

# WORLD-WIDE PRECISION AIRPORT MAPPING DATABASES FOR AVIATION APPLICATIONS

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## Abstract

Future cockpit and aviation applications require high quality airport databases. Accuracy, resolution, integrity, completeness, traceability, and timeliness [1] are key requirements. For most aviation applications, attributed vector databases are needed. The geometry is based on points, lines, and closed polygons. To document the needs for aviation industry RTCA and EUROCAE developed in a joint committee, the DO-272/ED-99 document. It states industry needs for data features, attributes, coding, and capture rules for Airport Mapping Databases (AMDB).

This paper describes the technical approach Jeppesen has taken to generate a world-wide set of three-hundred AMDB airports. All AMDB airports are DO-200A/ED-76 [1] and DO-272/ED-99 [2] compliant. Jeppesen airports have a 5m (CE90) accuracy and an  $10^{-3}$  integrity. World-wide all AMDB data is delivered in WGS84 coordinates. Jeppesen continually updates the databases.

## Introduction

First, remote sensing imagery is used to capture the airport image. The image is then geo-referenced to existing or surveyed ground control points.

Next, the geo-referenced image is digitized according to DO-272/ED-99 [2] requirements. All visible features such as runways, taxiways, APRON, shoulders, stand areas, taxi-lines, hold-lines, parking positions, and buildings are captured. In addition, an enhancement to the feature capture rules has been developed to better suit the needs of aviation customers.

Attributes are added from Jeppesen's navigation database and charts, and from image inspection. All available DO-272/ED-99 [2] attributes are included in the dataset. Typical attributes are runway or taxi-way names, stand names, surface material, or pavement classification number (pcn).

In a final step, all data is validated to ensure the integrity of the entire dataset.

All airports in the Jeppesen AMDB are monitored for changes. Only the changed areas are updated. All other data is revalidated. When a change effects the airport surface geometry, new remote sensing imagery is acquired.

## AMDB Content

Jeppesen AMDB contains all features and attributes defined in DO-272/ED-99 [2]. Additional features and attributes have also been captured to meet customer requirements.

## Features

Features represent defined geometry on an airport. Figure 1 shows the features defined in DO-272/ED-99 [2]. Features can be hard surfaces such as runways, taxiways, or aprons. Features can also be represented by operational functions such as taxi-lines, aircraft stands, or holding positions. Finally, features can represent virtually defined geometries such as communication frequency areas.

All AMDB features can be geometrically classified as:

- Points (single location)
- Lines (sequence of points)
- Polygons (closed sequence of points)

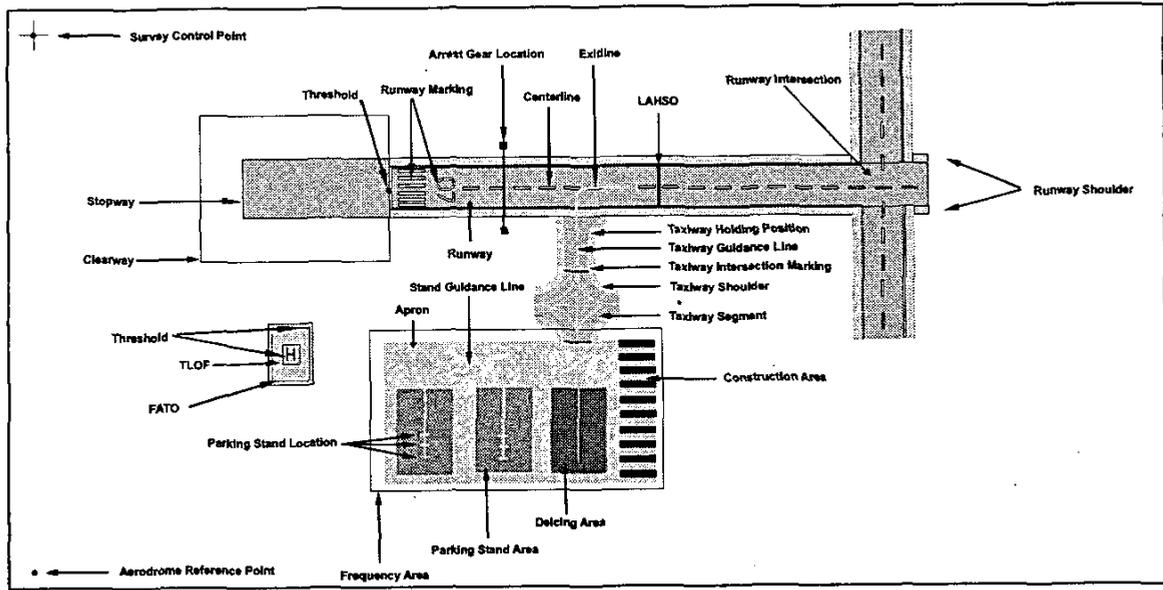


Figure 1. Jeppesen AMDB Coverage

Following DO-272/ED99 [2] requirements, all AMDB data is topologically clean: There are no overlaps or gaps between surfaces; all vertices between two polygonal edges are shared and all geometry is counterclockwise orientated. Jeppesen has developed a quality system that ensures that polygon resolution is adequate for avionics graphics and CPU performance. The consequence is that AMDB data can be directly integrated into avionics systems without additional manual work.

Table 1 list DO-272/ED-99 [2] based AMDB features. Features fall into the class of runways, taxiways, apron, vertical structures (obstacles), and/or restricted areas.

Table 1. DO-272/ED-99 Features [2]

Description	Geometry type
apron / ramp area	poly
airport ref. point	point
arrest gear locator	line
blastpad / stopway area	poly
clearway / outer blastpad area	poly
runway centerline	line
construction area	poly
deicing pads	poly
runway exit centerline	line
frequency area	poly
heli final approach/takeoff area	poly

Description	Geometry type
heli touchdown and lift off area	poly
heli threshold location	point
land and hold short bar	line
markings – runway paint	poly
road, service roads	poly
runway area	poly
runway intersection	poly
runway shoulder area	poly
parking stand area	poly
parking stand line	line
parking stand stop point	point
stopbar line	line
stopway area	poly
threshold point	point
taxiway intersection line	line
taxiway centerline	line
taxiway shoulder area	poly
taxiway area segment	poly
vertical line object	line
vertical point object	point
vertical poly object	poly

**Attributes**

An attribute is information that is attached to a specific feature. For instance, a runway has a worldwide unique name (e.g. EDDF 07R 25L) or material (e.g. concrete) attached as an attribute. All

Jeppesen AMDB airports contain attribute fields required by DO-272/ED-99 [2]. As an example, Table 2 lists attributes required by DO-272/ED-99 [2] for runway features.

**Table 2. DO-272/ED-99 Runway Attributes [2]**

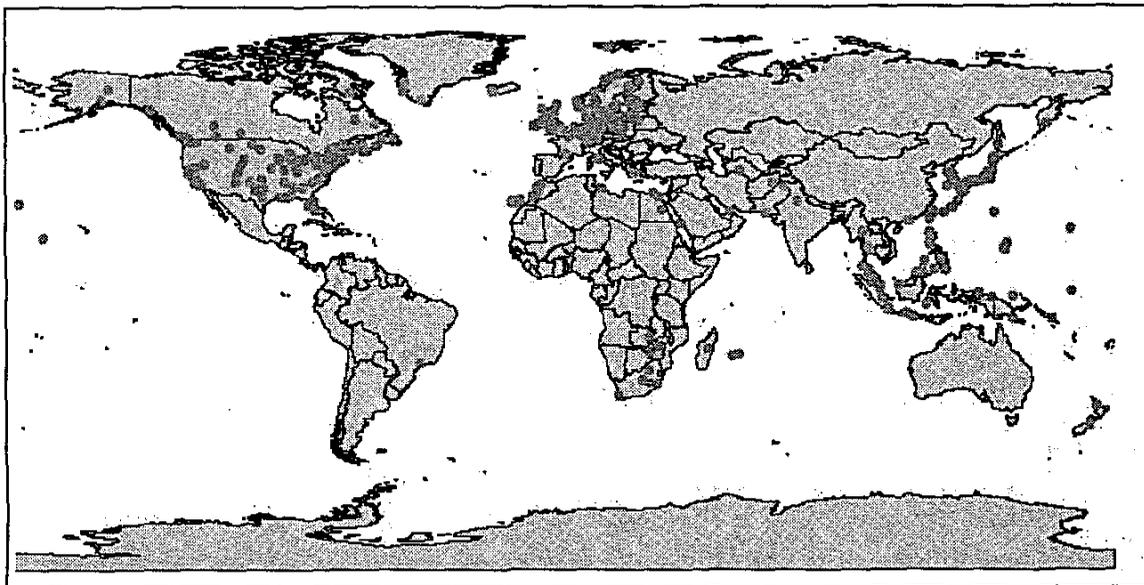
Attribute name	Description
Featype	runway feature type identifier
Arptid	icao aerodrome location indicator
Rwyid	runway designator of both runway directions
Hacc	horizontal accuracy
Hres	horizontal resolution
Source	name of entity or organization that supplied data
Integr	data integrity to support the end-to-end quality system from provider to end user
Revdate	date of last revision or generation of source data
Pcn	aircraft/pavement classification number (acn-pcn)
Width	average width of runway
Length	average length of runway
Material	predominant surface type of runway

Not all attribute information specified is published worldwide or available to Jeppesen. For instance, Taxiway PCN (pavement classification numbers) [3] or maximal aircraft wingspans are not published for most airports. In these cases, attributes are listed but the content is marked as unknown. Jeppesen uses all available sources such as national Aeronautical Information Publications (AIP), Notice to Airmen (NOTAM), or direct airport contact to airports to maximize attribute completeness.

### AMDB Coverage

Jeppesen AMDB includes 300 airports worldwide. Figure 2 shows the distribution of airports. Airports were selected based on potential customer interest. The basic assumption is that all markets and all Part121 airframes will be supported. As a starting point for the AMDB database development, airports in South-East Asia, the Middle East, Europe, Southern Africa, and North America are identified. Between these regions, typical airport alternates are included.

The airport locations depicted in Figure 2 are only a starting point for a much more comprehensive worldwide database. Jeppesen plans to continually expand the coverage list as customer requirements dictate.



**Figure 2. Jeppesen AMDB Coverage**

## AMDB Quality

The definition of data quality is contained in DO-200A/ED-76 [1], ICAO Annex 14 [3], and ICAO Annex 15 [4]. Data quality is described by seven parameters:

- *Accuracy* - degree of conformance between the estimated or measured value and the true value.
- *Integrity* - degree of assurance that an aeronautical data and its value has not been lost or altered since the data origination or authorized amendment.
- *Resolution* - number of units or digits to which a measured or calculated value is expressed and used.
- *Traceability* - Ability to trace the history, application or location of an entity by means of recorded identifications.
- *Timeliness* - the data is applicable to the period of intended use.
- *Completeness* - Describes the degree of conformance of a subset of data compared to its nominal ground with respect to the presence of objects.
- *Format* - the process of translating, arranging, packaging, and compressing a selected set of data for distribution.

The 300 Jeppesen AMDB airports fulfill the DO-272/ED-99 medium quality requirements. The provided medium quality makes the data usable for all situation awareness function on the airport surface.

### Accuracy

The overall Jeppesen AMDB accuracy is 5m (CE90). The accuracy has been validated in manual ground-truth surveys at several airports. The validation revealed that the optimally achievable accuracy is 1.4m (CE90). This is only achievable with optimal ground control point (GCP) coverage based on surveyed GCPs.

### Integrity

Jeppesen AMDB exceeds the DO-272/ED-99 [2] requirement. All AMDB airports have routine integrity ( $10^{-3}$ ). Routine integrity is achieved by developing a data generation processes in

compliance with the DO-200A/ED-76 [1] guidance. One of the key steps to achieve this accuracy is data validation at different levels of the data generation.

### Traceability

Traceability is achieved by complying with DO-272/ED-99 Appendix E [2] attribute requirements. Each feature has a "source" (see Table 2) attribute. This attribute lists the current data provider. In addition, Jeppesen keeps track of all original source data providers for each data element. This approach ensures that all data can be traced to the data originator.

### Timeliness (Update)

AMDB airports are updated upon notified change. Notifications can come from multiple sources. This includes Aeronautical Information Publications (AIP), NOTAMS, pilot feedback, airport feedback, and/or change detection.

### Resolution

The data resolution is compliant to DO-272/ED-99 [2] Appendix E definitions.

### Completeness

The Jeppesen AMDB supports all features and attributes as they are listed in DO-272/ED-99 [2]. Only features that are visible on the remote sensing imagery are captured.



Figure 3. Obstructed Features

Parked or taxiing aircraft sometimes obstruct the features. Figure 3 depicts a taxiing aircraft that prohibits the underlying taxi line from being captured. Some attributes, such as pcn or aircraft wingspan are rarely published. Attributes that are not available for capture are accordingly marked in the database.

Still, approximately 99% of features and 95% of attributes are available.

### Format

Currently, RTCA-SC 193/EUROCAE WG44 defines an AMDB exchange standard. Jeppesen intends to comply with this standard. AMDBs are currently exchanged using the DO-272/ED-99 Appendix E [2] specification. In addition, AMDBs can be provided in any customer-defined format.

### AMDB Generation Process

The Jeppesen generation process for AMDB has evolved from research conducted in different R&D efforts over the last several years.

Publications [6], [7], and [8] describe the photogrammetrical AMDB generation process in detail. The activities of the RTCA SC-193 / EUROCAE WG-44 committee indicated aviation industry interest and showed the commercial need for AMDB medium quality for use in aviation applications [5].

Figure 4 through Figure 10 depicts the Jeppesen AMDB for the Seattle Tacoma Intl. (KSEA) airport. In Figure 4, identical feature types are depicted in the same color. Figure 5 shows the scaled detail from the south apron in the area of runway threshold 34L.

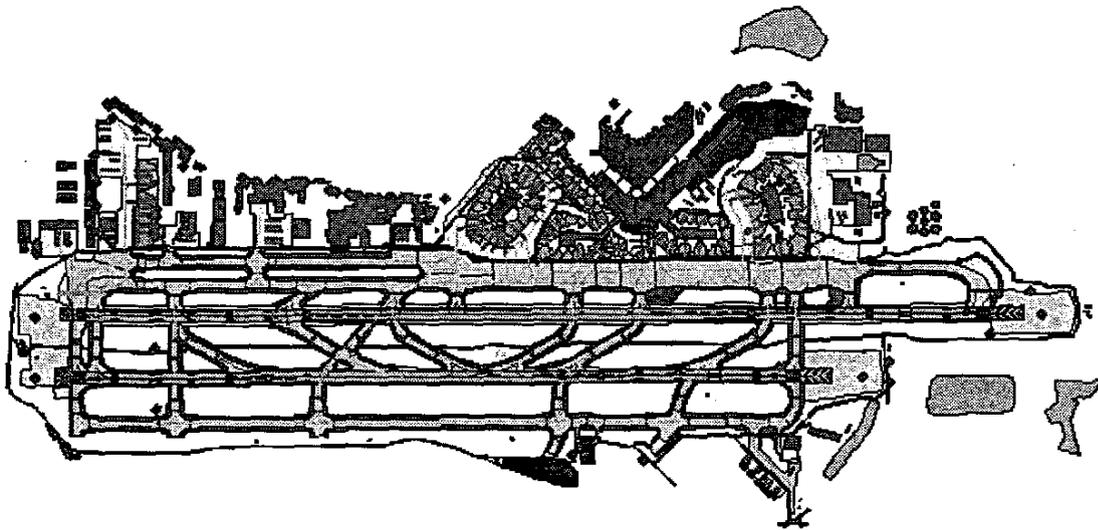


Figure 4. Jeppesen AMDB Overview

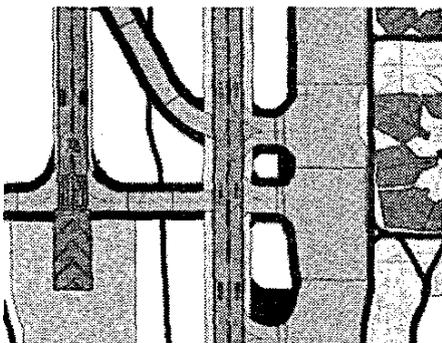


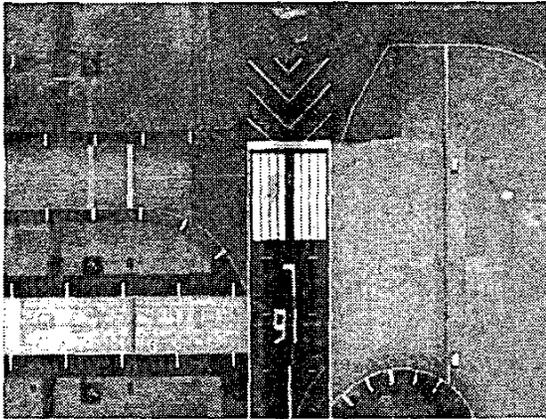
Figure 5. Jeppesen AMDB Detail

Runway, runway markings, blast-pad, clearway, hold short bars, taxiways, airport roads,

parking areas (S11-S15), and parking lines (S11-S14) are visible. On parking stand S15 (on the center-right edge of the image), an aircraft was parked during image acquisition. Runway, taxiway, and gate names are not visualized. Names (identifiers) are stored as attributes attached to each feature. It is left to the AMDB user (aviation function) how to best locate and render labels. The resolution of feature geometry (lines and polygons) allows adaptation to the graphics performance of state-of-the-art cockpit display systems (CDS).

### ***Remote Sensing***

The Jeppesen data generation process is based on remote sensing. Figure 6 shows a typical remote sensing image. All DO-272/ED-99 [2] features are visible on the image. For faithful feature extraction, panchromatic as well as multi-spectral imagery is required. Particular, color determines the operational meaning of lines. Image processing problems can arise from cloud coverage; image contrast or resolution due to sun angle, instrument elevation, or off-nadir angle; or surface material.

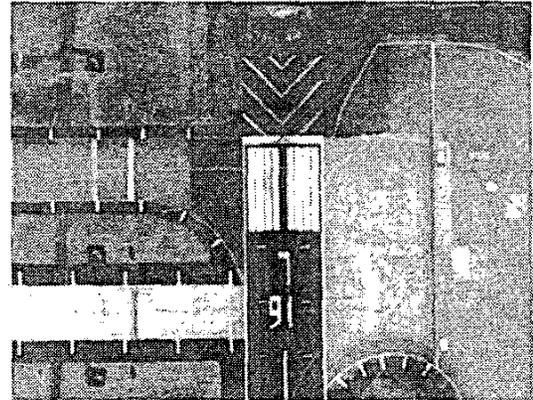


**Figure 6. Remote Sensing Image**

### ***Geo-Referencing***

The image is geo-referenced using Jeppesen ground control points (GCP). For certain airports, acquisition of additional third-party GCPs is required to improve positional accuracy of the entire scene. Figure 7 shows a geo-referencing example based on runway thresholds. Jeppesen has established image geo-referencing by GCPs that are visible on any stable airport surface.

Currently, the Federal Aviation Administration (FAA) is evaluating the possibility of creating high accuracy GCPs markings (25m<sup>2</sup>) painted on airport surfaces. These markings would be visible from remotely sensed imagery. Universal application of these survey points would increase the accuracy of AMDBs significantly.

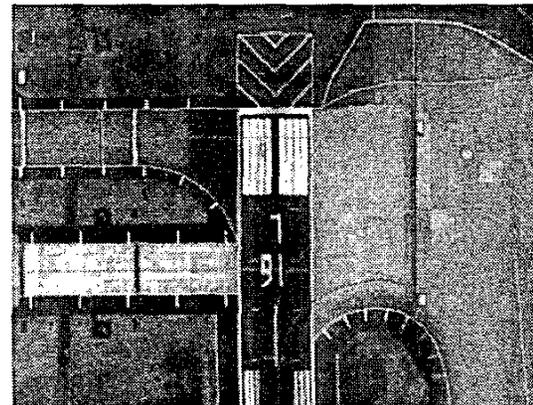


**Figure 7. Geo-Referencing**

### ***Vector Feature Extraction***

The geo-referenced image is digitized based on DO-272/ED-99 [2] features, attributes, and capture rules. Jeppesen has developed an independent capture rule catalogue. Capture rules ensure that all AMDB airports are captured in a standardized way. Rules are based on aviation safety, visibility, today's computer graphics performance, and intended function on the database. Jeppesen has extended the DO-272/ED-99 [2] feature catalogue to support customer needs.

Figure 8 shows the northern end of runway 16L/34L at Seattle Tacoma (KSEA). It includes the runway polygon, taxilines, and stop-bars.



**Figure 8 Vector-Feature Extraction**

Figure 9 depicts concourse C north of the tower. The image shows building perimeters and gates. Aircrafts are parked at gates C16 and C18 (upper center edge of Figure 9). Stand-lines are not captured for these gates.

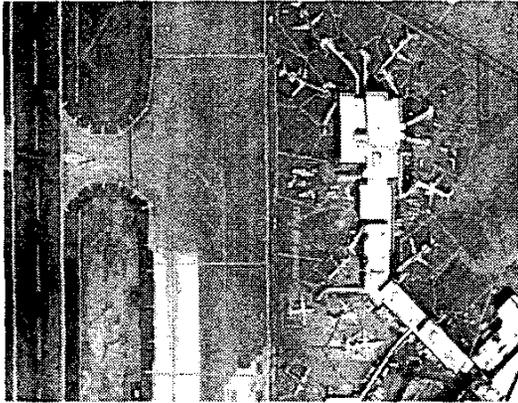


Figure 9. Vector-Feature Extraction II

**Attribution**

In a final step, DO-272/ED-99 [2] compliant attributes are attached to features. Attribute content is gathered from all available sources. In Figure 10, the attribute table for runway holding positions is depicted:

- featype (feature type),
- arptid (airport identification code),
- objectid (object identification),
- hacc (horizontal accuracy),
- hres (horizontal resolution),
- etc.

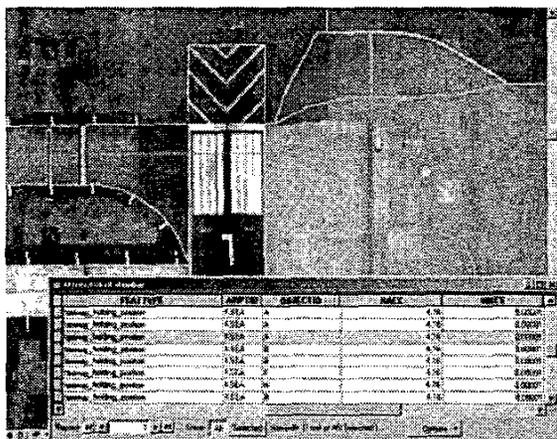


Figure 10. Attribution

Each feature has a complete quality data set attached. Therefore, data of different qualities can be integrated into a single AMDB. This might range from high quality geo-referenced features to low-quality temporary updates.

**Validation**

In a last step, independent personnel validate the entire data set. The basis for the validation is the Jeppesen capture and feature catalogue. Validation reduces the numbers of wrongly captured feature types, geometry errors, wrongly captured attributes, and typos. Therefore, validation increases confidence and integrity of the entire Jeppesen AMDB dataset.

Finally, the data is protected using a cyclic redundancy check (CRC) algorithm to ensure that it is not altered or corrupted after validation.

**Distribution**

AMDB data may be distributed directly to the customer using Jeppesen’s advanced Data Distribution Management (DDM) process. The DDM process is driven by customer needs. It extends from the use of semi-manual portable data-loaders to fully automatic gate delivery.

Figure 11 shows the Jeppesen taxi positional awareness (TPA) application for an Electronic Flight Bag (EFB). TPA automatically integrates AMDBs. There is no database customization needed.



**Figure 11 AMDB Data in a Jeppesen EFB Taxi Position Awareness Function (TPA)**

## Conclusion

This paper describes the generation of 300 DO-272/ED-99 compliant airport mapping databases. It describes in detail the approach that was taken to capture features from remote sensing and attributes from Jeppesen sources. The photogrammetrical approach is described in detail.

## Future Work

The number of Jeppesen AMDBs will grow with additional customer needs well beyond the original 300 airports. With the integration of TPA applications in more airline cockpits, the number will further increase. In addition, airport Geographic Information Systems (GIS) may also drive the requirements for additional airports or businesses.

Finally, AMDBs will be integrated into future 3D Synthetic Vision Systems [9]. AMDBs will be enhanced to support 3D vertical objects (e.g. buildings). To achieve this goal, stereo imagery will be utilized in the future.

## Acknowledgements

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Finally, we would like to thank the Boeing Surface Guidance System team. They demonstrated the viability of AMDB on the Boeing 737-900 technology demonstrator airplane.

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