# Rethinking Overrun Protection

**Midway International Airport's December 2005 accident makes airport operators reconsider installing the latest engineered materials arresting system.**

BY WAYNE ROSENKRANS

Engineered Arresting Systems Corp.

Workers install EMAS blocks during 2006 beyond the departure end of Runway 17R at Laredo (Texas, U.S.) International Airport.

Airports with substandard runway overrun areas are rethinking installing engineered materials arresting systems (EMAS) in light of the availability of improved materials and a demonstration of the tragic consequences of failing to arrest an aircraft sliding off the end of a runway.

The process many airport operators used to conclude EMAS would not be practical at their facilities captured attention at a U.S. National Transportation Safety Board (NTSB) June 2006 public hearing on the Dec. 8, 2005, overrun accident at Midway International Airport in Chicago. Southwest Airlines Flight 1248, a Boeing 737-700, landed on snow-contaminated Runway 31C, rolled past the end of the runway at a groundspeed of about 50 kt, and knocked down a blast fence and a perimeter fence to encounter motor vehicle traffic on an off-airport street, NTSB said. A six-year-old boy was killed in a car hit by the 737.

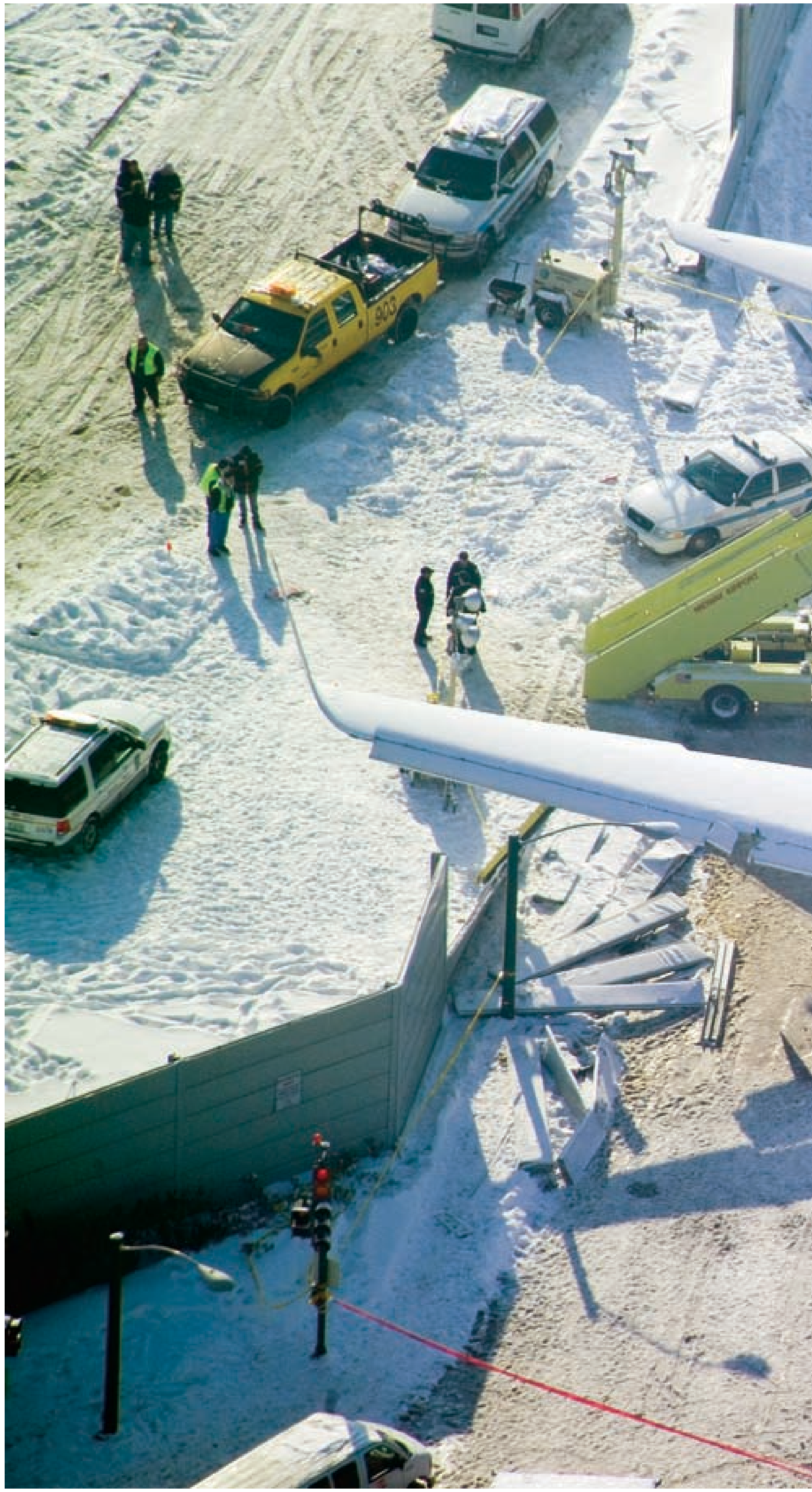
Each generation of EMAS in service — developed since 1986 by Engineered Arresting Systems Corp. (ESCO), FAA and the Port Authority of New York and New Jersey — has provided an elevated arrestor bed, composed of prefabricated blocks of aerated portland cement, beyond the departure end of a runway. "First and foremost, we are trying to maximize deceleration within the limits of the landing gear," said G. Kent Thompson, vice president of airport engineering and sales for ESCO, during the hearing. "As tires crush the material, it creates a tire–material interface at the leading edge of the wheel [that] provides a decelerative load, a drag load, to slow the airplane down. That load is transmitted up through the landing gear and the support structure for the landing gear to decelerate and stop the aircraft. A very important point is that EMAS does not rely on friction."

A computer model showed that the latest-generation EMAS would have safely stopped the 737 at Midway, according to testimony at the hearing. ESCO performed modeling with data from the NTSB investigation to simulate the Midway overrun. "We did a quick design simulation with EMAS at the end [of Runway 31C]. … The weight of the aircraft was about 118,000 lb [53,524 kg]," Thompson said. "The runway exit speed was based on a couple of different ways that the data were [obtained by NTSB] — one indicated 51 kt and the other 53 kt, so we looked at both [speeds]. The conditions [also included] maximum reverse thrust by the time the aircraft left the runway end and the 0.08 runway friction [coefficient]. The performance model indicated that the plane would stop from 51 kt at 198 ft [60 m] beyond the runway end, or about 206 ft [63 m] beyond the runway end if the airplane was going 53 kt. The key [finding] is that [the airplane] would stop before it reached the existing blast fence, which was at 229 ft [70 m] from the runway end."

## Technology Opens Possibilities

A few years before the accident, the City of Chicago Department of Aviation and the U.S. Federal Aviation Administration (FAA) had determined that EMAS was not practical at the airport. In 2000 and 2004, EMAS for Midway "was rejected as a standard option because there was not enough room for a standard EMAS system," said David L. Bennett, director of the FAA Office of Airport Safety and Standards. "The technology for getting a 40 kt-plus performance [nonstandard EMAS] in an area that size … was really just not known to us. [Soon after the Midway accident, the City of Chicago] and FAA … took another really hard look at what could be done with runway safety areas at the airport. What had changed was the availability of some new technology."

Nonstandard EMAS installations later were approved by FAA for Midway, funded and


Allan Goldstein, Aerial Images Photography


The Southwest Airlines Boeing 737 overrun accident in December 2005 has inspired a closer look at protective measures.

Engineered Arresting Systems Corp.

Loads generated by tires crushing the arrestor-bed material — not friction — safely decelerate the airplane.

scheduled for installation in 2006 and 2007 at four runway ends. Rick Marinelli, manager of the FAA Airport Engineering Division, said that jet blast-resistant materials recently tested at La Guardia Airport in New York enable Midway "to put an EMAS about 35 ft (11 m) from the end of a runway instead of 75 ft (23 m), so we get 40 more ft (12 m) of arrestor bed, which makes the difference between it being a practical solution at Midway and not being a practical solution, according to our published guidance."

In a presentation to directors of civil aviation participating in an October 2005 International Civil Aviation Organization (ICAO) meeting, FAA said that, on average, 10 overruns annually occur in the United States. "Since 1982, there have been 23 fatalities, over 300 injuries and uncounted millions of dollars in aircraft damage at U.S. [air carrier] airports," FAA said. "The majority of the severe overruns occurred at airports where the runway does not have a [runway] safety area that extends the full … 1,000 ft (300 m) beyond the runway end. There are many reasons for an overrun: engine failures which result in insufficient power to complete the takeoff, thrust reverse failures, brake failures, improper flap settings, pilot misjudgments and snow/ice on the runway surface."[1]

## Five Enhancement Choices

Planning an EMAS installation involves selecting one "design aircraft," also called the "critical aircraft" — an airplane type that regularly uses the runway and would place the greatest demand on the EMAS. Usually, this is the largest or heaviest airplane. EMAS is one of five options that FAA says must be considered by airport operators subject to U.S. Federal Aviation Regulations Part 139, *Certification of Airports,* for improving runway safety areas. The other options are relocating, shifting or realigning the runway; reducing runway length to create a larger runway safety area when the existing runway length exceeds what is required for the existing or projected design aircraft; a combination of runway relocation, shifting, grading, realignment or reduction; or declared distances. Declared distances is an alternative airport-design methodology allowing the airport owner, subject to FAA approval, to publish distances to satisfy airplane operators' requirements for takeoff run available, takeoff distance available, accelerate-stop distance available and landing distance available — with the runway beyond these distances available as runway safety area.

## Typically Nonstandard

FAA designates an EMAS installation as "standard" if it can safely decelerate the design aircraft from a maximum runway exit speed of 70 kt and if it includes 600 ft (183 m) of space for undershoot (i.e., a total 600 ft length of runway safety area). To be designated as a "nonstandard" EMAS, the arrestor bed either provides deceleration for the design aircraft from a slower maximum runway-exit speed (40 kt to 70 kt) or has less than 600 ft available for undershoots. "Thirteen of 20 systems [in service] are nonstandard EMAS," Thompson said. "[Their] performance ranges from the minimum [runway exit speed] of 40 kt up to about 60 kt with the Boeing 767."

The width of an arrestor bed is the same as the runway width. Its "setback" — which provides a buffer for jet blast — has the shape of a shallow ramp ascending from the runway level and is 75 ft (23 m) long for a standard EMAS. Stepped areas along two sides and the back help aircraft occupants to descend from the arrestor bed to ground level without falling. The ramp and steps also facilitate access by aircraft rescue and fire fighting (ARFF) vehicles. "The ramp allows a smooth transition as the nosewheel and main [landing] gear of the aircraft roll into the [shallowest part of the arrestor] bed, and minimizes the vertical loads on the aircraft," Thompson said. "The rear of the bed is the deepest part, and that is where the maximum depth [of crushed blocks provides] the maximum deceleration for the airplane."

The new assumptions that make EMAS installations at Midway practical send a signal to many U.S. and non-U.S. airport operators that this solution might, after all, enhance their overrun protection. Fifteen months earlier, EMAS technology passed another milestone when FAA for the first time accepted a standard EMAS as equivalent to a standard runway safety area when vertical guidance from a glideslope or visual navigation aid (such as a precision approach path indicator) is available for undershoot protection.[2]

By June 2006, arrestor beds had been installed beyond the ends of 20 runways at 15 U.S. airports and one runway at the airport in Jiuzhaigou, China. More installations are scheduled at five airports in the United States, the Jiuzhaigou airport and one airport in Madrid. Some U.S. airports — such as Little Rock, Arkansas — have installed EMAS and brought the dimensions of their runway safety areas into conformance with Part 139.

After the design phase and fabrication of blocks, a typical EMAS installation takes six weeks: four weeks for site preparation and two weeks to install the blocks. Blocks typically represent 80 to 90 percent of overall cost, and site-preparation work is a significant variable. A standard EMAS typically costs US$3 million to $6 million, not counting changes such as relocation of a localizer antenna, Thompson said. A nonstandard EMAS typically costs $2 million to $4 million.

Airplane arrestments, although few, have shown that airport operators usually need to replace only the damaged portion of an arrestor bed if the EMAS is used. Repair of the arrestor bed that stopped a Boeing 747 at John F. Kennedy International Airport in New York in December 2005 cost about $2 million, the most expensive repair known to ESCO.

## Surviving Jet Blast

Like other airport authorities, Chicago officials had monitored EMAS developments through forums such as Airports Council International conferences and communication with other airports, airlines and ESCO, according to James Szczesniak, assistant commissioner, airport planning, Chicago Department of Aviation. Their thinking about EMAS also has been influenced by early reports and photographs from La Guardia, he said at the hearing.

Compared with La Guardia, "we have similar fleet mixes, similar weather conditions and similar setback constraints," Szczesniak said. "With a 35 ft setback and the fleet mixes that exist at both Midway and La Guardia, an EMAS is subject to [forces similar to] Category 5 hurricane winds on a regular basis when aircraft are departing. We knew technology would ultimately solve our issues, but … there was no way we would be able to install the old-generation EMAS without it being destroyed [by jet blast]."

FAA explained the source of this concern during the ICAO meeting. "The early problem with the [La Guardia] EMAS top coating related to jet-blast damage has been solved," FAA said. "At the time an EMAS was installed on the rollout end of Runway 22 at La Guardia [in 1997], the recommended setback distance was for the arresting system to start 100 ft [30 m] from the runway end. Due to a very short [runway] safety area and a desire to obtain as much arresting capability as possible, the La Guardia EMAS started 35 ft (10.5 m) from the runway end. Repeated exposure to jet blast from departures damaged the EMAS beyond repair, and it was removed." During the hearing, Marinelli clarified that this EMAS gradually was destroyed by "a combination of jet blast and acoustic energy, the low-frequency vibration from the engines."

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An arrestor bed at John F. Kennedy International Airport was crushed by a McDonnell Douglas MD-11 in 2003.

Port Authority of New York and New Jersey

Beyond Chicago officials' qualms about durability, maintenance costs were a concern, Szczesniak said. Maintenance of early arrestor beds involved repainting the exposed cement-type hardcoat surface with an elastomeric paint and recaulking external seams between blocks to control moisture. Current EMAS installations typically have a factory-applied or site-upgraded jet blast-resistant coating designed to last three to five years; the "next generation" jet blast-resistant coating currently used has been designed for more than 10 years of service before repainting, according to ESCO. "Minimal recaulking" has been required at most installations, and the latest sealant reduces maintenance, the company said.

FAA's June 2006 practicability determination for Midway concurred with Chicago officials' judgment that they could not extend their runway safety areas outside of airport property, shorten runways or use declared distances without adversely disrupting operations, Szczesniak said. An aerial image of the airport with color overlay "shows areas outside airport boundaries that would [have been] required, [including] numerous residential dwellings, commercial [buildings] and major arterial roadways," he said. "[We would have had] to acquire about 700 houses and 130 businesses, relocate a number of major roadways and do some rail work … to provide a full standard [runway] safety area for the airport. That was going to cost, in land acquisition alone, $300 million, approximately … We could see that was impracticable. For all four installations, [the total cost will be] approximately $40 million," a price that includes localizer antenna relocations.

## EMAS Arrestments

According to FAA, NTSB, ESCO and JDA Aviation Technology Solutions, a consultant to airport operators on EMAS issues, recent U.S. commercial airplane arrestments help confirm that EMAS performs as predicted by the ESCO computer model:

- In May 1999, American Eagle Flight 4925, a Saab 340B commuter aircraft weighing about 22,000 lbs (9,979 kg) with 30 occupants, overran the departure end of Runway 4R at Kennedy with an estimated runway-exit speed of 75 kt. NTSB said that the airplane traveled approximately 248 ft (76 m) across the arrestor bed before it came to a stop. "Computer modeling indicates that in the absence of the EMAS, an exit speed of only 70 kt would have resulted in the aircraft reaching Thurston Basin [a waterway approximately 600 ft (183 m) beyond the end of the runway]," FAA said. "The aircraft … was brought to a halt with only minor damage. The only injury occurred during the evacuation of the aircraft when a passenger twisted an ankle." ESCO said that this airplane was extracted from the EMAS within four hours by removing crushed blocks and pulling the airplane backwards with a tow vehicle attached to each main gear. The runway reopened without delay, and repairs to the arrestor bed were completed in 15 days.

- In May 2003, a McDonnell Douglas MD-11 operated by Gemini Air Cargo with a weight of about 470,000 lb (213,191 kg) was safely arrested during a low-speed overrun on Runway 4R at Kennedy. The aircraft was extracted from the arrestor bed within a few hours.

- In the January 2005 overrun on Runway 4R at Kennedy, a Polar Air Express cargo 747 with a weight of about 610,000 lb (276,694 kg) and an exit speed greater than 70 kt was stopped safely by the arrestor bed.

Damage to aircraft during these arrestments has been minimal, according to ESCO. Thompson said that he received reports that the 747 — following airworthiness inspections and replacement of nine tires — was returned to normal flight operations within a few days.

The FAA *Airport/Facility Directory* contains entries about the installation

Port Authority of New York and New Jersey

A Saab 340B arrestment occurred in 1999 at John F. Kennedy International Airport.

of EMAS at specific runway ends, and the Notice to Airmen (NOTAM) system communicates advisory information to pilots about an EMAS out of service, such as during repairs after the arrestment of an airplane.

NTSB has advocated and supported wider use of EMAS. "EMAS is not a substitute for, nor a safety equivalent to, a standard-size [runway safety area]," NTSB said in 2003. "However, because EMAS does provide an additional level of safety for those runways at which it is installed, the Board supports the installation of EMAS at those runways in which the [runway safety area] is less than the minimum standards," established in FAA Advisory Circular 150/5300-13, *Airport Design*.

Citing a March 2000 overrun in Burbank, California, U.S., NTSB recommended that FAA proactively require that all Part 139 certificated airports "upgrade all runway safety areas that could, with feasible improvements, be made to meet the minimum standards," and "install [EMAS] in each runway safety area available for air carrier use that could not … be made to meet the minimum standards."

## Improvement Targets

These recommendations influenced FAA's Runway Safety Area Program, implemented in October 1999, which currently aims to accelerate the improvement of runway safety areas to standard — or within 90 percent of standard — faster than relying on Part 139, Bennett said. "We found 456 runways that were not within [90 percent of] standard but could be improved, and that became our target group," he said. In the 2000–2006 period, "we have done more than 200 [runway safety area] projects … and 34 are scheduled for completion in fiscal year 2006." The schedule calls for airport operators to complete upgrades at 92 percent of the targeted runways by 2010 and for 86 percent of all Part 139 runways to "substantially meet" standards by 2015.

Hearing participants raised a common question about EMAS: What would happen to an airplane striking an arrestor bed during an undershoot? The EMAS advisory circular says, "EMAS shall be designed so as not to cause control problems for aircraft undershoots touching down in the arresting system." Thompson added, "[FAA] ran a series of simulations, landing into an EMAS at different flap settings and conditions, and their conclusion was that there was no loss of control of the aircraft. Basically, [the airplane does not experience enough] strut compression while still flying to substantially penetrate the [arrestor] bed, so it skips off of the arrestor [bed] and at flying speeds, one skip and you're on the runway."

Recent reports from ICAO meetings of civil aviation authorities show a continuing process of correcting substandard runway end safety areas. Nevertheless, few countries have reported their compliance with ICAO standards. In 2002, "of 188 signatories to ICAO, 136 have not provided information on compliance, 24 advise they are in compliance [and] 13 advise there are differences [compared with standards for the runway end safety area in Annex 14, *Aerodromes*]," the New Zealand Civil Aviation Authority (CAA) said.[3]

Although EMAS is not covered in ICAO standards and recommended practices, some countries anticipate this technology in current or pending regulations. The Australian Civil Aviation Safety Authority, for example, says, "Where it is not practicable to provide the full length of runway end safety area, the [aerodrome's] provision may include an engineering solution to achieve the objective of the runway end safety area, which is to enhance airplane deceleration."[4] In September 2005, CAA also discussed EMAS in its proposal to implement runway end safety areas on specified runways. CAA said, "ICAO and other regulatory authorities do not approve engineered solutions as an equivalent for a 240 m runway end safety area. The CAA does not consider that these engineered materials provide an equivalent for the runway end safety area, and currently none provide for undershoot."

Regarding international acceptance, Bennett said, "FAA plans to present a discussion paper to the Aerodrome Working Group of the [ICAO] Aerodromes Panel at its next meeting. FAA will share the U.S. experience with [EMAS] and propose that ICAO adopt standards/recommendations similar to ours." ●

### Notes

1. International Civil Aviation Organization. "Runway Safety Areas/Engineered Materials Arresting Systems." A presentation by the United States of America to the North American, Central American and Caribbean directors of civil aviation meeting in Tegucigalpa, Honduras, Oct. 11–14, 2005.
2. U.S. Federal Aviation Administration. Order 5200.9, *Financial Feasibility and Equivalency of Runway Safety Area Improvements and Engineered Material Arresting Systems.* March 15, 2004.
3. Watson, Doug. New Zealand Civil Aviation Authority. "Runway End Safety Area (RESA)" NPRM 04–03 Part 139 *Aerodromes — Certification, Operation and Use.* September 2005.
4. Australian Civil Aviation Safety Authority. *Manual of Standards Part 139 — Aerodromes.*