***Background (Impact of Technology)***

The goal of this project is to develop a framework of algorithms that enables multiple target engagement with a swarm of low-cost, heterogeneous autonomous weapons systems. Currently, the Air Force faces asymmetrical conflict scenarios in which expensive, highly precise weapons are used against low-cost targets that may be easily replaced or are even considered expendable. These scenarios commonly require prohibitive operator involvement, which can significantly reduce overall operational efficiency. The fundamental mismatch between the cost to destroy a target and the cost to replace it creates an environment of diminishing return in terms of Air Force resources and investment.

In more symmetric conflict scenarios, anti-access and area denial (A2AD) considerations are becoming increasingly important. In these instances, air superiority is typically not guaranteed (initially) and thus it may not make sense to deploy precise, expensive weapons systems highly susceptible to air defenses. Instead, it may be desirable to first overwhelm air defenses with low-cost expendable munitions, which increases survivability and effectiveness of precision weapons that may be deployed later. Whereas this engagement model is attractive, current Air Force technology is challenged to support it due to excessive required operator oversight and the lack of feasible low-cost autonomous munitions systems.

As an alternative to the current paradigm, the Air Force is now developing affordable weapons technology that can leverage low-cost sensors and new advances in autonomy to create decentralized systems that require little operator oversight and are robust against various types of countermeasures. These weapons systems may have limited communications abilities, maneuver authority, and sensing capabilities, but may be deployed in large quantities and be provided a great deal of autonomy. Additionally, the weapons systems must perform autonomous task assignment, coordination, and planning in a reconfigurable manner that can handle weapon attrition and target uncertainty. While individual vehicles may be susceptible to kinetic, directed energy, or RF countermeasures, the collective system must be survivable and robust, degrading gracefully as individual nodes drop out. Finally, weapons guidance and coordination must be carried out in a decentralized manner due to communication constraints between vehicles.

Although reliability of each individual engagement vehicle may suffer when compared to expensive and more precise weapons systems, such low-cost weapons would rely on cooperative engagement to maximize kill probabilities rather than relying on a single hit from a single weapon. These cooperative engagement algorithms should easily adapt to losses of individual vehicles due to countermeasures or target uncertainty with little or no operator intervention. Successful deployment of this affordable weapons technology could alter the economic balance of many military conflicts and significantly reduce required operator oversight. At the same time, extensive research is required to develop cooperative engagement algorithms, dual-use sensors, and large-scale deployment technology if such autonomous systems are ever to be realized.

Significant research gaps exist that currently limit the ability to perform autonomous cooperative engagement of multiple targets with low-cost weapons systems. At the vehicle level, major challenges exist in cooperative decentralized vehicle path planning and timing. If multiple weapons engage multiple targets, it is desired that all targets be engaged according to a prescribed timing sequence to maximize surprise and effectiveness. Without central operator oversight, this requires precise coordination amongst all weapons even with very limited communications bandwidth and robust algorithms that can compensate for real-time loss of individual weapons. Likewise, decentralized asset assignment can be difficult among heterogeneous vehicles of varying capabilities, but is no less important to ensure an adequate distribution of weapons to targets. Deployment systems must be capable of maintaining multiple (possibly moving) targets within a kill radius at all times, perhaps greatly altering control strategies for delivery platforms. Finally, sensor technologies such as seekers must be leveraged for multiple purposes to reduce weapon costs while promoting vehicle-level autonomy.

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