FF-ICE Release 2 Services Towards Trajectory-Based Operations (TBO)

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Overview

- Trajectory-Based Operations (TBO)
- FF-ICE a necessary mechanism for TBO
- Phased Implementation of FF-ICE
- Focus on Release 2 features and expected services
- Possible evolution from Release 1 services
- Release 2 is a work in progress
  - Example areas that are being developed
ATM – Distributed Participants & Decisions

Manage single flight within global network
Ground Resources
Connectivity – Airframes, Crew, Passengers, Cargo
Flight Time & Rest Requirements
Equipment Qualifications
And Others
  Winds
  Weather
  Fuel
  Alternates
  Performance
  Obstacles
  Weight & Balance
  De-icing
  Volcanic Ash
  ETOPS Requirements
  Minimum Equipment Lists

ATM: Air Traffic Management
ETOPS: Extended Twin Engine Operations
ATFM: Air Traffic Flow Management
ATM – Distributed Participants & Decisions

- **Aircraft Operator**
  - Manage single flight within global network
  - Ground Resources
  - Connectivity – Airframes, Crew, Passengers, Cargo
  - Flight Time & Rest Requirements
  - Equipment Qualifications
  - And Others
    - Winds
    - Weather
    - Fuel
    - Alternates
    - Performance
    - Obstacles
    - Weight & Balance
    - De-icing
    - Volcanic Ash
    - ETOPS Requirements
    - Minimum Equipment Lists

- **ATFM Strategic**
  - Plan workforce
  - Manage airspace

- **ATFM Tactical**
  - Manage flows
  - Congestion, Weather, Outages

- **Air Traffic Control**
  - Synchronize Flights
  - Separation

- Every participant makes decisions pertaining to a flight
- Decisions are hierarchical, some are coordinated
- TBO seeks to develop solutions across decisions using the trajectory as the common currency
  - Strategic decisions accommodate tactical actions
  - Tactical decisions respect the strategic plans
Trajectory-Based Operations

- Every participant / system is operating to a plan
- Everyone operates to the same plan
- That plan is expressed & shared through the trajectory

- Sharing trajectory information
- Managing that information
- Using it as reference for the flight

Draft Global TBO Concept can be found at: [https://www.icao.int/airnavigation/tbo/Pages/Why-Global-TBO-Concept.aspx](https://www.icao.int/airnavigation/tbo/Pages/Why-Global-TBO-Concept.aspx)

FOC: Flight Operations Center
ATC: Air Traffic Control
TMU: Traffic Management Unit
TM: Traffic Manager
ATCSCC: Air Traffic Control System Command Center

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Each participant influences the trajectory:
- ATM imposes constraints (e.g., routing, altitudes, speeds)
- ATC may provide tactical clearances
- AOC plans the route and profile (w/ Flight Crew)
- Flight Crew selects appropriate modes, controls and targets

Ensure resulting trajectory meets their needs
An Information Problem

- **Trajectory Prediction**
  - We know the physics
  - Models make assumptions

- **We don’t all know:**
  - Aircraft performance
  - Met data
  - Future ATC commands
  - How the aircraft will operate (Aircraft intent)

To achieve TBO, we must address the information problem

Etkin, Dynamics of Flight, 2nd Ed.
FF-ICE Releases

- A phased approach to delivering the FF-ICE Concept
- No “big-bang” = mixed environment

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Agreed Trajectory | Established pre-departure | Modified strategically | Fully Integrated |
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Post-departure Negotiation - Framework

Changing Circumstances

- New constraints
  Changing MET
  Fleet considerations

Re-optimize

- Keep up with uncertainty & clearances

Maintain

- Tactical Interventions

Negotiation

Manage Agreed Trajectory

Deliver Clearance

Legend

- Flight Information Sharing

- Share and ensure agreement reflects what has happened
- ATC delivers the Agreed Trajectory using clearances
- FF-ICE/1
  Re-negotiation in FF-ICE/2

MET: Meteorology

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Features of FF-ICE / Release 2 (1 of 2)

ATC not involved in negotiation

Smooth transition: Release 1 $\rightarrow$ 2
- No service interruption
- Continuous services

Agreed Trajectory obtained via FF-ICE/R1

Agreed Negotiation Horizon

eAU/r2 & eASP/r2 may negotiate on Agreed Trajectory

Tactical ATC

eAU includes Flight Deck via EFB & Dispatch as applicable

AU: Airspace User
ASP: ATM Service Provider
eAU/eASP: FF-ICE-enabled AU/ASP

All eAU & eASP/r2 are R1 capable

ATFM not required for FF-ICE. If present, an ATFM system might implement FF-ICE capabilities.
Agreed Trajectory does not constitute a clearance

Manual coordination interfaces may limit re-routing.

ATC delivers clearance in time for Agreed Trajectory

eASP-1

Agreed

eASP-2

Some ASPs might allow re-routing through their airspace under specified circumstances.

eASPs maintain the Agreed Trajectory

eAU

Say these are not eASPs

ATC Coordination processes remain as-is.
FF-ICE/Release 2 Services

- Publish known constraints
- Negotiation† involves two processes:
  - Evaluation of a Desired Trajectory across multiple ASP
  - Commitment to revise the Agreed Trajectory
- Update and publication of the Agreed Trajectory as it changes
- Clearance delivery → via existing methods (Voice, CPDLC)

†Must communicate negotiation horizon

CPDLC: Controller/Pilot Data Link Communications
FF-ICE/Release 1 Services

ICAO draft documents defined Release 1 services

- Operator submits Prelim. Flight Plan
- Operator submits Filed Flight Plan
- Point defined by eASP where ATC coord required
- ATC delivers clearance
- Aircraft off Blocks
- Aircraft wheels up

Planning Service
Filing Service
Trial Service
Flight Data Request Service
Publication Service
Notification Service

Provide early demand, get feedback on a plan
File the plan, get re-evaluation
Obtain feedback on a trial
Request and obtain flight data
Flight data is published and received
Departure/arrival notification

Seek to leverage & evolve these to FF-ICE/ Release 2

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Operator Submits Prelim. Flight Plan

Operator Submits Filed Flight Plan

Point defined by eASP where ATC coord required

ATC delivers clearance

Aircraft Off Blocks

Aircraft Wheels Up

Planning Service

Filing Service

Trial Service

Flight Data Request Service

Publication Service

Notification Service

Evolution of Services

Planning Service:
- Request change to Agreed Trajectory
- AU-proposed
- Respects applicable change horizons

Filing Service (after ATC involvement):
- ATC implements Agreed Trajectory

Trial service continues:
- Evolves to be fit for execution phase
- Used to evaluate options before providing a proposal

Flight Data Request continues

Publication service continues:
- Provides means to share & update

Notification service:
- Possibly for events such as a revision

Image: FAA

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FF-ICE/Release 2 is a work in progress

Example areas of further development
Transition from Release 1 to Release 2

Negotiation Horizon takes on a different context:

- **Flight may be in a tactical phase**
  - Maneuvering on surface towards departure runway
  - Imminent takeoff
  -> eAU may negotiate downstream changes to be implemented later. However, flight deck involvement would be limited.

- **Clearance may have been delivered but flight is delayed**
  - Prior to or subsequent to surface movement
  -> eAU may negotiate entire flight plan, process is required to synchronize plan with ATC & clearance prior to committing to agreement

- **Existing surface CDM processes expected to interact with Agreed Trajectory**
Update of Agreed Trajectory

Who updates, how and when?

Many possible options, process not yet defined

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**Flight Data Sharing**

- Participants maintain local flight data as required
- Flight data is shared between participants using standardized Information exchange models
- Flight data is consistent, update as necessary (e.g., thresholds, events or periodic)
- Used to maintain the Agreed Trajectory across participants
- Notification that flight data is modified might be variable (e.g., by look-ahead)
- Other participants (e.g. Upper airspace) exchange flight data for their operations and transition

*Participants may have different models for internal data storage and management (e.g., internal databases, cloud services, private vendors)*

FD: Flight Deck

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Images: NASA, Google
Example – Describing exchanges

- **Aircraft Operations**
  - Execute Clearance
  - Execute Trajectory

- **Aircraft Services**
  - Update Plan
  - TFM Trajectory

- **ATM Services**
  - Monitor
  - Amend Clearance
  - TFM Trajectory

- **FOC Planning**
  - Create Optimal Trajectory
  - Extract and Apply Constraints
  - Filing ready

- **Filing Services**
  - Evaluate
  - Filing ready

- **Planning Services**
  - Evaluate
  - TFM Trajectory

- **TFM**
  - Evaluate
  - Modify Plan

- **Airspace User**
  - Negotiating
  - Desired

- **ATC**
  - Obtain Filed Plan
  - Provide Clearance

- **ATM Service Provider**
  - Modify Plan
  - Executed Trajectory
Many Additional Areas under Investigation

- **Negotiation processes**
  - Initiation of negotiation
  - Identifying the negotiation horizon
  - Multi-ASP negotiation and agreement processes
  - ATFM Interactions
  - Obtaining an end-to-end trajectory
  - Mixed-mode

- **Clearance delivery**
  - Across multiple eASP, across an ASP
  - Communicating what has been & remains to be cleared

- **Managing the Agreed**
  - Tactical interventions
  - Use of tolerances
  - Flight through legacy ASPs

- **ATC Interactions**
  - ATC Coordination processes
  - Arrival and Extended arrival management tools
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