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AIRCRAFT TOWING FEASIBILITY STUDY

Final Report

September 1980

Work Performed Under Contract No. AC01-79CS50069

Peat, Marwick, Mitchell & Company
San Francisco, California

U. S. DEPARTMENT OF ENERGY

Division of Transportation Energy Conservation

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FINAL REPORT

September 1980

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San Francisco, California 94128

Prepared for the
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Office of Conservation and Solar Energy
Under Contract DE-AC01-79CS50069

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ABSTRACT

Energy costs and availability are major concerns in most parts of the world. Many ways of increasing energy supply and reducing consumption are being proposed and investigated. One that holds considerable promise is the extended towing of aircraft between airport runways and terminal gate areas with engines shut down. This study provides a preliminary assessment of the constraints on and feasibility of extended aircraft towing.

Past aircraft towing experience and the state-of-the-art in towing equipment are reviewed. Safety and operational concerns associated with aircraft towing are identified, and the benefits and costs of implementing aircraft towing at 20 major U.S. airports are analyzed.

It was concluded that extended aircraft towing is technically feasible and that substantial reductions in aircraft fuel consumption and air pollutant emissions can be achieved through its implementation. It was also concluded that, although capital and operating costs associated with towing would be increased, net savings could generally be attained at these airports.

Because of the lack of past experience and the necessity of proving the cost effectiveness of the towing concept, a demonstration of the feasibility of large-scale aircraft towing is necessary. The study evaluates the suitability of the 20 study airports as potential demonstration sites and makes recommendations for the first demonstration project.

EXECUTIVE SUMMARY

After the deregulation of the airline industry in 1978, air traffic increased at a record pace,* and aircraft fuel consumption also increased, albeit at a slower pace. Moreover, congestion at airports caused significant additional fuel consumption while aircraft were delayed. To compound the problem, increases in air traffic also resulted in increases in aircraft emissions of air pollutants.

The cost of jet fuel has increased more than sevenfold since the oil embargo of 1973, and its availability is becoming uncertain. The outlook is not only for more expensive fuel but also for scarce fuel supplies. Partly because of higher air fares (reflecting increased fuel costs) and partly because of the state of the economy, traffic activity was leveling off as of December 1979 and continuing into the first half of 1980, and at some airports it was below the activity levels of the previous year.

Many ways of conserving fuel and reducing aircraft noise and emissions of air pollutants are being investigated, including the holding of aircraft at the gate (when a delay on the airfield is expected to exceed a certain time) and taxiing with one engine shut down. One option that holds considerable promise is the extended towing of aircraft between airport runways and terminal gate areas. In extended towing, an arriving aircraft would taxi to a conveniently located area where tow tractors would be stationed. The aircraft would shut down its engines and would then be connected to a tow tractor which would tow the aircraft to the terminal gate area. Similarly, a departing aircraft would be towed from its parking position to an area adjacent to its takeoff point. The tow tractor would then be disconnected from the aircraft before the aircraft engines are started. Because the fuel consumption and emission rates of tow tractor engines are thought to be much lower than those of jet aircraft engines, considerable reductions in fuel consumption and emissions of air pollutants appear to be possible with extended aircraft towing.

Although the towing of aircraft has been practiced for a long time on a small scale--for example, during push-back operations from the terminal gate and movements to maintenance areas--there are no known extended towing operations at U.S. airports

*The actual level of aircraft operations in 1979 did not indicate any significant trends because of the United Airlines strike and the grounding of DC-10 aircraft.

which have high levels of aircraft activity. Experience with towing operations to date seems to be satisfactory from technical and safety standpoints, but this experience is very limited, and extended towing could be quite a different matter. The actual feasibility of extended towing can be determined only through a real-world demonstration project.

The main purpose of this study was to make a preliminary assessment of the constraints on and the feasibility of towing aircraft between runways and terminal gate areas at 20 major U.S. airports and to recommend potential sites for a towing demonstration project. The study tasks included: (1) a review of towing experience to date; (2) a review of two Federal Aviation Administration (FAA) studies on the potential impact of towing on the aircraft nose gear structure and the safety of aircraft operations; (3) a review of the state-of-the-art in towing equipment; (4) an assessment of the effects of towing on the efficiency of airfield operations and the potential benefits and costs involved; and (5) the recommendation of potential sites for a towing demonstration project.

It was assumed in this study that towing would not be applied to general aviation and propeller-type air taxi aircraft, because their fuel consumption and air pollutant emissions are low relative to those of jet aircraft commonly used by air carrier and some commuter airlines.

The main findings and conclusions of this preliminary study are that:

- Substantial fuel savings could result from extended aircraft towing at the 20 study airports, as shown in the table on the following page. The annual savings, using currently available tow tractors, range from 1.5 million gallons at New Orleans International Airport to 39.1 million gallons at Chicago-O'Hare International Airport.
- Substantial reductions in aircraft emissions could also result from extended aircraft towing at the 20 study airports.
- The extended towing of aircraft is technically feasible but there are institutional and other issues that need to be considered. These include the co-operation of parties who may be affected by towing (e.g., airlines, airport operators, pilots, and air traffic controllers); the training of tractor drivers; and public relations programs for air travelers.

ESTIMATED POTENTIAL ANNUAL FUEL SAVINGS
FROM EXTENDED AIRCRAFT TOWING
(Millions of Gallons)

<u>Airport</u>	<u>Currently available tow tractors</u>	<u>Proposed tow tractors</u>
Atlanta	14.29	13.84
Boston	6.75	6.03
Chicago O'Hare	39.12	35.76
Dallas/Fort Worth	10.41	10.30
Denver	8.20	7.45
Honolulu	2.42	3.53
Houston	3.76	3.43
Kennedy (New York)	22.63	21.76
LaGuardia (New York)	10.04	8.91
Los Angeles	16.52	15.59
Miami	7.71	7.35
Minneapolis-St. Paul	2.99	2.62
New Orleans	1.46	1.26
Philadelphia	3.77	3.33
Pittsburgh	2.64	2.30
St. Louis	5.07	4.39
San Francisco	9.83	9.20
Seattle-Tacoma	2.50	2.35
Tampa	3.68	3.35
Washington, D.C.		
(National)	<u>4.02</u>	<u>3.49</u>
Total	177.01	165.23

Note: The estimates shown are based on 1978 levels of aircraft operations.

Source: Peat, Marwick, Mitchell & Co.

- Because of the lack of previous experience in extended towing of aircraft, its effects at highly congested airports are uncertain. Experience with extended towing should be gained at less congested airports before it is tried at such airports.

Other findings and conclusions are as follows:

1. Towing Equipment. Currently available tow tractors are designed only for low-speed towing (an average of 8 to 12 miles per hour versus an average aircraft taxi speed of 20 to 30 miles per hour). The use of these low-speed tractors would therefore result in (1) longer taxi times for aircraft traveling between the runways and terminal areas; (2) additional flight and ground crew costs, and (3) additional towing equipment costs.

Future towing equipment, as proposed by several manufacturers, is capable of high-speed towing and has several attractive features that would facilitate aircraft towing operations.

2. Safety and Operational Concerns. On the basis of results of two FAA-sponsored engineering studies by Lockheed-California Company and Douglas Aircraft Company, it appears that extended aircraft towing would not impose safety problems, although proper training of tow tractor drivers and close coordination between aircraft pilots and tractor drivers would be required. The Lockheed study concluded that extended towing would not reduce the fatigue life of the nose gear structure of L-1011 aircraft to below its design value. The Douglas study found that certain nose gear components of the DC-9 aircraft may be affected by extended towing. However, safety could be ensured by more frequent inspection of the nose gear components and by removal and replacement of these components when necessary.

There would be some operational difficulties associated with aircraft towing at the 20 study airports, but these could be reduced by constructing tractor roadways and other special facilities, by developing improved towing equipment, and by other means described in this report.

3. Benefits and Costs. The potential costs and savings associated with aircraft towing at the 20 study airports, using currently available and proposed towing equipment, are summarized in the table on the following page. Net savings ranging from \$100,000 to \$23.8 million per year can be achieved at certain airports (assuming a fuel cost of \$1.00 per gallon).

At many airports, however, significant capital and operating costs would be incurred to implement towing operations. Also, at some airports, new tractor roadways or tractor-aircraft connection and disconnection areas would have to be built to avoid additional airfield congestion. Only rough estimates of these construction costs were included in this study. Construction now under way or planned at many airports could substantially reduce these construction requirements.

The feasibility of aircraft towing depends heavily on the cost of jet fuel. At a cost of \$1.00 per gallon, 18 of the 20 study airports would achieve net savings. At a cost of \$1.50 per gallon, all 20 study airports would achieve net savings. (As of April 1980, the cost of jet fuel averaged \$0.885 per gallon for domestic trunk carriers.)

The reductions in aircraft air pollutant emissions are difficult to quantify in monetary terms, but they may be sufficient at some airports to justify the implementation of aircraft towing. The estimated total annual reductions in air pollutant emissions at the 20 study airports would be about the same with currently available and proposed equipment: 31,000 to 33,000 tons of carbon monoxide; 20,000 tons of hydrocarbons; 1,500 to 1,700 tons of oxides of nitrogen; and 240 to 260 tons of total suspended particulates.

Although no attempt was made in this study to estimate changes in noise levels, it is thought that aircraft towing may also result in some noise reduction.

Airfield operations could be conducted more efficiently with the proposed towing equipment than with the currently available equipment; however, the cost savings in many cases would be lower (according to estimates based on data provided by one manufacturer).

4. Demonstration Project. Regardless of the level of accuracy and sophistication of analytical work performed on aircraft towing, debates about the feasibility of towing will continue until it is actually demonstrated in real-world situations. On the basis of seven selection criteria and the analyses performed in this study, Honolulu International Airport and Seattle-Tacoma International Airport were found to be the most suitable airports for a potential aircraft towing demonstration project. It is recommended that the Department of Energy select one or both of these airports for further assessment. The planning and implementation phases of the demonstration project are expected to take about 2 years.

It is also recommended that arrangements be made to observe and monitor any towing operations that may occur before the start of an extended towing demonstration.

SUMMARY OF NET ANNUAL SAVINGS (COSTS) ASSOCIATED WITH
CURRENTLY AVAILABLE AND PROPOSED AIRCRAFT TOWING EQUIPMENT
(Millions of Dollars)

<u>Airport</u>	<u>Currently available towing equipment</u>	<u>Proposed towing equipment</u>
Atlanta	\$ 3.5	\$ 4.8
Boston	2.6	2.2
Chicago O'Hare	23.8	19.5
Dallas/Fort Worth	(2.4)	4.6
Denver	3.1	2.7
Honolulu	0.3	1.4
Houston	0.1	1.1
Kennedy (New York)	10.2	14.2
LaGuardia (New York)	5.2	3.9
Los Angeles	7.8	9.6
Miami	0.2	3.7
Minneapolis-St. Paul	0.9	1.1
New Orleans	0.3	0.4
Philadelphia	1.7	1.3
Pittsburgh	(1.1)	(0.3)
St. Louis	1.3	1.3
San Francisco	3.8	5.3
Seattle-Tacoma	0.6	1.1
Tampa	0.9	1.1
Washington, D.C. (National)	1.6	1.0

Note: Numbers in parentheses indicate net costs.

Source: Peat, Marwick, Mitchell & Co.

Chapter 1

INTRODUCTION

BACKGROUND

The use of air transportation as a major mode of intercity travel is becoming increasingly popular. This higher demand for air transportation has resulted in proportionately higher fuel consumption by the aviation industry, and the added congestion at airports has caused significant additional fuel consumption while aircraft are delayed. To compound the problem, increased air traffic has also resulted in increased aircraft emissions of air pollutants and increased exposure to aircraft noise.

The cost of jet fuel has increased more than sevenfold since the oil embargo of 1973, and its availability is becoming uncertain. The outlook is not only for more expensive fuel but also for scarce fuel supplies (jet fuel competes with home heating oil and diesel fuel). Partly because of higher air fares (reflecting increased fuel costs) and partly because of the state of the economy, traffic activity was leveling off as of December 1979 and continuing into the first half of 1980, and at some airports it was below the activity levels of the previous year.

It is important that all possible steps be taken to conserve fuel and to reduce aircraft emissions of air pollutants. A number of fuel conservation programs are being considered by the federal, state, and local government agencies, aerospace manufacturers, the airlines, and airport sponsors. Programs are under way (or can be established) to increase the operational efficiency of aircraft; to develop more fuel-efficient, quieter, and cleaner aircraft engines; to implement changes in aircraft maintenance and airline scheduling practices; and to improve the air traffic control system.

One program that holds promise to reduce both fuel consumption and emissions of air pollutants is the extended towing of aircraft between runways and terminal gate areas. The potential benefits achievable by towing aircraft at two major U.S. airports--Los Angeles International Airport and San Francisco International Airport--were investigated in a study conducted for the California Air Resources Board in 1978 (Ref. 1).^{*} It was concluded that substantial savings in fuel consumption and reductions in emissions of air pollutants could be attained if certain operational and safety issues could be resolved. In a

^{*}Cited references are listed at the end of this report.

separate study performed for the Department of Energy, also in 1978 (Ref. 2), aircraft towing was identified as one of the most promising of 47 fuel conservation options that were evaluated.

In extended towing, an arriving aircraft would taxi to a conveniently located area where tow tractors would be stationed. The aircraft would shut down its engines and would then be connected to a tow tractor which would tow the aircraft to the terminal gate area. Similarly, a departing aircraft would be towed from its parking position to an area adjacent to its takeoff point. The tow tractor would then be disconnected from the aircraft before the aircraft engines are started. Because the fuel consumption and emission rates of tow tractor engines are thought to be much lower than those of jet aircraft engines, considerable reductions in fuel consumption and emissions of air pollutants appear to be possible with extended aircraft towing.

STUDY OBJECTIVES AND SCOPE

The objectives of this study are (1) to make a preliminary assessment of the constraints on and the feasibility of extended towing of aircraft between the terminal areas and runways at 20 major U.S. airports, and (2) if towing is considered feasible, to recommend potential airport sites for an extended towing demonstration project. It was assumed in this study that extended towing would not be applied to general aviation and propeller-type air taxi aircraft, because their fuel consumption and air pollutant emissions are low relative to those of jet aircraft commonly used by air carrier airlines and some commuter airlines. The findings of this preliminary study are presented in the six chapters of this report.

Chapter 2 describes previous aircraft towing experience, and Chapter 3 reviews the state-of-the-art in towing equipment. Data are presented on both currently available and proposed tow tractors (those in the planning or design stage). Particular emphasis is given to the technical capabilities of tractors, such as towing speed and pulling capacity, and to the unit capital costs and maintenance and operating costs associated with aircraft towing.

The potential effects of extended towing on the aircraft nose gear structure and on the safety of aircraft operations are discussed in Chapter 4. The potential effects of aircraft towing on the efficiency of airfield operations are also described and the conditions that would minimize these effects are delineated.

Chapter 5 presents estimates of the potential fuel savings and environmental impacts, and estimates of the costs associated with implementing extended towing at 20 U.S. airports.

The 20 study airports, listed below, accounted for 5.0 million air carrier operations in 1979, or about half of the total 1979 air carrier operations in the United States. They also accounted for 188 million enplaned passengers, or 58% of the total enplaned passengers in the United States. Because of the 1978 Airline Deregulation Act, these 20 airports can be expected to account for an even larger share of total aircraft operations during the 1980s.

William B. Hartsfield Atlanta International
Airport

Boston-Logan International Airport

Chicago-O'Hare International Airport

Dallas/Fort Worth Airport

Denver Stapleton International Airport

Honolulu International Airport

Houston Intercontinental Airport

John F. Kennedy International Airport

LaGuardia Airport

Los Angeles International Airport

Miami International Airport

Minneapolis-St. Paul International Airport

New Orleans International Airport

Philadelphia International Airport

Greater Pittsburgh International Airport

Lambert-St. Louis International Airport

San Francisco International Airport

Seattle-Tacoma International Airport

Tampa International Airport

Washington National Airport

Finally, Chapter 6 recommends two airport sites for an aircraft towing demonstration project. Preliminary estimates of the resources required to plan and implement such a project are also provided.

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Chapter 2

REVIEW OF EXISTING AIRCRAFT TOWING EXPERIENCE

The maneuvering of aircraft with tow tractors has been practiced for a long time, but traditionally it has been limited to: (1) push-back operations, where an aircraft is pushed back from the gate and maneuvered into position so it can taxi out under its own power; (2) ferrying of aircraft between the maintenance area and the gate position; and (3) special instances involving constrained apron layouts, where aircraft are towed short distances to their parking positions.

There has been very little experience in the extended towing of arriving and departing aircraft between gates and runways. Experience at Roissy-Charles De Gaulle Airport in Paris and at Boston-Logan International Airport is described below. Experience at Los Angeles International Airport and San Francisco International Airport is also briefly described.

ROISSY-CHARLES De GAULLE AIRPORT, PARIS

Aircraft towing at Roissy-Charles De Gaulle Airport was initiated by Air France to help solve the problem of a long taxiing distance (about 5 miles) between its maintenance area and the terminal gates. A special experimental tractor was built to evaluate the capability of current designs. The tractor weighs 85 tons and is powered by a 2,400-horsepower engine. It is equipped with hydraulic transmission and an integrated tow bar.

Tests were conducted with a B-747 aircraft weighing 200 tons. Towing speed was increased in increments of 3 miles per hour during the tests. The results showed that there was no special problem with towing speeds up to about 20 miles per hour. However, with speeds above 20 miles per hour (up to 30 miles per hour), there was a yaw phenomenon with an amplitude of 2 to 3 feet and a frequency of one oscillation every 4 to 5 seconds. The stopping distance for braking action was also recorded. At a speed of 20 miles per hour, the stopping distance was 240 feet with a deceleration rate of 1.875 feet per second per second. The yaw phenomenon was also observed when a B-707 aircraft was towed at practically the same speed.

The major conclusion of these tests was that the current designs of the tractor and tow bar restrict aircraft towing speed to a maximum of 20 miles per hour.

In an effort to improve towing speed, Air France contracted with a French tractor manufacturer (Secmafer) to develop a new tractor that would be capable of towing aircraft at high speeds. This new tractor is designed to reach a maximum speed of 38 miles per hour with no towed load. The tractor is equipped with a turntable to carry the nose gear of the aircraft and to operate without a tow bar. A description of the operation of this tractor is given in Chapter 3.

Air France and Airbus Industrie were scheduled to conduct high-speed tests of the new tractor in early 1980. If successful, this new tractor would offer several advantages:

1. Smaller tractor size, since the weight of the aircraft is used to improve traction.
2. Lower purchase costs because of the smaller tractor size (the unit price in 1978 for this high-speed tractor was approximately \$330,000).
3. High maneuverability, because the tractor could fit under the airplane body more easily.
4. Savings in ground support equipment and personnel, because tow bars would no longer be needed and the tractor could be operated by one person.

It is reported that if the tests prove to be satisfactory and a commercial market develops, the new tractors could be ready for sale in 1980.

The towing operation (ferrying of aircraft to and from hangars) at Roissy-Charles De Gaulle Airport currently differs very little from that at U.S. airports which have major airline maintenance facilities. The only difference at Roissy-Charles De Gaulle Airport is that the design of the tractor is based on a concept different from that used for conventional tractors, and towing is performed at speeds higher than are achievable with conventional tractors.

BOSTON-LOGAN INTERNATIONAL AIRPORT

In 1976, the Massachusetts Port Authority (Massport) proposed a regulation to prohibit aircraft from using self-propulsion at Boston-Logan International Airport west of an area near the Airport fire station, designated by airport management as the area for towing initiation (inbound) or towing termination (outbound).

The purpose of this regulation was to reduce aircraft noise impacts on nearby residential communities. The regulation was scheduled to become effective during nighttime hours starting on February 1, 1977, and throughout the 24-hour day starting January 1, 1978.

Figure 1 shows the terminal and airfield area at Boston-Logan International Airport. The aircraft towing area is west of the South Terminal, which includes some gates of Allegheny Airlines, all gates of Eastern Airlines in the Southwest Terminal, and the general aviation area. The plan provides for arriving aircraft to be towed from the area south of the fire and crash station to the gates, and for departing aircraft to be towed from the gates to this same area.

On the basis of available information, the major concerns with respect to aircraft towing at Boston-Logan International Airport included the following:

1. The structural integrity of aircraft nose gear under frequent towing conditions.
2. Ramp and taxiway congestion and the addition of tow tractor traffic.
3. The definition of responsibility for aircraft and passenger safety (whether the tractor driver or the pilot is responsible when aircraft are being towed).
4. A possible competitive edge for the unaffected carriers, since the ground travel times of their aircraft are shorter (tow tractor speed is slower than self-propelled aircraft speed).
5. Additional equipment and crew costs borne by the affected carriers (Eastern Airlines and Allegheny Airlines).
6. Extra air traffic controller workload.

Because of these concerns, the regulation was never fully implemented at Boston-Logan. As a result of the concerns regarding aircraft nose gear safety, the FAA initiated two studies by aircraft manufacturers (Douglas Aircraft Company and Lockheed-California Company) to investigate the effect of extended towing on the aircraft nose gear structure. The findings of these studies are reviewed in Chapter 4.

Figure 1

BOSTON-LOGAN INTERNATIONAL AIRPORT

OTHER TOWING EXPERIENCE

Towing operations are being conducted at several other airports in the United States. For example, Trans World Airlines and Eastern Airlines aircraft are towed at Los Angeles International Airport because of engine blast problems in the terminal-apron area (see layout of airport on page 34). These towing movements are limited to the maneuvering of aircraft between the gate area (Satellite 3) and the adjacent taxiways. The actual tow distance is less than 1,000 feet, and towing is conducted at speeds up to 8 miles per hour using conventional tractors.

For all towing that originates in the terminal gate area, the engines are shut off during the push-back phase, and generally, the start-up of the No. 1 or No. 2 engine is initiated during the pull-forward phase. Trans World Airlines also tows aircraft between the terminal gate positions and the hangar. The tow distance in this case is about 6,000 feet.

Continental Airlines has also implemented towing procedures for moving aircraft between its terminal gates and hangar area at Los Angeles International Airport. The tow distance is about 6,300 feet. Preliminary results provided by Continental staff indicated savings of about \$150,000 (or about 200,000 gallons of fuel) per year through the use of towing procedures for an average of six aircraft per day.

Another example of aircraft towing is the ferrying of aircraft between terminal gate positions and airline maintenance areas at San Francisco International Airport. United Airlines regularly uses towing to reposition aircraft. American Airlines aircraft are towed across active runways from their gate positions to the maintenance area and vice versa. Similar maneuvers are conducted at other airports. No special problems are encountered in these towing operations.

The towing of aircraft between gates and maintenance areas usually covers a long distance; however, such towing normally involves lightly loaded aircraft with no passengers on board.

SUMMARY OF EXISTING EXPERIENCE

In summary, existing experience with extended towing operations between runways and terminal gate positions is very limited. Much of the experience to date has involved either short-distance maneuvers, or extended towing between maintenance areas and terminal gate positions with no passengers on board. On the basis of this experience, towing operations appear to be satisfactory from technical and safety standpoints. The safety concern will be addressed in more detail in Chapter 4 which includes a review of the two FAA-sponsored nose gear studies mentioned earlier.

Concern regarding towing costs and operational efficiency also will be dealt with in Chapters 3 and 4.

It should be pointed out here that because of the limited experience with extended aircraft towing, many of the concerns or issues cannot be resolved through "paper studies." Debates about the feasibility of aircraft towing will continue until it is actually demonstrated in real-world situations.

Chapter 3

REVIEW OF THE STATE-OF-THE-ART IN TOWING EQUIPMENT AND ASSOCIATED COSTS

Two categories of towing equipment were reviewed: (1) tow tractors that are currently available and commonly used for push-back and ferrying operations at most airports, and (2) tractors that are in the testing or proposal stage. Representative equipment in each category was reviewed in terms of technical capability, unit capital costs and maintenance and operating costs, and staffing and equipment requirements.

CURRENTLY AVAILABLE TOWING EQUIPMENT

Currently available tow tractors are not designed for extended towing of fully loaded aircraft or for high speeds. They are used mostly for push-back operations and for ferrying unloaded aircraft between the airline maintenance area and the passenger terminal gate area.

The push-back operation starts at the gate prior to aircraft departure. Two ground personnel are normally involved in connecting the aircraft to the tractor. One connects and disconnects the tow bar and communicates with the pilot; the other drives the tractor. The driver normally receives directions from the other member of the ground crew, who walks alongside the tractor, making sure the aircraft wing-tips clear adjacent obstacles. Thus, the speed of push-back is normally 2 to 3 miles per hour.

The time from the start of push-back to the movement of the aircraft under its own power varies greatly by aircraft type and push-back distance. Normally, one aircraft engine is started during push-back; the remaining engines are started while the aircraft is taxiing out to the runway.

Tractors manufactured by International Harvester Company are representative of currently available towing equipment.* Several models are available. The choice of model is normally based on the gross weight of the aircraft to be towed.

*Reference to any specific towing equipment or manufacturer does not constitute or imply its endorsement or recommendation by either the Department of Energy or Peat, Marwick, Mitchell & Co.

Four models of currently available tractors were reviewed in this study. All four models were manufactured by International Harvester Company and involved the use of a tow bar in their operations. The models were: model T-800S, which is designed primarily for towing B-747 aircraft; model T-500S, which is designed for towing L-1011 and DC-10 aircraft; and models T-225SL and T-300SL, which are designed for smaller aircraft such as the B-727, B-737, and DC-9. A photograph of the model T-500S with an L-1011 aircraft is reproduced in Figure 2.

The maximum speed these tractors can achieve is 19 to 21 miles per hour without tow loads and 8 to 10 miles per hour with heavy tow loads. The average fuel consumption of these tractors is about 6 gallons per hour. The performance data for these four models are as follows:

<u>Tractor model</u>	<u>Maximum weight of tractor (lb)</u>	<u>Maximum pull (lb)</u>	<u>Maximum speed</u>
T-225SL	32,000	22,500	10 mph maintaining a pull of 5,000 lb
T-300SL	40,000	30,000	10 mph maintaining a pull of 5,000 lb
T-500S	110,000	58,000	9 mph maintaining a pull of 10,000 lb
T-800S	155,000	80,000	8 mph maintaining a pull of 15,000 lb

Airlines have been known to use the smaller tractors to tow the larger aircraft on occasion, since current towing operations involve mainly push-back maneuvers and repositioning of empty aircraft. In such cases, towing time is of little concern. It was assumed in this study, however, that for long-distance towing of heavily loaded aircraft, the appropriate tractors would be used to minimize towing time.

Since extended towing requires much longer tractor time than today's push-back operations, additional equipment and ground service crew personnel would be needed. For purposes of this preliminary study, the evaluation of extended towing considered (1) capital costs for the purchase of tow tractors, tow bars, communication equipment, and fire extinguishers; (2) direct maintenance costs; and (3) direct operating costs.

Figure 2

EXAMPLE OF CURRENTLY AVAILABLE TOWING TRACTOR

Capital costs for tractors range from \$75,000 for the smaller models to \$300,000 for the large models. The actual purchase price varies, depending on the optional equipment ordered and negotiation between the airline and the tractor manufacturer. For the purpose of this analysis, the following unit costs for equipment were assumed:

<u>Equipment</u>	<u>Capital cost per unit</u>
Tractors	
Large (T-800S)	\$300,000
Medium (T-500S)	200,000
Small (T-300SL)	90,000
Small (T-225SL)	75,000
Tow bar	2,000
Communication equipment	2,000
Fire extinguisher	1,000

Direct maintenance costs of tractors (mainly tractor engine overhaul) amount to about \$3,200 per unit. The frequency of tractor engine overhaul varies from once every 3 years for gasoline engines to once every 7 years for diesel engines. However, under extended towing conditions, the interval between overhauls would probably be shorter. In this study, an average maintenance cost of \$1,000 per unit per year was assumed.

Direct operating costs included personnel costs and fuel costs. Personnel costs for staffing towing equipment consist mainly of salary and benefits for the tractor crew. Assuming a two-man crew per tractor and an average hourly rate of \$11 per person, the annual cost of operating a tractor would be \$46,000 per crew per 8-hour shift. The unit fuel cost for tow tractors was assumed to be the same as the cost of jet fuel.

PROPOSED TOWING EQUIPMENT

As mentioned in the previous section, existing models of tractors are designed for low-speed push-back and towing operations. The use of these tractors for extended towing between terminal gate areas and runways would result in much longer taxi times (compared with no towing) in most cases, since average aircraft taxi speeds are between 20 and 30 miles per hour. The difference in aircraft taxi speed and tractor tow speed is the major impetus behind the development of new tow tractors proposed by advocates of aircraft towing operations.

In this study, tractors proposed by two manufacturers were reviewed: Secmafer of France and Vanley Systems of Renton, Washington.* The designs of these tractors are based on the concept of lifting aircraft nose gear onto the tractor itself to reduce tractor size and to eliminate the need for tow bars. Both tractors are designed for high-speed towing.

The tractor being manufactured by Secmafer, shown in Figure 3, is powered by a 1,200-horsepower engine, and it would operate as follows.

The tractor moves back toward the aircraft, lowers the ramp at the back of the tractor, and pushes it under the tires of the nose gear. The ramp exerts a vertical thrust lifting the nose gear wheel off the ground and up the ramp toward the turntable. After the nose wheel is properly located, the tractor driver activates a remote-control locking device to keep the nose wheel in place.

The force applied to the hydraulically controlled lock depends on the preset power range which corresponds to the type and weight of aircraft to be towed. If the force exerted by the aircraft on the locking device exceeds this preset value, the locking device opens immediately, lowering the ramp at the same time, and the aircraft is released at once. This allows the pilot to disengage the aircraft from the tractor in an emergency by applying the aircraft brakes during towing. The hydrostatic transmission on the tractor also keeps the aircraft from jerking while being towed.

The maximum speed while towing is expected to be between 30 and 35 miles per hour. The tractor was priced at \$330,000 per unit in 1978. Data on tractor fuel consumption, emission rates, and maintenance costs were not available. It is assumed that fuel consumption and emission rates of the Secmafer tractor would be the same as those of the tractor proposed by Vanley Systems. Tractor maintenance costs are assumed to be the same as those of conventional tractors.

The Aircraft Movement System (AMS) proposed by Vanley Systems is to be powered by a 1,200-horsepower diesel engine. It would weigh 160,000 pounds and reportedly would be capable of towing 116,000 pounds at speeds up to 35 miles per hour or 1,000,000 pounds at speeds up to 15 miles per hour. (A fully loaded

*Reference to any specific towing equipment or manufacturer does not constitute or imply its endorsement or recommendation by either the Department of Energy or Peat, Marwick, Mitchell & Co.

GENERAL VIEW

THE RAMP IS PUSHED UNDER THE TIRE

Figure 3

EXAMPLE OF PROPOSED TOWING TRACTOR

B-737 aircraft weighs about 116,000 pounds, and a fully loaded B-747 aircraft weighs between 710,000 and 820,000 pounds, depending on the aircraft model.) The fuel consumption of the AMS is reported to be 41 gallons per hour.

The envisioned operating cycle of the AMS is as follows: The AMS fleet would be parked at convenient locations on the airport. When an aircraft arrives, an AMS would be driven, either manually or under automatic guidance, to the hook-up area. The AMS ground personnel would engage the aircraft to the tractor and connect an umbilical cord to the aircraft. The umbilical cord allows control of the tractor by the pilot.

After the aircraft is connected to the AMS, control would be transferred to the pilot. The ground personnel would not operate the AMS again until control is relinquished by the pilot. A control unit would therefore need to be installed in the cockpit of each towed aircraft for this purpose.

As with the use of existing tractors, the aircraft brakes would have to be used to stop the combined tractor and aircraft. Forward or reverse movement would be powered by the AMS. When the towed aircraft reaches its gate, the AMS would be disconnected and used elsewhere. The process for towing a departing aircraft would be similar to that described for an arriving aircraft.

The AMS would provide electrical power and pneumatic supply for air conditioning and engine start. This would eliminate the need for aircraft to use an auxiliary power unit (APU).

The AMS would be equipped with a collision avoidance and alarm system consisting of a mounted ground surveillance radar and a computer. The system would minimize the number of full stop-and-start cycles. It would detect the need to stop because of interference from other aircraft and thus would allow gradual reduction of towing speed to avoid the need for a full stop.

Vanley Systems proposes to provide contract tow service to airlines at a fixed rate per minute, rather than sell tractors to each airline. The final cost of this service is not available at this time, but, according to Vanley, it is likely to be about \$4 per minute (for AMS service). This figure compares with \$8.62 per minute (at \$1.00 per gallon of fuel) for the fuel burn of a B-727 aircraft, at 57 pounds of fuel per minute of taxi time. Reportedly, the AMS will have an on-board bookkeeping device to record the time each tractor is used by each customer. The Vanley plan is that, with its AMS service, the airlines would not have to increase their ground service crew personnel or purchase additional equipment.

SUMMARY OF FINDINGS ON TOWING EQUIPMENT

Currently available tow tractors are designed only for low-speed operation. The use of these tractors would result in (1) longer taxi times for aircraft traveling between the runway and the terminal area, (2) additional crew costs, and (3) additional towing equipment costs.

Future towing equipment, as proposed, for example, by Secmafer and Vanley Systems, would be designed for high-speed towing and would have several attractive features that would facilitate aircraft towing operations. These include: (1) the elimination of the use of tow bars, thereby enhancing the safe operation of aircraft nose gear; (2) the capability of some designs to provide electrical power and pneumatic supply to service the aircraft; and (3) the ability (of the Vanley tractors) to transfer control of the tractor to aircraft pilots.

Chapter 4

REVIEW OF SAFETY, OPERATIONAL, AND OTHER CONCERNS ASSOCIATED WITH AIRCRAFT TOWING

The major concerns with respect to extended aircraft towing operations are safety, operational effects, and costs. The safety, operational, and other concerns are discussed in this chapter. In particular, the effects of large-scale aircraft towing on airfield operations at each of the 20 study airports are addressed. The cost implications are dealt with in Chapter 5.

SAFETY CONCERNS

Concerns about the safety of both the passengers and the aircraft during towing operations have resulted in some of the strongest objections to aircraft towing. These concerns center mainly on (1) the effects of extended towing on the structural integrity of the aircraft nose gear; and (2) the question of who is responsible for the control of towed aircraft.

Many people have expressed doubts about the ability of aircraft nose gear to withstand the stress and strain of extended towing. Failure of the nose gear structure would have grave consequences, especially during the takeoff and landing phases of an aircraft operation.

There is also the question of who is responsible for the safety of the aircraft and passengers while the aircraft is being towed. At the present time, the pilot is legally charged with that responsibility, but the tractor driver is the one who would actually conduct the ground maneuvers. There is a strong need for close coordination between the pilot and the tractor driver for such maneuvers, not only because stopping the aircraft would usually require the use of brakes on the aircraft but also because the pilots must relay requests and clearances between the air traffic controller and the tractor driver.

These same concerns were raised when the Massachusetts Port Authority (Massport) proposed a regulation to require aircraft towing for certain operations at Boston-Logan International Airport (see Chapter 2). To address the nose gear safety issue, the FAA contracted with Lockheed-California Company and Douglas Aircraft Company to undertake studies of the effect of extended towing at Boston-Logan on the structural integrity of aircraft nose gear.

The studies involved actual field testing and measuring the stress of towing on the nose gear structure. Lockheed used the L-1011 aircraft in its study, and Douglas used the DC-9 aircraft.

The Lockheed Study

In the Lockheed study (Ref. 3), the actual towing of the L-1011 took place under both operational and controlled conditions. The operational towing took place at Los Angeles International Airport, where Trans World Airlines and Eastern Airlines aircraft were towed to and from gates at Satellite 3, the runway, and the Trans World Airlines maintenance hangar. An International Harvester Paymover T-500S tow tractor was used for all towing. The tow distances varied from a few hundred feet (just push-back) to 6,400 feet (to the hangar).

Operational testing was also conducted at Dorval Airport in Montreal, Canada, to study the effect of towing under snow and ice conditions. Again, International Harvester tractors were used (with chains mounted on all of their wheels). Towing distances ranged from 200 to 8,700 feet. In all cases, the towing load (compression or tension), velocity, aircraft weight, and other pertinent data were compiled.

The controlled testing site was at Palmdale, California. The tow paths were approximately the same as those used at Boston-Logan. In all except one of the towing tests, the largest International Harvester tractor (T-800) currently available was used. The maximum tow distance was 1,400 feet.

During the control testing, the following characteristics and movements were varied from test to test: aircraft weight, position of center of gravity, tire pressure, towing velocity, towing uphill and downhill, abrupt start and stop, towing in a circular path, and towing across a drainage ditch. As in the case of operational towing, relevant measurements were taken.

Data from all tests were then analyzed and used to validate an analytical model developed by Lockheed to investigate the effects of aircraft towing. The correlation between analytical and test results was reported to be good.

The conclusions of the Lockheed study were as follows:

1. The proposed extended towing at Boston-Logan International Airport would not reduce the fatigue life of the L-1011 nose gear and supporting structure below the design value.

2. Dynamic towing loads are very sensitive to tractor driver technique. Peak dynamic loads (three times as large as typical dynamic loads) were observed during the testing. These measured loads were considered to be typical of those handled by experienced tractor drivers. Deviations from accepted towing procedures can result in dynamic loads of sufficient magnitude to reduce the fatigue life of the nose gear.
3. Dynamic towing loads are also sensitive to the transmission characteristics of tow vehicles, particularly during gear shifting.
4. No unusually high towing loads were measured during testing at Dorval Airport (Montreal) on taxiways covered with snow and ice. No difficulties were encountered in controlling the combined tractor and aircraft under these conditions.
5. Dynamic towing loads large enough to be significant from a fatigue damage viewpoint normally occur at the start and stop of a towing operation. The only exceptions are occasional large dynamic loads during tractor gear shifts.

The Douglas Study

In the Douglas study (Ref. 4), measurements of DC-9 tow loads were made to obtain parametric data that could be applied to any towing operation at any airport. Powered operations at Boston-Logan International Airport were observed to obtain data on typical aircraft maneuvers. Towing loads were measured under a variety of conditions that could be expected to occur in service. These measurements were made at the Long Beach Municipal Airport and the Douglas Aircraft Facility, Long Beach, California, using a DC-9 Series 40 aircraft with a gross weight of 100,000 pounds. The tow vehicle was a United Shop Mule weighing 22,380 pounds and with a rated constant pulling power of 16,200 pounds. The vehicle had sufficient power to tow the DC-9 at speeds up to 15 knots.

The weather conditions during testing were generally overcast with partial clearing in the afternoon. The temperature was in the low 60s and the winds were light. Winds of moderate force were not considered to have a significant effect on towing loads for the DC-9. The effect of high winds was included in the development of the Douglas loads model that was used to determine the fatigue of critical structural components.

All towing was conducted on asphalt surfaces. Towing on slopes as well as on wet and dry surfaces was investigated. Light-to-heavy tow vehicle braking from speeds up to 14 knots was studied.

The conclusions of the Douglas study were as follows:

1. The only significant loads encountered during towing were those associated with the start and stop portions of the maneuvers.
2. Loads due to runway/taxiway cross slopes and intersections, turning and steady-state towing, and wet and rough surfaces were not found to be significant.
3. Several nose landing gear components of the DC-9 could be affected by extended towing (as proposed at Boston-Logan), especially on aircraft that have already accumulated a large number of flights.
4. The safety of the DC-9 nose landing gear subjected to extended towing can be ensured through periodic inspection of parts to detect fatigue damage, and the removal and replacement of parts as their life limits are reached. (Note: On the basis of costs provided in the Douglas report, the replacement of parts would cost about \$16,000 per aircraft during the design lifetime of the nose gear structure, which is 40,000 flights.)
5. Loads applied to the nose gear could also be reduced by having a shock-absorbing device built into existing tow bars. No such tow bars currently exist for the DC-9, and the design, production, and testing of one could take several months.

Findings on Safety

On the basis of the conclusions reached in the Lockheed and Douglas studies, it appears that, from an engineering point of view, towing would not degrade the safety of the nose gear structure of aircraft.

The Lockheed report indicated that towing loads were well within the safe range of design loads of the nose gear of L-1011 aircraft. The Douglas report concluded that certain nose gear components could be affected. However, safety could be ensured through more frequent inspection and, if necessary, replacement of these component parts.

The nose gear studies were limited to towing at relatively low speeds (maximum speed was 12 miles per hour for the L-1011). Towing at major airports would have to be conducted at speeds close to normal aircraft taxiing speeds (an average of 20 to 25 miles per hour). Otherwise, airfield congestion would result.

Under high-speed towing, nose gear loads are not critical, but the loads encountered during maneuvering and braking at those high speeds may be critical. In addition, controlling the aircraft under high-speed towing is a safety issue. Because the brakes on the tractor are not sufficient to stop the aircraft, close coordination is required between the pilot and the tractor driver. Until it is possible for the towing operation to be controlled entirely by the cockpit crew, proper tractor driver techniques must be carefully maintained, and the number of stops and starts during aircraft towing must be minimized so that the fatigue life of the nose gear would not be reduced. Uniform training and certification of tractor drivers may alleviate this concern.

OPERATIONAL CONCERNS

Ideally, extended aircraft towing operations would not cause additional airfield congestion or extra workload for air traffic controllers and pilots. In order that airfield operations are not significantly affected by aircraft towing, the following conditions should exist:

1. There should be adequate space adjacent to the runway exits for connecting the tractor and aircraft so that runway operations and other ground movements would not be affected.
2. There should be adequate space adjacent to the departure takeoff point for disconnecting the aircraft and tractor. This area should be large enough to hold several departing aircraft so that (1) aircraft engines can be warmed up before takeoff (engines need to reach thermal stability); and (2) under strong wind conditions, aircraft can be turned favorably for engine startup.
3. There should be a separate roadway or taxiway for use by tractors to return to their stations after completing a towing operation. The stations would be at the terminal area if the tractor is to pick up a departing aircraft or at an area adjacent to arrival exit taxiways if it is to pick up an arriving aircraft.

4. The crossing of active runways by towed aircraft and tow tractors should be kept to an absolute minimum.
5. Tractor tow speeds should be as comparable as possible to aircraft taxi speeds, subject to limitations imposed by tractor technology.
6. Extended towing should be avoided under icy conditions or extremely strong crosswind conditions that may reduce the controllability of the aircraft.

The actual effects of extended aircraft towing on airfield operations at any airport would of course depend on the specific characteristics of that airport, including the physical layout of the terminal and gate area, runways, taxiways, and roadways; ground movement patterns; runway use; the types and number of aircraft using the airport; and congestion levels.

These characteristics and their operational implications at the 20 study airports were reviewed in this study, and the preliminary findings are described in the following text.

Before discussing the individual airports, however, it should be noted that two assumptions were made in assessing the operational impacts. First, it was assumed that if an airport has runways that are laterally separated by less than 1,000 feet, aircraft arriving or departing on these runways would be allowed to taxi (rather than be towed) across an active runway. Aircraft would be towed only between the terminal/gate area and the point where aircraft taxiing starts (for departing aircraft) or stops (for arriving aircraft).

Second, it was assumed that roadways for the return of tractors to their stations after towing operations could be constructed if necessary to provide separate paths for tractors towing aircraft and tractors not towing aircraft. If such separate paths are not provided, the flows of traffic would be interrupted frequently to allow two-way movement on the same path.

The major operational implications at the 20 study airports, as described on the following 20 pages, involve three factors:

- (1) the percentage of aircraft operations that could be towed under practical conditions without incurring significant delays;
- (2) the need for towing operations to cross active runways; and
- (3) the need for constructing additional roadways or other facilities for tow tractors. For this preliminary study, the operational information was based on a review of available maps and data. Table 1 (on page 45) summarizes this information.

Other concerns (controller workload, etc.) are identified at the end of the chapter.

William B. Hartsfield Atlanta International Airport

There are three parallel east-west runways at Atlanta International Airport, all located south of the existing passenger terminal. Currently, over 50% of the arriving and departing aircraft would need to cross an active runway.

The construction of a new passenger terminal is now under way at a location that will significantly reduce runway crossing activities and taxi distances. This new terminal is scheduled to be opened in September 1980. In the operational analysis in this study, it was assumed that the new terminal would be in use, and towing across active runways would not be necessary.

The taxiway and roadway systems can accommodate tow tractors returning to their stations without conflicts with aircraft being towed. There is adequate space for connecting and disconnecting tractors and aircraft as well as for engine warmup of departing aircraft. To ensure smooth flows of traffic, it is estimated that a tractor roadway/staging area covering about 50,000 square yards would have to be constructed.

Boston-Logan International Airport

For some aircraft operations at Boston-Logan International Airport, the taxi distance between the gate position and the runway is very short. The time it would take for the aircraft to come to a complete stop, be hooked up with a tractor, and then be towed to its assigned gate would far exceed the normal taxi time, and towing would be uneconomical and inefficient. Therefore, it is assumed these operations would not be included in a towing program.

Operations that would not be included for this reason are arriving aircraft on Runway 33L destined for the North Terminal; arriving aircraft landing on Runway 22R or 22L or Runway 27 destined for the South Terminal; and departing aircraft from the South Terminal destined for Runway 9. On the basis of runway use and the distribution of aircraft operations among terminal gate areas, it is estimated that about 10% of the departing air carrier operations and 20% of the arriving air carrier operations would not be towed.

A review of the airfield layout and ground movement patterns indicates that departing aircraft using Runway 27 would need to be towed across active Runway 33L, and that departing aircraft using Runways 22L or 22R would need to be towed across active Runway 15R. This towing would cause some delays and operational inefficiencies. It is estimated that tractor roadways/staging areas covering about 45,000 square yards would have to be constructed.

Chicago O'Hare International Airport

At Chicago O'Hare International Airport, taxi distances are short for aircraft departing from or arriving at Terminal Concourses B and C, using Runways 22R or 27R for landings and Runways 4L or 9L for takeoffs. The normal taxi time for such a distance would be about 1 minute, which is very short compared with the 4 to 5 minutes required to tow these aircraft from the exit taxiways to their assigned gates. Therefore, it is assumed these aircraft operations would not be towed. On the basis of runway use and the distribution of aircraft operations among gate areas, it is estimated that about 8% of the total air carrier operations would not be towed.

Departing aircraft using Runway 4R would have to be towed across active Runway 9R.

There are sufficient taxiways and roadways to permit towing maneuvers, except for departing aircraft using Runway 4R. In this case, it is estimated that a roadway covering about 10,000 square yards would have to be constructed.

Dallas/Fort Worth Airport

Operationally, Dallas/Fort Worth Airport is very well suited for towing operations. The average towing distance is about 8,800 feet.

There is minimal crossing of active runways--only when aircraft use Runway 13L-31R, which accounts for a small portion of the traffic.

The taxiways are adequate, and there is sufficient space for towing maneuvers, so no tractor roadways would need to be constructed.

Denver Stapleton International Airport

At Stapleton International Airport, taxi distances are very short for aircraft arriving on Runways 26R and 26L and destined for gates around Terminal Concourses A and B; aircraft departing from Terminal Concourses A and B using Runways 8L and 8R; and aircraft departing from Concourse C and some gates in Concourses B and D using Runways 35L and 35R. These operations account for about 35% of the air carrier arrivals and 45% of the air carrier departures. Therefore, only about 55% to 65% of the air carrier operations would be towed.

Since the parallel runways are closely spaced, aircraft would be allowed to taxi (rather than be towed) across an active runway. However, tow tractors might need to cross active runways on their return trip after towing aircraft.

For aircraft using Runways 35L and 35R for landings and Runways 17L and 17R for takeoffs, taxi distances are considerable (2 to 3 miles, depending on the actual runway used). However, there would be considerable two-way traffic flows if tractor roadways were not provided. In addition to the construction of a roadway covering about 50,000 square yards, costly bridges or overpasses would have to be built for the roadways to cross railroad tracks and an interstate freeway (I-70).

Honolulu International Airport

Significant portions of aircraft operations at Honolulu International Airport are sightseeing flights or interisland flights (between Honolulu and other islands in the Hawaiian chain) whose total trip times are very short.

In addition, the interisland departures routinely conduct intersection takeoffs on Runway 8L-26R. That is to say, rather than taxiing to the end of the runway for takeoff, the aircraft take off from a point on the runway where a convenient taxiway intersects the runway. The taxi-out distances for these interisland departures are quite short, since their terminal area is very close to the intersection takeoff point.

For these reasons, it is assumed towing such operations would not occur. Therefore, only about 35% of the air carrier operations would be towed. However, these operations represent very significant towing distances since many of them would use Runway 8R-26L (known as the "Reef Runway"). The distance between the terminal and gate area and the Reef Runway is 2 to 3 miles.

Aircraft using Runway 8R-26L would have to be towed across Runway 8L-26R and/or Runways 4L-22R and 4R-22L.

No roadway construction would be required to implement aircraft towing.

Houston Intercontinental Airport

At Houston Intercontinental Airport, aircraft arriving on Runway 26 and destined for Satellite Terminals 1, 2, and 6 would have a short tow distance, so these aircraft (about 6% of total air carrier arrival operations) would not be towed.

Since the terminal area is located between the only two runways at the airport, there would be no need to tow aircraft across an active runway.

The taxiways are adequate for towing maneuvers, except for departing aircraft using Runway 32. For this airport, it is estimated that a tractor roadway/staging area covering about 21,000 square yards would have to be constructed.

John F. Kennedy International Airport

John F. Kennedy International Airport has an extensive taxiway system which would normally allow aircraft towing to be conducted without disrupting airfield operations. However, Kennedy is not well suited for towing operations using currently available tractors because it is one of the most congested airports in the world and has very high delays. Therefore, it is important that towing operations do not cause additional delays. More advanced towing equipment than is now available would probably be required to implement aircraft towing.

Interactions between towed aircraft and aircraft operations on active runways do not usually occur at Kennedy, except for arrivals on Runway 4R-22L which would have to be towed across active Runway 4L-22R.

LaGuardia Airport

At LaGuardia Airport, some arriving aircraft using Runway 31 and destined for the central terminal gate area have very short taxi distances (about 1,000 feet), if they are able to use exit Taxiways J, T, V, and R. These aircraft, which represent about 10% of the jet arrivals, would not be towed.

Active runways would have to be crossed frequently by towed aircraft. For example, departing aircraft using Runway 13 would be towed across active Runway 4-22, and arriving aircraft using Runway 4 would be towed across Runway 13-31. This situation occurs about 30% to 40% of the year.

There is adequate space for connecting and disconnecting tractors and aircraft as well as for other towing maneuvers. However, for departing aircraft using Runway 4, a tractor roadway covering about 1,500 square yards would be needed.

Los Angeles International Airport

At Los Angeles International Airport, a majority of the arriving aircraft using Runway 25R or Runway 25L and destined for gates in Satellite Terminals 4, 5, 6, and 7 have short taxi distances. Towing of these aircraft operations would cause taxiway congestion and very inefficient operations. It is estimated that about 50% of the air carrier arrivals are in this category and therefore would not be towed.

There would be no crossing of active runways by towed aircraft since the outer runways (24R and 25L) are quite close to the inner runways (24L and 25R).

A tractor roadway/staging area covering about 30,000 square yards would have to be constructed.

Miami International Airport

At Miami International Airport, about 30% of air carrier arrivals and 5% of air carrier departures have short taxi distances and would not be towed. These include arriving aircraft from Runway 9L going to gates in Terminal Concourses B, C, and D; arriving aircraft from Runway 9R going to gates in Terminal Concourses F, G, and H; and departing aircraft from gates in Terminal Concourses G and H going to Runway 27L or Runway 30.

The only crossing of active runways would be by aircraft departing on Runway 9R which would be towed across active Runway 12.

For departing aircraft using Runway 27R, returning tractors would need an additional roadway covering about 12,000 square yards. Otherwise, they would have to take a circuitous route that would also involve crossing active Runway 27R.

Minneapolis-St. Paul International Airport

At Minneapolis-St. Paul International Airport, about 45% of the arriving air carrier aircraft would not be towed because of short taxi distances. These include arrivals on Runway 11R-29L going to gates on the south side of the passenger terminal, and arrivals on Runway 4 going to gates on the northwest side of the terminal.

When Runway 4-22 and either one or both of the parallel Runways 11L-29R and 11R-29L are in use, significant crossing of active runways by towed aircraft would occur. At today's air traffic level, this may not be a severe problem, but as traffic increases in the future, congestion caused by aircraft towed across active runways might be quite significant.

A tractor roadway/staging area covering about 35,000 square yards would have to be constructed.

New Orleans International Airport

At New Orleans International Airport, arriving aircraft using Runway 10 and destined for gates on the north and northwest sides of the terminal, and those using Runway 19 and destined for gates on the eastern half of the terminal, would have short taxi distances and would not be towed. These operations account for about 60% of the arriving air carrier aircraft. Similarly, approximately 40% of the departing aircraft--those leaving gates on the east side of the terminal going to Runway 1 for takeoff--would not be towed.

For arrivals on Runway 1 and departures on Runway 19, aircraft would usually need to be towed across active Runway 10-28 (except for the occasional periods when wind conditions do not permit the use of Runway 10-28).

A tractor roadway/staging area covering about 28,000 square yards would have to be constructed.

Philadelphia International Airport

At Philadelphia International Airport, air carrier arrivals landing on Runway 27R have a very short taxi distance to gates in the southern part of the passenger terminal. These aircraft, which represent about 50% of the air carrier arrivals, would not be towed.

The predominant runway use is to land on Runway 27R and depart on Runway 27L. Therefore, departing aircraft would be towed across active Runway 27R, and the returning tractors would either have to cross Runway 27R again or take a circuitous route.

Departing aircraft using Runway 9R would require a long section of tractor roadway. However, this runway is used infrequently.

Greater Pittsburgh International Airport

At Greater Pittsburgh International Airport, arriving aircraft on Runway 32 and departing aircraft on Runway 14 would not be towed because of the short taxi distance. These aircraft account for about 25% of the air carrier arrivals and 50% of the air carrier departures. Towing of these aircraft would cause congestion in the terminal ramp area.

Arriving aircraft on Runway 10C may need to be towed across active Runway 14 if they exit prior to the runway intersection.

When conditions do not permit the use of Runway 14-32, arrivals usually land on Runways 10L and 10R and departures take off on Runway 10C. In such conditions, a tractor roadway would be required to provide separate paths for tractors meeting arriving aircraft on Runway 10L and for tractors returning after towing a departing aircraft to Runway 10C. A staging area covering about 44,000 square yards would have to be constructed.

Lambert-St. Louis International Airport

At Lambert-St. Louis International Airport, it would be feasible to tow all air carrier aircraft operations.

There is an adequate taxiway system for tractor circulation. However, some tractors would have to cross active runways. The crossing of active runways by towed aircraft would occur only when Runway 6-24 and the parallel runways would all be in use.

It is estimated that a roadway/staging area covering about 33,000 square yards would have to be constructed.

San Francisco International Airport

The predominant landing runways at San Francisco International Airport are Runways 28R and 28L. Arriving aircraft going to gates in Concourses B, C, and parts of Concourse D, as well as those going to parts of the North Terminal, would not be towed because of short towing distances. Therefore, only 60% of arriving air carrier aircraft would be towed.

Normally, no towed aircraft would have to cross an active runway, except for occasional international flights. Pilots of these aircraft sometimes request the longer Runway 28R for takeoff rather than Runway 1R, which is the predominant departure runway, and these aircraft would have to be towed across active Runways 1L and 1R.

A tractor roadway/staging area covering about 21,000 square yards would have to be constructed.

Seattle-Tacoma International Airport

At Seattle-Tacoma International Airport, about 15% of the air carrier operations would not be towed because of short towing distances. These would include some arriving aircraft on Runway 16R going to gates in the south satellite and parts of the central passenger terminal, and departing aircraft using Runway 34L leaving from gates in the south satellite and the southern part of the passenger terminal.

No aircraft would be towed across active runways.

The existing taxiway and roadway system is adequate to accommodate towing maneuvers assumed in this study. The completion of a planned taxiway east of and parallel to the existing Taxiway A would greatly increase fuel savings.

Tampa International Airport

At Tampa International Airport, approximately 25% of arriving air carrier aircraft and 15% of departing air carrier aircraft would not be towed because of short towing distances. These aircraft include arrivals on Runway 36L going to gates in Airsides D and E; and departing aircraft going from parts of Airside D and parts of Airside E to Runway 18R.

Arriving aircraft on Runway 9 and departing aircraft on Runway 27 would have to be towed across active Runway 18L-36R.

Extensive new tractor roadways/staging areas covering about 91,000 square yards would be needed to provide for an efficient flow of towed aircraft.

Washington National Airport

Approximately 33% of arriving and departing air carrier aircraft at Washington National Airport would not be towed because of short taxi distances. These aircraft include some arrivals on Runways 18 or 21 going to gates in the south finger or South Terminal; some arrivals on Runways 3 or 36 going to gates in the North Terminal; and departures going from gates in the south finger to Runways 3 or 36.

Departing aircraft using Runway 18-36 would have to be towed across either Runway 15-33 or Runway 3-21, depending on the takeoff direction.

About 1,500 square yards of additional roadway would be needed at this airport.

Table 1

SUMMARY OF OPERATIONAL DATA FOR AIRCRAFT TOWING AT
20 STUDY AIRPORTS

Airport	Average number of daily air carrier operations	Estimated percentage of operations towed		Need to tow across active runway	Additional construction required (square yards)
		Arrival	Departure		
Atlanta	1,311	100%	100%	No	50,000
Boston	593	80	90	Yes	45,000
Chicago O'Hare	1,640	92	100	Yes	10,000
Dallas/Fort Worth	854	100	100	No	0
Denver	736	67	55	No	50,000
Honolulu	322	32	35	Yes	0
Houston	441	94	100	No	21,000
Kennedy (New York)	703	100	100	Yes	0
LaGuardia (New York)	647	90	100	Yes	1,500
Los Angeles	1,058	47	100	No	30,000
Miami	673	70	95	Yes	12,000
Minneapolis-St. Paul	348	55	100	Yes	35,000
New Orleans	281	40	60	Yes	28,000
Philadelphia	399	50	100	Yes	0
Pittsburgh	534	75	50	Yes	44,000
St. Louis	521	100	100	Yes	33,000
San Francisco	720	60	100	No	21,000
Seattle-Tacoma	323	80	85	No	0
Tampa	350	75	85	Yes	91,000
Washington, D.C. (National)	564	67	67	Yes	1,500

Source: Peat, Marwick, Mitchell & Co.

OTHER CONCERNS

In addition to the safety and operational concerns discussed in the preceding sections, there are several other concerns that can be identified at this time and perhaps resolved during a demonstration project.

One concern is the additional workload for air traffic controllers resulting from the need to control an increased number of tractors that have to move around the taxiway system and possibly cross active runways.

A second concern is the use of conventional tractors which would result in increased block times for aircraft because of the slower towing speed. The effect of this slower towing speed on aircraft use and scheduling must be considered. A preliminary analysis indicates that the effect would probably be minimal because aircraft ground time is a relatively small percentage of the total block time. For example, the difference between powered taxiing (average speed 25 miles per hour) and towing (average speed 10 miles per hour) for a distance of 1 mile is 3.6 minutes. Moreover, if there are runway capacity constraints or if gates are not available, aircraft operations would be delayed in any event. The only difference in such cases would be in where the delay time is spent--waiting in the queue or being towed at a slower speed.

A third concern is the perception of the extra delay in the eyes of the passenger. Even though the actual additional delay is quite brief, it may be perceived differently.

There are also concerns about ground crew staffing and the availability of appropriate equipment at the departure disconnect area to troubleshoot aborted starts and for protection against possible engine fires.

These concerns are very real. Their resolution may involve a public relations or educational program for the passengers and the provision of ground crew by the airport sponsor in much the same way that crash, fire, and rescue (CFR) services are being provided at airports today. This is not to imply that implementing aircraft towing would be without problems--only that extended towing appears to be feasible. The real test would come during a demonstration of aircraft towing.

SUMMARY OF SAFETY, OPERATIONAL, AND OTHER CONCERNS

Safety, operational, and other concerns related to aircraft towing were reviewed in this chapter. The safety concerns centered mainly on the potential effect of towing on the aircraft nose gear structure and on the control of towing tractors and aircraft on the airfield.

On the basis of two FAA-sponsored studies, it appears that the structural integrity of the nose gear on some aircraft (e.g., the L-1011) would not be compromised by towing. On other aircraft, such as the DC-9, the life limit of certain nose gear components may be reduced. This problem could be resolved, however, by establishing an inspection and replacement program.

The operation of the tractor-aircraft combination would require close coordination among the pilot, tractor driver, and air traffic controllers. Until it is possible for the towing operation to be controlled entirely by the cockpit crew (perhaps through new tractor designs), proper tractor driver techniques would be mandatory, and the uniform training and certification of tractor drivers would probably be required.

This study also found that there would be some operational difficulties associated with extended aircraft towing at the 20 study airports, but these could be reduced by constructing tractor roadways and staging areas, reducing the number of aircraft towed, and developing better towing equipment, which is now being proposed by tractor manufacturers.

Several other concerns relating to extra air traffic controller workload, disruption of airline schedules, and passenger comfort were identified. The severity of these concerns is difficult to determine in an analytical study. It is hoped that the problems involved can be studied in more detail, and perhaps even resolved, during an actual field demonstration of aircraft towing.

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Chapter 5

POTENTIAL BENEFITS AND COSTS OF AIRCRAFT TOWING AT 20 U.S. AIRPORTS

Preliminary estimates of the potential benefits and costs of extended aircraft towing at the 20 study airports are presented in this chapter. Separate estimates are provided for currently available towing equipment and proposed towing equipment.

DATA BASE FOR ESTIMATING AIRCRAFT TOWING BENEFITS

The estimates of benefits that would result from extended aircraft towing are based on analyses of data on (1) the aircraft fleet mix, aircraft operations, and taxi distances; (2) fuel consumption and air pollutant emission rates for aircraft and tow tractor engines and for aircraft auxiliary power units; and (3) aircraft engine shutdown times during towing.

Aircraft Fleet Mix, Aircraft Operations, and Taxi Distances

Data on the aircraft fleet mix and aircraft operations were obtained from FAA and Civil Aeronautics Board (CAB) records for 1978 (Refs. 5 and 6). Table 2 presents these data for the 20 study airports.

Average taxi distances between runways and the terminal areas were determined from airfield layout plans for each airport and from discussions with local FAA air traffic control tower staff.

Fuel Consumption and Air Pollutant Emission Rates

Aircraft engine fuel consumption and air pollutant emission rates were obtained from publications of the Environmental Protection Agency (Refs. 7 and 8). Tow tractor fuel consumption and emission rates were obtained from these same publications and supplemented by information from tractor manufacturers. It was assumed that every aircraft would be equipped with an auxiliary power unit (APU)* to provide power for lights

*Some aircraft (e.g., B-707 and DC-8) are not equipped with APUs, and it was assumed that these aircraft would be supplied with electrical power and pneumatic supply from ground equipment. These aircraft are being phased out because of noise and fuel efficiency concerns.

Table 2

DATA ON AIRCRAFT MIX AND AIRCRAFT OPERATIONS AT 20 U.S. AIRPORTS

Airport	Percent of total operations by type of aircraft										Average number of daily operations
	B-747	DC-10	L-1011	DC-8/ B-707	B-727	B-737/ DC-9	A-300	B-111	Turbo-prop	General aviation	
Atlanta	--%	0.5%	6.8%	4.4%	39.7%	36.5%	0.1%	--%	3.4%	8.6%	1,490
Boston	1.0	1.9	2.8	6.8	29.9	15.9	--	3.8	20.9	17.0	955
Chicago O'Hare	2.3	6.9	1.6	11.9	36.7	19.9	--	--	12.6	8.1	2,068
Dallas/Fort Worth	0.4	0.2	3.1	7.6	50.9	16.0	--	--	16.2	5.6	1,092
Denver	0.3	4.6	0.2	6.7	27.7	17.8	--	--	13.1	29.6	1,284
Honolulu	5.6	2.4	--	3.0	0.1	21.1	--	--	22.2	45.6	1,001
Houston	0.1	4.5	1.2	2.0	36.4	16.9	--	--	16.4	22.5	771
Kennedy (New York)	10.8	4.7	7.1	27.3	22.1	5.4	0.5	3.8	8.9	9.4	860
LaGuardia (New York)	--	1.1	1.3	--	45.8	23.4	--	1.3	8.4	18.7	888
Los Angeles	6.2	12.0	5.2	12.0	28.4	9.3	--	--	12.4	14.5	1,448
Miami	0.5	6.1	5.9	6.9	39.7	10.8	0.5	--	8.2	21.4	956
Minneapolis-St. Paul	1.2	4.5	--	0.7	25.7	17.3	--	--	7.6	43.0	705
New Orleans	--	2.7	1.4	3.6	31.8	19.0	--	--	9.6	31.9	480
Philadelphia	0.2	1.7	2.5	5.7	18.0	12.6	--	3.3	31.2	24.8	907
Pittsburgh	0.1	0.5	0.8	3.4	14.2	32.1	--	8.0	20.9	20.0	903
St. Louis	--	--	1.5	8.2	21.3	24.6	--	0.4	11.4	32.6	931
San Francisco	5.9	6.3	2.6	14.3	30.5	14.9	--	--	9.9	15.6	966
Seattle-Tacoma	4.0	10.1	0.9	7.0	28.5	10.6	--	--	21.9	17.0	528
Tampa	--	3.7	2.0	1.3	35.4	16.5	--	--	8.9	32.2	595
Washington, D.C. (National)	--	--	--	--	37.5	18.4	--	3.0	14.7	26.4	957

Sources: Records of Federal Aviation Administration and Civil Aeronautics Board for 1978 (Refs. 5 and 6).

and, air conditioning when aircraft engines are shut down (most commercial aircraft today are equipped with an APU). Data on fuel consumption and emissions associated with APUs were obtained from APU manufacturers.

Aircraft Engine Shutdown Times

It was assumed that arriving aircraft would taxi to a convenient area designated for tractor hook-up before shutting down their engines. Therefore, the engine shutdown time for an arrival would be the taxi and idle time that an aircraft normally would incur between the hook-up area and its gate or parking position.

Departing aircraft would not start their engines until they are towed to an area designated for tractor disconnection. The engines would require time to warm up and the aircraft would then taxi to its takeoff point.

Therefore, engine shutdown time for a departing aircraft would be the sum of push-back time and taxi and idle (or waiting) time that an aircraft normally would incur between its gate or parking position and the tractor disconnection area, less the time required for engine warmup. (Engine warmup currently takes place during push-back and taxi-out.)

The average taxi times were computed from average taxi distances and taxi speeds at each airport. The average idle times were estimated for aircraft operations on an average day at each airport using FAA-approved techniques that were developed by Peat, Marwick, Mitchell & Co. (Ref. 9). These techniques were used to estimate delays to aircraft (i.e., idle times), given information on demand and capacity. They have been thoroughly validated at many of the busiest U.S. airports, including most of the airports considered in this study.

Table 3 presents the estimated average engine shutdown times (per aircraft) for arrivals and departures on an average day in 1978 at the 20 study airports. These values are not strictly comparable to ground time reported by airlines. The reason is that airline ground time is computed as the difference between block time (i.e., gate-to-gate time) and airborne time. For arrivals, this is the time from touchdown to gate. Consequently, the airline ground time includes arrival runway occupancy time, exit clear time, and the nominal ground taxi and idle times. For departures, airline ground time is the time from gate to wheels-off, which includes push-back time, nominal ground taxi and idle time, and departure roll to lift-off time.

Table 3

ESTIMATED AVERAGE ENGINE SHUTDOWN TIMES
AT 20 U.S. AIRPORTS ON AN AVERAGE DAY IN 1978

<u>Airport</u>	<u>Estimated engine shutdown time (minutes per aircraft)</u>	
	<u>Arrivals</u>	<u>Departures</u>
Atlanta	6	8
Boston	4	6
Chicago O'Hare	8	11
Dallas/Fort Worth	5	6
Denver	5	7
Honolulu	4	5
Houston	4	4
Kennedy (New York)	8	13
LaGuardia (New York)	5	9
Los Angeles	4	8
Miami	4	6
Minneapolis-St. Paul	3	5
New Orleans	2	4
Philadelphia	4	5
Pittsburgh	3	4
St. Louis	4	5
San Francisco	4	7
Seattle-Tacoma	3	5
Tampa	5	5
Washington, D.C. (National)	3	5

Source: Peat, Marwick, Mitchell & Co.

Part of the time included in airline ground time cannot be included in the estimates of engine shutdown time shown in Table 3 because the engines will be running whether towing is implemented or not. Examples of such times are the runway time during landing and takeoff and the taxi and idle time between the hook-up and disconnect areas and the runway(s).

The estimates in Table 3 are average times for all aircraft types on an average day of the year. Higher values would be obtained during peak periods and lower values could be expected during periods of low demand. The airline ground time is used by airlines to prepare their schedules. It varies according to the time of day and is different for each airline and for each aircraft type in the schedule. Therefore, comparisons of airline ground time with the engine shutdown time shown in Table 3 should be made with caution.

PRELIMINARY ESTIMATES OF POTENTIAL BENEFITS OF AIRCRAFT TOWING

Fuel consumption and air pollutant emissions for aircraft ground movements were estimated using data described in the preceding section.* Potential savings in fuel consumption and reductions in emissions achievable by extended towing were then determined by subtracting tow tractor fuel consumption and emissions from these estimates. The increased amounts for APUs were also deducted from the potential benefits achievable with aircraft towing. No attempt was made in this study to estimate changes in noise levels. It is thought, however, that aircraft towing may also result in some noise reduction.

Currently Available Tow Tractors

As described in Chapter 3, the disadvantages of currently available tractors are that (1) they cannot tow aircraft at high speeds (i.e., speeds comparable to aircraft taxi speeds); and (2) they use tow bars which not only limit maneuverability but also result in greater exposure of aircraft nose gear to damage. A maximum speed of 12 miles per hour was used in the analyses in this study. Since aircraft taxi speeds average 20 to 30 miles per hour, the slower towing speed means that taxi times with towing will be longer. It also means that APUs will be running for a longer period and hence will have higher fuel consumption and air pollutant emissions than APUs used with proposed high-speed tractors.

*Estimates were provided by AeroVironment, Inc., Pasadena, California, a subcontractor to Peat, Marwick, Mitchell & Co. in this study.

Table 4 presents the estimated potential benefits of extended aircraft towing at the 20 study airports using currently available tractors. As shown, potential savings of fuel (assuming 1978 levels of aircraft operations) would be about 178 million gallons per year. Potential reductions in aircraft engine air pollutant emissions would be about 31,000 tons of carbon monoxide, 20,000 tons of hydrocarbons, 1,500 tons of oxides of nitrogen, and 240 tons of total suspended particulates.

Proposed Tow Tractors

As also described in Chapter 3, the proposed tow tractors being developed by Secmafer and Vanley Systems would allow towing at speeds up to 35 miles per hour, matching the normal taxi speeds of aircraft. Vanley indicated that the fuel consumption rate for its proposed tractor will be 41 gallons per hour (compared with 6 gallons per hour for currently available tractors). Vanley did not provide data on emission rates but stated that its rates would either meet or be better than those stipulated by the State of California standards. For purposes of this study, it was assumed that the proposed tractors would have the same emission rates as the currently available tractors.

Table 5 presents the estimated potential benefits of extended aircraft towing at the 20 study airports using the proposed tow tractors. As shown, potential savings of fuel (assuming 1978 levels of aircraft operations) would be about 165 million gallons per year. These savings are about 13 million gallons per year lower than those achievable with currently available tractors, because of the higher fuel consumption rate of the proposed tractors. The annual savings in aircraft engine air pollutant emissions using proposed tow tractors would be slightly higher than those achievable with currently available tractors: 33,500 tons of carbon monoxide, 20,700 tons of hydrocarbons, 1,700 tons of oxides of nitrogen, and 260 tons of total suspended particulates.

PRELIMINARY ESTIMATES OF AIRCRAFT TOWING COSTS AND SAVINGS

Separate estimates of costs and savings associated with extended towing of aircraft were developed for currently available towing equipment and for proposed towing equipment. These costs and savings were then compared in order to derive net costs or savings resulting from extended aircraft towing at each of the 20 study airports.

Table 4

ESTIMATED POTENTIAL BENEFITS OF EXTENDED
AIRCRAFT TOWING
Using Currently Available Tow Tractors

Airport	Potential annual fuel savings (millions of gallons)	Potential annual emission reductions (thousands of tons)			
		CO	HC	NO _x	TSP
Atlanta	14.29	1.75	0.98	0.13	0.02
Boston	6.75	1.14	0.75	0.06	0.01
Chicago O'Hare	39.12	7.29	4.67	0.35	0.05
Dallas/Fort Worth	10.41	1.44	0.95	0.09	0.01
Denver	8.20	1.38	0.85	0.07	0.01
Honolulu	2.42	0.56	0.37	0.02	0.00
Houston	3.76	0.41	0.20	0.03	0.00
Kennedy (New York)	22.63	5.97	4.59	0.18	0.04
LaGuardia (New York)	10.04	0.98	0.33	0.10	0.01
Los Angeles	16.52	3.28	2.12	0.14	0.03
Miami	7.71	1.20	0.76	0.07	0.01
Minneapolis-St. Paul	2.99	0.33	0.13	0.03	0.00
New Orleans	1.46	0.19	0.10	0.01	0.00
Philadelphia	3.77	0.70	0.48	0.03	0.00
Pittsburgh	2.64	0.40	0.28	0.02	0.00
St. Louis	5.07	0.88	0.64	0.04	0.01
San Francisco	9.83	1.99	1.37	0.08	0.02
Seattle-Tacoma	2.50	0.43	0.27	0.02	0.00
Tampa	3.68	0.41	0.18	0.03	0.00
Washington, D.C. (National)	<u>4.02</u>	<u>0.38</u>	<u>0.14</u>	<u>0.04</u>	<u>0.00</u>
Total	177.81	31.10	20.17	1.52	0.24

Note: The estimates shown are based on 1978 levels of aircraft operations.

CO = carbon monoxide

HC = hydrocarbons

NO_x = oxides of nitrogen

TSP = total suspended particulates

Source: Peat, Marwick, Mitchell & Co.

Table 5

ESTIMATED POTENTIAL BENEFITS OF EXTENDED
AIRCRAFT TOWING
Using Proposed Tow Tractors

Airport	Potential annual fuel savings (millions of gallons)	Potential annual emission reductions (thousands of tons)			
		CO	HC	NO _x	TSP
Atlanta	13.84	2.06	1.05	0.15	0.02
Boston	6.03	1.21	0.77	0.06	0.01
Chicago O'Hare	35.76	7.56	4.73	0.37	0.05
Dallas/Fort Worth	10.30	1.76	1.02	0.11	0.01
Denver	7.45	1.46	0.87	0.08	0.01
Honolulu	2.53	0.63	0.39	0.03	0.01
Houston	3.43	0.50	0.23	0.04	0.00
Kennedy (New York)	21.76	6.24	4.66	0.19	0.05
LaGuardia (New York)	8.91	1.05	0.35	0.10	0.01
Los Angeles	15.59	3.48	2.18	0.15	0.03
Miami	7.35	1.37	0.80	0.08	0.01
Minneapolis-St. Paul	2.62	0.36	0.13	0.03	0.00
New Orleans	1.26	0.20	0.10	0.01	0.00
Philadelphia	3.33	0.73	0.49	0.03	0.00
Pittsburgh	2.30	0.46	0.30	0.02	0.00
St. Louis	4.39	0.94	0.65	0.05	0.01
San Francisco	9.20	2.12	1.40	0.09	0.02
Seattle-Tacoma	2.35	0.48	0.28	0.02	0.00
Tampa	3.35	0.46	0.19	0.04	0.00
Washington, D.C. (National)	<u>3.49</u>	<u>0.42</u>	<u>0.15</u>	<u>0.04</u>	<u>0.01</u>
Total	165.23	33.50	20.74	1.70	0.26

Note: The estimates shown are based on 1978 levels of aircraft operations.

CO = carbon monoxide

HC = hydrocarbons

NO_x = oxides of nitrogen

TSP = total suspended particulates

Source: Peat, Marwick, Mitchell & Co.

Currently Available Towing Equipment

For each airport, the cost estimates for currently available towing equipment included both annualized capital costs for additional equipment required and increases in annual direct operating costs. Rough estimates of annualized construction costs, if any, for tractor roadways and staging areas were also included. Indirect or overhead costs were not included because it was assumed that they would not be significantly affected by changes in aircraft ground procedures or the associated direct costs. The dollar savings resulting from reductions in jet fuel consumption were then deducted from these costs. The assumptions and sources of data used in developing the preliminary cost estimates are discussed in the following paragraphs.

Annualized Capital Costs. Annualized capital costs were determined by estimating (1) the quantity of additional equipment required for extended towing operations and (2) the useful life of that equipment. The following procedure was used to derive the quantity of additional equipment required.

First, to assure sufficient availability of tractors during peak periods, information on peak hour aircraft operations for an average day of the peak month (which is a typical "design day" for planning airport facilities) was compiled for each airport. On the basis of this information and the aircraft mix data developed earlier, it was possible to determine the number of aircraft operations to be towed at a given airport. From this estimate, and from airfield layout and average speed data, the total number of tractors required to service peak hour traffic was determined. To account for breakdowns in tractors and other emergencies, the actual number of tractors required for extended towing operations was increased by 10%.

A similar process was used to estimate the number of tractors required under existing practice (push-back only). The difference in the two requirements then yielded the additional number of tractors needed to implement extended towing.

An implicit assumption in this procedure is that tractors at a given airport will be shared among the airlines whose operations are subject to towing. If each airline were to have tractors exclusively for its own use, the number of tractors required would of course be higher.

The final step in developing annualized capital costs was to determine the useful life of tractors and related towing equipment. For purposes of this study, a useful life of 6 years was assumed (the same period normally used for equipment depreciation).

Annual Operating Costs. Three components constituted the additional annual operating costs used in this study. These were increases in (1) tractor engine overhaul costs, (2) tractor crew costs, and (3) flight crew costs.

As discussed earlier, the direct costs for tractor engine overhaul were estimated to be about \$1,000 per tractor per year, and the direct tractor crew costs were estimated to be about \$46,000 per crew (8-hour shift) per year.

Flight crew costs (for both cockpit and cabin crews) were estimated using the "Aircraft Operating Cost and Performance Report for Calendar Year 1978" (CAB Form 41), published by the CAB (Ref. 10). This report contains summaries of flight crew costs per block hour* and other information filed by the airlines. These costs include direct salaries, overtime, and fringe benefit costs. An inflation rate of 11.2% (the rise in the Consumer Price Index from July 1978 to July 1979) was used to bring the 1978 block hour cost to 1979 values. The flight crew costs per block hour by type of aircraft vary from airline to airline. Representative costs are as follows:

<u>4-engine widebody</u>	<u>4-engine regular body</u>	<u>3-engine widebody</u>	<u>3-engine regular body</u>	<u>2-engine</u>
\$675	\$564	\$530	\$451	\$373

Next, an average flight crew cost per block hour was developed for each study airport using the aircraft mix information presented in Table 1. The increase in flight crew block hours at each airport was then estimated on the basis of additional ground time incurred per aircraft operation and the number of operations towed. These data, together with the crew cost per block hour, yielded the increased flight crew costs.

*The flight crew cost per block hour is the cost of crew time from gate departure at one airport to gate arrival at another airport. This cost is the basis for crew pay and utilization.

Annualized Construction Costs. The annualized construction costs consist of annualized capital construction costs and annual maintenance costs. The annualized capital construction costs were arrived at by (1) estimating the amount of construction required for tractor roadways and staging areas, (2) multiplying by the unit construction cost, and (3) annualizing over the useful life of the construction.

The amount of construction required for extended towing was estimated by reviewing airfield layout plans, as presented in Chapter 4. It was assumed that the strength requirements for taxiways would be adequate and that the unit construction cost for taxiways would be applicable. This unit cost was assumed to be \$16.80 per square yard, which was obtained from guidelines the FAA used in developing the "National Airport System Plan," (Ref. 11) and adjusted by the rise in the Consumer Price Index. For the purpose of this study, tractor roadways and staging areas were assumed to have a useful life of 20 years.

On the basis of financial records provided by some airport sponsors, the annual airfield maintenance cost was determined to average \$1.10 per square yard in 1979. This unit maintenance cost was used to develop annual maintenance costs for tractor roadways and staging areas.

Fuel Savings. Savings in fuel consumption at each study airport were reported in Tables 4 and 5. The values reported represent the net savings from reductions in aircraft engine fuel consumption and increases in fuel consumption for tractors and auxiliary power units. In the estimate of fuel cost savings, an average cost of \$1.00 per gallon was assumed for both jet fuel and tractor fuel.

Net Costs and Savings Associated With Currently Available Towing Equipment. As has been described, the capital, operating, and construction costs associated with towing using currently available equipment were determined for each of the 20 study airports. These costs were then compared with savings resulting from reductions in fuel costs to arrive at net costs or savings.

Table 6 presents a summary of this comparison. As shown, 18 of the 20 study airports would achieve net savings with towing operations. The annual savings range from about \$23,800,000 at Chicago O'Hare International Airport to \$100,000 at Houston Intercontinental Airport.

Table 6

SUMMARY OF ANNUAL COSTS AND SAVINGS ASSOCIATED WITH
CURRENTLY AVAILABLE AIRCRAFT TOWING EQUIPMENT
(Dollars in Millions)

Airport	Number of additional tractors required	Costs			Savings	Net savings (costs) ^c
		Annualized capital	Direct operating ^a	Annualized construction	Net fuel ^b	
Atlanta	16	\$0.3	\$10.4	\$0.1	\$14.3	\$ 3.5
Boston	7	0.1	4.0	0.1	6.8	2.6
Chicago O'Hare	31	0.6	14.7	d	39.1	23.8
Dallas/Fort Worth	25	0.4	12.4	0	10.4	(2.4)
Denver	10	0.2	4.8	0.1	8.2	3.1
Honolulu	3	0.1	2.1	0	2.5	0.3
Houston	7	0.1	3.6	d	3.8	0.1
Kennedy (New York)	25	0.6	11.8	0	22.6	10.2
LaGuardia (New York)	13	0.2	4.6	d	10.0	5.2
Los Angeles	14	0.3	8.3	0.1	16.5	7.8
Miami	16	0.3	7.2	d	7.7	0.2
Minneapolis-St. Paul	6	0.1	1.9	0.1	3.0	0.9
New Orleans	3	0.1	1.0	0.1	1.5	0.3
Philadelphia	5	0.1	2.0	0	3.8	1.7
Pittsburgh	5	0.1	3.5	0.1	2.6	(1.1)
St. Louis	10	0.1	3.6	0.1	5.1	1.3
San Francisco	10	0.2	5.8	d	9.8	3.8
Seattle-Tacoma	5	0.1	1.9	0	2.6	0.6
Tampa	5	0.1	2.5	0.2	3.7	0.9
Washington, D.C. (National)	5	0.1	2.3	d	4.0	1.6

a. Including direct flight crew costs and direct tractor maintenance costs.

b. Including increases in tractor and auxiliary power unit fuel consumption, and assuming an average cost of \$1.50 per gallon of fuel.

c. Numbers in parentheses indicate net costs.

d. Annualized construction cost is less than \$50,000.

Source: Peat, Marwick, Mitchell & Co.

Proposed Towing Equipment

As discussed previously, the proposed towing equipment was assumed to have the same towing speeds as aircraft taxi speeds. For purposes of this study, an operating and capital cost (unit rate) of \$4 per minute was assumed. Increases in flight crew costs were limited to those for tractor connect time for arrivals and disconnect time for departures, because of the comparable speeds for towing and taxiing.

Table 7 presents a summary of the costs and savings comparison using proposed towing equipment. As noted in the table, towing costs include tractor costs, construction costs, and increases in direct flight crew costs. Savings come from reductions in fuel costs.

On the basis of the costs assumed in this study, the results of this comparison show that only one airport would not achieve savings from aircraft towing. The annual savings range from \$19,000,000 at Chicago-O'Hare International Airport to \$400,000 at New Orleans International Airport.

EFFECT OF CHANGE IN FUEL COSTS

In the preceding analysis, the cost of jet fuel was assumed to be \$1.00 per gallon. As an indication of the sensitivity of net savings from extended aircraft towing to fuel costs, another set of computations was prepared using an average jet fuel cost of \$1.50 per gallon.

Table 8 shows the net savings and costs resulting from aircraft towing with this higher fuel cost for both currently available and proposed towing equipment. All airports studied would achieve net savings using either the currently available or proposed tractors.

OTHER CONSIDERATIONS

Other factors beyond those quantified in monetary terms, as described above, are also important in evaluating extended aircraft towing. Although reductions in aircraft air pollutant emissions were discussed earlier in this chapter, it is difficult to estimate what monetary savings these reductions represent.

Table 7

SUMMARY OF ANNUAL COSTS AND SAVINGS
ASSOCIATED WITH PROPOSED AIRCRAFT TOWING EQUIPMENT
(Millions of Dollars)

Airport	Costs		Savings	Net savings (costs) ^c
	Towing ^a	Annualized construction	Net fuel ^b	
Atlanta	\$13.9	\$0.1	\$18.8	\$ 4.8
Boston	6.2	0.1	8.5	2.2
Chicago O'Hare	28.2	d	47.7	19.5
Dallas/Fort Worth	9.8	0	14.4	4.6
Denver	7.5	0.1	10.3	2.7
Honolulu	2.0	0	3.4	1.4
Houston	4.0	d	5.1	1.1
Kennedy (New York)	13.8	0	28.0	14.2
LaGuardia (New York)	8.6	d	12.5	3.9
Los Angeles	10.8	0.1	20.5	9.6
Miami	6.4	d	10.1	3.7
Minneapolis-St. Paul	2.6	0.1	3.8	1.1
New Orleans	1.3	0.1	1.8	0.4
Philadelphia	3.4	0	4.7	1.3
Pittsburgh	4.0	0.1	3.8	(0.3)
St. Louis	5.2	0.1	6.6	1.3
San Francisco	7.1	d	12.4	5.3
Seattle-Tacoma	2.3	0	3.4	1.1
Tampa	3.4	0.2	4.7	1.1
Washington, D.C. (National)	4.2	d	5.2	1.0

- a. Towing costs include a tractor cost of \$4 per minute of tractor time and increases in flight crew costs.
b. Assuming an average cost of \$1.00 per gallon for jet fuel.
c. Numbers in parentheses indicate net costs.
d. Annualized construction cost is less than \$50,000.

Source: Peat, Marwick, Mitchell & Co.

Table 8

SENSITIVITY OF AIRCRAFT TOWING SAVINGS AND
COSTS TO FUEL COST^a
(Millions of Dollars)

<u>Airport</u>	<u>Net savings (costs) from aircraft towing</u>	
	<u>Currently available equipment</u>	<u>Proposed equipment</u>
Atlanta	\$10.7	\$14.2
Boston	5.9	6.5
Chicago O'Hare	43.4	43.4
Dallas/Fort Worth	3.0	11.8
Denver	7.2	7.9
Honolulu	1.6	3.1
Houston	1.9	3.7
Kennedy (New York)	21.5	28.2
LaGuardia (New York)	10.3	10.2
Los Angeles	16.1	19.9
Miami	4.1	8.8
Minneapolis-St. Paul	2.4	3.0
New Orleans	1.0	1.3
Philadelphia	3.6	3.7
Pittsburgh	0.3	1.6
St. Louis	3.8	4.6
San Francisco	8.7	11.5
Seattle-Tacoma	1.9	2.8
Tampa	2.7	3.5
Washington, D.C. (National)	3.6	3.6

Note: Numbers in parentheses indicate costs.

a. Assuming an average cost of \$1.50 per gallon for fuel.

Source: Peat, Marwick, Mitchell & Co.

In addition, since aircraft jet engines create louder noise than tow tractor engines, noise from taxiing aircraft may be reduced by aircraft towing. Again, it is difficult to convert the noise benefits into monetary terms.

Therefore, at airports where there may not be net savings from extended aircraft towing, the perceived value of these environmental benefits might be considered sufficiently high that towing of aircraft would prove to be beneficial in spite of the additional costs incurred.

At some airports where the taxiing distance between the terminal area and the runway is very long, such as at Honolulu International Airport when departing aircraft use Runway 8R (the Reef Runway), there is the potential of tire failure resulting from overheating. Towing at lower speeds would reduce tire stress and help prevent tire failures.

SUMMARY OF BENEFITS AND COSTS

On the basis of the preliminary analyses described in this chapter, substantial fuel savings (up to 178 million gallons per year) and reductions in aircraft emissions of air pollutants could be achieved through extended aircraft towing. However, significant capital and operating costs would be incurred. Moreover, new tractor roadways or tractor-aircraft connection and disconnection areas would have to be built at some of the airports to avoid additional airfield congestion.

The feasibility of implementing extended aircraft towing depends heavily on the cost of jet fuel. At a cost of \$1.00 per gallon for jet fuel, 18 of the 20 study airports would achieve net savings with aircraft towing. At a cost of \$1.50 per gallon, all of the study airports would achieve net savings with extended aircraft towing. Jet fuel cost as of April 1980 averaged \$0.885 per gallon for U.S. trunk carriers.

In addition to fuel savings, there are other benefits, such as reductions in aircraft emissions of air pollutants and noise, which are difficult to quantify in monetary terms. Nevertheless, these less tangible benefits may be sufficient at some airports to justify the implementation of aircraft towing.

The preliminary analysis in this chapter also showed that towing operations could be conducted more efficiently with the proposed towing equipment than with the currently available towing equipment.

Chapter 6

EVALUATION OF POTENTIAL AIRPORTS FOR AIRCRAFT TOWING DEMONSTRATION

As reported in Chapters 4 and 5, preliminary analyses show that significant benefits in aircraft fuel savings and reductions in aircraft emissions of air pollutants are achievable through the implementation of extended aircraft towing at the 20 study airports. The analyses also show that there would be some technical and operational difficulties associated with aircraft towing, but these could be reduced by constructing tractor roadways and developing improved towing equipment as is now being proposed by tractor manufacturers.

Before a nationwide aircraft towing program is established, it is necessary to demonstrate the feasibility and the costs and benefits of extended aircraft towing to all parties who may potentially be affected.

This chapter presents (1) the results of a preliminary evaluation of the feasibility of aircraft towing at each of the 20 study airports, (2) recommendations of potential sites for an initial demonstration project, and (3) preliminary estimates of the resources required for such a demonstration project.

CRITERIA FOR EVALUATING POTENTIAL SITES FOR AIRCRAFT TOWING DEMONSTRATION PROJECT

The following criteria, developed jointly by the Department of Energy (DOE) and Peat, Marwick, Mitchell & Co., were used in the preliminary evaluation of potential demonstration sites. They are listed in the order of their importance to the demonstration project.

1. No major construction or equipment purchases should be required to implement aircraft towing. In order that day-to-day airport operations are disrupted as little as possible during the demonstration project, the selected airport should have adequate taxiways, roadways, and the necessary space for towing maneuvers.

These facilities should already be available so that no new construction would be required before the project could begin. New construction would result in delays to the project (not only during actual construction but also beforehand when the necessary planning would have to be done and financing would have to be arranged).

In a similar vein, it is important that adequate tow tractors at the selected airport are either readily available or can be obtained without major costs or delays.

2. There should be a reasonable level of confidence that cooperation can be expected from the airport operator, local agencies, and the airlines. The cooperation of potential participants is a prerequisite to successful aircraft towing at any airport. For purposes of the demonstration project, however, the emphasis is on the level of cooperation that can be expected from the local participants, especially the airport operator and the airlines.
3. There should be little need to tow aircraft across active runways. Towing across active runways would mean additional delays to towing operations which could result in severe airfield congestion. Therefore, the towing routes at a selected airport should be such that there would be very little, if any, need to cross active runways.
4. The airfield and terminal area should be clearly visible from the air traffic control tower. Because extended towing operations would require much more communication between the air traffic controllers and pilots and tractor drivers, this requirement would facilitate airfield operations and enhance safety.
5. The potential aircraft fuel savings and emission reductions resulting from aircraft towing should be significant. In order to demonstrate the benefits of aircraft towing, the amounts of aircraft fuel consumption and air pollutant emissions with towing should be significantly different from those without towing. The percentage of fuel savings or emission reductions per towed operation should be significant--which means that either towing distances or aircraft delays (i.e., idle time) should be considerable.
6. The runway use should be consistent and predictable throughout most of the day. If runway use changes frequently throughout the day, ground movement patterns would change accordingly and would cause operational inefficiency even without aircraft towing. Conditions would worsen with aircraft towing and the additional tractor traffic. Ideally, the number of possible runway uses at the selected airport should be very low.

7. The level of existing airfield congestion should be moderate or low. Because extended aircraft towing has not been fully implemented at U.S. airports previously, a trial period is needed to develop operational practices not foreseen in the planning phase.

Before these unforeseen practices are developed, it would not be advisable to undertake aircraft towing at a highly congested airport. The likelihood of a successful demonstration project would be diminished if no previous experience is available to guide the design of towing operations.

Therefore, it would be desirable to select an airport that is only moderately busy for the first demonstration project. After sufficient knowledge is gained at a moderately busy airport, a second demonstration project could be planned at a more congested airport with reasonable expectation that it would be successful.

PRELIMINARY EVALUATION OF THE FEASIBILITY OF AN AIRCRAFT TOWING DEMONSTRATION PROJECT AT THE 20 STUDY AIRPORTS

The evaluation of the feasibility of conducting an aircraft towing demonstration project at the 20 study airports was based on the seven criteria set forth in the preceding section and the analyses described in Chapters 4 and 5.

As a first step in the evaluation, airports that would require either new construction of roadways or staging areas,* or a large number of additional tow tractors,** were eliminated from further consideration, because they could not satisfy the first criterion. This does not mean that aircraft towing cannot be implemented at airports that do not satisfy the first criterion; it means only that they would not be suitable sites for the first demonstration project.

*For tractor connection and disconnection or aircraft engine warmup.

**This requirement (i.e., that a large number of additional tow tractors would not be needed) applies to both currently available and proposed towing equipment. Even though the proposed Aircraft Movement System (AMS) by Vanley Systems would not require capital investment by participants, it is doubtful that a significant number of AMS could be produced in the near future for any large-scale towing operation.

The construction requirements and the number of additional tractors needed for an aircraft towing demonstration project at the 20 study airports are presented in Table 9. As shown, only three airports satisfy the first criterion: Honolulu International Airport, Philadelphia International Airport, and Seattle-Tacoma International Airport.

A further evaluation of these three airports on the basis of the remaining six criteria is summarized in Table 10. As shown, Honolulu International Airport and Seattle-Tacoma International Airport satisfy the six criteria to about the same degree and therefore rank first and second. Philadelphia International Airport satisfies the criteria to a lesser degree and ranks third.

Because of the resource constraints in this study, it was not possible to obtain definitive ratings of airports with regard to the second criterion (the level of cooperation that can be expected). Preliminary and unofficial discussions with airport sponsors indicated that there would be no objections to conducting an aircraft demonstration project at either Honolulu International Airport or Seattle-Tacoma International Airport.

RECOMMENDED POTENTIAL DEMONSTRATION AIRPORTS

On the basis of the preceding evaluation, Honolulu International Airport and Seattle-Tacoma International Airport are recommended as potential sites for an initial aircraft towing demonstration project. As experience and knowledge gained from the initial project allow more efficient towing operations to be planned, other airports evaluated in this study could be selected for additional demonstration projects without major difficulties, especially if construction requirements decrease and more advanced towing equipment becomes available.

Many of the airports studied have ongoing or planned airfield construction that may, in the future, reduce requirements for building tractor roadways. At the same time, as the feasibility of aircraft towing and the need for it becomes apparent, advanced towing equipment that will allow more efficient towing operations may also become more readily available.

The initial demonstration project should include provisions for monitoring any towing operations to be conducted at a domestic airport before the start of the demonstration project. The experience to be gained should provide valuable guidance for the planning and implementation of the demonstration project.

Table 9

CONSTRUCTION AND TOW TRACTOR REQUIREMENTS
TO IMPLEMENT AIRCRAFT TOWING

<u>Airport</u>	<u>Estimated construction required^a (square feet)</u>	<u>Number of additional tractors required</u>
Atlanta	50,000	16
Boston	45,000	7
Chicago O'Hare	10,000	31
Dallas/Fort Worth	0	25
Denver	50,000	10
Honolulu	0	3
Houston	21,000	7
Kennedy (New York)	0	25
LaGuardia (New York)	1,500	13
Los Angeles	30,000	14
Miami	12,000	16
Minneapolis-St. Paul	35,000	6
New Orleans	28,000	3
Philadelphia	0	5
Pittsburgh	44,000	5
St. Louis	33,000	10
San Francisco	21,000	10
Seattle-Tacoma	0	5
Tampa	91,000	5
Washington D.C. (National)	1,500	5

a. Roadways and staging areas.

Source: Peat, Marwick, Mitchell & Co.

Table 10

PRELIMINARY EVALUATION OF FEASIBILITY OF AIRCRAFT TOWING
AT AIRPORTS THAT DO NOT REQUIRE MAJOR CAPITAL INVESTMENTS

Criterion	Airport rating ^a		
	Honolulu	Philadelphia	Seattle-Tacoma
There should be a reasonable level of confidence that cooperation can be expected from the airport operator, local agencies, and the airlines.	Above average ^b	Average ^b	Above average ^b
There should be little need to tow aircraft across active runways.	Medium	Medium	High
The airfield and terminal area should be clearly visible from the air traffic control tower.	High	Medium	High
The potential aircraft fuel savings and emission reductions resulting from aircraft towing should be significant.	Medium ^c	Medium ^c	Medium ^c
The runway use should be consistent and predictable throughout most of the day.	High	High	High
The level of existing airfield congestion should be moderate or low.	High	Medium	High

a. The ratings indicate the degree to which the criterion is satisfied at a given airport.

b. These ratings are preliminary and apply only to airport operators.

c. These ratings are based on benefits achievable per towed operation.

Source: Peat, Marwick, Mitchell & Co.

RESOURCE REQUIREMENTS FOR DEMONSTRATION PROJECT

Preliminary estimates of resource requirements were prepared for (1) developing a comprehensive plan for an aircraft towing demonstration project at an airport to be selected by DOE, and (2) implementing the plan at the selected airport.

The Planning Phase

In the planning phase, the major work to be performed would include:

- Coordination with the Federal Aviation Administration (FAA) and the Environmental Protection Agency (EPA) to gain support and cooperation for the demonstration project.
- Identification and coordination of potential participants to gain cooperation and to reach a consensus on the scope of the demonstration and on evaluation criteria.
- Monitoring of any planned towing at domestic airports. The primary purpose of the monitoring would be to observe and evaluate potential operational effects that could result from aircraft towing.
- Development of a comprehensive demonstration plan to implement aircraft towing at the selected airport. The plan should include a detailed work scope for the implementation phase, the responsibilities of participants, cost and schedule estimates, types of data required and analyses to be performed, and contingency plans to allow a redirection of the effort if that becomes necessary. This plan should serve as a blueprint to be followed during the implementation phase of the demonstration project.
- Preparation of requests for proposals for evaluating aircraft emission and noise benefits of aircraft towing.

It is estimated that the planning phase would require about 6 man-months of DOE staff time and a funding level of about \$100,000 for contracting support. This phase would cover a period of 9 to 12 months. The actual cost and schedule would largely depend on the level of support and cooperation from the potential participants.

The Implementation Phase

Work to be performed during the implementation phase would include:

- Negotiation and signing of interagency agreements between DOE and FAA, and between DOE and EPA. The responsibilities of each agency in the demonstration project should be clearly identified in these agreements.
- Evaluation of proposals for the project studies.
- Selection of contractors to perform project studies.
- Coordination with all participants to establish data requirements, data collection, and analysis responsibilities.
- Actual field demonstration of aircraft towing at a selected airport.
- Field data collection and analysis of aircraft towing at the demonstration airport.
- Evaluation of the degree of success of towing operations by participants.
- Dissemination of demonstration results.

Because extended towing operations have not been attempted previously in the United States, a trial demonstration period should be planned to refine procedures.

It is estimated that the implementation phase would require about 9 man-months of DOE staff time and a funding level of about \$500,000 for contracting support. This phase would cover a period of 12 to 15 months.

SUMMARY OF PRELIMINARY EVALUATIONS FOR DEMONSTRATION PROJECT

On the basis of seven selection criteria and the analyses performed in this study, Honolulu International Airport and Seattle-Tacoma International Airport were found to be the most suitable airports for a potential aircraft towing demonstration project. It is recommended that DOE select one or both of these airports for further assessment.

In addition, to assist the planning and implementation of the demonstration project, it is recommended that provisions be made to observe and monitor any towing operations at domestic airports.

It is estimated that the planning and implementation phases would require about 2 years. The demonstration project would require about 15 man-months of DOE staff time and a funding level of approximately \$600,000 for contracting support over this period (order-of-magnitude estimates only). These estimates are intended for preliminary planning purposes only. Actual resource requirements will depend on the level of cooperation from the participants.

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