

FAA Operational Concept Validation - High Altitude Airspace Analysis

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Abstract

The High Altitude Airspace Concept proposes that the airspace would be split at some flight level, for example FL350, and the higher altitude airspace would be managed with much larger volumes than is the case in the present 20-center system. Creating larger sector volumes within the current center structure is a mid-term (2003-2007) operational concept that aims to make advantage of improved data availability and enhanced decision making aids in moving towards the High Altitude Concept.

This paper provides the results of a “first-look” at the High Altitude Airspace Concept.

The study hypothesized one implementation of the concept by taking the terminology...

“a sector as big as a center”

...literally as a basis for investigating both the potential feasibility of large sector design and to develop, as part of the analysis, techniques to evaluate the concept. This first look provides a series of observations that are both intriguing and challenging in that a number of questions are revealed that will need to be addressed in more detail.

The exercise has proven to be a very valuable first step, and the metrics used provide a very accurate and realistic description of the nature of each of the different airspace regions. As a consequence, further, more in-depth studies are already being identified using the results and observations made by this analysis.

Additional studies were undertaken at the end of the analysis to evaluate the additional effects of the introduction of Domestic Reduced Vertical Separation Minima (DRVSM) on the high altitude airspace, providing very interesting results, particularly in regions where high levels of conflict are found under conventional flying rules.

Following the completion of this work, further studies have been started in this area including the evaluation of such a concept and its impact on the service provider in a human centric paradigm. In the follow on study, human

factors issues will be considered in the changing environment and the experiments will also include proposed procedures and decision support tools for use with SSV. The evaluation will be applied to a selected group of SSV and the model will use the FAA distributed modeling architecture.

Introduction

The High Altitude Concept suggests that the airspace would be split at some flight level, for example FL350, and the higher altitude airspace would be managed with much larger volumes than is the case in the present 20-center system. The analysis therefore considers the feasibility of reorganizing High Altitude Airspace in the NAS in a sectorisation using much larger areas. The study has used as its base assumption that the first implementation will not transcend the boundaries of a center, i.e. it will be done within the confines of airspace in which full Communication, Navigation and Surveillance (CNS) for any position can be assured. The High Altitude Airspace has therefore been subdivided into a number of larger service volumes – one per control center. These service volumes have been named “Super-high Service Volumes” or SSV’s.

The study used the RAMS Plus™ ATC simulator to simulate 48 hours of NAS traffic and 20 SSV control regions in the upper airspace (FL350 and above). It does not attempt to redesign the sectorisation in the High Altitude Airspace, but merely compiles and presents useful statistics to characterize the number and nature of operations occurring in each of the SSV regions.

The results, which include traffic load and demand, conflicts, conflict characteristics and conflict likelihood for each control volume, have already provoked further discussion about the concept, and related concepts, and have been found to provide an excellent indication of the different types of operation that occur in the different regions of the NAS.

A more in-depth human-factors analysis is currently underway to determine the effect on the controller of the introduction of the concept, and it is currently anticipated to introduce the concept in the National Airspace System as early as spring 2004.

Study Assumptions

It is assumed that the technologies being researched and developed today throughout the ATM industry will be available to support improvements in both the quality and availability of data amongst the system users such that:

- 1) The service provider will have the capabilities to receive reliable and highly accurate data on the position of aircraft in the Ultra High Airspace over a much wider region than is available today.
- 2) Additional decision making tools will be available, and effective so that the service provider can undertake management of a larger number of aircraft than is the case in the current system.
- 3) Improved communication technology will allow the service provider and the cockpit to communicate and exchange data over a greater range than is the case in the current system.

In the first implementation, it is expected that facilities to support the improvements described above will be introduced on a center-oriented basis. In this study therefore, we began by considering that in the majority of cases, we remain constrained by the current center boundaries.

In future implementations, as decision-making tools become more sophisticated and hi-fidelity system-wide data becomes more available, we can further assume that the limitations of the present center-sector based system can be ignored and that we can transcend the center boundaries in defining larger and perhaps more appropriate airspace control areas.

Thus, from a top down view, it is thought that increasing the size of the control volumes in the Ultra High Airspace to create Super-high Service Volumes can be achieved successfully on the assumption that CNS facilities can be safely and surely provided, and that the

Controller is able to manage the levels of traffic expected to traverse the control volume. The characteristics of each SSV are carefully analyzed according to a pre-determined set of metrics to determine the characteristics of each of the regions and to consider whether it is possible to assure a safe and efficient service to the users.

The remainder of this section describes the tools and approach used to evaluate the feasibility of the concept and develop the corresponding metrics.

Modeling tools

RAMS Plus™ served as the primary simulation tool. It was used to simulate the NAS and provided a majority of the results. RAMS Plus offers a high fidelity model of an ATM environment and produces very detailed outputs, from which a variety of reports and metrics concerning conflicts, sector and controller task loads, and flight outcomes can be extracted.

No enhancements or modifications were required for RAMS Plus™ to support the needs of this study. The version of RAMS Plus™ used to undertake the study was release 3.1 from June 2001.

Results were generated using the ATM Analyser and Microsoft Excel.

Modeling Approach

The continental airspace in the Ultra High Airspace region for the entire continental NAS has been divided into a set of 20 Super-high Service Volumes. Each volume corresponds to the boundary of one of the 20 continental control centers and extends from FL350 to FL550. For ease of identification, the resulting 20 Super-high Service Volumes are named after the center that they cover (e.g. ZKC = SSVKC)

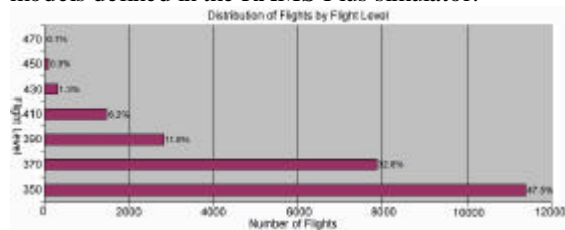


NAS CONUS High Altitude Airspace divided into 20 Super-high Service Volumes – FL350 and above

On the east coast, we have only created a small SSV to represent the New York high-level airspace region, and have not included the oceanic New York airspace, a region that is considered to be outside the scope of this study.

Traffic Sample (ETMS)

The simulation was carried out for 48 hours of typical NAS traffic that included all the active traffic (except military) that was recorded in the ETMS (national and international). The resulting 24010 flights were carefully analyzed using the RAMS Plus traffic validation and editing facilities and erroneous flight plan data found in the ETMS extract was corrected to ensure that all flights followed the correct flight plan and routing. Levels over each of the flight plan point were recalculated using the aircraft models defined in the RAMS Plus simulator.



Distribution of Traffic by Flight Level – FL350 and above

No fixed procedures (e.g. LOAs) were placed on flight operations – thus each flight was flown the best (user-preferred) trajectory according to the type of aircraft being used.

Controllers / Flight Rules

Each area was assigned a single active controller that detected and recorded conflict situations using standard NAS separation parameters.

Following completion of the analysis, an additional study exercise was simulated using DRVSM flight rules.

MOA / Military Areas

Military Operating Area (MOA) data was obtained from the FAA ATA SDAT program, and was converted into RAMS formats (SUA) using suitable parsers. High altitude special use airspace (known as ATCAAs) sit above the MOAs and extend from FL180 to FL510. These do not tend to be included in the FAA

SUA databases, but normally they follow the same horizontal boundaries as the underlying MOAs. The assumption made in regard to Special Use Areas was, therefore, that each MOA had a corresponding high-level ATCAA above it, extending to FL510.

Like MOAs, ATCAA activity is generally scheduled 24 hours in advance but they are rarely used for the full time period for which they are scheduled. In normal operation, ARTCC controllers continue to use the airspace until the last possible minute, then reroute everyone else around the airspace until it is available again.

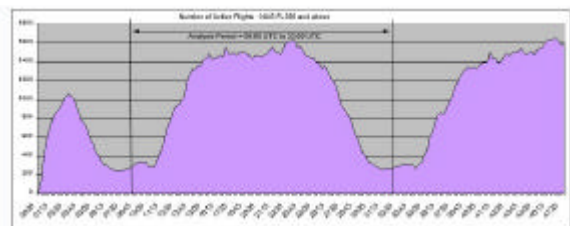
It is clear that the control of a given airspace region is more complex when SUA activity is present since additional activities are necessary, for example:

- ✂✂ Flight re-routing has to be carried out by the service provider
- ✂✂ Communication to present re-routing to flights is required
- ✂✂ Re-routing has to be carefully monitored
- ✂✂ The available airspace control volume is reduced

Since we are considering the complexity of SSV we have activated SUAs during the entire study period, thereby ensuring that we evaluate the *worst-case* scenario for any given SSV.

Simulation Analysis Period

Based on the active flights, analysis was restricted to use samples from a 24-hour period, starting at 09:00 UTC on the 20th to cater for the majority of the upper airspace usage. This time period caters for peaks in both east coast and west coast traffic levels.



Simulation Analysis Period – NAS-Wide Traffic Load FL350 and above

Analysis Metrics

There have been many studies undertaken through which formulae and indicators to evaluate the complexity of a given area have been proposed. Many of the most renowned approaches rely on measurements of traffic complexity, based on demand (instantaneous and projected), distribution across the control volume, relative heading, and variation in speeds. Additionally, the interaction of flights in the control region (conflict or conflict potential) is thought to be a significant factor contributing to the overall complexity value.

In this study, we have taken a filtered approach, looking at traffic demand across the simulated period and focusing on periods of heavy demand. In those periods, the number and characteristics of the conflicts is considered to evaluate the high level complexity of the sector.

Thus, for each SSV, we consider:

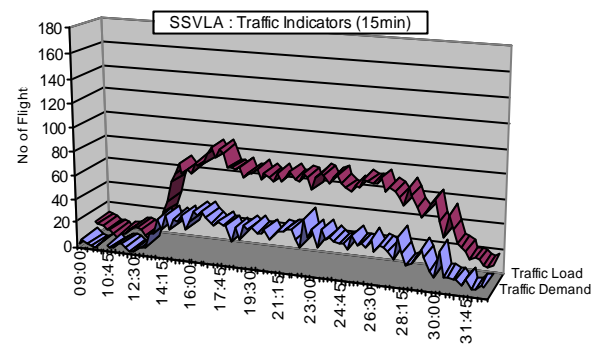
1. Number of active flights in each 15min period (**Traffic Load**)
2. Number of flights entering SSV in each 15min period (**Traffic Demand**)
3. Number of conflicts identified in each 15min period (**Conflict Load**)
4. Characteristics of the conflicts identified in the sector (**Conflict Characteristics**)
5. Relationship between active flights and no of conflicts (**Conflict Likelihood**)

Traffic Load / Traffic Demand

The *Traffic Load* indicator provides a view of the number of *Active Flights* being controlled by a given unit at any time during the simulated period. However, for better presentation of the active flight count, the number of active flights is partitioned into periods of 15-minutes (as opposed to each time the count changes). This means that for any given SSV, a flight that is in the sector between 12:00 and 12:14 will be counted as 1 active flight in the 12:00 – 12:15 time slot. A flight that remains in an SSV between 11:55 and 12:05 will be counted once in the 11:45 – 12:00 slot and once more in the 12:00 – 12:15 slot. Consequently, the sum of active flight counts is not equal to the number of flights that pass through the sector. Taking

a 15 minute count, instead of instantaneous, provides a better indicator of the short-term loading.

The *Traffic Demand* indicator uses the same time slot as *Traffic Load*, i.e. 15 minute reporting bins, but provides a count of the number of *Flight Entry* to the given SSV during that 15 minute period. In this case, a flight entry to a given SSV is recorded once only (unless the flight leaves the SSV and re-enters at a later time). Thus *Traffic Demand* provides an indicator of how much ‘new’ traffic enters the SSV in the 15-minute time slot.



Typical Traffic Load / Demand Chart

Min, max, average and median *Traffic Load* and *Traffic Demand* are presented for each SSV as well as a graph of load and demand by 15-minute time slot.

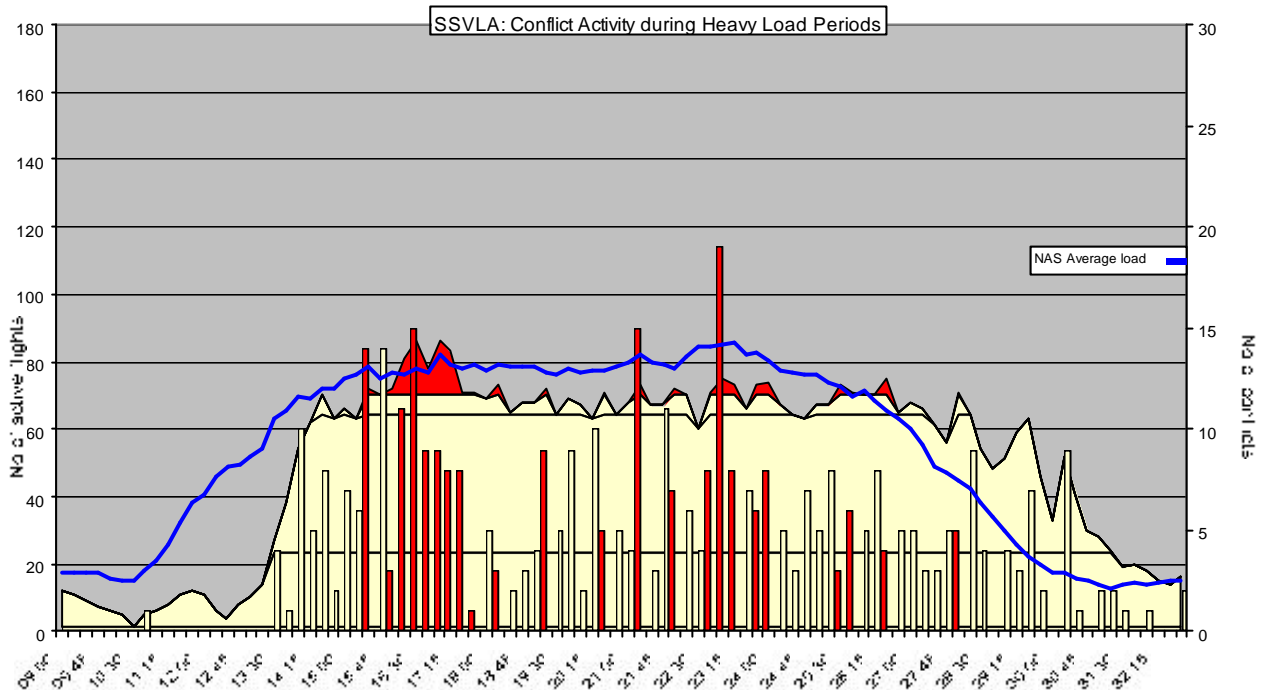
Conflict Load & High Traffic Load Analysis

Using the same 15-minute time slots, the number of *Conflicts* identified by the simulator are measured to provide a *Conflict Load* indicator. A spatial conflict is recorded when two flights are identified as encroaching the required separation minima (front-back, side and vertical). Only the start point of a given spatial conflict between any 2 flights is recorded for the purpose of this indicator, since it is assumed that a maneuver would be carried out by ATC to ensure that the separation encroachment would not occur.

In addition to the presentation of the conflict load, which is presented by a bar chart for each of the 15-minute counting bins as seen on the chart above, and measured according to the scale on the right-hand y-axis, the conflict load indicator also considers periods of heavy load. The rationale behind the presentation of the information in this way is to offer the reader a clear visual representation of the levels of conflict expected in an SSV during periods of heavy and less heavy traffic load.

The definition of a *heavy load* is somewhat heuristic, and can vary according to the region being considered. For this reason, we have made an assumption through which we can identify periods where the loads are higher than desired.

The average traffic load for the NAS as a whole is also presented as a thick blue time-line on each conflict load graphic. This is included as a means of illustrating the loading of the current SSV in relation to the NAS as a whole. The reader should note, however, that average NAS loading has no influence on the heavy load value used for each specific SSV. The heavy load limit is relevant to traffic in the current SSV only.



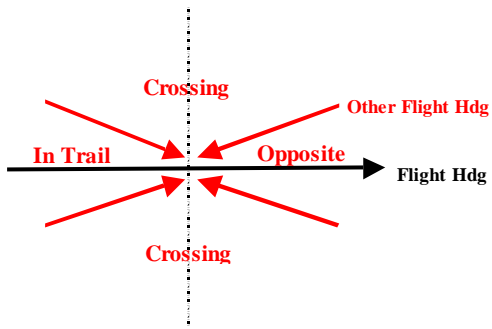
The approach taken was as follows:

- ⌘ Assume that the traffic passing through a given region (as recorded by ETMS) was manageable in the current system, but also had periods of high load
- ⌘ Identify periods where the measured load is in the top 25% – these are considered to be the *Heavy Load Periods*

Conflict Type, Attitudes & Characteristics

In addition to the number of conflicts encountered in a given regions, the characteristics of those conflicts provides a further insight into the manageability of a larger airspace region. Hence, the analysis considers the distribution of conflicts in each SSV by conflict type, conflict attitude and conflict characteristics (to define the overall conflict geometry) as follows:

On the graphical presentation shown above, **Heavy Load Periods** are shaded using red for the period that the traffic load is in excess of the 3rd Quartile load limit (or in the top 25%). Conflict counts that correspond to the same 15-minute period as one that is in the *Heavy Load* zone are also colored in red to allow easy identification. As a result, the reader can easily evaluate the conflict load in heavy and less heavy traffic load situations.



Conflict Types Diagram

The other three categories are for conflicts where neither of the aircraft is in stable flight at the start of conflict:

CICI – Both aircraft are in Climb at the start of conflict

DeDe – Both aircraft in Descent at start of conflict

CIDe – One aircraft in Climb, other in Descent at start of conflict

Conflict types - are recorded using 3 basic categories, *In Trail*, *Opposite* and *Crossing*.

Conflict Attitude is recorded using six categories. The first three involve at least one aircraft that is in stable flight:

CrCr Both aircraft are in Cruise at the start of conflict

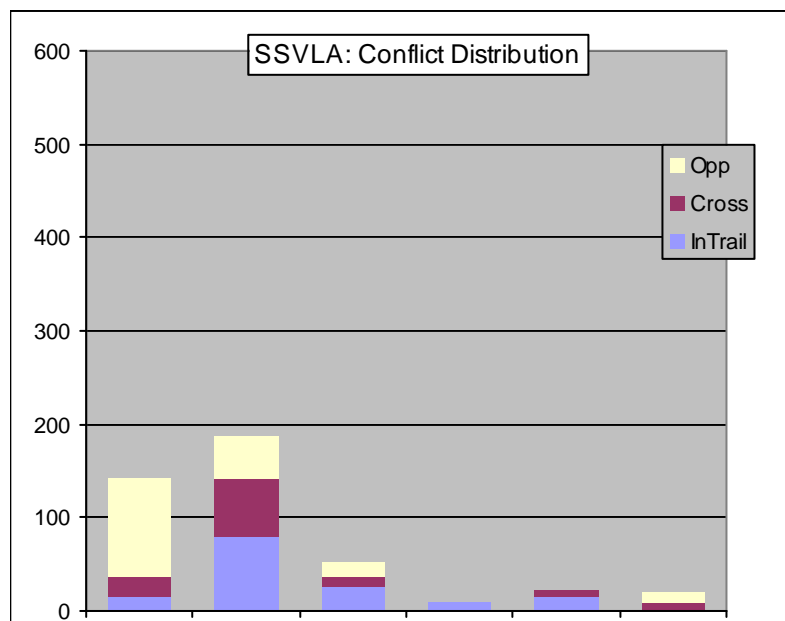
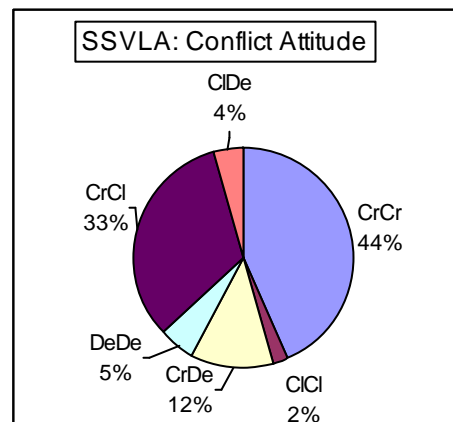
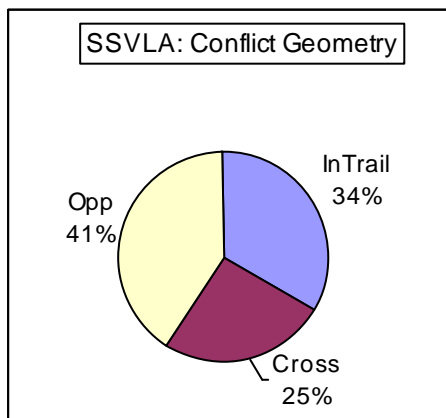
CrCl – One aircraft in cruise, other in climb at start of conflict

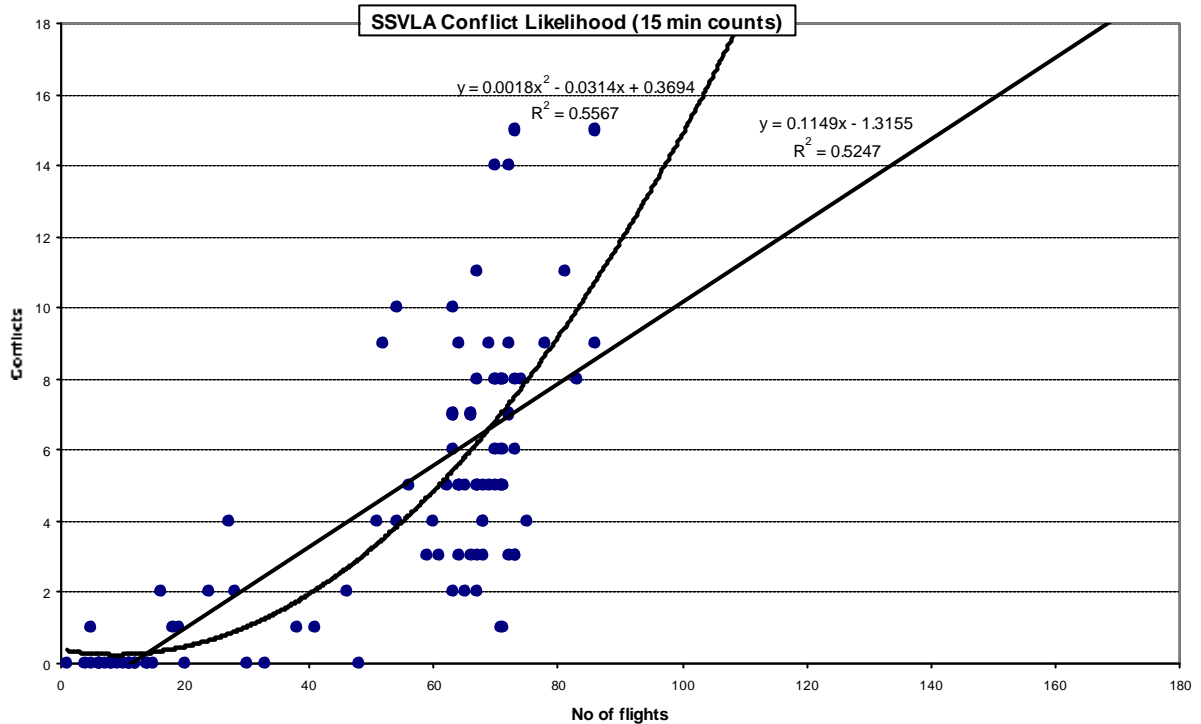
CrDe – One aircraft in Cruise, other in descent at start of conflict

Conflict Characteristics are presented using three charts.

The first two show the relative distribution of conflicts by geometry and conflicts by attitude. The third chart shows the numbers of conflicts of each type combined.

Conflict Likelihood





It is assumed that conflict is more likely to occur in regions with higher traffic loads than those with lower, however the relationship between the traffic and conflict likelihood is non-linear. Thus, in creating a metric with which the conflict likelihood can be measured, we consider the relationship between the traffic load, as represented by the number of active flights in a region and the likelihood of encountering a conflict as a 2nd order equation.

those regions where the number of flights, and corresponding number of conflicts tends to be very low where results become unreliable.

The approach used to derive the relationship is to consider the 15-minute instantaneous traffic load and plot the conflict count for the corresponding period. Applying standard curve fitting techniques permits us to determine the possible relationship.

The example shown above plots the number of active flights in a given 15-min period for the region along the x-axis and the corresponding number of conflicts in the same period along the y-axis. Two curves have been generated, a quadratic and a linear relationship (shown for reference only). Both curves are calculated using a least-squares fit. The R^2 value, or the coefficient of determination, is an indicator that ranges from 0 to 1 and shows how closely the curve represents the data sample. As the value tends to 1, the curve is more reliable. In general, the metric seems to provide representative results, with the exception of

Results

Recalling the study assumption – *the Ultra-high Airspace region (FL350+) of the continental NAS can be divided into a set of 20 Super-high Service Volumes where each SSV is delimited geographically by the corresponding center boundary.*

For the purpose of the analysis, the 20 SSVs have been further grouped into five sets of SSV that are in the same geographic region.

Each of the five regions, and the SSVs in those regions is considered in turn where the following analysis was carried out:

- ✍✍ Each SSV has been analyzed to review the general characteristics of the traffic in the control volume followed by the loading of the SSV in terms of (local) heavy load periods, and in comparison to the national average (for all SSVs).
- ✍✍ Conflict activity and the characteristics of the conflicts for each of the SSVs, have been measured and are presented through a variety of metrics.
- ✍✍ Finally, the risk of encountering a conflict was evaluated for each of the regions to help form preliminary conclusions to the suitability of each region for the introduction of Super-high Service Volumes in the high level airspace.

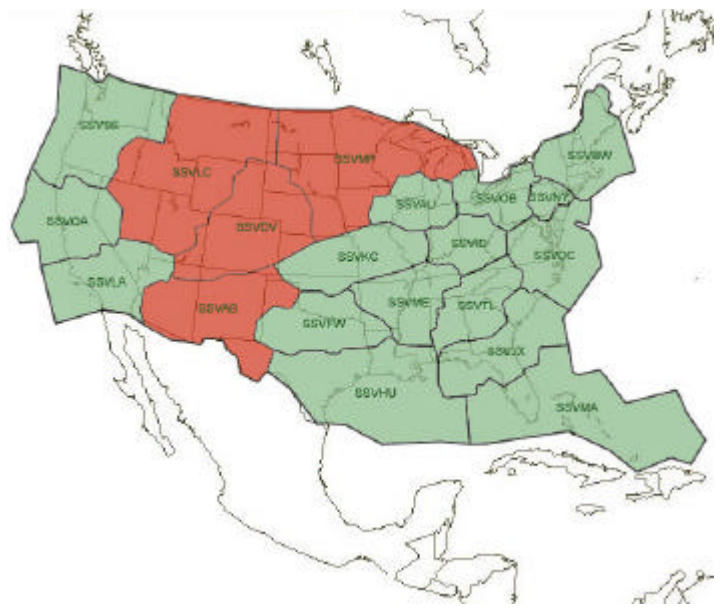
*Special Note Concerning Edit for ATM Research Submission

The High Altitude Airspace Analysis has been carried out for all 20 of the SSV's defined in the NAS CONUS. Readers should note, however that for the purposes of this paper and to respect the limitation of 10 pages for submissions to the ATM R&D symposium, results for 2 SSV's only are presented. Readers that are interested in obtaining the complete report should contact Diana Liang at the FAA to obtain a full copy of the final study report.

The two SSV's selected for this publication are as follows:

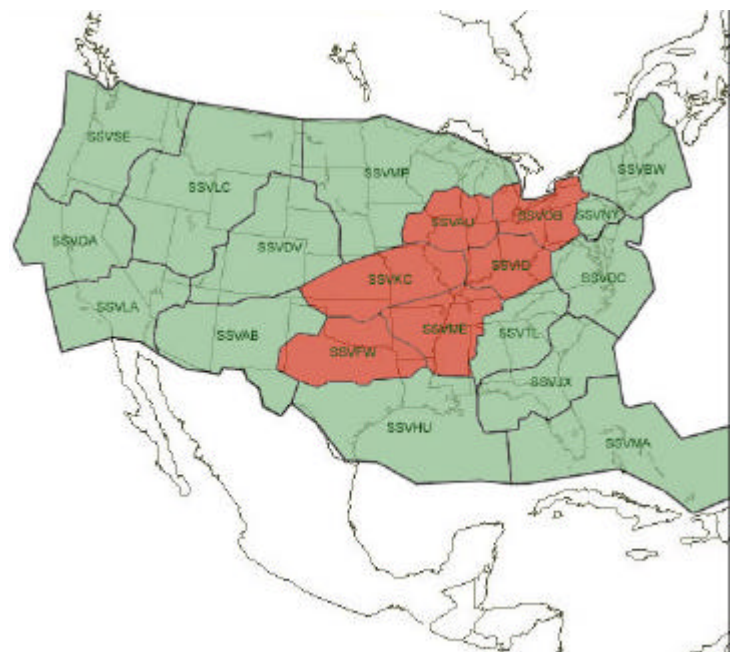
SSVDV - Denver

The Denver Super-high Service Volume (SSVDV) is one of the largest high altitude airspace regions and is located in the center of the West-Central grouping of SSV's.

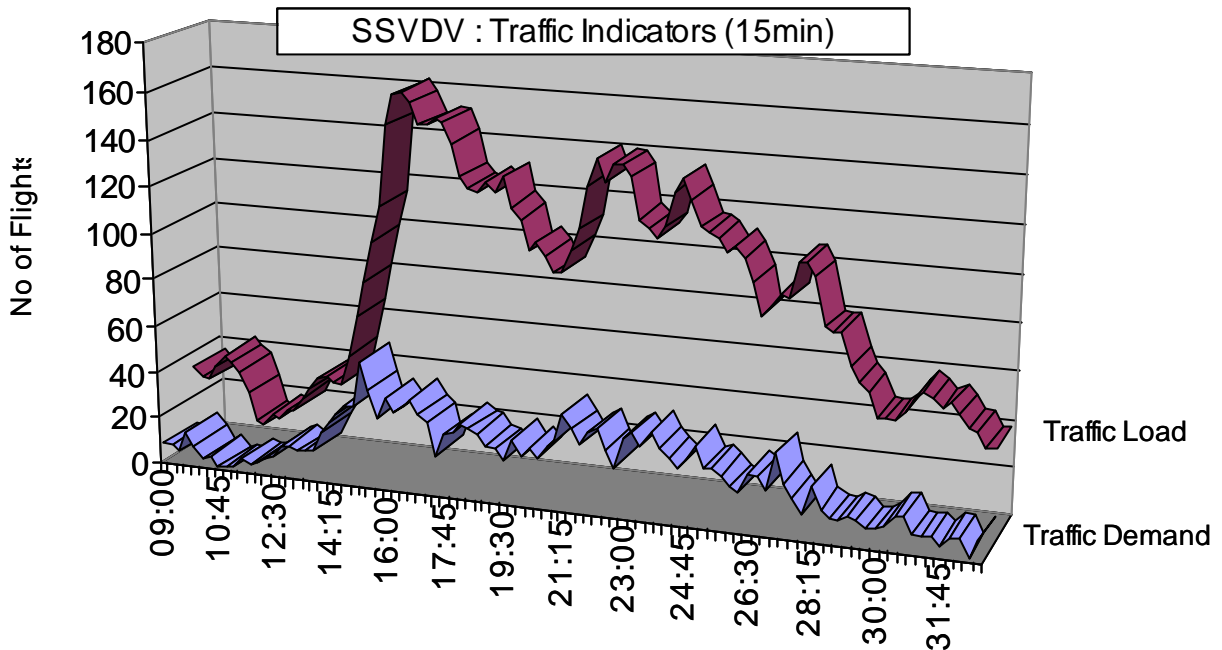


SSVID - Indianapolis

The Indianapolis SSV (SSVID) is located on the eastern border of the Central grouping of SSV's and is much smaller in volume than SSVDV but is considered to be one of the most complex traffic regions in the NAS CONUS.



Presentation of Results for SSV DV



| Region | Active Flights | | | | | Flight Entry | | | |
|--------------|----------------|-----|---------|--------|--|--------------|-----|---------|--------|
| | Min | Max | Average | Median | | Min | Max | Average | Median |
| SSVDV | 11 | 161 | 85 | 91 | | 1 | 54 | 21 | 22 |

The Denver Super High Service Volume, **SSVDV** is located in the middle of the West Central block of Airspace. The West-Central region comprises four of the largest SSVs, SSVAB, SSV DV, SSVLC and SSVMP. Not surprisingly, the SSV's in this region yield some of the highest average numbers of active flights with one or two very high peaks during the analysis period. In contrast, all of the areas still show a relatively low average traffic demand suggesting that flights remain in the regions for fairly long flight times.

SSVDV has the highest average loading (85 flights/15-min period) of the West-Central SSVs and one of the highest in the NAS. Like other areas in the West-Central region, however, it shows relatively low average traffic demand (entries) throughout the analysis period with counts around the low 20's.

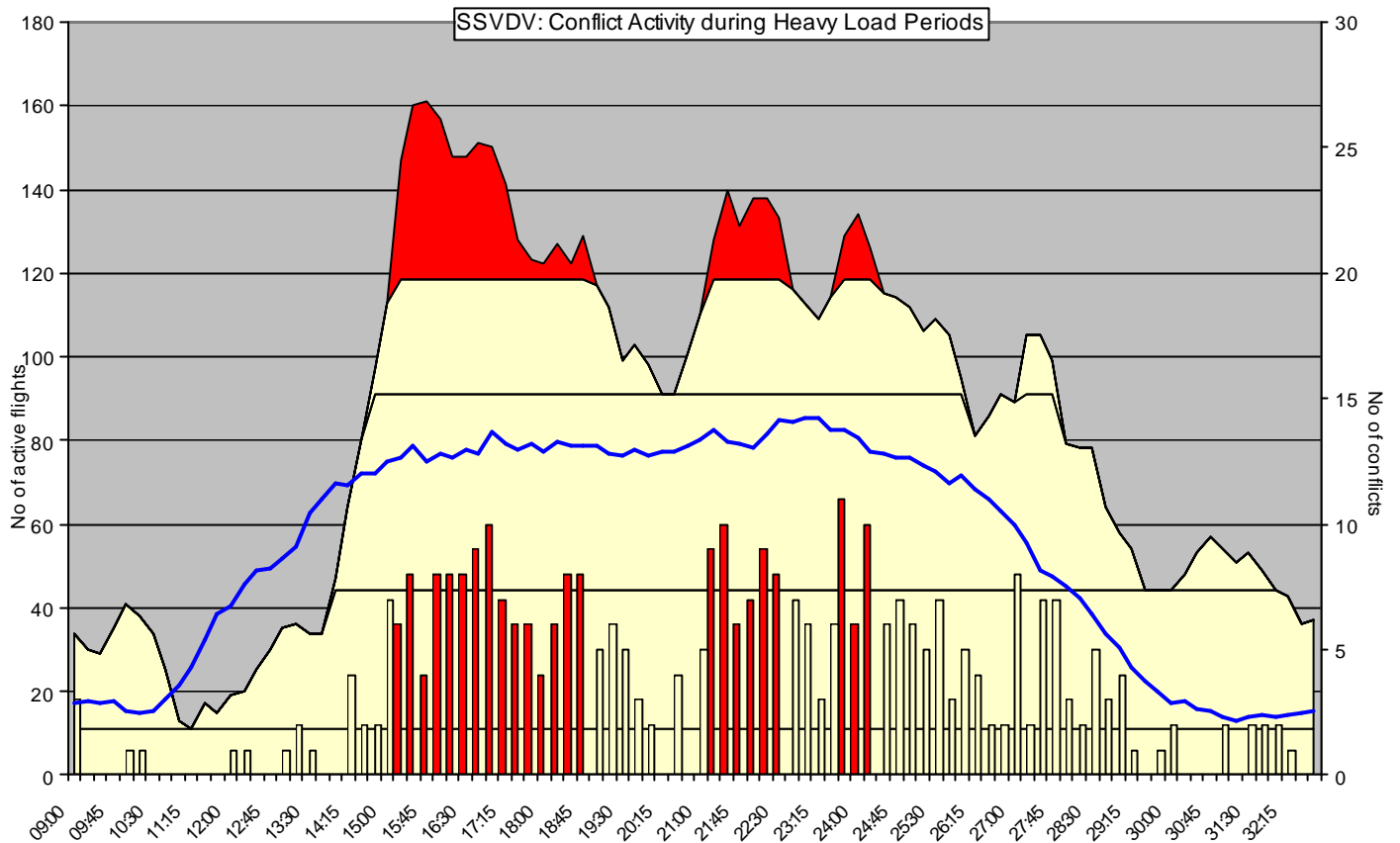
The SSV has a very large peak loading of 161 flights in a 15 min period at 15:45, with a rapid rise in both demand and loading over the hour preceding this peak.

Following the initial and rapidly rising load peak, both load and the demand taper off before a second peak load occurs at around 23:00. The load then remains high for a period of around 3 hours before descending to the end of the day.

The shape of the two curves, and the very high load along side a relatively low demand is typical of SSV's where the upper airspace is used as a transit zone for long-distance traffic.

The high peak early in the analysis period undoubtedly corresponds to an influx of traffic departing from airports close to the region (e.g. Los Angeles morning departures heading across country towards the east-coast).

The difference between heavy loads and light demand is typical of very large transit zones where aircraft enter the region in cruise and remain in the zone for extended periods.



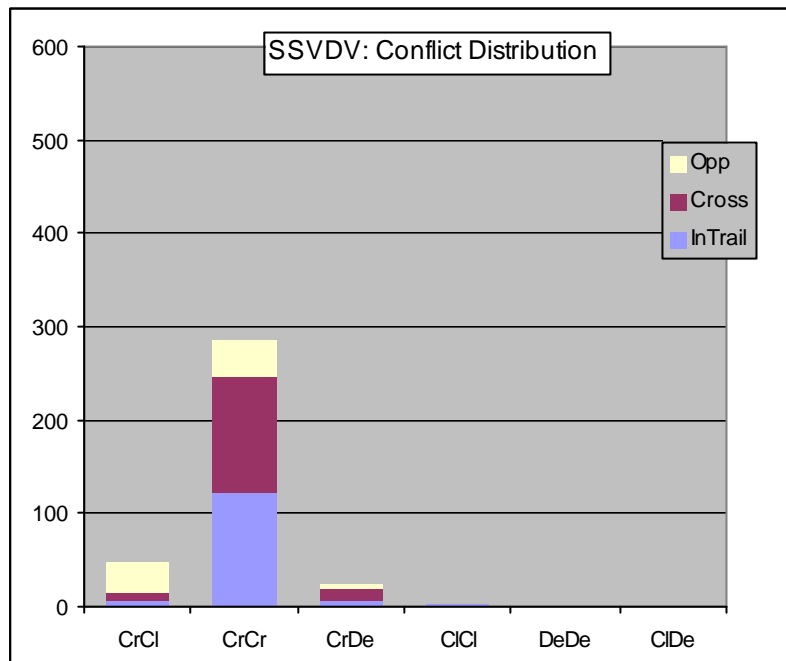
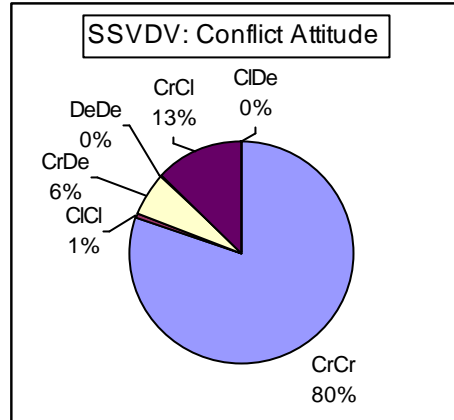
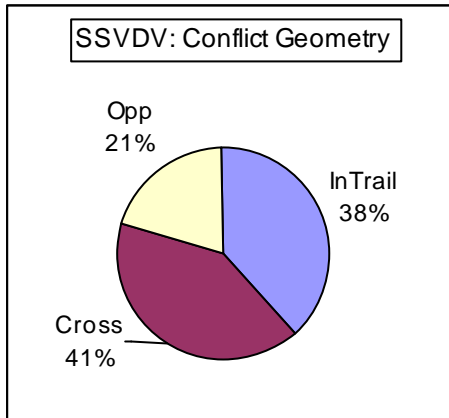
Although SSVDV is one of the most heavily loaded areas in the study, we recall that the traffic demand in the region was fairly consistent around the average of 21 flights per 15-minute period, suggesting that flights tend to remain in the region for longer periods of time.

The details of the conflicts in this SSV, particularly the configuration and attitude of those conflicts will be interesting in determining the suitability of introducing Super-high Service Volume(s) in this region. Conflict characteristics are considered in the next section of the analysis.

The enhanced traffic-load curve clearly shows how the traffic load in the sector remains substantially higher than the NAS average throughout the majority of the core period. During this time, we see three sustained periods where the traffic load remains above the 75% quartile limit, the longest period being 5 hours between 14:30 and 19:30.

It is interesting to note, however that within the excess load periods, conflict levels remain relatively low, ranging between 5 and 10 per 15 minute period and conflict counts exceeds 10 on only one occasion, at 24:00.

In light of the conflict levels, and the length of time that flights appear to spend in the region, the high load could be sustainable given the low levels of conflict.

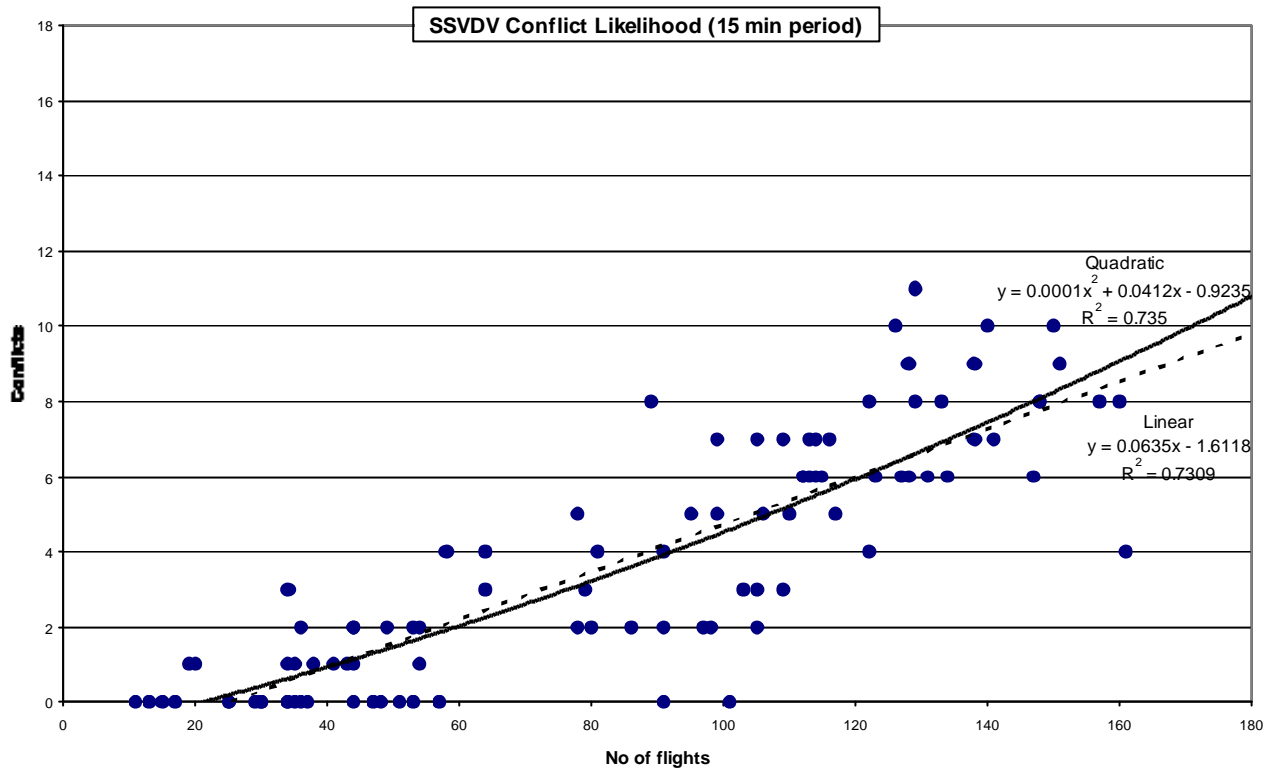


Despite the high traffic load, the contrasting low conflict counts suggest that the traffic in the region is relatively well structured.

As we come to analyze the conflicts, we can confirm that as expected in this region, a large majority of those conflicts involve situations where both flights are in Cruise (80%).

Furthermore, the main conflict geometries for those are equally split between In Track and Crossing conflicts – giving further weight to the idea that the traffic is well structured in the region. Furthermore, there are little or no conflicts where neither flight is in cruise (1%).

Given the geographical location of SSVDV, this comes as no surprise. The high level airspace in the region is clearly used as a transit zone for flights to and from other parts of the NAS.



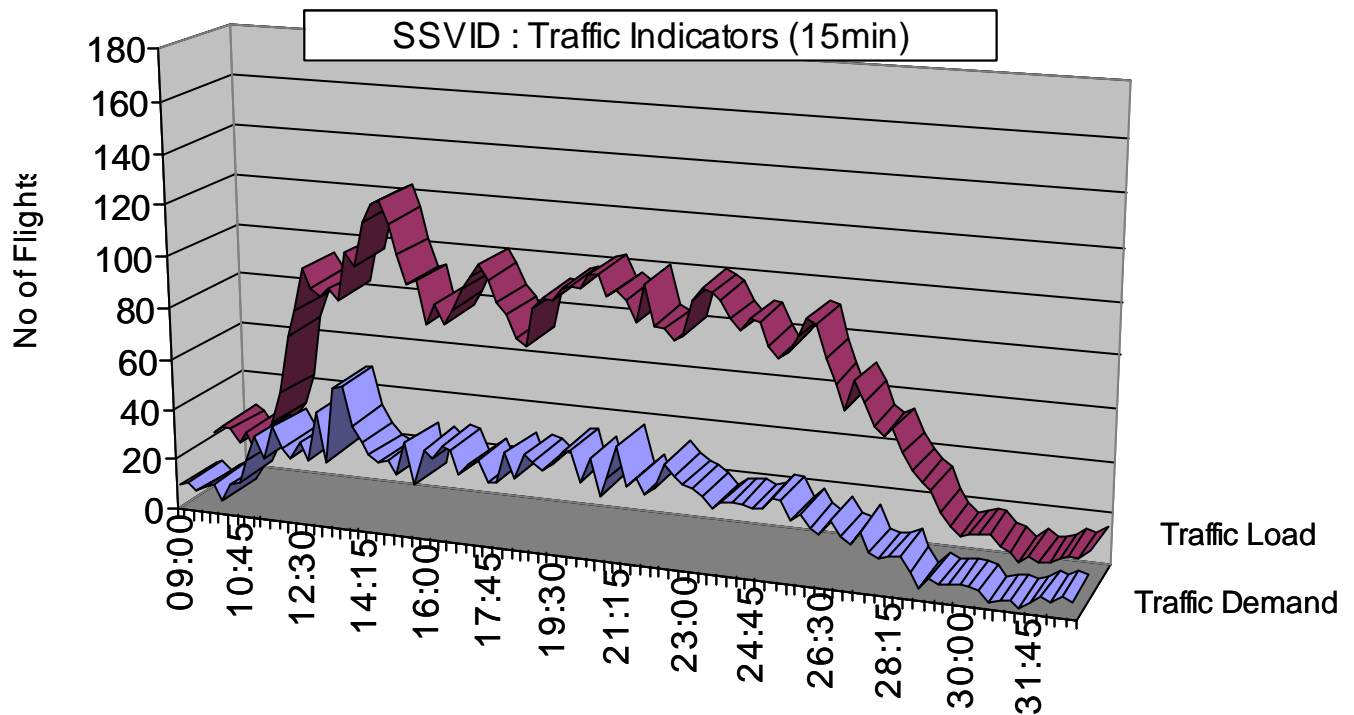
Considering the conflict likelihood and recalling that we consider conflicts in a given 15-minute period to be related to the traffic by a 2nd order relationship, we note that the quadratic curve provide a good representation of the data sample ($R^2 > 0.735$).

On the basis of the results for SSVDV, we can conclude that the region is very interesting to consider in more detail as a candidate for the introduction of large super-high service volumes.

Further, it can be clearly seen that the quadratic fit lies very close to a linear curve fit (shown with the --- line).

This being the case, we can conclude that SSVDV has well-structured traffic and a clear relationship between the number of flights crossing the region and the likelihood of conflict. This is a good sign and means that the behavior of the region is very predictable, thus, even as traffic loads reach 180 or more (in the future as demand increases), the numbers of conflicts will remain constrained to a relatively low number (<12).

Presentation of Results for SSVID



| Region | Active Flights | | | | Flight Entry | | | |
|--------------|----------------|-----|---------|--------|--------------|-----|---------|--------|
| | Min | Max | Average | Median | Min | Max | Average | Median |
| SSVID | 8 | 122 | 66 | 81 | 2 | 56 | 24 | 27 |

Seven SSVs have been grouped together in the Central region. Despite being generally smaller than the other SSVs in the NAS, each of these regions still have above average flight loads, ranging from 54 to 70 active flights on average for a 15 min period, with peaks higher than 100 flights for all of the SSVs that have been grouped in this region. Average traffic demand is similar to some of the other regions, ranging between 18 and 25 flight entries in a 15 min period, but the peak demand tends to be a little higher than elsewhere.

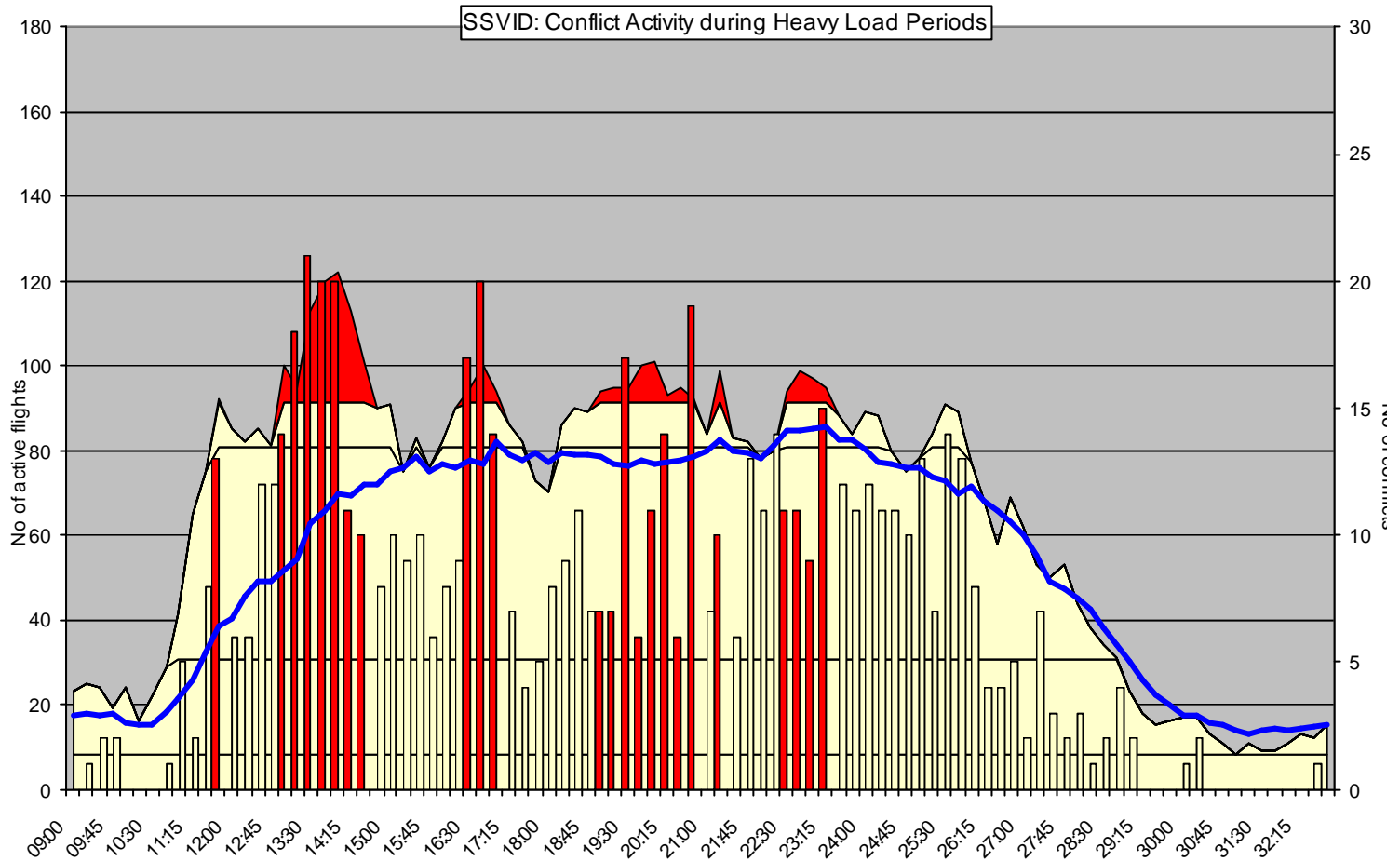
In particular **SSVID** on the eastern boundary, despite being one of the smallest SSVs, shows an average loading across the period that is very high, with 66 active flights in a 15 min period.

Following a peak of 122 active flights at 14:00, the load continues to be high (with a median of 81), and remains in the range between 85 and 100 active flights until 25:30 before tailing off to the end of the day.

The traffic demand in this SSV shows a lot of variation over the analysis period and remains high for a sustained period between 11:00 and 21:15, ranging between 25 and 56 flight entries in a 15 min period.

Several peaks with demand greater than 35 can be observed across the busy load period (11:45, 13:00-14:15, 15:30, 16:00, 16:30, 18:15, 18:45, 19:45, 20:30, 21:15, 22:30).

As with the traffic loading, traffic demand stabilizes after 23:00 and gradually reduces to the end of the day to give an overall average traffic demand in SSVID of 24 flights entering in a 15 min period.



SSVID has traffic loads that remain higher, sometimes significantly, than the NAS average across the majority of the analysis period, with 4 significant heavy load peaks, evenly distributed across the 13 hour period between 12:00 and 25:00.

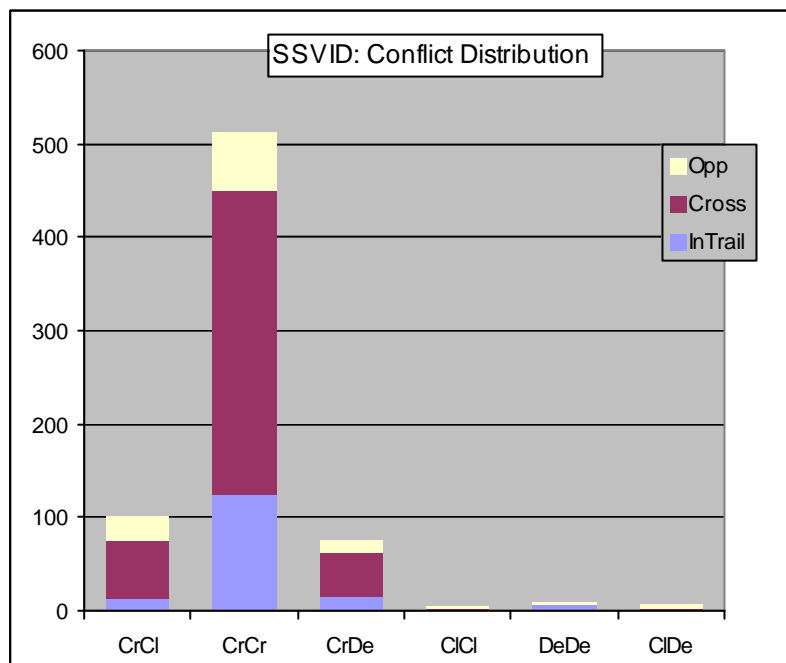
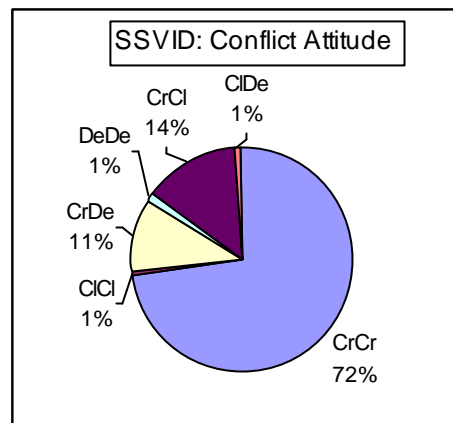
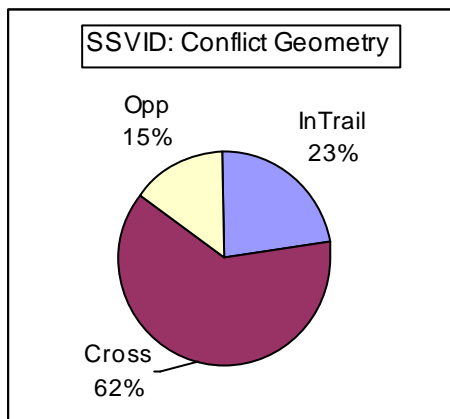
For each of these heavy load peaks, conflict counts are extremely high, often exceeding 15 conflicts in a 15 min period and sometimes reaching 20 or more.

In the USA, it is commonly stated that the Indianapolis airspace region is one with a very high traffic complexity, since it is influenced by a lot of traffic from very busy regions (New York, Washington, Chicago etc). The region is well-known as an area where many tracks cross and where traffic is not easily separated into distinct flows. The load / conflict indicators we see here certainly support that view.

Indeed, the traffic patterns typically found in the region have often been likened to a “*a plate of spaghetti*”.

On the basis of the very high loads being observed for a relatively small SSV, and the often very heavy conflict counts, it seems unlikely at this stage that the area would be a good candidate as a single SSV under current operating conditions.

It will be interesting to see how the situation changes under alternate operating conditions that have been proposed for the near-term, and in particular Domestic Reduced Vertical Separation Minima (DRVSM) traffic conditions.



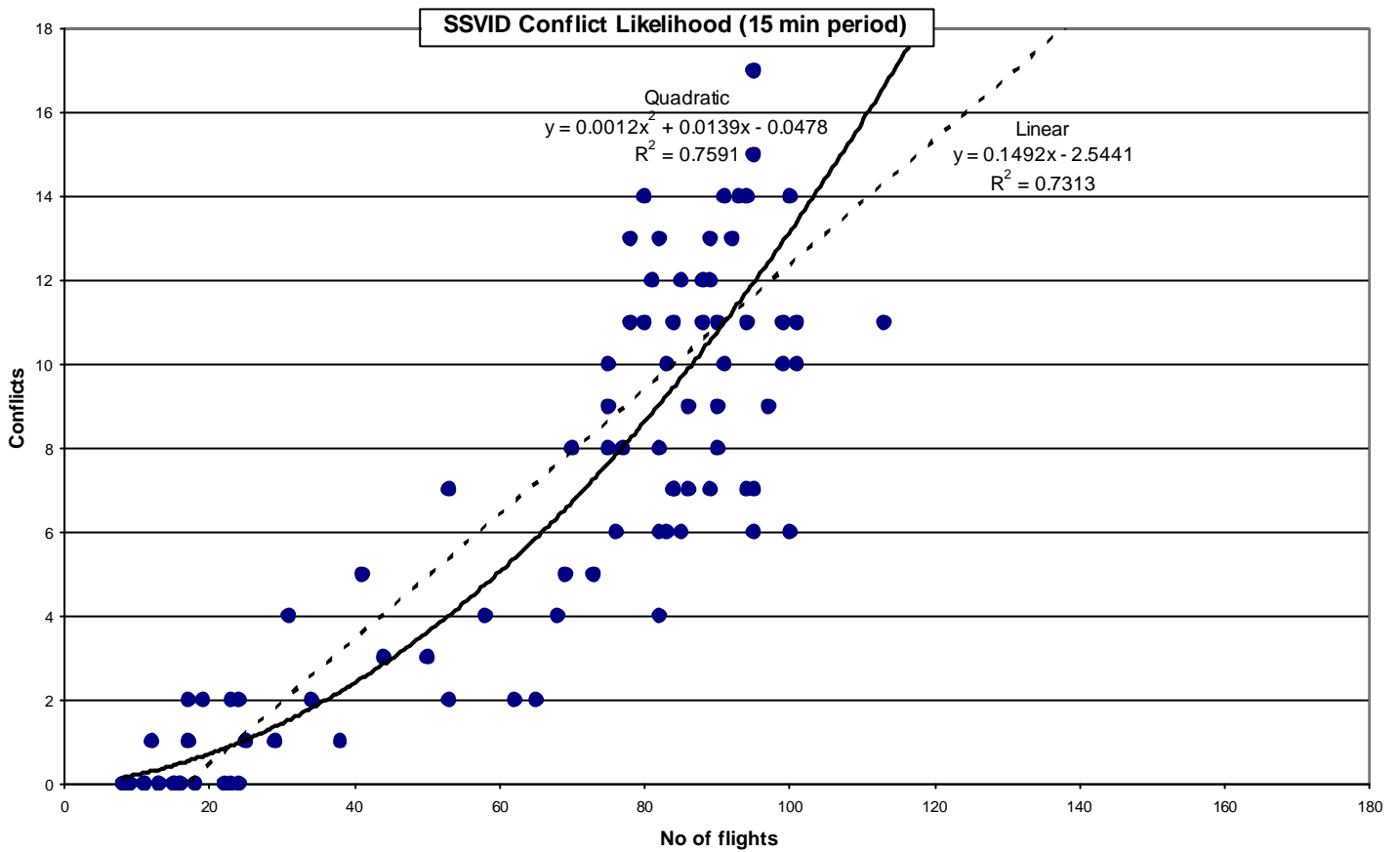
Recalling that, despite being relatively small, SSVID is one of the regions that is most heavily loaded, and conflict counts in this region are often very high, even during periods of lower load, it is interesting to note that almost all the conflicts involve at least one flight in Cruise (97%) and the majority of those have both flights in Cruise (72%).

As we expected, and as is commonly known in the USA, the conflict analysis reveals huge numbers of Crossing conflicts in the region (62%). In particular, we observe a large number of crossing conflicts that involve two cruising flights.

The results that we are seeing for the region confirm the original hypothesis that the region is regularly subjected to highly complex traffic.

The conflict characteristics of the region confirm that many tracks are crossing and suggest that the traffic cannot be easily organized into distinct flows.

Given that this SSV is relatively small and that loads are heavy, introducing one or more SSV's in this region could prove problematic.



To further support the observation that the region is subject to complex traffic that is difficult to organize into distinct flows under current operations, the conflict likelihood analysis for SSVID shows a rapid rise in conflict levels as the number of flights increases with the quadratic curve.

With an R^2 value approaching 0.76, the steep curve suggests that even slight increases in traffic in the region will result in many more conflict situations.

In a region where there are already high numbers of conflicts, small increases in traffic load will result in considerable increases in conflict.

Clearly traffic loads similar to those observed in the SSVDV region (160+) would be unmanageable given the estimated trend for conflicts as traffic increases, adding further weight to the argument that the region is not a good candidate under current flight conditions for the introduction of Super-large control volumes.

Domestic Reduced Vertical Separation Minima (DRVSM)

Following the preparation and presentation of the High Altitude Airspace Analysis study report, a great deal of interest was shown in carrying out a supplementary simulation exercise to analyze the impact of Domestic Reduced Vertical Separation Minima (DRVSM) operations in the High Level Airspace (FL350 and above). Whilst the results of the DRVSM study are not included in this abridged version of the report (which has been specifically edited for the ATM research conference submission), they proved to be very interesting and are summarized in brief here.

The FAA has finalized a draft rule proposing a one-step transition of flight operations in the NAS to introduce Domestic Reduced Vertical Separation Minima (DRVSM) in December 2004.

DRVSM will introduce six (6) new flight levels between FL290 and FL410 by reducing the current 2000 feet separation requirement to 1000 feet. The flight level strategy provides alternative levels for traffic according to the direction of travel (0-180 and 180-360).

The introduction of these new flight levels is expected to allow better support for operator preferred routings and is also expected to reduce the conflict likelihood in the upper airspace, as well as providing additional airspace capacity to allow the service provider more options when dealing with conflicting flight paths.

For the purpose of the High Level Airspace analysis, however, we do not consider how the operator might take advantage of the increased flexibility, and maintain the same operator filed routings used for the Conventional RVSM study described in the main body of this report.

Traffic Load & Demand

The traffic in the High Level Airspace is simply redistributed to make use of the newly accessible flight levels, and controller separation rules are modified to use 1000 feet separations in place of 2000 feet when considering potential conflict cases.

In general, all SSV's in the NAS showed slightly lower traffic demand and load (around 80%) due to some of the traffic that had been using the very popular FL350, now using FL340 which is below the base of our SSV volumes.

Conflicts

As expected with the introduction of DRVSM and the additional flight levels associated with the concept, we observed reduced conflict levels across all SSV's in the NAS. What was encouraging, however, was the magnitude of this reduction.

Recalling that the **SSVDV** region already showed relatively low conflict counts under CRVSM, (*ranging between 5 and 10 per 15 minute period and conflict counts exceeds 10 on only one occasion*), under DRVSM conditions we noted that conflict counts *rarely exceed 3 or 4* in any 15-min period and *often there are only 1 or no conflicts encountered*.

Similarly, for the **SSVID**, where previously we had seen extremely high conflict counts, regularly above 20, with DRVSM operation, conflicts generally remained lower than 5 in any 15-minute period, with only 4 peaks above 5 of 8, 11, 6 and 7 during the four main busy load periods.

Conclusions & Follow on Activities

The analysis of Super-High Service Volumes in the upper airspace has been a very useful exercise and confirms some of the thoughts that have been expressed with regard to different parts of the National Airspace system.

It is already clear that some regions are potentially well suited to the concept of the introduction of super-sectors of Super-High Service Volumes that cover a much larger area than those used in the current system. We also note that, even though traffic loads can become very high, we have not always seen an equivalent increase in the conflict counts, nor in the conflict potential.

In addition, the study has shown that even taking a first look at a concept in a somewhat low-grain manner ("sector as big as a centre") through the use of appropriate indicators we can readily ascertain information about the different parts of the airspace system that support the popular consensus and confirm our heuristic views of the NAS through clear and concise statistics.

The analysis gives rise to a number of important questions, not least concerning the fundamental problem as to how many flights can a Controller be realistically expected to manage over a given time period, and more

importantly, when traffic load or traffic demand becomes very high (as we chose to illustrate using the various quartile loading during this study), what duration could we reasonably expect a controller to maintain the demand, and which tools can be introduced to better support that role?

Additional research to address these questions is underway within the FAA, where the MIDAS model of the controller will be used to analyse the human side of SSV management in greater detail.

As various research groups look towards new concepts, perhaps involving super-sectors, meta-sectors or even sector-less airspace, it will be important to evaluate the response to these questions. This study has taken a first step by

analysing each of the different NAS centres as a single entity in the high level airspace. The next step will be to focus on particular types of Super-high Service Volume and evaluate how the controller might react to higher loads of this nature, and what levels will be realistic in the future. This being done, we will need to evaluate what will be the kind of decision support tools and new procedures that will be needed to render these areas more manageable and ensure a safe and durable future ATM system.

Author Biographies

Ian Crook has over 17 years experience in computing, specializing in the application of leading edge technologies to user oriented software systems. Specific skills include the use of Object Oriented methods, Artificial Intelligence, Discrete Event Simulation and Distributed Object Architectures.

Having spent his formative years working in the aviation manufacturing industry, specializing in the development of on-board aircraft control software, Ian spent five years developing telecommunication systems, before returning to the aviation industry in 1991.

Since then, Ian has specialized in the design of ATM-oriented simulation systems.

Recent projects include the Eurocontrol Airspace Model (EAM), Capacity Analysis Facility (CAPAN), Reorganised ATC Mathematical Simulator (RAMS), Airspace-Airport Integrated Modeling System (AIMS), FAA RAMS-OPGEN dynamic link and the ISA Software/FAA ATMOS Weather server.

Diana Liang works for the Office of System Architecture and Investment Analysis for the Architecture and System Engineering Division of the FAA. She is responsible for the development of the NAS Architecture Tool and Interface called CATS-I, directing analyses in support of NAS Concept Validation, and the development of Modeling Tools and Fast-Time Simulations to support that validation. This work includes several models she is developing jointly with NASA and cooperative efforts with Europe via Eurocontrol. Prior to working for ASD, Ms. Liang worked in the Office of Energy and Environment for two years as the lead for the Emissions and Dispersion Modeling System (EDMS), updated the FAA's Air Quality Handbook and reviewed Environmental Impact Statements related to emissions. Ms. Liang holds a BS in Computer Science and is currently attending George Washington University.