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PAN AIR Summary Document

(Version 1.0)

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1.0 Introduction

This report gives a brief description of the PAN AIR (for Panel Aerodynamics) computer program system. The purpose is to provide information on the suitability of PAN AIR for solving aerodynamic or hydrodynamic problems of interest and to describe the capabilities and limitations of the program system. Additional information is available in other PAN AIR documents (see References).

PAN AIR uses a higher order panel method to solve boundary value problems involving the Prandtl-Glauert equation for subsonic and supersonic potential flows. The basic features of the PAN AIR program system are summarized in figure 1.1. Examples illustrating potential applications of the method are shown in figure 1.2. Noteworthy capabilities of the PAN AIR system are:

Analysis of Nearly Arbitrary Configurations in Supersonic or Subsonic Flow

PAN AIR provides a unique capability for actual-surface modeling in supersonic flow (as opposed to mean-surface formulations). This capability is essential for accurately predicting the interfering flow field due to the true wing surface geometry, complex fuselage contours, canopies, engine inlets, external stores and other real airplane surface geometries. In most cases the same paneling can be used in both subsonic and supersonic analysis. An example of a panel simulation used for both subsonic and supersonic flow analysis of a complex configuration is shown in figure 1.3 (from reference 1).

Actual-surface modeling is not new in subsonic analysis, but here too, the advanced higher order panel technology of the PAN AIR system yields significant gains over existing methods (reference 2). For a given number of panels, more accurate velocity distributions (necessary for interfacing with three dimensional boundary layer codes) are produced by this method than by lower order codes. Results are relatively insensitive to paneling arrangements, thus enhancing program usability. The above attributes also apply to solutions for supersonic flow.

"Design" of Arbitrary Configurations

PAN AIR has a non-iterative design capability which can be used to modify configuration surface contours. Starting with a configuration exhibiting surface pressures which are "somewhat close" to those desired, the tangential velocities corresponding to the desired pressures are prescribed over the region to be modified. The method yields a set of revised surface normal velocity vectors which are then lofted (external to PAN AIR) to produce the revised surface exhibiting the desired pressures. The PAN AIR approach is applicable to general, rounded and/or flat surfaces and is not limited to perturbations about a uniform stream.

Designed to be Easy to Use

In the analysis of complex configurations it is often the engineering manpower resources and the need for highly experienced personnel which dominate the cost of a solution. In order to reduce these requirements a central theme underlying the design of PAN AIR was the desire to make it easy to use without sacrificing the capabilities of the method for solving general boundary value problems.

One particular feature is its higher order panel technology which renders the results very insensitive to panel arrangement. This makes it very convenient to the user, allowing him to panel an arbitrary shape according to its geometrical dictates and desired "solution resolution" with little concern about uneven panel spacing and other paneling limitations that are frequently constraints in older, lower order methods. He also need concern himself only with the vehicle's actual surface geometry, with no need for inventing "internal lifting systems" or "interference shells."

Another very effective feature for the user is found in the design and presentation of the input formats. PAN AIR possesses a large array of general capabilities, and the pioneering user who is exploring new modeling concepts will have to acquire a command of the general input capabilitities of the program. However, the vast majority of users will be dealing only with standard model problems (such as impermeable surfaces for wings, bodies, and so forth). For them, the PAN AIR input scheme and associated documentation have been subdivided into various levels such that the typical user needs only a knowledge of the simple, well-structured instruction sets that are appropriate for his problem. For example, the PAN AIR User's Manual includes a Beginner's Guide which describes in detail an application to a small, standard problem.

A comprehensive error detection and diagnostic description capability is provided to promote rapid learning and easy usage. Data checking and resource estimating facilities are provided to reduce the number of aborted runs.

Software Reliability and Maintainability

PAN AIR is a modular software system for use on CDC 6600 and 7600, and CYBER 170 and 700 series computers. The system was designed and fabricated in a modular fashion, using structured design techniques to promote improved software reliability and maintainability. With these objectives in mind, the computer code is heavily embedded with comments which describe in detail the modular hierarchy of the system design, the purpose and function of each module, the method of solution employed, and the interrelationships of each module with others in the system. In addition, the PAN AIR Maintenance Document describes the design of the program system and the maintenance of each program module.

Features of PAN AIR

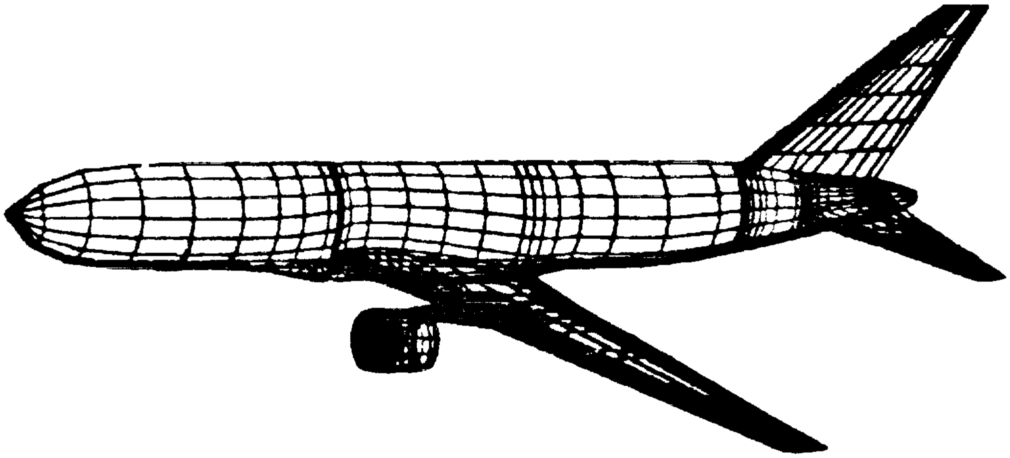
Capabilities

- Aerodynamic Analysis
- Aerodynamic Design
- Nearly Arbitrary Configurations
- Subsonic and Supersonic Regimes
- Potential Flow
- Higher Order Panel Method
- Very General Boundary Conditions
- Velocities, Pressures, Forces and Moments
- Engineering Documentation

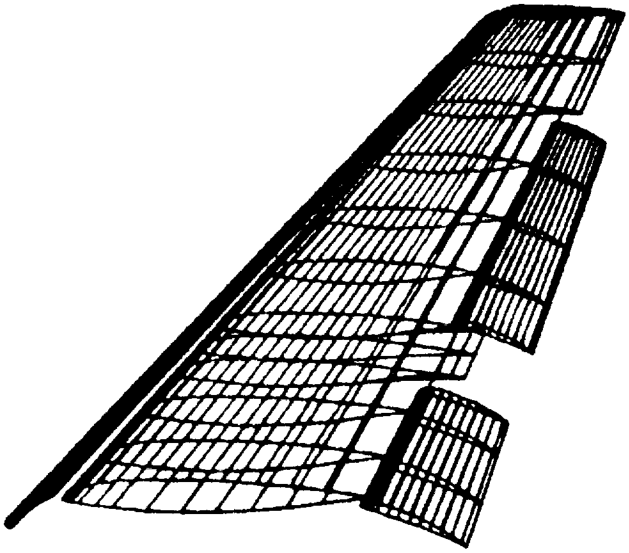
Program System

- Modular Software
- CDC 6600 and 7600, CYBER 170 and 700 Series
- Operating Systems: SCOPE 2, NOS 1 and NOS/BE
- Structured Software and Data
- User-oriented Input and Output Formats
- Diagnostics and Data Checking
- Program Documentation

Figure 1.1 Basic features of the PAN AIR system

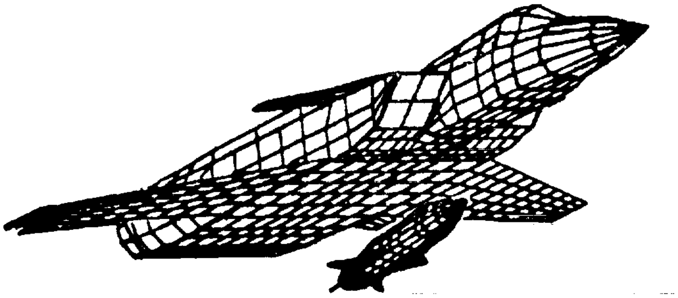


a) subsonic transport

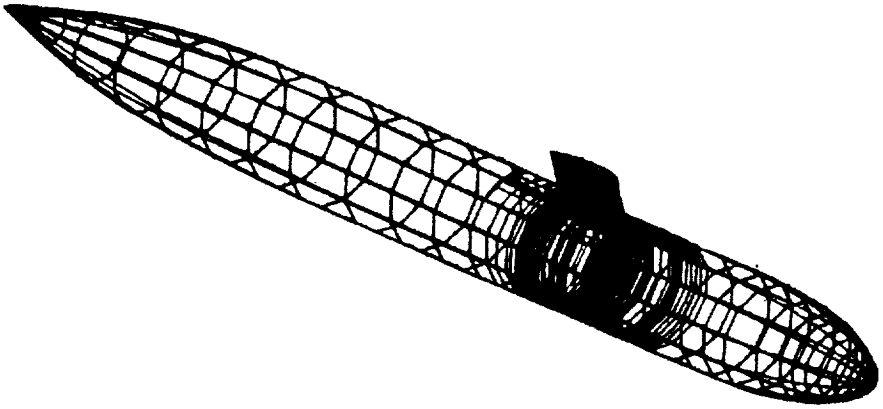


b) wing with slat and flaps

Figure 1.2 Panel simulations of detailed, arbitrary configurations



c) supersonic aircraft with store



d) submarine

Figure 1.2 Concluded

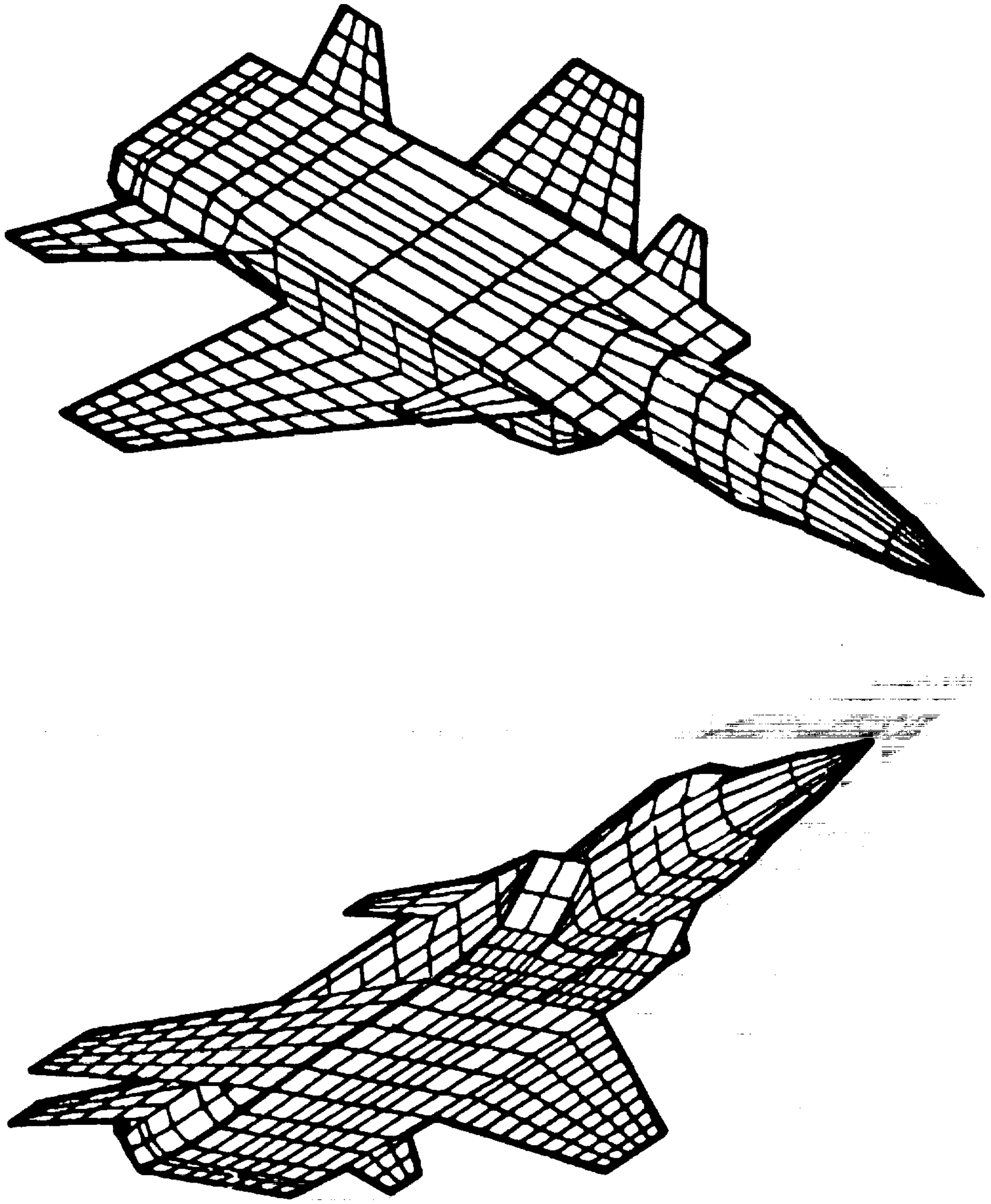


Figure 1.3 Panel simulation used in both subsonic and supersonic flow analysis

2.0 Summary of PAN AIR Capabilities and Limitations

The PAN AIR system offers a comprehensive aerodynamic analysis and design capability for nearly arbitrary configurations in subsonic and supersonic flows. The capabilities and limitations of PAN AIR are discussed in the following.

2.1 Basic Approach

The PAN AIR system is capable of solving boundary value problems of the type governed by the three dimensional Prandtl-Glauert equation

$$(1 - M_\infty^2)\, \phi_{xx} + \phi_{yy} + \phi_{zz} = 0 \qquad (1)$$

PAN AIR is suitable for the solution of problems involving configurations in either subsonic or supersonic flow, wherein the above equation provides an adequate representation of the inviscid aerodynamics. This is generally true throughout the subsonic regime up to Mach numbers where significant zones of locally supersonic flows appear, and in the supersonic regime for configurations whose surfaces are generally inclined to the freestream flow at angles significantly less than the Mach angle. The method cannot be directly applied in the transonic flow regime. Applicability of the method to predominantly viscous flows is limited, requiring special considerations in modeling the flow field.

PAN AIR enables flight vehicles of essentially arbitrary surface geometry to be modeled. This is illustrated in figure 2.1 where the aircraft surface has been partitioned into several networks of surface grid points. Several examples of surface configurations modeled by arrays of grid points which define a mosaic of surface panels are shown in figure 1.2. In addition to networks which represent parts of the physical configuration, "wake" networks are used to represent shear layers such as wakes, free vortex sheets, and so forth.

In subsonic flow, the panels can be oriented arbitrarily in space. For supersonic flow, panels representing solid boundaries must be inclined to the flow at angles less than the Mach angle. (The real flow for more steeply inclined surfaces would contain a detached bow shock which is outside the limits of validity of the linear governing equation.) PAN AIR also provides for the representation of permeable boundaries (typically at an engine inlet or exhaust). Such boundaries can be inclined at angles greater than the Mach angle without violating linear theory assumptions, and for these applications a special "superinclined" type of panel is available. These are typically used to seal off inlets to prevent the propagation of wave-like disturbances into the interior, to enable the specification of exhaust mass flows, and to swallow (in a sink fashion) oncoming inlet flow.

The user defines each network as a separate entity. This allows considerable freedom in modeling the configuration, but gaps can be inadvertantly created at network abutments. PAN AIR has a capability of adding "gap-filling" panels which insure the continuity of configuration geometry at network abutments.

Each panel which represents a physical surface contains singularities comprised of source and/or doublet distributions. Panels comprised of both sources and doublets are called "composite" panels. The source strength varies linearly over each panel and the doublet strength varies quadratically. The term "higher order" refers to these higher order strength distributions, as opposed to "lower order" panels having constant strengths.

These higher order panels eliminate many of the modeling problems and restrictions that lower order panels typically have. Two important aspects of the present higher order panel method formulation are that (1) the doublet strength is continuous across all panel edges, and (2) all adjacent panels can have contiguous edges. This eliminates the generation of spurious line vortex behavior which can produce disasterous numerical effects in supersonic flow.

2.2 Modeling Generality

Although PAN AIR provides for very general boundary conditions, this can be a burden to the user who does not need the full generality. Consequently, PAN AIR supports several levels of user knowledge. For example, for cases involving impermeable surfaces (for example, wing-body-tail combinations with no engines) PAN AIR will automatically construct the boundary condition equations from a simple input instruction.

Experience with existing panel methods has shown that they are capable of many applications, some of which were not foreseen at the time of system design. It is clear that the design of any general program should anticipate every foreseeable application. It is also clear that, even then, some applications will be overlooked. However, if the problem and program formulation is general enough, even the innovative, future user can be provided for. In PAN AIR, this generality is provided not only in the geometry but also in the boundary value modeling. The key feature in the latter is the generality of boundary condition formulation. The user can:

(a) choose from several different types of boundary condition terms which specify normal mass flux, normal velocity, tangential velocity and velocity potential,

(b) control the flow on both sides of a singularity sheet since the composite panel formulation allows for separate boundary conditions at opposite sides of a panel, and

(c) construct a linear combination of different boundary condition types.

It is highly desirable to provide the user with the freedom to determine a modeling scheme compatible with the requirements for a particular application. The complexity of the problem formulation is determined by the user to suit the particular needs in terms of accuracy and resolution versus computing and manpower costs. The system can be applied to preliminary design problems, involving linearized modeling approximations for simple configurations. It can also be used in an "analytical wind tunnel" sense to determine the detailed flow characteristics and the forces and moments about complex configurations.

The input records in PAN AIR have been designed to simplify the data preparation for standard aerodynamic analysis problems. For example, in these standard problems most of the input records can be omitted, since the program assigns standard options as default values. PAN AIR also has many options which allow a variety of computational relations and types of boundary conditions. Use of non-standard options allow the program to be used in non-standard problems, but with increased user knowledge and input data required.

In the PAN AIR system the primary input data requirement in standard aerodynamic problems is the configuration geometry. This consists of the coordinates of all panel corner points. These must be generated by the user; PAN AIR does not provide a geometry definition capability.

2.3 Application Examples

The PAN AIR system uses a higher order panel method to solve boundary value problems for subsonic and supersonic potential flows. Its principal applications are:

Analysis of Supersonic Flow over Nearly Arbitrary Configurations

An example of analysis of supersonic flow (Mach 1.2) over a complex configuration is given in figure 2.2. The configuration is a lightweight experimental supercruiser. The paneling is shown in figure 2.2a (the wake paneling has been removed). The critical modeling features are the large canopy and the diverter-chin inlet combination (reference 3). Comparisons of PAN AIR and experimental values (reference 4) of vehicle lift and moment coefficients are shown in figure 2.2b. Comparisons of wing pressures are shown in figure 2.2c. The agreement between the calculated and experimental pressure values is very good. PAN AIR gives better agreement than both a mean-surface constant-pressure panel method, which cannot provide accurate modeling of the canopy and inlet (reference 5), and a Mach box method (reference 6).

A second example of supersonic flow analysis (Mach 3.0) of a complex configuration is given in figure 2.3. The example is a long range reconnaissance strike aircraft. The paneling used to represent the configuration is shown in figure 2.3a (the wake paneling has been removed). Special features are the triangular shape of the fuselage cross-section and the wing-body intersection details. The calculated force and moment data show a very good comparison with experimental data (reference 3) as shown in figure 2.3b. PAN AIR gives better agreement with experimental data than either the constant-pressure panel method or the Mach box method. Comparison of wing surface pressure distributions are shown in figure 2.3c. Except at the upper surface leading edge, PAN AIR gives a good comparison with the experimental surface pressures.

Analysis of Subsonic Flow over Arbitrary Configurations

One of the main advantages of the higher order panel method is the reliable accuracy of the method under extreme conditions of panel size and shape, enabling the user to select panel sizes according to the geometrical dictates of the configuration. An example of this is the randomly paneled sphere shown in figure 2.4 (reference 7). The paneling layout shown in figure 2.4a was defined by means of a random number generator, resulting in panels that vary considerably in shape and size, and that are occasionally nonconvex. Nevertheless, the PAN AIR calculated velocity magnitudes shown in figure 2.4b are accurate.

Another example of a complex configuration is given in figure 2.5a. The configuration is a V/STOL fighter intended for flight at subsonic and supersonic speeds. A total of 882 panels is used to represent the details of the geometry. A comparison of PAN AIR and wind tunnel pressures (reference 8) near the 3/4 semi-span location is shown in figures 2.5b and 2.5c.

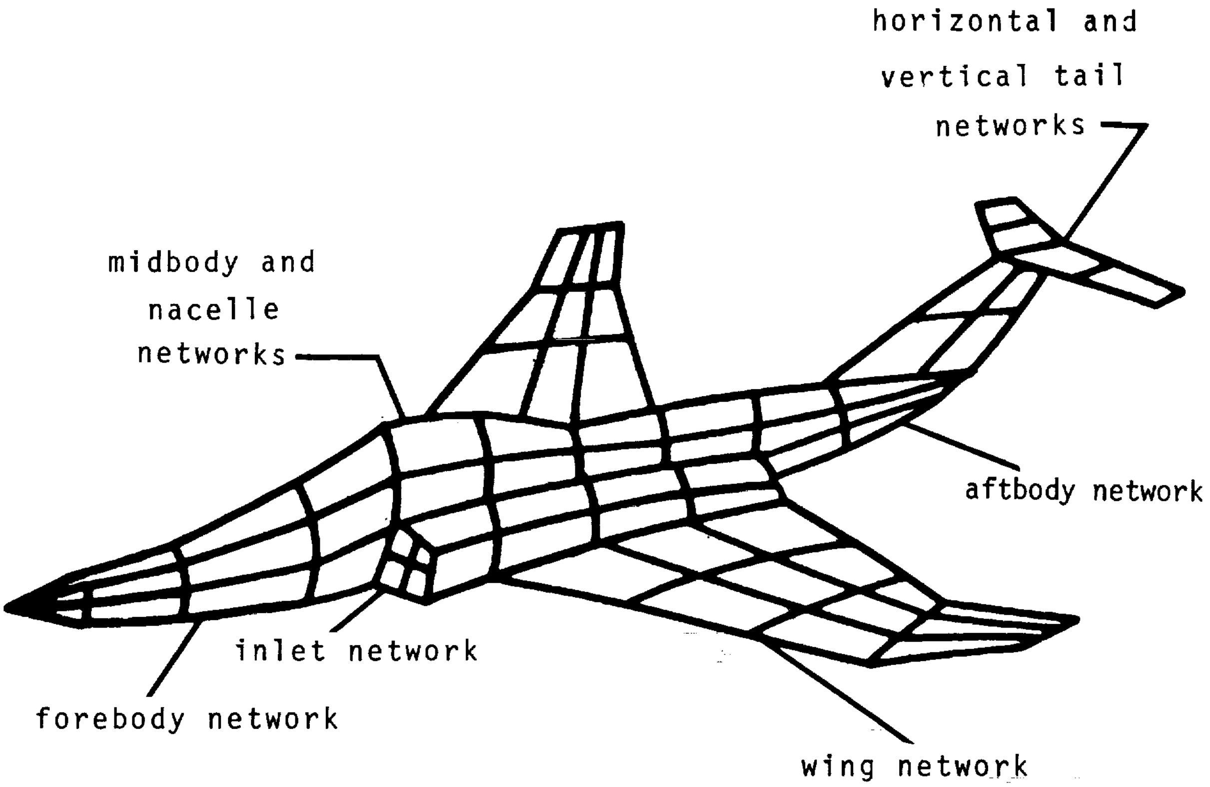
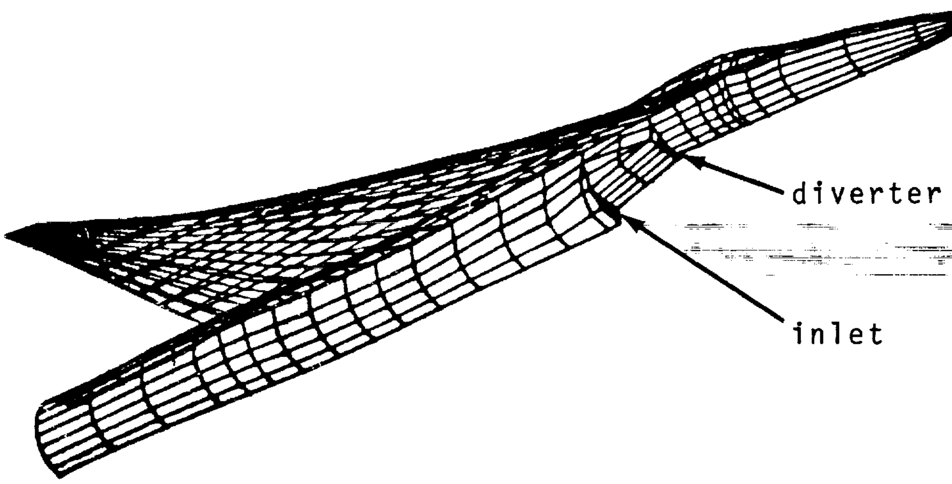
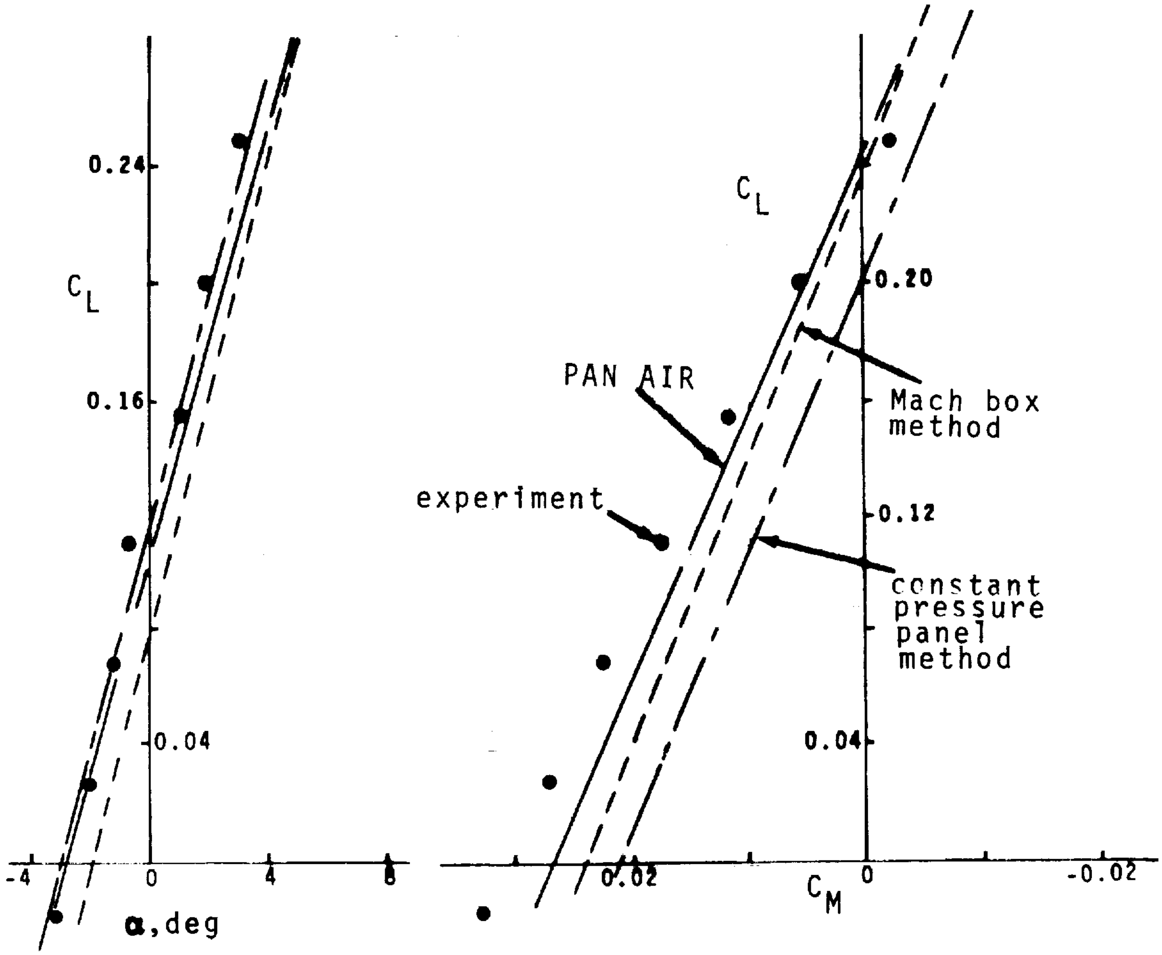


Figure 2.1 Representation of aircraft surface by networks of panels



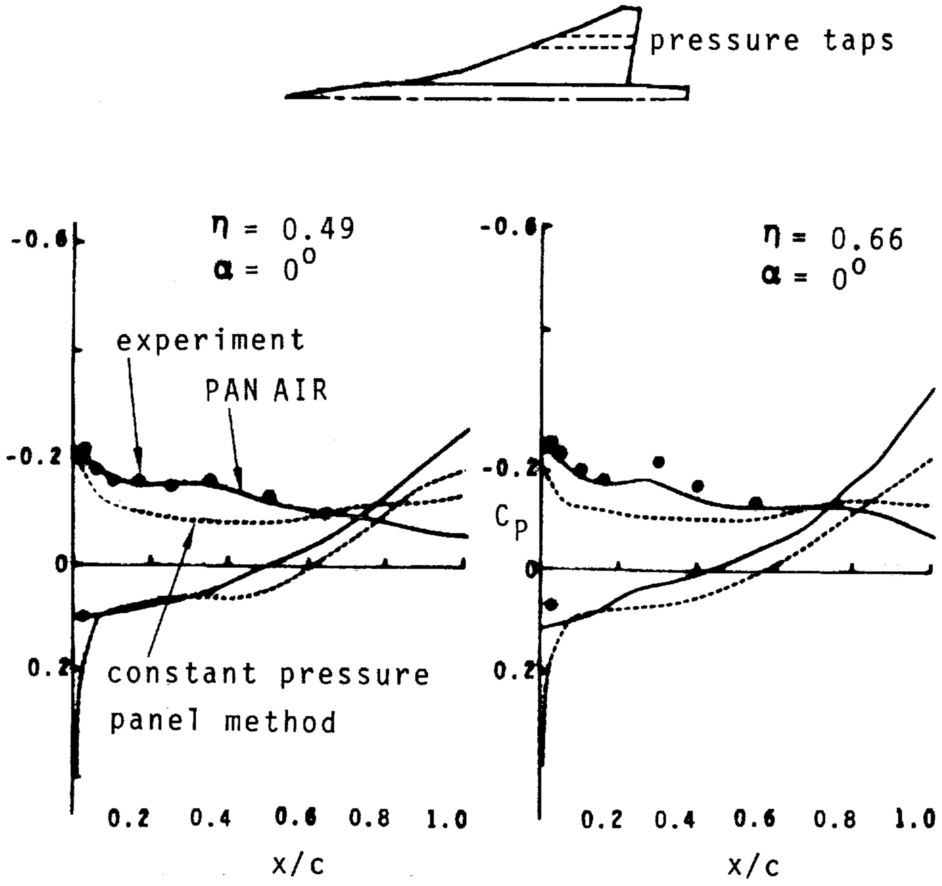
a) paneling representation

Figure 2.2 Example of supersonic flow analysis of a complex configuration



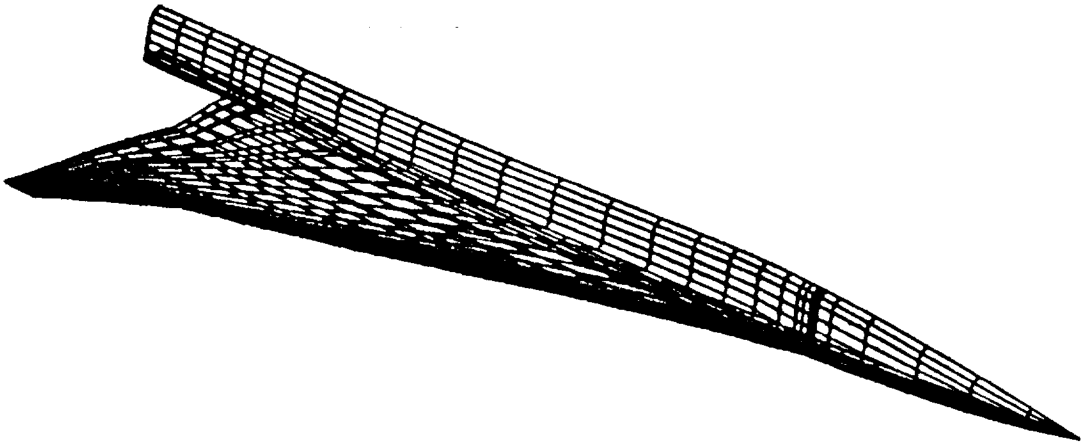
b) longitudinal characteristics

Figure 2.2 Continued



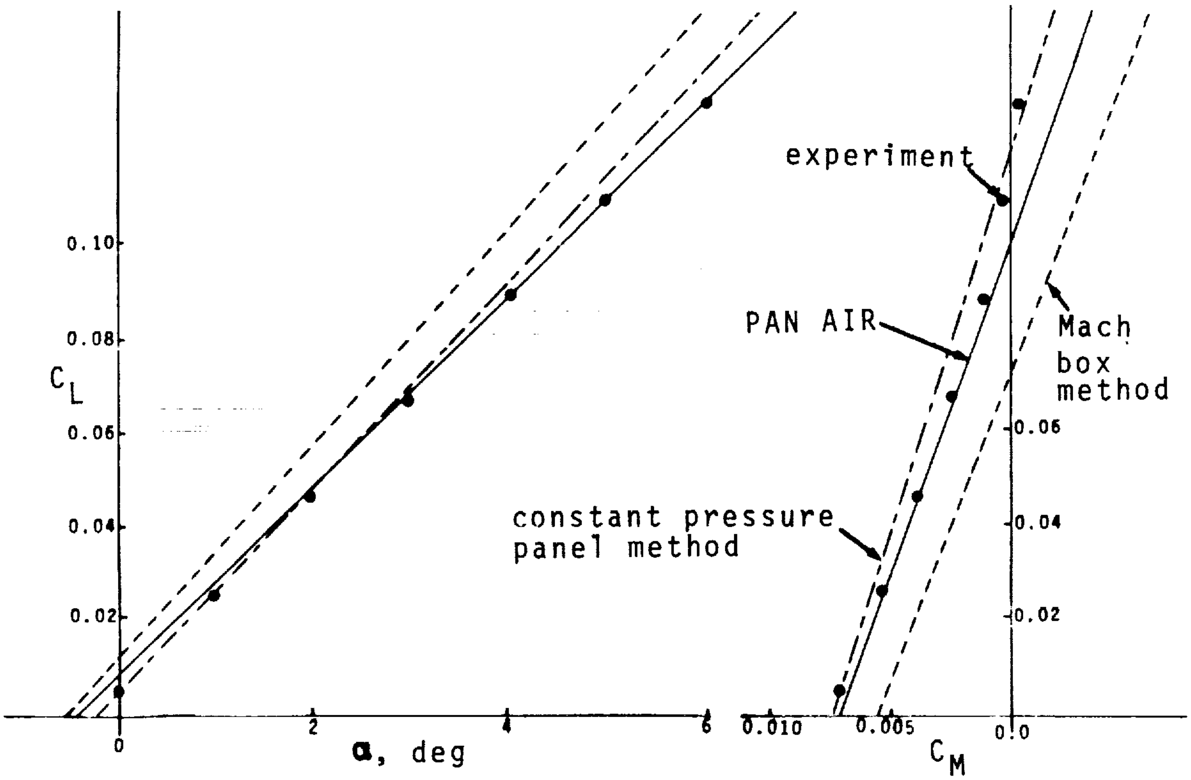
c) wing pressure distribution

Figure 2.2 Concluded



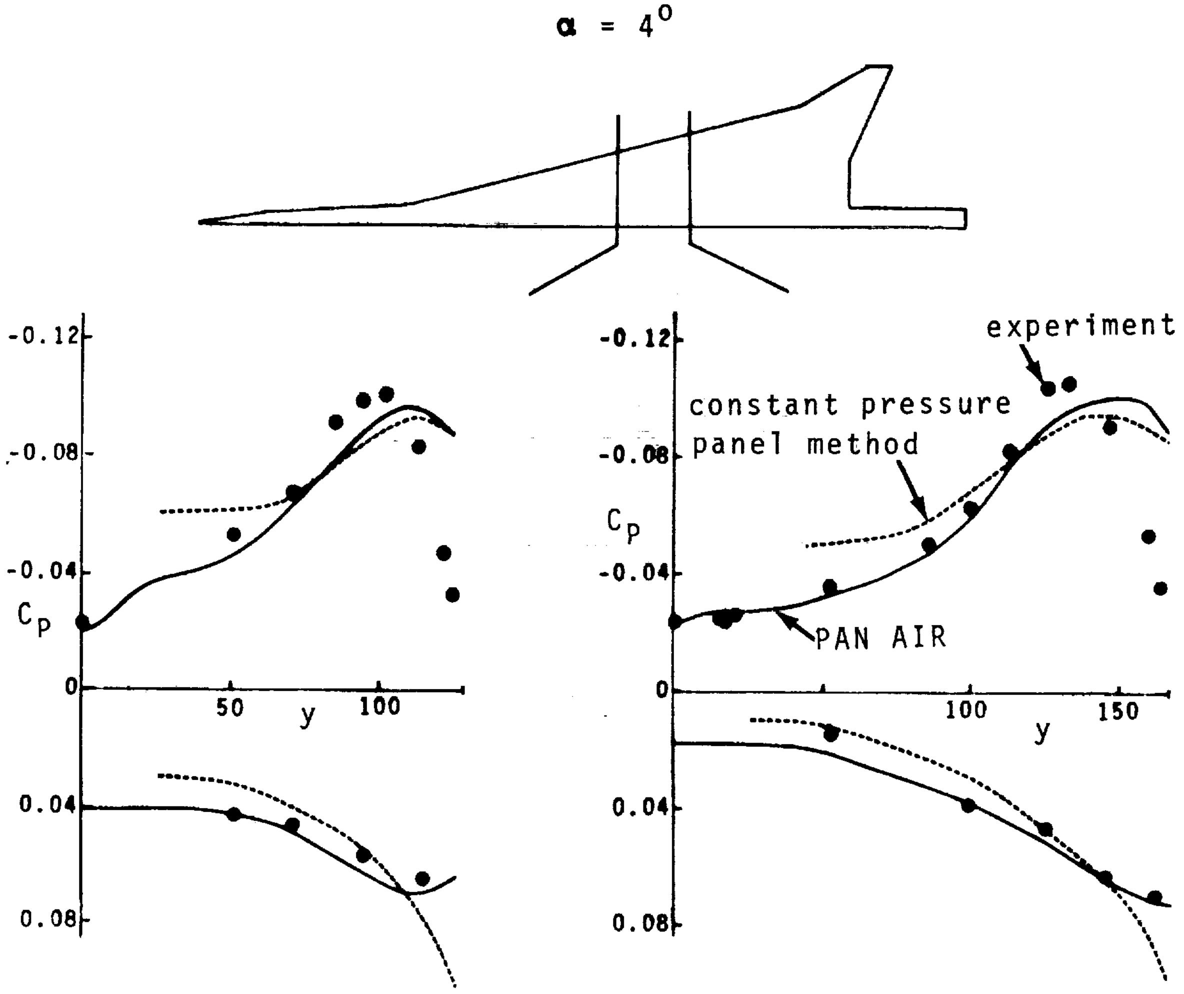
a) paneling representation

Figure 2.3 Example of supersonic flow analysis of a complex configuration



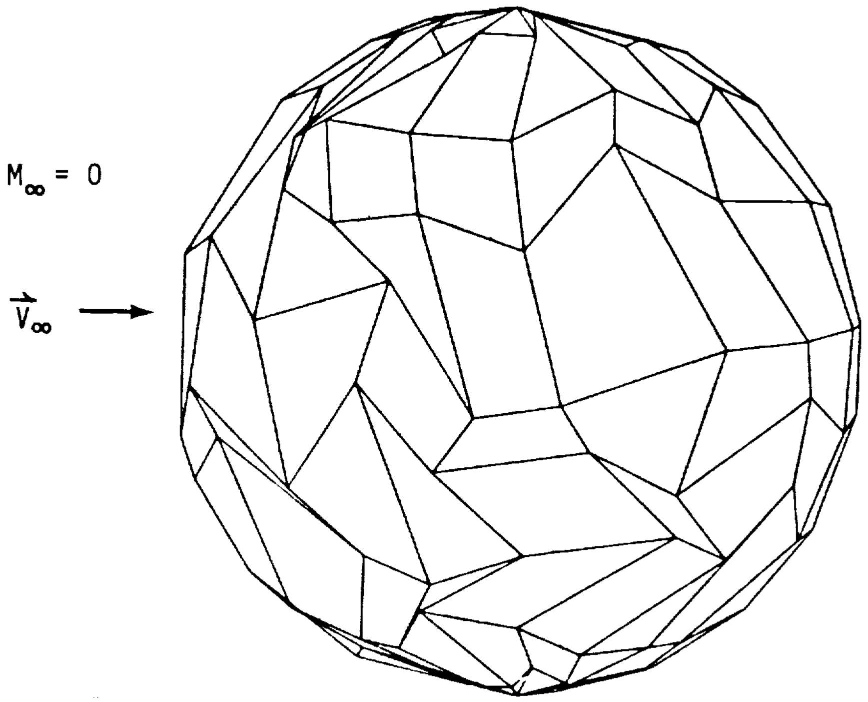
b) longitudinal characteristics

Figure 2.3 Continued

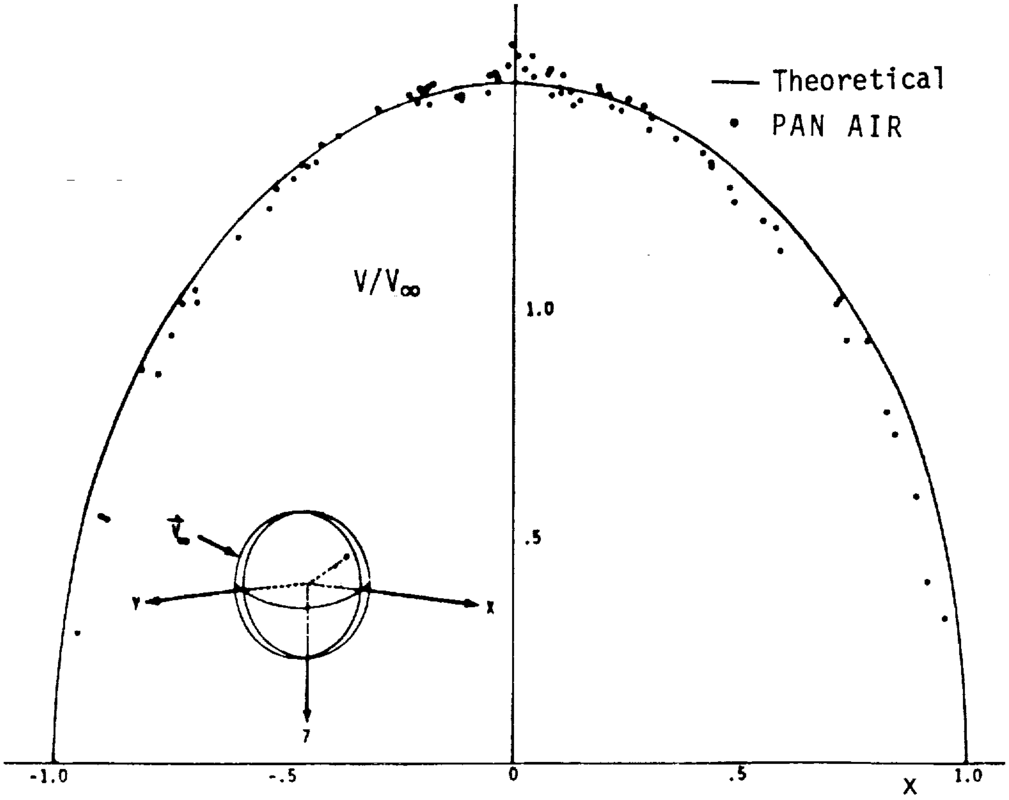


c) wing pressure distribution

Figure 2.3 Concluded

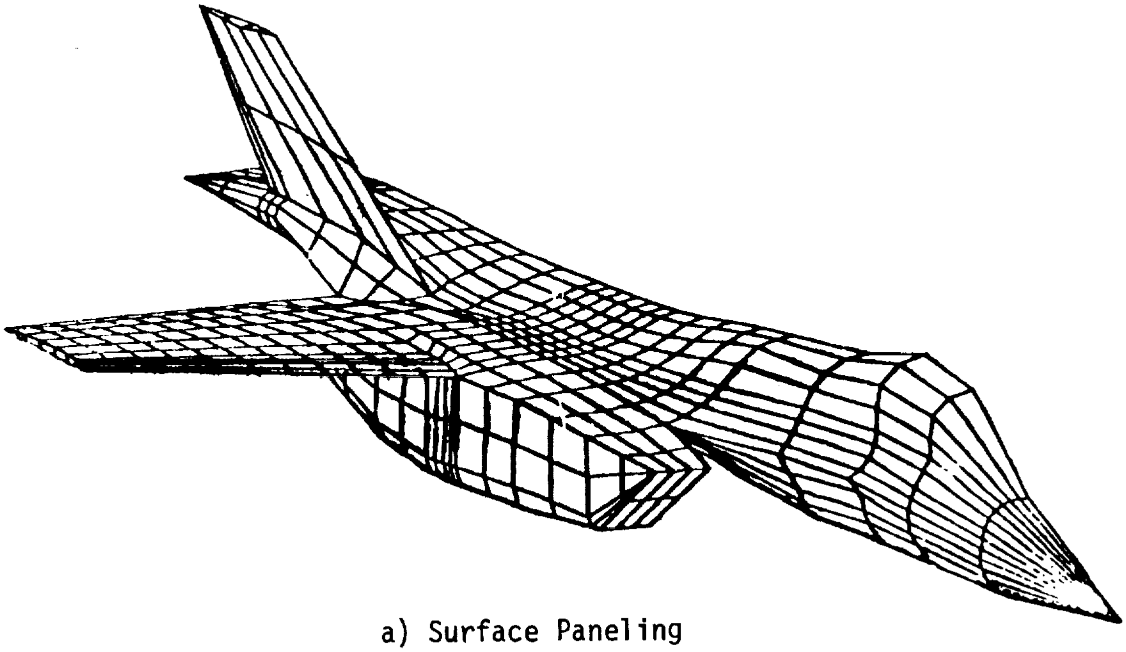


(a) random paneling of sphere, side view



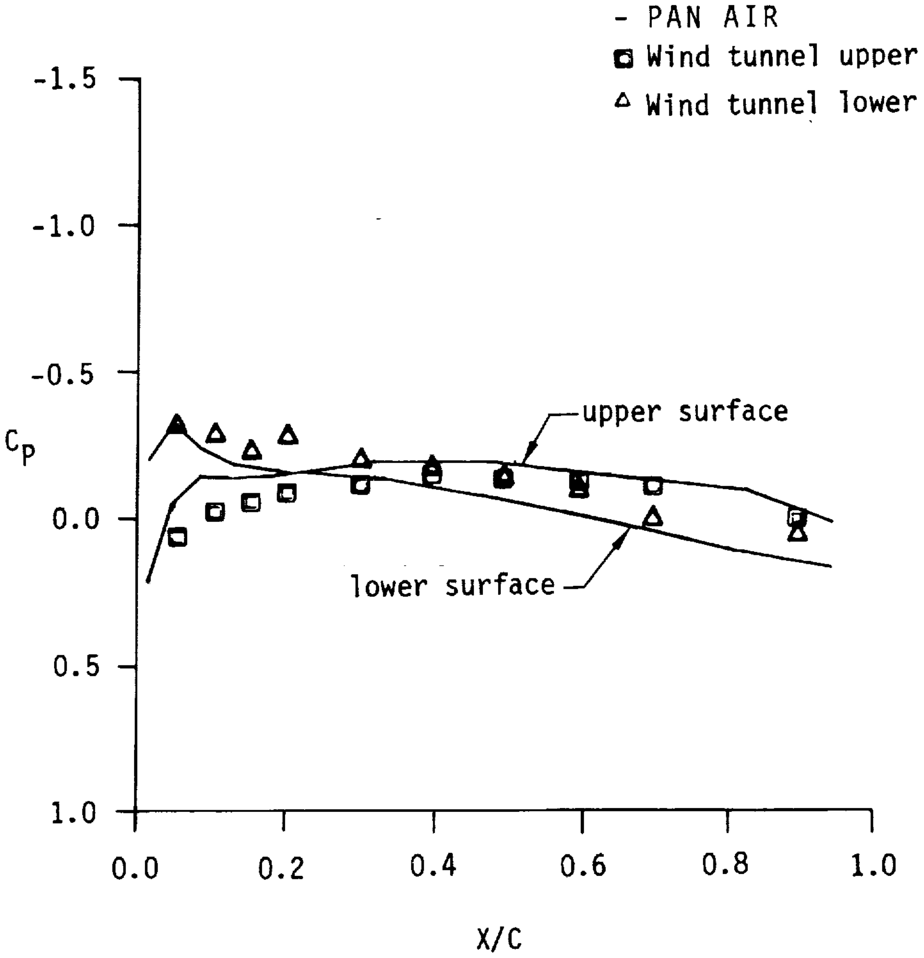
(b) velocity magnitude at control points

Figure 2.4 Subsonic flow analysis of a randomly paneled sphere



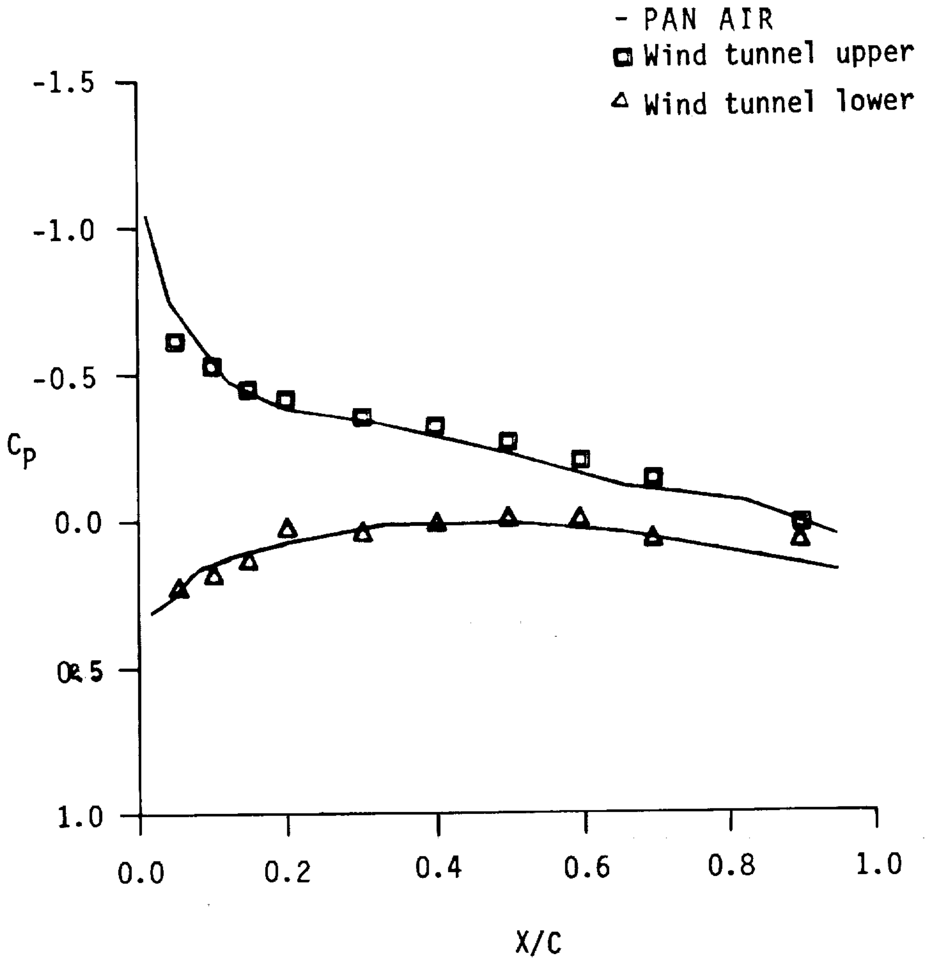
a) Surface Paneling

Figure 2.5 Subsonic flow analysis of a V/STOL fighter



b) Wing pressure distribution, alpha = -.048 degrees

Figure 2.5 Continued



c) Wing pressure distribution, alpha = 6.5 degrees

Figure 2.5 Concluded

3.0 PAN AIR Modeling Features

The PAN AIR system has many features which allow considerable flexibility in modeling flow problems and which can also be used to increase the execution efficiency of the problem simulation. The features which highlight modeling flexibility are summarized in figure 3.1 and are briefly discussed in this section. They are discussed in more detail in the PAN AIR User's Manual.

3.1 Aerodynamic Analysis Features

The modeling features of the aerodynamic analysis capability are illustrated in the following.

3.1.1 Modeling Flexibility

A configuration is amenable to processing by PAN AIR as long as the surfaces of the configuration can be approximated by an array of grid points which represent a mosaic of surface panels. The manner in which a configuration is constructed from a number of networks is illustrated in figure 3.2 for a typical transport type wing-body configuration. Here the networks are shown in a developed or "folded out" fashion. The number, sizes and arrangement of the networks are at the discretion of the user within broad limits.

In addition, wake networks are used to represent shear layers in the flow field. Examples of the use of wake networks are shown in figure 3.3. The most common application is the simulation of wakes starting at the trailing edge of lifting surfaces. Wake networks can also be used to simulate separated flow from lifting surfaces and engine effluxes.

3.1.2 Configuration Symmetries

The PAN AIR user may take advantage of geometric symmetry properties of the configuration to be processed. This reduces both the amount of data input and the cost of the solution. The symmetry option may be invoked not only for the obvious cases involving one or two planes of configuration symmetry but also for the solution of ground effect problems.

PAN AIR also has asymmetry features designed to efficiently process cases for which the panel geometry is symmetric but the flow is not. Examples are aircraft in sideslip and symmetrically disposed engines at different power settings.

3.1.3 Thick and Thin Configurations

The fundamental composite PAN AIR panel provides the user with a great deal of flexibility in modeling various types of configurations.

In the most frequent type of usage, panels are distributed over the surface of a "thick" configuration (for example, figure 3.4a) to provide a very detailed simulation of the actual geometric shape.

Some types of problems may warrant a "thin" surface treatment in which the panels are placed at the mean surface of the component (for example, figure 3.4b). Thin surface simulation will, in most cases, be substantially cheaper in terms of computer cost and input effort required than corresponding thick configuration cases. This provides the user with an important flexibility in weighing the requirements of accuracy versus incurred cost.

Included within this option is the conventional treatment of linearized boundary conditions. For instance, finite wing thickness may be simulated with a thin surface representation by specifying a source singularity distribution (in addition to the doublet distribution) whose strength is equal to the rate of change of thickness. Both thick and thin surface (that is, actual and mean surface) representations may be used in the same analysis as shown in figure 3.4c and in figure 1.3.

3.1.4 Exact and Linearized Modeling

The terms "exact" or "linearized" pertain to whether the boundary conditions applied on the network surface represent the flow conditions at the network surface itself (exact), or at some small, but finite, distance away from the network surface (linearized), as in a representation of surface thickness by source strength.

An example of the difference between exact and linearized modeling is the alternate representations of boundary layer displacement effects on a wing as shown in figure 3.5. In exact modeling, the user would estimate the displacement thickness of the boundary layer at all points on the wing surface, add this thickness to the actual wing profile, panel the resulting shape of the wing plus boundary layer and apply the flow tangency boundary condition at the outer edge of the boundary layer (figure 3.5a). In linearized modeling on the other hand, the user could simulate the effects of the boundary layer by imposing suitable boundary conditions on the paneled surface of the actual wing, causing the surface to emit fluid so as to create the appropriate displacement effect (figure 3.5b).

Some potential applications of linearized modeling are given below.

(a) Thickness Distributions

(b) Camber Distributions

(c) Linearized Control Surface Deflections

(d) Linearized Asymmetric Effects

(e) Boundary Layers

(f) Flow Entrainment by Jet Effluxes

PAN AIR allows the user complete flexibility in selecting whatever combination of modeling is suitable for a particular application. The models discussed heretofore can be used either individually or in combination with one another.

3.1.5 Onset Flows

In the most frequent usage, the configuration is exposed to a uniform onset flow (freestream) whose direction is determined by the angles of attack and sideslip specified by the user. In addition to the freestream, the user may specify two other types of onset flows.

(a) Rotational Onset Flows

These are used for the simulation of steady rotational motions of the configuration within a "quasi-steady" approximation.

(b) Local Onset Flows

The user may specify the components of a local onset flow. Among other things this feature may be used to simulate, in a linearized fashion, a change in tail incidence relative to the remainder of the configuration, without changing the geometry of the panel arrangement.

3.1.6 Surface Flow Property Options

Surface flow properties (velocities and pressures) can be calculated in several ways and in varying detail, depending on the user's choice, from the following options.

(a) Surface Selection Options

PAN AIR provides flow results on both sides of a singularity sheet. In addition, the difference and average of the two values can be obtained, which is a convenience when using linearized modeling.

(b) Velocity Computation Methods

Two methods are available for computing surface velocities: the calculations can be performed by using the appropriate flow properties defined by the boundary conditions, or by using the "velocity influence coefficients" originally used to construct the aerodynamic influence coefficients.

(c) Velocity Correction Options

Because of the small perturbation assumptions implicit in the Prandtl-Glauert equation, errors are introduced when the local velocity deviates substantially from the freestream. To produce improved velocity and pressure results in such regions, two semi-empirical velocity corrections are available.

(d) Pressure Coefficient Formula Options

Several formulas are available for converting the velocities into pressure coefficients: isentropic, linear, second-order, reduced second-order, and slender body.

The flow properties on the surface of wake networks can be calculated if desired. This option is useful in determining whether the specified wake surface has a reasonable location: large differences in pressure coefficient between the two sides of the wake surface and/or large velocity components through the wake imply an inaccurate estimation of the wake location.

3.1.7 Force and Moment Calculation Options

Force and moment coefficients can be calculated in various ways at the discretion of the user. The velocity and pressure options available for surface flow calculations are also available for force and moment calculations. These include velocity computation options, velocity correction options, and pressure coefficient formula options. Other options available are:

(a) Surface Selection Options

Force and moment coefficients can be computed individually on selected surfaces.

(b) Force and Moment Summation Options

The force and moment calculations can be computed, printed and summed in varying degrees of detail: for the configuration as a whole, for each individual network, for each column of panels in individual networks, and for each panel in individual networks. An additional option enables individual networks to be eliminated from the force and moment summation for the total configuration.

(c) Edge Force Option

In PAN AIR an option is available by which the edge forces (such as leading edge thrust or suction) on thin surfaces can be calculated in the manner of reference 9.

(d) Axis System Options

Force and moment coefficients can be calculated and printed in several axis systems. The options available are: reference coordinate system, wind axis system, stability axis system, and body axis system.

3.2 Aerodynamic Design Features

The PAN AIR design capability, termed non-iterative design, consists of the ability of taking a first approximation to the shape of a particular portion of a configuration. This is accomplished in conjunction with a specification of tangential velocities corresponding to the desired pressures on that portion and performing an inverse aerodynamic computation to produce relofting information from which a second estimate of the desired shape can be calculated.

3.3 System Usage Features

The PAN AIR system offers several modes of operation other than the normal one-pass, input-solution-output mode. These modes facilitate use of the system for data checking, processing of additional flow cases, processing of configurations which differ in a limited way from a previously analyzed problem, and extraction of data after an initial data-creation run.

3.3.1 Data Checking

To avoid wasting computing resources on an incorrectly formulated or erroneous submission, the user can take advantage of the data checking and diagnostic capabilities of the system. To use this capability the user submits a complete input deck or file along with a simple "CHECK DATA" command, which instructs the system to execute the first two main programs only. These two programs read and echo the user-supplied input information, check for syntactical errors, for problem formulation errors and for logic errors, and print diagnostic messages describing each error. They also print pertinent geometric data and set up a file for configuration panel arrangement display. Further details on the checkout capability are given in section 4 of the PAN AIR User's Manual.

3.3.2 Additional Flow Cases (Solution Update)

The boundary value problem formulation involves the construction of a system of linear algebraic equations, which can be expressed in matrix form as:

$$[AIC]\{\lambda\} = \{b\} \qquad (2)$$

In this equation $\{\lambda\}$ is the set of unknown singularity parameters to be solved for. The matrix $[AIC]$ is composed of "aerodynamic influence coefficients." The "right hand side" of the equation, namely the vector $\{b\}$ consists of terms which are related to the flow boundary conditions.

The construction and triangular decomposition of the AIC matrix is by far the most costly operation in PAN AIR. Once this is performed, multiple solutions involving different right hand sides, without changes in any elements of the AIC matrix, can be executed economically. In PAN AIR, multiple flow cases can be processed either in the initial submission run or at any time after the initial submission.

3.3.3 Limited Configuration Changes (IC Update)

It may be desired to process configurations which differ from one already processed in a limited fashion with respect to geometry or boundary condition type. This type of change involves changes in portions of the AIC matrix, and can be handled efficiently by an "IC update" capability.

This feature is designed to enable the user to execute efficiently the following types of cases:

(a) Design

(b) Addition, Deletion, or Modification of Configuration Components

(c) Successive Geometric Control Surface Deflections

(d) Stores Separation

3.3.4 Separate Post-Processing

The structure of PAN AIR is arranged so that the final output data can be extracted from the system either at the time of problem solution or at any time afterwards. A minimal data set required for all final configuration data extractions is generated and placed on a data base. In subsequent post-processing, this data base is used as a starting point to construct surface flow properties and force and moment coefficients for all networks.

3.3.5 Peripheral Plotting

The data generated in the post-processing operations described above can be printed by each of the post-processing programs concerned. The data can also be placed on the appropriate program data bases and used to set up standard format plot files for subsequent interactive graphics display or hardcopy plotting by user supplied software.

Aerodynamic Analysis Features

- Modeling and Usage Flexibility
- Configuration Symmetries
- Thick and Thin Configurations
- Exact and Linearized Modeling
- Onset Flows
- Surface Flow Property Options
- Force and Moment Calculation Options

Aerodynamic Design Features

- Non-iterative Design

System Usage Features

- Data Checking
- Additional Flow Cases (Solution Update)
- Limited Configuration Changes (IC Update)
- Separate Post-Processing
- Peripheral Plotting

Figure 3.1 PAN AIR efficiency and modeling features

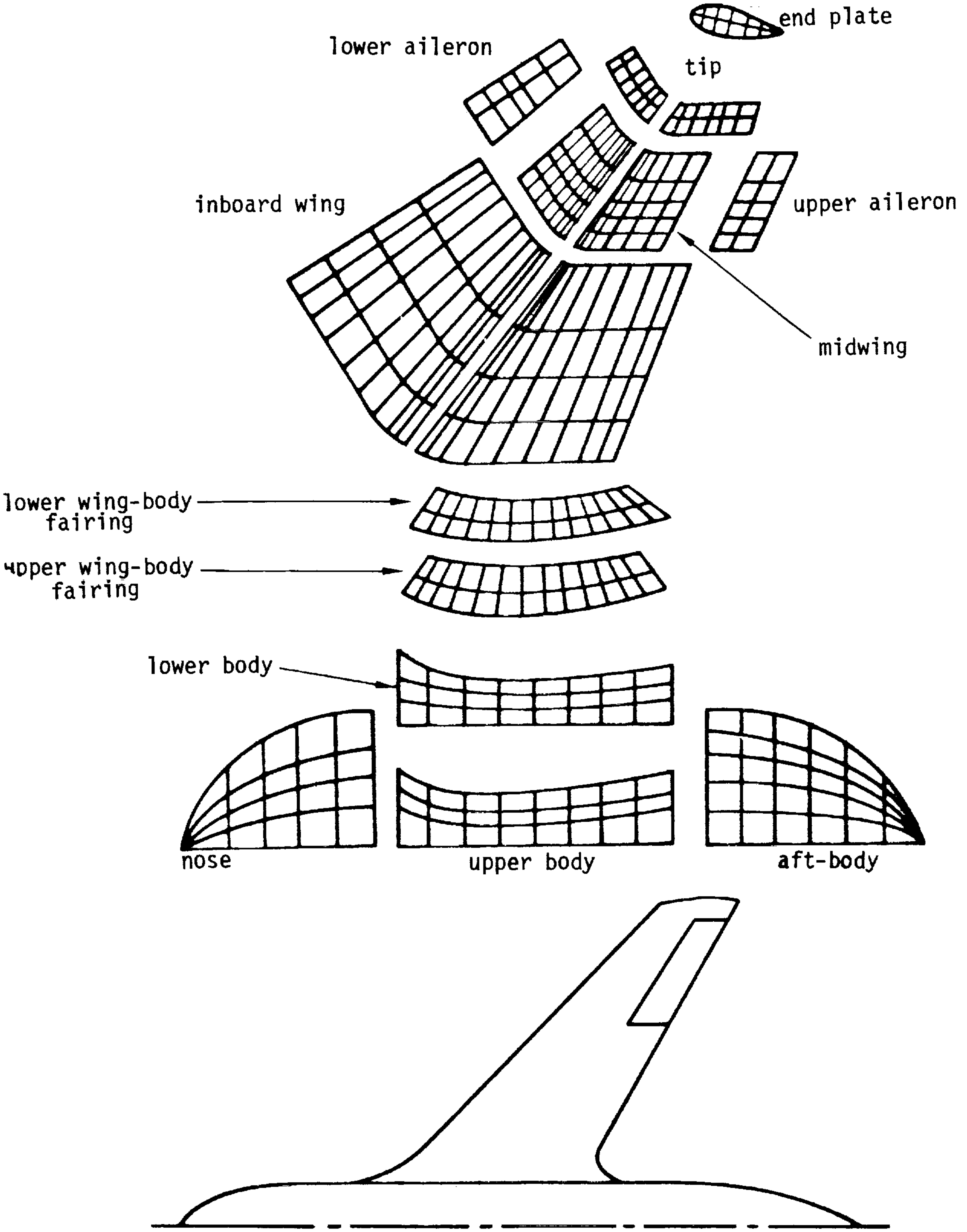
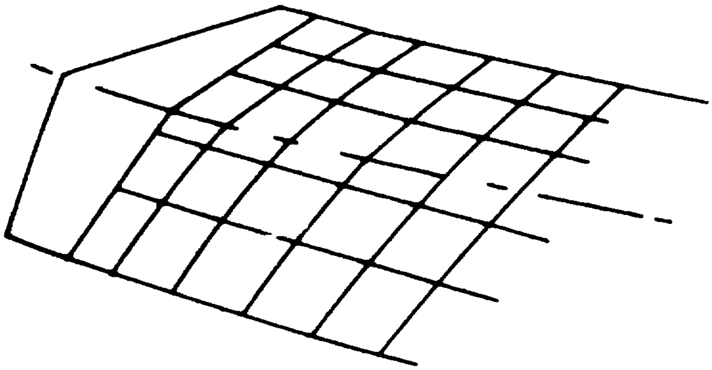
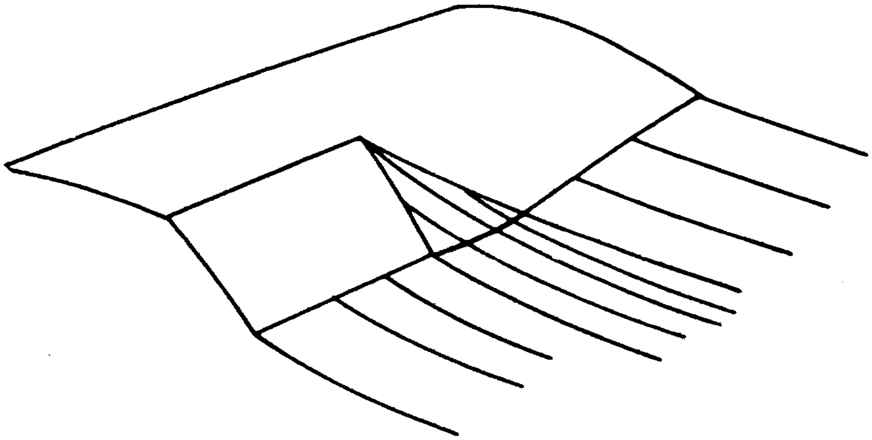


Figure 3.2 Construction of a configuration from a set of networks

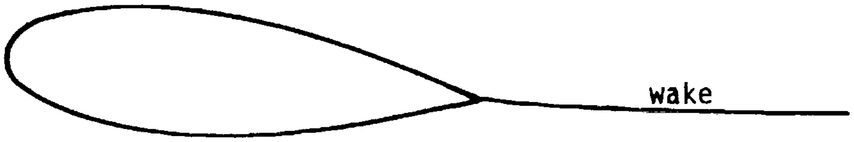


a) simple wake



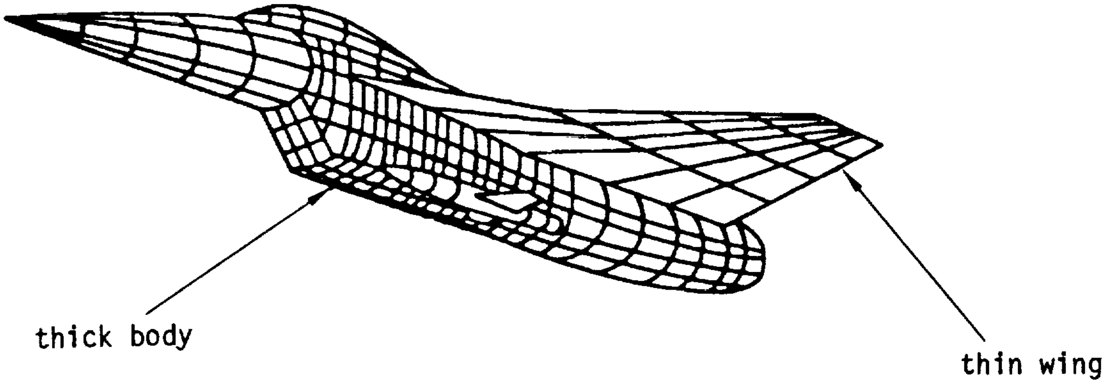
b) flapped configuration wake

Figure 3.3 - Examples of use of wake networks



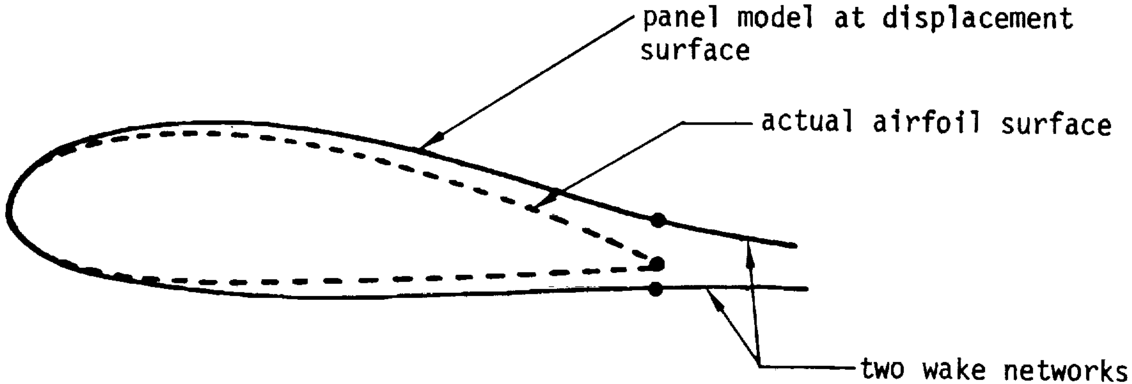
a) thick configuration (actual surface paneling)

b) thin configuration (mean-surface paneling)



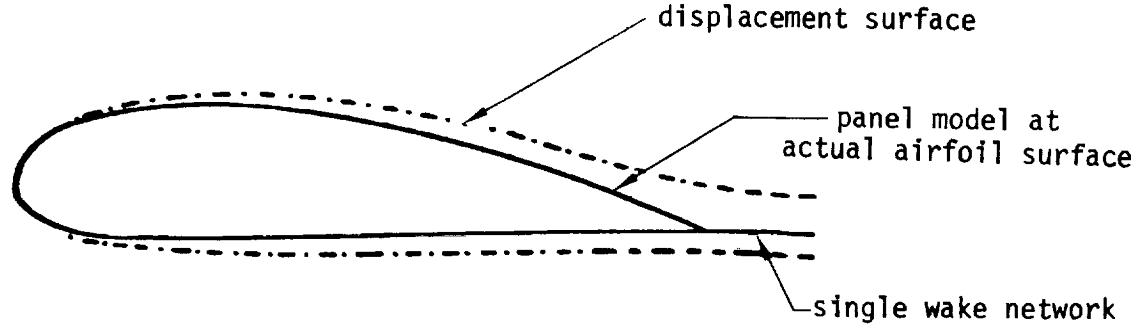
c) combinations

Figure 3.4 - Examples of thick and thin configuration modeling



a)"exact" modeling

panels and boundary conditions on surface representing airfoil plus boundary layer (displacement modeling)



b)"linearized" modeling

- panels and boundary conditions on actual airfoil surface
- source strength distribution specified to simulate boundary layer thickness

——————paneled surface

Figure 3.5 Use of exact and linearized modeling of boundary layer displacement effects

4.0 PAN AIR Program Configuration

PAN AIR consists of a total of ten program modules, a library of specialized and frequently used subroutines, and the Scientific Data Management System (SDMS). The modules are run in specific sequences according to the PAN AIR problem definition. The modules communicate within themselves and with each other by means of data bases generated by SDMS. Figure 4.1 illustrates a common run sequence for a typical problem.

4.1 Input Data

The input data needed to run PAN AIR consist of two parts. The MEC (Module Execution Control) module, which generates the major portion of the job control cards required to run PAN AIR, needs a set of input cards. The DIP (Data Input Processor) module processes the engineering data needed to solve a particular PAN AIR problem.

4.1.1 Module Execution Control Data

The MEC module interprets a few simple user directives defining the type of PAN AIR problem to be run, such as, FIND POTENTIAL FLOW WITH PLOTS, FIND SOLUTION UPDATE, etc. These user directives also include names and locations of the data bases to be generated or used for the run. MEC stores the data base information in the MEC data base for use of other modules and generates the job control cards necessary to execute the PAN AIR modules in the proper sequence.

4.1.2 Engineering Input Data

This section of the input data consists of five major groups: global, network, geometric edge matching, flow properties and plot options selected by the user. The data are processed by the DIP module and stored in the DIP data base for use of all other modules. Free field input makes the data definition problem relatively easy for the user. Also, user comments can be included with the input data as separate cards or on the data cards themselves.

4.2 Output

The PAN AIR software system is shown in Figure 4.2 for a standard type problem. A small set of user-supplied control cards accesses MEC which, in turn, generates the job control cards for the other modules. As indicated, the modules run in a prescribed sequence generating one or more data bases. The data bases are used to communicate within the module and with other modules. Not all data bases are used by each module. All modules produce some output but MEC, DIP, DQG, PDP, CDP and PPP produce the bulk of the output.

4.3 Software Standards and Machine Resource Requirements

Structured Fortran coding principles were used throughout the PAN AIR software system. Deviations from ANSI FORTRAN code were used as sparingly as possible. CDC (Control Data Corporation) machine dependent code was used for disk I/O in the data base manager (SDMS) and for efficient computation in the PAN AIR library and in some modules.

The PAN AIR Maintenance Document and the comments in the code may be used to guide an analyst during software revision.

4.3.1 Operating and Computer System Environment

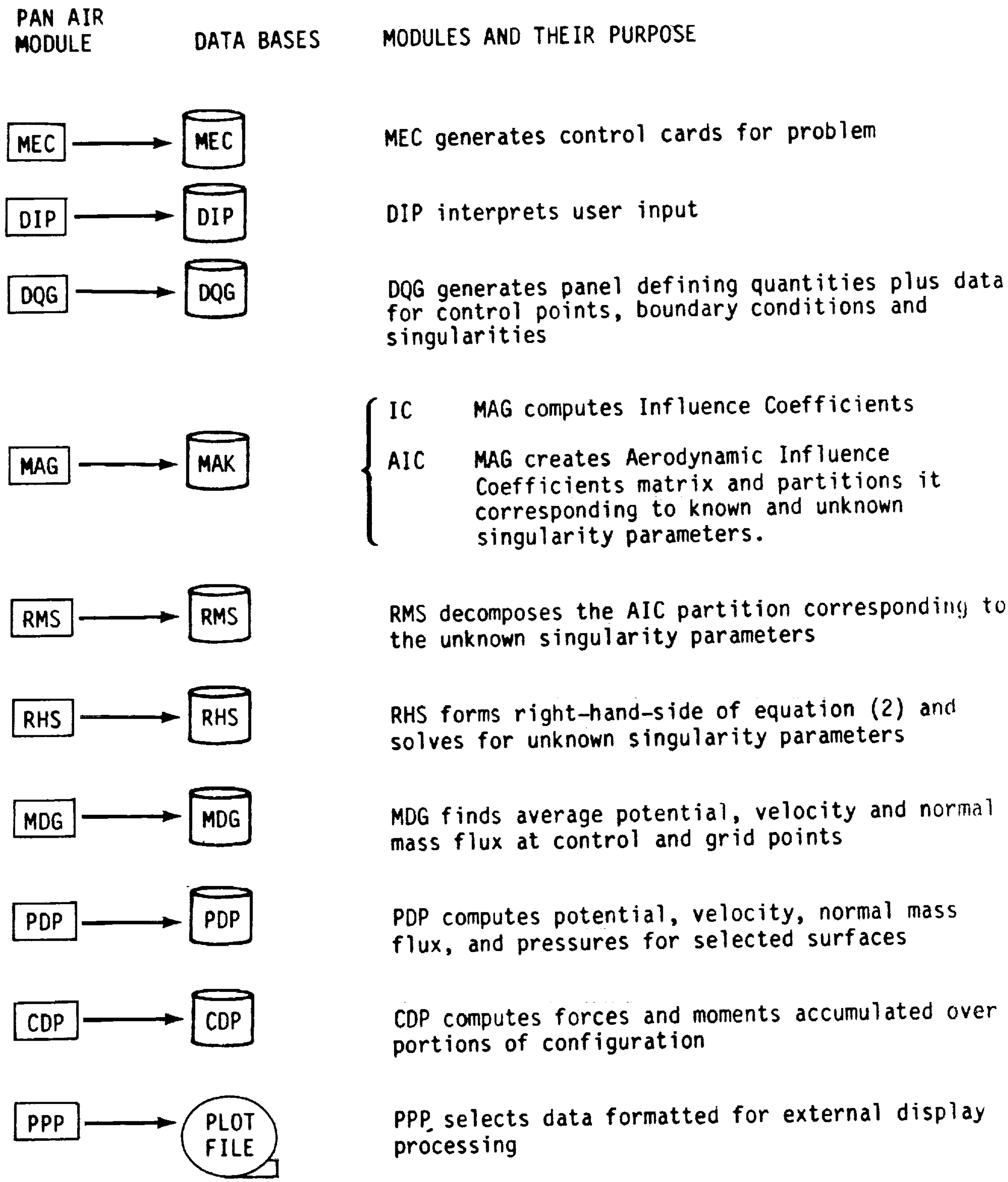
The PAN AIR software will run on the Control Data 6600, 7600, and CYBER 170 series computer systems. Operating systems of NOS 1, NOS/BE, SCOPE 2.1 and SCOPE 3.4 are all accommodated. All modules are designed to use 130000 octal words or less of core storage. However, the MAG module will run more efficiently for large problems if a larger amount of core storage is made available.

4.3.2 CPU Time Requirements

The CPU time requirements will vary from problem to problem and with the particular computer installation. Also, the number of output and run options will influence the estimates greatly for some of the modules. Table 4.1 indicates PAN AIR version 1.0 CPU times obtained from typical problems run on the NASA Ames 7600 computer. It is seen that the MAG module accounts for most of the time of a run. Improvements in the code are currently being made to reduce the CPU times.

4.3.3 Disk Storage Requirements

The disk storage requirements will vary greatly for some of the modules depending upon the user requested output. The modules PDP and CDP produce most of the output data. This, in turn, requires disk storage for data bases prior to the output of the data. Table 4.2 indicates PAN AIR version 1.0 (NASA Ames 7600 computer) disk storage used by typical problems for a reasonable amount of output data.



PAN AIR MODULE	DATA BASES	MODULES AND THEIR PURPOSE
MEC	MEC	MEC generates control cards for problem
DIP	DIP	DIP interprets user input
DQG	DQG	DQG generates panel defining quantities plus data for control points, boundary conditions and singularities
MAG	MAK	IC MAG computes Influence Coefficients AIC MAG creates Aerodynamic Influence Coefficients matrix and partitions it corresponding to known and unknown singularity parameters.
RMS	RMS	RMS decomposes the AIC partition corresponding to the unknown singularity parameters
RHS	RHS	RHS forms right-hand-side of equation (2) and solves for unknown singularity parameters
MDG	MDG	MDG finds average potential, velocity and normal mass flux at control and grid points
PDP	PDP	PDP computes potential, velocity, normal mass flux, and pressures for selected surfaces
CDP	CDP	CDP computes forces and moments accumulated over portions of configuration
PPP	PLOT FILE	PPP selects data formatted for external display processing

Figure 4.1 Typical PAN AIR sequence

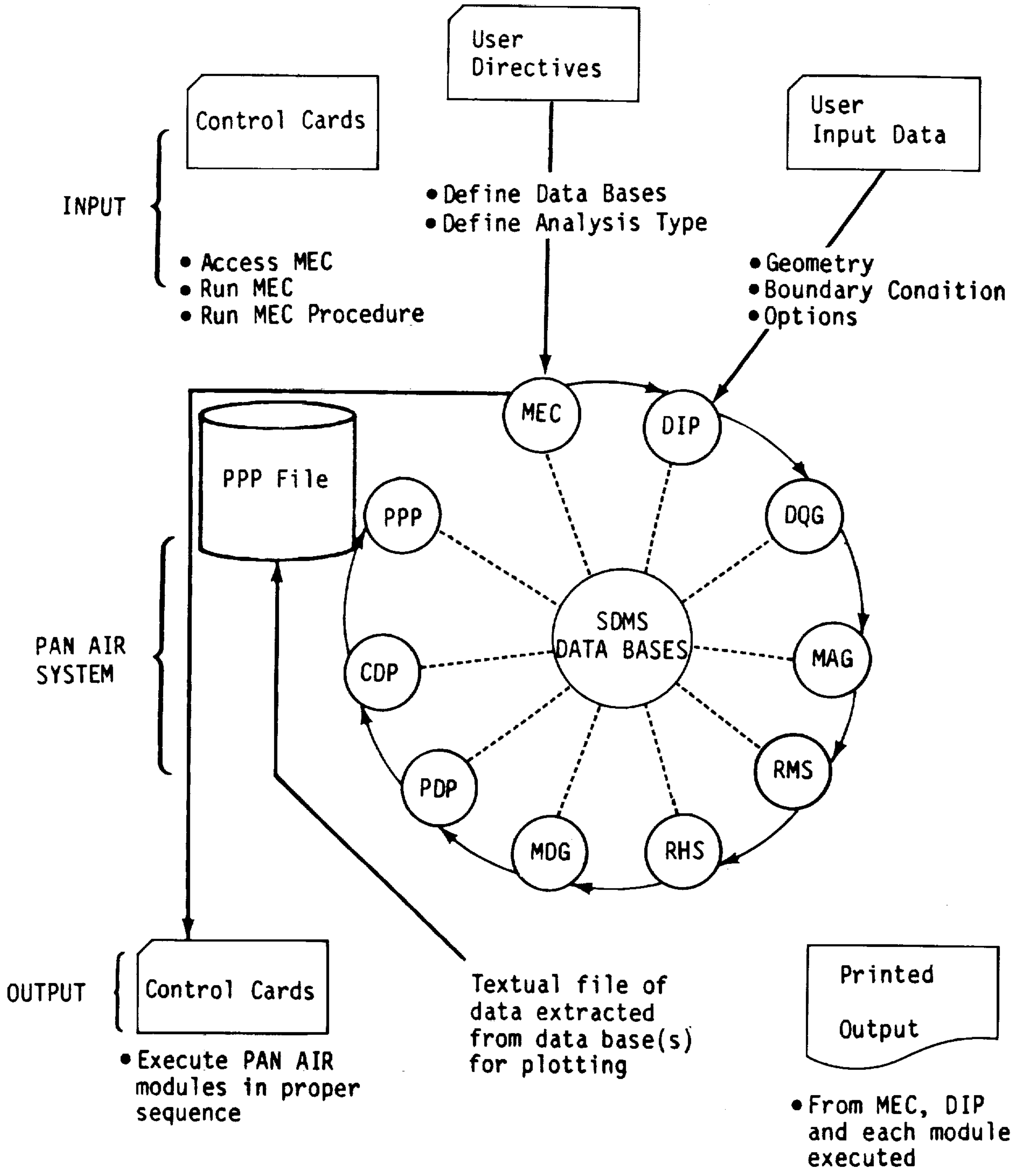


Figure 4.2 PAN AIR data flow

Module \ Problem	110 Panel Thin Wing, Supersonic	257 Panel Wing/Body, Supersonic	172 Panel Thin Wing, Subsonic	258 Panel Nacelle, Supersonic
MEC	.1	.1	.1	.1
DIP	.6	.7	1.0	.8
DQG	18.9	46.7	37.1	44.8
MAG	42.6	198.4	284.8	202.4
RMS	1.5	8.6	5.3	14.7
RHS	2.1	9.1	6.4	11.2
MDG	22.4	20.4	36.0	31.8
PDP	2.7	4.2	9.2	4.7
CDP	3.7	6.6	8.0	7.1
PPP	1.6	2.2	2.3	3.0

Table 4.1 CPU time (seconds)

Module \ Problem	110 Panel Thin Wing, Supersonic	257 Panel Wing/Body, Supersonic	172 Panel Thin Wing, Subsonic	258 Panel Nacelle, Supersonic
DIP	21	23	28	23
DQG	297	696	515	679
MAG	134	270	497	407
RMS	199	134	89	202
RHS	10	45	18	29
MDG	45	96	120	97
PDP	11	17	26	22
CDP	4	7	10	7

Table 4.2 Disk storage requirements (K words)

5.0 PAN AIR Documentation

This Summary Document is one in a series of documents which describe the various aspects of the PAN AIR system. For more detailed information, the reader should refer to the following documents:

The PAN AIR Theory Document. This is written primarily for the mathematician or engineer who wishes to determine the how and why of the PAN AIR technology. The appendices provide a detailed treatment of the higher order panel method theory and the mathematics which are behind the computer code.

The PAN AIR User's Manual. This is aimed at the user or potential user of PAN AIR and provides a description of system capabilities, a treatment of flow modelling techniques, instructions on system usage, a detailed listing of input parameters, and specimen output formats.

The PAN AIR Case Manual. This is a compendium of problems that have been solved using PAN AIR. It is intended primarily as a source of examples of PAN AIR usage from which the user or potential user can quickly learn how to set up a model for his own problem.

The PAN AIR Maintenance Document. This document provides the functional decompositions, data flow and other information for the PAN AIR modules. It is intended for the programmer/analyst assigned to PAN AIR maintenance. The decomposition of the system is carried out down to the subroutine level.

Besides the material described above, each document contains either one or both of two PAN AIR common Glossaries. These provide an explanation of PAN AIR terminology. They also reference the documents and sections where the particular item of terminology is used. The first is the Engineering Glossary, devoted to the engineering, aerodynamic and mathematical terminology used in PAN AIR. This glossary appears in the Theory Document and the User's Manual. The second is the Software Glossary which deals with computing terminology. It appears in the User's Manual and the Maintenance Document.

6.0 Recommendations for the New User

For the potential user who is a complete newcomer, section 2.0 of this document is recommended as a first step. This gives an overview of the system's capabilities together with examples of possible applications, and should provide an answer as to whether PAN AIR is applicable to the individual's particular problem. An elaboration of this material appears in section 2.0 of the User's Manual.

Reference 10 is recommended as an introduction to the theoretical and numerical approaches used in PAN AIR, and to PAN AIR modeling techniques.

If the user is interested in getting "up to speed" fairly quickly, he should consult the Beginner's Guide, section 3.0 of the User's Manual. This describes standard aerodynamic analysis problems and includes a simple example problem complete with its input records and an explanation of each record. His next step should be to consult the PAN AIR Case Manual to determine whether an analysis similar to his particular problem is documented therein. This process is facilitated by the "Directory of Cases" section of the Case Manual which lists the individual example cases and provides a string of keywords for each case. Once the user has located an example case similar to his particular problem, he can use the input deck listing as a guide for his own inputs. He may then wish to synthesize a small exercise problem consisting of relatively few panels and networks in order to gain "hands-on" experience.

Construction of the input deck should be performed in conjunction with section 7.0 of the User's Manual, which provides a listing and explanation of all input records. Many of these records are not mandatory, being defaulted to standard values by the system for many common applications. Other records, relating to boundary condition specification, need or need not appear in the input listing depending on the complexity of the boundary conditions as defined by a "boundary condition classification system." This classification system is summarized in sections 3.3 and B.3 of the User's Manual. To take full advantage of the general boundary condition capability, the user must understand the jump properties of source and doublet panels and the requirements for well-posed boundary value problems. These are discussed in appendix A of the User's Manual.

If the user is not pressed by schedule, he should familiarize himself with the remaining sections of the User's Manual, and read the "body" of the Theory Document for additional background material.

Once the input deck has been assembled, the system's data checking and diagnostic capabilities should be used. This can be performed by inserting a "CHECK DATA" command into the executive instruction portion of the input deck (see section 3.3.1 of this document and section 6 of the User's Manual) and then submitting the job for processing. Since the data check process terminates only in the event of a major error, several lesser errors can be diagnosed and disclosed in each submission, leading to rapid check out of the input deck.

In conjunction with the checking of the logic and consistency of the inputs, the geometric correctness of the configuration panel arrangement should also be verified. This is best performed during the data check process by requesting creation of a file containing the configuration panel geometry. This file can be used to display the geometry, using programs external to PAN AIR. More details on this process are contained in section 7.7 of the User's Manual.

The programmer/analyst should start with this, the Summary Document. In particular, section 4 will provide him with overview information on the program modules of the PAN AIR system, the data bases used, the data flow, computer system environment, typical run times and disk storage requirements. The system architecture and usage are discussed in sections 4 and 5 of the User's Manual. The modules of the PAN AIR program are described in detail in the Maintenance Document.

7.0 Acknowledgements

The development of the PAN AIR system was and is a team effort involving engineers, mathematicians, computer scientists and managerial and secretarial personnel. Many of these people were not "in the limelight" during system development, but it is because of their professional efforts and expertise that PAN AIR is now a fact. We hereby acknowledge the contributions of the following individuals.

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Glen N. Bates - Assistant Project Manager, development phase

Gary R. Bills - Preliminary design of RMS module

Pat Bradley - Typing and administrative work, librarian for PAN AIR documents

John E. Bussoletti - Design and implementation of DQG module, portions of MDG module, system validation

David T. Chiang - Testing and validation of DQG module, system validation, documentation and configuration control

Richard E. Clemmons - Lead Analyst during system design phase, preliminary system design

Kathleen J. Crites - Typing and secretarial work

Thomas Derbyshire - Lead Engineer during system design phase, Summary Document, engineering documentation coordination

Lawrence C. Dickmann - Design and implementation of MDG module, preliminary design of post-processing functions

F. Edward Ehlers - Development of supersonic technology, specifications for CDP program

Michael A. Epton - Mathematics of panel influence coefficients, system validation, Theory Document

Babarinde Harrison - Design and implementation of CDP module

Gary R. Hink - Assistant Project Manager during later part of development phase

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Paul B. Liebelt - Lead Analyst during later part of development phase, detailed design of MEC program, documentation coordination

Wen Fan Lin - Specifications and validation plan for PDP module

E. Kris Loodus - Testing and validation procedures, design and implementation of portions of DQG module

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William A. Massena - Design and implementation of SDMS

Richard T. Medan - Editor of PAN AIR Case Manual, PAN AIR user's classes, Lead Analyst sustaining phase

Franklin D. Nelson - Design and implementation of DIP module

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Deborah J. Roll - Adminstrative assistant during development phase

Paul E. Rubbert - Program Manager

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8.0 References

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Volume II, User's Manual (Version 1.0), by K. W. Sidwell, P. K. Baruah, and J. E. Bussoletti, NASA CR-3252, 1980.

Volume III, Case Manual (Version 1.0), by R. T. Medan (editor), A. E. Magnus, K. W. Sidwell and M. A. Epton, NASA CR-3253, 1981.

Volume IV, Maintenance Document (Version 1.0), by P. K. Baruah, et. al., NASA CR-3254, 1980.

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16. Abstract

PAN AIR is a system of computer programs for the aerodynamic analysis and non-iterative design of nearly arbitrary configurations in subsonic and supersonic flows. This report provides a brief description of the capabilities and limitations of the program system. The wide variety of modeling features provided by PAN AIR is summarized. The computer program configuration and the documentation are also described, together with recommendations for the beginning user.

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