4.0 The Implementation Plan

A Safe, Timely, Affordable Transition

The proposed air traffic management implementation plan builds on the FAA OEP. The implementation plan will focus on both the operational and architectural transformation of the current system, to accomplish a smooth transition to a highly integrated air traffic management system that provides greater capabilities than those envisioned in the OEP. This plan, which leverages a Working Together approach, will be implemented in three phases.

Commercial pilots will fly coast to coast without repetitive air-to-ground voice interactions.

The three phases will deploy the following technology elements in increasing levels of functionality and integration:

- Aircraft trajectories as the basis for flight planning and air traffic flow management.
- A Common Information Network to facilitate air traffic management.
- Criteria for airspace and air traffic procedure changes that will take advantage of the common trajectory-based information network to integrate flight and flow planning, traffic planning, and aircraft separation management activities throughout the NAS.

The system architecture will supply information in the appropriate level of detail for each of the various services and functions within the NAS. All information will be based on the same data sources and assumptions, to support a common view of system status and air traffic planning.

Phase 1. The Working Together team will develop a trajectory-based flow planning system to integrate and enhance the existing set of national, regional, and airport-level planning tools and procedures.

Phase 2. The Working Together team will apply trajectory-based tools to sector traffic planning to enable dynamic, in-flight flow planning.

Phase 3. The Working Together team will develop trajectory-based separation management functions, which will be integrated with the flow planning and traffic planning systems. Criteria for new airspace operations and procedures will also be developed.

If the plan were initiated today, it could produce significant benefits in three years with completion of phase 1. A complete NAS solution could be in place in seven years, and the system would continue to meet NAS capacity requirements for at least 25 years (sec. 5.0). Beyond that, system capability could be extended through insertion of emergent technologies. This technically feasible schedule would require extensive stakeholder cooperation to be acheived.

Enabling elements

- Flight trajectories
- Common Information Network
- Airspace and procedures changes
- Satellite-based CNS

	Phase 1 Year 3	Phase 2 Year 5	Phase 3 Year 7
Flow functions	Trajectory-based flow planning Predeparture flow planning	Post departure flow planning	Flow planning integrated with traffic and separation management
Traffic planning functions		Trajectory-based, en route traffic planning Dynamic airport planner and airplane trajectory exchange	Trajectory-based terminal traffic planning
Separation management functions			Full trajectory-based traffic planning and separation management

The three definitive features of the proposed concept are incorporated incrementally throughout the three-phase implementation plan. Satellite-based CNS produces significant benefits during the later phases of implementation.

Each phase introduces incremental information infrastructure changes, including CNS elements. The most significant infrastructure changes and operational improvements occur during the later stages of implementation, providing the most dramatic improvements to capacity and delays. The common trajectory-based planning capability initiated during phase 1 will support the transition to the new traffic planning and separation management concept.

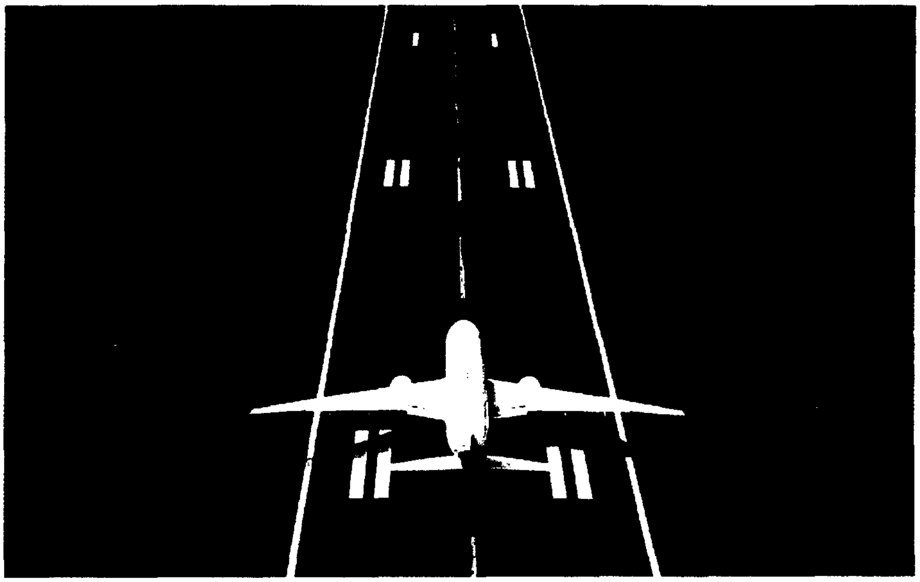
Integration With Existing and Planned NAS Technology Upgrade Programs.

The implementation plan supports existing FAA programs, such as the previously mentioned FAA OEP, which are vital to improving current NAS performance and mitigating operational shortcomings. We recognize the substantial efforts that the FAA architecture team made in developing NAS 4.0 and its extensions. The implementation plan makes extensive use of the FAA architecture to harmonize near-term and mid-term transitions. FAA work on NAS information architecture evolution provides a solid foundation for our development approach (app. B). The implementation plan, however, proceeds at a much more rapid pace to accelerate system capacity growth ahead of predicted traffic growth.

Boeing has been involved through RTCA[1] in the original concept and

1. RTCA, Inc. is a private, not-for-profit corporation that develops consensus-based recommendations regarding CNS and air traffic management system issues. Organized in 1935 as the Radio Technical Commission for Aeronautics, RTCA today includes more than 200 government, industry, and academic organizations from around the world.

development of Free Flight Phase 1 (FFP1) and Free Flight Phase 2 (FFP2) and remains committed to their implementation. We understand that FFP1 and FFP2 are endorsed by all stakeholders. Many elements of both FFP1 and FFP2 are needed to achieve the vision of a demand-driven air traffic system. Stakeholders may, during the Working Together process, elect to revise some elements of these programs to integrate them with other envisioned air traffic management capabilities.



The envisioned concept complements crucial efforts to increase runway capacity.

Elements of CTAS (Center-TRACON Automation System) (a trajectory-based airport planning tool), conflict-free advisories to controllers as currently provided by URET (user requested evaluation tool), data link, and CPDLC (controller-pilot data link communications) are already assumed or will be built on in the implementation plan. We will, likewise, build on collaborative decision-making, as a vital element of collaborative planning. Other elements of FFP2, such as designated high-altitude airspace and research and development elements will also be incorporated into the implementation plan.

Requirements for New Runways.

Although the implementation plan focuses on air traffic management and CNS capabilities, we recognize that significant numbers of new runways will be needed to meet the traffic growth expected during the next 12 to 25 years. Boeing initiatives complement efforts to increase runway capacity in two significant ways. Air traffic management and CNS technologies

- Will improve the capacity of airports and runways operating under instrument flight rules in marginal weather, for example.
- Can relieve constraints on airspace as runway capacity grows. Modeling of national air traffic flows that Boeing will use during the requirements

development process will help coordinate efforts to expand airport capacity with airspace capacity efforts. The flow model will identify and prioritize airport improvement requirements and help quantify the air traffic consequences of specific airport and runway improvements.

Transition of the NAS will require large-scale systems integration experience, a proven Working Together approach, and a diversity of resources that Boeing can bring to bear on the task. Boeing anticipates that several crucial factors will affect program schedule and achievement of full program benefits. We will develop strategies early in the program definition to address considerations, including the amount of time required to deploy an integrated satellite-based CNS capability that is key to capacity improvements in later phases; the transition timing for moving to en route and terminal automation during phases 2 and 3; and the time required to develop and deploy airspace configuration and procedures changes during phase 3.

The need to integrate these and other factors into the systems integration plan makes it imperative to continue the systems engineering process at an urgent pace.

4.1 Phase 1: Trajectory-based flow planning improves schedule integrity.

Phase 1 will introduce significant changes to the flow management operation in the NAS. The plan calls for rapid introduction of a new national-level flow planning and management system to improve schedule integrity during periods of NAS disruptions. The engine of this system planning, coordination, and information exchange will be the National System Flow Model.

This central planning system will provide the national-level delay allocation and coordinate flow responses initiated at the regional and airport levels. The National System Flow Model, which will be hosted at the FAA Air Traffic Control System Command Center (ATCSCC), will support

- A trajectory-based projection of system loading.
- A common view of system status and predictions for service provider and system operators.
- Generation and assessment of alternatives against user and service-provider criteria.

- Coordination of replanning efforts to ensure that air traffic services providers and system users work to common objectives and all users are treated equitably.
- Communication of replanning information to and collaboration with all affected stakeholders.
- System metrics for operational assessment and analysis.

During this phase, flight replanning in response to NAS operating constraints will be limited to predeparture plan changes. Changes will be communicated using existing data link capability, which already resides in transport aircraft. The participating flight planning and user (airline, business, general aviation, and military) operations centers will use their existing systems to develop and accept revised flight plans.

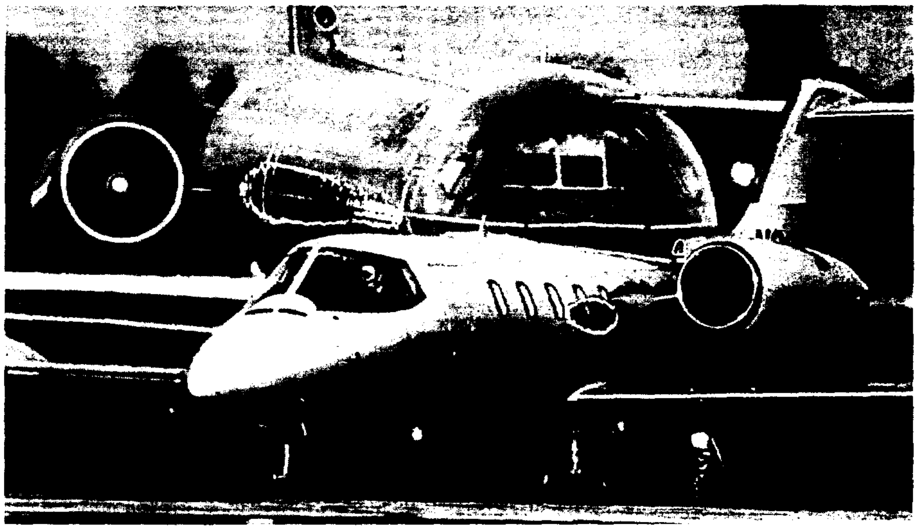
Flight planners will build their plans using the same view of national airspace that air traffic managers use to plan traffic flow.

Common Information Network. Development of the new Common Information Network will be initiated during this phase to provide coordinated delay responses for national, regional, and airport-level flow planning. It will also be necessary to provide information exchange between the ATCSCC and the users' flight operating centers. Much of the telephone exchange in the current system will be replaced by high-bandwidth data exchange. This enhancement will initially support preflight replanning but will later transition to in-flight replanning capability.

During this phase we will develop a sophisticated information exchange that will enable the air traffic services provider to coordinate changes in response to disruptive events. This initial predeparture capability will serve as the foundation for further improvements in later phases.

Communications. The data link to aircraft will initially use the existing ACARS (airline communications addressing and reporting system) network and existing aircraft data link equipment capable of pilot-controller communication. The plan will accommodate transition to anticipated, more efficient air-to-ground communications architectures. The evolution of FAA air-to-ground data link capability to an integrated system allowing flight plan exchange and FMS loading would also be accommodated. Information links between future airport traffic movement systems (e.g., ASDE-X [airport surface detection equipment–X]) and the National System Flow Model would be added.

Aircraft-to-ATC communication during this phase will use data link for predeparture pilot-to-tower coordination among aircraft. Control of traffic by terminal radar approach control (TRACON), airport tower, and regional control would continue to be based primarily on voice, but planning revisions would be transferred to the emerging data link capability. The interfacility communications backbone, including user connectivity, will be developed during this phase.



General aviation and business flyers will enjoy reduced delays as the air traffic system is optimized for prevailing traffic volumes.

Navigation. Navigation will initially use existing ground navigation aids. Satellite-based navigation will become more prevalent as the number of aircraft with primary global positioning system (GPS) authority increases and an augmented GPS constellation provides sole-source data.

Surveillance. Surveillance would continue to use en route and terminal control radar. Airport surface surveillance systems will be gradually introduced during this phase, and linked to the central flow planning facility.

Airspace Management and Procedures. We envision that the implementation plan will integrate with FAA OEP activities to optimize airspace during this phase. The major operational change will be to the flow planning system. NAS air traffic service providers currently use a set of national-level technologies and tools, which provide coarse data derived from filed flight plans, to conduct a largely decoupled flow planning activity at the regional and airport levels. During this phase, air traffic managers will use an integrated set of tools and methods, based on the National System Flow Model, coordinated with operators at flight centers and among the various ATC flow agents. It is expected that flow planning will be needed at all levels in the fully operational system, but local and regional flow actions will be much better coordinated with national flow planning.

4.2 Phase 2: Trajectory-based traffic planning integrates flow and traffic planning system.

During this phase, trajectory-based flight planning and dynamic replanning will be implemented in the en route regions and in the outer terminal regions of the airspace. This phase will transform the flight planning function within the NAS from the current flight strips–based planning to a full trajectory-based capability. The trajectory-based traffic planning will be integrated with the flow replanning system and with the traffic planning system to provide coherent views of NAS status and plans across operational domains.

Current aircraft flight data processing systems cannot accommodate large en route flight plan changes. Time estimates are crude, especially where climb or descent occurs. Therefore, automated flight plan tracking is not possible.

This phase of our plan calls for application of trajectory-based flight planning to the flight plan processing system. This will give en route and terminal controllers integrated trajectory-based planning tools. This capability can support a variety of applications, including conflict probes, dynamic replanning tools, and airport metering tools such as CTAS. This capability will facilitate sector planning, intersector coordination and sector–traffic management unit coordination, and airport traffic planning.

Air traffic managers will have a dependable picture of the entire national airspace, extending 40 minutes or more into the future.

We expect that many new applications based on the precision management of trajectories will be developed. Initially, the deployment will be to a single facility, but deployments to other facilities will rapidly follow. Transition to the overall architecture will be paced by the rates at which en route and terminal automation systems can support change, based on aircraft equipage updating schedules and on development of airspace and traffic planning procedures and training times.

Common Information Network. Trajectory and other flight information will require airplane-ground information exchange and development of new Common Information Network air traffic data exchanges, including regional traffic flow management exchange with sector-level flight planning and replanning activities.

Development of robust planning and replanning tools for terminal area operations will be a particular challenge, because current busy terminal-area operations are almost exclusively tactical when traffic volumes are high. However, by building more robust terminal-area planning and replanning functions, we will provide substantial airspace and air traffic operator productivity gains.

Further incremental communication enhancements include the addition of dynamic data inputs and the ability to expand the capability of the system command center. The use of trajectories in regional flow applications will be integrated with the center's planning system during later phases of the program. The functions of allocation of delay across control domains; central accounting for delay already imposed on a flight; and exchange of data between central, regional, and airport planning will be provided in the mature system. Airport-level arrival and departure as well as en route flow planning tools also will be integrated into a seamless and coordinated set of flow planning tools.

Communications. Participating aircraft will require a data link (ACARS VDL2 [very high frequency data link mode 2] will be adequate), an FMS, and a GPS navigation system (for a high-integrity time fix). By this phase, we will need to have achieved air-to-ground data link exchange of dynamic flight replanning data. Early applications could be for FMS-to-sector planning tools, such as a second-generation conflict probe. Equipped aircraft also would provide current state information and trajectory to the National System Flow Model to improve the fidelity of its solutions.

Voice communications for tactical intervention will continue, but we expect that the frequency of voice communications will drop dramatically with the availability of en route trajectory management. The dynamic replanning communications mode is assumed to be by data link. A key transition issue is the technical performance adequacy of the initial data link to support terminal-area trajectory exchanges. Interfacility communications will provide connectivity of flow planning and flight planning elements.

Navigation. Navigation during this phase will be based on GPS, both for navigation and time estimation. There will be a ground-based backup system.

Surveillance. Surveillance on the airport surface and in the terminal area will use a fusion of data: aircraft position and intent, radar, and surface secondary-source position.

Airspace Management and Procedures Changes. Sector boundaries and terminal control region boundaries will be modified, consistent with phase 2 implementation. The introduction of significant trajectory-based terminal planning and replanning activities will be limited to prototyping activities and to better coordinated use of tools such as CTAS with FMS data exchanges.

The phase 2 implementation strategy considers issues of ground system and airspace development timing, airplane equipage, and training cycles. The strategy requires airlines operating at affected locations to implement the changes but limits air traffic training require-ments to personnel associated with affected facilities. This approach gives aircraft operators the flexibility to set the timing for installing new equipment (managed by locality), makes the air traffic training schedule manageable, and allows the phased introduction of new procedures. Operator benefits associated with the implementation are substantial.

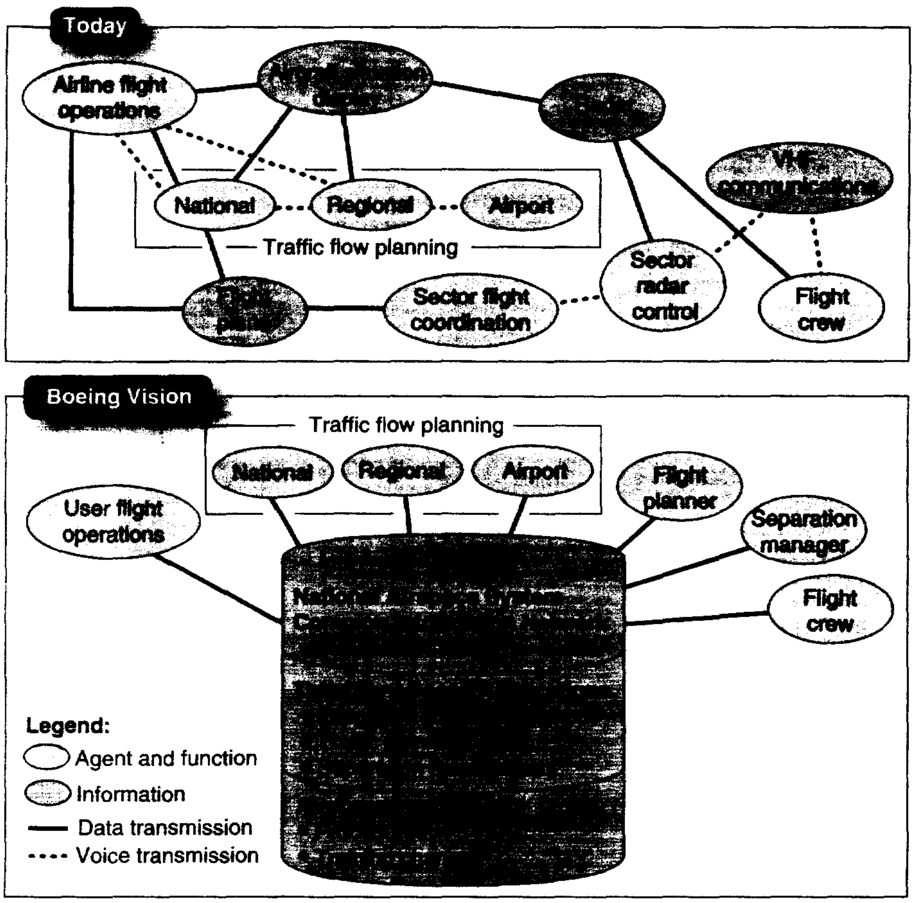
Air traffic managers will be able to concentrate on planning a conflict-free airspace, rather than seeking remedies for conflicts that are already imminent.

4.3 Phase 3: Trajectory-based separation management provides significant capacity growth.

The third phase of the program will introduce precise trajectories into the air traffic separation management process. This step will provide the greatest capacity benefits but will require the most exacting performance requirements. High levels of CNS accuracy, integrity, and availability will be needed. In fact, a significant upgrade of current CNS capabilities will be required, both in the infrastructure and on the airplane.

This phase introduces high-integrity, trajectory-based flight plans, designated here as flight contracts, which are mutually agreed to by aircraft operators and ground planning functions. These contracts will stipulate the precise procedure to be flown. Various integrity-enhancing capabilities will provide conformance monitoring, both within ground automation and on the airplanes. We expect that transition and approach/departure airspace operations will accommodate much higher capacities as a result of these new capabilities. During this phase a new process based on these high-integrity contracts will replace the radar-based separation assurance process.

This phase will require significant development of en route, arrival, departure, and missed-approach planning and replanning tools to provide accurate, deconflicted flight profiles to the aircraft and to monitor aircraft conformance to planned descent profiles. Time planning horizons and replanning rates will be a key design trade off study of this phase of operation. It will probably be necessary to modify the existing air traffic controller displays to present the trajectory information. The controller's procedures, tasks, and training regimes will change. The planning tools will be coupled with new space-based CNS capability, which will create opportunities for the development of a new capacity-enhancing approach, departure, and missed approach procedures and other airspace operating changes.



In the Boeing vision, integrated satellite-based CNS services will foster a much higher degree of cooperation between system agents and functions. Resulting high-integrity forecasts will enable trajectory-based separation management.

Common Information Network. Significant investment in the information architecture is expected to be required for the successful completion of this phase. One of the governing principles of our open air traffic management architecture will be the facilitation of technology insertion at block point change times. The subsequent capabilities will be phased into the architecture, consistent with technology readiness and operational need.

During phase 3 we will extend the NAS Common Information Network to provide near-real-time airplane status data with the development of a Global

CNS System (GCNSS). This CNS information will be integrated with other NAS operations information. The GCNSS would be a significant extension of the current GPS. It would encompass and extend the functionality provided by GPS by enhancing position, velocity, and time services sufficiently to support safety-of-flight civil applications. The GCNSS would also provide additional services and capabilities by adding communications and surveillance functions. The integration of CNS services, coupled with the focus on high-integrity services to support safety-of-flight applications, will result in a system of tremendous utility (app. A).

The GCNSS concept represents a complete paradigm shift, compared with the legacy navigation systems and the existing communications and surveillance technologies. Properly implemented, the fusion and integration of CNS provides inherent redundancy that enhances total system integrity and reliability. This GCNSS capability will meet the new CNS requirements of our separation management and other advanced concepts.

Pilots landing or taking off from the smallest unimproved general aviation airfields will enjoy safety features that equal or surpass those at today's best equipped international airports.

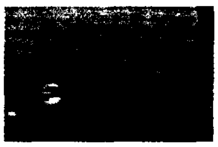
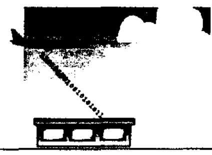
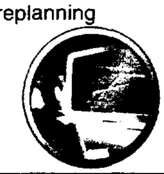
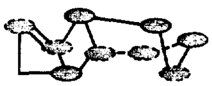
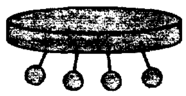
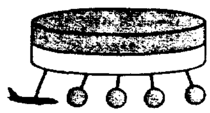
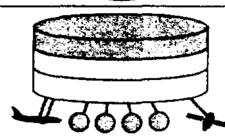
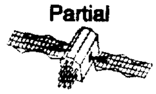
Communication. High performance, digital air-to-ground and ground-to-ground communications will be required during phase 3. Implementation of a satellite-based communication system would cause minimal disruption to the system. Because safety-of-flight services share the same communications (the user-airline operational data link and the ATC data link), the decision to move to a new communications band will be made by the NAS and users, based on economics and performance.

Navigation. The evolution toward reliance on satellite navigation has been slowed somewhat by the implementation of augmentation systems to provide increased integrity. New satellite systems will improve performance of the Wide Area Augmentation System and provide reliability sufficient to allow aircraft to navigate using a single set of navigation satellites.

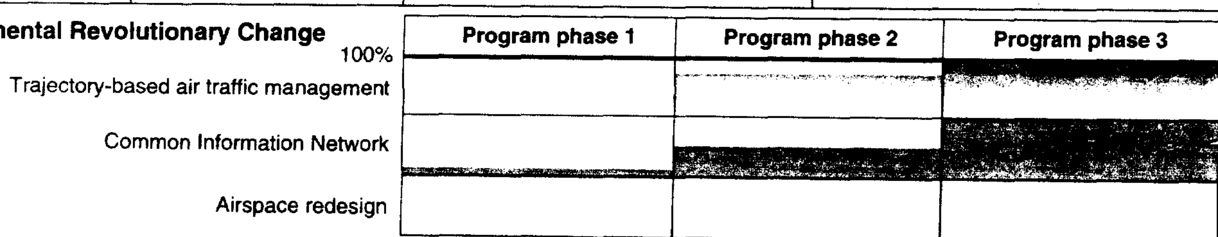
Surveillance. While surveillance is currently conducted primarily using radar and Mode S/C transponders, advances in satellite surveillance techniques will

Proposed Schedule

Establish stakeholder requirements (Years 0–1) — Complete operational implementation: Phase 1 (Year 3), Phase 2 (Year 5), Phase 3 (Year 7)

Year	0 / 1	2 / 3	4 / 5	6 / 7
	Current situation	**Program phase 1**	**Program phase 2**	**Program phase 3**
Trajectory-based air traffic management	Radar- and flight plan-based tactical air traffic control 	Trajectory-based flow management • Integrated national and regional flow planning system • Dynamic replanning consistent with airline planning 	Trajectory-based flight planning • Integrated national and regional flow and flight planning • Trajectory for individual flight plans 	Trajectory-based separation management • Strategic separation assurance • Trajectory conformance monitoring • Dynamic flight replanning 
Common Information Network	 • Numerous data sources (e.g. radar, flight strips) • Limited data connectivity • CNS environment • Voice for ATC • Land-based navigation aids, GPS backup • Radar-based surveillance	 • Common traffic flow-planning database • Flow planning data connectivity • CNS environment • Initial data link • Increased GPS use • Radar-based surveillance	 • Common traffic flow and flight-planning database • Flow and flight data connectivity • CNS environment • Data link, voice backup • GPS primary navigation • Radar and data fusion	 • Common NAS database • Systemwide connectivity • Global CNS satellite services
Airspace redesign		See FAA OEP	Transition to new airspace design	Implement new sector, en route, and terminal airspace
Satellite-enabled system	—	—	Partial 	Full 
FAA OEP	• Resolve choke points • Collaboration and information sharing	• Optimize airspace design • Widespread use of Free Flight tools • Reduced vertical separation • Enhanced navigation procedures	• Data communications • Satellite navigation • Enhanced surveillance	

Incremental Revolutionary Change



Note: This plan is technically feasible, but timing requires extensive collaborative action among stakeholders, industry, and policymakers.

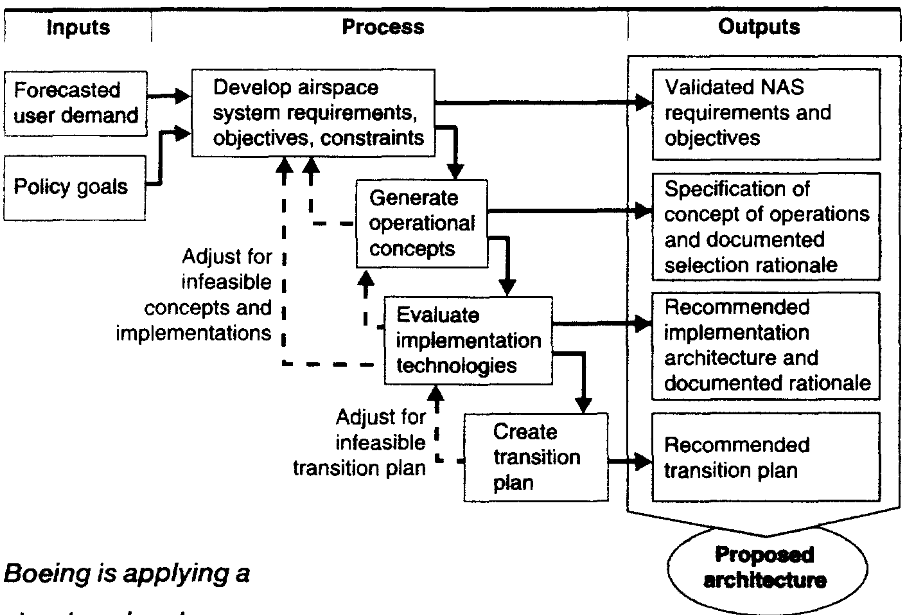
provide this function with greater accuracy and equivalent or enhanced integrity and availability.

Airspace Management and Procedures. Extensive changes to airspace structures, airspace management, and procedure definition will be needed to achieve the safety and capacity objectives of this phase. Fundamental changes to the air traffic controller's job are envisioned—a transformation from air traffic controller to air traffic manager. Even the separation assurance function is envisioned as one of management, not control. In this program phase, many significant changes to current controller automation tools and the airspace operating rules and procedures will need to be developed and implemented. Significant controller training will be required.

Completion of phase 3 constitutes the development and integration of a new information infrastructure across flow management, flight planning, and separation assurance domains. This phased approach enables the development of numerous applications that exploit the core trajectory-based concept developed during phase 1. The open systems architecture of this concept will support incorporation of future technologies as they become available and affordable.

Boeing proposes a process to conduct a complete systems engineering regimen on the NAS—the first in the history of the system. In the past, new technologies were incorporated into the NAS as opportunity arose. The new process will integrate future technologies across functions to maximize synergy among new systems and create standard interfaces to related systems or for human users.

The proposed systems engineering process will ensure the use of a common data standard, maximize hardware and software compatibility and interoperability, standardize system interfaces, unify the user interface, and optimize the utility among cooperative systems.



Boeing is applying a structured systems engineering process to build user requirements into the concept design at the earliest program stages.

Performance objectives, defined through working with stakeholder representatives, will drive every step of the design process. The validated performance objectives and NAS requirements will become the basis for a specification that will define the concept of operation and establish the criteria for selecting technologies to be incorporated into the system.

We will use sophisticated modeling and simulation tools to evaluate the implementation of selected technologies. Boeing will apply its experience with digital design, mockup, and preassembly, to identify a detailed system architecture that meets operational requirements and can be implemented while the existing system continues to operate.

We will use specific case studies and sample operational problems from the existing NAS data to model the system and simulate actual situations and system interactions. Models and simulations will validate the choice of technologies, verify their integration into the system, and demonstrate the functional effectiveness of the system with human operators and users in the loop. They will also help us determine the affordability of solutions and predict the benefits of the system.

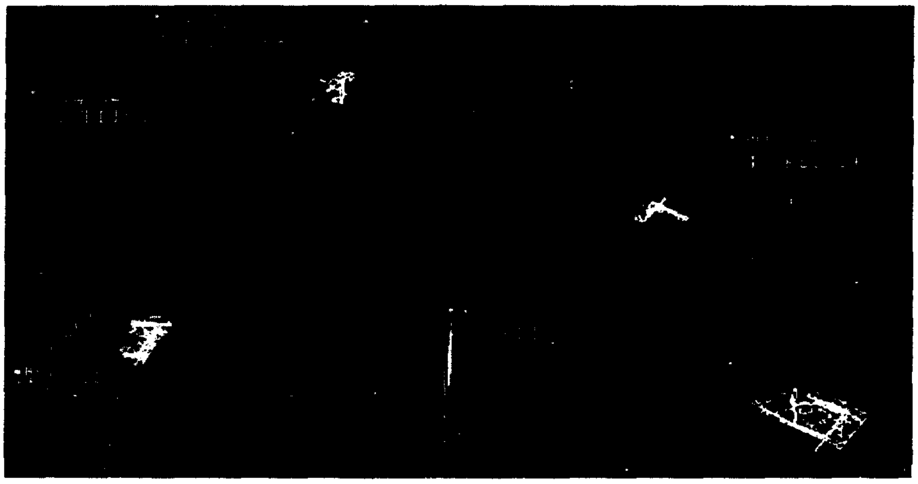
The digital prototype of the system will be used to design and validate the implementation plan, which will establish the more precise phasing for installation and changeover to the new system.

Expected System Benefits. Boeing has completed an initial estimate of the benefits of our proposed architecture. This new air traffic system builds on and enhances the current modernization plans of the FAA, which Boeing supports. Once fully implemented, the new system, in combination with FAA modernization plans, will create capacity for 15 to 17 years of growth. This improvement is equivalent to a 45% reduction in delays. Boeing assumes that there will be significant changes in separation standards to achieve this delay reduction. If runway approval and development, including advanced runway concepts, are accelerated, the system would accommodate 25 years of growth in projected traffic. This benefits assessment assumes increased performance of the current NAS modernization initiatives because of the proposed Boeing trajectory-based air traffic management, Common Information Network, and airspace changes. Safety will also be enhanced as a common, more precise view of airplane locations and flight paths significantly raises situational awareness for all system users.

This analysis is based on multiple FAA, industry, and internal Boeing data sources; airspace operational modeling; and Boeing and industry demand growth analysis and models (app. C). The methodology calibrates the base NAS delay in the year 2000 using CODAS (Consolidated Operations and Delay Analysis System) and OPSNET (operations network) data sources. This base delay is allocated across the following contributing causes: airspace (volume and convective weather), airport region, and other effects such as block time padding and airline operations. The resulting delay percentages are applied to estimated future traffic levels. Estimates of the delay reduction achieved by the proposed concept are derived from airspace modeling and industry work such as that of the CNS/ATM Focused Team (C/AFT), MITRE, and NASA.

The segmentation of the base delay is made to identify delay elements. These delay elements are estimated from a number of sources including Total Airspace and Airport Modeler (TAAM) airspace models developed for this analysis. Other estimates of delay include an internal Boeing terminal area operations study, studies of industry airport analyses, and the Boeing Airport Delay Database. A special statistical analysis was undertaken to provide national-level correlation and coupling of NAS delay with regional and airport-level convective weather and airport ceiling and visibility conditions.

The impact assessment of the Boeing concepts are based in part on TAAM airspace modeling. These TAAM models represented current and future operations in the Chicago and New York airspace regions. This analysis was augmented by various industry reports, including the C/AFT analyses of navigation, ADS-B (automatic dependent surveillance–broadcast) and VDL2 benefits, the Government Industry Partnership for LAAS benefits and MITRE and NASA work on air traffic management tools benefits.



The TAAM uses actual operations data to produce highly detailed, fast-time air traffic simulations in support of benefits analysis and assessment.

Traffic growth projections are based on the Boeing *Current Market Outlook* and internal demand growth models developed by our mathematics staff. Delay growth is based on historical extrapolation of delay, factored for increased operations growth.

The Boeing benefits assessment process is an integral element of our airspace systems engineering process. Data analysis, database generation, and airspace modeling tools (including technology assessment tools) are being developed with internal Boeing funding to refine these estimates. This work builds on the Boeing role in developing industry investment analyses working with FAA, MITRE, and other industry participants.

5.1 Characterizing current system performance establishes a baseline.

The current system is being characterized using a set of operational scenarios to represent normal system operation, rare normal operation, and nonnormal operation. These scenarios will be used both to identify specific regions of the current airspace that need operational improvement and to evaluate proposed alternatives. In accordance with our vision, proposed alternatives will be evaluated against several key criteria, including operational safety, air traffic capacity improvement, access for all system users, affordability, and sustainability.

5.2 Modeling future operations determines whether concepts will satisfy requirements.

Our requirements-driven approach ensures that the system will meet the needs of the users. We will use forecasts of commercial, general aviation, military, and business jet traffic to characterize future demand levels. When we model future air traffic management systems, the primary input to the model will be a set of schedules that represent commercial flights. We will use our models to measure how well alternative system concepts accommodate this demand.

Instead of finding new ways to report and analyze delays, we will add sufficient capacity to make reporting delays unnecessary.

Detailed and realistic schedules are crucial for air traffic management models—not just for certain routes or regions, but for the entire U.S. system. Because of the uncertainty inherent in forecasting need decades into the future, a system design must be robust enough to accommodate a wide variety of possible outcomes. Industry projections, including the Boeing *Current Market Outlook*, have successfully forecast travel in terms of revenue passenger miles, a measure of how many people fly and how far they travel. Over a 10- to 20-year time frame, estimates of revenue passenger miles have been forecast to within a few percentage points.

It is, however, more difficult to forecast how people will fly, which determines the demand on the air traffic system. The industry has, for example, consistently underestimated the demand for smaller airplanes that fly longer distances.

Boeing is creating a set of tools, based primarily on research and analysis conducted by Boeing Commercial Airplanes and Phantom Works, to generate alternative schedule scenarios many years into the future. With these scenarios we are measuring the ability of various air traffic management proposals and airline schedule alternatives to meet user needs.

For example, in a congestion-constrained environment, an airline may only offer a late-night flight to connect a particular pair of cities. Freed of the congestion constraint, the airline would be able to offer more frequent or more convenient service. Though both the constrained and unconstrained systems deliver passengers, only the unconstrained system has the flexibility and convenience that passengers prefer. Our tools will ensure that this issue of service schedule quality is included in the criteria for system design.

5.3 Evaluation ensures selecting the best operational concept.

The operational concept describes how the system delivers required services and the method used to assign the various system functions to the appropriate equipment or system users. We will evaluate alternative operational concepts for effectiveness in increasing system throughput under a variety of airspace environments and for a range of coordinated traffic flow planning options. We will also measure the effectiveness of various operational concepts in handling increased traffic volumes under a variety of situations. We will quantify the relative advantages of various strategies for dynamic flight replanning and flexible airspace design in terms of their ability to optimally allocate delay across airports, regions, and the entire NAS.

The study will examine the allocation of NAS services and functions among users and space-based, airborne, and ground-based equipment. This evaluation will help define the appropriate span of control for air traffic services providers, which in turn will indicate the magnitude of improvement required for navigation and surveillance technologies. The evaluation will also indicate which methods and tools are required to support traffic flow planning and management, given human performance capabilities under a spectrum of normal to nonnormal system operational conditions.

The roles of human users and operators of the system will be represented by parameters defined through detailed simulations or experiments or both.

5.4 Next steps involve stakeholders.

Boeing is proceeding with modeling, analysis, and systems engineering. The next step is to involve stakeholder groups in refining the requirements, operational concept, and analysis process and assisting with modeling. Boeing is providing input into the systems engineering process by validating the results of the modeling activity. Having stakeholders in the major design trades participate in the development of the architecture will reinforce this close involvement. We will continue to develop the tools used to evaluate our requirements-based design because they play a major part in the evaluation of design tradeoffs.

6.0 Unique Qualifications and Program Benefits

The 777 jetliner is the first of many major systems engineering and integration products of the Boeing Working Together process.

Although Boeing is new to air traffic management as a business, our core business of selling commercial jetliners gives us a vital interest in the ability of the airspace system to accommodate more airplanes. We do have significant experience working with airlines and the FAA on ATC-related topics, including airplane and procedure certification. In addition, we have more than 30 years' experience improving airport and airspace operations around the world. With our broad portfolio of commercial and Government programs, we have unique systems integration capabilities and an outstanding record of delivering service-ready, safety-certified products on time.

We are applying our thorough understanding of requirements-based design, working together with diverse stakeholder groups, and our unique and broad set of capabilities and technologies to develop air traffic management solutions.

We are prepared to place the significant resources of The Boeing Company behind our efforts—to consider a new model of Government and corporate partnership, fund research and development, integrate existing tools and systems, and invest in new technologies and infrastructure.

6.1 Boeing brings broad capability to the effort.

Many stakeholders will be involved in any fundamental change to the air traffic system. For decades, we have joined with diverse stakeholders under our Working Together philosophy to design, build, test, and field some of the world's most complex, integrated systems. Successful large-scale systems integration—from Space Shuttle operations to the Space Station, from Joint Strike Fighter development to the GPS network—is a recognized, proven Boeing core competency.

Eighty percent of the operating commercial airplane fleet are Boeing aircraft—few companies could claim the understanding that we bring to airplane performance during all phases of flight. With each new airplane design, we have added to our expertise and understanding.

Solid research and development, coupled with investment in analysis, methodology, and tools—areas in which we have extensive experience—must be the basis for new solutions to the air traffic problem:

- We understand how to estimate future air transportation system requirements. Our annual *Current Market Outlook* and biannual *World Air Cargo Forecast*—industry standards—are used as a basis for worldwide aviation forecasting.
- We have worked with the airlines, the FAA, NASA, Eurocontrol, and other airframe manufacturers to develop tools and methods for evaluating the ability of alternative technologies to increase capacity and reduce delay.
- We developed a methodology for analyzing delay reduction alternatives at airports, thereby allowing us to quantify the cost of delays, by weather condition, over a period of time. We then developed a cost benefit analysis for exploring alternative technologies to reduce delays.
- The engineers and scientists of our Phantom Works Innovation Center are recognized leaders in the creation and application of breakthrough technologies.
- Boeing Air Traffic Management comprises recognized industry experts—people active in the formulation of policy for aviation infrastructure development and members of formal and informal industry working groups, key committees, and industry teams.

6.2 Accomplishments include extensive work in certification, safety analysis.

Airspace redesign will be a critical element of any new air traffic management system. We have worked with the FAA, NASA, and others to analyze the operational suitability of proposed changes in complex, high-density airspace, such as that of New York and Chicago.

Our extensive experience in certification will be essential in determining the most effective processes to advance new concepts in air traffic management. Our insights into safety objectives and assurance have enabled us to determine appropriate methods and processes for safety assessment and analyses and to establish requirements for testing and verification and validation of complex systems hardware and software.

We have developed criteria for system applications where none have previously existed. For example, Boeing took the concept of RNP (required navigation performance) and led the industry in developing airborne systems capabilities that have since been recognized as a means to enable landings under lower weather minimums and to using curved approaches. We accomplished this through close collaboration with the FAA and airline customers, achieving consensus on new approaches to the certification of aircraft and ground system capability and gaining operational approvals. We now design, equip, and support our aircraft fleet to take advantage of these procedures. We have also led the specification of interim criteria and new required navigational performance standards within the industry, so all airplanes can benefit.

Working together with industry and the FAA, Boeing successfully led the integration of satellite, aircraft, and ground systems to achieve FAA certification for FANS1 operations.

We designed the first GPS satellites and are the single-system integrator for the newest system of the U.S. Air Force, providing engineering, satellite production, and operations support. We also lead a team that is developing the GPS III system architecture that will help define the future capability of GPS.

Boeing was the leading developer of the Future Air Navigation System (FANS 1), which allows aircraft to make primary use of GPS equipment for navigation. FANS 1 also provides flight crews with satellite communications and accurate, automatic position reports from anywhere in the world. The FANS 1 two-way data link between air traffic controllers and the flight crew enables inflight course adjustments and prompt clearances, thus giving pilots the ability to fly direct, fuel-efficient routes, especially over oceans. This was achieved through collaboration with all affected stakeholders and through leading-edge innovation in certification safety and hazard methodologies that now serve as de facto standards for all FANS-type programs and emerging certification guidance materials.

These qualifications constitute a significant body of experience that is directly applicable to the major technical issues of fundamental air traffic system modernization.

6.3 New acquisitions contribute to air traffic management.

Recent acquisitions have added significant competencies and intellectual capital to our air traffic management portfolio:

- The Preston Group, a Boeing subsidiary, is an international leader in simulation and in scheduling systems for the global aviation industry. Its TAAM is the leading simulation tool for studying airspace and airport operational change.
- Jeppesen Sanderson, another Boeing subsidiary, is recognized around the world as the premier provider of navigation data, real-time weather information, and aviation information services.
- Our acquisition of three units within Hughes, now operating as Boeing Satellite Systems, gives us even greater expertise in the development and production of state-of-the-art satellite systems for CNS.
- Our acquisition of Autometric, a recognized leader in geospatial modeling, visualization, simulation, and analysis, adds one of the foremost space imagery visualization companies to the Boeing team.

7.0 Conclusion

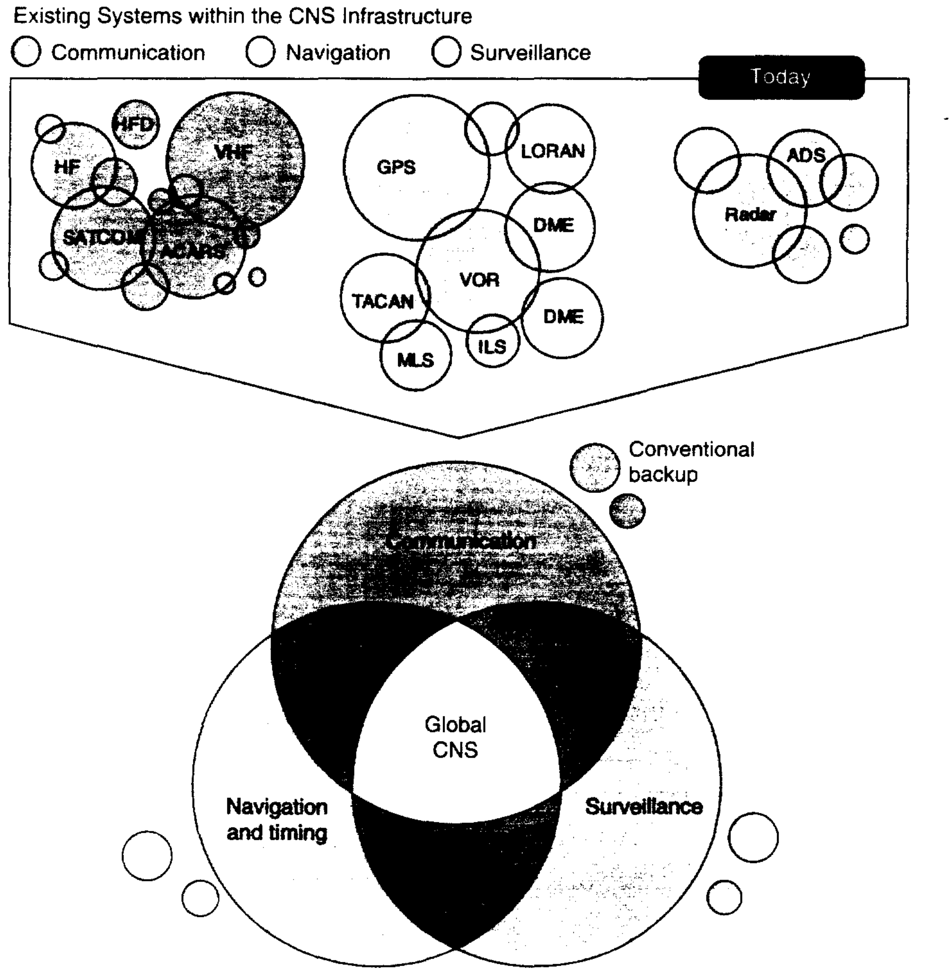
The Boeing vision embraces the day when commercial passengers will board their flights with every expectation of arriving at their destinations on time; general aviation and business flyers will be confident of timely clearance and favorable routings; military operators will have clear access to special use zones; and shippers will be able to count on convenient, affordable air cargo deliveries.

To achieve this vision, the nation must act now. We are proposing profound change and, with that, a feasible plan, using available technologies. Success depends only on the concerted will and coordinated action of all stakeholders.

ACARS	airline communications addressing and reporting system
ADS-B	automatic dependent surveillance–broadcast
ASDE-X	airport surface detection equipment–X
ATC	air traffic control
ATCSCC	Air Traffic Control System Command Center
C/AFT	CNS/ATM Focused Team
CNS	communication, navigation, and surveillance
CODAS	Consolidated Operations and Delay Analysis System
CPDLC	controller-pilot data link communications
CTAS	Center-TRACON Automation System
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FFP1	Free Flight Phase 1
FFP2	Free Flight Phase 2
FMS	flight management system
GCNSS	Global Communications, Navigation, and Surveillance System
GPS	global positioning system
LAAS	Local Area Augmentation System
MCS	master control station
MITRE	a company
Mode S/C	two interrogation methods for radar
MS	monitor station
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
OEP	Operational Evolution Plan
OPSNET	operations network
RNP	required navigation performance
RTCA	a company (formerly Radio Technical Commission for Aeronautics)
TAAM	Total Airspace and Airport Modeler
TRACON	terminal radar approach control
URET	user requested evaluation tool
VDL2	very high frequency data link mode 2

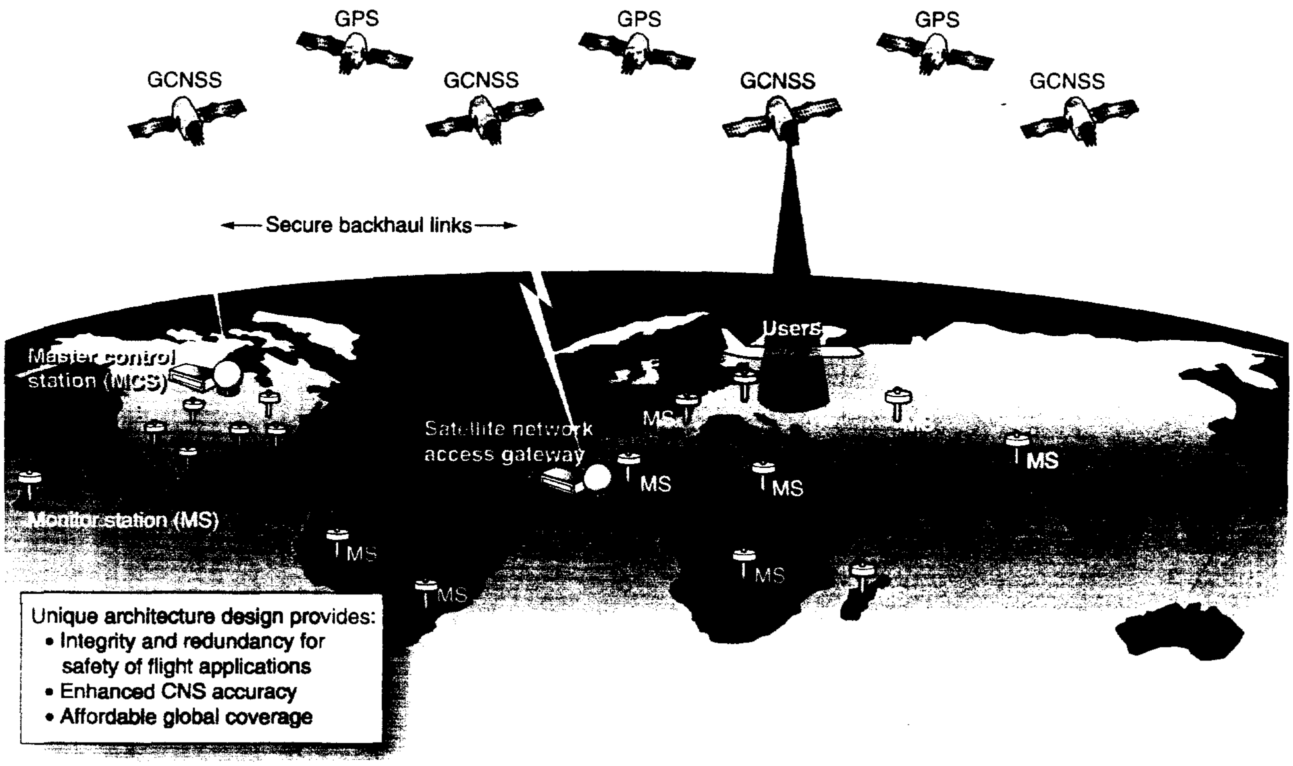
The US National Airspace System is at a Crossroads

The current system has evolved by adding technology to communication, navigation, and surveillance services.



We can choose to continue this proliferation of CNS technology elements or we can choose unprecedented integration.

An innovative system of CNS satellites can unify and enhance air traffic management capability.

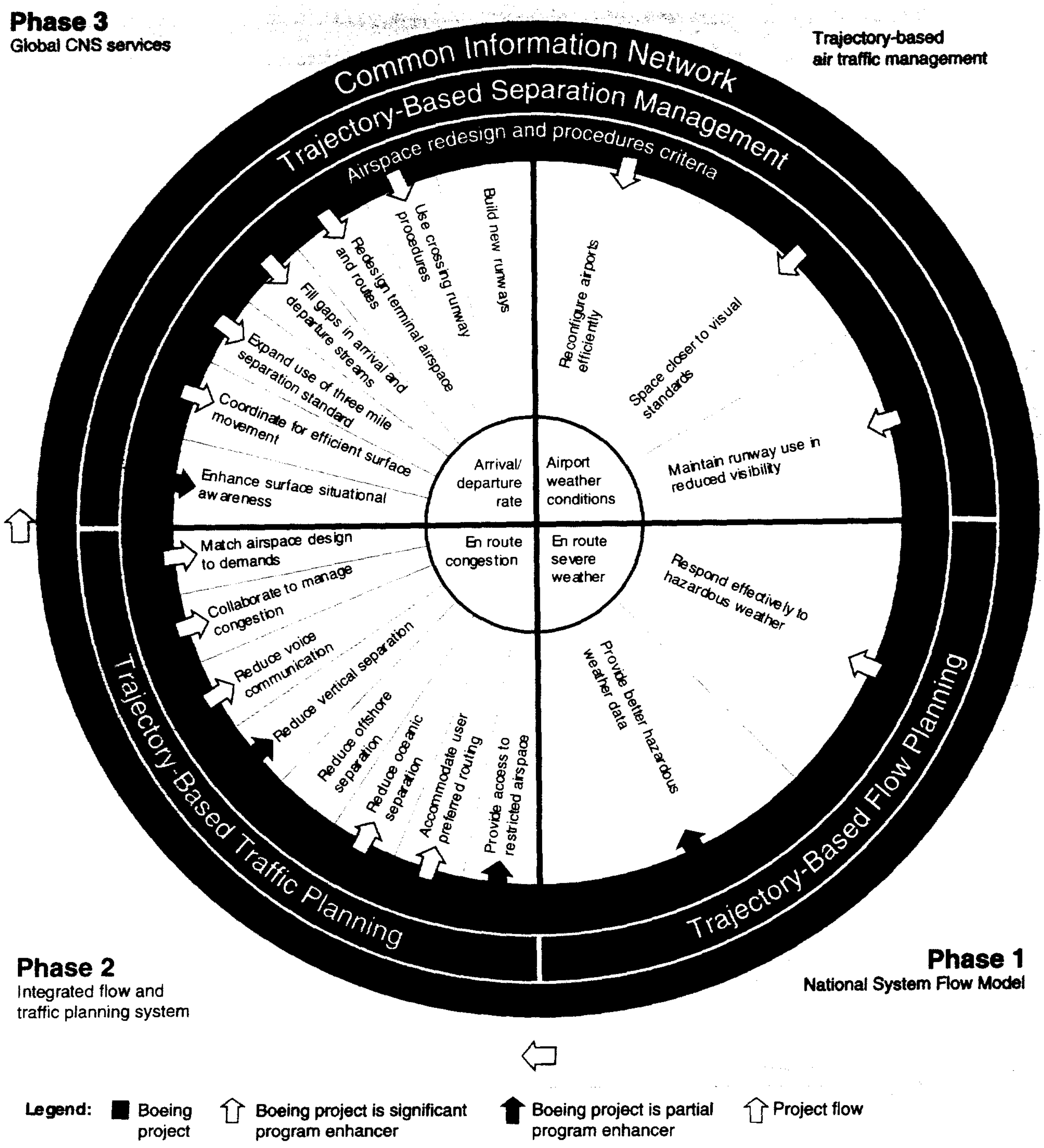


Integration of the OEP and the Proposed Implementation Plan

The figure on page 37 summarizes the relationship between the proposed Boeing implementation plan and the FAA OEP. The FAA OEP is divided into four general areas: En Route Severe Weather, En Route Congestion, Arrival/Departure Rate, and Airport Weather Conditions. These four areas are further divided into twenty program elements. The figure illustrates how the phases of the Boeing implementation plan correspond to FAA plan elements. It depicts functional overlap but does not show timing.

Phase 1 of the implementation plan, Trajectory-Based Flow Planning complements the En Route Severe Weather program elements of the FAA. Phase 2, Trajectory-Based Traffic Planning aligns with the FAA En Route Congestion iniatives. Phase 3, Trajectory-Based Separation Assurance overlays both the Arrival/Departure Rate elements and the Airport Weather Condition elements. Black arrows indicate areas of strong contribution. Blue arrows indicate areas of limited impact. Where there is no impact, no arrow is indicated.

A review of the program elements indicates a good synergy between the FAA OEP elements and those of the Boeing plan. In general, the FAA plan focuses on the near term and assumes minimal infrastructure change. The Boeing proposed implementation plan provides trajectory-based applications, a common information infrastructure, and airspace redesign and procedures criteria to augment and enhance many FAA OEP elements. An initial assessment of benefits indicates that the proposed implementation plan increases the value of the OEP by nearly 90 percent as a result of synergies with the implementation plan elements.


Phase 3
Global CNS services
Trajectory-based
air traffic management
Common Information Network
Trajectory-Based Separation Management
Airspace redesign and procedures criteria
Build new runways
Use crossing runway procedures
Redesign terminal airspace and routes
Fill gaps in arrival and departure streams
Expand use of three mile separation standard
Coordinate for efficient surface movement
Enhance surface situational awareness
Reconfigure airports efficiently
Space closer to visual standards
Maintain runway use in reduced visibility
Arrival/ departure rate
Airport weather conditions
En route congestion
En route severe weather
Match airspace design to demands
Collaborate to manage congestion
Reduce voice communication
Reduce vertical separation
Reduce offshore separation
Reduce oceanic separation
Accommodate user preferred routing
Provide access to restricted airspace
Respond effectively to hazardous weather
Provide better hazardous weather data
Trajectory-Based Traffic Planning
Trajectory-Based Flow Planning
Phase 2
Integrated flow and traffic planning system
Phase 1
National System Flow Model
Legend:
Boeing project
Boeing project is significant program enhancer
Boeing project is partial program enhancer
Project flow

Appendix C

Boeing NAS Benefits Analysis Sources

Base Delay Estimation (year 2000)	
CODAS (FAA)	Base year delay per arrival
OPSNET (FAA)	Base year operations counts
En Route Volume and Convective Weather Delays	
Industry analysis (Lincoln Laboratories)	NAS convective weather impact
Internal estimates (WCG and Boeing domain experts)	NAS Volume Impact
NAS Weather Data Base (Boeing statistics group)	NAS weather correlation analysis
Terminal Weather Delays	
Boeing airport database	100 NAS airports: weather and annual operations and delays
Airport analyses (FAA, Landrum & Brown, Leigh Fisher Associates)	ORD, MDW, EWR, LGA, JFK, DEN current and projected operations and delays
Terminal Area Operations Study (TAOS)	25 top NAS airport delay correlation
Aviation Capacity Enhancement Plan, Capacity Benchmark Study (FAA)	VFR capacities for top 30 airports
Terminal Area Forecasts (FAA)	25 Top NAS Airports: Current and Forecast Operations
Other Delay Effects	
Block time pad effects	MITRE study, IG report, LMI study
Boeing Program Impact Assessments	
Airspace modeling (TAAM ORD and NY airspace regions)	VMC, MVMC, and IMC capacities
Boeing GIP support	24 LAAS Airports
Boeing C/AFT Working Groups	LAAS, ADS-B, VDL/2 Impacts, Performance Metrics, OEIA
Boeing airport database	100 NAS Airports: weather and annual operations and delays
Air Traffic Management tools	NASA and MITRE reports
Free flight, preserving airline opportunity (American Airlines)	Delay reduction estimates
Growth Assumptions	
Traffic demand	Boeing Current Market Outlook and Schedule Modeling
Delay growth	FAA and MITRE Reports

BOEING

The Boeing Company
Air Traffic Management
P.O. Box 3707 MC 80-RP
Seattle, WA 98124-2207

www.boeing.com/atm

Printed in U.S.A
291063 6/01