THE DYNA-RIG: EFFICIENT, SAFE AND HIGH-PERFORMANCE SAILING SYSTEM FOR TOMORROW’S SAILING SUPERYACHTS

UNIQUE CHALLENGES: ENGINEERED

Innovative solutions in composites to meet a complex array of design challenges
Magma Structures is a global leader in composite technology, providing world-class structural engineering expertise and flexible manufacturing resources and processes to deliver high-performance solutions for unique and challenging requirements.
INTRODUCING THE DYNARIG

A safe, high-performance sailing system, delivering ease of handling, reliability and efficiency, even when sailing at 18 knots.

The DynaRig addresses key challenges from escalated loads and unprecedented scale, making it especially suitable for two and three masted performance cruising yachts from 60m to 110m in length.
Private sailing yachts are increasing in size year by year. Today’s sailing superyachts are approaching, and in some cases surpassing, the size of the major sailing vessels of the late 18th and early 19th century; huge vessels that carried rigs developed over years that distributed the sail area into reasonable portions enabling them to be sailed efficiently by relatively small crews.

Today, many of the large yachts recently built or currently in build have rigs based on scaling up sailing rigs that owe their origin to dinghies and small sailing vessels. This scaling leads to escalated loads, resulting in today’s vessels carrying highly loaded lines across decks with huge sails that harness potentially lethal loads.

Today’s super-sized sailing yachts need to deliver safe sailing systems, be practical and easy to use whilst guaranteeing performance. Crew numbers should be minimal and the crew must be able to perform all sailing manoeuvres with ease and at short notice. Large loads, flogging sails and moving deck lines should be avoided. The pleasure of a sailing vessel underway, powered up in a seaway, should not be tempered by any concerns of safety and ease of handling by the crew or guests on board.

The DynaRig meets all of these requirements; its sails can be deployed and furled away with considerable ease, the loads are significantly reduced and the masts can rotate to depower the rig and feather the sails quickly. In addition, embedded fibre optic sensors can give a comprehensive load status of all aspects of the rig and provide warnings, historical data and information to optimise the sail sets.

The Maltese Falcon, launched in 2006, has proved that the DynaRig is a highly efficient, reliable, practical, easy to use and, above all, safe solution for meeting the challenges of today’s superyacht.
The DynaRig owes its origins to work carried out in the 60s as a potential fuel saving solution for large commercial vessels. Wilhelm Prölss believed such a system could provide additional propulsion for ships in the face of a looming energy crisis. Despite refinement and some wind tunnel tests, no DynaShips were ever built and the idea went into the archives.

This initial work however provided a starting point in 2000 for the team to design and engineer the working solution for the sailing yacht Maltese Falcon. The high strength, lightweight and fatigue resistant nature of modern advanced materials (carbon fibre) has been the key enabler.

The DynaRig solution can be seen as a modern, evolutionary development of classic, very large sailing vessel rigs. In a limited way, its appearance can be likened to a square-rigger. However, in practice, it is very different.
The masts are free-standing and rotating; the yards are curved and are rigidly connected to the mast via trusses. Sails are set individually, using automated systems, in such a way that when deployed there are no gaps between the sails enabling each spar’s sail plan to work as a single sail.

The mast and all its sails rotate, enabling optimum trimming to take place at the bridge or remote station by simple push button activity.

The sails furl into the mast and the sail is trimmed to the wind by rotating the mast.

The low windage spars fitted with curved yards, the effectively single piece sails and the freedom from rotation limits, all combine to give the rig improved aerodynamic efficiency when compared to a traditional square-rigged vessel.
PERFORMANCE

Extensive wind tunnel testing shows the performance comparison of two and three masted DynaRig vessels against their ketch or schooner rigged counterparts. In general, the polar curves show improved straight line performance in most downwind reaching and running angles. These polar curves are however somewhat theoretical. What really counts are practical aspects such as:

- Ease of setting and recovering sails, enabling the crew to set the sails at every opportunity
- Balanced nature of the individual rigs, resulting in overall balanced rigs (i.e. half sail to windward and half to leeward).

This not only reduces rotation loads and sheet loads, but also makes the vessel easier to steer (with much less weather helm) enabling the vessel to bear away, luff, tack and gybe at any moment
- Ease of manoeuvring; the ability of the Master to carry out any manoeuvres unassisted encourages the use of the sails
- Ease of sail set and recovery; the ability to set sails individually or remove sails in one minute encourages the use of the vessel as a sailing vessel rather than as a power boat
- Safe, fast speeds are easily achievable for ocean sailing
- Sailing off the wind requires no additional costly, specialist sails, handling systems or specialised crew
- At anchor, the mizzen sail can be used for stabilizing the yacht.

HOW DOES THIS AFFECT A TYPICAL DAY SAIL?

On a DynaRig yacht, the Captain would hoist the sails as soon as guests were on board, would sail off the anchor and be sailing to the next destination within six minutes of guests boarding the vessel. Thus enabling the guests’ instant relaxation, no engine noise and the enjoyment of hassle-free, exhilarating sailing to and from each anchorage.
On a typical downwind transatlantic crossing, a DynaRig yacht would outperform a ketch rigged yacht without the need for ever setting additional downwind sails.
EASE OF HANDLING

- Push button sail handling means sailing can be managed by significantly less crew than conventionally rigged yachts.
- All the sails can be deployed or furled away in six minutes.
- The unique sail handling system results in much more precise manoeuvring under sail enabling the sails to be used on more occasions and for much longer periods, including in close quarters of harbours and sailing on and off moorings.
- Having multiple sails means that they can be progressively furled into the mast in a controlled manner and without the need for highly loaded sheets or captive winches.
- Rotating rigs mean that the vessel does not need to be head to wind to hoist or reef the sails. The masts can also rotate to depower the rig and feather the sails.
- The sail load in each sail is low.

The DynaRig enables large sailing superyachts to leave anchorages under sail and to cross oceans without having to start the engine.
# SAILING COMPARISON

## GYBING THE BOAT

<table>
<thead>
<tr>
<th>70M KETCH - 30 MIN</th>
<th>70M DYNAIRG - 2 MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep all guests out of the way</td>
<td>Turn rig through 60 degrees while turning to new course</td>
</tr>
<tr>
<td>Drop mizzen stayail, remove stay</td>
<td>GYBE</td>
</tr>
<tr>
<td>Pull in mainsheet</td>
<td>Guests can circulate anywhere on deck</td>
</tr>
<tr>
<td>Pull in mizzen sheet</td>
<td></td>
</tr>
<tr>
<td>Pull in leeward main runners</td>
<td></td>
</tr>
<tr>
<td>Pull in mizzen runners</td>
<td></td>
</tr>
<tr>
<td>Fly asymmetric and pull in windward sheet</td>
<td></td>
</tr>
<tr>
<td>GYBE</td>
<td></td>
</tr>
<tr>
<td>Ease leeward runners</td>
<td></td>
</tr>
<tr>
<td>Pull in asymmetric sheet</td>
<td></td>
</tr>
<tr>
<td>Set mizzen stayail</td>
<td></td>
</tr>
<tr>
<td>Host mizzen stayail</td>
<td></td>
</tr>
<tr>
<td>Guests must not circulate near highly loaded lines, winches, the foredeck or other sail movement areas</td>
<td></td>
</tr>
</tbody>
</table>

## TACKING THE BOAT

<table>
<thead>
<tr>
<th>70M KETCH - 5 MIN</th>
<th>70M DYNARIG - 5 MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep all guests out of the way</td>
<td>Turn rig through 120 degrees while turning to new course</td>
</tr>
<tr>
<td>Take up leeward runners</td>
<td>GACK</td>
</tr>
<tr>
<td>Furl headail or remove babystay</td>
<td>Guests can circulate anywhere on deck</td>
</tr>
<tr>
<td>Pull in main and mizzen</td>
<td></td>
</tr>
<tr>
<td>TACK</td>
<td></td>
</tr>
<tr>
<td>Tension new main and mizzen runners</td>
<td></td>
</tr>
<tr>
<td>Ease leeward main and mizzen runners</td>
<td></td>
</tr>
<tr>
<td>Set headsail and sheet in</td>
<td></td>
</tr>
<tr>
<td>Trim main and mizzen</td>
<td></td>
</tr>
<tr>
<td>Guests must not circulate near highly loaded lines, winches, the foredeck or other sail movement areas</td>
<td></td>
</tr>
</tbody>
</table>

## HOISTING SAIL

### 70M KETCH - 30 MIN
- Keep all guests out of the way
- Get sea room
- Turn head to wind and hold head to wind and sea
- Throttle back engine
- Ease leeward main runner and take forwards
- Ease mainsheet
- Hoist main (main flogs)
- Ease leeward mizzen runner and take forwards
- Ease mizzen sheet
- Bear away easing sheets
- Unfurl headail(s)
- Pull in headail sheets
- Guests must not circulate near highly loaded lines, winches, the foredeck or other sail movement areas

### 70M DYNARIG - 6 MIN
- Immediate bear away and gybe
- Set sequence on touch screen
- Set sails
- Guests can circulate anywhere on deck

## DROPPING SAIL

### 70M KETCH - 25 MIN
- Keep all guests out of the way
- Get sea room
- Start and engage engines
- Furl headail(s)
- Turn head to wind and hold head to wind and sea
- Pull in mainsheet
- Tighten leeward runners
- Furl mainail
- Furl mizen
- Guests must not circulate near highly loaded lines, winches, the foredeck or other sail movement areas

### 70M DYNARIG - 6 MIN
- Immediate bear away and gybe
- Set sequence on touch screen
- Set sails
- Guests can circulate anywhere on deck

## MOB / EMERGENCY

### 70M KETCH - 20 MIN
- Keep all guests out of the way
- Drop any downwind sails
- Get sea room
- Start and engage engines
- Furl headail(s)
- Turn head to wind and hold head to wind and sea
- Pull in mainsheet
- Tighten leeward runners
- Deploy rescue boat and crew
- Guests must not circulate near highly loaded lines, winches, the foredeck or other sail movement areas

### 70M DYNARIG - 3 MIN
- Immediate bear away and gybe
- Luff and stop boat
- Deploy rescue boat and crew
- Guests can circulate anywhere on deck
SAFETY

- Free-standing rigs are intrinsically safer and more reliable than conventional rigs where failure, through fatigue or overload of any single rigging element, or termination can lead to catastrophic mast failure

- The absence of highly loaded lines or flogging sails on deck mean that crew and guests can move safely around the decks at all times

- The absence of standing rigging and sheets result in a much cleaner and uncluttered deck plan

- The automated sail handling systems mean that no crew have to climb the rig to set or furl the sails.

- Gybing is safe and easy with a DynaRig

- Load sensors can communicate the status of all aspects of the rig and provide safety warnings

- The DynaRig strength has been determined based on a theoretical capability to carry full sail plan in wind speeds of 50 to 60 knots; traditional rigs are not able to come even close to this

- The DynaRig offers a backup to the operating system; either the handheld controls or the CPU control panel can furl the sails in an emergency.

MAINTENANCE

- The DynaRig offers significantly reduced wear and tear than a conventional rig, with no standing or running rigging to maintain and replace

- The 15 or so balanced sails take the load of the boat, rather than 2 or 3 in a conventional rig. Each sail therefore is lightly loaded, has no rigging to chafe on, and is held by tracks top and bottom so there is no possibility of flogging. This results in significantly reduced wear and an exceptionally longer sail life

- The reduced loads mean that the sails can be built out of robust, simple Dacron-type materials and will last significantly longer in terms of shape and ultimate life span than conventional rig sails

- The free-standing rig has only two attachment points, the upper and lower bearing; both easily accessible for regular inspection, servicing and maintenance

- Other than the built inouthauls and man aloft hoist (gant) lines, which need occasional servicing, there is no running rigging that, on a conventional rig, would require constant maintenance and replacement.
PROVEN DESIGN

- Maltese Falcon has been successfully cruising and racing since 2006, covering well over 100,000 miles with the large majority of these under sail. The yacht has executed more than 11,000 individual sail sets, through storms, gales and calms, and raced in many superyacht events and transatlantic regattas without any failures.

- The rigs on Maltese Falcon have an embedded optical fibre based system for monitoring loads and providing a comprehensive load history of the rig.

- This fibre optic monitoring data is invaluable to show that the rigs have never been overloaded and provide a wealth of information, ranging from details of specific incidents to long-term data analysis.

- The data also provides evidenced verification of the design concepts of the DynaRig.

- The fibre optic monitoring data gives the crew complete confidence when sailing and limits any potential safety risks.

“The DynaRig is the safest, easiest, most trouble-free rig I have ever utilized to power a sailing vessel. In the Trans-Atlantic race the DynaRig allowed us to go where we wanted, when we wanted. No big decision of getting the other watch up to tack, gybe or reef.”

Robbie Doyle, Sailmaker
The DynaRig is a state-of-the-art, modern, high-tech rig, relying on the use of cutting edge, high-strength materials, currently widely used in advanced aerospace, race cars and high-performance racing yachts.
SUMMARY OF THE KEY COMPONENTS OF A KETCH AND DYNARIG YACHT

KETCH RIG COMPONENTS
- Masts (main and mizzen, carbon fibre)
- Boom (main and mizzen, carbon fibre)
- Mast heel fittings, hydraulic jack system. Including load sensing mast compression
- Mast collars
- Spreaders (approx 8 sets, carbon fibre)
- Structural reinforcing in both hull and deck to take the high rig loads
- Standing rigging set, shrouds, fore stays, back stays, runners including load sensing gins (carbon and aramid fibre)
- Running rigging: Halyards (approx 5), man hoist, sheets
- Boom vangs (hydraulic cylinder)
- Boom furling systems (mandrel, hydraulic or electric)
- Foresail furling system
- Deck winches (mast winches, 4 per mast, primaries MPS sheet, mizzen staysail sheet)
- Reef winches (main sheet, jib sheet, genoa sheet, mizzen sheet)
- Deck foundations for winches
- Deck lockers for reef winches
- Hydraulic lines to all winches
- Mizen staysail furling system
- MPS system
- Sails (Carbon, 3DI)
- Mast track system & cars
- Sail battens
- Storage and access hatches for downwind sails and their handling equipment
- Complex sail handling control panel

DYNARIG COMPONENTS
- Masts (Carbon fibre, fibre optic load sensing)
- Yards (6 per mast, carbon fibre)
- Mandrel (electrically driven)
- Outhaul winches (4 per sail, electrically driven)
- Tensioners (4 per sail)
- Sails (Dacron, includingouthauls and luff tapes)
- Standing rigging: yard cross braces (Aramid fibre)
- Deck bearing
- Lower bearing and mast rotation unit (hydraulically driven)
- Mast winches (4 per mast, deck mounted for man/sail hoist)
- CPU control panel and handheld control boxes

COST BENEFITS OF THE DYNARIG
The high-strength materials used can be more expensive than traditional materials but the benefits are not necessarily only in performance but also in longevity. Combining these aspects as well as the reduction in running costs can make for an interesting cost comparison for traditionally rigged versus DynaRig yachts and can make running a DynaRig yacht more cost effective.
GREEN BENEFITS

A fuel consumption reduction of approximately 300 tonnes can be achieved based on the operational profile presented on this page.

This profile shows a typical fuel consumption calculation comparison between a motor yacht and a sailing yacht based on the following criteria:

- 1,100 GT yacht
- 6,000 hours use per year (250 days)
- 31,000 nautical miles per year
DynaRig yachts consume much less fuel over their lifetime due to sailing much more than comparable ketch, schooner or sloop rig yachts.
THE DEVELOPMENT OF THE DYNARIG FOR THE SUPERYACHT MALTESE FALCON
In 2000, Dykstra Naval Architects were one of a number of naval architects asked to come up with a proposal for a Perini Navi 87m hull for a fast and safe ocean passage making rig.

Several rig options were proposed, including a schooner rig, a traditional and modernised barque rig and the DynaRig. The owner quickly selected the DynaRig as he was trying to revive the ‘Clipper’ sailing concept of safe, fast sailing speeds in ocean conditions, together with single person button-controlled sail handling and good windward performance.

The rig for the yacht was developed, tested and built by a specialist engineering team with years of successful large yacht and rig experience, under the personal guidance of the yacht’s first visionary owner, Tom Perkins.

The team spent over 90,000 design and development hours on the rig, the fittings, the sails and the sailing systems.

The fully automated, precise control of the setting and recovering sails using this system had never been done successfully before.
“On some of the big schooners, it’s a real trial to get all the sails up and go for a sail, whereas on the Maltese Falcon, it only takes one guy to press the buttons and you’re off.”

Andy Claughton, Naval Architect
The Maltese Falcon was launched in 2006. The yacht has 3 free-standing, rotating masts approximately 58m in height which hoist a total sail area of 2400m².

Since its launch, the vessel has cruised and raced extensively in the Pacific, Caribbean, Atlantic and Mediterranean, covering well over 100,000 miles; a large majority under sail. The yacht has executed more than 11,000 individual sail sets, through storms, gales and calms and raced in many superyacht events and transatlantic regattas.

“When the free-standing, carbon spars on Maltese Falcon stand 200 ft tall and support nearly the same bending moment as the wings on 767. Each of three carries more sail area than the entire wing on a 747 or A380. The wall thickness at the deck level is over two inches, which exceeds that of the 787 wing, which is the thickest, most highly loaded part of our Dreamliner. There is a display in the wheelhouse on Maltese Falcon based on 96 fiber optic sensors that tell the crew what percent of design load they are at when sailing. This is more advanced than any aerospace application for composite structure.”

Boeing Aircraft Corporation
William Roeseler, Technical Fellow Boeing
(Composites and Structural Engineering)
Advisory Board AIAA, MIT
The system has proved so reliable and easy to sail that Maltese Falcon is considered to be one of the greenest superyachts afloat, having the capability to rely, in the main, on sailing performance, therefore minimising fuel consumption.
Remarkably, for a 1200 tonne, 89m LOA vessel, Maltese Falcon has won several regattas including wins in three consecutive Perini Navi Cups in conditions ranging from flat calm to 35 knots plus. In each of these regattas, the entire sailing operation was carried by a crew of just three; helmsman, trimmer and tactician.

The unique characteristics of her rig enable Maltese Falcon to be sailed easily by just a few crew, as well as being able to manoeuvre confidently in confined waters, sail on and off her mooring and set sails for even very short trips; something other sailing superyachts are not able to achieve.

“We just dropped the anchor in the harbour of St Barth’s after almost exactly 16 days of sailing from Gibraltar. We sailed every inch and remained totally ‘green’, but at times it was quite difficult to keep our speed. There were no trade winds; the hurricanes on the American East Coast totally disrupted the Atlantic wind. We had to find our way through some baffling low troughs drifting across our course.

We sailed every point on our polars and at times our speed was only three knots, but we always kept going; our top speed (briefly) was 18 knots, a fraction of the Falcon’s potential. Finally, we finished with a good breeze and made a great show of sailing around this island among a racing fleet to the final spot to drop the hook in bright sunshine.

We averaged 10.25 knots for the passage of 3,900 nautical miles and burned only 11,000 litres of fuel for our generators. This is about 5 hours worth of fuel for a big motor yacht going at a similar speed! The Maltese Falcon is unquestionably the greenest yacht ever created and the sails, now with some 100,000 miles on their clock, still look brand new. There is no wear and tear or chafe on this rig, unlike all other sailing yachts. It is not a modest thing to say, but my creation remains an unrivaled masterpiece!”

Tom Perkins
The original owner and builder of Maltese Falcon
If you would like to talk to Magma Structures about your specific requirements, please contact us for an informal discussion.

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