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MARS OBSERVER SCREEN DISPLAY DESIGN FOR A MULTIMISSION ENVIRONMENT

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1. INTRODUCTION

The Multi Mission Control Team (MMCT) is responsible for support to real time operations of the Mars Observer Mission. The team has the responsibility for monitoring the ground data system for the integrity of the telemetry and command data links. It also supports the Mars Observers Spacecraft Team in monitoring spacecraft events. The Data Monitor and Display subsystem (DMD) workstation provides the data interface with the ground data system.

DMD workstation displays were developed to support the Mission Controllers in accomplishing their assigned tasks for supporting the Mars Observer mission. This paper presents the display design concepts that were used in the Mar Observer MMCT displays to minimize the cognitive demands on the controllers and enhance the MMCT operations.

1.1 Data Monitor and Display Subsystem

The Data Monitor and Display subsystem (DMD) is the controllers window into the spacecraft and the ground data system. The DMD is a workstation that provides a variety of formatted data displays to the controller. The displays present both spacecraft telemetry data and ground system monitor data. Some displays are preplanned and developed prior to the operations in which they are used. These are called fixed displays and are quite versatile in format and content. Other displays and plots can be created in real time. These displays have limited formats but flexibility in content. These are called list or message displays. They can be rapidly generated by the controller as needed. The MMCT display repertoire provides a mix of displays appropriate to the needs of the MMCT controllers. Figure 1 illustrates both the fixed and message display formats.

2. DISPLAY DESIGN CONCEPTS

2.1 Operational System Context

Displays should be developed in context of the operational system. That is, displays should be developed that respond to the operations systems requirement (Ref. 1).

In order to be effective, displays must focus on the need of operations system. The display should focus on specific information that is required to complete a task.
Superfluous display information creates confusion and requires extra effort from the controller for filtering. Of course, missing display information reduces the display effectiveness.

2.2 Knowledge based vs Procedural based

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. Thus the operator cost can 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 frequently, 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 so that he can recognize when problems occur and can formulate plans to resolve the problems. The advantage of a Knowledge based system is that more complex and variable precesses can be handled. Preplanning is minimized. Another advantage is that the operator responds to problem when they occur, that is when they are the most well defined.

2.3 Focus and Structure

To support Procedural based operations displays should be designed to ease the cognitive load on the controller. The cognitive load on the controller can be eased by focusing the display on only the data needed for the tasks that he is performing. Thus he does not need to filter data. Figure 1 illustrates both focused and unfocused displays. Relationships and conditions can be emphasized, such as color coding the display elements that are active as against those that are not active. Visual and graphic display elements can be used to indicate the condition of more abstract conditions.

2.4 Hierarchic Displays

System troubleshooting is enhanced by providing a hierarchic system of displays. They start with a high level system displays containing the basic elements of the system, preferably in a block diagram format, with GO/NOGO indications. Lower level displays expand the displayed information for the system elements identified as faulty by the higher level display. This display concept can be continued until the lowest level of interest is displayed.

2.5 Compatibility

Compatibility eases the controllers cognitive load by presenting like things the same on different displays. The cognitive effort is reduced because the display elements are recognized and do not have to be deduced (Refs. 2 & 3).

Compatibility also refers to naming the display elements with names that are the same as those used in other activities i.e. common names. Conventions used in various displays should be similar. For example, in both the Down Link display (Fig. 2) and the Up Link display (Fig. 3) the existence of the telecommunications link is indicated by an arrow connecting the spacecraft box with the ground system box.

2.6 Example

The Down Link Display (Fig. 2) illustrates these concepts. The display is focused on the down link telemetry system. The spacecraft elements of the downlink are displayed in a box. The ground station elements of the downlink are displayed in a separate box. The display identifies the systems elements that are active by being presented in bold. The overall status of the down link is visually presented by the arrow from the spacecraft box to the ground station box. The existence of the arrow very rapidly identifies that the down link exists. The absence of the arrow indicates that the down link is broken and that no data is flowing.

3. TYPES OF DISPLAYS

Three types of displays were developed for the Mars Observer mission support. They are Multimission system displays, mission sequence displays, and controller discretionary displays.

3.1 Multimission System Displays

System displays provide the controller with the information about the overall performance of the system. They quickly indicate that the system is operating as expected or conversely, that something is wrong. The Ground Data System display (Fig. 4) illustrates this type of display.

System displays for mission controller (MMCT) need to support the controller in three areas, configuration, performance, and sequence.

3.1.1 Configuration

The mission controller must confirm that the configuration of the ground data system and the spacecraft are proper for the transmission of telemetry data and spacecraft commands. That the planned system elements are up and operating correctly, and that the system elements are set with the proper parameters such as bit rate. The system displays should help the controllers verify the integrity of the spacecraft/ground data system.

3.1.2 Performance

The mission controller display should also provide an indication of the performance of the data and command systems. That is, the signal levels and signal to noise ratios (SNR) are as predicted. If the performance is not as predicted, action is required to investigate and resolve discrepancies before data degradation occurs. The ground data system display provides this information (Fig. 4).

3.1.3 Sequence

Occurrence of expected events are confirmed, and the occurrence of unexpected events is detected. For example, receiver lock up times are displayed in the ground data system display to confirm that the tracking station is operating correctly and that the data is flowing (Fig. 4).

3.1.4 Users Responsibilities

The mission system displays allow the Mission Controller to meet their responsibilities to the project in confirming the integrity of the data and command systems.

3.1.5 Procedural Based

Top level system displays indicate the overall performance of the ground data system. They tend to support Procedural based operation in that they provide information to confirm preplanned configurations and performance. Lower level subsystem displays provide more detail about the configuration and performance and tend to support Knowledged based operation. The high level displays are usually fixed DMD displays. The lower level displays may be fixed displays but often are list or message displays.

3.2 Mission Sequence Displays

These are displays that support the mission controller in confirming the sequence of spacecraft and ground data systems events. The sequence of spacecraft and ground data system events is preplanned and documented in the Project SOE (Sequence Of Events). The mission sequence displays provides the controller with information which allows him to confirm that the spacecraft and the ground system in fact operating according to the SOE.
During some parts of the mission, the Mars Observer Spacecraft Team is staffed for only 40 hours per week. The MMCT controllers being on duty continuously, support the Spacecraft Team by monitoring the spacecraft.

The Spacecraft Team provides the standards and limits for the DMD displays. The MMCT responsibility then is to monitor the display for out of limit conditions. This removes the requirement that the controllers be trained in the spacecraft system.
There are two basic kinds of mission sequence displays: displays for unique sequences and displays for repeated sequences.

Unique sequences are sequences of events that occur only once during the mission. Displays for unique sequences focus on the specific events as they occur and reduce the work load on the controller in that he doesn't have to interpret the SOE and search the telemetry data stream displays for the information that confirms the event. Since they occur only once, and for cost considerations, they may not be developed as fixed displays but as list or message displays.

Some spacecraft sequences are repeated many times, such as the spacecraft data recorder operations. These displays are valuable and should be well designed and well focused since they are used repeatedly. The DTR display (Fig. 1) illustrates a repeated sequence display. They allow the controller to focus on just the data that pertains to the event occurring. The controllers become very familiar with the display and thus reduce their workload.

The mission sequence displays tend to be procedural based in that they provide the mission controller with information that allows them to confirm preplanned events. Fixed displays are cost effective for repeated sequence displays. List or message displays may be more appropriate for unique sequence displays.

3.3 Controller Discretionary Displays

The displays discussed above, must be designed in advance of their use. In addition to the fixed displays presented above, the DMD provides the flexibility for mission controllers to construct displays list and message displays in real-time. This is needed for unanticipated events.

Invariably, things happen that are not anticipated. Controller discretionary displays allow the mission controller to look at these events and evaluate their consequences to the mission.

Some times it is desirable to investigate events deeper in detail to better understand what is happening. This may be to confirm unanticipated spacecraft or ground data system operation. It may also be used by the mission controller for his own satisfaction so that he can understands the spacecraft or ground data system better.

The controllers knowledge of the spacecraft or ground system can often be used to anticipate problems. Controller discretionary displays allow the controller to investigate things that look suspicious and to avoid problems before they occur.

3.3.1 Knowledge based

The controller discretionary displays tend to be Knowledge based in that they are used to provide unstructured information that is used by the mission controller to develop his own understanding of the process. This understanding allows the controller to take actions on situations that were not covered by procedures.

4. CONCLUSIONS

Well designed displays are developed by careful considerations of basic display concepts. They are well <u>focused</u>, in <u>context</u>, and <u>compatible</u>. These displays enhance the controller mission support by reducing his cognitive load.

Well designed displays are cost effective because they are easy to use.

5. REFERENCES

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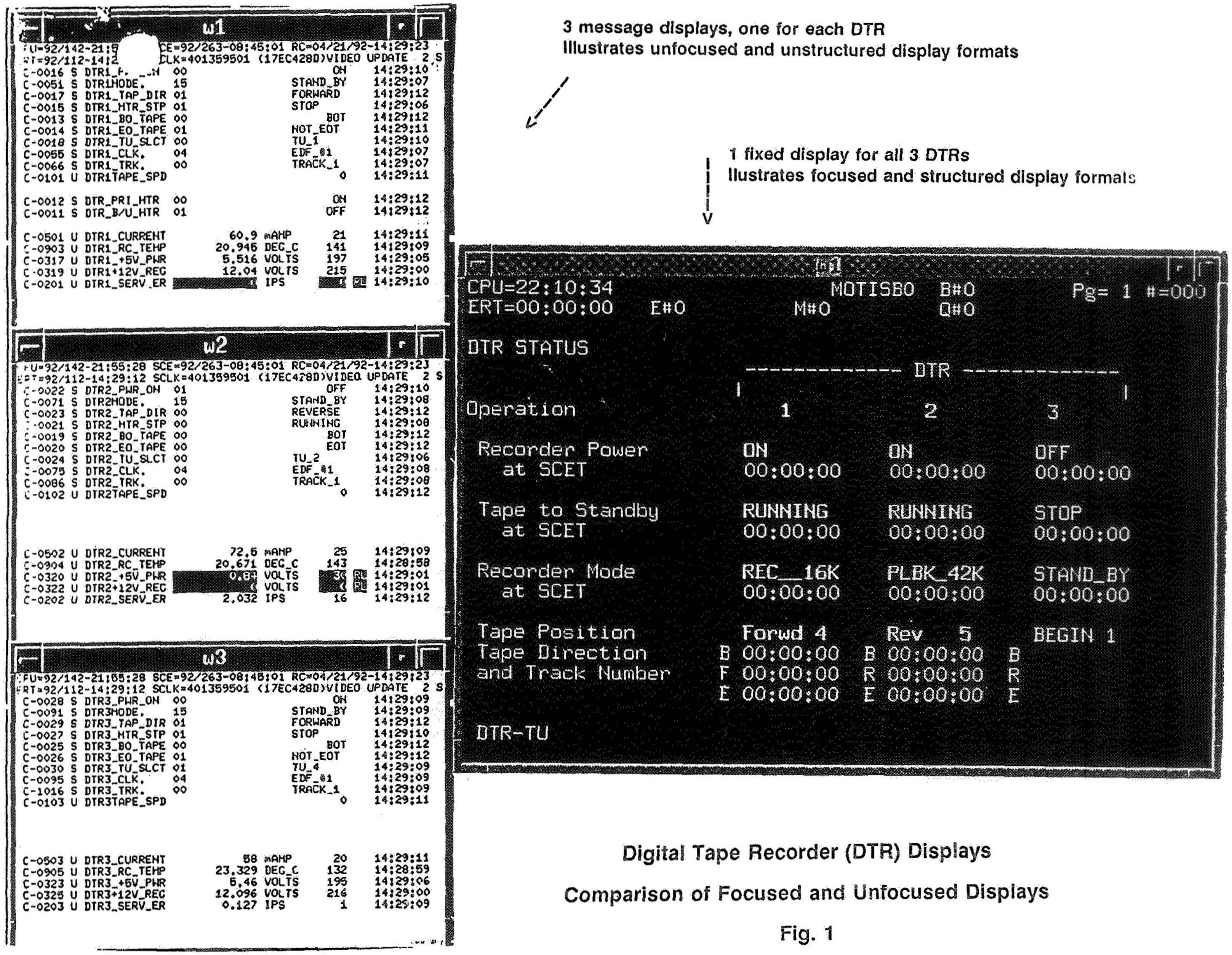
3. Shneiderman, Ben. 1987. Designing the User Interface, Addison-Wesley Publishing Company. Reading, MA.

3 message displays, one for each DTR
Illustrates unfocused and unstructured display formats

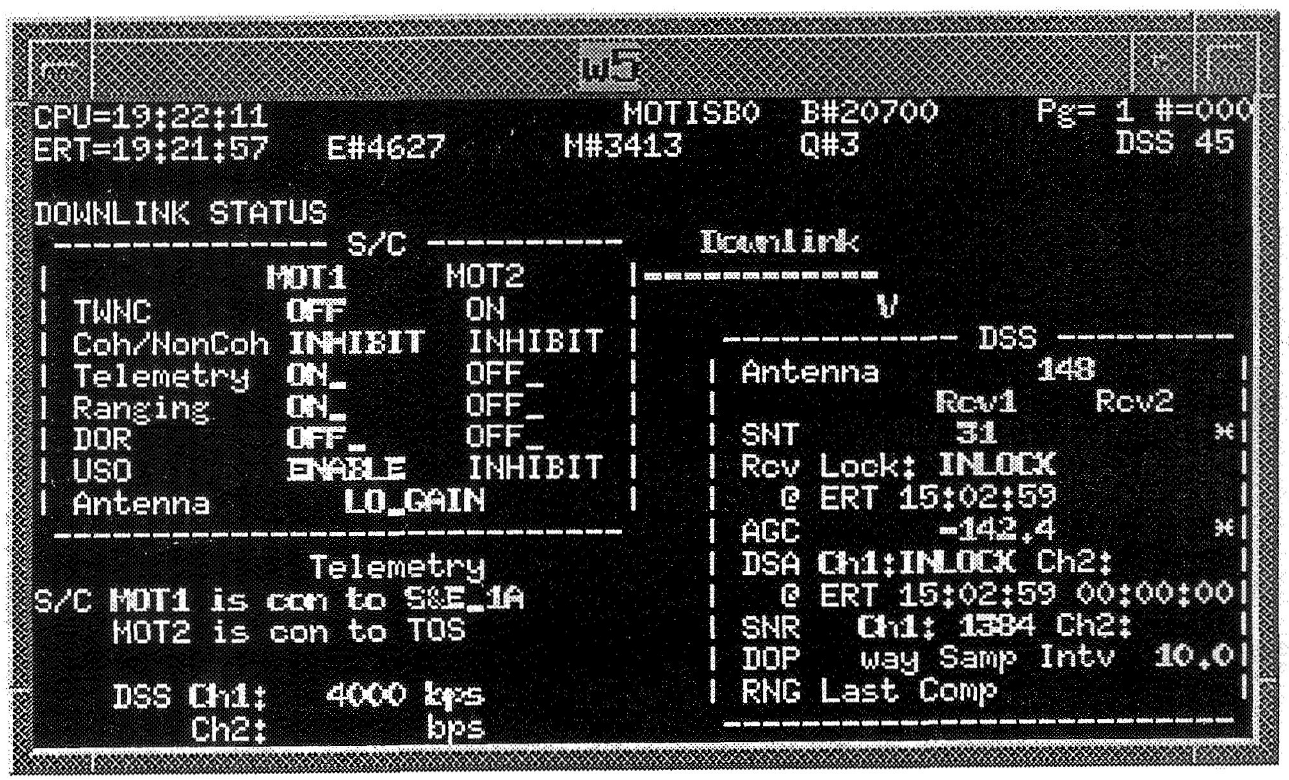
1 fixed display for all 3 DTRs
Illustrates focused and structured display formats



Digital Tape Recorder (DTR) Displays

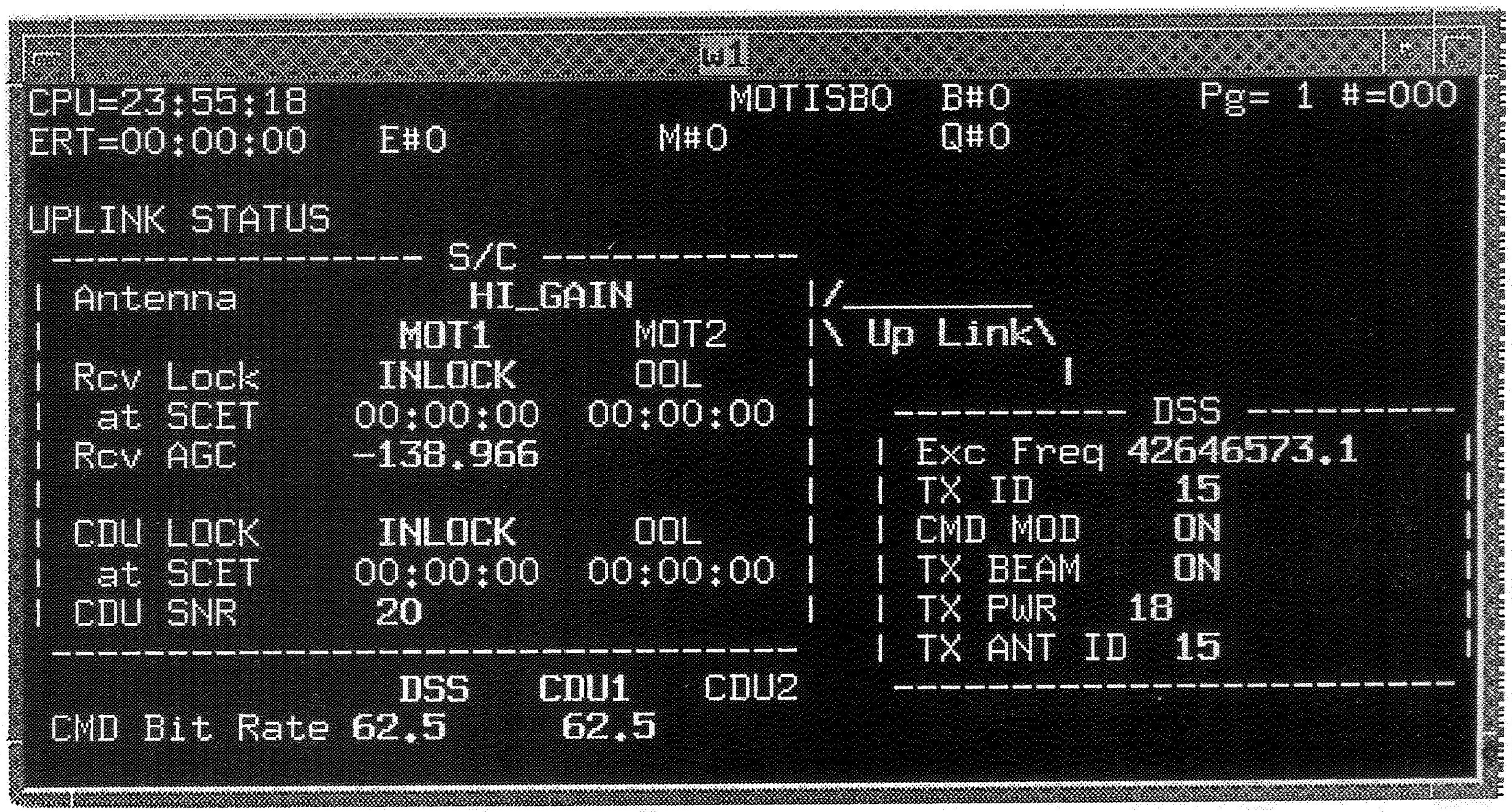
Comparison of Focused and Unfocused Displays

Fig. 1



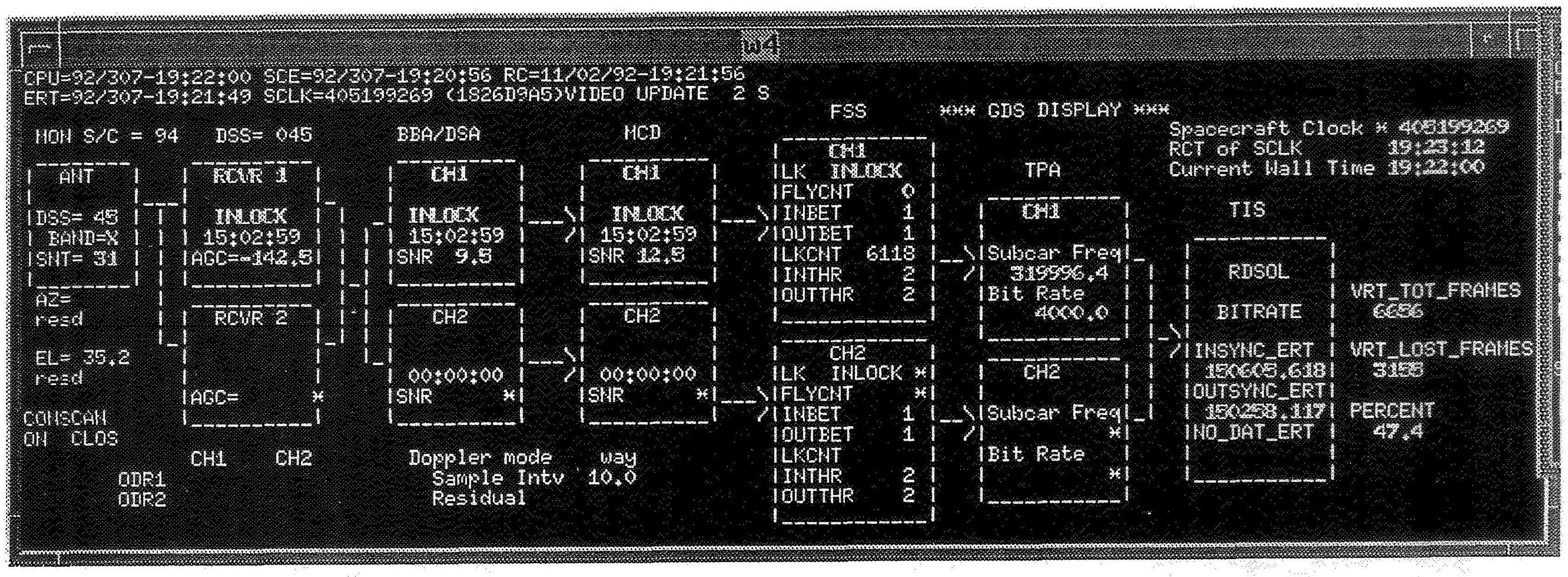
Down Link Display

Fig. 2



Up Link Display

Fig. 3



Ground Data System Display

Fig. 4