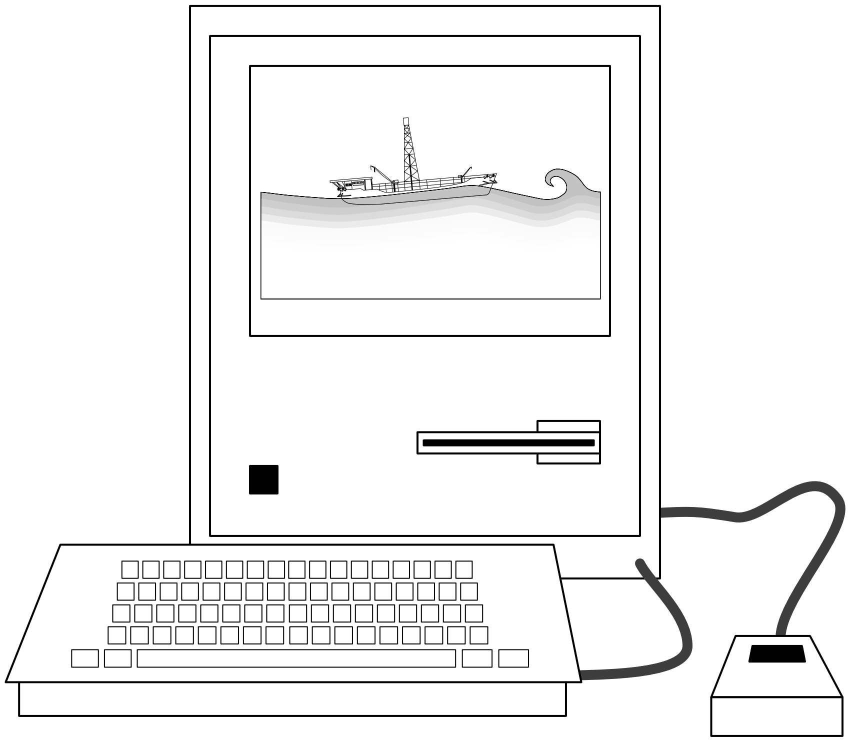
Introducing Shipsim™

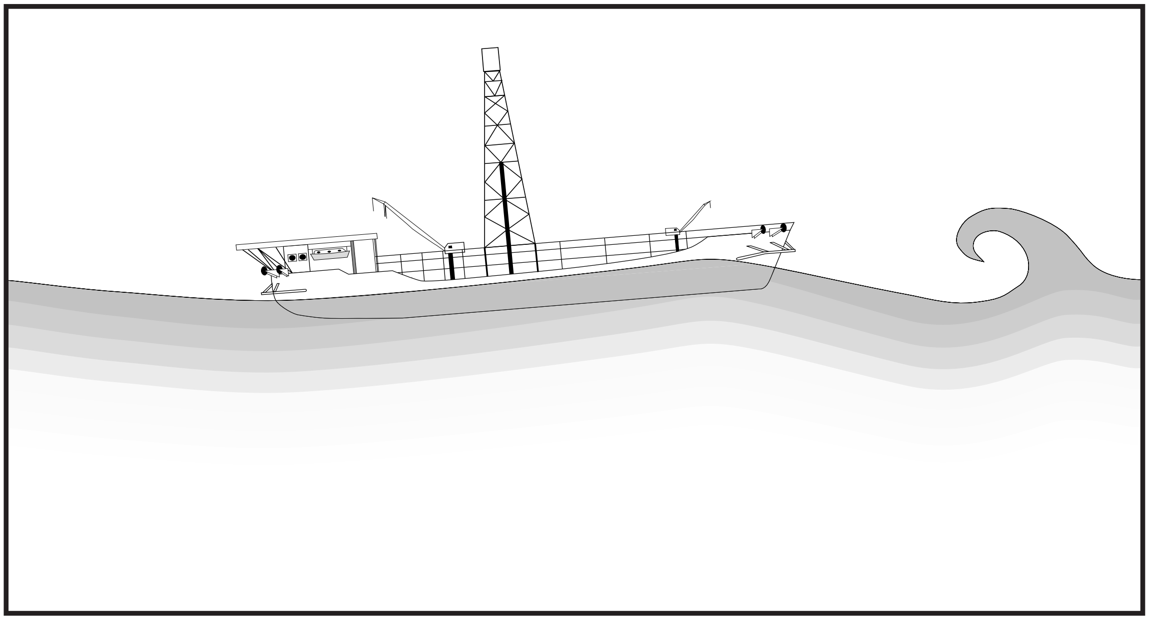
Displacement-Hull Vessel Seakeeping

from SeaSoft® Systems



CONTENTS

Description and Capabilities of Shipsim



Executive Summary

Shipsim is a general-purpose six degree-of-freedom wave-frequency vessel motions program specifically enhanced for displacement-hull vessels with relatively large block coefficients. Vessels in this category include drillships, barges and tankers. **Shipsim** utilizes an efficient algorithm for calculating wave-frequency forces and moments which permits accurate modeling using as input only gross hydrostatic and mass properties (metacentric heights, displacements, overall dimensions, centers of gravity, gyradii, etc.), eliminating the need for tedious and error-prone input of vessel lines details. This typically permits comprehensive executions to be completed in one hour or less. Non-linear effects, particularly in the roll degree of freedom, are fully modeled, leading to realistic roll response predictions which depend on details of bilge geometry. A wide range of environmental conditions is accommodated, including extensive built-in wave spectral types, azimuthal spreading of wave directions and an optional independent background swell. Accelerations, velocities and displacements at any point on the vessel can be computed. Effects of finite water depth are fully modeled and either English or metric units may be selected for vessel specification and data output. Output is in the form of amplitude and phase of vessel Response Amplitude Operators (RAOs) and/or statistical characterizations of vessel response to irregular wave conditions. Execution is carried out in the frequency domain, resulting in short run times and unambiguous predictions of statistical response values.

INTRODUCTION

In the development of **Shipsim**, the principal objective has been to produce a state-of-the-art modeling package accessible to any technically trained individual with a need for the capability. The package is thus oriented specifically towards the practicing marine / offshore engineer and naval architect; the software has been designed so that even a first-time or infrequent user can produce meaningful results. Ease of use represents, second only to program quality, the most important design consideration; this has resulted in a tool which, in the hands of a single individual, can usually produce completed executions "from scratch" in one hour or less, including data input and output report generation.

Scope of the Package

Shipsim is a general-purpose program for estimating wave-frequency loads and motions of displacement-hull vessels of all types. Although designed primarily to accommodate the rather full vessels with large block and prismatic coefficients which are common in the offshore industry, **Shipsim** is sufficiently versatile to be used for modeling of seagoing vessels with finer lines, such as container ships and liners.

Required Vessel Data

Shipsim has been designed to require an absolute minimum of vessel information for its execution; in particular, it is not necessary to be in possession of lines drawings to perform meaningful motion programs. It is necessary, however, to assemble the following minimum hydrostatic and mass distribution information: Displacement, transverse and longitudinal metacentric heights, vertical centers of gravity and buoyancy, waterplane area, pitch, roll and yaw gyradii, bilge radii and bilge keel detail.

Comparison with Existing Mainframe Codes

Comparisons with model test data show that **Shipsim** produces results comparable in overall quality to the best available mainframe codes in all six degrees of freedom. Indeed, because it is designed to accommodate the most blocky of offshore structures, including those of square plan view, **Shipsim** will generally outperform strip theories of considerable sophistication when models of such structures are involved. **Shipsim**'s results also compare favorably with three-dimensional diffraction programs which require large computation facilities for execution and are prohibitively complex and expensive for all but the simplest programs and most sophisticated users. For example, the complete dynamic analysis of a single loading condition of a rectangular offshore platform in short-crested irregular waves with a broad-banded wave energy spectrum might require two to three hours of computation time on a large mainframe computer. Data preparation and input might require several man-days. In addition, the data input process must be repeated and the program rerun in its entirety for each distinct load line required. The same program can be executed in seconds using **Shipsim** on a modern microcomputer after perhaps twenty minutes of data input. **Shipsim**'s results are quite in accord with these more computationally intensive codes; in all cases they are suitable for both absolute performance estimation and for comparative studies between different vessels in the same environment or the same vessel in different environments.

Comparison with Time-Domain Simulations

In offshore engineering analysis, fundamental dynamical nonlinearities are normally addressed analytically by a brute force attack in the time domain; this need not be the case in general. In fact, accumulated evidence from experienced offshore engineering analysts suggests that this is rarely the most productive procedure and seldom results in a software solution which is usable on a day-to-day basis by engineering staff. Too cumbersome to use and too demanding of computational resources, time-domain simulations are characterized by voluminous output streams and difficult-to-interpret results; they are unlikely to find a permanent place in the "engineers toolbox".

(An Aside on Mooring Analyses)

With regard to the role of time domain analysis for wave-frequency vessel motion studies, we would note that such motion studies are frequently undertaken in conjunction with analyses of mooring system dynamics. Although most would agree that wave-frequency vessel motion analysis is better carried out in the frequency domain for day-to-day applications, many would argue that a comprehensive mooring analysis, which involves both wave-frequency and low-frequency dynamical considerations, should be carried out in the time domain because of the inherent nonlinear characteristics of these systems. However, many of the most important features of moored vessel dynamics cannot in fact be adequately addressed in a time-domain simulation. For example, in the analysis of moored vessels in deep water, it is not uncommon to find natural periods of surge, sway and yaw of order 10 minutes or more. Even in shallow water, single point mooring systems often have natural periods of sway / yaw motions exceeding 20 minutes. In order to obtain meaningful statistical information on the low-frequency component of mooring system motions and loads under these conditions, one should simulate at least 20 cycles of low-frequency motion, and preferably 50 to 100 cycles since the nonlinearity of the processes formally precludes inferring the probability distribution for mooring loads and other dynamical variables from a short time history. (By contrast, linear systems excited by Gaussian input variables can be characterized by a relatively short time history since only the rms amplitudes of the output variables need be determined to completely specify the Gaussian output probability distributions). Clearly, time-domain simulation of 3 to 20 prototype-scale hours of a system as complex as a spread-moored vessel in deep water is out of the question for day-to-day engineering practice, even on the next generation of supercomputers. These problems are much more sensibly treated according to nonlinear approximation methods applicable to narrow-banded spectral processes that bypass entirely the time-domain approach in favor of the solution of nonlinear quasi-periodic systems. There is therefore no rational argument for choosing a time-domain simulation of wave-frequency vessel motions in a stand-alone program OR as a subset of a more comprehensive mooring analysis.

GENERAL FEATURES

Shipsim shares with all **SeaSoft** program packages the following general features and capabilities:

• Input / output of data in either English or metric units.

• Complete six-degree-of-freedom motion and load analysis and estimation of acceleration, velocity or displacement response at any point on the vessel. The latter ability facilitates many important engineering calculations. For example:

❖ dynamic mooring loads due to fairlead motions

❖ motions relative to a fixed platform or crane load

❖ deck-fixed accelerations at cargo anchor points

❖ relative water-surface / vessel air gap variations

• Attractive formatted tabular output on 8-1 / 2 x 11 inch sheets for easy inclusion in reports or other documentation.

• Transportability to virtually any computer, achieved by careful adherence to ANSI FORTRAN-77 standards in source code preparation. All code has been carefully optimized to execute efficiently on microcomputers.

• Output control, allowing user selection of output variables for each run and specification of output device (console, printer or magnetic media).

• Complete control over water depth, with full accommodation of shallow-water wave effects which generally become significant in water less than 300 feet deep whenever wave periods exceed about 14 seconds or when wind-driven seas exceed a significant wave height of about 30 feet.

• Interface to **SeaSoft**'s universal plotting routine to produce x-y point plots of selected tabular data.

• A comprehensive user manual which outlines program use and explains in detail its capabilities. The manual contains a detailed sample input / output session comprising a realistic application. The manual includes a table of contents and an index.

• A data entry and editing interface (the "editor") which provides simplified access to the main computational program. The editor permits input files, once created, to be easily modified to account for major or minor changes or errors. The editor program utilizes an easy-to-use single-item replacement format for data entry and update. Input files can be archived and reused any number of times. Backup files are made each time an input file is modified, facilitating the archival process and protecting against inadvertent loss of important data. Built-in "help" menus reduce the need for user manual reference. Insofar as possible, **Shipsim** uses the same input / output format, procedures and nomenclature conventions as other **SeaSoft** programs so that the user of any other program will easily be able to use and interpret **Shipsim** procedures and results.

Shipsim shares with all **SeaSoft** program packages the following *REGULAR WAVE* capabilities:

• Complete user control over regular wave periods, directions, and wave heights or slopes used in calculation of regular wave response characteristics (RAOs).

• Output of both amplitude and phase of regular wave response characteristics for all requested regular wave conditions and all requested output variables.

• In addition, **Shipsim** features user control over the regular wave output stream allowing suppression or inclusion of:

❖ Regular wave motion response for any or all six degrees of freedom.

❖ Acceleration, velocity or displacement response characteristics at user-specified points on the vessel.

❖ Net regular wave force / moment responses for any or all six degrees of freedom.

Shipsim produces wave-height dependent RAOs, reflecting important system nonlinearities.

Shipsim shares with all **SeaSoft** program packages the following *IRREGULAR WAVE* capabilities:

• Wave spectral type specification, including:

❖ Pierson-Moskowitz

❖ Mean, Sharp, Very Sharp JONSWAP

❖ Bretschneider / ISSC

❖ User-Specified

• Calculation of r.m.s. values, r.m.s. rates and characteristic spectral periods of all requested variables.

• Specification of the degree of azimuthal spreading of irregular wave energy; i.e., the degree of wave crest shortening due to cross seas, leading to modeling of operations in short-crested irregular waves.

• Specification of simultaneous swell (period, height, direction).

• Calculation of "air-gap" statistics at any point on the vessel to estimate wave clearance characteristics.

PROGRAM PACKAGE CONTENTS

The **Shipsim** package comprises the users manual, the machine-executable program units, and support services provided by **SeaSoft**. The latter include bug reports, corrections and support for problems encountered during execution of **Shipsim**.

Editor

The Editor module is used to create an input data file which is required for execution of the program. This input file contains physical information necessary for the program such as water depths, vessel physical characteristics, and so on. The file results from an interactive session between the user and the Editor. The Editor can also be used to modify any previously created input data file, which will be necessary if the vessel characteristics or site or environmental characteristics need to be changed prior to another execution of the program.

Executor

The Executoris the heart of the **Shipsim** package. It carries out all computations requested during input file creation and prepares formatted tabular output containing results of the run. The formatted output will be transmitted to the console, the print device, or to a formatted output file according to instructions given by the user during preparation of the input file.

Users Manual

The users manual constitutes the major tutorial tool provided with the program package. The manual includes an extensive glossary and an index, which, along with the table of contents, permits quick location of specific topics.

Support Services

SeaSoft provides software maintenance and support services at no cost for a six month period following license purchase and on a contractual basis thereafter; support is generally included in the lease fee for software lease agreements.

INPUT FILE PREPARATION

For its execution, **Shipsim** requires data of three distinct generic types: (1) site data consisting of water depth and water density, (2) physical data on the mass and geometrical properties of the vessel and (3) environmental data comprising principally regular and irregular wave conditions desired for the execution.

Site Data and Units of Measure

The characteristics of the site chosen for the execution must be available to the program; these are site water depth and water density. Fluid density is completely specifiable so that unusual conditions, such as very high salinity (and hence high density) water, can be easily modeled. The water depth is required so that correct shallow-water wave characteristics will be used in the program. **Shipsim** accounts automatically for all shallow water effects, including wavelength foreshortening and wave speed reduction. The choice of units to be used in the program may be either English (e.g., foot-pound-second) or metric (meter-kilogram weight-second).

Vessel Data

For purposes of a dynamic model of vessel performance, it is unnecessary to define vessel geometry with the great precision normally associated with hydrostatic evaluation. This state of affairs arises from two distinct facts of life, one physical, the second computational:

1. The physical point: thorough hydrostatic and damage stability evaluation of a vessel requires highly detailed information on the underwater form of the vessel including, for example, complete lines specification and the precise characterization of structures (moon pools, bow / stern configurations, etc.) of dimension small compared to wavelengths of importance for dynamical analysis. Long waves (i.e., long relative to dimensions of sub-vessel structures of the type under discussion), which always play the central role in operational or survival analyses, simply do not "feel" fine details of hull form, which fact results in extreme simplification of data specification for dynamical models such as **Shipsim**.

2. The computational point: even the most sophisticated dynamic models can not be expected to produce better than ten or fifteen percent accuracy across the entire range of vessel and wave conditions of interest. This is a natural consequence of the immense difficulty of the full dynamic problem which is one of a coupled, infinite degree of freedom nonlinear dynamic system comprising vessel and surrounding fluid. In addition, model tests required to provide baseline data are themselves extremely difficult to carry out. Indeed, model test data is rarely, if ever, associated with measurement uncertainties of less than ten to fifteen percent. Therefore a precise definition of vessel geometrical characteristics for the purpose of a dynamic model is unjustified, although it is nonetheless routinely carried out during execution of many mainframe vessel dynamics codes. Hydrostatic analysis, by contrast, is essentially an exact science, being simply an exercise in solid geometry. One is therefore justified in requiring that input data to a hydrostatics program be of high precision.

The vessel data required by **Shipsim** is the minimum necessary to permit faithful modeling of the vessel's dynamic characteristics. This minimum data comprises:

1. Vessel displacement.
2. Longitudinal, transverse metacentric heights.
3. Vertical, longitudinal centers of buoyancy.
4. Vertical, longitudinal centers of gravity.
5. Vessel water-plane area.
6. Pitch, roll and yaw gyradii.
7. Bilge characteristics.
8. Forward speed.

DESCRIPTION OF WAVE TYPES SUPPORTED

The environmental conditions that can be specified for modeling comprise three classes of wave data: regular waves, irregular waves and swell. Because one often finds "cross seas" in which irregular waves from a local weather disturbance are superimposed upon an unrelated swell from a distant storm, **Shipsim** permits specification of either irregular waves or background swell or both.

Regular Wave Characteristics

Regular waves are simply long-crested surface waves of well-defined period. Waves of this type are commonly used in wave basin measurements to determine the RAOs ("Response Amplitude Operators") of a vessel. **Shipsim** begins all runs by calculating, at a user-specified collection of regular wave periods, vessel force, torque and motion response characteristics (i.e., RAOs). The choice of regular wave periods to be used in RAO calculations will depend on whether or not irregular wave performance is to be estimated.

Irregular Wave Characteristics

Irregular waves in nature can be considered a superposition of regular waves of differing periods and directions. In test facilities, however, it is generally not feasible to obtain a spread in wave directions due to the need to generate waves with a single monolithic wavemaker, although some testing facilities do have limited capabilities for generating multi-directional waves. **Shipsim** permits analysis of both types of irregular waves (i.e. short and long crested) so that both model basin tests and open ocean conditions may easily be modeled. The degree of wave-crest shortening due to azimuthal spreading of wave energy is under precise user control.

Many standard irregular wave spectra are built into **Shipsim**, including Bretschneider, Pierson-Moskowitz, and Mean, Sharp and Very Sharp Jonswap. In addition, there is provision for a user-specified spectrum.

Swell Characteristics

Swell is a special class of irregular wave which is important in nature and therefore has been incorporated into **Shipsim**. Swell can be considered a superposition of regular waves of differing, but nearly equal, wave periods all with the same direction (i.e. the frequency spectrum is very narrow banded and the swell is long crested). This type of irregular wave is characterized by the phenomenon of "beats" or "sets" in which one observes clusters of larger waves separated by quieter periods with much smaller waves. Swell is generally associated with relatively long waves from the site of distant weather systems. Irregular seas, by contrast, are normally considered to have developed locally and recently by action of local winds. They therefore have a relatively high content of short-period waves which have not had sufficient time to decay due to dissipative and nonlinear mechanisms or to propagate away from the local area.

The swell spectrum utilized in **Shipsim** is a characteristic narrow-banded spectrum with user-specifiable direction, height and period.

THEORETICAL CONSIDERATIONS

This discussion is intended to give a brief overview of the theoretical basis underlying **Shipsim** and an outline of the considerations involved in choosing which aspects of the physical system to emphasize, and which to de-emphasize, in the mathematical model which forms the underlying structure of **Shipsim**. The general approach to the development of **Shipsim** has been to emphasize performance in the cases of principal interest to the offshore industry. This choice has led to particularizations which favor relatively large block coefficients, prismatic coefficients and beam-to-draft ratios.

Two- and three-dimensional "diffraction theories" comprise the two most common methods for determining hydrodynamic driving forces required for vessel motions calculations. A detailed discussion of these methods goes beyond the scope of these limited comments, but it should be noted that two-dimensional ("strip") theories make use of large length / beam and length / draft ratios and fine bow / stern profiles common to seagoing ship-shaped vessels in an approximate "slender-body" scheme that is compromised for extremely blocky vessels with blunt bow and stern profiles and, unless artificially corrected for end effects, produces erroneous hydrodynamic coefficients in the long-wave limit. Three-dimensional theories are based on a "brute force" calculation of hydrodynamic coefficients using finite-element source-sink calculations that are extremely computer-intensive and unsuitable for day-to-day engineering applications. Programs based on the three-dimensional model are often considered "exact" because they are based on a formal approximation to an unambiguous set of linear governing equations which represent the "exact" dynamics of a vessel interacting with the potential flow of an ideal, inviscid fluid. This view is unjustified in general since these inviscid equations in no way represent the full complexity of the nonlinear coupled hydrodynamic problem. The shortcomings of the linear equations are especially apparent in the pitch / roll degrees of freedom, for which even the most sophisticated linear three-dimensional diffraction treatments must be supplemented to give physically meaningful results.

Wave Period Considerations

Shipsim was designed to give reliable estimates of loads and motions for a wide range of displacement-hull vessels operating in a variety of sea conditions under those circumstances in which the loads and motions are most important. This choice dictates that performance estimates for long period waves take precedence over those for relatively shorter period waves. (For our purposes the dividing line between 'longer' and 'shorter' wave lengths can be taken to be the vessel length.) This central role for longer wave periods arises because of the physical connection between larger waves (and therefore greater motions and loads) and longer wave periods. Briefly, the connection results from the following facts: (1) big waves are generated by high wind speeds; (2) the phase speed of the largest waves produced is directly proportional to wind speed; (3) the phase speed of surface waves increases with wave period; hence higher winds give bigger waves of longer wave period and greater wavelength. For "fully developed" deep-water waves the wave period is proportional to the wind speed while the significant wave height is proportional to the square of the wind speed. Note that because of the monotonic relationship between wave period and wave length for surface gravity waves, "long period" and "long wavelength" are synonymous in this discussion.

Mathematical Model

In order to reduce user workload in program preparation and execution, simplify geometrical specification of the vessel and minimize execution time, the decision was made to take maximum advantage of the powerful simplifications arising naturally out of a long-wave asymptotic approach to vessel dynamics. Intuitively, it is clear that waves of length comparable to or greater than the vessel length do not appreciably "feel" hull geometrical variations, such as fine bow or stern lines or large bilge radii, whose geometrical dimensions are much less than the vessel length and hence very much less than the wavelength. (However, these features can and do effect second-order forces, such as wave drift forces and square-law bilge forces, which are not considered in the calculation of the first-order potential theory hydrodynamic loads under discussion. These second-order phenomena must be handled separately from the potential-flow analysis; for instance, the specification of bilge radius and bilge keel characteristics in **Shipsim** are used in a nonlinear roll response calculation of this type.) To capitalize on the simplifications arising from the long-wave analytical approach, **Shipsim** determines the dimensions of a "dynamically similar box" whose beam, length, draft and mass properties (gyradii and centers of gravity) are chosen to insure that the dynamical properties of the box, especially the important natural periods of roll, pitch and heave, are the same as those of the vessel to be modeled. This procedure evidently is more justifiable for vessels of large block coefficient involved in typical offshore operations than for vessels with very fine lines of the type used in high-speed ocean transport. However, experience has shown that the procedure results in excellent performance estimates even for vessels with block coefficients of .6 and less.

The use of an equivalent box as an aid in determining the hydrodynamic properties of a vessel is of great utility, given the desired emphasis on long-period waves, for three reasons:

1. Extreme simplification of underwater geometry specification. The alternative, which requires tedious input of vessel lines and facets, is error-prone, time-consuming and wholly unnecessary for wave-frequency motion program.

2. The ability to make use of limited, but extremely powerful, analytical results for the three-dimensional added mass and damping properties of simple geometrical shapes in the long period limit. This ability eliminates one of the most objectionable features of strip theories for the analysis of the very blocky vessels common to the offshore industry; namely the unrealistic logarithmic divergence of the sectional heave and pitch added mass coefficients with increasing period of motion.

3. The ability to use analytically exact closed form expressions for the dominant long-wave contributions to the wave forces and torques acting on the body. In order to arrive at the overall driving forces, these dominant long-wave contributions (the so-called Froude-Krilov contributions) are supplemented by frequency-dependent contributions, related to wave diffraction phenomenon, which are associated with hydrodynamic added mass and damping effects. These frequency-dependent modifications to the long-wave contributions are taken from analytical results for various simple underwater shapes.

TYPICAL APPLICATIONS

• A crane barge moves outside the exposed mouth of a sea-facing channel from inside the channel proper; how will crane motions and accelerations be affected by the deeper water and increased directional spreading of the seas at the new location?

• An ocean-going barge under tow is forecast to penetrate an area with wave conditions dominated by intense, locally generated wind driven waves from an area with wave conditions dominated by heavy, unidirectional quartering swell from a distant storm. Will the anticipated conditions produce cargo accelerations within the design tolerance of the load tie-down points?

• A drilling contract is to be awarded for an area in which the environmental forces are highly unidirectional year round except for a small likelihood of rogue storms producing wind and waves at 45 degrees to the normal direction. Can the drilling contract be carried out by a drillship, or must another, more costly, alternative be considered to deal with the rogue storm conditions?

• A drillship moves from the North Sea, where wind-wave frequency spectra are typically sharply peaked, to offshore Africa where normal conditions include a persistent background ocean swell and where wind-wave energy is generally spread over a larger frequency bandwidth; how will motion-related downtime be affected by the move?

• The bow-mounted turret on a turret-moored tanker has been designed under the assumption that it will not be subjected to wave slap in even the 100 year design storm. Is the turret-water surface clearance sufficient at full load to avoid wave slap on the turret, or will the vessel need bow-up trim, and if so, how much?

APPENDICES

The following appendices document a trial run of **Shipsim**. Appendix A contains samples of operator console displays presented during a session with the user-interface program used to create and modify the data file required for program execution. Appendix B contains tabular output samples from **Shipsim**.

APPENDIX A: Sample Input Stream

NOTES:

The following pages are hardcopy images of console screens which might occur during a typical execution of **Shipsim**. These screens will be referred to by their "Console Page Numbers", as given in the starred headers, rather than by appendix page number appearing at the bottom of the page. (For example, "Console Page 1" corresponds to "**** Page 1: Site conditions *****" below.)

Data input is accomplished by selecting the number of a data value which is to be changed whereupon the user is prompted for the new value. (For example, selection of item 4 on Console Page 1 below will produce a prompt to input a new "Site water depth".) Some items are "toggles"; selection of such items results in the "toggling" of the item to its alternative value. For example, selection of item 3 ("Units of measure") on Console Page 1 below would induce a toggle from "English" to "Metric" units.

Operations requiring the input of a large number of equally spaced values (for example, the wave period array on Console Page 4) may be carried out, at user discretion, by a fast automated procedure which permits input of an entire array by specifying its initial value and the increment between values.

```
+=======================================================+
|                                                       |
|                                                       |
|                                                       |
|            **   Welcome to ShipSim   **               |
|                                                       |
|                                                       |
|                ShipSim  Version 3.20                  |
|                Copyright (C) 1988 by                  |
|               Richard J. Hartman, Ph.D.               |
|                                                       |
|                                                       |
+=======================================================+
```

```
****  Page 1: Site conditions  ****


    Two-line Identification for this execution:

1) [Series 60 vessel                                             ]
2) [Sample Execution                                              ]

3) Units of measure: English

4) Site water depth:        4000.00 feet
5) Water density:             64.00 lbs/cubic foot


****  Page 2: Vessel Hydrostatic Characteristics  ****

 1) Vessel displacement ....................   9256.00 kips
 2) Transverse metacentric height (KMT).....     17.60 feet
 3) Longitudinal metacentric height (KML)...    485.00 feet
 4) Vertical center of buoyancy (VKB).......      8.00 feet
 5) Vertical center of gravity (VKG)........      9.00 feet
 6) Vessel water plane area ................  11700.00 square feet
 7) Length of vessel at waterline ..........    315.00 feet
 8) Beam of vessel at waterline ............     45.00 feet
 9) Vessel draft ...........................     15.00 feet

10) Pitch damping is .......................  Computed
12) Roll damping is ........................  Computed
14) Heave damping is .......................  Computed

16) Pitch period is ........................  Computed
18) Roll period is .........................  Computed
20) Heave period is ........................  Computed
```

```
****  Page 3: Vessel Gyradii and Bilge Specifications  ****

 1) Pitch Gyradius .........................     79.00 feet
 2) Roll Gyradius ..........................     15.30 feet
 3) Yaw Gyradius ...........................     81.00 feet
 4) Bilge radius at maximum beam station ...      1.50 feet

 5) Is there a bilge keel ..................   No
 9) Forward speed (knots) ..................       .00

10) Specify passive roll-supression system?    No


****  Page 4: Regular Wave Characteristics  ****


1) Number of different periods (Max 30): 30
2) Periods (seconds) -
        4.00        4.50        5.00        5.50        6.00        6.50
        7.00        7.50        8.00        8.50        9.00        9.50
       10.00       10.50       11.00       11.50       12.00       12.50
       13.00       13.50       14.00       14.50       15.00       15.50
       16.00       16.50       17.00       17.50       18.00       18.50
3) Use constant wave height or wave slope:  slope
4) Wave slope       3.00  degrees

5) Number of wave directions (Max  4):  1
6) Wave directions (degrees) -
      150.00



****  Page 5: Irregular wave specifications  ****

 1) Include irregular waves?   Yes
 2) Wave type:  Bretschneider
 3) Number of wave directions (Max  4):   2
 4) Wave directions (degrees) -
      180.00       90.00

                        - Wave parameters -
 5) Number of irregular wave cases for each direction (Max  6):  2

 6) Significant height in feet
        7.00       10.00
 7) Spectrum peak period (seconds)
        6.50        8.50

 8) Use azimuthal spreading of irregular wave energy
 9) Wave spreading index ....................................   2.00
10) Number of angular wedges (Max 12) .......................   6
11) Storm duration (hours) for peak value statistics ........   4.00
```

```
****  Page 6: Background swell characteristics  ***

 1) Specify background swell?   Yes


 2) Swell height:                 3.00 feet
 3) Swell period:                11.00 seconds
 4) Swell heading:               30.00 degrees



****  Page 7: Output options  ****

 1) Surge  2) Sway   3) Heave  4) Roll   5) Pitch  6) Yaw
     Yes       Yes       Yes       Yes       Yes       Yes

 7) RAO units for angular motions: degrees/ degrees

Note -> Coordinates for the following are in feet

 8) Output accelerations at selected points on vessel?  Yes
 9) Number of acceleration points of interest (Max  4):  2
10) Enter coordinates for accelerations

11) Output velocities at selected points on vessel?    No

14) Output displacements at selected points on vessel?  No

>>> Enter coordinates for Accelerations
           x         y         z
 1)      150.00       .00      17.00
 2)     -150.00       .00      17.00



****  Page 8: More output options  ****


 1) Output force/torque RAOs ................. Yes
 2) Output motion RAOs ....................... Yes
 3) Output RAOs for all spread sea angles .... No
 7) Create plotter file ...................... No
 8) Output goes to Console
 8) Output goes to Disk, on logged drive
 9) Debug option is off
```

APPENDIX B: Sample Output

SeaSoft Systems Program Library

Volume 1

Displacement-Hull Offshore Vessels

SHIPSIM Version 3.2

By Richard J. Hartman, Ph.D.

Series 60 vessel
Sample Execution

```
**                                                              **
*****************   I.  PHYSICAL CHARACTERISTICS SUMMARY   *****************
**                                                              **

 —— SITE CHARACTERISTICS ——

        WATER DEPTH ..........................  4000.00 FEET
        WATER DENSITY ........................    64.00 LBS/CUBIC FOOT

 —— VESSEL CHARACTERISTICS ——

        DISPLACEMENT .........................  9256.00 K.LBS
        VERTICAL (Z) KB ......................     8.00 FEET
        VERTICAL (Z) KG ......................     9.00 FEET
        LONGITUDINAL GM ......................   476.00 FEET
        TRANSVERSE GM ........................     8.60 FEET
        PITCH GYRADIUS .......................    79.00 FEET
        ROLL GYRADIUS ........................    15.30 FEET
        YAW GYRADIUS .........................    81.00 FEET

 —— DYNAMICALLY SIMILAR BOX CHARACTERISTICS ——

        BOX LENGTH ...........................   271.50 FEET
        BOX WIDTH ............................    41.50 FEET
        BOX DRAFT ............................    12.84 FEET
```

```
 **                                                                    **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
 **                                                                    **


  ——  NATURAL PERIODS AT ZERO SPEED  ——


         NATURAL ROLL PERIOD ....................   7.1 SECONDS
         NATURAL PITCH PERIOD ...................   5.7 SECONDS
         NATURAL HEAVE PERIOD ...................   5.8 SECONDS


  ——  QUASI-LINEAR ZERO SPEED DAMPING COEFFICIENTS  ——


         NATURAL ROLL DAMPING ...................   5.3 PERCENT
         NATURAL PITCH DAMPING ..................  11.2 PERCENT
         NATURAL HEAVE DAMPING ..................  16.8 PERCENT


         REGULAR WAVE SLOPE .....................   3.0 DEGREES
         WATER DEPTH ............................4000.0 FEET
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***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
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  ——  REGULAR WAVE DATA:  WAVE HEADING  = 150.0 DEG
                           WAVE SLOPE    =   3.0 DEG
                           FORWARD SPEED =    .0 FT/SEC

                         +++  DIMENSIONLESS DRIVING FORCE/TORQUE RAOS  +++
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WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE AM/PHASE	SWAY AM/PHASE	HEAVE AM/PHASE
4.00	82.0	1.37	.03/ -90.2	.02/ 89.8	.01/ 32.2
4.50	103.8	1.73	.07/ -91.3	.06/ 89.1	.02/ 29.4
5.00	128.1	2.14	.06/ 85.8	.05/ -92.7	.03/-153.8
5.50	155.0	2.58	.16/ 81.0	.14/ -95.9	.08/-156.8
6.00	184.5	3.07	.16/ 74.9	.14/ -99.9	.08/-159.4
6.50	216.5	3.61	.07/ 68.8	.06/-104.1	.04/-161.7
7.00	251.1	4.19	.06/-116.4	.05/ 72.1	.03/ 16.3
7.50	288.3	4.80	.22/-120.2	.18/ 69.3	.12/ 14.6
8.00	328.0	5.47	.37/-122.8	.30/ 67.3	.20/ 13.1
8.50	370.3	6.17	.50/-124.2	.40/ 66.1	.28/ 11.8
9.00	415.1	6.92	.61/-124.8	.49/ 65.7	.35/ 10.6
9.50	462.5	7.71	.70/-124.6	.56/ 65.8	.41/ 9.6
10.00	512.5	8.54	.77/-123.9	.62/ 66.4	.47/ 8.6
10.50	565.0	9.42	.83/-122.9	.67/ 67.2	.51/ 7.8
11.00	620.1	10.33	.87/-121.5	.71/ 68.3	.55/ 7.1
11.50	677.8	11.30	.89/-120.0	.73/ 69.4	.59/ 6.4
12.00	738.0	12.30	.91/-118.4	.76/ 70.7	.62/ 5.8
12.50	800.7	13.35	.93/-116.7	.78/ 71.9	.65/ 5.3
13.00	866.1	14.43	.94/-114.9	.79/ 73.2	.67/ 4.8
13.50	934.0	15.57	.95/-113.2	.80/ 74.4	.70/ 4.3
14.00	1004.5	16.74	.95/-111.6	.81/ 75.6	.72/ 3.9
14.50	1077.5	17.96	.96/-110.0	.82/ 76.7	.73/ 3.6
15.00	1153.1	19.22	.96/-108.5	.83/ 77.7	.75/ 3.3
15.50	1231.2	20.52	.96/-107.1	.83/ 78.7	.76/ 3.0
16.00	1311.9	21.87	.97/-105.8	.84/ 79.6	.78/ 2.7
16.50	1395.2	23.25	.97/-104.6	.84/ 80.4	.79/ 2.5
17.00	1481.1	24.68	.97/-103.5	.85/ 81.2	.80/ 2.3
17.50	1569.5	26.16	.97/-102.4	.85/ 81.9	.81/ 2.1
18.00	1660.4	27.67	.97/-101.5	.85/ 82.5	.82/ 1.9
18.50	1754.0	29.23	.98/-100.6	.86/ 83.1	.83/ 1.8

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  ——  REGULAR WAVE FORCE/TORQUE SCALE FACTORS  ——

    SURGE ..................................     167.7 KIPS/DEG
    SWAY  ..................................     167.7 KIPS/DEG
    HEAVE ..................................     748.8 KIPS/FT
    ROLL  ..................................    1442.6 FT-KIPS/DEG
    PITCH ..................................   79847.1 FT-KIPS/DEG
    YAW   ..................................   79847.1 FT-KIPS/DEG
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**                                                                  **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
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— REGULAR WAVE DATA: WAVE HEADING = 150.0 DEG
WAVE SLOPE = 3.0 DEG
FORWARD SPEED = .0 FT/SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOS +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL AM/PHASE	PITCH AM/PHASE	YAW AM/PHASE
4.00	82.0	1.37	0.00/ -85.8	0.00/ -84.8	.02/ 179.8
4.50	103.8	1.73	.01/ -81.5	.01/ 99.5	.01/ -.9
5.00	128.1	2.14	.01/ 101.4	.02/ 103.6	.03/ -2.7
5.50	155.0	2.58	.03/ 102.5	.01/ 106.0	.01/ -5.9
6.00	184.5	3.07	.03/ 102.1	.03/ -75.0	.02/ 170.1
6.50	216.5	3.61	.02/ 100.8	.10/ -75.7	.06/ 165.9
7.00	251.1	4.19	.02/ -80.7	.16/ -77.1	.08/ 162.1
7.50	288.3	4.80	.05/ -82.2	.23/ -78.8	.10/ 159.3
8.00	328.0	5.47	.10/ -83.6	.29/ -80.4	.10/ 157.3
8.50	370.3	6.17	.14/ -84.8	.34/ -81.9	.11/ 156.1
9.00	415.1	6.92	.17/ -85.7	.39/ -83.3	.11/ 155.7
9.50	462.5	7.71	.21/ -86.6	.43/ -84.5	.10/ 155.8
10.00	512.5	8.54	.24/ -87.2	.46/ -85.5	.10/ 156.4
10.50	565.0	9.42	.26/ -87.7	.50/ -86.3	.09/ 157.2
11.00	620.1	10.33	.29/ -88.2	.53/ -87.0	.09/ 158.3
11.50	677.8	11.30	.31/ -88.5	.55/ -87.5	.08/ 159.4
12.00	738.0	12.30	.33/ -88.8	.58/ -88.0	.08/ 160.7
12.50	800.7	13.35	.34/ -89.0	.60/ -88.3	.07/ 161.9
13.00	866.1	14.43	.35/ -89.2	.62/ -88.6	.07/ 163.2
13.50	934.0	15.57	.37/ -89.3	.64/ -88.9	.06/ 164.4
14.00	1004.5	16.74	.38/ -89.4	.65/ -89.1	.06/ 165.6
14.50	1077.5	17.96	.39/ -89.5	.67/ -89.2	.05/ 166.7
15.00	1153.1	19.22	.40/ -89.6	.68/ -89.3	.05/ 167.7
15.50	1231.2	20.52	.40/ -89.7	.69/ -89.5	.05/ 168.7
16.00	1311.9	21.87	.41/ -89.7	.70/ -89.5	.04/ 169.6
16.50	1395.2	23.25	.42/ -89.8	.72/ -89.6	.04/ 170.4
17.00	1481.1	24.68	.42/ -89.8	.72/ -89.7	.04/ 171.2
17.50	1569.5	26.16	.43/ -89.8	.73/ -89.7	.04/ 171.9
18.00	1660.4	27.67	.43/ -89.8	.74/ -89.8	.04/ 172.5
18.50	1754.0	29.23	.44/ -89.9	.75/ -89.8	.03/ 173.1

— REGULAR WAVE FORCE/TORQUE SCALE FACTORS —

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SURGE ..................................    167.7 KIPS/DEG
SWAY  ..................................    167.7 KIPS/DEG
HEAVE ..................................    748.8 KIPS/FT
ROLL  ..................................   1442.6 FT-KIPS/DEG
PITCH ..................................  79847.1 FT-KIPS/DEG
YAW   ..................................  79847.1 FT-KIPS/DEG
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**                                                                  **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
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— REGULAR WAVE DATA: WAVE HEADING = 150.0 DEG
WAVE SLOPE = 3.0 DEG
FORWARD SPEED = .0 FT/SEC

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE (FT./FT.) AM/PHASE	SWAY (FT./FT.) AM/PHASE	HEAVE (FT./FT.) AM/PHASE
4.00	82.0	1.37	.02/ 89.8	.01/ -90.2	.01/-122.3
4.50	103.8	1.73	.06/ 88.7	.03/ -90.9	.03/-115.6
5.00	128.1	2.14	.05/ -94.2	.03/ 87.3	.05/ 76.3
5.50	155.0	2.58	.14/ -99.0	.08/ 84.1	.21/ 96.8
6.00	184.5	3.07	.13/-105.1	.08/ 80.1	.25/ 122.8
6.50	216.5	3.61	.06/-111.2	.03/ 75.9	.11/ 143.8
7.00	251.1	4.19	.06/ 63.6	.03/-107.9	.09/ -23.4
7.50	288.3	4.80	.19/ 59.8	.10/-110.7	.27/ -15.8
8.00	328.0	5.47	.31/ 57.2	.16/-112.7	.41/ -11.2
8.50	370.3	6.17	.43/ 55.8	.22/-113.9	.53/ -8.2
9.00	415.1	6.92	.52/ 55.2	.27/-114.3	.62/ -6.1
9.50	462.5	7.71	.60/ 55.4	.31/-114.2	.69/ -4.7
10.00	512.5	8.54	.66/ 56.1	.35/-113.6	.75/ -3.6
10.50	565.0	9.42	.71/ 57.1	.37/-112.8	.79/ -2.9
11.00	620.1	10.33	.74/ 58.5	.39/-111.7	.83/ -2.3
11.50	677.8	11.30	.77/ 60.0	.41/-110.6	.86/ -1.8
12.00	738.0	12.30	.78/ 61.6	.42/-109.3	.88/ -1.5
12.50	800.7	13.35	.80/ 63.3	.43/-108.1	.90/ -1.2
13.00	866.1	14.43	.80/ 65.1	.44/-106.8	.91/ -1.0
13.50	934.0	15.57	.81/ 66.8	.45/-105.6	.92/ -.8
14.00	1004.5	16.74	.82/ 68.4	.45/-104.4	.93/ -.7
14.50	1077.5	17.96	.82/ 70.0	.46/-103.3	.94/ -.6
15.00	1153.1	19.22	.82/ 71.5	.46/-102.3	.95/ -.5
15.50	1231.2	20.52	.83/ 72.9	.46/-101.3	.96/ -.4
16.00	1311.9	21.87	.83/ 74.2	.47/-100.4	.96/ -.3
16.50	1395.2	23.25	.83/ 75.4	.47/ -99.6	.97/ -.3
17.00	1481.1	24.68	.83/ 76.5	.47/ -98.8	.97/ -.2
17.50	1569.5	26.16	.83/ 77.6	.47/ -98.1	.97/ -.2
18.00	1660.4	27.67	.83/ 78.5	.48/ -97.5	.98/ -.2
18.50	1754.0	29.23	.84/ 79.4	.48/ -96.9	.98/ -.2