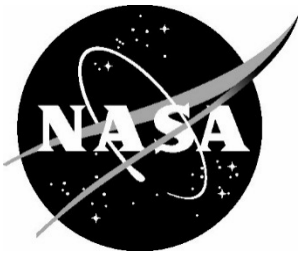
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Tactical Aircraft Spacing – En route (TAS-E)
Concept Overview

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February 2021

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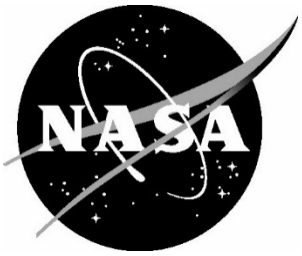
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Symbols & Abbreviations

4DT	Four Dimensional Trajectory
AAtS	Aircraft Access to SWIM
AC	Aircraft
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
AOC	Airline Operations Center
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATM	Air Traffic Management
ATM-X	Air Traffic Management – Exploration
CPA	Closest Point of Approach
DA	Designated Aircraft
ERAM	En Route Automation Modernization
FAA	Federal Aviation Administration
FC	Flight crew
FL	Flight Level
FMS	Flight Management System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
NM	nautical miles
PBN	Performance Based Navigation
PLOSp	Predicted Loss of Spacing
SAA	Special Access Airspace
SWIM	System Wide Information Management
TAS-E	Tactical Aircraft Spacing – En route
TBM	Time-Based Management
TBO	Trajectory Based Operations
TOD	Top of Descent
TRACON	Terminal RADAR Approach Control Facility

Definitions

Automatic Dependent Surveillance - Broadcast: A means by which aircraft, aerodrome vehicles, and other entities can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

Designated aircraft: An aircraft from which the TAS-E equipped aircraft must get no closer than to a set distance during a TAS-E operation.

Ground automation system: Computer automation that assists the controller by providing a means for communication, separation, and decision support.

Minimum spacing distance: A distance that must be maintained from another aircraft for specific operations.

Predicted Loss of Spacing: A forecasted point or region along the ownship trajectory that will come closer to another aircraft or its trajectory than the minimum spacing distance.

1 Introduction

The FAA's Next Generation Air Transportation System (NextGen) program has been tasked with developing concepts and plans to transition today's National Airspace System (NAS) to a Trajectory Based Operations (TBO) system of Air Traffic Management (ATM). The goal of a TBO system is to increase the efficiency and predictability of flight operations while maintaining operational flexibility in an increasingly diverse air traffic system. The FAA's NextGen organization has published documents that provide a vision of these proposed changes[1, 2, 3]. This vision includes transitioning to a time-based system of ATM, increasing the use of information exchanged between air and ground systems, and taking advantage of an aircraft's ability to fly precise and predictable trajectories using Performance Based Navigation (PBN).

NASA formed the Air Traffic Management - Exploration (ATM-X) project to investigate concepts and technologies that would enable and enhance the TBO concept. Based on previous research that has been conducted and supported by NASA[4, 5, 6, 7, 8, 9, 10], a portion of the ATM-X project is focused on developing concepts and technologies that will support strategic flight planning and execution as well as optimizing trajectories while in flight.

Strategic planning and en route optimization are key components for achieving the benefits anticipated with the TBO concept. However, even in TBO, there are times when unpredicted traffic conflicts can develop between two aircraft that are in close proximity to each other. One approach to solving this situation is to require an air traffic controller to intervene and provide an open loop solution to the problem (e.g., provide headings or altitude changes to one or both aircraft). Another approach might be to allow the aircraft to resolve the predicted loss of spacing using a new distributed air-ground concept known as Tactical Aircraft Spacing – En route (TAS-E). TAS-E is a proposed Automatic Dependent Surveillance – Broadcast (ADS-B) In based concept that uses an airborne generated trajectory to resolve these near-term conflicts with a predictable, closed-loop solution. The TAS-E concept builds on current capabilities and assumed improvements to avionics, ground automation, and NAS infrastructure that are expected to be in place in the 2040-2045 timeframe. The concept also leverages TBO enabled information exchanges of data between the air and ground systems along with airborne-based traffic computer solutions to develop a new aircraft trajectory which will minimize changes from the current cleared four-Dimensional Trajectory (4DT) while resolving all traffic conflicts and attempting to meet original downstream trajectory constraints.

This paper provides a detailed overview of the TAS-E concept and a description of representative scenarios.

2 TBO Operational Environment

The TBO concept is based on strategically planning, managing and optimizing flights. The FAA recognizes that there have been several advancements in the development of Time-Based Management (TBM) tools, PBN and several enabling technologies (e.g., DataComm, System-Wide Information Management (SWIM))[11]. TBO is a concept that attempts to leverage and integrate these capabilities to address the challenges of ATM in the future.

In the TBO concept, TBM ground automation systems will be used to generate 4DTs that aircraft will be expected to comply with during their flight. According to the FAA's "Vision for Trajectory-Based Operations"[1], these trajectories will include a planned departure and arrival schedule and may include additional en route crossing times and altitude restrictions at select points along the trajectory. These trajectories will have been planned and agreed upon by all involved parties. These parties could include controllers, traffic managers, Airline Operations Center (AOC) dispatchers

and fleet managers, pilots, and the FAA command center. These trajectories should result in safe, efficient, and predictable operations.

According to Hatton, in the FAA document "NextGen Trajectory Negotiation Concept of Operations"[3], these trajectories can be renegotiated during the flight by any party, based on changing constraints, performance, traffic, or environmental changes. Under normal operations, renegotiations should avoid any strategic conflicts caused by changes to the surrounding traffic situation. In this context, a strategic conflict is one that is far enough away, that TBO planning tools can be used to manage trajectories.

In section 4.4.1 of reference 3, Hatton presents a number of key temporal events that must be satisfied to negotiate a new trajectory successfully. Three significant times are the trajectory change time, the trajectory implementation duration, and the negotiation deadline. The trajectory change time is the time at which the aircraft reaches a trajectory change point and begins to fly the updated/amended trajectory. The trajectory implementation duration is the time required for controllers and flight crews to load and accept the updated/amended trajectory and for the ground automation to verify the amended trajectory is shared by all parties. The negotiation deadline is the trajectory implementation deadline minus the trajectory implementation duration. In other words, it is the deadline of when all negotiations much be completed.

According to Hatton, the negotiation deadline is a topic of research and discussion. Several factors must be accounted for in order to determine the negotiation deadline. This deadline is not necessarily a fixed time—it is a function of the traffic situation, the complexity of the airspace, and any external factors (such as weather) that may influence negotiations. Hatton does point out that some subject matter experts have stated that the negotiation deadline needs to be at least 100 nautical miles (NM) (approximately 12 minutes) from the constraint for cruise scenarios. Hatton also highlights other issues and points out that some conflicts may need to be addressed up to an hour from the constraint.

The paper "4D Trajectory Based Operations Concept of Operations"[12] written by C.M. Buntin and T. Funari also addresses a similar issue. In section 2.4, the authors postulate that a time horizon exists that separates the use of strategic tools versus tactical tools for solving traffic conflicts in a TBO concept. This time horizon is assumed to be approximately 20 minutes. If the conflict is greater than 20 minutes away, the conflict can be addressed using strategic 4DT tools. If a conflict is closer than 20 minutes, then a tactical approach is suggested.

"Vision for Trajectory Based Operations"[1] also addresses the question of needing a tactical tool in a TBO environment, (page 15) under "Guiding Principles and Assumptions". Within this section the paper states that while the number of conflicts that controllers need to address should be diminished in the TBO concept, there will still be a need to resolve conflicts in a TBO environment tactically.

These references point out that even in a well-organized TBO concept of operations, there are times when a strategic plan cannot be achieved, and a more near-term, tactical solution is required. References 1-3, 11 and 12 all assume this will be addressed in ways similar to today's operations. These references assume the controller will intervene and provide heading or altitude changes to solve the conflict. Once the conflict is resolved, the controller will then use ground-based tools to "reconnect" the aircraft to a negotiated 4DT. While this is a safe and effective approach, it will remove the aircraft from the strategic plan and may disrupt downstream plans, depending on the extent of the deviation. Additionally, since more aircraft will be operating on optimized, preferred trajectories, the traffic flows may be less structured than today's traffic flows. This may make it more difficult for controllers to provide tactical conflict resolutions.

Another approach to solving near-term conflicts might be to make use of a proposed airborne concept being developed by NASA known as TAS-E. TAS-E is a new concept that uses airborne generated trajectories and spacing constraints to resolve these near-term conflicts with predictable, closed-loop solutions. The TAS-E avionics will develop a new aircraft trajectory that will minimize changes from the current cleared 4DT with the intent to resolve all airborne predicted losses of spacing while attempting to meet original downstream trajectory constraints.

3 Concept Description

3.1 Overview

The TAS-E concept leverages TBO enabled information exchanges of data between air and ground systems, aircraft-to-aircraft sharing of ADS-B data ("ADS-B In"), and an onboard avionics suite that can identify and resolve near-term, predicted losses of spacing (PLOSp) with surrounding aircraft, hereafter referred to as the "TAS-E Avionics". Further, an assumption of the future existence of ground-based infrastructure enhancements generally required for any advanced TBO operations has also been included as a baseline future ground capability required as a part of this concept; more details are provided in Section 5. For TAS-E, this ground automation side will also monitor aircraft parameters in real time and determine whether to allow TAS-E operations.

Once an aircraft has been authorized by ATC to perform TAS-E operations, the TAS-E avionics considers all airborne traffic with valid ADS-B signals as designated aircraft and monitors these designated aircraft for any predicted losses of spacing. When the TAS-E avionics identify a near-term PLOSp with another aircraft, the avionics develop a proposed trajectory modification that resolves the PLOSp with the intent to resolve all airborne predicted losses of spacing while attempting to meet original downstream trajectory constraints. TAS-E is designed to provide flight crews with updated trajectories that involve relatively minor deviations from their assigned trajectory without the need to renegotiate the entire trajectory. The goal of TAS-E is to allow the aircraft to remain on a predictable trajectory at all times without requiring air traffic control open-loop intervention. It is envisioned that an aircraft equipped and certified to perform TAS-E would be capable of performing TAS-E from the time that it exits the departure TRACON until it reaches the arrival TRACON.

3.2 Technical Considerations

When the TAS-E equipped aircraft generate new 4DTs, these trajectories must comply with any constraints established and data linked by the ground automation system to the TAS-E aircraft. These constraints can include ownship constraints or the definition of certain airspace areas the TAS-E aircraft is required to avoid. This airspace could be regulatory (e.g., Special Access Airspace, sector boundaries) or areas of weather to be avoided. All ground-initiated limits serve as constraints on the TAS-E aircraft throughout its flight. They are updated as needed by the ground automation system or controller. It is also possible that the flight crew could enter or expand areas to be avoided; this could be especially useful with regard to weather.

TAS-E aircraft avionics will receive ADS-B In information from all surrounding traffic at regular intervals (nominally once a second). In addition to the state data received via ADS-B In, the avionics must also receive intent information on designated aircraft. This is required to avoid unnecessary trajectory changes by the TAS-E aircraft caused by false identification of PLOSp when based on aircraft state data only. This intent information may be available from multiple potential sources including: Aircraft Access to SWIM[13] (AAtS), data-link messages from the ground (rebroadcast of Automatic Dependent Surveillance-Contract (ADS-C) data), future revisions of ADS-B, or other available means.

3.3 Roles and Responsibilities

In a TBO environment, the flight crew is still responsible for operating the aircraft in compliance with all ATC clearances. In the TAS-E concept, flight crews are also responsible for ensuring their aircraft get "no closer than" a minimum spacing distance from other aircraft. Another concept that makes use of a no closer than clearance is described in a paper by MITRE[14] entitled "Air Traffic Controller and Flight Crew Conduct of a No-Closer-Than Spacing Task utilizing a Cockpit Display of Traffic Information". Flight crews accomplish this task using guidance obtained from their onboard TAS-E avionics. Once a new 4DT is generated by the TAS-E avionics, the flight crew will be responsible for reviewing and accepting/rejecting the trajectory change. If the flight crew does not respond to the TAS-E avionics generated trajectory modification within a required time interval, then an alert is generated in the cockpit. If a flight crew fails to act on the trajectory modification after an alert is generated, a notification of any outstanding alerts would be sent to the ground system. This is to ensure controller awareness and alert them that they may need to intervene.

Once loaded and executed by the flight crew, this modified trajectory is communicated through data link to the ground automation to provide awareness to controllers and to disseminate this information to surrounding aircraft. The TAS-E aircraft remains on a 4DT while resolving the PLOSp; maintaining predictable, closed-loop operations the entire time.

During TAS-E operations, the controller will be responsible for monitoring key datalink parameters from TAS-E aircraft to ensure compliance. The controller meanwhile remains responsible for separation at all times, and with the aid of the ground automation system, monitors traffic in his or her sector for any traffic conflicts.

3.4 Benefits

There are various benefits expected from the TAS-E concept. There will be a system wide benefit from the ability to maintain all aircraft on cleared, predictable, closed-loop 4DTs. If all aircraft (other than rare exceptions) can maintain their trajectory and therefore enable the system strategic plan to be maintained, then there will be less re-planning and renegotiation required. For TAS-E equipped aircraft, once a preferred trajectory is negotiated, the aircraft should be able to remain on a trajectory that is very close to the original negotiated trajectory. It is assumed that the negotiated trajectory is as close to an optimal solution as possible. TAS-E does not try to optimize that trajectory or any modifications, but simply tries to minimize deviations from the original trajectory with a priority on maintaining the required spacing.

4 Sequence of TAS-E Operations

4.1 Pre-TAS-E Initiation

In the future air traffic management system, the trajectory for a given flight will be negotiated between key parties prior to the flight. These parties include, but are not limited to, the AOC, FAA command center, impacted TRACONs, impacted Air Route Traffic Control Centers (ARTCCs), and the flight crew. These negotiated trajectories incorporate airline preferences, airspace constraints and air traffic management plans. Part of this negotiation would also include an indication that an aircraft and flight crew are approved for TAS-E operations. Knowledge of TAS-E capability may provide greater degrees of freedom when negotiating a trajectory. Once a 4DT has been established, the flight plan is filed. Part of that flight plan includes an indication that the aircraft will be operating as a TAS-E flight.

4.2 Initiating TAS-E Operations

While at the departure gate, the TAS-E aircraft must log into the ground automation system, to establish two-way TAS-E communication. Once logged in, the TAS-E avionics will provide a status message to the ground automation at regular intervals. This message would include information on the operational health of the TAS-E avionics, any outstanding alerts that have not been addressed by the flight crew, the current ability of the aircraft to follow its 4DT, as well as other TAS-E relevant information that the ground system needs for monitoring compliance. The ground automation will alert the controller of any failures in the avionics, to maintain awareness of TAS-E aircraft availability.

For an aircraft to perform TAS-E operations, the aircraft must meet certain TAS-E criteria. Aircraft must be logged into the ground automation system, transmit the status of the TAS-E avionics, be surveilled and managed by an ARTCC, and comply with the cleared 4DT. If any of these conditions are not satisfied, the aircraft cannot perform TAS-E operations.

The ground automation system keeps track of the TAS-E criteria and periodic status message information and only allows the aircraft to perform TAS-E operations when all parameters are met. The status of these parameters are summarized in a TAS-E Mode Message, which has three possible values: standby, armed, or active. These modes are described as follows:

- Standby: TAS-E avionics are powered on but not logged on and/or not sending valid periodic status messages
- Armed: TAS-E avionics are logged on with the ground automation system, the avionics are sending valid periodic status messages, but not all criteria are met
- Active: TAS-E avionics are logged on with the ground automation system, the avionics are sending valid periodic status messages and all criteria are met

If the TAS-E Mode changes due to a change in the required criteria, then a TAS-E Mode Message is sent from the ground automation system to the avionics and the flight crew is made aware of the current mode. This helps eliminate any TAS-E mode confusion between the ground and airborne systems. This TAS-E mode message can be used by the ground to indicate to the avionics/flight crew that they are no longer able to conduct TAS-E operations (i.e., inform the TAS-E avionics to switch to armed or standby mode).

4.3 En Route TAS-E Operations

As the flight progresses, the aircraft leaves the departure airport's TRACON and enters airspace managed by an ARTCC. If all criteria are met for TAS-E operations, the ground automation changes the TAS-E mode from armed to active.

Once the TAS-E mode changes to active, the TAS-E avionics identify all airborne traffic with valid ADS-B signals and intent data as designated aircraft. The TAS-E avionics then monitor each designated aircraft for a PLOSp with the TAS-E aircraft. In **Error! Reference source not found.**, AC1 has been monitoring designated aircraft AC2. Using the ADS-B and intent data the TAS-E avionics detect that AC2 is on a trajectory that will result in a PLOSp with the TAS-E aircraft.

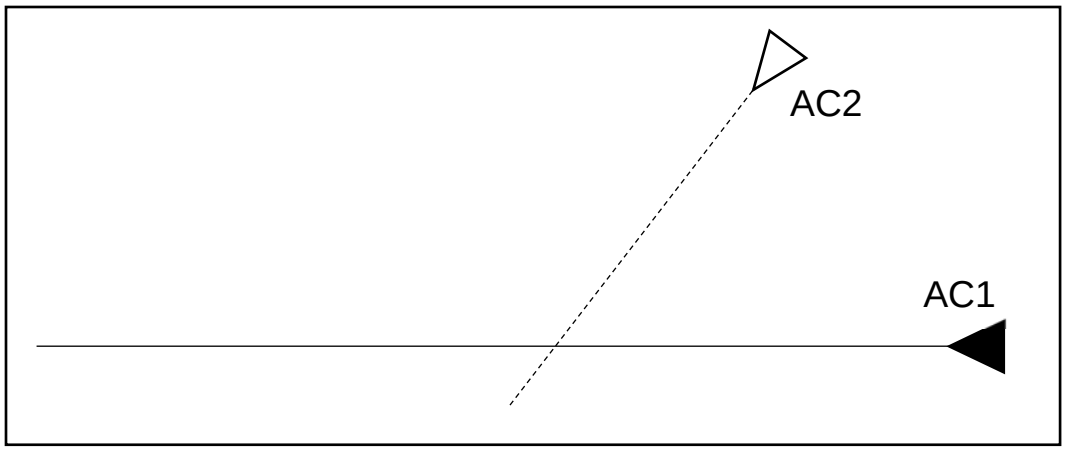


Figure 1. En route operations; initial condition (top-down view)

After detecting a PLOSp, the system generates a new trajectory that solves the PLOSp while attempting to meet downstream trajectory constraints. Each new trajectory will avoid the creation of any new PLOSp. In this case there are no other relevant designated aircraft and a slight path stretch to the right will resolve the current PLOSp, shown in Figure 2. When a new trajectory is generated, the flight crew is expected to review it and execute it promptly unless they have an operational objection. Once executed, this new trajectory is shared with the ground automation system and distributed to other aircraft through networks such as datalink or AAtS. As a flight progresses, the TAS-E avionics continuously evaluate the traffic situation based on the location and intent of all designated aircraft and any Air Traffic Control (ATC) provided constraints.

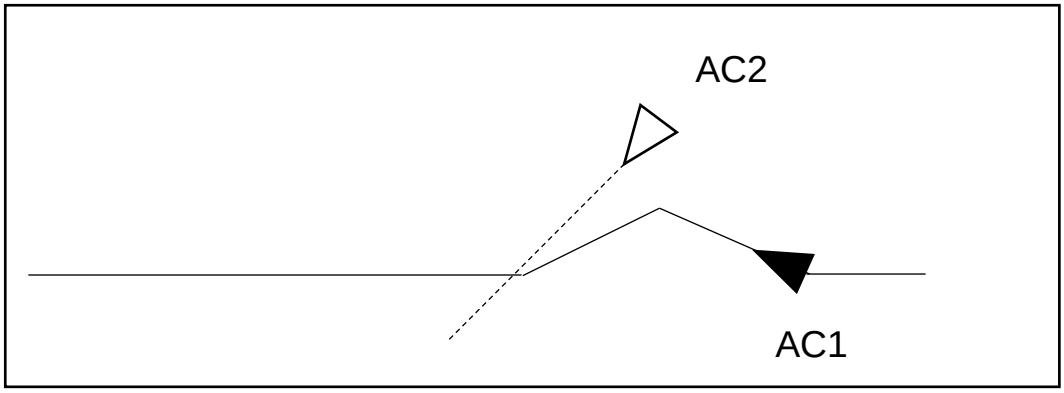


Figure 2. En route operations; solution to PLOSp (top-down view)

The ground automation continues to monitor that the TAS-E system is working properly, through the periodic status messages. The TAS-E avionics continue to monitor AC2 and all other designated aircraft to ensure there is no new predicted loss of spacing.

Once the TAS-E system detects that it is no longer receiving valid ADS-B data from AC2 (e.g., it is no longer within range) it will no longer be considered a designated aircraft by the TAS-E system and the TAS-E aircraft will no longer monitor AC2.

4.4 TAS-E Descent Operations

TAS-E can also be used for altitude change situations. This is particularly helpful near TRACON boundaries when an aircraft desires to climb to or descend through en route traffic. In today's system, aircraft that climb out of TRACON airspace into an overhead stream of en route traffic can create an increased workload for a controller. If there is a significant amount of en route traffic at

different altitudes, controllers will often need to issue several clearances to level aircraft off at intermediate altitudes as the aircraft climbs to its desired altitude, commonly referred to as a step climb. Similarly, descending from an en route altitude into a TRACON's airspace in the presence of departing traffic can involve a number of clearances to level off during the descent, vectors around traffic, and/or a clearance to direct the aircraft to descend prematurely to a low altitude to avoid traffic conflicts. Due to the unpredictable nature of these operations, even in a TBO environment, these operations could be complicated and require a more tactical, near-term solution.

Consider a Descent Scenario: As AC1 continues its flight, it is now approaching the Top of Descent (TOD), shown in Figure 3 below. AC3 has become established as a designated aircraft by AC1, by receiving valid ADS-B and intent data. AC1 has already been cleared to descend via a charted procedure as part of normal operations in the TBO strategic plan to deliver the aircraft to a TRACON gate at a predicted time and altitude. Based on the current trajectories of AC1 and AC3, the TAS-E avionics have determined that AC3 will create a PLOSp at the time when the TAS-E aircraft will no longer have the required vertical spacing with AC3.

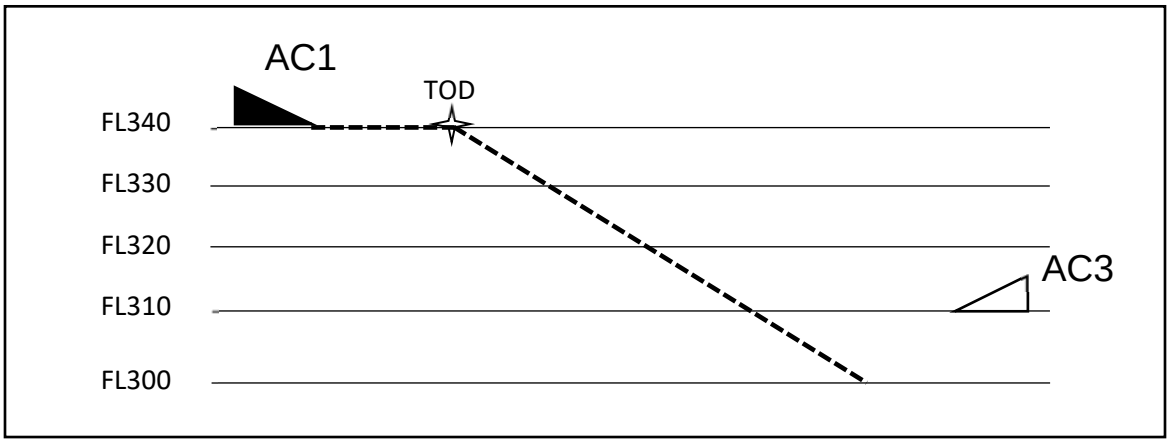


Figure 3. Descent Scenario; initial conditions including desired intent (profile view)

TAS-E avionics calculate a trajectory with a brief level off at FL320 that will allow the TAS-E aircraft to pass behind AC3 and avoid any PLOSp when considered co-altitude with AC3. The flight crew reviews the proposed trajectory modification and, finding it acceptable, executes the new 4DT shown in Figure 4. Once the modification has been executed, the new trajectory is shared with the ground automation. If AC3 flies out of ADS-B range, then the TAS-E avionics would drop it from being considered a designated aircraft.

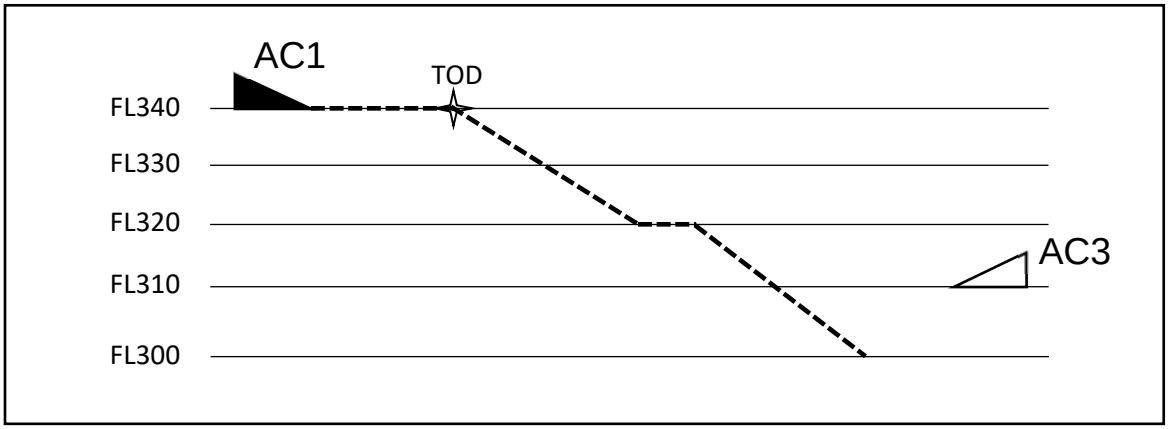


Figure 4. Descent Scenario; initial conditions with updated intent (profile view)

For a more detailed explanation of the sequence of operations and phases that the operation has been broken down into, see the phase diagrams and descriptions in the Appendix.

5 Key Assumptions and Constraints

There are several key definitions, assumptions and constraints associated with TAS-E operations. These are outlined below.

5.1 TAS-E Aircraft Modified Trajectory Considerations

If a TAS-E aircraft determines that a designated aircraft will be closer than the required minimum spacing from its current 4DT, the TAS-E aircraft will generate a new trajectory to solve the predicted loss of spacing. In a TAS-E environment, TAS-E aircraft are permitted to generate new trajectories within horizontal and/or vertical airspace limits set by the ground. These airspace limits are transmitted by the ground (could be ATC or a third party) to each TAS-E aircraft. These limits are discussed further in the future research section. These new trajectories ensure a trajectory free of any losses of spacing between the TAS-E aircraft and all designated aircraft for a minimum time (nominally 20 minutes). The TAS-E aircraft is authorized to make these trajectory changes without prior approval from the ground. However, the TAS-E aircraft will transmit these trajectory changes to the ground for increased controller situation awareness, and to update their trajectory in the air traffic management system.

Trajectory modifications include a common segment between the existing 4DT and the new trajectory. This allows flight crews time to review and execute the new trajectory. Depending on the traffic geometry and number of designated aircraft, the TAS-E avionics can make a variety of trajectory modifications. The modifications are limited to changes in speed, vertical rate, lateral path, and vertical path. It is expected, due to the importance of avoiding a loss of spacing, that only a single trajectory will be provided to the flight crew at any one time.

5.2 TAS-E Ownship Constraints Impacting Modified Trajectories

When the TAS-E avionics detect that there is a predicted loss of spacing, the avionics develop a new 4DT for the TAS-E aircraft. There are several potential TAS-E ownship constraints that the TAS-E avionics will need to consider when generating these new trajectories. Some of these constraints are as follows:

- Speed: these could include performance limitations of the aircraft (e.g., stall, over speed), a speed assigned by ATC, or procedural speeds.
- Altitude: altitude restrictions are a part of the original 4DT. At times, the controller may need the TAS-E aircraft to be at a certain altitude due to other aircraft that could be a factor. An example of this could be an aircraft that is at a different altitude and planning to remain there but may be a factor in the near future. The controller may be considering changing the aircraft's altitude and needs the TAS-E aircraft to be at an assigned altitude to avoid a future conflict.
- Airspace: the TAS-E avionics needs to be aware of airspace constraints or airspace avoidance areas that exist near the TAS-E aircraft. Airspace avoidance areas define areas of airspace the TAS-E aircraft should remain clear of when generating new 4DTs. Examples of these areas include sector boundaries, Special Access Airspace (SAA), temporary airspace restrictions and areas of significant weather. Many of these areas are only known by the controller or ground automation and need to be data linked to the TAS-E aircraft. While the exact implementation method needs to be determined, it has been proposed that these areas could be communicated as a set of coordinates that define

a polygon (“airspace avoidance polygons”). These areas could be displayed to flight crews to enhance their situation awareness. It has also been proposed that TAS-E flight crews could have the option of generating their own airspace avoidance areas based on their observations of the weather near their route of flight. In addition to ensuring the TAS-E system does not generate a trajectory that would be unacceptable to the flight crew, these areas could be data linked to the ground system to give controllers a real time update on airline/flight crew preferences in their sector. Additional discussion of the aspects of this topic which require future research are covered in the future research section.

5.3 Ground Automation System Monitoring of Key Parameters

During TAS-E operations, there are data linked messages and parameters that must be monitored by the ground automation system. The monitoring of these parameters is required to support TAS-E operations. Key parameters are listed and discussed below:

- Avionics health status: These messages contain information on the state of the TAS-E avionics system. These messages indicate if the TAS-E avionics system is working properly and ready to perform TAS-E functions. This information is sent periodically as part of a TAS-E periodic status message.
- TAS-E guidance alerts: The ground automation system needs to be informed of any TAS-E guidance alerts. These alerts could include the avionics inability to compute a guidance solution or a failure of the flight crew to follow the guidance provided. These events are assumed to be non-normal events.

TAS-E operations are only allowed when the aircraft is following a prescribed trajectory at a required performance level that is consistent with TBO. This ensures TAS-E is predictable and consistent with TBO ATM plans. When the aircraft is not TBO compliant and communicated to the ground automation through one or more key parameters, the controller will treat this aircraft as non-TAS-E.

5.4 Weather and wind data

The TAS-E avionics will require up to date information on the winds and weather along the ownship trajectory as well as along designated aircraft trajectories. The FAA is currently working to standardize weather information and provide a common platform for all types of weather information in support of improved ATM. It is assumed that these weather / wind data, along with timely updates, will also be required by other new strategic TBO tool(s), and therefore, these data are expected to be readily available.

5.5 TAS-E Equipment Assumptions

There are a few key assumptions about ground and airborne equipment that are needed to support TAS-E. Given the expected timeframe for TAS-E implementation, it is assumed that there will be numerous changes to the current existing infrastructure. These changes will have an impact on what information is available and how it can be communicated. The key assumptions are listed below.

5.5.1 Data link systems

There will be no requirement to change the current system-wide voice communication requirements. However, it is assumed there will be one of more air/ground datalinks that will

support both ground and airborne functions. These could include CPDLC, ADS-C, AAtS, ACARS, or other systems.

For the ground automation system, the datalink would be used to send the following messages to the TAS-E aircraft:

- Identification of airspace to avoid
- TAS-E Mode Messages

For the TAS-E aircraft, the datalink would be used to send the following messages to the ground automation system:

- Periodic status messages
- TAS-E aircraft trajectory change information resulting from an accepted airborne resolution (at a minimum the portion of the trajectory that changed needs to be sent)
- Airspace avoidance polygons (if implemented)

5.5.2 Ground automation system

While TAS-E is primarily an airborne operation, the ground automation system will be generating Mode settings, and there will also be other communications that must occur between the aircraft and the ground automation system as well. Current ground automation systems such as En Route Automation Modernization (ERAM) would need to be modified to support TAS-E operations. This would include enabling controllers to identify which aircraft are involved in a TAS-E operation easily, the ability to generate and send TAS-E mode messages, and the ability to receive, process, and display messages sent by the TAS-E avionics to the ground automation.

5.5.3 TAS-E aircraft

The TAS-E avionics will need to contain a lot of the functionality required for the TAS-E operation. It is assumed that the avionics will have the ability to identify designated aircraft and calculate if there will be a PLOSp with any designated aircraft based on their state and intent information. Once a PLOSp is identified, TAS-E avionics would have the ability to provide a new trajectory to the flight crew that would resolve the PLOSp. This new trajectory is assumed to be automatically loaded, but not executed, into the Flight Management System (FMS).

TAS-E avionics would also include a new human machine interface for the flight crew. This interface would need to enable the crew to review which aircraft are causing the PLOSp, the trajectory modifications, any additional restrictions on the operation, any polygon functionality, as well as any future concept development features.

TAS-E avionics would also include the generation of periodic status messages, flight crew alerts and trajectory change information; all of which is assumed to be sent to the ground automation system.

6 Additional TAS-E Scenarios

The following two scenarios describe in further detail some example TAS-E operations. They provide some additional variants to be explored and build off the previously described sequence of operations.

6.1 TAS-E Co-Altitude Scenario with two designed aircraft

This scenario, shown in **Error! Reference source not found.**, is similar to the previously discussed co-altitude scenario. The difference between this scenario and the previous scenario is the presence of a second designated aircraft.

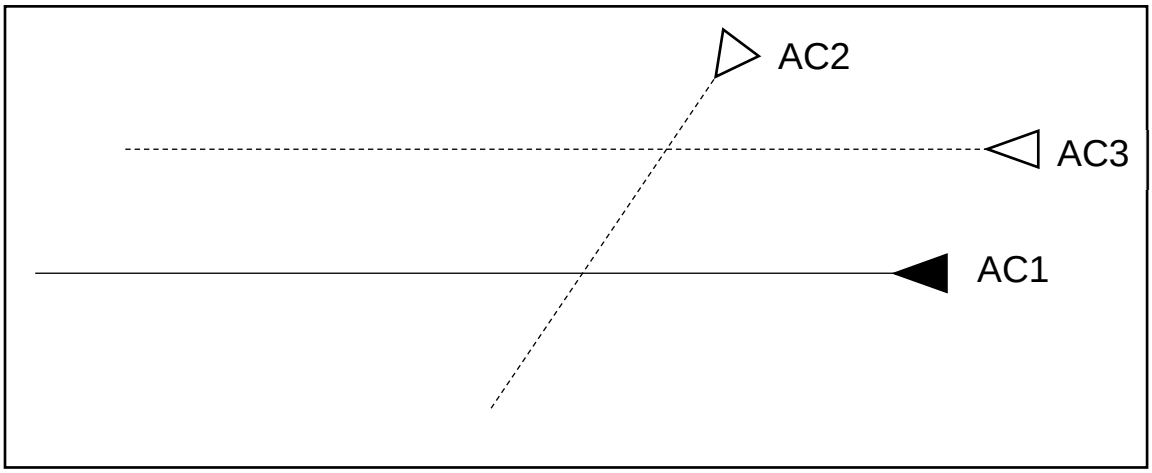


Figure 5. Scenario with additional traffic constraint (top-down view)

In accordance with normal TAS-E operations, the TAS-E aircraft (AC1) has designated all aircraft from which valid ADS-B signals are received. The TAS-E avionics evaluates the traffic situation based on the location and intent of the designated aircraft and any additional ATC provided constraints. If the onboard system does not identify a PLOSp between AC1 and AC2 or AC1 and AC3, no new trajectory is provided. As envisioned, the TAS-E system onboard AC1 does not check for PLOSp between AC2 and AC3.

In this specific scenario, AC2 will pass in front of the TAS-E aircraft but will not be clear of the TAS-E aircraft by more than the minimum required spacing distance by the time the TAS-E aircraft reaches the closest point of approach (CPA). As a result, the onboard system predicts that there will be a loss of spacing between AC2 and AC1. Although there is no PLOSp with the second designated aircraft (AC3), the position of AC3 will restrict the available solutions to resolve the PLOSp with AC2.

In the earlier example, a slight trajectory modification to the right allowed the ownship (AC1) to pass behind AC2. However, in this case, a trajectory modification to the right is not an option due to AC3 flying an offset route behind the ownship to the right. To resolve this PLOSp, the TAS-E aircraft will slow down enough to solve the PLOSp with AC2, as shown in **Error! Reference source not found.**.

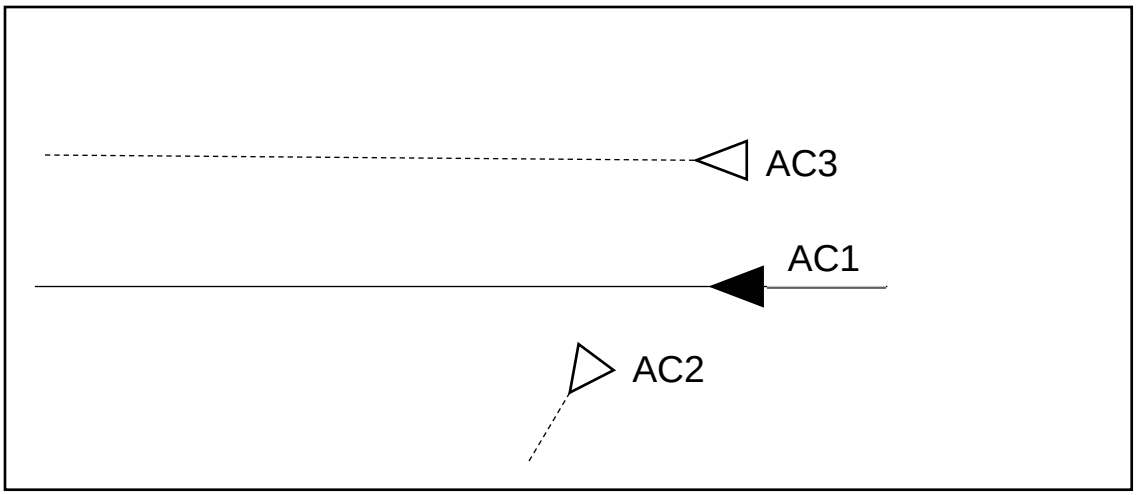


Figure 6. Post PLOSp traffic configuration

The avionics generates a new 4DT that includes this initial reduction in speed by the TAS-E aircraft, followed by an increase in speed in order for the TAS-E aircraft to meet its original downstream 4DT constraints. The flight crew is then responsible for evaluating and executing the TAS-E generated 4DT. The ground automation system continues to monitor the TAS-E aircraft's compliance with the procedure, ensuring that no trajectory changes are generated onboard the aircraft that have not been acted upon by the flight crew.

6.2 Descent scenario with lateral path change

In the descent scenario previously shown in Figure 4, the TAS-E avionics provided a new 4DT that included a brief level off to avoid the PLOSp with the designated aircraft. Another potential resolution could have been to create a trajectory modification that allows the aircraft to pass the designated aircraft laterally during the descent. In some cases, this type of solution could be preferable to a brief level off.

In the descent scenario shown in Figure 7 below, the TAS-E aircraft, AC1, is at FL340 and nearing its TOD location. AC2 is flying level at FL310 in the opposite direction. AC1 has already been cleared to FL180 as part of normal operations in TBO environment. The TAS-E system identified AC2 as a designated aircraft when it first began receiving valid ADS-B data from AC2. Based on the current positions and intent information of AC1 and AC2, the TAS-E avionics identifies a predicted loss of spacing with AC2 as it transitions through FL310.

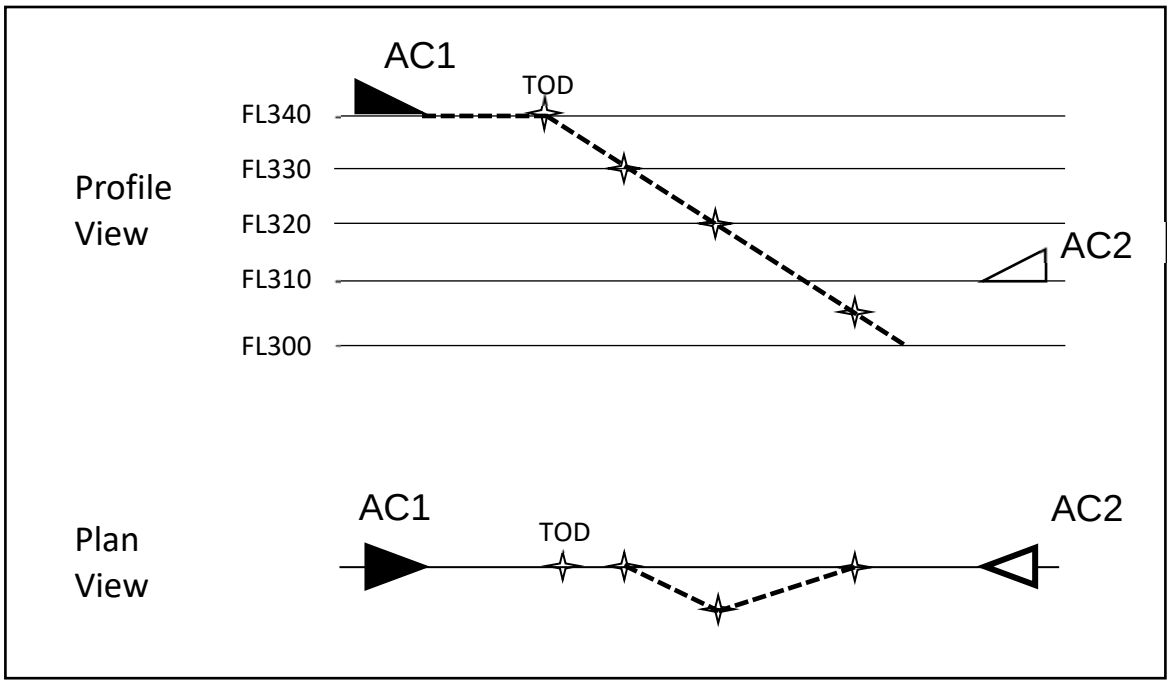


Figure 7. Descent scenario with lateral path change

The TAS-E avionics calculate that a lateral path change to the right beginning at FL330 and completed by FL320 will provide the required distance to prevent a loss of spacing. The TAS-E avionics generate a 4DT which will meet the spacing constraints and including a segment that will enable AC1 to rejoin its previous trajectory. This new trajectory is provided to the flight crew. The flight crew reviews the proposed trajectory modification and, finding it acceptable, executes the new 4DT.

After AC1 no longer receives valid ADS-B data from AC2, AC2 is no longer identified as a designated aircraft. At that time, the TAS-E aircraft stops monitoring AC2.

7 Future Considerations on TAS-E

This section discusses several aspects of the TAS-E concept that have been identified as being important aspects of the concept but that need to be addressed in greater detail.

7.1 Safety Analysis

A significant portion of any future research effort or NAS implementation of TAS-E would require the inclusion of a safety analysis. The safety analysis would influence and inform many of the decisions that would be made as part of future concept development. It would also provide specific values and justification for many of the assumed/estimated parameters used in the current concept.

7.2 All Necessary Aircraft Tracked

The TAS-E system will require a high level of confidence that all relevant aircraft are tracked by the airborne system. There are a number of ways that this might be accomplished. Some of the methods of ensuring that the TAS-E aircraft tracks all relevant aircraft could include:

- No additional validation required: It may be adequate to assume that the ground and airborne systems see all the same relevant traffic.
- Use SWIM data to validate traffic: If the future SWIM environment is as robust as it is planned to be, frequent updates and rapid data access will be available. The TAS-E aircraft could be required to perform a periodic check (with an interval on the order of minutes) of the SWIM data to identify any surrounding aircraft for which ADS-B has never been received. Then those aircraft would have to be denoted as not suitable to be considered a designated aircraft.
- Ground system identification of relevant traffic: The ground system could be designed to send up a list of relevant aircraft to each TAS-E aircraft. The TAS-E aircraft would be required to acknowledge the list and confirm each aircraft is tracked. There is possibly a significant communication overhead in managing these signals.
- Ground system verification of all tracked aircraft: The TAS-E aircraft could send down a list of all tracked aircraft, and the ground system would verify that all necessary aircraft are included in the list.

There are a number of options to be considered for this critical task. It will require significant research to determine if any of the above are adequate, and then to select the most suitable.

7.3 Designated Aircraft intent data

In addition to ensuring that all necessary aircraft are tracked, the TAS-E aircraft will require intent data on each aircraft that is designated. The extent of the intent information and level of detail of the intent that will be required on designated aircraft will also need to be a topic of future research.

7.4 Airspace avoidance

It is expected that the TAS-E avionics will need to be aware of airspace regions to avoid. These may consist of regions of convective weather, sector boundaries, or other controller identified regions. Initial research suggests that the use of polygons would be appropriate to convey this information to the avionics and flight crew (if necessary). It might be possible to have the definition of any long duration or unchanging regions be built directly into the avionics without the need for communication. Further research is required to define the level of definition that would be required both spatially and temporally.

7.5 TAS-E Airborne System Aware of all Tactical Trajectory Changes

In order to avoid losses of spacing it will be necessary for the TAS-E airborne system to be aware of all planned (near term) trajectory changes for surrounding aircraft. For example, if a TAS-E designated aircraft makes a request to ATC for an altitude or trajectory change, the TAS-E aircraft may require advance notice if it is approved. The reason for this involves the need to avoid the creation of an immediate loss of spacing. This protection is similar to operations in today's system when a controller needs to coordinate any changes to an aircraft's trajectory with the next sector if the flight is approaching the boundary (~40 miles) prior to approval of the change. There are a number of ways to achieve this, and controller acceptance may be the determining factor.

- SWIM data could have a currency requirement that is adequate for the TAS-E airborne system to have on all designated aircraft.
- The ground system could be designed to send all trajectory change information for relevant aircraft to the TAS-E aircraft and get a favorable response prior to allowing any near-term trajectory change clearances.

7.6 Communication of TAS-E trajectory changes

Research will need to be done to define how trajectory changes will be implemented in a future TBO environment. It is expected that communication of trajectories will be common place. Research would need to be conducted to determine the level and duration of trajectory intent that is needed by the ground (controller and ground automation) when a TAS-E modification is executed. Initial research has suggested that a common segment will be required between the modified trajectory and the trajectory that it is replacing. While a specific value would require testing, it is believed at this time that something on the order of one minute might be sufficient.

7.7 Timing of TAS-E tactical maneuvers

Additional research needs to be completed to determine the proper timing for when a TAS-E airborne system should command a trajectory change to avoid a predicted loss of spacing. At the maximum range expected for en route ADS-B[15] signals, a loss could be detected up to approximately 180 NM prior to the actual loss. Depending on the geometry of the aircraft involved, the time to the loss would vary. If a trajectory change is done immediately when a loss is first predicted, it could minimize the magnitude of any changes. However, it could also introduce a number of problems. If a TAS-E aircraft maneuvers far from a PLOSp, it may be in another controller's sector. It is unknown if that would be of concern to or problematic for controllers. Additionally, the TBO system or controller may be planning a change to the other aircraft's trajectory that has not yet been entered into the system. These examples would indicate that it may be prudent for TAS-E avionics not to resolve a PLOSp as soon as it is detected if it is beyond some time limit away.

However, the other extreme of delaying action until the TAS-E aircraft is too close to a PLOSp can also present complications. If the TAS-E system waits until the predicted loss is imminent, there is a risk of activating the controller's conflict alert and the controller having to take immediate action. The current ERAM conflict alert[16] alerts the controller at 180-240 seconds (depending on the facility) prior to the conflict. If a trajectory change occurs close to this threshold, it may interfere with a solution that the controller would be developing to avoid the conflict alert. Another problem with waiting until the loss of spacing is imminent is that communication and/or pilot delays could result in an actual loss of spacing.

Another situation where the timing of a TAS-E trajectory change could be critical is when an aircraft is approaching a sector boundary. This could be handled through airspace restrictions or pre-coordination of any changes near or over a sector boundary.

These are only a few examples of factors that will need to be considered when specifying the criteria for TAS-E trajectory changes. All these timing issues will require controller subject matter expertise and detailed research to resolve.

8 Summary

The National Airspace System (NAS) will evolve and transform by using time-based management in a Trajectory Based Operations (TBO) system to accommodate increasingly diverse operations and increasing levels of air traffic. The goal of a TBO system is to increase the efficiency and predictability of flight operations while maintaining operational flexibility. NASA formed the Air Traffic Management - Exploration (ATM-X) project to develop concepts that could support TBO. Tactical Aircraft Spacing – En route (TAS-E) is one concept that was being developed. In a TBO environment there will be times when the strategic plan cannot be complied with and a more near-term, tactical solution is required. One approach to solving these situations is to require the air

traffic controller to intervene. TAS-E was developed as an alternative concept to make use of airborne avionics and ADS-B In technology.

The TAS-E concept leverages TBO enabled information exchanges of data between aircraft and ground systems, aircraft-to-aircraft sharing of ADS-B data, an avionics suite that can detect predicted losses of spacing with designated aircraft and provide trajectory modifications. When the TAS-E avionics develop a trajectory modification to solve a PLOSp, it will minimize changes from the current cleared 4DT and attempt to meet downstream trajectory constraints. New trajectories will also avoid the creation of any new PLOSp. The concept can handle multiple different traffic geometries between the TAS-E aircraft and designated aircraft but is expected to be primarily used in en route airspace. The vertical capabilities could provide assistance to operations during climb to cruise and initial descent from cruise.

There are various benefits expected from the TAS-E concept in a TBO environment. The overall system will benefit from fewer aircraft deviating from 4DTs, and the TAS-E aircraft will benefit from onboard solutions when a predicted loss of spacing does develop.

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Appendix: Phase Diagrams

The TAS-E application is divided into phases, which describe the sequence of actions and identify information exchanges between the agents (e.g., flight crew, ATC, ground, airborne automation). This section describes the phase diagrams that have been developed for the TAS-E operation. Figure A1 contains a high-level overview of the phase diagrams. In the overview, orange lines represent the flow of ground automation through the operation, blue lines represent the flow of airborne avionics through the operation, green lines represent the flight crew (FC) tasks in the operation, black lines are the flow of information from the air to the ground, and grey lines are the flow of information from the ground to the air. Information is also conveyed through the operational flow in addition to the black and grey lines. The thickness of lines attempts to convey temporal state in the process along with general flow from top to bottom (the thicker the line the later it occurs in the operational flow). Every line has an arrowhead that terminates it, but the arrows from multiple lines may overlap at the end of the line.

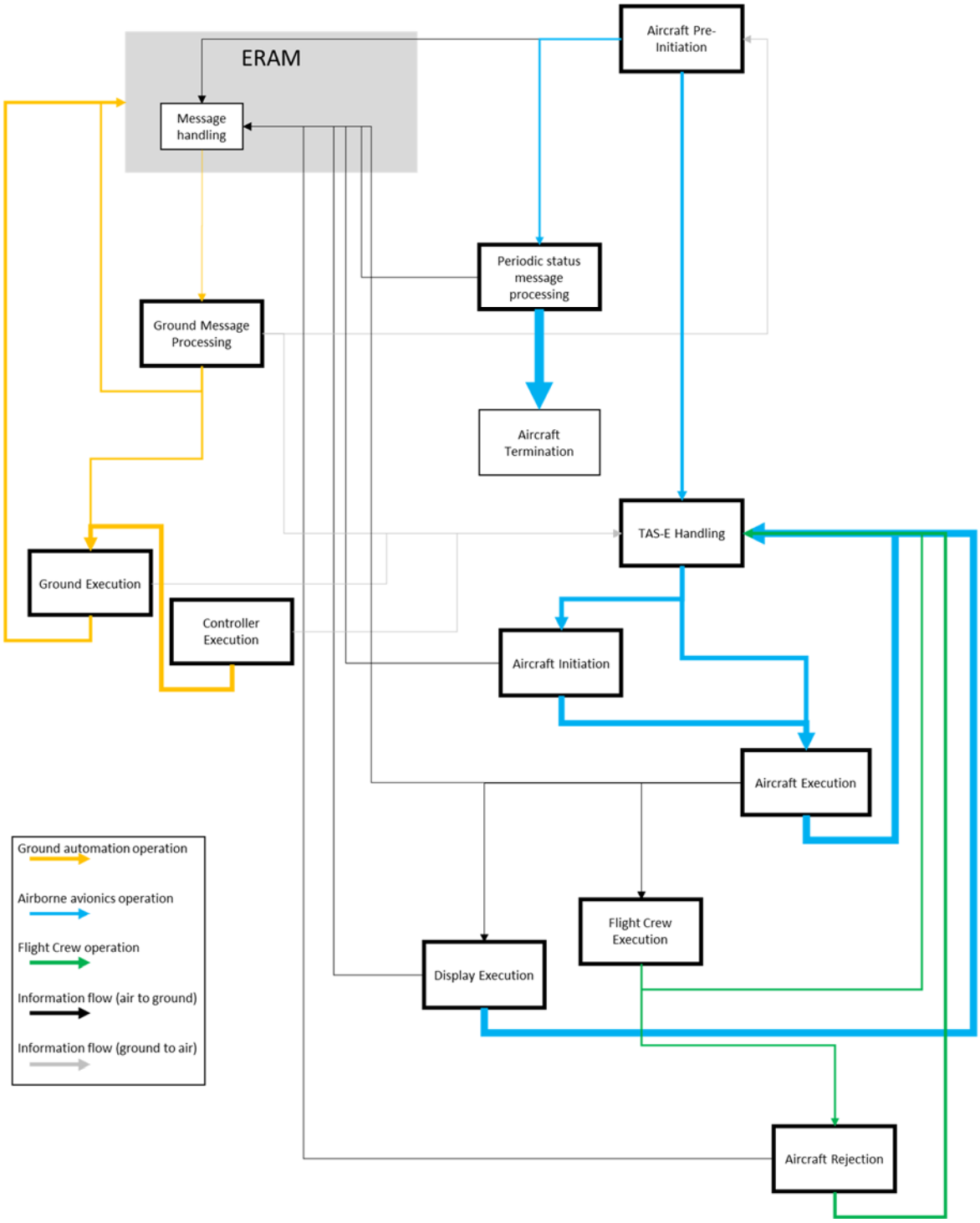


Figure A1: TAS-E high level overview phase diagram

The first box on the high-level diagram that is used to start the TAS-E operation is the Aircraft Pre-Initiation phase (located in the upper-right corner). This phase is shown in Figure A2. The Aircraft Pre-Initiation phase begins with the crew applying power to the aircraft for the purposes of flight during their pre-flight checks. The avionics must be logged into the ground automation system and receive a confirmation once the log on has been successful. A further detailed description of some of the key tasks in this diagram include:

- Log on Avionics
  - This task involves the process of logging the TAS-E Avionics into the ground automation system for the purpose of flight. Example inputs include aircraft number, flight identification, origin, destination, proposed departure UTC, etc.
- Verify that logon confirmation has been received
  - Once the log on has been confirmed, through reception of a message, it is displayed to notify the flight crew of the confirmation.
- Notify FC of failure to receive confirmation
  - If the expected time for response has expired an indication that a confirmation failure exists is displayed and the flight crew needs to intervene.
- Periodic status message processing
  - The box with the dark outline in this phase represents an additional level of detail. This next level of detail is shown in Figure A3. The main purpose of this phase is to send the status message to the ground automation at the required periodic interval. There are checks to control when the status messages need to be sent and when it is necessary to stop sending them. Once started, this process runs continuously until the operation is terminated at which point the operational flow transitions to the Aircraft Termination phase. The Aircraft Termination phase has not been developed yet but would include processes/tasks related to ending a TAS-E operation and logging off the communications channels.

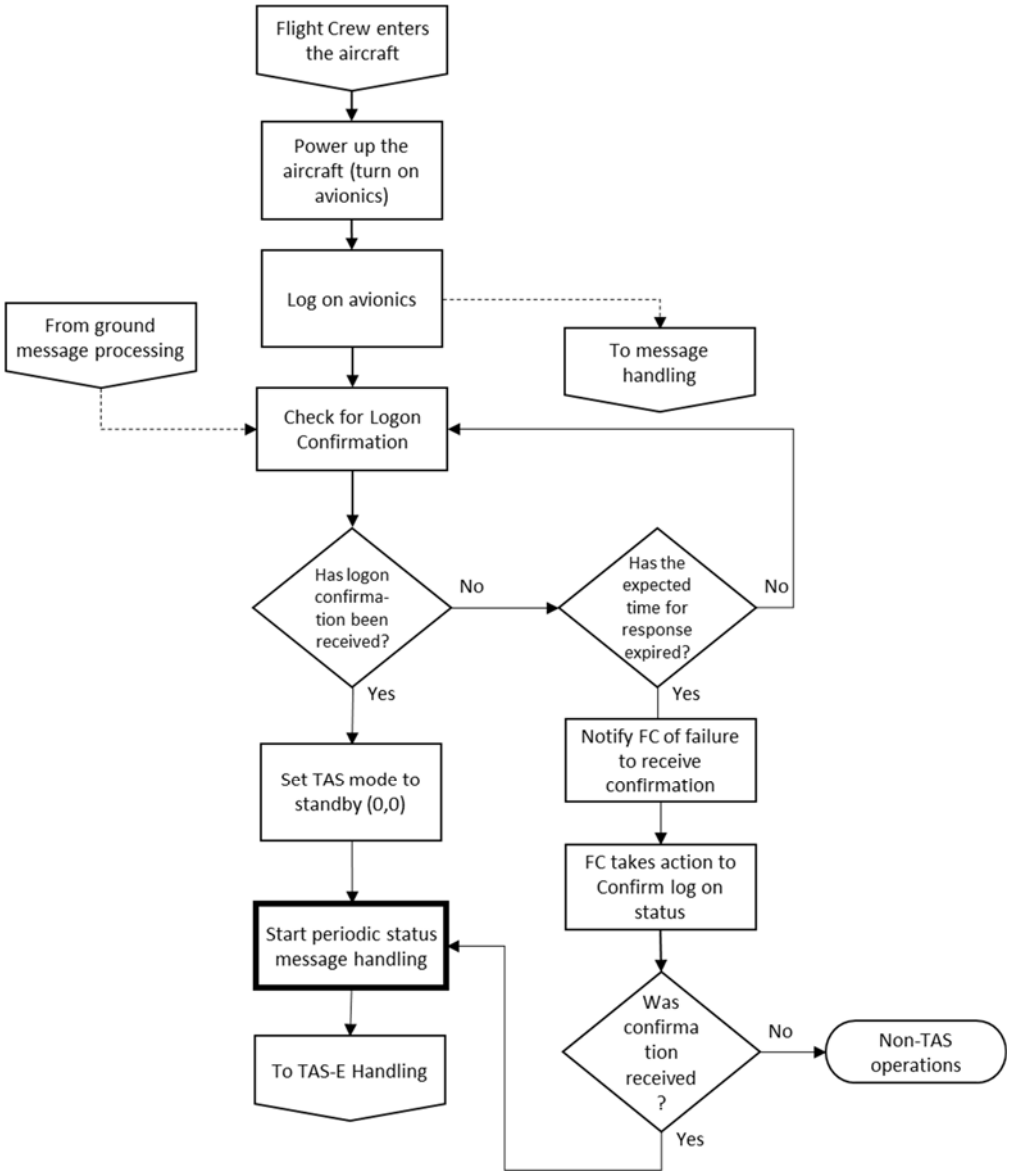


Figure A2: Aircraft Pre-Initiation

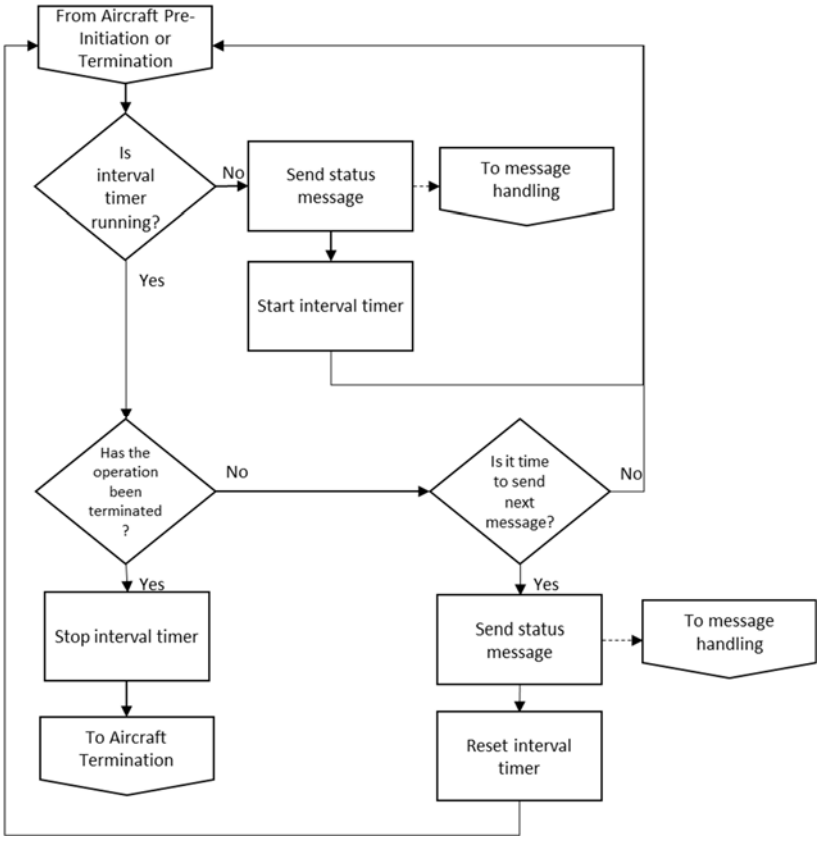


Figure A3: Periodic Status Message Processing

The airborne avionics will need to have a process running that checks for incoming TAS-E messages from the ground and to ensure that the Aircraft Execution phase is run at the proper interval as required. This phase, called TAS-E Handling, is shown in Figure A4.

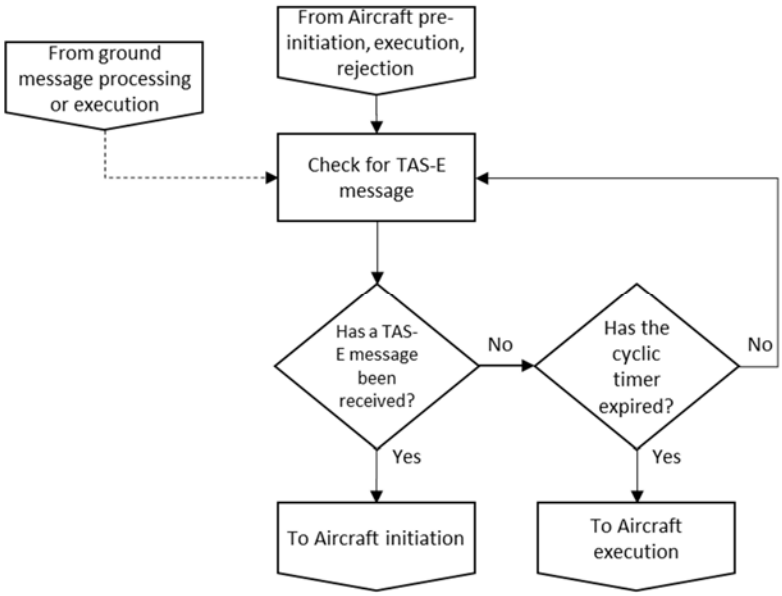


Figure A4: TAS-E Handling

One outcome from the previous phase is for the avionics to enter the Aircraft Initiation phase (Figure A5). This phase, Aircraft Initiation, receives message from the TAS-E Handling phase. The Aircraft Initiation phase determines if the message is a TAS-E Mode message, a polygon list, or a Designated Aircraft (DA) ineligibility message and performs the appropriate processing function.

- TAS-E Mode message
  - Updates TAS-E Mode
  - Setting of TAS-E mode then determines available TAS-E capabilities
  - Used in Aircraft Execution and Periodic Status Message Processing phases
- Polygon list message
  - Updates the polygon List
  - Updated information will be used in the Aircraft Execution phase
- DA Ineligibility message
  - Updates the ineligibility/eligibility of DA or potential DA
  - Updated information will be used in the Aircraft Execution phase

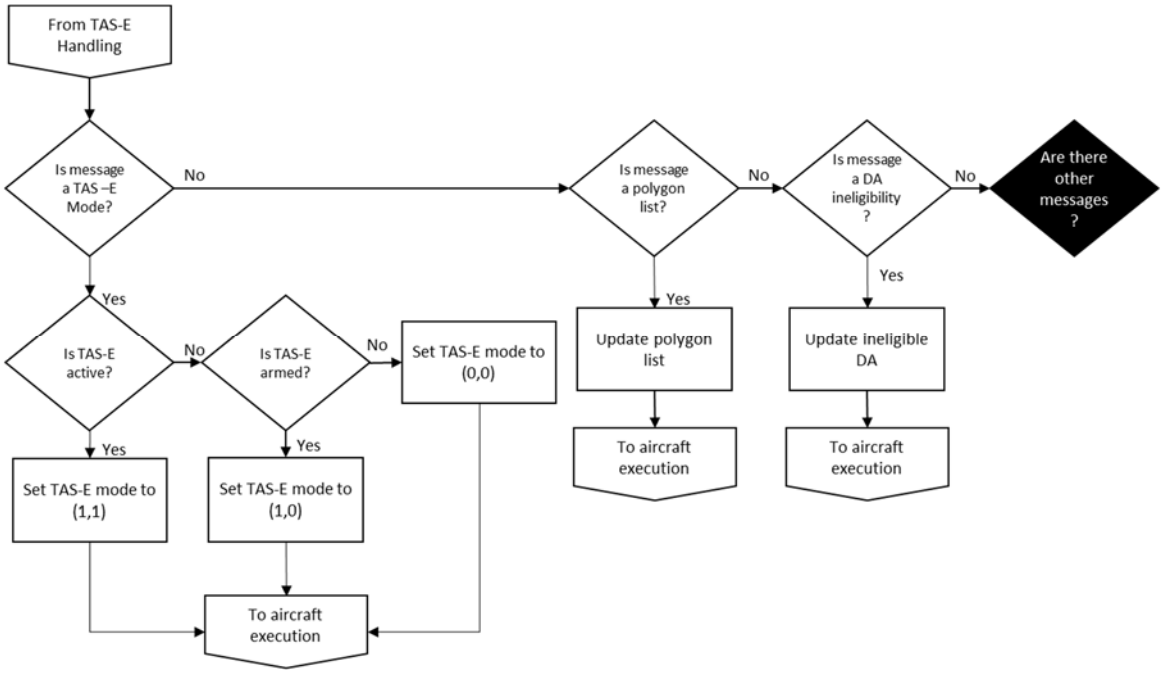


Figure A5: Aircraft Initiation

The second possible outcome from the TAS-E Handling phase is for the avionics to enter the Aircraft Execution phase. This phase, shown in Figure A6, is performing multiple functions. Functions include validation of DA data, PLOSp Detection, and PLOSp Resolution on designated aircraft. Entry in to the Aircraft Execution phase is achieved by expiration of the cyclic timer in the TAS-E Handling phase or the completion of message processing in the Aircraft Initiation phase. Aircraft Execution resets the cyclic timer and utilizes algorithms to identify predicted losses of spacing and resolves them.

- Aircraft Execution – DA
  - The purpose of this process is to ensure that the required information exists and is valid for each aircraft seen by the TAS-E aircraft. It gathers and validates required data for all aircraft visible through ADS-B and SWIM. If all the data meets the requirements for TAS-E, then the aircraft are added to a list of designated aircraft to be used by the avionics. If there are any failures in the data requirements, then messages are sent to the Ground automation system.
  - Examples of required data for DA consist of: ADS-B for state data and SWIM for intent data.
  - Due to the amount of processing being done in this step an additional phase diagram has been included for it in Figure A7.
- Check for PLOSp against DA and polygon lists
  - Utilizes the resulting list of designated aircraft from the ‘Aircraft Execution–DA’ process to perform PLOSp detection on designated aircraft and polygons.
- Compute new trajectory to resolve all PLOSp
  - This process generates a new trajectory that will resolve any identified PLOSp.
  - If there is not a valid trajectory available, notification will be sent to the ground including the reason for no trajectory being available.

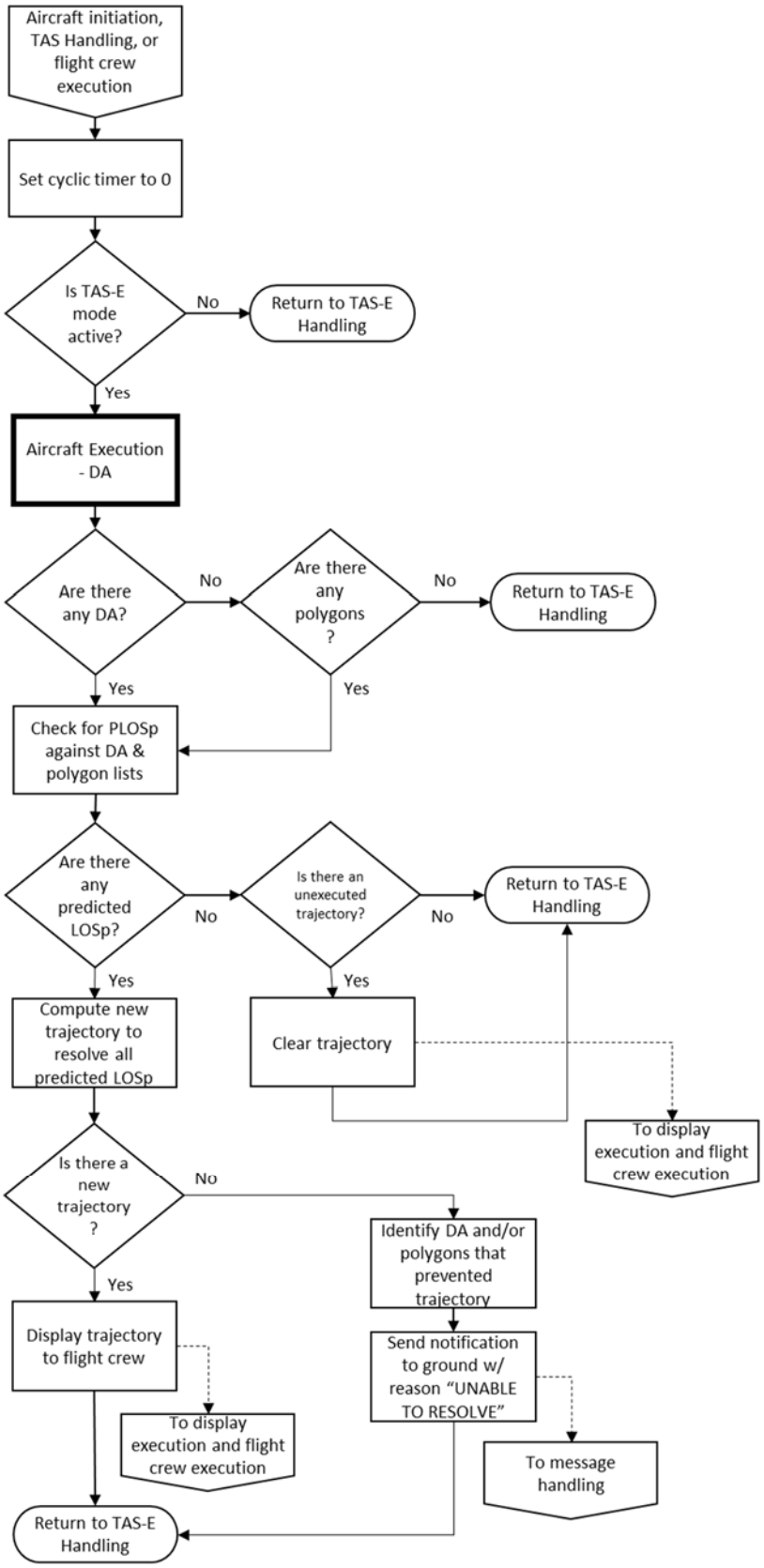


Figure A6: Aircraft Execution

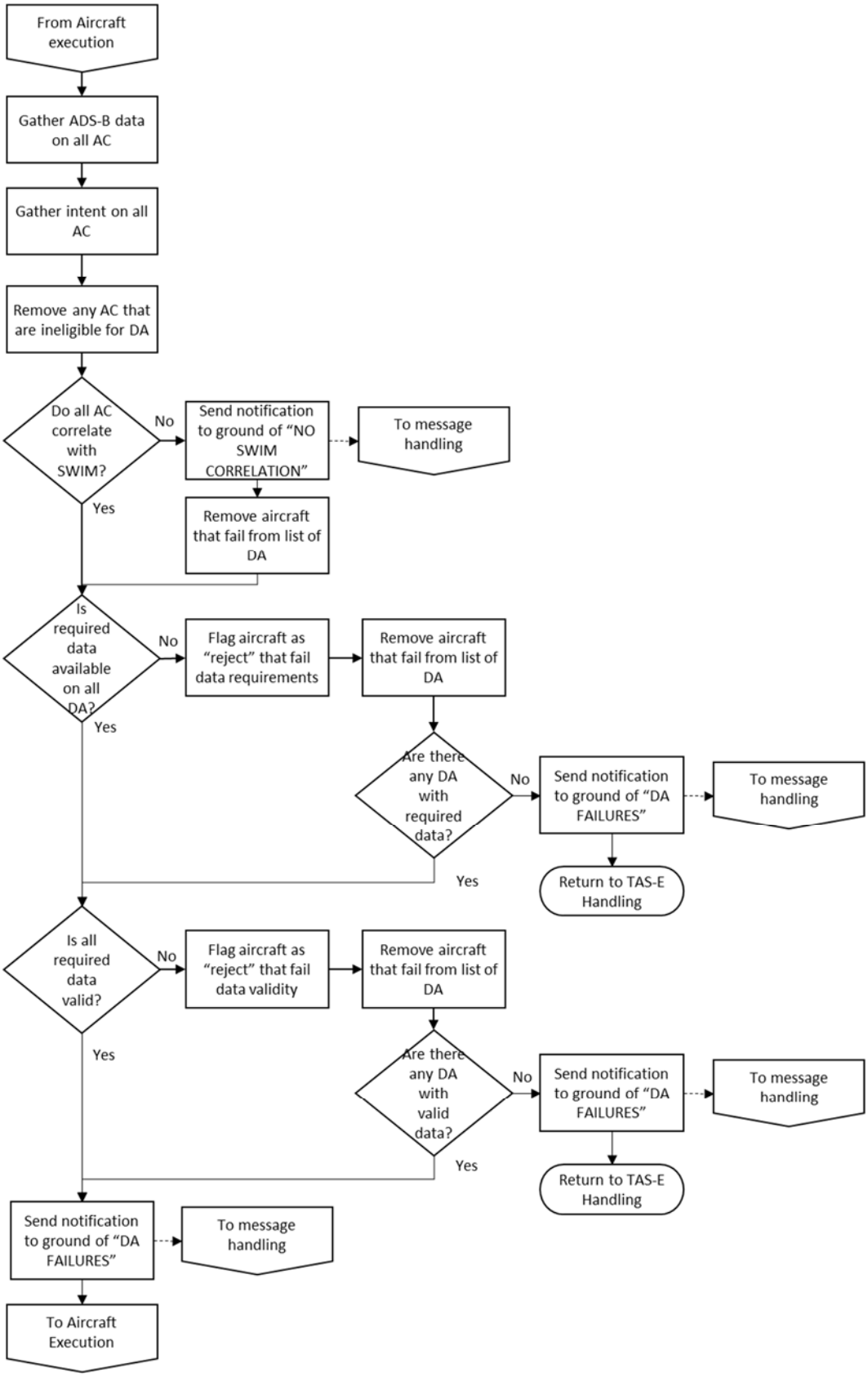


Figure A7: Aircraft Execution - DA

The next phase diagram is for the Display Execution phase, shown in Figure A8. This phase shows an initial outline for some of the steps and processes that would need to be handled by/or shown on the display(s). The Display Execution flow addresses a myriad of possible outcomes after a new trajectory is presented.

- Has the trajectory cleared
  - These outcomes include: the new trajectory has been cleared either by the flight crew executing it as presented in the prescribed timeframe, the flight crew rejecting the new trajectory, or the PLOSp no longer exists.
- Is there a change to the trajectory
  - Once a new trajectory is displayed, a change to the trajectory can be necessary due to a delay in flight crew action, a change to the DA list, a maneuver by a DA, action by the controller, etc.
- Has the flight crew time to react expired
  - Once a new trajectory is displayed a timer is utilized and appropriately timed messages are sent to the flight crew and controller to ensure the flight crew responds to each trajectory. When the timer is exceeded the notification type and level increase to attempt to gain flight crew response to the trajectory.
  - Notifications include a flight crew alert to a presented PLOSp trajectory and a controller alert to bring attention to the flight crew's failure to act. The alerts increase in level as time passes.

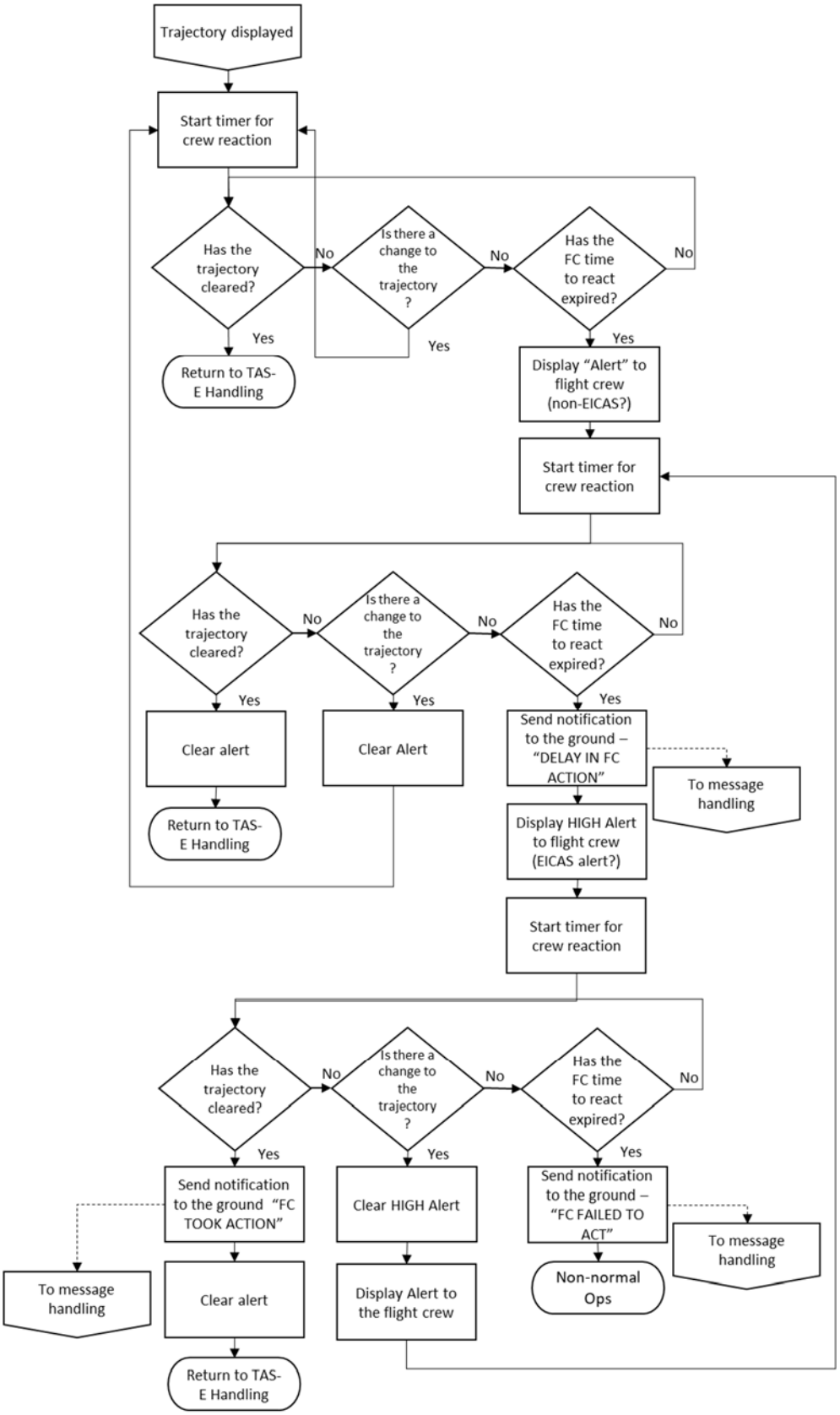


Figure A8: Display Execution

The Flight Crew Execution phase is shown in Figure A9. This phase covers some of the tasks that the flight crew might have to deal with during TAS-E Operations.

- Has a controller instruction been issued
  - This takes place if the controller in the process of managing their sector needs to instruct the TAS-E aircraft to do something specific. This could result in the aircraft being able to continue with TAS-E Operations or result in the aircraft exiting TAS-E operations (such as a vector instruction).
- Has a trajectory been displayed
  - This task determines if a new trajectory has been displayed, gives the flight crew time to respond, and provides instructions to contact the controller in the event of the trajectory being rejected. Acceptance of the presented resolution results in continuing normal TAS-E Operations. If the flight crew is not willing to execute a resolution, it results in “Aural and Visual alerts presented to FC to contact ATC” and proceeds to the Aircraft Rejection phase.
- Do any polygons need to be changed
  - This task allows for polygon creation, editing, and removal by the flight crew. These inputs are utilized in the Aircraft Execution Phase.

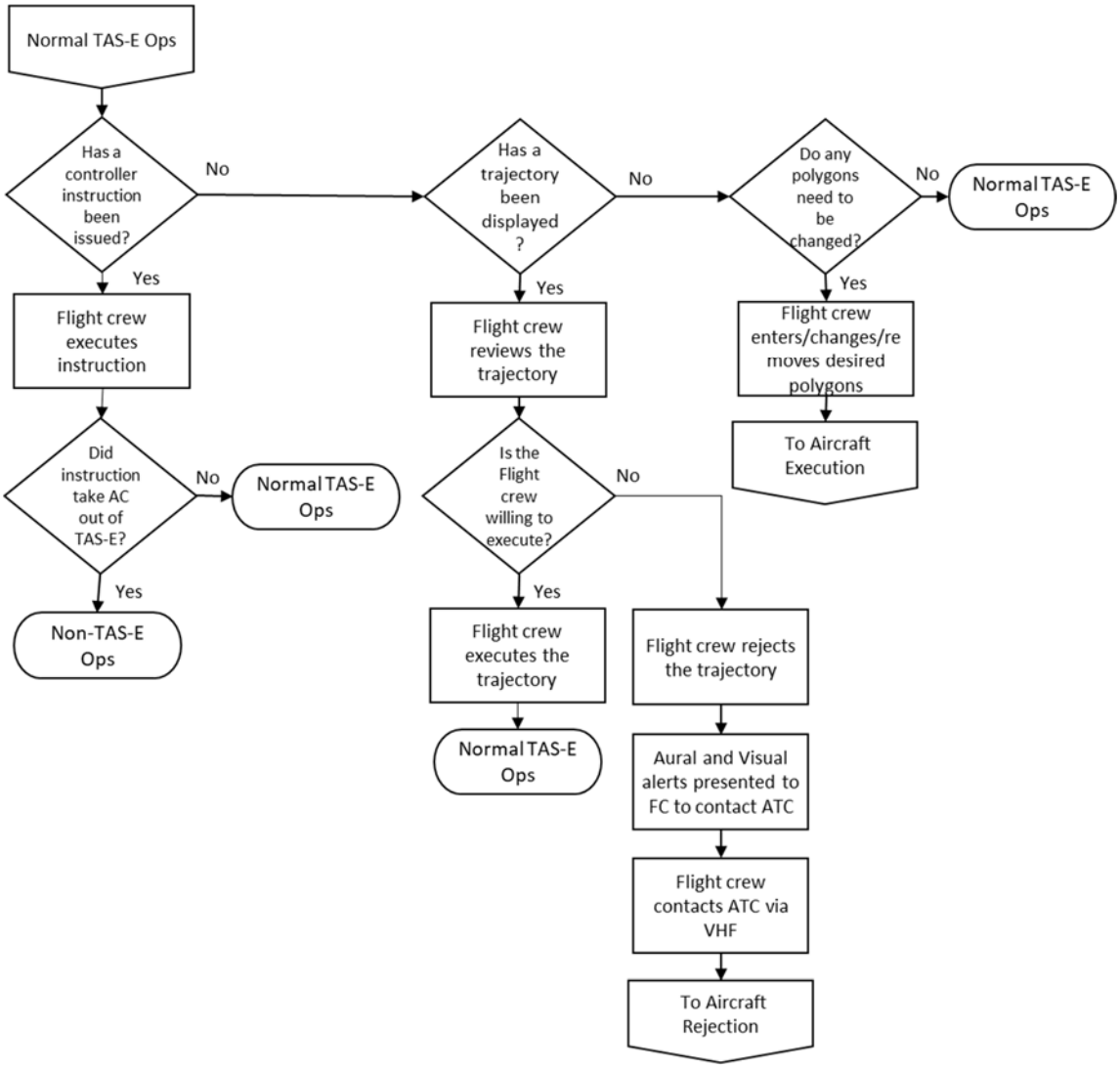


Figure A9: Flight Crew Execution

The Aircraft Rejection phase is shown in Figure A10. This phase is executed when the flight crew determines that they are unable to proceed with a new TAS-E trajectory. A message is sent to the ground automation to alert the controller that the flight crew has rejected a PLOSp trajectory and includes the designated aircraft/polygon(s) involved.

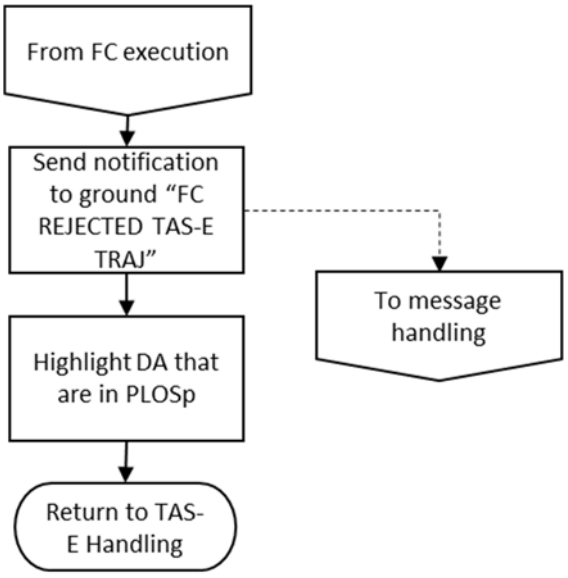


Figure A10: Aircraft Rejection

The Ground Message Processing phase interacts with multiple airborne phases throughout the operation and is shown in Figure A11. This phase begins when the ground automation receives a TAS-E message. All the messages received by the Ground Message Processing will be covered here. A description of the key boxes in this phase follows:

- If the message is a "TAS-E logon"
  - It is processed, and a confirmation is sent to the aircraft (pre-initiation) and the ground system (ERAM) is notified through ground execution.
- If the message is a "no SWIM correlation"
  - The identified aircraft should be called-out as ineligible.
  - The controller must monitor TAS-E aircraft and ineligible aircraft to ensure separation is maintained.
- If the message is a "status message"
  - Process the status message and return to ERAM. A status message reflects a change in TAS-E status such as flight crew selection of Heading Select.
- If the message is a "DA failure"
  - The identified aircraft should be called-out as ineligible.
  - The controller must monitor TAS-E aircraft and ineligible aircraft to ensure separation is maintained.
- If the message is a "FC rejected a TAS-E trajectory"
  - (such as one that would take the aircraft into significant weather), display to the controller the reason for the route modification that was rejected. Return to ERAM.
- If the message is "Unable to resolve"
  - The controller should be alerted to the failure and prepare a non-TAS-E solution.
- If the message is a "Delay in FC action"
  - notify the controller to monitor the TAS-E aircraft and prepare for controller intervention.
- If the message is a "FC took action"
  - After a reported "delay in FC action" it is hoped that the flight crew will shortly take the appropriate action. When this happens, the ground will receive a message that the

"FC took action". The controller may elect to enhance the level of monitoring of that specific TAS-E aircraft.

- If the message is a "FC has failed to act"
  - (this would be sent to the ground after the flight crew has failed to respond to the full set of TAS-E alerts), suspend TAS-E operations for this aircraft and alert the controller.
- Unknown message
  - Provides for additional TAS-E related messages to be added if identified during future development.

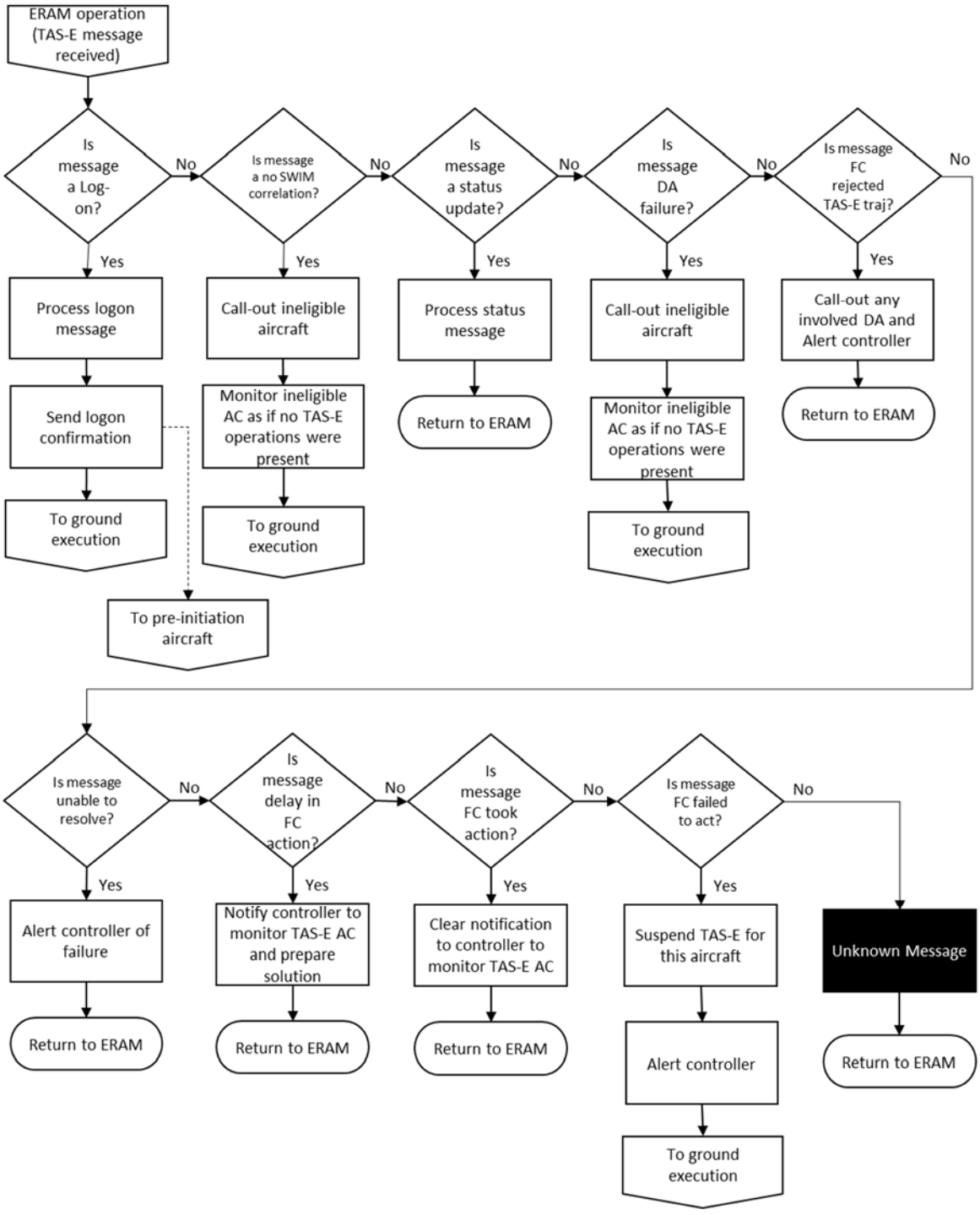


Figure A11: Ground Message Processing

The Ground Execution phase is shown in Figure A12. This phase controls the main flow of TAS-E information from the ground to the aircraft. There are three primary tasks contained within this phase:

- Set TAS-E mode
  - The details of this task are shown in Figure A13.

    - Management of TAS-E mode is based on information received from the aircraft and ground automation, to set the TAS-E mode on the ground which is then sent to the aircraft anytime there is a mode change.
        - Periodic status messages must be received from all TAS-E aircraft. If a message has not been received from a TAS-E aircraft by the required time interval, set the TAS-E mode to STANDBY and notify the controller of the status change due to a lack of status message.
        - If a periodic status message is received that indicates that the TAS-E avionics do not pass the health status, set the mode to STANDBY, and alert the controller of TAS-E avionics failure.
        - If the periodic status message is healthy and the TAS-E aircraft does not meet the criteria to do TAS-E operations (such as it has departed and not yet entered en route airspace), set the TAS-E mode to ARMED.
        - If the periodic status message is healthy and the criteria for TAS-E operations are met and the TAS-E operations are not suspended, set the TAS-E mode to ACTIVE.
        - If TAS-E has been suspended for the aircraft, set TAS-E mode to ARMED.
- Are any aircraft ineligible?
    - If there are any range appropriate ineligible aircraft, then a list of them should be sent to the TAS-E aircraft.
- Generate Polygon list
    - The details of this task are shown in Figure A14.
    - This task will compare the current TAS-E aircraft's trajectory against known hazardous polygons or airspace regions that will need to be avoided.
    - When there are changes to the list, then the updated list will be sent to the TAS-E aircraft.

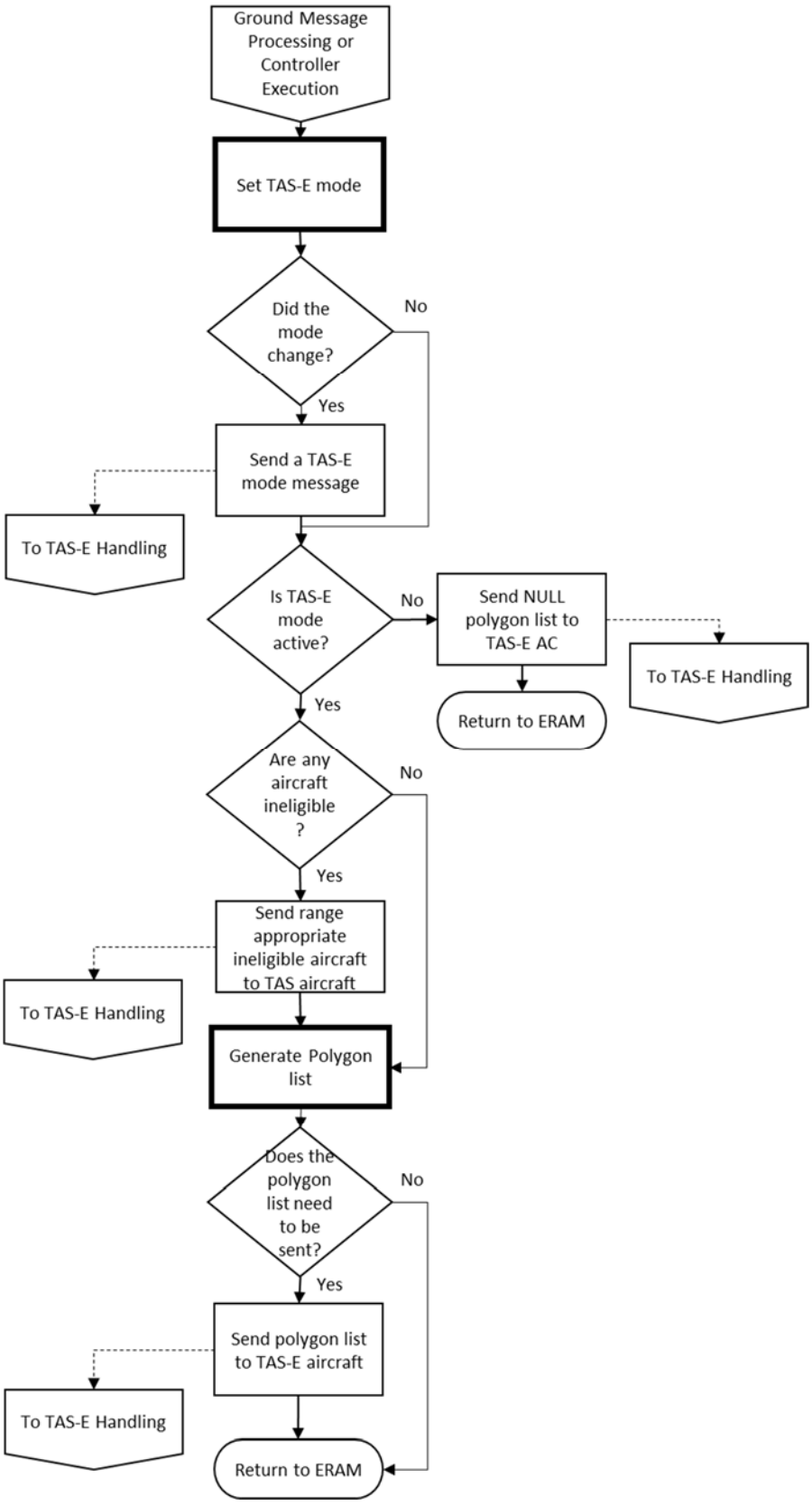


Figure A12: Ground Execution

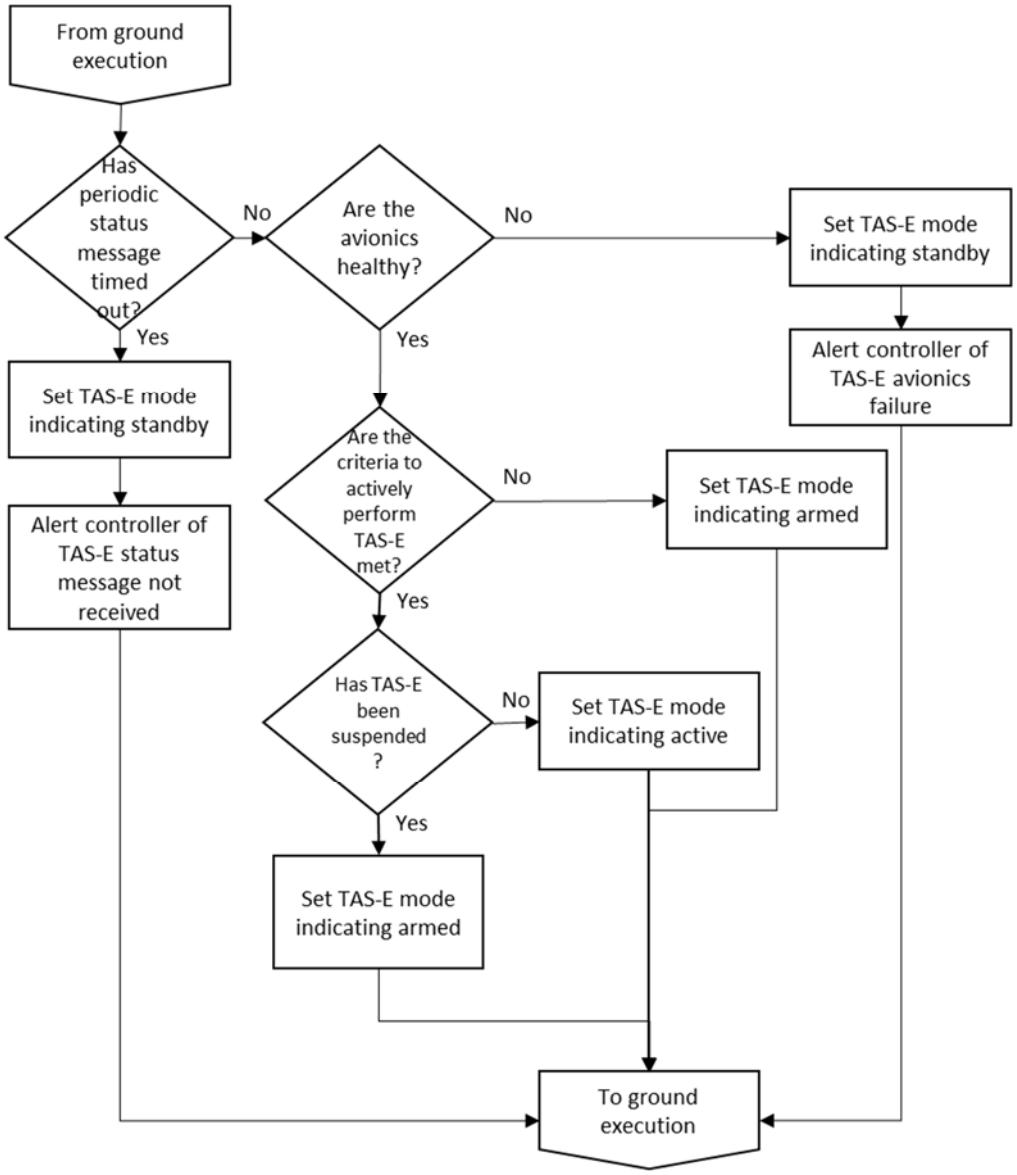


Figure A13: Set TAS-E Mode

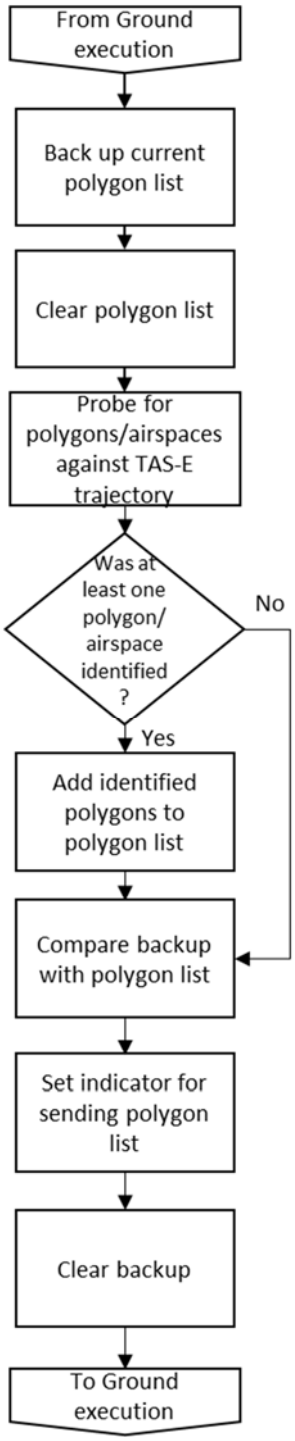


Figure A14: Generate Polygon List

The Controller Execution phase is shown in Figure A15. This phase covers some of the tasks that the controller might have to deal with during TAS-E Operations. This covers a subset that would be in addition to normal (non-TAS) sector operations.

- Has a "Reject Trajectory" message been received?
  - This would be sent in the unusual event that a flight crew is unwilling or unable to comply with a new TAS-E trajectory.
  - The controller would monitor and resolve any conflicts with the TAS-E and other aircraft.
- Is an aircraft's ADS-B inadequate?
  - If an aircraft's ADS-B is or becomes inadequate to be a participant in TAS-E operations, highlight aircraft to controller, set aircraft as ineligible, and manage separation for this aircraft as if TAS-E were not available.
- Does TAS-E need to be suspended?
  - This refers to a temporary suspension of TAS-E operations, which can later be reinstated. It is possible there are certain situations where a controller will need to retain full control of a particular TAS-E aircraft (such as flying in the vicinity of Air Force One).
  - If this occurs, suspend TAS-E for this aircraft (changes TAS-E Mode to armed), and continue operations as if this aircraft is not TAS-E equipped.
- Can a suspended TAS-E operation be resumed?
  - If an aircraft had its TAS-E operations suspended and is now suitable for TAS-E operations, clear the suspended status (changes TAS-E Mode to active) and return to normal TAS-E operations.
- Is an aircraft ineligible to serve as a TAS-E DA?
  - If an aircraft becomes ineligible to be a participant in TAS-E operations (such as ADS-B failure), highlight aircraft to controller, and manage separation for this aircraft as if TAS-E were not available.
- Can an ineligible aircraft now serve as a TAS-E DA?
  - If an aircraft that was ineligible becomes suitable, clear the ineligible status and resume normal TAS-E operations.
- Is there a trajectory failure alert?
  - If there is time to negotiate a new trajectory, then the controller can start the renegotiation process.
  - If there is not time to negotiate a new trajectory, then the controller should develop a solution that conforms with their sector management plan to ensure separation.

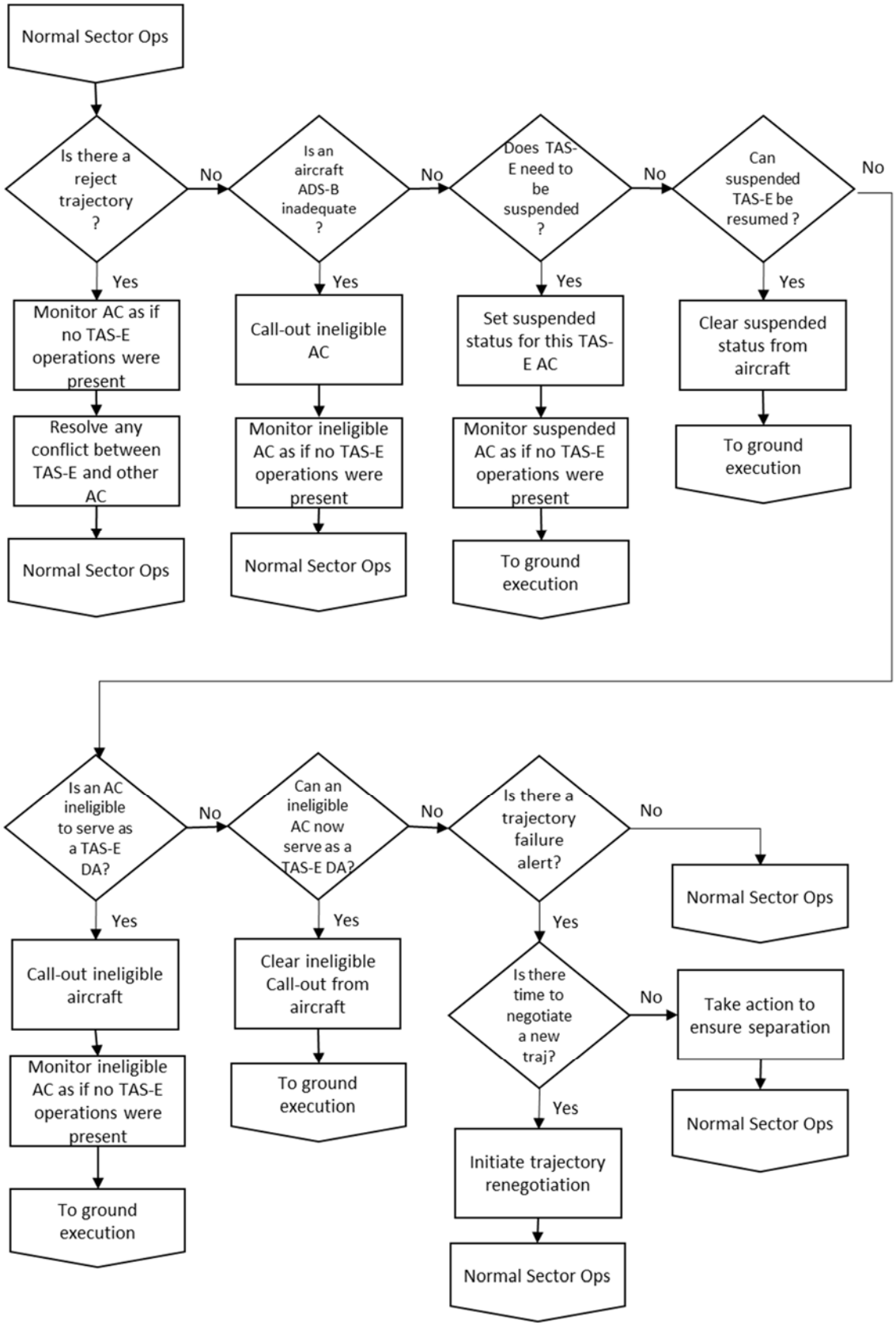


Figure A15: Controller Execution

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14. ABSTRACT

The TAS-E concept leverages TBO enabled information exchanges of data between air and ground systems, aircraft-to-aircraft sharing of ADS-B data, and an avionics suite that can identify and resolve near-term, predicted losses of spacing (PLOSp) with designated aircraft. If a PLOSp is detected, the avionics develop a proposed trajectory modification that resolves the PLOSp while attempting to minimize changes from the current cleared 4DT and attempting to meet original downstream trajectory constraints. It is envisioned that TAS-E could be conducted from TRACON exit to entry. The goal of TAS-E is to allow the aircraft to remain on a predictable trajectory at all times without the need for ATC intervention.

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