N94-23884

AN APPROACH TO THE DESIGN OF OPERATIONS SYSTEMS

Roy L. Chafin and Patrick S. Curran
Space Flight Operations Section
NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91106
818/354-325
818/393-4110 (FAX)

1. BACKGROUND

The MultiMission Control Team (MMCT) consists of mission controllers which provides Real-Time operations support for the Mars Observer project. The Real-Time Operations task is to insure the integrity of the ground data system, to insure that the configuration is correct to support the mission, and to monitor the spacecraft for the Spacecraft Team. Operations systems are typically developed by adapting operations systems from previous projects. Problems tend to be solved empirically when they are either anticipated or observed in testing. This development method has worked in the past when time was available for extensive Ops testing. In the present NASA budget environment a more cost conscious design approach has become necessary. Cost is a concern because operations is an ongoing, continuous activity. Reducing costs entails reducing staff. Reducing staffing levels potentially increases the risk of mission failure. Therefore, keeping track of the risk level is necessary.

2. INTRODUCTION

The role of the MMCT is to interact with the process (Mars Observer mission) to accomplish required tasks. The organizations design discussed here is to develop an organization of people, equipment, software, and procedures that will accomplish these tasks. The goal is to provide a design technique that can produce an operations organization that will meet the requirements placed on it, with minimum costs and with the understanding of the risks involved.

The design approach is based on considering the Mars Observer mission as a process. The Mars Observer mission is a rather linear process. The spacecraft is launched; then, it goes through a well specified sequence of actions until the end of the mission.

The following Operations System design approach was developed for the design of the MMCT to support the Mars Observer mission.

The design technique consists of:

Identifying the Mars Observer Mission process.

Modeling the process.

Identifying the requirements imposed by the Mars Observer Project on the MMCT.

Synthesizing the MMCT scenarios that respond to the mission requirements, both imposed and implied requirements.

Derive requirements for support from other parts of the operations organization.

Analyzing scenarios for staffing requirements, training requirements, workload problems, etc.

Reviewing the imposed requirements from the Project for feasibility. Requirements that cannot be accommodated are negotiated.

Developing staffing plans, training plans, test plans, etc.

The Mission sequence model is documented in the MMCT Design Document. The Project requirements and the MMCT operating scenarios are integrated into the design document.

This approach to the design of the MMCT provides a more complete understanding of the mission processes and a cost effective method of the tailoring of the MMCT operations system to support the Mars Observer mission. The purpose of this paper is to present this approach and discuss its merits.

3. APPROACH

The Mars Observer mission process is identified from the Mars Observer Mission Sequence Plan (Ref. 1). This document identifies the spacecraft activities that are to be supported by the MMCT. The Mars Observer Mission Operations specification Volume 3: Operations (Ref. 2) present the requirements that the MMCT must meet to support the project.

The mission sequence is modeled in a form that allows for hierarchic refinements. To facilitate this effort, the commercial computer program SDDL was chosen. SDDL is a Pseudo English language intended for software program design. The Mars Observer Mission Sequence Plan was the basis for decomposing the mission process from an overall description through subprocesses to elementary processes. Typically, these elementary processes were sufficiently simple to be described on a single page. SDDL provided the capability to reference subprocesses through CALL statements in the manner of a software subroutine. Figures 1 and 2 illustrate the decomposition of the mission process.

Verification of the process model is provided by joint reviews between the Mars Observer MMCT design team and the Spacecraft Control Team (SCT). The requirements presented by the Mars Observer Project are analyzed in terms of their impact on the Mars Observer MMCT organization system. The requirements are clarified so that they are consistent for both the originating and the responding organizations. The imposed requirements are integrated into the design document where they apply. SDDL has the capability of indexing the requirements and placing the index at the end of the design document. Figure 3 illustrates the requirements and the requirements index.

MMCT operations scenarios are developed to accomplish the required tasks. They are written into the Mars Observer process model to form the MMCT Design Document. Scenarios that satisfy the imposed requirements are integrated with the requirements to provide requirements traceability. Operations scenarios are illustrated in Figures 2 and 3.

The requirements are then negotiated between the Mars Observer MMCT and the Mars Observer Project. Requirements are accepted, waived, or when problems exist workaround solutions are identified. The requirements are refined and documented in the design document.

The operating scenarios are reviewed by experienced mission controllers. Experience from prior missions is used to test the validity of the scenarios. A person with actual experience usually can tell whether a task (scenario) can be accomplished in the time required and with the resources allowed.

From the Mission Controller Team scenarios, the resources required to support the Mars Observer mission are identified. These resources include staffing, data, hardware, software, work- station displays, procedures, logs, reports, and management interactions. Displays that are required to support specific MMCT tasks are identified, specified, and indexed in the design document.

Derived requirements identified above are placed in the Design Document at their point of application and again are indexed with the SDDL indexing capability. Derived requirements are illustrated in Figures 2 and 4. Derived requirements are requirements that are derived from the exposition of the operating scenarios. They are the data, procedures, equipments, support, etc. that are recognized as needed to accomplish the required MMCT tasks.

Discrepancies discovered in the process of developing and analyzing scenarios are recorded as unresolved issues. Unresolved issues are identified and indexed. This allows unresolved issues to be tracked. The unresolved issues index is illustrated in Figure 5.

Scenarios are analyzed and workload studies are performed. These workload studies are used to identify when controllers are overloaded. They also identify when one controller may be available for additional mission responsibilities, thereby improving multimission operation.

The detailed workload studies and requirements analyses indicate when a specific spacecraft sequence overloads the mission controller, or when resources are not adequate to support the mission operations. This provides an understanding of specific risks of failure. It provides the basis for the MMCT development team to negotiate additional staffing, specific workstation displays, software tools, data validation programs, additional spacecraft or mission information, or if required additional time to accomplish specific tasks.

The MMCT Design Document then provides the basis for staffing and training plans. The design document provides the basis for determining whether the mission controller will be operating the Knowledge based mode or the Procedural based mode.

One of the basic parameters of designing an operations system is whether the operation will be Knowledge based or Procedural based. That is, will the normal operation be based on the operators knowledge of the process or will the operator normally be guided by preplanned procedures. The advantage of Procedural based operations design is that the skill requirements on the operator is less than for a Knowledge based operations system. We can expect the operator costs to be less for Procedural based system than for Knowledge based system. Procedural based system design can be used when the basic process is well known and relatively simple (i.e. procedures can be written), and the basic system is stable (i.e. procedures are continuously valid).

When the basic system process is not well understood or the process changes, adequate procedures are difficult, therefore the system must be operated as a Knowledge based system. This requires that the operator be sufficiently knowledgeable of the system process that he can recognize when problems occur and can formulate plans to resolve the problems. The advantage of a Knowledge based system is that preplanning is minimized, and the operator responds to problems when they occur. If a Procedural based operation is appropriate, then the necessary procedures are identified and plans for developing them are generated. If a Knowledge based operations is more appropriate, then the necessary training plans are identified and developed.

4. CONCLUSION

The Mars Observer MMCT Design Document, as presented in the SDDL format, serves as the repository for the Mars Observer mission process model, the imposed requirements, the synthesized Mars Observer Controller responsibilities, the derived requirements, and unresolved issues.

The Mars Observer MMCT Design Document provides the basis for developing operations procedures, staffing plans, and training plans.

The Mars Observer MMCT Design Document provides a clear basis for the negotiation of resources with other organizations. It also provides the tracking of derived requirements and unresolved issues. It provides a tool for working out the details of the implementation. It provides the structure on which the details of the operations scenarios are analyzed to uncover problems and inconsistencies.

The design techniques presented for the MMCT Operations design provide a clear, rational, cost effective design process.

With a better understanding of the Operations System development come better cost control and risk management.

5. REFERENCES

1. Mars Observer Mission Sequence Plan, Vol 1: Mission Sequencing Scenarios, 642-313, Vol. 1. November, 1991. Jet Propulsion Laboratory, JPL D-3826, Vol 1.

2. Mars Observer Mission Operations Specifications, Vol 3: Operations Encounter Version, 642-315, Vol 3. September, 1991. Jet Propulsion Laboratory, JPL D-3822.

```
                                                                    PAGE    2
PROGRAM Mission_Phase
   ************************************************************************
   * This module is the top level of the mission activity hierarchy.      *
   ************************************************************************

   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   + At any point in the MO mission activity the MCT has                  +
   + the capability to:                                                   +
   +     * Transmit required commands to spacecraft                       +
   +     * Verify spacecraft receipt of commands                          +
   +     * Identify GDS conditions that interrupt or                      +
   +         degrade command transmissions                                +
   +     * Assure continued acquisition, safeing of required data         +
   +     * Verify accomplishment of the SOE                               +
   +     * Identify unexpected interruptions or degradations              +
   +         of the required data                                         +
   +     * Initiate troubleshooting procedures when data product,         +
   +         command interruptions, degradations occur                    +
   +     * Coordinate GDS recovery from data product and                  +
   +         command interruptions and degradation                        +
   +     * Develop, analyze real-time S/C, GDS trends                     +
   +     * Report observed spacecraft data anomalies to SCT               +
   +     * Respond to and coordinate real-time SOE changes                +
   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   + Note: A success-oriented mission activity is assumed in the         +
   + following analysis                                                   +
   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   SELECT Mission Phase

   CASE Launch
      CALL Launch_Phase--------------------------------------------->(  3)

   CASE Inner Cruise
      CALL Inner_Cruise--------------------------------------------->(  4)  ---->

   CASE Outer Cruise
      CALL Outer_Cruise--------------------------------------------->(  5)

   CASE Orbit Insertion
      CALL Orbit_Insertion------------------------------------------>(  6)

   CASE Mapping
      CALL Mapping-------------------------------------------------->(  7)

END
```

```
                                                                    PAGE    4
PROGRAM Inner_Cruise
   ************************************************************************
   * Mission actaivities in the Inner Cruise Phase                         *
   ************************************************************************

   SELECT Inner cruise phase sequence

   CASE Spacecraft checkout (C1)
      CALL Spacecraft_Checkout-------------------------------------->(  8)

   CASE TCM_1 (C2)
      CALL TCM_1---------------------------------------------------->( 23)

   CASE Payload Checkout (C3)
      ---------------------------------------------------------------->( 25)
                                                             -------->( 32)
                                                             -------->( 34)
                                                             -------->(  2)
```

```
                                                         PAGE    8
PROGRAM Spacecraft_Checkout
   ************************************************************************
   * ID C1, Duration 13 days, Start I+2 days, End I+15 days               *
   * Continuous DSN coverage                                               *
   ************************************************************************

   !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
   ! ASSUMPTIONS                                                          !
   ! The SCT is on duty                                                   !
   !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!


   LOOP for duration of C1

      CALL Monitor-------------------------------------------------->( 55)

      Do the C1 activities as they are required
      CALL C1_Activities-------------------------------------------->(  9)   ---->   Figure 2

      IF Shift change
         CALL Shift_Change------------------------------------------>( 48)
      ENDIF

      IF Station transfer
         CALL Station_Transfer-------------------------------------->( 51)
      ENDIF

   ENDLOOP

   Return to
   CALL Inner_Cruise------------------------------------------------>(  4)
```

Figure 1

```
PROGRAM C1_Activities
   SELECT
   CASE Launch playback, load A
      Send command load C1A                              (I+1/12:00:00)

      CALL Commanding--------------------------------------------->(  46)
      CALL C1A_Activities----------------------------------------->(  11)

   CASE REDMAN load
      Send command REDMAN load
      CALL Commanding--------------------------------------------->(  46)
      CALL REDMAN_Activities-------------------------------------->(  13)

   CASE Propulsion priming, MAG & GRS boom extensions, load B
      Send command load C1B                              (I+3/12:00:00)
      CALL Commanding--------------------------------------------->(  46)
      CALL C1B_Activities----------------------------------------->(  14)

   CASE PDS health check & GRS calibration data, load C
      ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      + If any anomaly or other difficulty is encountered during       +
      + the spacecraft checkout, this sequence load may be omitted     +
      + to allow more time for the ground to interact with             +
      + the spacecraft.                                                +
      ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

      Send command load C1C                              (I+5/12:00:00)

      CALL Commanding--------------------------------------------->(  46)
      CALL C1C_Activities----------------------------------------->(  17)

   CASE Tank Pressurization, load D
      Send command load C1D to open valve 7
      (I+11/12:00:00)
      CALL Commanding--------------------------------------------->(  46)
      CALL C1D_Activities----------------------------------------->(  18)

   CASE Tank Pressurization, Load E
      IF valve 7 was successfully opened
         Send command load C1-E(P) to open valve 5       (I+13/04:00:00)
         CALL Commanding------------------------------------------>(  46)
         CALL C1EP_Activities------------------------------------->(  20)
      ELSE
         Send command load C1-E(B) to open
               both valves 5 and 8                       (I+13/04:00:00)
         CALL Commanding------------------------------------------>(  46)
         CALL C1EB_Activities------------------------------------->(  21)
      ENDIF

   CASE Tank Pressurization, Load F
      IF valve 5 was not successfully opened
         Send command load C1F to open valve 6           (I+13/12:00:00)
         CALL Commanding------------------------------------------>(  46)
         CALL C1F_Activities-------------------------------------->(  22)
      ENDIF
   ENDSELECT
```



```
PROGRAM C1A_Activities
    ********************************************************************
    * This is the scenario for the mission controller to handle       *
    * the C1A activities                                              *
    ********************************************************************

    | C1A activities scenario |
    [IN.01.1 C1A activities scenario should be reviewed with SCT]

    Callup the -C1A display-
    'D.3.1 C1A display'

    Confirm USO selected              (L0013/L0020)     (I+2/16:00:00)
    Confirm Ranging enabled           (L0009/L0016)     (I+2/16:00:00)
    Confirm RPA 2 filiment is off     (L0029)           (I+2/16:00:30)
    Callup -DTR display-
    Confirm that DTR1 is active       (C0016)           (I+2/16:01:00)
    Confirm Sun Monitor disabled (?)                    (I+2/16:...
    [IN.01.2 What is the Sun Monitor disabled channel number]

    Conf long-term gyro recovery enabled  (F4064)    (I+2/16:03:00)

    Confirm new battery charge rate                     (I+2/16:04:00)
          Charge rate 1: E0501      2: E0503
           Voltage limits 1: E0301(H)
                          2: E0303(H)

    Playback DTR3 at 8 kbps                             (I+2/16:30:00)

    CALL DTR_Playback---------------------------------------------->(  41)
    Playback DTR2 at 32 kbps                            (I+2/20:00:00)

    CALL DTR_Playback---------------------------------------------->(  41)
    Return to 2 kbps ENG telemetry                      (I+2/23:00:30)
```

Derived Requirement ---> (points to the [IN.01.1 …] entry)

<--- MMCT Scenario (points to the Confirm lines)

<--- Unresolved Issue (points to the [IN.01.2 …] entry)

Figure 2

```
1891 PROGRAM Station_Data_Recall
1892
1893      ****************************************************************************
1894      * The following procedure is used to recall recorded data                  *
1895      * from the station that for some reason did not get into the PDB.          *
1896      ****************************************************************************
1897
1898      "R 5.2.2.1.7 Telemetry data gaps, playback"     <----   Requirement
1899
1900      | Telemetry data playback from DSCC scenario |
          [IN.29.1 TLM data playback from DSCC scenarion needs validation]
MMCT Scenario
          Request DSCC to playback required telemetry data

          Configure SFOC for DSCC data playback

1907      Confirm DSCC playback
1908
1909      Confirm telemetry playback data received at PDB
1910
1911      Log telemetry playback
1912
1913      Return to
1914      CALL Outgoing_Station------------------------------------------->( 52)
1915
1916 ENDPROGRAM
```



```
1979 PROGRAM Imposed_Requirements
1980
1981      ****************************************************************************
1982      * All the imposed requirements are obtained from the                       *
1983      * Mission Operations Specification Volume 3: Operations                    *
1984      ****************************************************************************
1985
1986      "R 2.3.1.3 Spacecraft and Ground Health Monitoring"
1987
1988      The FPSO/MCT shall monitor the spacecraft and GDS data when
1989      provided with valid spacecraft/ground predicts, standards,
1990      and limits.  The following monitoring scenario supports
1991      this requirement.
          CALL Monitor------------------------------------------------------>( 55)
Requirements Definition
          "R 5.2.2.1.7 Telemetry data gaps, playback"

          In the event of telemetry data gaps that need to be filled to
          meet Project requirements, the MCT shall coordinate with DSOT
1998      and DAT to asure that telemetry data is recalled from the GIF
1999      or DSCC as soon as possible after the end of the tracking pass
2000      but not to exceed 12 hours.
2001      CALL Station_Data_Recall------------------------------------------>( 53)
2002
2003 ENDPROGRAM
```

```
                        Imposed Requirements
                        CROSS REFERENCE LISTING                      PAGE  71
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

R 2.3.1.3 Spacecraft and Ground Health Monitoring
     PAGE   56   PROGRAM Imposed_Requirements             1986
R 5.2.1.3
     PAGE   61   PROGRAM Unallocated_Requirements         2213
R 5.2.1.4
     PAGE   61   PROGRAM Unallocated_Requirements         2206
R 5.2.1.6.1
     PAGE   61   PROGRAM Unallocated_Requirements         2218
R 5.2.1.6.2
     PAGE   61   PROGRAM Unallocated_Requirements         2233
R 5.2.1.6.3
     PAGE   61   PROGRAM Unallocated_Requirements         2239
R 5.2.1.7.2
     PAGE   61   PROGRAM Unallocated_Requirements         2245
R 5.2.1.7.3
     PAGE   61   PROGRAM Unallocated_Requirements         2252
R 5.2.2.1.1.1
     PAGE   62   PROGRAM Unallocated_Requirements         2259
R 5.2.2.1.1.2
     PAGE   62   PROGRAM Unallocated_Requirements         2264
R 5.2.2.1.1.3
     PAGE   62   PROGRAM Unallocated_Requirements         2270
R 5.2.2.1.5.2
     PAGE   62   PROGRAM Unallocated_Requirements         2275
R 5.2.2.1.6
     PAGE   62   PROGRAM Unallocated_Requirements         2281
R 5.2.2.1.7
     PAGE   62   PROGRAM Unallocated_Requirements         2291
R 5.2.2.1.7 Telemetry data gaps, playback
     PAGE   53   PROGRAM Station_Data_Recall              1898   <----   Requirements Index
     PAGE   56   PROGRAM Imposed_Requirements             1994
```

Figure 3

```
                                                                    PAGE   57
2007 PROGRAM Derived_Requirements
2008
2009     'D.1 A top level display is required'
2010
2011     This display provides a GO/NOGO indication of the configuration
2012     and performance of each of the S/C and GDS system.
2013     CALL Monitor---------------------------------------------------->(  55)
2014
2015     'D.2.1 DTR playback display'
2016
2017     A display is required to support the DTR activities scenarios.
2018     CALL DTR_Playback----------------------------------------------->(  41)
2019     CALL DTR_Repack------------------------------------------------->(  42)
2020     CALL DTR_End_of_Record------------------------------------------>(  43)
2021
         'D.2.4 Spacecraft Maneuver display'

         A display is required to support the spacecraft maneuver
2025     scenario.
         CALL Maneuver--------------------------------------------------->(  24)

         'D.3.1 C1A display'

2030     A display is required to support the C1A mission segment.
2031     CALL C1A_Activities--------------------------------------------->(  11)
2032     CALL REDMAN_Activities------------------------------------------>(  13)
2033
2034     'D.3.2 C1B display'
2035
2036     A display is required to support the C1B mission segment.
2037     CALL C1B_Activities--------------------------------------------->(  14)
2038
2039     'D.3.3 C1C display'
2040
2041     A display is required to support the C1C mission segment.
2042     CALL C1C_Activities--------------------------------------------->(  17)
2043
2044     'D.3.4 C1D display'
2045
2046     A display is required to support the C1D mission segment.
2047     CALL C1D_Activities--------------------------------------------->(  18)
2048     CALL C1EP_Activities-------------------------------------------->(  20)
2049     CALL C1EB_Activities-------------------------------------------->(  21)
2050     CALL C1F_Activities--------------------------------------------->(  22)
2051
2052     'D.3.6 C3A display'
2053
2054     A display is required to support the C3A mission segment.
2055
2056     CALL C3A-------------------------------------------------------->(  26)
2057
```

Derived Requirements Definition

```
                         Derived Requirements
                       CROSS REFERENCE LISTING                        PAGE   72
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

D.1 A top level display is required
    PAGE   57  PROGRAM Derived_Requirements              2009
D.2.1 DTR display
    PAGE   41  PROGRAM DTR_Playback                      1522
    PAGE   42  PROGRAM DTR_Repack                        1570
    PAGE   43  PROGRAM DTR_End_of_Record                 1629
D.2.1 DTR playback display
    PAGE   57  PROGRAM Derived_Requirements              2015
D.2.4 Spacecraft Maneuver display
    PAGE   57  PROGRAM Derived_Requirements              2022
D.2.5 Spacecraft Maneuver display
    PAGE   24  PROGRAM Maneuver                           822
D.3.1 C1A display
    PAGE   11  PROGRAM C1A_Activities                    <---
    PAGE   57  PROGRAM Derived_Requirements              ----
D.3.10 C5 display
    PAGE   34  PROGRAM Outer_Cruise_Transition           1269
    PAGE   58  PROGRAM Derived_Requirements              2075
D.3.2 C1B display
    PAGE   14  PROGRAM C1B_Activities                     403
    PAGE   57  PROGRAM Derived_Requirements              2034
D.3.3 C1C display
    PAGE   17  PROGRAM C1C_Activities                     509
    PAGE   57  PROGRAM Derived_Requirements              2039
D.3.4 C1D display
    PAGE   18  PROGRAM C1D_Activities                     543
    PAGE   57  PROGRAM Derived_Requirements              2044
```

Derived Requirements Index

Figure 4

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
IN.01.1 C1A activities scenario should be reviewed with SCT
    PAGE   11  PROGRAM C1A_Activities                      [illegible]
IN.01.2 What is the Sun Monitor disabled channel number  <---  Unresolved Issue Index
    PAGE   11  PROGRAM C1A_Activities
IN.01.4 How to confirm that heads are parked
    PAGE   11  PROGRAM C1A_Activities                      345
IN.02.1 REDMAN activities scenario should be reviewed with SCT
    PAGE   13  PROGRAM REDMAN_Activities                   360
IN.02.2 What is the battery temp cont channel number
    PAGE   13  PROGRAM REDMAN_Activities                   364
IN.02.3 What is the battery charge contr channel number
    PAGE   13  PROGRAM REDMAN_Activities                   367
IN.02.4 Is E0001 the correct CN for battery backup charge?
    PAGE   13  PROGRAM REDMAN_Activities                   371
IN.02.5 How is the contingency alert enable confirmed
    PAGE   13  PROGRAM REDMAN_Activities                   374
IN.02.6 How is the telemetry verification enable confirmed
    PAGE   13  PROGRAM REDMAN_Activities                   377
IN.02.8 What parameters and thresholds are used in REDMAN
    PAGE   13  PROGRAM REDMAN_Activities                   386
IN.03.1 C1B activities scenario needs validation
    PAGE   14  PROGRAM C1B_Activities                      400
IN.03.2 How is Biprop system vented and primed confirmed
    PAGE   14  PROGRAM C1B_Activities                      411
IN.03.3 Do we need to look at the HGA GDE on signal?
    PAGE   14  PROGRAM C1B_Activities                      416
IN.05.1 C1C activities scenario should be reviewed with SCT
    PAGE   17  PROGRAM C1C_Activities                      506
IN.06.1 C1D activities scenario should be reviewed with SCT
    PAGE   18  PROGRAM C1D_Activities                      540
IN.07.1 C1-E(P) activities scenario should be reviewed with SCT
    PAGE   20  PROGRAM C1EP_Activities                     608
IN.08.1 C1-E(B) activities scenario should be reviewed with SCT
    PAGE   21  PROGRAM C1EB_Activities                     662
IN.09.1 C1-F activities scenario should be reviewed with SCT
    PAGE   22  PROGRAM C1F_Activities                      718
IN.10.1 TCM-1 Operational scenario should be reviewed with SCT
    PAGE   23  PROGRAM TCM_1                               772
IN.11.1 Maneuver scenario should be reviewed with SCT
    PAGE   24  PROGRAM Maneuver                            817
IN.11.2 What is MCT responsibility during manuevers
    PAGE   24  PROGRAM Maneuver                            819
IN.11.3 How do we confirm spacecraft momentum unload
    PAGE   24  PROGRAM Maneuver                            825
IN.11.4 What does MCT do on a faulty manuever
    PAGE   24  PROGRAM Maneuver                            863
IN.12.1 Payload checkout scenario should be reviewed with SCT
    PAGE   26  PROGRAM C3A                                 936
IN.12.2 What is the PDS write protect on/off channel number
    PAGE   26  PROGRAM C3A                                 949
IN.12.3 How are three redundant PDS memory readouts confirmed
    PAGE   26  PROGRAM C3A                                 960
IN.12.4 How is command PDS to RAM confirmed
    PAGE   26  PROGRAM C3A                                 963
IN.12.5 On switch to S&E-1 MBR, is there any effect on GDS
```

Figure 5