# REALTIME HIERARCHICAL GRAPHIC DISPLAY OF SPACECRAFT STATUS MIMIC DIAGRAMS

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ABSTRACT. ISRO carried out spacecraft mission operations with the support of conventional alphanumeric health displays for many years. Parameter plots on the graphic devices also were used for the spacecraft health analysis. It was also attempted to use single page mimic displays for some missions. With this past experience need was felt for a better approach for presenting the health display by mixing of alphanumeric and pictorial representations. These two types of representations are believed to be complementary. The alphanumeric display gives accurate information but is difficult to read whereas the pictorial display gives less accurate but easily readable information. The display of alphanumeric matters and animated pictures together improves understanding of the spacecraft status during any phase of the mission. This new man-machine interface provides the hierarchical display structure which gives the spacecraft controllers the choice of monitoring the spacecraft health either in brief or detailed mode. This paper describes a software package which has realized this concept for the recent ISRO satellite missions.

## 1. BACKGROUND

Satellite health monitoring and analysis for the early missions of ISRO (ARYABHATA and BHASKARA series) involved generating large chunks of binary data generated as paper printouts. These schemes were improved with the introduction of alphanumeric soft copy displays for the later missions like APPLE and ROHINI series. Addition of realtime plots of health parameters resulted in further ease in the mission operations. The first ever mimic display of the spacecraft was introduced during the IRS-1A mission. This was intended to show the functional status of the spacecraft in a pictorial way using the overall block schematics of IRS-1A. It was a hardwired computer driven single page wall display where the glowing of some bulbs would indicate status of some change-of-state type parameters. This was replaced by the computerized graphics version during the IRS-1B mission. With this background now we planned for a much more useful, illustrative, multi mission, multi paged, interactive display with facilities like navigating through the hierarchical display structure, online reference, windows etc.

This advanced man-machine interface (MMI) method uses mimic diagrams - animated, graphic representations of a monitoring system. It provides a user friendly interface for spacecraft controllers, particularly during the most critical phases like contingency phase and initial phase. This new MMI enables the staff - may it be, managerial or operational to understand the current status of the spacecraft without putting much effort and avoids making mistakes in grasping the status since the spacecraft/subsystem status is displayed in the form of mimic diagrams with varying colors and patterns instead of chunks of alphanumeric matter. The software package - 'Realtime Hierarchical Graphic Display of Spacecraft status Mimic Diagrams' (GDSP) implements the above mentioned facilities. The software is currently operational for IRS-1C and INSAT-2C missions.

## 2. FEATURES

Following are the important features of GDSP:

. Realtime operation.
. Multi mission support.
. Unlimited graphic display pages.
. Graphical user interface.
. Hierarchical display structure.
. Dynamically changeable online reference.
. Online programmable inter-update-loop interval.
. Informative messages to the user.
. Overall alarm status monitoring.

## 3. SOFTWARE CONFIGURATION

GDSP package comprises of four software tools namely- MIMIC, GRAPHED, DATA_CREATE (DCR) and MIMIC_POST_READ (MPR). MIMIC is the main tool providing the functionality of realtime display of mimic diagrams. The MIMIC uses a set of data files viz. page files, query files, update files, hierarchy files and message files which are explained at the appropriate places in the paper. This is a tool for data presentation which utilizes the processed health parameters delivered by the telemetry data processing software package. MIMIC controls the layouts for each graphic page using the corresponding page file. These page files are created/edited using the tool GRAPHED. MIMIC updates information on each graphic page using the corresponding update file. These update files are generated using DCR. MPR is a testing software used to test the functioning of the GDSP in the absence of the actual telemetry data.

## 4. GRAPHIC LAYOUT

The software uses several graphic layouts which include one overview layout for the entire space craft and one for each subsystem of the spacecraft. Each graphic layout of a mimic diagram includes both static and dynamic objects. The static objects are used to represent system components that are not driven by any parameters. They are usually a simple graphic representations of the subsystems or components to be monitored without any graphic animation. They are used only to illustrate the subsystem or components and sometimes part of subsystem. Dynamic objects are used to represent system components whose attributes change according to the value of the driving parameters which are derived from a telemetry parameter or from a logical combination of telemetry parameters.

The dynamic objects include both analog and digital objects. Analog objects give a synoptic representation of the parameter. For example, a barometer may be used to represent pressure. Digital objects use alphanumeric characters to provide the user with a digital representation of associated parameter values. The two types of representing a parameter namely analog and digital representa tions are believed to be complementary. A digital representation provides precise information about the parameter but is difficult to read, while analog representation, like a barometer with a deflecting needle and color changes gives less accurate information but is easier to read. GDSP gives the better approach of supplementing the analog representations with the digital ones for displaying the param eter values. The graphic objects like barometer or some other type of meter which have both analog and digital representations of the same parameter may be used.

## 5. MAN MACHINE INTERFACE

Alarm monitoring: Every page consists of blocks each of which represents one subsystem thus enabling the user to monitor the overall alarm status of all the subsystems simultaneously; one subsystem in detail-mode and the others brief-mode. The alarm condition in any other subsystem whose diagrams are not currently displayed on the screen results in the highlighting of the corre sponding block. At this stage the page changeover can be achieved in one of the two ways. Depend ing on whether the auto-changeover flag is set or not, the changeover takes place automatically, or the user has to click on the block highlighted to changeover to the relevant page. The page to be selected, when the alarm condition occurs, is predetermined.

Online reference: Every graphic page is associated with a query page and a query file. This query page contains information like reference plots, tables, processing constants, limit tables etc. related to the currently displayed page. These data files are created using GRAPHED or a simple text editor depending on whether the query page contains plots and text or only text. This information can be changed as and when necessary without modifying the software thus updating the old information which loses the relevance during the course of the mission life. The online reference is changeable dynamically while the mimic is running by modifying the relevant data file. However this is done from a separate graphic/alphanumeric terminal. It is just required to change the page once to bring the new reference matter into effect. The query page is generated automatically whenever a page change over takes place.

Hierarchical navigation: From any page, the user can migrate to any other page of lower level by picking the appropriate segment of the page. Once the required mimic is running, any explodable segment of the current page can be exploded with the help of the mouse into another page which contains the more detailed form of that segment . After the explosion to a new page it is always possible to go back to the parent page. Pages are organized in the order of level of details under each subsystem.

Display structure reconfigurability: The hierarchical structure of the different pages defined for a mission is maintained in a data file identified as hierarchy file. It is easy to reconfigure the hierarchical structure by simple modification to this file. Howev er this facility is not on-line since MIMIC has to be reinitiated.

Inter-update-loop interval: Inter_update_loop interval defines the frequency of update of the selected graphic page. It is possible to program this parameter value when MIMIC is running. This facility should be judiciously used with a desirable tradeoff between the overhead of the graphic activity and the successful rendering of the graphic information for comprehension by mission personnel.

Informative messages: The informative messages are stored in the message files. These files are created using the simple text editor. The informative messages also may be altered as and when required by simple modification to these data files. This is an offline facility since the MIMIC needs to be reinitiated.

## 6. UTILITY

GDSP renders itself as a very effective tool to monitor all the effects of any particular telecommand, as the on-board effects of the command are displayed in the form of colorful pictures. These pictures change their colors based on the status of some parameters. Based on a particular telecommand the entire path that a signal takes is displayed with a bright color while making the alternate path to have a dull color. This facilitates the mission operations team to easily monitor the telecommands and their effects. This also enables a novice operating staff to understand the spacecraft thoroughly.

Thermal subsystems can be configured as a set of pages with the identification of different types of sensors and heaters. All these give the clear picture of the thermal distribution over any subsystem or part of a subsystem. Accordingly an appropriate heater can be switched on or off. The digital display of the values of temperatures can also be included as annotations near the sensor locations. The color for the display of the temperature values can change so as to depict the limit status of the temperatures.

It is also possible to identify the levels of some parameters associated with a part of the component of a subsystem, graphically like the on-board memory usage for data storing, the length of the tape of the on-board tape recorder used for payload data recording or available fuel in the tank etc. Exact values of these parameters can however be obtained from the associated digital display.

The reaction control system pages can be configured to depict which thrusters are firing using the animation technique, thruster temperatures at firing, the location of the thrusters in the three dimensional view, the positions, speeds and directions of reaction wheels.

GDSP can also serve as a very effective training tool for mission operations team. With the space-craft simulator in the loop, the effects of telecommands can be visually understood since the effects in the telemetry are rendered through colors and animation for the components of the subsystem. This facility also helps in studying the effects of any telecommand visually prior to the actual up link to the spacecraft during mission phase.

## 7. UPDATE TYPES

GDSP facilitates several ways of rendering different types of information related to spacecrafts. These are characterized as update types and are listed below:

- Display of alphanumeric values of parameters with limit-status based background color change.
- Display of alphanumeric values of parameters with their digital status based background color change, including facility to control the number of characters to be displayed.
- Display of alphanumeric characters of user choice with the digital parameter status based background color change.
- Visibility control of parts of a page.
- Discrete/continuous rotation of a segment based on a parameter value.
- Segment translation in the x-y plane.
- Segment highlighting to indicate the status change over of a parameter.
- Icons display indicating the limit status by color change and parameter value in the digital form.
- Bar charts.

## 8. CREATION OF MIMIC DIAGRAMS

The page files that hold the relevant data to be used by the GDSP for drawing the mimic layouts are developed using GRAPHED. GRAPHED is a graphic editor used to create pictures of any kind. It has several editing tools which help the user to create and modify the pictures and help in creating the update files. The editing tools are:

- Dragging a segment to a different location and getting the new pivot point of the segment.
- Listing all the segments so far created.
- Checking for the existence of a segment.
- Getting the coordinates of a point.
- Detecting a segment and displaying its name and its pivot point.
- Detecting a segment and getting the coordinates of some point on the figure for displaying text or something else.
- Getting the distance between any two points.

GRAPHED also has some tools to test the graphical manipulations of figures, like

- Rotation of a segment.
- Visibility swapping of two segments.

. Highlighting of a segment.

## 9. CREATION OF UPDATE FILES

One update file is associated with every mimic diagram. The dynamic objects of the mimic diagram are linked to the telemetry parameters through the data records stored in an update file. These records store the parameter identification codes (PID) and their possible values to check against. The raw telemetry channel identification code can also be used instead of PID's. These records also store the information used by the software to produce the required dynamic graphic updates.

Update file is generated using a menu driven software DCR which takes care of controlling the validity of the input like PID, channel number, frame identification code, bit status, and status mnemonic. It also displays the previous record entered for the user's reference. The software dis plays the last record of the file if the existing file is opened for appending some more records to the file.

## 10. TESTING

Once the mimic diagrams and relevant update files are generated there is a need to test the integrity of the MIMIC software, mimic diagrams and the update files. This is achieved using the telemetry data if available. However a software MPR is developed to test the GDSP in the absence of the real telemetry data. It allows the user to post/read the telemetry data, the limits of the telemetry parame ters, telemetry bit patterns of any channel id to/from the shared memory and testing the effects on the graphic pages with MIMIC concurrently running. MPR also provides for batch posting of a set of identified parameter values to shared memory from a file to simulate near simultaneous actions with respect to various components in an on-board subsystem. It is also possible to introduce specific time delays between successive postings of parameter values to simulate near realistic chronology of events on-board the spacecraft.

## 11. IMPLEMENTATION

The GDSP represents an interactive task; it responds to the input provided by the user via different input devices, namely keyboard and pointing device like mouse or joy disk.

The mimic diagrams are made available to the software in the form of page files.

Two versions of GDSP are developed. The first version is based on VAX/VMS utilizing PLOT-10 IGL graphics library used for IRS-1C mission. The second version is based on DEC ALPHA OSF-1 utilizing PHIGS graphic library used for INSAT-2C mission. The later version is also based on MOTIF GUI. It uses only mouse and various dialogue widgets for the activities like selecting the spacecraft or graphic page, explosion of a block of a graphic page, quitting etc. Samples of graphic page layouts for IRS-1C are provided in fig. 1 and 2.

## 12. ADAPTABILITY

Currently both OSF/1 and VMS versions are available for MIMIC where as only VMS/IGL version of GRAPHED, DCR and MPR are available. We are working on the OSF/1 version for the same. However it is possible to generate the page files for any layout using VMS/IGL version of GRAPHED and use the same ASCII file on OSF/1 environment for MIMIC software. Other data files namely hierarchy files, query files, message files and update files required for OSF/1 version of MIMIC are generated using the any text editor. This has been illustrated by generating all the mimic diagrams for INSAT-2C on VMS environment, and supporting the MIMIC software on the OSF/1 environment of the control center.

OSF/1 version of GDSP can be very easily adapted to any standard UNIX environment supported by PHIGS graphics library.

GRAPHED makes it possible to adapt the mimic diagrams across missions of same class with whatever changes necessary.

## 13. FUTURE PLANS

Future work will be only with respect to the UNIX version of GDSP. Following are the enhancements planned:

GRAPHED will be adapted to OSF/1/PHIGS environment.

MOTIF based GUI will be built in for all the modules of GDSP.

GDSP will be integrated with other tools for data presentation - alphanumeric multi paged display, graphic display etc. including the interactions between them like selection of a parameter for plot by clicking on a segment of a mimic display.

By establishing the link between GDSP and the diagnostic software like Anomaly Driven Health Analysis Expert System of IRS1-C mission or similar software the alarm conditions and the appropriate corrective measures can be displayed. Provision will be made in GRAPHED to identify critical parameters for display as a separate page.

Further plans also include building realtime animation features for the visual representation of the dynamic behavior of spacecraft subsystems

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