



ICAO



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



空中交通管理系统全国重点实验室  
State Key Laboratory of  
Air Traffic Management System, China

# Introduction to Research and Validation on SWIM and FF-ICE

State Key Laboratory of Air Traffic Management System, China

June 2023

# Introduction of SKL-ATMS

**The State Key Laboratory of ATMS** was established in 2015, located in Nanjing, China. As the national-level laboratory in China's ATM field, our laboratory is committed to:

## 1. Frontier Technology Research

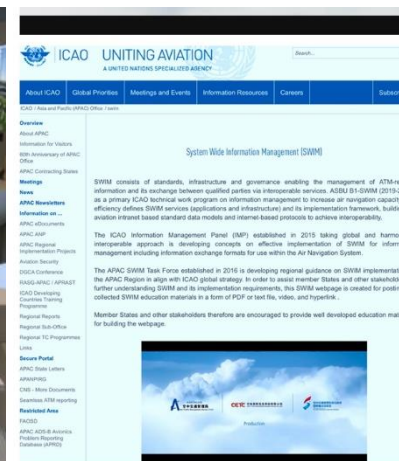
- ◆ ATMS architecture design and simulation
- ◆ Information collaborative environment for ATM
- ◆ Flight flow management
- ◆ ATM simulation

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## 2. Pre-research on Concept and Specification

- ◆ Smart Civil Aviation Roadmap
- ◆ TBO Implementation Strategy
- ◆ SWIM Concept
- ◆ CATFM Manual (Doc.9971 4<sup>th</sup> Edition)

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# Content

**1.**

**TBO-oriented Information Collaborative Technology**

**2.**

**Works on SWIM and FF-ICE**

**3.**

**Conclusion & Prospects**

# TBO: Key concept for future ATM operation

As a system-level solution for the future development of ATM systems, TBO aims to promote innovative changes in **operational modes**, achieve effective **collaboration** among various operational elements and refined **trajectory management** throughout all operational phases.

Past

Infer  
where the airplane is



Procedure-based ATM

Now

Know  
where the airplane is



Surveillance-based ATM

Future

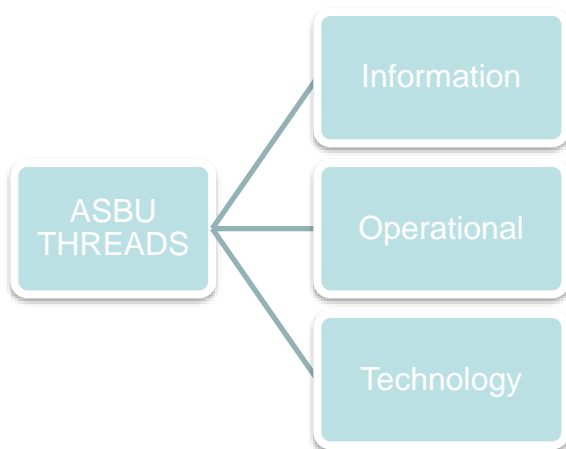
Know  
where the airplane will be



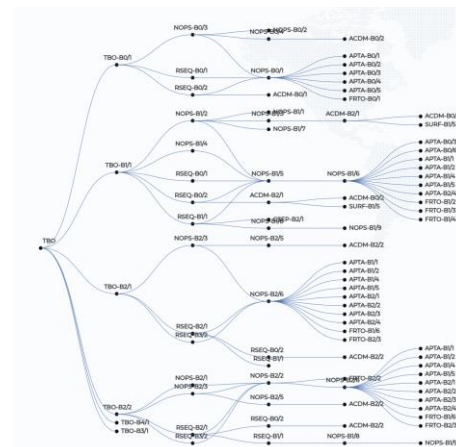
Trajectory-based ATM

# Global TBO Plan

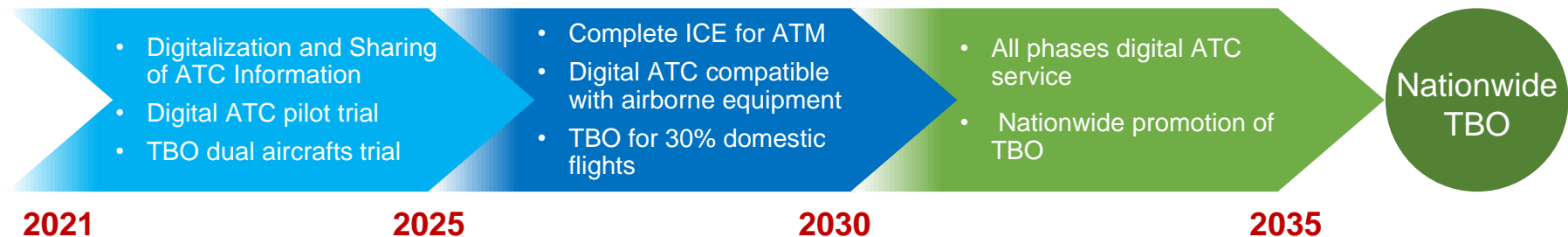
The Global Air Navigation Plan (Doc 9750) clarifies that TBO is the overall integration and ultimate goal of various ASBU threads.



TBO	Trajectory-based operations	Operational
CONCEPT OF OPERATIONS BY BLOCK		
Block Description		
Block 0 Introduction of time-based management within a flow centric approach.		
Block 1 Initial Integration of time-based decision making processes.		
Block 2 Pre-departure trajectory synchronization within a flight centric and network performance approach. Extended time-based management across multiple FIRs for active flight synchronization.		
Block 3 Network performance on demand synchronization of trajectory-based operations.		
Block 4 Total airspace management performance system.		

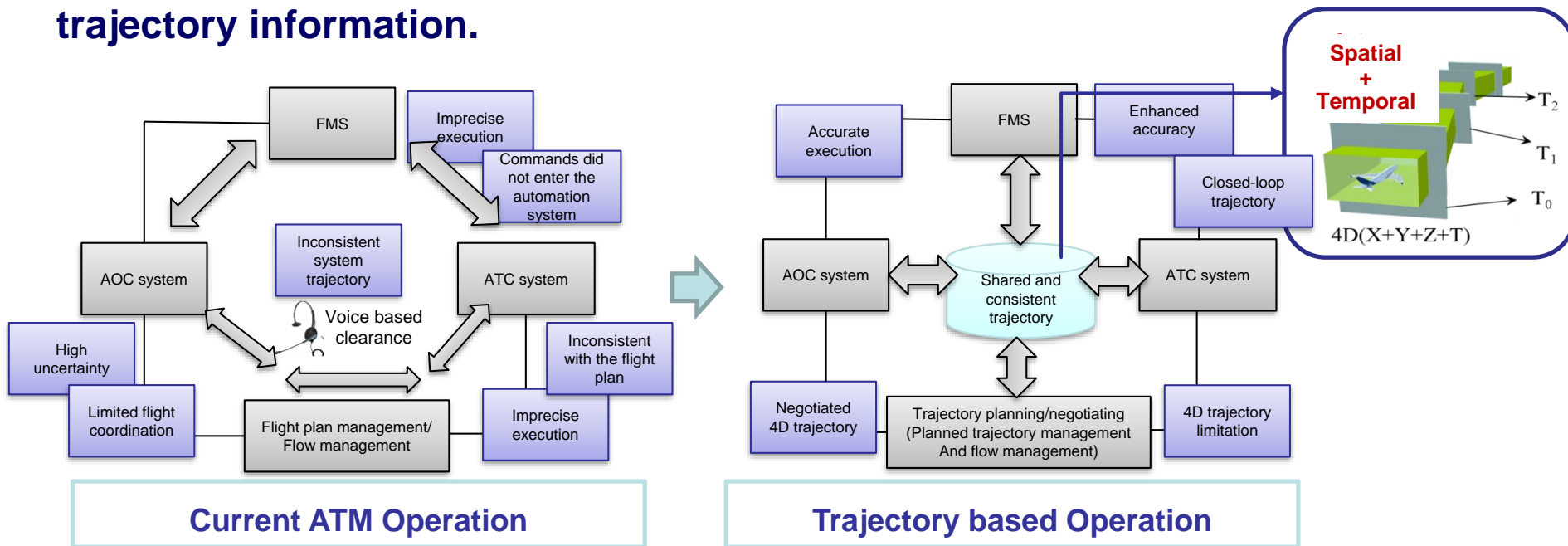


## China: Roadmap for Smart Civil Aviation



# TBO vision

TBO achieves collaborative decision-making among multiple stakeholders through real-time sharing and dynamic maintenance of 4D trajectory information.

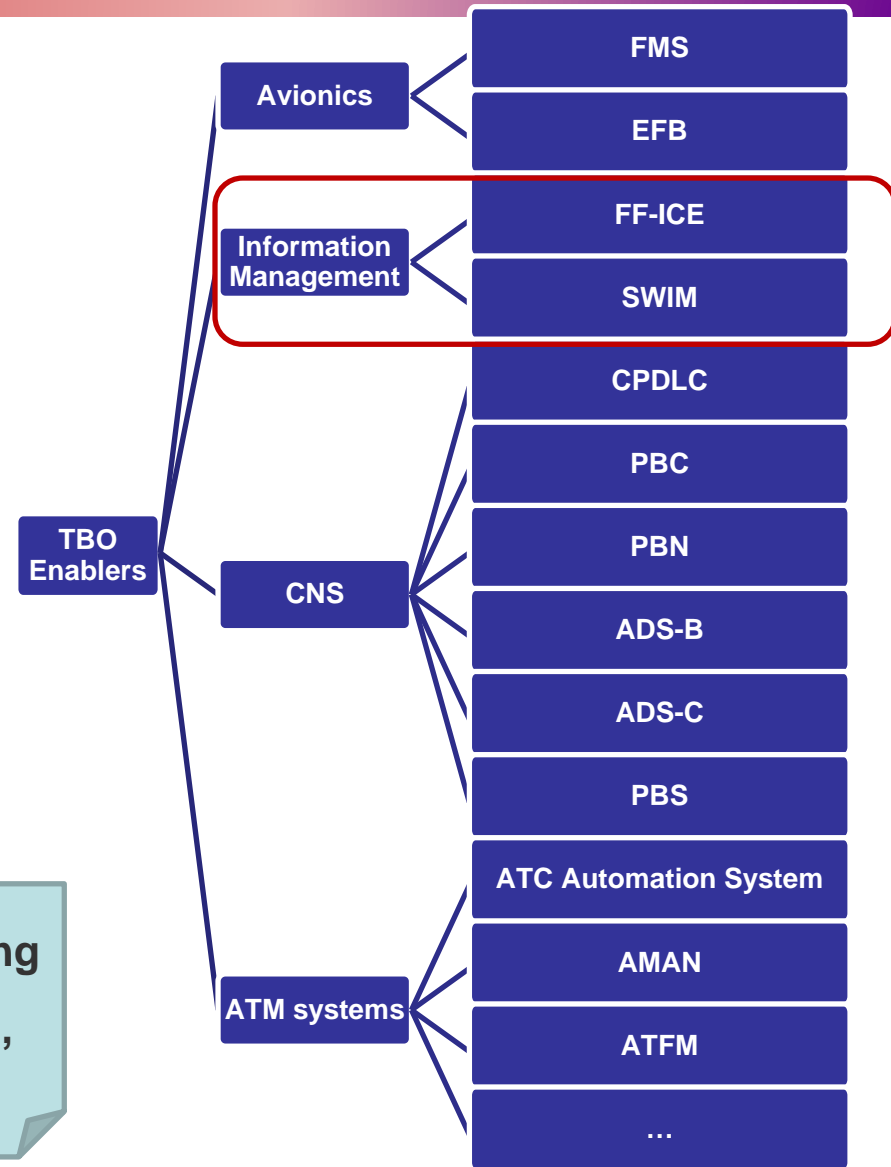


- **System Collaboration**, the interconnection among ground ATM systems and airborne avionics systems.
- **Information Collaboration**, an ICE integrating information for meteorology, flight and flow, etc.
- **Operational Collaboration**, CDM by all stakeholders through the ICE.

# TBO Capabilities and Enablers

## Capabilities

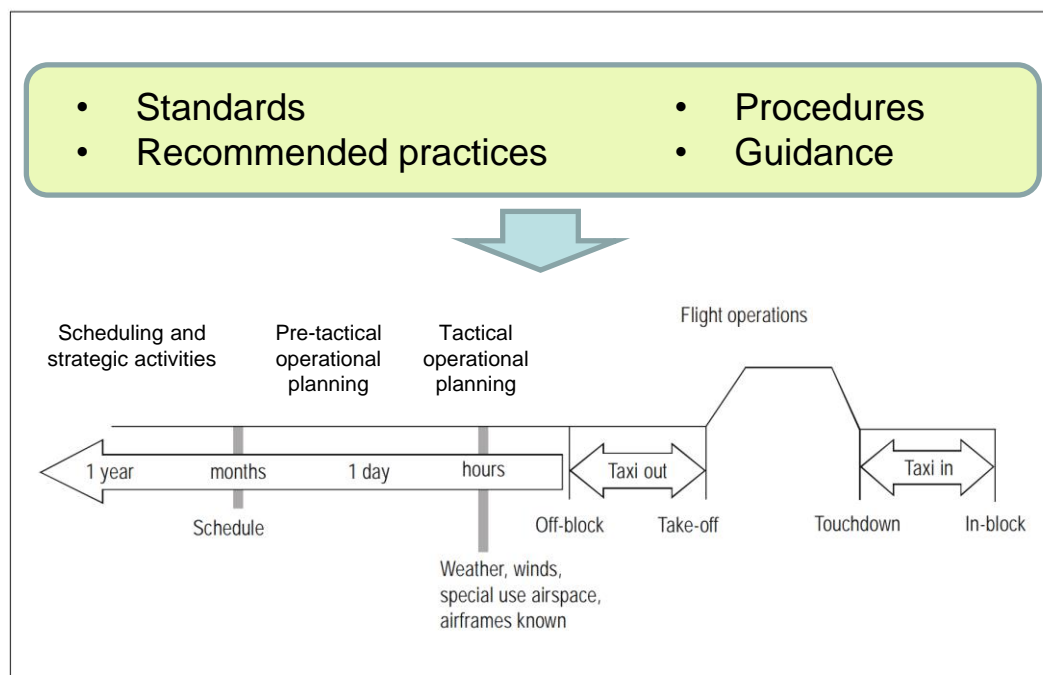
- Pre-Departure Trajectory Negotiation
- Post-Departure Trajectory Negotiation
- Trajectory Parameter Exchange
- TBO Clearances
- Sharing of Aircraft-Derived Trajectory
- Precise Clearance Execution
- ATM Concept Component Integration
- ASP Coordination & Negotiation
- Trajectory Prediction



The foundation of TBO is the consistent sharing of 4DT among multiple stakeholders (G/G, A/G, A/A).

# Concept of FF-ICE

The FF-ICE concept illustrates information for flow management, flight planning, and trajectory management associated with ATM operational components, as appropriate to ensure global harmonization.



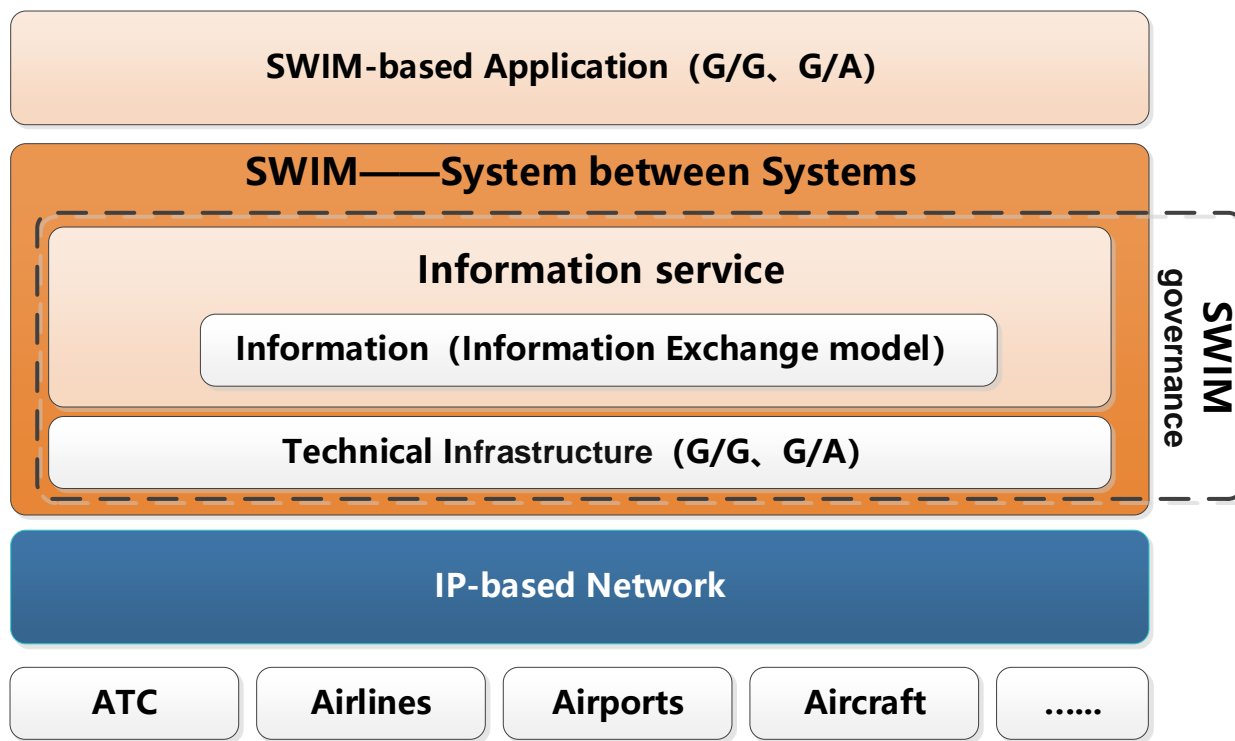
## Enabling TBO capabilities:

- Trajectory Negotiation both prior to and subsequent to flight departure
- Coordination of trajectory information across concept components and between ASPs
- Provision of Trajectory Parameters, AU constraints and AU trajectory preferences

ICAO Doc 9965 《Manual on Flight and Flow Information for a Collaborative Environment》

# Concept of SWIM

**SWIM consists of standards, infrastructure and governance, enabling the management of ATM-related information and its exchange between qualified parties via interoperable services.**

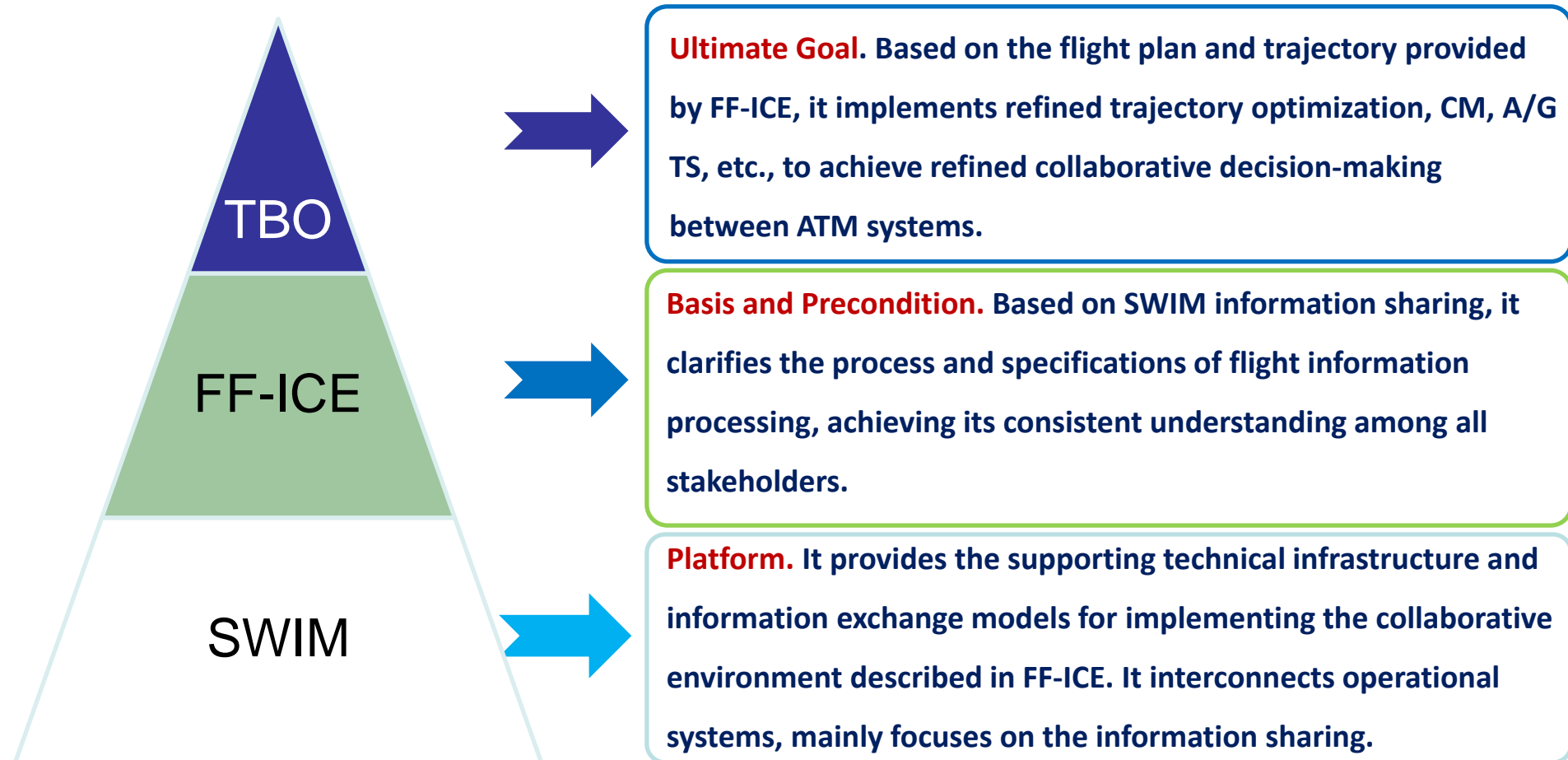


By providing global connectivity across ASPs and making information “system-wide”, the transition environment supports the exchange of a richer set of data amongst SWIM-enabled participants regardless of their relative geographical location.

## The Scope of SWIM

# TBO、FF-ICE and SWIM

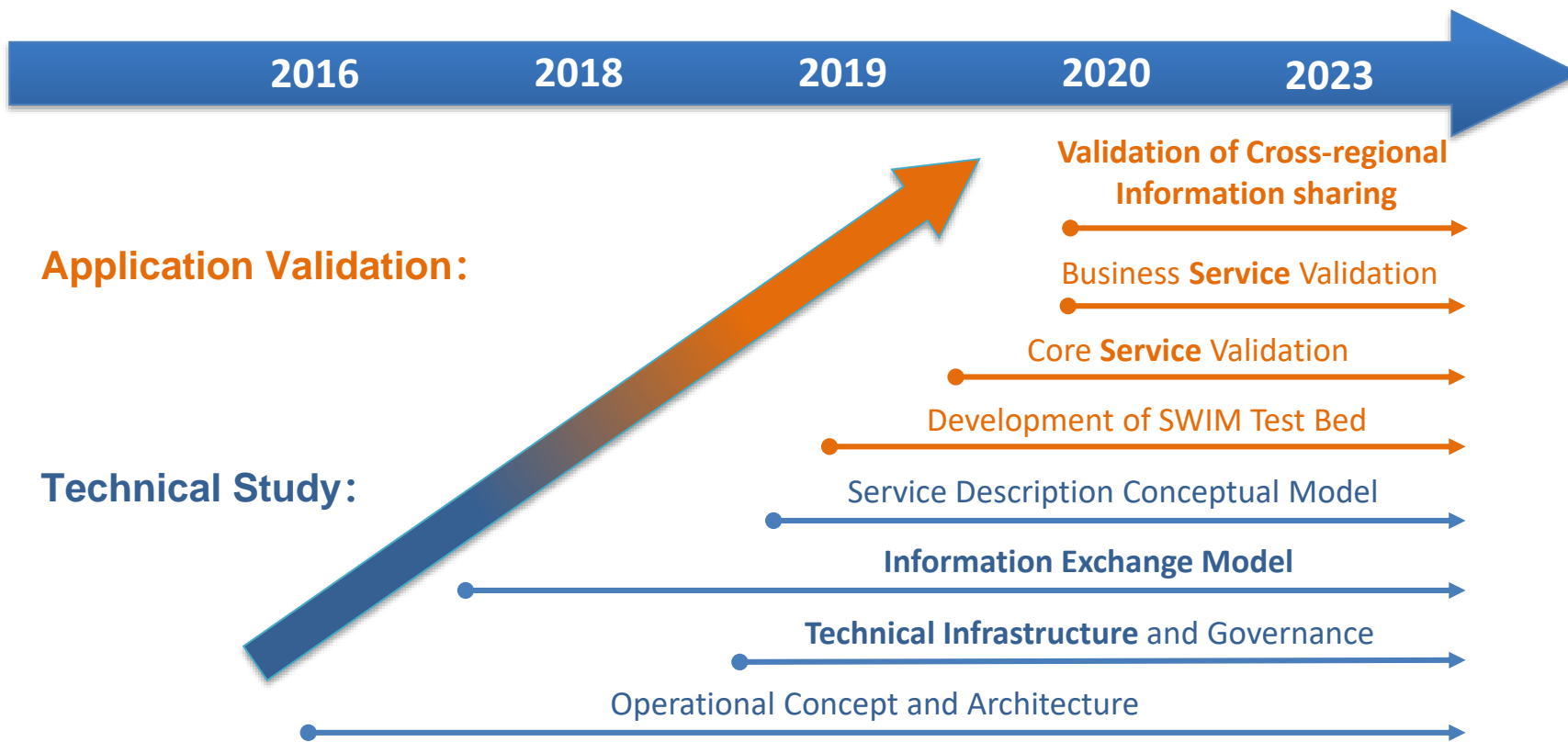
FF-ICE integrates all ATM related data and exchanges data and services throughout ATM systems within a SWIM environment, thereby supporting TBO for all flight phases.



# Conclusion

**Information collaboration is a key technology to achieve TBO vision.**

Our group has long been committed to the technical study and application validation on TBO-oriented SWIM and FF-ICE, and has achieved meaningful results.



# Content

**1.**

**TBO-oriented Information Collaborative Technology**

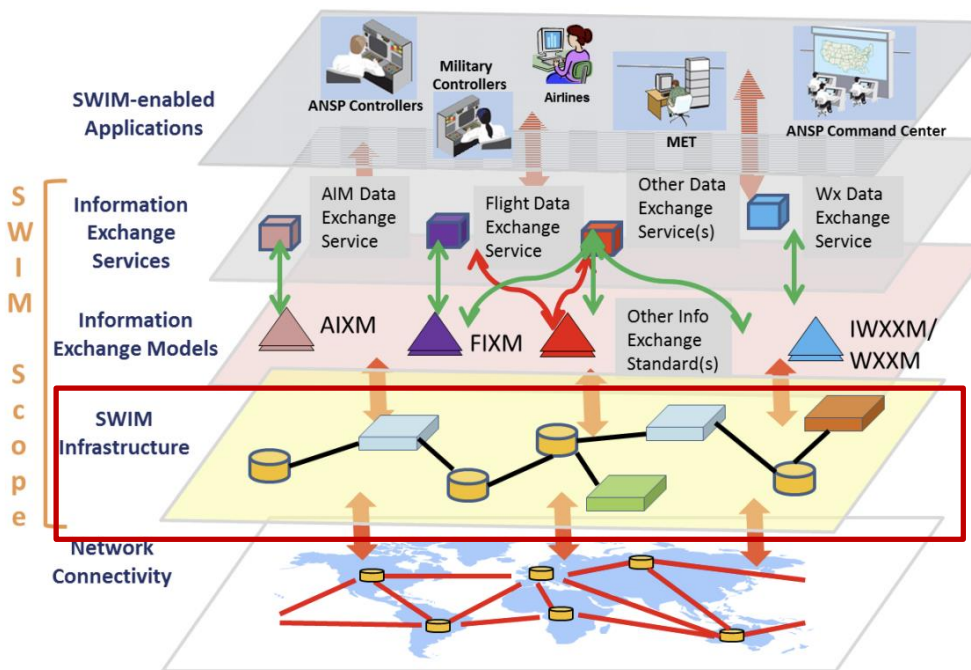
**2.**

**Works on SWIM and FF-ICE**

**3.**

**Conclusion & Prospects**

# 1. Technology Infrastructure



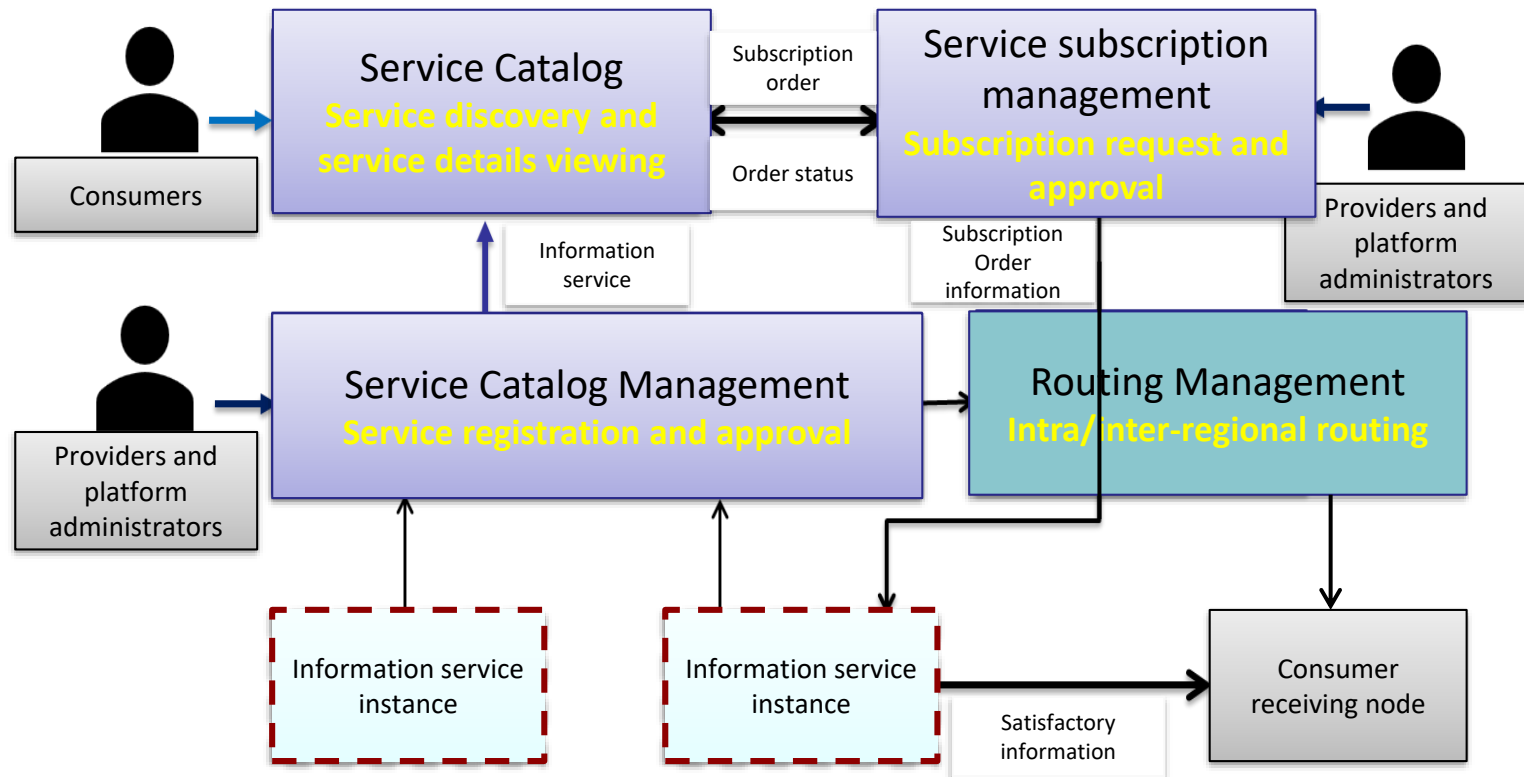
**SWIM Global Interoperability Framework  
– SWIM Layers (Doc10039)**

**Technical foundation for achieving interoperability, ensuring the security of information exchange.**

The technical infrastructure serves as a regional SWIM management node, realizing information service management, message routing, security management for various participants in the region, and providing users with service registration, service discovery, service status change notification and other capabilities.

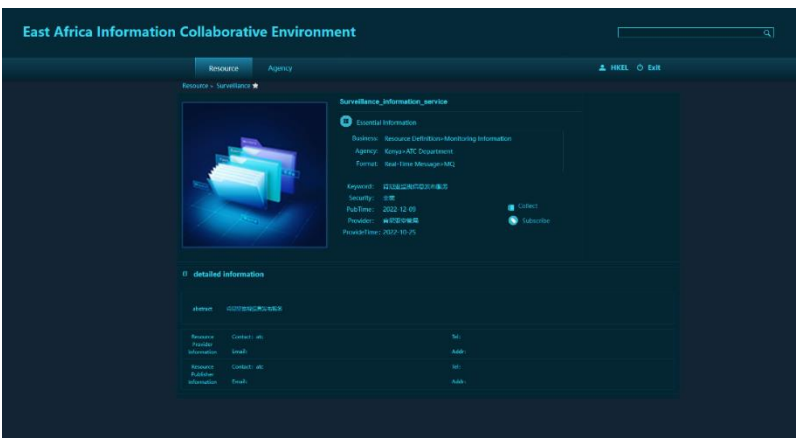
# 1. Technology Infrastructure

To validate the SWIM capabilities, the SWIM technology infrastructure platform is developed, supporting the service catalog, service registry and approval management, and service subscription management.

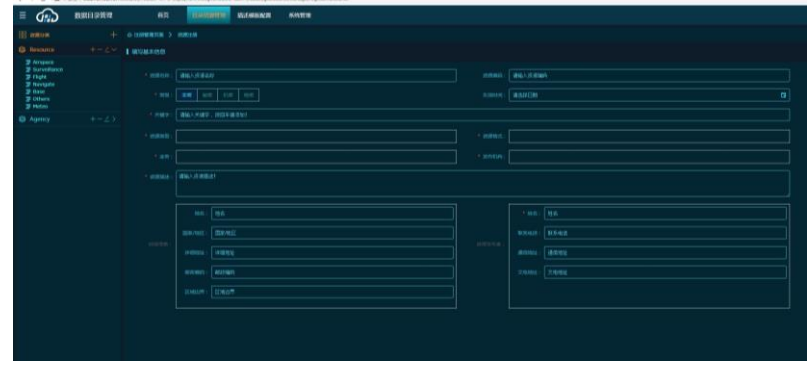


# 1. Technology Infrastructure

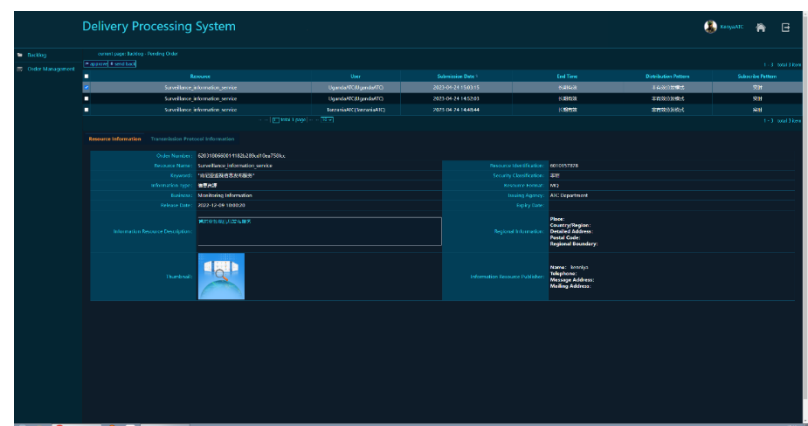
**Service Registration.** It provides service providers with the ability to register two types of services: publish-subscribe and request-query. The registered information services need to be reviewed before they can be officially announced to the public.



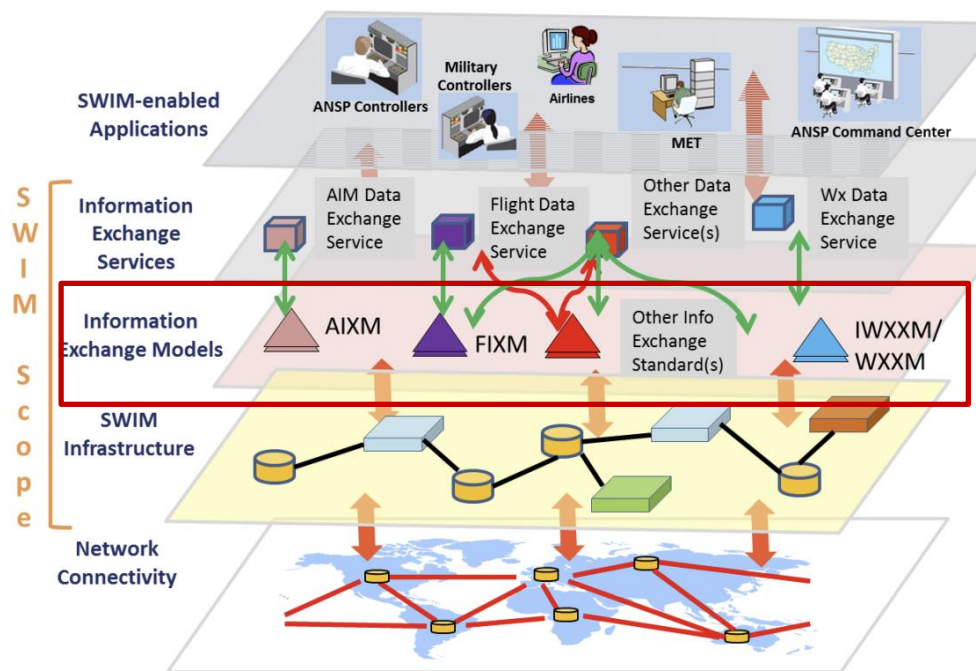
**Service subscription management.** It supports the message service filtering. Service consumers can subscribe to messages related to themselves according to the subscription conditions. The subscription needs to be approved by the service provider or administrator.



**Service Catalog.** It provides service consumers with the ability to view services by categories such as information type, publishing organization, etc., and provides detailed information, including service provider, contact info, provision method, etc.



## 2. Information Exchange Model



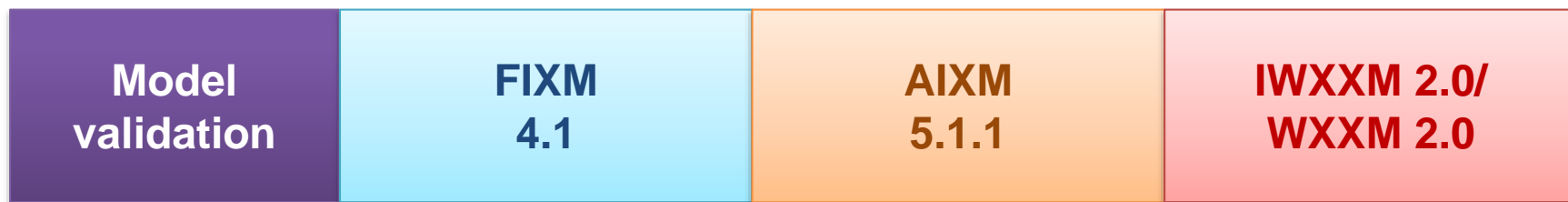
**SWIM Global Interoperability Framework  
– SWIM Layers (Doc10039)**

**Defining the  
syntax and semantics of the  
data exchanged by applications**

The information exchange model clarifies the data characteristics of each information domain, defines the effective payload of information services, which includes information content, structure and format, and supports the consistency of information interaction.

## 2. Information Exchange Model

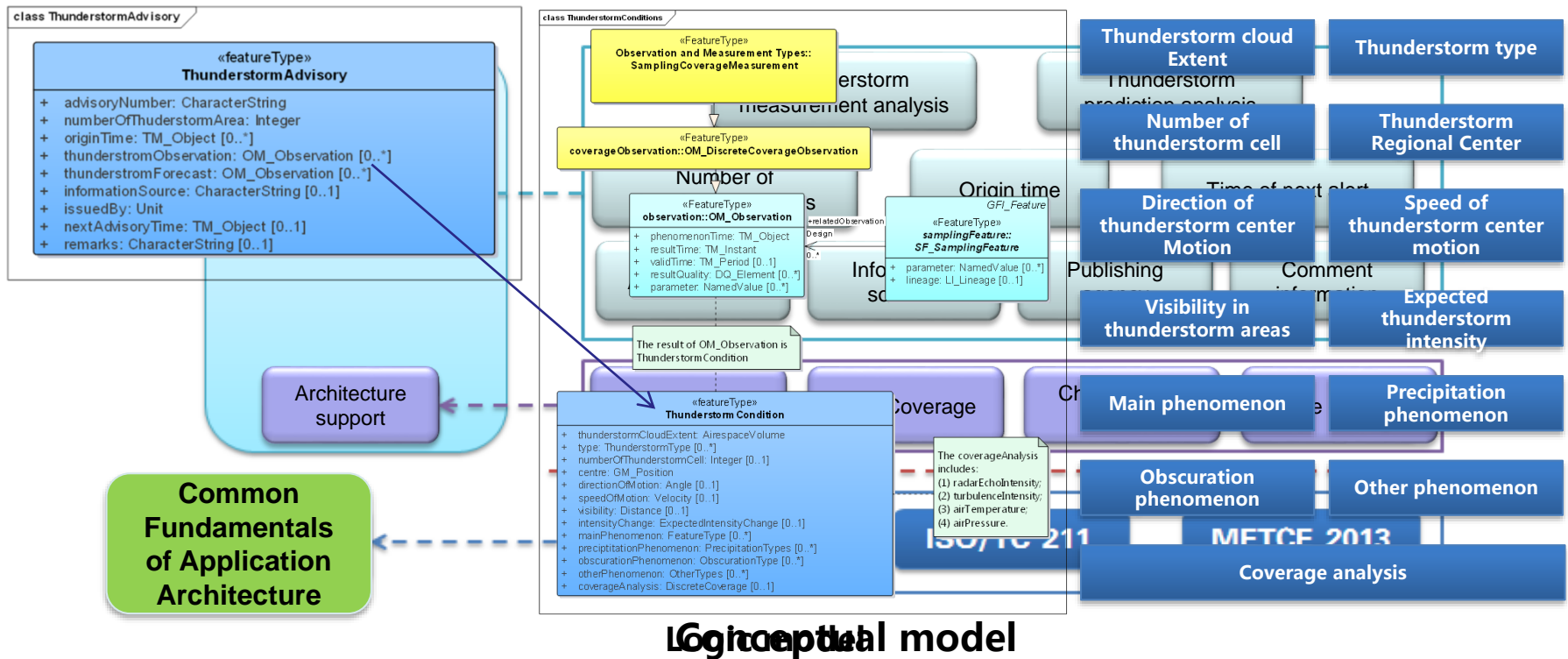
Based on FIXM, AIXM and IWXXM/WXXM, specific information exchange models such as flow control measures, airspace use plan, thunderstorm alarm, etc. are constructed to support ATM applications.



- |  |  |  |
|--|--|--|
| <ul style="list-style-type: none"> <li>● <b>FIXM data</b></li> <li>• FPL</li> <li>• DEP</li> <li>• AR</li> <li>• Surveillance Information</li> <li>• Trajectory data</li> <li>• Flow control measures</li> </ul> | <ul style="list-style-type: none"> <li>● <b>AIXM data</b></li> <li>• Airspace usage plan</li> <li>• NOTAM</li> </ul> | <ul style="list-style-type: none"> <li>● <b>IWXXM data</b></li> <li>• METAR</li> <li>• SPECI</li> <li>• TAF</li> <li>• SIGMET</li> <li>● <b>WXXM data</b></li> <li>• Thunderstorm alarm</li> </ul> |
|--|--|--|

# 2. Information Exchange Model

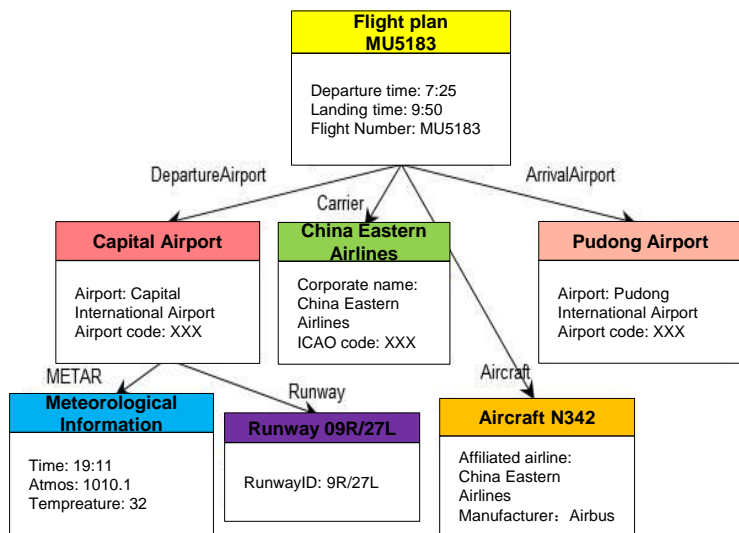
Following the WXXM 2.0, a **thunderstorm MET information exchange model** is built, which supports the publication and query of digital thunderstorm observation and forecast information, and promotes the further integration and application of thunderstorm information with ATM.



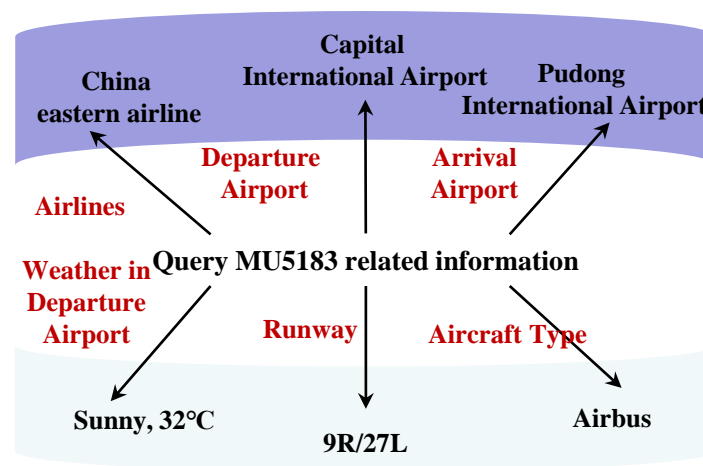
## 2. Information Exchange Model

### Ontology and Knowledge Graph

The mapping method from unified modeling language information model to ontology model is studied to address the **semantic inconsistency** among information exchange models. On this basis, a dynamic ATM knowledge graph is built, which establishes the dynamic correlation between aviation, flight and meteorological information for effectively ATM decision making.

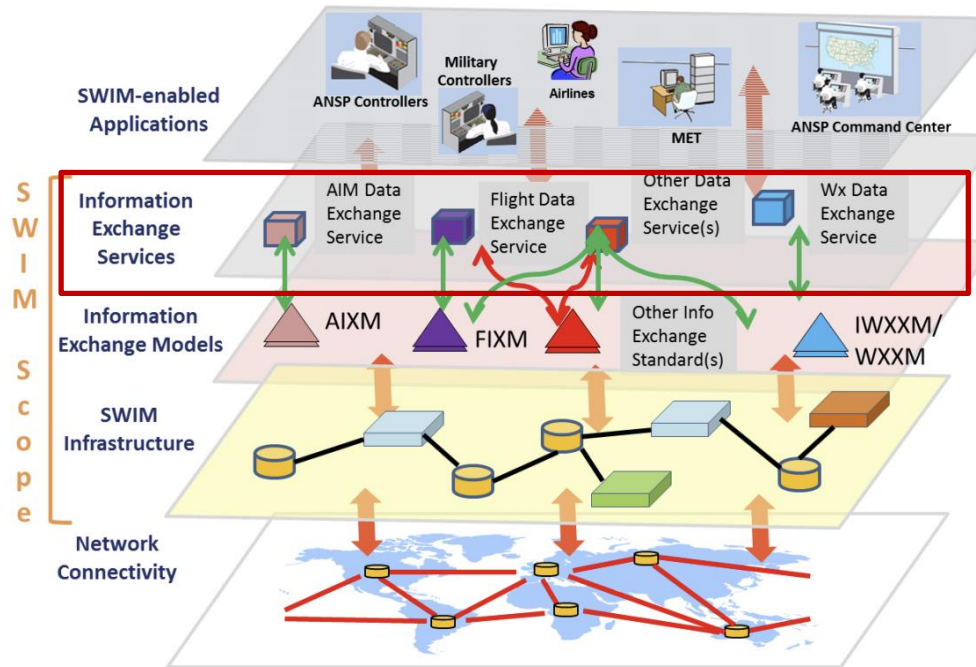


Knowledge Graph



Relevancy Searching

# 3. Information Exchange Services



**Performing the specific information exchange**

Information services adopt Service Oriented Architecture. It establishes replicable information service modules, which supports intra-regional or cross-regional ATM information interaction, and ensures the standardization, uniformity and availability of services.

**SWIM Global Interoperability Framework – SWIM Layers (Doc10039)**

# 3. Information Exchange Services

## Information Service Products

Flight and Flow

### Flight Publish Service

- ✓ FPL Msg publish
- ✓ Arrival Msg publish
- ✓ Departure Msg publish

### Flight Query Service

- ✓ Arrival Flights by Airport
- ✓ Departure Flights by Airport
- ✓ Query Flights by ACID
- ✓ Query Flight by GUF1

### Flow Control Measures Transfer

- ✓ Convert MIT Measure to Model
- ✓ Fix Point Miles-in-trail (MIT) publish

### Flow Control Measures Query

- ✓ Query MIT by ID
- ✓ Query MIT by Point

MET

### Meteorological Message

- ✓ METAR/SPECI/TAF/SIGMET/AIRMET publish
- ✓ Query METAR/SPECI/TAF/SIGMET/AIRMET

### Thunderstorm Weather

- ✓ Publish Thunderstorm Data
- ✓ Query Thunderstorm Data

Avia

### Special Activity Airspace Service

- ✓ SAA msg Publish

### NOTAM publish

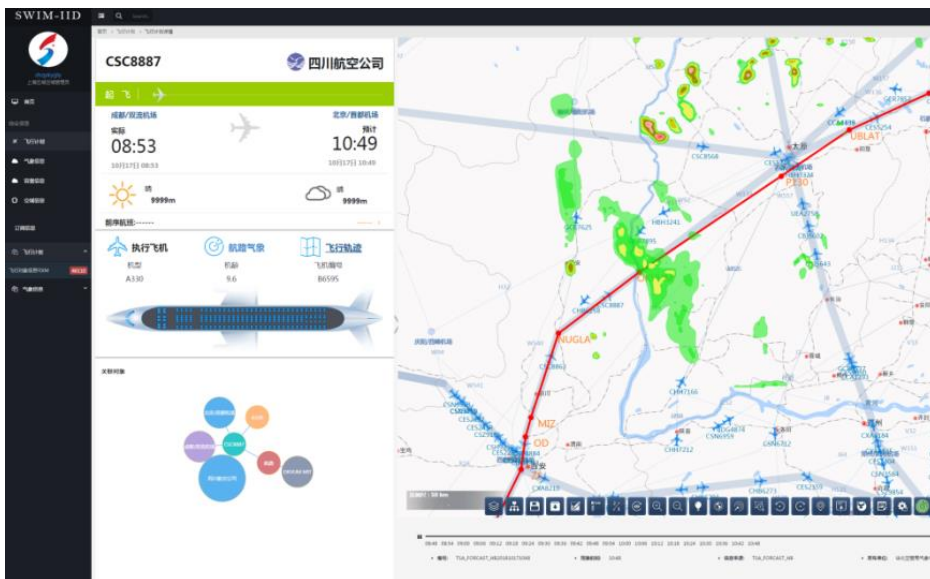
- ✓ Runway open/close publish

These provide more comprehensive information sharing and more efficient interaction mechanisms for multiple ATM stakeholders.

# 3. Information Exchange Services

## Information Services Based on the FIXM 4.1

The publication, subscription and query services for flight plan and flow control strategy are provided. The capabilities for subscription and query service of flight plan and flow control strategy has been validated.



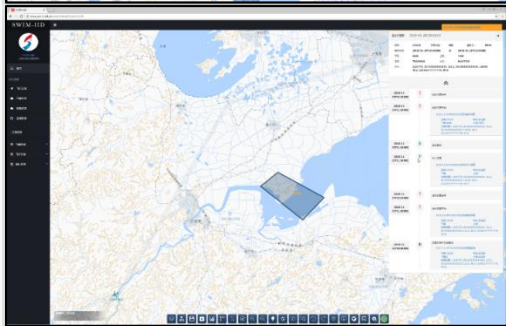
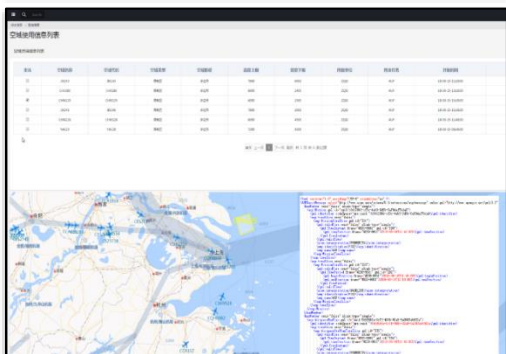
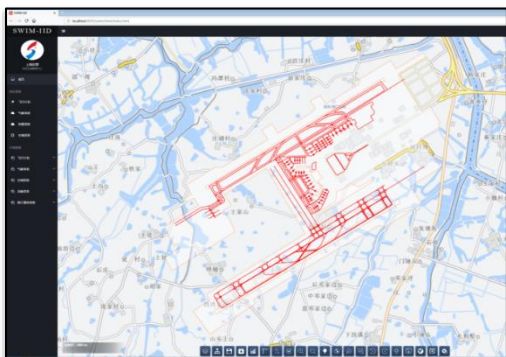
Association between Dynamic Information and Flight Plan



Association between Flow Control Strategy and Flight Plan

# 3. Information Exchange Services

## Aviation Information Services Based on the AIXM 5.1

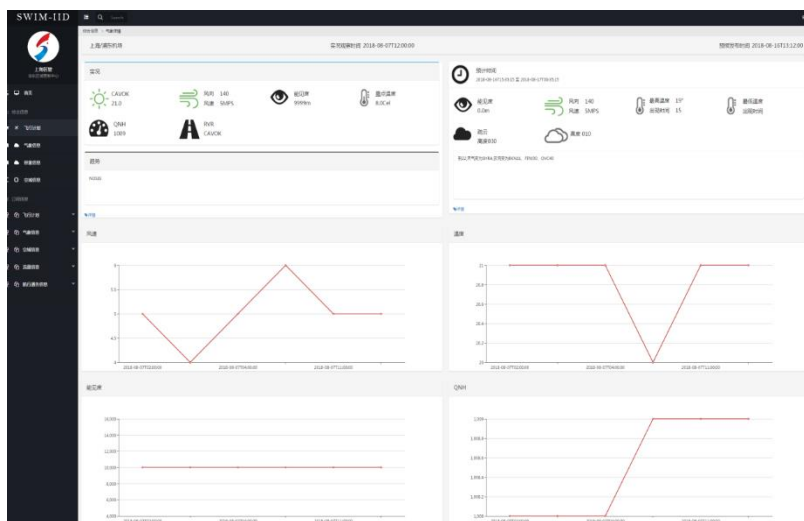


- **Aviation Information Query Service.** The basic data in traditional formats, such as airports, airways, waypoints, and landmarks are consistently converted to models.
- **SAA Publish and Query Service.** AU can timely obtain airspace usage information by these Services.
- **NOTAM Service.** The subscription, publication, and conditional query of NOTAM is implemented.

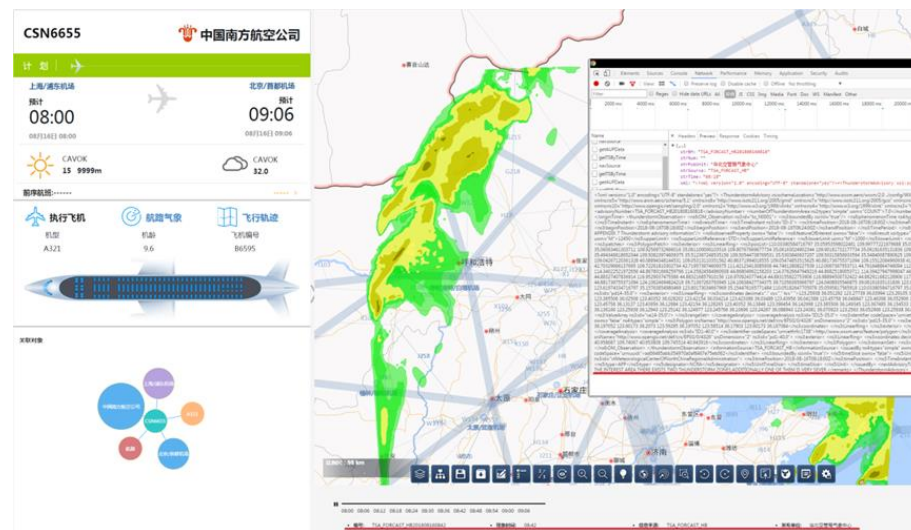
# 3. Information Exchange Services

## Meteorological Information Services based on IWXXM/WXXM

The subscription, publishing and conditional query service of meteorological message are provided, as well as the subscription and publishing service of real-time thunderstorm and the corresponding prediction, and the thunderstorm query service based on spatial-temporal conditions.



Meteorological Message Query



Thunderstorm Information Query

## 3. Information Exchange Services

### FF-ICE/R1 Services

#### Planning Service:

**Preliminary Flight Plan Message**

**Flight Plan Update Message**

Flight Plan Cancellation Message

**Submission Response Message**

**Planning Status Message**

#### Trial Service:

**Trail Request Message**

**Submission Response Message**

**Trail Status Message**

#### Filing Service:

**Filed Flight Plan Message**

**Flight Plan Update Message**

Flight Plan Cancellation Message

**Submission Response Message**

**Filing Status Message**

#### Flight Data Request Service:

Flight Data Request Message

Submission Response Message

Flight Data Response Message

#### Notification Service:

Flight Departure Message

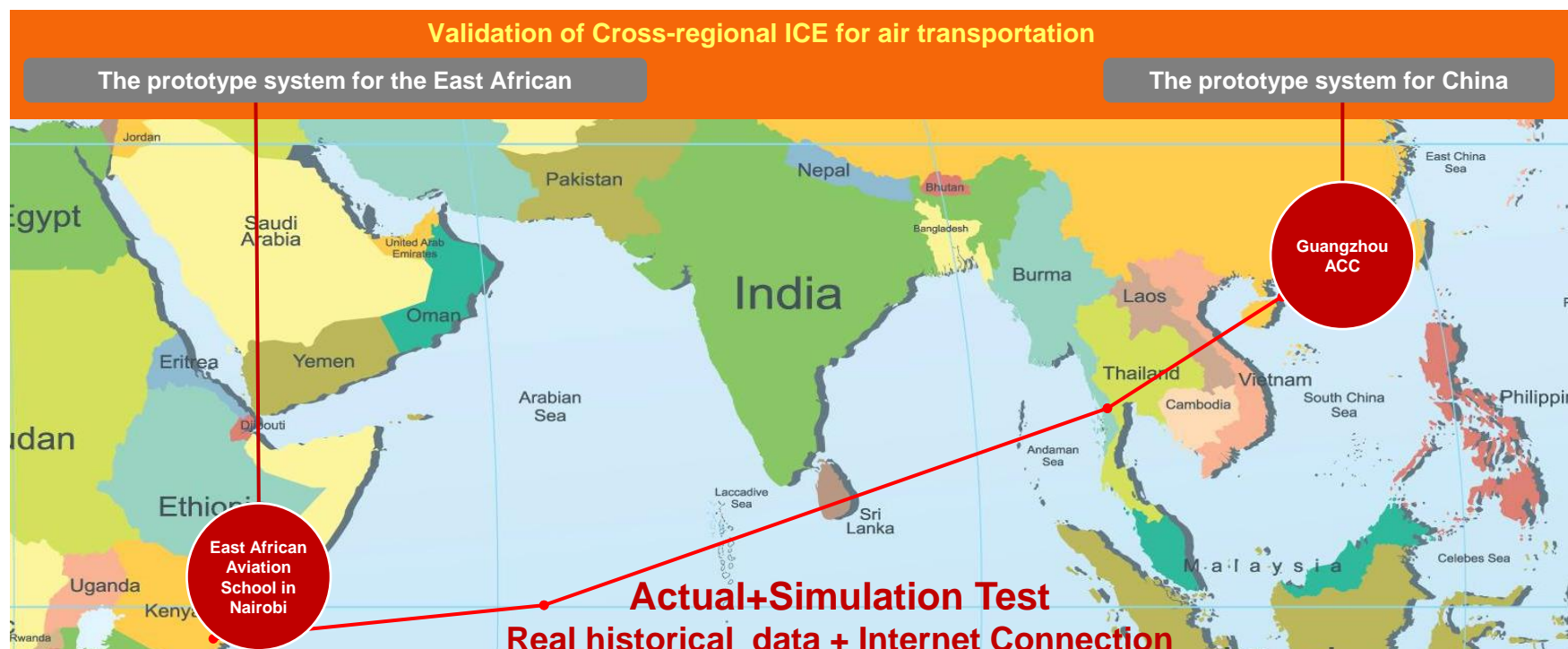
Flight Arrival Message

Submission Response Message

## 4. Cross-regional Validation

Supported by our national key R&D program, cross-regional ICE is studied for pre-departure trajectory negotiation of long-haul flights.

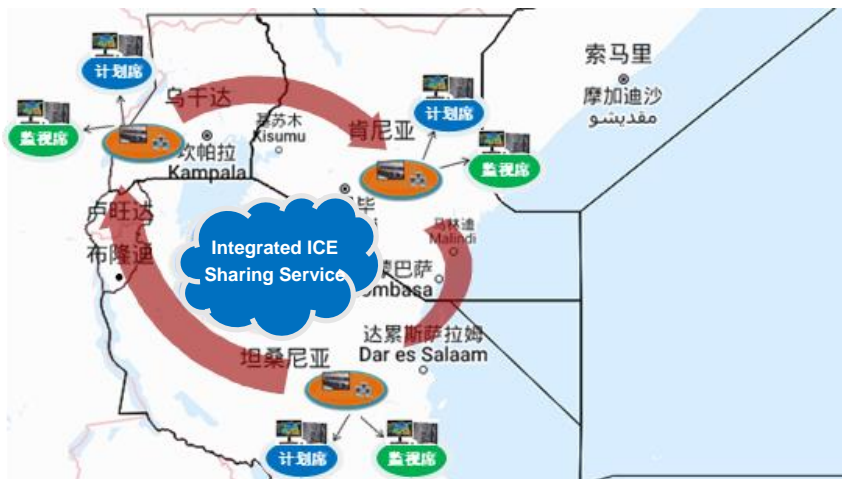
The flight from Guangzhou to Nairobi is selected for technical validation, providing feasible solution for the practical application of SWIM and FF-ICE.



# 4. Cross-regional Validation

In 2022 – 2023, two typical scenarios test is carried out, respectively, to validate the enhancements brought about by the developed integrated ICE for air transportation.

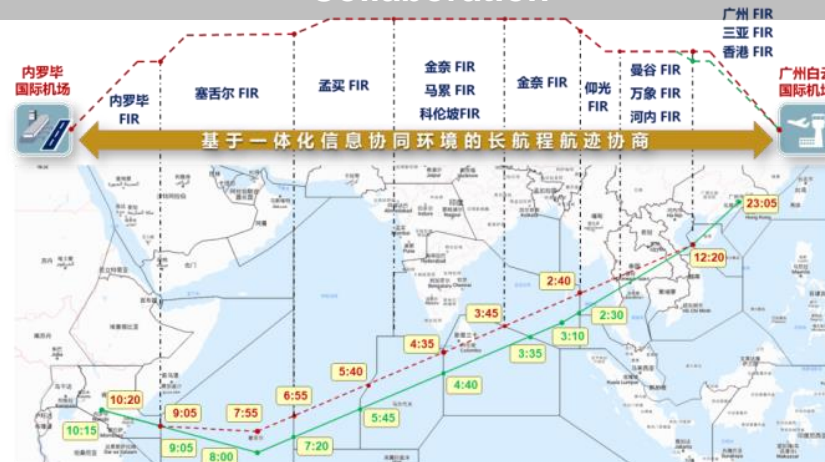
## Cross-regional ATM Information Sharing



**Capacity  
Validation**

Cross-regional information consistent sharing based on SWIM registry

## Long-haul Situational Monitoring and Collaboration

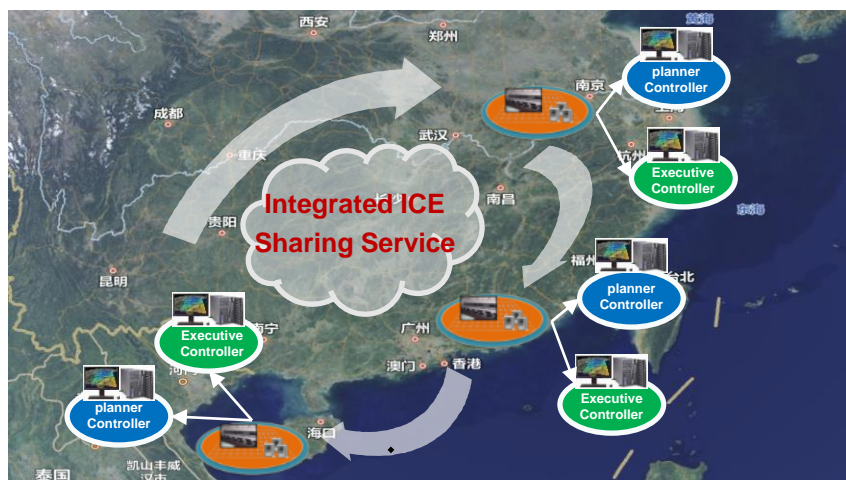


Collaborative trajectory planning for long-haul flight among AU and ASPs

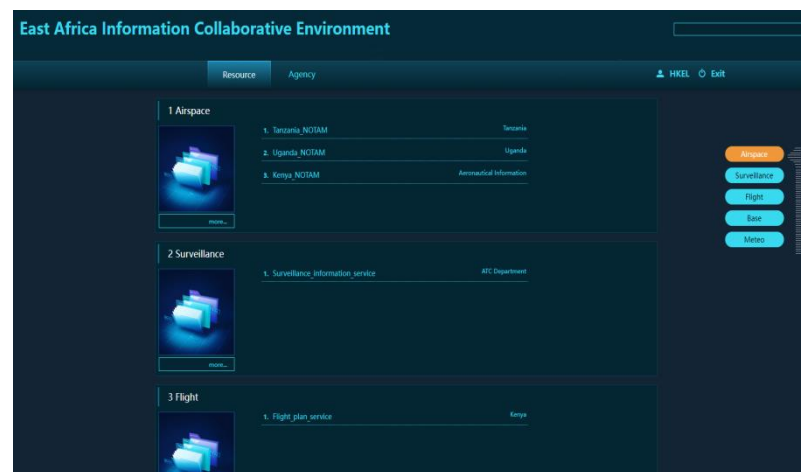
# 4. Cross-regional Validation

## (1) Cross-regional ATM Information Sharing

An integrated ICE is built by simulating Nanjing SKL, Guangzhou ACC, and Sanya ACC as Kenya, Tanzania, and Uganda ACCs in East Africa, respectively. Its service management and information sharing capabilities are validated by implementing surveillance information service subscription, approval and other activities.



Cross-regional ATM Information Sharing



Service Catalog in ICE for East Africa

Solving: 1) Flexibly access to services 2) Cross-regional information sharing



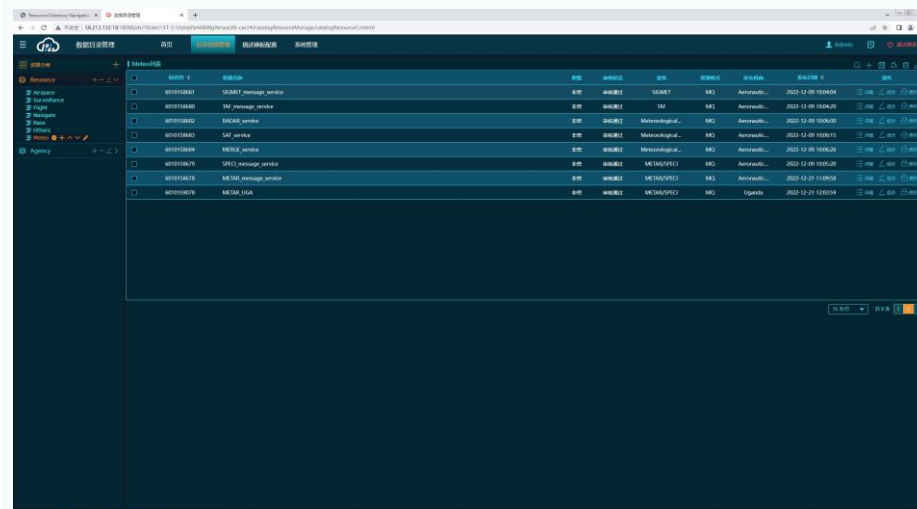
# 4. Cross-regional Validation

## (1) Cross-regional ATM Information Sharing

Validation steps:



## Service Approval



ID	Name	Status	Version	Created	Updated
00000001	SCAMT_message_service	正常	0.0.1	2022-12-09 10:04:54	
00000002	TAF_message_service	正常	0.0.1	2022-12-09 10:04:20	
00000003	RADAR_service	正常	0.0.1	2022-12-09 10:04:00	
00000004	SAT_service	正常	0.0.1	2022-12-09 10:03:15	
00000005	MBE_service	正常	0.0.1	2022-12-09 10:03:00	
00000006	SPCC_message_service	正常	0.0.1	2022-12-09 10:02:20	
00000007	NETM_message_service	正常	0.0.1	2022-12-21 11:09:58	
00000008	NETM_UCA	正常	0.0.1	2022-12-21 11:09:58	

(2) Service registry approves and publishes services;

# 4. Cross-regional Validation

## (1) Cross-regional ATM Information Sharing

Validation steps:



## Service Catalog → Service Subscription



(3) Kenya (Nanjing) ACC reviews the service catalog and subscribe to the surveillance information services;

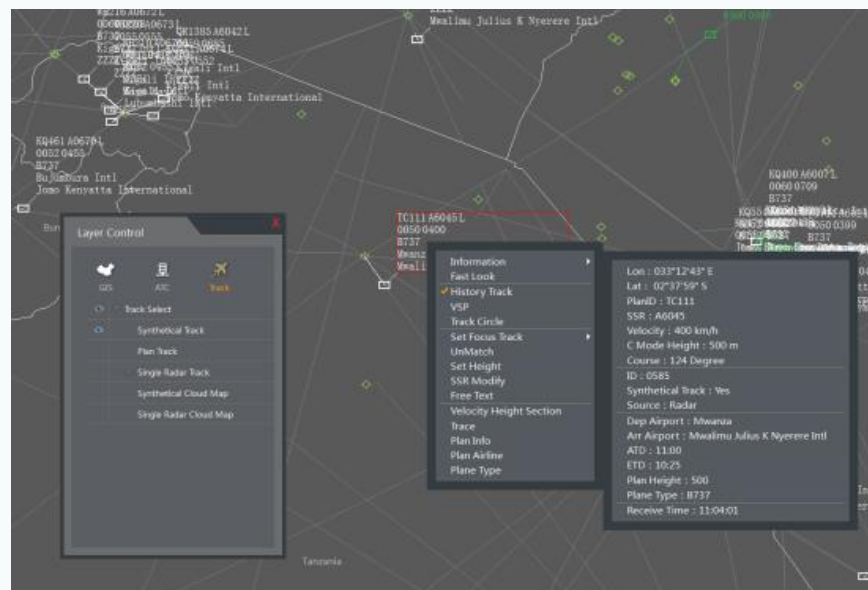
# 4. Cross-regional Validation

## (1) Cross-regional ATM Information Sharing

Validation steps:



## Surveillance Information Sharing



(4) The service registry approves the service subscription, and the Kenya (Nanjing) client successfully displays the cross-regional surveillance information.

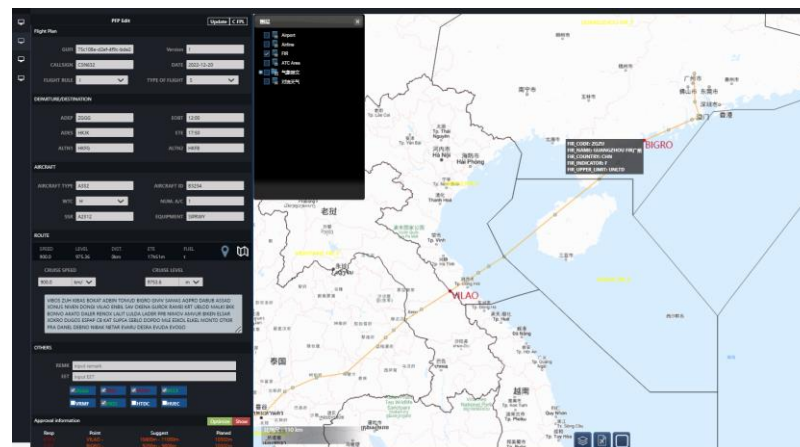
# 4. Cross-regional Validation

## (2) Long-haul Situational Monitoring and Collaboration

Before departure, China Southern Airlines plans a long-haul PFP (trajectory) from Guangzhou to Kenya, and sends it to ASPs along the route. ASPs examine the trajectory according to the relevant restrictions and the airline adjusts the trajectory according to their feedbacks. Finally, They reaches a consistent flight intention understanding and filing the agreed trajectory.



Long-haul Situational Monitoring and Collaboration



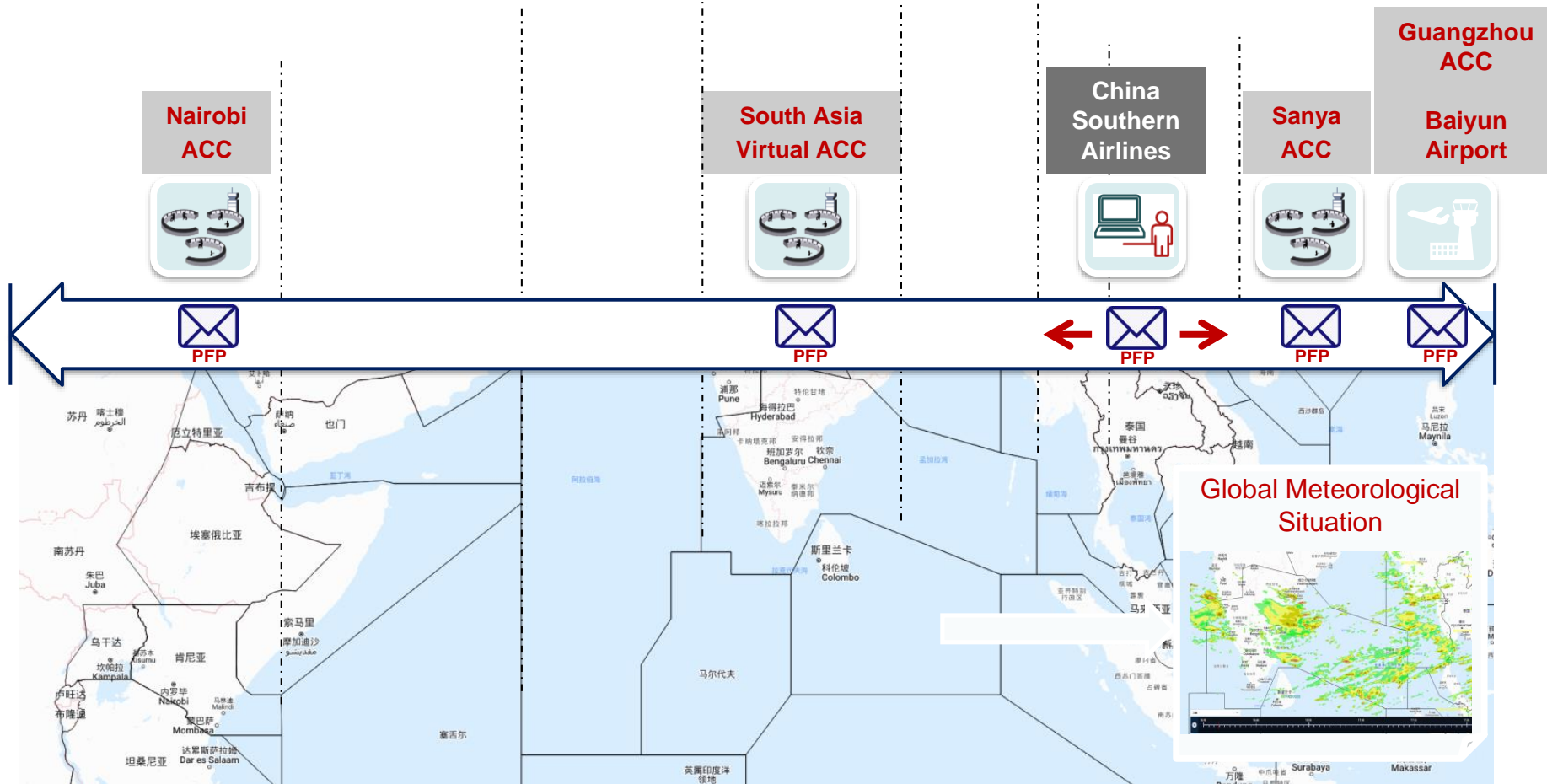
List of Trajectories to Be Negotiated and The Feeding Back Constraints

- Solving:
- 1) The inconsistent understanding of flight intention before departure
  - 2) Lots of temporary ATC adjustments are needed after departure

# 4. Cross-regional Validation

## (2) Long-haul Situational Monitoring and Collaboration

### Validation steps:

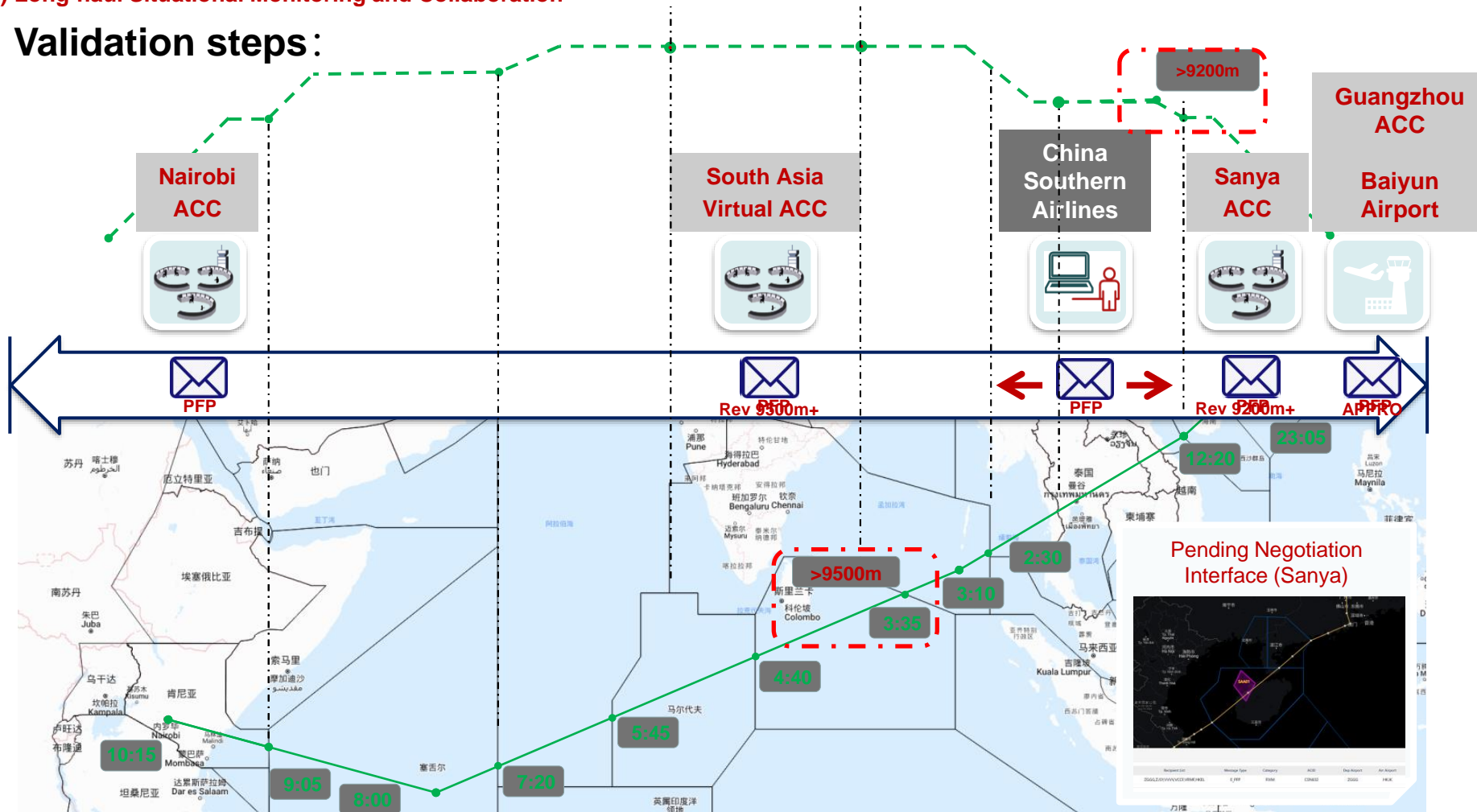


(2) CSA plans a PFP, and publish it to the selected ASPs through ICE;

# 4. Cross-regional Validation

## (2) Long-haul Situational Monitoring and Collaboration

### Validation steps:

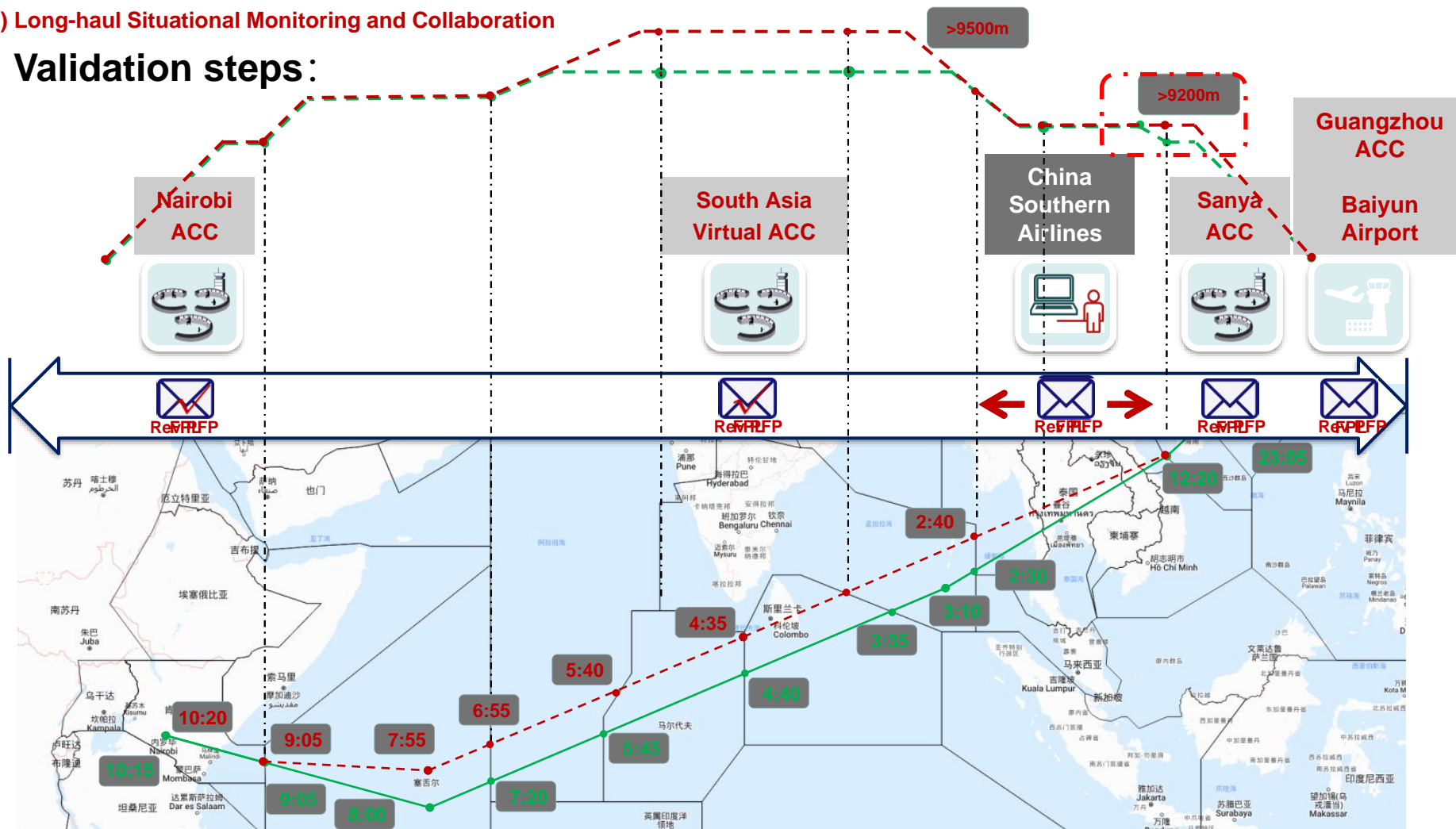


(6) South Asia gives its feedback on the Flight level in its FIR

# 4. Cross-regional Validation

## (2) Long-haul Situational Monitoring and Collaboration

### Validation steps:



(9) CSA confirms that all ASPs have approved the trajectory and submits the FPL several hours before takeoff.

# Content

**1.**

**TBO-oriented Information Collaborative Technology**

**2.**

**Works on SWIM and FF-ICE**

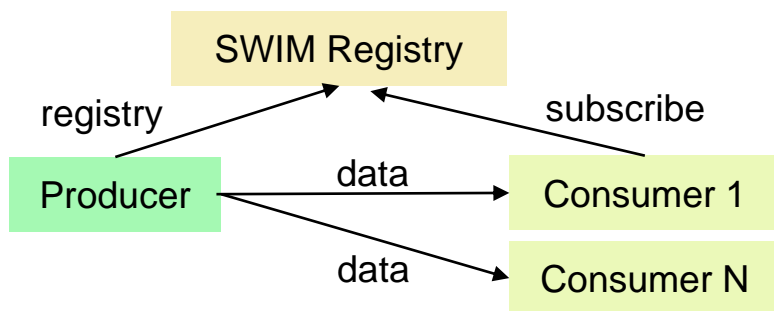
**3.**

**Conclusion & Prospects**

# Conclusion

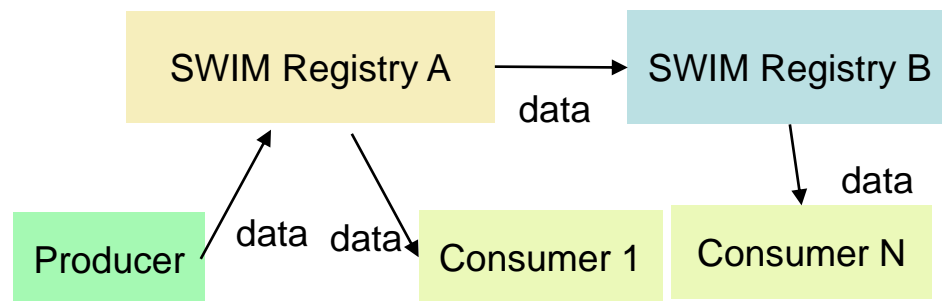
## Technical Infrastructure

The IP network is essential to support the interconnection of systems.



**Advantage:** All shared information is only transmitted between the service providers and consumers

**Disadvantage:** IP-based network between the service provider and all consumers is necessary



**Advantage:** Each service provider and consumer only needs to connect to the local message bus through IP network

**Disadvantage:** All shared data will pass through EMS, increasing the risk of data leakage

# Conclusion

## Technical Infrastructure

### Message routing rules between different SWIM nodes are required

- ① Addresses are divided into two categories, one is SWIM node message receiving address, the other is user message receiving address.
- ② Each SWIM node needs to maintain the addresses of all interconnected SWIM nodes and the mapping relationship between SWIM nodes and users.
- ③ Each SWIM node needs to maintain the addresses of all users in its region
- ④ Each user needs to firstly send the message to the SWIM node in its local region, and then the regional node uniformly performs intra-regional routing and inter-regional routing.
- ⑤ When SWIM node routes within the region, it directly sends the message to the receiving address of internal user
- ⑥ When SWIM node routes outside the region, it only sends the message to the corresponding SWIM node. The message is routed to the final user by that SWIM node.

# Conclusion

## Information Exchange Model

### How to reach an agreement on trajectory negotiation?

- ① It is necessary to reach an agreement on the mandatory elements in FF-ICE Message.
- ② It is necessary to formulate governance rules to ensure the quality of negotiated trajectory elements in the information exchange model, including the waypoint time, altitude, position, etc.
- ③ It is necessary to develop a trajectory negotiation implementation specification, guiding how to generate a feasible trajectory when there are inconsistent trajectory constraints among multiple stakeholders.

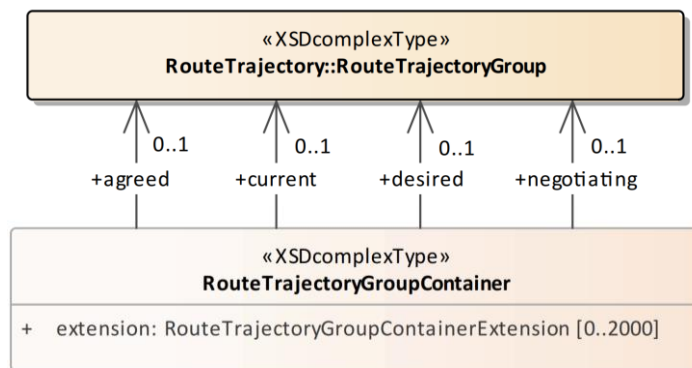
# Prospects

## 1) ATM automation system improvement for post-departure trajectory negotiation:

- It should support the functions of sharing, displaying, processing, predicting of all-phase 4DTs (strategic, pre-tactical, tactical) based on the FIXM.
- It should support the processing of multi-trajectory for one flight.



**FIXM Core v4.3.0**  
Logical Model Diagrams



## 2) ATM automation system improvement for information exchange services:

- It should flexibly access to the future SWIM, so as to subscribe and publish corresponding information.
- For future large scale service requests to ATM automation systems, we suggested to establish service centers between the ATM automation systems and the SWIM ( for information services of surveillance, meteorological, flight plan, etc.).

# ***Thanks!***

*Looking forward to progress together !*

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*Responsibility Innovation Excellence Shared*