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DESCRIPTION OF AN AERONAUTICAL GEOMETRY CONVERSION PACKAGE: WAVE-DRAG TO LAWGS TO SIMP

MICHAEL R. WIESE
Computer Sciences Corporation
Hampton, Virginia

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Langley Research Center
Hampton, Virginia 23665-5225

FOREWORD

This document was prepared by Computer Sciences Corporation, Applied Technology Division, for the National Aeronautics and Space Administration, Langley Research Center at Hampton, Virginia. The work was performed under contract No. NAS1-17999. Mr. Kenneth Jones was the NASA Project Monitor for this task.

SUMMARY

This document describes a translator that will convert a model data file described in either wave-drag or LaWGS geometry format into the Supersonic Implicit Marching Potential (SIMP) program input format. Four programs are incorporated into the procedure used to generate the cross-sectional data required by SIMP. Each program is described and a sample case is presented.

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INTRODUCTION

Many programs have been developed to allow researchers to numerically define arbitrary shapes for analysis or construction of experimental models. One frequently used program is the geometry generation portion of the supersonic zero-lift wave-drag computer program[1]. With this program the configuration geometry is described with discrete points. The contours of the configuration are then formed by connecting the points with straight lines. The discrete points are set up so that when the proper connection scheme is followed the result is a wireframe model representation of the geometry.

The Langley Wireframe Geometry Standard[2] (LaWGS) has been established so that the same numerical model can be used by many application programs. This wireframe geometry standard provides the common link and simplifies the translation of geometry from one format to another. Existing programs that use geometry formats that are not LaWGS compatible need translators that will convert their non-standard formats into the LaWGS format.

A geometry can be described as one complete component or a sum of individual components (e.g. body, wing, tail). Typically, complex aircraft configurations are defined as a sum of components. Fuselage type components are defined by sets of discrete points at constant X locations while lifting surface type components are defined at constant Y locations. These components are then merged together to form the complete configuration. This type of geometry definition works well for

the zero-lift wave-drag computer program but not for all aerodynamic analysis programs.

One program this geometry is not compatible with is the Supersonic Implicit Marching Potential[3] (SIMP) program. The SIMP code is an aerodynamic analysis program that is formulated from the conservative potential equation. Configurations must be defined with discrete points at constant X locations. These X location descriptions must be for all components at that X location, including lifting surface type components. Since many aircraft configuration geometry definitions can be written in LaWGS format or can be translated to that format, a procedure was needed to allow these configurations to be examined with the SIMP code.

Four computer programs have been developed that convert wave-drag geometry to the LaWGS input format and then into an input format compatible with the SIMP code. The first program, KWD2LWG, converts the wave-drag geometry description into the LaWGS input format. The second program, KINTERL, is used to calculate the leading and trailing intersection points between the fuselage and lifting surfaces intersecting the fuselage (e.g. fuselage/wing, fuselage/canard, fuselage/fin). The third program KLINCRX, is used to generate the discrete points at constant X locations. This translation of the LaWGS input format to the discrete point SIMP input is accomplished using linear interpolation between the wave-drag fuselage type components and the lifting surface type components. The fourth program, KLINFIX, is used to interactively enhance the output from program KLINCRX.

A functional flow diagram of this translator that converts wave-drag format to the SIMP format is provided in figure 1.

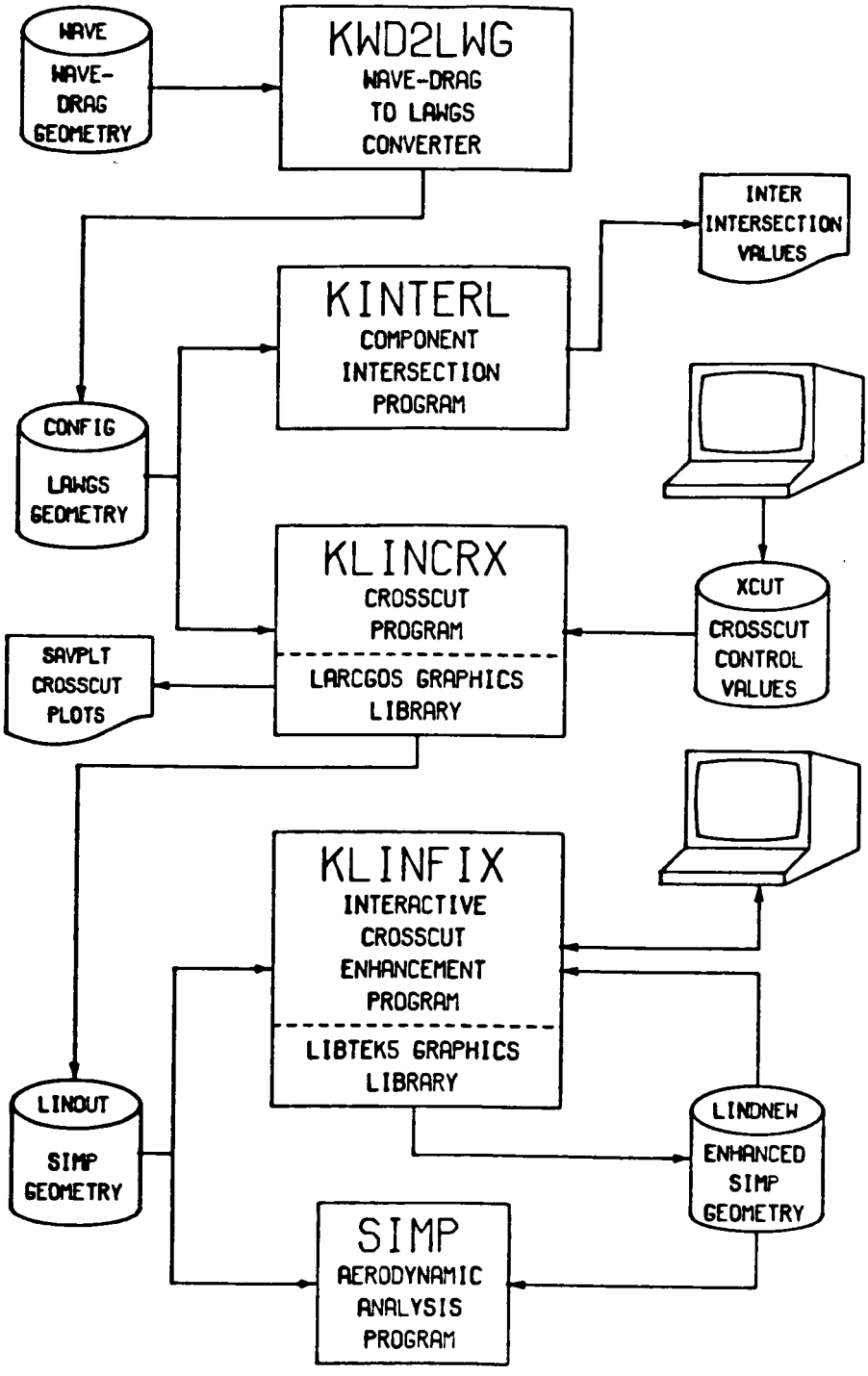

Figure 1: Functional Flow Of Translator

MODEL GEOMETRY

The wireframe geometry uses points and lines rather than solid elements or surfaces in its definition. A 3-D right-handed Cartesian coordinate system is used with the Z-axis positive upward, the Y-axis positive out the right wing, and the X-axis positive down the body. It is assumed that the configuration is symmetric about the X-Z plane at a Y value of zero and that all components are defined with respect to a global coordinate system. Therefore, only those parts of the fuselage, pod, wing, horizontal tail, and canard on the positive side of the Y-axis are described in the model geometry database. For a fin centered on the line of symmetry, both left and right sides of each airfoil must be described in the database. Figure 2 illustrates the coordinate system conventions.

The fuselage is described by a series of cross sections in the X-axis direction. The data at each unique axial location is ordered clockwise top to bottom when viewed from the rear looking toward the nose.

The wing, canard, and horizontal tail (if present) are defined by unique airfoil sections which proceed inboard to outboard in the Y-axis direction. All three must intersect the fuselage. Airfoil data is ordered clockwise leading edge to trailing edge (top) and then trailing edge to leading edge (bottom). The number of points on top must equal the number of points on the bottom. The tip chord of the wing and canard must be an airfoil with zero thickness. An open ended component is not allowed.

The fin is defined by unique airfoil sections which proceed inboard to outboard in the Z-axis direction. It must intersect the fuselage. Airfoil data is ordered clockwise leading edge to trailing edge (positive Y) and then trailing edge to leading edge (negative Y). The number of points on the right and left sides must be equal.

A pod is described by a series of unique cross sections in the X-axis direction. The data at each axial location is ordered clockwise and the last point must equal the first point. The pod must intersect the wing.

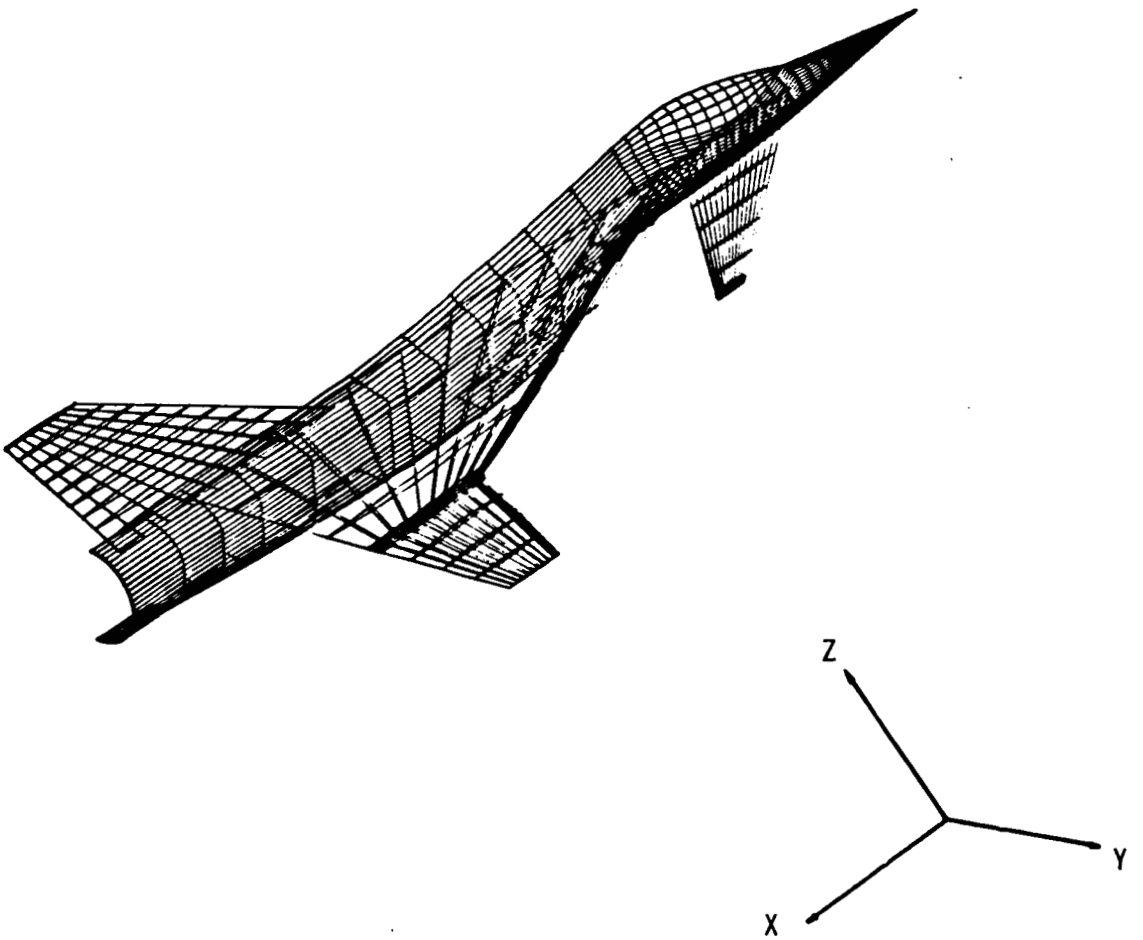

Figure 2: Coordinate System Conventions

PROGRAM KWD2LWG

Program KWD2LWG is used to translate the wave-drag geometry description into the LaWGS input format. The file descriptions are:

File Name	Description
WAVE	wave-drag geometry
CONFIG	LaWGS geometry

Arrays in KWD2LWG are sized via parameter statements. These parameter variables are:

Variable	Description
NVL	maximum number of contour lines per component, currently 50
NVP	maximum number of points per contour line, currently 50

GEOMETRY INPUT FILE CONFIG

The data description file which is used as input to KINTERL and KLINCRX is named CONFIG. A maximum of one fuselage, one wing, one canard or horizontal tail, one fin, and one pod are allowed. The structure of this file follows the Langley Wireframe Geometry Standard (LaWGS) format.

Data is entered into a LaWGS file in list-directed format which complies with the American National Standards Institute (ANSI) FORTRAN 77 language. List-directed input/output processes coded data without a FORMAT statement. The input data values are free-form with separators rather than fixed-size fields. Separators can be one or more blanks, commas, or slashes, either of which can be preceded or followed by any number of blanks. Character strings must be enclosed in single quotes. The LaWGS input format is:

Record	Variable	Description
1	IDCONF	Identification of LaWGS configuration (1-80 alphanumeric characters enclosed in single quotes).
	(Repeat record sets 2, 3, and 4 for each object.)	
2	IDOBJ	Object identification (1-80 alphanumeric characters enclosed in single quotes).
3	NOBJ	Object number (integer identification unique to object).
	NLINE	Number of contour lines to be listed for object.
	NPNT	Number of points listed for each contour line.

Record	Variable	Description
	ISYML	In its local coordinate system, the object is = 0, not symmetrical. = 1, symmetrical about its local X-Z axis. = 2, symmetrical about its local X-Y axis. = 3, symmetrical about its local Y-Z axis.
	RX RY RZ	Rotation of the object about its local X, Y, Z axes, respectively (roll, pitch, yaw), in degrees.
	TX TY TZ	Translation of the object along the X, Y, Z axes, respectively, to move the object to the global system from its local system, in units consistent with object input points.
	XSCALE YSCALE ZSCALE	Scale factors applied to the X, Y, Z coordinates, respectively, that will transform the object points into global units.
	ISYMG	In the global coordinate system, the object is = 0, not symmetrical. = 1, symmetrical about the global X-Z axis. = 2, symmetrical about the global X-Y axis. = 3, symmetrical about the global Y-Z axis.
4	$(x,y,z)_{m,n}$	Point coordinates of the object, where m = 1 to NPNT for each n = 1 to NLINE. For readability, begin a new record image for each contour: $(x,y,z)_{1,1}$ --- $(x,y,z)_{NPNT,1}$ $(x,y,z)_{1,2}$ --- $(x,y,z)_{NPNT,2}$ - - - $(x,y,z)_{1,NLINE}$ --- $(x,y,z)_{NPNT,NLINE}$

An example of this format is shown in figures 3a thru 3i.

```
' PAB102 FORWARD FUSELAGE '
' FUSELAGE '
 1 32 30  0  .0  .0  .0  .0  .0  .0 1.0 1.0 1.0  1
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000   .000
  .000   .000   .000   .000   .000   .000
 1.000   .000   .213  1.000   .000   .213  1.000   .000   .213  1.000   .000   .213
 1.000   .000   .213  1.000   .017   .211  1.000   .034   .207  1.000   .051   .201
 1.000   .067   .193  1.000   .081   .183  1.000   .094   .171  1.000   .106   .158
 1.000   .115   .143  1.000   .124   .128  1.000   .131   .112  1.000   .136   .095
 1.000   .140   .078  1.000   .142   .060  1.000   .141   .043  1.000   .138   .025
 1.000   .132   .009  1.000   .123  -.006  1.000   .111  -.020  1.000   .098  -.031
 1.000   .084  -.041  1.000   .068  -.049  1.000   .052  -.055  1.000   .035  -.060
 1.000   .017  -.062  1.000   .000  -.064
 2.000   .000   .427  2.000   .000   .427  2.000   .000   .427  2.000   .000   .427
 2.000   .000   .427  2.000   .035   .422  2.000   .069   .415  2.000   .102   .403
 2.000   .133   .387  2.000   .162   .366  2.000   .188   .342  2.000   .211   .315
 2.000   .231   .287  2.000   .247   .256  2.000   .261   .223  2.000   .272   .190
 2.000   .280   .156  2.000   .284   .121  2.000   .283   .086  2.000   .276   .051
 2.000   .264   .018  2.000   .246  -.012  2.000   .223  -.039  2.000   .197  -.062
 2.000   .167  -.082  2.000   .136  -.098  2.000   .103  -.111  2.000   .070  -.120
 2.000   .035  -.125  2.000   .000  -.128
 3.000   .000   .640  3.000   .000   .640  3.000   .000   .640  3.000   .000   .640
 3.000   .000   .640  3.000   .052   .632  3.000   .103   .620  3.000   .153   .603
 3.000   .200   .579  3.000   .243   .548  3.000   .282   .513  3.000   .317   .473
 3.000   .346   .429  3.000   .371   .383  3.000   .392   .335  3.000   .408   .284
 3.000   .420   .233  3.000   .426   .181  3.000   .424   .128  3.000   .414   .076
 3.000   .396   .027  3.000   .369  -.019  3.000   .335  -.059  3.000   .295  -.093
 3.000   .251  -.123  3.000   .204  -.147  3.000   .155  -.166  3.000   .104  -.179
 3.000   .052  -.187  3.000   .000  -.192
 3.500   .000   .747  3.500   .000   .747  3.500   .000   .747  3.500   .000   .747
 3.500   .000   .747  3.500   .061   .737  3.500   .121   .723  3.500   .178   .703
 3.500   .233   .675  3.500   .284   .640  3.500   .329   .598  3.500   .369   .552
 3.500   .404   .501  3.500   .433   .447  3.500   .457   .390  3.500   .476   .332
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 3.500   .293  -.143  3.500   .238  -.172  3.500   .181  -.194  3.500   .122  -.209
 3.500   .061  -.218  3.500   .000  -.224
 4.000   .000   .854  4.000   .000   .854  4.000   .000   .854  4.000   .000   .854
 4.000   .000   .846  4.000   .070   .838  4.000   .139   .825  4.000   .205   .804
 4.000   .268   .772  4.000   .325   .730  4.000   .377   .683  4.000   .423   .629
 4.000   .462   .572  4.000   .495   .510  4.000   .523   .445  4.000   .544   .378
 4.000   .560   .310  4.000   .568   .240  4.000   .566   .170  4.000   .552   .101
 4.000   .527   .035  4.000   .491  -.025  4.000   .446  -.079  4.000   .393  -.125
 4.000   .334  -.164  4.000   .272  -.196  4.000   .207  -.222  4.000   .139  -.239
 4.000   .070  -.250  4.000   .000  -.256
 4.500   .000   .960  4.500   .000   .960  4.500   .000   .960  4.500   .000   .960
 4.500   .000   .960  4.500   .078   .947  4.500   .155   .930  4.500   .229   .904
 4.500   .300   .868  4.500   .365   .823  4.500   .423   .769  4.500   .475   .709
 4.500   .520   .644  4.500   .557   .575  4.500   .587   .502  4.500   .612   .427
 4.500   .630   .349  4.500   .639   .271  4.500   .636   .192  4.500   .622   .114
 4.500   .594   .040  4.500   .553  -.028  4.500   .502  -.088  4.500   .442  -.140
 4.500   .377  -.184  4.500   .306  -.221  4.500   .233  -.249  4.500   .157  -.269
 4.500   .079  -.281  4.500   .000  -.288
 5.000   .000  1.067  5.000   .000  1.067  5.000   .000  1.067  5.000   .000  1.067
```

Figure 3a: File CONFIG

5.000	.000	1.067	5.000	.087	1.053	5.000	.172	1.033	5.000	.255	1.005
5.000	.333	.965	5.000	.405	.914	5.000	.470	.855	5.000	.528	.788
5.000	.577	.716	5.000	.619	.639	5.000	.653	.558	5.000	.680	.474
5.000	.700	.388	5.000	.710	.301	5.000	.707	.213	5.000	.691	.127
5.000	.660	.045	5.000	.614	-.031	5.000	.558	-.098	5.000	.492	-.156
5.000	.418	-.205	5.000	.340	-.245	5.000	.259	-.277	5.000	.174	-.299
5.000	.087	-.312	5.000	.000	-.320						
5.500	.000	1.258	5.500	.066	1.229	5.500	.114	1.176	5.500	.152	1.114
5.500	.180	1.047	5.500	.261	1.018	5.500	.341	.985	5.500	.415	.943
5.500	.484	.892	5.500	.547	.832	5.500	.602	.767	5.500	.651	.696
5.500	.692	.620	5.500	.725	.541	5.500	.750	.459	5.500	.768	.374
5.500	.776	.289	5.500	.773	.203	5.500	.755	.118	5.500	.725	.038
5.500	.680	-.036	5.500	.625	-.103	5.500	.561	-.160	5.500	.490	-.209
5.500	.414	-.250	5.500	.336	-.285	5.500	.254	-.312	5.500	.171	-.331
5.500	.086	-.343	5.500	.000	-.351						
6.000	.000	1.436	6.000	.124	1.386	6.000	.218	1.289	6.000	.290	1.174
6.000	.346	1.050	6.000	.417	1.004	6.000	.486	.954	6.000	.550	.899
6.000	.609	.837	6.000	.663	.771	6.000	.710	.700	6.000	.751	.626
6.000	.784	.547	6.000	.809	.466	6.000	.826	.382	6.000	.833	.298
6.000	.830	.212	6.000	.814	.128	6.000	.786	.047	6.000	.745	-.027
6.000	.693	-.095	6.000	.631	-.154	6.000	.563	-.205	6.000	.490	-.249
6.000	.413	-.286	6.000	.334	-.317	6.000	.252	-.342	6.000	.169	-.359
6.000	.085	-.370	6.000	.000	-.378						
6.500	.000	1.603	6.500	.176	1.535	6.500	.311	1.401	6.500	.416	1.241
6.500	.496	1.067	6.500	.556	1.007	6.500	.614	.944	6.500	.667	.878
6.500	.715	.807	6.500	.759	.734	6.500	.798	.658	6.500	.830	.579
6.500	.855	.498	6.500	.872	.414	6.500	.882	.329	6.500	.882	.244
6.500	.870	.159	6.500	.847	.076	6.500	.811	-.001	6.500	.763	-.072
6.500	.705	-.136	6.500	.640	-.191	6.500	.568	-.238	6.500	.493	-.279
6.500	.415	-.314	6.500	.335	-.344	6.500	.253	-.367	6.500	.170	-.383
6.500	.085	-.393	6.500	.000	-.401						
7.000	.000	1.756	7.000	.220	1.675	7.000	.392	1.510	7.000	.524	1.313
7.000	.627	1.098	7.000	.676	1.027	7.000	.723	.954	7.000	.766	.879
7.000	.804	.801	7.000	.839	.722	7.000	.869	.640	7.000	.893	.557
7.000	.911	.473	7.000	.922	.387	7.000	.927	.300	7.000	.921	.213
7.000	.905	.128	7.000	.877	.045	7.000	.836	-.031	7.000	.783	-.101
7.000	.721	-.162	7.000	.653	-.216	7.000	.579	-.262	7.000	.502	-.301
7.000	.422	-.336	7.000	.341	-.365	7.000	.257	-.388	7.000	.172	-.403
7.000	.086	-.414	7.000	.000	-.422						
7.500	.000	1.896	7.500	.256	1.804	7.500	.456	1.616	7.500	.611	1.389
7.500	.731	1.142	7.500	.772	1.063	7.500	.811	.983	7.500	.845	.901
7.500	.876	.817	7.500	.903	.732	7.500	.926	.646	7.500	.944	.559
7.500	.956	.471	7.500	.964	.382	7.500	.966	.293	7.500	.958	.204
7.500	.939	.117	7.500	.908	.033	7.500	.864	-.045	7.500	.808	-.115
7.500	.744	-.177	7.500	.672	-.231	7.500	.596	-.277	7.500	.517	-.318
7.500	.435	-.352	7.500	.350	-.382	7.500	.264	-.405	7.500	.177	-.421
7.500	.089	-.432	7.500	.000	-.440						
8.000	.000	2.019	8.000	.275	1.918	8.000	.489	1.713	8.000	.654	1.466
8.000	.783	1.199	8.000	.822	1.115	8.000	.860	1.031	8.000	.893	.944
8.000	.921	.856	8.000	.946	.767	8.000	.967	.677	8.000	.982	.586
8.000	.992	.494	8.000	.999	.402	8.000	1.000	.309	8.000	.993	.217
8.000	.974	.125	8.000	.942	.038	8.000	.897	-.043	8.000	.840	-.116
8.000	.773	-.181	8.000	.699	-.238	8.000	.620	-.286	8.000	.537	-.328
8.000	.452	-.364	8.000	.364	-.394	8.000	.275	-.418	8.000	.184	-.435
8.000	.092	-.447	8.000	.000	-.456						
8.500	.000	2.123	8.500	.271	2.012	8.500	.476	1.796	8.500	.632	1.542
8.500	.751	1.269	8.500	.800	1.185	8.500	.846	1.099	8.500	.887	1.011
8.500	.923	.920	8.500	.954	.828	8.500	.980	.734	8.500	1.001	.639
8.500	1.015	.543	8.500	1.026	.446	8.500	1.031	.349	8.500	1.027	.252
8.500	1.010	.155	8.500	.980	.062	8.500	.936	-.025	8.500	.878	-.104

Figure 3b: File CONFIG (cont.)

8.500	.810	-.174	8.500	.733	-.235	8.500	.651	-.287	8.500	.564	-.331
8.500	.474	-.370	8.500	.383	-.403	8.500	.289	-.429	8.500	.194	-.447
8.500	.097	-.459	8.500	.000	-.469						
9.000	.000	2.203	9.000	.255	2.086	9.000	.440	1.869	9.000	.579	1.619
9.000	.683	1.353	9.000	.742	1.268	9.000	.798	1.182	9.000	.849	1.093
9.000	.895	1.001	9.000	.936	.906	9.000	.972	.810	9.000	1.002	.711
9.000	1.025	.611	9.000	1.042	.509	9.000	1.053	.407	9.000	1.057	.304
9.000	1.046	.201	9.000	1.019	.101	9.000	.977	.006	9.000	.920	-.080
9.000	.851	-.157	9.000	.772	-.224	9.000	.686	-.281	9.000	.595	-.330
9.000	.501	-.372	9.000	.404	-.407	9.000	.305	-.436	9.000	.205	-.456
9.000	.103	-.469	9.000	.000	-.480						
9.500	.000	2.246	9.500	.227	2.131	9.500	.387	1.927	9.500	.504	1.695
9.500	.591	1.450	9.500	.659	1.365	9.500	.725	1.277	9.500	.787	1.187
9.500	.843	1.093	9.500	.894	.997	9.500	.942	.898	9.500	.983	.797
9.500	1.017	.693	9.500	1.044	.587	9.500	1.064	.479	9.500	1.078	.370
9.500	1.077	.261	9.500	1.058	.153	9.500	1.020	.050	9.500	.965	-.046
9.500	.895	-.131	9.500	.815	-.206	9.500	.726	-.269	9.500	.631	-.323
9.500	.531	-.369	9.500	.429	-.409	9.500	.324	-.440	9.500	.217	-.462
9.500	.109	-.477	9.500	.000	-.489						
10.000	.000	2.228	10.000	.190	2.127	10.000	.319	1.951	10.000	.413	1.752
10.000	.480	1.542	10.000	.557	1.456	10.000	.632	1.368	10.000	.703	1.277
10.000	.769	1.182	10.000	.832	1.085	10.000	.890	.985	10.000	.943	.882
10.000	.990	.777	10.000	1.029	.668	10.000	1.061	.556	10.000	1.086	.442
10.000	1.099	.327	10.000	1.091	.212	10.000	1.060	.100	10.000	1.007	-.004
10.000	.938	-.098	10.000	.856	-.179	10.000	.763	-.249	10.000	.664	-.308
10.000	.559	-.359	10.000	.452	-.402	10.000	.342	-.437	10.000	.229	-.463
10.000	.115	-.481	10.000	.000	-.495						
10.500	.000	2.171	10.500	.154	2.084	10.500	.259	1.936	10.500	.336	1.771
10.500	.394	1.599	10.500	.477	1.512	10.500	.559	1.424	10.500	.637	1.332
10.500	.711	1.238	10.500	.780	1.140	10.500	.847	1.039	10.500	.908	.936
10.500	.964	.830	10.500	1.012	.720	10.500	1.054	.607	10.500	1.089	.490
10.500	1.111	.371	10.500	1.114	.252	10.500	1.090	.133	10.500	1.041	.022
10.500	.972	-.078	10.500	.887	-.163	10.500	.791	-.237	10.500	.688	-.299
10.500	.580	-.352	10.500	.469	-.397	10.500	.354	-.435	10.500	.238	-.463
10.500	.119	-.484	10.500	.000	-.500						
11.000	.000	2.099	11.000	.127	2.026	11.000	.216	1.905	11.000	.283	1.771
11.000	.334	1.629	11.000	.421	1.542	11.000	.507	1.454	11.000	.590	1.363
11.000	.669	1.268	11.000	.744	1.170	11.000	.815	1.069	11.000	.883	.966
11.000	.945	.860	11.000	1.000	.750	11.000	1.048	.636	11.000	1.090	.519
11.000	1.120	.398	11.000	1.130	.275	11.000	1.111	.153	11.000	1.065	.037
11.000	.995	-.066	11.000	.909	-.155	11.000	.811	-.230	11.000	.705	-.294
11.000	.595	-.348	11.000	.480	-.395	11.000	.363	-.434	11.000	.243	-.463
11.000	.122	-.485	11.000	.000	-.503						
11.500	.000	2.017	11.500	.110	1.957	11.500	.186	1.858	11.500	.244	1.747
11.500	.291	1.632	11.500	.368	1.537	11.500	.465	1.455	11.500	.561	1.371
11.500	.644	1.277	11.500	.720	1.178	11.500	.793	1.077	11.500	.865	.975
11.500	.932	.869	11.500	.992	.761	11.500	1.045	.647	11.500	1.092	.530
11.500	1.128	.408	11.500	1.142	.284	11.500	1.125	.161	11.500	1.079	.043
11.500	1.009	-.062	11.500	.921	-.152	11.500	.822	-.228	11.500	.715	-.293
11.500	.603	-.348	11.500	.487	-.395	11.500	.368	-.434	11.500	.247	-.464
11.500	.124	-.486	11.500	.000	-.504						
13.200	.000	1.684	13.200	.122	1.628	13.200	.212	1.525	13.200	.316	1.436
13.200	.419	1.346	13.200	.515	1.250	13.200	.611	1.153	13.200	.703	1.052
13.200	.791	.947	13.200	.878	.843	13.200	.953	.729	13.200	1.032	.617
13.200	1.087	.494	13.200	1.130	.362	13.200	1.161	.232	13.200	1.161	.095
13.200	1.161	-.042	13.200	1.161	-.178	13.200	1.161	-.314	13.200	1.161	-.451
13.200	1.161	-.588	13.200	1.092	-.689	13.200	.955	-.705	13.200	.819	-.705
13.200	.682	-.705	13.200	.546	-.705	13.200	.409	-.705	13.200	.273	-.705
13.200	.136	-.705	13.200	.000	-.705						
15.000	.000	1.349	15.000	.144	1.260	15.000	.277	1.154	15.000	.437	1.081

Figure 3c: File CONFIG (cont.)

```
15.000   .583   .988 15.000   .718   .881 15.000   .850   .770 15.000   .972   .647
15.000  1.075   .508 15.000  1.143   .348 15.000  1.168   .178 15.000  1.166   .005
15.000  1.168  -.168 15.000  1.172  -.340 15.000  1.175  -.513 15.000  1.178  -.686
15.000  1.178  -.858 15.000  1.178 -1.031 15.000  1.178 -1.204 15.000  1.178 -1.376
15.000  1.178 -1.549 15.000  1.178 -1.722 15.000  1.168 -1.894 15.000  1.038 -1.971
15.000   .863 -1.971 15.000   .690 -1.971 15.000   .518 -1.971 15.000   .345 -1.971
15.000   .173 -1.971 15.000   .000 -1.971
16.500   .000  1.134 16.500   .145  1.035 16.500   .278   .923 16.500   .457   .888
16.500   .625   .825 16.500   .780   .741 16.500   .930   .644 16.500  1.061   .522
16.500  1.140   .364 16.500  1.169   .188 16.500  1.173   .010 16.500  1.180  -.167
16.500  1.188  -.345 16.500  1.195  -.522 16.500  1.204  -.700 16.500  1.205  -.877
16.500  1.205 -1.055 16.500  1.205 -1.233 16.500  1.205 -1.410 16.500  1.205 -1.588
16.500  1.205 -1.766 16.500  1.205 -1.944 16.500  1.195 -2.121 16.500  1.069 -2.209
16.500   .888 -2.209 16.500   .711 -2.209 16.500   .533 -2.209 16.500   .355 -2.209
16.500   .178 -2.209 16.500   .000 -2.209
18.000   .000   .965 18.000   .167   .897 18.000   .319   .800 18.000   .484   .740
18.000   .665   .712 18.000   .834   .650 18.000   .994   .568 18.000  1.131   .449
18.000  1.210   .289 18.000  1.222   .107 18.000  1.238  -.072 18.000  1.252  -.252
18.000  1.266  -.432 18.000  1.282  -.611 18.000  1.294  -.791 18.000  1.294  -.972
18.000  1.294 -1.152 18.000  1.294 -1.332 18.000  1.294 -1.513 18.000  1.294 -1.693
18.000  1.294 -1.874 18.000  1.287 -2.053 18.000  1.232 -2.225 18.000  1.083 -2.317
18.000   .902 -2.317 18.000   .722 -2.317 18.000   .541 -2.317 18.000   .361 -2.317
18.000   .180 -2.317 18.000   .000 -2.317
20.000   .000   .797 20.000   .182   .767 20.000   .356   .704 20.000   .523   .624
20.000   .699   .567 20.000   .881   .533 20.000  1.064   .512 20.000  1.250   .495
20.000  1.391   .381 20.000  1.388   .193 20.000  1.389   .009 20.000  1.390  -.176
20.000  1.391  -.360 20.000  1.395  -.545 20.000  1.400  -.730 20.000  1.400  -.915
20.000  1.400 -1.100 20.000  1.400 -1.285 20.000  1.400 -1.470 20.000  1.392 -1.654
20.000  1.374 -1.839 20.000  1.315 -2.012 20.000  1.245 -2.183 20.000  1.091 -2.290
20.000   .926 -2.348 20.000   .740 -2.348 20.000   .555 -2.348 20.000   .370 -2.348
20.000   .185 -2.348 20.000   .000 -2.348
22.000   .000   .661 22.000   .179   .635 22.000   .357   .599 22.000   .534   .560
22.000   .711   .519 22.000   .887   .477 22.000  1.067   .457 22.000  1.248   .451
22.000  1.390   .352 22.000  1.400   .171 22.000  1.400  -.010 22.000  1.400  -.191
22.000  1.400  -.372 22.000  1.400  -.554 22.000  1.400  -.735 22.000  1.400  -.916
22.000  1.400 -1.097 22.000  1.400 -1.279 22.000  1.400 -1.460 22.000  1.399 -1.641
22.000  1.374 -1.821 22.000  1.316 -1.994 22.000  1.217 -2.147 22.000  1.077 -2.266
22.000   .906 -2.332 22.000   .725 -2.340 22.000   .544 -2.340 22.000   .362 -2.340
22.000   .181 -2.340 22.000   .000 -2.340
25.000   .000   .620 25.000   .173   .596 25.000   .346   .572 25.000   .516   .531
25.000   .685   .489 25.000   .853   .440 25.000  1.020   .390 25.000  1.185   .335
25.000  1.353   .284 25.000  1.400   .123 25.000  1.400  -.052 25.000  1.400  -.227
25.000  1.400  -.401 25.000  1.400  -.576 25.000  1.400  -.751 25.000  1.400  -.925
25.000  1.400 -1.100 25.000  1.400 -1.274 25.000  1.390 -1.449 25.000  1.360 -1.621
25.000  1.331 -1.793 25.000  1.261 -1.953 25.000  1.151 -2.092 25.000  1.015 -2.202
25.000   .859 -2.280 25.000   .752 -2.285 25.000   .644 -2.289 25.000   .430 -2.299
25.000   .215 -2.308 25.000   .000 -2.317
27.000   .000   .620 27.000   .167   .603 27.000   .335   .590 27.000   .498   .551
27.000   .661   .509 27.000   .818   .451 27.000   .971   .381 27.000  1.121   .306
27.000  1.263   .216 27.000  1.369   .086 27.000  1.400  -.076 27.000  1.400  -.245
27.000  1.400  -.413 27.000  1.400  -.581 27.000  1.400  -.749 27.000  1.400  -.917
27.000  1.399 -1.084 27.000  1.382 -1.252 27.000  1.361 -1.418 27.000  1.331 -1.584
27.000  1.279 -1.747 27.000  1.202 -1.899 27.000  1.098 -2.030 27.000   .967 -2.136
27.000   .821 -2.223 27.000   .665 -2.287 27.000   .499 -2.290 27.000   .332 -2.292
27.000   .166 -2.294 27.000   .000 -2.297
28.500   .000   .620 28.500   .163   .609 28.500   .324   .592 28.500   .484   .561
28.500   .641   .517 28.500   .793   .459 28.500   .941   .391 28.500  1.085   .314
28.500  1.208   .207 28.500  1.303   .075 28.500  1.388  -.063 28.500  1.400  -.226
28.500  1.400  -.388 28.500  1.400  -.551 28.500  1.400  -.714 28.500  1.400  -.877
28.500  1.400 -1.040 28.500  1.374 -1.201 28.500  1.336 -1.359 28.500  1.298 -1.517
```

Figure 3d: File CONFIG (cont.)

```
28.500  1.247 -1.672 28.500  1.164 -1.810 28.500  1.053 -1.932 28.500   .924 -2.038
28.500   .784 -2.130 28.500   .637 -2.206 28.500   .484 -2.261 28.500   .363 -2.265
28.500   .242 -2.269 28.500   .000 -2.278
30.000   .000   .620 30.000   .156   .601 30.000   .313   .584 30.000   .468   .561
30.000   .622   .523 30.000   .771   .469 30.000   .911   .397 30.000  1.040   .307
30.000  1.159   .203 30.000  1.263   .085 30.000  1.327  -.057 30.000  1.368  -.212
30.000  1.400  -.366 30.000  1.400  -.523 30.000  1.400  -.681 30.000  1.400  -.838
30.000  1.400  -.995 30.000  1.395 -1.153 30.000  1.364 -1.307 30.000  1.305 -1.455
30.000  1.223 -1.594 30.000  1.123 -1.720 30.000  1.007 -1.830 30.000   .881 -1.925
30.000   .745 -2.006 30.000   .602 -2.074 30.000   .455 -2.131 30.000   .305 -2.178
30.000   .153 -2.219 30.000   .000 -2.257
32.000   .000   .620 32.000   .151   .601 32.000   .301   .576 32.000   .449   .539
32.000   .592   .486 32.000   .726   .414 32.000   .851   .327 32.000   .965   .226
32.000  1.068   .113 32.000  1.158  -.009 32.000  1.235  -.140 32.000  1.299  -.279
32.000  1.348  -.423 32.000  1.381  -.572 32.000  1.398  -.723 32.000  1.397  -.875
32.000  1.379 -1.026 32.000  1.344 -1.175 32.000  1.294 -1.318 32.000  1.230 -1.457
32.000  1.154 -1.589 32.000  1.066 -1.713 32.000   .965 -1.827 32.000   .852 -1.930
32.000   .727 -2.016 32.000   .591 -2.084 32.000   .447 -2.135 32.000   .300 -2.172
32.000   .150 -2.201 32.000   .000 -2.226
 WING
 2 13 30  0  .0  .0  .0  .0  .0  .0 1.0 1.0 1.0  1
 7.700   .000   .230  8.111   .000   .242  8.523   .000   .254  8.934   .000   .266
 9.346   .000   .277  9.758   .000   .288 11.815   .000   .333 13.873   .000   .365
15.932   .000   .385 17.990   .000   .391 20.048   .000   .385 22.107   .000   .365
24.165   .000   .333 26.222   .000   .288 28.280   .000   .230 28.280   .000   .230
26.222   .000   .172 24.165   .000   .127 22.107   .000   .095 20.048   .000   .075
17.990   .000   .069 15.932   .000   .075 13.873   .000   .095 11.815   .000   .127
 9.758   .000   .172  9.346   .000   .183  8.934   .000   .194  8.523   .000   .206
 8.111   .000   .218  7.700   .000   .230
11.450  1.365   .230 11.781  1.365   .242 12.111  1.365   .255 12.441  1.365   .267
12.771  1.365   .279 13.102  1.365   .290 14.753  1.365   .337 16.405  1.365   .370
18.058  1.365   .391 19.710  1.365   .397 21.362  1.365   .391 23.015  1.365   .370
24.667  1.365   .337 26.318  1.365   .290 27.970  1.365   .230 27.970  1.365   .230
26.318  1.365   .170 24.667  1.365   .123 23.015  1.365   .090 21.362  1.365   .069
19.710  1.365   .063 18.058  1.365   .069 16.405  1.365   .090 14.753  1.365   .123
13.102  1.365   .170 12.771  1.365   .181 12.441  1.365   .193 12.111  1.365   .205
11.781  1.365   .218 11.450  1.365   .230
15.200  2.730   .230 15.449  2.730   .243 15.698  2.730   .256 15.947  2.730   .268
16.196  2.730   .281 16.445  2.730   .292 17.691  2.730   .341 18.937  2.730   .376
20.183  2.730   .396 21.430  2.730   .403 22.676  2.730   .396 23.923  2.730   .376
25.169  2.730   .341 26.414  2.730   .292 27.659  2.730   .230 27.659  2.730   .230
26.414  2.730   .168 25.169  2.730   .119 23.923  2.730   .084 22.676  2.730   .064
21.430  2.730   .057 20.183  2.730   .064 18.937  2.730   .084 17.691  2.730   .119
16.445  2.730   .168 16.196  2.730   .179 15.947  2.730   .192 15.698  2.730   .204
15.449  2.730   .217 15.200  2.730   .230
18.951  4.095   .230 19.119  4.095   .240 19.286  4.095   .249 19.454  4.095   .259
19.622  4.095   .268 19.790  4.095   .277 20.629  4.095   .313 21.469  4.095   .339
22.310  4.095   .355 23.150  4.095   .360 23.990  4.095   .355 24.831  4.095   .339
25.670  4.095   .313 26.510  4.095   .277 27.349  4.095   .230 27.349  4.095   .230
26.510  4.095   .183 25.670  4.095   .147 24.831  4.095   .121 23.990  4.095   .105
23.150  4.095   .100 22.310  4.095   .105 21.469  4.095   .121 20.629  4.095   .147
19.790  4.095   .183 19.622  4.095   .192 19.454  4.095   .201 19.286  4.095   .211
19.119  4.095   .220 18.951  4.095   .230
22.124  5.250   .230 22.223  5.250   .237 22.322  5.250   .244 22.421  5.250   .251
22.521  5.250   .257 22.620  5.250   .264 23.116  5.250   .290 23.612  5.250   .308
24.109  5.250   .320 24.605  5.250   .323 25.102  5.250   .320 25.599  5.250   .308
26.095  5.250   .290 26.591  5.250   .264 27.086  5.250   .230 27.086  5.250   .230
26.591  5.250   .196 26.095  5.250   .170 25.599  5.250   .152 25.102  5.250   .140
24.605  5.250   .137 24.109  5.250   .140 23.612  5.250   .152 23.116  5.250   .170
22.620  5.250   .196 22.521  5.250   .203 22.421  5.250   .209 22.322  5.250   .216
```

Figure 3e: File CONFIG (cont.)

```
22.223  5.250   .223 22.124  5.250   .230
22.399  5.350   .230 22.492  5.350   .237 22.585  5.350   .243 22.678  5.350   .250
22.772  5.350   .256 22.865  5.350   .262 23.331  5.350   .288 23.798  5.350   .306
24.264  5.350   .317 24.731  5.350   .320 25.198  5.350   .317 25.665  5.350   .306
26.132  5.350   .288 26.598  5.350   .262 27.064  5.350   .230 27.064  5.350   .230
26.598  5.350   .198 26.132  5.350   .172 25.665  5.350   .154 25.198  5.350   .143
24.731  5.350   .140 24.264  5.350   .143 23.798  5.350   .154 23.331  5.350   .172
22.865  5.350   .198 22.772  5.350   .204 22.678  5.350   .210 22.585  5.350   .217
22.492  5.350   .223 22.399  5.350   .230
22.700  5.460   .230 22.787  5.460   .236 22.873  5.460   .243 22.960  5.460   .249
23.047  5.460   .255 23.133  5.460   .261 23.567  5.460   .286 24.001  5.460   .303
24.435  5.460   .313 24.870  5.460   .317 25.304  5.460   .313 25.738  5.460   .303
26.172  5.460   .286 26.606  5.460   .261 27.039  5.460   .230 27.039  5.460   .230
26.606  5.460   .199 26.172  5.460   .174 25.738  5.460   .157 25.304  5.460   .147
24.870  5.460   .143 24.435  5.460   .147 24.001  5.460   .157 23.567  5.460   .174
23.133  5.460   .199 23.047  5.460   .205 22.960  5.460   .211 22.873  5.460   .217
22.787  5.460   .224 22.700  5.460   .230
22.733  5.550   .230 22.819  5.550   .236 22.904  5.550   .243 22.990  5.550   .249
23.075  5.550   .255 23.161  5.550   .261 23.589  5.550   .285 24.018  5.550   .302
24.447  5.550   .312 24.876  5.550   .316 25.305  5.550   .312 25.733  5.550   .302
26.162  5.550   .285 26.590  5.550   .261 27.018  5.550   .230 27.018  5.550   .230
26.590  5.550   .199 26.162  5.550   .175 25.733  5.550   .158 25.305  5.550   .148
24.876  5.550   .144 24.447  5.550   .148 24.018  5.550   .158 23.589  5.550   .175
23.161  5.550   .199 23.075  5.550   .205 22.990  5.550   .211 22.904  5.550   .217
22.819  5.550   .224 22.733  5.550   .230
22.769  5.650   .230 22.854  5.650   .236 22.938  5.650   .243 23.023  5.650   .249
23.107  5.650   .255 23.191  5.650   .260 23.614  5.650   .284 24.037  5.650   .301
24.459  5.650   .311 24.882  5.650   .315 25.306  5.650   .311 25.728  5.650   .301
26.151  5.650   .284 26.574  5.650   .260 26.996  5.650   .230 26.996  5.650   .230
26.574  5.650   .200 26.151  5.650   .176 25.728  5.650   .159 25.306  5.650   .149
24.882  5.650   .145 24.459  5.650   .149 24.037  5.650   .159 23.614  5.650   .176
23.191  5.650   .200 23.107  5.650   .205 23.023  5.650   .211 22.938  5.650   .217
22.854  5.650   .224 22.769  5.650   .230
23.068  6.470   .230 23.143  6.470   .236 23.217  6.470   .241 23.292  6.470   .247
23.367  6.470   .252 23.441  6.470   .257 23.815  6.470   .278 24.190  6.470   .293
24.564  6.470   .302 24.938  6.470   .305 25.313  6.470   .302 25.687  6.470   .293
26.062  6.470   .278 26.435  6.470   .257 26.809  6.470   .230 26.809  6.470   .230
26.435  6.470   .203 26.062  6.470   .182 25.687  6.470   .167 25.313  6.470   .158
24.938  6.470   .155 24.564  6.470   .158 24.190  6.470   .167 23.815  6.470   .182
23.441  6.470   .203 23.367  6.470   .208 23.292  6.470   .213 23.217  6.470   .219
23.143  6.470   .224 23.068  6.470   .230
23.436  7.480   .230 23.498  7.480   .235 23.561  7.480   .239 23.624  7.480   .244
23.687  7.480   .248 23.749  7.480   .253 24.064  7.480   .270 24.378  7.480   .283
24.693  7.480   .290 25.007  7.480   .293 25.322  7.480   .290 25.637  7.480   .283
25.951  7.480   .270 26.265  7.480   .253 26.579  7.480   .230 26.579  7.480   .230
26.265  7.480   .207 25.951  7.480   .190 25.637  7.480   .177 25.322  7.480   .170
25.007  7.480   .167 24.693  7.480   .170 24.378  7.480   .177 24.064  7.480   .190
23.749  7.480   .207 23.687  7.480   .212 23.624  7.480   .216 23.561  7.480   .221
23.498  7.480   .225 23.436  7.480   .230
23.803  8.490   .230 23.854  8.490   .234 23.905  8.490   .238 23.956  8.490   .241
24.007  8.490   .245 24.057  8.490   .248 24.312  8.490   .263 24.567  8.490   .273
24.821  8.490   .279 25.076  8.490   .281 25.331  8.490   .279 25.586  8.490   .273
25.841  8.490   .263 26.095  8.490   .248 26.349  8.490   .230 26.349  8.490   .230
26.095  8.490   .212 25.841  8.490   .197 25.586  8.490   .187 25.331  8.490   .181
25.076  8.490   .179 24.821  8.490   .181 24.567  8.490   .187 24.312  8.490   .197
24.057  8.490   .212 24.007  8.490   .215 23.956  8.490   .219 23.905  8.490   .222
23.854  8.490   .226 23.803  8.490   .230
24.171  9.500   .230 24.210  9.500   .233 24.249  9.500   .236 24.288  9.500   .239
24.326  9.500   .241 24.365  9.500   .244 24.560  9.500   .255 24.755  9.500   .263
24.950  9.500   .267 25.145  9.500   .269 25.340  9.500   .267 25.535  9.500   .263
```

Figure 3f: File CONFIG (cont.)

```
25.730  9.500   .255 25.925  9.500   .244 26.120  9.500   .230 26.120  9.500   .230
25.925  9.500   .216 25.730  9.500   .205 25.535  9.500   .197 25.340  9.500   .193
25.145  9.500   .191 24.950  9.500   .193 24.755  9.500   .197 24.560  9.500   .205
24.365  9.500   .216 24.326  9.500   .219 24.288  9.500   .221 24.249  9.500   .224
24.210  9.500   .227 24.171  9.500   .230
 CANARD
 3  7 30  0  .0  .0  .0  .0  .0  .0 1.0 1.0 1.0  1
 4.850   .000   .230  5.152   .000   .249  5.454   .000   .267  5.756   .000   .284
 6.058   .000   .298  6.360   .000   .308  6.663   .000   .314  6.965   .000   .316
 7.267   .000   .314  7.570   .000   .308  7.872   .000   .298  8.174   .000   .284
 8.476   .000   .267  8.778   .000   .249  9.080   .000   .230  9.080   .000   .230
 8.778   .000   .211  8.476   .000   .193  8.174   .000   .176  7.872   .000   .162
 7.570   .000   .152  7.267   .000   .146  6.965   .000   .144  6.663   .000   .146
 6.360   .000   .152  6.058   .000   .162  5.756   .000   .176  5.454   .000   .193
 5.152   .000   .211  4.850   .000   .230
 6.040   .833   .230  6.304   .833   .247  6.567   .833   .263  6.831   .833   .277
 7.094   .833   .289  7.358   .833   .298  7.622   .833   .304  7.886   .833   .305
 8.150   .833   .304  8.414   .833   .298  8.678   .833   .289  8.941   .833   .277
 9.205   .833   .263  9.468   .833   .247  9.732   .833   .230  9.732   .833   .230
 9.468   .833   .213  9.205   .833   .197  8.941   .833   .183  8.678   .833   .171
 8.414   .833   .162  8.150   .833   .156  7.886   .833   .155  7.622   .833   .156
 7.358   .833   .162  7.094   .833   .171  6.831   .833   .183  6.567   .833   .197
 6.304   .833   .213  6.040   .833   .230
 7.230  1.667   .230  7.455  1.667   .244  7.680  1.667   .258  7.905  1.667   .270
 8.131  1.667   .281  8.356  1.667   .288  8.581  1.667   .293  8.807  1.667   .294
 9.032  1.667   .293  9.258  1.667   .288  9.483  1.667   .281  9.708  1.667   .270
 9.934  1.667   .258 10.159  1.667   .244 10.384  1.667   .230 10.384  1.667   .230
10.159  1.667   .216  9.934  1.667   .202  9.708  1.667   .190  9.483  1.667   .179
 9.258  1.667   .172  9.032  1.667   .167  8.807  1.667   .166  8.581  1.667   .167
 8.356  1.667   .172  8.131  1.667   .179  7.905  1.667   .190  7.680  1.667   .202
 7.455  1.667   .216  7.230  1.667   .230
 8.420  2.500   .230  8.607  2.500   .242  8.794  2.500   .253  8.980  2.500   .263
 9.167  2.500   .272  9.354  2.500   .278  9.541  2.500   .282  9.728  2.500   .283
 9.915  2.500   .282 10.102  2.500   .278 10.289  2.500   .272 10.475  2.500   .263
10.662  2.500   .253 10.849  2.500   .242 11.035  2.500   .230 11.035  2.500   .230
10.849  2.500   .218 10.662  2.500   .207 10.475  2.500   .197 10.289  2.500   .188
10.102  2.500   .182  9.915  2.500   .178  9.728  2.500   .177  9.541  2.500   .178
 9.354  2.500   .182  9.167  2.500   .188  8.980  2.500   .197  8.794  2.500   .207
 8.607  2.500   .218  8.420  2.500   .230
 9.610  3.333   .230  9.759  3.333   .239  9.907  3.333   .248 10.055  3.333   .257
10.203  3.333   .263 10.352  3.333   .268 10.500  3.333   .271 10.649  3.333   .272
10.797  3.333   .271 10.946  3.333   .268 11.094  3.333   .263 11.242  3.333   .257
11.391  3.333   .248 11.539  3.333   .239 11.687  3.333   .230 11.687  3.333   .230
11.539  3.333   .221 11.391  3.333   .212 11.242  3.333   .203 11.094  3.333   .197
10.946  3.333   .192 10.797  3.333   .189 10.649  3.333   .188 10.500  3.333   .189
10.352  3.333   .192 10.203  3.333   .197 10.055  3.333   .203  9.907  3.333   .212
 9.759  3.333   .221  9.610  3.333   .230
10.801  4.167   .230 10.910  4.167   .237 11.020  4.167   .244 11.130  4.167   .250
11.240  4.167   .255 11.350  4.167   .258 11.460  4.167   .261 11.570  4.167   .261
11.680  4.167   .261 11.790  4.167   .258 11.900  4.167   .255 12.010  4.167   .250
12.119  4.167   .244 12.229  4.167   .237 12.339  4.167   .230 12.339  4.167   .230
12.229  4.167   .223 12.119  4.167   .216 12.010  4.167   .210 11.900  4.167   .205
11.790  4.167   .202 11.680  4.167   .199 11.570  4.167   .199 11.460  4.167   .199
11.350  4.167   .202 11.240  4.167   .205 11.130  4.167   .210 11.020  4.167   .216
10.910  4.167   .223 10.801  4.167   .230
11.991  5.000   .230 12.062  5.000   .235 12.133  5.000   .239 12.205  5.000   .243
12.276  5.000   .246 12.348  5.000   .248 12.419  5.000   .250 12.491  5.000   .250
12.562  5.000   .250 12.634  5.000   .248 12.705  5.000   .246 12.777  5.000   .243
12.848  5.000   .239 12.919  5.000   .235 12.991  5.000   .230 12.991  5.000   .230
12.919  5.000   .225 12.848  5.000   .221 12.777  5.000   .217 12.705  5.000   .214
```

Figure 3g: File CONFIG (cont.)

```
12.634  5.000   .212 12.562  5.000   .210 12.491  5.000   .210 12.419  5.000   .210
12.348  5.000   .212 12.276  5.000   .214 12.205  5.000   .217 12.133  5.000   .221
12.062  5.000   .225 11.991  5.000   .230
 FIN
 4 10 28  0  .0  .0  .0  .0  .0  .0 1.0 1.0 1.0  1
22.650   .000   .000 22.650   .002   .000 22.651   .003   .000 22.653   .005   .000
22.655   .005   .000 23.576   .069   .000 24.498   .117   .000 25.420   .148   .000
26.341   .164   .000 27.263   .163   .000 28.185   .147   .000 29.107   .114   .000
30.028   .065   .000 30.950   .000   .000 30.950   .000   .000 30.028  -.065   .000
29.107  -.114   .000 28.185  -.147   .000 27.263  -.163   .000 26.341  -.164   .000
25.420  -.148   .000 24.498  -.117   .000 23.576  -.069   .000 22.655  -.005   .000
22.653  -.005   .000 22.651  -.003   .000 22.650  -.002   .000 22.650   .000   .000
23.709   .000   .611 23.709   .002   .611 23.710   .003   .611 23.711   .005   .611
23.713   .005   .611 24.564   .064   .611 25.416   .108   .611 26.267   .137   .611
27.119   .152   .611 27.970   .151   .611 28.821   .136   .611 29.673   .105   .611
30.524   .060   .611 31.375   .000   .611 31.375   .000   .611 30.524  -.060   .611
29.673  -.105   .611 28.821  -.136   .611 27.970  -.151   .611 27.119  -.152   .611
26.267  -.137   .611 25.416  -.108   .611 24.564  -.064   .611 23.713  -.005   .611
23.711  -.005   .611 23.710  -.003   .611 23.709  -.002   .611 23.709   .000   .611
24.767   .000  1.222 24.767   .002  1.222 24.768   .003  1.222 24.770   .005  1.222
24.772   .005  1.222 25.553   .059  1.222 26.334   .099  1.222 27.115   .126  1.222
27.896   .139  1.222 28.676   .138  1.222 29.457   .124  1.222 30.238   .097  1.222
31.019   .055  1.222 31.800   .000  1.222 31.800   .000  1.222 31.019  -.055  1.222
30.238  -.097  1.222 29.457  -.124  1.222 28.676  -.138  1.222 27.896  -.139  1.222
27.115  -.126  1.222 26.334  -.099  1.222 25.553  -.059  1.222 24.772  -.005  1.222
24.770  -.005  1.222 24.768  -.003  1.222 24.767  -.002  1.222 24.767   .000  1.222
25.825   .000  1.833 25.826   .002  1.833 25.827   .003  1.833 25.828   .005  1.833
25.830   .005  1.833 26.541   .054  1.833 27.251   .091  1.833 27.962   .115  1.833
28.673   .127  1.833 29.383   .126  1.833 30.094   .113  1.833 30.804   .088  1.833
31.515   .050  1.833 32.226   .000  1.833 32.226   .000  1.833 31.515  -.050  1.833
30.804  -.088  1.833 30.094  -.113  1.833 29.383  -.126  1.833 28.673  -.127  1.833
27.962  -.115  1.833 27.251  -.091  1.833 26.541  -.054  1.833 25.830  -.005  1.833
25.828  -.005  1.833 25.827  -.003  1.833 25.826  -.002  1.833 25.825   .000  1.833
26.884   .000  2.444 26.884   .002  2.444 26.885   .003  2.444 26.887   .005  2.444
26.889   .005  2.444 27.529   .049  2.444 28.169   .082  2.444 28.809   .104  2.444
29.450   .114  2.444 30.090   .114  2.444 30.730   .102  2.444 31.370   .079  2.444
32.011   .045  2.444 32.651   .000  2.444 32.651   .000  2.444 32.011  -.045  2.444
31.370  -.079  2.444 30.730  -.102  2.444 30.090  -.114  2.444 29.450  -.114  2.444
28.809  -.104  2.444 28.169  -.082  2.444 27.529  -.049  2.444 26.889  -.005  2.444
26.887  -.005  2.444 26.885  -.003  2.444 26.884  -.002  2.444 26.884   .000  2.444
27.942   .000  3.056 27.943   .002  3.056 27.944   .003  3.056 27.945   .005  3.056
27.947   .005  3.056 28.517   .044  3.056 29.087   .073  3.056 29.657   .092  3.056
30.227   .102  3.056 30.796   .101  3.056 31.366   .091  3.056 31.936   .070  3.056
32.506   .040  3.056 33.076   .000  3.056 33.076   .000  3.056 32.506  -.040  3.056
31.936  -.070  3.056 31.366  -.091  3.056 30.796  -.101  3.056 30.227  -.102  3.056
29.657  -.092  3.056 29.087  -.073  3.056 28.517  -.044  3.056 27.947  -.005  3.056
27.945  -.005  3.056 27.944  -.003  3.056 27.943  -.002  3.056 27.942   .000  3.056
29.001   .000  3.667 29.001   .002  3.667 29.002   .003  3.667 29.004   .005  3.667
29.006   .005  3.667 29.505   .039  3.667 30.005   .064  3.667 30.504   .081  3.667
31.004   .089  3.667 31.503   .089  3.667 32.003   .079  3.667 32.502   .062  3.667
33.002   .035  3.667 33.501   .000  3.667 33.501   .000  3.667 33.002  -.035  3.667
32.502  -.062  3.667 32.003  -.079  3.667 31.503  -.089  3.667 31.004  -.089  3.667
30.504  -.081  3.667 30.005  -.064  3.667 29.505  -.039  3.667 29.006  -.005  3.667
29.004  -.005  3.667 29.002  -.003  3.667 29.001  -.002  3.667 29.001   .000  3.667
30.059   .000  4.278 30.060   .002  4.278 30.061   .003  4.278 30.062   .005  4.278
30.064   .005  4.278 30.493   .034  4.278 30.922   .056  4.278 31.351   .070  4.278
31.781   .077  4.278 32.210   .076  4.278 32.639   .068  4.278 33.068   .053  4.278
33.497   .030  4.278 33.926   .000  4.278 33.926   .000  4.278 33.497  -.030  4.278
33.068  -.053  4.278 32.639  -.068  4.278 32.210  -.076  4.278 31.781  -.077  4.278
31.351  -.070  4.278 30.922  -.056  4.278 30.493  -.034  4.278 30.064  -.005  4.278
```

Figure 3h: File CONFIG (cont.)

```
30.062  -.005  4.278 30.061  -.003  4.278 30.060  -.002  4.278 30.059   .000  4.278
31.118   .000  4.889 31.118   .002  4.889 31.119   .003  4.889 31.121   .005  4.889
31.122   .005  4.889 31.481   .029  4.889 31.840   .047  4.889 32.199   .059  4.889
32.558   .064  4.889 32.916   .064  4.889 33.275   .057  4.889 33.634   .044  4.889
33.993   .025  4.889 34.351   .000  4.889 34.351   .000  4.889 33.993  -.025  4.889
33.634  -.044  4.889 33.275  -.057  4.889 32.916  -.064  4.889 32.558  -.064  4.889
32.199  -.059  4.889 31.840  -.047  4.889 31.481  -.029  4.889 31.122  -.005  4.889
31.121  -.005  4.889 31.119  -.003  4.889 31.118  -.002  4.889 31.118   .000  4.889
32.176   .000  5.500 32.177   .002  5.500 32.178   .003  5.500 32.179   .005  5.500
32.181   .005  5.500 32.469   .024  5.500 32.758   .038  5.500 33.046   .047  5.500
33.335   .052  5.500 33.623   .051  5.500 33.911   .046  5.500 34.200   .035  5.500
34.488   .020  5.500 34.777   .000  5.500 34.777   .000  5.500 34.488  -.020  5.500
34.200  -.035  5.500 33.911  -.046  5.500 33.623  -.051  5.500 33.335  -.052  5.500
33.046  -.047  5.500 32.758  -.038  5.500 32.469  -.024  5.500 32.181  -.005  5.500
32.179  -.005  5.500 32.178  -.003  5.500 32.177  -.002  5.500 32.176   .000  5.500
 POD
 5  3  9  0  .0  .0  .0  .0  .0  .0 1.0 1.0 1.0  1
22.500  6.500   .230 22.500  7.250   .230 22.500  8.500   .230 22.500  8.500   .000
22.500  8.500  -.770 22.500  7.250  -.770 22.500  6.500  -.770 22.500  6.500   .000
22.500  6.500   .230
25.000  6.500   .230 25.000  7.250   .230 25.000  8.500   .230 25.000  8.500   .000
25.000  8.500  -.770 25.000  7.250  -.770 25.000  6.500  -.770 25.000  6.500   .000
25.000  6.500   .230
27.500  6.500   .230 27.500  7.250   .230 27.500  8.500   .230 27.500  8.500   .000
27.500  8.500  -.770 27.500  7.250  -.770 27.500  6.500  -.770 27.500  6.500   .000
27.500  6.500   .230
```

Figure 3i: File CONFIG (concluded)

PROGRAM KINTERL

Program KINTERL is used to obtain the leading and trailing intersection points between a fuselage and a wing/canard/fin/horizontal tail. The file descriptions are:

File Name	Description
CONFIG	input file containing model geometry description
INTER	output file containing intersection values

Arrays in KINTERL are sized via parameter statements. These parameter variables are:

Variable	Description
NVL	maximum number of contour lines per component, currently 50
NVP	maximum number of points per contour line, currently 50

An example of output file INTER appears in figure 4. Note that an intersection point is listed for each spanwise line of the lifting surface and that the most leading and trailing intersection points are given at the end of this list.

```
 INTERSECTION RESULTS FOR PAB102 FORWARD FUSELAGE
      FUSELAGE & WING
LINE  1   X=  .107605E+02   Y=  .111394E+01   Z=  .230000E+00
LINE  2   X=  .111390E+02   Y=  .112631E+01   Z=  .242399E+00
LINE  3   X=  .115119E+02   Y=  .113716E+01   Z=  .254706E+00
LINE  4   X=  .118834E+02   Y=  .114795E+01   Z=  .266777E+00
LINE  5   X=  .122486E+02   Y=  .115673E+01   Z=  .278488E+00
LINE  6   X=  .125886E+02   Y=  .115563E+01   Z=  .289703E+00
LINE  7   X=  .142452E+02   Y=  .112895E+01   Z=  .336418E+00
LINE  8   X=  .159811E+02   Y=  .113629E+01   Z=  .369567E+00
LINE  9   X=  .177310E+02   Y=  .115533E+01   Z=  .389657E+00
LINE 10   X=  .195886E+02   Y=  .126865E+01   Z=  .396802E+00
LINE 11   X=  .213405E+02   Y=  .134227E+01   Z=  .390460E+00
LINE 12   X=  .229650E+02   Y=  .129027E+01   Z=  .370147E+00
LINE 13   X=  .246106E+02   Y=  .121249E+01   Z=  .336658E+00
LINE 14   X=  .263089E+02   Y=  .122902E+01   Z=  .289821E+00
LINE 15   X=  .280012E+02   Y=  .122641E+01   Z=  .230000E+00
LINE 16   X=  .280012E+02   Y=  .122641E+01   Z=  .230000E+00
LINE 17   X=  .263149E+02   Y=  .131413E+01   Z=  .170042E+00
LINE 18   X=  .246796E+02   Y=  .140000E+01   Z=  .122802E+00
LINE 19   X=  .230380E+02   Y=  .140000E+01   Z=  .894392E-01
LINE 20   X=  .213930E+02   Y=  .139680E+01   Z=  .693052E-01
LINE 21   X=  .197227E+02   Y=  .137509E+01   Z=  .627221E-01
LINE 22   X=  .178269E+02   Y=  .121688E+01   Z=  .700787E-01
LINE 23   X=  .160666E+02   Y=  .118241E+01   Z=  .902590E-01
LINE 24   X=  .143237E+02   Y=  .116543E+01   Z=  .123477E+00
LINE 25   X=  .125983E+02   Y=  .115957E+01   Z=  .170291E+00
LINE 26   X=  .122088E+02   Y=  .114086E+01   Z=  .181532E+00
LINE 27   X=  .118424E+02   Y=  .113197E+01   Z=  .193239E+00
LINE 28   X=  .114768E+02   Y=  .112380E+01   Z=  .205303E+00
LINE 29   X=  .111189E+02   Y=  .111886E+01   Z=  .217603E+00
LINE 30   X=  .107605E+02   Y=  .111394E+01   Z=  .230000E+00


LEADING INTERSECTION :
     X =  .107605E+02     Y =  .111394E+01     Z =  .230000E+00


TRAILING INTERSECTION :
     X =  .280012E+02     Y =  .122641E+01     Z =  .230000E+00
```

Figure 4: KINTERL Output File INTER

PROGRAM KLINCRX

Program KLINCRX is used to obtain the crosscut data. The file descriptions are:

File Name	Description
CONFIG	input file containing model geometry description
XCUT	input file containing crosscut control parameters
LINOUT	output file containing the crosscut data
SAVPLT	output plot vector file containing plots of each crosscut, maybe plotted on Tektronix terminal or sent to line plotter

Note that KLINCRX requires NASA Langley graphics library LARCGOS.

Arrays in KLINCRX are sized via parameter statements. These parameter variables are:

Variable	Description
NVL	maximum number of contour lines per component, currently 50
NVP	maximum number of points per contour line, currently 50
NCT	maximum number of crosscuts, currently 150
NVS	maximum number of separation lines, currently 5

CROSS CUT INPUT FILE XCUT

The crosscut control file which is used as input to KLINCRX is named XCUT. This file is list directed and is comprised of:

Record	Variable	Description
1	NIP	integer value for the number of fuselage separation lines; along with the fuselage-wing/ canard intersection lines, these separation lines define a top/bottom split for the fuselage
2	XI1,ZI1,XI2,ZI2	real values for X-Z pair defining the start and stop of separation line 1; XI1, ZI1 should be the nose of the fuselage and XI2, ZI2 is the leading intersection of the wing or canard
	.	.
	.	.
	.	.
	XI1,ZI1,XI2,ZI2	real values for X-Z pair defining the start and stop of separation line NIP; XI1, ZI1 should be the trailing intersection of the wing or canard and XI2, ZI2 is at the end of the fuselage
3	NXCT	integer number of cross-cuts to take
4	XCT	real X value for crosscut 1
	.	
	.	
	.	
	XCT	real X value for crosscut NXCT

Figure 5 lists an example of file XCUT. Figure 6 presents a picture of the separation lines. Note that for this configuration, line 1 is from the fuselage nose to the leading intersection point for the canard; line 2 is from the canard trailing intersection point to the wing leading intersection point; and line 3 is from the wing trailing intersection point to the rear of the fuselage. Also note that the intersection values which are entered into file XCUT are obtained from running program KINTERL.

```
3
0. 0. 6.05 .23
9.9 .23 10.8 .23
28. .23 32. .23
5
3.5
7.5
11.5
26.
31.5
```

Figure 5: File XCUT

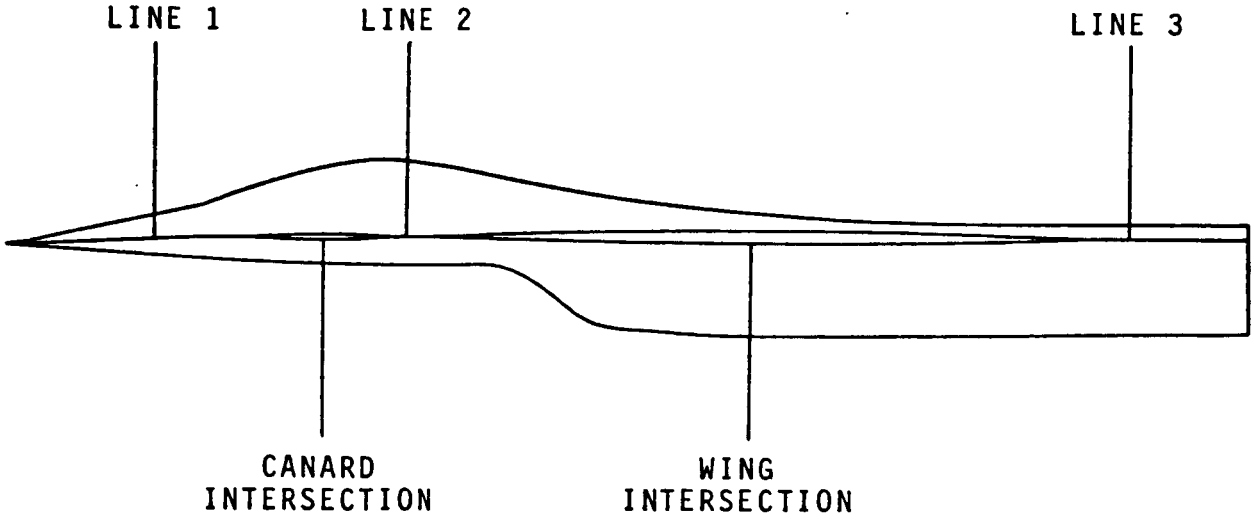


Figure 6: Separation Lines

CROSSCUT OUTPUT FILE LINOUT

The crosscut data output file from KLINCRX is named LINOUT. This formatted file lists the data as a set of patches (with Z-Y valued points) for each crosscut. The structure of file LINOUT corresponds to the input format that the SIMP program requires. Each patch corresponds to a piece of a component. Those points which were inside another component have been deleted and the patches thus constitute a continuous set of discrete points. The contents of file LINOUT are:

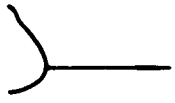
Record	Variable	Description
1	NX	Integer I5 value defining the number of crosscuts taken
	(Records 2 thru 4 are repeated for each crosscut)	
2	XC, IP	real F15.6 value for the X value of the crosscut, integer I5 value for the number of patches.
	(Records 3 thru 4 are repeated for each patch)	
3	ID,NN,IC	integer 3I5 values for the patch number, number of points in the patch, and point concentration flag
4	Z,Y	real 2F15.6 Z-Y values for point 1
	.	
	.	
	.	
	Z,Y	point NN

An example of KLINCRX output file LINOUT is shown in figure 7 and output file SAVPLT in figure 8.

```
5
   3.500000    2
1   20    0
     .746900          .000000
     .746900          .000000
     .746900          .000000
     .746900          .000000
     .746900          .000000
     .736799          .060892
     .723413          .120718
     .703473          .178414
     .675244          .232977
     .639730          .283510
     .598205          .329154
     .551701          .369423
     .501058          .404132
     .447086          .433182
     .390463          .456915
     .331824          .475819
     .271759          .489689
     .210762          .496754
     .149346          .495059
     .133058          .491942
2   12    0
     .133058          .491942
     .088802          .483473
     .031212          .461704
    -.021626          .430086
    -.068638          .390271
    -.109045          .344042
    -.143145          .292907
    -.171541          .238250
    -.193932          .181015
    -.209354          .121803
    -.218345          .061241
    -.224000          .000000
```

Figure 7: KLINCRX Output File LINOUT

*PAB102 FORWARD FUSELAGE

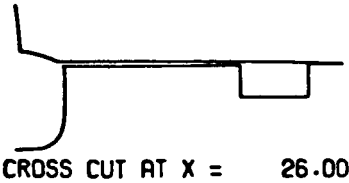


CROSS CUT AT X = 11.500000

CROSS CUT AT X = 7.500000

CROSS CUT AT X = 31.500000

CROSS CUT AT X = 3.500000



CROSS CUT AT X = 26.000000

Figure 8: KLINCRX Output File SAVPLT

PROGRAM KLINFIX

Program KLINFIX is used to interactively enhance the LINOUT output file from KLINCRX. The user has the option of separating any patch into two patches and then saving the modified crosscut as a replacement to the old cut or as an added new cut. This program requires the NASA Langley PLOT10 graphics library LIBTEK5.

The files for KLINFIX are:

File Name	Description
LINOUT or LINDNEW	input crosscut data file, it is either the output from KLINCRX or the KLINFIX output file LINDNEW
LINDNEW	output file containing the enhanced crosscut data, its structure is the same as LINOUT
TTOUT, TTIN	Terminal output, input, used by user to enhance crosscut data for SIMP geometry.

Arrays in KLINFIX are sized via parameter statements. These parameter variables are:

Variable	Description
NCT	maximum number of original crosscuts, currently 200
NPT	maximum number of points per crosscut, currently 150
NCA	maximum number of added crosscuts, currently 20
NPX	maximum number of points per patch, currently 30
IPH	maximum number of patches per crosscut, currently 10

Figures 9 thru 14 present an example of an interactive session of KLINFIX which was conducted on a Tektronix 4014 terminal. Baud rate selection (Figure 9) is a required USER entry when using the LIBTEK5 plotting library.

Information pertaining to program purpose and limits are shown in figure 10. Figure 11 is a list of processing options that can be performed. When option 1 is selected, the list of crosscut locations and the number of patches in each cut are displayed as shown in figure 12. Figure 13 is an example of selecting option 2, operate on a cut, and then entering the number of the crosscut which is to be enhanced. In this example cut number 4 is selected. From figure 12, this corresponds to a X-location of 26.0 and a crosscut which has 5 patches.

As shown in figure 14, once the cut number has been entered the crosscut is drawn and information pertaining to the cut is written above it. Every 10 percent of arclength is denoted with a plus (+) sign. The patch endpoints are highlighted by a square symbol. The user is then prompted to select how many patches are to be subdivided, what each selected patch number is, and where in percent arclength the patch is to be split. In figure 14, patch number 1 has been selected to be subdivided at 8 percent arclength. The location of the split is marked by a diamond symbol.

Once all selected patches have been processed, the user is then prompted to select a completion option. Valid selections are:

1) cancel these changes,
2) apply these changes to the crosscut, or
3) regard these changes as creating an additional cross-cut.

If number 3 is selected the user is then prompted to select if this new cut goes before or after (enter a 0 or 1) the original crosscut. This option is included so that transition regions can be properly anayzed.

For example, prior to the first lifting surface, all cross-cuts are fuselage sections which originally contain two patches each. On the lifting surface an original crosscut has four patches (two for the fuselage and two for the lifting surface). Therefore, an additional fuselage crosscut which contains four patches would be created at the leading edge of the lifting surface. An additional option that can be selected under completion options 2 and 3 is multi-cut processing. This option allows the user to apply the changes made on a crosscut to other crosscuts which have the same number of patches as the cut that was enhanced.

```
ENTER BAUD RATE (120 OR 960)

?960
```

Figure 9: KLINFIX Terminal Output (Baud Rate)

```
THIS PROGRAM WAS DESIGNED TO USE THE OUTPUT FROM
KLINFIX.  ITS PURPOSE IS TO ENHANCE EXISTING CROSSCUTS
AND TO ADD NEW ONES.

NEW CROSSCUTS ARE CREATED FROM EXISTING ONES.  AS AN
EXAMPLE, SUPPOSE CUT # 10 OCCURS WHERE A FUSELAGE / WING
FIRST MEET.  THE ORIGINAL CROSSCUT HAS TWO PATCHES AND A
TRANSITION CUT IS REQUIRED INTO THE FOUR PATCH CUT #11
WHERE BOTH FUSELAGE AND WING OCCUR.  THEREFORE, CUT #10
WOULD BE USED TO CREATE A NEW FOUR PATCH CUT #10B.

PROGRAM LIMITS ARE :
  MAX # OF ORIGINAL CUTS = 200
  MAX # OF POINTS PER CUT = 150
  MAX # OF ADDED CROSSCUTS = 20
  MAX # OF PATCHES PER CUT = 10
  MAX # OF POINTS PER PATCH = 30

          PRESS RETURN KEY TO CONTINUE
```

Figure 10: KLINFIX Terminal Output (Limits)

```
        ENTER OPTION :
          1 : DISPLAY ORIGINAL CUT LOCATIONS
          2 : OPERATE ON A CUT
          3 : END PROGRAM AND WRITE NEW DATABASE
 ? 1
```

Figure 11: KLINFIX Terminal Output (Option Selection 1)

```
LISTED BELOW ARE THE X VALUES FOR THE 5 CROSSCUTS AND THE # OF PATCHES

        I=   1  X=    3.50000000  #= 2
        I=   2  X=    7.50000000  #= 4
        I=   3  X=   11.50000000  #= 7
        I=   4  X=   26.00000000  #= 5
        I=   5  X=   31.50000000  #= 3

     PRESS RETURN KEY TO CONTINUE
```

Figure 12: KLINFIX Terminal Output (Crosscuts)

```
        ENTER OPTION :
          1 :  DISPLAY ORIGINAL CUT LOCATIONS
          2 :  OPERATE ON A CUT
          3 :  END PROGRAM AND WRITE NEW DATABASE
? 2
        ENTER THE CROSSCUT #, RANGE IS 1 THRU 5
? 4
```

Figure 13: KLINFIX Terminal Output (Option Selection 2)

```
NOTE:  DATA IS ORDERED TOP TO BOTTOM
       PATCH ENDPOINTS ARE MARKED BY A SQUARE
       A + SIGN IS AT EVERY 10% ARC LENGTH
       NEW ENDPOINTS ARE MARKED BY A DIAMOND
CUT#    4   X=     26.0        # PATCHES = 5

   ENTER HOW MANY PATCHES ARE TO BE SUBDIVIDED
? 1
   ENTER THE 1 PATCH NUMBERS
? 2
   ENTER THE % ARC LENGTH WHERE SPLIT OCCURS
   PATCH # 2 RANGE IS 5.49267 TO 10.10325
?
  8.

      SELECT COMPLETION OPTION :
       1:  CANCEL THESE CHANGES
       2:  APPLY THESE CHANGES TO THE CROSSCUT
       3:  REGARD THIS AS AN ADDED CROSSCUT
  ? 3
      SELECT LOCATION OPTION :
       0:  ADD BEFORE THIS CUT
       1:  ADD AFTER THIS CUT
  ? 0
```

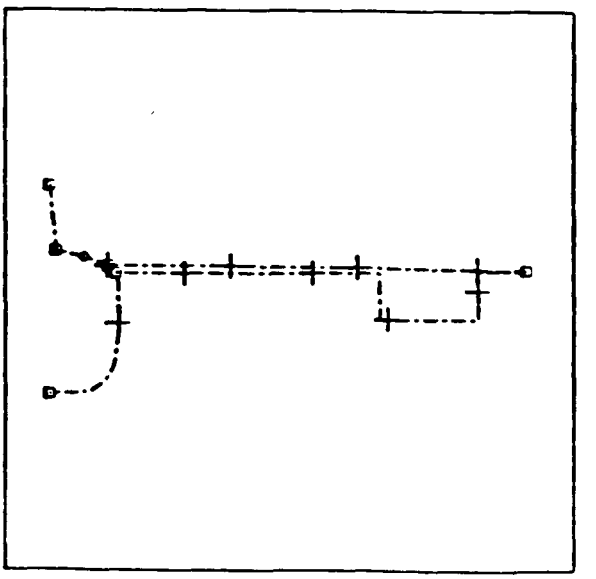


Figure 14: KLINFIX Terminal Output (Patches)

CONCLUDING REMARKS

Three computer programs have been developed to convert geometry that is originally in wave-drag input format to an input format compatible with the SIMP code. The SIMP input is generated by using linear interpolation between the LaWGS definitions of the fuselage type components and the lifting surface components. An additional program was developed which enables a user to interactively enhance the output obtained from the geometry conversion program.

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15. Supplementary Notes

Langley Technical Monitors: John E. Hogge and Kenneth M. Jones

16. Abstract

This paper documents an aeronautical geometry conversion package which translates wave-drag geometry into the Langley Wireframe Geometry Standard (LaWGS) format and then into a format which is used by the Supersonic Implicit Marching Potential (SIMP) program. The programs described in this paper were developed by Computer Sciences Corporation for the Advanced Vehicles Division/Advanced Concepts Branch at NASA Langley Research Center.

Included in this document are the input and output from a benchmark test case.

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