Righting the ill-fated liner *Costa Concordia* off the environmentally-sensitive Tuscan coast has challenged engineers to the world’s largest maritime salvage project ever.

**Largest ever maritime salvage challenges engineers**

On 13 January 2012, the 114 000 tonne cruise liner *Costa Concordia* came fatally close to the Italian shore and ripped a 49 m tear in its hull on submerged rocks, killing 32 people. The vessel is more than twice the size of the *Titanic* which, ironically, befall a similar fate a century ago almost to the day, on 15 April 1912.

The urgency to deal with the wreck has since grown steadily – the ship was only partially submerged and created an eye-sore while it was in danger of being damaged further by the ravages of wind and sea.

Two issues, however, prevented the authorities from rushing in with previously used salvage methods which are destructive in nature; it is the largest capsized passenger ship in history, and it ran aground in a protected marine environment.

Explosives were touted as a possibility to dislodge the ship and gigantic chain saws were considered to slice it into smaller, more manageable parts. Both these approaches were, however, rejected and deemed too damaging to the environment and the tourist industry.

Environmental protection was to take top priority. To this end, the marine environment around the wreck and along the whole east coast of the island of Giglio had to be understood clearly before the salvage operation could begin.

A study was conducted to address all components of the marine environment including the chemical and physical characteristics of the water column; the plankton and benthic ecosystems; underwater noise and marine mammals. This acted as the baseline against which the impact of the salvage operation could be assessed, as the seabed had to be cleaned and marine flora replanted after the salvage operation.

To make matters worse, the liner had just departed on a week-long cruise in the Mediterranean when it capsized and its pantries and freezers were packed to capacity with vast quantities of fresh food, dried goods, drinks and other supplies for its 4200 passengers and crew.

The foodstuff on board included 10 800 kg of fish, some 2500 kg of cheese and 5700 l of ice cream while other incidentals included 246 l of paint and 38 l of insecticide. A total of 29 000 m$^3$ of contaminated water was expected to flow out when the ship was righted. Some 2170 tonnes of engine oil and diesel had been extracted from the fuel tanks by a Dutch salvage firm. Absorbent booms were laid on the water surface with nets extending towards the seabed to limit the spread of tainted water once the rotation of the ship would begin.

The Italian government eventually selected a salvage process which would entail two main phases, neither of which had been attempted previously on this scale: a parbuckling process and re-floating and towing away. Parbuckling is the process by which a sunken vessel is righted using rotational leverage.

The salvage operation was awarded to Titan Salvage on 21 April 2012 (with South African Nick Sloane as chief salvage master), in partnership with the Italian firm Micoperi. Titan Salvage is an American-owned company specialising in marine salvage and wreck removal while Micoperi is a marine contractor with a long history in underwater construction and engineering.

The salvage plan involved six stages, the final two of which were yet to be achieved at the time of writing.

**Stabilisation**

Here, the wreck was anchored and...
stabilised to prevent slippage or sinking along the steep seabed. This step was imperative to ensure the safety of the teams working around-the-clock. To achieve this, four submarine anchor blocks were fixed to the seabed between the center of the wreck and the coast.

Installation of hull supports
The building of the false bottom on top of which the wreck’s flat hull would rest after being righted involved two stages. Firstly, grout bags were positioned along and under the damaged edge of the ship and filled with cement (in the spaces between the rock spurs on which the ship foundered). These were designed for easy removal at the culmination of the salvage process.

The second part of the base required more substantial construction as the length of the ship along the deeper, outer edge had to be strengthened and entailed three large and three smaller undersea platforms (see Fig. 1). To support these, piles were drilled into the granite seabed using a closed system so that no waste entered the sea. UK offshore drilling company Frugo Seacore was subcontracted for this delicate, tricky phase of work.

Attachment of portside caissons
After preparing the false bottom, a Micoperi 30 crane was used to place 15 re-floating sponsons or caissons onto the exposed portside of the ship (see Figs. 2 and 3). These were then welded onto her flank. Some 30 vessels and 500 workers representing 21 nationalities and including engineers and divers were active at the site day and night, seven days a week for this stage of the operation.

Parbuckling
The righting of the steel hulk captured the imagination of the world – its sheer scale, potential for failure and its tragic legacy (two bodies had at that stage still to be recovered) all played a part.

Cables attached to strand jacks were tightened to pull the ship seaward slowly. Other cables attached to the starboard turrets were used for balance. This process needed to remain deliberate and measured to avoid the distortion of the ship’s hull (see Fig. 3).

This stage presented the team with the most critical moment of the operation, when the Concordia failed to dislodge from the reef embedded in her starboard side – even after some 6000 tonnes of force was applied.

Then, at 6200 tonnes of pressure, she started moving and was dislodged off the rocks at 6800 tonnes of pressure. In the latter part of this phase, the caissons, which had already been attached, were allowed to fill with water to help pull the portside down. Finally, gravity began to assert itself and pulled the ship toward its corrected, vertical position (see Fig. 5).

Starboard caissons, re-floating
Once the repairs have been made to the damaged starboard side 15 re-floating sponsons will be attached to this flank – to mirror those already installed portside.

Refloating the Concordia will be the penultimate phase in this, the largest maritime salvage in history. The water in the caissons will be emptied by means of a pneumatic system. It is estimated that, with the 30 empty caissons on the ship’s flanks, she will begin to float above her 30 m artificial seabed platform with only an 18 m section remaining submerged.

In April, teams will begin to fit 19 buoyancy tanks to the side of the ship, adding to the eleven already in place. Once the tanks are fitted, the Concordia will be ready to be refloated, weather permitting. The plan is to pump air into and water out of the tanks and the wreck is expected to lift off the seabed over a period of ten days, after which it will be ready to be towed away for dismantling. Twelve companies from China, France, the Netherlands, Norway, Turkey, the UK and Italy are currently tendering for the dismantling project.

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Fig. 2: Positioning the first portside sponson.
Fig. 3: Positioning and installation of two sponsons (‘‘blister tanks’’) on the wreck’s bow.
Fig. 4: Parbuckling: the vessel is righted by means of rotational leverage.
Fig. 5: After parbuckling, the wreck is righted and ready to be refloated.