Supervisory Control of Multiple Autonomous Airborne Vehicles: Lessons Learned from Tactical Tomahawk Human-in-the-Loop Experiments.

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There is significant interest in the Department of Defense to design networks of unmanned vehicles that can operate autonomously, which will in effect, take the human out of the loop at certain levels of tasking. While unmanned systems will not necessarily require a human for manual control, humans will be necessarily involved in the planning, higher-level operations, and contingency interventions. Thus, especially in command and control domains, a cluster of unmanned vehicles is still a manned system. While supervisory simultaneous control of multiple unmanned air vehicles (UAV) in real-time does not yet exist, recent research exploring human performance issues for the in-flight control of Tactical Tomahawk missiles can provide significant insight into the overall multiple autonomous vehicle control problem.

The Tomahawk missile can be fired from over 1000 miles away from its intended target with an accuracy of meters. Currently, these missiles are "fire-and-forget" in that once launched, their courses of action could not be modified (e.g., those used in Iraq in 2003). The newest version, the Tactical Tomahawk, will have the capability of redirection in-flight through transmission of GPS data. In addition, this new version of the missile will have the capability of loitering over a geographic region for an extended period of time. This loiter capability will allow commanders to use the missile against emergent targets (such as mobile surface-to-air missile vehicles), and indeed, this same loiter capability has been envisioned for surveillance UAVs as well as for UCAVs (unmanned combat air vehicles.)

This new capability of retargeting missiles or UAVs in flight represents a major shift in the human supervisory control issues for traditional UAV and missile control. It also highlights the need for research into the development of a dynamic decision support system which must support human rapid replanning in time pressure scenarios. To this end, we developed a rapid prototype to investigate this dynamic replanning problem and conducted a human-in-the-loop study with 42 Navy subjects. One central question addressed was how many GPS equipped missiles could one operator manage, given various retargeting scenarios occurring at rapid intervals. Dependent variables were decision quality, workload, and situational awareness measured through secondary tasking requests through a communications chat window. The results across all dependent variables was consistent: given this domain and user interface, operator workload and performance degraded significantly if controlling 16 missiles as compared to 8 or 12 missiles. This research gives initial manning estimates and provides the basis for future workload studies as task demands or decision support tools vary. Comparing these findings to similar studies in the UAV domain will lead to further insights into the general supervisory control and rapid replanning problem.