Free Flight

Reinventing Air Traffic Control:

The Economic Impact

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Note:

This document reviews the issue of air traffic control, and postulates an alternative option that should be considered. This information is intended to contribute to the forum of aviation ideas. ***This study is produced entirely independently, without financial assistance or direction of any kind from any entity involved in any way with air traffic control systems.***

Neither RMB nor ASRC have any conflicts of interest in the matter of air traffic control. We have no financial interest in any entity involved in any way in the building or supply of air traffic control systems, or involved in any way with the rebuilding of the current system. Furthermore, we have no clients that are involved in any way with the building of an ATM system, or any part thereof. This is not an advocacy document that promotes anything that will provide direct economic benefit to RMB or ASRC. Indeed, whether or not the ATM system is rebuilt has no direct effect on the two companies.

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I. Prologue

The subject of Air Traffic Control, referred to most commonly as "ATC", is one that has been at the forefront of media coverage in the past few years, both in the United States, as well as in the rest of the world.

ATC is the current system that controls how aircraft are routed from one point to another. **B*ecause air transportation is critical to the economic system of the world, how ATC does its intended job is critical to commerce and industry.***

Today, however, we have an ATC system that increasingly does not meet the needs of the air transportation industry. This statement is agreed upon in virtually all quarters that are studying the issue. But problems cannot be solved unless they can be clearly identified. In the case of ATC, the symptoms are being mistaken for the disease. Too many assumptions have been accepted without question. Let's start with the first assumption: there are air traffic delays, ergo the reason being the sky is crowded. Wrong.

The sky, despite what we may be led to believe, is not crowded. To be sure, certain parts of the sky at certain times of the day seem congested, but this congestion is the result of the fact that the current approach to air traffic control is obsolete and inefficient.

The current system does not allow efficient use of the available resource that can loosely be described as "the sky." The current system relies on an approach that draws two-lane highways in the sky, and funnels the nation's growing air traffic through them. These are like two-lane blacktop with no passing lanes. Traffic backs up at the gate, on the ground, and in the air. While airplanes often wait to get take off clearance, there are enormous areas of sky that are not being used.

Another assumption is that adding more computers, adding more manpower, and replacing some old equipment will lead to a material reduction in ATC delays and a material improvement in air traffic efficiency. Wrong.

- *The problem, as will be outlined in this study, is that the system itself is obsolete and inefficient, regardless of how may computers are added, or how many tax dollars are thrown at it.*

Another assumption - at least by the Department of Transportation - is that placing the air traffic management system into a "corporatized" structure is part of the solution. Wrong again.

The fundamental problem is not the cumbersome procurement procedures of the federal government. Nor is it personnel procedures of the federal government. *The fundamental problem is a structural inefficiency with the current way air traffic is managed*. It will be repeated again in this document: privatization (or "corporatization") will only change the helmsman on a leaking ship.

There is a better way. And it can be achieved.

A. Updating the Past - Or Building For The Future?

The United States needs to implement an Air Traffic Management (ATM) system that is compatible with the needs of the future. The current approach is one designed in the 1950s, for a 1950s transportation system. Instead of viewing the problem from the perspective of the future, it is being seen in the context of the rearview mirror.

In this document, ASRC and RMB Associates outline challenges of the current inefficient system. Additionally, it provides an alternative approach to ATM, a clean-sheet set of concepts. Current proposals are aimed at fixing the ATC system, instead of more correctly improving the US air transportation system to make it safer, materially more efficient, and more convenient. This difference in perspective is the key to understanding the concepts raised in this document.

In this study ASRC and RMB Associates have covered new territory, but none of it is "uncharted." Individually, the concepts are not new, but taken together they have never been extended to their logical conclusion. The technologies involved are currently available. The infrastructure needed is largely in place. *It is only the perspectives and the assumptions that differ from today's thinking.*

Cost is a key focus. We have researched and analyzed the current ATC system, and have looked at the needs of the 21st century, and the costs that are borne by both aviation users, as well as entire US economy. The costs go far beyond software and hardware to replace the current system: these economic costs affect almost every sector of the US economy. If we do nothing, there are huge costs. If we merely upgrade the current system, efficiency and capacity, at best, are increased marginally. If, on the other hand, we set about to craft an air traffic management system for the future, there will not be "costs" per se, but investments that will pay dividends well into the 21st century.

B. The Role Of The FAA

Much of the data and many of the conclusions in this document are critical of the current direction of the FAA in regard to air traffic control planning. This should be understood to be criticism of the process undertaken in regard to future development of Air Traffic Management (ATM), and in no way is it criticism of the FAA as a whole, nor of any of the individuals involved. The staff at RMB Associates and at ASRC have had the opportunity and pleasure of working with FAA staff over the years, and hold the highest respect for the professionals at that important agency.

C. Challenging Accepted Assumptions

The concepts raised in this document often vary from ambient beliefs. We understand that new ideas are often treated roughly in the mainstream of aviation ideas. But that is the nature of new ideas: they challenge, and indeed, they often threaten, and this often results in harsh reactions from those used to thinking within the mainstream.

ASRC is no stranger to this dynamic. In the past decade, our studies have often taken “contrarian” positions. For example, we said in 1989 that America was “over-hubbed,” and that airlines would begin to pull down several hubbing operations. This was at a time that most consultants were preaching that more hub airports must be built. In 1986, we projected that code-sharing would change the very nature of regional airlines in the US. Not agreed with at the time by most other analysts, but such has come to pass.

And in 1990 we were alone in our accurate analysis of the new Denver airport project. We projected that the enormous costs of the project would drive airlines away, cost consumers more, and lose airline jobs, instead of being more efficient. We projected - correctly - that the FAA traffic projections for Denver were dead wrong. All of this has come to pass, and the project is rapidly becoming a case study in public policy run amok. Our stand on this was not politically correct, but unlike most consultants, we are not concerned with such aims. We are proud of our record of stating the facts as they are, regardless of ambient thinking. And we are proud that we have contributed in a positive way to the forum of aviation ideas.

RMB Associates has long been involved in researching new approaches in the use and application of new aircraft technology to improve air traffic control. In 1990, RMB concluded that the limiting factor in flight efficiency is not aircraft equipment. Instead, it is the ATC system as it is now structured that is the real problem.

Air Traffic Control is an essential part of the nation’s transportation infrastructure. Before the nation accepts a singular Chicken Little approach to solving the ATM challenge, ASRC/RMB strongly urge that a wider and, indeed, futurist view be adopted. This study is aimed at engendering such a view.

D. Scope of Study

This study purposely encompasses only the contiguous US airspace. ASRC and RMB recognize that the future ATM system must encompass a world wide solution. The US provides a more simple case since it accounts for the largest single share of worldwide traffic, and does not have the geopolitical problems encountered elsewhere around the globe. Noise, small sovereign airspace, military restrictions, border clashes, etc. provide significant restrictions to aviation efficiency and capacity. Although recognizing these limitations, this study only focuses on those restrictions to efficiency based on the current ATC system.

II. Executive Summary

Air transportation is a critical part of the national transportation infrastructure. It is a major part of the total economic infrastructure of not only the US, but of the world wide economy. And it goes well beyond scheduled air service. General and business aviation are critical parts of the infrastructure as well. Today's ATC system is restraining aviation growth, and in doing so is restraining economic growth as well.

The Air Traffic Control System in the United States is outdated. While it is safe, it cannot handle current and projected demand adequately nor efficiently. The delays, congestion, and inconveniences resulting from this are obvious, well documented, and are experienced by millions of consumers each year. Worse, the unseen economic impacts - loss of jobs, slowed economic growth, loss of productivity, even higher pollution due to unnecessary excess flying - are costing the nation additional billions of dollars each year.

Clearly, there is no question that the system cannot remain as it is today. It must be reinvented. Not "upgraded" - but *reinvented*.

A. General Economic Impacts

From the results of this study, the following facts are quite clear:

- *The current approach to ATC in the US is a* <u>*primary cause*</u> *of the billions in losses experienced by the US airline industry. The US airline industry is being forced to operate within an ATC system that unnecessarily adds billions to operational costs, and as a result has contributed in a material way to the continuing loss of thousands of airline jobs.*

- *The current approach to ATC in the US is a hindrance to economic growth. Many communities are deprived of the air service levels they truly need because of the costs that the current approach to ATC imposes on aviation.*

- *The true growth potential of aviation - commercial and general - is being suppressed by the continued imposition of an ATC system that in concept is essentially four decades out of date.*

- *Upgrading the present system, as currently proposed, will only serve to continue a system that is obsolete in methodology and approach. Only a complete reinvention of the system will meet the needs of the 21st century.*

B. Need For A New Approach

The current approach used is one based on the concept of *control*. Airliners are forced in most cases to operate within thin pre-defined "airways". Often these airways are not the most efficient routing for an individual aircraft. In the 1950s, this worked. Today, we must *manage aircraft separation*, instead of *controlling aircraft*. The technology exists to allow this to happen safely and with enormous increases in aviation efficiency.

Free Flight is an alternative to the existing outdated approach. It is a system wherein aircraft are allowed to operate using the flight path that is determined to be best suited by each individual operator. No pre-defined airways or altitudes would be used. Each operator would take the path and altitudes that maximized efficiency for its particular needs. Capacity would be increased so that slots, delays and system limitations to aviation growth would be removed. Admittedly, this sounds radical. It questions some of the basic assumptions now held regarding how air traffic should be handled. But many of these "basic assumptions" used today are simply not valid.

Each airline must begin to optimize each individual flight as it relates to their system that day. There is no valid reason for ATM to dictate every phase of flight based on its interpretation of capacity constraints, as it does today. In fact, these constraints are not physical constraints, but ones placed on the system by ATC.

C. Basic Conclusions

In this exhaustive study, we have reviewed the entire range of ATM (air traffic management) issues. We started with open minds and unanswered questions. In the forum of ideas regarding the need to craft an ATM system for the future, the following factors are critical to understand. Virtually none of these are seriously being considered, and until they are, no meaningful solutions will be found to solve today's ATM challenges.

Conclusion One: The US airline industry would have seen robust profits in the past five years if a reinvented air traffic management system had been in place. Thousands of high paying jobs have been lost and are continuing to be lost as a result of the FAA insistence upon keeping outdated ATC methodology in place.

Conclusion Two: The current approach to Air Traffic Control in the US is not just part of the problem, it *is* the problem. It is root cause of much of the congestion, delays, and capacity constraints we today witness. It is obsolete and inappropriate to the needs of today and of the future. Upgrading this approach will only waste more taxpayer dollars. It must be replaced.

Conclusion Three: Proposals to add additional technology to the current system do not address the core problems that exist today. Adding more computers and technology to the current approach to air traffic control will only make an obsolete system marginally more effective, and do little to prepare for long term growth.

Conclusion Four: ***There is no shortage of airspace***. The corollary to this is that ***the sky is not crowded.*** There is enormous airspace available, but the current approach to ATC does not make efficient use of it.

Conclusion Five: Analysis of the financial projections for a "privatized" ATM system indicates that the income stream is questionable. The assumptions made regarding traffic growth and yield increases are not consistent with reality. Disturbingly, no significant analysis has been given to downside risks. It is likely that revenues would fall short of those projected by the DOT.

Conclusion Six: Privatization (alternatively called "corporatization") is eyewash - a political Trojan Horse that has nothing to do with increasing capacity. It merely relieves the federal government of the costs of funding ATM, and dumps it into the laps of the consumer. Furthermore, it does so without any corresponding reduction in current taxes.

Conclusion Seven: It is not ***if*** a Free Flight system approach will replace the current one. The question is ***when***. The US can continue to wear blinders that restrict wider consideration of new concepts, but eventually the current approach to ATC will be replaced.

D. Defining The Challenge & The Need

As the original ATC system evolved over the last 50 years to its present state the only requirement put on its developers was the safety of the system. Even today safety is still the only significant requirement. Although obvious that safety is paramount, we must also address the fact that an inadequate *ATC system is an economic millstone for the nation*. The nation can and must develop an ATM approach that is both safe and allows materially higher capacities and efficiencies.

To date, the majority of proposals regarding ATM improvement have centered around merely updating the current approach. *Insufficient consideration has been given to the investigation of other near-term approaches to ATM beyond that which has been in place since the 1950s.* Of even more concern is the fact that the current approach is not even being questioned regarding its ability to meet the future needs of aviation.

These two assumptions - that the current approach "works," and that the near term solution lies in merely "upgrading" it - are invalid. Wrong. Inaccurate. Yet they are the foundation of today's thought patterns regarding air traffic control.

E. Vacuum Tubes and Privatization

Within the Administration, there seems to be a fascination with vacuum tubes, as if replacing them will solve the problems we face. Somehow the vacuum tube has become a rallying point - a craven idol that suddenly must be vanquished to save the system. Even the documents produced by the FAA of late regarding ATM have a vacuum tube emblazoned on the cover. In "Air Traffic Control Corporation Study" published by the FAA, and dated May 3, 1994, the term "vacuum tube" is used over and over again as an example of the problem. But replacing this equipment is not a singular solution.

This needs to be put into perspective: the use of vacuum tubes in today's ATC equipment is an indictment of incredibly poor management and incompetent planning on the part of the FAA. It is not, as some claim, a mere result of the Byzantine bureaucracy of the federal government. Were this the case, all federal agencies would still be using vacuum tubes, which they are not.

Along with vacuum tubes, privatization is another rallying cry - a panacea that will somehow relieve the ATM system of its problems. Will privatization fix the system? No. Will privatization allow more aircraft to operate more safely across the sky. No. Privatizing the ATM system will only change helmsmen at the wheel of a lumbering and leaking ship. It is a political side-show that makes great press and great photo opportunities. America needs a reinvented ATM system. Attempting to turn the process into a political bandwagon is not consistent with this goal.

As will be outlined in this document, the financial projections made to support corporatizing ATM are not consistent with the realities of the US airline industry. The report, "Air Traffic Control: Analysis of Illustrative Corporate Financial Scenarios" dated May 3, 1994 is little more than a blind advocacy document - a public relations piece that outlines glowingly the projected benefits of corporatization. But it provides little or no hard discussion of the unpleasant potential downsides. What if traffic does not expand as it projects? What if yields do not increase as is projected? What happens then? Essentially, this is ignored.

It is claimed that corporatizing will move the ATM system away from massive bureaucracy, and allow it to become more efficient. Aside from the fact that this argument is not supported by the facts, nor by the GAO, proposals for privatization evade the real problems. *Who* is running the system is not the key question. It is *how* the system is running that is paramount.

F. Defining ATM Requirements For The 21st Century

In this document, we review an approach to ATM that steps outside the confines of 1950s thinking and the 1950s environment. Free Flight is a concept where the technology of the 1990s is applied to an ATM system of the 1990s and beyond. The economic impact is substantial. The savings to the taxpayer and consumer are substantial. It is an approach that takes ATM out of the 1950s and allows aviation to take its full place in assisting economic growth in the US and worldwide.

The answer is not more technology applied to an outdated system. It is not simply adding computers, or replacing vacuum tubes. And it won't be found in attempts to cram more airplanes into more airborne highways. The answer - *and it can be implemented safely* - is to allow today's aircraft to use *all* resources available, including the entire sky.

1. Template For A New Air Traffic Management System

Unfortunately, the requirements for a new ATM system have not been adequately defined. For the purposes of this study, the following requirements are stated regarding what must be accomplished in rebuilding the ATM system:

- ***Provide absolute safety;***
- ***Reduce restrictions on usage of airspace, which is the production line for air transportation;***
- ***Accommodate projected traffic growth safely and cost-efficiently, particularly at hub site airports;***
- ***Encourage and accommodate additional efficient expansion of the air transportation system.***

This last point is critical: *Today's traffic projections are based upon the accepted assumptions and constraints attendant to the present costs and approach to ATC. Removal of the current ATC restrictions will result in demand far above projections.* What must be developed is a system that provides an environment where aviation is much more free to grow and expand safely, efficiently and economically.

Clearly, the current approach to ATC, and the current proposals to "upgrade" it do not meet this template.

G. Overall Conclusion

The basic conclusion of this study is that the current ATC approach and methodology must be replaced, not upgraded, because it is hopelessly incapable of efficiently handling the traffic demands that are expected in the future, and is based on hopelessly outdated assumptions regarding air traffic management.

This must be done quickly. Otherwise the costs to ATM, the users, and the economy as a whole will be enormous.

As will be reviewed in this document, we must break out of the confines of today's thinking and today's assumptions regarding ATM. We can no longer accept proposals that merely attempt the catch up with the past. Instead we must build a system that is compatible with the future.

III. Genesis of the ATC System

Understanding how the current system developed is of value in understanding why the system is inefficient to the airline needs of the 1990s.

The original ATC system has evolved over the last 60 years to its present state. In the beginning of aviation, the system was originally based on "see and avoid." This concept put the responsibility of aircraft to aircraft separation squarely on the pilots.

As air traffic expanded in the 1930s, the first air traffic control system, per se, was established in 1934 by American Airlines to monitor their own aircraft. The other airlines quickly recognized the importance of tracking their aircraft and in 1935 they set up a cooperative "mechanism to handle the airline traffic" at Chicago and Newark airports.

These informal private-sector efforts expanded into three Air Traffic Centers to handle enroute aircraft. In 1936, this enroute ATC responsibility was turned over to the Federal Government. In 1938, the Civil Aeronautics Authority (CAA) was formed and the Civil Air Regulations came into being and new Air Traffic Rules were established. [1]

With the post-WW2 boom in air travel, it became necessary to address the issue of safely controlling air traffic. In 1952, President Harry Truman formed the Airport Commission to study the issue. Headed by General James Doolittle, the commission recommended "positive air traffic control regardless of weather, especially in high density zones". This made a fundamental change in air traffic control, moving the responsibility for separation from the pilot to the air traffic controller.

A. The Implementation of Positive Control Airspace

Shortly thereafter came the President's Air Coordinating Committee (ACC) from which the basic structure of today's air traffic control system was developed. This consisted of a group of panels reporting to the main ACC committee. Of particular interest was the Air Navigation and Traffic Control Panel, and specifically, Special Working Group (SWG) 13, formed in 1954. The final report of SWG 13 (released March 1957) and the discussions during SWG 13 are the basis of the current ATC system and the concept of positive control. Although positive air traffic control increased safety, it removed much of the flexibility the airlines had in the old system. The positive control concept firmly established the differentiation of Visual Flight Rules (VFR[1]) and Instrument Flight Rules (IFR[2]).

On June 15, 1958, the CAA first implemented positive control on a very limited basis. On January 1, 1959, the Federal Aviation Administration (FAA) was created and took over responsibility for the United States aviation system from the CAA. After numerous studies and evaluations, the FAA instituted positive air traffic control procedures between 24,000 and 60,000 feet in March 1965. In November 1967 this positive control airspace was lowered to 18,000 feet. With the implementation of Positive Control Airspace (PCA) all airlines are required to file IFR flight plans and be under the control of the air traffic controller. **Positive control of the airspace changed separation responsibility from the pilot to the controller.[2]**

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[1] VFR - Basically, flying in clear weather with the pilot accepting responsibility for separation.
[2] IFR - Flying in or out of the weather with ATC accepting responsibility for separation.

The result of this developmental process since 1934 is a system that is inherently designed to force the majority of air traffic into tight corridors where it can be “controlled.” Today the technology exists to allow safe use of all the sky, without need to funnel traffic into narrow bands. It ignores the advances in technology that would allow air traffic to use the entire sky, thereby eliminating the enormous waste of fuel and other resources caused by continuing to treat modern 767s as if they were Ford Tri-Motors.

B. Advent of “Flow Control”

After the controllers strike in the 1980s, the FAA began to seriously manage the "flow" of the ATC system. The goal was to prevent any one controller from becoming overloaded with traffic. Rather than airborne holding of the aircraft, FAA Flow Control (as it was named) would keep the aircraft on the ground to avoid congestion while rebuilding from the effects of the strike.

While in theory this sounds very efficient, the outcome was severe limitations on airline efficiency. Flow Control (which began as a few people in a small room with telephones) recently moved into new state of the art facility near Dulles airport. The new System Control Center (SCC), as it is now called, has access to considerably more information than before. The limiting factor is still the subjective decisions based on inaccurate or fuzzy weather predictions. The other problem is that the control is still with the FAA that makes these subjective operational and business decisions on the capacity capability of individual components of the system.

Airliners in flow control situations often wait for a "wheels up" departure time issued by the SCC and upon arrival find that the weather is clear and the original restriction has long since disappeared. This total control of the flight, outside the control of the airline, is a key part of the cost factors that affect airlines and the consumer.

Flow control is effectively the traffic cop that meters aircraft into and out of the airborne highways. This causes delays and enormous costs to airlines and to the consumer.

C. ATC Current Separation Methodology

With the lack of automation in the 1950's, when positive control was initiated, the only safe method to insure separation is to use the human brain as the main tool and the way it is done is to linearize the traffic based in only two dimensions. Separation should be a quad-dimensional (the three dimensions of the sky, plus time).

Today, the ATC systems - in the US and worldwide - are based primarily on a “positive” air traffic control environment. Positive air traffic control is a relatively simple concept. In the US, commercial air traffic (VFR or IFR) and all other IFR traffic in the system are controlled by, and **must** follow the direction of, the controlling ATC facility. This control methodology assures separation of the aircraft, the controller’s responsibility. Although safe, this system has almost no flexibility. This is true whether the aircraft is flying above the United Sates, Europe, Asia or any other country. In some nations, such as the Peoples’ Republic of China, airspace is controlled by the military.

The positive control system is just that - constant surveillance and control of the aircraft by radar or radio contact, by the ATC facility responsible for the airspace. Most airspace over developed countries is monitored by radar facilities, through a radar display (a 18" circular video screen) used by ATC controllers.

Prior to flight, each aircraft sends its route of flight (flight plan) to ATC. Based on this flight plan, the aircraft is strictly controlled as to what route and altitude it is allowed to fly, usually on a specific airway. Any changes must be requested and the pilot must receive an amended "clearance" from the ATC controller before the aircraft can deviate from that flight plan. The only exception to this is the Captains emergency authority, used only to maintain the safety of the flight.

Within the ATC system, each individual controller is manually responsible for a very small segment of airspace. An aircraft is “passed” from one controller to another as it progresses on its flight plan. Each controller uses a separate radio frequency, which requires coordination with the pilot when switching. This mundane task of switching frequencies compromises a significant portion of the radio chatter and limits the controller’s ability to “manage” the airspace. As an aircraft enters a controller's sector, that controller becomes responsible to assure separation between aircraft in that sector. This separation is based on the controller's ability to project the path of the two aircraft, see a conflict and resolve it.

This results in the traffic being “linearized” - i.e., essentially being reduced to two dimensions on a flat screen. Aircraft are given fixed altitudes and routes through each sector. This allows the controller to know and visualize what each aircraft is going to do and allows the controller to assure that separation is maintained. This procedural type of separation forces controllers to separate aircraft from airspace, airspace which is often empty.

“Conflicts” - the potential for aircraft meeting within a set horizontal separation of 5 miles, must be avoided. To prevent the protective “bubble” of one aircraft to overlap that of another aircraft, controllers must visualize the conflict and decide a resolution 40 to 50 miles before it happens to prevent what is termed “loss of separation.” Loss of separation is defined as two aircraft within 5 miles of each other, *at the same altitude*, effectively setting a protective bubble of 2.5 miles around each aircraft. The “same altitude” (or the height dimension of the bubble) is defined as within 1000 feet at or below 29,000 ft altitude, and 2,000 feet above 29,000 ft altitude.

The ATC controller is under enormous pressure to avoid conflicts. Not only is safety paramount in the controller's mind, but the ATC computer is programmed to automatically report when this 5 mile buffer is lost. If the controller has three occurrences of loss of separation, he or she are pulled from their position and “retrained,” and in come instances, they can even be fired. Because of this, controllers are very careful to avoid the possibility of conflicts, so the actual lateral separation is more like 8 to 10 miles or more and can approach 20 miles based on the controller’s capabilities.

To simplify the understanding the controller's problem, imagine watching 30 marbles as they bounce (not roll, but *bounce*) across a table and it's your responsibility to assure they do not touch each other. As a manual problem, this task is impossible unless each marble is rolled across the table individually and not all the marbles all at once. Or unless the marbles are kept in single file. With this in mind, it can be seen that there are two main problems severely limiting capacity in the air traffic system today.

- Traffic must be linearized (vertically and horizontally) to allow the human controller the manual ability to visualize and separate the aircraft.

- Once a problem - a conflict or potential conflict - is identified, the controller is responsible to resolve it, and must have the ability to communicate to the aircraft to assure the conflict is resolved.

The bottom line is that with today's technology, this process can be largely relegated to automated systems that will project the flight path forward, detect conflicts, and provide a resolution advisory to allow the controller time to manage the separation task. Most individuals concerned with ATC have this same view of what is required, the significant differences arises as to the timing to accomplish this. ATM should only provide the minimum amount of control necessary that will assure safety and provide the flexibility required by the customers, the aircraft operators. Repeating the main theme of this paper, ATC must only manage separation (thus insuring safety), not control the airlines production line decisions. The approach to air traffic management must be fundamentally altered to achieve this.

D. Separation versus Flow Management

The airlines, and in fact all aviation, has only one requirement for the ATM provider - separation of aircraft while moving. As we have discussed the FAA's method of providing this service, developed in the 1950s, is control of the flight path, through the linearization of the traffic, with total system control in the hands of the ATC controller. The ATC systems primary requirement with this control methodology has been the "safety" of the aircraft. This goal has been met because no two aircraft, under positive control, have collided. At the far end of the spectrum, this goal could be met by allowing movement of only one aircraft in the US at a time. Unfortunately, this solution has minimal flexibility and limited availability to increase capacity, or more importantly, efficiency. Because of the randomness of the "Free Flight" system not only is the system safer (by not forcing all traffic through the same funnel), but system efficiency would take a quantum leap.

A subset of the separation services, occasionally required by the airlines, is Flow management. In actuality, flow management should take place at the individual airlines to optimize their individual arrival banks, specifically at their hubs. The Flow Control function currently implemented by ATC is a geared to prevent any one controller or sector from becoming overloaded. Today Flow Control restricts aircraft not on real constraints, but on artificial constraints. These artificial constraints, although real to the FAA, are a result of FAA's methodology of separation and are not "laws of physics". Most delays attributed to weather in today's system are, in reality, ATC's inability to handle the changes required by the weather phenomenon. ***Flow management should only be applied when access to a limited resource is limited to assure separation of aircraft.*** The industry must work to apply only limitations are real, e.g. Runway Occupancy Time (ROT) or weather.

E. FAA Automation Update - AAS

Many years ago the FAA embarked on an system upgrade to introduce more automation into the existing ATC system. The primary goals of this upgrade were the automation of many controller functions as they exist today. This enhancement, called the Advanced Automation System (AAS), envisioned centralizing the ATM system and providing more control. The users, or the ATM customers, were not extensively consulted as to their requirements. To be fair, the users would probably not have come up with a solution much different than the FAA.

The original AAS package was forecast to cost $3.6 billion dollars to fully implement. With the program years behind and billions over budget (now estimated at $5.9 billion), the FAA on June 3, 1994 drastically scaled back AAS. The only two parts of the four part program still planed to go forward are a scaled back implementations of the Tower Computer Control Complex (TCCC) and the Initial Sector Suite System (ISSS). Even the ISSS may be scaled back or cut completely, because of the software problems which have been encountered. By allowing definition of the problem as a complex control problem this significantly increased the complexity of the solution. AAS shortfalls epitomizes the difficulty inherent in designing a complex control system. This added complexity, and floating goal, as to what AAS really was doomed the project before it even began.

F. Air Transport Association (ATA) Vision

The Airline Transport Association (ATA) has also recognized the requirement for change. The recent publication of an ATM "vision" document[3] outlines the airline requirements for ATM and lays out the "Free Flight" concept as envisioned by the ATA airlines. This paper is one of the first times the airlines have mutually agreed to a long term vision of the airspace system. In this vacuum of consensus of the users' needs and desires, the aviation authorities developed the vision and future timing based on the ATC's control-oriented biases and perspective. As outlined below, technology is available today to solve these problems and alleviate the airspace capacity problems.

G. Future Air Navigation System (FANS)

Fact: FANS is the core starting point of the Free Flight system.

Most of the aviation authorities follow the general direction and coordinate their activities through the International Civil Aviation Organization (ICAO). In 1983, recognizing the ATC system was out of date, ICAO established the Future Air Navigation System (FANS) committee. The committee's task was to study and access new concepts and make recommendations based on advanced technology. This application of advanced technology is planned to allow a productivity leap on the order of that gained by the airline industry when it moved from propeller aircraft to jets.

The technology envisioned by the FANS committee has been directed towards a more *management based* ATM system. FANS was not originally intended to base separation methodology on ground based control by ATM. However, current airspace control systems (ATC) are predicated on total ground based control of the aircraft's flight path. In fact, the incorrect vision of FANS currently held by the ATC authorities is *more* control of the system, instead of FANS real intent, separation management. Beyond the fact that airspace management (ATM) and airspace control (ATC) both deal with aircraft, they have little in common. The ramifications of the "control" methodology to separation on the airspace users is that they will receive little, if any of the flexibility required to operate profitably. Unfortunately, many of those who are using or operating the current system or designing and/or implementing the new system:

- Do not understand or refuse to acknowledge that FANS, from a system perspective, espouses airspace management in lieu of control. The consequences of any other orientation, primarily control, negatively impacts the system implementation.

- Disagree as to the details, design and implementation of the future system.

- Refuse to recognize that the current control methodology is flawed and must to be changed to assure the continued financial viability of their major customers, the airlines.

The world's airlines, through ICAO, must take a more proactive role to assure the near term, worldwide implementation of the FANS, primarily in the area of ATM. This implementation must be based on a Free Flight approach.

IV. Analysis of Airspace Capacity

A key question is, of course, what is the ultimate capacity of the airspace system? We know that there is a lot of space, but how much is that?

Let's start with just one aircraft - we can state with certainty that the airspace system has capacity for at least one airplane.

If there was only one aircraft allowed in the sky at any given point in time, the airspace would be safe and that single aircraft could operate on any route or altitude it chose. No chance of a mid-air collision, except maybe with an unfortunate seagull. No need to "see and avoid" on the part of the crew. No other airplanes to see or to avoid. This one aircraft could taxi directly from the gate to the runway without delay. It could takeoff and fly the most efficient routing and altitude based on the criteria set by the airline without encountering traffic-related arrival delays.

But If we add another aircraft, the chance of the two bumping into each other becomes at least a distant possibility. If we add ten more airplanes, the chances of a mid-air collision go up, although if they are not all at the same airport or in the same proximity at one time, the chances in absolute terms are zero. If we add one hundred more airplanes, the chances of "conflict" go up again.

Without belaboring the issue, it becomes obvious that at some point subsequent to the second airplane being added to the sky, a methodology must be developed to keep airplanes from running into each other.

To address this, today we have the current ATC system. The basic approach of this system is to control aircraft into thin portions of the sky (airways) so that they can be watched, or as the term implies, *controlled*.

This linearization of the traffic flows severely limits the amount of traffic that can use the airspace. In fact, it has been said that the only way ATC can separate traffic is to put them all together so that they can be monitored and controlled - i.e., kept from running into each other.

Today, the reason the skies are considered to be "crowded" is because aircraft are on the most part directed to fly through predetermined, set "funnels" - or airways - as directed by ATC to reach their destination. In fact, outside of five miles from the hubs pilots rarely see other aircraft, even though being forced to fly the same "funnels".

The beginning of this document stated that there was not a capacity problem. While we do face ATC capacity constraints, it is not a lack of airspace that causes them. *It is the approach we have chosen to control these aircraft that causes the constraints.* These constraints are a direct outcome of the lack of procedure development for the technology that is available, and future technology implementation of ATC, not an airspace limitation.

A. *Sizing Up Airspace Capacity*

So how much air space is there compared to the aircraft in the sky? Shortly after Kitty Hawk we exceeded the one-plane-in-the-sky-at-a-time scenario. Today, an average peak count of all transponder-equipped aircraft in the sky at single point in time in the US is approximately 5,200 aircraft. During non-peak times, such as in the middle of the night, the number is far less, considerably under 1,000.

While 5,200 aircraft appears to be an enormous number, it pales when compared to the available airspace. Stated again - there is no airspace capacity shortage. Let's look at some data:

The Boeing 737 is an "average" size aircraft. In US domestic service, the average size aircraft is approximately 140 seats in mega-airline fleets, which is about the maximum high-density capacity of a 737-300. This average-seat figure includes the entire operated fleets of airline systems such as American, United, and Delta. (Remember that today's mega-airlines operate fleets from 19-seaters flown by their commuter arms, up to giant 747s.)

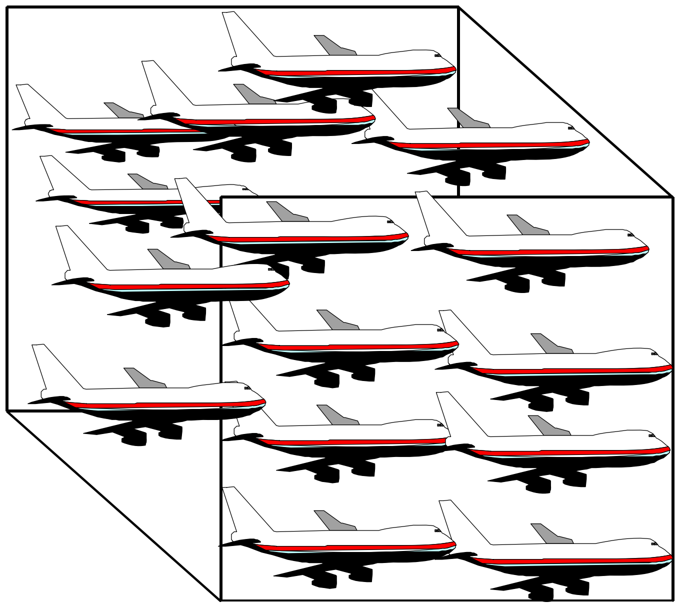
There are today about 2,500 Boeing 737 variants in world wide operation. But it would take all of these *plus another 278,000* 737s to completely fill just one (1) cubic mile of airspace without touching, wing tip to wing tip, nose to tail, belly to top of vertical stabilizer. That's a lot of airplanes, and they are crammed in on top of each other in a static fashion. But it gives an idea of just how big the sky really is.

To bring this figure into some context, at any one point in time, we estimate that there are no more than 12,000 to 15,000 aircraft flying in the entire world.

Moving this into the realm of the United States, let's remember that the average number of transponder-equipped aircraft that are in the air during *peak* periods is approximately 5,200.

Example Of Airspace Availability

One Cubic Mile Of Airspace



Over 280,000 737 aircraft can be neatly parked in one cubic mile of airspace without touching.

Take one cubic mile of airspace. One mile long, one mile wide, one mile high. In this cube can fit more than 281,000 Boeing 737 airliners. All are stacked neatly, without touching.

This gives an idea of the size of the available airspace, especially in light of the fact that an average peak of aircraft in the entire US sky at any one point in time is approximately 1.8% of this number.

But this is just one cubic mile. The entire land surface of the continental US comprises approximately 3,120,000 square miles. Therefore, if we just take the airspace between 18,000 ft and 37,000 ft, the US has over 11 *million* cubic miles of airspace. This means that during an average peak period, there is an average of one airplane for roughly every *2,000 cubic miles* of airspace.

map of US

Clearly, the raw airspace available is enormous. Using the example above, in one cubic mile of airspace we could fit approximately 18 times all the aircraft flying in the world at any one point in time. And 54 times the number of aircraft operating during an average peak period in the US. In the US, every transponder-equipped airplane has 2,000 cubic miles of its own - on average. Granted, this is only theoretical, but it shows that we do not use the airspace very efficiently.

Truly, in the New York metropolitan area, or in the Los Angeles basin, there are a lot more airplanes in the sky than the examples above indicate. Separating aircraft into and out of airports in regions such as this is important. The question is how this separation is approached. Assuring that all aircraft are tightly packed into specific air lanes in such regions may not be the most efficient, nor the safest approach.

Now, with these broad-brush data in mind, let us again move back to the basic question, system capacity. If someone could remove all ATC limitations to the airspace the true limiters on the system are:

1. Runway occupancy time (how long the landing airplane stays on the runway, especially at busy airports);

2. Available parking spots (gates) for aircraft on the ground.

Under a Free Flight system, the sky, unlike today, would not be a limiting factor.

V. Analysis of The Current Air Traffic Control System

There is no question that there are problems with the current air traffic control system. Congestion, delays, and restricted ability to expand the air transport system are obvious. The solutions to these problems have centered around proposals to spend billions of dollars in upgrading the current ATC computers.

In brief, the ATC system uses "airways" to route most airline traffic. Airplanes file flight plans based on these existing airways, and cannot deviate from their filed plan without prior clearance from an air traffic control. Airways criss-cross the nation. They do not allow the shortest distance between two cities, nor do they allow aircraft to take advantage of ambient wind conditions.

ATC Today: The Airborne Highway System

map of airway examples

The four states shown comprise approximately 524,000 (over one half million) cubic miles of airspace, just between 18,000 ft and 37,000 ft. Yet the majority of airline traffic is routed over thin air routes, ***that if shown to scale on this map, would be so thin that they could not be seen***.

The system has some advantages. By keeping aircraft in these airborne highways, they are easier to "control" from a two-dimensional perspective. The disadvantage is that most traffic is crammed into small portions of the sky, and are not operating on routings that are the most direct, or take highest advantage of wind conditions. The result is more flying that is necessary, and wasted dollars. Billions of wasted dollars.

A. ATC Approach: Adequate For The 1950s. Now Obsolete.

The system of airways used today was quite acceptable 40 years ago. In the 1950s, aircraft were fewer. Aircraft were slower. Fuel was cheap. Air travel had not yet developed into a mainline mode of transport. Airlines and the routes they flew were regulated, and the high concentrations of traffic we now see at today's hub-site airports were unknown. The two-dimensional, linear approach to air traffic control was workable, safe, and adequate.

Today's system is safe, but only at an enormous cost, and at the expense of restricting and hampering the capacity necessary for a growing economy*. Indeed, it is even ill-suited to the performance characteristics of today's aircraft.*

B. Efforts To Increase Efficiency By FAA

To be sure, there are exceptions to the adherence to using established airways. The FAA has made limited attempts in this regard. But they are within the context of the current overall approach to ATC. As a result, they are not destined to provide the type of capacity increases that are truly needed now and in the years ahead.

In limited cases, airliners are occasionally allowed to "go direct" on parts of their flight plan, without following an airway. And the FAA has implemented what is called the National Route Program (NRP) which allows airliners to fly the flight plan which they feel is best suited for their needs. But even here, the program is limited to specific city pairs and altitudes, the flight plan must be filed, and deviations must be cleared with a controller in advance. While the NRP is a step - it remains within the confines of the current ATC approach. And it is this approach that is the problem.

C. A two-dimensional Approach To A Quad-Dimensional Problem

The current system applies *two-dimensional thinking to a quad-dimensional system*. Essentially, air traffic control is approached in the same two-dimensional manner as is highway traffic. Keep aircraft in clearly-defined "highways" where they can be "controlled" to provide a safe system. And while there are varying altitudes applied to these airborne highways, the approach remains essentially one that restricts the use of available airspace. Because the system is not approached in a quad-dimensional context, we are not achieving the efficiencies that can be attained, and indeed, must be attained.

Free Flight allows the use of the sky on a quad-dimensional basis. Instead of using just vertical and lateral separation, it uses all three dimensions of the sky plus time. Instead of keeping aircraft confined to a thin airway, it allows full quad-dimensional use of the airspace. By allowing full use of the entire sky, and not being confined to a single-lane airborne highway (with no passing lane), airlines are allowed to make fuller use of all their assets, which include the entire sky, aircraft, employees, and airport facilities.

D. The Economics of Jet Operation

The piston-engine airliners of the 1950s were not as altitude-critical in regard to operational efficiencies as today's jets. At lower altitudes, they did not burn significantly more fuel than at higher altitudes. In fact, some airlines preferred to keep their DC-7s operating at lower altitudes to reduce oil-burn and engine wear caused by the strain of climbing to higher altitudes. In the same manner, within a wide latitude, they did not lose fuel efficiencies when forced to fly at slower speeds.

Modern jets travel at substantially higher speeds than the piston engine aircraft of the 1950s. Fuel is a major cost factor. But just as importantly, *jet aircraft have very different sets of operational efficiencies than did the aircraft they replaced*. Our 1950s approach to ATC often requires that jets operate in modes that are not suited to maximum efficiency.

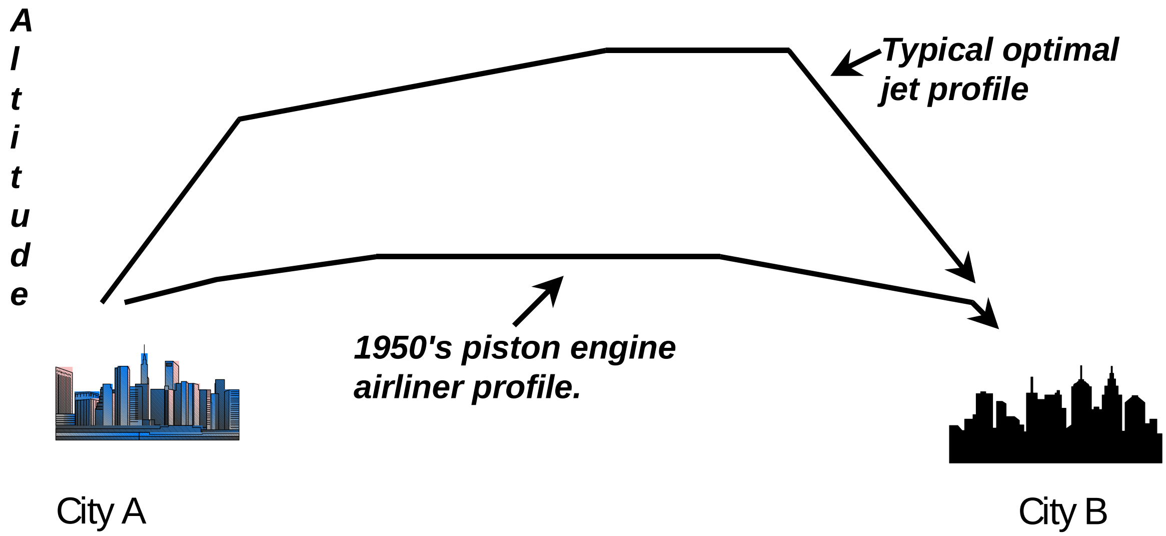
Low altitudes and slow speeds materially decrease fuel efficiencies. The current system is one that very often requires jets immediately after take off and on arrival approach to remain at very low altitudes and lower than optimal speeds often for extended periods of time. This is because the current ATC system forces jets into long "conga lines" especially when approaching major hub airports. Every day, thousands of gallons of jet fuel are unnecessarily wasted in this process.

The cost is borne by the consumer who pays higher fares. It is borne by the taxpayer, who often foots the bill for additional airport facilities. It is borne by smaller communities to which air service is restricted by high costs of ATC and slot constraints at gateway airports. And it is borne by airline employees, whose jobs are threatened because their employers must operate 1990s aircraft in a 1950s environment.

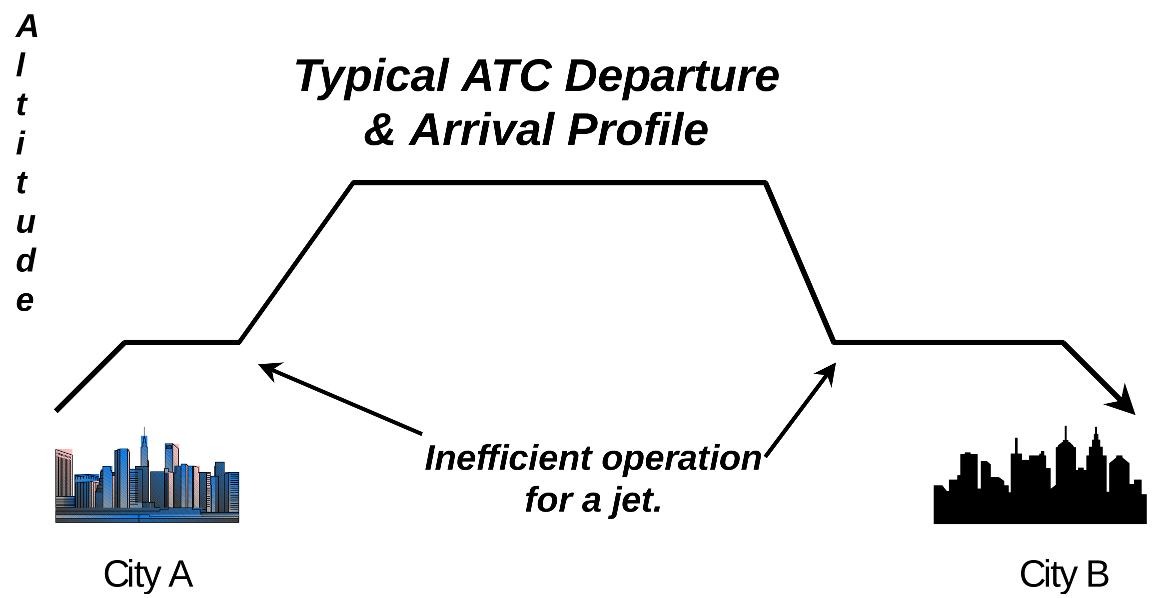
On the following page is an illustration of flight profiles. A jet aircraft is most fuel efficient at higher altitudes. It operates best when it can climb to its cruising altitude and descend only when it is in close proximity to its destination. The aircraft used in the 1950s did not have this operational criticality, and could be kept at lower altitudes without enormous cost penalties. The upper illustration shows a general profile of each aircraft.

The lower profile is one that is more common today. While not to scale, it shows how today's jet aircraft are often held at low altitudes after takeoff and before arrival at the destination airport. This is the result of the need to "linearize" traffic. It also causes significantly higher operating costs for the carriers.

Optimal Flight Profiles



Typical ATC Departure & Arrival Profile



E. Airspace System Efficiency

All areas of cost are coming under increasing scrutiny by airline management. More efficient utilization of resources - aircraft, employees, and airport facilities - is an imperative that airlines must achieve.

An example of this is USAir's "Operation High Ground". The carrier has announced that it will "turn" flights more quickly, with the ultimate goal of using the aircraft asset more efficiently. The company aims to reduce standard "turn time" on a 737 or DC-9 from 45 to 25 minutes. The goal is to try to get more flights out of the same number of aircraft. Unfortunately, the current ATC system is a barrier to this objective.

This illustrates a point: "turn time" is adversely affected at hub-site airports because of the requirement to interconnect passengers. Because of the outdated ATC system, scheduling accuracy is difficult, and "padding" must be built into airline schedules. An example of this "block time creep", on the following page, shows Southwest flying Albuquerque to Lubbock in 17 minutes less time than CALite flies between Providence and Newark. Yet the Southwest segment is 130 miles longer. The reason is the restrictions placed on the CALite flight by ATC.

Airlines make money only when the aircraft asset is moving, i.e., flying with a load of passengers and/or cargo. *Under the current air traffic control system, carriers are unable to maximize this efficiency.* They must pad flight times and ground times, because control of their aircraft asset, once it is airborne, shifts to an ATC system approach designed when Eisenhower was in office. Under a Free Flight system, much of that control is returned to the airlines, and, along with it, much higher system efficiencies.

This is not to say that a more efficient air traffic control system can solve the financial problems facing USAir, or any other carrier more that matter, because ATC is just part of the efficiency-dysfunctional system in which major airlines operate today. A better system - namely, one that allows Free Flight - can, however, allow each airline to make business choices currently denied by the ATC system. This would make a major contribution to reducing overall direct operating costs. By allowing airlines to operate the routings best for their individual needs, less block hours would be needed for their scheduled operations. Additionally, scheduling efficiency and accuracy would also allow reduction of gate time at airports, thereby improving utilization of these expensive assets as well. At $500,000 or more per boarding bridge (as just one example of how much groundside facilities cost) this is not insignificant.

SHORT-HAUL BLOCK TIME COMPARISON

CALite vs Southwest

CALite

Routing	Mileage	Block Time	Speed (MPH)
Providence - Newark	160	1:12	133
Newark - Baltimore	169	1:00	169
Newark - Buffalo	282	1:12	235
Greensboro - Newark	446	1:32	291
Boston - Norfolk	468	1:40	280
Newark - Dayton	533	1:56	276

Southwest

Routing	Mileage	Block Time	Speed (MPH)
Dallas(Love) - Austin	183	:50	221
Corpus Christi - Houston (Hobby)	187	:45	249
Abuquerque - Lubbock	289	:55	307
Harlingen - San Antonio	233	:50	280
Amarillo - Albuquerque	277	:55	302
Austin - El Paso	525	1:30	350

Southwest's Texas Network Experiences Block Speeds 20% to 25% Higher Than CALite.

NOTES:
1. Scheduled block times as shown in May 1994, OAG
2. All flights operated with Boeing 737-300 equipment

F. Addressing Connecting Hub Needs

In analyzing the type of ATC approach that is needed for the future, one major factor that must be considered is the hub-and-spoke system. Substantial percentages of the delays, congestion, and public inconvenience within today's air transport system are involved with the practice of "hubbing." Hubs offer consumers a significant benefit by allowing many more destination choices per aircraft departure. Hubs are *not* inefficient. The way ATC handles the traffic flows is the problem. And indeed, the way some airlines operate connecting hubs contributes to their own inefficiencies.

The current air transport system in the US is built primarily around the hub-and-spoke system, which simply stated is where an airline concentrates aircraft at specified periods of time for the specific purpose of interconnecting passengers between flights. The location of these hubs is the result of corporate decisions of the airlines involved. This is a key point - connecting hubs are the result of subjective corporate decisions. In other words, airlines create connecting hubs, airports do not. And these subjective corporate decisions can (and indeed have) been reversed. Dayton, and San Jose are examples of former connecting hubs.

(*Note: the term "hub" used in this document refers to airports where an airline has made the cognizant decision to interconnect passengers. This is not to be confused with the FAA's definitions of "hub" which are based only on size of the traffic base, not on the levels of interconnected passengers. The FAA definition is an anachronism from the 1950s, and has no relationship with the common understanding or usage of the word "hub" in today's aviation industry.)*

Much has been written and opined about the hub system in the past year. Five years ago, hubbing was hailed as the model of efficiency. Politicians, special interests, and their paid consultants worked feverishly to produce "studies" that urgently demanded more hub airports be built. At that same time, ASRC correctly indicated that the nation was in reality "over hubbed" and would experience a down turn in the number of such airports where connecting hubs were operated. History has proven that prediction correct.

Today, with the demise of certain hubbing operations (American as San Jose, United at Washington/Dulles, Eastern at Atlanta, USAir at Dayton, to name a few) clearly appearing in the rearview mirror, many of the same consultants and analysts who formerly urged the building of more hub airports are now claiming that connecting hubs are inefficient. The growth area, some now predict, is in point to point traffic that eliminates or "bypasses" a connecting hub.

Again, this prediction is based on what is seen in the rearview mirror. And again, the veneer analysts are wrong. *For while the hub-and-spoke system is evolving, it will still remain the dominant factor in the US transportation system*. ASRC forecasts indicate that by the end of the decade, approximately 63% of all US enplanements will either originate or connect at a major hub-site airport - essentially the same as in 1993.

Deregulation allowed hubs to proliferate without an ATM system in place to support them. Therefore, for planners working to craft an ATM system for the future, hubs are a crucial factor. The ATC system was designed in a time when connecting hubs did not exist. In 1960 airlines did not schedule 35, 40, or even more aircraft to funnel into and out of a single airport in an hour's time period. Today they do, yet the ATC system does not efficiently address this.

The connecting flight banks at the hub-site airports can range in size from 15 aircraft to 45 or even more aircraft. These aircraft are timed to arrive and depart within close time frames. In the current system, the ability for the ATC system to handle a group of aircraft is limited, especially when weather, runway closure or any other variable enters the system. As stated, the result of this control methodology is minimal flexibility to handle these normal perturbations of the airspace system. As a result, the losses airlines can experience due to misconnections and poor aircraft utilization can be astronomical.

The issue here - the one that must be newly addressed by a reinvented ATM system - is accommodating this "rush" on hub-site airports at specific times of the day. Often this exceeds the current "acceptance rate" at the hub-site airport.

This acceptance rate of an airport is tied to the following factors:

- The number of runways available for the arrival aircraft.
- The final approach segment spacing and aircraft arrival mix.
- Runway occupancy time - how long each airplane is on the runway.
- The weather in the local area.

With good weather, the individual runway arrival rate today is approximately 35 to 40 aircraft per hour per runway. When the weather deteriorates the arrival rate can drop to 25 to 30 aircraft per hour per runway. Also, as the weather deteriorates, the number of runways available for landings typically drops.

To illustrate the dilemma at many hub-site airports, let's look at Chicago O'Hare. Under the current ATC system, when the weather is good the airport uses three runways for arrivals. This equates to approximately an airport acceptance rate of 110 aircraft per hour (based on a runway acceptance rate of 35 to 40 aircraft per hour in good weather). When the weather deteriorates, O'Hare drops to two arrival runways and an airport acceptance rate of 55 aircraft per hour (based on a runway acceptance rate of 25 to 30 aircraft per hour in bad weather) effectively cutting the arrival rate in half. Under the current slot restrictions, at the busiest times O'Hare has a demand for 110 aircraft per hour to meet the airlines' requirements.

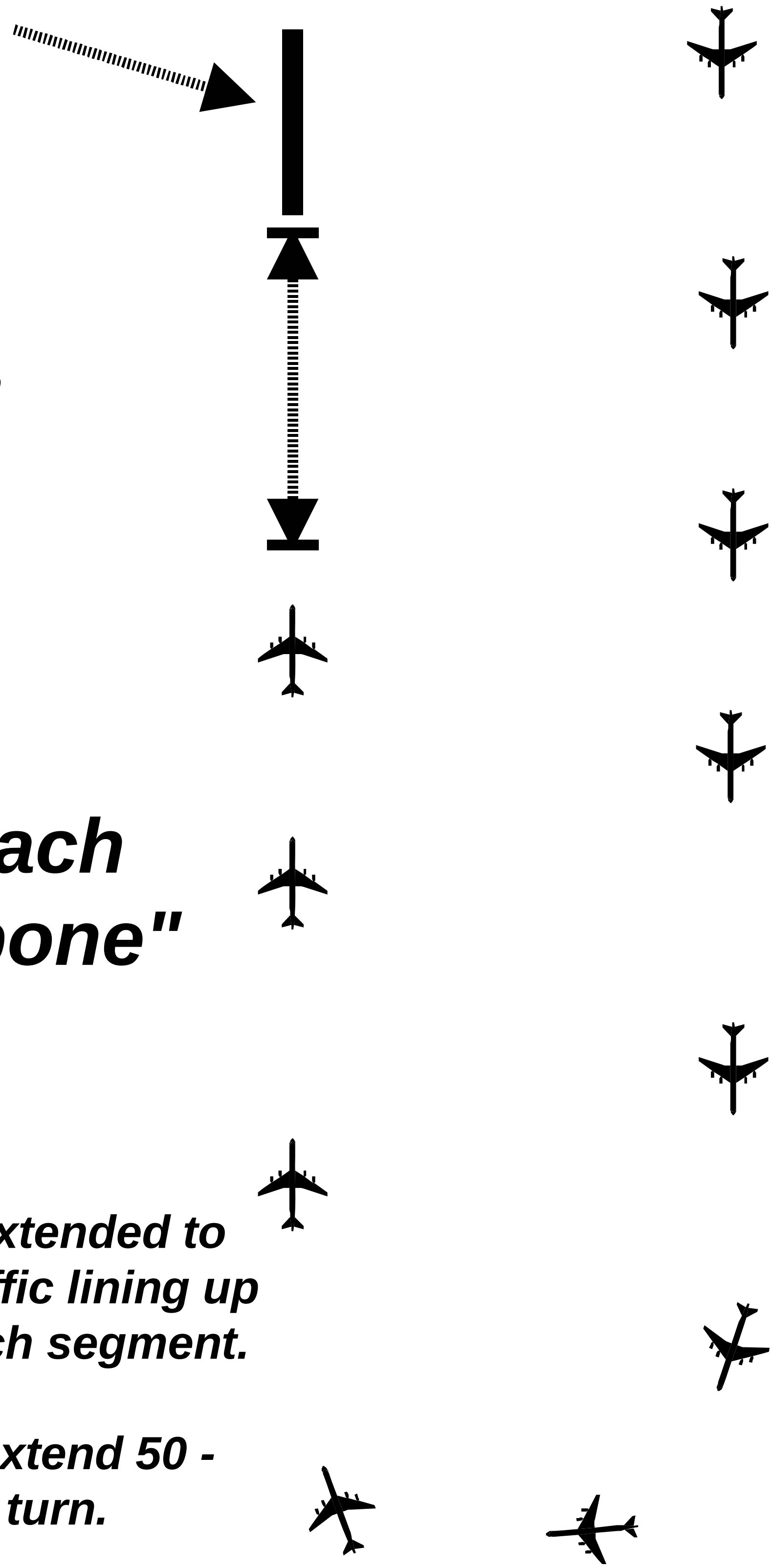
The problem with today's system of using pre-defined routings is that these often become "congested" into and out of hub-site airports, such as O'Hare. Airplanes headed toward the hub-site airport can often be lined up for hundreds of miles on these thin airborne highways, often having to slow down or speed up. Often having to operate at altitudes that are not maximally efficient. This is especially true when weather impacts the hub area.

On arrival in the hub-site airport area, further airborne gymnastics are often required. Because the system is approached in essentially a linearized, two-dimensional view, the aircraft must now line up for the runway in a single file. This often results in a "trombone" routing at the airport that causes jets to fly longer distances, at inefficient low altitudes at inefficiently slow speeds. Enormous amounts of excess fuel is burned.

Airlines see higher costs, resources (gates, aircraft, crews, etc.) are poorly utilized, enormous amounts of productive time is lost and the consumer pays higher fares.

G. Current ATC: Built-in Inefficiencies at Hub-site Airports

The following is an illustration of a typical approach pattern for a large airport. To line up for the runway, aircraft are directed to fly around and form a line up well in advance of the final approach segment. This often creates a "trombone" where aircraft must maneuver into a long line that, in the worst cases, can result in 50 to 60 miles or more of excess flying. This keeps the aircraft "linearized" but also causes them to often fly farther than necessary, at much slower speeds, and at lower altitudes than is optimal for operational efficiency.



Approach "Trombone"

Downwind leg extended to accomodate traffic lining up for final approach segment.

Trombone can extend 50 - 60 miles before turn.

H. ATC - Limiting The Aviation "Production Line"

The cost problems facing the airline industry are immense and in many cases the very survival of certain airlines is at stake. The airline industry's problems are rooted in systems, procedures, and thinking that was developed in the 1940s and 1950s. Today, airlines are saddled with three generalized problems:

- a distribution system that is controlled by outsiders - i.e., the travel agent industry, at a very hefty price (commissions).
- a product that is often viewed negatively by the consumer.
- a production line that is controlled by the government.

The first two bullets deal with the revenue side of the profit equation. The third is a cost item and one that can, and must, be controlled.

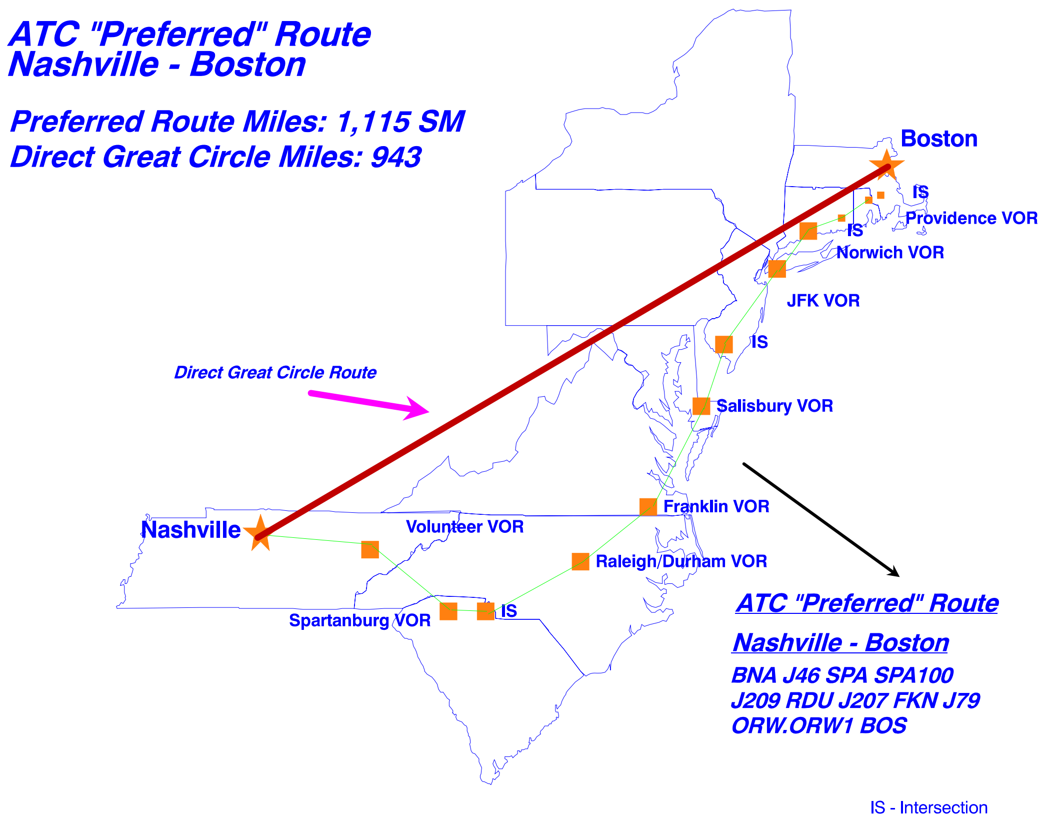
This analysis addresses the lack of production line control by the airlines. What does the lack of production line control cost of each flight? How do airplanes fly from departure to destination? How are they separated while in the air? Why do we have capacity problems? These issues are very important to all airlines operating today, but unfortunately, few top executives in the airline industry have the background expertise to understand the problem except when told that no slots are available. Yet it is a problem that is as critical to airline survival as is fuel or labor.

If a supplier to Ford Motor Company stated that they could not deliver enough parts to meet the needs of Ford's production line, Ford would not slow the line. Instead it would find another supplier. Airlines have a similar problem with airspace, but the supplier - the ATC system - has monopoly control on this resource. The airline industry today is faced with a similar dilemma. The movement of the aircraft is the production line, and yet it is being controlled and limited by the ATC system.

I. ATC "Preferred Routes" - Built-In Inefficiencies

An example of why "upgrading" the current system won't work is displayed in the what is called the ATC "Preferred Routes" program. Unfortunately, preferred does not mean preferential treatment for air carriers. Instead, "preferred routes" waste millions of dollars yearly, and are in place to accommodate the outdated ATC system, not provide the aircraft with the optimum routing. These circuitous routes cost the airlines millions of dollars per year and add a significant amount of additional block time to the airlines operations. The result is a *created scarcity of airspace,* because the remainder of the sky - that outside of the airways - is not fully used.

On the following page is a comparison of an actual ATC "preferred" route - the one airliners are required to take, compared with a direct route. *This is not a hypothetical example.* Airliners today are using this "preferred" routing, wasting fuel, wasting passenger time, costing the airline money, and flying about 18% farther than necessary to get from Nashville to Boston.



This linearized, outdated approach to ATC must be replaced. All the computerization in the world, and making extinct all the vacuum tubes in the world won't change the fact that this type or ATC is inherently inefficient.

J. Under-Utilization Of Aircraft Performance Capabilities

Over half of the airline aircraft flying today have sophisticated, advanced navigation equipment, but today's ATC system has no way to allow the newer technology aircraft to gain full benefits from it.

A Boeing 727-200 built in 1968 flies the same routes as a B-737 or Airbus A-320 built in 1993. The newer aircraft have better fuel economy, and much more advanced navigational avionics. But since the newer aircraft is forced to fly the same roundabout routes and navigational airways as the older aircraft, a large percentage of these new-technology cost advantages are squandered in delays and non direct routings. A quarter-century of advances in navigational technology is wasted.

The airlines have paid millions of dollars to install advanced equipment and continue to pay millions of dollars to maintain it. Unfortunately, airplanes are controlled to the lowest common denominator, effectively negating all this high priced equipment.

VI. Free Flight - A Futurist Approach

Free Flight is a system where today's technology is used to allow full use of the airspace that is available. Free Flight will allow today's jets to operate more efficiently. Free Flight will allow airlines to save billions annually. Free Flight will allow airlines to offer lower fares, thereby opening air service to a wider range of consumers. By vastly increasing the efficiency of air travel, Free Flight will increase the potential for 800 seat VLCT (Very large Commercial Transports) to be an economically-viable reality.

- Simply stated, Free Flight is an ATC approach that allows every operator to fly the routing that is most advantageous to its operational needs at the time of the flight. Aircraft will be free to operate "direct", or to operate at the altitudes and routings that make best advantage of the wind conditions. There would be no more airways or fixed altitudes into which airliners would be forced to line up. There would be no more time-consuming and wasteful approach gymnastics such as the approach "trombones."

Free Flight varies from ambient mainstream thinking. That notwithstanding*, it is the system that will be used in the future*. If not in the next five years, then in the next 15, 20 or 30. The only question is how long aviation authorities (both in the US and in other countries) continue to dither around with trying to update the current obsolete ATC approach. Free Flight is not a question of *if.* It is a question of *when*. The sooner it is pursued, the greater the economic benefits.

While radical in concept, in reality this approach would allow enormous new capacity, and do so with safety at or above current levels. With currently available technology, conflicts would be resolved quickly and safely, and workload pressures on ATC controllers can be significantly reduced.

Two initial - and quite understandable - questions arise when Free Flight comes into consideration. The first is the issue of whether such a system would result in airborne chaos, and the second is whether aircraft would fly de facto airways as a result of all aircraft flying between two points trying to take the same routing.

The first, regarding airborne chaos, is answered by technology. The technology now exists where the routing of each aircraft, and its protective "bubble" (a defined area around the aircraft), would be projected forward, and conflicts with other craft identified well in advance. In fact the Free Flight system will actually increase safety. Put simply, two aircraft flying at the same fixed altitude or on the same lateral path, as done today, are more likely to collide than are two aircraft flying at random (or cruise climb) altitudes. System control which forces aircraft to fly on a limited set of common routes, fix points and altitudes can actually increase the statistical probability of a collision, were it not for air traffic control. This issue is not a technical or safety issue, but a political one.

The second concern is whether all aircraft traveling between the same points would naturally seek the same flight path. The answer here is simply, no. Let us first remember that the system is **not** two-dimensional, as is a highway. It is in fact *quad-dimensional* - the three dimensions that make up the sky, plus the additional dimension of time. Within this quad-dimensional environment is the fact that virtually every aircraft has a different set of variables - load, corporate objectives, wind interpretation, flight technique (or in the case of airlines, flight standards), plus several more.

The reason is that each aircraft is different - even if not a different type, the chances of having the exact same load, the same individual needs, and the exact flight path are almost nil.

Let's use to Chicago/O'Hare to DFW as an example. And let's say that both United Airlines and American Airlines both have DC-10-10s leaving at 0900. True, both aircraft are essentially the same in seating configuration and cargo capacity. But the chances of the load on both flights being the same are quite slim. American might have more cargo. United's Captain may call for a different fuel load than the American Captain. And the loads on each aircraft would be different - passenger, baggage, cargo, would all vary, thereby affecting the flight regime chosen by the crew of each aircraft. Additionally, each airline will plan the route of flight with its own flight planning computer, based on that airline's interpretation of the wind data. The output of these two flight planing computers for the "optimum" path is typically different.

Add to this that the corporate objectives for each flight will be different as well. The AA flight may have a 40 minute ground time scheduled at DFW, and has 150 passengers connecting at DFW. The need to be on-time is essential to make these connections. The United flight, on the other hand, may have 60 minutes ground time at DFW, with its return departure time from that airport "paced" to arrive within a United flight bank at ORD.

The AA flight has an interest in being at DFW to meet a bank of outbound connecting flights. The United flight has DFW as an end point for its passengers, as UA does not have a connecting operation at that airport. Therefore, American may fly at a speed that provides the fastest en-route time. United may fly at the speed that provides the most fuel economy. Finally, even if all the variables matched, the aircraft would be spaced on takeoff. This time variable alone may mean that the two aircraft never are within a miles of each other enroute.

With these variances, it is almost impossible that these two aircraft will each seek the exact *same* altitude and the *same* routings at the *same* time. This is a simplistic example, but it provides an idea of the range of variables that enter the picture. Even in the example given, it is more likely that the United flight would be operated by a 737, which typically has a slower cruise speed and different optimum altitude (a function of weight) than the DC-10, thereby adding another entire set of variables. The bottom line is that "optimum" is a function of the complex set of variables that are applied by each individual airline. The chances that all these variables would match and the airline process them the same way is almost nil.

A. The Goal

The ultimate goal of Free Flight is to have each aircraft depart on the operator's schedule, fly the optimum route and altitude as defined by the operator and arrive at the gate within a few minutes of the same time day after day, with zero delays. For scheduled airlines, the movement and speed of the aircraft is effectively the airline's "production line". The management of any company's production line is critical to the profit or loss of that company. Today ATC controls the airline's production line. *Free Flight returns control back where it should be, the airline.*

This is made even more critical with the evolvement of the hub and spoke system. For while today the airspace resource is rationed and controlled by the current ATC system, under Free Flight the route optimization and hub arrival stream must be choreographed by the airline. In other words the airline would move to a “just in time” aircraft scheduling system instead of a “waste of time” system.

This optimum route is based on fuel, time, crew costs, connections, weather, etc. for each individual flight. Hub arrival streams must be optimized for minimum taxi time, gate availability, zero congestion and minimum bank time.

These production line choices must be given back to the airline. The question is do the laws of physics preclude this capability. The answer is emphatically no, it's not physics that precludes this -- it's the separation methodology of the current ATC system. The solution is the Free Flight system.

B. Example of A Free Flight Operation

Let’s look at how the Free Flight system will work. First let us examine a typical flight controlled by the airline, (rather than by ATC, as is done today) into a hub operation, devoid of artificial constraints and apply only physical constraints based on technology available today. The key word here is "available" since a lot of the "available" technology is not implemented.

The following example, Utopia Airlines flight 697 Los Angeles (LAX) to Chicago O'Hare (ORD), will illustrate this future system.

- **TAKEOFF MINUS 15 minutes** - Utopia Airlines dispatch department forwards flight 697's 4D (four-dimensional) flight plan to the reinvented ATM system. Note that this is to notify ATC of the flight plan, not seek approval.

- **TAKEOFF MINUS 10 minutes** - The crew of Utopia flight 697 receives the 4D flight plan, via data link, fed *directly into the aircraft Flight Management System (FMS) from Utopia Airlines dispatch department*. The pilots verify it and forward it to ATM to complete the loop.

- **TAKEOFF MINUS 8 minutes** - Utopia 697 receives taxi and local area departure clearance from ATM. For sake of realism, let’s now add some weather problems - a line of thunderstorms approaching the destination airport. Utopia dispatch is advised by ATM that “scheduled arrivals” may require a 12 minute hold (under today’s ATC system, this typically causes 30 minutes to hours of delay) at the destination. Utopia Airlines dispatch makes the decision to depart Los Angeles on schedule, instead of waiting on the ground at LAX for 12 minutes. The reasoning is that Utopia feels that the thunderstorm will not truly effect the arrivals as forecast by ATM. Free Flight allows these business decisions to be made by the operator. This also gives the operator the flexibility required to run their business efficiently.

- **TAKEOFF MINUS 5 minutes** - Utopia flight 697 taxis to runway 24L for departure.

- **TAKEOFF** - Utopia 697 departs and an Automatic Dependent Surveillance (ADS[3]) data link message is sent to both ATM and Utopia dispatch. Immediately upon breaking ground, the aircraft turns to the optimized route and climbs to the optimum altitude as defined by the airline.

- **TAKEOFF PLUS 8 minutes** - Still under local radar control, ATM detects that a bubble to bubble conflict will take place in 9 minutes (Takeoff plus 17 minutes) between Utopia 697 and Delta flight 102, which is out of Salt Lake City for San Diego. They then inform Utopia 697 of this future conflict. The Captain of Utopia 697 chooses to speed up slightly to avoid the conflict and advises ATM and dispatch.

- **TAKEOFF PLUS 16.8 minutes** - At Flight Level (FL) 312.3 (equates to an altitude of 31,230 feet), Utopia 697 enters the Vertical Navigation (VNAV) cruise climb mode (slow climb to maintain optimum performance altitude as fuel is burned) and slows climb to the optimum continuous climb.

- **TAKEOFF PLUS 1:08 minutes** -- ATM uplinks an ADS request and an ADS message is sent to ATM and dispatch. The request was triggered by a computer predicted potential conflict at TAKEOFF PLUS 1:22 minutes at FL 334.7. Since the rate of climb has slowed considerably and the Flight 697 was off the 4D plan by 3.1 minutes and 247 feet, it is determined that no conflict (defined as the protective bubbles touching) will occur.

- **TAKEOFF PLUS 2:49 minutes** - Based on updated wind forecasts, Utopia dispatch has determined a more favorable routing for flight 697, and sends an updated 4D flight plan to both the flight 697 and ATM. The pilots of flight 697 verify and accept it. The new flight plan is then resent to ATM from the aircraft to close the loop.

- **TAKEOFF PLUS 2:52 minutes** - The movement of the line of thunderstorms that were predicted for O'Hare has shifted in the past two hours and is no longer a threat. However, Utopia dispatch advises Utopia 697 of a 3 minute delay for touchdown and gives Utopia 697 the Required Time of Arrival[4] (RTA) to the end of the Runway 27L. The three minute delay was based Utopia dispatch wanting to move two other ORD-bound Utopia flights ahead of 697. Both these flights are behind schedule due to weather en-route, and this will allow Utopia ground crews more time to get passengers and bags transferred to the rest of the connecting flight bank. The pilots of Utopia 697 slow down to meet RTA over the end of the runway within plus/minus 5 seconds. ATM is also advised.

- **TAKEOFF PLUS 3:07 minutes** - The pilots of Utopia 697 advises ATM of the descent point and planned rate of descent as they near O'Hare.

[3] ADS - Automatic Dependent Surveillance - This is a data link message sent from the aircraft to ATM and Dispatch providing the aircraft position, speed, winds and the aircraft flight path for the next 20 minutes. This function is planned to replace radar.

[4] RTA - The ability of the FMS to navigate to a point in space and arrive at a specific time. The FMS will speed up or slow down the aircraft automatically, to arrive as required. Future functional FMS requirements, as defined by International Air Transport Association (IATA), define RTA at plus or minus 5 seconds.

- **TAKEOFF PLUS 3:20 minutes** - ATM uplinks an ADS request and an ADS message is sent to ATM and dispatch. The request was triggered by a computer predicted potential conflict at TAKEOFF PLUS 3:27 minutes at FL 184.3 with Utopia Airlines 737-300, flight 202 westbound from Buffalo to Tucson. It is determined by ATM that a conflict, in fact, will occur and Utopia 697 is advised. Since both aircraft are Utopia Airlines flights, the Tucson-bound flight, ahead of schedule, slows down to avoid a conflict. ADS messages continue until the conflict is resolved at a rate increasing from 5 minutes to 30 seconds.

- **TAKEOFF PLUS 3:45 minutes** - Utopia 697 touches down and taxis to the gate.

As described below in the Technical Analysis section, the equipment and software to allow the above flight to happen are available today. This is not "rocket science" we are dealing with here.

C. Capacity Constraints Within A Free Flight System

Under a Free Flight, the only real capacity constraint in the airspace system will be the Runway Occupancy Time (ROT). Under a Free Flight, airport demand will be limited by the airline itself because of available gate space at the hub airports. It is not feasible to land 50 aircraft at an airport for a hub operation if there only parking or gates for 30. As real capacity at the airport rises to the physical limits of the airline to utilize the gates and facilities in place or those that may be built in the future.

At a large connecting-hub operation with scheduling accuracy down to the plus/minus 5 seconds **in all types of weather** the banks and efficiencies would increase dramatically.

With the aircraft and runways in place today (no new technology required) the theoretical runway capacity equates to 55 seconds between landings. This 55 seconds allows the first aircraft to land and exit the runway before the next aircraft lands. Today this is done by visual radar interpretation of the traffic by either the ATC controller or the pilot. This method of arrival sequencing, however, limits arrivals to every 1.5 minutes in good weather and every 2 minutes when the weather is bad. A significant portion of the runway resource is wasted.

With a high degree of scheduling accuracy, limiting the "waste" of the runway asset, and three arrival runways operating at O'Hare all 45 aircraft in the bank could land in 13 minutes. Calculating 5 minutes to taxi to the gates, 20 minutes at the gate for the last aircraft to arrive, 5 minutes to taxi out, and departure in 13 minutes, total bank time is 56 minutes. Misconnects, lost baggage would be zero except for mechanical problems and gate space could be utilized to the maximum.

With schedule accuracy, bank times would be based on each airline's ability to move the passengers and baggage from aircraft to aircraft, not the airspace system. Using this scenario, the efficiency of an airline's hub would be based on its internal organization, not outside control. In other words, the airline that does a better job would have the lowest costs and maximum productivity.

D. Technical Analysis

1. FAA Data ATC Flow

The FAA already has a considerable amount of data which could be used in a Free Flight system.

Pilots are required to file flight plans (FZ) which enter the "Host" Air Traffic Control Center (ARTCC) computer at the point of departure. Airlines store pre-programmed bulk flight plans to reduce the communication requirements. As mentioned earlier the airlines are required to file a "Preferred Route" to meet ATC's requirements.

Once airborne a departure message (DZ) is generated. Thirty minutes prior to entering the next Air Route Traffic Control Center (ARTCC) the first Host computer alerts the second ARTCC Host computer that forwards the flight plan (FZ).

Once in the sky, as the aircraft moves, each few seconds the position of the aircraft is monitored and a position update (TZ) is generated. When the aircraft crosses from one ARTCC to the next a boundary crossing (UZ) message is recorded. Changes to the flight path are recorded as flight plan amendment (AF). These messages are sent every minute on all IFR, transponder equipped aircraft to System Control Center. The SCC can view the position and track of all the aircraft within radar coverage of the US. The US data is also sent back to each ARTCC for situational awareness outside the ARTCC's local area. Airlines also have access to this data to monitor the ATC system. The end result of the travel path of this data is that every ARTCC has:

- direct access to all local data of all aircraft within 30 minute of and flying in its geographical control area.
- network access to all US aircraft flying.

With this data available the Free Flight system becomes much easier to design and build.

2. Conflict Rate Analysis

Free Flight sounds like a great concept. But is it really possible? Is it feasible? And is it safe? The answer to these questions is, emphatically, yes.

Using just the United States, the average peak number of aircraft flying (IFR and/ or transponder equipped) at any given point in time in the airspace above the U.S. averages 5,200 aircraft (as computed at the SCC). The maximum number ever seen at the SCC is 7,200 aircraft. Given that over 200,000 aircraft can theoretically fit in one statute cubic mile, with today's technology, monitoring only 5,200 aircraft in the airspace above the United States should not be a problem. The problem lies in assuring that two aircraft do not collide.

The FAA has 20 enroute Air Route Traffic Control Centers located throughout the contiguous US. These ARTCCs control all the IFR and some VFR aircraft traffic airborne within the boundaries of the US. The first question that should be asked is "What would happen if every aircraft flew its optimum four dimensional path?" The answer from ATC is that we would have chaos. Remember that the ATC perspective of this problem is based on a view of the world through an 18" screen. Even knowing that this view represents hundreds of cubic miles of airspace, the normal controllers screen looks very crowded with only 10 to 15 aircraft on the screen. We must step back from this view of the problem and examine the true conflict potential in a "Free Flight" environment.

Preliminary computer modeling provides a positive picture. Initial studies by Mr. Norm Watts, FAA Technical Center, indicate that chaos is not the outcome of Free Flight. Mr. Watts has written a simple computer flow analysis simulation (964 lines of code) that looks at actual aircraft data over a 8 hour period. Using this simple aircraft flow, coupled with a comprehensive aircraft flow library (AERALIB[4]) simulation Mr. Watts can predict the number of conflicts by time and altitude. The input parameters can be varied as to the protective bubble size in both the lateral and vertical plane. On the next page, Mr. Watts outcome shows that the conflict rate to be manageable even in the current manual conflict detection system.

Analysis of Predicted Conflicts
Per Hour Per Controller in a Free Flight Environment

Air Route Traffic Control Centers (ARTCC)	FAA Reported Aircraft Handled Annually 1,992	Calculated Daily Aircraft Handled	Calculated % of Total Aircraft Handled	Extrapolated Max PIAC[5] Per Center	Predicted Conflicts Per Hour Per Center	Predicted Conflicts Per Hour Per Controller
Chicago Center	2,580,000	7,068	7.09%	511	140	3.49
Cleveland Center	2,423,000	6,638	6.66%	480	131	3.28
Atlanta Center	2,231,000	6,112	6.14%	442	121	3.10
Washington Center	2,221,000	6,085	6.11%	440	120	3.08
Fort Worth Center	1,992,000	5,458	5.48%	394	108	2.84
New York Center	1,984,000	5,436	5.46%	393	107	2.83
Indianapolis Center	1,915,000	5,247	5.27%	379	104	2.80
Memphis Center	1,878,000	5,145	5.16%	372	102	2.75
Minneapolis Center	1,806,000	4,948	4.97%	358	98	2.64
Miami Center	1,793,000	4,912	4.93%	355	97	2.70
Los Angeles Center	1,793,000	4,912	4.93%	355	97	2.70
Kansas City Center	1,774,000	4,860	4.88%	351	96	2.67
Houston Center	1,668,000	4,570	4.59%	330	90	2.51
Jacksonville Center	1,663,000	4,556	4.57%	329	90	2.50
Boston Center	1,606,000	4,400	4.42%	318	87	2.48
Oakland Center	1,590,000	4,356	4.37%	315	86	2.46
Denver Center	1,400,000	3,836	3.85%	277	76	2.16
Salt Lake Center	1,379,000	3,778	3.79%	273	75	2.13
Albuquerque Center	1,364,000	3,737	3.75%	270	74	2.11
Seattle Center	1,305,000	3,575	3.59%	258	71	2.02
Total	36,365,000	99,630	100.00%	7,200	1,968	

[5] PIAC - Peak Instantaneous Airborne Count. This is the number of total aircraft flying at any single point in time.

Total A/C processed over 8 hours by Mr. Watt's simulation	13,520
Total conflicts identified over 8 hours	4,611
PIAC per Mr. Watts' simulation over the US	3,153
Highest approximate PIAC (US) recorded per FAA SCC (real data)	7,200
Maximum conflicts in a single hour per Mr. Watts' simulation	862
Extrapolated maximum conflicts in a single hour	1,968
Controller sectors (workstations) available at each ARTCC	35 - 40

The data provided from the simulation and the above analysis is not meant to model a real world scenario, but give an order of magnitude of the predicted conflicts, or in other words the controller's workload in a Free Flight environment. *Using the above example, the most conflicts any one controller would work is on the order of 3 to 4 an hour.* The linear extrapolation of the conflicts per hour is based on the simulation data. This data shows that changing the variables (e.g., separation bubble size) changes the conflict rate as a linear function.

The simulation uses the great circle route (not the airlines optimum routes based on winds), fixed altitudes and disregards conflicts within 5 miles of the airport. Because of these basic assumptions a slightly more in depth program must be developed. The ideal would be for the airlines to send a optimum flight plan to the simulation on a real time basis. In fact, this approach is being advocated by ATA.

3. Free Flight Separation Methodology

A Free Flight path is technically defined as a flight plan specified by a four dimensional polyline, as opposed to a flight plan specified by fixed track, points and fixed altitudes or altitude blocks. ATM automation must be able to look ahead on the aircraft's flight path to determine if a future conflict exists. This "conflict probe" will allow ATM personnel to see not only the occurrence of the conflict, but also the exact distance between the two aircraft a the closest point, long before the conflict occurs. At first blush this type of flight planning and conflict monitoring may seem more complex and in fact, less safe than a fixed track based system. However there are significant factors that may make Free Flight based conflict monitoring not only more efficient but safer than track-based systems.

Conflict resolution could be made by limiting one of the aircraft's flight path in any of four dimensions (lateral (length or width), vertical or time). As new technology is applied, the separation required between two aircraft can safely be reduced. This not only reduces the number of conflicts, but the required change to avoid a conflict becomes minimal. An example of the required maneuvers to provide a conflict resolution is provided on the following page. The table shows that the maneuver is considerable smaller than the normal 10 to 15 degrees required by controllers today. The excessive maneuvers required by the controller are caused because of the requirement to "visualize" the conflict and calculate the resolution mentally. With accurate information the identification of the problem and the solution become "simple".

Lateral Maneuver (e.g., turn)

Separation Required	Minutes From Conflict	Degrees of turn
5	5	7.50
5	10	3.75
3	5	4.50
1	5	1.50

Note: 1 minute of flight time equates to an approximate distance of 8 miles.

The management of the final approach segment is one of the major limiting factors in today's ATC system, therefore solving this problem must have a very high priority. In the Free Flight environment the final approach segment should change to a time-based separation methodology, rather than distance-based separation, as is done today. On the next page is an example of this methodology. Not only is the low altitude, wasteful "trombone" removed, the arrival path becomes much more flexible.

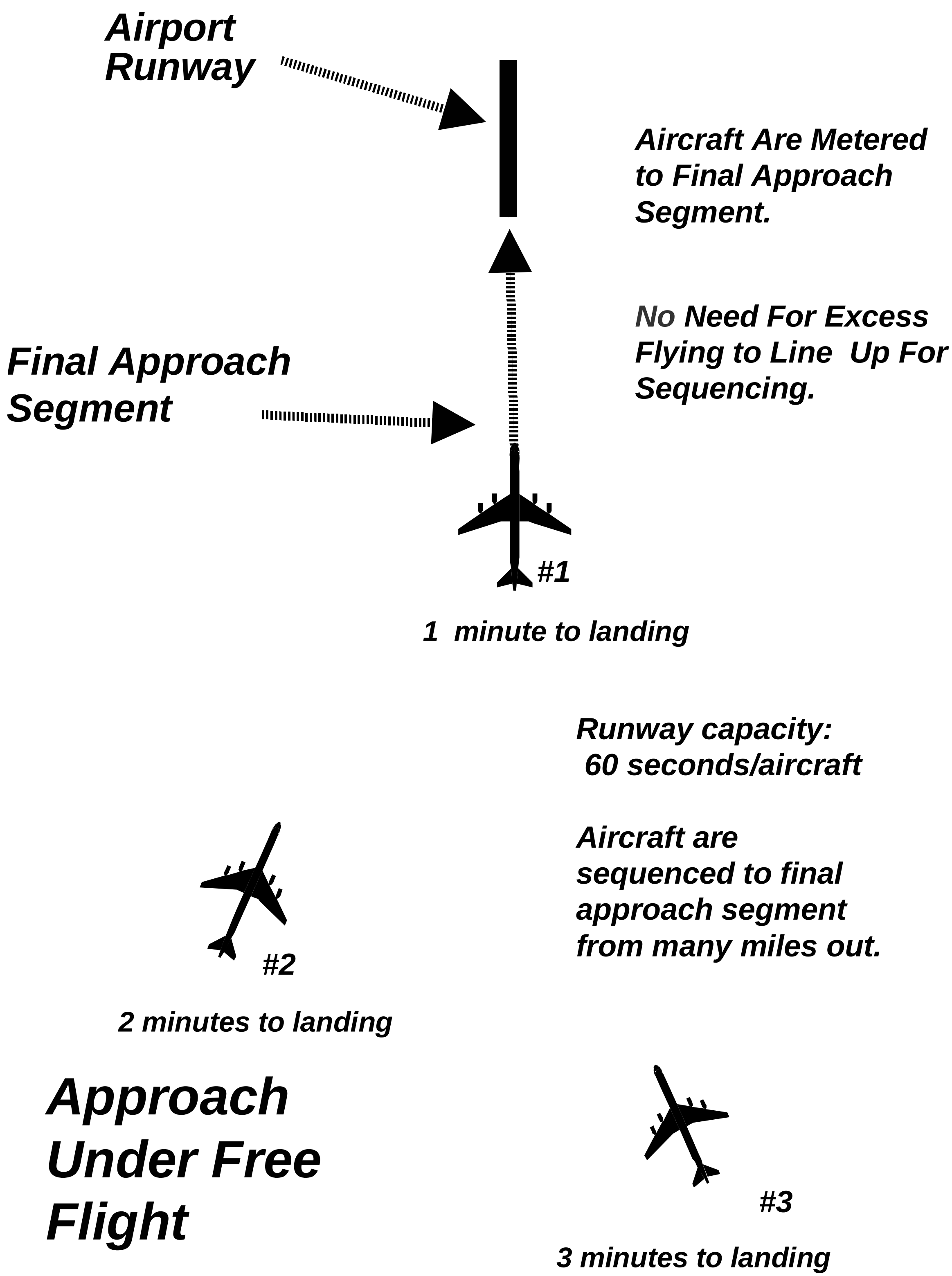
Airlines today already generate quad-dimensional flight plans. These paper flight plans typically are accurate to within one to two minutes, absent of ATC restrictions. Many commercial aircraft also use Flight Management Computers (FMC) which operate on quad-dimensional (4D) flight profiles. These FMCs are capable of operating accuracy measured in seconds, with some of the current systems able to meet specific RTA requirements.

A prime delay generator today is runway changes required by winds or other weather problems. In today's ATC system this can take 10 to 20 minutes which puts significant delays into the system. Under the Free Flight "time based" arrival system this becomes a much easier problem. Since the aircraft are enroute to a point only a few miles from the end of the runway with a set RTA, all arrivals are now given a new RTA to the new runway. Reordering the first few affected flights to the new runway becomes easy based on their previous RTA and distance to the new runway. The wasted runway asset drops by a factor of 10, from 20 minutes to under two minutes.

Another important factor limiting today's final approach segment is wake vortices. This are small areas of circular wind that are generated by the aircraft wing tips. Because of the severity of this circular wind, spacing of aircraft on final approach is elongated, with the largest spacing when a small, light aircraft is following a heavy aircraft (e.g., a Beech 1900 following a B747). Under Free Flight two solutions can be applied to this problem.

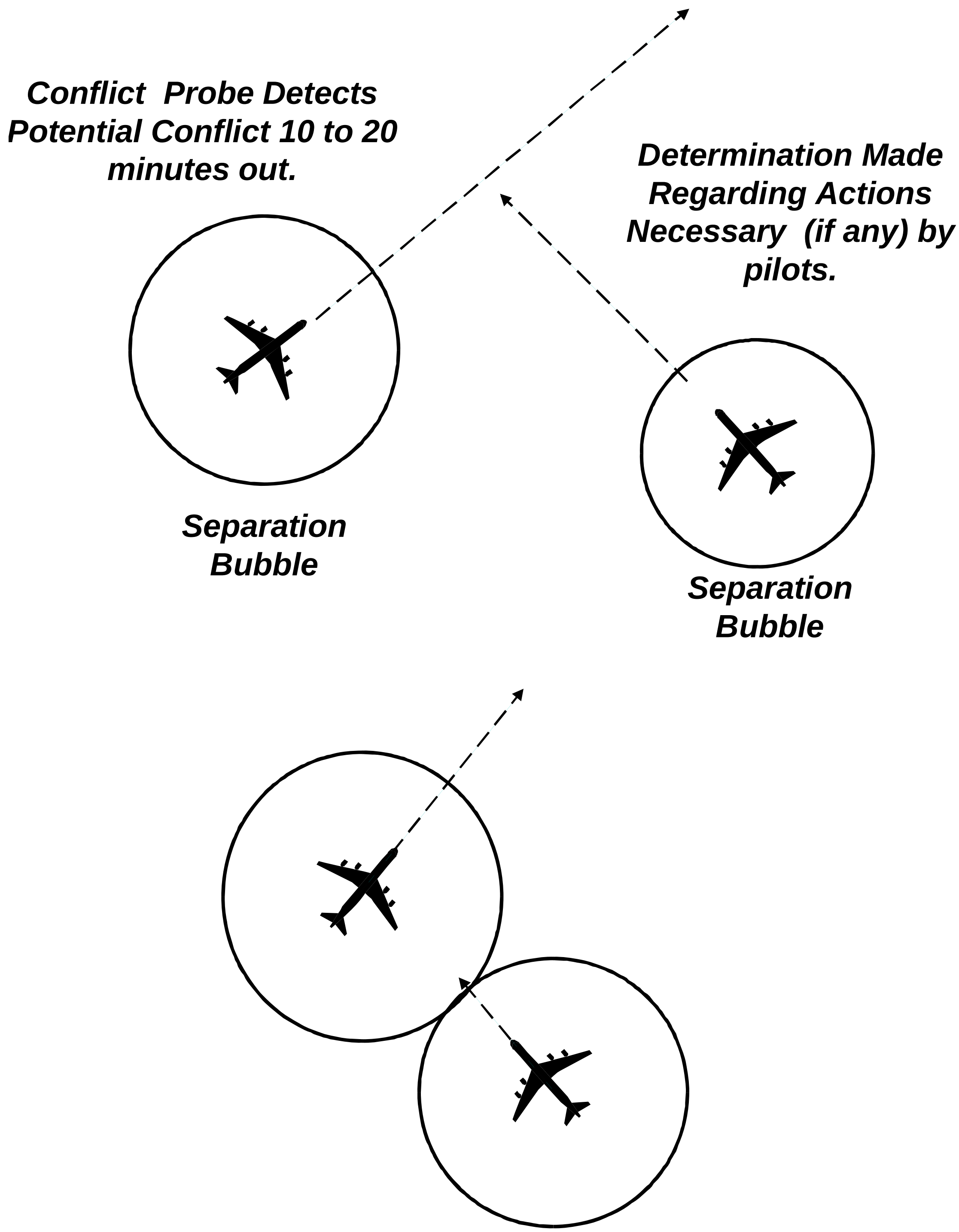
The first, especially important at the hubs, is for the *airline* to choreograph their arrivals so that all heavy aircraft arrive to the same runway, one after another. This lowers the separation between aircraft since a heavy aircraft following another heavy aircraft is not as affected by the vortices. This also makes good operational sense, since the largest aircraft have the longest ground turn time, and could be bunched to arrive at the beginning of the operators bank and all depart at the end of the bank.

Secondly, the aircraft glide path (or vertical descent path) near the runway can be varied. Since, as a rule of thumb, the vortices travel down and out from the aircraft wingtip at 5 MPH, flying above the preceding aircraft significantly reduces the probability of encountering the vortex. In fact, this is exactly what is being done today by pilots in good weather and is one of the largest factors in VFR runway acceptance rates being 30% to 40% higher than IFR rates. GPS, would be an important part of the this solution. Using GPS, smaller aircraft could be put on a higher glide path with a touchdown point farther down the runway. All these technologies exist, the industry needs the political will to demand their implementation.


Airport
Runway
Aircraft Are Metered
to Final Approach
Segment.
No Need For Excess
Flying to Line Up For
Sequencing.
Final Approach
Segment
#1
1 minute to landing
Runway capacity:
60 seconds/aircraft
Aircraft are
sequenced to final
approach segment
from many miles out.
#2
2 minutes to landing
Approach
Under Free
Flight
#3
3 minutes to landing

Enroute separation under Free Flight must also takes on a new approach. The example of the Free Flight separation model below shows two aircraft approaching the same point at the same altitude. With a conflict probe, ATM would know 10 to 20 minutes ahead (top drawing) of the two bubbles touching that no action is required. The bottom drawing shows the closest two aircraft could pass without ATM action. The protective "bubble" size is determined by the Actual System Performance (ASP) of the aircraft. The ASP would be measured based on the aircraft's real time C/N/S capability projected through the conflict area. If the two bubbles were predicted to overlap, ATM would give the pilot a small restriction or maneuver to prevent the overlap.

Free Flight Separation Model



4. Technology Required

It is true that new computer algorithms and equipment both on the ground and in the air will be needed to do the job. Based on the control oriented view of the solution by ATC the equipment required is very complex. Free Flight essentially reduces the complexity of the problem, and therefore the solution. **The hardware and software algorithms required for ATC side of Free Flight currently exist off-the-shelf**.

a) Ground Side

According to Mr. Lonnie Bowlin (President, Aerospace Engineering & Research Associates (AERA), Landover, MD this traffic could be easily handled. Mr. Bowlin's company licenses software (AERALIB) that can predict conflicts for all ATC simulations. Mr. Bowlin estimates that a single 90 MIP engineering workstation computer at a cost of about $37,000 could monitor all airborne traffic within the ARTCCs control plus all traffic predicted to enter that center within 15 minutes. This single computer would be able to project each aircraft's flight path for the next hour, predict conflicts and provide a conflict resolution every two minutes or less. AERA has commercially licensing the software to do this task for about four years.

Two to three of these computers would provide the integrity for each of the ARTCCs. By decentralizing the conflict detection and resolution into each center the computational power can be reduced. Even if the SCC did the conflict probe on twice the maximum aircraft (7200) aircraft ever recorded flying at the same time, computational power would not jump significantly.

Medium size airports and above have local control towers (400 airports), with the large airports also having local area radar approach control. Once aircraft are in the area of the airport (departing or arriving) these local facilities take control (there is that dreaded word again) of the aircraft. The technological requirements to provide "Free Flight" by each of these ATM facilities would be exactly the same.

b) Airborne Side

As discussed the ATM system must move to a time based flow management system. This will require significant upgrades to the airborne equipment. Although, most new airliners have advanced equipment, as stated above they are unable to use it. Free Flight will require an upgrade for new FMCs, communication and surveillance equipment even for the newest aircraft. But the technology is available today. The corporate commitment, based on the lack of Return on Investment (ROI), is missing. Free Flight will provide this positive ROI.

VII.Non Solutions to The Problem

A. Privatization of ATC

One of the major problems with privatization is the belief that it is the panacea for all that is wrong with the Air Traffic Control system in the United States. Simply, it is not. This is not say that privatization as a general concept is a bad one per se. But the proposal on the table to privatize ATC is not consistent with the goal of reinventing ATC. Instead, it is a political side-show, accessorized by "studies'" that are little more than glowing sales brochures.

Under the current plan to privatize, air traffic would continue to be controlled in the same manner as it currently is, and not *managed* as it needs to be. That is the same basic principle of airway routings, trombone approach procedures and standards of separation would continue to be employed. The operational capacity of the system would not be significantly improved, and would not provide near the gains in operational efficiencies that the Free Flight approach would.

The Federal Aviation Administration, Corporation Assessment Task Force completed a study in May 1994 entitled Air Traffic Control: Analysis of Illustrative Financial Scenarios. The study was intended as a financial analysis of the proposed US Air Traffic Services (USATS) Corporation. It can best be described and an advocacy document extolling the virtues of privatization. This is not a document that would be useful in the private sector for the purpose of making an investment or business decision.

1. Revenue and Cost Projections

The document states that funding for the USATS would come in the form of user fees, primarily airline passengers. Beginning in 1996, revenues for the privatized ATC system would be generated as follows:

Passenger Ticket Tax	8.15%	This is generated from the existing 10% tax already assessed on airline tickets and used to fund the FAA.
Freight Waybill Tax	5.00%	This is generated from the existing 6.25% tax assessed on all cargo/package shipments.
International Departure	$4.80	Assessed per departure, and generated from the existing assessment on all passengers departing the United States.

It is important to note that the burden of funding is on the airline industry (and its customers), a group that after years of losses totaling billions of dollars can ill-afford additional expenses. Yet it is likely that this will be the case under a privatized ATC as currently proposed by the DOT.

The range of revenue and expenditure scenarios in the FAA document is limited, and does not provide enough information and analysis to make an educated decision regarding the true financial viability of privatization. Therefore, given the gravity of the subject matter, this FAA report is not felt to be reliable.

Two expenditure scenarios are discussed, base spending and accelerated spending. These focus on operational costs, with little analysis provided regarding different revenue scenarios. As in private industry, downside risk must be given adequate attention in order to make an informed investment decision. The FAA document is essentially devoid of any such analyses.

The basic revenue growth assumption through the forecast period appears optimistic, exceeding 6.0 percent annually. Limited analysis of slower growth was conducted by the FAA's consultant, which stated that "if the passenger-ticket revenue growth were only 5 or 4 percent, then user fees would need to be increased 7.6 or 12.2 percent, respectively, to achieve break-even results (assuming no reduction in expenditures)..."

The FAA document further states: "Passenger ticket revenues are projected to grow based on increases in air traffic (revenue passenger miles) and on improved yields. Based on the latest FAA forecast, domestic RPMs would increase 3.7 percent annually between 1994 and 1998. Yields are expected to improve based in part on inflation, which projected at an average annual rate of 3.2 percent over the next several years. The combined total indicates that aviation revenues would be growing at a nominal rate of around 7.2 percent a year through 1998. The task force projection reflects a slightly lower growth rate in later years, resulting in an average growth rate of 6.4 percent through 2005."

There are some core problems with these assumptions:

- *Based on the fact that the passenger-ticket revenues are tied directly to airline strategies, the assumption the industry as a whole will achieve 7.2, and later, 6.4 percent annual growth rate is aggressive and not consistent with airline industry trends. This is particularly true as airlines currently re-shape a significant amount of their capacity. Southwest, Continental, USAir and now United are all focusing on implementation of low fare services. Passenger numbers may grow at a faster rate than RPMs and average yield may, or may not, increase, however average fare paid (and hence taxed) may actually decline. This possibility is not discussed in the FAA report.*

- *Between the first quarter of 1991 and the last quarter of 1993, passenger yield for the major airlines in the United States grew an anemic 2.3% (NOTE: This figure has not been adjusted for inflation, so true percentage is actually lower). As low-fare, new entrant carriers emerge and the influence of Southwest Airlines pricing structure spreads, yield growth can be expected to grow at the same slow (if not slower) pace. Again, the FAA report fails to mention this.*

- *Unfortunately, FAA traffic projections may be optimistic. Between 1987 and 1993 passenger enplanements in the United States grew a mere 5.8% <u>total</u>. It can be assumed that RPM growth tracked similarly, possibly with only a minor variance due to minor changes in average trip length. For the periods 1993 through 1998, ASRC, in its publication* ***Airports:USA*** *which is the only 5-year forecast produced independently in the private sector, projects 13.8 percent growth in enplanements is projected, which equates to an annualized average of 2.3 percent. This is below the*

3.7 percent growth rate optimistically forecasted by the FAA, but well above the 1987-93 enplanement growth actually experienced.

- *The overstated projections are critical to the financial viability of the ATS, particularly when passenger ticket tax revenues are forecasted to represent approximately 67% of total annual funding. Considering that history, as well as our independently produced traffic forecast, it appears that the projections in this study are optimistic, and a revenue short fall by ATS appears very possible.*

An analysis of differing revenue scenarios is important to ensure that a viability determination of USATS is approached from all angles. The FAA study assumes that a revenue short-fall would be made up either by cost-cutting measures or increased user fees. There are fundamental problems with this assertion:

- *One would hope that a newly privatized ATC system would have few costs to cut. Like any business in the private sector, it should be as efficient and tight-belted as possible. It is assumed that the corporation would already be a lean and highly efficient "business". The major cost cutting area in a normal business would be to reduce services, and in the ATC business a reduction in services would mean either a reduction in safety or a reduction is available traffic management. The first would be intolerable, and the second would result in delays.*

- *An increase in user fees is not the solution. As passenger ticket tax revenues comprise approximately 67 percent of the annual funding required to run the system, a revenue short fall to USATS would likely mean higher airline costs that would likely contribute to a decline in passenger traffic and/or airline yields. A revenue short fall could be cause by numerous factors, including recessionary factors. In this situation, airlines would need to stimulate the market, probably with lower fares, which would increase revenues. Imposing increased fees and taxes would force airlines to pass the cost onto consumers which would slow down any stimulation. Its a vicious cycle in which nobody wins. The FAA report does not address this.*

The document goes onto say: "A one percentage-point change in the revenue growth rate would reduce the corporation's annual revenues by an average of about $300 million. At a higher revenue growth, user fee rates could be reduced further; at lower growth user fee rates would need to be increased (and/or expenditures cut) in order to avoid losses."

- *The variance between the ASRC projected revenue growth of 6% (not adjusted for inflation) and the FAA projected growth of 7.2% equates to a 1.2%. This variance affects 67% of the total revenues, or a reduction in the total revenue picture of 8/10ths of 1 percent. In dollar amounts, this represents a revenue reduction of $240 million dollars annually in projected funding for the air traffic control system.*

- *Tacked onto the projected operating expenses for the period 1996-2005, the privatized air traffic control system is facing a cumulative deficit of $2.24 billion dollars.*

- *This projection is likely conservative, as the FAA has been given the benefit of the doubt that its revenue projections derived from cargo waybills and international enplanements are correct, and it is assumed that the cost projections are also* *correct. Judging by the lack of attention to potential downside risks in the FAA report, this assumption is questionable*

The document states that "in all scenarios examined, USATS is financially viable with revenues sufficient to cover operating and investment costs". The problem with this statement is that, conveniently, only positive scenarios were examined, and only minimal and optimistic analyses were conducted of the possibility and implications of a revenue short-fall. Insufficient attention has been given to downside events that would have material negative effects on the USATS revenue stream.

2. Assumed Benefits of Privatization

The report makes assumptions as to the benefits which a privatized ATC system will provide users. Unfortunately, these do not appear consistent with reality.

The report states: "From the users perspective, benefits would be realized in two ways: through a new and structure of user fees and taxes that would be at or below the current levels, and through enhanced service in the form of improved efficiency and safety"

- *The report issued by the FAA states that under the Accelerated Investment scenario there would be substantial safety, delay reduction and operating cost savings. The Accelerated Investment scenario was, basically, the re-equipment program which was recently cut-back due to continuing problems, delays, and cost overruns. Worse, it is based on retaining the current approach to ATC, which in itself is the problem.*

- *The odds of seeing reduced user fees and taxes appear slim. In contrast, unless significant cost savings are achieved, a revenue/expense shortfall is likely and user fees will need to be increased.*

- *The talk of efficiency in the FAA document focuses on the internal customer, i.e.: the corporation, but ignores the user base, namely the airline industry and other users. It does not address in any substantive way how aircraft are managed and separated. Operating efficiency gains are questionable. Mention is made of GPS, digital communication, data links and like items, however use of these items would still in many cases require employment of the old airway routing system. Further, a dollar amount of $4.2 billion is credited to user efficiency with no explanation as to how this figure was derived. It is felt that this number is impossible to achieve under the current ATC approach.*

- *Under the proposal, safety is also allocated a gain to users of $600 million. This raises two unanswered questions: a) What is the standard methodology for valuation of safety, and b) what makes this private system any safer than the current?*

3. Summary of Privatization

The assumptions that are currently being employed to determine the viability of a private system are faulty, and any reliance upon the assumptions given in the FAA document are risky at best. In reality though, the issue is not one of privatization but of re-inventing the system. The current system does not need to privatized, it needs to be replaced. Then we can talk about privatization.

B. GPS

Everyone from Congress to the FAA has touted the satellite based Global Navigation System (GPS) as the savior of the ATC system. In March of 1994 the House of Representatives Committee on Science, Space, and Technology held hearings on GPS. One of the goals of these hearings was to determine if the U.S. is doing enough to advance these unique navigation system. What most do not seem to understand is that GPS is only part of the solution, not the complete solution.

As discussed earlier, the airlines have excellent navigation capabilities throughout the U.S. that have limited use because of the antiquated ATC equipment and procedures. Why should the airlines upgrade one of the strongest links in the system, if they cannot take credit for the navigational capability they already have? An analogy would be like buying the latest video card for a ten year-old PC, such as an Intel 286 based system. This would be a waste of money since the throughput of the system is limited by the slowest part of the system. In the airline industry, the ATC system is the limiting factor to increased throughput.

Is GPS very important for the full Free Flight FANS implementation? Yes. Will GPS provide worldwide navigation capabilities from departure to destination, including approach and taxi? Yes. *But before the airlines purchase significant upgrades to their current equipment, ATC must change its procedures to allow use of the advanced capability the airlines already have*. The airlines cannot continue to operate on the false assumption that "if we buy it they will come". The airlines have already bellied up to the technology bar to the tune of millions of dollars. This investment has been wasted by the "slowest part of the system" -- ATC.

C. Upgrading The Current System

Some argue that the solution lies in merely upgrading the current ATC system - adding more modern equipment, more staff, etc. This is the equivalent of computerizing the buggy whip - it might work better, but the original purpose for which it was designed no longer exists. The objective must be to develop a system that meets the needs of the customer today, one that makes full use of the technology available. Like any supplier, ATC must deliver the product required. To be sure, in the realm of ideas today, Free Flight may appear radical. But it can be implemented safely and cost-effectively.

Today’s call to upgrade the current system has strong proponents. There are two basic arguments that might be raised regarding the benefits of sticking with the current approach.

<u>Argument One</u>: The Current ATC Approach Is The Only Viable Path

The question must be asked regarding the economic benefits of retaining the current approach versus pursuing a new clean-sheet approach. The current system is safe, so it can be argued that the simple addition of new technology would be the solution to adding more capacity.

This argument fails because it is based on the assumption that the current approach is the only one possible to air traffic management. The enclosed examples of actual operation make it very clear that the current system is inherently inefficient in today’s air transport system. Retaining the current system, and spending billions to upgrade it, is not the only option available. In fact, in terms of long-term increases in efficiency, it ranks closely with doing nothing.

The AAS program was a case in point. AAS, years behind and billions over budget was recently scaled back with whole sections canceled. FAA's plan was to use the new technology to better computerize the current ATC system. Instead of computerize an obsolete system, the US must step out of "it's cave" to see what is possible with the new technology. The FAA continues to satisfy and listen to their internal customers, the controllers, but not their external, and true customer, the aircraft operators. Just upgrading the current system is a waste of technology, and although the system might be improved, the improvement will be marginal.

Argument Two: Untried Approaches Threaten Air Safety

It may be argued that it would be unwise to pursue new approaches to ATC. Trying different approaches may compromise safety, not to mention potentially waste billions on untried technologies.

Simply stated, this argument is stupid. First, the current approach to ATC isn't working efficiently. Secondly, the technologies exist to allow the implementation of a system that is as safe or even safer than that of today. And finally, the real waste of money is to spend it on a system that is inherently obsolete, instead of building a new one that will allow a more efficient aviation system.

VIII.Costs Of The Current System

A. Airline Industry Realities

Fact: Today's ATC approach is one of the major problems that is causing airlines to lose money.

Air Traffic Control today is a cost that US carriers can no longer afford. Airline management must recognize that *the current ATC system is cost item -- a vehicle to produce the product.* It is, in effect, the equivalent of a production line operated by the manufacturer of goods. If the Ford Motor Company were faced with such an antiquated approach to production, it would have junked the old system years ago in favor of a more automated, technologically advanced and efficient system, or gone out of business.

We have heard in the past year that labor costs are the major malaise of the US airline industry. Most aviation analysts have repeatedly stated that labor is the only "controllable" cost airlines face. Just about all other portions of the airline industry cost mix, they claim, are not "controllable." This point of view is fashionable, trendy, and almost universally accepted as fact.

It is also flat wrong.

The ATC system, in which the US airline industry operates, is just one of an entire range of structural expense areas that airlines must address. These "analysts" make the assumptions that the structure of the airline industry, *and the structure within which the airline industry operates,* are set in concrete, i.e., that they are not fundamentally changeable. Both these assumptions are in error. The corporate thinking and many of the systems airlines use to produce their product today have their genesis in the 1940s and 1950s.

But getting costs down is not an easy or quick process. And unfortunately, nor is it one that airlines fully understand. Carriers can easily lower fares. Reducing costs to levels where these new fares can make money is more difficult.

As noted above, too much of the focus in the analysis of airline costs has revolved around inaccurate determinations regarding "controllable" costs versus "uncontrollable" costs. Unfortunately, too much of this discussion has focused on labor costs as the fundamental solution. Labor costs, despite the trendy belief, are not the core problem, *per se*, in the airline industry today. The problem is that the structure airlines use - and in the case of ATC, the structure airlines operate within - is dysfunctional. They no longer work within the environment of the 1990s and beyond.

This dysfunction includes the inability - and in some instances, the unwillingness - of airline executives to question their own fundamental assumptions. As one example, in 1990, an ASRC study noted that airport costs would become a critical item in the future. At that time, only one airline - American Airlines - was attempting to forcefully make this point.[5] Today, other airlines are beginning to understand that every excess dollar unnecessarily spent on airport costs comes out of the bottom line.[6] Likewise, *every extra operational dollar that is spent due to an outdated approach to ATC also comes off* *the bottom line.* Airlines have not yet addressed this issue as such, but as will be seen below, the wasted dollars are enormous and easily identifiable.

- *Let's go back to the earlier example of the "preferred" ATC route between Nashville and Boston. The extra expense of flying 18% more on this one route is chilling. American Airlines has three round-trips per day in that market. If all are required to use the ATC "preferred" routing (or another just as inefficient), the estimated cost to American Airlines is over $900,000 annually.*[7] *Nearly one million dollars spent no more productively than if it were stuffed down a garbage disposal.*[8]

In light of costs like this, the time for quiet reflection, and innocuous industry meetings is over. At a time when airlines are asking employees for salary give-backs, cutting back on capital expenditures, and are laying off staff, to allow the continuation of the current ATC approach is not consistent with prudent management.

B. Putting ATC Costs Into Perspective

It has been estimated by the ATA that $3.5 billion dollars in excess costs are incurred by its member airlines annually due to air traffic delays.

This figure, while substantial, does not include all the costs that will be eliminated, nor does it include important sections of the industry, such as "regional" carriers. There are far more savings that the industry can gain from a reinvented ATM system. And while these costs are difficult to precisely project, they likely go into the billions annually.

One area is in hub-site operations. Approximately 63% of all US scheduled passenger enplanements are generated at or through the 28 largest hub-site airports.[9] In 1995, 345 million passengers will either begin a journey or connect at these airports. Despite the trendy projections of rearview mirror analysts, the hub-and-spoke system will remain the dominant factor in the US air transportation system. It is the core of the US airline system, and it is a system that has brought new levels air access between cities across the nation.

Accommodating the inefficiencies of the current ATC system is literally making an otherwise profitable airline industry bleed cash. The system as structured allows carriers little leeway in making up for delays caused by the current system, and therefore carriers must "pad" scheduled times (block time creep) to accommodate this system. The costs of this inefficiency is joined by the costs of mis-connecting passengers and bags due to the current airway-based ATC system. These unnecessary costs are astronomical to airlines, but they can be materially reduced under a reinvented and efficient ATM system. Some points:

- Hub-site airports will account for approximately 345 million enplanements in 1995 (local and connecting passengers). Another 199 million enplanements will be generated at non hub-site airports.

- Using the 1993 DOT statistic of 5.6 lost bags per 1000 passengers, this means that over 3.04 million bags will be lost - most of them temporarily. The majority of these will be due to misconnected flights at hub-site airports.[10]

- The cost of the resources airlines must apply in dealing with lost bags is exceedingly high. Rates vary from location to location, but it can be $100 or more per bag just to deliver it to the customer's home or hotel in some regions. Other costs, such as expensive computer programs to track and find lost bags, are also considerable. Add to this the manpower in dealing with the bags and their owners and an average cost of $75 per lost bag is not unreasonable. Based on this, the annual bill to the US airline industry may be as high as $220 million dollars yearly. (Sidebar: make note that even in light of this, some analysts still claim that labor costs are the only "controllable" expenses.)

- Because the majority of US traffic flows through hub-site airports, improvements in the airlines' ability to increase hub-site scheduling efficiency could reduce lost baggage expenses considerably, and it is not unlikely that this cost could be cut by three fourths. Saving: over $165 million yearly.

- It isn't only bags that get lost or mis-connected. Passengers also suffer the same fate. When flow control causes flights to arrive late, passengers miss their connecting flights, and the airline must re-book and re-schedule these customers. It is not readily realized that for one airline to re-book (sometimes called "to rule 240") a misconnected passenger on another carrier, the first airline pays a big price, as the second airline generally bills back the first airline at a rate best represented by the Jolly Roger. "Involuntary" refunds of the remaining portion of the passenger's ticket can easily make the entire trip revenue-negative for the airline. It is also not generally recognized that hotel, meal and other incidental costs for misconnected passengers can also be very high. Not to mention the loss of goodwill. All of this comes out of the carrier's bottom line, and much of it is the direct result of the obsolete ATC system in which carriers must operate.

- The total costs of caused by handling misconnected passengers varies from region to region, and from airline to airline, but an estimate of $100 per passenger on average is not unreasonable. At first pass this may sound high. However, the *total* costs imposed by misconnected passengers should be considered, including the spill-over effects that reduce the efficiency of the carrier's entire operation. Employees must divert energies to deal with "miscons". The levels of re-work (tickets, vouchers, re-bookings, finding and re-tagging baggage, re-routings, higher calls to reservations staff, etc.) are substantial. This reduces the quality of service to other customers, causing a ripple effect throughout other parts of the carrier's service operation. If the rate of misconnected passengers (a difficult number to accurately estimate) is half that of baggage, the estimated cost to airlines in 1995 will be just over $150 million. This number may be highly conservative.

- US airlines must "pad" scheduled flight times to assure that connections are made with reasonable reliability. Flight times on the ground and in the air must be padded to accommodate the potential for ATC delays. This has several costly results. First, aircraft are not utilized as efficiently as they can be. In large airline fleets, it takes more aircraft to maintain a given schedule. Result: higher capital costs of having more aircraft than otherwise necessary. (Lease costs on a 757 can be $4 million dollars or more per year, per airplane.) Another is facilities costs: because aircraft must be scheduled with more ground time than absolutely necessary, expensive ground facilities are not efficiently utilized. It is not unreasonable to expect that carriers can achieve an improvement in overall cost efficiency of between 1% and 2% with a reinvented ATM system. Savings: $660 million to $1.6 billion yearly.

The final tally: somewhere between $4.4 billion and $5.4 billion annually.

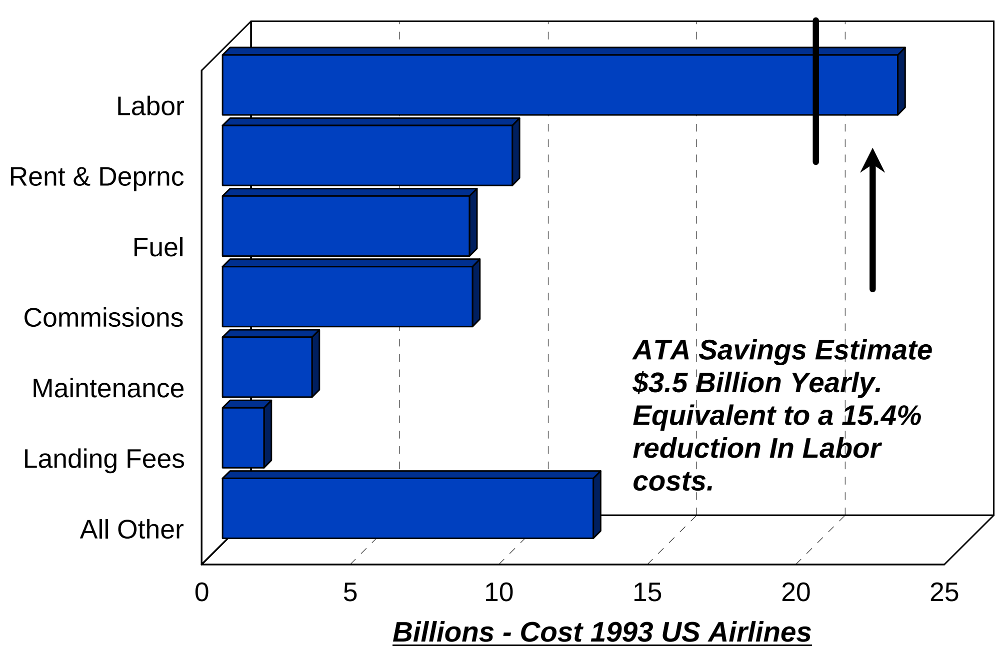
Moving on to what this figure means to the airline industry, we can work just with the base number of $3.5 billion, and see some startling comparisons:

- The airline industry - particularly major airlines - have been working to bring their costs down to levels that can produce a profit. As we noted, labor costs seems to be the trendy bugaboo. Analysts keep parroting that it is here where the major cost reductions must be made. But let's follow this path for a moment, and apply the ATC savings that are estimated to labor costs. The following chart shows reported major airline costs for 1993. Note that in 1993, labor expense comprised nearly 35% of all costs at major US airlines - a total of $22.7 billion dollars.[11]

- The ATA estimate of $3.5 billion in unnecessary costs does not cover all airlines, nor, as noted, all aspects of operations. However, this amount still provides the equivalent of negotiating a *15% labor cost reduction* with employees and unions. And it can be achieved without management and labor hissing at each other across the bargaining table. No slowdowns, or the rest of the game that usually ends up with both management and employees having a bad attitude. And best of all, airlines would increase cost efficiency, and employees would not have to undergo reduced pay. Customers would see better service. Everyone wins.

Airline Cost Structure

Free Flight Savings Equal To 15% Reduction In Labor Costs for US Carriers



If we use the earlier-derived range of $4.4 to $5.5 billion, it is the equivalent of between a 19% to 25% reduction in labor rates. To put it in another context, it would be the same as if the airline industry received their maintenance and landing fees for free.

To be sure, it must be stated that ATC inefficiencies are not the only problems faced by US major airlines, nor are they the only inefficiencies facing US majors. Within the major airline corporate systems, there are entire areas that are similar to ATC in that they are sacred relics of the 1940s and 1950s, and until recently, have not been questioned. [12] Indeed, one major airline stated in its employee newsletter that to claim that management mistakes were at fault for the company's losses was a "myth." [13] Attitudinal problems like this can't be fixed by the ATM system. However, it does indicate that US major airlines can be strongly profitable. They aren't dinosaurs. They're just operating within an outdated operational context. ATM is a cornerstone part of the solution.

C. Economic Costs To Communities

The economic growth that is being stifled by the current system is an enormous cost factor that extends well beyond the $3.5 billion figure. We can look at communities where the population and economic base cannot support air service at today's costs. The improvements in air traffic management efficiency could allow many smaller communities to attract new and increased air service.

Chicago/O'Hare (ORD) is a prime example. Currently the airport's capacity is constricted by the implementation of "slots" that control the number of arrivals and departures allowed each hour. The intent of slots is to safely meter traffic into ORD - i.e., linearize it - so that traffic can be controlled. The result is less than optimal ability on the part of airlines to schedule efficiently. Another result is that smaller communities get short shrift in terms of access to this important gateway. There is a difference between slots used by large jets and commuter aircraft. This was supposed to protect air service access for smaller cities, but airlines have successfully lobbied around this.[14]

Because ORD is not only the most important commercial center in the immediate region, but is also a major gateway to the US air transportation system, access to this airport is essential to the economic well being of many smaller communities. The problem is that a "slot" at ORD is a valuable asset. And as such airlines will use them where they can provide the highest and best return for the carrier. As a result, airlines favor use of slots for flights that can produce the most revenue. That's Phoenix, not Pellston. That's New York, not Menominee.

So these smaller communities either are relegated to multi-stop service to ORD, or service at off-peak hours. Or no service at all. The result is that the smaller community sees its traffic "leak" away to other airports at larger cities in the region that have better service. Smaller cities in Wisconsin and in the Upper Peninsula of Michigan have seen traffic shift from their local airport to Green Bay, which is a larger city and enjoys much better air service to ORD. The result is lost dollars to the smaller communities, and less attractiveness to business, because they do not have adequate local air service.

Slots are the result of today's linearized, tightly-controlled ATC system. A Free Flight approach would allow traffic to use ORD much more efficiently, and would allow greater access to this airport from smaller communities.

D. Economic Contribution of Additional Traffic

In the United States alone, the airline industry provides for over 400,000 jobs, according to ASRC analyses. Simply using the ATA estimate of $3.5 billion in excess costs caused by the current ATC system would indicate that as a start, a reinvented ATM system can cause a reduction in airline costs of over 5 percent, not including additional efficiencies that are gained. Using what is felt to be a more complete estimate of $4.4 to $5.4 billion, the reducing in airline costs could exceed 8 percent. As noted earlier, when carriers can effectively reduce costs, fares go down. Current experience shows that when fares drop, traffic increases. Every additional passenger that an airline attracts results in additional economic impacts to local communities.

There are direct economic impacts of additional passengers carried. Employment at the local airport. Sales tax revenues from airport shops. They include additional capital expenditures on facilities.

In addition, there are indirect economic impacts. The travel agency sales. Hotels. Taxis and ground transportation. Finally, there is the distant area of induced impacts - the multiplier effect of dollars generated by the airport. The money spent at the concert by the employee of the airport newsstand, for example. Additional dollars that are circulated through the community because of the revenues initially generated by the airport.

Beyond the boundaries of airports, the interaction of business people facilitated by air travel also contributes billions to the national economy and provides for further job stimulus, in industries totally unrelated to air transportation. And these activities must also be supported, with restaurants, hotels, general services, etc. Further, the payroll of employees either directly or indirectly tied to the airlines provides for immense amounts of tax revenues to communities and further expenditures, which in turn creates more jobs.

One of the industries most dependent on the health of commercial aviation is tourism. Worldwide tourism is an industry representing $3 trillion in annual revenues, and domestically it represents in excess of 6 percent of the gross domestic product.

The simulative effect of lower airfares varies market to market, and is dependent upon a complex set of factors. We do know that when carriers are able (or forced) to lower fares, traffic tends to rise. There are a number of approaches used to compute the economic impact of increased passenger travel at a given airport or community. Here again, the effects vary by location, economic conditions and time.

The chart on the next page illustrates in very brief terms the flow of money, through the free-market economic system that is the result of each additional passenger carried. The chart, while a good example, is the tip of the iceberg and the money trickles all the way down past the Wrigley Doublemint twins, whose gum was purchased at the corner 7-11 by the hotel van driver with his tip that the customers gave him when they were dropped off at the airport. This two-dimensional example does not reflect all the economic results that every additional passenger and every additional flight and every additional airline employee provides to a local community.

The ATC system today is an unseen straight jacket that prevents aviation - both commercial and general - to develop to its full potential. It cannot - indeed, should not be “upgraded” nor “privatized”. It must be reinvented.

PULL OUT CHART OF ECONOMIC IMPACT OF AVIATION

IX. Recommendations - Where We Go From Here

As explained earlier, the world's aviation organizations follow the ICAO in terms of international conventions.

FANS is underway. That is a positive step. But without the full recognition on the part of the airline industry, and the world's economy in general, that it delivers dollars to the airline's bottom line, it will happen very slowly. Remember the aviation authorities only responsibility is the safety of the system, and not the efficiency of the system. *The airlines are the only ones who can require the system to be efficient, and up until now efficiency has been increased based on the outdated, inadequate technology.* The analogy is that there are 100 caves in a mountain. Each cave has the latest equipment and is optimized for that part of the mountain it can see. Unfortunately, no one steps out of their cave to see that the mountain is crumbling around them.

No approach is going to be cheap in fixing the air traffic management system. The Free Flight program will not be inexpensive for either the aviation authorities or the airlines. The current FAA estimate to replace their current computer system is budgeted at many billions, yet the improvement will be marginal at best. Airlines in the US need a system that provides quantum improvements in efficiencies.

A. Government Role(s)

The current proposal on the part of the federal government is inadequate to meet the needs of the 21st century. Essentially, it is updating the past, not preparing for the future.

The issue of privatization, regardless of the glowing reports about its use in other countries, is a *non sequitur*. We need to reinvent the system so that it works for the future, and privatization is nothing more than political smoke and mirrors that do nothing - nothing - of substance to fix the real problems.

We cannot stay with the current approach, regardless of how much it is politically supported, and regardless of how many computers and dollars are thrown at it. The linearized system used today is inefficient and must be replaced. In this, we should expect more substantive activities from the DOT, and fewer photo ops taken with vacuum tubes.

Since the United States is the dominant single nation in terms of air traffic, the US is in a position to take the lead in moving into Free Flight. In this, the cooperation of other nations, driven by a unilateral force such as IATA, through ICAO, must cooperate to insure the Free Flight implementation of FANS worldwide. This must be done in cooperation with the airline industry, manufacturers, and other segments of aviation, such as general aviation and component manufacturers.

B. Role of The Financial Industry

The financial community - lenders, underwriters, investors, aircraft leasing companies - do not understand the negative effects that today's ATC system has upon their industry. The likely do not have any idea regarding what the airlines are paying to use the airspace system today, and how it directly affects the financial industry.

The financial industry has a vital interest in the growth and expansion of the air transportation system. Free Flight will permit aviation to expand and grow far more than it can do under the current ATC system. Capital will be needed for new infrastructure, as well as to meet the needs of airlines as they add more aircraft within the newly-efficient ATM environment. Unless the ATM system is reinvented, such investments will continue to be materially constrained.

ATA has projected savings of $3.5 Billion dollars per year for major U.S. airlines when the industry has fully implemented what should develop into a Free Flight environment, i.e., the evolving ICAO Communication/Navigation/Surveillance Air Traffic Management (CNS/ATM) environment. ASRC/RMB analyses indicate the savings will be between 25% and 50% higher than the ATA's estimate. An additional $5 billion in the airline industry's pocket each year will translate into new investment and expansion of air travel.

The excess costs of the current ATC system constricts capital expenditures on the part of the airline industry by raising operational costs. In an environment where ATM is reinvented, profit margins would improve dramatically. The problems with today's ATC system must not remain abstract technical concepts to the financial community. Instead, they must understand that reinventing the system will determine whether aviation is a healthy and expanding industry, one that needs more capital, or that is constantly swimming in red ink, often with some members unable to pay their bills.

C. Airline Industry Roles

First of all the airlines must recognize that they are the customers of the air traffic management system (albeit representing the passenger). And as customers, they must demand that the FAA provide a better product. At stake is profit or loss. At stake, for some carriers, is survival. At stake are thousands of airline jobs.

If the chairman of Delta Airlines became aware that his company was paying more than necessary for jet fuel, he would take action. If the chairman of Northwest found that a department was spending 5% too much on maintenance parts, he would take immediate action. *But in the case of ATC, the <u>billions</u> of dollars wasted are, apparently, being considered a cost of doing business.* At the very at least, the urgency of the situation is just not evident. But the money is being wasted right now, even as we speak, and in huge amounts.

If the management of American or Northwest found a vendor that was giving them poor service at high rates, they would take action. Yet in the case of ATC that is exactly what they put up with. In the case of ATC, airlines are the customer, and the FAA is the vendor. The product is inefficient and is costing carriers billions of dollars. The role of the airline industry today should be one of aggressive proactiveness: they should be right in the face of the FAA, demanding - not asking - but *demanding* changes be made immediately. No longer should they accept political babbling about “privatization” or “vacuum tubes” or “reinventing government.” These are not substantive suggestions that will solve the problems we face. Billions of dollars are being lost, and jobs are at stake. What needs to be “reinvented” is the air traffic management system. And there should be no tolerance for any further political grandstanding

Air traffic management is not a subject that most airline CEOs are familiar with. The alphabet soup of ATM terms are far removed from the general day-to-day demands and pressures in the executive offices. As a result, ATM issues have not been on the front burner in the CEOs’ minds. But they will become so in the months ahead. ATC is a major expense item for airlines, just as is fuel, commissions, and labor. ATC must eclipse the issue of labor costs in the industry’s attempts to restructure in a meaningful way to the future.

Up until now, possibly due to corporate "cost constraints" and an unclear understanding of the savings involved, airlines have allocated very limited resources to the research and study of ATC solutions. The airlines must realize the true cost of operating the current air traffic control system, and that savings over the current system can be achieved, but only with their interaction and placement of efficiency demands on the service provider -- in this case the government.

This must a be joint industry effort, reaching across inter- and intra- company boundaries. The airline industry must take a take a more proactive role in determining their futures. As we have shown, the future viability of the industry is directly tied to the new ATM System. If the implementation is done poorly, slowly or not at all many of the airlines will not survive. Jobs will be lost, and the economy adversely affected.

The airlines must realize that they are the customers in the new ATM FANS System and must drive the system and not be driven by the new system. They must become proactive, and position their companies to take advantage of Free Flight as soon as it is implemented. It may be literally the difference between survival and failure.

X. Approaching Free Flight

The concepts raised in this document vary from ambient thinking. And whenever new ideas are postulated, there are always questions. Sometimes there is skepticism. In the case of implementing a Free Flight system, the break from past thinking is dramatic.

One suggestion is to begin Free Flight in stages. Establish a free flight zone for appropriately-equipped aircraft operating above 37,000 ft, and move this zone quickly downward as more confidence in the concept builds, and the ATM system develops.

We know this: the current system is inefficient. The proposals to corporatize the system, and to upgrade existing computer equipment essentially ignore the real problem. Indeed, they will tend to support and feed the problem. Nothing short of a complete reinventing of the entire way aircraft are separated in the airspace will be adequate.

XI. Appendix A

A. About Aviation Systems Research Corporation

ASRC is a multi-dimensional consulting and research firm, assisting clients in all areas of aviation. Founded in 1984, ASRC has become a leader in providing accurate forecasts and trend analysis.

A cornerstone of ASRC is the publishing of white papers and studies that focus on issues that will be critical to the future of aviation. The firm also publishes Airports:USA, the only comprehensive traffic forecasts produced in the private sector. Airports:USA addresses traffic trends within the context of the changes expected in the airline industry. As a result, our forecasts are the most accurate available.

Among the independent studies published by ASRC:

- *Regional Airline Industry - The Effects of Code-Sharing* (1986). The first analysis of the effects that code-sharing would have on the regional airline industry. Findings presented to the RAA Presidents Council. In this study, the term "fortress hub" was first used and defined.

- *The Regional Transport Jet* (1989). This was the first analysis of the 50-seat jet transport produced independently of an aircraft manufacturer, and was the first such study to project a strong need for this category aircraft in the 1990s.

- *Analysis Of The Wayport Concept* (1989). An in-depth study of the potential for using remote airports specifically for interconnecting passengers and cargo. The study determined that the concept was inconsistent with economic realities of the airline industry.

- *Airport Capacity Needs In The 21st Century* (1990). This study provided an overview of the demands on current airport capacity, as well as the demands that will be placed on airport facilities in the years ahead.

- *The Continuous Hub Concept* (1991). An analysis of alternatives to increasing the efficiency of the hub-and-spoke system. First coined by ASRC, the term "continuous hub" is now discussed widely in the U.S. airline industry.

- *The U.S. Airline Industry: Reassessing & Rebuilding* (1993). This extensive study outlines the problems facing airlines, and projects the positive changes the industry will see in the years ahead.

In its independent studies, ASRC publishes its findings, recommendations and conclusions “as is” and “where is.” We endeavor to provide the hard facts, regardless of their “political correctness.” ASRC as a result has earned the reputation for honesty and integrity.

In our consulting projects, we use the same approach. We help our clients to objectively weigh alternatives and we state the results in a forthright and openly honest manner.

ASRC feels that if America is to have the air transportation system it needs in the future, the politically-correct and sugar-coated consulting that is today all too common is not consistent with integrity.

Clients of ASRC include airlines, airports, aviation authorities, and aircraft manufacturers. In addition, hundreds of other aviation-related companies have purchased our many independent studies.

If your aviation related company is planning for the future, Aviation Systems Research can help. We specialize in straight talk and direct answers. Give us a call.

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B. About RMB Associates

RMB Associates was founded in 1981 to provide in depth analysis of airline operations and to identify and seek out solutions to their operational problems.

RMB Associates primary focus is to provide the airlines with a broader view and help identify their structural weaknesses. The airlines' dismal financial performance will continue unless the industry, as a whole, rethinks the basic assumptions on which they operate and works to provide correct solutions for the real problems.

RMB Associates' insights bring considerable expertise to its papers. The experiences RMB Associates draws from include: airline and avionics engineering, avionics marketing, piloting as an airline captain, airline management and extensive dealings with the FAA and ATC . These unique experiences can identify and help solve the right problem, rather than wasting time and money solving the wrong problem.

RMB Associates independently published papers include:

- ***Survival: Airlines, Competition and Profits***, February 1, 1994 - Airlines face many competitors today that remain unchallenged. This report identifies these competitors and other revenue negative aspects of the airline industry. This paper discuses the impacts of pricing, reservation agents, etc. that the airlines must begin to address.

- ***United Airlines versus Southwest Airlines - Below the Surface*****,** May 1, 1994 - In depth analysis of the operational and product differences between United Airlines and Southwest Airlines. This independent study breaks down the cost per Available Seat Mile (ASM), based on individual aspects of each carriers operations. The study shows United's higher cost is a function of differing product/operational choices.

- ***Free Flight - Reinventing ATC: The Economic Impact*****, June 1994 - ATC** is the largest controllable cost the airlines face. Unfortunately, it is relegated to midlevel managers and technocrats, instead of receiving executive level attention. This report identifies the costs to airlines, and the entire United States economy, that go unchallenged because of the inefficient Air Traffic Control (ATC) system. These costs, borne by the consumer are unacceptable, and this report offers solutions that are critical to continued airline viability.

- ***Free Flight - Reinventing Air Traffic Control: The "Minimalist" Solution***, October 2, 1994 - ATC is viewed as a very complex command and control system. This paper examines the underlying task of the Air Traffic Service (ATS) - separation. It postulates that the numerous layers of system complexity today are in place for only one reason - to protect the manual conflict probe. Therefore, computerizing the conflict probe process simplifies the ATS task

For further information on these important studies, contact:

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XII.Appendix B

A. Endnotes

[1] Historical Information taken from Air Traffic Control: The Uncrowded Sky, Glen A. Gilbert, Smithsonian Institution Press, 1973.
[2] Historical information about Positive Control taken from *The History of Positive Control*, Stanley L. Seltzer, Journal of ATC, July 1992 through March 1994.
[3] *Air Traffic Management in the Future Air Navigation*, Air Transport Association, April 29, 1994
[4] Aerospace Engineering & Research Associates, Landover, MD
[5] *US Airport Capacity*, produced by ASRC, 1990.
[6] Five years ago, airport expenses were considered an ambient cost of doing business. This is now changing, however, as airlines become concerned regarding the building of politicized and unnecessary airport facilities. In 1990, American Airlines proposed adding surcharges for passengers at airports that had inordinately high costs, the reasoning being that the inordinately high costs of unnecessarily grandiose local facilities should not be borne by the entire passenger base. In June, 1994, the Chairman of USAir noted the airport cost issue in the carrier's inflight magazine. In 1991, the Chairman of American Airlines described Denver's expensive new airport as a "field of dreams" (Time Magazine, October 1991). In 1993, the chairman of Southwest Airlines noted that his airline would not serve Denver's new airport because of its high costs. We can expect that ATC costs will soon enter this category of concern.
[7] Based on three round trips daily, $2,500 direct operating cost per hour. This does not include the costs of mis-connected baggage or passengers caused due to the carrier's inability to make up time when necessary by taking a direct routing.
[8] This "preferred" routing makes the airline fly approximately 18% more miles, taking the aircraft on a guided tour of the Deep South and Mid Atlantic coast. This could vary due to several factors, but the hard reality is that the flight is much longer than it needs to be.
[9] ***Airports USA***, 1993-1998 Forecast, ASRC
[10] This figure is used with caution, as airline-reported data on such issues as lost luggage, delays, and bumped passengers get very little audit oversight. For example, data reported on "voluntary" and "involuntary" bumped passengers is meaningless, as airlines hold different interpretations of the word "voluntary."
[11] The *Airline Monitor*, ESG Aviation Services, June 1994
[12] *The US Airline Industry - Reassessing & Rebuilding*, ASRC 1993
[13] A major US airline, listing "myths" regarding causes of its recent problems, noted that one of the myths was that the carrier's management had made mistakes. Delusional statements such as this point to some of the core problems of the US major airline industry that reinventing ATC won't solve.
[14] In 1991, American Airlines convinced several communities to support its petition to turn a substantial percentage of its commuter slots into "jet" slots allowing jets of 110 seats or less to use them. The initial result was short-term jet service to ORD from Peoria, Springfield, and Fargo. All this has now been dropped, and the jet service is used at larger cities. *The Continuous Hub Concept*, ASRC, 1991.

Free Flight

Reinventing Air Traffic Control

Production Line Management

Analysis Conducted and Study Jointly Produced By:

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Free Flight
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The Economic Impact, June 1994

Production Line Management, March 1995

Blueprint To Free Flight, April 1996

Note:

This document reviews the concept of Production Line Management as it relates to the airline industry. This information is intended to contribute to the forum of aviation ideas. ***This study is produced entirely independently, without financial assistance or direction of any kind from any entity.*** This is not an advocacy document that promotes anything that will provide direct economic benefit to RMB or ASRC.

I. Assessing The Challenge

The fundamental premise of this document is very simple:

The core part of the "production line" - where airlines and aviation produce their product - is the <u>movement of the aircraft</u>. This production line is still being managed in essentially the same way it was 40 years ago. The result of this stagnation in the production process is inefficiencies that adversely affect the entire US aviation industry.

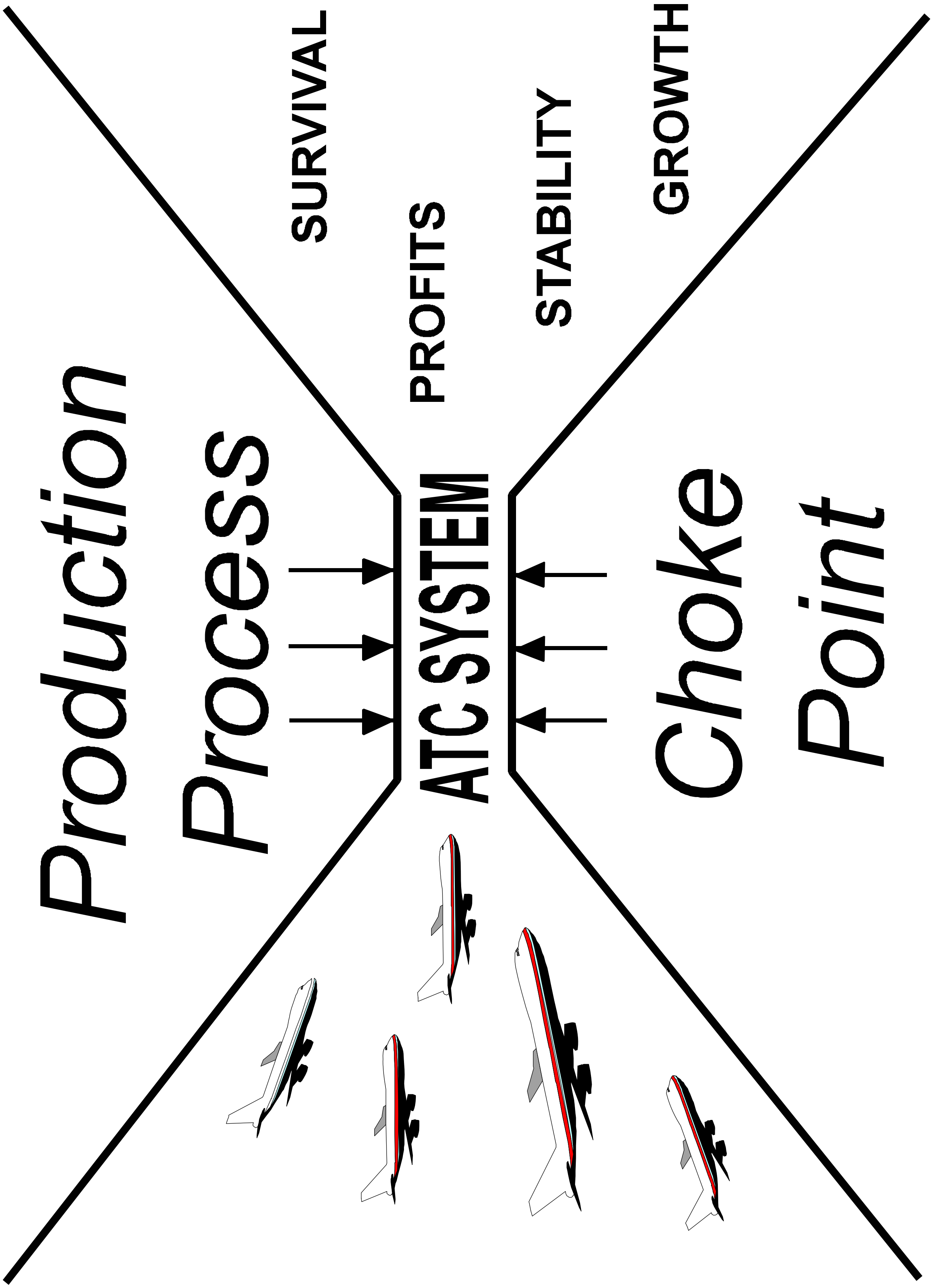
No other US industry has let its production line management fall so far behind. It is somewhat comparable to the auto industry attempting to build new Cadillacs with the same production techniques that produced '55 Studebakers.

<u>Billions For New Technology - Yet Productivity Has Dropped</u>

Over the last few years Wall Street has been looking for the reason airlines are not profitable. *One main reason is that airline system productivity has remained stagnant or decreased in the last 15 years.* In many cases, more sophisticated, faster and efficient aircraft have been purchased by the airline industry during this period, but the fact is that the airlines have seen little or no benefit of these newer aircraft, except for minimal fuel savings. And even then the benefit has been far less than it could be.

Airline productivity is, at the bottom level, measured in how many seats it can produce. Using this measure system productivity has actually dropped approximately 8% over the last 15 years.

Air Traffic Management (ATM), which is today generally referred to as "air traffic control," is clearly the single greatest cause of this productivity decline. In fact, ATC is now the single greatest controllable cost facing the airline industry. It is also the single greatest barrier to the healthy expansion of the general aviation industry. Because of the current manually run ATC system, billions of dollars are being lost, as are thousands of aviation-related jobs.


Production
Process
ATC SYSTEM
Choke
Point
SURVIVAL
PROFITS
STABILITY
GROWTH

Unfortunately, the airline industry does not measure system productivity in this manner, or even how much product they actually deliver (defined as a passenger at the destination, baggage in hand, within 5 minutes of schedule), yet alone understand what it does to their bottom line. Timetables are adjusted to accommodate the obsolete ATC system, and as long as the timetable schedule is met, all is right with the world. *What needs to change is that the air traffic management system must now be changed to meet the needs of aviation, instead of the other way around.* This document will help illuminate this issue.

Free Flight - The Future ATM Approach

The air traffic management system is a problem because aviation authorities around the world have not planned properly. It has not accurately forecast the needs that the aviation industry *in today's deregulated environment*. But the fault doesn't lie entirely with the FAA. The fault is shared also by the airline industry that has not provided the leadership required to focus on this issue. With annual waste in the *billions* of dollars caused by the ATC system, the industry, at the highest management levels, must take an active and direct role in exploring all avenues to solve this problem.

The solution does not require Buck Rogers technology. Safety, productivity, capacity and, most importantly, *profits* can be increased dramatically in the aviation industry in the near term with existing technology. This can be done through a major philosophical change in the approach to Air Traffic Management.

The solution to this problem is a concept called *Free Flight*[1]. Essentially, Free Flight returns operational control of the aircraft asset back to the owner, the airline. This basic business premise, normal in other industries, has never been available to the aviation industry. Under this concept, ATC would stop *controlling* aircraft. Instead, the system would be managed to provide aircraft to aircraft separation. All the sky would be used, instead of cramming airliners into tight airborne corridors.

Free Flight is not a new concept. But it has been only since the middle of 1994 that it has been at the forefront of aviation thinking.

[1] The RTCA Free Flight Select Committee's has completed a draft definition of Free Flight. Free Flight is "A term used to describe a safe and efficient flight operating capability under instrument flight rules in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, and to prevent unauthorized flight through special use airspace. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward Free Flight.

DOT Efforts: Politics Instead of Solutions

Even in light of the enormous cost-inefficiencies and job losses caused by the current approach to ATC, until very recently the main activities of the DOT to address this problem were essentially political in nature.

Billions of dollars were wasted on ill-managed automation projects. The main solutions suggested by the Secretary of Transportation were to replace vacuum-tube equipment and to dump the ATM functions into an off-budget "semi-private" corporation. These suggestions were made essentially to gain political press, not fix the air traffic management problem. Very clearly there has been a lack of leadership and vision on the part of the DOT and the FAA.

Moving Free Flight to the front burner required actions outside of the slow-moving, "politically correct" world of the FAA and Washington insider organizations.

Congressional Hearings - The Turning Point

In light of the non-solutions suggested by the DOT, (which, of course, were amply "supported" by appropriate studies based on questionable assumptions), by early 1994, it became obvious that the process of crafting meaningful solutions to the ATC crises was hopelessly mired in political game-playing.

The FAA, as well as some industry organizations such at the Air Transport Association will correctly note that they were aware of the Free Flight concept prior to this time. But little was done about it.

As a result, in June 1994, ASRC and RMB Associates accomplished the first independent study of the issue. The intent was simply to bring the subject matter to a wider and less political forum.

That study, which was the first of the Free Flight studies, was titled *Free Flight - Reinventing ATC: The Economic Impact.* This study quickly resulted in Congressional hearings, and was the catalyst for today's discussions of Free Flight. It is unfortunate that it took a study completed in the private sector to get the FAA to give consideration to meaningful and fundamental structural changes to move Air Traffic Management out of the 1950s and into the 21st century.

The Congressional hearings, held August 9, 1994, were chaired by The Honorable Collin Peterson on our study *Free Flight - Reinventing ATC: The Economic Impact*. During these hearings, FAA officials attempted to claim that a Free Flight system was a decade or more away - a statement quite correctly characterized as "crazy" by Chairman Peterson. Congressman Shays observed that the FAA showed little "enthusiasm" about fixing the ATC problem. It was not a good day for the FAA, but it was a great moment for the US consumer and the aviation industry, because the FAA was put on notice that moving to a Free Flight system must become a priority.

The ASRC/RMB study has now had a noticeable effect on the FAA's planning. Since those hearings, Free Flight has become a common subject of discussion and study. To their credit, the FAA has begun the first small steps in the direction of Free Flight, by expanding the "National Route Program" that allows aircraft more direct flight routings under certain conditions. The airline industry has benefited by saving millions of dollars as a result.

Impact of Deregulation

To further understand the problem, one must also look at the problem from a historical point of view. In 1978, the CAB, under Alfred Kahn, set about deregulating the airline industry. Unfortunately, they only did half the job.

Expanding on this, from a business point of view, deregulation has allowed the large airlines to form "fortress hubs," a term first coined by ASRC in 1986. The formation of these fortress hubs significantly increased the traffic demand at airports chosen by the individual airlines as hub-sites. Unfortunately, this increase in time-specific air traffic demand often exceeds the current 1950's based manual ATC system capacity, even under the best of conditions. Any small change in weather or runway availability and demand far outstrips ATC's ability to meet that demand. Therefore, at these fortress hub-sites, because of this inadequate ATC system, the operational costs have skyrocketed, sometimes in excess of the additional revenue they produce.

The revenue negative aspects of hubs will be questioned by many. Since the airlines do not measure production line productivity per se, one cannot know for sure. The astronomical costs inflicted on airlines by the current ATC system - *in excess of $5 billion annually* - supports the revenue negative aspect of the fortress hubs. (The Nashville example given below is just one example.) At the very least, the result is lower profits, losses, and less employment. Obviously, the Air Traffic system has been unable to meet its customers' requirements in the deregulated environment.

This does not mean that major airlines should abandon the hub system, as the result would be devastating to smaller communities across the nation. Let's face the fact that Fresno to Des Moines will never support non stop service. Only hubs can provide economical flights between these cities. Therefore, the only choice then is to change their operating environment. It is not hubbing that is inefficient. Instead, it is the current manually run airspace system that does not allow the hub-site airports to operate efficiently. **The ATC system inefficiencies cause the largest controllable expense facing airlines**, and rebuilding an ATC system must become a priority task. The issue is not the unit cost of labor, but the additional units of labor required to operate a large hub system in the current ATC system.

This Study - Volume Three of A Series On Free Flight

This document is a follow-up to the first study. Herein, we discuss how air traffic control is essentially the “production line” for the airline industry, and how the airlines have ignored their production lines and have not kept up with technology.

Indeed, the air traffic control system is a major cause of the decline in airline productivity since 1980. Whether it is privatized or kept under FAA control, and whether it uses vacuum tubes or not, are non-sequiturs. Using ATC as a political football must stop. The dollars wasted are real. The jobs lost are real. The hindrance to general aviation growth is real. The production line must first be conceptually brought into the 21st century.

II. The Production Line & US Airlines

Over the last several years there have been numerous economic studies on airline profitability. These papers generally have had a single conclusion - that unit labor cost reductions, in some way, shape or form, are the only way airlines can substantively reduce costs.

This assumption is wrong, because it is based on another erroneous assumption - that the "production line" - the way airlines produce their product and the environment it is in - cannot be improved.

The fact is that the way airlines do business involve inefficiencies that go beyond labor costs. Well beyond. Most of these are inherited from the past 40 years, and are assumed to be unquestionable parts of how to run an airline system. One of these "unquestioned" parts is how the current ATC system operates. Airline analysts aren't even aware of the problem. Airlines, as noted earlier, assume that they must adjust their flying and timetables to fit the vagaries of the existing ATC methodologies.

The economic assumptions that have led to these conclusions were developed over the last 15 years. These very turbulent years have seen deregulation, new entrants, low cost carriers, mileage award programs, delays, congestion, the formation of fortress hubs along with external economic catastrophes, all affecting airline profitability.

One of the unspoken "assumptions" in most analyses of the airline industry is that aircraft productivity is at or near its maximum. The airline analysts see little, if anything, on the technical horizon to dramatically increase system productivity. This is where they are wrong again.

Unfortunately many of these analysts have little knowledge of the "production line" in which airlines operate - how, for example, pilots operate and aircraft are routed within the current airspace system. If they understood these issues and the available solutions, they would easily understand that the US aviation industry is at the threshold of an increase in productivity that matches the productivity jump when aviation moved from propeller aircraft to jets. The driver of this jump will be an air traffic management system called Free Flight. It will move the aviation industry out of the Studebaker era.

<u>Bringing Airline CEOs Into The Issue</u>

The problem is real, yet it has been given little of the priority it needs in the front offices of America's airlines.

The unnecessary costs foisted upon US airlines by the lack of production line controls are staggering. They exceed the wildest dreams of any airline negotiator trying to wring concessions from a labor union. The recent Congressional hearings[2] that were held as a direct response to the original RMB/ASRC study found the ATC system to be woefully inadequate and a financial drain on the entire US economy. RMB/ASRC estimates annual airline losses, directly attributable to ATC, at over $5 billion. At the same hearing the Air Transport Association testified that the ATC losses for its members total over $3.5 billion per year.

United Airlines estimates excess costs just to its system alone of $670 million annually due to the outdated ATC system. American Airlines has publicly stated that its internal estimates are similar. UAL also estimates an additional $1.3 billion in lost productivity for a total UAL loss of **$2 billion annually directly attributable to ATC**.

Even with these staggering numbers, the FAA and others indicate that the problem is unsolvable in the near term. This is another indication of how the FAA must be brought back into reality. The outcome of RMB/ASRC's research is that the nation's airline industry as whole cannot be consistently profitable until they recapture control of their production lines from ATC. It can be done, and indeed, it must be done if we are to have a viable air transportation system that is available to an increasingly wider range of consumers.

Although the losses are enormous, major airline CEOs are not facing it. Many are not even aware of it. Some may be reticent to address it for fear of offending the FAA or DOT, the very groups that are strangling their business environment. The time for laying low and/or playing to politicians is over. Airline CEOs must take the matter seriously and, as suggested in the Congressional hearings on Free Flight, form a "conga line" into the FAA Administrator's office to demand change.

Both American and United know that the ATC system is costing them hundreds of millions of dollars annually. Yet there has been virtually no strong public comment about ATC by the chairman of either company. Until the mega carriers directly and aggressively take a position on this matter (as opposed to funneling such efforts through Washington organizations and lobbyists) the FAA will not have the incentive to continue its recent moves toward a Free Flight system.

To be sure, the Air Transport Association (ATA) and other organizations lobby for the airlines on Capitol Hill, but the approach in regard to air traffic issues appears to have been one of working within a dysfunctional FAA planning system. This may be "politically correct" but it has been woefully unsuccessful in getting the program on a fast track. Again, it was not inside-the-beltway organizations that

[2] House Committee on Government Operations, Employment, Housing & Aviation Subcommittee, August 9, 1994, chaired by The Honorable Collin C. Peterson.

put Free Flight on the front burner. *Instead, it took an outside, independent study by two Colorado firms to get this done.*

Building an air traffic management system for the 21st century has been misinterpreted by many as a technical problem. But is it not. It is an economic problem. Even though *safety will be enhanced* and, implementation of technology will be required for full implementation, these are secondary issues. The issue of airline production line management, is more correctly a business and financial problem requiring changes in both the political and the cultural views held about the subject.

Furthermore, financial analysts that follow the airline industry also ignore this cost area. But if ATC were a line item on the airline annual reports, the financial community would demand a speedy solution. Shareholders would be outraged. Analysts would be apoplectic. *But with or without an ATC line item the fact remains that airlines are losing billions due to the current air traffic management system.*

III. The Need For Production Line Management

Volume One of the Free Flight[3] study dealt with the ATC system, or the external environment as it relates to the airline industry. That study, by design, primarily dealt with only half the equation. To take advantage of the implementation of Free Flight, airlines and all of aviation must "reinvent" their business practices as well.

This paper deals with the concept that the airlines must also restructure their internal environment to fully benefit as aviation moves towards Free Flight. This restructuring will allow the airlines to maximize their production lines, the movement of their aircraft, to optimize their profitability.

As stated in the original Free Flight study, airlines almost completely ignore the largest controllable cost facing them today -- *the outdated, inefficient, manual Air Traffic Control (ATC) system*. Although extremely safe, through the efforts of air traffic controllers and pilots, the current airspace management system is strangling aviation productivity. Up until now the FAA, and even airlines themselves, blame airline schedules for creating bottlenecks and delays thus failing to recognize the true throughput problem. The bottom line is that the current system no longer provides its customers the service they required in the deregulated, hub and spoke environment. Blaming the airlines for hub congestion is akin to Goodyear blaming Ford for tire production problems and telling them to build fewer cars because tire production can not meet demand. This is obviously not acceptable, yet the aviation industry has accepted this line of thinking for over four decades.

Not Just More Runways, But Better Utilization of Runways

No matter what the reader has heard, system efficiency can be dramatically increased, while at the same time increasing safety. The problem is not physical plant and facilities, it is the inefficient use of these plants and facilities that is the cause of the productivity decrease.

Unquestionably, new airports, like the new Denver International Airport (DIA), may provide significant operational benefits over the airports they replace. But we must realize that new $5 Billion airports, like DIA, are only single nodes in a much larger dysfunctional system, and in the case of DIA, the main benefits are enjoyed by the dominant airline, not by the nation as a whole. Additionally, the questionable financial state of DIA, its long history of delays and all the surrounding construction controversy, put building additional new airports into the realm of fantasy, not

[3]*Free Flight - Reinventing Air Traffic Control: The Economic Impact* - An independent economic analysis co-authored by Captain R. Michael Baiada, RMB Associates, Evergreen, CO (303-674-0229) and Michael Boyd, Aviation Systems Research Corporation, Golden, CO (303-526-2000). This in depth study outlines Free Flight economics, concepts and implementation issues.

reality. This is especially true in the areas FAA has identified as the "Fastest-growing airports". The very reason new capacity is needed, a large population base, makes even acquiring the necessary land to build a new airport an impossible task.

Unfortunately, even if Free Flight was magically implemented tomorrow, airlines would not do things dramatically different. Airlines are ill prepared to operationally manage their airplanes effectively in the current ATC system, let alone manage them in a Free Flight environment. What must occur is a fundamental change in the way airlines view the movement of their aircraft - their production line.

Although the Free Flight and Production Line concepts are simple, the issues around them are complex. The following tries to state the tasks required as simply as possible. These are that:

- Airlines must maximize their internal production lines, movement of the aircraft, to take full advantage of the current environment.

- Airlines must work to fundamentally change the external environment, ATC, to allow full production line control.

IV.Production Line Management

The production line management concept is simple and a must for profitability in the airline industry.

If the aircraft is viewed as a factory, the factory is idle when it is at the gate -- no product is produced. Product is only produced when the aircraft is moving, carrying passengers and/or cargo from departure to destination.

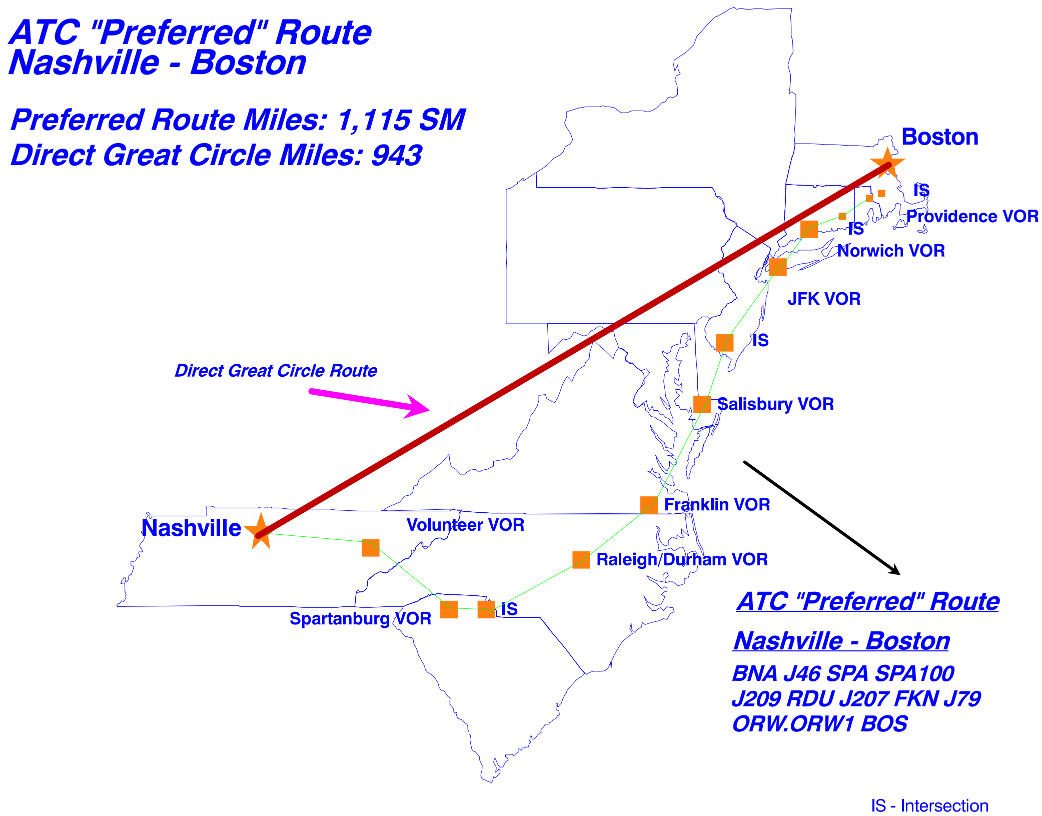
To be sure, there must be economic demand for such services, because simply moving empty aircraft around the sky is a waste of money. But given the assumption that there is market demand to carry such passengers and cargo, the airline only makes money when the aircraft is moving.

Many airlines have only recently recognized that the “factory” is idle at the gate, as evidenced by their interest in reducing ground turn times. USAir has said that “Operation High Ground” has allowed USAir to add 12,500 seats per day to their system by reducing the amount of time the aircraft is at the gate. The result is that USAir has the ability to use its equipment and personnel more productively. United Airlines has stated that its Shuttle can fly the same number of flights with 30 aircraft that previously took 39, because of reduced gate times.

But the biggest savings are not at the gate, where airlines have control of how and where they manage their “factory” down time. The biggest potential savings is when the aircraft is moving. But it is at this cost-critical point that airlines, are currently forced to turn their production line over to an outside entity - the ATC system - a system that is woefully inadequate to make the myriad of operational decisions required to profitability run a complicated hub airline operation. Why airline management continues to quietly accept this structure is an unanswered question.

Once the airliner is moving, the “production line” is not designed for efficiency, or more importantly, operational flexibility. As a result, the costs really become staggering. Airlines are forced to allow the manually operated ATC system to determine the route and speed that their “factory” takes to the destination. Sometimes, the airline and the aircraft captain are allowed some input, but usually, the routing is what is called “preferred” - preferred, that is, to meet the convenience of a 1950s ATC system.

Just one example, is the "preferred" routing between Nashville and Boston. Flights are forced to fly 18% longer, simply to meet the needs of the ATC system.



The excess operating cost to American Airlines for this one route is $1 million annually. Multiply this by the thousands of other daily American Airlines flights and you get an idea of the magnitude of the problem. This is not an abstract example: *This type of ATC system is certainly a contributing cost factor to the pull-down of that airline's hub at Nashville. Jobs lost, and a community's air service adversely affected.*

Since the sky is the core part of the airline "production line" it is obvious from this example that allowing an outdated ATC system to determine how the production line is used is not particularly good business. Up until now, airline CEOs have been very quiet about ATC and Production Line issues. It is time that they took aggressive action beyond passing the problem off to committees, industry organizations, and Washington insiders.

V. Productivity Losses Due ATC

Allowing the current ATC system to determine how, where, and in what direction the airline production line will operate has resulted in real losses in efficiency and the operational flexibility airlines and general aviation require.

The reason the airlines are in business in the first place is the profitable movement of people and cargo from departure to destination. The more cost-effectively they can accomplish this, the better for both the airline and the consumer.

This makes the production line the core of the whole airline business. It is the only area in which a product is actually produced. Therefore the lack of production line controls effects all aspects of the airline business. Without Production Line Management, areas affected go well beyond just aircraft and crew scheduling. It also affects marketing, maintenance, baggage, food services, gate utilization, and most of all it strangles total system productivity.

Because they are not in control their own production line, the airlines have built their business practices around what the ATC system will allow. This should be turned around and the airlines provide the leadership required to rebuild the ATC system around the way the airlines want to do business.

The productivity losses are not inconsequential. The following example, taken from *Free Flight - Reinventing Air Traffic Control: The Economic Impact*, compares a Southwest flight to a Continental flight. Both airlines use B737s on these routes, with the schedule data taken from the May 1994 Official Airline Guide.

Airline	**Route**	**Block Time**	**Distance**	**Speed**
SW	Albuquerque to Lubbock	55 min.	289 miles	315 mph
CO	Providence to Newark	72 min.	160 miles	133 mph

The Continental aircraft flies 17 minutes longer for 130 miles less distance. If Continental could match SW's speed of 315 MPH, the block time for the Providence to Newark flight would be only 30 minutes. This would free Continental’s resources (essentially the aircraft and crew) for an additional 42 minutes to be used productively on another flight.

The reasons Continental loses 42 minutes of “factory time” is that its flight is because of a) it is flying in what the ATC system views as “congested” airspace, and b) it is flying into a hub-site airport in the Northeast US, a double whammy by productivity standards. *But this excess flying is a function of ATC capacity limitations, not airspace or airport limitations.*

This "block time creep", as it is called, has happened gradually over the years. Airline schedulers have continued to add block time into their schedules to accommodate the decreasing efficiency of the ATC system. To maintain Department of Transportation "on time" rankings, airlines continue to artificially add block time to each segment. Without an overview of Production Line Management, the total cost of this effective slowing of the airline production line remains unrecognized.

A quote from a recent article about USAir correctly identifies the major problem facing airlines today. The article's lead in states that:

"Some airlines pay their people more than USAir. So why then is USAir struggling so much? The answer may lie in the inefficient way in which USAir schedules and runs its planes." [4]

What the article did not address is the real reason for this inefficient use of their aircraft. If the reader is thinking the primary reason is lack of Production Line controls, with ATC at the top of the list, the reader is correct. Although other minor factors are involved, just as for the Continental example above, USAir must schedule a lot of excess block time for each flight segment. Additionally, once weather or other capacity limitations are imposed by ATC, hub operations (and therefore profitability) deteriorate rapidly.

Measuring System Productivity

Clearly, one of the problems is that today no airline, nor FAA, nor DOT, nor any union has a true measure of *system productivity*. ASMs, RPMs or aircraft utilization do not reflect the changes - positive or negative - that may take place in the operational environment. Nor do indices such as "on-time performance."

Traditionally, airlines measure and analyze *actual* aircraft performance against *scheduled* aircraft performance. But timetable "on-time" does not mean efficiency nor is it an indice of productivity, because airlines now must adjust their timetables to accommodate ATC system inefficiencies.

In the above example using the Continental flight, it will show 100% on-time just by meeting its 72-minute, 130-mph block time. It may be on time, but for a 737, the fact remains that the *productivity* of this aircraft, designed to fly at 500 mph, is abominable.

The first task in measuring true system productivity is to *determine what the airline wants the aircraft to do*. After 30 years of "positive control" by ATC most airlines

[4] *High - Flying Costs* - Pittsburgh Post-Gazette, November 13, 1994, Len Boselovic

do not have a clear idea of how it would like each flight to operate. Currently, the flight plans are generally those “preferred” by the ATC system, regardless of whether they make sense for that particular flight, on that particular day, with that particular load, under prevailing wind and weather conditions.

Therefore, to measure the productivity of its flights, each airline must first determine the optimum for each aircraft on each flight, as if that aircraft was the only one in the sky and perfect weather was the order of the day. This not only sets the goal to strive for, but it will also highlight the inefficiencies and throughput problems in the system. Airlines should then analyze the efficiency of the ATC system measuring what actually happened to each flight against this optimum.

The results of such an exercise would likely be shocking to an airline CEO - or more likely, to the CFO. On the following pages are some data that may start the shock therapy by outlining the scope of the loss of productivity due to the current ATC system.

Initial System Productivity Analysis

To underscore the failure of the ATC system to keep up with demand, let’s look at where we stand today. Below is one method of calculating and comparing a system productivity model. The fact is that under the current ATC system, the relative efficiencies of newer aircraft (avionics, speed, and to some degree fuel efficiency) are just plain wasted.

The methodology chosen determines an aggregate ground speed[5] for all fleets for each domestic airline operation. Calculations were made from the beginning of deregulation, 1980, until 1992. Because ground speed is not measured by DOT (or anyone for that matter) individual ground speed numbers for each airline are not as important as the percentage difference between 1980 and 1992. Although this initial productivity measure must be fine tuned, it highlights the critical negative productivity trend that must be reversed, which has nothing to do with labor issues.

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[5] Ground speed was calculated via the following formula using DOT Form 41 data.

(Total Annual ASMs/Total Block Hours)/Average Seats Per Aircraft

Airline	American	Continental	TWA	United	Southwest
1992 Ground speed	359	350	344	365	312
1980 Ground speed	388	388	376	400	303
% Difference	-8.07%	-10.8%	-9.3%	-9.58%	2.88%
1980 Stage Length	889	692	776	885	276
1992 Stage Length	807	777	710	802	380

This analysis is only meant to provide an overview of system productivity and not meant to provide the complete or final measure. Clearly business choices like fleet mix, operational cruise speeds and stage length should impact ground speed.

Because of this, the first objection to the above that will be brought up is that during the analyzed years American and United's fleets moved to MD-80/F100 and B737-300, respectively. The argument would be that these aircraft are slower than the aircraft they replace, thus accounting for the speed drop. If this was true the current airline schedules, a reflection of the previous years actual block times, should show an appreciable difference in schedule times for the same route using different aircraft types. They don't, as shown below.

Schedule Ground Speed Comparison[6]

United ORD-LGA (710 miles)

Flt 698	A320	1:56	379 mph
Flt 696	A320	2:00	366 mph
Flt 694	B757	1:59	369 mph
Flt 692	B737	1:55	382 mph
Flt 690	B737	1:54	386 mph
Flt 688	B727	1:53	389 mph
Flt 686	A320	1:56	379 mph
Flt 684	B737	1:59	379 mph
Flt 128	A320	1:59	379 mph
Flt 682	B737	2:02	360 mph
Flt 102	A320	1:59	379 mph
Flt 678	B737	2:00	366 mph
Flt 676	B727	2:02	360 mph
Flt 674	B737	1:58	372 mph
Flt 672	B737	2:00	366 mph
Flt 670	B727	1:53	389 mph

American DFW-DCA (1192 miles)

Flt 733	B757	3:17	363 mph
Flt 1973	B757	3:22	354 mph
Flt 1527	M80	3:26	347 mph
Flt 1043	M80	3:23	352 mph
Flt 2075	B757	3:31	339 mph
Flt 1587	M80	3:28	344 mph
Flt 577	M80	3:31	339 mph
Flt 1123	M80	3:30	341 mph
Flt 1877	B757	3:24	351 mph

Continental IAH-DEN (864 miles)

Flt 667	B727	2:18	376 mph
Flt 169	B727	2:20	370 mph
Flt 121	B727	2:19	373 mph
Flt 773	B727	2:19	368 mph
Flt 593	B727	2:19	373 mph
Flt 542	M80	2:21	368 mph
Flt 91	D10	2:25	358 mph
Flt 761	B727	2:21	368 mph
Flt 525	M80	2:21	368 mph

The above comparison shows that aircraft speeds are more affected by time of day than aircraft type. The above also shows that airlines have been unable to capitalize on the use of faster aircraft. The dollars spent on newer, sophisticated or faster aircraft are not producing all the in-service efficiencies that are possible. Analyzing CO Flt 91, a DC10, shows a 10 mph slower ground speed than the Flt 542 , an MD80. Theoretically, the DC10 should cruise at approximately 50 to 80 mph *faster* than an MD80, not 10 mph *slower*. This comparison shows that something other than fleet mix is primarily responsible for the 8% to 10% productivity loss above. That “something else” is the current Air Traffic Control system’s inability to meet the demands of its customers in today’s hub airline system.

Airlines today base their business decisions on the invalid assumption that way their production lines operate is unchangeable. Assuming runway acceptance rates, taxi speeds, gate congestion, or the requirement to fly a maximum of 250 knots below 10,000 feet are fixed in concrete and can not be changed is foolhardy. These ATC system-driven delays and procedures, implemented to protect the manually run system, can be changed and removed from the business equation.

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[6] Chart shows flight number, scheduled gate to gate block time from the March 1995 OAG and ground speed. Speed calculated by dividing block time by great circle distance between the two airports.

An example that highlights the philosophical problem facing the industry today is the building of the new airport in Shanghai. Until recently, the Chinese authorities assumed that this one runway airport is absolutely maxed out. Totaled. They can not get another aircraft in or out, so their obvious solution is to start digging and build another airport.

All this sounds dangerously familiar to the folks at home in Denver. Significantly, (and perhaps, similar to the Denver situation) the crux of the matter at Shanghai is the definition of “at capacity.” *The Chinese definition is 19 operations per hour.* They cannot conceive that there could possibly be any more use of their runway. So they run off and build a new airport. Also with 19-per-hour capacity runways. Even with low cost labor, this process is going to get real expensive, real fast for our friends in the Middle Kingdom.

In the US, we share a similar disbelief regarding our own runway capacity. We are a bit higher than our colleagues in Shanghai, with accepted good weather maximum of approximately 40 operations per hour (landings or takeoffs) per runway. But is that really the capacity? It is under the current ATC system. This is not a physical limit, i.e., plant and facilities, it is the limit based on the way we have chosen to operate our airspace system.

In other words, we must assume nothing is fixed, remove the blinders and shackles of history. Using the excuses that "that's the way we always did it" or “that’s the way it’s always been measured” are just no longer acceptable. It is a new world. In fact, we could build new airports at every rural speed trap in America, and it would do little to fix the current production line problem.

Airlines Need To Develop Their Own Productivity Measurements

What must be done is for each airline to devise its own measure of system productivity. Once the methodology of measuring system productivity is developed, airlines should calculate their fleet, hub, domestic system, international system and total system production line (read ATC) productivity. These inefficiencies may tend to look small on an individual aircraft basis, but calculated on a fleet wide, annual basis the numbers quickly add up to the Billions of dollars.

The fact, worth repeating, is that the airline industry continues to measure its actual performance against the scheduled performance, effectively what ATC will allow, rather than the optimum. This skews the operational data, allowing the airlines to miscalculate how much the current *ATC system - the one that the DOT simply wants to privatize - is strangling productivity.*

Flow Sequencing

Another primary production line task, now left to ATC, is aircraft flow sequencing.

Flow sequencing is the choreographing of the aircraft flows into and out of the hub on an aircraft by aircraft basis, for each arrival and departure bank. Under a Free Flight system, airlines would have the operation flexibility to maximize connections, efficiency, revenue, or a host of other operational or business goals. The current "first come, first serve" system, controlled by the Air Traffic Controller near the airport, once again, no longer meet the needs of the FAA's customers.

Recognizing that this is a major cultural change and that the current ATC environment will not fully allow this, major airlines can begin the process and the planning now.

Some suggested simple first steps or inroads into Production Line Management would be gate departure sequencing to set up taxi and departure flows. Numerous times aircraft will push off the hub gates, controlled by the airline itself, blocking other aircraft from that same airline. The blocked aircraft must then sit and wait with engines running to get in behind the blocking aircraft. Another benefit is pilots would know their takeoff sequence and timing, when leaving the gate. They could then better manage engine start, thus saving fuel.

Once the Production Line Management concept becomes the normal thought process, many other new ideas, with significant financial impact, would continue to surface.

VI.Conclusions

Over the past 50 years, the airlines have built their business practices around what ATC (a primary supplier to the airlines) would allow, instead of what is needed for profitable operations that are consistent with safety.

To reverse this, the airlines should first work to maximize management of their production lines within the current environment. Second, they should set up company wide production goals with direction from the highest corporate levels. This goal should encompass changing the basic external environment (read ATC) to allow full production line control within 5 to 8 years. Once the airlines orient their business under a "Production Line Management" culture, it will become obvious that the rapid implementation of Free Flight is required.

In other words, once airlines begin to take tactical control of their production lines the concept will expand rapidly. If the airlines cannot do this, or refuse to recognize that this is a critical task, the future of the airline industry is cloudy at best.

Fifteen years of research have led to the following conclusions.

- The operators and pilots are the *customers*, and the FAA is the service *provider*. With the implementation of positive control (early 1960s), the Air Traffic Service provider has trained the customer to accept what is offered. Today, this business relationship is 180^{o} out of kilter. This situation must be reversed and the customer must set the functional requirements with the service provider striving to meet them. Once the functional requirements are defined, the Air Traffic Service should apply only the minimum technology to meet those requirements.

- *The ATC system, as currently implemented, is the problem.* The aviation industry, working with FAA, must find solutions outside this current paradigm. ATC continues to automate the past control oriented methodology of separation. We must investigate every avenue to allow Free Flight to move forward safely and quickly, but not be constrained by historical views of ATC requirements, or by political considerations.

- The ATC issue is a business and financial problem requiring political and cultural change, *technology is not the issue*. Although not implemented, technology exists to solve the external ATC problem within 5 to 8 years. The question is whether the aviation industry is ready to tackle the major philosophical change required in the corporate and business culture. The industry can no longer relegate this problem to middle management R & D committees, or rely only on Washington lobbyists, which has been the case up until now.

- Recapturing control of the production process must become a "front burner" item for the CEOs and upper management at American, United, Northwest, and other major airlines. If ATC was a line item cost on the airline's annual report, the financial community would demand a speedy solution. Should the industry demand less -- obviously not, but top level management has yet to address this multi billion dollar problem.

The end result is that ATC must stop controlling aircraft and begin managing separation. The airlines are beginning to recognize this and coalesce on the Free Flight requirement.

As suggested by RMB Associates, RTCA, Inc. and the Federal Aviation Administration (FAA) have now developed an industry wide definition of Free Flight. Whether the approach as offered in Volume Two of the Free Flight study, *Free Flight - Reinventing ATC: The Minimalist Solution* study[7] , is correct or not is immaterial. With annual waste in the **Billions** of dollars caused by ATC, the industry must explore every avenue to solve this problem. This can only be done by a full court press on Congress, DOT, and FAA by the airlines, manufacturers and labor unions. Today, if Henry Ford walked into an auto factory he would recognize very little. Unfortunately, Wilber and Orville would feel right at home in today's aviation environment.

The aviation industry must examine all alternatives to the ATC problem. The industry cannot continue to wear blinders to new solutions that can increase safety and profits, and decrease system complexity. The bottom line is that the airlines can no longer afford to allow the government to dictate their business practices and control their production line direction and speed.

Deregulation allowed the airlines to pick where to fly, but how and when is still controlled by ATC. To use the auto industry analogy for the final time, the industry can now build Cadillacs, but are forced to do so using production techniques designed to build Pakards. It is time that the environment - the production process - be brought into the 21st century.

[7] *Free Flight - Reinventing Air Traffic Control: The "Minimalist" Solution,* October 1994, RMB Associates, Evergreen, CO

VII.About RMB Associates & ASRC

RMB Associates

RMB Associates was founded in 1981 to provide in depth analysis of airline/aircraft operations and to identify and seek out solutions to their operational problems. RMB Associates' primary focus is to provide the airlines and aircraft operators with a broader view and help identify their structural operational weaknesses. The aviation industry's dismal financial performance will continue unless the industry, as a whole, rethinks the basic assumptions on which they operate and then works to provide correct solutions for the real problems.

RMB Associates' has considerable expertise in the aviation industry. The experiences RMB Associates draws from include: airline and avionics engineering, avionics marketing, piloting as an airline captain, airline management and extensive dealings with the FAA and ATC. These unique experiences can identify and help solve the right problem, rather than wasting time and money solving the wrong problem. RMB Associates' papers include:

Survival: Airlines, Competition and Profits**,** February 1, 1994 - Airlines face many competitors today that remain unchallenged. This report identifies these competitors and other revenue negative aspects of the airline industry. This paper discusses the impacts of pricing, reservation agents, etc., that the airlines must begin to address.

United Airlines versus Southwest Airlines - Below the Surface**,** May 1, 1994 - In depth analysis of the operational and product differences between United Airlines and Southwest Airlines. This independent study breaks down the cost per Available Seat Mile (ASM), based on individual aspects of each carriers' operation. The study concludes that United's higher costs are a function of differing product/operational choices.

Free Flight - Reinventing Air Traffic Control: The Economic Impact, June 1994 - ATC is the largest controllable cost the airlines face. Unfortunately, it is relegated to mid level managers and technocrats, instead of receiving executive level attention. This report identifies the costs to airlines and the entire United States economy that go unchallenged because of the inefficient Air Traffic Control (ATC) system. These costs, borne by the consumer, are unacceptable and this report offers solutions that are critical to continued airline viability. This is the first independent analysis of international airspace management requirements and the cost to the airlines and economy in general.

Free Flight - Reinventing Air Traffic Control: Production Line Management, March 15, 1995 - If the aircraft is viewed as a factory, the factory is shut down when it is at the gate -- no product is produced. The airlines have recognized this recently, as evidenced by their interest in reducing ground turn times. Away from the gate, the factory is open and the production line is running. The study indicates that airline system productivity, measured in ability to produce ASMs per block hour, has decreased by over 8% since 1980. Unfortunately, the airlines have yet to fully recognize that, once running, ATC controls the speed and direction of their production lines.

Blueprint To Free Flight, April 1, 1996 - ATC is viewed as a very complex command and control system. This paper examines the underlying task of the Air Traffic Service (ATM) - separation. It postulates that the numerous layers of system complexity today are in place for only one reason - to protect the manual conflict probe. Therefore, computerizing the conflict probe process simplifies the ATM task. This document outlines a step by step process to replace the aging ATC equipment, build a Free Flight airspace by the year 2000 at zero cost to the airspace users and dramatically reduce FAA's procurement costs.

For further information on these important studies, contact:

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Aviation Systems Research Corporation

ASRC is a multi-dimensional consulting and research firm, assisting clients in all areas of aviation. Founded in 1984, ASRC has become a leader in providing accurate forecasts and trend analysis. Consulting clients include airports, airlines, and Fortune 500 companies in the aviation industry.

A cornerstone of ASRC is the publishing of white papers and studies that focus on issues that will be critical to the future of aviation. ASRC was the only consulting firm to publish data accurately predicting and discussing the major problems with the new Denver airport. The firm also publishes ***Airports:USA***, the only comprehensive traffic forecasts produced in the private sector. ***Airports:USA*** addresses traffic trends within the context of the changes expected in the airline industry. As a result, our forecasts are the most accurate available.

In addition to the *Free Flight* series of studies, other independent studies published by ASRC include:

- *Regional Airline Industry - The Effects of Code-Sharing* (1986). The first analysis of the effects that code-sharing would have on the regional airline industry. Findings presented to the RAA Presidents Council. In this study, the term "fortress hub" was first used and defined.

- *The Regional Transport Jet* (1989). This was the first analysis of the 50-seat jet transport produced independently of an aircraft manufacturer, and was the first such study to project a strong need for this category aircraft in the 1990s.

- *Analysis Of The Wayport Concept* (1989). An in-depth study of the potential for using remote airports specifically for interconnecting passengers and cargo. The study determined that the concept was inconsistent with economic realities of the airline industry.

- *Airport Capacity Needs In The 21st Century* (1990). This study provided an overview of the demands on current airport capacity, as well as the demands that will be placed on airport facilities in the years ahead.

- *The Continuous Hub Concept* (1991). An analysis of alternatives to increasing the efficiency of the hub-and-spoke system. First coined by ASRC, the term "continuous hub" is now discussed widely in the U.S. airline industry.

- *The U.S. Airline Industry: Reassessing & Rebuilding* (1993). This extensive study outlines the problems facing airlines, and projects the positive changes the industry will see in the years ahead.

In its independent studies, ASRC publishes its findings, recommendations and conclusions “as is” and “where is.” We endeavor to provide the hard facts, regardless of their “political correctness.” ASRC as a result has earned the reputation for honesty and integrity.

In our consulting projects, we use the same approach. We help our clients to objectively weigh alternatives and we state the results in a forthright and openly honest manner. ASRC feels that if America is to have the air transportation system it needs in the future, the politically-correct and sugar-coated consulting that is today all too common is not consistent with integrity.

Clients of ASRC include airlines, airports, aviation authorities, and aircraft manufacturers. In addition, hundreds of other aviation-related companies have purchased our many independent studies.

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Acknowledgment

The technical content of this paper is significantly tied to and influenced by Mr. Norman W. Watts of the FAA Technical Center. Mr. Watts conceived, formalized, designed and initially implemented an automated Air Traffic Management System based on Cybernetic Modeling, called Projected Flow Analysis (now called ATOM). His endeavors are well documented and Mr. Watts is truly deserving of recognition as the original "Father of Free Flight". In our view, there is no one within the FAA, or elsewhere, more deserving of recognition as one of the foremost proponents of Free Flight than Mr. Watts.

We have been honored to have been both influenced by and make use of many of Mr. Watts' astute technical views on and insights into automated air traffic management, in general, and Free Flight, in particular, throughout this paper.

Note:

This document reviews the issue of air traffic control, and postulates an alternative option that should be considered. This information is intended to contribute to the forum of aviation ideas. ***This study is produced entirely independently, without financial assistance or direction of any kind from any entity involved in any way with air traffic control systems.***

RMB or ASRC does not have a conflict of interest in the matter of air traffic control. It has no financial interest in any entity involved in any way in the building or supply of air traffic control systems, or involved in any way with the rebuilding of the current system. Furthermore, it has no clients that are involved in any way with the building of an ATM system, or any part thereof. This is not an advocacy document that promotes anything that will provide direct economic benefit to RMB or ASRC.

1. Executive Summary

The aviation industry has taken the first important step towards Free Flight -- FAA acceptance. Ever since the 1994 Congressional hearings on Free Flight, held as a direct result of our study, *Free Flight - Reinventing Air Traffic Control: The Economic Impact*, FAA's progress towards Free Flight acceptance has been extraordinary.

But we must recognize that endorsement of Free Flight and implementation of Free Flight are two completely different things. We cannot afford to waste scarce resources applied down the wrong path. In this regard, a comment made in the best-selling book, *Reengineering the Corporation* (a manufacturing oriented business book) hits the nail on the head.

> *"The fundamental error that most companies commit when they look at technology is to view it through the lens of their existing processes."*

Unfortunately, this pitfall - looking at the future through the lens of the past - is now hampering the development of a safer, more efficient air traffic management system. The objective of this document is to assist aviation leaders in focusing more clearly on this goal.

To start with, a clear and simple definition of the goal is needed. The goal is not "air traffic control". The real goal is significantly and fundamentally different: *it is to craft a system that will maintain the safe separation of aircraft while providing the airspace users the flexibility to meet their individual requirements.* Next, it must be recognized that just because the problem is complex, the solution need not be. Therefore, an important component of the task is to accomplish the goal using the minimum tools and technology necessary to do the job.

The current ATC process is mired in 40 year old technology and procedures. Accomplishing Free Flight will require new thinking, new perspectives, and a clear futurist focus that is not clouded by an unnecessary reliance upon outdated assumptions.

1.1. Bullet Summary

Today, the Air Traffic Management system in the United States faces a myriad of problems that are considered to be complex and almost unmanageable. From this the conclusion is often reached that the solution will be many years and billions of dollars in coming. *This view is entirely inaccurate, and can only be described as rearview mirror planning*. The current system and its problems <u>are</u> complex, but the solutions are not. Fortunately, the ATC crisis can be solved within three years, and for far less money than some may expect. To accomplish this, however, it will require strong, sharply-focused leadership that looks to the future instead of trying to build a new air traffic system on the rotted foundations of the old one.

1.1.1. Problems

There is no argument that the current system is experiencing a wide range of problems:

- Increased rsik of a complete ATC system shutdown caused by the Year 2000 (Y2K) computer problem.
- Continuing failure of display components used by FAA's Host Computer System (HCS), specifically, the 1970 and earlier vintage Display Channel Complex (DCC), Computer Display Channel, and Plan View Display (PVD) or Controller Workstations.
- Requirement by FAA's customer (airlines, general aviation, military, etc.) for a Free Flight airspace.
- Budget constraints forcing all government agencies to do more with less.
- The difficulty in transitioning to Free Flight assuring equitable access of all the airspace and runway assets at minimal costs to the airspace users.
- The software running in the ATC computers is such an undocumented kluge it will not meet the 10 to the minus 9th criteria required of flight critical functions.
- An ATC operation that would not pass a Flight Standards NASIP "White Glove" inspection routinely given to the airlines.
- Loss of state of the art technical expertise within the FAA.
- Loss of maintenance experts required to operate the current HCS/DCC/PVD system.
- An ATC system running on less computing power than most desktop computers.

1.1.2. Blueprinting The Solution

Solving the current ATC crisis can be accomplished in a manner that does not impair safety, nor the taxpayers' wallets:

- The near term (by the year 2000) partial construction of an ATC system built around an automated 4D conflict probe based on hardware independent, off the self software using on a common ATM framework. This software should be based on a distributed processing system hosted in commercial engineering work stations. This new system would initially shadow the current HCS/PVD/EDARC system. Once safety is assured, confidence is built and training is complete the separation manager (nee controller) would transition completely to the new system.
- Immediate implementation of a timed based metering system to the outer fixes or corner posts at the congested airports. This would be controlled by the users and monitored and made equitable by FAA.
- Implementation of CTAS in conjunction with the above to solve the hub arrival problem. CTAS, a NASA program, automates the arrival and departure sequences at airports with high density traffic.
- Center and approach control backup of the HCS/PVD with ATOM/BDACS hosted on engineering workstations initially shadowing two sectors in each facility for training and backup

1.1.3. Benefits

The benefits of RMB Blueprint will be immediately seen by all areas of aviation - airlines, general aviation, and the military.

- Rapid contingencl solution to the Year 2000 (Y2K) computer problem. The partial implementation of the Blueprint solution (15 workstations per enroute center would provide a very inexpensive backup to FAA's current Y2K paln.
- Increase in ATC system integrity, reliability and safety. A distributed processing system removes the potential single point failure, thus providing a "fail active" ATC system, standard in the most flight critical aircraft equipment. The ATOM/BDACS/CTAS solution would also provide a catastrophic failure backup for the HCS/PVD.
- A Free Flight airspace environment, returning operational control of the aircraft asset back to the pilot, airline or operator, except for actual conflicts and safety.
- Phased implementation reduces cost, complexity and anxiety during the transition. It allows reuse of the ancillary components and previously purchased technology (VSCS) by the new system.
- Zero cost to FAA's customers, and it can be accomplished at lower cost to FAA than current ongoing DSR/DCC program.
- Rapid installation of complete, new ATC system equipment (by the year 2000).
- Global separation management unconstrained by artificial sector/center boundaries. Although ground based separation managers would still monitor a specific piece of airspace, the global conflict probe would provide conflict information for aircraft departing or entering that airspace. This simple benefit alone removes most of the complexity from the current system.
- Real time reallocation and resectorization of airspace based on tactical information and the actual dynamic conflict density of the airspace.
- Retention of military airspace by DOD with real time use by commercial aircraft when not required by military aircraft. To the conflict probe, military airspace is simply another conflict (albeit fixed conflict) to avoid when active.
- The ATOM/BDACS/CTAS solution is an obvious political winner from a budget perspective since the total cost for the 22 ATC centers and 225 approach control facilities would be less than FAA has budgeted for the current DSR/DCC program.
- *All* of FAA's customers benefit regardless of the equipment in the aircraft. The minimum aircraft requirement to participate is a radio and transponder at current separation distances. This removes a critical barrier to Free Flight implementation -- the cost of airborne avionics equipment to participate.
- Hardware independence allowing the ATC system to inexpensively take advantage of the rapid increase in processing power.
- Common ATM software (Windows environment) framework allows new Air Traffic procedures and features to be implemented rapidly.
- Ability to evaluate avionics purchases based on real benefits with a measurable return on investment.

This new Air Traffic system would be built around the simple concept of *'Here is my intent, is it safe?'* Initial intent would be communicated through a flight plan. The separation manager (air traffic controller) would continuously use a 4D conflict probe to determine if the aircraft's protected area would overlap with another aircraft's protected area in the near term (i.e., 10 to 20 minutes). If no real conflicts existed, the path is determined safe and the aircraft would proceed per its intent.

Airborne conflicts would be handled tactically and changes could be communicated orally or via data link when available. Data link, including ADS/GPS and other advanced avionics are not requirements for Free Flight, but maximize operational efficiency within a Free Flight environment by increasing the accuracy of the navigation and surveillance position and the speed of communication. The key is putting a four dimensional computerized conflict probe in the ATC facilities and transitioning to time based sequencing for restricted resources. Technically, this can be done quickly with available software and hardware, and at zero cost to the users.

Bottom line: the failing ATC equipment can be replaced and Free Flight can be implemented by the year 2000. But before we begin solving this critical problem we must define the goal -- Free Flight.

1.2. Free Flight?

Free Flight is today's alternative to the existing outdated approach to Air Traffic Management. It is a system wherein each aircraft is allowed to operate using the flight path, in all four dimensions, that is determined to be best suited by each individual operator or pilot for their aircraft. Free Flight would apply from gate to gate and to all aircraft, from the biggest jumbo jet to the smallest home-built, from the military aircraft to the most advanced business jet. And to dispel a commonly held misconception*, all users of the airspace system would benefit without regard to the airborne avionics.* The aviation authorities, through separation managers (nee controllers), would still provide separation services. Defined from an economic perspective:

> *Free Flight is the safe removal of ATC from the business equation by the year 2000, allowing airlines, operators and pilots the operational flexibility to meet their individual goals. Free Flight should be accomplished by completely re engineering the ATC system* ***at zero cost to the operators****.*

Although thought of as revolutionary, there is nothing new about the Free Flight concept. In fact, the first pilot to fly in a Free Flight system was Orville Wright. He could do anything he wanted and was guaranteed not to hit another aircraft. Unfortunately, Orville was limited by his equipment, today pilots are limited by the ATC system.

1.3. Automated Conflict Identification - Free Flight's Missing Link

Admittedly, RMB Associates has focused on the what most call a "simplistic" approach to the implementation of Free Flight. This approach has grown out of attacking Free Flight implementation by asking a different question than most in relation to the problem. Many ask the question "How can GPS, datalink, ADS-B, TCAS, etc., be utilized to usher in a Free Flight environment." RMB/ASRC approached the problem from a different perspective and with a different question, "What is stopping the pilot from taking off and flying their preferred path to the destination and, if so desired, changing that path enroute." Both of these questions, answered correctly, can lead to the implementation of Free Flight, but only the second question minimizes the task.

The domestic United States already has excellent communications, navigation and surveillance functionality. What the nation does not have is an automated conflict detection capability. This is the only real constraint to moving to a Free Flight environment.

The current structured ATC system is in place to accommodate the manual conflict probe -- the controller. Free Flight removes that structure, allowing the conflicts to occur randomly within the separation manager's airspace. To assure the equivalent level of safety within Free Flight, something most replace the structure that helps the controller minimize and identify conflicts. This requirement is only fulfilled by providing the separation manager the correct tool -- a 4D computerized conflict probe using global data that can not be overloaded.

1.4. The Solution

By changing the common factor to all aircraft - the ATC separation methodology - all of FAA's customers benefit regardless of the equipment in the aircraft. The task is to define the minimum technology, and its display methodology, required in a Free Flight environment. In the aircraft*, the minimum equipment needed is a radio and transponder that is already installed in most aircraft.*

On the ground, RMB/ASRC contend that the only additional equipment required is a 4D computerized conflict probe. The technical task then becomes how to put a conflict probe in front of the Separation Manager as quickly as possible. This can happen considerably faster than most think. The following outlines the components required to accomplish this task.

- Install BDACS software (providing state of the art radar processing capability) from BDM Federal (Robin Deyoe, 303-541-3128) hosted on commercially available engineering workstation at the ATC centers and approach control facilities using the current radar data.
- Install ATOM, a conflict probe software tool into the ATC centers and approach control facilities. Atom, a commercial off the shelf ATC system, provides a state of the art conflict probe based on Aerospace Engineering & Research Associates (Mr. Lonnie Bowlin, 301-459-7890) AERALIB software.
- Implementation of CTAS, a NASA system, in conjunction with the above to solve the hub arrival problem at the congested and connecting-hub airports.

The next step would be the phased replacement of the HOST/PVD one sector at a time. This new system would initially shadow the current HCS/PVD system at two to three sectors. Once safety is assured, confidence is built and training is complete the separation manager (nee controller) would transition completely to the new system sector by sector.

ATOM/BDACS/CTAS is a complete ATC system built around hardware independent, off the self software based on a common ATM framework. This software is based on a distributed processing system hosted in commercial engineering work stations that would increase ATC system integrity, reliability and safety. A distributed processing system removes the potential single point.

Since the ATOM/BDACS/CTAS solution is an all-in-view, global system it would provide a catastrophic failure backup for the HOST/PVD prior to its full certification, even with only a few sectors at each center. This system could be installed at each ATC facility by the year 2000 for less than $500 million. This is considerably less than the $2.5 billion the FAA has already squandered in the ill fated Advanced Automation System (AAS) that was canceled in 1994 or the $800 million FAA is now spending to replace the controller's displays.

2. Prologue

Over the past 10 years, as the ICAO Future Air Navigation System (FANS) evolved, almost all attention was focused on airborne technology. The fundamental philosophical change[1] required by the Air Traffic Service (ATM) providers and the FAA corporate commitment to effect this change was not addressed. It has only been recently that the users (read FAA customers) have begun to focus attention on Air Traffic Management (ATM), recognizing that the benefits of the FANS technology flow through ATM.

At the August 9, 1994, Congressional Hearing[2] precipitated by the RMB/ASRC study, *“Free Flight - Reinventing ATC: The Economic Impact*”, the principals of RMB and ASRC, Captain R. Michael Baiada and Mr. Michael Boyd, presented the Free Flight concept to Congress. At that hearing the Air Transport Association (ATA), Small Aircraft Manufacturers Association (SAMA), National Air Transportation Association (NATA), United Airlines and the Aircraft Owners and Pilots Association (AOPA) also endorsed the Free Flight concept as the required FANS ATM end state.

The Free Flight Air Traffic Management concept was outlined in the in depth economic analysis *Free Flight - Reinventing Air Traffic Control: The Economic Impact*[3]. This study identified the current, inefficient ATM system as the major controllable cost (over **$5.0 Billion**) the airlines face today. The ATA calculated the airline loses, directly attributable to the Air Traffic System, at **$3.5 Billion** annually. These studies show that the airlines, and **the entire aviation community, can ill afford to equip with the new FANS technologies until the ATM philosophy is fundamentally changed**.

Simply put, Free Flight is a user preferred trajectory, the pilot or operator chooses the path, not ATC. All lateral and vertical airspace constraints, now in place, would be removed. The only acceptable constraints would be conflict resolution or safety. Conversely, one thing Free Flight is not is random action. Pilots will always adhere to some level of restrictions, whether put in place by ATM or the operator's dispatch. The difference is that the ATM restrictions will only apply to insure separation of aircraft and prevent conflicts in the short term tactical sense. Strategic planing and aircraft control should always fall to the operators.

Over 30 years ago, the FAA implemented Positive Control. The effect on the safety side has been extremely positive. The effect on the efficiency and profit side has been disastrous, especially over the last 15 years in a deregulated industry. The objective at hand is to craft a new air traffic management system that is safer than the current system,

[1] Removal of the control oriented philosophy and replacing it with airspace management philosophy allowing return of operational control of the aircraft back to the operator.
[2] House Committee on Government Operations, Employment, Housing & Aviation Subcommittee, chaired by The Honorable Collin C. Peterson. Hearing held in direct response to our initial Free Flight study *Free Flight - Reinventing ATC: The Economic Impact*.
[3] *Free Flight - Reinventing ATC: The Economic Impact*, June 1994, co-produced by RMB Associates, (303) 674-0229 and Aviation Systems Research Corporation (303) 526-2000

and is at the same time more efficient for the aviation industry. The two goals - safety and cost-efficiency - are not mutually exclusive. Both can be attained.

To explain the reason for this we use the analogy of the factory. If the aircraft is viewed as a factory, the factory shut down when it is at the gate -- no product is produced. The airlines have become increasingly aware of this, as evidenced by the interest in reducing ground turn times.

Conversely, once away from the gate. the factory is open and the airline production line is running. Unfortunately, this is where airlines have failed to take full advantage of the factory, for today, ATC controls the speed and direction of the production line. The airlines seem to disregard production line speed as if it is of zero consequence to their bottom line. Effectively, the airlines do not get anywhere near full productivity of their “factory” (the aircraft) once it leaves the gate. One major airline estimates, just in the domestic US, that it wastes 18 minutes per flight away from the gate. This equates to an **annual lost profit for that one airline of over $1.3 Billion** in productivity. Unfortunately. airline management has assumed - incorrectly - that this loss due to ATC inefficiency is a cost of doing business.

The end result is that airline production line control has been given over to the ATM supplier. The current ATM system has traditionally been felt to be a structural cost that can not be addressed. Additionally, since the ATC problem is erroneously viewed to affect all competitors equally, even today with all the fan fare surrounding Free Fight, limited resources are being applied. With the implementation of positive control the ATM provider has trained the customer to accept what is offered. This business relationship is 180^{o} out of kilter. This situation must be reversed and the customer must set the functional requirements with the service provider striving to meet them.

3. Free Flight Implementation and Technology

A common misbelief is that, despite the urgency to replace today's deteriorating ATC system, the technology is not yet available to move quickly. The thought process that has led to this misconception is flat wrong.

It is important to understand that there is a difference in the demands of domestic flight operations, and those on transoceanic routes. When the FANS was first conceived (early 1980s), the oceans were the likely target for implementation. The constraints of large separation standards, inefficient altitudes and limited access made any advance significant. Additionally, the traffic density was felt to be low enough to quickly support the FANS concept. With this in mind, everyone began working to improve oceanic Communication/Navigation/Surveillance (CNS), a cornerstone of Oceanic FANS implementation. The current oceanic CNS consists of HF radio, inertial navigation and hourly position reports. Engineers are working to advance the CNS technology towards Satellite Communications (SATCOM), Satellite Navigation (GPS) and Automatic Dependent Surveillance[4] (ADS). Unfortunately, this process requires significant investment by the airlines and the Air Traffic Management (ATM) providers.

Somehow, this gave rise to the belief that once oceanic airspace and procedures are in place the process can be transferred to the denser domestic airspace can begin. The belief became accepted that all the technologies developed for the oceans will be absolutely required for the domestic FANS application. This conclusion can be described in at least three ways: *Wrong. Incorrect. Not accurate*.

In the United States (and most other developed areas) these advanced CNS technologies are not required to move to Free Flight. These advanced technologies simply make Free Flight more efficient. A radical statement. But then again, most dismissed the entire concept of Free Flight at radical less than two years ago. Read further: **In the US today we have - already in place - all the CNS *functionality* required for Free Flight.** We have excellent communication -- VHF radio, which is as good as SATCOM. We have excellent navigation -- aircraft Flight Management Systems (FMS) providing accuracy of .1 of a mile, GPS systems providing even more accuracy or even VOR navigation. And finally, we have excellent surveillance -- radar that, if properly processed, provides real time aircraft position to the separation manager[5] on 10 to 12 second intervals.

In other words, in the domestic airspace today, we already have the CNS capabilities that the engineers are working so feverishly to provide in the oceans, yet we do not have Free Flight. The $64,000 question is why.

[4] ADS - Provides aircraft position and near term flight path (intent) to other aircraft and ground system via datalink.

[5] The term separation manager and air traffic controller are used interchangeably. This is done on purpose to facilitate the thought that the airlines can no longer accept the idea that ATM is in total "control" of their aircraft. Aircraft should be controlled by operators and pilots. The separation manager need not control the aircraft except to prevent aircraft to aircraft conflicts or provide other safety services.

4. Automated Conflict Identification

Admittedly, RMB Associates has focused on the what most call a "simplistic" approach to the implementation of Free Flight. This approach has grown out of attacking Free Flight implementation by asking a different question than most in relation to the problem.

Most ask the question "How can GPS, datalink, ADS-B, TCAS, etc., be utilized to usher in a Free Flight environment." RMB Associates and ASRC approached the problem from a different perspective and with a different question, "What is stopping the pilot from taking off and flying their preferred path to the destination and, if so desired, changing that path enroute." Both of these questions, answered correctly, can lead to the implementation of Free Flight, but only the second question minimizes the task.

The aviation industry can not continue to throw technology at the problem of Free Flight implementation. We must define the underlying task, which is safe separation of aircraft in a random path Free Flight system, and apply the minimum technology required. The following will look at the Communication/Navigation/Surveillance (C/N/S) components of the United States **domestic airspace system** covered by radar surveillance and answer the latter question. Although recognizing that some areas (especially those used by GA) do not have radar surveillance, this is a question of how to provide separation services, or if there are even desired, not how to move to Free Flight.

4.1. Communication

Aircraft already have excellent VHF voice communication available. Although many say the frequencies are congested, much of this congestion is requests for changes because the pilot was unable to file the preferred path from departure to destination. Also, since today normal enroute separations are 6 to 9 NM, if the separation manager only vectored the aircraft for real conflicts (5/3 NM separation) communications requirements would diminish significantly. Therefore, increased communication speed (datalink) by itself will not allow the use of a user defined path.

4.2. Navigation

Since the essence of Free Flight is the users chosen flight path, whether the pilot chooses to fly an RNAV direct route, VOR airways, or S turns to the destination there is already onboard navigation capability to fly the path chosen by the user, given the navigation equipment the user chooses to install. Therefore, increased navigation accuracy will not allow the use of a user defined path.

4.3. Surveillance

The surveillance issue has more than one component. Each will be discussed separately.

4.3.1. Surveillance position accuracy

The radar position (transponder or primary where available), as determined by the HOST tracker, has safely supported 5/3 NM separation for 30 years. Although it would bolster the confidence of the controller by providing a more accurate target, the airspace system could not be changed based on increasing surveillance position accuracy alone. By itself, increasing the surveillance position accuracy will not allow the use of a user defined path.

4.3.2. Intent

This is a critical component of conflict identification. The flight plan intent has been validated for years as the primary intent information used by the separation manager supporting 5/3 NM separation. The automated conflict probe must be able to use all known path intent (flight plan, velocity vector, etc.) information to provide conformance monitoring and conflict detection. Implementing Free Flight using flight plan intent and properly processed radar data providing velocity vector at the 5 NM separation standard is possible **without** ADS-B or other datalink intent information. Increased intent alone will not significantly alter the controller's ability to identify conflicts. Therefore, increased intent information will not allow the use of a user defined path.

4.3.3. Separation

The current 5/3 NM separation standards has served us well for many years. Free Flight is not about reducing separation, it is about the airspace user choosing their individual flight path. The separation standard determines the number of conflicts that will occur, and therefore, determines how efficiently the aircraft can keep to the user defined path. If the separation requirement was 1000 NM, Free Flight would be very difficult to justify as an efficient system. By the same token, the structured airspace now in place would also be very inefficient at such large separation standards. But the 5/3 NM separation now in place is more than adequate to support an efficient Free Flight environment.

Once Free Flight is in place, and after a careful safety analysis, the increased surveillance position accuracy of advanced radar processing and airborne avionics may support reduced separation. That same analysis may determine that a drop from something less than the current 5/3 NM separation (which we feel ATOM/BDACS will support) may not justify the cost of new avionics to lower the separation standard farther. Therefore, the size of the separation criteria does not help or hinder the use of a user defined path.

4.3.4. Conflict resolution

The separation manager has successfully manually resolved all known conflicts since the ATC system was put in place. FAA's analysis has shown that the number of conflicts is about the same in Free Flight as it is in today's structured system. RMB/ASRC contends that given an accurate computerized 4D conflict probe the number of required conflict resolutions will actually decrease. This is based on today's applied separation of 6 NM to 9 NM given the inaccuracy of the HCS tracker and Snitch patch. Since, at the worst, the number of conflicts stays approximately the same, the separation manager should not have a problem manually resolving conflicts in a Free Flight airspace system once they have been identified. Also using ATOM's look ahead capability, if a multiple conflict resolution is required, ATOM could provide an earlier alert to the separation manager. Therefore, automating conflict resolution does not allow the use of a user defined path.

4.3.5. Local data

Today, the manual conflict probe (controller) has limited to no data on potential conflicts outside their sector. This leads to considerable coordination for even minor changes requested by the pilot. But this coordination does not stop downline conflicts, it only alerts the next controller that something outside the standard structure is occurring. Sector boundary airspace (boundary running) and Letters of Agreement (more structure) further limit the controller from granting the pilot's request, even if no conflict exists along the new path. Except for the airspace they are monitoring, the controller does not know whether a conflict exists or not. The application of 4D computerized conflict probe, using global data (a minimum of 30 or more minutes outside the individual sector), will allow the separation manager to look down the new intent (shadow flight plan) for potential conflicts out to N (10 to 20?) minutes. This conflict look ahead is not limited by arbitrary sector or center boundaries. Since the separation manager must assure separation, the concept of global data, local separation utilized by a computerized conflict probe provides the tool to meet the most stringent safety requirements. Simply providing more data into the current system will overload the already overloaded manual conflict probe - the controller. By itself, expanding to a global data set does not allow the use of a user defined path.

4.3.6. Conflict detection

Now we come to what is the only true constraint to moving to a Free Flight environment. Although misunderstood by many, the main impetus to increase surveillance position accuracy is to allow the implementation of a computerized 4D conflict probe. It is questionable whether installing a computerized conflict probe using HOST or ASD data would be viable. Although the above indicates that globally based, more accurate surveillance position data may be required, its purpose is to simply make the computerized conflict probe work. The current structured system is in place to accommodate the identification of conflicts for the manual conflict probe -- the controller. As aircraft density increases the current ATC system requires more and more structure (i.e., New York Tracon). This minimizes the number of conflicts and if conflicts occur, puts most of them in the same place time after time. This helps assure the controller that no conflicts will be missed, something that is clearly unacceptable from all viewpoints.

What Free Flight does is remove that structure allowing the conflicts to occur randomly within the separation manager's airspace. To assure the equivalent level of safety within Free Flight, something most replace the structure that helps identify conflicts. This requirement is only fulfilled by providing the separation manager the correct tool -- a 4D computerized conflict probe. Therefore, a computerized 4D conflict probe based on accurate, global position data and intent **will allow** the use of a user defined path.

4.4. Free Flight's Missing Link

Although each of the above components will increase the efficiency of a Free Flight system, only automated conflict identification in a random route system can, by itself, provide a significant move to Free Flight. Today, most airspace restrictions are in place simply to assure conflict identification by the controller in the manual airspace system.

The primary requirement of a Free Flight system is a computerized 4D conflict probe using global, highly accurate surveillance position data. From a logistical point of view, the hard way to do this is by installing GPS and datalink in all the aircraft (200,000 plus) and datalink capability in the ATC facilities on the ground. Even with the airborne avionics in place, an advanced computer tracker (like the BDM Data Acquisition and Conversion

System - BDACS) and a computerized conflict probe (like the Atom ATC software package) would still be required in the centers and Tracons.

An alternative to the aviation authorities current plan-- ATOM/BDACS/CTAS -- is outlined herein. Logistically this is a much simpler implementation that replaces the aging ATC equipment infrastructure (22 centers and 225 Tracons). Using ATOM/BDACS to properly process radar data increases surveillance position accuracy, provides global aircraft position data and installs a 4D computerized conflict probe. **No airborne equipment, other than a VHF radio and transponder, is required to move to a Free Flight airspace system.**

Additionally, as users invest in advanced avionics within a Free Flight system, based on ATOM/BDACS/CTAS, the infrastructure and operational flexibility are available to immediately benefit the user. The converse of this, purchasing advanced avionics in today's positive control airspace, will yield limited benefits at best. Also, by replacing the ATC system, except for the radar, the transition and system integration becomes considerably less complex. Using software that is hardware independent, providing a common ATM framework, ala Windows, decreases the complexity of implementation and future upgrades.

Finally, the separation problem is the same any time the aircraft is moving, in any airspace, even on the ground. This allows the same system to be deployed in all ATM facilities, the training to be the same for all controllers and the implementation costs to drop significantly. The ATOM/BDACS/CTAS solution rapidly replaces the aging ATC equipment infrastructure, reduces the cost of the new system below the budget for new system displays (DSR) and puts in place the basis for a Free Flight airspace -- automated conflict detection.

There is an old adage that sums up the true path the industry must take to reach a Free Flight airspace - **"Solve the right problem, Keep the solution simple."**

5. Separation

Before proceeding any further we must define the primary job of the ATM provider. This is very simple -- **separation of aircraft**. The current structured, control oriented[6] ATM system is not the goal, but rather the method chosen to accomplish the basic task -- **separation**. Flow management is not an end point of ATM, it is only a method to accomplish the basic goal -- **separation**[7]. Notice a theme developing here. The ATM provider's primary task is **separation of aircraft** -- do not let two aircraft collide. And, as we all recognize, anything less than 100% in accomplishing this task is unacceptable. Will ATM provide other services, i.e., emergency services, search and rescue, etc. -- absolutely, but these services are not addressed in this paper since they do not detract from or complicate the primary task -- **separation**.

Now that the goal of separation is firmly planted, let us examine what is required, at the basic level, to meet this goal. This includes only four items:

1. The knowledge of the position of each aircraft.
2. The knowledge of the intent of each aircraft.
3. The ability to compare the positions of two aircraft, and their intent, to determine if they will conflict.
4. The ability to communicate to the aircraft to resolve the conflict, if and when necessary.

The method chosen and the technology applied to these four items determines the amount of separation required between the two aircraft. In fact, we would contend that even intent is not required. But without it, the required separation would be too large to be economically feasible. Remember, it is economics that drives the application of new technology to the above four items to safely reduce the required separation.

As an example, for two B737 aircraft flying 500 NM apart, physics dictates that it is impossible for them to collide within 10 minutes. If the two aircraft cannot collide, why then, should they be controlled in any way by the separation manager? But to limit complexity, all the pilot need do is provide intent. As the aircraft approach each other this intent becomes important. As the distance between the aircraft is further reduced, the separation manager may be required to limit the approach dynamics of the aircraft to

[6] Today aircraft in the IFR ATC system can not deviate or change its flight path except through prior approval from ATC. The assumption, by the controllers, that they must be complete control of the aircraft extends from gate to gate.
[7] The view that the task of flow management is separation is a rather controversial conclusion, thus requiring an explanation. Most views on flow management stop with the thought that it's role is to insure that demand does not exceed ATM capability (real or imaginary). As far as this goes this is true, but the question needs to be asked "What happens if real demand exceeds flow capability?" Well the obvious reason demand should not exceed capability is to insure that the limited resource or local separation manager is not overloaded. And overloading could lead to potential conflicts and loss of separation, therefore leading to the conclusion that the basic underlying goal of flow management is, once again, **separation**.

maintain separation (i.e., conflict resolution). Remember, Free Flight is not random action but, conversely, the separation manager's separation advisory actions should only be limited to conflict resolution. Most flights, including all airline flights, normally do not have a requirement to deviate immediately from the planned flight path. But, these flights must have the flexibility to continually optimize their path[8]. As more advanced technology is put in place, aircraft separation will be reduced and arrival capacity will increase, thus reducing these constraints more and more.

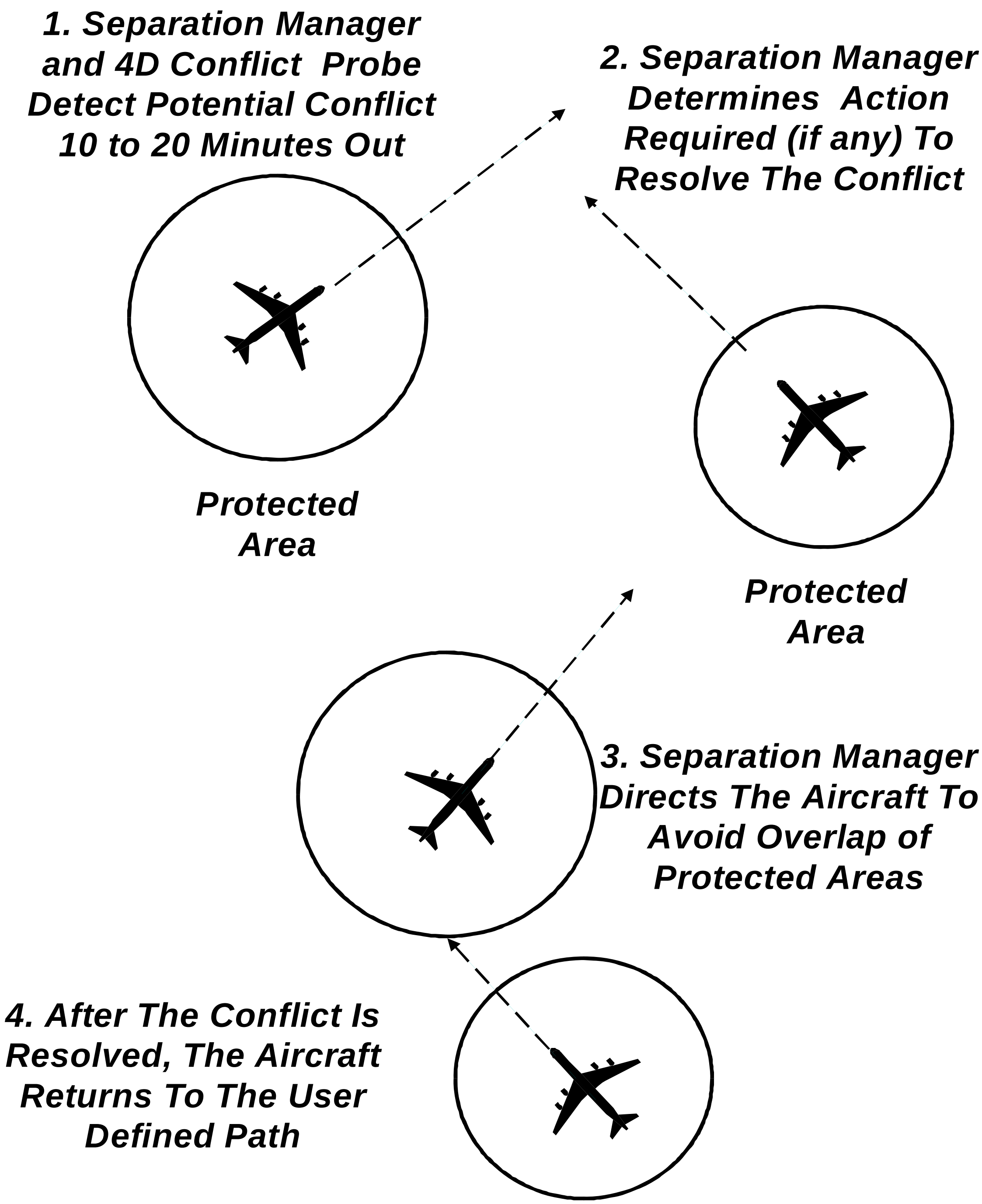
With the four requirements of separation and the user requirement of Free Flight in mind, we must now examine new methods to meet these requirements. The first step is to move forward based, as much as possible, on the technology and resources in place today. Since, as discussed, the domestic airspace already has all the functional CNS capability for Free Flight in place, the only new technology required to accomplish the task is a "conflict probe". Actually, this is not a new requirement, since the current system is already built around a conflict probe, albeit a manual conflict probe -- the separation manager or, in today's terms, the air traffic controller. Unfortunately, requiring the separation manager to a make real time, manual visualization of the aircraft position and intent and to determine if a conflict will occur does not lend itself to an efficient system. What is new is the requirement for an accurate computerized conflict probe which cannot be overloaded. **Basing separation on a computerized conflict probe significantly reduces the complexity of the ATM provider's task.**

The computerized conflict probe would monitor large chunks of airspace, much larger than the current separation manager's sector. Unfortunately, the air traffic controller's view of the world only encompasses the sector being controlled. This limited view of the world, by itself, causes significant inefficiencies because of the coordination required to make even small changes. Because the computerized conflict probe is not limited to arbitrary boundaries, the separation manager has considerable flexibility, therefore the aircraft are able to optimize their path and still maintain separation. This negates the requirement to "control" the aircraft from gate to gate. Under Free Flight, separation managers would not have to coordinate changes with the next sector to determine if the near term aircraft path is conflict free.

The computerized conflict probe always knows whether a conflict exists for the next x minutes (estimated at 10 to 20 minutes) when the change is entered, regardless of arbitrary sector boundaries. Hence, the fear of a potential conflict immediately after transfer from one sector to another becomes a moot point. Additionally, numerous other protective layers of procedures and software, built to prevent separation manager overload, can be removed.

[8] Some of the optimization factors operators must have the flexibility to control include: bank arrival sequence, block time, fuel, speed, route, altitude, weather, turbulence, etc.

Free Flight
Separation Model



At the lowest level of complexity, each separation manager's workstation would only require access to the four requirements of separation for all aircraft in the area monitored and the position and intent of the aircraft in the areas immediately adjoining.

Many functions, now felt as absolutely essential for ATM, are a function of the control methodology chosen to accomplish separation. As an example, the controller to controller network, including electronic hand-offs and numerous other functions, would not be required. Change the methodology to accomplish separation by introducing a computerized conflict probe and the requirement for these functions will be diminished, or removed completely. In other words, the current system complexities are caused by 30 year old equipment and procedures in place to prevent the manual conflict probe from being overloaded. Install a computerized conflict probe, which cannot be overloaded, and system complexity is significantly reduced.

The control oriented methodology, currently in use to accomplish separation, is firmly routed in the technology of the 1940s and is no longer required. Once the control oriented solution is changed to separation management based on a computerized conflict probe, Free Flight becomes much easier to implement. Remember, Free Flight can be implemented with a transponder (surveillance), a flight plan (intent), an air traffic controller (conflict probe) and a radio (communication). In this scenario the only concern is when the manual conflict probe will be overloaded[9]. One of the main reasons the linear system is in place (also a carry over of the VOR/ADF ground based navigation system) is to prevent overload of the manual conflict probe and prevent the requirement for manual conflict resolution. This is true whether enroute or in the local area of the airport. Essentially, the traffic is deconflicted through linearization and structure. Unfortunately, under a linear system, as navigation becomes more accurate, airspace system safety is actually reduced by aiming everyone, extremely accurately, into the same funnel.

Finally, as mentioned above, **we already have the CNS capability in the domestic US today to support Free Flight using the current 5 NM radar separation**. Above 37,000 feet, the minimal aircraft count should allow Free Flight today with only the manual conflict probe -- the air traffic controller. This is a very important point -- **new aircraft equipment including datalink, SATCOM and GPS are not presently required for Free Flight** in the domestic US airspace system. These new technologies only maximize operational efficiency within a Free Flight environment. At some altitude below 37,000 feet, as aircraft density increases, the only additional requirement would be a ground based four dimensional computerized conflict probe with additional aircraft equipment not required. The determination of the altitude where the separation manager would be overloaded in a Free Flight environment is a prime concern and is a prime goal of a Free Flight simulation.

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[9] The workload limit of the new separation manager in the end state Free Flight airspace is a critical question. With the current number of air traffic center sectors in use, initial studies show the Free Flight conflict rate to be 3 to 4 conflicts per hour per separation manager, which is actually lower than the conflict rate in the current linear system. Obviously, a more detailed analysis should be run. This analysis time frame should be on the order of 3 to 4 months, not 10 to 20 years.

6. Arrivals

Because the runway is linear, at some point in the flight, the aircraft must line up with the runway to land. Safe aircraft procedures dictates this point to be on the order of 2 to 5 NM from the end of the runway[10]. The current requirement to merge the arrival aircraft into a linear stream 30, 100, 500 or 1,000 NM (i.e., "ATC" preferred routes, etc.) from the airport is for the convenience of the ATM provider or a limitation of the manual conflict probe used by ATM, and is not required because of aircraft or separation requirements.

Obviously, when numerous aircraft approach the airport at the same time the aircraft arrival stream must be coordinated by a schedule or equivalent process to facilitate merging of the aircraft from different directions. Therefore, at the hubs and other large airports, the separation requirement at the end of the runway becomes a more complex problem. This is based on the fact that all the aircraft must use the same piece of concrete. But even here the problem is still separation. The answer is separation based on time. After departure at the outlying airports, the user/operator (not ATM) should manage the enroute speed to choreograph the arrival stream of their aircraft at the destination hub airport.

The separation manager should then monitor the arrival stream to assure separation (using the computerized conflict probe and the traffic display) and only interfere if separation would be lost. The question most asked at this point concerns simultaneous access for two different carriers. This is not the problem most people think. First, the problem is only a factor at connecting-hub airports. Let's face it, Des Moines or Tulsa will never have a major problem.

Secondly, the hubbing carriers want to bunch their arrival bank as close as possible. As the arrival rates increase, given gates available today even the largest hub bank could be easily landed in 15 minutes. Third, there are only a few dual hub airports where bank arrival competition would be a problem. Even today, with the lower arrival rates, most carriers endeavor where possible to schedule their arrival and departure banks[11] so as not to interfere with another carrier's arrival or departure bank. As an example, a carrier noticed that taxi time at St. Louis was above normal. Upon closer examination, the departure time was found to be in the middle of a small TWA arrival bank. The carrier tweaked the departure time about 10 minutes and the taxi time went back to normal.

There is also a misconception that the top 20 pacing hub airports are maxed out. This is wrong. Even a casual observer can easily determine that a significant amount of the runway usage is wasted. But to utilize this wasted runway capacity, the aircraft, and the air traffic system, must be able to accomplish **time based separation at the runway end**.

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[10] Noise, terrain and other environmental issues could move this point father from the runway end. This in no way changes the dynamics required to implement this system.

[11] Some airlines purposely overlay a competitors bank for marketing reasons. The question is whether these airlines understand the operational costs.

This will significantly increase the arrival rate, but to accommodate additional aircraft will require new equipment. In the near term, this can be accomplished by the FAST (Final Approach Spacing Tool) tool in CTAS. In the future, CTAS will become a monitoring tool and the Flight Management System (FMS) will take over this job. To do it properly, the FMS must be able to arrive at the merge point within plus/minus 5 seconds. This 5 second requirement would be a major factor in maximizing runway throughput. This will allow arrival/departure capacity to rise above airport demand[12], a prerequisite for the most efficient gate to gate Free Flight.

Time based navigation is not new technology, but has not been economically justifiable under the current control oriented ATM system. The B737 has had this ability for over 5 years (Required Time of Arrival - RTA), *but has been unable to use it.* This inability to use purchased technology is due to ATM's inability to credit "equipped aircraft" in what is viewed as a mixed environment. The ATM philosophy is to limit airspace procedures to the least common denominator aircraft. The computerized conflict probe (ATOM) can differentiate between aircraft based on actual aircraft equipage. In the terminal area, when arrival streams dictates flow sequencing procedures be in place, the time window of the non equipped aircraft can be expanded to accommodate the less accurate system.

Once again, **why buy more sophisticated aircraft equipment when we cannot use what we have? The answer is you do not.** New equipment will only be purchased when the actual benefits of the new equipment exceeds the cost to install and maintain it within the framework of an adequate return on investment.

The impetus for the airlines to begin to equip, with advanced CNS and FANS technologies, would be to institute Free Flight (departure fix to arrival fix) and allow the airlines to begin to choreograph their arrival streams at the arrival fixes already in place. This could be done today without any advanced aircraft technology. Personal experience supports using RTA, ETA, pilotage, or the airline ground based flight planning computer and ACARS to merge the aircraft at an arrival fix within 1 minute. This could be started by individual airlines, at off peak periods, at a single arrival fix, using manual procedures.

Once the concept is established as financially beneficial, moving towards operator sequencing at all hubs is justifiable. This first step, using currently installed equipment, would begin the process of shifting operational control of the aircraft from the ATM provider back to the operator. The separation manager would monitor the enroute arrival stream to assure separation. This process could begin under the current ATM system. Once in place, the merge point could be moved closer to the runway as new procedures and technologies are implemented.

[12] Gates are the true demand limit at an airport. If a hub airport only has 100 gates, the likelihood that all gate are empty is low thus limiting normal airport demand per hour somewhere around 75% of the available gates. The maximum arrival rate target per hour at an airport need not be much more than 100% of available gates. The bottom line is that airlines must have gates to park the aircraft and load/unload the passengers.

In the near future (5 years), if applied properly, technology and procedures can allow airport capacity per hour to approach 100% of the available gates in almost all weather conditions. And, as explained in our first two Free Flight studies, gates are the main factor in determining true airport demand. Because of this, airports and enroute airspace should never limit aircraft flow. Consequently, the ATM part of the flow management task will revert to a monitor function to assure separation.

7. Flow Capacity versus Flow Sequencing

Much has been said about the requirement of flow control. In a Free Flight environment, flow control, as presently practiced, is unnecessary and should be replaced with flow management.

The flow management concept is actually two distinct and different tasks. The first is flow capacity, the determination of constraints to flow and the available flow rate to assure separation in limited airspace, runway or airport capacity (an ATM task). The second part of flow management is flow sequencing, the choreographing of the aircraft (primarily a user/operator task) into the area restricted by flow capacity. Although the ATM provider must have flow sequencing capability they should only interfere or provide sequencing if safe separation (the only true ATM task) is predicted to be lost or two operators could not agree. This would be the case for aircraft without a dispatch or strategic planning capability, inability of the operators to merge competing arrival streams, and at the smaller airports. Let's face it, racing to the end of the runway is not an acceptable procedure.

A brief description of the current flow control system would be helpful. As stated earlier, flow control is just one of many methods to assure separation. Today, it attempts to maintain separation by limiting access into and out of a limited resource, usually the airport area, so as not to overload the terminal area air traffic controller. If a restriction to an airport is in effect (snow, fog, etc.), someone must decide how to allocate the available resource that remains.

For example, if the airport demand is 90 aircraft an hour and fog closes one of the three available arrival runways, the airport arrival flow capability would fall to 60 aircraft per hour. Someone must allocate use of the remaining two runways. Today, the FAA Air Traffic Control System Command Center allocates the individual arrivals on an aircraft by aircraft basis. This is done through a flow control program. Additionally, once a flow control program is put in place, ATM limits individual departures based on its determination of some future acceptance rate at an airport or sector[13]. This puts the airline production line speed into the hands of an external control, not a path to profitability.

Under Free Flight, the ATM provider would only apply flow capability constraints where a limited resource (weather, demand above flow capability) exists. Under the realistic presumption that the airspace is never overcrowded (only the air traffic controller's display is crowded), each airline should only be advised of the potential future constraints. FAA would still partition the available arrivals based on some equitable format (read political solution required here). Once allocated, each airline would decide which of its flights is the most important and utilize those arrivals to maximize its operation. The airline should not be made to accept constraints based on the ATM provider's view of the future, but should

[13] Sectors should not limit flow. ATM should provide flexibility sector boundaries to accommodate all required traffic loads.

decide, on its own, whether to launch an aircraft or not. The control of the aircraft or command to depart or hold should come from the operator, not ATM.

The question is always asked "What if the airline guesses wrong and launches the fleet"? If this happens, the operator would assume increasing airborne delay constraints as the number of aircraft in the system grew beyond the ATM real time flow capacity in the constrained area. The airline would decide how to implement the required airborne delay and its aircraft would have to divert or hold **as directed by the operator**. Although a considerable problem in a linear system, it is handled much easier in if a Free Flight system is in place. Remember, the flow restriction only applies at the arrival airport. The airspace outside the local runway area can handle a much larger capacity, even if aircraft are required to reduce speed or enter a holding pattern. With the operator communicating the hold or divert command to the aircraft (many airlines already have data link capability to their aircraft) and a computerized conflict probe, entering holding and separation of holding aircraft in random locations is no different from two aircraft on linear routes. To the computerized conflict probe, the holding aircraft is viewed the same as any other enroute aircraft.

Flow sequencing, on the other hand, is the task of choreographing the arrival stream into an airport, or any area that is restricted (i.e., a single hole in a line of thunderstorms versus a landing runway). The operator should manage the arrival flow to choreograph aircraft sequencing to meet their operational and economic requirements, not the ATM provider's connivance. Because of this, flow sequencing is operationally and financially critical at the hubs. Whether a flow capacity restriction is in place or not, arrival aircraft, especially at a hub, must be sequenced by the user/operator to maximize operational efficiency and meet internal business requirements. Once the sequencing is accomplished, the separation manager's job would be to monitor the flow for separation and merge additional aircraft into the flow as required. The bottom line is that managing the mix of the arrival flow is a function best handled by the airline or operator.

As discussed, airlines can begin flow sequencing at arrival fixes on a trial basis very quickly using manual procedures. Once established as viable, more ground based computer power could be applied. Using the real time departure time and flight time, the operator can sequence hub arrival aircraft on a personal computer. Prior to or just after departure, sequencing the arrival stream at a hub is not very difficult once arrival rate capacity and arrival demand is known. More complex sequencing, required for optimum financial results in a Free Flight system would require more sophisticated software and hardware capability.

To maximize the benefits inherent in Free Flight will require an investment by the operators and aviation authorities. This vision of the future should not limit initial flow sequencing with the equipment currently in place. Even manual sequencing would provide financial benefits. The sooner the operators begin to regain production line control, the better.

8. The Fallacy of Alert Zones

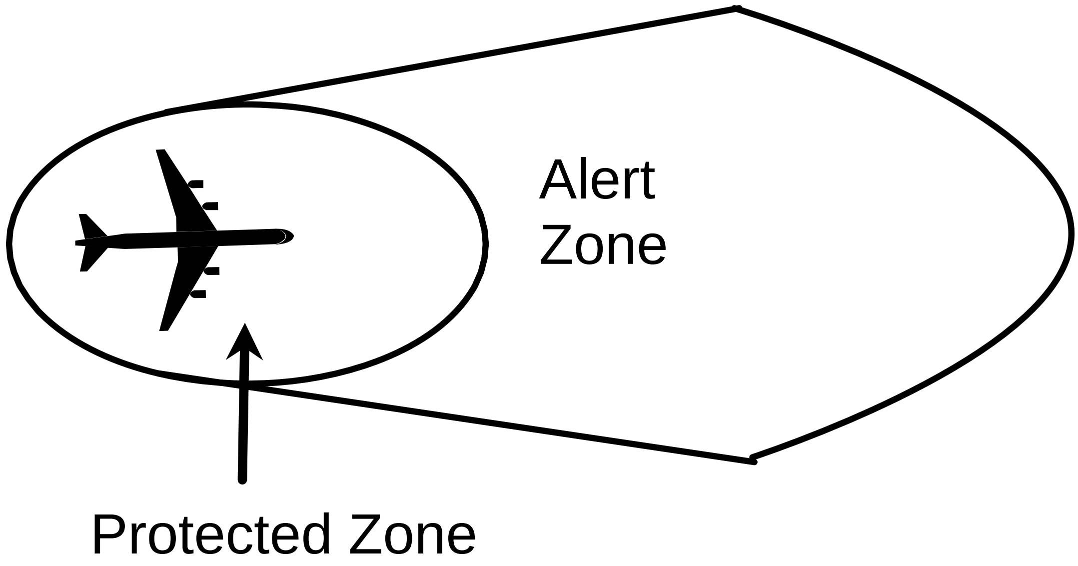
One of the biggest conceptual mistakes that is driving the industry to seek unnecessarily complex technologies for Free Flight is a perceived need for “alert zones”. Stated simply, alert zones are not necessary, and pursuing this concept will delay and possibly torpedo the timely replacement of today’s failing ATC system.

Under the alert zone concept, current FAA thinking places two areas around each aircraft, a protected area and an alert zone. The protected area is analogous to what we use today for the 5 NM separation, effectively a 2.5 NM circle around each aircraft. If the controller manually identifies that two protected areas are anticipated to overlap, they alter the aircraft’s flight path to avoid a conflict.

The alert zone, a new concept, is an area where a pilot can maneuver at will. The alert zone concept is based around the philosophy “Here is my velocity vector, make it safe.” In other words, while still requiring a ground based separation service (which RMB/ASRC feels is the safest way to provide separation services), the pilot will maneuver the aircraft at will, and then tell the separation manager after the fact. The maneuvering is only allowed within certain parameters (hence alert *zone*) as long as the alert zones for two aircraft do not overlap. If the alert zones of two aircraft overlap the separation manager will require further restrictions to assure separation. Unfortunately, without clear “intent” it is impossible for the separation manager to determine if a conflict will occur.

Now if all this sounds complex, it is. All the data that must be transferred under an alert zone concept makes data-link a necessity. Alert zones also forces the requirement of other expensive avionics into the unsuspecting aviation user’s cockpit. This causes problems with mixed fleet issues and implementation costs that will continue to derail progress towards Free Flight.

To understand the reason for the alert zone concept, one must understand the issue of Positive Control. The alert zone concept is an attempt to throw off the bridle of the ATC system. As one airline engineer stated, ”The less information I give the ATC system, the less they will have to use against me.” Additionally, many have a vision of Free Flight that follows the eagle - the pilot can do anything they want, while providing their own separation. Although noble visions, basing Free Flight implementation on these concepts leads to a very complex, logistically difficult Free Flight implementation that has little chance of success.



Backing off the “Here-is-my-velocity-vector-make-it-safe” concept only slightly, greatly simplifies the implementation of Free Flight. What we should really be saying is "Here is my intent, make it safe". This is a considerably easier and less expensive to implement, with the same operational benefits. *Alert zones, and all the complex baggage they represent, would not be required*. The separation manager would use a 4D conflict probe (ATOM/BDACS), based on radar surveillance data and flight plan intent, to determine if the aircraft's protected area would overlap with another aircraft's protected area in the near term (i.e., 10 to 20 minutes). If not, the path is determined safe and the aircraft proceeds along it. Initial intent would be communicated through a flight plan. The difference from today’s system is that the path on the flight plan would be chosen by the pilot from takeoff to touchdown.

Airborne conflicts would be handled tactically and changes would be communicated verbally (repeat: *verbally*). If the pilot requires a change, they would alert the separation manager of the new intent. The separation manager would check the proposed path for safety, and if determined safe, the separation manager would be required to allow the change. The concept of alert zones is an expensive way to keep the controllers out of the cockpit. This is an extreme overreaction to the control oriented ATC system in place today.

In fact, this is the major philosophical change required for any form of Free Flight that is built around a ground based separation service. The only reason the separation manager should deny any request for a specific flight path is that the flight path is unsafe. The reason they do not do this today is the lack of knowledge of potential conflicts with aircraft outside their sector. How many times has an aircraft been routed around empty airspace simply because the controller does not know the airspace is empty?

Although, the “Here is my intent, is it safe”, concept may seem to contradict the time based sequencing outlined for arrivals, the two concepts agree completely. The only reason the aircraft is given a timed arrival at a congested airport is to avoid a conflict at the end of the runway. This longer term conflict resolution is based on the increased predictability of the conflict. The reason the tactically conflict probe is limited to 10 to 20 minutes is the validity of the predicted conflict drops with time. By assigning sequencing arrival times, based on the users' requirements, the system deconflicts the aircraft further out in time to maximize arrivals. In other words, aviation gives up some flexibility so as to increase throughput at a possible constraint point, the runway surface. The two solutions, time based sequencing and tactical conflict resolution, are actually resolving the same problem - assuring two aircraft do not hit each other

In his 5/95 editorial, J. A. Donoghue of *Air Transport World* magazine, said *"If you have a problem, FAA will launch a program to develop a device, then require airlines to buy it".* Although misunderstood by many, Free Flight is not about "devices". We have more "devices" than we use now. **Most of the benefit from Free Flight comes with a change in separation methodology and ground based equipment -- at no cost to the aircraft operators.**

Technically, this can be done quickly with off the shelf software and hardware. The industry, including the airlines, using the alert zone concept are already predisposed to requiring "devices", GPS, data link, SATCOM, etc., for Free Flight. The technical path currently driving the business problem of Free Flight will only reinforce this position and cost airlines millions in advanced avionics, with no guaranteed return on investment (ROI). Implement Free Flight first and then investments in advanced airborne equipment based on gains in the production process become a business decision with measurable ROI.

9. Safety

Conclusively -- both the replacement of the antiquated HOST/PVD system and Free Flight increases safety. Although budget constraints are forcing all government agencies to do more with less, the continuing disintegration of HCS's DCC/PVD requires immediate replacement. Doing nothing or continuing with only the DCC/DSR program puts the safety of the airspace system and the traveling public at risk. Although traffic separation of IFR aircraft is a flight critical function, the software running in the ATC computers is an undocumented kluge of patches and fixes installed over the last 20 years. The 10 to the minus 9th criteria so routinely applied to aircraft flight critical functions (i.e., autoland) is not equally applied to the ATC computer system. It should, and must be! The aviation community continues to view the reliability of the ATC service in the same light as a telephone dial tone -- it is always available. But what are the safety and financial implications for all of aviation if it is not? We have already seen this on more than one occasion for a limited period of time. Although not probable, there exists a real possibility for a major ATC facility to be off line for an extended period of time. This is something no one wants to think about, but we must.

Secondly, Free Flight is simply the removal the restrictions to flight when not required for actual aircraft to aircraft separation. There would still be restrictions to flight when, and only when, a real aircraft to aircraft conflict exists (projected overlapping of the protected areas). If a near term (10 to 20 minutes) conflict exists, the separation manager would restrict the flight path of one, or both of the aircraft until the conflict is resolved. Remember Free Flight is not random actions, it is random paths. An FAA expert, Norm Watts, with 30 years experience in this area outlined Free Flight as follows.

- Free Flight should be considered the inalienable right of all airspace operators. In a Free Flight context, a flight plan is merely a statement of intent rather than a contractual binding declaration of purpose.

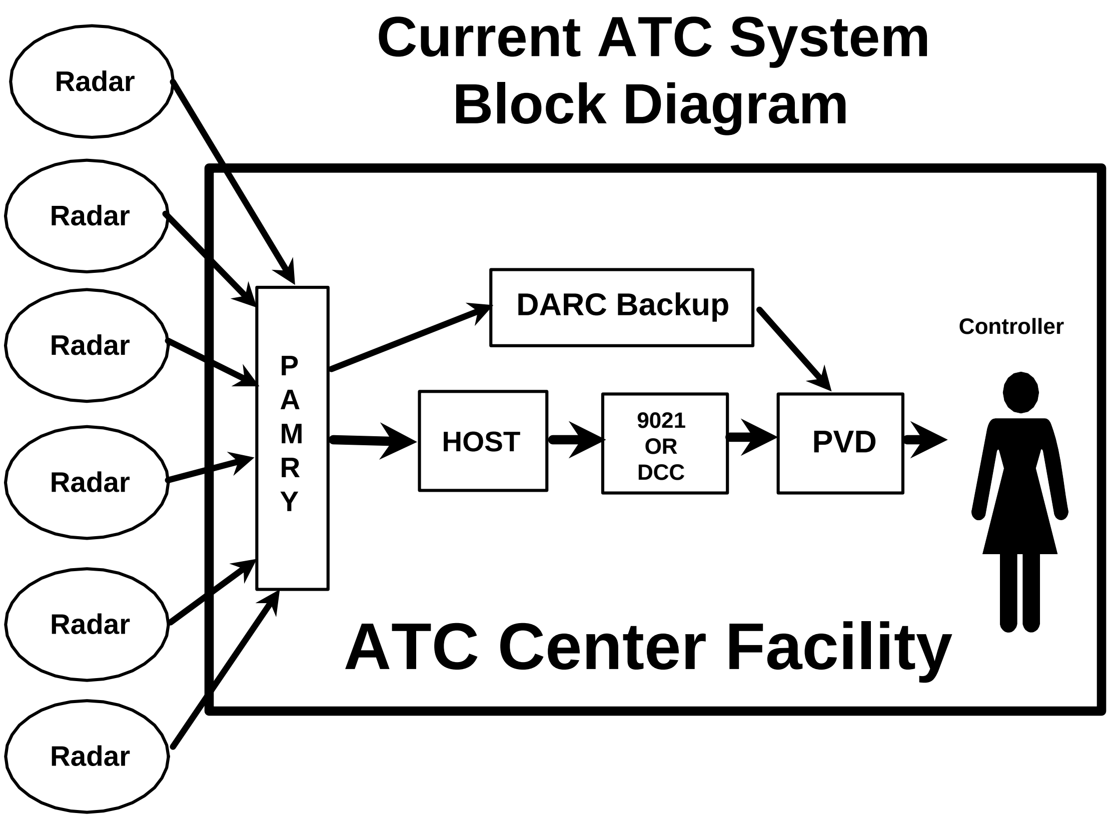
- Free Flight is not a carte blanche right for users to make sudden, arbitrary, and unnecessary modifications to their intent as defined in a Flight Plan (any other provided declarations of intent). Obviously, Free Flight is impossible with a helter-skelter modus operandi. Free Flight does not afford one user's best interest unfair advantage over the best interests of all other users.

Until recently safe separation of aircraft in IFR conditions had only one layer of safety to prevent conflicts, the mental capabilities of the air traffic controller. With the introduction of TCAS, a second layer of safety was added to the system through the implementation of an independent separation monitor. The scenario outlined herein not only leaves these two systems in place, but adds a third layer of safety, the computerized conflict probe hosted in a very robust, distributed processing system. This three layered system -- a separation manager, a computerized conflict probe and an independent airborne collision avoidance system is the safest, most robust system that we can implement. Even for those who chose to not install an airborne TCAS system, the remaining two layers would still provide a higher level of safety than in today's system.

Finally, the safety of any new system must be equal to or better than the old system. This is an obvious. **Free Flight** increases safety -- period.

10. The System

Given the above assumptions, the system design of an ATM system is much easier to implement. The failure of the Advanced Automation System (AAS) was trying to automate the complex control methodology of separation. As in any engineering task, we must determine the task (separation) and apply the minimal technology and procedures to accomplish that task.



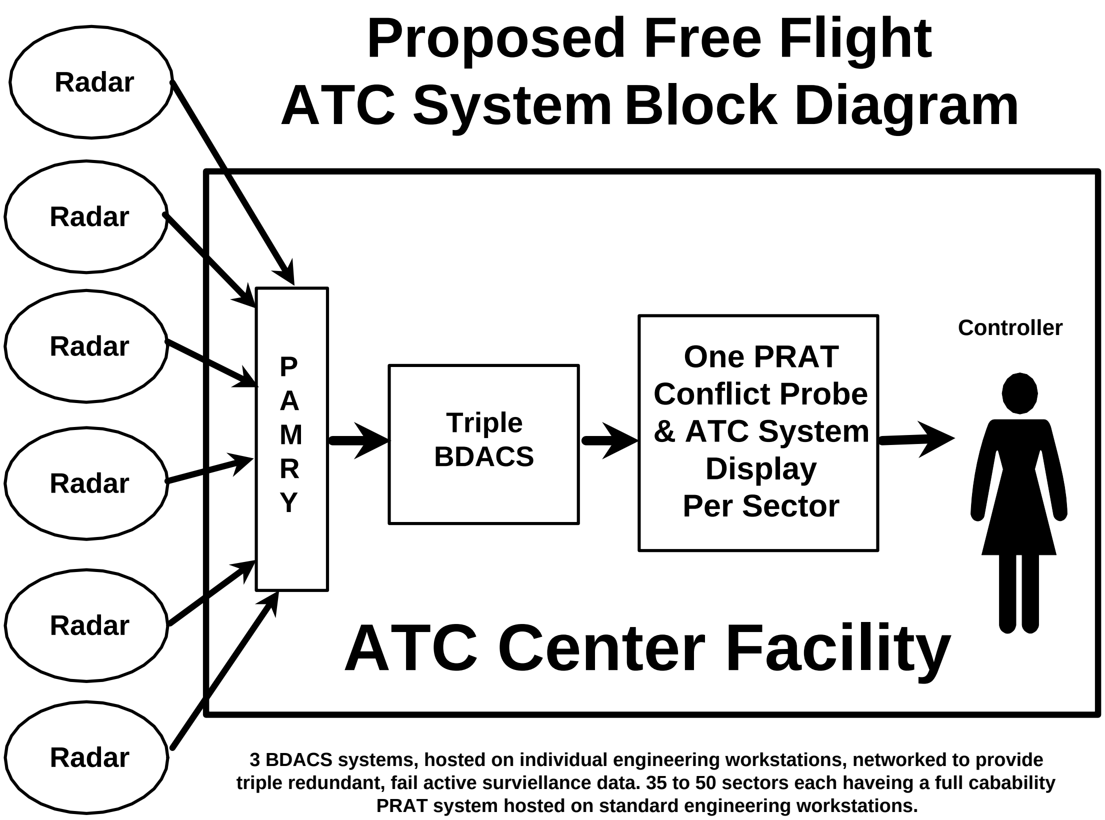
Abiding by the above premise, each separation manager would have an off the shelf engineering display and workstation loaded with ATOM's conflict probe and ATC front end software (what the separation manager looks at). Each workstation would receive all the surveillance and intent information of all aircraft in the area and areas adjacent. When the computer identifies a near term conflict (10 to 20 minutes out), the manager would provide the resolution to the pilot via the VHF radio. Since the aircraft is on the user preferred trajectory, the major radio conversation would be frequency changes and aircraft to aircraft conflict resolution.

10.1. Purpose

The current Air Traffic Control (ATC) system's primary display component, DCC, is over 20 years old. Consequently, the Host Computer System (HCS) is experiencing numerous outages. (Note: HCS is also experiencing outages for non-display related reasons, but far less frequently.) Another problem is that the current system design is two tiered. The Traffic Management System (TMS) tier addresses capacity and workload related issues. The second tier is the HCS running the National Airspace System (NAS) en route ATC that addresses safety-of-flight related issues. This two tiered base design resulted in an airspace control oriented solution to an airspace management problem that is excessively complex and does not lend itself to transitioning to a user driven Free Flight-like design. This plan will introduce **a safety enhancing, low-risk and inexpensive approach to HCS Replacement** that maximally supports Free Flight using existing avionics and ground equipage. It is imperative to note that because all radar data processing is now performed within the HCS, any HCS Replacement automatically demands some type of radar data processing sub-system be procured or developed. This plan fully addresses the problems facing the HCS and at the same time provides the ground based infrastructure required for Free Flight.

10.2. Background

This plan uses a single tiered airspace management oriented method with the potential to promote rapid and inexpensive implementation of a system that fully supports Free Flight to the maximum extent possible while using existing avionics and ground-based surveillance equipment (radar). The current ATC system is truly a ground-based, air traffic controller centered, airspace control oriented solution to our Nation’s airspace management problem. Because of this no attempt will be made to compare the proposed management oriented method to any method predicated on making enhancements to or evolving from the current HCS based ATC system. Simply upgrading and patching the current system will not work.



3 BDACS systems, hosted on individual engineering workstations, networked to provide triple redundant, fail active surviellance data. 35 to 50 sectors each haveing a full cabability PRAT system hosted on standard engineering workstations.

The recent ISSS/AAS problems and failures should preclude any attempt to pursue an evolutionary HCS control based follow-on. Surely such an enhancement is unnecessarily complex, faulty, expensive and does not fully support Free Flight. Furthermore, following FAA's current HCS step by step upgrade plan (DCC/DSR) is analogous to installing Windows 95 into an 8086 computer. Given a few hundred million dollars and 5 to 10 years it surely could be done, but it begs the question -- why? However, the proposed single tiered method, by design, can undergo adjunct or background operations (shadow mode operational evaluation) to the current-day two tiered Enhanced TMS (ETMS)-Airport Radar Tracking System (ARTS) and/or Terminal Radar CONtrol (TRACON)/HCS, hereafter called ETMS-ARTS/HCS. Additionally, because the major portion of the proposed method adheres to the principles and practices of Object-Oriented Design & Programming (OOD&P), it also lends itself to rapid-prototyping.

10.3. Method

The only plausible solution to our the airspace management problem is a single tiered separation oriented solution that combines processing of all capacity and safety-of-flight related issues using the most accurate and timely source of **global** surveillance information available. Because such a system will unconditionally be driven to maximally support the needs and best interests of all airspace users, it is also characteristically a Free Flight driven system. Furthermore, the fact that such a solution is addressing the right problem, it will invariably be the simplest solution.

10.4. Solution

The proposed solution advocates the integration of three discrete sub-systems that are already complete and in service or very close to completion.

10.4.1.Atom

Atom is stae of the art, ful capability commercially available off-the-shelf ATC system. ATOM, by design, deals with the total-flows of all aircraft using the total system, unconstrained by artificial sector/center boundaries. Hence, ATOM can fill both global and local needs: any system that addresses total-flows on a total system basis intrinsically has global interests and needs for the total system demand, environment, capacity and accurate global actual flow information. On the other hand, short-term conflict resolutions invariably can only be satisfied locally. ATOM's base design fully satisfies all global and local needs.

One aspect of ATOM is its ability to model conflict-free total-flow aircraft profiles. However, ATOM does not demand conflict-free total-flows in its flow (flight plan) approval and monitoring processes. It merely uses such predictions as an indicator of potential conflicts, if all effected aircraft indeed executed the exact flows upon which the conflict is predicated. Having such a global knowledge base significantly simplifies the flow-error analyses and resolution processes.

One salient feature of ATOM is that total-flow analyses inherently demands an all encompassing data base that contains accurate and timely information on everything that impacts or restricts flows or influences the long- and short-term capacity of any part of the total system. Another salient feature is that ATOM's design simultaneously addresses both capacity and management related issues. Hence, ATOM thrives on having accurate and timely information on all things that singularly or collectively impact both system capacity and/or aircraft flows. It also needs and will automatically use the most accurate and timely information on the actual real-time flows of all aircraft, specifically, aircraft positions and velocity vectors.

FAA's evaluation of Atom's predessor, ATOM was tested in Boston Center This implementation was forced to use HCS track information for those aircraft within Boston Center's airspace. For those aircraft not in ZBW airspace, ATOM will be forced to use Aircraft Situation Display (ASD) data as the only source of global aircraft surveillance information. Sadly, both of these input-streams, especially ASD data, because it never intended to be used as a source of surveillance data, have known inaccuracies, anomalies, and update timeliness deficiencies. Hence, the usefulness of either data stream for highly automated conflict prediction is suspect.

One significant consequence of ATOM in Boston is that it will provide the FAA with invaluable information on the usability of ASD and HCS track data for automated conflict prediction and resolution functions. For **$150,000**, the FAA could place another source of surveillance information in the Boston Center, called BDACS[14]. This would allow operational evaluation of ATOM's conflict prediction and resolution performance using the most accurate and timely aircraft position and velocity vector information that can be obtained from properly processed radar data.

10.4.2.BDM Data Acquisition and Conversion System (BDACS)

BDACS is considered to more than adequately satisfy ATOM's intrinsic need for global, accurate and timely aircraft position and velocity vector information required in a Free Flight system. The fact that BDACS has already been operationally tested, certified and sanctioned by the FAA for the High Desert TRACON makes BDACS even more attractive. Hence, **because any HCS Replacement must include some type of high resolution track output**, BDACS, a certified system already in use by FAA, is obviously a prime candidate for this role. BDACS uses the information from up to 16 long-range remote ARSR radar and co-located Mode S secondary surveillance systems. Track information is correlated and sent to each Air Route Traffic Control Center (ARTCC) by Common Digitizers (CDs).

A BDACS would ultimately be placed in each ARTCC and, at least initially, use the existing CD's feed from each remote site to provide high resolution track output data (primary radar and Mode S). Each ARTCC already has spare bit serial parallel ports identical to those that now feed remote radar data into HCS. **Hence, BDACS could be placed in every ARTCC with absolutely no impact on the operations or performance of HCS.** BDACS in the Boston Center could be operationally tested as the best source of surveillance data. BDACS, as is, can also accept and process the more accurate and timely data from the short-range Airport Surveillance Radar (ASR) and its co-located Mode S. Because BDACS does not perform any type of flight plan conformance monitoring, this function is already available in the ATOM software or could be implemented in updates to the BDACS software.

In Mode S, there exists an Advanced Surveillance Message (ASM) format wherein the 24 bit aircraft identification (aid) hardwired into every Mode S transponder accompanies every Mode S correlated surveillance report. Using ASM's unique identification of exactly which aircraft responded, significantly simplifies the conformance monitoring because the 24 bit aid could be directly mapped to its Flight Plan, i.e., one always knows the flight plan assigned to each unique aid.

As stated above, for $150,000, an operation evaluation of the usability of BDACS accurate and timely track data could be tied to ATOM's conflict prediction and resolution processes in the Boston Center. Knowing this could be instrumental in establishing what level of Automatic Dependent Surveillance (ADS)/Global Positioning System (GPS) is needed to support Free Flight. *BD*ACS[15] coupled with ATOM has the potential to support Free Flight with virtually no changes in existing ground or airborne equipage. Additionally, any future

[14] Because of the recognized inaccuracies of Host and ASD data, BDACS is being installed in the Denver Center as part of NASA's CTAS and Free Flight studies.

[15] For those readers who need more information, Appendix B is a verbatim extraction from a paper that fully discusses ASD, HCS and BDACS related issues.

system would still require the same tracking processing required of radar data, making BDACS a solution that will accommodate future upgrades in avionics capability. Having a BDACS in every Center also has the potential to ensure ASD's global position related information is the most accurate and timely available.

10.4.3.Center TRACON Automation System (CTAS)

CTAS, a NASA program to time sequence aircraft, automates the arrival and departure sequences at airports with high density traffic. Inherent in CTAS is the extensive terminal area data base that knows such things as: runway configurations, weight limitations and capacities, multiple runway approach and departure paths (noise abatement, surface winds, etc.), departure and arrival routes, transition fixes, et al. Hence, the marriage of ATOM/BDACS to CTAS fully covers the total flows of all aircraft using terminals with heavy traffic.

For those airports that do not warrant having a full-blown CTAS, CTAS-like functions that deal with terminal area issues on a much less complex basis are incorporated into ATOM. In the Denver study, ATOM should be added to the ongoing CTAS system evaluation at Denver International Airport. Operationally, ATOM would inform CTAS of pending traffic demand at its airport. CTAS would then inform ATOM of the exact landing and departure sequences by aircraft type and size based on the current airport capacity. ATOM would then attempt to interface with Airline Operation Centers (AOCs)/Dispatchers so that the AOC can establish exactly which aircraft will be in each arrival slot. One important function of ATOM will be to always ensure equitable use of any constrained resource. ATOM will then give the user preferred sequence list to CTAS.

Finally, CTAS will provide ATOM with the timed-flows of aircraft scheduled to use the airport from terminal area penetration point(s) to touch-down. Obviously, ATOM must somehow get these terminal area timed-flows into the cockpits. This is not a CTAS problem, but a user problem. Already many airline aircraft, the primary user of the congested airports, have ARINC's ACARS system installed that could fill this requirement. ATOM, through the airline AOCs, would make excellent use of this **existing** form of two-way digital data link.

10.4.4.System Solution Summary

Having ATOM coupled with BDACS and CTAS in the Boston and Denver Centers will provide the FAA and the airspace user community with critical information on the degree to which existing ground and airborne equipage supports Free Flight. Conversely, not including BDACS in the Boston Center ATOM evaluation may merely indicate that HCS and ASD data, as is, is not accurate or timely enough to adequately support automated conflict prediction and resolution, in general, and Free Flight, in particular.

Because the cost of BDACS for the Boston Center is so low ($150,000), it appears foolhardy not to include it, especially because some form of BDACS is needed in HCS Replacement. The remainder of this plan will assume BDACS, as implemented, lived up to its expectations and will eventually be placed in every Center as the first step in HCS Replacement. This automatically ensures a highly accurate and timely ASD-type global position and velocity vector information will be available for ATOM's global needs.

10.5. The Integrated Follow-On HCS Replacement

Once ATOM, BDACS and CTAS have each proven their collective viability to rapidly and inexpensively support end-state Free Flight in a select ZBW control sector, this step will address how to efficiently and expeditiously execute HCS Replacement. It's proposed that the *'How do you eat an elephant?'* approach of *'One bite at a time'* be used. But using *'How do you replace an HCS?' - 'One control sector at a time'* instead. As the conflict prediction and resolution processing of ATOM in each ZBW control sector is successfully op-evaled, ATOM and its associated Computer Human Interface (CHI) will then be *given* operational control over that sector. This is possible since ATOM/BDACS is a distributed processing system where each sector is effectively autonomous and can be installed with no impact to the current HCS or other sectors that have migrated to the ATOM BDACS solution. This process will be repeated until all control sectors in the Boston Center have been placed under ATOM control. An advantage of this *'One control sector at a time.'* approach is that should various control sectors have unique requirements not adequately serviced by current ATOM functionality and CHI, then ATOM and it associated CHI could be revamped to address them - rapid-prototyping personified. Interestingly, when BDACS is operational in every center this would become the source of highly accurate and timely ASD data.

Once ATOM has conclusively proven it can service the entire Boston Center, the FAA could initiate installing it as an HCS Replacement *'One control sector at a time.'* at another center. The same *learn-as-you-go rapid-prototyping* will be used until every control sector in a given center transitions to ATOM. This step will culminate when every control sector in every center is using ATOM coupled with BDACS. Because everything in ATOM's base design is directed towards end-state Free Flight the end result of this step will be a CONUS implementation that supports Free Flight to the maximum extent possible using existing ground radar and airborne equipage.

11. Phased Implementation Plan

11.1. Introduction

The three phases discussed herein have considerable overlap, particularly 1 & 2. Their differences are more related to the base intent of the phase rather than discrete content. Tying BDACS to ATOM in the Boston Center will be more of a formality because both FAA's High Desert TRACON and NASA Ames' CTAS program have already determined that it provides highly accurate and timely surveillance information using existing ground radars.

The Boston experiment will merely show how well BDACS performs in an operational center environment and the degree to which properly processed radar data supports Free Flight. Similarly, ATOM's automated conflict prediction and resolution have already been proven to be mathematically consistent and accurate. Hence, the pairing of ATOM with BDACS is a necessary step whose results are already known -- ATOM needs accurate and timely aircraft surveillance information -- BDACS has already been shown to provide exactly such information.

Having BDACS in every center coupled with a global ATOM implementation will insure the ASD input-stream to ETMS is the most accurate and timely available in properly processed radar data. This entire plan is predicated on using proven sub-systems -- ATOM's conflict probe uses the mathematically correct and proven AERALIB -- BDACS is already sanctioned for operational use by the FAA and been assessed and selected by NASA Ames. Financial analysis is provided to show order of magnitude costs, not actual costs.

11.2. Phase 1 - ATC Catastrophic Failure Protection

- Installation of a single BDACS at all 22 en route centers. Installation at all centers of two engineering work stations with the FAA certified ATC operating system from the High Desert TRACON. Installation of VSCS units and ARINC ACARS data link at these work stations. This will provide voice and data link backup communications. Cost - less than $10 million, Timing - 6/1/96 to 1/1/97.

- Reroute the feed of the ASD data from Host to BDACS. Add an additional data line from the radar common digitizer to the adjacent center's BDACS processing unit. This will allow identification of radar targets outside the center control area. The accuracy of ASD based on BDACS should provide any remote work station receiving ASD to act as a backup to the HOST/PVD. Therefore by also installing VSCS and an ARINC data link at the SCC and the 22 en route center's TMU station these will be able to provide Catastrophic Failure Protection in the event a sector, group of sectors or entire center goes off line. Cost - less than $5 million, Timing - 6/1/96 to 1/1/97.

11.3. Phase 2 - Host/PVD Replacement

- Immediate addition of BDACS to the operational evaluation ATOM in Boston center. Evaluation of ATOM to assure it meets current ATC system functionality, including NAS interface, flight plan capability and flight conformance monitoring. Cost - $150,000, Timing - 5/1/96.

- Addition of ATOM to the operational evaluation of CTAS in the Denver center. Cost - $200,000, Timing - 6/1/96.

- Once traditional ATC functionality is certified in ATOM it should be introduced into the work stations already installed (Phase 1 above) at the 22 centers. ATOM would be added to the BDM TRACON software initially installed with BDACS continuing to providing the aircraft tracking, position and velocity vector information to ATOM. Cost - less than $10 million, Timing - 6/1/96 to 1/1/97.

- Training would begin upon installation of ATOM to have the new ATOM/BDACS systems transition control of two center sectors full time from HOST/PVD to ATOM/BDACS. Cost - less than $5 million, Timing - 6/1/96 to 1/1/97.

- Addition of two BDACS systems in each center to assure integrity and availability of a highly accurate data source. Cost - less than $10 million, Timing - 1/1/97.

- Sector by sector replacement of HOST/PVD with ATOM/BDACS, initially at the Boston Center. Retention of VSCS and ACARS data link. Cost - less than $150 million, Timing - 1/1/97 to 1/1/98.

11.4. Phase 3 - Free Flight

- Procedural development focusing on utilization of the global 4D conflict probe inherent in ATOM, allowing aircraft en route flexibility. Cost - less than $5 million, Timing - 6/1/96 to 1/1/98.

- Immediate implementation of a timed based metering system to the outer fixes or corner posts at the congested airports. This can be done with or without FMS equipment. NASA calculates that normal pilotage techniques will provide accuracy's of plus or minus 1 minute. This level of accuracy is more than adequate to remove some of the random arrival sequencing in the current merging sector. At connecting-hub airports this would be controlled by the individual airline when single airline aircraft are involved. When numerous users are involved at the hub or at the non hubs, the users would still control the process, but FAA would provide equitable access by extending their metering system (now only used in bad weather) out to 1 to 1.5 hours from touchdown. The increased accuracy of the ASD feed using BDACS should easily support this capability. Cost - less than $1 million, Timing - 6/1/96 to 6/1/97.

- Installation of ATOM/BDACS in conjunction with CTAS at the hub or congested approach control facilities, one sector at a time. Once in full use, CTAS would should be able to takeover the already sequenced arrival stream and begin to move the merge point closer to the runway. The goal is to merge the aircraft on a 3 to 5 NM final. Cost - less than $25 million, Timing - 6/1/97 to 6/1/98.

- Installation of ATOM/BDACS at the non hub and non congested approach control facilities. Cost - less than $100 million, Timing - 1/1/98 to 1/1/99.

11.5. Miscellaneous

- Miscellaneous changes and requirements. Cost - less than $150 million.

11.6. Implementation Cost Summary

ATC Catastrophic Failure Protection	less than $15 million
Host/PVD Replacement	less than $180 million
Free Flight	less than $135 million
Miscellaneous	less than $150 million
Total Implementation Costs	**less than $480 million**

12. Conclusion

The ***Blueprint To Free Flight*** plan allows the aviation community to have a major portion of, if not total, end-state Free Flight far sooner than most within both the aviation community and the FAA thought possible. While greatly increasing safety even prior to full implementation, this plan will not interfere or impact the current operations of the HCS and its ancillary sub-systems. Executing this plan will independently assess the viability of each of the primary sub-systems, namely ATOM, BDACS and CTAS, as well as a fully integrated operational all encompassing highly automated ATMS using all three. Strictly from an airspace user's perspective, the fact that the resultant ATMS supports Free Flight to the maximum degree possible virtually makes its execution imperative.

The implementation approach also lends itself to rapid-prototyping which will ensure the final total ATMS fielded is controller accepted and friendly. It behooves the aviation community and the FAA to extensively appraise this plan, not executing it may well repeat the costly and time-burning abject failure of ISSS/AAS while forcing Free Flight to be placed on the long drawn-out time-line of most experts within the aviation community and the FAA.

Near term Free Flight is a function of the changed separation methodology and minimal ground automation, not advanced CNS technology. With Free Flight in place, the operators would have an economic reason to begin equipping with the advanced CNS technologies. Datalink, GPS, advanced FMS, etc., would now safely allow shrinking of the separation distance, reducing conflicts and increasing efficiency. Once again, the airlines can not afford to equip based on a promise of future benefits. The shareholders and the managers who sign the checks want real, quantifiable returns for any money invested. Who can blame them?

The ATOM/BDACS/CTAS solution is a win-win program with considerable upside and zero downside potential for the FAA, government and most importantly, the airspace users and traveling public.

- ***Win 1 -*** ATOM/BDACS can be validated as a complete ATC equipment replacement package and Free Flight system within 6 months at a cost of less than $3 million.
- ***Win 2 -*** ATOM/BDACS can quickly replace the deteriorating ATC equipment by the year 2000. This can be done sector by sector, thus eliminating or significantly decreasing logistical and training problems.
- ***Win 3 -*** FAA's customers are provided the benefit of Free Flight 10+ years ahead of FAA's current schedule at minimal to zero cost. Airline, general aviation, military and corporate aircraft all benefit with only a VHF radio and transponder, equipment already installed in most aircraft.
- ***Win 4 -*** The ATOM/BDACS system offers additional benefits to those aircraft who equip with advanced avionics like GPS. This will accelerate the movement to radar and VOR replacement systems, thus reducing FAA's capital and recurring costs.

- ***Win 5 -*** Taxpayers benefit because the total cost of this program (4 years & $500 million) is less than the current DSR program (5 years and $800 million) which simply replaces the controller's displays providing conventional ATC services.
- ***Win 6 -*** ATOM/BDACS are hardware independent systems using commercial, off the shelf, engineering workstations and Windows like displays. This allows for very rapid protoyping and simple upgrades as new concepts and systems come on line in the future.
- ***Win 7 -*** Finally, and most importantly, the safety of the system will rapidly increase.

The Free Flight implementation proposed by the FAA and RTCA, even if successful, will require until beyond the year 2010 for any significant benefits to accrue to FAA's customers. From a business perspective, it is simply not acceptable for the airspace users supplier (FAA)to take 15 years to implement something the customers require today. In addition, general aviation and military aircraft, which make up the majority of airspace users, should not be required to purchase thousands of dollars worth of unnecessary equipment for their aircraft. The aviation industry must ***wake up*** to the fact that the ATC problem will only be solved through leadership and vision. The current ATC problems and Free Flight implementation are not about procurement, bureaucracy, privatization or user fees. The time for consensus management is long past -- billions of dollars past. Finally, there are numerous papers concerning Free Flight on the Internet at http://www.freeflight.com/ff/.

Finally, to repeat the two main points:

- The complexity of the current ATM system is built around preventing the manual conflict probe (the air traffic controller) from being overloaded. Implementation of **a 4D computerized conflict probe using a accurate global data set**, which can not be overloaded, and time based sequencing significantly reduces system complexity.

- We already have the CNS **capability** in the domestic US today to **support a substantial implementation of Free Flight** using the current 5 NM radar separation, while at the same time **increasing safety**. Data link, including ADS/GPS and other advanced avionics are not requirements for Free Flight, but maximize operational efficiency within a Free Flight environment by increasing the accuracy of the navigation and surveillance position and the speed of communication.

13. Appendix A - HCS, ASD & BDACS

13.1. Major Problems in Both HCS Track Data and ASD Data

HCS track data possesses some questionable attributes. All HCS internal track stores use an internal clock with a 6 second tick, a.k.a., 6 second scan (note: a 600 knot aircraft goes 1 NM in 6 seconds, 300 knots - 1/2 NM, 450 knots - 3/4 NM, et al.). HCS does use a 12 second scan for most other functions. HCS also uses radar mosaicing. Only one of many radars scanning the same 16 NM radar sort bins will be the primary radar (and effectively only radar) reporting on an aircraft within the bin. Controllers have reported one to two NM position jumps when an aircraft transitions from a certain remote (long-range) sort bin to a remote sort bin being serviced by a different primary radar. This mosaicing also automatically forces HCS track stores to be updated at the scan rate of long range radar, approximately every 12 seconds. Furthermore, all HCS internal track stores are derived using a highly dampened alpha, beta gamma (α,β,γ) tracking algorithm. An intrinsic attribute of this tracking algorithm is the relatively long time required to transition to actual maneuver following settings of α and β. The end result is the relatively long delay in detecting and responding to heading or speed-change type maneuvers. Velocity and heading are impacted in any heavily dampened tracking function such as the HCS's (α,β,γ) tracking filter. NASA-AMES scientists have documented instances where 150-200 knot swings in velocity have occurred in one 12 second HCS scan. During rapid heading changes, the HCS (α,β,γ) tracking filter was found to lag actual headings by up to 150 degrees. These observations should not surprise anyone who has investigated adaptive filtering, because any heavily damped smoothing algorithm will characteristically experience significant discontinuities somewhat in position, more so in velocity and heading, upon transitioning to a maneuver following setting.

Sadly, the HCS software only fields and records an air traffic controller's temporary altitude reassignments (Interim Altitude). HCS has absolutely no knowledge of any short-term controller directives to change heading or speed (a.k.a., vectoring to resolve conflicts). Significant unknown modifications to an aircraft's flow, such as change heading by 20 degrees for 5 minutes because of a conflict, speed reduction by 50 knots for sequencing, etc., degrades HCS's already inaccurate track data even more. Because of HCS's heavily dampened (α,β,γ) tracking filter, one can not even derive instantaneous heading and ground speed from HCS track store data. Worse yet, a slight heading change of 5 or so degrees may never trigger a maneuver following status (the tracking filter would meander around and towards the true heading, but would never be a true indicator of instantaneous heading). The end result is that the HCS tracking function may never detect some heading or velocity changes Certainly, these inaccuracies and anomalies inherent in HCS track stores data raises many potential red flags on their use as the primary input stream to any end-state highly automated conflict prediction or resolution function such as end-state ATOM.

Using ASD data significantly magnifies the inaccuracies and problems inherent in HCS track data because of the five minute time between each track's ASD data position and velocity update report from HCS. The accuracy of ASD data position and velocity reports will be much less accurate than HCS's. Furthermore, the fact that HCS will only send out position reports on those tracks with either a flat-or free-straight status (i.e., level and non-turning) means that some tracks will not be updated for 10 or more seconds (2 times the update interval). Mitre studies have shown that 95% of the time ASD data is within 4 NM of HCS track stores positions, the other 5% of the time errors are significantly larger. Unknown maneuvers partially explains why 95% of the time ASD data was within 4 NM of HCS track data versus the 1 NM or so uncertainty built into every HCS track position. They certainly explain why 5% of the time the errors were significantly larger.

Now, because end-state ATOM or any similar tool is predicated on performing conflict predictions and resolutions, it is desirable, if not necessary, to know whenever any action that changes an aircraft's heading or velocity has occurred. At this juncture, the impact of these HCS tracking idiosyncrasies on the initial implementation of ATOM's conflict prediction is not known. The same problem ATOM is experiencing with HCS derived track data will equally plague any system attempting to automate conflict prediction and resolution. For example, Mitre's URET Indianapolis Center study may have to resort to analyzing controller voice recording to address problems embedded in not knowing when a maneuver is in progress -- more complexity to solve what is a simple problem. Lonnie Bowlin's Figure of Merit (FOM) of ATOM's performance per the characteristics of the surveillance data stream may provide a means of addressing these anomalies and deficiencies in the input data - at least we know what to look for when and if ATOM's conflict prediction degrades significantly based on the inaccuracies of the position data source. Some NASA AMES Scientists consider HCS track information to be unusable for their expanded CTAS Denver study. They appear to feel the same about its usefulness for ATOM or any other conflict prediction-resolution application.

13.2. BDACS, a Promising Alternative to the Faulty HCS/ASD Track Data Streams

In their Denver CTAS operational evaluation, NASA AMES scientists have installed a source of highly accurate track information, namely BDACS. BDACS was developed for the FAA by BDM Corp., Boulder, CO. It is the track data source for the FAA's operational "**High Desert TRACON**" at Edwards AFB. BDACS accepts inputs from multiple Common Digitizers, Mode S's collocated with terminal radar (ASRs), special military tracking radar (16 or so total interfacing radar). BDACS, currently hosted in Sun SPARC work-stations, uses information from all radar to update tracks (not mosaicing), performs tracking functions using Kalman filtering techniques, provides accurate time tagged position reports including accurate velocity vectors. BDACS has non-maneuvering relative position accuracy approaching 1/4 nautical mile (NM) (absolute accuracy of approximately 1 NM), a time tag of 1/8 of a second and a maneuver response time of 18 seconds or less (four 4.5 second updates), i.e., BDACS appears to be everything HCS track stores is not now nor can ever be.

Because end-state Free Flight is sorely dependent on highly accurate position and velocity vector information, all who have the authority to sponsor an immediate FAA study of BDACS (possible eventual procurement) should act accordingly. It is proposed that a BDACS be installed at each ARTCC with inputs from every Common Digitizer (about 8-10 per center) that now interface with each Center's HCS in addition inputs from every Mode

S collocated with all ASR's within the Center's boundary. Output from each BDACS would be sent to the purveyor of TMS's ASD data, ATOM and any other tool and/or study of Free Flight with their intrinsic need for highly accurate track related data. TMS's ASD data functions could effectively be reduced to merely deleting multiple tracks that results from the same aircraft being seen by the same radar servicing multiple centers. It certainly would not have to perform any of its current complex but highly questionable tracking functions because of the inaccurate HCS input-stream.

The previously discussed problems in HCS not knowing when a control action maneuver was in progress virtually disappear because any short-term change in velocity vector information could raise a flag that some type of control action was in progress. If ATOM has a pending conflict prediction or resolution on any aircraft whose flow was so flagged, then the prediction and resolution functions would make appropriate adjustments. One tests revealed that BDACS's Kalman filter takes two 4.5 second updates (9 seconds total) for the heading to be within 10 degrees of the post-maneuver heading, while HCS's (α,β,γ) filter required eight 6 second updates (48 seconds total) to achieve the same state. One additional value of BDACS is that forwarding its track data to HCS's track stores would automatically cause a 35-40% reduction in the real-time processing of each HCS while insuring that the track information is of the highest possible accuracy and integrity: BDACS could even use HCS's 6 second tick and put the data into the exact format of HCS internal track stores - all this while insuring that HCS track stores are the most accurate maneuver-following available. Remember, any HCS Replacement must include some form radar data processing and tracking functions. BDACS is a FAA/ATC certified system that does this today.

14. Appendix B - Common Questions

Define Free Flight.

Free Flight is a very simply concept. Effectively, it allows the pilot or operator of an aircraft to choose the path of their aircraft and change that path as required to meet their individual needs. The ultimate Free Flight is that of an eagle. An eagle chooses when, where and how it wants to fly, while providing its own separation.

The current FAA and RTCA definition of Free Flight is based around the philosophy, “Here is my velocity vector, make it safe.” This is obviously less of a Free Flight system than enjoyed by the eagle because under the FAA/RTCA plan the ground based system would be responsible for separation. Unfortunately, the FAA/RTCA Free Flight solution is technically very complex because the pilot only tells the ground system of any flight path change after the change is made. This forces the requirement for GNSS and data link because the “after the fact” declaration must be immediate and very accurate. This is a very expensive technical solution to a political problem - the perceived requirement to remove the controller form the cockpit. Backing off this position only slightly provides 99% of the benefit at 1% of the cost. Instead of the technically complex, *Star Wars* avionics based system requiring immediate velocity vector information after the fact, Free Flight can be implemented based on the premise, “Here is my intent, is it safe.” In other words, the pilot will tell the ground system what is planed prior to doing it. The main difference in the RMB proposal and today is that the ground based separation system can only deny the new path if a real, near term (10 to 20 minutes) conflict will occur. This can only be done by giving the controller the proper tools to look beyond their individual sector and assure no near term conflict exists.

What are the functional requirements (not equipment, but functions) necessary (for the pilots, for the controllers) to implement of Free Flight?

The current separation methodology was built, procedure by procedure, over the last 35 years since the initial implementation of Positive Control in the early 1960s. The primary goal of this process is to prevent the controller from being overloaded. As many agree, we need to provide the "separation manager" (nee controller) the proper tools to assure safety in a Free Flight airspace. This is a computerized conflict probe that cannot be overloaded. This alone would provide the basis of Free Flight and once in place, layers of procedural and system complexity now thought of as absolutely necessary become no longer relevant.

Secondly, an important question that must be answered here is whether to continue a ground based separation system or not under Free Flight. Although the eagle provides the ultimate Free Flight model, our airspace system must provide a higher level of safety. This can only be provided with the continuation of a ground based separation service.

Until recently safe separation of aircraft in IFR conditions had only one layer of safety to prevent conflicts, the mental capabilities of the air traffic controller. With the introduction of TCAS, a second layer of safety was added to the system through the implementation of an independent separation monitor. The RMB Associates ATOM/BDACS (**P**rediction **R**esolution **A**nalysis **T**ool and **B**DM **D**ata **A**cquisition and **C**onversion **S**ystem) proposal not only leaves these two systems in place, but adds a third layer of safety, the computerized conflict probe hosted in a very robust, distributed processing system. This three layered system -- a separation manager, a computerized conflict probe and an independent airborne collision avoidance system is the safest, most robust system that we can implement. Even for those who chose to not install an airborne TCAS system, the remaining two layers would still provide a higher level of safety than in today's system.

Now to the task of defining the primary function of the separation manager -- **separation of aircraft**. The current control oriented, highly structuralized ATM system is not the goal, but rather the method chosen to accomplish the basic task -- **separation**. Flow Control is not an end point, but only a method to accomplish the task -- **separation**. Notice a theme developing here. The ATM provider's one and only task is **separation of aircraft** -- do not let two aircraft collide. And, as we all recognize, anything less than 100% in accomplishing this task is unacceptable.

Now that the goal of separation is firmly planted, let us examine what is required, at the basic level, to meet this goal. RMB Associates *Blueprint To Free Flight* study concludes that only four items are needed:

1. Knowledge of the position of the aircraft.
2. Knowledge of the intent of the aircraft.
3. Ability to compare the positions of two aircraft, and their intent, to determine if they will conflict.
4. Ability to communicate to the aircraft to resolve the conflict, only when necessary.

The combination of these four items is all that is required for any type of separation system, today’s structuralized system or Free Flight. The level of accuracy, integrity and availability of each of the four components will determine the level of operational freedom provided the airspace user. We know what today’s combination provides the airspace user. The task is to determine the minimum equipment to meet these four criteria in a Free Flight airspace.

The functions required on the pilot's side of the equation under the RMB proposal are also simple - intent. This includes filing a flight plan and advising of any change prior to making the change. This sounds suspiciously like today’s system and it should. The difference being that 1) the pilot/operator chooses the path and 2) the separation manager can only deny the proposed path to prevent an aircraft to aircraft conflict.

What is the minimum equipment required (for the pilots, for the controllers) to meet the functional requirements described above?

With the four requirements of separation and the user requirement of Free Flight in mind, what new tools will meet these requirements. The first step is to move forward based, as much as possible, on the technology in place today. The domestic airspace already has excellent communications, navigation and surveillance capability. The only new technology required to accomplish the task of enroute Free Flight is a 4D computerized "conflict probe" using a much more global aircraft position data base. A conflict probe uses the aircraft position and intent (flight plan and velocity vector from properly processed radar) of the aircraft to project its path forward and determine if its protected area would overlap with that of another aircraft in a defined period of time. Obviously, the higher the accuracy of the position and intent the higher the accuracy of the conflict prediction. But radar data and flight plan intent should support Free Flight at current separation levels.

Actually, a conflict probe is not a completely new requirement, since today's system is built around protecting the conflict probe, albeit a manual one -- the air traffic controller. Today, the controller's job is to monitor an 18" two dimensional screen, mentally visualize the position of the aircraft in three dimensions and its intent 5 to 10 minutes into the future and, then mentally determine if a conflict (overlapping of the protected areas) will occur. As stated above, numerous layers of complexity in today's system are there simply to prevent this manual conflict probe, the controller, from being overloaded.

What is new is the requirement for an accurate computerized conflict probe, using a more global view, which cannot be overloaded. Although viewed as a monumental task, private vendors already have the capability to provide this software, off the shelf, hosted in engineering workstations. As an outcome of the Congressional hearings on RMB Associates and Aviation System Research Corporation’s Free Flight study, *Free Flight - Reinventing ATC: The Economic Impact*, FAA has two conflict probe evaluations ongoing in Boston Center (ATOM) and Indianapolis Center (URET).

Part of the complexity seen for a conflict probe is the requirement to detect conflicts hours into the future. RMB continues to question why anyone cares about potential conflicts more than 20 minutes into the future. Operational choices, wind, fuel burn, etc., significantly reduces the validity of any potential conflict beyond a 20 minute threshold. The separation manager typically would not provide a resolution more than 10 minutes prior to an actual conflict to assure that a conflict would have actually occurred. This is a very critical point and needs reiteration -- The separation manager should not provide a resolution more than 10 minutes prior to an actual conflict to assure that a conflict would have actually occurred. This premise alone strips away a significant portion of the complexity surrounding the computerized conflict probe. The only reason to look farther into the flight path is system loading capabilities. If a resource is projected to be overloaded, a Flow Management system is the most efficient way to avoid overloading. This is typically only a problem at hub airports and should primarily be handled by the airlines using time based sequencing rather than distance based sequencing. FAA must obviously monitor the system and would assure separation and the equitable allocation of any system resource that becomes limited .

Must a Free Flight path be efficient (i.e., is a VOR path Free Flight)? Is their only one "most efficient" or Free Flight path between two cities.

The answer is an emphatic no. Free Flight is about letting the pilot/operator choose the path. The reasons for choosing a particular path are irrelevant to the ground based separation service provider. As an example, if a pilot only chooses to install VOR equipment and chooses, files and flies a VOR based path - that's Free Flight.

Secondly, there are many "most efficient" paths between two points. Aircraft weight, speed, fuel economy, passenger connections, sight seeing, time over target, etc., lead to each aircraft choosing different paths. Many operational considerations will force each pilot/operator to choose different 4D paths to meet their individual requirements.

What is stopping the pilot today from flying from Seattle to Des Moines on the four dimensional path they choose?

The ATC system (read system here, not controller) forced to use local data processed locally, based on structure and manual procedures to assure separation. As a B737-300 Captain I can easily fly a Free Flight path from SEA to DSM, but the ATC system will not let me. Why? Equipment and procedure that force the controllers to use a considerable amount of structure and communication to assure the identification of conflicts.

Admittedly, RMB Associates has focused on the what most call a "simplistic" approach to the implementation of Free Flight. This approach has grown out of attacking Free Flight implementation by asking a different question than most in relation to the problem. Many ask the question "How can GPS, datalink, ADS-B, TCAS, etc., be utilized to usher in a Free Flight environment." RMB Associates approached the problem from a different perspective and with a different question, "What is stopping the pilot from taking off and flying their preferred path to the destination and, if so desired, changing that path enroute." Both of these questions, answered correctly, can lead to the implementation of Free Flight, but only the second question minimizes the task. The aviation industry can not continue to throw technology at the problem of Free Flight implementation. We must define the underlying task, safe separation of aircraft in a random path Free Flight system, and apply the minimum technology required. The following looks at the Communication/Navigation/Surveillance (C/N/S) components of our **domestic airspace system** covered by radar surveillance and answer the latter question. Although recognizing that some areas (especially those used by GA) do not have radar surveillance, this is a question of how to provide separation services and if there are even wanted, not how to move to Free Flight.

Communication - Aircraft already have excellent VHF voice communication available. Although many say the frequencies are congested, much of this congestion is requests for changes because the pilot was unable to file the preferred path from departure to destination. Also, if the separation manager only vectored the aircraft for real conflicts (5/3 NM separation) communications requirements would diminish significantly. Therefore, increased communication speed (datalink) by itself will not allow the use of a user defined path.

Navigation - Since the essence of Free Flight is the users chosen flight path, whether the pilot chooses to fly an RNAV direct route, VOR airways, or S turns to the destination there is already onboard navigation capability to fly the path chosen by the user, given the navigation equipment the user chooses to install. Therefore, increased navigation accuracy will not allow the use of a user defined path.

Surveillance - The surveillance issue has more than one component. Each will be discussed separately.

Surveillance position accuracy - The radar position (transponder or primary where available), as determined by the HOST tracker, has safely supported 5/3 NM separation for 30 years. Although it would bolster the confidence of the controller by providing a more accurate target, the airspace system could not be changed based on increasing surveillance position accuracy alone. The main impetus to increase surveillance position accuracy is to allow the implementation of a computerized 4D conflict probe. Replacing the HOST tracker with BDACS (BDM Data Acquisition and Conversion System) will increase the accuracy of the aircraft radar generated position and velocity vector data enough to support a 4D computerized conflict probe. This increased accuracy allows the separation manager and ATOM's (Prediction Resolution Analysis Tool) 4D conflict probe to identify all real conflicts. It is questionable whether installing a conflict probe using HOST or ASD data would be viable. The ongoing installation of ATOM in the Boston Center should quickly answer this question. By itself, increasing the surveillance position accuracy will not allow the use of a user defined path.

Intent - This is a critical component of conflict identification. The flight plan intent has been validated for years as the primary intent information used by the separation manager supporting 5/3 NM separation. ATOM's conflict probe uses all known path intent (flight plan, velocity vector, etc.) information to provide conformance monitoring and conflict detection. Implementing Free Flight using flight plan intent and BDACS velocity vector at the 5 NM separation standard is possible without ADS-B or other datalink intent information. But, conversely simply increasing intent alone will not significantly alter the controller's ability to identify conflicts. What would the controller do with better intent? Nothing because they cannot manually process the better data for any benefit, let alone Free Flight. Therefore, increased intent information will not allow the use of a user defined path.

Conflict resolution - The separation manager has successfully manually resolved all known conflicts since the ATC system was put in place. FAA's analysis has shown that the number of conflicts is about the same in Free Flight as it is in today's structured system. RMB contends that given an accurate computerized 4D conflict probe the number of required conflict resolutions will actually significantly decrease. This is based on today's actual separation of 7 NM to 9 NM given the inaccuracy of the HOST tracker and Snitch patch. Since the number of conflicts decreases, the separation manager should not have a problem manually resolving conflicts in a Free Flight airspace system once they have been identified. Also using ATOM's look ahead capability, if a multiple conflict resolution is required, ATOM could provide an earlier alert to the separation manager. Therefore, automating conflict resolution is not needed and alone does not allow the use of a user defined path.

Local data - Today, the manual conflict probe (controller) has limited to no data on potential conflicts outside their sector. This leads to considerable coordination for even minor changes requested by the pilot. But this coordination does not stop downline conflicts, it only alerts the next controller that something outside the standard structure is occurring. Sector boundary airspace (boundary running) and Letters of Agreement (more structure) further limit the controller from granting the pilot's request, even if no conflict exists along the new path. The problem is, except for the airspace they are monitoring, the controller does not know whether a conflict exists or not. The application of 4D computerized conflict probe, using a more global view, will allow the separation manager to look down the new intent (shadow flight plan) for potential conflicts out to N (10 to 15?) minutes. This conflict look ahead is not limited by arbitrary sector or center boundaries. Since the separation manager must assure separation, the concept of global data, local separation utilized by a computerized conflict probe provides the tool to meet the most stringent safety requirements. But, by itself, expanding to a global data set does not allow the use of a user defined path because the controller can not process it effectively.

Conflict detection - Now we come to what is the only true constraint to moving to a Free Flight environment. Although the above indicates that globally based, more accurate surveillance position data is required as part of the complete solution, its purpose is to simply make the computerized conflict probe work. The current structured system is in place to accommodate the manual conflict probe -- the controller. By requiring a very rigid structure as aircraft density increases, it minimizes the number of conflicts and puts most of the conflicts in the same place time after time. This helps assure the controller that no conflicts will be missed, something that is clearly unacceptable from all viewpoints. What Free Flight does is remove that structure allowing the conflicts to occur randomly within the separation manager's airspace. To assure the equivalent level of safety within Free Flight, something most replace the structure that helps identify conflicts. This requirement is only fulfilled by providing the separation manager the correct tool -- a 4D computerized conflict probe. Therefore, a computerized 4D conflict probe based on accurate, global position data and intent **will allow** the use of a user defined path.

Although each of the above components can be used to reduce separation in a Free Flight system, only automated conflict identification in a random path system can, by itself, provide a significant move to Free Flight. Today, most airspace restrictions are in place simply to assure conflict identification by the controller in the manual airspace system. The key is providing the controller the proper tools to replace the structure, which is removed in Free Flight, and now required by the manual conflict probe.

The primary “tool” the controller needs in a Free Flight system is a computerized 4D conflict probe using global, highly accurate surveillance position data. From a logistical point of view, the hard way to do this is by installing GPS and datalink in all the aircraft (200,000 plus) and datalink capability in the ATC facilities on the ground. Even with the airborne avionics in place, an advanced computer tracker and a computerized conflict probe would still be required in the centers and Tracons for conflict identification in a random Free Flight environment.

Is reduced separation required for Free Flight?

Absolutely not. The current 5/3 NM separation standards has served us well for many years. Free Flight is not about reducing separation, it is about the airspace user choosing their individual flight path. The separation standard determines the number of conflicts that will occur, and therefore, determines how efficiently the aircraft can keep to the user defined path. If the separation requirement was 1000 NM, Free Flight would be very difficult to justify as an efficient system. By the same token, the structured airspace now in place would also be very inefficient at such large separation standards. But the 5/3 NM separation now in place is more than adequate to support an efficient Free Flight environment. Once in place, and after a careful safety analysis, the increased surveillance position accuracy of BDACS combined with ATOM may support reduced separation without requiring new airborne avionics. That same analysis may determine that a drop from something less than the current 5/3 NM separation (which we feel ATOM/BDACS will support) may not justify the cost of new avionics to lower the separation standard farther. Therefore, the size of the separation criteria does not help or hinder the use of a user defined path.

Are advanced avionics (GPS, datalink, ADS-B, etc.) required for Free Flight? If so, how will the users be able to afford this new technology?

Absolutely not. Advanced avionics are not a requirement of Free Flight, but should be installed to enhance Free Flight. Unfortunately, many still mistakenly tie the initial movement towards a Free Flight environment to enhanced aircraft CNS capability rather than to updates to the ATC ground system.

The airlines have been buying new CNS avionics for years with little return for their investment, a concept RMB calls the "stuff" theory. Basically the airlines have worked under the "stuff" premise for years by convincing themselves that "if we just buy more stuff, we know the FAA will allow us to use it this time". Unfortunately history shows the "stuff" theory as incorrect. Boeing 777s fly the same routes, and are provided the same separation, as a Cessna 150. In effect, millions in advanced avionics to more accurately fly over the VOR, something that should make the financial people lose more than a little sleep. GPS is another system that fits very nicely into the "stuff" concept. Numerous experts have stated that GPS will revolutionize the airspace system and is required for any form of Free Flight. They are flat wrong, GPS is a waste of money for the airlines today in the domestic United States. Today, Flight Management Systems (FMS) provide the same functional capability touted by the GPS advocates, yet Free Flight is no where to be found.

Over the last 30 years the aviation community has significantly increased it's CNS capability without a corresponding change in ATC procedures or user benefits. Domestic aircraft routinely use the FMS to more accurately (+/- 600') fly over the VOR. Oceanic aircraft have 2 to 3 times the navigation accuracy than required when the procedural separation system was put in place, once again with zero benefit to the operator. The ATC system is still routed in 1950's technology and procedures and until this is changed adding aircraft capability will provide marginal benefits at best. Conversely, change the ground based system and provide the airspace managers new tools based on 1990's technology and new airborne CNS functionality becomes a valid business decision. Buying new avionics based on FAA's promise of future benefits is plain bad business. It's a sad statement, but Wilbur and Orville would have little difficulty recognizing the ATC system today. It's no wonder the aviation industry is in financial trouble, the core problem being that it has allowed the production process to stagnate for over 30 years.

What is the controller’s role in Free Flight

The primary task of the controller is very simple -- **separation of aircraft**. The current control oriented ATM system is not the goal, but rather the method chosen to accomplish the basic task -- **separation**. Flow Control is not an end point, but only a method to accomplish the task -- **separation**. Notice a theme developing here. The ATM provider's one and only task is **separation of aircraft** -- do not let two aircraft collide. And, as mentioned above, anything less than 100% in accomplishing this task is unacceptable.

Under Free Flight the above does not change. The controller will still sit at a screen, monitor a defined piece of airspace and prevent two aircraft from hitting each other. Today this is done through structure and the controller’s mental abilities. When Free Flight removes the structure now in place to facilitate the manual identification of conflicts, we must give the controller the proper tools to continue to identify and resolve conflicts in a random path environment.

Can Free Flight be applied in what we now call the terminal area?

Absolutely. The current very structured terminal airspace is in place to limit the number of conflict and provide structure so that the manual conflict probe does not become overloaded.

RMB is convinced that there are two critical factors for Free Flight -- a 4D computerized conflict probe and time based sequencing at the merge point of aircraft entering a limited resource. Although most do not think about it, even a two aircraft conflict is two aircraft wanting to use the same piece of air -- therefore a limited resource. But that said, the most beneficial use of time based sequencing is for runway arrivals.

Granted the merging of the arrival traffic at a 3 NM point from touchdown based on time +/- 5 seconds will require new equipment, including GNSS -- more for a common time reference than navigation. But the key is to establish this concept at the current corner posts of the busy airports and the 8 NM finals of the less congested airports. These corner post merge points are 40 to 80 NM from touchdown and do not require the same level of accuracy as the 3 M point. RMB contends that basic pilotage would allow hitting the corner posts at +/- 30 seconds to 1 minute. Even this level of accuracy would smooth the arrival flow. Now add in some upline rationalization of the flow by the airline and the arrival pipe would flow continuously and smoothly. In other words we eliminate the air bubbles in the pipe based on the random arrival process now used. Changing speed or even upline holding at high altitude would be much more efficient (to a 4D computerized conflict probe a holding aircraft is just another conflict to avoid). Once this concept is proven and accepted new avionics would allow the merge point to moved closer to the end of the runway, with the goal at about 3 NM final.

Also, the addition of a 4D computerized conflict probe to the tool kit of the separation manager would allow them to routinely apply angular separation for arrivals and departures. Geometry says that the chances of an aircraft departing from one end of a runway with a continuous climb would rarely conflict with another aircraft in an idle descent to a 3 NM final. Obviously, more runways increase the complexity of this equation therefore requiring the 4D computerized conflict probe

What is the single most important benefit of Free Flight?

Operational flexibility. Although many focus on fuel savings as the primary benefit, they are mistaken. The key in the airline world is delivering the product (a happy passenger at the destination curb, bag in hand). The key in the military world is the mission. The key in the GA world is meeting the individual pilot's immediate requirements. Although fuel factors into all these equations, it is nothing more than a basic necessity to meet the requirements of the pilot/operator.

Are GPS and data link required for Free Flight*?*

The answer is no.

GPS, data link, ADS-B and other advanced avionics are *enhancements* to Free Flight, not *requirements* of Free Flight. The real problems are in that there are three important political factors that must be considered.

1. We have radar installed, we do not have GPS installed. All agree that GPS will do a better job of navigation and surveillance (ADS-B), but the logistics of installing it in a few hundred thousand aircraft is difficult at best. Even though data link position reporting will cost less in the future, today it costs upwards of $250,000 to install GPS/FMS/data link into a transport category aircraft. Even at less than $5000 US for general aviation aircraft, how do we get the VFR pilot

to equip, because if they do not the system still will not see them. We could divert the radar maintenance budget to subsidize the installations, but this would be a political nightmare. Better to show the aircraft owners there are real benefits for the installation by providing everyone a Free Flight system independent of airborne avionics other than a transponder and VHF radio. Then advanced avionics become a business decision

2. The current ATC system equipment in the US is falling apart. It must be replaced and fairly quickly. Waiting for a GPS/ADS-B system to be installed in all aircraft will not meet the critical time constraints now imposed by the deterioration of the current ATC equipment. ATOM/BDACS solves this problem within three years without any major technical hurdles to overcome. Once installed, ATOM/BDACS can use the GPS/ADS-B when available. This system allows benefits to individual aircraft based on the actual avionics equipage, so the system can handle the weakest link while still providing significant benefits to the power user. Computerize the conflict identification process that can differentiate between actual aircraft equipment and this problem becomes moot. Also, no matter the position source we still require a tracking algorithm, something BDACS does today for radar.

3. No matter the source of surveillance or its accuracy, what will the system do with it? Simply putting GPS position into the traditional ATC system is of zero benefit. Since we feel a ground based separation system is the safest system, we must build a ground infrastructure that is robust, has very high integrity , uses any positioning source available and only controls the flight path of the aircraft to avoid real aircraft to aircraft conflicts

The use of ATOM/BDACS, based on radar (even with radars shortcomings), meets the near term objective we all want. It will provide enough accuracy for a Free Flight system using 5 NM separation. Also by giving the controllers the tools to make them separation managers (only call the pilot if they are going to conflict with another aircraft) and a system that will use any positioning source (GPS or radar) we now have an incentive for FAA’s customers to move to GPS and data link. ATOM/BDACS, based on radar, is simply the easiest, most economical first step towards a more advanced Free Flight system.

Once we have built the Free Flight procedures and understand the equipment needed, moving to more advanced avionics based on real benefits becomes obvious. Remember we have increased our airborne navigational accuracy by a factor of 10 over the last 15 years to more accurately fly over the VORs. Also, FAA's track record in meeting their stated objectives is less than sterling (If possible read ATC: Status of FAA's Modernization Program, GAO/RCED-95-175FS). To say that we are skeptical of FAA installing the ground equipment that will use the increased accuracy of the airborne GPS/data link equipment is putting it mildly.

No matter what we do, radar will be around for a minimum of 10 years. Let's use it to build a Free Flight system that moves away from the traditional ATC services and then build forward from there.

Do Military Operations stop Free Flight *implementation?*

No.

Most people assume that today's military operations stop any movement to Free Flight. We disagree. Military restricted areas can be programmed into ATOM as simply large non moving aircraft. ATOM has the ability to assign individual protected areas to each aircraft, military airspace or any other potential conflict or safety hazard (terrain, noise sensitive areas) that must be avoided. Then ATOM's conflict probe will automatically identify any aircraft whose intent "conflicts" with the military airspace. The military airspace could then be turned on and off in ATOM as required by the military. Military airspace is simply another constraint (like thunderstorms) that must be accounted for in the airspace system. ATOM can accomplish this task without any investment in airborne avionics.

Additionally, FAA's current avionics based Free Flight implementation forces the military to purchase thousands of ship sets avionics. This is not only expensive, but is a logistics nightmare that will drastically slow the movement to Free Flight.

Keeping in mind your proposed time schedule of implementing Free Flight by the year 2000, how are the controllers supposed to be trained on this entirely new way of operating?

There is in fact no real change in the way controllers operate. The stress levels will be less, but conceptually they will be doing much the same work as they are today.

Most continue to think that Free Flight will significantly change the way the controller does their job. It will not. There will still be a human sitting in front of a scope and still monitoring a defined piece of airspace. The separation manager will still be required to identify and resolve conflicts.

The difference is that today, controllers rely on a very local set of data, an almost impossible communications requirement to coordinate any change, and a mental calculation to identify conflicts. With Free Flight, there will be a 4D computerized conflict probe tool that will aid the separation manager by continually looking forward to assure that a conflict does, or does not, exist.

How many "deals" (losses of separation) are caused by a controller missing a conflict or by missed communications during hand-offs? Each conflict will be handled exactly the same way it is done today. But today, to assure identification of conflicts we have implemented a very complex structuralized system. All that is suggested is aiding the manual conflict identification tool now in use (the controller) to minimize and help identify conflicts with a

4D computerized conflict probe using global (instead of local) data that cuts across the arbitrary sector boundaries.

If there are 200 airliners all converging on an airport and Inbound #1 cannot clear the ramp because of a disabled aircraft in its gate, what happens to all these arrivals as the delays begin to propagate outward. How is this handled at an extremely cramped airport like LGA?

First, we never have "200" aircraft converging on an airport. Typically the number at the high end is more like 50 to 100 depending on the number of gates at the arrival airport. And that is only at connecting-hub airports. Let's not continue to put draconian requirements on a new system when the controller is already accomplishing the task today.

But there is an issue here. Obviously, all agree that LGA is a tough nut to crack. But this is one of the worst scenarios at one of the worst airports. Rarely are pilots restricted form taxing to the gate at any airport, including LGA. This is simply not the limiting factor.

The real issue driving demand at the airport is gates versus runways. LGA has a 50-to-1 gate to runway ratio while ORD's ratio is 30 to one. If the scenario develops as described, which is not likely, the same thing would happen as it does today, except the airline would decide where to hold, or what to do with the aircraft.

Before the reader jumps to conclusions, in Free Flight with good position data and a 4D conflict probe (available today using radar data) a holding aircraft looks the same as one enroute. Why do we continue to need great chunks of airspace for holding. With FMSs and better intent, although a radical thought, we would venture that even two aircraft could be in the same holding pattern.

What happens when Inbound Number 1 blows a load of Hydraulic fluid all over the runway? Although most congested airports have more than one runway, the loss of one runway can diminish the arrival capacity of the airport by MORE THAN HALF.

As long as airplanes are built, flown, and managed by the hand of man, and weather is uncontrollable, there will be operational dislocations. And this will, under any system (toady's or Free Flight), sometimes cause massive problems to the system. *But we must not continue to live with an air traffic management system that routinely maxes out based on normal events, or require unbuildable capabilities of a new ATM system.*

Will there always be some restriction to throughput - absolutely. But what does the controller do today with 15 aircraft in the approach trombone at somewhere like DEN if the above scenario develops. They deal with it.

The same is true in Free Flight, except there is not an approach trombone and the separation manager will have a 4D conflict probe tool to assure that as the confusion develops the separation manager does not do something that leads to a real conflict*. A Free Flight system provides the tools to minimize the shock that extraordinary events may cause the system.* The problem is easier to solve using a time based sequencing system since aircraft #10 for arrival is still 30 NM from touchdown in less congested airspace. Additionally, if the airlines are continually monitoring their production lines (movement of their aircraft), something they do not do today, they should rapidly be able to provide the most profitable restricted sequence for the remaining runway availability.

FAA does not allow the airlines to use operational equipment that is not certified in revenue flight for safety reasons. The same is true for ATC equipment.

Given the shadow implementation of ATOM/BDACS some of the sectors would be operating prior to certification. All that is proposed is that if any catastrophic failure of the HOST/PVD/EDARC wiped it out completely, what controller would not walk down to the fully functional, although not certified, ATOM/BDACS system to assure safety? In the airplane, pilots would have no qualms hand flying a CAT III ILS, if that was the only option, even though not "certified" for that approach.

Will the ATC system need to help supply clearances to the aircraft?

Free Flight is based on the operator choosing the flight path, not ATC. On the matter of clearance, the system would work exactly as it does today. The pilot would file a flight plan (their chosen path), that would be entered into the NAS. The pilot would fly that flight plan laterally just as they do today. Although there would be much less requirement for changes if the pilot was allowed to do what they wanted to begin with, before the pilot made changes they would be required to ask if the new path was safe. If safety is not impacted, the change is approved, the separation manager would still refile a full lateral flight path. Vertically the pilot would cruise climb using the BDACS tracker for near term (10 minutes) intent. They would again announce their new intent if they wanted to make any change and the separation manager would assure the new vertical path is safe. The only difference from today is that the pilot would get to choose the path as long as it is safe and the separation manager would have the tools (visual display, mental ability and computerized 4D conflict probe) to assure it is safe.

Will workload increase for the controllers under Free Flight?

No. It will make their jobs less stressful. And to answer another question, Free Flight does not threaten the job security of controllers.

Will the tasks and procedures be slightly different under Free Flight. Absolutely? But the workload should not change significantly and should actually decline slightly.

What about the areas where there are lots of aircraft climbing and descending and holding. Will the RMB/ASRC concept of Free Flight cause a greater workload in the arrival and departure phases of flight?

Of course the congested terminal area is very difficult for the manual controller, but much less difficult for a computer that can aid the separation manager. Once again FAA continues to apply new technology to today's process. We must rethink the separation task given a human managed, computerized 4D conflict probe using global data.

Additionally, most assume that departure and arrival traffic will continually conflict and lead to chaos. Given an idle descent to a 5 NM final and a continuous climb from the departure end the conflicts will be less than many anticipate. And armed with a 4D conflict tool, the separation manager will be able to handle those that do occur. A simple analysis should prove this one way or the other. Please do not look at this through the lens of the today's ATC system.

For the oceanic traffic there will inevitably be a massive increase in conflicts, if we were to allow pilots to file their ideal flight plans - due to the prevailing weather patterns funneling everyone onto the same path.

Not true.

Many in the FAA do not fully understand the requirements of different aircraft types and operations. A recent oceanic flight plan analysis had three flight planning systems plan the "most efficient" route for the same aircraft, on the same day, using the same winds. The three solutions were hundreds of miles apart. Obviously this will not always be the case, but in the oceans we are only dealing with a few aircraft.

On a recent day the number of aircraft actually crossing the Atlantic Ocean varied between three to eight hundred at any given point in time.

For clearances in 10 minute chunks, in congested airspace, this will inevitably create very inefficient flight profiles, and massive workload for Controllers.

Not true.

To start with, clearances are not in 10 to 20 minute chunks, only the look ahead by the separation manager using ATOM. Intent will be given by the pilot for the entire route, the same as today. In a radar environment the 10 to 20 minutes refers to the time that the probability of a real conflict will occur.

Any farther out on the timeline and the variables of the system makes the probability of a real conflict occurring drop dramatically. In non-radar the problem is the same. The less accurate CNS will simply dictate a longer lead time and larger separations.

The controllers could increase efficiency over the ocean now by ensuring fast traffic is not sequenced behind slower aircraft. Sounds simple, and some controllers do try it, but the effort involved is too high, and the result is 'first come, first served' - even though it wastes airspace.

Once again we continue to apply the restrictions of the current linear, manual track system to what can be done with advance computer as tools for the separation manager. The reason the system looses efficiency is that the faster aircraft must follow the slow one. This is today's restriction that is not applicable in a Free Flight environment.

The Free Flight extremists just want to blast off without restrictions and be able to do a 360 any old time, but that plays heck with conflict detection: effectively aircraft behind you become traffic, and alert zones get positively huge.

Although accused of being Free Flight extremists, we agree completely with the above statement. Building Free Flight around the concept "Here is my velocity vector, make it safe" is extremely complex and to be honest, not that beneficial.

RMB/ASRC continues to advocate a Free Flight system based on the premise "Here is my intent, is it safe?" This is a much simpler and less expensive to implement, with the same operational outcome.

Alert zones, and all the complexity they require, would not be required. The separation manager would use a 4D conflict probe (ATOM/BDACS) to determine if the aircraft's protected area would overlap with another aircraft's protected area in the near term (i.e., 10 to 20 minutes). If not, the new path is determined safe and the aircraft would proceed along it. Initial intent would be communicated through a flight plan. Airborne conflicts would be handled tactically and changes could be communicated orally or via data link when available. The concept of alert zones is simply a way to keep the controllers out of the cockpit. We view this is a very expensive overreaction to the control oriented ATC system in place today.

The premise is that pilots will continue in their wish to have the runway all to themselves for a brief period, which implies that temporal spacing at the threshold will still need to be applied and worked backward into space.

Free Flight is built on two primary premises, and automated conflict probe and time based sequencing when resources are limited. This limited resource allocation can be a runway or a hole in a line of thunderstorms, the problem is the same. Time based sequencing can be accomplished today at the outer fixes at the hubs using pilotage alone (+/- 1 minute).

Let's start the process today and then slowly move the merge point closer to the runway as safety and technology permit. Today, with the use of ASD data fed from the SCC to the airlines, along with ACARS, the airline could know (even though they have the data they do not do this today) fairly accurately when the aircraft will arrive at the outer fix to a hub. In other words, they could estimate when AAL 378 will arrive at Boids (arrival fix for DFW on the Boids arrival). Through the use of ASD they could also tell the potential traffic load at Boids at that time.

Let's say that shortly after takeoff from the west coast AAL dispatch saw that 6 aircraft (4 AAL, 1 DAL, 1 TWA) were going to arrive at Boids at 1546z. Today as this grouping arrives in the Boids controller's sector, they are brought to a common altitude and speed sequenced. If the grouping is much larger, the Boids controller passes speeds or holds up the line. Additionally, the Boids controller sequences the aircraft on a first come first serve basis. Well this bunching was evident long before it occurred, for anyone who cares to look today. AAL could rationalize the flow of its aircraft to avoid this bunching and the Boids controller would never know. All of a sudden the aircraft would need much less sequencing.

Remember even though the airline would set up the sequence for its aircraft, the FAA would assure equitable use of the system. There are only 22 large airline connecting hub airports across the whole US. Of these there are only two dual hubs (ORD and DFW), the rest are one carrier hub-sites, with PIT and CLT being those most dominated by one airline (and both are well under half as busy as ORD and DFW). This leaves a lot of airports and airspace that will not have this problem. Simply rationalizing the hub carrier's flow by that carrier around the single aircraft arrivals would pay large dividends.

Will a good deal of structure remain in the major terminal areas, just because of traffic density, the number of crossing points, and crew desires to keep the number of conflicts sane while they are trying to do all their high-workload low and slow stuff?

Implementing Free Flight enroute based on ATOM/BDACS and initially leaving the "congested terminal areas" alone for now is what we have been advocating for a long time. Additionally, we do not believe that the number of conflicts in a Free Flight terminal area is as large as many now think. The addition of a 4D computerized conflict probe to the tool kit of the separation manager would allow them to routinely apply angular separation for arrivals and departures. Geometry says that the chances of an aircraft departing from one end of a runway with a continuous climb would rarely conflict with another aircraft in an idle descent to a 3 NM final (4 to 5 NM from the departure end). Obviously, more runways increase the complexity of this equation therefore requiring the 4D computerized conflict probe. A simple simulation could prove this concept very quickly.

Will ATOM/BDACS have the same problems AERA had in trying to do transcontinental conflict probes. ATC certainly has no short-horizon data exchange hardware coming that would fill in all the non-aircraft-related potential conflicts you point out, so ATOM will cheerfully approve all sorts of unflyable trajectories?

First of all why do a transcontinental conflict probe? The variables of the system (wind, operational considerations, aircraft type, etc.) will significantly lower the probability of a tactical conflict past 20 minutes. Although ATOM can look as far down stream as the separation manager wants, beyond 20 minutes it really becomes a sequencing problem, not a tactical conflict.

ATOM has the ability to assign a geometric protected area around each individual aircraft. It can also do the same for warning areas or other non-aircraft-related potential conflicts. RTCA has already advocated the more rapid data exchange of warning area usage. ATOM could use this data to switch on and off the stationary "protected" area of the warning area. Finally, ATOM will not approve anything. ATOM/BDACS is simply a tool to allow the separation manager to more accurately determine if a "real" aircraft to aircraft conflict will occur.

The "airline sorts out their own mess" scenario sounds nice, but there needs to be some mechanism for preventing individual airline decisions from playing against each other.

Airlines will ultimately schedule their flights in a manner that fits available resources. The main places where this question would come into play would be ORD and DFW, where two hubbing airlines operate. Scheduling decisions at these airports and at others will be made often based on competitive business decisions. The cost results upon the carrier making these decisions will determine the ultimate outcome.

But the problem is the question itself, which assumes that the runway is the limiting resource. We have said it many times, *There is no runway or airspace limitation to aviation anywhere in the world today.* Every constraint encountered stems from the antiquated ATC system and structure now in place to protect the controller from becoming overloaded.

Granted, controllers would probably disagree, but from our perspective rarely is there another aircraft within 10 to 20 NM of another aircraft. Even in what most would call the "dense" terminal areas, the TCAS shows that the path the pilot desires is typically conflict free. Unfortunately, because of the local nature of the data the controller now uses and the coordination required to access the additional data required, the controller does not know this.

Airport neighbors are not necessarily going to tolerate everybody screaming off on a great circle route after takeoff.

Agreed. Environmental issues must always factor into the equation. But let's design the system to allow time merging of the arriving aircraft from there preferred path at a point 3 to 5 NM from the runway. And an ATM system that allows the aircraft to depart on that great circle path. Noise issues, like thunderstorms, will always alter the pilot’s preferred path. We just do not want the separation manager doing it unless the aircraft is going to conflict with another aircraft.

From your papers on the subject, a pilot in Free Flight may alter its trajectory at any time and then notify the separation manager of their change after the fact.

What the question refers to is the "Here is my velocity vector, make it safe" concept of Free flight. We STRONGLY DISAGREE with it. The RMB/ASRC concept is "Here is my intent, is it safe". By providing the separation manager with the intent prior to the maneuver (which is what we endorse) greatly simplifies the separation task. Just consider the complex solution of alert zones and datalink that is needed to meet the ill advised velocity vector approach. From an operational standpoint the difference between the two is minuscule as long as the aircraft can proceed down the new path and not hit another aircraft.

Free Flight is random routings using GPS and not being tied into predefined routes.

To RMB/ASRC, Free Flight is about who gets to choose the path, not how the path is navigated.

If the pilot chooses to only install ADF and files a flight plan based on the pilots' requirements via ADF navigational aids and can fly that path without artificial restrictions, that's Free Flight. The pilot would only alter the path for the separation manager for an actual aircraft to aircraft conflict. If the pilot chooses to fly in a non radar environment the protective area would grow to match the lack of surveillance. Although this is not Free Flight like for an eagle or Icarus, it is close enough based on the equipage in which the pilot wishes to invest.

West of the Mississippi, most aircraft get the route they want, including vectors for direct.

Agreed. Pilots receive a fair amount of directs east of the Mississippi, but that saves just the fuel. Unfortunately, because the aircraft is scheduled for the longer route significant productivity is lost since the aircraft must sit on the ground for the next scheduled trip regardless of how early it lands. This is the big bucks.

Watching the finals at ORD most of the time shows they are full for about 15 mile finals when the airport is busy.

The key here is the definition of "full". Is each aircraft 2.5, 3,4, or 5 NM behind the aircraft in front according to size? This does not happen very often, if ever. The normal distance between approach aircraft is 3 to 4 NM and 6 to 7 when a B737-300 is following a heavy. Runways are simply not the limiting factor today.

In the busy metropolitan areas, with more than just a couple of airports, aircraft just going off the ends of the runways and going direct is not going to work all that well.

Controllers vector aircraft around the arrival/departure corridors from adjacent airports, even if there are no aircraft in those corridors (something like spaghetti tubes). RMB/ASRC is not criticizing the controller or even this methodology in the context of the antiquated equipment. What is presented is a very difficult geometric problem to resolve by a human, especially with little or no knowledge of the events in the sector next to you. But a computer based 4D conflict probe, using more global data, makes it an easy task and will provide the separation manager the tools to identify conflicts in what most see as chaos. And if the separation manager is only resolving conflicts rather than controlling the aircraft's path, the communication problem diminishes. Also today's geometry is forced since the system keeps the departure and arrivals on an inflexible path. Free Flight will spread these potential conflicts out considerably.

Using PHL as an example, an aircraft would depart the end of 27R and proceed on course climbing at 2500 to 3000 FPM. Now imagine another aircraft descending to a 3 NM final (900' AGL) for 27L. There is only one particular geometry that these two aircraft will conflict that could be 20 to 30 NM from the airport. Now let's add in departures from BWI. These departures if left to climb immediately, the most efficient path would rarely conflict with the PHL traffic on an angular basis. Remember, we said a 4D computerized conflict probe that cannot be overloaded. This is an angular separation problem that is difficult for a human, but easy for the computer. Think of the geometry as arrival and departure cones. After 30 NM from the airport the cone is at or above 10,000' AGL and the traffic begins to diverge.

The supplier has to provide safe, operational area altitudes, below which Free Flight is history.

RMB/ASRC agree. Free Flight does not replace the requirement for TERPS, MEAs, etc.

How would a controller re-establish non-radar routings if and when an ARTCC's radar failed?

First of all most would consider this to be a chaotic situation. What chaos? The ATOM/BDACS system identifies all conflicts for the next X minutes (we recommend 10 to 20 minutes). We assume in the 8 to 10 minute time frame from the projected conflict the separation manager would take control of the flight path and resolve the conflict, just like the controller does today. Given that ATOM actually identifies all conflicts out in time as far as the separation manager wants, even with the loss of radar data, ATOM still knows that the conflict will occur.

Under ATOM/BDACS this could be handled a few ways. First the problem of a single radar failure. Today there are 8 to 10 radars per center. Since BDACS takes inputs from 16 radars simultaneously, usually two, but maybe three to four other radars are also looking at that airspace. Remember approach radars could also be integrated into the center's BDACS. BDACS automatically integrates all radar positions of each aircraft, so the controller may never know the radar went off line. Second, what if all radar coverage is lost (i.e., the PAMRI burned up). ATOM could use the last velocity vector (in an advanced coast mode, not today’s HOST version of coast) and determine a projected path with a protected area that grows the longer in time from when the radar data was lost. This is an important point. Today if the HOST or DCC fails, the controller must rely on the limited capabilities of DARC. Under ATOM/BDACS no functionality is lost, only separation criteria is increased because of the loss of accurate surveillance data. Third, since ATOM/BDACS is a distributive processing system, no single or even dual point failure (at $40,000 per backup, this is cheap insurance) could cause the loss of data. Fourth, what if the entire center was off line? The radars in each center should also port data to the adjoining centers that could then protect the airspace.

Most controllers believe that the airline is the culprit here. And we need a recognition by airlines that their scheduling practices will control congestion.

Airlines will schedule based upon a variety of reasons. Sometimes this may result in less efficient operations, but that is the decision (and the cost) to be determined by the airline, not by the air traffic control system. Actually, airline marketing people sometimes make scheduling decisions that are not always compatible with available resources or operational efficiency. Basic economics are the corrective factor. If, for example, USAir at PIT decides to launch 100 planes in a 30 minute period, they certainly will incur long taxi times. Basic economics would soon result in the carrier revising its schedule based on the constraints in place.

The important part is that these are airline decisions, and until the FAA accepts a system that makes maximum use of available ground and airside resources, the question is moot. Today, the supplier (the FAA) should never blame the customer (aviation users). In a competitive environment (something we do not have) this is one of the fastest ways to go out of business. The fact is that the system has not kept up with the customers' demands, and forces airlines to make inefficient use of resources.

The question also assumes that no further supply can be built for the present demand. We do not think this a true statement in any situation. There was a story about the formation of the US patent office. The argument against it was "why would you need a patent office, since everything that could be invented has been invented."

Rolling in one sector at a time is not feasible. Physically, of course, that will happen, but training will need to be done for every controller first.

RMB/ASRC disagrees with the belief that rolling in one sector at a time is not feasible. We agree that training, not technology is the critical path, in accomplishing the sector by sector implementation. We must train the separation manager with a generic set of separation tools. By taking away the fixed geographic boundaries and sector idiosyncrasies the training issue becomes much less critical.

The separation manager will still monitor a defined piece of airspace, still have a display of the traffic situation and still resolve conflicts. Although some training will be required, any controller should be able to sit down at a ATOM workstation, monitoring any sector and identify and resolve all conflicts with zero training. Can ATOM do all this? It is to be hoped that the ZBW evaluation will show that it can.

What good is saving a few bucks on some enroute leg, to blow it all and then some, in the final 150 miles of dodge ball?

That is why ATOM must be implemented with a time based sequencing system. Even if the time based sequence is set up to the current arrival fixes (which we think is a good idea) the users gain a large benefit. For example, departing from Des Moines to Boston. After TO the pilot turns to the point in space (radial/DME) flight path filed direct to Gardner. After airborne two conflicts occur that are identified by ATOM and resolved by the separation manager. Sometime over an hour from GDM the pilot receives a GDM time based on position, speed, BOS traffic inbound, etc. The pilot then tries to meet the GDM time +/- minute. About 30 minutes from GDM, ATOM shows the aircraft 30 seconds off the assigned GDM sequence time. The pilot is advised to speed up and does. The aircraft arrives over GDM +5 seconds and flies the GDM.GDM2 to BOS. Obviously, the B737-300 FMS can accomplish the above +/- 10 seconds automatically, but pilots (with practice) can do all of the above with using VORs and a whiz wheel. When more sophisticated equipment is added to the majority of the fleet or CTAS is installed, the merge point can be moved closer to BOS.

15. Appendix C - RMB Associates & ASRC

15.1. RMB Associates

RMB Associates was founded in 1981 to provide in depth analysis of airline/aircraft operations and to identify and seek out solutions to their operational problems. RMB Associates' primary focus is to provide the airlines and aircraft operators with a broader view and helps identify their structural operational weaknesses. The aviation industry's dismal financial performance will continue unless the industry, as a whole, rethinks the basic assumptions on which they operate and then works to provide correct solutions for the real problems.

RMB Associates' has considerable expertise in the aviation industry. The experiences RMB Associates draws from include: airline and avionics engineering, avionics marketing, piloting as an airline captain, airline management and extensive dealings with the FAA and ATC. These unique experiences can identify and help solve the right problem, rather than wasting time and money solving the wrong problem. RMB Associates' papers include:

Survival: Airlines, Competition and Profits**,** February 1, 1994 - Airlines face many competitors today that remain unchallenged. This report identifies these competitors and other revenue negative aspects of the airline industry. This paper discusses the impacts of pricing, reservation agents, etc., that the airlines must begin to address.

United Airlines versus Southwest Airlines - Below the Surface**,** May 1, 1994 -
In depth analysis of the operational and product differences between United Airlines and Southwest Airlines. This independent study breaks down the cost per Available Seat Mile (ASM), based on individual aspects of each carriers' operation. The study concludes that United's higher costs are a function of differing product/operational choices.

Free Flight - Reinventing Air Traffic Control: The Economic Impact, June 1994 - ATC is the largest controllable cost the airlines face. Unfortunately, it is relegated to mid level managers and technocrats, instead of receiving executive level attention. This report identifies the costs to airlines and the entire United States economy that go unchallenged because of the inefficient Air Traffic Control (ATC) system. These costs, borne by the consumer, are unacceptable and this report offers solutions that are critical to continued airline viability. This is the first independent analysis of international airspace management requirements and the cost to the airlines and economy in general.

Free Flight - Reinventing Air Traffic Control: Production Line Management, March 15, 1995 - If the aircraft is viewed as a factory, the factory is shut down when it is at the gate -- no product is produced. The airlines have recognized this recently, as evidenced by their interest in reducing ground turn times. Away from the gate, the factory is open and the production line is running. The study indicates that airline system productivity, measured in ability to produce ASMs per block hour, has decreased by over 8% since 1980.

Unfortunately, the airlines have yet to fully recognize that, once running, ATC controls the speed and direction of their production lines.

Blueprint To Free Flight, April 1, 1996 - ATC is viewed as a very complex command and control system. This paper examines the underlying task of the Air Traffic Service (ATM) - separation. It postulates that the numerous layers of system complexity today are in place for only one reason - to protect the manual conflict probe. Therefore, computerizing the conflict probe process simplifies the ATM task. This document outlines a step by step process to replace the aging ATC equipment, build a Free Flight airspace by the year 2000 at zero cost to the airspace users and dramatically reduce FAA's procurement costs.

For further information on these important studies, contact:

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15.2. Aviation Systems Research Corporation

ASRC is a multi-dimensional consulting and research firm, assisting clients in all areas of aviation. Founded in 1984, ASRC has become a leader in providing accurate forecasts and trend analysis. Consulting clients include airports, airlines, and Fortune 500 companies in the aviation industry.

A cornerstone of ASRC is the publishing of white papers and studies that focus on issues that will be critical to the future of aviation. ASRC was the only consulting firm to publish data accurately predicting and discussing the major problems with the new Denver airport. The firm also publishes ***Airports:USA***, the only comprehensive traffic forecasts produced in the private sector. ***Airports:USA*** addresses traffic trends within the context of the changes expected in the airline industry. As a result, our forecasts are the most accurate available.

In addition to the Free Flight series of studies, other independent studies published by ASRC include:

- *Regional Airline Industry - The Effects of Code-Sharing* (1986). The first analysis of the effects that code-sharing would have on the regional airline industry. Findings presented to the RAA Presidents Council. In this study, the term "fortress hub" was first used and defined.

- *The Regional Transport Jet* (1989). This was the first analysis of the 50-seat jet transport produced independently of an aircraft manufacturer, and was the first such study to project a strong need for this category aircraft in the 1990s.

- *Analysis Of The Wayport Concept* (1989). An in-depth study of the potential for using remote airports specifically for interconnecting passengers and cargo. The study determined that the concept was inconsistent with economic realities of the airline industry.

- *Airport Capacity Needs In The 21st Century* (1990). This study provided an overview of the demands on current airport capacity, as well as the demands that will be placed on airport facilities in the years ahead.

- *The Continuous Hub Concept* (1991). An analysis of alternatives to increasing the efficiency of the hub-and-spoke system. First coined by ASRC, the term "continuous hub" is now discussed widely in the U.S. airline industry.

- *The U.S. Airline Industry: Reassessing & Rebuilding* (1993). This extensive study outlines the problems facing airlines, and projects the positive changes the industry will see in the years ahead.

In its independent studies, ASRC publishes its findings, recommendations and conclusions "as is" and "where is." We endeavor to provide the hard facts, regardless of their "political correctness." Integrity is far more important than political correctness.

In our consulting projects, we use the same approach. We help our clients to objectively weigh alternatives and we state the results in a forthright and openly honest manner. ASRC feels that if America is to have the air transportation system it needs in the future, the politically-correct and sugar-coated consulting that is today all too common is not consistent with integrity.

Clients of ASRC include airlines, airports, aviation authorities, and aircraft manufacturers. In addition, hundreds of other aviation-related companies have purchased our many independent studies.

If your aviation related company is planning for the future, Aviation Systems Research can help. We specialize in straight talk and direct answers. Give us a call.

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