User Manual for MDO-v1 Optimization Program

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Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels

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Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels

Task 4.8 Final Project Report

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Scope of Method

This manual describes the operation of MDO-v1 for the "Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels". MDO-v1 uses iSIGHT as the driver of the MDO process. The user must have iSIGHT license and use the .desc file option of it to run this program. This manual describes objectives, design variables, input model parameters and the process set up in iSIGHT [Ref. 1] and its application to a generic Trimaran configuration optimization illustrating the use of Neural Networks and C programming. The mathematical description of the model is explained in detail in Ref. 2. The design problem consists of various inputs (Design Variables and Input Parameters), objectives functions and constraints. The demonstration case presented here is for a Trimaran configuration on a shipping line with the range of of 800 nm. For the purpose of demonstration, the range of design space and constraints for these cases are chosen to be broad. For applications to specific missions, various optimization parameters need to be carefully defined.

Chapter 2 describes how the Trimaran Model is implemented in iSIGHT. Chapter 3 discusses the different objectives functions and optimization techniques. Chapter 4 shows the Design Variables and Input Parameters used in the Trimaran Model and Chapter 5 describe the constraints.

Appendix A, B, and C contain the iSIGHT description file (newsubtask.desc), and the various inputs, outputs files and codes needed to run this optimization.

1 iSIGHT Implementation

1.1 Process Integration for Trimaran

A "*Trimaran"* task has been set up in iSIGHT 8.0.[Ref. 1] It is divided into 5 subtasks; *Power*, *StabilityModel*, *LightShipWeight*, *PayloadModel*, *CostModel* as shown in Figure 1. This division in subtasks follows the model description in Reference 2.

The *Power* subtask calculates the dependent geometrical variables of the model and the Total Resistance of Trimaran configuration leading to its Power Requirement at full speed. This task is further divided into two calculations modules; *PoweringA*, *PoweringB* and two simcodes; *CO* and *Engine*. These will be explained in detail in section 2.2.

The *StabilityModel* subtask consists of a single calculation module named *Stability* to determine the metacentric height of the ship, giving information on the boat stability.

The *LightShipWeight* subtask, also a single calculation module called *LWT*, evaluates all weights for the Trimaran except for the deck weight which is calculated in the *PayloadModel.*

The *PayloadModel*'s calculation is called *Payload* and the *CostModel* one is *Cost.* The payload calculates the fuel weight and the number of containers that can be carried onboard the Trimaran. This determines the area of cargo required and thus the number and dimensions of decks. The deck weight can then be calculated and added to the weights calculated in the previous calculation to determine the Trimaran weight.

The *Cost* module calculates all costs incurring in building and operating the Trimaran as well as the Required Freight rate.

Figure 1 shows in iSIGHT the program control sequence (left hand window) and data flow between the programs (right hand window). The detail of the flow of variables, inputs, auxiliaries and the outputs from one sub task to another is described in detail in the flow of variables section (section 7).

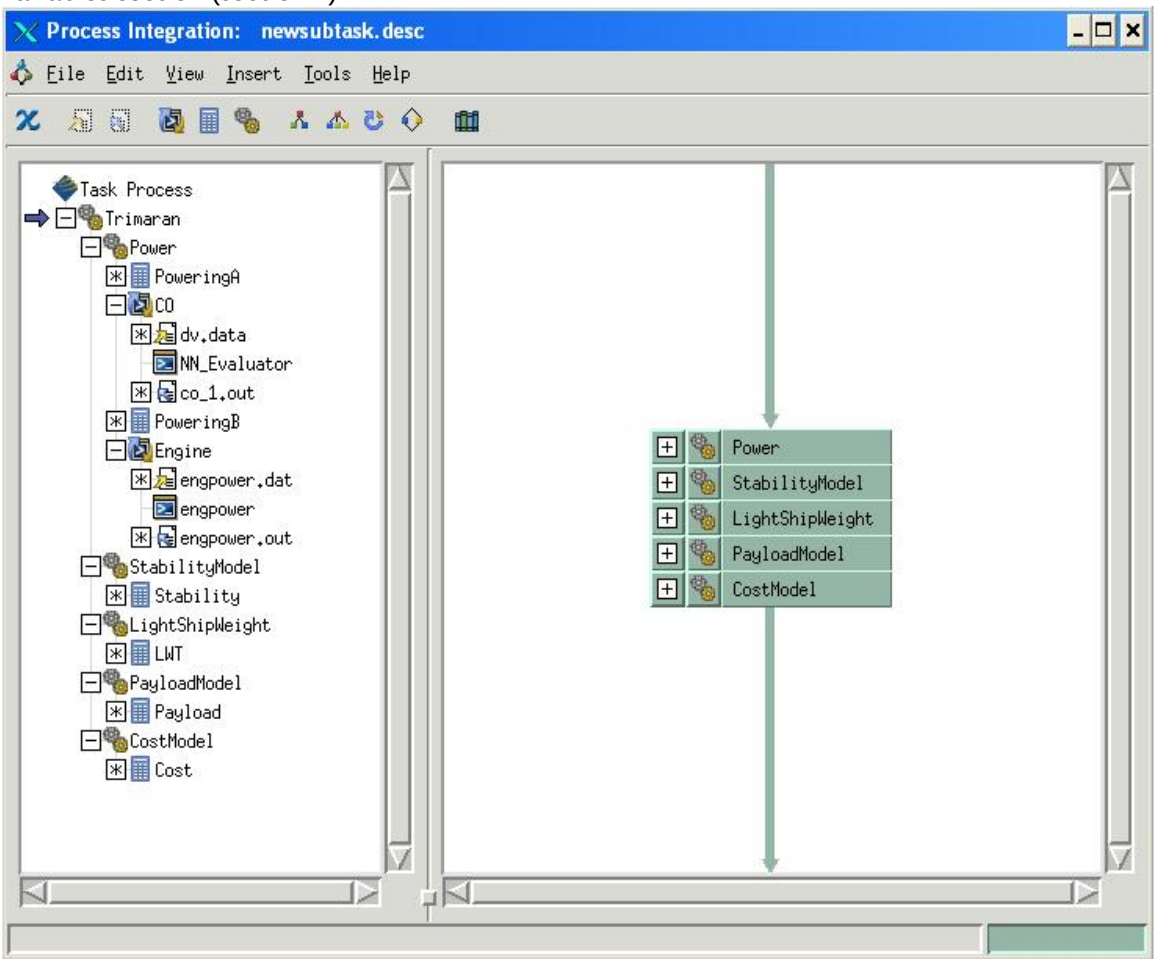

Figure 1. Process Integration of Trimaran task in iSIGHT

1.2 Process Integration for Power Model

The *Power* subtask is further divided into two calculations *PoweringA* and *PoweringB* and two simcodes *CO* and *Engine*. The sequencing order is *PoweringA, CO, PoweringB,* and last *Engine.*

PoweringA determines all geometrical and speed dependent variables, including the Slenderness (Sl) and Froude Number (Fn) which are then passed to the *CO* simcode along with the design variables Stagger (alpha) and Separation (beta) to evaluate the coefficient of residual resistance (CO). This coefficient is then passed to the *PoweringB* calculation block along with other variables defined in *PoweringA* and more DV's to determine the ship total resistance and thus the Power required to navigate at full speed (Pfullspeed). This value is then passed to the *Engine* simcode which determines the number of diesel and gas turbines (Ndiesel, Ngt) engines required as well as their respective Power (Pdiesel, Pgt). The process integration (left hand window)and flow of variables for the power subtask (right hand window) is shown in iSIGHT in figure 2.

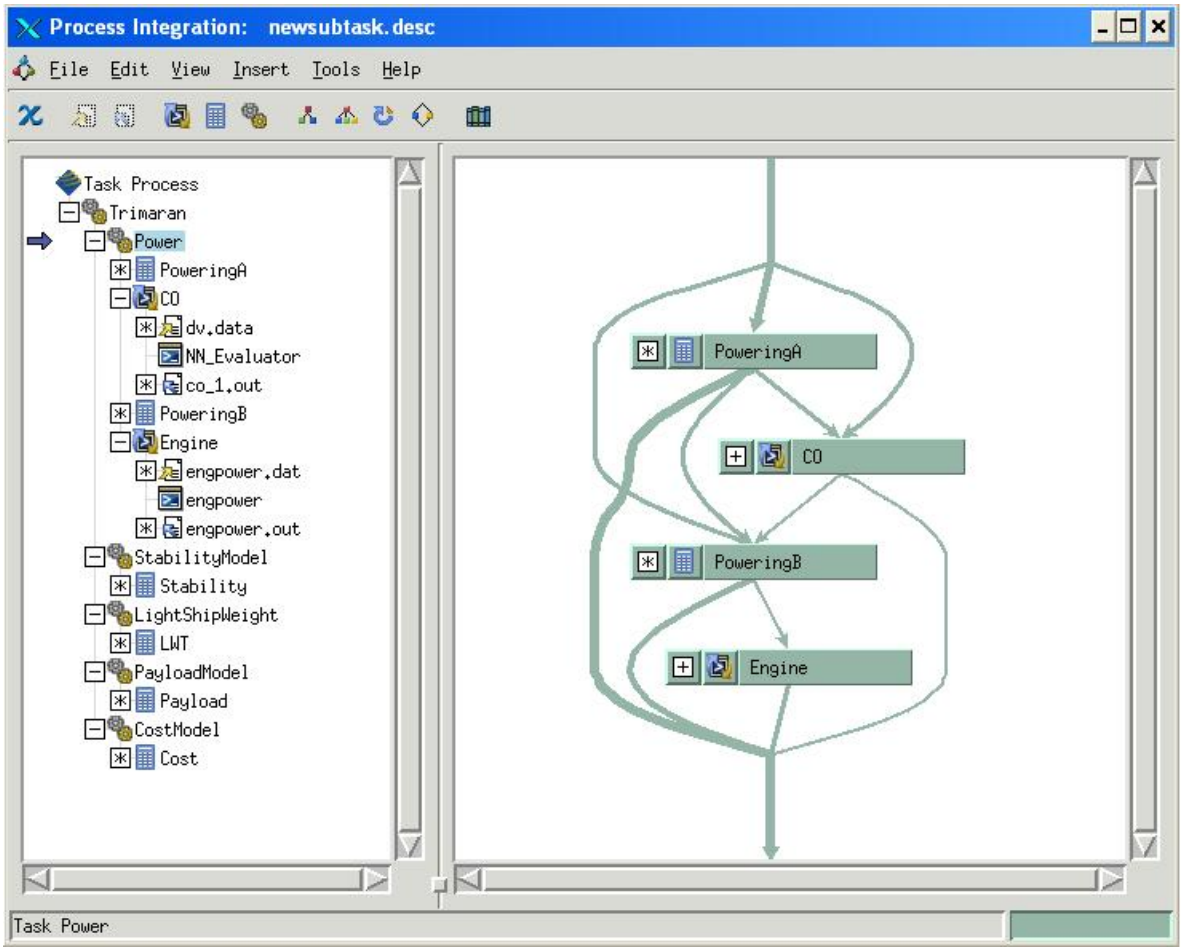

Figure 2. Process Integration of Trimaran task in iSIGHT, detail for *Power* subtask

The input files, executable files and output files are parsed in the simcode. The flow of variables from *PoweringA, PoweringB, CO* & *Engine* is shown in the figure 2.
CO simcode consists of an input block, an executable block and an output block. An Input block consists of an input file (dv.data) and a template file (dv_temp.data). Executable block consists of an evaluator file (NN_Evaluator) which is generated from the neural network. Output block consists of an output file (co_1.out) which provides the values for coefficient of residual resistance. This output is used in the *PoweringB*. Refer figure 3.

The equations used in *PoweringA* and *PoweringB* are not be described here, see the iSIGHT desc file in Appendix A for a list of the equations and reference 2 for more details.

The *CO* simcode requires an input file (dv.data), a template file (dv_temp.data), an executable file (NN_evaluator) and a standard output file (co_1.out) as shown in figure 3.

And similarly, the *Engine* simcode requires an input file (engpower.dat) and a template file (engpower_temp.dat), an executable file (engpower) and an output file (engpower.out) as shown in figure 4.

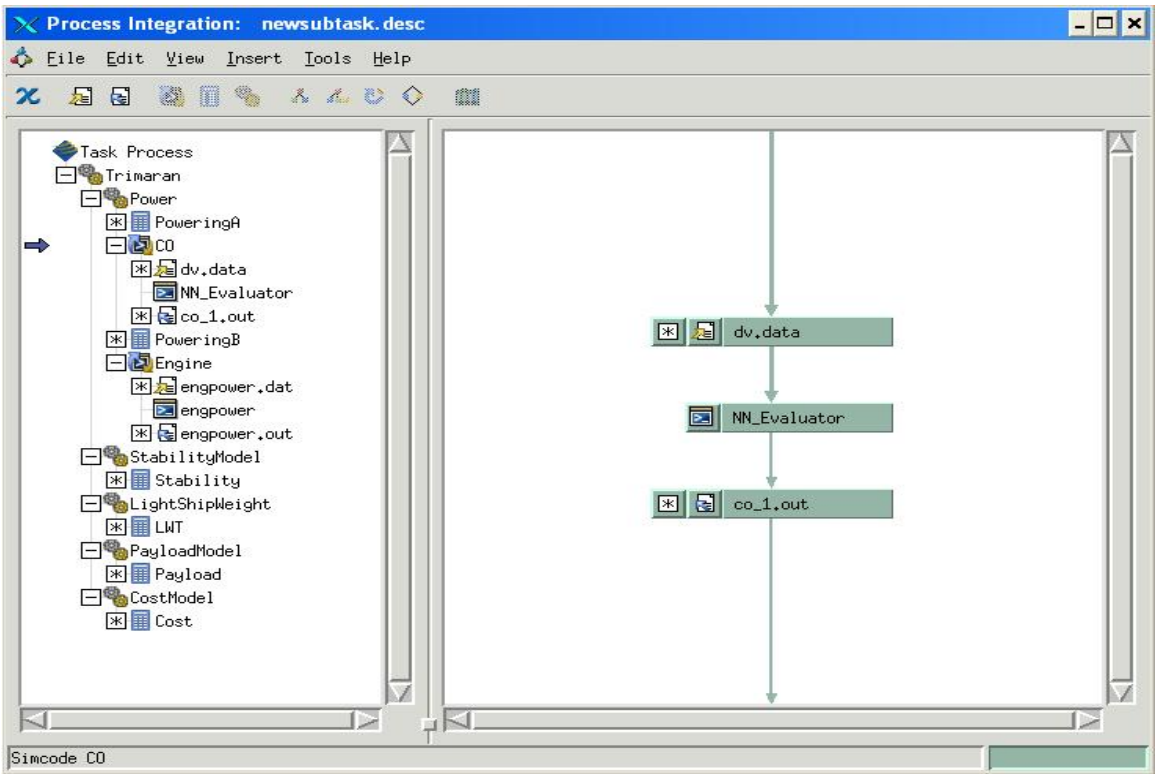

Figure 3. iSIGHT Process Integration, detail for *CO* simcode

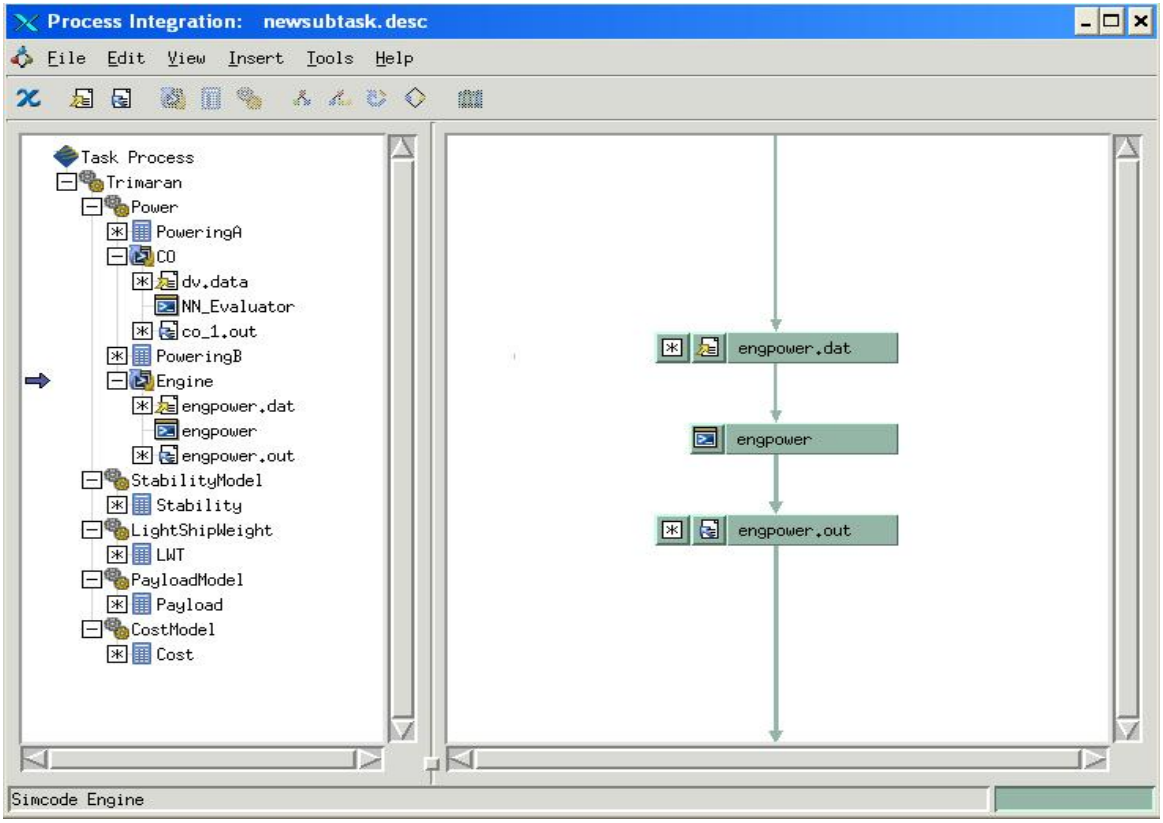

Figure 4 iSIGHT Process Integration, detail for *Engine* simcode

Sample Data for Coefficient of residual resistance (*CO*)

Sample Input file

The sample input file (dv.data) shown below is used in the *CO* of the powering section in iSIGHT. The Sl and the Fn values are calculated in the *PoweringA* and then provided to the input file. Alpha & beta are the design variables Separation and Stagger. The dv.data file is parsed in iSIGHT. The Coefficient of Residual Resistance is evaluated by NN_Evaluator which is a neural network trained as function approximation. Please see Reference 2 for more details.

dv.data file

```
Sl                    beta          alpha       Fn
7.63950133999022     0.084084     0.57407    0.357121049302874
```

The template file dv_temp.data is simply a copy of the dv.data file and is required by iSIGHT for parsing purposes.

Sample Output file

The output of the neural network is the coefficient of residual resistance (CO) which is a function of the inputs given in the dv.data file.
The output file (co_1.out) provides also the user with the minimum and maximum values of slenderness, beta, alpha and Froude number as well as the average value of *CO*. These values are not parsed in iSIGHT, they just give information on the size of the domain for which the function approximation (*CO*) is valid.

The *co_1.out* is a standard output file, so the Standard Output File Box should be checked in iSIGHT when defining the properties of this file. In UNIX the equivalent command would be "`NN_evaluator > co_1.out`".

co_1.out file

```
output= 4.618502
MinInput[j]= {6.000000,0.000000,0.500000,0.200000}
MaxInput[j]= {12.000000,1.000000,2.000000,1.000000}
MeanTarget= 2.534722
```

Sample Data for Engine Power

Sample input file

The sample input file (engpower.dat) shown below is used in the *Engine* of the powering section, it contains the Power required at full speed (PfullSpeed) that is calculated in the *PoweringB* section and provided by iSIGHT the to file via file parsing. This value is then used by

the executable enginepower, a code written in C++, which determines the number of diesel and gas turbine engines and their respective power. The C++ code is given in Appendix a detailed explanation on how power is calculated is provided in Ref. 2.

enginepower.dat file

```
*******************************************************
      Input data for engpower.C as defined 05/24/05
*******************************************************
      PfullSpeed(in MW)
      -----------------
          173.515010
```

Sample output file

The output file (enginepower.out) is a standard output file created by enginepower. It provides with the number of diesel engines (Ndiesel), number of gas turbines (Ngt), power generated by diesel engines (Pdiesel) and power generated by gas turbines (Pgt). These values are passed back to iSIGHT via file parsing.

enginepower.out file

```
*************************************************************************
     Power output (in MW) for diesel and gas turbines calculated by
engpower.C (5/24/05)

*************************************************************************
      Ndiesel = 2
      Ngt     = 4
      Pdiesel = 40
      Pgt     = 133.515
```

1.3 Process Integration for StabilityModel, LightShipWeight, PayloadModel and CostModel

Those four subtasks consists only of each a calculation block. The equations can be found in the iSIGHT desc file in Appendix A and a detailed explanation in Ref. 2.

The flow of variables within the subtask *StabilityModel* is shown in figure 5. The task process is the same for all other subtasks, i.e., *LightShipWeight, PayloadModel* and *CostModel.*

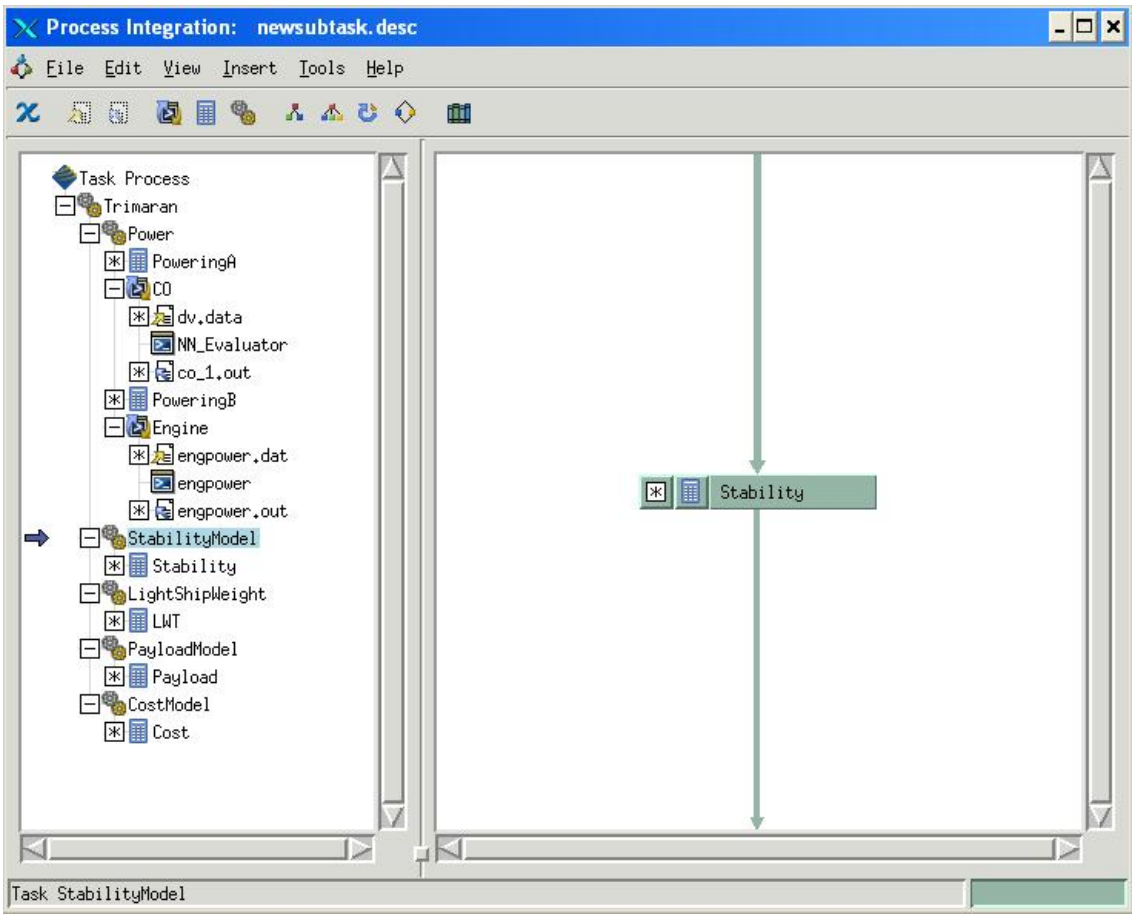

Figure 5. iSIGHT Process Integration, detail for *StabilityModel* Calculation.

2 Objectives Functions & iSIGHT Optimization Plans

The user has the choice of running single or multiple criterion optimization. The recommended optimization plans are NLPQL for single objective and NCGA (or NSGA II) for multi- objective [Ref 1]. NewPlan is the name for the plans that are being set up in iSIGHT for NLPQL as well as NCGA. The Optimization plans in iSIGHT can be changed in the task plan section under optimization plans.

2.1 Multiple Criterion: (NCGAgene40)

In this plan the user can optimize several objectives at the same time and results from the optimization give the Pareto Optimal Solution from which the user can then select a most desirable combination of the objectives. Parameters chosen for the optimization plan are shown in table 1–

Table 1 List of parameters used in iSIGHT's (NCGA)

Parameters

SR NO	OPTIONS	VALUES
1.	Population Size	50
2.	Number of generations	100
3.	Crossover type	Two
4.	Crossover rate	1.0
5.	Use optimal mutation rate	Yes
6.	Mutation Rate	0.01
7.	Gene Size (bits)	40
8.	Use initialization files	No
9.	Initialize file name	init_ncga.db
10.	Iterations for constraint violation	0

For this application the chosen objective functions are the annual cargo and the building cost. The objectives functions are selected in the Parameters list in iSIGHT [Ref 1].

2.1.1 Minimize Building Cost

The Building cost is the cost incurred in the construction of the ship which includes the hull cost, machinery cost, outfit cost and miscellaneous cost. [Ref. 2]

SCOST=CHULL+CMACHINERY+COUTFIT+CMISC

2.1.2 Maximize Annual Cargo

The Annual cargo is the product of Number of 20 ft' equivalent containers (or trailers see section OPP) and Number of trips the ship makes per year. [Ref. 2]

AnnualCargo=Nteutrai x NTRIP

2.2 Single Criterion: (NLPQL200)

In this plan the best solution is found using the NLPQL method of iSIGHT [Ref. 2] with the task plan parameters described in table 2. The customer can choose which objective function to minimize or maximize in the parameters list in iSIGHT. The Required Freight Rate was chosen for this application.

Basic Parameters

Table 2 List of parameters used in iSIGHT's NLPQL

SR NO	OPTIONS	VALUES
1.	Maximum Iterations	200
2.	Termination Accuracy	0.001
3.	Relative Gradient Step	0.01
4.	Minimum Absolute Gradient Step	0.001

Minimize Required Freight Rate (RFR)

Required freight rate depends on Annual Cost per 1 vessel fleet (ACFLEET), Annual freight volume per 1 vessel fleet (AFvolume) and the Range / Length of shipping line of operation (R). RFR is to be minimized In order to reduce the cost incurred per 20ft equivalent container (TEU) or trailer.

RFR=ACFLEET/AFvolume/R

3 Design Variables & Parameters

The Design Variables (DV), Input Model Parameters (IMP) and Optimization Problem Parameters (OPP) are briefly described in this chapter. The DV's define the Trimaran configuration (geometry and speed), these are considered as input to iSIGHT. Whereas IMP and OPP are part of the definition of the model, they do not vary during optimization, they are defined as auxiliaries in iSIGHT. The OPP's are IMP which are problem dependent and can be changed by the user according to the type of ship (conventional side hull or small waterplane area (SWA) type), the shipping line, type of cargo that will be handled, and shipyard chosen to build the ship.

3.1 Design Variables

The model has a maximum of 11 design variables that define the model (see table 3). The design variables along with their lower and upper bounds are chosen in the parameters list in iSIGHT. These values can be adjusted depending on building/shipping line constraints. These are the values chosen for the current application.

Table 3 List of design variables

SR NO	ISIGHT NAME	LOWER BOUND	UPPER BOUND	DESCRIPTION
1.	Lch	100	250	Length of Center Hull
2.	Bch	12	24	Beam of Center Hull
3.	Bsh	3	8	Beam of Side Hull
4.	Tch	4	12	Draft of Center Hull
5.	Cbch	0.45	0.60	Block Coefficient of Center Hull
6.	Cbsh	0.45	0.60	Block Coefficient of Side Hull
7.	Vk	25	45	Speed (knots)
8.	alpha	0.5	2.0	Separation
9.	beta	0	1.0	Stagger
10.	lambda	0.03	0.15	Lambda
11.	lamdash	0.1	0.75	Lambda-sh

3.2 Input Model Parameters

The following table gives a brief description of the auxiliaries input in iSIGHT. Only the parameters defined in the OPP's should be changed by the user. A comprehensive description of variables can be found in Ref. 2. The variables are sorted according to the calculation block in which they are used (Powering, Stability, LightShip Weight, Payload, Cost).

Table 4 List of auxiliaries inputs to iSIGHT Model

POWERING			
SR No	Input Model Parameters	Values	Description
1.	AA1	9.15	Shape coefficient
2.	v	1.187×10^{-6}	Viscosity (m^2/s)
3.	PEC	0.65	Propulsion efficiency coefficient
STABILITY			
4.	C_{wl}^{ch}	0.75	Waterline coefficient for center hull
5.	C_{wl}^{sh}	0.75	Waterline coefficient for side hull
6.	F_{ch}	1	Proportionality factor for center hull
7.	F_{sh}	1	Proportionality factor for side hull
LIGHT SHIP WEIGHT			
8.	K_{ch}	0.075	Center hull weight dimensional coefficient in $tons/m^3$
9.	C_m^{ch}	0.75	Midship coefficient of center hull
10.	K_{sh_conv}	0.1	Side Hull Weight dimensional coefficient (conventional type) in $tons/m^3$
11.	K_{sh_swa}	0.13	Side Hull Weight dimensional coefficient (SWA type) in $tons/m^3$
12.	C_m^{sh}	0.75	Midship coefficient of side hull
13.	K_{ss}	0.04	Superstructure weight dimensional coefficient
14.	N_{crew}	18	Number of crew
15.	N_{pas}	12	Number of passengers
16.	$K_{hull-misc}$	0.025	Miscellaneous weight dimensional coefficient of hulls in $tons/m^3$
17.	K_o	0.03	Dimensional statistic coefficient for outfit weight estimate in $tons/m^3$
18.	K_{m_GT}	13	Statistical dimensional coefficient for gas turbines in machinery and propulsion weight estimate in tons/MW
19.	K_{m_diesel}	25	Statistical dimensional coefficient for diesel in machinery and propulsion weight estimate in tons/MW
20.	$K_{LWT-misc}$	0.02	Miscellaneous weight dimensional coefficient of light ship in $tons/m^3$
PAYLOAD			
21.	K_{bd}	0.3	Deck weight dimensional coefficient in $tons/m^2$
22.	$CDAU$	0.75	Deck area utilization coefficient
23.	$NTEUTRAI_{rows}$	2	Number of rows for containers
24.	$STOW_{TEUTRAI}$	1.4865	Cargo stowage factor for TEU in m^2/ton

25.	$STOW_{TEUTRAI}$	1.6722	Cargo stowage factor for trailer in m^2/ton
26.	$W_{TEUTRAI}$	10	Weight of TEU in tons
27.	$W_{TEUTRAI}$	18	Weight of Trailer in tons
28.	SFC_{GT}	0.210	Specific fuel consumption for gas turbines in kg/hr/kW
29.	SFC_{diesel}	0.16	Specific fuel consumption for diesel engines in kg/hr/kW
30.	SFC_{pilot}	0.35	Specific fuel consumption at pilotage for gas turbines in kg/hr/kW
31.	SFC_{pilot}	0.25	Specific fuel consumption at pilotage for diesel engines in kg/hr/kW
32.	SFC_{aux}	0.16	Auxiliary specific fuel consumption in kg/hr/kW
33.	N_{d_MAX}	4	Maximum number of decks
34.	V_{pilot}	10	Speed at pilotage
35.	R_{pilot}	50	Range at pilotage in nm
36.	$BOL_{\max}$	57	Maximum beam overall length in meters
COST			
37.	H_H	90 hrs/ton	Productivity rate for hull manufacturing and assembly
38.	H_M	120 hrs/ton	Productivity rate for machinery assembly and installation
39.	H_o	80 hrs/ton	Productivity rate for outfit sys
40.	H_{misc}	15 hrs/ton	Productivity rate for other systems
41.	R_H	50 $/hr	Labor rate for hull construction
42.	R_M	60 $/hr	Labor rate for machinery installation
43.	R_o	50 $/hr	Labor rate for outfit works
44.	R_{misc}	60 $/hr	Labor rate for engineering and shipyard support
45.	M_H	720 $/ton	Relative material cost for hull

46.	M_M	27800 $/ton	Relative material cost for machinery (Gas turbines)
47.	M_M	10000 $/ton	Relative material cost for machinery (diesel engine)
48.	M_o	4000 $/ton	Relative material cost for outfit
49.	$M_{LWT-misc}$	17500 $/ton	Relative material cost for electric, electronics, navig.
50.	AAC_{crew}	140000 $/yr	Average annual cost of 1 member of the crew
51.	$COST_{maint}$	1% $SCOST$	General annual cost of ship maintenance
52.	$COST_{ins}$	0.8% $SCOST$	Annual insurance cost
53.	$COST_{supply}$	100 $/day/person	Provision & hotel supply
54.	TOP	350 days	Annual operational period
55.	$COST\_M_{maint}GT$	150 $/hr	Cost of machinery maintenance for gas turbine
56.	$COST\_M_{maint}diesel$	25 $/hr	Cost of machinery maintenance for diesel engine
57.	R	800 nm	Range / Length of shipping line of operation
58.	R_{pilot}	50	Range of pilotage
59.	T_{aux}	5 hrs	Engine time (Auxiliary engines for generators)
60.	$COST\_FUEL$	400 $/ton	Fuel Cost

61.	$COST_{LUBE}$	8.96 $/kg	Lube oil cost
62.	$SLOC$	0.45kg/hr	Specific lube oil consumption
63.	$COST_{pilot}$	650 $/port	Pilotage cost per port
64.	$COST_{TEUTRAI}$	$ 125	TEU cost
65.	$COST_{TEUTRAI}$	$ 30	Trailer cost
66.	$KOEF_{cap\_cost}$	0.115	Capital cost coefficient

3.3 Optimization Problem Parameters

The Optimization Problem Parameters (OPP) are the parameters that can be input by the user/customer depending on the Optimization Problem. All these parameters can be changed in the Parameters list in iSIGHT Process Integration module.

3.3.1 Type of Cargo

The model has been programmed to handle two basic types of freight; 20 ft equivalent containers (TEU) or trailers (TRAI). The customer must define the Stowage Factor (STOWteutrai), Weight of trailer/container (Wteutrai) and Number of rows of Trailer per deck (Nteutrairows), as well of the Cost of cargo handling (COSTteutrai) which can also depend on the ports of shipping line (see section 4.3.2).

Recommended values for TEU or 20ft equivalent containers:

STOWteutrai=$1.4865\ m^2/ton$
Wteutrai=10 tons
Nteutrairows = 2 or more
COSTteutrai = $ 125/TEU

Recommended values for Trailers:

STOWteutrai = $1.6723\ m^2/ton$
Wteutrai = 10 tons
Nteutrairows = 2
COSTteutrai = $ 30/TEU

3.3.2 Minimum Payload, Maximum Beam Overall Length, Maximum Number of Decks

The current values are:
PayloadMIN = 1000 tons
BOLMAX = 57 m
NdMAX = 4

3.3.3 Shipping Line information

3.3.3.1 Range of Shipping Line

Range (R) must be changed according to shipping line length in nautical miles. Currently R is set to 800nm.

3.3.3.2 Port information

a. Length of restricted speed (low speed & pilotage) and speed of pilotage (low speed) can be chosen. For the current application the speed of pilotage (Vpilot) is assumed to be 10 knots and the Length of restricted speed (Rpilot) is set to 50 nm.
b. Cost of port pilot services – COSTpilot currently set to 650 $/port
c. Cost of cargo handling operations in the ports of shipping line COSTteutrai. (Also depends on the type of cargo used (see subsection above)

3.3.4 Cost of Fuel – COSTFUEL [$/ton]

COSTFUEL is assumed to be 400 $/ton in this application

3.3.5 Type of Trimaran configuration – TYPEsh

TYPEsh=1, if Side hulls are conventional high speed ship hull forms (of Serial 64 type);
TYPEsh=0 if Side hulls are of Small Waterplane Area (SWA) type.

3.3.6 Type of building facility (where the ship is supposed to be built)

TYPEbuild_yard=1, if the ship would be built in international commercial ship yard;
TYPEbuild_yard=2, if the ship would be built in US commercial ship yard
TYPEbuild_yard=3, if the ship would be built in US Navy yard

This parameter indicates the various production rates for hull, machinery and outfit as well as labor rates, which can change and will considerably influence the building cost of ship. An accurate database (corresponding to this parameter) requires considerable data and would be included in the future version of the code.

4 Constraints

Some dependent variables must be restricted during optimization to avoid unrealistic ship designs, 7 constraints (G1 to G7) have been set up for the current optimizations. In iSIGHT, constraints are calculated in the subtasks and their bounds are defined in the Parameters List.

G1 restricts the ratio of the draft of side hull to center hull.
G1 = Tsh/Tch/1.5 and G1≤1

G2 restricts the ratio of the beam of center hull and draft of center hull.
G2 = Bch/Tch/4 and .375≤G2≤1

G3 restricts the ratio of the beam of side hull an draft of side hull.
G3 = Bsh/Tsh/3 and ⅓≤G3≤1

G4 limits the Volumetric Froude number
G4= Fnvol/1.5 and G4≤1

G5 limits the Power at Full Speed
G5= Pfullspeed/200 and G5≤1

G6 limits the payload to values above the minimum payload desired
G6=PayloadMIN/Payload and G6≤1

G7 limits the Beam Overall Length to values below the maximum desired BOL.
G7=BOL/BOLMAX and G7≤1

5 Dependent Variables

Many intermediate variables are calculated in order to evaluate the objective(s) and Constraints. Table 6 shows the list of all dependent variables organized by subtask. These dependent variables can all be set as objectives depending on user's requirements.

Table 5 List of all dependent variables defined in iSIGHT, organized by subtask

SR NO	OUTPUTS	DESCRIPTION
		POWERING A
1.	Vch	Volume displacement for center hull in m^3
2.	Displch	Displacement of center hull in tons
3.	Displsh	Displacement of side hull in tons
4.	Slch	Slenderness of center hull
5.	Lsh	Length of side hull
6.	Tsh	Draft of side hull
7.	Vsh	Volume displacement for side hull in m^3
8.	V	Total volume displacement in m^3
9.	WS	Wetted surface in m^2
10.	Slsh	Slenderness of side hull
11.	WSch	Wetted surface of center hull in m^2
12.	WSsh	Wetted surface of side hull in m^2
13.	Sl	Slenderness
14.	Vs	Speed in m/s
15.	REch	Reynolds number for center hull
16.	REsh	Reynolds number for side hull
17.	RE	Reynolds number
18.	Fn	Froude number
19.	Fnvol	Volumetric froude number
20.	G1	Ratio of the draft of side hull to center hull
21.	G2	Ratio of the beam of center hull and draft of center hull
22.	G3	Ratio of the beam of side hull an draft of side hull
23.	G4	Limits Volumetric Froude number
		POWERING B

24.	CF	Coefficient of friction
25.	CK	Correlation coefficient
26.	CR	Total resistance coefficient
27.	RES	Resistance of Trimaran in Newtons
28.	Peffective	Effective power in MW
29.	PfullSpeed	Power at full speed in MW
30.	G5	Limits the Power at Full Speed
COEFFICIENT OF RESIDUAL RESISTANCE		
31.	CO	Coefficient of residual resistance
ENGINE POWER		
32.	Ngt	Number of gas turbines
33.	Ndiesel	Number of diesel engines
34.	Pdiesel	Power generated by diesel engines in MW
35.	Pgt	Power generated by gas turbines in MW

Stability

SR NO	OUTPUTS	DESCRIPTION
36.	B	Clearance between center hull and side hull in meters
37.	KBch	Vertical center of buoyancy for center hull in meters
38.	KBsh	Vertical center of buoyancy for side hull in meters
39.	KB	Vertical center of buoyancy for trimaran in meters
40.	KGch	Vertical center of gravity of center hull in meters
41.	KGsh	Vertical center of gravity of side hull in meters
42.	KG	Vertical center of gravity for Trimaran in meters
43.	BM	Metacentric radius of Trimaran in meters
44.	GMt	Metacentric height of trimaran in meters

Light Ship Weight

SR NO	OUTPUTS	DESCRIPTION
45.	HWCch	Height of water clearance of center hull in meters
46.	HWCsh	Height of water clearance of side hull in meters
47.	Cdch	Block coefficient of depth volume of center hull
48.	Cdsh	Block coefficient of depth volume of side hull
49.	Vdch	Volume of depth displacement of center hull in m^3
50.	Vdsh	Volume of depth displacement of side hull in m^3
51.	Wch	Weight of center hull in tons
52.	Wsh	Weight of side hull in tons
53.	Wss	Weight of Superstructure in tons
54.	Whullmisc	Miscellaneous hull weight in tons
55.	Whullnodeck	Weight of hull without the decks in tons
56.	Wmgt	Machinery & propulsion weight for gas turbines in tons
57.	Wmdiesel	Machinery & propulsion weight in tons for diesel engines
58.	Vd	Total volume of depth displacement in m^3
59.	Wo	Outfit weight in tons
60.	Wlwtmisc	Miscellaneous light ship weight in tons
61.	LWTnodeck	Light ship weight without the decks in tons

Payload

SR NO	OUTPUTS	DESCRIPTION
62.	Tfullspeed	Time at full speed in hours
63.	Tpilot	Time at pilotage in hours
64.	Ttrip	Total time for trip in hours
65.	WFUELfullspeed	Weight of fuel at full speed in tons
66.	Ppilot	Power at pilotage in MW
67.	WFUELpilot	Weight of fuel at pilotage in tons
68.	Paux	Auxiliary power in MW
69.	WFUELaux	Weight of fuel for auxiliary engines in MW
70.	WFUEL	Total weight of fuel in tons
71.	TotalDeckArea	Total Area of all decks in m^2
72.	BOL	Beam overall length in meters
73.	A	Clearance between aft perpendiculars of center hulls and side hulls
74.	Ldmax	Maximum length of deck in meters
75.	AreaCargodeckMAX	Maximum cargo deck area in m^2
76.	Nd	Number of decks
77.	AreaCargodeck	Cargo deck area per one deck in m^2
78.	Ld	Deck length in meters
79.	Wdeck	Weight of bridge deck in tons
80.	Whull	Weight of hulls in tons
81.	LWT	Lightship weight in tons
82.	Hship	Height of ship in meters
83.	CARGOarea	Cargo area for containers in m^2
84.	Nteutrai	Number of equivalent 20' containers (TEU) or trailers per trip
85.	Payload	Total weight of containers / trailers in tons
86.	NTRIP	Number of trips
87.	AnnualCargo	Total cargo that Trimaran can carry in one year in tons
88.	G6	limits the payload to values above the minimum payload desired
89.	G7	limits the Beam Overall Length to values below the maximum desired BOL

Cost

SR NO	OUTPUTS	DESCRIPTION
90.	CHULL	Cost of hull in $
91.	CMACHINERYgt	Cost of machinery for gas turbines in $
92.	CMACHINERYdiesel	Cost of machinery for diesel engines in $
93.	CMACHINERY	Total cost of machinery in $
94.	COUTFIT	Outfit cost in $
95.	CMISC	Miscellaneous cost in $
96.	SCOST	Total ship cost in $
97.	Ccrew	Annual payroll cost in $/year
98.	Cmi	Cost of vessel maintenance & insurance in $
99.	Ccs	Cost of annual consumable supplies in $
100.	CMm	Annual cost of machinery maintenance in $
101.	ACF	Annual cost of fuel in $
102.	ACLO	Annual cost of lube oil in $
103.	ACpilot	Cost of pilotage in $

104.	ACch	Annual cost of cargo handling in $
105.	ACC	Annual capital cost in $
106.	ACFLEET	Annual cost of fleet in $
107.	AFvolume	Annual freight volume per 1 vessel fleet
108.	RFR	Required freight rate

6 Flow of Variables between subtasks

Figure 6 shows the inputs, outputs and Constraints and the flow of variables between all subtasks.

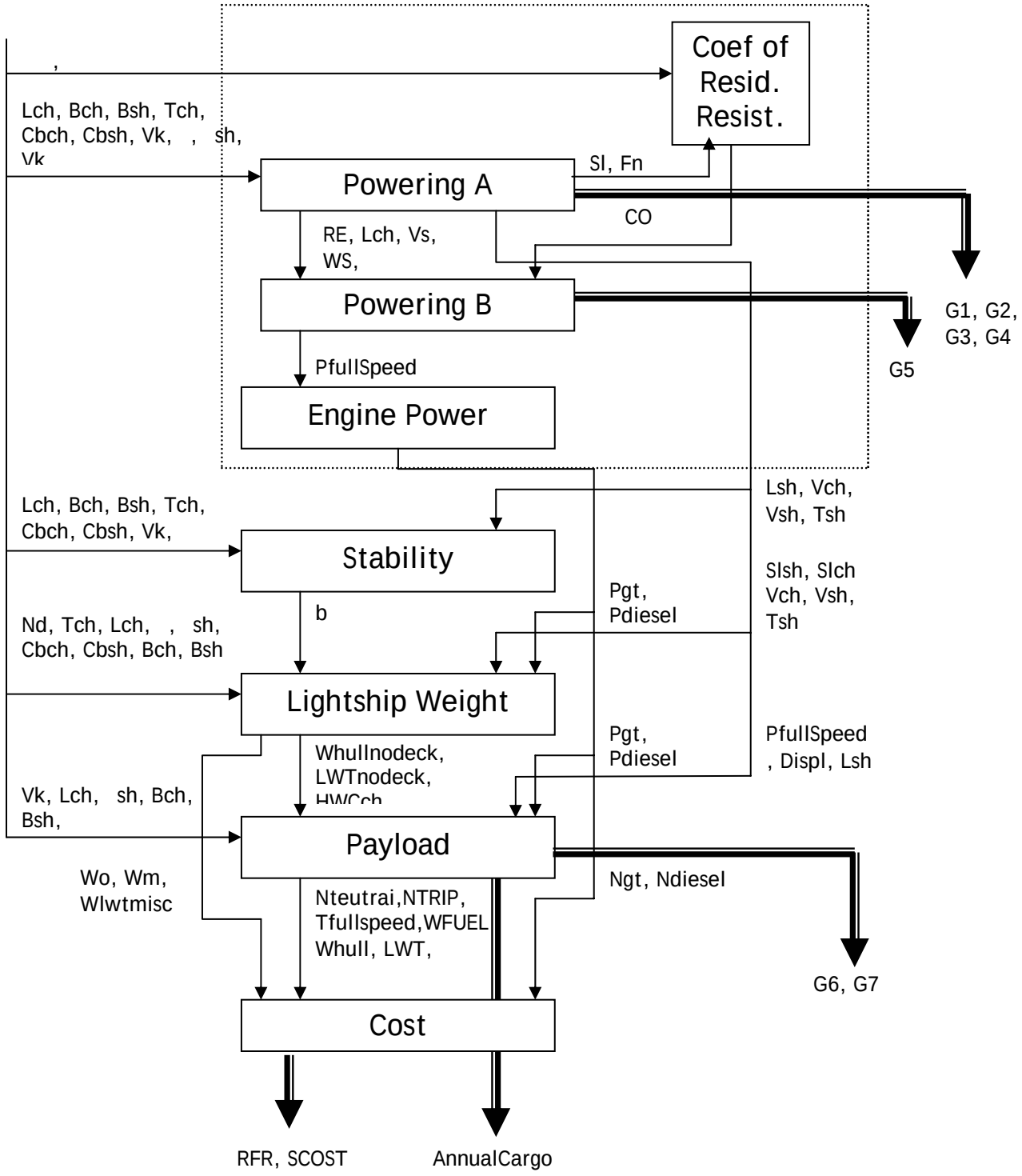

Figure 6: Inputs, outputs and Constraints and the flow of variables between all subtasks.

References

1. Isight Users Manual. Engineous Software, www.engineous.com.
2. H. Hefazi, A. Schmitz , R Shinde and I. Mizine , "Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels" , Center for Comercial Deployment of Transportaion Technology CCDoTT FY 04 Task 2 Final Project Report , July 2005 , www.ccdott.org
3. H. Hefazi et al, "Optimization Tool Development Based on Neural Networks" , Center for Comercial Deployment of Transportaion Technology CCDoTT FY 02 Project Report DI-MCCR-80700, 2003, www.ccdott.org

Appendix A: iSIGHT desc file newsubtask.desc

```
MDOLVersion: 8.0
CompilerOptions: warn

Task Trimaran

    TaskHeader Trimaran
        Version: 1.0
        Evaluation: optimize NLPQL200
        ControlMode: user
        RunCounter: 83
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader Trimaran

    Inputs Trimaran
        Parameter: Cbsh Type: real InitialValue: 0.558252811431885
        Parameter: Cbch Type: real InitialValue: 0.451333665847778
        Parameter: Vk Type: real InitialValue: 36.0350036621094
        Parameter: Bch Type: real InitialValue: 13.6501121520996
        Parameter: Bsh Type: real InitialValue: 7.04721260070801
        Parameter: Tch Type: real InitialValue: 4.3309326171875
        Parameter: lambda Type: real InitialValue: 0.0524355697631836
        Parameter: lamdash Type: real InitialValue: 0.164082813262939
        Parameter: Lch Type: real InitialValue: 206.041383743286
        Parameter: beta Type: real InitialValue: 0.00396347045898438
        Parameter: alpha Type: real InitialValue: 1.5718822479248
    End Inputs Trimaran

    Auxiliaries Trimaran
        Parameter: Mmdiesel Type: real InitialValue: 10000.0
        Parameter: Mmgt Type: real InitialValue: 40000.0
        Parameter: PayloadMIN Type: real InitialValue: 1000.0
        Parameter: Ndmax Type: integer InitialValue: 4
        Parameter: Rpilot Type: real InitialValue: 50.0
        Parameter: Cwlch Type: real InitialValue: 0.75
        Parameter: Cwlsh Type: real InitialValue: 0.75
        Parameter: Fsh Type: real InitialValue: 1.0
        Parameter: Fch Type: real InitialValue: 1.0
        Parameter: PEC Type: real InitialValue: 0.65
        Parameter: v Type: real InitialValue: 1.187e-06
        Parameter: g Type: real InitialValue: 9.8065
        Parameter: rho Type: real InitialValue: 1025.0
        Parameter: AA1 Type: real InitialValue: 9.15
        Parameter: Kshconv Type: real InitialValue: 0.1
        Parameter: Ncrew Type: real InitialValue: 18.0
        Parameter: Kbd Type: real InitialValue: 0.3
        Parameter: Ko Type: real InitialValue: 0.03
        Parameter: Kmdiesel Type: real InitialValue: 25.0
        Parameter: Deckcl Type: real InitialValue: 2.25
        Parameter: Khullmisc Type: real InitialValue: 0.025
        Parameter: Kch Type: real InitialValue: 0.075
        Parameter: Kmgt Type: real InitialValue: 13.0
        Parameter: Npas Type: real InitialValue: 12.0
```

```
        Parameter: Cmch Type: real InitialValue: 0.75
        Parameter: CDAU Type: real InitialValue: 0.75
        Parameter: Klwtmisc Type: real InitialValue: 0.02
        Parameter: Hdeckstr Type: real InitialValue: 2.25
        Parameter: Kss Type: real InitialValue: 0.04
        Parameter: hwc Type: real InitialValue: 1.0
        Parameter: Cmsh Type: real InitialValue: 0.75
        Parameter: SFCdiesel Type: real InitialValue: 0.16
        Parameter: R Type: real InitialValue: 800.0
        Parameter: STOWteutrai Type: real InitialValue: 1.4865
        Parameter: SFCpilot Type: real InitialValue: 0.25
        Parameter: Taux Type: real InitialValue: 5.0
        Parameter: Tpilot Type: real InitialValue: 5.0
        Parameter: Wteutrai Type: real InitialValue: 10.0
        Parameter: SFCgt Type: real InitialValue: 0.21
        Parameter: Nteutrairows Type: real InitialValue: 2.0
        Parameter: SFCaux Type: real InitialValue: 0.16
        Parameter: COSTmaint Type: real InitialValue: 0.1
        Parameter: Rh Type: real InitialValue: 50.0
        Parameter: Rm Type: real InitialValue: 60.0
        Parameter: Ro Type: real InitialValue: 50.0
        Parameter: KOEFcapcost Type: real InitialValue: 0.175
        Parameter: Hmisc Type: real InitialValue: 15.0
        Parameter: Mh Type: real InitialValue: 720.0
        Parameter: COSTFUEL Type: real InitialValue: 400.0
        Parameter: Rmisc Type: real InitialValue: 60.0
        Parameter: COSTsupply Type: real InitialValue: 100.0
        Parameter: Mlwtmisc Type: real InitialValue: 17500.0
        Parameter: COSTMmaintgt Type: real InitialValue: 150.0
        Parameter: Mo Type: real InitialValue: 4000.0
        Parameter: COSTpilot Type: real InitialValue: 650.0
        Parameter: COSTins Type: real InitialValue: 0.008
        Parameter: TOP Type: real InitialValue: 350.0
        Parameter: COSTteutrai Type: real InitialValue: 125.0
        Parameter: Hh Type: real InitialValue: 90.0
        Parameter: Costlube Type: real InitialValue: 8.96
        Parameter: SLOC Type: real InitialValue: 0.45
        Parameter: Hm Type: real InitialValue: 120.0
        Parameter: COSTMmaintdiesel Type: real InitialValue: 25.0
        Parameter: Ho Type: real InitialValue: 80.0
        Parameter: AACcrew Type: real InitialValue: 140000.0
        Parameter: Vpilot Type: real InitialValue: 10.0
        Parameter: BOLmax Type: real InitialValue: 57.0
        Parameter: Kshswa Type: real InitialValue: 0.13
        Parameter: Typesh Type: real InitialValue: 1.0
    End Auxiliaries Trimaran

    Outputs Trimaran
        Parameter: Nd Type: integer
        Parameter: CO Type: real
        Parameter: CF Type: real
        Parameter: RES Type: real
        Parameter: WS Type: real
        Parameter: PfullSpeed Type: real
        Parameter: Fn Type: real
        Parameter: Displ Type: real
        Parameter: WSsh Type: real
```

```
Parameter: WSch Type: real
Parameter: CK Type: real
Parameter: V Type: real
Parameter: RE Type: real
Parameter: Sl Type: real
Parameter: Displch Type: real
Parameter: Displsh Type: real
Parameter: Tsh Type: real
Parameter: Peffective Type: real
Parameter: Vs Type: real
Parameter: Vch Type: real
Parameter: Vsh Type: real
Parameter: REsh Type: real
Parameter: REch Type: real
Parameter: Slch Type: real
Parameter: Slsh Type: real
Parameter: CR Type: real
Parameter: Lsh Type: real
Parameter: GMt Type: real
Parameter: KBsh Type: real
Parameter: KBch Type: real
Parameter: KGsh Type: real
Parameter: KGch Type: real
Parameter: KB Type: real
Parameter: KG Type: real
Parameter: b Type: real
Parameter: BM Type: real
Parameter: Ndiesel Type: integer
Parameter: Ngt Type: integer
Parameter: Pdiesel Type: real
Parameter: Pgt Type: real
Parameter: Ld Type: real
Parameter: a Type: real
Parameter: Cdch Type: real
Parameter: Cdsh Type: real
Parameter: Wss Type: real
Parameter: BOL Type: real
Parameter: Wdeck Type: real
Parameter: Whullmisc Type: real
Parameter: Wlwtmisc Type: real
Parameter: Vd Type: real
Parameter: Wsh Type: real
Parameter: Wch Type: real
Parameter: Hwc Type: real
Parameter: Whull Type: real
Parameter: AreaCargodeck Type: real
Parameter: Hship Type: real
Parameter: Vdch Type: real
Parameter: Vdsh Type: real
Parameter: Wo Type: real
Parameter: LWT Type: real
Parameter: AnnualCargo Type: real
Parameter: NTRIP Type: real
Parameter: CARGOarea Type: real
Parameter: Paux Type: real
Parameter: WFUELfullspeed Type: real
Parameter: Tfullspeed Type: real
```

```
        Parameter: Ppilot Type: real
        Parameter: WFUELaux Type: real
        Parameter: Payload Type: real
        Parameter: Ttrip Type: real
        Parameter: WFUELpilot Type: real
        Parameter: WFUEL Type: real
        Parameter: Nteutrai Type: real
        Parameter: RFR Type: real
        Parameter: SCOST Type: real
        Parameter: Cmi Type: real
        Parameter: Ccs Type: real
        Parameter: ACF Type: real
        Parameter: CMACHINERY Type: real
        Parameter: ACFLEET Type: real
        Parameter: Ccrew Type: real
        Parameter: ACpilot Type: real
        Parameter: CMm Type: real
        Parameter: ACLO Type: real
        Parameter: CHULL Type: real
        Parameter: COUTFIT Type: real
        Parameter: AFvolume Type: real
        Parameter: ACC Type: real
        Parameter: ACch Type: real
        Parameter: CMISC Type: real
        Parameter: G1 Type: real
        Parameter: G2 Type: real
        Parameter: G3 Type: real
        Parameter: G4 Type: real
        Parameter: G5 Type: real
        Parameter: Fnvol Type: real
        Parameter: G6 Type: real
        Parameter: Whullnodeck Type: real
        Parameter: LWTnodeck Type: real
        Parameter: AreaCargodeckMAX Type: real
        Parameter: TotalDeckArea Type: real
        Parameter: LdMAX Type: real
        Parameter: HWCch Type: real
        Parameter: HWCsh Type: real
        Parameter: G7 Type: real
        Parameter: Wmdiesel Type: real
        Parameter: Wmgt Type: real
        Parameter: CMACHINERYgt Type: real
        Parameter: CMACHINERYdiesel Type: real
    End Outputs Trimaran

    Task Power

        TaskHeader Power
            Version: 1.0
            Evaluation: single
            ControlMode: user
            RunCounter: 85
            BoundsPolicy: adjustvalue
            CheckPoint: unknown
        End TaskHeader Power

        Inputs Power
```

```
            Parameter: Cbsh Type: real InitialValue: 0.558252811431885
            Parameter: Cbch Type: real InitialValue: 0.451333665847778
            Parameter: Vk Type: real InitialValue: 36.0350036621094
            Parameter: Bch Type: real InitialValue: 13.6501121520996
            Parameter: Bsh Type: real InitialValue: 7.04721260070801
            Parameter: Tch Type: real InitialValue: 4.3309326171875
            Parameter: lambda Type: real InitialValue:
0.0524355697631836
            Parameter: lamdash Type: real InitialValue:
0.164082813262939
            Parameter: Lch Type: real InitialValue: 206.041383743286
            Parameter: beta Type: real InitialValue:
0.00396347045898438
            Parameter: alpha Type: real InitialValue: 1.5718822479248
        End Inputs Power

        Auxiliaries Power
            Parameter: PEC Type: real InitialValue: 0.65
            Parameter: v Type: real InitialValue: 1.187e-06
            Parameter: g Type: real InitialValue: 9.8065
            Parameter: rho Type: real InitialValue: 1025.0
            Parameter: AA1 Type: real InitialValue: 9.15
        End Auxiliaries Power

        Outputs Power
            Parameter: CO Type: real
            Parameter: CF Type: real
            Parameter: RES Type: real
            Parameter: WS Type: real
            Parameter: PfullSpeed Type: real
            Parameter: Fn Type: real
            Parameter: Displ Type: real
            Parameter: WSsh Type: real
            Parameter: WSch Type: real
            Parameter: CK Type: real
            Parameter: V Type: real
            Parameter: RE Type: real
            Parameter: Sl Type: real
            Parameter: Displch Type: real
            Parameter: Displsh Type: real
            Parameter: Tsh Type: real
            Parameter: Peffective Type: real
            Parameter: Vs Type: real
            Parameter: Vch Type: real
            Parameter: Vsh Type: real
            Parameter: REsh Type: real
            Parameter: REch Type: real
            Parameter: Slch Type: real
            Parameter: Slsh Type: real
            Parameter: CR Type: real
            Parameter: Lsh Type: real
            Parameter: Ndiesel Type: integer
            Parameter: Ngt Type: integer
            Parameter: Pdiesel Type: real
            Parameter: Pgt Type: real
            Parameter: G1 Type: real
            Parameter: G2 Type: real
```

```
        Parameter: G3 Type: real
        Parameter: G4 Type: real
        Parameter: G5 Type: real
        Parameter: Fnvol Type: real
    End Outputs Power

    Calculations Power
        Calculation PoweringA
            Parameters
                Cbsh Cbch Vk Bch Bsh v g Tch lambda lamdash
                AA1 Lch G1 G2 G3 WS G4 Fn Displ WSch
                WSsh V RE Sl Displch Displsh Tsh Vs Vch Vsh
                REsh REch Slch Slsh Fnvol Lsh
            Statements
                Vch=Cbch*Lch*Bch*Tch
                Displch=1.025*Vch
                Displ=Displch/(1-2*lambda)
                Displsh=Displ*lambda
                Slch=Lch/(Vch^(1/3))
                Lsh=lamdash*Lch
                Tsh=Displsh/(1.025*Lsh*Bsh*Cbsh)
                Vsh=Cbsh*Lsh*Bsh*Tsh
                V=Vch+2*Vsh
                Slsh=Lsh/(Vsh^(1/3))
                WSch=AA1*Slch*(Vch^(2/3))*(0.3048^2)
                WSsh=AA1*Slsh*(Vsh^(2/3))*(0.3048^2)
                WS=WSch+2*WSsh
                Sl=(Slch*WSch+2*Slsh*WSsh)/WS
                Vs=Vk*0.515
                REch=Vs*Lch/v
                REsh=Vs*Lsh/v
                RE=(REch*WSch+2*REsh*WSsh)/(WSch+2*WSsh)
                Fn=Vs/((g*Lch)^0.5)
                G1=Tsh/(1.5*Tch)
                G2=Bch/(4*Tch)
                G3=Bsh/(3*Tsh)
                Fnvol=Vs/((g*V^(1/3))^0.5)
                G4=Fnvol/1.5
            End Statements
        End Calculation PoweringA

        Calculation PoweringB
            Parameters
                PEC WS RE rho Vs CO Lch G5 PfullSpeed Peffective
                CR CF RES CK
            Statements
                CF=0.075/((log10(RE)-2)^2)
                CK=(-0.003*Lch+0.6)/1000
                CR=(CO/1000)+CF+CK
                RES=(1/2)*(rho)*(Vs^2)*WS*CR
                Peffective=Vs*RES/1.0e6
                PfullSpeed=Peffective/PEC
                G5=PfullSpeed/200
            End Statements
        End Calculation PoweringB
    End Calculations Power
```

```
SimCode CO
    InputFiles CO
        FileDescription dvdata
            FileType: standard
            TemplateFile: "dv_temp.data"
            InputFile: "dv.data"
            Parameters
                Fn Sl beta alpha
            Instructions
                require Fn Sl beta alpha
                find "Sl" ignore
                find "beta" ignore
                find "alpha" ignore
                find "Fn" ignore
                replace word with $Sl
                replace word with $beta
                replace word with $alpha
                replace word with $Fn
            End Instructions
        End FileDescription dvdata
    End InputFiles CO

    OutputFiles CO
        FileDescription co1out
            FileType: standard
            OutputFile: "co_1.out"
            Parameters
                CO
            Instructions
                find "      output= " ignore
                read CO as "%f"
                provide $CO
            End Instructions
        End FileDescription co1out
    End OutputFiles CO

    SimCodeProcess CO
        Program: "./co_evaluator"
        ProcessType: transient
        Environment: unrestored
        ElapseTime: 5m
        Prologue
            WriteInputSpecs: dvdata
        Epilogue
            ReadOutputSpecs: co1out
        Stdout: co1out
    End SimCodeProcess CO

End SimCode CO

SimCode Engine
    InputFiles Engine
        FileDescription engpowerdat
            FileType: standard
            TemplateFile: "engpower_temp.dat"
            InputFile: "engpower.dat"
            Parameters
```

```
                    PfullSpeed
                Instructions
                    require PfullSpeed
                    moveto $File_Start
                    moveto line + 5
                    replace word with $PfullSpeed as "%f"
                End Instructions
            End FileDescription engpowerdat
        End InputFiles Engine

        OutputFiles Engine
            FileDescription engpowerout
                FileType: standard
                OutputFile: "engpower.out"
                Parameters
                    Ndiesel Ngt Pdiesel Pgt
                Instructions
                    find "      Ndiesel = " ignore
                    read Ndiesel as "%d"
                    provide $Ndiesel
                    find "      Ngt     = " ignore
                    read Ngt as "%d"
                    provide $Ngt
                    find "      Pdiesel = " ignore
                    read Pdiesel as "%f"
                    provide $Pdiesel
                    find "      Pgt     = " ignore
                    read Pgt as "%f"
                    provide $Pgt
                End Instructions
            End FileDescription engpowerout
        End OutputFiles Engine

        SimCodeProcess Engine
            Program: "./engpower"
            ProcessType: transient
            Environment: unrestored
            ReturnCodes: 1
            ElapseTime: 5m
            Prologue
                WriteInputSpecs: engpowerdat
            Epilogue
                ReadOutputSpecs: engpowerout
            Stdout: engpowerout
        End SimCodeProcess Engine

    End SimCode Engine

    TaskProcess Power
        Control: [
            PoweringA
            Sequential [
                CO
            ]
            PoweringB
            Engine
        ]
```

```
        End TaskProcess Power

        Optimization Power
            PotentialVariables:
                Cbsh Cbch Vk Bch Bsh Tch lambda lamdash Lch beta
                alpha
            Variables:
                Cbsh Cbch Vk Bch Bsh Tch lambda lamdash Lch beta
                alpha
            VariableScaling
                Parameter: Cbsh ScaleFactor: 1.0
                Parameter: Cbch ScaleFactor: 1.0
                Parameter: Vk ScaleFactor: 1.0
                Parameter: Bch ScaleFactor: 1.0
                Parameter: Bsh ScaleFactor: 1.0
                Parameter: Tch ScaleFactor: 1.0
                Parameter: lambda ScaleFactor: 1.0
                Parameter: lamdash ScaleFactor: 1.0
                Parameter: Lch ScaleFactor: 1.0
                Parameter: beta ScaleFactor: 1.0
                Parameter: alpha ScaleFactor: 1.0
            InputConstraints
                Parameter: Cbsh LowerBound: 0.45 UpperBound: 0.6
                Parameter: Cbch LowerBound: 0.45 UpperBound: 0.6
                Parameter: Vk LowerBound: 25.0 UpperBound: 45.0
                Parameter: Bch LowerBound: 12.0 UpperBound: 24.0
                Parameter: Bsh LowerBound: 3.0 UpperBound: 8.0
                Parameter: Tch LowerBound: 4.0 UpperBound: 12.0
                Parameter: lambda LowerBound: 0.03 UpperBound: 0.15
                Parameter: lamdash LowerBound: 0.1 UpperBound: 0.75
                Parameter: Lch LowerBound: 100.0 UpperBound: 250.0
                Parameter: beta LowerBound: 0.0 UpperBound: 1.0
                Parameter: alpha LowerBound: 0.5 UpperBound: 2.0
            PotentialObjectives:
                CO CF RES WS PfullSpeed Fn Displ WSsh WSch CK
                V RE Sl Displch Displsh Tsh Peffective Vs Vch Vsh
                REsh REch Slch Slsh CR Lsh Ndiesel Ngt Pdiesel Pgt
                G1 G2 G3 G4 G5 Fnvol Cbsh Cbch Vk Bch
                Bsh Tch lambda lamdash Lch beta alpha
            OutputConstraints
                Parameter: Fn LowerBound: 0.2 Weight: 1.0 ScaleFactor:
1.0 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
                Parameter: G1 UpperBound: 1.0 Weight: 1.0 ScaleFactor:
1.0
                Parameter: G2 LowerBound: 0.375 Weight: 1.0
ScaleFactor: 1.0 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
                Parameter: G3 LowerBound: 0.33 Weight: 1.0 ScaleFactor:
1.0 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
                Parameter: G4 UpperBound: 1.0 Weight: 1.0 ScaleFactor:
1.0
                Parameter: G5 UpperBound: 1.0 Weight: 1.0 ScaleFactor:
1.0

            OptimizePlan NewPlan
                DefaultUpperBound: 1E15
                UseScaling: yes
                Control: [
```

```
            ]
        End Optimization Power

        TaskPlan Power
            StopTaskPlanOnError: no
            Control: [
                NewPlan
            ]
        End TaskPlan Power

        DataStorage Power
            Restore: no
            DataLog: "Power.db" Mode: overwrite
            DataLookUp: "Power.db"
            MatchMode: Exact
            Levels: all
            StoreGradRuns: yes
            StoreApproxRuns: yes
        End DataStorage Power

    End Task Power


    Task StabilityModel

        TaskHeader StabilityModel
            Version: 1.0
            Evaluation: single
            ControlMode: user
            RunCounter: 84
            BoundsPolicy: adjustvalue
            CheckPoint: unknown
        End TaskHeader StabilityModel

        Inputs StabilityModel
            Parameter: Cbsh Type: real InitialValue: 0.558252811431885
            Parameter: Cbch Type: real InitialValue: 0.451333665847778
            Parameter: Bch Type: real InitialValue: 13.6501121520996
            Parameter: Bsh Type: real InitialValue: 7.04721260070801
            Parameter: alpha Type: real InitialValue: 1.5718822479248
            Parameter: Tch Type: real InitialValue: 4.3309326171875
            Parameter: Lch Type: real InitialValue: 206.041383743286
        End Inputs StabilityModel

        Auxiliaries StabilityModel
            Parameter: Cwlch Type: real InitialValue: 0.75
            Parameter: Cwlsh Type: real InitialValue: 0.75
            Parameter: Fsh Type: real InitialValue: 1.0
            Parameter: Fch Type: real InitialValue: 1.0
        End Auxiliaries StabilityModel

        Outputs StabilityModel
            Parameter: Tsh Type: real
            Parameter: Vch Type: real
            Parameter: Vsh Type: real
            Parameter: Lsh Type: real
            Parameter: GMt Type: real
```

```
            Parameter: KBsh Type: real
            Parameter: KBch Type: real
            Parameter: KGsh Type: real
            Parameter: KGch Type: real
            Parameter: KB Type: real
            Parameter: KG Type: real
            Parameter: b Type: real
            Parameter: BM Type: real
        End Outputs StabilityModel

        Calculations StabilityModel
            Calculation Stability
                Parameters
                    Cbch Cbsh Cwlch Cwlsh Bch Bsh alpha Tch Tsh Fsh
                    Fch Vsh Vch Lsh Lch GMt KBsh KBch KGsh KGch
                    KB KG b BM
                Statements
                    b=((1+alpha)*Bch/2)+(Bsh/2)
                    KBch=(Tch*(2.5-Cbch/Cwlch))/3
                    KBsh=(Tsh*(2.5-Cbsh/Cwlsh))/3
                    KB=(KBch*Vch+2*KBsh*Vsh)/(Vch+2*Vsh)
                    KGch=Fch*Tch
                    KGsh=Fsh*Tsh
                    KG=(KGch*Vch+2*KGsh*Vsh)/(Vch+2*Vsh)

BM=(((Bch^2)*(0.0106+0.0727*Cwlch)*Cwlch*Bch*Lch)+2*(((Bsh^2)*(0.0106+0
.0727*Cwlsh)+b^2)*Cwlsh*Bsh*Lsh))/(Vch+2*Vsh)
                    GMt=KB+BM-KG
                End Statements
            End Calculation Stability
        End Calculations StabilityModel

        TaskProcess StabilityModel
            Control: [
                Stability
            ]
        End TaskProcess StabilityModel

        Optimization StabilityModel
            PotentialVariables:
                Cbsh Cbch Bch Bsh alpha Tch Lch
            Variables:
                Cbsh Cbch Bch Bsh alpha Tch Lch
            VariableScaling
                Parameter: Cbsh ScaleFactor: 1.0
                Parameter: Cbch ScaleFactor: 1.0
                Parameter: Bch ScaleFactor: 1.0
                Parameter: Bsh ScaleFactor: 1.0
                Parameter: alpha ScaleFactor: 1.0
                Parameter: Tch ScaleFactor: 1.0
                Parameter: Lch ScaleFactor: 1.0
            InputConstraints
                Parameter: Cbsh LowerBound: 0.45 UpperBound: 0.6
                Parameter: Cbch LowerBound: 0.45 UpperBound: 0.6
                Parameter: Bch LowerBound: 12.0 UpperBound: 24.0
                Parameter: Bsh LowerBound: 3.0 UpperBound: 8.0
                Parameter: alpha LowerBound: 0.5 UpperBound: 1.5
```

```
            Parameter: Tch LowerBound: 4.0 UpperBound: 12.0
            Parameter: Lch LowerBound: 100.0 UpperBound: 250.0
        PotentialObjectives:
            Tsh Vch Vsh Lsh GMt KBsh KBch KGsh KGch KB
            KG b BM Cbsh Cbch Bch Bsh alpha Tch Lch

        OptimizePlan NewPlan
            DefaultUpperBound: 1E15
            UseScaling: yes
            Control: [
            ]
    End Optimization StabilityModel

    TaskPlan StabilityModel
        StopTaskPlanOnError: no
        Control: [
            NewPlan
        ]
    End TaskPlan StabilityModel

    DataStorage StabilityModel
        Restore: no
        DataLog: "StabilityModel.db" Mode: overwrite
        DataLookUp: "StabilityModel.db"
        MatchMode: Exact
        Levels: all
        StoreGradRuns: yes
        StoreApproxRuns: yes
    End DataStorage StabilityModel

End Task StabilityModel


Task LightShipWeight

    TaskHeader LightShipWeight
        Version: 1.0
        Evaluation: single
        ControlMode: user
        RunCounter: 83
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader LightShipWeight

    Inputs LightShipWeight
        Parameter: Bch Type: real InitialValue: 13.6501121520996
        Parameter: Bsh Type: real InitialValue: 7.04721260070801
        Parameter: Lch Type: real InitialValue: 206.041383743286
        Parameter: Tch Type: real InitialValue: 4.3309326171875
        Parameter: Cbch Type: real InitialValue: 0.451333665847778
        Parameter: Cbsh Type: real InitialValue: 0.558252811431885
    End Inputs LightShipWeight

    Auxiliaries LightShipWeight
        Parameter: Kshconv Type: real InitialValue: 0.1
        Parameter: Ncrew Type: integer InitialValue: 18
        Parameter: Ko Type: real InitialValue: 0.03
```

```
            Parameter: Kmdiesel Type: real InitialValue: 25.0
            Parameter: Khullmisc Type: real InitialValue: 0.025
            Parameter: Kch Type: real InitialValue: 0.075
            Parameter: Kmgt Type: real InitialValue: 13.0
            Parameter: Npas Type: integer InitialValue: 12
            Parameter: Cmch Type: real InitialValue: 0.75
            Parameter: Klwtmisc Type: real InitialValue: 0.02
            Parameter: Kss Type: real InitialValue: 0.04
            Parameter: hwc Type: real InitialValue: 1.0
            Parameter: Cmsh Type: real InitialValue: 0.75
            Parameter: Kshswa Type: real InitialValue: 0.13
            Parameter: Typesh Type: integer InitialValue: 1
        End Auxiliaries LightShipWeight

        Outputs LightShipWeight
            Parameter: Tsh Type: real
            Parameter: Pdiesel Type: real
            Parameter: Vch Type: real
            Parameter: Vsh Type: real
            Parameter: Slch Type: real
            Parameter: Slsh Type: real
            Parameter: Lsh Type: real
            Parameter: Pgt Type: real
            Parameter: Cdch Type: real
            Parameter: Cdsh Type: real
            Parameter: Wss Type: real
            Parameter: Whullmisc Type: real
            Parameter: Wlwtmisc Type: real
            Parameter: Vd Type: real
            Parameter: Wsh Type: real
            Parameter: Wch Type: real
            Parameter: Hwc Type: real
            Parameter: Vdch Type: real
            Parameter: Vdsh Type: real
            Parameter: Wo Type: real
            Parameter: Whullnodeck Type: real
            Parameter: LWTnodeck Type: real
            Parameter: HWCch Type: real
            Parameter: HWCsh Type: real
            Parameter: Wmdiesel Type: real
            Parameter: Wmgt Type: real
        End Outputs LightShipWeight

        Calculations LightShipWeight
            Calculation LWT
                Parameters
                    Cbch Cbsh Kshswa Ko Pgt Kmgt Typesh Bsh Bch Pdiesel
                    Kmdiesel Tch Tsh Vsh Vch Kss Npas Slsh Slch hwc
                    Cmch Cmsh Khullmisc Kshconv Klwtmisc Kch Ncrew Lsh
Lch Wmdiesel
                    Cdch Cdsh Wss Whullmisc Whullnodeck Wlwtmisc Vd Wch
Wsh LWTnodeck
                    HWCch HWCsh Vdch Vdsh Wo Wmgt
                Statements
                    HWCch=(1+hwc)*Tch
                    HWCsh=HWCch-(Tch-Tsh)
                    Cdch=(Cbch/Cmch)*(Tch/HWCch)*(Cmch+(HWCch-Tch)/Tch)
```

```
                    Cdsh=(Cbsh/Cmsh)*(Tsh/HWCsh)*(Cmsh+(HWCsh-Tsh)/Tsh)
                    Vdch=Cdch*Lch*Bch*HWCch
                    Vdsh=Cdsh*Lsh*Bsh*HWCsh
                    Wch=(0.1*Slch+0.2)*Vdch*Kch
                    Wsh=(Typesh*((0.05*Slsh+0.6)*Kshconv)+(1-
Typesh)*Kshswa)*Vdsh
                    Wss=((Ncrew+Npas)/(470+0.94))*Kss*(Vch+2*Vsh)
                    Whullmisc=Khullmisc*(Vch+2*Vsh)
                    Whullnodeck=Wch+(2*Wsh)+Wss+Whullmisc
                    Wmgt=Kmgt*Pgt
                    Wmdiesel=Kmdiesel*Pdiesel
                    Vd=Vdch+2*Vdsh
                    Wo=Ko*Vd
                    Wlwtmisc=Klwtmisc*Vd
                    LWTnodeck=Whullnodeck+Wmgt+Wmdiesel+Wo+Wlwtmisc
                End Statements
            End Calculation LWT
        End Calculations LightShipWeight

        TaskProcess LightShipWeight
            Control: [
                LWT
            ]
        End TaskProcess LightShipWeight

        Optimization LightShipWeight
            PotentialVariables:
                Bch Bsh Lch Tch Cbch Cbsh
            Variables:
                Bch Bsh Lch Tch Cbch Cbsh
            VariableScaling
                Parameter: Bch ScaleFactor: 1.0
                Parameter: Bsh ScaleFactor: 1.0
                Parameter: Lch ScaleFactor: 1.0
                Parameter: Tch ScaleFactor: 1.0
                Parameter: Cbch ScaleFactor: 1.0
                Parameter: Cbsh ScaleFactor: 1.0
            InputConstraints
                Parameter: Bch LowerBound: 12.0 UpperBound: 24.0
                Parameter: Bsh LowerBound: 3.0 UpperBound: 8.0
                Parameter: Lch LowerBound: 100.0 UpperBound: 250.0
                Parameter: Tch LowerBound: 4.0 UpperBound: 12.0
                Parameter: Cbch LowerBound: 0.45 UpperBound: 0.6
                Parameter: Cbsh LowerBound: 0.45 UpperBound: 0.6
            PotentialObjectives:
                Tsh Pdiesel Vch Vsh Slch Slsh Lsh Pgt Cdch Cdsh
                Wss Whullmisc Wlwtmisc Vd Wsh Wch Hwc Vdch Vdsh Wo
                Whullnodeck LWTnodeck HWCch HWCsh Wmdiesel Wmgt Bch Bsh
Lch Tch
                Cbch Cbsh

            OptimizePlan NewPlan
                DefaultUpperBound: 1E15
                UseScaling: yes
                Control: [
                ]
        End Optimization LightShipWeight
```

```
        TaskPlan LightShipWeight
            StopTaskPlanOnError: no
            Control: [
                NewPlan
            ]
        End TaskPlan LightShipWeight

        DataStorage LightShipWeight
            Restore: no
            DataLog: "LightShipWeight.db" Mode: overwrite
            DataLookUp: "LightShipWeight.db"
            MatchMode: Exact
            Levels: all
            StoreGradRuns: yes
            StoreApproxRuns: yes
        End DataStorage LightShipWeight

    End Task LightShipWeight


    Task PayloadModel

        TaskHeader PayloadModel
            Version: 1.0
            Evaluation: single
            ControlMode: user
            RunCounter: 83
            BoundsPolicy: adjustvalue
            CheckPoint: unknown
        End TaskHeader PayloadModel

        Inputs PayloadModel
            Parameter: lamdash Type: real InitialValue:
0.164082813262939
            Parameter: Lch Type: real InitialValue: 206.041383743286
            Parameter: beta Type: real InitialValue:
0.00396347045898438
            Parameter: Vk Type: real InitialValue: 36.0350036621094
            Parameter: Bsh Type: real InitialValue: 0.0
            Parameter: Bch Type: real InitialValue: 0.0
            Parameter: alpha Type: real InitialValue: 0.0
        End Inputs PayloadModel

        Auxiliaries PayloadModel
            Parameter: PayloadMIN Type: real InitialValue: 1000.0
            Parameter: Ndmax Type: integer InitialValue: 4
            Parameter: Deckcl Type: real InitialValue: 2.25
            Parameter: CDAU Type: real InitialValue: 0.75
            Parameter: Hdeckstr Type: real InitialValue: 2.25
            Parameter: Rpilot Type: real InitialValue: 50.0
            Parameter: Kbd Type: real InitialValue: 0.3
            Parameter: SFCdiesel Type: real InitialValue: 0.16
            Parameter: R Type: real InitialValue: 800.0
            Parameter: STOWteutrai Type: real InitialValue: 1.4865
            Parameter: SFCpilot Type: real InitialValue: 0.25
            Parameter: Taux Type: real InitialValue: 5.0
```

```
            Parameter: Wteutrai Type: real InitialValue: 10.0
            Parameter: SFCgt Type: real InitialValue: 0.21
            Parameter: Nteutrairows Type: integer InitialValue: 2
            Parameter: SFCaux Type: real InitialValue: 0.16
            Parameter: Vpilot Type: real InitialValue: 10.0
            Parameter: BOLmax Type: real InitialValue: 57.0
        End Auxiliaries PayloadModel

        Outputs PayloadModel
            Parameter: PfullSpeed Type: real
            Parameter: HWCch Type: real
            Parameter: Whullnodeck Type: real
            Parameter: Nd Type: integer
            Parameter: Wdeck Type: real
            Parameter: Whull Type: real
            Parameter: Pgt Type: real
            Parameter: Displ Type: real
            Parameter: Pdiesel Type: real
            Parameter: AreaCargodeck Type: real
            Parameter: LWT Type: real
            Parameter: AnnualCargo Type: real
            Parameter: NTRIP Type: real
            Parameter: CARGOarea Type: real
            Parameter: Paux Type: real
            Parameter: WFUELfullspeed Type: real
            Parameter: Tfullspeed Type: real
            Parameter: Ppilot Type: real
            Parameter: Vs Type: real
            Parameter: WFUELaux Type: real
            Parameter: Payload Type: real
            Parameter: Ttrip Type: real
            Parameter: WFUELpilot Type: real
            Parameter: WFUEL Type: real
            Parameter: Nteutrai Type: real
            Parameter: Tpilot Type: real
            Parameter: LWTnodeck Type: real
            Parameter: TotalDeckArea Type: real
            Parameter: Lsh Type: real
            Parameter: Ld Type: real
            Parameter: a Type: real
            Parameter: BOL Type: real
            Parameter: AreaCargodeckMAX Type: real
            Parameter: Hship Type: real
            Parameter: LdMAX Type: real
            Parameter: G6 Type: real
            Parameter: G7 Type: real
        End Outputs PayloadModel

        Calculations PayloadModel
            Calculation Payload
                Parameters
                    SFCdiesel PfullSpeed Displ Bch alpha BOLmax
LWTnodeck Wteutrai SFCgt Kbd
                    R STOWteutrai SFCpilot Bsh PayloadMIN Pdiesel
Deckcl Rpilot HWCch SFCaux
                    Pgt Whullnodeck lamdash CDAU Nteutrairows Lch Ndmax
Vk Hdeckstr Vs
```

```
                    Taux beta Vpilot Lsh Ld a Nd AnnualCargo G6 NTRIP
                    CARGOarea BOL G7 Wdeck Paux WFUELfullspeed
Tfullspeed Ppilot WFUELaux Payload
                    AreaCargodeckMAX Ttrip WFUELpilot WFUEL Nteutrai
Hship Whull AreaCargodeck Tpilot TotalDeckArea
                    LdMAX LWT
                Statements
                    Tfullspeed=(R-Rpilot)/Vk
                    Tpilot=Rpilot/Vpilot
                    Ttrip=Tfullspeed+Tpilot+Taux

WFUELfullspeed=(SFCgt*Pgt+SFCdiesel*Pdiesel)*Tfullspeed
                    Ppilot=(PfullSpeed*1000)/(Vs^3)
                    WFUELpilot=SFCpilot*Tpilot*Ppilot
                    Paux=0.01*PfullSpeed
                    WFUELaux=SFCaux*Taux*Paux
                    WFUEL=WFUELfullspeed+WFUELpilot+WFUELaux
                    TotalDeckArea=((Displ-LWTnodeck)/1.1-
WFUEL)*STOWteutrai/((Nteutrairows-1)+Kbd*STOWteutrai/1.1)
                    BOL=(Bch*(1+alpha))+(2*Bsh)
                    a=beta*Lch*(1-lamdash)
                    LdMAX=a+1.25*Lsh
                    AreaCargodeckMAX=CDAU*BOL*LdMAX
                    Nd=min(ceil(TotalDeckArea/AreaCargodeckMAX), Ndmax)
                    AreaCargodeck =
min(TotalDeckArea/Nd,AreaCargodeckMAX)
                    Ld=AreaCargodeck/(CDAU*BOL)
                    Wdeck=Kbd*Nd*AreaCargodeck
                    Whull=Whullnodeck+Wdeck
                    LWT=LWTnodeck+Wdeck
                    Hship=HWCch+Deckcl*(Nd-1)+Hdeckstr
                    CARGOarea=Nd*(Nteutrairows-1)*AreaCargodeck
                    Nteutrai=int(CARGOarea/(STOWteutrai*Wteutrai))
                    Payload=Nteutrai*Wteutrai
                    NTRIP=(350*24)/Ttrip
                    AnnualCargo=Nteutrai*NTRIP
                    G6=PayloadMIN/Payload
                    G7=BOL/BOLmax
                End Statements
            End Calculation Payload
        End Calculations PayloadModel

        TaskProcess PayloadModel
            Control: [
                Payload
            ]
        End TaskProcess PayloadModel

        Optimization PayloadModel
            PotentialVariables:
                lamdash Lch beta Vk Bsh Bch alpha
            Variables:
                lamdash Lch beta Vk Bsh Bch alpha
            VariableScaling
                Parameter: lamdash ScaleFactor: 1.0
                Parameter: Lch ScaleFactor: 1.0
                Parameter: beta ScaleFactor: 1.0
```

```
                Parameter: Vk ScaleFactor: 1.0
                Parameter: Bsh ScaleFactor: 1.0
                Parameter: Bch ScaleFactor: 1.0
                Parameter: alpha ScaleFactor: 1.0
            PotentialObjectives:
                PfullSpeed HWCch Whullnodeck Nd Wdeck Whull Pgt Displ
Pdiesel AreaCargodeck
                LWT AnnualCargo NTRIP CARGOarea Paux WFUELfullspeed
Tfullspeed Ppilot Vs WFUELaux
                Payload Ttrip WFUELpilot WFUEL Nteutrai Tpilot
LWTnodeck TotalDeckArea Lsh Ld
                a BOL AreaCargodeckMAX Hship LdMAX G6 G7 lamdash Lch
beta
                Vk Bsh Bch alpha
            Objectives
                Parameter: AnnualCargo Direction: maximize Weight: 1.0
ScaleFactor: 1.0

            OptimizePlan NewPlan
                DefaultUpperBound: 1E15
                UseScaling: yes
                Control: [
                ]
        End Optimization PayloadModel

        TaskPlan PayloadModel
            StopTaskPlanOnError: no
            Control: [
                NewPlan
            ]
        End TaskPlan PayloadModel

        DataStorage PayloadModel
            Restore: no
            DataLog: "PayloadModel.db" Mode: overwrite
            DataLookUp: "PayloadModel.db"
            MatchMode: Exact
            Levels: all
            StoreGradRuns: yes
            StoreApproxRuns: yes
        End DataStorage PayloadModel

    End Task PayloadModel


    Task CostModel

        TaskHeader CostModel
            Version: 1.0
            Evaluation: single
            ControlMode: user
            RunCounter: 83
            BoundsPolicy: adjustvalue
            CheckPoint: unknown
        End TaskHeader CostModel

        Auxiliaries CostModel
```

```
        Parameter: COSTmaint Type: real InitialValue: 0.1
        Parameter: Rh Type: real InitialValue: 50.0
        Parameter: Rm Type: real InitialValue: 60.0
        Parameter: Ncrew Type: real InitialValue: 18.0
        Parameter: Ro Type: real InitialValue: 50.0
        Parameter: KOEFcapcost Type: real InitialValue: 0.175
        Parameter: R Type: real InitialValue: 800.0
        Parameter: Hmisc Type: real InitialValue: 15.0
        Parameter: Mh Type: real InitialValue: 720.0
        Parameter: COSTFUEL Type: real InitialValue: 400.0
        Parameter: Rmisc Type: real InitialValue: 60.0
        Parameter: COSTsupply Type: real InitialValue: 100.0
        Parameter: Mlwtmisc Type: real InitialValue: 17500.0
        Parameter: COSTMmaintgt Type: real InitialValue: 150.0
        Parameter: Mo Type: real InitialValue: 4000.0
        Parameter: COSTpilot Type: real InitialValue: 650.0
        Parameter: Npas Type: real InitialValue: 12.0
        Parameter: COSTins Type: real InitialValue: 0.008
        Parameter: TOP Type: real InitialValue: 350.0
        Parameter: COSTteutrai Type: real InitialValue: 125.0
        Parameter: Hh Type: real InitialValue: 90.0
        Parameter: Costlube Type: real InitialValue: 8.96
        Parameter: SLOC Type: real InitialValue: 0.45
        Parameter: Hm Type: real InitialValue: 120.0
        Parameter: COSTMmaintdiesel Type: real InitialValue: 25.0
        Parameter: Ho Type: real InitialValue: 80.0
        Parameter: AACcrew Type: real InitialValue: 140000.0
        Parameter: Mmdiesel Type: real InitialValue: 10000.0
        Parameter: Mmgt Type: real InitialValue: 40000.0
    End Auxiliaries CostModel

    Outputs CostModel
        Parameter: Ngt Type: integer
        Parameter: Nteutrai Type: real
        Parameter: Wlwtmisc Type: real
        Parameter: Whull Type: real
        Parameter: WFUEL Type: real
        Parameter: LWT Type: real
        Parameter: Ndiesel Type: integer
        Parameter: Wo Type: real
        Parameter: Cmi Type: real
        Parameter: Ccs Type: real
        Parameter: ACF Type: real
        Parameter: CMACHINERY Type: real
        Parameter: ACFLEET Type: real
        Parameter: ACpilot Type: real
        Parameter: Ccrew Type: real
        Parameter: CMm Type: real
        Parameter: NTRIP Type: real
        Parameter: ACLO Type: real
        Parameter: CHULL Type: real
        Parameter: Tfullspeed Type: real
        Parameter: RFR Type: real
        Parameter: Ttrip Type: real
        Parameter: SCOST Type: real
        Parameter: COUTFIT Type: real
        Parameter: AFvolume Type: real
```

```
            Parameter: ACC Type: real
            Parameter: ACch Type: real
            Parameter: CMISC Type: real
            Parameter: Wmdiesel Type: real
            Parameter: Wmgt Type: real
            Parameter: CMACHINERYgt Type: real
            Parameter: CMACHINERYdiesel Type: real
        End Outputs CostModel

        Calculations CostModel
            Calculation Cost
                Parameters
                    Ngt Wmdiesel COSTmaint Mmdiesel Tfullspeed Rh
Nteutrai Rm Wmgt Ncrew
                    Ro R KOEFcapcost Hmisc Mmgt NTRIP Wlwtmisc Ttrip
Whull Mh
                    COSTFUEL Rmisc COSTsupply Mlwtmisc COSTMmaintgt Mo
COSTpilot Npas COSTins TOP
                    WFUEL LWT COSTteutrai Hh Costlube SLOC Ndiesel Hm
COSTMmaintdiesel Ho
                    Wo AACcrew Cmi Ccs ACF CMACHINERY ACFLEET ACpilot
Ccrew CMm
                    CMACHINERYgt ACLO CHULL CMACHINERYdiesel RFR SCOST
COUTFIT AFvolume ACC ACch
                    CMISC
                Statements
                    CHULL=Whull*(Hh*Rh+Mh)
                    CMACHINERYgt=Wmgt*(Hm*Rm+Mmgt)
                    CMACHINERYdiesel=Wmdiesel*(Hm*Rm+Mmdiesel)
                    CMACHINERY=CMACHINERYgt+CMACHINERYdiesel
                    COUTFIT=Wo*(Ho*Ro+Mo)
                    CMISC=(Wlwtmisc*Mlwtmisc)+(LWT*(Hmisc*Rmisc))
                    SCOST=CHULL+CMACHINERY+COUTFIT+CMISC
                    Ccrew=Ncrew*AACcrew
                    Cmi=(COSTmaint+COSTins)*SCOST
                    Ccs=COSTsupply*(Ncrew+Npas)*TOP

CMm=(COSTMmaintdiesel*Ndiesel+COSTMmaintgt*Ngt)*Ttrip
                    ACF=NTRIP*COSTFUEL*WFUEL
                    ACLO=Costlube*SLOC*Ngt*Tfullspeed
                    ACpilot=COSTpilot*2*NTRIP
                    ACch=2*Nteutrai*COSTteutrai*NTRIP
                    ACC=KOEFcapcost*SCOST
                    ACFLEET=Ccrew+Cmi+Ccs+CMm+ACF+ACLO+ACpilot+ACch+ACC
                    AFvolume=Nteutrai*NTRIP
                    RFR=ACFLEET/AFvolume/R
                End Statements
            End Calculation Cost
        End Calculations CostModel

        TaskProcess CostModel
            Control: [
                Cost
            ]
        End TaskProcess CostModel

        Optimization CostModel
```

```
            Variables: none
            VariableScaling
            PotentialObjectives:
                Ngt Nteutrai Wlwtmisc Whull WFUEL LWT Ndiesel Wo Cmi
Ccs
                ACF CMACHINERY ACFLEET ACpilot Ccrew CMm NTRIP ACLO
CHULL Tfullspeed
                RFR Ttrip SCOST COUTFIT AFvolume ACC ACch CMISC
Wmdiesel Wmgt
                CMACHINERYgt CMACHINERYdiesel

            OptimizePlan NewPlan
                DefaultUpperBound: 1E15
                UseScaling: yes
                Control: [
                ]
        End Optimization CostModel

        TaskPlan CostModel
            StopTaskPlanOnError: no
            Control: [
                NewPlan
            ]
        End TaskPlan CostModel

        DataStorage CostModel
            Restore: no
            DataLog: "CostModel.db" Mode: overwrite
            DataLookUp: "CostModel.db"
            MatchMode: Exact
            Levels: all
            StoreGradRuns: yes
            StoreApproxRuns: yes
        End DataStorage CostModel

    End Task CostModel


    TaskProcess Trimaran
        Control: [
            Sequential [
                Power
                StabilityModel
                LightShipWeight
                PayloadModel
                CostModel
            ]
        ]

        SubTask Power
            InputToSubtask
                Send:
                    AA1 Bch Bsh Cbch Cbsh Fn Lch PEC PfullSpeed RE
                    Sl Tch Vk Vs alpha beta g lambda lamdash rho
                    v
            OutputFromSubtask
                Receive:
```

```
                    CF CK CO CR Displ Displch Displsh Fn Fnvol G1
                    G2 G3 G4 G5 Lsh Ndiesel Ngt Pdiesel Peffective
PfullSpeed
                    Pgt RE RES REch REsh Sl Slch Slsh Tsh V
                    Vch Vs Vsh WS WSch WSsh
        End SubTask Power

        SubTask StabilityModel
            InputToSubtask
                Send:
                    Bch Bsh Cbch Cbsh Cwlch Cwlsh Fch Fsh Lch Lsh
                    Tch Tsh Vch Vsh alpha
            OutputFromSubtask
                Receive:
                    BM GMt KB KBch KBsh KG KGch KGsh b
        End SubTask StabilityModel

        SubTask LightShipWeight
            InputToSubtask
                Send:
                    Bch Bsh Cbch Cbsh Cmch Cmsh Kch Khullmisc Klwtmisc
Kmdiesel
                    Kmgt Ko Kshconv Kshswa Kss Lch Lsh Ncrew Npas
Pdiesel
                    Pgt Slch Slsh Tch Tsh Typesh Vch Vsh hwc
            OutputFromSubtask
                Receive:
                    Cdch Cdsh HWCch HWCsh Hwc LWTnodeck Vd Vdch Vdsh
Wch
                    Whullmisc Whullnodeck Wlwtmisc Wmdiesel Wmgt Wo Wsh
Wss
        End SubTask LightShipWeight

        SubTask PayloadModel
            InputToSubtask
                Send:
                    BOLmax Bch Bsh CDAU Deckcl Displ HWCch Hdeckstr Kbd
LWTnodeck
                    Lch Lsh Ndmax Nteutrairows PayloadMIN Pdiesel
PfullSpeed Pgt R Rpilot
                    SFCaux SFCdiesel SFCgt SFCpilot STOWteutrai Taux Vk
Vpilot Vs Whullnodeck
                    Wteutrai alpha beta lamdash
            OutputFromSubtask
                Receive:
                    AnnualCargo AreaCargodeck AreaCargodeckMAX BOL
CARGOarea G6 G7 Hship LWT Ld
                    LdMAX NTRIP Nd Nteutrai Paux Payload Ppilot
Tfullspeed TotalDeckArea Tpilot
                    Ttrip WFUEL WFUELaux WFUELfullspeed WFUELpilot
Wdeck Whull a
        End SubTask PayloadModel

        SubTask CostModel
            InputToSubtask
                Send:
```

```
                    AACcrew COSTFUEL COSTMmaintdiesel COSTMmaintgt
COSTins COSTmaint COSTpilot COSTsupply COSTteutrai Costlube
                    Hh Hm Hmisc Ho KOEFcapcost LWT Mh Mlwtmisc Mmdiesel
Mmgt
                    Mo NTRIP Ncrew Ndiesel Ngt Npas Nteutrai R Rh Rm
                    Rmisc Ro SLOC TOP Tfullspeed Ttrip WFUEL Whull
Wlwtmisc Wmdiesel
                    Wmgt Wo
            OutputFromSubtask
                Receive:
                    ACC ACF ACFLEET ACLO ACch ACpilot AFvolume CHULL
CMACHINERY CMACHINERYdiesel
                    CMACHINERYgt CMISC CMm COUTFIT Ccrew Ccs Cmi RFR
SCOST
        End SubTask CostModel

    End TaskProcess Trimaran

    Optimization Trimaran
        PotentialVariables:
            Cbsh Cbch Vk Bch Bsh Tch lambda lamdash Lch beta
            alpha
        Variables:
            Cbsh Cbch Vk Bch Bsh Tch lambda lamdash Lch beta
            alpha
        VariableScaling
            Parameter: Cbsh ScaleFactor: 1.0
            Parameter: Cbch ScaleFactor: 1.0
            Parameter: Vk ScaleFactor: 1.0
            Parameter: Bch ScaleFactor: 1.0
            Parameter: Bsh ScaleFactor: 1.0
            Parameter: Tch ScaleFactor: 1.0
            Parameter: lambda ScaleFactor: 1.0
            Parameter: lamdash ScaleFactor: 1.0
            Parameter: Lch ScaleFactor: 1.0
            Parameter: beta ScaleFactor: 1.0
            Parameter: alpha ScaleFactor: 1.0
        InputConstraints
            Parameter: Cbsh LowerBound: 0.45 UpperBound: 0.6
            Parameter: Cbch LowerBound: 0.45 UpperBound: 0.6
            Parameter: Vk LowerBound: 25.0 UpperBound: 45.0
            Parameter: Bch LowerBound: 12.0 UpperBound: 24.0
            Parameter: Bsh LowerBound: 3.0 UpperBound: 8.0
            Parameter: Tch LowerBound: 4.0 UpperBound: 12.0
            Parameter: lambda LowerBound: 0.03 UpperBound: 0.15
            Parameter: lamdash LowerBound: 0.1 UpperBound: 0.75
            Parameter: Lch LowerBound: 100.0 UpperBound: 250.0
            Parameter: beta LowerBound: 0.0 UpperBound: 1.0
            Parameter: alpha LowerBound: 0.5 UpperBound: 2.0
        PotentialObjectives:
            Nd CO CF RES WS PfullSpeed Fn Displ WSsh WSch
            CK V RE Sl Displch Displsh Tsh Peffective Vs Vch
            Vsh REsh REch Slch Slsh CR Lsh GMt KBsh KBch
            KGsh KGch KB KG b BM Ndiesel Ngt Pdiesel Pgt
            Ld a Cdch Cdsh Wss BOL Wdeck Whullmisc Wlwtmisc Vd
            Wsh Wch Hwc Whull AreaCargodeck Hship Vdch Vdsh Wo LWT
```

```
            AnnualCargo NTRIP CARGOarea Paux WFUELfullspeed Tfullspeed
Ppilot WFUELaux Payload Ttrip
            WFUELpilot WFUEL Nteutrai RFR SCOST Cmi Ccs ACF CMACHINERY
ACFLEET
            Ccrew ACpilot CMm ACLO CHULL COUTFIT AFvolume ACC ACch
CMISC
            G1 G2 G3 G4 G5 Fnvol G6 Whullnodeck LWTnodeck
AreaCargodeckMAX
            TotalDeckArea LdMAX HWCch HWCsh G7 Wmdiesel Wmgt
CMACHINERYgt CMACHINERYdiesel Cbsh
            Cbch Vk Bch Bsh Tch lambda lamdash Lch beta alpha
        Objectives
            Parameter: AnnualCargo Direction: maximize Weight: 1.0
ScaleFactor: 1.0
        OutputConstraints
            Parameter: G1 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G2 LowerBound: 0.375 Weight: 1.0 ScaleFactor:
1.0 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G3 LowerBound: 0.33 Weight: 1.0 ScaleFactor: 1.0
UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G4 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G5 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G6 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0
            Parameter: G7 UpperBound: 1.0 Weight: 1.0 ScaleFactor: 1.0

        AdvisorCriteria
            DiscontinuousSpace: no
            MultiObjectiveOptimization: no
            InitialDesignPoint: infeasible
            AnalysisType: nonlinear
            ExecutionTime: 1s
            IORelationships: no
            GradientsAvailable: no
        End AdvisorCriteria

        OptimizePlan NLPQL
            DefaultUpperBound: 1.0E15
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Sequential Quadratic Programming - NLPQL"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    MaxIterations: 100
                    Accuracy: 0.0001
                    FiniteDifference: 0.01
                    MinimumFiniteDifference: 0.001
            Control: [
                Step1
            ]

        OptimizePlan NCGA1
            DefaultUpperBound: 1.0E15
```

```
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Neighborhood Cultivation Genetic Algorithm
- NCGA"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    NumPopulation: 50
                    NumGeneration: 100
            Control: [
                Step1
            ]

        OptimizePlan NCGAgene40
            DefaultUpperBound: 1.0E15
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Neighborhood Cultivation Genetic Algorithm
- NCGA"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    NumPopulation: 50
                    NumGeneration: 100
                    CrossoverMethod: two
                    GeneSize: 40
            Control: [
                Step1
            ]

        OptimizePlan NSGA2refine1
            DefaultUpperBound: 1.0E15
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Non-dominated Sorting Genetic Algorithm -
NSGA-II"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    CrossoverRate: 1.0
                    XoverDistIndex: 50
                    MutDistIndex: 300.0
            Control: [
                Step1
            ]
```

```
        OptimizePlan MOST
            DefaultUpperBound: 1.0E15
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Mixed Integer Optimization - MOST"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    FiniteDifference: 0.01
                    Convergence: 0.01
            Control: [
                Step1
            ]

        OptimizePlan NLPQL200
            DefaultUpperBound: 1.0E15
            UseScaling: yes
            OptimizeStep Step1
                Technique: "Sequential Quadratic Programming - NLPQL"
                Prologue
                    RestoreBestSolution: no
                    RerunTask: no
                Epilogue
                    RestoreBestSolution: no
                    RerunTask: no
                Options
                    MaxIterations: 200
                    Accuracy: 0.0001
                    FiniteDifference: 0.01
                    MinimumFiniteDifference: 0.001
            Control: [
                Step1
            ]

        # PLAN TO BE CONFIGURED BY ADVISOR:
        OptimizePlan PriorityRankedPlan
            Control: [
            ]
    End Optimization Trimaran

    DesignOfExperiments Trimaran
        Plan DOEPlan1
            Technique: LatinHypercube
                NumberOfPoints: 1000
            Factors
                ParameterList
                    Type: control
                    Parameters
                        Cbsh BaseLine: 0.5 Levels: values [ 0.45 0.6 ]
                        Cbch BaseLine: 0.5 Levels: values [ 0.45 0.6 ]
                        Vk BaseLine: 35.0 Levels: values [ 25.0 45.0 ]
                        Bch BaseLine: 18.0 Levels: values [ 12.0 24.0 ]
```

```
                        Bsh BaseLine: 7.0 Levels: values [ 3.0 8.0 ]
                        Tch BaseLine: 10.0 Levels: values [ 4.0 12.0 ]
                        lambda BaseLine: 0.1 Levels: values [ 0.03 0.15
]
                        lamdash BaseLine: 0.5 Levels: values [ 0.1 0.75
]
                        Lch BaseLine: 160.0 Levels: values [ 100.0
250.0 ]
                        beta BaseLine: 0.3 Levels: values [ 0.0 1.0 ]
                        alpha BaseLine: 0.75 Levels: values [ 0.5 1.5 ]
                End ParameterList
            End Factors
        End Plan DOEPlan1

        Study DOEStudy1
            Plan: DOEPlan1
            Responses
                Outputs:
                    ObjectiveAndPenalty
            End Responses
            Actions
                Objective: ObjectiveAndPenalty
                Direction: minimize
            End Actions
            ResultsFile: "doe_Study.DOEStudy1"
            Prologue
                Tcl
                End Tcl
            Epilogue
                Tcl
                End Tcl
        End Study DOEStudy1
    End DesignOfExperiments Trimaran

    TaskPlan Trimaran
        StopTaskPlanOnError: no
        Control: [
            NLPQL200
        ]
    End TaskPlan Trimaran

    DataStorage Trimaran
        Restore: no
        DataLog: "Trimaran.db" Mode: overwrite
        DataLookUp: "Trimaran.db"
        MatchMode: Exact
        Levels: all
        StoreGradRuns: yes
        StoreApproxRuns: yes
    End DataStorage Trimaran

End Task Trimaran
```

Appendix B: Files for the Coefficient of Residual Resistance

main.C file

```
#include "NN.H"
#include <iostream.h>
#include <fstream.h>
#include <stdlib.h>
//#include <time.h>
/*      Evaluator (NN1_Evaluator)
        Calculation of the NN output, an input vector being given
        The code looks for a dv.data file in the current folder, this
        file contains the values for the DV.
          PS: INPUTS-OUTPUTS ARE SUPPOSED DIMENSIONALIZED */


int main()
{
        int i;
        int j;
        double aux1,aux2;
      NN* Network;
//    Neural Network Generated by NN_OPT_1
//    Best Mean squarred Error = 0.011845051476775165 for try number 1
      const int n1=4;
      const int m1=1;
      const int h1=16;
//    MinInput[j] & MaxInput[j] for j=1,n
      double MinInput[n1]= {6,0,0.5,0.20000000000000001};
      double MaxInput[n1]= {12,1,2,1};
//    MeanTarget[j] for j=1,m
      double MeanTarget[m1] = {2.5347222222222223};
      double vij[m1*(n1+h1+1)]={-0.22064838417197499,-
0.95688149502972686,-0.070399398065978266,-
0.31742936263594101,2.3336079271968786,0.56949655143029787,-
1.4090144569873981,1.3321966910981182,0.52045927559291361,-
0.4154579336052539,0.63762576419142569,-0.415992339964395,-
0.60262287601795983,0.20785634137319284,-0.30132222590015895,-
0.26914208910273868,-0.19013955422436393,-
0.14595989321291841,0.14161597597083167,-0.13893728565341515,-
0.14189023191820382};
      double wij[h1*(n1+h1)]={-10,-0.033358303647003512,-
1.1164252327731854,-
4.6551871673098022,3.9169704223461843,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
      ,-1.2206922774834987,-1.1010553417224858,0.1665276651352959,-
10,1.9272207734610238,0.20733137721875844,0,0,0,0,0,0,0,0,0,0,0,0,0,0
      ,1.8891951626718582,10,2.7174960577775416,-10,-
7.7140581914243436,4.2857828684424186,-
9.978569397751972,0,0,0,0,0,0,0,0,0,0,0,0,0,0
      ,1.375835753814866,10,-2.4901895505701956,-0.90725272245630173,-
1.3973720921025716,4.1247422306336583,9.9975187822242564,-
9.7093719426723109,0,0,0,0,0,0,0,0,0,0,0,0
```

,-5.4198570352270936,8.6596707678971079,-
1.7980468750422851,10,1.6114371066450173,-4.1569582758930217,-10,-10,-
1.8215714770456826,0,0,0,0,0,0,0,0,0,0,0
,-10,-0.044880748077077023,-10,6.5850541014299964,-
1.2428506553406544,9.8586084429920877,-2.2259872199467075,10,-
5.6051303956428651,-5.8171048687336553,0,0,0,0,0,0,0,0,0,0
,0.20961876656263903,-10,-
9.4461663442218082,3.2273713814140312,8.1107317814376128,-
0.19633448179072799,-1.389409060761861,-
0.26521741396955584,2.3535739219876448,-
3.4685892326322643,9.0897022226054975,0,0,0,0,0,0,0,0,0
,-0.1139944900249345,7.3927779074325999,6.9861435031507604,-
0.96775886416578305,-1.3919839170384003,3.2958264562729562,-10,10,-10,-
4.0970510093623371,4.8315535257999223,7.2877696914046233,0,0,0,0,0,0,0,
0
,-6.8578412607503161,-5.0611859282887055,1.4743741695553645,-
9.9834106057474958,5.0636626864051433,2.3771415757857328,3.865875548715
7137,-9.2018006487392032,9.4270462992566273,-10,-
9.9179907724996745,10,-2.5423643656578272,0,0,0,0,0,0,0
,7.5648859832362518,9.9996756800691031,2.8226458766703928,-
9.5024966659454932,0.39447287121491165,-1.7041770413733572,10,-
0.24803086680809269,3.3997476075350264,6.4146892444737853,1.67283955595
35973,-2.0946449452099984,-8.3445738169367587,-10,0,0,0,0,0,0
,-10,-1.5335711791796014,10,0.31146994828905356,-
0.24450173189675409,2.038807936863007,-5.5207530562769342,-
5.0411362723400632,-2.5622812478718613,0.64575976697857418,-
2.2078194256124468,-5.1262483302822544,-
9.2553419892433748,10,7.565331002248632,0,0,0,0,0
,2.8458478144466812,-
9.9646247374478314,10,6.6493381384821157,9.6989101269475402,-
4.0689083316088936,-5.6966509389844271,-6.6412394698693626,-
2.8025400134209701,4.3016770528444228,1.9812687243761598,-
7.2868385277257151,5.7670018731844737,-4.7595090365112807,-
4.1939204973960669,-0.36680621005569219,0,0,0,0
,10,-10.000000000000002,9.5596409073229189,-
1.2250366968891175,4.0426153009596284,-
5.9020839532500675,2.5832670871394425,-
0.59288669485785173,6.0467927450501264,-9.2506033745065999,-
3.3768129518588497,-8.1821547754816457,-
3.4397839269032908,4.0880160924600109,-5.6365519723969699,-
10,4.6916565297421684,0,0,0
,-6.3492166677741055,10,-6.451912865235097,8.2180631377573761,-
0.91204402928337702,10,-6.3183124340429542,3.4779148615082431,-
9.7622682392726503,-4.8962260287805899,-
0.73731122566018958,2.764561825491886,9.9909930916766072,6.688492549835
2965,-6.0071482835296113,3.0391860055101354,9.9673810496959092,-
9.2778109820491252,0,0
,3.7690208225444399,-3.8847146093300209,-
3.3570246115986206,10,0.2472195048005576,-2.1349239426950257,-
9.3413345010869513,-10,3.5405870498542882,2.6411164531878759,-10,-
7.490893209826381,-10,6.0653697528677988,-8.7613823354177498,-
3.303478083426072,4.7977422950334381,-
2.4276998208867684,3.7514134820963219,0
,-10,-1.3651281511789304,-8.8885428506391442,-
9.3561892726122888,-
4.4042390110986895,0.74836598578036773,4.047324668163446,-10,-
4.6990816495594938,-6.8542658958491689,-

```
2.9916228946014432,8.6658708475536272,10,6.2007580084634286,-
4.7155493888140052,10,-7.2647175980811936,0.63472977169770195,-
9.9816837594061916,10
      };
        cout.setf(ios::fixed);
        char buffer[1000];
        Vector x(n1);
        Vector y(m1);
        cout<<"   output= ";
        ifstream fin("dv.data");
        fin.getline(buffer,1000);// this throws away the comment line;
        for(i=0;i<n1;i++)
        {
             fin>>aux1;
             //non-dimensionalize the inputs
             aux2=(aux1-MinInput[i])/(MaxInput[i]- MinInput[i]);
             x.initialize_element(i,aux2);
        }
        fin.ignore(80,'\n'); //this throws away the endline character
        Network= new NN(m1, n1, h1,vij,wij);
        y=Network->Evaluate3(x);
        for(j=0;j<m1;j++) cout<<y.element(j)*MeanTarget[j]<<endl;
        cout<<"   MinInput[j]= {"<<MinInput[0];
        for(j=1;j<n1;j++) cout<<","<<MinInput[j];
        cout<<"}"<<endl;
        cout<<"   MaxInput[j]= {"<<MaxInput[0];
        for(j=1;j<n1;j++) cout<<","<<MaxInput[j];
        cout<<"}"<<endl;
        cout<<"   MeanTarget= "<<MeanTarget[0];
        for(j=1;j<m1;j++) cout<<"      "<<MeanTarget[j];
        cout<<endl;
        delete Network;
}
```

makefile

The file main.C is to be used with the source code NN_OPT_1, which is the code used to train the Network. The source code was released as part of task 2.1 in the DI-MCCR-80700 Report in 2002 (Ref .3). The makefile for creating the Neural Network evaluator is shown below. The source code can be found in Appendix A of Reference 3 and is therefore not repeated here.

```
PATH_NN=/disk6/mu/schmitz/Neural_net/NN_OPT_1

OBJSC=  main.o          $(PATH_NN)/DataSet.o          $(PATH_NN)/NN.o
      $(PATH_NN)/Matrix.o     $(PATH_NN)/Vector.o
$(PATH_NN)/NN_Constructor_SC1.o     $(PATH_NN)/NN_Constructor_SC5.o
OBJSF= $(PATH_NN)/ddot1.o     $(PATH_NN)/ddot2.o
      $(PATH_NN)/ddot3.o      $(PATH_NN)/ddot4.o
      $(PATH_NN)/ddot5.o      $(PATH_NN)/ddot6.o
INCLUDE=/disk6/mu/schmitz/Neural_net/NN_OPT_1

C_COMPILER=CC -I $(INCLUDE) -g
F_COMPILER=f77 -n32 -O2 -g

COMMAND= ./NN1_Evaluator

$(COMMAND): $(OBJSC) $(OBJSF)
```

```
	$(C_COMPILER) -o $(COMMAND) $(OBJSC) $(OBJSF) -lm -lftn

$(OBJSF):
.f.o:
	$(F_COMPILER) -c $< -o $*.o

$(OBJSC): $(PATH_NN)/*.H
.C.o:
	$(C_COMPILER) -c $< -o $*.o
```

dv.data file

```
 Sl                   beta                  alpha    Fn
 8.92736825912478     0.788024343862314     2.0    0.342348148491101
```

co_1.out

```
	output= 2.207557
	MinInput[j]= {6.000000,0.000000,0.500000,0.200000}
	MaxInput[j]= {12.000000,1.000000,2.000000,1.000000}
	MeanTarget= 2.534722
```

Appendix C: Files for the Engine Power Calculation

engpower.C file

```
#include <iostream.h>
#include <fstream.h>
#include <stdlib.h>
//Author: Adeline Schmitz, 05/24/05
//This program calculates the number of engines for Diesels and Gas
Turbines
// as well as the Power generated by them in MegaWatts
// power table requirement defined by SAIC May 05.
void main()
{
        int Ngt;
        int Ndiesel;
      char buffer[256];
        double Pfullspeed,Pgt,Pdiesel;
      ifstream fin("engpower.dat",ios::nocreate);
      if (!fin)
      {
            cout<< "Error, file engpower.dat does not exist in
directory\n";
            exit(0);
      }
      fin.getline(buffer,256); //LINES 1 to 5 ARE title LINES
      fin.getline(buffer,256);
      fin.getline(buffer,256);
      fin.getline(buffer,256);
      fin.getline(buffer,256);
      fin>>Pfullspeed; //line 6 has the value calculated for the full
speed power required (in MW)
      fin.ignore(80,'\n');//this throws away the endline character
      if (Pfullspeed<20)
      {
            Ndiesel=2;Ngt=0;Pdiesel=Pfullspeed;Pgt=0.;
      }
      else if (Pfullspeed<40)
      {
            Ndiesel=2;Ngt=1;Pdiesel=18.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<60)
      {
            Ndiesel=2;Ngt=2;Pdiesel=18.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<80)
      {
            Ndiesel=2;Ngt=2;Pdiesel=18.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<100)
      {
            Ndiesel=4;Ngt=2;Pdiesel=36.;Pgt=Pfullspeed-Pdiesel;
      }
```

```
      else if (Pfullspeed<120)
      {
            Ndiesel=4;Ngt=2;Pdiesel=36.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<140)
      {
            Ndiesel=2;Ngt=3;Pdiesel=40.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<160)
      {
            Ndiesel=2;Ngt=4;Pdiesel=40.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<180)
      {
            Ndiesel=2;Ngt=4;Pdiesel=40.;Pgt=Pfullspeed-Pdiesel;
      }
      else if (Pfullspeed<200)
      {
            Ndiesel=0;Ngt=5;Pdiesel=0.;Pgt=Pfullspeed;
      }
      else
      {
            Ndiesel=0;Ngt=5;Pdiesel=0.;Pgt=Pfullspeed;
            cout<< "Error, Pfullspeed is greater than 200MW";
            //exit(0);

      }
      cout<<"
**************************************************************************
**********************\n";
      cout<<"     Power output (in MW) for diesel and gas turbines
calculated by engpower.C (5/24/05)\n";
      cout<<"
**************************************************************************
**********************\n";
      cout<<" \tNdiesel = "<<Ndiesel<<"\n";
      cout<<" \tNgt     = "<<Ngt<<"\n";
      cout<<" \tPdiesel = "<<Pdiesel<<"\n";
      cout<<" \tPgt     = "<<Pgt<<"\n";
}
```

engpower.dat file

```
*********************************************************
      Input data for engpower.C as defined 05/24/05
*********************************************************
      PfullSpeed(in MW)
      -----------------
          199.841270
```

engpower.out file

```
**********************************************************************
     Power output (in MW) for diesel and gas turbines calculated by
engpower.C (5/24/05)

**********************************************************************
      Ndiesel = 0
      Ngt     = 5
      Pdiesel = 0
      Pgt     = 199.841
```