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Abstract

This document contains four reports pertaining to the Monitor Alert Function (MAF) of the Traffic Situation Display (TSD) and to the job called the Monitor Alert Position (MAP). Most Traffic Management Units (TMUs) at Air Route Traffic Control Centers (ARTCCs) have at least one MAP. MAPs are staffed by Traffic Management Coordinators (TMCs). Taken together, the reports document the status and uses of one of the more critical but maligned sources of information in the TMU as of the period of observation, the 1999 convective weather season. The reports are

- Initial Cognitive Task Analysis of the Monitor Alert Position (MAP)
- Three Critical Incident Analyses of MAF Use
- Human Factors Issues with the MAF and the TSD
- Towards the Next-Generation Monitor Alert Function

The task analysis describes the MAF and what TMCs who use the MAF must do to perform the job of the Monitor Alert Position (MAP). The critical incident analyses illustrate how the MAF is (or is not) actually used by TMCs at three different ARTCCs. The third report identifies and makes recommendations on 11 areas where there is room for improvement in the design of the MAF and the TSD. The final report suggests directions for the wholesale redesign of a next generation MAF.

General Introduction

TMUs and the MAP

The Traffic Management Unit (TMU) is responsible for managing sector controller workload (Smith, 1999, 2000). There are five positions in the TMU (Smith and Murphy, 2000). The names of positions reflect the duties to be performed: En-route Spacing Program, Metering, Severe Weather Avoidance Program, Traffic Management Coordinator in Charge and the Monitor Alert Position (MAP). These reports focus on the MAP and the Monitor Alert Function (MAF) of the Traffic Situation Display (TSD). The MAF is the tool that is the primary source of information used by the Traffic Management Coordinator (TMC) working the Monitor Alert Position.

The primary task at the MAP is to monitor the MAF and to perform Proactive Traffic Management (PTM). PTM is the name we give to the tasks of monitoring sector demand and of creating plans for how traffic might be rerouted to avoid excessive sector demand. Of the five TMU tasks, the MAP is the task where the use of the TSD and the goal of managing sector controller workload are the most intertwined and salient.

Acronyms

ARTCC	Air Route Traffic Control Center
ATCSCC	Air Traffic Control System Command Center
Center	An ARTCC
MAF	Monitor Alert Function – A part of the TSD, a source of information
MAP	Monitor Alert Position – A job in the TMU
PTM	Proactive traffic management – Preplanning for traffic rushes, the task performed by the TMC at the MAP
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TSD	Traffic Situation Display
ZFW	Fort Worth Center
ZID	Indianapolis Center
ZKC	Kansas City Center
ZME	Memphis Center
ZMP	Minneapolis Center
ZOB	Cleveland Center (Oberlin, OH)

Acknowledgements

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Initial Cognitive Task Analysis of the Monitor Alert Position (MAP)

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Introduction

This report presents a task analysis of the Monitor Alert Position (MAP) that specifies the sequence and cycles of operations and decisions that must be made in order to meet the goal of the MAP - managing sector controller workload. The term 'goal' refers to a desired state. For air traffic management, the desired state is the safe and expedient flow of aircraft. The likelihood of safe and expedient traffic flow is increased when sector controller workload is kept within reasonable bounds. The MAP exists specifically to ensure that sector controller workload remains tolerable.

The term 'plan' refers to the method adopted to attain a goal. A task analysis uncovers and explains the plans used by experienced practitioners to perform a task. Here, the task is to manage sector controller workload and the practitioners are Traffic Management Coordinators (TMCs) working at the MAP.

The analysis decomposes the goal of managing sector controller workload into a series of subgoals. Figure A1 illustrates this decomposition into subgoals. Each subgoal is associated with sequence of 'operations.' Operations are the fundamental units of behavior, the things people must do to achieve a goal.

This structural decomposition of the MAP task yields a step-by-step description of how to function at the MAP. The analysis identifies Proactive Traffic Management (PTM) as the critical sequence of subgoals within the overall task of manning the Monitor Alert Position. PTM is the name we give to the subgoals of monitoring sector demand and of planning reroutes for specific flights in order to avoid excessive sector demand.

Information sources

The methods used to conduct the task analysis and organize the report were informal expert walk-throughs and talk-throughs. Over a period of several months, TMCs working at the MAP would voluntarily comment on what they were doing as they did it. Additional sources were training manuals, procedure books, and job descriptions.

What the TMC at the MAP does

Overview

To manage sector controller workload, the TMC at the MAP uses the MAF of the TSD to create a graphic display of sectors filtered according to altitude (superhigh, high, and low or high, low, superlow). This display makes it possible to examine sectors (a) that currently contain more flights than their designated capacity limit (red alert), (b) that are predicted to contain more flights than their capacity limit (yellow alert), and (c) may contain more flights than their limit sometime in the future (no alert). The examination of sectors makes it possible to preplan for traffic rushes and to respond to existing rushes.

Plan 1: Activate the MAP

The MAP is not very active when the weather is clear and when traffic is flowing on schedule. However, during bad weather and times of high traffic volume, the MAP can become quite busy. When it appears that traffic volume may increase, the first step the TMC takes is to activate the MAP.

To function in the role of MAP, the TMC activates the position by following Plan 1. As shown in Figure A1, Plan 1 states that the TMC must accomplish two subgoals: (1.1) start the MAF, and (1.2) monitor the MAF and engage in proactive traffic management (PTM). Each of the subgoals has its own plan.

Activate the MAP, Plan 1:
1.1 Start the MAF - Plan 2
1.2 Monitor the MAF, Engage in Proactive Traffic Management (PTM) - Plan 3

Start the MAF, Plan 2:
2.1 Computer on
2.2 Password
2.3 TSD icon
2.4 Customize windows

Monitor the MAF & Engage in PTM, Plan 3:
3.1 Identify sector(s) of interest
3.2 Examine sector(s) - Plan 4
3.3 Obtain list of flights
3.4 Extract information - requires additional research
3.5 Select flights - requires additional research
3.6 Devise reroute plan - requires additional research
3.7 Implement the plan

Examine Sectors, Plan 4
4.1 Click on sector, type E
4.2 Click on timeline, get chart
4.3 (If red alert), count excess aircraft
4.4 (If red alert), inform area supervisor

Figure A1 – Initial specification of the four plans of action and decision making at the Monitor Alert Position

Plan 2: Start the MAF

The first subgoal is to start the TSD. The plan for starting the TSD consists of a sequence of four operations: (2.1) turning on the computer, (2.2) typing in the password, (2.3) using the mouse to click on the TSD icon, and (2.4) customizing the TSD and MAF windows to fit the user's individual preferences.

The operation of customizing the windows is itself a subgoal that was not pursued for this analysis. The operations involved in customizing the window vary from center to center, and TMC to TMC. Most TMCs choose to display at least two windows. The first generally shows the entire country and all air traffic (±that will pass though their center). The second window generally displays their ARTCC, its sectors, and filters traffic by color traffic according to destination.

When customizing the MAF windows, the TMC encounters several curious human factors issues that could be readily mitigated. The issues and recommendations for MAF improvements are listed in the third report in this document. For example, the "Select Alerts" and "Examine Alerts" functions of the MAF have three options, "Airports", "Fixes", and "Sectors." In centers with heavy overflight traffic, the MAF is used primarily for examining sectors. The MAF defaults to Airports. This setting works well for centers like ZFW that focus on large hub airports but forces TMCs to click on the "Sector" option every time they want to examine a sector. It centers like ZKC and ZMP, the "Airport" default makes selecting alerts more time-consuming than it should be. Selecting the sectors option is a routine part of customizing the MAF window in many TMUs.

Plan 3: Monitor the MAF and Engage in Proactive Traffic Management

The second subgoal in Plan 1 is to monitor the MAF and engage in proactive traffic management (PTM). The plan to do this is shown as Plan 3 in Figure A1. There are seven operations in this plan. The first operation is (3.1) to identify sectors of interest. The MAF has two level of alert that facilitate this step. When the MAF receives information that suggests demand for a sector that may exceed the sector's capacity sometime in the future, it highlights that sector in yellow. A 'yellow alert' indicates that levels of controller workload are likely to become dangerously high. Similarly, whenever sector demand exceeds capacity, the MAF automatically highlights that sector in red. A 'red alert' indicates that the MAF has received information that suggests that the current level of controller workload may already be dangerously high. In the absence of MAF alerts, identification of sector(s) of interest is guided by knowledge of traffic patterns and of sectors that regularly experience traffic rushes.

The second operation in the plan for PTM is (3.2) to examine the sector(s) of interest during the time of the projected rush. Examining sectors is a subgoal that is met by following Plan 4 (below).

The third operation in PTM is (3.3) to obtain a list of flights projected to be in the sector(s) during the rush period. The MAF forces the TMC to take four steps to obtain a paper copy of this list. The extra steps are a source of unnecessary workload and frustration.

The fourth operation in PTM is (3.4) to extract information about aircraft and flight plans from the list. The act of extracting information from the flight list is itself a subgoal that needs further elaboration. It involves filtering flights according to implicit criteria. For example, international flights are typically filtered out of consideration. Their fuel limitations generally make them poor candidates for rerouting. Developing an improved understanding of how TMCs extract information would be a valuable contribution to the process of redesigning the MAF to better fit TMC needs.

Next the TMC must (3.5) decide which flights are best suited for rerouting. Once again, this operation is itself a subgoal that needs further elaboration. As discussed in the second report in this document, we have an inkling about how the decision is made. For at least one TMC, flights must meet three criteria to be considered candidates for rerouting: (a) ease of reroute, (b) impact of reroute, and (c) time of day in the sector. Understanding how this decision is made should be a major thrust of research sponsored by FAA Air Traffic Management.

The most visible step in the PTM process is (3.6) devising a reroute plan. Several TMCs generally collaborate to formulate the plan. The give and take is always collegial rather than competitive. Options are offered and weighed. Alternatives are often combined. To observe TMCs working together to devise a plan is to see collaborative, distributed decision making in its finest hour. FAA Air Traffic Management should be keenly interested in documenting how it works.

The last operation in PTM is (3.7) to implement the plan by advising area supervisors to inform sector controllers to issue reroutes to specific flights to alleviate the anticipated traffic rush.

Plan 4: Examine Sectors

The first operation in Plan 3 for PTM is to identify the sector(s) of interest. Red and yellow alerts facilitate this process. The second operation is to examine the sectors. To do this, the TMC follows Plan 4. The first operation is (4.1) to use the mouse to highlight the alerted sector and to press the 'E' key on the keyboard. This causes an alert timeline to appear. The TMC then (4.2) clicks on the time period of interest. This causes a chart will appear displaying current information about the number of aircraft (projected to be) in the alerted sector. In the case of a red alert, the TMC (4.3) counts the number of flights over the sector capacity, and (4.4) informs the area supervisor about (a) the number of flights over the sector capacity and (b) the expected duration of the red alert state.

Summary

Three critical plans at the heart of PTM need additional investigation. We do not have sufficient information to detail the operations involved in (3.4) extracting information from the flight list, in (3.5) deciding which flights are best suited for rerouting, and (3.6) devising the reroute plan. Each of the processes involves a significant amount of decision making based on experience and intimate knowledge of traffic patterns.

This knowledge is a priceless asset. Elucidation of this knowledge should be a high research priority.

Three Critical Incident Analyses of MAF Use

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Introduction

This report presents three case studies that reveal substantial differences in how the MAF is used in different TMUs. Analysis of these critical incidents demonstrates that the effectiveness of the MAF varies across different ARTCCs. Its effectiveness is compromised by several factors, including but not limited to

- the complexity of the airspace,
- sector geometry,
- procedures (such as those found in Letters of Agreement [LOAs]),
- rate of traffic and
- traffic-flow patterns.

During the period of observation (the 1999 convective weather season), the MAF of the TSD was not an efficient and effective tool for every ARTCC. The analyses suggest that there is room for improving the MAF of the TSD.

The second case study, Proactive Traffic Planning at ZMP, describes an implicit decision-making model for rerouting flights. The model categorizes flights along three dimensions (1) ease with which the aircraft can be rerouted, (2) the impact of a reroute on the flight, and (3) the time of day when the flight will be in the sector of concern. The criterion for rerouting is the intersection of the three dimensions; flights that pass all three tests are candidates for rerouting.

1 The Reaction at ZKC to the Outage at ZME

One day in September 1999, the Kansas City (ZKC) TMU was notified by ATCSCC that Memphis Center (ZME) was experiencing an equipment (live radar return) outage. The ZKC TMU was well prepared for the outage at ZME having practiced what to do in the case of an equipment outage at any ARTCC. The TMCIC was the first to receive the news. He immediately issued a ground stop for all ZKC departures scheduled to land in ZME airspace. He also notified the area supervisors who, in turn, notified the sectors controllers about the ZME equipment outage. The controllers were told to hold all flights with flightplans through ZME airspace until a re-routing plan could be implemented.

Simultaneously, one of the TMCs used the TSD to filter all ZME arrivals and all flights scheduled to fly through ZME that were in ZKC airspace. The MAF provided information about the routes of the flights. The MAF and TSD made this complex retrieval of information relatively simple.

In short order, the MAF status of all sectors around ZME changed to red alerts. The TMCs used the MAF to examine these sectors for volume. Controllers were notified about the number of flights that were over the capacity of the sector. The TMCs used the information provided by the MAF to devise and implement a plan to reroute these flights around ZME airspace. All flights that were being held were rerouted around ZME.

The MAF was also used to obtain information about the ground-stopped flights scheduled to fly through the Memphis Center. Those flights were rerouted around ZME before departure.

It is clear from this example that the MAF can be a useful tool for planning reroutes.

2 Proactive Traffic Planning at ZMP

During the month of May 1999, when I spent time at ZMP, I observed the activities of J*, am experienced TMC working the monitor alert position. (I use J* to ensure anonymity.) J* knew which sectors had recurrently gone ‘red’ during the morning rush of east coast traffic (e.g., ZMP 39 at noon). His knowledge of the pattern of red alerts was developed through his experience with the MAF.

I watched J* as he used the MAF of the TSD to obtain information that he then used to prevent these sectors from turning ‘red’ later in the morning. He used the MAF, two to three hours in advance, to help prevent ‘red alerts’ from reoccurring. He achieved this by obtaining information about flights projected to be in these sectors during the impending traffic rush and rerouting several flights before departure.

To do this, he first used the MAF to obtain a list of flights that were projected to be in the high volume sectors during the traffic rush. He noticed that the number of projected flights was over the capacity of these sectors. He then printed out the lists of flights and began to decide which flights to reroute.

The criterion that J* used for deciding how many and which flights to reroute was based on answers to three questions that he asked himself. These questions were

(1) Which flights will be the easiest to reroute?

J* decided to reroute flights that would "just miss" the sector if one fix and only one fix in it’s flight plan were changed. The idea is to create the largest impact with the least amount of change. It is efficient for both J* and the airlines to keep route changes at a minimum.

(2) Which flights are the least impacted by being rerouted?

J* contemplated the economic efficiency of aircraft when considering which flights to reroute. The size and type of aircraft and the destination of the flights were taken into account. For example, international flights are less likely to be rerouted because of fuel considerations.

(3) What time of day will they be entering and exiting sectors of concern?

J* was concerned with sectors that regularly become very busy at certain times during the day and did not reroute flights into these sectors at those times.

Figure B1 represents the decision making process that led J* to identify the most appropriate flights for reroutes. The three circles represent the three questions used to categorize flights. Flights that meet all three occupy the intersection of the three circles. They become candidates for reroutes.

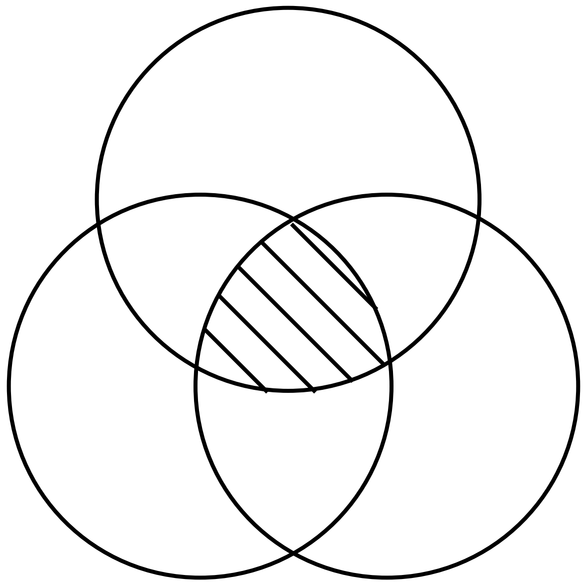

Figure B1 Venn diagram showing the criterion used by J* to identify candidates for reroutes. The three circles represent the three questions used to categorize flights. Candidates for reroutes occupy the intersection of the three circles.

Flights must meet all three criteria to be rerouted. Most flights do not meet all three criteria. Those portions of the circles outside the intersection represent these flights. For example, the circle labeled 'Ease' represents flights that are easy to reroute. Some that are relatively easy to reroute would be negatively impacted. Others enter the sector at the wrong time.

This case study is prime example of how the MAF can be an invaluable decision aid. J*'s proactive traffic management made it unnecessary to issue restrictions (e.g., as miles-in-trail with two streams of traffic) later in the day. He used to MAF to manage sector controller workload by preventing volume overload in high volume sectors.

3 ZOB and the Inaccuracy of the MAF

The previous case study illustrated how the MAF can be used to prevent sector volume overload. In contrast, this example shows how certain variables (i.e., climb and descend profiles, and letters of agreement, LOA) can compromise its utility.

During the months July and August of 1999, I spent more than 200 hours in the TMU of the Cleveland Center (ZOB). When I first arrived, I was surprised to find that the MAF predictions were never accurate. During the time that I spent at ZOB, the MAF consistently displayed red and yellow alerts for sectors ZOB 49 (Lorain) and ZOB 48 (Ravenna) with inaccurate numbers for the sector load. The two major causes of inaccuracy were (1) climb and descend profiles, and (2) letters of agreement. The MAF did not account for either the altitude transitions or the LOAs.

ZOB has many major airports. These airports add to the complexity of the airspace because each airport has specified climb and descend profiles. The climb and descend profiles are effective within the center's jurisdiction (boundary).

ZOB has a complex airspace with a high volume of traffic and many different LOA with adjacent ARTCCs. The LOAs specify altitude transitions, the altitudes at which flights must cross into an adjacent facility's (i.e. from ZOB into Indianapolis Center, ZID) airspace.

As of August 1999, the MAF was compromised by its failure to take into account climb and descend profiles and LOAs. While I was at ZOB, accommodation to the climb and descent profiles had just begun. Evaluation of the impact of this modifications on MAF errors had not begun.

Discussion

These case studies illustrate that the MAF is a highly useful but far from flawless tool. The case study with J* is a prime example of how the MAF should ideally be used. It describes an implicit decision-making model for rerouting flights. The model categorizes flights along three dimensions. The MAF and the TSD provide information pertinent to all three. They made J*'s proactive traffic management (PTM) possible.

J* was able to use the MAF because ZMP's airspace is large and relatively low in complexity. In other facilities, where the airspace is cramped and complex, the utility of the MAF is compromised.

As of August 1999, the MAF did not take into account climb and descent profiles and LOAs concerning altitude transitions. The MAF consistently produced inaccurate information. As a result, TMCs at ZOB tended to discount information displayed by the MAF. Instead, they relied on their experience and knowledge about when and where traffic rushes occur and which sectors are likely to be compromised.

The next report enumerates recommendations for improvements to the MAF.

Human Factors Issues with the MAF and the TSD

July, 1999

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This report enumerates recommendations for improvements to the Monitor Alert Function (MAF) of the Traffic Situation Display (TSD). The initial version of this report was delivered to Mr. James Wetherly of FAA AUA-500 (?) in late July, 1999. At that time we indicated that the recommended updates to software “should be relatively easy for programmers to complete and distribute prior to the next convective weather season (e.g., by March 31, 2000).” Some of the recommendations apply to the TSD generally. Others apply specifically to the MAF.

1 TSD Log

HF Issue

The TSD log can be edited or amended at only one TSD at a time. However, it can be accessed from several TSDs simultaneously. Attempting to access newly input data can cause that data to be dropped or lost. There appears to be a time lag between log entry on one TSD and its availability on other TSDs. Specifically, when the log is opened too soon after data entry, the TSD loses the newly saved input.

Recommendation

A window needs to appear whenever Traffic Management Coordinators (TMCs) try to open the log immediately after or during data entry. This window should warn these data might be lost if the log is opened. The warning should also incorporate a protective delay that would give the TSD sufficient time to save and disseminate new input. Note: Longer strings of input may require longer protective delays.

The next-generation MAF should allow simultaneous access to the log from multiple TSDs.

2 Weather, Default Settings

HF Issue

TMCs usually prefer the weather option to show NOWRADS 8 and Lightning. The “Select Weather” menu defaults to “Radar Tops” and “Jet Streams”. This forces TMCs to select the options they want every time they display weather.

A related HF Issue is the inability to display NOWRAD 2 data. The large volume of data invariably makes the system crash.

Recommendation

The select weather menu should default to NOWRADS 8 and Lightning.

3 Printing

HF Issue

The Printing function takes too many steps. An extraneous window appears after the print command is given. This window asks the TMCs if they are “sure” about printing and forces them to click an “OK” button. This extra step is time-consuming and unnecessary.

Recommendations

There are two complementary fixes. (a) Eliminate the window asking the TMCs about being “sure” about printing. (b) Incorporate a quick keystroke command enabling one copy to be printed.

4 Flights / Customize Flights Display / Draw Route

HF Issue

The Flights/Customize Flights Display function can be set to show the data blocks of all flights. It does not give the option to select (filter) those flights for which data blocks are to be shown. This all-or-none option applies to the Draw Route function as well. It too can be set to show routes of all flights but cannot be filtered.

The TMCs work around this HF Issue by using the menu that appears by clicking with the right mouse button on an aircraft shown in the display. The right-click menu allows the TMCs to toggle data blocks and/or routes specific flights.

Recommendation

Add a feature that would enable TMCs to select specific flights for which routes are to be drawn and/or data blocks shown.

5 Part-time sectors and Split sectors

Background

Some sectors can be split by altitude. For example, ZMP12 is often split vertically into ZMP12 and ZMP13. Other sectors can be split laterally. For example, ZMP16 is often split laterally into ZMP16 and ZMP15. Many of the "splitable" sectors are actually split only part of the time.

HF Issue

The TSD and MAF do not recognize split sectors. Further, TMCs cannot "inform" the TSD that a sector has been split.

Recommendation

The TSD needs a feature that allows TMCs to indicate which sectors are active.

6 Default Settings, Select Alerts and Examine Alerts

HF Issue

The "Select Alerts" and "Examine Alerts" functions of the MAF have three options. These options are "Airports", "Fixes", and "Sectors". In centers with heavy overflight traffic, the MAF is used primarily for examining sectors. The MAF defaults to Airports. This setting works well for centers like ZFW that focus on large hub airports but forces TMCs to click on the “Sector” option every time they want to examine a sector. It centers like ZKC and ZMP, the “Airport” default makes selecting alerts more time-consuming than it should be.

Recommendation

TMCs should be able to specify the default setting for the “Select Alerts” and “Examine Alerts” functions of the MAF.

7 Default window positions, Examine Alerts

HF Issue

The “Examine Alerts” option of the MAF displays a window containing a timeline. The default location of this window is directly on top of the relevant TSD window. Similarly, when Charts are pulled up they also default to a location on top of the relevant TSD window. TMCs dislike having to spend time moving the windows for timelines and charts out of the way.

Recommendation

New windows should default to locations on the periphery of relevant TSD windows.

8 Lists

Background

The MAF allows TMCs to obtain lists that indicate (a) the flights that are active and going through a sector/airport/fix and (b) the flights that are proposed to be there (in a sector/airport/fix) at a certain time. These lists are very useful.

HF Issue

These lists are static. Once a list is obtained it does not update. The static nature of the lists forces the TMCs to (a) close the lists and then (b) re-open them in order to obtain updated information. This is time consuming.

Recommendation

The MAF lists of flights need to update automatically every time flight data are updated. Currently, the flight data displayed on the TSD are updated in five-minute increments. The MAF lists should be refreshed every update cycle. This would eliminate many extra steps and save much time.

9 Part-time sectors and Split sectors

9.1 HF Issue 1:

Like the TSD generally, the MAF does recognize sectors that have been split by altitude (see item 5 above). The inability to recognize split sectors creates extra workload for TMCs when the MAF indicates that a split sector is alerted, e.g., “goes red” or “goes yellow.” The TMCs need to determine whether both sectors are alerted or only one of the sectors is alerted.

Compounding this HF Issue is the inability to filter flights by altitude within a specific sector.

Recommendation

Currently the TSD allows filtering of flights by altitude. This filtering capability applies to all flights displayed on the TSD. This capability needs to refined so that the TMCs can specify a filter (e.g., by altitude) to apply to aircraft in specific sectors only. This would enable the TMCs to ascertain if only one of the split sectors is alerted or if both (e.g., high and superhigh) are alerted.

9.2 HF Issue 2:

Some sectors are part time sectors. The MAF does not recognize these splits. The TMCs must use local host data (shown on the DSR) to ascertain whether one, both or none of the sectors warrant an alert.

Recommendation

The MAF needs to account for part time sectors. The fix here is the same as in problem 5 above: The TSD needs a menu that allows TMCs to indicate which sectors are active.

10 Show Examined Flights

10.1 HF Issue 1:

The “Show Examine Flights” function does not allow the TMCs to filter the flights highlighted by the function. For example, the TMCs at ZFW often want to filter examined flights to discriminate between overhead traffic and flights that are DFW arrivals. Being able to apply such a filter would make it much easier for the TMCs to reroute overflights away from the alerted sector.

Compounding this HF Issue is the inability to filter flights using the MAF and to show those filters in a variety of colors. Currently, “Show Examine Flights” or, equivalently, the “+=” quick keystroke command shows flights in Red, and only Red. No other colors are available. Similarly, the MAF does not allow the TMCs to change the icons of selected flights.

Recommendation 1:

The “Show Examine Flights” needs to have a filtering capability that operates like - but is functionally independent of - the filtering performed by the “Flights/Select Flights” function. The TMCs need to be able to filter and to assign colors and icons to flights highlighted by the MAF.

The ability to change colors and icons will produce a tool that will enable the TMCs to respond quickly to specific and unique situations in individual sectors.

10.2 HF Issue 2:

When the “Show Examine Flights” displays the flights with a history, it displays the flights in triplicate.

Recommendation 2:

Display a flight once and only once.

10.3 HF Issue 3:

When the “Show Examine Flights” predicts a flight will be in a sector during more than one 15 minute increment, the MAF lists that flight as many times as there are increments during which the flight is predicted to be in the sector. This produces duplication and triplication, etc. For instance, if a flight is proposed to be in a sector for three 15-minute increments, the flight will be listed three times.

The redundancy is a source of inaccuracy that shows up not only in the lists of examined flights but also in the menus associated with the circles that appear at departure airports for purposed flights. This becomes confusing.

Recommendation 3:

Flights need to be listed once and only once.

10.4 HF Issue 4:

The “Show Examine Flights” of the MAF does not allow TMCs to filter flights in a manner that suppresses flights that have already (entered and) exited a sector. This function was in the ASD. The TMCs miss it.

Recommendation 4:

Incorporate the option in the “Show Examine Flights” to view or not to view flights that have already exited a sector.

11 Link the Chart and the List

HF Issue

The TMCs need to be able to obtain a list of examined flights simply by clicking on a bar in the Bar Chart.

Recommendation

Double clicking on a bar in the bar chart should automatically activate the "Show Examined Flights" list.

Towards the Next-Generation Monitor Alert Function

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The palpable demand for MAF revision

The ease and speed of information access is a major factor in TMC job satisfaction. As one TMC put it "The times we need to use it [the MAF], we don't have time to use it." In this report we discuss updates to software and system design that our observations have led to believe need to be included in the re-engineered MAF. We believe the enhancements proposed here would make the MAF easier and faster to use.

Some of the recommendations discussed in the previous report may be more complex than we envision. If they are, they should be not be forgotten but be included in a wholesale re-engineering of the MAF.

Raw Airplane Count ≠ Complexity

The prime directive of the TMU is to dampen oscillations in the variability of traffic flow in order to manage sector controller workload. The MAF does not always serve this goal. One source of concern is its arbitrary metric of sector capacity. This metric is based on a simple count of the number of aircraft in the sector. The basic issue is that a count of aircraft is an inadequate predictor of controller workload. More factors go into workload than the number of aircraft, and some of these factors, as we can see, are complicated. As one TMU staff member put it "Complexity is more important than volume." The MAF needs a better metric of sector capacity.

This concern echoes the RTCA Task Force for Free Flight. In their position paper, the RTCA coined the term 'dynamic density' without offering a concise definition. Subsequently, planners from the FAA and the aviation industry adopted the concept of dynamic density when framing their <u>Action Plan for Free Flight Implementation</u>:

Recommendation 24 in their Action Plan for Free Flight Implementation:

> Recommendation 24. Develop methodology and tools to measure and predict dynamic density.
>
> a. Use modeling tools to identify the parameters of dynamic density and to characterize issues.
>
> b. Develop concept for how metrics would be used operationally for both Traffic Flow Management and ATC.
>
> c. Plan and conduct human-in-the-loop experiments to develop dynamic density metrics and to understand the predictability of airspace density. Determine the level of intent information required.
>
> d. Investigate impact of dynamic density on free scheduling, routing, and maneuvering.
>
> e. Perform field tests at selected sites to validate the operations concept and the ability of metrics to predict airspace manageability.
>
> f. Incorporate successful metrics into Monitor Alert (or its replacement) and into ATC decision support systems, as appropriate.

Note that the authors of the action plan, like the RTCA Task Force, did not offer a definition of dynamic density. However, they did make clear that they envision dynamic density, whatever it might be, as the foundation for retooling the MAF. They foresee funding research to define dynamic density and to develop metrics of sector capacity.

The MAF Should Reflect Factors that Influence Sector Controller Workload

What is needed is a capacity metric that is sensitive to sector controller workload. The assumptions of this metric need to be clearly spelled out, and they need to be good predictors of workload. Attempts to do this have been made. Laudeman, Shelden, Branstrom, and Brasil (1998) tested a factor-weighted workload metric based on the following complexity factors:

1. Heading change.
2. Speed change.
3. Altitude change.
4. Current minimum range.
   A. 0-5 nm. horizontal.
   B. 5-10 nm. horizontal.
5. Predicted conflicts
   A. 0-25 nm. distant now.
   B. 25-40 nm. distant now.
   C. 40-70 nm. distant now.

This study reported correlations in the range of .08-.79 with controller activity, as rated by the Activity Catalog Tool (ACT; Segal, & Andre, 1993). While the maximum correlations reported were good, the variation in predictive ability gave cause for concern. What is needed is simply better predictors.

Demand is, of course, partly a function of aircraft count. But a more comprehensive way to conceptualize demand is as “demand for the sector controller’s time and effort”. Viewed from that perspective, demand becomes equivalent to controller workload. This principle could be called *demand-as-workload*.

One group of factors that are clearly accessible to assessment are controller interventions. The number and type of interventions a controller has to make per aircraft can be seen as “units of workload” which vary in amount, depending on the intervention in question. This type of approach has been used by others (Laudeman, Shelden, Branstrom, & Brasil, 1998).

Some of these “units” are mathematically additive. We can simply count the total number of each type and add them up to make a total. For instance, all aircraft in a sector need to be handed off as they leave the sector. This is relatively fixed level work the controller has to do. It increases in direct proportion to the number of aircraft in the sector. In mathematical terms this is an example of a *linear* relationship between the number of aircraft *(n)* and the subsequent work due to handoffs. We can therefore express this particular "unit" as an equation

$$workload_H \quad n$$

which can be read as "Handoff workload is proportional to the number of aircraft in the sector". Twice as many aircraft means twice as many handoffs and, therefore, twice as much work.

Non-linearity

However, some "units" cannot simply be added. This makes representing them slightly more complex. Separation maintenance is a good example. The demand on attention made by having to attend to pairs of aircraft is *non-linear*. It rises much faster than the mere number of aircraft. This particular relationship can be expressed as

$$workload_A \quad \frac{n(n-1)}{2} \sim \frac{n^2}{2}$$

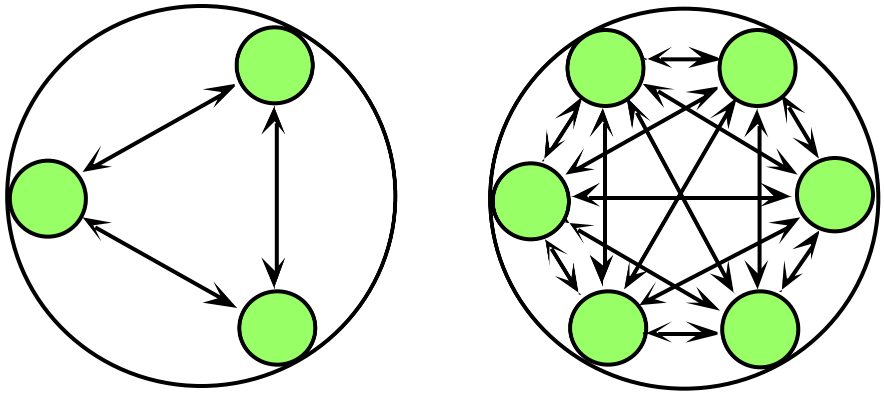
which can be read as "Separation maintenance makes theoretical demands on attention which are approximately proportional to the number of aircraft squared." Twice as many aircraft means roughly four times the attention needed to keep track of them. This is because the number of aircraft *pairs* is what has to be examined, and the number of pairs increases as $n(n-1)/2$. Figure D1 shows this graphically.

The true situation is slightly more complex. The human perceptual/ cognitive system has extremely clever ways of reducing this "combinatorial explosion" to more manageable levels. But the essential principle of workload non-linearity for certain tasks still remains. This task workload may be expressed as

$$W \sim n^a; \quad a > 1.0$$

which reads as "Workload is approximately proportional to the number n of aircraft present, raised to some exponent a", where a is greater than 1.0".

Workload non-linearity is a powerful reason why the MAF metric needs to be updated.



n=3
n(n-1)/2=3(2)/2
= 3 pairs

n=6
n(n-1)/2=6(5)/2
= 15 pairs

Figure D1. The number of pairwise interactions between units increases non-linearly. In practical terms, this means that the demand on a controller's attention skyrockets as the number of aircraft *(n)* grows large. If there were 20 aircraft in a sector, *n(n-1)/2 = 190* ways the pairs could interact.

Counts of interventions

An idea that deserves testing is to take the information in each aircraft's flight plan and come up with an index of the *expected number and type of controller interventions required vs. the time available to make those intervention.* This formula could be based on each aircraft's current position vs. its destination, taking into consideration how much time the controller has left to issue those instructions. There is no reason we cannot incorporate that information into the next-generation MAF. That way, aircraft requiring extra controller effort will have a greater influence on sector demand estimate than aircraft simply passing through.

The MAF already calculates time-left-in-the-sector. This number could simply be used in a different way than it is now. Given some "standard workload unit" associated with a specific controller action, we could tie the final value of that work to the amount of time available. The less time available to perform the action, the bigger the effect on workload. This approach is consistent with some of our previous research (Knecht, 1997) which indicates that operator failure rates increase as time decreases, often according to an S-shaped function of available maneuver time.

Make bar height proportional to impact

One way to take advantage of this approach would be to change the MAF chart so that it represents a sum of components, one component bar for each aircraft in the sector. The height of each component bar would represent not just the aircraft's presence, but its anticipated *contribution to sector controller workload*. Some bars would be higher than others, thus representing more (or more difficult) controller actions necessary to get that aircraft through the sector as needed.

This kind of display would look something like this:

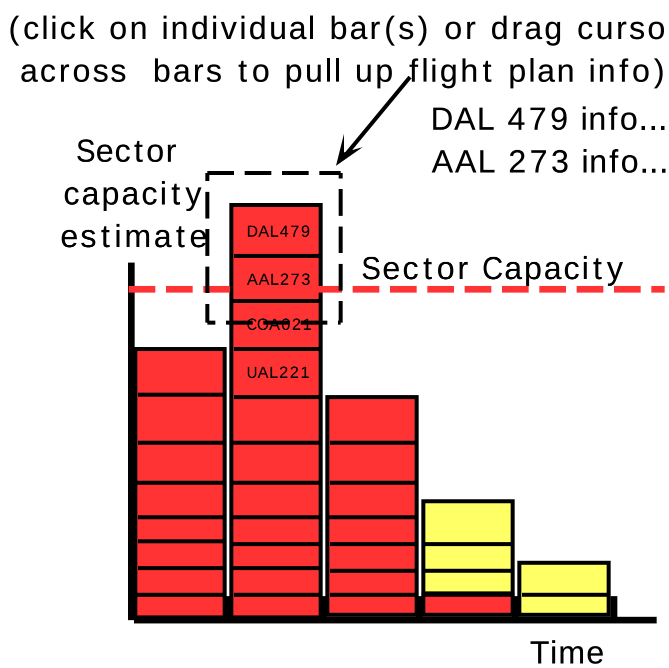


Figure D2. Proposed MAF enhancement. The height of vertical bars now represents controller workload, aircraft-by-aircraft. "Capacity" now becomes defined as "Maximum allowable controller workload". Speed-of-use is increased by sorting the aircraft. A variety of sorting algorithms could be tested, e.g. putting aircraft easiest to move on top.

This variable-bar height scheme is highly flexible and powerful. Enhancements could be made easily each time a new workload factor becomes quantified and/or better understood. Moreover, an additional enhancement could be added: Put the aircraft predicted to induce the most work at the top of the bar in the MAF chart. The chart would then function as a priority list.

Consistency across Platforms

Link the MAF chart to the main TSD display

By clicking on a bar (representing a particular aircraft) in the MAF chart, the TMC ought to be able to highlight that aircraft on the main TSD display. Similarly, the TMCs ought to be able to drag the cursor around a group of aircraft in the MAF chart to reveal the whereabouts of those aircraft.

MAF and Delay Manager

The MAF and the Delay Manager are inconsistent with each other. Consistency across platforms improves user performance. For example, the TMCs can click on a bar in the Bar Chart shown by the delay manager to obtain a list of flights in that time increment. The comparable ability is not available when using the Bar Chart in the MAF (see 2.6 above).

MAF Timeline and Chart

Combine the Timeline and Chart into one window.

Incorporate different colors into the Bar Chart indicating the four levels of flight status. For example, the Bar Chart could display active flights in red, proposals in yellow, delayed flights in green and out-put-not-off in orange. The ability to apply a color code to the additional status categories will provide useful information to the TMCs about flights that may or may not become involved in an alert.

The Data Feed Needs to be More Accurate and Timely

MAF information is based on projected flightplans which quite often bear little or no resemblance to how the actual situation will evolve or to how that situation affects the TMU planning. TMCs therefore tend to ignore the MAF and concentrate on the DSR.

OAG data

A major concerns is the data feed itself. The MAF depends on the ETMS data feed for aircraft currently in the air and on OAG (marketing) data for flights that have yet to depart. The OAG data are inappropriate whenever there are delays in the system. A better estimate of wheels-up time is needed. We do not have a solution to offer for this source of concern.

Currently, departure times for flights that are delayed (for whatever reason) are simply ‘rolled over,’ that is, they are treated as if they will be released at the earliest possible moment, whether that is true or not. TMCs who use the MAF need some a more reasonable estimate of the expected delay. Even if this estimate is not precise, (1) it would be more accurate than the “roll-over” method used now, and (2) it could be updated as conditions warranted.

Climbing and Descending Traffic

The TSD and MAF need to account for altitude transitions. This is a large problem for ARTCCs east of the Mississippi. A possible solution would be to tap into the local host in order to get accurate climbing and descending traffic: tie the TSD into the local host as well as the ETMS feed. The local host data would have to “trump” the ETMS data for flights covered by both.

Quicker updates rates from the host to the ETMS system (e.g., once a minute rather than once every four minutes) might meet this need as well.

Additional Categories of Flight Status

The TSD and MAF currently show only two categories of flight status: “Active” and “Proposed.” While these categories are mutually exclusive, they are not exhaustive. They fail to account for flights that are “out-but-not-off” or that are known to be otherwise delayed. Aircraft that have pushed back from the gate but have not launched define the category “out-but-not-off.” The TSD does not recognize these flights. It lumps them with OAG proposals into the category “Proposed.” Similarly, the TSD lumps into “Proposed” all flights that have been delayed during a previous (current) leg and will necessarily be delayed on their next leg.

The ETMS data feed needs to discriminate among the following categories of flight status:

- Active – in the air

- Out but not off – off the gate, waiting for clearance to depart
- Delayed – known to be late (due to a myriad of factors) but not off the gate
- Proposals – OAG default information

Dispatch is a likely source of data on delayed flights. The ‘daily download’ initiative may address a portion of this need.

Advanced automation

Pre-Play

A “pre-play” would be similar to a replay but it would show tracks of flights proposed to be in a specific sector during a future time frame. Time would be compressed to facilitate identification of potential traffic rushes.

What-Ifs

Incorporate the ability to simulate restrictions such as miles-in-trail, streams of traffic, delay programs, and ground stop as well as re-routing and swapping. This would be a useful tool that would be used to view how restrictions and re-routes will change the flow of traffic currently or at a projected time in the future.

Summary

The MAF is the primary source of information used at the Monitor Alert Position of the TMU. The MAF often falls short of meeting TMC needs. We encourage FAA ATM to take a serious look at conducting human factors research that will guide the design of the next-generation MAF. The ideas presented here point in several of the directions this research will have to pursue.