THE QUARTERLY DIGEST

of CDI Marine Systems Development Division (SDD)

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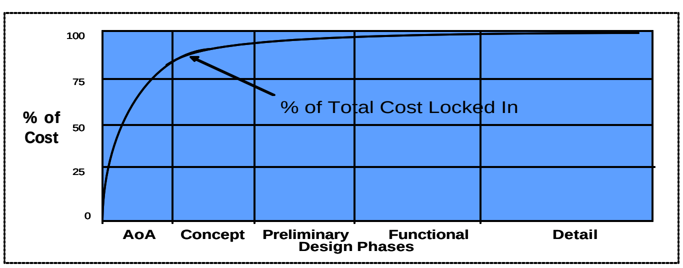
FROM DAVE'S DESK

APPETITE SUPPRESSION FOR ESCALATING REQUIREMENTS ACHIEVED BY "STICKER SHOCK"

Last month, I gave a technical paper at the ASNE Day Conference in Alexandria, Virginia, which had the main theme of **"Acquiring the Future Sea Force, Balancing Capability and Affordability."** The title of the paper was **"The Cost of Requirements & Emerging Technologies."** My co-author on this paper was Brian Forstell of CDIM-SDD, but we received significant input from Robert Percival and Dr. Bob Johnson, also of our office in Severna Park, Maryland, and from Bob Wilson of West Shore Associates in Edgewater, Maryland.

In summary, the paper served to illustrate that in today's fiscally constrained environment, most new ship and upgrade programs are faced with a significantly increased challenge of determining how best to balance capabilities within set budgetary limits. This is particularly challenging when there is a serious **appetite for increasing requirements** during the formative stages of a program. One key element we have found to help curb this appetite is "**Sticker Shock.**" This is achieved by gaining clear visibility on the cost of mission requirements and the cost of including new technologies by playing fast turn-around **"What If Games"** early in a program, during which most of the costs of buying and owning a ship are locked in, as illustrated in the figure below.

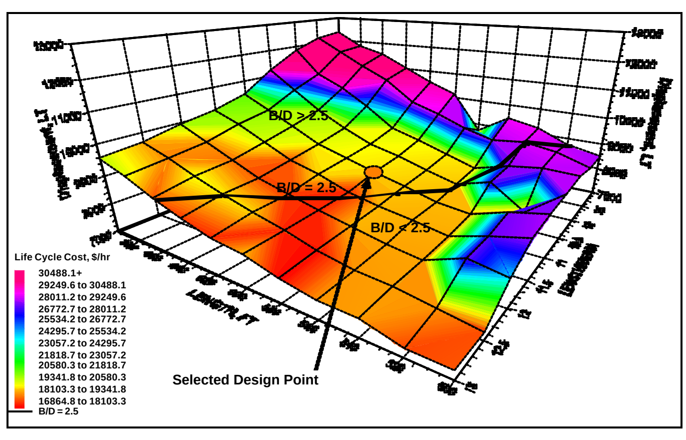


Making Sure Early Choices Do Not Lock In <u>Unaffordable Requirements</u> for Performance and Systems

Assessing and understanding the cost of possible escalating requirements and of technology options early in a program has, in our experience, been the principal key to minimizing or eliminating the potential for spiraling cost over runs.

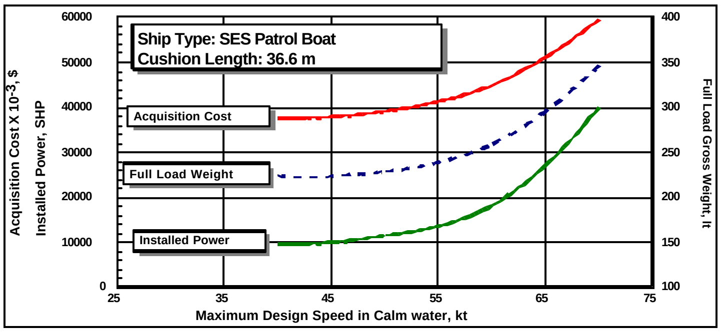
The main feature of the process to create "Sticker Shock" is a computer program, referred to as ComPASS™, which we have been developing for more than 28 years. This tool is designed to rapidly automate the traditional ship-design spiral with emphasis on the use of physics-based algorithms and the prediction of cost. Not all relationships in the process of ship design can be easily made to be physics based, but the emphasis on physics has been achieved to help ensure that extrapolations to new **"out-of-the-box"** designs can be accomplished with a higher degree of confidence than could be expected with more traditional methods that rely heavily on both empirical and historical trends. The software has been extensively Beta tested and used to support many high-profile, foreign and domestic, warship and commercial ship programs, including ships that have been built and others that are currently under study or in detail design. Predicted total cost is not precise, but typically within about 15% (or much better with calibrated predictions). With this accuracy, ComPASS™ has already helped numerous acquisition programs establish balanced and affordable requirements, and the designers select affordable technologies.

With the recent huge advances in desktop computing capability, combined with the speed and technical accuracy of ComPASS™, our engineers are able to rapidly explore the solution space for a multitude of design options to assist the customer in arriving at a set of parameters representing the most cost-effective variant. The figure below shows, for a fast commercial RO/RO ferry, a 4-dimensional surface contour plot of ship life-cycle cost and displacement versus ship dimensions (L & L/B) generated by ComPASS™.



4-D Plot of Ship LC Cost & Displacement vs. Ship L & L/B

This figure shows the design space for which every design on the surface has the same mission and design requirements. A ship draft limit is also shown. Many other similar surface plots have been prepared for clients with operational requirements or technology choices as input variables, and cost and capability as the output result, as shown in the next figure. Even for a ship designed for high speed, such as an SES, the cost of increasing speed can quickly get out of hand.



The Price of Speed

More detailed operational parameters and design discriminators, such as seakeeping performance, are also commonly introduced into our studies through file translators and interfaces with several industry-standard, or our own, stand-alone motion prediction software programs.

Of course, using ComPASS™ to curb cost through "Sticker Shock" is but one of numerous ways to help avoid cost escalation. Minimizing the size of the total team involved, avoiding incremental funding, and minimizing the overall process time are also important. A relatively recent good example of efficient use of resources is the Finnish Navy's T-2000 70-knot combat ACV, which took only 26 months from Aug. 99 to Oct. 01, for concept design to sea trials. However, for this program, all required funds were available at the start, and it was completed with just four program reviews and an IPT of six, of which only two represented the Navy meeting by phone every two weeks. Another good example was the Swedish Navy's Fast Visby-Class Corvette. This is also an excellent example of an equally important factor in moving a program quickly through the acquisition process, i.e., prompt decision-making once the data is presented.

We have long been an industry leader in the evaluation of the impacts of varying operational requirements and sub-system technology options on the acquisition and life-cycle costs of advanced ship solutions. With the current industry focus on smaller, high-speed vessels, and the renewed interest in the exploration, within serious budget constraints, of alternative hullforms, materials and propulsion systems, the need for this unique capability has never been greater.

WATERJET SYSTEM MODEL COMPONENTS USING RAPID PROTOTYPING
By John Purnell, Senior Engineer

CDIM-SDD has been under contract to the Center for Commercial Deployment of Transportation Technologies (CCDoTT) for development of an advanced marine waterjet propulsion system for high-speed vessels. This has been a multi-phased program and, as part of this year's effort, model self-propulsion tests of a high-speed catamaran were performed at the Naval Surface Warfare Center, Carderock Division. For these tests, a 19.8-foot model of the full-scale vessel was fabricated with accurately-scaled flush waterjet inlets. These tests were undertaken to establish, and to allow us to better understand, the interaction effects between the hull and the waterjet inlets. Flush inlets will ingest significant portions of the lower momentum fluid in the hull boundary layer, which will improve propulsive efficiency, but will also affect the waterjet pump sizing and operating speed design conditions. Flush inlets have also been shown to produce negative thrust deductions, which further impacts the proper sizing of the waterjet pump.

A flush inlet has a constantly changing geometry since it must transition from the hull shape at one end, including a lip region that separates internal and external flows, to a circular shape at its exit end to match the pump face. To build these complicated but properly scaled waterjet inlets, we used the latest rapid-prototyping techniques by Solid Concepts, Inc. This company uses a Selective Laser Sintering (SLS) process which employs a high-power CO_2 laser to selectively sinter a variety of powdered materials into a solid object. The process starts with a 3D CAD file of the object, which is mathematically sliced into multiple thin 2D layers. A thin, uniform layer of powdered material is deposited in a fabrication cylinder where the laser scanning system then draws the 2D cross-section on the surface of the build material, which sinters that scanned material into a solid layer. The cylinder floor is then lowered to allow another thin, uniform layer of powdered material to be deposited across the cylinder, and the next 2D cross-section is scanned and builds on the previous solid layer. The process is repeated until the object is completed.

Surface 3D files of the inlet and hull region were available, and by extending these surfaces to add thickness, a solid 3D CAD model of the inlet with a portion of the hull was developed. Figure 1 shows the 3D rendering of the waterjet inlet with a cut-out to show the waterjet pump.

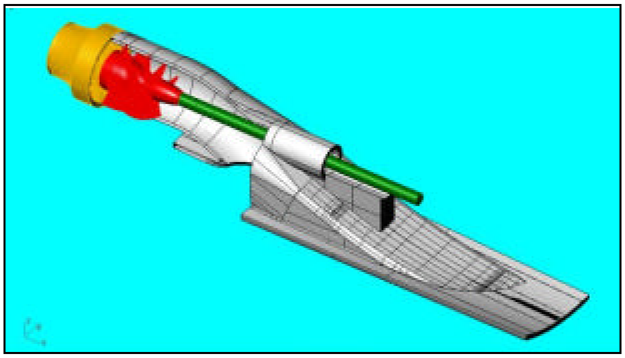


Figure 1. Rhino 3D Rendering of the Model Waterjet Inlet With Cut-out to Show the Pump

Figure 2 shows the two mirror-image waterjet inlets needed for the hull model that were fabricated with the SLS process using a nylon-based powdered material. The inlets were about 25 inches in overall length and they accommodate a pump diameter of 3-3/8 inches. Of particular interest is that the two inlets were both fabricated and then received by CDIM-SDD exactly one week after the data files were submitted. The inlets were well made and the material was very robust compared to past rapid prototyping experience where the material was rather brittle. In addition, SLS pump parts, impellers and stator/nozzle pieces to match up with the inlets were also made, as shown in Figure 3. The pump parts are representative in that the blade sections become too thin to accurately model the full-scale pump and the blades were made much thicker to operate reliably for the testing. The pump basically only needs to develop the required flow rate through the scaled inlet to allow us to model the inlet-hull interactions.

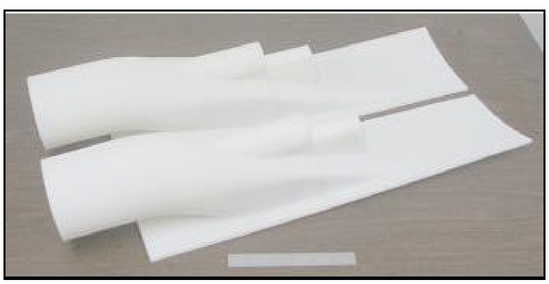


Figure 2. Two Mirror-Image SLS Waterjet Inlets for the Model Hull

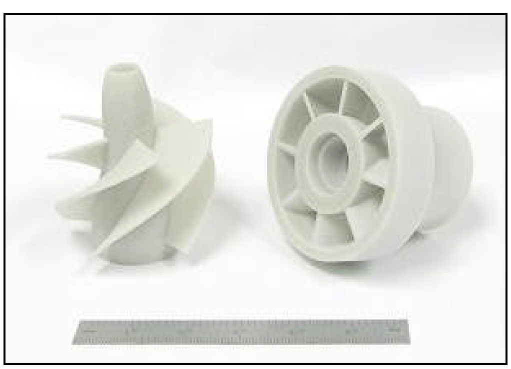


Figure 3. SLS Model Impeller and Stator/Nozzle Pieces

Separate water tunnel tests of a larger scale model of the pump were performed in the last phase of CCDoTT work to establish the hydrodynamic and cavitation performance of the full-scale waterjet pump. Results from these earlier tests are being combined with the self-propulsion test data to establish the overall waterjet system performance. The use of rapid prototyping for waterjet system model components has greatly simplified the testing of waterjet-propelled models and all those involved in such testing should be aware of its interesting possibilities.

BALTIMORE FIRE BOAT CONSTRUCTION PROGRESS

By Dan Bagnell, Director of Naval Architecture

For the past 15 months, CDI Marine Systems Development Division (CDIM-SDD) has been assisting the Baltimore City Fire Department with the acquisition of a new 87-foot Class-A Fireboat. A series of design reviews with the builder, Hike Metal, have been completed and construction has started. Steel for the hull was laid the first week of June and progress on erecting the hull framing continues. Over the next 11 months, CDIM-SDD personnel will be making a series of trips to conduct specification compliance inspections as well as conduct the acceptance trials for the City.

During the past two months, a full-scale mock-up was built to assist the City in developing the final arrangement for the EMS workspace and fire fighting equipment storage areas. This mock-up was built at the CDIM-SDD prototyping shop in Arnold, Maryland.

To view weekly construction progress, you can visit the website CDIM-SDD has set up for the City. Go to www.BALTIMOREFIREBOAT.com and click on "Construction Photos". A General Arrangements drawing can also be found there.

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THE QUARTERLY DIGEST

of CDI Marine Systems Development Division

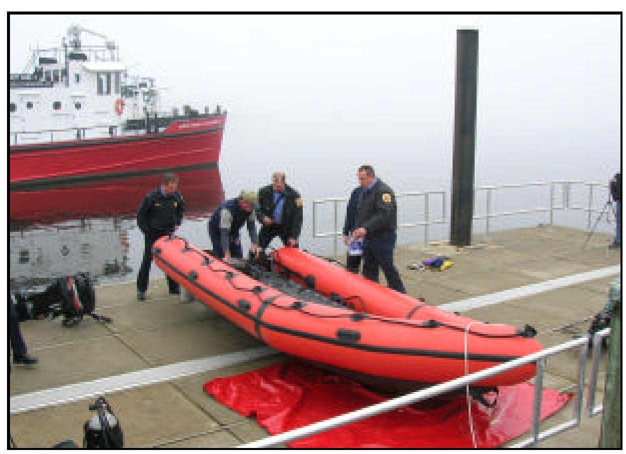
"BOAT-IN-A-BAG"
By Dan Bagnell, Director of Naval Architecture

The development of our Rigid Inflatable Bottom Boat (RIBB) has been going on for the last 15 years. Recently, a 5.5-meter Demonstration Rescue Boat was built and demonstrated to the Baltimore Fire Department. When not in use, this boat is folded and stored "in a bag."

At 5.5 meters (18 feet) in length, this is quite a large boat, but only requires two scuba bottles and five minutes to inflate. There is no floor to assemble; just mount the outboard motor and add in the fuel tank and it is ready to go.

Designs for 4.0 meters, 4.5 meters, 5.0 meters and 5.5 meters have been built.

Currently, a 4.5-meter rescue/work boat is planned for the new City of Baltimore 87-foot Fire Boat due to be delivered next spring.



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