The Race for More Oil

Best Practices for
Safer, Stronger Offshore Structures

Schnitger
Corporation

Contents

About this report

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In Brief

With an ever-increasing demand for oil, companies are exploiting harder-to-reach reservoirs and operating existing assets much longer. But the challenge of designing platforms for Arctic or deep-water exploration that are easy to build, cost-effective to install, and safe to operate is not easily overcome. Moreover, operating assets for 20 to 30 years, or longer, to extract every last molecule of hydrocarbon from existing sources requires constant monitoring to ensure that modifications are safe and effective.

How are world-class offshore engineering teams boosting their chances of success? By using modern design and simulation technology to create better, safer structures that meet the operational needs of the platform. They

1. **Collaborate** effectively with asset owners, design partners, and subcontractors;
2. **Innovate** with consistent, high fidelity analytical models;
3. **Comply** with changing regulations and operating requirements, and;
4. **Simulate** complex effects such as wave fatigue, collisions, and explosions to design new platforms and extend the life of existing assets.

It's All About Maximizing Production

The offshore industry is driven by the need to increase production of hydrocarbons, both oil and natural gas. Oil companies are building new offshore exploration and production facilities and extending the life of existing assets to meet demand that is expected to grow by 30 percent over the next 25 years.

Much of the investment in new platforms is in regions that had been considered too difficult or not cost-effective. The International Energy Agency estimates that 25 percent of the remaining recoverable conventional oil is in reservoirs that are under 500 meters of water; the U.S. Geological Survey estimates that 25 percent of the remaining recoverable undiscovered oil and gas resources are located in the Arctic. Drilling in deepwater and Arctic reservoirs has become much more attractive in recent years, with the high price of oil and gas fuelling the profitability of these projects. Meanwhile, improved extraction technology and the ability to predict the performance of fixed and floating structures in these environments make these reservoirs accessible.

Many offshore projects are designed to lengthen the productive lives of existing platforms. New drilling technologies and production methods can enable an existing facility to handle a different grade of crude or add a new well to the platform. Even so, with an average age of well over 30 years, the reality is that exploration and production companies will increasingly have to invest in decommissioning activities, such as safely capping wells that are no longer producing and dismantling and removing the platforms.

Whether a new-build or a retrofit, analysis of offshore structures is one of the most demanding and complex tasks performed by engineers. In addition to the usual conditions seen by land-based structures, offshore structures are subjected to the full force of their ocean environment. The effect of hydrodynamic loads like waves and currents on the platform and its supports, along with the structure's response, are major design considerations. Soil-pile interaction, possible impact by support ships and potential explosions in such hazardous environments further complicate what could be a simple analysis on dry land. These complex, often non-linear, analyses are best conducted using specialized software that takes account of static and live loads, fatigue, transport, installation and other factors unique to offshore structures.

Shifting Global Ecosystems

The offshore industry is characterized by constantly shifting project ecosystems. Even smaller projects often involve a consortium of design, construction and installation partners. Within firms, specialist talent may be located anywhere in the world.

This talent is not static, as very experienced designers and engineers from the North Sea and Gulf of Mexico are retiring and very capable but as yet inexperienced engineers are entering the industry. These engineers may be in offices that are closer to projects in Asia, Oceania, or Africa, so pairing novice engineers with experienced ones isn't simple. Bottom line, offshore projects involve distributed teams that must work together to bring a project to completion. Firms increasingly rely upon collaboration technologies to leverage expertise, transfer knowledge, and work with partners.

Staying on top of standards isn't easy. Sophisticated IT tools are required to analyze loads and compare results to current codes.

Projects that use common technologies, integrated project workflows, and collaboration tools can confirm that everyone is working on the latest design, with a known history – whether iterating on an early concept, sharing the final design with the client, or building hardware to spec.

Ensuring Safety

International standards have long governed the construction and operation of offshore structures because the risks to human life and marine environment are just too great. Codes such as the American Petroleum Institute's API RP 2A are recommended practices for designing and building offshore platforms and have been evolving since the first platform was placed in the 1940s. The APIs are not the only codes specified on global offshore projects. The European EC3 for steel design, Canada's CSA S16, ISO 19902, NORSOK N-004, among others, can be specified.

As technology and requirements constantly advance, these standards are moving targets. As platforms become larger and more complex, our understanding of their responses to loads such as wind, waves, and currents, and to extreme events like hurricanes, is constantly evolving and standards must, too. API RP WSD has been modified more than 20 times since its initial publication in 1969 and engineers must certify that their design complies with the latest version of the appropriate standard before a regulator will issue an operating permit. Staying on top of these standards is not easy and requires sophisticated IT tools to both analyze loads and then compare the results to the most relevant, current codes.

But a good engineer doesn't just validate against codes. Truly innovative designs come from evaluating dozens of possible scenarios with high-fidelity models to create the best-case design.

Image courtesy of EDG Inc.

Collaborating for Project Execution

Offshore projects, whether large or small require collaboration among the partners, owners, and classification societies that make up this distributed team. This is critical to ensure project success. Integrated project workflows make it possible to carry out projects with very tight deadlines to exacting criteria.

As a result, software systems have become an important part of project collaboration, enabling project participants to share data. With a 40-year heritage, SACS—software for the structural analysis, design, fabrication, installation, operation, and decommissioning of offshore structures—is in such widespread use in the offshore industry that it, itself, has become a means of project and industry collaboration.

L.T. Cooper, P.E., structural engineering manager at EDG Consulting Engineers, began using SACS almost 25 years ago when it was menu-driven and cumbersome. Now, says Mr. Cooper,

SACS is the "bread and butter"; the industry standard for Gulf of Mexico projects and most of the others we work on worldwide. We use SACS on fixed platforms, for new design, and to assess existing platforms for structural integrity given changes in loading and today's more robust environmental loads.

When a customer wants to add a piece of equipment or otherwise modify an existing platform, we use SACS to determine how those changes will affect the structure from a local (individual or small group of members) and/or global (overall) standpoint with an array of analyses that spans from fabrication support, load-out, transportation, installation, and operating the new equipment, to modifying the existing structure to account for gravity, operational (including vibration), and environmental loading.

By using the industry standard, EDG is able to communicate quickly and effectively with partner companies who are also using SACS.

Mr. Cooper also highlights the importance of collaborating between and among disciplines.

I tell young engineers, "What you design isn't what gets built – what gets built is what drafting produces. It's your job to make sure that what you design gets properly developed by drafting." We use model walk-throughs to verify that what is drawn is what we're designing. We'll have the CAD model side-by-side with the structural model from SACS to get visual verification that we're on the right track.

The SACS development team has many years of in-depth experience in the codes and requirements of the offshore industry to support the end-users. This experience, and acting on customer feedback and requests, is a big part of why SACS is so trusted in the industry.

Mr. Cooper also points out how much analysis has evolved over the years. Faster processors and multi-core machines enable his team to explore many more alternatives than before, to manage risk, prove compliance and create the best possible design.

Twenty-five years ago, engineers would model a structure and look at about eight to 10 basic load cases. The analysis would take all night on a mainframe computer! We would make conservative assumptions and, 99 times out of 100, the structure would behave as predicted. We would spend the next day reviewing the model, revising calculations, and hand-editing the model changes before rerunning the analysis the next evening.

SACS is the industry standard for Gulf of Mexico projects and most of the others we work on worldwide.
- L.T. Cooper, P.E., EDG Consulting Engineers

Today, we seem to look at every possible load case, even those that do not apparently govern. If a member or connection does not work properly, that individual member or connection is modified and instantly reanalyzed. With today's graphical interface and advanced processing, modeling and design have become easier and more powerful *allowing for a new paradigm in the way people approach these tasks.*

Mr. Cooper also sees a way to use SACS to enable EDG to stand out from among its peers.

We want to position ourselves as not just as a general engineering firm but also as one that can perform some of the more exotic analyses that boutique engineering firms handle – EDG being a one-stop-shop for our clients. Working with clients, contractors, and other consultants on a project, we look for ways to add value – working collaboratively to develop the most effective and efficient design – to design the best product for the client. SACS helps us achieve this through its ability to allow the project team to visualize the product and perform modifications before the design and fabrication effort has progressed too far.

Optimizing the Installation

Getting a 20,000-ton jacket from the fabrication yard to the production area is a job for transportation and installation specialists like Dockwise Ltd. Dockwise uses SACS to analyze the construction, load-out, transport and offshore installation in an offshore project.

This involves collaborating and coordinating with the client and construction team. In fact, explains Nathan Contreras, structural engineering manager, Dockwise,

We're involved upfront, in the conceptual studies, as the client works out if installation by vessel or crane makes the most sense based on the site investigation. How to install has to do with modularization, where it will be fabricated, if the fab yard can handle modules of that size, and its location in the world. Many variables and a lot of study go into the decision of how a platform is going to be installed.

Again, the SACS model proves to be the basis for the collaboration on a project. Mr. Contreras says,

The client may send over a SACS model and drawings of whatever it is we're transporting. If we don't get the model from the client, we may have to build it ourselves from drawings.

Mr. Contreras adds,

We market our operational expertise; the fact that we provide engineering service is a plus, and companies like having compatible software. Since most companies use SACS, it's a benefit. We have the expertise to transport different types of cargo and having SACS lets our engineers streamline that analysis.

Rodrigo Corona, engineering manager, and Wenjie Wu, senior structural engineer, add,

We use SACS and other FEA programs. We have several SACS modules: structural, structural offshore, pile, collapse. The majority of the time we use structural and structural offshore for static and sometimes dynamic loading. If the owner requests it, we may do collapse analysis -- and if we determine in a hazard meeting that we need a blast analysis, we'll do that too.

Dr. Wu says that Dockwise is currently using SACS to model transportation and installation, including load-out and launch-related activities, for a major project in the South China Sea.

In addition to SACS, Dockwise uses Bentley's ProjectWise to integrate its worldwide engineering teams. The company has a central ProjectWise integration server at its headquarters in Breda, the Netherlands, with caching servers in engineering offices in Houston and Shanghai. Dockwise finds that ProjectWise improves efficiency and quality control, streamlines approval processes, and allows access to and reuse of project history.

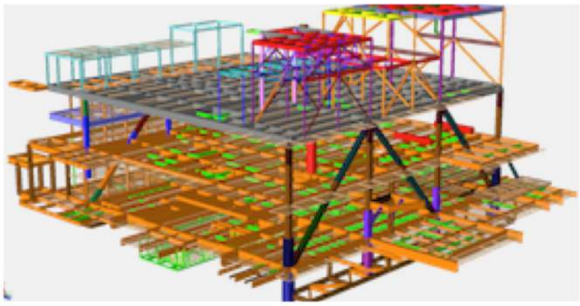
Image courtesy of Dockwise Ltd.

Ian Emery, Dockwise information coordinator global engineering, says that tighter integration between ProjectWise and SACS will increase Dockwise's agility, since they'll be able to staff a project globally to support the team close to the installation site. ProjectWise's Delta File Transfer, which speeds large file synchronization by moving only the changes made, together with its upload compression algorithm, gives users fast access to the latest instance of their designs and other data.

Innovating with High Fidelity Analysis

As we've seen, many companies adopted SACS decades ago. Wood Group Mustang (formerly Mustang Engineering) may well have been one of SACS's earliest adopters. Dr. Farrel Zwerneman, technical authority, civil/structural engineering offshore, says that SACS has been a mainstay at Wood Group Mustang for many years.

Today, we use SACS for the design of the primary and secondary steel on offshore structures. For fixed offshore platforms it's the immediate choice – the default.



Dr. Zwerneman highlights current work processes that begin structural simulation as soon as there is a design concept and refine the model as the design evolves.

SACS modeling starts very early. At the start of a project, we build a model of the initial concept, select preliminary member sizes, perform basic analyses, and slowly refine from there. We continue [to refine the model] for the duration of the project. The bulk of the work - the big stuff, beams and columns - is done in SACS. The more local, specialized, detailed finite element analysis work is usually done using another FEA code. Work is performed in parallel, so we analyze with SACS then move to the other code for a complex joint. We may have to iterate between the two, but not that much.

Dr. Zwerneman says his clients are very knowledgeable and often request SACS.

Some even ask for specific kinds of analyses. The super-majors have structural people familiar with SACS. They know that SACS has incorporated offshore specific structural codes – such as API, which was developed in the U.S. and is used in many of places in the world, as well as international codes such as ISO and NORSOK. We need SACS to continue to incorporate code updates as the updates become available to make sure our designs comply.

Meeting Evolving Compliance Targets

Code compliance comes up time and again as a critical issue for the offshore industry. To a large extent, that's because the codes continue to evolve. Dr. Liew Ken Hin, senior structural engineer at Ranhill WorleyParsons in Malaysia (RWP), is also a long-time user of SACS and finds its compliance tools to be critical to project success:

We started using SACS for linear elastic analysis more than 20 years ago to design fixed offshore platforms – wellhead, production, riser platforms—and do code checks.

Depending on the project, says Dr. Liew,

The substructure can be installed either by lifting or launch. We use SACS to analyze the substructure for in-service conditions (pile/soil non-linear interaction behavior) and pre-service conditions (load-out, transportation, lifting/float-over, mating, launch, flotation, up-ending, and on-bottom stability).

SACS comes with various design code checks like API, ISO, NORSOK, or DNV, which may not be covered in other commercial finite element programs. In addition, the latest API design codes are always up to date in SACS. These API code checks save us a lot of time and money as they confirm that the model is compliant with recommended practice for planning, designing, and construction.

Dr. Liew's clients ask for SACS on their projects.

Many of the asset owners recommend that we use SACS. So, it is important to have the SACS program included as part of the design [proposal] package.

Dr. Liew says that RWP recently finished a project on the Zawtika Development, where RWP

used SACS to design both superstructure and substructure. The superstructure analysis covered load-out, transportation, mating, in-place, and seismic conditions. The substructure analysis covered load-out transportation, launch, float-over and upending, on-bottom stability, in-place, dynamic, fatigue, and seismic condition. We also use SACS to analyze the bridge, flare boom, and plated light steel frame structure.

These code checks save us a lot of time and money as they confirm that the model is compliant with recommended practice. - Dr. Liew, RWP

Repurposing for New Uses

Another WorleyParsons company, INTECSEA, works on floating offshore structure projects. One recent project is a floating production, storage and offloading (FPSO) vessel off the coast of Northwestern Australia. Naval architect Geoff Leggatt, supervising engineering specialist, highlights how Bentley's software helps INTECSEA complete engineering projects to meet client requirements.

We've been working on the Ningaloo Vision, an

Apache FPSO. In combination with some vessel upgrades being undertaken, two new additional fields will be tied back via subsea flowlines and umbilicals to the Ningaloo Vision, resulting in the produced oil having a higher specific gravity than is currently stored onboard. As a result, we have been requested by our client to review the vessel's stability and longitudinal strength subject to the revised lightship mass distribution and the loads imposed by this different cargo. It is a very large project with hundreds of possible load cases and damage conditions to examine. The owner wants to cover all bases, from typical and cyclone season load and discharge cycles to ballast and crude compartment maintenance and inspection scenarios.

We modeled the hull from the existing vessel offsets table, and defined all tanks and compartments as per the vessel tank plan and structural drawings. The revised lightship mass distribution, in combination with allowable stillwater bending moments and shear forces determined from both class rule and hydrodynamic calculations, were applied within Bentley's stability software in order to derive revised loading and discharge sequence load conditions. Both intact and damaged stability analysis were conducted for all load conditions and damage scenarios using the batch analysis functionality within Bentley's naval architecture software.

We've created extensive intact and damage stability books that cover every operating scenario to maximize the amount of product they could store onboard and offload given the higher specific gravity.

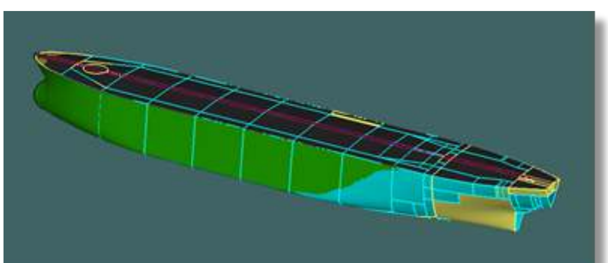


Image courtesy of INTECSEA

As to whether this is even doable without software like Bentley's naval architecture software,

It would be impractical to undertake such a comprehensive analysis without the capabilities of Bentley's stability software.

The user interface and functionality of the Bentley hull modeling and stability software aids our productivity for conducting stability analysis. Integration of the Bentley hull modeling and stability package with advanced motions analysis and structural analysis will offer distinct advantages.

A major disadvantage of using different packages for different aspects of vessel design and analysis is the potential for error resulting from the inconsistent coordinate systems employed by the various software vendors.

Supporting Long-lived Assets

As we learned from the repurposed tanker, these assets can have a very long life. Production platforms are initially designed to operate for a specific number of years – a function of the size of the reservoir, available extraction technology and projected demand as of the date of original installation. But the high price of petroleum products leads many owners to keep existing platforms going by adding wells, updating equipment, and using new extraction techniques to capture more hydrocarbons from existing locations.

Ensuring that these older platforms remain operational is not as simple as analyzing a new structure to see how it will behave with a slightly different topside configuration. A 25-year-old platform has been pounded by its ocean environment, perhaps survived hurricanes and boat impacts, and certainly seen its share of marine growth. Engineers must simulate cumulative effects such as wave fatigue and marine growth on these structures, as well as point events like collisions and explosions.

It is also worth noting that many oil fields in the mature offshore industry are going to stop producing soon, leading to platform decommissioning – creating new logistical and environmental issues whose resolution is still being worked out but which will present an enormous opportunity for engineering contractors over the next 50 years. Safely taking apart an offshore platform after 25 or 30 years of operation also requires significant analysis.

Working on existing assets is often an area of specialization for smaller firms like Alliance Engineering Consultants (AEC). AEC uses a number of framing analysis packages and SolidWorks (and its built-in analysis capability) for detailed modeling of structures and switches to SACS for larger offshore-specific analyses involving wave loading, tubular connections, or fatigue.

Len Sgherza, lead structural engineer at AEC, says AEC uses SACS because,

We simply couldn't design an offshore structure as efficiently and economically without it.

The complexity of wave load generation, pile/soil *interaction or tubular joint fatigue checks is such that [the calculations] can't be performed by hand, or by general-purpose structural software. Another benefit is that even though volumes of output can be generated, extracting small discrete sets of relevant output from SACS is a lot simpler than most other packages.*

Image courtesy of AEC and ROC Oil Company Ltd

SACS is an important part of marketing our capabilities to clients. We have to be able to demonstrate our ability to solve complex offshore-specific problems in a timely and accurate manner. Showing mastery of specific tools like SACS to support this is an important part of winning the work. Our clients develop a high level of confidence that AEC will be able to deliver on time and with high value-for-money.

AEC recently completed work on a project to add a bi-directional skidding system for a temporary hydraulic work over unit and laydown area to the Cliff Head A platform off the coast of Western Australia. The platform's original topsides operating weight was around 1,200 metric tonnes and the skid addition weighs 315 metric tonnes, which, Mr. Sgherza points out, is

Very substantial relative to the original design capacity. The skidding system enables the hydraulic unit to access all of the wells on the facility. There were also jacking forces of 210 metric tonnes to take into account. We used SACS to determine how best to support the skid to ensure that all parts of the topsides remained within design capacity and to check the jacket and the foundations for the increased loads.

We see SACS as a technical decision support tool to help our engineers make appropriate design decisions, resulting in fit-for-purpose solutions for our clients.

Solving Problems Others Can't

As Mr. Sgherza points out, platforms that are in service are constantly changing. FuryConsult is a specialty offshore structural analysis services firm that often participates in refit projects. Gavin Fury says his business acts as an outsourced resource to other engineering firms.

We enable other firms to bid on projects they ordinarily wouldn't be able to. We do blast analysis, wind loads, pushover, nonlinear collapse ... Most of the time, we're hired to come in and solve a particular problem because other firms can't.

Mr. Fury gained his expertise in SACS while working at EDI, the original developer of SACS. He remembers that,

SACS had a strong foothold as far back as 1992. The major oil companies and fabricators drive the industry in their regions; we were attentive to those companies' needs and had such positive relationships with them that SACS became the de facto standard.

Early on, says Mr. Fury, SACS needed to gain credibility as being accurate. But it's difficult to verify SACS' results against physical testing because, in many cases, it's impossible to actually build and test a structure. However, says Mr. Fury,

Some elements, like joint cans, can be tested. SACS was calibrated against those tests and joint checks are an important part of SACS. In another example, SACS' collapse module was developed using data from pushover tests conducted by the industry; SACS' results were compared to the actual lab test.

But, really, it comes down to track record. SACS has been available since the early 1980s and has a demonstrated track record of accurately analyzing and code checking offshore structures.

Given that numerous platforms in the Gulf of Mexico were destroyed during hurricane Katrina in 2005 and many more were damaged, structural collapse is a major concern of all platform owners and operators – and one that they take pains to simulate**.**

One of FuryConsult's recent projects was in support of a more than 20-year-old platform off the California coast. Mr. Fury explains that the project involved,

Metocean – the physical environment of a platform, wind, waves, current, etc. — and seismic assessments with updated environmental criteria for a new configuration that included additional wells. We had to assess how much reserve capacity each of four possible configurations had. We built the structure in SACS then applied wave heights, current velocity, wave direction, and wind direction. We then did a seismic analysis to determine the reserve capacity for earthquake.

We couldn't have done this in a general-purpose FEA code. We needed a product specially geared to offshore since we were dealing with hydrodynamic and metocean loading. The seismic analysis had to model the special tubular connections we use in offshore.

Another part of FuryConsult's assignments was to assess the impact of adding new equipment to this decades-old operating asset.

We had to model the accumulated fatigue over the 20+ years it's been operating, since adding new equipment would change load characteristics. We had to accumulate fatigue as is, then accumulate for new loading condition, then forecast fatigue with the complete new configuration -- then accumulate all fatigue to ensure that it wasn't greater than fatigue life of the platform.

SACS as a Decision Support Tool

The thousands of platforms operating today require constant monitoring, updating and, eventually, decommissioning and careful deconstruction. For new builds, size and location challenge design and construction contractors, requiring updated methods for platform installation that are safe and also meet their economic targets.

Whether existing or new, all platforms must comply with evolving codes and standards, which are expected to grow more complex in light of increased scrutiny of the offshore industry.

Operators still want the lowest cost, quickest installed platform possible. But today they also look at operating cost over the life of the asset and seek ways to extend that life, if it becomes economically viable. Adding new equipment to the topsides, upgrades for production, safety or habitability, taking into account how marine growth changes weight – all of these require the design team to simulate new use cases, many of which are very complex. In this context, analysis truly does become, as AEC's Mr. Sgherza said, a decision support tool.

By using modern design and simulation technology to create better, safer structures that meet operational needs, the companies profiled here:

1. **Collaborate** effectively with asset owners, design partners, and subcontractors;
2. **Innovate** with consistent, high-fidelity analytical models;
3. **Comply** with changing regulations and operating requirements, and;
4. **Simulate** complex effects such as wave fatigue, collisions, and explosions to design new platforms and extend the life of existing assets.

By using Bentley's offshore engineering products, these firms see business advantages for themselves and better project outcomes for their clients.

These engineering teams used SACS to create realistic simulations that revealed how their designs would perform and confirmed that they would be safely within recommended limits and compliant with relevant codes. Using Bentley Systems' collaboration solutions, all engineers have access to the same model and can work simultaneously on the project, working as an integrated team with partners, owners and classification societies. The visualization tools built into SACS and ProjectWise enable better, clearer communication.

If you don't have all of the analytical skills you need, don't worry. As L.T. Cooper of EDG pointed out,

It's not just the tool; the difference is in knowing the best use of the tool... Anyone can push buttons, put data in a model, and create an output file -- but you need experience to know whether the results make sense. To develop that proficiency, we begin by working on a project alongside an engineer who has that skill and a proven track record. We learn from their knowledge base, advancing through similar projects to develop the skills and experience until we can confidently market those services.

SACS has been proven over the last 40+ years to be accurate, easy to use, and comprehensive. Start learning and build your expertise. That investment can lead to new opportunities for your firm and a stronger, more strategic relationship with your clients.

Bentley SACS:
Purpose-built for Offshore Projects

Bentley Systems' SACS is created specifically for the design, fabrication, installation, operation, and decommissioning of offshore structures. At its simplest, given initial steel member sizes and platform loads, SACS computes the structural deflections, member loads, stresses, utilization ratios, and support reactions of the jacket and topside. It can also check results against international offshore-specific design codes such as API, AISC, NPD, DNV, BS5950, API 2U Bulletins, ACI 318R-89, and the European EC3 steel design and ISO codes.

SACS' specialized analysis and design capabilities for offshore projects include:

- non-linear structural analysis;
- dynamic response analysis due to wind, current, waves, and seismic loads;
- analysis for dropped object and vessel impact effects;
- collapse analysis for re-assessment and severe accidental loadings (such as blast);
- automated check and redesign for compliance with offshore codes;
- spectral and deterministic fatigue calculations.

Virtually all of the major oil companies and many of the world's offshore engineering contractors use SACS for platform design, as do classification societies like the American Bureau of Shipping, Bureau Veritas, China Classification Society, Det Norske Veritas, Germanischer Lloyd, and Lloyd's Register. Platform owners often mandate the use of SACS for the design of jacket structures.

Bentley's recent acquisition of the MOSES marine simulation software extends SACS to floating offshore structures. Naval architects use SACS Marine Enterprise to model and analyze the hull, compartmentation and weight distribution of FPSOs and other structures. As in SACS, a common 3D model flows through concept, initial and detailed design stages to assess stability and strength, predict motions and ensure compliance with relevant criteria.

SACS Marine Enterprise includes modules for hull modeling, stability, motions prediction, and meshing of hull structures:

- Hull modeling using 3D NURB surfaces for any type of hull shape and superstructure;
- Intact and damage stability and strength including compliance with stability criteria;
- Motions prediction using radiation-diffraction techniques for RAOs and accelerations;
- Meshing of stiffened plate structures commonly found in vessel and platform hulls.

Technological excellence is a must. The real power of SACS, however, lies in its ability to help engineers quickly analyze and examine more complex design alternatives and leverage the expertise of global design team members to collaboratively arrive at the optimal solution.

SACS version 5.5 and above is integrated with Bentley's broader structural portfolio. This enables engineering design teams to take advantage of workflows that interoperate between specialized applications, CAD and design review tools for authors, and consumers of a project's structural information. Greater collaboration and data reuse among structural engineers, detailers and fabricators leads to more efficient delivery of high-quality designs and well-coordinated and accurate documentation. This, in turn, leads to higher project productivity, fewer errors and better quality control.

Forthcoming releases will enable users to create i-models from SACS, for even greater collaboration and management of structural data. i-models are containers for the open exchange of infrastructure information that allow SACS users and other project stakeholders to share and interact with project data regardless of authoring application.

By building structural analysis into the overall project workflow, Bentley has taken what was often an asynchronous process and placed it squarely at the heart of offshore design. SACS, MOSES and Bentley's structural-specific software are part of its portfolio of solutions targeted at the oil and gas industry.