Author Biographies

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Andrew Mason is a co-founder of Formation Design Systems and has a long standing interest in all aspects of design dating from his studies in Architecture at the University of NSW. He has over 20 years industry experience in software development and has managed complex projects implementing ship modelling for naval architecture, hydrostatic analysis and performance prediction in his role as the principal architect of the Maxsurf marine design system.

## Summary

Computer Aided Design tools for Naval Architecture Design and Construction have undergone significant development in the last thirty years. Not only have they improved dramatically in capability, they have become more affordable as the cost of computers has reduced and become accessible to the designers and builders of even the smallest vessels.

There is now a significant difference between the software used by large shipyards and that used by workboat designers and builders. This paper describes these differences and details why the approach to Computer Aided Design and Manufacture(CAD/CAM) adopted by workboat designers and builders needs to be fundamentally different from the methods adopted by large shipyards.

# Fourth Generation Software Tools for Workboat Design and Construction

Andrew Mason & Philip Christensen
Formation Design Systems

## Introduction

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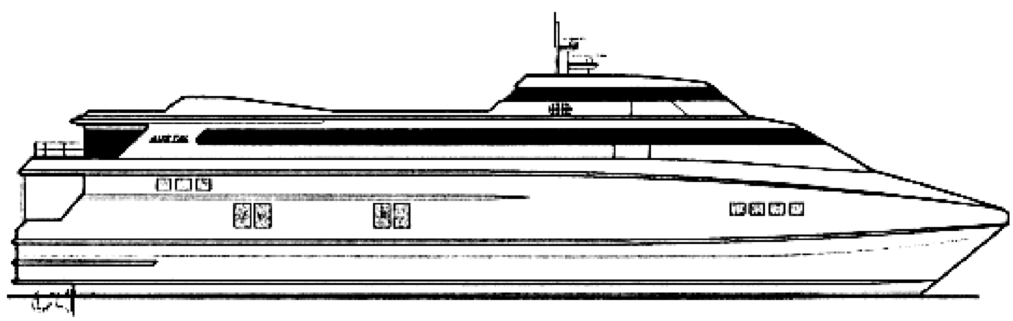
There is now a significant difference between the software used by large shipyards and that used by workboat designers and builders. This paper describes these differences and details why the approach to Computer Aided Design and Manufacture(CAD/CAM) adopted by workboat designers and builders needs to be fundamentally different from the methods adopted by large shipyards.

## CAD Requirements for Workboats

In this discussion we define Workboats as vessels typically built of steel, aluminium, or less commonly, GRP. Workboats include trawlers and other fishing vessels, tugs, tenders, patrol boats, ferries, pilot boats, lifeboats, crew boats, supply boats and many other specialised craft. They vary in length from 5m to 50m, with the larger fast ferries reaching extremes of over 100m.



86m Aluminium Ferry by Austal Ships

Workboats generally cost a small percentage of the cost of a large ship, and tend to be built by small to medium sized shipyards which have lower levels of automation than the large shipyards. Because of the smaller size of components, many workboats are built with minimal machinery but large amounts of labour.

It is possible for productivity gains offered by the adoption of CAD/CAM to rapidly improve the profitability of a workboat builder. However, over-capitalisation on an inappropriate CAD system with high operator and maintenance costs can be a significant drain on the finances of a small yard.

Many workboat builders are now automating their construction processes, installing numerically controlled plasma cutters coupled to CAD systems. For these yards it is tempting to assume that because the large shipyards use complex and expensive CAD systems, that they should also make large investments in computer hardware and software. In fact there are many reasons that the CAD requirements of the workboat builder are totally different from those of the large shipyard.

### The Aerospace industry approach to CAD.

The developers of CAD systems for large shipbuilders promote the concept of the "Product Model" where the entire structure of the vessel and all its mechanical components are modelled in the computer to a high level of detail. The "Product Model" concept originated in the Aerospace and Automotive industries and it is tempting to think that the CAD models needed for a smaller shipyard should contain a similar level of detail. Although the graphical presentations of such detailed CAD models are impressive, the reality is that the Aerospace or Automotive industries are fundamentally different from the workboat industry.

The Aerospace and Automotive industries typically deal with objects that are to be produced in quantity, and contain thousands or tens of thousands of complex components. These are usually manufactured by a large number of subcontractors, from a wide range of materials and to very high tolerances. Many of these components, although small, are parts of mechanisms that are critical to the safe operation and even the survival of the vehicle.

In contrast, the workboat industry usually manufactures objects from a relatively smaller number of components, primarily pieces of sheet material and strips of rolled or extruded sections. Tolerances are significantly looser and very few individual components are of a critical nature.

It is true that the detail required in large ships can be very high. For specialised vessels such as frigates or submarines the detail required can be equivalent to that required by the Aerospace industry. This is because the level of detail required is determined by how critical each component is to the operational integrity of the vessel and by the level to which each assembly needs to be documented.

Extremely detailed CAD models are less important for workboats, however, and their value reduces further as the scale and cost of the vessel is reduced. While the size and cost of the components of a large ship can justify the expense , the modelling of every component down to the finest level of detail becomes an unnecessary burden in the design of a smaller vessel.

### Appropriate Levels of Complexity

When using a CAD system for vessel design and construction, it is important to choose an appropriate level of complexity for the CAD model. The idea that it will always be beneficial to create an entire "product model" of the vessel, complete down to the smallest detail, is not necessarily applicable to the construction of workboats.

The cost of any vessel incorporates a percentage allocated to the design. The larger the vessel, the more money is available to be spent in the design process, even though this may be a lower percentage of the total construction cost than for the design phase of a smaller workboat.

After the bare minimum of design data have been generated, further time can be justified in increasing the level of design detail if it results in an equivalent saving during the construction phase, or lower repair and maintenance costs during the life of the vessel.

As more detail is modelled in the CAD system, a point will be reached where the downstream savings are outweighed by the additional costs. This point varies based on the cost, size and complexity of the vessel, the cost of available labour, the level of automation in the shipyard and the number of vessels being produced. For example, if a vessel is a one off design, the amount of detail modelled may necessarily be less than for a production run of many vessels.

## The Current State of Marine CAD software

Before further discussing the needs of the workboat builder, it is worth reviewing the history and current state of Computer Aided Design and Manufacturing Systems for the shipbuilding industry.

## Mainframe Power - The First Generation

In the early days of computer use in the shipbuilding industry, the expense of both computers and software development precluded all but the largest shipbuilders utilising the advantages of Computer Aided Design. Many programs were developed in-house by the various shipyards for lines fairing, hydrostatics, resistance calculations etc., but little software was available for sale commercially. The software that was available was typically written to run in batch mode on a mainframe or mini computer, and produced text output. Hull designs were generally drawn by hand and stored on the computer as tables of offsets, with lines fairing programs being used to fair the hullshapes for production.

## Second Generation – Interactive Computer Graphics

In the late 1970s the graphics terminal and the Engineering Workstation became commonplace and were usually linked to a mini computer such as a PDP11 or VAX. These computers cost significantly less then the previous generation of mainframes, and this allowed commercially viable Ship Design and Construction systems to be marketed. These included the Steerbear, Autokon and Schiffko systems. Hull designs were typically stored as 3D wirefames, with later systems incorporating surfaces patched together from a large number of Coons patches.
While the software was still expensive, it was more cost effective than software developed in-house, and was quickly adopted by large shipyards worldwide.

These systems developed further in the 1980s and 1990s to run on UNIX Workstations and Windows NT machines and are still available today. They have expanded to cover virtually every aspect of computing needs required by the large shipyard. The most widely known is the Tribon suite from Kockums Computer Systems. KCS has amalgamated the Steerbear, Autokon, Schiffko and BMT Icons software to create a large and powerful but complex system.

## Third Generation – Personal Computing

The Third Generation of software began in the early 1980s with the appearance of the Personal Computer. Several low cost systems appeared (Maxsurf, Autoship, Fastship) that performed simple hull design, hydrostatics and performance prediction tasks. These programs were affordable and appealed to the individual Naval Architect and the smaller boatbuilders and shipyards but lacked integration with the powerful 3D CAD tools available to the larger yards. A variety of incompatible operating systems (Apple II, Macintosh, DOS and HP UNIX) and programming languages (FORTRAN, BASIC, Pascal and C) were chosen by the various developers making it difficult for users to mix software from different vendors.

The drawback with the early PC programs was that they relied on a variety of incompatible representations for hull geometry and communicated with analysis programs via a variety of different file types and geometries. For example, some hydrostatics programs would read files of offset data, some would read wireframe data and some would read surface data. Standard data interchange file formats such as IGES and DXF were not widely supported and it was difficult to build a complete system that covered all of the requirements from preliminary design through to drafting, parts generation, nesting and cutting.

These systems were most popular with workboat designers and builders who saw the opportunity to make dramatic productivity improvements at a low cost. Surprisingly, they were often adopted by larger shipyards for preliminary design and proposal work, as this work was often difficult to achieve with the large production oriented systems.

## Fourth Generation – the Modern Synthesis

The fourth generation of software evolved in the 1990s as the vendors of PC software standardised on hardware, operating systems, programming languages, data interchange file formats, and hull geometry.

**Hardware**
The Intel Pentium based personal computer has become the dominant computer in the industry, outselling other PC's and Workstations by a factor of more than 20 to 1. The performance of PC's has improved so dramatically that it is easy to take for granted. A 450 MHz Pentium II can perform floating point arithmetic more than 1000 times faster than the Apple II of 1980. A megabyte of memory that cost $100,000 in the early 1970s and $1000 in the mid 1980s, now costs less than $2.

**Operating Systems**
Like Intel in the hardware business, Microsoft has similarly dominated the market for operating systems, with its latest offerings, Windows 98 and Windows NT being almost universally adopted by industry worldwide.

**Programming Languages**
Programming languages are constantly evolving and new ones are always appearing. In spite of this, commercial software developers have largely standardised on C++ for their development work. This is largely because of the support of Microsoft and the UNIX market, but also because C++ is a fundamentally more robust language for the development of large and complex computer programs.

**General purpose CAD Systems**
In the Mid 1980s, PC based CAD programs such as Autocad and Microstation became available and rapidly developed into low cost competitors to the established general purpose CAD systems. Virtually all of the major 3D CAD systems have now created versions for Windows NT based PC's. Powerful Solid Modellers such as Solid Edge and Solid Works are also now available for Windows NT, rivaling the capabilities of the most powerful workstation based systems.

**Data Interchange Files**
The migration of the major CAD systems to Windows NT has driven data interchange formats to standardise, , with the Initial Graphics Exchange Standard (IGES)and the Autocad Data Exchange File (DXF) becoming the de-facto standards.

**Hull Geometry -NURBS Surfaces**
In the area of hull geometry, all of the major vendors of PC based Naval Architecture software have standardised on the use of Non Uniform Rational B-Spline (NURBS) surfaces for their hull definitions.

There are many reasons for the adoption of NURBS surfaces as the standard geometry. Although not perfect, NURBS surfaces have advantages over all competing geometries. In addition, the fact that the NURBS geometry was included in the earliest versions of the IGES standard has been a major factor in its adoption by the Aerospace and Automotive industries. NURBS surfaces are now included in virtually every major general purpose CAD program.

One early disadvantage of NURBS surfaces arose when the user wished to model a surface shape that was fair but had discontinuities in the surface edges. Examples of this include a hull with a stepped sheerline or cutouts in a hull due to bow thruster or keel appendages. Modelling such shapes required the user to either join surfaces together, compact control points together within a surface, or to modify the underlying knot vector which controls the distribution of shape within the surface. Joining surfaces together (also known as stitching or bonding) requires that the joined surfaces share exactly the same edge with identical control points. This tends to limit this technique to surfaces that run along the full length or breadth of a hull.

These difficulties have almost completely disappeared with the introduction of trimmed NURBS surfaces. The use of trimmed NURBS surfaces is an extension of the standard usage of NURBS to allow unwanted portions of a surface to be trimmed off, without affecting the underlying surface modelling or manipulation techniques.

The area to be trimmed off is defined by a curve in the surface, often defined as in intersection line between the surface to be trimmed and other surfaces. Thus a fair shape can be designed using a NURB surface with the complex boundary being created by trimming the surface to the desired intersection line. These trimmed surfaces can be exported via an IGES file to compatible CAD programs with no loss of information.

In the authors' implementation of trimmed surfaces in the Maxsurf computer aided design system, trimmed NURBS surfaces can be dynamically intersected and re-displayed as the user modifies the design.

## Other Issues

There are several other factors that offer benefits to the workboat designer and builder using 4$^{th}$ generation CAD systems. They are often not considered when evaluating CAD systems, but they can be of great importance in reducing the overheads and improving the efficiency of a business.

### Compatibility with Office Systems

In a small to medium sized yard it is important that costs be minimised by using standard low cost hardware and software. It is also important that CAD/CAM software be compatible with other software used as part of the day to day running of the business. It is essential that data produced by the CAD system be capable of being used directly in software used for documentation, specification writing, accounting, estimating, project management, marketing materials, databases etc.

The most widely used business software is the Office 97 suite of programs from Microsoft. The standards used by Microsoft for communication between programs running under Windows 95/NT (RTF, OLE, COM) are generally not available to CAD programs running on other operating systems, making it difficult to integrate data from these CAD programs into the business systems used by the yard.

It is important to distinguish between CAD systems written specifically for the Windows operating system  and those written for UNIX that are able to run under Windows using an X emulator. These are not true Windows programs and generally do not support the full range of Windows features.

### Operator Costs

One of the greatest costs associated with the older generation systems used by the large shipbuilders is the cost of trained operators. Because the level of training required is high, trained staff are valuable and command higher salaries. Replacing them can be time consuming and expensive.

If the CAD software adopted is low cost and widely used, it is far more likely that trained operators can be employed for a reasonable price. In the case of Autocad, there is a large pool of contract draftsmen available should a job require additional manpower, a benefit not available with the higher cost CAD systems.

## Conclusion

There are a relatively small number of shipyards capable of building large ships in the world. Most of these have established computer based design and construction systems. As a result there is little growth in the market for software for these yards.

On the other hand, there is a large number of small to medium sized yards in the world building workboats, and a very high percentage of these currently have limited CAD/CAM capabilities. This means that the market for CAD/CAM software for small to medium sized shipyards has a significant amount of growth potential. The result will be further strong competition between software developers, who will continue to actively develop solutions for this market that are powerful yet low in cost.

Modern PC based Marine CAD/CAM systems have converged on a set of standards that permit a great deal of compatibility and inter-operability with each other as well as with widely used office systems. The areas of commonality can be summarised as follows -

Common Hardware (Intel)
Common Operating System (Microsoft Windows)
Common User Interface (Microsoft Windows)
Common Geometry Types (NURBS)
Common Interchange Files (DXF, IGES)
Multiple Vendors – Users can choose "Best of Breed"
Low Cost, High Volume components.
High level of integration with other commonly used software

The popularity of these 4th generation systems has occurred because many workboat builders have found the large shipbuilding systems to be too complex and expensive for their needs. As more inter-operable programs become available and with PC hardware increasing in power, the advantages of low cost, commercial off the shelf, Microsoft Windows based systems will present an even more compelling business case for the workboat builder.