



# SWIMによる軌道ベース運用 に関する実証実験

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○呂 暁東, 森岡 和行, 金田 直樹, 古賀 禎,  
ビクラマシンハナヴィンダ キトマル, 平林 博子, ブラウン マーク

電子航法研究所 監視通信領域 航空交通管理領域

2022年6月17日

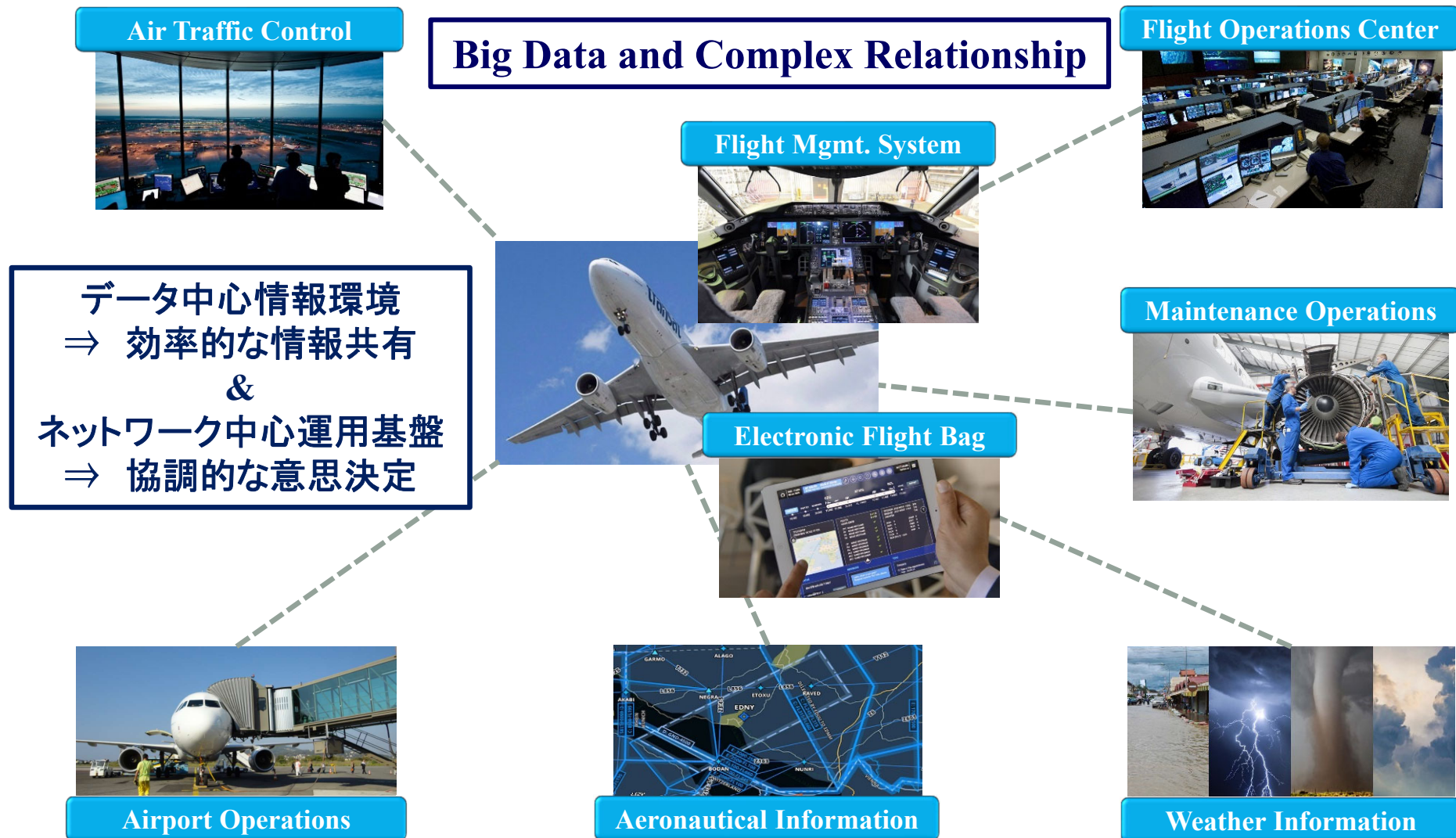
# Agenda

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1. 背景
2. 軌道ベース運用について
3. 実証実験の概要
4. TBO実証実験
5. 分析と課題
6. まとめ

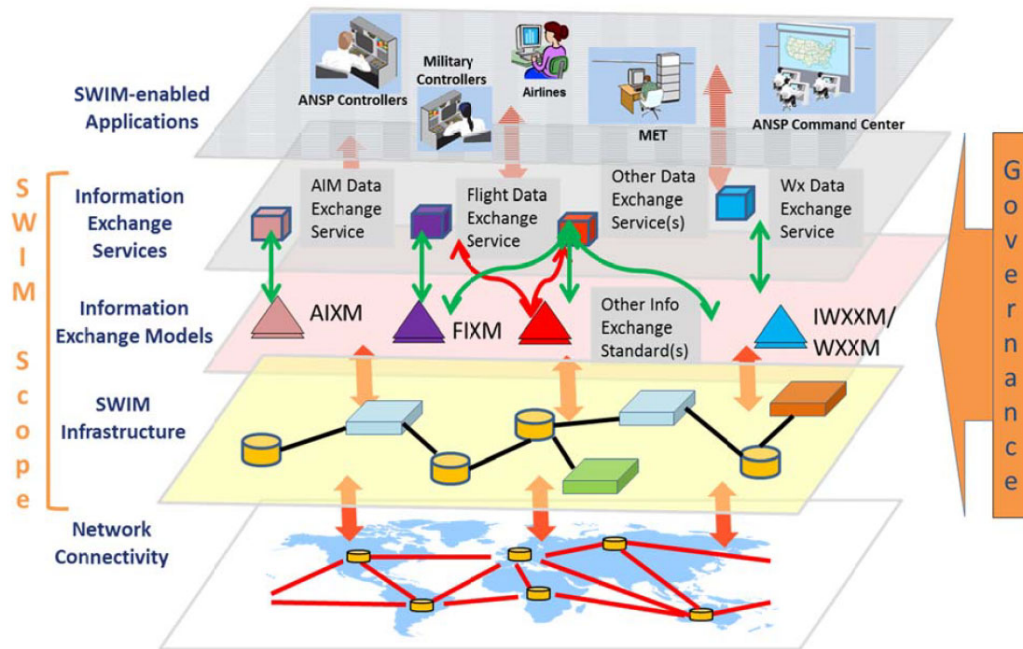
# 背景：航空機

## ➤ Connected Aircraft



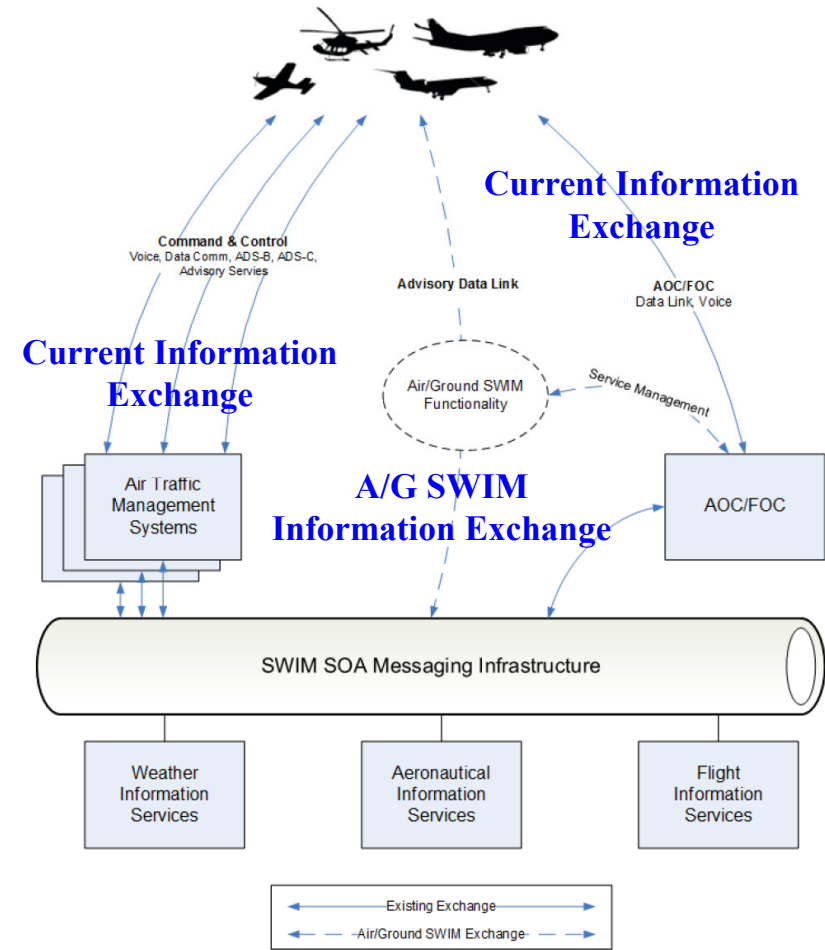
# 背景：情報共有基盤

## ➤ System Wide Information Management (SWIM)



### ICAO SWIM Framework

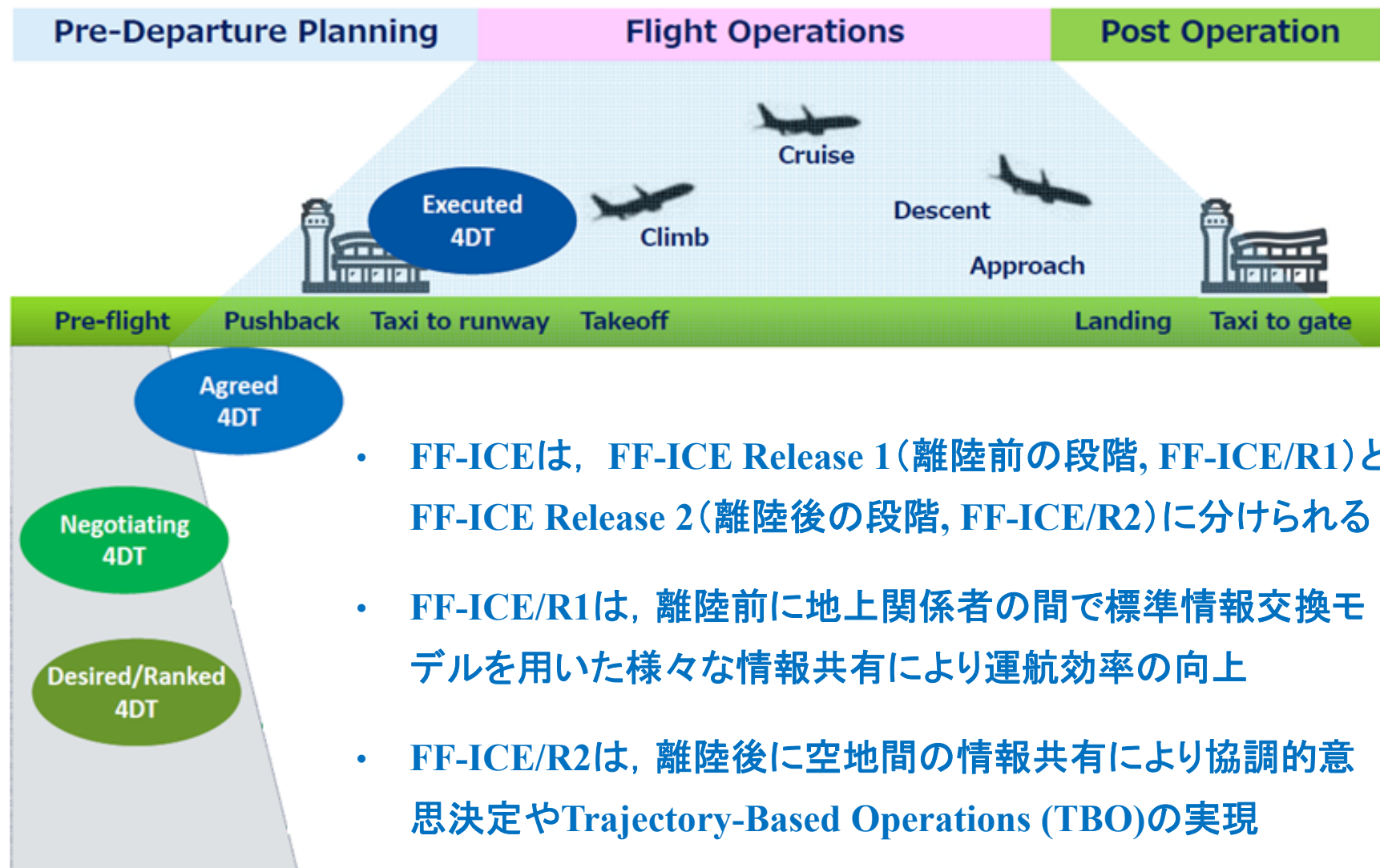
- FIXM (Flight Information eXchange Model)
- AIXM (Aeronautical Information eXchange Model)
- IWXXM (ICAO Weather Information eXchange Model)



### A/G Information Exchange with SWIM

# 背景：運用方式

## ➤ Flight and Flow Information for Collaborative Environment (FF-ICE)



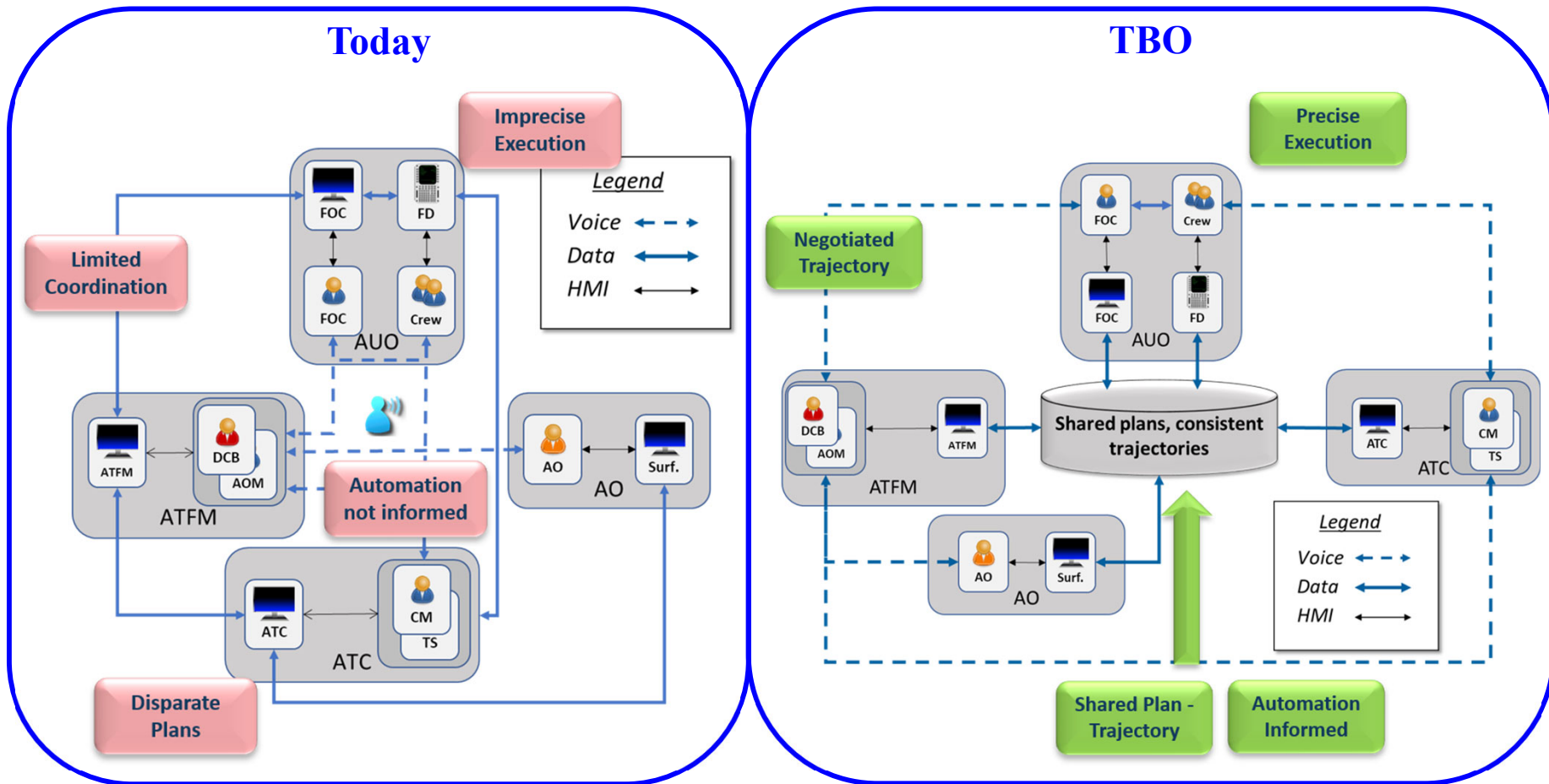
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# 軌道ベース運用について

## ➤ Trajectory-Based Operations (TBO)

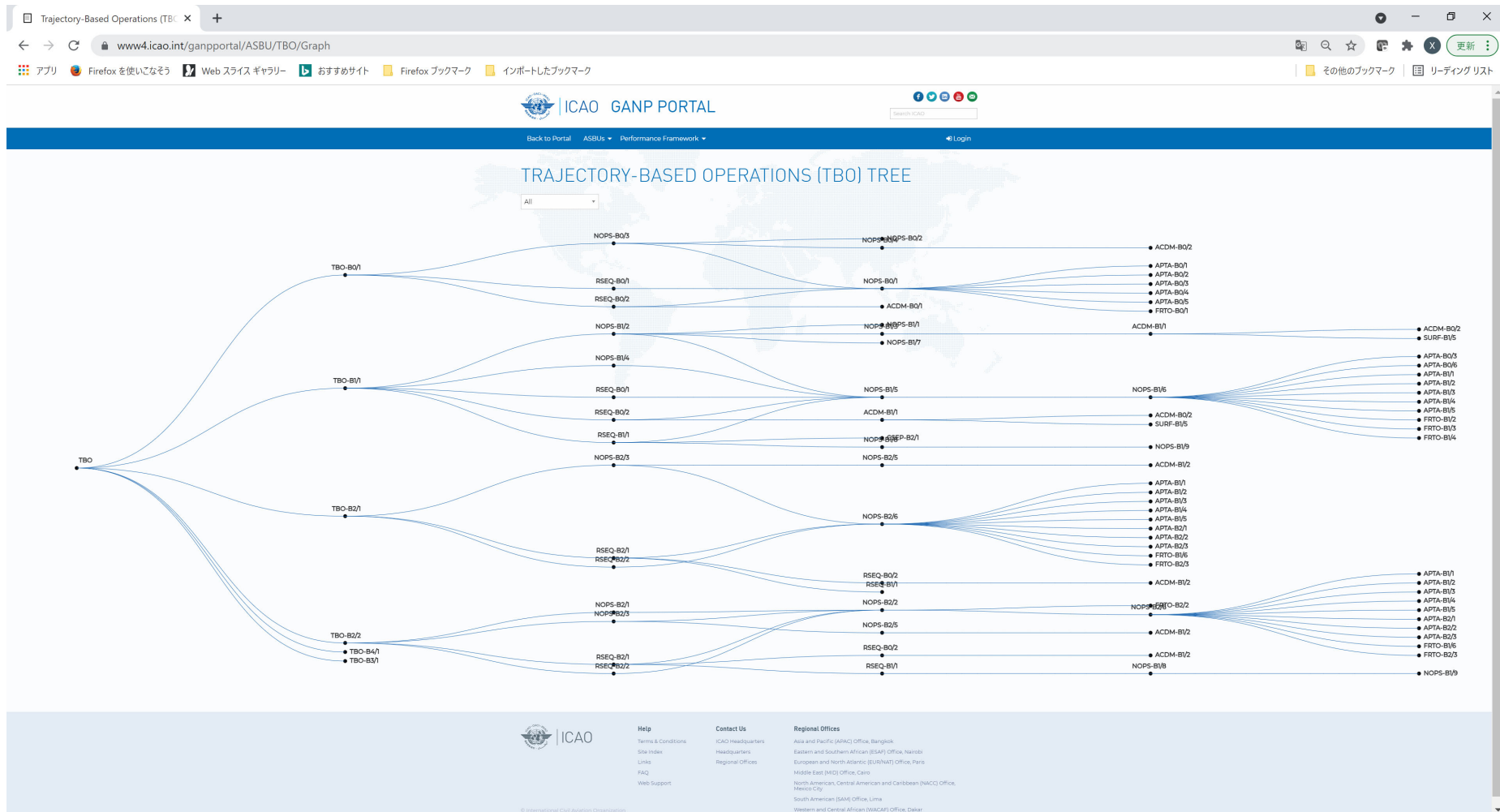


Voice-centric Communication  
Point based Negotiation

Data-centric Communication  
Trajectory based Negotiation

# 軌道ベース運用について



## ➤ TBO Tree in ICAO GANP





# 軌道ベース運用について

## ➤ Threads and Elements

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.		
ELEMENTS			
Element ID	Title		
TBO-B0/1	Introduction of time-based management within a flow centric approach.		
TBO-B1/1	Initial Integration of time-based decision making processes		
TBO-B2/1	Pre-departure trajectory synchronization within a flight centric and network performance approach		
TBO-B2/2	Extended time-based management across multiple FIRs for active flight synchronization		
TBO-B3/1	Network based on-demand synchronization of trajectory based operations		
TBO-B4/1	Total airspace management performance system		

# Agenda

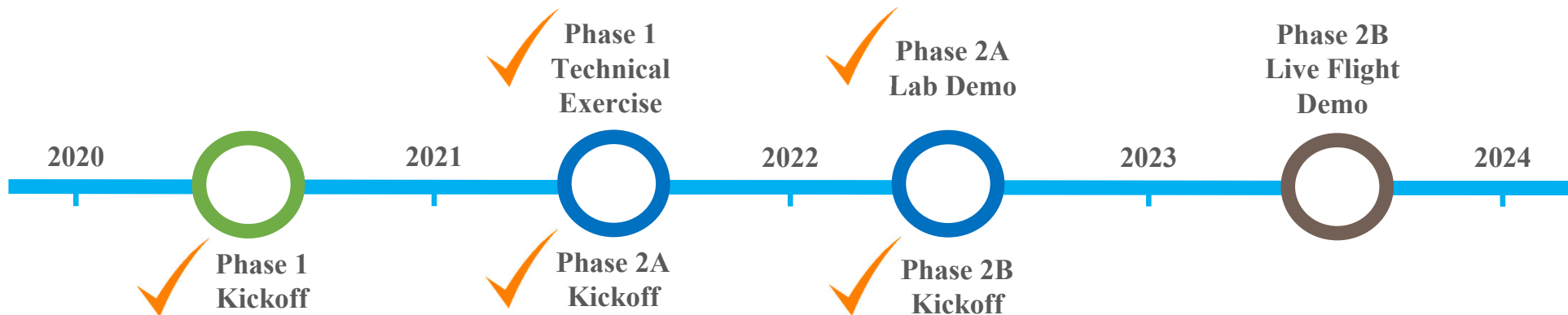
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# 実証実験の概要

## ➤ Multiple-Regional TBO Demonstration (MR TBO)

- Approach
  - Phase 1: 単独航空機に対する運用要件と技術要件の検討
  - Phase 2A: 複数航空機に対する飛行軌道と交通流の管理
  - Phase 2B: 実際の飛行実証実験による技術標準の検討
- Partners
  - FAA, NAV CANADA
  - AEROTHIAI, CAAS, JCAB



# 実証実験の概要

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## ➤ 実施目的

- 必要な軌道情報や交通流情報の共有
  - 交通流情報交換モデル(FLXM)の検証
- 協調的な軌道管理と交通流管理の実現
  - 既存航空交通管理システムとの連携
- 軌道情報の効率的な利活用方法の検討
  - 状況認識や予測精度の向上
- SWIMに基づいた航空情報信頼基盤の構築
  - セキュリティサービス基本機能の検証

# 実証実験の概要

## ➤ 運用面と技術面の検討

Operational Value	Operational Capability	Technical Capability
予測可能性の強化	離陸前の飛行計画の調整	FF-ICE/R1 + 標準情報交換モデル (FIXM, AIXM, IWXXM)
戦略的計画と 戦術的処理の調整	離陸後の飛行軌道の調整	FF-ICE/R2 + 協調的意思決定 (FLXM)
信頼性と柔軟性の向上	ATMサービス提供者間での 軌道管理	FF-ICE/R2 + AIDC
戦略的計画の改善	戦術的介入の調和	ATC + FMS + EFB
状況認識の向上 と不確実性の低減	空地情報共有	IP Connectivity + Connected Aircraft

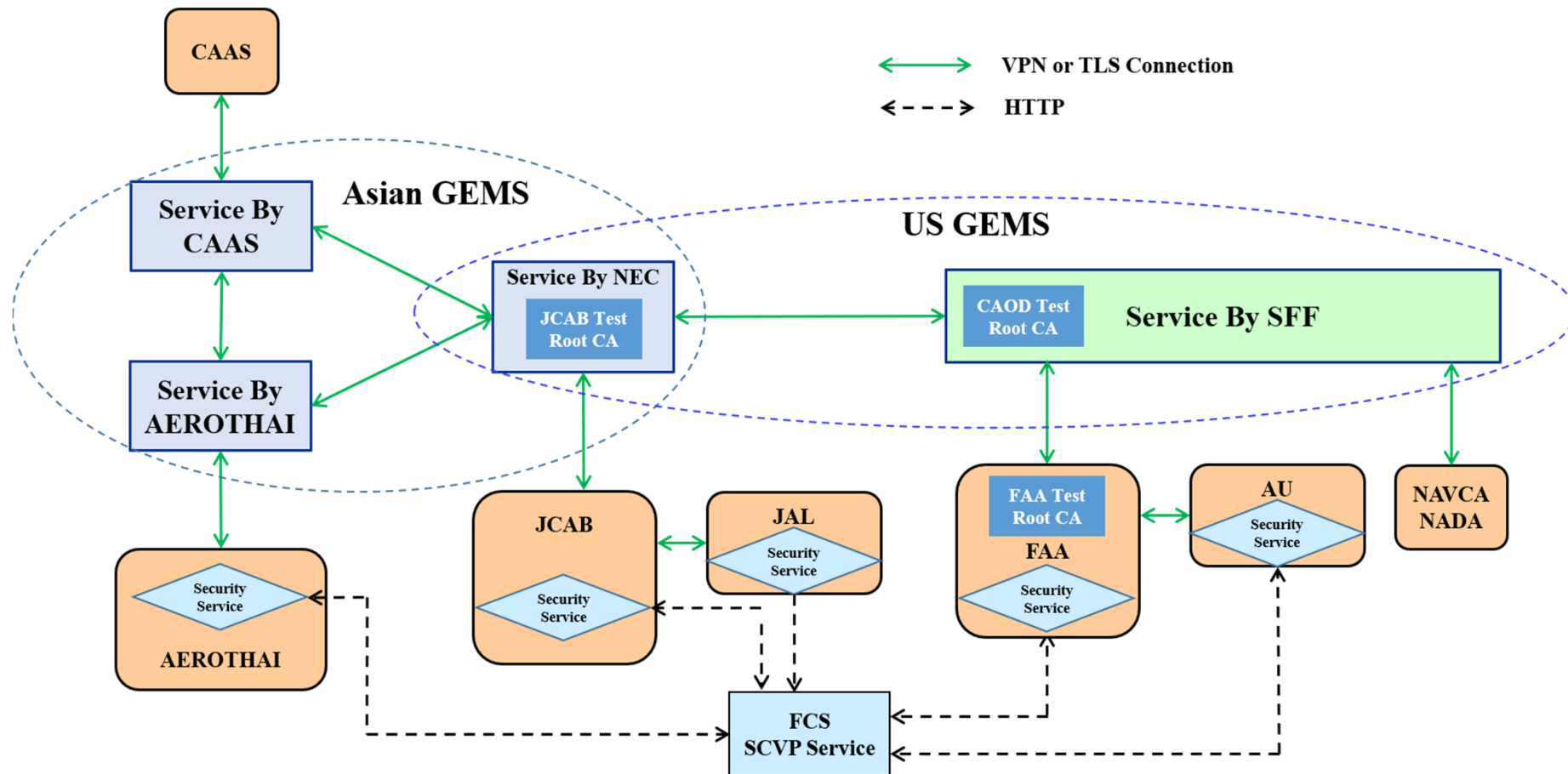
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# TBO実証実験

## ➤ High Level Architecture

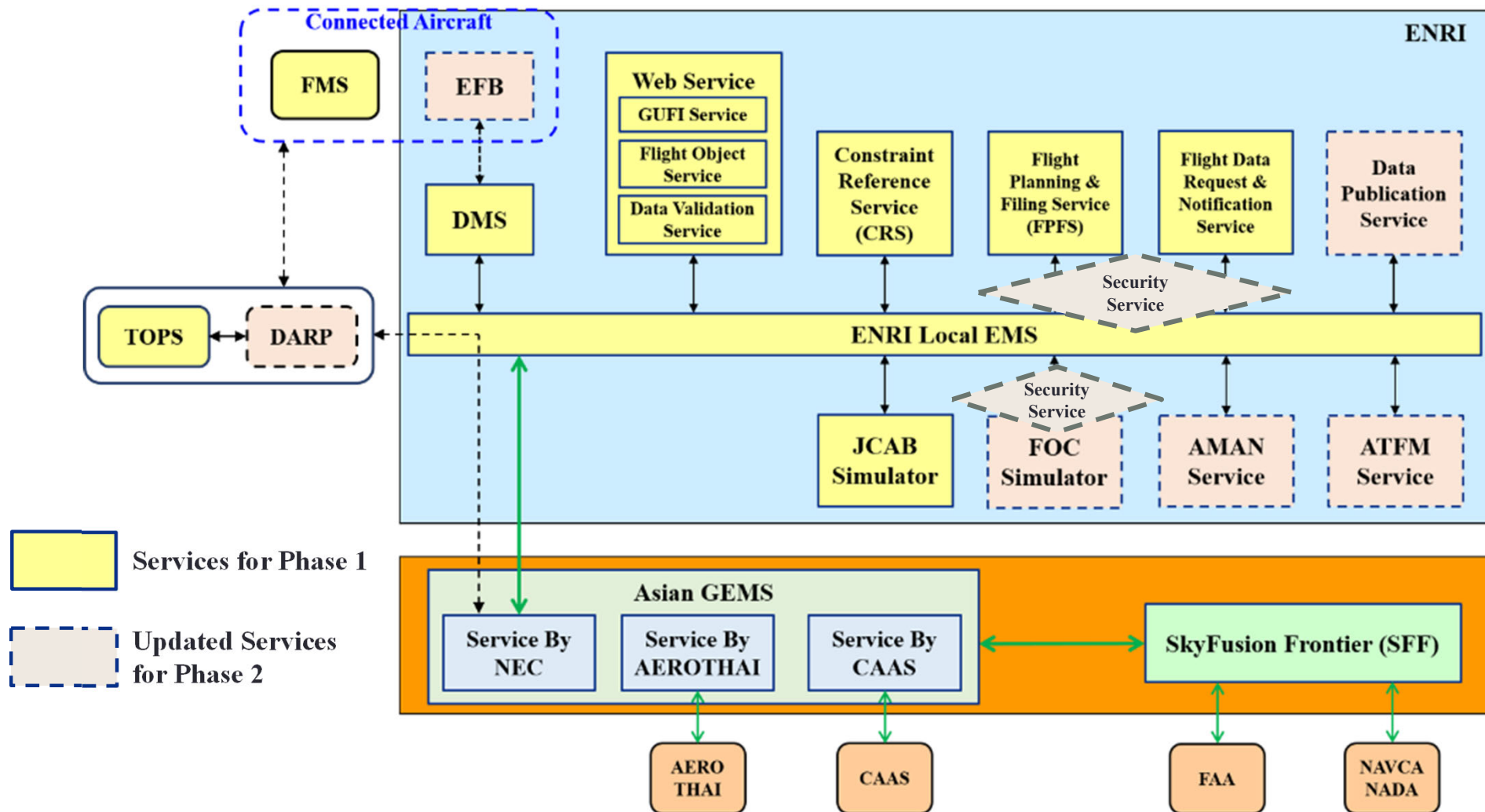


\* GEMS: Global Enterprise Messaging Service

\* SCVP: Server-based Certificate Validation Protocol

# TBO実証実験

## ➤ ENRI Test System





# TBO実証実験

## ➤ Scenarios: Trajectory-Based Multiple Flights Operation

**Simulator**

CONTROL FF-ICE TRACK METAR/TAF MESSAGE

No. 52

Scenario SC1: JCAB (For running multiple scenarios)

Index 10176

Time 2022-04-28T13:23:15.415Z

Status RECV

Header Validation OK

Body Validation OK

Modified 1651152195415

**MESSAGE HEADER**

SOURCE BOEINGDMS

RECIPIENT\_LIST JCAB,FAA

SYSTEM BOEINGDMS

CATEGORY FIXM

CATEGORY\_VERSION FIXM\_4\_2\_FF-ICE

MESSAGE\_TYPE E\_TRIAL\_REQ

FFICE\_PHASE FILED

DEP\_AIRPORT KIAH

ARR\_AIRPORT RJAA

AIRLINE UAL

ACID UAL7

GUF 298bc90c-d4d1-4502-aa61-f7f83d59af72

EOBT 2022-04-28T12:30:00.000Z

TIMESTAMP ENR\_OUTSIDE\_IN:1651151602443,ENR\_OUTSIDE\_OUT:1651152444,ENR\_EMS\_IN:1651152192879,ENR\_EMS\_OUT:1651152195415,JCAB\_IN:1651152195415

ESHPOC\_VALIDATION\_STATUS SUCCESSFUL\_VALIDATION

**FIXM**

Message Id 46aca325-fcdf-47c8-a439-7508197d1a7a

Flight Plan Version

Status

Status Explanation

**RWY CLSD at RJAA**

**Volcanic Ashe**

**SIGMET of Typhoon**

**Signed message from UAL and FAA**

**JAL9: KSFO -> RJAA**

**SIA37: KLAX -> WSSS**

**JAL707X: RJAA -> VTBS**  
**SIA7473: RJAA -> VTBS**

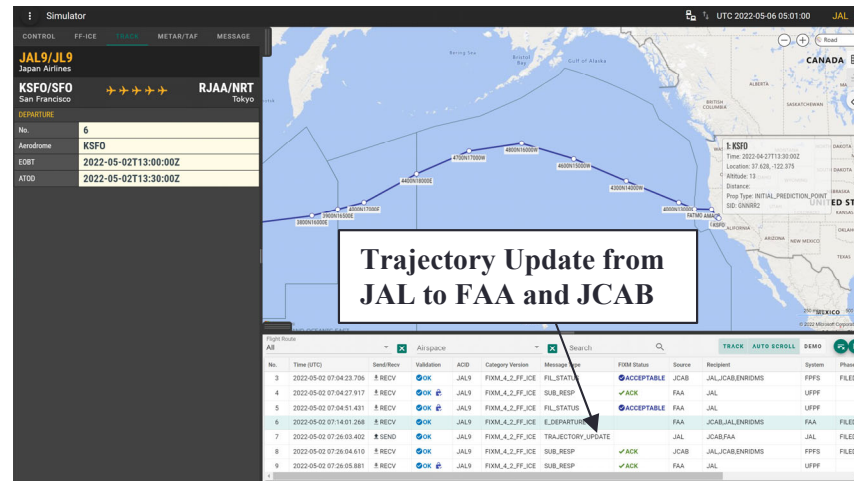
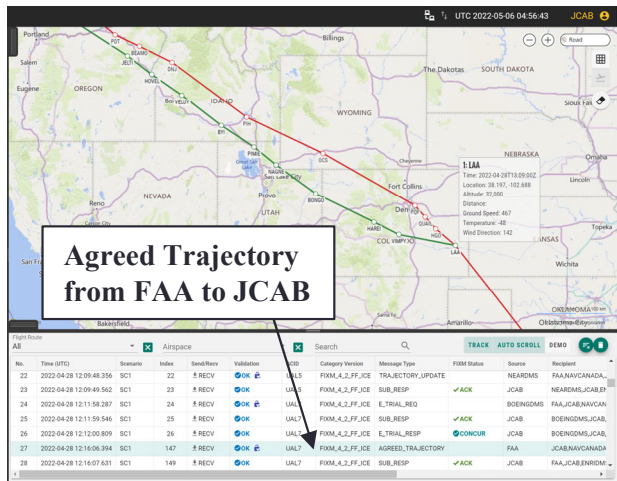
**UAL5: KDEN -> RJAA**  
**UAL7: KIAH -> RJAA**

No.	Time (UTC)	Scenario	Index	Send/Recv	Validation	ACID	Category Version	Message Type	FIXM Status	Source	Recipient
51	2022-04-28 13:22:43.178	SC1	10110	SEND	OK	JAL9	FIXM_4_2_NAS	TRACK		JCAB	JAL_ENRDMMS,JCAB
52	2022-04-28 13:23:15.415	SC1	10176	RECV	OK	UAL7	FIXM_4_2_FF-ICE	E_TRIAL_REQ		BOEINGDMS	JCAB,FAA
53	2022-04-28 13:23:16.516	SC1	10179	RECV	OK	UAL7	FIXM_4_2_FF-ICE	SUB_RESP	ACK	JCAB	BOEINGDMS,JCAB,I
54	2022-04-28 13:23:17.646	SC1	10182	RECV	OK	UAL7	FIXM_4_2_FF-ICE	E_TRIAL_RESP	CONCUR	JCAB	BOEINGDMS,JCAB,I
55	2022-04-28 13:24:56.165	SC1	10381	RECV	OK	UAL7	FIXM_4_2_FF-ICE	AGREED_TRAJECTORY		FAA	FAA,JCAB,NAVCAN
56	2022-04-28 13:24:57.261	SC1	10384	RECV	OK	UAL7	FIXM_4_2_FF-ICE	SUB_RESP	ACK	JCAB	FAA,JCAB,ENRDMMS
57	2022-04-28 13:31:36.956	SC1	11185	SEND	OK	AIXM_5_1		NOTAM		JCAB	JAL_FAA,ENRDMMS,E

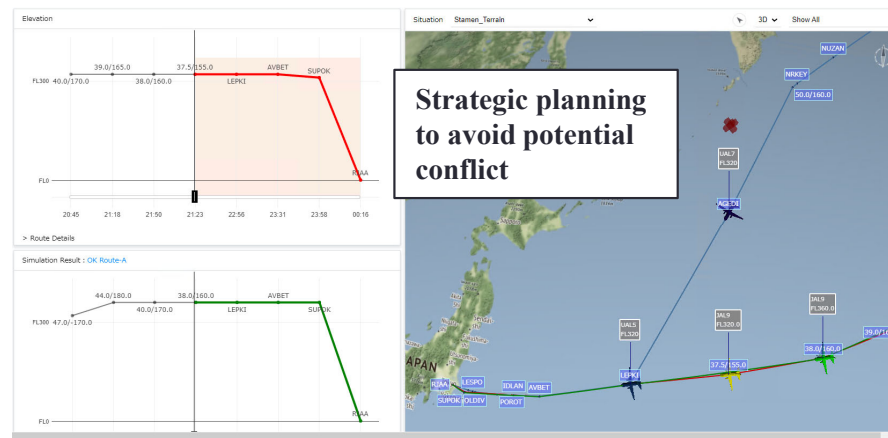
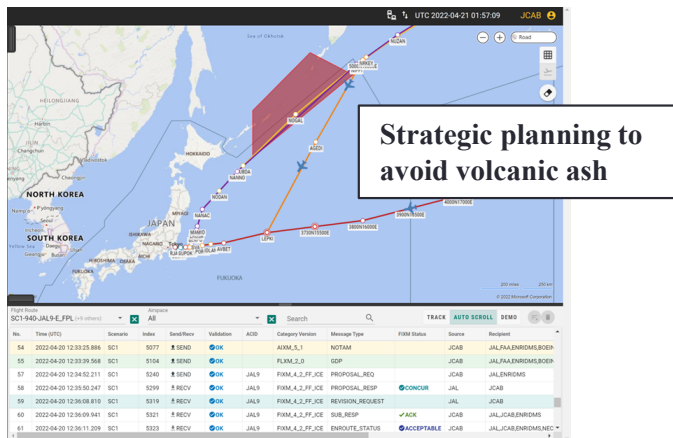
# TBO実証実験

## ➤ Trajectory Sharing, Management and Utilization

### Trajectory Sharing



### Trajectory based Evaluation



# TBO実証実験

## ➤ Trajectory Sharing, Management and Utilization

### Trajectory Based Flow Management

ENRI SWIM Departure Arrival Management System (DAMS)

Capacity (2)

MsgType	MsgID	Start Time
NOTAM	NOTAM_RIAA_RVY_CLSO_TBO_Phase2	2022-03-30 10:00

AMQP Header

FLXM GDP Message

```

1: {
2:   "header": {
3:     "version": "1.0",
4:     "sender": "JAL",
5:     "receiver": "JAL",
6:     "type": "FLXM_GDP",
7:     "priority": "NORMAL",
8:     "subject": "FLXM_GDP",
9:     "body": "FLXM_GDP",
10:    "timestamp": "2022-03-30 10:00:00",
11:    "sender_ref": "1",
12:    "receiver_ref": "1",
13:    "sender_ref_time": "2022-03-30 10:00:00",
14:    "receiver_ref_time": "2022-03-30 10:00:00",
15:    "sender_ref_timezone": "JST",
16:    "receiver_ref_timezone": "JST",
17:    "sender_ref_offset": "+09:00",
18:    "receiver_ref_offset": "+09:00",
19:    "sender_ref_datetime": "2022-03-30 19:19:19",
20:    "receiver_ref_datetime": "2022-03-30 19:19:19",
21:    "sender_ref_timezone_offset": "+09:00",
22:    "receiver_ref_timezone_offset": "+09:00",
23:    "sender_ref_datetime_offset": "+09:00",
24:    "receiver_ref_datetime_offset": "+09:00"
25:  },
26:   "body": {
27:     "type": "FLXM_GDP",
28:     "priority": "NORMAL",
29:     "subject": "FLXM_GDP",
30:     "body": "FLXM_GDP"
31:   }
32: }
  
```

Arrival Demand (4)

ACID	DEP	ARR	EOST/ADT
UAL5	KDEN	RIAA	2022-03-29 19:18
JAL9	KFSO	RIAA	2022-03-30 02:15
UAL5	KDEN	RIAA	2022-03-30 00:59
UAL7	KJAH	RIAA	2022-03-30 01:25

Time Crossing Time Loss/Gain Time

Time	Crossing Time	Loss/Gain Time
0:00:00	0:00:00	0:00:00
10:58:18	0:00:00	-0:00:19
10:44:44	0:00:00	-0:00:38
10:41:43	0:00:00	-0:00:57
10:14:35	0:00:00	-0:01:16
09:39:02	0:00:00	-0:01:35
08:33:26	0:00:00	-0:01:54

FLXM GDP Message with CLDT to related eAUs

Proposed CTO and Altitude to JAL and UAL7

5-LEPU  
Time: 2022-04-20 11:17:39  
Location: 37.465, 140.000  
Altitude: 3500  
Distance: 7395  
Alt: Level: 400  
Prop Type: TOP\_OF\_DESCENT

Modified Route  
Condition: AT\_OR\_BEFORE  
Value: 2022-04-20 11:17:39  
Condition: AT\_OR\_ABOVE  
Value: 3500

No.	Time (UTC)	Scenario	Index	Send/Rev	Validation	ACID	Category	Version	Message Type	FIM Status	Source	Recipient
57	2022-04-20 12:34:52.211	SCI	5240	SEND	OK	JAL9	FIMM_4_2_FF_JCE	PROPOSAL_REQ		CONCUR	JAL	JALENRIMS
58	2022-04-20 12:55:24.7	SCI	5299	RECV	OK	JAL9	FIMM_4_2_FF_JCE	PROPOSAL_RESP		CONCUR	JAL	JCAB
59	2022-04-20 12:58:08.810	SCI	5319	RECV	OK	JAL9	FIMM_4_2_FF_JCE	REVISION_REQUEST		ACK	JCAB	JAL_CJAHENRIMS
60	2022-04-20 12:58:09.941	SCI	5321	RECV	OK	JAL9	FIMM_4_2_FF_JCE	SUB_RESP		ACCEPTABLE	JCAB	JAL_CJAHENRIMS
61	2022-04-20 12:58:11.209	SCI	5323	RECV	OK	JAL9	FIMM_4_2_FF_JCE	ENROUTE_STATUS		ACCEPTABLE	JCAB	JAL_CJAHENRIMS
62	2022-04-20 12:58:17.966	SCI	5347	RECV	OK	UAL7	FIMM_4_2_FF_JCE	PROPOSAL_REQ		CONCUR	JCAB	BOENIGMS
64	2022-04-20 12:58:46.634	SCI	5351	RECV	OK	UAL7	FIMM_4_2_FF_JCE	PROPOSAL_RESP		CONCUR	BOENIGMS	JCAB

### Trajectory Based A/G Coordination

Electronic Flight Bag for JAL7/JL0

Flight: JAL7/JL0  
Route: KFSO/SFO → RJAA/NRT  
Altitude: 400,000 ft  
Speed: 35,700 kts  
Fuel: 141,404 kgs

EFB for Trajectory Sharing, Management and Utilization

TQPS MsgData

No.	Time (UTC)	Scenario	Index	Send/Rev	Validation	ACID	Category	Version	Message Type	FIM Status	Source	Recipient
3	2022-04-27 07:19:54.553	R	NEC	FMS	ATS	DEP_CLEARANCE	TOPS	RIAA	VTBS	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:19:54.553
4	2022-04-27 07:20:13.648	S	NEC	TOPS	FMS	DEP_CLEARANCE	FMS	RIAA	VTBS	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:20:13.648
5	2022-04-27 07:20:58.974	S	NEC	TOPS	FIMM	DEPARTURE	JCAB	RIAA	VTBS	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:20:58.974
6	2022-04-27 07:21:02.966	R	JCAB	FIMM	FIMM	DEPARTURE	AEROTHANE	RIAA	VTBS	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:21:02.966
7	2022-04-27 07:14:52.597	R	FAA	ADOP	FIMM	CPL	NEC	UAL5	UAL5	UAL5	bef17805-a68-467-8177-08b203546092	null
8	2022-04-27 07:15:08.134	S	NEC	TOPS	FIMM	ACP	JCAB/FAA	KDEN	RIAA	UAL5	bef17805-a68-467-8177-08b203546092	2022-04-27 07:15:08.134
9	2022-04-27 07:17:20.894	R	FAA	ADOP	FIMM	CDN	NEC	UAL5	UAL5	bef17805-a68-467-8177-08b203546092	null	
10	2022-04-27 07:17:34.712	S	NEC	TOPS	FIMM	ACP	JCAB/FAA	KDEN	RIAA	UAL5	bef17805-a68-467-8177-08b203546092	2022-04-27 07:17:34.712
11	2022-04-27 07:37:07.983	R	JCAB	PPFS	FIMM	ENROUTE_STATUS	NEC	KFSO	RIAA	JAL9	bef7baac-9929-4c3-90d8-a51b2632182	2022-04-27 07:37:07.983
12	2022-04-27 07:40:53.088	R	NEC	FMS	ATS	CPDCL-DOWNLINK	TOPS	KFSO	RIAA	JAL9	bef7baac-9929-4c3-90d8-a51b2632182	2022-04-27 07:40:53.088
13	2022-04-27 07:41:01.791	S	NEC	TOPS	ATS	CPDCL-UPLINK	FMS	KFSO	RIAA	JAL9	bef7baac-9929-4c3-90d8-a51b2632182	2022-04-27 07:41:01.791

FMS MsgData

FMS Simulator

Msg Data

No.	Time	Type	Source	System	Category	ACID	EOST	MsgData		
1	2022-04-27 07:19:46.716	S	NEC	FMS	ATS	DEP_CLEARANCE	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:19:46.716	+msg-DEP-LOG-CONNECT+msg+
2	2022-04-27 07:20:19.072	S	NEC	TOPS	ATS	DEP_CLEARANCE	JAL707X	E313212-348-424-bbec-a83747280	2022-04-27 07:20:19.072	+msg-ACCEPT+msg+
3	2022-04-27 07:24:46.048	S	NEC	FMS	ATS	CPDCL-DOWNLINK	JAL9	bef7baac-9929-4c3-90d8-a51b2632182	2022-04-27 07:24:46.048	+msg-REQUEST CLIMB TO FL360+msg+
4	2022-04-27 07:41:04.420	R	NEC	TOPS	ATS	CPDCL-UPLINK	JAL9	bef7baac-9929-4c3-90d8-a51b2632182	2022-04-27 07:41:04.420	+msg-CLIMB TO AND MAINTAIN FL360REPORT LEVEL FL360+msg+

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# 分析と課題

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- SWIM技術インフラの構築について
  - 異なる技術仕様を使う GEMS提供者の間で接続するための技術標準が必要
  - 異なるメッセージングサービス間でメッセージ転送のガバナンスが必要
- 飛行情報交換モデル(FIXM)について
  - 監視情報を共有するため、共通のスキーマやパッケージが必要
  - 軌道記述の正確性を検証できる高度な4DTパッケージモデルが必要
- FF-ICEサービスについて
  - メッセージごとの検証ルールやエラー処理が必要
  - 現在のWaypointに基づいた記述からFull 4D Pointにシフトする必要がある
- TBOの実現について
  - 4次元軌道品質を保証できる評価モデルが必要
  - Gate-to-Gateの運用を実現するため、離着陸や交通流の情報も必要

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# まとめ

## 運用基盤

- ・ TBO
  - － 4DT共有・管理・利用

- ・ FF-ICE
  - － FlightとFlow情報の共有

## 情報基盤

- ・ SWIM
  - － メッセージングインフラ
  - － 標準情報交換モデル
  - － 情報サービス

## 通信基盤

- ・ IP based Connectivity
  - － 地上通信ネットワーク
  - － 空地データリンク

環境保全

安全性

効率性

協調的  
意思決定

相互運用性

ご清聴



ありがとう

ございました



M P A T



# Appendix: Acronyms and Terminology

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Term	Definition
4DT	4 Dimension Trajectory
AIXM	Aeronautical Information Exchange Model
ASP	ATM Service Provider
AU	Airspace User
DARP	Dynamic Airborne Reroute Procedure
FF-ICE	Flight and Flow Information for a Collaborative Environment
FIXM	Flight Information Exchange Model
GEMS	Global Enterprise Messaging Service
GUFID	Globally Unique Flight Identifier
IWXXM	ICAO Weather Information Exchange Model
NOTAM	Notification to Airman
SCVP	Server-based Certificate Validation Protocol
TBO	Trajectory Based Operation
TOPS	Trajectorized Oceanic Traffic Data Processing System
VPN	Virtual Private Network
XML	Extensible Markup Language