

# Chapter 1

## INTRODUCTION

This manual describes the use of WAMIT (Version 6.4). This program exists in the standard source-code form, designated as ‘V6.4’, and in the PC-executable version ‘V6.4PC’ which is logically equivalent to ‘V6.4’. A chapter concerning the use of the second-order extension ‘V6.4S’ is included for completeness. V6.4S includes the analysis for the second-order solution in bichromatic and bidirectional waves, including sum- and difference-frequency components.

V6.4 is a radiation/diffraction panel program developed for the linear analysis of the interaction of surface waves with offshore structures. A major feature of V6.0 and higher is the option to use a higher-order method based on B-splines to represent the velocity potential and pressure on the body surface, and to represent the geometry of the body surface in various manners. In addition to the conventional low-order panel discretization, these include new options to represent the body surface more accurately and/or with less work.

In V6.1, an option was introduced to link WAMIT with the Relational Geometry Kernel (RGKernel) of the CAD program MultiSurf. With this option MultiSurf can be used to represent a wide variety of body geometries, and the same representation can be input directly in the higher-order solution of WAMIT. With this technique there is no need to approximate the geometry or to prepare extensive input files. (To take advantage of this approach the user must license MultiSurf and special .DLL files in addition to the standard WAMIT software.)

Starting in V6.2, a separate utility program, F2T (Frequency-to-Time domain), has been provided. F2T evaluates time-domain impulse-response functions (IRF’s), from the outputs of WAMIT. IRF’s can be evaluated for any combinations of linear outputs options 1-7 described in Chapter 4. IRF’s may be useful for the time-domain simulation based on the linear hydrodynamic loads and other nonlinear constraints or excitations.

The execution of WAMIT has been simplified relative to earlier versions where two main programs (‘POTEN’ and ‘FORCE’) were invoked sequentially. In Version 6.0 and higher only one main program ‘WAMIT’ is used, with options to control the separate functions of the earlier two programs in the most effective manner for each application.

The remainder of this Chapter gives a general description of WAMIT Version 6.4 and changes made from earlier versions. Users of earlier versions should refer particularly to Sections 1.2 to 1.6 concerning changes and extensions introduced in Versions 6.0, 6.1, 6.2, 6.3 and 6.4, respectively. A mark in the left margin, as on this line, is used throughout this User Manual to call attention to changes in Version 6.4.

The description and use of WAMIT for both the low-order and higher-order methods of solution has been unified as much as possible. Most but not all of the input and output files are ‘generic’, applicable to both methods in the same form. The principal exception is the Geometric Data File, which specifies the geometry of the body surface. To simplify the understanding and use of this User Manual, chapters are organized separately for generic information common to both methods, and for specific information which refers to either the low- or higher-order method separately.

In Chapter 2 a tutorial description is given to help the user get started using WAMIT in the PC environment. Source-code users may also benefit by reading this tutorial, or following the indicated examples on a PC. The examples described in Chapter 2 are for the simplest context of a single body.

Chapter 3 gives more detailed information regarding the generic input files, including the Potential Control File (POT) and Force Control File (FRC) which specify the principal non-geometric inputs for WAMIT. Also described in this Chapter are the optional files FNAMES.WAM and CONFIG.WAM, which are useful to specify input filenames and to specify various options.

Chapter 4 defines the various quantities which can be evaluated by WAMIT, and which are contained in the output files.

Chapter 5 describes special topics which are relevant only to the low-order method. This includes the Geometric Data File (GDF), which defines the coordinates of panel vertices, the use of the source formulation to evaluate the fluid velocity and second-order mean pressure on the body surface, the analysis of a body in the presence of vertical walls, and the analysis of bodies with thin elements such as damping plates or strakes.

Chapter 6 describes special topics which are relevant only to the higher-order method, including the subdivision used to represent the body surface and velocity potential on this surface, and the representation of the potential in terms of B-splines. Alternative methods for defining the body geometry are described including the use of low-order panels, the use of B-splines to provide a higher-order continuous definition, the use of explicit analytical formulae, and the use of MultiSurf geometry files. Starting with V6.2 WAMIT permits ‘dipole patches’ to represent thin submerged elements and their use is described in Section 6.10.

Chapters 7-9, which are generic, describe the use of extended features in WAMIT. These include the analysis of multiple interacting bodies (Chapter 7), the use of generalized modes of body motion which can be used to describe structural deformations, motions of hinged bodies, etc. (Chapter 8), and the use of a method to remove the effect of the irregular frequencies (Chapter 9).

Chapter 10 describes the relationships between memory requirements, numbers of un-

knowns, and input parameters, to provide a qualitative basis for estimating the requirements for RAM and hard disk storage, and for estimating run times. This Chapter also outlines the procedure for modification and use of .dll files, which can be used in Version 6 to describe the geometry and generalized modes.

Chapter 11 describes the second-order module V6.4S, including descriptions of the additional input files and definitions of the additional outputs.

A brief outline for the theoretical basis of WAMIT is presented in Chapter 12. Reference 26 contains a more complete review of the pertinent theory.

Chapter 13 describes the utility F2T (Frequency-to-Time domain) which can be used to transform the linear WAMIT outputs to the corresponding time-domain impulse-response functions.

Chapter 14 describes the procedure for evaluating the mean drift forces and moments by integration of the momentum flux on a control surface which surrounds the body surface in the fluid.

A list of pertinent references and descriptions of the test runs are appended.

## **1.1 WAMIT Version 6**

WAMIT is a radiation/diffraction program developed for the analysis of the interaction of surface waves with offshore structures. WAMIT is based on a three-dimensional panel method, following the theory which is outlined in Chapter 12. The main program consists of two top-level sub-programs POTEN and FORCE which evaluate the velocity potentials and desired hydrodynamic parameters, respectively. The water depth can be infinite or finite, and either one or multiple interacting bodies can be analyzed. The bodies may be located on the free surface, submerged, or mounted on the sea bottom. A variety of options permit the dynamic analysis of bodies which are freely floating, restrained, or fixed in position.

The flow is assumed to be ideal and time-harmonic. The free-surface condition is linearized (except in Version 6.1S where the second-order free-surface condition and body boundary conditions are imposed). We refer to this as the ‘linear’ or ‘first-order’ analysis. Mean second-order forces are included in this analysis, since they can be computed rigorously from the linear solution.

The radiation and diffraction velocity potentials on the body wetted surface are determined from the solution of an integral equation obtained by using Green’s theorem with the free-surface source-potential as the Green function.

All earlier versions of WAMIT were based strictly on the low-order panel method, where the geometric form of the submerged body surface is defined by flat quadrilateral elements (low-order panels), and the solutions for the velocity potential and/or source strength are assumed constant on each panel. WAMIT Version 6 has been extended to include the complementary higher-order panel method based on a continuous B-spline representation for the velocity potential, and several alternative schemes for defining the body surface

including explicit analytic formulae. The order of the B-splines is controlled by user-specified input parameters.

The two different uses of the word *order* should be noted to avoid confusion. Following the usual conventions of marine hydrodynamics, *first-order* and *second-order* are always used here to refer to linearization of the boundary conditions and solution, whereas *low-order* and *higher-order* are used to refer to the method for representation of the body surface and solution.

The following quantities can be evaluated by WAMIT Version 6.4:

- Hydrostatic coefficients
- Added-mass and damping coefficients for all modes
- Added-mass coefficients for the limiting cases of zero or infinite wave periods
- Wave exciting forces and moments using the Haskind relations, or directly by pressure-integration from the solutions of the diffraction or scattering problems.
- Motion amplitudes and phases for a freely-floating body
- Forces restraining a body which is freely-floating in some but not all modes
- Hydrodynamic pressure and fluid velocity on the body surface
- Hydrodynamic pressure and fluid velocity in the fluid domain
- Free-surface elevation
- Horizontal drift forces and mean yaw moment by momentum integration
- All quantities listed above for user-specified generalized modes
- All components of the drift force and moment by pressure integration
- Drift force and moment in bidirectional waves

The following additional quantities can be evaluated by WAMIT Version 6.3S:

- Second-order forces on fixed or floating bodies
- Second-order pressure on the body surface
- Second-order pressure force on the waterline
- Second-order pressure in the fluid domain
- Second-order free-surface elevation
- Second-order motion amplitude on floating bodies

Two, one or no planes of geometric symmetry may be present. Part or all of the rigid-body modes can be analyzed. The program is designed to optimize the use of the available storage and minimize the computational effort for the specified planes of symmetry and modes. Matrix elements that share evaluations of the wave source potential are evaluated simultaneously.

Several techniques have been developed and implemented in WAMIT to improve the accuracy and efficiency of the solution and exploit the capabilities of a wide range of contemporary computing systems, ranging from personal computers to supercomputers. Important features of WAMIT include the use of special algorithms for the evaluation of the free-surface wave-source potential, the option to use direct, iterative, or block-iterative solution algorithms for the complex matrix equation, and the option to use either the low-order or higher-order panel methods. In combination these result in a fast, versatile, and robust code capable of analyzing offshore structures with complicated geometry.

WAMIT is designed to be flexible in its use with a variety of practical applications. It consists of two subprograms, POTEN and FORCE, which normally are run sequentially. POTEN solves for the radiation and diffraction velocity potentials (and source strengths) on the body surface for the specified modes, frequencies and wave headings. FORCE computes global quantities including the hydrodynamic coefficients, motions, and first- and second-order forces. Velocities and pressures on the body surface are evaluated by FORCE. Additional field data may also be evaluated by FORCE, including velocities and pressures at specified positions in the fluid domain and wave elevations on the free surface. Since the principal computational burden is in POTEN, the intermediate output data from this subprogram is saved in a binary ‘P2F’ file. Thus it is possible to make several runs with FORCE, varying the requested parameters to be output, without re-running POTEN in each instance. (V6.4S is an exception where the computational burden in FORCE can be greater than that in POTEN.)

In Version 6 the separate functions of POTEN and FORCE have been integrated into a single main program WAMIT, for ease of use. This differs from all prior versions where two separate main programs were employed. The use of Version 6 is initiated in all cases by executing the single command ‘WAMIT’. This integration simplifies the use of WAMIT in typical applications where POTEN and FORCE are required sequentially, and options can be specified in the configuration file to perform separate runs of either subprogram, as explained in Chapter 2 and in Section 3.7.

Figure 1.1 shows the architecture of the two subprograms and the principal input/output files. (For simplification this figure does not include additional input files required for the case of multiple bodies, the optional spline control file which may be used to vary B-spline parameters in the higher-order analysis, additional input files which are required for the second-order analysis program V6.4S, and three output files which log errors, warnings, and other auxiliary data.)

The analysis for the generalized modes also requires an additional input file or special subroutine, to define the user-specified modes. Figure 9.1 in Chapter 9 shows the flow chart of POTEN for this case.

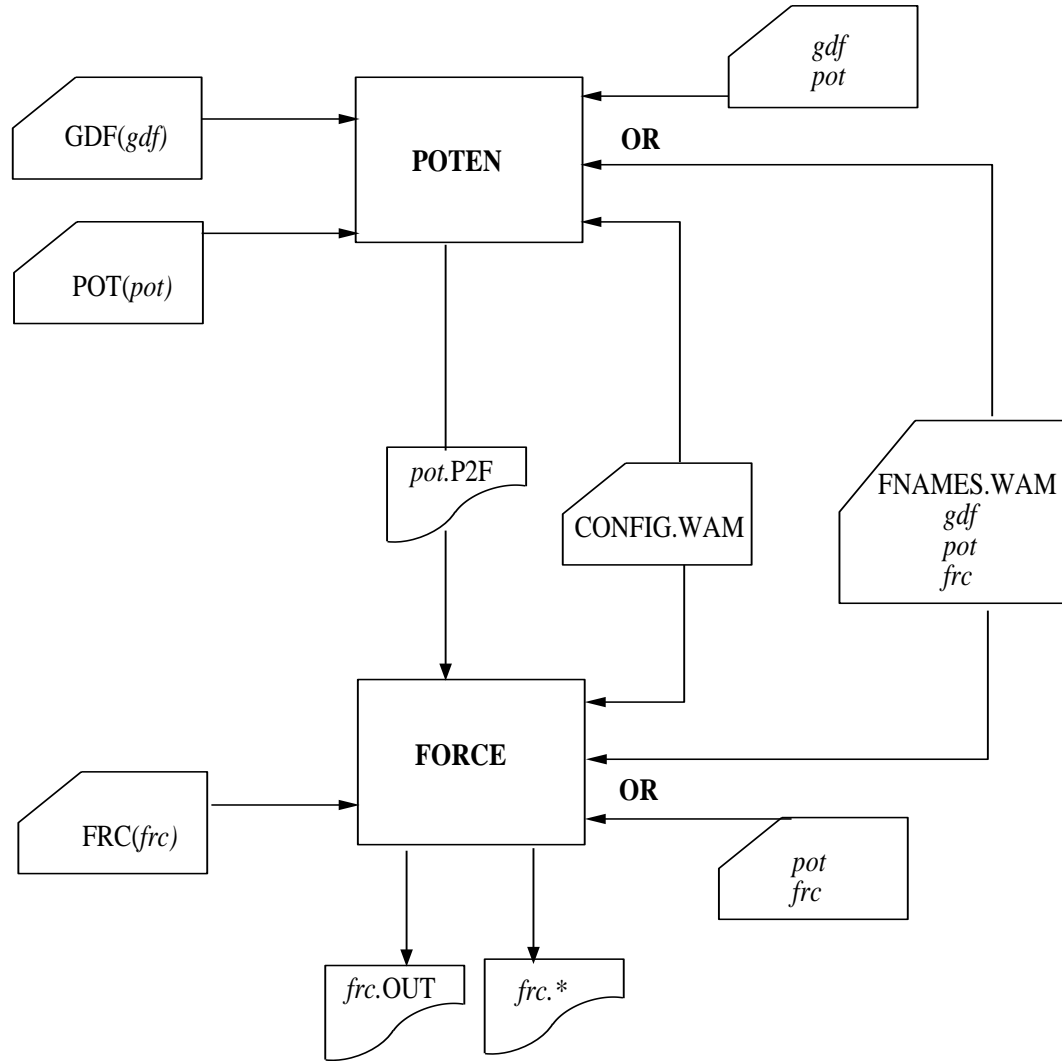


Figure 1.1: Flow chart of WAMIT showing the subprograms POTEN and FORCE with their associated input and output files. Filenames in italics are specified by the user. The three primary input files described in Chapters 3, 5, and 6 are indicated in the left-hand column. The names of these files are prescribed either by the optional file FNames.WAM, or by the interactive inputs represented by the top and bottom arrows in the right-hand column. Note that the P2F file output from POTEN is given the same filename as the input control file, with the extension P2F. The output file from FORCE is given the same filename as the force control file, with the extension OUT. The P2F file may be saved and reused for various applications of the FORCE module where the same velocity potentials apply. Asterisks (\*) denote the extensions corresponding to each option in the numeric output files, as listed in the table in Section 3.3.

WAMIT Version 6 is written in FORTRAN-90 (ANSI/ISO Standard) and has been tested on a wide variety of contemporary computer systems. The subroutine DATTIM, which is used to set the date and time of the run, uses a generic F-90 intrinsic function and no longer requires modification of the source code for use on different systems. The only non-standard extension which has been retained from previous versions of WAMIT is the dollar-sign prompt '\$', which facilitates interactive data input. Source-code users who are not able to use this extension should remove the symbol \$ by editing the source file RDFILESC.F.

The source code of WAMIT assumes the use of a PC-based Windows/DOS operating system. 'README.TXT' contains information regarding system requirements and configuration to run the PC-executable version of WAMIT. Appropriate modifications of the source code may be necessary for all other compilers.

## 1.2 CHANGES INTRODUCED IN Version 6.0

In relation to WAMIT Version 5.4, new features which affect the use of Version 6 are outlined below. For users familiar with versions of WAMIT prior to V5.4, and earlier versions of the higher-order code HIPAN, additional changes are also listed below. More detailed information is provided in the subsequent chapters as indicated.

- The main program WAMIT includes POTEN and FORCE as subprograms.
- The new input parameter ILOWHI has been added to control the use of the low- or higher-order panel methods.
- Alternative options have been introduced to specify the input filenames.
- Faster algorithms have been implemented to reduce redundant evaluations of the Green function.
- In the low-order method, some or all of the body panels can be defined to represent thin plates or appendages of small thickness, such as damper plates or strakes.
- For generalized modes the mode shapes can be specified in a separate .dll file.
- In the higher-order method the geometry can be specified by B-splines, explicit algorithms, or flat panels.
- Explicit algorithms to specify the geometry can be included in a .dll file, and related body dimensions can be specified in the .gdf input file. Several different generic types of bodies can be analyzed simply by inputting the relevant dimensions, without the effort required to prepare a conventional panelization.
- New parameters IALTPOT and IALTFRC have been included to provide a more unified and flexible range of input formats.
- Version 6.0PC has been compiled with the Compaq Digital Fortran compiler, optimized for use on PC systems with the Pentium CPU.

In relation to WAMIT Version 5.3, additional new features which were incorporated in Version 5.4 also apply to Version 6.0 as outlined below.

- All restrictions on the maximum number of inputs are removed. In V6.0 all of the relevant arrays are dimensioned at run time. In practice there may be practical limitations, e.g. regarding the number of panels, depending on the memory and disk capacity of the hardware and on the run time, but these limits will generally be much larger than in earlier versions.
- A new direct-solver subroutine has been utilized. This substantially reduces the run time when the direct solution method (ISOLVE=1) or block-iteration (ISOLVE>1) are used.
- The PC-executable code is compiled in a generic form for all licensed users, and specific licensees are identified by including a special binary input file **userid.wam**. This file must be available for input during the WAMIT runs. Provision has been made in the **config.wam** file to permit users to access this input file from a specified sub-directory, as explained in Section 3.9; this option avoids the need to copy **userid.wam** to all directories where WAMIT is used.
- Provision has been made in the configuration file (**config.wam** or **\*.cfg**) to permit users to specify a different sub-directory or drive for scratch storage of large arrays, as explained in Section 3.9. This option effectively doubles the maximum limit on available disk memory for systems with multiple hard drives and/or partitions.
- The warning and error messages have been extended to provide more specific information concerning errors in input files.
- A new optional input array has been added to the .frc control file, as explained in Sections 3.3 and 3.4. This permits the user to specify that some or all of the modes selected in the inputs to POTEN are restrained with zero amplitude, and to re-run the FORCE subprogram alone. (Previously this required re-running POTEN without such modes.)
- Optional output files can be used to generate low-order GDF files and to generate data files for perspective plots of the panels and/or patches.

In relation to the higher-order code HIPAN Version 2, additional new features which are incorporated in WAMIT Version 6.0 are listed below. These features are described in Chapter 6.

- Options exist to define the B-spline parameters automatically, to achieve a specified maximum panel size.
- Multiple bodies with separate planes of symmetry can be input, with automatic reflection of the geometry.
- In the higher-order method the geometry can be specified by B-splines, explicit algorithms, or flat panels.



- Body geometry for barges and similar structures can be defined using a minimum number of flat quadrilateral elements, with the same input format as for the low-order analysis.
- Explicit algorithms to specify the geometry can be specified in a .dll file and related body dimensions can be specified in the .gdf input file.
- Filenames for the .gdf files and related data can be input either in the .pot file, as in HIPAN, or in the same format as used in earlier versions of WAMIT.

### 1.3 ADDITIONAL CHANGES IN Version 6.1

New features which are included in Version 6.1 are outlined below.

- Arrays of uniformly spaced wave periods and heading angles can be input more compactly in the Potential Control File, by specifying the number, first value, and increment (see Section 3.1).
- The configuration file CONFIG.WAM can be assigned a different filename, defined by the user, with the extension .CFG (see Section 3.7).
- In the higher-order method, the default points for hydrodynamic pressure on the body surface are modified, as described in Section 4.10.
- The hydrodynamic pressure on the body surface can be evaluated at user-specified points  $(x, y, z)$  which are listed in a special input file. This extension, which is available in both the low-order and higher-order solutions, facilitates the integration of WAMIT with structural-analysis codes where the hydrodynamic pressure is required at specified locations. This procedure is described in Section 4.11.
- The separate components of the hydrodynamic pressure on the body surface due to each of the radiation modes and due to the diffraction field can be output separately. This extension is useful for post-processing when the dynamics of the body are modified. This procedure is described in Section 4.12.
- In the higher-order solution method geometry models developed with MultiSurf can be used directly in WAMIT. This procedure is described in Section 6.7.
- One or two additional .dll files are required to run Version 6.1PC (see Sections 2.1 and 6.7)
- The second-order extension has been updated to include both the low-order and higher-order methods of solution, and to include other features of the V6 first-order code. Chapter 11 contains a description of these features.

## 1.4 ADDITIONAL CHANGES IN Version 6.2

New features which are included in Version 6.2 are outlined below.

- Internal tanks with free surfaces can be analysed either separately or coupled with the dynamics of vessels. (See Section 10.7)
- Impulse response functions (IRFs) in the time domain can be evaluated for the output options 1-7 using a utility program F2T. F2T is provided as a separate program along with WAMIT V6.2. F2T converts the outputs of WAMIT into IRFs using Fourier transforms. (See Chapter 13 and TEST 14A in Appendix A14.)
- In addition to the added mass and damping, the pressure and the fluid velocity on the body surface (Option 5) and at the field points (Options 6 and 7) can be evaluated for zero and infinite wave frequencies (Section 3.1).
- The domain of the parameters for B-Splines representing the body surface is no longer limited to  $(-1, 1)$  and B-Splines defined over an arbitrary domain can be accepted. (Section 6.6)
- Zero and infinite frequencies can be specified with  $IRR > 0$  (irregular frequency removal option), which was not permitted in the previous version.  $IRR > 0$  is ignored for these two frequencies. This update enables users to run these frequencies with other frequencies in one execution of WAMIT. (Section 3.1)
- The subroutine FGR0I1, evaluating the Rankine source in two parallel horizontal walls, is extended to calculate double derivatives and renamed as FGR0I2. This extension is necessary to evaluate the fluid velocity at zero and infinite frequencies when  $IOPTION(7)=1$ .
- The separate components of the hydrodynamic pressure and the fluid velocity at the field points due to each of the radiation modes and due to the diffraction field can be output separately. This extension is useful for post-processing when the dynamics of the body are modified. This procedure is described in Section 4.12.
- In the higher-order method, some or all of the body surface can be defined to represent thin structures (see Section 6.10). Similar extension was made in conjunction with the low-order method in V6.0.
- Mean drift forces by pressure integration on the rigid bodies can be evaluated when the generalized modes are used on other bodies in multi-body interaction. This option was not supported in previous versions.
- A new output file `wamitlog.txt` is created during the WAMIT run to provide an archival record of the run, including copies of the principal input files, and various auxiliary information. Further information is provided in Section 10.1.

## 1.5 ADDITIONAL CHANGES IN Version 6.3

New features which are included in Version 6.3 are outlined below.

- Uniform arrays of field points can be input in a more convenient manner. (See Section 3.10)
- A special option can be used to efficiently analyze the wave field generated by one or more wavemakers situated in planes of symmetry. (See Section 10.8)
- All six components of the mean drift forces and moments can be evaluated from the momentum flux through a control surface surrounding the body.
- A symmetry plane can be used when there are flat dipole elements on the plane of symmetry. (See Section 5.4 and Section 6.10)
- A supplementary output file *out.hst* is created to output the hydrostatic matrix of restoring coefficients, including generalized modes and/or tanks. (See Sections 4.9, 8.4, and 10.7.)
- The DLL library file GEOMXACT has been extended to include several new analytical geometries.
- The DLL library file NEWMODES has been extended to include generalized modes to represent a bank of paddle-type wavemakers, and to represent the vertical modes of a vessel with hinges.

## ■ 1.6 ADDITIONAL CHANGES IN Version 6.4

New features which are included in Version 6.4 are outlined below.

- It is possible to interrupt a run and save the results already computed. (See Section 3.11)
- RAO's can be modified or assigned by the user. (See Section 3.12)
- Improved algorithms are used for automatic discretization of the interior free surface using the option IRR=2 with the lower-order method (ILOWHI=0). (See Section 9.2)
- Automatic discretization of the interior free surface can be performed using the higher-order method (ILOWHI=1). (See Section 9.4)
- Trimmed waterlines can be specified, with prescribed vertical and angular displacement from the original waterline defined in the GDF file. (See Section 10.8)
- Vertical walls can be represented, coinciding with planes of symmetry, with bodies in the fluid domain and wavemakers in the walls. (See Section 10.10)

- Automatic discretization of the control surface surrounding the body can be performed using either the low-order or higher-order method. (See Section 14.5)
- The inputs ISX, ISY, IRR and NPATCH in the input files for each body are available to use in GEOMXACT.DLL subroutines modified by the user. (See Section 6.9)
- The parameter IGENMDS, identifying appropriate subroutines to define generalized modes, may be assigned different values for each body when NBODY>1. (See Section 8.5)
- The parameter IRR, specifying options for irregular-frequency removal, may be assigned different values for each body when NBODY>1. (See Section 3.7 and Chapter 9)
- The filename of the GDF file can be used in NEWMODES.DLL subroutines modified by the user, to relate special input data for generalized modes to the GDF filename. (See Section 8.3)
- The indices of dipole panels or patches, used to represent zero-thickness elements, can be input either in the GDF file, as in previous versions, or with greater flexibility in the CFG file. (See Sections 3.7, 5.4 and 6.10)
- The MultiSurf interface can be used to generate and output low-order GDF files. This procedure is described in Appendix C.
- Extended versions of the DLL files GEOMXACT and NEWMODES can be downloaded from the website [www.wamit.com](http://www.wamit.com). Also available on the website are zip files which contain supplementary test input files and descriptions of these tests, in a format similar to Appendix A.
- Version 6.4PC is compiled using Intel Visual Fortran (IVF), Version 10.1. The executable code runs somewhat faster than earlier versions, which were compiled using Compaq Visual Fortran (CVF). Installation instructions for Version 6.4PC are in Section 2.1 Users can modify and compile the DLL files GEOMXACT and NEWMODES using either IVF or CVF, following the instructions in Section 10.5.