GRAPHICAL DISPLAY OF WHOLE ORBIT TYPE 1 TELEMETRY FROM UoSAT-OSCAR-9

CS 595: GRADUATE PROJECT
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ABSTRACT

The purpose of this project is to expand upon an existing set of computer programs and hardware configuration so that additional methods of data presentation may be incorporated. The software system currently is oriented for automated data collection and evaluation of spacecraft system status. The programs and documentation resulting from this project will provide additional methods for graphical display of both spacecraft systems and scientific experimental telemetry. Specific examples produced by this project include two and three dimensional graphs of whole orbit type 1 telemetry from UoSAT-OSCAR-9.

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BACKGROUND

Since its launch in October 1981, UoSAT-OSCAR-9 has provided a unique opportunity for scientific observation by satellite through amateur radio. Built by the Department of Electrical Engineering at University of Surrey, its mission objectives include broader access to information on space sciences for academic and amateur organizations. The satellite accomplishes this objective by providing a variety of communication media and formats for data collection spanning a range of scientific and housekeeping functions onboard the satellite. Through the automated tracking and receiving facilities developed at Corpus Christi State University, data has been gathered over the lifetime of the satellite.

Telemetry editing software at CCSU refines several different telemetry formats transmitted by the satellite. Using standard and checksummed sixty channel format, the satellite samples each of the telemetry sensors and transmits the current value of each channel, along with the current status of various spacecraft housekeeping systems and onboard experiments. Use of whole orbit type 1 and whole orbit type 2 telemetry gives a more detailed view of a single orbit. During whole orbit data capture, a program

loaded onboard the spacecraft by the command station stores several telemetry channels, sampled and digitized every 5.28 seconds, during a partial or complete orbit. This data may then be transmitted on command, so that observers may receive multiple copies of a single recorded whole orbit rather than remain limited to observations of the real time data received while the satellite is visible at their ground stations. Whole orbit type 1 telemetry contains seven channels of housekeeping and experimental data, while whole orbit type 2 contains radiation data measurements together with measurements from eight telemetry channels. Both whole orbit telemetry formats provide a detailed set of information for a single orbit.

Whole orbit telemetry type 1 contains information about the telemetry channels in the first logical line of the file; the serial number 0000 is followed by the channel numbers of the seven channels from which measurements were stored. The following lines, ranging from 0001 to as high as 046D hex, each contain a line serial number, the raw measurement value of the channel recorded, and a check digit. Telemetry editing software verifies each line of the captured data file by calculation of a checksum. Each pair of ASCII characters is used as a hex byte value and summed, if correct, to produce a constant result of AA hex or 170 decimal. A typical type 1 telemetry file would appear in the following form:

```
00000020220230300320430540xx
 ....
    ....
       ....
 040F753703135280660811935BE
 041075670801940066802080 86F
 041176070900528066801360709
 041275570601537066800261914
 041376071107939066800282967
 041475870612526066801093 7E0
```

With the launch of UoSAT-OSCAR-11 in March 1984, the range of information to be collected and analyzed has expanded, providing a wider range of telemetry in all formats, together with improved time tagging of that telemetry. The increase in information presents the potential for developing a wider data base of refined telemetry over the lifetime of both satellites.

Through the efforts of Robert Diersing and students working with him, there currently exists, at CCSU, hardware and associated software for the tracking, reception, and general editing of UoSAT telemetry, together with a library of telemetry received since the launch of the satellite. At present, the emphasis of the software has been directed toward automated station control and telemetry capture. The goal of this project is to supplement telemetry and software to present specified areas of telemetry as meaningful information. In this case, whole orbit type 1 telemetry from UoSAT-OSCAR-9 will be reorganized and graphically displayed in order to present a visual overview of selected telemetry from satellite housekeeping and experimental

channels. New software and data file generated from this project may then be incorporated into the existing software to expand available information and methods of evaluation for UoSAT telemetry at CCSU.

ENVIRONMENT

A detailed description of the hardware and software currently in use for automated station control and telemetry capture is included in Diersing, "Notes on Microcomputer Applications in Automated Station Control and Telemetry Data Processing for UoSAT-OSCAR-9 and UoSAT-OSCAR-11." The primary computer system involved is a Cromemco Z-2D with software using Cromemco 32K Structured BASIC, Z-80 assembly language, and Digital Research PL/I-80. Programs and data files from this system (and other related implementations) form the basis of the software implemented in this project.

The software involved in this project has been written to operate in an IBM-PC hardware environment: 1) IBM-PC, 256K memory, two 360K disk drives, and monochrome monitor, 2) color monitor and 3) graphics capable dot matrix printer. Project development was done on a Compaq Personal Computer system: 1) Compaq Deskpro 2, 640K memory, two 360K disk drive, and monochrome monitor, 2) Amdek Color-I color monitor, and 3) IBM Graphics Printer.

Languages selected for use in this project include Digital Research PL/I-86 and BORLAND International Turbo Pascal Version 3.0. The DR PL/I-86, source code compatible with DR PL/I-80 already present in the original satellite system, provides a simple means of conversion of most existing programs to the IBM-PC environment. Turbo Pascal's extensive use of IBM-PC graphics capabilities, simplicity of use, and low cost to the user make it a

practical compiler for program development in the IBM-PC environment and will allow for modification of the programs by the end user.

METHODS

In order to produce graphs from the sample data files of whole orbit type 1 telemetry from UoSAT-OSCAR-9, several existing data files must be combined with existing and modified programs. In certain areas, information is incomplete, therefore assumptions are made to approximate necessary values. For example, in the calculation of orbits for whole orbit telemetry projection, if the actual orbit used was not indicated in the satellite bulletin, a sample orbit from the date of capture has been included for demonstration. From these files and programs, incorporated with new programs, demonstration color graphics displays are generated.

For the following files:
" #####" indicates the orbit number
"ccc" indicates the channel number selected.

Generation of two dimensional graph, time vrs channel value, on the IBM-PC graphics printer requires the following files and programs:

1) U1T#####.CPY--Data file generate by TLMWHOLE.PLI, where several orbits containing the same whole orbit telemetry information are collected and merged into a single file.

2) W01GRIBM.PLI, a PL/I-86 modification of W01GRAPH.PLI, where count information is calibrated then plotted against a time axis. In the PL/I-86 version for the IBM-PC, the program has been modified to produce the graph

on an IBM-PC graphics printer. The program has been further modified to produce an output file of selected channel date in calibrated engineering units to be plotted by TRIGRAPH.PAS.

Generation of three dimensional color graphics display, latitude vrs longitude (the sub satellite point of the orbit ground track) vrs channel values, requires the following files and programs:

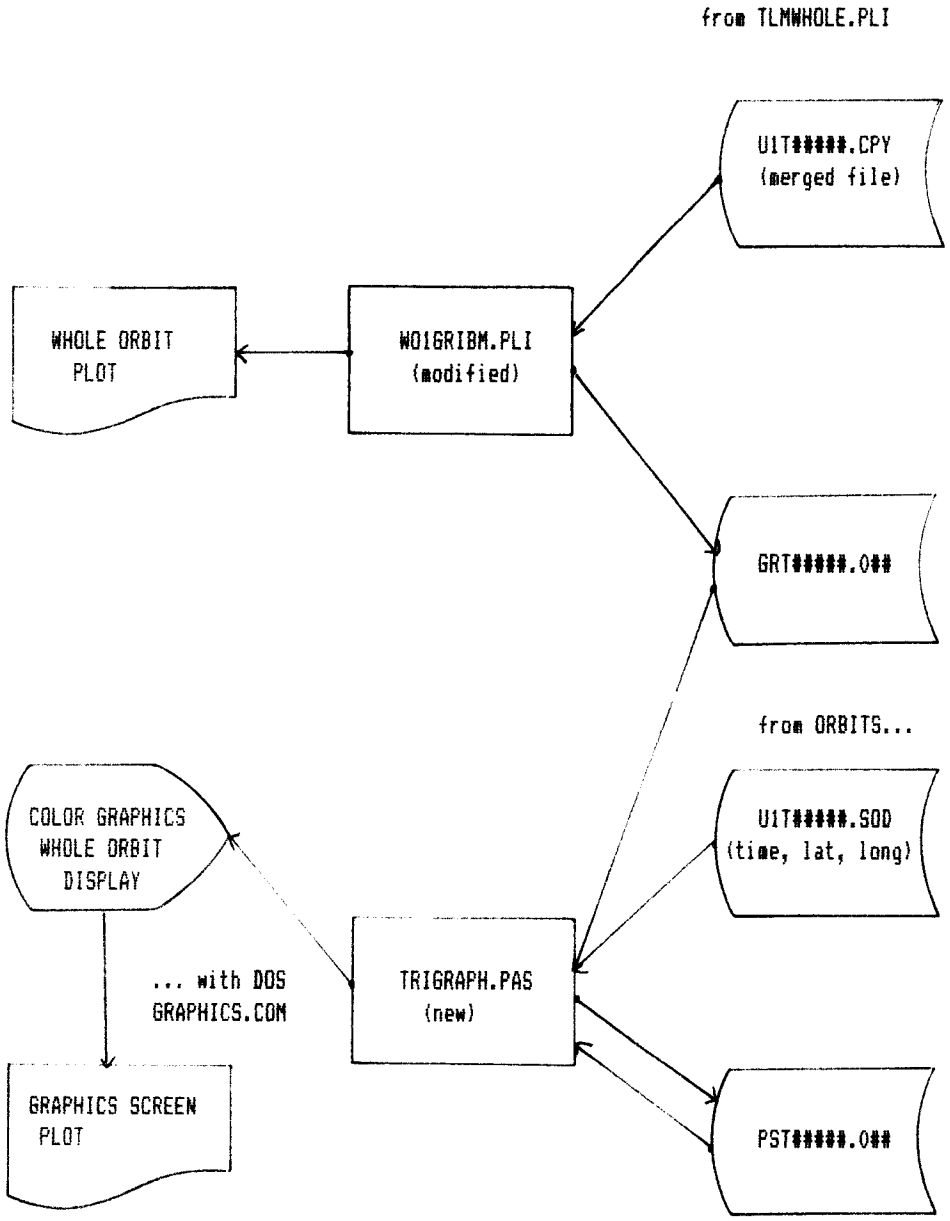
1) GRT#####.ccc -- Channel Data file, generated by W01GRIBM.PLI

2) U1T#####.SOD -- Satellite Orbit Data file, containing time, latitude, and longitude for a specified orbit. The beginning point of the orbit is assumed to be the point at which the satellite crossed the equator moving in a northerly direction. The actual time of the data capture by the satellite is not available, so an orbit within twelve hours of the transmission orbit has been used.

3) DOS GRAPHICS.COM -- DOS utility which must be run initially to provide ability to print graphics screen.

4) TRIGRAPH.PAS -- program in which orbit data and channel values are correlated by time and plotted to the color graphics display. A printed copy of the display screen may be obtained by [SHIFT]+[PrtSc] while the graph is displayed on the screen (and GRAPHICS.COM has been appended to the operating system.) This display may be saved to disk as a data file for later recall and display. The color graph displays channel values in bar graph format with highlighted maxima for contour charting.

5) PST#####.ccc -- generated by save of color screen display may be recalled by TRIGRAPH.PAS; does not require orbit or data information.



OVERVIEW OF PROGRAMS, INPUT, AND OUTPUT

FOR WHOLE ORBIT 1 GRAPHICS PRESENTATION

LIST OF SAMPLE FILES FOR W01GRIBM.PLI AND TRIGRAPH.PAS

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************************* ORBIT 12260 ********************

Orbit Number:  12260     Date: 12/23/83     Time:  08:22:00

Data File:  U1T12260.CPY       89% complete

Channels :   002     Battery Half Voltage
             022     Battery/BCR 14 V Bus
             023     Sun Sensor +Z Axis
             030     Battery Charge Current
             032     Power Cond Module +10V
             043     Sun Sensor -Z Axis
             054     Nav Magnetometer Z-Axis

Orbit Data File   U1T12260.SOD

************************* ORBIT 12466 ********************

Orbit Number:  12466     Date:  01/05/84    Time:  21:00:00

Data File:  U1T12466.CPY        90% complete

Channels :   002     Battery Half Voltage
             022     Battery/BCR 14 V Bus
             023     Sun Sensor +Z Axis
             030     Battery Charge Current
             032     Power Cond Module +10V
             043     Sun Sensor -Z Axis
             054     Nav Magnetometer Z-Axis

Orbit Data File:  U1T12466.SOD

************************* ORBIT 12694 ********************

Orbit Number:  12694     Date:  01/20/84    Time:  20:18:00

Data File:  U1T12694.CPY        98% complete

Channels:    002     Battery Half Voltage
             009     +X Facet Temp
             022     Battery/BCR 14V Bus
             029     +Y Facet Temp
             030     Battery Charge Current
             032     Power Cond Module +10V
             039     -Y Facet Temp

Orbit Data File:  U1T12694.SOD
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CONCLUSIONS

The combination of files and programs included in this project produce a set of graphical displays that illustrate general trends in information from whole orbit type 1 telemetry generated by UoSAT-OSCAR-9. Several sources of error, including missing lines of channel information from merged files, rounding and truncation loss in calculation for screen plotting, and screen size limitations (320 x 200 pixels) in screen display, reduce the level of detail for presentation, but still provide an overview of activity in onboard housekeeping systems and general scientific data collected. The graphs provide another interpretation of the available information and add to the overall collection of information from UoSAT-OSCAR-9.

Study of the graphs produced suggests several areas of expansion and further modification of the existing software for UoSAT-OSCAR telemetry collection and presentation. Additional information about the physical environment of the satellite, such as day/night terminator position, and status of the satellite, spin and attitude for position of detectors, could add meaning to basic graphs. Additional modification of type 2 telemetry graphics programs could produce detailed radiation information to be used with housekeeping information from type 1 graphs to better describe conditions during type 2 data collection. Improved graphics resolution together with better time-location

information could produce a more accurate graphical description. These expansions could be incorporated into the base of programs already in operation to extend the information base provided by UoSAT-OSCAR-9 telemetry. With UoSAT-OSCAR-11, where the problems of cor
relating time to data capture are handled by the satellite itself, the techniques for data presentation used in this project could be applied directly to the calibrated data to produce information graphics displays.

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