

Publication Date: 3/15/04

**SUBJ: FINANCIAL FEASIBILITY AND EQUIVALENCY OF RUNWAY SAFETY AREA IMPROVEMENTS AND ENGINEERED MATERIAL ARRESTING SYSTEMS**

---

**1. PURPOSE.**

This is guidance for (a) comparing various runway safety area (RSA) improvement alternatives with improvements that use Engineered Material Arresting Systems (EMAS); and (b) determining the maximum financially feasible cost for RSA improvements, whether they involve EMAS or not. This guidance will help airport sponsors develop a sound proposed action for environmental review purposes. Regional Airports Division Managers should also use it when preparing an RSA practicability determination as required by FAA Order 5200.8, *Runway Safety Area Program*.

This guidance uses a standard EMAS installation as a benchmark for comparing and determining the best financially feasible alternative for RSA improvements. It should be used for new runway projects when comparing the costs of providing a standard RSA to the costs of installing EMAS. It may also be used to justify decreasing the dimensions of existing RSAs in connection with runway extension projects (see Paragraph 8).

**2. DISTRIBUTION.**

This order is distributed to branch level in Washington, to the section level in regions and centers, and to all Airports Field Offices.

Table of Contents

- 1. PURPOSE..... 1
- 2. DISTRIBUTION..... 1
- 3. IMPLEMENTATION SCHEDULE..... 2
- 4. APPLICATION ..... 2
- 5. BACKGROUND ..... 3
- 6. STANDARD EMAS INSTALLATION..... 3
- 7. NON-STANDARD EMAS INSTALLATION..... 4
- 8. RUNWAY EXTENSIONS..... 7
- 9. EVALUATION PROCESS ..... 7
- 10. DECISION TABLE..... 12
- 11. LIFE CYCLE COSTS ..... 12
- 12. COST ESTIMATES ..... 13
- 13. OTHER FACTORS..... 14
- APPENDIX A. EMAS COST ASSUMPTIONS..... 17
- APPENDIX B. LIFE CYCLE COSTS ..... 19

### 3. IMPLEMENTATION SCHEDULE

This guidance should be applied to projects identified in Paragraph 4 where the Federal environmental action (including a draft EIS), finding, or decision has not yet been completed and issued.

### 4. APPLICATION

- a. Use this guidance in connection with practicability determinations required by FAA Order 5200.8, *Runway Safety Area Program*. Previous determinations of projects subject to this order should be reevaluated using this guidance to decide whether EMAS should be included in the determination, on the basis that it can provide a level of safety that is generally equivalent to a standard RSA and may be financially advantageous. Use this guidance where:
  - (1) Either:
    - i. The existing RSA determination (Order 5200.8) says that the existing RSA does not meet standards but it is practicable to improve the RSA so that it will meet current standards, or
    - ii. New or revised RSA determinations are required by Order 5200.8, and
  - (2) The runway serves air carriers at a commercial service airport or is required to meet FAA design standards under federal grant obligations, and
  - (3) The runway serves aircraft with a maximum takeoff weight (MTOW) of 25,000 pounds or more, and
  - (4) The width of the RSA or its length beyond the runway end is less than 90% of the RSA standard. While improvements are always desirable, this guidance is not appropriate for situations where there is a limited safety enhancement potential. Refer to Order 5200.8 to decide the appropriate course of action when both RSA length beyond the runway ends and its width are within 90% of the RSA standard.
- b. The Regional Division Manager retains the authority to decide the best practicable RSA improvements under Order 5200.8, in consideration of all circumstances at a particular airport.
- c. This guidance is not a design standard. Use it only as an evaluation guide for determining the best financially feasible alternative for RSA improvements. Actual EMAS design, including designation of the design aircraft and other critical performance factors, is the responsibility of the airport sponsor's design engineer in consultation with the EMAS manufacturer. AC 150/5220-22, *Engineered Material Arresting System (EMAS) for Aircraft Overruns*, provides detailed planning, design, and installation requirements for EMAS.
- d. A life cycle cost comparison between EMAS and a standard RSA is only appropriate when the RSA can either be improved to standards or to an equivalent level of safety using EMAS. Life cycle cost comparison is not appropriate for comparing non-standard RSA improvements with a non-standard EMAS installation (as defined by Paragraph 7).
- e. This guidance addresses only financial feasibility. It does not affect the requirements for environmental review that apply to airport projects. The life cycle cost analysis of both alternatives (EMAS and standard RSA) will support and facilitate the environmental

process requirements for reasonable alternatives analysis, but consideration of other factors is necessary before reaching a final environmental determination. In some cases, this guidance will establish a clear safety need for a particular alternative consistent with this guidance. In other cases, the final decision may vary from the recommendation of this guidance to protect environmentally sensitive areas.

## 5. BACKGROUND

Improving RSAs that do not meet current dimensional standards is often difficult. Terrain and environmental considerations can result in improvements that cost in the tens of millions of dollars. Analysis shows that for aircraft overruns, EMAS can provide a safety enhancement, while requiring less land disturbance and lower construction costs, thereby reducing significant overall costs. EMAS does not provide a benefit for short landings, so a standard EMAS installation might also include a displaced threshold. In order to preserve existing runway dimensions where one end of the runway meets RSA dimensional standards, and the other end does not, a runway extension and second EMAS may be required. This does not mean that EMAS should never be installed in other than this standard configuration. EMAS will often be the appropriate safety enhancement even when undershoot protection cannot be provided, if a standard solution is not available.

## 6. STANDARD EMAS INSTALLATION

- a. A standard EMAS installation provides a level of safety that is generally equivalent to a full RSA constructed to the standards of AC 150/5300-13 for overruns. It also provides an acceptable level of safety for undershoots. Studies have shown that a standard EMAS installation will arrest 90% of overruns and accommodate 90% of undershoots. Follow the EMAS design requirements in AC 150/5220-22 in the event of any conflicts with this guidance. A standard EMAS installation must meet the following conditions:
  - (1) The EMAS is constructed in accordance with AC 150/5220-22.
  - (2) The EMAS must be capable of safely stopping a design aircraft that leaves the runway traveling at 70 knots.
  - (3) The resulting RSA must provide adequate protection for aircraft that touch down prior to the runway threshold (undershoot). Adequate protection is provided by either:
    - i. If the approach end of the runway has vertical guidance, then provide at least 600 ft (or the length of the standard RSA beyond the runway threshold, whichever is less) between the end of the EMAS bed and the runway threshold to accommodate undershoots, or
    - ii. If vertical guidance is not available, then the full length of the standard RSA must be provided for protection against undershoots.
  - (4) If the existing RSA does not provide adequate protection for short landings as described above, then one of the following two options should be selected:

NOTE: Vertical guidance consists of either an instrument approach procedure that includes vertical guidance or a visual guidance lighting aid (such as a PAPI),

- i. Acquire additional property to provide the adequate undershoot protection, or
- ii. Displace the threshold for landings a sufficient length to meet the undershoot requirement.

The cost to accomplish either (i) or (ii) above should be included in the life cycle cost for EMAS (Paragraph 11). If the threshold displacement option is selected, the standard EMAS installation will usually require two EMAS beds and a runway threshold displacement on each runway end as shown in Figure 1. However, it may be possible and cost effective to expand the RSA on one end and thereby eliminate the need for a second EMAS bed and second runway displacement, as shown by Figure 2.

- b. A standard EMAS installation in some cases might result in a shorter runway that could affect aircraft operations. Refer to FAA Order 5200.8 to determine whether shortening the runway is a practicable alternative.

## **7. NON-STANDARD EMAS INSTALLATION**

- a. It will often not be practicable to provide either a standard RSA or a standard EMAS installation, either because the cost of both is above the maximum feasible cost, or because displacing the landing threshold will adversely affect operations. Consider not only the possible loss of runway length, but also effects on taxiing aircraft, including changes in required holding positions. When neither a standard RSA nor a standard EMAS system can be provided within maximum feasible costs, a non-standard EMAS that will stop the design aircraft traveling at 40 knots or more should be considered. An EMAS that cannot provide at least this minimum performance is not considered a cost-effective safety enhancement.
- b. While relative benefits have not been quantified, protection against overruns appears to be more valuable than protection against short landings. Short landings are less common and usually occur close to the runway threshold. Therefore, consider eliminating the displaced threshold when a standard RSA or a standard EMAS is not financially feasible - i.e. install EMAS to provide maximum protection against overruns by the design aircraft exiting the runway at 70 knots (but no less than 40 knots), and provide protection against short landings to the maximum extent feasible, up to the maximum feasible improvement cost.

Figure 1. Standard EMAS Installation

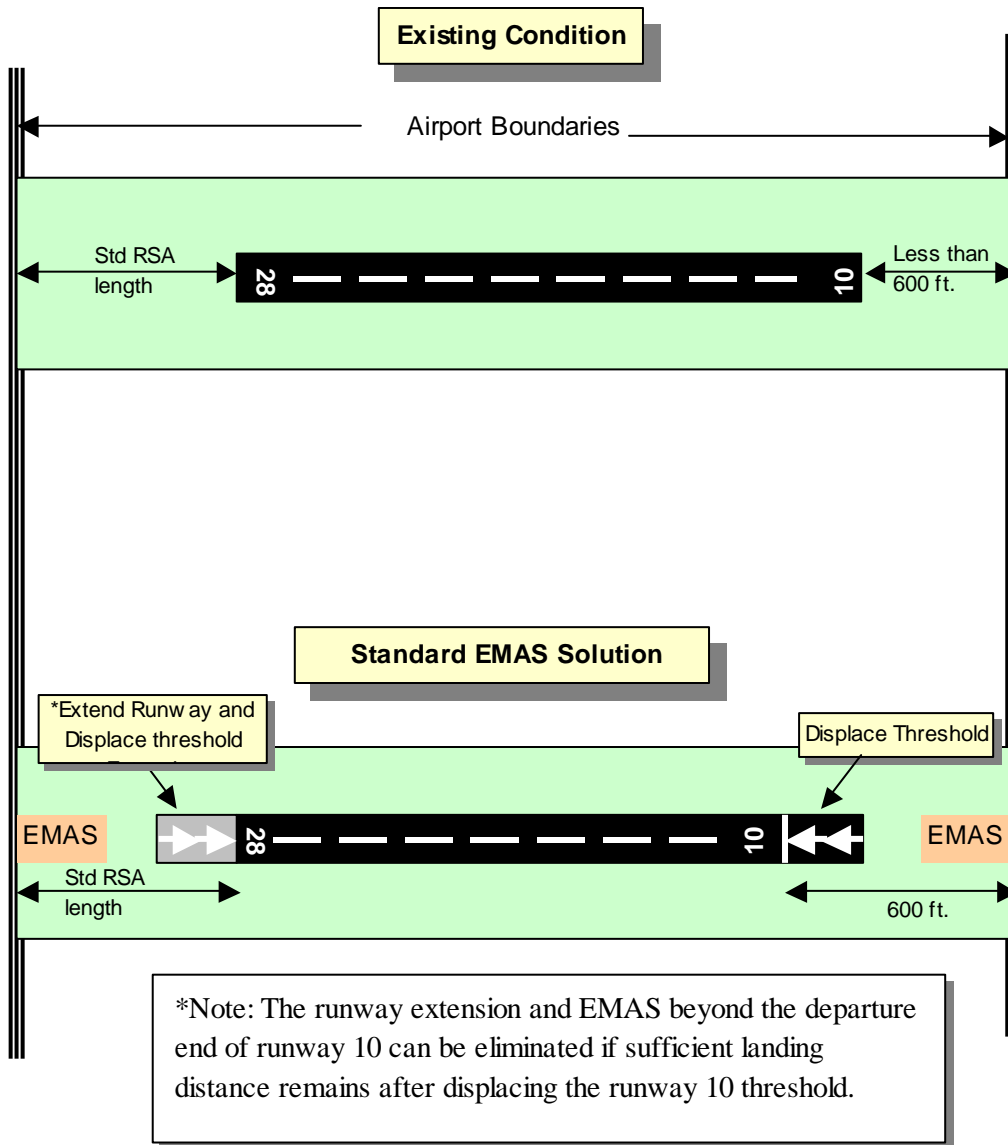
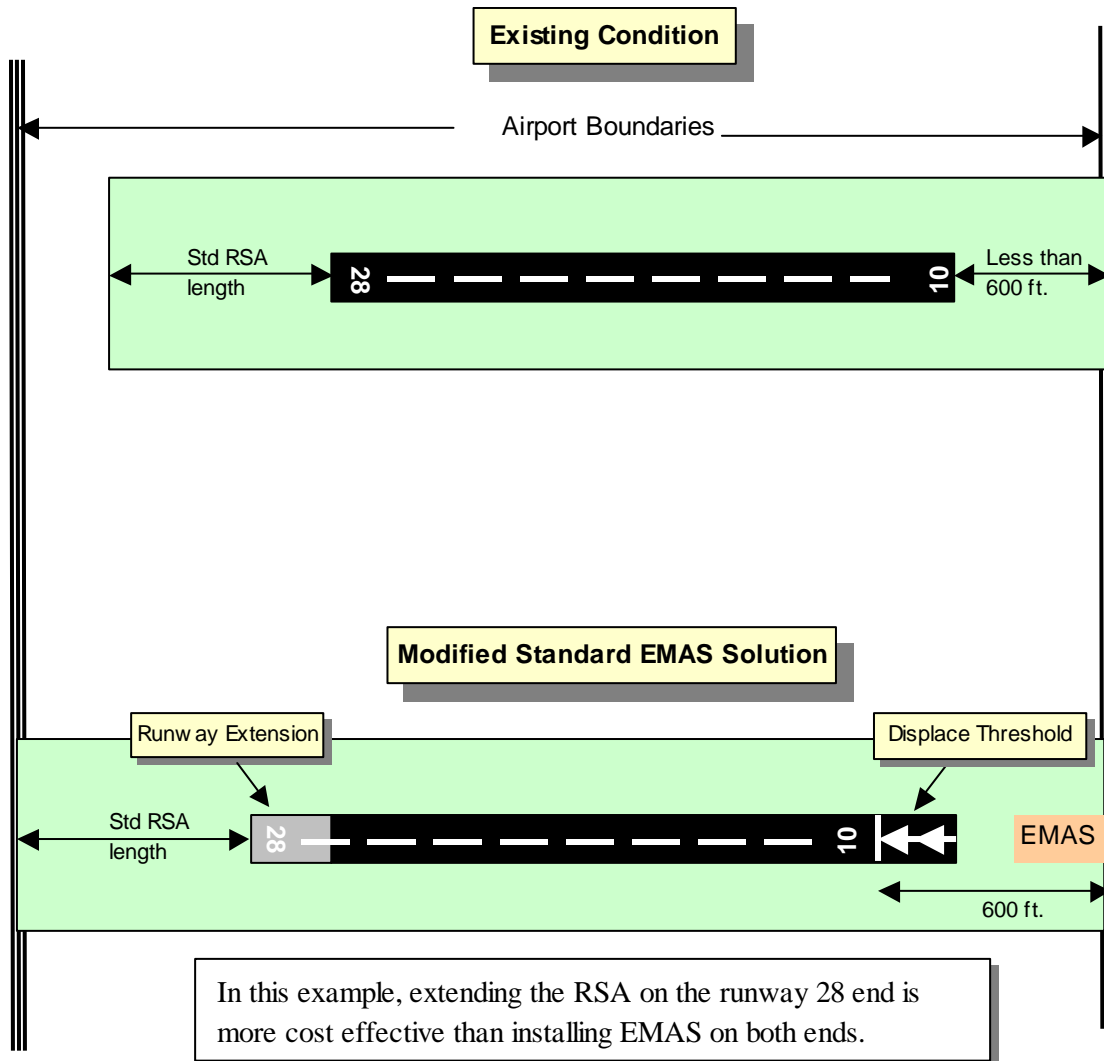


Figure 2. Modified Standard EMAS Installation



## 8. RUNWAY EXTENSIONS

When using this guidance in connection with runway extensions, it is preferable that the existing RSA available to protect aircraft in short landings be maintained. Refer to Figures 1 and 2. However, the area for protection for short landings may be shortened to 600 feet if the Regional Division Manager decides it is necessary as a part of the RSA determination required by Order 5200.8.

## 9. EVALUATION PROCESS

The evaluation process answers five (5) questions:

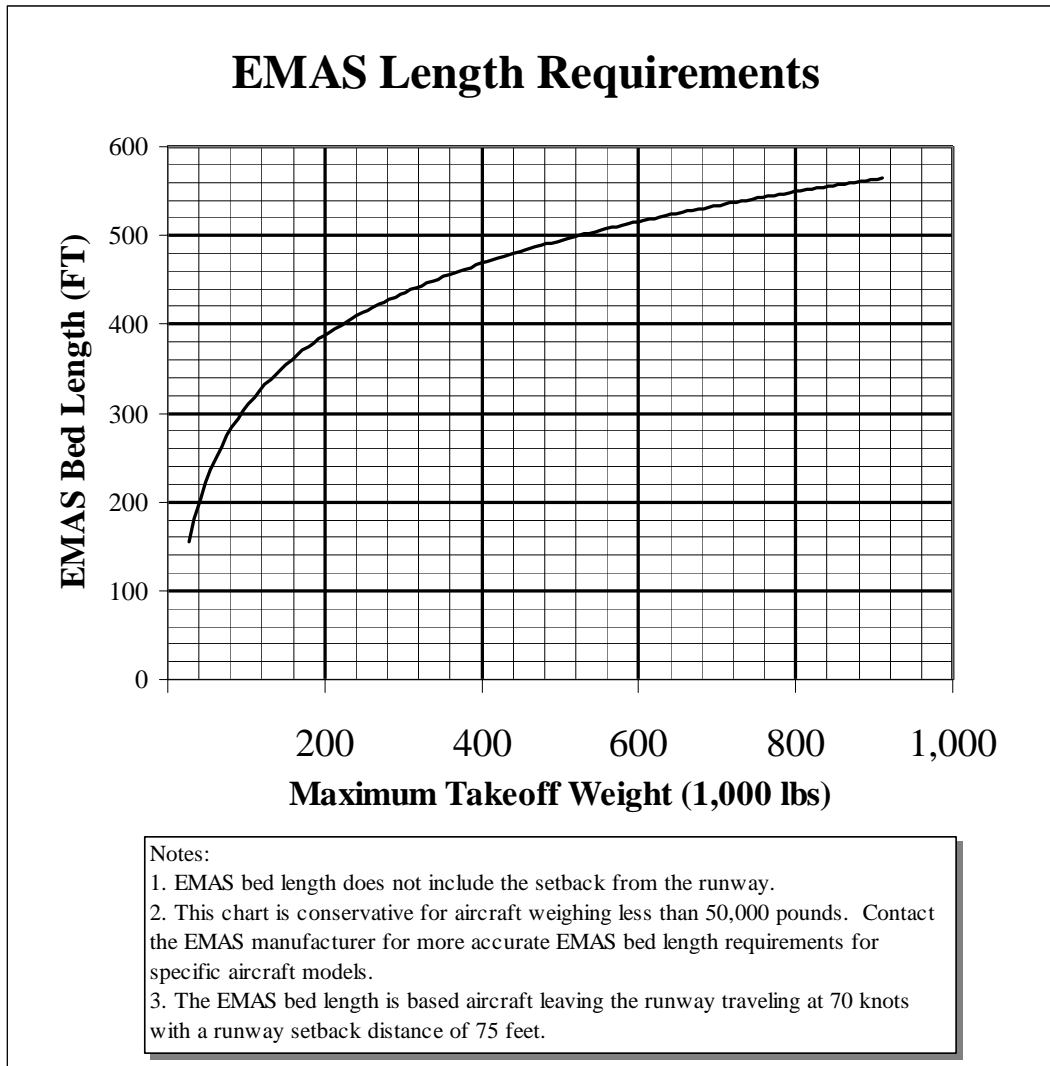
a. What is the EMAS design aircraft?

The design (or critical) aircraft is the aircraft that regularly uses the runway that places the greatest demand on the EMAS. This is usually, but not always, the heaviest or largest aircraft that regularly uses the runway. EMAS performance is dependent not only on aircraft weight, but landing gear configuration and tire pressure. Contact the EMAS manufacturer if there is any doubt as to the design aircraft. Normally, "regular use" for federal funding is at least 500 annual operations on the runway, but consider future trends in runway use before making a final determination of design aircraft. Use the MTOW for the design aircraft and the runway in question. Note that short runways may require the design aircraft to operate at a weight that is lower than MTOW for ideal conditions. Also, note that the design aircraft for EMAS is not related to the Airport Reference Code aircraft defined by AC 150/5300-13, and it might not be the same as the design aircraft for runway length. For example, a B737 aircraft serving a 1500-mile haul route requires a longer runway than a B727 even though the B727 is heavier. In this example, a B727 that regularly uses the runway is the design aircraft for EMAS.

b. What length does the EMAS bed need to be to safely stop the design aircraft?

Heavier aircraft usually require longer EMAS beds. For an estimate, find the EMAS bed length from Figure 3. Enter the aircraft weight at the bottom of the chart and read the corresponding length on the left hand side of the chart. Figure 3 is to be used for planning and evaluation purposes only. It is not a design requirement. Actual EMAS design is the responsibility of the design engineer in consultation with the EMAS manufacturer. The actual EMAS bed design length may be somewhat less than the dimension indicated by Figure 3 if the distance from the end of the runway to the start of the EMAS bed is greater than 75 feet. In most cases, the EMAS bed should be positioned as far from the runway end as possible to reduce the EMAS bed size and hence the cost. (In any case, there is no requirement to reduce the dimension indicated by Figure 3 for the purposes of this guidance.)

Figure 3. EMAS Length Requirements





c. What is the maximum feasible expenditure (cost) for improving the RSA?

(1) Use the EMAS bed length (Paragraph 9b) and Figure 4 to determine the maximum feasible cost for improving the RSA. Any alternative that exceeds this amount is normally not financially feasible, whether the alternative includes EMAS or not. The maximum feasible expenditure is applied to the improvement of the entire RSA, including both runway ends and the full width of the RSA. The total cost to improve the RSA is generally considered financially feasible if the total costs are less than or equal to the amount found from Figure 4. For example, if the design EMAS bed length is 350 and the runway is 150 feet wide, then the maximum feasible RSA improvement cost is about \$15,000,000. If the runway is 200 feet wide then the maximum feasible RSA improvement cost is  $\$15,000,000 \times 1.33$  or \$20,000,000.

(2) If neither the standard RSA nor the standard EMAS is financially feasible, then it is not financially feasible to improve the RSA to standards or to an equivalent level of safety with EMAS. Under these circumstances, implement the best alternative for enhancing safety (including EMAS) as required by Order 5200.8 that does not exceed the maximum feasible cost. EMAS should always be considered for enhancing safety, even when a standard EMAS installation is not financially feasible.

(3) Note that the amount in Figure 4 is based only on EMAS length, which in turn is based only on the weight of the design aircraft. This assumes that a certain amount of passenger or cargo activity is associated with regular service by aircraft types of a particular size. If the design aircraft is, for some reason, not generally representative of the other activity at the airport, the potential benefits of the RSA improvement may be less than assumed. This would be an additional factor that could indicate a lower maximum feasible expenditure.

d. What are the life cycle costs of EMAS and non-EMAS alternatives for improving the RSA?

Calculate the life cycle cost for a standard EMAS (Paragraph 6) and any other non-EMAS solution that results in an RSA with full standard dimensions. Paragraph 11 and Appendix B provide guidance for calculating life cycle costs. Be sure to include all construction and maintenance costs associated with the standard EMAS installation including threshold displacement, NAVAID adjustments, runway extension, and taxiway re-alignments, as needed.

e. What is the best financially feasible alternative for improving the RSA considering life cycle costs and other factors?

Use the decision table (Paragraph 10) to determine the best financially feasible alternative for improving the RSA. Figure 5 also presents a flow chart description of the decision process.

Figure 4. Maximum Feasible Cost for RSA Improvement

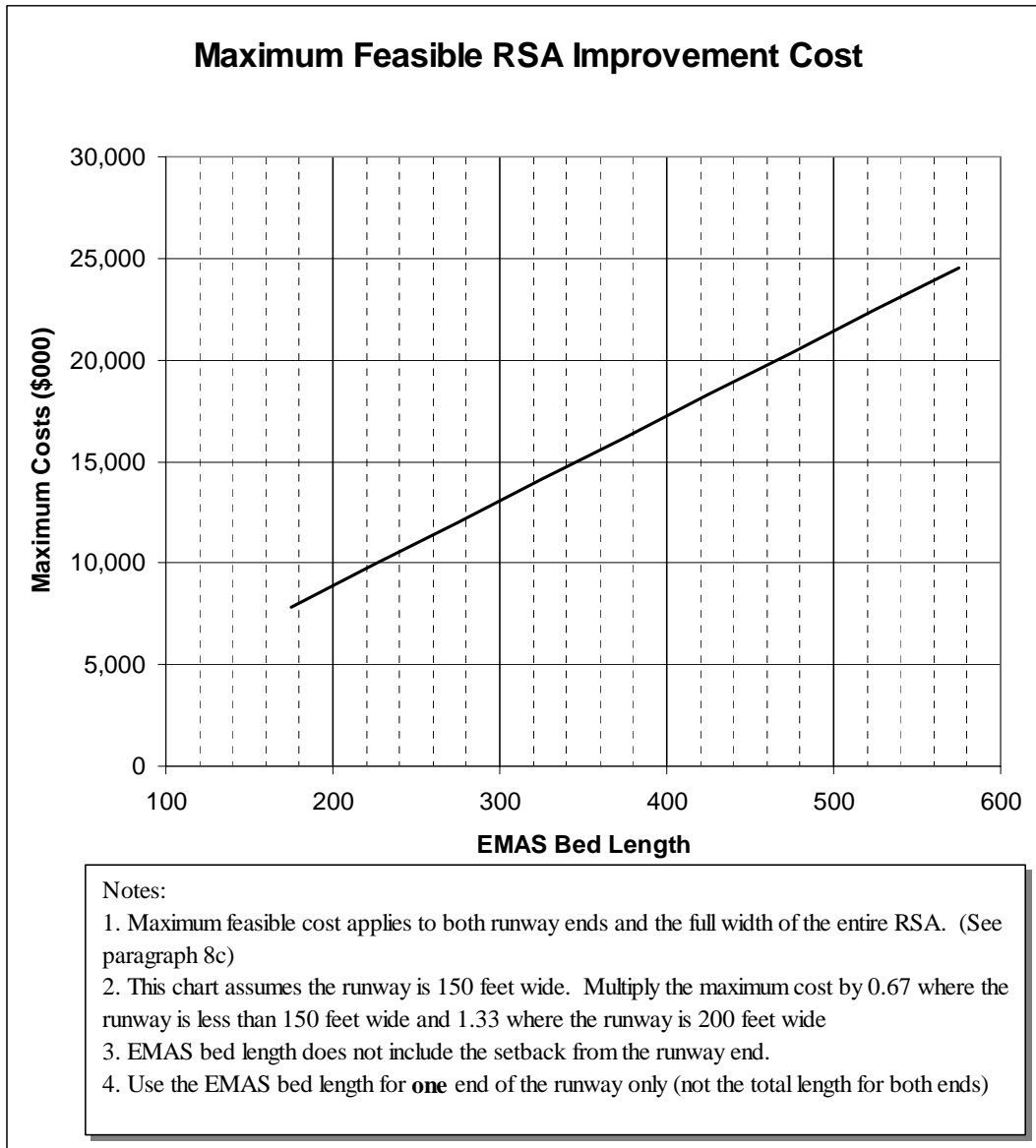
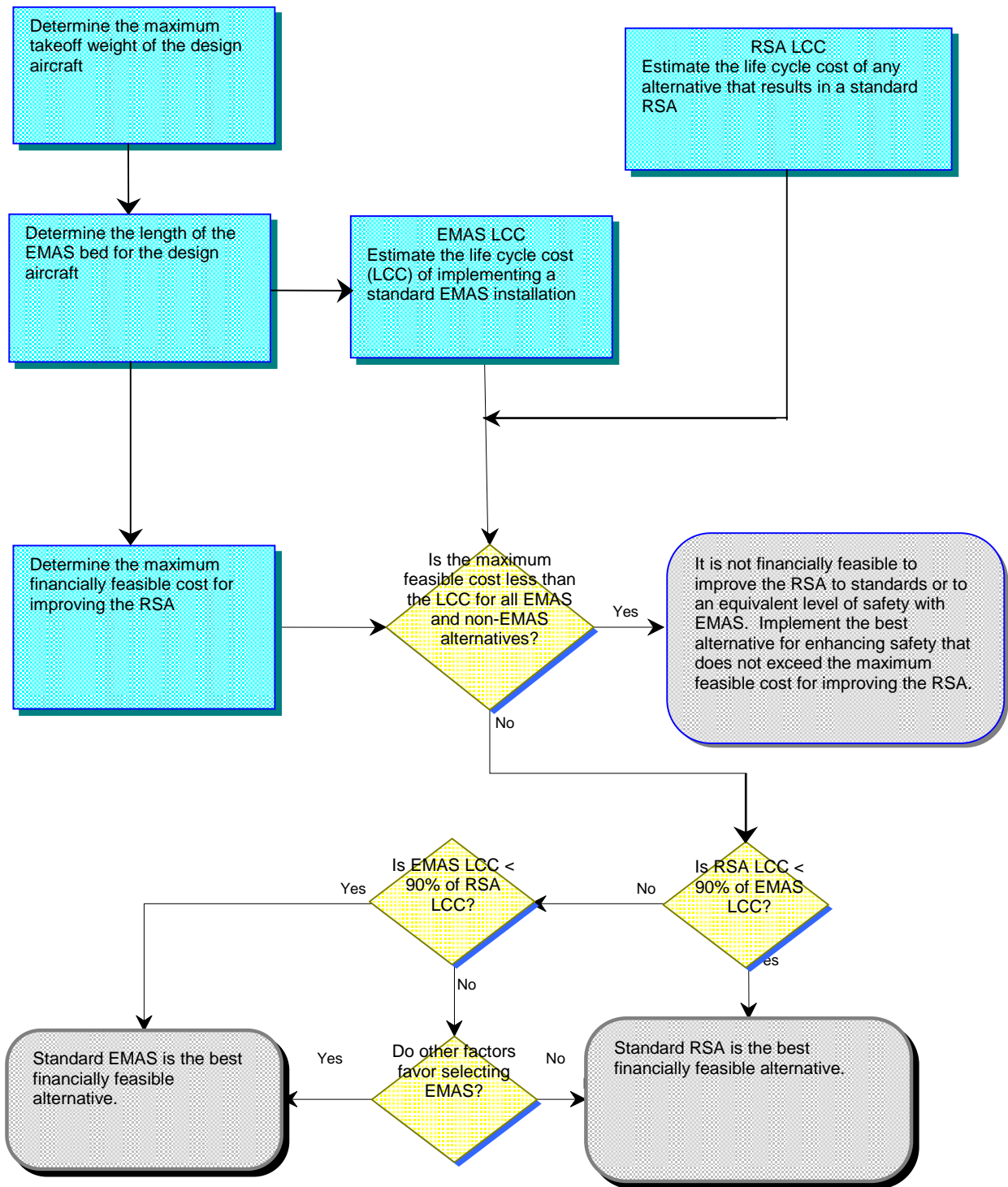


Figure 5. Decision Flow Chart for Evaluating EMAS and RSA Improvements



## 10. DECISION TABLE

If...	Then...
a. The cost of all alternatives examined in Paragraph 9d are greater than the maximum feasible cost for improving the RSA (Paragraph 9c).	It is not financially feasible to improve the RSA to standards or to an equivalent level of safety using EMAS. EMAS may still be used as an RSA safety enhancement even if full performance cannot be achieved. See Paragraph 7.
b. The life cycle cost (LCC) for any full length RSA alternative is less than 90% of the EMAS LCC.	The full length RSA alternative is the best a financially feasible alternative for improving the RSA.
c. The EMAS LCC is less than 90% of the LCC of any other alternative.	The EMAS alternative is the best financially feasible alternative for improving the RSA.
d. The EMAS LCC and the LCC for the full length RSA alternative are within 10% of each other.	Select the alternative after considering other factors (Paragraph 13).

## 11. LIFE CYCLE COSTS

- a. Life cycle costs are used to compare EMAS with non-EMAS alternatives. They account for periodic inspections, maintenance, and replacement of the EMAS material. The present value of the life cycle costs of the EMAS solution ( $P_{life}$ ) is the sum of:

(1) The cost to establish the standard EMAS installation ( $P_{emas}$ )

This cost includes:

- Site preparation and EMAS material installation
- Displacing runway thresholds
- Relocating and/or modifying visual and electronic NAVAIDS
- Taxiway realignment and construction
- Runway extensions
- Other costs to provide the standard EMAS installation as defined by this guidance

(2) The present value of the EMAS replacement after 10 years (we may change the replacement interval as we gain more experience with the material).

(3) The present value of the annual maintenance and inspection costs for 9 years. Maintenance and inspection are not required for year 10 because the EMAS will be replaced.

(4) The present value of the annual maintenance and inspection costs for years 11 through 19

- b.  $P_{life}$  costs can be calculated using the following formula:

$$P_{life} = P_{emas} + F/1.97 + A \times 9.83 \text{ where,}$$

$P_{emas}$  is the cost to establish the standard EMAS installation (see above).

**F** is the future EMAS replacement cost in current dollars. This cost is primarily for replacing the EMAS material only. Engineering and site preparation, if any, would be minimal compared to the original installation.

**A** is the annual inspection and maintenance costs. Use a maintenance cost of \$1 per square foot every three years (or \$.33 per square foot per year).

Appendix B provides more information on the calculation of present value.

## 12. COST ESTIMATES

### a. General

(1) This guidance is highly dependent upon cost estimates—both for determining the maximum feasible cost for RSA improvement and for comparing full RSA construction with the standard EMAS. Therefore, all cost estimates must be carefully reviewed to ensure that all assumptions are reasonable and that there is sufficient justification and background material to concur with the estimates. Appendix A contains EMAS cost assumptions that may be useful for reviewing the estimates. The purpose of the review is to ensure a sound decision, considering safety, economic, and preliminary environmental factors.

(2) Be sure the cost estimate includes a brief description or summary of any obvious terrain and environmental resources. Also, document any alternatives that might avoid or lessen construction-induced impacts to those resources. NEPA procedures require a balanced decision considering FAA's mission, transportation factors, environmental impacts, costs, and safety benefits. Decisions that appear to ignore important environmental issues can later delay the FAA's environmental approval. Consult with an FAA environmental specialist to assure that the airport sponsor properly justifies the proposed action. Alternatives analysis, including cost estimating, is a responsible action that is part of NEPA's preferred alternatives requirement and is in no way a pre-decisional action.

(3) Major improvements, such as filling navigable rivers, moving major highways, and relocating railroad tracks, might be technically infeasible or extremely costly. Technically infeasible projects can be eliminated without a cost analysis. Other major projects only require enough documentation to show that the costs would exceed the maximum feasible RSA improvements costs given by Figure 4.

### b. Real Estate

Real estate costs should be limited to those costs that specifically allow the airport to develop the expanded RSA. Sufficient property interest to control land use compatible with airport operations is already a requirement of the Runway Protection Zone (RPZ) standard (See AC 150/5300-13, Paragraph 212) and AIP grant assurance number 21. Therefore, land costs can be limited to those that are only necessary to allow development of the RSA. In cases where these costs cannot be segregated, it is permissible to use the total cost for analysis purposes. Note that the RPZ land requirements are larger than RSA requirements. Therefore, airports should be encouraged to acquire the RPZ land in connection with the RSA improvement alternative. In this case, prorate the RSA requirement against the total land acquisition cost. For example, assume that an airport needs to acquire land that is 500 feet by 500 feet (250,000 Sq. Ft.) for the RSA as well as a total of 20 acres (871,200 Sq. Ft.) for the RPZ at a

cost of \$20 million. The RSA land cost in this example is  $(250,000/871,200) * 20,000,000 = \$5,739,210$ .

c. Environmental Mitigation.

The airport sponsor should realize most RSA proposals will likely require mitigation because the proposals will disturb the environment. As a result, potential environmental mitigation costs could pose a significant monetary concern for FAA.

The sponsor should conceptually plan mitigation and related preliminary cost estimates early in the RSA planning process. To do this, the sponsor, after consulting with the FAA environmental specialist, should be sure its RSA proposal includes preliminary mitigation measures and preliminary estimated costs for those measures. NEPA and other environmental laws and regulations do not require a detailed mitigation plan for agency approval. Exact costs for preliminary mitigation are not available when FAA completes the NEPA analysis for RSA proposals. Nevertheless, conceptual mitigation information ensures the well-planned RSA proposal will contain preliminary mitigation ideas and costs when the sponsor sends the proposal to FAA to complete the financial feasibility and the necessary NEPA analysis.

### 13. OTHER FACTORS

Cost is important, but it is not the only factor to consider in making a sound decision on RSA improvements. Other factors should be considered before deciding on the best financially feasible alternative, including the following:

a. Extreme climate conditions.

Extreme cold locations with high flood potential might limit the effectiveness and/or durability of an EMAS installation. These factors are based in part on our collective experience with EMAS installations to date. With more experience, the application of this factor may change. Examine other existing EMAS installations with similar environmental conditions when applying this factor.

b. Airport sponsor support for the EMAS solution.

EMAS requires continuous inspections and periodic maintenance to ensure that it performs as intended. Some airports, particularly smaller commercial service airports, may not be able to easily provide the resources necessary to properly manage an EMAS installation. In some cases, maintenance costs, although small, could place a financial strain on the airport. Poor maintenance could shorten the useful life of the EMAS and/or result in a system that does not perform to its design requirements. On the other hand, a standard EMAS installation can actually result in a longer runway for takeoff, may take less time to implement, may decrease environmental concerns, and may save the airport sponsor money, resulting in positive support for an EMAS solution.

c. Operational considerations.

The standard EMAS solution may require runway threshold displacement on each end of the runway. Undesirable taxiway configurations and/or new limitations on approach procedures could create unintended results when thresholds are displaced.

For example, if EMAS were installed without the need for a displaced landing threshold, aircraft would be able to hold at the runway end at the typical 250 ft hold line on the end connector taxiway. Under ILS conditions, EMAS with a displaced landing threshold (and assuming the typical 400 ft runway to taxiway centerline separation) will require aircraft to hold at a position behind the Precision Object Free Area (POFA). (The POFA surface requirements move from the physical end of the runway to the displaced threshold location.) This could create longer taxiing times for the aircraft to move into position on the runway for takeoff.

d. Time to implement.

Some RSA improvement alternatives might take longer to implement than others. Safety benefits are not realized until the improvement is actually completed. Projects that require land acquisition or where local opposition is strong may take longer to complete.

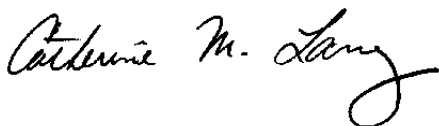
Alternatives that are expected to be completed significantly sooner should receive favorable consideration when determining the best alternative.

e. Unknown environmental mitigation costs.

When added to the total project cost, mitigation costs can affect the results of the life cycle cost analysis. Unfortunately, as noted in paragraph 12c, environmental mitigation costs are not fully defined until after preparation of the environmental assessment or environmental impact statement. For example, consider a case where RSA expansion beyond airport boundaries will require an EIS and where at least some mitigation costs are expected. If the life cycle cost analysis excluding mitigation is already near the threshold that favors EMAS, then any additional mitigation costs would likely make EMAS the best financially feasible alternative. Under these circumstances, consider selecting the EMAS option because of the likelihood that the increased mitigation costs would actually result in a decision in favor of EMAS.

f. Airport activity

As discussed in paragraph 9c(3) above, if the design aircraft is not generally representative of total activity at the airport, a maximum feasible expenditure lower than represented in Figure 4 may be indicated.



Catherine M. Lang

Deputy Associate Administrator for Airports

This page intentionally left blank



## APPENDIX A. EMAS COST ASSUMPTIONS

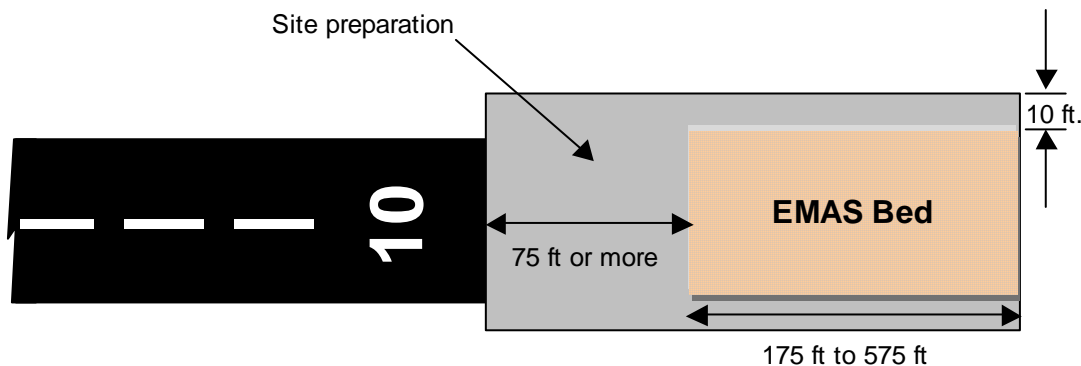
The evaluation process uses EMAS as a benchmark for comparison purposes. The EMAS life cycle cost determines when other non-EMAS improvements are, in fact, the best alternative for improving the RSA. EMAS cost is also a key factor for determining when the cost of any RSA improvement is no longer financially feasible.

Financial feasibility costs are based on the cost to install an EMAS bed for the design aircraft. This guidance uses a cost model that applies unit costs for site preparation and for the EMAS bed. The unit costs are derived from the average of four actual installations. For example, Figure A1 shows a typical EMAS installation. Site preparation costs normally consist of:

- Removal of existing surface material
- Installation of an aggregate base material
- Installation of an asphalt surface course
- An appropriate share of the contract mobilization and demobilization costs
- An appropriate share of engineering and inspection costs

Unit costs for site preparation are calculated by dividing the sum of all site preparation costs by the total area of the site preparation. Note that site preparation includes the entire setback beginning at the end of the runway and extending all the way to the far end of the EMAS bed.

Figure A1. Typical EMAS Installation Detail



EMAS costs include the EMAS bedding material, installation, and surface coating and marking. Contract bids usually include these costs as a lump sum figure. Unit costs are calculated by dividing the area of the EMAS bed (runway width times EMAS bed length). Mobilization, demobilization, engineering, and inspection costs are not included because they are normally already factored into the EMAS material and installation costs.

This guidance uses average unit costs based on four actual EMAS installations as follows:

- Site Preparation.....\$14.00/SF
- EMAS Bed Installation.....\$78.00/SF

Using these two unit cost figures, it is easy to estimate a generic EMAS installation given the EMAS bed setback, the EMAS bed length, and the runway width. At the present time, Figure 4 (Maximum Feasible Cost for RSA Improvement) is based on a factor of three times the site preparation and installation costs for one generic EMAS bed installation for the design aircraft\*. For example, if the runway width is 100 feet and the required EMAS bed length is 400 feet, the generic EMAS cost is:

- Site preparation:  $100 \times (400+75) \times 14 = \$665,000$
- EMAS bed installation:  $100 \times 400 \times 78 = \$3,120,000$
- Total generic EMAS cost: \$3,785,000
- Maximum feasible cost for improving the RSA:  $\$3,785,000 \times 3^* = \$11,355,000$  (see Figure 4)

\* This factor will change as necessary to support RSA program goals and available funding.

Note that these estimates are rough because they include an average amount of miscellaneous site work such as utility relocation and lighting. However, they can be used to develop an estimate for the standard EMAS alternative life cycle cost calculation. Use this approach to quickly estimate EMAS costs before deciding whether to proceed with a detailed design and cost analysis.

Site preparation and EMAS unit costs will be updated annually and as cost information from actual installations is received. Figure 4 will be updated and distributed accordingly. Regional Division Managers may also want to develop their own cost model based on actual EMAS installations in their region. Region-specific cost information could be used to develop an individual Figure 4 for each region.

The guidance pertaining to maintenance costs will also be adjusted as we obtain more specific information on the actual costs involved. At the present time, we believe maintenance will be about \$1 per square foot every three years. Specific costs for periodic inspections are not available at this time. Regions may also want to track and use their own maintenance figures for EMAS. However, be careful not to grossly over estimate maintenance costs. We recommend that regions obtain an inspection and maintenance proposal directly from the EMAS manufacturer before using significantly higher maintenance cost estimates.

## APPENDIX B. LIFE CYCLE COSTS

Use life cycle costs to compare EMAS with non-EMAS alternatives. Life cycle costs account for periodic inspections, maintenance, and replacement of the EMAS bed material. Life cycle costs should be calculated using present value analysis and real dollars.

Use a discount rate of 7% to calculate the time value of money. The FAA Airport Benefit-Cost Analysis Guidance recommends the use of constant dollar cash streams that exclude the effects of inflation. This net-of-inflation rate is called the real discount rate. The Office of Management and Budget (OMB) of the Executive Office of the President of the United States specifies appropriate real discount rates for investments of Federal funds in Circular No. A-94 (October 29, 1992). The real discount rate relevant for all airport projects to be funded with Federal grant funds is 7 percent.

Use a life cycle of 20 years and assume that the EMAS material will be replaced after 10 years. Figure B1 presents the cash flow diagrams for EMAS and standard RSA construction. Year 0 for each analysis is the year that the airport attains beneficial usage of the improvement. Calculate the present value for year 0. Sometimes, the completion year for standard RSA option may not be the same as the EMAS solution. Consider this difference, if any, separately along with other factors (see Paragraph 12). Refer the FAA Airport Benefit-Cost Analysis Guidance at [http://api.hq.faa.gov/cost\\_ben/faabca.pdf](http://api.hq.faa.gov/cost_ben/faabca.pdf) for more information on life cycle cost analysis.

The present value of the life cycle costs of the EMAS solution ( $P_{life}$ ) is the sum of:

- a. The present value of the EMAS installation ( $P_{emas}$ ).

This is simply the cost of the contract(s) to install the standard EMAS

- b. The present value of the EMAS replacement after 10 years ( $P_{repl}$ ).

Calculate  $P_{repl}$  using the following formula:

$$P = F / (1+i)^n \text{ where,}$$

$P_{repl}$  is the present value

$F$  is the future replacement costs (in current dollars)

$i$  is the discount rate or 7%

$n$  is the number of interest periods or 10

- c. The present value of the annual maintenance and inspection costs for 9 years . ( $P_{m9}$ )

Maintenance and inspection are not needed for year 10 because the EMAS will be replaced in year 10. Calculate  $P_{m9}$  using the following formula:

$$P_{m9} = A [((1+i)^n - 1) / (i(1+i)^n)] \text{ where:}$$

$P_{m9}$  is the present value of maintenance and inspection for 9 years

$A$  is the annual recurring maintenance and inspection costs (this value does not change)

$i$  is the discount rate or 7%

**n** is the number of periods or 9

- d. The present value of the annual maintenance and inspection costs for years 11 through 19 (**P<sub>m19</sub>**).

Maintenance is not required for year 20 because that is the end of the life cycle. Calculate **P<sub>m19</sub>** using the following formula:

$$\mathbf{P_{m19}} = \mathbf{P_{m9}} / (1+i)^n, \text{ where:}$$

**P<sub>m19</sub>** is the present value of maintenance and inspection for years 11-19

**P<sub>m9</sub>** is the present value of maintenance and inspection for 9 years

**i** is the discount rate or 7%

**n** is the number of periods or 10 [finding the present value of cost 10 years in future]

### Calculation Example

Assume the following costs:

EMAS installation = \$5,000,000

EMAS replacement = \$2,000,000

Annual inspection and maintenance = \$20,000

$$\mathbf{P_{emas}} = \quad \quad \quad \$5,000,000$$

$$\mathbf{P_{repl}} = 2,000,000 / (1+0.07)^{10} = \quad \quad \quad 1,017,000$$

$$\mathbf{P_{m9}} = 20,000((1+0.07)^9 - 1) / (.07(1+0.07)^9) = \quad \quad \quad 130,300$$

$$\mathbf{P_{m19}} = 130,300 / (1+0.07)^{10} = \quad \quad \quad \underline{\underline{66,200}}$$

$$\mathbf{P_{life}} = \quad \quad \quad \$6,213,500$$

Figure B1. Life Cycle Cash Flow

