	P-File
					NAV007	Planetary Ephemeris File	
					NAV018	Small Forces File	SFF
S03	AIE	NAE	MNS/NAIF	MNS/NAV	NAF004	SPICE Orientation Kernel (aka C-Matrix Kernel)	CK
					NAF006	SPICE Leapseconds Kernel	LSK
					NAF007	SPICE Spacecraft Clock Kernel	SCLK
					NAV018	Small Forces File?	

Figure 9: List of Software Interface Specification (partial)

3.5. Network Architecture

Figure 10 is a depiction of the high-level hardware architecture with each box representing a hardware environment with 10-20 workstations. Some of the boxes are multi-mission sites, some are MRO-unique. Blue represents a contractor's facility; green refers to a site where the instrument is managed; yellow is the Deep Space Network; and gray is Jet Propulsion Laboratory. The intended audience for this view is the hardware engineers, procurement engineers, network engineers, and science users.

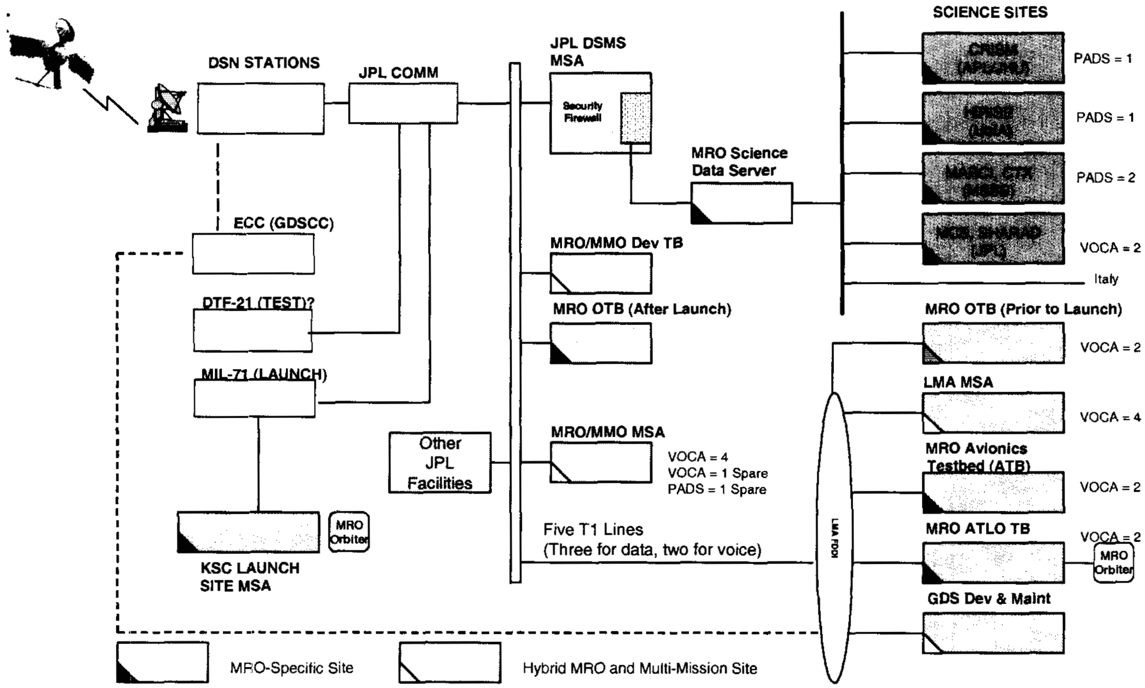

Figure 10: MRO GDS Network Hardware Architecture

4. Conclusion

GDS will be completed before the 2005 launch of MRO. Modeling with multiple views has greatly enhanced communication among Project groups and contributed to mission success. Each project needs to assess which views are needed to meet the goals of systems engineering. The next logical step is to establish standards for the various views and selection of views for mission families.

[1] Philippe Kruchten, "Architectural Blueprint – The 4+1 View Model of Software Architecture", IEEE Software 12 (6), November 1995, pp. 42-50.