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Airline Command and Control: An Ethnographic Study

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AIRLINE COMMAND AND CONTROL: AN ETHNOGRAPHIC STUDY

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The role of airline operations control centers in the national air transportation system is increasing. Yet, the role of airline operations personnel has not been well studied. This paper presents the findings of a series of ethnographic studies examining the work of airline Operational Managers (OMs) across several major and regional airlines. The role of airline OMs, and the information and tools they use to solve problems and maintain the airline's published schedule are discussed. Additionally, several work models developed as a result of the ethnography are presented and discussed. The work models include an information flow model, cultural model, artifact models, and sequence models. Implications are presented and discussed which transcend airline operations and are applicable to command and control more generally.

Introduction and Motivation

The national air transportation system has three main players: air traffic controllers, pilots and the airlines that employ them. Up to now most of the advances in air traffic management have focused on the interaction of controllers and pilots as well as technology to aid both of these roles. However, with drastic improvements in the communication equipment available on most commercial aircraft, increased communications between the flight deck and the airline operational control centers (OCCs) has become commonplace. As a result airline operations personnel including: dispatchers, operations managers, customer service and crew representatives now play a much larger role in making tactical decisions.

To date the job and role of both pilots and air traffic controllers has been well documented [1-6]. Less, however, has been written about airline operations[7,8]. Airlines develop optimized schedules months in advance to maximize profit and aircraft utilization, and then implement these schedules for several months according to strategic corporate plans. However these optimal schedules are often disrupted during the course of normal operations. Just as flow control happens at many levels, so too disruptions impact the NAS at many levels. At the national level disruptions due to convective weather often call for the implementation of a ground delay program, a ground stop, or playbook reroute. At a lower level, airline responses, include flight delays, flight cancellations, the addition of new flight segments, and new flights.

Considering the number of deviations and their impact on the NAS, it is of interest then to examine how airlines make daily operational decisions. The decisions about how to cope with deviations and how to return to the normal operating schedule are made and executed by a team of individuals at each airline. At most carriers these teams are centered around an Operations Managers or Operations Coordinators (OMs or OCs) who have the complex task of maintaining the overall schedule while minimizing disruptions to passengers, maximizing aircraft utilization, and minimizing revenue impact while complying with all federal regulations and contractual obligations for staff and crew.

To help these OMs, optimization software packages have been designed and implemented to improve airline schedule recovery performance. However many of these decision support tools have been developed without proper consideration for the work that OMs perform. The tools are often inappropriate for routine tasks. As a result, they are rarely used. Disuse and lack of understanding of how the tools work, causes their results for the tasks which they are used to be disregarded.

The growing importance of the role of airline OCCs in the national transportation system alone merits a better understanding of the workings of airline OCCs, but there are additional factors which make the study and understanding of airline OCCs desirable. First, most of the work of an airline OCC is cognitive in nature – problems arise, information must be gathered, and solutions must be devised, coordinated, and implemented. Second, airline OCCs are representative of command and control centers which have been successfully operating for several years. As airline operations begin to transition toward the greater reliance on support systems and optimization to minimize costs, many lessons will need to be learned about how best to design support systems for command and control environments in both the military and in air traffic control.

In this paper we present the findings of a series of ethnographic studies specifically examining the work performed by airline Operational Managers (OMs) across a number of major and regional airlines. This paper discusses the role of OMs, and the information and tools they use to solve problems and maintain the airline's published schedule. Additionally, several work models developed as a result of the ethnography are presented and discussed. The work models include an information flow model, cultural model, artifact models, and sequence models. Implications are discussed which transcend airline operations and are applicable to command and control more generally.

Methods

The ethnographic technique used for this study is contextual inquiry, described by Beyer and Holtzblatt (1). Contextual inquiry facilitates an examination of how a system operates, while taking into account not only the users but also everyone actively dependent upon the work. Contextual inquiry is an interviewing technique centered on four guiding principles: context, partnership, interpretation and focus. The first principle, context, implies that the interview must take place where the work is being conducted. Conducting the interview in context allows the interviewee's actions and their answers to questions to be much more accurate. The second principle, partnership, requires that the traditional role of interviewer-interviewee is replaced with the familiar role of mentor-mentee. This relationship enables the interviewee to take more control in the interview and thus impart the knowledge that they feel is important instead of simply answering questions specifically asked of them. The third principle, interpretation, signifies that a shared understanding must be developed about all aspects of work that matter. To accomplish this, the data collected must be transformed into meaningful information before it is useful. Contextual Inquiries use a set of models to bring about this transformation. The fourth principle of focus implies, that unlike pure observation, contextual inquiry allows the interviewer to steer the conversation gently, to remain on task, and to capitalize on unexpected insights.

The results presented here are drawn from a set of contextual inquiries which were conducted on four different airlines over the course of two years (February 2004 – November 2006) for a total of over eighty hours of direct observations. The airlines ranged in size from large major carriers to small regional carriers.

Operations Managers

Job Description and Duties

The following job description has been derived directly from the contextual inquiry, and provides a summary of the work models which are described in subsequent sections. The primary task of an Operations Manager is to maintain the airline's published schedule by ensuring that the on-time arrival and departure rates are within acceptable limits for the prevalent external conditions. External conditions nominally include weather related difficulties and air traffic control restrictions, but can also include temporary issues like inoperable equipment at airports. The OMs maintain the flight schedule by making decisions about how to address deviations from the published flight schedule. Often these decisions are non-time-critical with a look-ahead between 30 minutes to 6 hours. However sometimes the decisions are very time critical such as the rescheduling of flights after an emergency shut-down of a runway or the unanticipated depletion of fuel or de-icing fluid at an airport.

OMs do not work in isolation. Instead, they function as part of a larger operations team in which they often play the coordinating role. Most of the OMs observed in this study were organized into three daily shifts. Each shift consisted of between one and six OMs each with responsibility divided (where applicable) geographically. At one airline the OMs were responsible for different sectors of the country: Eastern, Central, Western, International, Main Hub and ATC Liaison. At another airline the OMs were assigned responsibility by airport.

Tools

The information required by the OMs is readily available through a variety of (sometimes redundant) sources. The most comprehensive source of information is a text-based interface into the primary scheduling computer system. This computer system contains data about aircraft and crew schedules as well as weather information, notices to airmen (NOTAM's), information about the facilities at all of the airline's serviced airports, and the current duty roster of all operations staff. For the two major airlines included in this study, a text-based terminal was their primary source of information. For the two smaller airlines, the primary source of information was a visual Gantt chart representation of the schedule.

The OMs are highly skilled at using their respective systems to find the information they require. They are often only one text command or click away from their intended information. OMs are also aware of what information cannot be found in their computer systems and are highly adept at finding the required information from the correct person. The one aspect that slowed down the OMs using the text-based interfaces was a high number of typographical errors made while entering commands into the system. As some of these commands were upwards of 20-30 characters in length, these errors were understandable. Additionally OMs working with text-based terminals occasionally had problems remembering obscure commands that were needed infrequently.

Cognitive Work Models

The data collected during the Contextual Inquiry was incorporated into a series of cognitive work models to facilitate understanding and to look at the role of an OM from a variety of viewpoints. The models presented here include a flow model to examine information flow, artifact models to illustrate sources and stores of information used by OMs, a cultural model to illustrate cultural forces and pressures which impact the work of OMs, and sequence models to examine the procedures and motivations behind some of the OMs' actions and decisions.

Information Flow Models

The purpose of an information flow model is to show the flow of information between individuals and artifacts within the system and to note any breakdowns in information flow. The flow model for the OMs includes both individuals and computer systems. Individuals are represented by ovals. Artifacts (tangible pieces of information) are represented by small rectangular boxes, and areas of information storage are represented by shaded boxes. The flow of information between these elements is illustrated by arrows with the thickness corresponding to the amount of information passed. Breakdowns in information flow are represented by lightning bolts.

Figures 1-3 contain information flow models for three airlines. The first two are similar as they are both smaller airlines and consequently use many of the same software systems and technologies for communication. Both place their OMs in the middle, as their job is to coordinate responses to schedule deviations; however, each gives their OM a different title. The third information flow model represents a much larger airline, and the greater specialization of each person's role within the OCC can be seen by how the OM (labeled here Ops Coordinator) is not the only focus point for information.

Sequence Models

The purpose of the sequence model is to examine procedures used by individuals to complete their work and to examine the motivations behind the actions taken, similar to many forms of task analysis. As the work of the OMs is more goal-driven than procedure-driven, sequence models provide limited utility in understanding the pattern of work done by OMs. However, sequence models can help begin to explain the tasks, and the motivations and intentions behind the OMs' actions.

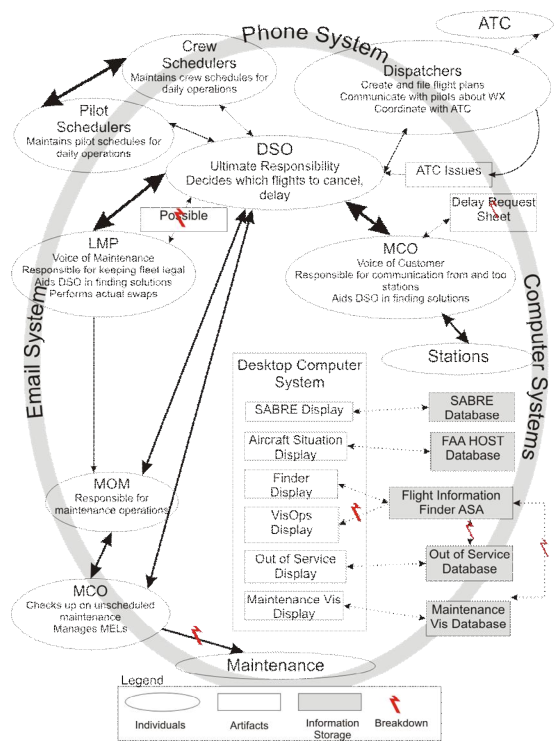

Figure 1. Information Flow Model Airline 1

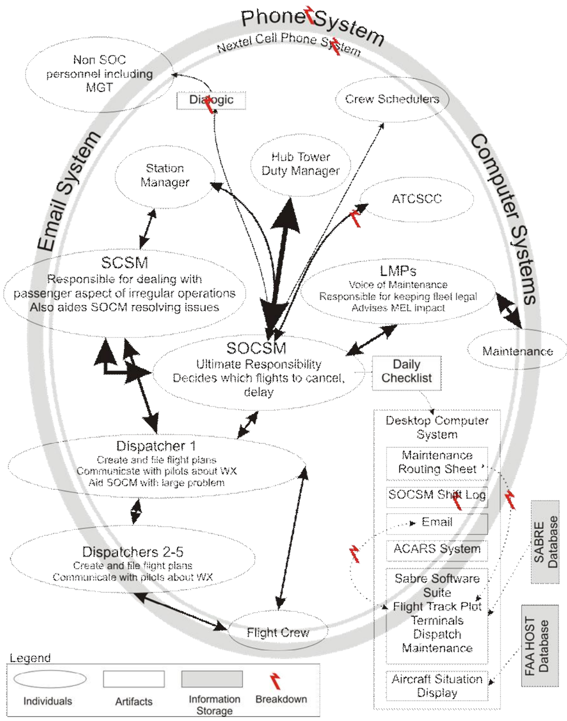

Figure 2. Information Flow Model Airline 2

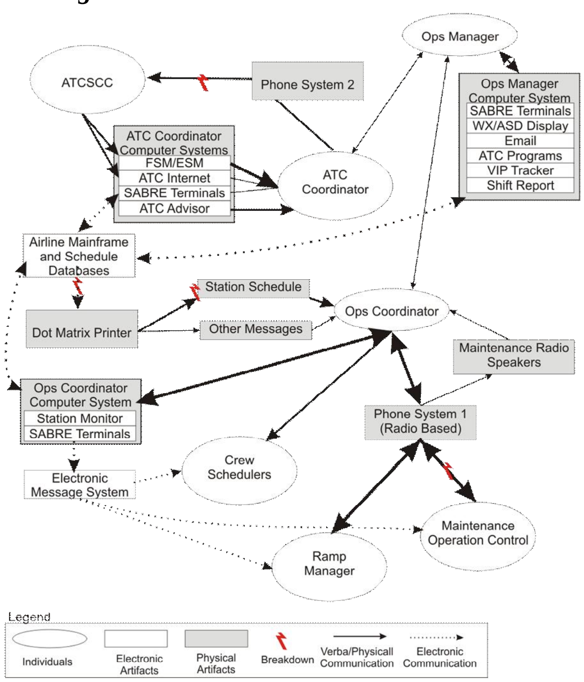

Figure 3: Information Flow Model Airline 3

As the work of the OMs is more goal-driven than procedure-driven, sequence models provide limited utility in understanding the pattern of work done by OMs. However, sequence models can help begin to explain the tasks, and the motivations and intentions behind the OMs' actions.

Three exemplar sequence models are presented here to illustrate the wide range of situations which arise in airline operations. Due to space limitations additional situations that were observed during the contextual inquiry include: unscheduled maintenance, maintenance ready time slips, bird strikes, international deviations, unruly passengers, break cooling delays, lightning strikes, gate printer outage, and internet disruption leading to an ACARs outage.

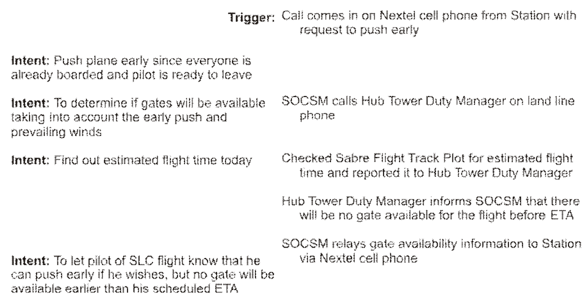

Figure 4. Sequence Model Example 1: Aircraft Request to Push Back from Gate Early

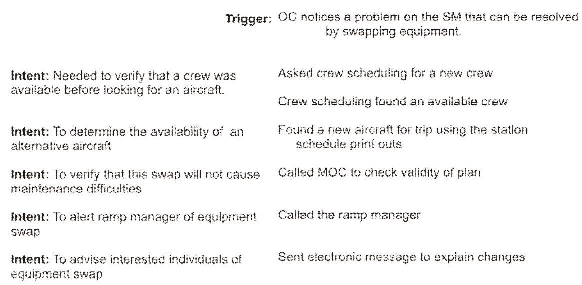

Figure 5. Sequence Model Example 2: Equipment (Aircraft) Swap

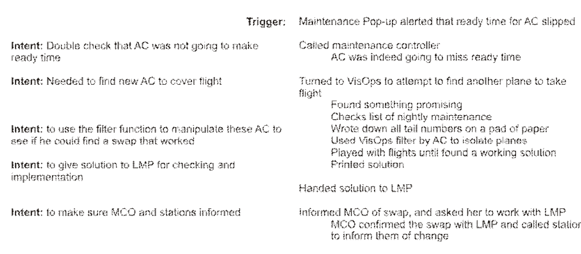

Figure 6. Sequence Model Example 3: Maintenance Not Completed on Time

Artifact Models

The purpose of the artifact models is to determine how artifacts help or hinder work. OMs use a variety of aids to help them with their work; however, few of them are physically tangible. The two most common

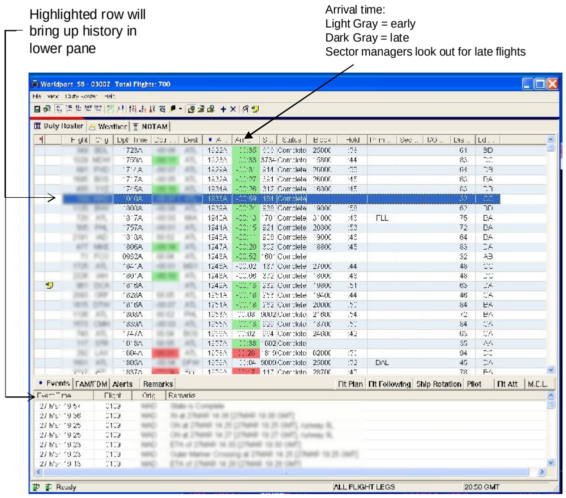

Figure 7. Problem Alerting System Airline 4

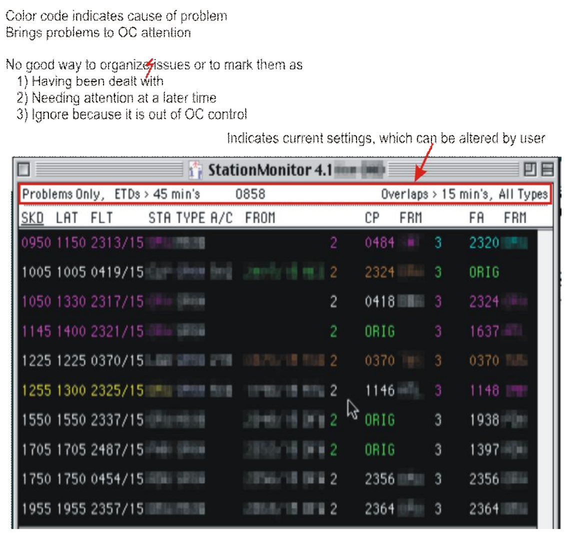

Figure 8. Problem Alerting System Airline 3

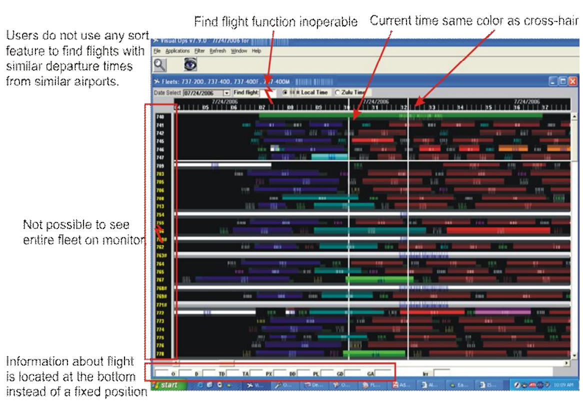

Figure 9. Schedule Visualization System Airline 1

physical artifacts are their workstations and their computer screens (Figures 7-9). The workstation is organized such that the OM has a computer display consisting of multiple 17 inch (or larger) computer monitors interconnected so as to display a single computer desktop. This large computer display area enables OMs to simultaneously display many of their software tools, such as radar tracks, weather radar and text-based terminal windows. OMs also had access to a printer (some within direct reach), which enables OMs to print out information displayed on the computer terminal. In addition, each work station is equipped with telephone system, a keyboard and a mouse. Some of the telephone systems at larger airlines were dual radio-land line phone systems with dedicated computer-monitor interfaces that could reach any aircraft anywhere in the world as well as company personnel stations.

Differences were discovered between work practices at larger and smaller airlines. The larger airlines did not directly observe their schedules, but instead relied upon software tools and alerts from their colleagues to identify potential disruptions. Two examples of these alerting tools are shown in Figures 7 and 8. Figure 9 shows a representative fleet/schedule visualization tool used by the smaller airlines. This tool enables the OM to directly observe the schedule and to scan for potential schedule disruptions. In addition to these tools, all of the airlines used a text-based terminal to access schedule and staffing data directly.

Cultural Models

The purpose of a cultural model is to understand the cultural forces which impact both the work environment and the work itself. In a cultural model the main influencers on a position are represented, be they people, policies, values, preferences, or points of pride. In addition, the specific topic of influence and direction of that influence are shown. The cultural models are illustrated in Figures 10 and 11.

Insights and Conclusions

The national air transportation system has three main players: air traffic controllers, pilots and the airlines that employ them. Up to now most of the advances in air traffic management have focused on the interaction of controllers and pilots as well as technology to aid both of these roles. However the role airlines and their operational personnel play in the smooth running and recovery of the air transportation system has been largely overlooked by the research community.

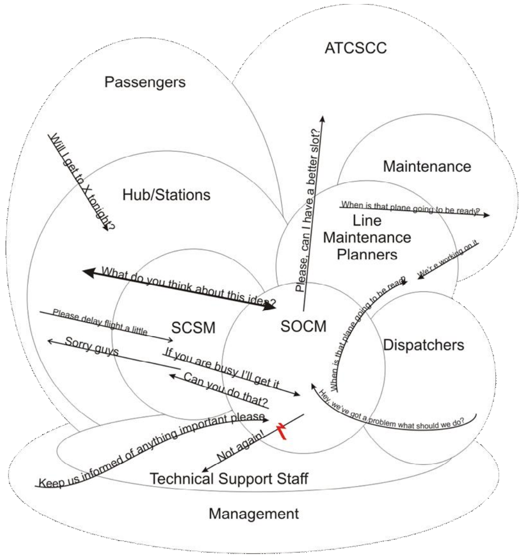

Figure 11: Cultural Model Airline 2

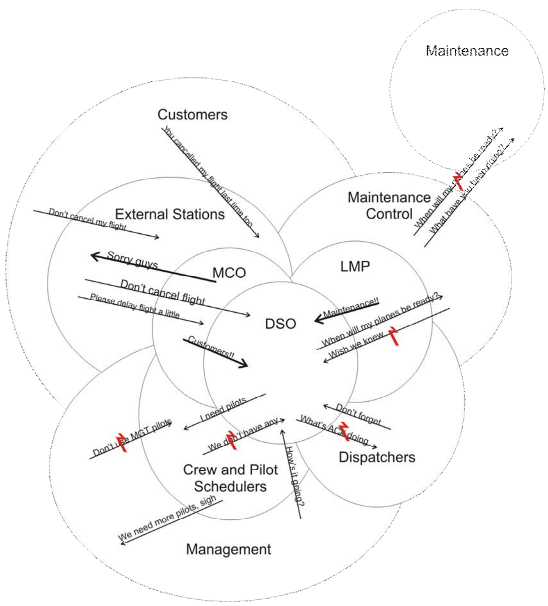

Figure 10: Cultural Model Airline 1

This paper has examined the work practices of OMs at four US airlines and has identified significant implications for the design of decision aides. First, a variation in work practice has been identified, not only between airlines, as might be reasonably expected, but within a specific OM. The apparent source of these variations is the context that the OM is situated, including such factors as the state of the air transportation system, number of spare aircraft and crews, number of simultaneous problems that the OM must address, etc.

Second, a variation in the way schedule deviations or "problems" which cause schedule deviations are identified varied between the larger airlines and the smaller airlines. The smaller airlines had schedule visualization software which organized the airline's fleet/schedule into an annotated Gantt chart which the OMs used to keep an eye on the schedule, actively scanning for any schedule deviations or potential deviations. The larger airlines had no such schedule visualization software and relied on problem identification software and other airline personnel to identify and alert them to the schedule deviation and, sometimes, its cause.

Third, the OMs at all airlines viewed their work in terms of specific "problems" that they were working on. All of these problems, if unresolved, would result in schedule deviations of varying size. The OMs also think of the problems in terms of their impact, e.g. a single flight, a series of flights, a group of flights, a station, or an entire region. Correspondingly each type of problem tends to have a different time scales. Some problems, such as those affecting an entire region or station, will present hours in advance and will be worked on and off for hours. During these situations, multiple solutions will be formulated, information will be gathered, and possible solutions and scenarios will be discussed. Other problems, such as those affecting a single flight, may only be noticed at the last minute and will require very quick decisions to be made with little time for information retrieval. At present most of the support systems available to the OMs only aided with the resolution of large impact problems such as those affecting an entire station (due to localized weather) or those affecting an entire region or airline (due to more widespread weather or ATC delays), which usually corresponded to those problems with the longest time to resolve.

Fourth, this study found that OMs perform ill defined tasks which they accomplish successfully aided by years of experience. The problems that they solve are diverse in nature and are often one-off occurrences which, although similar in nature to previous incidents, are dissimilar enough to preclude the explicit execution of detailed preset procedures. Often these problems are unique because of the uniqueness of their context, e.g.. a plane has mechanical trouble on a Tuesday night in Cleveland on the Winter Schedule for 2004. Even if the same plane had presented with the same mechanical problem on the following Tuesday night in Cleveland, many of the incident recovery parameters would be different, e.g., the number of reserve crew, weather conditions, number and location of reserve aircraft, etc.

These preliminary findings suggest that any decision aid designed to assist OMs will need to be flexible both in terms of the types of situations that is designed to assist with and in the amount of time and information that it will require to provide useful assistance.

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