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INSTALLATION CRITERIA FOR THE APPROACH LIGHTING SYSTEM IMPROVEM--ETC(U)
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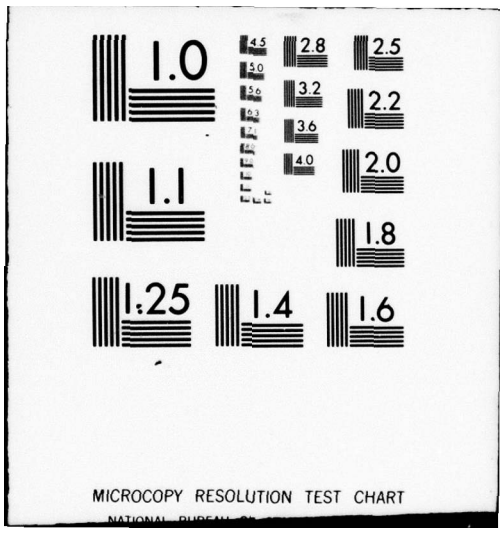
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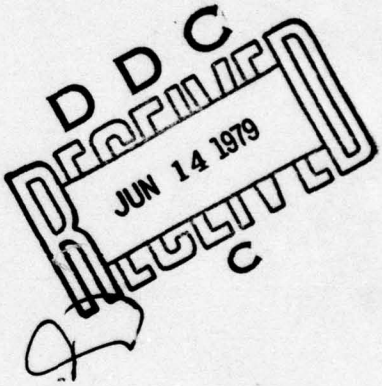
Report No. FAA-ASP-78-5

LEVEL II

INSTALLATION CRITERIA FOR THE APPROACH LIGHTING SYSTEM IMPROVEMENT PROGRAM (ALSIP)



November 1978

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16. Abstract

This report develops investment criteria for retrofit of runway approach lighting systems under the Approach Lighting System Improvement Program (ALSIP). A major component of this program is the retrofit of existing rigid light support structures with frangible mountings. Other aspects include conversion of high-intensity lighting systems to more energy-efficient configurations.

There are 397 approach lighting systems eligible for retrofit under the ALSI Program. The cost of modifying these systems is $77.7 million.

Criteria are developed by benefit-versus-cost analysis. Each lighting system under ALSIP will be evaluated using the appropriate benefit/cost (B/C) formula. All systems will be ranked by order of B/C ratio. Implementation of the program will continue within approved funding levels in accordance with the criteria ranking.

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EXECUTIVE SUMMARY

This report develops economic investment criteria for frangible approach light structures installed as part of the Approach Lighting System Improvement Program (ALSIP).

Criteria are empirically derived from a benefit-versus-cost (B/C) evaluation of each of three ALSIP subprogram elements:

- Convert existing ALSF-2 (and ALSF-1's designated for ALSF-2 conversion) to low-impact resistant switchable ALSF-2.
- Convert ALSF-1 (not designated for ALSF-2 conversion) to low-impact resistant MALSR.
- Convert rigid MALSR to low-impact resistant MALSR.

Benefits considered are enhanced safety due to frangibility of new light support structures, reduction in maintenance requirements, and savings due to energy conservation where appropriate.

All rigid approach lighting systems are to be ranked for system implementation according to benefit/cost ratio by using the appropriate formula, below.

For rigid ALSF-2 retrofit to switchable low-impact ALSF-2:

$$\frac{\text{Annual Air Carrier Operations on Candidate Runway} \times 14.59 + 52{,}700}{\text{Washington + Region Cost}} = \text{B/C Ratio Value}$$

For rigid ALSF-1 retrofit to low-impact MALSR:

$$\frac{\text{Annual Air Carrier Operations on Candidate Runway} \times 14.59 + 132{,}900}{\text{Washington + Region Cost}} = \text{B/C Ratio Value}$$

For rigid MALSR retrofit to low-impact MALSR:

$$\frac{\text{Annual Air Carrier Operations on Candidate Runway} \times 14.59}{\text{Washington + Region Cost}} = \text{B/C Ratio Value}$$

Benefit/cost criteria will be used to determine the priority of specific locations for retrofit of frangible approach lighting towers, subject to hardware and personnel constraints. Implementation of the program will continue within approved funding levels in accordance with the application of the criteria. When completed, all 397 rigid light towers will be retrofitted at a cost of $77.7 million.

I. INTRODUCTION AND PURPOSE

The purpose of this study is to provide F&E investment criteria for the Approach Lighting System Improvement Program (ALSIP), previously known as the Low-Impact Resistant (LIR) Retrofit Program. Criteria are developed from a survey of the costs of providing the improved light system, a detailed analysis of aircraft accidents involving non-frangible approach light structures, and examination of maintenance requirement reductions and energy savings. The investment standards, which are empirically derived from a benefit-versus-cost analysis, will determine the priority of all locations for retrofit of frangible approach light towers.

FAA Order 6850.9, Revised Approach Lighting Criteria, dated 4/9/75, calls for the installation of frangible structures with all new systems. The order goes on to state that a frangible retrofit program will be considered in future budgets for all presently commissioned facilities when standards and criteria have been developed.

In 1976 when the FAA's Agency Review Board (ARB) was reviewing the FY 1978 Facilities and Equipment budget, they approved a retrofit program for $5.2 million. (The funding was later cut to $4.0 million.) Consistent with the requirement in Order 6850.9 for criteria development, the ARB directed that benefit/cost criteria be developed for the frangible tower retrofit program prior to inclusion in future budgets. ALSIP criteria developed in the study will provide the guidance mandated by the agency for future F&E budget considerations.

In June 1978 the Department of Transportation's Transportation System Acquisition Review Council (TSARC) approved funding of the entire ALSI Program. Under the program, 397 rigid approach light systems will be retrofitted at a cost of $77.7 million. Funding will be approved within each budget year for locations on a priority basis. The implementation priority will be decided by ordering on benefit/cost values.

II. ALSIP COSTS AND PROGRAM DESCRIPTION

The ALSI Program can be segmented into three independent subprograms. It is the intent of this study to develop criteria for each. A comprehensive description of each ALS and associated procurement costs can be found in an Airway Facilities Service Acquisition Paper entitled "Acquisition

Paper for the Retrofit of Approach Lighting Systems with Low-Impact Resistant Light Support Structures."

The total ALSIP cost is $77.7 million. The funding breakdown is currently planned as follows:

FY 77 (assigned)	$ 3.3 million
FY 78 (assigned)	4.0
FY 79	6.0
FY 80-86 ($8.0 million/year)	56.0
FY 87	8.4
	$77.7 million

The description and funding requirements for each subprogram are outlined below.

A. Subprogram I. Convert existing ALSF-2 (and ALSF-1's designated for ALSF-2 conversion) to low-impact resistant (LIR) switchable ALSF-2. The switching feature could convert an ALSF-2 configuration to an SSALR configuration (Simplified Short Approach Lighting System with Runway Alignment Indicator Lights) when weather ceiling and visibility permit.

Program cost for 70 systems = $35.3 million @ $503,900/unit

Washington office furnished equipment	$288,900
Regional engineering and construction	175,000
Removal of old equipment	40,000
Total Unit Cost	$503,900

B. Subprogram II. Convert ALSF-1 (not designated for ALSF-2 conversion) to LIR MALSR.

Program cost for 197 systems = $28.5 million @ $144,700/unit

Washington office furnished equipment	$ 32,200
Regional engineering and construction	72,500
Removal of old equipment	40,000
Total Unit Cost	$144,700

C. Subprogram III. Convert nonfrangible MALSR to LIR MALSR.

Program cost for 130 systems = $13.9 million @ $107,100/unit

Washington office furnished equipment	$ 25,900
Regional engineering and construction	68,700
Removal of old equipment	12,500
Total Unit Cost	$107,100

III. ALSIP PAYOFFS

The ALSI Program is designed to reduce hazards to aircraft departing and arriving the airport approach area, reduce energy consumption, and reduce maintenance requirements at selected ALS runways. Hazard reduction is the primary payoff or benefit while maintenance and energy savings are of secondary importance. The following material is principally taken from the Airway Facilities Service Acquisition Paper on the LIR Program.

A. Hazard Reduction. In terms of the overall program, the reduction of hazards to arriving and departing aircraft is solely attributable to the frangible nature of the ALS. If struck by an aircraft, the light structure is designed to yield without causing major structural damage or loss of aircraft control. The structure is designed not to yield or break when subject to high winds, ice, or other normal meteorological or environmental conditions. Hazard reduction (i.e., safety enhancement) is a common element to all three ALSIP subprogram elements.

B. Energy Conservation. Besides being the lowest cost system in the ALS inventory, medium-intensity approach light systems (MALS) are the least energy-intensive. Coupled with RAILS (or Runway Alignment Indicator Lights), an MALS forms an MALSR configuration. The MALSR is required to provide the basic approach guidance for Category I landing minimums. Replacing ALSF-1 systems on Category I runways with MALSR systems provides a potential energy saving of 89 percent, or 190,000 kilowatt hours per year per system. Accrued benefits here are directly attributable to Subprogram II, as identified on page 2.

There are also energy conservation savings attributable to Subprogram I elements. The latest standard design of the ALSF-2 is more energy-efficient. While a full panoply of lights is required for landings conducted in weather with ceilings below 200 feet or visibility of less than 1/2 mile (Category II), the SSALR configuration using less than half the lights is perfectly adequate for all higher visibility conditions that predominate. The decision to replace existing ALSF-2 (and ALSF-1's designated for ALSF-2 conversion) with switchable ALSF-2 configuration will produce an energy saving of approximately 43 percent, or 138,700 kilowatt hours per year per system.

C. Maintenance Savings. While a saving in staffing is not, by itself, an objective of the program, a saving will result from the conversion of existing ALSF-1 facilities to the MALSR configuration. An ALSF-1 requires approximately 0.77 man-years for maintenance, while an MALSR requires only 0.35. Thus, a saving of 0.42 man-years/year is realized for each conversion of an ALSF-1 to MALSR (Subprogram II). It is not anticipated that any separation of personnel would result from these savings, but the effort saved could avoid staffing increases that might otherwise be required. The possibility of a long-term reduction in Airway Facilities Service staffing is not considered in the analysis.

IV. SAFETY ANALYSIS

Statistical Data on Aircraft Striking ALS Structures

An Office of Aviation Systems Plans report entitled "Retrofit Frangible Towers Program Study," dated July 19, 1977, documented the historical costs associated with aircraft damage and injury to occupants for air carrier and general aviation aircraft which struck approach light structures. The following material is taken primarily from that report:

A. Review of Accidents. Based on a review of (1) NTSB briefs of U.S. air carrier accidents for the years 1966-1975, (2) FAA accident/incident reports, and (3) NTSB accident investigation files and reports, it has been established that 12 air carrier accidents involving aircraft striking ALS structures occurred in the United States during the period 1966-1976. However, three of these accidents involved the aircraft first striking the ILS localizer, and consequently these accidents were not included in this study. A number of incidents (i.e.,

an aircraft occurrence which is not classified as an accident and in which a hazard or potential hazard to safety is involved) were identified in which the air carrier aircraft struck ALS structures, but these also were not included in this study.

FAA and NTSB records were also reviewed to determine general aviation accidents which involved aircraft striking nonfrangible ALS structures. This review, which only covered a five-year period, identified 10 such general aviation accidents that occurred during 1972 to 1976.

The accidents considered in this study are listed in Tables 1 and 2 along with data on the type of aircraft, extent and costs of damage, and the number and imputed costs of fatalities and injuries. Also, a brief resume of each accident is set forth in Appendix A.

B. Cost Factors. The cost of the accidents identified in this study was quantified in dollars consistent with previous studies conducted by the Office of Aviation System Plans to determine the effectiveness of FAA National Aviation System safety programs. The values used are as follows:

1. Air carrier aircraft

a. Destroyed - The average selling price of an identical make and model used aircraft in the year of the accident.

b. Substantial damage - One-third of the cost of a replacement aircraft.

c. Minor damage - No monetary value assigned.

2. General aviation aircraft

a. Destroyed - General aviation aircraft were first categorized by size, and through a computer process, the average age of destroyed aircraft in each category was determined annually and a representative value assigned.

b. Substantial damage - One-third of the cost of a replacement aircraft.

c. Minor damage - No monetary value assigned.

TABLE 1

Air Carrier Accidents

No.	Date	Location	Aircraft Data			Injuries					Total Cost (Millions)
			Type	Damage	Cost (Millions)	F	S	M	N	Cost (Millions)	
A-1	11/02/66	Jamaica, N.Y. (LGA)	B-727	Substantial	3.48	---	---	---	75	-----	3.48
A-2	11/29/66	New Cumberland, Pa.	CV-340	Substantial	0.18	---	---	---	16	-----	0.18
A-3	06/03/68	Jamaica, N.Y. (LGA)	B-727	Substantial	3.23	---	1	3	98	0.06	3.29
A-4	07/30/71	San Francisco, Calif.	B-747-121	Substantial	9.31	---	10	19	180	0.56	9.87
A-5	12/12/72	Jamaica, N.Y. (JFK)	B-707-331	Substantial	3.11	---	---	---	3	-----	3.11
A-6	11/27/73	Chattanooga, Tenn.	DC-9-32	Demolished	5.04	---	4	38	37	0.41	5.45
A-7	12/17/73	Boston, Mass.	DC-10-30	Substantial	8.40	---	3	13	151	0.21	8.61
A-8	06/24/75	Jamaica, N.Y. (JFK)	B-727-225	Demolished	6.61	112	12	---	---	34.14	40.75
A-9	11/16/76	Denver, Colo.	DC-9-10	Demolished	4.10	---	---	9	76	0.05	4.15
				Totals	43.46	112	30	82	636	35.43	78.89

TABLE 2

General Aviation Accidents

No.	Date	Location	Aircraft Data			Injuries					Total Cost (Millions)
			Type	Damage	Cost (Millions)	F	S	M	N	Cost (Millions)	
G-1	01/12/72	Greer, S.C.	C-172	Substantial	0.008	---	2	---	---	0.090	0.098
G-2	09/06/72	Ft. Benning, Ga.	AA-1A	Substantial	0.007	---	---	---	1	-----	0.007
G-3	08/01/73	Oshkosh, Wisc.	BD-5J	Substantial	0.009	---	---	---	1	-----	0.009
G-4	10/19/73	Cheyenne, Wyo.	PA-20	Substantial	0.003	---	---	---	2	-----	0.003
G-5	10/22/73	Anchorage, Alas.	C-150	Substantial	0.002	---	---	---	1	-----	0.002
G-6	08/19/74	Lake Jackson, Tex.	BE-88-55	Substantial	0.022	---	---	---	1	-----	0.022
G-7	06/14/75	Watertown, S.D.	NA-265-80	Substantial	0.323	---	3	---	3	0.135	0.458
G-8	06/29/75	New Cumberland, Pa.	PA-28-140	Demolished	0.022	---	1	---	---	0.045	0.067
G-9	09/03/75	Orlando, Fla.	PA-28-140	Substantial	0.007	---	---	---	1	-----	0.007
G-10	09/06/75	Hyannis, Mass.	BE-95-A55	Demolished	0.040	3	---	---	---	0.900	0.940
				Totals	0.443	3	6	---	10	1.170	1.613

3. Value of human life - The economic loss of human life was selected to be $300,000. This value was arrived at by projection of five years of non-Warsaw actual settlements. This figure has also been previously used by the agency in its facility criteria studies.

4. Cost of injury

a. Serious injury - A value of $45,000 was used for each serious injury. This value was also based on a projection of five years of non-Warsaw actual settlements.

b. Minor injury - A value of $6,000 was used for each minor injury.

Based on the above figures, the total historical cost of the accidents considered in this study is $80.5 million. Of this amount, approximately half was accounted for by one accident (the Eastern Airlines Flight 66 accident at J. F. Kennedy in 1975), while two other air carrier accidents accounted for another 23 percent of the total.

The complete ALSIP retrofit program costs $77.7 million. Although accident costs exceed ALS retrofit costs, this alone is not a sufficient basis for program approval. The reason is that not all ALSI Program elements may prove economic when considered separately. The problem reduces to determining the crossover point--the point at which ALS retrofit becomes advantageous for the Federal Government to fund. Maximum ALSIP cost-effectiveness can be achieved by retrofitting only those structures which satisfy economic criteria on a site-by-site basis.

C. Benefit Quantification. FAA's National Flight Data Center (NFDC) provided most of the data required for the ALS safety analysis. Using the NFDC computer file, runways having rigid ALS structures were isolated. Air carrier and general aviation (including air taxi) operations on the subset of ALS runways were computed by applying the runway activity distribution factors published in Order 7031.2B, Airway Planning Standard Number One, paragraph 16. Base-year activity data was FY 1976. Historical (1966-1976) aviation activity data were obtained from the FAA's Aviation Forecast series. The data, appearing in Table 3, are used to determine accident rate statistics.

TABLE 3

Operations on ALS Runways
(in millions)

Fiscal Year	Air Carrier	General Aviation Including Air Taxi*
1966	2.5	
1967	2.9	
1968	4.0	
1969	4.9	
1970	5.1	
1971	5.0	
1972	4.9	12.6
1973	5.3	13.7
1974	5.3	16.1
1975	5.6	18.0
1976	5.7	20.3
	51.2 million	80.7 million

*1966-71 activity data not required for general aviation accident analysis

Pre-1976 activity on ALS runways was adjusted downward because only half of the current ALS inventory was operational in 1966.

The accident rate, as defined in this study, is the number of accidents in which an aircraft struck a rigid ALS resulting in either significant structural damage or injury to occupants divided by the total operations at runways having nonfrangible ALS's.

The accident rate is simply the probability of an aircraft striking a rigid ALS. Because of the nature of and availability of data, two discrete probability figures can be discerned--one for air carrier and one for general aviation including air taxi accidents. The average or expected accident value per aircraft operation can then be computed by multiplying the probability of an accident (i.e., accident rate) by the average damage sustained by impacting rigid approach light structures.

Over the period of study, there were 9 air carrier and 10 general aviation accidents in which substantial damage resulted by the aircraft striking rigid ALS's. As documented in Tables 1 and 2, the total accident costs are $78.89 million and $1.61 million, respectively. The average cost per air carrier accident is then $78.89 million divided by 9, or $8.77 million/accident. The average cost for a typical general aviation accident is $1.61 million divided by 10, or $0.16 million/accident.

The accident rates for air carrier and general aviation are derived by dividing the number of accidents by total operations conducted on ALS runways (Table 3).

For air carrier: 9 accidents in 51.2×10^6 operations

or $.18 \times 10^{-6}$ accidents/operation

For general aviation: 10 accidents in 80.7×10^6 operations

or $.12 \times 10^{-6}$ accidents/operation

The average safety benefit per operation is as follows:

For air carrier: $.18 \times 10^{-6}$ accident/operation x

$\$8.77 \times 10^6$/accident = $1.58/operation

For general aviation: $.12 \times 10^{-6}$ accident/operation x

$\$0.16 \times 10^6$/accident = $0.02/operation

Values used in the computation of present worth costs and benefits are based upon a 10 percent annual rate of return over a 15-year economic life. These parameters are consistent with OMB guidelines and with previous economic studies published by the Office of Aviation System Plans.

A discount factor of 7.605 is used to compute aviation payoffs and recurring O&M costs over the 15-year

frame. This factor is increased in proportion to expected aviation growth for benefits that vary with activity levels--i.e., safety. For expected safety payoffs, discounted growth factors of 9.237 and 10.833 are used for air carrier and general aviation, respectively. These factors are derived in Table 4.

The 15-year discounted values can be applied to the average air carrier and general aviation safety benefits per operation to compute the discounted safety benefits per operation, as follows:

For air carrier: $1.58/operation x 9.237 =

$14.59/operation (discounted)

For general aviation (including air taxi): $0.02/operation x 10.833 =

$0.22/operation (discounted)

Accident costs are assumed totally attributable to the lack of frangible light structures. This assumption allows all possible consideration to the safety benefit of retrofitting rigid ALS with low-impact resistant supports--the classic risk avoidance argument for benefit assessment. This approach typically overstates ALSIP safety payoffs; however, there are two conclusions that can be inferred:

- No additional safety benefit enhancement is possible as all accidents have already been included in the analysis.
- Investment guidelines, empirically derived from the economic analysis, describe the "worst-case situation."

Discounted Growth Factors

Year After Funding	Discount Factor	Growth Factor		Discounted Growth Factor	
		Air Carrier	General Aviation	Air Carrier	General Aviation
1	0.9091	1.04	1.08	0.945	0.982
2	0.8264	1.06	1.14	0.876	0.942
3	0.7513	1.10	1.19	0.826	0.894
4	0.6830	1.13	1.27	0.772	0.820
5	0.6209	1.17	1.35	0.726	0.838
6	0.5645	1.19	1.45	0.672	0.819
7	0.5132	1.23	1.51	0.631	0.775
8	0.4665	1.26	1.58	0.588	0.737
9	0.4241	1.30	1.64	0.551	0.696
10	0.3855	1.34	1.69	0.517	0.651
11	0.3505	1.38	1.75	0.484	0.613
12	0.3186	1.42	1.82	0.452	0.580
13	0.2897	1.47	1.85	0.426	0.536
14	0.2633	1.52	1.88	0.400	0.495
15	0.2394	1.55	1.90	0.371	0.455
	7.605			9.237	10.833

V. MAINTENANCE SAVINGS QUANTIFICATION

A potential saving in maintenance expenses can be realized from conversion of each existing ALSF light system to the MALSR configuration. An ALSF-1 requires approximately 0.77 man-years for maintenance, while an MALSR requires only 0.35. This means that a net saving of 0.42 man-years is possible for each ALSF-1 to MALSR conversion. While reductions in personnel are not expected, existing staff might become increasingly available for other Airway Facilities Service requirements without hiring additional personnel. Costed at $19,000 per year, each 0.42 man-year saving per system amounts to $19,000 x .42, or $7,980 annual savings per system; 15-year discounted savings are then:

$7,980 x 7.605 = $60,688 per system

Remember that this maintenance saving refers only to high-intensity to medium-intensity system retrofit. There are no maintenance savings anticipated under the remaining two portions of the ALSI Program (MALSR to MALSR and ALSF-2 to ALSF-2).

VI. ENERGY CONSERVATION QUANTIFICATION

This benefit category applies to high-intensity (ALSF-1) retrofit to medium-intensity (MALSR) and to modification of existing ALSF-2 systems to switchable SSALR.

The medium-intensity approach light system has inherent virtues. Besides being the lowest cost system in the approach light inventory, it also consumes the least amount of energy, while still providing the basis approach guidance required for Category I landing minimums. Replacing ALSF-1 systems on Category I runways with MALSR systems provides a potential energy saving of 84 percent or 190,000 kilowatt hours per year per system. At 5¢ per kilowatt hour, the annual saving is $9,500. This estimate is based upon 12-hour/day operation at the medium-intensity setting.

The latest standard design of the ALSF-2 is more energy-efficient than former systems. While a full panoply of lights is required for landings conducted in weather with ceilings below 200 feet and visibility less than 1/2 mile

(Category II, the SSALR configuration, using less than half the lights, is adequate for all higher visibility conditions. Thus the decision to replace existing ALSF-2's and ALSF-1's designated for ALSF-2 conversion with switchable ALSF-2 configuration will produce an energy saving of approximately 43 percent or 138,700 kilowatt hour per year. Again, this assumes 12-hour/day operation at the middle step intensity setting. Annual savings per system amount to $6,935.

Recapping, per-site annual energy benefits are:

For ALSF-1 to MALSR:

$0.05/kwh x 190,000 kwh =

$9,500 x 7.605 = $72,248 (discounted)

For ALSF-2 to switchable ALSF-2 (SSALR):

$0.05/kwh x 138,700 kwh =

$6,935 x 7.605 = $52,741 (discounted)

VII. DERIVATION OF INVESTMENT GUIDELINES

The development of investment guidelines for replacement of existing approach light systems involve assessing the relative costs and benefits of each of the three ALSIP subprograms:

- ALSF-2 to switchable ALSF-2/SSALR
- ALSF-1 to frangible MALSR
- MALSR to frangible MALSR

The approach will be to consider nonactivity-related maintenance and energy savings apart from safety benefits which are activity-dependent. A benefit-versus-cost relationship can then be developed based upon air traffic counts. The benefit/cost formulae use air carrier activity for safety benefit computations. Each operation is costed at $14.59 (discounted dollars) for benefit computations.

Payoffs attributable to general aviation activity are considered negligible and are not addressed in the benefit/cost calculation. Evaluation of the potential safety benefits of general aviation results in a 22-cent per operation payoff, or 1.5 percent of the value of an air carrier operation.

There may be isolated circumstances, however, where the level of general aviation activity is significant to influence the benefit/cost computation. The following expression, when added to the numerator of the benefit/cost ratio, will enable calculation of total safety benefits for air carrier and general aviation aircraft:

$$\text{Annual general aviation airport operations} \times \text{\% general aviation usage on candidate runway} \times 0.22$$

It will be evident from discussion following that general aviation safety payoffs provide little impact on benefit/cost ratio values. For this reason, and to keep computation complexity to a minimum, general aviation benefits have been deleted from formulae appearing in Airway Planning Standard Number One. It is emphasized, however, that the user does have the option of inserting and computing the above expression if the volume and type of traffic warrant general aviation consideration.

The remainder of the section describes both benefit/cost and activity formulae for each ALSIP subprogram. Activity formulae may be used in lieu of the benefit/cost equations when per-site installation costs are not available. These formulae will yield ratio values nearly identical to the benefit/cost values when ALS retrofit costs are close to those listed in this report. As per-site costs diverge from average values, the correlation of ratio values between activity and benefit/cost formulae decreases. Nevertheless, activity formulae are useful for purposes of long-range budget planning.

Activity formulae are derived by subtracting discounted maintenance savings and energy conservation benefits whenever applicable from nonrecurring ALS installation costs (discounted using a 1.0 factor). The difference yields the amount of safety payoffs necessary to be commensurate with facility

costs. Since the safety payoff per operation has been computed previously, the requisite operations for ALS retrofit can then be calculated by simple arithmetic.

A. Subprogram I (ALSF-2 to switchable ALSF-2/SSALR) (70 systems).

Program cost/system	$503,900
Energy savings (discounted)	-52,700
Maintenance savings	0
Net cost	$451,200

Safety benefits (discounted) = $14.59/air carrier operation

= $0.22/general aviation operation

Runway operations required to justify net costs:

For air carrier:	30,925
For general aviation (including air taxi):	2,050,000

In the absence of air carrier activity, general aviation activity requirements are clearly infeasible for this subprogram.

Activity Criteria (to be used when per-site retrofit costs have not yet been determined)

$$\frac{\text{Annual airport air carrier operations}}{31{,}000} \times \text{Fraction air carrier usage on candidate runway*} = \text{Ratio value}$$

*See Part D of this section on recommended runway usage factors in absence of specific data.

Benefit/Cost Criteria

$$\frac{\text{Air carrier safety + ALS energy benefits}}{\text{F\&E cost}} = \text{B/C ratio}$$

or

$$\frac{\text{Air carrier airport operations} \times \text{Fraction air carrier usage on candidate runway} \times 14.59 + 52{,}700}{\text{Washington + regional F\&E cost}} = \text{B/C ratio}$$

B. Subprogram II (ALSF-1 to MALSR) (197 systems).

Program cost/system	$144,700
Energy savings (discounted)	-72,200
Maintenance savings	-60,700
Net cost	$ 11,800

Safety benefits (discounted) = $14.59/air carrier operation

= $0.22/general aviation operation

Runway operations required to justify net costs:

For air carrier: 809

For general aviation: 53,636

Activity Criteria (to be used when per-site retrofit costs have not yet been determined).

$$\frac{\text{Annual airport air carrier operations}}{800} \times \text{Fraction air carrier usage on candidate runway} = \text{Ratio value}$$

Benefit/Cost Criteria

$$\frac{\text{Air carrier Safety} + \text{ALS Energy} + \text{ALS Maintenance Benefits}}{\text{F\&E Cost}} = \text{B/C ratio}$$

or

$$\frac{\text{Air carrier airport operations} \times \text{Fraction air carrier usage on candidate runway} \times 14.59 + 132{,}900}{\text{Washington + regional F\&E cost}}$$

C. Subprogram III (MALSR to low-impact resistant MALSR) (130 systems).

Program cost/system	$107,100
Energy savings	0
Maintenance savings	0
Net cost	$107,000

Safety benefits (discounted) = $14.59/air carrier operation
= $0.22/general aviation operation

Runway operations required to justify average net costs:

For air carrier:	7,341
For general aviation (includes air taxi):	486,818

In the absence of air carrier activity, general aviation activity requirements are judged infeasible for this subprogram.

Activity Criteria (to be used when per-site retrofit costs have not yet been determined).

$$\frac{\text{Annual airport air carrier operations}}{7{,}300} \times \text{Fraction air carrier usage on candidate runway} = \text{Ratio value}$$

Benefit/Cost Criteria

$$\frac{\text{Air carrier safety benefits}}{\text{F\&E cost}} = \text{B/C ratio}$$

or

$$\frac{\text{Air carrier airport operations} \times \text{Fraction air carrier usage on candidate runway} \times 14.59}{\text{Washington + regional F\&E cost}} = \text{B/C ratio}$$

D. Note on Runway Utilization. Air carrier usage on the candidate runway is the fraction of current activity which departs or lands over the particular rigid approach lighting system. For runways having rigid ALS's at each end, runway usage fraction should include all air carrier activity at both arrival and departure ends.

If runway utilization is not known or cannot be otherwise estimated, it is suggested that the following values (consistent with previous ILS criteria studies) be used:

Primary ALS runway	60% air carrier usage
Secondary ALS runway	30% air carrier usage
Tertiary and subsequent ALS runways	15% air carrier usage

VIII. IMPACT ASSESSMENT - FY 1978 PROPOSED LOCATIONS

The preliminary FY 1980 budget originally contained 178 proposed runways for possible approach lighting system retrofit under ALSIP. Three ALSIP budget blocks are listed:

- Provide frangible towers - ALS/ALSF (25 sites)
- Provide frangible towers - MALSR (149 sites)
- Provide frangible towers - MALS (4 sites)

The latest FY 1980 budget proposal, using ALSIP criteria evaluation and ranking, is as follows:

Validated Projects	
Provide frangible ALS/ALSF	11 sites at $ 5,204,100
Provide frangible MALSR	51 sites at $ 7,341,100
Totals	62 sites at $12,545,200
Validated Projects Moved to FY 1979	
Provide frangible MALSR	11 sites at $ 1,727,800
Cut Due to Funding Limitations	
Provide frangible ALS/ALSF	14 sites at $ 6,425,700
Provide frangible MALSR	77 sites at $11,926,300
Provide frangible MALS	2 sites at $ 151,200
Totals	93 sites at $18,503,200

Nonvalidated Projects*	
Provide frangible MALSR	10 sites at $ 1,987,200
Provide frangible MALS	2 sites at $ 158,000
Totals	12 sites at $ 2,145,200

*Nonvalidated due to U.S. Air Force objections. The Air Force recommends that only full-length ALS's be employed at all joint-use fields used by high-performance military aircraft. As a result, LIR retrofit of ALSF systems to MALSR or MALS is a nonvalidated budget item in FY 1980.

All runways budgeted in FY 1980 for ALSI retrofit have benefit/cost ratios of 1.0 or greater. Full descriptions of place names and associated costs for the proposed FY 1980 ALSI Program are found in Tables 5 through 8. Locations are listed by priority order within each region as determined by FAA's Flight Standards Service and the Office of Aviation System Plans.

IX. ECONOMIC ASSESSMENT - COMPLETE ALSI PROGRAM

The previous section described the effects of applying ALSIP criteria to the FY 1980 FAA budget proposal. This section illustrates the economic impact for the total ALSI Program.

Runways listed for frangible retrofit in the initial FY 1978 and FY 1979 FAA budget proposals were also evaluated using the criteria developed in this study. It was found that many duplicate runways appeared in subsequent budget submissions. For these cases, only the last year of request was retained, eliminating the possibility of double counting identical ALSIP requests. In all, some 400 ALS runways were assessed for retrofit using FY 1977 air traffic activity and current cost estimates.

ALSIP economic assessment was obtained by merging the results of each budget request, 1978 to 1980. The results of applying benefit/cost evaluation to all potential ALS retrofit projects are as follows:

TABLE 5

Validated ALSIP Projects
FY 1980 Budget Proposal

Region	Airport/Runway	Unit Cost	Cumulative Cost
	Provide Frangible ALS/ALSF		
Southwest	Dallas/Ft. Worth R/W 17L ALSF-2 TX	391.3	391.3
Rocky Mountain	Salt Lake City R/W 34L UT	503.0	894.3
Great Lakes	Indianapolis R/W 04L ALSF-1 IN	539.8	1,434.1
Southern	Nashville R/W 02L TN	403.4	1,837.5
Eastern	New York JFK R/W 13L NY	620.5	2,458.0
Southwest	Houston R/W 08 TX	391.3	2,849.3
Southwest	San Antonio R/W 12R ALSF-2 TX	391.3	3,240.6
Western	San Francisco R/W 28R CA	443.4	3,684.0
Eastern	Buffalo R/W 23 NY	626.7	4,310.7
Western	Los Angeles R/W 24R CA	440.0	4,750.7
Western	San Francisco R/W 28L CA	453.4	5,204.1
	Number = 11		
	Provide Frangible MALSR		
Western	Santa Ana R/W 19R CA	108.9	108.9
Southwest	Austin R/W 30L TX	123.3	232.2
New England	Boston R/W 33L MA	132.7	364.9
Northwest	Seattle R/W 13R WA	144.2	509.1
Southwest	Little Rock R/W 04 AR	123.3	632.4
Northwest	Yakima R/W 27WA	157.8	790.2
New England	Hyannis R/W 24 MA	183.4	973.6
Western	Bakersfield R/W 30R CA	187.7	1,161.3
Southwest	Beaumont R/W 11 TX	123.3	1,284.6

TABLE 5

(Continued)

Region	Airport/Runway	Unit Cost	Cumulative Cost
New England	Nantucket R/W 24 MA	202.4	1,487.0
Southwest	Houston R/W 04 TX	123.3	1,610.3
Northwest	Pendleton R/W 25R OR	163.0	1,773.3
Western	Los Angeles R/W 25R CA	195.7	1,969.0
New England	Burlington R/W 15 VT	283.5	2,252,5
Northwest	Salem R/W 31 OR	122.0	2,374.5
Southwest	Tulsa R/W 17L OK	123.3	2,497.8
Southwest	Amarillo R/W 03 TX	123.3	2,621.1
Northwest	Medford R/W 14 OR	142.7	2,763.8
Western	Ontario R/W 25 CA	206.8	2,970.6
Southwest	Shreveport R/W 13 LA	123.3	3,093.9
Southern	St. Petersburg R/W 17 FL	139.3	3,233.2
Northwest	Eugene R/W 16 OR	160.5	3,393.7
Western	Burbank R/W 07 CA	197.8	3,591.5
Northwest	Moses Lake R/W 32R WA	173.1	3,764.6
Southwest	Tyler R/W 13 TX	123.3	3,887.9
Northwest	Klamath Falls R/W 32 OR	173.7	4,061.6
Southwest	Corpus Christi R/W 13 TX	123.3	4,184.9
Southwest	Monroe R/W 04 LA	123.3	4,308.2
Western	Arcata R/W 31 CA	189.9	4,498.1
Southwest	Wichita Falls R/W 33L TX	123.3	4,621.4
Western	Monterey R/W 10 CA	186.4	4,807.8
Southwest	Dallas R/W 13L TX	123.3	4,931.1
Western	San Francisco R/W 19L CA	135.3	5,066.4
Southwest	Dallas R/W 31L TX	123.3	5,189.7
Western	Long Beach R/W 30 CA	169.9	5,359.6
Southwest	Longview R/W 13 TX	123.3	5,482.9
Southwest	Lake Charles R/W 15 LA	123.3	5,606.2
Southwest	Abilene R/W 35R TX	123.3	5,729.5

TABLE 5

(Continued)

Region	Airport/Runway	Unit Cost	Cumulative Cost
Southwest	San Angelo R/W 03 TX	123.3	5,852.8
Southwest	Waco R/W 19 TX	123.3	5,976.1
Southwest	El Paso R/W 22 TX	123.3	6,099.4
Southwest	Laredo T/W 17C TX	123.3	6,222.7
Southwest	Dallas/Fort Worth R/W 35R TX	123.3	6,346.0
Southwest	Dallas/Fort Worth R/W 35L TX	123.3	6,469.3
Southwest	Dallas/Fort Worth R/W 17R TX	123.3	6,592.6
Central	Burlington R/W 36 IA	85.8	6,678.4
Western	Phoenix R/W 08R AZ	92.2	6,770.6
Rocky Mountain	Cheyenne R/W 26 WY	157.2	6,927.8
Southern	Nashville R/W 31 TN	97.3	7,025.1
Alaskan	Bethel R/W 18 AK	221.4	7,246.5
Western	Ontario R/W 07L CA	94.6	7,341.1

Number = 51

TABLE 6

Validated ALSIP Projects
Moved to FY 1979 Budget

Region	Airport/Runway	Unit Cost	Cumulative Cost
	Provide Frangible MALSR		
Southern	Mobile R/W 32 AL	105.3	105.3
Southwest	Corpus Christi R/W 35 TX	115.6	220.9
Southwest	Alexandria R/W 26 LA	115.6	336.5
Great Lakes	Rochester R/W 31 MN	142.5	479.0
Central	Kansas City R/W 01 MO	133.3	612.3
Great Lakes	Flint R/W 09 MI	136.6	748.9
Eastern	New York JFK R/W 22L NY	245.6	994.5
Eastern	Ithica R/W 32 NY	152.3	1,146.8
Eastern	Lancaster R/W 08 PA	179.0	1,325.8
Eastern	Charlottesville R/W 03 VA	194.5	1,520.3
Eastern	Johnstown R/W 33 PA	207.5	1,727.8
	Number = 11		

TABLE 7

ALSIP Projects Cut Due to Funding Limitations

Region	Airport/Runway	Unit Cost	Cumulative Cost
	Provide Frangible ALS/ALSF		
Northwest	Portland R/W 10R OR	154.3	154.3
Southern	Columbia R/W 11 SC	420.5	574.8
Eastern	Pittsburgh R/W 10L PA	587.6	1,162.4
Alaskan	Fairbanks R/W 01L ALSF-2 AK	654.8	1,817.2
Southern	Augusta R/W 35 GA	411.6	2,228.8
Western	Sacramento R/W 16 ALSF-2 CA	465.4	2,694.2
Eastern	Syracuse R/W 28 NY	545.2	3,239.4
Southern	Louisville R/W 01 KY	443.6	3,683.0
Southern	Huntsville R/W 18R AL	465.6	4,148.6
Southern	Chattanooga R/W 20 TN	518.4	4,667.0
Southwest	New Orleans R/W 10 LA	416.0	5,083.0
Southern	Birmingham R/W 05 AL	484.0	5,567.0
Western	Oakland R/W 29 CA	467.4	6,034.4
Southwest	Oklahoma City R/W 35R ALSF-2 OK	391.3	6,425.7
	Number = 14		
	Provide Frangible MALSR		
Eastern	La Guardia R/W 04 NY	212.5	212.5
Eastern	Buffalo R/W 05 NY	228.9	441.4
Eastern	Baltimore R/W 15R MD	254.2	695.6
Eastern	La Guardia R/W 13 NY	262.3	957.9
New England	Westfield R/W 20 MA	150.8	1,108.7

TABLE 7

(Continued)

Region	Airport/Runway	Unit Cost	Cumulative Cost
Southern	Montgomery R/W 27 AL	84.7	1,193.4
Central	St. Louis R/W 30L MO	85.8	1,279.2
Eastern	Chantilly R/W 19 VA	86.5	1,365.7
Central	Wichita R/W 01R KS	181.4	1,547.1
Southwest	Oklahoma City R/W 17R OK	115.6	1,662.7
Southwest	Oklahoma City R/W 17L OK	115.6	1,778.3
Central	Cedar Rapids R/W 08 IA	133.3	1,911.6
Southwest	Shreveport R/W 31 LA	115.6	2,027.2
Central	Waterloo R/W 12 IA	133.3	2,160.5
Central	Springfield R/W 01 MO	133.3	2,293.8
Central	Topeka R/W 13 KS	133.3	2,427.1
Central	Kansas City R/W 09 MO	85.8	2,512.9
Eastern	Newark R/W 04L NJ	203.3	2,716.2
Central	Ottumwa R/W 31 IA	85.8	2,802.0
Eastern	Norfolk R/W 05 VA	200.1	3,002.1
Eastern	Jamestown R/W 25 NY	391.9	3,394.0
Central	Cape Girardeau R/W 10 MO	85.8	3,479.8
Eastern	Wilmington R/W 01 DE	217.1	3,696.9
Eastern	Middletown R/W 13 PA	192.9	3,889.8
Eastern	Allegheny R/W 27 PA	263.9	4,153.7
Eastern	Rochester R/W 28 NY	222.2	4,375.9
Eastern	Erie R/W 06 PA	206.2	4,582.1
Eastern	Roanoke R/W 33 VA	240.3	4,822.4
Eastern	Harrisburg R/W 08 PA	219.0	5,041.4
Eastern	Huntington R/W 12 WV	219.3	5,260.7
Eastern	Utica R/W 33 NY	188.5	5,449.2
Eastern	Lynchburg R/W 03 VA	195.2	5,644.4

TABLE 7

(Continued)

Region	Airport/Runway	Unit Cost	Cumulative Cost
Eastern	Newport News R/W 06 VA	205.4	5,849.8
Central	Scottsbluff R/W 30 NB	85.8	5,935.6
Central	Dubuque R/W 31 IA	85.8	6,021.4
Central	Mason City R/W 35 IA	85.8	6,107.2
Central	Columbia R/W 02 MO	85.8	6,193.0
Eastern	Saranac Lake R/W 23 NY	91.4	6,284.4
Great Lakes	Eau Claire R/W 22 WI	95.4	6,379.8
Southern	Augusta R/W 17 GA	99.8	6,479.6
Eastern	North Philadelphia R/W 24 PA	100.1	6,579.7
Eastern	Hagerstown R/W 27 MD	104.2	6,683.9
Eastern	Glens Falls R/W 01 NY	104.7	6,788.6
Great Lakes	Traverse City R/W 28 MI	109.1	6,897.7
Great Lakes	Cleveland Cuy. R/W 23 OH	109.1	7,006.8
Great Lakes	Bloomington R/W 35 IN	109.1	7,115.9
Western	Crescent City R/W 11 CA	110.2	7,226.1
Northwest	Bremerton R/W 19 WA	112.7	7,338.8
Southwest	Temple R/W 15 TX	115.6	7,454.4
Southwest	College Station R/W 34 TX	115.6	7,570.0
Southwest	Brownsville R/W 13R TX	115.6	7,685.6
Southwest	Fort Worth R/W 16L TX	115.6	7,801.2
Southwest	Hot Springs R/W 05 OK	115.6	7,916.8
Southwest	Lawton R/W 35 OK	115.6	8,032.4
Southwest	McAllen R/W 13TX	115.6	8,148.0
Southwest	Texarkana R/W 22 AR	115.6	8,263.6
Southern	Jackson R/W 33L MS	119.6	8,383.2
Northwest	Twin Falls R/W 25 WA	128.2	8,511.4
Central	Grand Island R/W 35 NB	133.3	8,644.7
Central	Sioux City R/W 31 IA	133.3	8,778.0

TABLE 7

(Continued)

Region	Airport/Runway	Unit Cost	Cumulative Cost
Great Lakes	Duluth R/W 27 MN	137.7	8,915.7
Eastern	Dublin R/W 06 VA	141.1	9,056.8
Eastern	Trenton R/W 06 NJ	141.7	9,198.5
Great Lakes	Cincinnati R/W 20L OH	150.7	9,349.2
New England	Keene R/W 02 NH	170.8	9,520.0
New England	Presque Isle R/W 01 ME	176.7	9,696.7
Eastern	Clarksburg R/W 21 WV	180.7	9,877.4
New England	Rockland R/W 03 ME	182.4	10,059.8
New England	Worcester R/W 11 MA	193.1	10,252.9
Eastern	Staunton R/W 04 VA	193.2	10,446.1
Alaskan	Ft. Yukon R/W 21 AK	197.2	10,643.3
Alaskan	Yakutat R/W 11 AK	203.0	10,846.3
Eastern	Morgantown R/W 18 WV	213.0	11,059.3
New England	Manchester R/W 35 NH	223.1	11,282.4
Alaskan	Nome R/W 27 AK	272.4	11,554.8
Northwest	Walla Walla R/W 20 WA	173.7	11,728.5
Eastern	Teterboro R/W 06 NJ	197.8	11,926.3
	Number = 77		
	Provide Frangible MALS		
Southwest	San Antonio R/W 03 TX	75.6	75.6
Southwest	Fayetteville R/W 16 AR	75.6	151.2
	Number = 2		

TABLE 8

Nonvalidated ALSIP Projects
FY 1980 Budget Proposal

Region	Airport/Runway	Unit Cost	Cumulative Cost
	Provide Frangible MALSR		
Rocky Mountain	Fargo R/W 35 ND	157.2	157.2
Western	Fresno R/W 29R CA	205.3	362.5
Northwest	Portland R/W 10R OR	410.3	772.8
Western	Reno R/W 16 NV	186.8	959.6
Southwest	Fort Smith R/W 25 AR	123.3	1,082.9
Rocky Mountain	Great Falls R/W 34 MT	147.2	1,230.1
Central	St. Louis R/W 24 MO	181.4	1,411.5
Central	Des Moines R/W 30R IA	181.4	1,592.9
Eastern	Niagara Falls R/W 28R NY	193.3	1,786.2
Eastern	Richmond R/W 06 VA	201.0	1,987.2
	Number = 10		
	Provide Frangible MALS		
Central	St. Louis R/W 06 MO	79.0	79.0
Central	Des Moines R/W 12L IA	79.0	158.0

Subprogram	Potential Number of Systems	Estimated Number Having B/C Ratios of 1.0 or Greater
ALSF-2 to switchable LIR ALSF-2	70	30
ALSF-1 to LIR MALSR	197	197
MALSR to LIR MALSR	130	45
Total	397	272

Projects having benefit/cost ratios equalling or exceeding unity amount to $48.4 million (which is some $30 million below the total program cost of $77.7 million).

APPENDIX A

Resumes of Air Carrier and General Aviation Accidents

The following resumes have been prepared on the basis of information contained in NTSB and FAA official accident reports and files.

AIR CARRIER

A-1 Date of Accident: November 2, 1966

Resume: During an ILS approach, the aircraft encountered heavy rain showers which obscured the airport. The aircraft struck the ALS pier located 120 feet (36m) short of the runway. The impact sheared the landing gear and the aircraft skidded down the runway.

A-2 Date of Accident: November 29, 1966

Resume: The aircraft aborted takeoff and continued off the end of the runway approximately 580 feet (176m). After leaving the runway, the pilot purposely turned the aircraft slightly to the right to avoid the approach light stanchions "to keep from being washed out," but the left wing contacted a pole and the aircraft came to a stop.

A-3 Date of Accident: June 3, 1968

Resume: During an instrument approach, the aircraft struck six approach light structures beginning approximately 700 feet (213m) from the runway threshold. Several of the 12"x10" timbers supporting the lights were broken off and punctured the cabin floor and were found embedded in the left wheel well and in two of the engines. The fuselage contained a 16"x8" (40cm x 20cm) piece of wood. The left main gear was torn off, and the right main gear separated on landing.

A-4 Date of Accident: July 30, 1971

Resume: During takeoff, the aircraft's right main body gear struck the lights of the first platform of the ALS. The left body gear struck each of the first three light platforms, and the underside of the fuselage came in contact with the handrail and walkway just past the third platform. Three pieces of angle iron (mainly the steel handrail sections) penetrated the passenger compartment. One section pierced the floor, passed through two seats (nearly severing the leg of one passenger and severely lacerating and crushing the upper arm of the other passenger), and then exited through the fuselage. A second piece of angle iron 17 feet (5.18m) in length penetrated the floor of the cabin and impaled four seats, but no injuries resulted as the seats were unoccupied. A third section penetrated the passenger cabin and passed through other unoccupied seats and lavatories. Other wood debris and metal pieces of the ALS struck the inboard section of the wing flaps, the horizontal stabilizer, and the elevators. Three of the four hydraulic systems failed immediately thereafter.

The aircraft continued in flight for 1 hour and 45 minutes while the flight crew assessed the structural damage and dumped fuel. The aircraft returned for a landing at San Francisco, touched down hard on the runway, and subsequently veered off the runway. During the aircraft evacuation, 27 other passengers were injured with 8 of these suffering serious back injuries.

A-5 Date of Accident: December 12, 1972

Resume: The flight had been conducting an autocoupled landing approach under Category II procedures. During the transition from instrument to visual reference, the aircraft continued below the glide slope and increased its rate of descent. The pilot applied thrust and rotated the aircraft seconds before it struck approach light bars which were mounted on a wooden pier just short of the runway threshold area. The aircraft momentarily became airborne again and then crashed onto the runway and slid approximately 2,600 feet (792m). The main landing gear and all of the engines separated along the deceleration path.

A-6 Date of Accident: November 27, 1973

Resume: The aircraft initiated an excessive rate of descent after passing the decision height. Although the sink rate was reported at 900 feet (274m) per minute, it could have been corrected at a point before the landing flare. However, the pilot maintained the sink rate until at an altitude where the aircraft could not recover. While corrective actions were taken, before any reaction to the control inputs could be noted, the aircraft struck the approach lights 1,600 feet (487m) from the runway threshold and approximately 20 feet (6.1m) above the ground. After initial impact, the aircraft continued to descend, striking additional rigid-mounted ALS structures and a flood control dike before coming to rest 450 feet (137m) beyond the threshold.

A-7 Date of Accident: December 17, 1973

Resume: While on an ILS approach an increased rate of descent was induced by an encounter with a low-altitude wind shear at a critical point in the landing approach where the pilot was transitioning from instrument to visual flight. This increased rate of descent was not recognized in time to arrest it before the aircraft struck the approach lights located approximately 25 feet (7.6m) above mean water level on wooden piers in the harbor about 500 feet (152m) short of the runway. The aircraft then struck an embankment about 200 feet (60m) short of the runway and sheared its right main landing gear. The aircraft then became airborne for about 1,200 feet (365m), landed on the runway, slid down the runway, and veered off to the right. The aircraft caught fire and sustained substantial damage. Two approach light piers were destroyed, and two others were heavily damaged.

A-8 Date of Accident: June 24, 1975

Resume: The aircraft encountered adverse winds which resulted in a high descent rate into the nonfrangible approach light towers. The aircraft's left wing first impacted the No. 7 ALS stanchion located 2,400 feet (731m) from the runway threshold at an elevation of 27 feet (8.2m) above the mean water level. Progressing in flight towards the runway, the aircraft struck

towers 8 and 9, and the aircraft's left wing was damaged severely by impact with these towers. The aircraft then rolled into a steep left bank, impacted the ground, and skidded through a number of approach light towers whichtogether with large boulders along the latter portion of the path caused the fuselage to collapse and disintegrate. Fire erupted after the left wing failed and released fuel which was ignited by numerous friction sources. Destruction of the fuselage caused more fuel to be released and the fire continued to burn after the aircraft came to rest.

The NTSB has stated that the adverse winds might have been too severe for a successful approach and landing. Also, NTSB concluded that the nonfrangible approach light towers were responsible for much of the severe destruction of the aircraft and that the accident was not survivable because the fuselage almost completely disintegrated, and the occupant restraint systems failed.

NOTE: The NTSB Accident Investigation Report noted that the need for frangible approach light towers on the approach paths to runways has been recognized by the FAA (by issuance of Order 6850.9). During the public hearing held on this accident, an FAA Airway Facilities Service representative testified that funding for part of the retrofit program was expected in the FY 1977 budget. It was also stated that the towers currently being installed were designed to fracture at impact speeds of 80 knots or higher and that the towers would probably fracture at speeds well below 80 knots depending on the type of aircraft involved.

A-9 Date of Accident: November 16, 1976

Resume: The aircraft ran off the end of a runway during an aborted takeoff and struck some nonfrangible steel structures supporting the ALS. Pieces of the ALS structures severed the left outer wingtip which caused fuel to leak and feed the fire that erupted on the left side of the fuselage. As a result of the aircraft impacting the nonfrangible ALS structures, the concrete support structures of the ALS had been pulled out of the ground.

In contrast, the first ALS structure, which had frangible fittings, broke off at the base and caused virtually no damage to the aircraft.

NOTE: Based on correspondence on file in the NTSB accident files, the Denver Area Air Line Pilots Association Safety Coordinator cited the need for special attention to be focused on the provisions of having frangible mounted supporting structures. This correspondence also indicates that FAA has promised that the replacement of the destroyed ALS structures at the airport will be frangible mounted.

GENERAL AVIATION

G-1 Date of Accident: January 12, 1972

Resume: While making an instrument approach at night and in fog conditions, the aircraft struck a steel ALS tower 800 feet (243m) from the runway threshold. The left wing was sheared off. The aircraft continued forward approximately 40 feet (12m) to the ground. The ALS tower received extensive damage: the top section was demolished (platform, transformer enclosure, and light fixture).

G-2 Date of Accident: September 6, 1972

Resume: During a night VFR landing, the aircraft struck an ALS structure (consisting of steel pipes 4 inches (10cm) to 5 inches(12.5cm) in diameter) 400 feet (121m) short of the runway threshold.

G-3 Date of Accident: August 1, 1973

Resume: Following a local acrobatic demonstration flight, the aircraft's engine failed, and the aircraft landed 1,100 feet (335m) short of the runway and skidded 130 feet (39.6m), breaking off two ALS posts with the leading edge of the left wing. The pilot reported he touched down intentionally short of the runway to avoid hitting the ALS structures while airborne.

G-4 Date of Accident: October 19, 1973

Resume: During a night VFR approach, the pilot mistook the approach lights to be runway centerline lights and stated that the ALS supporting towers (approximately 25 feet (7.6m) in height) were not visible to either himself or his passenger. At the time of the accident, the runway lights were not lit.

G-5 Date of Accident: October 22, 1973

Resume: During a landing approach, the pilot became confused and struck the two ALS supporting structures nearest to the approach end of the runway. A go around was then initiated and a landing was made on another runway.

G-6 Date of Accident: August 19, 1974

Resume: During a night approach, the pilot descended into a shallow fog and struck the second ALS "T" bar located 400 feet (121m) from the threshold. The left main gear struck the "T" bar located 200 feet (60m) from the end of the runway and broke off the left side of the approach lights. The aircraft touched down on the left main landing gear and the nose gear, then veered off the runway, and came into contact with a ditch on the side of the runway.

G-7 Date of Accident: June 29, 1975

Resume: A student pilot making touch and go landings undershot the runway and struck the 1,000-foot (300m) ALS tower. The wreckage of the aircraft remained entangled in the tower which was substantially damaged.

G-8 Date of Accident: September 3, 1975

Resume: On a touch and go approach, a student pilot came in too low and struck the fourth bar of the ALS. The left wing and left landing gear were sheared off by the impact and remained with the light bar. The aircraft projected forward and struck the third light bar, veered off to the left, inverted, and skidded to a stop approximately 200 feet (60m) from the first impact.

G-9 Date of Accident: September 6, 1975

Resume The aircraft struck ALS towers at stations 27, 26, and 25. The aircraft continued for an approximate distance of 330 feet (100m) after the impact before coming to rest in an inverted position. The cabin, aft fuselage, and tail section of the aircraft were destroyed by fire which followed impact. All three occupants were killed.

NOTE: Information pertaining to the height and damage of the ALS towers is as follows:

Station	Height (above ground level)		Damage
27	50 feet	(15.2m)	Lights knocked out of position. Railings and flasher lights destroyed.
26	47 feet	(14.3m)	Lights torn out from mountings. Cable to transformer box pulled out.
25	45 feet	(13.7m)	One light knocked out of position. Flasher and front railing damaged.

G-10 Date of Accident: June 14, 1976

Resume: The aircraft reportedly incurred a multiple bird strike immediately after rotation during takeoff and the pilot elected to land in an open field to the right of the runway. The aircraft's right wing tip contacted the 18-foot (5.4m) high ALS bar located 1,000 feet (300m) from the runway, and the aircraft then impacted into the field.

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