

Boeing Edge

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Dynamic Navigation  
Charting

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Safe Ramp and  
Maintenance  
Operations

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Transport of Live  
Animal Cargo

# AERO



# AERO

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Boeing provides airplane operators and owners with the industry's largest portfolio of services, support, and solutions — all organized around their business operations.

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# AERO

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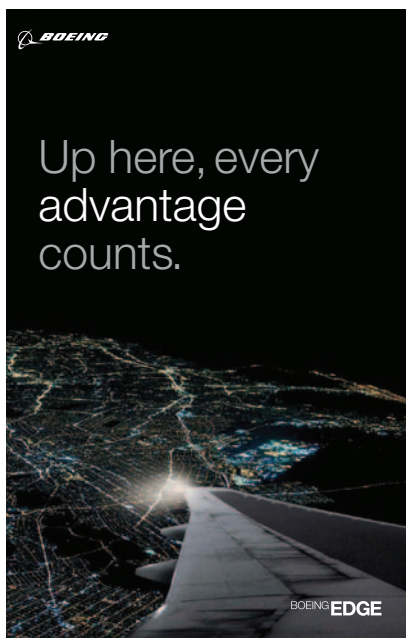
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Lou Mancini  
Senior Vice President,  
Boeing Commercial Aviation Services







Real-time route planning streamlines onboard operations, reduces fuel burn and delays, and improves on-time performance.

# Operational Efficiency of Dynamic Navigation Charting

Benefits such as improved safety margins, reduced pilot workload, and greater operating efficiency are driving the aviation industry's move from primarily paper-based navigation charts to fully digital charting technology. While worldwide digital terminal charts have been available in electronic flight bags (EFBs) for some time, recently released data-driven en route charting is the first step in moving to an entirely new charting technology. Future applications are expected to extend data-driven technology from gate to gate, and include valuable, up-to-the-minute flight information onto charts, providing more complete and timely situational awareness to the pilot.

**By Rick Ellerbrock**, Director, Aviation Strategy, Jeppesen, and  
**Skip Haffner**, Manager, Global Strategic Relationships, Jeppesen

More and more airlines are using EFBs to enhance the accuracy and efficiency of flight deck operations. Boeing and its subsidiary Jeppesen currently provide a number of applications for all EFB classes, including airport moving map (AMM), en route and terminal charting, onboard performance tool, video surveillance, and document browser. Included in Jeppesen's charting application is an en route dynamic, seamless worldwide visual representation of en route chart data during flight, updated to keep pace with the airplane's location and overlaid with the planned route of flight.

The next step in creating a completely digital flight deck will be adding real-time geo-referenced information and extending

data-driven technology beyond the en route phase of flight.

This article provides details about the currently available data-driven en route charting solutions, along with an overview of developing technologies that will contribute to further enhancing safety margins and operational efficiencies in the future.

## REPLACING PAPER CHARTS ON THE FLIGHT DECK

A data-driven, en route charting application, such as that currently offered by Jeppesen, can not only eliminate the need for cumbersome paper en route charts but also provide

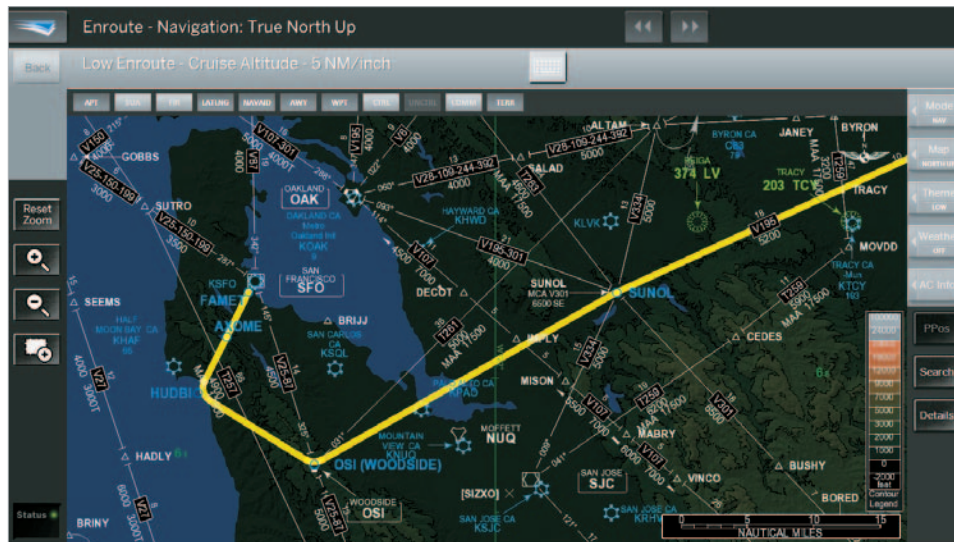
operators with real-time route planning capabilities and global positioning system (GPS)-based positional awareness in-flight. Jeppesen's EFB digital data-driven en route charting application was recently determined by the U.S. Federal Aviation Administration (FAA) to be suitable as an in-flight paper chart replacement (see fig. 1). The digital data-driven en route charting application uses real-time GPS data to enable accurate route planning and on-ground positional awareness.

An FAA authorized version of Jeppesen charting for iPad is also available (see fig. 2). iPad gained rapid, unprecedented popularity as an EFB in all aviation market segments. Jeppesen's charting app gained initial FAA authorization with Executive Jet Management in February 2011. In December,



## Figure 1: Data-driven en route charting application

En route data-driven charting includes a variety of information, including airports, airways, waypoints, navigational aids, airspace, and terrain information, and thousands of regional and operational notes that enable the elimination of traditional paper charts. The solution is available on a number of platforms, including the Boeing electronic flight bag (EFB).



## Figure 2: Data-driven en route charting on iPad

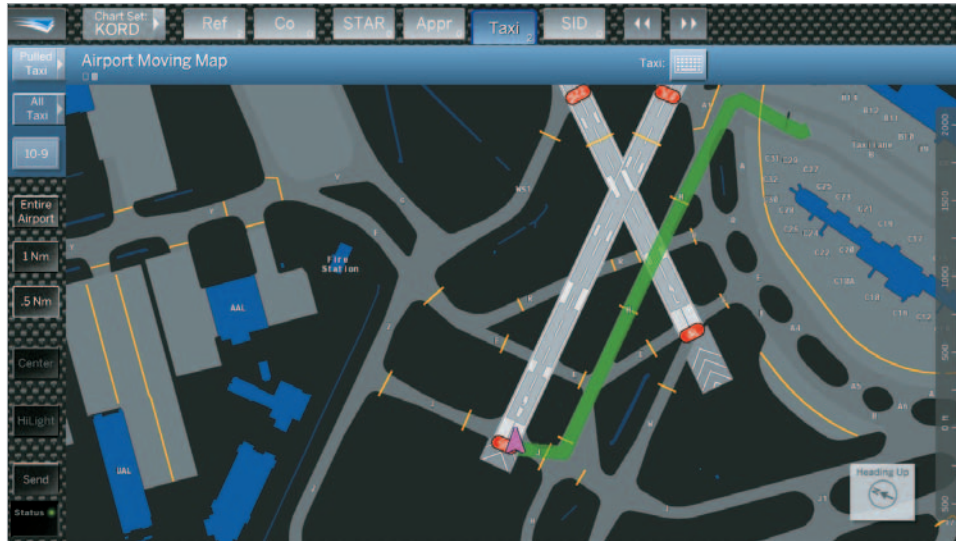
Jeppesen Mobile FliteDeck for iPad offers a full paper replacement on the device, making it a popular EFB choice.





### Figure 3: Airport moving map

An airport moving map, such as this one of Chicago O'Hare airport (ORD), improves positional awareness among flight crews.



American Airlines became the first airline to receive FAA authorization to use Jeppesen charts on iPad during all phases of flight. Many air carriers around the globe are actively evaluating mobile EFB platforms including iPad, with simulator and in-flight evaluations to help develop required operating procedures and training programs, and to validate its use in all phases of flight for paper chart elimination.

Data-driven charting offers more flexibility and intelligence than precomposed chart images. It allows the user to activate and deactivate certain functions, apply filters to control presentation, and otherwise manipulate, within predetermined parameters, what is displayed on the chart and how. Being dynamically rendered, data-driven charts enable information readability and usability across a broad range of map scales, a new feature that is not available with en route charts that have fixed presentation, also referred to as "precomposed." In addition, data-driven charting requires significantly less storage capacity than precomposed images.

Digitally enhanced full-color, high-quality, vector-based data with zoom and pan

features allow greater detail to be rendered on the EFB display. The map can be re-rendered with one click to show either low-altitude or high-altitude information, as needed. The search function allows immediate access and display of a needed chart feature, such as an airport, navigational aids, or waypoint. The technology also enables flight crewmembers to more easily collaborate and share information. Pilots can also choose what flight data is displayed, including airports, airways, waypoints, navigational aids, airspace, and terrain information, allowing for an individualized, dynamically rendered on-screen presentation that best supports the task at hand.

#### AMM IMPROVES RUNWAY SAFETY

Since 2003, Jeppesen has offered AMM for EFB that dynamically renders high-resolution Jeppesen maps of the airport surface. Through the use of GPS technology, AMM shows pilots their position ("own-ship") on the airport surface (see fig. 3). The result is significantly improved positional awareness

for the pilot, which has led to proven improvements in taxi efficiency, i.e., less fuel burn, and reduction in runway incursions during ground operations, especially at busy airports with complex runway and taxiway layouts.

Jeppesen conducted numerous field studies using simulators and airline flight crews to validate the benefit of AMM technology for EFBs. These studies revealed consistent improvement in pilot performance because flight crews are better able to anticipate their location in relationship to runways, taxiways, and parking locations. Additional research by the Commercial Aviation Safety Team estimates that runway incursions caused by pilot deviations could be reduced by as much as 50 percent when flight crews use AMM.

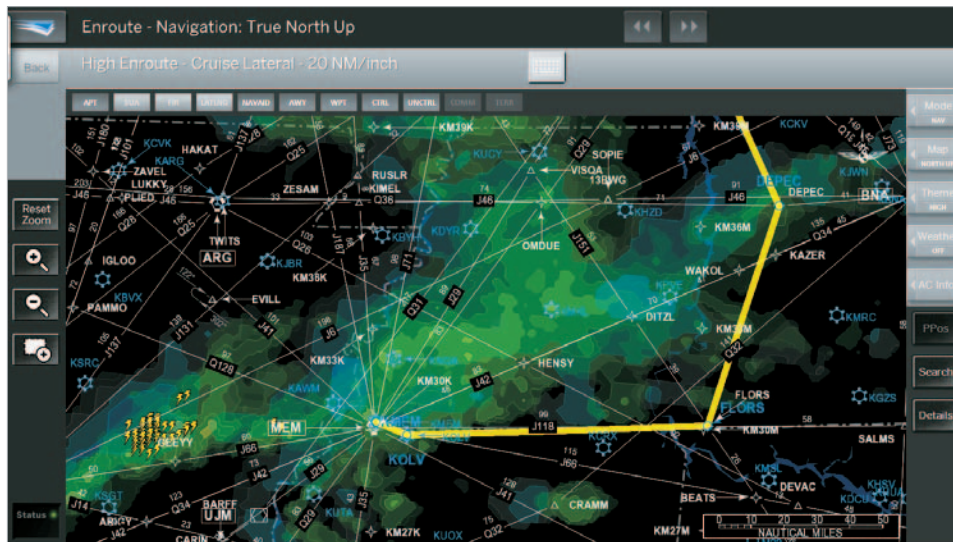
The AMM application is available for Class 2 and Class 3 EFBs.

#### THE FUTURE OF DATA-DRIVEN CHARTS

The next step in the evolution of the data-driven en route EFB will be to add enhanced routing functions and highly

## Figure 4: Weather data on en route navigation chart

Adding weather data to data-driven en route navigation provides flight crews with valuable information at a glance.



integrated real-time weather data (see fig. 4).

The future of advanced information management technologies for navigation includes a flight deck that is connected to the airline operations center with real-time data, integration of ground-based and airborne information systems, and leveraging of the growing data-link capabilities of commercial airplanes.

The next generation of electronic data-driven charting will extend today's digital charting by providing a seamless gate-to-gate solution. It will also include smart information layers that overlay information such as Notices to Airmen (NOTAMs) and new weather products such as four-dimensional "weather cube" data being developed in support of NextGen.

Traffic overlays using ADS-B technology are also supported in the data-driven framework, providing even more situational awareness and enabling fuel- and time-efficient functions to manage merging and spacing of traffic in the terminal area and in-trail procedures over the ocean. The result will be an integrated flight deck approach that will allow flight crews to view the information

they need in a single place, with an airport map or navigation chart as a background layer, whether they're taxiing from the gate, taking off, cruising, or landing (see fig. 5).

In addition, the system is being designed for context awareness, automatically updating what is depicted onscreen to reflect the current phase of flight. For example, when entering the geometry of an assigned runway and being aligned within a defined tolerance of the bearing of the runway, the system detects the upcoming departure and switches to departure mode, changing the field of view and information content.

### BENEFITS TO OPERATORS

Data-driven charting applications can help operators improve their safety margins, reduce pilot workload, and increase operational efficiencies.

**Safety.** The system supports safety objectives by improving situational awareness through the availability of more complete and timely information about the airplane's navigation, weather, terrain, and traffic


situation. AMMs help enable enhanced safety during ground operations.

**Reduced workload.** By providing flight crews with charting and other relevant flight information in one place, the system eliminates the need to carry and sort through large amounts of unlinked printed information.

**Operational efficiency.** Replacing paper charts, providing operators with real-time route planning capabilities, and delivering intelligent information when and where it's needed will help streamline onboard operations, reduce fuel burn, reduce delays, and improve on-time performance.

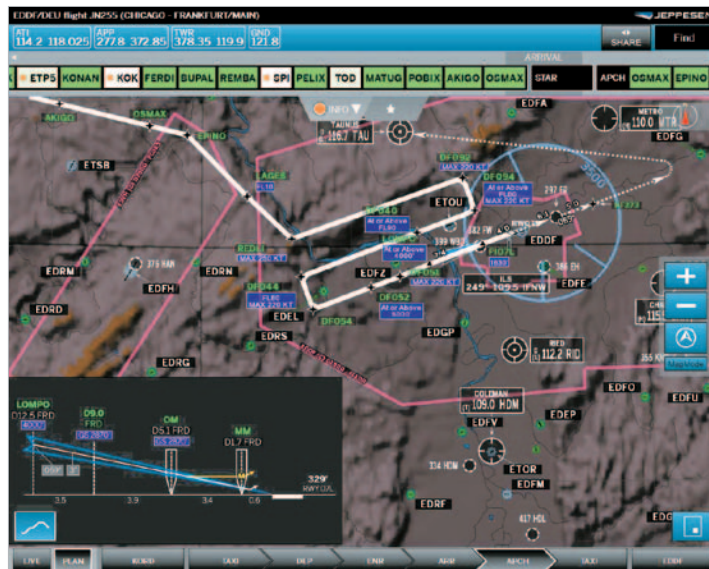
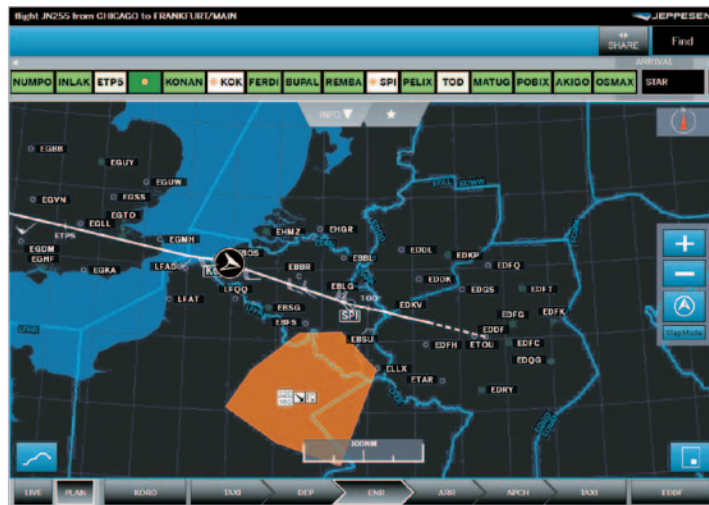
### SUMMARY

Jeppesen offers a variety of EFB-based digital charting applications, including iPad applications. It is also developing ways to display real-time flight information, such as NOTAMs and ground-based weather forecasts, for display on digital navigation charts.

For more information, please contact [airlineservices@jeppesen.com](mailto:airlineservices@jeppesen.com). 

## Figure 5: The next generation of digital charting

Future charting technologies will provide flight crews with the information they need from gate to gate, including airport taxi (top), en route navigation (center), and arrival and approach (bottom), all linked seamlessly. The application will display NOTAMs and weather alerts as overlays directly on the chart, providing flight crews with a single view of flight information that improves situational awareness, decision making, and flight efficiency.







The tools for ramp LOSA and maintenance LOSA include a ready-to-use database and data analysis software that stay with the operator.



# Assessing the Safety of Ramp and Maintenance Operations

The successful process for assessing line operations safety in the airline flight environment has now been extended into the areas of ramp and maintenance operations. The ramp line operations safety assessment (LOSA) and maintenance LOSA are intended to enhance ramp and maintenance safety, respectively, through voluntary, peer-to-peer observations under strict nonpunitive conditions.

**By William Rankin**, Ph.D., Technical Fellow, Maintenance Human Factors, and  
**Bill Carlyon**, Program Manager, Environment, Health and Safety Support

Flight LOSA has proved its value as a predictive safety process in airline flight operations. The assessment process is based on peers observing peers during normal operations. Observation data are kept anonymous, there is a clear no-punishment policy, and the observations can be used as a basis for making safety improvements.

Recently, the Airlines for America (A4A) Joint Engineering, Maintenance & Material Council and Safety Council Human Factors Task Force has extended the LOSA concept to ramp and maintenance operations. The task force included A4A

member airlines, Boeing representatives, ground service providers, and members of the U.S. Federal Aviation Administration (FAA). The term “assessment” was purposefully chosen instead of “audit” because the task force wanted to separate LOSA from the traditional airline quality control or safety audit processes.

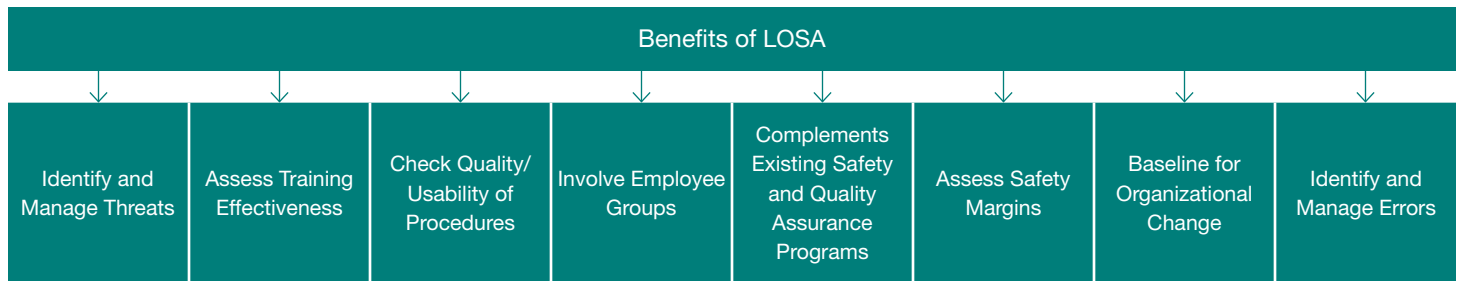
This article provides a summary of the LOSA process and how to implement the process using the observation tools, observer training materials, and database software available for ramp LOSA and maintenance LOSA.

## THE LOSA PROCESS

Flight LOSA has been demonstrated to be a valuable safety tool. It was developed as a joint endeavor between the University of Texas at Austin (UTA) and Continental Airlines. LOSA is based on the UTA Threat and Error Management (TEM) model, which hypothesizes that threats and errors are integral parts of daily flight operations and must be managed. Therefore, observing the management or mismanagement of threats and errors during normal operations can provide a clear picture of actual performance. Flight LOSA has been a very successful program with most large international airlines using the process and reporting safety benefits from the program.

## Figure 1: Benefits of line operations safety assessments (LOSA)

Ramp LOSA and maintenance LOSA offer airlines a number of benefits that can improve safety and enhance existing procedures.



The ramp LOSA effort was initiated at Continental Airlines in early 2007. Its LOSA implementation contributed to a dramatic decrease in airplane ground damage. This caught the industry's attention, which led to the creation of the A4A Human Factors Task Force. Through this task force, the industry and government continue to partner closely to improve the safety of ramp and maintenance operations by developing LOSA tools. The available LOSA materials describe the process; provide the ramp LOSA and maintenance LOSA observation tools, database software, and training materials; and list the active industry partners.

Like flight LOSA, ramp LOSA and maintenance LOSA are based on the TEM model and offer airlines similar benefits (see fig. 1). Ramp LOSA and maintenance LOSA are centered on observations made during normal operations by trained observers with a goal of stopping errors from occurring that lead to injuries and damage to equipment or airplanes. LOSA is a voluntary process that is nonthreatening and nonpunitive.

Observations of ramp and maintenance activities enable the airline to acquire data about actual day-to-day safe and at-risk behaviors in real-time, normal operations; discover procedural or systemic flaws that might lower safety margins; determine good practices that are in place; and provide baseline data that can be used to assess the effectiveness of safety interventions that were implemented to correct the at-risk behaviors.

### KEY LOSA CHARACTERISTICS

LOSA is characterized by observations made during normal ramp operations or normal maintenance operations. Data are collected anonymously and confidentially by trusted and trained observers from the ramp or maintenance staff, respectively. The effort is sponsored jointly by management and ramp or maintenance staff, and participation is voluntary.

Although the philosophy and principles for ramp LOSA and maintenance LOSA are the same as for flight LOSA, the systems used are very different from each other. Flight LOSA relies on trained pilots using open-ended text to record observations. Ramp LOSA and maintenance LOSA have structured observation checklists that are used by an airline's own staff (see fig. 2). The tools developed for ramp LOSA and maintenance LOSA include a ready-to-use database and data analysis software that are kept with the operator. There is no need for outside data storage and analysis. This ensures that company data are secure and that analysis does not require external consultants.

Data verification roundtables are used to reveal any data inaccuracies due to differences in opinion about company policies, processes, and procedures by the LOSA observers. The results of the observations are provided to the ramp or maintenance crews in summary form. Then data-derived targets for improvement are established,

interventions are put in place to address these targets, and additional observations are carried out to determine if the interventions brought about the desired changes.

### THREATS AND ERROR MANAGEMENT

The foundation of LOSA is the TEM model. In this model, the ramp or maintenance worker is to actively identify threats, develop strategies to manage the threats so that they do not lead to errors, manage the errors that do occur, and learn from past errors in order to anticipate future threats and ultimately manage the threats better in the future to prevent errors.

**Threats.** Threats are any condition that increases the complexity of the operations and if not managed properly can decrease the safety margin during ramp or maintenance operations. There are two types of threats:

- **External threats are threats outside control**, including weather, a late gate change, lack of the correct tool to do a maintenance task, pressure from management, and a poorly written task handover log entry.
- **Internal threats are threats within control**, including fatigue, preoccupation (i.e., loss of situation awareness), time pressure, lack of training, and disregard for following processes and procedures.



**Figure 2: Ramp LOSA and maintenance LOSA observation forms**

The ramp LOSA observation form (top) and maintenance LOSA observation form (bottom) provide observers with clear indications of the activity that should be observed and recorded.

Ramp LOSA Observation Form

**1. Arrival**

Observation Number: \_\_\_\_\_  Did not observe this section

Scheduled Time of Arrival: \_\_\_\_\_ Estimated Time of Arrival: \_\_\_\_\_ Actual Time of Arrival: \_\_\_\_\_

	Safety Risk				Error Code	Threat Code	Threat Effectively Managed Y/N	Error Outcome	Remarks
	N/A, Safe (S), At Risk (AR), Did Not Observe (DNO)								
Preflight briefing (a.k.a. huddle) held	S	AR	DNO	N/A					
Ramp crew ready prior to A/C arrival	S	AR	DNO	N/A					
Arrival FOD/trash walk complete	S	AR	DNO	N/A					
Gate area cleared (clean and orderly)	S	AR	DNO	N/A					

Maintenance LOSA Observation Form

**B.4 Install**

Observation Number: \_\_\_\_\_  Did not observe this section

		Safety Risk	Threat Code	Threat Effectively Managed	Error Outcome
		N/A, Safe (S), At Risk (AR), Did Not Observe (DNO)	(See Threat Codes List)	Y/N	1. Inconsequential 2. Undesired state 3. Additional error & Remarks
<b>Safety</b>					
1	Notes, cautions, and warnings reviewed				
2	Notes, cautions, and warnings followed				
<b>Personnel</b>					
3	Required personnel available				
<b>Procedures</b>					
4	Current documentation (e.g., task cards, AMM, service bulletins) available and reviewed				
5	Effectivity/configuration verified				
6	Materials utilized				
7	Servicing procedures followed				
8	Installation procedures followed				
<b>Communication &amp; Coordination</b>					
9	Communication among technicians accomplished				
10	Communication to other departments accomplished				
<b>Threat Management</b>					
11	Strategies developed for identified threats				
12	Generated non-routines for work-not-specified in the tech publications				
<b>Turnover or Completion</b>					
13	Task/shift turnover completed				
14	Individual work step signoff completed				
15	QC inspection signoff completed				
16	Access panels installed				
<b>Other</b>					
17					
18					
19					
Describe the threat(s). How did the technician(s) manage or mismanage the threat(s)?					
Describe the technician error(s) and associated undesired states					
Comments—Good or bad (Please provide examples)					

# Implementing a line operations safety assessment

Here are general guidelines for implementing a LOSA for ramp or maintenance operations.

1. Form an initial development team/LOSA steering committee made up of management, safety staff, and ramp or maintenance staff. This team will handle planning, scheduling, observer support, and data verification.
2. Gather information from other companies that are using ramp LOSA or maintenance LOSA and get their input on benefits, their process, and implementation issues (see A4A or FAA Web site).
3. Identify problem areas to observe.
4. For ramp LOSA, determine how many airplane turns to observe and where. For maintenance LOSA, determine the type and number of maintenance tasks to observe.
5. Schedule observation dates and select observers.
6. Develop or modify the observation forms (e.g., to use airline-specific terminology).
7. Train all ramp or maintenance staff on ramp LOSA or maintenance LOSA and its characteristics.
8. Train observers.
9. Perform observations.
10. Perform data verification.
11. Analyze data.
12. Write report and give to the steering committee, management, and relevant training, standards, and safety organizations. The report is to list problems, not solutions.
13. Develop interventions, including enhanced policies, procedures, training, or equipment, based on the findings.

Materials to implement ramp LOSA and maintenance LOSA are available at no charge on the FAA Web site at <http://www.mrlosa.com>. The materials include LOSA posters, implementation guidance for management, LOSA observer training materials, LOSA observation forms, and LOSA database software.

**Errors.** Errors are the mistakes that are made when threats are mismanaged. It is an action or inaction by the ramp or maintenance crew that leads to deviations from organizational or crew intentions or expectations. There are five categories of error:

- **Intentional noncompliance error.** Willful deviation from regulations and/or operator procedures.
- **Procedural error.** Deficient execution of regulations and/or operator procedures. The intention is correct, but the execution is flawed. This also includes errors in which the crew forgot to do something. It may only differ from an intentional noncompliance error based on intention.
- **Communication error.** Miscommunication, misinterpretation, or failure to communicate pertinent information, e.g., among the ramp or maintenance crew, between the ramp or maintenance crew and an external agent (e.g., flight crew), or between work shifts.

- **Proficiency error.** Lack of knowledge or psychomotor skills (e.g., driving a belt loader or lockwiring a component on an engine).
- **Operational decision error.** Decision-making error that is not standardized by regulations or operator procedures and that unnecessarily compromises safety. Three conditions must exist to have this error:
  - The decision was selected by the crew from two or more options.
  - The decision was not shared among crew members.
  - The decision selected by the crew was not adequately evaluated even though the crew had sufficient time.

**Types of error responses.** LOSA considers three possible responses by crews to errors:

- **Trap or mitigate.** An error is detected and managed so that the result no longer affects safety or performance.

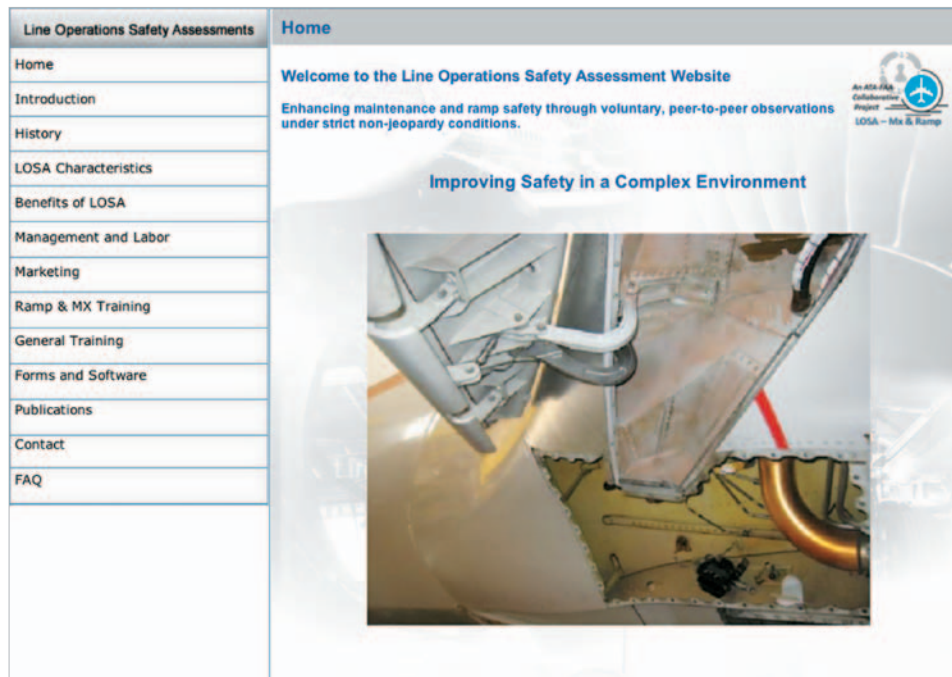
- **Exacerbate.** An error is detected, but the crew actions or inactions cause the situation to worsen.
- **Fail to respond.** An error is undetected or ignored by the crew.

**Error outcomes.** Crew responses to an error can result in one of three outcomes:

- **Inconsequential.** The risk caused by the error does not produce any negative consequence.
- **Undesired state.** The error puts staff or equipment in a situation where safety is compromised. This occurs when the ramp or maintenance crew exposes people, equipment, or airplanes to unnecessary risk (e.g., improperly using equipment). An undesired state is different from an error in that it is a condition or situation that results from an error. It may also result from external threats.
- **Additional error.** The mistake leads to an additional error.

**Figure 3: The LOSA section of the FAA Web site**

Airlines can download forms and software for implementing a ramp or maintenance LOSA from the FAA Web site at [www.mrlosa.com](http://www.mrlosa.com).



### CONDUCTING A RAMP LOSA OR MAINTENANCE LOSA

A ramp LOSA is carried out during an airplane turn. Since so much is happening in a short time frame, a ramp LOSA is typically carried out by a team of two or three trained ramp peer observers. Maintenance LOSAs are typically conducted by one trained maintenance peer observer. Two or more observers may be used for complex tasks (e.g., engine change). Observers need to be vigilant to the possibility that years of exposure may have desensitized them to ongoing threats and errors.

The ramp LOSA observation form has 11 sections:

1. Arrival.
2. Downloading.
3. Lavatory and potable water service.
4. Catering.
5. Cleaning service.
6. Fuel service.
7. Uploading.
8. Departure.

9. Airplane maintenance.
10. Deice and anti-ice.
11. Pilot walk-around.

It is up to the organization to determine what is to be observed. For example, a decision could be made not to observe the cleaning service. Also, the observations of airplane maintenance or deice and anti-ice can only be made when the conditions warrant these tasks. Each section of the observation form provides observers with specific observations that should be made and recorded.


The maintenance LOSA observation form has nine sections:

1. Planning.
2. Prepare for removal.
3. Removal.
4. Prepare to install.
5. Install.
6. Installation test.
7. Close-up and complete restore.
8. Fault isolation/Troubleshooting/Deferral.
9. Servicing.

### DEVELOPING A LINE OPERATIONS SAFETY ASSESSMENT

Airlines interested in developing a LOSA can read more about the process on page 14. The materials developed by the task force can be found on the FAA Web site at [www.mrlosa.com](http://www.mrlosa.com) (see fig. 3). These materials include LOSA posters, implementation guidance for management, observer training materials, observation forms, and database software.

### SUMMARY

Effective management of threats is a decisive factor in reducing the severity of errors. LOSA is a positive means for identifying threats and managing them before safety margins are reduced below acceptable levels. The result is a safer operation. Forms, training materials, implementation guidance, and software for use in developing a ramp LOSA and a maintenance LOSA are available online. 





Boeing recommends limiting the time animals are in cargo compartments prior to takeoff by coordinating closely with the ground crew.

FARE 2120

# Safe Transport of Live Animal Cargo

Transporting live animals requires special attention to the operation of the airplane's environmental control system (ECS). Optimal settings vary by animal species. By following recommended guidelines, operators can maximize animal cargo revenue and reduce unnecessary fuel burn.

By **Luong Le**, System Engineer, Environmental Control Systems

Airplane ECS control settings, animal physiology, airport and en route environments, and ground handling affect the safe transport of live animal cargo. To ensure the health of the live animals and maximize animal cargo revenue, proper ECS settings, animal handling (and packaging), and appropriate animal loading configuration should be used.

This article provides general information about safe transportation of live animal cargo and introduces cargo operators

to Boeing's live-animal cargo guidelines and service.

## THE FUNDAMENTALS OF SAFE LIVE ANIMAL TRANSPORT

The safe transportation of live animals as air cargo is based on controlling three environmental factors: temperature, relative humidity level, and cargo compartment carbon dioxide (CO<sub>2</sub>) concentration. Each type of animal has unique environmental

requirements for optimal health (see fig. 1). Failure to properly control these environmental factors may have an impact on animal welfare, comfort, and survivability, affecting animal cargo revenue.

The compartment temperature, CO<sub>2</sub> level, and humidity levels depend on the ambient temperature, animal type, the number of animals to be transported, airplane air-conditioning pack capability, and the ECS settings. Setting to the desired compartment temperature for the animal does not



**Figure 1: Recommended temperature, humidity, and CO<sub>2</sub> requirements for various animal species**

ANIMAL*	DESIRABLE TEMPERATURE RANGE	RECOMMENDED RELATIVE HUMIDITY (RH)	RECOMMENDED CO <sub>2</sub>
Beef cattle	40–80 deg F (4.4–26.6 deg C)	0–75% RH for swine/hog  0–80% RH for cattle/poultry	0–0.5% for 1-day-old chicks  0–3% for most other animals
Dairy cows, mature, dry	40–80 deg F (4.4–26.6 deg C)		
Dairy heifers, pregnant	40–75 deg F (4.4–23.8 deg C)		
Dairy calves	50–75 deg F (10–23.8 deg C)		
Hogs: Over 15 lb	50–75 deg F (10–23.8 deg C)		
Hogs: Pregnant gilts	50–70 deg F (10–21.1 deg C)		
Horses	40–80 deg F (4.4–26.6 deg C)		
Poultry: Over 10 days old	50–80 deg F (10–26.6 deg C)		
Poultry: 1-day-old (unfed)	90–100 deg F (carton) (32–37 deg C)		
Sheep	50–75 deg F (10–23.8 deg C)		

\*Recommended environmental control system (ECS) settings are determined based on the type of animals being transported.  
Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers and Society of Automotive Engineers Aerospace Information Report 1600.

necessarily result in the temperature that is set from the flight deck. The animal heat load can result in higher compartment temperatures than that set from the flight deck. The humidity and CO<sub>2</sub> levels inside the compartment are not controllable by the ECS settings. The conditioned supply air from the air distribution nozzles, which are located in the ceiling or the sidewall (depending on aircraft design and model), contain some moisture and CO<sub>2</sub> prior to mixing with the air inside the compartment. The supply air properties combined with the animal heat load, CO<sub>2</sub>, and moisture

generation determine the overall compartment air properties (see fig. 2).

A preliminary animal carriage calculation (based on past in-service experience) should be performed to predict the compartment temperature, humidity, and CO<sub>2</sub> prior to animal shipment. If the compartment temperature, relative humidity, and CO<sub>2</sub> are beyond the recommended level for the specific animal after following the general guidance below, the number of animals to be transported should be reduced.

Animals can be transported in all airplane compartments. Depending on

the environmental control availability and flexibility of the ECS system, the number of animals in a load to be transported can vary. The right side of figure 3 shows the forward main deck, aft main deck, forward cargo compartment, aft cargo compartment, and the bulk cargo compartment. Some airplane models combine the aft and bulk cargo compartments into one temperature control (for example, the 777 freighter). Passenger airplanes have lower lobe compartments, which also may be used for animal transport.



## Figure 2: Supplied air and animal environmental factors schematic

This sectional view shows how the air supply mixes with the animal environmental factors.

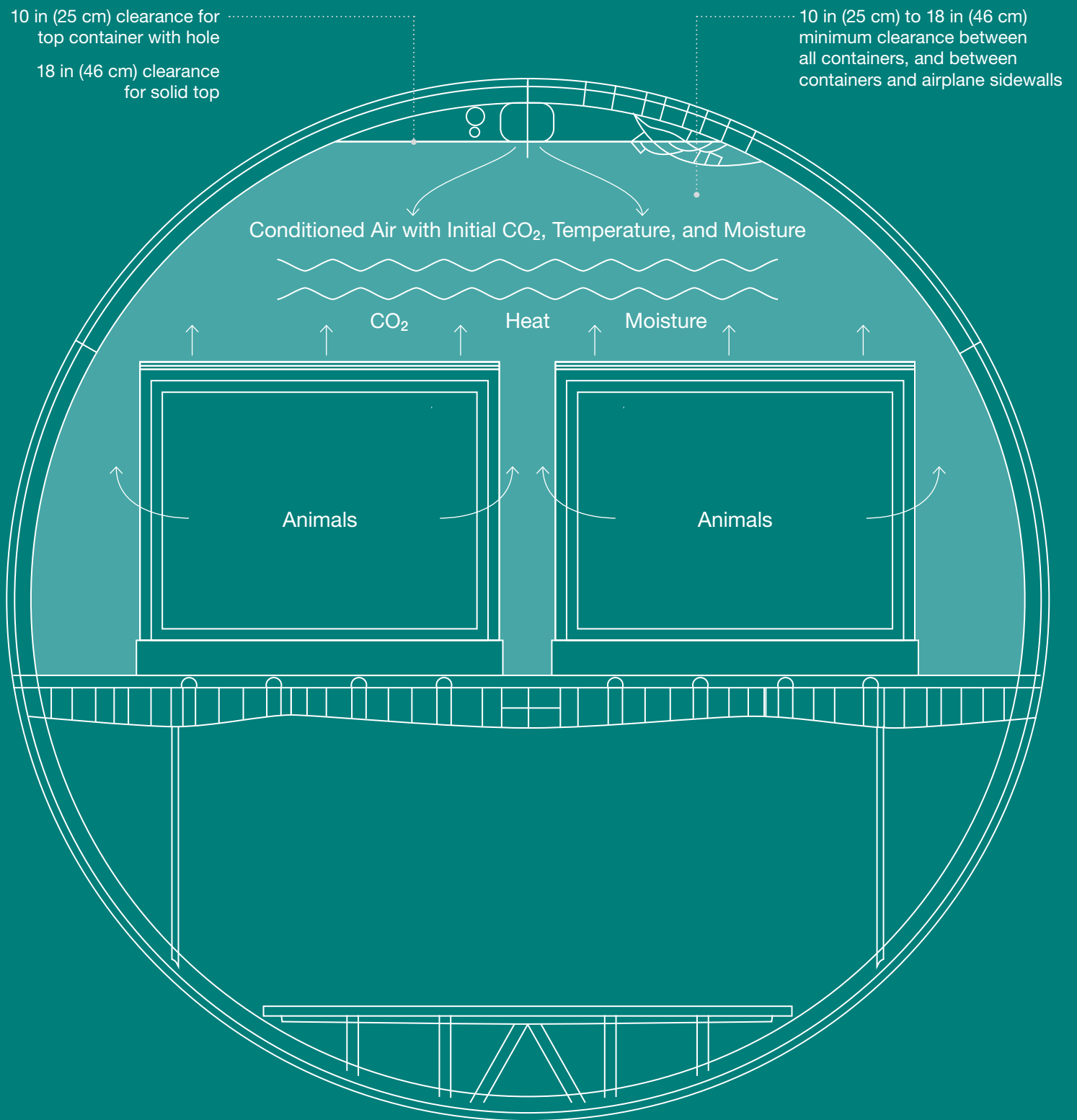


Figure 3: ECS flight deck panel and aircraft compartment identification (777F typical example)

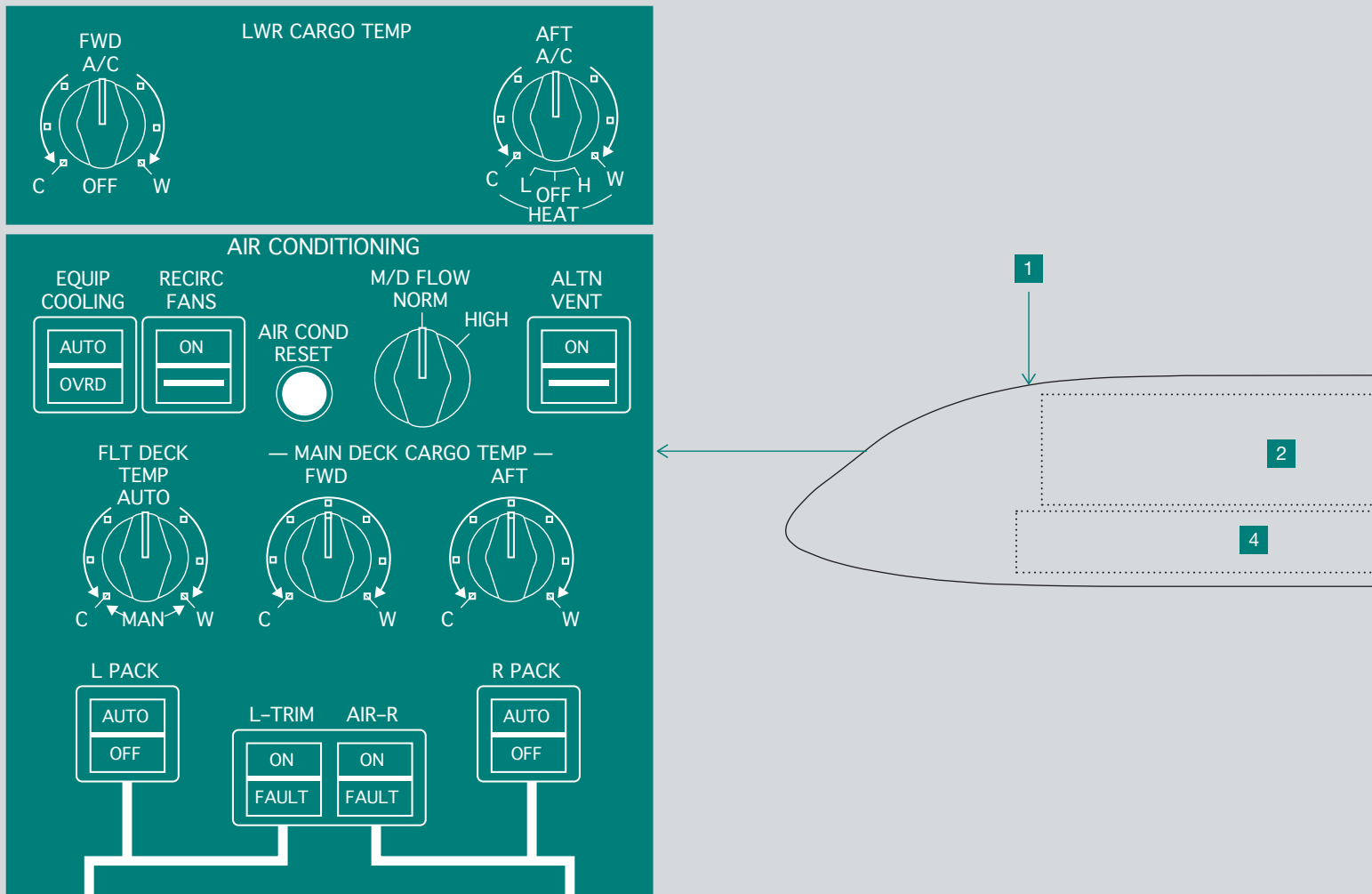


Figure 3 shows a typical 777F ECS control panel in the flight deck. For all freighters, the main deck compartments have the capability of temperature control (heating and cooling) for animal and temperature-sensitive cargo. Lower lobe compartments equipped with optional air-conditioning systems have temperature control for freighter and passenger airplanes. High and normal airflow options provide different supply airflow rates. A high airflow rate should be selected for high-density animal loads, thus increasing the animal transport capacity. A normal airflow option should be selected for low-density animal transport or other type of non-heat-generating cargo for fuel savings.

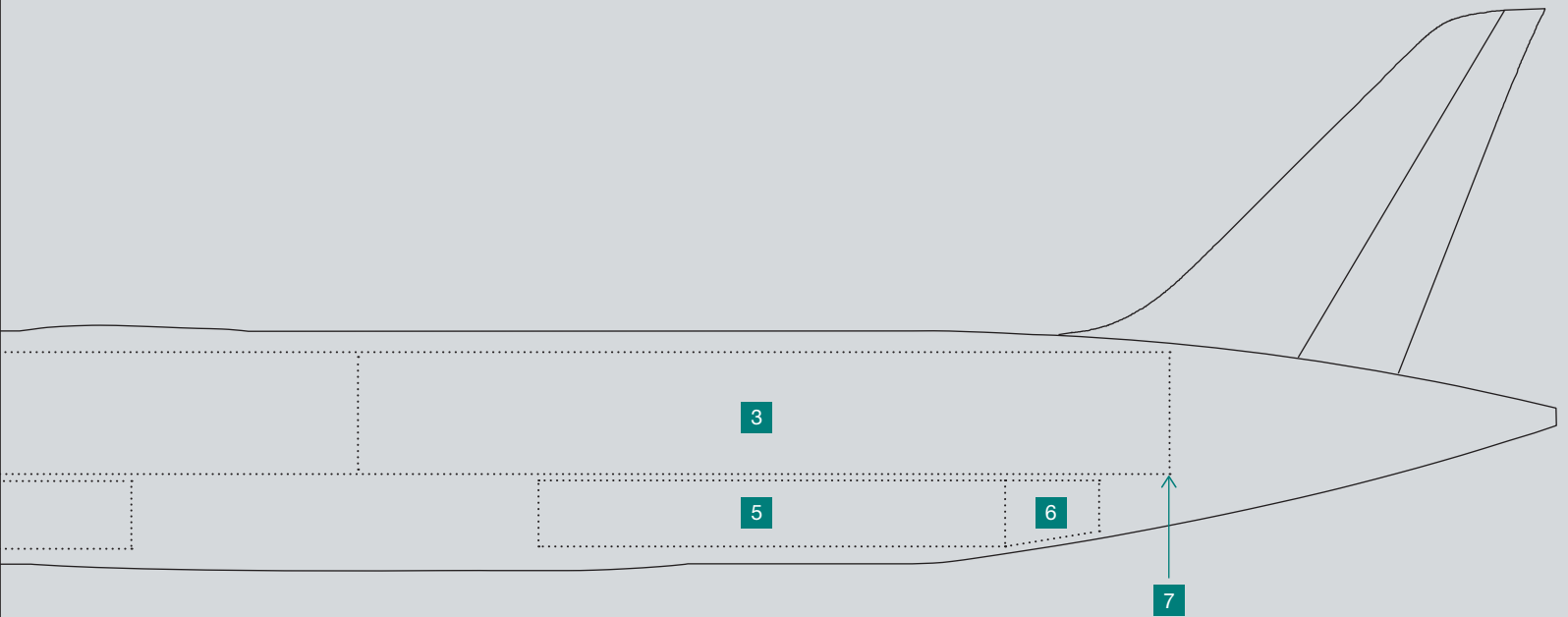
Lower lobe compartments in freighter or passenger model airplanes that only have cargo heat do not control temperature for cooling. Cargo heat only has the ability to control the compartment temperature to specific predefined temperatures (for example, keeping the compartment at 40 degrees F (4 degrees C) at a low setting and 65 degrees F (18 degrees C) at a high setting). These settings are when cargo heat is commanded on and the cargo heat is commanded off when the compartment temperature is 10 degrees F (-12 degrees C) above the setting. Cargo heat operates intermittently and does not have the ability to provide direct ventilation into the compartment. Some heated air may migrate into the compartment due

to the cargo floor design. Cargo heat selection is not recommended for animal transport; however, it is possible to transport a limited amount of live animal cargo with airplanes equipped only with cargo heat temperature control in the lower lobe compartment, depending on the operating conditions, the type of animal, and the duration of the trip.

**KEY FACTORS THAT INFLUENCE ANIMAL CARRIAGE**

A number of environmental factors influence the welfare of live animal cargo. In cases of extreme heat, many environmental factors

- 1 Rigid Cargo Barrier
- 2 Forward Main Deck Compartment
- 3 Aft Main Deck Compartment
- 4 Forward Lower Lobe Cargo Compartment
- 5 Aft Cargo Compartment
- 6 Bulk Cargo Compartment
- 7 End Wall



can be reduced or eliminated by loading live animal cargo at night.

- **Outside air temperature.** The higher the air temperature, the more time is required to cool the cargo compartment prior to loading animals.
- **Quantity, size, and type of animal cargo.** These factors affect the heat load, moisture, and CO<sub>2</sub> in the cargo compartment.
- **Airplane environmental systems' capability and configuration.** Auxiliary power unit (APU) and air-conditioning performance are affected by the ambient air temperature relative to ventilation capability. (APU gets higher efficiency for cooling the airplane when the ambient

temperature is cooler.) Some Boeing airplane models have lower lobe air conditioning, that enhance live animal transportation. (Note: This lower lobe cargo compartment air conditioning may reduce main deck compartment cooling capacity.)

- **Airplane condition prior to loading animals.** Heat soak (caused by an airplane sitting on the ground in the sun in high outside temperatures with the air conditioning off) and preconditioning the cargo compartment both affect the amount of time required for the compartment to reach the desired temperature.

- **Time on ground with loaded cargo.** The longer the time that the airplane is on the ground with loaded live animal cargo, the longer the airplane will be required to cool the cargo compartment to a desired temperature.
- **Animal packaging and stocking densities.** The longer the time on the ground and the duration of flight, the lower the recommended density of animals in the cargo compartment.

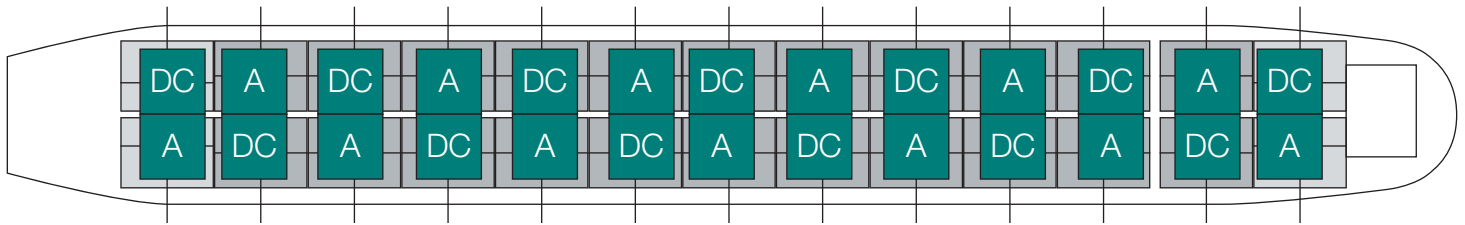
#### PREPARING FOR ANIMAL TRANSPORT

Prior to loading live animals, prepare the airplane's air-conditioning system, keeping in mind the expected airport ambient conditions,



## Figure 4: Typical animal cargo loading

This represents a typical arrangement of animals (A) and dry cargo (DC) to improve ventilation and heat/moisture mitigation.



the animal's physiology, and the airplane's air-conditioning variable settings. Providing the greatest air ventilation flow throughout the pallets and containers by setting to the highest air-conditioning setting available helps ensure animal welfare for large loads.

Boeing recommends limiting the amount of time animals are in cargo compartments prior to takeoff by coordinating the airplane's departure closely with the ground crew. In addition, by briefing the flight crew about the animal cargo, operators can help ensure that ventilation in the cargo compartment is not cut off or reduced to save fuel.

These guidelines can help operators optimize animal welfare and maximize animal cargo revenue.

- Precondition the cargo compartment prior to loading the animals. If possible, use the airplane's ECS to achieve the ideal temperature for the type of animals being transported.
- Limit the time the airplane spends on the ground — including stopovers — while animal cargo is onboard.
- Load animals as close to the departure time as possible.
- Unload animals immediately upon arrival at the destination. Ensure that ground crew personnel are standing by and ready to unload animal cargo as soon as the airplane lands.
- Close cargo doors last before departure and open cargo doors first upon arrival. Adequate ventilation helps prevent unhealthy levels of CO<sub>2</sub> and humidity accumulating in the closed cargo compartment.

- Avoid holding animals in the airplane in the sun. Load at night if possible to avoid high temperatures and solar exposure.
- Do not transport animals and carbon dioxide (usually in dry ice form) in the same compartment.
- Avoid carriage of live animals with cargo with a lot of moisture on the container, such as rain, snow, or ice, or liquids inside the container.

### LOADING GUIDANCE

Boeing recommends these guidelines for the actual loading of animal cargo.

- Load animals so that there is space between the pallets to allow air to freely circulate among the live animals if space is available.
- Spread the loading of the animals evenly between the forward and aft of the airplane to reduce local moisture condensation inside the cargo compartment. In general, a weight and balance load sheet should be considered prior to loading animals (see fig. 4).
- Fewer animals should be placed in the furthest most forward and aft walls of the airplane due to the higher temperatures that are found there due to heat transfer through the forward and aft walls.
- Pallets or stalls must be designed to avoid breaking free during turbulence. Feet and hooves of heavy animals, such as horses and cattle, can puncture the airplane floor.

- Follow International Air Transport Association (IATA) Live Animals Regulations (LAR) Manual guidelines.

### ADDITIONAL GUIDANCE

If possible, provide additional cooling or ventilation to the airplane when it is on the ground. Portable air-conditioning units or fans can be used via the cargo door during refueling, loading, and unloading.

Operators may also consider adding additional fuel if still under the allowable takeoff weight to reduce the time required to refuel at stopovers en route to the cargo's final destination.

Animals should not be loaded until the airplane is ready to fly in all other respects.

### CONTAINER RECOMMENDATIONS

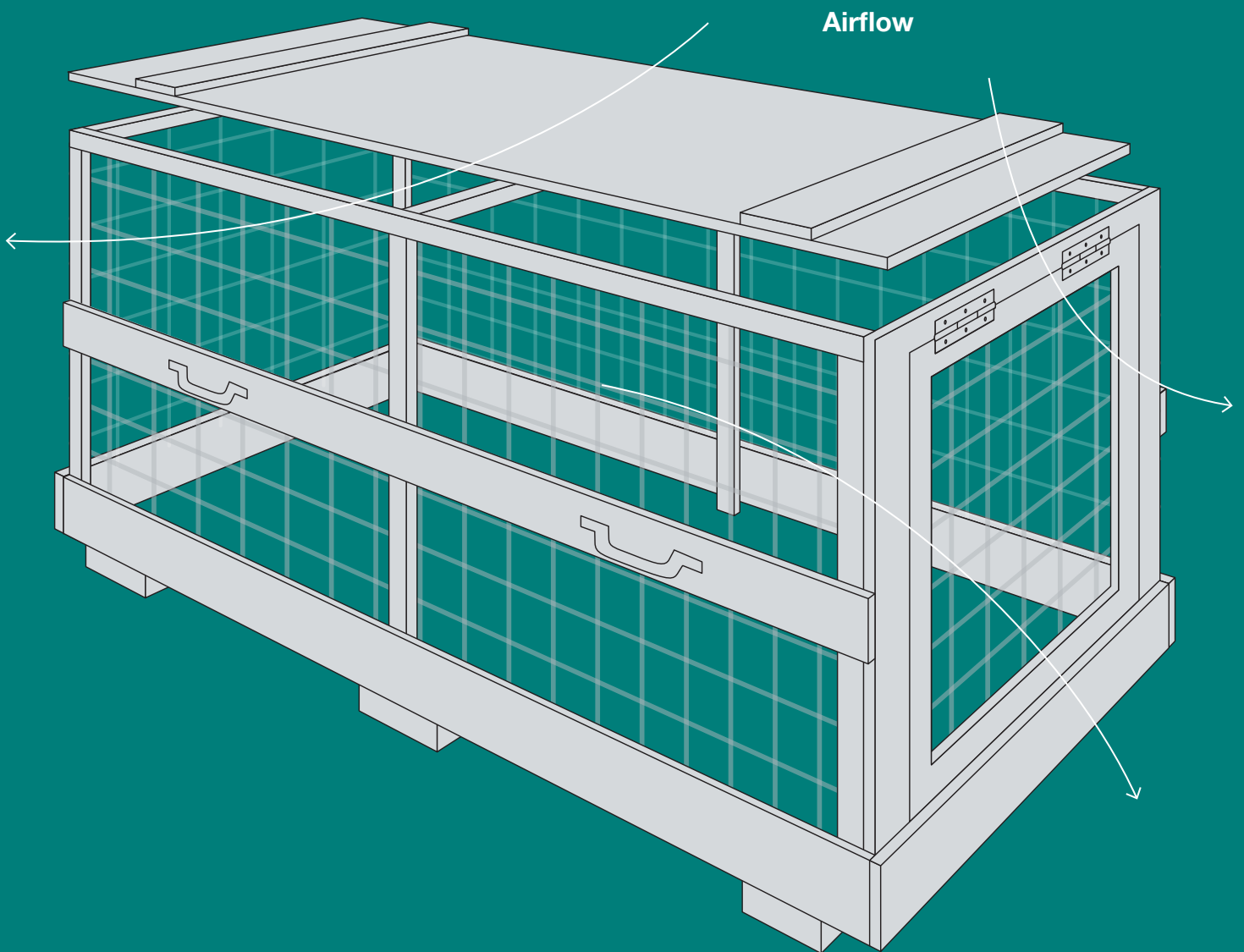
Follow IATA recommendations for containers for specific types of animal. In general, containers should be designed so that there are gaps or holes on the sides and on the top to allow air circulation throughout the containers (see fig. 5). Multi-tier containers should have gaps or holes between the top tier and the bottom tier to reduce CO<sub>2</sub> and local heat for animals in the lower container tier.

### MAXIMIZING VENTILATION AND REDUCING FUEL BURN

Flight crews should set the airplane's ECS for high flow to provide the most ventilation to the animals in the cargo compartment.

### Figure 5: Typical container/pallet ventilation paths

Adequate ventilation prevents unhealthy or stressful levels of CO<sub>2</sub> and humidity from building up in the cargo compartment. Have 10 in (25 cm) to 18 in (46 cm) spacing to the sidewall and space between crates to establish good compartment air circulation around the crates.



Boeing offers operators information about the transport of live animals, including detailed guidelines and methods to determine safe transport of live animal cargo in the cargo compartments of specific Boeing airplane models. The information can be accessed on the Web portal [MyBoeingFleet.com](http://MyBoeingFleet.com) or by contacting your Field Service representative.

If the lower compartment does not contain any animal or temperature-sensitive cargo, air conditioning to this area can be turned off to provide greater ventilation in the main deck compartment. This step will also help reduce fuel burn.

#### **MAIN DECK COMPARTMENT TEMPERATURE SELECTION**

Freighters typically have independent temperature controls for the forward and aft main deck cargo compartments. Boeing recommends that both the forward and aft compartments be set to the same temperature, using the

temperature range appropriate for the type of animals being transported.

#### **GETTING ADDITIONAL INFORMATION**

Boeing offers operators information about the transport of live animals, including detailed guidelines and methods to determine safe transport of live animal cargo in the cargo compartments of specific Boeing airplane models. The information can be accessed on the Web portal [MyBoeingFleet.com](http://MyBoeingFleet.com) or by contacting your Field Service representative.

In addition, IATA LAR provides a detailed classification of animal species, along with the container specifications required for

their transport. It also includes the most up-to-date airline and government requirements pertaining to the transport of live animals; information on handling, marking, and labeling; and the documentation that is necessary when transporting animals by air. The LAR is available from the IATA Web site at [www.iata.org](http://www.iata.org).

#### **SUMMARY**

Following the recommended guidelines can help operators ensure the welfare of live animal cargo. Operators can get detailed guidelines and recommendations from Boeing and IATA. 