Mars Reconnaissance Orbiter, Ground Data System, Receivables and Deliverables (REC/DELs)

Magdi Carlton

MS 264-544

Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive

Pasadena, California, 91109, USA

Magdi.Carlton@jpl.nasa.gov

1. Abstract

This paper presents one JPL element manager's approach to describe a complex Ground Data System (GDS) with its receivables and deliverables (REC/DEL).

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

REC/DEL is a powerful tool for specifying hierarchy of commitments among systems and teams. Receivable of a system is a deliverable of another system. Focusing on tangible products enables the manager to objectively measure progress in a schedule. Jet Propulsion Laboratory mandates the use of REC/DEL for flight projects. Tutorial and training is provided for managers to create integrated REC/DEL database using automated systems. Project schedules are based on REC/DELs. This paper is not focusing on the mechanics of REC/DEL database creation, but it provides a guideline how one systematically creates categories of deliverables and receivables for ground data system components.

There are five systems of the MRO project: Launch System (LS), Orbiter System (OS), Mission and Navigation Design System (MNDS), Science and Payload System (SPS), and Mission Operations System/Ground Data System (MOS/GDS). The outside project interfaces are Interplanetary Network Directorate (IND) Deep Space Mission System (DSMS), Planetary Data System (PDS), Mars Exploration Program (MEP) and Mission Ground Services System (MGSS).

From the point of view of GDS this represents nine major interface groups, counting MOS a separate system. Each group can be considered a “giver” to GDS, and each group can be considered as a “receiver” of some products from GDS. Products can be defined as hardware, network, software, service agreement, interface agreement, documentation, or procedure.

This paper describes the difficulties in creating a complete list of GDS receivables and deliverables due to the complex contractor/subcontractor relationship. The presence of a comprehensive, project-wide work breakdown structure was a great navigation tool. Despite that it was considerable effort to map the work breakdown structure to the organization.

MRO GDS today consists of 16 geographically distributed sites with 130 computers, configured with identical software of 4-5 million lines of code, hundreds of software modules, 80 software interface agreements, dozens of documents. The launch version of GDS was preceded by four other builds. GDS transformed from an orbiter testbed version to an ATLO testbed version to a final operational system. None of them was possible without a comprehensive REC/DEL system, the heart of MRO GDS development schedule. REC/DEL also helped in implementing margin management, earned value, and cross impact analysis.

2. Description of REC/DEL

A strict definition is based on “Network Based Task Management”, Patent 5893074. This patent covers methods implemented on components including an electronic user interface, relational database, and computational component. These components are designed to process input data in a well-defined format called a receivable/deliverable (rec/del) format. Using this format, the project is broken down into a series of smaller components or "tasks". Each task involves a contract between a supplier and a receiver, and results in the production of a "product". Suppliers and receivers can enter up-to-the-minute input data in the rec/del format concerning a particular product. Input data are entered through the electronic user interface which can be e-mail or a user-interface computer program. Data are entered into tables of the relational database in the rec/del format. The input data are then rapidly processed with the computational component to generate output data indicating the status of the project.

Definitions used in this paper rely on a broader concept of REC/DELs tailored for the project. The product described in the patent was not used for MRO/GDS.

3. Why REC/DEL?

Construction of complex systems requires requirements, design, work breakdown structure, and schedule. Sharp focus on the end goal is essential, instead of getting lost in the process oriented paradigm. Classic project management tools are not always enough. The receivable / deliverable (REC/DEL) approach augments traditional project management methods to help resolve a number of critical issues such as:

- Allows a project manager to maintain a level of plan that is manageable while providing for the detail required to achieve success on a task.
- Provides a framework for work delegation and communication of work related issues. This includes assuring that the proper work is done without constraining the methods by which the assignee accomplishes the work.
- Facilitate communications amongst related projects and internally across component sub-projects of a large undertaking such as a space mission.
- Provide a framework for effective quality management.
- Allow for improved risk and change management on a project.

A REC/DEL database assists by capturing and storing the answers to the following critical questions:

- Who is the customer?
- What are the products require by the customer (deliverables)?
- What are the attribute of deliverables?

4. How REC/DELs relate to a project plan

The generation of REC/DELs is based on a common-sense approach to information discovery. REC/DELs use a model of a work unit that defines three states for work: pending, in progress and complete. A work unit is defined by specifying the product or products that are expected to be created. It is constrained by the prerequisite products (information or material) that are needed to accomplish the work unit. A work unit is in pending state as long as sufficient prerequisites to begin the work are not available. A work unit is in-progress until all products are complete. Each work unit has “consumers” and “producers.” Consumers are the groups or individuals that receive a product. Producers are the groups or individuals that perform the work in a work unit and create the products. Work units thus defined can be accumulated into manageable work assignments and added to a project plan.

A REC/DEL network is a mapping of the products of work units to the prerequisites of work units. This defined set of relationships can then be applied to the work assignments to yield project task dependencies.

5. General Construction Steps

5.1. Construction Steps - Phase 1

The generation of REC/DELs begins by definition of the overall context of the effort and understanding the deliverable products for the customer and the managing enterprise. The products for the customer are the reason for the effort. The products to the managing enterprise are those things required to carry-out product sustaining work or to add to the overall body of knowledge about this type of work. This initialization of the REC/DEL process is unique in that the receivables are generally not produced by work units under the control of the project. No work unit that is assignable is defined, only the context of the project. Instead of product "producers" the receivables come from "providers." Once the context is set, the following steps provide the REC/DEL definitions:

Step 1: Identify Deliverables for each consumer
Step 2: Define initial set of work units to provide deliverables
Step 3: Identify receivables required to construct deliverables
Step 4: Communicate assumptions to consumers and producers
Step 5: Make changes and adjustments as needed

5.2. Construction Steps - Phase 2

The process continues iteratively by breaking the products down into continually more granular pieces, first by phase or delivery and then by task. This is similar to producing a work breakdown structure in a traditional project management approach (and from a project management sense is intended to yield the same end result). Phases should have meaning in the context of overall project. For example, in case of MRO GDS Delivery 3 coincides with start of Assembly Test for Launch Operation (ATLO).

Step 1: Divide deliverables into deliveries (and then components, sub-components and so on)
Step 2: Define the receivable required to create the deliverable
Step 3: Define attributes such as necessary condition to begin work, ability to release partial deliverable, etc.
Step 4: Communicate assumptions to consumers and producers
Step 5: Make changes and adjustments as needed

Step 6: Iterate throughout entire life cycle

6. MRO GDS Implementation Examples

Six examples were selected. The first two deal with decomposition, as it is defined in Step 1 of Section 5.1. Third and fourth examples deal with deliverables as defined in Steps 2 and 3 in Section 5.1. These views are the closest to the actual REC/DEL database. The last 2 examples are schedule related. One is at a macro level, and the other is a section of the actual MS schedule used for construction of GDS. These illustrate Step 1 to 3 of Section 5.2.

6.1. Setting up the Context

First order of priority was to determine the place of GDS in the MRO Project System Hierarchy. There are five systems of the MRO project: Launch System (LS), Orbiter System (OS), Mission and Navigation Design System (MNDS), Science and Payload System (SPS), and Mission Operations System/Ground Data System (MOS/GDS). The outside project interfaces are Interplanetary Network Directorate (IND) Deep Space Mission System (DSMS), Planetary Data System (PDS), Mars Exploration Program (MEP) and Mission Ground Services System (MGSS).
From the point of view of GDS this represents nine major interface groups, counting MOS as a separate system. Each group can be considered a “provider” to GDS, and each group can be considered as a “consumer” of some products from GDS. Refer to Figure 1.

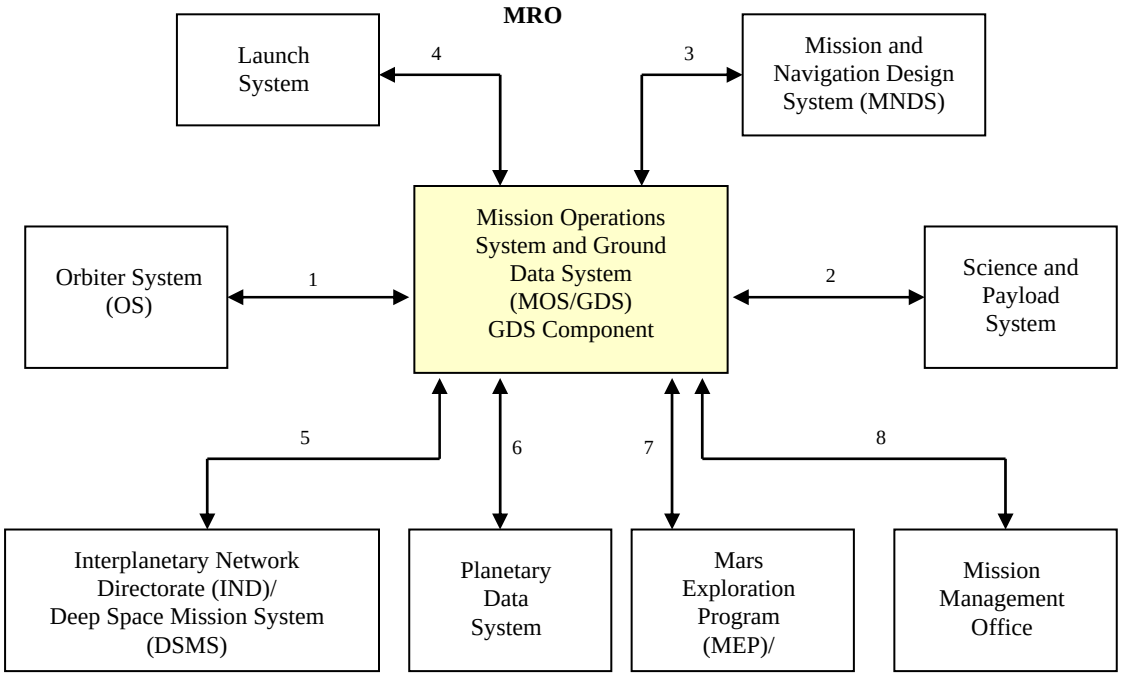

Figure 1. MRO GDS System Context for REC/DELs

6.2. Subsystems of GDS

Figure 2 describes the next level of breakdown of GDS. These components correspond to the basic work units which produce all GDS deliverables.

6.3. GDS Deliverables to Payload System

Table 1 is the negotiated deliverables from GDS to the Payload System. The required dates are part of the GDS Delivery 3 Schedule. This is a summary view of the REC/DEL database and reflects a specific consumer's point of view. In the actual database, data was represented in more detail, and more attributes were recorded. For example, not only were the model number and configuration of the workstation listed, but the purchase order, inventory tag, and shipper numbers were recorded.

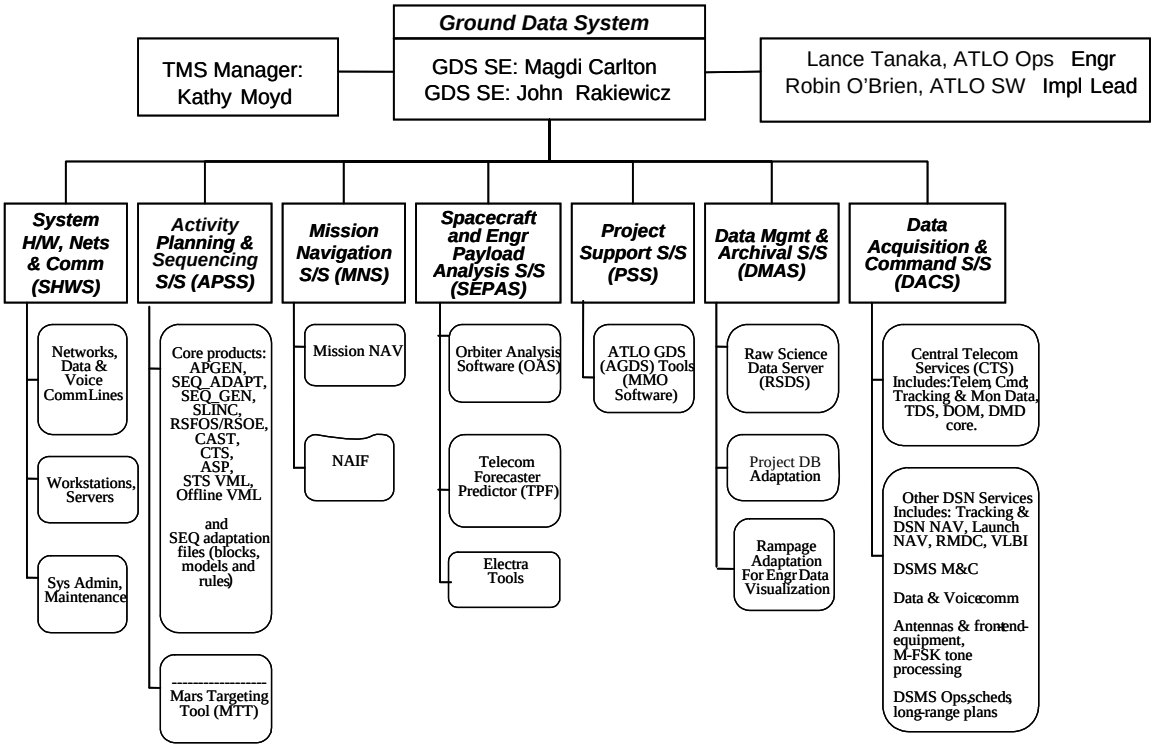

Figure 2: GDS Subsystems and Components

Number	Item	CTX/MARCI, HiRISE, CRISM	MCS and SHARAD at JPL	SHARAD in Italy	Accelerometer, Gravity Experiments, Electra, ONC
1	**Workstation: Science Planning and Operations Computer (SOPC) with DVD Reader and CD-ROM Writer**	**Yes, one unit to each location**	**Yes, one unit to each location**	**No**	**No**
2	**Workstation: SOPC Backup at JPL**	**Yes, one shared unit at JPL**	**Yes, one shared unit at JPL**	**Not applicable**	**Not applicable**
3	**Circuits: Dedicated Dual T1 Lines**	**Yes, one pair to each location**	**No** (Institutional lines will be used instead)	**No** (Secure Internet will be used instead)	**No** (Institutional lines or public Internet will be used instead)
4	**Voice Equipment: Voice Over IP "PADS"**	**Yes, one unit to each location**	**No** (VOCA will be used	**No** (Dial In	**No**

			instead)	Modem will be used)	
5	**Voice Equipment: VOCA**	**No** (PADS used instead)	**Yes**	**No**	**No**
6	**Remote Comm Terminal (RCT) (dual homed)**	**Yes, one unit to each location**	**Not applicable**	**No**	**No**
7	**Internet connection via RCT**	**Yes, one connection to each location**	**No** (Institutional lines will be used instead)	**No** (ASI will take care of Internet connection)	**One unit to each experiment**
8	**Virtual Private Network Encoding/Decoding Service**	**No**	**No**	**Yes** (VPN HW provided by ASI)	**No**
9	**SOPC Software**	**Yes**	**Yes**	**No**	**No**
10	**Raw Science Data Server (RSDS) Client Software**	**Yes**	**Yes**	**Yes**	**Yes**
11	**Training, Documentation**	**Yes**	**Yes**	**Yes**	**Yes**
12	**Instrument Science and Engineering Data via RSDS**	**Yes**	**Yes for MCS, No for SHARAD**	**Yes**	**Yes**
13	**Spacecraft Engineering Data via RSDS or via TDS Query**	**Yes**	**Yes**	**Selected parameters only via RSDS**	**Yes**
14	**Read/Write access to Project Database**	**Yes**	**Yes**	**No**	**Yes**
15	**Ancillary Data via NAIF Server**	**Yes**	**Yes**	**Yes**	**Yes**

Table 1: GDS Deliverables to Payload System

6.4. SHWS Deliverables

Table 2 describes the deliverables of the “Communication” component of the System Hardware, Nets, & Comm Subsystem (SHWS). First part of the table lists the one time deliverables related to installation of circuits. Second part of the table describes the recurring “service” deliverables. This view of the REC/DEL database is to communicate deliverables amongst teams. In the actual database, we also record the name of the carrier and charges associated with each line item.

ITEM #		QTY
	One Time	
1	Remote Comm terminals for HiRISE, CRISM, and CTX/MARCI	2
2	VPN Accelerator (Russ Byrne)	1
3	JPL Interface to SOPCs (Email from Russ Byrne)	2
4	Circuits Install - HiRISE, CRISM, CTX/MARCI	6
5	Circuit Install - first T1 in LMA	1
6	Circuit Install - T1---ATLO	3
7	Routers U/G (From Markley's Material)	1
	Annual	
8	VOCA (JPL 7, LMA -10)	
9	Security and Common Network Services	
10	Network Administration	1
11	Circuit- 1 T1 between JPL and LMA for life of mission	1
12	Circuit -1 T1 beteen JPL and LMA for life of mission- MRO share of multi-mission voicw T1s	1
13	Circuits - LMA 3 T1s (July 2004 to June 2005) 13 months (4 mos. In FY04, (mos. In FY05)	3
14	Circuits - MRO share of multi-mission voice T1s	
15	Circuit - LMA 1 T1 for life of mission	
16	Circuits - HiRISE 2 T1s 11.5K each; commercial, dedicated lines (Schedule Start March 1, 2004)	2
17	Circuits - CRISM 2 T1s 29.5K each; commercial, dedicated lines (Schedule Start March 1, 2004)	2
18	Circuits - CTX/MARCI 2 T1s 8.7K each; commercial, dedicated lines (Schedule Start March 1, 2004)	2
19	Circuit - KSC	

Table 2: Deliverables of SHWS Subsystem

6.5. GDS Deliveries

GDS was constructed in five increments. Each build had its associated list of deliverables and receivables. Table 3 is an example of GDS Delivery 3. This is a very high level summary of REC/DELs for the purpose of management overview. The next level of detail is recorded in the schedule, which is 19 pages long. The detailed schedule is not enough to keep track of all the deliverables. The only place everything is found is the actual REC/DEL database.

Functional Capability	*Receivables*			*Deliverables*			
	Item	*Due Date*	*From*	*Item*	*Due Date/ Need Date*	*To*	*Final User*
Support for AOS Frame Accountability; RSDS final version; System Integration and ATLO Support (Solaris 9)	For D/L: Prelim Release of TLM Dictionary, CCL, TDL, CPT; For U/L: Prelim release of Flight Rules, Command DB/CDL	11/1/2003	LMA	LMA-JPL Comm Upgrade	3/12/2004/ 4/12/2004	LMA I&T	FSW Build 2-6 Telecommand, S/C, GN&C, Payloads, and Launch/Updates), OTB-1, OTB-2, SoftSim, ATLO
				GDS Software, includes AGDS	7/1/2004/ 8/1/2004		
				SOPC WSs and Comm Lines	4/9/2004	SOPC Sites	
				SOPC/Science Software	7/1/2004/ 8/1/2004	SOPCs/Science Sites	
				GDS Software and MSA Hardware	7/1/2004/ 8/1/2004	JPL MSAs; LMA MSA	

Table 3: GDS Delivery 3 REC/DELs

6.6. GDS WBS and Schedule

Table 4 is a segment of a 19 pages long schedule. This page illustrates the subcomponents of each delivery from the point of view of system-level integration and test. For example, “Rec” Receivables for Delivery 3 are listed as components of GDS Delivery 3 prior to integration and test.. Line 471 represent the actual work, I&T, which producing a “Del” Deliverables for GDS Build 3.

ID	WBS	Task Name	Start	Finish
456	**6.4.2**	**GDS 3**	**11/7/03**	**5/28/04**
457	6.4.2	Development of System	12/17/03	1/19/04
458	6.4.2	Rec AMMOS TTC & DMV 28.1 DDR	11/7/03	11/7/03
459	6.4.2	Rec AGDS Tools (3) (MRO version for Sys Integration)	3/9/04	3/9/04
460	6.4.2	Rec SEQ Core (3) (Version 27.1 with MRO Mods)	1/12/04	1/12/04
461	6.4.2	Rec SEQ Adaption (3) (MRO version for Sys Integration)	3/9/04	3/9/04
462	6.4.2	Rec Rampage Adaption (3) version for sys integration	5/1/04	5/1/04
463	6.4.2	Rec NAIF (3) MRO Version for Sys Integration	5/1/04	5/1/04
464	6.4.2	Rec NAV (3) MRO Version for Sys Integration	5/1/04	5/1/04
465	6.4.2	Rec TFP (3) version for sys integration	5/1/04	5/1/04
466	6.4.2	Rec OAS (3) MRO version for Sys Integration	4/30/04	4/30/04
467	6.4.2	Rec MTT (3) Version for Sys Integration	4/30/04	4/30/04
468	6.4.2	Rec Electra Tools (3)	4/30/04	4/30/04
469	6.4.2	Rec RSDS (Final version) 3	5/1/04	5/1/04
470	6.4.2	Rec GDS Network Hardware (3) (SCPC commline)	4/9/04	4/9/04
471	6.4.2	GDS sIwtests for SystemI&T delivery	5/3/04	5/28/04
472	6.4.2	Del GDS Build 3	5/28/04	5/28/04
473	**6.4.2**	**GDS 4**	**6/1/04**	**10/29/04**
474	6.4.2	Development of System	6/1/04	8/3/04
475	6.2.2	Rec AMMOS TTC&DMV29.0 DDR	6/1/04	6/1/04
476	6.4.2	Rec AGDS Tools (4) (MRO version for Sys Integration)	8/24/04	8/24/04
477	6.4.2	Rec SEQ Core (4) (version 28.0 with MRO Adaption)	6/28/04	6/28/04
478	6.4.2	Rec SEQ Adaption (4) (MRO version for Sys Integration)	7/27/04	7/27/04
479	6.4.2	Rec Rampage Adaption (4) version for sys integration	9/1/04	9/1/04
480	6.4.2	Rec NAIF (4) MRO Version for Sys Integration	9/1/04	9/1/04
481	6.4.2	Rec OAS (4) MRO version for Sys Integration	9/1/04	9/1/04
482	6.4.2	Rec MTT (4) Version for Sys Integration	9/1/04	9/1/04
483	6.4.2	Rec Electra Tools (4)	9/1/04	9/1/04
484	6.4.2	GDS sIwtests for CRT delivery	9/2/04	10/29/04
485	6.4.2	Del GDS Build 4	10/28/04	10/28/04
486	**6.4.2**	**GDS 5**	**10/29/04**	**3/14/05**
487	6.4.2	Development of System	10/29/04	12/30/04
488	6.2.2	Rec AMMOS TTC&DMV29.1 DDR	11/8/04	11/8/04
489	6.4.2	Rec AGDS Tools (5) (MRO version for Launch Support)	12/15/04	12/15/04
490	6.4.2	Rec SEQ Core (5) (Version 28.0 with MRO Adaption)	12/6/04	12/6/04
491	6.4.2	Rec SEQ Adaption (5) (MRO version for Launch Support)	1/3/05	1/3/05
492	6.4.2	Rec Rampage Adaption (5) version for launch support	2/1/05	2/1/05
493	6.4.2	Rec NAIF (5) MRO Version for Launch Support	2/1/05	2/1/05
494	6.4.2	Rec OAS (5) MRO version for Sys Integration	2/1/05	2/1/05
495	6.4.2	Rec MTT (5) Version for Sys Integration	2/1/05	2/1/05
496	6.4.2	Rec Electra Tools (5)	2/1/05	2/1/05
497	6.4.2	Rec GDS Computer Hardware (5) (LMA-MSA)	2/3/05	2/3/05
498	6.4.2	GDS sIwtests for Launch delivery	2/1/05	3/14/05
499	6.4.2	Del GDS Build 5	3/14/05	3/14/05

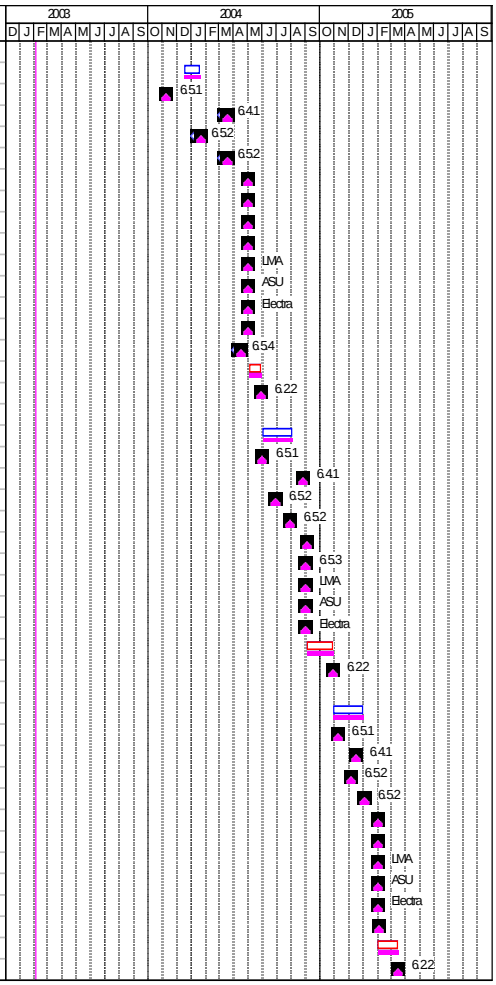

Table 4: Part of GDS Schedule with REc/DELs

References

United States Patent 5893074 Network Based Task management