Undergraduate Thesis Prospectus

Development of a Search-and-Rescue Drone Constellation Interface

(technical research project in Systems Engineering)

How the Hiking Community Leads to Lost Adventurers and Lost Lives

(sociotechnical research project)

by

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November 2, 2020

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.
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STS advisor: Peter Norton, Department of Engineering and Society

General Research Problem

What factors contribute to effective search and rescue?

From 1985 to 2017, the number of search and response (SAR) cases called in to the U.S. Coast Guard decreased by 74 percent. Yet within the same time frame, the "lives lost" count has only decreased by 54 percent (BTS, n.d.). This is despite a number of impressive technological advancements since 1985, like the internet, smartphones, and commercially available drones. So why is there a discrepancy?

Efforts to improve SAR have prioritized locating victims quickly (Alotaibi et al., 2019). According to Heggie & Amundson (2009), hiking makes up 48 percent of SAR calls and 22.8 percent of reported deaths. Because National Park attendance is at an all-time high and hiking is growing in popularity (Vollman, 2019), total risk exposure is rising. To save lives, the experts who administer SAR programs must better understand SAR requirements and the behavioral factors that contribute to risk taking among hikers.

Development of a Search-and-Rescue Drone Constellation Interface

What is the optimal interface design to facilitate effective search and rescue utilizing a drone constellation?

The success of a SAR mission is highly dependent on search time (Dinh et al, 2019). Currently, for wilderness scenarios, older methods of SAR that are heavily reliant on ground teams are being utilized (Bryant, 2008). These methods lead to longer search times and can potentially increase the number of lives lost. Use of unmanned aerial systems (UAS) may enhance SAR missions by reducing search time and supplying aerial support during the search process (Dinh et al, 2019).

Commanding Unmanned Assets for Search and Rescue (CUASAR) is a year-long capstone project advised by Gregory Gerling in the Department of Engineering Systems and Environment and sponsored by the Johns Hopkins University Applied Physics Laboratory (APL). At a high level, the purpose of CUASAR is to expedite and lower the risk of civilian lives lost despite SAR efforts through phone signal detection.

The project will be focused on designing the user interface (UI) for the drone operator. The team's contribution to the UI is centered around the pre-launch and in-flight configurations of a fleet of SAR drones. This interface will represent spatial and temporal elements of the SAR process as conducted by a constellation of drones detecting mobile phone to locate missing adventurers. Developing algorithms is outside of the scope of the project, but the team will be utilizing independently developed algorithms that the drone will be equipped with to inform the design of the UI. The main algorithm that the drones will be equipped with is known as the dynamic co-fields method (DCF). The DCF dictates how the drone navigates a search area (Fig. 1). CUASAR uses human-machine teaming between the drones and the operator as well as human-human teaming between operator and ground team to serve the overarching SAR mission.

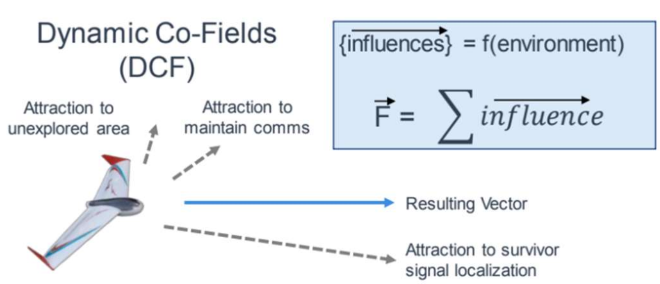

Figure 1. Drone Autonomy Algorithm: Individual drones navigate using dynamic co-fields to balance multiple influences. (Image from John's Hopkins University Applied Physics Lab, 2020)

As the project is interface design, no physical resources are needed; the team will complete their work through online collaboration platforms including Google Drive and a web-based interface design tool known as Figma™. Additional resources available for this technical project include support from sponsors at APL and guidance from technical advisor Gregory Gerling. As shown in in Figure 2, the team has already defined the scope of the project and

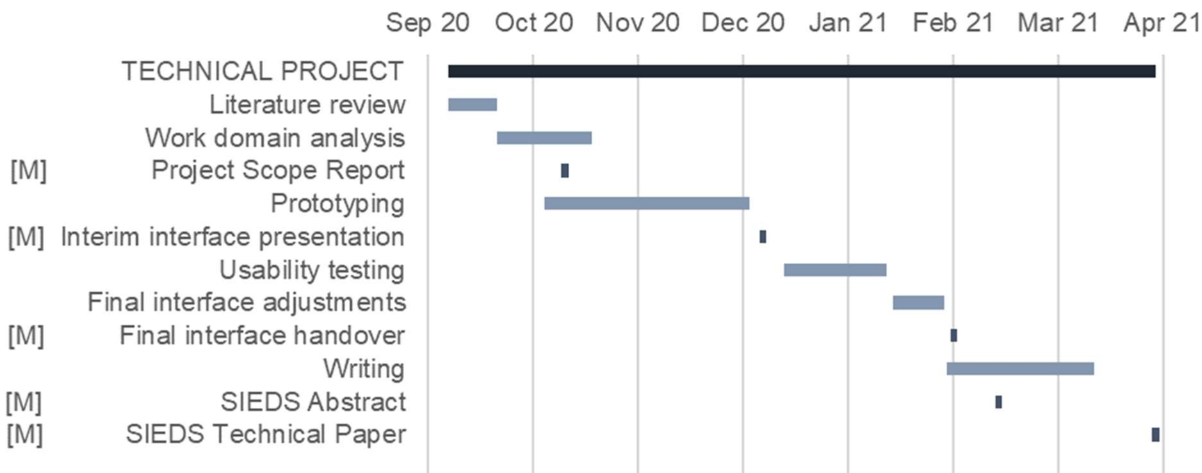

Figure 2. Proposed Research Timeline: Tasks and milestones (M), which include both internal and external deliverables (Sarah Zhou, 2020).

performed work domain analysis to understand the problem. The most recent iteration of the work domain analysis is shown in Figure 3. This figure will continue evolving with the team's understanding of project requirements set by APL. Currently, the project is in the iterative design phase, in which prototypes are created and refined with client input. A solid working prototype will be finished by the end of the fall semester and submitted to the client for review and usability testing. At this point, the team will present the client with a working prototype interface that they can use for user experience testing. Final adjustments to the interface will be made in January and early February. The project team will also be participating in the IEEE Systems and Information Engineering Design Symposium (SIEDS) in which they will submit an abstract and paper, presentation, and poster, contingent on the abstract being accepted.

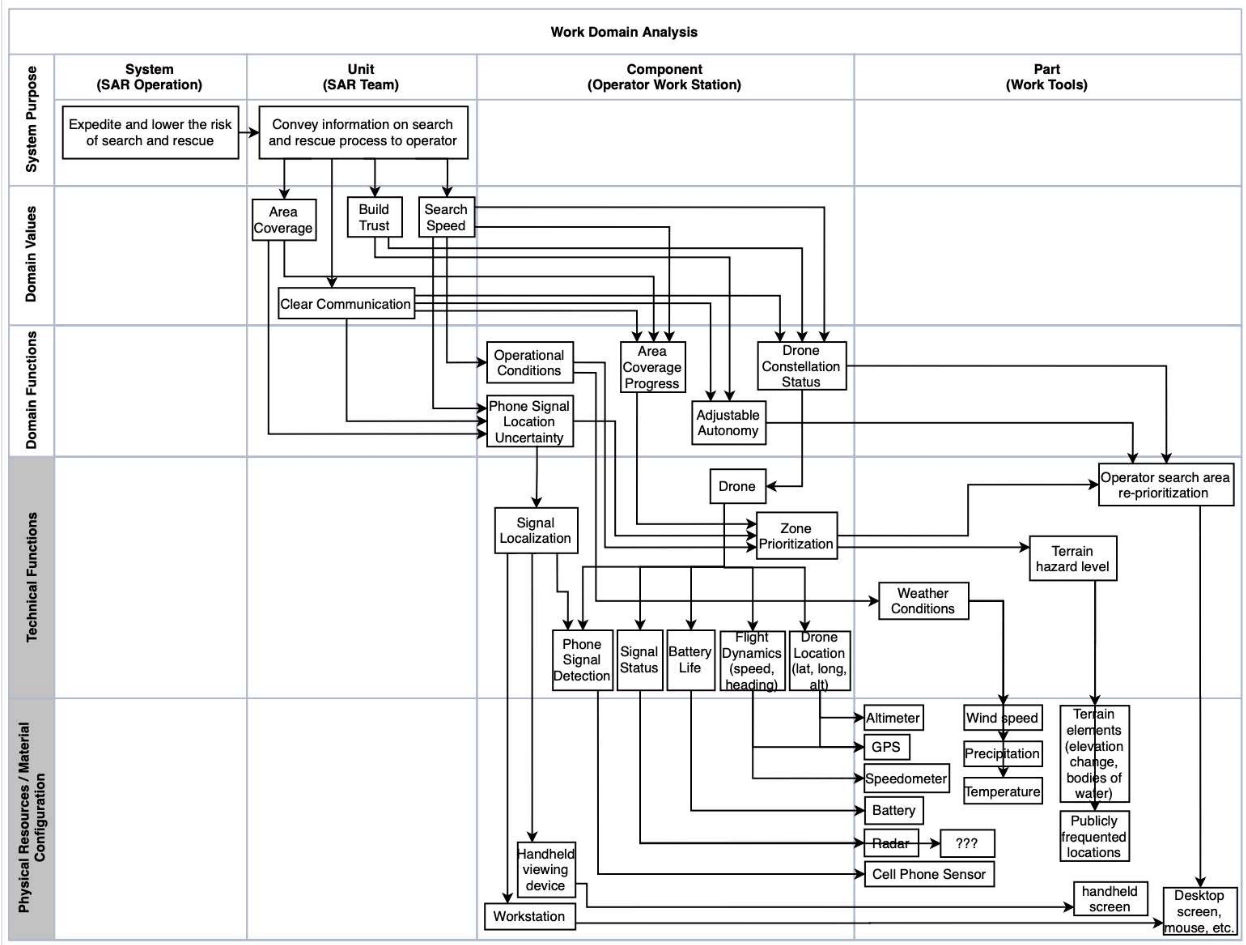

Figure 3. Work Domain Analysis: Used to build understanding of the system's problems and needs at different levels of abstraction (Author, Troy Anderson, Katherine Fogarty, Hannah Kenkel, & Sarah Zhou, 2020)

Risk Taking in the Hiking Community

Among hikers, given the attractions of risk and the improving capacities of digital navigation and of search-and-rescue techniques, how do hikers and park authorities compete to draw the lines between worthy and unworthy hiking risks, and between responsible and irresponsible hiking?

SAR continually improves, yet the number of calls and operators needed continues to rise (Brown, n.d.). Hikers' perceived risk may vary widely from their actual risk. When hikers are aware of safety measures, they perceive less risk. Hikers tend to compensate by taking greater risks themselves, a behavioral response that negates at least some of the benefit of the safety measures. This effect is called *risk compensation* (Lund & O'neill, 1986). As hikers' perception of risk goes down, decisions they would have regarded as rash become decisions they regard as reasonable. To members of the outdoors community, safety is but one value in competition with others. Among hikers, the experience of natural majesty is worth a degree of risk (Parmeter et al., 2018), and to some, risk is itself an attraction.

Participants include two main classes of adventurers: thrill seekers and the risk-minded. Thrill seekers are often prone to taking risks and braving dangerous conditions because “they had committed to making it all the way through” (Hanks, 2014). However, the risk-minded are more likely to take measured risks and rarely overestimate their abilities. In a risk-minded hiking guide, Montem (2018) recommends that prospective hikers “think carefully about your capabilities before selecting the best trail.” To the risk-minded, hikers must not exceed their capabilities; thrill seekers strive to increase their capabilities by exceeding them.

Additional participants include personnel tasked with promoting adventurers' safety: SAR operators (CCGSR, 2020), who respond to emergencies, and park authorities, such as the National Park Service (NPS) (NPS, 2020), who take a more preventative role. SAR operators primarily track down lost persons and bringing them back safely. Most are volunteers whose sole mission is to save lives. Kristia Check-Hill, a SAR officer, advises: “Don't hesitate to call because Search and Rescue does not charge” (Anderson, 2020). The NPS has other tasks, aside from SAR, such as conservation and trail upkeep, but safety is a priority for them. According to an NPS mission statement, the service strives “to protect park resources and values and promote visitor safety and enjoyment” (NPS, n.d.).

Researchers have studied risk taking and risk compensation extensively. Lund and O'Neill (1986) found that as safety features in cars increase, so do the risks drivers are comfortable taking. 11 years earlier, in a 1975 work, Sam Peltzman came to a similar conclusion when he found "…the only response of drivers to safety regulation has been to have more severe accidents, while continuing to have fewer accidents." She et al. (2019) studied how hikers' perception of risk influenced their choice of routes, finding that perceived physical risk often deterred hikers, but that psychological feelings, like fear and danger, are attractive. Alotaibi et al. (2019) evaluated the possibility of using unmanned aerial vehicles (UAVs) in SAR to reduce search time and maximize people saved and found that their algorithm alone could find approximately 74 percent of victims without the aid of ground teams. If similar technology were to be implemented on a large scale, the time and manpower requirements of SAR would be drastically reduced. Yet because of risk compensation, without attention to behavioral factors, these measures will invite riskier behavior by reducing perceived risk, thereby diminishing the measures' safety benefit.

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