In order to achieve major productivity and cost-efficient breakthroughs, a solution is required that can manage today’s accelerated speed of change and provide significant returns on investment in technology. A broader horizontal strategy is needed that extends across engineering, business, material management, production, and lifecycle management domains. Most importantly, ships and marine structures must operate within a strict regulatory framework, as well as in a safe manner, often while transporting hazardous materials. Having this safety structure integrated during intelligent design is an obvious advantage for globally competitive shipyards.

Sophisticated applications dedicated to plant and marine industries nowadays provide specifications to rule the outfitting design and the best solutions are able to generate typical drawings and reports automatically. However, in order to reach the highest levels of automation, the system has to introduce automation in the
DESIGNING TOMORROW’S VESSELS

Figure 1. 3D model of a vessel.
workflow and must have the ability to capture the design intention and maintain it while the design and building conditions are changing. Even the simplest 2D and 3D generic CAD systems allow for ‘macros’ to address repetitive tasks, but the application of these macros is left to the designers’ decision, i.e. the rules are not triggered automatically, as in the case of the ‘smart occurrence’.

A smart occurrence is a small tessella in Intergraph’s SmartMarine Enterprise solution; the latest solution for design, construction, and lifecycle management of ships and marine structures, aiming at business process improvements, not only at design improvements.

The design-for-production process

Currently, out of many solutions available in the market for LNG vessel design, only Intergraph SmartMarine 3D (SM3D) is able to support three different structural views with a unique association between them in order to avoid redundancies and duplication of design work. The views follow the usual design macro-steps: conceptual (basic design), detail design and manufacturing. The SmartMarine Structural business objects (BOs) feature is able to follow the various phases of the evolving design in terms of attributes and graphical representation, i.e. from thickened surfaces at the beginning of the design to solids during detailing, and 2D contours when it comes to defining the cutting paths for piece-parts to be sent to production.

The way the relationship (between the BOs in various maturity stages) is defined, propagated and maintained has been patented and it represents a key element in dealing with structural topology that is essential in shipbuilding structural design. Logical connections representing the relationships during the early stages will become automatic assembly connections during the detail design and then assembly connections will automatically generate important BOs like welds. This is valid for any vessel designed with SM3D.

Many of today’s dedicated shipbuilding and offshore systems still use 2D views to define and interactively detail structural elements; this is quite inefficient in complex areas. Moving to a fully-integrated 3D design brings an additional competitive advantage; advantage that in the case of SM3D must be added to the full integration and automation.

Automation saves time, provides consistent accuracy, and improves design quality, positively influencing production processes and schedules. Ultimately this allows for more comprehensive basic design and simultaneously shortens the delivery time.

Finally it is important to mention that the SM3D ‘design-for-production’ paradigm includes planning during any of the design stages; this frees users from the constraints of outdated computer-aided design when applied to LNG carriers or other complex and technologically advanced vessels.

Customisation of rule-driven design

Detailed design of vessels is a tedious non value-added, error prone, time consuming task where rule-base automation is showing many potential benefits. Rule-driven detailing provides the possibility of enforcing industry and company standards and generating the automatic creation of objects and reports. The description of the ship (design constrains, structural strength), assembly methods and production database can be governed by rules that can be modified adding elements or cases, according to the needs of the vessel or the yard standards and procedures.

In the currently available out-of-the-box rules, the penetration details (e.g. the stiffener crossing a bulkhead or a deck) is solved by using an attribute assigned to the plate system. By default, a plate system can be watertight or non-watertight. More often it is the nature of the space bounded by the plate system that determines whether a penetration should be tight or not: if one of the two spaces (compartments) is a ‘structural tank’ this, of course, must be tight. As a consequence, all the penetrations in the bounding plate systems of such a tank should be obtained with appropriate fully welded collars. At the same time, all the penetrations inside a structural tank or outside a tight compartment should be solved with typical clips instead. This is just one example of the possibilities of changing the rules and increasing the level of the rule-based automation. Functional subdivisions of the ship (e.g. different fire-proof zones, or safety zone or arbitrarily

Figure 2. LNG carrier.

Figure 3. FPSO.
defined user-zones) can be used to trigger dedicated rules and corresponding solutions.

The fully (100%) automated detailing is of course a goal and the final target. The best users of SmartMarine Structural already exceed 85% of automatic ‘remodelling’ usually required when transitioning from preliminary design applications to detailed design. This is achieved by combining out-of-the-box with users’ customised rules.

It must be noted that the target of ‘fully automated detailing’ does not exclude the possibility of the end-user interactively overwriting singular cases, but this should be limited and considered as an exception to the rule.

The SmartMarine 3D rule-driven solution streamlines design processes, preserving existing data and making it more usable without duplication. A substantial reduction in man-hours spent on structural detailing has been obtained in various kinds of vessels, inclusive of LNG carriers.

**Full interdisciplinary integration**

The structural model is fully integrated with the 3D outfitting model that is carried out in a ‘seamless’ process through basic design, detailed design, and construction without remodelling. Changes to the hull form or the position of any plate system (e.g. bulkheads or decks) trigger the automatic update of the related structure and, given permission, also trigger the re-positioning of the outfitting components related to the modified structure.

Structural openings generated by pipe/duct/cableway penetrations are all generated automatically following appropriate rules, generally dependent upon the tightness of the parent plate system.

The ability to treat the model of an LNG vessel holistically during all phases of the design, together with comprehensive interdisciplinary integration and a planning task able to manage any 3D business object provides yards with a considerable competitive advantage.

**Data sharing versus data exchange**

Traditional CAD/CAM systems evolved from a paradigm in which the software application would read/write to files. In mechanical CAD systems, this often meant that a file represented a part, and that visualisation or digital mock-up software manipulated how the parts were assembled together. This methodology is still appropriate in discrete manufacturing companies where the parts can be isolated, and various tools - from concept design to manufacturing - can all work on the same file format.

CAD for the process, power, and marine industries originated from the same roots, but exposed some fundamental limitations. A single file could not support the size of a whole ship, nor could it accept simultaneous input from multiple users. Consequently, the LNG ship model would be divided into many files, where each file may represent a chunk of the ship, therefore missing the possibility of getting the complete systems simultaneously (piping, instrumentation, electrical, etc.), that span across these files.
The simplest solution for most software vendors was to leave the CAD engine largely intact, but develop software (PDM) for their tools to communicate between the files via a database application. This software would manage the interfaces, whether they be logical (e.g., to/from) or physical (e.g., co-ordinates) connections between the files. This approach applies equally to schematic (for example, to accommodate ‘off-page connectors’) and 3D software applications, and works fine up to a point. In other words, as shipbuilders started to optimise their vessel designs into configurable blocks to support experienced design and building strategy, the integrity of the network systems (piping, electrical, instrumentation) was put at risk as each discipline and each chunk of the model modified their data within each file.

The development of digital mock-up (DMU) software partially addressed this problem, essentially putting the whole model back together again to ensure the connectivity/integrity of the interfaces between each file.

Intergraph's SmartMarine Enterprise suite of tools is data-centric: a user interacts with the application that reads/writes to a multi-user, multi-discipline database, as opposed to a CAD system that reads/writes to files on the file system. Filters allow specific data to be retrieved from the database in a user friendly manner without having to write complex queries. All the deliverables like drawings and reports are extracted in the same way (via queries to the relational database) at any point in time during the project.

The total integration of the engineering data in a single-source data entry enables quick identification and resolution of potential problems; timely information and project reporting with seamless interfaces with corporate financial, accounting, and planning applications. In addition, data-centric systems deliver a reduction in the number of staff required for project management, increases standardisation across projects and programmes and provides overall cost savings of 5% - 20% of total project costs when used in conjunction with earned value techniques and sound project management procedures.

The impact on production

Since manufacturing capabilities are often not in a single geographical location, the distributed manufacturing and ‘just-in-time’ generation of the manufacturing data is an essential part of the solution. It begins with pre-nesting material ordering and it continues through the actual cutting of the parts. Production facilities often depend on the capabilities of local workshops and require a flexible solution to transform the engineering part into a manufacturing part. Through user-defined rules, this transformation process can be automated based on the local workshop requirements and capabilities.

Building blocks are defined in the early stages of the design. This enables the definition of assembly and sub-assembly structures, specifies the work-centre assignments and determines assembly sequencing. Without rework, this will be refined to the lowest level during the progress of the project. A building simulation can be provided at any stage of the project.

Planning data can be linked with schedule information (master and procurement) so that they can be aligned with the build strategy. The links with external/third party planning and scheduling systems are easily made, especially with Microsoft OLE-enabled applications. Such tight integration makes changes and schedule updates smoother and more efficient.

All relevant production data is exported to production management systems (PMS), NC cutting machines, profile cutting robots, welding robots, pipe cutting/bending automates. Error reduction prior to production represents substantial cost savings. Complex floater 3D structure can be easily solved with appropriate functions and the use of sophisticated User Interface. Beside weights and CoGs, the assembly planning task enables the user to define the assembly orientation, the footprint and the mounting sequence, which are all pre-requisites for the automatic generation of building instructions for the workshop (including dedicated assembly drawings).

Through user-defined rules, different production scenarios can be checked to determine if parts can be manufactured in other locations without being modified. All parts of the workflow can be managed and reported on, sorted out by block, zone, section, or item.

With all the above, accuracy has improved in vessel design, significantly reducing the total amount of labour hours needed, hence enhancing efficiency and reducing cost in the building dock. Logistics for materials distribution has also dramatically improved following similar improvements in planning and scheduling. Beside drawings and other paper outputs that can be produced at the shopfloor (‘on-demand’); the digital 3D product model is available also, for assembly, dimensional, and any sort of quality checks.

In summary, the latest available technology for ship design aims at providing solutions for integrated cPLM (capital Project Lifecycle Management) systems, by offering a suite of data-centric design tools and a workflow oriented integration framework that shares engineering information with the extended enterprise. It promotes:

- Data sharing; controlled release of data to domains for various applications to reuse while initial source data continues to progress.
- Inter-discipline data reuse; retrieve released data into application via interaction with ‘to-do’ list.
- Consistency; inter-discipline data comparison.

The above makes it possible to ensure that engineering goes first, prior to operations in order to have a clear project overview and to achieve and maintain data integrity, which is the prerequisite for error-free schedule shrinkage.

In the coming years, automation will continue to grow up to a level compatible with the very complex one-of-a-kind (or short-series) large capital projects. Overall production time will continue to shrink to a level compatible with the business model of the yard. For example, large shipyards (‘ship factories’) will produce ships faster with full control of the schedule while small to medium shipyards (‘assembly shipyards’), where competitiveness is provided by their production flexibility and minimum overheads will produce vessels efficiently, including subcontractors in all phases of the project, with full control of the process and the costs.