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Impact of Automation Support on the Conflict Resolution Task in a Human-in-the-Loop Air Traffic Control Simulation

Joey Mercer*, Ashley Gomez, Cynthia Gabets**, Nancy Bienert**, Tamsyn Edwards**, Lynne Martin**, Vimmy Gujral**, and Jeffrey Homola***

**NASA Ames Research Center, Moffett Field, CA, USA, 94035*
(e-mail: [joey.mercer, jeffrey.r.homola]@nasa.gov)
***San Jose State University / NASA Ames Research Center, Moffett Field, CA, USA, 94035*
(e-mail: [ashley.n.gomez, cynthia.gabets, nancy.bienert, tamsyn.e.edwards, lynne.h.martin, vimmy.gujral]@nasa.gov)

Abstract: To determine the capabilities and limitations of human operators and automation in separation assurance roles, the second of three Human-in-the-Loop (HITL) part-task studies investigated air traffic controllers' ability to detect and resolve conflicts under varying task sets, traffic densities, and run lengths. Operations remained within a single sector, staffed by a single controller, and explored, among other things, the controller's responsibility for conflict resolution with or without their involvement in the conflict detection task. Furthermore, these conditions were examined across two different traffic densities; 1x (current-day traffic) and a 20% increase above current-day traffic levels (1.2x).

Analyses herein offer an examination of the conflict resolution strategies employed by controllers. In particular, data in the form of elapsed time between conflict detection and conflict resolution are used to assess if, and how, the controllers' involvement in the conflict detection task affected the way in which they resolved traffic conflicts.

Keywords: Human factors, air traffic control, human-in-the-loop simulation, function allocation, human-automation interaction.

1. INTRODUCTION

The transition to NextGen will likely include increasing levels of automation to help controllers perform their duties. A progression towards higher levels of automation could enable the controllers' working environment to move from tactical separation management to strategic decision-making. Such automation is envisioned to expand performance beyond today's limits by off-loading workload from controllers onto automated functions for the majority of routine operations (JPDO, 2010). However, the nature of this human-automation team is not well understood. It is still unknown exactly which tasks are best allocated to the human operator as opposed to the automation, and vice-versa. In considering this system as a whole, careful and thorough investigation is needed to better understand, not only how each team member performs in such environments, but also any associated human-automation cooperation issues.

1.1 Motivation

The motivation behind these investigations is to address a well-known problem: current-day air traffic control techniques are very labor intensive, and are limited to the amount of information controllers can process and keep in their working memory (Ericsson & Kintsch, 1995). Function allocation is but one approach to this problem, wherein automation can take responsibility for some tasks, theoretically easing the controller's workload.

The current series of studies fall under NASA's revised function-allocation research plan, which calls for advancing our understanding of the related air-ground and human-automation issues. In particular, the Airspace Operations Laboratory (AOL) focused on the following question: "Which separation assurance functions can air traffic controllers effectively perform in future air traffic management systems?" Understanding the strengths and weaknesses of individual team members is an important aspect in determining how to distribute tasks between team members. As a first step towards gaining such insights into human-automation teaming, our approach has been to conduct part-task HITL simulations that identify the capabilities and limitations of the controller in key separation assurance tasks.

1.2 Function Allocation Research

In May of 2015, the AOL at NASA's Ames Research Center (see Prevôt, 2014) conducted the second in a series of studies that explored the capabilities and limitations of human operators with regard to the separation assurance element of air traffic control. Specifically, the research sought to better understand how best to allocate functions between controllers and automation, using the conflict-related tasks as its main focus. The general approach sought to tease apart a primary

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task from related secondary tasks. While looking across varying levels of automation, the studies measured the overall impact on the performance of the primary task. Of particular interest to the second study was discovering whether removing controllers' involvement in the detection task would impact their ability to resolve conflicts.

The first study, referred to as the Human-Automation Conflict Detection study (or HACD), and the second study, referred to as the Human-Automation Conflict Resolution study (or HACR), are reported by Edwards (2016), Homola (2016), Mercer (2016a), and Mercer (2016b). However, this paper also includes, in the following section, a brief description of the HACR simulation environment, establishing the appropriate context for the later discussions.

2. METHOD

HACR examined controller performance on the conflict resolution task under different run lengths, traffic density levels, and task sets, where the group of tasks under the controller's responsibility (versus those under the automation's responsibility) defined a given task set. Although the full study featured a 5x2x2 within-subject repeated-measures design, the scope of this paper and its analyses are limited to the following two of the study's five task sets: *Conflict Resolution* and *Conflict Detection & Resolution*. This paper also examines the traffic density variable.

2.1 Conflict Resolution Condition

The *Conflict Resolution* condition's aim was to fully isolate the conflict resolution task, and in doing so, removed the controller from the conflict detection task. The study accomplished such isolation by developing a display capability that suppressed all air traffic from the radar display unless the automation (i.e., a trajectory-aided conflict probe) detected a potential conflict. Once the automation detected a conflict, the system would turn off the 'blackout' mode, and display all traffic as it normally would, albeit with the aircraft in conflict highlighted (see Figure 1). At this point, the automation's task of detecting the conflict was complete, and it was then the controller's responsibility to issue whatever control instructions they deemed appropriate. When the automation no longer detected any conflicts, the blackout mode resumed, and remained in effect until the next conflict presentation.

2.2 Conflict Detection & Resolution Condition

The Conflict Detection & Resolution condition operated much like current-day air traffic control. In addition to resolving conflicts, the controller was responsible for all conflict detection efforts, necessarily keeping constant watch over their sector's radar display, observing the progress of air traffic in and around their sector, and issuing control instructions they deemed necessary.

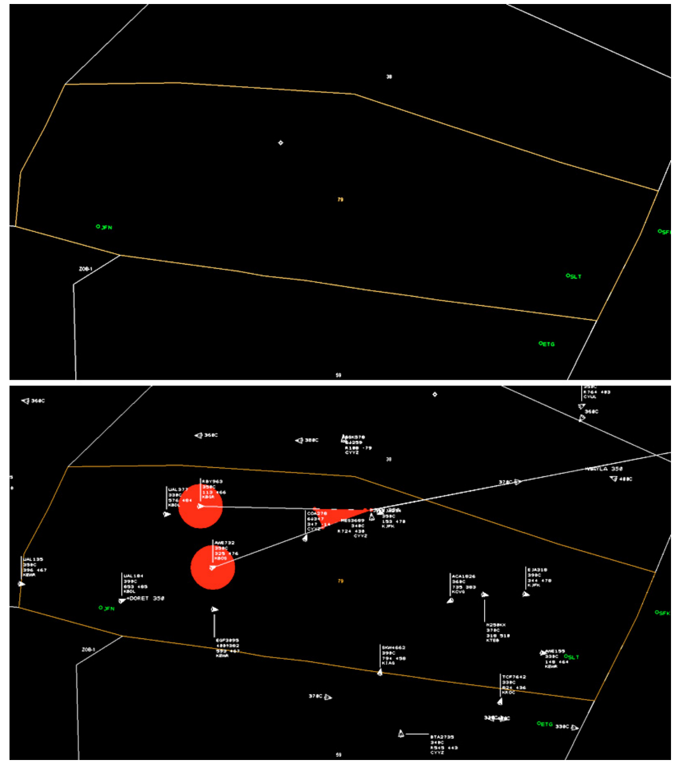

Fig. 1. Screen capture of the controller's radar display in the Conflict Resolution condition before the automation detects a conflict (top), and after the automation detects a conflict (bottom).

In order to get a clear measurement of when controllers detected a conflict, throughout the study they made keyboard entries to signal when they believed an aircraft pair to be in conflict. Without this procedure, characterizing (i.e., quantifying) the conflict resolution process across the two conditions would have been difficult. In the *Conflict Resolution* condition, measurements between an encounter's 'start' time (i.e., screen 'on' time) and the resolution time were clear. A comparable measurement from the *Conflict Detection & Resolution* condition therefore, needed a similar encounter start time, ultimately satisfied by using the time of controller's keyboard entry.

2.3 Airspace and Traffic

The airspace used during the simulation consisted of a single high-altitude sector, with a mix of overflights passing through at level altitudes, and transitioning aircraft descending to or climbing out from area airports. The scenarios progressed through a ramp-up, peak, and ramp-down phase, with each phase lasting approximately 20 minutes. Traffic levels reached 18 aircraft in the sector in the 1x traffic density, and 22 aircraft in the 1.2x density. The simulation environment also included winds for the area, which were constant-at-altitude with a nominal forecast error.

2.4 Participants