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Research on the Design Method of GLS Procedure Based on Ground Based Augmentation Systems

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Abstract. The development of civil aviation technology cannot be separated from the innovation of navigation systems, and satellite based navigation technology has gradually replaced ground navigation as the mainstream of flight procedures. The Satellite Landing System (GLS) based on Ground Augmentation System (GBAS) has gradually been able to achieve precision approach and landing by receiving the final approach segment data block transmitted by ground VHF data broadcasting. Currently, multiple countries have completed the verification of the GLS procedure. Compared to traditional blind landing procedures, GLS procedures have significant advantages in terms of operational maintenance costs and flexibility. This article will propose a design method for the GLS procedure based on the design specifications of the GLS procedure in Annex 10 of the International Civil Aviation Organization Convention on Aviation Telecommunications and the Visual and Instrument Flight Procedure Design Specification for Aircraft Operations. Through practical cases, navigation data such as approach charts, database coding tables, and FAS data blocks will be compiled. Finally, based on the subsequent verification direction and operational impact, the future development direction of GLS procedure design is proposed.

Keywords: Flight procedure design, Satellite landing system, Ground-Based Augmentation System, Design method，Navigation information..

1. Introduction

1.1. Basic Concepts

Ground Based Augmentation System (GBAS) is a satellite navigation enhancement system that receives navigation enhancement information from ground transmitters. The Satellite Landing System (GLS) is based on the flight guidance and landing functions provided by the GBAS system, including onboard GLS equipment interconnected with autopilot and other related systems, as well as precision approach and landing functions based on the enhanced satellite positioning information of GBAS [1], [6], [7].

In the GLS approach, the onboard system defines a virtual heading/glide path by receiving the Final Approach Segment (FAS) data block transmitted by the Ground Very High Frequency Data Broadcast (VDB). Combined with the high-precision 3D positioning output of the GBAS receiver/Multimode Receiver (MMR), it calculates the deviation of the aircraft from the defined trajectory, forms horizontal and vertical deviations, and the distance to the runway entrance, and displays them on relevant instruments, [2].

1.2. The Current Application Situation of GLS Procedure

The FAA in the United States conducted GBAS CAT Class I facility and operational certification work at airports such as Memphis and Seattle in 2010, and Zheng organized the development and operational testing of CATII/III navigation equipment; European countries such as France, Italy, and Spain have conducted GLS related experiments; The Australian ASA launched the GLS procedure design for RNP connection at Sydney and Melbourne airports at the end of 2016. Currently, Qantas has completed over 1500 GLS approach flights [8], [9].

In April 2015, Shanghai Pudong Airport conducted its first GLS validation flight. In April 2017, the flight procedure management unit organized a simulator validation of the GLS independent parallel approach procedure at Shenzhen Bao'an Airport, indicating that the implementation of GBAS navigation new

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technology at Shenzhen Airport is feasible and conducive to improving the operational efficiency of the airport[3],[4][10].

2. Compared to traditional navigation

2.1. ILS and GLS Navigation Methods

The Instrument Landing System (ILS) has undergone half a century of development and is currently the most widely used precision approach procedure in various countries. The ILS uses ground-based equipment such as the localizer (LOC), glide slope (GP), and DME rangefinder. When the aircraft reaches the final approach point FAP and enters the ILS glide slope, it is guided horizontally by the LOC and vertically by the GP, enabling the crew to implement precision approach procedures [5].

GLS is a precision approach and landing system based on GBAS. Receive FAS data blocks from ground-based equipment through onboard equipment and calculate a virtual glide slope to implement precision approach. The Flight Management System (FMS) will combine with the GBAS system to calculate the deviation of the aircraft from the planned trajectory, determine the horizontal and vertical error information, and display it on the onboard equipment.

2.2. Differences between ILS and GLS

A complete set of ILS ground equipment can only serve one runway, while a set of GBAS facilities can provide corresponding approach procedures for all runways of an airport. At the same time, GBAS's ground facilities are simpler in terms of site protection and maintenance verification, with longer verification cycles and lower maintenance costs. Therefore, GLS has lower maintenance costs compared to ILS, which is more prominent in multi runway airports.

The ILS procedure mainly considers single path landing procedures, and GLS combined with RNAV/RNP operation can achieve better navigation performance, and even approach through the implementation of curves, thereby improving the airport's airspace utilization and shortening the aircraft's operating range.

After the ILS system is set up, the sliding angle should not be easily changed in subsequent procedure design; after the runway is extended, the ILS system will also be relocated accordingly. The GLS procedure can modify the approach procedure in a certain direction by adjusting parameters such as runway threshold changes and glide slope angles in the FAS data block, with strong design flexibility.

3. GLS Procedure Design Specification Requirements

3.1. Design Requirements for Each Segment

The design rules for the initial approach segment of GLS are consistent with the PBN procedure, and the width of the protected area is defined by the navigation accuracy of RNAV or RNP. The intermediate approach segment of GLS should be aligned with the final approach path segment, unless an RF is used to enter the final approach segment and allow the aircraft to enter the final approach path and glide slope. The total width at the beginning of the intermediate approach segment is determined by the total width of the initial approach segment, and then uniformly reduced to the same horizontal spacing as the OAS X plane at FAP.

The GLS precision segment is aligned with the final approach path, and the precision segment begins at the Final Approach Point (FAP), which is the intersection point between the lowest altitude of the previous segment and the nominal glide slope. If necessary, a positioning point is set at the FAP to allow comparison between the displayed glide slope and the aircraft altitude table information. The GLS operational evaluation criteria can calculate the obstacle clearance altitude/height (OCA/H) for each aircraft type, which needs to meet the overall safety goal of a risk of collision between the aircraft and obstacles of 1×10^{-7}. There are three calculation methods for OCA/H:

- Basic ILS surface evaluation.
- Obstacle evaluation surface (OAS) evaluation.
- Evaluation based on Collision Risk Model.

3.2. Using OAS Surface Evaluation Method to Calculate OCA/H

Taking into account the overall safety margin and practical operability of obstacle assessment, OAS surface assessment is currently the main evaluation method, and the size of OAS is related to GARP-LTP distance, sliding angle, and operating type. For GBAS Class I operations at specific airports, a table of OCA/H values used for each aircraft type should be published. GARP is a fixed offset point of 305m before FPAP on the procedure centerline. When equipped with ILS/DME system, if the distance between the heading station and the end of the runway is greater than 305m, GARP is the position of the heading station.

The OAS surface consists of six slopes that are symmetrical about the precise flight path, namely W, X, Y, Z, and horizontal planes. These slopes are precisely defined by four simple linear equations (1), where x and y are positional coordinates, and z is the height of the evaluation surface at that position.

$$z=Ax+By+C \tag{1}$$

3.3. FAS Data Block

According to Annex 10 "Aviation Telecommunications", the structure of the GBAS FAS data block encoding includes a cyclic redundancy code check residue field (CRC) with a total of 20 fields. The first 19 data fields are protected by CRC. Channel number equations in equations (2).

$$\text{Channel number equations} = 20000+40 \times (F-108.0)+411 \times (S) \tag{2}$$

4. GLS Procedure Design Case

4.1. Overall Framework of GLS Procedure Design

The GLS procedure is a precision approach procedure based on the RNP procedure. As an extension of the PBN procedure, the GLS procedure design framework is similar to the PBN procedure, but there are certain differences in evaluation methods, design ideas, and design products in Fig.1.This section will propose the following design framework based on the GLS procedure design criteria in DOC8168:

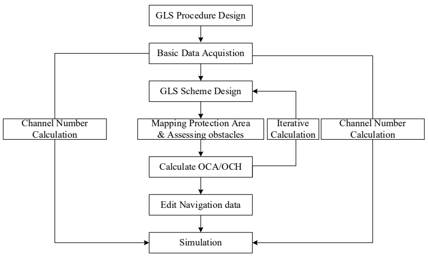

Fig. 1: Overall framework of GLS procedure design.

4.2. GLS Flight Procedure Design and Evaluation

Basic Data Acquisition: The basic data for GLS flight procedure design mainly includes runway related data, navigation facility related data, obstacle basic data, and local airspace information. The first step in GLS procedure design should be to complete the improvement of basic data (such as runway, navigation station, waypoint coordinates, etc. based on basic data.) in Fig.2.

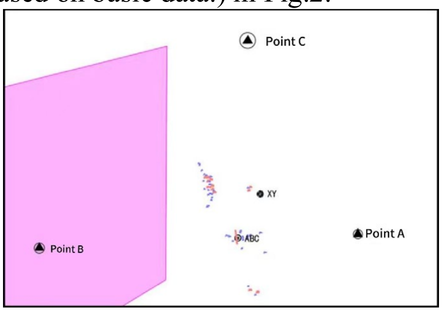

Fig. 2: Basic data acquisition.

Flight Procedure Design: The GLS procedure mainly includes the approach procedure after the initial approach procedure: the initial approach segment, the intermediate approach segment, the final approach segment, and the go around segment. The flight procedure plan can be designed based on the PBN approach plan, and corresponding protection areas can be drawn according to the procedure plan in Fig.3.

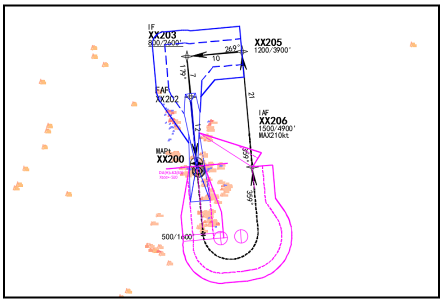

Fig. 3: GLS procedure protection area

- Based on the flight procedure protection zone and obstacle data, conduct obstacle clearance assessment.
- Initial approach segment procedure altitude>OCA=Hobs+300m;
- Intermediate approach segment procedure altitude>OCA=Hobs+300m;
- **Precision Approach Segment Obstacle Assessment:** According to OAS surface evaluation, when the go around gradient is 2.5%, obstacle A3 is a control obstacle with an equivalent height of 19.19m, OCHA/B=19.19+43=62.19m, DH=65m, OCHA/B=19.19+49=68.19m, and DH=70m; When the go around gradient is 4.0%, obstacle A3 is the control obstacle with an equivalent height of 1.32m, OCH=1.32+49=50.32m, and DH is taken as 60m
- **Assessment of Missed Approach Segment:** Based on the drawn protected area of the missed approach segment, when the gradient of the missed approach is 2.5%, it is considered that there are relatively high natural obstacles in the protected area, with DHA/B=135m, DHC/D=140m, and procedure altitude>OCA=Hobs+50m; When the go around gradient is 4.0%, it is not possible to meet the obstacle clearance requirements. It is necessary to further raise the go around gradient to 5.0%, with a procedure altitude greater than OCA=Hobs+50m and DH=60m.

4.3. FAS Data Block Editing

FAS Data Block Compilation: According to the compilation rules in Section 3.4, the FAS data block compilation for a certain airport RWY18 has been completed in Table.1.

Table 1: FAS Data Block

Parameter	Content	Notes
Operation category	0	Linear approach procedure
Service Provider ID	14	Representing GBAS
Airport ID	ABCD	Airport four character code
Runway number	18	Runway number
Runway letter recognition	0	1 represents R, 3 represents L
Approach indication performance	1	Representing Class I approach
Reference path data selector	1	The channel number is available and unique
Reference path identification	G18A	G represents the system as GBAS, with runway number 18
Entrance point/hypothetical entrance point height	+1.8	Entrance altitude
TCH	15.00	Crossing entrance high
TCH unit selection	1	TCH units, 1 in meters and 0 in feet
GPA	3.00	Gliding angle
Entrance channel width	105	Half of the track width of 210 meters
Length offset	0	

Channel Number Calculation: According to the preparation rules in Section 3.5, the channel number calculation for RWY18 at the certain airport has been completed in Table.2.

Table 2: Channel number calculation

Approach procedure code	Reference path data selector (RPDS)	Data broadcast frequency	Channel number
RWY18	1	115.85	20725

4.4. Publish information and data

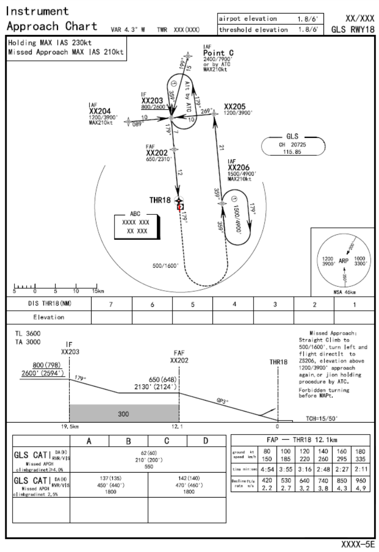

Fig. 4: Approach Chart.

Table 3: Database coding table

Navigation path describe	Positioning point identification	whether flybys	Magnetic heading (°)	Turning indicate	Height (m)	Speed limit (kt)	VPA/TCH	Navigation performance
RWY18 GLS approach								
IF	XX203				800			RNP1
TF	XX202				650			GLS APCH
TF	XX200	Y					-3°/15m	GLS APCH
CA			179		500			RNP1
DF	XX206			L	1200 or by ATC	MAX 210		RNP1

According the GLS Flight procedure design and evaluation, Fig.4 show the approach chart, Table.2.show the database coding table.

5. Summarize

5.1. Verification Content

The GLS procedure should combine the above design results and actively promote subsequent verification work. The verification work of simulation and real flight tests ensures the rationality of the GBAS system and GLS procedure design. During the simulation validation period, the validation team needs to verify the rationality of the procedure, the elements of the navigation chart, and other content; During the actual flight test verification period, it is necessary to comprehensively verify the stability of ground and onboard signals, as well as the safety of operating standards, to ensure the possibility of implementing the GLS procedure on the aircraft after it is published.

5.2. Operational Impact

At present, the main navigation methods used at domestic and foreign airports are PBN to ILS approach procedures, and the application of GLS procedures will have a certain impact on equipment maintenance and control operation methods. Considering that the International Civil Aviation Organization has not yet issued corresponding regulations for the implementation of GLS procedures on multiple runways, it still requires a lot of time and samples to verify whether GLS procedures can meet the requirements of multi runway isolation and independent operation. Under the simultaneous implementation of new systems and regulations, higher technical requirements have been put forward for regulatory operations, accompanied by certain uncertainties.

5.3. Future Development Direction

Compared to land-based navigation, satellite based navigation has a certain degree of improvement in flexibility and accuracy. With the continuous improvement of navigation signal accuracy and stability both domestically and internationally, satellite based navigation has gradually replaced ground based navigation in overall air transportation. For example, PBN procedures have become the main means of control operation in various airports. Considering that the GLS procedure is still in trial operation in some parts of China, except for some regions, and the implementation of the GLS procedure in multi runway airports has greater profitability. In the future, more support from the International Civil Aviation Organization is needed for the implementation of GLS procedures on multiple runways. Based on the safety margin maintained by existing navigation systems, a large number of sample experiments will be conducted to gradually transition from traditional ILS operations to GLS operations, ensuring flexible procedure control while reducing operational costs.

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