COMPUTER GRAPHICS APPLICATIONS
TO CREW DISPLAYS

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ABSTRACT

Astronauts are provided much data and information via the
monchrome CRT displays on the orbiter. For this project two
areas were investigated for the possible introduction of computer
graphics to enhance and extend the utility of these displays.
One involved reviewing the current orbiter displays and
identifying those which could be improved via computer graphics.
As an example, the tabular data on electrical power distribution
and control was enhanced by the addition of color and bar charts.
The other dealt with the development of an aid to berthing a
payload with the Remote Manipulator System (RMS). This aid
consists of a graphics display of the top, front and side views
of the payload and cargo bay and point of resolution (POR)
position and attitude data for the current location of the
payload. The initial implementation was on an IBM PC clone.
This program previews the demonstration software installed in the
Johnson Space Center Manipulator Development Facility (MDF). Due
to current hardware limitations, the MDF version is slow, i.e.
about a 40+ second update rate and, hence, not "real-time."
Despite this fact, the evaluation of this additional visual cue
as an RMS operator aid indicates that this display, with
modifications for speed, etc., can assist the crew. Further
development is appropriate.

INTRODUCTION

Color and graphics, if carefully selected, enhance the
display and understanding of data. Computer graphics, in
particular color graphics, furnishes an excellent means to
improve the presentation of information. This, in turn,
encourages quicker interpretation and, hence, response to data.
More efficient response to information facilitates man-machine
interaction.

Orbiter computer CRT displays provide much data and
information to the crew. Reviewing these displays and
identifying those which can be enhanced via computer graphics was
one facet of the project. The other area of investigation
involved the development of an aid to facilitate payload berthing
by the Remote Manipulator System (RMS) operator.

Displays

Numerous CRT displays are selectable by the crew during each
flight of the shuttle. These show data and information in a
variety of formats. Some are quite specific and apply to the
ascent and reentry of the orbiter. Others indicate the status of
the various shuttle systems and typically are in tabular form.

All the displays were reviewed. A display of the data on
electrical power distribution and control was chosen to
demonstrate a possible enhancement of displays. Color and bar
charts replace tabular digital data. Most entries have a
high(H), medium(M) or low(L) range. Red, green and yellow,
respectively indicate each range. In order to respond to the

high range of a particular portion of the electrical system,
spotting a "red" condition is easier than spotting an "H".

Payload Berthing Aid

To berth a payload the RMS operator, working in the aft
flight deck, currently uses several visual cues. In most cases a
portion of the payload can be viewed from the two aft payload bay
viewing windows. Starboard and port TV cameras are positioned on
the fore and aft bulkheads of the cargo bay. Two others are
located at the elbow and wrist, respectively, of the manipulator
arm. On monitors, located in the aft flight deck, the operator
can select views from up to four of the cameras. Digital
information about the position and attitude of the point of
resolution (POR) of the payload (This is explained in the Theory
section.) is also available.

An additional visual cue to aid in payload berthing was
developed. This aid consists of a computer graphics display of
the top, front and side views of the payload and cargo bay along
with the POR position and attitude data. See figures 1 and 2.

THEORY

The choice of colors and the selection of an appropriate
graphic played major roles in the implementation of an enhanced
display for the orbiter.

Developing the software to display the updated views of the
payload required some mathematical analysis and computation. As
shown in figure 3, the orbiter coordinate system is a
right-handed system. The positive x-axis is forward, the y-axis
is starboard and z is down. The FOR is a preselected point
within the payload. The position is indicated as x, y, z values
in the orbiter coordinate system. The attitude of the payload,
or the pitch, yaw and roll of the payload which would orient it
into its present attitude, is a series of rotations about lines
passing through the specified control point and parallel to the
appropriate orbiter axis. Pitch is a rotation about the orbiter
y-axis in a clockwise direction. A counterclockwise rotation
about the orbiter's z-axis produces yaw. While a clockwise
rotation about the x-axis of the orbiter causes the payload to
roll.

Three dimensional data bases along with the appropriate
move/draw specifications were defined for the cargo bay and
payload, respectively. These data points are placed in n(# of
data points for the cargo bay or payload) by 3 matrices. The
updated position of the payload is a translation by the change in
x, y and z, respectively. These changes are added to the
respective coordinates of each data point for the payload. The
rotations to accomplish pitch, yaw and roll are easily
represented as 3 by 3 matrices (See Foley and Van Dam, 1982, pp.
255-258. Note, 4 by 4 matrices are not necessary for this
application.). Composition of these matrices and then a matrix
multiplication of the data set with the FOR centered at the

origin of the orbiter coordinate system, create new, transformed
data points of the payload.

To show the top view, the x,y values, transformed to screen
coordinates, are plotted. The front view is a plot of the y,z
values and the x,z values are drawn for the side view.

IMPLEMENTATION

The sample orbiter display, the current and enhanced
versions, and the RMS berthing aid were implemented in color on
an IBM PC clone. These programs are basically for
demonstrations, although much potential exists for application
of computer graphics on the orbiter. Using the POR data from an
actual berthing procedure, the berthing display updated
approximately every 12 seconds. See figures 1 and 2.

In order to evaluate the effectiveness of this payload
berthing aid, the displays were implemented on a Z80
microprocessor equipped with a Microangelo card and displayed on
a monochrome graphics monitor. This is interfaced with the SEI
computer which controls and monitors the Manipulator Development
Facility (MDF). [The MDF is a JSC training facility for RMS
operators.] During a payload berthing maneuver, current POR data
is sent to the Z80 microprocessor, which draws the appropriate
display for the operator to view. Due to the limitations of the
hardware, especially the 8 bit processor, the update rate is
about 40 seconds for a full display.

RESULTS

The sample displays appear to have potential but have not
been adequately evaluated. This is mainly due to the emphasis
and time devoted to the MDF berthing aid.

The response by the MDF/RMS operators to the payload
berthing aid has been very favorable. The present system was
developed with the hardware which was on hand at JSC and costs
less than $4000. Viewed as an initial step in the development of
a close to real-time berthing aid, the current system shows much
potential. The slow update rate of the display, except as a
demonstration, is not acceptable. This is easily remedied by a
better, more powerful processor which is readily available.

FUTURE ENHANCEMENTS AND DIRECTIONS

An obvious direction of the orbiter display portion of the
project is additional review of the displays in order to identify
specific categories of the displays and the corresponding color
computer graphics enhancements. This review will also benefit
current definition of space station systems display requirements.

The utility of the payload berthing aid has been
demonstrated. It is apparent that speeding up the refresh rate
of the display is the first goal. Other enhancements could
include graphical indications of the collision of the payload
with the cargo bay and the ability to select, via keystrokes,

light pen or some other interactive device, a portion of the

display on which to zoom. Zooming in on a particular segment of

the display would allow the operator to see the fine detail that

is helpful in the final stages of berthing. Further development

of this computer graphics payload/cargo bay display will

certainly indicate additional refinements and enhancements.

REFERENCES

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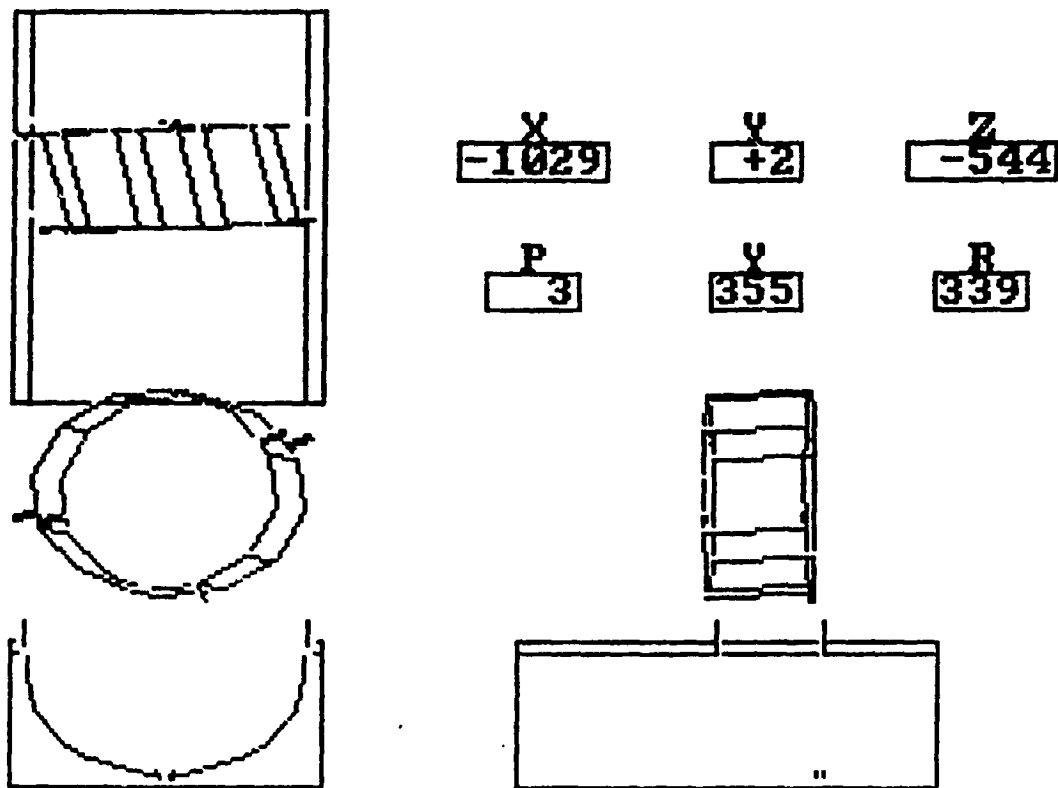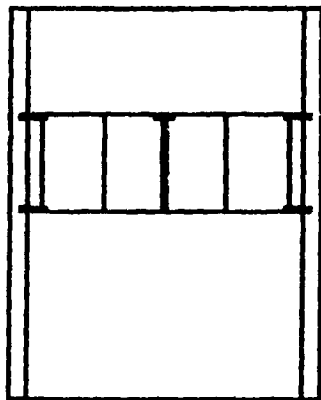   COMPUTER GRAPHICS, McGraw-Hill, NY, 1976.

Figure 1.   IBM PC demonstration of a typical payload berthing display.
Beginning in the upper left-hand corner in a counterclockwise
direction, the top, front and side views of the payload and
cargo bay, and the point of resolution position and attitude
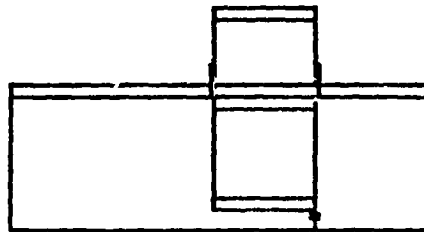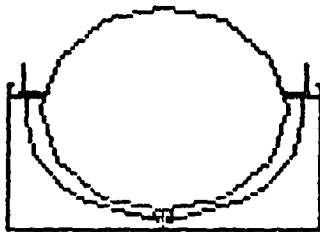data are displayed

Figure 2. IBM PC demonstration of a berthed payload display.
Beginning in the upper left-hand corner and moving in
a counterclockwise direction, the top, front and side
views of the payload and cargo bay, and the point of
resolution position and attitude data are displayed.

ORBITER BODY AXIS SYSTEM

OPERATOR
ROTATION
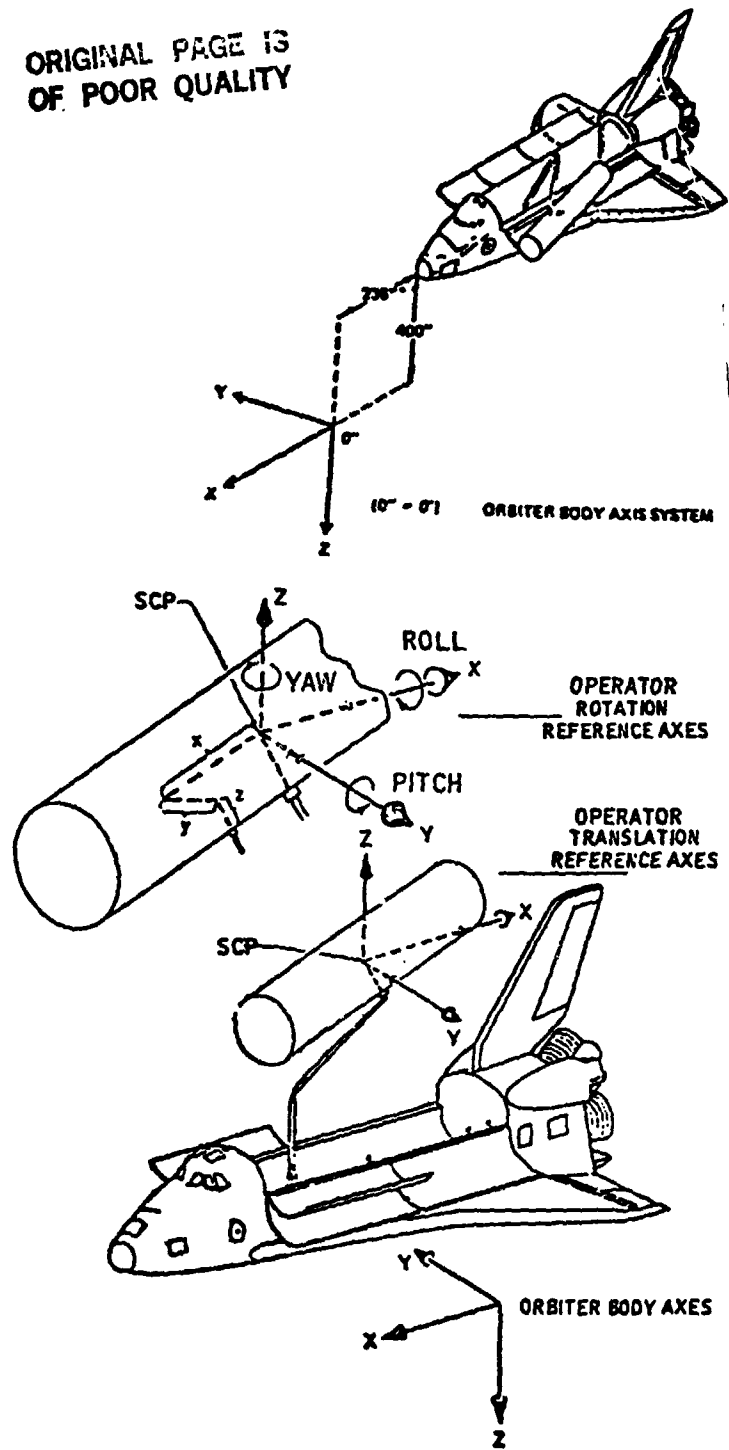REFERENCE AXES

OPERATOR
TRANSLATION
REFERENCE AXES

ORBITER BODY AXES

Figure 3. Orbiter Body and Payload Reference Axes