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Inspector Mk2
Multi-mission USV gives up its secrets
Extended family

Peter Donaldson reports on how this unmanned surface craft forms the core of a selection of systems for a host of marine missions.

The way to sell a USV in revolution, says ECA's USV product manager Vincent Clavier, because customers expect a complete capability. With its Inspector Mk2, though, ECA, based in Toulon, France, has developed such a capability.

Much more than a robotic boat, the purpose-built, optionally manned surface vessel is designed to form the core of a capability that encompasses modular onboard sensors and effectors for a wide variety of missions, providing easy reconfiguration, support for and cooperation with other unmanned vehicles and integration into command and control networks.

The Inspector Mk2 marine ITS offers marine navigation and protection of coasts, ports, and offshore platforms; mine countermeasures; rapid environmental assessment (REA); support for special operations forces; anti-smuggling and anti-terrorist missions; and surveillance and observation for various applications, such as fisheries, pollution control, and border protection.

Its suite of modular, scalable systems, designed to be easily integrated with other sensors and effectors, enables the vessel to perform a wide range of tasks, from surveillance and reconnaissance to search and rescue operations.

The mission system of the Inspector Mk2 is designed to be highly flexible, allowing for the quick and easy integration of additional sensors and effectors to meet specific operational requirements. Its modular architecture enables a high level of reusability, reducing the cost of developing and maintaining systems.

The Inspector Mk2 is designed with a robust and durable hull, capable of withstanding harsh environmental conditions. Its powerful propulsion system ensures high-speed operation, while its advanced navigation and control systems ensure precise and accurate positioning.

The boat is equipped with a wide range of sensors, including sonar, radar, and other imaging systems, allowing for effective detection and tracking of targets. Its advanced communication systems enable efficient coordination and collaboration with other vessels, enabling seamless integration into joint operations.

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The water jet's input coupling, with its supporting bearing, attaches to the engine adapter (which is a flange assembly specific to the selected engine type) to the water jet's integral reduction gearbox that can be matched to the power unit's input speed – 3600-4000 rpm for Stary SE 236 engines, for example – eliminating the need for a separate marine gear set. The reduction box uses robust wide-faced, ground helical gears. Next in line come the intake body and grate, which prevents large items of debris being sucked in, then the impeller and its casing, and then the stator with its vanes that remove the swirl given to the water flow by the impeller. After that come the steering bowl, which is the fixed structure in which the steering nozzle moves, then the steering nozzle itself and the thrust reverser bucket which, when deployed, splits the flow into backward-angled jets. With a diameter of 245 mm, the impeller is of axial flow design and delivers high thrust over the vessel's entire speed range and offers high resistance to cavitation (the formation and collapse of water vapour bubbles that could damage low-pressure impeller surfaces) at low speeds. The reverse bucket features a split duct operated either by 12 V d.c. actuator or a hydraulic alternative, with follow-up control managed by a position-sensing control box.

Installation options are a simple transom mounting and, as in the Inspector Mk2's case, an in-line unit that forms an integral part of the hull structure. The Inspector Mk2's compact dimensions and weight of less than 5 tonnes keep it compliant with French road transport rules and to fit on a single trailer. This also makes it compatible with the boat-launching systems of most of the surface ships likely to operate it, Clavier points out. Other key requirements included high levels of stability despite large variations in weight distribution, and great accuracy in positioning and steering control for applications such as underwater survey work.

This demanding set of requirements for a small vessel presented a significant naval architectural challenge, leading ECA to partner with Orion Naval Engineering, based in Canetan, near Bordeaux in France.

"We designed this boat together to be able to integrate a lot of payloads," Clavier says, "but stability was a very big issue because if you have to put, say, 500 kg on the aft deck to operate another ROV then stability is a major challenge." Solving that problem involved compromises to come up with the correct positions of the major masses within the boat, such as the engines and the fuel tank, and optimising ballast capabilities. As well as coping with the extreme fore-to-aft weight distribution changes that occur during daughter vehicle launch and recovery operations, the requirement also called for high levels of stability during high-speed runs tracking surface targets and at the low speeds typical of underwater survey work.

ECA solved the low-speed issue by developing a novel, and now patented, bow keel arm, which is deployed when the arm pivots down into the water along a slot built into the bow. Useable at speeds of up to 10 knots, the keel has a symmetrical profile and, positioned ahead of the boat's bow wave, it significantly enhances stability at low speeds. Rather than simply deploying weight and a hydrodynamic surface, however, it normally carries a sensor such as a side-scan sonar.

Other payloads that the bow keel arm can accommodate include a multi-beam echo sounder and acoustic modems to enable communications with UUVs and so on; in its above-deck position it can support other sensors and effectors such as pulsed electro-optical systems or loudspeakers. The mechanical and hydrodynamic solutions to good steering control and very accurate path tracking at speed in high sea states include combining a unique and proprietary hull design with water-jet propulsion; ECA determined that water jets provide finer directional control at critical speeds.

This chimes with the acknowledged advantages of well-designed water jets, which include elimination of any dead band – a lack of steering response immediately adjacent to the dead-ahead position – along with the ability for infinite adjustment of the split-draft thrust reverser between full ahead and full astern so that the vessel can be held against a current or crept ahead or astern, plus plenty of steering authority.

Like the hulls of most small powerboats, the Inspector Mk2 functions as a displacement hull at low speeds, at which its weight is supported by its buoyancy, and as a planing hull at high speeds when hydrodynamic lift dominates. For ECA, it was critical to ensure that the boat would always climb onto the plane at a speed much higher than the patrol speed to ensure that any instability around the transitional drag-increasing 'hump' between buoyant running and planing cannot degrade the performance of the underwater sensor during surveys.

Unlike many boats of this size, the Inspector Mk2's hull is made of aluminium rather than fibre-reinforced plastic.

The conflicting speed and stability requirements demanded an innovative hull design, as survey ships are usually dedicated to their specific role and not expected to perform target tracking tasks at high speeds in a homeland security application as well. "The design of the hull is a very big compromise," Clavier says, although he would not be drawn further on the details of that. However, one area of compromise in hull design for boats that must operate over a wide speed range is in deadrise, which is the sharpness of the hull's vee-shape or, more technically, the angle the bottom makes with the horizontal when seen from in front or behind, and which is a strong determinant of the speed at which a planing boat runs most efficiently. Flat-bottomed boats – with little or no deadrise – are more efficient in smooth water but don't handle rough water very well, while the opposite species to deep-vee hulls – with large deadrise angles – which cut through waves well but produce more drag.

This is a sound reason for customers who want their USV system to perform one role only to select their own boat, perhaps from another manufacturer, and have ECA integrate its sensors and so on into it, Clavier says.

Unlike many boats of this size, the Inspector Mk2's hull is made of aluminium rather than a composite of fibre-reinforced plastics. Clavier explains that the prototype was built from aluminium because at the beginning of the project the team wanted to be able to make any changes to the hull easily. For electronics, they considered including a well to accommodate a through-hull sensor.

Recent developments in new alloys, and fabrication techniques including cutting and welding, along with inherent corrosion resistance and impact toughness – particularly important in rivers where semi-submerged logs can be hazardous – and growing familiarity with drawbacks such as contamination, blistering and structural fatigue of composites, have increased the popularity of aluminium as a hull material. The riverine environment is important to some of ECA's customers, Clavier says, "So for all our applications the best compromise was aluminium because we thought that for river applications it would be better than fibre."

Aluminium also makes it easier to include strengthening members to support the removable top of the canopy roof, which is important to
The Inspector Mk2 running at speed in displacement mode. The yellow-and-black sensor is a side-scan sonar.

The Inspector Mk2's ability to mount a variety of payloads and to accommodate interfaces with handling equipment such as cranes and davits used to launch and recover the USV from larger vessels, more of which later.

"We have some mechanical ports inside to make the roof stiff for the anti-pendulum interlock, and in time it would be more difficult to achieve that," Claver explains, alluding to the complexity of the moulds required. The anti-pendulum interlock is the connection with the mechanism on modern cranes that prevents dangerous swing during hoisting.

The aft deck features a wide range of mechanical, electrical and data connections for payloads and payload support equipment. This amounts to a very flexible architecture through which it is possible to rapidly change the USV's configuration for different missions by switching modules. For example, the deck can accommodate launch and recovery systems for two UUVs or ROVs. ECA is now producing its third generation of launch and recovery systems, which can be integrated with manned surface vessels as well as USVs. Another optional module is a towed side-scan sonar, which can be deployed at depths down to 100 m and which includes a winch to control the sensor's depth and distance behind the vehicle.

Also mounted on the aft deck is the mast structure, which supports equipment including data link antennas, a radar and an associated camera for visual identification of radar targets and so on, and smaller cameras facing to the front, rear and sides to assist with close-quarters manoeuvring and docking. Claver says this is a minimum camera fit, normally augmented by more sophisticated stabilised cameras depending on the mission. The mast fits for trailer transport or storage aboard other vessels.

Another sensor of note is the Maretron WSG100 anemometer and weather station module that, in addition to wind speed and direction, measures barometric pressure, air temperature and relative humidity. Wind measurements are taken with ultrasonic sensors that have no moving parts to snag on other equipment or wear out.

Comms links

ECA offers several comms link options covering radio frequencies between 700 MHz and 5.4 GHz. The standard single link has sufficient bandwidth for full-motion video and both vehicle and sensor payload control and display data, and incorporates high levels of redundancy and security. Claver says some customers ask for different types of link, which the company can provide, and although he declined to go into details, he emphasised the company's confidence in the comms system's compatibility and performance with standard sonars, for example.

The distance at which the USV can be controlled remotely, and thus its effective operational radius, depends on antenna height. "For that reason it is always difficult to talk about radio range," Claver says. "For some customers we propose a secondary comms link based on link 16, but that depends on what they want exactly."

Although NATO and the US in particular are pushing hard for standardisation and compatibility among comms systems, and widespread adoption of solutions such as the Tactical Data Link (TDL) family – Link 16, Link 11 and Link 22, for example – this does not yet seem to be a major concern for ECA as far as the Inspector Mk2 is concerned.

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Equipment options

For the harbour surveillance and protection role, ECA offers the Inspector Mk2 with the Triton Harbour software, plus the same set of surface sensors and effectors proposed for the mobile mission referred to in the main text.

For offshore platform surveillance and rapid threat intervention missions, ECA offers the Inspector Mk2 with equipment certified on the Triton Harbour software plus the usual surface situational awareness sensors and controlled by a single operator. In addition to a loudspeaker, the USV can be fitted with a non-lethal gas grenade launcher and programmed with interdiction manoeuvres including ramming.

The Inspector Mk2 can also take on less aggressive, even life-saving duties when equipped for fighting offshore fires. Options include IR and daylight TV cameras, and a high-pressure foam projector capable of delivering 4500 litres at 15 bar pressure from a tank that holds 400 litres of liquid foam concentrate. The craft can also deploy two automatically inflating rafts under remote control.

Chemical, biological, radiological and nuclear detection and analysis sensors can also be integrated, including photoionisation detectors, toxic industrial chemical detectors, multi-gas detectors, and gamma ray and neutron meters.

For the mine identification and neutralisation role, ECA offers the Inspector Mk2 fitted with the Triton MCM suite, which is a mine warfare data post-processing software package featuring several of the modules incorporated into other Triton sonar packages such as Perspective SSS and Perspective MBE. These enable it to display multi-layered maps populated with mission data, survey lines and bathymetric data, show mosaics and waterfolds and acquire targets from within them, crucially likely targets for the operator to save time. It can also measure and analyse targets and extract images and location data.

In terms of sensors, ECA proposes an Eidsedge ED4600 side-scan sonar mounted on the bow keel arm. This has an interferometric capability, enabling it to produce imagery and bathymetric data simultaneously in water 2.25 m deep. The bow keel arm protects the sensor from shock during transit and simplifies maintenance.

The vehicle is also fitted with electro-optical sensors and equipment to control synthetic aperture sonar, a towed side-scan sonar and a towed mine sweep, and can work with divers.

While ECA offers a side-scan sonar for MCM, product manager Vincent Clavier regards the bow keel arm as the first choice for deployment of such a sensor because of its ability to conduct surveys accurately in shallow water. If he were to recommend a solution, he says, it would be to use a USV with the bow keel arm in the shallows and an AUV in deeper water, but for customers who decide they need a towed side-scan sonar, ECA has a module that it can integrate.

The MCM increases the level of integration with other unmanned vehicles including the K-Star-1 mine identification ROV, the K-Star-2 expendable mine disposal vehicle and the Swedish Mk2 Inspection ROV. Two 1.5 m-long, 50 kg K Stars can be carried on the launch and recovery system ready for deployment, for example.

The smallest standard configuration can be operated with a PC, while there is also a version integrated into a naval-qualified console for warships. While the USV command and control software can run on standard warship consoles, Clavier points out that such a configuration would also require the installation of an additional electronics bay to house dedicated command links and power supplies.

Control system

The control system is divided broadly into guidance and steering modes. In steering mode, Clavier says, the operator always has control of the vehicle, whereas in guidance mode the vehicle is completely under the system's control.

Guidance mode is further divided into autonomous and assisted modes. In autonomous mode, the operator supervises the vehicle as it carries out its mission plan; while in assisted mode the operator controls the vehicle through a selection of preset menus. For example:

- One type of event that demarcates rapid real-time reaction is the detection of an obstacle — usually by radar — that presents a collision risk, for which ECA has developed a set of alarms that, depending on the situation, initiate a number of different reactions, such as a standby mode or a navigation procedure such as an avoidance manoeuvre.
- More challenging than ensuring the correct reaction, however, is the reliable detection of obstacles in the first place.

The navigator is then able to steer the Inspector Mk2 directly, even here the computer system provides assistance in the way an aircraft's fly-by-wire controls would. In direct remote control steering mode, the operator uses the normal interface but the software intervenes to provide a smooth, predictable and intuitive response.

Regardless of whether the USV is operating in an autonomous or assisted mode, underwater imaging sensors such as side-scan sonars and multi-beam echo-sounders demand very accurate steering to preserve their data quality. The Inspector Mk2 however stays within 5 m of the planned track thanks to the hull and propulsion system design in combination with the steering software. A compromise has to be made though between the highest accuracy of position and stability of the sensor. If the system is constantly making small, rapid corrections for the sake of path accuracy it destabilises the sensor and degrades the imagery.

For this reason, Clavier explains, development of the steering commands was a slow process that started with the USV programme in 2008. "We didn't have the correct commands at the beginning, but it was perfectible and now I think we are very accurate. I think we have the best place at the beginning, but perfectible," he says.

Customer requests for a version of the craft able to tow mine-weeping gear provided an opportunity to refine the command set further. Developing commands suitable for a towed system alongside those optimised for hull-mounted sensors enhanced their ability to ensure that they could steer a USV in a sufficiently accurate track while maintaining the stability that the sensors demanded. "At the beginning that wasn't the case, the first USV was not at the stability level that this one is," Clavier says.

As the Inspector Mk2 is an optionally manned vessel, it has a full set of controls in its six-seat cabin, and the control system enables the driver to use all of the autonomous guidance and assisted steering modes in addition to direct steering. It also allows the crew to use all the mission system's functionality. The boat can be considered a means of putting a set of sensors and effectors into the right place at the right time to collect information and act on it, or get it to others who can act on it. ECA offers a number of mission-focused suites that have many items in common, mixed and matched to produce different emphasis for different but related missions.

None of the combinations are set in stone though, as all of them can be tailored to a customer's needs. For example, in missions that primarily involve surface surveillance and/or protection, the bow keel arm is most likely to be in its above-deck position and fitted with a searchlight rather than a sonar. For missions requiring interdiction...
of threats, there are various non-lethal weapon options but also the option of firing something definitely lethal in the form of a 12.7 mm heavy machine gun in a roof-mounted turret.

Different mission suites also feature different levels of interaction with other types of unmanned systems in the ECA range.

**Sonar software**

ECA does not make sonars but it can integrate various third-party units, and its Triton Imaging subsidiary offers a range of sensor- and mission-focused sonar data processing software suites.

The sensor-focused software of the Triton Perspective family includes packages to handle multibeam echo sounder (MBE), sub-bottom profiler (SBP) and side-scan sonar (SSS) data, all sharing the common Perspective environment including a graphical user interface. The mission-focused suites include Triton Harbour and Triton Rapid Environmental Assessment (REA).

The Harbour suite provides protection from underwater IEDs using a database of historical side-scan sonar and MBE survey data, as well as change-detection tools to find new objects in sensor data and locate them accurately for later inspection by divers or unmanned vehicles. Configurations are available that use existing port hydrographic survey assets or complete integrated AUV or ship-based hardware/software systems including sonars and ancillary survey equipment. The system exploits the Inspector Mk2’s high positional accuracy to perform image co-registration as a change detection technique.

The REA suite turns the Inspector Mk2 into a tool for the preparation of amphibious landings, enabling it to collect sea floor, bathymetric and oceanographic data, current and tidal information, measure turbulence and ambient noise, detect obstacles and mines and even collect intelligence on the surface situation through the electro-optical sensors.

MBE sonars generate very good bathymetric data, but side-scan sonars produce higher resolution imagery, so detailed surveys of harbours, canals, rivers and other stretches of shallow water often require both. Perspective MBE software includes a bathymetric module that enables rapid creation of digital terrain models, quality control tools and data interpretation aids, and change detection tools.

Perspective SSS features a module that enables rapid creation of mosaics, and ensures they are geographically correct, as well as a traditional side-scan waterfall display with automatic line-finding tools and playback controls linked to the map display. Also included is a target module designed to acquire targets from mosaics or waterfall displays and measure, analyse and classify them. The module includes image enhancement tools and a facility to export target images and locations.

While MBE and SSS sensors create detailed 3D images of the seabed and what lies on it, SBP sonars generate pictures of what lies below it, including buried objects and the bed’s composition. Perspective SBP is designed as a complete software toolbox for producing and processing SBP data.

**Port and coastal mobile surveillance**

Building on its systems integration capabilities, ECA now offers a mobile system for port and coastal surveillance centred on the Inspector Mk2, a diver detection sonar that can be placed on the seabed by it, and an IT 190-3EL-1 coaxial VTOL mini-UAV, all deployable within two hours from a truck with a trailer.

For this role, the USV is fitted with ECA’s harbour surveillance and protection package, which includes a radar and multiple electro-optical sensors including thermal imaging and low-light video cameras in a stabilised turret, all mounted on the mast. Software enables fusion of radar and IR outputs for more reliable target discrimination and tracking. It is also fitted with the Triton Harbour suite of sonar database and change detection software tools.

A searchlight turret mounted on the bow keel arm provides long-range detection and identification in coordination with other sensors, and can also serve as a non-lethal weapon with significant dazzling capability. Warning signals from an LRAD loudspeaker mounted on the cabin roof are claimed to be intelligible at ranges of up to 1700 m, and at shorter ranges – and like the searchlight – it can serve as a non-lethal weapon thanks to an acoustic astonishing effect.

The concept of operations is straightforward. Assuming the diver detection sonar is not in its place on the seabed, the Inspector Mk2’s first job once launched is to deploy this sonar in its planned position, maintaining a direct link with the control station in the truck, which has placed for two operators. After that, the craft switches to its surface control mission, in which its sensor suite provides target detection at ranges of up to 15 nautical miles (nearly 28 km), equaling to a coverage area of more than 3400 sq km.

The craft’s radar would probably be the first of its sensors to detect a surface target and would cue the electro-optical turret to take an initial visual look at it. This would give the operator the information needed to make a decision about launching the UAV which would be waiting onshore near the truck.

**Working with mother**

ECA also offers a mine-weeping (MCM) mission module for large multi-purpose vessels. Operated from the mother ship, the Inspector Mk2 with Triton MCM suite forms part of an integrated system that can include the 195 m-long, 70 kg AS-M man-portable AUV, the K-Rater-1 and 2.

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**Non-lethal weapon options are available but there's also the option of fitting a lethal weapon – a 12.7 mm machine gun – in a roof-mounted turret.**

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The K-9er C, the 1.58 m, 52 kg Seascan Mk2, and the 99 kg H800-INS inspection and light-work class ROV, all of which is capable of launching, operating, and recovering, although not all at once.

The Inspector Mk2 can also work with much larger vessels that would be launched and recovered separately by the mother ship, including the RGP Mk6 mine warfare ROV, the 370 kg A-8 M mine detection, classification and localisation AUV, the 950 kg A27 M CCM and sea bed survey AUV as well as the IT80. This is where the value of the common data link and HMI comes in, Clavier says.

ECA proposes the Inspector Mk2 for operations in very shallow waters and for delivery of the K-9er for close inspection and/or disposal, plus small, medium or large AUVs for detection, classification and localisation duties in shallow-to-deep water. It also provides a complete mission management system for the full set of vehicles, a system that also supervises all phases of the MCM operation from preparation to target database management.

Launch and recovery

Naturally, the system involves launch and recovery of the USV by the mother ship, and the company has engineered a number of systems to make this process safe and easy.

The strength, rigidity and design flexibility of the removable aluminum roof allows a lifting eye for a single-point crane to be incorporated without a spider sling, and ECA also offers an interface that works with the anti-pendulum devices found increasingly on modern ships that enable them to lift and lower boats using standard boat davits without the risks associated with swinging.

Another solution to the launch and recovery problem is a docking frame developed for the Inspector Mk2 in partnership with another company. The frame takes the form of a cage that is lowered into the water so that the boat can drive into it and lock into place automatically, eliminating the need for a manual hook-up. Once lifted back aboard the ship, the frame also serves as a support cradle for the USV.

This is what Clavier means when he talks of offering complete capabilities. “Sometimes USV manufacturers want to sell only an unmanned surface vehicle; we however aim to offer an unmanned surface system - a complete system of systems.”