TECHNICAL REPORT

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Contextual Inquiry of a Major US Airline Systems Operation Center

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Acknowledgment

Thanks to Tim for coordinating my visit and for the SOC personnel for their patience and enthusiasm for their jobs, especially Mike, Bob, Paul, David, Jim, Carl, Joe and Roger.

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Executive Summary

A contextual inquiry was conducted at the airline's Systems Operations Control (SOC) from the 13-15th of November 2006. A total of 26 hours of direct observation were conducted with various members of the SOC Staff including several of the Operations Coordinators, the ATC Coordinators, and the Operations Manager. During the inquiry a wide variety of situations occurred: unscheduled maintenance delays, estimated ready time slips, multiple hub ground delay programs, severely reduced arrival rates due to cross-directional winds, ground delay program revisions, and diversions of international flights.

The vast majority of these situations were handled as if they were no different from routine operations; however, there were moments when the key SOC personnel were fully involved in the situation and the normal coordination and collaboration between the ATCCs, OCs, MOC and crew coordinators reverted to top down command and control. Thus the workload is not evenly distributed across all SOC personnel because of the geographic distribution of responsibilities. In addition to these observations this inquiry identified three issues with specific design implications, all centered around the OC's work practices: overly involved coordination sessions with MOC, lack of control of printer output, and the use of schedule printouts as a primary source of solution information.

All three of these issues lead to inefficiencies in the SOC operation, despite which, however, the SOC in general and the OCs in particular are able to remain effective. This report suggests that the OCs could become more efficient by shedding some of their printer maintenance tasks, extended MOC coordination sessions, and more effectively using software tools. In order to achieve this high level of effectiveness the SOC personnel actively adapt their roles and the balance of power depending on the level of operational disruption. With the addition of an MOC representative in the SOC or the availability of key maintenance-related scheduling data, increased effectiveness may also be achievable under conditions of limited disruption. Changing the flow of messages from the printer to an on-screen system will help minimize the 'busy' work associated with maintaining the printer and keeping up with the printouts. Introducing new hardware and software tools to aid with the schedule sorting and filtering may also provide increased efficiency, especially for the more junior OCs.

Nomenclature

SOC Systems Operation Control

OM Systems Operations Manager

OC Operations Coordinator

MOC Maintenance Operations Control

MEL Minimum Equipment List

CAC Company Arrival Control

ESM Enhanced Substitution Module

FSM Flight Schedule Monitor

GDP Ground Delay Program

1 SOC Overview

1.1 Introduction to the Airline

The airline presented in this report is one of the largest airline in the world in terms of both passengers transported and fleet size. It consists of five major hubs, four minor hubs and hundreds of additional destinations throughout North and South America. At the time of this contextual inquiry, the airline had approximately 700 aircraft split between ”Super 80s” (MD-82 and MD-83 aircraft, 300 aircraft), Boeing 737s (80 aircraft), 757s (140 aircraft), 767s (75 aircraft), 777s (50 aircraft), and a small number of other aircraft types. While primarily a Boeing company the airline operates a large enough fleet of non-flight deck compatible aircraft such that the airline must maintain several sets of pilot groups with appropriate type ratings.

1.2 SOC Organization and Personnel

The Systems Operations Control (SOC) has a large number of people performing very specialized tasks. Dispatchers and crew schedulers make up a majority of the SOC personnel. In addition, the SOC also contains Operations Coordinators (OCs), ATC Coordinators (ATCCs), Dispatch Managers (DMs) and a Operations Manager (OM). These personnel coordinate with Maintenance Operational Control (MOC) in a different state and with the Air Traffic Control Systems Control Center (ATCSCC) in Herndon, VA to keep the airline running on schedule. The contextual inquiry included observations of the OCs, the ATCCs and the OMs, as they were of primary interest and are responsible for the delay, equipment swap and cancelation decisions.

The OCs are responsible for overseeing fleet assignment and maintaining the schedule of the flights under their control. While they do not have direct responsibility for posting the actual delays, cancelations or swaps, they are responsible for coordinating their creation. The coordination often involves the MOC, corresponding dispatchers, station ramp control and crew schedulers. During the inquiry there were four OCs on duty, occupying four conjoining workstations which surrounded a large work surface. The OCs divided the fleet by airport (usually major hubs) and then again, if necessary (e.g. for the largest hub) by fleet type. Consequently each OC was in charge of approximately 175 aircraft or 230 flights over the course of their shift. This arrangement makes it simple to correctly identify which OC has responsibility for each flight and allowed an OC to have a good mental picture of the state of their respective hubs or stations. However, this allocation of responsibility often means that the distribution of work is often uneven as many problems often affect one station more severely than the others.

The same individuals who work as OCs also work as ATCCs. There are usually two ATCCs on duty and responsibilities are split between tactical and strategic. ATCCs coordinate with the ATCSCC and focus entirely upon minimizing the impact that ground delay programs (GDPs) and ground stops (GS) have on the airline's schedule. They use the Enhanced Substitution Module (ESM) for the Flight Schedule Monitor (FSM), a tool provided by the FAA to airlines to swap flights between the slots allotted to the airline for a specific GDP. To help them use ESM more effectively, the ariline's OR group has also provided the ATCCs with an ATC Adviser which highlights crew legality, lay over, and curfew issues and aides the ATCCs finding suitable swaps for each slot and the compression of the airline's schedule. The ATCCs can choose to optimize the GDP slots for either duty day or misconnecting passengers. The results are then exported to the ESM from where they can be posted.

There is a distinct divide between management positions and union positions at the airline. On the management side in the SOC are the Dispatch Managers (DMs) and the Operations Manager. The DMs monitor the workload in the SOC and if necessary will open up extra dispatcher stations. They create the work assignments for each dispatcher and may adjust them, if necessary. They mediate any problems with departments outside of the SOC and help dispatchers with problems. They are also responsible for filing shift reports outlining the issues of the day such as emergencies, non-routine delays, out of service aircraft greater than eight yours and what the current priority is, aircraft or passengers. As the DMs are responsible for staffing, they manage the sick calls and no-shows.

The Operations Manager is responsible for the overall operation of the airline. He gives directions to the floor such as whether the current strategy is to cancel or delay flights. He resolves any conflict with standard operating procedures and the current situation, as well as having authority for all international flights. He is also the point of contact for outside authorities contacting the airline and manages the VIP flight list. Examples of issues that Operations Manager will deal with include calls from the VP of customer service regarding the days operation, inquiries from Air Rescue, serious security threats, diverted aircraft, company arrival control program (CAC) planning, and new flight creation.

Another key member of the the airline's operational staff, not physically located in the SOC are the MOC personnel. MOC schedulers work in close coordination with the OCs and are often given the authority to reject recovery plans devised by the OCs if they believe that the plan would overly disrupt the maintenance schedule. Under nominal circumstances with minimal disruptions, the MOCs are given considerable authority in the schedule recovery process. However during irregular operations, the OCs and the ATCCs become the final authority on schedule recovery, and the MOCs only alter the recovery plan if absolutely necessary. It was not possible to observe the MOC directly as it is located in a different state from the SOC.

Table 1. SOC Operations Control Group Roles

Position	Roles
Operations Manager	Managing irregular operations recovery strategy Communicating irregular events to the entire organization Creating any required CACs Policy conflict resolution Working knowledge of all diverted flights medical or otherwise
Dispatch Manager	Dispatcher workload allocation Dispatch certification paperwork Shift log maintenance
Operations Coordinators	Devising and coordinating routing changes due to equipment swaps Maintaining the published schedule Filtering through printouts looking for useful information Disposing of disregarded printouts Implementing any CACs
Air Traffic Control Coordinators	Maintaining the published schedule Coordinating irregular operations recovery Managing slot allocation during GDPs Ensuring crew legality

2 Information Flow Model

The purpose of a 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 the airline's SOC involved both individuals and computer systems. Individuals are represented by ovals. Artifacts (tangible pieces of information) are represented by small rectangular boxes. The white boxes represent electronic artifacts and the shaded boxes represent physical artifacts. The flow of information between these elements is illustrated by arrows. The arrow size represents the frequency or amount of information transfer. Breakdowns in information flow are represented by lightning bolts.

Figure 1 is the information flow model for the airline's SOC with a focus on the individuals interviewed in this inquiry. From the model it is clear that the OC plays a central coordination roll, harmonizing the efforts of the crew schedulers, ramp managers and MOC personnel. The OCs get the majority of their information from either the station monitor software on their computer terminal or from the ramp managers via the telephone.

The SOC has two distinct telephone systems. The first is an integrated telephone/radio communications system which consists of a CRT screen with a dedicated directory display, speakers, and a hand set. The second is a standard commercial telephone system which consists of a standard multi-line office phone.

Depending on the day's circumstances the relationship between the OCs and the MOCs can vary dramatically. On quiet days the MOCs tend to have more authority over operation recovery solutions than on busy days. Consequently on quiet days the OCs spend a lot of time on the phone with the MOCs determining which aircraft are 1) really available (see Sequence Model in Figure 15) and 2) can be used to cover flights other than those which they are currently assigned to. All of this information appears to reside solely with the MOCs and often results in additional work by the OC as the OCs have no practical way of predicting which aircraft can be used in a swap. Additionally, as the MOC staff are not represented in the SOC, all communication must be done verbally. This makes the accurate and clear explanation of complicated solutions difficult, leading to frequent frustration and misunderstanding by both parties. If it is not practical to have the MOC represented in the SOC then, more of the information held by the MOC should be available to the OCs so that their work may be more efficient. Presently in order to make the coordination more efficient, i.e. during highly irregular operations, the MOC is left out of the loop and forced to make do as best it can, calling to ask for recovery routing changes only where absolutely necessary.

The dot matrix printers are a large source of information and work. The majority of the material printed by the printers is not actually requested by the OCs or ATCCs, but is instead information in the form of alerts, routing changes, GDP slot assignments, etc., which are sent to the printer via electronic message from various sources in the airline. Consequently on busy days the printer is almost constantly printing and just sorting through the printouts and keeping the paper contained can take a large amount of time. The printers

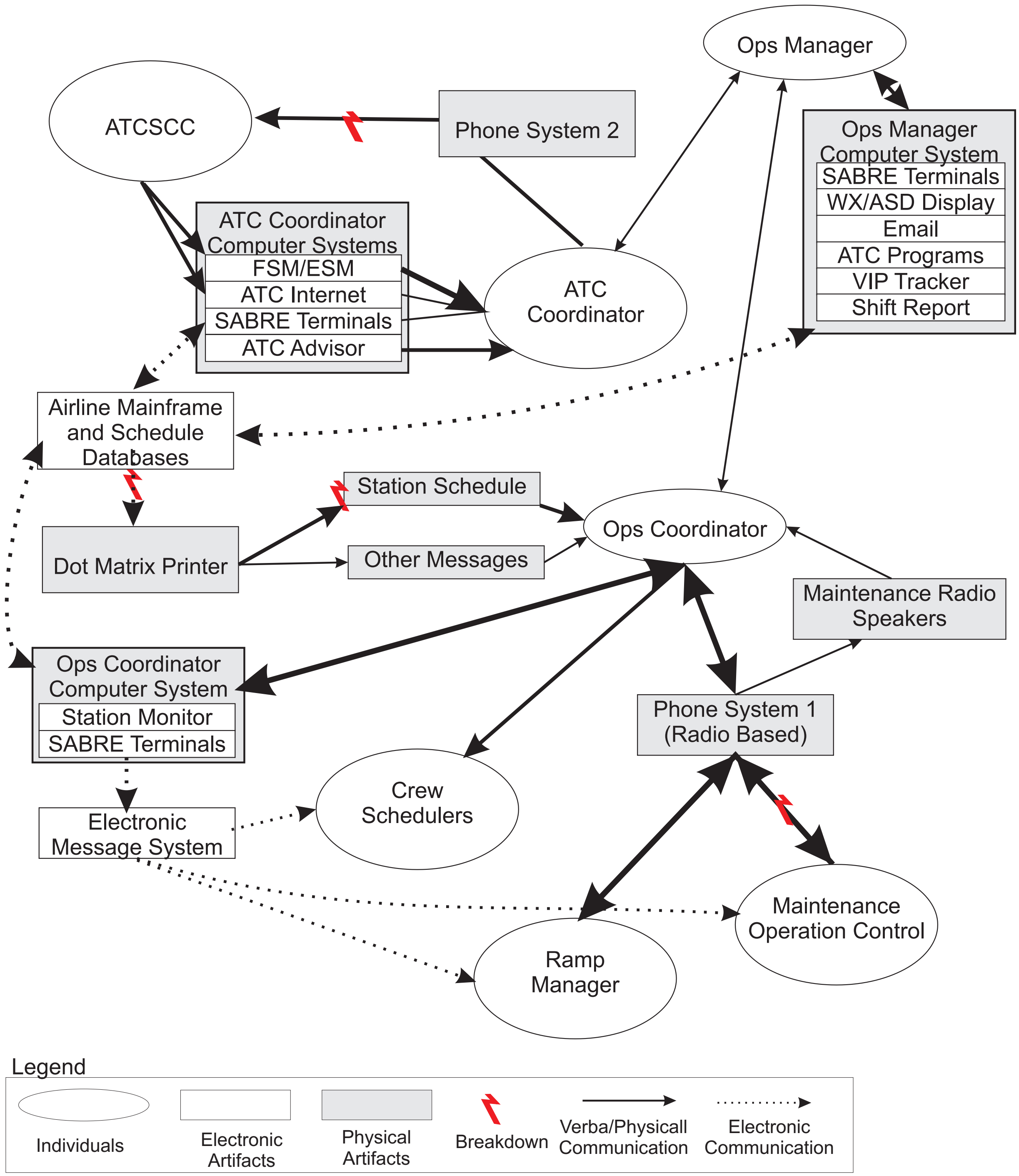


Figure 1. Information Flow Model

also make a great deal of noise leading one OC to comment that an outside observer could easily tell how busy the day was by how loud the SOC was. These unsolicited printouts are not only a waste of paper but a waste of the OC and ATCCs time.

It is also clear that the ATC coordinators do not actively coordinate directly with the OCs. Instead they formulate plans which are best overall for the airline and send them to the printers throughout the airline via electronic alerts and schedule changes which automatically print out. The ATCCs communicate regularly with the ATCSCC in Herndon, VA during both the regularly scheduled teleconference and the ad hoc teleconferences which take place between the scheduled teleconferences. A common complaint heard from the ATCCs is that the scheduled teleconferences aren't really conferences at all, but are instead statements of intent. Instead, most of the actual negotiating happens during the ad hoc teleconferences, reducing the benefit, from an ATCC perspective, of the scheduled teleconferences.

3 Artifact Models

The purpose of the artifact models is to determine how artifacts help or hinder work. The OCs use a variety of aids to help them with their work; artifacts modeled here include hardware artifacts such as schedule printouts and software artifacts such as the station monitor and the Sabre terminals.

3.1 OC Hardware Artifacts

The OCs preference for schedule visualization is a printout of the entire day's schedule. Each print out corresponds to a specific aircraft type and hub. An truncated example of the printouts can be seen in Figure 2. Actual print outs vary in length, and can be several feet in length. This allows the OCs to scan for possible equipment swaps easily while also allowing them to annotate the schedule. Depending on the day, the number of schedule printouts required, and the degree to which they are marked up varies. The printouts work well, however, they have the drawback that they are obsolete the moment they are printed, as the schedule continuously evolves. Additionally the printouts are limited in them amount of information that they can hold by their width, and further by the printer. For, while the printer paper is 8.5 inches wide, the printer can only print 6.125 inches leaving a blank space of over an inch in addition to the necessary margin for dot-matrix paper holes. While the extra space itself is provides ample space for the annotations, the OCs would prefer that an additional column of data be printed instead. Much of the OCs time is spent mentally filtering and searching through the printouts for aircraft or flights that meet certain criteria, a process which could be more efficiently handled electronically.

In addition to the schedule printouts, the printer is also a source for many of the system wide messages which are issued by the ATCSCC, ATCCs or the OM. An example can

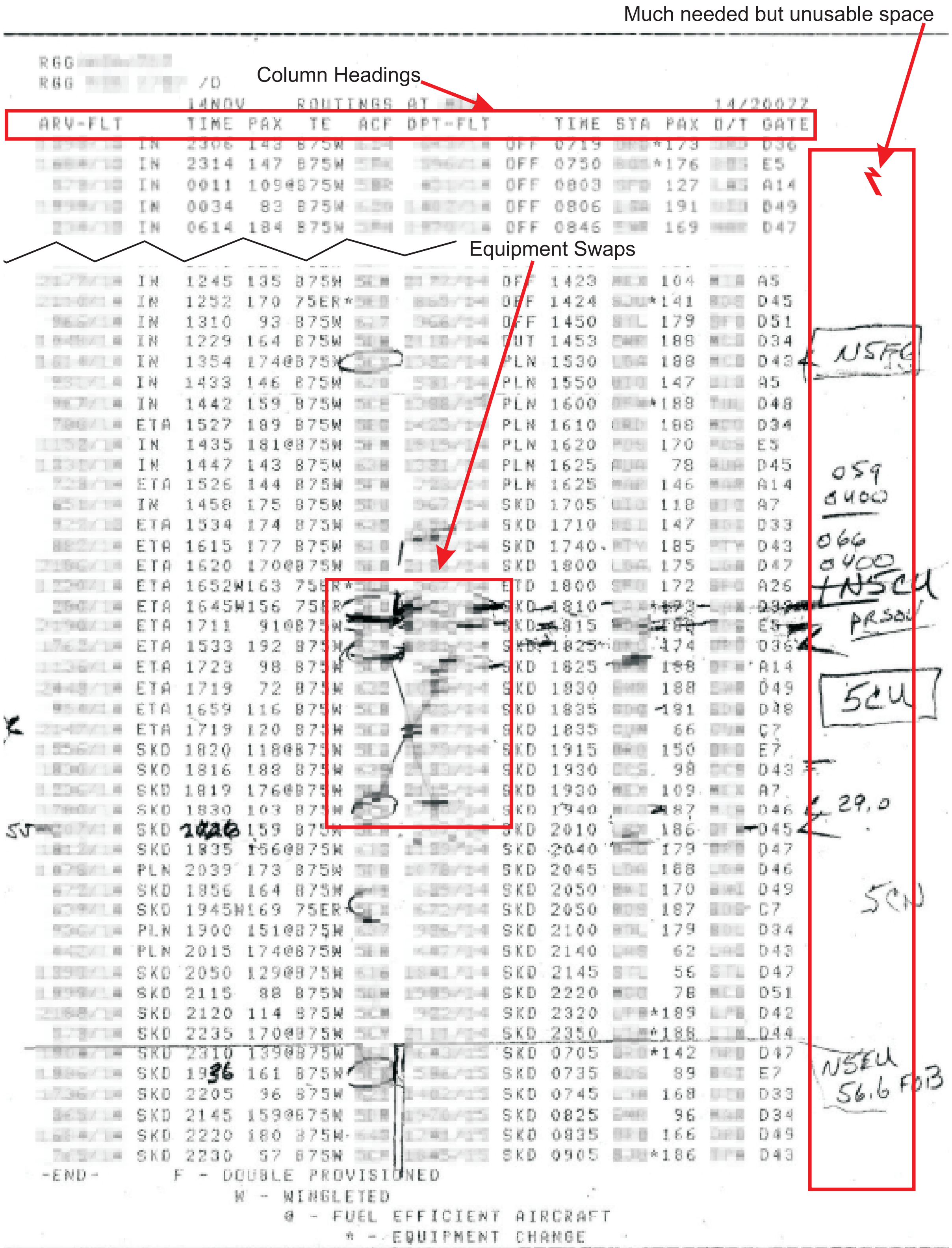
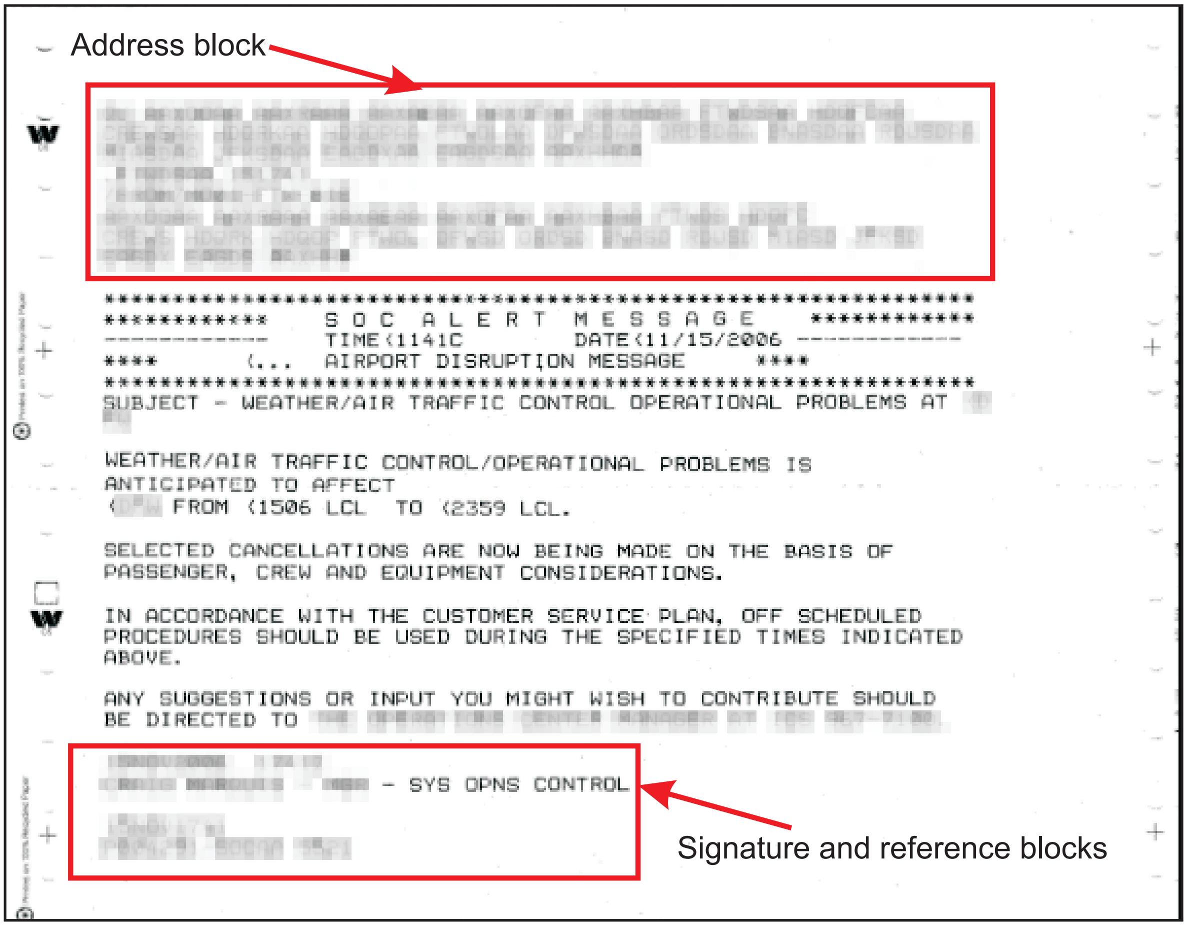


Figure 2. Artifact Model: Schedule Printout



[redacted]

```
*************************************************************
************    S O C  A L E R T  M E S S A G E    ************
------------    TIME(1141C        DATE(11/15/2006 -----------
****      (...  AIRPORT DISRUPTION MESSAGE      ****
*************************************************************
SUBJECT - WEATHER/AIR TRAFFIC CONTROL OPERATIONAL PROBLEMS AT [redacted]

WEATHER/AIR TRAFFIC CONTROL/OPERATIONAL PROBLEMS IS
ANTICIPATED TO AFFECT
([redacted] FROM (1506 LCL  TO (2359 LCL.

SELECTED CANCELLATIONS ARE NOW BEING MADE ON THE BASIS OF
PASSENGER, CREW AND EQUIPMENT CONSIDERATIONS.

IN ACCORDANCE WITH THE CUSTOMER SERVICE PLAN, OFF SCHEDULED
PROCEDURES SHOULD BE USED DURING THE SPECIFIED TIMES INDICATED
ABOVE.

ANY SUGGESTIONS OR INPUT YOU MIGHT WISH TO CONTRIBUTE SHOULD
BE DIRECTED TO [redacted]
[redacted] - SYS OPNS CONTROL
[redacted]
```

Figure 3. Artifact Model: SOC Alert Message

be seen in Figure 3 which shows a standard SOC Alert Message regarding weather issues affecting one of the airline's hub airports.

3.2 OC Software Artifacts

Figure 4 is a representative image of the software tools displayed on the OC's dual monitors. The monitors are connected to a single PC which means that both monitors can be controlled from a single mouse and keyboard. The dual monitors allows the OC an entire monitor to arrange and view multiple SABRE terminals and a second monitor to display the station monitor and any other auxiliary software tools such as web pages. In this case the OC has a Turnover Report Program on the screen. Using dual monitors allows the OC to access both monitors with a single mouse and keyboard. The only drawback to the current OC software set up is that the airline's scheduling tools are based on a now obsolete operating system, which means that most of their current tools will need to be either replaced or rewritten when the airline transitions to a new computer platform.

The OCs primarily use two software tools: SABRE Terminals and a Station Monitor which are shown in Figures 5 and 6. The SABRE Terminals are text based terminals which allow an experienced user to access all of the schedule information that the airline has and to display that information in an almost infinite number of ways. Unfortunately, this power and flexibility is offset by the need to remember complex and cryptic command sequences. As most command sequences are quickly forgotten, if not used regularly, most OCs know only a subset of the total number of commands. This subset appears to be more than adequate for most purposes, but during this inquiry, more than once one of the OCs asked a colleague for the command that would access and display the information in a specific way. Further a comment was made that SABRE terminal training was conducted “by rumor.”

As the airline has over 700 aircraft and each OC is responsible for over 200 flights during their shift, the OCs do not use any kind of Gantt-chart schedule visualization tool. Instead they work on schedule anomalies which are brought to their attention via phone calls or the Station Monitor. The Station Monitor is a software tool which monitors the airline’s schedule for anomalies according to parameters specified by the OC. Parameters include the station of interest, the aircraft type, estimated delay time, estimated turn time, estimated crew arrival time, etc. The problems identified by the Station Monitor are color coded and allow the OC to quickly identify which issues that an OC is capable of attending to, versus those which are beyond the control of the OC position. Unfortunately once this assessment has been made, there is no good way to sort the list such that issues beyond an OC’s control, or issues which need attending to at a later time can be separated from other impending issues. Once the issue has been resolved, either by the OC or by someone else, the problem disappears from the Station Monitor. This disappearance can also cause confusion as there is no indication to the OC (who may have been working on the issue) why or how the issue was resolved. Overall, the OCs are adept at mentally filtering the list and using it to identify problems, which they then address and coordinate a response.

3.3 ATCC Software Artifacts

As the job of the ATCCs centers around minimizing the impact of ground delay programs, the ATCCs use different tools than the OCs. Instead of using the Station Monitors they use a combination of the SABRE Terminals, FAA websites containing GDP and arrival information, the Flight Schedule Monitor (FSM) and Enhanced Substitution Module (ESM). As the airline is such a large airline with multiple hubs, both ATCC stations have an entire computer and monitor dedicated to displaying the FSM and ESM, with the ESM often taking priority. The ATCCs use the ESM to identify possible slot swaps so that the overall airline delay is minimized. The top section of the ESM contains summary statistics for the current GDP and for any changes made by the ATCCs. As the GDPs are continuously under scrutiny and are often revised once an hour due to improving or deteriorating weather conditions, managing the GDPs for the entire airline is a full time task.

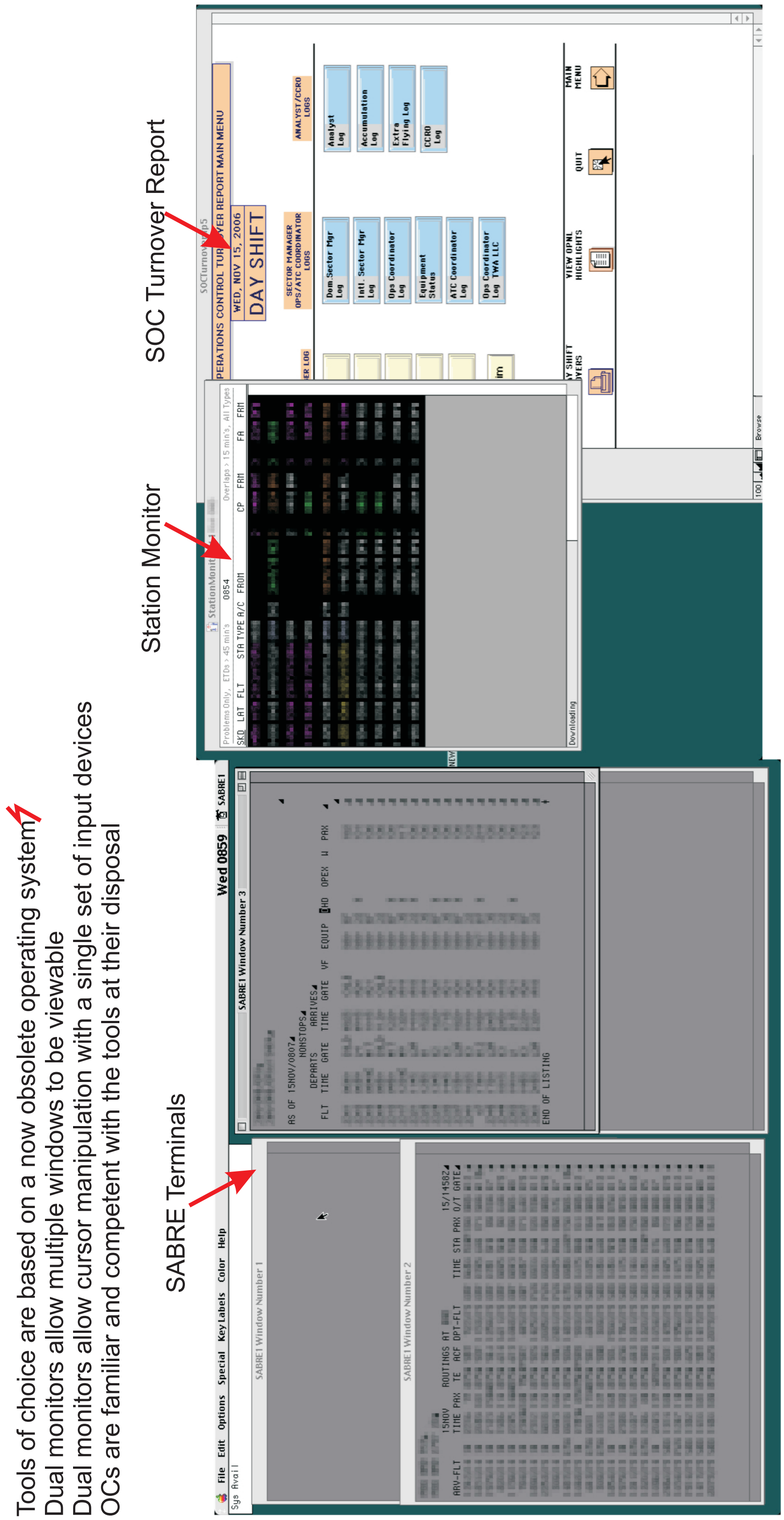
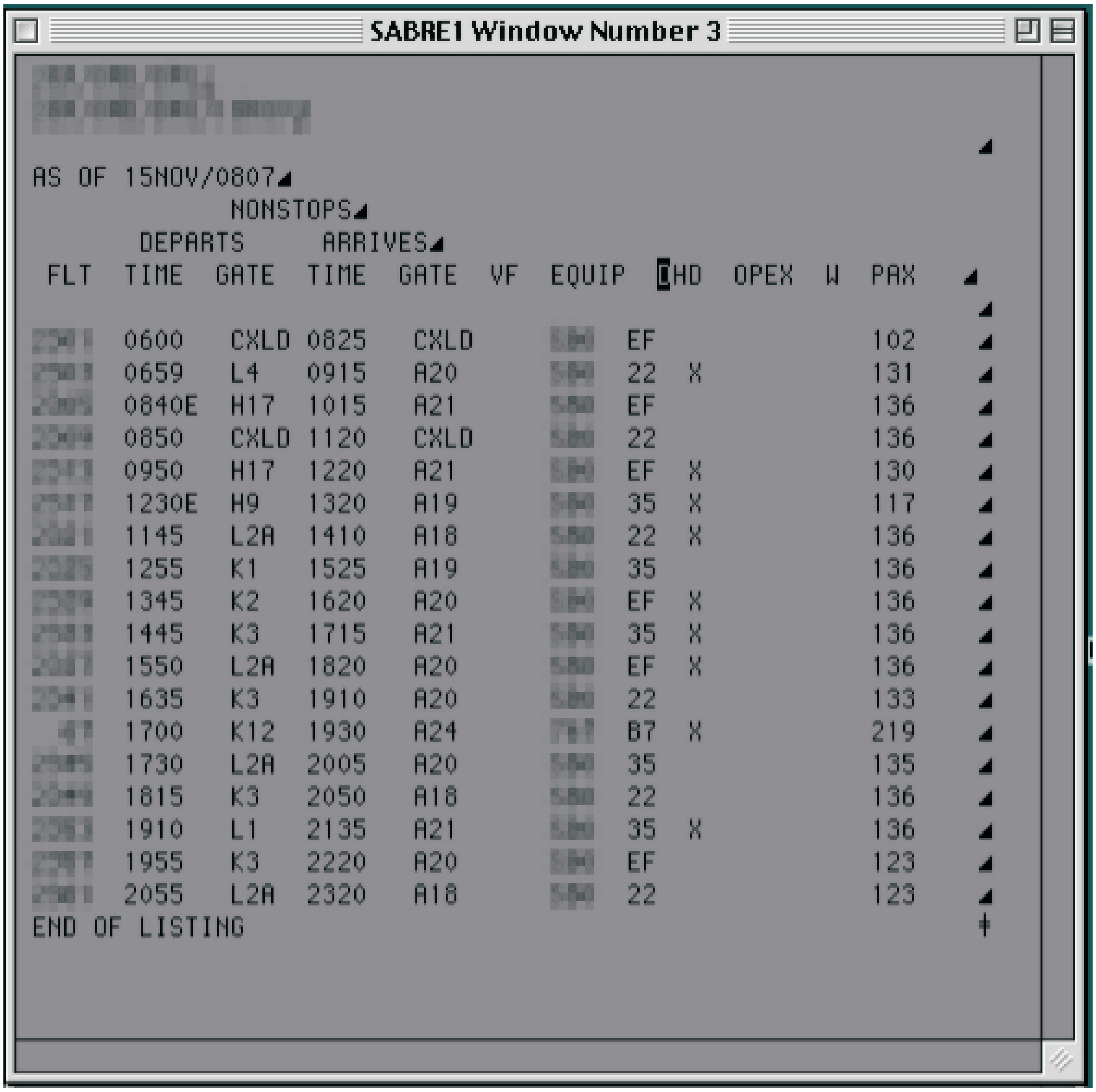


Figure 4. Artifact Model: Operations Coordinator Computer Monitor

Standard SABRE text terminal
Extremely powerful and versatile tool

So many commands available that only a subset are known to the users


SABRE1 Window Number 3

AS OF 15NOV/0807

NONSTOPS

	DEPARTS		ARRIVES							
FLT	TIME	GATE	TIME	GATE	VF	EQUIP	CHD	OPEX	W	PAX
[illegible]	0600	CXLD	0825	CXLD		[illegible] EF				102
[illegible]	0659	L4	0915	A20		[illegible] 22	X			131
[illegible]	0840E	H17	1015	A21		[illegible] EF				136
[illegible]	0850	CXLD	1120	CXLD		[illegible] 22				136
[illegible]	0950	H17	1220	A21		[illegible] EF	X			130
[illegible]	1230E	H9	1320	A19		[illegible] 35	X			117
[illegible]	1145	L2A	1410	A18		[illegible] 22	X			136
[illegible]	1255	K1	1525	A19		[illegible] 35				136
[illegible]	1345	K2	1620	A20		[illegible] EF	X			136
[illegible]	1445	K3	1715	A21		[illegible] 35	X			136
[illegible]	1550	L2A	1820	A20		[illegible] EF	X			136
[illegible]	1635	K3	1910	A20		[illegible] 22				133
[illegible]	1700	K12	1930	A24		[illegible] B7	X			219
[illegible]	1730	L2A	2005	A20		[illegible] 35				135
[illegible]	1815	K3	2050	A18		[illegible] 22				136
[illegible]	1910	L1	2135	A21		[illegible] 35	X			136
[illegible]	1955	K3	2220	A20		[illegible] EF				123
[illegible]	2055	L2A	2320	A18		[illegible] 22				123

END OF LISTING

Figure 5. Artifact Model: SABRE Terminal

Color code indicates cause of problem
Brings problems to OC attention

No good way to organize issues or to mark them as
1) Having been dealt with
2) Needing attention at a later time
3) Ignore because it is out of OC control

Indicates current settings, which can be altered by user

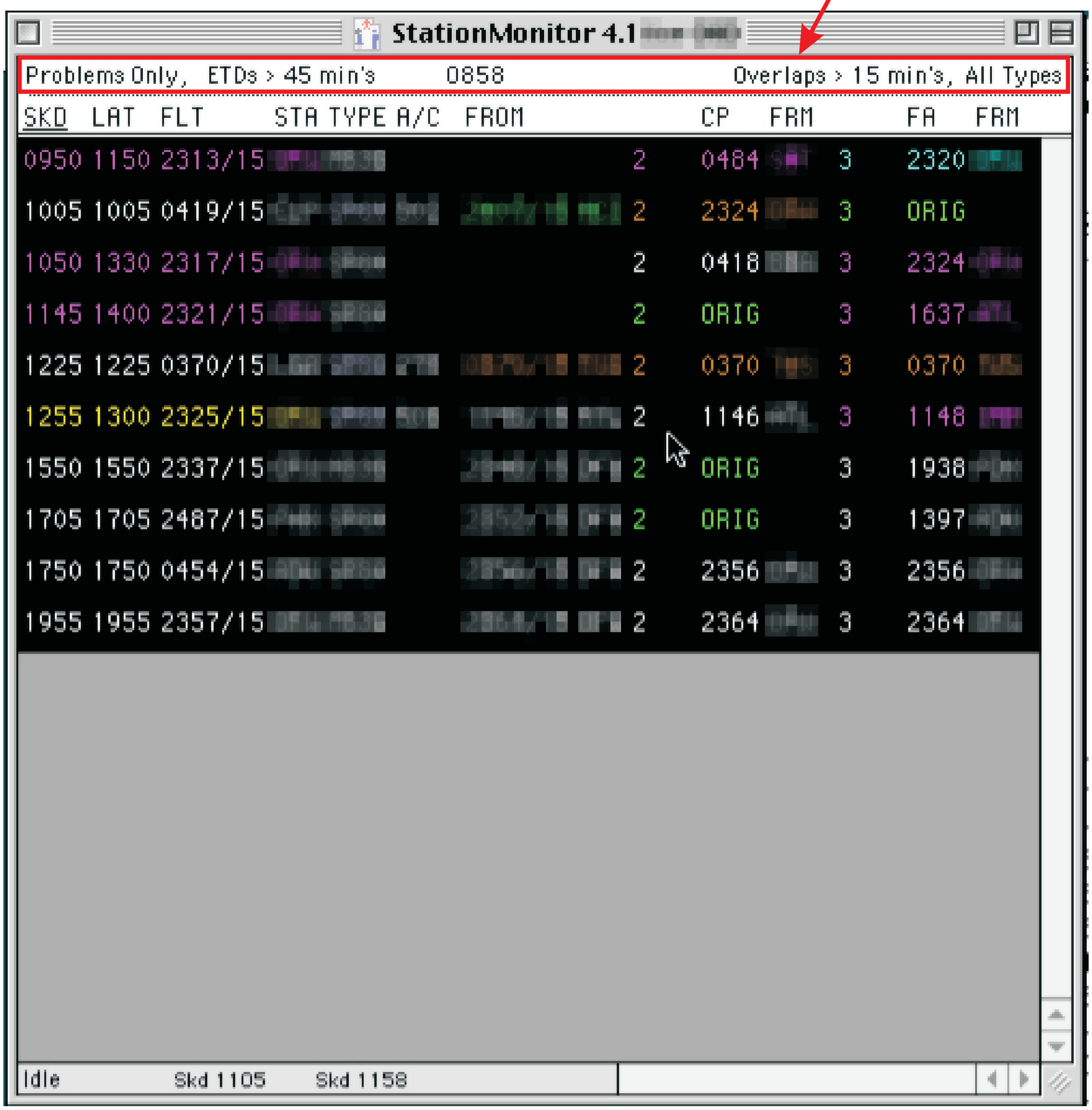


Figure 6. Artifact Model: Station Monitor

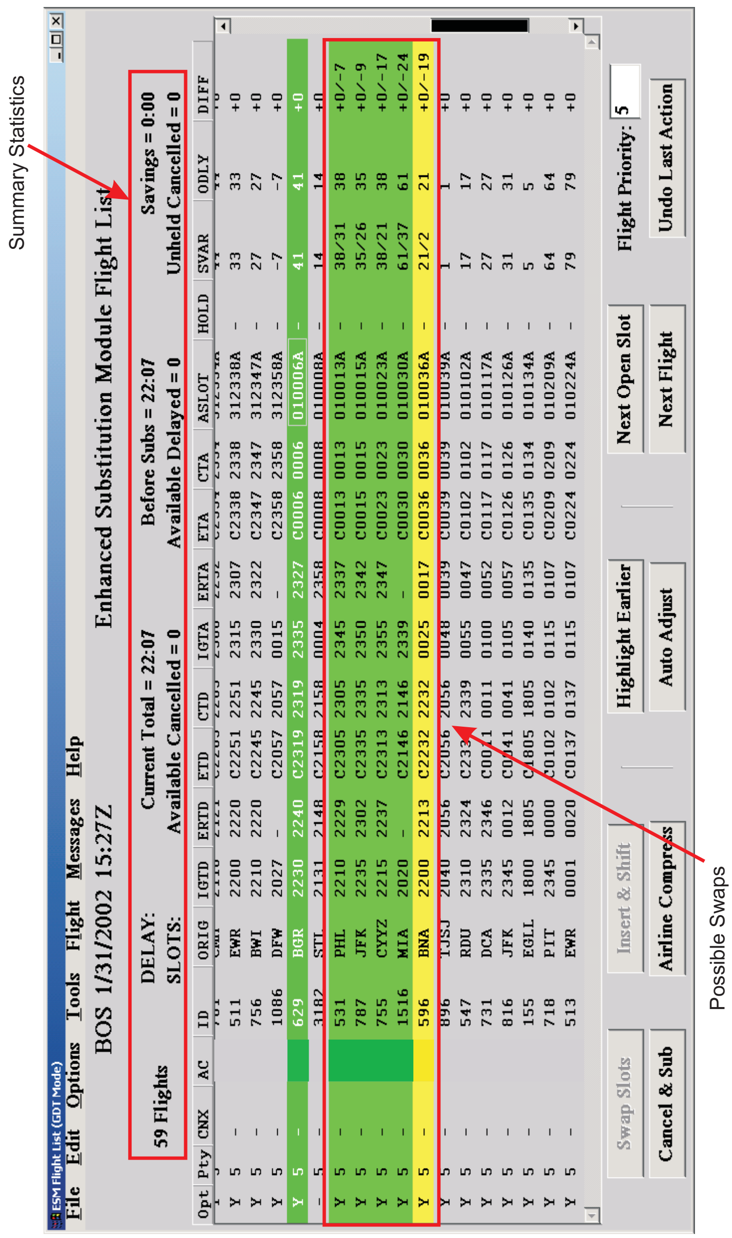


Figure 7. Artifact Model: Enhanced Substitution Module Artifact Model

When multiple GDPs are in place, however, the job becomes even more difficult because in addition to minimizing the GDP impact on the airline's schedule, the ATCCs may also wish to minimize passenger mis-connections, account for crew duty time, and to minimize disruption to specific flights with VIPs aboard. To aid with all of these tasks, the ATCCs also have access to an in-house tool called the ATC Advisor which works with the ESM and uses additional data on crew schedules and passenger itinerary to more effectively optimize the GDP slots.

4 Cultural Model

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, including people, policies, values, preferences, or points of pride. In addition, the specific topic of influence and direction of that influence are shown. The cultural model for the airline is shown in Figure 8.

The airline was hit hard both emotionally and financially by the September 11th attacks. Those experiences permeate the SOC and all of the SOC personnel. It manifests itself as a combination of pride, resourcefulness and unwavering self assurance.

Additionally, as the airline is one of the largest US air carrier, there is a much higher level of job compartmentalization than at other airlines. Consequently SOC personnel tend to only interact with a small number of other SOC personnel – usually defined by their job description. For example, the OCs coordinate rerouting in response to irregular operations. They work primarily at the level of individual flights and coordinate heavily with crew schedulers, ramp managers (for their specific hub/stations) and MOC. While they deal with the consequences of the ATC Coordinators and even rotate through that position, they do not interact with the ATCC position. Within these positions there is an undercurrent of tension as each individual tries to find a solution which best fulfills his individual goal. In some cases the OC has final say, but in most cases the OC actually must defer to the MOC or the crew schedulers, if either claims that a suggested solution cannot be accomplished. The give and take between all of these positions however, is highly dependent upon the situation as periods of highly irregular operations often lead to greater flexibility by all parties in cooperating with the OC.

The OCs were originally trained as dispatchers and think of themselves as senior dispatchers. Consequently most of the OCs are very senior personnel with an average of over 20 years with the airline. As they have been successfully performing their jobs for several years now, they see little need for increased automation, preferring the systems that they know and understand to newer systems. They are not, however, opposed to enhanced automation that aids their jobs, such as a cancelation advisor which aids with the strategic thinning of the schedule due to severe schedule disruptions, e.g. adverse weather conditions.

The ATCC position is perceived as a fairly thankless job, and as one of the ATCCs put it, “you can never win” in that position. The cards are stacked against you from the beginning. The lack of feedback is particularly difficult for individuals in this position because they feel like most choices are bad. In the end the ATCCs take their lead from the Operations Manager and communicate the new schedule to the rest of the airline via electronic messages and print-outs.

What is particularly interesting about this model is what is lacking. During the inquiry very little managerial oversight or pressure was felt or indicated by the SOC personnel. Perhaps this is the result of having successfully weathered the civil aviation downturn of the early 2000’s. Everyone seemed to be acutely aware of the the airline’s stock price. Similarly absent were customers or a dedicated customer advocate, although, customers were specifically accounted for in several of the in-house optimization tools.

5 Physical Models

The purpose of the physical model is to depict the physical environment in which the work takes place and to detect any physical barriers to productive work. Figure 9 is the physical model of the airline’s SOC. The SOC is housed in a large open room approximately the size of a large aircraft hangar and is divided into five main areas. Within each area the work stations are arranged in groups of three forming squares with an entrance at one corner. The two largest areas are for the crew schedulers and the dispatchers. Other areas of interest include the bridge, the OC area, the ATCC area and the SC area. The bridge, located at the right of the physical model, is an elevated area which holds the Operations Manager, and several managerial support personnel. The OC area is located to the bottom left of the physical model and consists of two contiguous sets of work stations, four of which are normally manned and one of which is only manned during significant irregular operations. Two crew scheduler stations are located across from the lower OC stations and are the work stations manned by crew schedulers with whom the OCs coordinate. The ATCC area is located in the upper righthand side of the physical model and is located adjacent to the DM work stations.

Figures 10 and 11 show half of the SC workstations and half of the central desktop. At the center of each of the two SC workstation areas resides a large dot-matrix printer which serves both to print information requested by the SCs but to also print all GDP revisions and other messages sent to the SCs. Since the SCs sit at the four adjacent work stations, they have a clear view of each other and can easily overhear one another’s conversations. Each station has a single computer connected to two monitors, a phone system displayed on a CRT monitor, and a corresponding phone handset. Between the four SC stations is a large, glass-topped desktop which is used by the SCs to examine the printouts of the day’s schedule. In addition, the desktop also holds a number of other common office supplies such as a stapler, pencil holder (holding multiple colored pencils), another phone system, hand sanitizer, reference materials and occasionally salt and pepper, as the SCs mostly eat

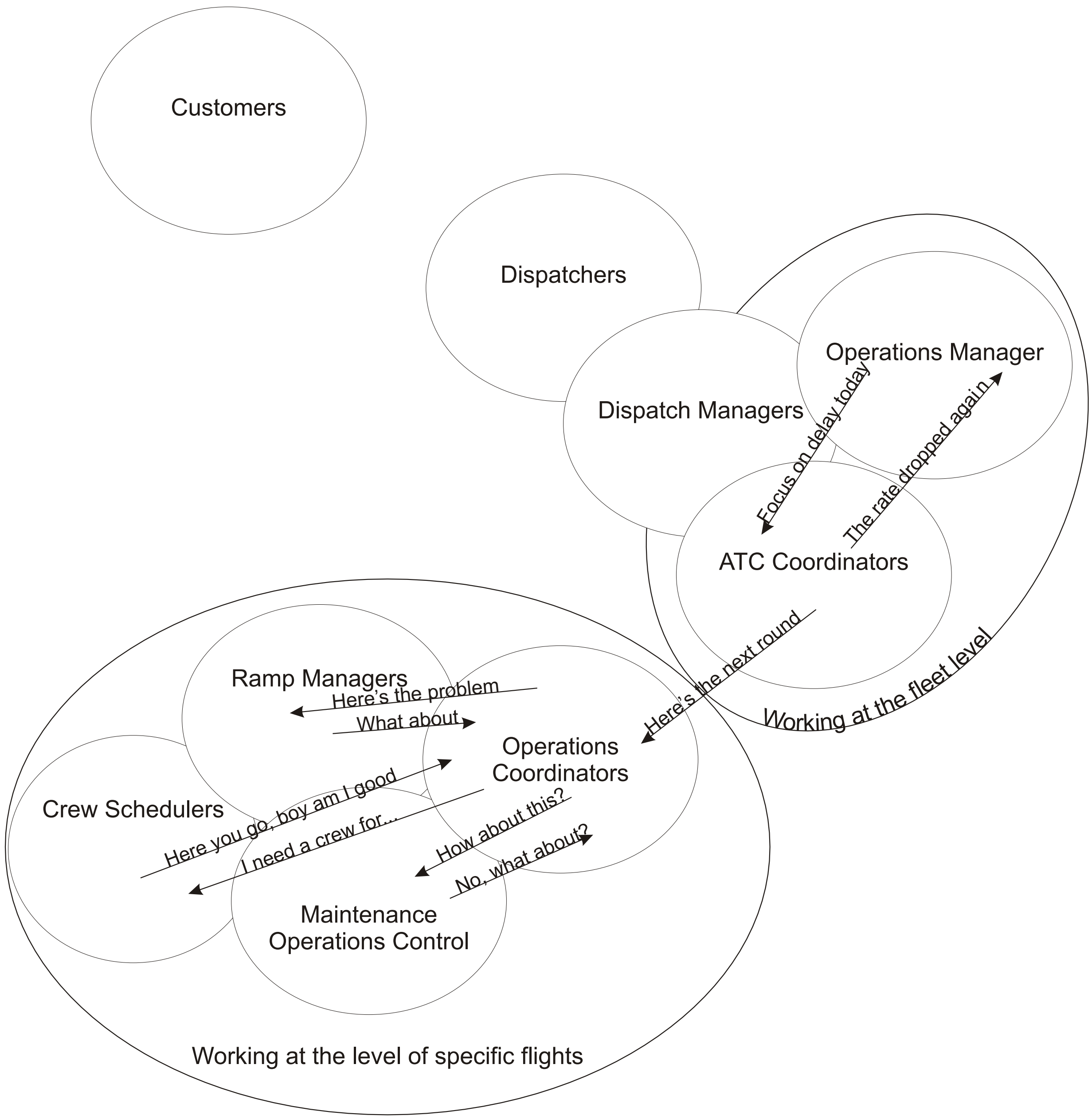


Figure 8. Cultural Model

Figure 9. Physical Model of SOC Centered on the SC Area

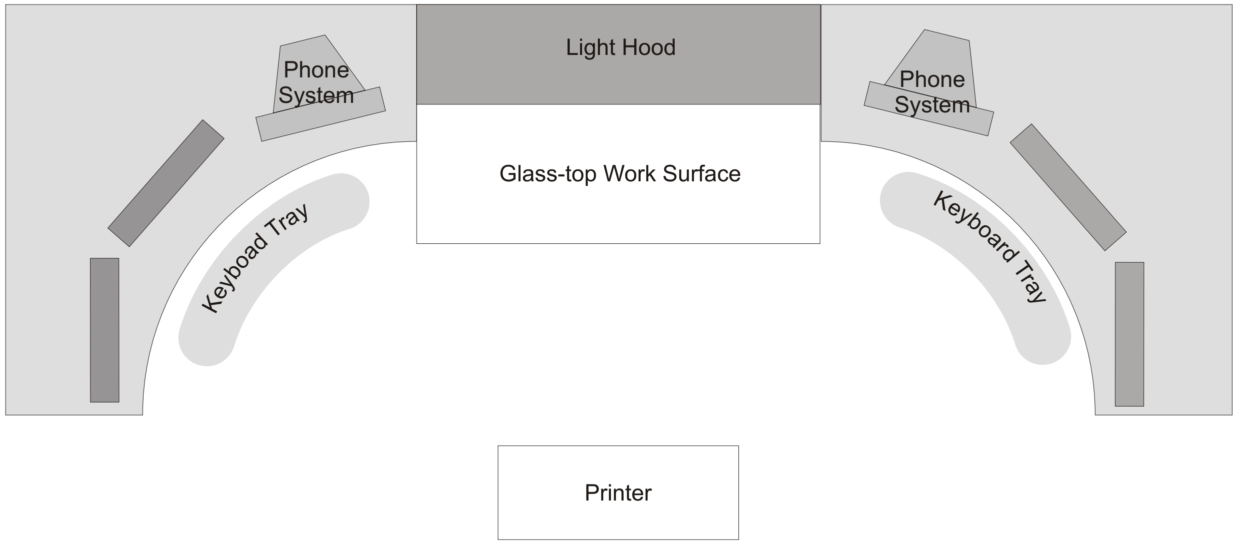


Figure 10. SC Workstation Physical Model

at their desks.

Figure 12 shows the two ATCC workstations. The ATCC workstations are covered with computer monitors. Each station has the internal phone system with corresponding CRT, a single computer is attached to two flat-screen monitors for accessing the airline schedule information. An additional computer which is usually used to run the FSM program, and a shared computer with monitor displaying the GDP programs and the internal ATC Advisor program are also located on the ATCC work stations. Due to a lack of space, the pointing devices (normally mice) have been replaced by track balls. In addition to all of the computers and corresponding monitors the ATCC stations also have an alarm clock which is used to remind the ATCCs about the regularly scheduled ATC teleconferences, as well as additional conventional phones.

6 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 actions taken, similar to many forms of task analysis. As the work of the Operations Coordinators is more goal-driven than procedure-driven, sequence models provide only a snapshot of the overall work structure of the SOC personnel. However, sequence models can illustrate frustrations that individuals may have with duplication of effort and can provide representative examples of the types of problems encountered on a daily basis. This section will present four sequence models,

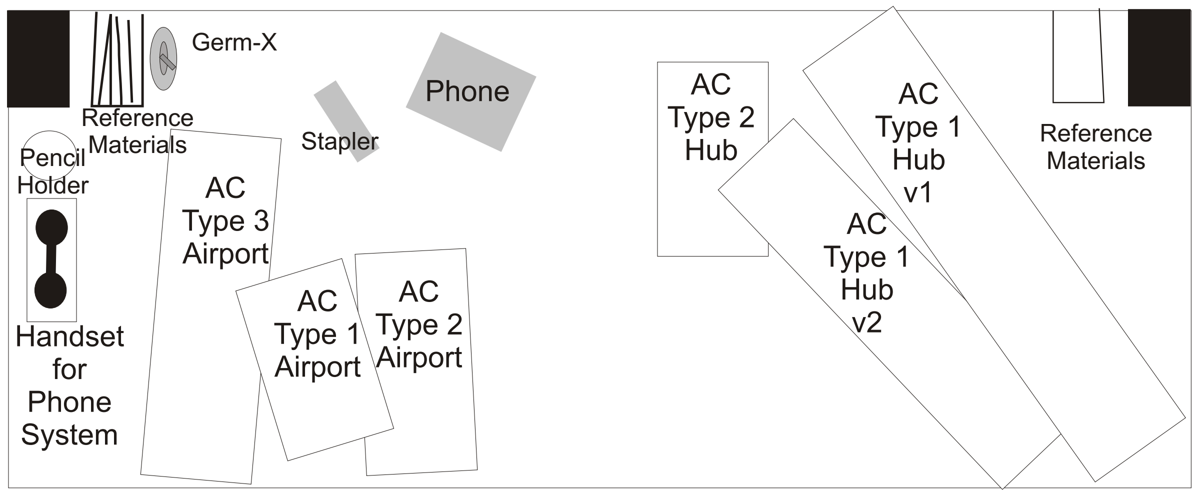


Figure 11. SC Glass-top Work Surface Physical Model

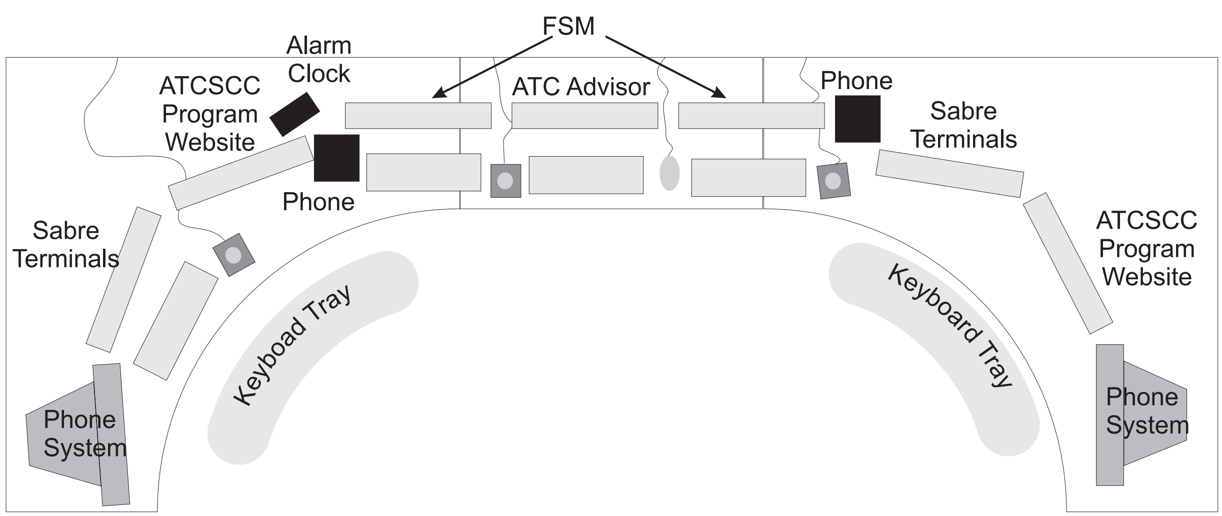


Figure 12. ATCC Workstation Physical Model

SM Initiated Equipment Swap	Operations Coordinator
Trigger:	OC notices a problem on the SM that can be resolved by swapping equipment.
Intent: Needed to verify that a crew was available before looking for an aircraft.	Asked crew scheduling for a new crew Crew scheduling found an available crew
Intent: To determine the availability of an alternative aircraft	Found a new aircraft for trip using the station schedule print outs
Intent: To verify that this swap will not cause maintenance difficulties	Called MOC to check validity of plan
Intent: To alert ramp manager of equipment swap	Called the ramp manager
Intent: To advise interested individuals of equipment swap	Sent electronic message to explain changes

Figure 13. Sequence Model: Equipment Swap

all of which will represent typical issues that are likely to be encountered frequently.

The first two sequence models (Figures 13 and 14) focus on two common OC's work practices. The first describes an equipment swap and is a task performed multiple times a shift. The second is describes a more complicated equipment swap where, the seemingly available aircraft chosen for the swap, is actually unavailable, but not listed as so by maintenance. This practice of not reporting an aircraft as out of service until it is paired to a flight is common because it reduces the official number of aircraft charged to maintenance. However, as the aircraft are not actually available it often leads to additional work by the OCs and frustration and ill will between the OCs and the MOCs. Both sequence models illustrate the extent to which the OC actually coordinates between all of the interested parties, instead of operating on their own.

The second two sequence models (Figures 15 and 16) focus on two common ATCC work practices. The first describes the steps taken when swapping GDP slots and the second describes the steps taken when "compressing" the airline following a GDP revision where the arrival rate has been increased. Neither procedure requires many steps. Additionally, the number of possibilities for GDP slot swaps is usually fairly small, which allows the ATCC to quickly choose the best and make the swap. The airline compression following a GDP revision is highly automated thanks to the ESM and requires the ATCC to make few choices. These two sequence models of common tasks illustrate the repetitive nature of

In Service Aircraft Unavailable	Operations Coordinator
Trigger:	Call from Ramp Manager notifying of a new advise time for Ac123 of 1500 from previously posted 0900
Intent: Needed to identify all unscheduled AC, as there isn't any good way to identify available AC	Looked up all 7X7s in at Station in a SABRE terminal
	Found possible AC with a through flight that could be broken into two flights so that it could be used for FLT1243 and a new AC could be found later for the 2nd half of its flight (FLT1067).
Intent: To see if crew schedule is amenable to breaking the through flight	Used SABRE terminal to look up crew sequence
Intent: To verify that this swap will not cause maintenance difficulties	Called MOC to coordinate new AC for FLT 1067
Intent: To advise interested individuals of equipment swap	Sent out message to swap break FLT 1067
Intent: To get them to put swap in computer system	Called MOC and told them to link up FLT 1067 (first half with FLT 452)
Intent: To inform OC that despite earlier coordination and the appearance that AC 055 is available, actually it is not	MOC calls back to say that the AC the OC has put on FLT 1243, while listed as unscheduled is actually not available, please use AC 075 instead.
Intent: To advise interested individuals of equipment swap	Sent out new electronic message to alter swap

Figure 14. Sequence Model: In Service Aircraft Unavailable

GDP Slot Swapping	ATC Coordinator
Trigger:	Call from dispatcher that FL 1659 will not make slot time
Intent: To take advantage of the newly available slot	Looked for possible slot swaps using EMS
Intent: To verify that intended swap will not cause any crew legality issues	Looked up crew legality for possible swap using the SABRE terminal – none found
Intent: To minimize the impact on the passengers and flights with the longest flight time	Decided on a swap based on distance to destination
I	Made swap in ESM

Figure 15. Sequence Model: GDP Slot Swap

the ATCC task. As things are continuously changing during a GDP, these procedures must be done repeatedly for multiple airports, which makes it hard to formulate or maintain a strategic vision.

7 Design Implications

The airline operates the largest fleet of aircraft in the world. Additionally it is one of the oldest US airlines, and the only major US airline never to have declared bankruptcy. Consequently, many of the employees who started out in a number of different airlines over the years that were eventually bought or merged with the airline, are still working in much the same way that they have been for the past ten years. Due to the large numbers of aircraft and crews, SOC positions are highly specialized, each with relatively few roles. Consequently, most positions have objectives which naturally compete with those of their colleagues working different positions, e.g. OCs and MOCs. The majority of decisions are made by consensus. An interesting dynamic, which has significant design implications, is the degree to which the shifting balance of power, such as how the OCs share decision making authority with the MOC, changes with circumstance.

This inquiry has three major findings. The first is that the current method of paper schedule printouts used by the OCs, while fairly effective, is largely effective because of the high experience level of the OCs using them. As the OCs begin to retire and are subsequently replaced by individuals with less experience, a better method can be envisioned which is more efficient then the current system. A replacement system would allow addi-

GDP Revision	ATC Coordinator
Trigger:	Call from Hub ATC advising of a possible revision to the current GDP and asking for opinions
Intent: To take advantage of the improving weather by increasing the arrival rate	Hub ATC made agreed upon revisions
Intent: To take advantage of all of the newly available slots allotted to the airline	Started ESM and using ESM, compressed airline
Intent: To advise OCs, dispatchers and others of the new slot times.	Sent out messages of GDP revision and new slot times electronically

Figure 16. Sequence Model: GDP Revision

tional columns of information to be listed and would support a more explicit form of the sorting and filtering which is currently done mentally. It would need to support free form annotations and manipulations with non-standard input devices, such as styluses. A replacement system's display may need to be oriented horizontally, instead of the traditional vertical orientation of many computer screens, to facilitate the annotation and manipulation using a stylus-like input device. Such displays are now well within technological capabilities.

The second major finding is that the level of coordination required between the MOC and the SOC is extremely high during normal operations, and that the level of coordination changes dramatically depending on the level of irregular operations. The coordination is substantial enough during nominal operations, that a MOC representative should be present in the SOC. If this is not possible then some form of general guidance about which planes are actually available, i.e. planes which are neither scheduled nor currently undergoing maintenance, information on which planes are due where at the end of the day's flying, and or how many more cycles/hours each plane has should be available to the OCs. Having access to additional information would save the OCs both time and frustration when attempting to identify suitable aircraft for the current routing. I believe that the effort and extensive coordination required for each aircraft routing change is the reason why, when large numbers of re-routes are required during irregular operations, decisions are largely made without input from the MOC.

The third major finding is that the announcements sent electronically to the dot-matrix printers are disruptive and often ignored or overlooked because of the vast amount of information being sent to the printers. The information overload is further exacerbated because the information is printed in no particular order, requiring the OCs to visually inspect all of the print outs to determine if anything of interest has been included. The messages should, instead, be routed to a computer screen program where they can be automatically sorted and reviewed before printing. This would allow the OCs to more easily find the messages that are important to them as well as free up their time which must be otherwise spent controlling the paper flow and reviewing all of the messages for those which are actually worthwhile.

8 Summary

In summary, the SOC at the airline works well in both low and high workload situations. In order to achieve this high level of effectiveness the SOC personnel actively adapt their roles and the balance of power depending on the level of operational disruption. The OCs could become more efficient by shedding some of their printer maintenance tasks, shedding the extended MOC coordination sessions and more effectively using software tools. With the addition of an MOC representative in the SOC or the availability of key maintenance related scheduling data increased effectiveness may also be achievable under conditions of limited disruption. Changing the flow of messages from the printer to an on-screen print system will help minimize the 'busy' work associated with maintaining the printer and keeping up with the printouts. Introducing new hardware and software tools with schedule sorting and filtering may also provide increased efficiency, particularly for the more junior OCs.

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