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An Empirical Study of Human-Robotic Teams with Three Levels of Autonomy

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Abstract **– Three search-and-identify experiments were conducted using the RoboFlag testbed to investigate the performance of human-robotic teams with different levels of autonomy. The first set of experiments required human operators to manually control robot trajectories by setting waypoints. In the second set, operators controlled robots via five pre-programmed plays. The third set allowed operators to operate waypoint control and automated plays, and performance feedback was provided to the user in real-time and/or at the end of each trial. Five performance metrics were analyzed across all experiments: game time, idle time, tag events, target location uncertainty, and target identity uncertainty. Performance increased with respect to all metrics when automated plays were available, and the addition of performance feedback in the third set of experiments further improved game time and idle time. Human efficiency and mission effectiveness are discussed with respect to autonomy level, form of performance feedback, and mission configuration.**

I. Introduction and Motivation

As systems requiring human-robotic interaction become more complex, it becomes crucial that reliable operator and team performance is maintained, even in the presence of uncertainty and varying levels of autonomy. While often tasks previously performed by humans can now be accomplished by modern robotics, many applications will continue to necessitate human interaction, such as interplanetary construction or cooperating uninhabited aerial vehicles.[1] Keeping humans operators in-the-loop is especially useful when the system encounters unexpected situations or sensor failures and when computationally-expensive sensing (such as vision or natural language processing) or higher-level decision making (such as cooperative strategizing) is required.

A seminal reference in the Cognitive Sciences community is given by Sheridan[2] which summarizes the results of operator-machine systems research. Examples include the average time for a person to physically select a choice with their hands, the level of short term memory, and comparison of interfaces. This work has led to integrated databased for modeling/prediction of perception and motor skills[3–5] and provides valuable insight into how users make decisions as a function of parameters such as stress, interface type, and time.

Human operators working with automated systems have been shown to have reduced physical and mental ability to react to direct system errors and to manually perform tasks during automation failure, compared with operators performing the same tasks without automation.[6] As a result, the prediction and optimization of human-robotic system behavior requires a thorough understanding of what influences human performance and decision making, as well as the proper quantity and quality of information shared at all levels of autonomy.