<u>Nautilus Autonomy-in-a-Box</u>

Platypus has developed the Nautilus hardware box and the Nemo software stack to provide mission level autonomy and cooperative autonomy to small UXVs, with a focus on USVs. The Nautilus box provides interfaces to plug into sensors and actuators on board existing platforms to immediately take a remotely operated or optionally manned vessel and allow it to autonomously execute interesting missions. Nautilus boxes, each about 35cm x 25cm x 20cm and weighing about 5kg, on homogeneous or heterogeneous vessels, can autonomously coordinate to create autonomous, intelligent teams capable of taking on larger objectives. The Nemo software which runs onboard the Nautilus, or independently on other hardware, is built on theoretically grounded, state-of-the-art AI and open standards and has been shown capable of coordinating 100s of assets in very complex and adversarial environments.

Nautilus and Nemo provide a way for UXV platform developers to quickly bring mission-level autonomy to their platforms. The hardware and software provide a low-risk, low-cost way of having single platforms or fleets of platforms be able to flexibly achieve complex objectives. The software can respond to changes in the environment, respond to sensor data, react to an opponent and recover from problems with the vessel. A Shore Control Station ensures an operator stays in control of the mission and understand mission status at an appropriate level of detail , while freeing the operator from having to look after the details of mission execution. As USV capabilities and needs rapidly evolve, autonomy is becoming more important, however R&D costs to internally develop an autonomy platform are still too high for many platform developers. The Nautilus fills an important gap, providing pre-built, platform agnostic mission level autonomy, for a fraction of the cost of prior solutions, accelerating the integration of AI into the defense industry. Over time, Nautilus will provide an app store for external developers to add capabilities and provide a smoother path to certification of new USV platforms.

The Nautilus prototype was completed in early January 2023. The Nautilus has been selected by Gibbs and Cox Australia as the autonomy provider for their new Environmentally Powered Modular Autonomous Platform (EMAPS) USV. Integration of the Nautilus into the platform will take place during October ’23 with initial testing at Autonomous Warrior ’23. Nautilus and Nemo provide a low-risk, cost-effective way for Gibbs and Cox to bring autonomy to this new platform and provide a pathway to implementing planned future missions with fleets of EMAPS working cooperatively.

Platypus is in late-stage negotiations with two other platform providers, one a USV provider and one a UAV provider to bring the Nautilus and Nemo to their platforms. This early traction with USVs shows the potential for the product in a market likely to take off after recent developments in Ukraine and the Black Sea. The UAV market is more competitive, but the Nemo software stands out with its ability to achieve flexible, autonomous coordination which is becoming increasingly necessary in modern battlefields.

Platypus software and hardware is the culmination of nearly 30 years of development expertise in academia and with the US military. The targeting of Nautilus and Nemo to mission and cooperative autonomy is in direct response to clients looking for a way to bring autonomy to single assets and fleets in a low-risk and extensible way. Our target customers are experts in platform development and even often have the lowest levels of autonomy, e.g., waypoint navigation, implemented. However, the AI background to build higher levels of autonomy is typically not available at platform developers. Hence, Platypus has designed a product that specifically and narrowly fits the gap our target clients have.

Platypus' Nautilus Autonomy Controller is an essential element of the Environmentally Powered Modular Autonomous Platform (EMAPS) Autonomous Surface Vessel (ASV). Nautilus' flexible architecture has greatly facilitated our prototype ASV development and integration of a complex suite of on-board systems and sensors, and its' multi-vessel collaboration capabilities will dynamically enhance the EMAPS operational efficiency.

Allen Stotz, MBA, PMP
Director, Maritime Autonomy
Gibbs & Cox Australia

"The US Military has dedicated a decade of effort to achieving "manned and unmanned teaming," the seamless, tactical partnership between Soldiers and autonomous systems on the battlefield, performing offensive, defensive, recon, and security tasks, and placing autonomous systems in roles that reduce risk to Soldiers while achieving superior results. This means getting beyond tele-operation and operator in the loop control schemes, and moving towards independent coordinated action between heterogenous agents, operating across multiple domains, in concert with human inputs, to achieve complex tasks defined by multiple competing conditions and variables. This is what Platypus's Nemo Autonomy brings to the battlefield. Their system provides applied behaviours previously only achievable in a lab, and operationalizes them for integration onto diverse platforms. They are a leading contender to provide applique and integrated autonomy solutions to the US Department of Defense for a range of systems and programs."

LTC, US Army (ret)
Owner, Mass XV Maneuver Combat Systems Consulting

The idea of making autonomy available in a standalone autonomy box is not completely new, although Nautilus has features never seen in existing products. Products such as the CUBE package for an Ardupilot controller have shown the value of providing a degree of autonomy with minimal integration. However, products such as the CUBE only provide waypoint level autonomy, not an ability to plan for how to achieve a mission objective, respond to changes in the environment and opponents, etc. (Nautilus actually includes a CUBE to provide the waypoint autonomy and builds higher levels of autonomy on top of it.) Moreover, the Nautilus adds features such as NMEA interfaces and an IP66 rating that make it more appropriate for USV missions.

The most innovative aspect of Nautilus and Nemo is the ability to complete cooperative missions, with many homogeneous or heterogeneous vessels working as a team. We are aware of no other product that can provide this functionality. Cooperative autonomy opens up a much wider range of mission objectives, reducing the costs and risks associated with human deployment. With this capability, vessels can coordinate on tasks such as triangulating an RF signal or rapidly building a picture of the environment over a large area, while reallocating roles to recover from failures or delays. Nemo ensures the fleet will find useful and effective ways to use available platforms, under prevailing conditions, to achieve operator provided mission objectives.

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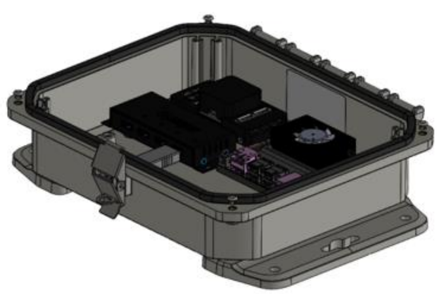
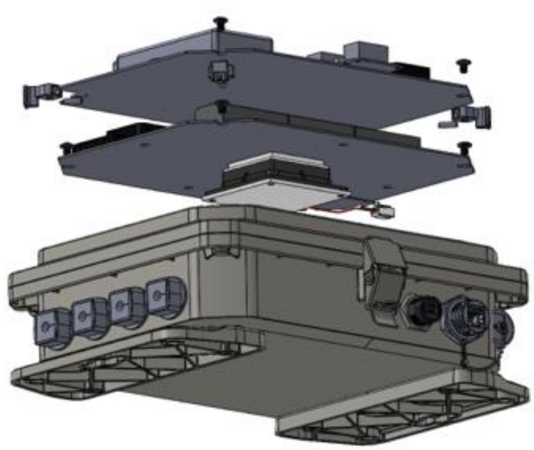
Appendix : Technical Detail

Hardware

This product, called Nautilus, is approximately 35cm x 25cm x 20cm and is IP-66 rated. The Nautilus features two computers, one for high frequency control of the actuators for low-level control of an ASV and another for running the autonomy and cooperative autonomy, plus any specialized AI algorithms.

  	Nautilus Specifications Electrical 10-30VDC Input Voltage (non-isolated) 450W Max Power Dissipation 3 Wire Terminal Connection (+, -, GND) Mechanical Approx. 5kg Approx. 350mm x 250mm x 200mm (L x W x H) Flange/Feet Mounting Environmental Ingression IP66 Shock/Vibration Approx 3G/50mm 1.5G 100Hz random -5 to 40C ambient (65C operating internal) Default Interfaces 1 x USBA 2.0 1 x 10/100/1000 Ethernet RJ45 2 x CAN 1 x Serial (RS232/485) 4 x PWM 8 x Multipurpose GPIO 1 x SDI-12 4 x Environmental Sensor (pH, DO, Temp, EC) Can be customized to include I2C, SPI and Analog interfaces.

While the core of the Nautilus is common across applications, we can change the available electrical interfaces to support different inputs and outputs. For example, ethernet is usually supported, but may be complemented with different interfaces, even custom ones for specific ASVs.

The control and autonomy software onboard the Nautilus has interfaces for consuming a range of different data types including external PNT sources, AIS data, local sensor data (e.g., lidar and sonar) and cameras. The software is designed to allow specialized filters to be developed and their products quickly made available to the autonomy. A general mission definition language is used to encode domain specific missions, with the core autonomy executing missions described in this language.

The autonomy computer in the Nautilus box has available processing power to run AI algorithms such as for sensor fusion, vision-based obstacle avoidance or SLAM algorithms for taking LIDAR data for navigation around shores or docks. Additional computing can be added for more computationally intensive algorithms.

Platypus is in process of customizing Nautilus boxes for Gibbs and Cox Australia's EMAPS ocean going catamaran. This customization includes new hardware interfaces to support CAN and NMEA 2000 protocol thrusters and software upgrades to support the use of sails to reduce battery energy use allowing for multi-weeklong missions.

Autonomy

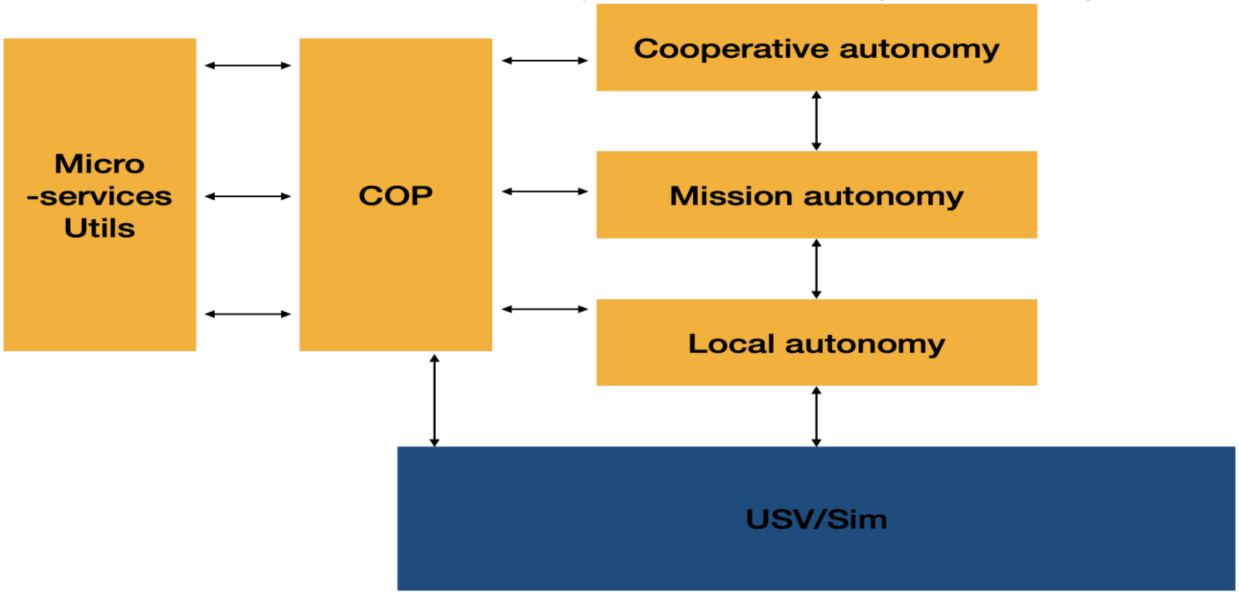
The Nautilus is the hardware platform on which the autonomy runs. Platypus has an extensive autonomy software stack, called Nemo, that runs on the Nautilus. The autonomy software is capable of both managing individual missions for a single vessel and missions involving teams of vessels.

Individual UxV autonomy starts with an ability to robustly and safely navigate to waypoints, and increases to mission-oriented behaviors such as collecting information within an area, searching for something of interest, and managing energy usage. The individual autonomy allows an operator to specify goals at a mission level and have the UxV intelligently work out how to achieve those goals.

Cooperative autonomy empowers UxVs to work together to achieve more complex and larger tasks. Members of the team will autonomously assign roles, synchronize behaviors, recover from the failure of individual team members and other behaviors that allow robust, safe, and efficient achievement of goals. With the cooperative autonomy, the operator gives a high-level goal to the team of UxVs, and they autonomously work out how to achieve the goal.

Software

The basic Nemo software consists of six components, shown at a high level in the figure below.



Generally, the components lower in the figure are at a lower level of abstraction and closer to the actual control of the vehicle. The vehicle manager deals with the actual interaction with the actuators and sensors of the vehicle, running typically at greater than 30Hz. This component keeps the vehicle moving along a heading, accelerating, or decelerating to a set speed.

The local autonomy component is responsible for determining headings and speeds, based on the current path the vehicle should be traveling.

The mission autonomy component determines where the vehicle should move to achieve its mission, e.g., the path required to complete the next stage of a survey or where to go to maximize information gain. For USVs COLREGS are handled in this component.

At the top, the cooperative autonomy component is responsible for working with the other vehicles, e.g., dividing up tasks amongst the vehicles to achieve the overall mission.

The Common Operating Picture (COP) is the memory of the autonomy, which is available to all other components to provide the understanding of the state of the vehicle and environment to all components.

Finally, the micro services component is the mechanism for plugging in specialized reasoning and AI services and making the available to all the core autonomy components. This architecture is based on well understood and heavily tested approaches to building extensible and robust autonomy.

For specific ASVs, the software is adapted to be able to control the specific geometry and controllers of the vessel and implement the missions for which the ASV is designed. Often this is a reasonably quick process of adjusting parameters and mission models, though for missions or control schemes that are significantly different to those Platypus has done before there may be a bigger effort required.

The whole Nemo autonomy stack is on board the Nautilus, hence the ability to work cooperatively with other UxVs running Platypus software (whether or not running on a Nautilus). With an appropriate radio plugged into the Nautilus, the ASV will be able to perform cooperative missions with other ASVs or, perhaps UAVs. Customization of the cooperative missions is often straightforward, though new CONOPs may require more work.

Platypus has a custom GCS to control Nautilus based ASVs. The GCS has the same basic features as many other GCS, however with more of a focus on interacting with autonomy, such as describing mission objectives rather than routes or waypoints. That software can be refactored to provide a widget to be integrated into an existing GCS. Optionally, the software can be configured to work with a common open-source GCS, such as QGroundControl.

The software on the Nautilus is being made more open to allow third-party software to be integrated easily. We envision an App Store type concept in the future, as well as a developer's conference.