1991 NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

DEVELOPMENT OF A COMMON USER INTERFACE FOR THE LAUNCH DECISION SUPPORT SYSTEM

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DATE:	August 23, 1991
CONTRACT NUMBER:	University of Central Florida NASA-NGT-60002 Supplement: 6

ACKNOWWLEDGEMENTS

I would like to thank Dr. Raymond Hosler of the University of Central Florida, Dr. Mark Beymer and Mr. Dennis Armstrong of the Kennedy Space Center for their efforts in making the NASA/ASEE Summer Faculty Fellowship Program an enjoyable and educational summer. Many thanks to Ms. Kari Stiles for answering so many questions prior to starting the summer program and for her efforts in making the program run so smoothly.

Special thanks to Art Beller,Greg Hadaller, Mark Ricci,and Mike Richardson for all their help with hardware and software issues. Their input throughout the summer was most valuable. Their efforts at making me feel welcome in the group were very much appreciated.

Thanks to Frank Merlino and members of the NTD staff for their assistance. Their input on suggested revisions was extremely helpful.

ABSTRACT

The Launch Decision Support System (LDSS) is software to be used by the NASA Test Director (NTD) in the firing room during countdown. This software is designed to assist the NTD with time management, that is, when to resume from a hold condition. This software will assist the NTD is making and evaluating alternate plans and will keep him advised of the existing situation. As such, the interface to this software must be designed to provide the maximum amount of information in the clearest fashion and in a timely manner. This research involves applying user interface guidelines to a mature prototype of LDSS and developing displays that will enable the users to easily and efficiently obtain information from the LDSS displays. This research also extends previous work on organizing and prioritizing human-computer interaction knowledge.

SUMMARY

The Launch Decision Support System (LDSS) is being developed as an aid to the NASA Test Director (NTD) during countdown activities. This report presents suggested revisions of many LDSS displays. The revisions were developed by applying human-computer interaction guidelines to the original interface. Data collected from potential users was also considered in developing the revisions. This data was collected via a think aloud protocol, numerous interviews, and a questionnaire. This data verified that users found the color coding of the revisions sufficient, that they could correctly interpret information coded into one window rather than three, and that reducing the time labels was acceptable. The emphasis in developing the revisions was on presenting the information so that it could be interpreted quickly, easily and unambiguously by casual users in a critical, real-time environment.

The task of applying Human-Computer Interaction knowledge is difficult because research done in this area is often difficult to translate into practical guidelines. A means of organizing human-computer interaction knowledge into a generic framework is discussed. However this method alone is not sufficient to be able to use HCI knowledge. Other problems still exist. For example, during the revision process many trade-offs were made when deciding which guidelines to apply. A method was used to prioritize guidelines by examining different characteristics of tasks and users. For various characteristics the criteria of primary importance are proposed. Using task and user characteristics of LDSS and applying this prioritizing method resulted in the following primary criteria: consistency, guidance, workload, and significance of code.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANTD	Assistant NASA Test Director
APU	Auxiliary Power Unit
CDT	Count Down Time
COBT	Crew on Back Time
COLA	Collision Avoidance
GLS	Ground Launch Sequencer
HCI	Human-Computer Interaction
LCC	Launch Commit Criteria
LDBT	LOX (Liquid Oxygen) Drain Back Time
LDSS	Launch Decision Support System
LOX	Liquid Oxygen
LOX DB	Liquid Oxygen Drain Back
LW	Launch Window
NTD	NASA Test Director
OIS	Operations Information System
OMI	Operations and Maintenance Instructions
TMID	Time Management Integrated Display
UT	Universal Time

I. INTRODUCTION

1.1 Organization of the Paper

This paper documents the application of Human-Computer Interaction knowledge to the interface for the LDSS software for use in the KSC firing room. The first section discusses the role of the NASA Test Director (NTD) who is seen as the principle user of LDSS. The functionality of LDSS is explained in this section. Section II presents redesigned displays and discusses the rationale behind the redesign. Also included in Section II are the results of data collection on usage of the displays. A discussion of complexity measures in original and revised displays is also presented. Section III discusses how human factors knowledge can be organized and applied to interface designs. A method of addressing the trade offs involved in interface design is presented. Section IV presents Interface Guidelines for future firing room software. Additional suggestions are included for a proposed windows version of such software. Section V contains concluding remarks.

1.2. The Role of the NTD

The NASA Test Director functions as the coordinator of information during a launch countdown. He receives information from several diverse sources: firing room clocks located on the wall in front of him and to his left, procedural information in hard copy from the OMI (Operations and Maintenance Instructions) and status information received over the OIS (Operations Information System). The current firing room clocks are universal time (UT), local time(local), countdown time (shuttle), window remaining, post LOX drain back elapsed, APU hold time remaining, time to T-0, and hold time remaining. Specific information about each launch, such as projected time of lift-off, launch window end,etc., is contained in a launch document for that particular mission. He also has access to closed circuit television which is directed at operations occurring around the launch pad. One of the many responsibilities of the NTD is that of time management. That is, given that a hold has occurred in the countdown, The NTD must decide upon the time to resume the count so that lift off will not occur within a COLA or with little contingency time. In making decisions concerning time management, the NTD has to carry out some arithmetic operations and base his decision on those calculations plus his knowledge of specific launch information. In addition, he uses knowledge of approaches used in previous launches.

The LDSS consists of several parts: the time management integrated display, the what-if capability, the

situation assessment capability, and anomoly management. The time management subsystem presents an integrated display. That is, all firing room clocks are duplicated on this display. Additionally, some clocks that perform arithmetic are displayed. The launch window is shown along with any COLAS (collision avoidance). These represent periods in the launch window such that a lift-off during this period could results in a collision with another orbiting vehicle. Contingency times are shown in the launch window as these also affect resumption from a hold. The time management display (shown in figure 1) calculates the advisability of resumming from a hold and displays this information in its resume window. A now bar displays the current position in the countdown and a projected T-0 bar is consistently updated to reflect where lift off will occur. The LOX DB is the contingency time currently deemed to be the most constraining.

1.3 The Need for Human-Computer Interaction Knowledge

LDSS is designed to assist an NTD during countdown activities. Activities such as these are performed on the order of every two weeks. This includes simulations and actual launch activities. The NTDs alternate with one NTD and one ANTD assigned to every launch team. Therefore, these are casual users. The activity they perform, launching a manned shuttle, is a critical operation. The countdown activity is a cognitively demanding activity that must be carried out in a real-time situation. This means that any tools designed to assist the NTD and ANTD need to present the needed information in such a fashion that it can be easily comprehended and used. This project reports on a suggested redesign of the user interface for the LDSS. Accomplishing this redesign led to many tradeoff decisions. This study also proposes a method for prioritizing guidelines in order to make consistent decisions about trade-offs.

II. LDSS Revised Displays and Data Collection Results

2.1 TMID Revised Display

Figure 1 shows the original TMID screen and Figures 2,3 and 4 show the revised display. The largest change was using one "window" on the display for information concerning the launch window. The original display contained a launch window which showed COLAS, a resume window which showed the advisability of resuming from a hold, and a LOX drain back window which showed the LOX contingency time remaining. In addition, the display contained a "now bar" and a projected T-0 bar, to show where the countdown currently was and where this meant that T-0 would occur. Interviews with members of the NTD staff indicated that there was confusion with using three different windows, especially the launch window and the resume window. Therefore, the display was reworked using only one window - the launch window - and incorporating the information about COLAS, contingency time and advisability of resumming in this window and elsewhere on the display. The revised display uses the stop light coloring coding on the launch window. Green indicates that the window is open at this point. Yelllow indicates contingency times and is seen prior to COLAS (indicated in red) and prior to the end of the launch window. The end of the launch window is labeled as such and nothing is displayed after this point. The "now bar" is coded to indicate the advisability of resumming at this point in time. Green indicates that resumption is safe (or that the countdown is not currently in a hold). Yellow indicates that a resumption at this time would not have the full contingency time. Red indicates that resumming from a hold at this time would place T-0 in a COLA. There are two methods of finding out how long the period for resumming exists. One is by looking at the launch window to see the amount of green, yellow or red (also labeled) displayed below the projected T-0 bar. At the beginning of the T-20 hold this information would have to be obtained by scrolling the launch window. Additionally, this information is contained in a new clock "Time to No Start". This will provide exact times that indicate how long the current condition exists.

The time labels were also changed. The original display labeled all times, universal time and countdown time. The revised display only labels significant times. That is, only the minutes in which a GLS event or a COLA or a contingency time appears will be labeled with the univeral and countdown time. Countdown times are only labeled for times prior to T-0. Positive countdown times make little sense for COLAS and contingency labels. The "now bar" always reflects the current time correct to the second.

Using a reduced amount of time labels will make those that are significant stand out and reduce the overall complexity of the display. More will be said about this in Section III.

The original TMID screen contained a scroll bar on the left side of the display which was used to indicate which portion of the display was being viewed. The revised TMID screen had more room so that the scroll bar could be moved to the right hand side of the display in keeping with an OSF/Motif presentation. The scroll bar was designed so that it resembles that of OSF/Motif. Recommended movement with the display window should be via the scroll bar or by using the up arrows and page keys. Either motion results in the slider of the scroll bar being changed to relfect what portion of the display one is viewing. In a direct manipulation version, the user should also be able to position the slider to cause movement.

Color coding on the revised TMID screen is consistent. Graphic information is color coded using the green (safe), yellow (cautionary), and red (warning) traffic light metaphor. However, the graphic data has also been labeled so that color coding is redundant and therefore, can be used by a visually impaired person. Text information uses cyan for labels and place holder values. White indicates information that needs to be input. Values in green are relevant; that is, data that has occurred. Yellow labels and values depict information concerning a hold. Red values are values that indicate a warning situation exists. One color change that was made to the original TMID screen is that recommendation of using cyan as the color for data that is not yet relevant. Previously non-relevant data had been displayed in white. White should be reserved for very important data. Data that is not yet relevant is not invalid, but merely serves as a placeholder. Therefore, using the same color as labels (cyan) is recommended for such data. In general, no more than four colors should be used for alphanumeric information. The revised TMID screen (and other screens in LDSS) use cyan, green, yellow and red. As red is used very sparingly and only in the case of warning situations, the use of the three colors to display text, plus the background color of black, closely adheres to this guideline.

The clocks in the original TMID screen were rearranged and "chunked" together according to function. For example, **time in hold** and **hold time remaining** were located together. This reduces the complexity for the user by presenting a few chunks of information rather than a large number of information pieces. In addition, the clocks were arranged in order from top to bottom with those on the top being the highest priority. This arrangement was based on interviews with the NTD staff. This rearrangement allowed enough room on the display to include the maximum hold time remaining and the latest resume time. For time values that are not currently in use the recommendation is

to use a default value of HHMM/SS or DDD:HHMM/SS as a prompt to the user of the format of the clocks. This is due to the lack of room for labels on the clock values. A graphic depiction of where the projected T-0 falls in the launch window was also incorporated into the clock display. This was purposely designed NOT to look like a scroll bar as it CANNOT be manipulated and is used to quickly show the NTD how close to the end of the launch window, the projected T-0 is.

2.2 Finer grain TMID Screen

Feedback from the users indicated that as T-0 neared, the minute resolution on the TMID screen was too coarse to follow. A finer grain of time, namely a 10 second resolution, is recommended. Figure 5 presents this new display. The same format as the TMID screen is used. The time bars in the launch window now become 10 second bars so that one rectangular box per line is used. Time labels are indicated on whole minute entries. This display should be included in the menu and the user could select to view this display when a certain point in the countdown is reached.

2.3 Overview Display

Another new display that was developed during this period of time is the overview display. The concept is that this display would present the entire launch window picture to the NTD. The display, shown in Figure 6, could be derived from the mission parameters that are input prior to bringing up LDSS. The entire window is displayed with COLAs, COBT, and built-in holds at T-20 and T-09. This display could be used in a static fashion. That is, hard copies of it could be printed and used by the NTD to get an overall picture of the launch window. Figure 7 shows that the same display might also be used in a dynamic fashion with the addition of a now bar and a projected T-0 bar.

2.4 Test Parameters Display

Figures 8 and 9 present the original and revised Test Parameters display. The original display listed the built-in holds by time. Normally, searching would be done according to the time of the hold. Therefore, these columns were rearranged to facilitate that search. As LDSS currently is designed to function from T-20, only those built-in holds at T-20 and T-9 need to be displayed. The original display contained only the start and end time of the launch window (unlabeled). The revised display contains the start, end and length of the launch window, COLAS, and COBT. In addition, the point of no recycle is now included on this display rather than on the TMID screen.

This same display could be used for input about each specific mission. The input display looks very much

like the mission parameters display but contains information on how to input new values. The data fields are displayed in white, indicating that these fields are to be filled in by the user. The fields indicate the number of positions that are to be filled in and the format of that data. For example, a length field in countdown time format would look like HHMM/SS. A universal time format would be coded as DDD:HHMM/SS. In entering data, the user should not have to enter the fixed delimiters, e.g., : and /. These delimiters are shown in cyan to indicate that they do not have to be typed in. Movement through the display should automatically position the user at the next number to be filled in, skipping over any fixed field delimiters.

An alternative suggestion is to retain values from a previous mission in these positions. This is feasible if many values do not change from launch to launch. Such items as LOX drain back and APU hold times and build-in hold times do not vary between launches. Therefore, some time could be saved when entering these parameters. With this method of entering data, the user should be able to retype only those positions within a field that need to be changed. For example, changing 0004/00 to 0007/00 should necessitate positioning the cursor on the 4 and retyping a 7. Deciding on the method to use depends on the ability to support the correct interaction method and on the amount of data entry that the user could be spared. This method should be used only if the above interaction can be implemented and if the users feel comfortable using cursor positioning and retyping data. If this is not the case, then the first method should be used.

2.5 What If Display

The What If display allows the user to do some calculation on various times that are adjustable. The end result is to determine the maximum hold time remaining and the latest possible resume time. These calculations are based on COLA and contingency information in the launch window and the current countdown time and universal time. A possibility that exists within these calculations is resuming the count and holding for a certain amount of time later in the countdown. Figure 10 is the current version of the display. As the what if portion of the program is now implemented, three displays are used. Each display presents a different default plan. One display reflects the situation where no intermediate hold is used. The second display uses this intermediate hold situation. The thought behind revising these displays was to create one generic template that would encompass both scenarios as well as other scenarios. Two possible revisions were developed. The first is a textual display and the other a graphic version.

Figure 11 presents the textual display. The times in the original display were presented in three columns,

universal time, countdown time, and interval time. The thought in revising the display was that the universal time and time intervals were most frequently used. Therefore, the countdown column was eliminated and the times were put into a middle column. The labels were put into two columns, one for events and the second for intervals. An up/down arrow beside of selected items indicates that the user may change the value of that item. The display allows for the user to choose the countdown time of the intermediate hold. The thought here is that by clicking on the selection arrows the times displayed would be the prescribed hold times, e.g., T-4M, T-2/55M, T-31S. The display includes start/end times for COLAS, but this information does not necessarily have to be included. As with the original display the events are ordered by time.

The graphical version (Figure 12) lends itself to full direct manipulation but could function in the same manner as the textual display thus allowing implementation to proceed in stages. In a full direct manipulation mode the user could position events by dragging them to a position on the time line. The time value would be shown as the item is being moved. This allows a finer grain of control than the user has by dragging. The user could also click on the up/down arrows and the item would be positioned on the time line relative to the value selected for it. Repositioning would only take place after the user has pressed "enter" to indicate he has selected the desired value. A first implementation involving selection of values in this manner is advocated before implementing the direct manipulation interface. The benefit of this type of interface is that it allows the user to easily accomplish such tasks as "position T-0 close to the end of the window". Figure 13 shows how the user could be notified of constraints.

In addition, a suggestion is to allow the user to setup several default plans, such as going to T-5M and holding for 5 minutes, prior to countdown and then selecting those plans by selecting the label. Input of these plans could be done via an input display that resembles the what if display. Figure 14 presents a prototype of an input display for default plans. These plans would be setup after the mission parameters have been input so that values for contingency time and launch window end would be obtained from there. These values could then be changed in the default plan. For example, the NTD could construct a default plan that would necessitate asking for an extra five minutes on the end of the launch window. These plans could then be filed and later retrieved and applied to the current situation.

Both the graphic and textual displays could be made available to the user and he could choose to display whichever is more appropriate to his style of decision making.

2.6 The Situation Assessment Display

The situation assessment display contains information about the hold, the end of launch window, projected T-0 and other information and makes a recommendation to resume or not based upon this information. This recommendation also includes the rationale for the decision. This module is still being developed and hence the information that will be displayed is not yet fully specified. Recommendations for a display are shown in Figures 15 and 16. A template of information should be developed and those labels should always be displayed. Information that is not relevant to the present situation should not be filled in. Furthermore, information should be color coded so as to convey to the user the values in the template that are contributing to the seriousness of the situation. For example, if the projected T-0 is within a cola, that text would be displayed in red. The assessment information would display information about resumming in red. This would allow the user to quickly assess that it is unadvisable to pick up by using the red indicators in the resume field. If he wishes to read the text to obtain more information, he may do so. But he would be able to obtain initial information via position and color. Further work is being done on this module. Using this initial display will help in defining a set of variables that should be examined in any given situation.

2.7 Data Collection

The revisions that were made to the displays are based upon guidelines and theories (Dumas, 1988; Galitz, 1989; Gilmore, Gertman, and Blackman, 1989; Helander, 1988; NASA, 1980; Smith and Mosier, 1986; Tullis, 1981) and upon data collected from the users. User data collection was difficult due to the workload on the NTD staff. Several launches were carried out during this research period and the NTDs were engaged in those as well as the simulation runs prior to each launch. However, the following procedure was carried out. The current system was used by an NTD during a simulation, his verbalizations were recorded on audio tape and notes were made about situations. The following items were noted during this process. Included is the resolution of each item.

1. Qualitative information on window remaining should be easily accessable.

Resolution: a graphical representation of projected T-0 within the window was incorporated into the clock section.

2. COLA information is used for picking up at T-9M.

Resolution: this information is shown in launch window but consideration should be given to including the exact times on the labels.

3. The point of no recycle should be included on the test parameter screen but does not need to be included with clock information.

Resolution: this has been incorporated in the revised TMID and test paramater display.

4. The major benefit of the what if display was envisioned to be taking the launch window end and working backwards from this. The time between launch window end and projected T-0 was seen to be dependent upon contingency time but not entirely.

Resolution: The textual version of the revised what if display breaks this time interval into two parts: contingency time plus an additional time. Both should be capable of being changed to give a resulting interval.

5. The clocks that are used differ in importance depending on the countdown time of the hold. At T-20M, the hold time remaining is most important. At T-9M the window remaining is important. At T-5M and under the hold time remaining (which increments at this point) is important.

Resolution: consideration should be given to incorporating code to highlight the appropriate clocks at these times in order to direct the user's attention.

6. When scrolling through the launch window it was easy for the user to loose his orientation.

Resolution: moving the scroll bar to the right hand side of the display and making it more visible is important. The user can use this information to judge which portion of the display he is viewing. This has been incorporated into the revised TMID screen.

7. A method of intially putting in parameters for each launch and for changing them during countdown should be provided.

Resolution: A display has been prototyped for this purpose. This feature is currently on the list of items to incorporate into LDSS.

The second method of data collection involved an initial series of displays, namely the TMID screen, which were revised based upon informal comments and guidelines. Several situations were setup in order to obtain information about interpretations of specific decision making processes. These were shown to an NTD and discussed. Based upon this information, further revisions were made and again shown to the same NTD. This set of displays was distributed to other members of the NTD staff along with a questionnaire. This data yielded the following information:

1. The clocks provided are sufficient.

2. The LOX drain back clock in the firing room has been changed. This change will soon be incorporated into LDSS.

3. Make sure that users understand which values in the clock section are static (Launch Window End) and which are computed. This needs further discussion with more members of the NTD staff. A color code could possibly be used here or the positioning could be changed.

4. Reduced time marks are suficient.

5. A finer grain of time (second resolution) was suggested. This is provided in two ways. First, when the LDSS runs the time shown is dynamic and updated on a second by second basis. Secondly, a new display has been developed which the user could switch to close to lift off which provides a ten second resolution.

6. The color coding of the graphic display was deemed useful and clear.

7. Color coding for the data values and time was questioned. The explanation of the color coding should be separated when presented to the user. For graphics, green represents safe, yellow cautionary and red represents a warning. For data values, cyan represents not yet relevant, green represents a valid, relevant data item, yellow represents a hold condition. Therefore, all clock values should appear either as cyan or green. The only exception is time to T-0 which should appear in yellow when there is a hold in the countdown. On the timeline of the TMID screen, the countdown times will be displayed in yellow when there is a hold. UT, CDT and event labels that have happened should change from cyan to green.

8. GLS milestones should be labeled to refect times accurate to seconds. This has been incorporated on the revised TMID screen.

9. Displaying latest resume time on TMID screen is useful. This was used in the decision making process. Therefore having this time available on the TMID screen will reduce movement between displays.

10. A suggestion was made that it would be useful to have more information on time crital actions such as *start recorders, APU Fuel ISO's,* etc. This information will be displayed on a planned configuration management display.

2.8 Complexity Issues

In predicting a user's ability to easily obtain information from a display several items must be taken into account (Tullis, 1981). The number of items in a group and the average size of the group is one determining factor in lowering search times. Results by Tullis suggest that the optimum range for alphanumeric displays is 40 groups averaging 4.9 degrees in size. Local density, how tightly packed a screen is, and layout complexity (the alignment) of the display also affects performance. Also important, these two issues affect subjective ratings by users. These issues were examined in the displays that are suggested for revision. The grouping of items and the size of the groups was considered somewhat in the revisions. This was mostly

in the clock information. Rather than keeping each clock as a separate entity, information was grouped according to functionality. The size of the groups was determined by the information presented and therefore, other rearrangements were limited.

Complexity was analyzed for an original TMID and a revised TMID screen. As the information presented on these displays changes, various complexity measures will be obtained. For this analysis, two displays were chosen that represent one of the more complex displays. Using a easier calculation than the original Tullis calculation from information theory (Galitz, 1989) the following are summed: the number of data fields, the number of horizontal alignments (columns) and the number of vertical alignments (rows). For the original TMID screen shown in Figure 17 this produces a complexity score of 177. For the revised TMID screen, the complexity score is 153. This revision is a 13.6% reduction from the original.

Density of a display is the proportion of characters displayed on the screen as opposed to the amount of blank screen. For density calculations, the screen was considered without its border. Dimensions were 70 by 28 resulting in 1960 positions. For the original TMID screen, the density was calculated to be 52 percent. The density calculation for the revised screen was 40 percent. Although, this revision is still higher than the overall recommended level of 25 to 30 percent the fact that a portion of it is graphical should still result in a usable display. Further reduction is impossible as a principle adhered to in redesign was to reduce the amount of movement between displays. Therefore, this trade-off of higher density versus time to switch displays was made.

III. Trade-offs in Organizing Human-Computer Interaction Knowledge

3.1. Introduction

Currently, a large body of human-computer interaction knowledge exists. Most of this exists in the form of recommendations and guidelines. One of the difficulties in interface design is transferring this information to interface designers in such a manner that it can be incorporated into the design. Scapin (1991) examined the problems encountered when trying to implement human-computer interaction knowledge into the design. Scapin developed a framework for organizing this knowledge. This section discusses this framework, the problems that arise in using this framework, and a method for resolving one of the problems, namely, that of weighing trade-offs.

3.2 Organization of HCI Data

Scapin collected HCI data with the intent of organizing it into a database accessible by attributes. Attributes that were used for characterizing HCI recommendations were: criterion or criteria describing the rationale, the level (conceptual, semantic, syntactic, lexical) that describes the outcome and rationale, and the type of interface object to which the recommendation applies. Several conclusions were drawn by Scapin during this process. He found that a recommendation in the literature could lead to more than one recommendation in terms of implementation. Many recommentations were too vague and needed elaboration in order to be useful in implmentation. Additionally, different authors used different wording for the same recommendations necessitating translation to a stable vocabulary.

Scapin proposed a generic deciphering framework of the form:

if (a premise)...(using **Criteria**)... **then** (a **Conclusion**)

Premises are defined to be of four types:

type/characteristics of user
type of user task
design activity of the interface for which the knowledge is being used.
context or the particular state of the user interface.

The criteria used are:

Compatability with past habits and skills of the user, between input and output, between noncomputerized support and software, and with interface standards.

Consistency in location, format, syntax and naming conventions.

User Workload with respect to minimizing mental and physical effort required.

Adaptability or the capability of the interface to adapt to various user actions.

User Explicit Control allows the user to control the dialogue and to explicitly enter information.

Significance of codes or use of labels, codes, and abbreviations that are meaningful to the user.

Guidance so that the user can identify what he can do next. This includes feedback and clarity in display.

Error Managment is the attempt to prevent or avoid errors and to give meaningful feedback when errors do occur.

Conclusions can be of two types: design activity which represents a conclusion or specific activity or an action item which is the type of activity required to apply a rule.

Scapin notes intrinsic and usage problems involved in applying human factors knowledge. Intrinsic problems consist of recommendations that are incomplete, recommendations that are too general to be useful and recommendations that lack robustness (apply only in limited contexts). Usage problems are accessing recommendations, making trade-offs in deciding which recommendations to apply, and the varying degree of detail of the recommendations.

3.3 A Method for Prioritizing Trade-offs

Recommendations do not come organized in a hierarchy. Therefore, the designer will often be faced with several approaches, each giving priority to different recommendations and resulting in different solutions. In order to balance trade-off decisions, several issues arise. The first is what factors should be used to determine weights for guidelines. The second issue is how to ensure that these trade-off decisions are made consistently. The method presented here builds on Scapin's work. As discussed in section 3.2, Scapin presented eight criteria and suggested the types of guidelines that pertain to each. In order to prioritize decision making, these criteria are used and weighted according to some known user and task information. During the evaluation of LDSS, the following information was used to prioritize guidelines: type of user, attention time, timing of task, critical aspect of task, and critical aspect of software. Each of these categories can have several different values which would dictate prioritizing different criteria and hence, guidelines. The following discussion is a suggested set of values and emphasized criteria.

Type of user refers to the novice, casual, expert classification. For a novice user the primary criteria

would be guidance. Error management, compatability with past habits, significance in codes, consistency workload and explicit control would be secondary criteria. A casual user would dictate the same criteria but consistency and workload would become primary criteria along with guidance, error management, and compatability. Expert users would be more concerned with adaptability than any of the other criteria.

The attention time of the user is also an important factor in determining trade-offs. What else competes for the user's attention while dealing with the software? Suggested values range from undivided attention to moderate attention to little attention. In the case of little attention, where the user is attending to many other tasks and using the software primarily for support, issues of consistency, guidance, workload and significance of code become the primary criteria. Compatability becomes a secondary concern. In the case of moderate attention the same criteria are important but could be considered secondary concerns rather than primary concerns. If the user has undivided attention to devote to the software then adaptability could be classified as a primary concern. The user has time to discover various aspects of the system and is able to choose a method of performing a task that is more suited to his individual style.

Task considerations should include whether the task is a real-time or nonreal-time task. That is, is the software supporting a shuttle launch or is the software an income tax spreadsheet? This consideration is similar to the attention of the user consideration in that the primary criteria for real-time tasks should be the same as for limited attention: workload, guidance and consistency. Nonreal-time tasks place adaptability as a primary concern. The critical issue of the task involves the importance of the software to the task. That is, can the task be completed without use of the software? Critical software would dictate that error management be a prime concern with guidance as a secondary concern. A second concern is the nature of the task. Software that aids in landing aircraft would be deemed more critical than software for producing slides. Criteria important for this type of critical software would be: significance of codes, guidance, and consistency. The emphasis is placed on the ability to correctly interpret information presented.

The method for prioritizing criteria and hence, guidelines, involves collecting this information concerning users and tasks. Then individual criterion is given two points for each time it appears as a primary concern and one point each time it appears as a secondary concern. The criteria with the highest scores should then be used as the deciding factor in trade-off decisions. Guidelines that support those high scoring criteria should be utilized over guidelines supporting criteria receiving lower scores.

The method used here needs further refinement to ensure that it correctly addresses all values for suggested

categories. Nonetheless, this method was used quite successfully in making consistent trade-off decisions during revision of the LDSS interface. In this case, the users were casual, the attention of the users limited, the task was real-time, and critical but the software is not critical for success of the task. Using this scheme an interface was produced in which priority was given to guidelines which enhance the users' ability to discern information from the screen and to minimize the amount of interaction required by the user. Consistency and guidance were the highest ranking criteria followed by work load and significance of codes. Little effort was put into making the system flexible. As the amount of interaction was limited, little effort was put into error management. In order to further refine this method and to determine its robustness, it will be necessary to evaluate more interfaces which have different tasks and users. A successful method would be capable of producing usable interfaces for a wide range of user and task characteristics.

IV. CONCLUSIONS

Suggested revisions for the LDSS interface have been developed using a combination of empirical information and application of human-computer interaction knowledge. The process of developing these revisions was tracked and led to a method for prioritizing criteria for use in trade-off decisions. As LDSS will now be field tested in the KSC firing room, the actual usability of the interface can be assessed. Due to the nature of the ANTD/NTD job, information concerning the use of the interface will have to be collected in a nonintrusive fashion. As the use of LDSS is optional and will require a change in the ANTD/NTD procedures during countdown, the initial and sustained use of LDSS will be a major indication of the usability of the system. Additionally, information must be collected after use of the system. This information should discriminated between missing information, misinterpreted information and mistrusted information. Audio tapes of countdown activities, especially S0044 simulations, along with observations by the LDSS staff can be used to obtain this information. In addition, post countdown interviews with the ANTD and NTD are very valuable. Any changes that are made to LDSS as a result of these observations and interviews should be documented in the form of guidelines. New software development will benefit in the form of time savings and monetary savings from use of these guidelines. Utimately, the users of these software tools will benefit from the increased usability of newly developed tools.

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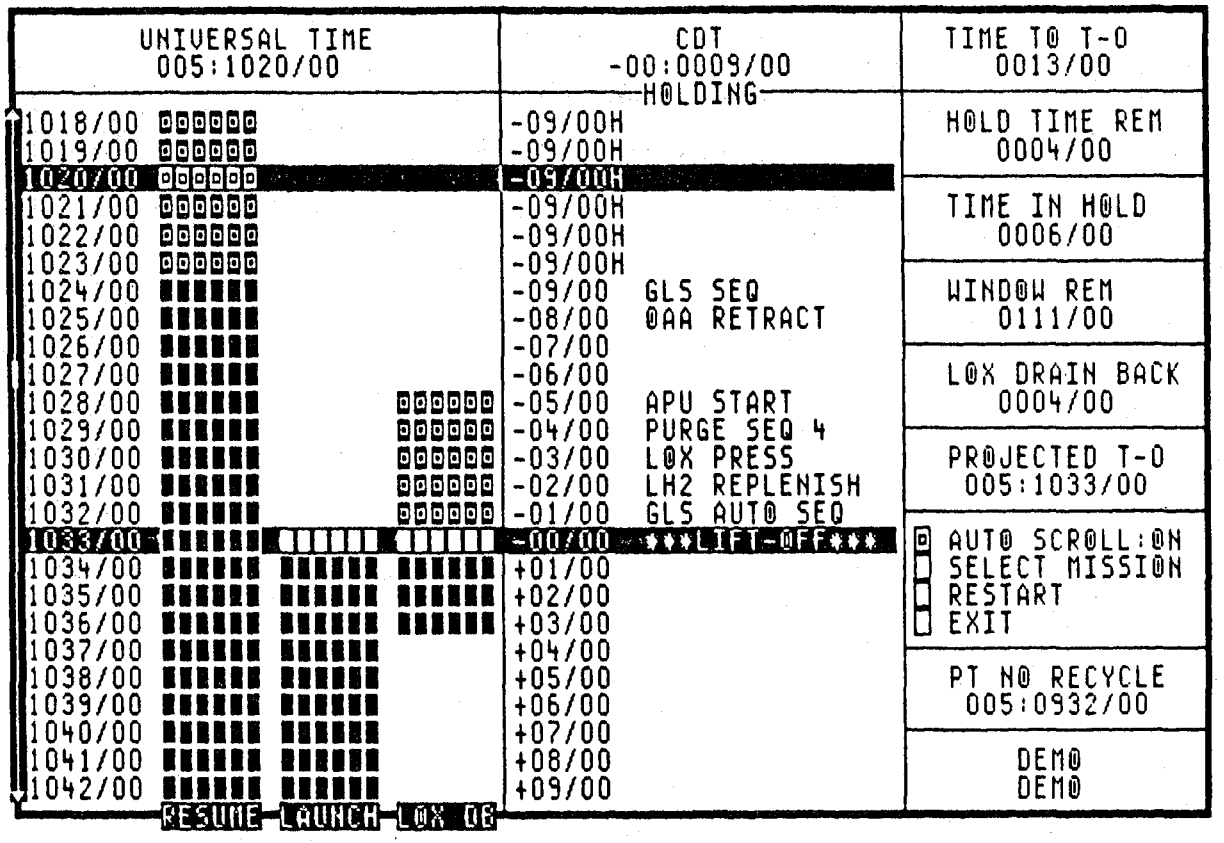

Figure 1: Original TMID

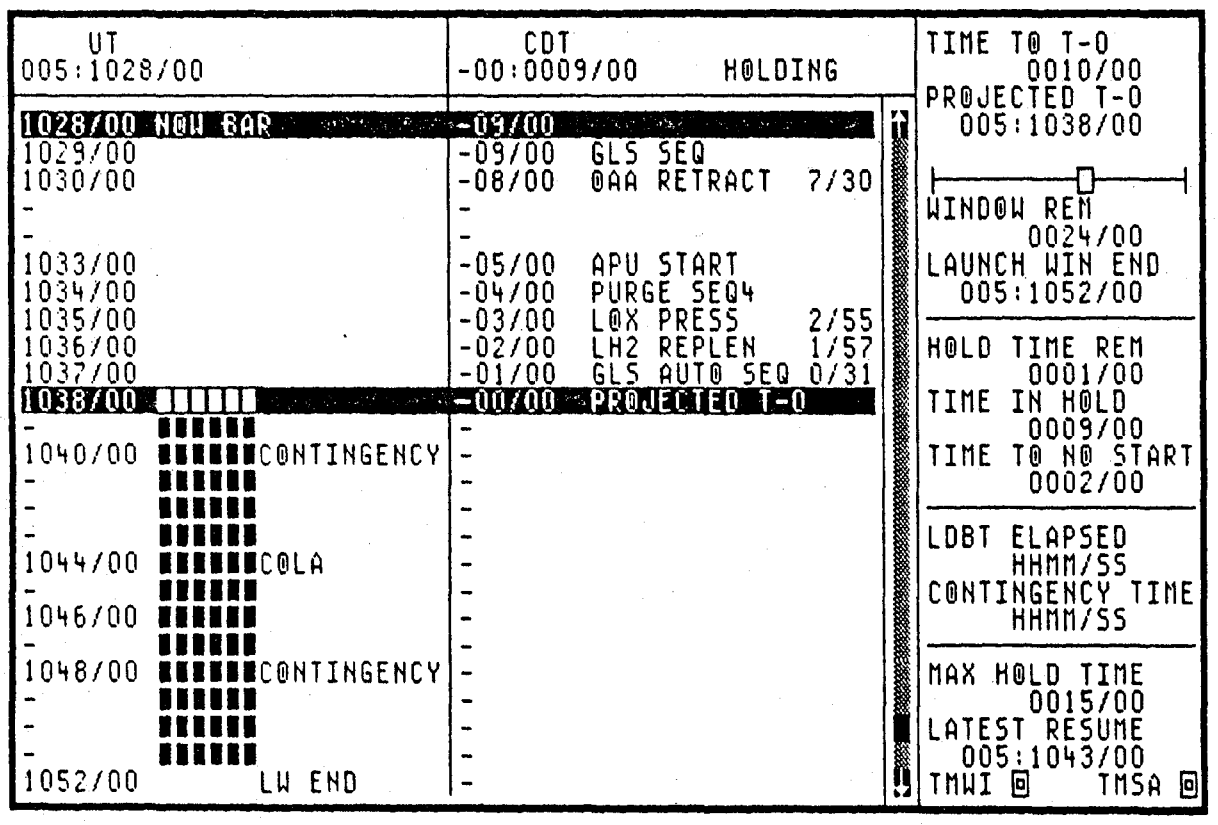

Figure 2: Revised TMID

```
    UT                          CDT                          TIME T0 T-0
005:1029/00                 -00:0020/00     H0LDING              0031/00
                                                             PR0JECTED T-0
1029/00 N0W BAR             -20/004                            005:1058/00
-                           -
-                           -
-                           -                                WIND0W REM
-                           -                                     0130/00
-                           -                                LAUNCH WIN END
-                           -                                 005:1159/00
-                           -
-                           -                                H0LD TIME REM
-                           -                                     0001/00
-                           -                                TIME IN H0LD
1040/00                     -09/00H                               0011/00
-                           -09/00H                          TIME T0 N0 START
-                           -09/00H                               0005/00
-                           -09/00H
-                           -09/00H                          LDBT ELAPSED
-                           -09/00H                               HHMM/SS
-                           -09/00H                          C0NTINGENCY TIME
-                           -09/00H                               HHMM/SS
-                           -09/00H
-                           -09/00H                          MAX H0LD TIME
1050/00                     -09/00   GLS SEQ                      0015/00
1051/00                     -08/00   0AA RETRACT 7/55        LATEST RESUME
-                           -                                 005:1043/00
1053/00                     -                                TMWI [0]     TMSA [0]
```

Figure 3: Revised TMID, T-20M

```
    UT                          CDT                          TIME T0 T-0
005:1029/00                 -00:0020/00     H0LDING              0031/00
                                                             PR0JECTED T-0
1029/00 N0W BAR             -20/004                            005:1058/00
-                           -
-                           -                                WIND0W REM
-                           -                                     0130/00
-                           -                                LAUNCH WIN END
-                           -                                 005:1159/00
-                           -
-                           -                                H0LD TIME REM
-                           -                                     0001/00
-                           -                                TIME IN H0LD
1040/00                     -09/00H                               0011/00
-                           -09/00H                          TIME T0 N0 START
-                           -09/00H                               0002/00
-                           -09/00H
-                           -09/00H                          LDBT ELAPSED
-                           -09/00H                               HHMM/SS
-                           -09/00H                          C0NTINGENCY TIME
-                           -09/00H                               HHMM/SS
-                           -09/00H
-                           -09/00H                          MAX H0LD TIME
1050/00                     -09/00   GLS SEQ                      0100/00
1051/00                     -08/00   0AA RETRACT 7/55        LATEST RESUME
-                           -                                 005:1129/00
1053/00                     -                                TMWI [0]     TMSA [0]
```

Figure 4: Revised TMID, T-20M, Unable to Resume

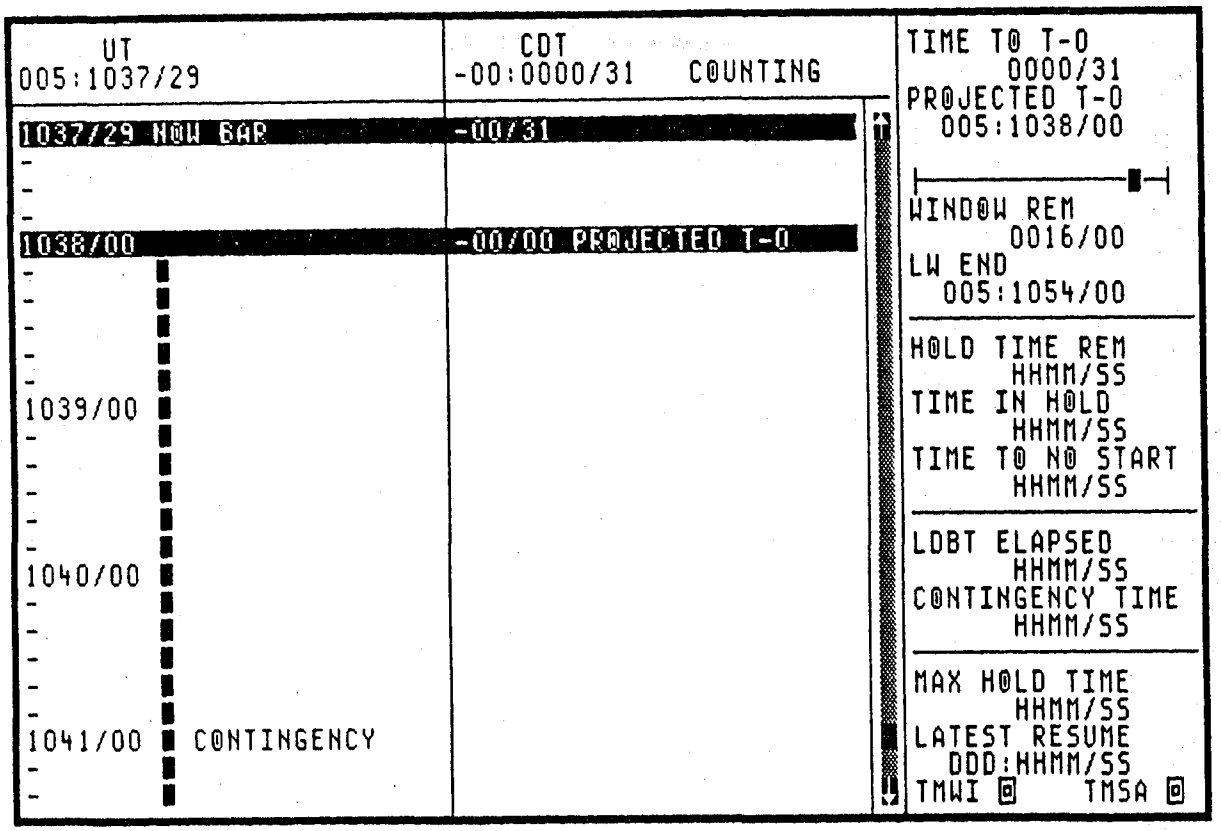

Figure 5: TMID with fine grain resolution

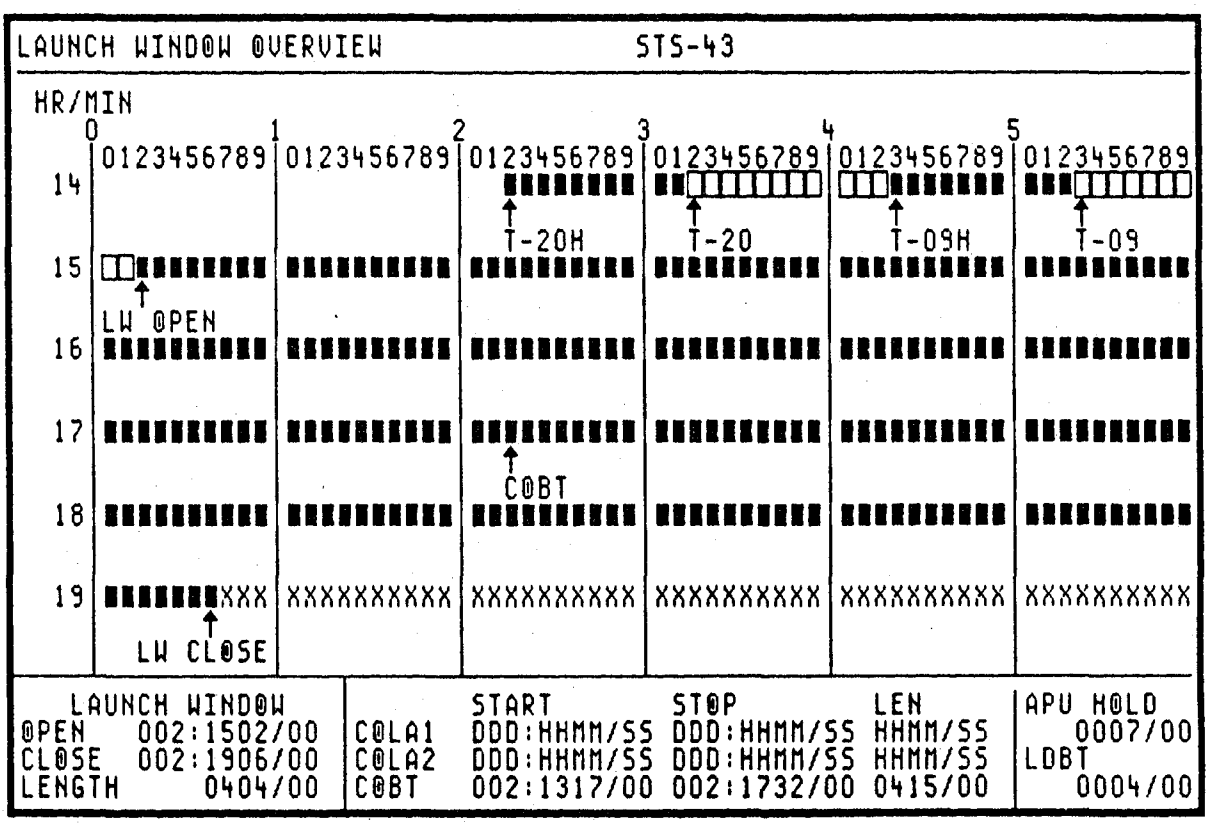

Figure 6: Overview Display

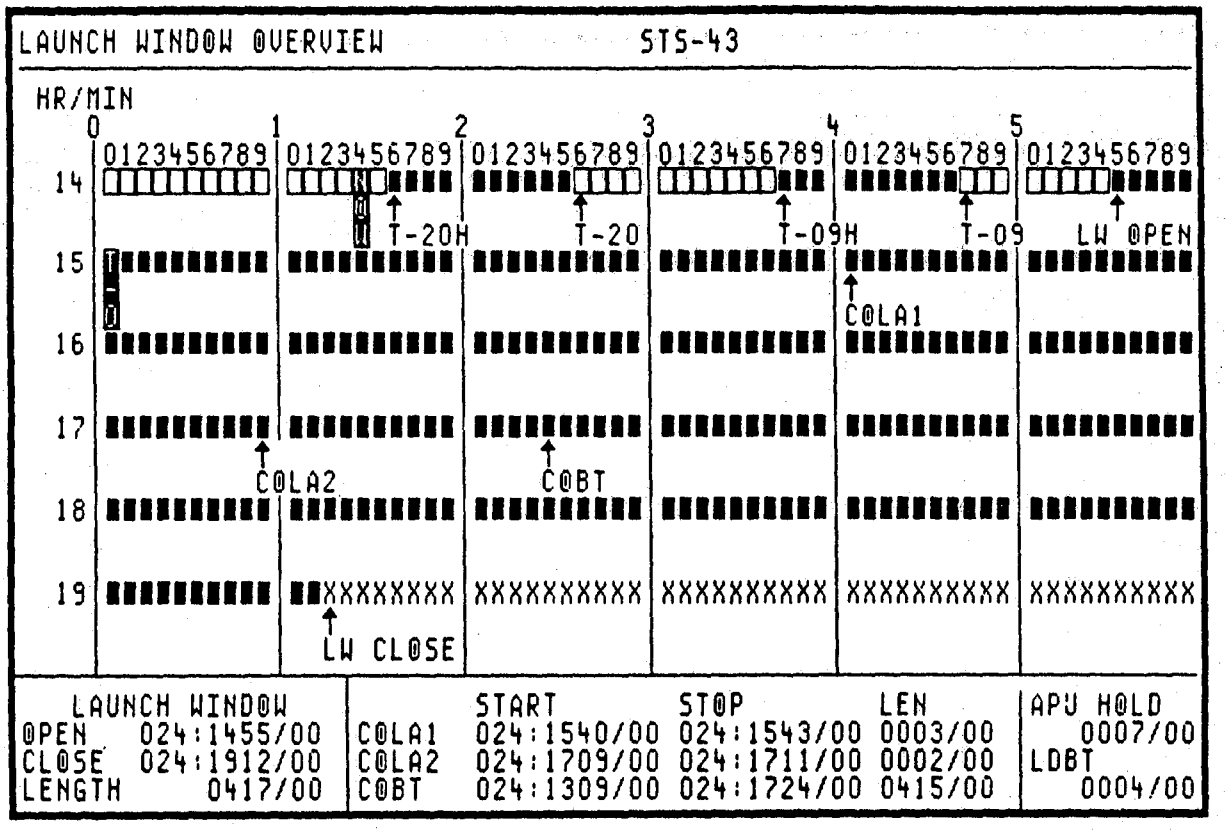

Figure 7: Dynamic Overview Display

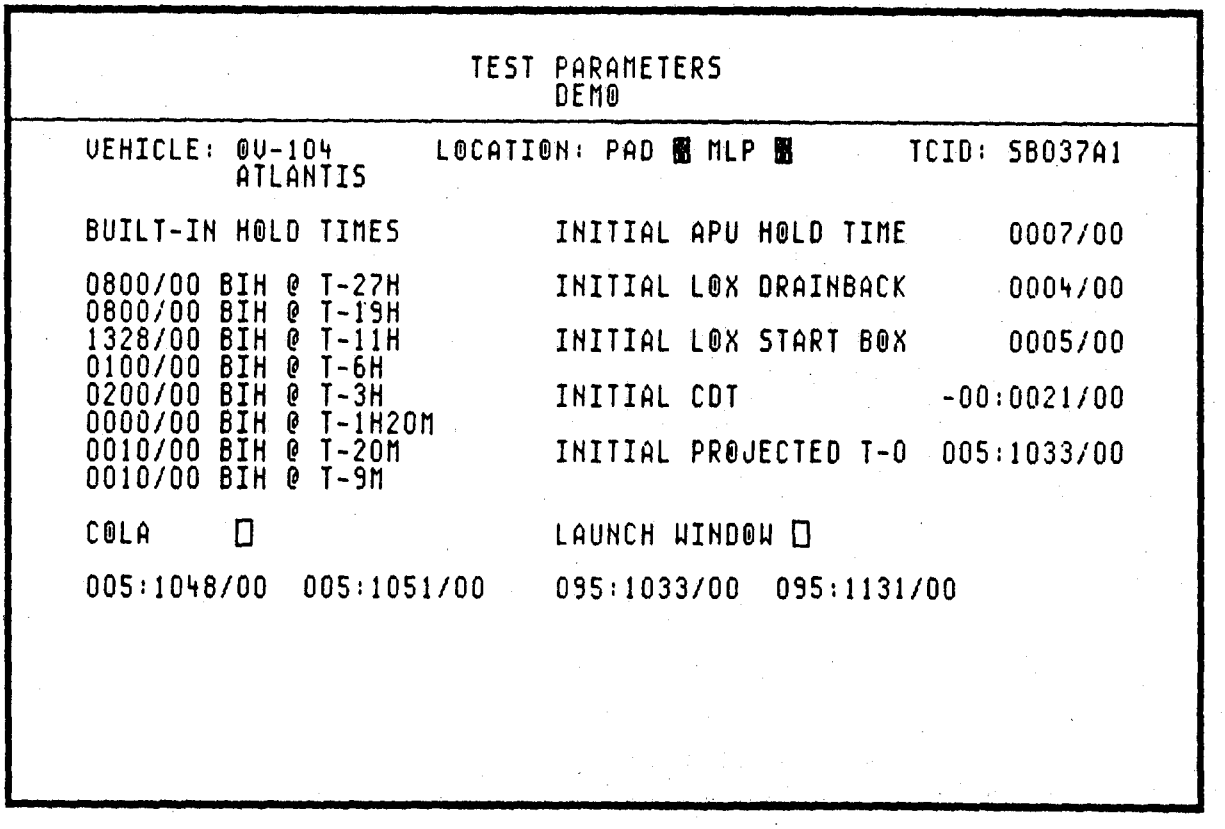

Figure 8: Original Test Parameters Screen

```
                         MISSION   STS48

VEHICLE: OV-XXX      LOCATION: PAD X MLP X        TCID: XXXXXXX

BIH        LENGTH                APU HOLD TIME       0007/00
                                 LDBT                0004/00
T-20M      0010/00               LOX START BOX       0000/00
T-9M       0010/00               PROJECTED T-0   000:0000/00
                                 PT NO RECYCLE   000:0000/00

                   START          END            LENGTH
LAUNCH WINDOW      000:0000/00    000:0000/00    0000/00

COLA1              000:0000/00    000:0000/00    0000/00
COLA2              000:0000/00    000:0000/00    0000/00
COLA3              000:0000/00    000:0000/00    0000/00

COBT               000:0000/00    000:0000/00    0000/00
```

Figure 9: Revised Test Parameters Screen

```
UNIVERSAL TIME          CDT                  TIME TO T-0
 005:1017/00          -00:0009/00              0016/00
                         HOLDING
                                              HOLD TIME REM
                  WHAT                           0007/00
          MAX HOLD TIME REM                0056/00   TIME IN HOLD
          LATEST RESUME TIME    1113/00              0003/00
                                              WINDOW REM
|--CDT--------DESCRIPTION----------UTC------INTERVAL|  0114/00
                                              CONTING TIME
                  IF                             0004/00
  -09/00  HOLD START TIME        1014/00
          TIME IN HOLD                     0003/00   PROJECTED T-0
          NOW                    1017/00              005:1033/00
          MAX HOLD TIME REM                0056/00
          LATEST RESUME TIME     1113/00

□ -05/00  HOLD START TIME        1117/00
          TIME IN HOLD                   □ 0005/00
          RESUME TIME            1122/00
                                              PT NO RECYCLE
  -00/00  DESIRED GMT OF T-0     1127/00          005:0932/00
          CONTINGENCY TIME               □ 0004/00
          LAUNCH WINDOW END    □ 1131/00
                                              DEMO
```

Figure 10: Original What If Display

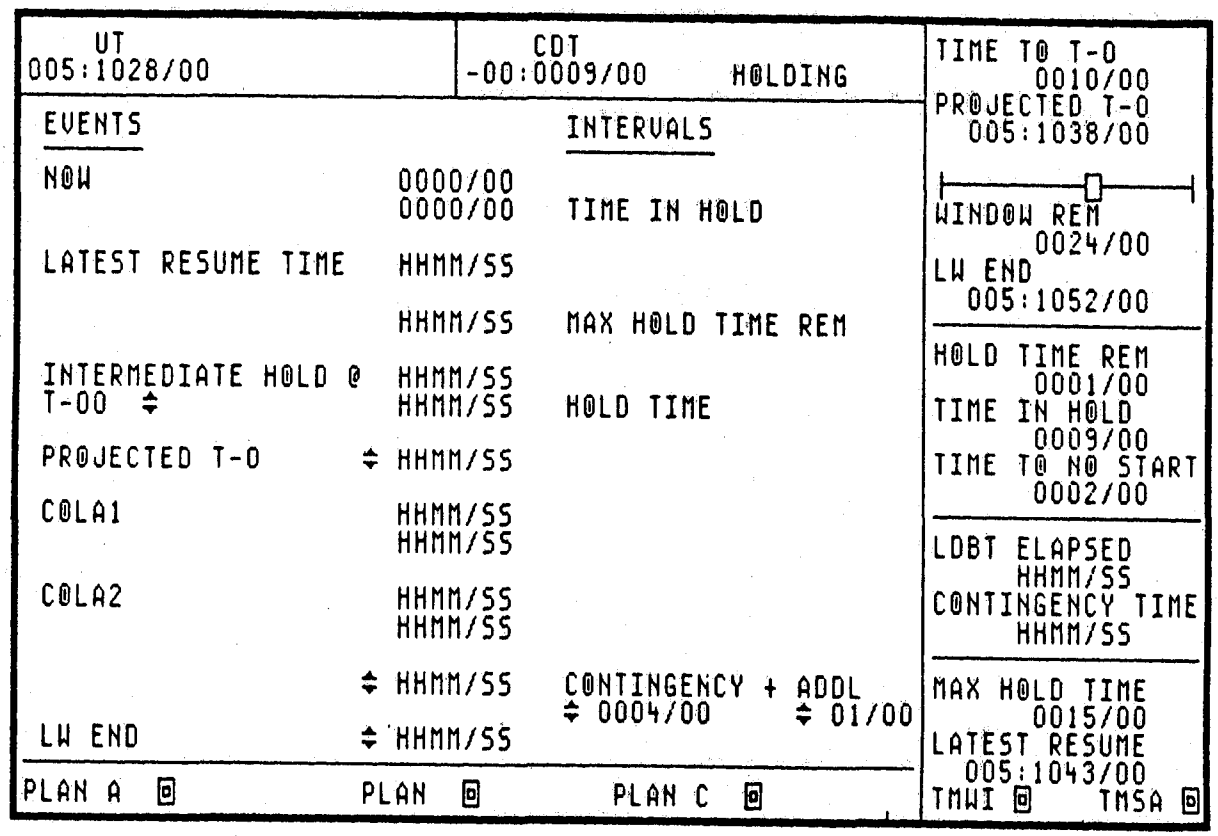

Figure 11: Revised What If Display, Textual Version

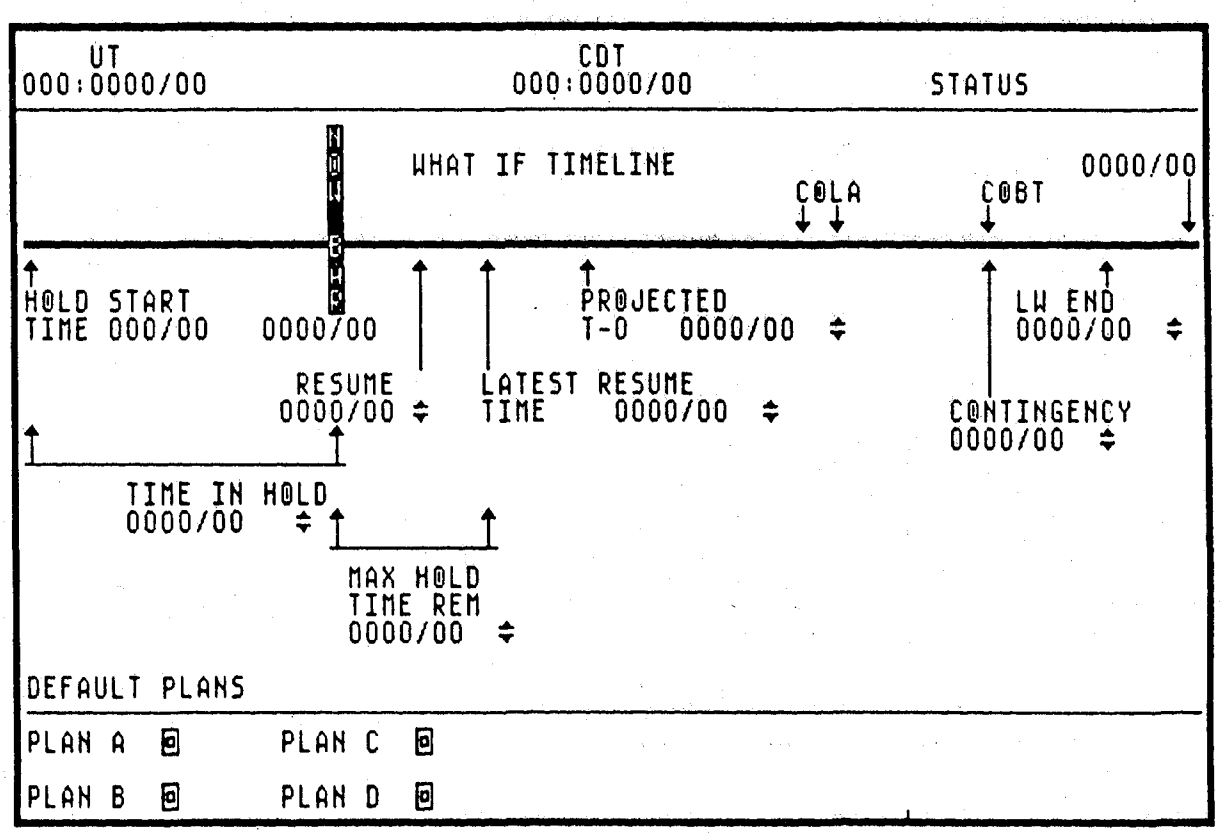

Figure 12: Revised What If Display, Graphical Version

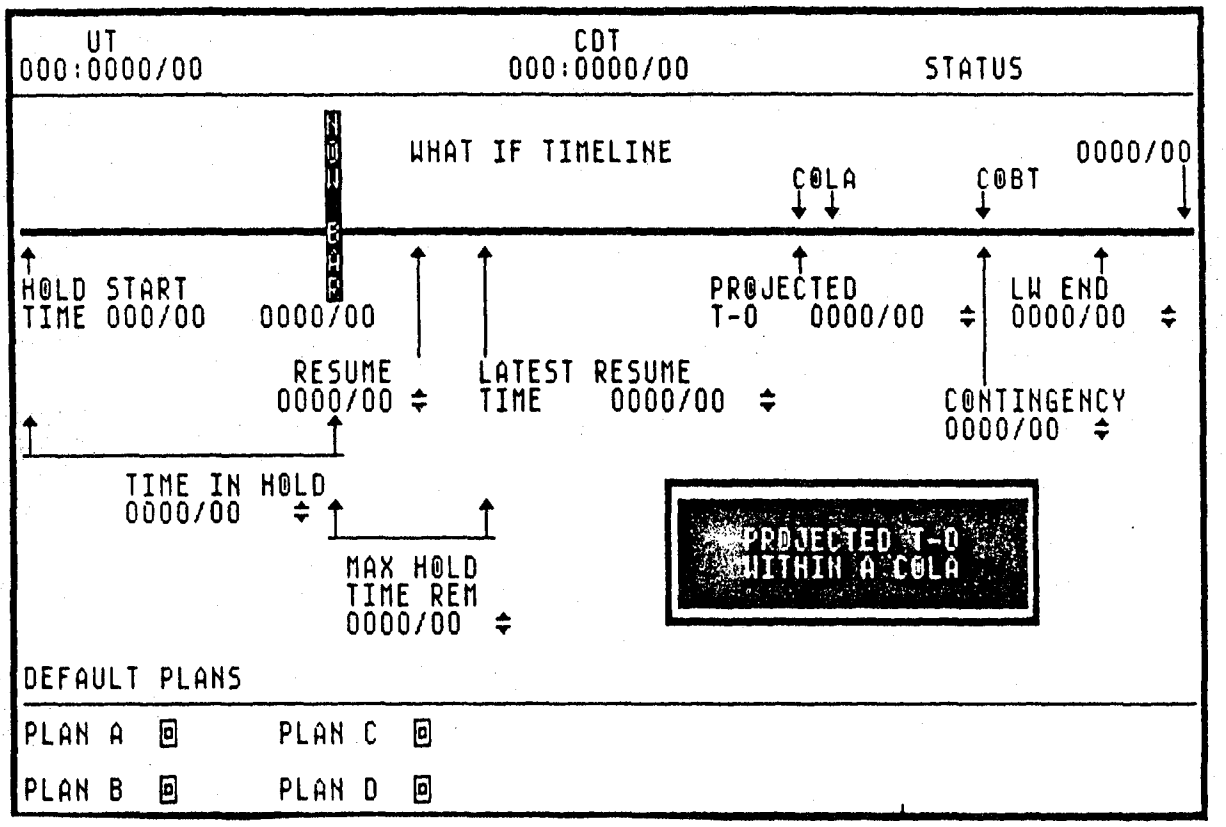

Figure 13: Revised What If Display, Graphical showing Constraints

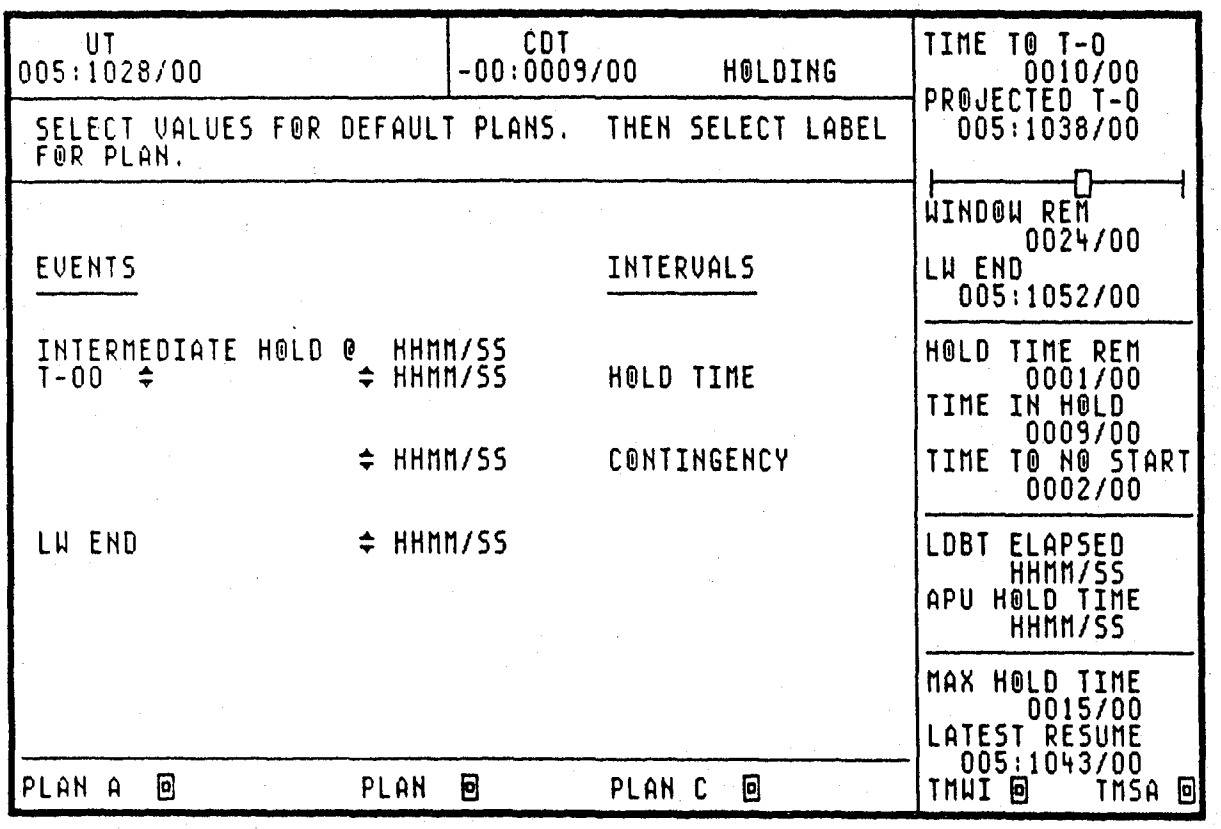

Figure 14: What If Default Input

```
   UT                          CDT
005:1035/15              -05:1009/00          HOLDING
SITUATION

TIME:              T-9M
HOLD:              EXTENDED
LAUNCH WINDOW:     LONG
CONTINGENCY:       NONE
PROJECTED T-0:     WITHIN CONTINGENCY OF A COLA

ASSESSMENT

RESUME: UNADVISABLE

WHY:    WILL NOT HAVE FULL CONTINGENCY TIME PRIOR
        TO COLA
```

```
TIME TO T-0
      HHMM/SS
PROJECTED T-0
  DDD:HHMM/SS

WINDOW REM
      HHMM/SS
LAUNCH WIN STOP
  DDD:HHMM/SS

HOLD TIME REM
      HHMM/SS
TIME IN HOLD
      HHMM/SS
TIME TO NO START
      HHMM/SS

LOX DRAIN BACK
      HHMM/SS
CONTINGENCY TIME
      HHMM/SS

MAX HOLD TIME
      HHMM/SS
LATEST RESUME
  DDD:HHMM/SS
TMWI ▣    TMSA ▣
```

Figure 15: Revised Situation Assessment

```
   UT                          CDT
005:1028/00              -00:0009/00          HOLDING
SITUATION

   TIME:              T-9M
   HOLD:              EXTERNAL
   LAUNCH WINDOW:     LONG
   MAX HOLD TIME:     LONG
   CONTINGENCY:
   PROJECTED T-0:     NO CONSTRAINTS UNTIL 0000/00

ASSESSMENT

   RESUME:  ADVISABLE UNTIL 0000/00

   WHY:     NO CONSTRAINTS
```

```
TIME TO T-0
      0010/00
PROJECTED T-0
  005:1038/00

WINDOW REM
      0024/00
LAUNCH WIN END
  005:1052/00

HOLD TIME REM
      0001/00
TIME IN HOLD
      0009/00
TIME TO NO START
      0002/00

LDBT ELAPSED
      0000/00
CONTINGENCY TIME
      0000/00

MAX HOLD TIME
      0015/00
LATEST RESUME
  005:1043/00
TMWI ▣    TMSA ▣
```

Figure 16: Revised Situation Assessment, Display 2