GLOBAL TBO CONCEPT

(VERSION 0.11)

OPERATIONAL SCENARIOS

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

APPENDIX A – TBO SCENARIOS FOR A NOMINAL FLIGHT

This Appendix describes the operation of a nominal flight from pre-departure to completion under TBO as identified in Section 3. The scenarios describe the following circumstances:

- Pre-departure planning
- Surface movement
- Take-off
- Trajectory updates
- Separation provision
- Planned climb
- AU-requested trajectory revisions
- Weather deviation
- Evolution of Coordination across ASP
- Traffic synchronization for arrival
- Arrival descent clearance
- Operator Constraints and Preferences

A.1 PRE-DEPARTURE PLANNING

Prior to departure, the AU and ASP engage in an information exchange for planning purposes as illustrated in Figure A1. This information exchange process is consistent with the process for FF-ICE ASBU Block 1. 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. Note, in FF-ICE/1, the trajectory is optional, as TBO develops further, coordination will necessitate agreement on an Agreed Trajectory. The plan is evaluated by the concept components of AOM, DCB and AO for data and operational acceptability 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.

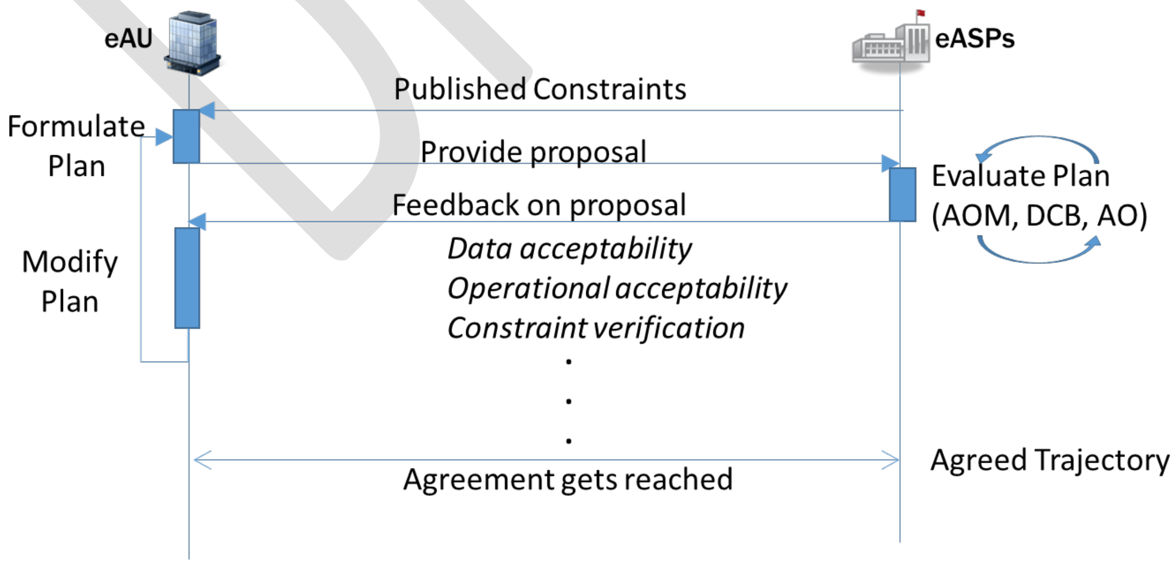

Figure A1 – Process for reaching an Agreed Trajectory between an ASP and the AU

The concept components of AUO, AOM, DCB and AO all use and affect trajectories during planning as follows:

- AUO: Proposes the trajectory for flights considering known constraints
- AOM: Trajectories determine flows from which the ATM Configuration is determined (which constrains the possible trajectories)
- AO: The demand, as computed using the trajectories, influences surface planning choices affecting ATM arrival/departure times and configuration (these constrain the ATM Configuration and the trajectories)
- DCB: Flows, as computed by the trajectories, impact the balance between demand and capacity. Where necessary DCB constrains flights to mitigate these imbalances using a Negotiating Trajectory.

The above processes rely on using the best available data for defining the trajectory. By doing so, a common and more accurate view of the Agreed Trajectory is obtained.

When flights are not subject to anticipated demand/capacity imbalances or other resource contention, agreement on the trajectory by DCB or AO does not involve the need for constraints on the time or flight path. In such a case, DCB and AO can agree with the AU proposal. However, when there is an imbalance, DCB and AO collaborate with the AU to determine a plan for departure that can accommodate any imbalances occurring: at the departure airport, at the arrival airport or en route. In the example shown in Figure A2, demand at the arrival airport requires DCB to control the departure time, within bounds, to ensure that arrival demand is not exceeded. Given knowledge of uncertainty on demand and capacity, some delay may be deferred to be absorbed in flight. As AO engages to develop a surface plan for departure, the time is refined, within the DCB bounds to deliver the departure time. As these plans are developed, the Agreed Trajectory is updated and refined as necessary.

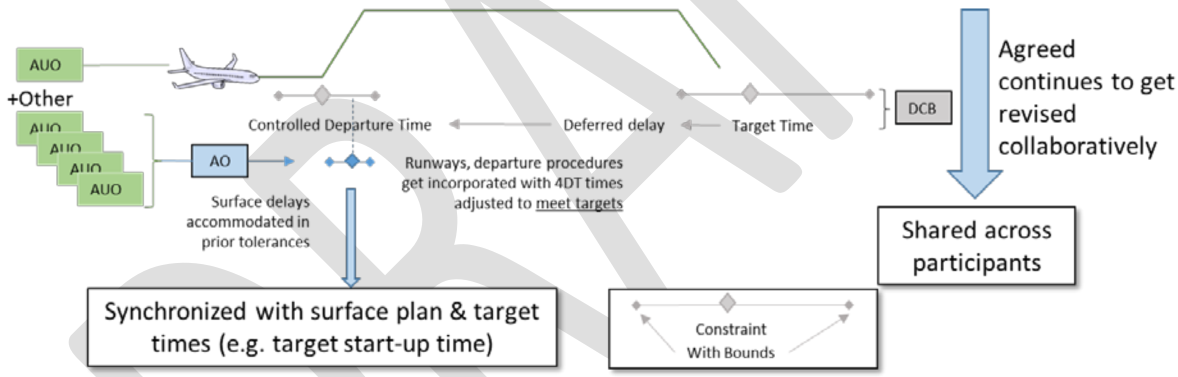

Figure A2. Interaction of DCB, AUO and AO when flights are constrained pre-departure.

At some time prior to departure, a pre-departure clearance can be provided to the flight upon request, allowing the aircraft to load the FMS with the clearance. The clearance that is delivered, when executed by the flight, should result in the Agreed Trajectory within the execution precision of the flight. For example, the Agreed Trajectory, as specified by the AU should describe the flight profile to be flown when executing a departure procedure. Suitably-equipped aircraft may provide an aircraft-derived trajectory prior to take-off.

Should a revision to the Agreed Trajectory become necessary prior to flight, the clearance should be revised to be in accordance with the Agreed. It is preferable that clearances be issued when the Agreed Trajectory has reached an acceptable level of stability.

A.2 SURFACE MOVEMENT

As the flight approaches the planned departure time, the flight crew requests a clearance to proceed (e.g., start up, taxi clearance). The issuance of this clearance should allow the departure time in the Agreed Trajectory to meet applicable constraints within bounds. These include constraints as necessary to meet the needs of all concept components such as DCB or TS as required. In this case, as the clearance is issued, the Agreed Trajectory can be updated to account for the actual time and any additional time on the surface (see Figure A3). If the clearance does not meet the constraints within bounds, a trajectory revision must be initiated in concert with the relevant participant discussed during planning. As events subject to uncertainty occur, such as pushback, the uncertainty of the remainder of the flight diminishes and may be used to adjust tolerances.

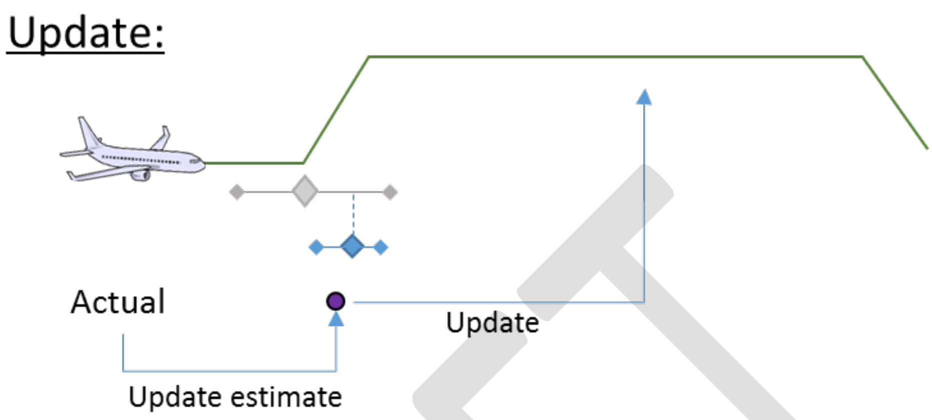

Figure A3. Update on the Agreed Trajectory as events occur on the surface.

The flight is provided a taxi clearance which delivers a take-off time consistent with the Agreed Trajectory. The flight proceeds along the taxi clearance and the estimated take-off time is monitored and updated as required and shown in Figure A3. Certain surface events, such as active runway crossings, will continue to require a clearance to proceed. While uncertainty may be reduced due to improved surface planning tools, small queues may continue to be required at times to manage uncertainty, deliver a more precise Executed Trajectory or improve throughput.

A.3 TAKE-OFF

A flight is provided a take-off clearance at the appropriate time, consistent with the Agreed Trajectory as it reaches the departure end of the runway in accordance with its taxi clearance. 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.

The clearance that was previously loaded into the FMS is consistent with the Agreed Trajectory and the flight executes the clearance. The clearance may include a cleared departure procedure with speed and altitude constraints. Aircraft that are suitably equipped downlink the aircraft-derived trajectory, consistent with the input in the FMS. This trajectory includes the effect of speed and altitude constraints. Ground systems use this aircraft-derived trajectory to ensure consistency with the Agreed Trajectory and update is as necessary.

Flights may have departed with a departure time that was constrained in order to meet a target time in the air. For example, a flight may have to merge into an overhead stream by meeting a target time at a fix within some bounds. To do so, traffic synchronization would be engaged to control the flight to a controlled time, accounting for the remaining uncertainty after the flight departed. Proper planning accounted for this uncertainty to ensure a high likelihood that the flight will meet the target time. The process is illustrated in Figure A4.

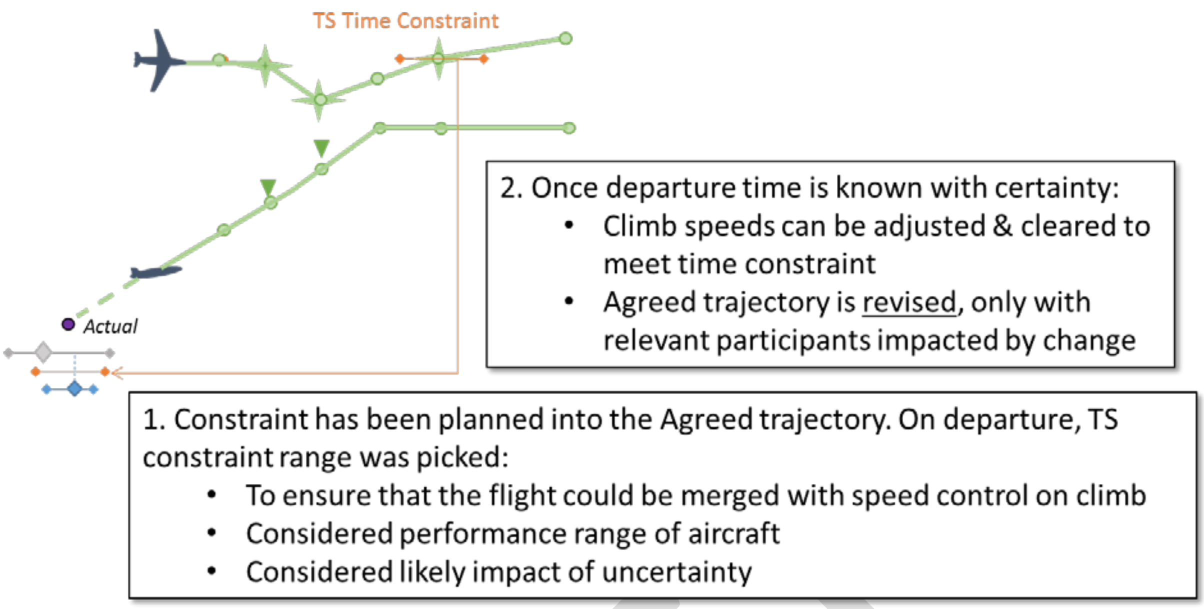

Figure A4. Engaging Traffic Synchronization on Departure, planning first followed by execution

A.4 TRAJECTORY UPDATES

The Agreed Trajectory contains an estimate of the 4DT of the flight complying with the agreements. As the flight operates, the aircraft will not fly exactly where predicted due to wind and performance uncertainty. As a result, the prediction will sometimes need to be adjusted to account for this uncertainty. For suitably-equipped flights, this is estimated using the aircraft-derived trajectory combined with surveillance data. Flights not so-equipped will have an estimate derived from ground systems.

Local systems using a prediction based upon surveillance data may update at a high-frequency to minimize the error in the short-term prediction. These predictions may be used for such applications as conflict detection and separation provision. However, other concept components not requiring such a high update rate will obtain an update based upon the prediction exceeding established tolerances. In this latter case, the Agreed Trajectory is updated and shared with all relevant participants.

A.5 SEPARATION PROVISION

As the flight proceeds, an accurate trajectory prediction (the high-frequency update above) is used to determine if a flight is projected to violate separation with another. In the event of a conflict, a preferably closed clearance is generated solving the conflict. To the extent practical, a closed clearance is constructed in such a manner as to ensure that downstream constraints contained in the Agreed Trajectory can continue to be met by the flight. The clearance is based upon a trajectory that is generated by ground systems, using information previously obtained from the flight.

For suitably equipped flights, the clearance is provided through CPDLC, allowing the clearance to be auto-loaded into the FMS and executed by the flight crew. The flight may downlink the new aircraft-derived trajectory allowing the Agreed Trajectory to be updated in accordance with the new clearance. Since downstream constraints have been respected, there should normally not be a need for other Concept Components to request a revision.

Separation Provision should be able to resolve conflicts while meeting downstream constraints when the constraints were developed to ensure a robust solution. For example, a traffic synchronization constraint might allow path or speed flexibility to allow resolution to expected conflicts.

There are times when separation provision must act tactically via voice or is unable to meet downstream constraints. For these cases, once a new clearance is provided, the Agreed Trajectory is updated, but must immediately be revised with other concept components.

There are also environments and circumstances where separation provision may provide sufficient time for collaboration with the AU on a trajectory revision to resolve the projected conflict through a revision to the Agreed Trajectory.

A.6 PLANNED CLIMBS

The goal of TBO is to have a clearance that is closed and provides the end-to-end Agreed Trajectory. For example, in Figure A5 a clearance provides the entire altitude clearance with no additional clearances required for the climb or the descent.

The advantage of this situation is that all participants have the same view of the Agreed Trajectory and are executing to it without awaiting further instruction to do so. Planning to these trajectories can be more consistent as the information is known to all participants engaged in planning. Human actors must be provided with appropriate tools providing sufficient situational awareness. Further the grantor of the clearance must be aware that the downstream airspace can accept such clearances prior to issuing them.

During transition, the mixed environment will make it difficult on longer flights to issue clearances including planned altitude changes. As TBO gets implemented we would expect the horizon of such clearances to extend further along the flight.

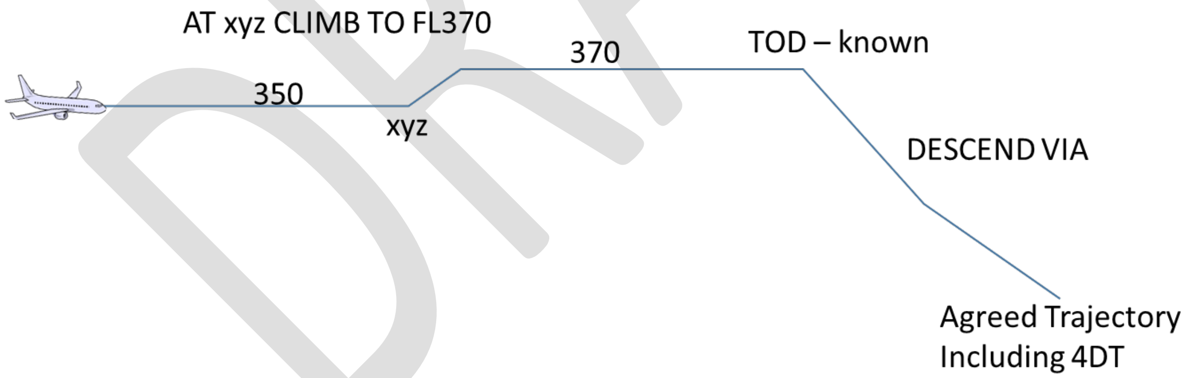

Figure A5. Clearance includes planned climbs and descents for the full trajectory.

A.7 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. As a flight is operating along an Agreed Trajectory, the flight operator may determine that there is an operational need to modify that flight's arrival time (expedite or delay). In this case, 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. In addition, 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 latter step 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.

The request for a revision is provided to those participants executing the planning for TS together with DCB. Suitably connected aircraft may request the trajectory revision through an appropriate mechanism. The revision process is initiated allowing feedback on constraints applicable to the proposed revised flight by the TS and DCB components. Convergence on an Agreed Trajectory results in this new agreement being shared across participants. The flight deck may request the new clearance from ATC via CPDLC, or the clearance may be delivered to the flight deck using CPDLC as a result of DCB or TS informing ATC through the sharing the new Agreed Trajectory. The flight deck verifies that the clearance matches the previously negotiated agreement and executes the new auto-loaded clearance. Prior to requesting the clearance, an AU may negotiate with a downstream ASP when operating in another ASP's airspace if so suitably connected.

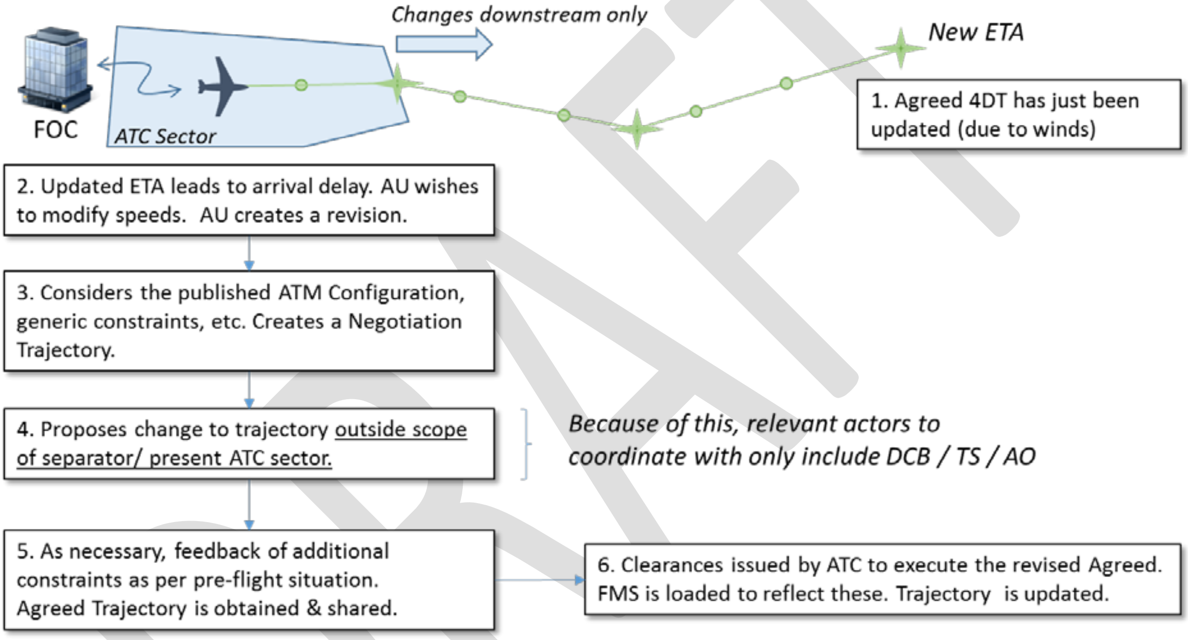

Figure A6. Process for AU-initiated Re-Planning

A.8 WEATHER DEVIATION

TBO must take into account that there will be circumstances, for example due to weather deviation, when a flight cannot operate on a fully closed trajectory. In this scenario, a flight experiences isolated convective activity that it wishes to operate through with some latitude for avoiding. The process is described in Figure A7. The flight is provided a clearance to deviate some number of nautical miles to the left of the route. During this manoeuvre, the Agreed Trajectory is maintained with knowledge of higher uncertainty after the expected end of the manoeuvre. During the manoeuvre, the high uncertainty may not require an update to the Agreed Trajectory as the information is uncertain. However, a new ADS-C report would be downlinked to reflect the updated predicted trajectory due to the trajectory revision. Downstream TS and DCB processes, informed of the higher uncertainty must take this into account and develop plans that are robust to the uncertainty. For example, if this flight is planned for metering, other flights would also be affected, a decision to act on those flights may be made pro-actively or delayed depending on the options and circumstance. Once the flight has passed through the convective activity, the trajectory may be revised and updated as necessary to account for the outcome.

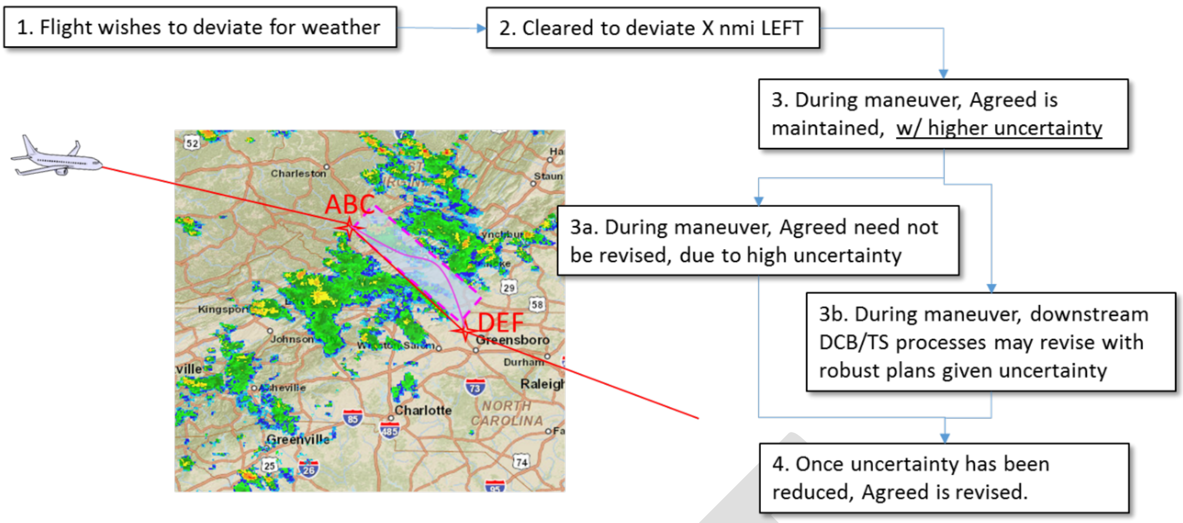

Figure A7. Flight provided latitude to operate around convective weather cells

A.9 EVOLUTION OF COORDINATION ACROSS ASP

In a TBO environment, the Agreed Trajectory is continually updated and shared across ASPs and AUs. Downstream ASPs no longer rely on a periodic update of data from the Flight Plan (FPL) to the Current Plan (CPL) or Advanced Boundary Information (ABI) ATS messages. Instead, downstream ASPs are constantly informed as the flight is being planned and executed via the Agreed Trajectory. As illustrated in Figure A8, the 4DT includes an update to the ETA, speed and altitude crossing conditions.

Additional information is also included through the Agreed Trajectory allowing for reduced ambiguity for cases where a flight leaves and re-enters an ASP's airspace. Under the FPL, named significant points outside of an ASP's airspace may not be known and create ambiguities regarding where the flight may enter or re-enter the airspace. In some circumstances today, significant points may have duplicate names in adjacent airspace which could be resolved by knowing the location on the Agreed Trajectory.

Revisions to the Agreed Trajectory allow the downstream ASP to be informed of anticipated boundary conditions as they are planned. Given the longer time horizon, these boundary crossing conditions can be planned with involvement of the Airspace User. For example, altitude conditions on the boundary may result in an AU wishing to negotiate for an alternate route without such conditions.

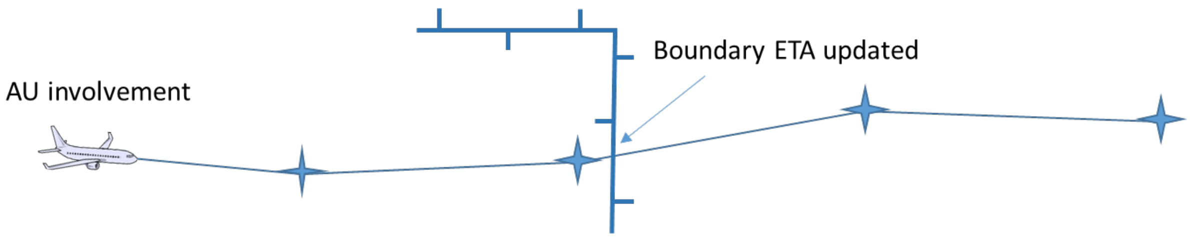

Figure A8. Boundary crossing conditions are shared as they are known to change.

A.10 TRAFFIC SYNCHRONIZATION FOR ARRIVAL

As the flight approaches the arrival airport, an Agreed Trajectory is being shared across participants and is being executed to. Where necessary, when demand and capacity are closely matched, Traffic Synchronization processes may need to provide a more constrained controlled time of arrival to synchronize arrivals. In this case, TS and AUO may collaborate on a trajectory revision to define the controlled time and the trajectory that delivers to that controlled time within desired bounds. The Agreed Trajectory is revised to account for any new constraints and a clearance is provided to the flight as described in the following section.

While this example describes traffic synchronization on arrival, TS may also be required throughout all phases of flight with a similar collaborative and coordinated process expected. When there is an expectation of TS being required, DCB processes should be engaged in a more strategic timeframe to appropriately condition the flow and trajectories enabling smooth TS execution.

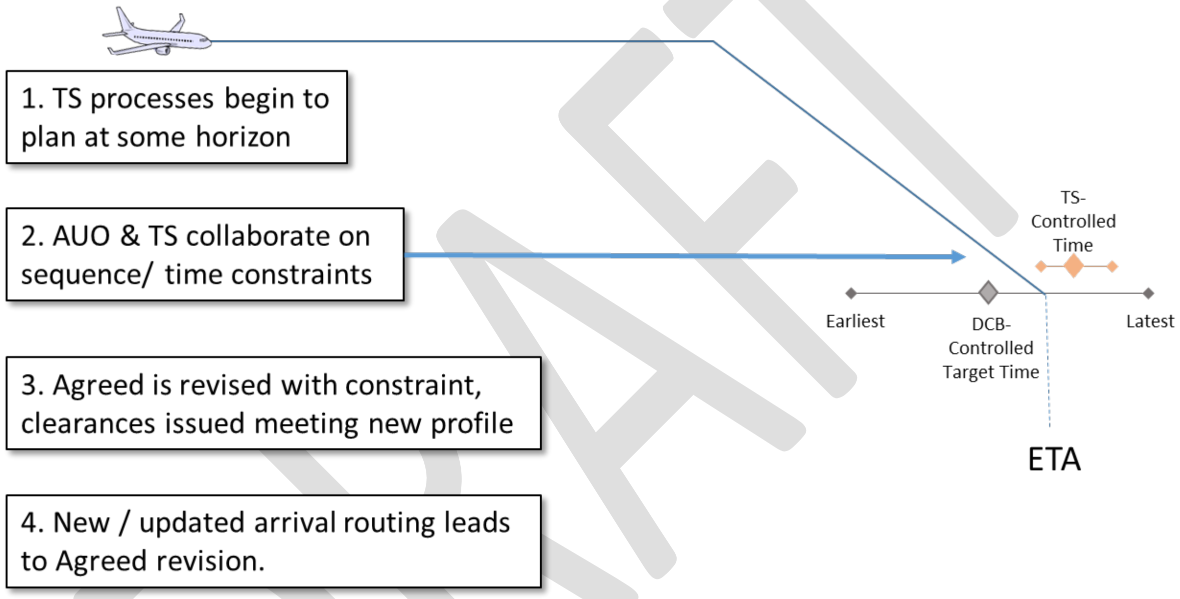

Figure A9. Process for Traffic Synchronization on Arrival.

A.11 ARRIVAL DESCENT CLEARANCE

As the flight approaches the top-of-descent, an Agreed Trajectory is being shared and executed to. This may include a constraint for Traffic Synchronization as described previously. For fully capable aircraft and ASPs, the flight has received a clearance including the top-of-descent, speed profiles and speed/altitude constraints on the descent profile. Aircraft equipped with ADS-C provide the aircraft-derived trajectory which is used by the ground systems to update the Agreed Trajectory as the flight executes. This provides a mechanism to pre-emptively monitor the delivery of the controlled time in the Agreed Trajectory. As prediction errors materialize, monitoring of the flight may require changes to the clearance to enable the flight to meet the constrained time within the window.

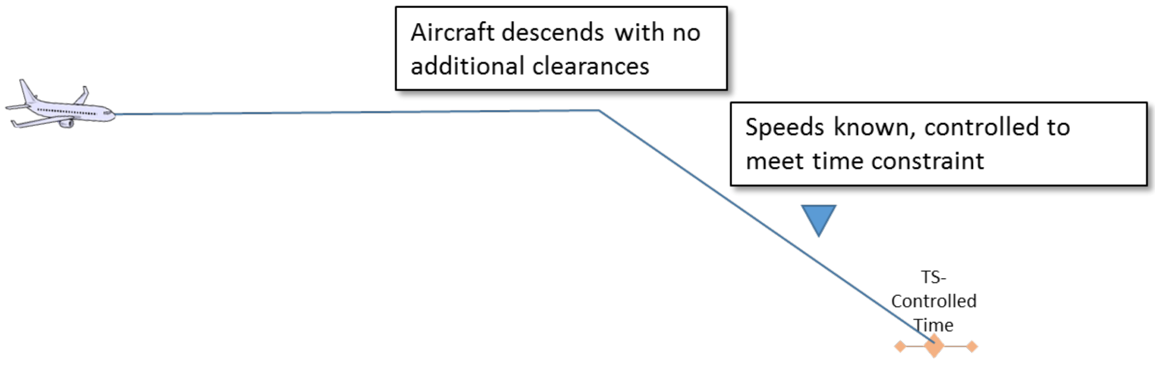

Figure A10. Issuance of Descent Clearance on Arrival

A.12 OPERATOR CONSTRAINTS AND PREFERENCES

Examples are provided below describing the provision and use of operator provided constraints and preferences.

A.12.1 OPERATOR CONSTRAINTS

Runway limitation

At the destination, the runway used as an “offload” for peak traffic periods does not meet the operational requirements for the flight. The requirement may be based on aircraft characteristics or operator procedures. From the ATM System’s perspective, it is better to know, even in the DCB and planning phases, which aircraft are unable to use the “offload” runway – especially if they constitute a majority of the demand for a short period.

No overwater equipage

In developing a DCB response to moving line of convective weather, one option is to route aircraft through a departure area still open via an overwater reroute that will avoid some of the ground delays (and possibly surface congestion). However, the aggregate ATM System response will be flawed if it is predicated on the effect of rerouting aircraft that lack overwater equipment and are unable to accept the route.

A.12.2 OPERATOR PREFERENCE

Runway preference

At destination, the AU requests to land in the direction and use the runway with greatest reduction in taxi distance/time to planned gate. For example:

- Multiple aircraft (even if operated by the same AU) submit a range of preferences. As illustrated in Figure A11, if airport operation plans landing west and south, aircraft parking east express a preference to land west but aircraft parking west prefer to land south. [Thus aircraft landing west end up on the east side of the airport and aircraft landing south end up on the west side.]
- From the ATM System’s perspective, knowing the planned airport configuration and AU preferences by individual aircraft in the strategic timeframe provides inputs for network management support automation to comply with AU preferences to the extent overall ATM System performance is not adversely impacted.

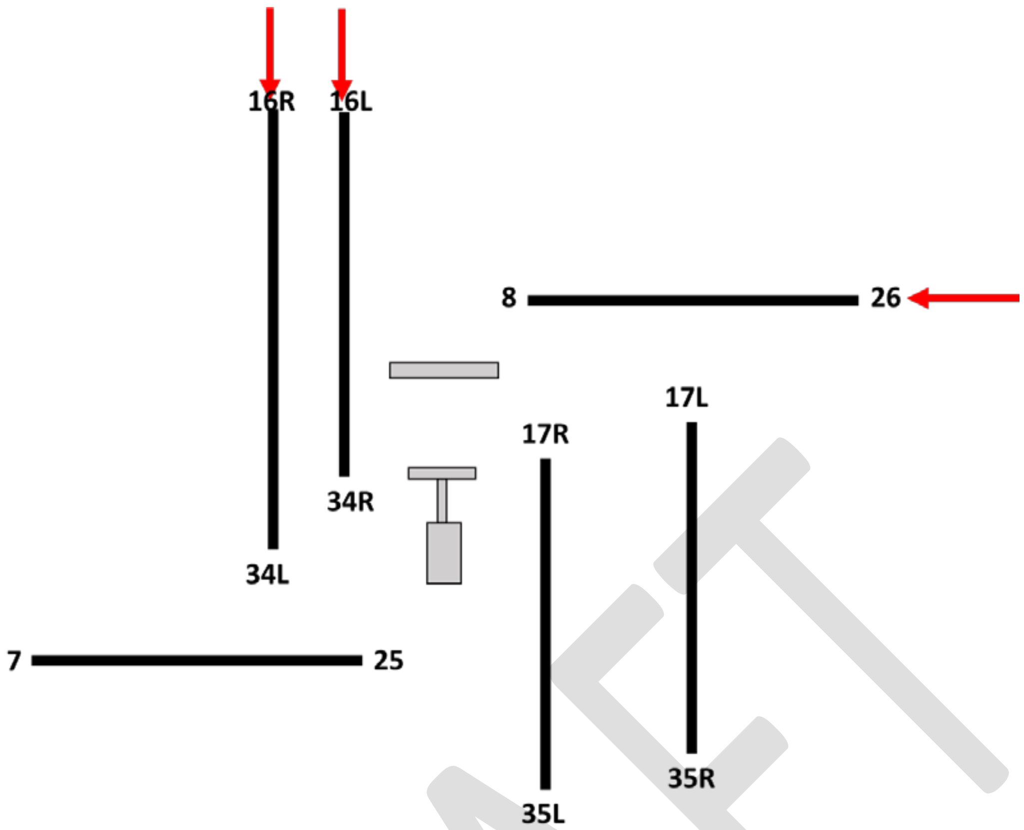

Figure A11. Preferences may impact runway selection

APPENDIX B – SCENARIOS FOR A MIXED ENVIRONMENT

Appendix A described scenarios for a nominal flight operating in a TBO environment from pre-departure to completion. However, transition, and the resulting mixed environment is envisaged for quite some time. During this period, fights will operate in an environment with ASPs not delivering the full set of TBO capabilities (mixed-mode) and with AUs not fully capable as well (mixed-equipage). This impact of this mixed-environment on the scenarios in Appendix A is described in this Section.

B.1 MIXED ENVIRONMENT

As described in Section 4, Airspace Users (AUs) operating in a TBO environment may possess a set of capabilities in concert with the ASP delivering the use of those capabilities. Additional capabilities may be provided by the ASP providing improved performance.

Capabilities for the AU are:

- Pre-departure trajectory negotiation
- Post-departure trajectory negotiation
- Trajectory parameter exchange
- Execution of TBO clearances
- Sharing of aircraft-derived trajectory either via A/G SWIM or ADS-C or both
- Precise clearance execution

For the purposes of the mixed-environment scenarios, the above capabilities are grouped into four categories impacting the behavior or benefits of TBO:

- Pre-departure negotiation is considered on its own.
- Post-departure negotiation is grouped with the sharing of an aircraft-derived trajectory enabling the synchronization of the negotiated trajectory with the flight deck.
- Trajectory prediction accuracy improvements can be delivered with a combination of trajectory parameter exchange and the sharing of an aircraft-derived trajectory. Additional accuracy is also provided through delivering TBO clearances and precise clearance execution.
- TBO clearances and precise clearance execution were joined in a category of precise TBO clearances, although it is recognized that additional benefits can be provided by layering precise clearances atop TBO clearances. These additional benefits are described separately.

In the case of mixed-mode operations, an ASP may support the following capabilities:

- No support for TBO, present-day operations occur.
- ASP supports negotiation both pre- and post-departure negotiation in concert with the use of information to improve trajectory prediction. The ASP is SWIM-enabled, publishes constraints applicable to the flight and supports FF-ICE.

- As necessary for performance, the ASP delivers ATM component integration (see 4.4.4).
- Depending on the neighboring ASP capability, the ASP supports enhanced coordination and negotiation using the 4DT across ASP boundaries.

The impact of not providing the above capabilities was investigated across the full-participation scenarios described in Appendix A. These are described in detail in Section 0.

When a flight is operating without the full-set of TBO capabilities, there is expected to be an impact on the individual flight and, in some cases, system-level effects on other flights.

B.1.1 INDIVIDUAL FLIGHT IMPACTS

In a mixed-mode environment, flights without a full set of TBO capabilities are impacted in the following manners:

- Lack of interaction between the ASP and the AU in development or revision of the plan can lead to sub-optimal planning with flight efficiency consequences.
- Higher margins to compensate for lack of prediction accuracy or control precision leading to a loss of efficiency and predictability through larger and more frequent maneuvers.
- Lack of flexibility may require early conservative decisions on re-routing around uncertain weather.
- Where there is a need for system performance, unequipped flights may be excluded from certain procedures, impacting flight efficiency.

B.1.2 SYSTEM-LEVEL IMPACTS

In the mixed environment, flights that are not equipped also may have an impact on system performance, and consequently on the performance of surrounding flights which possess various TBO capabilities. Some of these impacts may be mitigated in such a manner as to offer benefits to capable flights without affecting performance of the unequipped flight.

Flights not providing early or accurate information affect the plans that are used to estimate demand for DCB. Poor demand forecasts lead to uncertainty regarding when flow management measures must be taken to reduce demand. The impact may be mitigated by considering a flight's uncertainty in the assignment of flow management measures.

Uncertain trajectories also affect buffers and look-ahead times for separation. Larger buffers and shorter look-ahead times are required for uncertain flights increasing the frequency and size of maneuvers for separation. The impact may be mitigated by considering the buffer required to manage the uncertainty in separation between flights, not the uncertainty in each single flight's predicted position. The result is that flights with improved accuracy obtain benefits under all of these circumstances.

Improved precision of execution allows for the design of higher-capacity and higher-efficiency procedures. If an insufficient number of flights are capable of taking advantage of such procedures, then the system benefits cannot be delivered. Additional buffers may be required to manage imprecise execution, affecting all flights in a mixed flow. As equipage increases, the system performance gains can be realized through exclusive use of higher-capacity and efficiency procedures.

Flights with higher uncertainty and inaccurate execution impact the ability to meet downstream constraints and may require a greater number of revisions. These revisions impact workload and may induce revisions in neighboring flights as well. Appropriate use of margin to ensure the plan is robust to uncertainty can manage the revision rate.

B.2 IMPACT OF MIXED ENVIRONMENT ON SCENARIOS

This section identifies the impact of removing AU and ASP capabilities in each of the scenarios described in Appendix A.

B.2.1 PRE-DEPARTURE PLANNING

The FF-ICE/1 flight planning and filing provisions under development for ICAO reflect the initial pre-departure planning capability. To deliver benefits, both the relevant ASPs and the AU must participate. In a mixed-mode environment, benefits can be limited as a result of lack of constraint knowledge by the AU when planning a flight through a non-participating ASP.

B.2.1.1 PRE-DEPARTURE NEGOTIATION

A participating AU uses constraints and flight-specific feedback provided by the ASP to optimize the flight and collection of flights across the fleet. Lack of knowledge of constraints can lead to selection of a route that appears optimal, but is less efficient as a result of the application of constraints.

Negotiation also allows for AU input into flight-specific ATFM decisions allowing an AU to optimize the allocation of ATFM delay across flights. This type of collaboration is in wide use today between some ASPs and AUs.

Table B-1 Lack of Pre-departure Negotiation Capability on Pre-departure Planning

	Impact
Unequipped flight	Flight sub-optimal around constraints known pre-departure. Less flexible response to constraints changing prior to departure.
System	AU cannot optimize impact of constraints across their own fleet.

B.2.1.2 POST-DEPARTURE NEGOTIATION

Flights that are not capable of post-departure negotiation may be provided a re-route during pre-departure planning to minimize the workload and impact during periods with uncertain capacity limitations.

As an example, consider Figure B-1. During planning, the specifics of the weather are not known, and airborne re-routing around a future convective weather system may be workload-intensive to ATC. However, flights may wish to plan through the area hoping that the weather will not materialize, or that they may be able to operate through the area due to sparse coverage. Flights that cannot take advantage of post-departure negotiation and the associated execution of the re-route obtain a pre-departure re-route. Flights that are capable may file through the area with expected convective activity. In-flight these may obtain a re-route in accordance with the more accurate near-real-time weather information.

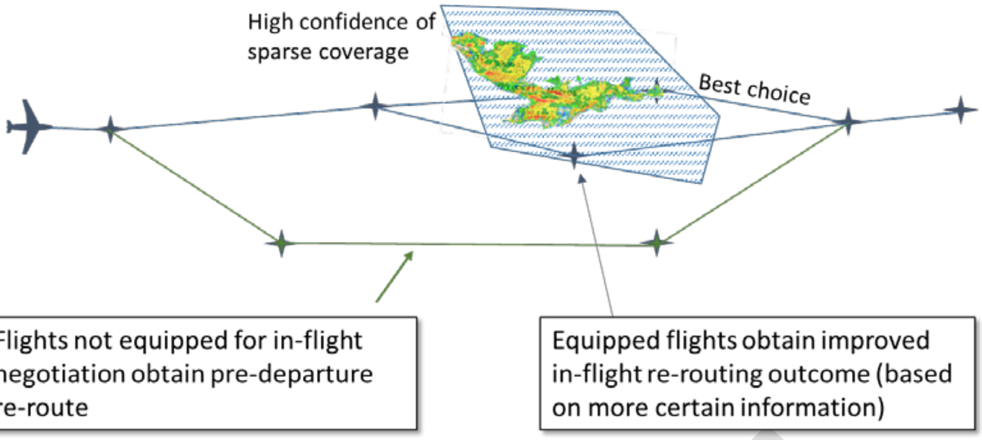

Figure B-1. Post-departure negotiation reduces need for pre-emptive re-routing prior to departure

Table B-2 Lack of Post-departure Negotiation Capability on Pre-departure Planning

	Impact
Unequipped flight	Reduced flexibility prevents the deferral of planning decisions based on uncertain capacity outcomes. Pre-departure options may be limited for flights not capable of post-departure negotiation.
System	Airspace capacity may not be fully utilized when available.

B.2.1.3 TRAJECTORY ACCURACY

Improved trajectory accuracy during planning increases the effectiveness of ATM component integration by allowing for more trajectory-based decisions to be made strategically. There are two effects at work:

- With improved trajectory accuracy, strategic decisions require less margin to be built into their solutions to be robust to perturbations and tactical actions.
- Fewer, smaller tactical actions are required due to earlier strategic actions mitigating potential flow problems and earlier, more accurate strategic conflict resolution.

Improved trajectory accuracy also improves demand forecasts on downstream resources. Flights that have lower accuracy impact the system by creating uncertainty in demand used for demand / capacity balancing. Constraints used in pre-departure planning will reflect this additional uncertainty in DCB. The impact of this uncertainty on flights with higher accuracy may be mitigated through the application of policies seeking delay allocation robust to uncertainty.

Table B-3 Lack of Trajectory Accuracy on Pre-departure Planning

	Impact
Unequipped flight	Flights with lower trajectory accuracy are planned, pre-departure, to take delay tactically versus strategically resulting in lower flight efficiency.

System	Flights with lower trajectory accuracy reduce the accuracy of demand forecasts used for DCB. Impact on higher accuracy flights may be mitigated.

B.2.1.4 PRECISE TBO CLEARANCES

There are circumstances under which demand/capacity imbalances will require the imposition of specific procedures necessitating precise TBO clearances in certain airspace. Flights not equipped will not be allowed to file for the procedures and may obtain a less desirable routing. In Figure B-2, during a period of high demand relative to capacity (e.g., perhaps an outage or temporary flight restriction requires displacing the arrival/departure routes) many flights wish to arrive from and depart towards the West. As a result, arrival/departure procedures requiring precise TBO clearances are expected to be defined allowing higher throughput. A flight planning to arrive at this destination without the ability to execute these procedures may have to fly around to arrive from the East.

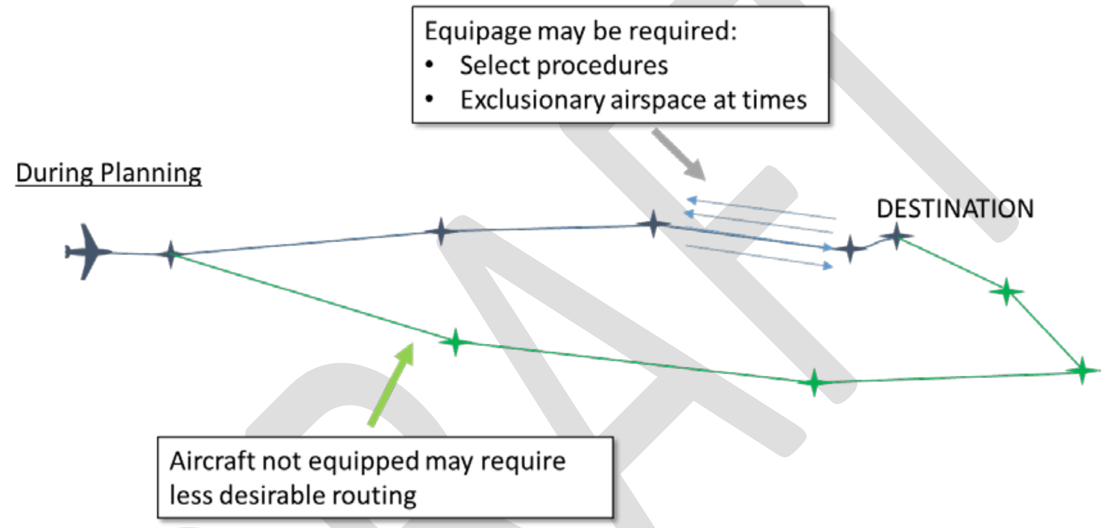

Figure B-2. Flight not capable of executing require procedures obtain less-desirable routing

Table B-4 Lack of Precise TBO Clearances on Pre-departure Planning

	Impact
Unequipped flight	Flights not capable of operating with precise TBO Clearances may be excluded from participating in procedures. Pre-departure planning will consider these to be a constraint on these flights resulting in a less efficient flight path.
System	In some dynamic, highly-constrained cases, TBO Clearances and associated procedures are necessary for any flight to proceed. In such a case, equipped flights obtain a benefit, unimpeded by the unequipped. For some applications, a minimum level of equipage is required to obtain system benefits by defining and using procedures requiring precise TBO clearances. Prior to reaching this minimum level, procedures are applied with lower capacity.

B.2.1.5 ATM COMPONENT INTEGRATION

With component integration, the ASP makes decisions across the concept components with the following properties:

- Strategic decisions consider tactical outcomes.
- Decisions are made as strategically as possible.
- Appropriate margins are included for a robust plan, based upon knowledge of uncertainty.
- Components make decisions respecting known constraints where possible.

Some of the considerations are illustrated in Figure B-3. An ASP that does not provide integration across components suffers the following consequences:

- Trajectory revisions are higher as a result of strategic decisions not being synchronized with tactical ones and components making decisions that may not respect other constraints.
- More actions are taken tactically as strategic decisions do not properly set up the flow for reduced tactical decisions.
- Component objectives are not always met as a result of tactical actions not respecting constraints.

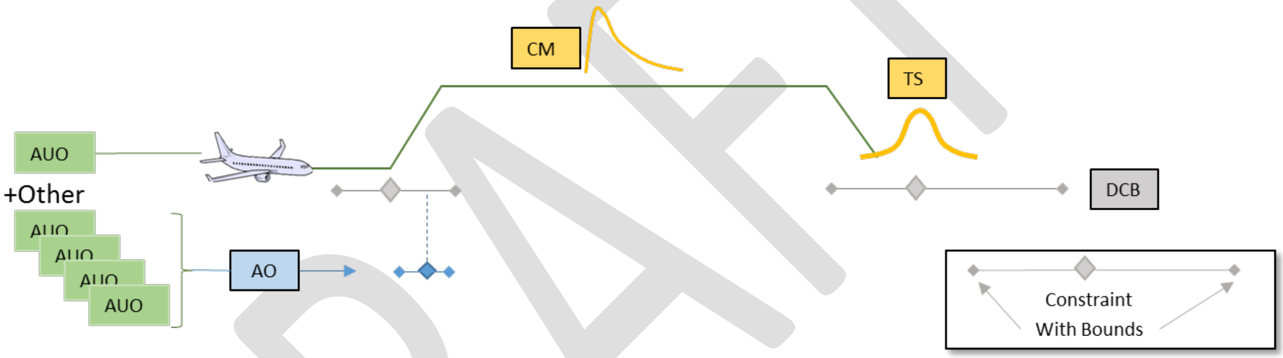

Figure B-3. Component Integration considers the interaction of components when making decisions

B.2.2 SURFACE MOVEMENT

During departure surface operations, a surface plan is executed to deliver the Agreed Trajectory obtained during pre-departure negotiation, including the meeting of known constraints. As surface events occur, the trajectory is updated to reflect the impact of the events on the trajectory. The trajectory may need to be revised if surface events result in larger perturbations on the trajectory.

The following capabilities do not have a large impact on surface movement:

- Pre-departure negotiation – AU-specific considerations pertaining to surface preferences may have been shared as part of pre-departure negotiation.
- Trajectory accuracy – Poor integration of surface movement with the trajectory can adversely affect trajectory accuracy. Low trajectory accuracy, in concert with its impact on other components, relaxes the need for surface tools to accurately deliver a departure time.
- Precise TBO clearances – If required for departure, aircraft not equipped may require delay absorption on the surface.

B.2.2.1 POST-DEPARTURE NEGOTIATION

Post-departure negotiation allows revisions to occur on the agreed trajectory with AU involvement as a result of surface events occurring after pushback. For example, delays on the surface resulting in downstream time constraints not being met require a trajectory revision. Without post-departure negotiation, the trajectory revision will occur with limited input from the AU (i.e., they may still be unable when the clearance is provided).

Table B-5 Lack of Post-Departure Negotiation on Departure Surface Movement

	Impact
Unequipped flight	Without post-departure negotiation, surface events affecting the departure time require a trajectory update/revision without AU negotiation.
System	None.

B.2.2.2 ATM COMPONENT INTEGRATION

The coordination of a surface plan to deliver the agreed trajectory requires that surface tools be sufficiently integrated to do so. Without this level of integration, the departure time delivered represents a large source of uncertainty on the downstream trajectory. Individual flights are affected by poor downstream component performance with consequence on their flight efficiency and predictability.

Strategic plans consider downstream tactical decisions and their uncertainty. These plans inform the departure time window to be delivered by aerodrome operations. Without ATM Component Integration, the departure time does not consider these factors and adversely affects performance.

B.2.2.3 ENHANCED COORDINATION ACROSS ASP

With enhanced coordination across ASPs, so-equipped downstream ASPs can obtain timely updates on the anticipated flight departure time as a result of events on the surface. This allows the downstream ASP to improve the use of the affected flight's data in flow planning decisions. Without this level of coordination, the surface delays are only detected upon receipt of a departure message without an updated forecast of departure time being made available. Downstream ASPs do not benefit from improved flow decisions as a result of improved surface tools and coordination with a consequential impact on throughput and efficiency.

B.2.3 TAKE-OFF

Prior to take-off, a flight has loaded the clearance into their FMS consistent with the agreed trajectory.

Subsequent to surface movement and prior to take-off, the flight is provided a take-off clearance consistent with the agreed trajectory. The aircraft departs and the trajectory is updated with the actual take-off time for accuracy and shared. New estimated times are more accurate. Aircraft equipped with the capability downlink an aircraft-derived trajectory to improve the accuracy of the updated trajectory that is shared on the ground.

Flights subject to a time constraint on climb, for example to merge into an overhead flow, depart to meet such a time constraint with minor trajectory modifications in climb.

Negotiation has no impact on take-off.

B.2.3.1 TRAJECTORY ACCURACY

As illustrated in Figure B-4, subsequent to take-off, a flight with a time constraint to merge into an overhead stream or meter on departure will be provided a take-off time to do so. Adjustments in the time will be required to compensate for the uncertainty. With higher trajectory accuracy at the time constraint, smaller manoeuvres are required on climb to compensate for any uncertainty. When uncertainty is lower on the own-ship and surrounding flights, buffers can also be reduced, allowing a greater level of throughput.

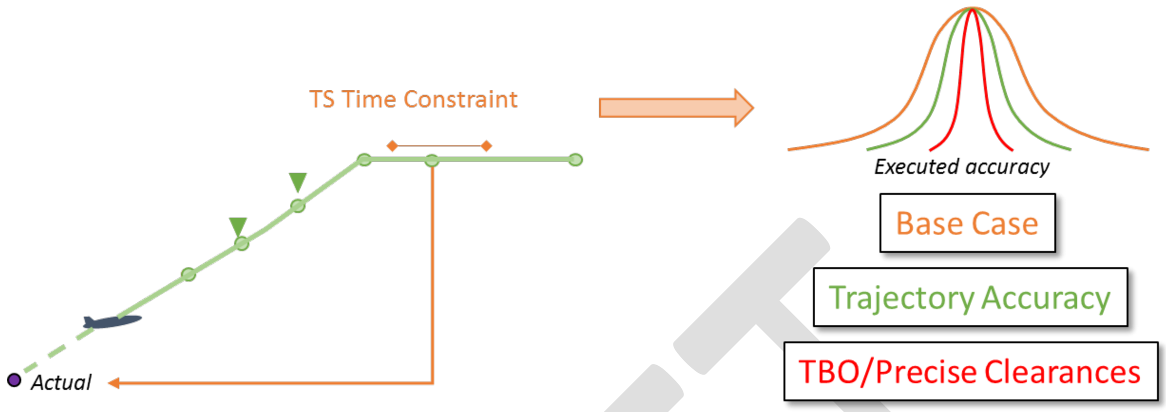

Figure B-4. Increased accuracy at a time constraint allows more circumstances to be feasible

Table B-6 Lack of Trajectory Accuracy or Precise TBO Clearances on Take-off scenario

	Impact
Unequipped flight	Flights with lower trajectory accuracy or without the ability to accept precise clearances have reduced opportunity for meeting time constraints (e.g. merging into an overhead stream) due to buffers for dealing with inaccuracy. Flights encounter greater pre-departure delays.
System	Depending on the airport layout and timing, flights with lack of accuracy and inability to control for inaccuracy, may delay flights behind them as they encounter departure delays for metering. Interacting flights that are not accurate will impact the buffers required for merging into a flow; however, equipped flights will get some benefit.

B.2.3.2 PRECISE TBO CLEARANCES

Similar to the trajectory accuracy (see *Table B-**6***), the ability to provide a precise TBO clearance with a time constraint enables the delivery of a time constraint more accurately with corresponding throughput benefits. Further, the accuracy of interacting aircraft will also impact the buffers and throughput.

B.2.3.3 ATM COMPONENT INTEGRATION

The integration of traffic synchronization with the delivery of a take-off time allows the time constraints to be delivered. This level of component integration is required for the described scenario. Where this is in practice today, departures are synchronized to deliver to a constraint. Further integration, using the trajectories of interacting flights, allows customized knowledge of the allowable buffer between flights.

B.2.3.4 ENHANCED COORDINATION ACROSS ASP

On departure, the time of flight, the updated trajectory of the departed flight and the impact of clearances to reach a constraint are all reflected in the trajectory and associated coordination conditions shared with neighbouring ASPs. Downstream ASPs are not updated of delays absorbed on departure until a departure message is received. Flow planning (e.g., DCB or TS if near the boundary) in the downstream ASP is based on information obtained later, with potential consequences to efficiency and throughput.

B.2.4 TRAJECTORY UPDATES

Trajectory updates are provided as the flight progresses to reduce the uncertainty of a prior predicted trajectory (e.g., due to wind uncertainty). Tactical actions also perturb the trajectory and require updates to the trajectory.

B.2.4.1 PRE-DEPARTURE NEGOTIATION

A flight that has not participated in pre-departure negotiation will observe previously not considered constraints tactically affecting and updating the trajectory. The AU may then wish to react to these updates by requesting changes.

Table B-7 Lack of Pre-departure Negotiation on Trajectory Update scenario

	Impact
Unequipped flight	AUs that have planned without considering the impact of constraints through pre-departure negotiation will observe updates to account for some of these constraints. The AU may wish to request a change, via available means.
System	The effect of a single flight may have fleet-wide impacts that need to be considered by the AU.

B.2.4.2 POST-DEPARTURE NEGOTIATION

Once an update occurs, a flight may recognize that the updated plan is no longer optimal. For example, a delay may need to be recovered with a speed increase. Without post-departure negotiation the options for an Airspace User to compensate for the impact of updates may be limited.

Table B-8 Lack of Post-departure Negotiation on Trajectory Update scenario

	Impact
Unequipped flight	Without post-departure negotiation, an AU may not be able to re-plan a flight to recover a delay detected by an update.
System	The effect of a single flight may have fleet-wide impacts that need to be considered by the AU. Without post-departure negotiation, these changes will be more difficult to coordinate.

B.2.4.3 TRAJECTORY ACCURACY

With lower trajectory accuracy, decisions are made more tactically and those tactical decisions have a larger impact on the trajectory. The result is an increase in the number and magnitude of trajectory updates with a further decrease in the a priori trajectory accuracy. With larger and more frequent updates, more trajectory revisions will need to occur. Each of these contribute to reduced flight efficiency:

- More frequent and larger tactical actions are less efficient.
- Later trajectory revisions have fewer options for optimizing the outcome of each ATM component.

The impact of the trajectory revisions can be mitigated through the development of robust solutions based upon the accuracy of the flight. In the case of robust solutions, flights with lower accuracy require higher margins to meet constraints impacting their individual flight efficiency. Since the revision rate can be mitigated through the robust solution, they do not adversely impact other flights.

Table B-9 Lack of Trajectory Accuracy and Precise TBO Clearances on Trajectory Update scenario

	Impact
Unequipped flight	Reduced trajectory accuracy and lack of Precise TBO Clearances leads to more tactical trajectory actions impacting the efficiency of imprecise flight.
System	Development of solutions robust to inaccuracy mitigates system-level impacts.

B.2.4.4 PRECISE TBO CLEARANCES

Precise TBO clearances have the same impact as trajectory accuracy (see *Table B-**9***). The lack of TBO clearances also increases the likelihood of having an open clearance which diminishes the trajectory accuracy further.

B.2.4.5 ATM COMPONENT INTEGRATION

With a lack of ATM component integration, the trajectory update may be local and not shared across concept components. Lack of integration without a common, shared trajectory plan results in more contradicting decisions (e.g., speed-up followed by slow-down), and decisions that no longer meet other constraints. Without the integration as the trajectory is updated, delay cannot be accounted for and equitably assigned across concept components.

B.2.4.6 ENHANCED COORDINATION ACROSS ASP

As trajectory updates occur, with enhanced coordination using the 4DT, a downstream ASP is notified of the update. The downstream ASP may use the updated information to inform flow decisions downstream. Without the updates, the downstream ASP may have out-of-date trajectory information with larger errors in timing and coordination conditions. These impact the ability to use the information for flow planning.

B.2.5 SEPARATION PROVISION

In the case of full TBO capabilities, separation provision uses a high accuracy trajectory prediction for conflict detection. A resolution is proposed involving a closed clearance which results in a trajectory meeting constraints stipulated in the Agreed Trajectory. This clearance is provided to the flight deck, loaded into the aircraft automation and executed. The downlink of aircraft intent allows the ground system to be assured that the trajectory being executed is synchronized with the expected one upon which resolution was based. This updated trajectory is shared, and may be further updated if so required.

Both pre- and post-departure negotiation are not involved during separation provision. Post-departure negotiation may be invoked subsequently if separation provision results in a trajectory update for which the AU wishes a revision.

The effect of enhanced coordination across ASPs using the 4DT occurs through the trajectory update and revision process.

B.2.5.1 TRAJECTORY ACCURACY

The trajectory is central to decision support automation detecting a conflict in need of resolution for separation provision. There is a significant body of literature indicating that conflict detection can be improved with better trajectory prediction accuracy. The consequences of inaccuracy are:

- Larger buffers are required to detect conflicts at any given look-ahead time.
- The application of the larger buffer results in more false alerts.
- More aircraft are displaced as a result of the false alerts.
- Attempts to reduce the buffer and false alerts require shorter look-ahead times which result in larger interventions to resolve the conflicts.

Separation provision between flights of low and high trajectory accuracy allows buffers to be tailored to the accuracy in relative position, thereby providing partial efficiency benefits to both.

Table B-10 Lack of Trajectory Accuracy on Separation Provision scenario

	Impact
Unequipped flight	Flights with lower trajectory accuracy subject to inefficiency due to greater and more frequent maneuvers for separation provision.
System	Flights with lower trajectory accuracy reduce the separation provision efficiency benefits of improved accuracy relative to the full-equipage circumstance for other flights. Flights with improved accuracy get reduced buffers in all circumstances.

B.2.5.2 PRECISE TBO CLEARANCES

Under TBO, conflicts are resolved with closed clearances. Without the use of closed clearances, the post-resolution trajectory is highly uncertain and is difficult to ensure that downstream constraints required by other components are met. The higher uncertainty of the post-resolution trajectory requires larger buffers for separation from this flight and more trajectory revisions to compensate for any missed constraints.

Higher margin in planning for downstream constraints can mitigate the impact of these flights missing constraints. When coupled with separation provision which respects downstream constraints, these flights may be displaced in preference when planned delays would have to be absorbed in any case.

Table B-11 Lack of Precise TBO Clearances on Separation Provision scenario

	Impact
Unequipped flight	Unequipped flight is subject to high uncertainty due to separation provision. Flight is subject to higher margin, and subsequent tactical maneuvers to meet constraints imposed by other components.
System	Flights unable to execute TBO Clearances have low post-resolution accuracy. The buffers

	to surrounding flights executing separation assurance is determined by the pre-resolution accuracy. The impact on downstream flow measures can be mitigated with larger buffers.

B.2.5.3 ATM COMPONENT INTEGRATION

If separation provision does not seek to meet constraints imposed by other components such as TS and DCB, a poorly conditioned flow will result. Consequences include tactical decisions to rectify the problem, or inefficiency from the poorly conditioned flow (i.e., gaps in the flow).

B.2.6 PLANNED CLIMBS

In this scenario, all participants (human and machine) have a shared view of the agreed trajectory. A clearance has been provided to the flight deck that, if executed to completion, results in the complete end-to-end agreed trajectory being flown. Appropriate tools are provided to ATC to ensure situational awareness is appropriate for conflict management (e.g., when a flight has previously been cleared to climb at a point).

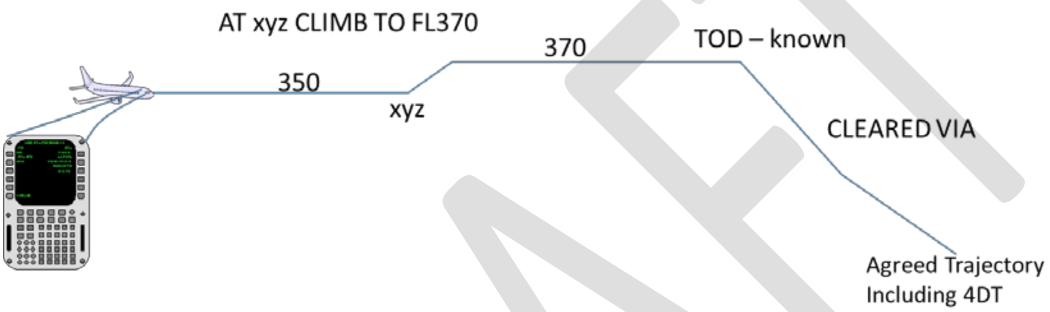

Figure B-5. An end-to-end trajectory is cleared

B.2.6.1 PRE-DEPARTURE NEGOTIATION

Points at which planned climbs are described in a trajectory should be negotiated with the AU to ensure that the planned climb point is not only desirable to the AU, but expected to be feasible. This capability is essential for this scenario as the ASP must be aware of the feasible clearance.

B.2.6.2 POST-DEPARTURE NEGOTIATION

Similar to the pre-departure case, if a change is required in the trajectory, the new trajectory should be negotiated with the AU to ensure planned transitions such as climb points and top-of-descent are both desirable and feasible. An AU not equipped with this capability will not likely receive a preferred end-to-end clearance subsequent to a revision.

Table B-12 Lack of Post-departure Negotiation on Planned Climb scenario

	Impact
Unequipped flight	Unequipped flight will not obtain a preferred end-to-end clearance subsequent to a revision.
System	No ATM system-level impacts.

B.2.6.3 TRAJECTORY ACCURACY

Improved trajectory accuracy reduces the need for revising the trajectory as a result of tactical decisions and subsequently re-issuing the clearance to the flight.

B.2.6.4 PRECISE TBO CLEARANCES

This capability to accept and execute TBO clearances is required for this scenario to occur. Without the ability to deliver and execute a closed clearance with appropriate constraints, a trajectory revision cannot be provided that maintains the end-to-end clearance. Without TBO clearances end-to-end, the means for synchronizing an in-flight trajectory revision between the aircraft and the ground system must be defined.

B.2.6.5 ATM COMPONENT INTEGRATION

This capability is required for this scenario. Downstream constraints imposed by other concept components must be reflected in the trajectory to ensure that the clearance provided meets the objectives of downstream concept components.

B.2.6.6 ENHANCED COORDINATION ACROSS ASP

This capability is required for this scenario for flights crossing into adjacent ASPs. An upstream ASP issuing the clearance must be aware of the ability of downstream ASP to operate with such a clearance. Constraints must be fully expressed in the trajectory to ensure that they are reflected in the agreement that is cleared.

B.2.7 AU-REQUESTED REVISIONS

This case is similar to the pre-departure negotiation case. Since, the flight may be airborne at the time of the requested revision, negotiation may need to be limited beyond the tactical horizon (i.e., the conflict horizon and the area-of-responsibility of the current ATC sector). An AU may or may not involve their FOC in this negotiation process.

An AU may also negotiate with any relevant ASP that is so-enabled. For example, an AU may be receiving updates on flight-specific constraints relevant to a flight from a downstream ASP. Even when that flight is operating under control of an ASP that is not TBO-enabled, a connected aircraft may use those capabilities to negotiate trajectory revisions with a downstream, TBO-enabled ASP. That ASP may coordinate with present-day ATS messages, if necessary, to deliver the clearance, when appropriate.

The pre-departure negotiation capability is not relevant to this scenario; however, it is unlikely that a flight would participate in post-trajectory negotiation without pre-departure negotiation.

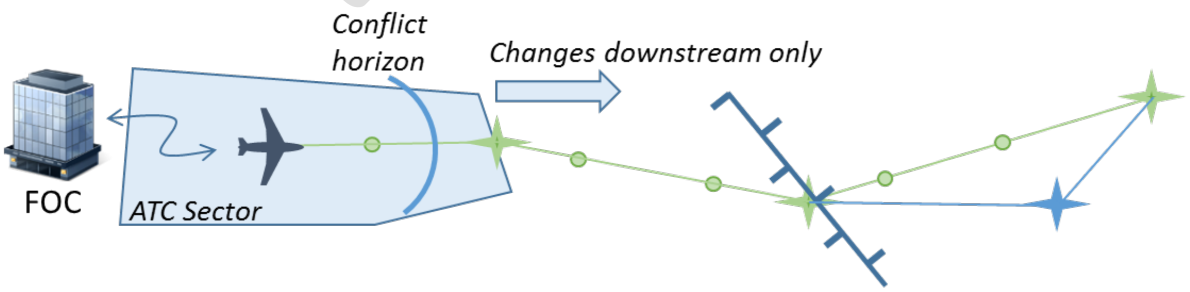

Figure B-6. In-flight AU-requested revisions

B.2.7.1 POST-DEPARTURE NEGOTIATION

This capability is essential for this scenario.

B.2.7.2 TRAJECTORY ACCURACY

As for the pre-departure planning case, any strategic decisions taken as part of the revision should consider the impact of future downstream tactical actions and disturbances. The plan developed should be robust to those disturbances. Higher trajectory accuracy allows more decisions to be taken strategically, with less margin needed for robustness. Conversely, without higher accuracy, more inefficient tactical actions are required on the flight.

Table B-13 Lack of Trajectory accuracy on AU-Requested Revisions scenario

	Impact
Unequipped flight	Revision requires larger margins on constraints issued by other GATMOC Components; thereby deferring more decisions to tactical timeframe.
System	Depending on the GATMOC Component, the deferred decision of the inaccurate flights impact the margins applied to the accurate flights. However, the margins required for accurate flights should be smaller than for the inaccurate flights.

B.2.7.3 PRECISE TBO CLEARANCES

Flights not capable of accepting TBO clearances have negotiation options that are limited to those that are executable via clearances which can be simply expressed. Some downstream procedures may require precise TBO clearances, also limiting options for flights not capable of receiving and executing precise TBO clearances.

Table B-14 Lack of Precise TBO Clearances on AU-Requested Revisions scenario

	Impact
Unequipped flight	Choices for re-routing options to the AU are limited without TBO clearances or precise TBO Clearances.
System	Higher workload to provide clearances if not equipped.

B.2.7.4 ATM COMPONENT INTEGRATION

With ATM component integration, the revision of the Agreed Trajectory considers the impact of future downstream tactical decisions on the trajectory and takes strategic actions incorporating those impacts. For example, without such integration, a revision may take too much or too little corrective action now to a downstream demand/capacity imbalance. The result is an inefficient allocation of delay. Further, without integration, downstream tactical decisions may not be aware of earlier strategic decisions making it difficult to allocate capacity utilization equitably.

B.2.7.5 ENHANCED COORDINATION ACROSS ASP

With enhanced coordination across ASPs, in-flight revisions to the trajectory can span across the ASPs providing more options to the AU for flight optimization. For example, a trajectory revision involving a non-standard coordination condition may be shared and pre-coordinated during negotiation, and include the involvement of the AU.

B.2.8 WEATHER DEVIATION

This scenario involves a flight which is subject to in-flight convective weather and requests permission to deviate in order to "pick their way" through the weather. The process consists of:

- A flight wishes to deviate for weather.
- ATC clears the flight to deviate some nautical miles left of the route.
- As the flight manoeuvres, the Agreed Trajectory is maintained by the ground ATM system, albeit with higher uncertainty.
    - o During the manoeuvre the agreed need not be revised due to the high uncertainty in doing so.
    - o During the manoeuvre, downstream components (e.g., DCB, TS) may update their plans to be robust to this larger uncertainty
- Once the flight has flown through the weather, the uncertainty is reduced and the agreed trajectory may be revised to reflect the latest update
- The revision is cleared to the flight.

The circumstance is illustrated in Figure B-7.

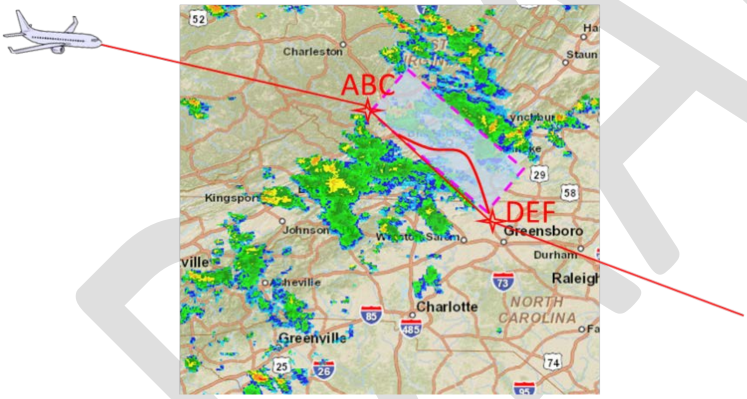

Figure B-7. Flight will deviate left for weather

B.2.8.1 PRE-DEPARTURE NEGOTIATION

The presence of pre-departure negotiation does not impact this scenario.

B.2.8.2 POST-DEPARTURE NEGOTIATION

Once a flight has passed the weather, the AU may wish to negotiate a revision taking into account any delay that was obtained and the downstream consequences. For those AU with the FOC involved in the revision process, considerations of flight priority may be taken into account.

Flights without post-departure negotiation may still require a revision to incorporate downstream DCB and TS impacts. However, these revisions would not directly consider AU input until the clearance is provided;

initially that input would be limited to circumstances where the flight is unable to comply. The AU might then attempt to initiate a change. The result is a longer time to recover to a stable agreed trajectory, or a less than optimal solution to the AU.

Table B-15 Lack of Post-Departure Negotiation on Weather Deviation scenario

	Impact
Unequipped flight	Flights without post-departure negotiation are assigned a revision. This provides a less than optimal solution to the AU, or solutions that the flight is unable to meet, extending the time to recover.
System	Longer revision process may impact surrounding flights (depending on how the revised flights get incorporated).

B.2.8.3 TRAJECTORY ACCURACY

The impact of the weather deviation on trajectory accuracy is likely to be large. The flight will also likely be operating using more manual modes of operation with the consequence that any aircraft-derived trajectory will not be accurate during the manoeuvre. As a result, capabilities delivering improved trajectory accuracy do not impact this scenario. More accurate flights may have more options for recovery.

B.2.8.4 PRECISE TBO CLEARANCES

Subsequent to the weather deviation manoeuvre, the issuance and execution of a new clearance to follow a modified agreed trajectory is simplified for those flights with TBO clearances. Workload for these flights will be reduced and throughput can be increased. The consequence is that flights that are so-capable have reduced demands on capacity. Depending on the extent of this reduction and the demand profile, flights not capable may need to be re-routed around the weather prior to it.

Table B-16 Lack of Precise TBO Clearances on Weather Deviation scenario

	Impact
Unequipped flight	Flights without precise TBO clearances may need to be re-routed around the weather prior to departure (as workload would not accommodate revisions).
System	Capacity is reduced in these circumstances if too few flights are equipped with TBO clearances to issue revisions as clearances.

B.2.8.5 ATM COMPONENT INTEGRATION

With component integration, the uncertainty in the prediction can be built into downstream plans for TS and DCB. For example, flights operating through a convective weather system as shown in Figure A-7 may be subject to large variance on their delay through it and subject to traffic synchronization downstream. With component integration, downstream traffic synchronization would plan all flights considering the impact of the higher uncertainty on those flights operating through the system. The result is an optimal allocation of decision timing based upon known uncertainty.

B.2.8.6 ENHANCED COORDINATION ACROSS ASP

With enhanced coordination across ASPs, downstream involved ASPs are provided information on the flight's trajectory and uncertainty in such a way that the flight's impact on other concept components can be considered as described in B.2.8.5.

B.2.9 ADVANCED COORDINATION

Coordination for fully TBO-capable ASPs and AUs exhibit the following characteristics:

- The Agreed Trajectory is continually shared & updated across ASPs.
- The receiving ASP is aware of relevant plan revisions as they happen.
- Early revisions mitigate need for tactical voice coordination.
- The AU is involved in revisions including coordination conditions, time permitting.
- Negotiation is supported across ASP boundaries, allowing more choices for the AU.

In a mixed mode environment, coordination continues to be accomplished through existing ATS messages. Any downstream ASP has higher uncertainty for flow planning.

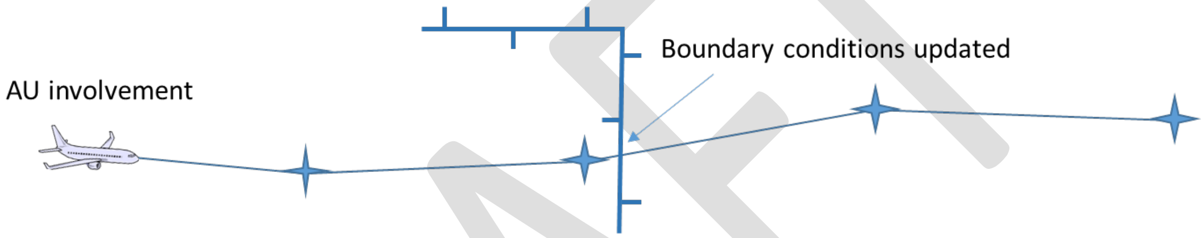

Figure B-8. Advanced coordination shares updates and revisions across ASPs

B.2.9.1 POST-DEPARTURE NEGOTIATION

Negotiation between the AU and relevant ASPs may result in changes to the agreed trajectory in a downstream ASP. In order for the corresponding clearance to be delivered to the flight deck, a mechanism for coordination of the clearance must be provided.

Table B-17 Lack of Post-Departure Negotiation on Advanced Coordination scenario

	Impact
Unequipped flight	AU perspective not fully incorporated into coordination decisions, flight may be sub-optimal.
System	None

B.2.9.2 TRAJECTORY ACCURACY

Estimates of boundary crossing data are only as accurate as the trajectory prediction. When estimates of the boundary crossing data are poor, there may be limited benefits of sharing that data earlier and more frequently.

Table B-18 Lack of Trajectory Accuracy on Advanced Coordination scenario

	Impact
Unequipped flight	Incorporation into downstream ASP flow plans will have higher margin with more tactical decisions.
System	Flights with lower accuracy mitigate impact of earlier sharing of information.

B.2.9.3 PRECISE TBO CLEARANCES

This capability allows complex 4DT clearances that have been negotiated across ASPs to be provided to the flight.

Table B-19 Lack of Precise TBO Clearances on Advanced Coordination scenario

	Impact
Unequipped flight	Constrains the clearances and trajectories that can be provided to the flight. Reduced options impact throughput and efficiency.
System	Throughput impact, if flows not segregated, may constrain all flights.

B.2.9.4 ATM COMPONENT INTEGRATION

With component integration, constraints may be shared across ASPs and considered when solving upstream problems to not be disruptive to the solution. Information pertaining to uncertainty can be used to determine the best time to develop a flow solution and identify how much margin is required.

B.2.9.5 ENHANCED COORDINATION ACROSS ASP

This capability is required of the coordinating ASPs for advanced coordination.

B.2.10 TRAFFIC SYNCHRONIZATION ON ARRIVAL

The process for synchronization on arrival is illustrated in Figure B-9. Prior to beginning to control the flights to a TS-specified controlled time, the trajectory has been managed by DCB processes which considered the expected TS behaviour.

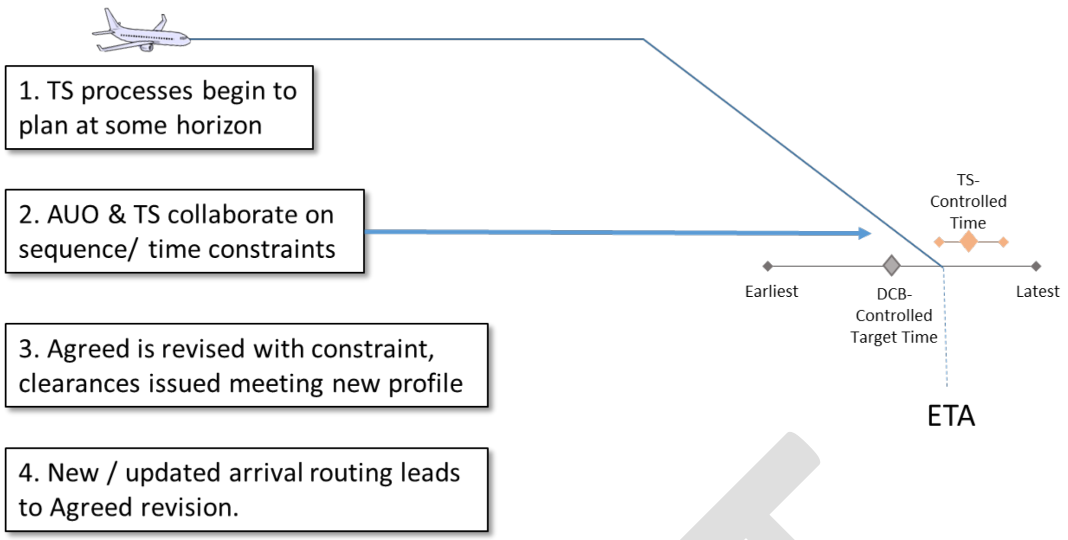

Figure B-9. Process for traffic synchronization on arrival

B.2.10.1 PRE-DEPARTURE NEGOTIATION

Some flights departing from airports close to the destination will require consideration of arrival traffic synchronization as part of pre-departure negotiation. As the flight approaches departure time, pre-departure negotiation can better refine the time of departure to ensure that the flight is incorporated into the arrival schedule planned by TS. Without pre-departure negotiation, in conjunction with component integration, TS is not aware of the flight with sufficient accuracy and lead time to incorporate it into the TS plan. As a result, the flight must be incorporated just prior to departure with potentially long delays.

Table B-20 Lack of Pre-departure Negotiation on Arrival TS scenario

	Impact
Unequipped flight	Long delays may be required to incorporate the flight into an already developed plan. May not negotiate to swap with another, same carrier, flight.
System	May introduce arrival demand uncertainty affecting stability of plans for other flights.

B.2.10.2 POST-DEPARTURE NEGOTIATION

A flight's agreed trajectory may be re-negotiated in flight as uncertainty becomes known. One application is to provide more efficient speed changes early allowing the flight to better meet a TS plan. This results in the flight requiring fewer inefficient path-stretches later. The AU may also choose to modify the agreed trajectory to allow a more fleet-optimal TS plan.

Table B-20 Lack of Post-departure Negotiation on Arrival TS scenario

	Impact
Unequipped flight	Decisions may not be taken at the best time for the individual flight, based upon remaining uncertainty.
System	AU may not optimize across the fleet as uncertainty develops for each flight.

B.2.10.3 TRAJECTORY ACCURACY

With increased trajectory accuracy fewer, smaller tactical manoeuvres are required to correct and meet a controlled time for traffic synchronization with corresponding impact on efficiency. A more accurate trajectory can also be planned for earlier.

With a more accurate trajectory, the issuance and execution of an uninterrupted descent in a higher density environment is also more likely to occur.

Table B-21 Lack of Trajectory Accuracy and Precise TBO Clearances on Arrival TS scenario

	Impact
Unequipped flight	More corrective tactical maneuvers are required to meet a time. Greater buffers are required, impacting capacity, for uninterrupted descents. As a result, flight may be ineligible for uninterrupted descents in higher density.
System	Impact on capacity for procedures with mixed operations.

B.2.10.4 PRECISE TBO CLEARANCES

The ability to deliver the TS plan more accurately allows an increase in the delivery accuracy of times at the metering fix with corresponding improved performance in terminal airspace. The impact is the same as that described in *Table B-**22***.

B.2.10.5 ATM COMPONENT INTEGRATION

Traffic synchronization works best if the flow is properly conditioned, this requires integration of earlier decisions with the synchronization. Without component integration, delay allocation to meet arrival capacity constraints may not be equitably allocated, gaps may be left in the flow, and delay is taken more tactically and inefficiently.

B.2.10.6 ENHANCED COORDINATION ACROSS ASP

Enhanced coordination across ASPs is not generally applicable to arrival traffic synchronization. For flights that arrive near an ASP boundary, the enhanced coordination can allow these flights to be more accurately incorporated into the flow.

— END —