Operations Research and Analysis

# Economic Justification for FAA's Flight 2000 Program

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## 1.0 Purpose

This paper summarizes the economic benefits that are anticipated to flow from the FAA's Flight 2000 operational demonstration program. This quick assessment is based on the Flight 2000 Initial Program Plan, dated July 16, 1997. The analysis shows there are sufficient economic merits to justify the projected investment of $390 million outlined in the plan. In particular, the safety benefits to users and potential cost avoidance are estimated to range between $2.6 and $6.6 billion as part of the overall NAS modernization effort.

## 2.0 Core Capabilities to be demonstrated in Flight 2000

Flight 2000 aims to provide early proof, in the relatively self-contained Alaska/ Hawaii environment, of the value of several emerging core technologies to pilots and controllers. Each of the technologies is crucial to subsequent achievement of greater safety and efficiency in the more complex, capacity-constrained CONUS National Airspace System. Table 1 depicts the avionics configuration for Flight 2000. The basic capabilities to be demonstrated are:

- Increased flight information and communications in the cockpit (weather, terrain, obstacles, Notices to Airmen, Special Use Airspace).
- Improved pilot and controller surveillance information and coverage with Automatic Dependent Surveillance (ADS) and Cockpit Display of Traffic Information (CDTI).
- Improved pilots' navigational capability through GPS-enabled operational capabilities (area navigation, approach guidance to all runways, precision missed approach guidance, more flexible arrival and departure routes, and low altitude random direct routes).
- Increased controllers'/pilots' flexibility and efficiency of operations from enhancement of Decision Support Systems (DSS) in Oceanic airspace.

**Table 1. Avionics Configuration for Flight 2000**

| Core System | Upgrade 1 | Upgrade 2 |
|---|---|---|
| • GPS/RNAV | • Multimode Communications | • Controller/Pilot two way data link communications |
| • Terrain and Obstacle data base | • Flight Information Services for NOTAMs and Special Use Airspace | |
| • Multifunction Display | • Weather Broadcast text and graphics | |
| • ADS-B with Traffic Information Service | | |
| • Cockpit Display of Traffic Information | • Weather (Request/Reply) | |

## 3.0 Economic Benefits of Flight 2000 Program

The Flight 2000 program is an early large-scale (Alaska and Hawaii) operational demonstration of the core technologies and operational procedures underlying the future NAS Architecture (draft version 3.0).

From an economic perspective, its benefits may be segregated into two basic categories, consistent with the dual basic objectives of the Flight 2000 Program itself :

(a) **Provide immediate direct benefits** in Hawaiian/ Alaskan/ Pacific airspace operations:
- Increase air traffic services to Hawaii and Alaska general aviation, air taxi, and regional carriers.
- Increase air carrier operational efficiency in the Pacific Ocean environment and associated CONUS transition airspace.
- Increase air transportation system safety in the Hawaiian and Alaskan airspace

(b) **Provide longer-term cost avoidance** through accelerated acceptance of the future NAS Architecture and minimized transition risk/ delay to its achievement
- Accelerate achievement of Free Flight safety increases and economic efficiencies in air traffic management and control operations.
- Reduce risk of development/ transition/ integration to the future NAS Architecture.
- Reduce costs for avionics and ground-based systems due to resolving design and operational issues prior to full-scale production of systems and equipment.

## 4.0 Immediate Flight 2000 Safety Benefits

For purposes of this study, only incremental safety benefits in Alaska and Hawaii were quantified, in the form of potentially avoided accidents that otherwise would be expected to occur. These benefits will be achieved as a consequence of outfitting participating aircraft with Flight 2000 advanced avionics (GPS/ WAAS receiver, datalink communications, ADS transceiver, and multi-function pilot's display) as compared to retaining their existing avionics suites.

The estimate of benefits was derived by analyzing every aircraft accident in Hawaii and Alaska between 1994 and 1996, and assessing which of those could have been prevented if Flight 2000 avionics had been available. Current safety procedures, including separation standards, were assumed to remain in place for this analysis.

During this three year period, there were 510 reported accidents, according to the National Aviation Safety Data Analysis Center (NASDAC) records. Part 91 operators (general aviation) accounted for 394 accidents, with the balance of 116 accidents occurring to Part 121/135 operators (aircraft carrying revenue passengers). In analyzing these accidents, it was estimated that 44 of the part 121/135 and 32 of the Part 91 accidents could have been averted with Flight 2000 avionics and capabilities.

Using standard Agency economic values (in constant 1997 dollars), the safety benefits to Part 121/135 and Part 91 users in Alaska and Hawaii, respectively, are estimated to be $111.8 million and $76.9 million over the 3-year analysis period. Table 2 provides a summary of the statistical results. In annual terms, the safety benefits to Part 121/135 operators are valued at $37.3 million.

Likewise, if Part 91 operators were equipped with the requisite avionics, the annual safety benefits to users in the two states are estimated to be $25.6 million. Over a ten year period, these safety benefits could potentially reach $629 million to all operators, or $373 million for Part 121/135 users and $256 million for Part 91 users. Note that current plans call for Flight 2000 to provide sufficient avionics systems to equip *commercial operators only*.

**Table 2. Statistical Summary of Accident Results (Constant $ 97 million)**

| **Hawaii** | | | | | |
|---|---|---|---|---|---|
| **Part 91 (General Aviation)** | | | **Part 121/135 (Commercial)** | | |
| | **Number** | **Cost** | **Number** | **Cost** | **Total** |
| Aircraft Destroyed | 2 | $.4 | 1 | $0.5 | |
| Aircraft Damaged | | | 4 | .3 | |
| Fatalities | 2 | 5.4 | 1 | 2.7 | |
| Serious Injury | | | 5 | 2.6 | |
| Minor Injury | | | 1 | 0.04 | |
| **Sub Total** | | 5.8 | | 6.1 | 11.9 |
| **Alaska** | | | | | |
| **Part 91 (General Aviation)** | | | **Part 121/135 (Commercial)** | | |
| | **Number** | **Cost** | **Number** | **Cost** | **Total** |
| Aircraft Destroyed | 12 | $2.1 | 17 | $7.4 | |
| Aircraft Damaged | 18 | .5 | 22 | 1.3 | |
| Fatalities | 22 | 59.4 | 33 | 89.1 | |
| Serious Injury | 6 | 3.1 | 15 | 7.8 | |
| Minor Injury | 5 | .2 | 2 | 0.08 | |
| **Sub Total** | | 71.1 | | 105.7 | 176.8 |
| **Total** | | **$76.9** | | **$111.8** | **$188.7** |

In Alaska, where hostile weather is commonplace and accident rates are the highest in the United States, Part 121/135 aircraft would experience the biggest potential gain with an avoidance, on average, of 13 statistical accidents, 11 statistical lives saved and 6 statistical injuries prevented annually. If all Part 91 aircraft were also outfitted in Alaska, there would be an average avoidance of 10 statistical accidents, 8 statistical lives saved and 4 statistical injuries prevented per year.

## 5.0 Longer-Term Cost Avoidance through Risk Reduction

While safety improvements are very important, the primary benefit of Flight 2000 is anticipated to be longer-term cost avoidance achieved through risk reduction in system acquisition and integration. Specifically, by demonstrating and shaking down the systems and procedures in a credible operational environment before national implementation, FAA will be able to produce, deploy, and integrate systems more quickly, at lower cost, and with lower risk. In this sense, the FAA is in a better position to identify and resolve the unknowns early in order to avoid costly mistakes of the past.

This technique of operational demonstration, “fly before buy” or “rapid prototyping” has been used extensively in software development programs outside of the FAA, with dramatic results. In an experiment in the 1980s, prototyping was compared to the classical “waterfall” process of system development, in which a specification of perceived user requirements is first developed and then the system is incrementally produced over a prolonged period before delivery. Prototyping/demonstration yielded products with equivalent performance, but required 40% less effort and cost. These savings translate directly to comparable cost and schedule reductions. (From “Wicked Problems, Righteous Solutions:” Peter De Grace and Leslie Stahl, p.146, 1990). Prototyping/ demonstration is particularly appropriate when there is significant uncertainty concerning true users' requirements and needs, which is precisely the case with the future NAS Architecture.

Aside from up-front investment savings, "fly before buy" also has demonstrated sizable cost savings in subsequent software maintenance and system support costs. Typically, prototype development incurs only half as many defects as specification-based development. Moreover, these defects are cured earlier in the process, avoiding the 100x increased cost associated with repairing defects at the time of system delivery. This is when they typically are discovered in "waterfall" development ( Barry Boehm, "Software Engineering Economics", 1981, p. 40-41).

For the NAS Architecture, this Flight 2000 operational demonstration is particularly crucial because of the operational changes implied by Architecture concepts. The entire NAS Architecture represents a revolution in the way air traffic management is conducted, with the Free Flight concept shifting the relative roles and responsibilities of pilots and controllers. Moreover, this revolution is intended to be accomplished quickly to maximize near-term airspace capacity use and to minimize the period of transition difficulties for users and the FAA.

In the past, FAA has had significant delays in its acquisitions, even when significant operational changes were not involved. For 7 major acquisitions begun in the early 1980s, the FAA experienced an average 6.4 years late delivery of the initial operational capability compared to predicted dates at project initiation. The average duration was predicted to be 4.9 years. This equates to an average schedule overrun of 131% ( length of schedule overrun divided by original predicted schedule duration). This was derived by analyzing and comparing GAO data in its annual reports on the FAA Capital Investment Plan for 1990 and 1997. Overruns were due to a variety of factors, but generally can be ascribed to unanticipated integration complexity (e.g., changing operational requirements since inception, design/ software changes to accommodate unforeseen problems, etc.). Table 3 summarizes this data.

**Table 3. FAA Schedule Performance (First Site Implementation) on Major System Acquisitions**

| System | Predicted First Site Implementation (1983 NAS Plan) | Actual First Site Implementation (1997 CIP) | Schedule Slip (Predicted vs. Actual) | Total Years Actually Required (Inception to Implementation) |
|---|---|---|---|---|
| Air Route Surveillance Radar (ARSR-4) | 1985 | 1996 | 11 Years | 15 Years |
| Airport Surface Detection Equipment (ASDE-3) | 1987 | 1993 | 6 Years | 12 Years |
| Airport Surveillance Radar (ASR-9) | 1985 | 1989 | 4 Years | 8 Years |
| Automated Weather Observing System (AWOS) | 1986 | 1989 | 3 Years | 8 Years |
| Flight Service Automation System (FSAS) | 1984 | 1991 | 7 Years | 10 Years |
| Mode-S | 1986 | 1994 | 8 Years | 13 Years |
| Voice Switching and Control System (VSCS) | 1989 | 1995 | 6 Years | 14 Years |
| Summary: Assumptions: All programs began in 1981 (inception date) Average years predicted from inception to initial implementation: 4.9 years. Average schedule slip: 6.4 years. Average years actually required from inception to initial implementation: 11.4 years | | | | |

While acquisition reform by itself will help FAA improve its schedule performance, reduction of this schedule risk (with its attendant cost growth) nonetheless remains the key focus of the Flight

2000 initiative. Simply put, Flight 2000 can reduce significantly the risk of unanticipated integration complexity by proving the technologies and procedures first.

## 6.0 Flight 2000 Contribution to Risk Reduction

To derive a quantitative assessment of Flight 2000's contribution to risk reduction, FAA conducted a risk assessment of the NAS Architecture with and without Flight 2000. Using a proven Air Force methodology with 12 professional FAA staff participating and evaluating 10 facets of risk, the results of the assessment show that the NAS Architecture without Flight 2000 had a consistently much higher risk rating than the NAS Architecture with Flight 2000. This risk assessment methodology is documented in the Volpe National Transportation Systems Center, "Risk Assessment Guidelines for the Investment Analysis Process," July 1997. Possible scores range from 0-2.9 for low risk initiatives, 3-6.9 for medium risk, and a score of 7-10 indicates a high risk situation. Table 4 below summarizes the relative importance of Flight 2000 for each of the ten risk facets.

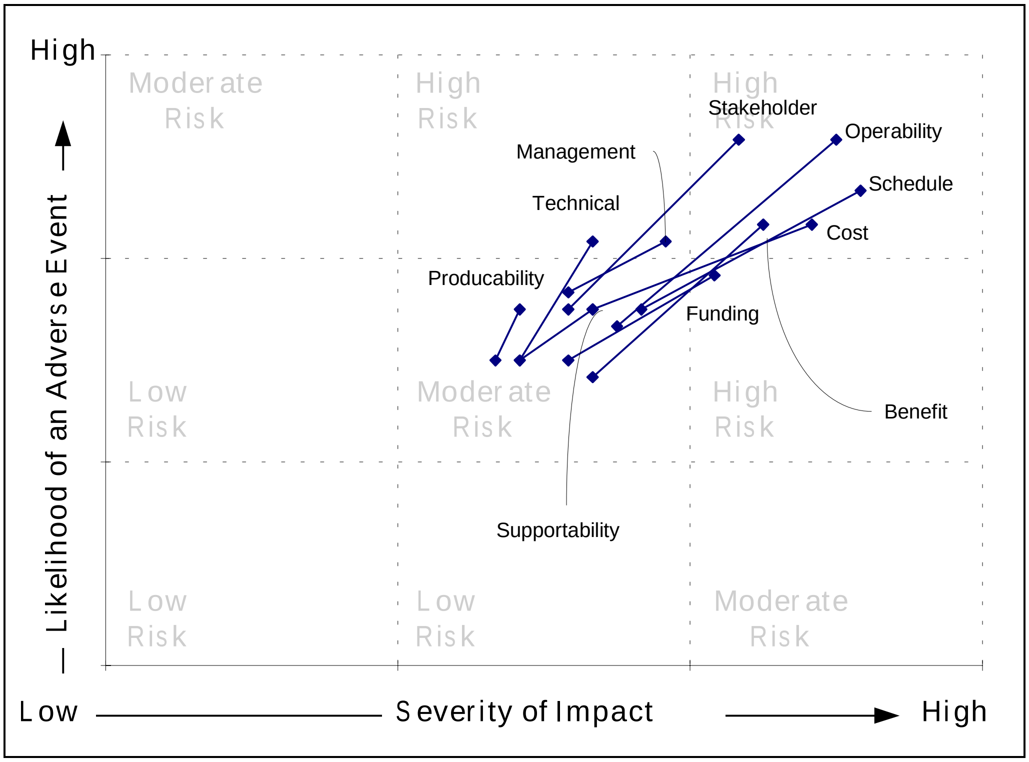
**Table 4. Summary of Risk Assessment**

| Risk Facet | Facet Weight | Without Flight 2000 | With Flight 2000 | % Risk Reduction |
|---|---|---|---|---|
| Operability/Capability | 0.30 | 2.58 | 1.18 | 54% |
| Benefit Estimate | 0.15 | 1.09 | 0.54 | 50% |
| Technical | 0.15 | 0.81 | 0.44 | 46% |
| Management | 0.10 | 0.63 | 0.41 | 35% |
| Cost Estimate | 0.05 | 0.38 | 0.19 | 50% |
| Funding | 0.05 | 0.30 | 0.15 | 50% |
| Producability/Integratability | 0.05 | 0.18 | 0.12 | 33% |
| Schedule/Programmatic | 0.05 | 0.41 | 0.21 | 49% |
| Stakeholder | 0.05 | 0.40 | 0.18 | 55% |
| Supportability | 0.05 | 0.23 | 0.15 | 35% |
| | | | | |
| **Total Risk** | | **7.01** | **3.57** | **49%** |

Particularly significant is the major reduction in operability/ capability risk (54%); i.e., the risk that the NAS Architecture will not provide the specific operational capabilities needed by users to operate more safely and efficiently in the future. This risk is deemed to be the greatest risk in NAS Architecture, consuming fully 37% of total anticipated Architecture development risk without Flight 2000. If it were not reduced, there is a strong probability that unforeseen operational problems would force a slowdown in the transition to new technologies and procedures. A 54% reduction in this area carries enormous significance for increased confidence in user/ controller acceptability.

In the aggregate, the risk assessment indicates that Flight 2000 can be expected to reduce overall Architecture risk by almost one-half (49%). While the quantitative relationship may be debated in terms of magnitude, there is no doubt that rapid prototyping, early integration of systems including demonstration and validation of operational concepts, will contribute toward reducing NAS Architecture cost and schedule risks. Figure 1 illustrates the direction and magnitude of the ratings for each of the 10 risk facets. The lower left end-point of each risk facet line represents the NAS modernization risk level with Flight 2000. The upper right end-point reflects the risk level without Flight 2000.

**Figure 1. Risk Assessment Trend Line**




## 7.0 Cost Savings/Avoidance Anticipated from Risk Reduction

The cost savings/avoidance impact from Flight 2000 is segregated into three areas: (1) reduced acquisition cost (cost avoidance) due to reduced integration risks from prototyping and early demonstrations and validation of requirements; (2) reduced operations and maintenance costs from better requirements definition and system performance; and (3) avoided operations and maintenance costs associated with accelerated decommissioning of obsolete legacy systems.

**7.1 Cost Savings due to Reduced Integration Risks:** Figures 2 and 3 show the methodology used to estimate the cost avoidance associated with Flight 2000 incorporation into the NAS Architecture.

Flight 2000 reduces the probability and consequences of schedule delays associated with unanticipated integration complexity for the approximately $5B cost for the capabilities directly associated with the demonstration. These are local-area GPS augmentation systems (LAAS), automatic dependent surveillance, controllers' decision support tools, and digital communications.

A triangular probability distribution of costs is assumed with and without Flight 2000, consistent with FAA's historical experience in comparing worst case (maximum) costs with most likely (mode) costs for the types of high technology, operationally complex systems that it needs. Within the future NAS Architecture, these systems carry the greatest cost risk from these technology/operational risk factors.

**Figure 2. Acquisition & Implementation Costs Directly Impacted**

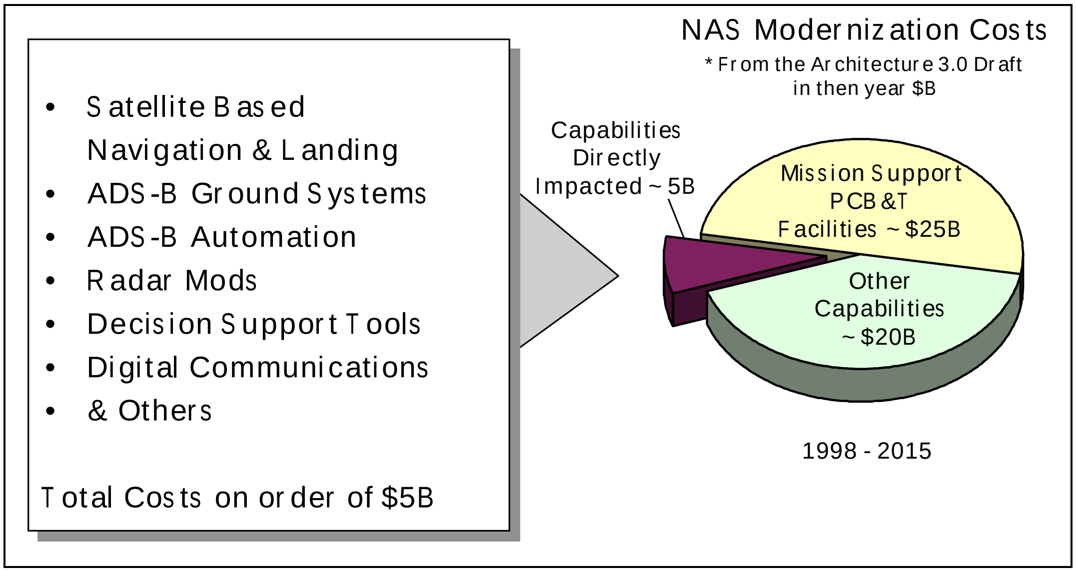
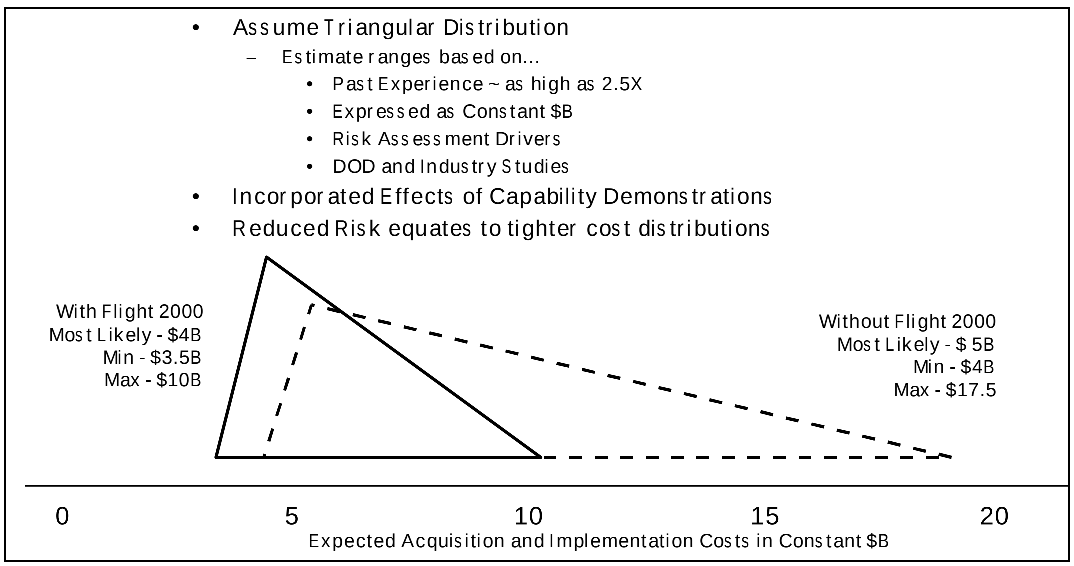
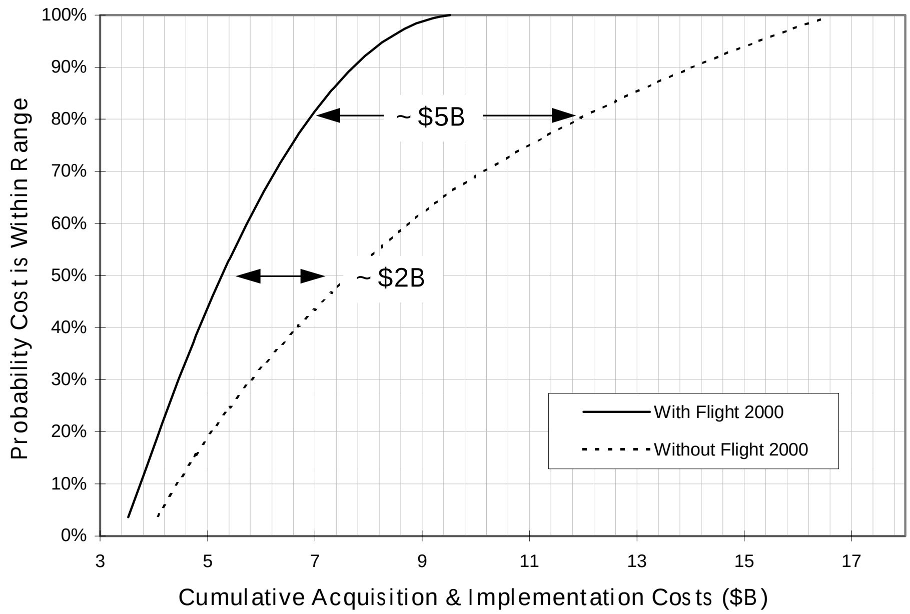



**Figure 3. Expected Cost Distributions**




The real contribution of risk reduction is to tighten the expected cost distribution for the NAS Architecture portion affected by Flight 2000. With Flight 2000, this cost has the same mode cost of $4B (in constant '97$), and a worst case/maximum cost of $10B. Without Flight 2000, however, the modal cost grows to $5B and the worst case cost estimate could be as high as $17.5B. Thus as figure 4 shows, the cost avoidance from Flight 2000 is likely to be somewhere between $2B (50% probability) and $5B (80% probability).

**Figure 4. Cumulative Cost distribution**




A risk reduction for the expected acquisition costs, for even a few of the near term NAS modernization programs, can have a dramatic ripple effect on the schedules of all the remaining programs. There is only a limited amount of money available from the annual modernization budget. Funds consumed for cost or schedule overruns will delay achieving desired capabilities in mid and far-term. Not only will needed capabilities be delivered later, delays for replacement and sustainment programs will increase operations and maintenance costs. Assuming the annual appropriation for facilities and equipment is approximately $2B, roughly 10%, or $200M is spent on modernization programs impacted by Flight 2000. For example, a cost increase of $1B would translate into a 5 year delay in delivery of new capabilities, and also in decommissioning of obsolete systems.

**7.2 Reduced Maintenance Costs:** It has been noted in several case studies that prototyped products yielded roughly the same performance with less code and effort than products developed in the waterfall process. Further, prototyped products demonstrated a more robust and coherent design, with software that was easier to integrate. One study found that prototyped products rated higher in maintainability than products that were developed using the waterfall method (Boehm, B.W., T.E. Gray, and T. Seewaldt, "Prototyping Versus Specifying: A Multi-project Experiment," IEEE Transactions on Software Engineering, Vol. SE-10, No.3., May 1984).

In the case of flight 2000, it is anticipated that the early integration and proof-of-concept demonstrations will lead to better requirements definition and design specifications. This can be expected to lead to a better software architecture which results in lower product maintenance costs to correct software bugs and incorporate requirements that were missed during development. Assuming that NAS modernization will experience the benefits of Flight 2000 prototyping realized by other programs, we anticipate maintenance cost avoidance in the range of $200 to $800 million.

**7.3 Cost Savings/Avoidance Associated with Decommissioning Obsolete Systems:**

By demonstrating operational suitability, Flight 2000 lowers significantly the users' risk perception of transitioning to the new NAS Architecture. This is true of space-based aeronautical navigation systems based on the Global Positioning System (GPS) and of GPS-based Automatic Dependent Surveillance.

Automatic Dependent Surveillance (ADS) has substantial promise for improved situational awareness for pilots and (together with cockpit display of traffic information) is considered the key capability required to achieve Free Flight. For the first time, pilots will have a complete picture of their position in the surrounding airspace. Nonetheless, its implementation will not substantially reduce operating system cost. This is because monopulse secondary surveillance radars (MSSR) will replace existing ATC Beacon Interrogators (ATCBI) before ADS is adopted in the United States, and MSSR and ADS will be roughly equivalent in operating and maintenance costs. Therefore, there won't be any significant cost savings in an MSSR-to-ADS transition.

Conversely, Flight 2000's demonstration of GPS-augmented navigation is crucial to FAA's plans for eventual termination of almost all existing ground-based navigation aids (VOR, DME, NDB, etc.). One of the goals of Flight 2000 is to fuel a national thirst for GPS navigation capabilities and lower its avionics costs, enabling the planned NAVAID decommissioning. The Federal Radio-navigation Plan (FRP) projects retiring VOR/DME/ and NDB systems from the NAS by 2011. If users in the CONUS don't equip as expected, a one year slip in the decommissioning schedule would cost the FAA slightly more than $100 million a year in continued operations and maintenance costs for ground-based systems, and a 4 year slip would thus carry penalty costs of over $400 million. It is anticipated that flight 2000 could help reduce the risks of schedule slippage in the decommissioning of these legacy systems by encouraging the users to equip via appropriate economic incentives and thereby facilitate their transition to a free flight environment.

FAA's investment in users' avionics for Flight 2000 may also have a highly salutary effect in reducing ultimate avionics purchase costs. For General Aviation (GA) users, the availability of low-cost avionics will be absolutely crucial to their willingness to permit termination of existing communications, navigation and surveillance systems that are unneeded in the future NAS Architecture. Previous experience with Loran-C conversion shows that relatively small Government investments can trigger dramatic price reductions. In 1972, the Coast Guard awarded two competing contracts at $300K total cost for Loran-C receiver design and fabrication. The contracts were successful in driving receiver costs down from $20K per unit (previous Navy submarine design) to $4K per unit (new Coast Guard/ commercial fishermen design), with only a 100 receiver quantity purchase. More importantly, Coast Guard stimulation of the market, coupled with the looming deadline for Loran-A termination, drew in numerous receiver manufacturers to the emerging Loran-C market, leading to rapid quality improvement and prices as low as $500 by 1980.

**7.4 Unquantified Cost Savings/Avoidance:** Equally important, some unquantified benefits attendant with flight 2000 should not be overlooked. These benefits include providing more direct routes and flexibility to users in Alaska and Hawaii; an oceanic conflict probe capability that is expected to lead to further separation reductions and accommodation of more user preferred altitudes and routes; potential economic stimulus to avionics design, costs and market demand as a by-product of FAA's initial investment in avionics equipage; and more efficient development of procedures and certification practices. Moreover, it signifies a new partnership with NAS users, offering an opportunity for collaborative development of capabilities needed to sustain and improve their economic performance.

## 8.0 Summary of Findings

This section summarizes the benefits discussions and estimates derived in the earlier parts of this paper. The four primary areas of benefits envisioned are: (1) reduced acquisition costs from lower developmental and integration risks; (2) reduced maintenance costs from better requirements, specifications and performance; (3) enhanced safety to users in Alaska and Hawaii; and (4) lowering schedule risks of decommissioning legacy systems through greater user acceptance of multi-function avionics. Table 5 summarizes the low and high range of these benefits.

**Table 5. Summary of Potential Benefits (Constant Yr $B)**

| | **Low** | **High** |
|---|---|---|
| Reduced Integration Cost Risk | $ 2.0 | $ 5.0 |
| Reduced Maintenance Cost | 0.2 | 0.8 |
| Increased Safety | 0.3 | 0.6 |
| NAVAID Decommissioning | 0.1 | 0.2 |
| **Total Potential Savings** | **$ 2.6** | **$ 6.6** |

## 9.0 Conclusion

Flight 2000 can be expected to prove the operational value and reduce the long-term risk of the NAS Architecture. Moreover, it offers immediate safety benefits in Alaska and Hawaii, two regions in need of upgraded ATC services and (particularly for Alaska) improved flight safety initiatives. Based on a quick assessment of its economic merits, it could offer potential safety benefits and cost avoidance of at least $2.6 billion dollars.