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Understanding Trajectory Based Operations (TBO) and Activities in Asia Pacific

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ACKNOWLEDGEMENT





The Multi-Regional TBO Demonstration led by FAA aims to <u>identify</u>, <u>mature</u>, <u>and demonstrate</u> <u>key TBO capabilities</u> with international and industry partners.



TBO: Paradigm Shift yet Evolutionary



What is TBO ?

It is a new paradigm in which flight trajectories are optimized on a transboundary basis, where ANSPs collaborate with Airspace users to make better decisions at various stages of a flight.



Key Elements of TBO

01

Time based management – manage traffic flows and trajectory by scheduling and metering aircraft to better manage congestion

3 02

Performance Based Navigation (PBN) – enable aircraft to more accurately navigate along the planned trajectory. Coupled with decision support tools, predictability and compliance to schedules are improved

03

Information exchange – utilise and exchange quality information across systems, capabilities, processes and people, working together to improve the performance of air navigation



Aircraft Trajectory

- Aircraft trajectory is the core tenet of TBO provides a common reference for where an aircraft is expected to be
- Defined in 4 Dimensions:
 - 1. Latitude
 - 2. Longitude
 - 3. Altitude
 - 4. Time
- Defined prior to departure, updated in response to changing conditions, shared between stakeholders' system

How does TBO work? (1/2)





How does TBO work? (2/2)





Transition to Future Info-Centric ATM (1/2)





- Reliance on voice communications between human participant
- Limited data exchange between supporting automation systems

- Every participant / system is operating to a same plan
- That plan is expressed & shared through the trajectory
- Automation of information flow

Transition to Future Info-Centric ATM (2/2)



Current Operations	Future Operations
Paper- and voice- based systems, information in silo	Data-based systems, automated sharing of information among stakeholders
Information not consistent and/or unavailable to automation systems supporting decision making	Automated sharing of information among participants and across different systems
Every participant makes their own decisions pertaining to flight	Decision-support automation for both aircraft operator and ANSP can use the same trajectory information for planning and tactical decision making , leveraging FF-ICE and SWIM
Current ATM environment is highly tactical by necessity	Strategic decisions accommodates tactical actions, and tactical decisions respects strategic plans
Aircraft operators plan to optimise their operations in the face of uncertain or unknown information – waste fuel, flight inefficiency. Their plans are often superseded as the tactical situation evolves	Availability and accessability to more accurate trajectory prediction and synchronisation across stakeholders increased, with automated sharing of known information



Achieving TBO together for sustainable aviation

- TBO ensures consistency between the trajectory and restrictions among aviation stakeholders
- TBO enhances strategic planning and tactical interventions through a common view of the trajectory between different actors in a collaborative environment
- TBO shifts operations towards greater predictability, with flightimpacting decisions being coordinated across concept components, allowing for safer and more efficient management of flight trajectories

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Operational Scenarios From ICAO GLOBAL TBO CONCEPT + TBO demonstration

The global TBO concept describes an ATM environment where the flown flight path is as close as possible to the userpreferred flight path by reducing potential conflicts and resolving demand/capacity imbalances earlier and more efficiently. In such an environment, a four-dimensional (4D) flight trajectory, collaboratively developed, managed and shared, would serve as a common reference for decisionmaking across all stakeholders.

ICAO Global TBO Concept

https://www.icao.int/airnavigation/tbo/Pages/Why-Global-TBO-Concept.aspx

Flight & Flow Information for a Collaborative Environment (FF-ICE)

https://www.icao.int/airnavigation/ffice/Pages/default.aspx

To be published...

GLOBAL TBO CONCEPT

(VERSION 0.11)

OPERATIONAL SCENARIOS

BY THE ICAO AIR TRAFFIC MANAGEMENT REQUIREMENTS AND PERFORMANCE PANEL (ATMRPP)

Shift to TBO environment

ATFM

ATC



Current situation

Disparate information across participants and automation systems which leads to inconsistent and inaccurate trajectory predictions.

Lack of information sharing

- AU and ASP
- within ASP systems
- between ASPs.
- Voice clearances may not be input into automation.



The **disparate** plan for a flight's trajectory

TBO environment

- Using TRAJECTORY that is shared and managed as a common plan for the flight by providing a common intent to be achieved prior to departure and during execution of the flight
- Information exchange by automation allows the provision of more accurate, consistent and operationally-relevant information to human actors.





The **common** plan for a flight's trajectory

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Operational Scenarios ~ ICAO GLOBAL TBO CONCEPT ~

Pre-departure planning



- Prior to departure, the AU and ASP engage in an information exchange for planning purposes as illustrated. This information exchange process is consistent with the process for FF-ICE.
- An AU obtains known constraints from the ASP, together with additional information on the flight and environment (e.g., MET)
- Consistent with this information, the AU develops a proposal for a flight including the trajectory.
- The plan is evaluated by the concept components of AOM, DCB and AO for data and <u>operational acceptability</u> together with applicable constraints.
- The AU is informed of any additional applicable constraints which may not have been included in the original constraint publication and the plan is revised by the AU.
- A common and more accurate view of the Agreed Trajectory is obtained among stakeholders concerned.



Operational Scenarios

~ TBO demonstration~

Pre-departure planning





Referring to the TBO and FF-ICE concepts, the demonstration uses scenarios such as the following to explore the problems to be solved and operational value.

- Significant Weather / Special Activity Airspace leads to required reroute
 Airspace congestion / ATFM initiatives
- Negotiation due to improving conditions



Operational Scenarios ~ ICAO GLOBAL TBO CONCEPT ~ Departure



- The issuance of the clearance should allow the departure time in the Agreed Trajectory to meet applicable constraints within bounds, such as DCB or TS as required.
- Once the flight departs, the actual departure time is known and the Agreed Trajectory is updated and shared to reflect the actual time.
- Downstream estimated times in this updated trajectory are more accurate as the departure time uncertainty no longer applies.





Operational Scenarios ~ ICAO GLOBAL TBO CONCEPT ~

AU-requested Trajectory Revisions





- One of the significant benefits provided to Airspace Users of TBO is the ability to request and engage in trajectory revisions during flight execution. (FF-ICE)
- As a flight is operating along an Agreed Trajectory, the flight operator may determine that there is <u>an</u> <u>operational need to modify.</u>
- The AU may request a revision of the Agreed Trajectory. As the AU formulates this request, the AU considers known information pertaining to the ATM configuration and system constraints.
- The request should be formulated in such a manner as to not affect the Agreed Trajectory within the scope of the present separator and ATC Sector.
- This allows the negotiation to occur outside the scope of the tactical actors. The AU may develop this through a combination of FOC or Flight Deck involvement.



. Etc.

Operational Scenarios ~ TBO demonstration ~ Trajectory Revisions (Post-departure)



A variety of unpredictable uncertainties causes the process of post-departure negotiation during execution.

- Significant Weather, Typhoon
- Volcanic Ash
- Special Airspace Activity
- Runway Configuration
- Negotiation for DCBO



Operational Values

Enhanced Predictability and Efficiency
 Alignment of Strategic Plan and Tactical Actions
 Increased, Reliable Flexibility
 Improved Strategic Planning
 Decreased Uncertainty
 Global Interoperability

and more...



Further challenges

Mixed-mode environment (AU, ASP)
 Trajectory negotiations between multiple ASPs
 Scenarios with multiple flights
 Impact of tactical decisions on the strategic plan

and more...



Exploring for the Future...



TBO is not a "one size fits all solution." Regional priorities can be emphasized in alignment with global TBO concept.

It is time to start to explore the future operation in our APAC region together.



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Trajectory-Based Operation

Sharing, Managing, and Using of Trajectory Information as a common plan for flight

Share	Manage
SWIM	CPDLC
CA	FMS
FF-ICE	PBC
ADS-B	PBN
ADS-C	PBS



SWIM: System-Wide Information Management



- Aviation Intranet
- Seamless and timely information exchange
- Awareness of the latest trajectory by all stakeholders



CA: Connected Aircraft

- Air/ground information exchange
- EFB combined with A/G SWIM; access to information available via SWIM
- Collaborate in trajectory negotiation
- Customized applications for flight crew





Current ATS-message-based environment



FF-ICE environment



FF-ICE: Flight and Flow Information for a Collaborative Environment

- Information requirements
- For flight planning, flow management, and trajectory management
- Coordination of trajectory information
- Pre-departure and post-departure trajectory negotiation
- Trajectory parameter exchange



ADS-B: Automatic Dependent Surveillance-Broadcast ADS-C: Automatic Dependent Surveillance-Contract

- Aircraft-derived trajectory (position, altitude, speed)
- Air/ground flight intent synchronization
- Improved trajectory prediction
- Conformance monitoring against the agreed trajectory



Managing of Trajectory Information

CPDLC: Controller-Pilot Data Link Communication

- Data communication with FMS
- TBO clearance delivery
- More extensive clearance than voice
- Ensuring awareness of ground and aircraft automation systems of clearances
- Improved quality of trajectory intent data contained in ground automation

FMS: Flight Management System

- Ability to input clearance
- Clearance execution
- Delivery of agreed trajectory within execution limits
- Aircraft-derived trajectory, computed from the present aircraft position



Managing of Trajectory Information

PBC: Performance-Based Communication

- Ensuring clearance delivery within integrity and timeliness requirements
- Different service functions, different RCP standards

PBN: Performance-Based Navigation

- Ensuring aircraft navigation accuracy within ATM performance needs
- Precise adherence to lateral clearance

PBS: Performance-Based Surveillance

- Managing aircraft position uncertainty
- Decision management reliant on (short-term) trajectory prediction accuracy
- Conformance monitoring for determining trajectory update



TBO Capabilities & TBO Enablers

TBO Capability	ADS-B	CPDLC	PBN	PBC	PBS	FMS	CA	FF-ICE	SWIM
Pre-departure trajectory negotiation							\uparrow	\checkmark	\checkmark
Trajectory parameter exchange							\checkmark	\checkmark	\checkmark
TBO clearances		\checkmark				\checkmark			
Sharing of a/c-derived trajectory						\checkmark	\checkmark	\checkmark	\checkmark
Flight-execution trajectory negotiation		\uparrow				\uparrow	~	~	\checkmark
Precise clearance execution		\checkmark	~	\uparrow	\uparrow	\checkmark			
Trajectory prediction accuracy	\uparrow	\uparrow	\uparrow	\uparrow	\uparrow	\uparrow	$\mathbf{\uparrow}$	\uparrow	
ASP coordination & negotiation								\checkmark	\checkmark
GATMOC component integration								\checkmark	\checkmark



TBO-Enabled ATM Service Provider

- Pre-departure and flight-execution trajectory negotiation
- Creation and delivery of TBO clearances
- Use of aircraft-derived trajectory
- If performance needs dictate
 - Use of AU-provided trajectory parameters
 - Creation and delivery of precise clearances
- Provision of decisions integrated across GATMOC components
- Sharing, updating, and revision of the agreed trajectory



AEROTHAI (Partial) TBO Testbed



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Next Steps – TBO Demo





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Next Steps – Scenarios Demonstration (1)

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Scenario	Capabilities	Flight Interactions	#eASPs
1	A – FLXM	UAL5, UAL7	3 (FAA, NavCanada, JCAB)
	B – Post Departure Negotiation	UAL7	3 (FAA, NavCanada, JCAB)
	C – Sharing Agreed Trajectory	SIA38	3 (FAA, JCAB, CAAS)
	D – Downstream Updates	JAL9	2 (FAA, JCAB)
'	E – Tactical/Strategic	SIA8, JAL9	3 (FAA, JCAB, CAAS)
	F – Sharing/Using Trajectory Information	UAL5, UAL7	3 (FAA, NavCanada, JCAB)
	G – Enhanced Predictability	UAL5, UAL7, JAL9	3 (FAA, NavCanada, JCAB)
	A - Taxi time analytics	ACA512	2 (FAA, NavCanada)
	B - Filed Flight Plan/Flight Plan Update	ACA108	2 (FAA, NavCanada)
2	C - Filed Flight Plan to Two eASPs	ACA512	2 (FAA, NavCanada)
	D - Update Request to avoid turbulence	ACA108	2 (FAA, NavCanada)
	E - Tactical Resolution/Strategic Update	ACA108, ACA512	2 (FAA, NavCanada)
	F - Event Causes Bedpost Overload	ACA108, ACA512	2 (FAA, NavCanada)
	G - eAU Assigns Higher Landing Priority	ACA108, ACA512	2 (FAA, NavCanada)

Next Steps – Scenarios Demonstration (2)



Scenario	Capabilities	Flight Interactions	#eASPs
3	A – Pre -departure flight planning and filing	JAL707X	2 (JCAB, Aerothai)
	B – Post-departure trajectory negotiation	JAL707X	2 (JCAB, AeroThai)
	C – ATFM and AMAN	JAL707X	2 (JCAB, AeroThai)
	D – Pre-departure flight planning and filing and A-CDM at VTBS	SQC473	3 (JCAB, AeroThai, CAAS)
	E – A-CDM and trajectory negotiation and revision	SQC474	3 (JCAB, AeroThai, CAAS)
4	A – Planning Service/Trial Service	SIA979	2 (CAAS, AeroThai)
	B - Filing Service/ Re-evaluation Service	SIA979	2 (CAAS, AeroThai)
	C – Post-Departure Negotiation (mixed mode)	SIA979	2 (CAAS, AeroThai)
	D – Traffic Synchronisation Measures	SIA979	2 (CAAS, AeroThai)
	A – Filed Flight Plan to Three eASPs	SIA38	3 (FAA, JCAB, CAAS)
5	 B – Post-departure negotiation with Three ASPs (mixed mode)/ Weather Publication and Trajectory Revision 	SIA38	2 (JCAB, CAAS)
	C – Traffic Synchronisation Measures	SIA38	1 (CAAS)



Next Steps – Phase 2B

Flight Trial

- TBO phase 2A focus on the ANSPs and their systems
- TBO phase 2B start to integrate eAUs and their systems
 - Develop prototype applications
 - Develop scenario(s) and procedures
 - Test systems interfaces
 - Conduct safety assessment and develop mitigation plan
 - Test flight(s)
 - Live flight(s)



Next Steps – Lessons Learned

Lessons Learned from Demonstration

- Learn by doing SWIM, Cyber Security, Information exchange and FF-ICE
- Interoperability and performance based allows for alternative technical solutions to best meet the need and policy of the states and regions
- Provide Feedback to various ICAO groups and panels for standards and procedures development
 - Global Air Navigation Plan and Aviation System Block Upgrade
 - Regional Implementation Roadmaps and Plans
 - Air Traffic Management Requirements and Performance Panel
 - Information Management Panel
 - Communication Panel



Conclusion - TBO Recap (1)

Information and Data Sharing Among Stakeholders

TBO Capabilities	ANSP(s)	Flight Deck	Flight Ops Center
Pre-departure Trajectory Negotiation	Х		Х
Flight Execution Trajectory Negotiation	Х	Х	Х
Trajectory Parameter Exchange	Х	Х	Х
Sharing of Aircraft Derived Trajectory	Х	Х	
ASP Coordination and Negotiation	Х		



Conclusion - TBO Recap (2)

Information Sharing at the right time to enable TBO in Asia

- TBO is to move toward more strategic decision making
- Technical focus: **Information** management and exchange to support decision making
- Successful Information sharing can enable TBO while respecting airspace sovereignty

Conclusion

Steps to TBO

- Implement TBO capabilities that best meet the Asia environment (e.g., airspace, policy)
- Robust **regional policy** for information exchange and sharing
- Establish the foundation for TBO:
 - Implement SWIM (ground and air)
 - Information exchange and management
 - Flight and Flow Information for a Collaborative Environment (FF-ICE)
 - Cyber Security



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QUESTIONS AND ANSWERS





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