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The HV-911 Eagle Eye Tiltrotor VUAV
An Exciting Future for Coast Guard Aviation

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The HV-911 Eagle Eye Tiltrotor Vertical Takeoff-and-Landing Unmanned Aerial Vehicle.
Photo Courtesy of Bell Helicopter

ABSTRACT

In February 2003, Bell Helicopter, Textron Inc., was awarded a contract to commence concept and preliminary design work on its HV-911 Eagle Eye tiltrotor vertical takeoff-and-landing unmanned aerial vehicle (VUAV) as part of the U.S. Coast Guard's Integrated Deepwater System (IDS) Program.

With initial operational capability (IOC) projected following the National Security Cutter's IOC in 2007, Eagle Eye will open a new and exciting chapter in Coast Guard's long aviation history—at a time when the military, multimission, and maritime service's responsibilities for U.S. maritime homeland security have taken on a heightened sense of urgency.

Assigned since March 2003 to the U.S. Department of Homeland Security, the Coast Guard also serves as one of the five U.S. armed services. Its core roles are to protect the public, the environment, and U.S. economic and security interests in any maritime region in which those interests may be at risk, including international waters and U.S. coasts, ports, and inland waterways.

The need to modernize the Coast Guard's aging and increasingly obsolete inventory of cutters and aircraft is compelling. Owing to a steadily increasing rate of systems failures, there are clear indicators that the Coast Guard's ability to sustain its current readiness and tempo of operations into the future is at risk. The Deepwater Program plays a critical role in the Coast Guard's ability to reverse such trends.

Deepwater's estimated $17 billion (fiscal year 1998 dollars) integrated "system-of-systems" acquisition will upgrade the Coast Guard's existing surface and air legacy assets while transitioning to more capable platforms—including highly improved systems for command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) and logistics.

When the Deepwater program is fully implemented, the total system will consist of three classes of new cutters and their associated small boats, a new and upgraded fixed-wing manned aircraft fleet, a combination of new and upgraded helicopters, and both cutter-based and land-based unmanned aerial vehicles.

Eagle Eye will satisfy the Coast Guard's requirement for a tactical cutter-based UAV capable of bolstering surveillance and intelligence-gathering capabilities for the detection, identification, and classification of targets at ranges out to 100 nautical miles.

Operating in conjunction with cutters and manned aircraft, Eagle Eye will significantly improve the Coast Guard's persistent surveillance capability. With its unique VUAV design and capable on-board systems, Eagle Eye promises to play a key role serving as the "eyes of the fleet" for tomorrow's Coast Guard.

INTRODUCTION

For a military service long accustomed to attempting to do more with less, the effects of many years of chronic under funding during the 1990s are now resulting in a downward spiral in Coast Guard operational readiness at precisely the *worst* time for the nation's national- and homeland-security needs.

"Our greatest threat to mission performance continues to be that our aircraft, boats and cutters are aging, technologically obsolete, and require replacement and modernization," Adm. Thomas H. Collins, Commandant of the Coast Guard, said in early March 2004[1].
Two weeks later, during his "State of the Coast Guard" address at the National Press Club in Washington, D.C., the Commandant elaborated. "There are storm warnings along our projected track line," he told a capacity audience. "There are clear warning signals that our ability to sustain our readiness into the future is increasingly at risk. We are experiencing system failures at a steadily increasing rate."[2]

Vice Adm. Thomas J. Barrett amplified the Commandant's concerns during a congressional hearing on the Deepwater Program in April. Noting that most Coast Guard cutters and aircraft will reach the end of their projected service lives by 2010, Barrett revealed that the service's annual safety review for fiscal year 2003 reflected a mishap rate for reported apparent in-flight engine power losses of 62.74 per 100,000 flight hours.[3]

Vice Adm. Thomas J. Barrett, Vice Commandant Of the Coast Guard, meets with reporters following his congressional testimony on the Deepwater Program in April 2004.
USCG Photo by Gordon I . Peterson

"This rate is unacceptable," Barrett told members of Congress, "and far exceeds the FAA [Federal Aviation Administration] guidelines of no more than 1 mishap per

100,000 hours or the U.S. Navy Safety Center guidelines of no more than 10 mishaps per 100,000 hours."

Early in 2004 the Coast Guard took steps to reprioritize the Deepwater Program's modernization planning to address the urgent need for corrective measures on legacy air and surface platforms.

Integrated Coast Guard Systems (ICGS), a joint venture between Northrop Grumman and Lockheed Martin serving as Deepwater's systems integrator, was directed to take immediate action to re-engine the Coast Guard's HH-65 helicopter fleet. The first upgraded, more powerful replacement engines and improved fuel-control system will be installed on an HH-65 helicopter this May, and the re-engining project will gain momentum in the months ahead.

Similar concerns exist in the Coast Guard's aging surface fleet. During 2003, Barrett testified, cutters experienced 676 unscheduled maintenance days—a 41 percent increase over 2002 and the equivalent of losing more than three-and-a-half cutters to service. In response to similar deteriorating conditions in its fleet of 110-foot Island-class patrol boats (WPBs), the Coast Guard's leadership ordered the acceleration of the design and development of Deepwater's Fast Response Cutter—the intended replacement for 110-foot WPBs.

"Looking ahead," Barrett told the Subcommittee, "it is clear that attaining additional capacity and capability is critical to the Coast Guard's ability to achieve the levels of future readiness needed to perform its expanded homeland-security tasks while concurrently carrying out its other responsibilities."

The Integrated Deepwater System—or Deepwater—is the answer to these concerns. In addition to its surface, C4ISR, and logistics product lines, Deepwater's tiered combination of manned and unmanned aerial platforms is designed to meet the Coast Guard's system-of-systems requirements for operational effectiveness at the lowest total ownership cost.
As a key element in Deepwater's plan to recapitalize Coast Guard aviation assets with a combination of manned and unmanned aircraft, the Eagle Eye VUAV will significantly improve operational capabilities and capacity at sea.

A Cutter-Based VUAV

Current Coast Guard planning calls for a total of 69 Eagle Eye VUAVs to be procured over the life of the Deepwater program. Deepwater's flight-testing of the first full-scale Eagle Eye prototype is slated to begin in 2006. With $50 million in UAV funding approved by the U.S. Congress for the Deepwater program in fiscal year 2004, the Coast Guard is on track to receive its first eight Eagle Eye systems following delivery of the National Security Cutter. Three VUAVs are earmarked for initial operational testing and evaluation, and five are slated for fleet use.

Artist's drawing of Eagle Eye preparing to land on a Deepwater National Security Cutter.
Northrop Grumman

Eagle Eye passed a critical acquisition milestone in January 2004 with the highly successful completion of its Preliminary Design Review (PDR), a required deliverable to proceed to the next stage of Bell Helicopter's contract with the Coast Guard.

The PDR ensured that Eagle Eye is responsive to the Deepwater System Performance Specification requirements. According to Bell Helicopter, the Eagle Eye system was well within margins for risk, performance, supportability, and cost allocations. The Coast Guard will validate Eagle Eye's ability to meet stated performance and mission operational requirements in the system design and demonstration phase of the acquisition program.

Eagle Eye's preliminary design is based on a 7/8-scale demonstrator of the production version that flew more than 90 hours and achieved an airspeed of 200 knots in level-cruise flight while carrying a payload of 210 pounds.

"This is a very important milestone within the Deepwater Program," said ICGS President Gerry Moorman, "and we are pleased to be able to turn the page to the next step needed to bring this new capability to reality."[4]

When modern Deepwater national security and offshore patrol cutters enter service in several years, they will typically deploy with two Eagle Eye tiltrotor VUAVs when a manned helicopter is embarked. Cutters deploying without a manned helicopter will typically carry four VUAVs. Should Eagle Eye deploy on the Coast Guard's older high- and medium-endurance legacy cutters, only two will be embarked owing to limited hangar space.

Eagle Eye will satisfy the Coast Guard's requirement for a tactical cutter-based UAV capable of bolstering surveillance and intelligence-gathering capabilities for the detection, identification, and classification of targets at ranges out to 100 nautical miles.

When it was compared to other rotary and fixed-wing UAV variants, Eagle Eye was identified as the best platform to satisfy the Coast Guard's multimission requirements. During national-defense, law-enforcement, search-and-rescue, or homeland-security missions, Coast Guard cutters require a UAV able to be launched for a fast transit out to 100 nautical miles.

TABLE 1. Eagle Eye VUAV

Eagle Eye Operational Attributes

The Eagle Eye VUAV variant offers numerous advantages during at-sea operations compared to its conventional, fixed-wing UAV counterparts: Fast dash speeds in fixed-wing mode

- Long (four hour) loiter time on target
- Vertical-landing capability for shipboard use and other areas with restricted access
- Improved control and handling while flying through the "burble" during shipboard landings owing to counter-rotating turbo-prop design
- High stability on deck; ease of access for maintenance
- Fully integrated, redundant flight-control system
- Built-in test software

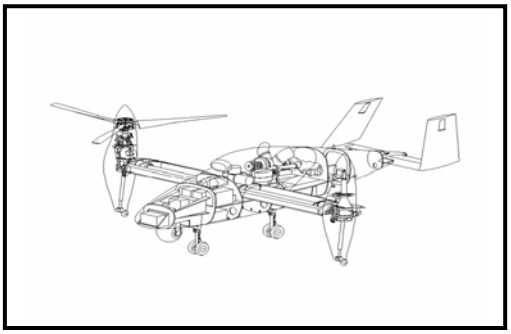
Its missions: to surveil a vast coastal or open-ocean search area, proceed quickly to intercept high-value targets of opportunity, loiter overhead if necessary, and return for a vertical landing on a small flight deck in up to sea state five conditions.

Eagle Eye's demonstrated tiltrotor technology combines the most advantageous operational characteristics of current UAVs on the market—the higher airspeed, range, endurance, and sensor payloads of fixed-wing models are available with the landing versatility of rotary-wing UAV variants.

The Eagle Eye's low center of gravity, inherent dynamic stability, and ease of access and maintenance also are appealing characteristics for shipboard use.

The Coast Guard expects that Eagle Eye will significantly improve its persistent surveillance capability—a critical factor in

the necessary ability to achieve the levels of maritime domain awareness needed to implement its layered defense-in-depth strategy for U.S. maritime homeland security. The 200-pound sensor package planned for Eagle Eye includes an EO/FLIR [electro-optical/forward-looking infrared] Star Safire III system, an air-to-air/air-to-surface/weather multimode radar, fully integrated inertial GPS (global positioning system), encryptable digital data links, and UHF/VHF radio-relay capability.



Schematic of the Bell Eagle Eye Tiltrotor VUAV
Bell Helicopter

Deepwater's ongoing C4ISR program will ensure that Eagle Eye's data stream and intelligence products can be shared widely with all Coast Guard units and other federal agencies—a critical requirement, especially during homeland-security and national-defense missions.

Eagle Eye will provide the Coast Guard with a tactical cutter-based UAV capable of bolstering surveillance and intelligence-gathering capabilities for the detection, identification, and classification of targets at ranges out to 100 nautical miles.

Improved Open-Water Surveillance

With each Eagle Eye projected to fly 1,200 hours annually, the U.S. Coast Guard estimates it will achieve a two- to three-fold improvement in its open-water surveillance effectiveness for a typical Deepwater cutter deployed with a single helicopter and two Eagle Eye VUAVs. Eagle Eye's intelligence-gathering and radio-relay capabilities also will improve safety for boarding parties and small boat crews operating at some distance from their parent cutter.

Bell Helicopter's initial flight tests (for the U.S. Navy and U.S. Marine Corps) of a $7/8^{th}$-scale operating Eagle Eye model during 1998 were instructive. Bell's design for its VUAV came in under schedule, under weight, and under budget.

Eagle Eye's safety and reliability also are forecasted to be high. Bell-Textron predicts a greater than 3,000 hour mean time between critical failure. Maintenance man-hours per flight hour are estimated at just over one hour.

Eagle Eye's operating systems are comparatively simple—a highly reliable Pratt and Whitney PW 200-55 turboshaft engine, a robust transmission (now in its final phase of test-bed testing), two short drive shafts, two 90-degree gear boxes for its variable-pitch rotors, a UCARS (UAV Common Approach and Recovery System) landing system, and an onboard computer.

Eagle Eye has no hydraulic systems; electro-servo actuators operate flight controls, and its twin tiltrotors are operated mechanically. Its innovative, retractable deck-securing system (to reduce parasitic drag) features a proven "two-claw" design suitable for the NATO landing grid that will be used on all U.S. Coast Guard cutters.

The Coast Guard plans to install the Eagle Eye's control console in a cutter's combat information center. Flight plans will be programmed prior to launching the VUAV on its mission, but a controller can easily modify Eagle Eye's route of flight, altitude, and mission profile at the control station.

On a typical mission, the Eagle Eye will be launched with a push of a button on the controller's console, rise with its tiltrotors in hover mode, begin a climb to 8,000 feet (an

optimum altitude for line-of-sight connectivity at extended ranges), transition to fixed-wing mode, and commence its programmed flight plan to search a triangular-shaped area extending well beyond the cutter's visual horizon.

TABLE 2. Eagle Eye Characteristics

Construction	All composite, fully shipboard deployable
Dimensions	
Wing span	23.6 ft
Length	17.23 ft
Rotor diameter	9.5 ft
Weights	
Prime mission payload	200 lbs
Mission payload growth	100 lbs
Propulsion	
Make	P&W 200-55 turboshaft engine
Fuel	JP/Diesel
Avionics	
Redundant Inertial/GPS	
IO/FLIR Systems Star Safire III	
Telephonics RDR-1700 multimode radar	
UAV Common Approach and Recovery System	
Performance	
High-speed dash	210 kts
Cruise speed	0 to 200 kts
Loiter speed	90 kts
Altitude	20,000 ft
Endurance	5 hours maximum, 3.0 hrs @ 100 nm

Recovery of the VUAV will be accomplished through Eagle Eye's UCARS landing system. The UCARS will interact with the VUAV's on-board computer to measure several aerodynamic and landing variables. As Eagle Eye approaches for landing, its two claws will come down to grip the flight-deck grid after touch down.

In addition to line-of-sight transmissions to its parent cutter, Eagle Eye's data could be transmitted directly to another site—a manned maritime patrol aircraft, for example, outfitted with a remote console.

The Road Ahead

The unit acquisition cost (CA) for an Eagle Eye VUAV system (two vehicles and ground control station) is $8.3 million. Annual unit operating costs are estimated at $504,000 (FY 2006 dollars). Total VUAV acquisition cost for the Integrated Deepwater System is estimated at $388.5 million. The Coast Guard's VUAV performance specification states that the VUAV "… shall have an unlimited service life."

It is anticipated that VUAVs will be scheduled for depot-level maintenance every 6,000 flight hours. When this maintenance is completed, the VUAV will return to service as a "zero-time" aerial vehicle. Mean time between removal will be in excess of 3,000 hours. System mean time between mission-critical failure is estimated to be 200 hours. Maintenance man-hours per flight hour are estimated to be one hour.

All Eagle Eye design reviews to date have been successfully completed; the VUAV's Critical Design Review (CDR) is scheduled in November. All testing (mainly VUAV subsystem components) conducted by Bell Helicopter, Textron Inc. to date have been successful and supported test-and-development design reviews. Bell Helicopter's flight-testing of the first full-scale Eagle Eye prototype is slated to begin in 2006. The current schedule projects operational testing to begin in September 2007 after operational testing and evaluation are completed for Deepwater's National Security Cutter.

At Bell Helicopter headquarters in Fort Worth, Texas, on November 5, 2003, Chief Executive Officer Mike Redenbaugh announced a major new effort to design, build, and fly a new full-scale Bell Eagle Eye before the end of 2004. Speaking to a team of aerospace engineers and manufacturing and production experts,

Redenbaugh said, "There is a strong worldwide interest in the Bell Eagle Eye, and we owe it to our customers to develop this full-scale prototype to demonstrate the full capacity of this great tiltrotor product."[5]

Bell's Director of UAV Programs Robert Dompka explained that while the one-year, flight-status goal is a challenge, "Bell has a great history of tackling ambitious projects with teams of dedicated employees—such as the great effort to produce the first Cobra attack helicopter back in the mid-1960s and, more recently, the development of the Bell 407 commercial helicopter in less than one year."[6]

Bell Helicopter's decision was based on what it described as "the remarkable success" of the 7/8-scale Bell Eagle Eye Tiltrotor VUAV prototype, according to Redenbaugh. The Bell Eagle Eye Tactical VTOL UAV Demonstrator, developed under a Naval Air Systems Command contract in the 1990s, flew at Yuma Proving Ground, Ariz. The contract required 50 hours of land-based flight tests to evaluate the performance and maturity of the aircraft and control system. The Eagle Eye Demonstrator aircraft was the first to finish the 50-hour "Land Based Flight Test Task." According to Bell Helicopter, its "flawless performance" has set the standard for VTOL UAV systems.[7]

In less than 90 days after its first flight on March 6, 1998, the single Eagle Eye Demonstrator flew 55.5 hours. It made 43 landings, 42 of which were within 15 minutes of the intended take-off time, and it completed tests that have expanded the aircraft's envelope and proven its advertised performance and technology maturity claims, Bell Helicopter said. During the tests, the flight envelope was expanded to over 14,600 feet and more than 200 knots true air speed (TAS) in level-cruise flight while carrying 210 pounds of payload plus mission fuel—exceeding the objectives substantially. Performance in the "best-endurance mission" was more than 1.7 hours on station. And in the "best-range" mission, the aircraft flew more than 315 nautical miles. Real-time target imagery was provided during the flights.

Both the aircraft and ground control station met every scheduled flight in a regimented two-hour range test period. Maintenance requirements (other than pre-flight checks) were almost nonexistent according to Bell Helicopter. The Eagle Eye Demonstrator executed all applicable demonstration objectives, and expanded the aircraft's flight envelope substantially.

TABLE 3. Eagle Eye Demonstrator

Bell Eagle Eye's 7/8th-Scale Demonstrator

- Routine VTOL take-off and landings to a 24-foot helicopter landing area;
- A launch-and-recovery accuracy better than the required 9.8ft.;
- Automated hover and landing in winds gusting to 32 knots;
- Stable hover out of ground effect at 1,100 feet MSL in 95° temperatures while carrying 210 pounds of payload and 350 pounds of fuel;
- Recovery at take-off gross weight;
- The ability to fly at speeds between 0 and 150 knots. (202 knots TAS cruise achieved with less than 90% power); and cruise at 14,600 ft. with a 200-pound payload.

The Navy's program office assessed the contractor's ability to provide the Demonstrator's required performance data. at 95 percent. According to Bell Helicopter, the next-best platform was rated 60 percent. Bell claims it can provide its VUAV capability to the military services as a relatively low-cost, low-risk process since most of the components are off-the-shelf man-rated helicopter parts.

Bell developed Eagle Eye's state-of-the-art, fully integrated redundant flight control system, which incorporates highly automated flight control and built-in test

software, as well as fully integrated surface-mount circuitry.

Rules of the Road

Although the U.S. Federal Aviation Administration (FAA) has not issued airworthiness certification regulations regarding UAV operations, the Coast Guard is anticipating that it will be required to certify Eagle Eye for operations in controlled U.S. airspace. The Coast Guard has established a working group (that includes representatives from ICGS and Bell Helicopter) to address FAA requirements and develop risk-mitigation. These operations include monitoring of, and participation in, FAA and other studies on UAV operations.

Because the Coast Guard regularly operates in U.S. coastal waters and controlled civil airspace, FAA certification will likely be needed to permit routine domestic operations when Eagle Eye is introduced to the Coast Guard's inventory. It is envisioned that the Coast Guard will seek to satisfy the FAA's requirements for safety and "see-and-avoid" airspace deconfliction through a combination of the Eagle Eye's multimode air-to-air radar, its EO/FLIR sensors, controller qualifications, and operational procedures.

UAV operations are currently allowed in non-special-use airspace provided a certificate of authorization (COA) is granted by an FAA regional office. COAs are granted on a case-by-case basis for a limited time period. For UAV airspace, the FAA issued Order 7610.4J for special military operations that details the requirements for operating UAVs in the national air space system.

The Coast Guard, working in collaboration with Integrated Coast Guard Systems, is continuing to study and coordinate with the FAA, the Department of Defense, and other airspace-deconfliction teams to determine the most effective approach to operate Eagle Eye safely under positive control in civil airspace. Among the options under consideration are patterning controller qualifications on FAA certification requirements for operating manned aircraft in controlled airspace or assigning a "mission commander" to a VUAV detachment possessing similar qualifications.

No decisions have been made, and the Coast Guard is not prepared to say which option is preferable until ongoing studies are completed. What is clear is that the policies and procedures eventually developed by the Coast Guard for its VUAV operations will ensure that Eagle Eye satisfies both Deepwater and FAA requirements for it to be operated safely in controlled airspace.

In addition to its “rules of the road” for operating UAVs in controlled airspace, Eagle Eye will have other safety features incorporated, including a built-in safety procedure for control so that if it loses its radio link it will go into a safety mode and try to reestablish contact. If the VUAV does not regain contact after a certain amount of time, it will return to a predetermined site—normally the ship.

The Coast Guard’s commitment to achieve necessary safety-of-flight standards in controlled airspace mirrors similar experiences in other branches of the U.S. armed forces. In addition, each service seeks to ensure a common approach and standards for operations, command, and control according to a study group organized by the National Defense Industrial Association.[8]

The Department of Defense is working on a new UAV roadmap to cover the rapid growth in UAV programs. According to Dyke Weatherington, the Deputy of the UAV Planning Task Force at the Office of the Secretary of Defense, the document will be updated by mid-2005.[9]

Interest Growing

Not surprisingly, the U.S. Department of Homeland Security, other branches of the U.S. armed forces, and the international community have expressed interest in the Coast Guard's Eagle Eye program. Representatives from the Australian and German armed forces already serve on Deepwater's VUAV program team under a Memorandum of Understanding. Opportunities for foreign collaboration are coordinated by Deepwater's International Office and the U.S. Navy's International Program Office.

In fiscal year 2004, the Coast Guard received a $10 million budget plus-up to permit the evaluation of land-based UAVs in support of its missions. In early November 2003 the Coast Guard deployed a pair of Predator A UAVs to King Salmon, Alaska, to demonstrate the logistical requirements necessary to support a large-scale exercise planned for June and July 2004.

The success of last autumn's exercise laid the foundation for this summer's event, which will use the more capable Altair UAV outfitted with a sensor suite that will enable high-altitude surveillance and reconnaissance. Additional modeling and simulation will then be conducted using data obtained during the exercise. It is expected that this modeling and simulation will lead to a more rigorous method to evaluate the utility and cost savings of employing unmanned aerial systems to meet the Coast Guard's mission needs.

Efforts also are in motion to ensure Eagle Eye will be more interoperable with the UAVs of the other armed services, but the specific degree of interoperability has not been defined at this time.

Eagle Eye's VTOL capabilities, speed, and endurance also have attracted the attention of the U.S. Marine Corps. Senior Marine officials are said to be interested in evaluating the Eagle Eye to determine its suitability for replacing its inventory of RQ-2 Pioneer fixed-wing UAVs in operation since the 1980s.[10] Eagle Eye's VTOL capabilities make it clearly appealing for use on ships assigned to Expeditionary Strike Groups, as well as with Marine units ashore.

CONCLUSION

The U.S. Coast Guard's affiliation with aviation began more than a century ago when surfmen from the Kill Devil Hill, N.C., Lifeboat Station assisted the Wright brothers during their epic first flight in 1903. The only photograph of that historic event, in fact, was taken by Surfman J.T. Daniels.[11]

Throughout its history, Coast Guard naval aviators—proudly wearing the same "wings of gold" as their Navy and Marine Corps counterparts—have displayed rich quantities of innovation, aeronautical prowess, and heroism while operating in the often harsh maritime environment.

Be it the pilot of the first aircraft to cross the Atlantic Ocean (Coast Guard Lt. Elmer Stone, piloting the U.S. Navy's NC-4 seaplane in May 1919), or his successors in the post-World War II era who pioneered the use of the helicopter for at-sea search-and-rescue missions, to today's use of armed helicopters to safeguard America's security and sovereignty, Coast Guard aviators boast a proud legacy of innovation and mission achievement.

For this reason, it seems appropriate that at a critical watershed in the service's 214-year history, Coast Guard aviation will enter a new era when the MV-911 Eagle Eye arrives on station to begin unmanned aerial operations.

Given the imperative to restore the Coast Guard's operational readiness and boost its capabilities and capacity to meet the nation's urgent defense and homeland security requirements, there is, to quote novelist Patrick O'Brien's Capt. Jack Aubrey in *Master and Commander,* "Not a moment to lose."

ACKNOWLEDGEMENTS

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