DEVELOPMENT OF A REQUIREMENTS REPOSITORY FOR THE ADVANCED DATA ACQUISITION AND PROCESSING SYSTEM (ADAPS)

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ABSTRACT

Standards lead to the creation of requirements listings and test verification matrices allow developer and acquirer to assure themselves and each other that the requested system is actually what is being constructed. Further, in the intricacy of the software test description, traceability of test process to the requirement under test is mandated so the acceptance test process can be accomplished in an efficient manner. In the view of the logistician, the maintainability of the software and the repair of fond faults is primary, while these statistics can be gathered by the producer to ultimately enhance the Capability Maturity Module (CMM) rating of the vendor.

KEY WORDS

Requirements, Validation, Verification, Traceability, database.

INTRODUCTION

Software development processes have driven the methodology of development for the past two decades with myriad required documents, plans, schedules and such. Several of these processes emerge as likely candidates for utilization of modern database technology. None is more appropriate for this designation than the processes of software test and verification and validation (V&V).

Invoked standards lead to the creation of requirements listings and the test verification matrices that allow both developer and acquirer to assure themselves, and each other, that the requested system is actually what is being constructed. Further, in the intricacy of the software test description (STD), traceability of test process to the requirement under test is mandated so the acceptance test process can be accomplished in an efficient manner.

In the view of the logistician, the maintainability of the software and the repair of found faults are primary. Statistics regarding these can be gathered by the developer and tester to ultimately enhance the CMM evaluation rating of the vendor.

This paper presents a case study of a database application that provides to the various stakeholders a single face data structure providing historical requirement, test and fault tracking, as well as flexible report generation, for all user levels.

The Project

The technology growth in the Aerospace industry, as manifested and embodied in the current fighter technology, presents many challenges in the area of flight test and data processing. The Air Force Flight Test Center (AFFTC) at Edwards Air Force Base supports operational and developmental flight testing programs. In this charter, the evolution of the test systems is as important as the evolution of the USAF fighters, bombers and special purpose aircraft that utilize the test ranges. This concept is brought to bear in the design and implementation of the AFFTC's latest generation of telemetry data systems-the Advanced Data Acquisition and Processing System (ADAPS) program. This program possesses elements with a significant software developmental effort that generate a system, which will efficiently provide capability for premier flight test support. The current development incorporates the planned approach of commercial-off-the-shelf (COTS) and government-off-the-shelf (GOTS) elements as basic to the system solution. Collectively, COTS and GOTS are referred to as non-development items (NDI). The state of the program has advanced through full development, delivery and performance testing. The system is currently deployed in support of flight testing at Edwards AFB.

When ADAPS was first introduced, the concept of including NDI was in its embryonic stage. [1] 'Re-use' and 'Open System' were institutional phrases that evoked followings only among purists wishing to theorize concerning cost savings. The ADAPS was conceived with these and other architectural innovations revolving about the evolving concept of a distributed systems design, allowing data flow at the base level and implementation of workstation terminals for data processing and display. If one were to review the early system concepts, today's manifestation would seem awesome. Such have the advances in computer technology been. This, though, is one of the incipient attributes of the ADAPS concept–adaptability to the state of the technological art. While the efforts at software generation for ADAPS were underway, the most changeable feature on the system landscape was the component parts.

BACKGROUND

The central system requirements introduced to the development process at Edwards were set forth in the Operational Requirements Document (ORD) and were driven by the anticipated telemetry data rates, data complexity, and perceived processing requirements. An exponential increase in complexity of analysis brought on by advances in airframe construction and weapons systems provided additional impetus for advancement. The ADAPS project was parsed into four segments. These were: 1) Automated Test Data Management System (ATDMS); 2) Real Time/Postflight Processing (RT/PFP); 3) Auxiliary Processing and Analysis System (APAS) and 4) AFFTC Post-Test Analysis System (APTAS)[2]. Each segment was assigned an Air Force Project Manager and a subcontract organization to accomplish the development. A fifth organization-the base Systems Engineering/Technical Assistance (SE/TA) subcontractor provided program systems engineering, software quality assurance and testing responsibility.

Automated Test Data Management System

The flight test scenario is programmed at the mission preparation workstation (MPWS). Here, onboard instrumentation is characterized as data cycle, transmission scheme, sensor characteristics (type, calibration factors, etc.) and a description of the processing to be performed in the telemetry pre-processor (TPP-OS/90 ™). The control room displays are defined, as well as requirements for data recording, chart recording, and function key definitions. The scenario is compiled and encapsulated into the mission load database (MLD). The MLD now contains two main elements–the mission configuration database (MCD) and the TPP setup information–the telemetry configuration files.

Real Time/Postflight Processing

The ADAPS system design is depicted in Figure 1. The RT/PFP segment was first on-line, having had a prototype system built in a laboratory environment for development contractors' use. Now the ADAPS consisted of the TPP, providing data to the distribution system (Universal Memory Network [UMN]) for display on the mission control room workstations (MCWS – SGI Indigo2). The original design called for the APAS functionality to be hosted upon the same MCWS in a multi-boot personality. In this manner, the functionality of a given workstation could be reconfigured at mission start for maximum flexibility. The design of the APAS segment called for two concurrent paths for the real-time data from the TPP–one path to the UMN and another to the auxiliary processor. The APAS MCWS's would be connected to a separate high speed data distribution (HSDD) network, again operating in parallel with the UMN. The implementation of the HSDD is high-speed (HS) Ethernet from TPP to the compute data server (CDS) and Asynchronous Transmission Mode (ATM) for workstation data. The hardware depicting the initial operational configuration (IOC) is presented in Figure 2.

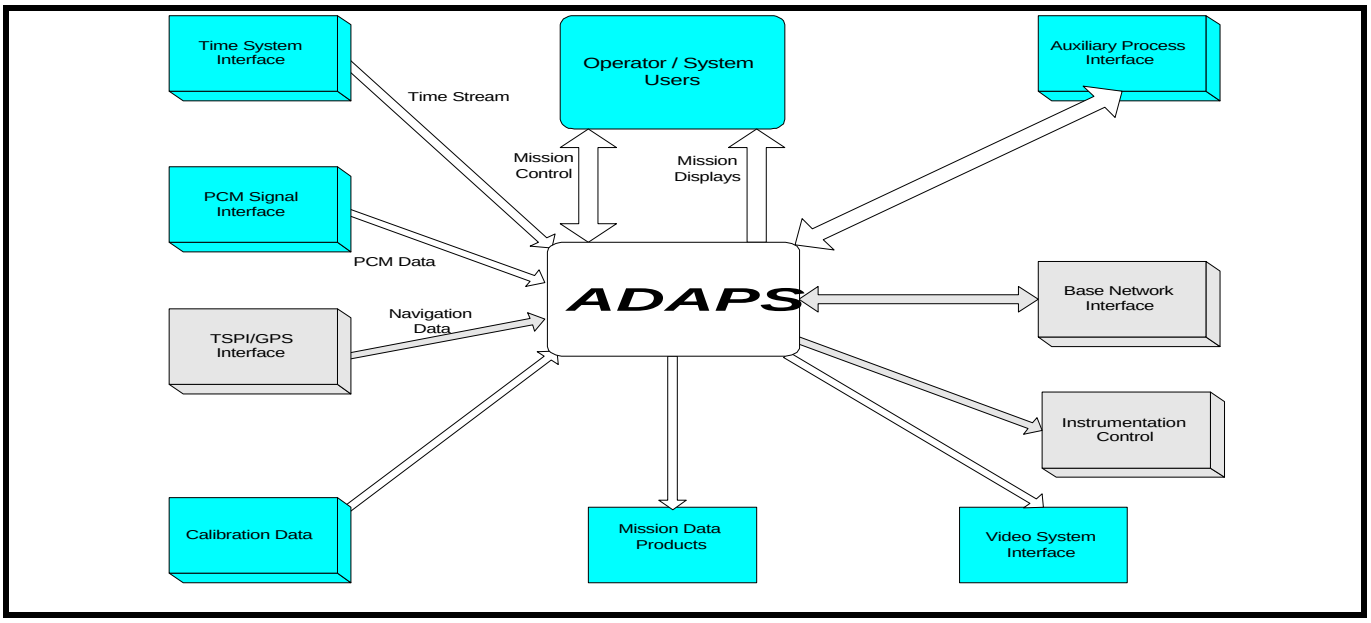

Figure 1: ADAPS Context Diagram

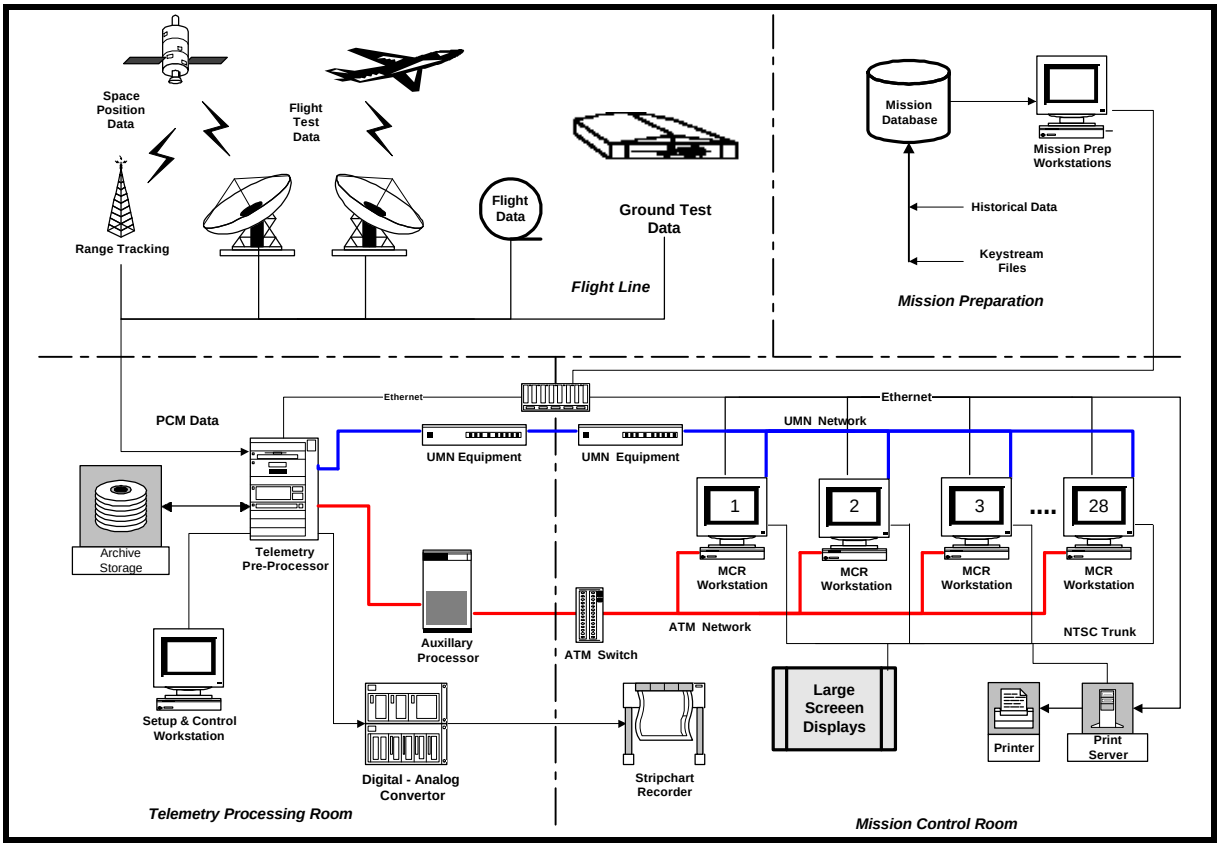

Figure 2: ADAPS Hardware – IOC Implementation

The RT/PFP software consists of two basic constructs. The first of these is the vendor software for the OS/90™. The operational RT/PFP software, the second element, integrates the vendor package, several COTS products, as previously mentioned, and a large segment of reuse from the Mission Display Subsystem (MDS) project[2]. The main functionality may be explained in the following manner.

When required, the appropriate MLD is loaded onto the setup and control workstation (SCW) and decomposed. The MCD is then distributed to each of the MCWS as they log in as operationally ready. Transmission takes place over regular Ethernet paths. The balance of the MLD elements are used to properly configure the TPP for operation.

The system underwent extensive requirement verification testing after initial installation. Since the RT/PFP segment was online ahead of the other segments, this system backbone received the major share of testing activity. The original deployment utilized the UNIX derivative operating system IRIX for the SGI environment. The initial version of IRIX was 5.2, but was upgraded during development. Major software subsystems were also the subject of revision, as the release of IRIX 5.3 required different interfaces and links. The most prominent of these was the DataViews™ package, extensively utilized for MCWS display to support the RT/PFP segment.

After the system is initialized and placed in an operational state, the telemetry data is ingested by the TPP, decommutated, processed and output to the UMN, CDS or strip charts as required. The format of data in the UMN resembles a data cycle in a current value table (CVT) view. The unique form in the UMN is that high-rate data is stored in a circular buffering scheme–rather like a 'three dimensional CVT'–to enable efficient processing at the MCWS. While not entirely a new concept, the ease of definition of this element allows the high rate nature of current data to be completely captured for analysis in a near-real-time system.[3]

The MCWS accesses the CVT data through the UMN as if it were part of the workstation memory. Applications such as display generation, local data recording, data analysis program (DAP) applications and system control are executed as required from the distributed MLD.

Auxiliary Processing and Analysis System

The APAS segment was envisioned to be flexible and provide ancillary processing systems with the access to real– and near-real-time flight test data. As such, several APAS configurations were thought to be available for inclusion. The initial instantiation of the APAS is the Interactive Analysis and Display System (IADS), first deployed to meet the rigors of structure and flutter testing for new aircraft.

The IADS package consists of data processing algorithms used mainly for frequency domain analysis of data in near-real-time. The CDS acquires data from the TPP (parametric definitions are defined in the MLD as to which measurands are to be sent to the CDS). The CDS acquires data via HS Ethernet link from the TPP and then sends these to the appropriate IADS workstation (IWS). The development effort included the creation of NT™-based plot, display and computation packages that will find extensive re-use application as ADAPS evolves.

AFFTC Post-Test Analysis System

The final segment, APTAS, is essentially a stand-alone element of the ADAPS system. It is an engineering tool employed to analyze flight-test data by using a common toolbox of algorithms, visualization utilities, and data management utilities.

The essential functions of APTAS are analysis, management, and visualization. These functions can be described as follows:

- ANALYSIS. Data analysis provides the user with the tools to analyze post-test data through each generation and perform comparative analysis between this data and the modeling or simulation data.
- DATA MANAGEMENT. Data management is a collection of file directories, databases, and application utilities that perform all of the tasks associated with the organization, storage, access, and tracking of post test data.
- DATA VISUALIZATION. Data visualization allows the user to visualize data in the form of plots and lists. It includes both onscreen interactive data display as well as hardcopy prints of plots and lists.

REQUIREMENTS GENERATION

The requirements gathering process employed a Total Quality Management (TQM) process called Quality Functional Deployment (QFD). QFD is simply a process in which the needs of the ultimate user (customer, stakeholder, etc.) are considered prior to the design phase of a project. The classical approach, as used here, requires the system engineering function to interview the stakeholders and ascertain the capabilities they would prefer in the ultimate system. The SE/TA contractor assumed the task. This process provided a cohesive set of required capabilities that were deemed important to the stakeholders taking part in the interview process. Since the task of acceptance testing also fell to SE/TA, the development of a V&V matrix, error reporting and tracking scheme, and an historical content revision process were also of immediate concern. Initial requirements analysis, flowdown and module assignment were the task of the developing contractor.

The QFD process produced 7,024 desired capabilities from the ORD, interview process and other inputs. Using classical TQM PARETO processes an initial slate of 1,375 requirements were extracted.[4,5] This original set was reduced to a core of 974 requirements and then decomposed into 1,674 derived requirements. The MIL-STD-2167A was initially followed, progressing to the variants offered by adoption of MIL-STD-498A. A representative set of management, development and test documentation was produced. These continue in use today as an aid in system maintenance and revision. These documents included System/Segment Specifications (SSS), System/Segment Design Documents (S/SDD), Software Development Plans (SDP), Configuration Management Plan (CMP), and a Software Test Description (STD).

The initial database contents included those requirements that were mentioned on a high percentage (more than 75 per cent) of the respondents questionnaires. Those stated on 50 percent were included as "good for the system" and those on 25 percent or less were adjudicated to be "nice to have." Four main populations were interviewed: flight test centers, airframe manufacturers, Air Force Test Pilot School, and general industrial contributors.

The development of the unique ADAPS database (ADB) was the result. In this database, created initially in **Q&A**, multiple tables contain the essential requirements. The original source and text of the requirement was included, including the paragraph citation. A contributor to the database was the SSS document, providing multiple citations of the same basic requirement, and thereby increasing the number of trees required to provide the systems requirements matrix (SRM).

ADDED COMPLEXITIES

As the developers (at this stage there were four) worked with the original SRM, allocations to specific builds were made. A phased development (now characterized as spiral) was selected to allow testing of developmental efforts as constructed, allowing a saner approach to the acceptance and functional testing. Test process for requirement verification, sequential operation fault tables with requirement association pointers, module assignment(s) for the software elements created to address requirements, module build assignments and requirement build assignments and status would all be added at later stages.

This, however, added complexity to the requirement traceability. Where was requirement 137 (for example) accounted for? In which segment? Which build? Has it been tested? Was it satisfied? Where in the test procedure (STD) was it accounted for?

In actuality, each developer had her/his own SRM, multiplying the complexity for the SE/TA watchdog. Management of one SRM is difficult enough when the validation

contractor is a different company than the developer, and each is often at odds with the other. In this case, the records must be consistent, accurate and timely.

FIRST SOLUTIONS

As ***Q&A*** waned and other relational database engines came to the front, the requirements were destined to be transcribed into a modern form database. But which one? Some thought (and effort) was given to migrating to Oracle™, but the eventual efforts were placed in ACCESS™. At that time SE/TA had control of only the requirements, and the developers were dashing about with the structures necessary to document their progresses and processes–other databases, spread sheets, Software Development Folder (SDF) structures and the like. At one time, there were six forms of ACCESS™ databases in various states of accuracy, defining the progress of the ADAPS project. Worse, ACCESS™ 2.0 was now on the scene and some organizational units embraced it as the advance that it was and needed now to provide sensible accountability. This did nothing but complicate the SE/TA task.

As the release dates drew close, and tracking responsibilities (and many headaches) now loomed for SE/TA, a concerted effort to combine the myriad of data structures took place. It was important as the V&V designee that SE/TA have an accurate, reliable and informed sense of where the project stood at any given day. With the support of the Program Office and the help of the various development contractors involved, the first attempts at an integrated data structure were begun.

ADAPS REQUIREMENTS DATABASE

At the base of the structure were the requirements. At this time, since the actual transcription of data from previous forms was necessary, the original wording and citation was not present. Economies of scale had presided and only the accepted requirement verbiage was input. The basis for the requirements database (RDB) was the SSS, incorporating any accepted engineering change proposal (ECP) enacted by the Configuration Control Board (CCB). As the maturity of ACCESS™ reached to the ACCESS™ 7.0 level, the tabular structures of the developers were added to gain a perspective as to the module or unit in which a requirement was to be addressed, and when it might be expected to be in the target system for testing.

The work on STDs was well underway and the RDB became the cornerstone for the test procedure. Requirements were cited in one section of the test procedure, requirement number parenthetically added to the procedure step(s) at which success of the test could be determined and the step numbers for qualification were added to the requirement attributes in the RDB. The RDB now had the structure of an SRM, development path document and traceability matrix in one structure. Using or developing unique queries, an

engineer could then establish the satisfaction of any authenticated requirement or the schedule for such to be included in a software release.

SYSTEM PROBLEM REPORTS

The evolution of development moves eventually to testing. System problem reports (SPRs) are generated whenever a problem is found in a unit of released code. The SPR contains information such as the system configuration, software releaser number/version, workstation number involved, process involved, etc. In short, enough information for the responsible party to understand the problem and establish a path for correction.

The first releases of the RT/PFP software were tested in June 1997. The faults found were reported on the SPR Form, a form fill word processing application available to all testers and frontline managers. An example of this form is presented in Figure 3. When a problem was found, the data entered on the form was passed to the SE/TA organization for entry into the SPR database. From there, tracking, report generation and V&V tasking was viable.

Eventually, this form became integrated into the SPR Database and available via network access to any concerned user or developer of ADAPS. Several problems occurred during the original deployment of the SPR Database in line with the form fill application. Permissions were necessary to allow only certain fields of the form to be manipulated by certain groups of users. One did not want the casual flight test engineer hypothecating concerning cause or cure for an observed system miscue.

FINAL STRUCTURE

Work began in the fall of 1998 to integrate the two ADAPS-related databases. The most stringent demand placed upon a user reporting a problem via the SPR form was citing the individual requirement not being satisfied. This meant that the person entering the data must open the RDB to find the associated requirement number, reopen the SPR Database to enter the data just obtained and complete entry on the original form. The organization responsible for correction must then execute the same procedures, unless the assigned programmer was familiar with the requirement verbiage. The SE/TA database analyst suggested to the Program Office that the integration of the two structures would be a timesaving task and laid out a plan to achieve the goal. As a background task, the two structures were integrated to form the ADAPS data repository (ADR).

As the 1999 opened, the completion of the integration task was announced. Now the efforts in resolution of the permissions problems were paramount, as one did not want the average user to be able to change requirement data!

ADAPS SPR REPORT

SPR Number: 1236

Originator:	B. Hafner	Segment:	RT/PFP	CURRENT STATUS:	OPEN
Phone No.:	75288	Subsystem:	MDS	DATE of Open:	2/25/99
		CI:	AUG	DATE of Hold:	
				DATE of Monitor:	
				DATE of Disapproved:	
				DATE of Canceled:	
				DATE of Closed:	
Title:	Testing Repository Example				
Key Words:	TEST				

Problem Statement Section:

Segment Version: 3.3.2 System: TPP 129 IRIX Version: 5.3 OS/90 Version: 4.1.1

Detailed Description of System Problem(s):

Testing process.

Problem Type: Hardware: X Software: Unknown: Documentation:

Related Document(s): SSDD, STD, SSS
Affected Requirement(s): 128, 3321

Root Cause Section:

Affected Unit(s): ALL

Description of Root Cause(s):

Examples

Assigned To: ETSS Assigned Date: 1/22/99 CAT: 2 Priority: 3

Corrective Action(s) Section:

Description of Corrective Action(s):

Test Results

Approval to Proceed: Date Authorized/Disapproved:

Date Fixed: Fixed By: Error Category:

Date Closed: Approved for Closure: Assigned to ECP #:

Figure 3 SPR Data Entry Form

Through the development of queries, a wide variety of reports can be generated, ranging from a large scale SRM for addenda for the SSS, to a list of faults to be addressed in the next repair release of the operational software. The latter serves to set the stance for regression testing and status change for the faults reported in the SPR forms.

CURRENT STATUS

The ADAPS Database

The ADR is in its third instantiation, having been migrated from ACCESS™ 2.0 to ACCESS™ 7.0 and thence to ACCESS™ 97. The system requirements contain in excess of 1850 first tier requirements across three existing segments, each capable of yielding independent SRM generation and V&V tracking. The SPR portion contains over 1,300 problem reports from the three segments. The ADR is exercised on a bi-weekly basis to produce reports for the SPR Review Board.

One project recently inaugurated has adopted the structure of the ADR in order to provide exceptional program visibility from inception. The process involved here was also the QFD approach. Here, the initial instance will include the requirement citation and source, since the effort to utilize the omnibus database is at project inception.

ADAPS Itself

The ADAPS currently has three segments in the IOC phase. Utilizing the ADR, remaining requirements are under study and planning for the next deployment phase– Final Operational Capability (FOC). In some instances, new requirements are added through modification processes, easily being integrated and revised in the SRM using the ADR functionality.

CONCLUSION

The construction of the ADB has eased the tracking and reporting tasks for program management. This has resulted in efficient control of maintenance releases and updated versions of the ADAPS software. It has been migrated to another task in which the promise of a total tracking solution presented by tool manufacturers can be implemented with the standard desktop software inventory. While by no means a total replacement for such specialty items, where rapid response to changing requirements and testing traceability are dominant, the ADR approach can solve problems.

24-Feb-99

All Current RT/PFP Requirements

REQ	VER	DER ID	VER	PKG	CSCI	REQUIREMENT TEXT	BUILD	DERIVED REQUIREMENT TEXT	PROCESS	PROCESS
3	0	1	0	35.00	MPC	The user shall have the capability to generate, remove, or modify presentation formats at any time prior, during, or after a mission.	1	The MPC shall execute on workstations used to prepare the setup files for a mission.	3.1	PMSNPREP
3	0	2	0	35.00	MPC	The user shall have the capability to generate, remove, or modify presentation formats at any time prior, during, or after a mission.	1	The MPC shall execute on mission control room workstations during a mission to modify the MCD.	3.1	PMSNPREP
4	0	1	0	35.00	MPC	The Presentation Generation Mode shall provide the users the capability, using a Motif style GUI, to create, edit and merge mission data presentations.	1	The MPC shall provide the users with the capability, using a Motif style GUI, to create, edit and merge mission data presentations.	3.1	PMSNPREP
5	0	1	0	35.00	MPC	The GUI shall be an icon/menu based, point and click interface.	1	The MPC GUI shall be an icon/menu based, point and click interface.	3.1	PMSNPREP
6	0	1	1	*45.05*	FEA	The user shall have the capability to organize presentation formats by user name and/or flight discipline to reduce the time required to search for a specific presentation format.	E	The FEA shall organize strip chart displays by flight discipline and user name.		
6	0	2	0	15.00	MPC	The user shall have the capability to organize presentation formats by user name and/or flight discipline to reduce the time required to search for a specific presentation format.	PD	The MPC shall organize printed reports by flight discipline and user name.	3.1.1.5	PDISCASS
6	0	3	0	39.00	MPC	The user shall have the capability to organize presentation formats by user name and/or flight discipline to reduce the time required to search for a specific presentation format.	1->2	The MPC shall organize graphic displays by flight discipline and user name.	3.1.1.5	PDISCASS
6	0	4	0	15.00	MPC	The user shall have the capability to organize presentation formats by user name and/or flight discipline to reduce the time required to search for a specific presentation format.	PD	The MPC shall provide a list of displays available for user selection for modification	3.1.1.1.1	PDISMENU
7	0	1	1	6.00	MPC	The RT/PFP system shall provide the user the capability to create new displays, modify existing displays, and remove displays.	PD	The MPC shall provide the user with the capability to create new displays and modify existing displays.	3.1.1.1.2	PDISPMOD
7	0	2	0	21.00	MSE	The RT/PFP system shall provide the user the capability to create new displays, modify existing displays, and remove displays.	PD	The MSE shall provide the user the capability to remove displays.		
8	0	1	0	6.00	MSE	The user shall be capable of defining and storing up to 1000 displays per mission.	PD	The MSE shall provide the user with the capability of creating and storing up to 1000 displays per mission.		

Figure 4: ADR Query, Typical

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