USER STORY

# International Salvage Team Brings Home the Kursk Submarine Using a Simulation Developed in Simulink®


Salvage barge towing the Kursk submarine to Murmansk.

## THE CHALLENGE

To develop a safe way to raise and salvage a 10,000-ton nuclear submarine in heavy seas

## THE SOLUTION

Model and simulate the entire salvage system in Simulink and then use the simulation to train operators and determine when and how to perform the salvage operation

## THE RESULTS

- Work completed within tight deadlines
- Fast, economical training for salvage operators
- Ability to act in response to unforeseen conditions

On August 12, 2000, the Russian atomic submarine, Kursk, exploded and sank in the Barents Sea with 118 men, two nuclear reactors, and several nuclear weapons on board.

Two Dutch companies, Mammoet and Smit International, contracted with the Russian government at the end of May 2001 to salvage the Kursk. Just over four months later, on October 8, 2001, the Kursk was raised and towed to Murmansk, where the weaponry and the bodies of the crew were removed.

The raising of the Kursk was the largest operation of its type ever undertaken. Key to its success was a simulation, built using Simulink® by the German engineering company, IgH, that enabled the salvage team to make key decisions on when and how to perform the operation.

## THE CHALLENGE

The Kursk was to be raised using Giant 4, a specially modified deck barge anchored above the submarine and equipped with 26 hoists attached by cables to the submarine's hull.

Among the challenges of the operation were the weight and depth of the water-filled submarine, the turbulent weather conditions, and the risks posed by the atomic reactors and weapons on board. The weight was compounded by the suction effect of the clay in which the Kursk was embedded.

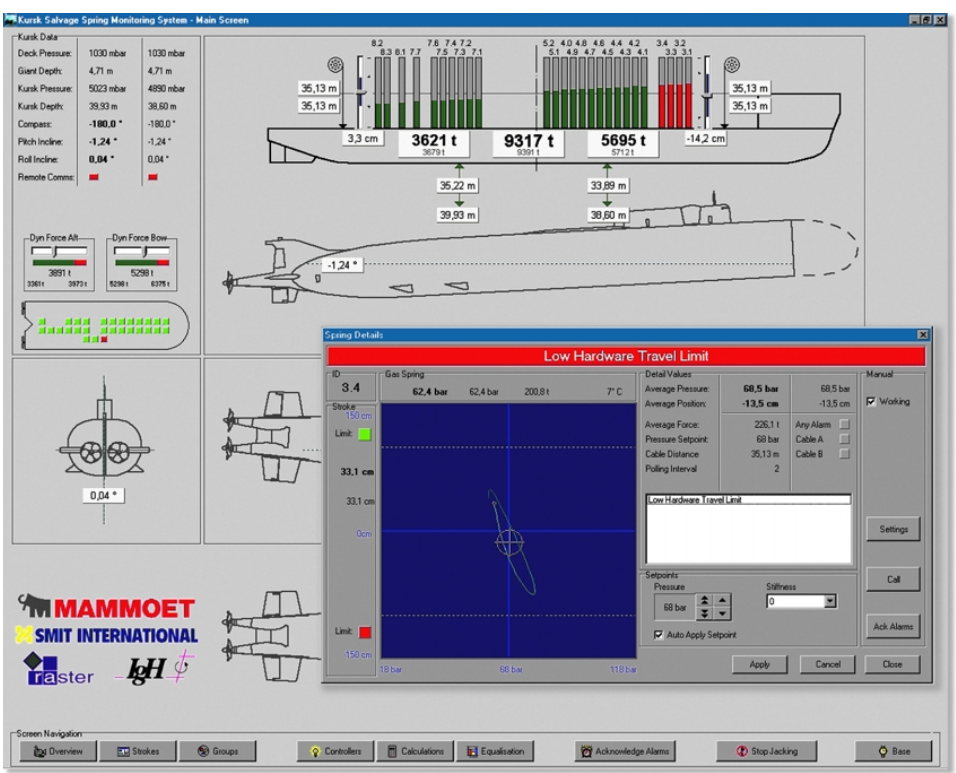
During lifting, it would be necessary to compensate for the effects of wave motion because rough seas could cause the cables connecting the barge to the Kursk to be severed. It would also be critical to gauge the orientation of the submarine accurately. A tilt of more than five degrees could damage the atomic reactors and endanger the salvage crew.

### The Lifting Mechanism

Each hoist had a hydraulic jack mounted on a pneumatic heave compensator. The heave compensators helped maintain tension on the lifting cables and compensated for the effects of wave motion. Each heave compensator had four nitrogen-filled pneumatic cylinders. The compressed gas inside each cylinder provided both lifting and spring-like forces for the heave compensators.

The control variables for the heave compensators were the gas pressure in the cylinders and the stiffness of the gas springs. IgH had to determine the optimal configuration of the gas pressure system and establish operating parameters for the heave compensators.

Without the gas springs properly controlled to prevent a piston from ramming into either end of the cylinder and destroying the heave compensator, the effect of wave motion could




Interface developed in MATLAB and used to monitor and control the entire operation.

Trainees using the Simulink model to simulate the lifting of the Kursk.

sever the lifting cable and cause successive heave compensators to fail and destroy the entire system.

IgH quickly realized that they could not consider the individual compensators in isolation. They would need to understand how the Giant 4, the Kursk, the compensators, and the weather-dependent effects of wave movement worked together.

## THE SOLUTION

IgH decided to use a model-based design approach. Using Simulink, they built a precise mathematical model of the entire salvage system. They could then evaluate options and predict system performance before testing their designs in real time.

The model included equations of movement for the barge and the Kursk, each in six degrees of freedom to account for the hydrodynamic forces generated by waves; a thermodynamic model of the gas pressure system; a mechanical model of the compensators and the hoists; a complete programmable logic controller (PLC) model, including connected sensors and actuators; and an interface to the computers controlling the PLCs. The cable lengths and the signals from two angle-of-tilt sensors were also modeled.

The model had to account for the position of the heave compensators with respect to the lifting cables and the weights to which each cable would be subjected.

### Determining the Parameters

Since the control parameters for the heave compensators were the gas pressure and the stiffness of the gas springs, one major objective of the simulation was to determine these parameters in light of the environmental conditions.

Parameters for the different simulation scenarios were selected through a graphical user interface developed in MATLAB.

The simulation model also provided an interface to the control computers, which contained automatic valves to regulate pressure in the gas cylinders, length sensors mounted on the anchor cables, and other components that controlled the lifting mechanism. Thus, the control computers could be operated alternatively with the simulator to test their functionality.

> *The model-based design approach supported by Simulink ensured an accurate overview of the complex overall system. Without MATLAB and Simulink, it would have been impossible to complete our task in the time available.*
>
> Dr. Wilhelm Hagemeister, IgH

IgH made full use of the open Simulink environment and the ability to integrate C code into the Simulink model. As Dr. Wilhelm Hagemeister, managing director of IgH, comments, "Most software packages for developing technical systems lack certain functions. That means that you have to program the whole solution yourself. In contrast, MATLAB and Simulink provide most of the functions required, and any other problems can be resolved by in-house development in MATLAB or by integrating our own source code."

IgH also used Simulink to develop control software for pressure regulation. This software could automatically calculate the optimum load distribution over the 26 lifting cables and adjust the gas energy in the heave compensators. It could be run with the Simulink model or directly with the PLC and could be fully tested before being used in action.

### An Expanding Role for IgH

By using a model-based design approach, IgH gained an exceptional understanding of the system as a whole. As a result, their role expanded from consultant on one specific technical issue to "scientific lead" for the entire project.

As the company's responsibilities broadened, it became clear that all their new tasks could be accomplished using MATLAB and Simulink.

Shortly before the operation began, Russian experts compared results obtained from their own calculations and physical trials using a modeled submarine with those achieved by the IgH simulation. Based on these extremely close results, the raising of the Kursk could begin and a tragic episode in naval history be brought to a close.

## THE RESULTS

- **Work completed within tight deadlines.** The teams had just four months to complete the operation. "Without MATLAB and Simulink, it would have been impossible to complete our task in time available," says Dr. Hagemeister.
- **Fast, economical training for salvage operators.** The simulation trained the operators of the Giant 4's five control computers, saving time and money and reducing project risk. The trainees simulated the lifting of the Kursk under varying weather conditions and experienced "operating errors" that, in the real situation, could have caused the project to fail.
- **Ability to act in response to unforeseen conditions.** As the deadline approached, it was no longer possible to wait for good weather. The simulation allowed the team to optimize performance criteria and include site data that was essential in deciding when, and under what conditions, the Kursk could be raised.

*To learn more about IgH and the raising of the Kursk, visit* **www.igh-essen.com** *or* **www.kursksalvage.com**

## APPLICATION AREAS

- Modeling and simulation
- Control design

## PRODUCTS USED

- MATLAB
- Simulink

www.mathworks.com



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