SANDIA REPORT

SAND98–0504 • UC–706
Unlimited Release
Printed March 1998

A User's Guide to LUGSAN II A Computer Program to Calculate and Archive Lug and Sway Brace Loads for Aircraft-Carried Stores

William N. Dunn

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A03
Microfiche copy: A01

SAND98-0504
Unlimited Release
Printed March 1998

Distribution
Category UC-706

A User's Guide to LUGSAN II
A Computer Program to Calculate and Archive Lug and Sway Brace Loads for Aircraft-Carried Stores

William N. Dunn
Mechanical & Thermal Environments Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM, 87185-0415

Abstract

LUG and Sway brace ANalysis (LUGSAN) II is an analysis and database computer program that is designed to calculate store lug and sway brace loads for aircraft captive carriage. LUGSAN II combines the rigid body dynamics code, SWAY85, with a Macintosh Hypercard database to function both as an analysis and archival system. This report describes the LUGSAN II application program, which operates on the Macintosh System (Hypercard 2.2 or later) and includes function descriptions, layout examples, and sample sessions. Although this report is primarily a user's manual, a brief overview of the LUGSAN II computer code is included with suggested resources for programmers.

Acknowledgment

The author acknowledges the following people, who contributed to the success of the work presented in this report. Included are Gerald R. Eisler, Department 9234, who was responsible for the initial development effort of the original LUGSAN; Robert P. Rechard, Department 6849, who wrote SWAY85; Clay W. G. Fulcher, Department 9234, who wrote MILGEN; and Malcolm Moore, a former RE/SPEC contractor, who began the process of creating the Hypercard database framework that today is LUGSAN II.

Contents

Illustrations

Tables

A User's Guide to LUGSAN II
A Computer Program to Calculate and Archive
Lug and Sway Brace Loads for Aircraft-Carried Stores

Overview

This report is a user's manual for LUGSAN II, which operates on a Macintosh System (Hypercard 2.2 or later). Because LUGSAN II is based on the rigid body dynamics code, SWAY85, the new user is instructed to refer to the *SWAY85 Manual*,[1] which describes the input data that is required to successfully complete a lug loads calculation, before proceeding to the Tutorial Section and the remainder of this report.

The Tutorial Section describes the data that is required for LUGSAN II and the general data flow (see also Figure 1), then leads the user through a sample session that shows the user how to enter data and submit an analysis.

The LUGSAN II Screen Reference Section describes how to use the seven information display screens and menus in the LUGSAN II program. For example, to verify the coordinate system of the x-axis moment location, the user would find this information in the Store Information Display Screen under X-Axis Moment Station. The Screen Reference Section is designed to aid the user in solving, screen by screen, problems that may occur while using the program.

Appendix A contains a discussion of aerodynamic coefficient data interpolation and the aerodynamic coefficient data file format. Appendix B reproduces a memo that documents several wind tunnel coordinate systems. Appendix C contains a brief programmer's overview of the LUGSAN II computer code and a flowchart that diagrams the important aspects of the code. Appendix D compares the results of benchmark cases that are presented in the *SWAY85 Manual*, against the results obtained with the Macintosh SWAY85 program. Appendix E describes the maneuver generation portion of LUGSAN II (MILGEN), and, finally, an extensive Index is included to facilitate the location of topical information.

---

[1] R. P. Rechard and P. K. Metzler, *SWAY85: A Computer Program for Calculating Lug and Sway Brace Loads*, SAND85-2178-UC-38.

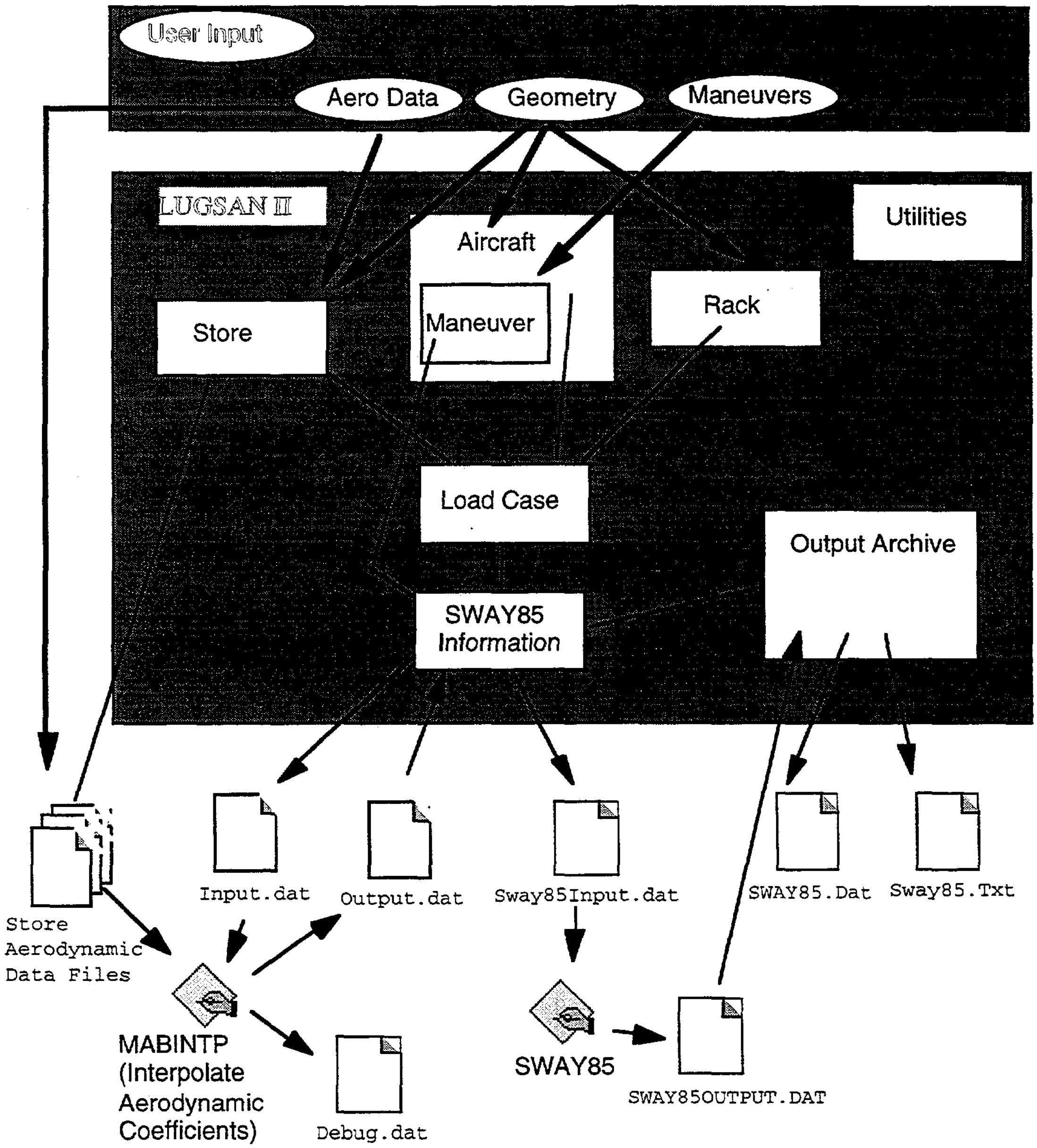


Figure 1. Flowchart of LUGSAN II Program Execution

Introduction

The LUGSAN II system consists of a database of aerodynamic, performance, and physical properties for aircraft and aircraft-carried stores used by Sandia National Laboratories to calculate store carriage loads. LUGSAN II runs the latest version of the Sandia SWAY85 code to calculate lug and sway brace forces, then saves both input data and results into a detailed database. SWAY85 uses rigid body equations to determine the forces on lugs and sway braces, and indeterminate portions of the calculations are resolved by bounding the yaw moment force distribution on the lugs and sway braces.

LUGSAN II can perform a specific analysis for an identified aircraft with a known set of flight maneuvers or a general analysis when the aircraft on which a store is to be carried is undetermined. Calculation of lug and sway brace loadings is then conducted using the SWAY85 rigid body analysis code.

LUGSAN II uses a Hypercard database system that is operated on a Macintosh hardware platform, and it replaces the original LUGSAN program, which was operated on a VAX/VMS platform using the INGRES database code. LUGSAN II was written using the Hypercard object oriented programming language to accomplish all of the following:

- Decrease programming time and effort
- Increase program functionality
- Simplify the usage of the code
- Eliminate the INGRES database licensing costs

Warning LUGSAN II operates on the Macintosh only.

Introduction to Aircraft and Store Data

Prior to performing a store loads calculation, data for the appropriate aircraft and store must be either entered or located within the database that LUGSAN II maintains. Once data for a particular aircraft or store has been entered, it does not have to be reentered; any combination of existing and newly entered data can be selected to use within the program.

Aircraft data. The data that make up a complete description of an aircraft include

- Aircraft geometry and general identification of the aircraft

- Aircraft flight conditions
- Aircraft maneuvers under given flight conditions
- Aircraft carriage rack configurations — aircraft attachment locations

Store data. The data required to describe a store include

- Store mass, geometry, and general identification
- Store lug locations
- Aerodynamic coefficient data

Introduction to Information Display Screens

The following eight information display screens allow the user to enter data, perform calculations, and review results:

Sway85 Information	Displays input for a SWAY85 calculation, which includes aircraft maneuver, load case, and store location.
Aircraft Information	Displays aircraft geometry and store positions description.
Store Information	Displays store mass and geometry; pointer to aerodynamic data.
Maneuver Information	Displays aircraft maneuver for a given Mach and altitude.
Rack Information	Displays rack geometry and information.
Load Case Information	Merges aircraft, rack, store, and rotary launcher information.
Sway85 Output	Displays SWAY85 load results, plus raw data.
Help	Describes each function display screen

Warning Data that is entered in the information display screens is archived on individual screens called cards. For archival quality assurance, once the information on a card is used in a calculation, it cannot be changed until the results of the calculation are deleted.

The following three system administration function display screens allow the user to manage access to the LUGSAN II system and the contents of the database:

Utilities	Displays LUGSAN II program routines, summaries of known cards, table of contents
Extra	Displays test utilities
Benchmark	Compares actual SWAY85 run output to expected output

Introduction to LUGSAN II Screens

LUGSAN II uses a display system that is based on the Hypercard programming system. This section explains these displays and the menu keys.

A typical screen in the LUGSAN II Program is shown in Figure 2. It consists of alphanumeric data entry and/or graphical data entry in a simplified format.

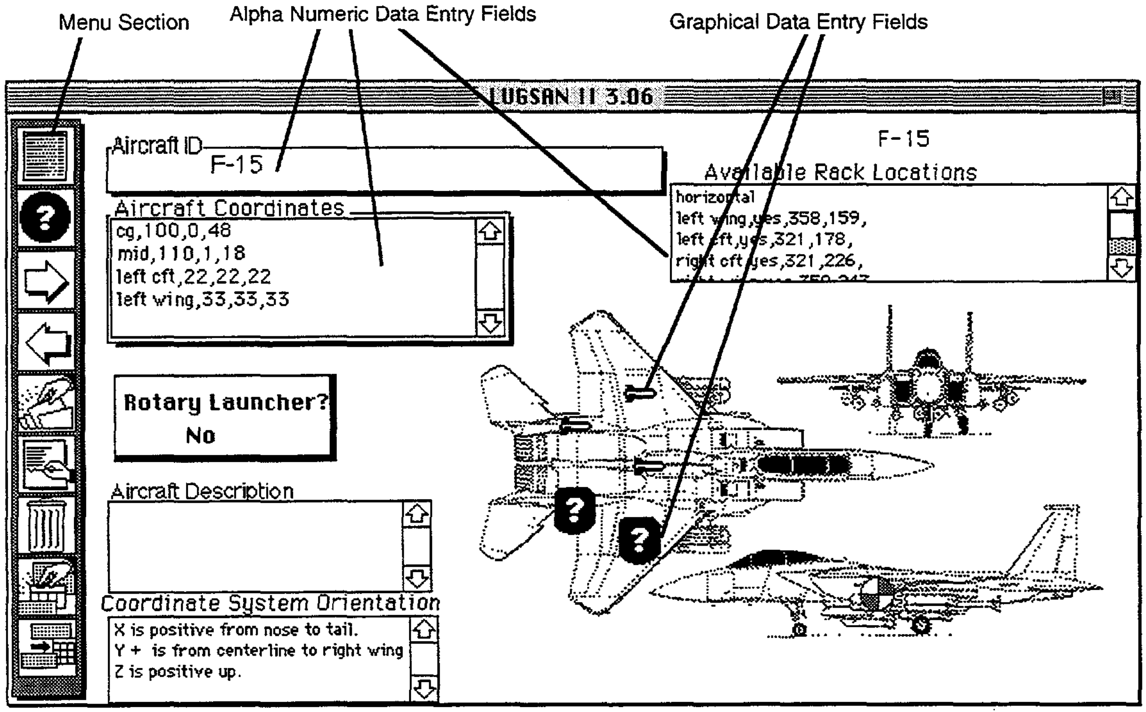
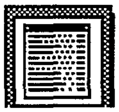
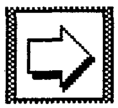
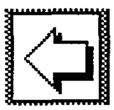


Figure 2. Typical LUGSAN II Functional Screen

The following menu icons are used in most every screen in LUGSAN II:

Introduction to Common Menu Icons

Menu Icons	Function
	**Menu Navigator.** Displays a list of the Function Screens. Click on a Function Screen Name to go to that screen.
	**Help screen.** Displays a context-sensitive help screen, which provides caveats related to your current location.
	**Next Card.** Displays the next card within this Function Screen.
	**Previous Card.** Displays the previous card within this Function Screen.
	**Insert a new card.** Insert a new, blank card.
	**Change data.** Enable writing to this card.

Introduction to LUGSAN II Improvements

LUGSAN II is an improvement over previous lug & sway analysis codes. Considerable licensing costs were saved by implementing HyperTalk, an inexpensive, easy to use programming language. Because the code is object oriented and the commands were simplified, the costs incurred to write and debug the program were lowered substantially. The graphical nature of the input and on-line help should reduce the time required to train a new user, and help to eradicate coordinate system misunderstandings that can cause erroneous data input. Further, the code has been accelerated using a flow analysis. At the key choke point, the aerodynamic coefficient interpolation routine was rewritten to expedite the execution by three orders of magnitude.

Two types of errors may be encountered in LUGSAN II: (1) user errors or (2) programming errors. The program should detect user errors, for example, using a rack with different lug spacing than the store. User errors that are not detected by the program indicate a programming error.

To resolve programming errors, the programmer must be familiar with the Hypercard language, HyperTalk, and possess a rudimentary understanding of the usage and installation (using ResEdit) of Macintosh extended functions "XFCNs" and Macintosh extended commands "XCMDs". Hypercard training video tapes are available, and a good Hypercard Language reference book is recommended. Additional details regarding programming (as well as a program flowchart) are located in Appendix C.

Tutorial

This section introduces sequentially the various Information screens in which specific and pertinent data regarding the subject aircraft must be entered so that LUGSAN II can perform an analysis. For detailed instructions regarding each Information screen, refer to the LUGSAN II Screen Reference section.

The actual order of data entry is as follows. First, the store aerodynamic data and geometry are entered in the Store Information screen. Then the aircraft geometry data is entered into the Aircraft Information screen. Rack geometry can be entered in the Rack Information screen. The rack, aircraft, and store are combined together into a load case in the Load Case screen. The aircraft, maneuver, load case, and store locations can be assembled together and executed in the SWAY85 Information screen. Finally, the results can be viewed in the SWAY85 Output screen.

Tutorial - SWAY85 Information Screen

Shown in Figure 3 is the **Sway85 Information** screen. This screen brings the aircraft, maneuver load case, and store location information together to conduct a lug and sway brace loads calculation. Specific information regarding the subject aircraft and store must have been entered prior to initiating a lug and sway brace loads calculation. The Load Case associates the Aircraft, Rack, Store, and Rotary Launcher together. Therefore, prior to submitting an analysis for lug and sway brace calculation, the user must enter the necessary information for the following information screens: **Aircraft, Rack, Store, Maneuver, Store Location**, and **Load Case**. Instructions for these screens are found on the following pages.

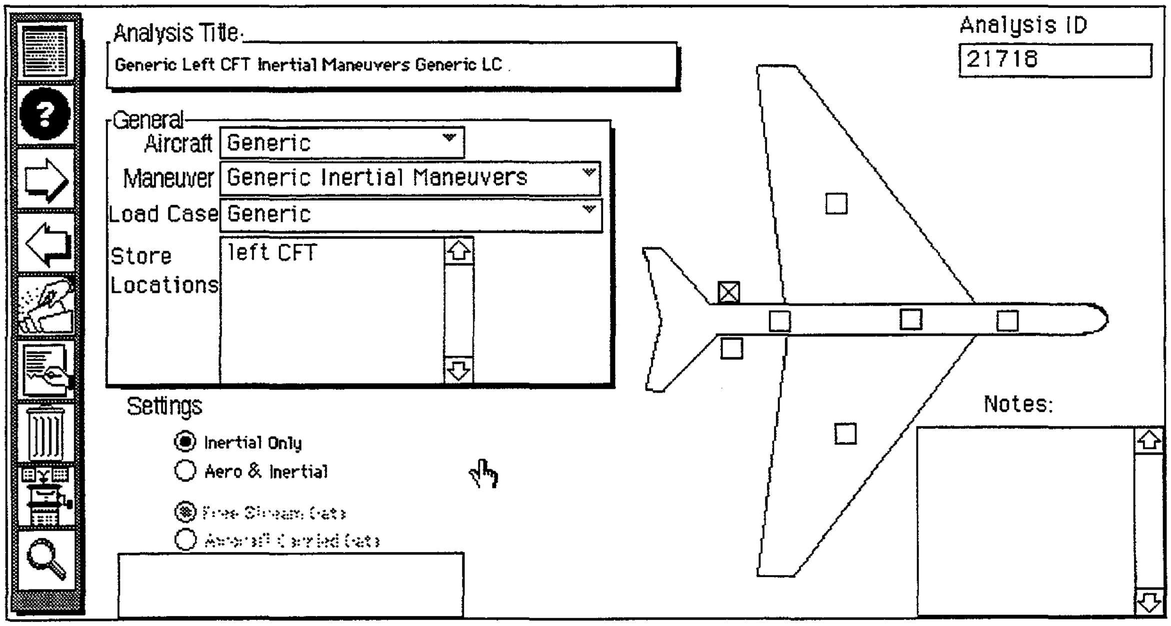


Figure 3. SWAY85 Information Screen

Tutorial - Aircraft Information Screen

Aircraft geometry and allowable rack locations are entered in the **Aircraft Information** screen, which is shown in Figure 4. A separate screen is generated for each aircraft or modification of an aircraft. The name of the aircraft is entered in the Aircraft ID field. The center of gravity (cg) location in aircraft coordinates is entered by clicking the cg symbol, which is shown on the aircraft illustration, lateral view. Inactive store locations are indicated by a (?) question mark icon, and active store locations are indicated by a ( ) store icon. The icons can be toggled from inactive to active, and the user is prompted to enter the coordinates. Typically, all probable store locations will be activated so that they are available for future analyses.

Data cannot be manipulated until the pre-existing analysis results regarding the subject aircraft are deleted. Permutations of cg, for example, to reflect changing fuel loads, must be entered as separate aircraft. Click the "Rotary Launcher?" field to indicate the presence of a rotary launcher. Two optional fields, "Aircraft Description" and "Origin Description," allow the user to describe the aircraft and its coordinate system, respectively. The Available Rack Locations field is used by the program to archive the store location status and display location on the current card. This field may be invisible in the future.

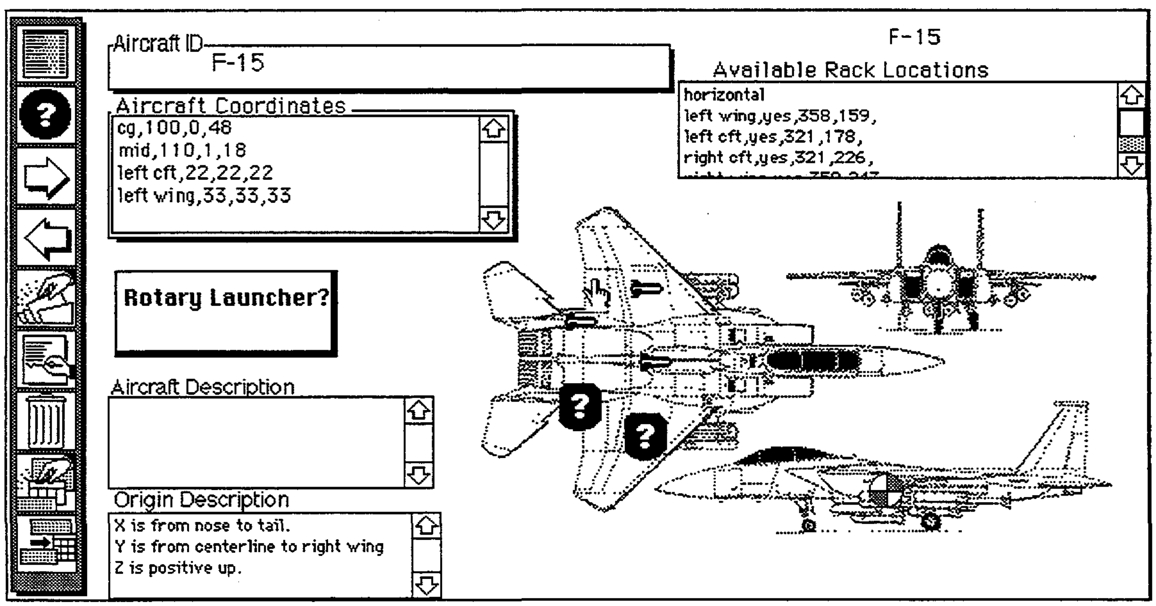


Figure 4. Aircraft Information Screen

Warning LUGSAN II uses only English engineering units (lbf, in).

Tutorial - Store Information

The **Store Information** screen (Figure 5) contains fields for store mass and geometry information. The store origin description button allows the user to enter a description of the store geometry coordinate system. The filename of the ASCII file that contains the store aerodynamic data is recorded on the **Store Information** screen.

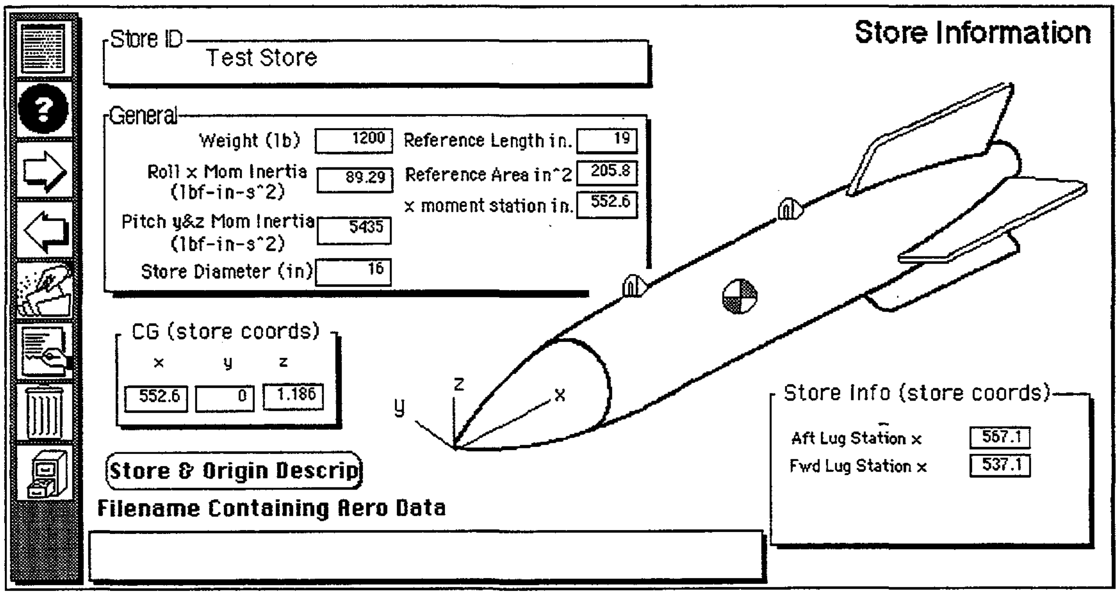


Figure 5. Store Information Screen

Tutorial - Maneuver Information

The **Maneuver Information** screen (Figure 6) contains fields to identify the aircraft, Mach, and altitude and the associated maneuver data. For a specific aircraft, the maneuver data can be obtained from either test or simulation results provided by the aircraft manufacturer. For a more general group or category of aircraft, the maneuver data can be envelopes of aircraft categories generated by the "Run MILGEN" button. The maneuver data is described in the aircraft coordinate system shown in Figure 7. The user can view this diagram in LUGSAN II by clicking the "Show Coord System" button.

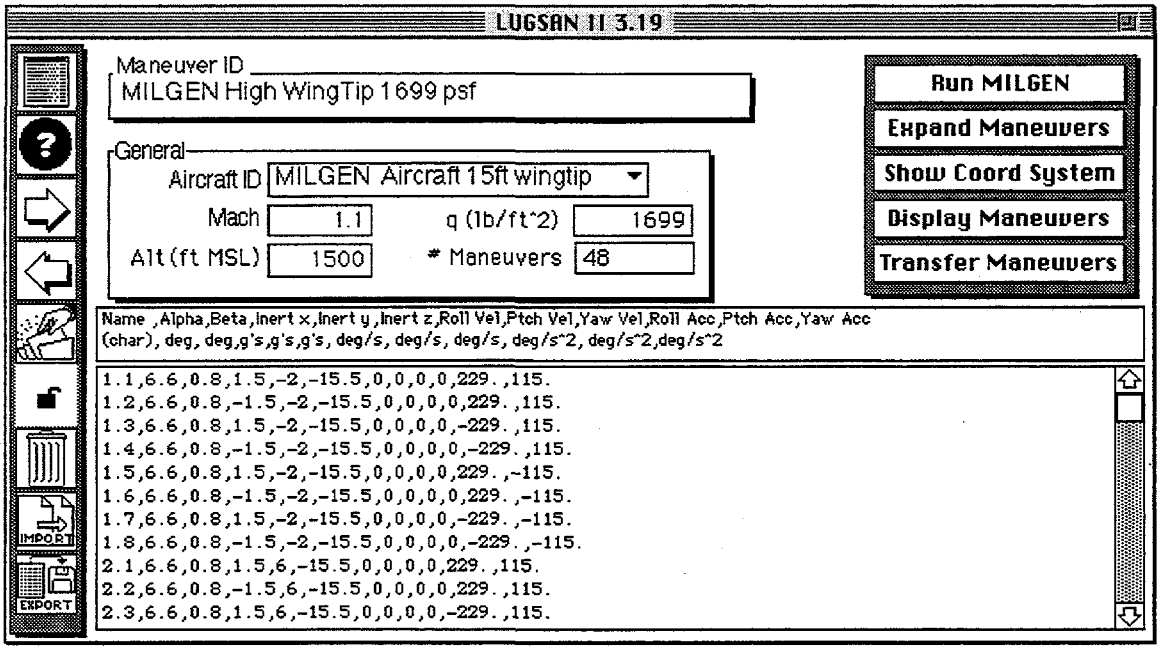


Figure 6. Maneuver Information Screen

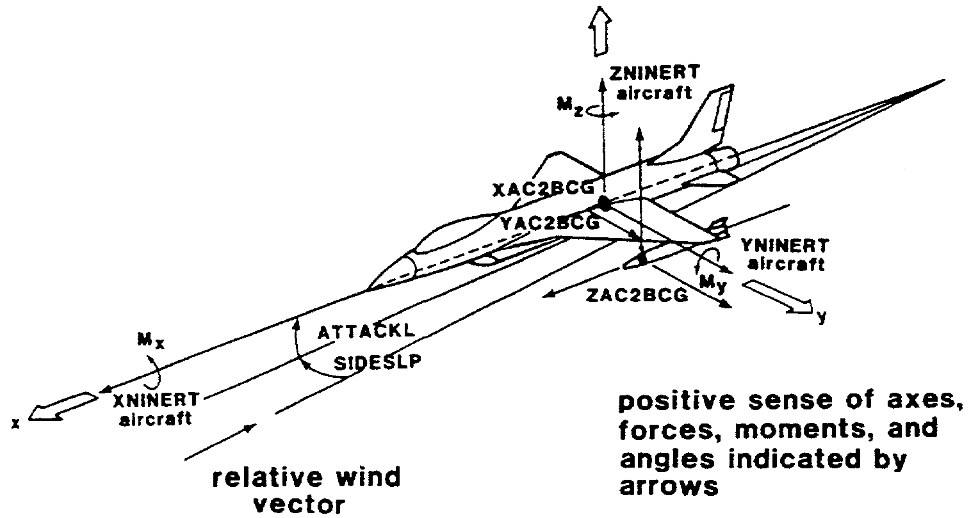


Figure 7. SWAY85 Force & Moment, Maneuver & Aero Coordinate Systems

The maneuver data consists of multiple comma-delimited entries that contain the following information:

Maneuver	Units	Description
Alpha	deg	Angle of attack (pitch) about the aircraft cg.
Beta	deg	Angle of yaw about the aircraft cg.
Inert x	g's	Inertial Acceleration along the aircraft length.
Inert y	g's	Inertial Acceleration along the aircraft lateral.
Inert z	g's	Inertial Acceleration along the aircraft vertical.
Roll Velocity	deg/s	Angular velocity about the aircraft longitudinal.
Pitch Velocity	deg/s	Angular velocity about the aircraft y axis.
Yaw Velocity	deg/s	Angular velocity about the aircraft z axis.
Roll Acceleration	deg/s^2	Angular acceleration about the aircraft longitudinal.
Pitch Acceleration	deg/s^2	Angular acceleration about the aircraft y axis.
Yaw Acceleration	deg/s^2	Angular acceleration about the aircraft z axis.

Each maneuver has a name, two associated aircraft angles, nine values corresponding to the inertial accelerations, angular velocities, and angular accelerations. Importing data can be accomplished either by a formatted input routine, or by using a Macintosh clipboard copy/paste from the data file to the maneuver field.

Tutorial - Rack Information

The **Rack Information** screen (Figure 8) contains only a name field, a description field, and four geometry fields that contain lug hook and sway brace spacing (in inches) and overall rack angle (deg), relative to the aircraft (positive nose up, negative nose down using the SWAY85 Aerodynamic Coordinate System). For example, the rack is often mounted on the aircraft with a small negative pitch so that during flight – while the aircraft is at the corresponding positive pitch angle of attack – the store is at zero angle of attack. This angle is added to the aircraft angle of attack to obtain the store angle of attack for aerodynamic loads determination.

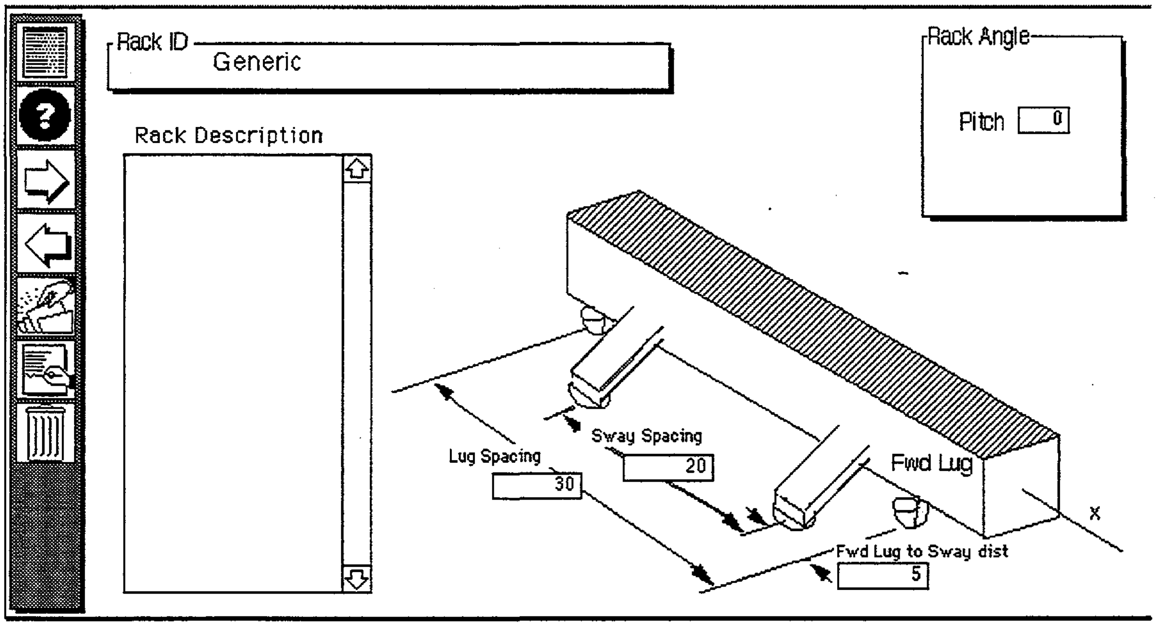


Figure 8. Rack Information Screen

Tutorial - Load Case Combined Store/Aircraft Information

The **Load Case** screen (Figure 9) contains the necessary information to tie together an aircraft, rack, and store under one load case name. This screen contains fields for the sway brace angles (degrees) and the distances from the surface to the hook, and from the sway brace intersection point to the store centerline. In addition, if the aircraft has a rotary launcher, the rotary launcher name and the launcher angle (degrees) are entered here.

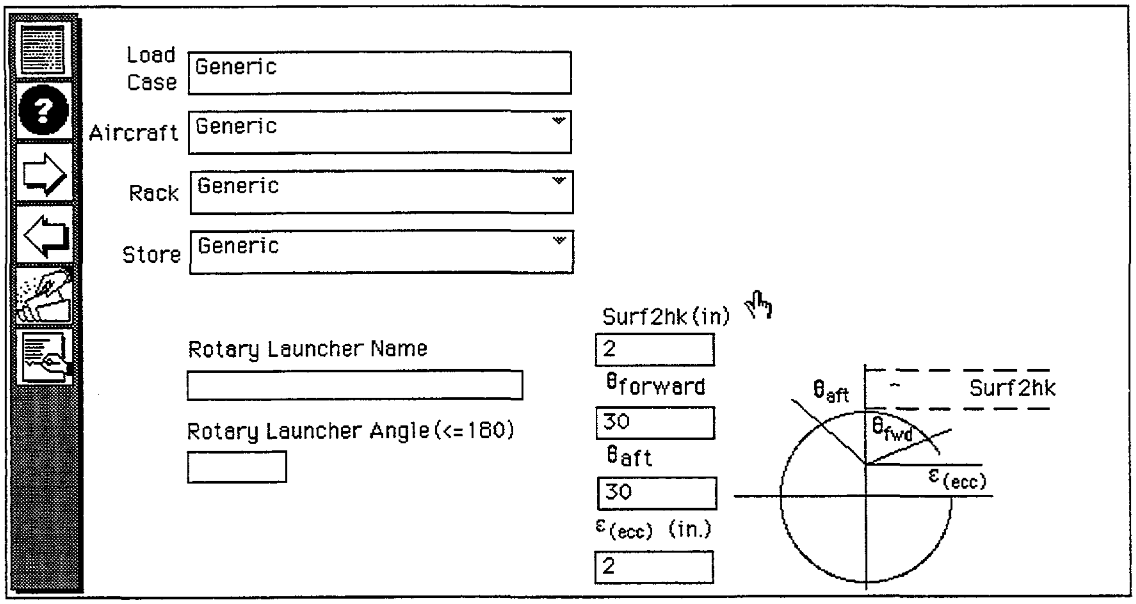


Figure 9. Load Case Information Screen

Tutorial - Running Load Analyses and Examining Results

Once all of the screens (Figures 3 through 9) have been completed, the user can go to the SWAY85 Information Screen (Figure 10) and make selections to run a SWAY85 load calculation. The user selects the **Aircraft**, **Store**, **Maneuver**, **Rack**, and **Load Case** in each of the pull-down fields. A run title, the store location, and the aerodynamics are then entered. A run can be submitted only if the Analysis ID field in the upper right corner is empty. Once a run is completed, a unique, computer generated run identification number is assigned to this calculation and put in the Analysis ID field. If the Analysis ID field is not empty, the user cannot proceed with the calculation until the current analysis results are deleted.

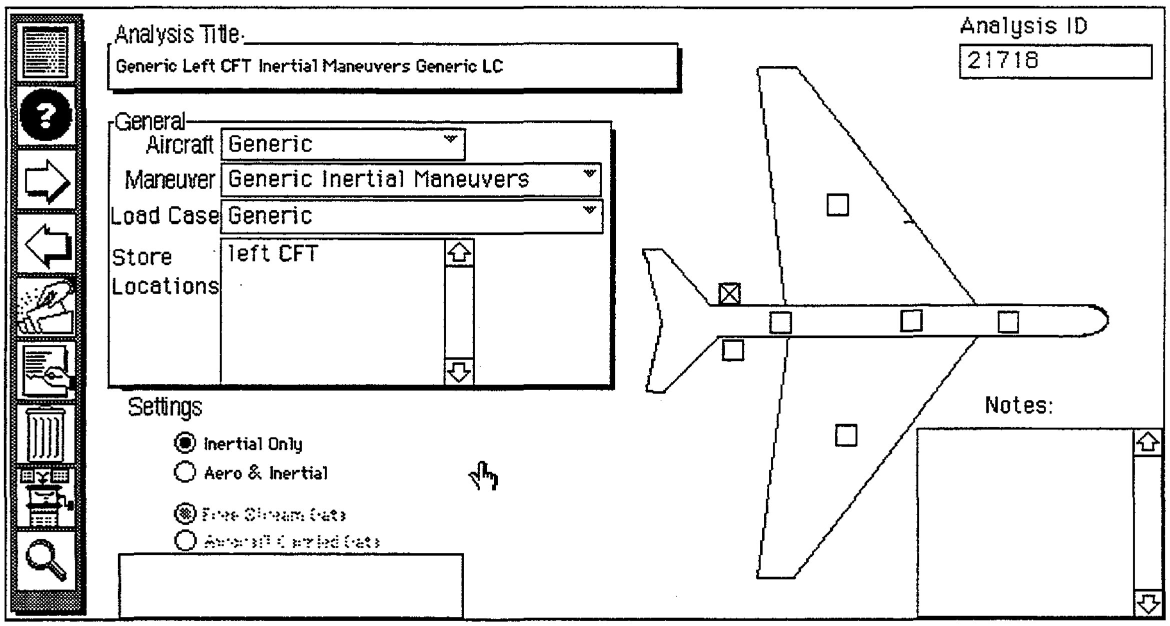


Figure 10. SWAY85 Information Screen

To review the analysis results, click the magnifying glass that is located at the bottom of the tool bar to display the **SWAY85 Output Information** screen (Figure 11) that corresponds to this input. From within the SWAY85 Output Information Screen, the output results can be displayed as formatted SWAY85 output, as tabular data, or as graphs.

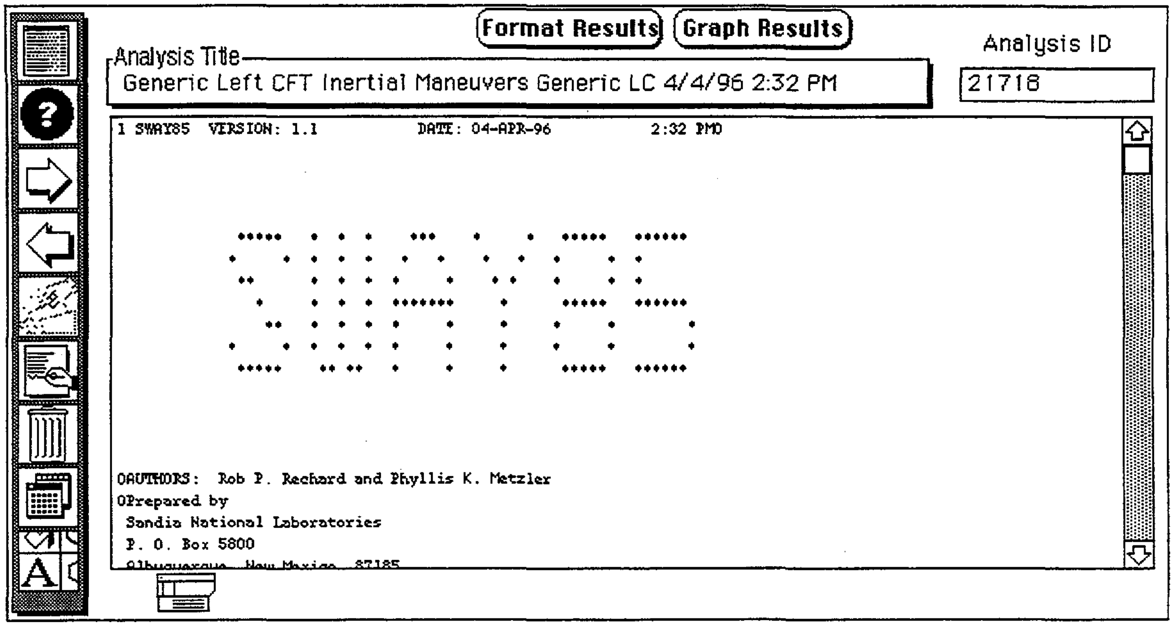


Figure 11. SWAY85 Output Screen

LUGSAN II Coordinate Systems

LUGSAN II uses four coordinate systems: the aircraft geometry coordinate system, the store geometry coordinate system, the SWAY85 force & moment coordinate system, and the SWAY85 Aerodynamic coordinate system.

LUGSAN II Aircraft Geometry Coordinate System

This coordinate system orientation is used in the **Aircraft Information** screen in terms of the origin and the direction. The origin description field includes the following text:

X = positive from nose to tail (station).

Y = positive from centerline to right wing (butt line).

Z = positive up (water line).

The LUGSAN II Aircraft Geometry Coordinate System orientation is designed to agree with the system used by all aircraft manufacturers. The location of the origin may vary and should be described in the Aircraft Description field. For example, the origin may be located at the aircraft nose, or 100 inches in front of the aircraft toward ground level. The aircraft coordinate system and the store coordinate system calculate the transfer distance vector from the aircraft to the store.

> ***Note*** Because SWAY85 recognizes only one input file using one coordinate system, all geometric references in LUGSAN II are converted to the aircraft geometry coordinate system prior to the creation of the SWAY85 input file.

LUGSAN II Store Geometry Coordinate System

This coordinate system is used in the **Store Information** screen in terms of the origin and the direction. This coordinate system is used to define the lug locations, the X-axis aerodynamic moment station, and the center of gravity of the store. The geometric information in this coordinate system is converted vectorially to the aircraft coordinate system using the aft lug of the store and the aft lug hook of the rack on the aircraft as a common intersection point. The orientation of the LUGSAN II Store Geometry Coordinate System is shown in the store diagram on the **Store Information** screen where x = positive from nose to tail and z = positive lugs up, with the origin at some point near the nose. The orientation of this coordinate system is the same as for the Aircraft Geometry coordinate system, but the origins are at different locations.

SWAY85 Force & Moment Coordinate System

This coordinate system is used in the Maneuver Information and the SWAY85 Output screens. The SWAY85 coordinate system for forces and moments follows:

x = forward, longitudinally along the aircraft

z = up

y = to the left, facing forward

Similarly, angular rotation and moments are defined about these axes: roll, pitch, and yaw angular velocities; accelerations are defined about these axes: positive according to the right-hand rule. Forces are defined positive in the positive direction of the axes. This coordinate system can be displayed by clicking the "Show Coord System" button that is located on the **Maneuver Information** screen.

> ***Warning*** Vectors must be entered with reference to the proper coordinate system.

SWAY85 Aerodynamic Coordinate System

The SWAY85 Aerodynamic Coordinate System is used in the aerodynamic coefficient file. The SWAY85 aerodynamic coordinate system is identical to the SWAY85 force and moment coordinate system in the translational coordinate system:

x = forward, longitudinally along the aircraft

z = up

y = to the left, facing forward

The SWAY85 Aerodynamic Coordinate System differs from the SWAY85 Force & Moment Coordinate System in terms of the positive direction of the angles, however, as shown in Figures 20 and 21. The positive direction of roll (phi), pitch (alpha, "angle of attack"), and yaw (Beta) are in the opposite directions from the SWAY85 Force & Moment Coordinate System. Positive pitch (alpha, "angle of attack") is defined as positive nose up, and thus positive about the -y axis according to the right-hand rule. Positive yaw (Beta, "angle of yaw") is defined as positive nose right (pilot's reference) and thus positive about the -z axis according to the right-hand rule. Positive roll (phi) is defined about the -x axis according to the right-hand rule. See Appendix B for further discussion.

Note The only difference between the SWAY85 Force & Moment Coordinate System and the SWAY85 Aerodynamic Coordinate System is that the positive orientation of the roll, pitch, and yaw angles are exactly opposite.

LUGSAN II Screen Reference

This section contains detailed information regarding each screen that the user will encounter in the program and includes

- Screen name
- Screen function
- Variables found in the screen, including those found in the tables
- Menu options available on each screen

How To Use The LUGSAN Screen Reference Section

The more experienced user will likely refer to this section to resolve questions regarding a specific screen, such as the meaning of a variable, the units with which LUGSAN II will interpret those variables, or to confirm which coordinate system is in use. The new user will benefit by reviewing all of the program screens, which are presented in this seetion, to become familiar with the variables, locations, units, and coordinate systems.

Screen Name LUGSAN II Program Introductory Screen

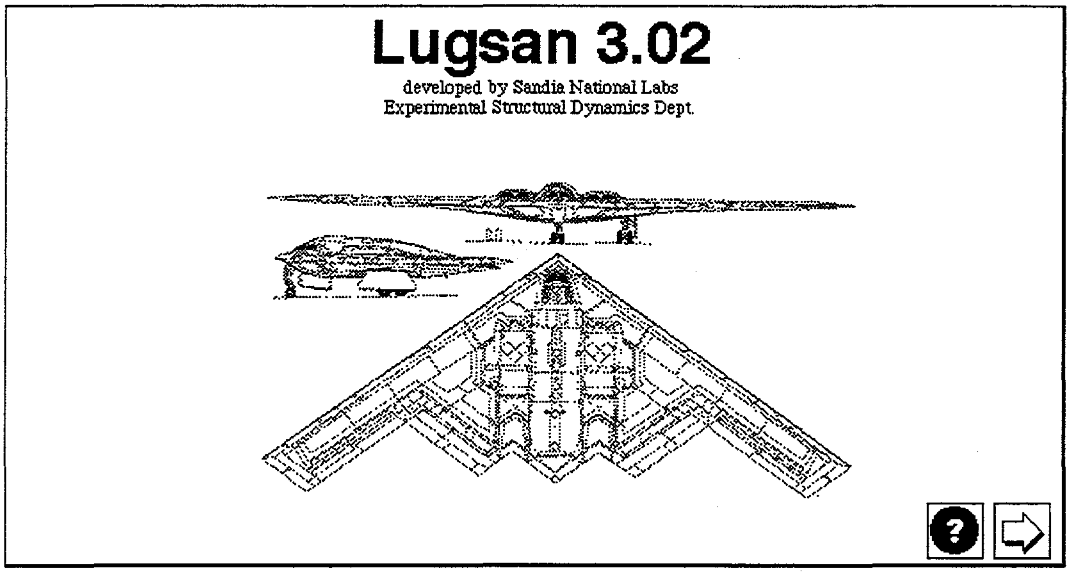


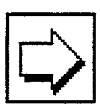
Figure 12. LUGSAN II Introduction Screen

Function

The **LUGSAN II Introduction** screen (Figure 12) displays when the program is opened. Users are encouraged to note the version number that is displayed on this screen to be cognizant of program upgrades.

Menu Options

Icons from the screen shown in Figure 12 are described below.



To continue running the program.

To go to the help Introduction screen, which provides an overview of LUSGAN II and suggested reading.

Screen Name **Sway85 Information**

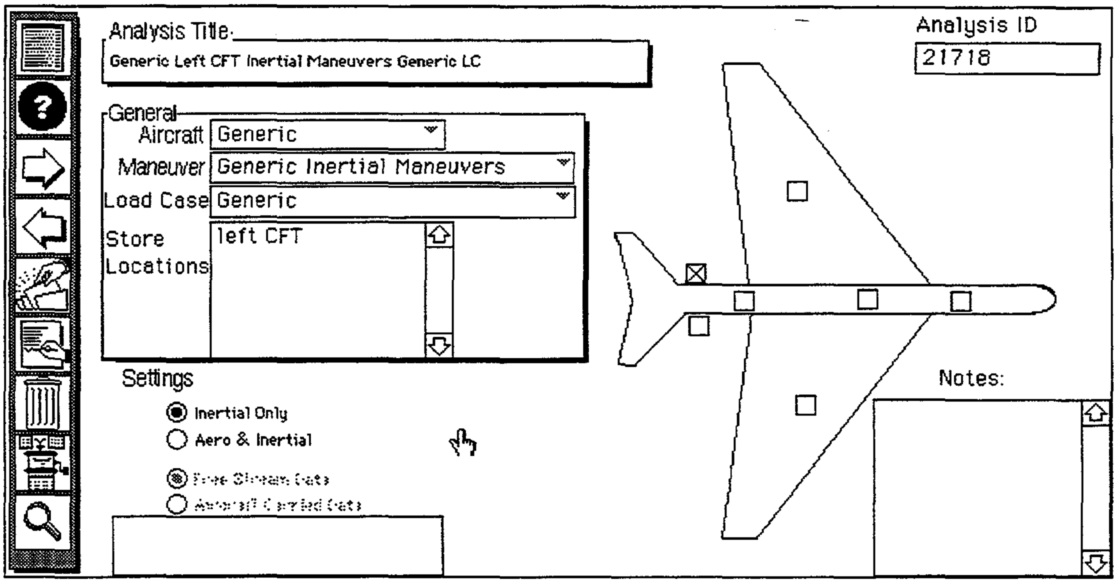


Figure 13. SWAY85 Information Screen.

Function

The **SWAY85 Information** screen (Figure 13) allows the user to set up and submit a SWAY85 run. If the Analysis ID field is empty, the user may begin entering information in the fields. The user must title the analysis, select an aircraft, a maneuver, a load case, and click on the aircraft to select a store location. The user must then choose whether to include aerodynamics ("Inertial only" versus "Aero & Inertial"). If aerodynamic loads are included, the user must select the source of the aerodynamic data ("Free Stream Data" versus "Aircraft Carried Data"). If aerodynamics data are used, the user will be prompted for the data filename. One store location box must be selected on the aircraft. Finally, any specific notes may be entered in the notes field.

Screen Data

Analysis Title	A title that is printed to the SWAY85 file and used to ID the analysis.
Aircraft	A pull-down menu of available aircraft in the database.
Maneuver	A pull-down menu of available maneuvers.
Load Case	A pull-down menu of available load cases.
Store Location	Click on the aircraft to select a store location. Possible locations include any one of the following: nose, mid, aft, left wing, right wing, left conformal fuel tank station, and right conformal fuel tank station.
Aerodynamics	Select either (1) aerodynamics and inertial loadings, or (2) inertial loadings only. If aerodynamic loadings are included (option 1), then the user must indicate whether the aerodynamics originate from freestream or carriage.
Notes	Any notes that are needed may be entered in this field prior to running an analysis.

> ***Warning*** If a pull-down menu does not display an aircraft, maneuver, store, or load case that is unequivocally in the database, then a system update must be performed in the **Utilities** screen. Select the Menu Navigator and go to the **Utilities** screen and click the *Update All* button, which is located in the Programming Utilities area at the bottom of the screen, then return to this screen and select the pull-down menu.

Instructions

If the analysis ID field contains an entry, then these data have been used in an analysis, and no changes may be made until the analysis results are deleted. To delete the analysis results, click the Magnifying Glass icon located in the Tool Box to display the Analysis Results. In the Analysis Results area, click on the Trash Can icon, which deletes the results permanently.

> ***Warning*** The user cannot modify the data in the SWAY85 Information screen if the Analysis ID field contains an entry because this input is linked to analysis results. In fact, the user cannot change aircraft, rack, store, maneuver, etc., data that has been used to obtain analysis results.

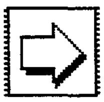
> ***Warning*** Select store location by clicking on the appropriate aircraft location. Only one store location can be selected at a time. Allowable store locations must be predefined in the **Aircraft** screen. A store location geometry that is not defined in the **Aircraft** screen cannot be selected.

Menu Options

Icons from the screen shown in Figure 13 are described below.

Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.

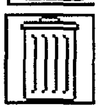


Next Card. Displays the next card within this Function Screen

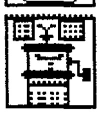
Previous Card. Displays the previous card within this Function Screen

Insert a new card.

Change data on this card.



Delete this card.



Creates a SWAY85 input file, runs the analysis, and places the output in the SWAY85 output screen.

View results. Display the SWAY85 output screen analysis results linked to this input data.

Screen Name Aircraft Information

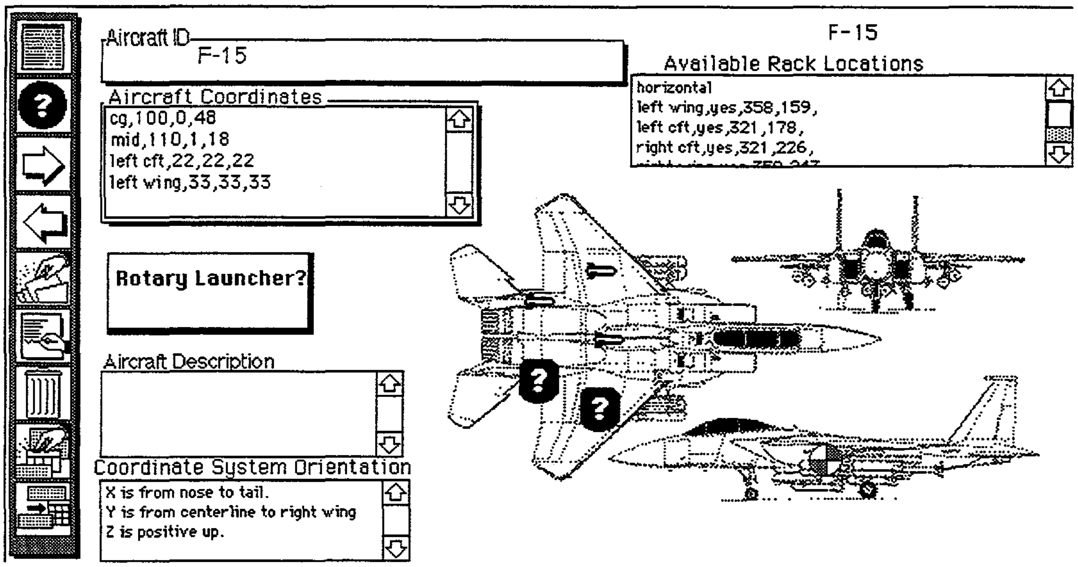


Figure 14. Aircraft Information Screen

Function

The **Aircraft Information** screen (Figure 14) allows the user to enter or review the general identification and geometric configuration of the aircraft. This information is typically obtained from drawings provided by the manufacturer.

Screen Data

Aircraft ID	A name that must be unique from all other Aircraft in the database. Click on the field and enter the name.
Aircraft Coordinates	The name and coordinates (aircraft coordinates) of each aircraft location. Click on a location on the aircraft to change or add its coordinates. A location is available if it displays a ( ) store icon on the aircraft picture, and is undefined if it displays a ( ) question mark icon. Click on the ( ) center of gravity (cg) icon to enter the cg in aircraft coordinates. The cg and at least one store location must be defined prior to running an analysis.
Rotary Launcher	Click within the Rotary Launcher field to indicate yes, if appropriate.
Aircraft Description	A field to enter a text description of the aircraft, for example, most forward cg, full of fuel or empty, new attachment location, or mod of the aircraft. Must describe the origin location, for example, point 50 inches forward of the nose.
Coordinate System	A fixed text field that describes the aircraft x,y,z coordinate system orientation and corresponds with all aircraft drawings. X direction coordinates = Station, Y direction coordinates = Butt Line, and Z direction coordinates = Water Line.
Available Rack Locations	Screen coordinates for the store, question mark, and cg icons. The user should ignore this field. Names of the possible locations include Left and right conformal fuel tank (CFT) station Left and right wing Tail – aft centerline Mid – mid centerline Nose – forward centerline

Instructions

The **Aircraft Information** screen uses the Aircraft Geometry Coordinate System. This system is described on this screen in the lower left portion of the screen under **Coordinate System Orientation.** Enter the distinguishing characteristics of this particular aircraft in the **Aircraft Description** field.

Warning An aircraft that has been used for an analysis is locked and cannot be edited until the corresponding analysis results are deleted.

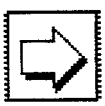
Warning In the **Aircraft Information** screen, the aircraft coordinates are those of the rack aft lug if there is no rotary launcher. If a rotary launcher is present, the aircraft coordinates are those of the rotary launcher mounting location and the **Load Case** screen will display a field that is the vector from the rotary launcher to the rack aft lug.

Menu Options

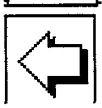
Icons from the screen shown in Figure 14 are described below.

Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.



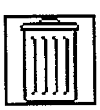
Next Card. Displays the next card within this Function Screen



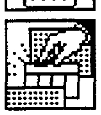
Previous Card. Displays the previous card within this Function Screen

Insert Card. Insert a new card in this Function Screen.

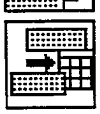
Change data on this card. Note the data on this card cannot be edited if this aircraft has been used in an analysis.



Delete this card.



Create a new maneuver associated with this aircraft.



To be written.

Screen Name **Benchmark**

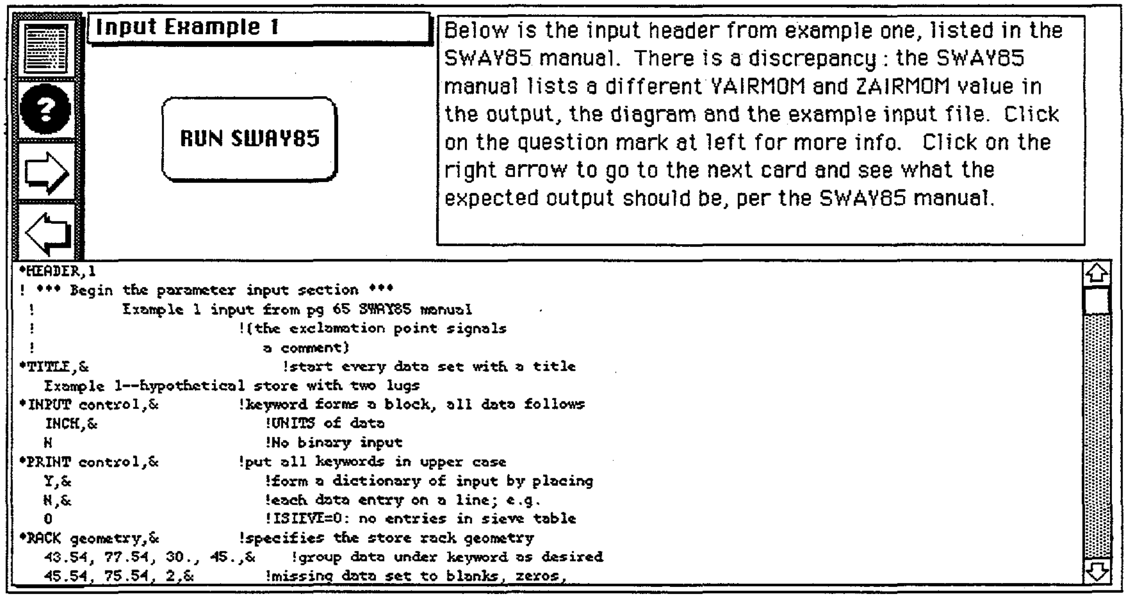


Figure 15. Benchmark Screen Input Example 1

Function

The Benchmark screen (Figure 15) is designed to

1. Archive the Example 1 SWAY85 Manual Benchmark input and output information,
2. Run SWAY85 on the Mac using this benchmark input, and
3. Preserve the Mac output for comparison to the expected output documented in the SWAY85 user manual.

Instructions

The three cards of the Benchmark screen are shown in Figures 15 through 17. Figure 15 shows the first card, which preserves the SWAY85 Example 1 input and provides a button to use this input in a SWAY85 run on the Macintosh.

Discrepancies were found in the *SWAY85 Manual,* in the aero moment loads. These discrepancies have been resolved, as described in Appendix D. The Macintosh SWAY85 output agrees with the Benchmark in the user manual.

Screen Data

RUN SWAY85	This executes SWAY85 on the input described in the field below the button. The MAC output can be compared to results documented in SWAY 85 manual in subsequent screens.

The next card in the Benchmark screen, Figure 16, preserves the SWAY85 User Manual Output: the lug and sway force predictions. Finally, Figure 17 shows that the output from the Macintosh (here, a IIci with a 68040 accelerator board running System 7.1) agrees exactly with the SWAY85 Benchmark in the manual.

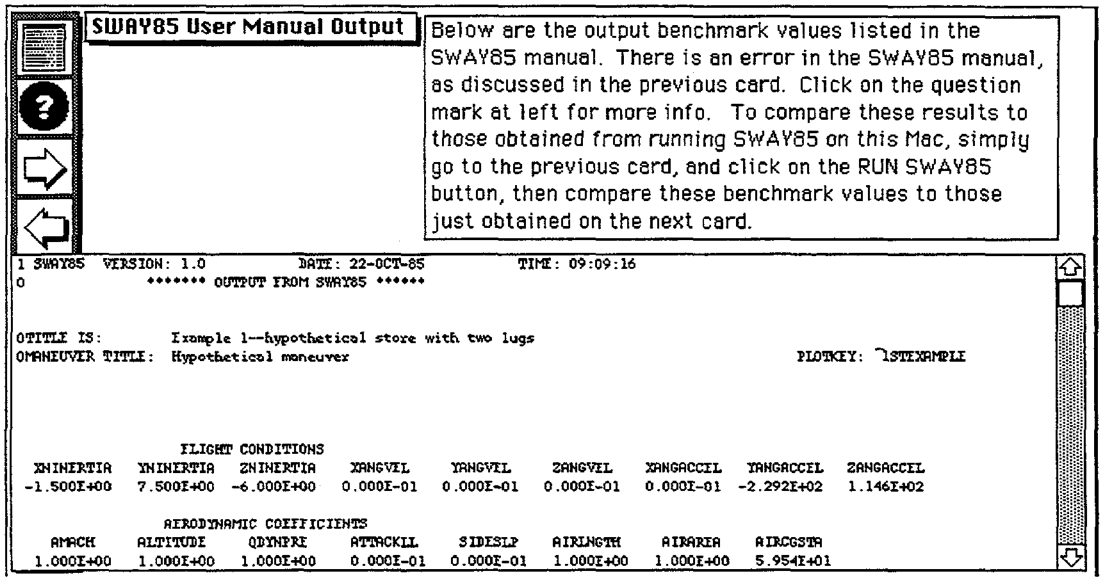


Figure 16. Benchmark Screen: SWAY85 User Manual Benchmark Output

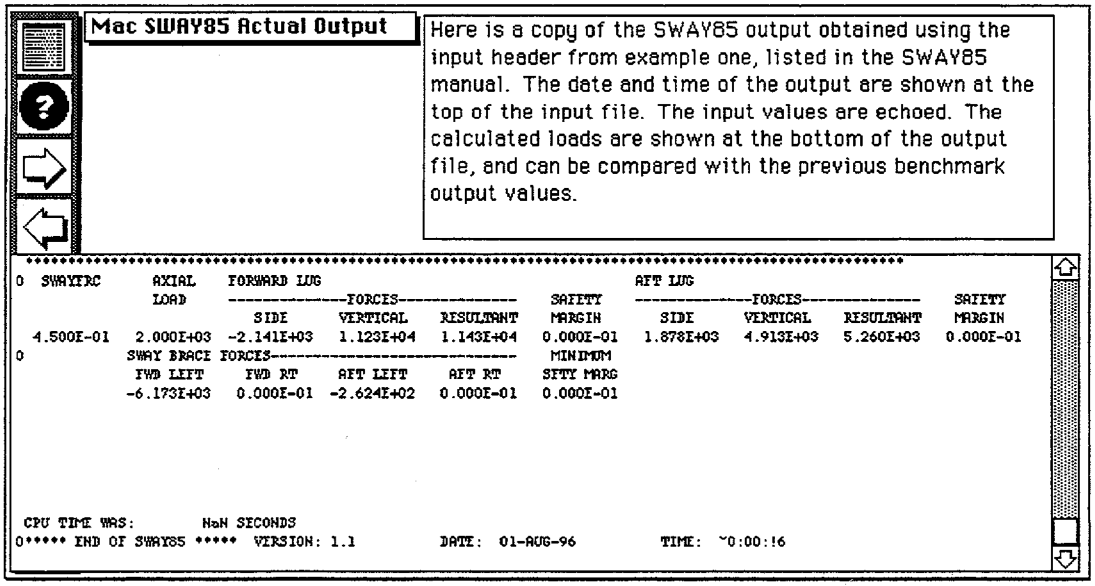
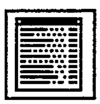


Figure 17. Benchmark Screen: Mac SWAY85

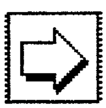
Menu Options

Icons from the screen shown in Figures 15 through 17 are described below.

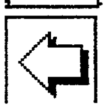


Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.



Next Card. Displays the next card within this Function Screen



Previous Card. Displays the previous card within this Function Screen

Screen Name **Load Case**

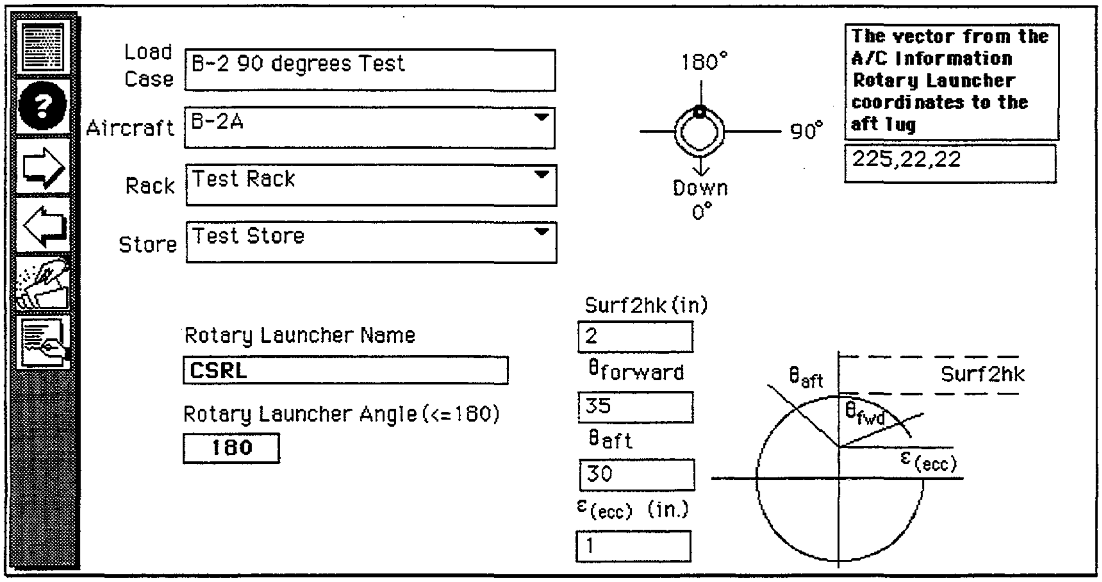


Figure 18. Load Case

Function

The **Load Case** screen (Figure 18) contains the necessary information to tie together an aircraft, rack, and store under one load case name. This screen contains fields for the sway brace angles and distances from the store surface to the hook, and from the sway brace intersection point to the store centerline. If applicable, a rotary launcher name and the launcher position are entered here.

Screen Data

Load Case	The user should select a Load Case Name that reflects the elements of the run; for example, rather than "Load Case 1," a more descriptive name is "B-2 90 deg test case."
Aircraft	A pull-down menu of available aircraft in the database.
Rack	A pull-down menu of available racks.
Store	A pull-down menu of available stores.
Rotary Launcher Name	Enter the launcher name and press Return. At the prompt, enter the Rotary Launcher Angle (<= 180 degrees) and press Return. The angle is rounded to the nearest 45 degrees, and the rotary launcher picture is updated to reflect the angle.
Rotary Launch Angle	Enter the rotary launcher angle (<= 180 degrees) and press Return. The angle is rounded to the nearest 45 degrees, and the rotary launcher picture is updated to reflect the angle.
Surf2hk	The magnitude (always positive) of the distance (in inches) from the store surface to the rack hook. To enter a new value, click on the Surf2hk name in the picture.

Continued . . .

$\Theta_{forward}$	The angle (always positive and in degrees) from vertical of the forward sway brace. To enter a new value, click on the name in the picture.
Θ_{aft}	The angle (always positive and in degrees) from vertical of the aft sway brace. To enter a new value, click on the name in the picture.
$\varepsilon_{(ecc)}$	The magnitude (always positive in inches) of the distance from the store center to the imaginary intersection point of the sway braces. To enter a new value, click on the name in the picture.
Rotary Launcher Vector	Enter the vector (in inches) from the rotary launcher to the aft lug of the store (in the Aircraft Geometry Coordinate System). The rotary launcher location is found in the **Aircraft Information** screen.

Instructions

Warning If a pull-down menu does not display an aircraft, maneuver, store, or load case that is unequivocally in the database, then a system update must be performed in the **Utilities** screen. Select the Menu Navigator button and go to the **Utilities** screen and click the *Update All* button, which is located in the Programming Utilities area at the bottom of the screen, then return to this screen and select the pull-down menu.

Note Surf2hk, $\Theta_{forward}$, Θ_{aft}, $\varepsilon_{(ecc)}$, are magnitudes, and thus always positive values. The vector from the Rotary Launcher to the store aft lug is a vector, which consists of x, y , and z directions, either positive or negative, in the Aircraft Geometry Coordinate System.

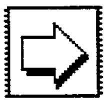
Warning In the **Aircraft Information** screen, the aircraft coordinates are those of the rack aft lug when there is no rotary launcher. When a rotary launcher is present, the aircraft coordinates are those of the rotary launcher mounting location and the **Load Case** screen will display a field that is the vector from the rotary launcher to the rack aft lug, in the Aircraft Geometry Coordinate System.

Menu Options

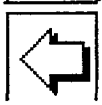
Icons from the screen shown in Figure 18 are described below.

Menu Navigator. Displays a list of the Function Screens. Click a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.

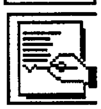


Next Card. Displays the next card within this Function Screen



Previous Card. Displays the previous card within this Function Screen

Insert Card. Insert a new card in this Function Screen.



Change data on this card.

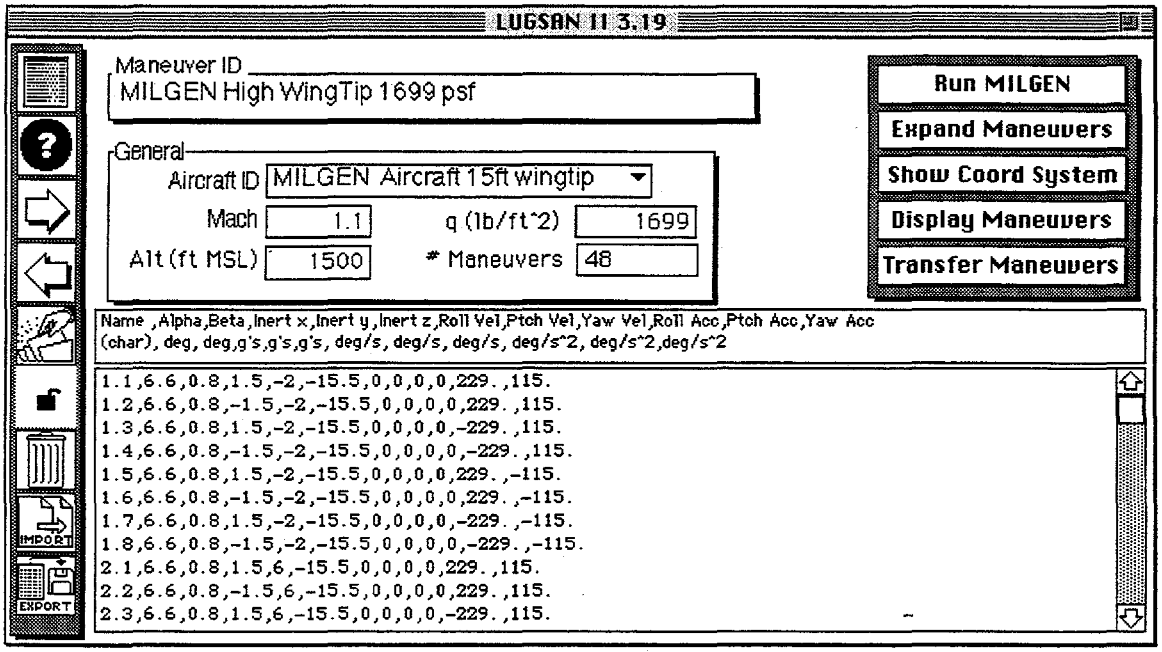


Figure 19. Maneuver Information Screen

Function

The **Maneuver Information** screen (Figure 19) contains the necessary information to define a series of snapshots in time that define a maneuver. Aircraft maneuvers are influenced by the type of aircraft, the Mach, and the altitude. When these parameters are entered, the maneuver data can be entered – comma delimited – until all entries are complete.

> ***Warning*** Altitude must be entered in ft above mean sea level (MSL), ***not*** above ground level (AGL).

Screen Data

Maneuver ID	Name the Maneuver.
Aircraft ID	A pull-down menu of available aircraft in the database.
Mach	The Mach number of the maneuver (assumed constant).
Altitude	The altitude above mean sea level in feet (constant).
Maneuver Description	Descriptions given below.
q	Dynamic pressure (lb/ft^2) calculated by LUGSAN II using Mach and altitude (assuming standard atmosphere).

Maneuver	Units	Description
Alpha	deg	The angle of attack. Nose up is positive.
Beta	deg	The angle of Yaw. Nose right is positive.
Inert x	g's	The G-Load force in the X direction.
Inert y	g's	The G-Load force in the Y direction.
Inert z	g's	The G-Load force in the Z direction.
Roll Vel	deg/s	The angular velocity about the x axis.
Pitch Vel	deg/s	The angular velocity about the y axis.
Yaw Vel	deg/s	The angular velocity about the z axis.
Roll Acc	deg/s^2	The angular acceleration about the x axis.
Ptch Acc	deg/s^2	The angular acceleration about the y axis.
Yaw Acc	deg/s^2	The angular acceleration about the z axis.

Maneuver Information Screen Buttons

Run MILGEN – Runs MILGEN to generate maneuvers for a generic aircraft (see Appendix E).

Expand Maneuvers – Expand shorthand notation to the full set of maneuvers and put them in a temporary maneuver field (see Appendix E).

Show Coord System – Click to show a drawing of the coordinate system.

Display Maneuvers – Click to display the maneuver information in a tabulated spreadsheet.

Transfer Maneuvers – Move maneuvers into archived maneuver field from temporary maneuver field (see Appendix E).

Instructions

Warning If a pull-down menu does not display an aircraft, maneuver, store, or load case that is unequivocally in the database, then a system update must be performed in the **Utilities** screen. Select the Menu Navigator and go to the **Utilities** screen and click the Update All button, which is located in the Programming Utilities area at the bottom of the screen, then return to this screen and select the pull-down menu.

Note The attitude angles, in degrees (alpha and beta), are used solely for interpolation of the aerodynamic coefficients, and thus should be in the SWAY85 aerodynamic coordinate system (see Figures 20 and 21).

Note The angular velocities and accelerations, and the linear acceleration(G-loads), are described in the SWAY85 Force and Moment coordinate system; they are ***not*** described in the aircraft coordinate system.

Warning Inertial loadings represent accelerations in the opposite direction

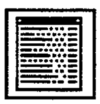
Inertx = 1: a 1 g acceleration in the -x direction, that is deceleration.

Inerty = 1: a 1 g acceleration in the -y direction.

Inertz = 1: a 1 g acceleration in the -z direction.

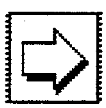
Menu Options

Icons from the screen shown in Figure 19 are described below.

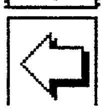


Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to go to that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.



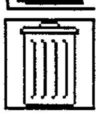
Next Card. Displays the next card within this Function Screen.



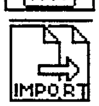
Previous Card. Displays the previous card within this Function Screen

Insert Card. Insert a new card in this Function Screen.

Change data on this card.



Delete this card.



Import a text file that contains the maneuver data.

Export a text file containing the maneuver data.

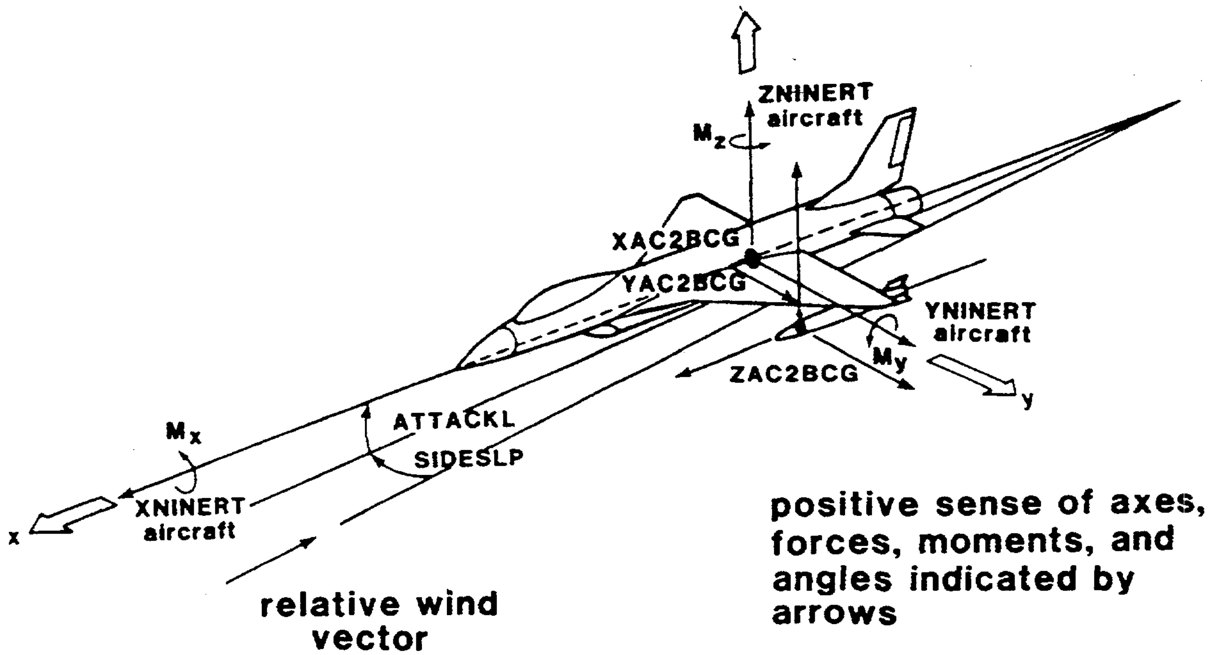


Figure 20. SWAY85 Force & Moment, Maneuver & Aero Coordinate Systems

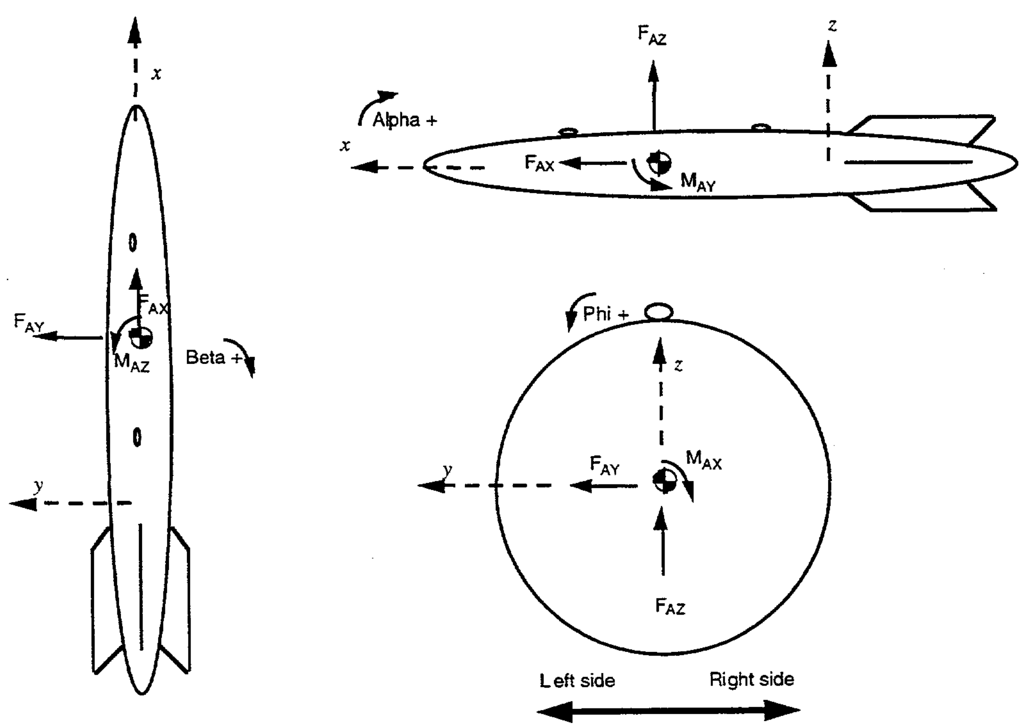


Figure 21. SWAY85 Aerodynamic Coordinate System

Screen Name **Rack Information**

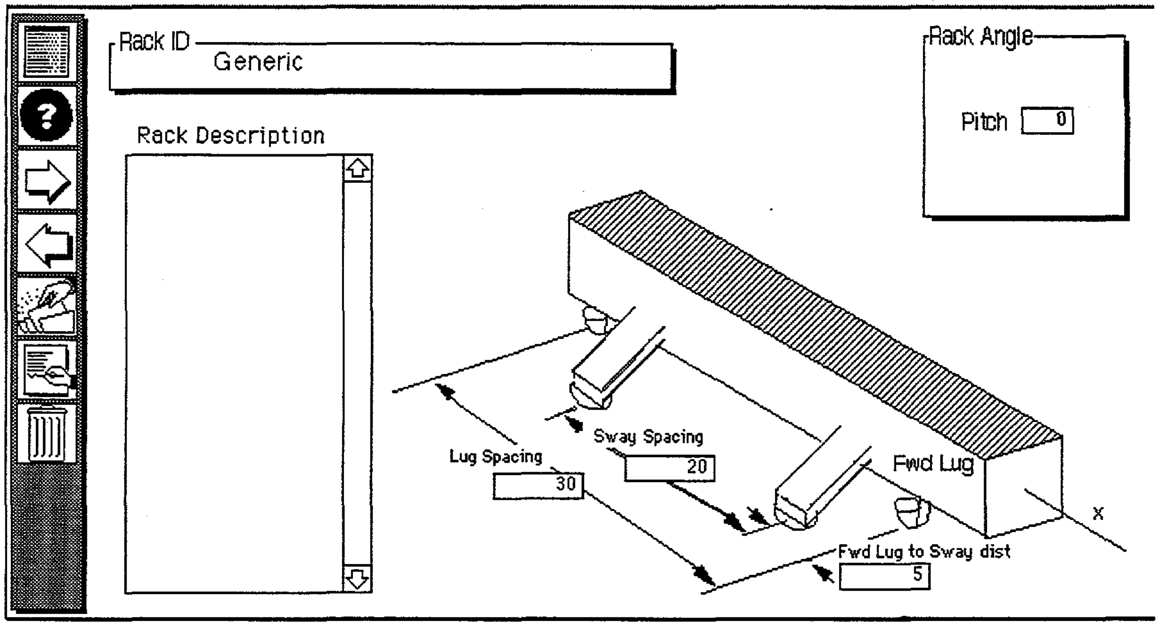


Figure 22. Rack Information Screen

Function

The **Rack Information** screen (Figure 22) contains the rack geometry data. Key information includes the rack name, description, angles, and lug and sway brace spacing.

Screen Data

Rack ID	The user should select a rack name that includes the name commonly used by the aircraft and rack manufacturer.
Rack Description	Enter modifications or references to drawings here.
Rack Angle Pitch	Pitch is about the y axis and is the same as the angle of attack. This feature is not yet available. When available, this angle will be added to the angle of attack of the aircraft to determine the store angle of attack. This uses the SWAY85 Aerodynamic Coordinate System: positive angle = nose up, negative = nose down. Units are in degrees.
Lug Spacing	The distance in inches between the two lugs (always positive).
Sway Spacing	The distance in inches between the sway braces (always positive).
Fwd Lug to Sway distance	The distance from the forward lug and the forward sway brace in inches (positive indicates the forward sway brace is between the lugs).

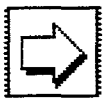
Warning In the **Rack Information** screen, distances are always magnitudes, and thus always positive. Units are always inches. The rack pitch angle (degrees) is positive nose up, negative nose down.

Menu Options

Icons from the screen shown in Figure 22 are described below.

Menu Navigator. Displays a list of the Function Screens. Click a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.

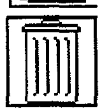


Next Card. Displays the next card within this Function Screen

Previous Card. Displays the previous card within this Function Screen

Insert Card. Insert a new card in this Function Screen.

Change data on this card.



Delete this card.

Screen Name Store Information

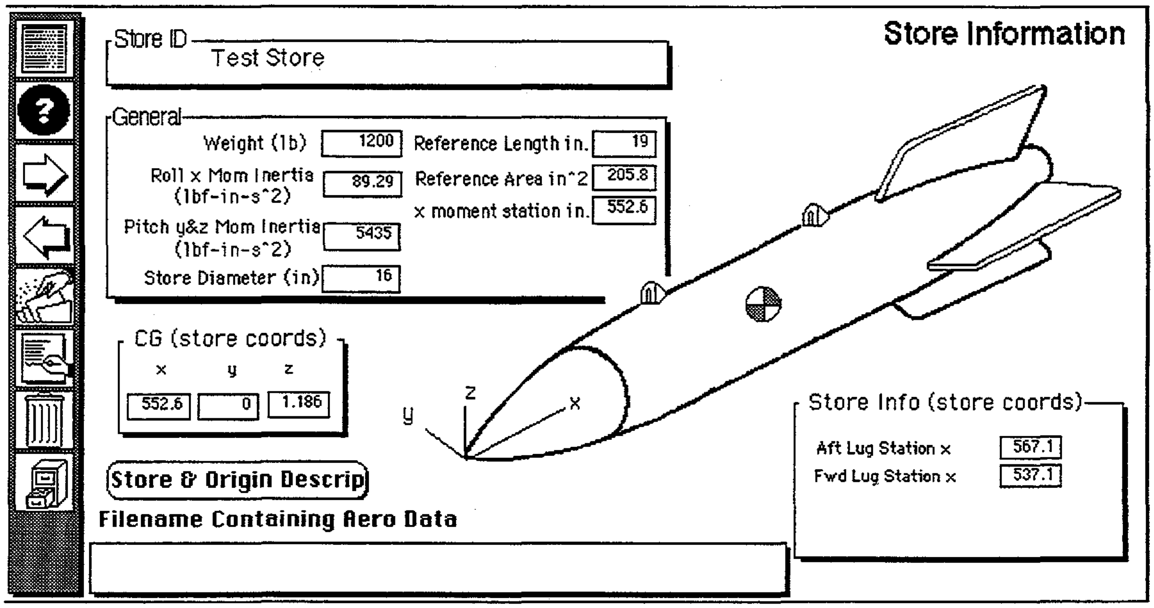


Figure 23. Store Information Screen

Function

The **Store Information** screen (Figure 23) contains the mass, geometry, and aerodynamics information for the store. Data entry is accomplished either by clicking on the fields and entering the data, or by clicking on the store cg and lug icons. If the weight of the store varies (example: full or empty of fuel), then each different weight must be entered as a different store. If the store name was "Store 1," the two cases could be named as "Store 1 full" and "Store 1 empty."

Screen Data

Store ID	Name of the store.
Weight	Weight in lb.
Roll Moment of Inertia	The roll moment of inertia in lbf-in-s^2. Roll is about the store x axis.
Pitch Moment of Inertia	The pitch moment of inertia in lbf-in-s^2. Pitch is about the store y axis.
Store Diameter	Diameter, (***not*** radius) in inches.
Reference Length	Aerodynamic reference length (always positive) in inches.
Reference Area	Aerodynamic reference area (always positive) in inches squared.
X moment station	The store moment station, in inches, about which the force and moment is measured. This quantity is a ***vector*** in the x (longitudinal) direction in the store reference coordinate system, whose origin (0) is the store origin.
CG	x, y, z coordinates of the center of gravity in store coordinates per the picture.

Continued . . .

Store & Origin Descrip	A description of the location of the origin of the axes if not at the store nose. Axes are always oriented per the drawing of the store in this screen.
Filename Data	The name of the file that contains the aerodynamics coefficients.
Aft Lug Station x	The x coordinate of the aft lug location in store coordinates. Per the drawing, x direction is positive from nose to tail.
Fwd Lug Station x	The x coordinate of the fwd lug location in store coordinates. Per the drawing, x direction is positive from nose to tail.

Instructions

Warning The most common user error on this screen is entering store *radius* rather than *diameter*!

Note The store axes are always oriented per the drawing of the store in this screen. The origin of the axes may be forward of the store. If so, this should be noted in the Store & Origin Description field.

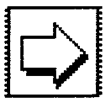
Note The Store Moment of Inertia about the vertical axis (Z) is assumed to be the same as for the lateral axis (Y), Units = lbf-in-s^2.

Menu Options

Icons from the screen shown in Figure 23 are described below.

Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to display that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.

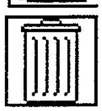


Next Card. Displays the next card within this Function Screen

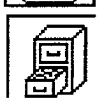
Previous Card. Displays the previous card within this Function Screen

Insert Card. Insert a new card in this Function Screen.

Change data on this card.



Delete this card.



Aerodynamics Field. If this field empty, then select an Aero file. If this field is not empty, then display the filename.

Screen Name **Sway85 Output**

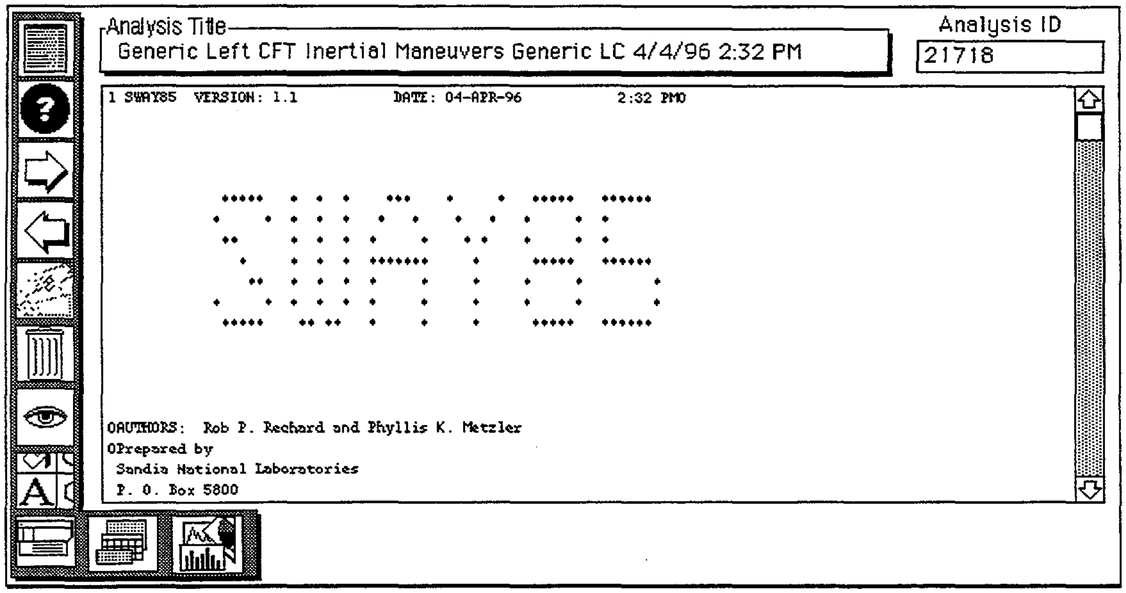


Figure 24. SWAY85 Output Screen

Function

The SWAY85 Output screen (Figure 24) contains the output of the SWAY85 program in two formats: the text directly from the SWAY85 output file and a comma delimited summary of the forces. Click on the icon to toggle between the formats. Shown on the example screen above is the SWAY85 text output format. If this output screen is entered from the view results menu option in the SWAY85 input screen, the output screen will display the results related to that input screen. This can be verified by confirming that both the SWAY85 input and output screens display the same analysis ID.

Screen Data

The text output can be viewed and the user can scroll up or down the screen using the scroll bar. All other actions are accomplished using the menu option icons described below. This is a view-only screen; the user cannot change data on this screen, except to click on the trash can icon to delete (permanently and irretrievably) this card on this screen.

> ***Warning*** All lug and sway brace loads are output using the SWAY85 Force and Moment Coordinate System.

Note Sway brace loads are always negative (compressive) or zero and cannot be positive because they cannot create a tensile load on the store.

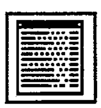
Note The axial load is listed twice in the SWAY85 output text: (1) on the forward and (2) on the aft lug. The axial load is the total lug load in the longitudinal direction, that is, applied only on *either* one of the lugs, but *not both* simultaneously.

Miscellaneous data. Data that the system uses include distribution of yaw moment between the lugs and sway braces. This distribution factor makes the rigid-body force equations determinate.

Note The standard method for handling the yaw moment distribution is to perform calculations first with all the moment and then with no moment carried by the sway braces, thus bounding the indeterminate problem.

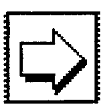
Menu Options

Icons from the screen shown in Figure 24 are described below.

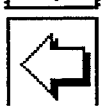


Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to go to that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.



Next Card. Displays the next card within this Function Screen..



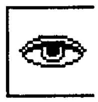
Previous Card. Displays the previous card within this Function Screen.

Continued . . .

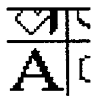
Insert Card. Insert a new card in this Function Screen.

Change data on this card.

Delete this card.

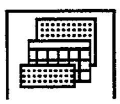


Toggle between viewing the SWAY85 Output and the comma-delimited lug and sway brace Force results, respectively.



Font size. Increase the size of the fonts. (Option-click) to reduce the font size.

Print. Print the Contents of the SWAY85 text ouput field concatenated with the formatted lug and sway forces.



View forces. View the lug and sway forces gleaned and formatted from the SWAY85 text output.

Graph forces. Graph the lug and sway forces gleaned and formatted from the SWAY85 text output.

Screen Name **Help**

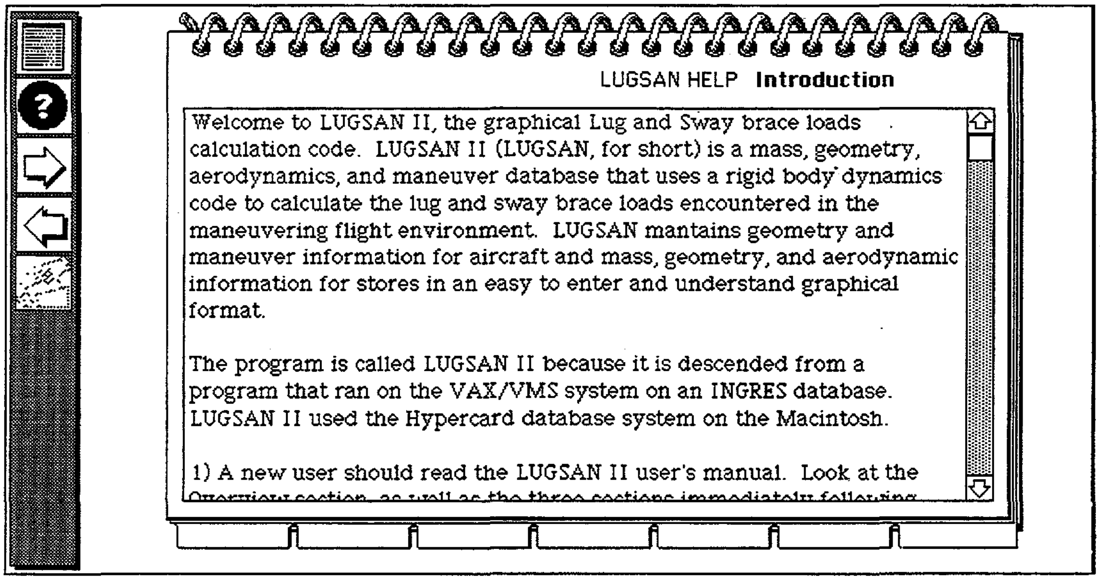


Figure 25. Help Screen

Function

When the icon is clicked in any screen, the user is transferred to the corresponding **Help** screen (Figure 25). That is, if the user clicks on the icon in the **Introduction** screen, LUGSAN will immediately display **LUGSAN HELP: Introduction screen**, which consists of context-sensitive help.

Screen Data

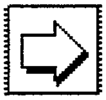
No entries are made in this screen; it is a read-only section.

Menu Options

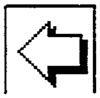
Icons from the screen shown in Figure 25 are described below.

Menu Navigator. Displays a list of the Function Screens. Click on a Function Screen Name to go to that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.



Next Card. Displays the next card within this Function Screen.



Previous Card. Displays the previous card within this Function Screen.

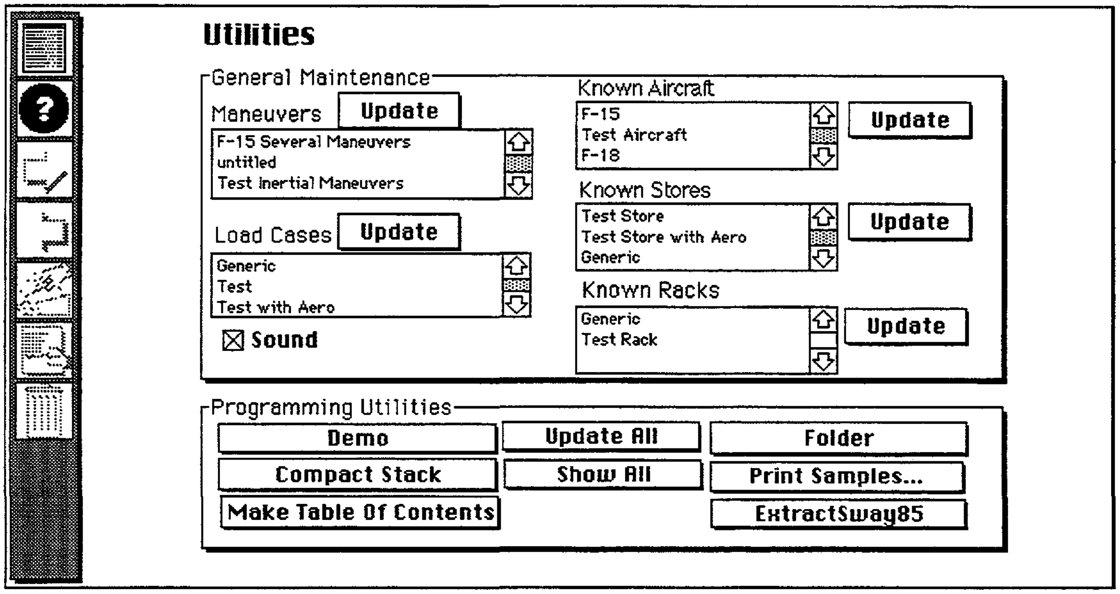


Figure 26. Utilities Screen

Function

The **Utilities** screen (Figure 26) is a collection of fields and buttons that are containers, housekeeping utilities, and maintenance routines. The General Maintenance section keeps track of the Maneuvers, Load Cases, Aircraft, Stores, and Racks available in the database. Click any of the Update buttons to update the names of that particular section. Click the Update All button in the Programming Utilities section to update all files simultaneously. The programming Utilities section contains several buttons (described below in the Screen Data section) that are useful for the operation of the program.

Screen Data: Programming Utilities

Update	Update the names of that particular section. For example, click the Update button that is adjacent to the Maneuvers to search the database and enter the Maneuver names in the Maneuvers field.
Sound	Toggle sound ON and OFF. Checked box indicates sound is ON.
Demo	Click to be fully prepared prior to a LUGSAN demo.
Compact Stack	"Cleans up" the stack and squeezes the inefficient wasted disk space out of your stack. You must have free space on your hard disk that is equal to the current size of the stack.
Make Table of Contents	Click to search all available screens and display them in the Table of Contents field. The Table of Contents field contains the screens that display when the Menu Navigator  icon is clicked.
Update All	Click to update all files simultaneously rather than clicking on each Update button individually.

Continued . . .

Show All	A toggle switch to show the Table of Contents field. The Table of Contents field is a listing of all the screens that the user must be able to navigate when the Menu Navigator icon is clicked. Click the Make Table of Contents button to search all of the available screens and display them in this field. Those screens that the user does not need to access routinely (like Demo) can be edited out so they do not display when the icon is clicked.
Folder	Click to update the directory location of your stack. This is the default location for reads and writes to disk.
Print Samples	Prints a representative card from each screen.
ExtractSway85	A button called from the SWAY85 Information section to extract and format important lug and sway load information from the SWAY85 output files. The user should never have to use this button.

Warning If a pull-down menu does not display an aircraft, maneuver, store, or load case that is unequivocally in the database, then a system update must be performed in the **Utilities** screen. Select the Menu Navigator button and go to the **Utilities** screen and click the Update All button, which is located in the Programming Utilities area at the bottom of the screen, then return to this screen and select the pull-down menu.

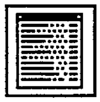
Instructions

When the Make Table of Contents button is clicked, all of the screen names are placed in the Make Table of Contents field in an order that may differ from the Menu Navigator. This field can be viewed using the Show All button and the contents rearranged by cutting and pasting the names into the desired order. It is recommended that "Demo," "Extra," and "Help" be deleted from the list. Also, "Benchmark" may be deleted from the list once you are satisfied with the accuracy of SWAY85 on your platform. The names can be reordered in a more natural order as follows:

- Aircraft Information
- Store Information
- Load Case
- Maneuver Information
- Rack Information
- Sway85 Information
- Sway85 Output
- Utilities
- Introduction

Menu Options

Icons from the screen shown in Figure 26 are described below.



Menu Navigator. Displays a list of the Function Screens from the Table of Contents field located in this screen. Click on a Screen Name to go to that screen.

Help screen. Displays a context-sensitive help screen. This provides caveats and warnings related to your current location.

Appendix A – Aerodynamic Coefficients

Interpolation

The interpolation program is called automatically when an analysis is submitted that includes aeroydynamics and contains maneuvers for which there is not an exact match of the aerodynamic coefficient data. If any of the maneuvers cannot be interpolated, the analysis will not be submitted.

> ***Warning*** The interpolation algorithm used by LUGSAN II will not attempt to *extrapolate* coefficients. There must be sufficient points in the aerodynamic coefficient data to completely surround the independent variables (Mach, α, and β) for each maneuver.

In the event that extrapolation is required, LUGSAN II will report that it *did not find surrounding data points for interpolation* and will not attempt to extrapolate for such maneuvers. The interpolation routine could also fail because of an internal failure, such as detection of a calculation that would result in a division by zero. When these errors occur, LUGSAN II aborts interpolation for the current maneuver and moves on to the next maneuver.

LUGSAN II attempts to detect known problems, such as division by zero; but some errors, such as memory allocation errors, cannot be anticipated easily. As with the other interpolation failures, LUGSAN II aborts interpolation for the current maneuver and moves on to the next maneuver.

Algorithm

Some discussion of the inner workings of the LUGSAN II interpolation mechanism is necessary to understand why it requires a full set of surrounding coefficient points for each maneuver to be interpolated and to understand other limitations of the interpolation routines. The approach is to first sort the store aerodynamic coefficient data, determine which of the coefficient data points are nearest to the maneuver's independent variable values (Mach, a, b), then interpolate using the nearest surrounding points.

For brevity and increased clarity, the store aerodynamic coefficient data will be referred to as "the data points" and the maneuver being interpolated will be "the interpolation point." Further, the independent variable names will be referred to as "z, y, and x" rather than "Mach, α, and β. As the order implies, z corresponds to Mach, y corresponds to β, and x corresponds to α. Also, because all of the aerodynamic coefficients are functions of three independent variables, the values of the aerodynamic coefficients will be referred to as some function, f(x,y,z) rather than f(β,α,Mach). The remainder of this discussion is mathematical in nature and uses the standard notation for a Cartesian coordinate system.

The first step is to determine which data points envelope the interpolation point. For example, in two dimensions, this would be analogous to determine in which quadrant each of the data points is located, with the interpolation point as the origin. (Figure A-1). As the figure shows, some points are clearly in Quadrant 1 and some are in Quadrant 2, but those points that lie on one of the two axes can be regarded as belonging to both quadrants that they touch. Because we are considering functions of three independent variables in LUGSAN II, this concept is expanded to three dimensions, which results in eight "quadrants."

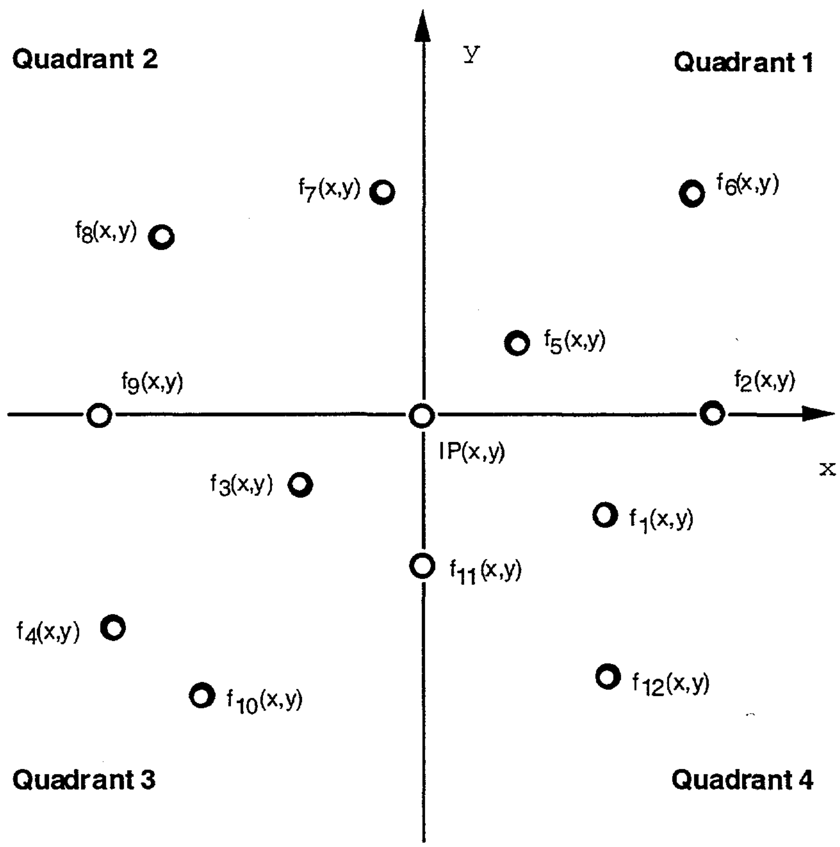


Figure A-1. Interpolation Quadrants

LUGSAN II sorts all of the data points and populates each "quadrant" with those data points that can be considered to fall within each quadrant, with the interpolation point being at the origin. As with the two-dimensional example above, each data point could be in one or more quadrants, depending on whether it touches a quadrant border, if any. After determining which points occupy which quadrants, the distance from each data point to the interpolation point is calculated using the Pythagorean theorem; and the data point that is nearest to the interpolation point is selected from each of the eight quadrants. These eight points are then used to perform the interpolation. The LUGSAN II interpolation process, on the Macintosh, has demonstrated a performance speed improvement of three orders of magnitude over the previous version of LUGSAN.

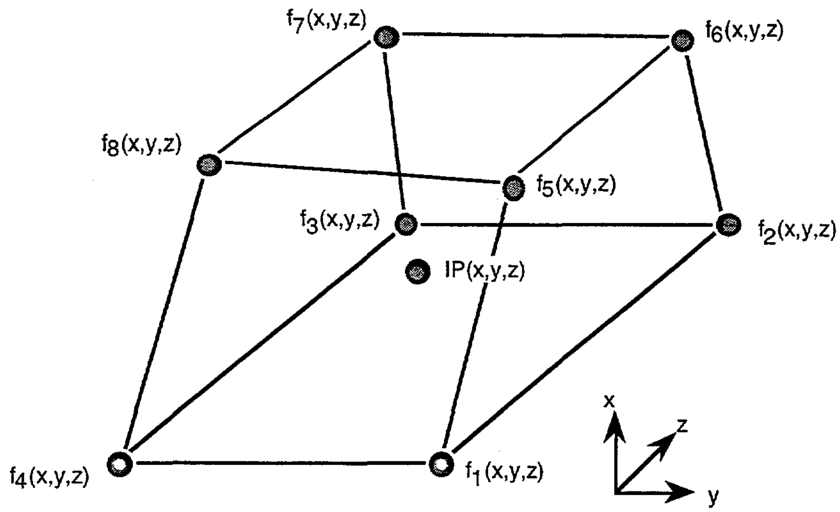


Figure A-2. Surrounding Data

When the LUGSAN II sorting task is complete, it will contain eight data points that completely envelope the interpolation point. These surrounding data points are shown in Figure A-2 as f1, f2, f3, f4, f5, f6, f7, and f8. The interpolation point that is located in the center of the figure is labeled IP. In this figure, the data points are not shown as a perfect cube because the data is not spaced regularly. However, it is important to note that for any given axis, the data points bracket IP. To simplify the diagrams for the following discussion, the fact that the data can be spaced irregularly is not illustrated; instead, these points are shown as though they form a perfect cube, as shown in Figure A-3.

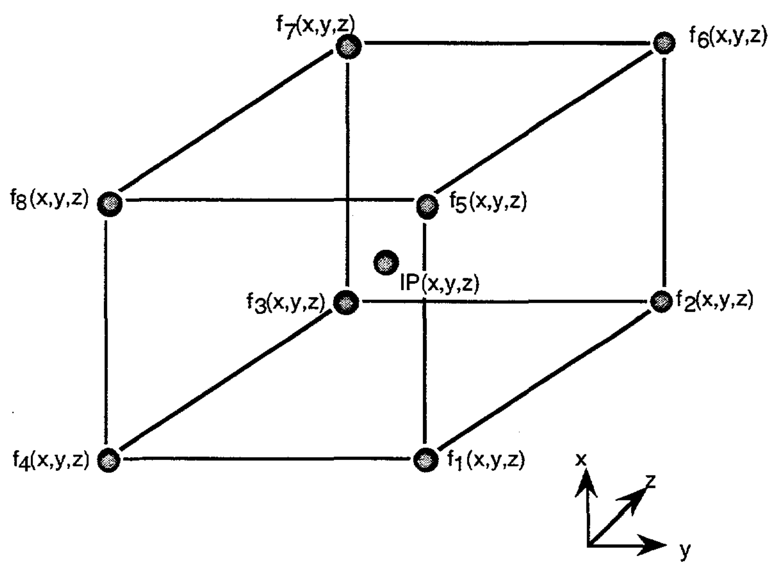


Figure A-3. Interpolation Points

The interpolation process then becomes a trilinear interpolation that is an expansion of the algorithm, which is given in **Numerical Recipes in C**, Cambridge University Press, 1988, pp. 104-106. The principal differences are, however, that the algorithm given in the reference is for two-dimensional (bilinear) interpolation and the algorithm employs gridded (regularly spaced) data only. In addition, it eliminates the assumptions that can be made for gridded data and evaluates each parametric equation of a line in 3-space independently. Finally, the process is repeated in the lower dimensions, 2-space, then as a single linear interpolation along the last axis. Because 4 points (2^n-1) are required for three-dimensional (bilinear) interpolation (functions of 2 variables), 2^3 or 8 data points that "bracket" the interpolation point are required to interpolate for four-dimensional interpolation, f(x,y,z).

The bilinear interpolation essentially determines the parametric equations of the 2 lines that are formed by connecting the 2 sets of points that point in the y direction and evaluates an f(x,y) at the required y value along the y axis, which gives 2 points, f(x1,y) and f(x2,y). Then, it determines the parametric equation of the line between f(x1,y) and f(x2,y) and evaluates at the required x value. The formula that is presented in the reference merely combines the two parametric evaluations along the 2 axes into a single equation (Equation 3.6.5). For non-gridded data, some of the assumptions made in the reference do not hold true; primarily in question is the assumption that the parametric coefficients of the 2 lines in y direction are equal. That is, the parametric equation given for the 2 y direction lines would be y1=t*v1+(1-t)*v4 and y2=u*v2+(1-u)*v3, where t = y-v1y/v4y-v1y and u = y-v2y/v3y-v2y. But for gridded data, v1y = v2y and v4y = v3y, so t = u. When t = u, many of the terms are omitted from the equation, but the same results can be achieved by evaluating successively the parametric equations along each of the axes without losing equal terms. For non-gridded data, no assumptions can be made regarding the equality of y values, so the parametric equations of each line are unique. However, you can use the parametric equations of the lines that point in the y direction, evaluate f(x1,y) and f(x2,y) at the interpolation y value, then repeat the process for the x axis. Again, the only difference with non-gridded data is that none of the parametric coefficients are guaranteed to be equal, so each line must be evaluated with its own parametric equation. The process is then repeated with those new points along the next lowest axis until a single linear interpolation on the last axis is reached.

To illustrate more graphically, the LUGSAN II interpolation algorithm first interpolates along the z axis (which would correspond to Mach number) as shown in Figure A-4. It does this by determining the parametric equations of the lines formed by f_1-f_2, f_5-f_6, f_8-f_7, and f_4-f_3, then evaluating them at the point where they would intersect a plane perpendicular to the z axis and containing the point IP. This will give us points Iz_1, Iz_2, Iz_3, and Iz_4.

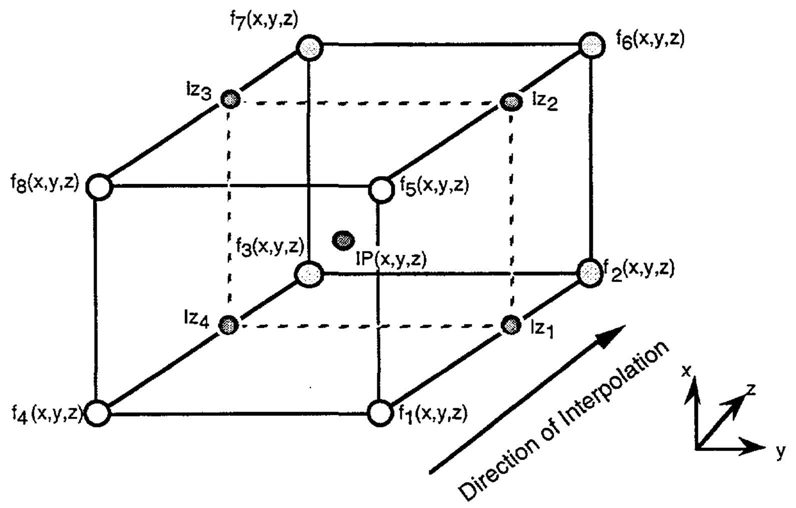


Figure A-4. Interpolation of Mach Number

These four points are then used to interpolate along the y axis (which would correspond to beta) as shown in Figure A-5. It does this by determining the parametric equations of the lines formed by Iz_3-Iz_2 and Iz_4-Iz_1, then evaluating them at the point where they would intersect a plane perpendicular to the y axis and containing the point IP. This will give us points Izy_1 and Izy_2.

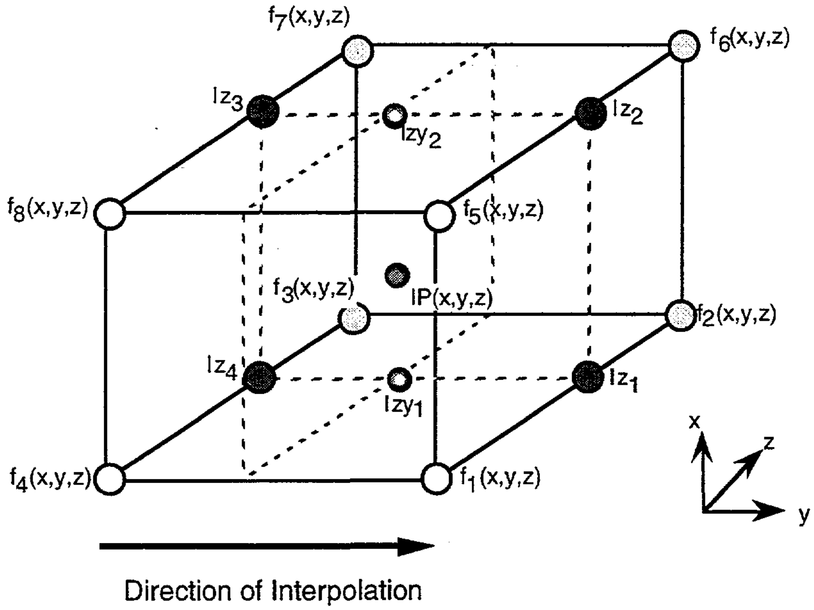


Figure A-5. Interpolation of Beta

Finally, the interpolation algorithm uses Izy_1 and Izy_2 to interpolate along the x axis (which would correspond to alpha) as shown in Figure A-6. It does this by determining the parametric equations of the line formed by Iz_3-Iz_2 and Iz_4-Iz_1, then evaluating them at the point where they would intersect a plane perpendicular to the y axis and containing the point IP. Because all of the dependent variables are carried along with each successive interpolation, the values for the dependent variables that are obtained during the last evaluation will be the dependent variables for the interpolated point, IP (the current maneuver).

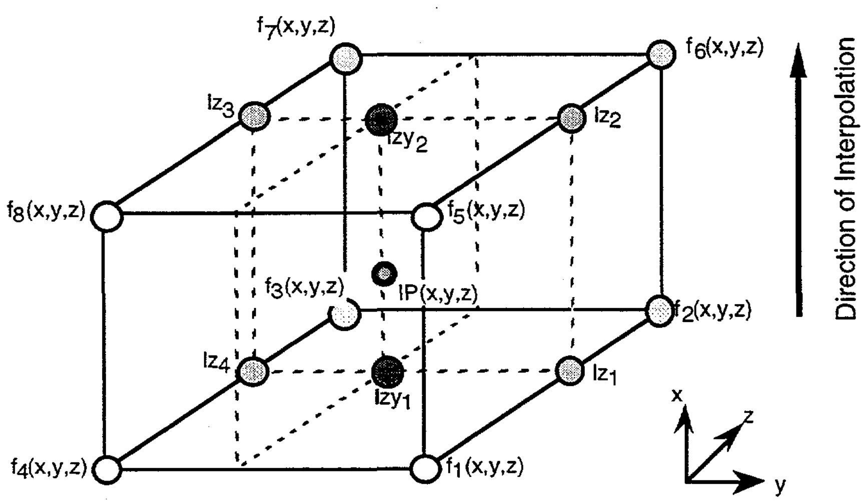


Figure A-6. Interpolation of Alpha

A sample store aerodynamic data file is shown in Table A-1.

Table A-1. Store Aerodynamic Data File Format

```
Sample data set
Number of Machs in dataset – 3

1st Mach,Number of aerocoeffs
0.,12
alpha,beta,Cx,Cy,Cz,Cmx,Cmy,Cmz
0.,1.,1.,1.,1.,1.,1.,1.
0.,2.,1.,1.,1.,1.,1.,1.
0.,3.,1.,1.,1.,1.,1.,1.
1.,1.,1.,1.,1.,1.,1.,1.
1.1,2.2,0.5,0.0,1.,1.,1.,1.
1.4,3.7,0.0,0.5,1.,1.,1.,1.
2.,1.,0.873,1.,1.,1.,1.,1.
2.3,2.5,0.675,1.,1.,1.,1.,1.
2.2,3.9,1.0,0.5,1.,1.,1.,1.
3.,1.,1.,1.,1.,1.,1.,1.
3.,2.,1.,1.,1.,1.,1.,1.
3.,3.,1.,1.,1.,1.,1.,1.
2nd Mach, Number of aerocoeffs
1.,12
alpha,beta,Cx,Cy,Cz,Cmx,Cmy,Cmz
0.,1.,1.,1.,1.,1.,1.,1.
0.,2.,1.,1.,1.,1.,1.,1.
0.,3.,1.,1.,1.,1.,1.,1.
1.,1.,1.,1.,1.,1.,1.,1.
1.,2.,1.,1.,1.,1.,1.,1.
1.,3.,1.,1.,1.,1.,1.,1.
2.,1.,1.,1.,1.,1.,1.,1.
2.,2.,1.,1.,1.,1.,1.,1.
2.,3.,1.,1.,1.,1.,1.,1.
3.,1.,1.,1.,1.,1.,1.,1.
3.,2.,1.,1.,1.,1.,1.,1.
3.,3.,1.,1.,1.,1.,1.,1.
3rd Mach, Number of aerocoeffs
1.5,12
alpha,beta,Cx,Cy,Cz,Cmx,Cmy,Cmz
0.,1.,1.,1.,1.,1.,1.,1.
0.,2.,1.,1.,1.,1.,1.,1.
0.,3.,1.,1.,1.,1.,1.,1.
1.,1.,1.,1.,1.,1.,1.,1.
1.,2.,1.,1.,1.,1.,1.,1.
1.,3.,1.,1.,1.,1.,1.,1.
2.,1.,1.,1.,1.,1.,1.,1.
2.,2.,1.,1.,1.,1.,1.,1.
2.,3.,1.,1.,1.,1.,1.,1.
3.,1.,1.,1.,1.,1.,1.,1.
3.,2.,1.,1.,1.,1.,1.,1.
3.,3.,1.,1.,1.,1.,1.,1.
```

As shown in Table A-1, the aerodynamic file format is an ASCII file whose format includes titles for readability. The control file (Table A-2) is used to provide the interpolation program with instructions.

Table A-2. Interpolation Control File (Input.dat).

One test case	< - - **Instruction Title**
AERO.DAT	< - - **Name of the file containing the Aerodynamic Coefficients**
Mach,Alpha,Beta	< - - **Title for listing that follows**
.3,1.9,2.1	< - - **First Mach, Alpha, Beta to interpolate**
etc.	< - - **Next Mach, Alpha, Beta to interpolate (until EOF).**

The results are output to a file called `OUTPUT.DAT`, formatted as follows.

```
Mach,Alpha,Beta,Cx,Cy,Cz,Cmx,Cmy,Cmz
   0.300, 1.900, 2.100, 0.773, 0.818, 1.000, 1.000, 1.000, 1.000
```

Finally, a programmer's status file, `DEBUG.DAT` is output when the interpolation program is run. `DEBUG.DAT` provides a step-by-step program echo to resolves errors.

Appendix B – Memo Comparing Wind Tunnel Coordinate System

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: August 5, 1987

to: ~~R.E. Tate, 1554~~

from: D.B. Landrum and W.H. Rutledge, 1555

subject: Coordinate Systems Used in SWERVE Aerodynamic Analysis

Recently, some confusion has developed over what axis system the Aerodynamics Department uses for the SWERVE aerodynamic analysis. This memo will discuss several possible systems which are valid depending on what characteristics are desired. This memo should also be used as a guideline for future wind tunnel test agents and contractors.

In general, a minimum of two aerodynamic angles are required to define a body's orientation relative to the velocity vector. For a missle configuration, which usually has several planes of symmetry, it is most convenient to consider use of the total angle of attack, α_T, and the aerodynamic roll angle, φ, to relate the velocity vector to the vehicle. The total angle of attack is the angle between the velocity vector and the centerline of the body (usually the x-axis). Therefore, α_T is defined in a plane which contains the aerodynamic lift vector of the vehicle (i.e., the lift plane). The aerodynamic roll angle defines the rotation angle of the lift plane about the body centerline relative to some body location (usually the top of the vehicle). Such a system is called an $\alpha_T - \varphi$ system. This is in contrast to the more traditional airplane system in which angle of attack, α, in the body's longitudinal plane is the primary aerodynamic angle and is complemented by a small sideslip angle, β, which subtends the α-plane and the velocity vector.

The Airplane or Etkin axis system is illustrated in Figure 1. This figure shows the body axes, x,y,z; the total velocity vector $\overline{V}_\infty$; and the orthognal components of this vector, $\overline{u}, \overline{v}, \overline{w}$. The angle of attack, α, is defined as the angle between the body's centerline (x-axis) and the projection of the velocity vector in the longitudinal or x-z plane. The sideslip angle, β, is defined between this x-z plane velocity projection and the total velocity vector. Note that this $\alpha - \beta$ system can be transformed to an $\alpha_T - \varphi$ system if it is so desired. The α and β angles are defined in Figure 1 in terms of the total velocity and its components and the total angle of attack and roll angle.

Another possible axis system is called the Body-Aero system and is shown in Figure 2. Here α is an angle measured between the total velocity vector and its projection in the body's lateral or x-y plane. β is then defined as an angle which subtends the region from the x-axis to the x-y plane velocity projection. Again, this $\alpha - \beta$ system can be related to the $\alpha_T - \varphi$ system. Figure 2 defines the Body-Aero α and β angles in terms of the total velocity and its components and the total angle of attack and roll angle.

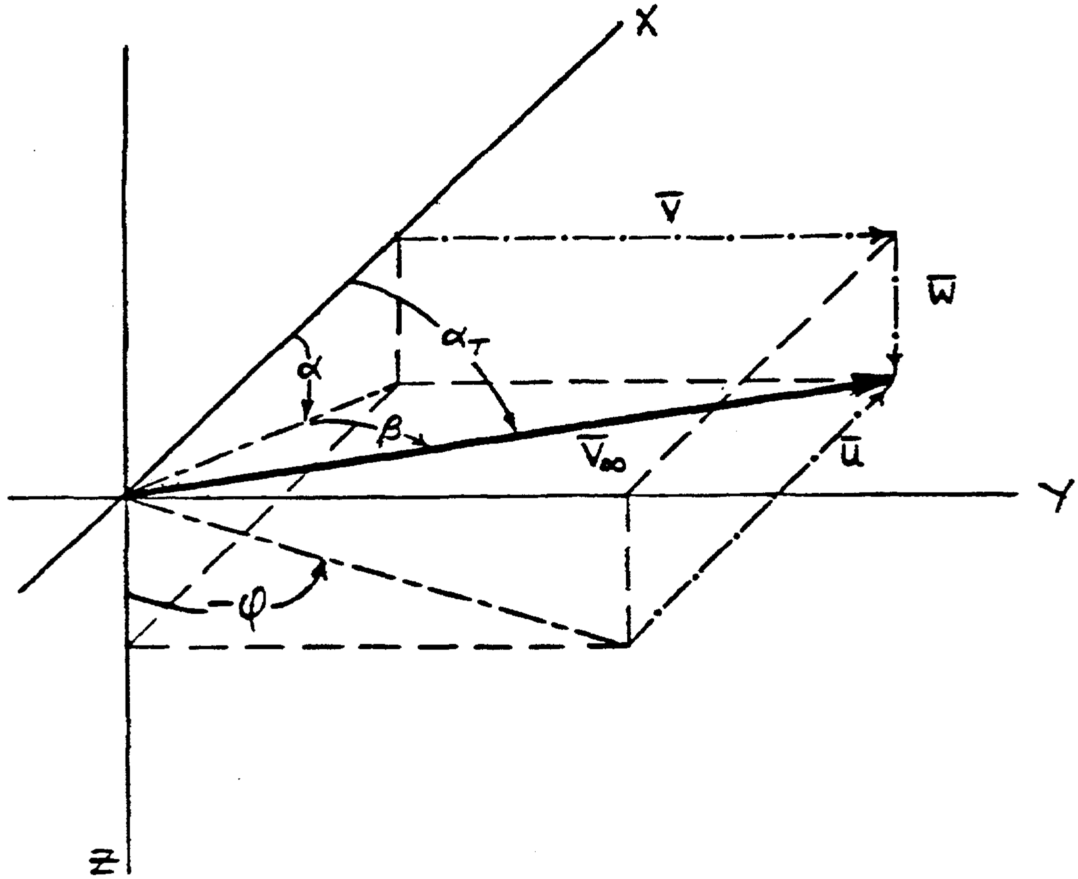
The $\alpha - \beta$ axis system chosen by Sandia has been designated the Plane system. This system is similar to both the Etkin and Body-Aero systems. Both α and β are referenced to the roll or x-axis of the vehicle. As shown in Figure 3, α is the angle between the x-axis and the total velocity projection in the x-z (longitudinal) plane. β is the angle from the x-axis to the projection of the total velocity vector in the x-y (lateral) plane. This system is defined in terms of the total velocity components and the total angle of attack and roll angle in Figure 3. Note that the definition of α is the same in both the Plane and Etkin (Airplane) systems. However, in the Plane system, β is equivalent to the "projection" of the Etkin β angle into the x-y plane.

One difficulty with the Plane system is that velocity-to-body transformations cannot be determined by successive axis rotations since both α and β originate from the x-axis. This means that a straightforward direction-cosine transformation cannot be used to move from a body axis to a stability axis system. The most useful characteristic of the Plane system is that at a roll angle of $\varphi = -45°$, α and β are the same. This implies that for this roll orientation and a given angle of attack, the body normal and side forces are the same. The Plane angle definition better represents how missle-type geometries "fly" along a given flight path. It also simplifies aerodynamic definitions and derivatives for vehicles which fly in the "x" orientation.

It should be noted that for small angle approximations (small α_T), all three of these axis systems are equivalent. This is shown in Figure 4. Also, these systems are arbitrary. Many other systems could be devised which are just as valid as these and such systems may yield more tractable characteristics for a particular problem. An example is given of a non-standard system in Figure 5. Here α is defined like that of the Body-Aero system, while β is that of the Etkin system. This system may appear awkward, but it is still a valid system.

This memo discusses several possible coordinate system choices for aerodynamic analysis. It also demonstrates that the choice of an $\alpha - \beta$ system is not unique. However, for most applications of maneuvering reentry vehicles, it is convenient to consider aerodynamics in an $\alpha_T - \varphi$ system. This is called a "missle" axis system that rolls with the windward ray as opposed to a body fixed $\alpha - \beta$ system. The confusion in the past has been with which body-fixed $\alpha - \beta$ system Sandia uses. Hopefully, this memo has eliminated further confusion by describing the Plane $\alpha - \beta$ system used at Sandia and its advantages as related to the SWERVE geometry. If any further questions arise, please feel free to contact us at 844-0119.

DBL:1555



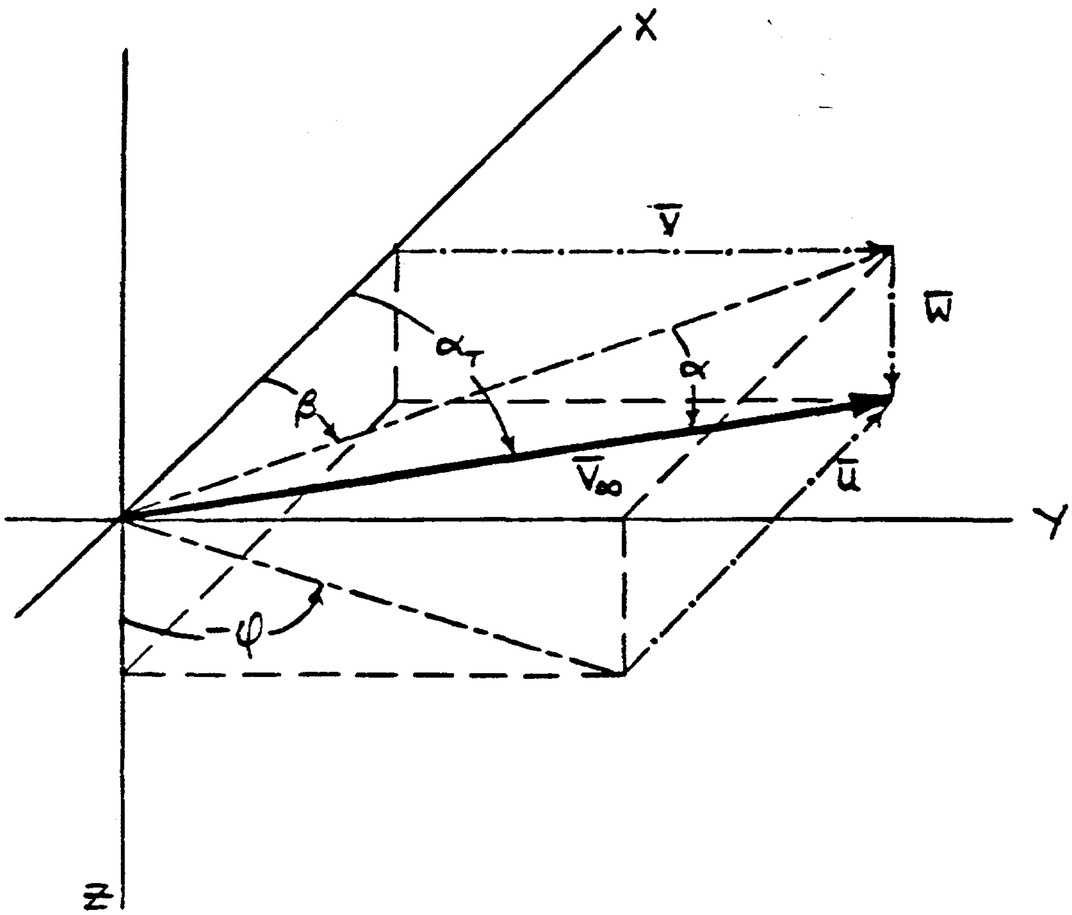
$$u = V_\infty \cos\beta \cos\alpha \quad = V_\infty \cos\alpha_T$$
$$V = V_\infty \sin\beta \quad = -V_\infty \sin\alpha_T \sin\varphi$$
$$W = V_\infty \cos\beta \sin\alpha \quad = V_\infty \sin\alpha_T \cos\varphi$$

$$\tan\alpha = \frac{W}{u} = \tan\alpha_T \cos\varphi$$

$$\sin\beta = \frac{V}{V_\infty} = -\sin\alpha_T \sin\varphi$$

Figure 1 Etkin Axis System

(also known as Airplane System)

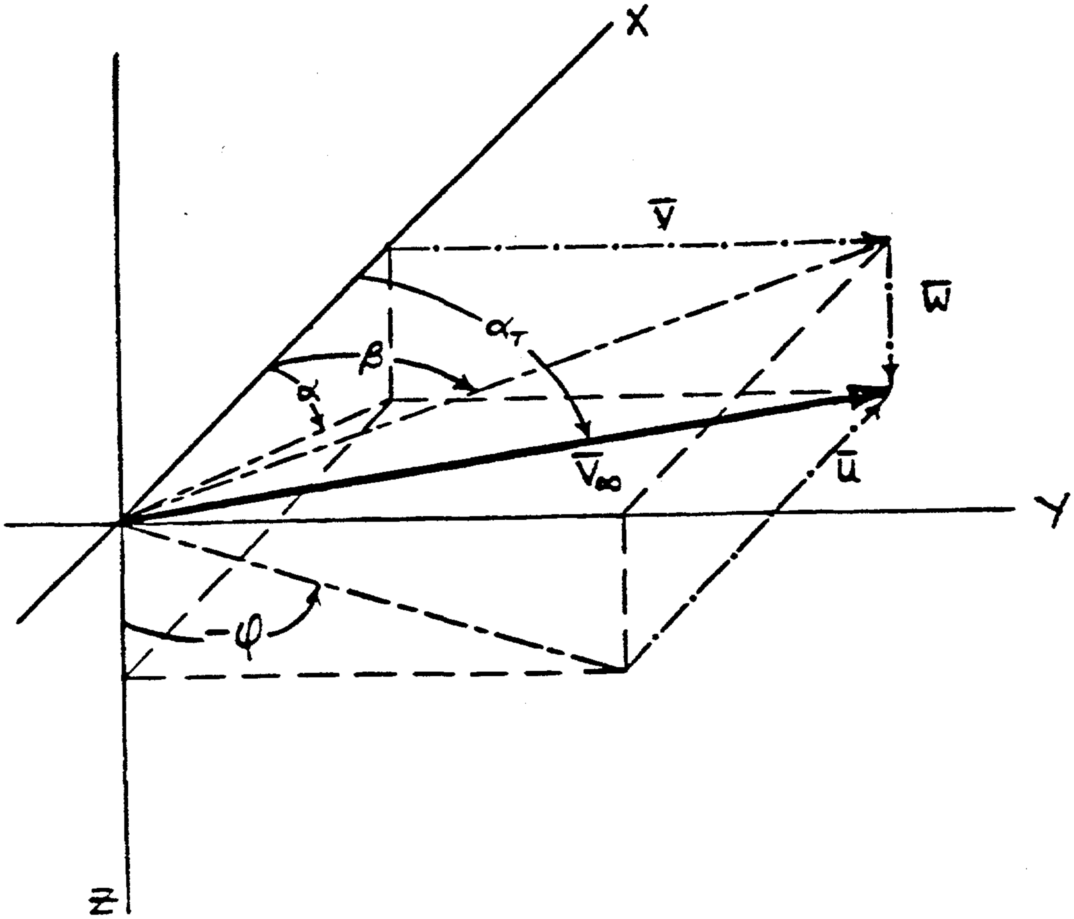


$$u = V_\infty \cos\alpha \cos\beta \quad = V_\infty \cos\alpha_T$$
$$v = V_\infty \cos\alpha \sin\beta \quad = -V_\infty \sin\alpha_T \sin\varphi$$
$$w = V_\infty \sin\alpha \quad = V_\infty \sin\alpha_T \cos\varphi$$

$$\sin\alpha = \frac{w}{V_\infty} = \sin\alpha_T \cos\varphi$$

$$\tan\beta = \frac{v}{u} = -\tan\alpha_T \sin\varphi$$

Figure 2 Body-Aero Axis System



$$u = V_\infty \cos\alpha \cos\beta / [1 - \sin^2\alpha \sin^2\beta]^{1/2} = V_\infty \cos\alpha_T$$

$$v = V_\infty \cos\alpha \sin\beta / [1 - \sin^2\alpha \sin^2\beta]^{1/2} = -V_\infty \sin\alpha_T \sin\varphi$$

$$w = V_\infty \sin\alpha \cos\beta / [1 - \sin^2\alpha \sin^2\beta]^{1/2} = V_\infty \sin\alpha_T \cos\varphi$$

$$\tan\alpha = \frac{w}{u} = \tan\alpha_T \cos\varphi$$

$$\tan\beta = \frac{v}{u} = -\tan\alpha_T \sin\varphi$$

For $\varphi = -45°$, $\alpha = \beta$

Figure 3 Plane (Sandia) Axis System

Plane	Etkin	Body-Aero
$\tan\alpha = \tan\alpha_T \cos\varphi$	$\tan\alpha = \tan\alpha_T \cos\varphi$	$\sin\alpha = \sin\alpha_T \cos\varphi$
$\tan\beta = -\tan\alpha_T \sin\varphi$	$\sin\beta = -\sin\alpha_T \sin\varphi$	$\tan\beta = -\tan\alpha_T \sin\varphi$

Assume α_T Small
(hence α and β small)

$$\alpha = \alpha_T \cos\varphi$$

$$\beta = -\alpha_T \sin\varphi$$

$$\Rightarrow \alpha_T = \sqrt{\alpha^2 + \beta^2}$$

$$\varphi = \tan^{-1}\left(\frac{-\beta}{\alpha}\right)$$

or

$$\varphi = \cos^{-1}\left(\frac{\alpha}{\alpha_T}\right)$$

Figure 4 Summary

Appendix C – Programmer's Reference

While this document is not intended to be a programmer's reference, including an overview of the code was considered a necessity. Figure C-1 shows a flowchart of the workings of LUGSAN II. The block diagram within the gray background is written in HyperTalk, the programming language of Hypercard. HyperTalk is a user readable object-oriented programming language that is easily learned, and simple to program, yet extremely powerful. An interested user can have a working knowledge of the language in about one week by viewing the training video tapes available from MacAcademy, and practicing writing simple code, called scripts. A good reference book on the Hypercard Language is *The Complete Hypercard 2.2 Handbook* by Danny Goodman.

Embedded within the program are XFCNs (pronounced "X functions") and XCMDs (pronounced "X commands") that extend the functionality of the HyperTalk language. This makes the language "open ended," which allows the user to customize it to specific needs. Several XFCNs and XCMDs from Rinaldi's archive and the Dartmouth collections were used to extend the functionality of LUGSAN II.

XCMD Chartoid
XCMD FullBalloons
XCMD PICToid
XCMD EraseFile
XCMD FileToField
XCMD FullMove
XCMD Tabloid
XCMD Textoid

and several XFCNs:

XFCN ListSelect
XFCN SelectDir
XFCN FullReplace
XFCN IsFile
XFCN IsFolder
XFCN FullHPop
XFCN FullResList
XFCN Align

Finally, Hypercard can call external programs. Two FORTRAN programs are called by Hypercard. The first one, MABINTP (Mach, Alpha, Beta, INTerPolate), was written to expedite the interpolation process. The interpolation process is discussed in detail in Appendix A. The second external program, SWAY85, is the original code used on the VAX, ported to the Macintosh. LUGSAN II simply writes out the necessary input files for these codes, calls them, and when they finish, LUGSAN II reads in their output.

The Aircraft, Store, Maneuver, Rack, and Load Case screens are data storage areas with each card on the screen containing information pertaining to a specific item. For example, the Aircraft and Store screen utilizes Hypercard's graphical user interface. The Maneuver and Rack screen simply contains fields of data. The Load Case screen has a rotary launcher that displays graphically the orientation of the store on the rotary launcher (or hides the whole rotary launcher display if the aircraft does not have a rotary launcher). The real meat of the code that assembles all of the various data from the cards is found in the SWAY85 Information screen. The background script contains a routine (called a handler) called MakeSway85InputFile, which is responsible for the assembly process. This routine reads the necessary data from all of the cards, interpolates if necessary, then makes a SWAY85 input file, runs SWAY85, and finally reads the SWAY85 output back into the SWAY85 Output area.

There are several important functions written within LUGSAN II:

function FindLine
function RemoteFindLine
function FindCard
function FindAllCards
function ExpFormat
function DeSpace
function GetRackandStoreGeometry
function GetTransferData
function GetManeuverData
function HandleInterpolation
function readAeroData
function FindAeroData
function FindHandlers
function FindRsrc
function FindAllLCs

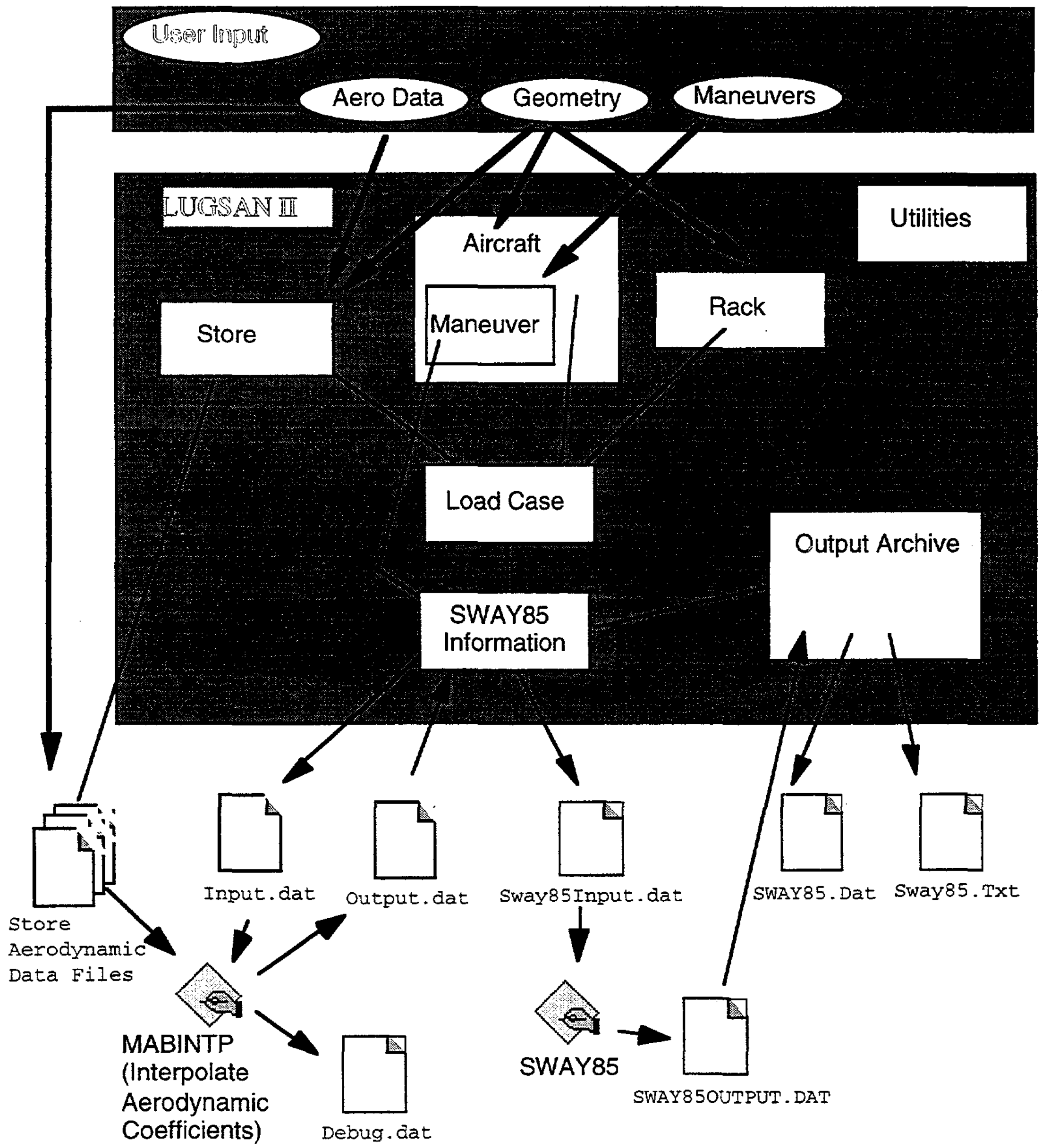


Figure C-1. Flowchart of LUGSAN II Program Execution

Appendix D – Benchmark Input Error in SWAY85 Manual

The SWAY85 code on the Macintosh was run with example cases included in the SWAY85 manual to verify the accuracy of the output. Example cases were fortunately included in the manual. Example case 1 was chosen as the most relevant to the specific kinds of calculations for which LUGSAN II will be using SWAY85. Unfortunately, Example 1 shows three different inputs for the same output: The diagram shows the y and z aero moment loads as -85000 and 42000, the input file shows -84000 and 42000, and the output results echo the input as -85000 and 44500. The Macintosh version of SWAY85 was run using the Example 1 input file using each of these three inputs. Table D-1 shows the results using the input file y and z aero moments: -84000 and 42000. The Table D-1 lug and sway forces agree exactly with those shown in the SWAY85 manual, which indicates that this is the correct input to use as a benchmark. Table D-2 shows the results using the drawing aero moment loads, and Table D-3 shows the results using the output results echo. Neither Table D-2 nor D-3 lug and sway forces agree with those echoed in the SWAY85 manual. Therefore, the input parameters documented in Table D-1 are those used in the benchmark section of LUGSAN II.

Table D-1. Lug and Sway Forces using Pg 67 Example 1 Input File

```
     0*****************************************************************************************
**********
```

From the example 1 input file pg 67 SWAY85 manual.

This matches the output lug and sway forces shown on pg 67.

```
     0*****************************************************************************************
**********
     0TITLE IS:          Example 1-hypothetical store with two lugs
     0MANEUVER TITLE:   Hypothetical maneuver                                                    PLOTKEY:   1STEXAMPLE

                         FLIGHT CONDITIONS
       XNINERTIA   YNINERTIA   ZNINERTIA    XANGVEL      YANGVEL      ZANGVEL     XANGACCEL    YANGACCEL    ZANGACCEL
     .   1.500E+00   7.500E+00  -6.000E+00   0.000E-01    0.000E-01    0.000E-01    0.000E-01  -2.292E+02    1.146E+02

                       AERODYNAMIC COEFFICIENTS
         AMACH       ALTITUDE     WINGSWP    ATTACKLL     SIDESLP      QDYNPRE     AIRLNGTH     AIRAREA     AIRCGSTA
       1.000E+00   1.000E+00   0.000E-01   0.000E-01   0.000E-01   1.000E+00   1.000E+00   1.000E+00   5.954E+01
         XCAIR       YCAIR       ZCAIR       XAIRMOM      YAIRMOM      ZAIRMOM
     .   5.000E+02   2.500E+03   1.000E+03  -4.000E+03  -8.400E+04   4.200E+04


      SAFEFAC =   0.100E+01
     0*********************************************************************************************************
                        Following data passed all error checks. Included in sieve output.
       ******************************************************************************************************
     0   SWAYFRC       AXIAL     FORWARD LUG                                          AFT LUG
                             LOAD      --------------FORCES--------------     SAFETY     --------------FORCES--------------
SAFETY
                                         SIDE        VERTICAL     RESULTANT     MARGIN        SIDE        VERTICAL      RESULTANT
MARGIN
        4.500E-01    2.000E+03   -2.141E+03    1.123E+04    1.143E+04    0.000E-01    1.878E+03    4.913E+03    5.260E+03
0.000E-01
     0                SWAY BRACE FORCES-----------------------------      MINIMUM
                      FWD LEFT     FWD RT      AFT LEFT     AFT RT      SFTY MARG
     .   6.173E+03    0.000E-01   -2.624E+02    0.000E-01    0.000E-01
```

Table D-2. Lug and Sway Forces using Pg 65 Example 1 Drawing Forces

```
      0*********************************************************************************************
**********
```

From the example 1 drawing pg 65 SWAY85 manual

```
      0*********************************************************************************************
**********
      0TITLE IS:          Example 1-hypothetical store with two lugs
      0MANEUVER TITLE:  Hypothetical maneuver                                                                   PLOTKEY:   1STEXAMPLE

                            FLIGHT CONDITIONS
        XNINERTIA    YNINERTIA    ZNINERTIA      XANGVEL       YANGVEL       ZANGVEL      XANGACCEL    YANGACCEL    ZANGACCEL
      .   1.500E+00    7.500E+00   -6.000E+00     0.000E-01     0.000E-01     0.000E-01     0.000E-01   -2.292E+02    1.146E+02

                          AERODYNAMIC COEFFICIENTS
          AMACH      ALTITUDE      WINGSWP      ATTACKLL       SIDESLP       QDYNPRE      AIRLNGTH      AIRAREA      AIRCGSTA
        1.000E+00    1.000E+00    0.000E-01    0.000E-01     0.000E-01    1.000E+00    1.000E+00     1.000E+00    5.954E+01
          XCAIR        YCAIR        ZCAIR       XAIRMOM       YAIRMOM       ZAIRMOM
      .   5.000E+02    2.500E+03    1.000E+03   -4.000E+03    -8.500E+04     4.200E+04


       SAFEFAC =    0.100E+01
      0**************************************************************************************************
                      Following data passed all error checks. Included in sieve output.
        **************************************************************************************************
      0   SWAYFRC        AXIAL     FORWARD LUG                                         AFT LUG
                          LOAD          --------------FORCES--------------      SAFETY       --------------FORCES--------------
SAFETY
                                          SIDE         VERTICAL      RESULTANT     MARGIN        SIDE         VERTICAL      RESULTANT
MARGIN
        4.500E-01     2.000E+03    -2.154E+03     1.122E+04     1.142E+04     0.000E-01     1.891E+03     4.926E+03     5.276E+03
0.000E-01
      0                  SWAY BRACE FORCES-----------------------------        MINIMUM
                        FWD LEFT      FWD RT     AFT LEFT      AFT RT        SFTY MARG
      .   6.192E+03    0.000E-01   -2.491E+02    0.000E-01    0.000E-01
```

Table D-3. Lug and Sway Forces using Pg 67 Example 1 Results Printout Forces

```
      0**************************************************************************************************
```

From the example 1 output printout pg 67 SWAY85 manual

```
      0**************************************************************************************************
      0TITLE IS:          Example 1-hypothetical store with two lugs
      0MANEUVER TITLE:  Hypothetical maneuver                                                                   PLOTKEY:   1STEXAMPLE

                            FLIGHT CONDITIONS
        XNINERTIA    YNINERTIA    ZNINERTIA      XANGVEL       YANGVEL       ZANGVEL      XANGACCEL    YANGACCEL    ZANGACCEL
      .   1.500E+00    7.500E+00   -6.000E+00     0.000E-01     0.000E-01     0.000E-01     0.000E-01   -2.292E+02    1.146E+02

                          AERODYNAMIC COEFFICIENTS
          AMACH      ALTITUDE      WINGSWP      ATTACKLL       SIDESLP       QDYNPRE      AIRLNGTH      AIRAREA      AIRCGSTA
        1.000E+00    1.000E+00    0.000E-01    0.000E-01     0.000E-01    1.000E+00    1.000E+00     1.000E+00    5.954E+01
          XCAIR        YCAIR        ZCAIR       XAIRMOM       YAIRMOM       ZAIRMOM
      .   5.000E+02    2.500E+03    1.000E+03   -4.000E+03    -8.500E+04     4.450E+04


       SAFEFAC =    0.100E+01
      0**************************************************************************************************
                      Following data passed all error checks.  Included in sieve output.
        **************************************************************************************************
      0   SWAYFRC        AXIAL     FORWARD LUG                                         AFT LUG
                          LOAD          --------------FORCES--------------      SAFETY       --------------FORCES--------------
SAFETY
                                          SIDE         VERTICAL      RESULTANT     MARGIN        SIDE         VERTICAL      RESULTANT
MARGIN
        4.500E-01     2.000E+03    -2.186E+03     1.132E+04     1.153E+04     0.000E-01     1.923E+03     4.839E+03     5.207E+03
0.000E-01
      0                  SWAY BRACE FORCES-----------------------------        MINIMUM
                        FWD LEFT      FWD RT     AFT LEFT      AFT RT        SFTY MARG
      .   6.239E+03    0.000E-01   -2.161E+02    0.000E-01    0.000E-01
```

Appendix E – MILGEN

Most general analyses are accomplished using the MILGEN maneuver generation code, which generates 384 generic maneuvers that define the performance envelope of a typical aircraft. These maneuvers can be run through SWAY85 to estimate conservative lug and sway brace loads for most general aircraft. MILGEN uses the calculation techniques of *MIL-A-8591H,* Amendment 5, 14 August 1987.

MILGEN

Sometimes the specific performance capabilities of an aircraft are not completely known. In this case, one of two options can be chosen, as follows. (1) If aircraft performance limits are known, worst-case combined maneuver envelopes can be used, or (2) If only a limited amount of information about the aircraft is known, estimates obtained from generic aircraft found in MIL-A-8591H can be used. These "bounding" analyses are accomplished using MILGEN, which can be accessed from the "Run MILGEN" button on the Maneuver screen.

Expand Maneuvers

The first option (entering the bounding performance limits) is facilitated using the **Expand Maneuvers** button. Simply enter the performance envelopes using shorthand notation (+-180) or (+180/-150) in the manuever field. For example, one line could be entered into the field as follows:

```
RPUW1,8.3,+-1.5,+3/-2,1,10.6,0,0,0,0,+-172,+-115
```

Each of the entries containing a "+-" or a "/" is a shorthand number. The shorthand entries can be expanded into all the permutations using the **Expand Maneuvers** button. Up to four shorthand numbers can be entered in one line, and then expanded. The above example expands to the following 16 permutations displayed in a special temporary field:

```
RPUW1.1,8.3,1.5,+3,1,10.6,0,0,0,0,172,115
RPUW1.2,8.3,1.5,+3,1,10.6,0,0,0,0,172,-115
RPUW1.3,8.3,1.5,+3,1,10.6,0,0,0,0,-172,115
RPUW1.4,8.3,1.5,+3,1,10.6,0,0,0,0,-172,-115
RPUW1.5,8.3,1.5,-2,1,10.6,0,0,0,0,172,115
RPUW1.6,8.3,1.5,-2,1,10.6,0,0,0,0,172,-115
RPUW1.7,8.3,1.5,-2,1,10.6,0,0,0,0,-172,115
RPUW1.8,8.3,1.5,-2,1,10.6,0,0,0,0,-172,-115
RPUW1.9,8.3,-1.5,+3,1,10.6,0,0,0,0,172,115
RPUW1.10,8.3,-1.5,+3,1,10.6,0,0,0,0,172,-115
RPUW1.11,8.3,-1.5,+3,1,10.6,0,0,0,0,-172,115
RPUW1.12,8.3,-1.5,+3,1,10.6,0,0,0,0,-172,-115
RPUW1.13,8.3,-1.5,-2,1,10.6,0,0,0,0,172,115
RPUW1.14,8.3,-1.5,-2,1,10.6,0,0,0,0,172,-115
RPUW1.15,8.3,-1.5,-2,1,10.6,0,0,0,0,-172,115
RPUW1.16,8.3,-1.5,-2,1,10.6,0,0,0,0,-172,-115
```

Now click **Transfer Maneuvers**, and, if the maneuvers are acceptable, click **XFR** to move them to the permanent maneuver field. If not, then click Toggle to hide the temporary display field. Click **Cancel** to leave everything unchanged.

Run MILGEN

The second option generates a bounding set of maneuvers using information you provide. First, the Aircraft ID, Mach, altitude must be chosen/filled in. Then, **Run MILGEN** can be clicked. The maneuver generator MILGEN will warn that it will overwrite the currently exisiting maneuvers. It then calculates the dynamic pressure in lb/ft^2. MILGEN queries the user for maximum allowable pitch (alpha) and yaw (beta) angles, general aircraft characteristics (high or low performance aircraft), and store location (wingtip or fuselage). It will then calculate the distance from the store to the aircraft cg using the aircraft chosen. Finally, the 48 maneuvers will be stored in the maneuver field.

Show Coord System

Display the SWAY85 Force & Moment Coordinate System used for maneuvers (see Figure 20).

Display Maneuvers

Display the maneuvers in an easily readable tabular format.

Transfer Maneuvers

See the Expand Maneuvers for discussion of the function of this button.

Index

Distribution

2	MS 0415	W. N. Dunn, Jr., 5411
5	MS 0436	G. L. Maxam, 2147
1	MS 0437	H. S. Morgan, 9117
1	MS 0437	C. R. Adams, 9117
1	MS 0437	J. B. Aidun, 9117
1	MS 0437	J. G. Arguello, Jr., 9117
1	MS 0437	S. W. Attaway, 9117
1	MS 0437	M. L. Blanford, 9117
1	MS 0437	K. H. Brown, 9117
1	MS 0437	S. N. Burchett, 9117
1	MS 0437	R. S. Chambers, 9117
1	MS 0437	A. F. Fossum, 9117
1	MS 0437	J. D. Gruda, 9117
1	MS 0437	M. W. Heinstein, 9117
1	MS 0437	E. L. Hoffman, 9117
1	MS 0437	J. Jung, 9117
1	MS 0437	S. W. Key, 9117
1	MS 0437	J. R. Koteras, 9117
1	MS 0437	C. S. Lo, 9117
1	MS 0437	F. J. Mello, 9117
1	MS 0437	K. E. Metzinger, 9117
1	MS 0437	J. A. Mitchell, 9117
1	MS 0437	M. K. Neilson, 9117
1	MS 0437	J. Pott, 9117
1	MS 0437	E. D. Reedy, Jr., 9117
1	MS 0437	L. A. Schoof, 9117
1	MS 0437	G. D. Sjaardema, 9117
1	MS 0437	J. R. Stewart, 9117
1	MS 0437	C. M. Stone, 9117
1	MS 0437	J. W. Swegle, 9117
1	MS 0437	M. R. Tabbara, 9117
1	MS 0437	L. M. Taylor, 9117
1	MS 0437	B. J. Thorne, 9117
1	MS 0437	G. W. Wellman, 9117
1	MS 0439	D. R. Martinez, 9234
1	MS 0439	K. F. Alvin, 9234
1	MS 0439	J. L. Dohner, 9234
1	MS 0439	C. R. Dohrmann, 9234
1	MS 0439	B. Driessen, 9234
1	MS 0439	M. S. Eldred, 9234
1	MS 0439	R. V. Field, Jr., 9234
1	MS 0439	C. W. G. Fulcher, 9234
1	MS 0439	D. W. Lobitz, 9234
1	MS 0439	D. B. Longcope, 9234
1	MS 0439	J. R. Red-Horse, 9234
1	MS 0439	J. M. Redmond, 9234
1	MS 0439	G. M. Reese, 9234
1	MS 0439	D. J. Segalman, 9234
1	MS 0439	H. P. Walther, 9234
1	MS 0439	W. R. Witkowski, 9234

Distribution (Continued)

1	MS 0469	K. G. McCaughy, 9700
1	MS 0469	R. A. May, 9706
1	MS 0555	D. B. Davis, 9732
1	MS 0555	M. S. Garrett, 9742
1	MS 0555	V. I. Bateman, 9742
1	MS 0555	D. L. Gregory, 9742
1	MS 0557	T. J. Baca, 9741
1	MS 0557	P. S. Barney, 9741
1	MS 0557	T. G. Carne, 9741
1	MS 0557	S. E. Klenke, 9741
1	MS 0557	J. P. Lauffer, 9741
1	MS 0557	R. L. Mayes, 9741
1	MS 0557	C. C. O'Gorman, 9741
1	MS 0557	T. L. Paez, 9741
1	MS 0557	R. Rodeman, 9741
1	MS 0557	M. J. Sagartz, 9741
1	MS 0557	T. W. Simmermacher, 9741
1	MS 0615	R. L. Perry, 9752
1	MS 0865	J. L. Moya, 9735
1	MS 0865	J. R. Barnum, 9735
15	MS 0865	J. S. Cap, 9735
2	MS 0865	J. E. C de Baca, 9735
1	MS 0865	T. Y. Chu, 9735
2	MS 0865	R. D. Foral, 9735
2	MS 0865	W. Gill, 9735
1	MS 0865	H. G. Hudson, 9735
1	MS 0865	W. A. Johnson, 9735
1	MS 0865	R. E. Jorgenson, 9735
1	MS 0865	K. O. Merewether, 9735
2	MS 0865	D. O. Smallwood, 9735
1	MS 0865	J. E. Solberg, 9735
1	MS 0865	L. K. Warne, 9735
1	MS 1135	J. R. Garcia, 9761
1	MS 1135	R. G. Coleman, 9761
1	MS 1135	N. T. Davie, 9761
1	MS 1135	T. C. Togami, 9761
1	MS 1392	V. Gabbard, 9719
1	MS 9018	Central Technical Files, 8940-2
2	MS 0899	Technical Library, 4916
2	MS 0619	Review and Approval Desk, 12690 For DOE/OSTI