IMPROVING ATC EFFICIENCY THROUGH AN IMPLEMENTATION OF A MULTI SECTOR PLANNER POSITION

Almira Williams, Mark D. Rodgers, Stephane Mondoloni
CSSI, Inc., Washington, DC, USA

Diana Liang
FAA, Washington, DC, USA

Abstract

This research investigates the introduction of a Multi Sector Planner (MSP) position relative to its potential to provide improvements in the efficiency of using limited ATC resources. The study uses sector Monitor Alert Parameter (MAP) as a simple approximation of workload and traffic complexity, and parametric analysis to determine the range of efficiency improvements that would become possible through the introduction of an MSP position. The research focused on the centers within the contiguous US (regardless of their altitude coverage); however current center area configurations were only considered for the Atlanta ARTCC. The improvement in efficiency of the ATC resource utilization was determined as the percent difference in ATC resources (controller positions) needed to safely monitor and control traffic in the current ATC and in the MSP scenarios. The findings suggest that in the context of current staffing levels, the introduction of the MSP position demonstrates a significant potential to improve the efficiency of ATC resource utilization. It should be noted that the potential improvement depends on the levels of percent MAP utilized at which D-side or MSP controllers would be introduced to support the R-side controllers.

Introduction

Several significant advances are proposed for the Next Generation Air Transportation System (NexGen). These advances are likely to include increased automation (both flight deck and ground systems), more dynamic airspace configurations, and modifications to pilot and controller roles and responsibilities. The NexGen Enterprise Architecture provides a blueprint for future Air Traffic Management (ATM) system design and development that includes the systems that will be needed, the timing for their development, and how they will work together. Additionally, it provides a capability for re-engineering business practices and the underlying technology that supports them.

The Joint Planning and Development Office (JPDO) has identified the following eight key capabilities associated with these advances: (1) Network Enabled Information Access; (2) Performance-Based Services; (3) Weather Assimilated Into Decision Making; (4) Layered, Adaptive Security; (5) Broad-Area Precision Navigation; (6) Aircraft Trajectory-Based Operations; (7) Equivalent-Visual Operations; and (8) Super Density Operations [1]. However, it is likely that in advance of the introduction of these key capabilities there will be a need to support an ever increasing demand for ATM services.

In order to accomplish the task of meeting future demand for ATM services in advance of the implementation of NexGen key capabilities it may be necessary to re-engineer the manner in which air traffic control services are provided. One means of addressing this need is the creation of a new type of ATM control position; the focus of this effort is the Multi-Sector Planner (MSP) position, which as a new position type has received considerable attention over the last decade [1]-[17]. Two versions of the MSP control concept have been studied; multi-D and Area Flow. The multi-D MSP control position provides a single D-side controller to assist multiple R-side controllers and to detect medium term conflicts, whereas the area flow MSP controller provides more strategic control to facilitate workload management across several sectors. In general, multi-sector planning has been described as an activity involving a Planning Controller (or tool) which is capable of reviewing a collection of sectors, rather than being limited to a single sector.

Eurocontrol evaluated the MSP concept as a means to support the near term (2005-2015) transitional introduction of 4D and Data-Link equipped aircraft [1]. They investigated an MSP position having responsibility for a MSP area (two sectors combined), two Planning/Tactical positions within the MSP area and two external sectors feeding traffic into the MSP area. In this study the area flow MSP concept is of primary interest, however the findings have relevance for the multi-D MSP capability as well. Implementation of the

MSP concept was proposed as a means to increase airspace capacity by providing strategic solutions that resolve traffic complexity; thereby reducing the workload of sector controllers and providing an improved traffic flow. Their findings indicated that the effect of the MSP actions appeared beneficial; however the MSP was not able to maintain a mental picture of the complete traffic situation. Furthermore, the use of current route structure caused inconsistencies in the controller working method and induced additional system interaction. They recommended further effort was required to define an appropriate working method and that further integration of decision support tools and information displays was required. They also considered controller training as a key factor in implementing an MSP capability.

Willems, et al. investigated whether an MSP position could assist sector controllers [3]. In their study Air Traffic Control Specialists (ATCS's) either worked as a radar controller (R-side), a radar associate with additional multi-sector responsibilities (multi-D), or as a multi-sector Airspace Coordinator (Area Flow). They found that as radar controllers, subjects devoted more resources to search for potential aircraft conflicts than when acting as Airspace Coordinators. As Airspace Coordinators, they devoted more resources to search for direct routes. They identified this finding as reflecting the differences between tactical and strategic control responsibilities. Additionally, they reported ATCS's were more favorable of the Airspace Coordinator who coordinated control actions through R-side ATCS's compared to a multi-sector planner who directly communicated control actions to aircraft. In general, they reported that an MSP Airspace Coordinator would "improve safety, increase efficiency, evenly distribute workload, and be more helpful and less interfering to the controller team." While they indicated that the MSP position can be introduced into the current Display System Replacement environment, also reported by some earlier studies, further work is required to define appropriate decision support tools.

Most recently, Corker at al. investigated the use of an MSP position as part of the controller team [4]. They investigated both the multi-D MSP capability, where a data-controller (D-side) provided services to several radar controllers, and a strategic MSP position (Area Flow) that served functions often associated with traffic flow management. Whereas the multi-D position served the function of D-side to multiple radar controllers and resolved medium-term conflicts, the Area Flow position coordinated with other MSP areas and managed sector traffic to keep the aircraft count below the Monitor Alert Parameter (MAP). They indicated that except for conflict probe and a ground-to-air data link capability, the Area Flow position was equipped with same tools as the multi-D. They found that the MSP capability (both multi-D and Area Flow) contributed to a more strategic operation. This was indicated by fewer late conflict avoidance maneuvers in high traffic conditions by the multi-D and a significant reduction in severe weather penetrations for both multi-D and Area Flow operations. Workload analyses indicated that the workload for radar-controllers did not increase, and somewhat decreased in Area Flow MSP operations. They also indicated that there was a more equitable balance of workload across the MSP teams than that reported in current R-side and D-side operations. Additionally, they reported a need to continue efforts to better understand coordination and communication needs that support the MSP capability.

In [4], Corker et al. demonstrated the feasibility of the concept of a MSP position in en route operations. In [3], Willems at al. demonstrated the ability to implement the MSP concept in the current Display System Replacement environment. Both studies indicated, along with earlier studies conducted by Eurocontrol, that further effort is needed to understand procedures, working methods, decision support tools and information displays necessary to support the implementation of the MSP operational concept. It is also important to note that Corker et al. suggested that the Area Flow MSP was more consistent with planned NexGen key capabilities that provide integration of information and planning for more strategic rerouting.

However, none of these studies investigated whether the current operational environment is able to support the MSP concept given current constraints such as ATC staffing. Further, none of these studies reported on the impact the MSP concept would have on the efficiency of utilizing these limited ATC resources. If the current staffing at En Route facilities supports the implementation of the concept in principle, it would not only provide justification to develop additional definition of the concept (e.g., procedures, information, displays, training), but might also provide a pre-NexGen benefit by addressing and alleviating the likely increased future demand for ATM services.

This research investigates the impact of introducing MSP position on the efficiency of ATC resource utilization (controller positions). The research does not address the issues associated with optimal task allocation between the R-side and MSP controller, nor does it investigate the conditions under which an MSP position may be most suitable for accomplishing the primary task of monitoring and controlling air traffic. It rather uses a parametric analysis to determine the range of efficiency improvements that would become possible through the introduction of an MSP position.

Approach

Typically based on the amount of time aircraft spend in a sector, Monitor Alert Parameter (MAP) represents a numerical trigger value used to point out that sector efficiency may be degraded during a specific period of time [18]. Based on sector MAP values and Enhanced Traffic Management System's (ETMS) traffic and sector load predictions, air traffic managers are alerted to the fact that certain sectors need special attention during specific time periods.

This research uses MAP values and parametric analysis to compare the efficiency in using limited ATC resources under two distinct scenarios. In both scenarios, each sector is controlled by at least an R-side controller. However, the first scenario assumes that a D-side controller will also be introduced in every sector that, during a given time period, has a maximum instantaneous number of flights above certain level relative to its MAP value (i.e., maximum %MAP utilized is above level *X*); this scenario will be further referred to as the current ATC scenario (Figure 1).

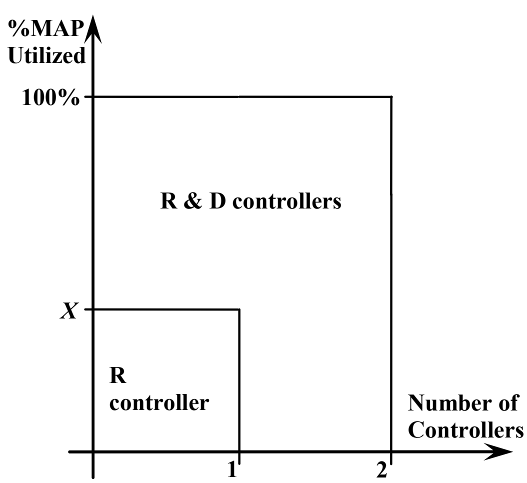

Figure 1. ATC Positions under the Current ATC Scenario

The second scenario assumes that if the maximum %MAP utilized is above level *X* in several adjacent sectors during the same time period, a single D-side controller will be sufficient to safely support the selected adjacent R-side controllers; this D-side is hereafter referred to as the MSP controller. However, if in any of these sectors the maximum %MAP utilized reaches level *Y*, where *Y* >*X,* a separate D-side will be needed for each such sector (Figure 2). This scenario will be further referred to as the MSP scenario.

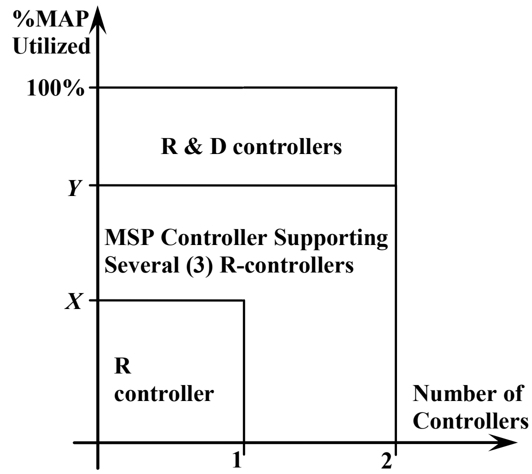

Figure 2. ATC Positions under the MSP Scenario

This approach was based on the observation that the level *X* is not strictly defined and used in practice. In fact, even if it were, the R-side controller may not need another whole position to support their tasks as soon as the traffic exceeds a certain level relative to the sector's MAP value (i.e., level *X*). The controller may simply require assistance initially, relative to the increased traffic level. An additional fully supported operational position may actually become required to safely and efficiently monitor and control the flights in the observed sector only after traffic reaches some higher level relative to the sector's MAP value (i.e., level *Y*). Thus, if the conditions (such as the positions of the observed sectors relative to each other, traffic complexities and others) allow, several R-side controllers may actually be assisted by a single other controller, i.e. an MSP controller.

In the MSP scenario, all of the sectors with their maximum %MAP utilized below level *Y* were considered candidates for forming MSP areas. Each MSP area consists of several adjacent sectors, each controlled by an R-side controller and one MSP controller shared across the sectors. Note that this research focuses on the improvements in efficiency in using ATC resources and does not address the issues associated with distribution of roles and responsibilities between the R-side and the new MSP position.

Clearly, there are numerous ways in which several adjacent sectors may be joined into MSP areas. This research assumed that an MSP area always consists of three adjacent sectors. The optimal MSP configuration within a center was determined by considering the number of boundary crossings between the sectors belonging to the same MSP area, and the improvement in efficiency in using ATC resources. In light of previously described findings that an Area Flow MSP position is slightly better than a Multi-D MSP position and is more consistent with planned NexGen key capabilities, this research also focused on establishing MSP areas around the major traffic flows. In other words, MSP areas were configured by joining the adjacent sectors with a high number of boundary crossings between sectors (or, high number of hand-offs within the MSP area). Therefore, the primary objective of the optimization algorithm developed to establish MSP areas within a center was to maximize the number of crossings within the MSP areas, and the secondary objective was to maximize the improvement in efficiency in using ATC resources.

The research focused on the centers within the contiguous US (CONUS). All sectors within each CONUS center were considered MSP candidates regardless of their altitude coverage. Current center area configurations and controller certification in specific areas of specialization were only considered for Atlanta ARTCC (ZTL). However, since the MSP concept is still in the research phase and area specialization may ultimately look different in the future, other centers were not analyzed with regard to area specialization. Furthermore, MSP controllers would require special training regardless of their area of specialization and it is not clear that it needs to be limited to the same subsets of sectors as defined by the current center areas. At the same time, MSP concept may be easier to test and transition to if initially implemented on the current ATC area structure; therefore, as an example, the ability to create MSP areas with and without the current center area limitations, and the corresponding impact on the efficiency in using ATC resources, were studied using ZTL as an example.

For each of the CONUS centers, MSP areas and the corresponding impact on the efficiency in ATC resource utilization were investigated on the busiest 4-hour period during one of the busiest days in 2006 (the day before the Thanksgiving Holiday, November 22). Traffic data set was obtained from the ETMS and contained 4D flight positions in about 1 minute increments, while the sector data set consisted of geographic boundary, altitude coverage and MAP values. In order to determine the busiest 4 hour period for a center, maximum instantaneous flight counts for each sector and number of transitions from one sector to another were generated for 15 minute time periods during the investigated day of operation. %MAP utilized were then calculated as the ratio between the maximum instantaneous flight counts for each sector and each 15 minute time period. The 15 minute periods were combined into 4 hour periods, and the corresponding maximum and average of the %MAP utilized was determined for each sector. Finally, the busiest 4 hr time period for the center was selected as the one during which the average of all maximums and the average of all averages of the %MAP utilized were the highest (across all sectors in the observed center).

Results

The improvement in efficiency of ATC resource utilization was determined as the percent difference in ATC resources (controller positions) needed to safely monitor and control traffic in the current ATC and in the MSP scenarios (this assumes the development and integration of MSP related procedures, information display, decision support, and training). Each center was processed independently from other centers. Unless indicated otherwise, the results presented below were aggregated across all CONUS centers.

Note that an MSP area will be created only when it is possible to improve the efficiency in using ATC resources. Therefore, for the improvement to be possible, the %MAP utilized has to be below Y in all of the candidate sectors, and above X in at least two of the candidate sectors.

In fact, if only a group of three adjacent sectors are considered in isolation, local improvement in efficiency can only be equal to 0%, 20% or 33%. In short, if %MAP utilized is below X or above Y in each of the three sectors, efficiency improvement will simply not be possible. Similarly, if %MAP utilized is below X in two of the sectors, and between X and Y in the third sector, efficiency improvement will again not be possible; this is because in both current ATC and MSP scenarios, 4 controllers would be needed: three R-side and one D-side or three R-side and one MSP, respectively. If, however, %MAP utilized is below Y in all three of the candidate sectors and above X in two of the candidate sectors, a 20% improvement will be realized by replacing three R-side and two D-side controllers with three R-side and a single MSP controller. Likewise, whenever %MAP utilized is below Y and above X in all three of the candidate sectors, a 33% improvement will be realized by replacing three R-side and three D-side controllers with three R-side and a single MSP controller. As a consequence, the actual improvement in efficiency across an observed center will be dependant on the number of MSP areas that could be established and the local efficiency improvement within each of these areas. Also, the overall efficiency improvement across the whole center cannot exceed 33%.

The number of MSP areas and the ATC resource efficiency improvement potential depend on the levels at which MSP and D-side controllers are introduced (levels *X* and *Y*, respectively). As expected, the results demonstrate that the higher the difference between the levels *X* and *Y*, the more MSP areas could be established and the higher the improvement in ATC efficiency is achieved.

Number of MSP Areas

On average, the number of MSP areas per center ranges from 0.8 to 9.0 (Figure 3). When the difference between the levels *X* and *Y* is small, the results reveal that it is often impossible to create any MSP areas in many of the CONUS centers. As this difference increases, the number of MSP areas increases as well. For the highest investigated difference, level *X* of 30% and level *Y* of 90%, the number of MSP areas ranged from 3 in Oakland ARTCC to 14 in Cleveland ARTCC (Table 2). For the same highest difference between levels *X* and *Y*, the average number of MSP areas across all CONUS centers was 9 and the corresponding standard deviation 2.9 (Table 1).

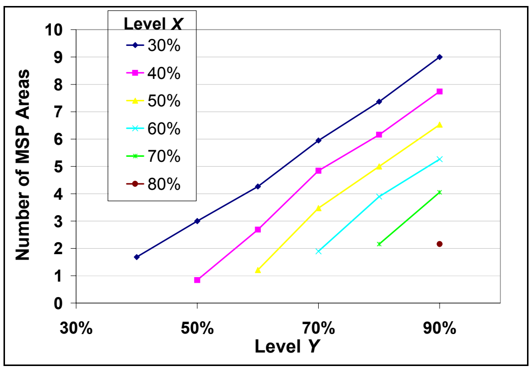

Figure 3. Average Number of MSP Areas per CONUS Center

The number of MSP areas becomes more stable and predictable with increased differences between levels *X* and *Y*: for lower values of the difference between *X* and *Y*, the standard deviation of the number of MSP areas is very similar in value to its average; however, for the higher differences between *X* and *Y*, the standard deviation is reduced to 30-40% of the average number of MSP areas (Table 1).

Table 1. Standard Deviation of the Number of MSP Areas per CONUS Center

X \ Y	40%	50%	60%	70%	80%	90%
30%	1.3	1.6	1.6	1.8	2.3	2.9
40%		1.0	1.4	1.5	1.9	2.4
50%			1.3	1.5	1.9	2.6
60%				1.4	2.0	2.8
70%					1.8	2.5
80%						1.6

The results indicate that the largest number of MSP areas would be created in the Indianapolis ARTCC (ZID); for a wide range of values of levels *X* and *Y*, the number of MSP areas is often the highest (and typically above 10); following closely behind are Cleveland, Chicago and Minneapolis, ARTCC's.

Table 2. Range for the Avg. Number of MSP Areas per CONUS Center (Min-Max)

X \ Y	40%	50%	60%	70%	80%	90%
30%	0 - 4	0 - 6	2 - 8	3 - 10	3 - 11	3 - 14
40%		0 - 3	0 - 5	2 - 7	3 - 10	3 - 12
50%			0 - 4	1 - 6	1 - 9	2 - 11
60%				0 - 4	0 - 7	0 - 9
70%					0 - 4	0 - 7
80%						0 - 5

Number of Sector Boundary Crossings within MSP Area

Number of sector boundary crossings within an MSP area can give us insight into the potential workload of an MSP controller. In addition to the actual number of flights instantaneously under the control of an MSP controller, represented here by the %MAP utilized, his or her workload will also be dependant on the complexity of flows from one sector within the MSP area to another (MSP area/sector). Thus, one of the criteria used for determining the optimal MSP configuration for each center was the number of sector boundary crossings.

During the observed busiest 4-hour period, average number of sector boundary crossing per MSP area across all centers ranged from 9.8 to 70.4 (Table 3). Average number of internal sector boundary crossing within an MSP area in individual centers rarely exceeded 90 (i.e., 22.5 crossings per hour within an MSP area). At low values of %MAP utilized and low differences between levels *X* and *Y*, this number rarely exceeded 40 (i.e., 10 crossings per hour per MSP area).

Table 3. Avg. Number of Internal Sector Crossings per MSP

X \ Y	40%	50%	60%	70%	80%	90%
30%	12.8	17.8	24.6	35.5	46.5	59.3
40%		9.8	23.9	37.0	48.5	62.9
50%			17.3	40.1	51.3	67.9
60%				36.6	51.1	70.4
70%					28.3	57.8
80%						63.0

The highest number of internal sector boundary crossing of 125 crossings per MSP area (about 31 crossing per hour within an MSP area) was recorded in Denver ARTCC for the levels *X* and *Y* of 30% and 90%, respectively (Tab.4).

Table 4. Range for the Avg. Number of Internal Sector Crossings per MSP Areas (Min-Max)

X \ Y	40%	50%	60%	70%	80%	90%
30%	0 - 45	0 - 37	9 - 38	22 - 54	27 - 71	27 - 102
40%		0 - 39	0 - 41	16 - 91	16 - 83	19 - 105
50%			0 - 63	10 - 91	10 - 89	16 - 111
60%				0 - 98	0 - 89	0 - 125
70%					0 - 113	0 - 119
80%						0 - 119

Improvement in ATC Efficiency

On average across all CONUS centers, implementing MSP positions would enable an improvement in efficiency in using ATC resources from 1.2% to 20.0% (Figure 4).

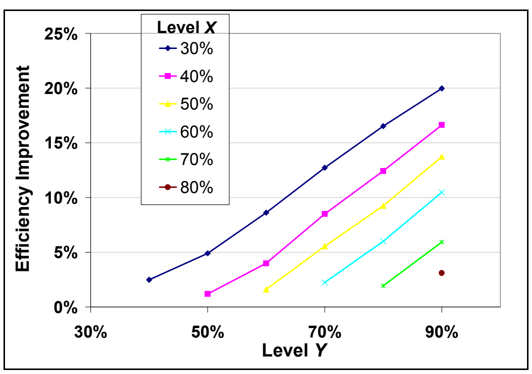

Figure 4. Average Improvement in Efficiency in Using ATC Resources across CONUS Centers

Similarly to the number of MSP areas, the average improvement in efficiency in using ATC resources becomes more stable and predictable with increased difference between levels X and Y: for lower values of the difference between X and Y, the standard deviation of this improvement is roughly equivalent to its average; however, for the higher differences between X and Y, the standard deviation is reduced to about 20-30% of the average improvement in efficiency (Table 5).

Table 5. Standard Deviation of Improvement in Efficiency in Using ATC Resources across CONUS Centers

X \ Y	40%	50%	60%	70%	80%	90%
30%	2.0%	3.1%	3.9%	3.8%	3.7%	4.3%
40%		1.1%	2.7%	3.1%	3.7%	5.3%
50%			1.5%	2.4%	3.6%	5.4%
60%				2.0%	3.9%	6.1%
70%					2.2%	4.8%
80%						2.8%

Again, the results indicate that the Indianapolis ARTCC (ZID) would benefit the most from MSP implementation; for a wide range of values of levels *X* and *Y*, the improvement in the efficiency of using ZID resources is often the highest (and typically above 10%); following closely behind are Cleveland, Minneapolis, Houston, Boston and Chicago ARTCC's.

Table 6. Range for Improvement in Efficiency in Using ATC Resources across CONUS Centers (Min - Max)

X \ Y	40%	50%	60%	70%	80%	90%
30%	0 - 9%	0 - 14%	1 - 19%	7 - 23%	11 - 24%	13 - 27%
40%		0 - 4%	0 - 11%	3 - 14%	7 - 21%	7 - 26%
50%			0 - 5%	2 - 10%	3 - 17%	3 - 22%
60%				0 - 8%	0 - 15%	0 - 19%
70%					0 - 8%	0 - 15%
80%						0 - 11%

Impact of Area Considerations on the Improvement in ATC Efficiency: ZTL Example

The number of MSP areas established without considering the current ZTL areas ranges from 1 to 11. If, on the other hand, the current ZTL area structures are imposed, the number of MSP areas that can be established will decrease to a range of 0 to 7 (Table 7).

Table 7. Number of MSP Areas in ZTL: without vs. with Consideration of Current Areas

X \ Y	40%	50%	60%	70%	80%	90%
30%	1 vs.0	2 vs.1	4 vs.1	7 vs.3	8 vs.4	11 vs.7
40%		1 vs.1	3 vs.1	6 vs.3	7 vs.4	10 vs.7
50%			2 vs.0	5 vs.3	6 vs.4	9 vs.5
60%				2 vs.2	5 vs.3	7 vs.4
70%					3 vs.0	6 vs.2
80%						4 vs.2

The number of internal sector boundary crossings within an MSP area decreases rather dramatically for the low values of both level *X* and level *Y* (Table 8). However, for the low values of level *X* and high values of level *Y* there is no significant change in the internal sector boundary crossings. Interestingly, for the high values of both level *X* and level *Y* an increase in boundary crossings is observed; this is due to a small number of MSP areas that could be established with consideration of the current areas in ZTL and still large number of boundary crossings within these MSP areas.

Table 8. Internal Sector Boundary Crossings within an MSP Area in ZTL: without vs. with Consideration of Current Areas

X \ Y	40%	50%	60%	70%	80%	90%
30%	15 vs. 0	11 vs. 3	22 vs. 3	30 vs. 33	33 vs. 34	57 vs. 50
40%		4 vs. 3	23 vs. 3	32 vs. 33	36 vs. 34	61 vs. 50
50%			15 vs. 0	38 vs. 28	39 vs. 30	67 vs. 66
60%				60 vs. 34	33 vs. 28	80 vs. 79
70%					18 vs. 0	70 vs. 129
80%						96 vs. 110

Typically, the improvement in efficiency in using ZTL resources is significantly affected by restricting the MSP area configurations with the current ZTL areas (Table 9). In most cases, a decrease in efficiency of 33-67% is observed, with an average of about 50%. Note that for level *X* of 40% and level *Y* of 50%, an actual increase in efficiency is observed. This is a consequence of the improvement in efficiency in the use ATC resources being the secondary objective of the optimization algorithm. In other words, the candidates for MSP areas are first established by considering the internal sector boundary crossings, and then, the optimal MSP areas are selected by considering the improvement in efficiency in using ATC resources. Therefore, it is possible to eliminate certain MSP configurations in the first optimization loop that would prove even more efficient.

Table 9. Efficiency Improvement in ZTL: without vs. with Consideration of Current Areas

X \ Y	40%	50%	60%	70%	80%	90%
30%	2% vs. 0%	4% vs. 2%	7% vs. 2%	13% vs. 4%	15% vs. 7%	22% vs. 13%
40%		1% vs. 2%	3% vs. 2%	10% vs. 5%	13% vs. 7%	19% vs. 13%
50%			1% vs. 0%	7% vs. 4%	10% vs. 6%	18% vs. 10%
60%				3% vs. 3%	6% vs. 4%	15% vs. 6%
70%					3% vs. 0%	8% vs. 3%
80%						5% vs. 3%

Conclusions

This research demonstrates a significant potential to improve the efficiency of ATC resource utilization through implementation of MSP positions. This potential is dependant on the levels of %MAP utilized at which D-side or MSP controllers would be introduced to support the R-side controllers, i.e., the levels *X* and *Y* respectively. Parametric analysis indicates that the improvement potential is the smallest for the small difference between levels *X* and *Y*, and increases with increase in difference between the two levels.

For the high traffic periods and the highest investigated difference between *X* and *Y* (30 vs. 90%, respectively), this research demonstrates the average improvement potential of about 20% across all CONUS centers. As an example, the improvement potential is the highest in the Indianapolis ARTCC (27%), Seattle ARTCC (26%), Houston ARTCC (25%), Minneapolis and Memphis ARTCC's (24%), Chicago ARTCC (23%), and Albuquerque, Atlanta, Cleveland and Denver ARTCC's (22%).

However, the improvement potential is likely to be even higher for the periods with lower traffic loads; in fact, the improvement potential will be the highest when large number of sectors experience %MAP utilized just above the level *X* (and, of course, still below the level *Y*). Further research is needed to determine the sensitivity of the outcomes to overall traffic levels.

Further research also needs to address the issue of what the realistic values for the levels *X* and *Y* could be for an MSP position to maintain safe and efficient air traffic operations. In addition, further research should also address the issues of interactions between the adjacent sectors and the corresponding values of %MAP utilized. In other words, instead of using individual %MAP values for each of the candidates for establishing an MSP area, it may be a better choice to use an average or some other mathematical combination of the three values. Additionally, it is important to point out that use of MAP is a simple approximation of workload and traffic complexity; further research should also look for other measures appropriate for indicating a need for MSP assistance. Finally, the results of this effort are dependent upon the development and integration of MSP related operational procedures, information displays, decision support systems, and training.

References

[1] JPDO, 2006, *Concept of Operations for the Next Generation Air Transportation System*, URL: http://TechHangar.JPDO.aero

[2] EUROCONTROL, 1997, *En-route Multi Sector Planning Procedures*, PHARE/EEC/PD3-3.1.3.2.5/SSR;01, DOC 97-70-15

[3] Willems, B., at al., 2005, *Study of an ATC Baseline for the Evaluation of Team Configurations: Effects of Allocating Multisector Control Functions to a Radar Associate or Airspace Coordinator Position*, FAA William J. Hughes Technical Center, NJ, Technical Report DOT/FAA/CT- 05/07

[4] Corker, K., at al., 2006, *Analysis of Multi-Sector Planner Concepts in U.S. Airspace*, San Jose State University and NASA Ames Research Center, CA, HAIL Laboratory Report 2006-3442-01

[5] Graham, R., A. Marsden, I.Pichancourt, F. Dowling, 2000, *Controller Tools – Time To Change*, 3rd USA/Europe Air Traffic Management R&D Seminar, Napoli, IT

[6] Meckiff, C., J.P. Nicolaon, R. Chone, 1998, *The Tactical Load Smoother Tool for Multi-Sector Planning*, 2nd USA/Europe Air Traffic Management R&D Seminar, Orlando, FL

[7] Schaefer, D. et al., 2001, *Air Traffic Complexity as a Key Concept for Multi-Sector Planning*, 21st Digital Avionics and Systems Conference, Daytona Beach, FL

[8] Herr, S., M. Teichmann, M. Poppe, N. Suarez, 2005, *The Impact of Multi Sector Planning and new working procedures on controller tasks*, 24th Digital Avionics and Systems Conference, Washington, DC

[9] Graham, B., 1999, *Multi Sector Planning*,18th Digital Avionics and Systems Conference

[10] Prevot, T., et al., 2006, *Tools for Trajectory-Based Air Traffic Control and Multi Sector Planning*, HCI-Aero, Seattle, WA

[11] Stark, H., 1999, *Multi-Sector Planning in the co-operative Air Traffic Management*, Berlin University of Technology Institute of Aeronautics and Astronautics

[12] Lee, P.. et al., 2006, *An evaluation of two multi-sector planner concepts: Multi-D and Area Flow*, 25th Digital Avionics and Systems Conference, Portland, OR

[13] Flener, P., et al., 2006, *Air-Traffic Complexity Resolution in Multi-Sector Planning*, 5th SweConsNet Workshop

[14] Garcia-Avello, C., 2004, *Decomplexing traffic in a multi sector planning environment*, Eurocontrol, DAS/ATS

[15] Vivona, R., Green, S., 2003, *En Route Descent Advisor Multi-Sector Planning using Active and Provisional Controller Plans*, AIAA-2003-5572, AIAA GN&C Conference, Austin, TX

[16] Prevot, T., et al., 2005, *Cooperative Air Traffic Management: Concept and Transition*, AIAA-2005-6045, AIAA GN&C Conference, San Francisco, CA

[17] Leiden, K., Green, S., 2000, *Inter-Sector Planning En Route Controllers Roles, Responsibilities and Procedures*, NASA Ames Research Center, RTO-34B report, Moffett Field, CA

[18] FAA, 2006, Order 7210.3U Facility Operation and Administration, Chapter 17, URL: http://www.faa.gov/atpubs/FAC/Ch17/s1707.html

Biographies

Almira Williams is a Sr. System Analyst at CSSI, Inc. She has recently been assigned a lead role for CSSI's ATM Transformation product. With just over 10 years of experience in aviation research, she was involved in a wide range of research topics, including demand and mode choice analyses, feasibility and benefits assessments, concept investigations, ATM system performance evaluation, etc. Prior to CSSI, she served as an assistant faculty in the Department for Airports and Air Traffic Control at the Belgrade University (Serbia, former Yugoslavia). Upon receiving her M.S. in Transportation from UC Berkeley, she worked as an independent consultant performing mostly airport and airspace simulation modeling.

Mark D. Rodgers is currently the Chief Technical Officer at CSSI Inc. Over the past 15 years Dr. Rodgers has held several positions at the Federal Aviation Administration, most recently Director of System Engineering for the Air Traffic Operations Planning Organization. Previously, he held positions at the FAA as Program Director for Human Factors, Chief Scientific and Technical Advisor for Human Factors, and as an Engineering Research Psychologist at the Civil Aerospace Medical Institute (CAMI) and Office of System Architecture. While at CAMI Dr. Rodgers was responsible for directing the development and initiating the national deployment of the Systematic Air Traffic Operations Research Initiative (SATORI) for use as an air traffic training and incident investigation tool. Dr. Rodgers has received numerous awards and honors such as the Air Traffic Control Association Special Medallion Award, Aerospace Medical Association R&D Innovation Award, FAA Technology Transfer

Award, and the FAA Vision of Tomorrow in Safety Award, to name a few. He is the author of over 50 technical reports, journal articles, book chapters, and presentations in the area of human performance and human factors and recently was co-editor of the book 'Human Factors Impacts in Air Traffic Management.' Dr. Rodgers received his B.A., M.A., and Ph.D. from the University of Louisville in Experimental Psychology.

Stéphane Mondoloni is Chief Scientist for CSSI Inc. where he leads CSSI's Research & Engineering ATM laboratory. For over 10 years, he has conducted research and analysis in Air Traffic Management for both the FAA and NASA. Dr. Mondoloni developed CSSI's OPGEN, a tool for aircraft trajectory optimization, and developed a prototype intent-based airborne conflict resolution function for NASA Langley Research Center. He has investigated the impact of uncertainty on aircraft trajectory prediction and is a contributor to the joint FAA/Eurocontrol Action Plan 16. Recent investigations have included: the development of approaches for investigating benefits of in-trail procedures in Oceanic airspace, the application of decision-analysis methods for investigating investment decisions and strategic planning for air carriers, the development of information needs within the flight object to support interoperability, and contributing to the development of performance-assessment methods for the ATM System. Dr. Mondoloni holds a B.S., M.S. and Ph.D. from the Massachusetts Institute of Technology all in Aeronautical Engineering.

Diana Liang is an operations research analyst for the FAA's Air Traffic Organization Operations Planning Systems Engineering Division. She is the project lead for the development of the NAS Enterprise Architecture. She is a technical advisor on several ICAO panels and she is also the lead for FAA/EUROCONTROL action plans on architecture, on concepts modeling, and on validation.