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Analysis of Controllers' Working Methods Supporting Safe and Efficient Air Traffic Operations

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Abstract: In daily air traffic control operations, controllers achieve safe and efficient air traffic flow even in varied and changing situations which inevitably involve safety risks. For revealing the contributing factors of the successful ATC operations, the present study analyzes the common parts of controllers' work process from the viewpoint of Safety-II, that is, why things go right. The results show that the typical working methods of controllers can be effective in preventing potential conflicts between aircraft, which can contribute to the reduction of controllers' workload for monitoring and resolving the potential conflicts especially in congested traffic situations. Through the analysis, a part of controllers' practical knowledge involved in their working methods is demonstrated.

Keywords: human performance, visualization, air traffic controller, Safety-II, human factors

1. INTRODUCTION

In response to the increasing volume of air traffic, the continuous enhancement of safety is a significant issue in the Air Traffic Control (ATC) domain. The traditional approaches to safety have mainly concentrated on removing the (potential) causes of unwanted outcomes through the careful investigations of things that go wrong, such as accidents and incidents. On the contrary, a new perspective of safety called Safety-II emphasizes the importance of looking not only into things that go wrong but also into things that go right (Hollnagel, E., 2014). A key aim of that is to increase the opportunities of acquiring safety lessons by analyzing things that go right which account for the great majority of the outcomes of the daily operations. As a lot of studies relating to Safety-II indicate, the normal functioning of systems is not a natural consequence, but a kind of product obtained through performance adjustments of the human operators responding to changing situations and requirements (Hollnagel, E., 2006, Dekker, S., 2006, Curvelier, L. and Falzon, P., 2010). Therefore, the detailed analyses of the normal operations are informative for increasing the number of normal functioning of the systems, which leads to enhance the safety.

In ATC tasks, controllers are required to handle multiple aircraft simultaneously under varied and changing situations. This fact strongly implies the existence of potential safety risks inevitably involved in ATC tasks. Nevertheless, in reality, controllers achieve safe and efficient air traffic operations in almost all cases. From the viewpoint of Safety-II, the contributing factors of the successful operations should be carefully analyzed for the purpose of the acquisition of lessons to promote things that go right. Our research group has already conducted the analysis studies of controllers work processes, using a process visualization tool of ATC tasks called COMPASi (COMPAS in interactive mode / COMPAS: COgnitive system Model for simulating Projection-based behavior of Air traffic controller in dynamic Situations) (Karikawa, D. et al., 2014a, Karikawa, D. et al., 2014b). Our previous studies analyzed the *differences* of performance characteristics of air traffic control strategies used by controllers in terms of efficiency in completing ATC tasks and of tolerance to changing traffic situations. This study, on the other hand, focuses on *common parts* in controllers' work processes contributing to safe and efficient air traffic operations. As an example of the common parts, how controllers use altitude instructions is analyzed in this paper. Based on the analysis results, controllers' practical knowledge for ensuring safe and efficient air traffic flow involved in their working methods is discussed.

2. STUDIED ATC SECTORS

The purpose of ATC services is to promote the safe, orderly and expeditious flow of air traffic. Although ATC services cover aircraft on the ground and in airspace, en-route air traffic control studied in our research is provided for in-flight aircraft as a part of ATC services. In en-route ATC, airspace is divided into smaller spaces called sectors. The sectors studied in the present research are sector T09 and sector T14 in Japan. As shown in Figure 1, the sectors are adjacent and located in the southwestern part of the Tokyo region. The distance from the western boundary of sector T09 to the eastern boundary of sector T14 is approximately 170 nautical miles (NM). The maximum north-south distance is about 50 NM.

In each of these sectors, en-route air traffic control services are provided by a team of controllers consisting of a radar controller and a coordinator. Sector T09 and sector T14 are

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two of the busiest sectors in Japan. The controllers of these sectors handle approximately 450-500 flights per day in this relatively small area. Dominant traffic in these sectors is arrival flights to Tokyo (Haneda) airport coming from airports located in the western part of Japan. The principal routes of the arrival flights are indicated by dotted lines in Fig. 1. In addition, the small white circle in Fig. 1 indicates a fix which is a geometrical point used for aiding in air navigation. The capital letters next to the white circle, that is, ADDUM, is the name of the fix. Besides the primary task of en-route ATC which is to assure minimum separation of 5 NM horizontally or 1,000 feet vertically between respective aircraft for safety, the controllers of these sectors are supposed to get the arrival flights flying on respective routes formed in a line, setting prescribed in-trail separation between a leading aircraft and a following aircraft by reaching the ADDUM point.

In sector T09 and sector T14, a special ATC operation method in which controllers of two consecutive ATC sectors cooperatively complete necessary ATC tasks for each aircraft is introduced in order to efficiently control a large amount of air traffic while regulating controllers' workload. Therefore, the target states of the arrival flights to Tokyo airport are set only in sector T14, which are at 7NM in-trail separation and 10,000 feet in altitude by the ADDUM point (see Fig. 1). The controllers of the two sectors cooperatively conduct necessary ATC tasks to achieve aircraft's target states. In other words, the arrival flights can be handed off from sector T09 to sector T14 on the way to achieve their target states.

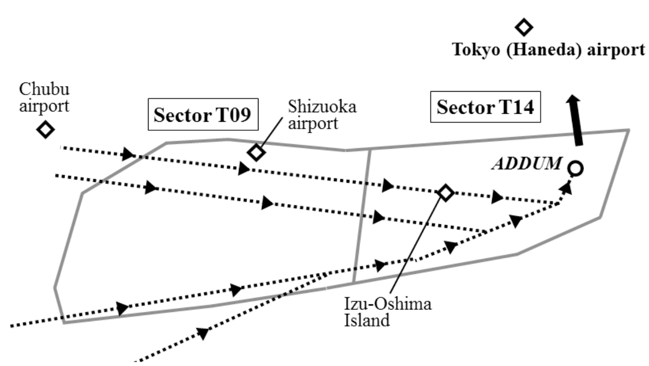

Fig. 1. Studied ATC sectors (Karikawa, D. et al., 2014b).

3. COMPASi

This section presents brief descriptions of COMPASi, our process visualization tool of ATC tasks, used in the present research. Figure 2 shows the conceptual diagram of COMPASi. COMPASi is an ATC simulation and visualization tool equipped with the Air Traffic Simulator (ATS) and the Situation Recognition Unit (SRU). Given the initial states of traffic (for example: aircraft's initial position, altitude, indicated air speed, and so on) and the log of ATC instructions, ATS simulates air traffic flows by the continuous performance calculation of aircraft and the issuing of ATC instructions. The simulated air traffic situations are analyzed by SRU using stored rule bases, and ATC tasks are automatically detected and classified according to the ATC task index called "Task Demand Levels (TDL)", which consists of 7 levels reflecting necessary ATC tasks for each aircraft (see Table 1). Aircraft coming from upstream sectors have various levels of TDLs ranging from Lv.1 to Lv.3++. However, by completing necessary ATC tasks, the TDLs of the aircraft are supposed to lower to Lv.1 before they are handed off to downstream sectors. Therefore, TDLs reflect the execution states of ATC tasks for respective aircraft. COMPASi presents TDLs by color-coded aircraft symbols and call signs on the simulated radar display (see Fig. 3) and in the time series graph called Chart of ATC task Processing State (CAPS) (Aoyama et al., 2010). Through the comparative analysis of CAPSs presenting the outcomes of different control strategies of air traffic, the strategies can be evaluated from the viewpoint of efficiency of completing necessary ATC tasks. In addition to TDLs, COMPASi is capable of offering multiple numerical data reflecting controllers' actions and the development of traffic situations in simulation cases, e.g., the number of issued ATC instructions, flight distances of respective aircraft, and so on. In this research, COMPASi was used as the simulation and data recording tool as described in Section 4.2.

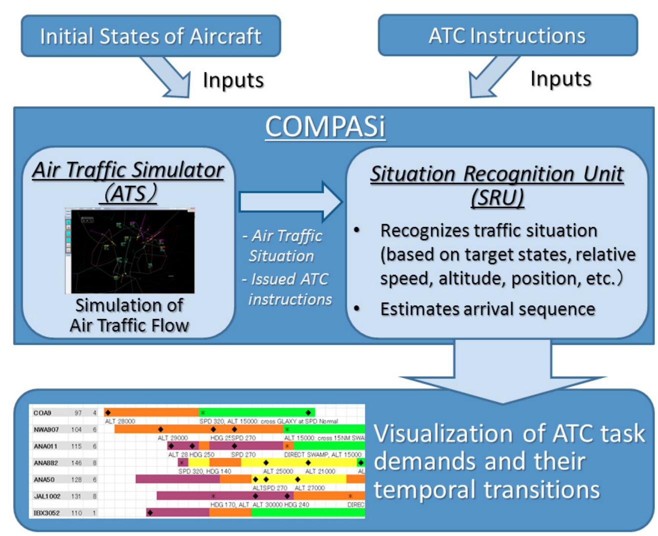

Fig. 2. Conceptual diagram of COMPASi (*Karikawa, D. et al., 2014a*).