Software helps unmanned aerial vehicles break records during Arctic test flight

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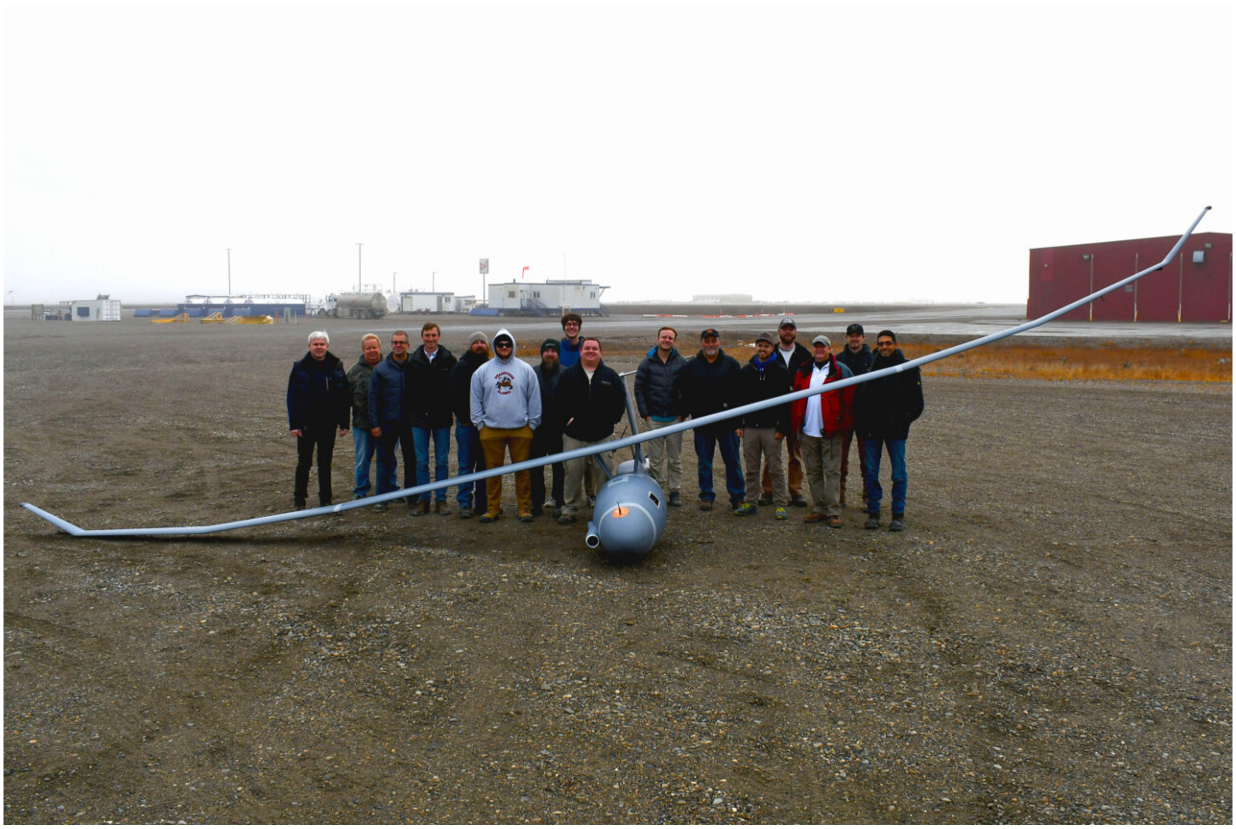

A team of researchers from Platform Aerospace, the Naval Postgraduate School (NPS) and the Naval Research Laboratory (NRL) recently used a Platform "Vanilla" unmanned aerial vehicle (UAV) to conduct testing of flight-path planning software developed at NPS. The flight tests above the Arctic Circle employed NPS' "POTION" software, which is intended to optimize the operational efficiency and endurance of manned and unmanned aircraft. Credit: U.S. Navy

Following years of dedicated work with unmanned aerial vehicles (UAVs), NPS and Naval Research Laboratory (NRL) partners have successfully concluded the ultimate test of a nine-year continuum of research and development in one of the world's most challenging environments: the Arctic Circle.

The collaborative team integrated NPS' own cutting-edge flight-path planning software known as POTION (Path Optimization) with the Vanilla UAV, developed and operated by Platform Aerospace. This initiative pushed the boundaries of their research, subjecting the Vanilla-POTION combination to rigorous testing in the daunting North Slope of Alaska, making the best of a narrow weather window.

Remarkably, the outcomes of the Arctic flight in September surpassed all expectations, as well as numerous records set by Vanilla in previous missions. This achievement underscores the exceptional capabilities of the Vanilla-POTION combination and represents a milestone in advancing UAV technology for naval operations within the scope of the long-term partnership.

Leading NPS efforts on what he terms "energy-aware aerial flight" is NPS Associate Professor of Mechanical and Aerospace Engineering (MAE) Dr. Vladimir Dobrokhodov, who began at NPS as a postdoctoral fellow in 2001.

"A glider's efficiency is quantified by its judicious energy utilization, a stark contrast to the combat efficiency metrics applied to fighter aircraft. Similar to transport planes, gliders aim to traverse vast distances with minimal fuel consumption," explained Dobrokhodov. "Over a meticulous nine-year collaboration between NPS and NRL, innovative approaches have been developed to optimize efficiency of long endurance aircraft."

Back in 2014, Dobrokhodov worked alongside NRL's Dr. Dan Edwards and Dr. Richard Stroman to explore energy-aware flight research with a novel hybrid UAV called Hybrid Tiger that integrated hydrogen fuel cell, solar and atmospheric wind energy-harvesting technologies. The project spanned three years.

Central to the project's achievements was the development of optimal trajectory planning software emulating the energy-conserving flight patterns of migrating birds navigating atmospheric wind rivers.

In the realm of energy-efficient flight, characterized by low airspeeds and altitudes, susceptibility to the adverse effects of strong winds and icing is amplified, making flight-path planning extremely challenging for human operators. Mathematical optimization of routing becomes vital, necessitating a complex software solution that enables the aircraft to skillfully navigate through diverse and potentially hazardous weather conditions.

Close collaboration with MAE professors Mark Karpenko and Kevin Jones, researchers who have spent years in the area of flight efficiency and optimal control engineering, helped to advance the energy optimal approach to what is now POTION. The team developed the propulsion efficiency model of an aircraft to model the Vanilla UAV's fuel consumption and used machine learning to integrate that model into the algorithm for route optimization.

"Using neural networks to represent and quickly execute an otherwise complicated energy model was a key enabler for optimizing Vanilla's flight path," Karpenko said.

Weather forecasts from Naval Meteorology and Oceanography Command (METOC) were used to inform multi-day missions of the weather conditions ahead. Just as with ships, an aircraft might waste precious energy flying directly into headwinds even if it is a more direct flight path. POTION designs a mission that finds the most energy-advantageous route through time-varying three-dimensional winds by referencing METOC weather forecasts that extend up to five to eight days.

To test the POTION software, researchers needed a unique aircraft to host the technology, and found one in Vanilla, a Group III UAV. Vanilla UAVs have a maximum endurance of 10 days, a payload capacity of 150 pounds, and a maximum range of 15,000 nautical miles. Vanilla's capability for long endurance flight makes it especially suitable for realistic testing of its flight performance in wind and icing conditions, and thus a prime candidate for testing the POTION software.

Originally, flight testing was to be conducted in California, but a last-minute change necessitated launching the Vanilla UAV from Alaska's North Slope—above the Arctic Circle—in rough weather. Typically, Vanilla is required to be "chased" by a manned aircraft in the terminal area of airports, but the weather was so intense that the escort aircraft could not take off. Instead, Vanilla was given a chance to fly using Instrument Flight Rules (IFR) fully autonomously and following the POTION-generated routes.

"In the most severe arctic conditions, Vanilla demonstrated exceptional performance, achieving unprecedented milestones in its operational history. Notably, it set records for the longest duration flown by a Vanilla aircraft in Arctic environments, covered the greatest distance at these latitudes, and marked its inaugural operation utilizing Instrument Flight Rules (IFR)," said Dobrokhodov.

"We had so many expectations and none of them were met. Just none. Every single one was exceeded, and it was incredible. At the time when Vanilla landed, we (Dobrokhodov, Edwards, and Stroman) just looked at each other knowing this took us nine years to make it happen. And now everything had finally clicked together."

In honor of the 101st flight by a Vanilla UAV and its unique location, the team named the flight Arctic 101. According to Karpenko, "Arctic 101 was also a fitting name for our first flight because we learned a lot, especially about deploying POTION software in the 'wild.'"

By adding NPS' POTION software to the Vanilla UAV, the team was able to significantly extend its endurance, and extending UAV endurance bears profound implications for military operations.

In this respect, the POTION software developed by NPS stands as a pivotal tool, facilitating the automation of mission optimization involving long endurance aircraft deployment from a base, navigating to a designated location for extended loitering, and subsequently returning to base. This versatile software is compatible with diverse aircraft platforms and could be seamlessly integrated with nearly any ground control station.

The operational scenario in the Arctic also showcased the transformative potential of POTION. Notably, it effectively mitigated the operator's cognitive load associated with the intricate multi-day mission design and management process, marking a substantial advancement in operational efficiency.

The POTION research initiative has proven instrumental in advancing the knowledge base of numerous NPS students. During the past three years, seven students in diverse NPS departments have chosen operational energy and its efficacy in aircraft applications as the focal point of their thesis topics.

While some students originated from the Mechanical and Aerospace

Engineering department—including U.S. Navy Ensign Luke Lalumandier, a June 2023 graduate whose work focused on the energy-optimal guidance of UAS systems in varying wind environments—it is noteworthy that Operations Research students in particular have significantly contributed valuable insights into the realm of optimization at the mission level.

One such OR student was U.S. Marine Corps Maj. Tyler Cotney, another June 2023 graduate whose thesis dealt with real-time solutions of robust, energy-aware UAV routing.

Dobrokhodov underscores his appreciation for the contributions from students across various disciplines.

"Active student engagement constitutes a cornerstone NPS endeavor. Many NPS students come in from the fleet. A lot of them already have operational experience flying UAVs, and they give us fruit for thought and advice on how UAVs should be operated. In part, the success of this project is also the success of our students. They come to NPS, learn from us, but, also, we learn from them. That's a significant part of what we all do here," said Dobrokhodov.

Although no NPS students were able to take part in the Arctic testing this September, NPS is already looking to incorporate results from the POTION research into a new project with opportunities for students and research partners alike.

Another proposal for NPS is a project entitled GUIDER (Guidance of UxS: Intelligent, Energy-aware Routing) that will be a natural extension of the work done with Vanilla, hopefully extending its applicability to a wider class of autonomous aircraft.

"We want to integrate the energy savings attained during transit to and from the operational zone with the aircraft's energy-aware performance during the mission execution phase," Dobrokhodov said of his goals for the GUIDER project.

"The question is how we can extend the energy efficient flight into typical mission tasks, like searching a huge area of the south Pacific, for example. Using what we have learned in the Arctic experiment, we can now study how to perform a large-scale search, optimally with respect to fuel and energy and apply that knowledge to other aircraft."

Use of the Vanilla UAV in research conducted by the Naval Postgraduate School does not constitute endorsement of Platform Aerospace or its products or services by NPS, the Department of the Navy, or the Department of Defense.

Provided by Naval Postgraduate School

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