中国民用航空局
空中交通管理局
Air Traffic Management Bureau. CAAC

Research on Key Technologies and Applications for Preventing Runway Incursions

Presented by China

Team Introduction

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- Senior Engineer
- Project Manager & 16 Years Maintenance Experience
- PM of A-SMGCS and EFS systems
- Leader of IT R&D department of EastChina ATMB
- Presenter

Xuedi Zhao

- Engineer
- 9 Yaers Maintenance Experience
- Participation Systems Design and Construction For ATC
- Daily maintenance & Updates

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- Senior Engineer
- 14 Yaers Maintenance Experience
- Participate in ATMAS Development & Maintenance
- Daily maintenance & Updates

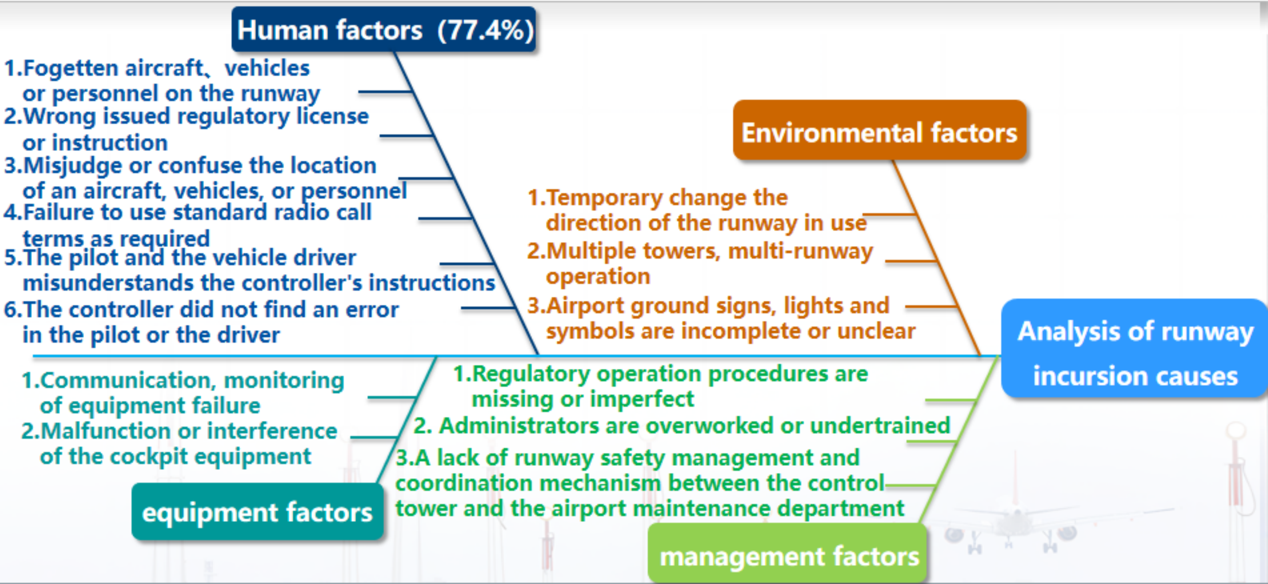
Part1: Research Background

Part2: Overall Objective

Part3: Key Technologies and Applications

Part4: Future Prospects

1 Research Background



Human factors（77.4%)

1.Fogetten aircraft、vehicles or personnel on the runway
2.Wrong issued regulatory license or instruction
3.Misjudge or confuse the location of an aircraft, vehicles, or personnel
4.Failure to use standard radio call terms as required
5.The pilot and the vehicle driver misunderstands the controller's instructions
6.The controller did not find an error in the pilot or the driver

Environmental factors

1.Temporary change the direction of the runway in use
2.Multiple towers, multi-runway operation
3.Airport ground signs, lights and symbols are incomplete or unclear

Analysis of runway incursion causes

1.Communication, monitoring of equipment failure
2.Malfunction or interference of the cockpit equipment

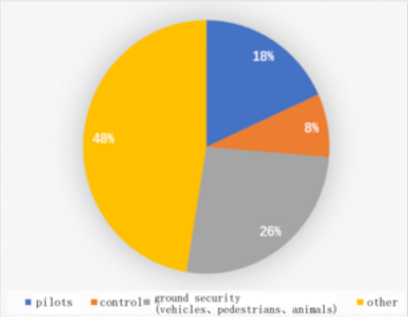
equipment factors

1.Regulatory operation procedures are missing or imperfect
2. Administrators are overworked or undertrained
3.A lack of runway safety management and coordination mechanism between the control tower and the airport maintenance department

management factors

1 Research Background

Runway incursion causes statistics



FROM CIVIL AVIATION SAFETY NET OF CHINA

Key points

1.How to reduce the safety loopholes caused by human factors (air traffic control, pilots, vehicle drivers, etc.)?

2.How to timely locate the incursion position and alarm?

3. How to choose the right technology to maximize returns with minimal investment?

4.How to increase the safety barrier without reducing the operation efficiency?...

The content of this SP is mainly about human factors of the pilots, controllers and vehicle drivers.

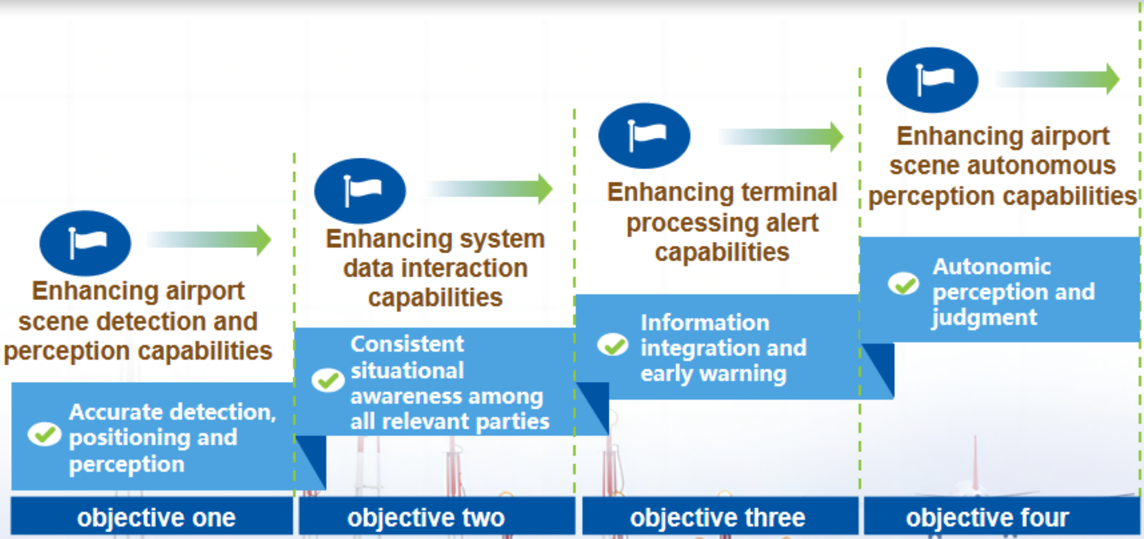
Part1: Research Background

Part2: Overall Objective

Part3: Key Technologies and Applications

Part4: Future Prospects

2 Overall Objective



objective one

Enhancing airport scene detection and perception capabilities

✓ Accurate detection, positioning and perception

objective two

Enhancing system data interaction capabilities

✓ Consistent situational awareness among all relevant parties

objective three

Enhancing terminal processing alert capabilities

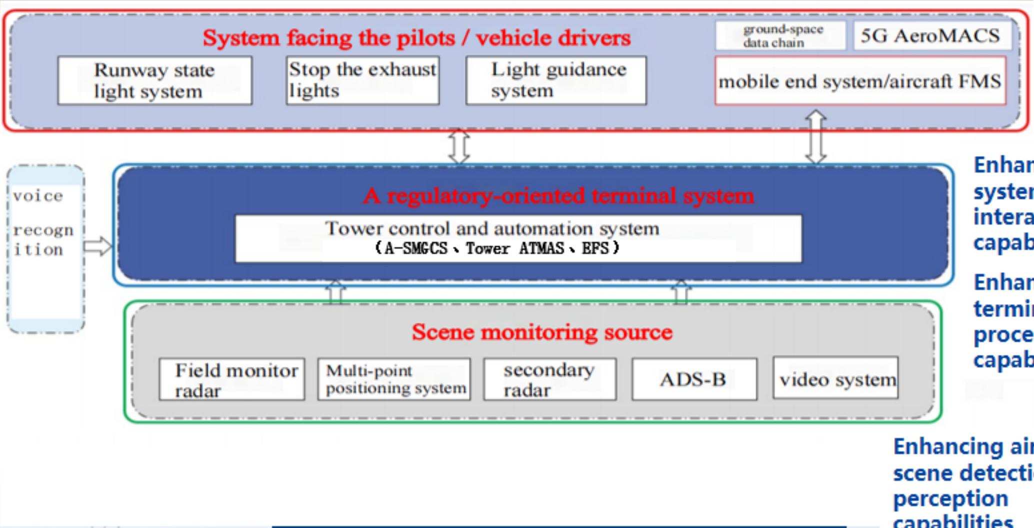
✓ Information integration and early warning

objective four

Enhancing airport scene autonomous perception capabilities

✓ Autonomic perception and judgment

2 Overall Objective



System facing the pilots / vehicle drivers

- Runway state light system
- Stop the exhaust lights
- Light guidance system
- ground-space data chain
- 5G AeroMACS
- mobile end system/aircraft FMS

A regulatory-oriented terminal system

Tower control and automation system
（A-SMGCS、Tower ATMAS、EFS）

voice recognition

Scene monitoring source

- Field monitor radar
- Multi-point positioning system
- secondary radar
- ADS-B
- video system

Enhancing airport scene autonomous perception capabilities

Enhancing system data interaction capabilities

Enhancing terminal processing alert capabilities

Enhancing airport scene detection and perception capabilities

Technology implementation ideas

Part1: Research background

Part2: Overall objective

Part3: Key Technologies and Applications

Part4: Future Prospects

3 Key Technologies and Applications

China's civil aviation is conducting research on the tower automation system's runway incursion prevention feature.

- **Enhancing airport scene detection and perception capabilities**
  - Traditional Technology: Surveillance Signals
  - Innovative Technology: Video Signals
  - Verification of vehicle BeiDou positioning signals
  - Installation of Vehicle Beacon Devices
- **Enhancing system data interaction capabilities**
  - Interaction between Electronic Flight Strips & surveillance signals
  - Verification of scene data interaction based on aviation 5G
  - CPDLC for runway incursion prevention
- **Enhancing terminal processing alert capabilities**
  - The upgrade and optimization of Electronic Flight Strips
  - Verification and application of speech recognition technology
- **Enhancing airport scene autonomous perception capabilities**
  - Runway Status lights
  - Stop-Bar lights
  - Vehicle safety management
  - End-Around Taxiways

Part3: Key Technologies and Application

—Enhancing airport scene detection and perception capabilities

① Traditional Technology: Surface surveillance signals

All airports are actively advancing related work, some airports already have surface surveillance capabilities.

Surveillance signals: SMR、MLAT、QUALIFIED ADS-B

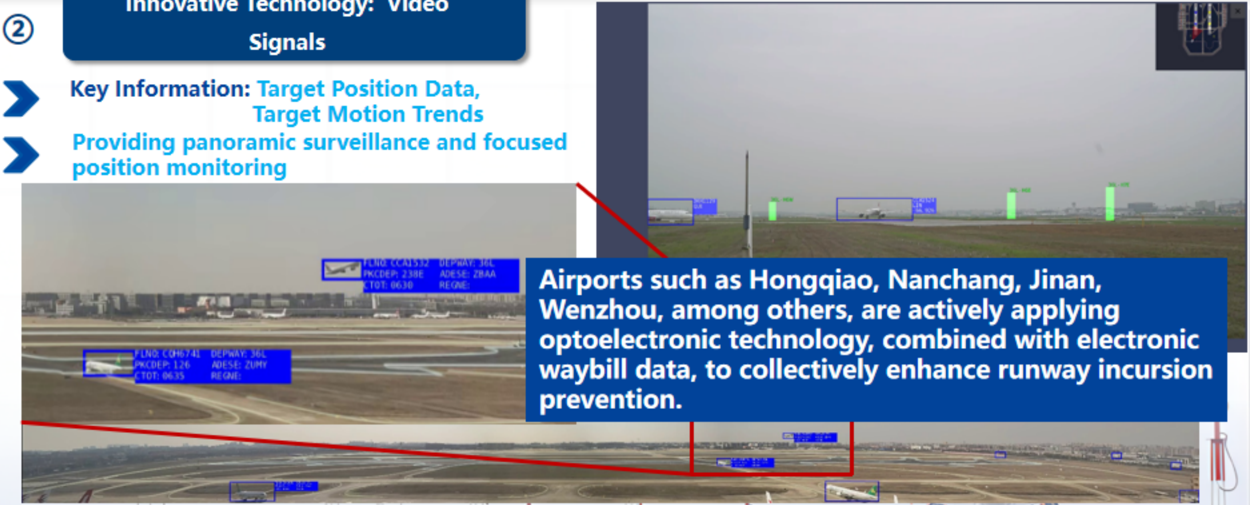
Surveillance information: Target Identification, position, speed, altitude, etc.

- **Surveillance coverage:** entire apron, airport perimeter
- **Planning information:** Flight number, Mode-S code, 24-bit address code
- **Key Technologies:**
  Related to achieving the goal, identifying target identity information, and integrating with airport maps, to realize a series of alarms related to target position, speed, and altitude.

3 Key Technologies and Applications
—— Enhancing airport scene detection and perception capabilities

② Innovative Technology: Video Signals

- **Key Information:** Target Position Data, Target Motion Trends
- Providing panoramic surveillance and focused position monitoring


FLNO: CCA1532 DEPWAY: 36L
PKCDEP: 238E ADESE: ZBAA
CTOT: 0630 REGNE:
FLNO: CQH6741 DEPWAY: 36L
PKCDEP: 126 ADESE: ZUMY
CTOT: 0635 REGNE:

Airports such as Hongqiao, Nanchang, Jinan, Wenzhou, among others, are actively applying optoelectronic technology, combined with electronic waybill data, to collectively enhance runway incursion prevention.

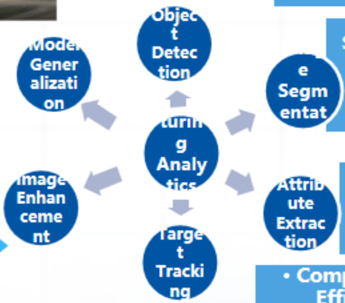
3 Key Technologies and Applications
—— Enhancing airport scene detection and perception capabilities

4K Remote Surveillance Cameras

4K High-Definition PTZ (Pan-Tilt-Zoom) Camera

4K Panoramic Camera

- Lateral expansion capability
- Image quality


Model Generalization
Object Detection
e Segmentat
turing Analytics
Image Enhancement
Target Tracking
Attribute Extraction

- Occlusion, Illumination
- Recall Rate

- Segmentation Algorithm
- Large Training Dataset

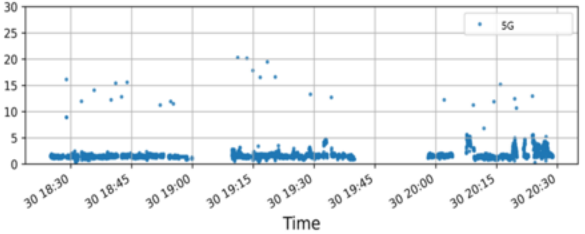
- Attribute Granularity
- Recognition Accuracy

- Computational Efficiency
- Cross-Device Tracking

③ Innovative Technology
——Verification of Vehicle BeiDou Positioning Signals

Through on-site vehicle test runs, the following have been accomplished:

- Verification of signal coverage;
- Verification of signal quality;
- Verification of signal accuracy and real-time performance;



3 Key Technologies and Applications
—— Enhancing airport scene detection and perception capabilities

④

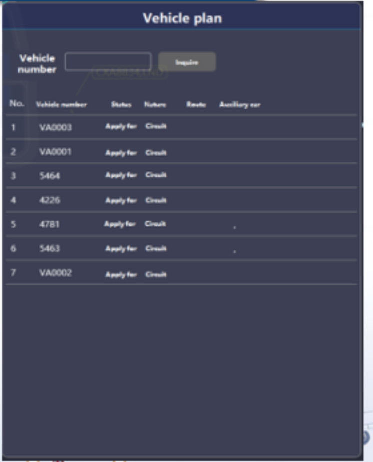
Innovative Technology
——Installation of Vehicle Beacon Devices

Key technology:

- Realizing MLAT vehicle positioning detection
- Improving Vehicle Positioning Accuracy
- Enhancing the accuracy of scene surveillance signal fusion

Hongqiao Airport is currently in the trial operation phase, and the following work will be carried out in the near future:

- Optimization of Vehicle Alarm Parameters
- Collaboratively develop management regulations for onboard beacon devices with the airport.



Vehicle plan

No.	Vehicle number	Status	Nature	Route	Auxiliary car
1	VA0003	Apply for	Circuit		
2	VA0001	Apply for	Circuit		
3	5464	Apply for	Circuit		
4	4226	Apply for	Circuit		
5	4781	Apply for	Circuit		
6	5463	Apply for	Circuit		
7	VA0002	Apply for	Circuit		

Part3: Key Technologies and Applications

——Enhancing system data interaction capabilities

3 Key Technologies and Applications
——Enhancing system data interaction capabilities

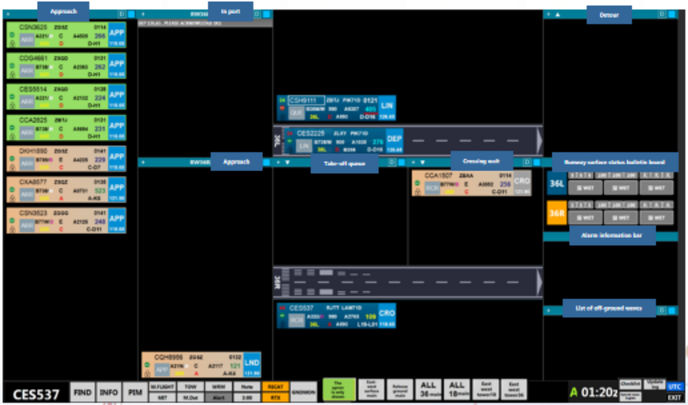
⑤ Interaction between Electronic Flight Strips & surveillance signals

Key information:

Flight identity information, flight command status, runway operation mode

Key technology:

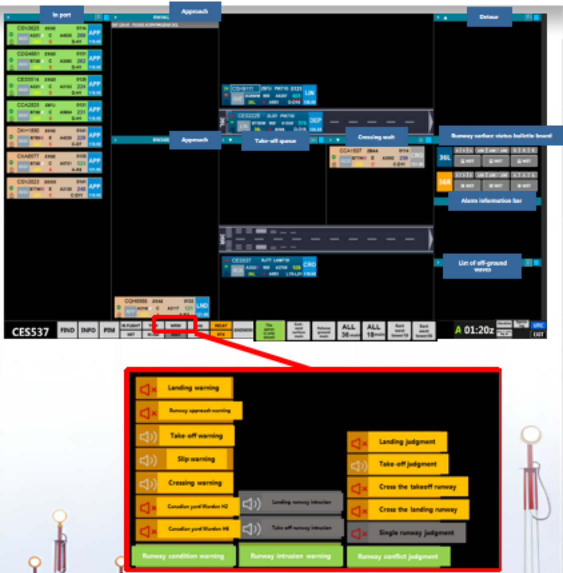
Combining surveillance signals, optoelectronic signals, and voice signals to jointly provide a series of alerts related to air traffic control commands.


Approach
In port
Detour
Approach
Take-off queue
Crossing wait
Runway surface status bulletin board
Alarm information bar
List of off-ground wares
36L
36R
APP
LIN
DEP
CRO
LND
CES537
FIND
INFO
PIM
ALL
ALL
A 01:20z
UTC
EXIT

3 Key Technologies and Applications
——Enhancing system data interaction capabilities

Continuously enhancing the functionality of the Hongqiao Airport Tower electrical system in 2023:

- **Integration of surveillance signals.**
- **Integrating graphical and digital modules to achieve real-time interaction between aircraft dynamics and the clickable status of electric flight strips.**
- **Enhancing functionality for status alerts and conflict detection.**

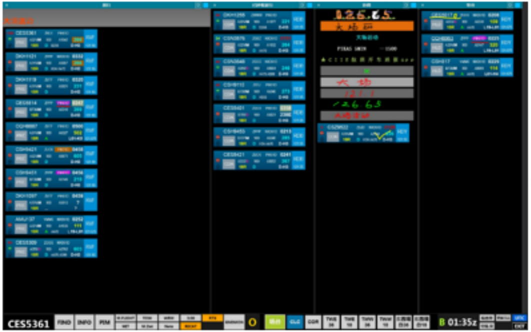

In port
Approach
Detour
Approach
Take-off queue
Crossing wait
Runway surface status bulletin board
Alarm information bar
List of off-ground waves
APP
LIN
DEP
CRO
LND
36L
36R
CES537
FIND
INFO
PSM
ALL
ALL
A 01:20z
Landing warning
Runway approach warning
Take-off warning
Slip warning
Crossing warning
Canadian yard Warden H2
Canadian yard Warden H8
Landing runway intrusion
Take-off runway intrusion
Landing judgment
Take-off judgment
Cross the takeoff runway
Cross the landing runway
Single runway judgment
Runway condition warning
Runway intrusion warning
Runway conflict judgment

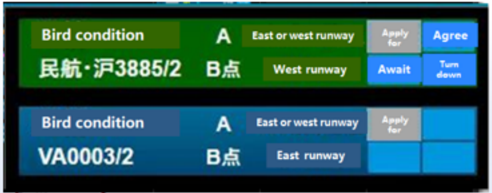
3 Key Technologies and Applications ——Enhancing system data interaction capabilities

⑥ Verification of scene data interaction based on aviation 5G

- Leverage 5G technology for validation;
- Complete a shared platform among air traffic control, airports, and airlines;
- Complete aircraft taxiing guidance scene tests;
- Complete runway incursion prevention scene tests.

Enhance operational mechanisms and foster greater situational awareness





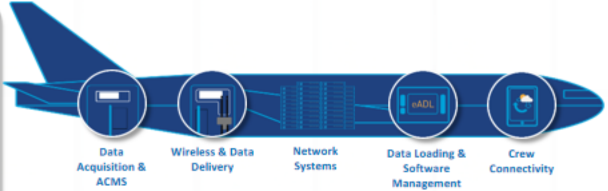
Bird condition	A	East or west runway	Apply for	Agree
民航·沪3885/2	B点	West runway	Await	Turn down
Bird condition	A	East or west runway	Apply for	
VA0003/2	B点	East runway		

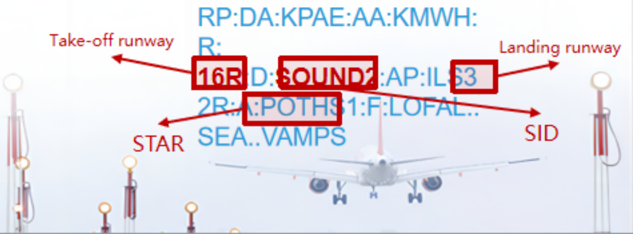
3 Key Technologies and Applications ——Enhancing system data interaction capabilities

⑦ CPDLC for runway incursion prevention

Key technology:

- Upload landing runway, arrival procedures;
- Real-time acquisition of aircraft operational parameters from the Flight Management System (FMS) to achieve flight intent recognition;
- Completing a comparison between landing runways and arrival procedures to provide error alert reminders, preventing incidents of landing on the wrong runway. (Bi-directional alerting)


eADL
Data Acquisition & ACMS
Wireless & Data Delivery
Network Systems
Data Loading & Software Management
Crew Connectivity

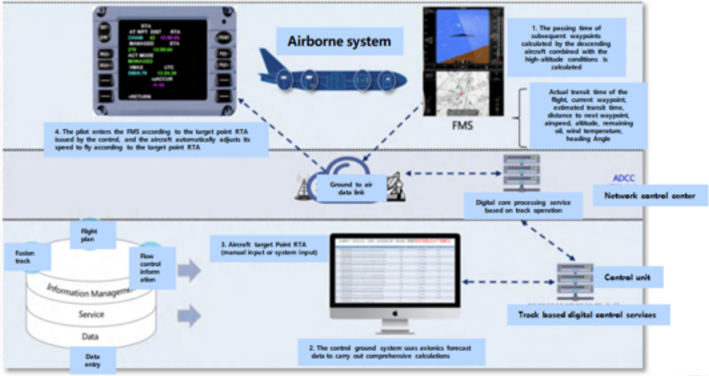

RP:DA:KPAE:AA:KMWH:
R:
16R:D:SOUND2:AP:ILS3
2R:A:POTHS1:F:LOFAL..
SEA..VAMPS
Take-off runway
Landing runway
STAR
SID

3 Key Technologies and Applications
——Enhancing system data interaction capabilities

⑦ CPDLC for runway incursion prevention

Work Progress Update:

- Verification work completed in 2022;
- Planned joint discussions with airports and some airlines in 2024 to explore application implementation and detailed functionality based on actual operational work.
- STAR & Landing Runway publish
- Aircraft land on wrong Runway Alarm


Airborne system
FMS
ADCC
Network control center
Ground to air data link
Digital core processing service based on track operation
Control unit
Track based digital control services
Fusion track
Flight plan
Flow control inform ation
Information Management
Service
Data
Data entry

1. The passing time of subsequent waypoints calculated by the descending aircraft combined with the high-altitude conditions is calculated

Actual transit time of the flight, current waypoint, estimated transit time, distance to next waypoint, airspeed, altitude, remaining oil, wind temperature, heading Angle

2. The control ground system uses avionics forecast data to carry out comprehensive calculations

3. Aircraft target Point RTA (manual input or system input)

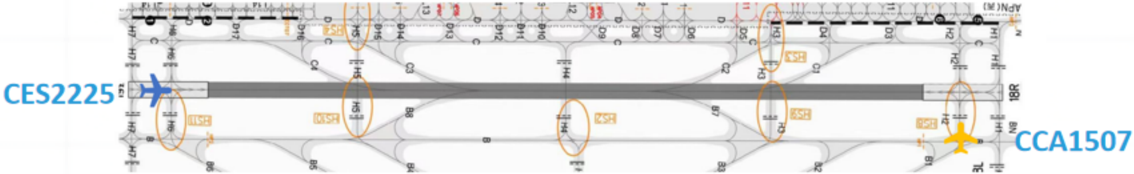
4. The pilot enters the FMS according to the target point RTA issued by the control, and the aircraft automatically adjusts its speed to fly according to the target point RTA

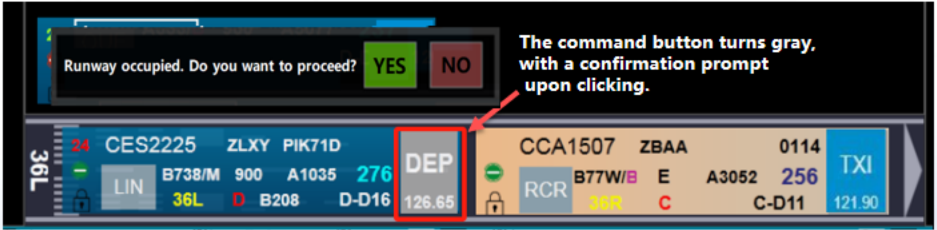
Part3: Key Technologies and Applications

——Enhancing terminal processing alert capabilities

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

⑧ The upgrade and optimization of electric flight strips





Runway occupied. Do you want to proceed?

The command button turns gray, with a confirmation prompt upon clicking.

36L | 24 | CES2225 | ZLXY | PIK71D | LIN | B738/M | 900 | A1035 | 276 | 36L | D | B208 | D-D16 | DEP | 126.65

CCA1507 | ZBAA | 0114 | RCR | B77W/B | E | A3052 | 256 | 36R | C | C-D11 | TXI | 121.90

Independent alert for the electronic waybill

Sample: Takeoff conflict alert

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

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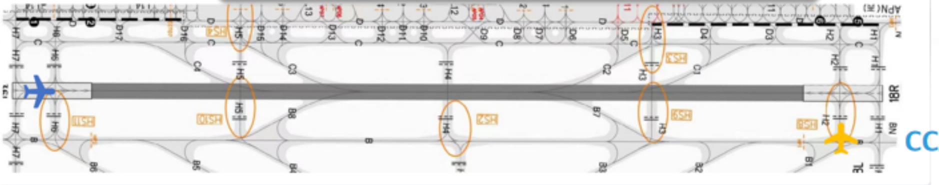
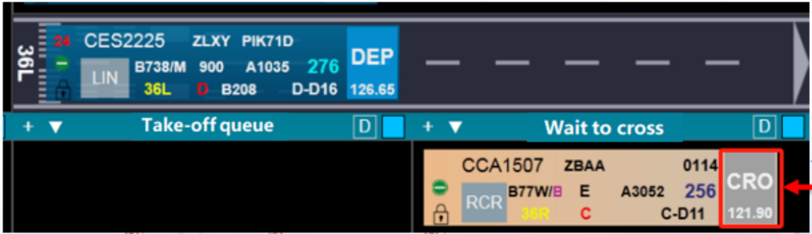
空中交通管理局
Air Traffic Management Bureau, CAAC

⑧ The upgrade and optimization of electric flight strips



CES2225

CCA1507


36L
24 CES2225 ZLXY PIK71D DEP
LIN B738/M 900 A1035 276
36L D B208 D-D16 126.65

CCA1507 ZBAA 0114 CRO
RCR B77W/B E A3052 256
36R C C-D11 121.90

The command button turns gray, with a confirmation prompt upon clicking.

Independent alert for the electronic waybill

Sample: Takeoff conflict alert

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

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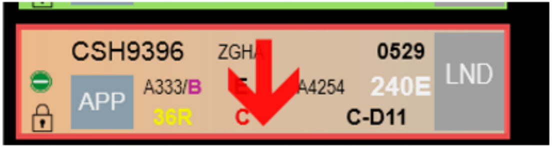
空中交通管理局
Air Traffic Management Bureau, CAAC

⑧ The upgrade and optimization of electric flight strips

Combining surveillance signals with electric flight strips



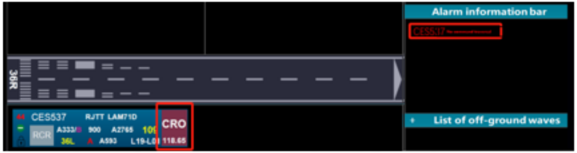
Sample: Reminder for missing landing instructions

When an aircraft on the five-mile final approach is within 2 kilometers of the runway threshold (configurable) and the electronic flight strip status of the aircraft is not in the LND state, a flashing downward arrow appears on the flight waybill to remind the controller that the landing instruction has not yet been issued.

3 Key Technologies and Applications ——Enhancing terminal processing alert capabilities

⑧ The upgrade and optimization of electric flight strips

Combining surveillance signals, video signals, and electric flight strips


Alarm information bar
CES537
36R
CES537
RJTT LAM71D
RCR
A333/
900
A2765
10
36L
A
A593
L19-L0
CRO
118.65
List of off-ground waves

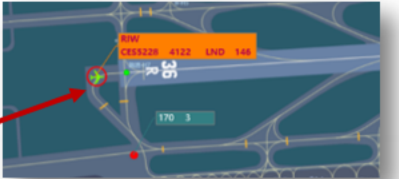
Sample: Unauthorized crossing Alert

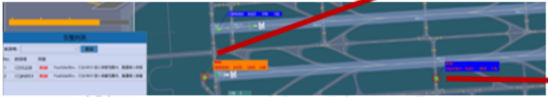
If a flight crosses the stop/wait line without authorization from air traffic control, it will trigger an unauthorized crossing alert. The status in the waybill will turn red, and there will be a corresponding prompt in the alert message bar.

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

⑧ The upgrade and optimization of Electronic Flight Strips

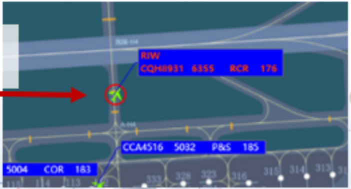
When an aircraft is in the process of taking off or landing, if another target appears on or near the runway that threatens or affects the aircraft's normal takeoff or landing, an alert will be generated.


RIW
CES5228 4122 LND 146
36R
170 3



Combining surveillance signals with electric flight strips

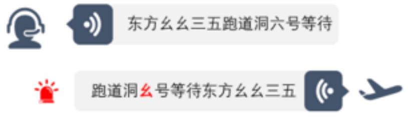
CQH8931 has crossed the hold short line


RIW
CQH8931 6355 RCR 176
CCA4516 5032 P&S 185
5004 COR 183
333
328
323
316
315
314
313
115
114
113

Sample: Runway Incursion Alert

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

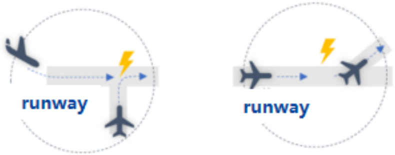
⑨ Verification and application of speech recognition technology



东方幺幺三五跑道洞六号等待

跑道洞幺号等待东方幺幺三五

Runway instruction reiteration consistency check

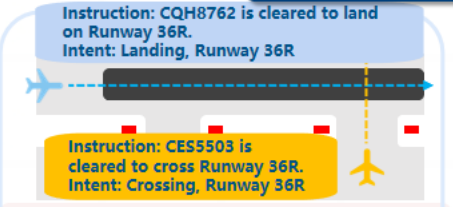


Intelligent runway incursion prevention based on speech recognition

Based on voice artificial intelligence, AI models identify bidirectional semantics of airport ground-to-air communication, combined with electronic process operation information and voice semantic information, to alert for conflicts with command intentions and crew execution instruction error.

3 Key Technologies and Applications
——Enhancing terminal processing alert capabilities

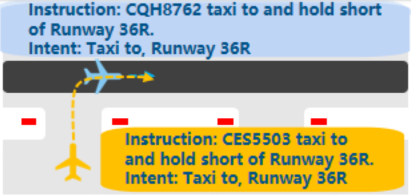
⑨ Verification and application of speech recognition technology



Instruction: CQH8762 is cleared to land on Runway 36R.
Intent: Landing, Runway 36R

Instruction: CES5503 is cleared to cross Runway 36R.
Intent: Crossing, Runway 36R

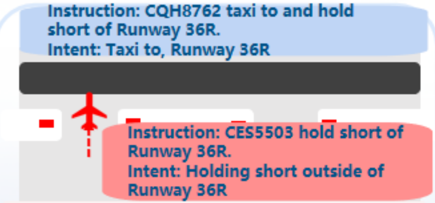
Recognition of crossing instructions when there is an inbound aircraft on the five-mile final approach



Instruction: CQH8762 taxi to and hold short of Runway 36R.
Intent: Taxi to, Runway 36R

Instruction: CES5503 taxi to and hold short of Runway 36R.
Intent: Taxi to, Runway 36R

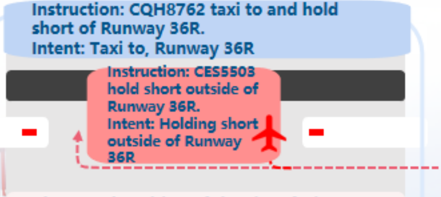
Recognition of taxi instructions when the runway is occupied



Instruction: CQH8762 taxi to and hold short of Runway 36R.
Intent: Taxi to, Runway 36R

Instruction: CES5503 hold short of Runway 36R.
Intent: Holding short outside of Runway 36R

The flight has violated the hold short instruction.



Instruction: CQH8762 taxi to and hold short of Runway 36R.
Intent: Taxi to, Runway 36R

Instruction: CES5503 hold short outside of Runway 36R.
Intent: Holding short outside of Runway 36R

The actual position of the aircraft does not match the intended instruction.

Three Elements of Safety Inspection

Current position	Destination	Conflict
Integrated track information	Instruction intent recognition	Instruction intent recognition
Video scene monitoring coordinates	Scene operational rules	Integrated track information
	Electronic Waybill	Video scene monitoring coordinates

Normal predicted taxi trajectory

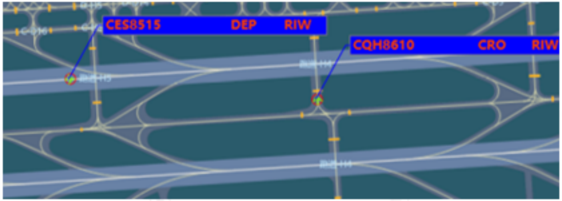
Normal predicted takeoff and landing trajectory

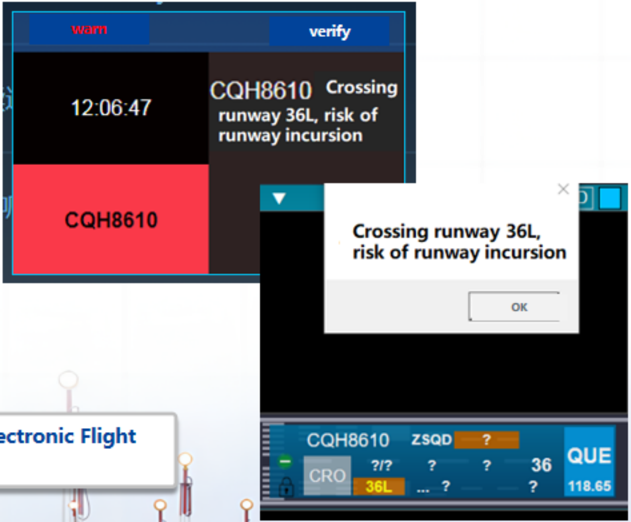
Predicted trajectory that will result in conflicts

Trajectory that has already deviated from the correct path

3 Key Technologies and Applications ——Enhancing terminal processing alert capabilities

⑨ Verification and application of speech recognition technology





12:06:47

CQH8610 Crossing runway 36L, risk of runway incursion

CQH8610

Crossing runway 36L, risk of runway incursion

CQH8610 ZSQD ?
CRO ?/? ? ? 36 QUE
36L ... ? ? 118.65

Combination of surveillance signals, voice, and Electronic Flight Strips (simulated schematic)

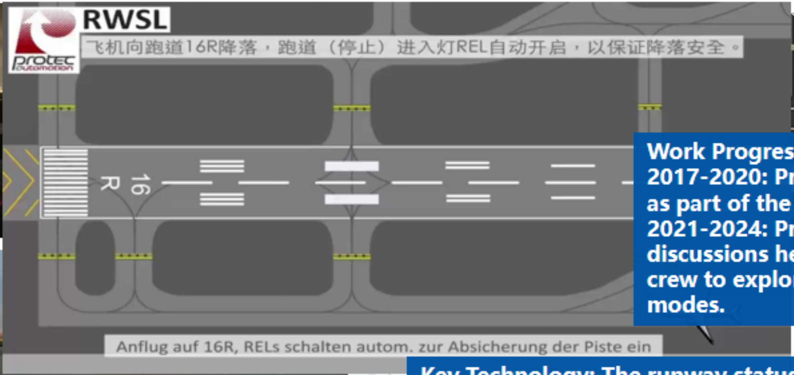
Part3:Key Technologies and Applications

——Enhancing scene autonomous perception capabilities

3 Key Technologies and Applications
——Enhancing scene autonomous perception capabilities

⑩ **Runway status lights**

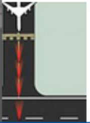
Independent automatic operation & autonomous alerts

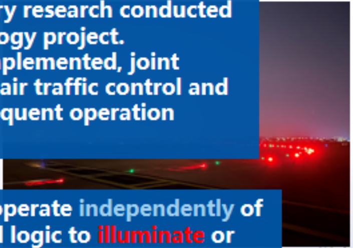


RWSL

飞机向跑道16R降落，跑道（停止）进入灯REL自动开启，以保证降落安全。

Anflug auf 16R, RELs schalten autom. zur Absicherung der Piste ein





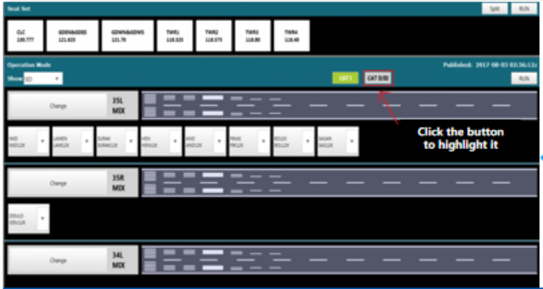
Work Progress:
2017-2020: Preliminary research conducted as part of the technology project.
2021-2024: Project implemented, joint discussions held with air traffic control and crew to explore subsequent operation modes.

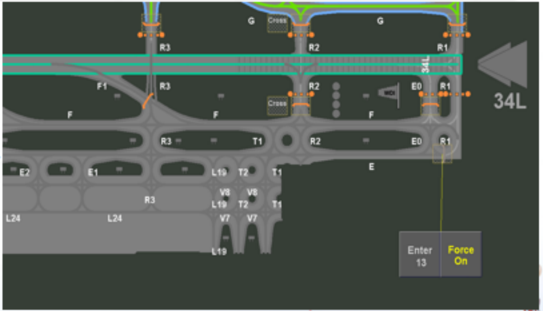
Key Technology: The runway status lights operate independently of air traffic controllers, controlled by internal logic to illuminate or extinguish runway entrance lights (RELs) and threshold lights (THLs). This enables accurate and timely indication of runway occupancy status, reducing the frequency and severity of runway incursions, and preventing runway accidents.

3 Key Technologies and Applications
——Enhancing scene autonomous perception capabilities

⑪ Stop-bar lights

- The tower electronic waybill system is linked with the airport's stop-bar lights, sending control signals to the lighting system and receiving feedback signals.


Seat Set
Split
RUN
Operation Mode
Published: 2017-08-03
CAT I
CAT II/III
RUN
Change
35L
MIX
Change
35R
MIX
Change
34L
MIX
Click the button
to highlight it


G
Cross
G
R3
R2
R1
34L
F1
R3
R2
E0
R1
Cross
34L
F
F
F
R3
T1
R2
E0
R1
E2
E1
L19
T2
T1
E
R3
V8
V8
L19
T2
T1
L24
L24
V7
V7
L19
Enter
13
Force
On

Work Progress:
2017-2020: Preliminary research conducted as part of the technology project.
2021-2024: Project implemented, joint discussions held with air traffic control and crew to explore subsequent operation modes.

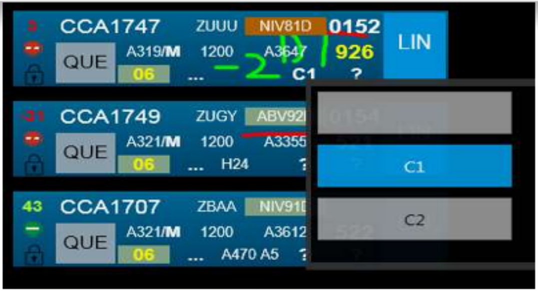
3 Key Technologies and Applications
——Enhancing scene autonomous perception capabilities

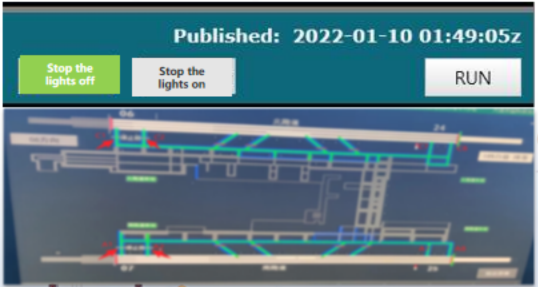
⑪ Stop-bar lights

Work Progress Update:

Pudong Airport: Achieved integration of the Pudong Tower electrical system with the runway stop-bar light system, allowing control of lights and switching between Category II /III operations via the chief's button.

Hangzhou Airport: Completed linkage testing and online upgrade of the backup system in the Hangzhou Tower electrical system. Hangzhou lighting upgrade completed and activated.

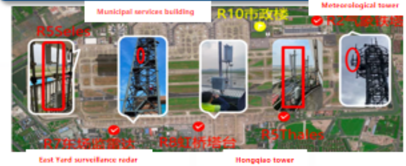

CCA1747
ZUUU
NIV81D
0152
LIN
QUE
A319/M
1200
A3647
926
06
...
C1
?
CCA1749
ZUGY
ABV92I
QUE
A321/M
1200
A3355
06
...
H24
?
43
CCA1707
ZBAA
NIV91D
QUE
A321/M
1200
A3612
06
...
A470 A5
?
C1
C2


Published: 2022-01-10 01:49:05z

Stop the lights off
Stop the lights on
RUN

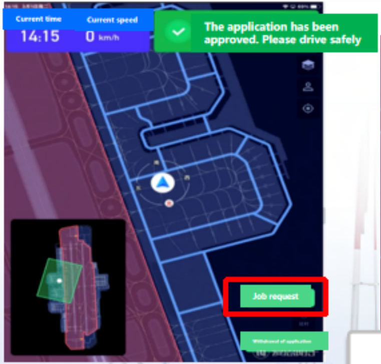
3 Key Technologies and Applications
——Enhancing scene autonomous perception capabilities

⑫ Vehicle safety management and control

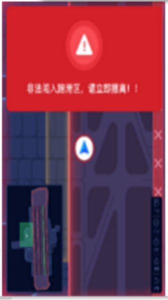

Municipal services building
R10市政楼
Meteorological tower
R2气象铁塔
R5Seles
R5Thales
R7东场监雷达
R8虹桥塔台
East Yard surveillance radar
Hongqiao tower

Key technology: collaboration among ATC, airports, and airlines to collectively achieve vehicle perception

- Conduct flight verification tests based on the 5GAeroMACS network at Hongqiao Airport
- Integrate the dynamics of mobile area aircraft and vehicles into one system
- Accurately determine the precise locations of vehicles and aircraft
- Establish electronic fenced-off areas to prevent vehicles from entering runways and maneuvering areas
- Vehicle information is also integrated into electric flight strips and advanced scene systems


Current time
14:15
Current speed
0 km/h
Job request
Withdrawal of application

The application has been approved. Please drive safely



非法进入跑滑区，请立即撤离！！

Vehicle mobile terminal actual interface

Part1: Research background

Part2: Overall objective

Part3: Key Technologies and Applications

Part4: Future Prospects

4 Future Prospects

Continuously carry out runway incursion prevention work

Adhere to the principle of customization, one airport one solution

Focus on:

- Enhancing airport scene detection and perception capabilities
- Enhancing system data interaction capabilities
- Enhancing terminal processing alert capabilities
- Enhancing airport scene autonomous perception capabilities

Continuously optimize technology and implement new technologies

Thanks!