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Special Programs
Administration**

Economic Analysis of Local Area Augmentation System and Alternative Architectures

Anand S. Prabhakar

Final Report
March 1996

U.S. Department of Transportation
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John A. Volpe National Transportation Systems Center
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13. ABSTRACT (Maximum 200 words)

The objective of this study has been to perform an economic comparison by conducting a cost-benefit analysis (CBA) of five Local Area Augmentation System (LAAS) and alternative architectures. The five architectures chosen by the FAA for the study are: Pseudolite Kinematic LAAS, Wide-Lane Kinematic LAAS, Code-Based LAAS, Instrument Landing System (ILS), and the LAAS-Glide Slope System. A comparison of architectures based on the benefit/cost (B/C) ratio and cost-effectiveness criterion indicates that the Code-Based LAAS architecture has, by far, the highest B/C ratio of 4.0 and the lowest life-cycle cost of $860.9 million over a 15-year time horizon. The B/C ratios of other non-ILS architectures are in the range of 3.4 to 3.7, and the life cycle costs in the range of $946.5 million to $1,014.6 million. For the reference ILS architecture, the study estimates a low B/C ratio of 0.4 and the life cycle cost of $921.2 million. The latter cost is not much different from other architecture life cycle costs, despite the exclusion of the substantial sunk cost of existing runway ILS and aircraft avionics equipment.

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PREFACE

The cost-benefit analysis (CBA) of the Global Positioning System Local Area Augmentation System (GPS LAAS) has benefited from the counsel and assistance of a number of persons.

As the sponsor of the project, Mr. Jim Y. K. Cha, Cost-Benefit Analysis Team Leader, ASD-420, and Mr. Edward G. Nedimala, Program Analysis, ASD-420, Federal Aviation Administration, have provided valuable technical input on the CBA methodology and its application to this study. Additional input has come from Mr. Raymond J. Swider, LAAS Program Manager, AND-510, and Mr. Mark C. Kipperman of Science Applications International Corporation. Their input and support are gratefully acknowledged.

Conducting the cost benefit analysis of GPS LAAS involved entering, organizing, and processing a very large data set, requiring what seemed like an unending series of spreadsheets. Mr. Andrew D. Semble of Camber Corporation ably performed this work. His services have been invaluable.

On many technical issues concerning the landing system architectures, Dr. E. Michael Geyer of TASC, Inc. has given expert guidance and advice. His contribution has been enormous.

Finally, this study benefited immensely from the technical knowledge and analytical insights of Mr. Edward A. Spitzer, Chief, Surveillance & Sensors Division, Volpe National Transportation Systems Center. He has been most generous with his time and counsel.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]$°F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5)(y + 32)]$°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0			1			2			3		4		5
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 9/29/95

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AIA	Annual Instrument Approaches
ALSF	Approach Light System with Sequenced Flashing Lights
ASDE	Airport Surveillance Detection Equipment
ASTA	Air Surface Traffic Automation
B/C	Benefit-Cost
CBA	Cost-Benefit Analysis
CDI	Course Deviation Indicator
DDM	Difference in Depth of Modulation
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
GPS	Global Positioning System
ICAO	International Civil Aviation Administration
IFR	Instrument Flight Rules
kt	Knot
ILS	Instrument Landing System
LAAS	Local Area Augmentation System
MALSR	Medium Intensity Approach Light System with Runway Alignment Indicator Lights
NAS	National Airspace System
NM	Nautical Miles
O&M	Operations and Maintenance
PALS	Precision Approach and Landing System
R&D	Research and Development
RVR	Runway Visual Range
SA	Selective Availability
TAF	Terminal Area Forecasts
TEC	Total Electron Content
WAAS	Wide Area Augmentation System

EXECUTIVE SUMMARY

The Global Positioning System (GPS) with satellite-transmitted signals for position determination offers new opportunities and challenges for a range of applications in transportation. Recognizing its potential for civil aviation, the Federal Aviation Administration (FAA) has initiated a series of programs aimed at meeting the precision landing requirements. The GPS with Selective Availability (S/A) provides accuracy levels good only for non-precision approaches, but with augmentations, the accuracy levels for precision approaches are achievable.

The FAA Satellite Navigation Program has settled on two augmentation systems: the Wide Area Augmentation System (WAAS) as a primary means of navigation during all phases of flight through CAT I precision approach, and the Local Area Augmentation System (LAAS) for the CAT II and CAT III precision approaches.

This study focuses on LAAS and alternative architectures. Since an economic comparison of architectures involves performing a cost-benefit analysis (CBA), the FAA has chosen for analysis three LAAS architectures, one ground-based, and a hybrid system architecture. The five architectures are:

- Pseudolite Kinematic LAAS
- Wide-Lane Kinematic LAAS
- Code-Based LAAS
- Instrument Landing System (ILS)
- LAAS and Glide Slope (G/S) System

The primary yardstick for the CBA is the benefit/cost (B/C) ratio. However, the inclusion of the reference ILS with all existing CAT II and CAT III runways slated to be equipped with the new MK-20 ILS by 1998, requires a comparison based on the cost effectiveness criterion as well. The approach used in the study has been to: (1) perform the runway qualification tests based on the FAA establishment criteria to determine CAT II or CAT III eligibility for new runways, (2) assess costs and benefits for a 15-year life cycle in 1995 dollars of landing systems and avionics based on architecture makeup, and (3) compute the B/C ratios.

The results of the CBA of all five architectures included in this study are shown in the table on the following page.

BENEFIT-COST RATIOS OF LAAS AND ALTERNATIVE ARCHITECTURES (millions of dollars)

ARCHITECTURE	BENEFIT VALUE	COST VALUE	B/C RATIO*
Pseudolite Kinematic LAAS	$3,464.2	$ 957.8	3.6
Wide-Lane Kinematic LAAS	$3,464.2	$ 946.5	3.7
Code-Based LAAS	$3,464.2	$ 860.9	4.0
ILS	$ 359.0	$ 921.2	0.4
LAAS/GS	$3,455.2	$1,014.6	3.4

*Per unit dollar total cost.

A review of the findings given in the above table leads to the following two conclusions: (1) using the yardstick of B/C ratios for comparing the non-ILS architectures, the Code-Based LAAS architecture has the highest ratio of 4.0, followed by other architectures in the range of 3.4 to 3.7; (2) employing the cost-effectiveness criterion for all architectures, the Code-Based LAAS has the lowest life-cycle cost of $860.9 million in comparison to other architectures whose costs range from $921.2 million to $1,014.6 million. The life-cycle cost of $921.2 million for the ILS architecture shows that ILS cost is not much different from others. This is significant because the ILS cost does not include the sunk cost of CAT II and CAT III ILS for 79 existing runways and of avionics for 6,711 existing CAT II and CAT III aircraft, but reflects only the life cycle cost of 85 newly qualified CAT II and CAT III runways and of avionics for 3,846 new CAT II and CAT III aircraft. In comparison, the life-cycle cost of Code-Based LAAS architecture, for instance, is for all 164 existing and newly qualified CAT II and CAT III runways and of avionics for all 10,557 existing and new CAT II and CAT III aircraft.

1. INTRODUCTION

The Federal Aviation Administration (FAA) has been assessing various technologies for Precision Approach and Landing System (PALS) architectures for CAT II and III operations in the National Airspace System (NAS). As part of this assessment process, the FAA has proposed performing an economic analysis of the Global Positioning System (GPS) candidate architectures for Local Area Augmentation System (LAAS) as well as other architectures, including an alternative hybrid architecture, to facilitate the choice of an optimum architecture.

This report presents the results of the cost-benefit analysis of LAAS and alternative architectures. The architectures are listed below, with details supplied in Section 2 of this report:

- Pseudolite Kinematic LAAS
- Wide-Lane Kinematic LAAS
- Code-based LAAS
- Instrument Landing System (ILS)
- LAAS and Glide Slope System

This report is organized into eight sections as follows: Section 1 gives the introduction, Section 2 describes the LAAS and alternative architectures, Section 3 presents the methodology, Section 4 discusses CAT II/III airports and runways, Section 5 assesses the CAT II/III architecture costs, Section 6 analyzes the CAT II/III architecture benefits, Section 7 discusses the benefit-cost ratios, and Section 8 provides the conclusions of this report. The results of the sensitivity analyses performed are given in Appendix B.

2. PRECISION APPROACH AND LANDING SYSTEM ARCHITECTURES

The international civil aviation community is divided on the issue of future PALS. Rather than choosing one common architecture, the International Civil Aviation Organization (ICAO) has, at the Montreal meeting in April 1995, given member countries the option to choose their own architectures. The U.S. position reflected both a decision already taken and one still pending. For the CAT I service in the NAS, the FAA has selected the GPS Wide Area Augmentation System (WAAS). A decision on the future CAT II and III landing system architecture, however, is still pending. In all, the FAA has chosen five CAT II/III candidate architectures for review. A brief description of each architecture follows.

2.1 PSEUDOLITE KINEMATIC LAAS

Stanford University has developed the integrity marker beacon pseudolite (Integrity Beacon) to augment the GPS to achieve the required performance according to CAT II and III specifications. A CAT III landing system, for instance, must meet a vertical position accuracy requirement of 2 feet (2σ) with the extremely demanding integrity risk requirement of 5×10^{-10}.[1] The latter parameter sets the probability of one false guidance occurrence (and detection) in two billion landing operations, or of not radiating false guidance signals to be 0.9999999995 per any one landing.

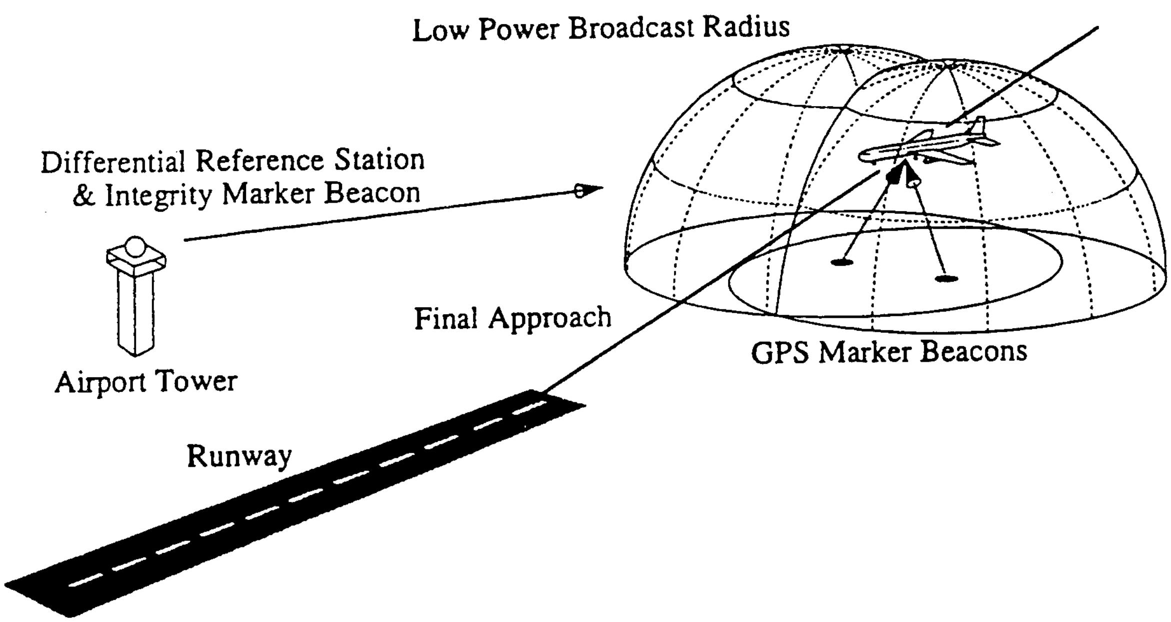

FIGURE 2-1. PSEUDOLITE KINEMATIC LAAS LANDING SYSTEM

[1]See International Civil Aviation Organization. Aeronautical Telecommunications, International Standards, Recommended Practices and Procedures for Air Navigation Services, Annex 10 to the Convention on International Civil Aviation, Vol. I, Part I - Equipment and Systems, Montreal, April 1985, pp. 7 and 197-202.

The Pseudolite Kinematic LAAS architecture uses a pair of Integrity Beacons that are placed on the ground adjacent to the approach path to a runway. These Integrity Beacons transmit low-power GPS-like signals in the L1 band (1575.42 MHz). Powered by low voltage batteries (about 9 volts), each Integrity Beacon broadcasts a signal inside a "bubble" as shown in Figure 2-1. The "bubble" has an upward signal range of only a few times the approach height.

The Pseudolite Kinematic LAAS architecture is carrier-based, but uses code to identify satellites whose carrier signals are used in solving for the position fix. Since the GPS receiver instantly measures only the fractional component of the carrier phase, the integer cycle components must be determined from the ground and uplinked to the aircraft. Several techniques are now known and have been tried for resolving the integer cycle ambiguities between two antennas, including double differencing (see section 2.2 below). Once determined and broadcasted to the aircraft, the GPS receiver couples the cycle count with the aircraft attitude information to fully resolve the phase cycle ambiguities in the airborne receiver.

The architecture has the following components:

TABLE 2-1. PSEUDOLITE KINEMATIC LAAS

ITEM	NUMBER PER AIRPORT	NUMBER PER RUNWAY APPROACH
Single-Frequency GPS/GEO Receivers	4	-
Computers/Processors	4	-
Datalink Transceivers	4	-
Integrity Beacon Pseudolites	-	2

The components listed in Table 2-1 show the basic configuration for a CAT II/III airport and for each of its runway approaches.

2.2 WIDE-LANE KINEMATIC LAAS

The Wide-Lane Kinematic LAAS architecture (see Figure 2-2) utilizes the carrier phase measurements, but, unlike the Pseudolite Kinematic LAAS, does not require any GPS-like ground transmitters. Carrier phase measurements are taken on both link frequencies of 1575.42 MHz (L1) and 1227.60 MHz (L2). Satellite clock errors are removed first through single differencing the L1 and L2 carrier phase measurements from the same satellite. The receiver clock errors are then eliminated by differencing again the single difference observables from two satellites in the same epoch; hence, double differencing. In addition, the dual frequency measurements are combined to cancel out the ionospheric delays. The carrier phase measurements, however, produce ambiguous results because of uncertainty about carrier cycles.

To remove ambiguities, the carrier phase measurements must be complemented with code measurements which must also be double differenced. By initializing the Kalman filter with the code double difference residuals and then complementing them with the carrier phase double differences, the carrier cycle integer ambiguities can be resolved up to the required accuracy. These results are then broadcast to the aircraft to resolve the ambiguities in the on-board receivers.

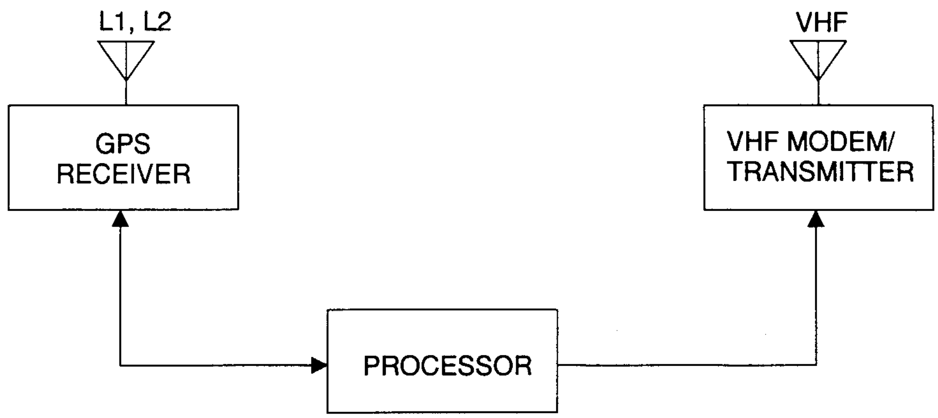

FIGURE 2-2. WIDE-LANE KINEMATIC LAAS GROUND STATION

Wide-lane carrier phase measurements are created as long as cycle slip discontinuities are not experienced. If a cycle slip occurs, however, it is automatically detected by the receiver, but no attempt is made to repair the carrier phase measurements. The data from the cycle skipping satellite is simply discarded. Data from another satellite or from a reacquired satellite following a waiting period, is substituted.

The Wide-Lane Kinematic LAAS architecture has the following components:

TABLE 2-2. WIDE-LANE KINEMATIC LAAS

ITEM	NUMBER PER AIRPORT
Dual-Frequency GPS/GEO Receivers	2
Single-Frequency GPS/GEO Receiver	2
Computers/Processors	4
Datalink Transceivers	4

The components as listed in Table 2-2 for the Wide-Lane Kinematic LAAS are configured for the airport rather than runway as was the case with the Pseudolite Kinematic LAAS architecture.

2.3 CODE-BASED LAAS

The Code-based LAAS architecture relies on code phase measurements, using single frequency (L1) receivers on the ground and in the aircraft. To contain the noise level, low noise pre-amplifiers are used with the GPS antenna and the received GPS signals are then routed to narrow correlator receivers. With residual noise still far too high for achieving CAT II/III precision landings, the code phase measurements are then carrier smoothed to minimize the noise level. The code phase measurements are smoothed outside the code tracking loop because the smoothing interval may be much longer than the time constant tracking loop. The ionospheric effects are compensated by applying to the pseudorange data, correction parameters derived from modeling the total electron content (TEC) of the ionosphere. The satellite and receiver clock offsets are removed through double differencing the single differences of each satellite in view against the single difference of a simulated satellite (see Figure 2-3).

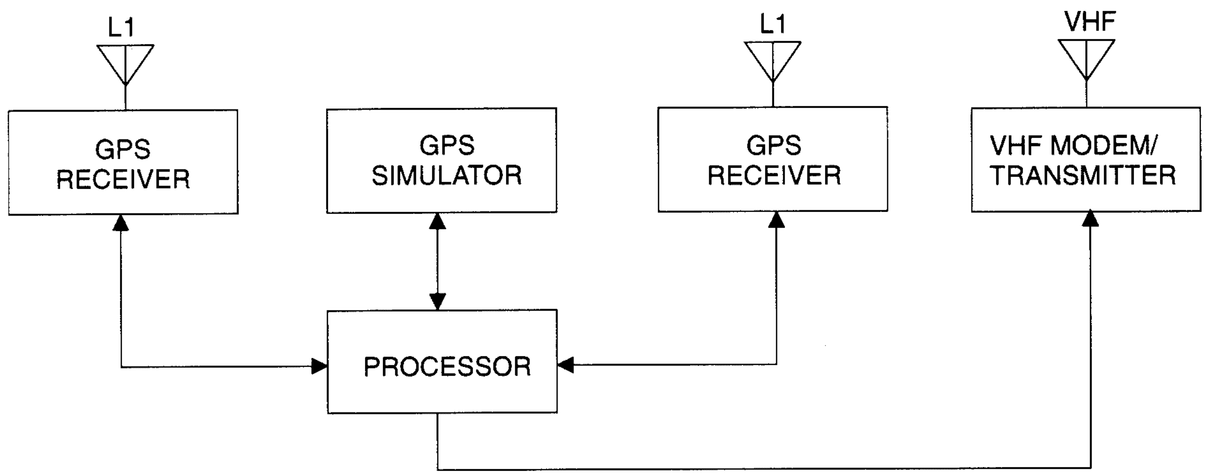

FIGURE 2-3. CODE-BASED LAAS GROUND STATION

The carrier phase smoothing of the code phase measurements works well as long as no cycle slips occur. If cycle slips are incurred and detected, they are corrected by evaluating the double-differenced phase measurements.

The ground reference station data is uplinked every second to the aircraft in the form of both raw pseudorange data and the Selective Availability (SA) range-rate corrections. The Code-Based LAAS architecture has the following components:

TABLE 2-3. CODE-BASED LAAS

ITEM	NUMBER PER AIRPORT
Single-Frequency GPS/GEO Receivers	4
Computers/Processors	4
Datalink Transceivers	4
Satellite Simulators	2

The components for the Code-based LAAS architecture as identified in Table 2-3 constitute the basic configuration for an airport.

2.4 INSTRUMENT LANDING SYSTEM (ILS)

The ILS architecture for CAT II/III operations has three main elements: glide slope, localizer, and marker beacons. The glide slope carrier frequency lies in the 329 to 335 MHz band and the localizer carrier in the 108 to 112 MHz band. Each is modulated by the 90 and 150 Hz audio tones, and the null between the modulated signals defines the approach path (see Figure 2-4).

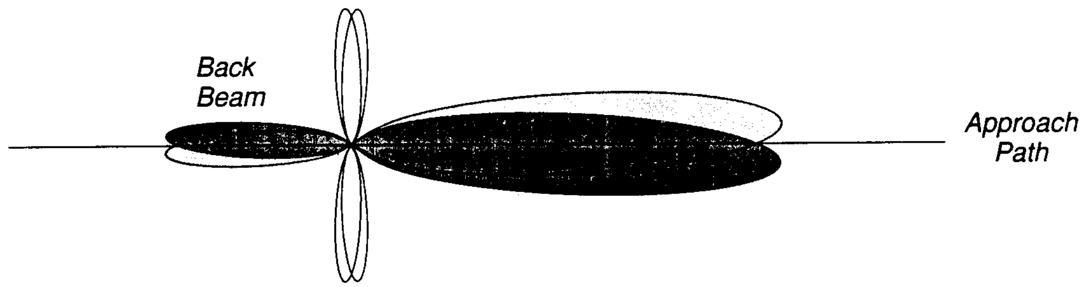

FIGURE 2-4. INSTRUMENT LANDING SYSTEM

Any deviation from the course is computed as a two-tone difference divided by the carrier amplitude and is called Difference in Depth of Modulation (DDM) and is portrayed as a cross hair in the airborne Course Deviation Indicator (CDI). The marker beacon radiates a vertical fan-shaped beam at a single frequency (75 MHz) that is modulated at 400 Hz, 1300 Hz, and 3000 Hz for outer, middle, and inner markers respectively. The marker beacons indicate the distance to the runway threshold. The ILS components are listed in Table 2-4.

TABLE 2-4. INSTRUMENT LANDING SYSTEM

ITEM	NUMBER PER RUNWAY APPROACH
VHF Localizer*	1
UHF Glide Slope*	1
VHF Marker Beacons	3
Portable ILS Receiver	1

*Includes "hot backup" equipment.

The basic configuration of an ILS runway approach is composed of the components as specified in Table 2-4.

2.5 LAAS AND GLIDE SLOPE SYSTEM

The LAAS and Glide Slope architecture combines the Code-Based LAAS and ILS Glide Slope elements to provide lateral and vertical guidance respectively. The components of hybrid architecture are shown in Table 2-5.

TABLE 2-5. CODE-BASED LAAS AND GLIDE SLOPE

ITEM	NUMBER PER AIRPORT	NUMBER PER RUNWAY APPROACH
Single-Frequency GPS/GEO Receivers	4	-
Computers/Processors	4	-
Datalink Transceivers	4	-
UHF Glide Slope*	-	1
Portable ILS Receiver	1	-

*Includes "hot backup" equipment.

The Code-based LAAS components listed in Table 2-5 service an airport, whereas the glide slope serves a runway approach.

3. METHODOLOGY

The methodology used in this cost-benefit analysis (CBA) is discussed in the following sections: 3.1 Objective, 3.2 Assumptions, and 3.3 Approach. The parameters used are defined in the Approach section under the sub-headings of Scope, Time Horizon, Unit of Analysis, Establishment Criteria, AIA Forecast Techniques, the Discount Rate, Benefit-Cost Ratio, and ILS Decommissioning Upon Launching the New System. The focus and scope of the study are limited to the economic analysis of alternative investment decisions regarding the future CAT II and III precision approach and landing systems.

3.1 OBJECTIVE

The objective of this study has been to conduct an economic assessment of LAAS architectures by performing a CBA of the LAAS and alternative architectures, including the ILS. Rather than apply the analysis to every conceivable alternative architecture, only a limited number of architectures have been selected for analysis by the FAA based on considerations of their operational feasibility and likelihood of being fielded by the U.S. or the international aviation community.

Given that the WAAS architecture is expected to provide precision guidance for CAT I operations, only CAT II and III architectures have been analyzed.

3.2 ASSUMPTIONS

Identifying the cost and benefit categories for this study involves characterizing accurately the status quo and the change state. The following observations on the ILS runway cost and benefit valuation also apply to the ILS avionics. To relate to avionics, the references to runway upgrades should be substituted with new aircraft avionics.

Ordinarily, if the change state was to be based on an irrevocable decision to discontinue ILS and replace it with one of the other alternative systems under consideration, the baseline ILS would become the status quo architecture. All existing runways and their ILS guidance systems would be frozen at a chosen time instant. No new benefits would be derived from the frozen architecture; hence, benefits for the ILS architecture would be null. Similarly, no new ILS equipment would be installed, since any upgrading of runways would be made with the proposed new non-ILS equipment, and investments already made in the ILS equipment would be sunk costs. Therefore, the ILS non-recurring costs would also be null. If existing ILSs were discontinued instantly, no ILS recurring costs would be incurred. In reality, however, the ILS decommissioning is likely to be spread over several years, and some recurring costs may occur beyond the time instant when the existing ILSs are frozen. Assuming no cap on societal income, the provisioning of ILS recurring costs will be made by setting up a reserve fund from current income in the year in which the decision is made to discontinue the ILS. The ILS recurring costs should, therefore, be regarded as societal costs already accounted for. Consequently, those recurring costs, even though expended over several years past the ILS decision year, would also be null from the societal viewpoint. Therefore, the benefit-cost (B/C) ratio of the baseline ILS architecture in the status quo state would be zero. Moreover, with zero costs, no ILS costs would be foregone, and no benefits of ILS costs foregone would accrue to the non-ILS architectures.

However, if the change state was to contain the ILS as a contender along with other alternative systems, ILS architecture could no longer be frozen at a chosen instant of time. Rather, it would be a dynamic architecture receiving new investments as would any newly proposed architecture. But, being an existing architecture, the ILS would be of a different genre and ought to be treated as a special case. For instance, the ILS costs would differ from those of other proposed architectures. Existing CAT II and III runways that do not qualify for upgrades would not experience any new non-recurring equipment costs; only those that qualify for upgrades would do so. On the other hand, both the existing CAT II and III runways and the newly qualified CAT II and III runways would incur recurring operations and maintenance (O&M) costs. All of these costs are ILS architecture costs because they are future outlays in the change state. The provisioning of future outlays, including the ILS recurring costs pertaining to existing and newly qualified runways, would be made from future income streams because of the decision to continue ILS. In other words, all future societal costs for ILS will be accounted for in the future, not in the present. Consequently, the ILS future outlays, including the recurring O&M costs of existing runways, cannot be regarded as null costs. As for the ILS benefits, no benefits from existing CAT II and III runways can be assessed since no new benefits are derived from those runways. Benefits from the newly qualified runways would, therefore, constitute the total ILS architecture benefits.

In contrast, in the case of the newly proposed non-ILS architectures, all runways, including the existing and newly qualified CAT II and III runways, will incur future costs. However, the benefits would be far greater than those of the ILS architecture because the following two benefits accrue only to new architectures: (1) cost-saving benefits of executing complex procedures on all runways, and (2) the cost foregone benefits of not implementing the ILS at the newly qualified CAT II and III runways and of not installing the ILS avionics in the new aircraft fleet. Consequently, the B/C ratio of the non-ILS architectures would be a high value, and for the ILS architecture, in comparison, a low value. Such a comparison biases the study in favor of non-ILS architectures against ILS. To avoid such a bias in evaluating architectures that include the ILS, the following approach has been adopted: (1) the B/C ratios are used as the primary yardstick for comparing the non-ILS architectures only, and (2) the total architecture costs are employed to compare all architectures, including the ILS, to determine a cost advantage, if any.

Based on the preceding considerations, the following assumptions have been made in this study concerning the benefit and cost categories.

3.2.1 Benefit Assumptions

In this CBA study, the benefit categories are characterized using standard FAA methodologies. According to the FAA, the investments and regulations confer benefits in several areas: safety improvement, service disruption reductions, and cost savings.[2] The safety improvement benefit is associated with a reduction in the risk of death, personal injury, and property damage. The service disruption reduction benefit is related to the difference between disruptions currently experienced and those which would occur following a service upgrade. These two benefits are incidental to runway upgrades. The cost saving benefit is, on the other hand, linked to gains from reducing or foregoing costs by adopting the change state, which otherwise would not be realized under the status quo state. This benefit arises from making an architectural change. In line with these benefit characterizations, the assumptions made in this study are listed here separately for benefits from runway upgrade, and architectural change.

The following two assumptions apply to benefits from upgrading a runway category of operation:

1. User and passenger safety benefits will accrue from reduced risk of accidents, fatalities, and injuries upon upgrading a runway category of operation.

2. Service disruption reduction benefits for users and passengers will result from shorter or fewer delays, cancellations, and diversions.

The following three assumptions apply to benefits from an architecture change to a non-ILS system:

1. Each architecture is a perfect substitute for the existing ILS. In fielding non-ILS systems, the FAA will benefit from cost savings from foregoing the future ILS non-recurrent and recurrent costs. However, in the case of ILS, the expected cost saving benefits in the form of reduced recurring costs from replacing the aged ILS with new ILS equipment at the existing CAT II and III facilities will not materialize during the analysis period. This is so because a new generation of ILS, MK-20, has been slated to replace the aged equipment prior to the analysis period.

2. All architectures, except ILS, permit execution of complex approaches; hence, user cost savings from complex approaches will accrue primarily to the airlines from the installation of non-ILS architectures. Such cost savings will be in the form of fuel savings due to a shortened final approach by 2 NM. Only one-half of the Annual Instrument Approaches (AIAs) executing complex approaches are factored in the cost savings; the other half are assumed to execute ILS-type straight-in approaches.

3. All architectures, except ILS, will benefit, according to the FAA, from the availability of more precise aircraft surface position and movement information and of automated surface movement guidance control capability provided by the LAAS

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[2]See U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Policy and Plans, Economic Analysis of Investment and Regulatory Decision - A Guide, FAA-APO-82-1, Washington, DC, 1982.

technology.[3] The LAAS surface benefits will accrue from the lowering of costs due to:

3.1 A reduction in delays in the taxi-out phase since such delays are quite significant in comparison to delays in other surface movement phases; and

3.2 A reduction in the incidence of surface accidents, fatalities, and injuries.

The GPS LAAS surface benefits are assumed to accrue from externalities (secondary effects), given that LAAS is primarily a landing system.[4] Although the Airport Surveillance Detection Equipment (ASDE-3 and ASDE-X) is a competing technology to the GPS LAAS, current FAA plans are to install the ASDE at 34 airports only. The GPS LAAS surface benefits included in this study are, therefore, for 66 other airports where ASDE will not be installed.

3.2.2 Cost Assumptions

The costs of the proposed investment projects and regulations are outlays which would be incurred when each alternative under consideration is implemented. These costs have been classified by the FAA under four general headings: (1) Research and Development Cost (R&D), (2) Investment Cost, (3) Operations and Maintenance Cost, and (4) Termination Cost.[5] The R&D costs cover all expenditures incurred prior to the procurement phase but excludes any R&D sunk costs. The investment cost includes non-recurring outlays on land, and facilities and equipment (F&E). The O&M costs cover all recurring expenditures for operating and maintaining the proposed investment project. The termination cost includes the cost of dismantling old equipment and restoring sites to original or near original condition. In line with these cost classifications, the assumptions made in this study are listed separately below for costs associated with implementing each architecture and installing the corresponding avionics configuration.

The following two assumptions apply to costs associated with implementing the architectures:

1. FAA non-recurring investment costs for ILS and non-ILS architectures have been determined as follows:

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[3]See Krishna K. Bachu, A Conceptual Cost-Benefit Analysis of Airport Surface Traffic Automation (ASTA), Washington, D.C. 1994. (This study was conducted by Martin Marietta on behalf of FAA ASD-420).

[4]No ASTA system-related direct cost is attributed to LAAS such as the expected cost of installing a moving map display system in the aircraft. Such costs are assumed to be accounted for in the surveillance program cost-benefit studies. Their inclusion in this study will be double counting.

[5]Economic Analysis of Investment and Regulatory Decision, op. cit., chapter 4.

1.1 For ILS elements in ILS or mixed architectures:

1.1.1 Non-recurring costs for all existing ILS equipment are nulled due to the sunk cost for non-upgradable CAT II runways, and for runways upgradable from CAT II to CAT III (because the ILS configuration does not change for CAT II upgrades to CAT III).

1.1.2 Future non-recurring costs for new ILS equipment and installation are assessed for runways upgraded from CAT I to CAT II or III.

1.2 For LAAS architectures:

1.2.1 Future non-recurring costs for new GPS equipment and installation are assessed for:

1.2.1.1 All non-upgradable and upgraded CAT II and CAT III runways.

1.2.1.2 All non-upgradable CAT I facilities which: (a) are outside the WAAS coverage area, and/or (2) have two or more ILSs and thus have higher availability requirements than the WAAS availability.

2. FAA recurring O&M costs for ILS and non-ILS architectures have been determined as follows:

2.1 For ILS elements in relevant architectures:

2.1.1 Future recurring costs are assessed based on estimated O&M costs incurred annually for ILS elements.

2.2 For LAAS elements in relevant architectures:

2.2.1 Future recurring costs are assessed at a fixed percentage of the new LAAS equipment cost. A rate of 7 percent is employed, based on the computation of O&M costs of generic LAAS components, such as receivers.[6]

The following two assumptions apply to costs associated with implementing the avionics suites for various architectures:

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[6]For a review of corporate sector practices and considerations in estimating maintenance rate as depreciation or as a percentage of current replacement cost or net book value, see Michael F. Hora, "The Unglamourous Game of Managing Maintenance," Business Horizons, Vol. 30, No. 3(May-June, 1987), pp. 67-85.

3. User non-recurring avionics investment costs for ILS and non-ILS architectures have been determined as follows:

   3.1 For ILS avionics in ILS or mixed architectures:

      3.1.1 Avionics non-recurring costs for the existing fleet are nulled due to sunk costs.

      3.1.2 Future avionics equipage non-recurring costs are assessed for the new aircraft added to the fleet.

   3.2 For LAAS architectures:

      3.2.1 Future avionics equipage non-recurring costs are assessed for the existing fleet at a retrofit rate of 25 percent per annum.

      3.2.2 Future avionics equipage non-recurring costs are assessed for the new aircraft added to the fleet.

4. User recurring avionics O&M costs for ILS and non-ILS architectures, including LAAS, have been determined as follows:

   4.1 For ILS avionics in ILS or mixed architectures:

      4.1.1 Future avionics recurring costs are assessed based on estimated ILS avionics O&M costs.

   4.2 For LAAS architectures:

      4.2.1 Future avionics recurring costs are assessed at the rate of 7 percent of new equipage cost based on the ILS avionics O&M rate.

3.3 APPROACH

The approach this study uses is specified in the following sub-sections: 3.3.1 Scope, 3.3.2 Time Horizon, 3.3.3 Unit of Analysis, 3.3.4 Establishment Criteria, 3.3.5 AIA Forecast Techniques, 3.3.6 Discount Rate, 3.3.7 Benefit-Cost Ratio, and 3.3.8 ILS Decommissioning. The details of the approach are discussed below.

3.3.1 Scope

The scope is limited to assessing annual and total costs and benefits for the CAT II and III operations for each architecture. Thus, this analysis is based on respective weather probabilities.

3.3.2 Time Horizon

The time horizon of 15 years has been chosen as the life cycle of the precision guidance system and avionics based on the expected economic life of those equipment.[7] The time horizon of 15 years of life cycle has been applied uniformly to all architectures. During its life cycle, the equipment is expected to be kept in a good state of repair through regular maintenance activity (including replacement of components as necessary).

In this study, although 1998 has been picked as the starting year, it is not a critical variable. The reason is that AIA is the only variable that is affected by a change in the starting year and the AIAs do not differ significantly during a short time interval. For instance, the cumulative total of AIAs for all 100 airports used in this study is 853,409 in 1998 versus 902,637 in 2001, an increase of 5.8%. However, only a fraction of the total AIAs, the CAT II and CAT III precision approach portions, have been used is this study which gives a delta value of approximately 2,460 AIAs for the two starting years of 1998 and 2001. A sensitivity analysis with 2001 as the starting year has not yielded different results when a time horizon of a 15-year life cycle is specified, and the benefit and cost valuations are made at the constant 1995 prices.

3.3.3 Unit of Analysis

The unit of analysis for an airport is the AIA. The AIA is the standard qualifying variable used by the FAA in determining whether a runway at a candidate airport qualifies for the establishment of an upgraded landing system. Where AIA data are not available, the itinerans are used to derive AIAs (see section 3.3.5). The itinerans are all aircraft operations other than local. The airports used in the analysis have been taken from the FAA Terminal Area Forecasts (TAF).[8]

3.3.4 Establishment Criteria

The establishment criteria used in this study were developed by the FAA and are based on air carrier AIAs. The establishment of an upgraded landing system at a runway is based on two numeric values: (1) the number of air carrier AIAs allotted to a runway, and (2) the minimum number of air carrier AIAs which must be exceeded for a runway to qualify.

The number of air carrier AIAs allotted to a runway is based on the number of CAT III runways found at an airport. The airport allotment schemes have been developed as follows:

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[7]See U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Policy and Plans, Establishment and Discontinuance Criteria for Precision Landing Systems, By Joseph A. Hawkins, FAA-APO-83-10, Washington, DC, 1983. Also, Economic Analysis of Investment and Regulatory Decisions - A Guide, pp. 5-13 to 5-17.

[8]See U.S. Department of Transportation, Federal Aviation Administration, Terminal Area Forecasts FY 1992-2005, FAA-APO-92-5, Washington, D.C., 1992.

- For airports with none or one CAT III runway, 70% of the AIAs are allotted to a primary runway, 25% to a secondary runway, and 5% to the remaining runways.[9]

- For airports with two CAT III runways, 35% of the AIAs are allotted to each CAT III runway, 15% to a secondary runway, and 15% to the remaining runways.[10]

The minimum number of air carrier AIAs used as the upgrade criteria have been separately determined for this study as follows:

- A minimum of 1,050 air carrier AIAs have been used for candidate runways (primary or secondary) to test their eligibility for upgrade from CAT I to CAT II status. This numeric value is a modified CAT II establishment criteria, based on the algorithms specified by the FAA.[11]

- A numeric value of minimum air carrier AIAs has been used for candidate runways (primary or secondary) to test their eligibility for upgrade from CAT II to CAT III status. This numeric value is derived from the formulas used by the FAA for airports that are classified by hub size as follows:[12]

Hub Size	Runway Air Carrier AIA
$S_{(n)}$	$X_{(n)} \frac{W_2}{W_3}$

where $S_{(n)}$ represents hub size and subscript n ranges from 1 to 4 for large, medium, small, and non-hub respectively; $X_{(n)}$ depicts a weight factor and subscript n ranges from 1 to 4 for numeric weights of 25, 35, 45, and 60 respectively, W_2 is the percent of time the weather is Instrument Flight Rules (IFR) to CAT II minimums, and W_3 is the percent of time the IFR weather is between CAT II and CAT IIIa minimums.

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[9]See Establishment and Discontinuance Criteria for Precision Landing Systems, p. 5.

[10]The allotment scheme for airports with two CAT III runways reflects averages derived from the data on runway AIA distribution patterns at the Atlanta International, Chicago O'Hare International, Dallas-Fort Worth International, and Orlando International airports.

[11]See U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation System Plans, Establishment Criteria for Category II Instrument Landing System (ILS), FAA-ASP-76-1, Washington, D.C., 1976. See also, Booz, Allen and Hamilton, Projected Requirement for Category II/III Microwave Landing Systems in the Year 2010, Final Report, Crystal City, VA, 1991.

[12]See U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation System Plans, Establishment Criteria for Category IIIa Microwave Landing System (MLS), FAA-ASP-77-5, Washington, D.C., 1977.

3.3.5 AIA Forecast Techniques

The TAF forecast data are available up to the year 2005. The post-2005 projections have been derived as follows for AIAs or itinerans:

- A growth factor of each airport is computed by using 2005 over 2004 AIAs (or itinerans, as appropriate).
- AIAs (or itinerans, as appropriate) for years 2006 and beyond are projected by using the straight line extrapolation technique based on the growth factor.

The TAF did not include AIA forecast data for seven airports, namely, Los Angeles International, Minneapolis-St. Paul, Newark International, Stewart (Newburg, NY), John F. Kennedy International, Lambert-St. Louis International, and San Francisco International. The AIA estimates for these airports have been derived as follows:

$$\text{(Airport) AIA} = \frac{ITINERANS}{2} * W_{ins}$$

where W_{ins} is the airport instrument weather ratio factor.

3.3.6 Discount Rate

Taking 1995 to be the reference year, the annual benefit and cost streams have been calculated in 1995 constant dollars. Such streams have been discounted at the rate of 7% per annum. The formula for discounting a benefit or cost stream to derive present value is as follows:

$$PV = \Sigma \frac{Y_i}{(1+r)^i}$$

where PV represents present value, Y_i is the annual benefit or cost stream value in the *i*th year, and r is the discount rate.

3.3.7 Benefit-Cost Ratio

The B/C ratio is a measure of benefit per unit dollar cost. The total values of benefits and costs used to compute the ratio are in present values. The equation for B/C ratio is:

$$B/C = \frac{PV_{benefits}}{PV_{costs}}$$

where $PV_{benefits}$ represents present value of benefits and PV_{costs} present value of costs.

3.3.8 ILS Decommissioning Upon Launching the New System

The launching of LAAS or hybrid architectures would result in the decommissioning of all or some elements of ILS. Generally, the approach to decommissioning has been to specify a phased process over four or five years after a non-ILS system has achieved parity with ILS.[13] In this CBA study, it is assumed that ILS parity will be achieved before the new system is commissioned by the FAA. Accordingly, the ILS will be phased out over a period of four years.

The implications of the four-year phase-out period for ILS and its collocation with other systems in the non-ILS architectures are as follows:

1. The installed ILSs at current (non-upgradable) and newly qualified CAT II and CAT III runways will continue to be operated for 4 years. The O&M costs for those 4 years include the maintenance cost of the ILSs.

2. At CAT I runways which have been upgraded to CAT II and CAT III status during the 4 years, no new ILSs will be installed (because it is not prudent to install the expensive new ILS equipment, only to dismantle them at the end of the four-year transition period) and the existing CAT I ILSs will be turned off since CAT I guidance will be provided by WAAS. Accordingly, no ILS maintenance cost are shown for these upgraded CAT I runways.

3. At CAT I runways which are not upgradable but are candidates for LAAS (because they are outside the WAAS coverage area and/or have higher availability requirements than the WAAS availability), no new ILSs will be installed and the existing CAT I ILSs will be turned off. However, the existing Medium Intensity Approach Light System with Runway Alignment Indicator Lights (MALSR) and Runway Visual Range (RVR) will be continually operated and maintained, and their maintenance costs are included in the O&M cost for the entire 15-year life cycle. Note that in the case of the LAAS/GS architecture, the existing glide slope will not be used to provide vertical guidance as LAAS is expected to meet all the required specifications for the CAT I service. Accordingly, no glide slope maintenance costs are shown for these CAT I runways in the LAAS/GS architecture.

Similar considerations have been extended to ILS avionics costs. In the case of LAAS architectures, the ILS avionics O&M costs have been added to the LAAS avionics O&M costs of the existing aircraft fleet during the four years of transition. On the new aircraft, the ILS avionics will not be installed, hence no ILS avionics maintenance costs are shown for the 15-year life cycle. However, with respect to the hybrid LAAS/GS architecture, the avionics O&M costs include the Glide Slope as well as the LAAS maintenance costs for the new aircraft.

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[13]See, for example, U.S. Congress, General Accounting Office, Air Traffic Control; Emerging Technologies May Offer Alternatives to the Instrument Landing System, A Draft Report, GAO/RCED-93-33, Washington, D.C., 1992. This report suggests a period of 5 years for decommissioning ILS.

4. CAT II/III AIRPORTS AND RUNWAYS

In 1995, the airports and runways which constitute the baseline of this analysis were distributed by the categories of operation as shown in Table 4-1.

TABLE 4-1. BASELINE AIRPORT AND RUNWAY CONFIGURATION

AIRPORTS	CAT III RUNWAYS	CAT II RUNWAYS	CAT I RUNWAYS
2	4 (2)	2 (1)	X*
5	10 (2)	0	X
4	4 (1)	4 (1)	X
26	26 (1)	0	X
29	0	29 (1)	X
Σ = 66	44	35	

*X represents an unspecified number.
(n) represents runways per airport.

Source: FAA

The baseline in 1995 is, as shown in Table 4-1, composed of a total of 66 airports, with 35 CAT II runways and 44 CAT III runways. The percentage distribution of the total 79 runways is shown in Figure 4-1, indicating a share of CAT III runways just above half (56%).

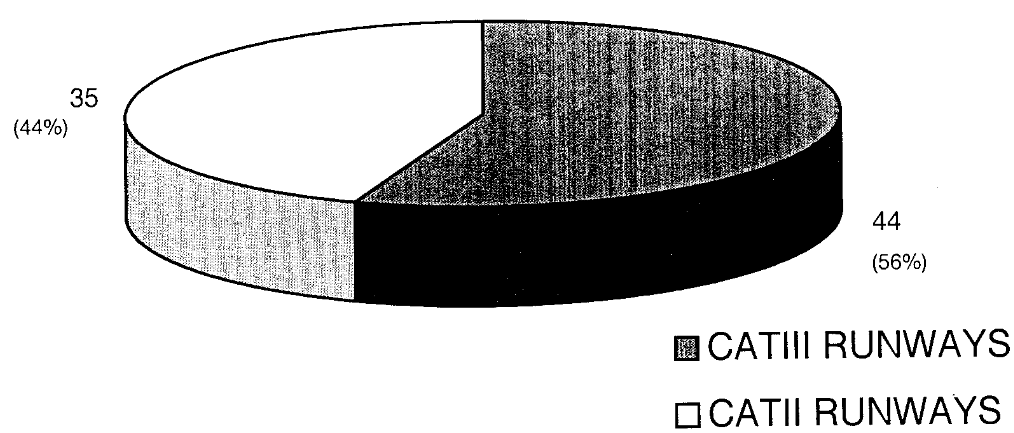

FIGURE 4-1. BASELINE RUNWAYS DISTRIBUTION

The end state after a 15-year life cycle provides a different distribution of the airports and runways as shown in Table 4-2. The share of CAT III runways increases to nearly two-thirds (65%) of all runways as shown in Figure 4-2.

TABLE 4-2. END STATE AIRPORT AND RUNWAY CONFIGURATION

AIRPORTS	CAT III RUNWAYS	CAT II RUNWAYS	CAT I RUNWAYS
5	15 (3)	0	X*
2[1]**	4 (2)	2 (1)	X
33	66 (2)	0	X
12	12 (1)	12 (1)	X
10[4]**	10 (1)	0	X
5	0	10 (2)	X
33[14]**	0	33 (1)	X
Σ=100	107	57	

*X represents an unspecified number.
(n) represents runways per airport.
**[m] represents airports whose runway configuration is unchanged.

The airports, as shown in Table 4-2, increased by almost 52% from 66 to 100, whereas CAT II runways rose by 63% from 35 to 57, and CAT III runways by nearly 143% from 44 to 107. Only a total of 19 out of 66 baseline airports did not experience any change in their configurations.

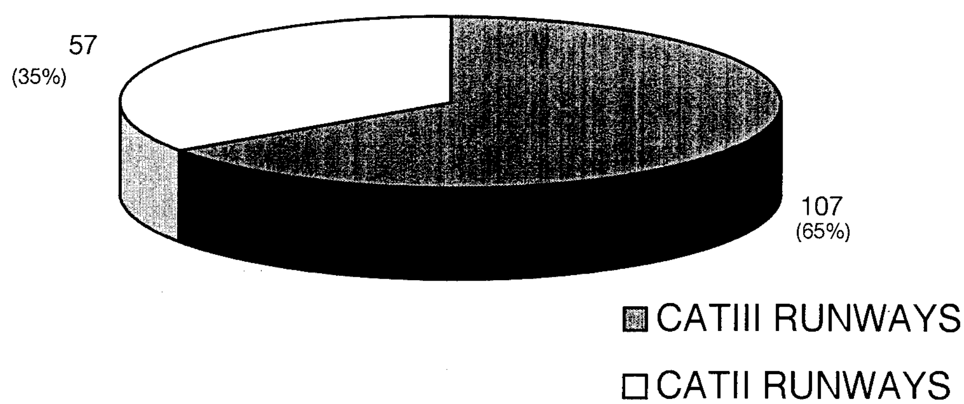

FIGURE 4-2. END STATE RUNWAYS DISTRIBUTION

5. CAT II/III ARCHITECTURE COSTS

Architecture cost estimates have been developed by employing various cost estimation methodologies which include analogy, parametric, component parts, industrial engineering, and vendor price methods for estimating F&E costs, and component parts and analogy methods for O&M costs.[14] The total cost of each architecture has two cost components: (1) the cost of the landing system elements, and (2) the cost of corresponding avionics suites. Each cost component, in turn, is a sum of non-recurring and recurring costs. The algorithms and item costs used in estimating the architecture costs are discussed below.

5.1 LANDING SYSTEM NON-RECURRING COSTS

The landing system non-recurring costs include the guidance system R&D, system acquisition, and installation costs. The treatment of these cost elements is discussed in the sub-sections below.

5.1.1 Guidance System R&D Cost

The guidance system R&D cost is a total cost independent of the number of system units to be produced. The R&D cost includes the cost of concept development, design, full-scale prototype development, and initial training of airport and depot government personnel. The R&D cost is allocated equally to CAT II and CAT III systems even though one LAAS guidance system will serve both categories of operations. The R&D cost allocation facilitates developing the architectural total costs separately for CAT II and CAT III operations since such a distinction must be made to reflect the differences in the avionics cost of the CAT II and CAT III aircraft. The projected R&D costs for different architectures are shown in Table 5-1.

TABLE 5-1. GUIDANCE SYSTEM R&D COST (thousands of dollars)

GUIDANCE SYSTEM	CAT II COST	CAT III COST	TOTAL COST
Kinematic Pseudolite LAAS	$20,000	$20,000	$ 40,000
Wide-Lane Kinematic LAAS	$15,000	$15,000	$ 30,000
Code-Based LAAS	$12,500	$12,500	$ 25,000
ILS	0	0	0
LAAS/GS	$12,500	$12,500	$ 25,000

Source: LAAS estimates were developed by TASC, Inc., Reading, MA.

[14]See FAA Order 1810.3, "Cost Estimation Policy and Procedures," May 15, 1984.

Table 5-1 shows that the guidance system R&D cost for Code-Based LAAS and for LAAS/GS architectures to be the lowest relative to other LAAS R&D costs. The R&D cost for ILS and for the Glide Slope system in the LAAS/GS architecture have been nulled as those systems are already in existence. The accompanying bar chart, Figure 5-1, illustrates the distribution of R&D costs by architectures.

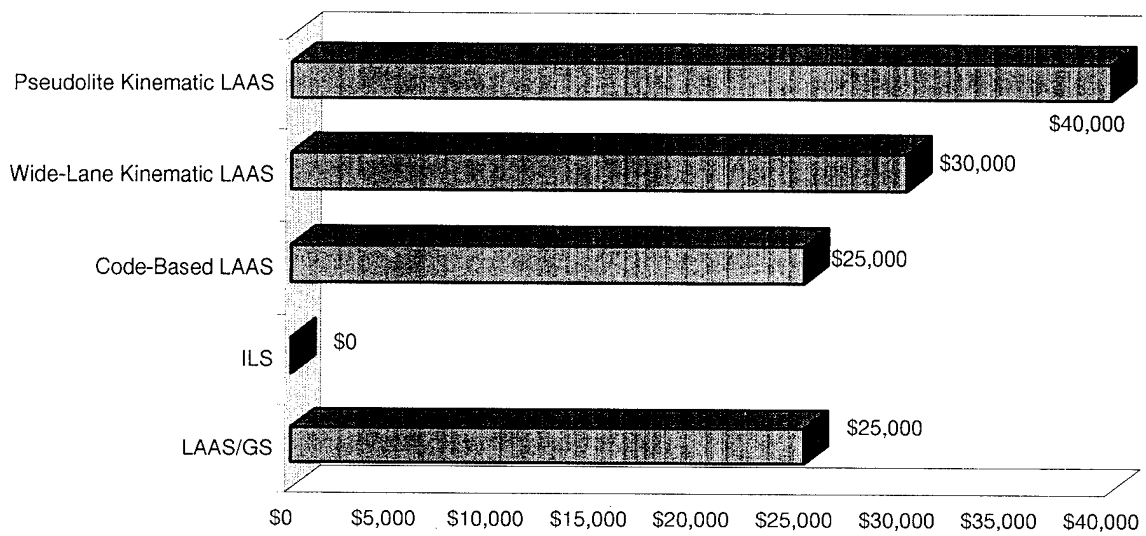

FIGURE 5-1. GUIDANCE SYSTEM R&D COST (thousands of dollars)

5.1.2 Landing System Unit Cost by Systems

The CAT II and CAT III landing system cost for a runway is dependent on the new elements that must be added to the existing runway landing system configuration. In general, the landing system configuration consists of an appropriate guidance system, the approach light system, and the RVR.

Table 5-2 shows the unit cost of systems which includes the unit installation cost for each architecture. The implicit assumption is that a CAT I runway is already equipped with a CAT I ILS, the MALSR, and the RVR with one sensor installed. Upgrading a CAT I runway to either CAT II or CAT III status will necessitate installing a CAT II/III guidance system, Approach Light System with Sequenced Flashing Lights (ALSF-2), and two additional RVR sensors. In all architectures, the guidance system for CAT II operations also services CAT III operations; hence, no additional cost is incurred in upgrading from a CAT II to a CAT III system. The costs shown in Table 5-2 are: (1) the unit cost of a CAT II/III guidance system, (2) the fixed unit cost of an ALSF-2, and (3) the fixed cost of adding two sensors to the runway RVR system.

TABLE 5-2. LANDING SYSTEM UNIT COST BY SYSTEM

ARCHITECTURE	GUIDANCE SYSTEM	ALSF-2	TWO RVR SENSORS	TOTAL
Pseudolite Kinematic LAAS				
Per Airport Cost	$214,000	-	-	$ 214,000
Per Runway Cost	$314,270	$1,750,000	$138,646	$2,202,916
Total Airprt & One Rwy Cost	$528,270	$1,750,000	$138,646	$2,416,916
Wide-Lane Kinematic LAAS	$256,270	$1,750,000	$138,646	$2,144,916
Code-Based LAAS	$238,270	$1,750,000	$138,646	$2,126,916
ILS	$600,270	$1,750,000	$138,646	$2,488,916
LAAS/GS				
Per Airport Cost	$238,270	-	-	$ 238,270
Per Runway Cost	$269,635	$1,750,000	$138,646	$2,158,281
Total Airprt & One Rwy Cost	$507,905	$1,750,000	$138,646	$2,396,551

Sources:
(1) LAAS estimates were developed by TASC.
(2) ILS estimates are from FAA.
(3) Glide Slope (GS) estimates were developed by Ohio University, Athens, OH.
(4) ALSF-2 and RVR estimates are from FAA.

As Table 5-2 indicates, the Code-Based LAAS (per airport) is the least expensive and the ILS (per runway) the most expensive among all the architectures. Figure 5-2 shows the distribution of the landing system unit cost for all architectures.

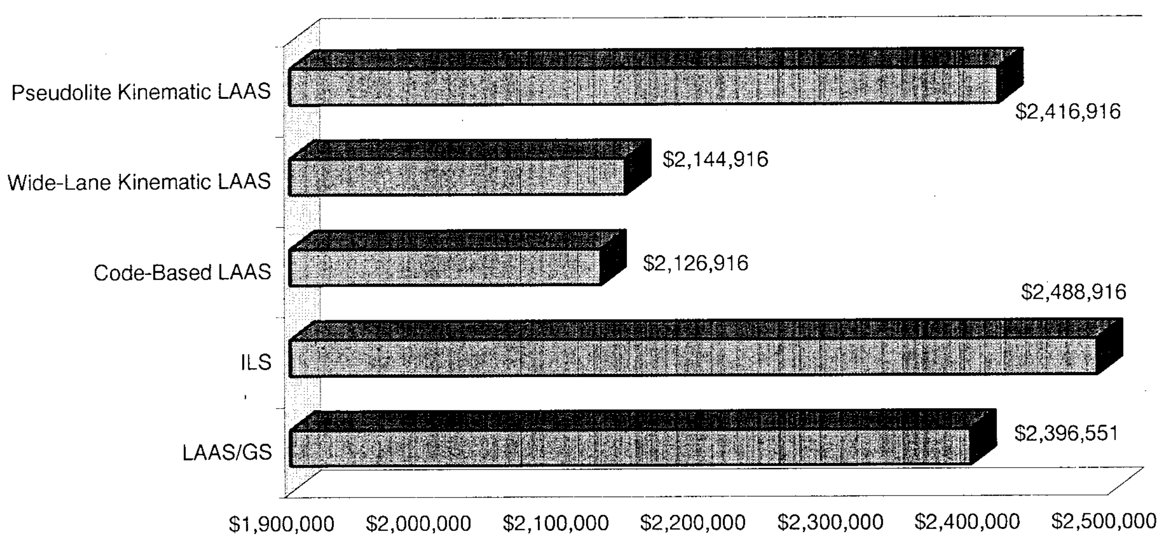

FIGURE 5-2. LANDING SYSTEM UNIT COST

The installation cost is included in the system unit cost. In the case of non-ILS architectures, the installation cost includes the shelter costs which have been estimated as refurbishment cost rather than as new shelter cost, since shelters for ILS already exist. The cost of a site commissioning flight check is also included. However, the cost of dismantling CAT I ILS in order to install a CAT II/III system and the salvage value of old ILS equipment are regarded as negligible and not factored in the architecture cost estimates.

5.2 LANDING SYSTEM RECURRING COSTS

The landing system recurring costs consist of the O&M cost of the three systems: (1) the guidance system, (2) the approach lighting system (MALSR or ALSF-2), and (3) the RVR. Table 5-3 lists the recurring costs by architectures.

TABLE 5-3. ARCHITECTURE RECURRING COSTS

ARCHITECTURE	GUIDANCE SYSTEM	ALSF-2	RVR	TOTAL
Pseudolite Kinematic LAAS				
Per Airport Cost	$10,160	-	-	$10,160
Per Runway Cost	$14,110	$39,030	$7,235	$60,375
Total Airprt & One Rwy Cost	$24,270	$39,030	$7,235	$70,535
Wide-Lane Kinematic LAAS	$12,135	$39,030	$7,235	$58,400
Code-Based LAAS	$10,865	$39,030	$7,235	$57,130
ILS - CAT II/III System	$19,034	$39,030	$7,235	$65,299
CAT I System	$17,188	$21,060*	$9,500**	$47,748
LAAS/GS - CAT II/III				
Per Airport Cost	$10,865	-	-	$10,865
Per CAT II/III Rwy Cost	$10,125***	$39,030	$7,235	$56,390
Total Airprt & One Rwy Cost	$20,990	$39,030	$7,235	$67,255
LAAS/GS - CAT I				
Per Airport Cost	$10,865	-	-	$10,865
Per CAT I Rwy Cost	$ 9,060***	$21,060*	$9,500**	$39,620
Total Airprt & One Rwy Cost	$19,925	$21,060	$9,500	$50,485

*MALSR O&M Cost
**RVR (TASKER-500) O&M Cost
***Glide Slope O&M Cost

Sources: Same as in Table 5-2.

Table 5-3 indicates that Pseudolite Kinematic LAAS architecture has the highest total O&M cost, followed by the CAT II/III LAAS/GS architecture. The CAT I ILS architecture has the lowest total O&M cost, CAT I LAAS/GS architecture the second lowest, and the Code-Based LAAS architecture the third lowest total O&M cost. The guidance system recurring costs for the Wide-Lane Kinematic LAAS and Code-Based LAAS architectures are for the airport, whereas the ILS recurring cost is for each runway. The total cost figures for Pseudolite Kinematic LAAS and LAAS/GS architectures reflect both the aggregate airport and one runway costs. Figure 5-3 illustrates the distribution of the total O&M costs by architectures.

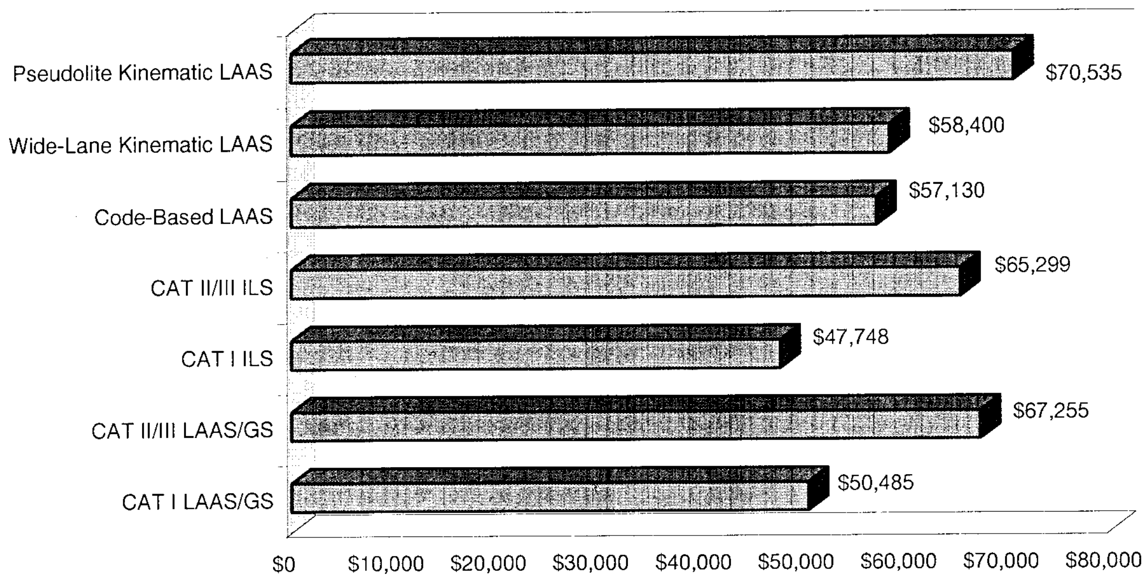

FIGURE 5-3. ARCHITECTURE RECURRING COSTS

5.3 AVIONICS NON-RECURRING COSTS

The avionics non-recurring cost per aircraft depends on the redundancy of equipment installed to meet the CAT II or CAT III equipage requirements. Costing of elements is discussed below. The total architecture non-recurring costs are computed by factoring the projected size of the aircraft fleet, the cost of CAT II or CAT III avionics suite, and the retrofit cost for the existing fleet in the case of non-ILS architectures. The following steps have been followed in estimating the architecture avionics non-recurring costs:

1. For air transport, commuter/air taxi, and general aviation, the fleet size is projected for the 15-year life cycle;

2. The equipage cost for CAT II and CAT III avionics suites for LAAS and alternative architectures is estimated; and

3. The cost of the avionics suite for retrofitting the existing fleet of CAT II and CAT III aircraft in the case of non-ILS architectures is estimated. The retrofit suite cost

includes the cost of integrating avionics with the flight control system, airframe manufacturers' certification cost, installation, and revenue loss from aircraft downtime.

The user fleet projections for CAT II and III aircraft are given in Table 5-4. The following annual fleet growth rates have been assumed: 3 percent for air transport, 8.5 percent for commuter/air taxi, and 1 percent for business class general aviation. A uniform annual retirement rate of 4 percent has been applied to the existing fleet.

TABLE 5-4. PROJECTED CAT II AND III FLEET SIZE

USER AIRCRAFT	FLEET IN 1997	FLEET IN 2012	NET ADDITION
Air Transport	3,340	5,202	1,862
Commuter/Air Taxi	644	2,189	1,545
General Aviation (Business Class)	2,727	3,166	439

Sources: Fleet in 1997 (end year) is derived from MITRE data for 1991 and extrapolated to 1997 by using FAA Aviation Forecasts growth rates. See Peter Wroblewski, et. al., NASPALS: System Descriptions, MITRE Corporation, McLean, VA, 1994; and U.S. Department of Transportation, Federal Aviation Administration, FAA Aviation Forecasts, Fiscal Years 1994-2005, FAA-APO-94-1, Washington, D.C., 1994.

As Table 5-4 indicates, the highest net addition to the fleet size is in air transport, followed by commuter/air taxi, and the smallest net addition is in the business class general aviation. The relative size of the aircraft fleet at year end in 1997 and 2012 is illustrated for each aircraft type in Figure 5-4.

The equipage cost per aircraft for LAAS and alternative architectures are given in Table 5-5. The data reflects the aggregate cost of elements which are either partially costed, based on their multi-functionality to navigate and land, or fully costed because of the single functionality (sole use) to land an aircraft (e.g., radio altimeters). Since both the GPS and ILS receivers and the associated antennas are multi-functional, their cost has been apportioned to the landing function at 20% of their total cost. The cost of a basic WAAS receiver, for instance, is expected to be about $15,000. It may be upgraded by adding a LAAS module at an additional cost of about $3,000. Similarly, an ILS/VOR receiver may be an apportioned cost between ILS and VOR based on dual functionalities. A basic ILS/VOR receiver (analog type) is currently priced at $25,000, and a VOR/Localizer (that is, without the Glide Slope) is about $18,000. An ILS receiver (digital type) is available at about $18,000. This ILS receiver, when integrated with VOR, is expected to be priced in the future at about $22,000.

The equipage cost also includes anticipated expenditures on avionics integration with the flight control system, a markup to cover airframe manufacturers' certification of new avionics suites for non-ILS architectures, and installation. Table 5-5 gives cost data separately for CAT II and CAT III equipages for air transport, and only CAT II cost data for commuter/air taxi and general aviation as the number of CAT III equipped aircraft among the latter two aircraft types are expected to be negligible.

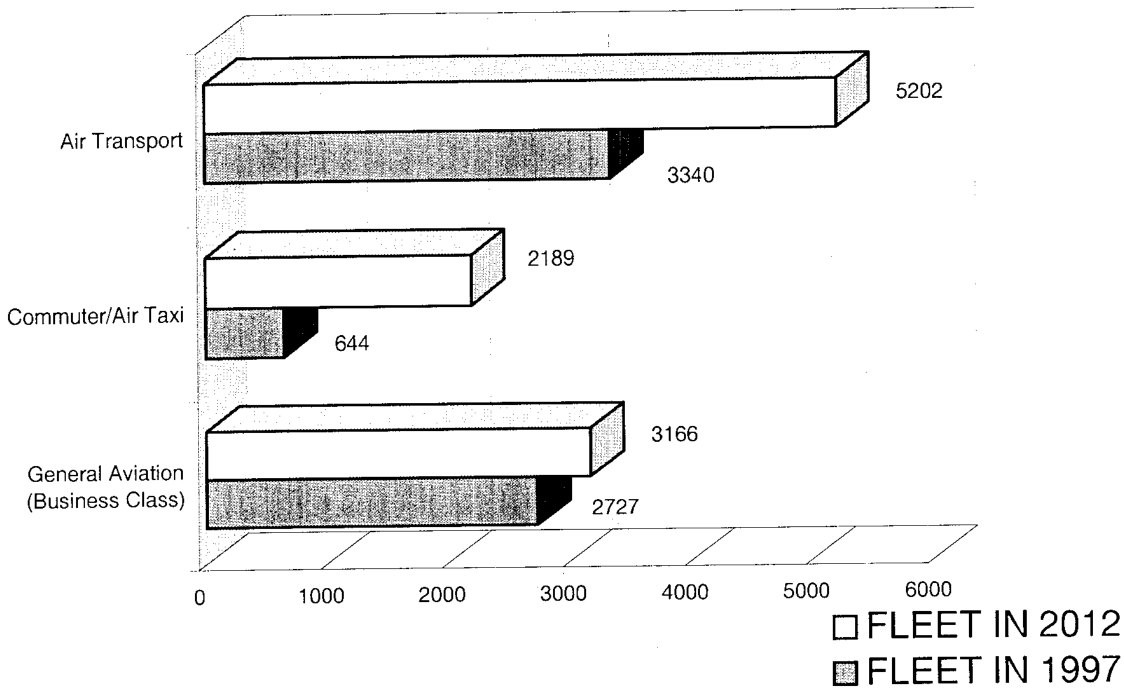

FIGURE 5-4. PROJECTED CAT II AND III FLEET SIZE

TABLE 5-5. CAT II AND III EQUIPAGE COST APPORTIONED TO LANDING PER AIRCRAFT (thousands of dollars)

ARCHITECTURE	AIR TRANSPORT		COMMUTER/ AIR TAXI		GENERAL AVIATION	
	CAT II	CAT III	CAT II	CAT III	CAT II	CAT III
Pseudolite Kinematic LAAS	$77	$ 81	$45	NA	$20	NA
Wide-Lane Kinematic LAAS	$83	$ 90	$48	NA	$24	NA
Code-Based LAAS	$77	$ 81	$45	NA	$20	NA
ILS	$95	$106	$50	NA	$18	NA
LAAS/GS	$96	$110	$59	NA	$32	NA

NA = Not Applicable.

Source: Aircraft Operators and Avionics Equipment Manufacturers.

For all aircraft types and across all categories of operations, as shown in Table 5-5, the LAAS/GS architecture will require the most expensive avionics suites, followed by ILS avionics cost (with the exception of general aviation). In contrast, the Pseudolite Kinematic LAAS and Code-Based LAAS architectures have the lowest avionics cost.

Table 5-6 shows the cost of the retrofit avionics suite per aircraft as apportioned to landing for each architecture.

TABLE 5-6. CAT II AND III RETROFIT COST APPORTIONED TO LANDING PER AIRCRAFT (thousands of dollars)

ARCHITECTURE	AIR TRANSPORT		COMMUTER/ AIR TAXI		GENERAL AVIATION	
	CAT II	CAT III	CAT II	CAT III	CAT II	CAT III
Pseudolite Kinematic LAAS	$20	$24	$ 9	NA	$ 7	NA
Wide-Lane Kinematic LAAS	$26	$33	$12	NA	$11	NA
Code-Based LAAS	$20	$24	$ 9	NA	$ 7	NA
ILS	$ 0	$ 0	$ 0	NA	$ 0	NA
LAAS/GS	$20	$24	$ 9	NA	$ 7	NA

NA = Not Applicable.

Source: Aircraft Operators and Avionics Equipment Manufacturers.

The retrofit avionics cost per aircraft apportioned to landing as shown in Table 5-6 is highest for the Wide-Lane Kinematic LAAS architecture for all user aircraft types and across all categories of operation. The costs for all other architectures are the same.

5.4 AVIONICS RECURRING COSTS

The major recurring cost relating to avionics is the periodic maintenance cost of components both on and off aircraft at repair depots or manufacturer repair facilities. The maintenance activity varies considerably among the airlines and also among the user aircraft types, such as commuter/air taxi and business class general aviation. Table 5-7 gives the avionics recurring cost per aircraft apportioned to landing on an annual basis. The estimates have been developed by deriving the ILS avionics recurring cost as a percentage of the new ILS avionics components cost and applying the same percentage rate to the raw avionics components cost of other architectures.

As shown in Table 5-7, for air transports, the annual avionics recurring cost for both CAT II- and III-equipped aircraft as apportioned to landing is the highest in the case of ILS architecture, and for commuter/air taxi and general aviation aircraft in the case of LAAS/GS architecture. In contrast, for the air transport and commuter/air taxi aircraft, the annual avionics recurring cost apportioned to landing is the lowest for the Pseudolite Kinematic and Code-Based LAAS architectures. For general aviation, the lowest cost is shown for the ILS architecture.

TABLE 5-7. AVIONICS RECURRING COST APPORTIONED TO LANDING PER AIRCRAFT (thousands of dollars)

ARCHITECTURE	AIR TRANSPORT		COMMUTER/ AIR TAXI		GENERAL AVIATION	
	CAT II	CAT III	CAT II	CAT III	CAT II	CAT III
Pseudolite Kinematic LAAS	$4.8	$5.0	$ 2.9	NA	$ 1.2	NA
Wide-Lane Kinematic LAAS	$5.2	$5.7	$ 3.1	NA	$ 1.5	NA
Code-Based LAAS	$4.8	$5.0	$ 2.9	NA	$ 1.2	NA
ILS	$6.2	$7.0	$ 3.2	NA	$ 1.1	NA
LAAS/GS	$5.9	$6.7	$ 3.6	NA	$ 1.9	NA

NA = Not Applicable.

Sources: (1) ILS estimates are from Aircraft Operators and Avionics Equipment Manufacturers.
(2) Non-ILS estimates have been derived based on the ILS estimates.

6. CAT II/III ARCHITECTURE BENEFITS

The architecture benefits include some or all of the following benefits depending on the architecture make-up: (1) the cost savings from executing complex approaches in the case of non-ILS architectures, (2) the costs foregone that accrue as gains for the non-ILS architectures from not continuing to implement the baseline ILS, (3) the differential gains in safety and disruptions achievable through runway upgrades in all PALS architectures (including ILS), and (4) the cost savings from a reduction in surface movement delays and accidents in the case of LAAS and hybrid architectures. The benefits are shared by the FAA, aircraft operators as users, and passengers. For each beneficiary group, the specific benefits have been classified as follows:

FAA Benefits

- ILS Non-recurring Equipment Costs Foregone for Newly Qualified Runways
- ILS Recurring Costs Foregone for All Runways

User Benefits

- Shortened Approach Cost Savings
- ILS Non-recurring Avionics Costs Foregone for New Additions to the Fleet
- ILS Recurring Avionics Costs Foregone for All Aircraft in the Fleet
- Cost Savings from Reduced Delays, Diversions, and Cancellations due to Runway Upgrades
- Cost Savings from Accidents Avoided due to Runway Upgrades
- Cost Savings from Reduced Surface Movement Delays
- Cost Savings from Reduced Surface Movement Accidents

Passenger Benefits

- Cost Savings from Reduced Delays, Diversions, and Cancellations due to Runway Upgrades
- Cost Savings from Fatalities and Injuries Avoided due to Runway Upgrades
- Cost Savings from Reduced Surface Movement Delays
- Cost Savings from Reduced Surface Movement Fatalities and Injuries

The above benefit categories indicate that benefits are generated as a result of an architectural change, a runway upgrade, or the ASTA system implementation. The architectural change benefits arise when future outlays on ILS are foregone and shortened approach cost savings are realized. The runway upgrade benefits flow from the lowering of minima which leads to reductions in weather-related disruptions, accidents, fatalities, and injuries. The ASTA system benefits accrue from enhanced safety and efficiency of operations through automation, such as target identification and position reporting, conflict alerts, and taxiway guidance in adverse weather conditions. The enhanced surface safety is expected to reduce the loss of life and aircraft equipment, and the enhanced surface efficiency to reduce taxi-out delays through improved aircraft departure processing. The algorithms and benefit values used in the valuation of these benefits are discussed below.

6.1 FAA BENEFITS ASSESSMENT

The FAA benefits represent ILS costs foregone as a result of an architectural change. The costs foregone includes all future non-recurring equipment and recurring O&M outlays on ILS. The benefit value of ILS non-recurring costs foregone is $2,488,916 as shown earlier in Table 5-2. The benefit value of ILS recurring costs foregone is $65,299 per CAT II/III runway and $47,748 per CAT I runway as shown in Table 5-3. The total benefit value of ILS non-recurring costs foregone has been assessed by multiplying the non-recurring ILS unit cost with the number of CAT I runways upgraded to CAT II or CAT III runways. Similarly, the total benefit value of ILS recurring O&M costs foregone has been estimated by multiplying the CAT I and CAT II/III O&M cost per runway with CAT I candidate LAAS and CAT II/III current and upgraded runways, respectively.

6.2 USER BENEFITS ASSESSMENT

The user benefits are derived from cost savings stemming from an architectural change, a runway upgrade, and ASTA system implementation. An architectural change leads to two types of user benefits: (1) cost savings from shortened approaches by executing complex approaches, and (2) ILS avionics costs foregone. The latter benefit includes both the non-recurring and recurring avionic costs forgone. A runway upgrade results in two types of user benefits: (1) cost savings from a reduction in weather-related flight disruptions, and (2) cost savings from a reduction in accidents based on lower probabilities of such accidents at lower landing minima. The ASTA system confers two types of benefits: (1) cost savings through a reduction in surface delays, and (2) cost savings through a reduction in surface accidents. The valuation of each benefit type is discussed below.

6.2.1 Shortened Approach Cost Savings

The cost savings from shortened approaches have been assessed for all user aircraft types: air transport, commuter/air taxi, and business class general aviation. As stated earlier, the savings have been attributed to only one-half of the projected instrument approaches for each user aircraft type, and that only 2 NM per instrument approach are saved during the final approach. The cost saving estimates are based on two critical values of landing speed and variable airborne operating cost. These values are shown in Table 6-1.

As Table 6-1 shows, the air transport landing speed differs from other user aircraft speeds by only a small margin of 25 kt. In contrast, the variable airborne operating cost for air transport aircraft type exceeds the other two aircraft types by $1,250 per hour. For the airline operators, therefore, the cost savings from shortened approaches can be significant as a result of an architecture change.

TABLE 6-1. USER AIRCRAFT LANDING SPEED AND VARIABLE OPERATING COST

USER AIRCRAFT	LANDING SPEED	VARIABLE AIRBORNE OPERATING COST PER HOUR
AIR TRANSPORT	145 kt	$2,150
COMMUTER/AIR TAXI	120 kt	$ 900
GENERAL AVIATION (BUSINESS CLASS)	120 kt	$ 900

Sources: FAA and Aircraft Operators.

6.2.2 ILS Avionics Cost Foregone

The benefit value of ILS avionics cost foregone is derived by applying part unit cost of ILS avionics suite apportioned to landing to the number of new aircraft added to the fleet of each user aircraft type, and by multiplying per aircraft ILS avionics maintenance cost apportioned to landing with the entire (old and new aircraft) fleet size. The former benefit value represents the ILS non-recurring costs foregone and the latter, the ILS recurring costs foregone. The unit value or per aircraft values used in the above computations are shown in Table 6-2.

TABLE 6-2. ILS AVIONICS NON-RECURRING AND RECURRING COSTS PER AIRCRAFT AS APPORTIONED TO LANDING (thousands of dollars)

ILS COST CATEGORY	AIR TRANSPORT		COMMUTER/ AIR TAXI		GENERAL AVIATION	
	CAT II	CAT III	CAT II	CAT III	CAT II	CAT III
NON-RECURRING	$95	$106	$ 50	NA	$ 18	NA
RECURRING	$6.2	$7.0	$ 3.2	NA	$ 1.1	NA

NA = Not Applicable

Source: Tables 5-5 and 5-7.

The total ILS avionics cost foregone, both non-recurring and recurring, represents a substantial benefit value for each non-ILS architecture (see Table 7-1).

6.2.3 Cost Savings from Reduced Flight Disruptions

The cost savings from reduced weather-related flight disruptions have been assessed only for the air transport user aircraft type. The savings have been estimated separately for the three types of disruptions: delays, diversions, and cancellations.

Upgrading a runway leads to a reduction in disruptions because of the extra landing capability afforded to the aircraft. Prior to the runway upgrade, a portion of the flights are either delayed, diverted, or canceled for lack of landing capability. By estimating the portion of such disrupted flights, the value of user benefits from reduced disruptions has been computed, based on the FAA critical values for block hour delay cost ($1,793) to derive the delay benefit, the industry estimate for passenger handling cost ($75) to estimate the diversion benefit, and industry estimate for passenger lodging cost ($45) to assess the cancellation benefit.

6.2.4 Cost Savings from Reduced Accidents

The valuation of benefits from reduced accidents is estimated by: (1) determining the differential in probable accidents expected in the pre- and post-runway upgrade states, and (2) applying critical values to the differential. The probable accident estimates are derived by applying the parameters of pre- and post-upgrade incidences of accidents (accident rates) to the projected precision instrument approaches. The former are based on a probabilistic model which uses historical data as input. In this model, the annual accident statistics for the period 1983 to 1993 and the corresponding annual precision instrument approaches have been used to compute a series of incidences of accidents for each user aircraft type. In the case of General Aviation, the incidence of accidents has been calculated for the entire aircraft group and this derived rate is then applied to the business class of General Aviation under the assumption that the rate is transferable. Since an accident can result in either destruction or damage to aircraft, overall incidences of

TABLE 6-3. CRITICAL VALUES AND INCIDENCES OF ACCIDENTS BY USER AIRCRAFT

USER AIRCRAFT	CRITICAL VALUES	CAT I*	CAT II*	CAT III*
AIR TRANSPORT:				
Destruction	$10,740,000	2.703 E-6	0	0
Substantial Damage	$ 1,400,000	1.351 E-6	4.601 E-6	1.0812 E-5
COMMUTER/AIR TAXI:				
Destruction	$ 413,000	3.1074 E-5	4.2314 E-5	7.4578 E-5
Substantial Damage	$ 58,000	1.8644 E-5	0	2.4859 E-5
GENERAL AVIATION:				
Destruction	$ 164,000	7.724 E-5	1.69036 E-4	1.98618 E-4
Substantial Damage	$ 26,000	4.4137 E-5	6.5736 E-5	1.32412 E-4

*Incidences are per precision instrument approach.

Sources:
(1) Critical Values from FAA.
(2) For rate derivation, accident data from National Transportation Safety Board and Annual Instrument Approaches from FAA, Statistical Handbook of Aviation, 1987 and 1992.

accidents were further broken into two related rates, one for the destruction of and another for the substantial damage to the aircraft. The critical values and the computed incidences of the latter are shown in Table 6-3.

Table 6-3 indicates that, for all user aircraft types, more aircraft are likely to be damaged under CAT III conditions than under CAT II or CAT I conditions. This is evident from the accident rates: highest under CAT III and lowest under CAT I conditions. The implication is that runway upgrades do not necessarily provide major user benefits by averting accidents.

6.2.5 Cost Savings from Reduced Surface Movement Delays

The airport surface movement delays are quite substantial in the taxi-out phase of flight. Estimates of taxi-out delay in 1993 vary from 6.9 minutes per flight to 8.7 minutes per operation.[15] Assuming that with the implementation of LAAS, precise target position measurements will be provided to the ASTA system as critical input in planning and controlling surface traffic movement, operational efficiency enhancements are expected in form of reduction in aircraft delays. In the most likely case, a reduction in taxi-out delay of 52 seconds per departure has been predicted in an FAA study.[16] This study applied the benefit parameter of 52-second delay reduction to the operations of 34 ASTA-qualified airports. To avoid double counting, the efficiency gain of 52 seconds taxi-out delay reduction has been applied in the present study to the departure operations of other 66 airports from a list of 100 airports that either currently qualify or are expected to qualify as CAT II and CAT III facilities during the LAAS equipment life cycle. The hours of expected delay reduction have then been converted to a benefit value by applying the FAA critical values or proxy values for variable operating costs per block hour of $1,502 for air carrier, $227 for commuter/air taxi, and $87 for general aviation aircraft types.

6.2.6 Cost Savings from Reduced Surface Movement Accidents

As in the case of efficiency improvements through reduced surface delays, the LAAS-derived precise target position measurements are expected to contribute crucial data to the ASTA system for target identification and position reporting, conflict alerts, and taxiway guidance in adverse weather conditions. The FAA study predicts 30% as the most likely estimate of additional safety benefit for the ASTA system.[17] For computing safety benefits of reduced aircraft surface accidents, the accident rates for different types of aircraft and damage sustained have been computed, based on the 1987-1994 historical data on surface accidents. These computed incidences of surface accidents involving aircraft and critical values are given in Table 6-4. To assess the benefit valuation of reduced surface accidents for each aircraft type and damage

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[15]See Bachu, op. cit.; Federal Aviation Administration, Office of System Capacity and Requirements, 1994 Aviation Capacity Enhancement Plan, DOT/FAA/ASC-94-1, Washington, D.C. 1994.

[16]Bachu, ibid.

[17]Ibid.

sustained, the itinerant operations for each type of aircraft are multiplied with the individual incidence of accident times the respective critical value. The sum of all computations gives the total benefit valuation of reduced surface accidents (see Table 7-1).

TABLE 6-4. CRITICAL VALUES AND INCIDENCES OF SURFACE ACCIDENTS INVOLVING AIRCRAFT

USER AIRCRAFT	CRITICAL VALUES	RATE*
AIR TRANSPORT:		
Total Destruction	$10,740,000	1.95939 E-8
Substantial Damage	$ 1, 400,000	2.36149 E-7
Minor Damage**	$ 700,000	2.36149 E-7
COMMUTER/AIR TAXI:		
Destruction	$ 413,000	2.04226 E-7
Substantial Damage	$ 58,000	5.10565 E-7
Minor Damage**	$ 29,000	0
GENERAL AVIATION:		
Total Destruction	$ 164,000	1.47087 E-7
Substantial Damage	$ 26,000	0
Minor Damage**	$ 13,000	0

*Rate is per aircraft type itinerant operation
**Critical value is half of Substantial Damage

Source: FAA

Table 6-4 indicates that the commuter/air taxi aircraft are more likely to sustain substantial damage than other aircraft, and the business class general aviation aircraft are likely to be totally destroyed in an accident rather than damaged.

6.3 PASSENGER BENEFITS ASSESSMENT

Passenger benefits arise from cost savings effects of runway upgrades, and ASTA system implementation. Two factors contribute to passenger cost saving benefits due to runway upgrade: (1) reduced flight disruptions through reduced delays, diversions, and cancellations, and (2) reduced injuries and fatalities. Similarly, two factors lead to passenger benefits on account of the ASTA system implementation: (1) reduced surface delays due to operational efficiency enhancements, and (2) reduced fatalities and injuries from safety enhancements. The valuation of these benefits are discussed below.

6.3.1 Cost Savings from Reduced Flight Disruptions

The passenger benefits from reduced flight disruptions are, as in the case of user benefits above, assessed for the air transport passengers only. Such benefits have been computed separately for delays, diversions, and cancellations.

The passenger benefits from reduced delays, diversions, and cancellations are, strictly speaking, the value of a certain portion of the passenger time that would have been lost prior to upgrade but whose loss is averted post upgrade. Thus, for the delay benefit, the value of averted delay time is estimated, and, for the diversion and cancellation benefits, the value of averted lost time from reduced diversions and cancellations is computed, respectively. For benefit valuation in each case, the critical value for the passenger time cost of $43.50 per hour has been applied.

6.3.2 Cost Savings from Reduced Fatalities and Injuries

In aircraft accidents, passengers either become fatalities or suffer from serious or minor injuries. By lowering the risk of accidents through runway upgrades, a reduction in the incidence of fatalities, or in serious or minor injuries is expected. As in the analysis of user cost savings from reduced accidents above, a series of such incidences have been computed from the annual statistics of fatalities, serious, and minor injuries for the period 1983 to 1993 and the corresponding annual precision instrument approaches which have been estimated from the AIAs. The incidences are listed along with critical values in Table 6-5.

TABLE 6-5. CRITICAL VALUES AND INCIDENCES OF FATALITIES AND INJURIES BY USER AIRCRAFT

USER AIRCRAFT	CRITICAL VALUES	CAT I*	CAT II*	CAT III*
AIR TRANSPORT:				
Fatalities	$2,600,000	1.87874E-4	0	0
Serious Injuries	$ 500,000	2.0274 E-5	0	1.08129E-5
Minor Injuries	$ 37,000	1.7571 E-5	4.6012 E-5	0
COMMUTER/AIR TAXI:				
Fatalities				
Serious Injuries	$2,600,000	6.8364 E-5	1.16363E-4	4.9719 E-5
Minor Injuries	$ 500,000	1.5537 E-5	6.3471 E-5	0
	$ 37,000	1.8645 E-5	4.2314 E-5	2.486 E-5
GENERAL AVIATION:				
Fatalities	$2,600,000	1.6 E-4	2.81727 E-4	2.64824 E-4
Serious Injuries	$ 500,000	2.4827 E-5	1.40863 E-4	1.32412 E-4
Minor Injuries	$ 37,000	1.6551 E-5	1.1269 E-4	2.64824 E-4

*Incidences are per precision instrument approach.

Sources: (1) Critical Values from FAA.
(2) For incidence rate derivation, accident data are taken from National Transportation Safety Board and AIAs from FAA, Statistical Handbook of Aviation, 1987 and 1992. The 1993 AIAs are linear projections.

In Table 6-5, the incidences of fatalities, serious injuries, and minor injuries do not show any trend. Some are high where they are expected be low and vice versa. For instance, the CAT III incidence of serious injuries for air transport should be lower than the CAT II value. But the former value is 1.08129 E-5 versus 0 for the latter. The implications of a mixed distribution of incidences is that passenger benefits will be lower than had the distribution followed the expected pattern of highs for CAT I and lows for CAT II rates or highs for CAT II and lows for CAT III rates.

6.3.3 Cost Savings from Reduced Surface Movement Delays

As in the case of user cost savings from reduced surface movement delays (section 6.2.5), the benefit valuation of passenger benefits of reduced aircraft surface delays is based on 66 out of 100 airports that are either currently or are expected to qualify as CAT II and CAT III airports. Using the ASTA system implementation benefit parameter of 52 seconds of taxi-out delay saving per instrument departure operation (as predicted in the FAA study referred to earlier), the total passenger benefit valuation is assessed based on computed delay hours saved times the critical value of the passenger time cost of $43.50.

6.3.4 Cost Savings from Reduced Surface Movement Fatalities and Injuries

The passenger benefit valuation of reduced aircraft surface accidents is also based on 66 airports out of 100 which either currently or are expected to qualify as CAT II and CAT III facilities. Since the surface aircraft-related fatalities and injuries statistics could not be separated for instrument and non-instrument operations, the incidence of fatalities and injuries have been developed per itinerant operation based on total itinerant operations. Similarly, the surface aircraft-related fatalities and injuries statistics could not be classified by aircraft types; hence, the same rate is assumed for all aircraft types. The passenger benefit valuation for each aircraft type is assessed by applying the incidence of fatalities or injuries to the total itinerant operations of that aircraft type times the respective critical value. The critical values and incidence of fatalities are given in Table 6-6.

TABLE 6-6. CRITICAL VALUES AND INCIDENCES OF SURFACE AIRCRAFT-RELATED FATALITIES AND INJURIES

SURFACE FATALITY/INJURY	CRITICAL VALUES	RATE*
Fatalities	$2,600,000	1.299772 E-7
Serious Injuries	$ 500,000	6.932100 E-8
Minor Injuries	$ 37,000	1.473075 E-7

*Rate is per itinerant operation

Source: FAA

Table 6-6 indicates the highest incidence for surface aircraft-related minor injuries, followed by fatalities. The lowest incidence is for serious injuries.

7. BENEFIT-COST RATIOS

The benefit-cost ratio is derived from aggregate present values of annual benefit and cost streams. The algorithms, item costs, and benefit values used in computing the streams were discussed earlier. This section gives the present values by major benefit and cost categories and discusses the B/C ratios.

7.1 TOTAL BENEFITS

The present value of total benefits for all architectures are shown in Table 7-1 where the total benefits have been distributed by five major benefits categories: (1) the ILS guidance system costs foregone, (2) the shortened approach, (3) the ILS avionics cost foregone, (4) the runway upgrade benefits, and (5) the aircraft surface movement automation savings.

TABLE 7-1. ARCHITECTURE TOTAL BENEFITS BY MAJOR CATEGORIES (millions of dollars)

ARCHITECTURE	ILS GUIDANCE SYS COST FOREGONE	SHORT-END APPROACH	ILS AVIONICS COST FOREGONE	RWY UPGRADE	SURFACE MOVEMENT SAVINGS	TOTAL
Pseudolite Kinematic LAAS	$299.5 (8.6)	$10.0 (0.3)	$621.7 (17.9)	$359.0 (10.4)	$2,174.0 (62.8)	$3,464.2 (100.0)
Wide-Lane LAAS	$299.5 (8.6)	$10.0 (0.3)	$621.7 (17.9)	$359.0 (10.4)	$2,174.0 (62.8)	$3,464.2 (100.0)
Code-Based LAAS	$299.5 (8.6)	$10.0 (0.3)	$621.7 (17.9)	$359.0 (10.4)	$2,174.0 (62.8)	$3,464.2 (100.0)
ILS	$0	$0	$0	$359.0 (100.0)	$0	$ 359.0 (100.0)
LAAS/GS	$299.5 (8.7)	$1.0 (0)	$621.7 (18.0)	$359.0 (10.4)	$2,174.0 (62.9)	$3,455.2 (100.0)

Note: Figures in parentheses are percentages.

Source: See Appendix A.

The benefit category of (aircraft) Surface Movement (automation) Savings is the highest contributor to the total benefit value of each architecture, except in the case of the ILS architecture. Table 7-1 shows that this category contributes a large share of about 63% to total benefits. In contrast, the ILS Avionics Cost Forgone adds only 18%, Runway Upgrade 10%, and

ILS Guidance System Cost Foregone about 9% to total benefits for the same architectures. The contribution by Shortened Path to total benefits is negligible.

7.2 TOTAL COSTS

The present value of total costs, as shown in Table 7-2, have been distributed across two major cost categories: the FAA landing system, and user avionics costs.

TABLE 7-2. ARCHITECTURE TOTAL COSTS BY MAJOR CATEGORIES (millions of dollars)

ARCHITECTURE	FAA LANDING SYSTEM COSTS	USER AVIONICS COSTS	TOTAL COSTS
Pseudolite Kinematic LAAS	$390.1 (40.7)	$567.7 (59.3)	$ 957.8 (100.0)
Wide-Lane Kinematic LAAS	$301.8 (31.9)	$644.7 (68.1)	$ 946.5 (100.0)
Code-Based LAAS	$293.2 (34.1)	$567.7 (65.9)	$ 860.9 (100.0)
ILS	$299.5 (32.5)	$621.7 (67.5)	$ 921.2 (100.0)
LAAS/GS	$300.8 (29.6)	$713.8 (70.4)	$1,014.6 (100.0)

Note: Figures in parentheses are percentages.

Source: See Appendix A.

User avionics is a major determinant of the architectural costs. As Table 7-2 shows, the share of avionics in total cost ranges from 59.3% for the Pseudolite Kinematic LAAS to 70.4% for the LAAS/GS architectures. The contribution of the FAA landing system costs to total costs varies from 29.6% to 40.7% for LAAS/GS and Pseudolite Kinematic architectures, respectively.

7.3 BENEFIT-COST RATIOS

Given the range of LAAS and alternative architectures that can provide future CAT II and CAT III services during a 15-year time horizon, a quantitative approach to evaluating the alternatives is to compare the benefit-cost ratios.

Table 7-3 gives the benefit and cost summary values and the B/C ratios of LAAS and alternative architectures, including the baseline ILS architecture. The detailed break-down of benefit and cost values are provided in Appendix A, where such values are shown in a table for each architecture.

TABLE 7-3. BENEFIT-COST RATIOS OF LAAS AND ALTERNATIVE ARCHITECTURES (millions of dollars)

ARCHITECTURE	BENEFIT VALUE	COST VALUE	B/C RATIO*
Pseudolite Kinematic LAAS	$3,464.2	$ 957.8	3.6
Wide-Lane Kinematic LAAS	$3,464.2	$ 946.5	3.7
Code-Based LAAS	$3,464.2	$ 860.9	4.0
ILS	$ 359.0	$ 921.2	0.4
LAAS/GS	$3,455.2	$1,014.6	3.4

*Per unit dollar total cost.

Table 7-3 shows that the Code-Based LAAS architecture has the highest B/C ratio of 4.0, the Wide-Lane Kinematic LAAS architecture ranks as the second highest with a B/C ratio of 3.7, followed by Pseudolite Kinematic LAAS architecture with 3.6, and LAAS/GS architecture with 3.4. The baseline ILS architecture has the lowest B/C ratio of 0.4. The ILS ratio is low because its benefit valuation of $359 million reflects the cost savings from runway upgrades only as cost savings from an architectural change and surface traffic movement automation benefits do not apply.

Figure 7-1 depicts the total benefit and cost values for all architectures, and Figure 7-2 gives the relative standing of architectures in terms of B/C ratios.

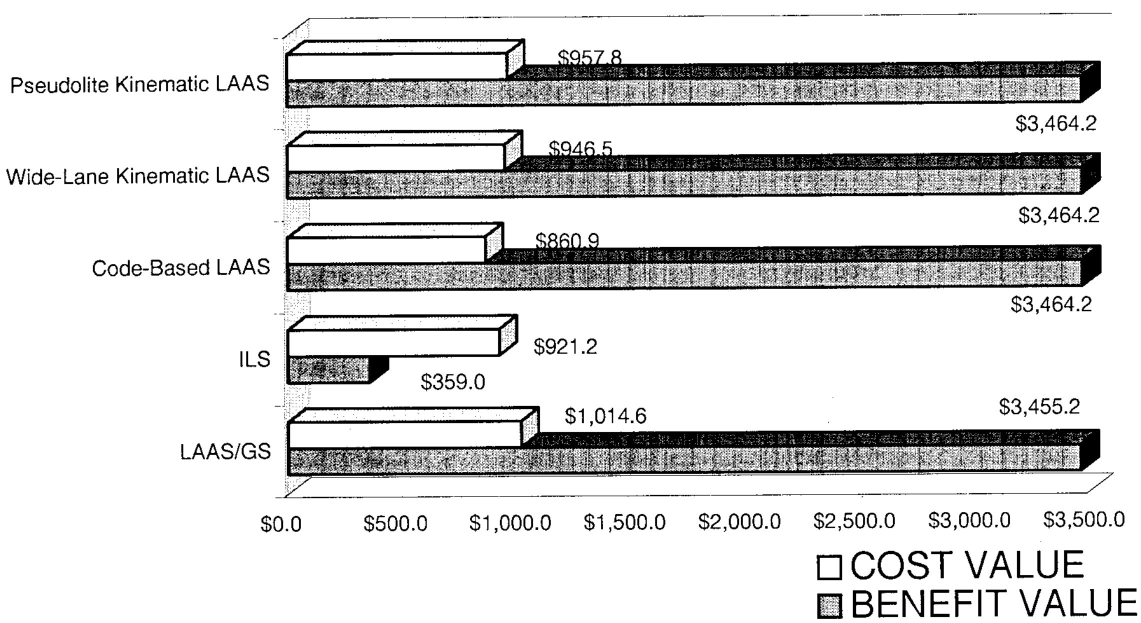

FIGURE 7-1. TOTAL BENEFIT AND COST VALUES OF LAAS AND ALTERNATIVE ARCHITECTURES (millions of dollars)

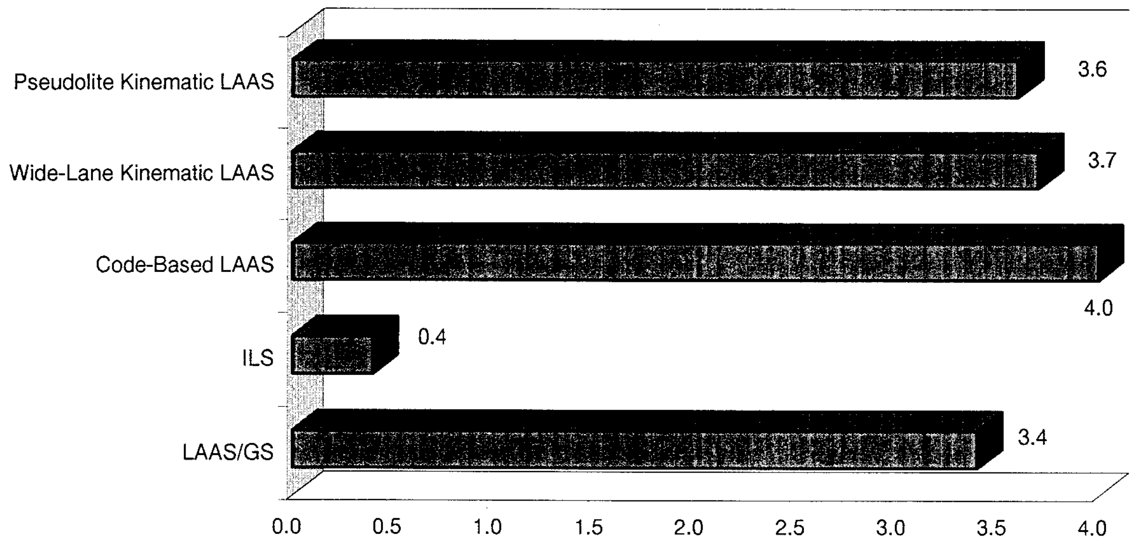

FIGURE 7-2. BENEFIT-COST RATIOS OF LAAS AND ALTERNATIVE ARCHITECTURES (per unit dollar total cost)

8. CONCLUSIONS

The FAA has proposed for review, five architectures for CAT II and III operations. They are: (1) Pseudolite Kinematic LAAS; (2) Wide-Lane Kinematic LAAS; (3) Code-based LAAS; (4) Instrument Landing System; and (5) LAAS and Glide Slope System.

As part of the FAA review process, a 15-year life cycle CBA of the proposed five architectures has been performed. The following conclusions emerge from the CBA:

1. The CAT II and III facilities are expected to expand by 52% from 66 facilities in the baseline year to 100 facilities at the end of the 15-year life cycle. The number of CAT II and III runways should increase by 108% from 79 in the baseline year to 164 runways during the same period.

2. The present value of the total ILS architecture cost is $921 million. In contrast, the present value of the total non-ILS architecture cost ranges from $861 million for Code-Based LAAS to $1,015 million for LAAS/GS architectures. The major element in the total cost of all architectures is user avionics whose contribution ranges from nearly six-tenths (59%) to seven-tenths (70%) of the total cost. On the other hand, the FAA landing systems contribute in the range of three-tenths (30%) to slightly above four-tenths (41%) to the total cost of the proposed architectures.

3. The present value of the total ILS architecture benefits is approximately $0.4 billion. The total benefits of a LAAS or hybrid LAAS/GS architecture is about $3.5 billion. In the case of the ILS architecture, the runway upgrades contribute 100% to its total benefits. In contrast, in the cases of LAAS and LAAS/GS architectures, the aircraft surface movement automation cost savings contribute more than six-tenths (63%), the ILS avionics cost foregone adds about two-tenths (18%), and the runway upgrades (10%) and ILS cost foregone (9%) each contribute about one-tenth to the total benefits. The contribution of the shortened approaches to total benefits is negligible.

4. The B/C ratio of the ILS architecture is only 0.4 per unit dollar total cost because the ILS architecture benefits are small. Moreover, the ILS does not contribute to the automation of airport surface traffic and, therefore, the ILS architecture derives no enhanced safety and efficiency benefits associated with the automation. In contrast, the LAAS and the hybrid LAAS/GS architectures provide the differential GPS navigation technology for automating the airport surface traffic control system and thus share in its benefits. Hence, their B/C ratios range from 3.4 for the LAAS/GS to 4.0 for Code-Based LAAS architectures.

In summary, the three LAAS and one hybrid LAAS/GS architectures show no disparity in benefits but significant variation in the B/C ratios. The variation is caused by disparities in the costs. In contrast, the ILS architecture shows far less benefits, depressing, in consequence, its B/C ratio.

Noting that the ILS is a dynamic architecture and not the usual baseline architecture in its frozen state, viewing it as a special case seems appropriate. Setting aside the B/C ratio as a yardstick and comparing instead the architectural costs, no special advantage accrues to the ILS architecture because the total cost of $921 million for ILS is not much different from the costs of other non-ILS architectures.

The choice of an architecture for the future is then limited to LAAS and the hybrid LAAS/GS architectures. Among them, the Code-Based LAAS architecture, in the final analysis, is the most prudent and cost-effective choice, with the highest B/C ratio of 4.0 per unit dollar total cost and the lowest architectural cost of $861 million.

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APPENDIX A

TABLE A-1
PSEUDOLITE KINEMATIC LAAS

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	998,684
2.1.2 CAT II Current Runways	450,331
2.1.3 CAT III Current Runways	176,166
2.1.4 CAT II Newly Qualified Runways	399,223
2.1.5 CAT III Newly Qualified Runways	7,994,117
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,464,218,673

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	20,000,000	20,000,000	40,000,000
1.2 CAT I System Production and Installation	18,029,542	--	--	18,029,542
1.3 CAT II/III System Production and Installation	--	57,083,414	152,111,063	209,194,477
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	22,508,994	--	--	22,508,994
2.2 CAT II/III System Operations and Maintenance	--	26,652,957	73,661,118	100,314,075
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	150,244,149	83,364,736	233,608,885
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	159,504,645	99,071,381	258,576,026
5. TOTAL COSTS	40,538,537	458,252,823	458,993,026	957,784,386
BENEFIT-COST RATIO	3.62			

TABLE A-2
WIDE-LANE KINEMATIC LAAS

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	998,684
2.1.2 CAT II Current Runways	450,331
2.1.3 CAT III Current Runways	176,166
2.1.4 CAT II Newly Qualified Runways	399,223
2.1.5 CAT III Newly Qualified Runways	7,994,117
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,464,218,673

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	15,000,000	15,000,000	30,000,000
1.2 CAT I System Production and Installation	6,466,626	--	--	6,466,626
1.3 CAT II/III System Production and Installation	--	46,189,013	119,849,288	166,038,301
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,394,611	--	--	17,394,611
2.2 CAT II/III System Operations and Maintenance	--	22,179,201	59,717,395	81,896,596
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	62,326,013	42,328,997	104,655,010
3.2 New Aircraft Equipage	--	163,896,912	92,627,484	256,524,396
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	174,015,424	109,509,963	283,525,387
5. TOTAL COSTS	23,861,237	483,606,563	439,033,127	946,500,927
BENEFIT-COST RATIO	3.66			

TABLE A-3
CODE-BASED LAAS

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	998,684
2.1.2 CAT II Current Runways	450,331
2.1.3 CAT III Current Runways	176,166
2.1.4 CAT II Newly Qualified Runways	399,223
2.1.5 CAT III Newly Qualified Runways	7,994,117
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,464,218,673

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	12,500,000	12,500,000	25,000,000
1.2 CAT I System Production and Installation	6,012,421	--	--	6,012,421
1.3 CAT II/III System Production and Installation	--	45,561,687	118,823,119	164,384,806
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,156,319	--	--	17,156,319
2.2 CAT II/III System Operations and Maintenance	--	21,759,091	58,842,734	80,601,825
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	150,244,149	83,364,736	233,608,885
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	159,504,645	99,071,381	258,576,026
5. TOTAL COSTS	23,168,740	434,337,230	403,386,698	860,892,668
BENEFIT-COST RATIO	4.02			

TABLE A-4
INSTRUMENT LANDING SYSTEM

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	0
1.1.5 CAT III Newly Qualified Runways	0
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	0
1.2.2 CAT II Current Runways	0
1.2.3 CAT III Current Runways	0
1.2.4 CAT II Newly Qualified Runways	0
1.2.5 CAT III Newly Qualified Runways	0
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	0
2.4.2 CAT III New Aircraft Equipage Cost	0
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	0
2.5.2 CAT III Operations and Maintenance Cost	0
2.6 Cost Savings from Reduced Surface Delays	0
2.7 Cost Savings from Reduced Surface Accidents	0
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	0
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	0
4. TOTAL BENEFITS	358,989,470

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	0	0	0
1.2 CAT I System Production and Installation	0	--	--	0
1.3 CAT II/III System Production and Installation	--	49,099,248	138,687,865	187,787,113
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	18,733,668	--	--	18,733,668
2.2 CAT II/III System Operations and Maintenance	--	23,727,367	69,316,569	93,043,936
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	0	0	0
3.2 New Aircraft Equipage	--	177,458,596	115,269,759	292,728,355
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	190,436,438	138,506,024	328,942,462
5. TOTAL COSTS	18,733,668	440,721,649	461,780,217	921,235,534

BENEFIT-COST RATIO 0.39

TABLE A-5
LAAS AND GLIDE SLOPE

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	998,684
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,455,198,836

COSTS	LIFE CYCLE TOTALS CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	12,500,000	12,500,000	25,000,000
1.2 CAT I System Production and Installation	6,012,421	--	--	6,012,421
1.3 CAT II/III System Production and Installation	--	50,880,823	133,847,774	184,728,597
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,272,163	--	--	17,272,163
2.2 CAT II/III System Operations and Maintenance	--	24,717,955	68,085,596	92,803,551
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	197,833,001	113,211,369	311,044,370
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	201,444,411	125,747,756	327,192,167
5. TOTAL COSTS	23,284,584	519,643,848	471,677,223	1,014,605,655
BENEFIT-COST RATIO	3.41			

APPENDIX B

B. SENSITIVITY ANALYSES

In performing the LAAS CBA, two key assumptions have been made about the LAAS architectures in their matured states. The first key assumption states that LAAS technology will enable aircraft to execute complex approaches and derive benefits of shortened path. In computing the benefits of the shortened path, the study used only half of all approaches as complex approaches. The second key assumption pertains to the LAAS/GS architecture, where LAAS provides lateral guidance, and Glide Slope vertical guidance. Implicit in this assumption is the belief that the LAAS technology may not meet the required integrity standards for the glide path (i.e., the total period of out-of-tolerance glide path shall not exceed 2 seconds), and the guidance system standards for continuity of service (i.e., the probability that LAAS will provide usable signals within the specified performance limits in any 30 seconds interval shall be 0.999998 or a maximum of 2 failures per million landings); hence, the need to complement LAAS with the ILS Glide Slope system.[18]

By relaxing these two key assumptions, their impact on B/C ratios can be gauged.

B.1 SHORTENED PATH BENEFITS NULLED

In Tables B-1 to B-5, the benefits of shortened path have been nulled. The results indicate a drop in the B/C ratios of one-hundredth of a point in all LAAS architecture tables. In other words, the nulling of shortened path benefits has, in effect, no impact on the B/C ratios.

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[18]See International Civil Aviation Organization, Aeronautical Telecommunications, op. cit. pp. 18 and 202. The 2 second interval set for allowable malfunction is for CAT II and III operations, and the 30 second interval set for the provision of usable signals is for CAT III operations.

TABLE B-1
PSEUDOLITE KINEMATIC LAAS (SHORTENED PATH EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,454,200,152

COSTS	LIFE CYCLE TOTALS CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	20,000,000	20,000,000	40,000,000
1.2 CAT I System Production and Installation	18,029,542	--	--	18,029,542
1.3 CAT II/III System Production and Installation	--	57,083,414	152,111,063	209,194,477
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	22,508,994	--	--	22,508,994
2.2 CAT II/III System Operations and Maintenance	--	26,652,957	73,661,118	100,314,075
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	150,244,149	83,364,736	233,608,885
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	159,504,645	99,071,381	258,576,026
5. TOTAL COSTS	40,538,537	458,252,823	458,993,026	957,784,386
BENEFIT-COST RATIO	3.61			

TABLE B-2
WIDE-LANE KINEMATIC LAAS (SHORTENED PATH EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,454,200,152

COSTS	LIFE CYCLE TOTALS			
	CAT I	CAT II	CAT III	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	15,000,000	15,000,000	30,000,000
1.2 CAT I System Production and Installation	6,466,626	--	--	6,466,626
1.3 CAT II/III System Production and Installation	--	46,189,013	119,849,288	166,038,301
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,394,611	--	--	17,394,611
2.2 CAT II/III System Operations and Maintenance	--	22,179,201	59,717,395	81,896,596
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	62,326,013	42,328,997	104,655,010
3.2 New Aircraft Equipage	--	163,896,912	92,627,484	256,524,396
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	174,015,424	109,509,963	283,525,387
5. TOTAL COSTS	23,861,237	483,606,563	439,033,127	946,500,927
BENEFIT-COST RATIO	3.65			

TABLE B-3
CODE-BASED LAAS (SHORTENED PATH EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,454,200,152

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	12,500,000	12,500,000	25,000,000
1.2 CAT I System Production and Installation	6,012,421	--	--	6,012,421
1.3 CAT II/III System Production and Installation	--	45,561,687	118,823,119	164,384,806
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,156,319	--	--	17,156,319
2.2 CAT II/III System Operations and Maintenance	--	21,759,091	58,842,734	80,601,825
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	150,244,149	83,364,736	233,608,885
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	159,504,645	99,071,381	258,576,026
5. TOTAL COSTS	23,168,740	434,337,230	403,386,698	860,892,668
BENEFIT-COST RATIO	4.01			

TABLE B-4
INSTRUMENT LANDING SYSTEM (SHORTENED PATH EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	0
1.1.5 CAT III Newly Qualified Runways	0
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	0
1.2.2 CAT II Current Runways	0
1.2.3 CAT III Current Runways	0
1.2.4 CAT II Newly Qualified Runways	0
1.2.5 CAT III Newly Qualified Runways	0
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	0
2.4.2 CAT III New Aircraft Equipage Cost	0
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	0
2.5.2 CAT III Operations and Maintenance Cost	0
2.6 Cost Savings from Reduced Surface Delays	0
2.7 Cost Savings from Reduced Surface Accidents	0
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	0
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	0
4. TOTAL BENEFITS	358,989,470

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	0	0	0
1.2 CAT I System Production and Installation	0	--	--	0
1.3 CAT II/III System Production and Installation	--	49,099,248	138,687,865	187,787,113
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	18,733,668	--	--	18,733,668
2.2 CAT II/III System Operations and Maintenance	--	23,727,367	69,316,569	93,043,936
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	0	0	0
3.2 New Aircraft Equipage	--	177,458,596	115,269,759	292,728,355
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	190,436,438	138,506,024	328,942,462
5. TOTAL COSTS	18,733,668	440,721,649	461,780,217	921,235,534

BENEFIT-COST RATIO 0.39

TABLE B-5
LAAS AND GLIDE SLOPE (SHORTENED PATH EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	0
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Reduced Surface Delays	539,244,018
2.7 Cost Savings from Reduced Surface Accidents	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Reduced Surface Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,454,200,152

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	12,500,000	12,500,000	25,000,000
1.2 CAT I System Production and Installation	6,012,421	--	--	6,012,421
1.3 CAT II/III System Production and Installation	--	50,880,823	133,847,774	184,728,597
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,272,163	--	--	17,272,163
2.2 CAT II/III System Operations and Maintenance	--	24,717,955	68,085,596	92,803,551
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	197,833,001	113,211,369	311,044,370
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	201,444,411	125,747,756	327,192,167
5. TOTAL COSTS	23,284,584	519,643,848	471,677,223	1,014,605,655
BENEFIT-COST RATIO	3.40			

B.2 EXCLUSION OF GLIDE SLOPE SYSTEM FROM LAAS/GS CAT II CONFIGURATION

A single table, Table B-6, shows the results of relaxing the basic assumption that Glide Slope system is a required element for CAT II operations in the LAAS/GS architecture. The new assumption specifies that LAAS by itself will achieve the performance standards for CAT II operations. The results indicate a significant increase in the B/C ratio from 3.4 to 3.7, an increase of 9% in the case of LAAS/GS architecture.

B.3 CONCLUSIONS

In conclusion, the sensitivity analyses show that, as far as the LAAS complex approaches are concerned, the B/C ratios of all LAAS architectures are not sensitive to the inclusion or exclusion of the shortened path benefits. In contrast, the B/C ratio of the LAAS/GS architecture shows particular sensitivity to the exclusion of Glide Slope system from the CAT II system configuration.

TABLE B-6
LAAS AND GLIDE SLOPE (CAT II GLIDE SLOPE EXCLUDED)

BENEFITS	LIFE CYCLE TOTALS
1. FAA BENEFITS	
1.1 ILS Non-recurring Equipment Cost Foregone	
1.1.1 CAT I Current Runways	0
1.1.2 CAT II Current Runways	0
1.1.3 CAT III Current Runways	0
1.1.4 CAT II Newly Qualified Runways	49,099,248
1.1.5 CAT III Newly Qualified Runways	138,687,865
1.2 ILS Recurring Cost Foregone	
1.2.1 CAT I Current Runways	18,733,668
1.2.2 CAT II Current Runways	10,110,539
1.2.3 CAT III Current Runways	2,378,949
1.2.4 CAT II Newly Qualified Runways	13,616,828
1.2.5 CAT III Newly Qualified Runways	66,937,620
2. USER BENEFITS	
2.1 Shortened Approach Cost Savings	
2.1.1 CAT I Current Runways	998,684
2.1.2 CAT II Current Runways	0
2.1.3 CAT III Current Runways	0
2.1.4 CAT II Newly Qualified Runways	0
2.1.5 CAT III Newly Qualified Runways	0
2.2 Cost Savings from Reduced Delays, Diversions, and Cancellations	
2.2.1 CAT II Newly Qualified Runways	972,269
2.2.2 CAT III Newly Qualified Runways	34,166,883
2.3 Cost Savings from Accidents Avoided	
2.3.1 CAT II Newly Qualified Runways	974,398
2.3.2 CAT III Newly Qualified Runways	12,616,108
2.4 ILS Non-recurring Avionics Cost Foregone	
2.4.1 CAT II New Aircraft Equipage Cost	177,458,596
2.4.2 CAT III New Aircraft Equipage Cost	115,269,759
2.5 ILS Recurring Avionics Cost Foregone	
2.5.1 CAT II Operations and Maintenance Cost	190,436,438
2.5.2 CAT III Operations and Maintenance Cost	138,506,024
2.6 Cost Savings from Surface Reduced Delays	539,244,018
2.7 Cost Savings from Surface Guidance Reduced	10,345,763
3. PASSENGER BENEFITS	
3.1 Cost Savings from Reduced Delays, Diversions, and Cancellations	
3.1.1 CAT II Newly Qualified Runways	3,743,103
3.1.2 CAT III Newly Qualified Runways	113,109,593
3.2 Cost Savings from Fatalities/Injuries Avoided	
3.2.1 CAT II Newly Qualified Runways	17,332,648
3.2.2 CAT III Newly Qualified Runways	176,074,468
3.3 Cost Savings from Surface Reduced Delays	1,610,777,671
3.4 Cost Savings from Surface Fatalities/Injuries Avoided	13,607,695
4. TOTAL BENEFITS	3,455,198,836

COSTS	LIFE CYCLE TOTALS			
	CATI	CATII	CATIII	TOTAL
1. FAA LANDING SYSTEM NON-RECURRING COSTS				
1.1 CAT II/III Research and Development	--	10,000,000	12,500,000	22,500,000
1.2 CAT I System Production and Installation	6,012,421	--	--	6,012,421
1.3 CAT II/III System Production and Installation	--	45,561,689	133,847,774	179,409,463
2. FAA LANDING SYSTEM RECURRING COSTS				
2.1 CAT I System Operations and Maintenance	17,272,163	--	--	17,272,163
2.2 CAT II/III System Operations and Maintenance	--	21,759,090	68,085,596	89,844,686
3. USER AVIONICS NON-RECURRING COSTS				
3.1 Fleet Retrofit	--	44,767,658	30,784,728	75,552,386
3.2 New Aircraft Equipage	--	142,010,595	113,211,369	255,221,964
4. USER AVIONICS RECURRING COSTS				
4.1 Operations and Maintenance	--	157,918,867	125,747,756	283,666,623
5. TOTAL COSTS	23,284,584	422,017,900	484,177,223	929,479,707
BENEFIT-COST RATIO	3.72			