International Journal of Maritime Engineering

PROJECT MANAGEMENT OF EARLY STAGE WARSHIP DESIGN

J P Stratmann, P A Wilson and **A F Molland** University of Southampton, UK
M D Courts, VT Shipbuilding, UK

SUMMARY

Warship Feasibility Studies are highly complex projects. The paper aims to highlight some of the factors inherent within industry and academia. The initial data were gathered at the VT shipyard by interviewing key personnel. The collected data are then analysed using the MS Visio flowchart package to create input/output diagrams for all existing domains. Identifying explicit and implicit links allows the existing domains to be linked and inherent domains to be identified. The resulting connection diagrams are then analysed and compared with existing literature. The analysis results in the creation of several loops depicting the data flow during feasibility studies. The 2-D loops are combined in a 3-D flowchart to further investigate the data flow across the domain interfaces and to incorporate a time scale. Carrying out in-depth domain and case studies at VT Shipbuilding has led to a continuous refinement of the 3-D loops.

NOMENCLATURE

COGAG	Combined Gas and Gas
FAC	Fast Attack Craft
FPC	Fast Patrol Craft
FSC	Future Surface Combatant
HF	Human Factors
ILS	Integrated Logistics Support
LSA	Logistics Support Analysis
MoD	Ministry of Defence
SRD	Systems Requirements Document
TLC	Through Life Costing
UPC	Upfront Capital
URD	User Requirements Document
VT	VT Shipbuilding
WLC	Whole Life Costs

1. INTRODUCTION

Warship Design is acknowledged to be a highly complex process [1], including conflicting demands, changing requirements and cost-benefit trade-offs. The aim of the research is to analyse and identify a potential project management methodology for early stage warship design.

The paper attempts to highlight some of the inherent knowledge contained within the individual departments of large shipbuilding companies, such as VT. An attempt is made to combine this knowledge with the current Ministry of Defence (MoD) requirements and existing published views to draw up a preliminary methodology for managing feasibility studies. The aim of the overall study is to provide a step-by-step guide to support young designers in their understanding of the feasibility study process.

2. WHAT ARE FEASIBILITY STUDIES?

Traditionally [1,2,3,4] feasibility studies were concerned with proving the viability and affordability of engineering designs. However, the current procurement process requires some of the boundaries to be redrawn. This is due to the increasing importance of through life costing and integrated logistics support as well as up front capital cost, amongst others, under SMART [5].

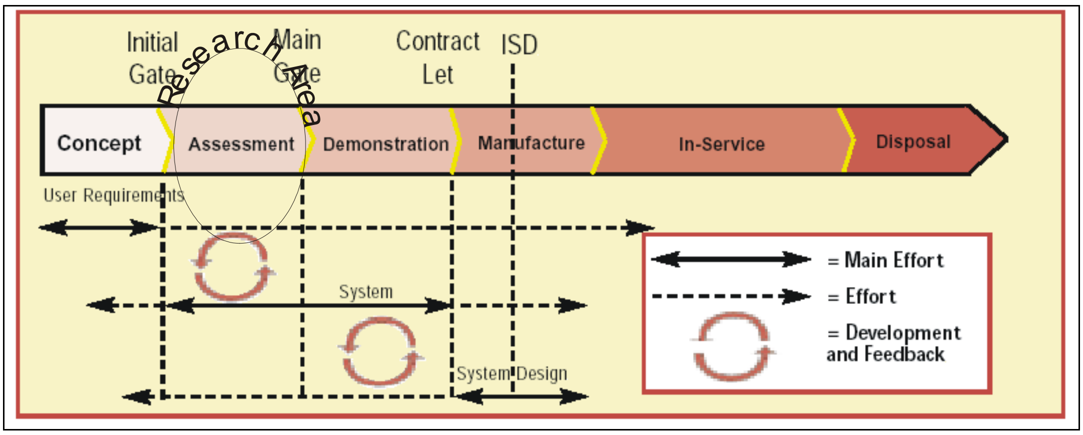

Figure 1: SMART Schematic [5]

SMART is the current procurement process of the MoD. It aims to enable the MoD to acquire defence capabilities faster, cheaper, better and more effectively integrated [5]. SMART encompasses the whole life approach, which is typified by the use of Through Life Costing (TLC). SMART does not have an area termed “feasibility study” but rather an “assessment phase”, see figure 1. During the assessment phase several designs are investigated and at main gate, figure 1, the most practical, cost-effective solution satisfying the user requirements is chosen.

It should be noted that the requirements are not fixed but rather tend to evolve during the assessment phase. The final outcome at main gate, in terms of the requirements, is the systems requirement document (SRD)[5]

3. WHAT IS INVOLVED?

This section aims to identify the “players”, termed domains for the purpose of this paper, involved in the ship design/build aspects of feasibility studies.

An initial domain list was created based on the explicit domains existing within VT Shipbuilding. Explicit domains are those that are actual departments within VT such as structures. The list is based on domains involved with technical aspects of the design process. However, later developments of the list include commercial factors as well.

- Naval Architecture
- Hydrodynamics
- Electrical Design
- Engineering
- Structures
- Combat System Design
- Integrated Logistics Support (ILS)
- Human Factors (HF)
- Quality Assurance
- Design Management

This list was then used to identify key personnel within VT. In most cases this meant approaching the line-managers of the various disciplines.

Interviews were used to gather information as it was felt that questionnaires would not provide the in-depth level of information required. The data from each interview was used to construct spider diagrams for each domain. These show the input and output data, during feasibility studies, as specified by the interviewees. An example is shown in figure 2.

Figure 2 clearly shows the complexity and amount of data gathered from the interviews.

To further analyse the interactions between domains these spider diagrams were linked together. This means that if the output of a domain matches the input into another domain, explicitly and/or implicitly, then these two are linked.

Explicit links exist where the output of any domain matches closely to the input into another domain. An example of this is shown in Figure 3

The method of implicit linking evolved as several domains specified output data that did not directly match any domain’s input requirements. However, based on discussions with VT personnel and applying sound engineering judgement several links, such as the vibration link identified in figure 4, were found

Connection diagrams were constructed using all the data available from explicit and implicit links as well as the redefined domain list. These diagrams show, for each domain, the input and output and respective associated domains. An example of this is shown in figure 5.

The results from the spider and connection diagrams led to a revision of the domain list. The revised list shows the implicit domains. This is to say that some of the initial domains were amalgamated whilst others were split up. It is felt by the author that this allows for a more accurate description of the design process.

- Naval Architecture
- Weapon Systems
- Integrated Logistics Support
- Human Factors
- Auxiliary, Domestic and Propulsion Systems
- Electrical Systems
- Structure
- Production
- Cost estimation
- Aviation
- General Vehicle Capability
- Customer

For example on the one hand Hydrodynamics was merged with Naval Architecture as this allowed for a more streamlined connection diagram without changing external connections. On the other hand the aviation domain was created as it was felt that this allowed for a more accurate representation of the actual design process.

4. INTERFACE INTERACTION

Once the involved domains were identified it was necessary to determine what the actual processes are that take place during feasibility studies and further investigate the interactions between interfaces.

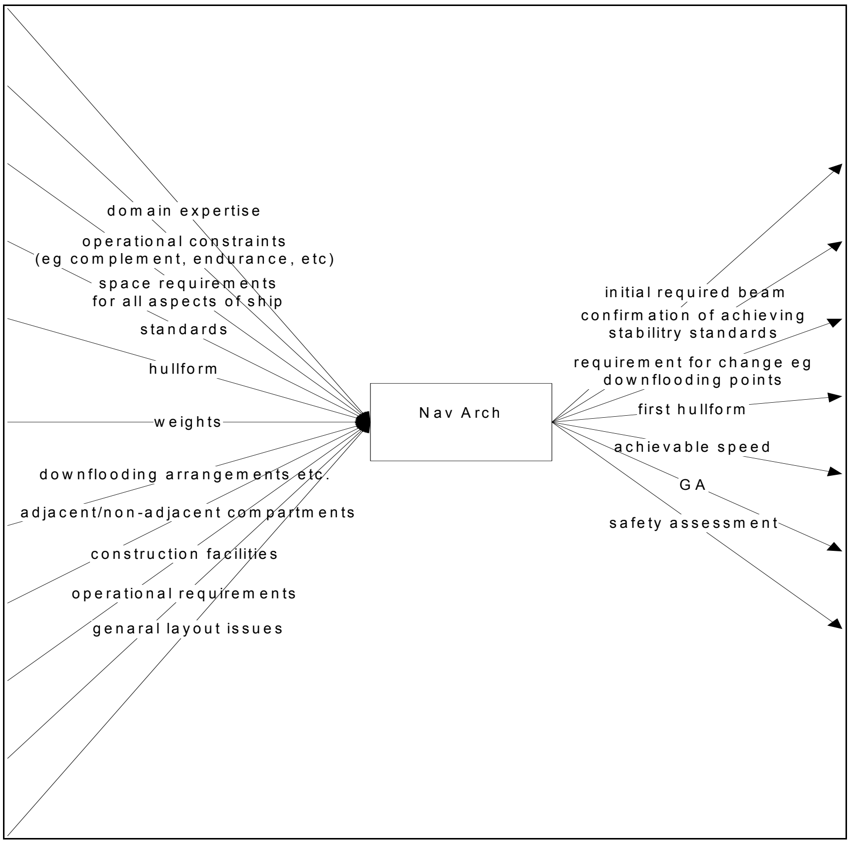

Figure 2: Spider Diagram Naval Architecture

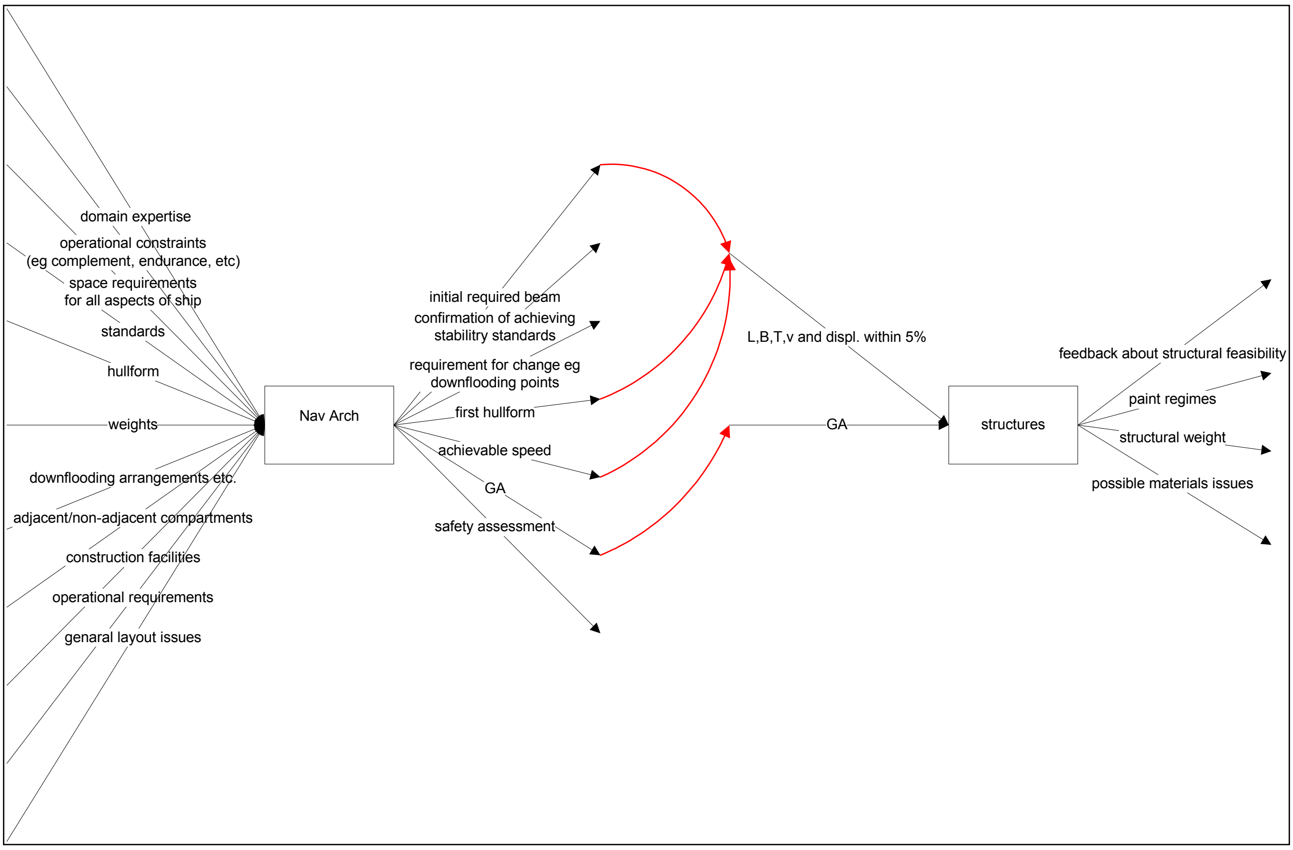

Figure 3: Explicit Link Example

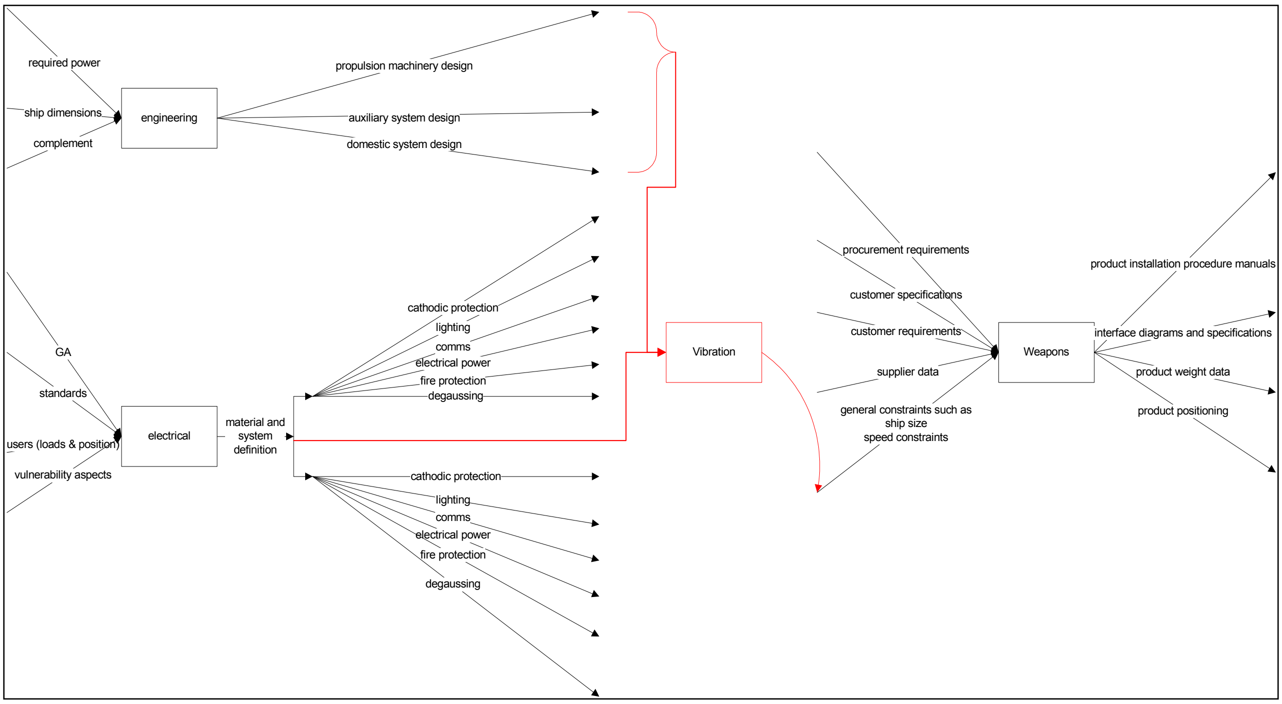

Figure 4: Implicit Link Example

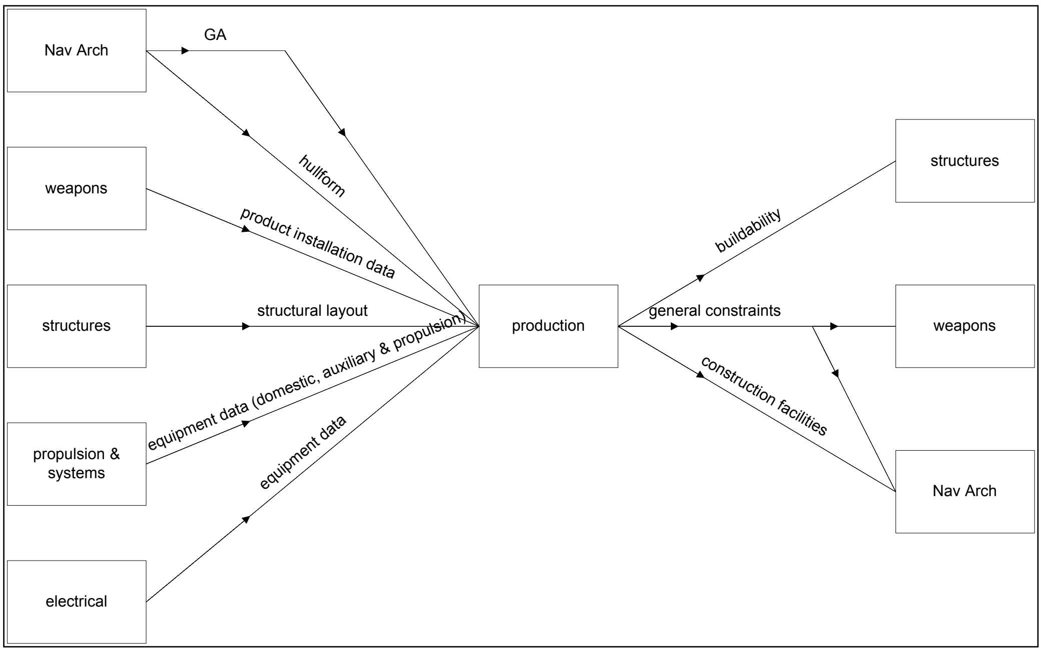

Figure 5: Connection Diagram Production

A high-level interface chart was created based on the initial spider diagrams and therefore does not accurately represent the revised domain list. However, it provided a useful tool to avoid losing the “bigger picture”.

The next step involved combining the individual connection charts. This involved trying to identify loops and predecessors, whilst operating within the overall framework provided by the high-level interface chart.

As a result of the initial studies three loops were created. These three loops were presented in a three-dimensional drawing. This 3-D view was used to show that several of the activities can be carried out in parallel and that the process allows for data to be sent up/downwards as well as forward. The 3-D view contains feedback loops and connections across several loops, see schematic shown in figure 6. However, it was quickly discovered that the 3D representation proved too complicated for a day-to-day environment and thus an alternative method of representing the process was sought. The loops used in the original model are shown in figure 7, 8, and 9.

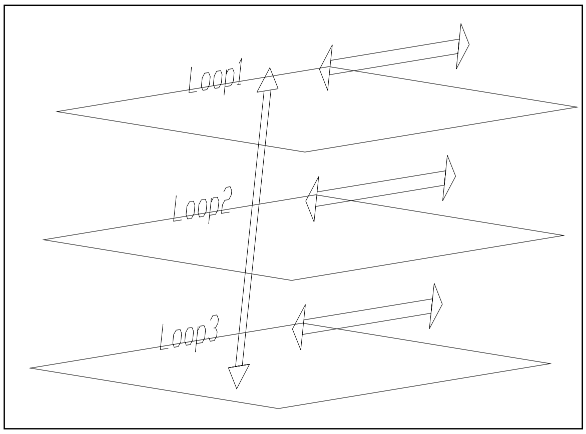

Figure 6: 3D Loop Schematics

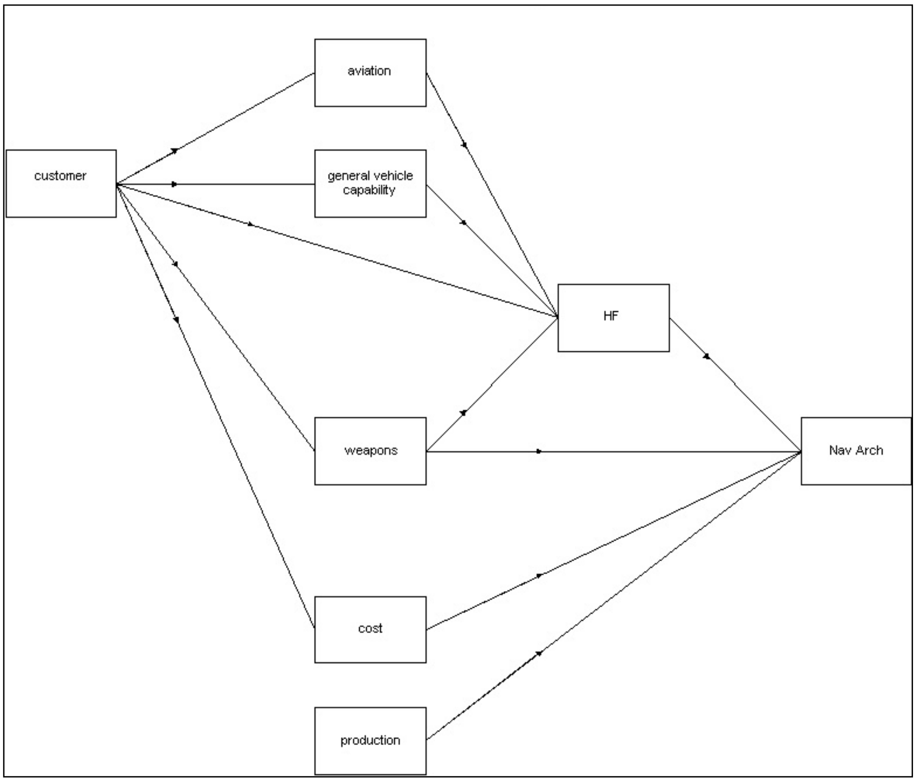

Figure 7: Loop1

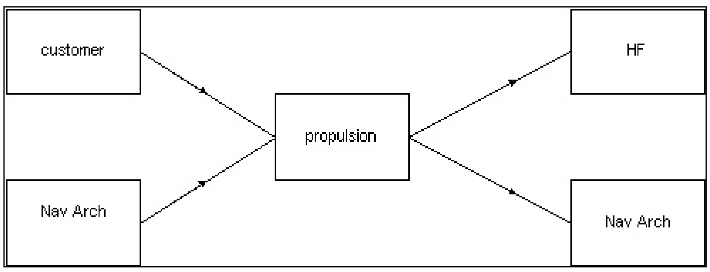

Figure 8: Loop2

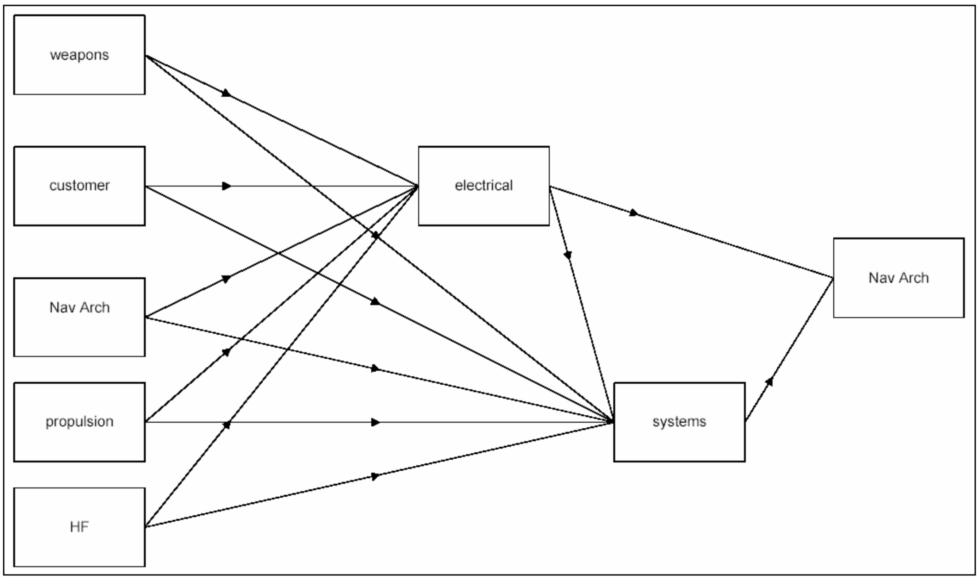

Figure 9: Loop 3

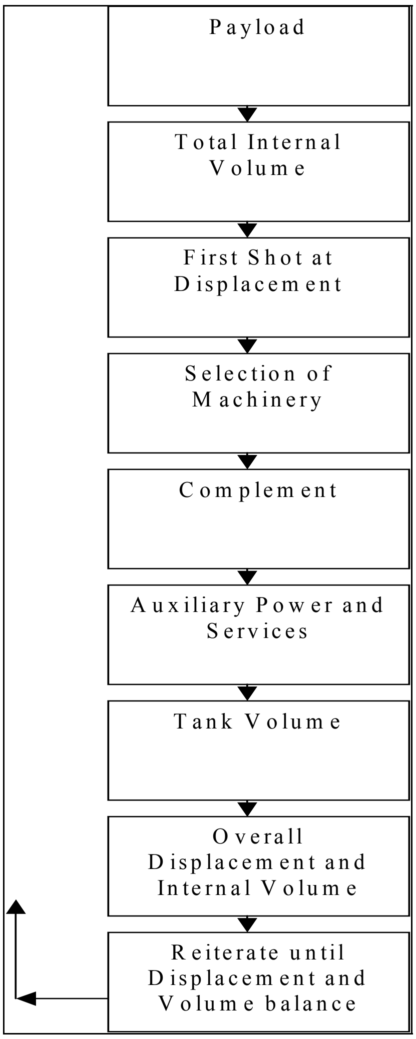

Figure 10: Traditional Ship Model [6]

To validate these initial results two comparisons were made with existing published data. The first compared the loops to the traditional view of ship design as depicted by Andrews [6], see figure 10, and was used to determine whether any domains had been omitted and whether the ship design process was represented properly in the initial loops.

The first loop of the 3D loop covers payload, internal volume and a first shot at displacement. The 2nd loop covers selection of machinery and complement. The 3rd loop covers auxiliary power and services, tank volume and overall displacement. Finally, the reiteration feature of figure 10 is covered using the feedback loops in the 3D representation.

The results from this comparison indicate that all major domains are included and that the overall design process is described accurately.

The 2nd comparison used data published by Scott [7] and obtained with assistance from Vosper Thornycroft (now VT Shipbuilding). The Scott study used a bottom-up synthesis approach whilst the 3-D loops are derived using a top-down analysis approach. The results from the comparison are shown in table 1.

Newcastle Study	3-D Loops
1st iterative loop is concerned with weapons system evaluation	Weapons – Customer interaction is contained on first loop
1st inside loop within major block contains hull form, propulsion and structural evaluation	Output of 1st loop is Naval Architecture and 2nd loop evaluates propulsion
2nd inside loop evaluates electrical systems,	3rd loop evaluates Naval Architecture, electrical

structure, hull form and domestic & auxiliary systems	systems and domestic & auxiliary systems
Major outside loop iterates Stability, Weight and Ship Size	3rd loop contains Naval Architecture output, which feedbacks into second loop

Table 1: Comparison 3D loops to Newcastle study [7]

The results from the comparative study are very encouraging as they indicate that both studies, despite taking different approaches, arrive at very similar results.

5. CASE STUDIES

Two case studies were carried out to analyse the interfaces on "real life" projects. This decision was made to provide a more objective view of the design process as opposed to the subjective interview analysis.

The first study evaluated the feasibility of a Fast Patrol Craft (FPC) whilst the second evaluated a concept study carried out as part of the Future Surface Combatant (FSC) program.

5.1 FPC

The FPC loops were developed in several stages. During the first stage the time log developed in the FPC Design Description, an internal study carried out by VT, was used to construct a flowchart depicting the sequence of events.

The sequence was then compressed. This means that the events were grouped under their respective domain headings. This was necessary to be able to draw a comparison to the theoretical 3D model.

Finally the domains were consolidated. This means that wherever a domain appeared more than once in succession it was grouped into a single appearance.

The resulting final flowchart is shown in figure 11.

5.1(a) Analysis of FPC process chart

The first loop contains the parametric study and the material concept study. During the loop the first sizing and the basic parameters of the vessel are derived. The parent hullform of the vessel was chosen during this loop.

The second loop provides information about the weapon payload, the frame spacing and the electrical power requirements. The weapon payload was not decided upon during the first loop as the main emphasis on the design was on speed. Also, the design brief did not call for any special weapon requirements. The second loop also contains a reiteration of the propulsion criteria based on a Combined Gas And Gas (COGAG) arrangement. At the end of this is loop is the first detailed weights estimate and a first stability check.

The third loop is mainly concerned with a reiteration of the propulsion machinery and the influence on the basic ship parameters. It finishes with a first accommodation layout.

The next loop contains the reversal of the propulsion arrangement back to its original COGAG asymmetric arrangement. It also contains a more detailed weights estimate, tank arrangement and a system route check. Finally, an alternative weapon payload is investigated.

The final loop contains several smaller, but nonetheless important items. These are items such as mooring arrangements and lifeboats. The loop (and design) is closed by a final performance check to ensure the vessel meets the criteria outlined in loop 1.

5.1(b) Comparison to 3D model

The first FPC loop is very similar to the 3D loop. It is used to determine a first shot at the basis parameters of the vessel. It can be argued that cost and production are included in the FPC loop as the vessel is based on an existing vessel to minimise cost and is within the boundaries of what VT can construct.

The FPC loop 1 does not contain a first crew estimate. This is not investigated until loop 2. This seems a better practice than the solution suggested in the 3D loop as the crew estimate for the FPC was based on similar vessels. The FPC design is derived from a baseship and no specific crewing requirements were given in the design brief. Therefore the crew estimate was carried out once the basis dimensions of the vessels were established.

The second FPC loop contains elements of the 2nd and 3rd 3D loops. If the FPC loop 2 was split up it might be possible to match it more closely to the 3D loops. This is attempted in section 5.1(c).

The main aim of the 2nd 3D loop is to give a more detailed analysis of the propulsion machinery arrangement. The FPC design contains a basic description of the propulsion arrangement at the start of loop 2. However, this is only based on data from previous vessels that were not designed to the same requirements and hence the 2nd FPC loop can be seen as a propulsion study by itself, if some of the other domains are isolated.

The weapons, electrical and structures domains of the vessel do not have to be carried out at this stage but can be moved further down the chart. This will then imply that the 2nd FPC loop is almost identical to the 2nd 3D loop. At this stage it is also noted that the structures domain, which is not included in the 3D loops, should be included on the 1st 3D loop. This is to ensure that a basic understanding of the required frame spacing is in place right from the start of the design process.

The 3rd FPC loop is mainly a check and control loop. It evaluates the powering and resistance data for the FPC and provides a first stability check.

The 4th FPC loop investigates a revised propulsion layout. Other issues considered include an investigation into systems (domestic and auxiliary) and their routes. This corresponds closely with the 3rd loop of the 3D representation. Some of the items investigated had an impact on the layout of the vessel; the naval architecture domain in the loop covers this.

The 5th FPC loop is essentially another check and control loop similar to the 3rd FPC loop. The minor corrections that were required are covered in the 3D representation by the provision of the feedback and iteration loops

5.1(c) Impacts on 3D loops

In general it appears that the FPC loops match closely to the 3D loops. The correlation between the two is increased if the FPC loops are amended to allow for mistakes in the process. However some changes to the 3D loops are recommended. For baseship derived designs the initial crew estimate should be carried out once the main parameters are fixed.

The 1st loop needs to contain the structures domain. This domain requires input from the naval architecture domain.

A check needs to be included to allow for the impact of the propulsion system on the topside design. It is therefore proposed to add weapons and general vehicle capability to loop 2.

5.2 FSC

Similar to the FPC study a time dependent log was created using data collected from all involved internal parties on the FSC project. This log was refined and consolidated and the final version is shown in figure 12.

5.2(a) Comparison to 3D loops

Figure 12 is used for the comparison to the 3D loop. The consolidated flowchart is divided into several loops to aid comparison with the 3D representation.

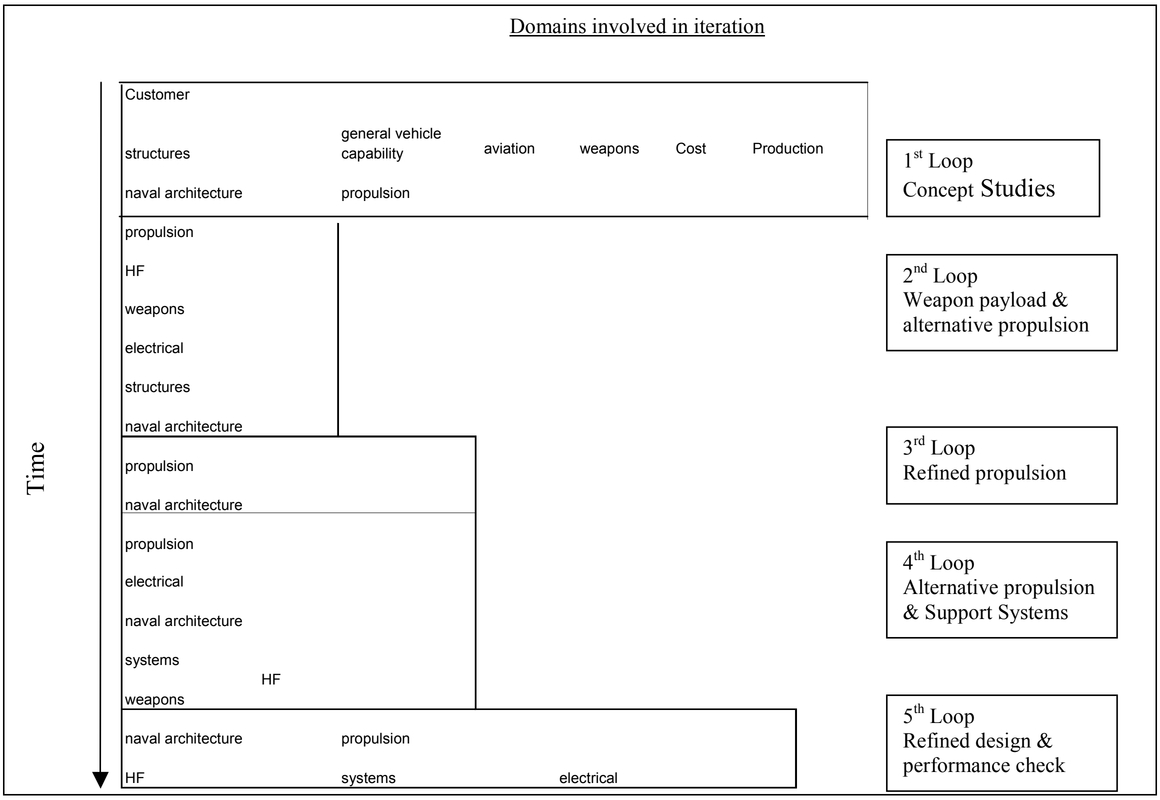

Figure 11: FPC Design Process Chart

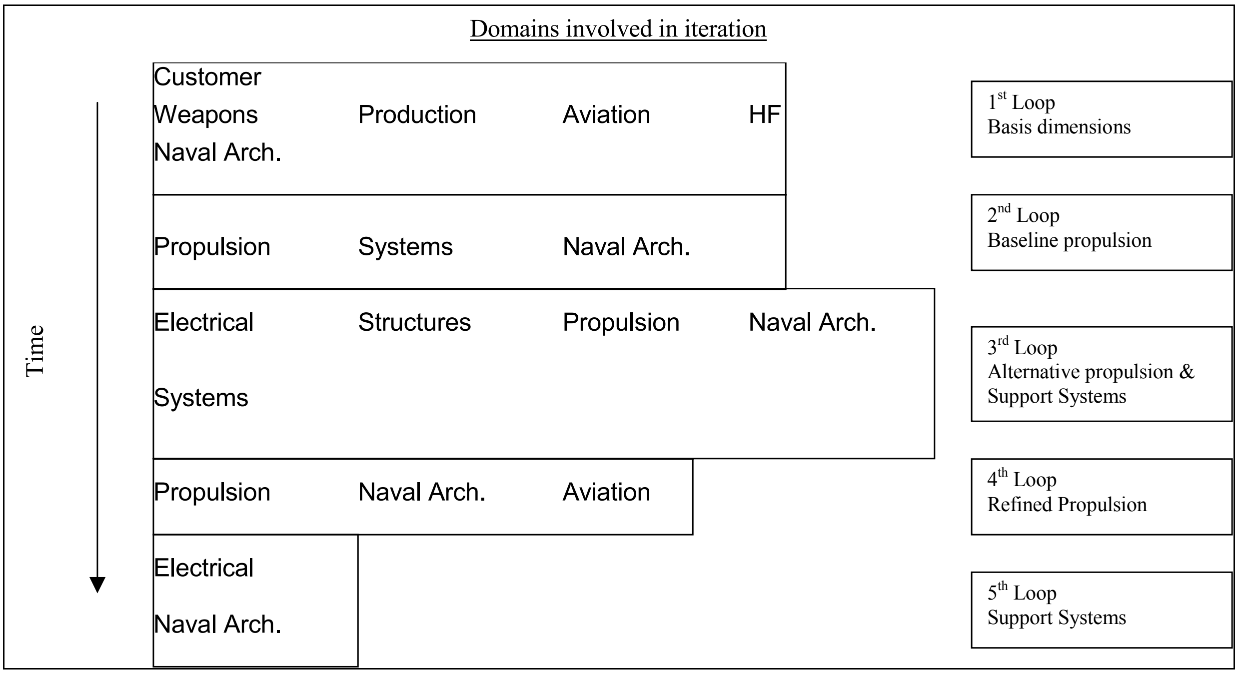

Figure 12: FSC Design Process Chart

The first loop is identical to the 1st loop of the 3D representation. The basic size of the vessel is determined from assumed customer requirements. Requirements were modified from the initial User Requirements Document (URD) in order to allow generation of a cost constrained solution.

The 2nd FSC loop investigates a baseline propulsion system. It also investigates issues arising due to errors in the engineering (propulsion, auxiliary and domestic systems) weights. This corresponds well with the 3D loop 2.

The 3rd FSC loop investigates several items. Most of these are in line with the 3D loops, however there are some discrepancies. Several alternative propulsion arrangements are studied during the 3rd FSC loop. This can be equated to the 3D loops by introducing a feedback loop linking propulsion loop 2 and propulsion loop 3 in the 3D view.

The 4th FSC loop is very similar to the 2nd 3D loop. The aviation domain is included as a basic check of the impact of exhaust fumes on helicopter operations is carried out.

The 5th FSC loop is similar to later parts of the 3rd 3D loop.

5.2(b) Impact on loops

It appears that some time was lost on the FSC project due to the propulsion layout being unclear. It might have been advantageous if some work was not carried out until the actual propulsion layout was known. Structures should be included in the 3D view after loop 1, so that a value for structural weight is included in the weights estimate.

5.3 COMBINED IMPACTS ON LOOPS

After the FSC and FPC studies were carried out a top-level loop was added. It was felt by the author that this would greatly enhance the management options available to a project manager and also provide a better model of the design process. The top-level loop is an attempt to include parts of the concept stage in the feasibility process. Figure 13, shows the initial proposal for the top-level loop.

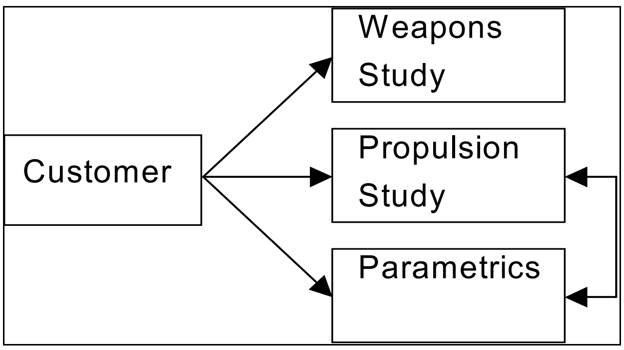

Figure 13: Initial Top Level Loop

The results from the top level loop then feed into the original loops. Adding the top-level loop allows the manager to explore more radical ideas without the need of major redesign work.

6. FURTHER DOMAIN INVESTIGATIONS

During the process of creating the flowcharts it became obvious that not enough was known about certain domains. Whereas the traditional technical domains, such as Naval Architecture, are investigated during the case studies, described in section, this is not necessarily the case for domains such as Human Factors, ILS and Production. To overcome this shortcoming more in-depth investigations into these domains were carried out. These studies were further necessitated by the need to include ILS as part of SMART procurement. The following sections provide an overview of the results from these studies. They also detail the derived impact on the loop model

6.1 HUMAN FACTORS

The analysis of the human factors domain consisted of three stages. The first stage investigated the factors affecting crewing [8,9,10], the second looked at the impact of habitability [11] and the third analysed a crewing study carried out by VT [12].

A study [12] carried out by VT indicates that the first crew estimate is solely based on basis parameters and operating profiles. No layout is known. This indicates that a first crew estimate can be carried out at the very top-level loop, using input data from the customer and the parametric study.

6.1(a) Impact on Loop Model

Crewing studies are a dynamic issue as they become more detailed and accurate once actual equipment data is known. A first high-level crewing study could be carried out at the top-level loop. This would allow for a more accurate determination of the initial dimensions in designs where complement is a major part of the requirements. HF should then act, as described above, as an input and advisory to other domains with regards to design issues. Once more equipment data is known, preferably after every completed design iteration, a more detailed study should be carried out. Again, this corresponds well with the iterative nature described by several references.

Some observations at VT have revealed the impact HF can have on designs. Assigning inappropriate habitability standards affected the payload capacity of a vessel, as insufficient deck area was available.

6.2 INTEGRATED LOGISTICS SUPPORT (ILS)

Most of the reports used during the ILS investigation were taken from the MoD website, however a series of interviews with the VT ILS Department Line Manager were also carried out.

6.2(a) Domain Definition

To identify the impact of ILS on feasibility studies it is first necessary to define ILS as a domain.

"ILS is a disciplined approach to managing Whole Life Costs (WLC) that affects both MoD and suppliers. Its aim is to optimise WLC by minimising the support system required for equipment, through influencing its design for supportability and determining support requirements. The end result is supportable and supported equipment at optimum cost." [13]

6.2(b) Assessment Phase

The aim of the assessment phase in terms of ILS is the determination of support requirements for the system solution [13].

6.2(c) General Techniques

Several general analysis techniques exist [14,15,16], which are applied throughout the project and not specific to any phase. These have to be considered as they form part of the Logistic Support Analysis (LSA) and should be used during feasibility studies.

- The most important ones are
- Failure Modes Effect and Criticality Analysis (FMECA)
- Reliability Centred Maintenance (RCM)
- Level of Repair Analysis (LORA)

6.2(d) Maritime applicability

In terms of ship design certain issues can be addressed during feasibility studies. These include

- Selection of equipment based on up front capital cost vs. through life support cost
- Frequency of service
- On board vs. on land maintenance
- Labour load
- Removal routes
- Access routes

If ILS was consulted when equipment choices are being made then most of the above issues could be resolved. This implies that ILS also communicates with procurement. Some of the studies and interviews at VT revealed that many of the aforementioned issues are considered by designers during feasibility studies but are not usually recorded explicitly. Therefore there is always the risk of designers omitting ILS requirements.

6.2(e) Tailoring

Tailoring is one of the major aspects of ILS under SMART procurement. It allows the level of analysis to be adjusted based on the project requirements. If the customer specifies that interests in up-front capital costs are more than interests in TLC then it is possible to minimise the activities carried out under ILS. On the other hand if the TLC is a priority then it is possible to increase the activities carried out by ILS. This allows the shipyard to decide the required ILS strategy on a study-by-study basis and thus it is important to integrate ILS across the design process

6.2(f) Cost Implications

An increase in up-front capital expenditure is often required to achieve a reduction in TLC. An increase of 10% in Upfront Capital (UPC) can lead to a reduction of 20 – 30% TLC, based on information received from VT ILS. This is based on internal information that shows that increasing up-front expenditure on ILS can reduce TLC through increased reliability and availability and thus decreased maintenance costs. However, to achieve these TLC savings it is important the ILS works in close conjunction with procurement and design.

6.2(g) Impact on Loop Model

ILS should be applied at all stages of the design process. Similar to human factors, it should be used as an input and advisory to all other domains with regards to design issues. At design reviews a formalised ILS feedback should be included.

Some up-front work is required by ILS to tailor their tasks to the project.

6.3 PRODUCTION

The investigation of the production domain consisted primarily of an interview with the Design for Production Manager at VT.

Production has a major impact on the UPC and to be competitive on an international level it is vital that production costs are reduced.

Productivity is a function of design. The better a design is adapted for producability the cheaper the building costs are likely to be. There are several factors that influence producability and some examples are shown below

- Cable runs
- Cofferdam placement
- Deck layouts

It is important to design the vessel so that it is easy to split the hull into building blocks. System routes need to be as straight and simple as possible, and the same is true for access routes.
The earlier production is involved the easier it is to reduce production costs, by optimising the design for producability.

6.3(a) Possible Integration

There is no need to consult production every time a change is made if designers are aware of producability implications. Some production decisions can be made up-front. However, production should be consulted for all major changes and at all review points.

6.3(b) Implications

A more in-depth production phase is required up-front and therefore a production input is connected to the parametric study on the top study loop; this is to allow for hull-form implications.

Production then needs to be included, as is already the case, on the 1st loop to provide input into the Naval Architecture domain.

Production should then act as a general input to all domains but only become visible in the template at review points. This is to aid clarity.

7. PARAMETRIC SURVEY

A parametric survey was carried out at VT to investigate the influences of a range of parameters on corvette type ships. The main reason for the survey was to aid the development of low-level management processes to control the feasibility study model. However, the results from the parametric survey showed that corvette type ships are very sensitive to aviation domain decisions especially with regards to providing a hangar and whether to provide non-organic or organic helicopter support. Therefore the aviation domain was moved from loop 1 to the top-level loop.

8. CUSTOMER FEEDBACK

To ensure that the design is always up to date with the latest customer requirements, the customer domain has been included at each review point. This allows the designer to present the current solution to the customer and incorporate eventual requirement changes into the design.

9. CURRENT LOOPS

The current loops are available in two different formats. The first format is stored in MS Visio and is described in more detail as follows.

The MS Visio flowchart format shows the functional breakdown of the domains. This format provides an overview to the designer of the relationships between the domains but does not give any timescales. It is a useful tool to ensure the designer is aware of the interfaces. It also shows which of the interfaces are locked into iterative cycles. Where an input/output is considered iterative, such as ILS with most other domains, this is illustrated by a dotted line connecting the domains.

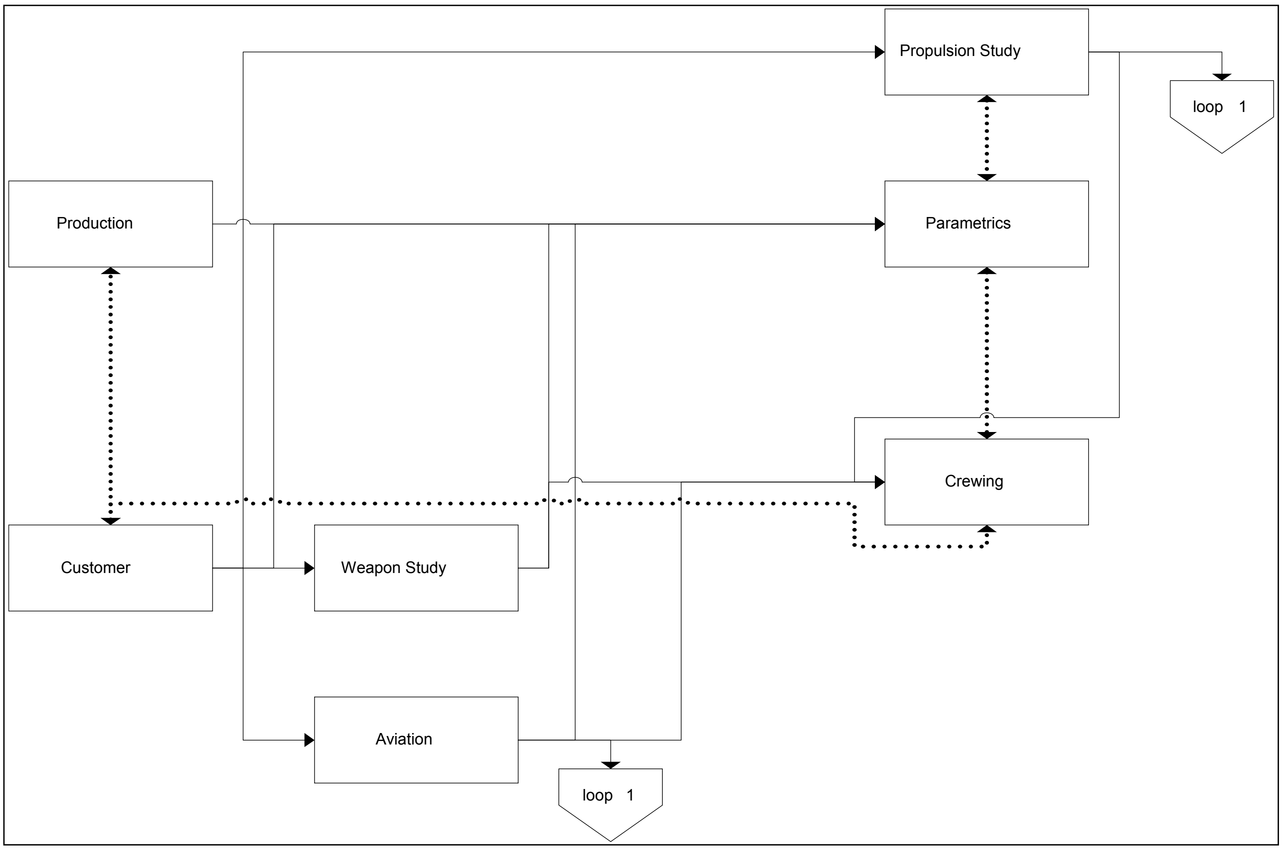

Figure 14: Top-Level Loop Functional Flowchart

The functional flowcharts are very complex and therefore only the top-level chart is shown in figure 14 as a representative figure.

The second format is stored in MS Project and provides a timeline for project managers based on the information gathered during the interviews and case studies. It allows project managers to evaluate when domains have to be started by and which domains can run in parallel, see figure 15. It also provides a tool to allow rescheduling of design activities when domains require time extensions. It is essentially a very simplified version of the functional flowcharts. A short description of the domain activities is provided in 9.1. All major iterative loops have been circled in figure 15.

The above described two formats are augmented by a user manual. The manual lists the required inputs and outputs, the approximate timing of the input/output, the likely issues faced and possible mitigation measures for each domain. Both, project managers and designers can use the handbook [17], which consists of 96 tables.

9.1 Domain Description

The following sections provide an overview of the actual work carried out during each loop. This is to support figure 15 and give an increased insight into the design process.

9.1(a) Top Loop

At this stage a first estimate of the likely weapon configuration and aviation capability is carried out. A short production study is also carried out to determine a possible build philosophy. A parametric study in conjunction with a propulsion study is used to determine the high-level propulsion arrangement and establish some baseline parameters. The aim of the HF study at this stage is to identify likely crew numbers and required standards of habitability.

9.1(b) Loop1

This loop is used to refine the concept solution determined in the top-loop. Also, the general vehicle equipment, such as cranes etc., is determined. In addition, a first cost estimate is carried out and, if relevant, budget levels are set. The iterative loop involving structures and naval architecture revolves around bulkhead locations, frame spacing and weights estimates.

9.2(c) Loop2

During this design stage a more detailed propulsion configuration study is carried out and its impact on the overall layout is evaluated. This results in the major iterative loop shown in figure 10. The naval architecture domain is used as the design integrator. The propulsion impact feedback task is used to allow for required changes to the overall propulsion configuration due to conflicts with other domains.

9.3(d) Loop3

The final loop of the design is mainly concerned with refining the overall design. All major domains are included at the start to ensure the latest equipment data is used. The iterative loop involves the electrical and auxiliary & domestic systems domains. Naval architecture as overall design integrator is also included. The aim of the iteration is to determine positions for electrical equipment and auxiliary & domestic systems such as air-conditioning units. At the end of the loop is a final cost estimate based on a more detailed production cost calculation.

10. CONCLUSION

The described case studies, further domain investigations and parametric survey resulted in the refinement of the initial loop model. All changes were crosschecked to satisfy that the overall design process was still described accurately.

The current loops provide a framework for warship feasibility studies based on shipyard data and academic research. The framework can be adapted to suit different types of ships. In its current form it is most suitable for Fast Attack Crafts (FAC) and Corvette type ships. This is the primary area of work for VT Shipbuilding.
The authors are currently working to provide an accompanying user manual for the two different formats. This will allow designer to look up their domain and to quickly identify the data they are required to receive and transmit and the relevant destination of said data.

12. REFERENCES

1. BROWN, D.K., Advanced Warship Design, Limited Resources, *Transactions of the Royal Institution of Naval Architects*, *Volume 137, pp 163 – 187*, 1995.
2. BRYSON, L., The Procurement of a Warship, *Transactions of the Royal Institution of Naval Architects, Volume 127, pp 21 – 51,* 1985.
3. ANDREWS, D., The Management of Warship Design - The MOD Warship Project Manager's Perspective, *Transactions of the Royal Institution of Naval Architects, Volume 135, pp 1 – 24,* 1993.
4. ANDREWS, D., Preliminary Warship Design, *Transactions of the Royal Institution of Naval Architects, Volume 136, pp 37 – 55,* 1994.
5. A Guide to SMART Procurement, *UK MoD*, 1999.
6. ANDREWS, D., A Comprehensive Methodology for the Design of Ships (and other complex systems), *Proceedings Royal Society London*, *A 454, pp. 187 –211,* 1998.
7. SCOTT, J., Collection of reports supporting PhD research, *Newcastle University EPSRC Engineering Design Centre.*
8. WOTTON, P., Integration of Complement Generation into Warship Design, *WARSHIP 2001, Conference Proceedings, RINA*, June 2001.
9. STRAIN, J., EASON, K., Exploring the implications of allocation of function for human resource management in the Royal Navy. *Int. Journal Human-Computer Studies, Volume 52, pp 319-334,* 2000.
10. OTTO, E., VISSER, K., WOLFF, PH.A., Application of functional analysis in naval platform specification, *11th Ship Control Symposium, University of Southampton, pp 353-364,* 1997.
11. MEERE, E.P., GRIECO, L., Ship Habitability – Preparing for the 21st Century, *Naval Engineers Journal, pp 21-27 ,* November 1997.
12. KERR, W., MRV Ship's Workforce Analysis – Project Protector, *VT Integrated Logistics, Internal Report*, 2003.
13. WEB SITE, MoD Guide to ILS. MoD UK, *http://www.ams.mod.uk/ams/content/docs/ils/ils_web/ils_gide/ils_gde.htm.*
14. WEB SITE, Warship Maintenance Policy: Reliability Centred Maintenance, *http://www.ams.mod.uk/ams/content/docs/shiprcm.doc.*
15. WEB SITE, Core Maritime Support Assumption (v1.0), *http://www.wsa.dlo.r.mil.uk/Functional/MSS/MarCore.htm.*
16. Integrated Logistic Support - Defence Standard 00-60. MoD UK, *UK MoD*, *Issue 5*, 2002.
17. STRATMANN, J.P., Management Manual for Warship Feasibility Studies, *Issue 01, VT Shipbuilding Document,* 2005.pp3-37.

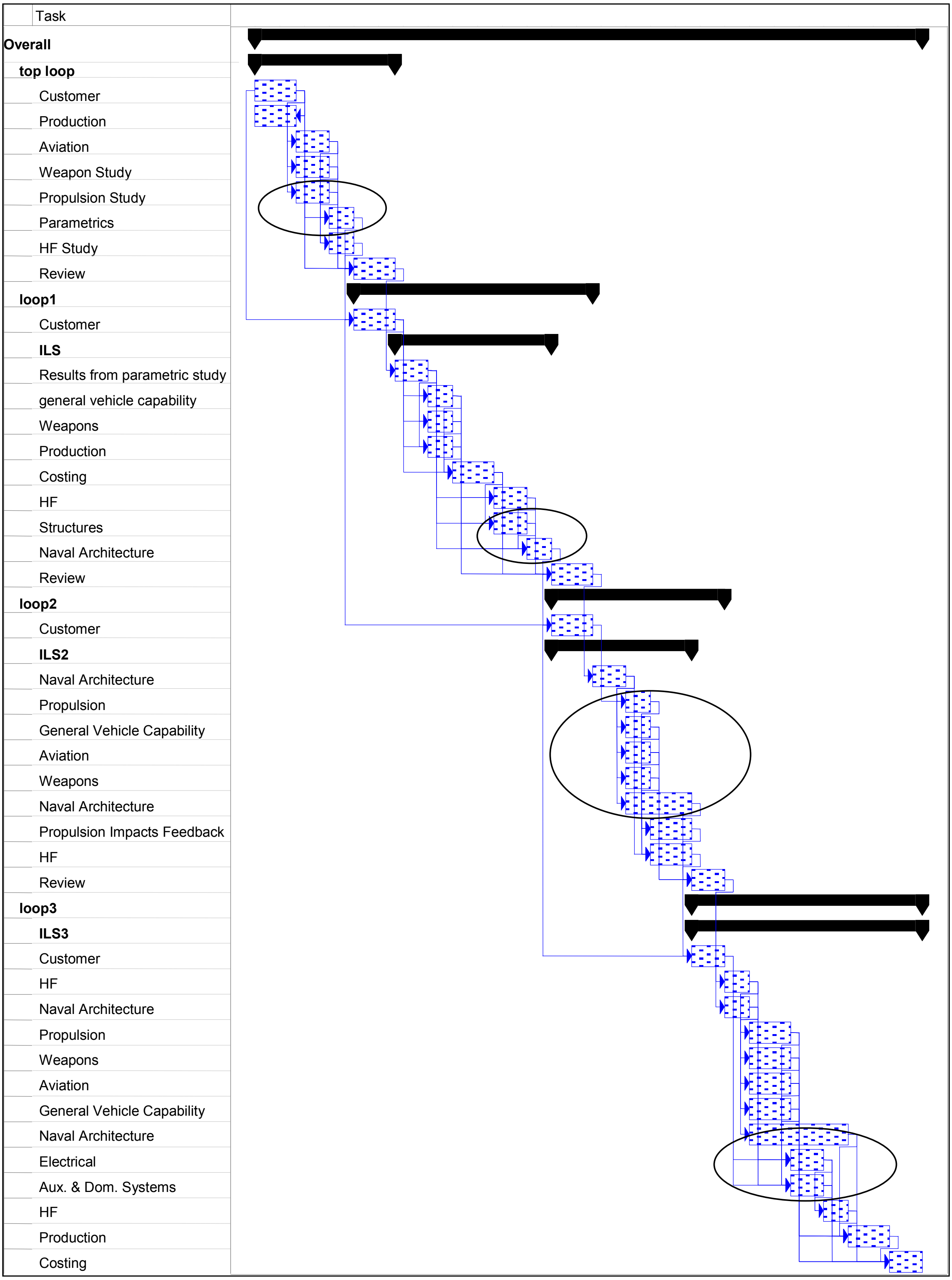

Figure 15: MS Project Schedule Overview