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Spacecraft Orbit Design and Analysis (SODA) Version 2.0 User's Guide

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Preface

This document describes the Spacecraft Orbit Design and Analysis (SODA) computer program, Version 2.0[1]. SODA is a space-flight mission planning system which consists of six program modules integrated around a common database and user interface. SODA was developed by Computer Sciences Corporation for the Spacecraft Analysis Branch, Space Systems Division of NASA Langley Research Center. The goal of SODA is to provide a simple, integrated environment for spaceflight mission planning software.

SODA runs on a VAX/VMS[2] computer with graphics produced on an Evans & Sutherland PS300 graphics workstation. In the current version, three program modules produce an interactive three-dimensional animation of one or more satellites in planetary orbit. Satellite sensor visibility and coverage capabilities are also provided. Circular and rectangular, off-nadir, fixed and scanning sensors are supported. One module produces an interactive three-dimensional animation of the solar system. Another module calculates cumulative satellite sensor coverage and revisit time for one or more satellites. Still another module calculates satellite and ground station visibility. Currently, Earth, Moon[3], and Mars systems are supported for all modules except the solar system module. SODA maintains orbit information, vehicle characteristics, vehicle sensor information, ground station locations, and other information required by each of the modules. The SODA user interface is terminal independent so data can be entered or edited on any terminal.

SODA owes some of its graphical heritage to MUTANI (A Multiple Trajectory Animation) and IVORY, which is a program in SOAP (Satellite Orbit Analysis Package), both developed by the Aerospace Corporation. Both MUTANI and SODA use the the ASTROLIB subroutine package for orbit propagation.

IVORY animates PATRAN[4] or NEVADA[5] spacecraft models, allowing one articulated part, in orbit about the Earth. IVORY evolved into VA (Vehicle Animation) module which animates a FLEXAN spacecraft model in orbit about the Earth, Moon, or Mars. FLEXAN is a flexible animation program which is called from within VA to process the spacecraft model files. VA supports animations of a spacecraft with hierarchical articulating parts and uses color and shape changes to represent temperatures, structural deformations, etc.

MUTANI animates one or more satellites in orbit about the Earth. Instantaneous on-nadir circular sensor coverage is also calculated and displayed. MUTANI evolved into the MVA (Multiple Vehicle Animation) module which produces animations of one or more satellites in orbit about the Earth, Moon, or Mars. Circular and rectangular off-nadir instantaneous sensor coverage is supported. Up to 10 sensors per vehicle are possible. Sensors

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[1] Appendix A describes the differences between Version 1.0 and Version 2.0 of SODA.

[2] VAX and VMS are registered trademarks of Digital Equipment Corporation.

[3] "Moon" refers to the natural satellite of the Earth. "moon" refers to any natural satellite of any other planet.

[4] PATRAN is a registered trademark of PDA Engineering.

[5] NEVADA is a registered trademark of Turner Associates Consultants.

may be fixed or scanning. Satellite-to-satellite and satellite-to-ground station visibility is also calculated and displayed.

The remaining four modules of SODA are completely original programs. The OD (Orbit Design) module animates a single spacecraft (an asterisk icon) in orbit about the Earth, Moon, or Mars. The SSS (Solar System Simulation) module animates the nine planets of the solar system for any specific time period. The CC (Cumulative Coverage) module calculates cumulative satellite sensor coverage as well as average and maximum revisit time. The VSV (Vehicle Sensor Visibility) module calculates satellite-to-satellite, satellite-to-ground station, and ground station-to-satellite visibility through sensors.

SODA was developed by Scott Stallcup of Computer Sciences Corporation (CSC). John Davis of CSC contributed many design suggestions. Jeffrey Zsoldos of CSC coded the VSV module and many of the version 2.0 SODA database features. James Garrison of the Spacecraft Analysis Branch (SAB) developed the transformations required to support the Moon and Mars orbit propagations using ASTROLIB. Cheryl Allen of SAB digitized the maps of the Moon and Mars. Larry Rowell of SAB provided the direction and motivation needed to produce SODA. SOAP, MUTANI and ASTROLIB were developed by the Aerospace Corporation.

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1.0 Introduction

The Spacecraft Orbit Design and Analysis (SODA) computer program is a graphical tool for visualizing space-flight mission planning problems. SODA allows the mission planner to quickly and easily produce a three-dimensional, interactive animation of one or more satellites in planetary orbit. The interactive animation of satellite trajectories, visibility periods, and sensor coverage frees the mission planner from the traditional analysis of tabular data produced from typical trajectory and satellite sensor coverage programs.

SODA consists of six program modules (figure 1) integrated around a common database and user interface. SODA runs on a VAX/VMS (version 4.6 or later) computer with an Evans & Sutherland PS300 graphics workstation. In the current version, three modules produce an interactive three-dimensional animation of one or more satellites in planetary orbit. Satellite visibility and sensor coverage capabilities are also provided. Circular and rectangular, off-nadir, fixed, and scanning sensors are supported. One module produces an animation of the solar system with an ecliptic plane and background star field for any specific time period. Another module calculates cumulative sensor coverage and sensor revisit times and produces static raster pictures. Still another module calculates satellite and ground station visibility and produces a tabular report of visibility windows. Currently Earth, Moon and Mars systems are supported for all modules except the solar system module.

SODA maintains orbit information, vehicle characteristics, vehicle sensor information, ground station locations, and other information required by each of the program modules in a flat file database system. Because the SODA user interface is terminal independent, data can be entered or edited on any terminal. A PS300 graphics workstation is required to run the current modules: OD (Orbit Design), SSS (Solar System Simulation), VA (Vehicle Animation), MVA (Multiple Vehicle Animation), and CC (Cumulative Coverage). The VSV (Vehicle Sensor Visibility) module produces a tabular report file and does not require a PS300.

The Evans & Sutherland PS300 family of graphics workstations supports real-time animations of wire-frame images. The PS300 dials and function keys are available for complete user control of animation sequences. SODA was developed specifically for the PS390, but the program will run on any PS300 system with little or no modifications required. A PS390 is required to display raster images.

CC produces generic raster data files. The SODA utility module DISPCC may be used to draw the pictures on the PS390 or to produce several common raster graphics files.

SSS animates the 9 planets of the solar system for any specific time period. A star field and an ecliptic plane are also available.

OD animates a single spacecraft (an asterisk icon) in orbit about the Earth, Moon, or Mars for the purpose of visualizing the effects of changes in any orbital parameter. All of the classical orbital parameters may be manipulated with the dials of the PS300. A cumulative ground track may be drawn on the surface of the planet as the spacecraft orbits. A circular and a rectangular sensor are attached to the satellite. These sensors may be scaled and rotated off-nadir.

VA animates a spacecraft model in orbit about the Earth, Moon, or Mars. VA supports FLEXAN spacecraft geometry and time-history files. FLEXAN is a flexible animation program which is called from within VA to process the spacecraft model and time-history files. A vehicle may be animated in orbit with structural shape changes, color changes (temperature, stress, etc.), and/or rotating parts (solar arrays, scanning sensors, etc.)

MVA supports animations of Earth, Moon, and Mars systems. Asterisk icons represent spacecraft in three windows: an overview of the planet and satellites, a view of the sky from a fixed observer on the planet, and a Cartesian projection of the planet with moving satellites, ground tracks, and circular and rectangular off-nadir instantaneous sensor coverage. Up to 10 sensors per vehicle are possible. Sensors may be fixed or scanning. Satellite-to-satellite, satellite-to-ground station, and ground station-to-satellite visibility is also calculated and displayed.

CC calculates cumulative satellite sensor coverage as well as average and maximum revisit time. CC is a batch-oriented program which produces three color-coded, raster pictures of the coverage data plotted onto Cartesian projections of the Earth, Moon, or Mars. One picture represents the total (cumulative) time of coverage. Another picture represents the average revisit time. The third picture represents the maximum revisit time.

VSV calculates satellite-to-satellite, satellite-to-ground station, and ground station-to-satellite visibility through sensors on satellites and ground stations. Line-of-sight visibility (no sensor used) may also be calculated. VSV produces a text file which shows the visibility windows on a time-line.

The general scenario in using SODA is to enter vehicle, sensor, ground station information, etc. into the database using the various SODA commands and menus on the VAX/VMS host computer. Appendix B contains a sumary of all SODA commands. A SODA module is run by issuing a module command with an argument. Arguments are module specific. They can represent a case name, vehicle name, file name or the number of simulation days. The OD, SSS, VA, and MVA modules then calculate and send the animation information to the PS300 workstation. A "beep" is sounded when all of the animation information is received by the PS300. The <linelocal>, <term>, and <graph> keys on the PS300 toggle between the terminal (line) and graphics (local) modes. Animations are completely controlled by the dials and function keys of the PS300 while in graphics (local) mode.

CC submits a detached process on the VAX/VMS host computer. A generic raster file is produced when the detached process is completed. The DISPCC utility module may then be used to draw CC pictures on a PS390 or produce PostScript[6] and SDRC[7] I-DEAS[8] picture files.

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[6] PostScript is a registered trademark of Adobe Systems Incorporated.

[7] SDRC is a service mark of Structural Dynamics Research Corporation.

[8] SDRC I-DEAS is a registered trademark of Structural Dynamics Research Corporation.

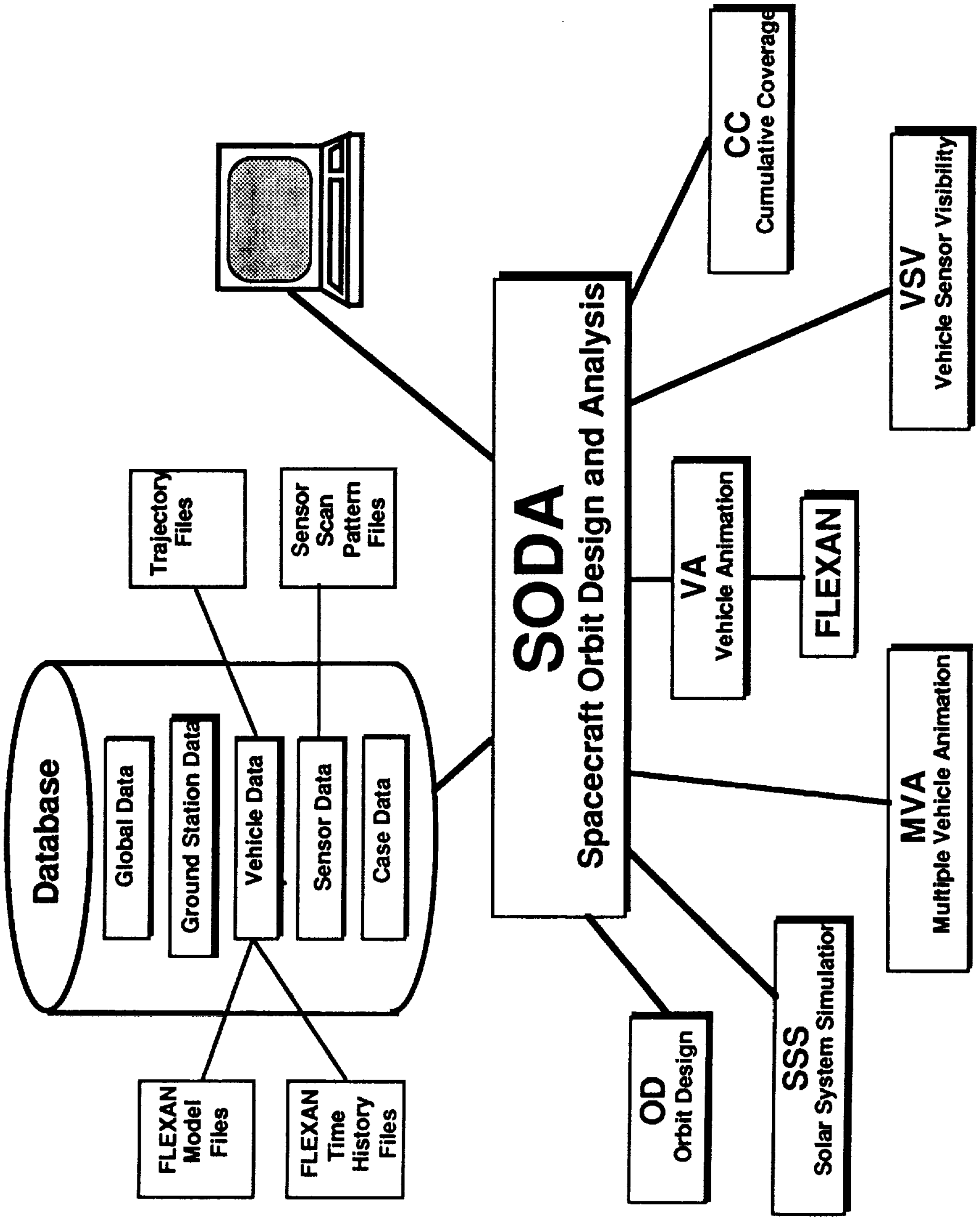

Figure 1 - Block Diagram of SODA.

2.0 SODA Database

The SODA user interface is command driven. All commands and prompt responses are case insensitive and may appear anywhere on a line with any number of spaces between commands and parameters. All commands which are not SODA commands are passed-on to the VAX/VMS DCL command interpreter in a spawned process. This allows non-SODA commands to be issued without exiting the SODA system. SODA may be run from any terminal, though a PS300 must be available if SSS, VA, OD, or MVA are to be used. SODA is executed by issuing the SODA command:

$ SODA *dbname*

Where *dbname* is the name of a new or existing SODA database. *dbname* may include a full VMS path specification. The default VMS file extension is ".DAT". If the database does not exist, then SODA will create *dbname*. If *dbname* is not supplied on the command line, then a prompt will be issued.

The /DEVICE = *device_number* command qualifier specifies a PS300 device to be used for all graphics. All terminal dialog is still performed on the current terminal. The *device_number* is an integer. The range of devices and the default is installation dependent. An example of the /DEVICE qualifier is:

$ SODA/DEVICE=2 *dbname*

The SODA command prompt is "SODA>". Entering the "EXIT" command or the *control* - Z character saves changes to the database and exits SODA. Entering "QUIT" will exit SODA without saving database changes. The "SAVE" command will save changes without exiting SODA. The following terminal session creates and opens a new SODA database named "POP" and then exits using the "EXIT" command. This terminal session and the sessions to follow in this document are presented in a monospaced font with user responses bold-faced.

```
$ SODA POP

    Spacecraft Orbit Design & Analysis (SODA)
         NASA Langley Research Center
          Spacecraft Analysis Branch

                 Version 2.0

         Computer Sciences Corporation

POP does not exist.  POP will be created.

SODA> EXIT
*** End SODA ***
$
```

2.1 Global Data

SODA maintains a list of values and options in the Global Data. Each of these values and options is used by one or more SODA program modules. The GLOBAL data items are:

1-6 **Epoch Date** - Numerical values for the reference year, month, day, hour, minute, and second. The epoch date is the reference date used for all orbit propagation calculations.

7 **Global Time Increment** - The time increment (time step) used for orbit propagation calculations and animation sequences.

8 **World Map** - Selects the size (level-of-detail) of the planetary map used in OD, MVA, and VA. Larger maps cost more in time and memory requirements.

9 **Star Field** - Select from options for presenting a field of over 5,000 stars in OD, MVA, and SSS.

The GLOBAL command, presented below, is used to edit the Global Data. The GLOBAL menu is typical of all SODA menus. A prompt for a new value is always issued when a numbered menu option is selected. Most prompts contain a default value between brackets "[ ]". The screen is refreshed after each prompt response is entered. The terminal session below and other sessions to follow assume an already open SODA database named POP.

```
SODA> GLOBAL

Global Data

1  - Epoch Year......................... 1988.0
2  - Epoch Month........................ 1.0
3  - Epoch Day.......................... 1.0
4  - Epoch Hour......................... 1.0
5  - Epoch Minute....................... 1.0
6  - Epoch Second....................... 1.0
7  - Global Time Inc..(HRS)............. 0.25
8  - World Map.......................... Large
9  - Star Field......................... Yes

Enter an item number to be corrected or X to return -> 2

Enter EPOCH month (1-12) -> 6
```

```
Global Data

1   - Epoch Year........................ 1988.0
2   - Epoch Month....................... 6.0
3   - Epoch Day......................... 1.0
4   - Epoch Hour........................ 1.0
5   - Epoch Minute...................... 1.0
6   - Epoch Second...................... 1.0
7   - Global Time Inc..(HRS)............ 0.25
8   - World Map......................... Large
9   - Star Field........................ Yes

Enter an item number to be corrected or X to return -> 8

Enter Map Size (Small, Medium, Large) -> M

Global Data

1   - Epoch Year........................ 1988.0
2   - Epoch Month....................... 6.0
3   - Epoch Day......................... 1.0
4   - Epoch Hour........................ 1.0
5   - Epoch Minute...................... 1.0
6   - Epoch Second...................... 1.0
7   - Global Time Inc..(HRS)............ 0.25
8   - World Map......................... Medium
9   - Star Field........................ Yes

Enter an item number to be corrected or X to return -> X
SODA>
```

2.2 Vehicle Data

SODA maintains spacecraft and orbit information in named VEHICLE records. VEHICLE names may be 10 characters long with no intervening spaces. The items contained in each VEHICLE are listed below. The items are broken into two groups or screens because all of the items will not fit on a standard 25-line by 80-column computer terminal.

Screen 1

1 **Vehicle Name** - Unique 10-character name of the vehicle.

2 **Planetary Body** - Planet to orbit. Currently the Earth, Moon, and Mars are supported.

3 **Propagation** - Select Keplerian or Keplerian with J2 effects propagation calculation.

4 **Groundtrack** - Select groundtrack calculation in MVA.

5 **Trajectory Lines** - Select solid or dotted trajectory lines in MVA.

6 **Color** - Select the color of the VEHICLE in MVA.

7 **Vehicle Start Time from Epoch** - The propagation start time, in hours, relative to the epoch date.

8 **Vehicle Stop Time from Epoch** - The propagation stop time, in hours, relative to the epoch date.

9 **Coordinate System** - Select the type of coordinate system to be used for specifying the orbital parameters. The following choices are available: Cartesian, Spherical, Classical, Geographic, and External Trajectory File. These coordinate systems correspond to those available in the ASTROLIB subroutine package. See Table 1 below.

10-15 **Orbital Parameters** - Each of these items is one orbital element in the coordinate system specified in item 9. Prompts and menu items change appropriately with the selected coordinate system. If the External Trajectory File option is selected in item 9, then item 10 contains the file name of an external trajectory file and items 11-15 are not used. See section 2.3 for a description of the trajectory file format.

Cartesian	Spherical	Classical	Geographic
X	Right Ascension (RA)	Semi-major axis	Longitude
Y	Declination	Eccentricity	Latitude
Z	Flight Path Angle	Inclination	Flight Path Angle
Velocity X	Azimuth	RA Ascending Node	Azimuth
Velocity Y	Dist. Planet Center	Arg. of Perigee	Dist. Planet Center
Velocity Z	Inertial Speed	Mean Anomaly	Inertial Speed

Table 1. - Satellite Coordinate Systems

Screen 2

1 **Model Filename** - FLEXAN geometry filename. This file is used in VA and will be described later.

2 **Color History Filename** - FLEXAN color history filename. This file is used in VA and will be described later.

3 **Delta History Filename** - FLEXAN delta history filename. This file is used in VA and will be described later.

4 **Rotation History Filename** - FLEXAN rotation history filename. This file is used in VA and will be described later.

5 **Vehicle Stabilization** - Select planet, orbit, space, or Sun vehicle stabilization.

6 **Type of Rotation** - Select coincident or rotated body (vehicle) coordinate system (BCS) and orbit coordinate system (OCS)

7-9 **(Yaw, Roll, Pitch) Angle** - Fixed yaw, roll and pitch angles. These items are only used if item 6 selects rotated coordinate systems.

The ADDV command creates a new VEHICLE. Prompts are issued for each item in the VEHICLE. An edit menu similar to the GLOBAL menu appears when all items have been entered. Prompts and menu items vary according to the options selected. The EDV command edits an existing VEHICLE. DELV deletes a VEHICLE from the database. COPYV copies information from an existing vehicle to a new vehicle. And LISTV lists the current VEHICLEs in the database. The following terminal session uses all five commands.

```
SODA> ADDV VEH1

Planetary Body

1 - Earth
2 - Moon
3 - Mars

Enter choice [1] ->

Type of Propagation

1 - Keplerian
2 - Keplerian with J2

Enter choice [1] -> 2

Groundtrack Type

1 - No Groundtrack
2 - Simple Line type Groundtrack

Enter choice [2] ->
```

```
Line Type

1 - Trajectory and Groundtracks are Dotted
2 - Trajectory and Groundtracks are solid lines

Enter choice [2] ->

Vehicle and Trajectory Color

  0 -  60 :     Blue    - Magenta
 60 - 120 :     Magenta - Red
120 - 180 :     Red     - Yellow
180 - 240 :     Yellow  - Green
240 - 300 :     Green   - Cyan
300 - 360 :     Cyan    - Blue

Enter choice [120.0] -> 240.0

Enter Vehicle start time in HOURS [0.0] ->

Enter Vehicle stop time in HOURS [24.0] ->

Satellite Coordinate System

1 - Cartesian
2 - Spherical
3 - Classical
4 - Geographic
5 - EXTERNAL Trajectory File

Enter choice [3] ->

Enter SEMI-MAJOR AXIS -> 15000.0

Enter ECCENTRICITY -> .1

Enter INCLINATION -> 23.5

Enter RIGHT ASCENSION OF ASCENDING NODE -> 90.0

Enter ARGUMENT OF PERIGEE -> 0.0

Enter MEAN ANOMALY -> 90.0

Enter a Model filename (or <cr>) -> VEH1.GEO

Enter a Color History filename (or <cr>) -> VEH1.CHY

Enter a Delta History filename (or <cr>) ->

Enter a Rotation History filename (or <cr>) -> VEH1.RHY
```

```
Vehicle Stabilization

1 - Planet Stabilized
2 - Orbit Stabilized
3 - Space Stabilized
4 - Sun Stabilized

Enter choice [1] ->

Type of Rotation

1 - BCS is Coincident with OCS
2 - Fixed Orientation of BCS to OCS

Enter choice [1] ->

Vehicle data #1 -- All units are hrs, km, and deg.

1  - Vehicle Name (Tag)...................... VEH1
2  - Planetary Body.......................... Earth
3  - Propagation............................. Keplerian with J2
4  - Groundtrack............................. Single line Groundtrack
5  - Trajectory Lines........................ Solid
6  - Color................................... 240.0
7  - Vehicle Start Time from Epoch........... 0.0
8  - Vehicle Stop Time from Epoch............ 24.0
9  - Coordinate System....................... Classical
10 - SEMI-MAJOR AXIS......................... 15000.0
11 - ECCENTRICITY............................ 0.1
12 - INCLINATION............................. 23.5
13 - RIGHT ASCENSION OF ASCENDING NODE....... 90.0
14 - ARGUMENT OF PERIGEE..................... 0.0
15 - MEAN ANOMALY............................ 90.0

Enter an item number to be corrected, or
<CR> to go to next screen, or
"X" to end ->

Vehicle data #2 -- All units are hrs, km, and deg.

1  - Model Filename................... VEH1.GEO
2  - Color History Filename........... VEH1.CHY
3  - Delta History Filename...........
4  - Rotation History Filename........ VEH1.RHY
5  - Vehicle Stabilization............ Planet Stabilized
6  - Type of Rotation................. BCS Coincident with OCS

Enter an item number to be corrected, or
<CR> to go to next screen, or
"X" to end -> x
```

```
SODA> EDV VEH1

Vehicle data #1 -- All units are hrs, km, and deg.

1  - Vehicle Name (Tag)...................... VEH1
2  - Planetary Body.......................... Earth
3  - Propagation............................. Keplerian with J2
4  - Groundtrack............................. Single line Groundtrack
5  - Trajectory Lines........................ Solid
6  - Color................................... 240.0
7  - Vehicle Start Time from Epoch........... 0.0
8  - Vehicle Stop Time from Epoch............ 24.0
9  - Coordinate System....................... Classical
10 - SEMI-MAJOR AXIS......................... 15000.0
11 - ECCENTRICITY............................ 0.1
12 - INCLINATION............................. 23.5
13 - RIGHT ASCENSION OF ASCENDING NODE....... 90.0
14 - ARGUMENT OF PERIGEE..................... 0.0
15 - MEAN ANOMALY............................ 90.0

Enter an item number to be corrected, or
<CR> to go to next screen, or
"X" to end -> X
SODA> LISTV

Current Vehicles - 1

  VEH1

SODA> COPYV VEH1 VEH2
SODA> DELV VEH2
SODA>
```

2.3 Vehicle Trajectory File Format

The vehicle trajectory file format is the same as that described in the ASTROLIB documentation (ref. 1). Trajectory files are unformatted files of 7-word records. Each record contains the time, inertial position vector, and the inertial velocity vector. SODA does not support the acceleration vector option described in the ASTROLIB documentation. SODA / ASTROLIB performs a Hermite interpolation to propagate the vehicle for the selected time period. The following FORTRAN code fragment shows how to write this file.

```
      .
      .
      .
      DOUBLE PRECISION  TIME(500), POS(3,500), VEL(3,500)
      .
      .
      .
      OPEN(10,FILE='TRAJ.DAT',FORM='UNFORMATTED')
      DO 100 J = 1, 500
           WRITE(10)    TIME(J),
     1                  POS(1,J), POS(2,J), POS(3,J),
     2                  VEL(1,J), VEL(2,J), VEL(3,J)
100   CONTINUE
      CLOSE(10)
      .
      .
      .
```

2.4 Sensor Data

SODA maintains sensor information in named SENSOR records. SENSOR names may be 10 characters long with no intervening spaces. SODA supports ground station and vehicle type sensors with both circular and rectangular shapes. Vehicle sensors are described in the vehicle coordinate system where the origin is the geometric center of the vehicle. Positive Z points at the center of the planet. Positive X points in the direction of the vehicle velocity vector. Positive Y completes the right-handed coordinate system. Ground station sensors have the origin of the coordinate system located at the geometric center of the ground station. Positive Z points from the origin to the zenith. Positive X points due east and positive Y points due north. The center axis or *Boresight* axis of the on-nadir sensor corresponds to the positive Z-axis for both types.

Circular sensors are described by a half-cone angle; the angle from the boresight axis to the edge of the sensor cone. Rectangular sensors are described by half-cone angles from the boresight axis to the adjacent sides of the viewing pyramid. Intrack angles are formed in the XZ plane of the vehicle coordinate system for vehicle sensors. East-West angles for ground station sensors are formed in the XZ plane of the ground station coordinate system. Crosstrack angles are formed in the YZ plane of the vehicle coordinate system for vehicle sensors and North-South angles are formed in the YZ plane of the ground station coordinate system for ground station sensors. Off-nadir sensors are described by rotating the sensor cone in any desired direction. For vehicle type sensors, the field of view can be limited by specifying a horizon constraint. The graphical increment determines the coarseness of the sensor's footprint.

An external file of scan instructions may be supplied for scanning sensors. See Section 2.5 for a description of the sensor scan pattern file format. SODA calculates the sensor position for scanning sensors at each time step of the simulation.

The items contained in each SENSOR are listed below. Items 1 - 5 are required for all SENSORs. Items 6 - 12 may be required depending on the SENSOR and scan types.

1 **Sensor Name** - Unique 10-character name of sensor.

2 **Sensor Type** - Select a ground station or vehicle type sensor.

3 **Sensor Shape** - Select circular or rectangular sensor.

4 **Scan Type** - Select a fixed or scanning sensor.

5 **Sensor Coverage Color** - Select the color of the coverage area in MVA.

6-12 **Half Cone Angle** - Angle from the boresight vector to the edge of the circular sensor cone.

Intrack (East-West) Cone Angle- Angle from the boresight vector to the edge of the rectangular sensor pyramid in the XZ plane.

Crosstrack (North-South) Cone Angle - Angle from the boresight vector to the edge of the rectangular sensor pyramid in the YZ plane.

Fixed Off-nadir Angle in (X,Y,Z) - Off-Nadir Rotation angles in the X, Y, Z directions (applied in that order) of the boresight axis. Appears in non-scanning sensors only.

Horizon Constraint - Angle between the ground station vector (from the center of the planet) and the vector joining the vehicle and ground station. Appears only in vehicle type sensors. See Figure 2 below.

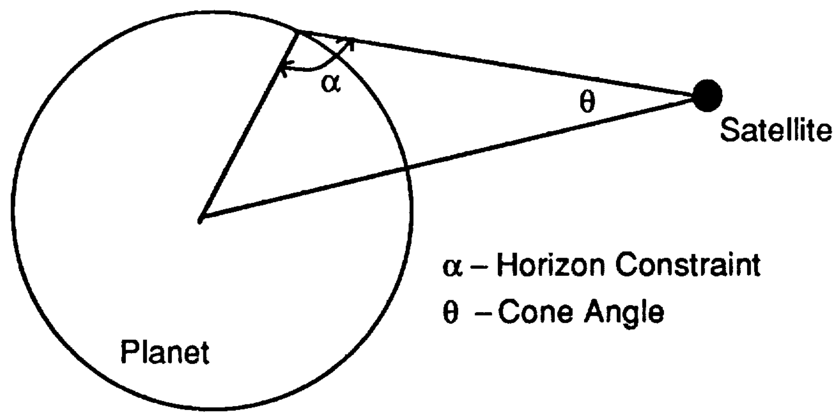

Figure 2 - Horizon Constraint Angles.

Graphical Increment - Increment value for modeling the edges of the sensor cone (determines the number of vectors in the sensor polygon). A value of 1.0 for a circular sensor results in 360 vectors in the sensor model. Rectangular sensors are calculated parametrically from -1.0 to 1.0 on each of the four sides. A value of 0.1 results in 20 vectors per side and a total of 80 vectors for the complete rectangular sensor. Low values yield more vectors and higher accuracy calculations at the cost of longer runs.

External Scan Pattern File - Filename of scan instructions.

The ADDS command creates a new SENSOR record. Prompts are issued for each item in the SENSOR. An edit menu similar to the GLOBAL menu appears when all items have been entered. Prompts and menu items vary according to the options selected. The EDS command edits an existing SENSOR. DELS deletes a SENSOR from the database. COPYS copies the information from an existing sensor to a new sensor. And LISTS lists the current SENSORs in the database. The following terminal session uses all five commands.

```
SODA> ADDS SEN1

SENSOR DATA  (Angles in Degrees)
Vehicle Sensor - Positive Z points at the center of the planet. Positive
X points in the direction of motion. And positive Y points out the right
wing.
Ground Station Sensor - Positive Z points from the center of the ground
station to the zenith.  Positive X is tangent to the surface pointing
due east.  Positive Y is tangent to the surface pointing due north.

Sensor Type

1 - Vehicle
2 - Ground Station

Enter choice [1] ->

Sensor Shape

1 - Circular
2 - Rectangular

Enter choice [1] -> 2

Scan Type

1 - Fixed
2 - Scanning

Enter choice [1] ->

Sensor Coverage Color

  0 -  60 :     Blue     - Magenta
 60 - 120 :     Magenta  - Red
120 - 180 :     Red      - Yellow
180 - 240 :     Yellow   - Green
240 - 300 :     Green    - Cyan
300 - 360 :     Cyan     - Blue

Enter choice [240.0] ->

Enter Sensor Intrack Cone Angle [20.0] ->

Enter Sensor Crosstrack Cone Angle [20.0] -> 10.0

Enter Fixed Off-nadir Angle in X [0.0] ->

Enter Fixed Off-nadir Angle in Y [0.0] -> 10.0

Enter Fixed Off-nadir Angle in Z [0.0] -> 12.0

Enter Sensor Horizon Constraint Angle [90.0] -> 100.0

Enter Graphical Increment value [0.05] ->
```

```
SENSOR DATA    (Angles in Degrees).
Vehicle Sensor - Positive Z points at the center of the planet. Positive
X points in the direction of motion. And positive Y points out the right
wing.
Ground Station Sensor - Positive Z points from the center of the ground
station to the zenith.  Positive X is tangent to the surface pointing
due east.  Positive Y is tangent to the surface pointing due north.

1  - Sensor Name............................ SEN1
2  - Sensor Type............................ Vehicle
3  - Sensor Shape........................... Rectangular
4  - Scan Type.............................. Fixed
5  - Sensor Coverage Color.................. 240.0
6  - Intrack Cone Angle..................... 20.0
7  - Crosstrack Cone Angle.................. 10.0
8  - Fixed Off-nadir Angle in X............. 0.0
9  - Fixed Off-nadir Angle in Y............. 10.0
10 - Fixed Off-nadir Angle in Z............. 12.0
11 - Horizon Constraint..................... 100.0
12 - Graphical Increment.................... 0.05

Enter an item number to be corrected, or
"X" to end -> 4

Scan Type

1 - Fixed
2 - Scanning

Enter choice [1] -> 2
Enter External Scan Filename -> SEN1.SCN

SENSOR DATA    (Angles in Degrees).
Vehicle Sensor - Positive Z points at the center of the planet. Positive
X points in the direction of motion. And positive Y points out the right
wing.
Ground Station Sensor - Positive Z points from the center of the ground
station to the zenith.  Positive X is tangent to the surface pointing
due east.  Positive Y is tangent to the surface pointing due north.

1  - Sensor Name............................ SEN1
2  - Sensor Type............................ Vehicle
3  - Sensor Shape........................... Rectangular
4  - Scan Type.............................. Scanning
5  - Sensor Coverage Color.................. 240.0
6  - Intrack Cone Angle..................... 20.0
7  - Crosstrack Cone Angle.................. 10.0
8  - External Scan File..................... SEN1.SCN
9  - Horizon Constraint..................... 100.0
10 - Graphical Increment.................... 0.05

Enter an item number to be corrected, or
"X" to end -> X
```

```
SODA> EDS SEN1

SENSOR DATA   (Angles in Degrees).
Vehicle Sensor - Positive Z points at the center of the planet. Positive
X points in the direction of motion. And positive Y points out the right
wing.
Ground Station Sensor - Positive Z points from the center of the ground
station to the zenith.  Positive X is tangent to the surface pointing
due east.  Positive Y is tangent to the surface pointing due north.

1  - Sensor Name............................ SEN1
2  - Sensor Type............................ Vehicle
3  - Sensor Shape........................... Rectangular
4  - Scan Type.............................. Scanning
5  - Sensor Coverage Color.................. 240.0
6  - Intrack Cone Angle..................... 20.0
7  - Crosstrack Cone Angle.................. 10.0
8  - External Scan File..................... SEN1.SCN
9  - Horizon Constraint..................... 100.0
10 - Graphical Increment.................... 0.05

Enter an item number to be corrected, or
"X" to end -> X

SODA> LISTS

Current Sensors - 1
  SEN1

SODA> COPYS SEN1 SEN2
SODA> DELS SEN2
SODA>
```

2.5 Sensor Scan Pattern File Format

Sensor scan pattern files are unformatted files of 4-word records. Each record contains the time and the off-nadir sensor rotations in the X, Y, and the Z directions. Time is specified in hours relative to the vehicle start time. Sensor rotations are expressed in the vehicle coordinate system described in Section 2.4. The rotation calculations are performed in the same order. SODA performs a Hermite interpolation to calculate the sensor rotation at each time step of MVA and CC. The following FORTRAN code fragment shows how to write this file.

```
      .
      .
      .
      DOUBLE PRECISION  TIME(500), ROT(3,500)
      .
      .
      .
      OPEN(10,FILE='SCAN.DAT',FORM='UNFORMATTED')
      DO 100 J = 1, 500
          WRITE(10)   TIME(J), ROT(1,J), ROT(2,J), ROT(3,J),
100   CONTINUE
      CLOSE(10)
      .
      .
      .
```

2.6 Ground Station Data

SODA maintains ground station information in named STATION records. STATION names may be 10 characters long with no intervening spaces. The items contained in each STATION are listed below.

1 **Station Name** - Unique 10-character name of the ground station.

2 **Planetary Body** - Planet to orbit, Earth, Moon or Mars.

3 **Longitude** - Longitudinal location of the ground station on the planet's surface.

4 **Latitude** - Latitudinal location of the ground station on the planet's surface.

5 **Color** - Select the color of the STATION in MVA.

The ADDGS command creates a new STATION. Prompts are issued for each item in the STATION. An edit menu similar to the previous menus appears when all items have been entered. The EDGS command edits an existing STATION. DELGS deletes a STATION from the SODA database. COPYGS copies an existing station to a new station. And LISTGS lists the current STATIONs in the database. The following terminal session uses all five commands.

```
SODA> ADDGS GS1

Which Planet
1 - Earth
2 - Moon
3 - Mars

Enter Choice [1] ->

Enter Ground Station Longitude -180.0 to 180.0 deg -> 60.0

Enter Ground Station Latitude -90.0 to 90.0 deg -> 45.0

Ground Station Color

  0 -  60 :     Blue    - Magenta
 60 - 120 :     Magenta - Red
120 - 180 :     Red     - Yellow
180 - 240 :     Yellow  - Green
240 - 300 :     Green   - Cyan
300 - 360 :     Cyan    - Blue

Enter Choice [240.0] ->
```

```
Ground Station Data

1   - Station Name........................... GS1
2   - Planet................................. Earth
3   - Latitude............................... 45.0
4   - Longitude.............................. 60.0
5   - Color.................................. 240.0

Enter an item number to be corrected, or
"X" to end -> x

SODA> EDGS GS1

Ground Station Data

1   - Station Name........................... GS1
2   - Planet................................. Earth
3   - Latitude............................... 45.0
4   - Longitude.............................. 60.0
5   - Color.................................. 240.0

Enter an item number to be corrected, or
"X" to end -> x

SODA> LISTGS

Current Stations - 1

  GS1

SODA> COPYGS GS1 GS2
SODA> DELS GS2
SODA>
```

2.7 Case Data

The CC, MVA, and VSV modules require that vehicles, ground stations and sensors be specified in a CASE. CASE data is entered into the SODA database using the VAX/VMS EDT editor. Each CASE contains a number of statements with each statement consisting of a combination of sensors, ground stations, and vehicles. Each statement must begin with a specified key word denoting the type of statement and end with a semicolon (";"). A statement may occupy multiple physical lines.

There are two main types of statements used in a SODA CASE; *override* statements and *combination* statements. Override statements specify the global data for the case thus overriding the SODA global values. Combination statements specify vehicles, sensors, and ground stations to be studied by a module.

There are four override statements available. Any number of these statements may appear in the CASE, in any order. Listed below is the syntax for the override statements. Each statement overrides a global value for the specific CASE without changing the global database values. Key words are shown here in bold face.

EPOCH year month day hour minute second ;
START start_time ;
STOP stop_time ;
INC time_step ;

The **EPOCH** values override the global epoch data in the SODA database. **START** and **STOP** times override all of the vehicle start and stop times (hours) for the CASE. The **INC** values override the global time step (hours) in the database.

The following example specifies an epoch of January 2, 1990 at 1:05:10 AM. The start time for all vehicles will be 1 hour after epoch (2:05:10). The stop time for all vehicles will be 24 hours after epoch (January 3, 1990 at 1:05:10 AM). The time step will be 15 minutes.

EPOCH 1990.0 1.0 2.0 5.0 10.0 ;
START 1.0 ;
STOP 24.0 ;
INC 0.25 ;

Combination statements specify the calculation of visibility, sensor coverage or position for combinations of vehicles, sensors, and ground stations. Each of the program modules CC, MVA and VSV require different types of combination statements.

The program module CC will accept sensor coverage statements only. VSV will accept visibility statements; either with a sensor or without a sensor (line-of-sight visibility). MVA will accept visibility, sensor and position statements.

The syntax and type of each statement is presented below. A statement must begin with a key word (boldfaced) and end with a semicolon. The arguments in the statements specify the names of vehicles, sensors and ground stations in the SODA database. Items enclosed in brackets ("[ ]") are optional. Each argument of the statement must be separated by one or more spaces with a colon (":") placed at specified locations to separate vehicles, sensors, and ground stations.

#	Type	Statement Syntax
1	**Position**	**VEH** veh1 ;
2	**Coverage**	**VEH** veh1 sen1 [sen2 sen3 ... senN] ;
3	**Visibility**	**VEH** veh1 sen1 : gs1 [gs2 gs3 ... gsN] ;
4	**Visibility**	**VEH** veh1 sen1 : : veh2 [veh3 veh4 ... vehN];
5	**Visibility**	**VEH** veh1 sen1 : gs1 [gs2 gs3 ... gsN] : veh2 [veh3 ... vehN] ;
6	**Visibility**	**VEH** veh1 : gs1 [gs2 gs3 ... gsN];
7	**Visibility**	**VEH** veh1 : : veh2 [veh3 veh4 ... vehN];
8	**Visibility**	**VEH** veh1 : gs1 [gs2 gs3 ... gsN] : veh2 [veh3 veh4 ... vehN] ;
9	**Position**	**GS** gs1 ;
10	**Visibility**	**GS** gs1 sen1 : : veh1 [veh2 veh3 ... vehN] ;
11	**Visibility**	**GS** gs1 : : veh1 [veh2 veh3 ... vehN] ;

Statement #1 specifies the propagation of vehicle veh1. It calculates the positions of the vehicle for animation with no sensor coverage or visibility calculations. This statement is only valid for MVA.

Statement #2 specifies the calculation of sensor coverage of the planet from the vehicle veh1 using the sensors sen1, sen2, ... senN. This statement is only valid for CC and MVA. ALL OTHER STATEMENTS are invalid for CC.

Statement #3 specifies the calculation of the visibility of the ground stations gs1, gs2, ..., gsN from the vehicle veh1 using the sensor sen1. This statement is valid for MVA and VSV.

Statement #4 specifies the calculation of the visibility of the vehicles veh2, veh3, ... , vehN from the vehicle veh1 using the sensor sen1. This statement is valid for MVA and VSV.

Statement #5 specifies the calculation of the visibility of the ground stations gs1, gs2, ..., gsN and the vehicles veh2, veh3, ... , vehN from the vehicle veh1 using the sensor sen1. This statement is valid for MVA and VSV.

Statement #6 specifies the calculation of line-of-sight visibility of the ground stations gs1, gs2, ..., gsN from the vehicle veh1. This statement is valid for MVA and VSV.

Statement #7 specifies the calculation of line-of-sight visibility of the vehicles veh2, veh3, ..., vehN from the vehicle veh1. This statement is valid for MVA and VSV.

Statement #8 specifies the calculation of line-of-sight visibility of the ground stations gs1, gs2, ..., gsN and the vehicles veh2, veh3, ... , vehN from the vehicle veh1. This statement is valid for MVA and VSV.

Statement #9 specifies the propagation of ground station gs1. It calculates the positions of the ground station for animation only. This statement is only valid for MVA.

Statement #10 specifies the calculation of the visibility of the vehicles veh1, veh2, ... , vehN from the ground station gs1 using the sensor sen1. This statement is only valid for MVA and VSV.

Statement #11 specifies the calculation of the line-of-sight visibility of the vehicles veh1, veh2, ... , vehN from the ground station gs1. This statement is only valid for MVA and VSV.

SODA analyzes the CASE data on each exit from the EDT editor. Error messages will be generated if the CASE is not consistent. A CASE is consistent if the following conditions are met :

1 All vehicles, sensors, and ground stations must first exist in the SODA database before a CASE is created. If a vehicle, sensor, or ground station is deleted which is referenced in a CASE, a warning message will be issued by the DELV, DELS, or DELGS commands. Error messages will be generated by MVA, CC, or VSV if the CASE contains nonexistent vehicles, sensors, or ground stations.

2 All vehicles and ground stations must be associated with the same planet.

3 The syntax of each statement must be correct.

4 A vehicle cannot view itself.

The ADDC command creates a new CASE. The VAX/VMS EDT editor is used to enter the information into the SODA database in a free-format manner. The EDT EXIT command saves the CASE statements and writes the information to the SODA database. The EDT QUIT command discards any changes made to the CASE. The EDC command edits an existing CASE. DELC deletes a CASE from the database. COPYC copies an existing case to a new case and LISTC lists all the current CASEs. The following terminal session uses all five commands.

```
SODA> ADDC CASE1

Use the VAX editor to enter/update the CASE using the following statements.

EPOCH year month day hour minute second ;
START time ;
STOP time ;
INC timestep ;

VEH veh1 ;
VEH veh1 sen1 [ sen2 sen3 ... senN ];
VEH veh1 sen1 : gs1 [ gs2 gs3 ... gsN ];
VEH veh1 sen1 : : veh2 [ veh3 veh4 ... vehN ];
VEH veh1 sen1 : gs1 [ gs2 gs3 ... gsN ] : veh2 [ veh3 veh4 ... vehN ];
VEH veh1 : gs1 [ gs2 gs3 ... gsN ];
VEH veh1 : : veh2 [ veh3 veh4 ... vehN ];
VEH veh1 : gs1 [ gs2 gs3 ... gsN ] : veh2 [ veh3 veh4 ... vehN ] ;

GS gs1;
GS gs1 sen1 : : veh1 [ veh2 veh3 ... vehN ] ;
GS gs1 : : veh1 [ veh2 veh3 ... vehN] ;

Input file does not exist
[EOB]
*C

START 0.0 ;
STOP 24.0 ;
INC   0.25 ;
VEH goes sensor1 : Langley ;
GS Langley : : goes ;
[EOB]


*exit
SAB1:[JSZ]TCASE.DAT;1 4 lines
```

```
SODA> EDC CASE1

 Use the VAX editor to enter/update the CASE using the following statements.

 EPOCH year month day hour minute second ;
 START time ;
 STOP time ;
 INC timestep ;

 VEH veh1 ;
 VEH veh1 sen1 [ sen2 sen3 ... senN ];
 VEH veh1 sen1 : gs1 [ gs2 gs3 ... gsN ];
 VEH veh1 sen1 : : veh2 [ veh3 veh4 ... vehN ];
 VEH veh1 sen1 : gs1 [ gs2 gs3 ... gsN ] : veh2 [ veh3 veh4 ... vehN ];
 VEH veh1 : gs1 [ gs2 gs3 ... gsN ];
 VEH veh1 : : veh2 [ veh3 veh4 ... vehN ];
 VEH veh1 : gs1 [ gs2 gs3 ... gsN ] : veh2 [ veh3 veh4 ... vehN ] ;

 GS gs1;
 GS gs1 sen1 : : veh1 [ veh2 veh3 ... vehN ] ;
 GS gs1 : : veh1 [ veh2 veh3 ... vehN] ;

    1        START 0.0 ;
*EXIT
SAB1:[JSZ]TCASE.DAT;2 4 lines


SODA> LISTC

Current Cases - 1

 CASE1

SODA> COPYC CASE1 CASE2
SODA> DELC CASE2
SODA>
```

3.0 SSS - Solar System Simulation

Solar System Simulation (SSS) animates the 9 planets of the solar system for any specific time period. A star field and an ecliptic plane are also available. Figure 3 is a still frame taken from an SSS animation. SSS uses the global epoch date as the start time of the animation. A prompt is issued for the number of days to animate. The time increment is 1 day. The following terminal session demonstrates the SSS command.

```
SODA> sss

Enter the number of days to animate [365.25] ->

SODA>
```

The solar system is shown to scale. The dials may be used to scale the Sun and planets. The scale factors are displayed in the lower right corner along with the day (or animation frame number) of the animation. The ecliptic plane is drawn in green and can be toggled on or off. Solid curves mark the trajectory of each planet during the simulation time period. Dotted curves mark the complete orbit of each planet. The MOTION key starts the animation. The planets move along the simulated trajectories until the end of the sequence. The PS300 function keys and dials are presented in Tables 2 and 3 respectively.

Keyset

Key	Label	Function
1	MOTION	Toggle motion of the planets.
2	KEYS	Not Used (for future expansion).
3	DIALS	Toggle dialsets.
4	VIEWS	Not Used (for future expansion).
5		
6	STARS	Toggle star magnitudes.
7	ECLIPTIC	Toggle ecliptic plane.
8	LABELS	Toggle display labels.
9	PLANETS	Toggle planets.
10	PLAN TAG	Toggle planet tags (names).
11	PLAN TRJ	Toggle planet solid trajectory for simulation time.
12	PLAN DOT	Toggle planet dotted trajectory (completes the orbit).

Table 2 SSS - Function Keys

Dialset #1

Dial	Label	Function
1	X TRAN	Translate Solar System in the X direction.
2	Y TRAN	Translate Solar System in the Y direction.
3	Z TRAN	Translate Solar System in the Z direction.
4		
5	X ROTATE	Rotate Solar System in the X direction.
6	Y ROTATE	Rotate Solar System in the X direction.
7	Z ROTATE	Rotate Solar System in the X direction.
8		

Dialset #2

Dial	Label	Function
1	PLA SIZE	Scale the planets.
2	SUN SIZE	Scale the Sun.
3		
4		
5		
6		
7		
8		

Table 3 SSS - Dialsets

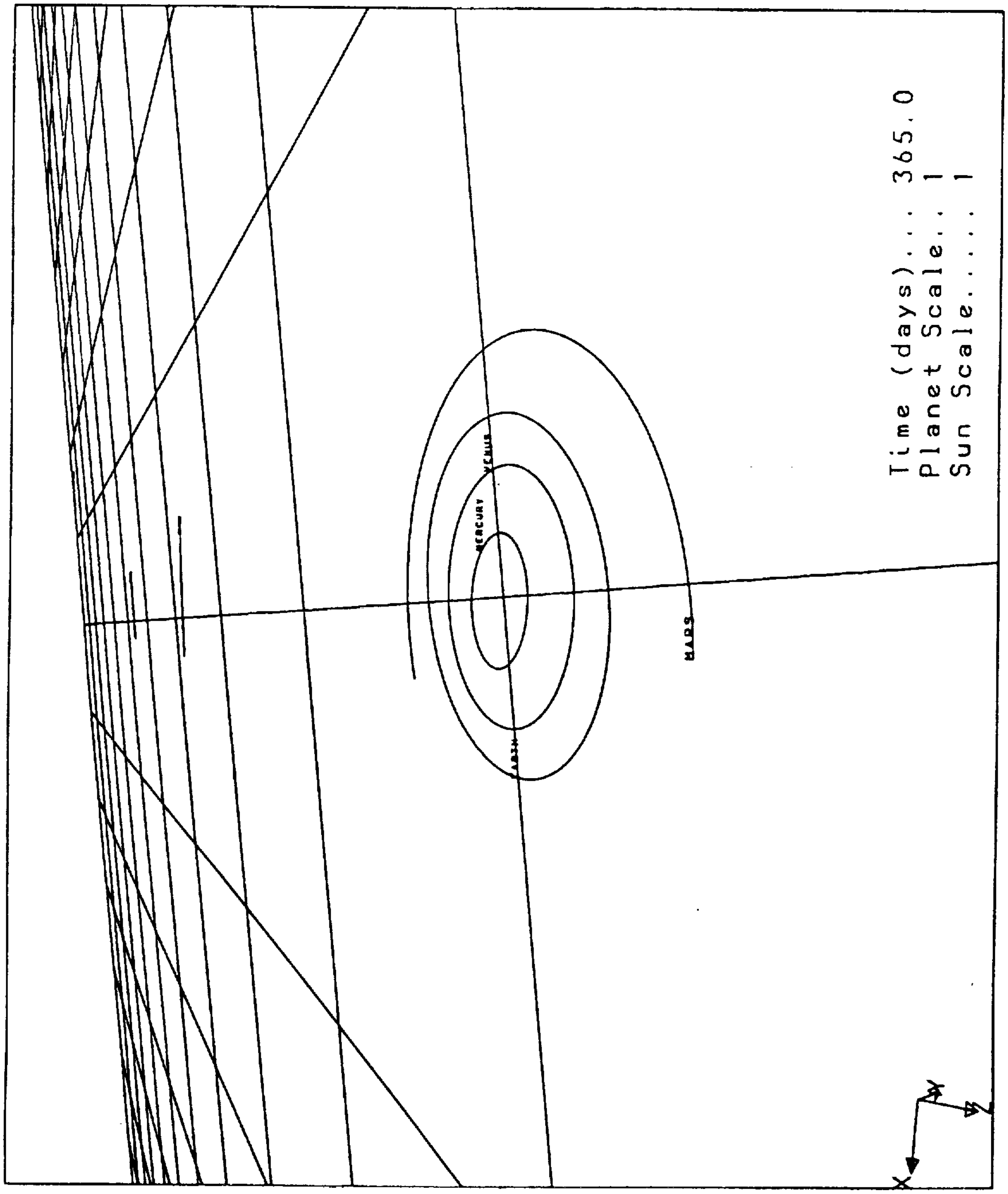

Figure 3 - Still Picture from SSS

4.0 OD - Orbit Design

Orbit Design (OD) animates a single spacecraft (an asterisk icon) in orbit about the Earth, Moon, or Mars. All of the classical orbital parameters may be manipulated by using the dials of the PS300. A cumulative ground track may be displayed on the surface of the planet. A circular and a rectangular sensor are attached to the satellite. These sensors may be scaled and rotated off-nadir. Figure 4 is a still frame taken from an OD session. The OD command requires one argument - a VEHICLE name. The orbital parameters of the VEHICLE record are used to initialize the OD session and choose the planet to be orbited. OD will not change any items in the VEHICLE record. The following terminal session demonstrates the OD command.

```
SODA> OD VEH1
SODA>
```

The PS300 function keys and dials are presented in Tables 4 and 5 respectively.

Keyset #1

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Not Used (for future expansion).
5		
6	STARS	Toggle background star magnitudes.
7	MAP	Toggle continents (features) of planet.
8	LIMB	Toggle planetary limb.
9	GRID	Toggle planetary grid lines.
10	LABELS	Toggle display labels.
11	STATIONS	Toggle ground stations.
12	SHADOW	Toggle planetary shadow.

Keyset #2

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Not Used (for future expansion).
5		
6	ORBIT	Toggle vehicle orbit.
7	CIRC SEN	Toggle circular sensor.
8	RECT SEN	Toggle rectangular sensor.
9	EQ PLANE	Toggle equatorial plane.
10	START GT	Start ground track display.
11	STOP GT	Stop ground track display.
12	RESET GT	Reset the ground track.

Keyset #3

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Not Used (for future expansion).
5		
6	VEH AXIS	Toggle vehicle coordinate axis.
7		
8		
9		
10		
11		
12		

Table 4 OD - Function Keys

Dialset #1

Dial	Label	Function
1	HORZNTAL	Translate the animation horizontally.
2	VERTICAL	Translate the animation vertically.
3	DEPTH	Translate the animation in Z (depth cueing).
4	SCALE	Scale the animation.
5	X ROTATE	Rotate the animation in the X direction.
6	Y ROTATE	Rotate the animation in the Y direction.
7	Z ROTATE	Rotate the animation in the Z direction.
8	VEH SCAL	Scale the vehicle.

Dialset #2

Dial	Label	Function
1	SEMI AXS	Semi-major axis.
2	ECCNTRTY	Eccentricity.
3	INCLNATN	Inclination.
4	INCREMEN	Propagation increment (animation speed).
5	RA ASC N	Right Ascension of the ascending node.
6	ARG PERI	Argument of perigee.
7	MEAN ANO	Mean Anomaly.
8	VEH AX S	Scale vehicle axis.

Dialset #3

Dial	Label	Function
1	CIRC SCL	Scale the circular sensor.
2	HALFCONE	Halfcone angle of the circular sensor.
3		
4		
5	NADIR X	Rotate circular sensor off-nadir in X.
6	NADIR Y	Rotate circular sensor off-nadir in Y.
7	NADIR Z	Rotate circular sensor off-nadir in Z.
8		

Dialset #4

Dial	Label	Function
1	RECT SCL	Scale the rectangular sensor.
2	INTRACK	Intrack half angle of the rectangular sensor.
3	CROSSTRA	Crosstrack half angle of the rectangular sensor.
4		
5	NADIR X	Rotate rectangular sensor off-nadir in X.
6	NADIR Y	Rotate rectangular sensor off-nadir in Y.
7	NADIR Z	Rotate rectangular sensor off-nadir in Z.
8		

Table 5 OD - Dialsets

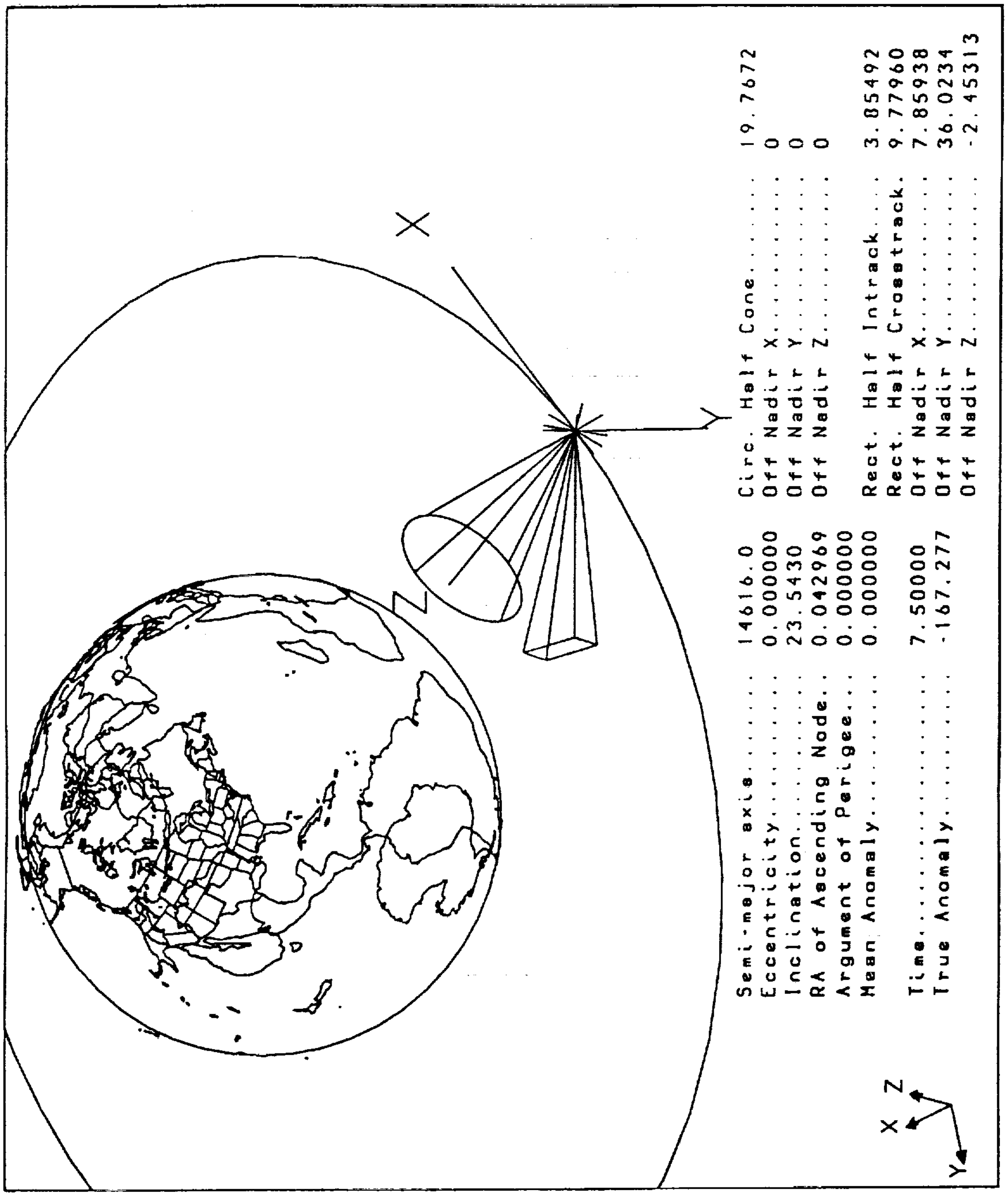

Figure 4 - Still Picture from OD

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5.0 VA - Vehicle Animation

Vehicle Animation (VA) animates a spacecraft model in orbit about the Earth, Moon, or Mars. VA supports FLEXAN spacecraft geometry and time-history files. A vehicle can be animated in orbit with structural shape changes, color changes (temperature, stress, etc.), and/or rotating parts (solar arrays, scanning sensors etc.) VA does not calculate stresses, temperatures, or rotation angles; it only reads data files produced by other programs. FLEXAN is described in NASA Contractor Report 4214, FLEXAN User's Guide (ref. 2). Figure 5 is a still frame from a typical VA animation. The VA command takes one argument - a VEHICLE name. The following terminal session demonstrates the VA command.

```
SODA> VA VEH1
SODA>
```

All of the items in the VEHICLE record except the color and groundtrack information are used in VA. A FLEXAN model file is required but the FLEXAN time history files (color, delta, and rotation) are optional. Any combination of FLEXAN time history files, including all three is acceptable. Vehicle models should be represented in the vehicle coordinate system described in section 2.3. VA will scale the vehicle to fit the animation windows. The FLEXAN file formats are completely described in the FLEXAN document (ref. 2).

Currently VA requires exactly 180 frames of data in the FLEXAN time history files. Each data frame represents the state of the vehicle at a particular point (every 2 degrees of true anomaly) in one complete orbit .

VA animates the vehicle in several views : planet-to-satellite, Sun-to-satellite, overview planet (orbit and vehicle included), overview satellite, and satellite-to-ground.

The PS300 function keys and dials are presented in Tables 6 and 7, respectively.

Keyset #1

Key	Label	Function
1	KEYS	Toggle keysets.
2	NEXTVIEW	Toggle views.
3	PLANET/SAT	Toggle dialsets (planet, satellite).
4	SOLAR	Toggle planetary shadow.
5	MERIDIAN	Toggle meridian (limb).
6	PLANET	Toggle planet continents (features).
7	ORBIT	Toggle vehicle orbit.
8	ECLIPTIC	Toggle ecliptic plane.
9	EQUATOR	Toggle equatorial plane.
10	BCS	Toggle body coordinate axis.
11	OCS	Toggle orbit coordinate axis.
12	TRIGGER	Toggle animation.

Keyset #2

Key	Label	Function
1	KEYS	Toggle keysets.
2	NEXTVIEW	Toggle views.
3	PLANET/SAT	Toggle dialsets (planet, satellite).
4	RESCALE	Rescale display to the default.
5	START	Start ground track.
6	STOP	Stop ground track.
7	RESET	Reset ground track.
8		
9		
10		
11		
12	TRIGGER	Toggle animation.

Table 6 VA - Function Keys

Dialset #1

Dial	Label	Function
1	ROTATE X	Rotate overview planet in the X direction.
2	ROTATE Y	Rotate overview planet in the Y direction.
3	ROTATE Z	Rotate overview planet in the Z direction.
4	SCALE	Scale overview planet .
5	HORZNTAL	Translate overview planet horizontally.
6	VERTICAL	Translate overview planet vertically.
7	DEPTH	Translate overview planet in Z (depth cueing).
8	SPEED	Speed of animation.

Dialset #2

Dial	Label	Function
1	ROTATE X	Rotate overview satellite in the X direction.
2	ROTATE Y	Rotate overview satellite in the Y direction.
3	ROTATE Z	Rotate overview satellite in the Z direction.
4	SCALE	Scale overview satellite.
5	HORZNTAL	Translate overview satellite horizontally.
6	VERTICAL	Translate overview satellite vertically.
7	DEPTH	Translate overview satellite in Z (depth cueing).
8	HALFCONE	Speed of animation.

Table 7 VA - Dialsets

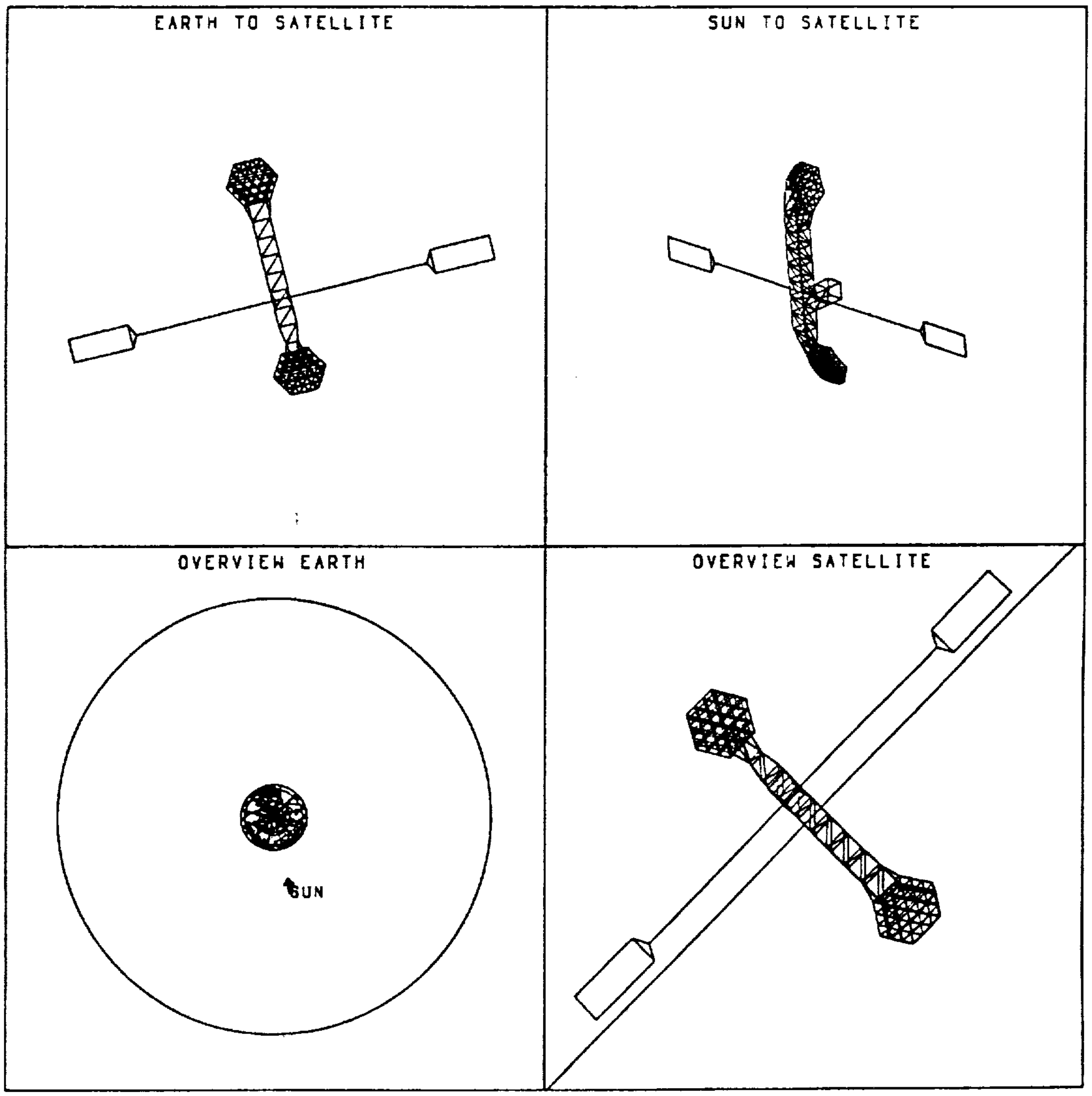

Figure 5 - Still Picture from VA

6.0 MVA - Multiple Vehicle Animation

Multiple Vehicle Animation (MVA) supports animations of Earth, Moon, and Mars systems. Asterisk icons represent spacecraft in three windows - an overview of the planet, and satellites, a view of the sky from a ground observer on the planet and a Cartesian projection of the planet with moving satellites, ground tracks, and circular and rectangular off-nadir instantaneous sensor coverage. Sensors may be fixed or scanning. Sensor visibility and line-of-sight visibility are also calculated with lines displayed between two objects when they are visible. The example CASE, "SEE" below requests line-of-sight visibility between two vehicles and sensor visibility for each vehicle. Figure 6 is a still frame taken from the MVA session in which the two vehicles, "NOAA6" and "GOESE", are orbiting the Earth. "GOESE" has one circular on-nadir sensor attached. "NOAA6" has one off-nadir circular sensor and one off-nadir rectangular sensor attached. The CASE "SEE" is :

```
VEH GOESE :: NOAA6 ;
VEH GOESE SEN1 : GS1 : NOAA6 ;
VEH NOAA6 SEN2 : GS1 ;
VEH NOAA6 SEN3 : GS1 ;
```

A solar terminator and subsolar point are shown moving across the planet . The ground station icon "GS1" appears in both the overview window and the Cartesian projection. A line segment between "NOAA6" and "GOESE" in the overview window shows that the two satellites have line-of-sight visibility with no sensor visibility. Both vehicles are able to view the ground station as seen in the Cartesian projection.

MVA prompts for a CASE name if one is not specified. Visibility statements and sensor coverage statements are used in the CASE. Up to 50 vehicles may be animated at once, each with up to 10 sensors, ground stations and vehicles attached (PS300 memory permitting). The following terminal session demonstrates the MVA command using the example CASE.

```
SODA> MVA SEE
SODA>
```

All of the items in the CASE must already exist before MVA is initiated. The simulation time for the animation starts at the earliest start time of the vehicles input since no override values are present. The stop time is the latest stop time of the vehicles input.

The PS300 function keys and dials are presented in Tables 8 and 9, respectively.

Keyset #1

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Toggle views.
5		
6	SHADOW	Toggle planetary shadow.
7	TAGS	Toggle vehicle tags (names).
8	VEHICLES	Toggle vehicle icons.
9	TRAJECTS	Toggle vehicle trajectories.
10	PLANET	Toggle planet in overview.
11	SAT LINK	Toggle satellite to satellite links.
12	GND LINK	Toggle ground station to satellite links.

Keyset #2

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Toggle views.
5		
6	STARS	Toggle stars in the sky view.
6*	STARS	Toggle stars in the overview.
6+	STARS	Toggle star magnitudes in sky view and overview.
7	SKY DATA	Toggle sky view labels.
8	OBSERVER	Toggle ground observer icons.
9		
10		
11		
12		

Keyset #3

Key	Label	Function
1	MOTION	Toggle motion.
2	KEYS	Toggle keysets.
3	DIALS	Toggle dialsets.
4	VIEWS	Toggle views.
5		
6	TRMNATOR	Toggle solar terminator on flat map.
7	VEHICLES	Toggle vehicle icons.
8	VEHICLES	Toggle vehicle icons.
9	TRACES	Toggle ground traces.
10	STATIONS	Toggle ground stations.
11	SKY GRID	Toggle viewing grid in sky view.
12	MAP	Toggle flat map grid and features.
12*	MAP	Toggle map grid only.

* Press SHIFT key.
+ Press CONTROL key.

Table 8 MVA - Function Keys

Dialset #1

Dial	Label	Function
1	HORZNTAL	Translate the overview horizontally.
2	VERTICAL	Translate the overview vertically.
3	DEPTH	Translate the overview in Z (depth cueing).
4	SCALE	Scale the overview.
5	X ROTATE	Rotate the overview in the X direction.
6	Y ROTATE	Rotate the overview in the Y direction.
7	Z ROTATE	Rotate the overview in the Z direction.
8	VEH SIZE	Scale the vehicles.

Dialset #2

Dial	Label	Function
1	LATITUDE	Move ground observer in latitude.
2	LNGITUDE	Move ground observer in longitude.
3	ALTITUDE	Move ground observer in altitude.
4	SCA FRUS	Scale ground observer frustum.
5		
6		
7		
8	FOV-GR	Ground observer field of view.

Table 9 MVA - Dialsets

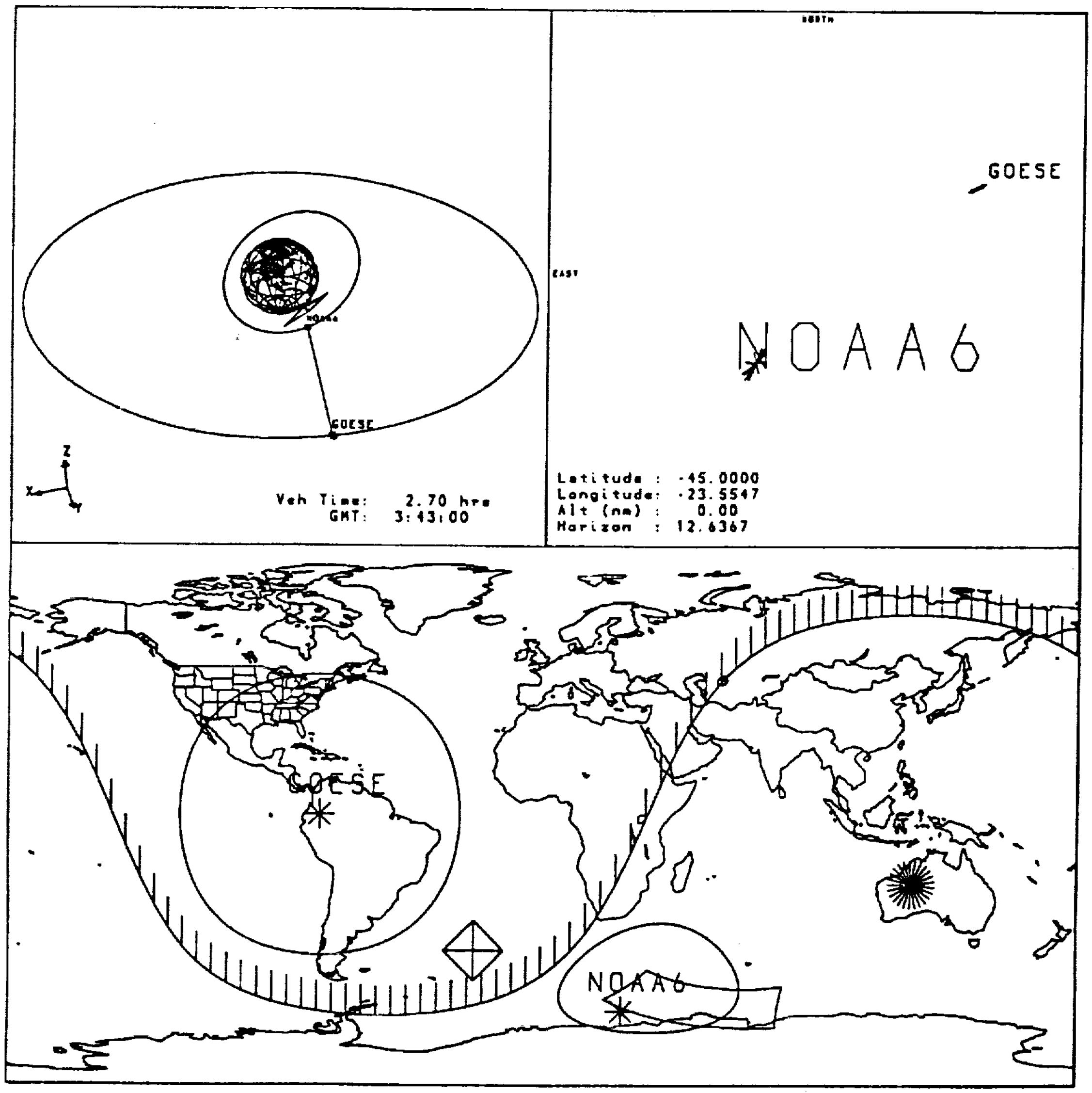

Figure 6 - Still Picture from MVA

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7.0 CC - Cumulative Coverage

Cumulative Coverage (CC) calculates cumulative satellite sensor coverage as well as average and maximum revisit time for the entire surface of a planet for some simulation time interval. Cumulative coverage is defined as the total time that a point (an area on a planet approximately 21' of longitude by 21' of latitude)[9] is covered by at least one sensor. A point on a planet is said to be *visited* when it is covered by one or more sensors at a particular instant of time. Revisit time is the length of time between successive visits of a point. Average and maximum revisit times are the respective average and maximum of a point's revisit times. In other words, these terms refer to individual points, not an average and maximum of all points. Revisit times of one time step (time increment in the global data) are not used in the calculation of average revisit time, since they indicate the point was continuously covered between two successive time steps.

CC is a batch-oriented program which may produce (with DISPCC) a tabular report and/or three color-coded, raster pictures of the coverage data in the form of 1024 x 512 pixel Cartesian projections of either the Earth, Moon, or Mars. Each pixel corresponds to a point on a planet. One picture represents the cumulative time of coverage. Another picture represents the average revisit time of coverage. The last picture represents the maximum revisit time. A labeled color or greyscale bar is appended to each picture to yield three 1024 x 800 pixel images.

The following terminal session creates a detached process using the example CASE, "COVER" to calculate the cumulative coverage and revisit time for three vehicles. An output file containing the coverage data is written to the file "COV1.DAT". The DISPCC utility module may be used to convert the data in this file into a tabular report and or graphical images. The CASE "COVER" is :

```
     VEH VEH1 SEN1 SEN2 ;
     VEH VEH2 SEN3 ;
     VEH VEH3 SEN1 SEN3 ;

SODA> CC COVER

Enter coverage output filename [COVERAGE.DAT] -> COV1.DAT
SODA>
```

The detached process will be named "CC_*Current time*". The current time is taken from the VAX/VMS system clock. The coverage output file will be written when the process completes. The VAX/VMS command "SHOW SYSTEM" may be used to determine the status of the detached process.

CC requires relatively long simulation runs with a short global time increment (in the GLOBAL data) for the best results. The sensors will tend to *skip* across the surface of the planet if the global time increment is too long. Typical runs can take from several hours to several days of CPU time.

---

[9] Refers to the area of a pixel at the equator. The area of pixels varies with latitude. Pixels at the poles approach 0 area.

8.0 DISPCC

The SODA utility module DISPCC may be used to produce tabular and graphical reports from the CC program module coverage output file. A graphical report may be generated to draw pictures on a PS390 or to produce Postscript files, SDRC I-DEAS picture files or Raster Metafiles (NASA Langley specific graphics file). Various mask and overlay options are available for enhanced output.

The maximum and minimum values of all points (pixels) on the planet are determined for the cumulative coverage time, average revisit time, and the maximum revisit time. A menu is presented which allows these values to be changed. When comparing multiple runs of CC it is often desirable to fix the color or range of colors across runs. All pixels above the range are printed with maximum color. All pixels below the range are printed with minimum color. A menu of output options is presented after the ranges have been determined.

Masks allow the calculation of statistics for large areas of the planet surface. The SODA system currently contains two masks: the land area of the Earth and the ocean area of the Earth. The tabular report contains average, maximum, minimum, and percentage area of coverage statistics for mask areas. Masks also cause the graphical reports to only color the areas in the mask; all of the area outside of the mask is drawn in black (0 intensity).

Overlays allow the drawing of continental boundaries or grid lines on top of the graphical images. Overlays are ignored for the tabular report. SODA currently contains the following overlays : Earth continents and borders, Mars major features, Earth Moon major features, and 30 degree longitude-latitude grid.

An example run of DISPCC is presented below.

```
SODA> DISPCC

Enter coverage filename [COVERAGE.DAT] -> COV.DAT

Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> 1


 99.9% of planet is covered.

 Actual Color Window (hours)

Cumulative Coverage Time........... 0.0 : 38.87
Average Revisit Time............... 0.5606 : 98.05
Maximum Revisit Time............... 1.995 : 98.05
```

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```
Set New Color Window for Graphics Report

1 - Min Cumulative Coverage Time... 0.0
2 - Max Cumulative Coverage Time... 38.87
3 - Min Average Revisit Time....... 0.5606
4 - Max Average Revisit Time....... 98.05
5 - Min Maximum Revisit Time....... 1.995
6 - Max Maximum Revisit Time....... 98.05

Enter an item number to be set or X to return -> X


Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> 2


Planetary Masks

 1 - Earth, Land Area
 2 - Earth, Ocean Area

Enter mask numbers, seperated by spaces, to be turned on,
(0 if no masking desired) -> 1


Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> 3
```

```
Planetary Overlays

 1 - Earth Features
 2 - Moon Features
 3 - Mars Features
 4 - 30 degree Longitude/Latitude Grid

Enter Overlay numbers, seperated by spaces, to be turned on,
(0 if no overlays desired) -> 1 4


Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> 5


Select Device/file type :

1 - Coverage on PS390 Terminal
2 - Avg. Revisit on PS390 Terminal
3 - Max. Revisit on PS390 Terminal
4 - Postscript Files
5 - IDEAS**2 Picture Files (binary)
6 - Raster Metafile

-> 4


Enter output filename without extension [COVERAGE] -> COV1

Cum. Coverage will be written to COV1.PSC
Avg. Revisit will be written to  COV1.PSA
Max. Revisit will be written to  COV1.PSM

This will take a few minutes...
```

```
Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> 4


Enter Longitude Band Increment in Degrees [10.0] ->


Enter Latitude Band Increment in Degrees [5.0] ->


Enter Output Report Filename [COVERAGE.REP] ->


Cumulative Coverage Post Processing

1 - Set Data/Color Ranges for Graphical Report
2 - Apply Masks for Tabular and Graphical Report
3 - Apply Overlays for Graphical Report

4 - Write Tabular Report
5 - Write Graphical Report

Enter Item Number or x to end -> X

SODA>
```

Figure 7 is a greyscale image of the cumulative coverage picture produced during the terminal session above. Appendix C is a listing of the tabular report produced during the same session.

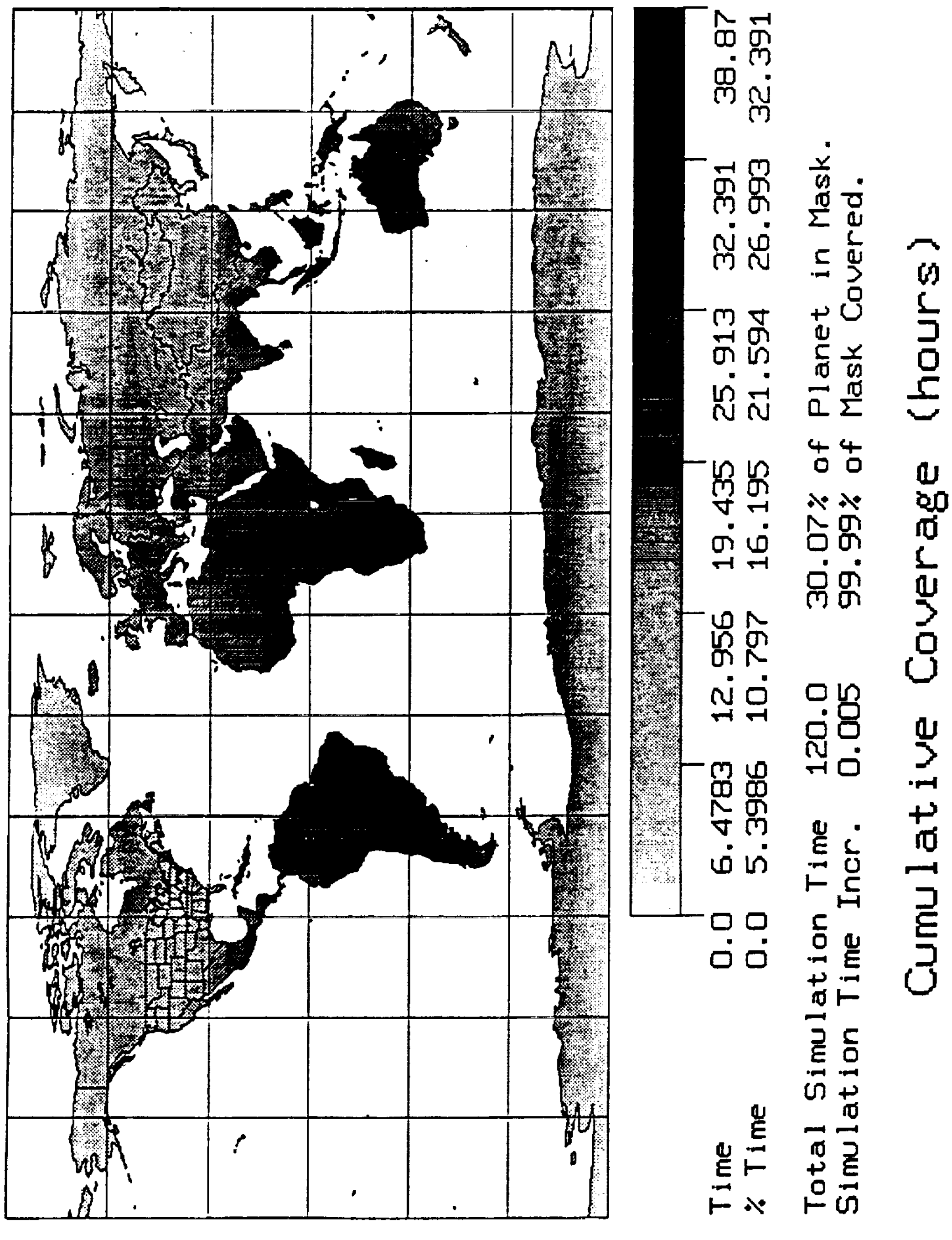

Figure 7- CC/DISPCC Cumulative Coverage Picture

9.0 VSV - Vehicle Sensor Visibility

Vehicle Sensor Visibility (VSV) determines at which time steps specified vehicles or ground stations are visible. This is accomplished using either sensor visibility or line-of-sight visibility between objects. The input CASE required for VSV may contain only visibility statements.

An output file is produced listing each time step and statement combination. If visibility exists for the combination at a particular time step, an "X" is placed at the intersection of a grid of combinations verses time steps. Statistical information is given for each combination such as total time visible and longest time visible.

The example CASE, "VIEW", below requests sensor visibility from ground stations to vehicles; line-of-sight visibility from ground stations to vehicles; sensor visibility from vehicles to ground stations; sensor visibility from vehicles to ground stations and vehicles; and line-of-sight visibility from vehicles to ground stations and vehicles. The CASE "VIEW" is:

```
GS BERLIN GNDRADAR ::  AMSAT LANDSAT ;
VEH NORAD SMCIR : LARC NOME BAIRES ;
VEH AMSAT LGCIR :  BERLIN : LANDSAT ;
VEH COMSAT : LARC NOME BAIRES : NORAD ;
VEH LANDSAT MEDCIR : BERLIN LARC NOME ;
GS NOME :: COMSAT NORAD ;
GS LARC :: AMSAT LANDSAT COMSAT NORAD ;
GS BAIRES :: NORAD ;
```

The following terminal session demonstrates the VSV command using the example CASE "VIEW".

```
SODA> VSV VIEW

Enter visibility output filename [VISIBLE.REP] -> VIS.REP

SODA>
```

All of the items in the CASE must already exist before VSV is initiated. The calculation time for visibility starts at the earliest start time of the vehicles since no override values are present. The ending time is the latest stop time of the CASE vehicles.

Appendix D contains a partial listing of the visibility output file VIS.REP.

Appendix A New and changed features in SODA version 2.0

Version 1.0 of SODA maintained all data in a BOEING[10] RIM Version 7 relational database. Version 2.0 of SODA maintains its data in a standard VAX/VMS binary file. As each version of a SODA database file is saved, a new VAX/VMS version of the file is created. This change makes the program more portable, faster, and more fault tolerant.

The program module VSV (Vehicle Sensor Visibility) was added. VSV calculates satellite-to-satellite, satellite-to-ground station, and ground station-to-satellite visibility through circular or rectangular sensors on satellites and ground stations. Line-of-sight visibility (no sensor used) may also be calculated. VSV produces a text file which shows the visibility windows on a time-line.

The CC, MVA, and VSV modules now require that vehicles, ground stations and sensors be specified in a CASE. CASE data is entered into the SODA database using the VAX/VMS EDT editor. Each CASE contains a number of SODA statements consisting of keywords and a combination of sensors, ground stations, and vehicles.

Ground stations are now entered into the database using menus similar to those for vehicles and sensors rather than the VAX/VMS EDT editor.

Sensors may now be circular or rectangular and may be associated with ground stations as well as vehicles. Ground station sensors "look up" toward the zenith at overhead vehicles.

Horizon constraints may now be applied to sensors when calculating coverage.

Visibility calculations in MVA now support visibility through sensors as well as line-of-sight visibility.

DISPCC now generates a tabular report in addition to the graphics images generated by version 1.0.

DISPCC may now apply masks to the planet surface to calculate coverage statistics for specific areas of a planet such as the land area of the Earth. Overlays may now be placed on top of the graphical images to provide grid patterns or to outline features of interest.

[10] BOEING is a registered trademark of the Boeing Company. RIM Version 7 is a product of Boeing Computer Services, a division of the Boeing Company.

Appendix B SODA Command Summary

All SODA commands are case insensitive. Some commands require arguments. If the arguments are not supplied on the command line a prompt will be issued for those arguments.

Vehicle Commands

In the following commands, "veh", "oldveh", and "newveh" refer to SODA vehicle names.

ADDV veh	- Add a new vehicle.
EDV veh	- Edit an existing vehicle.
COPYV oldveh newveh	- Copy an existing vehicle to a new vehicle.
LISTV	- List all vehicles in the database.
DELV veh	- Delete a vehicle

Sensor Commands

In the following commands, "sen", "oldsen", and "newsen" refer to SODA sensor names.

ADDS sen	- Add a new sensor.
EDS sen	- Edit an existing sensor.
COPYS oldsen newsen	- Copy an existing sensor to a new sensor.
LISTS	- List all sensors in the database.
DELS sen	- Delete a sensor.

Ground Station Commands

In the following commands, "gs", "oldgs", and "newgs" refer to SODA ground station names.

ADDGS gs	- Add a new ground station
EDGS gs	- Edit an existing ground station.
COPYGS oldgs newgs	- Copy an existing gs. to a new gs.
LISTGS	- List all ground stations in the database.
DELGS gs	- Delete a ground station.

Case Commands

In the following commands, "case", "oldcase", and "newcase" refer to SODA case names.

ADDC case	- Add a new case.
EDC case	- Edit an existing case.
COPYC oldcase newcase	- Copy an existing case to a new case.
LISTC	- List all cases in the database.
DELC case	- Delete a case.

General Commands

GLOBAL	- Edit the global data.
SAVE	- Save the current state of the database.
PSINIT	- Initialize the E&S PS 300.
EXIT	- Exit from SODA and save the database.
QUIT	- Quit from SODA, do not save the database.

Program Module Commands

In the following commands, "case" refers to a case name, "veh" refers to a vehicle name, "file" is the coverage output file from CC, and "days" refers to a number of days.

SSS days	- Run the SSS program module.
OD veh	- Run the OD program module.
VA veh	- Run the VA program module.
MVA case	- Run the MVA program module.
VSV case	- Run the VSV program module.
CC case	- Run the CC program module.
DISPCC file	- Run the DISPCC utility program.

Appendix C CC/DISPCC Tabular Report

Soda Cumulative Coverage Tabular Report for the Planet Earth. 16-OCT-90

Epoch Year...... 1988.0
Epoch Month..... 1.0
Epoch Day....... 1.0
Epoch Hour...... 1.0
Epoch Minute.... 1.0
Epoch Second.... 1.0

Total Simulation Time (hours)............... 120.0
Simulation Time Increment (hours)........... 0.005
Percentage of Entire Planet Covered......... 99.89888

Pixel Statistics

Time (hours)	Minimum	Maximum	Average
Entire Planet Cumulative Coverage	0.0	38.87	16.32422
Entire Planet Average Revisit	0.5606	98.05	1.90275
Entire Planet Maximum Revisit	1.995	98.05	4.82373

Vehicles and Sensors (km, hours, Degrees)

Vehicle Name (Tag)...................... NOAA6
Propagation............................. Keplerian
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System....................... Classical
SEMI-MAJOR AXIS......................... 12000.0
ECCENTRICITY............................ 0.2
INCLINATION............................. 89.0
RIGHT ASCENSION OF ASCENDING NODE....... 0.0
ARGUMENT OF PERIGEE..................... 90.0
MEAN ANOMALY............................ 0.0

Sensor Name............................. SEN1
Sensor Type............................. Vehicle
Sensor Shape............................ Circular
Scan Type............................... Fixed
Half Cone Angle......................... 40.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint...................... 0.0
Graphical Increment..................... 1.0

Sensor Name............................. SEN2
Sensor Type............................. Vehicle
Sensor Shape............................ Circular
Scan Type............................... Fixed
Half Cone Angle......................... 10.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint...................... 0.0
Graphical Increment..................... 1.0

Sensor Name............................. SEN3
Sensor Type............................. Vehicle
Sensor Shape............................ Rectangular
Scan Type............................... Fixed
Intrack Cone Angle...................... 5.0
Crosstrack Cone Angle................... 10.0
Fixed Offnadir Angle in X............... 3.0
Fixed Offnadir Angle in Y............... 2.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint...................... 0.0
Graphical Increment..................... 0.05

Vehicles and Sensors (km, hours, Degrees)

```
Vehicle Name (Tag)...................... STATION
Propagation............................. Keplerian
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System....................... Classical
SEMI-MAJOR AXIS......................... 10000.0
ECCENTRICITY............................ 0.0
INCLINATION............................. 28.5
RIGHT ASCENSION OF ASCENDING NODE....... 0.0
ARGUMENT OF PERIGEE..................... 0.0
MEAN ANOMALY............................ 0.0

Sensor Name............................. SEN2
Sensor Type............................. Vehicle
Sensor Shape............................ Circular
Scan Type............................... Fixed
Half Cone Angle......................... 10.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint...................... 0.0
Graphical Increment..................... 1.0

Sensor Name............................. SEN3
Sensor Type............................. Vehicle
Sensor Shape............................ Rectangular
Scan Type............................... Fixed
Intrack Cone Angle...................... 5.0
Crosstrack Cone Angle................... 10.0
Fixed Offnadir Angle in X............... 3.0
Fixed Offnadir Angle in Y............... 2.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint...................... 0.0
Graphical Increment..................... 0.05
```

Tabular Coverage for Surface of Planet

The tabular data is printed by latitude bands. The following key shows the corrisponding longitudes in degrees. Each entry in the actual list represents the average of all of the pixels in the rectangular patch whose upper left corner has the given longitude-latitude coordinates.

```
 Latitude = W              Band Average = X              Patch Area % = Y              Band Area % = Z
-180.000 -170.000 -160.000 -150.000 -140.000 -130.000 -120.000 -110.000 -100.000  -90.000  -80.000  -70.000  -60.000
 -50.000  -40.000  -30.000  -20.000  -10.000    0.000   10.000   20.000   30.000   40.000   50.000   60.000   70.000
  80.000   90.000  100.000  110.000  120.000  130.000  140.000  150.000  160.000  170.000
```

W = the Latitude coordinate of a band in degrees.
X = the average of all pixels across the latitude band.
Y = the geographic percentage of planetary surface area of each patch in the band.
Z = the geographic percentage of planetary surface area of all patches in the band.

```
Longitude Increment (degrees)....... 10.0
Latitude Increment (degrees)........ 5.0
```

Cumulative Coverage Time (hours)

Latitude = 90.0 Band Average = 2.0665 Patch Area % = 0.00658 Band Area % = 0.237
1.2658 1.4615 1.5899 1.6931 1.7890 1.8765 1.9507 2.0034 2.0648 2.1272 2.1935 2.2492 2.2984
2.3491 2.3963 2.4289 2.4469 2.4641 2.4706 2.4640 2.4410 2.4161 2.3857 2.3527 2.3184 2.2755
2.2165 2.1623 2.1010 2.0405 1.9653 1.8724 1.7695 1.6563 1.5178 1.3059

Latitude = 85.0 Band Average = 3.75168 Patch Area % = 0.01962 Band Area % = 0.70623
2.3701 2.8310 3.0812 3.2131 3.3252 3.4336 3.5263 3.6086 3.7161 3.8128 3.9073 3.9953 4.0913
4.2244 4.3672 4.4397 4.4973 4.5526 4.5452 4.5003 4.4210 4.3370 4.2808 4.2005 4.1154 4.0302
3.9387 3.8379 3.7241 3.6040 3.4890 3.3611 3.2403 3.1182 2.8768 2.4191

Latitude = 80.0 Band Average = 4.82332 Patch Area % = 0.0302 Band Area % = 1.08718
2.9308 3.4283 3.9100 4.2327 4.3858 4.5175 4.6202 4.7205 4.8553 4.9757 5.0665 5.1640 5.2589
5.3760 5.5092 5.6382 5.7773 5.8289 5.8204 5.7714 5.6846 5.5698 5.4976 5.4012 5.2975 5.1850
5.0671 4.9592 4.8338 4.6884 4.5531 4.4075 4.2348 3.9699 3.4971 2.9694

Latitude = 75.0 Band Average = 6.26925 Patch Area % = 0.0413 Band Area % = 1.48694
3.6716 4.2035 4.7946 5.3551 5.7682 5.9976 6.1441 6.2863 6.4580 6.6204 6.7319 6.8272 6.9258
7.0341 7.1670 7.2484 7.2945 7.3636 7.4008 7.4214 7.3995 7.3010 7.2205 7.0899 6.9783 6.8769
6.7275 6.5777 6.4205 6.2158 6.0309 5.8060 5.4123 4.8860 4.2683 3.7031

Latitude = 70.0 Band Average = 8.23044 Patch Area % = 0.0521 Band Area % = 1.87575
4.9704 5.5185 6.1396 6.7997 7.4598 7.9292 8.2110 8.4223 8.5798 8.7364 8.8985 9.0301 9.1729
9.3160 9.4497 9.4838 9.4592 9.4331 9.4610 9.5689 9.6692 9.6605 9.5237 9.3635 9.1692 9.0408
8.8979 8.7366 8.5515 8.3187 7.9968 7.5299 6.9155 6.2157 5.5930 4.9870

Latitude = 65.0 Band Average = 10.97455 Patch Area % = 0.06252 Band Area % = 2.25071
7.0354 7.6259 8.2279 8.8467 9.6248 10.3506 10.8998 11.3358 11.5355 11.7476 12.0036 12.1655 12.3610
12.4725 12.4733 12.4856 12.5113 12.5268 12.5485 12.5408 12.5930 12.7331 12.7510 12.6046 12.3593 12.1391
11.9461 11.7170 11.4684 11.0765 10.4765 9.7742 9.0022 8.2626 7.6793 7.0709

Latitude = 60.0 Band Average = 13.12033 Patch Area % = 0.07737 Band Area % = 2.78524
8.5436 9.1394 9.7226 10.2920 10.9609 11.6778 12.4831 13.3104 13.9613 14.4329 14.7668 14.9372 15.0240
15.0557 15.0892 15.1180 15.1437 15.1373 15.1514 15.1745 15.1290 15.1519 15.1889 15.2753 15.2077 14.9707
14.6887 14.2387 13.5891 12.8105 11.9120 11.0991 10.3964 9.7434 9.1369 8.5404

Latitude = 55.0 Band Average = 14.12782 Patch Area % = 0.08255 Band Area % = 2.97163
9.6474 10.3219 10.8051 11.4471 12.0824 12.5699 13.1602 13.8649 14.4502 15.3053 15.8665 15.9925 16.2108
16.3304 16.2884 16.4045 16.3684 16.3311 16.4901 16.3517 16.3802 16.3778 16.2201 16.2935 16.2641 15.9593
15.6023 14.7880 13.9495 13.4313 12.6008 12.0388 11.5405 10.7930 10.2583 9.6880

Latitude = 50.0 Band Average = 14.34072 Patch Area % = 0.09132 Band Area % = 3.28737
10.6586 11.3562 11.7661 12.3259 12.9868 13.2866 13.6876 14.0193 14.3377 14.8512 15.1643 15.5120 16.0091
16.2024 16.2621 16.4579 16.3585 16.3687 16.5564 16.3679 16.4541 16.2910 16.1103 16.0805 15.7051 15.2122
14.9645 14.5176 14.0925 13.8162 13.2711 12.7900 12.4396 11.7835 11.2855 10.7976

Latitude = 45.0 Band Average = 14.67332 Patch Area % = 0.09941 Band Area % = 3.57887
11.7121 12.3152 12.6914 13.1151 13.6898 13.9821 14.1973 14.5464 14.6367 14.9187 15.1337 15.2751 15.6945
16.0436 16.3136 16.5561 16.4596 16.4958 16.6172 16.4959 16.5215 16.3816 16.0276 15.7862 15.4186 15.1072
14.9942 14.6515 14.4098 14.2678 13.8733 13.6075 13.3028 12.7376 12.3231 11.8315

Latitude = 40.0 Band Average = 15.1576 Patch Area % = 0.10678 Band Area % = 3.84397
12.7475 13.2782 13.6369 13.9645 14.4373 14.7118 14.9622 15.1727 15.1793 15.3811 15.5508 15.5583 15.8089
16.0198 16.2169 16.5883 16.6822 16.7808 16.9076 16.7483 16.6275 16.3553 15.9759 15.8309 15.6199 15.3763
15.3841 15.2008 15.0678 14.9489 14.5484 14.3535 14.1147 13.6301 13.3238 12.8827

Latitude = 35.0 Band Average = 16.14065 Patch Area % = 0.12067 Band Area % = 4.34394
14.1716 14.6716 14.9006 15.2309 15.7223 15.9419 16.1007 16.2864 16.2269 16.4002 16.5422 16.5302 16.7039
16.8008 16.8905 17.1301 17.1384 17.2082 17.3873 17.1607 17.0946 16.9647 16.6696 16.6843 16.5453 16.3642
16.4534 16.3188 16.1225 16.0994 15.7898 15.5916 15.2629 14.8461 14.6804 14.3370

Latitude = 30.0 Band Average = 17.32481 Patch Area % = 0.11947 Band Area % = 4.30095
15.4804 16.0227 16.3223 16.6729 17.0681 17.3082 17.3626 17.5892 17.5076 17.6900 17.7753 17.7492 17.9172
17.9445 18.0034 18.0648 17.9372 17.7949 17.9165 17.8239 17.9425 18.0033 17.7879 17.8870 17.7346 17.6219
17.7467 17.6032 17.4076 17.3712 17.1385 17.0452 16.7047 16.1326 15.9666 15.5545

Latitude = 25.0 Band Average = 18.00274 Patch Area % = 0.12427 Band Area % = 4.47368
15.9132 16.5723 17.0276 17.3284 17.5260 18.0078 18.1302 18.3440 18.3602 18.6220 18.5711 18.5270 18.6594
18.6631 18.7226 18.5541 18.5061 18.5100 18.5528 18.4656 18.4832 18.5768 18.5512 18.6041 18.5134 18.5005
18.5853 18.3988 18.2305 18.0411 17.7657 17.6652 17.3866 16.8558 16.4622 15.8068

Latitude = 20.0 Band Average = 18.27238 Patch Area % = 0.12815 Band Area % = 4.61343
15.7564 16.6448 17.0948 17.4460 17.6916 18.1808 18.4261 18.6024 18.7766 19.0037 18.9460 18.9926 19.0647
19.0453 19.1174 18.8715 18.8470 18.8514 18.8090 18.8540 18.8493 18.9291 18.9993 19.0749 18.9734 18.9643
18.9413 18.7996 18.6024 18.2328 17.9035 17.7567 17.5312 17.0465 16.4442 15.6194

Latitude = 15.0 Band Average = 18.77259 Patch Area % = 0.13109 Band Area % = 4.71915
15.5648 16.5272 17.3285 17.8446 18.1029 18.5939 18.8293 19.2028 19.3742 19.4748 19.5780 19.7920 19.8644
19.7752 19.8046 19.6097 19.5957 19.4890 19.3680 19.5475 19.6468 19.6471 19.7659 19.8172 19.7483 19.6186
19.5159 19.4141 19.1327 18.6838 18.4102 18.1466 17.7304 17.1827 16.4291 15.5281

Latitude = 10.0 Band Average = 19.46411 Patch Area % = 0.14142 Band Area % = 5.09117
15.1559 16.2310 17.5167 18.1833 18.6547 19.2322 19.3960 19.8572 20.1067 20.2443 20.4862 20.7945 20.9538
20.9417 20.9766 20.6957 20.6577 20.5853 20.4703 20.5978 20.8528 20.9074 20.9634 20.8332 20.7155 20.5763
20.3589 20.1224 19.7841 19.4134 19.0826 18.5389 17.9870 17.2461 16.2575 15.1792

Latitude = 5.0 Band Average = 20.38777 Patch Area % = 0.13408 Band Area % = 4.82683
14.6398 15.9143 17.2589 18.4863 19.2797 20.0794 20.2860 20.7522 21.1087 21.4153 21.7438 21.9877 22.2903
22.4736 22.6026 22.4642 22.3295 22.0880 22.0612 22.2744 22.5937 22.5116 22.3804 22.2073 21.9851 21.8078
21.4151 21.0863 20.7126 20.3989 19.8552 19.1106 18.2365 17.3063 15.9546 14.7048

Latitude = 0.0 Band Average = 21.45676 Patch Area % = 0.13401 Band Area % = 4.82428
14.2055 15.6058 17.0279 18.6721 20.0380 20.9805 21.3769 21.7741 22.2353 22.6566 23.1160 23.4393 23.7779
24.0445 24.3054 24.2940 24.4051 24.5212 24.5385 24.5408 24.3844 24.1046 23.8437 23.6884 23.3778 23.0776
22.6250 22.2698 21.8128 21.4158 20.7256 19.6459 18.5125 17.1414 15.7715 14.3032

Latitude = -5.0 Band Average = 22.6894 Patch Area % = 0.13295 Band Area % = 4.78616
13.9338 15.3833 16.9069 18.6748 20.4219 21.9325 22.5758 23.0662 23.6451 24.0727 24.5144 24.9678 25.3754
25.6555 26.2761 26.6503 27.0699 27.7719 27.7352 27.3447 26.5820 25.9872 25.5495 25.2690 24.7819 24.3707
23.9246 23.6264 23.1510 22.5314 21.5948 20.1959 18.7783 17.0215 15.4168 13.8419

Latitude = -10.0 Band Average = 24.11865 Patch Area % = 0.13091 Band Area % = 4.71274
13.4419 15.2212 17.0261 18.8267 20.7672 22.6799 23.9123 24.4697 24.9935 25.5918 26.0021 26.7114 27.3236
27.8341 28.9138 29.9175 30.4281 30.7602 30.6806 30.5046 29.9131 28.5599 27.7290 27.0994 26.4648 26.0692
25.4292 24.9670 24.5012 23.5076 22.4358 20.6809 18.9906 17.1975 15.1037 13.3872

Latitude = -15.0 Band Average = 25.85248 Patch Area % = 0.13576 Band Area % = 4.88731
12.9708 15.1146 17.2542 19.0233 21.0237 22.9334 24.6450 26.1625 26.8263 27.6809 28.2627 28.9628 30.1222
31.4892 32.8678 33.4957 33.4875 33.6177 33.5985 33.4692 33.4190 32.7133 31.3617 29.8995 28.7684 28.3646
27.4728 26.6030 25.8134 24.4383 22.9083 21.2119 19.1106 17.1506 15.1711 13.0007

Latitude = -20.0 Band Average = 28.03379 Patch Area % = 0.12364 Band Area % = 4.451
12.6486 15.0083 17.3652 19.6194 21.7156 23.6459 25.1461 27.4023 29.2501 30.5094 31.7343 33.2385 34.9360
36.0802 36.4904 36.7201 36.7364 36.5052 36.6916 36.6917 36.5998 36.4684 35.8966 34.9125 33.3945 31.6351
30.2706 28.7391 27.0041 25.3180 23.5247 21.8257 19.4958 17.3090 15.4082 12.9480

Latitude = -25.0 Band Average = 28.67929 Patch Area % = 0.11871 Band Area % = 4.27365
12.5546 14.6079 16.9527 19.3460 21.4163 23.0663 24.8236 26.6211 29.3170 32.2274 34.8334 36.1397 36.6322
36.9723 37.1318 37.3330 37.3774 37.1749 37.2212 37.4179 37.1705 37.1759 37.0083 36.6225 36.2490 34.9111
32.4746 29.7905 27.0135 25.0328 23.5487 21.6034 19.5718 17.2765 14.8720 12.6620

Latitude = -30.0 Band Average = 26.20233 Patch Area % = 0.11291 Band Area % = 4.06479
11.6515 13.6533 15.6262 17.7839 19.7710 21.5656 23.2356 25.3422 27.5691 29.5719 31.2417 32.0770 32.5675
32.9762 33.2230 33.4586 33.6039 33.5170 33.5492 33.6427 33.4774 33.3863 33.1522 32.8218 32.5059 31.6426
30.2841 28.2856 25.9767 23.8241 22.0051 20.1736 18.1362 15.9928 13.8719 11.8315

Latitude = -35.0 Band Average = 23.99011 Patch Area % = 0.10628 Band Area % = 3.82596
11.0644 12.9341 14.7691 16.7431 18.6208 20.5247 22.3555 24.0506 25.5849 26.8736 27.8708 28.4642 28.9648
29.4009 29.7480 29.9885 30.1479 30.1198 30.1416 30.1943 30.0727 29.9367 29.7227 29.5555 29.2051 28.5136
27.5436 26.2909 24.6865 22.8398 20.9407 19.0048 17.0164 15.1164 13.1370 11.2295

Latitude = -40.0 Band Average = 21.94076 Patch Area % = 0.10474 Band Area % = 3.77047
10.6277 12.3421 14.0406 15.9040 17.7221 19.6445 21.3089 22.5399 23.4481 24.1652 24.8080 25.3446 25.7728
26.1892 26.5448 26.7960 26.9703 26.9649 27.0114 27.0349 26.9753 26.8714 26.8686 26.5783 26.0757 25.5325
24.8423 24.0604 23.0820 21.7478 20.0548 18.0501 16.1592 14.3241 12.5014 10.7165

Latitude = -45.0 Band Average = 19.96346 Patch Area % = 0.0901 Band Area % = 3.2437
10.1351 11.7321 13.3182 15.0559 16.8375 18.5374 19.8992 20.7790 21.3313 21.7662 22.1348 22.5397 22.8678
23.2274 23.5659 23.7992 23.9258 23.9933 24.0666 24.1017 24.2105 24.2802 24.0618 23.6605 23.1669 22.7616
22.3109 21.8504 21.2536 20.3666 18.9318 17.1616 15.2948 13.4968 11.8629 10.1800

Latitude = -50.0 Band Average = 18.24899 Patch Area % = 0.08124 Band Area % = 2.92468
9.6849 11.1724 12.7334 14.3024 15.9517 17.3318 18.3275 18.9390 19.4118 19.7818 20.0836 20.3432 20.5402
20.8138 21.0810 21.2126 21.3189 21.4687 21.5704 21.7486 22.0288 21.8581 21.5176 21.2229 20.9101 20.6523
20.3133 19.8913 19.3818 18.7168 17.7245 16.2785 14.5533 12.8255 11.3177 9.7590

Latitude = -55.0 Band Average = 16.80443 Patch Area % = 0.07178 Band Area % = 2.58409
9.3459 10.7440 12.2319 13.6783 15.0538 16.0297 16.6415 17.1110 17.5104 17.9108 18.2478 18.4818 18.7187
18.9571 19.2304 19.3828 19.5254 19.7142 19.9081 20.1655 20.1348 19.8932 19.6058 19.3659 19.1629 18.8829
18.4676 17.9931 17.4947 17.0430 16.3429 15.3044 13.8889 12.3228 10.8625 9.4214

Latitude = -60.0 Band Average = 15.52784 Patch Area % = 0.06179 Band Area % = 2.22445
9.1400 10.5365 11.8760 13.1413 14.1377 14.6914 15.1246 15.5360 15.7868 16.1629 16.4939 16.7507 17.1178
17.3625 17.6246 17.9122 18.1434 18.4715 18.6775 18.5818 18.4538 18.2106 17.9545 17.6781 17.4330 17.0346
16.7094 16.2661 15.8679 15.4650 14.9549 14.3444 13.3139 12.0195 10.5990 9.2557

Latitude = -65.0 Band Average = 14.75753 Patch Area % = 0.05415 Band Area % = 1.94927
9.0969 10.5438 11.8674 12.8972 13.5049 13.9325 14.3399 14.6731 14.9664 15.2352 15.5155 15.8284 16.1426
16.4132 16.7202 17.0590 17.3776 17.5290 17.5526 17.4250 17.2039 16.9742 16.7715 16.5581 16.2571 15.9608
15.6457 15.3178 14.9161 14.5310 14.1065 13.6228 12.9786 11.9372 10.5857 9.1208

Latitude = -70.0 Band Average = 15.3917 Patch Area % = 0.03973 Band Area % = 1.43044
8.8883 10.5357 11.9153 12.8276 13.5217 14.1382 14.6750 15.1779 15.6490 16.0737 16.5055 16.9048 17.3398
17.8348 18.3521 18.7546 19.0216 19.1567 19.1649 18.9781 18.6508 18.3081 17.9008 17.4398 16.9412 16.4260
15.9703 15.4863 15.0460 14.5859 14.0263 13.4548 12.8333 11.9612 10.5667 8.9111

Latitude = -75.0 Band Average = 15.00088 Patch Area % = 0.02859 Band Area % = 1.02934
8.0819 9.9259 11.2380 12.0831 12.8440 13.4929 14.1204 14.7572 15.3793 15.9298 16.4321 16.8902 17.3359
17.7497 18.0370 18.2410 18.3459 18.4092 18.3877 18.2592 18.1246 17.9829 17.8101 17.5882 17.3107 16.8517
16.3429 15.7049 14.9978 14.2388 13.4466 12.6799 11.8789 11.0016 9.8244 8.1208

Latitude = -80.0 Band Average = 10.95923 Patch Area % = 0.01724 Band Area % = 0.62066
6.0472 7.5130 8.4225 9.0870 9.6541 10.1254 10.5152 10.8493 11.1438 11.4146 11.6645 11.8988 12.1091
12.2931 12.4927 12.6525 12.7768 12.8934 12.9716 12.9791 12.9653 12.9036 12.7427 12.5595 12.3810 12.1879
11.9968 11.7697 11.5180 11.2061 10.7898 10.2301 9.4894 8.5685 7.5230 6.0598

Latitude = -85.0 Band Average = 4.23846 Patch Area % = 0.00579 Band Area % = 0.20832
2.4193 3.0321 3.4024 3.6321 3.7858 3.9037 4.0304 4.1488 4.2427 4.3247 4.4401 4.5773 4.7093
4.8215 4.9214 5.0225 5.0902 5.1207 5.1171 5.0824 5.0348 4.9655 4.8549 4.7585 4.6741 4.5733
4.4676 4.3568 4.2703 4.1793 4.0429 3.8744 3.6934 3.4543 3.0754 2.4491

Average Revisit Time (hours)

Latitude = 90.0 Band Average = 3.31564 Patch Area % = 0.00658 Band Area % = 0.237
6.9239 3.2762 2.1806 2.9840 2.9652 3.0547 3.8614 3.8803 3.3432 3.0359 3.0406 2.7161 2.3547
2.3885 2.3003 2.2619 2.2804 2.2724 2.6216 2.7018 2.7099 2.7405 2.7225 2.7211 2.7324 2.7263
2.9580 4.5742 4.5618 4.5573 5.0859 3.8748 4.8695 7.0609 2.8652 2.2436

Latitude = 85.0 Band Average = 1.21783 Patch Area % = 0.01962 Band Area % = 0.70623
1.5378 1.3288 1.2996 1.2759 1.2750 1.2736 1.2724 1.2630 1.2394 1.2224 1.1907 1.1465 1.1358
1.1273 1.1137 1.1061 1.1036 1.1016 1.1091 1.1085 1.1167 1.1295 1.1323 1.1657 1.1727 1.1876
1.1946 1.2054 1.2200 1.2350 1.2438 1.2661 1.2690 1.2760 1.3248 1.4788

Latitude = 80.0 Band Average = 1.54154 Patch Area % = 0.0302 Band Area % = 1.08718
1.8126 1.5944 1.5696 1.5562 1.5851 1.5814 1.5834 1.5811 1.5677 1.5514 1.5474 1.5261 1.4922
1.4730 1.4452 1.4138 1.3963 1.4291 1.4568 1.4689 1.4613 1.4833 1.4741 1.4975 1.5325 1.5413
1.5566 1.5647 1.5551 1.5671 1.5678 1.5812 1.5851 1.5696 1.5869 1.7451

Latitude = 75.0 Band Average = 1.61069 Patch Area % = 0.0413 Band Area % = 1.48694
1.8603 1.6366 1.6005 1.6047 1.6252 1.6220 1.6220 1.6272 1.6145 1.6215 1.6317 1.6468 1.6479
1.6419 1.5873 1.5682 1.5298 1.4735 1.4862 1.5303 1.5475 1.5651 1.5682 1.5868 1.6036 1.5994
1.6145 1.5953 1.5870 1.6132 1.6110 1.6175 1.6374 1.6176 1.6534 1.7951

Latitude = 70.0 Band Average = 1.47346 Patch Area % = 0.0521 Band Area % = 1.87575
1.6842 1.5060 1.4694 1.4638 1.4806 1.4774 1.4805 1.4921 1.5127 1.5169 1.5064 1.5114 1.4973
1.4997 1.4743 1.4568 1.4265 1.4049 1.3620 1.3357 1.3633 1.3986 1.4171 1.4290 1.4622 1.4780
1.4839 1.4724 1.4495 1.4572 1.4672 1.4788 1.4874 1.4863 1.5119 1.6483

Latitude = 65.0 Band Average = 1.51874 Patch Area % = 0.06252 Band Area % = 2.25071
1.8231 1.6244 1.5423 1.5180 1.5292 1.5257 1.5470 1.5630 1.5513 1.5513 1.5467 1.5282 1.5168
1.4986 1.4754 1.5081 1.5005 1.4726 1.4612 1.4123 1.3648 1.3652 1.4029 1.4430 1.4689 1.4661
1.5009 1.5048 1.5021 1.5145 1.4970 1.5221 1.5387 1.5456 1.5838 1.7653

Latitude = 60.0 Band Average = 1.65106 Patch Area % = 0.07737 Band Area % = 2.78524
2.1989 1.9554 1.8521 1.7719 1.6938 1.6703 1.6377 1.6066 1.6318 1.6135 1.5838 1.6048 1.6050
1.6226 1.6372 1.6209 1.6359 1.6451 1.6173 1.6033 1.5635 1.5030 1.4496 1.4377 1.4632 1.4996
1.5043 1.5331 1.5607 1.5803 1.6317 1.6528 1.6771 1.7541 1.8056 2.0259

Latitude = 55.0 Band Average = 1.88739 Patch Area % = 0.08255 Band Area % = 2.97163
2.6918 2.2872 2.1063 1.9985 1.9301 1.8826 1.8360 1.7792 1.6830 1.6426 1.6757 1.7404 1.7541
1.7500 1.7655 1.7593 1.7845 1.7941 1.8038 1.8223 1.8093 1.7965 1.7571 1.6748 1.6172 1.5892
1.6099 1.6623 1.7495 1.8558 1.9460 2.0279 2.1057 2.1875 2.3689 2.7182

Latitude = 50.0 Band Average = 2.04111 Patch Area % = 0.09132 Band Area % = 3.28737
2.7871 2.3640 2.2529 2.2084 2.1225 2.1111 2.0790 2.0556 2.0588 2.0659 1.9916 1.8982 1.8453
1.8516 1.8452 1.8390 1.8781 1.8617 1.8602 1.8632 1.8629 1.8567 1.8353 1.8081 1.7747 1.7589
1.8457 1.9254 1.9559 2.0006 2.0589 2.1462 2.2241 2.3283 2.4594 2.8146

Latitude = 45.0 Band Average = 2.14873 Patch Area % = 0.09941 Band Area % = 3.57887
2.7593 2.4108 2.3349 2.2835 2.2448 2.2560 2.2723 2.3629 2.3867 2.2964 2.2095 2.1478 2.0279
1.9376 1.8661 1.8555 1.8702 1.8513 1.8429 1.8467 1.8394 1.8506 1.8915 1.9829 2.0953 2.1040
2.0546 2.0748 2.1223 2.1547 2.1608 2.1956 2.2746 2.3350 2.4127 2.7545

Latitude = 40.0 Band Average = 2.20357 Patch Area % = 0.10678 Band Area % = 3.84397
2.6060 2.3335 2.3231 2.2784 2.2870 2.4006 2.5245 2.5207 2.4466 2.3345 2.2435 2.2073 2.1485
2.1010 1.9929 1.9043 1.8611 1.8261 1.8299 1.8312 1.8697 1.9489 2.0374 2.1400 2.2606 2.3335
2.3199 2.2426 2.1770 2.2056 2.2159 2.2202 2.2086 2.2430 2.3309 2.5847

Latitude = 35.0 Band Average = 2.05558 Patch Area % = 0.12067 Band Area % = 4.34394
2.2727 2.0700 2.1003 2.1403 2.1803 2.3420 2.3235 2.2244 2.1969 2.1421 2.0756 2.0305 1.9694
1.9797 1.9048 1.8233 1.7998 1.7381 1.7217 1.7731 1.8230 1.8920 1.9625 2.0014 2.0933 2.1738
2.1855 2.2154 2.2415 2.1252 2.0875 2.0557 2.0561 2.0427 2.0416 2.2034

Latitude = 30.0 Band Average = 1.84905 Patch Area % = 0.11947 Band Area % = 4.30095
2.0861 1.9045 1.9429 2.0543 2.0570 1.9738 1.9327 1.8792 1.8356 1.8133 1.7833 1.7868 1.7500
1.7589 1.7338 1.6601 1.6874 1.6942 1.6786 1.7082 1.7126 1.7037 1.7588 1.7889 1.8637 1.8961
1.8704 1.8915 1.9794 1.9561 1.9359 1.8507 1.9073 1.8881 1.8704 1.9737

Latitude = 25.0 Band Average = 1.80787 Patch Area % = 0.12427 Band Area % = 4.47368
2.0005 1.9728 2.0992 2.1913 2.0953 1.9665 1.9204 1.8168 1.7669 1.6690 1.6394 1.6500 1.6094
1.6198 1.6398 1.6534 1.6892 1.7212 1.6914 1.7034 1.6903 1.6519 1.6369 1.6375 1.6935 1.6985
1.6936 1.7646 1.8376 1.9365 2.0369 2.0238 1.9758 1.9843 1.8400 1.8696

Latitude = 20.0 Band Average = 1.94911 Patch Area % = 0.12815 Band Area % = 4.61343
2.1929 2.3125 2.5211 2.3976 2.2055 2.1598 2.0748 1.9393 1.8959 1.7824 1.7102 1.6882 1.6521
1.7228 1.7754 1.7759 1.8189 1.8322 1.8310 1.8507 1.8291 1.8001 1.7541 1.7035 1.7272 1.7220
1.7511 1.8504 1.9454 2.0605 2.1390 2.2333 2.3273 2.2101 1.9548 2.0225

Latitude = 15.0 Band Average = 2.03193 Patch Area % = 0.13109 Band Area % = 4.71915
2.3716 2.5316 2.6444 2.4570 2.3224 2.2429 2.1961 1.9678 1.9509 1.8586 1.7884 1.7481 1.7099
1.7648 1.8356 1.8876 1.8945 1.9702 2.0014 1.9715 1.9146 1.8737 1.8476 1.8074 1.8259 1.7959
1.8133 1.8755 2.0026 2.1040 2.2261 2.1907 2.2077 2.3138 2.1318 2.1092

Latitude = 10.0 Band Average = 2.18613 Patch Area % = 0.14142 Band Area % = 5.09117
2.5630 2.5425 2.6364 2.6854 2.5393 2.4354 2.3320 2.1723 2.1162 2.0848 2.0315 1.9221 1.8816
1.8945 1.9927 2.0483 2.0449 2.1694 2.1810 2.1605 2.0445 1.9321 1.9784 2.0018 2.0155 2.0189
2.0239 2.1080 2.1973 2.2382 2.3286 2.2206 2.2162 2.2602 2.2926 2.3939

Latitude = 5.0 Band Average = 2.15183 Patch Area % = 0.13408 Band Area % = 4.82683
2.4864 2.4443 2.5262 2.6969 2.6658 2.5094 2.2967 2.2192 2.1527 2.0737 2.0324 1.9719 1.8820
1.8595 1.9369 1.9351 1.9582 2.0281 2.0411 2.0086 1.9799 1.8499 1.9186 1.9393 1.9561 1.9847
2.0488 2.1665 2.2625 2.2021 2.1977 2.2086 2.1635 2.1697 2.2437 2.4537

Latitude = 0.0 Band Average = 2.01262 Patch Area % = 0.13401 Band Area % = 4.82428
2.3920 2.2438 2.3053 2.3986 2.4732 2.3903 2.2101 2.1381 2.0457 1.9669 1.9129 1.8420 1.7855
1.7636 1.7787 1.8043 1.8036 1.7533 1.7513 1.7908 1.8091 1.7755 1.8216 1.8662 1.8696 1.9494
1.9501 2.0070 2.0443 2.0280 2.0172 2.0145 2.0445 2.1064 2.2425 2.3644

Latitude = -5.0 Band Average = 1.8674 Patch Area % = 0.13295 Band Area % = 4.78616
2.2361 2.1266 2.1403 2.1544 2.1415 2.2285 2.0597 1.9979 1.8939 1.8835 1.8274 1.7174 1.6652
1.6383 1.6411 1.6218 1.6240 1.5625 1.5879 1.5756 1.6643 1.7107 1.6846 1.7200 1.8100 1.8968
1.8973 1.8118 1.8125 1.8563 1.8386 1.8243 1.9362 2.0791 2.1166 2.2551

Latitude = -10.0 Band Average = 1.70653 Patch Area % = 0.13091 Band Area % = 4.71274
2.0712 2.0137 1.9621 1.8693 1.9059 1.9059 1.9238 1.8344 1.7758 1.7354 1.6865 1.5683 1.5250
1.5289 1.4620 1.4400 1.4152 1.4520 1.4680 1.4472 1.4567 1.5329 1.5766 1.5853 1.6702 1.7195
1.7223 1.6627 1.6456 1.7002 1.6688 1.7184 1.8022 1.8949 1.9840 2.1096

Latitude = -15.0 Band Average = 1.51301 Patch Area % = 0.13576 Band Area % = 4.88731
1.9475 1.7785 1.7304 1.6623 1.6481 1.6423 1.6137 1.6064 1.5747 1.5435 1.4756 1.4349 1.3554
1.3151 1.2949 1.2668 1.2724 1.3025 1.2999 1.3099 1.3174 1.3039 1.3626 1.4166 1.4538 1.4832
1.4945 1.4854 1.5067 1.4752 1.4829 1.5735 1.6355 1.6803 1.7867 1.9418

Latitude = -20.0 Band Average = 1.2899 Patch Area % = 0.12364 Band Area % = 4.451
1.7401 1.5183 1.4399 1.4003 1.3475 1.3660 1.3356 1.2956 1.3475 1.2978 1.2452 1.1962 1.1632
1.1508 1.1616 1.1314 1.1390 1.1295 1.1226 1.1438 1.1565 1.1442 1.1514 1.1482 1.1682 1.1989
1.2293 1.2838 1.2629 1.2503 1.2923 1.3496 1.3994 1.4635 1.5648 1.7106

Latitude = -25.0 Band Average = 1.2378 Patch Area % = 0.11871 Band Area % = 4.27365
1.7373 1.5246 1.4213 1.3525 1.2964 1.2685 1.2636 1.2401 1.1790 1.1782 1.1812 1.1796 1.1782
1.1656 1.1401 1.1373 1.1352 1.1335 1.1233 1.1106 1.1360 1.1549 1.1181 1.0996 1.0763 1.0737
1.1005 1.1256 1.1613 1.2207 1.2571 1.2941 1.3086 1.3635 1.4715 1.6642

Latitude = -30.0 Band Average = 1.35894 Patch Area % = 0.11291 Band Area % = 4.06479
1.7621 1.5948 1.5490 1.4918 1.4480 1.4301 1.4280 1.3957 1.3660 1.3365 1.3103 1.2848 1.2659
1.2690 1.2688 1.2480 1.2394 1.2503 1.2473 1.2491 1.2493 1.2281 1.1879 1.1634 1.1623 1.1873
1.2362 1.2808 1.3554 1.3931 1.4035 1.4175 1.4707 1.5112 1.5478 1.7000

Latitude = -35.0 Band Average = 1.41532 Patch Area % = 0.10628 Band Area % = 3.82596
1.7474 1.6090 1.5816 1.5325 1.5010 1.4711 1.4662 1.4518 1.4276 1.3999 1.3861 1.3643 1.3498
1.3520 1.3388 1.3371 1.3336 1.3339 1.3336 1.3260 1.2768 1.2585 1.2289 1.2176 1.2568 1.3094
1.3243 1.3550 1.3918 1.4189 1.4417 1.4809 1.5000 1.5405 1.5970 1.7161

Latitude = -40.0 Band Average = 1.38203 Patch Area % = 0.10474 Band Area % = 3.77047
1.6219 1.5271 1.4955 1.4551 1.4288 1.3989 1.4051 1.4177 1.4025 1.3957 1.3838 1.3662 1.3569
1.3582 1.3430 1.3418 1.3346 1.3320 1.3072 1.2722 1.2423 1.2177 1.2191 1.2635 1.3140 1.3290
1.3427 1.3479 1.3544 1.3579 1.3852 1.4181 1.4351 1.4725 1.5130 1.6008

Latitude = -45.0 Band Average = 1.38735 Patch Area % = 0.0901 Band Area % = 3.2437
1.5853 1.5040 1.4775 1.4504 1.4211 1.3986 1.3841 1.4039 1.3964 1.4083 1.4027 1.3949 1.3909
1.3900 1.3748 1.3741 1.3582 1.3175 1.2799 1.2607 1.2327 1.2509 1.2907 1.3158 1.3394 1.3594
1.3683 1.3712 1.3671 1.3584 1.3723 1.3975 1.4349 1.4662 1.4903 1.5590

Latitude = -50.0 Band Average = 1.38733 Patch Area % = 0.08124 Band Area % = 2.92468
1.5755 1.4916 1.4581 1.4394 1.4156 1.3938 1.3813 1.3763 1.3875 1.4035 1.3998 1.4054 1.4045
1.4101 1.4011 1.3743 1.3304 1.2924 1.2732 1.2613 1.2735 1.3044 1.3234 1.3366 1.3660 1.3832
1.3808 1.3640 1.3482 1.3483 1.3700 1.3966 1.4214 1.4455 1.4713 1.5396

Latitude = -55.0 Band Average = 1.36988 Patch Area % = 0.07178 Band Area % = 2.58409
1.5421 1.4678 1.4345 1.4155 1.3986 1.3829 1.3795 1.3578 1.3535 1.3632 1.3776 1.3872 1.3919
1.3905 1.3517 1.3157 1.2917 1.2717 1.2673 1.2772 1.2971 1.3227 1.3281 1.3439 1.3466 1.3566
1.3457 1.3301 1.3353 1.3541 1.3631 1.3845 1.4058 1.4211 1.4509 1.5160

Latitude = -60.0 Band Average = 1.31588 Patch Area % = 0.06179 Band Area % = 2.22445
1.5016 1.4167 1.3933 1.3687 1.3614 1.3471 1.3379 1.3179 1.3193 1.3091 1.3145 1.3119 1.2965
1.2711 1.2459 1.2399 1.2144 1.2082 1.2240 1.2430 1.2566 1.2706 1.2621 1.2743 1.2794 1.2898
1.2980 1.2993 1.3124 1.3239 1.3272 1.3415 1.3616 1.3691 1.4006 1.4673

Latitude = -65.0 Band Average = 1.08279 Patch Area % = 0.05415 Band Area % = 1.94927
1.3038 1.2268 1.2144 1.1834 1.1575 1.1303 1.1079 1.0892 1.0684 1.0606 1.0453 1.0127 0.9881
0.9715 0.9602 0.9559 0.9635 0.9705 0.9833 0.9890 1.0011 1.0095 1.0129 1.0269 1.0333 1.0534
1.0744 1.0815 1.0978 1.1220 1.1278 1.1516 1.1733 1.1722 1.1989 1.2652

Latitude = -70.0 Band Average = 0.87422 Patch Area % = 0.03973 Band Area % = 1.43044
1.0718 0.9951 0.9876 0.9762 0.9585 0.9429 0.9242 0.9011 0.8786 0.8601 0.8225 0.8037 0.7789
0.7660 0.7555 0.7476 0.7392 0.7388 0.7394 0.7459 0.7562 0.7680 0.7857 0.8087 0.8297 0.8649
0.8886 0.9021 0.9170 0.9330 0.9507 0.9682 0.9705 0.9722 0.9829 1.0434

Latitude = -75.0 Band Average = 0.78399 Patch Area % = 0.02859 Band Area % = 1.02934
0.8769 0.7828 0.7799 0.7804 0.7802 0.7806 0.7789 0.7725 0.7642 0.7672 0.7698 0.7716 0.7836
0.7903 0.7889 0.7910 0.7944 0.7950 0.7946 0.7936 0.7851 0.7804 0.7793 0.7731 0.7735 0.7784
0.7746 0.7798 0.7801 0.7709 0.7640 0.7598 0.7628 0.7745 0.7893 0.8638

Latitude = -80.0 Band Average = 0.66182 Patch Area % = 0.01724 Band Area % = 0.62066
0.7653 0.6620 0.6703 0.6837 0.6792 0.6746 0.6671 0.6605 0.6551 0.6526 0.6571 0.6590 0.6586
0.6573 0.6513 0.6526 0.6525 0.6493 0.6470 0.6529 0.6573 0.6585 0.6670 0.6647 0.6651 0.6727
0.6629 0.6599 0.6520 0.6445 0.6418 0.6327 0.6212 0.6262 0.6438 0.7503

Latitude = -85.0 Band Average = 7.17451 Patch Area % = 0.00579 Band Area % = 0.20832
7.4307 7.2793 7.2373 7.2025 7.1821 7.1794 7.1628 7.1567 7.1538 7.1621 7.1571 7.1416 7.1273
7.1264 7.1324 7.1270 7.1226 7.1211 7.1203 7.1225 7.1280 7.1313 7.1392 7.1453 7.1466 7.1566
7.1553 7.1579 7.1514 7.1496 7.1651 7.1755 7.1814 7.2036 7.2591 7.3959

Maximum Revisit Time (hours)

Latitude = 90.0 Band Average = 6.79646 Patch Area % = 0.00658 Band Area % = 0.237
11.0920 6.9389 5.5038 6.9629 6.9421 6.7331 6.9791 7.1970 6.9090 7.4702 7.3778 6.4251 5.8629
5.7166 5.7317 5.9186 5.7241 5.5159 6.0490 6.0720 6.1436 6.2629 6.3176 6.5494 6.3886 6.3210
6.5706 7.6220 7.3818 7.3939 7.7470 6.4611 7.6798 9.9109 6.1196 6.7805

Latitude = 85.0 Band Average = 3.72773 Patch Area % = 0.01962 Band Area % = 0.70623
5.0629 4.0359 4.3719 3.5882 3.9407 3.6726 4.1980 4.0412 4.0296 3.8262 3.9955 3.8373 4.1203
3.8957 3.3818 3.9483 3.5089 3.4066 3.4224 3.4256 3.4627 3.5029 3.3592 3.5498 3.5295 3.4641
3.4718 3.4666 3.4552 3.4797 3.4480 3.4920 3.5059 3.4989 3.5549 4.2755

Latitude = 80.0 Band Average = 3.59435 Patch Area % = 0.0302 Band Area % = 1.08718
4.9379 3.6225 3.6775 3.5052 3.6480 3.5138 3.6509 3.6450 3.6277 3.5255 3.6022 3.5937 3.5923
3.8572 3.3955 3.5409 3.3897 3.5861 3.4530 3.3791 3.3773 3.5406 3.4518 3.5587 3.6143 3.5020
3.5036 3.4944 3.4583 3.5013 3.4897 3.5012 3.5181 3.4746 3.5159 4.1787

Latitude = 75.0 Band Average = 3.52085 Patch Area % = 0.0413 Band Area % = 1.48694
4.4343 3.5067 3.4883 3.4846 3.5106 3.5123 3.4986 3.5276 3.5166 3.4757 3.4508 3.4850 3.4354
3.4588 3.3145 3.4850 3.4286 3.4529 3.3802 3.4762 3.3965 3.4334 3.5266 3.5785 3.5988 3.5474
3.4981 3.4975 3.4394 3.4778 3.4774 3.4577 3.4952 3.4737 3.4582 4.0917

Latitude = 70.0 Band Average = 3.50627 Patch Area % = 0.0521 Band Area % = 1.87575
4.1618 3.6593 3.5124 3.4642 3.4666 3.4590 3.4506 3.4591 3.4561 3.4357 3.4143 3.4142 3.4021
3.4026 3.3665 3.3644 3.3836 3.4000 3.5170 3.4382 3.5155 3.5208 3.5065 3.5986 3.5971 3.5778
3.5278 3.5130 3.4743 3.4760 3.5009 3.4829 3.4715 3.4550 3.4690 3.9318

Latitude = 65.0 Band Average = 3.52637 Patch Area % = 0.06252 Band Area % = 2.25071
4.1539 3.7181 3.5154 3.4765 3.4187 3.4279 3.4038 3.4045 3.3967 3.3931 3.4039 3.3907 3.3826
3.3910 3.4031 3.4245 3.4684 3.4817 3.5624 3.5485 3.5884 3.6180 3.6013 3.6088 3.6090 3.5957
3.5509 3.5287 3.5455 3.5296 3.5423 3.5287 3.4873 3.4742 3.4825 3.9141

Latitude = 60.0 Band Average = 3.65534 Patch Area % = 0.07737 Band Area % = 2.78524
4.4752 3.9559 3.7968 3.7260 3.6490 3.6211 3.5465 3.5063 3.4972 3.5063 3.4936 3.5101 3.5214
3.5259 3.5634 3.5665 3.6217 3.6122 3.6602 3.6239 3.6184 3.6170 3.6143 3.5993 3.5909 3.5924
3.5803 3.5582 3.5762 3.5369 3.5635 3.5462 3.5700 3.8828 3.8897 4.2998

Latitude = 55.0 Band Average = 4.28304 Patch Area % = 0.08255 Band Area % = 2.97163
7.2211 6.9225 6.2496 4.8968 4.2973 3.8035 3.7453 3.7133 3.6904 3.6565 3.5812 3.5655 3.5351
3.5389 3.5581 3.5479 3.5520 3.5506 3.5634 3.6106 3.5954 3.6057 3.6210 3.6410 3.6397 3.6314
3.6233 3.6151 3.6341 3.6294 3.6834 4.7919 5.7589 6.1197 6.6377 7.1941

Latitude = 50.0 Band Average = 5.02495 Patch Area % = 0.09132 Band Area % = 3.28737
7.7124 7.6058 7.5123 7.3525 5.8373 5.9697 5.8591 5.8995 5.8869 6.1007 5.4057 4.2153 3.6083
3.5266 3.5202 3.5238 3.5289 3.5285 3.5096 3.5766 3.5851 3.5672 3.6041 3.6988 4.4519 3.6578
3.6225 3.6321 4.0568 4.0750 5.0622 6.1258 6.1141 7.0165 7.3778 7.6249

Latitude = 45.0 Band Average = 5.84425 Patch Area % = 0.09941 Band Area % = 3.57887
7.6664 7.5605 7.4851 7.4503 7.2564 7.4227 7.4228 7.4234 7.4246 7.4238 7.4222 7.2147 6.2297
4.7987 3.9308 3.5506 3.5507 3.5476 3.5382 3.5508 3.5659 3.7221 4.6980 5.6849 5.9492 5.5073
4.1868 3.6478 5.6919 5.9189 5.7368 6.0598 6.0465 7.2229 7.4056 7.5162

Latitude = 40.0 Band Average = 6.25804 Patch Area % = 0.10678 Band Area % = 3.84397
7.5182 7.4533 7.4167 7.3339 7.3617 7.0919 7.1529 7.1104 6.7653 6.7137 6.9718 7.0599 7.3314
7.1965 6.6990 5.3840 4.1275 3.5664 3.5626 3.7000 4.6927 5.7585 6.0265 6.0506 6.0649 6.0712
5.9437 5.5137 5.8870 6.0224 6.0147 6.0251 6.0045 6.9795 7.3401 7.3877

Latitude = 35.0 Band Average = 5.79323 Patch Area % = 0.12067 Band Area % = 4.34394
6.4411 6.1160 6.1506 6.1085 6.0888 5.4635 4.6701 4.1861 4.1817 4.2191 4.5477 4.5754 4.5410
4.9067 4.5721 4.4055 4.4398 4.0253 4.6635 5.7269 6.6854 7.0549 7.3271 7.5365 7.1629 7.6527
6.6471 7.2801 7.1973 6.1805 6.0630 6.0613 6.0454 6.0940 6.2390 7.3343

Latitude = 30.0 Band Average = 5.95055 Patch Area % = 0.11947 Band Area % = 4.30095
8.4910 7.1826 6.0745 6.0759 6.0645 5.9608 4.2226 3.8748 3.8264 4.0363 4.1908 4.0136 3.8204
3.7289 3.7198 3.6656 4.9061 6.1385 6.7156 7.8014 7.8208 7.3394 7.3169 7.2734 6.3468 6.2277
5.6410 5.4946 5.6682 6.0220 6.5001 6.3234 6.7261 8.0987 8.2935 8.6638

Latitude = 25.0 Band Average = 5.98732 Patch Area % = 0.12427 Band Area % = 4.47368
8.8273 8.3431 6.1780 6.0897 6.0435 6.0411 5.7742 4.3840 3.8573 3.8106 3.6833 3.6358 3.9161
4.4735 4.9016 5.9129 6.3913 6.4471 7.0018 7.2540 7.2409 7.2466 6.9566 4.9095 3.7884 3.6504
4.9627 5.1522 5.2315 5.3459 5.8859 7.2606 8.6423 8.7724 8.7913 8.8101

Latitude = 20.0 Band Average = 6.16505 Patch Area % = 0.12815 Band Area % = 4.61343
8.7139 8.6937 8.4219 7.6865 6.3987 5.9756 5.9536 5.5068 4.8330 3.8549 3.6218 3.5741 4.1381
5.6823 6.3466 6.3777 6.3760 6.5610 7.2589 7.2770 7.2368 6.9900 5.8415 3.7589 3.6272 3.6192
4.2148 4.9821 5.0457 5.1722 6.0592 7.5486 8.5871 8.6712 8.6709 8.6869

Latitude = 15.0 Band Average = 6.55718 Patch Area % = 0.13109 Band Area % = 4.71915
8.5773 8.5767 8.5666 8.5343 7.9595 6.2896 5.9260 5.9137 5.8345 5.0532 3.8813 3.6567 5.0302
6.2678 6.3572 6.6100 7.0126 7.2761 7.3610 7.3762 7.3229 7.1693 6.6343 5.1385 3.8057 3.8662
4.1836 4.8502 5.2617 6.5867 7.5464 7.6421 8.3694 8.4834 8.5409 8.5622

Latitude = 10.0 Band Average = 7.7415 Patch Area % = 0.14142 Band Area % = 5.09117
8.4541 8.4359 8.4343 8.4307 8.4295 7.9524 7.4364 7.1055 7.4310 7.4910 7.5413 7.3279 7.3813
7.6567 8.0290 8.3412 7.9477 7.1873 7.5284 7.6797 7.6520 7.6562 7.7073 7.6645 7.2433 6.9059
6.4713 6.8100 7.5737 7.8139 7.8173 7.7932 8.1895 8.3288 8.3919 8.4361

Latitude = 5.0 Band Average = 8.04056 Patch Area % = 0.13408 Band Area % = 4.82683
8.3125 8.2808 8.2791 8.2786 8.2800 8.2643 8.2718 8.2818 8.2592 8.2763 8.2818 8.2546 8.2794
8.2785 8.2493 8.2683 7.6778 6.9862 7.2445 7.7114 7.8957 7.8973 7.9468 7.9322 7.9296 7.9419
7.9309 7.9394 7.9478 7.9293 7.9325 7.8936 7.6901 8.1549 8.1955 8.2745

Latitude = 0.0 Band Average = 7.74816 Patch Area % = 0.13401 Band Area % = 4.82428
8.1561 8.1189 8.1171 8.1108 8.1082 8.1029 8.1095 8.1154 8.0956 8.1129 8.1188 8.0876 8.1053
8.1108 8.0896 7.7521 7.1082 6.5222 6.0826 6.5922 7.7781 7.9631 7.9958 7.9821 7.9835 7.9948
7.9809 7.9930 7.9758 7.1792 7.4478 7.0996 5.6989 8.0267 8.0468 8.1043

Latitude = -5.0 Band Average = 7.0683 Patch Area % = 0.13295 Band Area % = 4.78616
8.1021 8.0332 7.9756 7.9338 7.9349 7.9307 7.9053 7.8436 7.9027 7.8955 7.9150 7.9071 7.8786
7.9245 7.6047 6.8678 5.6983 3.7494 3.5515 5.1011 6.5628 7.6468 8.0202 8.0370 8.0348 8.0449
7.8297 6.5125 5.8197 5.1300 5.2838 5.1605 5.1412 7.5380 8.0356 8.0533

Latitude = -10.0 Band Average = 6.21205 Patch Area % = 0.13091 Band Area % = 4.71274
8.0711 7.8897 7.6037 7.6997 7.7049 7.5669 7.2325 6.9726 7.3256 7.1497 7.3488 7.5207 6.7428
6.8781 5.7689 4.5508 3.3040 3.2003 3.1912 3.1550 3.9546 5.4804 6.1126 7.1832 8.0915 7.5309
5.6605 5.0812 5.0524 5.0527 5.0834 5.0753 5.0804 6.1499 8.0902 8.1033

Latitude = -15.0 Band Average = 5.06547 Patch Area % = 0.13576 Band Area % = 4.88731
6.7078 6.1920 6.2322 6.1553 5.9188 5.9689 6.1172 5.9093 6.3273 6.1711 6.1260 5.5841 4.4944
4.1907 3.3317 3.1239 3.1085 3.0687 3.0756 3.0231 3.0904 3.3056 4.1848 5.2105 6.5699 5.6305
5.0617 5.0756 4.3775 5.0110 5.1044 5.0926 5.1022 5.1607 6.3562 7.2102

Latitude = -20.0 Band Average = 3.75255 Patch Area % = 0.12364 Band Area % = 4.451
5.1151 4.9758 4.7223 4.2578 3.2776 3.3328 3.4399 3.3403 3.4759 3.4355 3.3999 3.2210 3.1656
3.0633 3.0398 3.0449 3.0149 3.0314 2.9848 2.9015 2.8980 2.9628 2.9790 3.2955 3.6453 3.6951
3.8254 3.8866 3.4715 3.8586 4.9221 5.0725 5.0847 5.0903 5.0902 5.1128

Latitude = -25.0 Band Average = 3.29271 Patch Area % = 0.11871 Band Area % = 4.27365
3.9165 3.5099 3.3430 3.3848 3.2404 3.2362 3.2762 3.2687 3.2479 3.2660 3.2615 3.2258 3.2299
3.2150 3.1716 3.2024 3.1802 3.1691 3.1051 2.9918 3.0356 3.1546 3.1631 3.1045 2.9926 3.0691
3.1865 3.2067 3.1471 3.0834 3.2763 3.6375 3.6819 3.6940 3.7986 3.8816

Latitude = -30.0 Band Average = 3.16829 Patch Area % = 0.11291 Band Area % = 4.06479
3.6250 3.4411 3.2828 3.2317 3.2074 3.1916 3.2011 3.1903 3.1580 3.1737 3.1638 3.1737 3.1007
3.1038 3.1505 3.0706 2.9538 3.1644 3.1395 3.2153 3.1702 3.1640 3.1151 3.1718 3.1207 3.0742
3.0203 3.0816 3.1596 3.1031 3.0459 3.0889 3.1987 3.1809 3.1946 3.2321

Latitude = -35.0 Band Average = 3.08465 Patch Area % = 0.10628 Band Area % = 3.82596
3.7517 3.3737 3.2936 3.2293 3.2201 3.1826 3.2030 3.2269 3.2091 3.1063 3.1045 3.0249 2.9907
2.8229 2.8896 2.8785 2.7761 2.9126 2.9256 3.0965 2.9712 3.1519 2.9809 3.0966 3.0558 3.0988
2.9842 2.7692 2.9722 3.0531 3.0539 3.0551 2.9656 3.1590 3.2067 3.2700

Latitude = -40.0 Band Average = 2.96872 Patch Area % = 0.10474 Band Area % = 3.77047
3.5874 3.2701 3.2574 3.2307 3.2541 3.1895 3.2167 3.2059 3.0835 3.0508 2.9000 2.8092 2.7387
2.6836 2.7169 2.7378 2.4721 2.7281 2.8298 2.7890 2.9651 2.7835 2.7382 3.0457 3.0661 2.9807
2.9530 2.6531 2.7831 2.9148 2.9614 2.9703 2.8171 3.0393 3.1802 3.2872

Latitude = -45.0 Band Average = 2.8781 Patch Area % = 0.0901 Band Area % = 3.2437
3.4280 3.2198 3.2851 3.2717 3.1721 3.2218 3.1892 3.1041 2.7642 2.9816 2.7047 2.6766 2.5492
2.6890 2.5135 2.6285 2.3707 2.6224 2.6331 2.6377 2.7265 2.6584 2.7559 2.7553 2.8997 2.9127
2.8585 2.7743 2.8721 2.8591 2.8039 2.7923 2.9650 2.9636 3.0463 3.3093

Latitude = -50.0 Band Average = 2.79841 Patch Area % = 0.08124 Band Area % = 2.92468
3.4539 3.2025 3.2063 3.1893 3.1219 3.1893 3.1566 2.9761 2.7647 2.9266 2.5008 2.6559 2.4085
2.5504 2.4822 2.4461 2.4543 2.5052 2.4226 2.5803 2.4602 2.5347 2.6646 2.6857 2.7889 2.8829
2.8817 2.7805 2.7569 2.7373 2.7051 2.8444 2.8612 2.7591 2.9079 3.3062

Latitude = -55.0 Band Average = 2.73866 Patch Area % = 0.07178 Band Area % = 2.58409
3.4239 3.1265 3.1387 3.0861 2.9978 3.0983 3.1549 2.8480 2.9519 2.7727 2.5278 2.6805 2.3999
2.3774 2.3852 2.3492 2.3173 2.3230 2.4201 2.3811 2.3234 2.4922 2.4813 2.6566 2.6534 2.8441
2.8677 2.7979 2.7296 2.7369 2.6422 2.7533 2.8711 2.8166 2.9152 3.2729

Latitude = -60.0 Band Average = 2.6795 Patch Area % = 0.06179 Band Area % = 2.22445
3.3455 2.9048 3.0253 2.9667 2.9375 2.9294 3.0103 2.6677 2.8846 2.4830 2.8118 2.4954 2.4859
2.3119 2.2049 2.4348 2.3152 2.3178 2.3401 2.3433 2.2709 2.5141 2.4122 2.6559 2.5948 2.7829
2.8486 2.7617 2.7204 2.7079 2.5634 2.7506 2.8586 2.7282 2.8356 3.2719

Latitude = -65.0 Band Average = 2.64089 Patch Area % = 0.05415 Band Area % = 1.94927
3.4536 2.9193 2.9440 2.8851 2.8474 2.8148 2.7806 2.5970 2.5170 2.4071 2.6183 2.3480 2.2753
2.4126 2.2043 2.3633 2.3485 2.3381 2.3034 2.3653 2.3548 2.4618 2.4489 2.5778 2.3545 2.8014
2.8320 2.6898 2.6561 2.7204 2.6638 2.7996 2.8925 2.7872 2.9722 3.3490

Latitude = -70.0 Band Average = 2.57659 Patch Area % = 0.03973 Band Area % = 1.43044
3.2372 2.9095 2.8076 2.7761 2.7864 2.7526 2.6746 2.6019 2.3031 2.5114 2.3624 2.3582 2.1775
2.2936 2.2435 2.2300 2.2655 2.1355 2.1964 2.2934 2.4466 2.3179 2.4083 2.4571 2.3610 2.7753
2.7705 2.7076 2.6502 2.6187 2.7311 2.8264 2.8288 2.8621 2.9088 3.1948

Latitude = -75.0 Band Average = 2.54333 Patch Area % = 0.02859 Band Area % = 1.02934

3.0771	2.8165	2.7801	2.7636	2.7518	2.7199	2.6522	2.6144	2.3521	2.4481	2.3832	2.2602	2.3975
2.2909	2.2235	2.3374	2.3480	2.1842	2.1895	2.3871	2.3774	2.2794	2.4519	2.3838	2.3038	2.6459
2.5835	2.5520	2.6217	2.5907	2.6737	2.7143	2.7610	2.7817	2.8074	3.0668			

Latitude = -80.0 Band Average = 2.61137 Patch Area % = 0.01724 Band Area % = 0.62066

3.0152	2.8039	2.7818	2.7691	2.7495	2.7211	2.6826	2.6370	2.5121	2.3743	2.5027	2.4181	2.4193
2.5187	2.4629	2.5068	2.5459	2.2751	2.4477	2.5405	2.4819	2.4067	2.5870	2.5283	2.5521	2.6888
2.6431	2.6653	2.6393	2.6304	2.6868	2.6922	2.6699	2.6891	2.7728	3.0071			

Latitude = -85.0 Band Average = 9.57904 Patch Area % = 0.00579 Band Area % = 0.20832

10.5121	9.9930	9.6479	9.4925	9.4916	9.7048	9.3050	9.3961	9.3990	9.5970	9.6289	9.4445	9.3744
9.5872	9.6798	9.4942	9.3465	9.3240	9.4991	9.3641	9.3914	9.5318	9.5479	9.5660	9.4840	9.5774
9.6060	9.6757	9.4710	9.5012	9.5261	9.6046	9.4724	9.5285	9.7294	10.3446			

Appendix D VSV Tabular Report

12-OCT-90 Soda Vehicle Sensor Visibility Tabular Report for the Planet Earth. Page 1

Global Data

Epoch Year...... 1990.0
Epoch Month..... 6.0
Epoch Day....... 1.0
Epoch Hour...... 1.0
Epoch Minute.... 1.0
Epoch Second.... 1.0

Total Simulation Time (hours)............... 120.0
Simulation Time Increment (hours)........... 0.25

12-OCT-90 Soda Vehicle Sensor Visibility Tabular Report for the Planet Earth. Page 2

Vehicle Data (km, hours, Degrees)

Vehicle Name (Tag)...................... AMSAT
Propagation............................. Keplerian with J2
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System....................... Classical
Semi-Major Axis......................... 20000.0
Eccentricity............................ 0.6
Inclination............................. 87.5
Right Ascension of Ascending Node....... 60.0
Argument of Perigee..................... 25.0
Mean Anomaly............................ 30.0

Vehicle Name (Tag)...................... LANDSAT
Propagation............................. Keplerian with J2
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System....................... Classical
Semi-Major Axis......................... 15000.0
Eccentricity............................ 0.1
Inclination............................. 23.5
Right Ascension of Ascending Node....... 90.0
Argument of Perigee..................... 0.0
Mean Anomaly............................ 90.0

Vehicle Name (Tag)...................... NORAD
Propagation............................. Keplerian with J2
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System....................... Classical
Semi-Major Axis......................... 17000.0
Eccentricity............................ 0.3
Inclination............................. 75.0
Right Ascension of Ascending Node....... 30.0
Argument of Perigee..................... 0.0
Mean Anomaly............................ 20.0

Vehicle Name (Tag)....................... COMSAT
Propagation.............................. Keplerian with J2
Vehicle Start Time from Epoch........... 0.0
Vehicle Stop Time from Epoch............ 120.0
Coordinate System........................ Classical
Semi-Major Axis.......................... 16000.0
Eccentricity............................. 0.2
Inclination.............................. 56.0
Right Ascension of Ascending Node....... 85.0
Argument of Perigee...................... 0.0
Mean Anomaly............................. 45.0

Sensor Data (km, hours, Degrees)

Sensor Name.............................. GNDRADAR
Sensor Type.............................. Ground Station
Sensor Shape............................. Circular
Scan Type................................ Fixed
Half Cone Angle.......................... 20.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0

Sensor Name.............................. SMCIR
Sensor Type.............................. Vehicle
Sensor Shape............................. Circular
Scan Type................................ Fixed
Half Cone Angle.......................... 10.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint....................... 90.0
Graphical Increment...................... 1.0

Sensor Name.............................. LGCIR
Sensor Type.............................. Vehicle
Sensor Shape............................. Circular
Scan Type................................ Fixed
Half Cone Angle.......................... 30.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint....................... 120.0
Graphical Increment...................... 1.0

Sensor Name.............................. MEDCIR
Sensor Type.............................. Vehicle
Sensor Shape............................. Circular
Scan Type................................ Fixed
Half Cone Angle.......................... 20.0
Fixed Offnadir Angle in X............... 0.0
Fixed Offnadir Angle in Y............... 0.0
Fixed Offnadir Angle in Z............... 0.0
Horizon Constraint....................... 90.0
Graphical Increment...................... 1.0

Ground Station Data (km, hours, Degrees)

Station Name............................ BERLIN
Longitude............................... -13.0
Latitude................................ 52.5

Station Name............................ LARC
Longitude............................... 77.0
Latitude................................ 37.0

Station Name............................ NOME
Longitude............................... 165.0
Latitude................................ 65.0

Station Name............................ BAIRES
Longitude............................... 59.0
Latitude................................ -35.0

Vehicle, Sensor, Ground Station Combination Key

Number	Veh/GS	Sensor	Ground Station	Vehicle
1	BERLIN	GNDRADAR		AMSAT
2	BERLIN	GNDRADAR		LANDSAT
3	NORAD	SMCIR	LARC	
4	NORAD	SMCIR	NOME	
5	NORAD	SMCIR	BAIRES	
6	AMSAT	LGCIR	BERLIN	
7	AMSAT	LGCIR		LANDSAT
8	COMSAT		LARC	
9	COMSAT		NOME	
10	COMSAT		BAIRES	
11	COMSAT			NORAD
12	LANDSAT	MEDCIR	BERLIN	
13	LANDSAT	MEDCIR	LARC	
14	LANDSAT	MEDCIR	NOME	
15	NOME			COMSAT
16	NOME			NORAD
17	LARC			AMSAT
18	LARC			LANDSAT
19	LARC			COMSAT
20	LARC			NORAD
21	BAIRES			NORAD

VSV Combination Key

Hours Into Simulation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0.000	X					X			X		X				X	X	X			X	
0.250				X					X		X				X	X	X			X	
0.500									X		X				X	X				X	
0.750							X		X		X				X	X				X	
1.000									X		X				X	X					
1.250											X					X					
1.500											X					X					
1.750											X					X					
2.000											X					X		X			
2.250							X				X					X		X			
2.500							X			X	X							X			
2.750							X			X	X							X			
3.000							X			X	X							X			
3.250							X			X	X							X			
3.500										X	X							X			
3.750							X			X	X							X			
4.000							X			X	X							X			
4.250							X			X	X							X			
4.500							X	X		X	X								X		X
4.750							X	X		X	X								X		X
5.000							X	X	X	X	X				X				X		X
5.250							X	X	X		X				X				X		X
5.500							X	X	X		X				X				X		X
5.750							X	X	X		X				X				X	X	X
6.000							X	X	X		X				X				X	X	X
6.250							X		X		X				X	X				X	
6.500				X					X		X				X	X				X	
6.750				X					X		X				X	X				X	
7.000									X		X				X	X	X			X	
7.250									X		X				X	X	X			X	
7.500									X		X				X	X	X			X	
7.750											X					X	X			X	
8.000											X					X				X	
8.250											X					X					
8.500											X					X		X			
8.750											X					X		X			
9.000											X					X		X			
9.250											X		X			X		X			
9.500										X	X		X					X			
9.750										X	X							X			

VSV Tabular Report pages 8 - 17 are intentionally omitted.

VSV Combination Key

Hours Into Simulation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
115.000								X		X	X								X		X
115.250										X	X										X
115.500										X	X										X
115.750										X	X										
116.000											X										
116.250											X					X					
116.500											X	X				X					
116.750											X	X				X				X	
117.000									X		X				X	X	X			X	
117.250						X			X		X				X	X	X	X		X	
117.500									X		X				X	X	X	X		X	
117.750									X		X				X	X	X	X		X	
118.000								X	X		X				X	X	X	X	X		
118.250								X	X		X				X		X	X	X		
118.500								X	X		X				X		X	X	X		
118.750								X			X							X	X		
119.000								X			X							X	X		
119.250							X	X		X	X							X	X		
119.500							X	X		X	X							X	X		
119.750							X			X	X							X			
120.000										X	X							X			

Statistical Information for VSV

Percentages for Each Combination Based On Shortest Simulation Time for Invloved Vehicles

			Total Time Visible hr	%	Longest Time Visible hr	%	Shortest Time Visible hr	%	Longest Time Not Visible hr	%	Shortest Time Not Visible hr	%	Number of transitions
1 BERLIN	GNDRADAR	::AMSAT	1.25	1.0	0.25	0.2	0.25	0.2	26.00	21.6	23.25	19.3	9
2 BERLIN	GNDRADAR	::LANDSAT	0.00	0.0	0.00	0.0	0.00	0.0	120.25	100.0	120.25	100.0	0
3 NORAD	SMCIR	: LARC	5.25	4.4	1.00	0.8	0.50	0.4	23.75	19.8	2.00	1.7	14
4 NORAD	SMCIR	: NOME	2.50	2.1	0.50	0.4	0.25	0.2	24.25	20.2	0.25	0.2	18
5 NORAD	SMCIR	: BAIRES	5.75	4.8	1.00	0.8	0.50	0.4	23.75	19.8	1.75	1.5	14
6 AMSAT	LGCIR	: BERLIN	2.00	1.7	0.50	0.4	0.25	0.2	23.25	19.3	2.75	2.3	11
7 AMSAT	LGCIR	::LANDSAT	36.00	29.9	4.50	3.7	0.25	0.2	11.25	9.4	0.25	0.2	54
8 COMSAT		: LARC	45.25	37.6	3.50	2.9	0.50	0.4	6.75	5.6	0.50	0.4	38
9 COMSAT		: NOME	51.25	42.6	3.00	2.5	1.25	1.0	3.75	3.1	1.50	1.2	43
10 COMSAT		: BAIRES	44.25	36.8	3.50	2.9	0.50	0.4	6.75	5.6	2.25	1.9	37
11 COMSAT		::NORAD	102.50	85.2	34.25	28.5	1.25	1.0	2.00	1.7	0.75	0.6	26
12 LANDSAT	MEDCIR	: BERLIN	2.00	1.7	0.50	0.4	0.50	0.4	44.75	37.2	3.25	2.7	8
13 LANDSAT	MEDCIR	: LARC	9.50	7.9	1.50	1.2	0.25	0.2	18.75	15.6	5.00	4.2	20
14 LANDSAT	MEDCIR	: NOME	0.00	0.0	0.00	0.0	0.00	0.0	120.25	100.0	120.25	100.0	0
15 NOME		::COMSAT	51.25	42.6	3.00	2.5	1.25	1.0	3.75	3.1	1.50	1.2	43
16 NOME		::NORAD	52.25	43.5	3.25	2.7	2.00	1.7	4.25	3.5	2.00	1.7	39
17 LARC		::AMSAT	36.00	29.9	5.00	4.2	0.50	0.4	7.50	6.2	1.50	1.2	31
18 LARC		::LANDSAT	49.50	41.2	3.00	2.5	2.00	1.7	4.75	4.0	2.00	1.7	37
19 LARC		::COMSAT	45.25	37.6	3.50	2.9	0.50	0.4	6.75	5.6	0.50	0.4	38
20 LARC		::NORAD	50.50	42.0	4.00	3.3	1.00	0.8	4.75	4.0	2.25	1.9	39
21 BAIRES		::NORAD	48.25	40.1	4.00	3.3	1.25	1.0	4.75	4.0	2.25	1.9	38

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16. Abstract

This document describes the Spacecraft Orbit Design and Analysis (SODA) computer program, Version 2.0. SODA is a spaceflight mission planning system which consists of six program modules integrated around a common database and user interface. SODA runs on a VAX/VMS computer with an EVANS & SUTHERLAND PS300 graphics workstation. In the current version three program modules produce an interactive three dimensional (3D) animation of one or more satellites in planetary orbit. Satellite visibility and sensor coverage capabilities are also provided. Circular and rectangular, off-nadir, fixed and scanning sensors are supported. One module produces an interactive 3D animation of the solar system. Another module calculates cumulative satellite sensor coverage and revisit time for one or more satellites. Currently Earth, Moon, and Mars systems are supported for all modules except the solar system module.

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