Abstract—Current air traffic demand has challenged the capability of the outdated National Airspace System (NAS) structure. Airport and passenger delays have hit their highest levels in recent years. An analysis of historical data has shown that of the daily NAS operations, 33% occur between several high density city pairs. Dynamic Airspace Super Sectors (DASS) propose to structure common flight paths/ribbons connecting the highest demand city pairs, which experience greater than 60 flights per day. These high occupancy ribbons would provide a more manageable traffic flow between these cities to reduce congestion and air traffic controller (ATC) workload. Data collected from the modeling and simulation of a ribbon will be used to evaluate DASS as a potential alternative to the current NAS structure. Modeling of the ribbon dimension and structure as relates to throughput of the system and ATC workload will be simulated with Total Airport & Airspace Modeler (TAAM). The effect of on and off ramps on the ribbon design will be modeled with Arena. Preliminary system analysis has shown that a primary consideration for DASS is the technological upgrades to both aircraft and air traffic controller systems which will be necessary for DASS to be an effective alternative. The technological infrastructure, in conjunction with operational performance analysis, will be the basis for our final recommendations.

I. INTRODUCTION

The National Airspace System (NAS) is currently at near capacity. The air traffic level in the U.S. is at its highest level since September 11, 2001 and as the commercial and general aviation traffic volume further increases, the Federal Aviation Administration (FAA) will have difficulty meeting the NAS traffic demands. In addition to the traffic volume increase, several other factors that further limit the capability of the NAS are the current NAS architecture, Air Traffic Controller (ATC) retirement and weather.

In its original design, the NAS was not created to handle the volume of air traffic flow that it is currently experiencing. The sectors were designed to aid air traffic controllers in the safe routing of aircraft and to facilitate communication between controllers and pilots. However, because of increased traffic demands, workloads in some sectors at peak times can still reach unmanageable and ultimately unsafe levels.

While traffic demand in the NAS is increasing, the FAA is facing the potential loss of nearly half of its current controller work force to retirement. According to the GAO, approximately 7,100 of the 15,000 controllers will be eligible to retire in the next nine years. It may take several years for newly hired controllers to reach the same efficiency levels of previously retired controllers, which could further strain the efficiency of the NAS.

The most uncontrollable factor affecting the NAS is en route weather. During certain weather conditions, aircraft must be rerouted which can overload operational sectors and significantly increase work levels for controllers. During weather conditions some areas of the NAS effectively experience capacity losses which cause significant passenger delays and cancellations and can result in unsafe operating conditions.

In addition to this interaction of factors, the demand and interest in NAS operations are generated by a multitude of stakeholders with various objectives. Some of the stakeholders in this system include the FAA, airlines, pilots, passengers and many businesses that are both directly and indirectly involved in aviation. Given this complex interaction of factors affecting the NAS and the numerous stakeholders, proposed solutions to overcome the operational challenges facing the NAS cannot address individual factors without regard to the system as a whole.

II. PROPOSAL

A histogram of daily operations in the NAS indicates that the highest demand cities experience greater than 60 operations daily and the activity between these cities accounts for nearly 33 percent of the scheduled NAS traffic. Changes to the NAS architecture that can reduce congestion and workload for these high density city pairs could have a significant impact on the NAS performance. One such proposal is the development of Dynamic Airspace Super...
Sectors (DASS). These sectors could be visualized as air highways connecting major high demand airports in which routes between these cities would be standardized and treated as independent sectors. With the appropriate technology and safety standards in place, this sectorization of these could decrease the required number of en route air traffic controllers while expanding the capacity of these high demand routes.

A. Value Hierarchy

The value hierarchy was developed to determine the most important project objectives and to help measure and rank our design alternatives. Despite the various stakeholders for this system, the three main objectives identified as common among stakeholders are: safety, operational performance and cost. Using the swing weight method to rank these objectives, the high level value hierarchy shown in Figure 1 was obtained. The simulated design alternatives are ranked using the utility function in Figure 2.

III. CONCEPT OF OPERATIONS

A. Vision

Within the operational complexity of the national airspace, high traffic areas with predictable routing can be identified and Dynamic Airspace Super Sectors (DASS) will be developed as highways connecting high demand airports. DASS operation should augment the current airspace structure and provide a more efficient and uninterrupted flow for aircraft to these airports. In its implementation, DASS should provide regular routing that requires less direct air traffic controller input.

B. Mission Requirements

The system should decrease the air traffic controller workload for en route air traffic controllers. The DASS system should also reduce overall airport wait times due to en route congestion. During daily operations, the DASS system should maintain operation during all weather conditions that permit safe aircraft operations. The DASS system should be modifiable due to seasonal weather and air traffic changes.

C. Functional Architecture

The functional architecture depicted here is an overview of the primary function of DASS: Route Aircraft between Cities. The primary sub-functions identified in this architecture illustrate that the major functionality of the system is supported by notifications in the form of requests and clearances and well as physical movements such as DASS modification and entry and exit from the system. This functional framework will be supported by the physical implementation of the system.

D. Physical Architecture

With the aid of new technologies, aircraft within these proposed ribbons of airspace could be self separated, thereby decreasing the number of controllers necessary for operation. The system has been envisioned as having a primary monitoring system which is further decomposed into surveillance and notification. This subsystem will be responsible for maintenance of aircraft separation via automatic surveillance and will provide notifications for aircraft and controllers regarding aircraft status as well as separation violations. The communication system is a unique component of DASS that must be able to notify all DASS aircraft of trajectory and route modifications in cases of weather. The physical dimensions of the DASS will vary between routes however FAA separation standards must be maintained in all implementations. The control of these ribbons will be assigned to specialized air traffic controllers that will be functionally distinct from en route controllers. DASS controllers will be responsible for monitoring aircraft and providing necessary communication between aircraft and non DASS controllers. Although separation has not been envisioned as a primary function of the DASS
controllers, in certain areas of the DASS and during certain weather conditions, separation may be aided by the DASS controllers.

IV. SIMULATION

A. Figures of Merit

To begin our modeling, several key figures of merit based on our value hierarchy were evaluated by our group for the proposed simulations. The separation of aircraft within the ribbon was identified as the key figure for evaluating the potential safety of this system. The ribbon capacity and throughput are measures for the evaluation of the operational performance of the system. The key cost measures provided by the simulations are based on fuel and delay costs. The proposed simulations for DASS make the basic assumption that the necessary technological infrastructure, as shown in the physical architecture, is in place. Thus, the simulations are not meant to address the cost of implementation for this system.

B. Design Alternatives

Primary considerations for the structure of the ribbon relate to the length, width, height, and number of entrances and exits. For the length of the ribbon, two main alternatives were chosen that included a long ribbon with multiple entry points and a shorter ribbon with a single entry point. Within these two alternatives, the lane configuration was varied to include a single lane as well as horizontally and vertically offset lanes. Additional variations included flight grouping within lanes based on aircraft type as well as flight destination. A traffic sample of west coast to east coast traffic was selected to allow for a larger area for variations in the ribbon design.

C. TAAM

The ribbon design in TAAM contained the most variations on the ribbon configuration with a total of nine. A system with direct routes from origin to destination was simulated as a baseline sample to compare with the eight alternatives shown in Figure 5.

The main objective of the TAAM simulation was to assess the effect of the configurations on the number of potential en route conflicts and to determine the level of controller workload generated. TAAM is able to generate a controller workload measure based on the type of traffic within the sector. For the purposes of this simulation, all cross traffic has been eliminated and the resulting controller workload is based on the volume of traffic being handled and the necessary conflict detection and resolution. The only defined sector for the TAAM simulation thus far is the DASS. Potential conflicts en route to the DASS are not used in the workload calculations.

D. Arena

An Arena model was developed to evaluate the effects of the number and location of entry points on the queuing delays for this type of system. Ribbon segments with entry ramps were simulated to evaluate the effect of different entry points on the delays for DASS aircraft. The data sample for this model also used transcontinental traffic schedules. In our initial data preparation for this simulation, it was identified that departure traffic patterns may have a significant impact on the delays and the design of north-south traffic flows in different regions of the NAS may not exhibit the same results.

V. SIMULATION RESULTS

The initial TAAM simulations were completed with a single data sample that included approximately 488 aircraft.

Figure 4: DASS Physical Architecture

Figure 5: Design Alternatives

Figure 6: Fuel Burn Results
The schedule was then doubled for all alternatives to determine the effect of the increased traffic volume on the DASS. The results for accumulated and hourly fuel burn remained consistent proportional to the number of aircraft in the ribbon and the results are shown in Figure 6.

The importance of this result is that the modified flight patterns to aggregate the aircraft did not significantly increase fuel burn. The direct routes alternative was nearly equal to the proposed alternatives.

To continue the analysis of the TAAM results, the workload and aircraft conflict were evaluated in the various alternatives. Initial evaluations of the data indicated that a significant difference existed between the alternatives. As expected the single lane design with a single entry point resulted in the highest number of potential conflicts. This was expected since all aircraft were forced to a single entry point which increased the potential for conflicts. Among the remaining alternatives, the ribbon design which separated aircraft by destination resulted in the lowest level of conflict. The number of conflicts for the initial traffic volume in the single lane averaged nearly 1050 potential conflicts. In comparison, the destination based structure averaged 430 conflicts during simulation runs. The initial results from the multiple run simulation with double the initial traffic volume for the single ribbon design are shown in Figure 7.

![Figure 7: Estimated Potential Conflicts](image)

Potential conflicts within Single Ribbon Design
(Double Volume)

Workload results from the simulation are still under analysis. The isolation of the DASS from other ATC sectors makes it difficult to compare the workload as a direct measure against other sectors. The primary complexity of DASS traffic is a result of merging which is not necessarily the case for other sectors. To compare with workload measure generated from other sector simulations, some normalization will have to occur. Appropriate methods for completing the normalization are still being evaluated to determine a method that will result in the most logical comparisons.

The TAAM simulation is currently ongoing with multiple runs underway with various traffic levels.

The initial focus of this project was directed toward the TAAM simulation because of the greater complexity of this simulation software and at this juncture the Arena results are highly preliminary. The actual location of entry points have been varied and even in preliminary results, it is apparent that continuous entry points along the length of the DASS will decrease the efficiency of the system and increase both controller workload and system delays. In the design of the Arena model, it was identified that the departure traffic patterns will likely have a significant effect on the placement and number of entry points. As we continue our runs, the entry points will be examined from the perspective of airport groupings. Airports have been assigned to entry points to determine if grouping based on specific departure patterns will result in increased efficiency. Regulating the entry groups may also affect the amount of workload generated for non DASS sectors. Based on the recommendations based on the Arena model analysis, modifications may be made to the TAAM simulation for workload estimates.

VI. CONCLUSION

In our preliminary analysis, it is evident that potential does exist for DASS to be an alternative to the current ATC structure for high density routes. The fuel burn estimates are an initial positive result for the feasibility of the system from an airline perspective. Given the high fuel costs, in order for this system to be acceptable for this group of stakeholders, the DASS system had to be feasible with minimal fuel increases. We believe that the predictability that would result in the implementation of DASS will provide benefits that outweigh the minimal fuel increase.

As conflict types within the DASS are identified, we will attempt to modify the system to decrease the probability of these occurrences. Entry points to the DASS must be regulated to maintain the efficiency of the system. As we complete this analysis we plan to provide a means to evaluate the effect of adding entry points for specific airports. By focusing on entry point conflicts, the overall workload should be further decreased. Based on improved analysis of workload measures, recommendations on the number of necessary controllers will be made.

Given the complex nature of the NAS, the DASS architecture is not being simulated as a replacement for the current structure but as an extension of the current system. As a more complete analysis is performed we will continue to analyze the limitations of DASS and to determine where this architecture may be the most effective.
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REFERENCES


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