AIRSPACE CONCEPT EVALUATIONS USING FASTE-CNS AS A SIMULATION ANALYSIS TOOL

Steve Mainger, NASA Glenn Research Center, Cleveland, OH

Chris Wargo, Anil Kumar, Sachin Lal, Kiran Vangamuru, Chris Dhas, CNS, Inc., Springfield, VA

Manu Khanna, Comptel, Falls Church, VA

Tom Mulkerin, Mulkerin Associates Inc., Springfield, VA

Abstract

As NASA speculates on and explores the future of aviation, the technological and physical aspects of our environment increasingly become hurdles that must be overcome for success. Several NASA research partners have purposed research into methods for overcoming some of these selected hurdles. The task of establishing a common evaluation environment was placed on NASA’s Virtual Airspace Simulation Technologies (VAST) project (sub-project of Virtual Airspace Modeling and Simulation Project). Their response was the development of the Airspace Concept Evaluation System (ACES).

As one examines the ACES environment from a communication, navigation or surveillance (CNS) perspective, the simulation environment made no provisions for realism in the simulation of CNS. To truly evaluate these concepts in a realistic sense, the contributions/effects of CNS must be part of the ACES.

NASAs Glenn Research Center (GRC) has supported the Virtual Airspace Modeling and Simulation (VAMS) project through the continued development of CNS models and analysis capabilities that supports the ACES environment. NASA GRC initiated the development a communications traffic loading analysis tool, called the Future Aeronautical Subnetwork Traffic Emulator for Communications, Navigation and Surveillance (FASTE-CNS), as part of this support. This tool allows for forecasting of communications load with the understanding that, there is no single source for loading models used to evaluate the existing and planned communications channels, and that consensus and accuracy in the traffic load models is a very important input to the decisions being made on the acceptability of communication techniques used to fulfill the aeronautical requirements.

Leveraging off the existing capabilities of the FASTE-CNS tool, GRC has called for FASTE-CNS to have the functionality to pre- and post-process the simulation runs of ACES to report on instances when traffic density, frequency congestion or aircraft spacing/distance violations have occurred. The integration of these functions require that the CNS models used to characterize these avionics systems be of higher fidelity and better consistency then is present in FASTE-CNS system.

This paper explores the capabilities of FASTE-CNS with renewed emphasis on the enhancements added to perform these processing functions; the fidelity and reliability of CNS models necessary to make the enhancements work.

Airspace Concept Evaluation System

The Virtual Airspace Simulation Technologies (VAST) sub-project was tasked to provide a validated virtual airspace simulation environment. This environment would be used to assess the integrated behavior of current and future air transportation system concepts. Two key simulation environments will be developed. They are system-level non real-time simulation and human-in-the-loop real time simulation. A natural development of the VAST project is a toolkit or collection of various simulation support components or stand-alone simulations. The elements of the toolkit can be mixed and matched to assist in crafting the necessary environment for analyzing the various operational concepts and validating the entire Air Traffic Service (ATS) concept under test.

The environments necessary to complete modeling the virtual airspace are both fast time and real time simulations. The components making up the fast time environment are referred to as the Airspace Concept Evaluation System (ACES). This is considered to be the most flexible and expandable
of the environments. Users will be able to select interactive agent-based models appropriate for their investigations. The real-time environment is made up of a distributed network that will combine simulation elements with an actual human operator suite. This results in the construction of an integrated environment that will simulate an environment in which human interactions are analyzed.

A crosscutting element of both simulation environments is the need for communication, navigation and surveillance (CNS). In an active National Airspace System (NAS) environment, all three elements of CNS play critical roles in enhancing the realism of the simulated environment. The challenge for augmenting the ACES environment with a CNS simulation capability is that ACES was not built to simulate realistic CNS transactions. Therefore, we are faced with the development of an ACES external capability which interprets the evaluation concept's pre-simulation CNS needs. It also provides an analysis of the post-simulation ACES data to identify the impact of CNS on the concept. The ability to model the true responses of the CNS elements in these simulation environments is the purpose of future CNS model entities that shall be integrated into the ACES environment.

**FASTE-CNS Architecture and Capabilities**

At present, ACES has a limited (virtually non-existent) CNS simulation capability. The analysis of CNS during concept evaluation simulations was not critical to the success of ACES development. However, the need for CNS analysis is coming into focus and integration of CNS capabilities is the next critical step in the on-going development of ACES. The integration of CNS into the ACES environment is a multiphase process. As a first step, the existing FASTE-CNS tool is viewed as an external analysis tool that can satisfy some of the programmatic requirements of the VAST project.

Figure 1 presents the FASTE-CNS functional architecture. It consists of loader, Pre-ACES and Post-ACES analysis functions. The loader functionality is part of the previous version of FASTE-CNS. It is a dynamic CNS estimating tool that is accessible through the Internet using a browser such as Internet Explorer or Netscape. It can be used to perform communications load predictions. FASTE-CNS's communications load prediction capability provides the means to study the impact of air/air and air/ground communications frequency and transmitter requirements in a geographic region. The load prediction capability provides a means to model the data communications traffic load associated with existing and new applications. It allows a user to dynamically define application message sets and communications media plus configure communications traffic profiles composed of those message sets and media. The user also can define a geographical region and assign a number of aircraft to the region. The combination of traffic profiles assigned to regions provides a researcher with an understanding of the quantity and type of air/ground and air/air data link communications that occur in the region. FASTE-CNS's loader capability also calculates the number of frequencies or transmitters needed to support communications using the specified media within the region.

**Figure 1. FASTE-CNS Functional Architecture**

FASTE-CNS's performance modeling capability consists of Pre-ACES and Post-ACES analysis functions. It is focused on supporting the VAMS project by producing CNS results from data generated during the run of an operational concept on NASA's Airspace Concept Evaluation System (ACES). Its performance capability adds fidelity to communications, navigation and surveillance system models using the delays and inaccuracies associated with the real-world systems. FASTE-
CNS's communications prediction capability provides subnetwork related performance data within a geographic region for VHF Digital Link (VDL) Mode 2 or Aircraft Communications Addressing and Reporting System (ACARS) data link systems during the execution of the operational scenario. It can also model voice communications performance.

The navigation and surveillance performance models indicate the number of aircraft separation violations that occur while executing the operational concept. The navigation systems are Global Positioning System (GPS) and VHF Omnidirectional Range/Distance Measuring Equipment (VOR/DME). The surveillance systems are Secondary Surveillance Radar (SSR) and Automatic Dependent Surveillance - Broadcast (ADS-B).

The main difference between the pre and post analysis function is the type of input data used to obtain the performance metrics. The post-ACES capability uses ACES output data while the pre-ACES capability does not.

FASTE-CNS will ultimately reside within GRC's multi-fidelity simulation environment and be an integrated component of GRC's modeling and simulation capability. It will be an Internet-based aeronautical communications calculation capability that will support geographically dispersed NASA, FAA, university, and contractor communications evaluations for the future aeronautical environment of the 48 contiguous states in the Continental United States (CONUS). Authorized users access the system using common web browsers such as Internet Explorer and Netscape.

Integration of a CNS Modeling Capability into FASTE-CNS

ACES contains several modules (agents) that emulate an entire period of operations of the NAS, and provides data to support validation and benefits assessment. The ACES environment supports models and data sets such as:

- Aircraft
- Air Traffic Control System Command Center (ATCSCC) including monitor alert
- En Route Traffic Flow Management (TFM) and Air Traffic Control (ATC) including Conflict Detection & Resolution (CD & R) or Advanced airspace Concepts (AAC)
- Terminal TFM & ATC
- Airport TFM & ATC including Surface Traffic Limitations (STL)
- Airline Operations Center (AOC)
- Traffic demand
- Winds
- Airspace

At present ACES assumes unlimited bandwidth, zero delay and instant message transferring for CNS. FASTE-CNS modeling is an attempt to introduce the CNS capability into ACES environment using a multiphase process. The first phase is to develop a CNS modeling capability in the FASTE-CNS environment. It consists of using FASTE-CNS as a pre and post analysis tool for ACES. Pre-ACES analysis allows the concept developer to understand the CNS requirements before executing the concept in the ACES environment. The results of pre analysis may allow the concept developer to fine-tune the concept before executing it in ACES. On the other hand, post analysis using the execution data collected from an ACES run may indicate the effect of CNS on the operational concept.

FASTE-CNS User Interface

FASTE-CNS supports a browser based user interface to collect data from the user and display model output data. Figure 2 presents a screen shot of the FASTE-CNS Graphical User Interface (GUI). All of the Pre-ACES analysis data is collected using the GUI. In Post-ACES analysis runs, the GUI is used to input the parameters for the analysis. Data collected by the ACES run is processed offline and then loaded into the FASTE-CNS database system. The end user will be able to select the appropriate data set using the GUI.
Figure 2. FASTE-CNS Graphical User Interface (GUI)

FASTE-CNS provides the mechanisms to assist users in creating various input data objects such as flight plans and includes the capability to add or delete information to/from the data object. It provides the user with the capability to assign an unique name to a data object. Each data object is associated with the user ID of the person who created it. A user has the capability to modify an object that he or she created. It identifies each created data object as private. A user has the ability to add private data objects that he/she created to a public library. If a data object is designated as private, only the user that created it has access to it and a user is able to delete private data objects.

FASTE-CNS supports the capability to create a library of public data objects. A user has the capability to add a private data object to the public library at any time after creation. All users are able to access data objects in the public library. A user is able to make a copy of a public data object and assign the copy an unique name. The user is designated as the creator of the newly designated data object. The user is able to designate this data object as either private or public. In addition, FASTE-CNS provides storage for user data objects.

Even though the input data used for Pre-ACES and Post-ACES analysis are different, they use the same simulation model to generate performance metrics. Therefore, the simulation related functional description associated with communication, navigation and surveillance models are presented in the Post-ACES analysis section.

Pre-ACES Analysis

Pre-ACES analysis consists of communication, navigation and surveillance models.

Pre-ACES Analysis – Communications Model

The input to the Pre-ACES Communications analysis function consists of a communication flight data set, a radio coverage area set, the communications subnetwork to be used for all of the air/ground communications analysis and the period of time to be analyzed. FASTE-CNS supports voice, VHF Digital Link (VDL) Mode 2, and Aircraft Communications Addressing and Reporting System (ACARS) protocols. The user enters the start time and duration of the analysis period and the delay constraint in seconds.

A communications flight data set contains one or more flight plans and associated application profiles. A flight plan can be used to determine the flight path of an aircraft from take-off to landing in one-minute segments. The characteristics associated with a flight plan are departure and arrival airports, time of departure and type of aircraft. The type of aircraft can be interpreted to determine an average speed for the aircraft. The application profile assigned to each flight plan represents the messages that the aircraft will send and receive throughout its flight. Users develop communication flight data set using the FASTE-CNS GUI. Since the communications modeling process involves only one communications type, the user is not allowed to create a communications flight data set that contains both voice and data application profiles.

In addition, FASTE-CNS supports the capability to create multiple flight plans and the capability to replicate a flight plan and its associated application profile (AP) such that each flight plan has a different identity and departure time.

An AP is a set of user selected application message sets (AMSSs). FASTE-CNS assists the users in creating application profiles. The message sets in an AP are either all data or all voice. FASTE-CNS does not allow the user to create an AP that contains both voice and data message sets.

FASTE-CNS provides the means for a user to create an application message set by allowing the user to identify an application and describe the
characteristics of the messages associated with the application. The characteristics for each message include (at a minimum) message size, frequency of transmission, and phase of flight (i.e., takeoff, en route, or landing). It provides the user the capability to assign an unique name to an AMS and each AMS is associated with the user ID of the person who created it. The system allocates the owner full access rights to act upon the AMS. FASTE-CNS supports the capability to create voice as well as data message sets.

Radio Coverage Area Sets (RCAS) is a grouping of radio coverage areas. The system supports the capability for the user to designate the geographic areas for which a communications analysis is to be performed. A single area is known as a Radio Coverage Area (RCA). It provides the mechanisms to assist users in creating a RCAS and provides the user with the capability to assign an unique name to a RCAS.

The pre-analysis model estimates the communications delays associated with aviation operations within a geographical area and the number of frequencies needed to remain within a user selected delay criterion.

Pre-ACES Analysis - Navigation Model
The concept for the pre-analysis navigation model is that a user will be able to enter a flight plan and designate a navigation system. FASTE-CNS graphically displays two tracks for the flight. One represents the true positions of the aircraft throughout its flight. The other track is the positions as determined by the navigation system, referred to herein as the reported position. FASTE-CNS supports GPS or VOR/DME as the navigation system. The navigation model process determines a reported position for every minute of the aircraft’s flight. The reported position represents the location indicated by the aircraft’s navigation system based upon biases and errors in the system. Random number generators are used to replicate the biases and errors. Since the results of each model run using the same inputs must be identical, the same seed is used to start the random number generation process for each model run.

The aircraft’s true position is used in determining the reported position. The reported position is determined using a normal distribution based random number generator. The process for determining the reported position is based upon the navigation system selected.

Pre-ACES Analysis - Surveillance Model
The concept for the pre-analysis surveillance model is that a user is able to enter a flight plan and designate a surveillance system that would provide aircraft locations that would be seen by an ATC controller. FASTE-CNS graphically displays two tracks for the flight. The other track is the positions as presented to an ATC controller by the surveillance system, referred to herein as the reported position. FASTE-CNS supports Secondary Surveillance Radar (SSR) and Automatic Dependent Surveillance - Broadcast (ADS-B) surveillance systems.

The Pre-ACES Surveillance model uses a flight plan and the surveillance system as input to perform the analysis. The surveillance system is ADS-B, the user is able to enter an Navigational Accuracy Category for Position (NACp) value between 0 and 11. The surveillance model process determines a reported position for every minute of the aircraft’s flight. The reported position represents the location as presented to an ATC controller based upon biases and errors in the SSR or ADS-B ground equipment to controller display system. Random number generators are used to replicate the biases and errors. Since the results of each model run using the same inputs must be identical, the same seed is used to start the

1.C.3-5
random number generation process for each model run.

The aircraft's true position is used in determining the reported position. The reported position is determined using a normal distribution based random number generator. The process for determining the reported position is based upon the surveillance system selected.

**Post-ACES Analysis**

The Post-ACES analysis consists of communication, navigation and surveillance simulation models. Figure 3 presents the logical architecture of the Post-ACES analysis subsystem. The input for the Post-ACES analysis comes from the data collected during ACES execution of an operation concept. In the ACES execution environment, system data collection is accomplished by capturing the data locally via the Local Data Collection subsystem. This subsystem collects all or a subset of the data from all the messages, and public and private information sent from agents. This system also consolidates the locally collected data into a centralized MySQL database at the end of the simulation run.

The Data Mapper takes the MySQL data as input and maps the relevant data objects into ordered communication, navigation and surveillance traffic profiles.

![Figure 3. Post-ACES Analysis System Logical Architecture](image)

**Post-ACES Analysis - Communications Model**

The communications model uses as input:

- A radio coverage area set
- The communications type to be used for all of the air/ground communications analysis. The communications types supported are voice, VDL Mode 2, or ACARS.
- The ACES simulation run data associated with simulated air/ground communications
- The period of time to be analyzed
- The amount of delay in air/ground communications considered acceptable

The FASTE-CNS simulator for communication generates the average and 95 percentile delays in each of the RCAs in the radio coverage area set. Then, the 95th percentile delay in each RCA is used to determine if the acceptable delay criterion was violated. For those RCAs where the delay exceeds the acceptable criterion, it determines the number of frequencies needed to support the communications load such that the 95th percentile delay will be less than or equal to the acceptable delay value. In addition, FASTE-CNS captures the number of communications errors and related link performance metrics as the simulation progresses in each of the RCAs in the radio coverage area set.

**VDL-2 Protocol Architecture and Simulation Model**

The VDL-2 subnetwork provides data communications services between the aircraft and ground entities. Its standards are defined in the ICAO VDL Mode 2 Standards and Recommended Practices (SARPs). It uses a network of ground stations to provide the desired airspace coverage using part of the VHF band allocated for aeronautical communications. This band is divided into multiple independent 25-KHz channels. A Carrier Sense Multiple Access (CSMA) protocol controls the media access between the aircraft and the ground station for each 25-KHz channel allocated for VDL-2.
The VDL-2 physical layer uses a differentially encoded 8-phase shift keying (D8PSK) modulation, and VDL Mode 2 operates at a burst rate of 31.5 kilobits per second (Kbps) for each 25-KHz channel. The physical layer generates a 108-bit training sequence for each frame transmitted.

The data link layer consists of two sublayers and a management entity. The Media Access Control (MAC) sublayer uses a p-persistence CSMA protocol to control access to a shared 25-KHz channel between the aircraft and the ground stations.

The ground and aircraft station node model is shown in Figure 4 and it consists of Data Link Service (DLS) sublayer process module, a MAC sublayer process module, a transmitter module, a receiver module, and an antenna module.

![Figure 4. VDL-2 Ground and Aircraft Node Model Process Models](image)

The model accepts messages received from the upper layer and sends packets to the DLS sublayer. The DLS sublayer records the received packet and forwards it to the MAC layer. For every packet received from the upper layer, the DLS sublayer sends a new frame to the MAC sublayer. For each frame requiring an acknowledgement, the DLS sublayer starts a retransmission timer, T1. If the timer expires, the DLS sublayer retransmits the same frame for up to N2 times.

On the other hand, the DLS sublayer receives frames from the MAC sublayer and forwards them to the upper layer. For each frame received that requires an acknowledgement, the DLS sublayer sends an acknowledgment frame.

After receiving a frame from the DLS sublayer, the MAC sublayer checks the channel status before transmitting the frame. If the channel is busy, the transmitting entity backs off for a fixed interval of time, TM1, before rechecking the channel status. If the channel is not busy, the transmitting entity attempts to transmit with a probability of p and backs off with a probability of (1-p).

The transmitter receives frames from the MAC sublayer and transmits them over a 25-KHz channel. The receiver receives frames over a 25-KHz channel and sends them to the MAC sublayer. The transmitter and receiver operate at 118 MHz with a 31.5 Kbps channel bit rate.

In addition, the Data Link Service provides error detection, error recovery, and address identification of frames. It supports unicast and broadcast capabilities plus uses a variant of the High-level Data Link Control (HDLC) protocol to provide sequencing and acknowledgement of frames. The Link Management Entity (LME) provides link management and release services between the local DLS and the remote DLS.

**Post-ACES Analysis - Navigation Model**

The post-analysis navigation model uses the minute-by-minute aircraft location information in the ACES output data to compare the four dimension reported locations of all of the aircraft in the areas of interest. The comparison determines if an aircraft separation violation occurred based on the horizontal and vertical separation criteria entered by the user. The AircraftStateMessages generated by ACES is used by the navigation model. FASTE-CNS imports the AircraftStateMessages collected by the ACES Local Data Collection subsystem. This data indicates the location of each of the aircraft at minute intervals and is used as the basis for performing post analysis navigation modeling. GPS and VOR/DME are the two navigation systems supported by the model.

Using the GUI, the end user designates the geographic areas for which a navigation system analysis is to be performed. A single area is known as a subregion. A grouping of subregions is known as a subregion set. The navigation model takes as input subregion set, the minimum allowed horizontal and vertical separation between adjacent aircraft, and the navigation system to be used - GPS or VOR/DME. The navigation model determines a reported position for every minute of the aircraft's flight. The reported position represents the location...
indicated by the aircraft’s navigation system based upon biases and errors in the system. Random number generators are used to replicate the biases and errors. Since the results of each model run using the same inputs must be identical, the same seed is used to start the random number generation process for each model run. The aircraft’s true position is used in determining the reported position. The reported position is determined using a normal distribution based random number generator. The process for determining the reported position is based upon the navigation system selected.

If GPS is selected as the navigation system, the process of determining the reported position for the aircraft involves determining the aircraft’s reported latitude, longitude and altitude. The aircraft’s true position components (latitude, longitude and altitude) are used as the mean in a normally distributed random number generator. The standard deviation for the longitude and latitude is 3.15 meters while the standard deviation for altitude is 4.75 meters.

If VOR/DME is the navigation system, the accuracy of course alignment of the VOR is considered generally to be within ±1 degree of the true heading. For modeling purposes the error is assumed to be normally distributed around the mean with a standard deviation of 0.5 degrees. The mean used in the calculation is the heading of the aircraft. DME has as much as a ±2 nautical miles error factor. For modeling purposes the error is considered to be normally distributed around the mean with a standard deviation of 1 nm. The mean will be the latitude and longitude of the reported position of the aircraft. Since a VOR/DME system does not provide an altitude indication, the reported position altitude is the same as the true position altitude.

The four dimensional reported positions for each equipped aircraft within the defined subregions is compared to see if they violate the user defined horizontal and vertical minimum separation criterion. The horizontal separation criterion is not violated if more than the minimum vertical separation distance separates the aircraft under consideration. The four dimensions are latitude, longitude, altitude and time.

Post-ACES Analysis - Surveillance Model

The post-analysis surveillance model uses the minute-by-minute aircraft location information in the ACES output data to compare the four dimension reported locations of all of the aircraft in the areas of interest. The comparison determines if an aircraft separation violation occurred based on the horizontal and vertical separation criteria entered by the user. FASTE-CNS imports the AircraftStateMessages collected by the ACES local data collection subsystem. This data is used as the basis for performing post analysis surveillance modeling. The FATE-CNS model supports Secondary Surveillance Radar (SSR) and Automatic Dependent Surveillance - Broadcast (ADS-B) surveillance systems.

The surveillance model uses as input a subregion set, the minimum allowed horizontal and vertical separation between adjacent aircraft and the surveillance system to be used - SSR or ADS-B. If the surveillance system is ADS-B, the user enters a navigational accuracy code (NAC) value between 0 and 11. The surveillance model process determines a reported position for every minute of the aircraft’s flight. The reported position represents the location as presented to an ATC controller based upon biases and errors in the SSR or ADS-B ground system to controller display system. Random number generators are used to replicate the biases and errors. Since the results of each model run using the same inputs must be identical, the same seed is used to start the random number generation process for each model run. The aircraft’s true position is used in determining the reported position. The reported position is determined using a normal distribution based random number generator. The process for determining the reported position is a function of the surveillance system selected.

The SSR processing accounts for SSR precision, smoothing of tracks, and display delay in determining the reported position of an aircraft. SSR precision includes the precision of the radar and the resolution of the position fields in the message that transmits the position data from the radar to the tracking system. Track smoothing is a function of the tracking system that keeps target reports from “jumping” on the controller’s console. Display delay accounts for the distance an aircraft
moves between the time the report is prepared at the radar and it is displayed on the controller's console.

The process of creating a reported position involves the use of a random number generator. The latitude and longitude associated with the aircraft's true position are treated separately. The true position components (latitude and longitude) are used as the mean in a normally distributed random number generator. The standard deviation used is an estimate of the standard deviation of the combined error (radar precision, smoothing and display delay) distribution. The estimate of the standard deviation is determined by using the Root Mean Square (RMS) technique. The two random numbers that are generated are the latitude and longitude of the reported position.

The first step is to determine if track smoothing is to be considered. Track smoothing could occur when an aircraft is in a turn when illuminated by the radar. A uniformly distributed random number generator is used to determine if smoothing should be employed. A random number between 0 and 1 is generated. If the number is greater than 0.9, smoothing is employed; i.e., smoothing will occur about 10% of the time.

There are two principal precision errors associated with a radar. One is the inherent accuracy of the radar. The other is the resolution of the field in a message that transmits the location from the radar to the tracking system. In general, the message field resolution is less precise than the radar's accuracy so the estimate of radar precision will be based upon message resolution. The FAA uses the Common Digitizer - 2 (CD-2) message to pass surveillance data from the radar to the tracking system. The CD-2 format limits range accuracies to ±1/8 nm for en route radars. The error associated with the message formats is uniformly distributed. The standard deviation of the errors is 439 feet for an en route radar.

Assuming a normal distribution for the delay, the standard deviation is 1.7 seconds. The distance that an aircraft will travel in 1.7 seconds is a function of the speed of the aircraft. Converting time to distance, the standard deviation for the delay is 1.7 seconds times the aircraft speed.

Automatic Dependent Surveillance - Broadcasting Processing (ADS-B) processing accounts for aircraft navigation system precision, smoothing of tracks, and display delay. Navigation system precision is normally transmitted in the NACp (Navigation Accuracy Category for Position) field of the ADS-B message. Track smoothing and display delay are the same as for SSR. The NACp value input by the user. Again, an RMS technique is used to estimate the standard deviation of the combined distributions.

The SSR and ADS-B algorithms only deal with the differences between the horizontal components of the true and reported positions. Thus, the reported position altitude is same as the true position altitude. The four dimensional reported positions for each equipped aircraft within the defined subregions is compared to see if they violate the user defined horizontal and vertical minimum separation criterion. The horizontal separation criterion is not violated if the aircraft of concern are separated by more than the minimum vertical separation distance. The four dimensions are latitude, longitude, altitude and time.

Conclusion

The addition of CNS performance modeling to FASTE-CNS provides the VAMS project with a more realistic environment to supplement ACES in evaluating NAS operational concepts. The communications models simulate the errors and delay associated with the VDL-2 and ACARS protocols as well as voice communications. The navigation models provide the reported positions as seen by a pilot on GPS and VORDME displays. This contrasts with the actual positions and can be used to assess inadvertent separation violations. The surveillance models provide imprecise reported positions an ATC controller would use in separating aircraft. Together, the CNS performance models add a level of fidelity that make ACES more effective in the evaluation of operational concepts. The utility of the models will be increased as the FASTE-CNS performance models are integrated into ACES.
Bibliography


