

# Safety and Business Benefit Analysis of NASA'S Aviation Safety Program

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NASA Aviation Safety Program elements encompass a wide range of products that require both public and private investment. Therefore, two methods of analysis, one relating to the public and the other to the private industry, must be combined to understand and evaluate the program elements. Standard benefit analysis is limited in its application to research and development programs where private industry is one of the primary vehicles to technology adoption. In general, benefit analysis is applied when a government decision is about to be made and the basis of the analysis assumptions are: (1) that the good to be mandated or purchased by the government is a public good and therefore the cumulative benefits to the public can be used to evaluate the investment and (2) that market is unlikely to make this investment on its own. In this case, the benefit analysis is required to identify both the public benefits of the proposed technologies, since safety is, indeed, a public good, as well as the private benefits to the industry likely to adopt the technology. In many cases private industry has been directly involved with the program as the products have been developed. Moreover, the private industry has contributed its perspective on the necessary conditions for investment.

## I. Introduction

THE goal of the National Aeronautics and Space Administration's (NASA) Aviation Safety and Security Program (AvSSP) is to “develop and demonstrate technologies that contribute to a reduction in the aviation fatal accident rate by a factor of 5 by year 2007.”<sup>1</sup> Proposed technologies act upon accident sequences by reducing reliability issues, or identifying the signature or taxonomy of unsafe events and allowing early diagnosis or ‘treatment’ of unsafe conditions. Furthermore, the technologies aim to increase survivability in accidents and post crash fires. Impacts of these technologies are likely to improve the overall performance of aircraft, crews, and airspace control, thereby providing system benefits over and above the specific safety affect that was their initial intent. As a result, standard benefit analysis methods are unlikely to provide the full benefit of the technologies.

In addition to direct safety impacts, operators who choose to implement the AvSSP project elements may experience significant business improvements in terms of revenue generation and/or operational cost savings. These benefits include increased throughput, higher aircraft utilization, and better onboard diagnostics, training, and flight planning tools. These tools will allow operators to experience higher crew and equipment utilization due to optimized routing, airplane management, and traffic management functions. Which in turn result in lower personnel, operational, and maintenance costs for the airline and can be reflected in fares that also result in higher net revenue.

Accident categories affected by the implementation of the products were identified as well as the distribution of fatalities, injuries, and hull-loss consequences associated with each category. Forecast flights, aircraft type, and load factors were used to construct an estimate of the potential dollar benefit value of implementation of the products. NASA's aviation safety program components demonstrated significant risk reduction potential, safety benefits, and business benefits to the airlines. Initial estimates of safety risk reduction are up to \$270<sup>‡</sup> per flight cycle for parts 121 and 135 and upwards to \$2,712 per flight cycle for business benefits.

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‡ Initial estimates of safety risk only account for U. S. accidents with at least one fatality.

This research into the safety and business benefits supports the work of NASA's AvSSP program assessment team. The AvSSP was created in 1997 based on the declaration of President Clinton's Commission on Aviation Safety and Security to improve aviation, increase capacity, and anticipate threats to air safety.<sup>2</sup> The AvSSP is a partnership of NASA, the Federal Aviation Administration (FAA), aviation industry, and the Department of Defense. The safety program is lead by NASA Headquarters in Washington D.C. The Langley Research Center, Ames Research Center, Dryden Flight Research Center, and Glenn Research Center have critical roles in the program.

The AvSSP is split into several product suites. Each suite focuses on a different threat to air safety and includes a group of products to counter the threat. Suites include: Aircraft Icing, Aviation System Monitoring and Modeling, System-Wide Accident Prevention, Single Aircraft Accident Prevention, Weather Accident Prevention, Accident Mitigation, and Synthetic Vision Systems. This paper provides a detailed overview of the safety and business benefit methodology used in the analysis of the Synthetic Vision Systems (SVS) product suite.

The goal of SVS is to "give pilots clear skies all the time" by providing a virtual display in the cockpit.<sup>3</sup> SVS offers a clear electronic picture of what lies ahead of the aircraft. Global Positioning System signals and terrain databases are incorporated into cockpit displays providing information on terrain, ground obstacles, air traffic, landing and approach patterns, runway surfaces and additional information relevant to the flight crew. Three products are included in the SVS product suite for part 121 and 135 operations: Synthetic Vision Technology – Commercial and Business Aircraft, World-Wide Geospatial Databases, and Runway Incursion Prevention Technologies.

## II. Safety Benefits Methodology

Safety benefits are defined as the monetary value of event avoidance due to implementation of the AvSSP project elements. The safety benefits estimate the expected costs of accidents, incidents and mishaps in terms of human injury and fatalities, equipment losses, and other operator impacts.

For all of the types of safety interventions within the AvSSP program, a methodology had to be developed to describe the maximum potential effect of the safety program (in terms of accident cost reduction) and to express the impact of the programs on other system behaviors or components. These interventions may act upon accident sequences by either reducing reliability issues, or identifying the signature or taxonomy of unsafe events (allowing early diagnosis and 'treatment' of unsafe conditions) or by increasing the survivability in accidents and post crash fires. These impacts are likely to improve the overall performance of aircraft, crews or airspace control, thereby providing system benefits over and above the specific safety effect that was their initial intent. Additional business effects (related to potential airline capital or human capital effects) are addressed in Section III.

### A. Passenger and Aircraft Costs

A significant issue in this program was attempting to define the categories of costs and benefits that should be included in the analysis. This definition drove the cost assessment, modeling of the relationships between costs, and included the broadest allowable definition of benefits. In general, analysts tend to count reciprocating categories of costs and benefits (e.g., if operational costs are evaluated for implementation of a program, then operational benefits can also be claimed). The FAA has published very detailed guidance for economic analyses of regulations and other investments. According to their guidelines, economic values that can be counted include:

"...[passenger values include] the value of passenger time, the value of an avoided fatality, and the value of avoided injuries. Aircraft related values include aircraft capacity and utilization factors, aircraft operating and ownership costs, and aircraft replacement and restoration costs."<sup>4</sup>

Passenger related values were established by Department of Transportation policy, and are applicable to all modal administrations within the Department. Recommended aircraft related values were developed by the Office of Aviation Policy and Plans from public and proprietary data sources.<sup>4</sup> Unfortunately, many cost components have implied or direct effects upon other cost components. For example new cockpit instruments require training, new training requires adaptation, training validation, testing and implementation, and these requirements in turn have an effect on aircraft and personnel operations. This cost cycle may be accounted for in the FAA's economic analysis methodology for routine changes in aircraft components or personnel requirements, but may be insufficient to account for the impacts of programs such as Aviation System Monitoring and Modeling or Flight Operations Quality Assurance (FOQA) management programs.

Factors included in evaluating the safety cost of accidents include:<sup>5</sup>

- Passenger/crew death and injury
- Aircraft physical damage
- Loss of aircraft resale value
- Loss of aircraft use
- Loss of staff investment
- Site contamination and clearance
- Search and rescue
- Airline response
- Accident investigation

Monetary values were assigned for life and injuries based on society's "willingness to pay" (WTP) scale. WTP specifies the value benefit from public investment or regulatory action (i.e., fatalities and injuries avoided) that the public is willing to pay as a result of aviation accident risk reduction. In addition to fatality and injury costs, additional costs include various emergency and medical costs as well as legal and court fees. Average commercial aircraft values for the current fleet and typical airline maintenance figures were used to estimate the aircraft physical damage and the loss of aircraft resale value. Remaining figures were based on recommended FAA values for economic analysis and airline financial data reported to the Bureau of Transportation Statistics (BTS).

## B. Accident Data

The National Transportation Safety Board (NTSB) database is the official collection of aviation accident data and causal factors. A total of 421 fatal part 121 and 135 accidents were examined from the NTSB database between 1988 and 2001 to determine a baseline safety cost for each of the products. Each accident was analyzed and placed into the appropriate accident category. Accident categories were developed by NASA to provide a common taxonomy for categorizing aviation accidents. Categories included: Controlled Flight into Terrain, Loss of Control, Maintenance, Runway Incursion, Mid-Air Collision, Ground Handling, Ground Collision, Jet Blast, Security, In-Flight Fire, Icing, In-Flight Fuel Related, Turbulence, and Other. Proposed NASA technologies were then examined to determine which if any accidents the technology may have been able to prevent and/or mitigate.

To determine an accurate likelihood of an accident occurring, the total number of accidents were normalized over the total exposure. The total number of flight cycles occurring over the fourteen-year analysis period was examined to determine an appropriate denominator for the benefit analysis. Each flight cycle was equivalent to the departure, en-route travel, and landing of that aircraft. Average yearly flight cycles were obtained from the BTS Air Carrier Statistics database and the FAA's OPSNET 45 database.

## C. SVS Safety Benefits

An examination of historical SVS related accidents yielded a range of accident related costs per flight cycle from \$49.55 to \$7.12, shown in Table 1. Some historical fatal Controlled Flight into Terrain accidents may have been prevented or the severity reduced had the aircraft been equipped with "Synthetic Vision Technology – Commercial & Business Aircraft" and/or "World-Wide Geospatial Databases." Mid-Air collisions may have been prevented with "Synthetic Vision Technology – Commercial & Business Aircraft"; furthermore, runway incursions may have been prevented with installation of the "Runway Incursion Prevention Technologies."

Since the SVS products are still in the early part of the development phase, an exact measure of product effectiveness has not yet been determined. The safety effectiveness for each product was hypothesized based on the estimates provided using the Aviation Safety Analysis and Functionality Evaluation (ASAFE) tool.<sup>6</sup> ASAFE is a NASA generated database tool that further examines select NTSB aviation accidents to determine causes, factors, and findings for each accident/incident.

After applying initial ASAFE technology effectiveness estimates, accident related safety costs were dramatically reduced.<sup>§</sup>

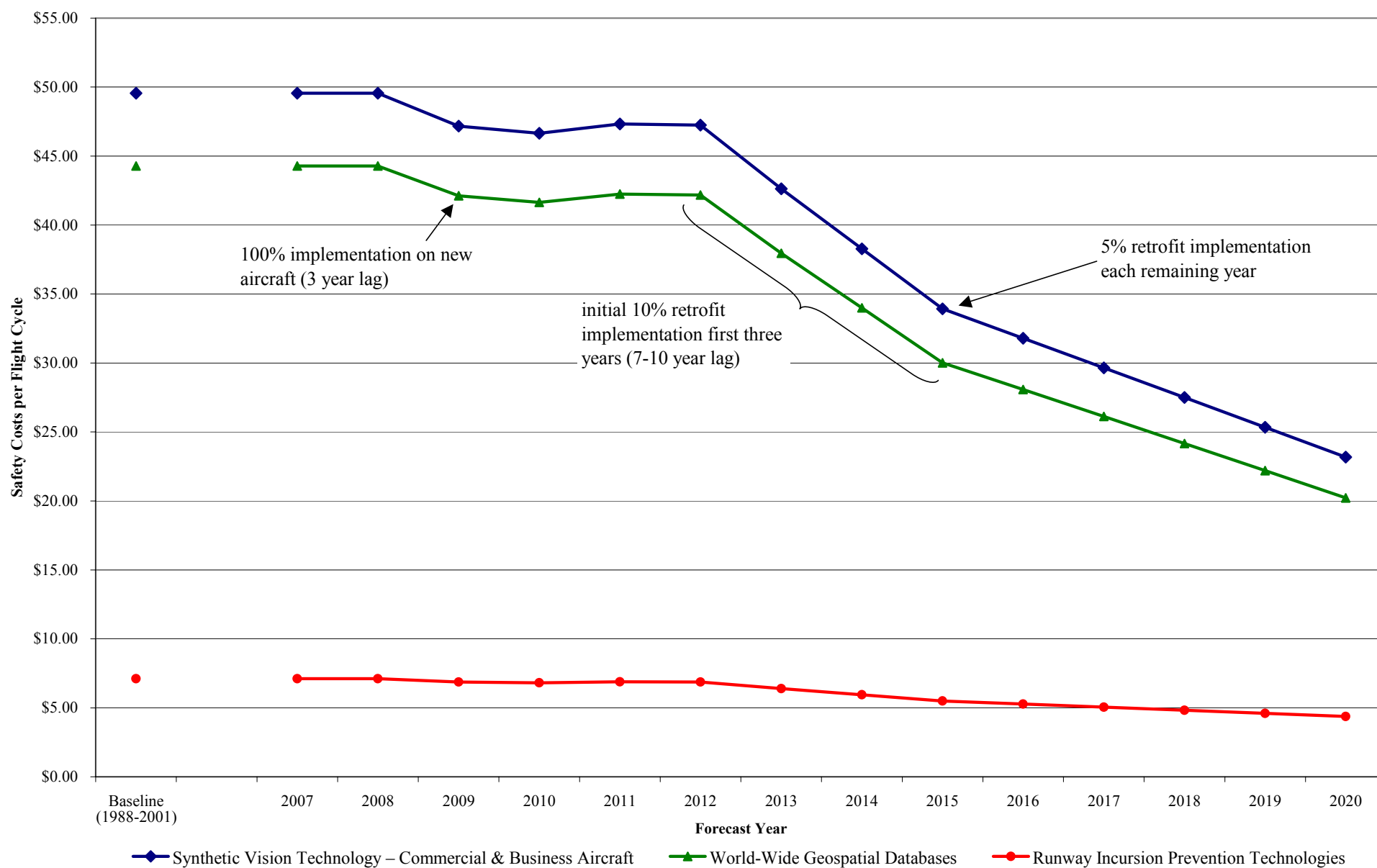
<sup>§</sup> It is important to note that these are initial estimates of the effectiveness of the products. As the products continued to be developed a more product specific effectiveness estimate will be able to be determined.

**Table 1: Historical Part 121 and 135 SVS Related Accident Costs.**

<b>SVS Part 121/135 Products</b>	<b>Historical Accident Related Cost per Flight Cycle</b>	<b>ASAFE Effectiveness Estimate</b>	<b>Remaining Cost per Flight Cycle</b>
Synthetic Vision Technology – Commercial & Business Aircraft	\$49.55	95%	\$2.48
World-Wide Geospatial Databases	\$44.28	96%	\$1.77
Runway Incursion Prevention Technologies	\$7.12	68%	\$2.28

Implementation levels for each individual product (as if no others are implemented) were constructed based on the FAA forecast of passenger aircraft. A 100% implementation level was assumed for a new aircraft following a three-year certification lag. Retrofit implementation levels for existing aircraft were estimated using a 10% implementation level for the first three years (e.g., 2012-2014), followed by a 5% implementation level for the remaining years. Retrofit certification was estimated to take approximately 7 to 10 years. The safety effectiveness parameter was estimated from ASAFE and estimated cost reductions due to accident prevention or mitigation were then calculated for the same period as the other forecast. Figure 1 provides a National Aviation System (NAS) wide reduction in expected safety costs per flight cycle for the pertinent accident categories. The baseline historical SVS fatal accident related costs were assumed to remain constant over the forecast period. Note that Table 1 predicts the reduced safety cost per flight cycle for aircraft equipped with the SVS technology, whereas Figure 1 presents the system-wide reduction in safety for all NAS aircraft flight cycles.\*\*

\*\* An updated implementation level analysis is current being conducted at NASA and will be incorporated in the safety and business benefits when completed.



**Figure 1: Forecast of Part 121 and 135 SVS Accident Costs.**

### III. Business Benefits

In addition to the direct safety impacts, operators who choose to implement the AvSSP project elements will experience significant business improvement in terms of revenue generation and/or operational cost savings. These benefits include increased throughput due to the implementation of a number of the components of the program. Higher utilization in previously inhibiting operational circumstances, such as low visibility and poor weather, will result in fewer delays and flight cancellations. Better onboard diagnostics, training, and flight planning tools will allow operators to experience higher crew and equipment utilization due to optimized routing, airplane management, and traffic management functions. These improvements in turn result in lower personnel, operational, and maintenance costs, and can be reflected in fares that also result in higher net revenue.

#### A. Operation Distinctions

Due to the unique financial situations and business models of each air carrier, part 121 operations were further segregated into hub/spoke, point-to-point, and regional jet carriers for a more accurate examination of potential business benefits. Hub/Spoke carriers operate by providing local flights from smaller second-tier “spoke” airports to a larger “hub” airport where the passengers then board long-distance or other local flights to reach their final destinations. Generally, hub/spoke carriers break-even or even take a small loss on the spoke-to-hub flights allowing them to maximize their profits on the hub-to-hub flights. The fixed costs (e.g., aircraft, gates, landing rights) are high when building a hub/spoke network; however, they create a barrier to other potential competitors, limiting supply, thus enabling the premium they can charge on these routes. Point-to-point carriers transfer passengers from point A to B without any transits. Point-to-point carriers typically fly shorter distances between secondary airports where landing rights are less expensive. The secondary airports are typically less congested, allowing a faster turnaround time, thus enabling more flights/more efficient aircraft usage, and increasing their revenue. Regional jets operate in a very similar manner as point-to-point carriers; the distinction is in the aircraft that are flown. Regional jets are generally smaller than the jets in major commercial airline fleets, typical models range from 32 to 85 seats. Regional jets fly at the same higher altitudes as the larger jets, allowing the aircraft to get “above the weather.” Regional jets are often more efficient on shorter routes than slower turboprops-historically used for the flights.

#### B. Disruption Model

Three types of disruptions were examined: delays, diversions, and cancellations. Delays were defined as a flight departing or arriving at the gate more than 15 minutes after the scheduled time shown in the carriers’ Computerized Reservation Systems (CRS). Diversions were defined as an irregular operation where the aircraft is forced to change its intended destination. Irregular operations where the flight does not occur were considered cancellations. Historically, delay and cancellation costs were calculated according to the following generic costing approach: <sup>7</sup>

$$\text{Delay Cost} = \text{Average Revenue per Flight} \times \text{Lost Passengers due to Competition} \times \text{Subsequent Flight Leg} \quad (1)$$

Where:

Lost Passengers due to Competition = 0.25

Subsequent Flight Leg = 2

$$\text{Cancellation Cost} = \text{Average Revenue per Flight} \times \text{Lost Passengers due to Competition} \times \text{Subsequent Flight Leg} \quad (2)$$

Where:

Lost Passengers due to Competition = 0.50

Subsequent Flight Leg = 2

Due to the highly competitive market, this approach has been found to underestimate the total costs of delays and cancellations experienced. Important factors that were not taken into account include: total length of delay incurred,

distance of the flight, type of aircraft, and typical load factor for that aircraft. Passengers may be willing to accommodate small delays (e.g., 1 to 2 hours) when more competitive fares are not available, and/or seats are unavailable on another aircraft. A more thorough approach was undertaken looking specifically at the distinctions between each of the operation categories and the types of disruptions.

Disruptions examined included: delays, diversions, and cancellations. Delays, followed by cancellations, are the most frequent types of disruptive events in the airline industry. Even though delays are the most frequent, they are the least damaging in terms of schedule disruptions and passenger ill will. The aircraft and crew are at least located at the correct location. Diversions, on the other hand, are the most costly disruption to the airlines. Passengers and crew find themselves at an airport not on their itinerary. Furthermore, the airline is likely to have few, if any, rebooking options. Passengers have to be transferred to another airline or accommodated until their flight can proceed to the intended destination. Additionally, airlines may not have gates or service facilities at the diverted airport, and may end up paying higher prices for fuel, catering, and gate fees.

Causes of disruptions were determined from the BTS Air Travel Consumer Report “Causes of National Aviation System Delays – Delay Minutes” and “Airline On-Time Statistics and Delay Causes.”<sup>8</sup> Four broad categories of disruptions were created to map the products to. Categories included:

- **Weather:** Disruptions caused by weather conditions (e.g., significant meteorological conditions), actual or forecasted at the point of departure, en route, or point of arrival that prevent operation of that flight and/or prevent operations of subsequent flights due to the intended aircraft being out of position as a result of a prior disruption attributable to weather.
- **National Aviation System (NAS):** Disruptions attributable to the national aviation system (e.g., airport operations, heavy traffic volume, air traffic control, etc.)
- **Equipment:** Disruptions caused by maintenance problems, fueling errors, etc.
- **Security:** Disruptions caused by the evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment and long lines in excess of 29 minutes at screening areas.

These causes of disruptions are self-reported by the airlines to the BTS on a monthly basis.

### 1. Delay Cost

The cost of a delay was calculated using average 2004 airline operating costs per minute, value of passenger time, and the average length of a delay. Airline operating costs were derived from the BTS Form 41 and Form 298-C data. Airline operating costs include: fuel and oil, maintenance costs (labor, parts, materials, etc.), crew, depreciation, rental fees, insurance, etc.

The value of passenger time was taken from the recommended values provided in the Office of the Secretary of Transportation Memorandum for aviation passenger travel time.<sup>9</sup> These values were derived from typical wage rates to cover the value of the passenger’s time in the foregone work or leisure activity. Some models value passenger time differently depending on the total length of time. Smaller increments are valued at lower rates than larger increments. This practice, however, emphasizes the difficulties of making effective use of smaller increments, especially when unanticipated.<sup>9</sup> Present knowledge does not support valuing smaller increments of time less than larger ones.

### 2. Diversion Cost

The cost of part 121 diversions were based on the estimates provided by Jenkins and Cotton.<sup>10</sup> Cost estimates were provided for a single diversion of a domestic flight with passengers having an overnight stay at another airport. Due to the unique nature of the type of aircraft, costs were estimated individually for narrow-bodied and wide-bodied jets. Jenkins and Cotton<sup>10</sup> provide both a low and a high estimate of diversion costs. The two values were proportionately weighted based on current fleets.

Substantial differences exist between the major air carriers and those operating under FAR part 135. The wide diversity of services and types of aircraft make estimating the cost of a diversion extremely difficult. FAR part 135 operates closer to “a la carte” service including corporate, business, and institutional flights as well as air tours and taxi services. The flight schedules are flexible and subject to more contingencies than commercial aviation.<sup>11</sup>

### 3. Cancellation Cost

Limited research exists on the cost of a cancellation to an airline. The only firm numbers found were in the estimates of the cost of a diversion by Jenkins and Cotton.<sup>10</sup> Jenkins and Cotton state that the airline's revenue for a wide-bodied jet is approximately \$150,000 and \$10,000 for a narrow-bodied jet.<sup>10</sup> These estimates were used as a conservative estimate for the revenue lost due to a cancellation of a flight.

### 4. Disruption Frequency

The BTS Air Travel Consumer Report "Causes of National Aviation System Delays – Delay Minutes" and "Airline On-Time Statistics and Delay Causes"<sup>7</sup> were used to determine the average percentage of total operations that were delayed and the average length of the delay in minutes. The frequency of diversions for each carrier were obtained from the BTS "Summary of Airline On-time Performance 1995-2003."<sup>12</sup> Since data prior to 1995 was unavailable, the diversion rate was estimated at constant rates. The BTS "Summary of Airline On-time Performance 1995-2003" was also used to obtain the frequency of cancellations for each carrier.<sup>12</sup> To match with the analysis of safety benefits, the disruption frequency was analyzed for 1988-2003 and disruption costs were calculated using 2004 dollars.

The summary of disruption costs per event combined with the frequency of disruptions were used to calculate the average disruption cost per flight cycle, provided in Table 2. A weighted average of total flight cycles was used to provide one estimate for part 121 operators (hub/spoke, point-to-point, and regional jet). Disruption costs for part 121 are \$1,167 per flight cycle for delay, \$159 per flight cycle for diversions, and \$1,388 per flight cycle for cancellations.

**Table 2: 2004 Disruption Costs per Flight Cycle.**

	<b>Hub/Spoke</b>	<b>Point-to-Point</b>	<b>Regional Jet</b>	<b>Part 135</b>
<b>Delay Cost:</b>	\$1,256	\$950	\$1,098	\$200
<b>Diversion Cost</b>	\$225	\$65	\$55	\$18
<b>Cancellation Cost</b>	\$1,768	\$571	\$1,015	\$96

### C. Unscheduled Maintenance

All airlines are responsible for ensuring their aircraft are airworthy and that they comply with the airworthiness maintenance programs set forth by the local government.<sup>13</sup> In order to optimize maintenance programs and keep costs at bay, airlines conduct scheduled checks of all aircraft at predetermined flight intervals. Maintenance programs are split into two types of tasks: (1) scheduled tasks and (2) unscheduled tasks. Scheduled tasks are conducted at predetermined intervals to ensure the aircraft are operating at an optimal condition. Unscheduled tasks are unanticipated maintenance that were found during the scheduled maintenance or occur based on operational data. Unscheduled maintenance may also be called condition-based maintenance, since it depends upon the condition of the aircraft from the scheduled maintenance. Typical examples of unscheduled maintenance include: fixing and repairing systems and component malfunctions, various modifications, and work done in response to pilot complaints such as abnormal flight occurrences, hard and overweight landings, foreign object damage, or lightning strikes.<sup>13</sup>

Maintenance programs vary between each airline and type of aircraft. However, all aircraft undergo a "turnaround check" prior to and after each flight as well as a "daily line check" each evening. A turnaround check typically lasts an hour in which the pilot and mechanics walk around the aircraft in addition to inspecting any warning lights in the cockpit. Additionally, each aircraft undergo an A, B, C, or D-check (or Light, Heavy, and Major-check) at scheduled intervals. Maintenance is an integral part of an airline's business and accounts for 9-13% of an airline's total operating costs. Table 3 provides typical inspection costs for a major airline.



**Table 3: Unscheduled Maintenance Costs for a Major Carrier.**

Description	Cost per Event
30 Minute Inspection with No Findings	\$1,715
30 Minute Inspection with Findings (requiring activity)	\$3,088 (parts and labor)
Out of Service – ½ day	\$9,000
Out of Service – full day	\$21,000

BTS Form 41 presents data on aircraft maintenance costs. However, all maintenance costs, both scheduled and unscheduled are included. A general rule of thumb in the aviation industry regarding unscheduled maintenance is: *“for each hour of routine maintenance an operator expends, it will generate one hour of nonroutine maintenance on a new and young airplane. As airplanes age, nonroutine maintenance will likely double or triple.”*<sup>14</sup> A conservative estimate of unscheduled maintenance costs was calculated by taking one half of the total BTS reported maintenance costs.

AvSSP products that reduce the unscheduled maintenance costs will also have an effect on the operational costs for the airline. By reducing operational costs the airline’s revenue will increase. A reduction of \$339 per flight cycle for hub/spoke carriers and \$181 per flight cycle for point-to-point carriers is possible pending the elimination of all unscheduled maintenance. However, a more realistic prediction may be a 50% reduction in unscheduled maintenance.

#### D. Aircraft Utilization

Aircraft capacity and utilization affect the costs that the airlines accrue and the overall costs absorbed by the passengers. Higher utilization of aircraft in previously inhibiting operational circumstances, such as low visibility and poor weather, will result in fewer delays and flight cancellations. Ideally, airlines will be able to better utilize their current fleet; possibly reducing the fleet size. Better onboard diagnostics, training, and flight planning tools will allow operators to experience higher crew and equipment utilization rates. Utilization rates will be increased due to optimized routing, airplane management, and traffic management functions. These improvements in turn result in lower personnel, operational, and maintenance costs, and are reflected in fares resulting in higher net revenues.

Aircraft capacity and utilization factors were collected for 2002 from the BTS Form 41 for large air carriers and Form 298C for small commuter carriers. Fractional values of aircraft represent aircraft operational less than the full year. On average, part 121 aircraft are utilized 9.5 hours a day with an average capacity of 157 seats and 5 crewmembers.

A rough estimate of the total number of excess aircraft for each carrier can be calculated using the average number of block hours per aircraft, length of delay, and frequency of delay. Table 4 presents an average number of excess aircraft for one operational carrier. It is important to note that the estimates shown in Table 4 are presented on a carrier level; furthermore, these estimates assume 100% of the delays are eliminated. Actual estimates of the percentage of delays reduced by the AvSSP products are typically around 50% of weather related delays.

**Table 4: 2002 Aircraft Utilization Factors per Airline.**

	Excess Aircraft <sup>1,2</sup>
Hub/Spoke	37.5
Point-to-Point	31.4
Regional Jet	30.9
<sup>1</sup> [total delay hours]/[average block hours per aircraft]	
<sup>2</sup> Assumes 100% of delays eliminated	

#### E. SVS Business Benefits

The analysis of operational benefits builds off of the safety benefits and constructs an analysis of the likely operational impact of the AvSSP products upon the business models for part 121 and 135 operators. Effectiveness

estimates for each product on specific disruptions (weather, NAS, equipment, and security) were hypothesized using the ASAFE tool. Tables 5 and 6 present the remaining disruption costs per flight cycle for part 121 and 135 carriers. SVS products “Synthetic Vision Technology – Commercial & Business Aircraft” and “World-Wide Geospatial Databases” provide the largest reduction in disruption costs, particularly those relating to weather. None of the SVS products provided any reduction in unscheduled maintenance costs.

The SVS products enable airlines to utilize their aircraft in some previously inhibiting operational conditions. Higher utilization rates may enable airlines to reduce the size of their current fleet. A possible revenue generating condition exists if the airlines choose to sell their excess aircraft. Current average resale values for aircraft were used to determine this possible benefit in dollars per flight cycle.

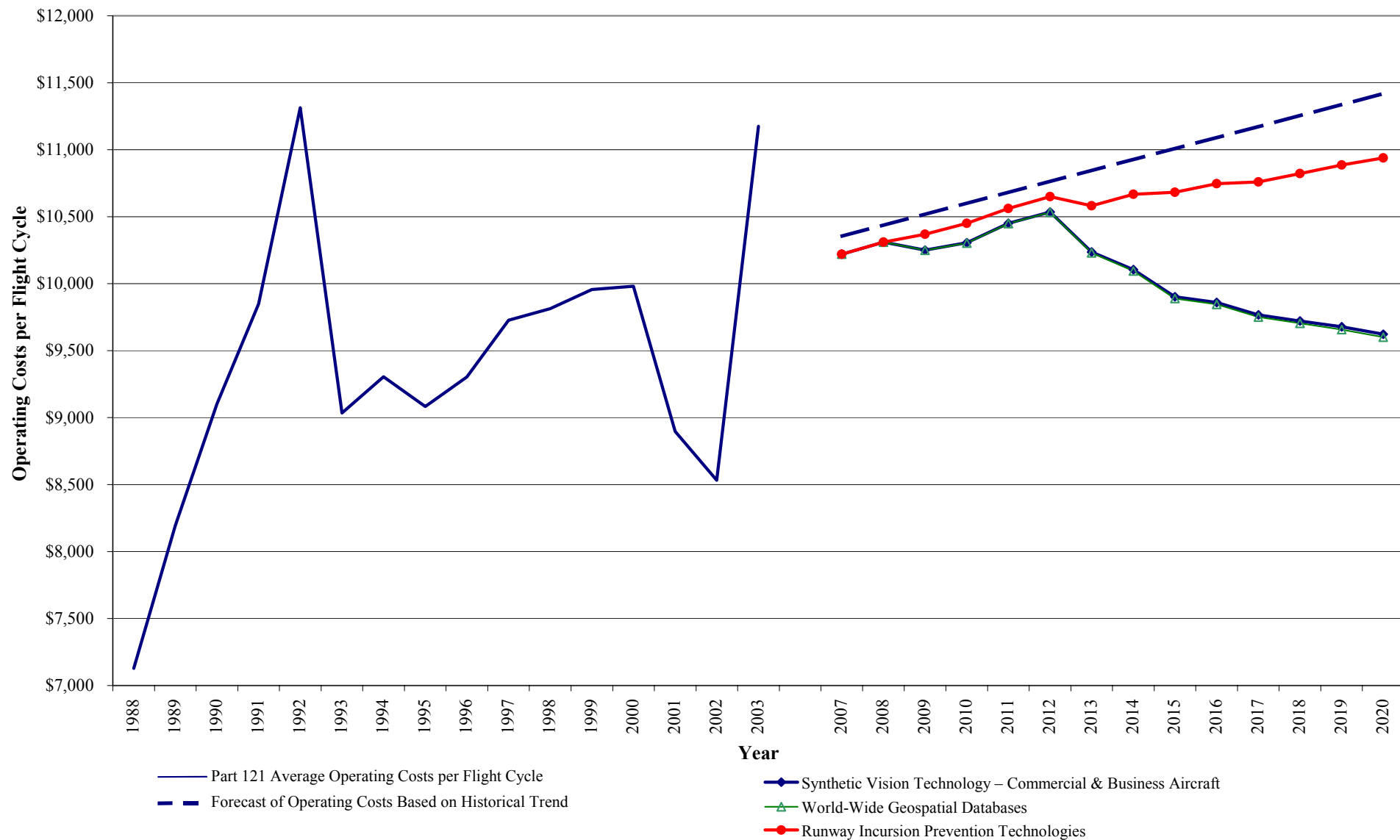
**Table 5: Historical Part 121 SVS Disruption Costs per Flight Cycle.**

<b>SVS Products</b>	<b>Delay Costs per Flight Cycle</b>	<b>Diversion Costs per Flight Cycle</b>	<b>Cancellation Costs per Flight Cycle</b>	<b>Disruption Costs per Flight Cycle</b>	<b>Unscheduled Maintenance Costs per Flight Cycle</b>
<b>Existing Costs:</b>	<b>\$1,166.85</b>	<b>\$158.54</b>	<b>\$1,388.08</b>	<b>\$2,713.47</b>	<b>\$296.68</b>
Synthetic Vision Technology – Commercial & Business Aircraft	\$197.63	\$39.84	\$348.85	\$586.32	\$296.68
World-Wide Geospatial Databases	\$198.82	\$40.33	\$353.12	\$592.27	\$296.68
Runway Incursion Prevention Technologies	\$815.94	\$115.44	\$1,010.75	\$1,939.13	\$296.68

**Table 6: Historical Part 135 SVS Disruption Costs per Flight Cycle.**

<b>SVS Products</b>	<b>Delay Costs per Flight Cycle</b>	<b>Diversion Costs per Flight Cycle</b>	<b>Cancellation Costs per Flight Cycle</b>	<b>Disruption Costs per Flight Cycle</b>	<b>Unscheduled Maintenance Costs per Flight Cycle</b>
<b>Existing Costs:</b>	<b>\$200.47</b>	<b>\$18.42</b>	<b>\$95.51</b>	<b>\$314.40</b>	<b>\$147.73</b>
Synthetic Vision Technology – Commercial & Business Aircraft	\$37.49	\$4.63	\$24.00	\$66.12	\$147.73
World-Wide Geospatial Databases	\$37.13	\$4.69	\$24.30	\$66.12	\$147.73
Runway Incursion Prevention Technologies	\$141.66	\$13.42	\$69.55	\$224.63	\$147.73

Figure 2 presents a forecast of the potential reduction in operating costs per flight cycle. The historical trend in operating costs per flight cycle was used to forecast the future costs. FAA forecasts of new passenger aircraft sales were used to construct the implementation levels for the SVS products. A 100% implementation level was assumed for all new aircraft following a three-year certification lag. Implementation levels for existing aircraft were estimated using a 10% implementation level for the first three years (e.g., year 7, 8, and 9), followed by a 5% implementation level for the remaining years. Retrofit certification was estimated to take 7 to 10 years.



**Figure 2: SVS Part 121 Forecast of Business Benefits.**

## IV. Conclusion

A benefit analysis of NASA's AvSSP products was performed taking into account the unique public/private industry relationship. The safety benefits for each of the SVS products remained fairly consistent. After implementation of the SVS products, remaining part 121 and 135 accident related costs varied from \$2.57 to \$1.38 per flight cycle. Conversely, the business benefits for each AvSSP safety product greatly vary. Disruption categories affected by the implementation of the products were identified as well as the effect on unscheduled maintenance and aircraft utilization associated with each category. Forecast flights, aircraft type, and load factors were used to construct an estimate of the potential business dollar benefit value of implementation of the products. NASA's safety program technologies demonstrate significant risk reduction potential and business benefit. SVS business benefits reach a maximum savings of \$2,127 per flight cycle for part 121 and \$248 per flight cycle for part 135. Results from the life cycle cost analysis will be forthcoming.

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