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MISSILELAB USER'S GUIDE

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13. ABSTRACT *(Maximum 200 Words)*

MissileLab is a Microsoft Windows based Graphical User Interface (GUI) written in Visual Basic that assists the user in running several Missile Aerodynamic Prediction codes. MissileLab allows the aerodynamicist to input one set of geometry and atmospheric conditions and then run several aerodynamic prediction codes with the click of a button. MissileLab creates input files for and executes Missile DATCOM, AeroPrediction Code, Nielsen Engineering and Research (NEAR) MISL3, MISDL, and HASC. A S/HABP geometry input file can also be created. In addition, MissileLab exports Three-Dimensional (3-D) triangulated surface geometry files in several formats. MissileLab features include a user-friendly GUI, Two-Dimensional (2-D) line sketch, a 3-D solid model display of the missile geometry, customizable help information, and display and plotting of the output files from the prediction codes.

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A. Guiding Philosophy Behind the Creation of MissileLab

- Fast, engineering-level, aerodynamic design codes are required in the early stages of missile design projects to perform numerous aerodynamic trade studies.
- It is highly desirable to use several techniques to predict the external aerodynamics because this approach produces higher confidence in the results (or points to weaknesses in the various methods).
- The MissileLab interface will map all common airframe geometry inputs to the respective Aerodynamic Prediction Engines (APEs). APE specific inputs will be called out for the given code.
- MissileLab will attempt to identify and warn the user of common input errors.
- MissileLab will communicate with the various APEs via their standard, documented input and output files and will read pre-existing DATCOM namelist input files.
- MissileLab will feature various graphic displays of the missile geometry to aid the user in verifying configuration input geometry data.
- MissileLab will export triangulated surface geometry in several formats.
- MissileLab will allow the user to set up a run matrix of flight conditions and fin deflections to rapidly generate DATCOM data for complex aerodynamic models.
- MissileLab will provide quick-look plots of the aerodynamic data generated by most of the APEs.
- The user is responsible for obtaining licensed copies of the various APEs that he/she wishes to use.
- Tools are needed to assist the engineer in analyzing the data in a timely fashion.

B. MissileLab Configuration Management Philosophy

A typical MissileLab project will consist of multiple configuration files (given an ".MLN" file extension) that contain the airframe geometry specific to a single configuration.

Results from a MissileLab run will be stored in a directory corresponding to the configuration file name. This directory may be deleted with no impact to MissileLab. When MissileLab is run, the results directory will be (re)created and contain all APE results and associated input files.

C. Background

In the early stages of missile system design, it is necessary to have the means to quickly and accurately estimate the aerodynamics of a wide variety of missile configuration designs operating over many different flight regimes. The ultimate shape and aerodynamic performance of a missile are highly dependent on mission requirements (range, maneuverability, weight, radar cross section) and subsystems (payload, propulsion, control actuation system, launch mechanism). Therefore, the applied aerodynamicist must be capable of reliably predicting aerodynamic trends on a wide variety of configurations in a timely manner.

Engineering-level codes provide an immediate means to determine the aerodynamic characteristics of a flight vehicle configuration. The foundations of these codes are extensive databases of experimental tests performed by the National Aeronautics and Space Administration (NASA), the Army, Air Force, and Navy. A combination of mathematical expressions and table lookups define the semi-empirical nature of these APEs.

For missile applications, the most frequently used semi-empirical codes are Missile DATCOM [1], AeroPrediction (AP) code (version AP98 [2,3], AP02 [4,5], AP05 [6,7], AP09 [8]), Nielsen Engineering and Research (NEAR) MISL3 [9], and NEAR MISDL [10]. Unfortunately, these codes require significantly different input decks; therefore, the applied aerodynamicist must work through the tedious process of setting up input files for the different codes. This process also introduces the potential for error, thereby slowing the aerodynamicist's ability to quickly and reliably provide results to the design team.

It is advisable to run multiple APEs during the design trade process to increase the confidence level associated with the results. However, with ever increasing demands to shorten program development timelines, the aerodynamicist must sometimes choose between conducting additional analysis and meeting schedule demands. The entire design team must find ways to increase the efficiency and accuracy of the initial configuration trade study phase.

To meet the aerodynamicist's needs, a tool named MissileLab has been developed to allow the aerodynamicist to input one set of geometry and atmospheric conditions and then run several missile APEs with the click of a button. MissileLab creates input files for and executes Missile DATCOM, AeroPrediction Code (AP98, AP02, and AP05), NEAR MISL3, MISDL, and HASC [11]. A S/HABP [12] geometry input file can also be created. In addition, MissileLab exports Three-Dimensional (3-D) triangulated surface geometry files in several formats. MissileLab features include a user-friendly Graphical User Interface (GUI), a Two-Dimensional (2-D) line sketch, a 3-D solid model display of the missile geometry, customizable help information, and display and plotting of the output files from the prediction codes.

II. INSTALLING MISSILELAB INTERFACE

MissileLab is a Microsoft Windows based GUI written in Visual Basic that assists the user in running several Missile Aerodynamic Prediction codes. In addition to the executables, Windows requires that several “OCX” and “DLL” files be registered on the computer. The MissileLab installation file automatically registers the files.

A. MissileLab Installation File

To install the MissileLab GUI, locate and run the setup file named “Setup_MissileLab_x_yy.exe” (n.b., “x_yy” indicates the MissileLab version that will be installed). Figure 1 presents the various setup screens that the user will encounter.

MissileLab will be installed in the “Program Files” directory, although the user can change this during installation. A “MissileLab Projects” working directory will be created in the user’s personal documents directory (“Documents” for Windows 7 and “My Documents” for earlier versions of Windows). This is where the Project and Configuration files will be stored. The working directory can be changed from MissileLab.

The MissileLab installation will create an “AeroEngines” directory in the root directory. Once MissileLab is installed, the user should copy the desired “AeroEngines” files that are discussed in Section II.B.

B. Copying the AeroEngine Files

After installation, the subdirectories in the “AeroEngine” directory contain contact information about how to obtain valid licenses for the various APEs and other stand-alone executables that MissileLab will need to have full functionality. Figure 2 presents an example of how the AeroEngines directory might appear.

While the various APEs may be located anywhere on the user’s computer, it is RECOMMENDED that the APEs, which MissileLab will utilize, be located in a directory under the AeroEngines directory. The rationale for this is that when the user “exports” the geometry,

(1) MissileLab deletes previous APE specific input and output files,

(2) MissileLab then creates the APE specific input files in the directory where the user has indicated the APE exists,

(3) MissileLab then runs the APE,

(4) MissileLab then copies and renames the output files into the appropriate MissileLab directory.

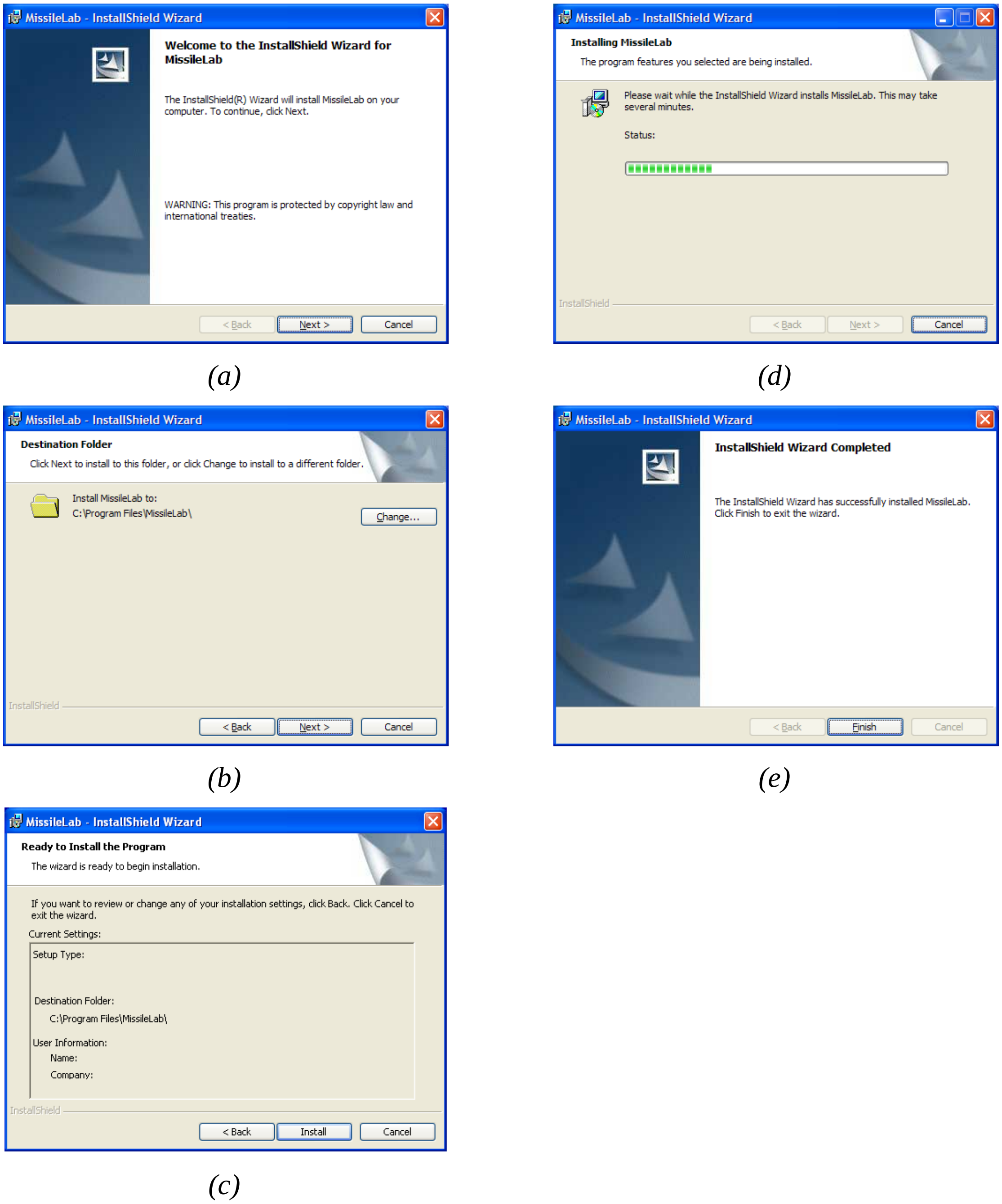


Figure 1. Installation Screens

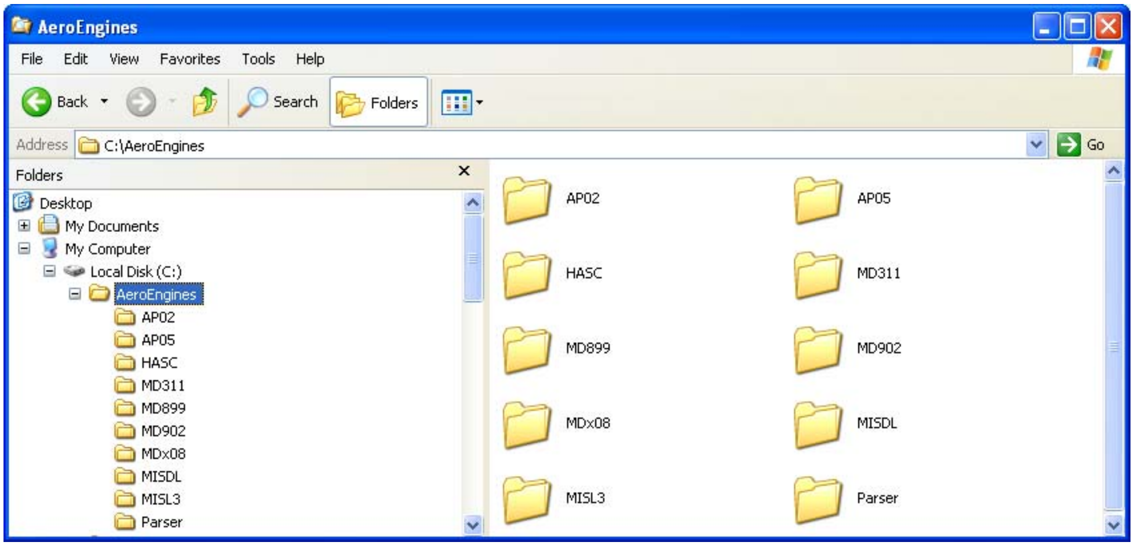


Figure 2. File Locations for the Aerodynamic Prediction Engines

III. THE MISSILELAB INTERFACE

MissileLab is a Microsoft Windows based Visual Basic GUI. A series of screens, loosely based on the Missile DATCOM input format, provides the user the ability to define the missile geometry, flight conditions, and reference conditions in a straightforward manner. MissileLab will process these inputs to create the input decks for *Missile DATCOM*, any of the *APxx* codes, *MISL3, MISDL, and/or HASC*. If the user has licensed copies of these and has defined the paths to these APEs in MissileLab, then MissileLab will execute the available APEs. It is noted, however, that it is the responsibility of the user to acquire the APE licenses from the appropriate vendor and that use of MissileLab does not constitute an agreement with the APE vendors.

A. Initial MissileLab Setup

When MissileLab is started for the first time following installation, the user must tell MissileLab where the APEs reside on the computer. Before describing this process, it is necessary to discuss the MissileLab Directory Structure.

1. MissileLab Recommended Directory Structure

While the APE and other stand-alone programs that MissileLab supports may be located anywhere on the computer, it is RECOMMENDED that they be located together, as shown previously in Figure 2. Each of the sub-directories under **AeroEngines** contains the respective executable. The MissileLab installation will create these directories and install an informational file that has contact information for each APE. Table 1 lists the recommended directory structure and required executable that MissileLab will need.

Table 1. Recommended Directory Structure for APEs

Directory	Executable	Description	Contact
/AeroEngines/MD899 /AeroEngines/MD902 /AeroEngines/MDx08 /AeroEngines/MD311 /AeroEngines/HASC	MDATCOM.EXE HASC.EXE	Missile DATCOM APE High Alpha Stability and Control Panel Code	Mr. William Blake AFRL/VACA 2210 Eighth St. Suite 21 Bldg 146, Area B Wright-Patterson AFB, OH 45433-7531 William.blake2@wpafb.af.mil
/AeroEngines/AP09 /AeroEngines/AP05 /AeroEngines/AP02 /AeroEngines/AP98	AP09FOR.EXE AP05FOR.EXE AP02FOR.EXE AP98FOR.EXE	AP09 APE (Latest Version) AP05 APE (no longer distributed) AP02 APE (no longer distributed) AP98 APE (no longer distributed)	Dr. Frank Moore 9449 Grover Drive, Suite 201 King George, VA 22485 drfgmoore@hotmail.com
/AeroEngines/MISL3 /AeroEngines/M3FLR /AeroEngines/MISDL	MISL3.EXE M3FLR.EXE MISDL.EXE	MISL3 APE (Latest Version) M3FLR APE (no longer supported by NEAR) NEAR Missile Distributed Load Code	Nielsen Engineering & Research Attn: Daniel J. Lesieutre 2700 Augustine Drive, Suite 200 Santa Clara, CA 95054 lesieutre@nearinc.com

The MissileLab project files and associated predicted results are organized according to the “Project” and the “Configuration.” Figure 3 shows an example directory structure. In this example, the project is named “SampleCases.” There are 5 configurations (“ap05ex-001” through “ap05ex-005”). Referencing this figure as the structure is described might be helpful. Under the working directory (My Documents/MissileLabProjects is the default), a parent folder will be created using the project name, and all files associated with this project will be stored in this directory. The MissileLab Project file for each configuration will be stored in this parent directory, named for the configuration (“*ConfigurationName*.mln”). When the APEs are run, a folder with the configuration name will be created, and the input and output files for the APEs will be in this directory. If 3-D models are exported, then a directory will be created using the configuration name with “_Models” appended. MissileLab9.0 has a new Run Matrix feature that is used to create Aerodynamic Models. When this feature is used, a directory will be created using the configuration name with “AeroModelBuild” appended, and the prediction files for that functionality will be placed in that folder.

Table 2 lists the most common output files of each APE, but not all output files.

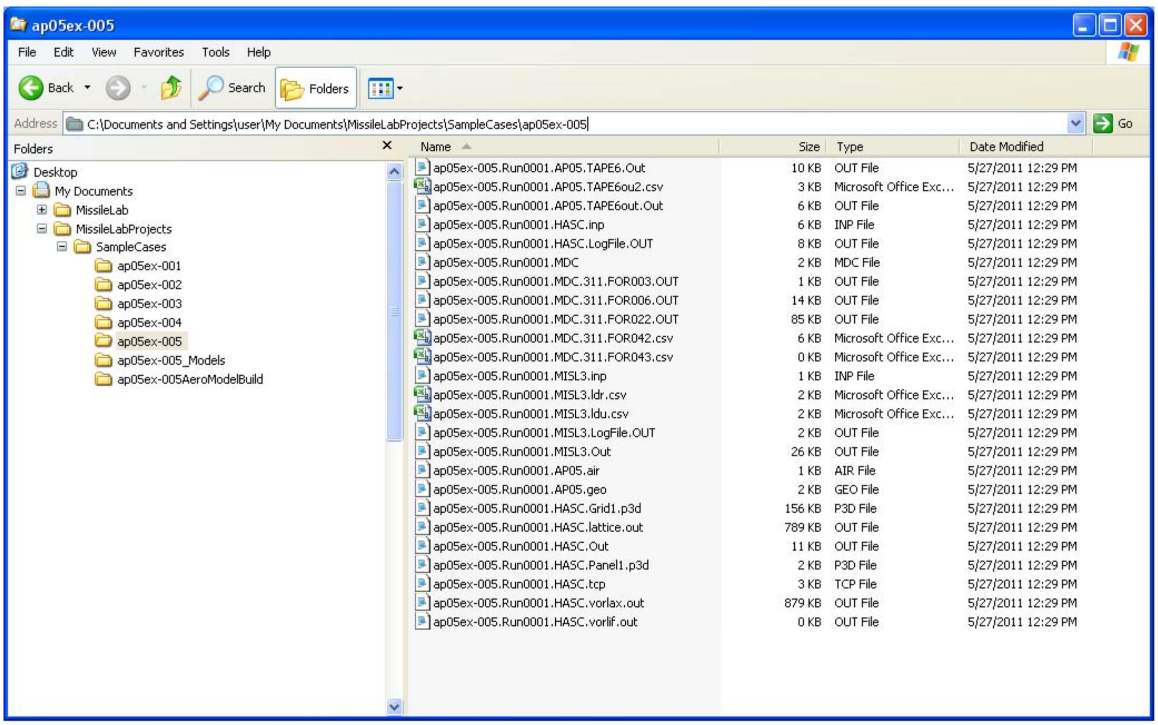


Figure 3. MissileLab Project Directory Structure

Table 2. MissileLab Project Files and Locations (MissileLabProjects is the Working Directory)

Directory	Files		Description
/MissileLab	MissileLab_Vxxx.EXE MissileLab.INI		MissileLab Executable MissileLab Initialization File
MissileLabProjects/Project_A	Config_001.MLN Config_002.MLN Config_003.MLN : Config_xxx.MLN		MissileLab Configuration Files for "Project_A" (Where "Project_A" and "Config_xxx" are defined by the user.)
MissileLabProjects/Project_A/Config_001_Models	Config_001.geo Config_001.stl Config_001.tri Config_001.pfgd Config_001.txt		S/HABP Geometry File Standard Tessellation Language File CART3D "Tri" File Plot3D File Coordinates File
MissileLabProjects/Project_A/Config_001AeroModelBuild	MasterFile.txt (Generated by MissileLab) ModelData.csv (Generated by MissileLab) Pitch_Finset#1_Def10.mdc (Generated by MissileLab) Pitch_Finset#1_Def10_Description.Txt (Generated by MissileLab) Pitch_Finset#1_Def10.mdc.311.FOR042.csv (Generated by DATCOM)		Master File that lists all cases being run in the Matrix AutoSaved Spreadsheet file with all Matrix Conditions Missile DATCOM input file for a specific case Text file listing the conditions for a specific case DATCOM output file for a specific case in column-format
MissileLabProjects/Project_A/Config_001	**Generated by MissileLab**		
	DATCOM	Config_001.Run0001.MDC	
	APxx	Config_001.Run0001.AP05.AIR Config_001.Run0001.AP05.GEOM Config_001.Run0001.AP02.AIR Config_001.Run0001.AP02.GEOM Config_001.Run0001.AP98.INP	
	MISL3	Config_001.Run0001.MISL3.INP	
	MISDL	Config_001.Run001.MISDL.inp Config_001.Run001.MISDL.29 Config_001.Run001.MISDL.50	
	HASC	Config_001.Run001.HASC.inp	
MissileLabProjects/Project_A/Config_001	**Generated by APE and Renamed by MissileLab** (Major Files Listed Only)		
	DATCOM	Config_001.Run0001.MDC.FOR006.OUT Config_001.Run0001.MDC.FOR042.CSV	
	APxx	Config_001.Run001.APxx.TAPE6.OUT Config_001.Run001.APxx.TAPE6out.OUT Config_001.Run001.APxx.TAPE6ou2.CSV	
	MISL3	Config_001.Run001.MISL3.OUT Config_001.Run001.MISL3.ldr.CSV	
	MISDL	Config_001.Run001.MISDL.OUT Config_001.Run001.MISDL.CSV	
	HASC	Config_001.Run001.HASC.OUT	

2. Locating Executables and Manuals

When MissileLab is run for the first time, the "Locate Prediction Codes" window, illustrated in Figure 4, will appear automatically. The user can also open this window at any time by selecting "Locate Prediction Codes" under the "Setup" menu bar. By clicking on the "Browse" button on this screen, the user can navigate through the computer directory structure to locate the respective aerodynamic prediction engines. After the APE is located, the user then defines which APE he has selected in Step 2 and assigns a version number. For APxx and MISL3, the version number is part of the "Define Program Type" pull-down and will determine what type of input file is written. In addition, it will be used to name the output files. Currently, input files for both HASC and MISDL are not version-specific, and version numbers are not listed for those codes. Finally, the user must click the "Add" button in Step 4.

If the various APE executables are NOT located, MissileLab will still create the input files for all codes, but it will not be able to execute the codes.

Once all desired APEs are located, the APE executables will appear on the "Export Data" screen.

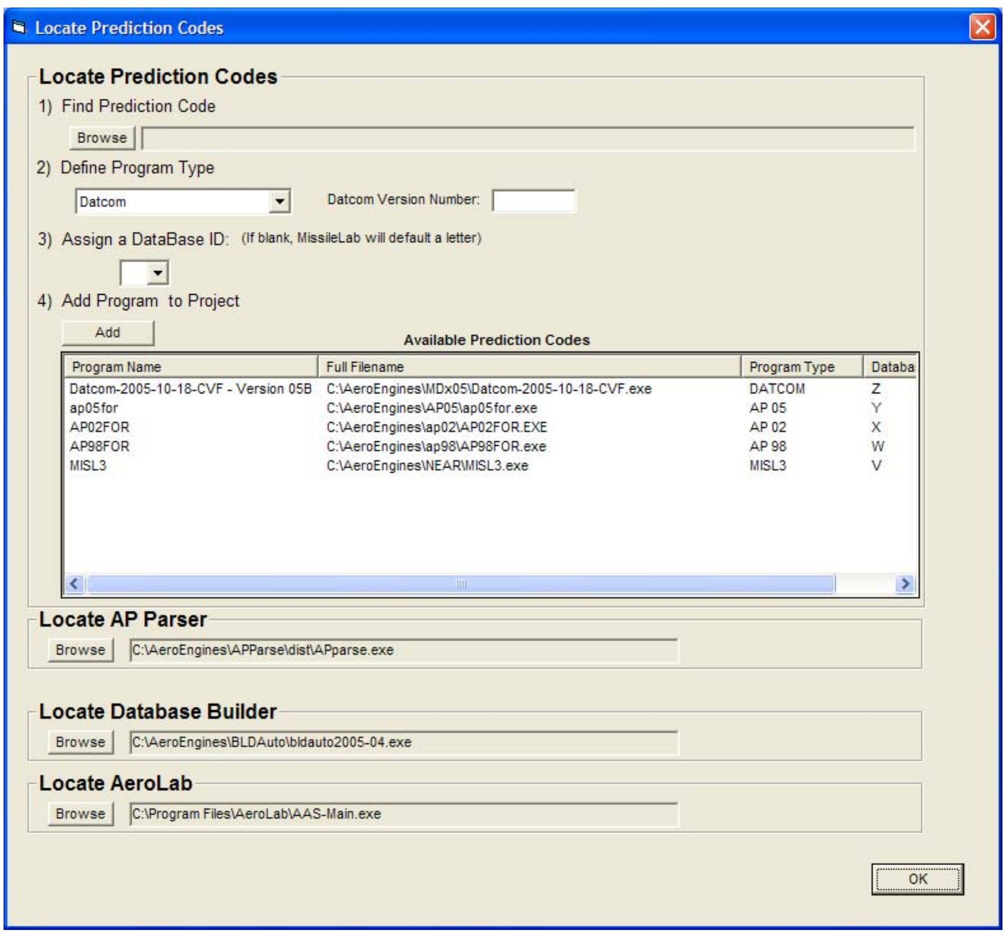


Figure 4. Locate Prediction Codes Setup Screen

Figure 5 presents the "Locate Manuals/Set Options" setup screen, which may be used to locate any number of Adobe PDF manuals (or any text document) that the user may want to easily access while using MissileLab. This page is available by selecting "Locate Manuals/Set Options" under the "Setup" menu. Once all the desired manuals are located, they will appear under "Help" in the MissileLab menu bar.

Manuals defined on this screen are available whenever MissileLab is open. As will be discussed later, the user may also locate manuals that are available for the specific configuration file that is currently loaded. These Adobe PDF manuals/documents are defined under the "Input Units" screen discussed in Section III.C.1.

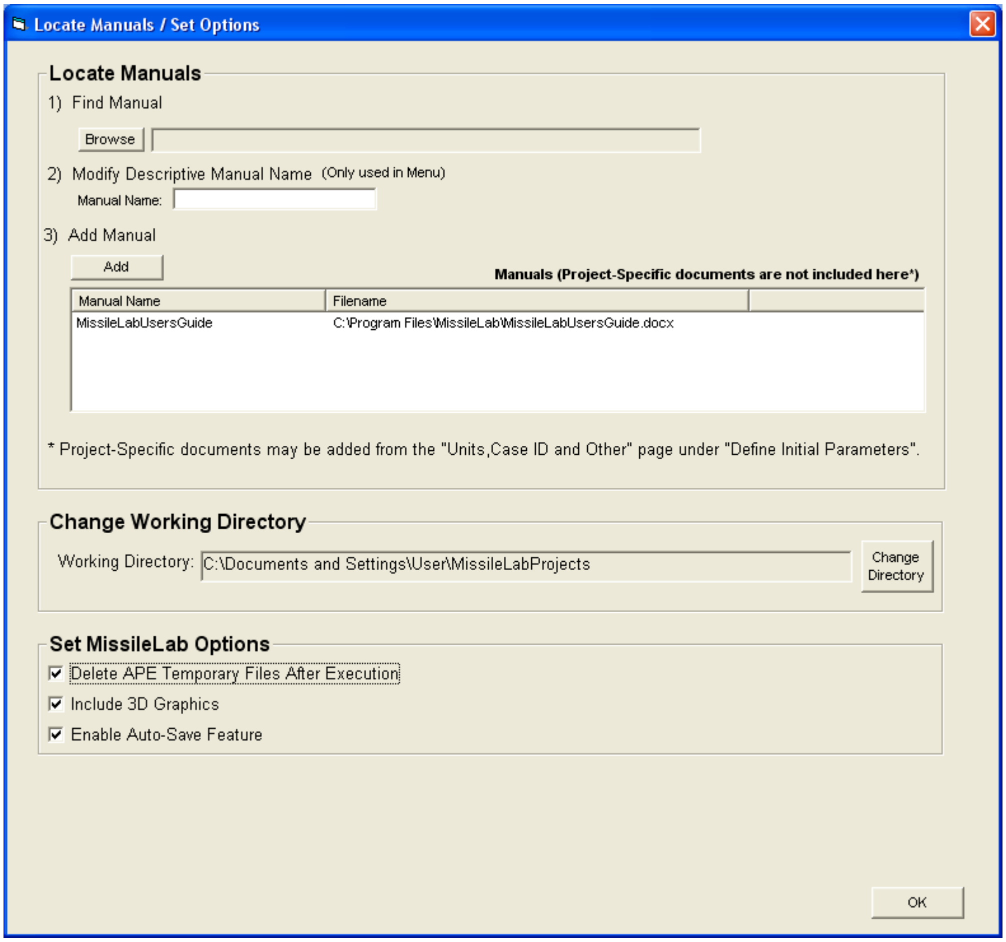


Figure 5. Locate Manuals Setup Screen

This screen also provides some general user options. The Working Directory is defaulted to the user's "My Documents" or "Documents" folder. It can be changed on this screen. The "Delete APE Temporary Files After Execution" option is used to determine whether input/output files in the APE directory are deleted after the APE is executed. These files are renamed and copied to the configuration directory before they are deleted from the APE directory. If the user prefers not to have access to the 3-D sketches, the "Include 3D Graphics" option can be deselected. This also denies access to the "Export 3D Models" page. MissileLab contains an auto-save feature that will save the entire project in a temp file every time the user switches forms. If MissileLab is not closed properly, the next time it is started, the user will be prompted to open this temp file. Checking the "Enable Auto-Save Feature" checkbox will enable this option.

When the user clicks on the "OK" button on either screen, MissileLab will query whether or not to store the setup information in the file named "MissileLab.ini." This is the MissileLab initialization file and is located in the working directory. After this file is created, it will be loaded when MissileLab is started and the "Locate Prediction Codes" window will no longer automatically appear. The initialization file is an ASCII text file, and while not recommended, the file may be edited by the user with an ASCII text editor.

B. Creating and Opening MissileLab Geometry Files

Figure 6 presents the initial project definition screen. As seen in this figure, there are four tabs (or options) for the user to choose. These options are: start a "New Project," open an "Existing Project," "Import (an existing) DATCOM File," or open a "Recent(ly)" used file. As discussed in Section III.A.1, MissileLab will create a project directory under the MissileLab home directory and then a configuration results directory under the project directory. As seen in Figure 6, the project directory may have several configuration files (*.MLN) and their corresponding configuration results directories.

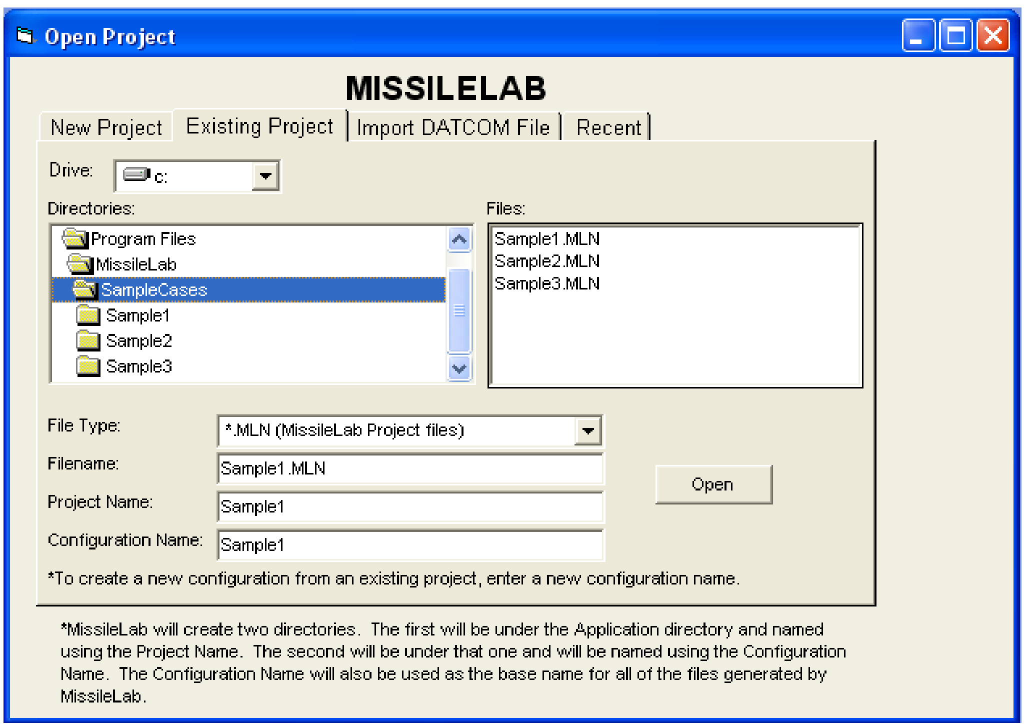


Figure 6. Project File Screen

> ***Change Note:***
>
> Recently used MissileLab files are now stored in the file named "MLRecentFiles.ini," which is located in the directory where the MissileLab executable is installed. Earlier versions of MissileLab stored recently used files in the Windows registry.

1. Creating a New Project

The "New Project" screen, shown in Figure 7 creates a new blank project for the user.

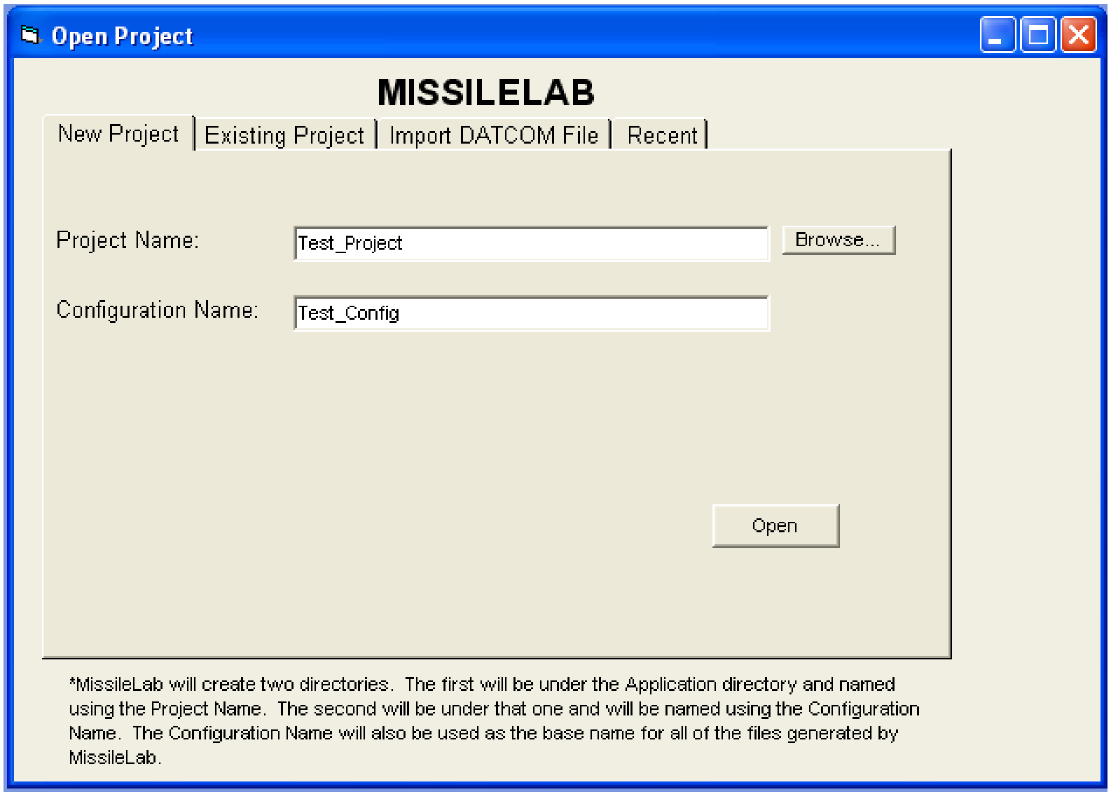


Figure 7. New Project Screen

2. Opening an Existing Project

The "Existing Project" screen, shown previously in Figure 6, opens an existing MissileLab file. The user may also open an existing project file and rename it by entering a new configuration name in the "Configuration Name" text box or a new project name in the "Project Name" text box.

3. Importing a Missile DATCOM File

MissileLab can read (import) existing Missile DATCOM namelist files. MissileLab attempts to detect (and correct if possible) common typographical input errors in the DATCOM file (such as missing or misplaced commas). MissileLab also attempts to identify, correct, and warn the user if it detects typical geometry input errors. Significant changes that are made by MissileLab when reading in an existing DATCOM file will be followed with a "confirmation" warning message.

Figure 8 presents the DATCOM import screen. As with the "Open Existing Projects" option, the user may rename the configuration and/or project name by entering a new name in the appropriate text box.

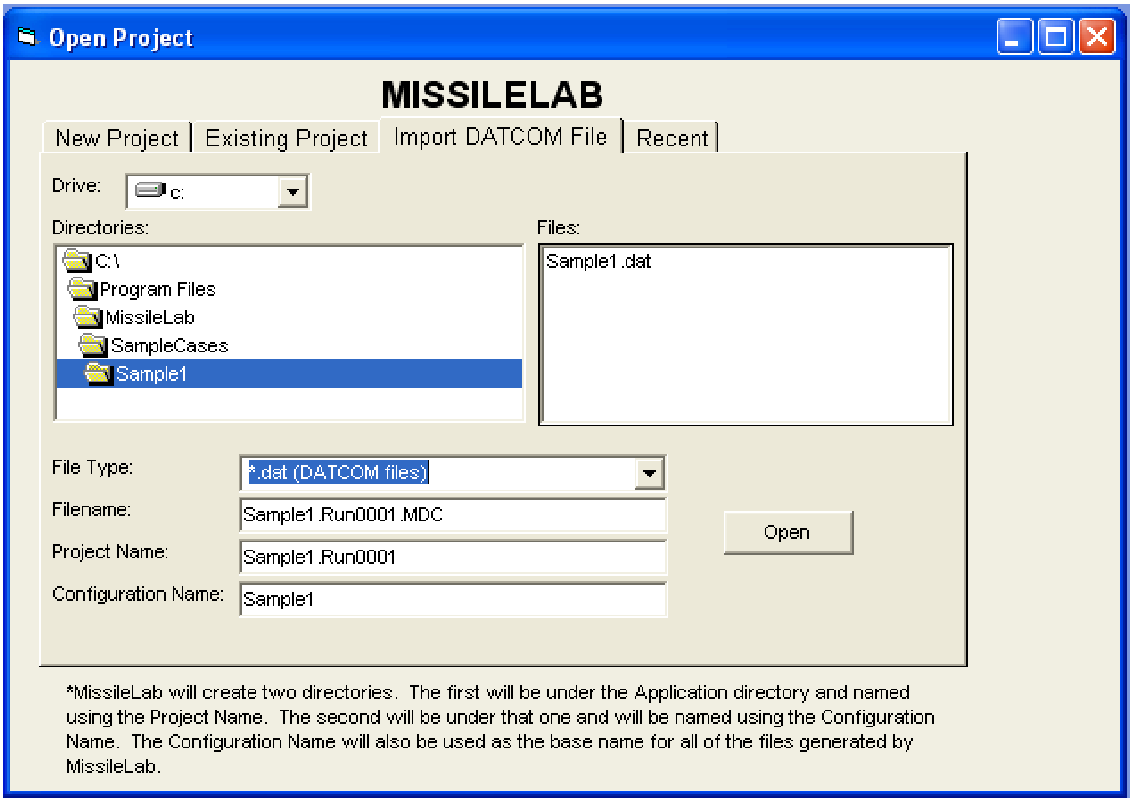


Figure 8. DATCOM Import Screen

If the user imports an existing DATCOM file where the body has been defined using the DATCOM "Axibod Option 2" method, then an additional screen appears. This screen, shown in Figure 9, is used to associate the input points with their respective body segment as required for compatibility with the AP codes. In the example shown in the figure, the first three points were "assigned" to the nose by selecting the points ("left clicking" on point 1, holding down the <SHIFT> key, and "left clicking" on point 3), then "right clicking." The "right click" of the mouse pops up a "copy to" menu that allows the user to select the nose, midbody section 1 through 4, or the aft body (boattail) section. After points have been copied to body segments, they can then be deleted from the segment or moved to a different segment by selecting them, "right clicking" the mouse, and choosing the appropriate pop-up menu option. Once all points have been assigned to a section, the user clicks on the "OK" button.

Because APxx's requirements for a certain number of points in certain segments can be problematic, the user is referred to the AP05 User's Guide for additional information about APs requirements for points per segment.

As far as DATCOM is concerned, these points are handled in the standard way for Axibod Option 2. As seen in Figure 9, certain cells are colored yellow. These yellow cells correspond to points where the DATCOM "DISCON" flag is set to 1, indicating that the slopes at those points are not continuous. Neither the body geometry nor the DISCON flags can be changed on this screen, but they can be changed on the MissileLab "Body Geometry" screen that will be discussed in Section III.C.3.

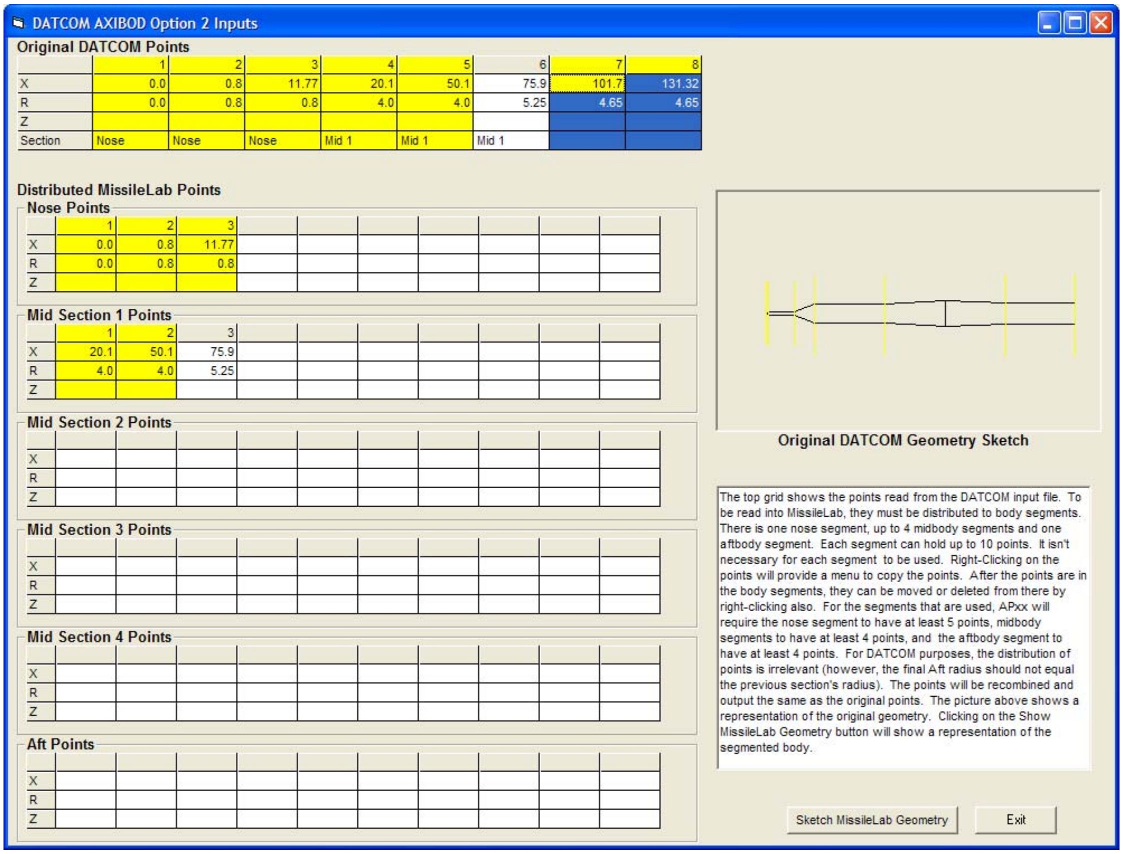


Figure 9. DATCOM Axibod Option 2 Import Screen

4. Opening Recent MissileLab Files

Figure 10 presents the recent files screen. As with the "Open Existing Projects" option and the "Import DATCOM" option, the user may rename the configuration by entering a new name in the "Configuration Name" and/or "Project Name" text box. Note that both ".mln" project files and DATCOM input files are listed here.

The list of recently used files is stored in the "MLRecentFiles.ini" located in the directory where the MissileLab executable is installed.

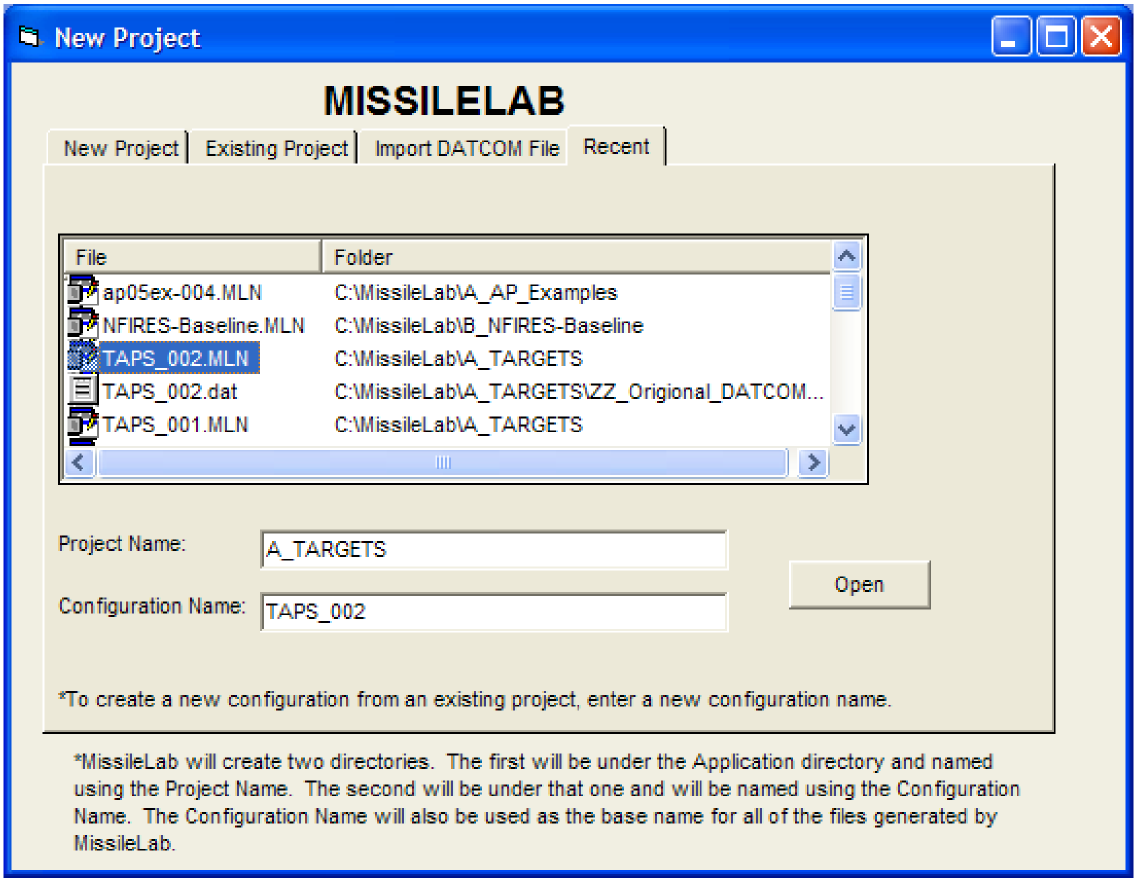


Figure 10. Open Recent Files Screen

C. Sketching Geometry

Any time after geometry has been defined, the missile can be viewed graphically using the "Sketch" menu option. Under this menu, there is a "Sketch 3D Missile" option. This will be enabled only when the appropriate libraries can be found and the "Include 3D Graphics" option is selected on the "Locate Manuals" screen. The 3-D solid model sketcher is shown in Figure 11. Here, functionality is provided to zoom in and out (right mouse button), rotate the camera around the fixed body (left mouse button), and pan (<SHFT> plus left mouse button). Detailed instructions for controlling the 3-D view can be found in the "Help" section on the screen.

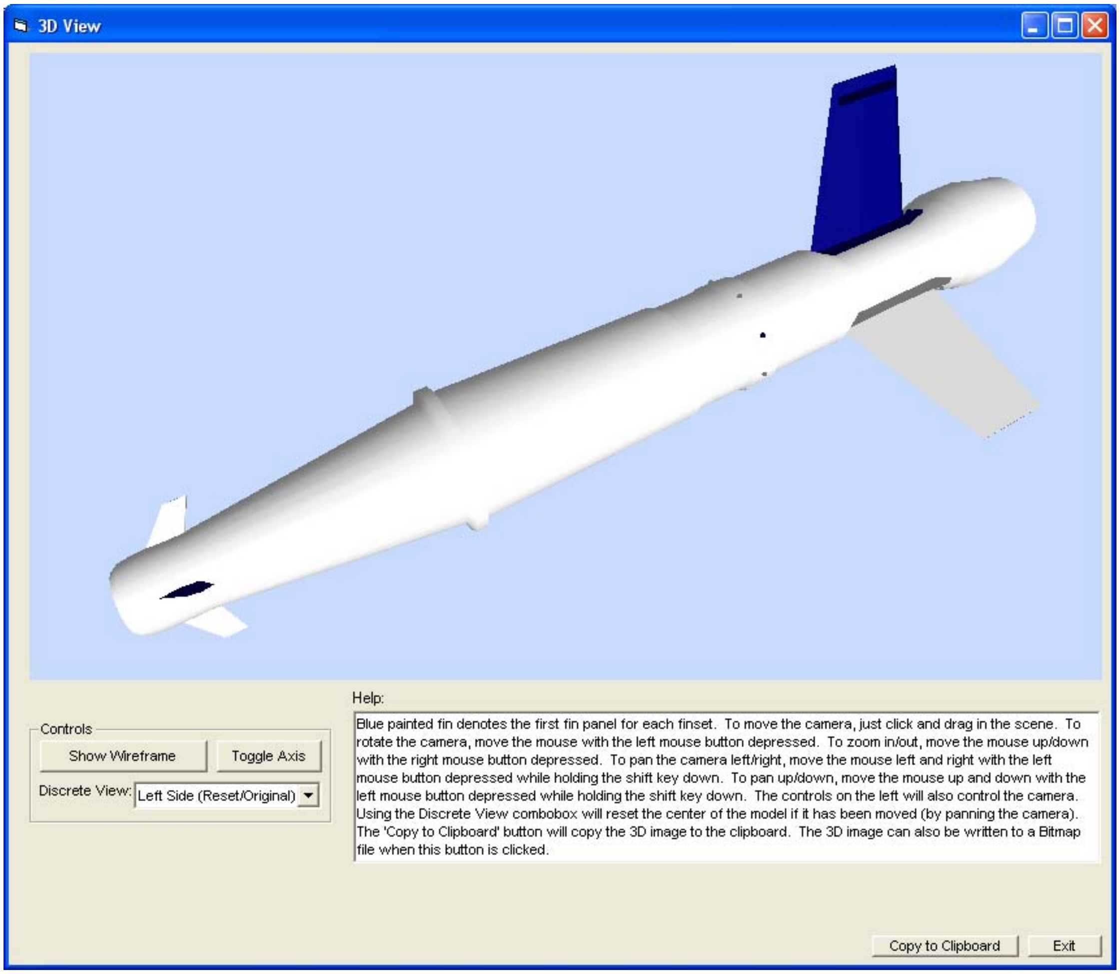


Figure 11. Sample MissileLab 3-D Sketch

MissileLab contains a simple 2-D sketch feature that is accessed by way of the "Sketch" menu. The user can sketch the body, an individual fin, or both by using the appropriate menu option. In the 2-D sketches, the body cross section is always drawn as a circle using the defined radius (or half-width for non-circular cross section). For an accurate depiction of a non-circular cross section, see the 3-D sketches discussed above. The 2-D sketches show various dimensions provided in labels. The user can click on the labels with the left mouse button and drag these to a new location. A sample sketch of both body and fin is presented in Figure 12. For each finset (when finsets are displayed), a box is displayed that shows the panel orientation and/or dihedral (looking from the rear of the missile). As seen in Figure 12, various user controls are provided. There is a button at the bottom of the screen that allows the user to copy the sketch to the clip-board so that it may be pasted into any Windows application that supports Windows Metafiles. A sample of the pasted Windows Metafile is presented in Figure 13. Also, check-box controls allow the user to turn on and off the panel displays and the body station information on the sketch, as well as, highlight body discontinuities and/or the Moment Reference Point (MRP). Another control enables a text screen to display body geometry data. When finsets are displayed, a control enables the leading edge locations to be shown.

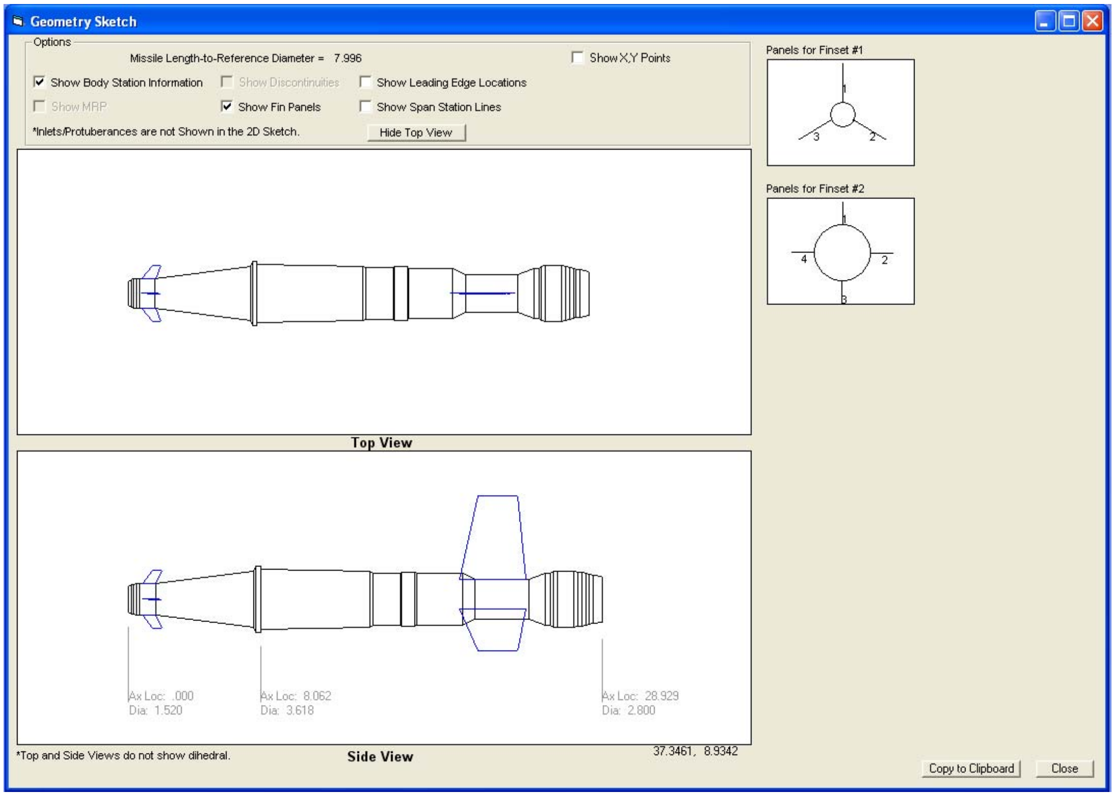


Figure 12. Sample MissileLab Sketch

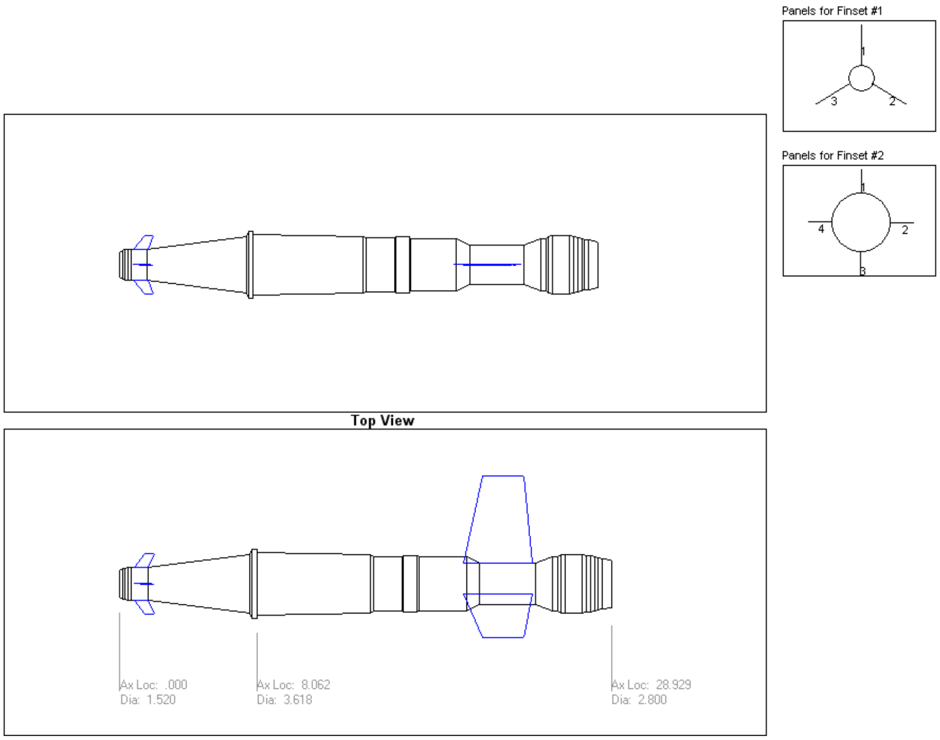


Figure 13. Sample MissileLab Sketch by way of Metafile

An individual finset can be displayed by using the "Sketch Fin" menu option. An example of this sketch is shown in Figure 14. The controls described above that are appropriate are also present on this screen. An additional check-box control is provided to set the leading edge location to 0.0. The blue striped area represents the trailing edge flap.

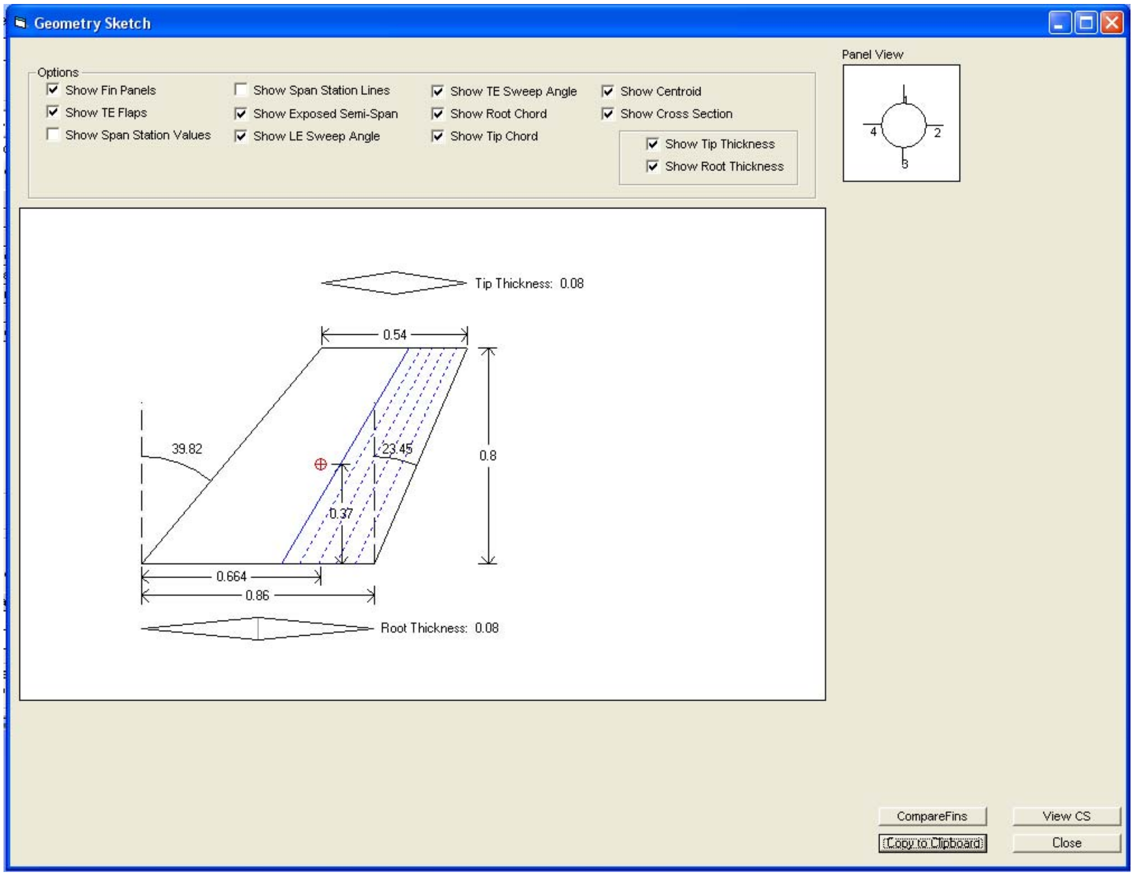


Figure 14. Sample MissileLab Fin Sketch

D. Entering MissileLab Geometry in the GUI

Figure 15 presents MissileLab's main interface screen with focus on the "Input Units" screen. As seen in this figure, the screen is divided into three panels: the Menu Options Panel (upper-left), the Help Topics Panel (lower-left), and the Work Area Panel (right; in this case, displaying the Input Units panel).

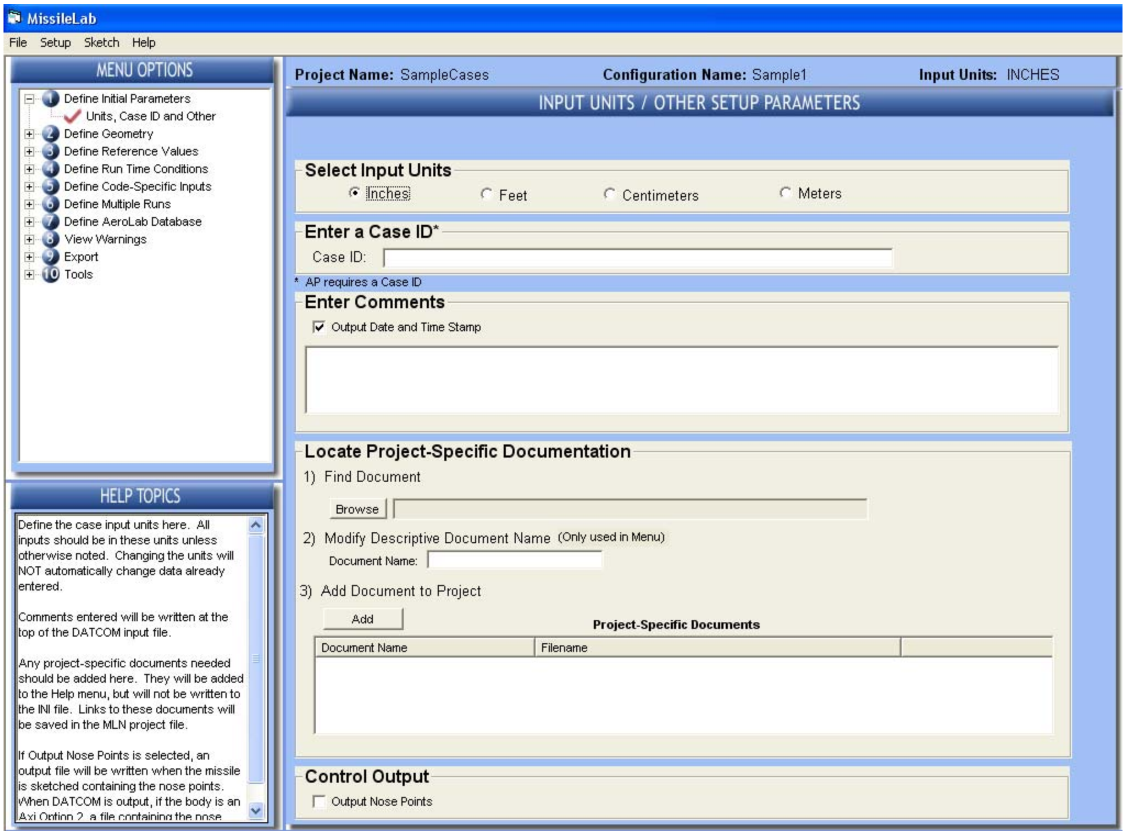


Figure 15. Units and Case ID Screen

Notice that the Menu Options Panel, located in the upper-left of the screen, is an expandable list that guides the user through the steps required to generate a valid input deck. Table 3 lists the contents of the Menu Options Panel. While this is a numbered list of the recommended data entry steps, the user may enter the data in any order, may return to any screen at any time during the input definition process, and may save the project configuration file at any point in the process. When a menu option is selected, the appropriate panel will be displayed in the "Work Area" that forms the right-hand side of the screen.

Table 3. Menu Options Panel

(1) Define Initial Parameters
    Units, Case ID, and Other
(2) Define Geometry
    Body
    Finsets
    Protuberances
    Inlets
(3) Define Reference Values
    Body References
(4) Define Run Time Conditions
    Geometry Parametrics
    Flight Conditions
    Deflection/Trim
    Base Effects
    Inlet Additive Drag
(5) Define Code Specific Inputs
    DATCOM Specific Inputs
        Prediction Method/Case Computations
        Output Options
        Common Block Output
    Define APxx Specific Inputs
        Run Time Conditions
        AP05 Protuberance Inputs
    Define NEAR MISL3 Specific Inputs
        Run Time Conditions
        Body Loads/Rotation Rates
    Define HASC Specific Inputs
        Run Time Conditions
    Define NEAR MISDL Specific Inputs
        Fin Parameters
        Run Time Conditions
(6) Define Multiple Runs
    Run Manager
(7) Define AeroLab Database
    Configure AeroLab Database Parameters
(8) View Warnings
    DATCOM Warnings
    AP Warnings
    MISL3 Warnings
    HASC Warnings
    MISDL Warnings
(9) Export
    Export Data Files/Run Predictions
    Export 3-D Geometric Files
    Export Run Matrix
(10)Tools
    Quick Look Plots
    View Data/Create Database
    Estimate Mass Properties

The Help Topics Panel, located directly below the Menu Options Panel, displays information the user may need while entering data on the given screen. Note that additional help information may be accessed by way of the pull-down Help menu item located in the menu bar at the top of the screen. From that menu, the user can access any number of previously user-defined text documents to aid in understanding the required input fields.

> ***Helpful Hint:*** Help Topics
>
> To increase the font size in the Help Topics Panel, click in the panel, hold down the <CTRL> key, and rotate the mouse wheel.
>
> This is a Microsoft Windows feature and may be useful in other applications such as Microsoft Windows WordPad.

The Work Area Panel displays the fields to be completed by the user. Once the user leaves the current Work Area Panel, a check-mark appears by the associated panel name in the Menu Options Panel, indicating that the user has visited the given panel during the current session. If the current configuration is closed and then re-opened, all checkmarks are reset.

All value-based text box entry fields (even those in grids) will accept equations as valid entries. These expressions are evaluated and the resulting value is placed in the text box field. For example, an entry of the expression “10-6/2” will be evaluated by MissileLab and the value of “7.00” will be placed in the field. A list of supported functions is presented in Figure 16 and may be accessed from MissileLab under the Help menu item.

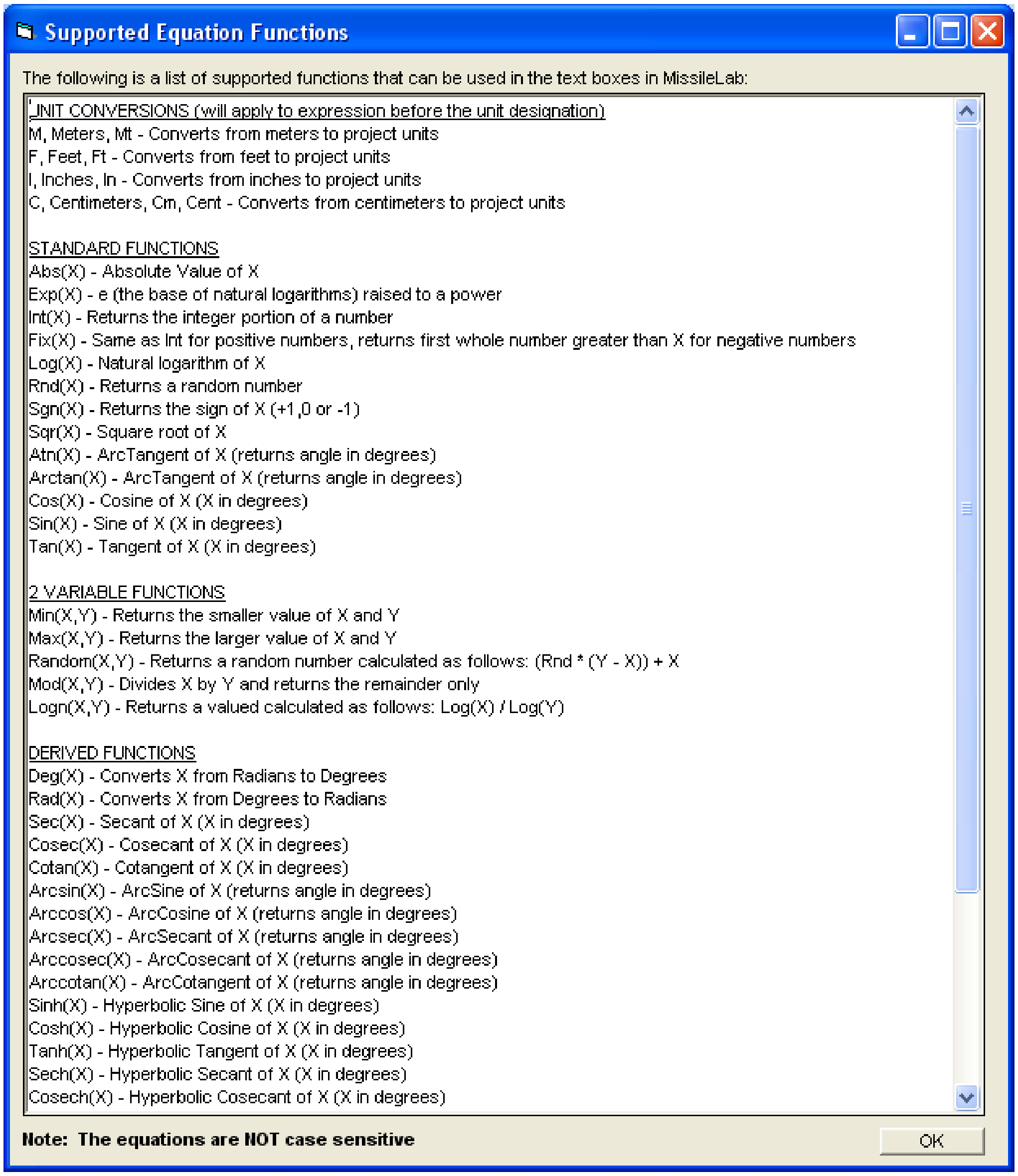


Figure 16. Supported Text Box Equation Functions

1. Define Initial Parameters Screens

   Units, Case ID, and Other Screen

The user defines the input units (default = inches), configuration case Identification (ID) (required input for the AP codes), comments regarding the configuration (optional), and project-specific text reference files (optional) on the “Units, Case ID, and Other” screen, shown in Figure 15. As previously discussed in Section III.A.2, text files defined on the “Set-Up” screen are always available by way of the “Help” menu, where as the text files that are defined on the “Input Units” screen, shown in Figure 15, are available only for the specific project where they were defined. Additionally, whereas the text files that are defined on the initial setup screen are stored in the MissileLab initialization file, the PDF files defined on the project screen, shown in Figure 15, are stored in the respective MissileLab project file (*.MLN).

2. Define Geometry Screens

Body Screen

The standard body geometry definition (Nose+Body+Boattail/Flare configurations) input screen is presented in Figure 17. This panel features a number of pull-down boxes, summarized in Table 4. Here the user may specify the cross-sectional shape as axisymmetric (circular), elliptic, square, diamond, or triangular. The APEs have varying capabilities for non-axisymmetric cross sections. APxx and MISDL can run any of the defined cross sections. For these codes, the input decks are generated based on the APE documentation. DATCOM can run circular and elliptical cross sections. NEAR MISL3 supports only a circular cross section. For all non-supported cross sections, an equivalent circular body (based on cross-sectional area) is created.

As seen in Figure 17, the Body Geometry Panel is subdivided into nose, center-body, and aft body sections. For each of these sub-panels, a geometry pull-down box is provided that allows the user to tailor the required inputs based upon available data. For multi-segmented bodies, as supported by both DATCOM and APxx, the user may define up to four center-body segments (a total of six segments, including the nose and boattail/flare). The majority of the MissileLab input fields are automatically mapped to the respective locations for the various aerodynamic prediction engines. However, because each APE has its own unique capabilities and input requirements, MissileLab lists APE code-specific variables separately for the user. The Body page provides examples of these. The “Height of Rotating Band” input is designated for APxx only. The “Corner Radius” (necessary only for square or triangular cross sections) and “Transition Length” (necessary only for a body with two different cross section shapes) apply to APxx and the 3-D models.

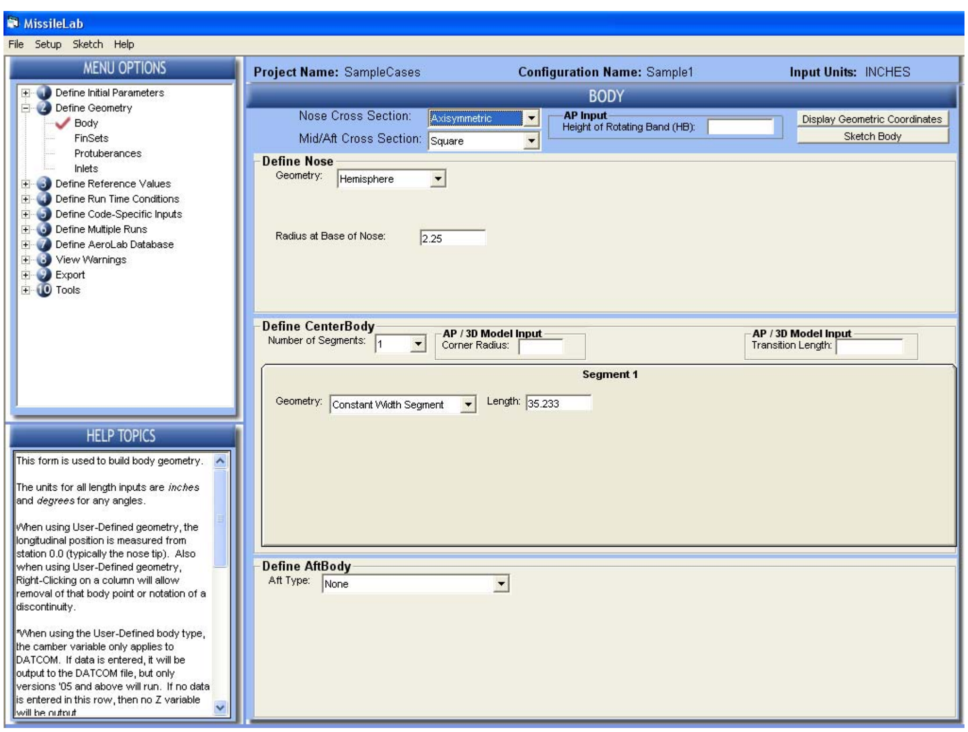


Figure 17. Body Geometry Screen

Table 4. Body Screen Pull-Down Fields

Field	Choices	Comments
Cross-Sectional Shape	Axisymmetric ………… Elliptical ……………… Square ………………… Diamond ……………… Triangle ……………… Inverted Triangle ………	All APEs Specific to DATCOM, APxx, MISDL Specific to APxx, MISDL Specific to APxx, MISDL Specific to APxx, MISDL Specific to APxx, MISDL
Nose Geometry	Ogive Conical Power Haack Karman Hemisphere Secant Ogive User Defined	A hemisphere can be modeled as a Tangent Ogive; however, as APxx input files are slightly different for the hemispherical case, it is recommended that the HEMISPHERE option be used when modeling a hemispherical nose. Secant Ogive and User Defined options force DATCOM into Axibod Option 2 mode.
Nose Tip Geometry	Pointed Blunted Truncated	The corresponding length for all nose tip geometries is the physical length of the nose (after blunting or truncating).
Number of Body Segments	1 to 4	Any value other than 1 forces DATCOM into Axibod Option 2 mode.
Center Body Geometry	Cylinder Cone – known radius Cone – known half-angle User Defined	User Defined options force DATCOM into Axibod Option 2 mode.
Aft Body Geometry	None Tangent Ogive Cone – known radius Cone – known half-angle User Defined	User Defined options force DATCOM into Axibod Option 2 mode.

NOTE: Non-Axisymmetric Nose and Body

If the nose or body is not a "revolved" part, then several additional fields appear that allow the user to enter corner radius and transition length values. **The transition length is part of the body length!** So, if the configuration is 10 calibers in total length with a 3-caliber nose and 1-caliber transition length, then the 1-caliber transition length is part of the 7-caliber body.

For cases where the body cannot be modeled by a simple nose+body+aft section, MissileLab allows the user to enter body point pairs, X & R (longitudinal 'X' station and radial 'R' station). For those familiar with Missile DATCOM, this would be the "Axibod Option 2" input method, and for those familiar with AP, this corresponds to the "Other" nose and body input method. Figure 18 presents an example of this screen.

The 2006 (and later) version of Missile DATCOM includes the capability to predict aerodynamic trends of a cambered (or bent) body at zero roll angle. This new DATCOM capability introduced a new "Z" input variable as part of the Axibod Option 2 "X" and "R" variables. MissileLab allows for this variable using the "Camber" field, shown in Figure 18.

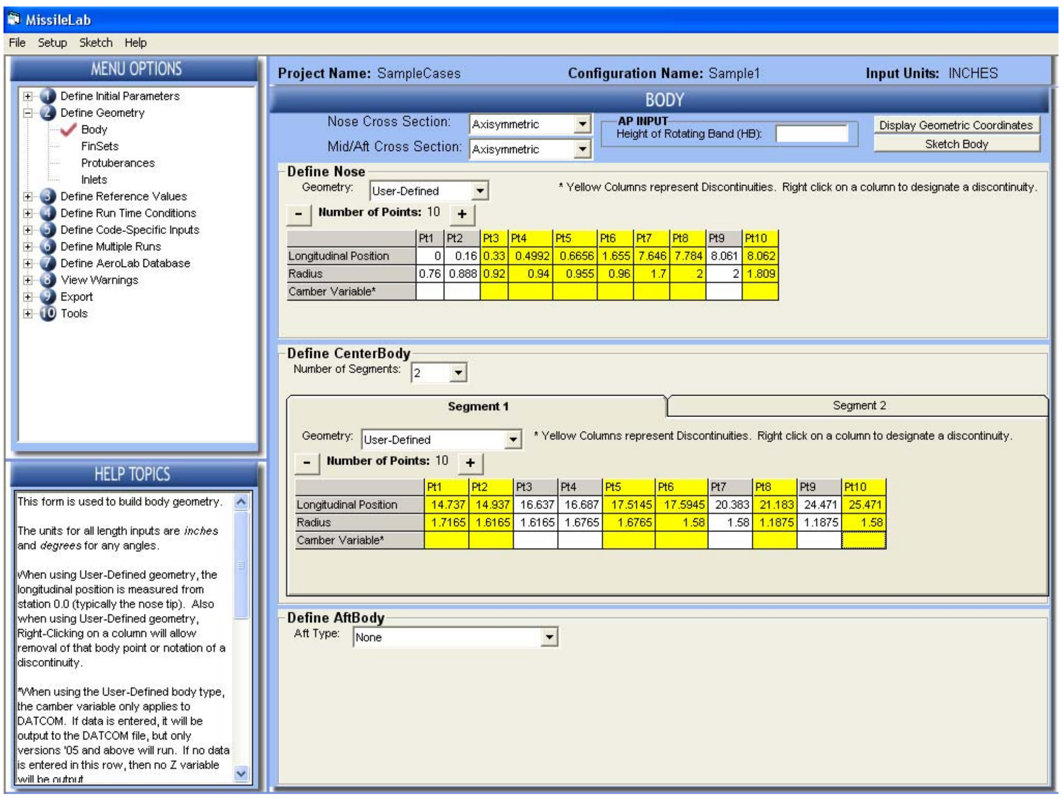
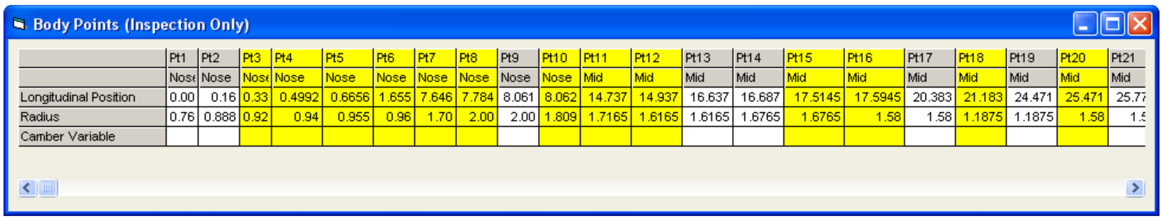


Figure 18. User-Defined Body Input Screen

From this screen it is seen that some of the user-defined body point cells are colored yellow, while some are colored white. Yellow shaded cells indicate points that do not have a continuous slope. In Missile DATCOM, these points would have the DISCON namelist variable set to a value of 1. The discontinuity slope flag may be toggled on and off by "left-clicking" on the point number, then "right-clicking." When this is done, a pop-up menu will appear that will allow the user to (1) remove the current point, (2) insert a point before the current point, (3) toggle the discontinuity flag of the current point.

Each section may have up to 10 pairs of points. This limitation is imposed for compatibility with the AP prediction codes. Up to six sections (one nose, four centerbody, and one aft body) may be entered. As this can lead to 60 discrete body points, and as DATCOM allows for a maximum of 50 body points, points over 50 will disable Missile DATCOM from running. It is noted that the distribution of points in the various sections affects only the AP input files. It is also noted that discrete steps are NOT allowed by MissileLab because none of the APEs are designed to account for forward/rearward facing steps along the body. Additionally, the user should avoid entering points that will produce very steep slopes along the body.

Figure 19 presents the body points display window. This screen is for point inspection alone and has no functionality other than allowing the user to view all the points in all the sections in order. This screen will open automatically when more complex or user-defined geometry is defined. It can also be displayed using the “Display Geometric Coordinates” button near the top right of the panel.



	Pt1	Pt2	Pt3	Pt4	Pt5	Pt6	Pt7	Pt8	Pt9	Pt10	Pt11	Pt12	Pt13	Pt14	Pt15	Pt16	Pt17	Pt18	Pt19	Pt20	Pt21
	Nos	Nose	Nos	Nose	Nose	Nose	Nose	Nose	Nose	Nose	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid
Longitudinal Position	0.00	0.16	0.33	0.4992	0.6656	1.655	7.646	7.784	8.061	8.062	14.737	14.937	16.637	16.687	17.5145	17.5945	20.383	21.183	24.471	25.471	25.77
Radius	0.76	0.888	0.92	0.94	0.955	0.96	1.70	2.00	2.00	1.809	1.7165	1.6165	1.6165	1.6765	1.6765	1.58	1.58	1.1875	1.1875	1.58	1.5
Camber Variable																					

Figure 19. User-Defined Body Points Screen

Below the “Display Geometric Coordinates” button, there is a “Sketch Body” button. This will display the same sketch as the “Sketch Body Only” menu option described in Section C.

<u>Finsets Screen</u>

Figure 20 presents the fin geometry input screen. Up to nine finsets may be specified using the pull-down box at the top of the screen. The current finset can be sketched using the “Sketch Fin” button at the top-right corner of the panel. This displays the same sketch as the “Sketch Fin” menu option described in Section C. As seen in Figure 20, many fin geometry variables follow the DATCOM namelist inputs. One difference is that most of the non-dimensional DATCOM inputs are entered into the grid as dimensional. To define trailing edge flaps, the “TE Flaps” checkbox must be checked. NEAR MISL3 does not support trailing edge flaps. If a finset is defined with flaps, MissileLab will give a critical error for MISL3 and will not export the input file for MISL3. Notice the code-specific inputs at the bottom of the “Define Fin” frame.

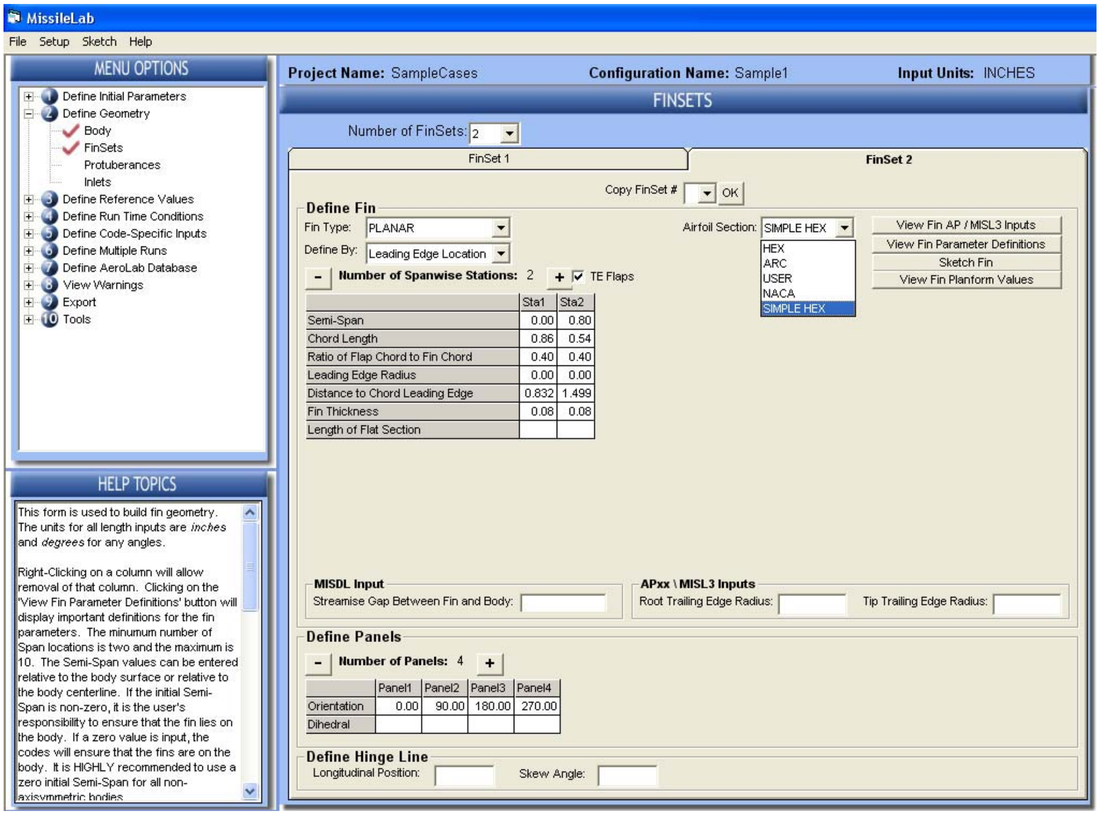
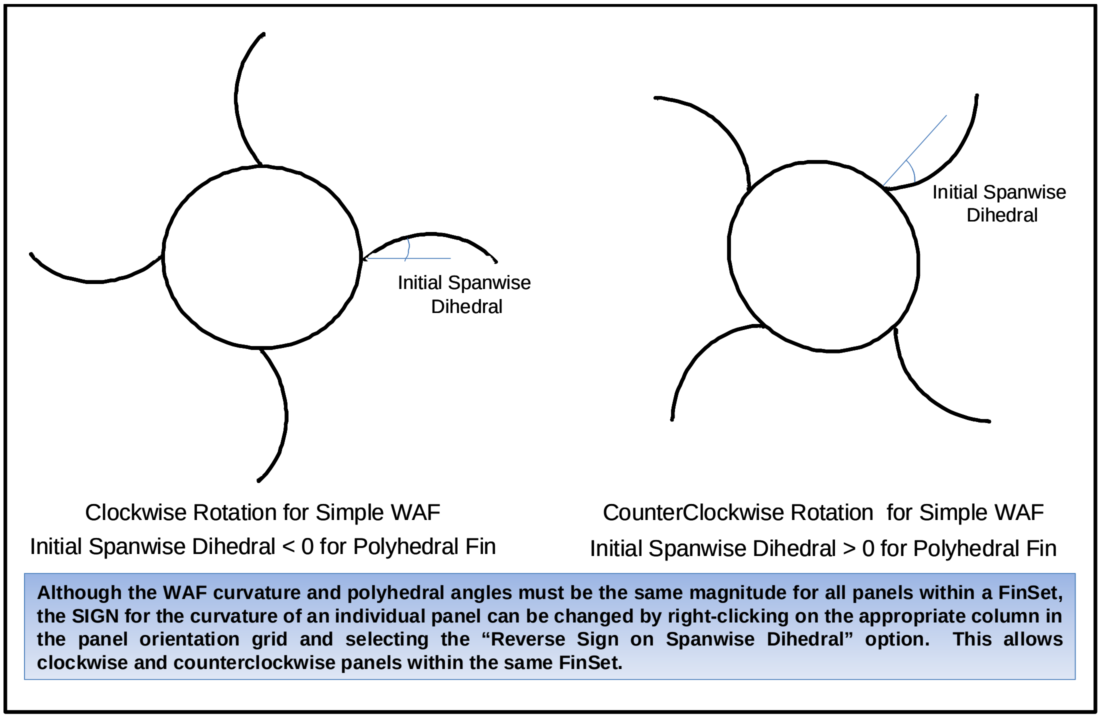


Figure 20. Fin Geometry Screen

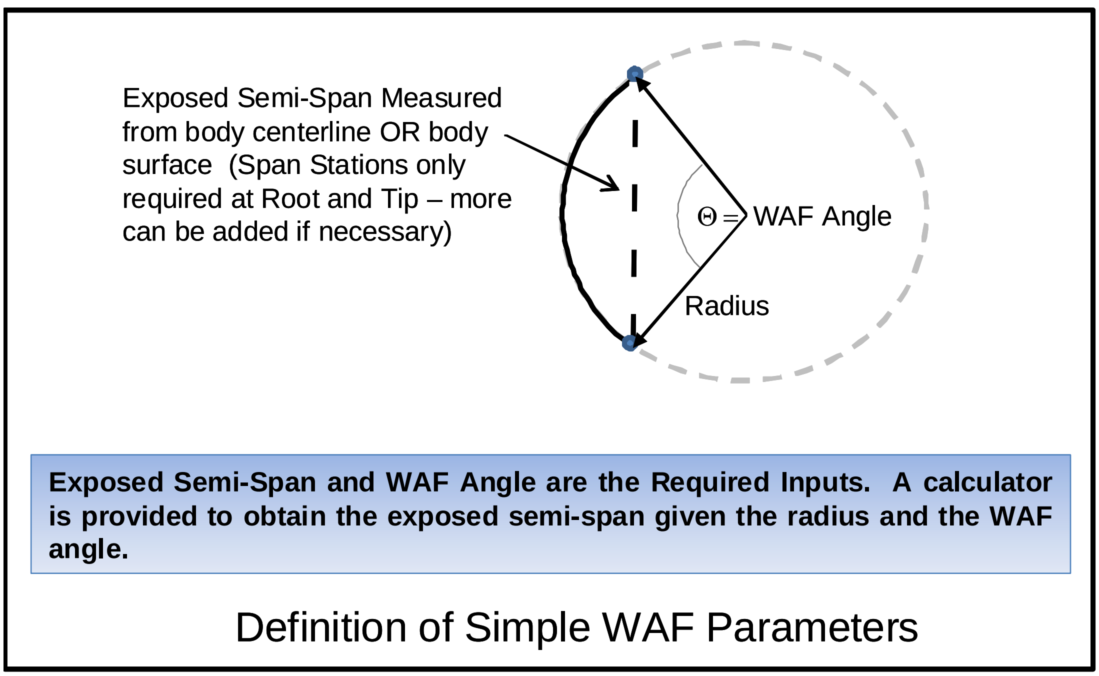
> ***NOTE: Number of Finsets***
>
> Because each APE supports a different number of finsets, the Geometry Parametrics page (discussed in greater detail in Section III.D.4) provides options for enabling/disabling finsets for each code. If more than two finsets are specified, the user must specify on the Geometry Parametrics Screen which two finsets are to be run for the APxx APEs. If more than three fins are specified, the user must specify on the Geometry Parametrics Screen which three finsets are to be run for the NEAR MISL3 APE and which three finsets are to be run for MISDL. Please note that versions of DATCOM, prior to August 2008, support only four finsets, while later versions will support nine finsets.

MissileLab (version 8 and above) supports the definition of Wrap-Around Fins (WAF). A "Simple WAF" is one that is defined using a single curvature angle. A "Polyhedral WAF" is one that has varying curvature. The "Fin Type" pull-down defines whether the fin is Planar, a Simple WAF, or a Polyhedral fin. Figure 21 describes the definitions for these fins types. Clicking on "View Fin Parameter Definitions" provides this graphical explanation of the variables needed for WAFs, as well as definitions of other fin parameters.

The direction of the WAF curvature can be changed for each fin in a finset by right-clicking on the "Panel" column. If the direction of the curvature is changed, the panel column will be highlighted in yellow.

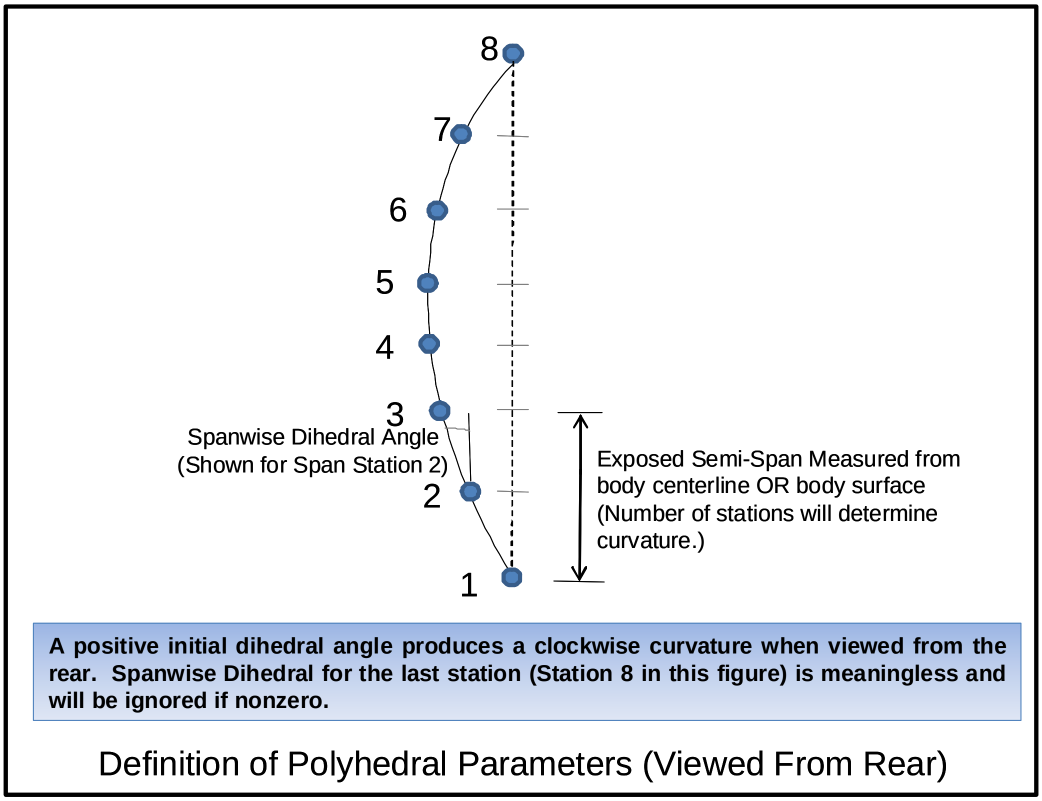


(a)



(b)

Figure 21. Definitions of WAF



Definition of Polyhedral Parameters (Viewed From Rear)

(c)

Figure 21. Definitions of WAF (Concluded)

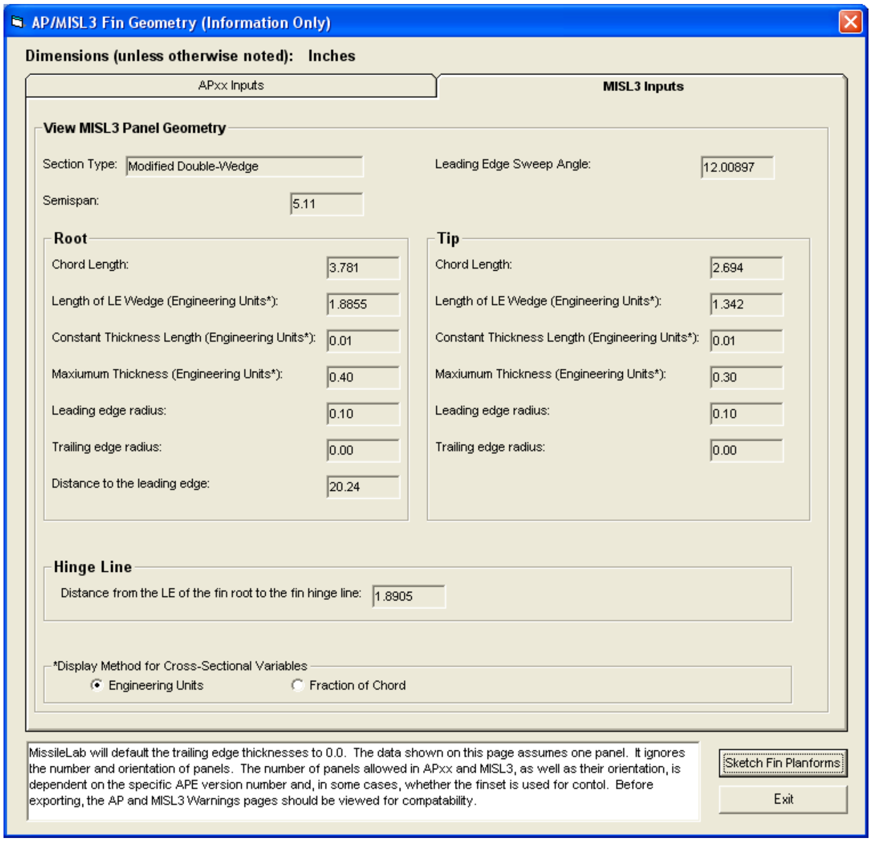
Like DATCOM and MISDL, MissileLab allows for multi-segmented lifting surfaces. As this feature is not supported by APxx and NEAR MISL3, routines have been added to MissileLab that create an equivalent single-segment wing panel [12]. This method involves modifying the leading edge sweep angle and tip and root chords while keeping the taper ratio, trailing edge sweep angle, span, and planform area constant. Regardless of the number of segments in the wing panel, a command button is provided that allows the user to view the wing geometry as it would be entered into APxx and NEAR MISL3, as shown in Figure 22. The user can not change the values shown on this page. If the user feels these values are incorrect, then the values must be changed on the main finset page. The “Sketch Fin Planform” button will show the defined fin (denoted as DATCOM, HASC, and MISDL Fin) beside the equivalent APxx and MISL3 fins in a window that is similar to the sketch windows described in Section C.

Equivalent Fin Equations

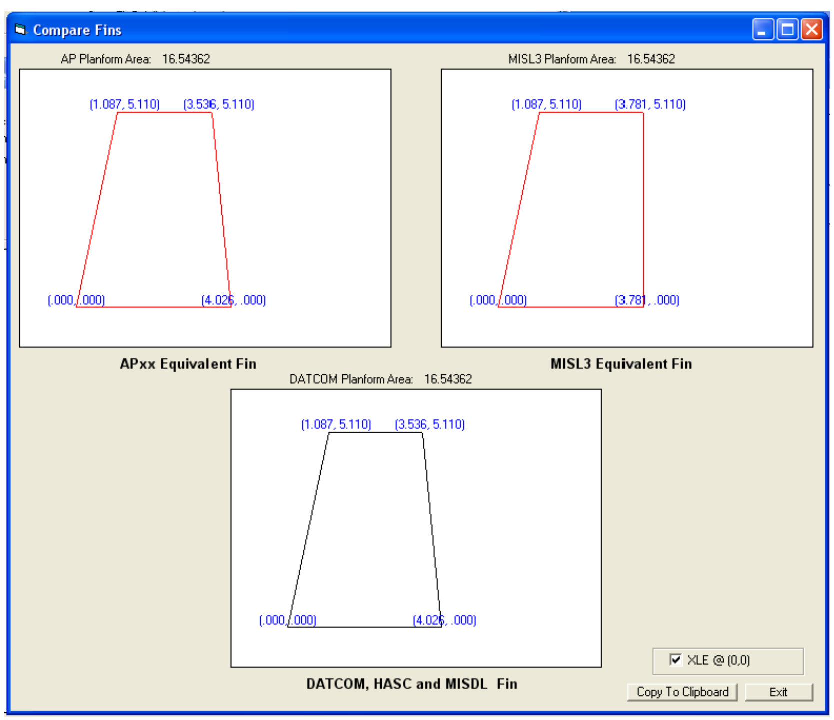
$$Sweep_{LE} = atn\left(\tan(Sweep_{TE}) + \frac{4(1 - Taper\ Ratio)}{AR(1 + Taper\ Ratio)}\right)$$

$$Chord_{Root} = \frac{2 * Planform\ Area}{Span(1 + Taper\ Ratio)}$$

$$Chord_{Tip} = Chord_{Root} * Taper\ Ratio$$



(a)



(b)

Figure 22. Equivalent Fin Panel Geometry Screen

Protuberances Screen

The protuberance geometry input screen is presented in Figure 23. Protuberance geometry as specified on this screen is specific to Missile DATCOM and the 3-D model geometry functions and has no bearing on the input deck generated for APxx, MISL3, MISDL, or HASC. Protuberance inputs for AP05 are entered later under the "APxx Specific Inputs," which will be discussed in Section III.D.6.

When the user clicks on the "Add Protuberance" button, the screen shown in Figure 24 appears. The user then selects the type of protuberance that most closely matches the actual geometry and clicks on "OK." This adds the protuberance type to the protuberance screen, and the actual geometry is then entered. The protuberances can be evenly spaced around the body by selecting the "Default Orientation" option. The "Enter Orientation" option should be selected for all other orientations. After this is selected, clicking on the "Enter/Edit Orientation" button will display the grid shown in Figure 25. The orientation of each individual protuberance around the body is defined here. These orientations are used for the 3-D sketches, DATCOM version 808, and later. Protuberances are not drawn in the 2-D sketches but are displayed in the 3-D sketches.

All or specific protuberance geometry can be turned on and off under the "Geometry Parametrics" screen, which will be discussed further in Section III.D.4.

NOTE: The 2008 (and later) version of Missile DATCOM introduces the new protuberance input "PHIPRO" which allows the user to define the angular location of a protuberance. DATCOM 808 and later versions use the protuberance axial force to calculate a moment. If PHIPRO is not defined, no moment calculations will be computed.

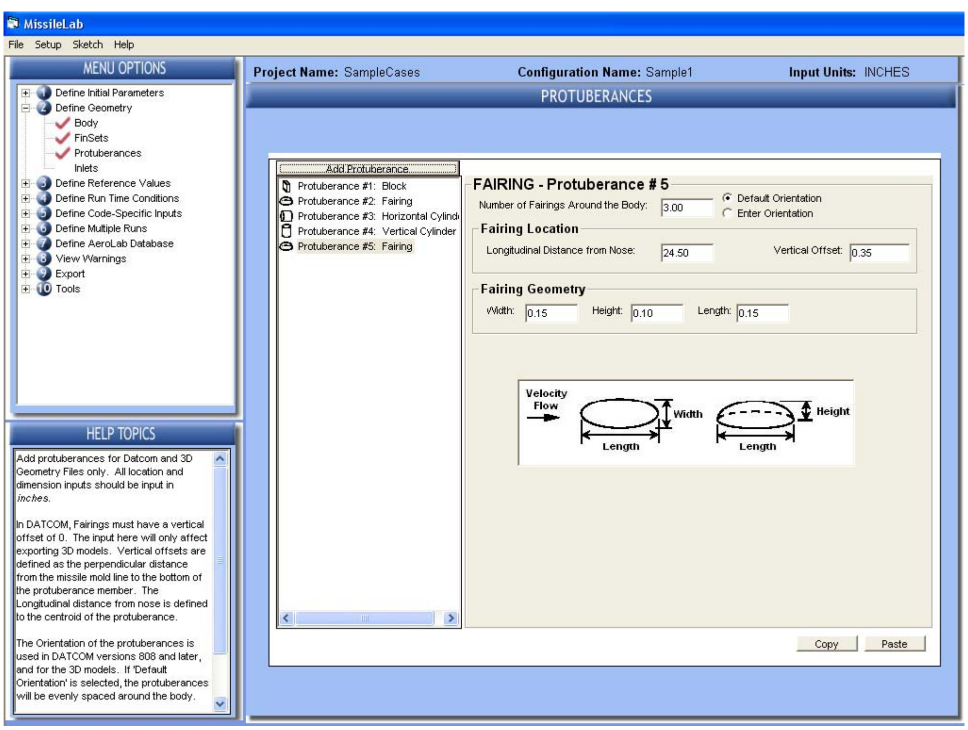


Figure 23. Protuberance Geometry Input Screen

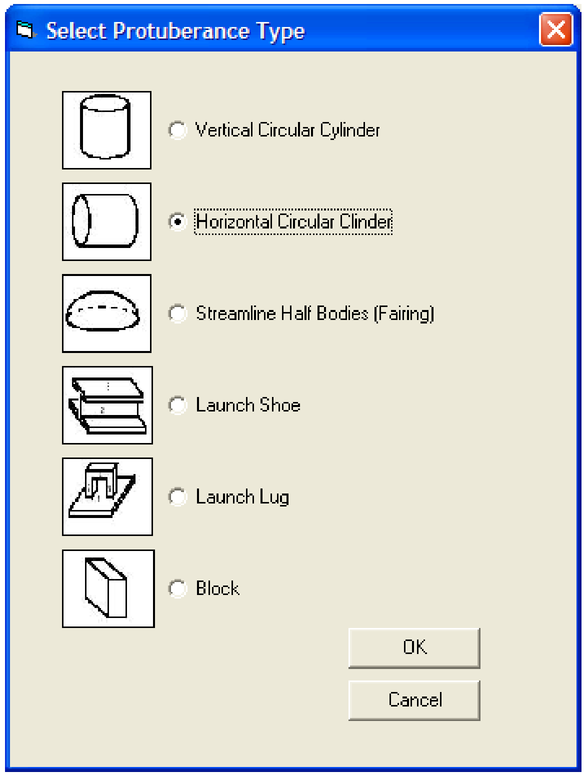


Figure 24. Protuberance Type Selection Screen

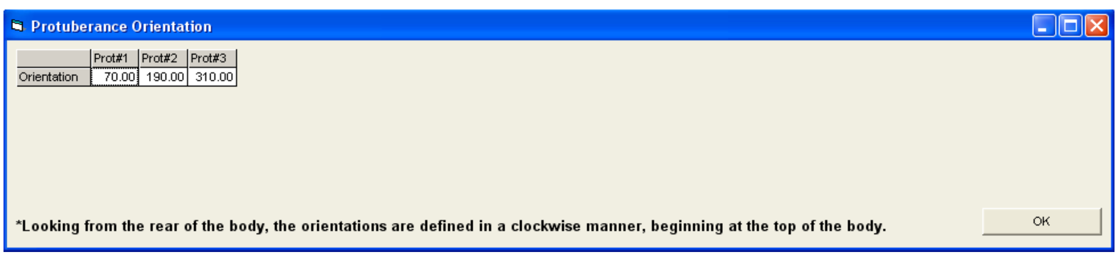
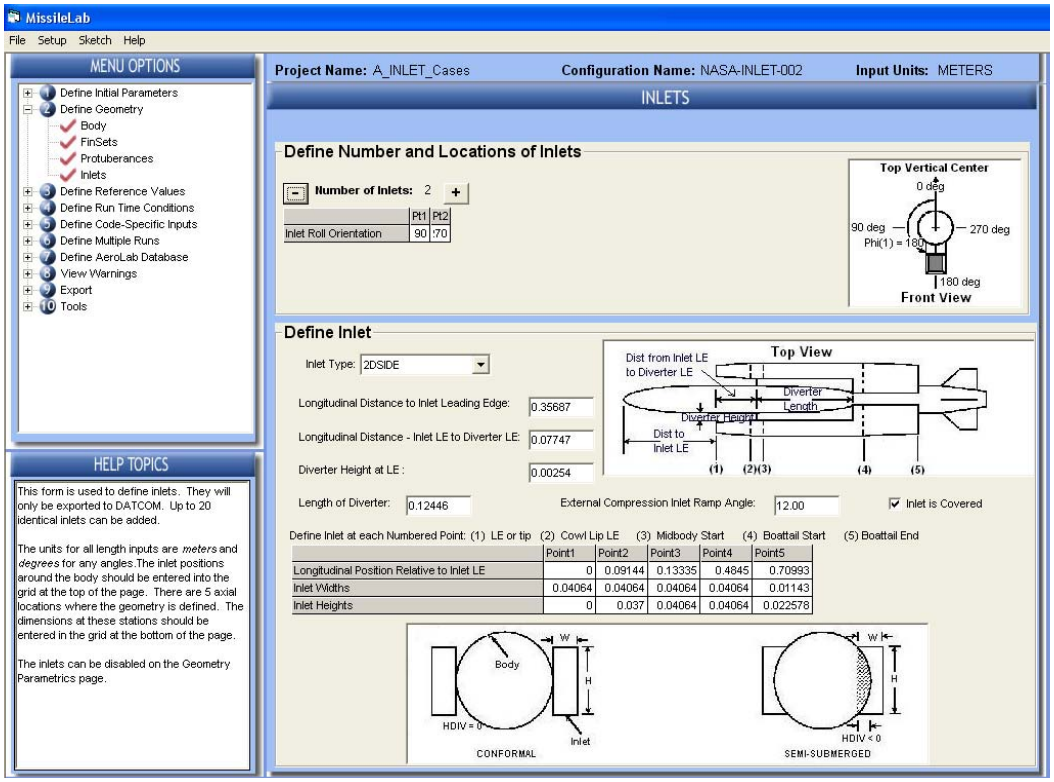


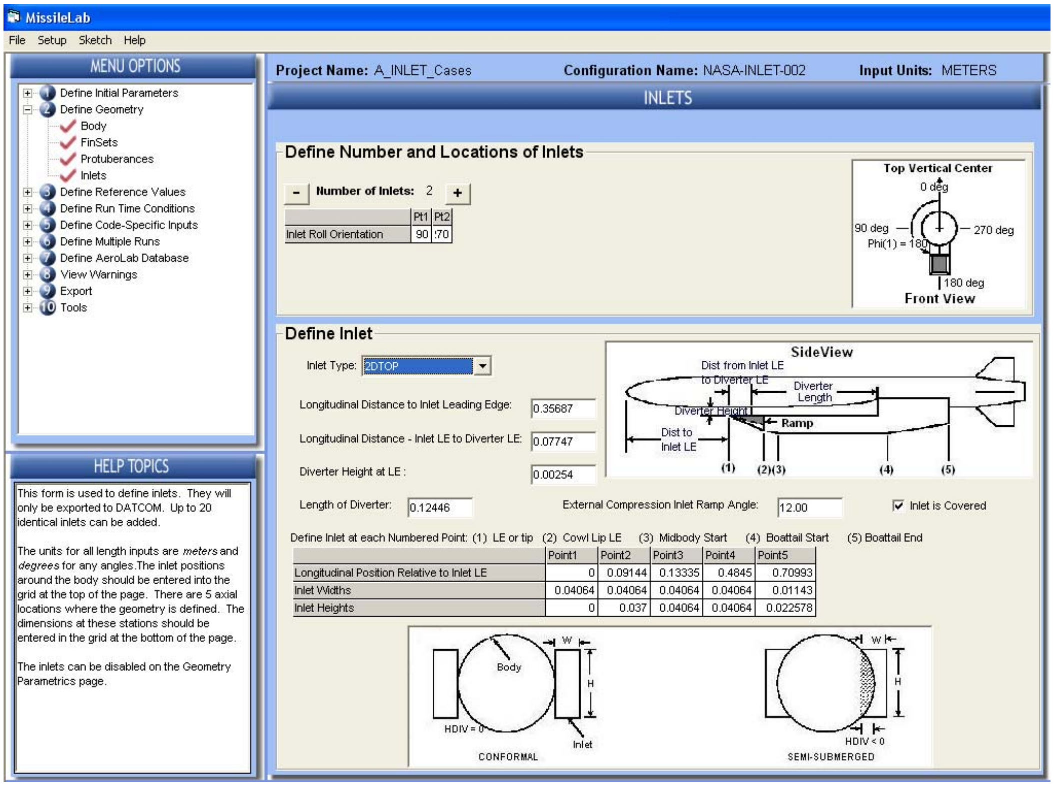
Figure 25. Protuberance Orientation Screen

<u>Inlets Screen</u>

The inlet geometry input screen is presented in Figure 26. Inlet geometry, as specified on this screen, is specific to Missile DATCOM and the 3-D model geometry functions and has no bearing on the input deck generated for APxx, MISL3, MISDL, or HASC. Inlets are not drawn in the 2-D sketches but are displayed in the 3-D sketches. Inlet geometry can be turned on and off under the "Geometry Parametrics" screen which will be discussed further in Section III.D.4.



(a)



(b)

Figure 26. Inlet Geometry Input Screen

3. Define Reference Values Screens

<u>Body Reference Screen</u>

Figure 27 presents the Body Reference screen. Here the user is prompted to enter the characteristic reference length, area, moment reference point, and boundary-layer transition information. For user convenience, a calculator command button is provided that automatically calculates the reference length and reference area based on the maximum body cross section. If other reference values are desired (for example, wing area, area of a non-cylindrical body cross section, and so forth), then the user simply enters the desired value in the text box fields.

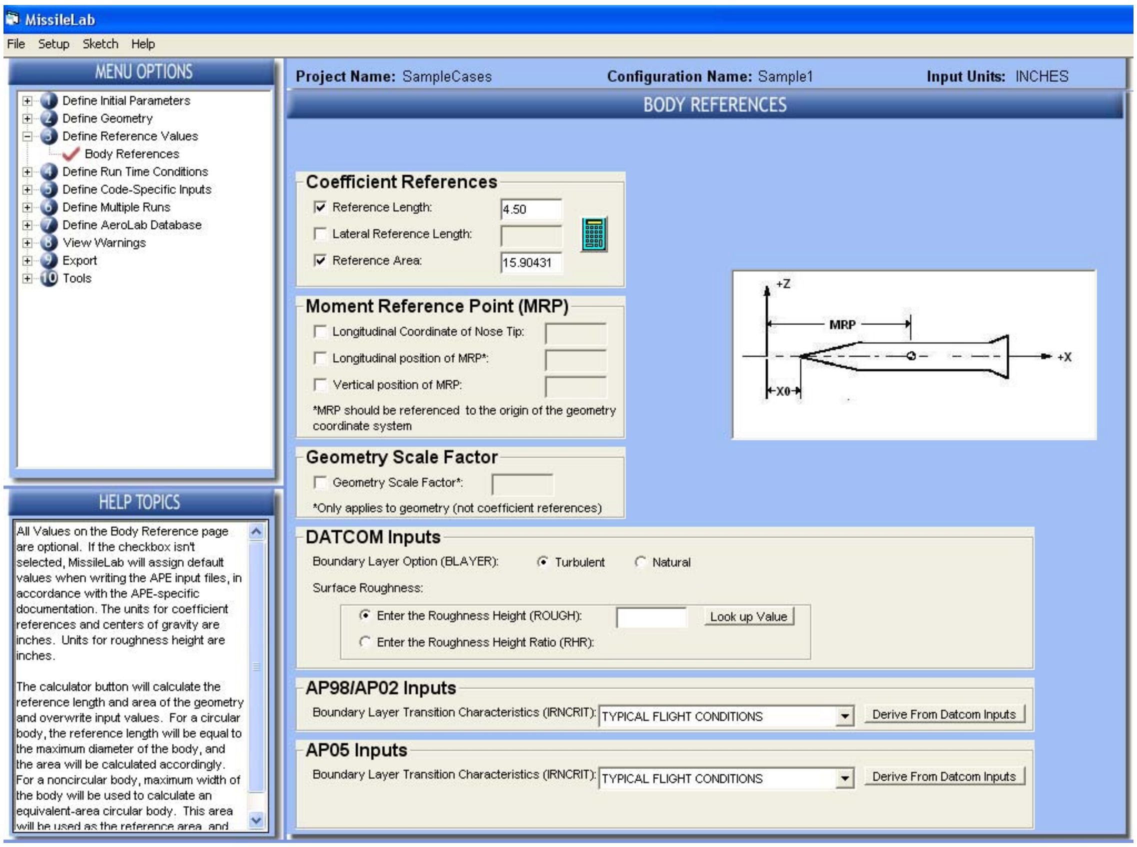


Figure 27. Reference Screen

> ***Change Note: Calculator button functionality.***
>
> The calculator button in previous versions of MissileLab calculated the reference area of a circle with a diameter equal to the reference length. MissileLab version 7 calculates the reference area of the maximum body cross section of the input body shape and sets the reference length to be the diameter of a circle with equivalent area.

Notice the code-specific inputs on the Body Reference page. The user must define the DATCOM boundary layer option and the APxx boundary layer transition characteristics. In this example, the user has the option of allowing MissileLab to derive the APxx boundary layer transition, based on the specified DATCOM inputs, or alternatively the user may select the desired AP boundary layer transition value by way of the pull-down selection box.

Notice that there is a "Look-up Value" button to the right of the roughness value entry field. Selecting this button opens the screen shown in Figure 28. Here the user may select the surface that he or she desires and click "OK." When the screen closes, the selected value is automatically entered into the roughness value field. Similarly, if the user had selected the roughness height ratio option and then selected the look-up value button, the screen shown in Figure 29 would have appeared.

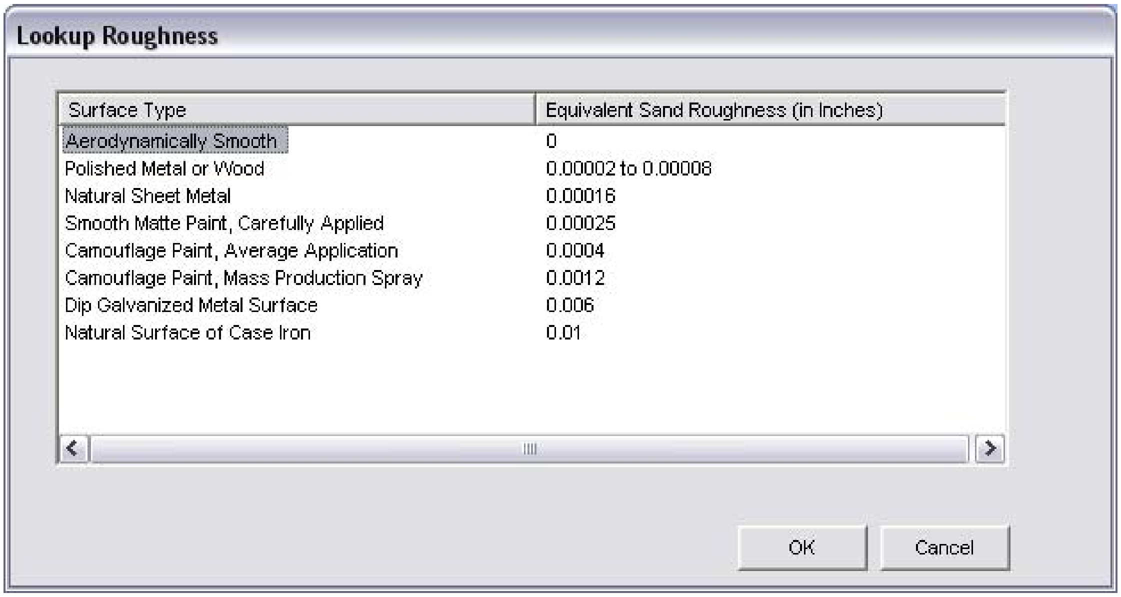


Figure 28. Roughness Height Selection Screen

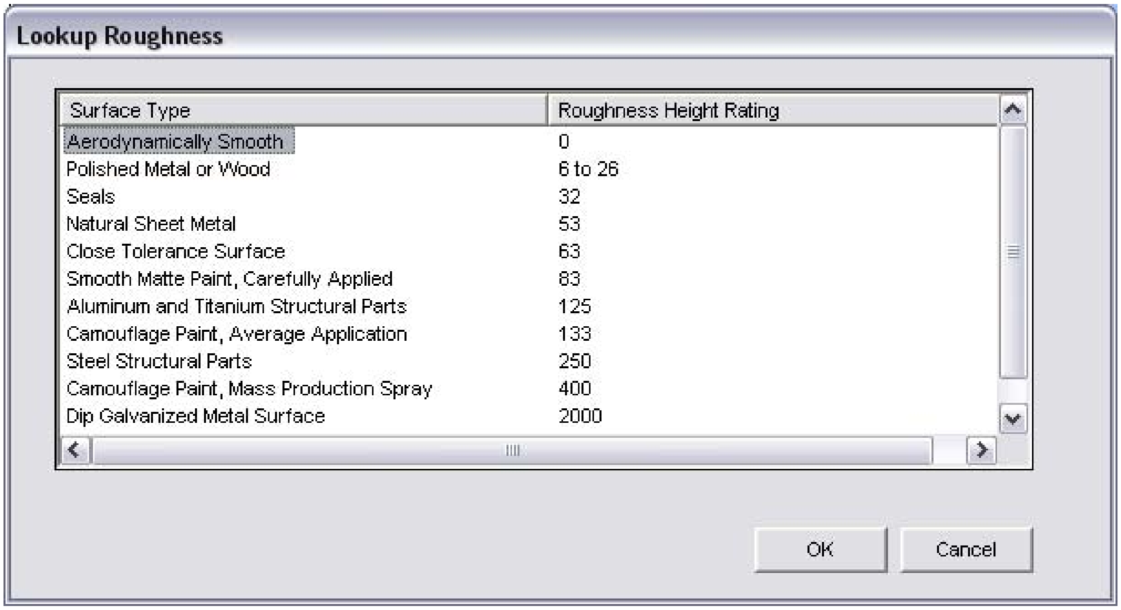


Figure 29. Roughness Height Ratio Selection Screen

4. Define Run Time Conditions Screens

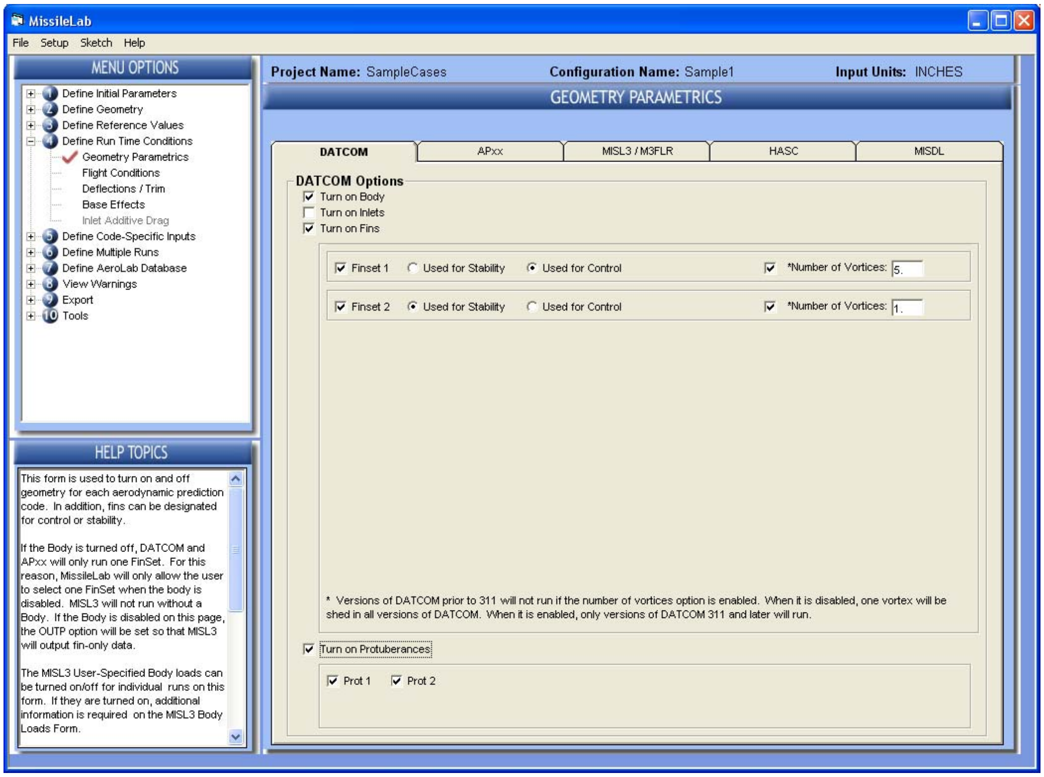
The "Run Time Conditions" screens control body-build-up runs, flight conditions such as Mach number and Angle-of-Attack (AOA), fin deflections, power-on and power-off base drag effects, and inlet-drag effects.

Geometry Parametrics Screen

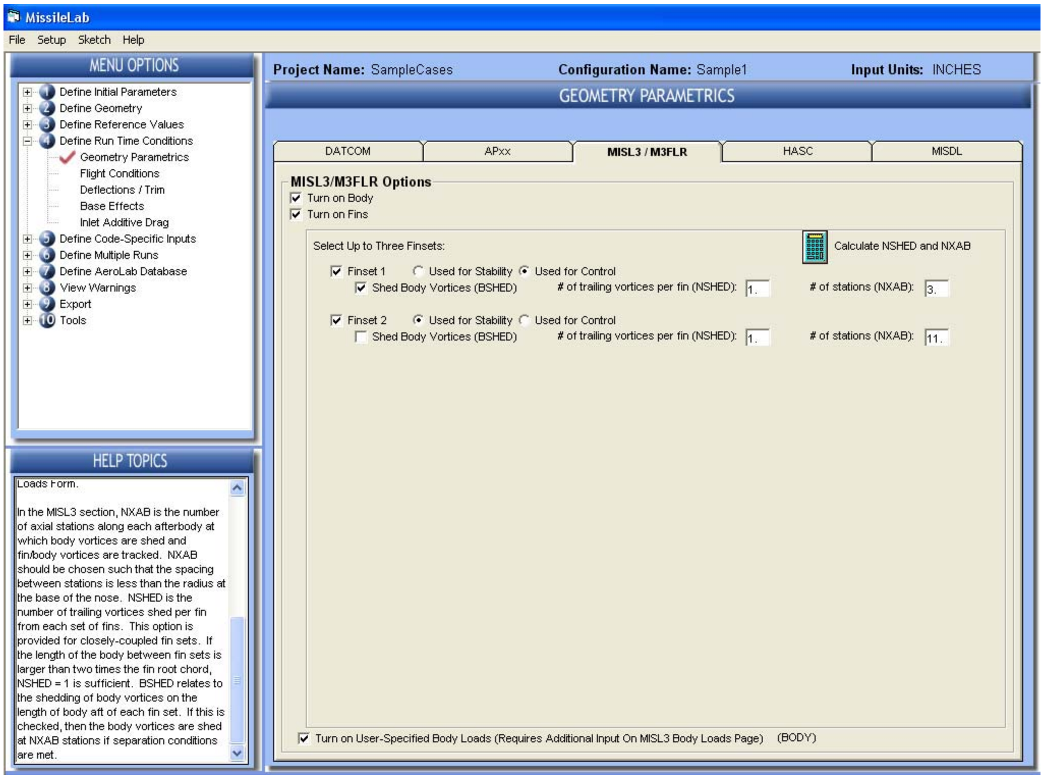
Control over APE geometry files is provided by way of the Geometry Parametrics screen, shown in Figure 30. This screen allows the user to turn on and off fins to conduct body build-up analysis; in the case of Missile DATCOM, inlets and protuberances may be turned on or off; and in the case of APxx, the body may be turned off to allow for wing alone calculations. On the DATCOM tab, vortex shedding information can be entered. If it is entered, versions of DATCOM prior to 311 will not run.

In addition to turning specific finsets on and off, the user should specify if the given finset is to be used for control. As Missile DATCOM, NEAR MISL3, MISDL, and HASC allow for dual control, all finsets may be specified as "Used for Control" for these codes. However, as APxx does not allow for dual control, selecting a given finset for control automatically sets the other finset for "Used for Stability." If fin deflections are to be entered in the "Deflections/Trim" screen that will be discussed later in this section, then one of the finsets must be selected for control.

Figure 30 presents the MISL3 Geometry Parametrics Page. In addition to enabling/disabling body and finsets, the user defines vortex shedding information for each finset enabled. At the bottom of the page is an option for enabling User-Specified Body Loads. If this is selected, the loads should be entered on the MISL3 Body Loads page (discussed later).

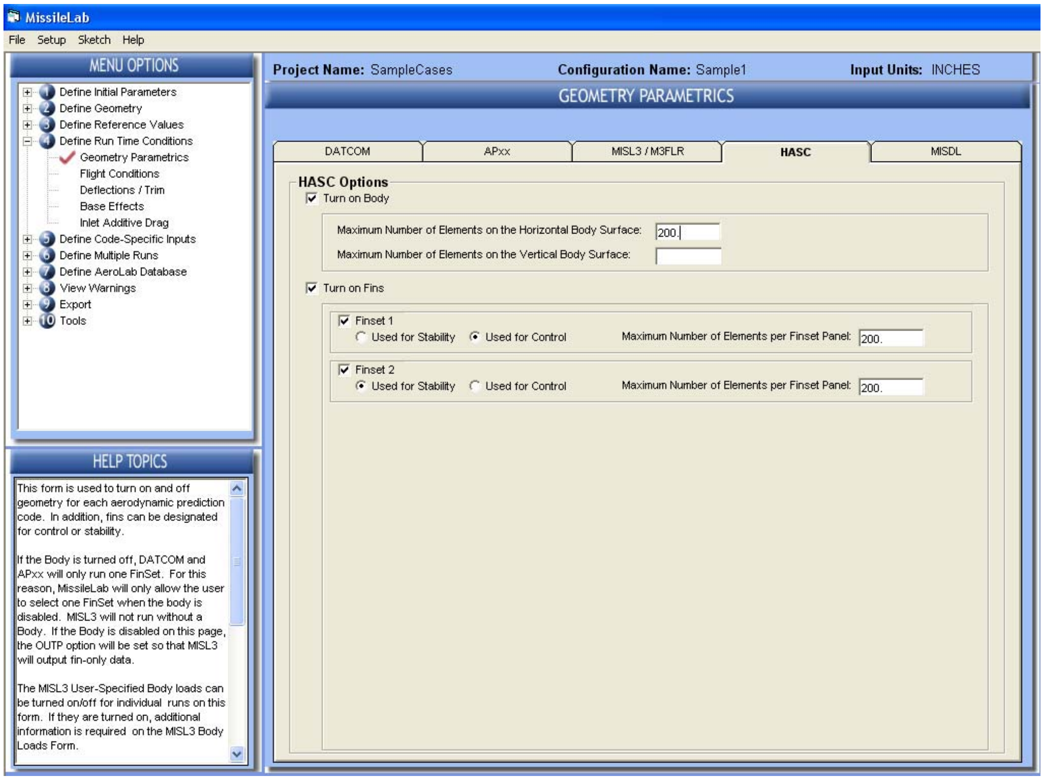


(a)



(b)

Figure 30. Geometry Parametrics Screen



(c)

Figure 30. Geometry Parametrics Screen (Concluded)

The HASC Geometry Parametrics page is shown in Figure 30. The user must enable/disable the body and finsets. In addition, the maximum number of elements to be used for the body and finsets must be defined.

<u>Flight Conditions Screen</u>

Flight conditions, such as Mach number, altitude, AOA, and roll angle are entered into MissileLab using the flight conditions input screen shown in Figure 31. The user has several ways to enter the desired velocity conditions, as shown in Table 5. As APxx, MISL3, and HASC require Mach number and Reynolds number as the input, these values are calculated by MissileLab using an atmosphere model if any values other than Mach and Reynolds number are entered.

Up to 20 Mach numbers and up to 20 AOAs may be entered for a given case. AOAs can be specified using a range and increment value by clicking on the “Enter Range and Increment” button. Also, the user may specify a Side-slip angle or an Aerodynamic roll angle. The Side-slip or roll angle is exported to DATCOM, MISL3, and MISDL but is not exported to APxx because AP supports roll angles of 0 and 45 degrees only. If Side-slip is defined, it will be exported to HASC. Roll angle is not exported to HASC. If the user wishes to export ϕ=45 degrees data from APxx, then this is specified by way of the APxx specific pull-down box on the Flight Conditions screen.

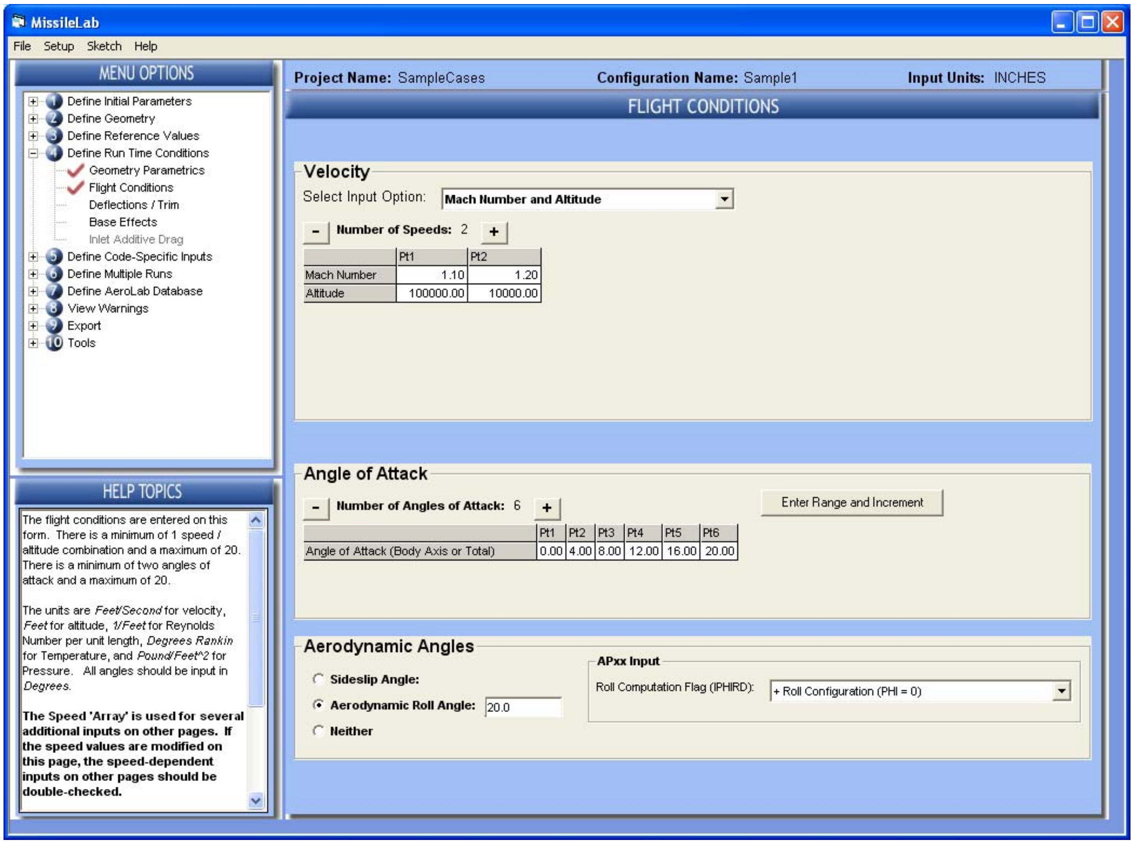


Figure 31. Flight Conditions Input Screen

Table 5. Flight Conditions Screen Pull-Down Fields

MissileLab	DATCOM	APxx, MISL3, HASC	MISDL
Mach & Altitude	As entered	Mach & Rn calculated using a standard Atmosphere model	As entered
Mach & Rn	As entered	As entered	As entered
Mach, Pressure, & Temperature	As entered	Mach & Rn calculated using a standard Atmosphere model	Mach & Rn calculated using a standard Atmosphere model
Velocity & Altitude	As entered	Mach & Rn calculated using a standard Atmosphere model	Mach & Rn calculated using a standard Atmosphere model
Velocity, Pressure, & Temperature	As entered	Mach & Rn calculated using a standard Atmosphere model	Mach & Rn calculated using a standard Atmosphere model

Deflections/Trim Screen

Canard/Wing/Fin control deflection inputs are specified in the "Deflections/Trim" screen, presented in Figure 32. As noted previously, for these fields to be active, the user must have selected a fin set for control on the "Geometry Parametrics" screen (see Figure 30). To simplify the "Deflections/Trim" page, the "DATCOM/MISL3/MISDL/HASC" section will use the finsets designated for control from the DATCOM option to enable finsets on the Geometry Parametrics page. If the deflections are being exported to an APE that does not have the same finset(s) designated for control, the deflections will not be exported. Always check the Geometry Parametrics page to ensure that the correct finsets are designated for control. Notice also the two styles for inputting control deflections. The first is per panel as used for DATCOM, NEAR MISL3, MISDL, and HASC, and the second is for an equivalent fin deflection angle as used in the APxx codes.

MissileLab and DATCOM define positive fin panel deflection angles that positive fin deflection angles produce a negative (or counterclockwise) rolling moment.

NEAR MISL3 and MISDL define positive fin panel deflections so that they produce a positive normal force. Therefore, when MissileLab is writing these input files, MissileLab will change the SIGN of the fins on the "left side" (that is, 180 < phi < 360) of the missile to conform to the NEAR MISL3 and MISDL fin deflection standard. Deflections in HASC also have the SIGN changed on the "left side" of the missile. If trailing edge flaps are defined, the fin deflections will be applied to the flap in DATCOM. For MISDL, the fin and the flap can be deflected independently. The MISDL flap deflections should be entered in the MissileLab sign convention.

APxx expects an equivalent fin deflection angle that will produce an in-plane pitch maneuver. Positive equivalent fin deflection angles in AP produce a positive normal force increment at zero AOA for both canard controlled and tail controlled configurations. Therefore, assuming that canards are forward of the MRP and the tails are aft of the MRP, then positive canard deflections in AP produce positive (nose up) pitching moments, and positive tail deflections in AP produce negative (nose down) pitching moments.

The "Run Trimmed Flight" option is used to obtain trim conditions. If this option is selected, the finset number to be used is input, as well as maximum and minimum deflections and the designation of which panels in the finset are used. Missile DATCOM 311 supports designation of how many deflections are used between the maximum and minimum values, which is entered here also. Trimmed flight applies only to DATCOM and MISL3.

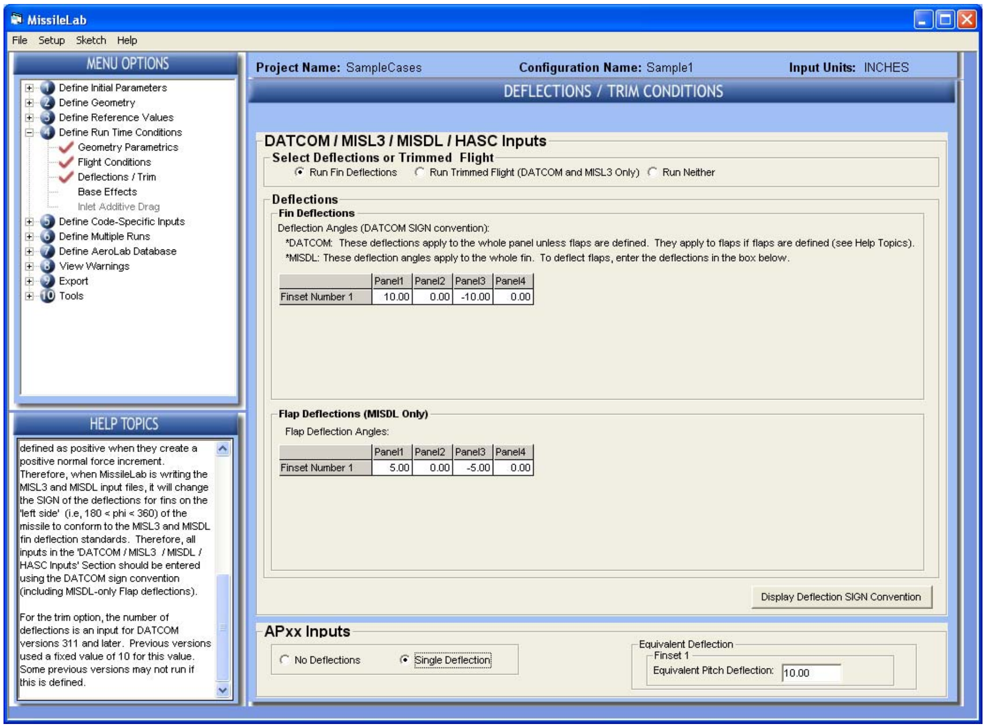


Figure 32. Control Deflections Input Screen

Base Effects Screen

Base drag effect information is entered by way of the panel presented in Figure 33.

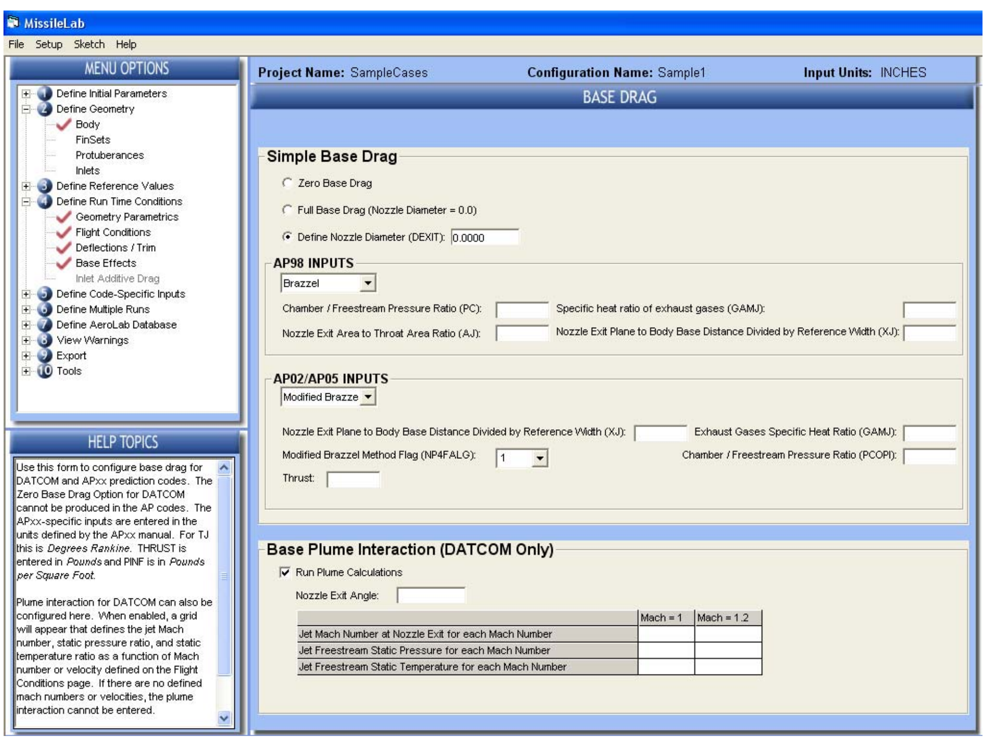


Figure 33. Power-On and Power-Off Base Drag Input Screen

Inlet Additive Drag Screen

Inlet Additive Drag information is entered by way of the panel presented in Figure 34. This option will be disabled (as shown in Figure 33) if no inlets have been defined.

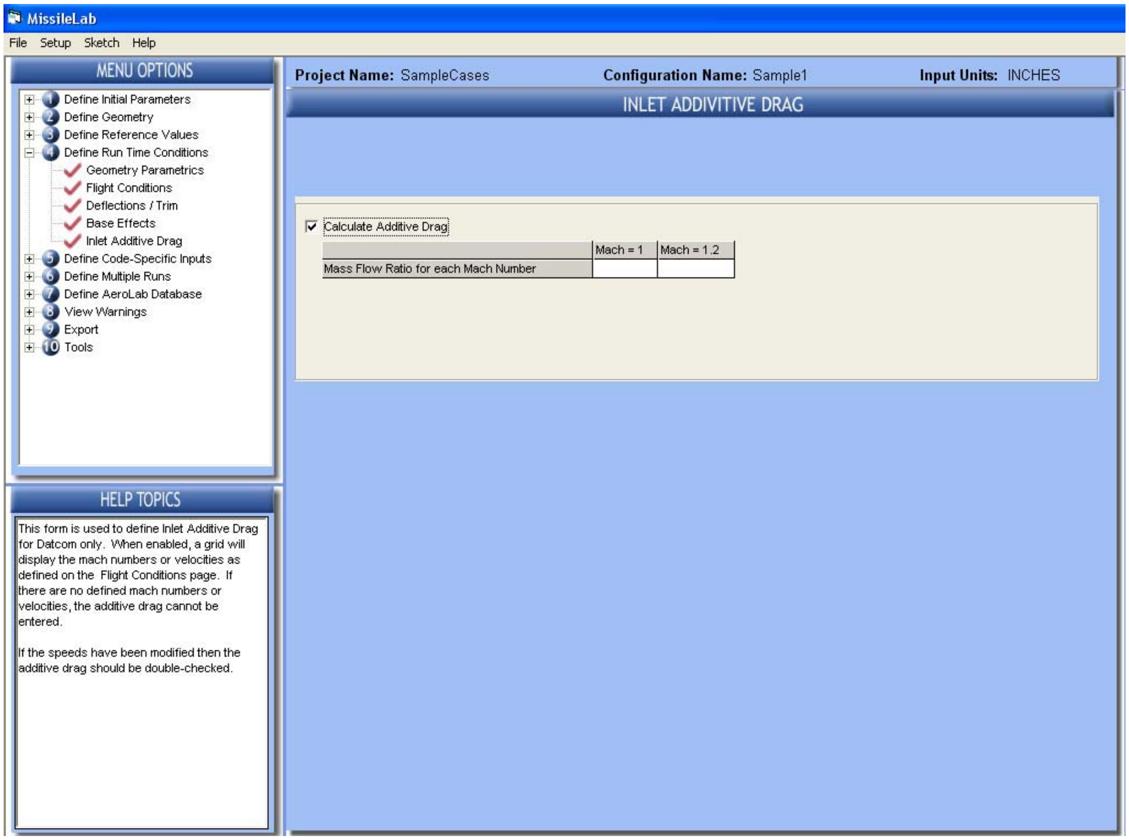


Figure 34. Inlet Additive Drag Input Screen

5. Code Specific Inputs Screens

DATCOM-Specific Inputs Screens

The "DATCOM-Specific Inputs" screens control various DATCOM cards such as SOSE, HYPERS, PART, BUILD, DAMP, SPIN, and so forth. As these control cards should be familiar to any experienced DATCOM user, nothing else will be discussed about them here, other than to show the various screens (see Figures 35 through 37). If additional information is required, please refer to the DATCOM user's manual.

The screen shown in Figure 37 provides controls for "WRITING" and "DUMPING" array data from older versions of Missile DATCOM (version 9/02 and earlier). This functionality has been deleted from DATCOM 1/06 and later versions of the code.

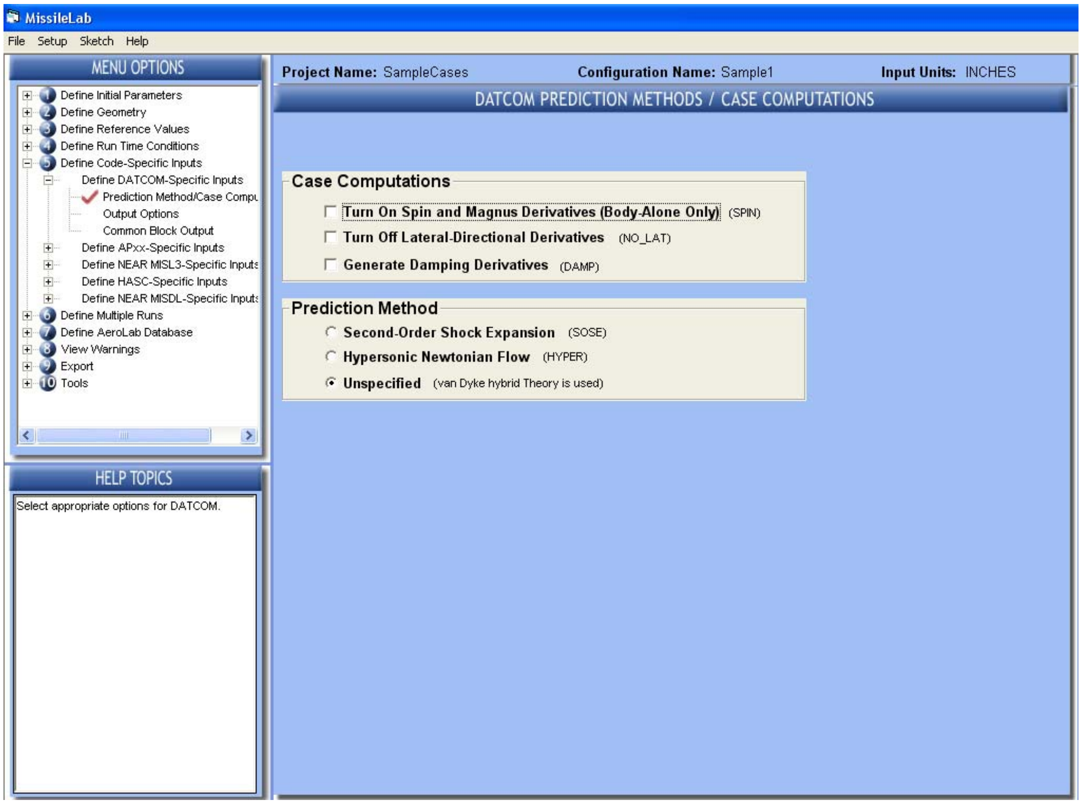


Figure 35. DATCOM Prediction Methods Screen

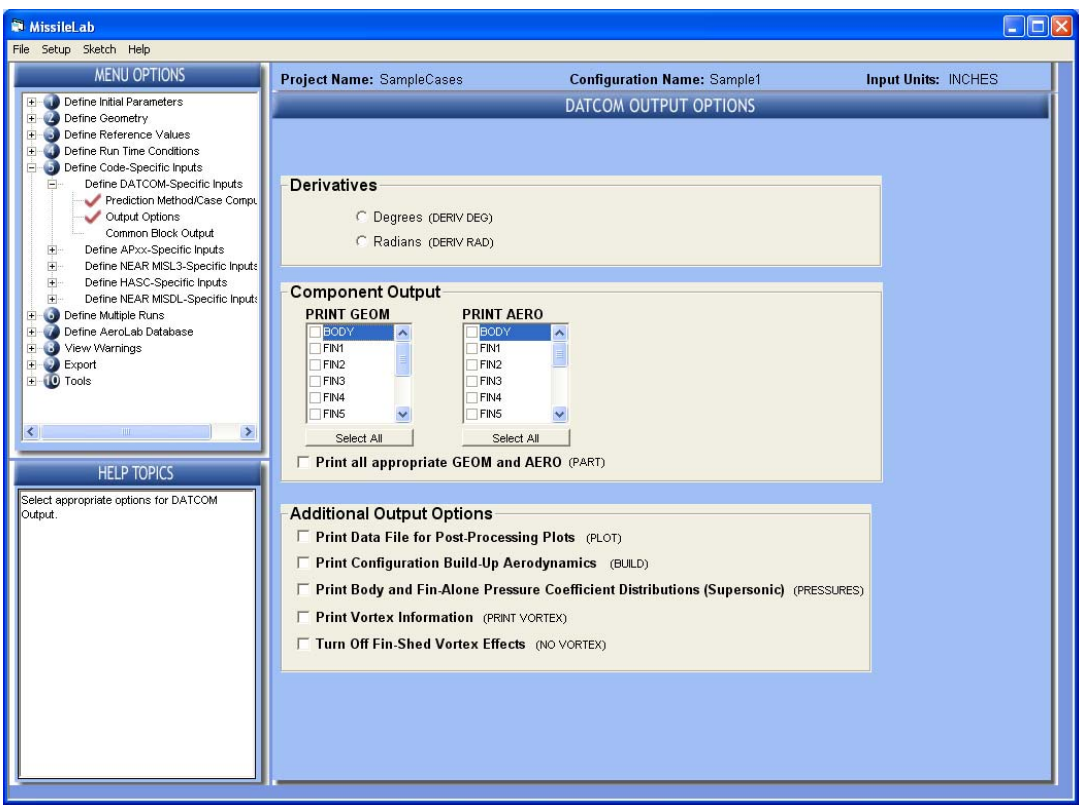


Figure 36. DATCOM Output Options Screen

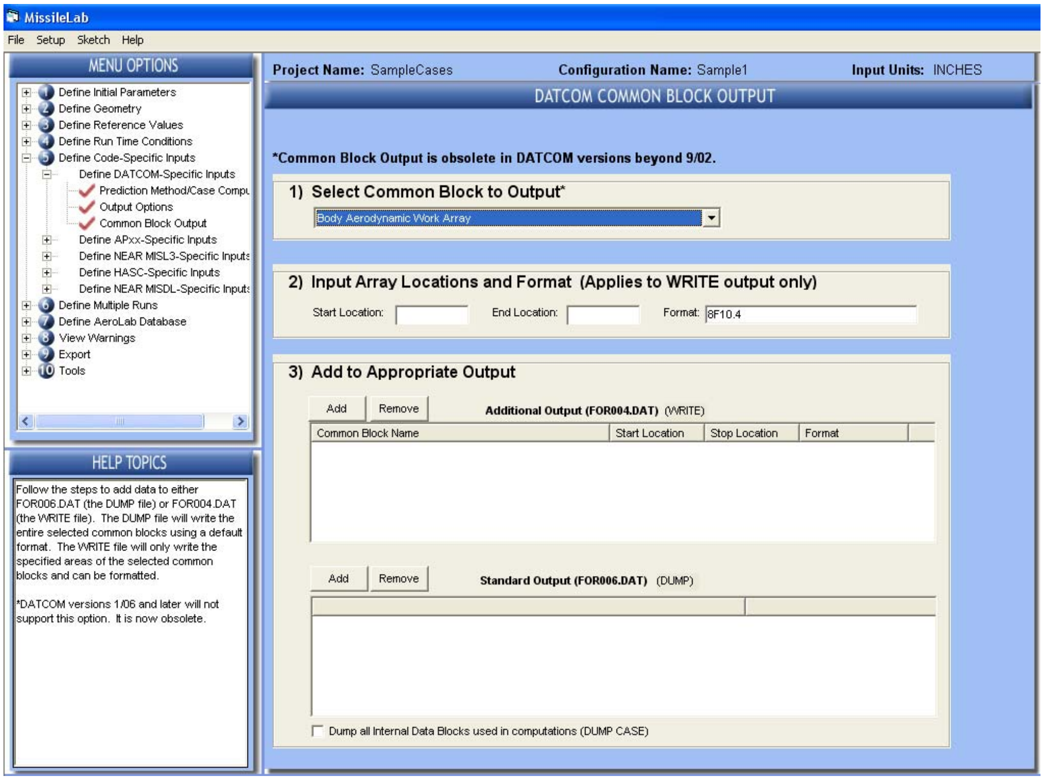


Figure 37. DATCOM Common Block Output Screen

<u>APxx-Specific Inputs Screens</u>

The "APxx-Specific Inputs" screens control various AP-xx control cards, such as ISPIN, IPRINT, ALIMIT, ALIMS, smoothing, and so forth. As these control cards should be familiar to any experienced AP user, nothing else will be discussed about them here, other than to show the screen in Figure 38. If additional information is required, please refer to the AP user's manual.

The AP05 protuberance screen is presented in Figure 39. Again, the user is referred to the AP05 manual for more information. However, there is one subtle point that is not covered in the AP05 manual that will be briefly discussed below.

MissileLab does NOT automatically populate the Mach array for the AP05 protuberance screen, as the inputs do not have to correspond to the Mach numbers input under the flight conditions input screen.

AP05 allows the user to input any number of Mach numbers and corresponding protuberance data. AP05 (that is, AP05FOR.EXE) then interpolates the protuberance data, given the input flight condition Mach number. For flight condition, Mach numbers that are outside the input protuberance Mach numbers, AP uses the nearest set of protuberance data. For example, suppose someone put in perturbation inputs at Mach 2.3 and 4.6, as was done in the AP05 User's Guide. The user then ran Mach numbers of 1.0, 2.3, 3.5, 4.6, and 7.0. AP05 would use the protuberance data defined for Mach 2.3 for flight conditions of Mach 1.0 and 2.3. For the flight condition of 3.5, AP05 would interpolate between the 2.3 and 4.6 protuberance data, and for the flight conditions of 4.6 and 7.0, AP05 would use the protuberance data defined at Mach 4.6.

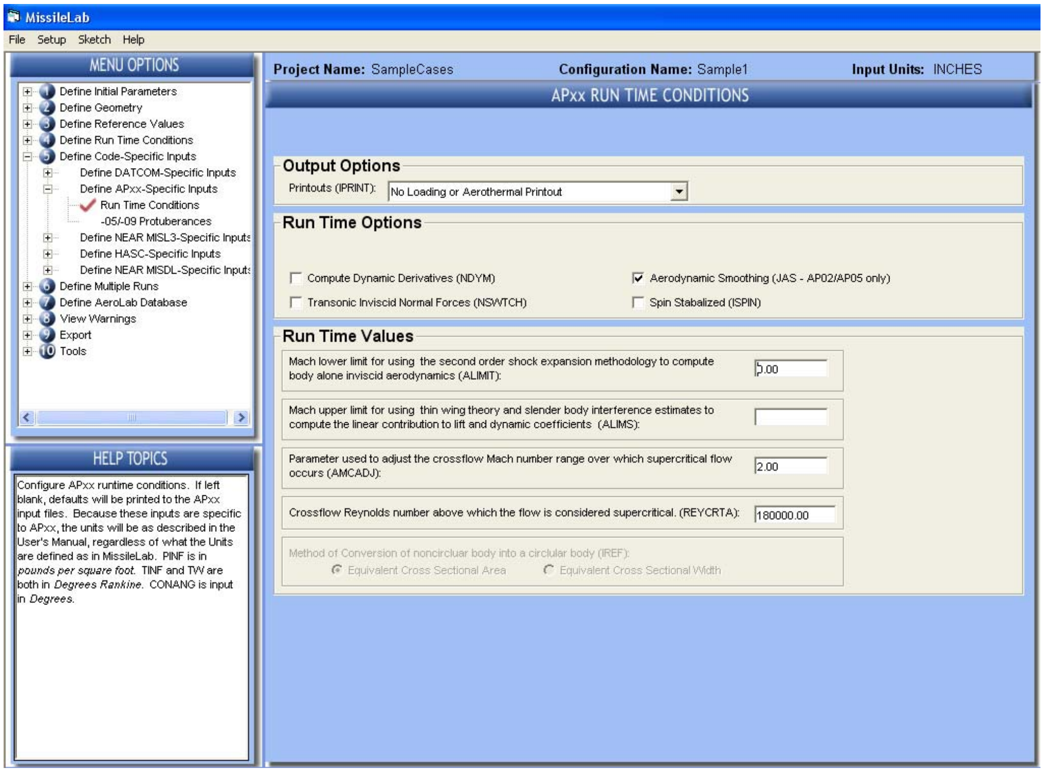


Figure 38. APxx Run Time Conditions Screen

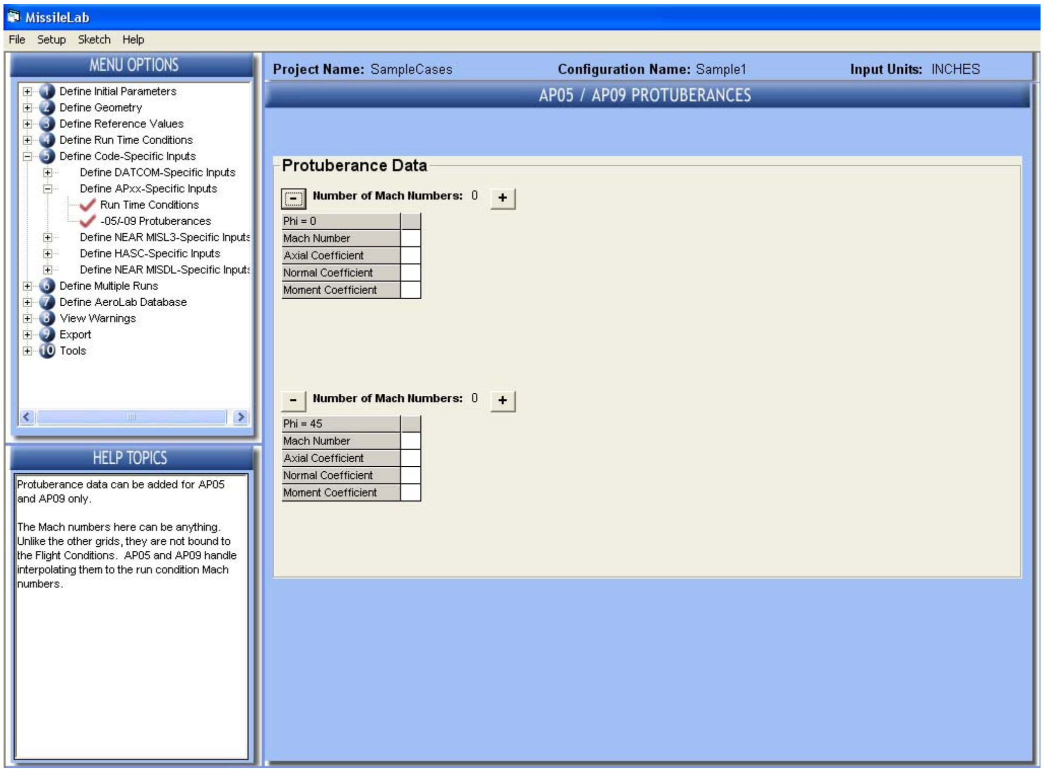


Figure 39. AP05 Protuberance Input Screen

NEAR MISL3-Specific Inputs Screens

The "NEAR MISL3-Specific Inputs" screens presented in Figures 40 and 41 control various NEAR MISL3 control cards such as body rotation rates, body loads, output options, and so forth. These control cards should be familiar to any experienced NEAR MISL3 user. If additional information is required, please refer to the NEAR MISL3 user's manual.

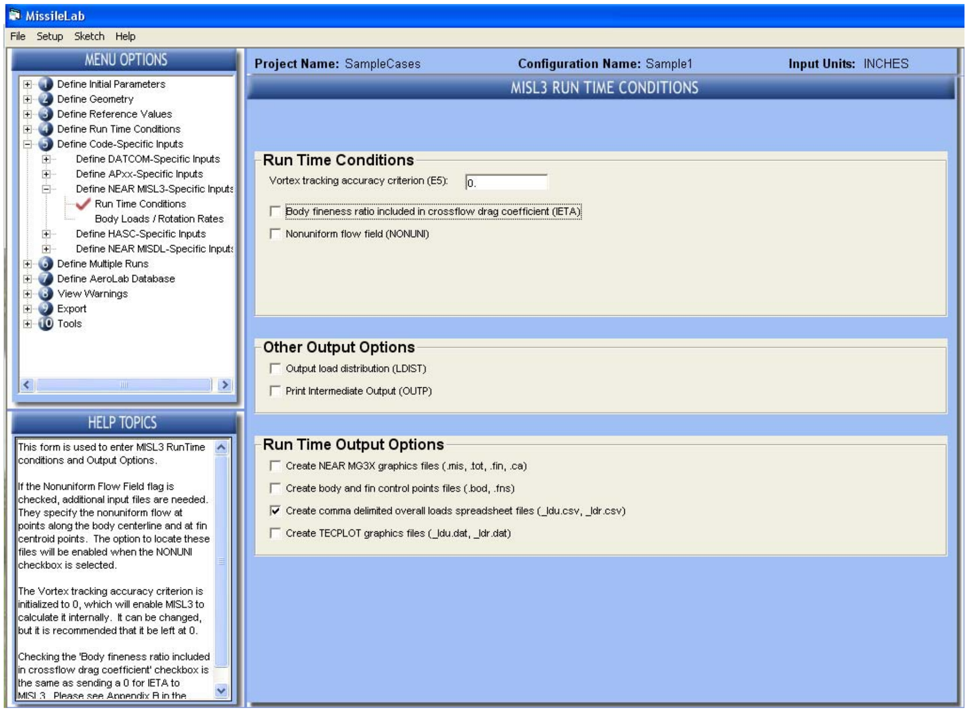


Figure 40. NEAR MISL3 Run Time Input Screen

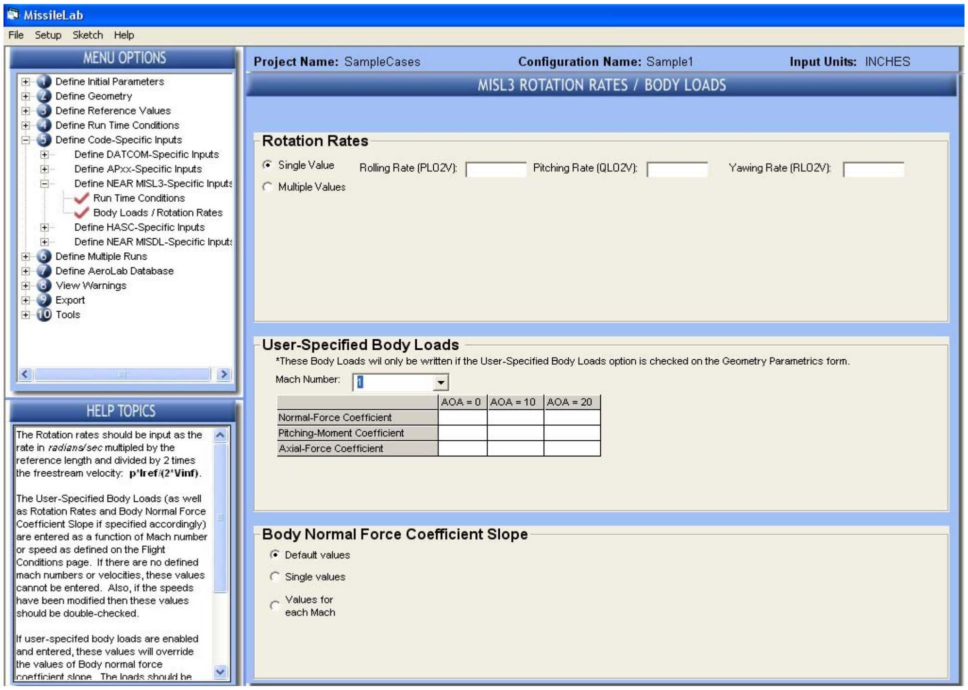


Figure 41. NEAR MISL3 Body Loads Input Screen

HASC-Specific Inputs Screens

The "HASC-Specific Inputs" screen presented in Figure 42 describes various run time conditions for HASC. These include vortex spacing, ground effects, output options, and rotation rates. Please refer to the HASC user's manual if additional information is required.

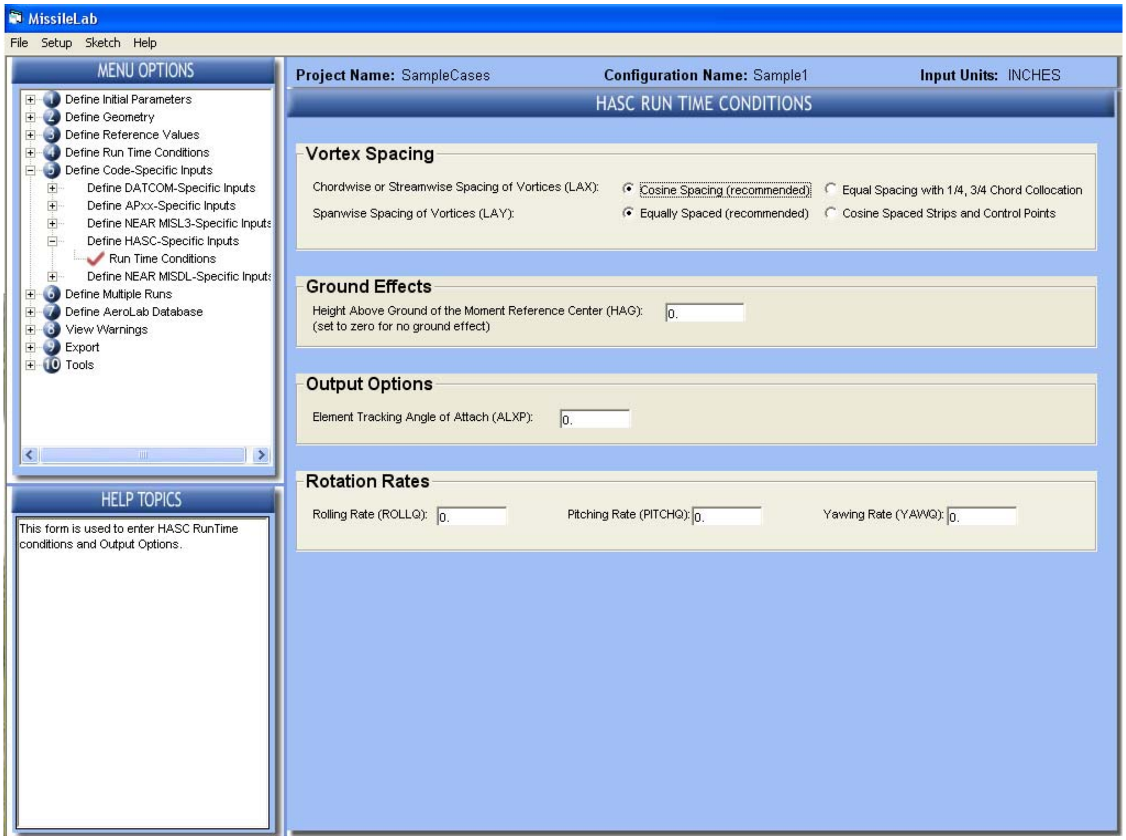


Figure 42. HASC Run Time Input Screen

MISDL-Specific Inputs Screens

The "MISDL-Specific Inputs" screens presented in Figures 43 and 44 control various MISDL inputs, such as additional fin information, run time conditions, and rotation rates. A few inputs are discussed here. Please refer to the MISDL user's manual if additional information is required. Note that the parameters that define the panel layout on the "MISDL Fin Parameters" page are not given default values. It is critical that these values be entered accurately. MissileLab gives suggested values (by clicking on the "Show Suggested Values" button), but it is the user's responsibility to verify these values and enter the appropriate panel layout information.

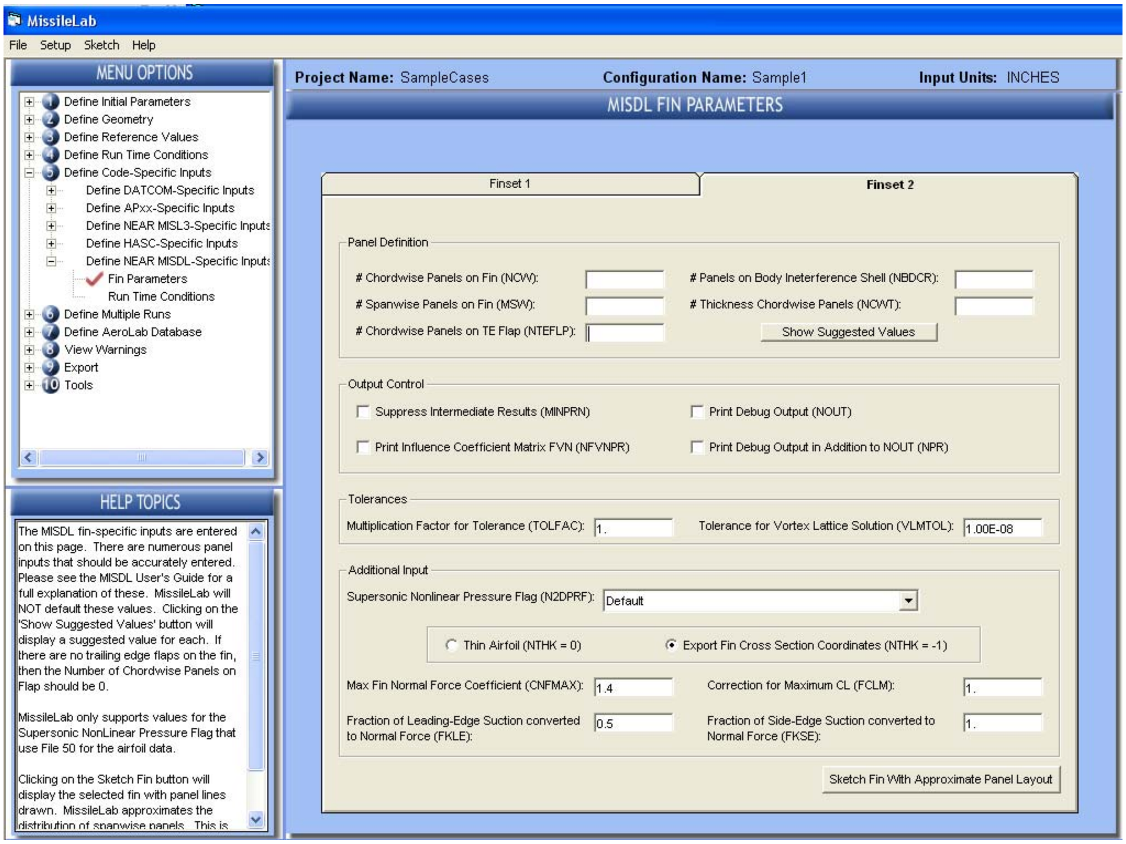


Figure 43. MISDL Fin Parameters Input Screen

On the Run Time Conditions page, there are four inputs that do not correspond directly to MISDL inputs. These inputs are used for an Arbitrary Body only, and the "View Arbitrary Body Definitions" button provides a graphical description of them. The first two are "Number of Radial Slices Around Body Cross Section" and "Number of Corner Slices." These two inputs will be used to determine the MISDL variable "NR." The "Number of Corner Slices" applies only to a non-circular, non-elliptical cross section that has a corner radius defined. It defines how many "slices" will be generated at EACH corner. The number of radial slices should INCLUDE the number of corner slices. Also, this number is defined around the ENTIRE cross section (not just one half, as NR is defined). The actual number of slices may be internally adjusted (slightly) by MissileLab if necessary. The maximum number of slices is 60.

The "Cylindrical/Conical Section Diameter Multiplier" is used to determine the spacing of the cross sections. For example, a value of 1.0 for a body with a diameter of .5 units would produce a cross section output every .5 units. This applies only to conical or cylindrical segments aft of the nose. The nose segment is always broken into 31 cross sections to provide an accurate geometry of the nose types. An Ogive aft segment also uses 31 sections. The "View Slices" button provides a 2-D sketch of the body showing the cross section divisions.

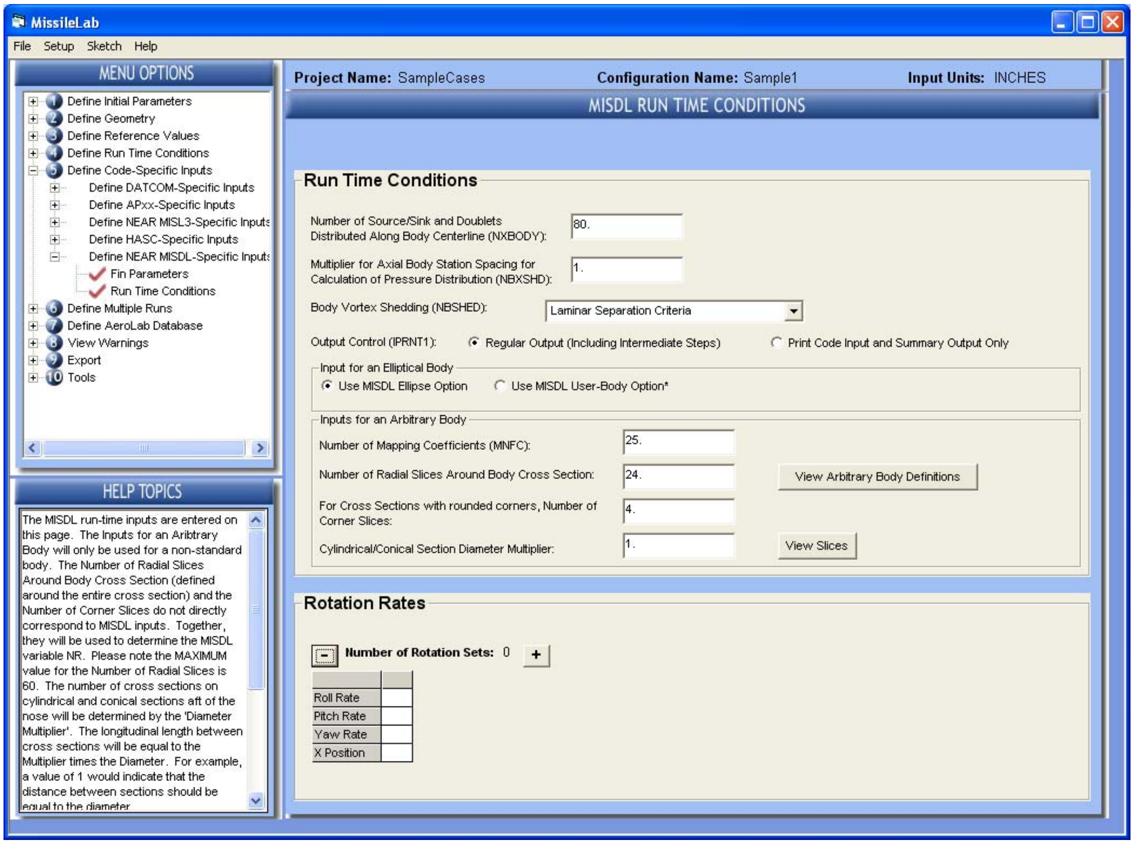


Figure 44. MISDL Run Time Input Screen

6. Define Multiple Runs Screen

<u>Run Manager Screen</u>

The "Multiple Runs" case manager screen is presented in Figure 45. In designing this screen and functionality, the question that must be addressed is: "What do we allow the user to change for a specific project configuration file?" Using the guidelines set out in Section I, it was decided that for a given configuration, the user should have control over (1) body build-up, (2) flight conditions, (3) control deflections, (4) power-on and power-off base drag, and (5) inlet drag. If, for example, the MissileLab user needs to change the wing geometry, this should be done by making a copy of the MissileLab geometry file (*.MNL) and then modifying the wing in that file. If, however, the MissileLab user wants to make various control deflection runs (for the given airframe geometry), then that will be handled by the case manager, as shown in Figure 45.

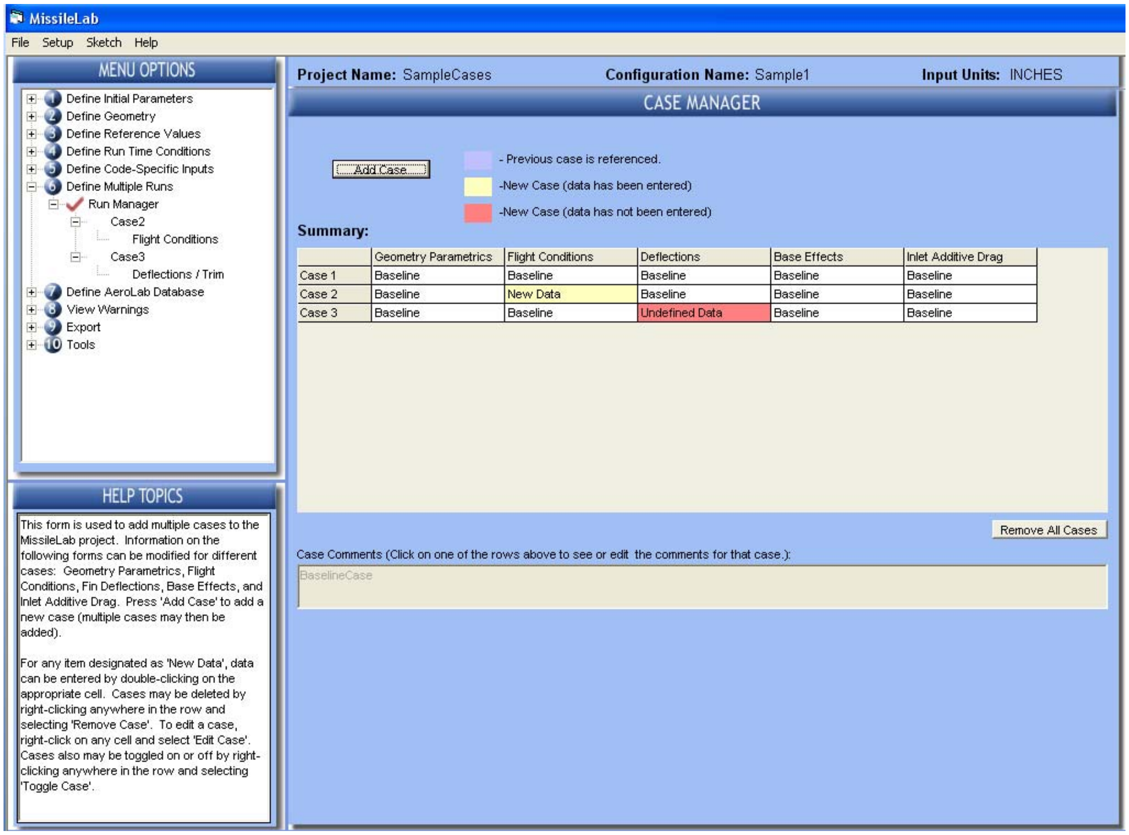


Figure 45. Multiple Run Case Manager Screen

Once the baseline geometry is defined, the user may add multiple cases (by clicking on the "Add Case" button), select what will change for that case, and then enter the new data. The data for the new case will be initialized with the data from the baseline case. To enter the new data, the user can "double-click" on the appropriate "Undefined Data" cell in the grid (likewise, "double-clicking" on a "New Data" cell will allow editing of the data). In addition, the cases will be added to the Menu Options tree under Run Manager (as seen in Figure 45), and selecting them works just like clicking on any other "Menu Option" item. When additional cases are defined, MissileLab LOCKS the baseline geometry to prevent the user from inadvertently modifying the baseline data. When this occurs, a red "KEY" command button appears in the upper left of each screen. Clicking on this button will unlock the screen and allow the user to modify the baseline configuration data.

7. Define AeroLab Database Parameters Screen

<u>Configure AeroLab Database Parameters Screen</u>

To facilitate comparison of predicted data to wind tunnel test results, functionality has been incorporated to have MissileLab automatically generate an AeroLab database. The AeroLab database interface screen is presented in Figure 46. On this screen, the user must specify the 6-character alphanumeric database name, a configuration name, and "database run numbers."

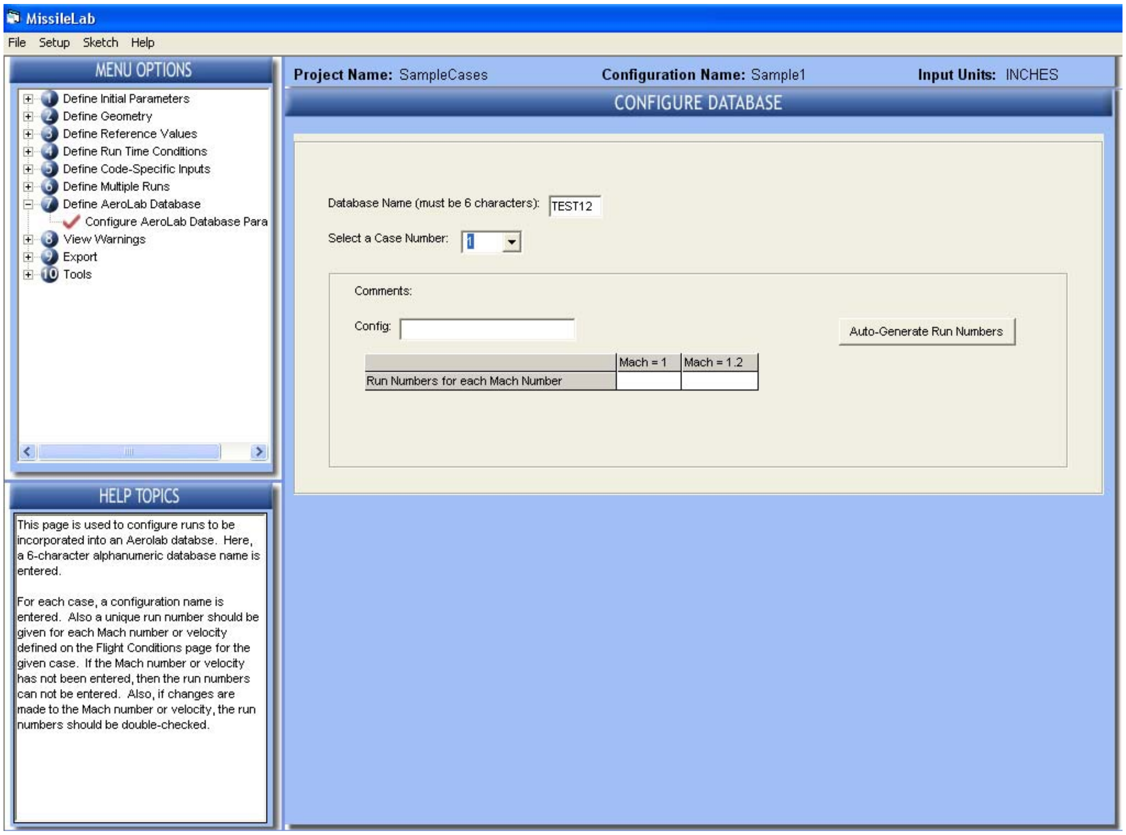


Figure 46. AeroLab Database Management Screen

8. View Warnings Screens

An attempt has been made to identify as many "problems" as possible before the specific APE input files are generated. MissileLab generates two types of warnings: ***CRITICAL ERROR*** and ***NONCRITICAL WARNING***. If MissileLab identifies a critical error for a given APE, that code is disabled and cannot be selected on the "Export Data" screen. MissileLab will allow the user to run APEs with noncritical warnings, but the user should review all warnings.

For example, some APEs allow for eight fins, while others do not. Therefore, if the airframe geometry is defined with eight wings/fins, MissileLab identifies this as a CRITICAL ERROR for the codes that will not run eight fin panels. An example of a noncritical warning would be if the user defined an airfoil section with a NACA airfoil. APxx does not have NACA airfoil capability, so MissileLab substitutes a bi-convex fin section when it writes the APxx input file.

Figures 47 through 51 present sample warning pages for a given airframe geometry. A summary list of the errors and warnings that MissileLab identifies is accessible under the Help menu item, and an example of this screen is presented in Figure 52.

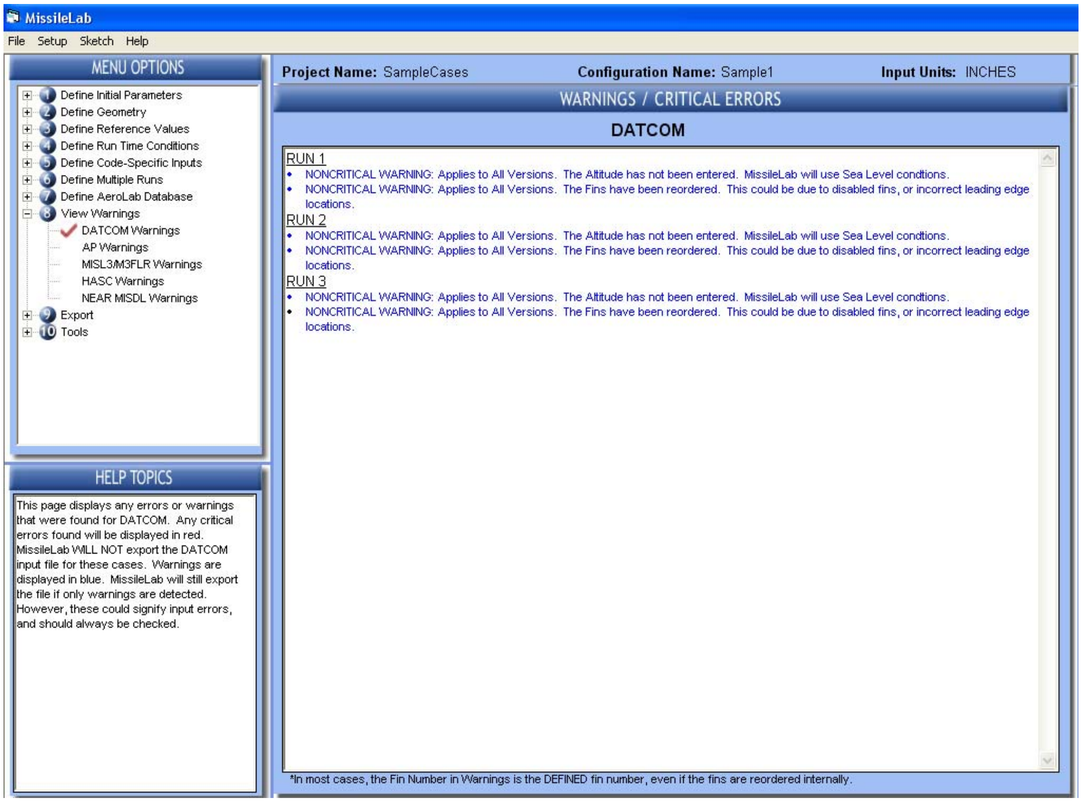


Figure 47. DATCOM Warning Screen

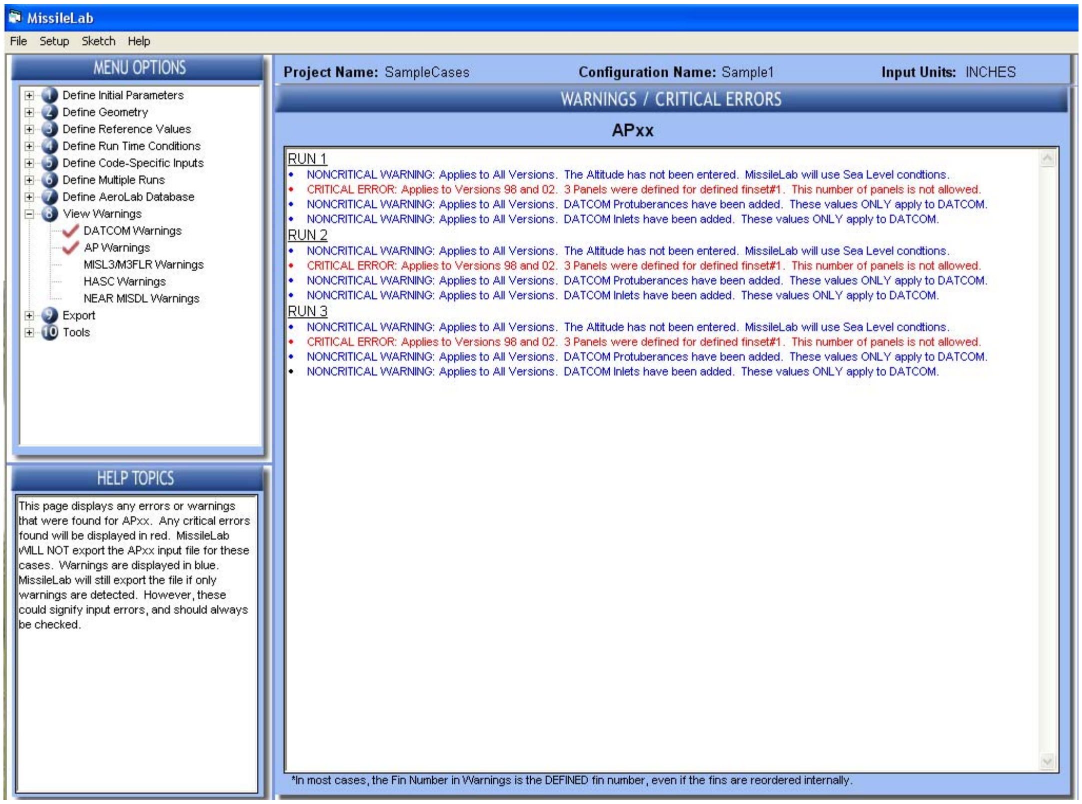


Figure 48. AP Warning Screen

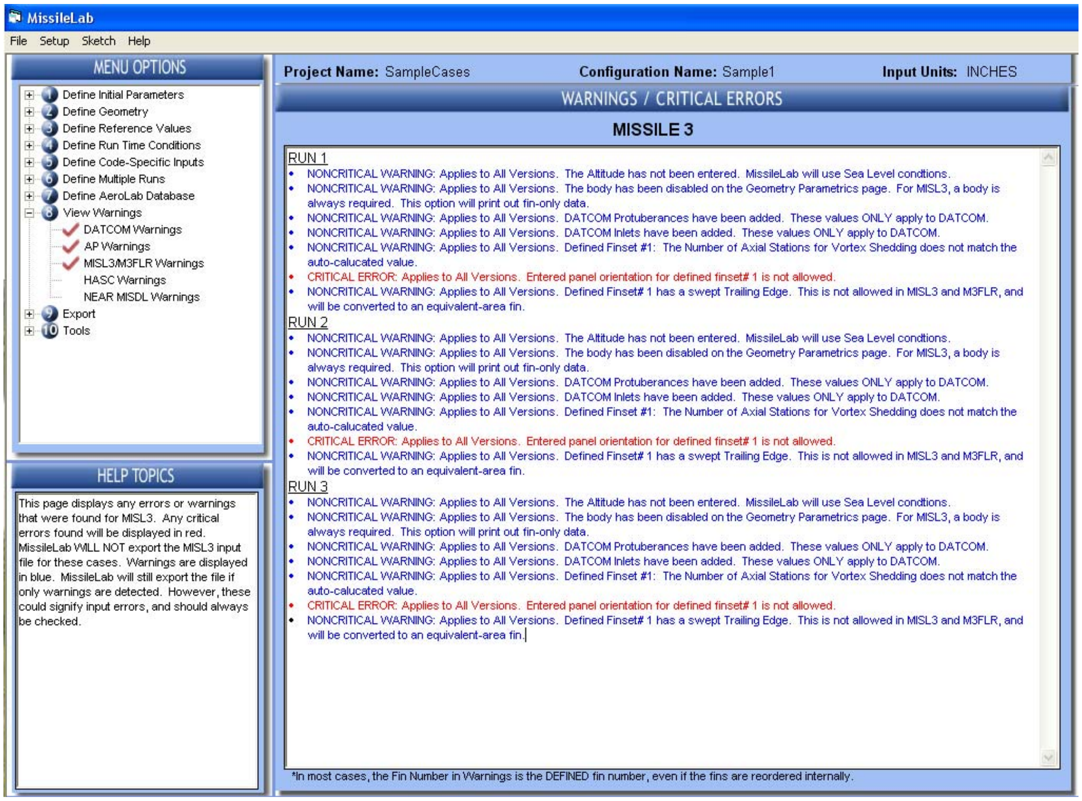


Figure 49. NEAR MISL3 Warning Screen

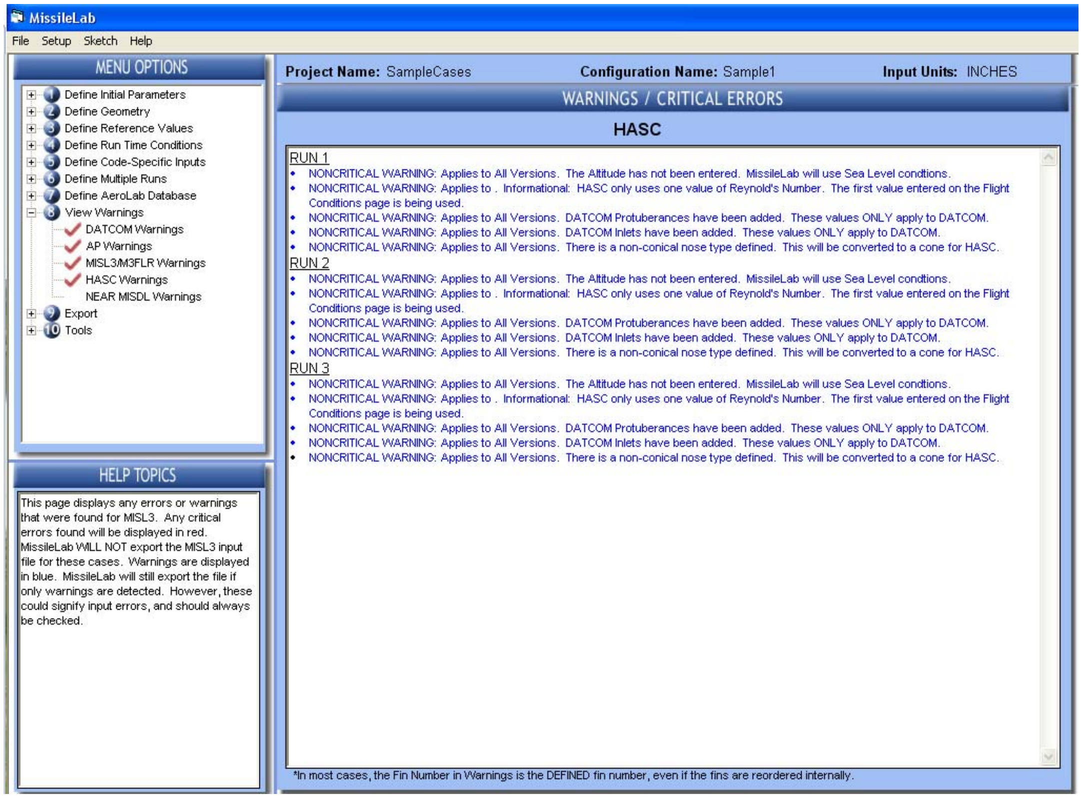


Figure 50. HASC Warning Screen

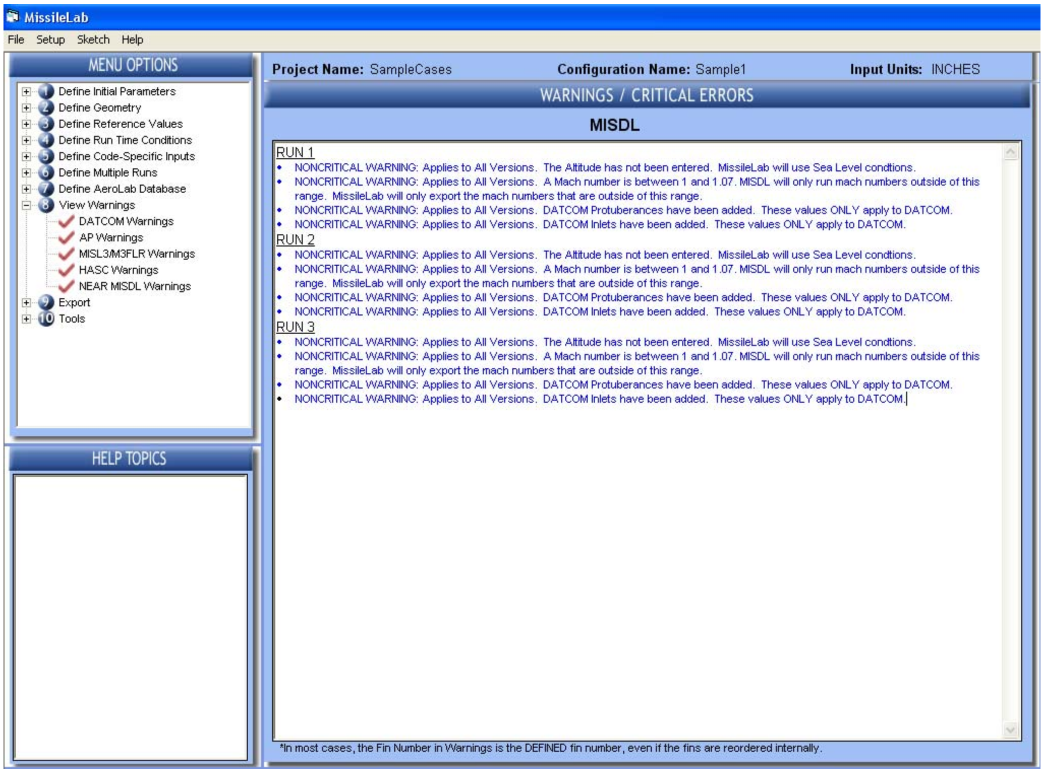


Figure 51. MISDL Warning Screen

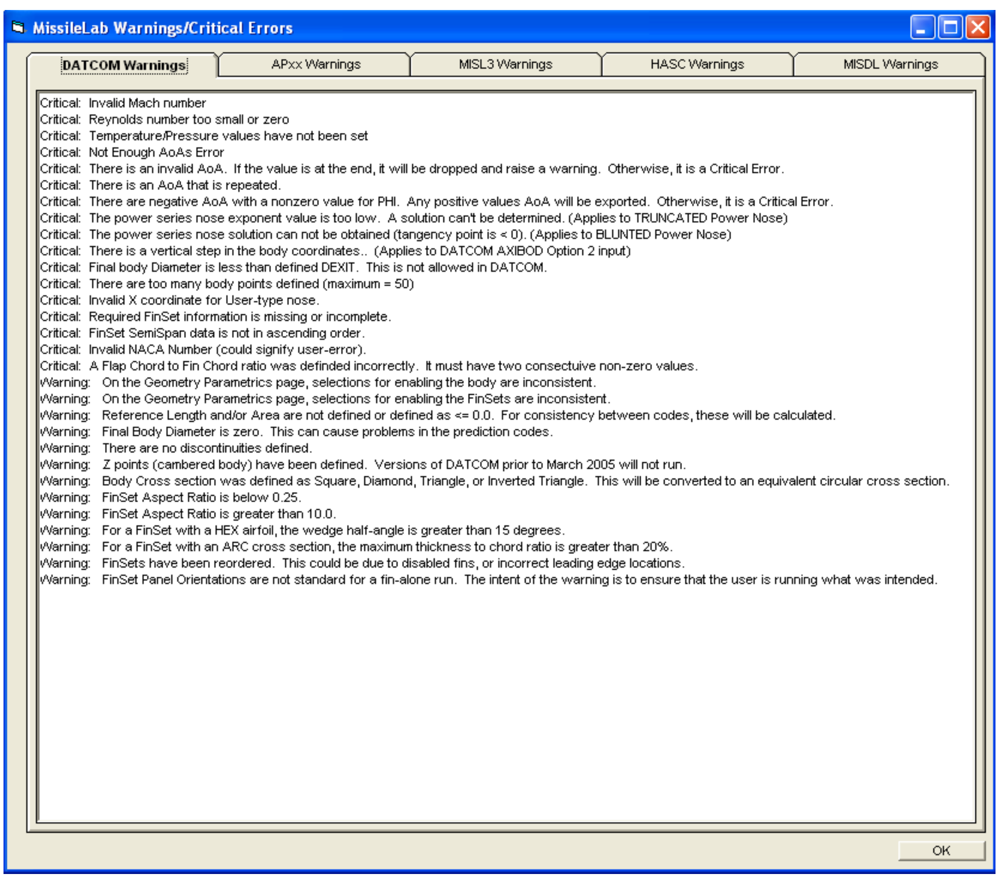


Figure 52. List of Error and Warning Checks

9. Export Data and 3-D Models Screen

Export Data Files/Run Predictions Screen

Figure 53 presents the "Export Data" screen. Here the user selects the desired prediction code(s) to be executed. As shown in the figure, if MissileLab identifies a critical error in the geometry input for a specific APE, then that code is disabled for the current case. The warnings page discussed previously lists the critical errors and warning messages. The user should always view the warnings page, even if no critical errors are noted.

The APEs may be selected only if no critical errors were found. If a critical error was found, MissileLab disables the specific APE. When a prediction code is selected, the associated input file is also selected for generation. Alternatively, the user may request that MissileLab produce a given input file without running the prediction program.

Once the desired APEs have been selected, the user clicks on the "Export Data/Run Codes" command button. This initiates generation of the APE input files and execution of the selected engines. As each engine terminates, its respective output file is saved to the hard disk, and if the "View Output Files" checkbox is checked, the results are then displayed in Windows NotePad text viewer.

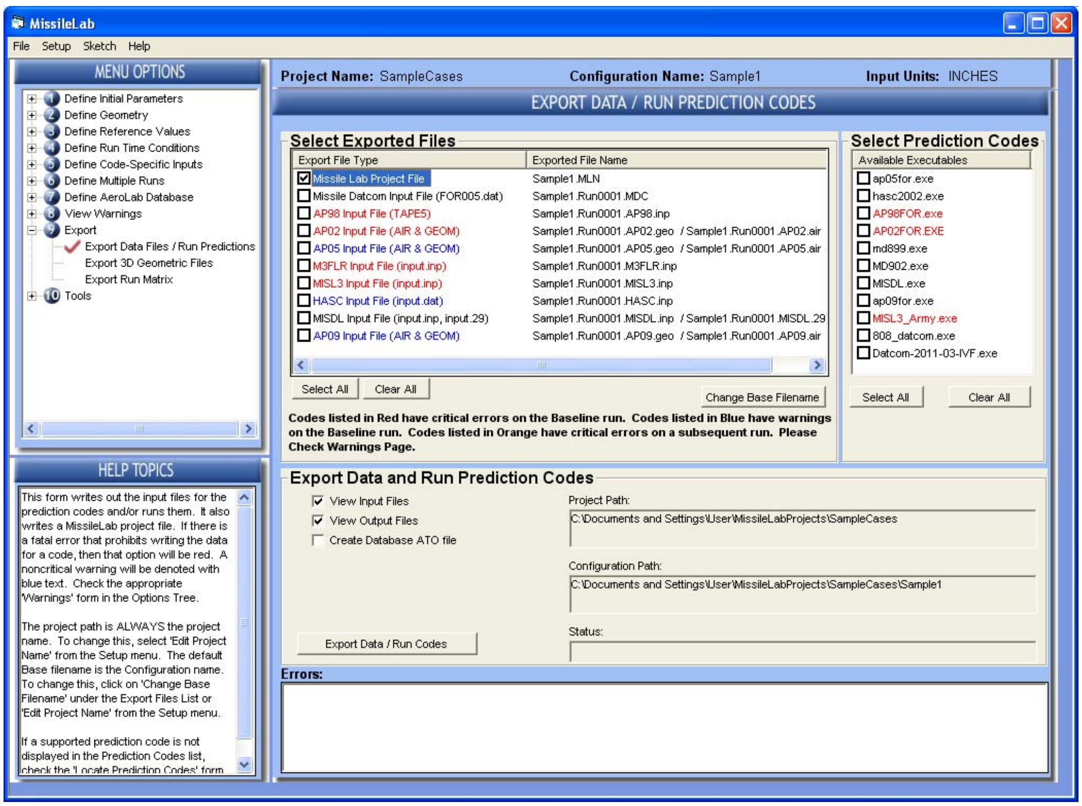


Figure 53. Export Data Screen

When the "Export Data/Run Codes" command button is selected, MissileLab creates the APE input files in the directory where the specific APE executable is located (as specified by the user under the "Locate Prediction Codes" screen discussed previously in Section III.A.2). Before these files are written, however, MissileLab DELETES any pre-existing native input/output files for the specific APE. This is why it is recommended that the user place the APEs in a separate directory that only MissileLab will access. After the specific APE terminates, MissileLab copies the native output files into the standard MissileLab directory structure.

Missile DATCOM and APxx codes do not require any extra input from the user apart from the input files. NEAR MISL3, however, requires “command prompt input” from the user in addition to the standard MISL3 input file. As this is not desirable from MissileLab’s perspective, the following additional files are created for NEAR MISL3 operation.

First, MissileLab creates a text file named “temp.txt” that is written to the directory where the MISL3 executable resides. This file contains the “command prompt” inputs that the user would normally have to enter, and the contents of this file are listed in Table 6. The values that are defined in this file are set on the MISL3 Specific Input screen discussed in Section III.D.7. MissileLab also creates a DOS batch file named “RunMISL3.exe.bat” that is also written to the directory where the MISL3 executable resides. This file contains one line, which is:

“MISL3.exe < temp.txt”

To run MISL3, MissileLab executes the “RunMISL3.exe.bat” batch file.

Table 6. MISL3 Command Prompt Inputs by way of Temp.txt File

Line	Value	Description
1	Input.inp	Input file name
2	Output	Output file name
3	“Y” or “N”	“Y” – Create NEAR MG3 output files (Units 1, 2, & 3)
4	“Y” or “N”	“Y” – Create Control Points output files (Units 16 & 17)
5	“Y” or “N”	“Y” – Create comma delimited output files (Units 60 & 61)
6	“Y” or “N”	“Y” – Create TechPlot output files (Units 62 & 63)

Export 3-D Geometric Files Screen

The Export 3-D Geometric File screen presents an export option for 3-D models in the NASA CART3D “tri” file format and the Standard Tessellation Language (STL) format. This capability allows the user to quickly generate 3-D models that may be read by NASA’s OVERGRID code, used as input to the NASA CART3D Euler flow solver suite or read into a number of CAD and other 3-D modeling applications.

This new functionality is accessed by way of the export screen shown in Figure 54 (a). These models may take several minutes to export!

Once the MissileLab generated “tri” file is created and ported to a Linux computer where OVERGRID and CART3D reside, the first step in the process is to perform a DOS2UNIX command on the “tri” file to ensure the proper end-of-line markers are present. Once this is done, the geometry may be viewed and manipulated (if desired) in OVERGRID. Use of OVERGRID is beyond the scope of this report.

With respect to the CART3D suite of codes, the “INTERSECT” application is used to read the MissileLab generated “tri” file and generate one single “water-tight” surface. Prior to running Intersect, the body, wing/fin panels, and protuberances are individual closed component surfaces. In this component form, OVERGRID may be used (if desired) to move, translate, rotate, and scale the individual “tri” file components. Once INTERSECT has been run, the resulting file is a single surface.

The CART3D intersect application is very sensitive to co-planar surfaces and surfaces that intersect exactly at vertices nodes from other components. Should these conditions occur , INTERSECT will fail, and typical intersect error messages will be extremely ineffective in identifying the problem. For this reason, a number of controls are provided in the MissileLab export page to greatly increase the success rate for 3-D “tri” model geometries passing through intersect on the first attempt. These controls are the subject of the following paragraphs.

A check-box control to enforce triangle aspect ratios that are less than 2 is provided. This control ensures that the individual facets do not become “long and skinny,” as this can at times cause erroneous moment results from CART3D.

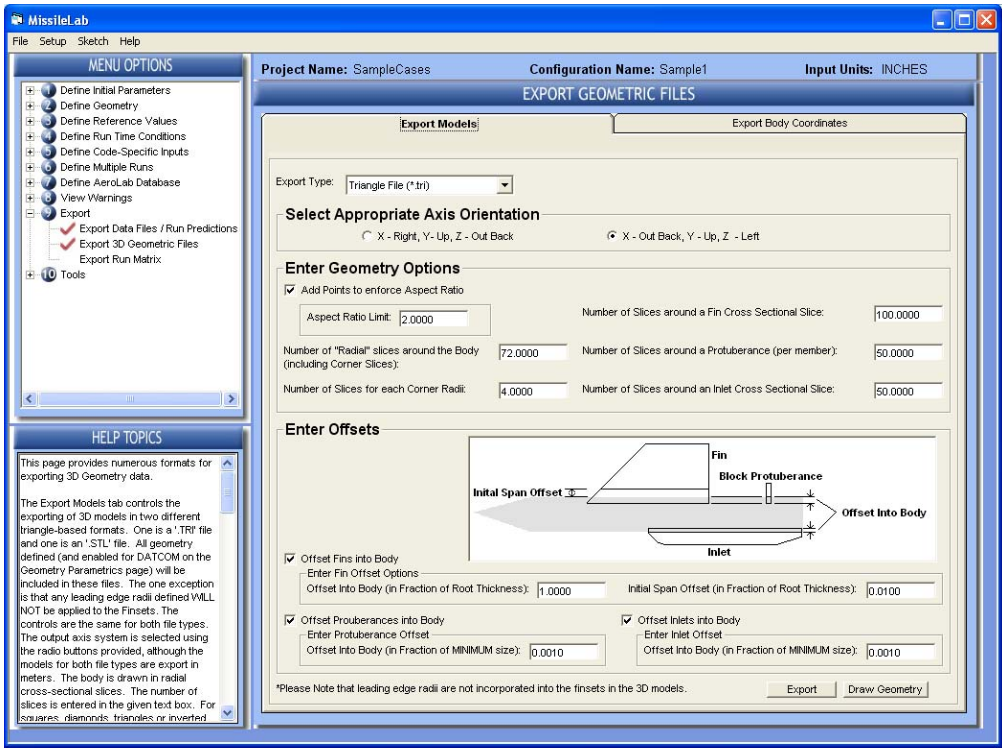
Check-box controls are provided to ensure that fins and protuberances extend into the body (that is, do, in fact, intersect and do not have surfaces that are co-planar). If “offset fins into the body” is checked, there are two values that refine the control, “Offset into the body” and “Initial span offset.” Both controls are given in fraction of root thickness. The first value projects the root chord towards the center of the body in increments of the root chord thickness. The second value applies a very small adjustment to the location of the fin root to ensure that the fin root is not co-planar with the body surface. The check-box controls for the protuberances and inlets work in a similar fashion.

By default, MissileLab places 72 slices (every 5 degrees) around the circumference of the body. If the body has a triangular or square cross section with corner radii, MissileLab uses four slices to model each radius by default. Similar controls are available for fins, protuberances, and inlets. These controls, coupled with the facet aspect-ratio control, can lead to a very large number of facets which may require several minutes to write to the geometry file.

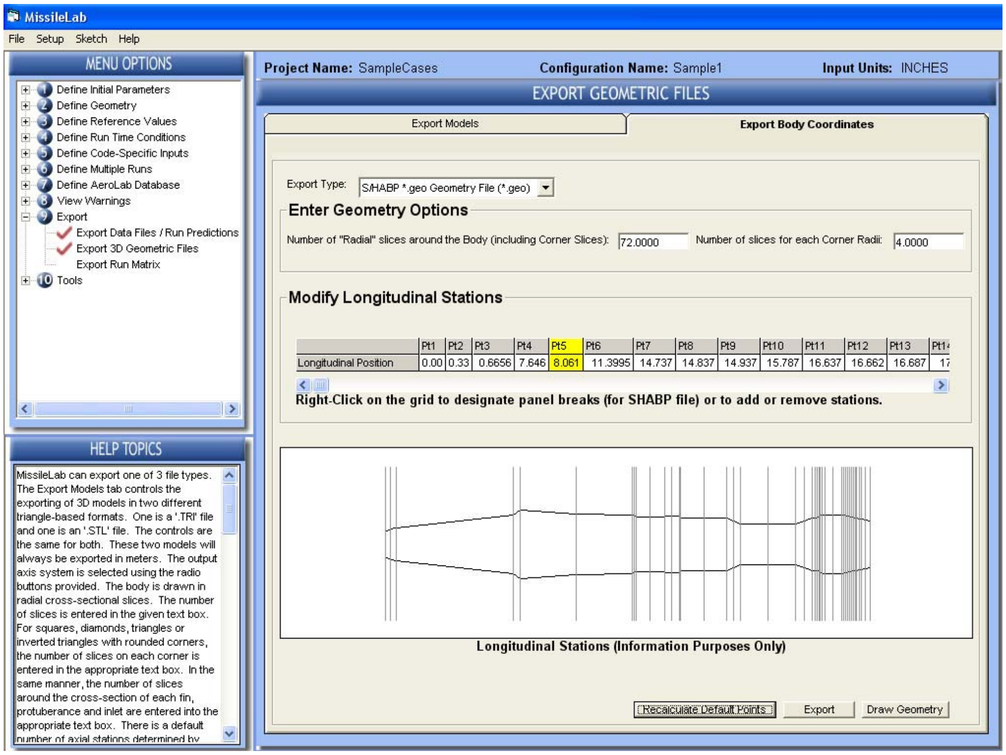
All facets are defined using the Right-Hand Rule (RHR), so that the facet surface normal is pointed out from the component.

The Draw Geometry and Export buttons in the lower-right corner of the screen allow the user to view and create the 3-D geometry model.

The Export Body Coordinates screen shown in Figure 54 (b) allows the user to define specific longitudinal coordinates for export to a text file. This information can be useful in setting up panel code input files. The three formats supported are a Plot3d file, a Coordinates file, and a S/HABP geometry input file. For the S/HABP file, panel breaks can be designated in the Longitudinal Stations grid by “right-clicking” on the point, and selecting “Toggle End of Panel.”



(a) STL and TRI 3-D Model Export



(b) Body Coordinate Export

Figure 54. Export 3-D Geometric Model Screen

Export Run Matrix Screen

The major innovation to MissileLab version 9 was the introduction of a Run Matrix screen that allows the user to quickly set up a matrix of run conditions that are exported to Missile DATCOM. The results of the runs are then renamed and stored in a new directory with a master file listing the output files. The directory will be created under the Project Folder and named using the configuration name with "AeroModelBuild" appended. Using the information in this directory, a complex aerodynamic model can be built for use in 6-DOF simulations.

This new functionality is accessed via the screens shown in Figure 55. The "Load Matrix Data" button at the top of the page loads a previously stored data file with all of the conditions on this page. The help button with the question mark will show the format of this file. When the Missile DATCOM files are exported (discussed shortly), MissileLab will always export the conditions into this "ModelData.csv" file in the AeroModelBuild directory.

Figure 55 (a) shows the Flight Conditions tab. The AOA, Roll Angles/Sideslip Angles, and Mach Numbers to be run are entered here. Note that they can be entered using Range and Increment, copied from the Baseline Flight Conditions, or entered directly into the grids. There is no limit to the number of AOA and Mach Numbers. The AOA will be broken into "sets" of 50. For example, if 60 AOAs are entered, the first 50 AOAs will be run, and then the next 10 AOAs will be run. For the last 10 AOAs, the data files will have "AS2" in the name to signify that they contain "**A**ngle of Attack **S**et **2**." Because versions of DATCOM prior to 707 were limited to 20 AOAs, these versions will not run and MissileLab will give a warning stating that. Likewise, the Mach Numbers are run in sets of 20, and will be designated "MS2," and so forth.

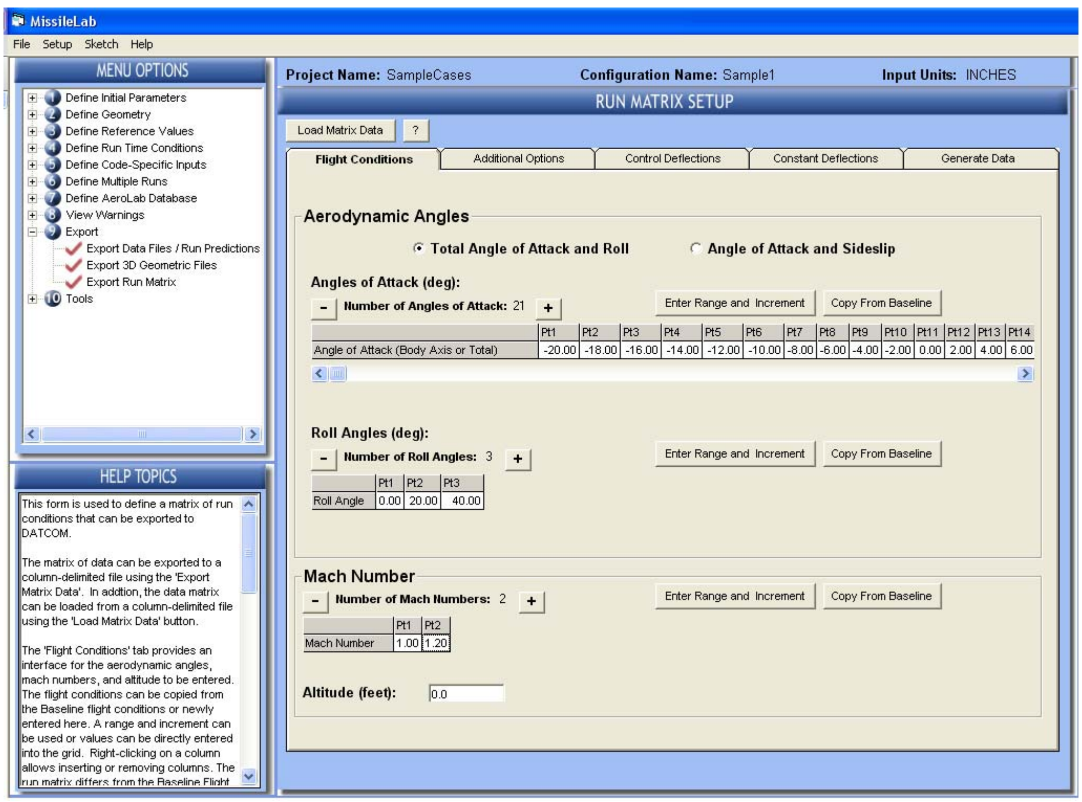
If multiple altitudes are needed for skin friction, they are entered on the "Additional Options" tab shown in Figure 55 (b). Any desired variation in Longitudinal Center of Gravity is also entered on this tab.

The Control Deflections are entered in a different manner than in the Baseline case so that multiple deflections can be easily run. When the Control Deflections tab is first viewed, there are no deflections defined. Click on the "Define/Add Deflection Type" button, and the top left screen in Figure 55 (c) will be displayed. Select the correct finset, the Deflection Type (Pitch, Yaw, Roll, Single Panel, and User-Defined), and then click on the "Define/Add Deflection Type" button. The second screen, shown in Figure 55 (c), will then be displayed with the fin panels that have been defined for the selected finset (in the figure, four panels in a "+" configuration). Each panel that should be deflected should be enabled by clicking on the panel. Clicking again will change the direction of the deflection, and clicking again will turn the deflection of that panel off. Each deflection will have a text box with a "1" in it that is a scale factor. The configuration of two panels deflected with a scale factor of 1 means that for a 10-degree deflection, each panel will be deflected 10 degrees. If the scale factor had been set to .5, then for a 10-degree deflection, each panel would be deflected 5 degrees. After the panel deflections are all defined, click on "OK," and the deflection type will show in the "Defined Deflection Types" shown in the upper left figure.

After the appropriate deflection types are defined, click the "OK" button and the "Control Deflection" tab will display each Deflection Type with a grid, as shown in Figure 55 (d). The deflections to be run can be entered directly into the grid or using a range and increment. A “stability” case will always be run using no deflections, so entering a deflection value of 0 is not required, but also is not prohibited.

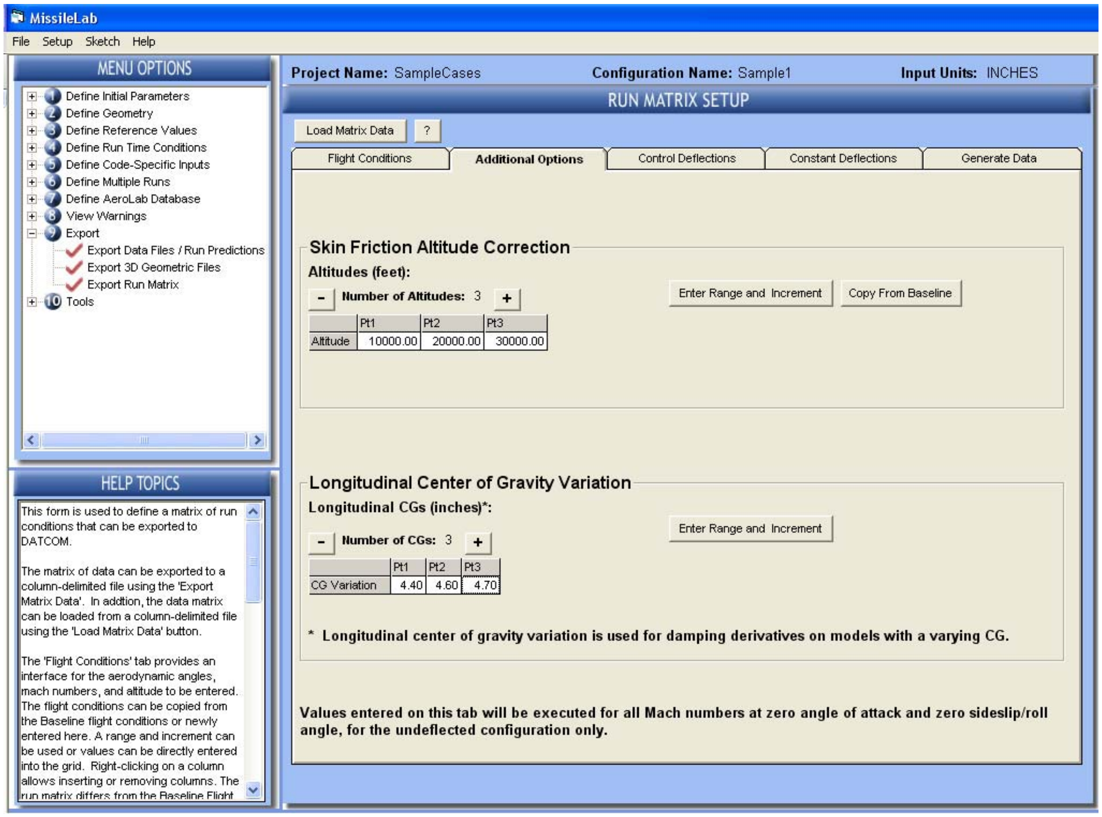
Figure 55 (e) shows the “Constant Deflections” tab. These are deflections that will be used for all of the runs. It is intended for canted fins. Even in the stability case, these deflections will be present. MissileLab will give a warning if constant deflections are entered for a finset that has been deflected for control.

The Generate Data tab is shown in Figure 55 (f). The user should select the version of DATCOM to be run. To export the data to the DATCOM input files without running the prediction code, click on the “Generate DATCOM Input Files Only” button. To generate these files and run DATCOM, click on the “Generate Files and Run Code(s)” button. Any warnings or errors that are generated are displayed in the text box at the bottom of the page.

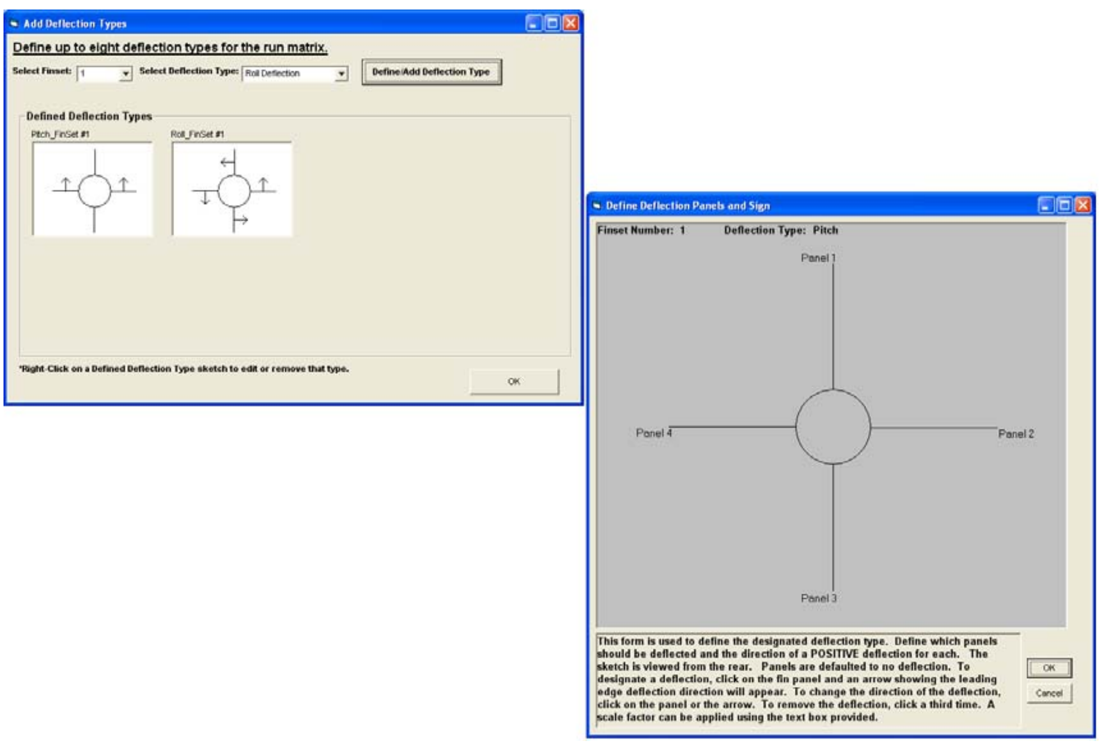


(a) Export Run Matrix Setup – Flight Conditions

Figure 55. Export Run Matrix

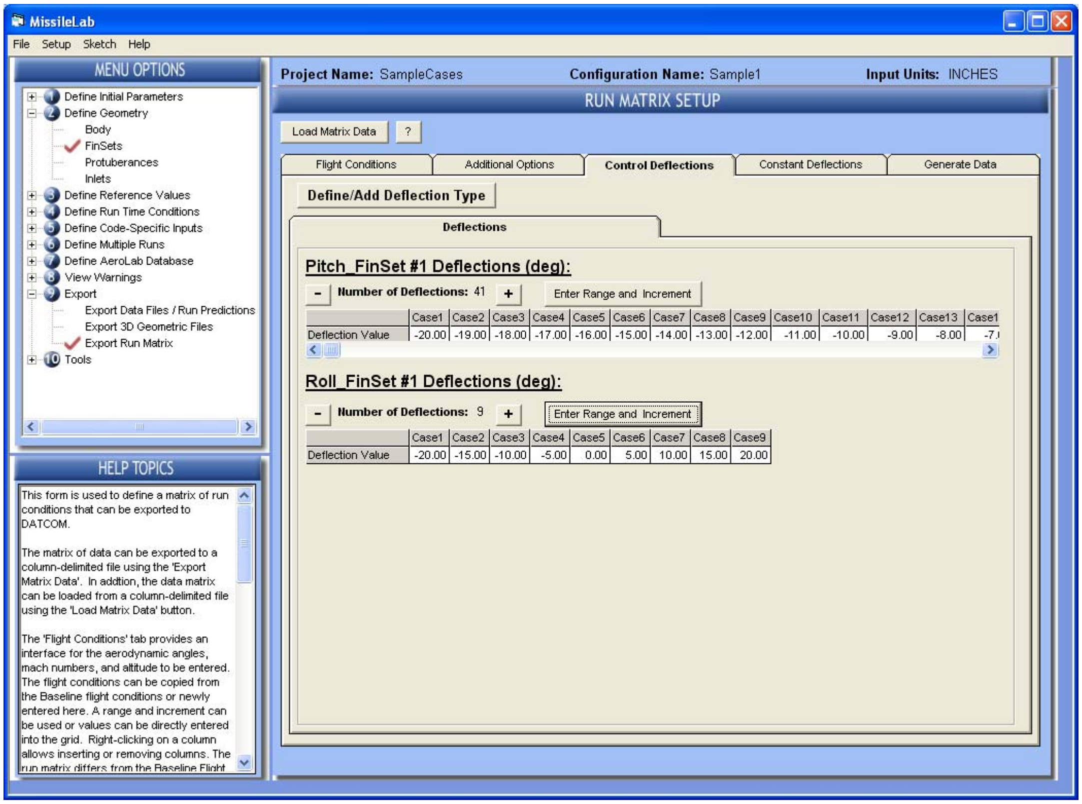


(b) Export Run Matrix Setup – Additional Options

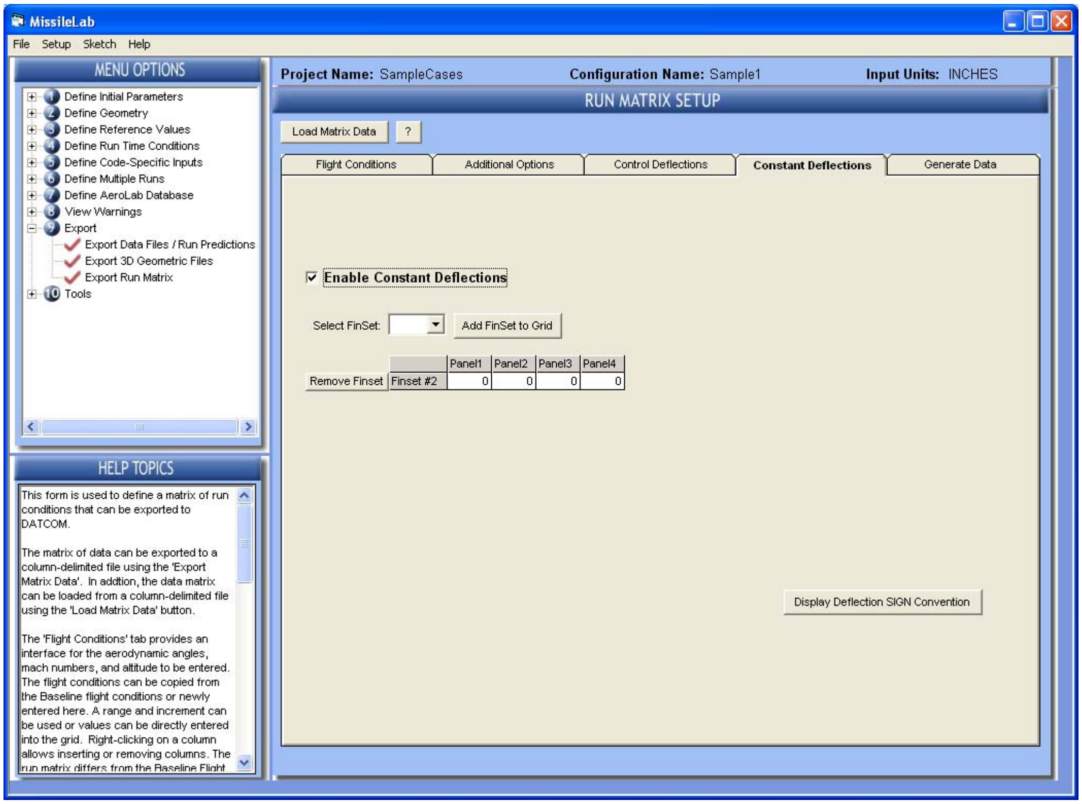


(c) Export Run Matrix Setup – Define Deflections

Figure 55. Export Run Matrix (Continued)

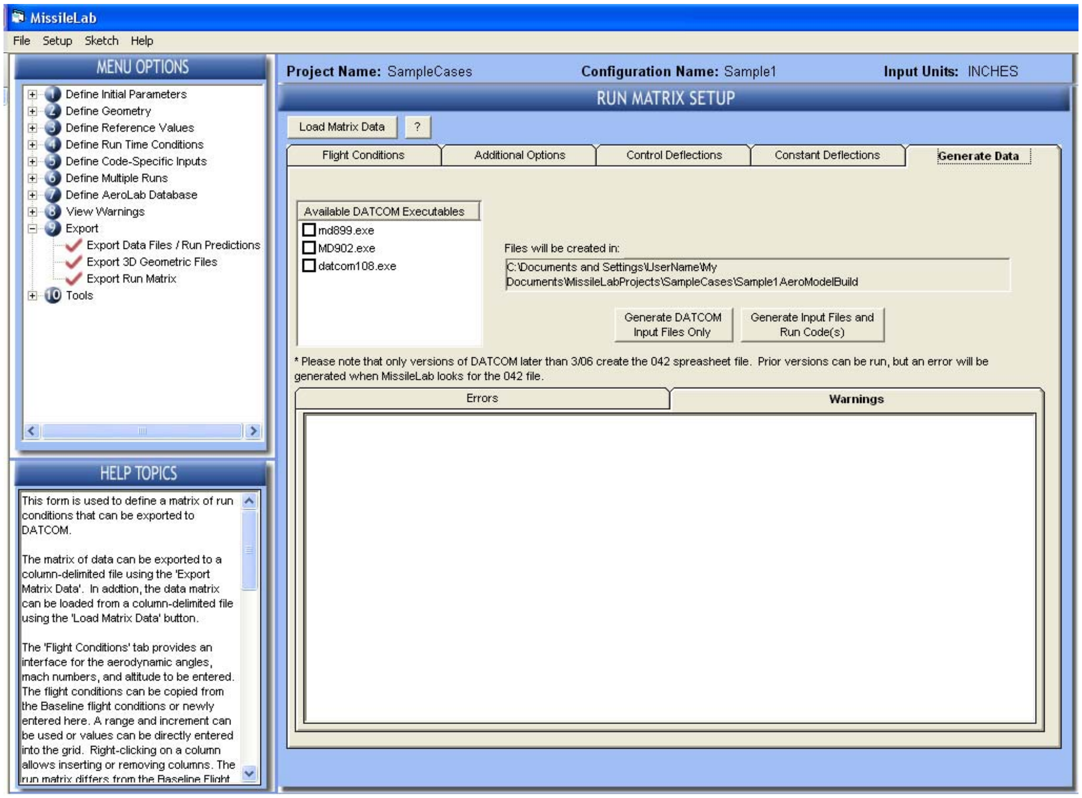


(d) Export Run Matrix Setup – Control Deflections



(e) Export Run Matrix Setup – Constant Deflections

Figure 55. Export Run Matrix (Continued)



(f) Export Run Matrix Setup – Generate Data

Figure 55. Export Run Matrix (Concluded)

10. Tools

<u>Quick Look Plots Screen</u>

The “Quick Look Plots” screen, shown in Figure 56, can be used to generate graphs of the APE output. This feature supports only the DATCOM 042 file, the APxx TAPE6.ou2 file (generated from APparser), the MISL3 ldr.csv file, and the MISDL .csv file. Any of these that were generated during the current session will automatically be loaded and a set of plots automatically generated. The “Add File” button will allow the user to open any other file that is in one of the formats listed above. In multiple-run sessions, only output files from the baseline run will automatically be loaded.

The panel on the left side of the screen shows loaded files in a treeview, with their variables listed below. These variables can be checked and then plotted versus either Mach or Alpha by clicking on the appropriate button below the panel. All variables that are checked will be plotted on the same graph. The “Select Graph” pull-down menu will contain all of the graphs that have been added. The selected graph will be displayed with buttons for each Alpha or Mach. The “Copy” button will copy the graph to the clip-board. There are buttons to toggle grid lines and the legend. The legend may also be moved by “clicking and dragging” the legend box. The “Remove Plot Group” button will remove the selected graph (for all mach numbers or alphas).

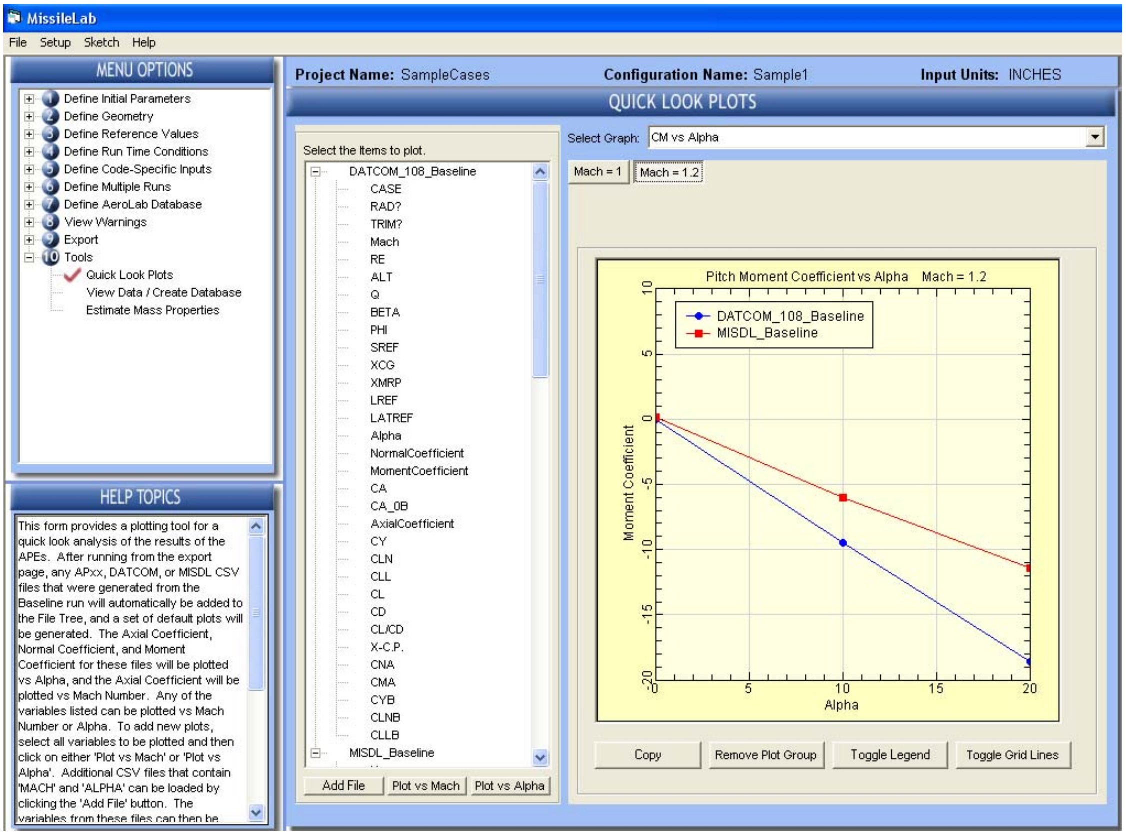


Figure 56. Quick Look Plots Screen

<u>View Data / Create Database Screen</u>

If the configuration has ever been run in MissileLab, regardless of if it was run in the current session or not, the results may be viewed by using the "View Data" screen shown in Figure 57. The latest version of Missile DATCOM (January 2006) outputs a new file referred to as the '042' file. Similarly, the Python script tool, APparse, discussed in this document, was written to post-process the APxx files and produce an AP results file that has a format very similar to the DATCOM 042 file.

This screen also contains the controls for building an AeroLab database, once all cases have been run.

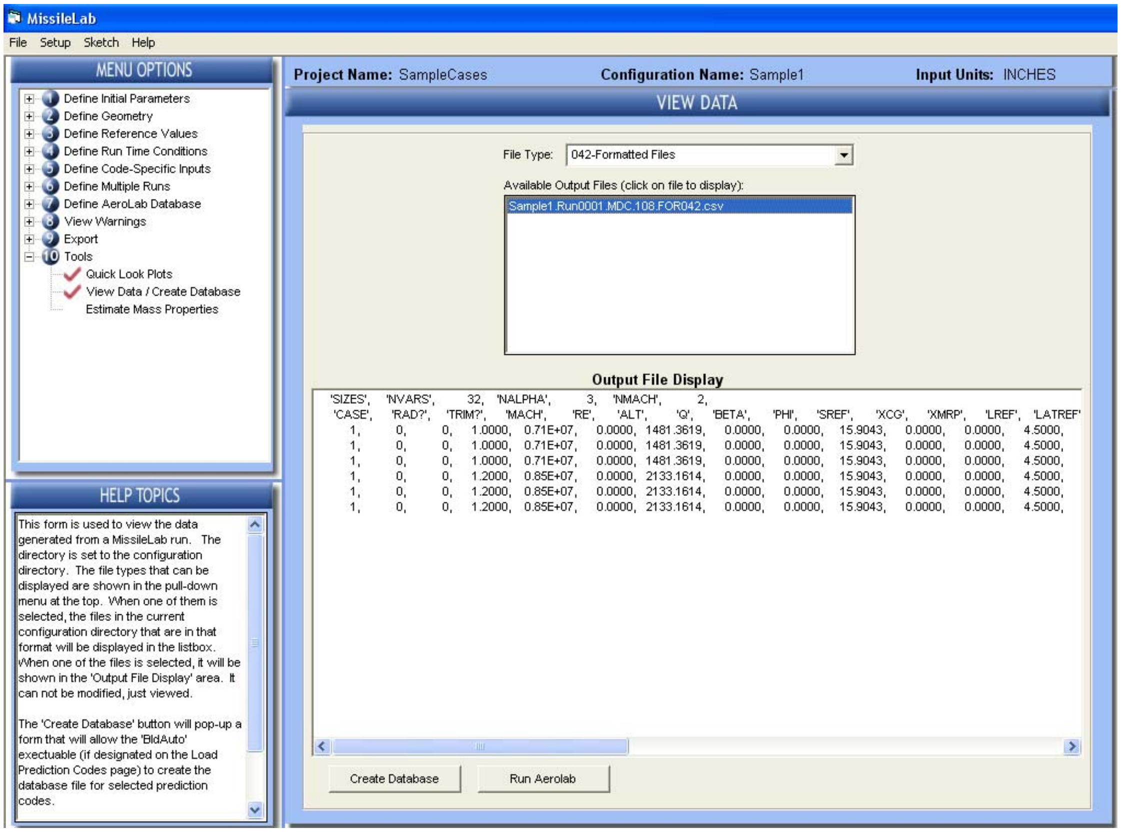


Figure 57. View Data Screen

Estimate Mass Properties Screen

A calculator for estimating mass properties of the configuration is provided and shown in Figure 58. Data from previous screens are used to automatically populate the screen as shown. The user may change these values and add or delete components. After entering weights for each component, the Calculate Mass Properties button estimates the mass properties of the configuration.

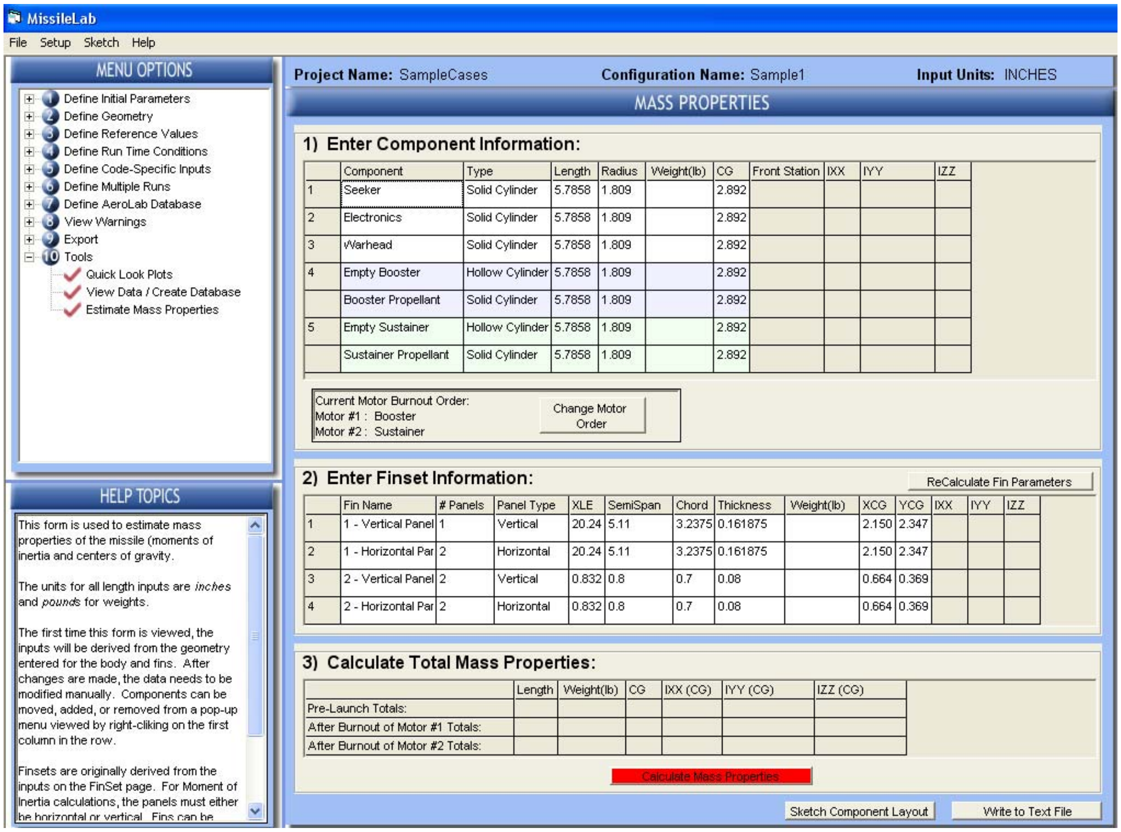


Figure 58. Mass Properties Estimator Tool

IV. EXAMPLE CASES

A. Project_101

This sample case is the canard-controlled missile illustrated in Figure 50 and is summarized in Tables 7 through 10.

As none of the canard or fin thickness or breaklines are specified in the tables listed, the DATCOM defaults are assumed and used to generate the APxx and NEAR MISL3 input decks.

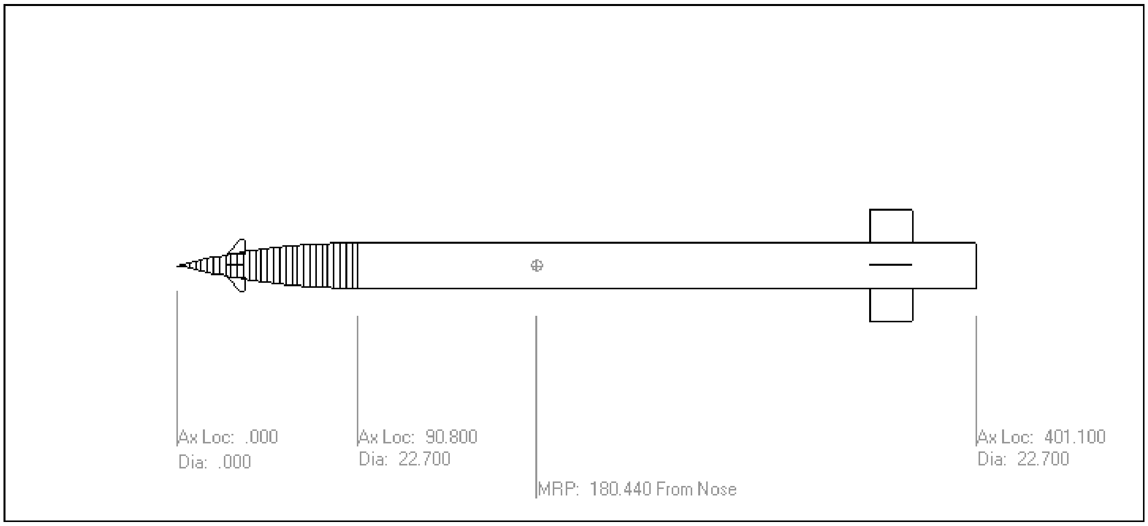


Figure 59. Project_101 Configuration

Table 7. Project_101 Reference Geometry

Reference Length	22.7000 cm
Reference Area	404.7079 cm2
Moment Reference Point (from Nose Tip)	180.4400 cm

Table 8. Project_101 Body Geometry

Type of Nose	Pointed Tangent Ogive
Length of Nose	90.80 cm
Diameter at Base of Nose*	22.70 cm
Length of Center-Body Section	310.30 cm
Diameter at base of the Center-Body Section*	22.70 cm

*MissileLab requires the RADIUS be entered.

Table 9. Project_101 Canard Geometry

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	25.01 cm
Distance from Nose Tip to LE of Tip Chord	31.70 cm
Radial Distance from Centerline to Root Chord	6.17 cm
Radial Distance from Centerline to Tip Chord	13.17 cm
Root Chord	9.19 cm
Tip Chord	2.50 cm
Leading Edge Radius	0.02 cm
Number of Panels	4
Location of Panels	0, 90, 180, 270 deg

Table 10. Project_101 Fin Geometry

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	347.80 cm
Distance from Nose Tip to LE of Tip Chord	347.80 cm
Radial Distance from Centerline to Root Chord	11.35 cm
Radial Distance from Centerline to Tip Chord	28.16 cm
Root Chord	21.50 cm
Tip Chord	21.50 cm
Leading Edge Radius	0.052 cm
Number of Panels	4
Location of Panels	0, 90, 180, 270 deg

B. Project_102

This sample case is the tail-controlled missile illustrated in Figure 60. As seen from the figure, the third finset is closely coupled with the second finset. As such, there are two possible ways to model this configuration. The first method is to model all three finsets, as shown in the figure and summarized in Tables 11 through 15. The second method is to model the body and first finset normally (as summarized in Tables 11 through 13), and then to treat the "wing+tail" as one finset but set the "flap to fin chord ratio" flag, as summarized in Table 16. As seen in this table, the chord of the wing and the chord of the tail were added together (and entered), and the ratio of the flap chord to the fin chord was included.

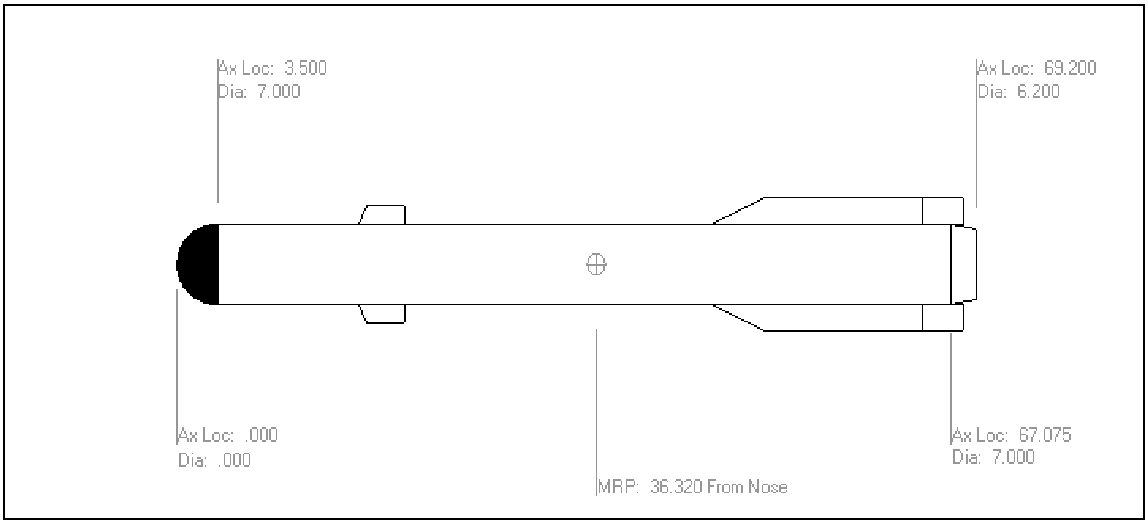


Figure 60. Project_102 Configuration

Table 11. Project_102 Reference Geometry

Reference Length	7.00 in
Reference Area	38.48451 in2
Moment Reference Point (from Nose Tip)	36.32 in

Table 12. Project_102 Body Geometry

Type of Nose	Pointed Tangent Ogive (Hemisphere)
Length of Nose	3.500 in
Diameter at Base of Nose*	7.000 in
Length of Center-Body Section	63.575 in
Diameter at base of Center-Body Section*	7.000 in
Type of After-Body	Conical
Length of After-Body Section	2.125 in
Diameter at base of After-Body Section*	6.200 in

*MissileLab requires the RADIUS be entered.

Table 13. Project_102 Canard Geometry

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	15.79 in
Distance from Nose Tip to LE of Tip Chord	16.37 in
Radial Distance from Outer Mold Line to Root Chord	0.000 in
Radial Distance from Outer Mold Line to Tip Chord	1.625 in
Root Chord	4.000 in
Tip Chord	3.420 in
Leading Edge Radius	0.000 in
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	Root 0.02; Tip 0.0092
Fraction of Chord from LE to Max Thickness	Root 0.05; Tip 0.05
Fraction of Chord of Constant Thickness	Root 0.90; Tip 0.90
Number of Panels	4
Location of Panels	45, 135, 225, 315 deg

Table 14. Project_102 Wing Geometry

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	46.23 in
Distance from Nose Tip to LE of Tip Chord	50.95 in
Radial Distance from Outer Mold Line to Root Chord	0.000 in
Radial Distance from Outer Mold Line to Tip Chord	2.320 in
Root Chord	18.340 in
Tip Chord	13.620 in
Leading Edge Radius	0.000 in
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	Root 0.01; Tip 0.01
Fraction of Chord from LE to Max Thickness	Root 0.05; Tip 0.05
Fraction of Chord of Constant Thickness	Root 0.90; Tip 0.90
Number of Panels	4
Location of Panels	45, 135, 225, 315 deg

Table 15. Project_102 Tail Geometry

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	64.57 in
Distance from Nose Tip to LE of Tip Chord	64.57 in
Radial Distance from Outer Mold Line to Root Chord	0.000 in
Radial Distance from Outer Mold Line to Tip Chord	2.320 in
Root Chord	3.500 in
Tip Chord	3.500 in
Leading Edge Radius	0.000 in
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	Root 0.05; Tip 0.02
Fraction of Chord from LE to Max Thickness	Root 0.05; Tip 0.05
Fraction of Chord of Constant Thickness	Root 0.90; Tip 0.90
Number of Panels	4
Location of Panels	45, 135, 225, 315 deg

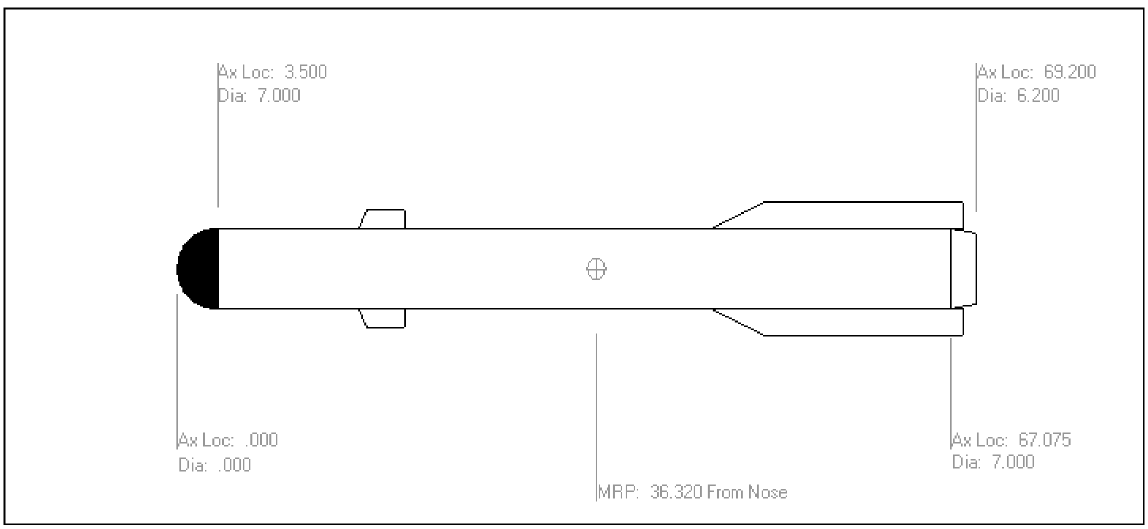


Figure 61. Project_102 Alternate Wing+Tail Modeling Approach

Table 16. Project_102 Alternate Wing+Tail Geometry Modeling Approach

Airfoil Section Type	Hex
Distance from Nose Tip to LE of Root Chord	46.23 in
Distance from Nose Tip to LE of Tip Chord	50.95 in
Radial Distance from Outer Mold Line to Root Chord	0.000 in
Radial Distance from Outer Mold Line to Tip Chord	2.320 in
Root Chord	21.840 in
Tip Chord	17.120 in
Ratio of Flap Chord to Fin Chord	Root 0.160; Tip 0.204
Leading Edge Radius	0.000 in
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	Root 0.01; Tip 0.01
Fraction of Chord from LE to Max Thickness	Root 0.05; Tip 0.05
Fraction of Chord of Constant Thickness	Root 0.90; Tip 0.90
Number of Panels	4
Location of Panels	45, 135, 225, 315 deg

C. Project_103

This sample case is the tail-controlled missile illustrated in Figures 62 and 63 and is summarized in Tables 17 through 20. As seen from the figure, the wing and the tail are made up of multiple sections.

As APxx and NEAR MISL3 require “simple” fin geometry, MissileLab takes the input geometry for a multi-section wing/fin panel and attempts to calculate an equivalent fin planform. When entering multi-section fin panels, it is always recommended that the user examine the equivalent wing/fin geometry with a critical eye.

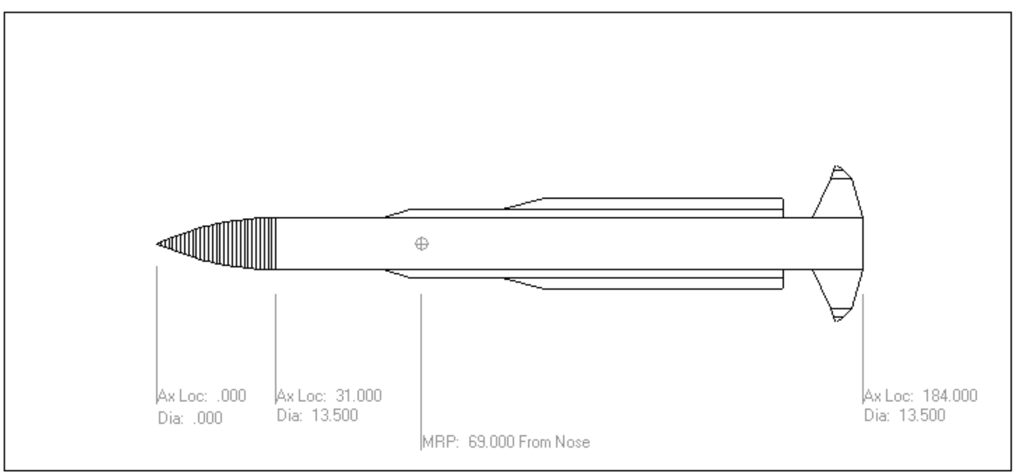


Figure 62. Project_103 Configuration Line Sketch

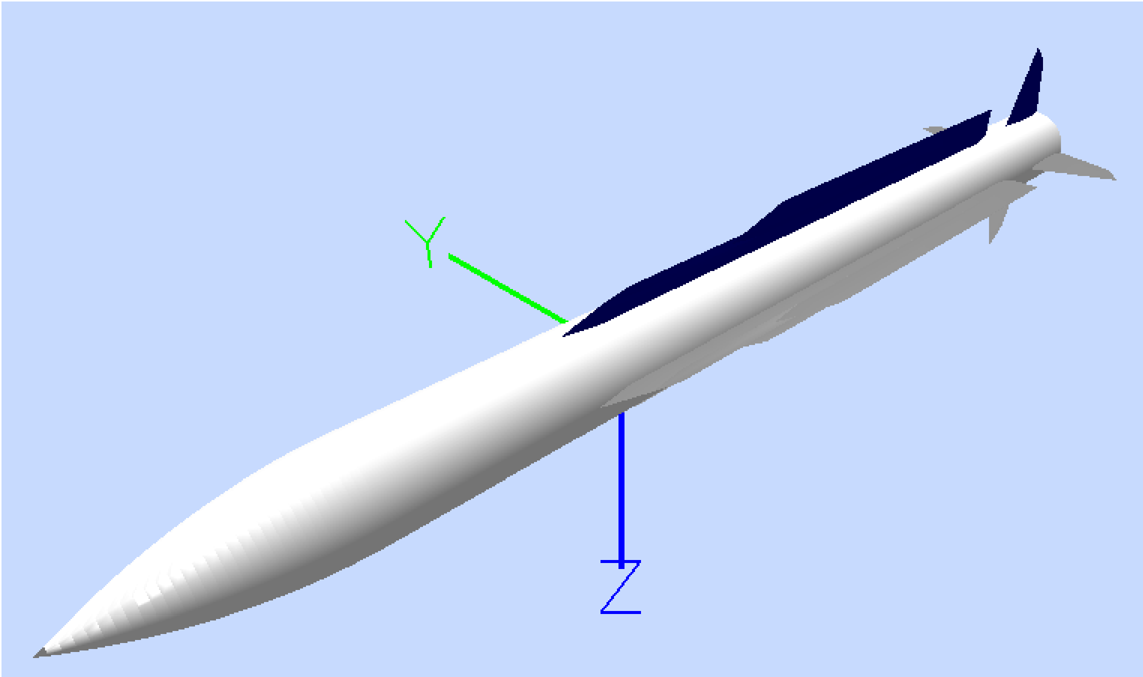


Figure 63. Project_103 Configuration 3-D Sketch

Table 17. Project_103 Reference Geometry

Reference Length	8.000 in
Reference Area	50.26548 in^2
Moment Reference Point (from Nose Tip)	69.000 in

Table 18. Project_103 Body Geometry

Type of Nose	Pointed Tangent Ogive
Length of Nose	31.00 in
Diameter at Base of Nose*	13.50 in
Length of Center-Body Section	153.00 in
Diameter at Base of Center-Body Section*	13.50 in

*MissileLab requires the RADIUS be entered.

Figures 64 and 65 present the MissileLab generated "equivalent fin" geometry for AP cases. If the user does not feel that this is an accurate "equivalent fin," then he/she must re-define the fin geometry on the main finset screen.

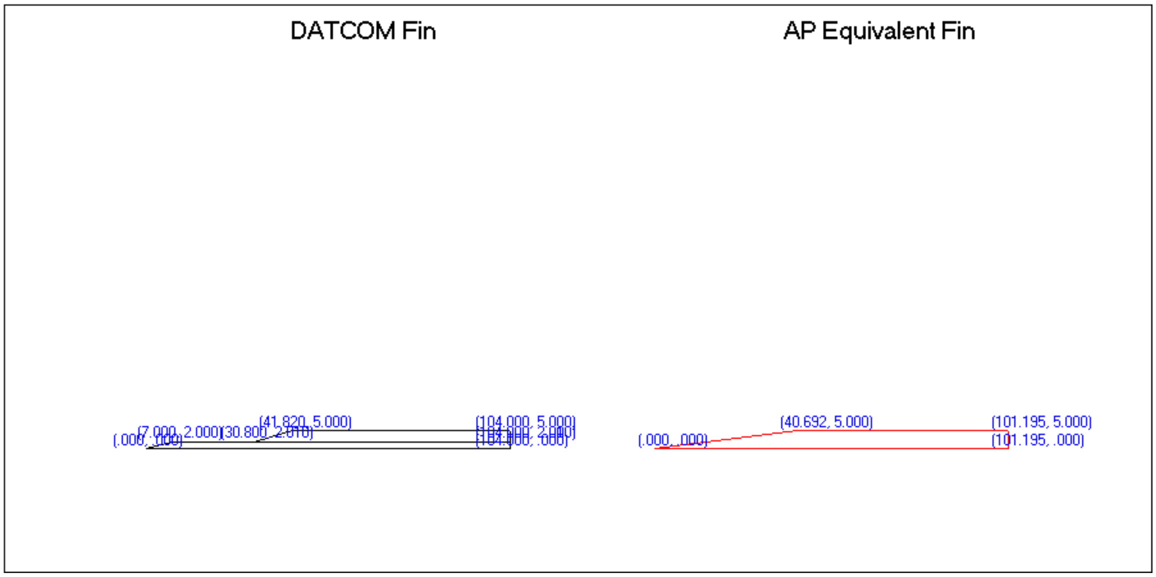


Figure 64. Project_103 Equivalent Wing Sketch

Table 19. Project_103 Wing Geometry

Airfoil Station	Root	2	3	Tip
Airfoil Section Type	Hex			
Distance from Nose Tip to LE of Root Chord	59.1	--	--	--
Radial Distance from Centerline to Chord Section	6.75	8.75	8.76	11.75
Chord	104.00	97.00	73.20	62.18
Sweep of TRAILING EDGE	0	0	0	0
Leading Edge Radius	0.125	0.125	0.050	0.050
Number of Panels	4			
Location of Panels	0, 90, 180, 270 deg			
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	0.0096	0.0103	0.0136	0.002
Fraction of Chord from LE to Max Thickness	0.500	0.055	0.070	0.080
Fraction of Chord of Constant Thickness	0.90	0.89	0.86	0.84

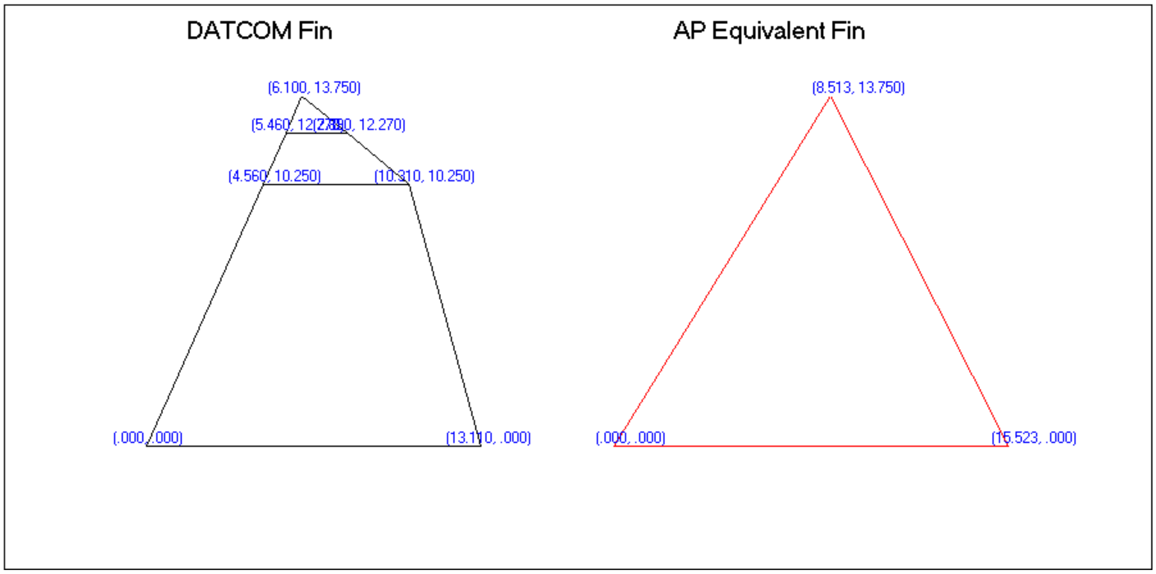


Figure 65. Project_103 Equivalent Wing Sketch

Table 20. Project_103 Tail Geometry

Airfoil Station	Root	2	3	Tip
Airfoil Section Type	Hex			
Distance from Nose Tip to LE of Root Chord	171.0	175.56	176.46	177.1
Radial Distance from Centerline to Chord Section	6.75	17.00	19.02	20.50
Chord	13.11	5.75	2.43	0.00
Leading Edge Radius	0.05	0.05	0.05	0.05
Number of Panels	4			
Location of Panels	0, 90, 180, 270 deg			
Thickness-to-Chord Ratio of UPPER HALF of Airfoil	0.0425	0.0425	0.0425	0.0425
Fraction of Chord from LE to Max Thickness	0.300	0.466	1.00	1.00
Fraction of Chord of Constant Thickness	0.40	0.00	0.00	0.00

FREQUENTLY ASKED QUESTIONS (FAQ)

(Q) I am trying to load an existing DATCOM file and MissileLab seems to "hang-up" when reading the file. What is the problem?

> (A) It is most likely that the existing DATCOM file is missing or has a misplaced comma. You should carefully inspect the DATCOM input file, then try and re-load the file after correcting any comma errors.

(Q) I am trying to read an existing DATCOM file and a variable is not being interpreted correctly.

> (A) The DATCOM reader was developed based on existing DATCOM documentation. Sometimes DATCOM allows things that the manual does not address. Check the manual, and try changing the input to conform to what the manual states.

(Q) How does the reference area calculator button (on the Body Reference screen) work with non-circular body cross sections (on the Body Geometry screen)?

> (A) **Version 6 and earlier:** The reference area calculator button calculates the area of a circle using the characteristic reference length as the diameter of the circle regardless of what body cross section is specified. If the user wishes to use any other value for reference area, simply enter that value in the reference area text box.

> (A) **Version 7 and later:** MissileLab version 7 calculates the reference area of the maximum body cross section of the input body shape and sets the reference length to be the diameter of a circle with equivalent area.

(Q) I entered the number of fin panels, but not the orientation. The AP codes will not run. Why?

> (A) If the fin panel orientations are not entered, then the DATCOM defaults are used. These may not be valid orientations for the other codes.

(Q) I opened an existing project and I can't modify anything now. Why?

> (A) If a project is opened with multiple cases, then the baseline case is automatically locked. This should be denoted by a "padlock" button at the top left corner of the form. To unlock the baseline case, simply click that button. However, BE CAREFUL. Changes to the baseline case might have an effect on other cases!

(Q) I added a case on the Case Manager page and now I can't modify my baseline case. Why?

> (A) If any additional cases were added, then the baseline case is automatically locked. This should be denoted by a "padlock" button at the top left corner of the form. To unlock the baseline case, simply click that button. However, BE CAREFUL. Changes to the baseline case might have an effect on other cases!

FREQUENTLY ASKED QUESTIONS (FAQ) (CONTINUED)

(Q) On the Body page, how do I designate Body Option 1 or 2 (AXIBOD or ELLBOD) for DATCOM?

(A) From MissileLab, this is not necessary. You can input the body in a way that makes sense. MissileLab will determine which option to send to DATCOM. If "User-Defined" is selected for the nose, a midbody segment, or the aft segment, then Option 2 is automatically used. Also, if multiple midbody segments are selected, Option 2 is used.

(Q) On the Base Effects page, I tried to enter Base Plume Interaction data but the grid was not large enough. Why?

(A) The Base Plume Interaction (as well as numerous other inputs) are Mach number dependent. Check to make sure that you have correctly input the Mach numbers on the Flight Conditions page.

(Q) I have entered a finset on the Finsets page but it does not get exported to the output files nor does it show up on the geometry sketcher.

(A) To allow easy changing of the body geometry, the Geometry Parametrics page allows the user to turn on and off fins and other geometric parameters. Check the Geometry Parametrics page to make sure that the finset is turned.

(Q) When I go to the Deflections/Trim page, the finset I want to deflect/trim doesn't show as an option.

(A) Check the Geometry Parametrics page to make sure that the finset is designated for Control.

(Q) How do I clear my "Recently Used Files" list?

(A) ***Version 6 and earlier:*** Locate the "REGEDT32.EXE" program, which is typically located in your "\Windows\System32" directory. ***BE VERY CAREFUL what you do here***! Locate the "MissileLab" entry, and under that, you should find a "Files" entry. This is where the "recently used files" are stored. Locate the files you wish to delete – and be VERY CAREFUL!

(A) ***Version 7 and later:*** Locate and delete the "MLRecentFiles.ini" in the directory where MissileLab is installed.

(Q) Why is the "Sketch 3D Missile" option under the "Sketch" menu grayed out?

A) If 3-D graphics are not desired, the Include3d Flag in the INI file can be set to 0. This can also be done from the Locate Manuals/Set Options menu under Options. Check to see if this has been set to 0. Setting it to 1 should enable this feature.

FREQUENTLY ASKED QUESTIONS (FAQ) (CONCLUDED)

(Q) Why does my computer seem to run slowly after using the 3-D sketch feature in MissileLab?

(A) On some graphics cards, the 3-D graphics will run slowly. To disable the 3-D graphics, go to the "Locate Manuals/Set Options." Allow MissileLab to write a new Initialization file to disable the 3-D graphics every time MissileLab is run.

(Q) Why does my computer not display the 3-D windows correctly?

A) MissileLab uses 3DLinx to generate the 3-D windows. This software uses OpenGL to draw the scene. Some graphics cards may not fully support OpenGL. Many times this can be corrected by downloading a new driver for the graphics card. This may need to be done even on brand new machines.

(Q) The windows in the Setup are transparent. Why is this?

A) Running the MissileLab installation on Windows 7 does sometimes cause the installation windows to be transparent. If you click in the window, it typically will refresh and will not cause any problem in the installation process.

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LIST OF ACRONYMS AND ABBREVIATIONS

2-D	Two-Dimensional
3-D	Three-Dimensional
AOA	Angle-of-Attack
AP	AeroPrediction
APE	Aerodynamic Prediction Engines
GUI	Graphical User Interface
ID	Identification
MRP	Moment Reference Point
NASA	National Aeronautics and Space Administration
RHR	Right-Hand Rule
STL	Standard Tessellation Language
WAF	Wrap-Around Fins

APPENDIX
GRAPHICAL DEPICTIONS AND EQUATIONS FOR VARIOUS NOSE SHAPES

APPENDIX

Graphical depictions, as well as the equations for the various nose shapes, are presented. The descriptions are for hemispherical and elliptical nose shapes, sharp, blunted, and truncated options for conical, tangent ogive, secant ogive, power series, and Haack/Karman series noses. In addition, airfoils, fins, and other useful equations are also presented.

Appendix Table of Contents

Appendix Table of Contents (Concluded)

Nomenclature

C	=	Haack series constant
R	=	tangent ogive radius
R_b	=	bluntness radius
R_j	=	junction radius
R_n	=	nose radius at base
R_t	=	truncation radius
L	=	nose length
L_H	=	theoretical length for blunted Haack series
L_o	=	offset length
X_H	=	adjusted x position for blunted Haack series
X_j	=	junction axial position
h	=	hypotenuse
n	=	power series exponent
r	=	local radius
r_x	=	local slope (dr/dx)
t_1, t_2, t_3, t_4, t_5	=	component terms used in determining power series junction point
$v_1, v_2, v_3, v_4, v_5, v_6$	=	component terms used in Haack series
x	=	local axial position starting at nose tip
Δx	=	change in x during Haack series Newton-Raphson
$\Theta, \Theta_1, \Theta_2, \beta$	=	included angles
Φ	=	Haack series variable
I_{xx}, I_{yy}, I_{zz}	=	principle moments of inertia
CG_{LC}	=	center of gravity of large cone
$m_{frustum}$	=	mass of frustum
m_{LC}	=	mass of large cone
m_{VC}	=	mass of virtual cone
L_{VC}	=	length of virtual cone
$CG_{frustum}$	=	frustum center of gravity
Υ	=	distance between the base of the nose and where the slope of the nose is zero
t	=	maximum thickness of an airfoil
c	=	chord length of an airfoil
x_{LER}, z_{LER}	=	center of leading edge radius of an airfoil
d	=	diameter of the nose
N	=	length of the nose in calibers
r_0	=	radius of the nose at slope equal to zero (virtual if the curve was extended for blunted or truncated)

I. HEMISPHERICAL

The hemispherical nose shape is characterized by being a special case of the tangent ogive, where the bluntness radius (R_b) is equal to the nose length (L). This geometry can be seen in Figure A-1. The equation of the nose shape is simply:

$$r = \sqrt{R_b^2 - (R_b - x)^2} \qquad \text{(A-1)}$$

The local slope is given by:

$$r_x = \frac{R_b - x}{r} \qquad \text{(A-2)}$$

These same equations are valid for blunted nose shapes from the nose tip to the junction point (X_j, R_j). The junction point is the point on a blunted nose where the slope of the hemispherical nose matches the slope of the remaining nose shape.

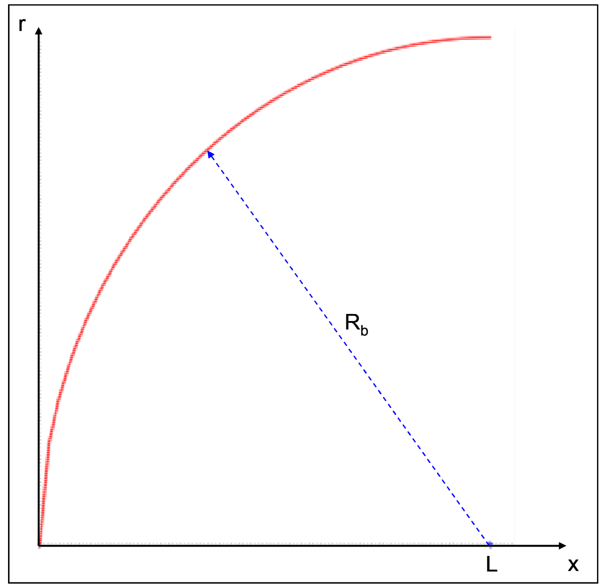


Figure A-1. Hemispherical Nose Geometry

II. ELLIPTICAL

The hemispherical is also a special case of the elliptical nose shape, where the major axis is along the center line (L) and minor axis at the base of the nose cone (R_n). This geometry can be seen in Figure A-2.

$$r = R_n \sqrt{1 - \frac{(L - x)^2}{L^2}} \qquad \text{(A-3)}$$

$$\tan \Theta_X = \frac{dr}{dx} = \frac{R_n \left(\frac{L - x}{L^2} \right)}{\sqrt{1 - \frac{(L - x)^2}{L^2}}} \qquad \text{(A-4)}$$

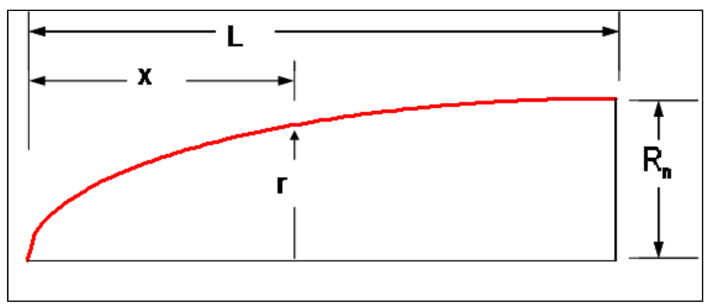


Figure A-2. Elliptical Nose Geometry

III. CONICAL

This section will detail the sharp, truncated, and blunted cone nose geometries.

A. Sharp Cone

Figure A-3 shows the geometry for a sharp cone nose shape. In this case, the equation of the nose shape is:

$$r = \frac{R_n}{L} x \qquad \text{(A-5)}$$

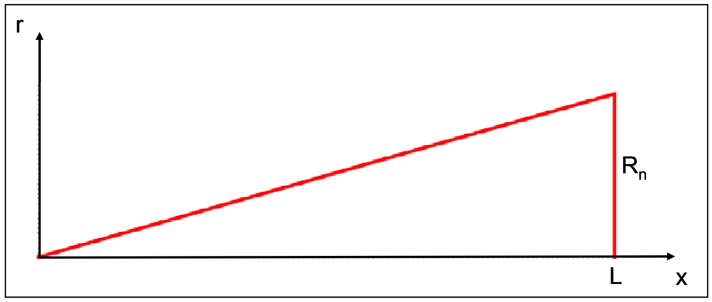


Figure A-3. Sharp Cone Nose Geometry

The local slope is:

$$r_x = \frac{R_n}{L} \qquad \text{(A-6)}$$

B. Truncated Cone

The geometry for a truncated cone is shown in Figure A-4. The equation of the nose shape is:

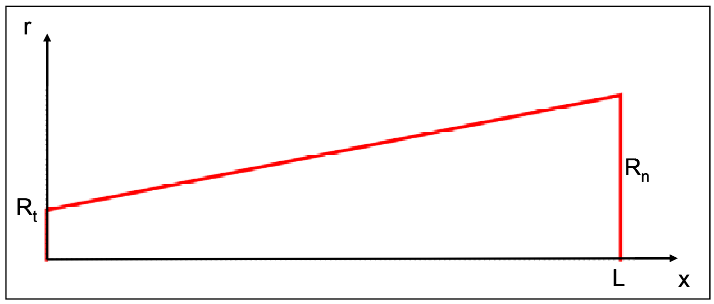


Figure A-4. Truncated Cone Nose Geometry

$$r = \frac{R_n - R_t}{L} x + R_t \qquad \text{(A-7)}$$

The local slope is:

$$r_x = \frac{R_n - R_t}{L} \qquad \text{(A-8)}$$

C. Blunted Cone

The blunted cone geometry is depicted in Figure A-5. For convenience, a hypotenuse can be given by:

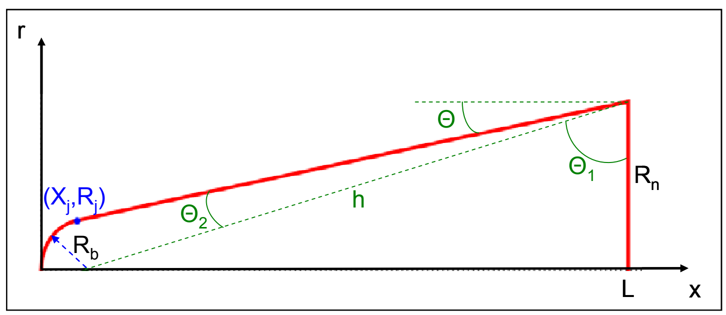


Figure A-5. Blunt Cone Nose Geometry

$$h = \sqrt{(L - R_b)^2 + R_n^2} \qquad \text{(A-9)}$$

Using this result, the included angles, Θ_1 and Θ_2, are:

$$\Theta_1 = \sin^{-1}\left(\frac{L - R_b}{h}\right) \qquad \text{(A-10)}$$

$$\Theta_2 = \sin^{-1}\left(\frac{R_b}{h}\right) \qquad \text{(A-11)}$$

The included angle, Θ, is then:

$$\Theta = 90° - \Theta_1 - \Theta_2 \qquad \text{(A-12)}$$

The junction point given by (X_j, R_j) can then be expressed as

$$R_j = R_b \cos(\Theta) \quad \text{(A-13)}$$

$$X_j = R_b(1 - \sin(\Theta)) \quad \text{(A-14)}$$

For the blunted region ($0 \le x \le X_j$), the equations for nose shape and local slope are given in the hemispherical nose section by Equations A-1 and A-2, respectively. For the conic region ($X_j \le x \le L$), the nose shape and local slope are

$$r = \frac{R_n - R_j}{L - X_j}(x - X_j) + R_j \quad \text{(A-15)}$$

$$r_x = \frac{R_n - R_j}{L - X_j} \quad \text{(A-16)}$$

IV. TANGENT OGIVE

This shape is formed from a circular arc with radius R and center at (L, R-R_n), where the equation for R varies based on whether the nose is sharp, truncated, or blunted. The nose shapes and local slope equations will be given in this section.

A. Sharp Ogive

Figure A-6 shows the geometry for a sharp tangent ogive. The ogive radius R is given by:

$$R = \frac{L^2 + R_n^2}{2R_n} \quad \text{(A-17)}$$

For a point on the nose shape curve, the following must be true:

$$R^2 = (R - R_n + r)^2 + (L - x)^2 \quad \text{(A.18)}$$

Rearranging:

$$r = \sqrt{R^2 - (L - x)^2} - (R - R_n) \quad \text{(A.19)}$$

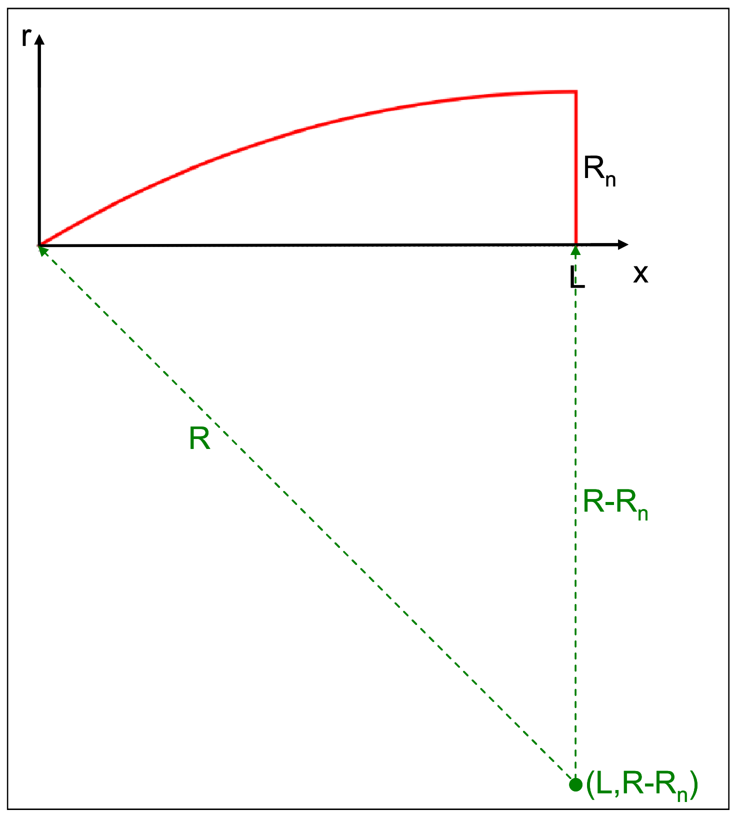


Figure A-6. Sharp Tangent Ogive Nose Geometry

Therefore, the local slope is:

$$r_x = \frac{L - x}{r + R - R_n} \qquad \text{(A-20)}$$

B. Truncated Ogive

The truncated tangent ogive nose shape is shown in Figure A-7. For this shape, the ogive radius R is

$$R = \frac{L^2 + R_n^2 + R_t^2 - 2R_n R_t}{2(R_n - R_t)} \qquad \text{(A-21)}$$

The equations for nose shape and the local slopes are given in Equations A-19 and A-20, respectively.

C. Blunted Ogive

The blunted tangent ogive geometry can be seen in Figure A-8. For the slopes to match at the junction point (X_j, R_j) between the blunted section and the ogive, the junction point as well as the center of the blunted section (R_b, 0) must be located on a radial line of length R that passes through the ogive center. It then follows that the ogive radius is

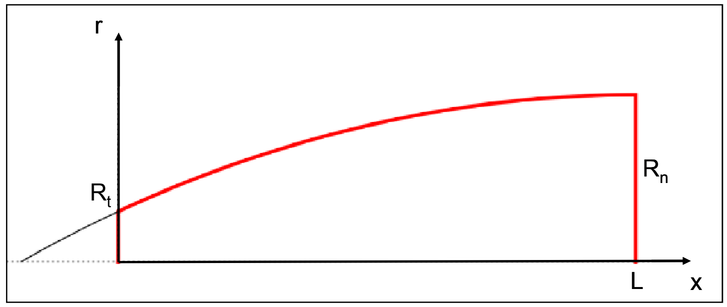
$$R = \frac{L^2 + R_n^2 - 2R_b L}{2(R_n - R_b)} \qquad \text{(A-22)}$$

The junction point given by (X_j, R_j) can then be expressed as

$$X_j = R_b\left(1 - \frac{L - R_b}{R - R_b}\right) \qquad \text{(A-23)}$$

$$R_j = R_b\left(\frac{R - R_n}{R - R_b}\right) \qquad \text{(A-24)}$$

For the blunted region ($0 \le x \le X_j$), the equations for nose shape and local slope are given in the hemispherical nose section by Equations A-1 and A-2, respectively. Similarly, for the ogive region ($X_j \le x \le L$), the nose shape and local slope are given in the sharp tangent ogive section by Equations A-19 and A-20.



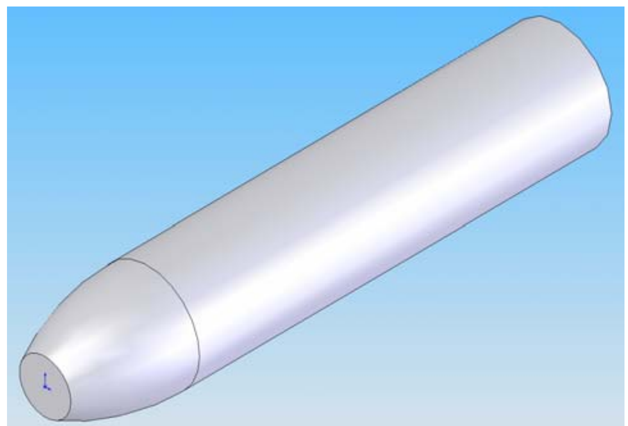
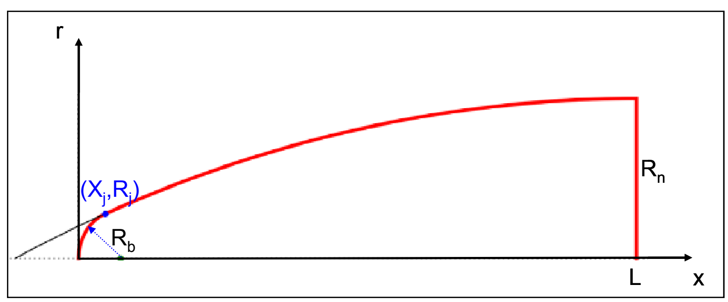


Figure A-7. Truncated Tangent Ogive Nose Geometry



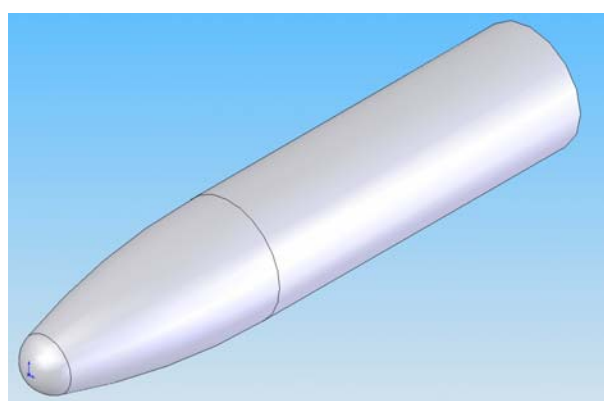


Figure A-8. Blunted Tangent Ogive Nose Geometry

V. SECANT OGIVE

Secants are tangent ogives which have had their aft section truncated either before reaching the apex as in Figure A-9 (a) or after the apex as in Figure A-9 (b).

A. Sharp Secant Ogive

For the geometry shown in Figure A-9, it is assumed that $0^o \leq \beta \leq 90^o$ such that

$$R^2 = (L+\gamma)^2 + (R-r_0)^2 \quad \text{(A-25)}$$

$$R^2 = (L + R\sin\beta)^2 + (R\cos\beta - R_n)^2 \quad \text{(A-26)}$$

$$R = \frac{(L^2 + R_n{}^2)}{2(R_n\cos\beta - L\sin\beta)} \quad \text{(A-27)}$$

$$\sin\beta = \frac{\gamma}{R} \quad \text{(A-28)}$$

$$\gamma = R\sin\beta \quad \text{(A-29)}$$

$$r_0 = R - R\cos\beta + R_n \quad \text{(A-30)}$$

For secants with aft truncation passed the apex, it is assumed that $0^o \leq \beta \leq 90^o$ such as in Figure A-9 (b). Therefore,

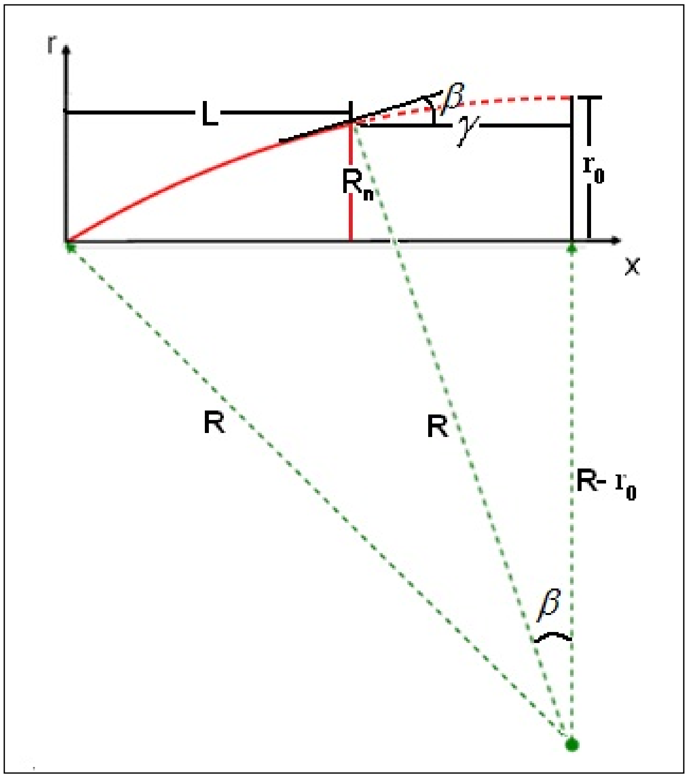
$$R^2 = (L-\gamma)^2 + (R-r_0)^2 \quad \text{(A-31)}$$

$$R^2 = (L - R\sin\beta)^2 + (R\cos\beta - R_n)^2 \quad \text{(A-32)}$$

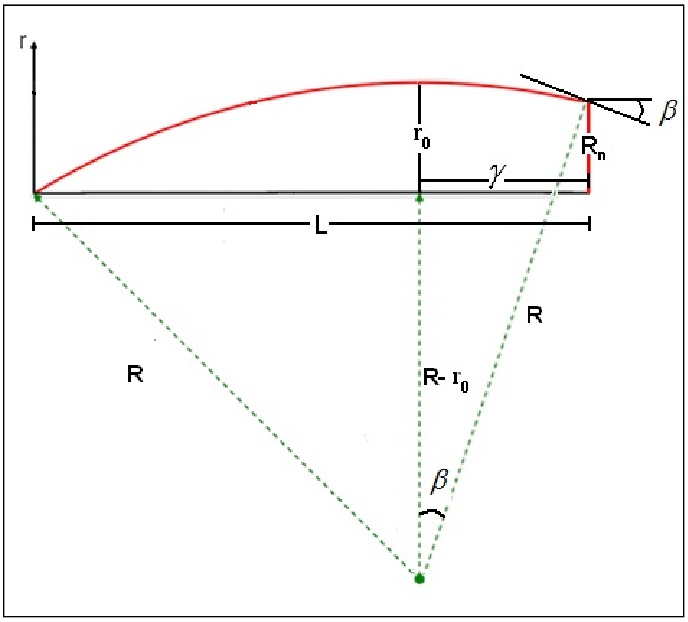
$$R = \frac{(L^2 + R_n{}^2)}{2(R_n\cos\beta + L\sin\beta)} \quad \text{(A-33)}$$

$$\sin\beta = \frac{\gamma}{R} \quad \text{(A-34)}$$

$$\gamma = R\sin\beta \quad \text{(A-35)}$$



(a)



(b)

Figure A-9. Sharp Secant Ogive Nose Geometry

$$r_0 = R - R\cos\beta + R_n \quad \text{(A-36)}$$

B. Truncated Secant Ogive

Figure A-10 shows the truncated secant ogive geometry.

$$\gamma = R\sin\beta \quad \text{(A-37)}$$

$$\Delta R = R_n - R_t \quad \text{(A-38)}$$

$$R = \frac{L^2 + \Delta R^2}{2(\Delta R\cos\beta - L\sin\beta)} \quad \text{(A-39)}$$

$$r_0 = R - R\cos\beta + R_n \quad \text{(A-40)}$$

C. Blunted Secant Ogive

Figure A-11 shows the blunted secant ogive geometry.

$$R = \frac{L^2 + R_n^{\ 2} - 2LR_b}{2(R_n\cos\beta - R_b + R_b\sin\beta - L\sin\beta)} \quad \text{(A-41)}$$

$$\gamma = R\sin\beta \quad \text{(A-42)}$$

$$r_0 = R - R\cos\beta + R_n \quad \text{(A-43)}$$

$$\tan\theta = \frac{L + \gamma - R_b}{R - R_0} \quad \text{(A-44)}$$

$$X_j = R_b - R_b\sin\theta \quad \text{(A-45)}$$

$$R_j = R_b\cos\theta \quad \text{(A-46)}$$

$$\gamma = R\sin\beta \quad \text{(A-47)}$$

$$r_0 = R - R\cos\beta + R_n \quad \text{(A-48)}$$

$$\tan\theta = \frac{L + \gamma - R_b}{R - R_0} \quad \text{(A-49)}$$

$$X_j = R_b - R_b\sin\theta \quad \text{(A-50)}$$

$$R_j = R_b\cos\theta \quad \text{(A-51)}$$

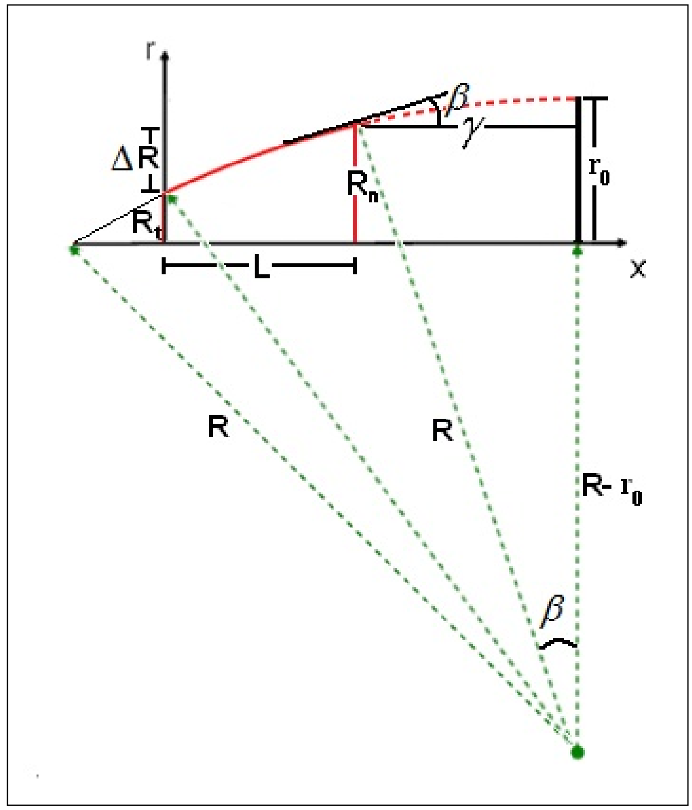


Figure A-10. Truncated Secant Ogive Nose Geometry

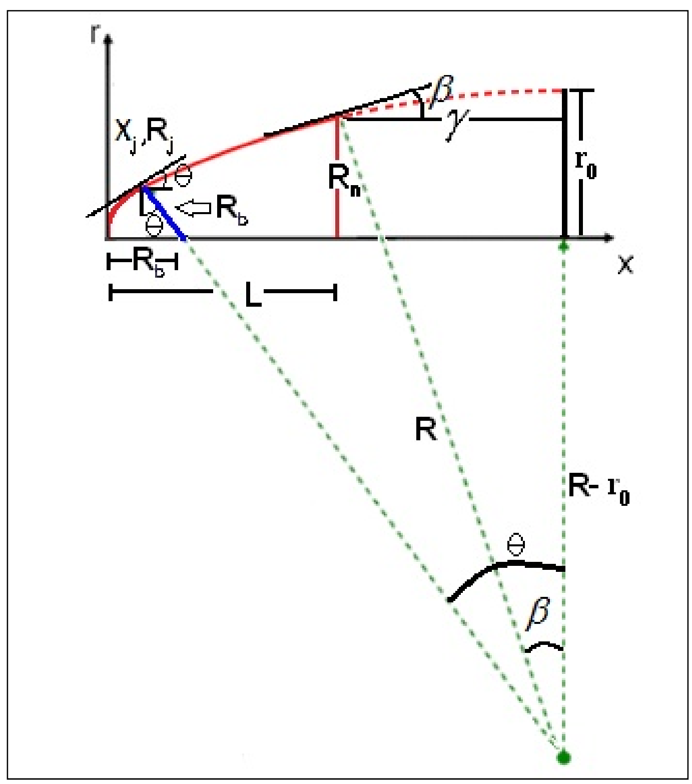


Figure A-11. Blunted Secant Ogive Nose Geometry

F. POWER SERIES

The nose shapes and local slope equations will be given in this section for sharp, truncated, and blunted power series nose types. For all of the power series noses, the power series exponent is bounded by

$$0 \le n \le 1 \tag{A-52}$$

A. Sharp Power Series

Figure A-12 depicts the sharp power series nose geometry. For this shape, the local radius is defined as

$$r = R_n \left(\frac{x}{L}\right)^n \tag{A-53}$$

The special cases of n=0, n=0.5, and n=1 are for a cylinder, a parabola, and a cone, respectively. The local slope is then given by

$$r_x = \frac{nR_n}{L}\left(\frac{x}{L}\right)^{n-1} \tag{A-54}$$

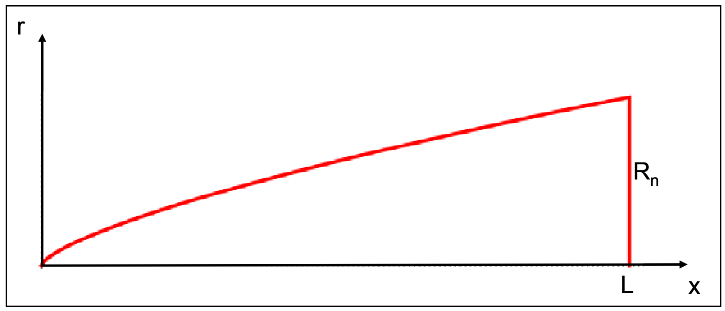


Figure A-12. Sharp Power Series Nose Geometry

B. Truncated Power Series

The truncated power series nose geometry is shown in Figure A-13. The local radius equation is similar to Equation A-53 but now contains an additional offset length (L_o) as in

$$r = R_n \left(\frac{x + L_o}{L + L_o}\right)^n \tag{A-55}$$

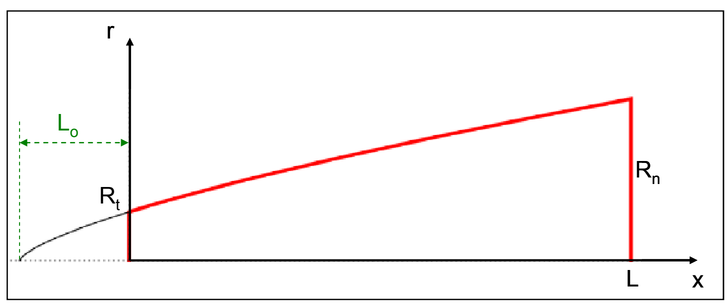


Figure A-13. Truncated Power Series Nose Geometry

Note that

$$r_t = R_n \left(\frac{L_o}{L + L_o}\right)^n \tag{A-56}$$

Therefore

$$L_o = \left(\frac{L\left(\frac{R_t}{R_n}\right)^{1/n}}{1 - \left(\frac{R_t}{R_n}\right)^{1/n}} \right) \tag{A-57}$$

The local slope equation is then

$$r_x = \frac{nR_n}{L + L_o}\left(\frac{x + L_o}{L + L_o}\right)^{n-1} \tag{A-58}$$

C. Blunted Power Series

Figure A-14 shows the blunted power series geometry. For the slopes to match at the junction point (X_j, R_j) between the blunted section and the power series section, the following must be true:

$$r_x\big|_{X_j} = \frac{R_b - X_j}{R_j} = \frac{nR_j}{X_j + L_o} \quad \text{(A-59)}$$

$$L_o = \left(\frac{L\left(\frac{R_j}{R_n}\right)^{1/n} - X_j}{1 - \left(\frac{R_j}{R_n}\right)^{1/n}} \right) \quad \text{(A-60)}$$

$$X_j = R_b - \sqrt{R_b^2 - R_j^2} \quad \text{(A-61)}$$

Note, that for small exponents ($n < 0.25$), there can be cases where L_o can become negative, meaning that there is no solution. Substituting equations A-60 and A-61 into A-59 results in an equation that can be written as:

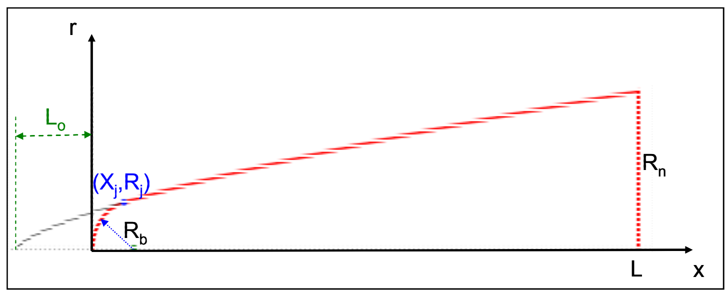


Figure A-14. Blunted Power Series Nose Geometry

$$f\left(R_j\right) = t_1 t_2 - t_3 t_4 t_5 \quad \text{(A-62)}$$

$$t_1 = nR_j^2 \quad \text{(A-63)}$$

$$t_2 = 1 - \left(\frac{R_j}{R_n}\right)^{1/n} \quad \text{(A-64)}$$

$$t_3 = \left(\frac{R_j}{R_n}\right)^{1/n} \quad \text{(A-65)}$$

$$t_4 = L + \sqrt{R_b^2 - R_j^2} - R_b \quad \text{(A-66)}$$

$$t_5 = \sqrt{R_b^2 - R_j^2} \quad \text{(A-67)}$$

Therefore,

$$f'(R_j) = t_1 \frac{dt_2}{dR_j} + t_2 \frac{dt_1}{dR_j} - t_3 t_4 \frac{dt_5}{dR_j} - t_3 t_5 \frac{dt_4}{dR_j} - t_4 t_5 \frac{dt_3}{dR_j} \qquad \text{(A-68)}$$

$$\frac{dt_1}{dR_j} = 2nR_j \qquad \text{(A-69)}$$

$$\frac{dt_2}{dR_j} = \frac{-1}{nR_n}\left(\frac{R_j}{R_n}\right)^{\left(\frac{1}{n}-1\right)} \qquad \text{(A-70)}$$

$$\frac{dt_3}{dR_j} = -\frac{dt_2}{dR_j} \qquad \text{(A-71)}$$

$$\frac{dt_4}{dR_j} = \frac{-R_j}{\sqrt{R_b^2 - R_j^2}} \qquad \text{(A-72)}$$

$$\frac{dt_5}{dR_j} = \frac{dt_4}{dR_j} \qquad \text{(A-73)}$$

These equations can then be solved iteratively using a Newton-Raphson approach that can be defined as

$$R_j^{(i+1)} = R_j^{(i)} - 0.1\frac{f\left(R_j^{(i)}\right)}{f'\left(R_j^{(i)}\right)} \qquad \text{(A-74)}$$

Generally, this method converges rather quickly given an initial guess of

$$R_j^{(0)} = 0.999R_b \qquad \text{(A-75)}$$

Once R_j, X_j, and L_o are determined, the equations for nose shape and local slope for the blunted region ($0 \le x \le X_j$) are given in the hemispherical nose section by Equations A-1 and A-2, respectively. Similarly, for the power series region ($X_j \le x \le L$), the nose shape and local slope are given in the truncated power series section by Equations A-55 and A-58.

VII. HAACK/KARMAN SERIES

The Haack series noses were designed to minimize drag. The Haack nose shape within Missile DATCOM is the same as the Haack-LV, which minimizes drag for a given length and volume, while the (Von) Karman nose shape is the Haack-LD, which minimizes drag for a given length and diameter. A comparison of the sharp Haack and Karman nose shapes can be seen in Figure A-15. The Von Karman nose shape is a special case of the Haack series where the Haack series constant (C) is 0, while the Haack (-LV) has a series constant of (1/3).

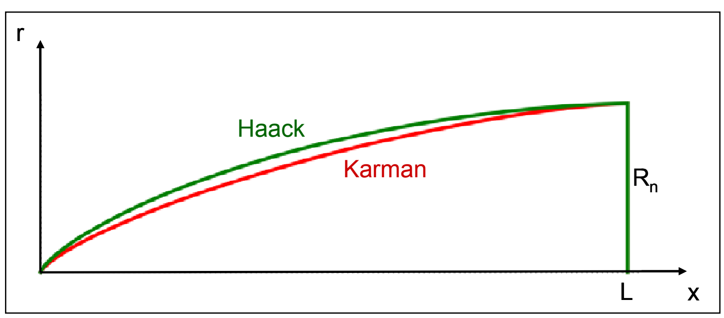


Figure A-15. Sharp Haack and Karman Nose Geometries

A. Sharp Haack/Karman

The general sharp Haack series nose geometry is shown in Figure A-16. The Haack series profile is defined by the following relations:

$$\Phi = \cos^{-1}\left(1 - \frac{2x}{L}\right) \quad \text{(A-76)}$$

$$v_1 = \Phi - \frac{\sin(2\Phi)}{2} + C\sin^3(\Phi) \quad \text{(A-77)}$$

$$r = \frac{R_n\sqrt{v_1}}{\sqrt{\pi}} \quad \text{(A-78)}$$

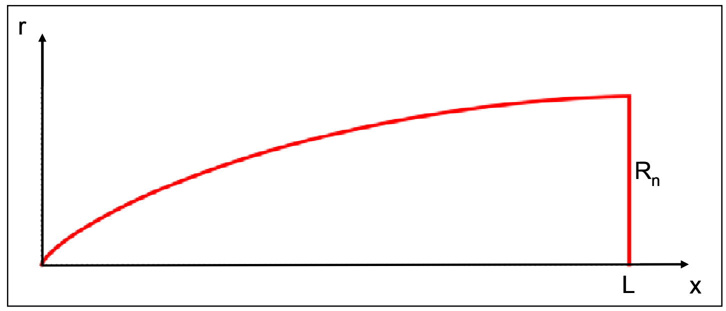


Figure A-16. Sharp Haack Nose Geometry

The local slope by the chain rule is then:

$$r_x = \frac{dr}{d\Phi}\frac{d\Phi}{dx} \quad \text{(A-79)}$$

where

$$v_2 = 1 - \cos(2\Phi) + 3C\sin^2(\Phi)\cos(\Phi) \quad \text{(A-80)}$$

$$\frac{dr}{d\Phi} = \frac{R_n}{2\sqrt{\pi}}\frac{v_2}{\sqrt{v_1}} \quad \text{(A-81)}$$

$$\frac{d\Phi}{dx} = \frac{1}{\sqrt{xL - x^2}} \quad \text{(A-82)}$$

B. Truncated Haack/Karman

Figure A-17 shows the truncated Haack nose shape. The equations for this shape are the same as for the sharp Haack nose (Equations A-76 through A-82), except Equations A-76 and A-82 are replaced, respectively, by the following:

$$X_H = x + L_o \quad \text{(A-83)}$$

$$L_H = L + L_o \quad \text{(A-84)}$$

$$\Phi = \cos^{-1}\left(1 - \frac{2X_H}{L_H}\right) \quad \text{(A-85)}$$

$$\frac{d\Phi}{dx} = \frac{1}{\sqrt{X_H L_H - X_H^2}} \quad \text{(A.86)}$$

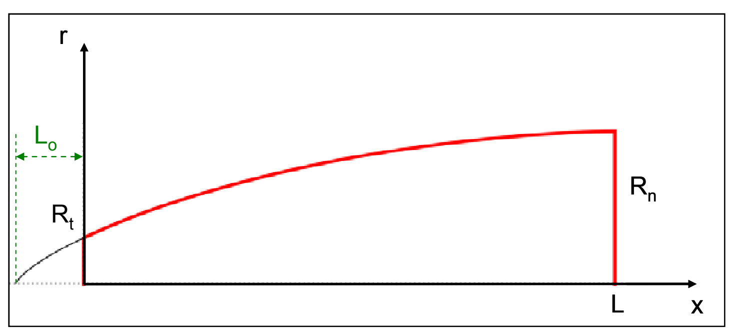


Figure A-17. Truncated Haack Nose Geometry

The offset length (L_o) can be iteratively solved using a Newton-Raphson approach so that the body passes through the point (0, R_t), such as

$$f(x) = r - R_t \tag{A-87}$$

$$f'(x) = r_x \tag{A-88}$$

$$\Delta x = 0.1\frac{f(0)}{f'(0)} \tag{A-89}$$

$$L_o = L_o - \Delta x \tag{A-90}$$

Generally, this method converges rather quickly given an initial guess of:

$$L_o = R_t \tag{A-91}$$

C. Blunted Haack/Karman

The blunted Haack nose geometry is shown in Figure A-18. The equations for the Haack portion of this shape are the same as for the sharp Haack nose (Equations A-76 through A-82), except Equations A-76 and A-82 are replaced, respectively, by the following:

$$X_H = x - X_j + L_o \tag{A-92}$$

$$L_H = L - X_j + L_o \tag{A-93}$$

$$\Phi = \cos^{-1}\left(1 - \frac{2X_H}{L_H}\right) \tag{A-94}$$

$$\frac{d\Phi}{dx} = \frac{1}{\sqrt{X_H L_H - X_H^2}} \tag{A-95}$$

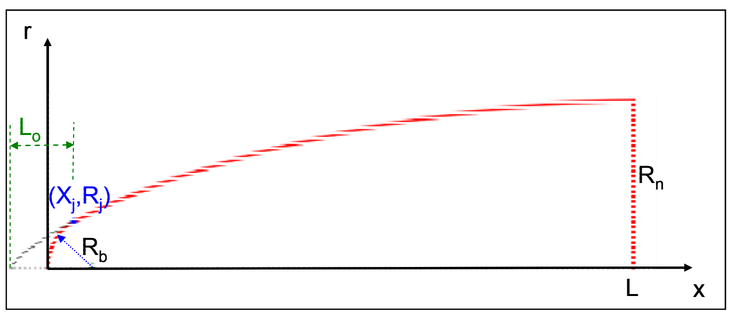


Figure A-18. Blunted Haack Nose Geometry

The offset length (L_o) and the junction point (X_j, R_j) can be iteratively solved using a two-layer nested Newton-Raphson approach. The inner loop iterates on Φ to match the body radius at the junction point and is defined as:

$$f(\Phi) = r - R_j \tag{A-96}$$

$$f'(\Phi) = \frac{dr}{d\Phi} \tag{A-97}$$

$$\Phi^{(i+1)} = \Phi^{(i)} - 0.1\frac{f(\Phi^{(i)})}{f'(\Phi^{(i)})} \tag{A-98}$$

Generally, this method converges rather quickly given an initial guess of:

$$\Phi^{(0)} = \cos^{-1}\left(1 - \frac{2R_j}{R_n}\right) \quad \text{(A-99)}$$

The outer loop iterates on X_j to match the slopes at the junction point as:

$$R_j = \sqrt{R_b^2 - (R_b - X_j)^2} \quad \text{(A-100)}$$

(Solve for Φ using inner Newton-Raphson.)

$$L_o = \left(L - X_j\right)\frac{1 - \cos(\Phi)}{1 + \cos(\Phi)} \quad \text{(A-101)}$$

$$L_H = L - X_j + L_o \quad \text{(A-102)}$$

$$X_H = L_o \quad \text{(A-103)}$$

(Use Equations A-77, A-80, A-81, and A-95.)

$$f(x) = \frac{dr}{d\Phi}\frac{d\Phi}{dx} - \frac{R_b - X_j}{R_j} \quad \text{(A-104)}$$

$$v_3 = \frac{X_H}{L_H} - \left(\frac{X_H}{L_H}\right)^2 \quad \text{(A-105)}$$

$$v_4 = \frac{1}{L_H} - 2\left(\frac{X_H}{L_H}\right)^2 \quad \text{(A-106)}$$

$$\frac{d^2\Phi}{dx^2} = \frac{\left(\frac{-v_4}{2L_H}\right)}{v_3^{\left(\frac{3}{2}\right)}} \quad \text{(A-107)}$$

$$v_5 = 2\sin(2\Phi) + 3C\left(2\sin(\Phi)*\cos(\Phi) - \sin^3(\Phi)\right) \quad \text{(A-108)}$$

$$v_6 = \frac{v_5}{\sqrt{v_1}} - \frac{v_2^2}{2v_1^{\left(\frac{3}{2}\right)}} \quad \text{(A-109)}$$

$$\frac{d^2r}{d\Phi^2} = \frac{R_n}{2\sqrt{\pi}}v_6 \quad \text{(A-110)}$$

$$f'(x) = \frac{dr}{dx}\frac{d^2r}{d\Phi^2} + \left(\frac{d\Phi}{dx}\right)^2 \frac{d^2r}{d\Phi^2} - \left(\frac{-1}{R_j} - \frac{(X_j - R_b)^2}{R_j^3}\right) \quad \text{(A-111)}$$

$$X_j^{(i+1)} = X_j^{(i)} - \frac{f\left(X_j^{(i)}\right)}{f'\left(X_j^{(i)}\right)} \quad \text{(A-112)}$$

Generally, this method converges rather quickly given an initial guess of:

$$X_j^{(0)} = 0.97R_b \quad \text{(A-113)}$$

VIII. AIRFOILS

A. Geometry of a Bi-Convex Airfoil

Note in Figure A-6 for the sharp tangent ogive that,

$$L = \frac{c}{2} \quad \text{(A-114)}$$

$$R_n = \frac{t}{2} \quad \text{(A-115)}$$

Then, the equations from Section IV.A can be applied to determine the upper surface.

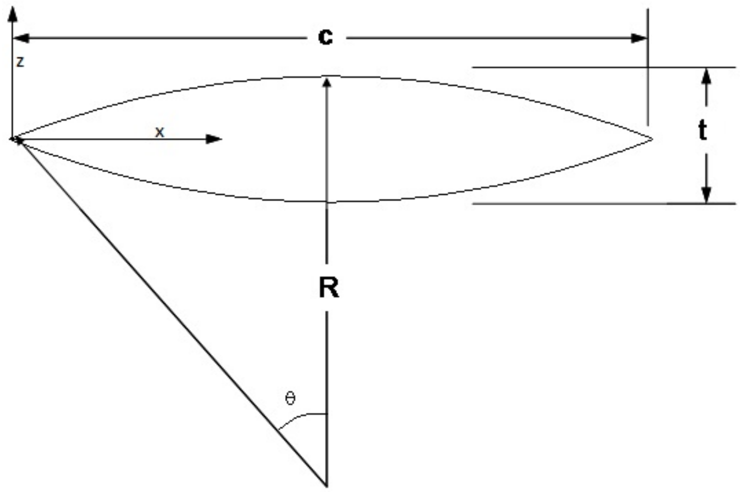


Figure A-19. Bi-Convex Airfoil Geometry

B. Geometry of a Blunted Bi-Convex Airfoil

Making the same assumptions from Equations A-114 and A-115, then likewise Figure A-8 and the equations from Section IV.C define the upper surface.

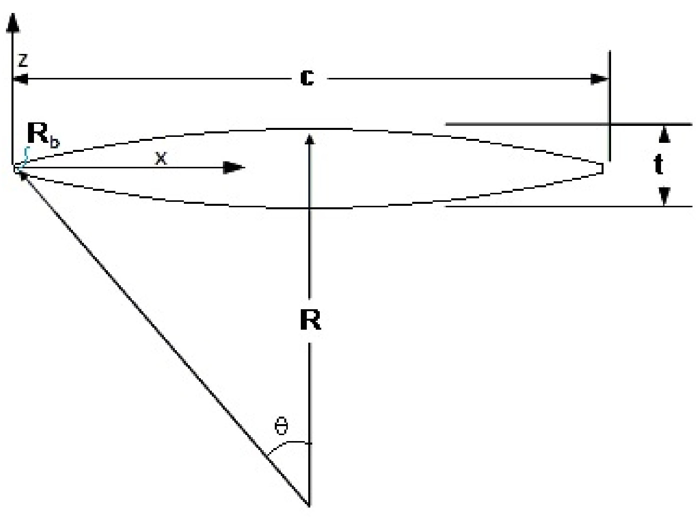


Figure A-20. Blunted Bi-Convex Airfoil Geometry

C. NACA 4-Digit Series Airfoils

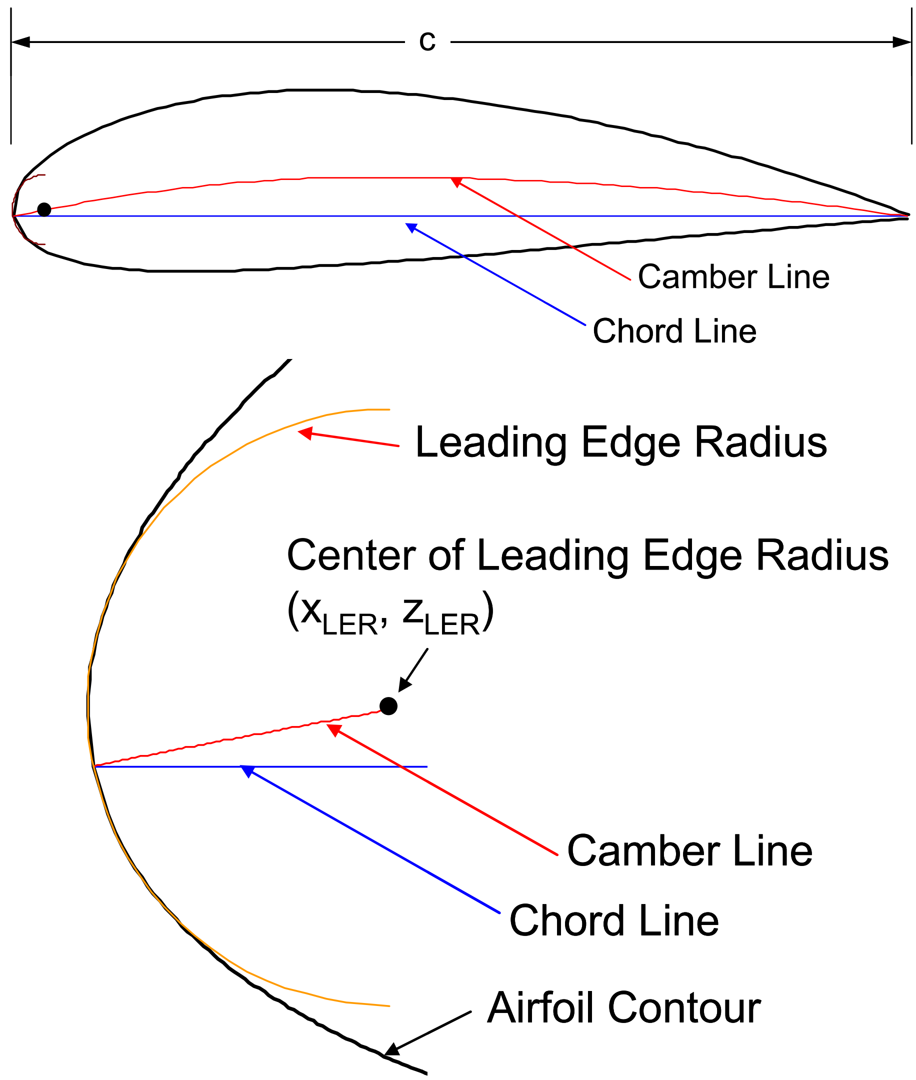


Figure A-21. NACA Four-Digit Series Airfoil Geometry

Note: See Abbott and von Doenhoff, "Theory of Wing Sections," Doever Press.

The NACA four-digit airfoil designation is of the form **NACA-mptt**, where

- **m**—maximum ordinate of the mean line in percent chord
- **p**—chordwise location of the maximum ordinate and is in tenths of chord
- **tt**—maximum thickness of the airfoil in percent chord

The first two digits (**mp**) taken together describe the camber line. For example a NACA-2415 airfoil has 2-percent camber, with maximum camber located at 40 percent of the chord length from the leading edge, and a maximum thickness of 15 percent. A NACA-0012 is an example of a symmetric airfoil (as **mp** = 00)

The thickness is defined as

$$z_t = \frac{t}{0.20}(0.29690\sqrt{x} - 0.12600x - 0.35160x^2 + 0.28430x^3 - 0.10150x^4) \quad \text{(A-116)}$$

The leading edge radius is defined as

$$r_t = 1.1019t^2 \quad \text{(A-117)}$$

Forward of the maximum ordinate, p, the mean camber line is defined as

$$z_c = \frac{m}{p^2}\left(2px - x^2\right) \quad \text{(A-118)}$$

$$\frac{dz_c}{dx} = \frac{m}{p^2}\left(2p - 2x\right) \quad \text{(A-119)}$$

Aft of the maximum ordinate, p, the mean camber line is defined as

$$z_c = \frac{m}{(1 - p)^2}\left((1 - 2p) + 2px - x^2\right) \quad \text{(A-120)}$$

$$\frac{dz_c}{dx} = \frac{m}{(1 - p)^2}\left(2p - 2x\right) \quad \text{(A-121)}$$

The upper surface of the airfoil is defined as

$$x_U = x - z_t \sin\Theta \quad \text{(A-122)}$$

$$z_U = z_c + z_t \cos\Theta \quad \text{(A-123)}$$

The lower surface of the airfoil is defined as

$$x_L = x + z_t \sin\Theta \quad \text{(A-124)}$$

$$z_L = z_c - z_t \cos\Theta \quad \text{(A-125)}$$

Where Θ is

$$\Theta = \tan^{-1}\left(\frac{dz_c}{dx}\right) \quad \text{(A-126)}$$

The center of the leading edge radius is defined as

$$x_{LER} = r_t \cos\Theta_{LE} \quad \text{(A-127)}$$

$$z_{LER} = r_t \sin\Theta_{LE} \quad \text{(A-128)}$$

Where Θ_{LE} is the result evaluated at x = 0.

X. Fins

A. Geometry of Fin Planforms

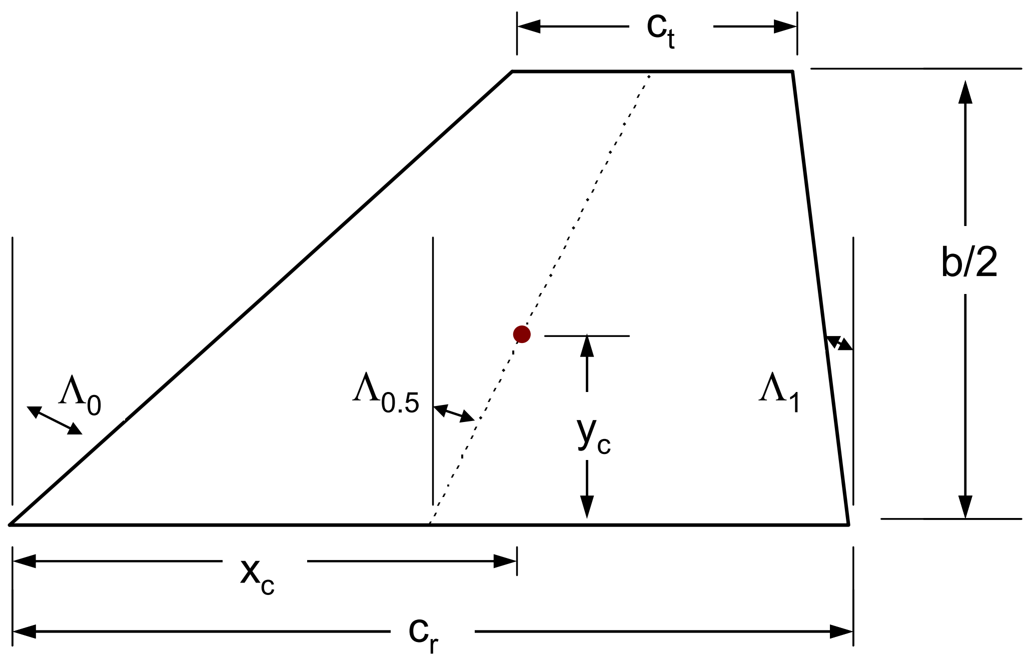


Figure A-22. Wing/Fin Planform Geometry

Definitions:

AR	Aspect Ratio
b/2	Exposed Semi-Span
C_r	Root Chord
C_t	Tip Chord
MAC	Mean Aerodynamic Chord
S	Planform Area
p	Percent of Chord where Sweep Angle is Defined (0 at Leading Edge → 1 at Trailing Edge)
(x_c, y_c)	Location of Area Centroid
λ	Taper Ratio
Λ_0	Leading Edge Sweep Angle
$\Lambda_{0.5}$	Mid-Chord Sweep Angle
Λ_1	Trailing Edge Sweep Angle

The x location of the tip leading edge relative to the root leading edge is defined by

$$x_t = \frac{b}{2}\tan\Lambda_0 \tag{A-129}$$

$$x_t = p\left(c_r - c_t\right) + \frac{b}{2}\tan\Lambda_0 \tag{A-130}$$

The Planform Area, S, of the fin is defined as

$$S = \frac{\frac{b}{2}\left(c_r + c_t\right)}{2} \tag{A-131}$$

The Taper Ratio of the fin is defined as

$$\lambda = \frac{c_t}{c_r} \tag{A-132}$$

The Aspect Ratio of a single fin panel is defined as

$$AR = \frac{\left(\frac{b}{2}\right)^2}{S} \tag{A-133}$$

The Spanwise location of the fin area centroid is defined as

$$y_c = \frac{\frac{b}{2}\left(c_r + 2c_t\right)}{3\left(c_r + c_t\right)} \tag{A-134}$$

The Chordwise location of the fin area centroid is defined as

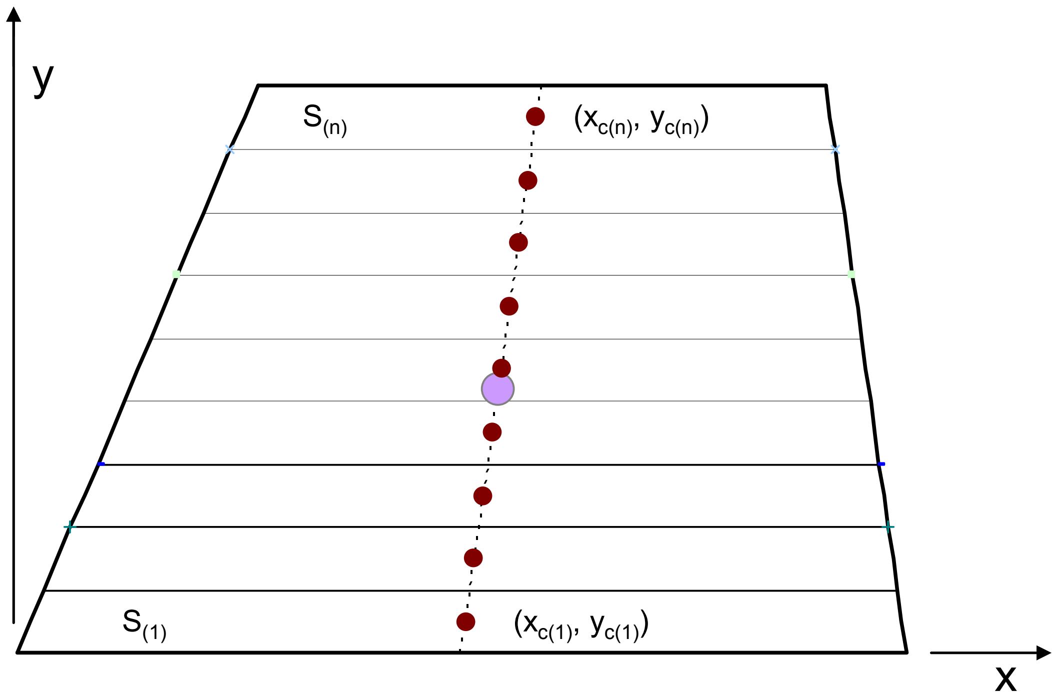
$$x_c = \frac{c_r}{2} + y_c \tan \Lambda_{0.5} \tag{A-135}$$

The chord length at a distance y from the root is defined as

$$c_y = c_r - y\left(\tan \Lambda_0 - \tan \Lambda_1\right) \tag{A-136}$$

Or,

$$c_y = c_r\left(\frac{y}{\left(\frac{b}{2}\right)}\left(\lambda - 1\right) + 1\right) \tag{A-137}$$



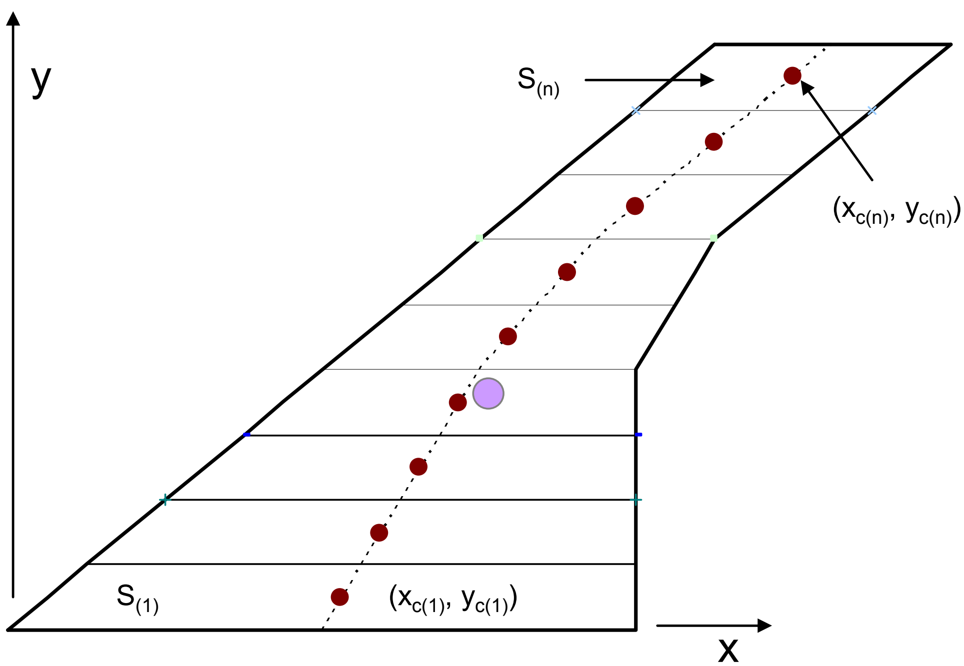


Figure A-23. Multi-Segment Wing/Fin Planform Geometry

To calculated the area centroid for a multi-segment fin, Equations A-134 and A-135 become

$$y_{c(i)} = y_{(i)} + \frac{\left(y_{(i+1)} - y_{(i)}\right)\left(c_{(i)} + 2c_{(i+1)}\right)}{3\left(c_{(i)} + c_{(i+1)}\right)} \qquad \text{(A-138)}$$

$$x_{c(i)} = x_{0.5(i)} + \left(y_{c(i)} - y_{0.5(i)}\right)\tan\Lambda_{0.5} \qquad \text{(A-139)}$$

And the area for each spanwise segment is

$$S_{(i)} = \frac{\left(y_{(i+1)} - y_{(i)}\right)\left(c_{(i)} + c_{(i+1)}\right)}{2} \qquad \text{(A-140)}$$

The total fin area is

$$S = \sum_{i=i}^{n} S_{(i)} \qquad \text{(A-141)}$$

And the area centroid for the fin panel is

$$x_c = \sum_{i-i}^{n} x_{c(i)} \frac{S_{(i)}}{S} \quad \text{and} \quad y_c = \sum_{i-i}^{n} y_{c(i)} \frac{S_{(i)}}{S} \qquad \text{(A-142)}$$

Some simple relationships:

Given C_r, Λ_{LE}, Λ_{TE}, b/2:

Find C_t:

$$C_t = C_r + \frac{b}{2}\left(-\tan\Lambda_{LE} + \tan\Lambda_{TE}\right) \qquad \text{(A-143)}$$

Given C_r, C_t, Λ_{TE}, b/2:

Find Λ_{LE}:

$$\Lambda_{LE} = \tan^{-1}\left(\frac{C_r - C_t + \frac{b}{2}\tan\Lambda_{TE}}{\frac{b}{2}}\right) \qquad \text{(A-144)}$$

Given C_r, C_t, Λ_{LE}, b/2:

Find Λ_{TE}:

$$\Lambda_{TE} = -\tan^{-1}\left(\frac{C_r - C_t - \frac{b}{2}\tan\Lambda_{LE}}{\frac{b}{2}}\right) \qquad \text{(A-145)}$$

The Mean Aerodynamic Chord (MAC) is defined as

$$\overline{C} = \frac{2}{S} \int_0^{b/2} C^2 dy \qquad \text{(A-146)}$$

For simple tapered wings, the MAC evaluates to

$$\overline{C} = \frac{2}{3} C_r \left(1 + \frac{\lambda^2}{1 + \lambda}\right) \qquad \text{(A-147)}$$

B. Geometry of Projected Fin Planforms

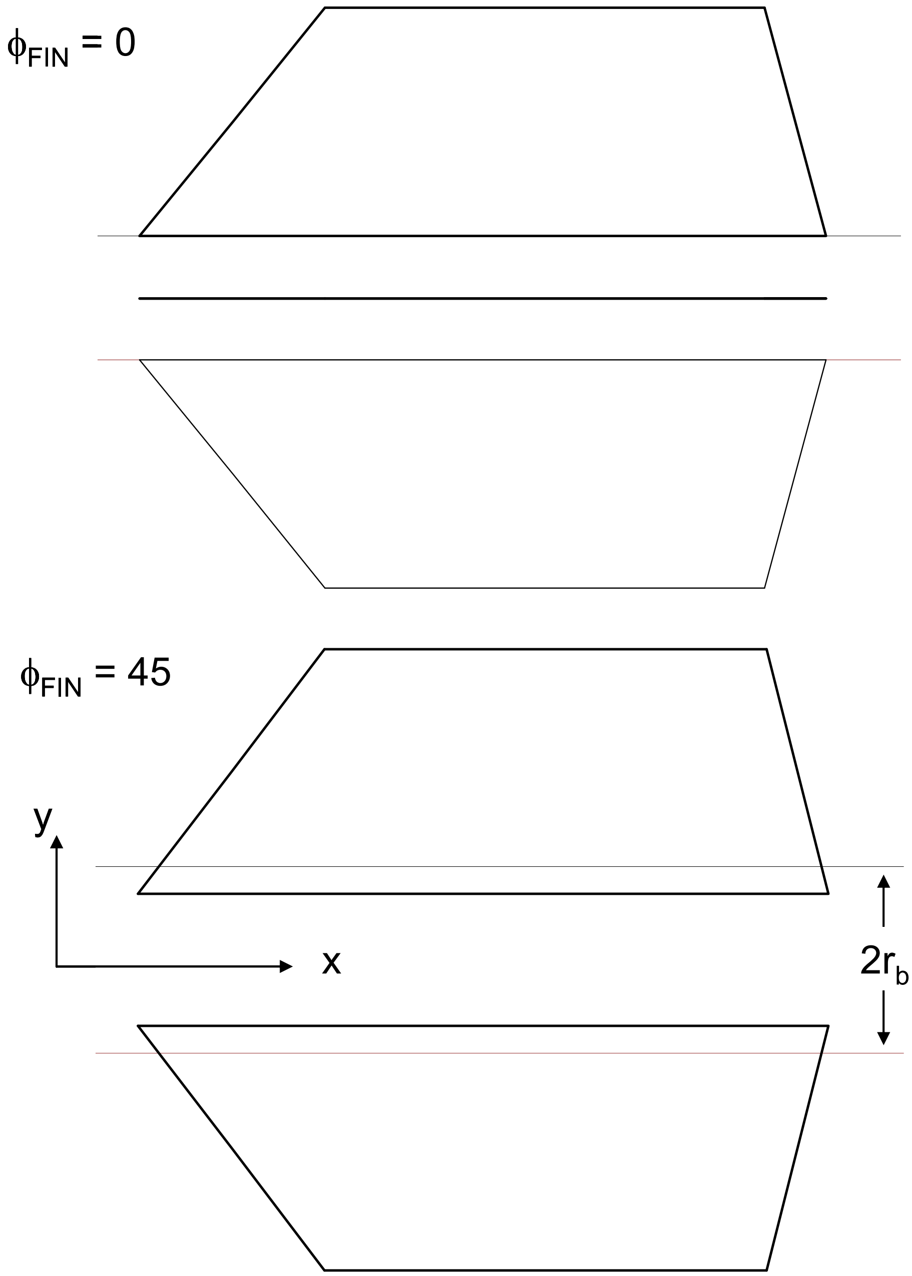


Figure A-24. Side View Fin Geometry

To make a quick side view sketch of fins at different fin attach angles, let

$$x' = x \tag{A-148}$$

$$y' = (y + r_b)\cos\Phi_{FIN} \tag{A-149}$$

C. WAF

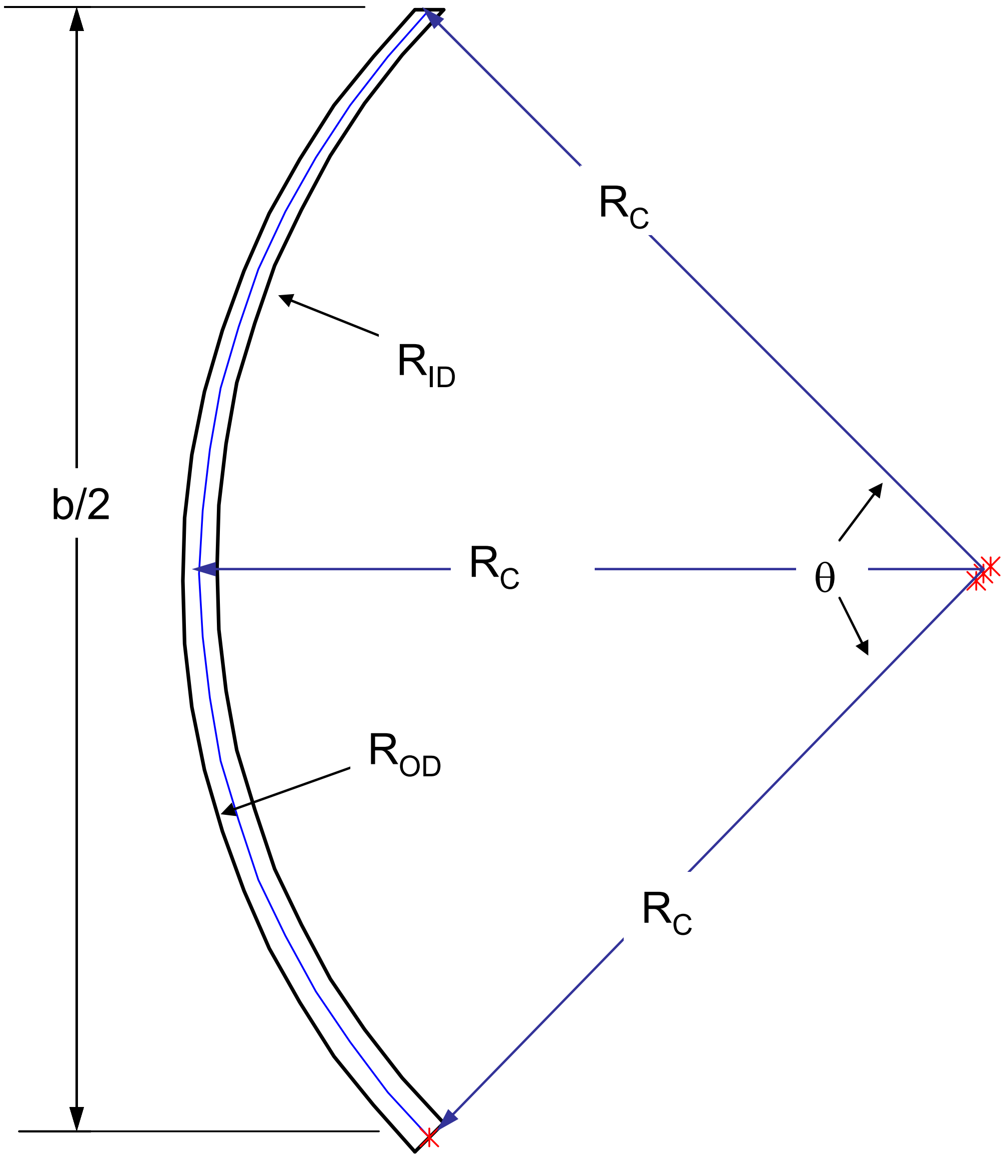


Figure A-25. WAF Geometry

Given the radius of the Body, R_C, the Wrap-Around Finds (WAF) sector angle, Θ, and the root half thickness, δ, calculate the geometry of a WAF.

The exposed semi-span is defined as

$$\frac{b}{2} = 2R_C \sin\left(\frac{\Theta}{2}\right) \tag{A-150}$$

The center of curvature for the WAF center-line is defined as

$$y_C = y_O + \frac{b/2}{2} \tag{A-151}$$

$$x_C = x_O + R_C \cos\left(\frac{\Theta}{2}\right) \tag{A-152}$$

The center of curvature and radius for the Inner surface is defined as

$$y_{ID} = y_C + \frac{\delta}{2}\sin\left(\frac{\Theta}{2}\right) \tag{A-153}$$

$$x_{ID} = x_C + \frac{\delta}{2}\cos\left(\frac{\Theta}{2}\right) \tag{A-154}$$

$$R_{ID} = R_C - \frac{\delta}{2} \tag{A-155}$$

The center of curvature and radius for the Outer surface is defined as

$$y_{OD} = y_C - \frac{\delta}{2}\sin\left(\frac{\Theta}{2}\right) \tag{A-156}$$

$$x_{OD} = x_C - \frac{\delta}{2}\cos\left(\frac{\Theta}{2}\right) \tag{A-157}$$

$$R_{OD} = R_C + \frac{\delta}{2} \tag{A-158}$$

X. Other Useful Equations

A. Conic Frustum

A common example of a conic frustum is a flare. The following equations define the geometry.

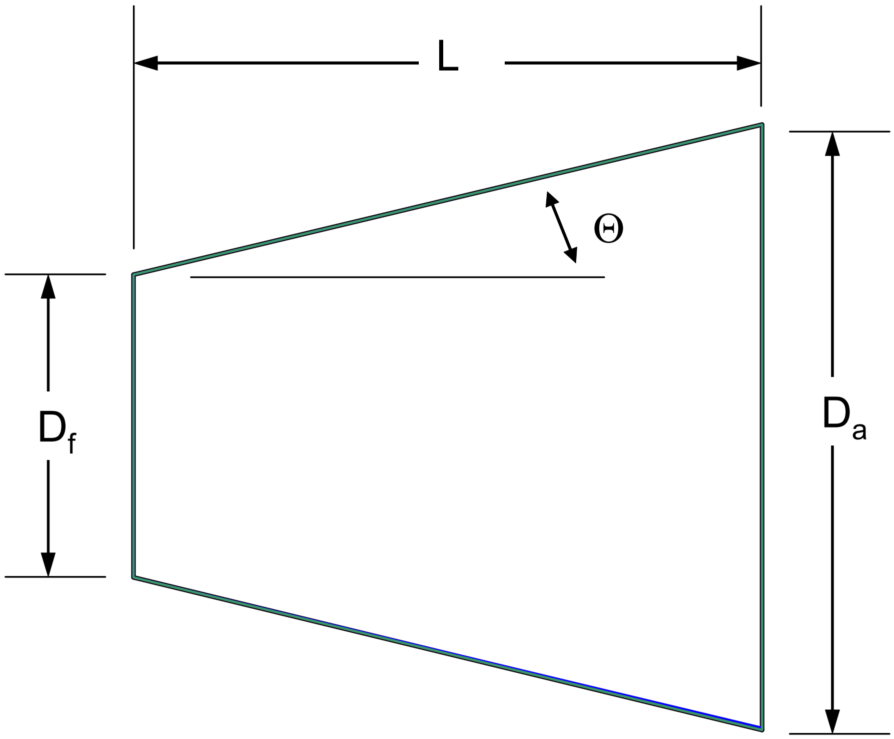


Figure A-26. Geometry of a Flare

Given L, D_f, D_a:

Find Θ:

$$\Theta = \tan^{-1}\left(\frac{D_a - D_f}{2L}\right) \tag{A-159}$$

Given L, D_f, Θ:

Find D_a:

$$D_a = D_f + 2L\tan\Theta \tag{A-160}$$

Given Θ, D_f, D_a:

Find L:

$$L = \frac{D_a - D_f}{2\tan\Theta} \tag{A-161}$$

Given L, Θ, D_a:

Find D_f:

$$D_f = D_a - 2L\tan\Theta \tag{A-162}$$

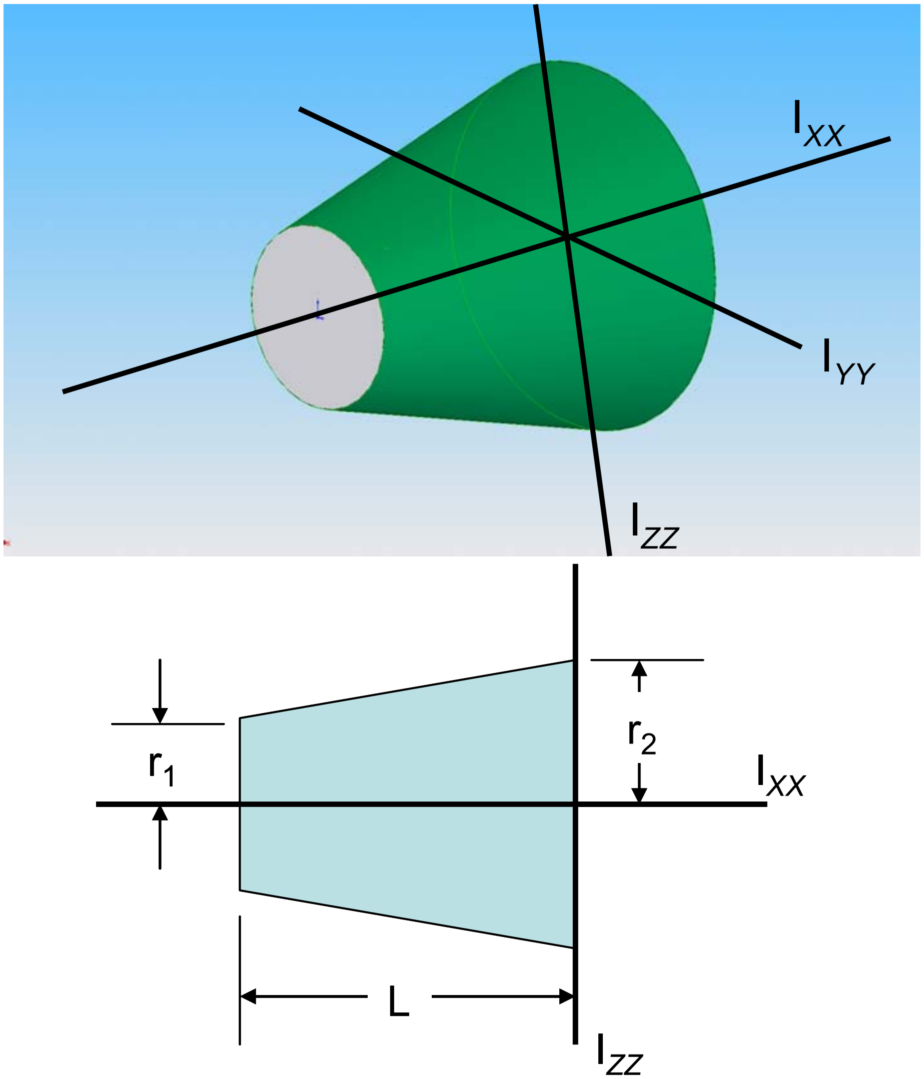


Figure A-27. Geometry of a Conic Frustum

Volume of a conic frustum

$$V = \frac{\Pi}{3} L \left(r_2^2 + r_1 r_2 + r_1^2 \right) \quad \text{(A-163)}$$

Center-of-Gravity of a homogeneous conic frustum

$$X_{CG} = \frac{L}{4} \left(\frac{3r_2^2 + 2r_1 r_2 + r_1^2}{r_2^2 + r_1 r_2 + r_1^2} \right) \quad \text{(A-164)}$$

Moment of Inertia, Ixx

$$I_{XX} = \frac{\rho \Pi}{10} L \left(r_2^4 + r_1 r_2^3 + r_1^2 r_2^2 + r_1^3 r_2 + r_1^4 \right) \quad \text{(A-165)}$$

Moment of Inertia, Iyy, Izz

$$I_{YY} = I_{ZZ} = 3m_{LC}\left(\frac{4R_n^2 + L_{LC}{}^2}{80}\right) + m_{LC}(CG_{LC} - CG_{frustum})^2 - 3m_{VC}\left(\frac{4R_t^2 + L_{VC}{}^2}{80}\right)$$

$$+ m_{VC}(CG_{LC} - CG_{frustum})^2 \tag{A-166}$$

Where,

$$\rho = density \tag{A-167}$$

$$m_{frustum} = \rho(V_{frustum}) \tag{A-168}$$

$$m_{LC} = m_{VC} + m_{frustum} \tag{A-169}$$

$$L_{VC} = \frac{R_t L}{R_n - R_t} \tag{A-170}$$

$$L_{LC} = L_{VC} + L \tag{A-171}$$

$$CG_{LC} = \frac{3}{4}L_{LC} - L_{VC} \tag{A-172}$$

$$CG_{VC} = -\frac{1}{4}L_{VC} \tag{A-173}$$

B. Planform Area of a Tangent Ogive

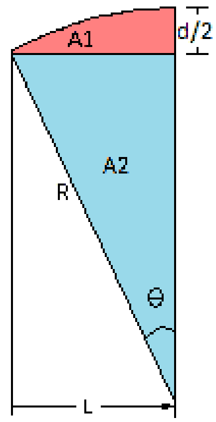


Figure A-28. Tangent Ogive Geometry for Local Radius

Ogive planform area is

$$A_0 = 2A_1 \tag{A-174}$$

The area of an arc is

$$A_3 = A_1 + A_2 = \frac{R^2\Theta}{2} \tag{A-175}$$

$$L = d\ N \tag{A-176}$$

$$A_0 = 2\left(\frac{R^2\Theta}{2} - \frac{\left(R - \frac{d}{2}\right)(dN)}{2}\right) \tag{A-177}$$

Substituting Θ and R yields,

$$A_0 = \left(d^2\left(N^2 + 0.25\right)^2\left(\sin^{-1}\left(\frac{N}{N^2 + 0.25}\right)\right)\right) - \left(d^2 N\left(N^2 - 0.25\right)\right)$$

Or

$$A_0 = d^2\left[\left(\left(N^2 + 0.25\right)^2\left(\sin^{-1}\left(\frac{N}{N^2 + 0.25}\right)\right)\right) - \left(N\left(N^2 - 0.25\right)\right)\right] \tag{A-178}$$

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