R/V ‘ Gunnerus’
Performance improvements by the propulsion system retrofit.

One of the vessels investigated in the SIMVAL project, NTNU’s research vessel ‘Gunnerus’, was converted from twin skeg shaft-line propellers with rudders to **P**ermanent **M**agnet driven **AZiM**uth Thrusters (**PMAZM**) in 2015.

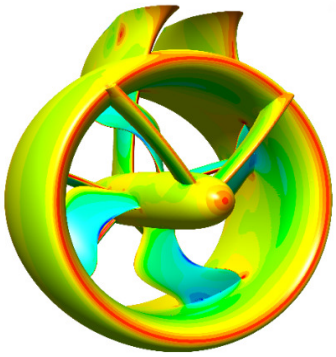
The pictures to the left displays the after body of ‘Gunnerus’ with the propulsion arrangements before and after the retrofit.

‘Gunnerus’ had a diesel-electric machinery in a conventional twin skeg hull with ducted propellers and flap-rudders. Power on each propulsion frequency drive was 500 kW. The same diesel-electric system supplied the propulsion and maneuvering power before and after the conversion.

The original propeller was a 5-bladed fixed pitch type with a diameter of 2.0 meters that rotated in a 19A type duct profile.

The **PMAZM** incorporates a ring propeller in a tailor-made duct with a diameter of 1.9 meter with four blades having a forward skewed shape.

In order to maximize hydrodynamic efficiency, the development of the external shape and all the geometrical features of the **PMAZM** including the propeller were obtained by an iterative design process using RANS CFD.



This process combined hydrodynamics with stress analysis for off-design conditions to obtain the extreme loads and responses to ensure acceptable structural integrity in all operating modes.

An array of five post-swirl stator fins are located in the rear of the duct. The geometry and orientation of the fins are designed in an attempt to regain the energy inherent in the swirling slipstream flow. These fins also provides support of the central shaft bearing and a structural link between the latter and the duct.

Another feature which is worth mentioning, is the twin stays that connect the lower **PMAZM** part to the azimuth disc which is flush mounted into the hull. The design of the twin stay arrangement is such that its overall geometrical shape leads to a mutual flow interaction resulting into almost zero drag.

Before the conversion of ‘Gunnerus’ in 2013, extensive measurements was performed as part of SIMVAL and another project. The corresponding measurement survey was repeated with the **PMAZM** units fitted to ‘Gunnerus’ in 2015 with Marintek being contracted to carry out the measurements and to analyze and compare the results before and after the retrofit. In addition to the maneuvering research, which is the main topic of SIMVAL, several other performance factors were compared.

This included the following tests and analysis:

- **Power-Speed performance**
- **Bollard Pull**
- **Low speed maneuvers including yaw step and thruster agility tests**
- **Hydro acoustic noise emissions and vibration/noise in the interior areas of the vessel.**

DNVGL were responsible for the hydro-acoustic noise and inboard vibration & noise survey with the corresponding analysis and comparative evaluations.

The following table summarize and compare the main results:

Test	Main Results
Power vs. Speed	**4-6 % less power demand at the same speed by the *PMAZM* for the 10-12 knots range. At 8-9 knots, the power demand was comparable for the old propulsion arrangement and the *PMAZM*.**
Bollard Pull	***PMAZM* generated 26 % higher bollard pull close to full power and significant higher pull over the entire power range.**
IMO Maneuvers and acceleration	**The *PMAZM* improved course steadiness and yaw checking ability and reduced time from zero to full speed.**
Low speed/ DP maneuver tests	**Surge- and yaw step tests demonstrated better maneuver response with the *PMAZM* system for the majority of the tests.**
Thruster agility tests	***PMAZM* demonstrated significant improvements of the vessel's ability to move in a certain direction without introducing yaw motion.**
Inboard noise	**For a typical transit condition at 85% MCR, the interior noise levels have been reduced by 2-3 dB(A) in average based on several measurement locations.**
Hydro-acoustic noise emissions	**For a so-called silent research condition at 8 knots, the hydrodynamic and mechanical generated noise contributions have diminished a lot with the PMAZM compared to the previous propulsion system. The switching frequencies from the permanent magnet motors, however, contributed to higher noise levels. The overall noise level reduction of *PMAZM* into the sea are in the range 1-7 db(A) considering all conditions being measured and compared.**