

Safety at Speed - S@S
STRUCTURAL FOUNDERING RISK COST
MODEL USER'S MANUAL
Document ID Code: S103.30.13.060.004a
Date: 2003-30-09
Contract No. G3RD-CT-2001-00331

CLASSIFICATION AND APPROVAL

Classification: Confidential

DEFINITION

Public after Review:

The document may be freely distributed after successful EC review, given the EC's permission. Publication is governed by the EC Contract and the S@S Consortium Agreement

Confidential for the Duration of the Project:

As for 'Confidential', but only for the duration of the Project. After final Project Approval by the EC, status for reports classified 'Confidential for the Duration of the Project' are automatically down-graded to 'Public'.

Confidential:

The document is for use of the G3RD-CT-2001-00331 Contractors within the S@S Consortium, and shall not be used or disclosed to third parties without the unanimous agreement within the S@S PMC and subsequent EC approval since document classification is part of the EC Contract.

Any executive summary specifically intended for publication may however be made known to the public by the author and/or the Coordinator.

AUTHORS:

Name	Date	Signature
MDC	<u>2003-30-09</u>	_____
APME	<u>2003-30-09</u>	_____

APPROVAL:

Approved for release by:

Name	Date	Signature
NN3	<u>Yyyy-mm-dd</u>	_____

DOCUMENT HISTORY:

Issue:	Date:	Initials:	Revised pages:	Short description of changes: File name:
004a	2003-19-09	MDC	--	First issue taken from D3.3 with plot/save descriptions added

DISCLAIMER

Use of any knowledge, information or data contained in this document shall be at the user's sole risk. Neither the S@S Consortium nor any of its members, their officers, employees or agents accept shall be liable or responsible, in negligence or otherwise, for any loss, damage or expense whatever sustained by any person as a result of the use, in any manner or form, of any knowledge, information or data contained in this document, or due to any inaccuracy, omission or error therein contained.

The European Community shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof.

CONTENTS

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION.....	5
2. USERS GUIDE TO RELIABILITY AND COST CALCULATION TOOL	6
2.1 CONCEPTUAL SUMMARY OF APPROACH	6
2.2 INSTALLING THE PROGRAM.....	7
2.3 ENTERING BASIC PARAMETERS, LOADING, AND MIDSHIP SECTION	7
2.3.1 Run Information	7
2.3.2 Long-Term Loading	8
2.3.3 Panel Array	8
2.3.4 Additional Fatigue Details and Ship's Length	10
2.3.5 Checking and Transferring Data.....	11
2.3.6 Running the Model	11
2.4 UNDERSTANDING OUTPUT FROM MODEL	11
2.5 CHANGING DEFAULT RISK AND COST PARAMETERS AND TROUBLESHOOTING	13
2.5.1 Changing Defaults	13
2.5.2 Troubleshooting	13
3. REFERENCES	15

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION

This report forms the user's guide to Workpackage Three's structural foundering risk-cost prediction software. It is intended to be used in conjunction with the software, and Deliverable 3.3, which contains descriptions of the theory, assumptions, and procedures implemented in the software.

S@S is the acronym for Safety at Speed, a project supported by the European Commission under the Growth Programme of the 5TH Framework Programme. The support is given under the scheme of RTD, Contract No. G3RD-CT-2001-00331.

2. USERS GUIDE TO RELIABILITY AND COST CALCULATION TOOL

As part of the integrated risk-cost approach, Workpackage Three has created a LabVIEW software tool which investigates the reliability and cost of a proposed high-speed craft midship section. This software automates the calculation of many of the required parameters for the overall risk and cost model, and also provides feedback to the designer about the reliability of a proposed structural design. This section describes how to use this software and the calculations and assumptions inherent in the tool. Information on how this piece of software integrates into the overall S@S approach is discussed in the previous sections of this deliverable.

2.1 Conceptual Summary of Approach

The software is designed to investigate the reliability and cost of a proposed high-speed craft midship section, using the loadings and parameter list available within the S@S project tool. It is envisioned that this tool will work in conjunction with the classification society rules spreadsheet produced by ABS in Task 3.2, which is described in D3.2.3. For the purposes of this discussion, it is suffice to say that the rule spreadsheet can be used to generate the preliminary scantlings of several alternative midship sections which meet the minimum classification society requirements. These midship sections can be entered into the software which will evaluate the risk and cost associated with each of them, allowing the designer to pick the optimum scantlings to use in the design.

The software is designed to operate within the S@S project tool, thus it is limited to using the inputs on the S@S parameter list and that available from other Workpackages. The loading available within the project consists of global vertical bending moments, limiting the structural analysis to longitudinally effective members in the midship section. These structures are entered as un-stiffened plates, stiffened plates, or extruded sections. Two types of structural performance are considered, collapse of members under compressive loads, and fatigue failures in structural details. The collapse stress of each panel is calculated through an empirical formulation. Miner's sum fatigue formulations are applied at structural details in the midship section. Each stiffened panel is assumed to have stiffener end connections which should be checked for fatigue with a user-specified stress concentration factor, and the user can specify additional details such as expansion joints or other cut-outs by providing their location in the midship cross-section and their stress concentration factor. The structural risk associated with these calculations is expressed in terms of the structural safety index, as discussed in Deliverable 3.3. Cost is calculated on a weight basis, specific material and labour costs are assigned to each form of each aluminium alloy, i.e., 5083 plating or 6082 extrusions. The amount of each material and form in the midship section are summed up and multiplied by these specific costs yielding the build costs. Overheads are treated as a percentage of the labour costs. Maintenance costs are also considered, using the *SuperSeaCats* as reference vessels.

Because of effort and time limitations, certain factors are not yet included in the model. This includes local pressure loadings and the associated structural response, transverse structures, and panels welded at locations other than their boundaries.

The general procedure for using the software tool consists of several sequential steps which are listed below.

1. Enter the basic vessel and run information
2. Enter the long-term loading from Workpackage Two's long-term loading spreadsheet.
3. Divide the midship section into un-stiffened panels, stiffened panels, and extruded panels with homogenous properties. Enter these into the software.
4. Enter any additional structural details to be checked for fatigue.
5. Confirm that the reliability constants and fatigue S-N curves enter as defaults are appropriate for the proposed vessel.
6. Confirm that the costing constants are appropriate for the proposed vessel.
7. Run the model.
8. Review the output to ensure that the data is correct and that the model ran without any errors.

The correct procedure for carrying out each of these steps will be reviewed below

2.2 Installing the Program

The risk-cost program comes with an integrated installer which installs all the necessary files to operate the program, including the LabVIEW runtime engine and the reliability DLL files. To install, double-click the provided installer on the distribution CD. You can then select the drive where you want to install it. The installation will create a folder called "Rcmodel" on the directory you have chosen, you will find there the executable file "RCModel.exe" To run the program, double-click the executable file. On some systems, a dialog box may appear asking you to select the runtime engine. If this occurs click "ok" and you will be able to use the risk-cost model.

2.3 Entering Basic Parameters, Loading, and Midship Section

When launched, the risk-cost software first loads the main data entry and control screen. On this screen, the basic information on the vessel, the long-term loading, and the midship section are entered, and the calculation procedures can be run. By default, the data from the *SuperSeaCat 3* appears in the input forms when the data is run. Each frame title is preceded by a number which indicates the recommend order of data entry.

2.3.1 Run Information

The first step is to enter the basic vessel and run information, in the frame titled "Run Information". The vessel name, engineer's name, model date and revision number, and output file location are entered here. The output file is written in HTML, so a .htm extension is recommended. Note that the software automatically will add the run date

to the output file, so the model date can be set to agree with a particular design iteration or option, it need not be the current date.

2.3.2 Long-Term Loading

The second type of input required is the long-term loading. This information primarily comes from Workpackage Two's long-term loading model. In this frame, the first information required is the long-term amplitude distribution of the vertical bending moment, calculated through linear seakeeping predictions. This loading is modelled by the Weibull distribution, as in Workpackage Two's spreadsheet, discussed in D232. This loading is used by the software for two purposes, it determines the stress range for fatigue details, and it is used to estimate the extreme hogging moment likely in the vessel's lifetime for the ultimate compressive strength safety index calculations for stiffened panels below the vessel's neutral axis. For the fatigue calculation, each of the two parameters of the Weibull distribution, the scale and shape parameters, must be modelled as random variables. Thus, the type of statistical distribution and coefficient of variation (COV) of the distribution must be supplied for each of the Weibull parameters. More information on how these distributions are used is available in Deliverable 3.2.4. The default recommended values from D3.2.4 are lognormal distributions for each of these with a COV of 0.1. Note that these uncertainties do not affect the extreme hogging moment calculation, the uncertainty used in this calculation is discussed below.

The next type of loading required is the stillwater bending moment, which is modelled by a normal distribution. Positive values are assumed to produce compression in the deck. This load is used in calculation of the local panel ultimate strength safety index and the global ultimate strength safety index. Note that this will increase the compressive strength of the panels on the side of the vessel on which the loading produces tensile stresses.

The third type of loading is the non-linear long-term sagging bending moment distribution which is taken from Workpackage Two's long-term loading sheet as a Weibull distribution. This distribution is converted into an extreme value sagging distribution by the software, and used to calculate the ultimate strength safety index of the panel above the neutral axis in the midship section and the global collapse safety index of the vessel. The uncertainty associated with the long-term estimation is entered as a separate factor in the following fields. This factor multiplies the extreme loading distribution in both hogging and sagging when carrying out the local and global ultimate strength safety index calculations. The mean value, distribution type, and COV of the distribution can be specified. This uncertainty should reflect the user's confidence in the long-term loading predictions, in the absence of better information, a mean value of 1.0 with a COV of 0.15 can be used [1]. Finally, the number of applied cycles in service should be entered from Workpackage Two's long-term loading sheet.

2.3.3 Panel Array

With the loading defined, the next step is to enter the midship section of the vessel. Four types of panels are currently supported, un-stiffened plates, stiffened plates, single-sided stiffened plate extrusions, and double-sided extrusions. For the risk calculations, the un-stiffened plates and double-sided extrusions are handled the same way, and the stiffened plates and single-sided stiffened plate extrusions are also handled the same way. However, each type of panel has its own cost properties. The

midship section is broken up into a series of plates and panels, each of which has homogenous properties, such a stiffener size, stiffener spacing, and plate thickness. This is shown for a hypothetical midship section in Figure 1 below.

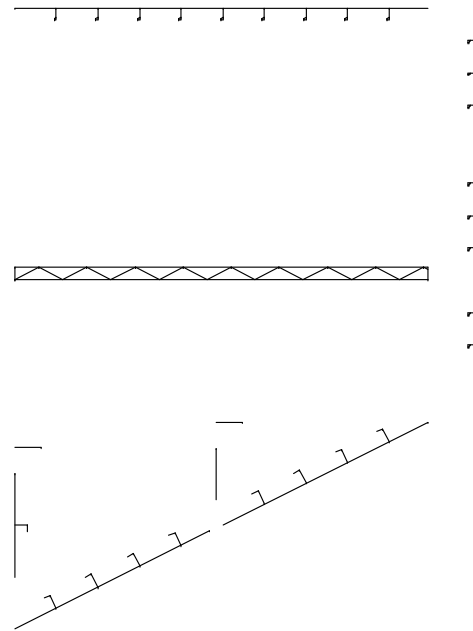


Figure 1: Midship section divided into panels

The panels are entered in an list, only one panel (element) of the list is visible at one time, to move up or down through the list of panels, the arrow buttons or number box on the upper left-hand side of the frame can be used. Additionally, the panels which form the upper strength deck of the vessel must be specified, as these govern the ultimate strength in sagging. These panels are specified by pressing the toggle switch in the panel frame labelled by "Part of deck flange?". Un-stiffened plates are entered by specifying their endpoints in the midship section, the plate thickness, frame spacing, elastic modulus, plate yield stress, and by specifying "unstiffend plate" in the drop-down menu at the lower right of the panel frame. The yield stress is taken as the plate's ultimate strength in compression, if there is a large section of un-stiffened plating that may not reach its yield stress in compression, the user can specify a lower value. The plating material type should also be specified for the cost calculations. A hot-spot stress concentration factor and S-N curve type may also be specified if there is a fatigue detail in the plating that should be investigated. The S-N curve types (0-3) specify different S-N curves, which may be modified by the user. Their default values, which are loaded when the program is first run, are as follows:

- Type 0: Average workmanship, welded or cut edges, not immersed in salt water
- Type 1: Excellent workmanship, welded or cut edges, not immersed in salt water
- Type 2: Average workmanship, welded or cut edges, immersed in salt water
- Type 3: Poor workmanship, welded or cut edges, not immersed in salt water

Further S-N curves and discussions on the properties of each curve can be found in D3.2.4. If a fatigue calculation is not required, the fatigue inputs and all remaining inputs may be left blank.

Stiffened plates and single-sided stiffened plate extrusions are both entered the same way. In addition to the plating variables discussed above, the stiffener dimensions, spacing, and material properties must be entered, and the stiffened plate or single-sided extrusion specified from the drop-down menu. The stiffener measurements are shown in the sketch below:

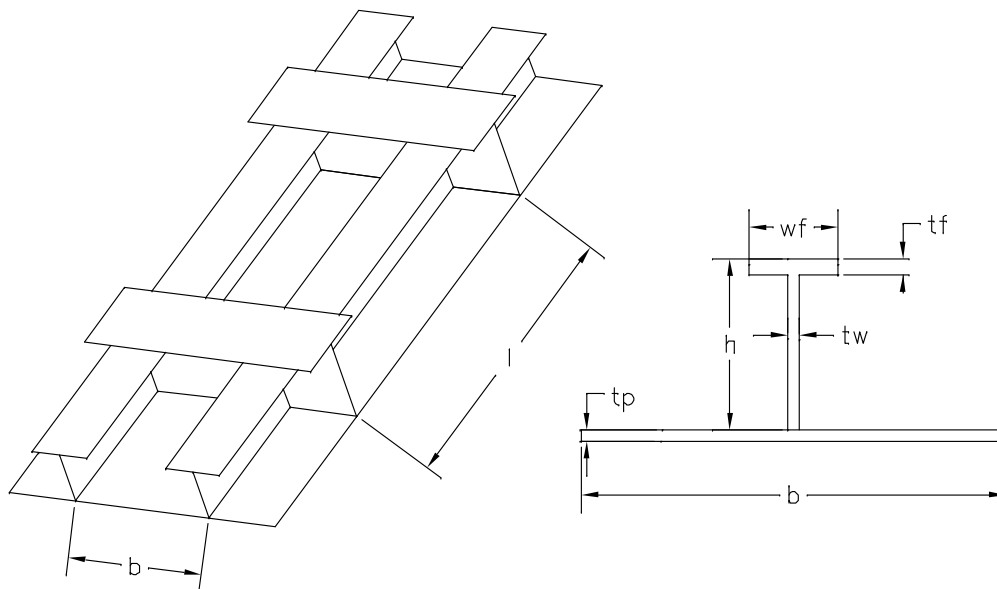


Figure 2: Stiffened panel dimensions

The exact locations of the stiffeners on the panel is not required, as the calculation routines reduce stiffened plates to equivalent un-stiffened plates by calculating their ultimate compressive strength on the basis of a single stiffener and attached width of plating equal to the stiffener spacing. The stiffener area is then smeared into a section of plate whose width is equal to the stiffener spacing to obtain an equivalent plate thickness. The stiffened plate is then treated as an un-stiffened plate with an ultimate strength and plate thickness equal to those calculated above. The fatigue stress-concentration factor should be that of the stiffener end-connections to transverse frames, and the S-N curves are as discussed above. Additional fatigue details in the panel may be entered later on. A material type should be specified for both the plate and stiffener for the cost calculations.

Double-sided extrusions are handled in the same way as un-stiffened plates, and should be entered the same way as well, with the plate thickness equal to effective thickness of the extrusion if it was a plate. The ultimate strength is taken as the user-specified yield strength, as no ultimate strength routines are currently available for double-sided extrusions.

2.3.4 Additional Fatigue Details and Ship's Length

This frame allows additional fatigue details which were not included in the panel list to be entered. These might be details such as expansion joints, hatch cut-outs, doubler

plates and shell penetrations. The details are entered into a list, in the same manner as the panel arrays. The name, location, stress concentration factor, and S-N curve are entered for each detail, as for the un-stiffened plates discussed above. If no additional details are required, this section may be left blank. Finally, the ship's overall length should be entered into the fifth frame.

2.3.5 Checking and Transferring Data

Once the model is complete, or even while the model is being built, the panel data can be checked, or alternatively transferred to Workpackage 5's design tool. To check the location and size of the panels being entered, press the "Plot Midship Section" button. This will bring up a picture window with all the panels in the midship section plotted as lines, labelled at their midpoint with PXX where XX is the panel number. Additional fatigue details are plotted as circles, and are labelled DXX, where XX is the detail number. Note that individual stiffeners are not shown. This screen is useful for checking the dimensions and locations of the panels to be sure that the midship section is entered correctly. To transfer the data to Workpackage 5's design tool, click on "Link to Safety@Speed Excel Sheet". This will save the data to a text file in a location of your choosing which can then be loaded into the design tool. Note that at the moment, it is not possible to save or load data to the LabVIEW risk-cost tool.

2.3.6 Running the Model

After all the data has been entered, the model may be run by pressing the "run" button. When the model is finished, the summary output to the right of the data input will be updated. Additionally, if an output file from an earlier run with the same name and location as the currently specified file exists, a warning message will appear asking if the file can be overwritten.

2.4 Understanding Output from Model

When the model is run, output appears in two places. Summary output is presented on-screen, to the right of the data input area (the screen must be scrolled right), additionally, a report is written to the specified output file. The summary information on-screen is meant to capture the major results of the output so that any significant problems can be spotted before reviewing the output file. A summary of the stresses and corresponding safety indexes for each panel is first presented, listing the Weibull (long-term) and Gumbel (extreme-value) stresses at the panel endpoints and midpoints for each panel in the midship section. Additionally, the reliability safety indexes for ultimate strength and fatigue strength are also presented. At the current time, the fatigue reliability safety indexes are quite low-in some cases negative. This should not cause undo alarm, as they are compared to those of the *SuperSeaCat 3* in order to determine the fatigue risk, so their absolute value is not as significant. A safety index of 1000 is used when there is no stress acting on a particular panel or fatigue detail. This may be caused by a zero being entered for the fatigue stress concentration factor, or one of the calculation points falling on the section neutral axis. When used to determine risk, these safety indexes evaluate to zero probability of failure. Additionally, an error code flag is presented at the bottom of the panel display area, which will indicate if any errors occurred when processing the panel. If this code is greater than zero, an error was encountered. Most likely, this would be caused by a required value being left blank, such as the stiffener spacing for stiffened panels. The global collapse safety index is also reported, along with building and maintenance

costs. This allows a proposed design change to be evaluated quickly without referring to the full report.

In addition to the on-screen summary, a full HTML report is produced, which includes all of the input information, the overall properties of the cross section, reliability safety indexes, and risk and cost inputs for the S@S risk tool. The report consists of 10 sections. At the beginning of the report, the basic ship information, file revision number and date, and computer run date are listed. The next section lists the applied loading. The linear long-term Weibull load distribution for the fatigue calculations is listed first, along with the distributions and COV of the Weibull parameters. The sagging and hogging extreme value (Gumbel) distributions are listed next, these are derived from the long-term Weibull distributions through the approximate methods described in Deliverable 3.3. This is followed by the number of applied cycles and the stillwater loading.

The next two sections contain the default statistical parameters used in the evaluation of the ultimate strength and fatigue limit state equations, which are reproduced here from Deliverable 3.3:

For fatigue:

Equation 1: Fatigue Limit State

$$G(\mathbf{X}) = D_{cr} - \frac{(2\alpha)^m \cdot N}{A} \Gamma\left(1 + \frac{m}{\beta}\right)$$

Where :

D_{cr} : Miner's sum damage at failure

α : Scale parameter for Weibull stress distribution at detail

β : Shape parameter for Weibull stress distribution at detail

A : S - N curve intercept parameter

m : S - N curve slope parameter

N : Number of applied cycles

$\Gamma(\bullet)$: Gamma function

For the local and global ultimate strength, the limit state was taken as:

Equation 2: Ultimate Strength Limit State

$$G(X) = X_s \sigma_u - \sigma_{sw} - X_{wave} \sigma_{wave}$$

Where :

X_s : Ultimate strength modelling uncertainty factor

σ_u : Ultimate strength from simplified model

σ_{sw} : Stress from stillwater bending moment

X_{wave} : Extreme wave stress modelling uncertainty factor

σ_{wave} : Extreme wave stress

One set of parameters is used for the ultimate strength calculation, and one set for each of the four different fatigue S-N curves. The following section lists the default cost information for each of the four kinds of materials (Types 1-4) in plate, stiffened plate, single-sided stiffened extrusions and double-sided extrusion forms. Material and

labour costs are listed per kilogram of material, and the building overheads as a percentage of the labour costs are listed along with the default maintenance parameters for the *SuperSeaCat Three*, which are used to calculate the relative maintenance costs.

The strength and reliability output is listed in the next several sections. First, the overall midship section properties, such as cross-section area, height of the neutral axis, and moment of inertia are listed, along with the safety index for overall sagging collapse of the vessel, termed the overall safety index of the vessel in the report. Then, each panel which has been entered is recorded, starting with the panel properties and dimensions that were entered into the program. The program records the properties of the panel, such as cross-sectional area, average yield stress, and ultimate compressive stress. Additionally, the panel's slenderness ratios, β and λ , are recorded (See D3.3 for a complete discussion of these ratios and the influence on strength). Finally, the safety indexes of the panel, as determined by the FOR reliability method in ultimate strength and fatigue (with the panel's stress concentration factor) are provided at the panel's endpoints and the panel's midpoint. Finally, a listing of any errors which occurred while processing the panel is provided. If any errors are reported, review the suggestions in the troubleshooting section below. After listing the output for all the panels in the midship section, the output for the additional fatigue details is given. Again, the input data is echoed and the calculated safety index is reported.

The final two sections of the report list the risk and cost information for the overall S@S risk and cost model created by Workpackage Five. The risk outputs listed line up with the required risk inputs in Workpackage Five's spreadsheet, allowing easy transfer of information.

2.5 Changing Default Risk and Cost Parameters and Troubleshooting

2.5.1 Changing Defaults

The default risk and cost values provided with the tool can be changed, to keep the tool current with future research. These parameters are listed on a separate panel, which is accessed by clicking on the yellow button labelled "Change Reliability and Cost Defaults". The information which can be changed in this panel includes the default S-N curves and their statistical parameters, the ultimate strength statistical parameters, and the cost information. Additionally, the starting point for the FOR algorithms may be modified by specifying an offset parameter, which multiplies the mean values of one or all of the statistical parameters in the limit state equation to determine the algorithm starting point. Once you have altered the data press the green "OK" button. You can now run the program as usual. Note that once the "Stop" button is pressed all the values will be set back to the original default values.

2.5.2 Troubleshooting

The risk and cost calculations at present have been tested and verified for a limited number of sample cross-sections, including a nominal HSC midship section and a box girder. While the algorithms have been proven to be quite stable, difficulties may still arise. Two potential difficulties relate to missing input data or trouble with the FOR solvers. It is possible to miss out a piece of required input information, which may result in the program producing "NaN" in place of the expected results. NaN stands

for not a number, meaning that an internal mathematical operation has failed. Often this is caused by entering a zero or negative number for something such as loading or stiffener spacing. If NaN appear, a careful check of the output report is often useful. If the overall cross-section properties appear close to correct, the problem may be only affecting one panel. In this case, investigating the summary panel output presented on-screen after running the model may also help. Note that if the program detects an error, the final risk information for the project tool will not print.

The FOR solution method is an iterative approach. While it is quite stable, the algorithms, especially the fatigue algorithms may not converge to a solution. In this case, usually an error code will be displayed underneath the panel or fatigue detail in which the problem has occurred. Most of these errors can be resolved by changing the algorithm starting point offset, discussed in the previous section. In general, lowering the fatigue starting point offset improves the stability of the approach.

3. REFERENCES

1. Hess, P.E., et al., *Uncertainties in Material and Geometric Strength and Load Variables*. Naval Engineers Journal, 2002. **114**(2): p. 139-165.