

Reimagining pod thrusters with the Helix Pod Cartridge

Cutting pod drive drag by 70%





Introduction

When it comes to propulsion, small- to medium-sized vessels have barely changed in the past century.

Today, as it was in the early 20th century, anyone who is operating a sub-megawatt (MW) craft usually picks one of two options: either an outboard motor, or an inboard motor connected to a static propeller shaft. This fact is so embedded in the DNA of marine that many haven't even asked themselves if there *could* be an alternative.

But we *should* consider alternatives to the status quo. Currently, the two “standard” options we choose to propel smaller vessels come with some major trade-offs. Whether it be noise and vibration, space reserved for engine compartments, exhaust fumes, or trip hazards, sub-MW vessels make some major concessions for their propulsion systems. We've spent so much time living with these trade-offs that we take them as a given, but should we?

In the mid-2000s, we all had simple expectations about what mobile phones should do: handle texts and calls. Then the iPhone came out. And within a few years, we had a completely different set of expectations for our handsets. Thanks to rapidly growing computing power, touchscreens, and wi-fi, we realised phones could be so much more.

I think something similar is going to happen to marine, and soon. Whether it be yachting, fishing, servicing a wind turbine, or ferrying passengers, we sacrifice a lot of space and comfort in small- and medium-sized ships in accommodating outboard

motors or inboard engines. And just as modern computing power caused us to revisit how we saw phones, electrification allows us to revisit our expectations for boats and ships.

This white paper is about electric pod drives, and how our team has developed a universal building block to allow these systems to disrupt the world of sub-MW vessels. The tangible benefits of this opportunity are self-evident – a major opportunity to reduce maintenance costs, unlock more efficient hull designs, and improve marine energy efficiency.

But, I'm most excited by something entirely different: the opportunity that this gives us to rethink many of our basic expectations about the ships and boats that we all depend upon. By using external pods for propulsion the space currently devoted to loud outboards, fuel lines, prop shafts, and engine rooms can be freed up. We can make service vessels more productive for workers, help trawlers to be more comfortable and productive for fisherman, or use newly liberated space on yachts to find entirely new ways to relax out at sea.

The Helix team has worked at the forefront of electric powertrains for decades, and we have seen first-hand how electrification can transform mobility experiences and expectations. With the Helix Pod Cartridge, we believe marine is now closer than ever to its own 'iPhone Moment'.



James Edwards
Marine Chief Engineer, Helix

The opportunity of electric pod drives

Debuting in the 1990s, electric pod drives are a category of propulsors which consist of a motor housed within a horizontally gimballed, subsurface 'pod' which drives a vessel's propeller.¹

The pod drive architecture offers some major advantages, particularly with regards to thrust efficiency. Through being able to rotate horizontally and subject to real-time control, pod thrusters can apply thrust in the most efficient direction at any given moment. Further, by eliminating the need for rudders and control surfaces, pod drives also reduce drag on a vessel.

What differentiates an electric pod drive from a traditional azimuth thruster is the integration of its power source. By incorporating the motor within the subsurface unit, the pod requires no in-hull drive unit or prop-shafts – just an electrical connection to the vessel's battery. This frees up considerable space, which in turn can be used to improve the comfort of passengers and crew, increase a vessel's cargo potential, or deploy entirely new capabilities on the ship.

Additionally, electric pod drives also pass on the benefits of marine electrification: virtually no fuel and maintenance burden from idling, a dramatic reduction in moving parts, an improved noise and vibration profile, and the elimination of fumes.



Discussion: How electric pod drives developed from traditional azimuth thrusters

An azimuth thruster refers to any marine propulsion system that mounts a propeller on a horizontally gimballed pod below a vessel's hull. By being able to rotate 360 degrees horizontally, they eliminate the need for rudders and bow thrusters while also improving vessel control and efficiency.

Today's azimuth thrusters can be traced back to designs developed in the 1870s.² Despite their proven advantages, however, the twentieth century did not see azimuth thrusters displace the dominance of fixed propellers, bow thrusters, outboard motors, or rudders.

This was because azimuth thrusters brought about their own set of challenges. They demanded that a power source be situated directly above the propeller (an "L-drive") or a connected to the propeller through a complex transmission system (a "Z-drive").

Compared to a traditional propeller, bow thruster, or outboard motor, these systems consumed space on-deck or within the hull to house engines or transmission systems and often entailed noisier environments for passengers and crew. Azimuth thrusters also brought about new complexities by introducing a range of new parts and interfaces – particularly in the case of Z-drive transmissions.

As a result, the market for azimuth thrusters was largely restricted to vessels where precise control was required, mostly because they spent a disproportionate amount of time operating in ports, coastlines, or near offshore installations. Examples of such vessels include tugs, offshore supply vessels, construction vessels, ferries, and cruise ships.

Beyond their inherent advantages, pod drives also serve as an enabling technology for the efficient, low-drag hull designs that are set to power the next generation of passenger vessels: hydrofoils. By using lift force to raise most of a vessel's hull above the waterline at high speeds, hydrofoils can cut the energy needed to propel a vessel by up to 80%.³

To achieve these efficiency gains, however, the foils which a hull rests upon will need to be as thin as possible while also hosting a propulsor. This makes pod drives an ideal solution, since they only need an electrical connection to the main hydrofoil hull – by contrast, traditional inboard or outboard motors would require bulky driveline connections or mountings that will increase strut thickness and drag.

Along with hydrofoils for passenger craft, electric pod drives also serve as an ideal upgrade and retrofit opportunity for many commercial craft that currently rely on traditional azimuth thrusters, inboard motors, or outboard motors. Good examples of these applications are fishing boats, service vessels, tugs, and supply vessels – these ships conduct regular, routine trips which often require precision manoeuvring. For these vessels, pod drives allow electrification with maximum range, while minimising maintenance burdens, and improving the working environment and productivity of their crews.

The challenges facing electric pod drives

Based on the above, electric pod drives seem an incredibly intuitive choice for a range of recreational, commercial, and passenger marine applications. This begs the question: why aren't electric pod drives already ubiquitous?

The answer to this lies in the topic of motor **power density**: the amount of power a motor can output per unit of mass. Until very recently, the power densities of available motors presented a major bottleneck to deploying electric pod drives for most vessels. That's because unlike inboard or outboard motors, the power density of an electric motor determines the drag force experienced by a pod drive.

To see this in action, we can examine the rapid growth in motor power density in recent decades. In 2004, one of the most powerful motors available to the public was the system powering the Toyota Prius, with a power density of 1.1kW/kg.⁴ For a small passenger ferry requiring a 100kW thruster, this power density would mean the motor would weigh 90.9kg.

Approximating this 100kW motor as having the density of iron (7.87g per cm³), that means it would have had a volume of around 11,600cm³. If we were to further approximate this motor as a cube, that means the 'face' of the motor that determines a pod drive's dimensions – and thus the amount of drag the system experiences – would have a surface area of 512cm².

In less than twenty years, motor power densities have grown dramatically. In 2022, the Lucid Air's motor achieved a power density of 16.1kW/kg.⁴ This means a 100kW motor of this density would weigh just 6.2kg, have a volume of 789cm³, and a frontal cubic surface area of only 85.4cm².

Year	Power density	Mass of 100kW motor	Volume of 100kW motor*	Front surface area of 100kW motor**
2004	1.1kW/kg	90.9kg	11,600cm ³	512cm ²
2022	16.1kW/kg	6.2kg	789cm ³	85.4cm ²

* Assuming 100% iron composition

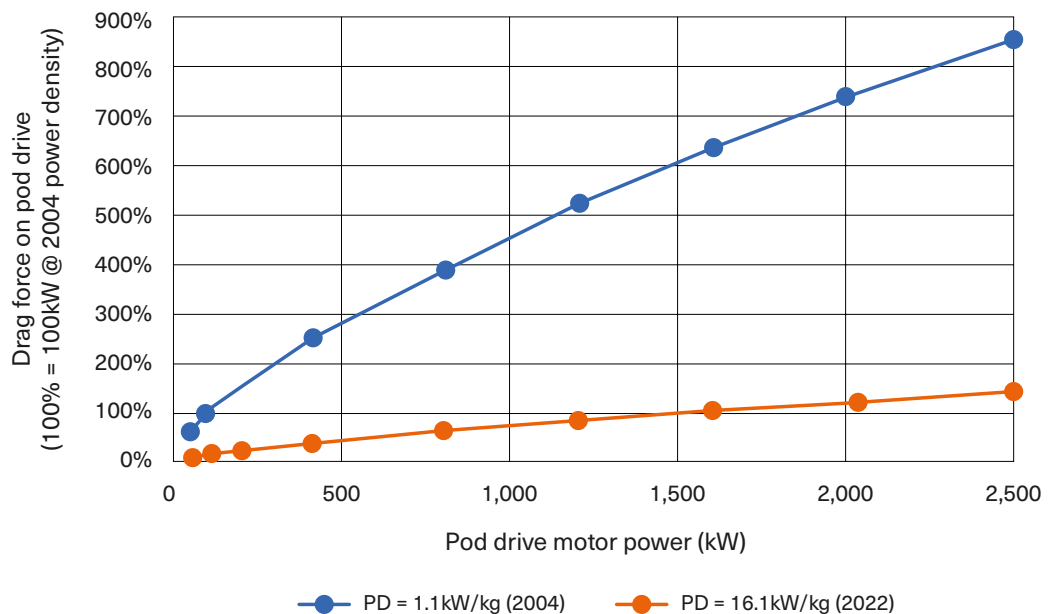
** Assuming motor is a cube



Drag is directly proportional to an object's cross-sectional area. In our simple model, that means a 100kW pod drive powered by a 2022 Lucid Air motor produces just 16.7% of the drag of the 2004 Prius motor: in just 18 years, power density gains have slashed the drag force accompanying pod drives by over 80%.

We can extrapolate this relationship out to a range of pod drives of various power outputs, as shown in the chart below.

Pod drive drag force vs power



Discussion: Why pod drives have stayed megawatt-scale

Aside from some boutique solutions that have begun to emerge in recent years, electric pod drives have largely remained synonymous with ABB, the technology's original developer. From the outset, ABB has focused exclusively on pod drives for megawatt-scale vessels – from the technology's roots as a solution to help Finnish icebreakers navigate narrow ice channels and merchant shipping.⁵

Despite the technology existing for well over 35 years, pod drives have not been marketed considerably to sub megawatt-scale vessels: a category that covers most recreational vessels, along with small-to-medium-sized commercial vessels.

The reason for this can be shown in the rough example modelling above: until recently, motor power densities were too low. This meant that pods would become a significant source of drag, eliminating the efficiency gains they might have otherwise achieved.

Taking the above chart's 2004 power densities, we can see this in action – the smaller the motor, the greater the proportional drag that it adds to a vessel:

- A 50kW system experiences 63% of the drag for 50% of the power
- A 200kW system experiences 159% of the drag for 200% of the power
- A 400kW system experiences 252% of the drag for 400% of the power

By contrast, we can see that that megawatt-scale systems on 2004-era power densities are able to 'brute force' their way through drag – growth in power outpaces increase in drag force. A 2MW system, for example, experiences 737% of the drag for 2000% of the power of a 100kW unit.

By contrast, by slashing drag force by over 80%, 2022-era power densities render drag trivial at both the kilowatt and megawatt scales:

- A 50kW system experiences 11% of the drag for 50% of the power
- A 200kW system experiences 17% of the drag for 200% of the power
- A 400kW system experiences 42% of the drag for 400% of the power

In short, until now there have been few motors with high enough power densities to enable sub-megawatt pods that offer low-drag, long-range propulsion.

But even beyond raw power density, minimising drag and maximising efficiency in a pod thruster requires delivering it with a well-integrated inverter and transmission system. Wasted mass or poor matching in an inverter or gearbox can easily wipe out the efficiencies of motor power density.



Deep system integration in an electric propulsion unit (EPU) – one that brings together a motor, inverter, and transmission – is key to ensuring any motor fully delivers on its power density. However, with marine still early in its electrification journey, there are few full-system experts in electric powertrain architecture currently in the market providing such integrated EPUs needed for sub-megawatt pod drives.

This ties into a final challenge facing the rollout of electric pod drives in marine: there are few systems that are designed to be flexibly adapted to reflect the diverse needs of marine system vendors, shipbuilders, operators, and applications. For example, a pod for a high-speed recreational hydrofoiling vessel will be radically different to one for a tugboat – they may require different body shapes, different sizes or speeds in their propellers, steering systems, and system control software.

However, this diversity of demand isn't reflected in the market. Rather, most pods are sold as "one-size-fits-all" solutions that are designed around specific propellers, body shapes, and EPUs. There is currently no standalone EPU in the market that is designed to support the diverse range of pod drive applications.

The Helix Pod Cartridge

Based in the UK, Helix is a full-service supplier of premium electric powertrains that produces the planet's most power-dense radial flux motors, inverters, and EPU's. The continuous power density of our systems – critical to marine applications – is unmatched, due to our world-class expertise around powertrain efficiency, thermal management, precision manufacturing, and EPU system integration.

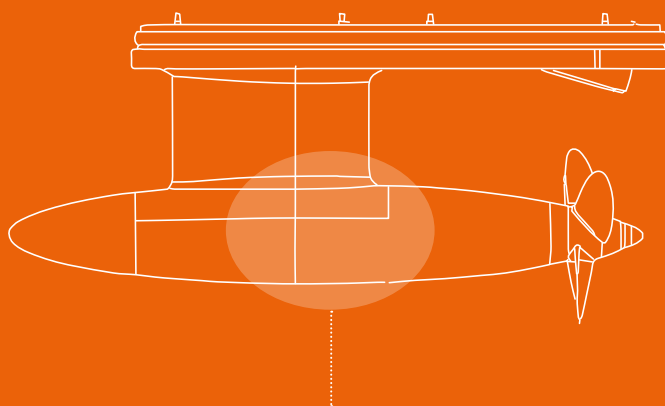
Leveraging our decades of experience and technology, the Helix team has developed an all-new system to address the three challenges to marine's adoption of electric pod drives: motor and inverter power density, EPU integration, and modularity.

The result is the **Helix Pod Cartridge**, an EPU designed for ease of installation and configuration to meet a range of market requirements. The Helix Pod Cartridge packages a Helix motor with a reduction gear system from Xtrac, the world's leading provider of high-performance transmissions.

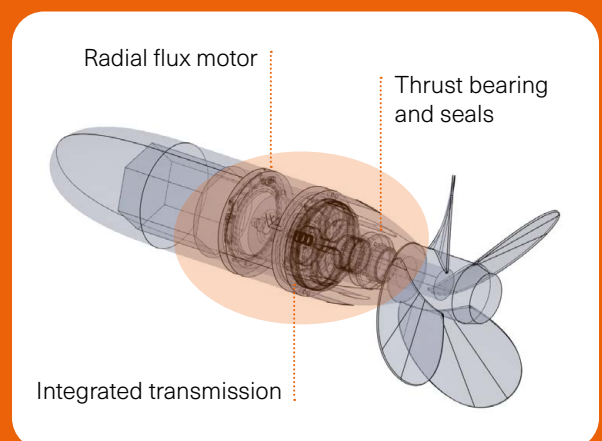
Together, these are integrated into a cylindrical package complete with thrust bearings and seals, CAN bus interfaces, and a Helix inverter housed within the hull (or an optional fully integrated inverter). From there, manufacturers employing the Helix Pod Cartridge can use the system as a foundation for the remainder of their pod drive offerings.

This “drop-in” design enables the Helix Pod Cartridge to be used in a variety of configurations:

- Integrated into pods and azimuth thrusters as the drive unit by third party powertrain suppliers
- Integrated into the hydrofoils of foiling vessels by naval architects and boat yards
- Integrated into the hulls of conventional vessels for new and retrofit applications



Helix Pod Cartridge



Initially intended to power a new generation of 100-1,000kW pod drives, the Helix Pod Cartridge aims to democratise electric pod drives for a range of sub-megawatt marine applications – spanning recreational, passenger, and commercial vessels.

The initial range of Helix Pod Cartridges will use Helix's **SPC177** platform as the motor. The SPC177 is one of Helix's most power-dense series production motors: despite weighing just 31kg, it can continuously output up to 300kW of shaft power.

The Helix Pod Cartridge integrates the SPC177 with a high ratio epicyclic transmission. This allows the system to comfortably operate across a vast range of applications, supporting propeller speeds from 1,000rpm to 2,750rpm.

The Helix Pod Cartridge is completed by Helix's **CTI-4** silicon carbide inverter. Installed in-hull or within a support strut, the CTI-4 controls the Pod Cartridge's motor with an output continuous phase current of 435 ARMS while weighing just 10.5kg.

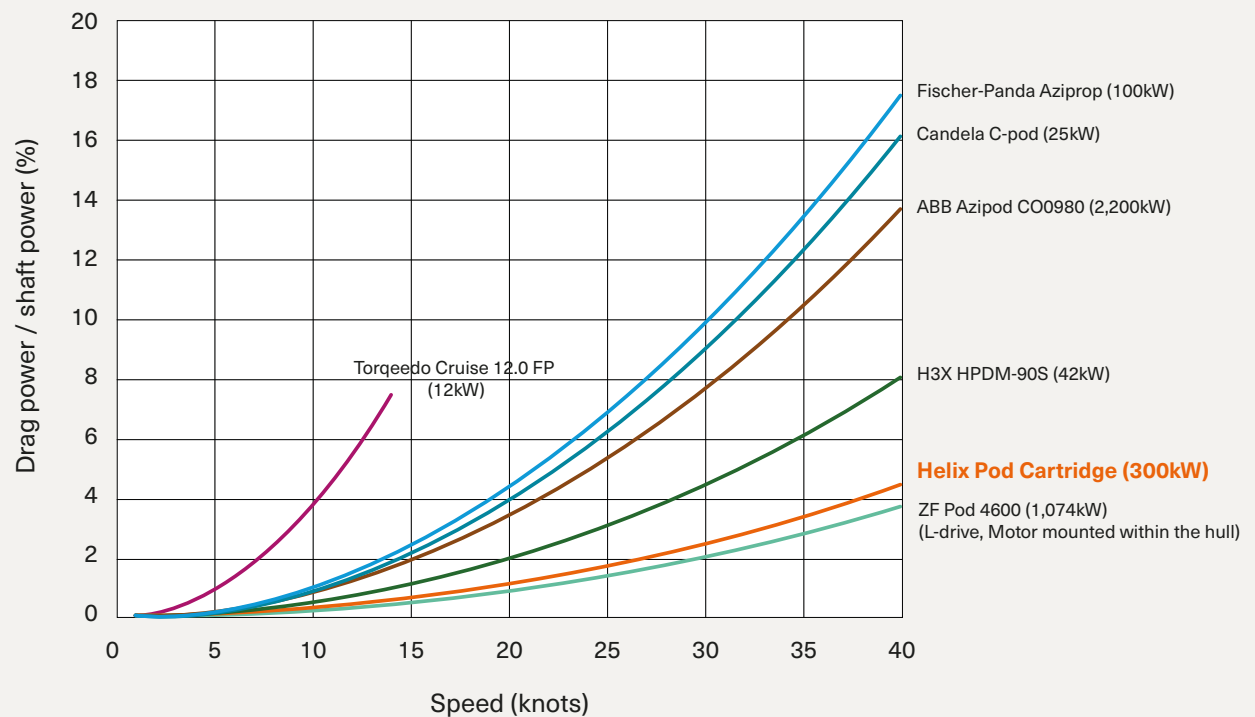
By varying the length and torque of the SPC177 motor, the Helix Pod Cartridge will initially be available in 100kW, 200kW, and 300kW variants, with low- and high-torque configurations available at both 100kW and 200kW.

Model	100kW Low-torque	100kW High-torque	200kW Low-torque	200kW High-torque	300kW
Helix motor model	SPC177-40	SPC177-80	SPC177-80	SPC177-160	SPC177-160
Speed at peak power (RPM)	2,750	1,000-2,500	2,750	1,000-2,750	1,850-2,300
Max shaft torque (Nm)	350	950	950	1,910	1,910
Pod diameter (mm)	217	217	217	217	217
Motor (kg)	14	20	20	31	31
Transmission (kg)	10	10	10	10	10
Total mass (kg)	46.5	52.5	52.5	63.5	63.5

Mass excludes support leg, turntable, and propeller(s) where appropriate. All motors assume radial cooling to seawater through hull.

To understand the performance advantage of the Helix Pod Cartridge, we can calculate its efficiency by looking at the share of its total shaft power lost to drag. Using publicly available data and assuming good hydrodynamic design, we can compare the Helix Pod Cartridge with other azimuth thrusters and pod drive systems currently available on the market.

Drag power as a percentage of total power



Through its world-class power density and integrated transmission, we can see the Helix Pod Cartridge achieves less than 30% of the drag of any other “true” pod drive solution – a system that houses an electric motor in the thruster’s housing. In fact, the Helix Pod Cartridge’s efficiency places it on par with market-leading L-drive azimuth thrusters that house motors in-hull – a category that until now has never been matched in efficiency by a pod drive.

Along with powering pod drive solutions for new vessels, the versatility of this range means the Helix Pod Cartridge can help solutions providers looking to offer retrofit pod drive solutions to mariners.

Altogether, the Helix Pod Cartridge is ideally placed to finally enable pod drives – and all they enable – to break out to small- and medium-sized commercial and passenger vessels looking to tap this ultra-efficient propulsion option.

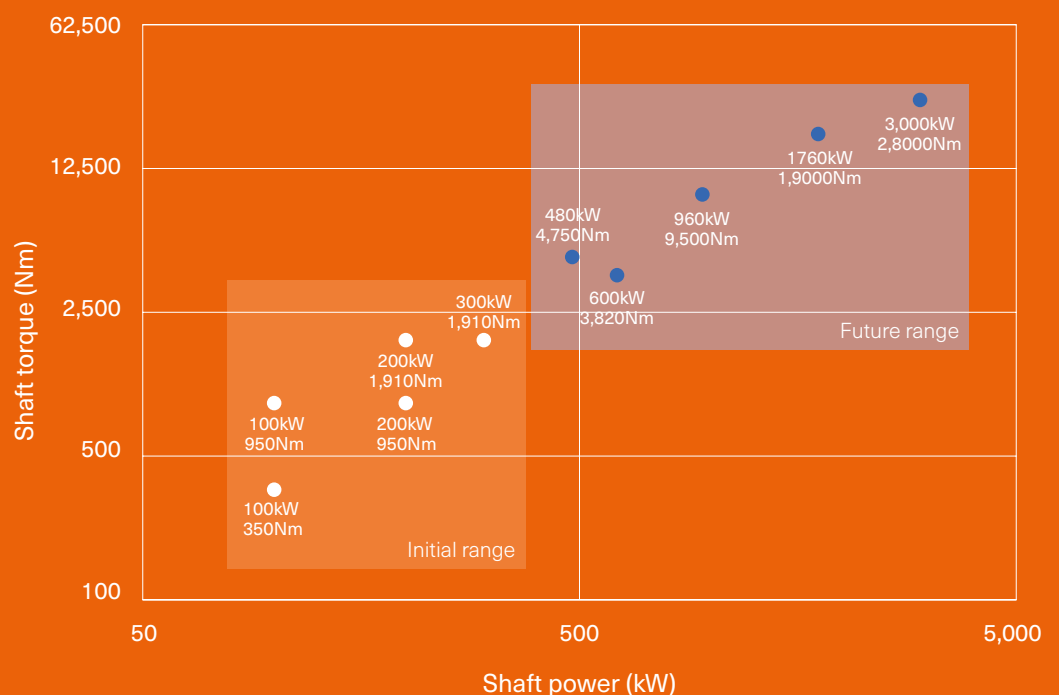
Future plans

The Helix Pod Cartridge family is intended as a standardised, modular building block for electric pod drives of all shapes, sizes, and vessel categories. This is reflected in the planned future line-up of Helix Pod Cartridge units, ranging from small kilowatt-scale solutions to powerful megawatt-scale EPUs.

Model	480kW	600kW (Dual-Propeller)	960kW (Dual-Propeller)	1760kW (Dual-Propeller)	3000kW (Dual-Propeller)
Speed at peak power (RPM)	1,230-1,450	1,850-2,300	1,230-1,450	500-1,600	500-1,600
Max shaft torque (Nm)	4,750	2x 1,910	2x 4,750	2x 9,500	2x 14,000
Pod diameter (mm)	280	217	280	370	500
Motor (kg)	57	62	114	212	440
Transmission (kg)	15	20	30	80	200
Total mass (kg)	154	125	298	515	1,000

Mass excludes support leg, turntable, and propeller(s) where appropriate. All motors assume radial cooling to seawater through hull.

Helix Pod Cartridge product range



Conclusion

By bringing world-class power density to the world of electric pod drives, the Helix Pod Cartridge serves as a foundation for a new generation of pod drive solutions for small- and medium-sized vessels.

For owners and operators, the Helix Pod Cartridge unlocks new opportunities to improve energy efficiency and fuel economy, enhance vessel manoeuvrability, reduce maintenance burdens, all while offering greater flexibility in operations.

For solutions providers, the Helix Pod Cartridge's versatility provides a scalable platform that allows them to provide quality, targeted solutions to a variety of markets, which can be supported by Helix's diverse line-up of motors that meet a wide range of size classes and applications.

For marine as a whole, the Helix Pod Cartridge can be a key solution in encouraging its broader electrification journey. It can also be an essential enabling technology for next-generation hulls for recreational and passenger transport, such as hydrofoils.

If you're interested in exploring how the Helix Pod Cartridge could help meet your needs, or if you want to leverage our decades of experience in developing the world's most power-dense motors and EPU's for your marine electrification project, get in touch with us today.



Reach out to us today
www.ehelix.com

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