COLORADO

Center of Excellence for Advanced Technology Aerial Firefighting

Department of Public Safety

2018–2019 Honda Autonomous Work Vehicle Research Report

CoE 19-001

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Purpose

This report describes the research conducted by the Center of Excellence for Advanced Technology Aerial Firefighting (CoE) on the Honda Autonomous Work Vehicle in wildland firefighting support scenarios.

Overview

Figure 1—High Park Fire in June 2012 seen from Louisville, CO (about 42 miles distant).

Honda announced the concept of the Autonomous Work Vehicle at the 2018 Consumer Electronics Show. Part of that announcement was an invitation for organizations to submit proposals for development and testing. Based upon that, the CoE contacted Honda to discuss opportunities to identify real-world applications in wildland firefighting. Honda asked the CoE to participate in a survey regarding opportunities and Garrett Seddon (CoE Unmanned Systems Projects Manager) completed the survey. Afterward, the CoE provided a research proposal to Honda focused on investigating opportunities in wildland firefighting in Colorado. In the proposal, the CoE highlighted our direct knowledge of wildland firefighting; access to possible testing locations, including potential access to past burn areas; and other benefits of testing the prototype with our organization. Three team members from Honda Research and Development (R&D) Americas, Inc. visited Colorado and met with CoE Deputy Director Robert Gann and Garrett Seddon, as well as toured the High Park Fire burn area to get a better understanding of the demands that wildland firefighting would place upon the Autonomous Work Vehicle. During those meetings, the CoE was able to provide realistic guidance to Honda in terms of the level of autonomy required, as well as typical missions and terrain that the vehicle would need to negotiate. It became clear, relatively quickly, that the level of autonomy required was potentially lower and the terrain

Figure 2—Initial fire behavior on the Lake Christine Fire

was perhaps less challenging than Honda initially expected. The result of this interaction was that Honda chose the CoE as one of three U.S. research partners.

In the fall of 2018, Honda brought two Autonomous Work Vehicle prototypes to Colorado to test in the state's wildland fire environment. Four team members from Honda R&D in Ohio and two from Honda R&D in Japan visited the CoE and the organizations jointly performed test missions at the Lake Christine Fire site. The CoE coordinated with the Lake Christine Incident Command and with Colorado Parks and Wildlife regarding testing in the Lake Christine Fire area. All testing was performed on State lands and in areas closed to the public. The goal was to test and understand the capability of the Honda Autonomous Work Vehicle in conditions as close as possible to actual wildland fire conditions, albeit after fire operations had concluded.

Figure 3—Honda Autonomous Work Vehicle at the 2019 Consumer Electronics Show in Las Vegas, NV

In addition to testing, the Honda public relations team filmed members of the Colorado Division of Fire Prevention and Control (DFPC) Montrose engine crew and CoE team members to produce the wildland use-case video to publicize worldwide. The video was highlighted at the 2019 Consumer Electronics Show. While video and publication were certainly important parts of the testing process, the primary goal of Honda R&D and the CoE was to explore three missions and allow Honda R&D to gather data regarding operations of the Autonomous Work Vehicle in wildland fire and public safety environments.

Missions

The three missions the CoE proposed and tested were:

- initial attack support for dismounted firefighters
- support of active fireline development
- autonomous deployment of a communications repeater to a remote site

Initial Attack Support for Dismounted Firefighters

This mission would require the unmanned ground vehicle (UGV) to directly support firefighters operating on foot prior to and during the construction of fireline during initial attack operations. This support would consist of the UGV carrying fire packs, chainsaws, saw fuel, and potentially hand tools and other supplies. The UGV would closely team with firefighters in this scenario and would follow just behind personnel as they hike into a fire and as they work to contain the fire through the digging of fireline. The carrying of fire equipment would relieve

the physical stress on firefighters and allow them to dig fireline and cut trees more quickly than is currently possible. The UGV would not necessarily have access to roads or trails under this scenario and, as a result, would have to travel at least part of the mission cross-country. Firefighters could provide some support to the UGV, such as removing downed trees; however, the vehicle would have to traverse off-camber terrain and overcome minor obstacles.

Support of Active Fireline Development

This mission would require the UGV to support firefighters in the suppression of a wildfire once a fireline has been created, which would ease the ability of the vehicle to travel autonomously. Once a fireline has been created, firefighters often require substantial amounts of equipment to put a fire out, including chainsaw gas, food, water, and—most notably—fire hose. Fire hose lays can be over 1 mile in length and require additional lateral hoses, appliances, and nozzles to spray water. To reach the firefighters, the UGV would make autonomous trips from a road or resupply point along a fireline created either by hand or by bulldozer. Cargo would be delivered by the UGV during each trip, relieving firefighters from having to carry these heavy loads over long distances. Alternatively, the UGV could come equipped with a tank, pump, and hose and would be used by firefighters to directly suppress the fire; the UGV would then autonomously travel to a point where its tank could be refilled with water.

Autonomous Deployment of a Communications Repeater to a Remote Site

This mission would require the UGV to team with a communications technician to ascend a mountain or ridge and establish a communications repeater site. The site would remain active for several days, requiring the UGV to conserve power or otherwise work to sustain operations over a long period of time. Key to this scenario would be the UGV's ability to autonomously execute a mission to descend from the site back to a road or safety zone. This would be pertinent if the wildfire began to grow to the site, particularly since this ability would preserve valuable communications equipment and prevent a human from being placed in harm's way to retrieve the equipment. The UGV could also be required to descend and ascend to the repeater site to allow technicians to replace batteries, fuel the UGV, or configure radios onto the vehicle.

Operations Summary

CoE and Honda R&D personnel conducted field tests October 2–4, 2018, at the site of the Lake Christine Fire near Basalt, Colorado.

Figure 4—Honda Autonomous Work Vehicle navigating terrain on the Lake Christine Fire in Basalt, CO

Day One

The first day of field testing started with area familiarization. The CoE showed Honda the equipment storage location and

staging area and conducted a survey of the field test locations to identify the starting location. The area received a significant amount of rain on the day prior to testing, as well as on the first day onsite, which created some safety concerns regarding driving vehicles on muddy roads. In addition, the team did not want to damage the area and create further erosion risk. For this reason, staging was conducted at a lower area that was accessible via a gravel road. In addition, only smaller vehicles and the Autonomous Work Vehicles proceeded further into the burn area. The CoE and the Honda R&D team walked potential testing areas and discussed the scenarios and how the Autonomous Work Vehicle would fit into those scenarios. We also assessed the level of autonomy required by the vehicles. Finally, the Honda R&D team began testing the Autonomous Work Vehicle on terrain and collecting data. The Honda team conducted about six runs up steep terrain to collect data and identify differential-lock needs.

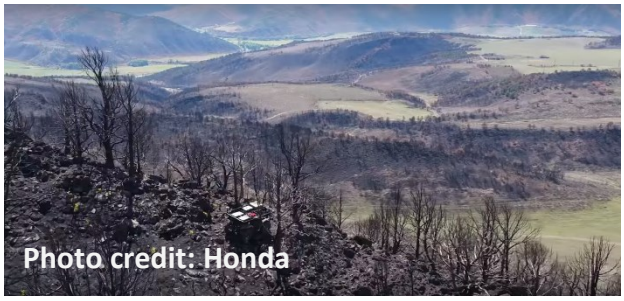

Figure 5—Honda Autonomous Work Vehicle navigating to a communications repeater site on the Lake Christine Fire in Basalt, CO

Day Two

The second day of field testing started in the same location as day one. Honda used some of the data gathered on day one to make some changes for day two. Honda conducted about four runs up the same terrain with the differentials locked. Day two of testing saw significant improvement in terrain-handling capability. Honda remotely controlled both Autonomous Work Vehicles up the access road to the location of the communications repeater site. The data collected along a segment of the road was later processed overnight to test the autonomous feature on day three. The Autonomous Work Vehicle handled the terrain of the road and off-road conditions well. The Honda public relations team joined the group to begin filming. Honda performed three off-road runs at this location before operating the vehicles back to the starting point via the access road.

Figure 6—The DFPC Montrose Engine Crew working with the Honda Autonomous Work Vehicle

Day Three

The third day included significant filming of CoE and DFPC personnel. One Autonomous Work Vehicle was used for filming and the other compiled data for the autonomous operation along the access road. The Honda public relations team conducted interviews and filmed the

DFPC Montrose engine crew working with the Autonomous Work Vehicle. Input was gathered from the DFPC Montrose engine crew on what they would expect from the Autonomous Work Vehicle in a real firefighting situation. After filming, the Honda R&D team focused on preparing the vehicle for an autonomous run. Honda completed an autonomous run along the access road with good success and then continued to operate the vehicle to gather more data.

Autonomous Vehicles

Figure 7— Honda Autonomous Work Vehicle at the Lake Christine Fire burn area

Autonomous Vehicles have been around for a while, whether it is in reference to machines performing tasks, self-driving cars, or unmanned aerial systems. Not many companies are focusing on autonomy for ground vehicles in off-road situations. In most cases, the task being performed by a robot autonomously is in a controlled environment with minimal variables. When it comes to automobiles, more variables do exist, but they have more infrastructure in place to help the cars make decisions (such as painted lines or shared information from other automobiles). Choosing a path with fewer obstacles and navigating uneven terrain autonomously is more of a challenge than is present in the current autonomous vehicle environment. Honda's Autonomous Work Vehicle is trying to overcome this challenge.

Figure 8—Honda Autonomous Work Vehicle operating in autonomous mode on a dirt road at the Lake Christine Fire burn area

The principle of the Autonomous Work Vehicle navigating wildfire terrain to assist firefighters is an exciting one. The apparatus can be operated in four different modes: remote control, learning, follow me, and autonomous mode. During the field testing, the Autonomous Work Vehicle was operated by using a remote control to navigate. While in remote control mode, data was collected to teach the software what it is able to navigate. The Honda R&D team was able to demonstrate the learning mode, in which they taught a route to the

Autonomous Work Vehicle along an improved road. It performed the task well with some minor inputs.

Safety

The utilization of all-terrain vehicles (ATVs) has declined over the years in the fire industry due to safety concerns; instead, firefighters currently use utility vehicles (UTVs) with seatbelts. ATV rollovers and speed-related incidents are the primary cause of ATV-related injuries on fires. In addition, ATVs have enabled firefighters to attempt terrain beyond safe limits and to carry passengers in unsafe conditions. The fire industry has trended towards UTVs as they are safer for the operator; however, even with the UTV, significant training and certification is required. The Honda Autonomous Work Vehicle removes the person from the ATV, which increases operator safety. In addition, by offloading firefighters of heavy gear, trip-, fall-, and sprain-type injuries are reduced while effectiveness is improved.

Figure 9— DFPC Montrose Engine Crew loading the Honda Autonomous Work Vehicle for a test run carrying equipment

Conclusion

The Honda Autonomous Work Vehicle showed great potential to assist firefighters with carrying equipment and supplies, thus reducing fatigue and injuries associated with those tasks; it also showed potential as a remotely deployed communications repeater. Honda was able to test the Autonomous Work Vehicle in terrain that they have never tested before, which led to Honda's observation that the data gathered in the CoE tests was extremely valuable and unique. In fact, Honda took lessons learned and data collected from the tests at the Lake Christine Fire site and is using it to develop the next prototype to test in Colorado. The conclusion was that since the Autonomous Work Vehicle is capable of accomplishing wildland firefighting missions in Colorado, that it could handle almost anything.

With additional development in autonomy, navigation, and interchangeable payloads, the Honda Autonomous Work Vehicle could provide a useful platform for wildland firefighters. Specifically, the vehicle's ability to autonomously navigate terrain would mitigate the need for firefighters to carry heavy equipment for long distances. The ability for the vehicle to become an autonomous equipment or supply hauler would be a force multiplier. Additionally, the vehicle's ability to carry interchangeable payloads—such as water tanks, hose reels, or plow attachments—would facilitate the successful performance of wildland firefighter duties.

Future Collaboration

As Honda continues development of the Autonomous Work Vehicle, the potential for future testing in Colorado throughout 2019 is highly probable. The CoE will continue to research potential use cases (such as digging a fireline with a hitched implement) and will conduct further field tests with Honda.

Appendix A—Original CoE Proposal to Honda

Author's Note: For completeness of documentation, this appendix includes the original proposal provided to Honda by the CoE. The final work differs in some ways from what was proposed and much of this appendix duplicates the material in the main body of the report.

Project Proposal

The Center of Excellence for Advanced Technology Aerial Firefighting (CoE) proposes to test and evaluate the Honda 3E-D18 autonomous all-terrain vehicle within the Colorado Division of Fire Prevention and Control (DFPC) to assist firefighting and emergency operations. The CoE will provide the access to firefighting operations to test and evaluate the apparatus's applicability to wildland fire and other emergency response operations. The Honda 3E-D18 will be used to support operational efforts with the intent to increase safety, efficacy, and efficiency on wildland fires and other emergency operations. Specific tasks to be evaluated are discussed further below.

Background

The CoE is part of DFPC, whose mission is to protect the citizens, land, and resources in Colorado. The CoE is tasked with developing, evaluating, and deploying advanced technologies to support wildland fire and other emergency operations.

The CoE was created by Senate Bill 14-164. During the legislative session, proponents of the CoE explained that there was, at the time, no mechanism for determining the efficacy of aerial firefighting practices, so a need existed for an innovative, science- and data-focused research entity. For this reason, the CoE is essential to ensuring the safety, efficiency, and sustainability of Colorado's aerial firefighting program. While the CoE's title indicates a focus on aerial technology, in practice the CoE is authorized to focus purely on technology.

Studying the potential of the Honda 3E-D18 to autonomously support wildland fire and emergency response operations is clearly within the purview of the CoE and is, in fact, an area the CoE has recognized as ripe for development.

Honda 3E-D18 Program Objectives

Objective 1

Identify, test, and evaluate firefighting operations that the Honda 3E-D18 can support. Potential tasks include, but are not limited to, autonomous cargo delivery (water, supplies, etc.); personnel evacuation, including medevac; intelligence, surveillance, and reconnaissance operations; mobile communications support (i.e., deploying a repeater); or direct fire suppression using water or other extinguishing agents.

Objective 2

Collect data on successes and failures with the intent to improve the use of the 3E-D18 for firefighting operations. CoE personnel and firefighters will test the 3E-D18 on wildland fire operations or training events and report on the findings.

Objective 3

Make recommendations regarding the deployment of the Honda 3E-D18 for emergency operations.

Approach

The CoE will perform research and identify how the Honda 3E-D18 could supplement existing operational efforts. The CoE will report the findings to the Honda Research and Development (R&D) team for review. After the findings are agreed upon, the CoE and Honda R&D will coordinate testing scenarios or potential live incidents to test and evaluate the apparatus in Colorado. Tests will be both operational (i.e., actual deployments) and structured (i.e., planned tests/events).

The CoE will gather objective, quantitative, and qualitative data based on 3E-D18 operations. When possible, the CoE will perform direct and measured comparisons with current methods with the goal of measuring the improvements or detriments to operations. The CoE will also conduct surveys of DFPC personnel to identify successes and areas for improvement within their respective operations.

Program Deliverables

The CoE will provide a final report to Honda R&D with the findings from the study. This report will be public, but the CoE can protect proprietary information.

CoE Contribution

The CoE can provide access to training and/or live events to test and evaluate potential capabilities of the Honda 3E-D18. The study will result in an understanding of whether the 3ED-18 could serve the wildland and emergency response community in a practical and cost-effective manner.

The CoE has five wildland-fire-qualified research personnel to support the study and provide access to DFPC firefighting resources. In addition, the CoE staff includes members with extensive wildland fire and law enforcement experience. DFPC resources include seven three-person engines, one five-person squad, two helitack crews, two Multi-Mission Aircraft, and various fire management staff. In addition, the CoE will work with local firefighting partners (i.e., local fire departments), local law enforcement, and local search and rescue, as well as with federal partners (i.e., the U.S. Forest Service, the Bureau of Land Management [BLM], and the U.S. Department of the Interior).

CoE Facility

The CoE office is located at the Rifle Garfield County Airport in Rifle, Colorado. The airport is an active base for aerial fire operations and also hosts BLM Rifle Helitack, as well as an interagency fire department. The CoE has rapid access to remote areas on public and private land and is centered in a region of Colorado with high wildland fire incidence and outdoor recreational activity. The CoE has secure office space available that Honda personnel could utilize free of charge, which would include free high-speed Internet access. The nearest commercial airport is in Grand Junction, Colorado (approximately 1 hour away). The CoE facility is 3 hours west of Denver, Colorado.

Budget

While the CoE does not have a dedicated research budget for this project, funding exists to support our personnel and administrative costs, as well as to lease office space (including office space we can provide to Honda personnel). We do have some discretionary funding we can apply to research projects and we also have limited prototyping capability. In addition, the CoE is authorized to accept tax-deductible donations and grants. Honda donations can be considered tax-deductible.

Program Timelines

To be determined by the CoE and Honda R&D.

Current Projects

Aerial Application of Water Enhancer Study

Water enhancers (commonly referred to as gels) have been limited in their operational use in recent years. The CoE, with support from DFPC's Aviation Unit and BLM, is conducting a study of data from the 2017 and 2018 wildland fire seasons to evaluate the effectiveness of water enhancers on wildfires. This is being accomplished by using single-engine air tankers to test three products.

Colorado Fire Prediction System

On May 20, 2015, Governor John Hickenlooper signed House Bill 15-1129 into law. This House Bill directs DFPC, through the CoE, to establish and support a Colorado Wildland Fire Prediction and Decision Support System. When implemented, the Colorado Fire Prediction

System will be able to predict fire extent, spread rate, heat release, winds, temperature, humidity, smoke concentration, and aviation hazards up to 18 hours in advance.

Data Link

The CoE is working to provide map-based situational awareness to firefighters and other first responders when traditional Internet access is unavailable or unreliable. Much of the CoE's work in this area has focused on the Team Awareness Kit (TAK). TAK is a geospatial mapping engine, originally developed for the Android operating system, that facilitates situational awareness, navigation, and data sharing.

Night Aerial Firefighting Operations

The CoE is investigating the goal of bringing safe, effective, and efficient night aerial firefighting operations to Colorado.

UAS Program

To facilitate the integration of unmanned aerial systems (UAS) into firefighting and public safety operations, the CoE is conducting research to evaluate the use of UAS in Colorado public safety operations. The CoE is evaluating different platforms, sensors, and software to develop information that can be used to help emergency agencies make informed decisions about how to utilize this technology effectively.

Personnel

Ben Miller, Director

Ben spent the first part of his career with 15 years of service at the Mesa County Sheriff's Office. Ben was the founder and program director of the first operational UAS program for a non-federal public safety agency in the United States. Throughout the industry, Ben is regarded as a thought leader on the applications of small unmanned aircraft in public safety. Beyond unmanned aircraft, Ben spent the latter part of his public safety career researching, testing, and evaluating public-safety-related technologies that increase safety and efficiency for first responders.

Bob Gann, Deputy Director

Dr. Gann is a Colorado native who received his PhD in Electrical Engineering—with an emphasis on semiconductor materials, physics, and spectroscopy—from Colorado State University in 1986. After joining Hewlett Packard, Bob shifted his emphasis to digital image capture and processing and worked in that field as a research scientist and product developer for nearly 30 years. In recent years, Bob worked in the intellectual property field assisting companies with the development, marketing, and defense of patents. In addition, Bob is both an inventor, with 17 imaging-related U.S. patents to his name, and a published author. Bob's firefighting career started in 1986 when he joined the Rist Canyon Volunteer Fire Department (RCVFD). Bob became Chief of RCVFD in 1992 and continued in that position (with one short break) until he retired from RCVFD in October 2015 to join the CoE.

Adam Trojanowski, Economic and Policy Analyst

Adam received a Juris Doctor degree from the University of Colorado Law School in 2004. After law school, Adam worked as a law clerk for a district judge in Colorado's 2nd Judicial District. Following his clerkship, Adam entered private law practice with a Denver law firm, specializing in real estate and lending transactions. However, Adam quickly found that he was more motivated by public service, so he became a police officer in 2007 and a police sergeant in 2012. During his police career in the Denver metropolitan area, Adam served as a patrol officer, firearms instructor, field trainer, and supervisor.

Dave Toelle, Aerial Firefighting Expert

Dave's career in wildland fire began in 1976 and he has primarily worked in BLM and U.S. Forest Service wildland fire programs since then. Dave completed the required Technical Fire Management coursework through Washington Institute and Colorado State University from 1994–1996. He has also served actively on Type 1 and Type 2 Incident Management Teams in the Northwest, Southwest, and Rocky Mountain regions as an Air Tactical Group Supervisor and Air Support Group Supervisor.

Brad Schmidt, Wildland Fire Technology Specialist

Brad joined DFPC in May 2015 as a helicopter crew member, supporting fire-suppression efforts in Colorado and other states through an exclusive-use helicopter module. Prior to joining DFPC, Brad worked for the Wyoming State Forestry Division as part of the Wyoming State Helitack crew, an interagency state-sponsored helicopter module. In his role as Wildland Fire Technology Specialist for the CoE, Brad focuses on projects related to geospatial and communications issues that affect wildland fire management. Brad has a master's degree in Public Administration and Environment/Natural Resources from the University of Wyoming.

Jessica Harstad, Program Assistant

Before beginning employment with DFPC in July 2015, Jessica Harstad worked as a technical editor on a U.S. Department of Energy contract. Jessica graduated summa cum laude from Colorado Mesa University in May 2013 with a bachelor's degree in English Literature. In addition, she received her associate's degree in Paralegal Studies from Kaplan University in December 2006 and spent a number of years working as a legal assistant for law firms on both the Western and Eastern Slopes of Colorado.

Garrett Seddon, Military and UAS Integration Specialist

Garrett has a Bachelor of Science in Aviation Management and an Associate of Applied Science in Aviation Flight from Southern Illinois University. He is also a certificated flight instructor with over 10 years of experience in the aviation industry. Before working at the CoE, Garrett worked in airport management at the Kissimmee Gateway Airport in Florida and the Aspen/ Pitkin County Airport in Colorado. While working in airport management, Garrett ensured airfield safety and compliance with the Federal Aviation Administration through safety oversight and Aircraft Rescue Firefighting. In 2009, Garrett commissioned in the United States Army into the Adjutant General Corps. He has served in the Colorado Army National Guard as

a human resource manager for multiple units and is currently the Commander of the 104th Public Affairs Detachment located on Buckley Air Force Base in Aurora, Colorado. In his current role as the Military and UAS Integration Specialist, Garrett manages the UAS program to integrate UAS into firefighting and other emergency operations.