## Title

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## Authors

Smirti, Megan
Hansen, Mark

## Publication Date

2009-02-01

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Megan Smirti and Mark Hansen

WORKING PAPER
UCB-ITS-WP-2009-1



February 2009
ISSN 0192 4141

# Achieving a Higher Capacity National Airspace System: An Analysis of the Virtual Airspace Modeling and Simulation Project

Megan Smirti[1]*, Mark Hansen[2]

[1]PhD Candidate in Civil and Environmental Engineering
University of California, Berkeley, National Center of Excellence for Aviation Operations Research,
109 McLaughlin Hall, Berkeley, CA 94720-1720, USA
E-mail address: msmirti@berkeley.edu
*Corresponding Author
Telephone: 415-816-0925
Fax: 510-642-5687

[2]Professor of Civil and Environmental Engineering
University of California, Berkeley, National Center of Excellence for Aviation Operations Research,
114 McLaughlin Hall, Berkeley, CA 94720-1720, USA
E-mail address: mhansen@ce.berkeley.edu

**Abstract**
The Virtual Airspace Modeling and Simulation (VAMS) project developed by the National Aeronautics and Space Administration (NASA) presents a detailed plan for increasing National Airspace System capacity. Interviews with aviation experts regarding the VAMS project led to lessons learned which can inform current modernization plans and processes, as the current system prepares for modernization. According to experts consulted, development should include a small number of project developers who provide periodic opportunities for wide stakeholder feedback; roadmaps should incorporate uncertainly and provide project guidance on a high level; and simulation tools are valuable to modernization efforts, yet assumptions should be documented and their sensitivity understood.

Keywords: Aviation System Modernization, Stakeholder Involvement

## 1. Introduction

The Virtual Airspace Modeling and Simulation (VAMS) project was a recently concluded effort to pinpoint and merge technologies and strategies to increase the capacity of the National Airspace System (NAS). It is believed by both domestic and European airspace authorities that current airport and airspace capacities are not enough to accommodate the demands of the future, and that capacity increases must be on a grand scale to handle this demand increase (Joint Planning and Development Office, 2006; Ky and Miaillier, 2006). Beginning in fiscal year 2002, the VAMS Project sought to provide the foundations required to define and assess a next generation air transportation system. The project supports National Aeronautics and Space Administration (NASA) strategic efforts to "enable a safer, more secure, efficient, and environmentally friendly air transportation system" (National Aeronautics and Space Administration, 2006).

The VAMS project was an innovative systems level effort to increase NAS capacity. It was one of few projects which did not solely develop individual component technology, but rather developed independent capacity enhancing concepts and then integrated them into a single concept. The project furthermore developed a plan for the research, development, and deployment of the concepts and created an assessment tool that can be used for a wide range of future concepts. NASA had many roles on the VAMS project, as they were a facilitator, a funding agency, and a concept developer. Five domestic aviation companies and NASA centers developed concepts to increase capacity independently, and then came together to further refine and blend the concepts, which led to an overall System Wide Concept (SWC). Next, a roadmap was developed based on the current federally-funded aviation projects through 2015. The SWC was then assessed with a non-real time assessment tool. Throughout the process, input was gathered through discussions and technical exchange involving NASA and the chosen developers.

NASA's effort, although not explicitly intended to be, was a precursor to the current federal initiative to modernize the NAS termed the Next Generation Air Transportation System (NextGen). This Joint Planning and Development Office (JPDO) effort has a larger scope than VAMS, in the number of stakeholders involved, in the domains covered, and in the magnitude of the targeted capacity increase. Therefore, the lessons learned from

VAMS will provide valuable insight into the development of NextGen, as well as other modernization efforts. To capture opinions and lessons learned, the authors spoke with multiple national and international authorities to gather their feedback regarding the VAMS development process and final product. This paper synthesizes the feedback from key aviation experts and comments on current aviation modernization efforts with regard to the insights collected.

To fully understand how VAMS can inform current modernization efforts, a review of the two modernizations underway is presented here. Currently, there are two efforts being undertaken to modernize the airspace system. These two efforts include the United States' initiative, NextGen, and the European initiative termed Single European Sky Air Traffic Management Research Program (SESAR). Both are large scale modernization initiatives with similar goals: both seek to transform the current air transportation system for their respective regions to meet the growing demand for air transportation (Joint Planning and Development Office, 2006; European Organization for the Safety of Air Navigation, 2006). SESAR is also looking to eliminate the fragmented approach to Air Traffic Management (ATM) in Europe (European Organization for the Safety of Air Navigation, 2006).

After determining that existing capacity must be increased to keep pace with the growing demand for air travel, the United States government, through VISION 100 legislation, mandated the multi-government agency JPDO and created the modernization initiative NextGen. The overarching vision was for a system that addresses critical safety and economic needs in civil aviation, such as increased capacity, while fully integrating environmental impact, national defense, and homeland security improvements in a cost effective manner (Joint Planning and Development Office, 2006). The JPDO is responsible for creating and implementing an integrated plan for NextGen and for leading the research required to support this plan (Dillingham, 2006). The JPDO itself is comprised of personnel from different government agencies with aviation-related missions, and incorporates working groups which include both private and public aviation experts. The JPDO also collaborates with private and public agencies that are working on NextGen capabilities (Dillingham, 2006).

SESAR, led by European Organization for the Safety of Air Navigation (EUROCONTROL) began in 2005 with a similar realization that air traffic in Europe is growing at a rapid rate, and the system will not keep pace with demand given the current capacity levels. SESAR is an in-depth reform of ATM, both technologically and institutionally. SESAR is being developed in two main phases, the definition phase and the implementation phase. The definition phase incorporates the development of the ATM master plan, which includes definition of performance targets and development of operational concepts and a roadmap for their implementation. The implementation phase will complete the development and deployment pieces which make up implementation. One stated key of SESAR is governance; there are over 600 participants involved in SESAR development, according to one respondent involved with the effort (Ky and Miaillier, 2006).

The following section will begin with a discussion of the research questions and methodology. A literature review on project development, planning and assessment follows. Next, a description of the VAMS project including the expert reactions and feedback to the project are presented. The paper concludes with statements and suggestions for current modernization development.

## 2. Research Questions

The motivation behind this research is to answer three key questions related to system wide modernization.

1. How should one develop system wide modernization concepts?
2. How should the modernization of a legacy system proceed?
3. How can one effectively evaluate and assess a particular system wide concept?

Through these questions, this research can inform current and future modernization efforts.

This research takes a unique approach by presenting a fully formed solution in the form of the VAMS project. The VAMS project will act as the completed project from which these research questions can be answered through expert feedback. This study therefore will use a 'learning by doing' approach. To focus this research on the VAMS project, certain targeted research questions related to the VAMS project will be addressed.

The following are the high level categories of the VAMS questions.

1. VAMS Development of System Wide Modernization Concepts
    - Is blending the way to combine multiple disparate capacity enhancing concepts?
    - Is the VAMS SWC acceptable?

2. Preparing Roadmaps for Modernization of the Legacy System
    - What role do top-down and bottom-up project plans play in planning for VAMS?
    - What types of roadmaps are needed to effectively plan for VAMS?
3. VAMS Evaluation of the System Wide Concepts Through the Use of Large Scale Models

These more targeted research questions related to VAMS will assist in answering the overarching research questions.

## 3. Methodology

To gain insight into the VAMS development process methodology and outcomes, the details of the project were presented to 12 individual recognized authorities. Some respondents spoke to the authors alone, while others included additional members of their organization due to different expertise. Each respondent or respondent group received a briefing on the details of VAMS. At different points during this presentation, the respondents were asked for feedback through specific and open-ended questions. Being exploratory questions, participant responses varied from direct answers to the questions to direct answers along with digressions to related topics they wanted to share.

Participants were selected because of their expertise and experience with aviation modernization efforts and aviation policy. They were also selected because they represent experts who would respond based on an evaluation of project and not necessarily the official position of their organization. The authors conducted interviews for this study from February through July 2007. Experts represented a wide variety of aviation organizations, including:

- Aeronautics Development
- Aviation Service Provider
- Consultant/Researcher
- Airport Authority
- Air Carrier

Their opinion and insight on VAMS and modernization processes are now discussed with the goal of informing modernization processes. The following section presents a literature review, followed by the details of the VAMS project and expert reaction and feedback.

## 4. Literature Review

VAMS was motivated by the ambitious goal of making major improvements to a large-scale, complex, safety-critical, and mature socio-technical system. Bringing change to such systems is difficult. Engineers, planners, policy analysts, and social scientists have investigated the challenges and means of overcoming them. Below we summarize key themes from this work that are most relevant to the VAMS endeavor, and which provide a framework for evaluating the development and planning of a system wide modernization efforts.

As the solutions proposed by a transformation project require acceptance from many stakeholders, a review of consensus building literature will prove helpful. Regarding consensus building, Innes (2004) notes eight conditions which need to hold for consensus building, or collaborative problem solving, to be successful. Of the eight, two are particularly relevant to this study: 1. the inclusion of a full range of stakeholders; and 2. a practice that begins with a mutual understanding of interest and avoids bargaining based on stakeholder position. Each aviation stakeholder group must be represented, and these groups must believe fully in the rationale for modernization. Each stakeholder group must also hold an important reason to participate in a collaborative effort, and therefore a common understanding of need must be present. Participating in such a collaboration effort is often seen as a drain by organizations, as each must expend valuable resources on the effort. Therefore, each organization must expect to benefit from participation, mainly because each groups' interests are not being served well by performing the tasks individually (Dillingham, 2006).

Related to aviation modernization efforts, a transition model was developed for large scale NAS modernization (Mozdzanowska et al., 2007). This transition model defines key points that lead to a transformation of the air transportation system. After a period of demand growth and behavior shifts, stakeholders enter into a period of awareness building, where each stakeholder forms its own mental model of the situation. What follows is a change process in which stakeholders evaluate the projections for the future, and influence one another through change discussions. This change process involves a negotiation loop because many stakeholders hold their own set of preferences and issues of importance, and because stakeholders are affected differently by potential changes to the system. The transition model involves two feedback loops, or iterative processes, which allow for negotiation

regarding the details of the solution in question and also a loop that allows for refinement of project details taking external factors into account. This type of planning model represents iterative planning, allowing for constant refinement of a solution until full stakeholder buy-in has been achieved. The idea that modernization efforts should be planned in this manner is also discussed by The Boeing Company, who noted that an operational concept should first be developed iteratively, with objectives, requirements, and the operational concept continually cycling until a final concept is reached (Sipe, 2005).

With regard to the transition model, it is noted that a successful transition hinges on a clear definition of the costs and benefits for each stakeholder (Mozdzanowska et al., 2007). This is an effective way of clearly understanding the agenda and position of each stakeholder, and also guides deliberations about project financing. Understanding and measuring costs and benefits is also an effective way for providing stakeholder incentives should a negotiation stall; this is important due to the potential for project time to increase rapidly if there is an inability to overcome strong stakeholder opposition. Developing true costs and benefits figures, however, is a challenge. There is much literature on the difficulty of understanding the true forecasts of costs and benefits. Basing plans on forecasts has a high level of uncertainty built in, as they tend to be highly flawed (Flyvbjerg et al., 2002).

The VAMS modernization effort is based around achievement of an end goal, and then the development of policies and concepts as the means to achieve this goal. This method of project and policy development is particularly challenging for complex projects, as discussed by Lindblom (1959), who states that in practice policies are formed through experiences rather than by defining a goal and the means to achieve that goal. Lindblom (1959) notes two policy making paths: 1. defining the end states and the means to achieve it (termed the root, or top-down method), and 2. determining policies through comparing a limited set without fully determining ends or means (branch, or bottom-up method). For transportation policy making, Garrison and Levinson (2005) note that a factor of the branch method, learning from direct experience, is a key factor of policy making; they develop an experiential policy model which incorporates experience and feedback from existing transportation policies, as these existing policies continually inform new policy development.

## 5. VAMS Project and Findings

The VAMS project had three objectives: (1) Define and evaluate system level air transportation operational concepts that extend to the year 2025; (2) generate enabling technology roadmaps for selected concepts; and (3) establish a set of capabilities such as performance measures, and tools for assessing these concepts (National Aeronautics and Space Administration, 2004). This section will describe these three objectives, which became the three main steps of the project. Expert feedback, including an incorporation of the categories of feedback, on key components of these objectives will also be discussed.

### 5.1 Overview of Stakeholder Feedback

A comprehensive analysis of the respondent input leads to four clear categories of responses. These characterizations and their explanations will assist in understanding the perspective of the respondents and also provide context of their feedback. These categories are the Pluralists, Economists, Incrementalists, and Traditionalists.

#### *5.1.1 Pluralists*

The pluralists are those respondents who were concerned primarily with the incorporation of stakeholder feedback in a system wide modernization effort. Regarding VAMS, their responses were focused around the need and importance of a diversity of developers and stakeholders. Pluralists also agreed roadmaps are a key part of development, and were glad to see the VAMS project included a project plan. However, pluralists warned against developing detailed roadmaps, and believed that planning should allow for multiple iterations of stakeholder feedback.

The following are some sentiments from respondents in this category.

> *"It was easier for NASA to defer stakeholder involvement until the end because you can't really get consensus if there are too many stakeholders from the beginning. Having the stakeholder involvement (in the beginning) would be good too, but it would also add cost."*

> *"I think more people (developers) might have picked up more concerns, but it also depends on what's the expected output of this process. What they (NASA) expect is something they can take out to the*

*broader community…(therefore) I would urge NASA to have a process to include everyone with every perspective."*

### *5.1.2 Economists*

The economists[1] pressed for VAMS development decisions to be grounded in economic theory, as well as the incorporation of economic instruments to manage capacity. They advocated for a cost and benefit analysis of the concepts before research, development, and implementation were planned. The economists also wanted economic constraints on capacity, such as auctions and pricing, evaluated along with the other capacity enhancing technologies proposed. The economists were encouraged by NASA's effort to incorporate policy into VAMS.

The following are some sentiments from respondents in this category.

*Regarding simulation tools, "any tool trying to bring us toward the future has got to look at some of these other very large factors, like economic forces, like public policy forces."*

*"It would be nice to see some data to start this off on – what are the problem sets and what's the value of solving these problem sets, what are the problems today and what are they tomorrow."*

*"I think this is a very nice and worthwhile thing (NASA) did, the independent concepts and blending… (But) in the end, we have to remain more conscious about what's going on economically. I believe the most economically efficient (capacity allocation method) is through auction, to determine who's going to use the resources. Economically, it's far more efficient than what's going on today."*

### *5.1.3 Incrementalists*

The incrementalists were concerned that planning for the VAMS project was top down, and did not incorporate the local needs and perspectives of individual airports and communities. These respondents felt that capacity enhancement is achieved through local efforts and small changes within these localities. Respondents in this category wanted to see more feedback loops involved in the VAMS development and planning process to allow for input and incremental changes. They also wanted to see more realism injected into the project, as these respondents do not consider large changes in policy and infrastructure to be realizable.

The following are some statements from those who are characterized as incrementalists.

*"Why model five additional runways when it will only be one in reality?"*

*"You have a goal, and (the roadmap is) trying to get the end state. But the roadmap is missing a little, because it put goals out there, but there has got to be more thought and detail to the middle process… There has to be a reason why (the roadmap schedules implementation) 12 yrs (away). It is like a business planning process, where do you want to be five years from now, what is it going to be, what does it take to get there, so at the end, they make sense."*

*"One of the ideas is that for every (item) that is necessary to realize that improvement, analyze where we are in the lifecycle so far, what the expected duration of the lifecycle phase is, up to deployment and identify what the earliest possible date of deployment could be for that particular item. If you know that for the various (items), then you can at least say something about the earliest date you might be able to realize the operational improvement.*

*This is typically a bottom up approach, because the performance driven perspective is the other way around. One says 'we need from the target setting this level of capacity by that year, then we say this and that solution will deliver it by that year, which means that this and that (item) needs to be operational by this year,' and then you start calculating backwards. But both need to come together at some point."*

### *5.1.4 Traditionalists*

The traditionalists were focused on achieving capacity enhancement through infrastructure expansion and policy changes. These respondents wanted to see a change in policies which are constraining capacity and also wanted to

[1] Economists that fall into this category are not necessarily economists by trade, but rather their feedback is focused on economic theory.

see new capacity built in the form of runways and supporting infrastructure. Traditionalists further believe that there should be less focus on technology for capacity enhancement.

Respondents in this category responded to technology advancements with the following policy comments.

*"We need to understand the fundamental need for capacity increases through building more runways."*

*"The FAA (Federal Aviation Administration) has to (change) the mandatory spacing. You can't get close to the person (aircraft) in front of you - jet blast and wake turbulence. Also, you have two sets of eyes watching the same airplane, crashes won't happen. Make the spacing 2 miles. It's safe. We can do closer spacing between airplanes. It's the rules, and someone needs to have the guts to say we need to change the rules, and for the last 20 years, no one is able to do that… We just work as close as we can with the rules, but there's a need to change some rules."*

All respondents shared both aspects of VAMS they felt should be emulated and also provided constructive criticism of aspects of the project. Figure 1 provides a summary of all expert responses to the three objectives of the VAMS project. Full Support indicates that one respondent fully supported the VAMS methodology used to achieve that objective; Limited Support means the respondent agreed with the methodology at a high level and provided constructive criticism of certain aspects of the methodology; No Support indicates the respondent did not agree with the methodology on a high level.

### 5.2 Step One: Development of the System Wide Concept

The first step of the VAMS project was the identification and development of specific capacity-enhancing concepts, and the blending of the best attributes of these concepts into an integrated SWC. This process occurred in two phases: the first phase involved NASA's solicitation of independent concepts from industry and academia; the second phase was the blending of these concepts together into a unified plan, or SWC, for the NAS. The SWC is envisioned as an integrated set of revolutionary technology concepts which will increase the capacity of the NAS. While many specific capacity-enhancing concepts have been developed by NASA and other organizations, they had not yet been brought together and blended into a coherent vision for large scale NAS modernization. The following discusses some details of the two phases.

#### *5.2.1 Phase One: Individual Concept Development*

##### *5.2.1.1 Overview*

The first phase of the SWC development focused on the identification and development of specific capacity-enhancing concepts. Independent concepts were solicited from NASA, industry, and academia through the use of a NASA Research Announcement process. Once concept proposals were selected, organizations developed their concepts independently, with periodic discussions amongst developers and NASA. As stated in the internal NASA VAMS Concept Blending Plan dated March 31, 2005, the organizations worked autonomously, and were provided with a functional model which fully encompassed government views of the "desired functionality of a future system-wide NAS concept" to act as a framework for development. The result of this solicitation process was eight concepts from five independent developers which collectively covered gate-to-gate operations of the NAS domains – Surface, Terminal, En Route, and National (Table 1). Other organizations were chosen as developers, however their concepts were either integrated into one of those developed by another organization or eliminated.

##### *5.2.1.2 Participant Feedback*

The experts had a great deal of feedback on the independent concept development. The number of stakeholders to involve in concept development is, as also suggested from the literature, a difficult decision. Respondents noted benefits of a small group of stakeholders, and that "a small group is able to accomplish a great deal in a short amount of time." It was also noted that a small group has the ability to produce very detailed concepts. In a small group, developers must still agree on a conclusion, but a small group can reach an agreement more quickly, and in more detail, than a large group. However, as noted in the literature discussed in Section 4, there are benefits from including a full range of stakeholders. One pluralist, while noting the ability of a small group to achieve a detailed concept, also noted "the ability of a small group to achieve buy in is almost zero… it is very difficult to get stakeholders to buy in to a concept they did not develop." While more developers and stakeholders lead to a less detailed concept, there exists a higher likelihood of concept acceptance. The pluralists also noted the issue of cost

involved with more stakeholders: NASA paid organizations to participate in VAMS, and it would have been cost prohibitive to do so for a larger set of stakeholders

Regarding this stakeholder inclusion issue, many respondents were concerned that the developers included were too similar: multiple NASA centers and multiple aviation system integrators. Incrementalists and Pluralists noted that a larger diversity of concepts could have been generated with more developers. More developers and increased developer diversity was considered desirable because one could develop a larger technology set. "The idea of blending is good, but you can't blend with such a limited set of technology. You have to blend a very broad set of technology" noted one pluralist. Concept diversity was viewed as a valuable contribution to the effort – an incrementalist respondent group noted they would like to see a diversity of concepts, and then a rank ordering of those diverse concepts, followed by a concept selection process.

Following up on concept diversity, respondents expressed frustration that VAMS did not employ airlines, airports, controllers, and pilots. One incrementalist noted "Controllers and pilots became one of my biggest assets in developing solutions for my airport (because) they get very creative in finding solutions." Furthermore, it would be exceptionally difficult to gain ex post buy in from these particular stakeholders. However, a traditionalist expert group disagreed, citing potential conflicts of viewpoint in clashes in stakeholder interest that would have slowed down, or even undermined, the process of attaining a consensus SWC. As VAMS was looking to document concepts, and did not wish to have these concepts go undocumented due to stakeholder disagreement, a full range of inclusion was not possible according to a respondent involved in the VAMS project; however, if VAMS was looking further to implement these concepts, the experts noted that opposition would be ahead.

All four respondent categories noted that inclusion of a full range of stakeholders could also include international stakeholders. One respondent noted, "I would even not limit (developers) to US companies, I would go world wide to get new concepts." While governmental restrictions can exclude international developers, international stakeholders have the ability to both provide information on initiatives abroad, and also ensure compatibility between domestic and international aeronautics systems. Respondents from airlines and aeronautics development were especially concerned that concepts developed without international input would not be developed with worldwide interoperability of their aircraft in mind. One respondent noted the difficulty in equipage if each ATM system needs separate equipment: "If an air traffic controller in US needs one kinds of box, and Europe has other kinds of requirements, and another one in Asia, there's not that much room in the aircraft to put different boxes. The boxes add weight, and take up space. What airlines do is to minimize the different kind of things they need to put on the aircraft because each one is costly."

Finally, regarding the actual concepts themselves, it was noted that while concept development is a key step towards system wide modernization, it should not be the exclusive focus. A pluralist respondent group noted that few of the concepts that are being entertained today by modernization processes are "new" concepts, but rather similar to ideas from past projects that have yet to reach fruition. Pluralist and incrementalists argued that concept refinement and project planning to establish a roadmap that has both political support and stakeholder buy in is the most important modernization challenge. One respondent noted that "the US should not invent JPDO III; they need to settle down and let people actually work." This respondent further noted that concept development should have a definitive end – at a point, it is crucial to end concept development and allow the concepts to become the vision. This will provide stakeholders with time to become familiar with the idea, a key stage of the transition model (Mozdzanowska et al., 2007). As defining the vision was included in the VAMS process, respondents applauded this step (Table 2).

### *5.2.2 Phase Two: Blending Process*

#### *5.2.2.1 Overview*

Phase Two involved concept "blending," where teams of developers formulated the synthesized concept by combining and choosing the best attributes of the independent concepts. The concepts were mapped to the functional model noted in Section 5.2.1.1, to functionally decompose each concept. Any gaps that the concepts presented, or overlaps between the concepts, were addressed by drawing on existing projects or modifying an aspect of one or more concepts.

The result of this blending process was the SWC, a synthesized version of the individual concepts that addresses all NAS domains and promises a major gain in system capacity. From the SWC, features, which are capabilities that fully comprise the goals and plans of the SWC, and enablers**,** which provide the infrastructure and interconnections between functions for a complete gate-to-gate concept, were developed. As the features and enablers technically define the VAMS SWC, one can envision the VAMS SWC as the set of established features and enablers.

*5.2.2.2 Participant Feedback*

Many respondents applauded the methodology of gathering independent concepts and blending the best attributes of these concepts (Table 3). Respondents across all categories were impressed by the thoughtfulness of the blending methodology; a process which did not simply group concepts but rather take many strong concepts and combine them into a synthesized idea. One pluralist noted "blending concepts is the most cost effective and efficient way to finalize a concept… it leverages ideas and concepts that have been tested and deemed important by industry or government."

Some of those consulted, however, noted many alternative methods of concept development and blending. Respondents were concerned over the difficulty of "start(ing) from a collage and put(ting) these concepts together" and that therefore there "needs to be an organization that develops concepts and generates a set of requirements for the implementation of the concepts" which would supersede the need for blending. Economists also felt that costs and benefits to meet these requirements should have been produced before the concepts. One economist noted "it would be nice to see some data to start this off on. What are the problem sets and what's the value of solving these problem sets, what are the problems today and what are they tomorrow… (We need to measure) the magnitude of problems." A full understanding of the costs and benefits would help prioritize the needs of a modernization effort, which would assist in understanding interdependencies in concepts and insure the most beneficial concept sets were implemented first.

Respondents felt that developing concepts, leading the blending and bringing together developers was a highly appropriate role for NASA. They agreed "NASA should bring people to the table" to be innovators of technology through research. Respondents felt this was a major step forward for NASA, noting "VAMS and ACES are wonderful work, (they have) economic, policy, (and) system complexity." However, many respondents across all categories were concerned that the VAMS product was very technology-focused, and that by having a technically focused research group perform this research other solutions were not given priority. It was recommended that another organization more focused on policy should be involved in the development so the policy issues could be fully addressed, and also that more time be spent on changing current aviation policies.

### 5.3 Step Two: Roadmap Development

*5.3.1 Overview*

A research, development and implementation schedule for the VAMS features and enablers from 2006 to 2025 was developed in this step. To build the transition strategy to the VAMS SWC, an assessment of the relationship between the goals of the FAA's Operational Evolution Plan (OEP) v5.0, which defines all funded aviation projects until 2015 at the 35 major airports, and the SWC concept was performed (NASA, 2006). This allowed the scheduling of VAMS research, development, and implementation of the features and enablers to best leverage OEP planned projects. Given this mapping and the schedules for the OEP and the VAMS SWC, it was then possible to determine the impacts of OEP and the VAMS SWC on one another. An actual roadmap for VAMS could then be developed with milestone dates to plan for the research and development and the implementation of the features and enablers.

*5.3.2 Participant Feedback*

This planning process used the goal of VAMS, which is to increase capacity levels by 2025, as the end state, and then looked backwards from that date to plan development. Incrementalists noted that the most effective planning method given funding and political constraints is to develop both a top-down and bottom-up road map. The bottom-up road map involves determining the current concepts which are already in development, and noting in which stage of the development lifecycle they are. The top-down roadmap involves starting with development targets, and planning backwards from these development targets. Than it can be determined how these plans work together and the realism in the top down roadmap.

Regarding the VAMS method of roadmap development, members of all respondent categories were pleased to see an effort to define a goal and mission to reach the end state, but noted that the roadmap did not fully address the means of accomplishment. The incorporation of OEP plans was considered by most interviewees to be an important step in the direction of a bottom-up roadmap; as OEP ends in 2015, however, most respondents felt that this fell short of what was needed to fully articulate a bottom-up roadmap. One noted that basing the roadmap on "OEP is giving too much credit to the OEP. The OEP is … a way to raise awareness to the program and way to organize the initiatives. OEP is a focusing mechanism." A roadmap focused on requirements and the current state of research was suggested by the incrementalists, for a more bottom-up perspective.

Another benefit of performing both top-down and bottom-up roadmaps is to decrease the uncertainty involved in planning for unknown technology developments. A top-down roadmap can help establish goals, while the bottom-up roadmap can determine the current state and then realistically plan the timeline to the end goal. If these timelines do not match up, priorities can be reordered, or the scope of the project changed. For this reason, many incrementalists and pluralists noted that exact dates in a roadmap, like those used in the VAMS roadmap, should not be included, but rather defined vaguely. Because dates are uncertain, they act like placeholders to rank order technology development and also set approximate targets for political and funding reasons. Respondents noted that this is also an effective way to capture the uncertainty due visualizing and understanding technology advances, because there is a great deal of uncertainty in what technology will be available in the future.

To effectively plan for uncertainty, incrementalists and pluralists suggested having development horizons (short term, medium, and long term) and activities which depend on one another in a plan, rather than mapping functions by specific date. Planning horizons would handle the issue of planning for the diversity of the system VAMS is working to modernize. This is important, as the economists pointed out, because implementation of many SWC elements depend on initiatives by local actors, such as airports. Each airport has its own unique needs, and therefore airports will need different concepts at different timelines. Furthermore, other plans must be determined to take the network nodes into consideration. Many economists expressed concern over the lack of an infrastructure roadmap, as airports would need expanded ground facilities to handle an increase in operations.

Beyond planning for technology, there is a great deal of uncertainty that comes into play when planning for institutional changes. Many respondents were concerned that NASA's focus on technology kept them from incorporating important factors into their roadmaps as "historically NASA is … heavily weighted towards technology and not enough on operations, economics, public policy, and the environment." Although VAMS had a stated ATM focus, there were some features, such as increased use of regional airports, and also enablers, such as performance-based services, that involve institutional changes and concerned economists and incrementalists. Incrementalists noted that these features and enablers require changes in deeply embedded policies that cannot be placed on a roadmap with a date, but instead must incorporate the uncertainty that comes with policymaking. To best plan for the uncertainty, a feedback loop that incorporates a chance for stakeholder reaction to the policy, and then policy refinement in response to stakeholder reaction, was suggested by many respondents. This iterative planning cycle was advocated by many incrementalists and pluralists, who noted that the more stakeholders are involved in this feedback loop, the stronger the prospects for success.

Because of the amount of institutional changes and policy making needed by VAMS, respondents from all stakeholder groups felt the roadmap development for concepts was out of touch with how policy and system changes are made. While goals and plans are important at a high level, they felt a more realistic roadmap should be developed, to show the incremental approach most effective in policy planning. This would be a more detailed map, noting the steps and feedback loops which would take place during research, development, and implementation. In general, traditionalists and incrementalists felt this would help focus on how the VAMS project can transition from the current state of the NAS to the VAMS goal. These respondents surmised that NASA may not feel like this is their work, and suggested NASA along with FAA should perform this kind of study. Respondents lastly expressed that planning for this type of wide scale modernization is difficult, and were concerned that planning processes focused on top down project plans are the norm. A feedback summary can be seen in Table 4.

### 5.4 Step Three: Preliminary Assessment of VAMS SWC

#### *5.4.1 Overview*

The third objective of VAMS was to develop a set of analytical and computational models and methods to conduct detailed and system-level assessments of the SWC. The core of this step was the development of the Airspace Concept Evaluation System (ACES) modeling and simulation tool. ACES is a non-real-time modeling and simulation environment that enables a comprehensive assessment of the impact of the SWC. To use ACES to assess the SWC, each concept was independently assessed (either by ACES or another tool). Thorough this assessment, the capacity enhancing ability of the concept was determined. This capacity enhancing ability could be an increased sector capacity, decreased queuing delays on the surface, or an increased airport throughput capacity. Then these capacity increases were applied toward the year that the roadmap states that the concept in question will be implemented (NASA, 2006).

To determine the impact of the SWC, ACES was used to model gate arrival delay in 2025 based on varying levels of traffic growth. Using demand forecasting tools, unconstrained and constrained traffic demand sets were developed to reflect the goal of doubling of system throughput. Next, airport demand to capacity ratios were calculated to determine if an airport was operating at or below 70%. If the ratio was above this threshold, a

feedback loop in the assessment process would utilize two VAMS features and allocate new closely spaced runways and increase the use of regional airports. The new runways are enabled by the Very Closely Spaced Parallel Runways (VCSPR) feature, which increases capacity through the use of paired operations for arrivals and departures in both instrument meteorological conditions (IMC) and visual meteorological conditions (VMC). The diversion of flights to regional airports is from the Increased Utilization of Regional Airports (IURA) feature of VAMS, which leverages enhanced ATM at regional airports to handle traffic from nearby congested hubs (NASA, 2006).

The resulting average gate arrival delays were then calculated by ACES to be less than 10 minutes. The VAMS SWC achieved its target increase in effective capacity of an additional 100% throughput at equal or reduced delay levels compared to the base year. The SWC assessments confirmed that no single feature of the SWC could in and of itself satisfy the throughput goal.

### *5.4.2 Participant Feedback*

Respondents in all categories agreed that an integrated modeling tool can be effective and powerful in assessing the capacity enhancing benefit of concepts, and noted that ACES is "a perfect tool to use." However, many respondents felt that just using the ACES assessment was limiting and that other assessments would be equally important. Economists were concerned that the assessment process did not include a cost benefit analysis. This is a noted "Next Step" in the VAMS documentation, however, economists noted that this is a crucial component of the entire development process. A cost benefit analysis should be done in the concept development phase, the planning phase, and the assessment phase, so the project insures each step makes sense to implement.

Traditionalists applauded VAMS for identifying the basic critical need for capacity, in the form of new runways built at certain airports. One traditionalist applauded a study that does "not just look at capacity expansion through technology" and that capacity must be increased on the ground. However, many respondents in other categories addressed the concern over issues new runways bring that were not addressed in the study. The first is that new runways bring enhanced traffic, and therefore the need for infrastructure. Next, inclement weather days continue to choke capacity, and respondents questioned the ability of all features to fully enable use of runways during IMC. Respondents were skeptical of ability of the concepts to close the capacity gap between IMC and VMC, and expressed concern that an increase in just VMC capacity could encourage airlines to increase their flight schedules leading to further delays and cancellations in IMC.

Many respondents were also concerned with the reliance on regional airports for capacity increases. Many regional airports do not have the ground crew or the transportation connection to desirable locations to act as reliever airports. Furthermore, many respondents noted these areas would be served more if there was more of a market, and economists in particular were concerned that this concept was encroaching on the business model of airlines. One traditionalist noted that "there are commercial reasons why we have hubs. The whole point of air travel is to get somewhere quickly, and if I land, and I have to drive two hours to get to where I need to be, I'm not going to do it unless there is no other option. The reason why (the New York metropolitan area airports) are so busy is because (there are) flights that go directly to a lot of cities, non-stop, and that saves people time and energy." The inter-modal aspect of the problem should be studied; furthermore, incrementalists noted some regional airports would work well, whereas some of them may not work at all. Respondents in all categories noted they would like to see a preliminary plan regarding the use of regional airports.

New runways and use of regional airports had many respondents calling for a focus on policy instead. Despite the promise of closely spaced runways, the environmental process and issues surrounding noise would not allow for the development of all those runways. All respondent categories pointed to current initiatives to close airports due to environmental and noise constraints, and incrementalists noted the extremely long lead times necessary to build runways. One traditionalist noted that capacity gains can come in the form of new policy, especially regarding minimum spacing rules and requirements. "We can do closer spacing between airplanes. It's the rules, and someone needs to have the guts to say we need to change the rules, and for the last 20 years, no one is able to do that…We just work as close as we can with the rules, but there need to be some change in the rules." This traditionalist feels it is political will that is barring some capacity increases.

Because of the additional runways needed, many experts felt that NASA had not met their burden of proof that VAMS is capable of handing a 100% increase in throughput. Experts noted that the number of additional runways and regional airports should have been limited in the modeling and simulation, because that would bring the process closer to realism due to political difficulty. A feedback summary is provided in Table 5.

## 6. Conclusions & Looking Ahead

Respondents were very interested in the future of VAMS and what could be learned from the VAMS effort. Respondents also were interested in seeing research on how to improve system wide modernization efforts. In the light of these comments, this section draws lessons for current modernization efforts based on the feedback of the respondents. Based on discussions and literature regarding these modernization efforts, it seems that both NextGen and SESAR are recognizing some of these lessons and while not adequately considering others.

### 6.1 Concept Development and Stakeholder Involvement

Both NextGen and SESAR involve a collection of concepts that have or will have been fully vetted by numerous stakeholders. The NextGen documentation was developed by numerous working groups from a large number of organizations. Other stakeholders, as well as the general public, participated by providing comments on the Concept of Operations (Federal Aviation Administration, 2007). According to NASA researchers, the JPDO has not excluded anyone or any group that is interested in participating in the development of NextGen. According to SESAR researchers, SESAR was developed by drawing on concepts from the member states, to insure that both these state's interests were met and also that strong concepts were leveraged. SESAR and NextGen share information through a Memorandum of Cooperation, which allows for the international interaction which was noted as a factor which could help the project by expert groups (Ky and Miaillier, 2006).

SESAR and NextGen incorporate independent concepts from multiple developers, a point that was discussed as being overall beneficial to a project. A blending process for these concepts however has not been explicitly performed. Both modernization efforts involve high level of stakeholder involvement, which, while slowing the projects down, will most likely contribute to more stakeholder buy-in.

The question of the level of stakeholders to involve in a project does not have a definite answer. However, there are conclusions that can be drawn from an analysis of the VAMS project. Allowing stakeholders a voice during each step of the development process is seen as important by the pluralists and the incrementalists. Either after or during each step of the a project, the ability for public comment or comment by key stakeholder groups who would be effected by the proposed changes would allow for stakeholders to voice their concerns, and also to feel that they had a hand in development, which was noted by the pluralists as a key to stakeholder acceptance. However, because having a large number of stakeholders slows a project, developing detailed concepts in a timely fashion may require keeping the number of developers fairly small but having an iterative, and intensive, stakeholder comment process.

### 6.2 Planning

VAMS was primarily a top-down planning endeavor, developing an end-state system that would attain certain specified capacity and performance goals in a future year. Planning theorists such as Lindblom (1959) distinguish this approach from a bottom-up, or incrementalist, approach. VAMS also incorporated bottom-up elements such as creating a roadmap based upon the OEP. Most respondents agreed that NAS modernization requires a combination of top-down and bottom-up planning. There was also strong, though not unanimous support, for an approach that, like VAMS, first develops an end-state solution and then performs bottom-up planning to assess "how to get there". A concern with this approach was that it does not assure sufficient progress in the nearer term to prevent major imbalances between demand and capacity.

SESAR has a project plan that is focused on the relationship between development steps rather than dates (Ky and Miaillier, 2006). In their plans, both NextGen and SESAR separate the near-, mid-, and long-term objectives and targets, which is important for setting priorities while a project is in development. NextGen is still focused on an end-state system as the goal is to satisfy an increase in throughput of 200% current traffic levels (Joint Planning and Development Office, 2006). Project planning success will partially depend on how the bottom-up and top-down roadmaps are mapped as discussed by the pluralists. Regarding iterative planning, the NextGen and SESAR development cycles allow for a great deal of stakeholder feedback and refinement of ideas (SESAR Consortium, 2007; Government Accountability Office, 2007). While this can allow for all stakeholders to agree on a concept and move forward, it also interferes with the ability to fully refine an idea and allow stakeholders to become familiar (Mozdzanowska et al., 2007). NextGen is also participating in iterative planning processes for their technical processes, which involves modeling concepts and their impact, and incorporating this into plans (Government Accountability Office, 2007).

A conclusion regarding detailed project planning is that it might best be carried out by an organization outside of the concept developers. Because planning is dependent on policy and funding issues, it may best be performed by an agency that has the political power to carry out, or fund, the steps in the planning process. What could be performed effectively by the concept development group is a high level project plan which is that is not focused on

dates but rather a sequence for development. This can assist the funding agency in prioritizing investments and development decisions as they create the detailed project plan.

### 6.3 Assessment

NextGen and SESAR both present their own modeling strengths and weaknesses. A tool to model and simulate the whole of SESAR does not yet exist according to discussions with project researchers. A modeling and simulation tool is considered important going forward, supported by the general respondent agreement. NextGen is able to leverage the ACES resource, and therefore assess concepts both independently and as a system wide concept (NASA, 2007). On the cost analysis side, SESAR has quantified the costs and benefits of the concepts early on in the development process to be able to understand the contributions of the concepts. NextGen has reported difficulty in developing detailed cost estimates for individual NextGen concepts (Government Accountability Office, 2007).

Some key lessons from this study is that both a system wide modeling tool and comprehensive cost estimates are needed to understand the impacts of individual concepts and a project as a whole. These research findings also recommended a sensitivity analysis on the assumptions made during an assessment process, something for both projects to take into consideration in their future use of assessment tools.

This study illustrates the challenges in identifying capacity enhancing concepts, planning for the research, development, and implementation of these concepts, and assessing the impact of these concepts. This study also recognizes the importance of incorporating sound planning methodologies into system wide modernization efforts. By discussing the VAMS project with a number senior members of the aviation community, this study has identified points of consensus on how modernization should proceed, as well as areas of disagreement requiring further reflection, discussion, and debate.

## 7. Acknowledgments

The authors would like to thank NASA, and Harry Swenson in particular, for their support of this research. A great deal of information was provided by those experts who were interviewed for this study, and the authors thank them for their time and support. The authors would also like to thank University of California, Berkeley Civil and Environmental Engineering Student Jue Wang for the support she provided collecting and synthesizing interview responses.

## 8. References

Dillingham, G. L., 2006. Air Traffic Control: Status of the Current Modernization Program and Planning for the Next Generation System. Testimony Before the Subcommittee on Transportation, Treasury, the Judiciary, Housing and Urban Development, and Related Agencies, Committee on Appropriations, U.S. Senate, Thursday, May 4, 2006. Available at: http://www.gao.gov/new.items/d06738t.pdf. Accessed June 27, 2007.

Eurocontrol, 2006. SESAR: Objectives and Scope.
Available at: http://www.eurocontrol.int/sesar/public/standard_page/overview.html. Accessed August 12, 2007.

Federal Aviation Administration, 2007. Capacity Needs of the National Airspace System: 2007-2025 (FACT 2). Available at: www.faa.gov/airports_airtraffic/airports/resources/publications/reports/media/fact_2.pdf. Accessed July 29, 2007.

Flyvbjerg, B., et al., 2002. Underestimating costs in public works projects: Error or lie? Journal of the American Planning Association. 68(3), Summer, 279-295.

Garrison, W., and Levinson, D., 2005. The Transportation Experience: Policy, Planning, and Deployment. New York: Oxford University Press, Chaps. 2-3.

Government Accountability Office, 2007. Next Generation Air Transportation System: Progress and Challenges in Planning and Implementing the Transformation of National Airspace System. GAO-07-649T, March 22, 2007. Available at: http://www.gao.gov/htext/d07649t.html. Accessed on July 29, 2007.

Innes, J. E., 2004. Consensus building: Clarification for the critics. Planning Theory 3; 5.

Joint Planning and Development Office, 2006. Concept of Operations for the Next Generation Air Transportation System. Version 0.2, July 24.

Ky, P., and Miaillier, B., 2006. SESAR: Towards the new generation of air traffic management systems in Europe. ATCA Journal of Air Traffic Control, January-March.

Lindblom, C. E., 1959. The Science of 'Muddling Through'. Public Administration Review, 19(2), Spring, 79-88.

Mozdzanowska, A., et al., 2007. The Dynamics of Air Transportation System Transition. In Proceedings of the 2007 Air Traffic Management Conference. Barcelona, Spain.

NASA, 2006. Virtual Airspace Modeling and Simulation System-Wide Concept Report Volume 2 Technical. VAMS Project Office, NASA Ames Research Center.

NASA, 2007. NASA & The Next Generation Air Transportation System (NEXTGEN): The Current National Airspace System. Available at: http://www.aeronautics.nasa.gov/docs/nextgen_whitepaper_06_26_07.pdf. Accessed July 29, 2007.

SESAR Consortium, 2007. SESAR D2 Feedback Report. Available at: http://www.sesar-consortium.aero/mediasandfiles/File/05_docs/SESAR_D2%20Feedback%20Report_final.pdf. Accessed September 15, 2007.

Sipe, A. L., et al., 2005. Capacity enhancing air traffic management concept. Journal of Aircraft, 42(1).

| Independent Concept | Concept Developer | Independent Concept Highlights |
|---|---|---|
| Advanced Airspace Concept (AAC) | NASA Ames Research Center | ▪ Automation of separation monitoring and control<br>▪ Assurance for ground and cockpit through technology<br>▪ Automated Trajectory Server |
| System Wide Optimizations (SWO) | NASA Ames Research Center | ▪ Optimal Routes For Aircrafts From Origin To Destination<br>▪ Neighboring optimal Wind Routing (NOWR)<br>▪ Enhancing Flight Plan (FP) and deconflicting conflicts |
| Point-To- Point Air Transportation System (PTP) | Sensis Corp. | ▪ Enhances major airports Air Traffic Management<br>▪ High degrees of automation<br>▪ Expands ground operations<br>▪ Advance en route ATM automation |
| Surface Operation Automation Research (SOAR) | Optimal Synthesis, Inc. | ▪ Surface Traffic Management (GoSAFE)<br>▪ Flight-Deck Automation (FARGO)<br>▪ Integrated operation of automation |
| Metron Weather, Technologies Enabling All-weather Maximum Capacity by 2020 (MW) | Metron Aviation, Inc. | ▪ Coupled weather and traffic prediction<br>▪ Flexible traffic management around weather constraints<br>▪ Shared situational awareness, coordination, and information distribution |
| Metron Surface, Automated Airport Surface Traffic Control (MS) | Metron Aviation, Inc. | ▪ Automated surface traffic control<br>▪ Terminal area-wide planning<br>▪ Improved NAS integration |
| Terminal Area Capacity Enhancing Concept (TACEC) | Raytheon Co. | ▪ Address the primary terminal capacity constraints<br>▪ Flight path boundaries free of any wake vortex hazard |
| Wake Vortex Avoidance Concept (WVAS) | NASA Langley Research Center | ▪ Sensor data fusion, terminal weather, and wake prediction<br>▪ Dynamic wake-safe reduced spacing for single runway arrivals |

**Table 1. Independent Concepts.**

| Category | Feedback Summary | Representative Quote |
|---|---|---|
| Pluralists | • A small group of developers can achieve a great detail of detail quickly<br>• A small group is unable to achieve their goals because stakeholders who were excluded from the development process will not buy-in to the idea | "The ability of a small group to achieve buy in is almost zero… it is very difficult to get stakeholders to buy in to a concept they did not develop." |
| Economists | • Hidden, unmentioned constraints such as funding concerns did not allow development to occur on a broad scale | "I think having more developers is better than having fewer. But from what you described, the developers, I don't think they looked as broad as they could have." |
| Incrementalists | • Inclusion of a full range of developers will allow for concept definition and refinement based on varied individual perspectives | "Controllers and pilots became one of my biggest assets in developing solutions for my airport because they get very creative in finding solutions." |
| Traditionalists | • Inclusion of international developers could have leveraged already existing research going on abroad | "There are concepts Europe is developing now that are far ahead of US development." |

**Table 2. Summary of Concept Development Feedback.**

| Category | Feedback Summary | Representative Quote |
|---|---|---|
| Pluralists | • Blending is an effective way to ensure all stakeholder ideas are incorporated into an integrated solution | "Blending concepts is the most cost effective and efficient way to finalize a concept… it leverages ideas and concepts that have been tested and deemed important by industry or government." |
| Economists | • Blending is one of many methods to come to a conclusion regarding capacity enhancing concepts | "I think it's (blending is) reasonable. Some methodology builds up as I read the document. I think there's inability to capture capacity. I think very nice and worthwhile thing they (NASA) did, the independent concepts and blending. In the end …we have to remain more conscious about what's going on economically." |
| Incrementalists | • Blending is effective; however more steps in blending were needed. The concepts should be ordered based on a certain criteria, and blending based on this criteria. | "If someone is going to do a follow up with the program, I would…pull together all resources and go through all that's available. And then rank order and blend them at the end." |
| Traditionalists | • Blending, or however concepts are agreed upon, is secondary next to securing approval for the concepts themselves | "We all know it takes…years to approve anything. That's the biggest hurdle that you have to overcome is how do you take the ideas or concepts, develop the infrastructures required and rapidly deploy the stuff...There have been lots of great ideas that never made it because by the time they approve the technology, it was so old that it's not worth putting it in place. " |

**Table 3. Summary of Concept Blending Feedback.**

| Category | Feedback Summary | Representative Quote |
|---|---|---|
| Pluralists | • The concepts involve implicit policy decisions which cannot be planned out on a roadmap with specific dates | "How do you schedule the time it takes to get Congress to agree on a new policy?" |
| Economists | • Date goals cannot be planned with certainty for business decisions | In regard to planning "the whole economic aspects have got to be considered in the user equipage. There's not business case for it. The faster people equip, the faster we will be able to implement." |
| Incrementalists | • Certain airports will need changes and enhancements out of order with the roadmap; the roadmap should be less focused on dates and more on the order of need for improvements | "Airport master plans should be considered. OEP is only 35 airports, which is kind of limiting things. The problem with OEP is you are assuming technology, assume something and may not be there, so should need a backup plan… The roadmap is missing a little, because it put goals out there, but there has got to be more thought and detail to the middle process." |
| Traditionalists | • It is impossible to put date goals on concepts without pinpointing a funding source for these concepts | "There has to be a cost and funding source. Because in these days, you can't just have an idea and concept hanging out there on their own, they have to be tied to different projects and programs or they will never get funded." |

**Table 4. Summary of Road Map Development Feedback.**

| Category | Feedback Summary | Representative Quote |
|---|---|---|
| Pluralists | • Number of stakeholders involved in land use changes is very large | Runway expansion "is not going to happen…with the environmental constraints." |
| Economists | • Concepts involve business decisions of airlines and airports | "The airlines have to have the people and the equipment at the regional airports and today, they don't find it financially successful to do it." |
| Incrementalists | • It is impossible to put date goals on concepts without pinpointing a funding source for these concepts | "NASA came up with great ideas, but they partially missed the physical details and constraints…these are local decisions" |
| Traditionalists | • Runway expansion is a necessary reality which VAMS incorporates into the model well | "We need to understand the fundamental need for capacity increases through building more runways." |

**Table 5. Summary of Assessment Process Feedback.**

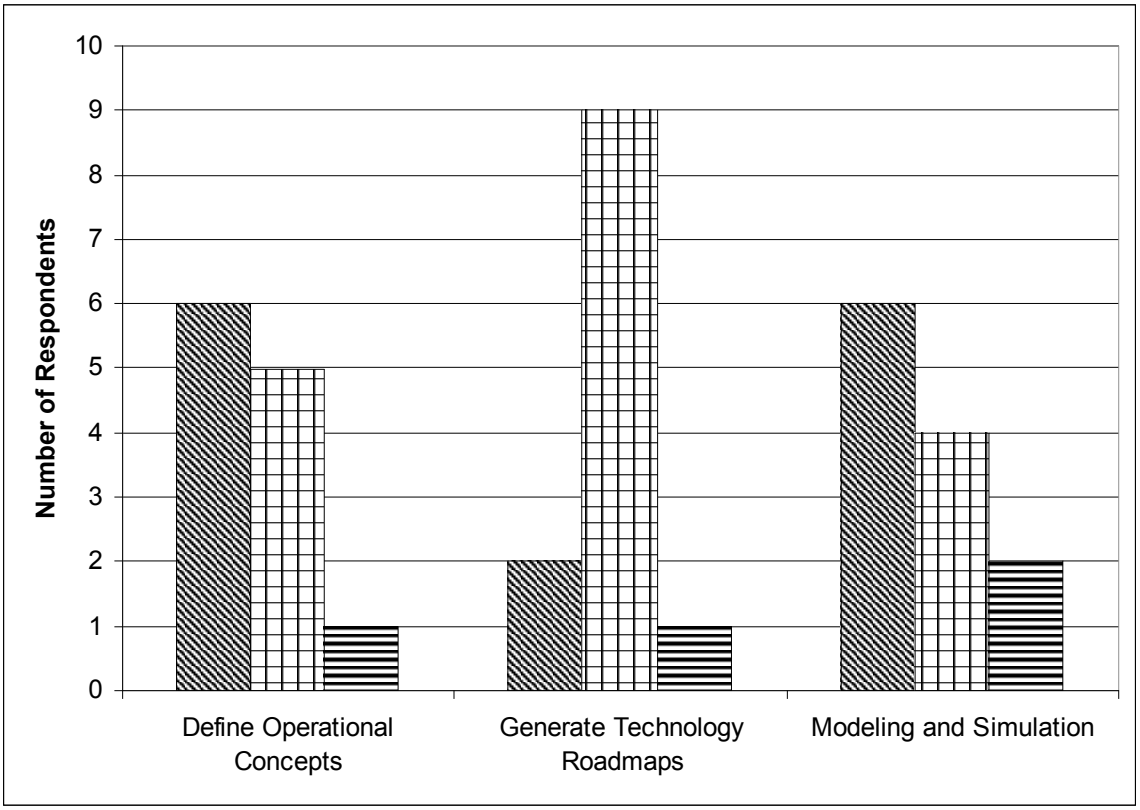


**Figure 1. VAMS Feedback Histogram.**

Figure 1 Legend

Full Support

Limited Support

No Support