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# INFORMATION FLOW ANALYSIS OF LEVEL IV PAYLOAD PROCESSING OPERATIONS


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Abstract

The Level IV Mission Sequence Test (MST) was studied to develop strategies and recommendations to facilitate information flow. Recommendations developed as a result of this study include revised format of the TAP document and a conceptualized software-based system to assist in the management of information flow during the MST.

## Summary

The Level IV Mission Sequence Test (MST) was studied to develop strategies and recommendations to facilitate information flow. Since payloads are becoming more complex, and the need for efficient processing continues, the MST which tests the payload at Level IV is a complex procedure which integrates technical equipment and personnel. The Test and Assembly Procedure (TAP) is the basis for information flow during the MST, and as such, the document should support its navigation in an optimum manner. Due to the relationship between the structure of the TAP and how it was used during the MST, suggested format changes were recommended.

Also, to support the information requirements of the MST personnel, an information support system was conceptualized. The progress to date on the system is identification of the desirable supporting functions in a series of screens which illustrate how a number of possible information areas could be supported.

The team members have developed successful strategies to compensate for the current TAP document and information support procedures. In this study, methods to further improve the TAP document and provide information support were researched with the aim of facilitating team dedication to the test and trouble-shooting functions of the Level IV MST.

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# Acronyms List

| | |
|---|---|
| CMD | Commander (for call signs) |
| EE | Experiment Engineer |
| K4TC | Level IV Test Conductor |
| MET | Mission Elapsed Time |
| MST | Mission Sequence Test |
| O&C | Operations and Checkout Building |
| OMI | Operation and Maintenance Instructions |
| PE | Project Engineer |
| PI | Principal Investigator |
| RESP | Recipient of command (for call signs) |
| SEQ | Sequence (in TAP) |
| STS | Space Transportation System |
| TAP | Test and Assembly Procedure |
| TQ | Multiple Inspection Verifications by Technician and Quality (in TAP) |
| WAD | Work Authorization Document |

# I. INTRODUCTION

1.1 MISSION SEQUENCE TEST (MST) BACKGROUND. The purpose of this study was to analyze the flow of information during the Level IV Mission Sequence Test (MST). The study of human-human communication is not new. However, the study of information flow, including documentation, is a relatively new field of research in the area of the human factors study of systems. This topic is attracting interest from various researchers, for example, Schmager (1991) recently reported a study of the information flow of batch production control in manufacturing.

The MST is a testing procedure which involves communication of numerous personnel and the generation of documents and forms. Actually, the information flow between the processing team members begins several months before the MST, when the procedures are being developed for each individual experiment of the payload. The project engineer (PE) assigned to the payload follows its progress throughout the integration process. The written procedures followed during the MST, called Test and Assembly Procedure (TAP), are authored by the PE as he/she combines input from the experiment principal investigators (PIs) and the experiment engineers (EEs). After the MST is completed, the team continues to work on trouble-shooting issues in the ongoing effort to prepare the payload for advancement to Level III/II. Since the TAP is the baseline for information flow during the MST, the process of generating the TAP was also studied.

1.2 PURPOSE OF STUDY. For the purpose of this study, three areas related to the MST were studied. The first area was preparation of the TAP by the PE. The second area was the design of the physical format of the TAP document with respect to its function of supporting the steps to be executed during the MST. The last area was a study of the MST in terms of overall information support. It was found that studying the MST in this progression was the best approach to identify attributes which make the team successful over the Level IV stage.

1.3 LEVEL IV BACKGROUND. Horizontal payloads are integrated in the Operations and Checkout Building (O&C). The payloads are delivered to KSC and are individually tested in Pre-Level IV. At Level IV, the experiments are integrated into racks or pallets for the first time. This is the first time the experiments are operated together, using the same power sources and the same computer data handling systems. The team concentrates its efforts on ensuring that the electrical and mechanical interfaces are error free, as well as confirming that the experiments are operating within specifications. Although each team member is a specialist in certain areas, many situations are first time encounters and must be solved without prior experience with similar solutions.

During development of the TAP to be used during the MST, the PE receives input from each of the specialists and PIs regarding their specific experiments. So during the time he/she prepares for the MST, the PE is becoming familiarized with the TAP. He/She and the counterpart develop an expert knowledge of the TAP content.

The Level IV MST usually spans one week. Three days are reserved for actual testing and two days in between are used from trouble-shooting. There are various participants in the MST and they are in different locations within the O&C. During an MST the PE and counterpart are now referred to as K4TC (test conductor). Depending on the type of payload, K4TC will be located in the Control Room or the Users Room. The mission and payload specialists are located in the payload within the bay, as are some technicians. The supporting engineers and personnel are in the Control Room, and the PIs and EEs are in the Users Room. A group of visitors may also observe the MST from a conference room. Quality are located in yet another room.

All personnel are interfaced with the audio network (net) which allows them to monitor active channels during the MST. The participating personnel have different levels of involvement and knowledge about the MST and the TAP content. Variations in the TAP and equipment problems are resolved as they are encountered, along with generation of the appropriate paperwork. These conditions challenge the K4TC to lead the team through a successful MST in a timely manner.

## II. METHODOLOGY

2.1 DATA COLLECTION AND ANALYSIS. Due to the dependence of the MST on previous team work and information flow, the study was approached from a systems viewpoint. Approximately the first five weeks were used to learn and observe the MST. Two MSTs were directly observed. Several documents were reviewed to familiarize the investigator with the background of Level IV activities. These documents included, but were not limited to: the STS Investigator's Guide (1989), the User's Guide to Spacelab Payload Processing (1986), the CS-EED Employee Reference Handbook, and the Spacelab News Reference. Engineers representing a variety of specialties were also interviewed and questioned to clarify questions and details. Successful team strategies were noted during the MST observation and interviews. During this time, the systems approach to investigating information flow during the MST was formulated and planned to be initiated during the next five weeks of the period.

2.2 DEVELOPMENT OF RECOMMENDATIONS. During these five weeks, the paper communication related to the MST was studied, including pre-TAP documents and deviations. The format of the TAP document was also reviewed based on observations during the MSTs and successful team strategies. Finally, a software-based information support system was conceptualized, using a simple prototyping method. During this five week period, the investigator also participated in a Workshop hosted by the Crew Factors Group of the Human Factors Division at NASA Ames Research Center. At this workshop, the work to date was presented to other investigators working in the areas of team performance and information flow.

# III. RESULTS AND DISCUSSION

3.1 DOCUMENT FINDINGS. Observations of the MST were the bases for recommendations on the format of the TAP document. The specifications were examined which define the format of a TAP document. The relationship of the document structure to how it was used on line was studied.

3.1.1 The TAP Specifications. The Work Authorization Document (WAD) says that a TAP is similar to an OMI, and is formatted to provide for easy development and processing during the Level IV tasks. It is specified that the TAP be organized in five sections. Section I should cover the test objective, special equipment, special instructions, acronyms, and call signs. Section II covers the pre-operation setup instructions which lists any special configurations required prior to beginning the operation instructions. Section III lists the operation support set up instructions. Section IV has the operation instructions which include call to stations, power up and down, as well as specific task instructions. Section V covers the post operation instructions, which are performed after Section IV is complete.

3.1.2 The TAP Currently Used in the MST. The following is a discussion on the format of the TAP with respect to the MST. It is recognized that there are at least three types of TAPs, and that numerous TAPs are developed in many organizations at KSC. However, the comments here are only applicable to Level IV MST and were specifically based on case study.

Given that the MST is a complex procedure integrating technical equipment and personnel, it is desirable that the document support its navigation in an optimum manner. This is becoming more important as the payloads become more complex and the need for more efficient processing increases. Increasing complexity was also cited by Wright and Aitken (1991) as motivation to develop a software based semi-automated network scheduling system for satellite payloads.

The team spent a considerable amount of audio time receiving inquiries and sending responses as to the current step in the document. During MST observation, navigation of the document was difficult and awkward. Even experts in the TAP used sticky notes to identify specific sections, as there was skipping and jumping around between steps and sections.

The PE has the task of editing and integrating the TAP as well as conducting the MST. If the document could better support personnel navigation during the test, this may relieve the team from answering the many inquiries of what is the current step in the test, and perhaps improve on the efficiency and interaction between test personnel, such as buy offs and generation of deviations.

By its nature, the TAP document guides the personnel through a first-time testing procedure which involves trouble-shooting activity on demand. Although the K4TC is acquainted with all the steps, and the engineers are familiar with their specific experiments, the steps have not actually been executed before. Thus, the TAP may be likened to a learning situation. This situation is in contrast to an Operations and Maintenance Instruction (OMI) which is a more established set of procedures and have been modified, but not extensively, for each session. In this case the personnel participating in the OMI have the advantage of instruction rehearsal. Due to the fundamental differences between the activities which the TAP and the OMI support, it is recommended that the format of the documents reflect the differences between the document functions.

3.1.3 Format Recommendations. The specific format recommendations are discussed below, and are suggested to enhance the readability, legibility, and navigation qualities of the TAP. Pages of the TAP in the old format, Tables 1 and 3, and in the new suggested format, Tables 2 and 4, have been included for comparison. The lettered areas of each page correspond to the following lettered points.

A. Upper and lower case letters are recommended for text. Upper case letters should be reserved for acronyms and call signs, or cases where emphasis is needed (Zimmerman & Campbell, 1988). Upper and lower case text is more readable than upper case only because upper case letters are indicators of the start of a new instruction, acronym, call sign or code. Also, upper case text is already used as a heading level in the TAP document. Utilizing lower and upper case in the general text reserves the upper case text as an important heading level. This is applicable to the TAP because much of the reading is quick scanning over the steps, yet must be performed with accurate attention to detail.

B. The 11 x 8 1/2 " landscape orientation of the page was selected to allow addition of another column, called type, and to allow the text lines of each step to be longer. This modification was made to facilitate the reading of the TAP by providing the sequence information in columns which are read consistently from left to right.

B.1. The column, type, was added so that notes, cautions and warnings could be designated without being embedded in the text. This change also saves a line of space for each note.

B.1.1. The warning notes are still set off by asterisks, although it is not necessary that the asterisks form an entire border around the message.

B.2. The procedures are written in the same style, but more space is available for a longer line of text. This should aid the reader so that the listener hears a more complete message. This is especially important if the respondent is not able to read the TAP while executing the steps.

B.2.1. The beginning of each phrase is a new line. This aids in distinguishing substeps within a step, and facilitates quick scanning of the text.

C. The detailed header of each page was removed and changed to a footer with section information only. It is suspected that the detailed header was necessary with the old format due to the frequent skipping of sections. However, with the new format the header is trimmed to the minimum necessary information and this results in additional space savings, as well. To make navigation easier footer noting the specific task being performed appears at the bottom left of the page, allowing the user to thumb through the document quickly.

D. The levels of heading in the old format were difficult to distinguish from the text. Since all text was in upper case letters, the level was limited. The main header was bold underlined upper case, the notes were bold upper case with a colon, and other levels were also underlined upper case text. The new format utilizes three levels of headings: (1) all bold upper case for header and remarks, (2) underlined text for emphasis within instructions and (3) asterisk notation with bold upper case for warnings.

E. The new format is arranged by the order in which the steps will be performed, instead of by the 5 standard sections (information, pre-operation setup, pre-operations, operations, and post-operations). The new document is subdivided by time slice. Each time slice has the pertinent sections included. The time slices are separated by colored title pages. The advantage of this organization is that it follows the actual itinerary of MST activity more closely, and will reduce the amount of page turning and step skipping since all activities occurring on the same day are located in the same section of the document. It is also suggested that text be copied and inserted where appropriate if the same steps must be repeated on another day.

F. The zero number and "oh" letter should be distinguishable so that codes will entered in without mistaken identities. On occasion personnel misread the code and an error message was received. Thus, it is recommended that at least in the codes to be entered, these characters be readily distinguishable.

These are formatting suggestions which have been developed without in depth analysis of the content of the steps. Currently audio tapes of the MST are being analyzed to identify the successful strategies of the team and altering the procedural content to reflect this. For example, in one MST the written TAP required verification of the illumination of two indicators in two separate steps. Although written as two steps, the respondent chose to verify both indicators in the same step. Perhaps the document content will be revised to accommodate the efficiency of the personnel responses.

3.2 INFORMATION SUPPORT SYSTEM. Next, the information flow of the MST was considered. A software-based system to support information management was conceptualized. The progress to date on this system is the identification of desirable supporting functions, and a series of screens which illustrate a number of possible areas which could be supported. The initial work has emphasized the development of the human computer interface, which is a key factor to the potential success of a system. O'Neal and Manahan (1991) also used the prototype method in the process of developing a human comuputer interface for a system which will provide computer supported procedures to the astronauts while on board spacecraft.

The process of collecting feedback on the functions has begun and the resulting recommendations are continuously being considered. It is envisioned that the information would be available to the MST participants with varying levels of interaction. The system would allow personnel to access current changes and status of MST, including deviations, quality activity and overall progress of the time slice. The purpose of the system is to improve information available to the participants and automate some low level functions.

3.2.1 Proposed Features of the System. The basic screen is shown in Figure 1, and the following points of discussion correspond to the items labelled in the figure.

A. The menu is shown in the right side of the screen and coexists with a window showing the current step of the TAP. The screen view of the TAP could be updated to show recent deviations and buy-offs as shown in A.1. It is suggested that the five digit identification numbers of the quality engineer and technician be entered by keyboard, perhaps in password format.

B. Another potentially useful feature is the status option of the menu. With this option, the team personnel could refer to the status of the activities for a slice, as well as find start and end times for power ups. Also available is a time slice status indicator to show the overall progress of the time slice.

C. The help button supplies general navigational instructions for using the system.

D. Color code information summary is shown under the help menu. Red indicates that a deviation has been initiated against that particular step. The specific deviation can also be viewed using the deviation selection. Any text in yellow is used to reference a figure, or to indicate quality activities.

E. The support includes applicable documents such as call signs, acronyms and safety requirements.

F. The display defaults would allow the user to display only the sequences or steps of interest by experiment, commander, responder or steps where quality is involved.

G. Print screen would provide printout of information on the screen.

H. The deviation button would allow review of the written deviations, or authoring of new ones right on the screen.

3.3 SUCCESSFUL STRATEGIES. Audiotapes are currently being analyzed to further develop details of successful team strategy. Successful strategy is dependent on team communication during the MST as well as throughout the Level IV processing operations. During the MST, the team is successful in communicating with team members in the trouble-shooting mode. The team uses a look-ahead strategy to point out future problems and events which are potentially difficult. Personnel offer to take duties which are not necessarily theirs (such as time keeping and monitoring) and the team cross checks and monitors each other. During the MST, the team behavior has evolved to include efficient responses over the net, and successful strategies for authoring and processing forms. These relationships begin to develop before the MST through communication which is fostered by the accessibility between team members and PIs.

The team develops confidence since the EEs are trusted and accept the responsibility for the well-being of the experiments.

3.4 FURTHER RECOMMENDATIONS. Introductory analysis of the preparation procedure showed that there would be a use for an improved method of incorporating suggested changes into the TAP drafts. Currently, the changes are reported by fax, letter, computer mail, red-lines and the change request form. This suggests that the form should be analyzed for its format with respect to what the team requires. The form could probably be designed so that it would be readily used and incorporated into the draft. Also, technologies and organizational methods for incorporating the changes should be researched. A similar situation exists with the deviation form. The deviations were reported consistently in a format which was not necessarily defined by the deviation form. Since the style of the deviation report has evolved to this format, perhaps the form should be changed to accommodate it.

## IV. CONCLUDING REMARKS

In general, team members have adapted successful strategies in spite of the TAP format. This investigation has researched ways to further improve the TAP document and associated forms so that the team can be dedicated their true testing trouble-shooting functions, rather than navigational attention required to track steps in the TAP. Further work is being done to incorporate successful strategies into recommendations for the actual procedural content of the TAP.

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Table 1. TAP Excerpt

DATE: 04-04-91 REV. BASIC T1-IML-1-0050

SECTION IV

OPERATION INSTRUCTIONS

| SEQ | CMD | RESP (MET) | DESCRIPTION | VERIF |
|---|---|---|---|---|
| 19-000 | | | EXP 10 - MVI OPERATIONS | |
| | | | NOTE: THE MVI OPERATIONS WILL BE PERFORMED DURING LVL III/II MST SLICE 1. | |
| | | | MVI TEST PREPARATIONS | |
| 19-001 | | PS2 | UNSTOW/CONFIGURE CASSETTE RECORDER FOR SUBJECT: | |
| | | | A. UNSTOW CASSETTE RECORDER AND SEVERAL UNUSED TAPES FROM CREW KIT - - TEMP STOW EXTRA TAPES IN POCKETS. | |
| | | | B. LABEL TAPE WITH SUBJECT ID AND MET LOAD TAPE IN RECORDER. | |
| | | | NOTE: CHANGEOUT BATTERY IF RECORDER DOES NOT WORK. | |
| | | | C. VOICE RECORD SUBJECT ID AND MET. PLAY BACK FOR VOICE CHECK. TEMP STOW RECORDER IN POCKET. | |
| | | | D. UNSTOW INDIVIDUAL NOSEPIECE FROM CREW KIT (IF DESIRED). TEMP STOW. | |

Table 2. Recommended TAP Format.



B.1

**EXPERIMENT 10 - MVI OPERATIONS**

| SEQ | CMD | RESP (MET) | REMARK | DESCRIPTIONS | VERIF |
|---|---|---|---|---|---|
| 11-000 | | | **NOTE** | The MVI Operations will be performed during LVL III/II MST Slice 1. | |
| | | | | **MVI TEST PREPARATIONS** B.2 | |
| 11-001 | | PS2 | D | Unstow/Configure cassette recorder for subject:<br>A. Unstow cassette recorder and several unused tapes from crew kit temp stow extra tapes in pockets.<br>B. Label tape with subject ID and MET load tape in recorder. | |
| | | | **NOTE** | Change out battery if recorder does not work. | |
| | | | | C. Voice record subject ID and MET. Play back for voice check. Temp stow recorder in pocket.<br>D. Unstow individual nosepiece from crew kit (if desired). Temp stow. | |
| 11-002 | | PS2 | | Install TPL liner in helmet, if required. | TQ___ |
| | | | **NOTE** | The following MVI preparations must be completed at least 20 minutes prior to the start of MVI MST Slice 1 Operations. | |
| | | | **NOTE** | If skin is very sensitive alcohol wipes may be substituted for Omniprep. | |
| 11-003 | | PS2 | | Prepare skin at electrode sites with Omniprep (or alcohol) and dry gauze. Remove electrodes from package in service kit, check electrode paste is on electrodes, and apply to the buffed areas. | |



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Table 3. TAP Excerpt

| DATE: 04-04-91 | REV. BASIC | T1-IML-1-0050 |
|---|---|---|

SECTION IV

OPERATION INSTRUCTIONS

| SEQ | CMD | RESP (MET) | DESCRIPTION | VERIF |
|---|---|---|---|---|
| 19-019 | | MS3 | ROUTE EOG ELECTRODE CABLE THROUGH HOLE IN HRD, PLUG INTO HIB J4 CONNECTOR (GREEN/BLACK COLOR CODE), AND SECURE EXCESS CABLE WITH VELCRO STRAP(S). | |
| 19-020 | | PS2 | CONFIGURE/POSITION POWER KILL SWITCH ON CHAIR RAIL. | |

WARNING

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************************************
* IF A WARNING TONE IS SOUNDED     *
* AT ANY TIME DURING MVI           *
* OPERATIONS, THE OPERATOR         *
* SHOULD IMMEDIATELY STOP          *
* PROCEDURES, SHUT DOWN CHAIR      *
* OPERATIONS BY FLIPPING           *
* ROTATOR SW, AND ASSIST           *
* SUBJECT FROM CHAIR.              *
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| SEQ | CMD | RESP (MET) | DESCRIPTION | VERIF |
|---|---|---|---|---|
| 19-021 | | PS2 | OPEN HELMET BLADDER VALVES, LOWER HRD/HELMET, CLOSE | |
| | | MS3 | INFLATE BLADDERS AS NEEDED (FRONT BULB = SIDE BLADDERS, BACK BULB = TOP BLADDERS | |
| 19-022 | | MS3 | CHECK HELMET VISORS ARE COMPLETELY LOWERED AND SUBJECT'S EYES CENTERED IN OPENINGS. | |

Table 4. Recommended TAP Format.



| SEQ | CMD | RESP (MET) | REMARK | DESCRIPTIONS | VERIF |
|---|---|---|---|---|---|
| 11-020 | | PS2 | | Configure/position power kill switch on chair rail. | |
| | | | (B.1.1) WARNING | ******************************************************************<br>If a warning tone is sounded at any time during MVI operations, the operator should immediately stop procedures, shut down chair operations by flipping rotator SW, and assist subject from chair.<br>****************************************************************** | |
| 11-021 | | PS2<br>MS3 | | Open helmet bladder valves, lower HRD/Helmet, close<br>Inflate bladders as needed (front bulb = side bladders, back bulb = top bladders) | |
| 11-022 | | MS3 | | Check helmet visors are completely lowered and subject's eyes centered in openings. | |
| 11-023 | | MS3<br>PS2 | | Adjust shoulder and hip pads, and tighten 4 point harness restraint (knee and root restraints). | |
| 11-024 | | MS3 | | Verify EOG signal polarity by having subject move eyes up, down, right, left (signal + for up and right, signal - for down and left). Scale display as necessary. | |
| 11-025 | | MS3 | | Verify/Power-on SL Rack 4 Monitor. | |
| 11-026 | | MS3 | | Confirm proper eye position:<br>A. Entire eye in video field<br>B. Helmet liner not visible<br>C. Video overlay or header information not covering any portion of the eye.<br><br>If proper eye position can not be attained, subject should attempt to adjust by inflating or deflating bladders. | |