* + 1. **Return to Base (RTB) Flight Mode**

The RTB flight mode is used for aircraft that have run out of weapons, targets, fuel, or time. The RTB Flight mode directs aircraft back to their home airbase, i.e., their first waypoint. The RTB mode expects aircraft to start from a normal flight mode, such as waypoints, rather than a reaction flight mode, such as Engage or Drag. When a platform is scheduled for the RTB mode, it is explicitly put into a normal flight mode.

The RTB mode sets the direction, velocity, force of gravity, and maximum altitude for the aircraft. A direction vector is obtained from the platform’s current position to the platform’s first waypoint. The velocity of the aircraft is adjusted according to its distance from its first waypoint. RTB aircraft are flown at their cornering speed if they are over 5,000 m from the base. Helicopter corner speed is 75% of maximum speed. Otherwise, the aircraft is flown at the greater rate of 50 m/sec or 30% above minimum velocity. The force of gravity used will be one half of the aircraft’s maximum force of gravity. The maximum altitude will be the greater of the aircraft’s commanded altitude at its current location or 5,000 m. Helicopters’ maximum altitude during RTB is set to 20 m.

The aircraft is flown at each internal time step. The angle between the airbase position and the direction vector is obtained. If the aircraft is less than 15 deg to the airbase’s position in the elevation plane and not out of fuel, terrain following will be used to adjust the climb angle of the aircraft. The terrain following methodology is described in Subsection 5.4.3. The floor altitude used by the terrain following is set by the commanded AGL altitude.

If terrain following is not necessary, the direction vector is modified to account for Earth curvature by flying the aircraft while maintaining a constant altitude rate. Subsection 5.4.4 explains the constant altitude rate methodology. If the direction vector causes the aircraft to fly above the ceiling altitude or below the floor altitude, it is adjusted, as described in Subsection 5.4.3, for altitude monitoring. The ceiling altitude for altitude monitoring is set to the airframe’s service altitude limit. The floor altitude is set to 200 m.

The angle between the aircraft’s velocity vector and the vector to the airbase determines the flight method to reach the climbing point. If the angle is less than 0.8 degrees, the aircraft will fly straight to the climbing point; otherwise, it will fly in a curve to the climbing point. If the distance to the airbase is less than 1,000 m, the aircraft’s velocity vector is set to the commanded speed (the greater of 50 m/s or 30% above minimum velocity, as explained above in this section) times each component of the unit velocity vector. The floor altitude is also set to 0m, so that the aircraft can fly as low as necessary to land.

The wingman will follow the Wingman Flight mode procedures until 5 Km from homebase. Its airspeed will be commanded to the maximum of the aircraft approach speed (1.3 Min Speed) and 50 m/sec. If the distance to the airbase is less than 1 Km, the wingman will land at the airbase.

As the distance to the airbase is updated, FP determines if the aircraft has landed. The aircraft has landed at the airbase when the distance to the airbase is less than or equal to the aircraft’s turning radius and the dot product of the unit direction and unit velocity vectors is negative.

* + 1. **Avoid Flight Mode**

The Avoid flight mode always uses the truth to navigate, because it is performed relative to targets that are in track. Perception errors will therefore wash out.

However, if the aircraft has a navigation element, the Avoid flight mode will update the aircraft’s perception of its own state, using the formulas in Section 5.5.1. If the aircraft has no navigation element, then perception will be set and updated with the same values as the truth.

The Avoid mode of flight for aircraft causes the aircraft to maintain a flight path normal to the vector for the aircraft being avoided. This flight mode is currently used by the Wild Weasel, AGAttacker, Fighter, and Flexible Commander rulesets. These rulesets makes use of this flight mode in a reaction to being locked by a SAM system.

The user controls the Avoid maneuver through the ruleset options.. The user can select the Wild Weasel or AGattacker to perform this maneuver during the lock phase. The use of this maneuver during the React-to-SAM-Lock phase is also controlled by the user. The user can specify the duration of the maneuver, as well as the altitude at which the maneuver will be performed. For more details on the ruleset control of this flight mode, see Subsection 4.7.24.

When operating in the Avoid flight mode, the aircraft attempts to maintain a course normal to the platform being avoided (i.e., the aircraft remains at a constant distance from the avoided platform). Within this flight mode, the aircraft may fly terrain following at the altitude commanded by the ruleset. The terrain following methodology is described in Subsection 5.4.3. The floor altitude used by the terrain following is set by the commanded AGL altitude.

If terrain following is not necessary and if the direction of flight causes the aircraft to fly above the ceiling altitude or below the floor altitude, it is adjusted as described in Subsection 5.4.3 for altitude monitoring. The ceiling altitude for altitude monitoring is set to the airframe’s service altitude limit. The floor altitude is set to 200 m.

The target vector from the avoiding platform to the avoided platform is first computed. The avoidance vector that is normal to the target vector is next computed as the cross product of the target vector with the avoiding platform’s position. This avoidance vector is the vector that defines the direction of flight for the platform. This avoidance vector will cause the platform to fly to the right while avoiding the platform. If the platform to be avoided is to the right of the avoiding platform’s current velocity vector, the avoidance vector undergoes a 180-deg phase shift to cause the platform to fly to the left to avoid the platform.

Once the avoidance vector, i.e., the direction vector, is established, the aircraft is flown using the aircraft flight modeling described in Subsection 5.4.

* + 1. **Vector Flight Mode**

This flight mode flies a fighter in a direction rather than on a pursuit course after another platform. The C3I model computes an Intercept Point (IP) for an incoming airborne platform and vectors the fighter by sending to FP the heading, the ground range to the interception point, the altitude, and the speed the fighter should fly. The decision to use the Vector flight mode is made by C3I based on the fighter’s ruleset. This flight mode is only available for aircraft using the fighter ruleset.

* + - 1. **Vector Flight Mode Initialization**

After making the decision to use the vector flight mode, the C3I model sends to FP the ground range and heading to the IP and the altitude and speed the fighter is to fly. This information is used to compute the intercept point including the ground range, heading and altitude. For the laser case, C3I sends to FP the position of the target centroid, so that the intercept point does not have to be computed from the heading and ground range. The calculation of the IP varies depending on the underlying Earth model.

* + - 1. **Vector Flight Mode Platform Update**

If the aircraft has a navigation element, the Vector flight mode will update perception according to the equations in Section 5.5.1. In order to navigate according to perception, it is also necessary that the Accumulate Error Only option is not selected, the laser target centroid maneuver is not being performed, and the target to which the aircraft is vectoring is not in track. If any of these conditions fails or if there is no navigation element, this flight mode navigates according to truth, and perception will be set and updated with the same values as the truth. Note that this means that in the following discussion, whenever it is stated that a perceived value is used, this will correspond with the truth value if the aircraft is flying according to the truth.

Platform movement for the vector flight mode is performed in steps up to the end of the update interval. At the beginning of the update interval, command speed VCmd is initialized to the desired speed sent from the C3I model. The perceived altitude HP of the aircraft is computed using DblECEFtoAlt described in Appendix B10. The aircraft is flown at a constant altitude.

Next, the desired direction of flight vector is calculated. First the direction vector is computed using the methodology described in section 5.5.1 with the intercept point position as the destination. Then, the cross product of that direction vector to the intercept point position and the perceived up direction at the aircraft position is found:

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The resultant vector is normal to the perceived up direction at the aircraft position and consequently is normal to the surface of the Earth. It also points in the direction of the intercept point. This is the desired perceived direction vector. If terrain following or an altitude adjustment is required, the terrain following methodology described in Subsection 5.5.3 is used to modify the direction vector. The floor altitude used by the terrain following is set by the commanded altitude. Due to the nature of the vector flight mode maneuver, the perceived altitude maintained will be measured MSL rather than AGL.

If terrain following or altitude adjustment is not necessary, the perceived direction vector is modified to account for Earth curvature by flying the aircraft while maintaining a constant altitude rate. Subsection 5.5.4 explains the constant altitude rate methodology. If the perceived direction vector causes the aircraft to fly above the ceiling altitude or below the floor altitude, it is adjusted as described in Subsection 5.5.3 for altitude monitoring. The ceiling altitude for altitude monitoring is set to the airframe’s service altitude limit. The floor altitude is set to 200 m.

Once terrain following, altitude adjustment, and constant altitude rate have been checked and the perceived direction vector modified accordingly, the truth direction vector is calculated according to the translation methodology laid down toward the end of Section 5.5.1.

Next, the aircraft climbs or descends to the commanded intercept altitude while turning and proceeding toward the target. The climb/descent angle is limited to give a reasonable climb/descent. Once the fighter perceives that it has reached the commanded altitude, it flies to the intercept point at that altitude.

Another property of the vector flight mode is that the fighter will fly to its perceived intercept point and then fly beyond the point to a reattack range specified in the Vector Phase of the fighter ruleset. This allows the fighter to search for the attacker target for some distance after passing the perceived intercept point. Consequently, the fighter must still fly along the current direction of flight after passing the intercept point until the reattack range has been surpassed. Therefore, once the fighter passes the perceived IP and the computed direction vector is in the opposite direction of the fighter direction of flight, the negative of the direction vector is used to guide the fighter.

If an aircraft located within a Missile Engagement Zone (MEZ) is being vectored at a heading to intercept a target aircraft, it will follow the associated Low-Level Transit Route (LLTR), if any, to exit the MEZ before flying to the perceived IP point. Once out of the MEZ, it will transition to the Vector flight mode and fly to the perceived IP as described above.

* + 1. **Maneuver Flight Mode**

The maneuver flight mode can be performed while an aircraft is executing a defensive maneuver to avoid a SAM Lock or SAM Launch or via a User Rules response. A maneuver is composed of multiple user-defined segments. The maneuver flight mode executes each of these segments and then returns to the default flight mode when the last segment is completed. Each segment lasts until one of the specified termination values has been reached, depending on the type of segment.

The aircraft is flown at internal time steps. At each time step, a check is performed to see if any of the segment’s termination conditions are satisfied. If so, the aircraft transitions to the next segment and performs that action.

If the aircraft has a navigation element, the Maneuver flight mode will update perception as described in Subsection 5.5.1. If the Apply Error to Navigation option is selected for the navigation element, then the aircraft navigates according to perception; otherwise it navigates according to the truth and perception is set and updated with the same values as the truth. Note that this means that in the following discussion, whenever it is stated that a perceived value is used, this will correspond with the truth value if the aircraft is flying according to the truth.

If the Define Direction of Flight option is selected, then a vector in the desired direction of flight is computed as described in Subsection 5.5.1. The destination position is computed based on the selected maneuver segment execution values. If the Compute Direction of Flight option is selected then the direction vector is computed as described in Subsection [0](#_bookmark21). Once a perceived direction vector has been computed according to the chosen maneuver segment definition, the angle between the aircraft’s current perceived direction and this new perceived direction is then found. If the angle is less than 0.8 degrees, the aircraft will fly straight; otherwise, it will fly in a curve.

When the maneuver has been completed, a check is made to determine if any waypoints are perceived to have been passed and should therefore be skipped. Only route type waypoints will be skipped. If the current simulation time has exceeded the off time of a waypoint, it will be skipped. If the simulation time does not exceed the waypoint off time, but the off time will be exceeded before the aircraft can reach the waypoint, then that waypoint will be skipped.

Maneuver elements are defined by the user in Scenario Generation. Maneuvers are limited by the user defined floor and ceiling altitudes. The floor altitude is the minimum AGL altitude at which the aircraft is allowed to fly during the maneuver. The ceiling altitude is the minimum of either the airframe’s service altitude limit or the maximum MSL altitude at which the aircraft is allowed to fly during the maneuver.

* + - 1. **Maneuver Segments**

Each maneuver segment type has different maneuver parameters available that can be used to define how the aircraft flies during the segment and when to transition to the next segment.

* + - * 1. Direction of Flight

There are two options available for determining the desired direction of flight during each maneuver segment. If the Compute Direction of Flight option is selected then the direction of flight is computed based on the Roll, Roll Rate, Max Turn G, and Bank Angle execution values. This option allows the flight dynamics associated with a turn to be defined resulting in the direction of flight as the final outcome of the segment as opposed to directly defining the desired direction of flight. The Roll and Roll Rate are used in conjunction with the Max Turn G and Bank Angle to determine the turn plane and turn radius as described in section [5.6.10.1.2.1.2](#_bookmark23). The turn plane and turn radius determine the direction of flight that results from the turn. The bank angle and the angle between the local zero roll plane and turn plane about the longitudinal axis are computed as described in section [5.6.10.1.2.1.2](#_bookmark23). These parameters are then used to compute a destination vector in the turn plane orthogonal to the current velocity vector in body frame coordinates. If the Max Turn G is positive then the destination vector is computed as follows.

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The destination vector is transformed from Body Frame coordinates to ECEF coordinates using the ECEF2Body and Rotate2 functions described in Subsections B10.2.4 and B10.3.14 respectively. The destination vector, turn plane, and turn radius are then used to fly the aircraft in a curved flight path as described in Subsection 5.5.3.2. The resulting aircraft position is computed at the end of each integration interval until a termination value is satisfied. When the segment terminates, the aircraft continues to fly at the resulting flight path angle, heading, and roll. The Compute Direction of Flight option is only available for the Custom segment type. Carefully select the termination values used with the Compute Direction of Flight option because it is possible to setup segments which never meet the termination conditions.

The velocity at the start of the maneuver segment lies in the turn plane. Therefore, the turn is made with the turn plane oriented at the flight path angle of the aircraft at the start of the segment. Two maneuver segments can be used to define a maneuver segment using the Compute Direction of Flight option relative to a given FPA. Define the first maneuver segment using Define Direction of Flight that orients the aircraft at the desired FPA. If the maneuver segment that follows uses the Compute Direction of Flight option, then it will initiate from the FPA achieved in the preceding segment. A single custom maneuver segment can be used with the Compute Direction of Flight option to achieve a particular FPA using the FPA termination value as described in Subsecti[on 5.6.10.1.2.2.2](#_bookmark26)

If the Define Direction of Flight option is selected then the Flight Path Angle, Heading Angle, or Altitude Execution Values can be used to define the desired final direction of flight for this maneuver segment and Roll, Turn G, and Bank Angle execution values are used to compute and limit the G’s used during the turn to point the aircraft in that direction.

* + - * 1. Maneuver Parameters

For each maneuver segment, maneuver parameters describe how the maneuver segment is flown and when it is complete. A maneuver parameter can be defined as either an execution value or a termination value, or as both. Each maneuver parameter is defined by a random number distribution type. A random draw is made from each distribution at the beginning of the maneuver segment to define the parameter used throughout the segment. This statistical representation can be used to create variability between aircraft maneuvers to simulate minor pilot adjustments. The mean value of each distribution is displayed in each maneuver parameter field. If randomness has been eliminated from the scenario, the mean value of each maneuver parameter is used.

Execution Values

The selected maneuver parameter execution values are applied to the aircraft while it is performing the current maneuver segment. These parameters can be used to define the desired final outcome of the maneuver segment or limit the aerodynamic flight of the aircraft during the segment. Only some execution values are applied as limits and they are only applied as limits for certain cases. The details of when and how these are applied as limits are discussed in each execution value subsection. If Define Direction of Flight is enabled then the Roll, Max Turn G, and Max Bank Angle are used to compute the G’s pulled during any turns used to achieve the desired direction of flight. If Define Direction of Flight is enabled and the Roll, Max Turn G, and Max Bank Angle are not selected as execution parameters, then a max G turn is performed in order to achieve the desired direction of flight.

Roll Rate

Roll Rate is applied as the rate of change of roll which the aircraft can achieve during this maneuver segment. If the Define Direction of Flight option is selected and the maneuver requires the aircraft to roll, then the specified Roll Rate will be utilized to achieve the required roll. If the Compute Direction of Flight option is selected then the Roll Rate can be used with the Max Turn G or the Max Bank Angle to define the turn plane and the radius of the turn without defining the Roll. The turn plane and turn radius determine the direction of flight that results from the turn. In this case the Roll Rate is applied to compute the resulting roll at the end of each integration interval. A positive roll rate will cause a clockwise roll from the pilot’s perspective in order to achieve the desired roll. A negative roll rate will cause a counterclockwise roll from the pilot’s perspective in order to achieve the desired roll.

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The resulting roll is then used in conjunction with either the defined Max Turn G or the Max Turn G computed from the Max Bank Angle to compute the turn plane and the turn radius as described in Subsecti[on 5.6.10.1.2.1.2](#_bookmark23).

Roll

Roll is defined as the angle about the lateral axis of the aircraft with zero roll defined as having the aircraft wings level in the lateral direction with the top of the aircraft pointing away from the ground. The aircraft may be pitched up or down, therefore the wings may or may not be level in the longitudinal direction. The wings of the aircraft with zero roll define the zero roll plane discussed below. The zero-roll plane remains level in the lateral direction but remains aligned with the pitch and azimuth of the aircraft. Note that the longitudinal axis of the aircraft is aligned with the velocity vector and that positive roll is defined as a clockwise rotation from the pilot’s perspective. If Compute Direction of Flight is selected and Roll is selected as an Execution Value then the Roll is used in conjunction with either the Max Turn G or the Bank Angle to determine the orientation of the turn plane and the turn radius, which define the direction of flight at the end of each integration interval until a termination value is satisfied. The Max Turn G is computed as described in Subsection [5.6.10.1.2.1.3](#_bookmark24). The Max Turn G is used to compute the bank angle relative to the turn plane. If the Max Turn G is positive then the bank angle is computed as follows.

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If the Roll Rate execution value is also selected then the roll achieved at each integration interval is computed as described in Subsection [5.6.10.1.2.1.1](#_bookmark22). If the Max Turn G is negative then a nose down turn is being performed therefore a scale factor is applied to the bank angle calculation.

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If the Bank Angle execution value is selected and if the magnitude of the Bank Angle is less than the magnitude of the computed bank angle then the Bank Angle execution value is used instead of the computed bank angle. Then, the bank angle and roll are used to compute the angle between the local zero roll plane and turn plane about the longitudinal axis.

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If Define Direction of Flight is enabled and Roll is selected as an Execution Value, then the Roll is used to limit the amount of roll that is achieved during a turn in this maneuver segment and hence limit the G’s available for turns during this maneuver segment. The Rotation angle between zero roll plane and turn plane about the longitudinal axis of the aircraft is computed by first converting the direction vector to body frame coordinates using the ECEF2BodyMatrix function described in Subsection B10.2.6. Then the angle is computed from the Y versor vector.

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The actual G used for the turn is set to the minimum of the G defined by the specified roll, the Max Turn G defined for the segment, and the max G available computed from the airframe.

Max Turn G

If Compute Direction of Flight is enabled and Max Turn G is selected as an Execution Value then the minimum of the Max Turn G, airframe available G, and the G computed from the Bank Angle is used in conjunction with the Roll and Roll Rate to determine the turn plane and radius which define the final direction of flight at the end of each integration interval until a termination value is satisfied.

If Define Direction of Flight is enabled and Max Turn G is selected as an Execution Value then the minimum of the Max Turn G, the turn G computed from the Bank Angle, the airframe available G, and the turn G computed from the Roll is used to define the amount of G’s that can be achieved to perform a turn during this maneuver segment.

The Max Turn G can be defined as positive or negative. Positive Max Turn G causes the aircraft to use a nose up to execute a turn or change altitude while a negative Max Turn G causes the aircraft to use a nose down to execute a turn or change altitude.

Max Turn G Mode defines how the Max Turn G is specified for the segment. The available options are Absolute, %MIL, and %AB. The Absolute Max Turn G mode is defined as the ratio of the total acceleration experienced by the aircraft and the acceleration due to gravity at sea level. The %MIL mode allows specification of the Max Turn G as a percentage of the available MIL G computed from the airframe MIL G available table for HIFI airframes or from the Max G airframe parameter for non-HIFI airframes. The %AB mode allows specification of the Max Turn G as a percentage of available MAX AB G computed from the airframe MAX AB G available table for HIFI or from the Max G airframe parameter for non-HIFI airframes.

Max Bank Angle

Bank angle is defined as the angle about the longitudinal axis of the aircraft relative to the turn plane of the aircraft. If Compute Direction of Flight is enabled and Max Bank Angle is selected as an Execution Value then the minimum of the Max Bank Angle and the bank angle computed from the Max Turn G is used in conjunction with the Roll and Roll Rate parameters to determine the turn plane and turn radius which define the direction of flight at the end of each integration interval until a termination value is satisfied.

If Define Direction of Flight is enabled and Max Bank Angle is selected as an Execution Value then the minimum of the Max Turn G, the turn G computed from the Bank Angle, the airframe available G, and the turn G computed from the Roll is used to define the amount of G’s that can be achieved to perform a turn during this maneuver segment.

Flight Path Angle

If the Define Direction of Flight option is selected and the Execution Value option is selected for Flight Path Angle (FPA) but not for Altitude then the user defined FPA defines the desired direction of flight. A positive value represents a FPA in the up direction and a negative value represents a FPA in the down direction. The Heading Angle Execution Value can be used in conjunction with the FPA to define the desired direction of flight. If the Altitude Execution Value is enabled then the FPA input limits the flight path angle that can be flown to achieve the desired altitude to the range [-FPA, FPA]. The altitude is achieved using the largest magnitude FPA that the aircraft is capable of achieving.

There are three options for defining the FPA. In Absolute FPA mode, the FPA is defined as the angle between the velocity of the aircraft and the local horizontal plane. This is also the angle between the nose of the aircraft and the local horizontal since the orientation is aligned with the velocity vector for all maneuver segment types except for TSPI. This mode can be used to define a desired pitch when using a yaw, pitch, roll absolute coordinate frame. In the Relative FPA mode, the FPA is defined as an angle in the vertical direction relative to the FPA at the start of the segment. In the Relative LOS FPA mode, the FPA is defined as the desired angle between the line of sight (LOS) between the aircraft and the target to which the maneuver is relative and the aircraft’s velocity vector. For example, this mode can be used to accomplish a drag away maneuver segment where the aircraft drags directly away from the target by setting the FPA to 180 degrees and setting the Heading Angle execution parameter to Relative LOS mode and 180 degrees. If the Altitude execution value is selected then the only mode available is the Absolute mode.

Heading Angle

Heading angle defines the heading to which the aircraft is to turn during the maneuver segment. The actual heading angle for the segment is determined by the specified value and the selected angle mode. If selected as an execution parameter, the aircraft will turn toward the specified heading until the angle is achieved or until the termination condition is reached. If the heading angle is achieved before a termination condition is met then the aircraft will continue to fly at that heading until a termination condition is met. If a termination condition is met before the heading angle is met then the current segment terminates.

There are four ways to define how the heading angle is specified for the segment. The available options are Absolute, Relative, Relative LOS, and Absolute LOS. An absolute heading is defined relative to North. A relative heading is defined relative to the aircraft’s heading at the initiation of the maneuver segment. Both LOS heading modes are defined relative to the current line of sight vector between the aircraft and its target/attacker. When the Relative LOS mode is selected, the aircraft will turn in the direction that requires the smallest angle of turn to achieve the heading angle relative to the target. When the Absolute LOS mode is selected, the aircraft will fly directly to the angle specified relative to the current heading to the target. To specify an angle to the right of the target use a positive value, to the left of the target use a negative value.

Altitude

As an Execution Value, Altitude defines to what altitude the aircraft is to fly during the maneuver segment. The actual altitude desired for the segment is determined by the specified value and the selected altitude mode. If selected as an execution parameter, the aircraft will climb or dive to the altitude specified as quickly as possible limited by the FPA and maintain that altitude until the segment is terminated. Section [5.6.10.1.2.1.5](#_bookmark25) describes how the FPA is used to limit the aircraft’s climb and descent.

Altitude mode defines how the altitude is specified for the maneuver segment. The available options for this field are 'Rel', 'AGL', and 'MSL'. Relative altitudes are specified as plus or minus the aircraft’s altitude at the start of the maneuver segment. If the AGL option is selected, then the aircraft will fly terrain following. If the MSL option is selected, then the aircraft is flown to the specified MSL altitude without terrain following.

Speed

Defines what commanded speed to use while the aircraft is flying the current maneuver segment. The actual speed desired for the segment is determined by the specified value and the selected speed mode. If selected as an execution parameter, the aircraft will attempt to fly at the speed specified during the maneuver segment and maintain that speed until the segment is terminated.

Speed mode defines how the speed is specified for the maneuver segment. The available options are Absolute, Relative, % MIL Throttle Setting, % AB Throttle Setting, Target Multiplier, and Platform Multiplier. Relative speeds are specified as plus or minus the aircraft’s speed at the start of the maneuver segment. Throttle Setting speeds are specified as a percentage of the thrust, AB thrust, or max thrust computed from the Hi-Fidelity thrust and AB thrust tables. For aircraft, the thrust is used to compute the acceleration which determines the speed. If the %AB option is used and the afterburners are not available for this airframe, then the maximum MIL thrust is used. For helicopters, if the %MIL option is selected, then the maximum thrust is computed as follows.

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If the %AB speed mode setting is selected for helicopters then the maximum thrust is computed using 100% or full Mil. If using Target Multiplier mode, the value specified is multiplied by the target’s speed at the start of the maneuver segment to obtain the desired speed. This speed mode option should only be used for maneuvers adopted relative to a target through the User Rules. If using Platform Multiplier mode, the value specified is multiplied by the aircraft’s speed at the start of the maneuver segment to obtain the desired speed.

Termination Values

The selected maneuver termination values determine the conditions for the aircraft to terminate the current maneuver segment when the specified values are reached. If multiple termination parameters are selected, the first termination criterion met will cause the transition to the next maneuver segment. The Duration termination value is monitored continuously to allow transition to the next segment at the exact time that the condition is met. All other termination values transition at the integration interval. If this is the last segment for this maneuver then the aircraft will transition back to default flight mode, or, if the maneuver was initiated from the User Rules, then the aircraft will transition back to ruleset control at the end of the current scenario interval. In this case, the aircraft is flown using the maneuver flight mode until the end of the current scenario interval.

Roll

If Roll is selected as a Termination Value, the absolute value of the roll of the aircraft reaching or exceeding the user defined Roll threshold will terminate the maneuver segment. Roll is defined as the angle about the lateral axis of the aircraft with zero roll defined as having the aircraft wings level in the lateral direction with the top of the aircraft pointing away from the ground.

Flight Path Angle

If the Flight Path Angle Termination Value option is selected, then the maneuver segment terminates when the flight path angle of the aircraft reaches or crosses the specified parameter. If the FPA at the beginning of the maneuver segment is greater than the specified FPA, then the segment terminates when the FPA is less than or equal to the specified FPA. If the FPA at the beginning of the maneuver segment is less than the specified FPA, then the segment terminates when the FPA is greater than or equal to the specified FPA.

There are three options for defining the FPA. In Absolute FPA mode, the FPA is defined as the angle between the velocity of the aircraft and the local horizontal plane. This is also the angle between the nose of the aircraft and the local horizontal since the orientation is aligned with the velocity vector for all maneuver segment types except for TSPI. This mode can be used to define a desired pitch when using a yaw, pitch, and roll absolute coordinate frame. In the Relative FPA mode, the FPA is defined as an angle in the vertical direction relative to the FPA at the start of the segment. In the Relative LOS FPA mode, the FPA is defined as the desired angle between the line of sight (LOS) between the LOS from the aircraft to the target and the aircraft’s velocity vector. If the Altitude execution value is selected, then the only mode available is the Absolute mode.

Heading Angle

If selected as a termination parameter, the segment will end when the aircraft reaches or crosses the specified heading angle. If the heading angle at the beginning of the maneuver segment is greater than the specified heading angle, then the segment terminates when the heading angle is less than or equal to the specified heading angle. If the heading angle at the beginning of the maneuver segment is less than the specified heading angle, then the segment terminates when the heading angle is greater than or equal to the specified heading angle.

There are four ways to define how the heading angle is specified for the segment. The available options are Absolute, Relative, Relative LOS, and Absolute LOS. An absolute heading is defined relative to North. A relative heading is defined relative to the aircraft’s heading at the initiation of the maneuver segment. Both LOS heading modes are defined relative to the current line of sight vector between the aircraft and its target/attacker. When the Relative LOS mode is selected, the aircraft will turn in the direction that requires the smallest angle of turn to achieve the heading angle relative to the target. When the Absolute LOS mode is selected, the aircraft will fly directly to the angle specified. Positive values specify an angle to the right of the target, while negative values specify an angle to the left of the target.

Altitude

If selected as a termination parameter, the segment will end once the aircraft crosses the altitude specified. If the altitude at the beginning of the maneuver segment is greater than the specified altitude, then the segment terminates when the altitude is less than or equal to the specified altitude. If the altitude at the beginning of the maneuver segment is less than the specified altitude, then the segment terminates when the altitude is greater than or equal to the specified altitude.

Altitude mode defines how the altitude is specified for the maneuver segment. The available options for this field are 'Rel', 'AGL', and 'MSL'. Relative altitudes are specified as plus or minus the aircraft’s altitude at the start of the maneuver segment. If the AGL option is selected, then the aircraft will fly terrain following. If the MSL option is selected, then the aircraft is flown to the specified MSL altitude without terrain following.

Speed

If selected as a termination parameter, the segment will end once the aircraft has reached or crossed the speed specified. If the speed at the beginning of the maneuver segment is greater than the specified speed, then the segment terminates when the speed is less than or equal to the specified speed. If the speed at the beginning of the maneuver segment is less than the specified speed, then the segment terminates when the altitude is greater than or equal to the specified speed.

Speed mode defines how the speed is specified for the maneuver segment. The available options are Absolute, Relative, % MIL Throttle Setting, % AB Throttle Setting, Target Multiplier, and Platform Multiplier. Relative speeds are specified as +/- the aircraft’s speed at the start of the maneuver segment. Throttle Setting speeds are specified as a percentage of the MIL thrust, AB thrust, or max thrust computed from the Hi-Fidelity thrust and AB thrust tables. For aircraft, the thrust is used to compute the acceleration which determines the speed. If the %AB option is used and the afterburners are not available for this airframe then the maximum MIL thrust is used. For helicopters, if the %MIL option is selected then the maximum thrust is computed as follows.

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If the %AB speed mode setting is selected for helicopters then the maximum thrust is computed using 100% Mil. If using Target Multiplier mode, the value specified is multiplied by the target’s speed at each integration interval to obtain the desired speed. This speed mode option should only be used for maneuvers adopted relative to a target through the User Rules. If using Platform Multiplier mode, the value specified is multiplied by the aircraft’s speed at the start of the maneuver segment to obtain the desired speed.

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Duration

Duration defines how long the current maneuver segment should be performed. If selected as a termination parameter, the aircraft will transition to the next maneuver segment in the maneuver element once the maneuver segment has been executed for the specified amount of time. The transition to another segment occurs at the exact time defined by duration regardless of the integration step size. If this is the last segment for this maneuver, then the aircraft will transition back to default flight mode, or, if the maneuver was initiated from the User Rules, then the aircraft will transition back to ruleset control at the end of the current scenario interval. In this case, the aircraft is flown using the maneuver flight mode until the end of the current scenario interval.

Min Vertical Velocity

When selected, the segment will end when the vertical component of the aircraft’s velocity vector falls below the specified value. The vertical component of the aircraft’s velocity is computed using the scalar projection of velocity onto a local up vector at the aircraft’s position. The DblECEFtoUp routine described in Subsection B10.2.21 is used to compute the local up vector.

vector in ECEF coordinates

Max Vertical Velocity

When selected, the segment will end when the vertical component of the aircraft’s velocity vector exceeds the specified value. The vertical velocity is computed as described in secti[on 5.6.10.1.2.2.7](#_bookmark27).

Min Available G

When selected, the segment will end when the aircraft’s available G falls below the specified value.

Max Available G

When selected, the segment will end when the aircraft’s available G meets or exceeds the specified value.

* + - * 1. Maneuver Segment Types

A maneuver is created using one or more of the pre-defined maneuver segment types or a Custom segment type. More than one segment can be used to define a maneuver. An example maneuver with just one segment is to Drag Away from the target for 30 seconds. An example of a maneuver with more than one segment is to Turn to Relative Angle and Fly Straight and Level for 30 seconds. Only the valid combinations of maneuver parameters are available for each pre-defined maneuver segment type. The speed execution value is available for all segment types. If Speed is not selected as an execution value, then the aircraft’s speed at the start of the segment will be maintained. Speed is used to set the commanded speed during each segment. The aircraft attempts to achieve the commanded speed using the aerodynamic parameters as described in Subsection 5.5.2.

Change Altitude Maneuver Segment

The Change Altitude maneuver segment can be used to specify a new altitude for the aircraft. The available execution values that apply are altitude, altitude mode, speed, speed mode, max turn G, Max Bank Angle, and FPA. The steepness of the climb or dive to the new altitude is limited to [-FPA, FPA]. The max turn G limits the turn used to achieve the FPA. The FPA allows the aircraft to achieve its new altitude as fast as possible given the specified elevation constraint. Altitude and duration are the termination values for the change altitude maneuver segment. The segment is flown until either the aircraft perceives that altitude has been reached or the segment Duration has been exceeded.

Drag Away Maneuver Segment

The Drag Away maneuver segment defines a type of maneuver which flies the aircraft directly away from the perceived location of the platform causing the reaction. If a drag maneuver is to be performed, the direction vector is calculated by using the methodology described in Subsection 5.5.1 with the attacker’s position as the destination. The negative of the direction vector is then computed. The calculations are similar to those in the discussion of the drag maneuver in Subsection 5.6.6. The execution values available for this maneuver are the Roll Rate, Roll, Max Turn G, Max Bank Angle, and the Speed at which the aircraft will attempt to fly during the drag maneuver. Roll Rate, Roll, Max turn G and Max Bank Angle are used as limits on the turn to the desired direction. The Duration of the drag is the only termination value that is used.

Drag Away Level Maneuver Segment

The Drag Away Level maneuver segment is similar to the Drag Away segment, except that the aircraft maintains its current perceived altitude. The segment is flown until the Duration time is reached.

Fly Abeam Maneuver Segment

The Fly Abeam maneuver segment causes the aircraft to fly with the LOS to the perceived location of the platform causing the reaction at a 90 degree heading relative to the nose of the aircraft. The direction vector is calculated as described for a beam maneuver in Methodology Manual Section 5.6. The execution values available for this maneuver are the Roll Rate, Roll, Max Turn G and the Speed of the aircraft. Roll Rate, Roll, and Max turn G are used to limit the turn to the desired direction as described in section [5.6.10.1.2.1.2](#_bookmark23) for Define Direction of Flight. The segment is flown until the Duration termination value is reached.

Fly Default Mode at New Altitude Maneuver Segment

The Fly Default Mode at New Altitude maneuver segment allows the user to specify a new altitude for the aircraft to fly during default flight mode. The default flight mode is the Waypoint flight mode for flight leaders or the Wingman flight mode for wingmen. Subsections 5.6.1 and 5.6.2 describe the Waypoint and Wingman flight modes respectively. The available execution values for this segment are the Max Turn G, Altitude, and Speed. The Altitude and Speed parameters are commanded values that the flight processing model attempts to achieve. The radius of the vertical turn used to achieve the altitude is limited by the Max Turn G. The segment is flown until the Duration termination value is reached.

Fly Straight and Level Maneuver Segment

The Fly Straight and Level maneuver segment allows the aircraft to fly at the current heading and MSL altitude. The available execution values for this maneuver are the Roll, Roll Rate, Max Turn G, Max Bank Angle, and Speed. The Speed is used to set the commanded speed and the minimum of the Max Turn G, the turn G computed from the Bank Angle, the airframe available G, and the turn G computed from the Roll is used to define the amount of G’s that can be achieved during the vertical turn to level, if required. The segment is flown until the Duration time is reached. If it is desired that a particular roll angle be maintained during the Fly Straight and Level segment, a Roll execution value can be specified, but the segment should be preceded by a Roll segment to get to aircraft to the desired angle.

Roll Maneuver Segment

The Roll maneuver segment allows the aircraft to perform a roll without resulting in a turn. The available execution values for this segment are the Roll Rate and speed. The aircraft rolls at the user-defined Roll Rate and attempts to accelerate to the Speed execution value for the Duration of the segment. The segment transitions to the next segment when the Duration termination value is reached.

Turn to Angle Off of LOS Maneuver Segment

The Turn to Angle Off of Line of Sight (LOS) maneuver segment allows the aircraft to turn to an angle relative to LOS to the perceived location of the target or platform initiating the maneuver response. The available execution values for this segment are Roll Rate, Roll, Max Turn G, Max Bank Angle, Heading Angle, Altitude, and Speed. The Heading Angle and Altitude parameters define the desired direction of flight during this segment. A perceived direction vector is computed from the target location and the perceived location of the aircraft.

The Roll Rate, Roll, Max Turn G, Max Bank Angle, Heading Angle, and Altitude parameters are used to limit the turn used to cause the aircraft to move in that direction. Once the aircraft has reached the Heading Angle termination value, the segment is terminated. To cause the aircraft to continue to fly at the new Heading Angle and Altitude, the Turn To Angle Off of LOS segment can be followed with the Fly Straight and Level segment. The Fly Straight and Level segment allows definition of the Duration of the aircraft flight at the current altitude and heading.

Turn to Beam Maneuver Segment

The Turn to Beam maneuver segment allows the aircraft to turn and fly such that the perceived target location is 90 degrees off nose in the horizontal direction. The available execution values for this segment are Roll Rate, Roll, Max Turn G, Max Bank Angle, and Speed. The Roll Rate, Roll, Max Turn G, and Max Bank Angle are used as limits on the G’s used in the turn as described in section [5.6.10.1.2.1.2](#_bookmark23) for the Define Direction of Flight option. Once the aircraft has reached the new heading angle, the segment will terminate. To cause the aircraft to fly for a specified duration at this altitude or heading, this maneuver segment can be followed by a Flight Straight and Level maneuver segment. The direction vector is calculated as described for a beam maneuver in Subsection 5.6.

Turn to Relative Angle Maneuver Segment

The Turn to Relative Angle maneuver segment allows the aircraft to turn to an angle relative to its orientation at the start of the segment. The execution values for this segment are Roll Rate, Roll, Max Turn G, Max Bank Angle, Heading Angle, and Speed. The Heading Angle defines the relative angle that is desired. The Heading Angle defines the desired direction of flight. The Roll Rate, Roll, Max Turn G, Max Bank Angle, and Heading Angle parameters are used to limit the turn used to cause the aircraft to move in that direction as described in section [5.6.10.1.2.1.2](#_bookmark23) for the Define Direction of Flight option. Once the aircraft reaches the new heading angle termination value it terminates the segment. To cause the aircraft to fly for a specified duration at this altitude or heading, this maneuver segment can be followed by a Fly Straight and Level maneuver segment.

Custom

The Custom segment type allows any valid combination of maneuver parameters to be used to define a maneuver segment. The definition of each of the execution value maneuver parameters depends on the Direction of Flight setting described in section [0](#_bookmark21). The custom segment type can be used to define any of the pre-defined segment types except for TSPI and Fly Default Mode at New Altitude. But the additional execution and termination values available allow more flexibility to customize the segment. To define a custom segment type that behaves like another segment type, create a new segment with the desired type and then change the segment type to Custom. This will bring the default options for that segment over to the custom segment. The custom segment type allows the use of the Compute Direction of Flight option described in section [0](#_bookmark21).

Time Space Position Indicated

Time Space Position Indicated (TSPI) data includes the actual measured position and orientation of an aircraft performing a maneuver. TSPI data can be collected for an aircraft and imported into EADSIM as a TSPI maneuver segment. The TSPI segment type allows TSPI data to be either imported from a text file or defined as inputs in Scenario Generation. The TSPI maneuver segment provides the specifics of a maneuver initiated relative to the current position and heading of the aircraft. When the segment is executed, the aircraft will snap to the defined flight path instead of using aerodynamic flight to fly to each point. This allows the exact flight path and orientation of the aircraft to be explicitly flown throughout the maneuver segment. The aircraft velocity is computed from the TSPI position and time data.

If the Apply Error to Navigation option is selected for a Navigation Device on the aircraft then the navigation error is accumulated throughout the maneuver segment and the aircraft is flown directly to the TSPI data points. When the segment completes the aircraft navigates according to perception.

Time

The time is defined in decimal seconds relative to the initiation of the maneuver. The data points do not have to be evenly spaced in time. In EADSIM, the position of each platform is updated at each integration interval in flight processing. There may not be a TSPI data point defined for each integration time step. Therefore the position and orientation at each integration time step are computed using the flight smoothing algorithm described in secti[on 5.6.10.1.3.12.9](#_bookmark30).

Position and Orientation Coordinates

The TSPI position is defined in a local body coordinate system that remains fixed with the origin located where the aircraft initiated the maneuver segment, thus each position is defined as the offset from the location of the aircraft at initiation of the maneuver segment. This body frame coordinate system is defined as follows:

Z: Local up

Y: Perpendicular to plane formed by Z and Velocity vector X: Orthogonal to YZ plane

The position is converted from body frame to ECEF coordinates using the DblECEF2BodyMatrix and Rotate2 routines described in Appendix sections B10.2.7 and B10.3.14 respectively.

The orientation is defined by the yaw, pitch, and roll rotation angles. Yaw is defined as the angle about the up vector measured positive clockwise relative to true north, pitch is defined as the angle between the nose of the aircraft and the local horizontal plane, and roll is defined as the angle about the lateral axis of the aircraft relative to level flight. Positive yaw is defined with the nose turning to right, positive pitch is defined as nose towards up, and positive roll is defined as the right wing moving down. At runtime, the yaw of the first TSPI data point is used to translate the yaw of all other data points based on the aircraft’s heading at the start of the segment.

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This allows the maneuver segment to be initiated from any angle in azimuth and still maintain its pitch and roll profile characteristics.

Segment Initialization

If the Smooth Transition option is selected then the transition to this maneuver segment from the default flight mode or previous segment is smoothed. Two segments of type Custom are automatically created to fly the aircraft to the initial orientation and velocity of the TSPI segment. The aircraft starts the TSPI segment when it reaches the orientation and velocity defined by the first two TSPI data points. This may cause a delay between when the segment starts and when the first TSPI point is reached. If the Smooth Transition option is not selected then the aircraft will snap directly to the first TSPI velocity and orientation at the start of the segment. This removes the possibility of a delay but adds the possibility for discontinuities in the aircraft orientation and velocity. If this option is not selected, a custom maneuver segment can be added by the user to precede the TSPI segment in order to allow the aircraft to reach a satisfactory state entry point.

Importing TSPI Data

TSPI data can be imported directly from a user-selected raw TSPI data file. User defined file format options allow flexibility in types of TSPI files that can be imported. There are several data format options which allow the raw TSPI data to be defined in different units and coordinate frames. Raw TSPI data is defined using absolute time and absolute position and orientation coordinates. Within the TSPI maneuver segment, TSPI data is defined using relative time and body frame coordinates for position of the aircraft. When the data is imported the time is translated into decimal seconds relative to the start of the maneuver segment and the position is transformed into local body frame coordinates.

EADSIM supports any ASCII text file format where the data is tab, comma, or space delimited. The user defines which column in the file contains each of the time, position, and orientation parameters, and what delimiter is used. The file can contain additional columns which are ignored during the import. If the first line of the file contains any characters other than the positive, negative, decimal point, and numeric characters (+ - . 1 2 3 4 5 6 7 8 9 0) then it is also ignored during import. This allows flexibility when importing raw TSPI data. The position and orientation must be in decimal notation.

There are several different data format options available for importing raw TSPI files. The time can be in either decimal seconds or decimal hours. The position can be defined in one of four available coordinate frames. There are two options available for the Latitude, Longitude, Altitude (LLA) coordinate frame and one option available for the Earth Centered Earth Fixed (ECEF) coordinate frame described in Methodology Manual section B10.1.1. Note that the ECEF coordinate frame must be defined relative to the WGS84 spheroid earth model. The ENU and NED coordinate frame options are also available. The ENU coordinate frame is described in section B10.1.3 and the NED coordinate frame is described in section 5.7.2.2. If the LLA option is selected, then the altitude can be defined in either feet or meters and the latitude and longitude can be defined as decimal degrees (dd.ddddd) or degrees minutes seconds (dd mm ss). The orientation is defined as a yaw, pitch, and roll which are described in section [5.6.10.1.3.12.2](#_bookmark28).

When the data is imported the time is translated from decimal hours to decimal seconds, if necessary, and then it is translated to be relative to the start of the segment. The time for the first point is set to zero. The time for all subsequent points is computed as follows.

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The orientation is imported directly without any translation. The position is transformed into relative local body frame coordinates based on the selected position format option as described in the following sections. The translated and transformed time, position, and orientation values are then displayed in the TSPI segment definition table.

Latitude Longitude Altitude to Body Frame

If the Latitude Longitude Altitude (LLA) position format is selected, then the raw TSPI position data is translated from geodetic LLA to the local body frame coordinates defined in section [5.6.10.1.3.12.2](#_bookmark28) upon import. The Latitude and Longitude are translated from degrees/minutes/seconds (DMS) to decimal degrees (DD), if necessary, when the raw TSPI data file is read in. The location of the first point in body frame coordinates is set to (0, 0, 0). Each subsequent point is first transformed from LLA to ECEF coordinates using the LLAtoDblECEF routine described in section B10.2.10 and then to body frame using the DblECEF2BodyMatrix and Rotate1 routines described in sections B10.2.7 and B10.3.10 respectively. The ECEF position of the first point is used as the origin of the body frame coordinate frame and is sent into DblECEF2BodyMatrix as Position. The velocity sent into DblECEF2BodyMatrix is computed as described in section [5.6.10.1.3.12.10](#_bookmark31). Spherical earth is used for this transformation since the ECEF coordinate frame is an intermediate step in the transformation.

WGS84 Earth Centered Earth Fixed to Body Frame

If the WGS 84 Earth Centered Earth Fixed (ECEF) position format is selected then the raw TSPI position data is translated from ECEF to the local body frame coordinates defined in section [5.6.10.1.3.12.2](#_bookmark28) upon import. The location of the first point in body frame coordinates is set to (0, 0, 0). Each subsequent point is transformed from ECEF to body frame coordinates using the DblECEF2BodyMatrix and Rotate1 routines described in sections B10.2.7 and B10.3.10 respectively. The ECEF position of the first point is used as the origin of the body frame coordinate frame and is sent into DblECEF2BodyMatrix as Position. The velocity sent into DblECEF2BodyMatrix is computed as described in section [5.6.10.1.3.12.10](#_bookmark31). Oblate earth is used for this transformation since the data being imported is assumed to be relative to WGS84 spheroid.

North-East-Down to Body Frame

If the North-East-Down (NED) position format is selected then the raw TSPI position data is translated from NED to the local body frame coordinates defined in secti[on 5.6.10.1.3.12.2](#_bookmark28) upon import. NED is an Earth-fixed system with the x-axis aligned with north, the y-axis aligned with east, and the z-axis opposing the local vertical as described in section 5.7.2.2. NED coordinates are first translated directly to ENU coordinates by swapping axes.

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The resulting ENU coordinate positions are transformed to body frame as described in secti[on 5.6.10.1.3.12.8](#_bookmark29).

East North Up to Body Frame

If the East North Up (ENU) position format is selected then the raw TSPI position data is translated from ENU to the local body frame coordinates defined in section [5.6.10.1.3.12.2](#_bookmark28) upon import. If the first ENU raw data position values are non-zero then the raw TSPI data is relative to a point other than the platform performing the maneuver, such as the location of the TSPI data collection sensor. The position points are translated so that they are relative to the aircraft location at the start of the maneuver with (0, 0, 0) as the position of the first ENU data point.

The location of the first point in body frame coordinates is set to (0, 0, 0). Each subsequent point is first transformed from ENU to BF coordinates using the DblENU2BodyMatrix and Rotate1 routines described in MM sections B10.2.28 and B10.3.10 respectively.

Flight Smoothing

A curve fit to a second order polynomial is used during runtime to determine the position and orientation at each integration interval. The curve fit is performed on each component of the position and orientation using the LeastSquares routine described in Subsection B10.4.22. LeastSquares computes the coefficients of the second order polynomial that most closely fits the data.

The number of points used in the curve fit is defined by the user. The points used

in the curve fit are selected so that the current point is as close to the middle of the curve as possible. No smoothing is performed for the first point since the aircraft will snap directly to it. For the first N/2 points in the segment, where N is the user defined number of points to use for smoothing and N/2 is rounded to the nearest integer, the smoothing is applied to the ith point using points zero to 2\*i where i is the point number starting with 1. For the last (N/2 – 1) points in the segment the smoothing is applied to the ith point using points (i - N/2 + 2) to k, where k is the total number of TSPI data points. But the minimum number of points used for smoothing is three, so the last three points are always used to smooth each of the last two points. For example, if the total number of TSPI data points is 50 and the number of points to use for smoothing is 4, then the first point is not smoothed, the second point is smoothed over points one through three, the third point is smoothed over points one through four, the fifth point is smoothed over points two through five, and so on. Points 49 and 50 are smoothed over points 48 through 50. The EvaluateLeastSquares routine described in section B10.4.23 is used to compute each component of the position and orientation from the polynomial coefficients at each integration time step.

Three or more points are necessary to fit to a second order polynomial. If the user defined number of points is two, then a linear interpolation between the two closest points is used to determine the position and orientation at each integration interval. If the user defined number of points is one, then the closest point is used for the position and orientation at each integration interval.

Flight smoothing is applied in body frame coordinates. The smoothed data point is then converted to ECEF coordinates using the DblECEF2BodyMatrix and Rotate2 routines described in Subsections B10.2.7 and B10.3.14 respectively.

Velocity Calculation

The TSPI data may not include the velocity of the aircraft. Velocity is necessary for all platforms in EADSIM. Therefore, the velocity is computed from the smoothed TSPI position. First, the position polynomial coefficients are computed for each component of the position as described in section [5.6.10.1.3.12.9](#_bookmark30). Then the derivatives of each component of the position polynomials are computed to get the velocity.

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The current time is then used to compute each component of the velocity. The velocity is converted from body frame to ECEF coordinates using the ECEF2BodyMatrix and Rotate2 routines described in Appendix sections B10.2.6 and B10.3.14 respectively. Coordinated flight causes the aircraft’s orientation vector to always be aligned with its velocity vector. When an aircraft is in the TSPI maneuver segment flight mode it is allowed to fly using uncoordinated flight if the defined orientation does not align with the computed velocity.

Fuel Consumption

There are two options available for calculation of fuel flow throughout the TSPI maneuver segment. The first option allows the fuel flow to be calculated from the TSPI position data. The second option allows an average fuel flow rate throughout the segment to be defined. In a tactical system, the ability to perform a maneuver segment and the fuel flow during the segment are both influenced by instantaneous weight throughout the segment. While performing a TSPI maneuver segment in EADSIM, the ability to perform a maneuver is only degraded if the aircraft runs out of fuel. The variable fuel flow throughout the segment can be captured using the Calculate Fuel Flow option.

If the Calculate option is selected, then the velocity computed as described in secti[on 5.6.10.1.3.12.10](#_bookmark31) from the TSPI position data is used to compute the instantaneous fuel flow throughout the maneuver segment.

First, the required acceleration from the previous to the current integration time step is computed as the derivative of the velocity polynomial.

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The required thrust is then used to compute the throttle setting and the throttle setting is used to compute the fuel consumed as described in Subsection 5.5.2.1. The thrust limits applied do not prevent the aircraft from being able to fly the TSPI data points. So if the thrust required is off the thrust tables or greater than the max thrust, the max fuel flow will be used but in reality the aircraft would consume more than this amount of fuel because it would be exceeding the max available thrust. To prevent this from happening, be sure the airframe is capable of producing the thrust and fuel flow required to fly the TSPI maneuver segment. Note that this is an approximate fuel consumption algorithm.

If fuel flow has been defined as an Average Fuel flow rate, then the specified value will be used to determine the fuel expended throughout the TSPI maneuver segment. If, at any time during the maneuver segment, the aircraft runs out of fuel, then the thrust is set to zero causing the aircraft to accelerate towards the center of the earth.

TSPI Report

The TSPI report within the Maneuver Definition can be used to view the smoothed position, velocity, average acceleration, orientation, and average orientation rates at a user specified time interval. The data will be smoothed using a curve fit to a second order polynomial over the user specified number of curve fit points as described in section [5.6.10.1.3.12.9](#_bookmark30). The segment data points can be generated relative to a starting location and heading of a platform. Selecting the LLA/ECEF Report option causes the report to be generated in absolute coordinates. The position will be generated in both LLA and ECEF (x, y, z) coordinates. The velocity will be generated in ECEF (x, y, z) coordinates. The orientation and orientation rates will be generated in absolute Yaw, Pitch, and Roll relative to the ENU coordinate axis. If the Body Frame Report option is selected, then the data will be generated in the relative body frame coordinate system defined in section B10.2.6.

Specify the same time interval that is used in runtime in order to generate data points that represent the smoothed data points that will be used in runtime. During runtime, if the scenario is running in an HLA federation and the ABT update rate is less than 1.0 second, the aircraft will be flown using the specified update time. Otherwise, a

0.5 second update time is used.

The velocity contained in the report is computed from the TSPI position data as described in section [5.6.10.1.3.12.10](#_bookmark31). The average acceleration is computed as described in section [0](#_bookmark32).

The average orientation rate is computed as the rate of change of orientation over the data time step.

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* + 1. **Processing of Captive Platforms**

Captive platforms are created by placing a specific platform on the target list of a ground-capable Fighter, Bomber, AGAttacker, Fighter-Bomber, Red TEL, or SSFU host platform and specifying a waypoint at which the captive platform will be launched from the host platform. This state of being a captive is not treated as a true flight mode; instead, it causes the platform to be inactive in the scenario, while potentially contributing to the RCS of an airborne host platform.

The ruleset of the host platform makes the decision to transition a captive platform to a fully operational platform, i.e., to launch the platform. The ruleset sends the engagement commands to launch the weapon system and to activate the captive platform. These commands require the initialization of the captive platform’s state. The initial state in terms of position and velocity of the captive platform is set to the state of the host platform at the time of launch. A captive launched by a stationary ground platform has its initial position set to that of the host platform at the time of launch, with its speed initialized to the airframe’s minimum speed and its orientation set in the direction of its first waypoint. The captive platform will then proceed to fly in the user-selected Waypoint flight mode. Unlike other platforms, the captive platform will fly to its first waypoint rather than use it only to set the initial state of the platform.

* + 1. **Low-Level Transit Routes (LLTRs)**

EADSIM models LLTRs across an MEZ. These routes allow for the safe passage of aircraft within an MEZ.

Aircraft will examine their flight routes at transitional times to see if the planned flight route will carry the aircraft within an MEZ that the aircraft knows about. Aircraft which determine that their planned flight route will carry them within an MEZ will search for and adopt an LLTR that allows them safe passage. If no LLTR is found which is suitable, the aircraft will proceed through the MEZ.

Once an LLTR has been adopted, it is simply followed as a set of waypoints. Normally, an aircraft will not depart the transit route once it is on the route. There are exception conditions which are described below. Aircraft may also adopt an LLTR and then abandon it prior to reaching the LLTR.

* + - 1. **Aircraft Determination of MEZ Crossings**

Aircraft will examine their flight routes at transitional times to see if the planned flight route will carry the aircraft within an MEZ of which the aircraft is aware.

The aircraft knowledge of the MEZ is based on the aircraft being explicitly associated with the MEZ during the setup of the scenario. This association is accomplished in Scenario Generation.

The transitional flight situations at which the aircraft examines the route

are:

* when it is activated, either at the beginning of the scenario or later
* when it reaches one of its waypoints
* when it vectors toward a target in the early stages of an engagement, unless that target is in an MEZ
* when it executes either a scripted or dynamically determined takeoff
* when it enters the RTB flight mode
* when it has reached the end of an LLTR
* when it skips a waypoint (platforms with Bomber or Fighter-Bomber ruleset types only)
* when it returns to normal flight mode.

The planned aircraft route is not examined when the aircraft enters the latter stages of an engagement or when it is reacting to an attack.

In all cases, the aircraft will examine its flight route from its current position to its intended destination. When an aircraft is vectored to a target, it uses the current target position as the intended destination.

The aircraft will determine the distance from its current position to the point at which it would cross the boundary of the MEZ. In the case where the planned flight path will carry it within multiple MEZs, the closest MEZ (as determined by the distance to the boundary crossing) will be considered for selection of an LLTR.

* + - 1. **Rules for Adoption of LLTRs**

Aircraft which determine that their planned flight route will carry them within an MEZ will search for an LLTR associated with that MEZ which allows them safe passage. An LLTR may be used to cross an MEZ only if all of the following conditions are true:

* It is a two-way LLTR or a one-way LLTR running in the direction the aircraft wishes to cross.
* The aircraft does not need to cross the MEZ to reach the starting point of the LLTR.
* The aircraft does not need to cross the MEZ to fly from the end of the LLTR to its destination.

If several LLTRs are found to be valid routes across an MEZ, the one which gives the shortest flight path to the aircraft’s objective will be used. If no valid LLTRs are found, the aircraft will fly across the MEZ.

* + - 1. **Aircraft Flight on an LLTR**

Once an LLTR has been adopted, it is simply followed as a set of waypoints. The aircraft will proceed from its current position to the entry point of the LLTR. During this time, it will be considered to be approaching the LLTR but not yet on it. It will then proceed from waypoint to waypoint along the LLTR.

A decision to stop or abort an engagement will interrupt the approach to the LLTR. The aircraft will drop the LLTR. A decision to stop or abort an engagement will not interrupt the transiting of the LLTR. The aircraft will proceed to the end of the LLTR. A decision to react to attack will cause the aircraft to be drawn off the LLTR. The aircraft will return to the LLTR later when the aircraft resumes normal flight.

A decision to return to base will cause the aircraft to drop the LLTR.

* + - 1. **Effects of LLTR Adoption**

The adoption of an LLTR has several impacts in the C3I model. These are briefly described here for clarity. A more in-depth description is contained in Section 4 of this document.

Aircraft on an LLTR are not considered for engagement by friendly SAMs operating in Truth mode. In this case, Friendly SAMs are those defined as being of the same alliance as the aircraft. If the aircraft is drawn off the LLTR by an enemy attack, it may be engaged by friendly SAMs until it returns to the LLTR. In perception mode, operating on an LLTR can feed point to the identification of the target through Procedural Identification.

Bombers and fighter-bombers will not select a target while on an LLTR. Fighters will select a target while on an LLTR but will not break off the LLTR to vector to the target.

* + 1. **Profile Deployment**

Deployment of profile waypoint sets provides a dynamic capability for adopting a certain flight profile when a platform engages against a ground target. It allows the platform to leave its original waypoint set and follow the profile waypoints until within range of the target to engage. Once the engagement has been completed, the platform can then return to its original set of waypoints. Since the profile waypoints are set up at the ruleset level, the same flight profile can be used by multiple aircraft within the scenario, regardless of which target is being engaged and where that target is located within the scenario.

* + - 1. **Profile Definition and Set-Up**

Profiles are set up in the Target Select Phase of the Bomber, Fighter-Bomber, and AGAttacker rulesets. A profile is a series of waypoints that defines the path the platform will follow when reaching the target area. The path will be followed until the platform is within weapon’s range of the target and the actual engagement can begin. The profile will be initiated once the flight leader flies to within a ruleset-defined initiation range of a target location. When this initiation range has been reached by the flight leader, each aircraft in the flight will adopt its individual profile and attempt to engage its target. Once the profiles have been initiated, the profile waypoints will be followed by each aircraft until it has found and engaged its targets or until the flight leader has orbited in its profile the number of orbits defined by the ruleset.

Each waypoint in the profile is defined relative to a generic target location. The waypoints are set by downrange and crossrange distances from the generic target location, speed at which to approach each waypoint, altitude of the waypoint in either MSL, AGL, or TGT units, and whether the platform should fly terrain following to the waypoint. TGT units are relative to the target. Terrain following is automatically set to ‘No’ when you select TGT or MSL altitude mode. Setting these waypoints using relative distances from a generic target rather than using absolute waypoint locations allows for the use of this ruleset and its defined profiles by multiple aircraft in the scenario engaging against a variety of ground targets located throughout the scenario.

Waypoint profiles can be set for each platform in a flight. The flight leader has its own unique profile. Each wingman can have the same default profile or a profile specific to the wingman position in the flight. For example, if a ruleset is set up with different profiles for the first two wingmen in the flight, the remainder of the wingmen will adopt the default wingman profile once the flight leader penetrates the initiation range to its target.

When defining the profiles for each aircraft in a flight, the user has the option to scale the profile for all platforms that use the ruleset, scale the profile for complex weapons only, or to not scale the profile. If profile scaling is enabled the profile will be scaled when the weapon is launched within the maximum profile waypoint downrange. Each waypoint is adjusted based on the horizontal and vertical scale factors.

The horizontal scale factor is computed by dividing the launch range from the target by the greatest downrange of the profile waypoints. The vertical scale factor is computed by dividing the launch altitude by the first profile waypoint altitude. The horizontal scale factor is then multiplied by the downrange and the vertical scale factor is multiplied by the altitude of each profile waypoint to scale the profile. If profile scaling is not enabled the user has the option to designate which waypoint leg can be adjusted for range and altitude. This capability has been provided to allow for profile adjustments should initiation of the profile be at a range or altitude relative to the target that is insufficient to allow the profile to be flown exactly as specified. Only one leg can be adjusted for range and only one for altitude. The same leg may be selected for both. Only legs where altitude changes occur may be selected for altitude adjustment. The minimum altitude for all waypoints can be designated using floor altitude. The default floor altitude is 200m.

When adoption of a profile occurs, absolute positions are computed for each profile waypoint. For flight leaders, the profile is simply inserted into its waypoint list prior to its next waypoint. The flight leader continues to fly in waypoint mode and flies these profile waypoints. For a wingman, the profile becomes its waypoint set since wingmen normally do not have waypoints. The wingman changes from Wingman flight mode to Waypoint flight mode and flies the waypoints. Once each aircraft is within weapon’s range to its respective target, the aircraft engages the target using the Bomber flight mode and then drops the profile once the engagement is complete. If the flight leader never engages its target, it will orbit the specified number of times and then drop its profile and return to its original waypoint set. If a wingman never engages, it will orbit until the flight leader drops its profile and then it, too, will drop its profile. When the flight leader drops its profile, all the profile waypoints are simply removed from the waypoint list and it flies to the next remaining waypoint in the list. When the wingman drops its profile, it switches back to Wingman flight mode and vectors to its formation location relative to the flight leader’s position.

To provide for a cruise missile capability, a profile option exists that allows the platform to drop all remaining original waypoints from its waypoint list when it adopts the profile. This allows for a one-way flight into the target. Once the last profile waypoint is reached, the platform will engage the target if it is within weapon’s range. If not, the platform will simply disappear, since no more waypoints exist. This option allows a very specific maneuver to be performed by a cruise missile-like platform when it flies into its target.

* + - 1. **Profile Waypoint Absolute Location Calculation**

When computing the profile waypoint absolute locations, the local reference frame must be computed. The up directions at the target and platform are obtained using ECEFtoUp with the target and platform locations respectively. Then, the cross product of the up directions at the target and platform is computed:

Yyyyyyyyyyyyyyyyyyyyyyyyy

Once the local reference frame has been computed, the profile for the platform must be found. If the platform is the flight leader, the first profile in the profile list off the ruleset structure is used. If the platform is a wingman and no specific profile was set up for it, the profile used is the default wingman profile which is the second profile in the list. If the platform is a wingman and a specific profile is set up for it, the profile list is looped over, starting from the third profile in the list until the correct profile is found.

After initializing the range and altitude adjustment variables to 0.0, the profile waypoints are looped over from the last waypoint to the first and each waypoint absolute position is computed in ECEF coordinates. Adjustments, if necessary, are dependent upon where in the profile waypoint list the adjustment legs are located. If the current profile waypoint is used to adjust both range and altitude, the range and altitude differences are stored in the adjustment variables:

Yyyyyyyyyyyyyyyyyyyyyyyyy

Then the range adjustment value is computed based on certain conditions. If a previous leg represented a waypoint altitude change, if the platform’s altitude above the target is greater than the previous waypoint’s altitude, and if adjusting for range is allowed and a range adjustment has not yet occurred, similar triangles are used to compute the range adjustment value. First, the altitude difference between waypoints is computed:

yyyyyyyyyyyyyyyyyyyyyyyyy

Next, the range difference is computed:

Since the actual altitude difference based on the platforms current position and the previous waypoints altitude can be computed by

the actual downrange difference can be computed according to:

The range adjustment is then computed as:

If a range adjustment has not yet occurred but is allowed, the altitude adjustment is left unchanged and the range adjustment is computed by:

yyyyyyyyyyyyyyyyyyyyyyyyy

If no leg adjustment for range is necessary or if the range adjustment leg has already been passed, the altitude adjustment is left unchanged and the range adjustment is set to the actual downrange difference:

If any adjustments were made in either altitude or downrange or both, the waypoint distances relative to the target location are computed as:

If no adjustments were allowed or necessary, the waypoint distances relative to the target location are set by:

Once the waypoint distances of downrange and altitude are set, the waypoint relative position direction vectors are computed relative to the target location in ECEF coordinates as:

The ECEF relative position vector of the waypoint is then computed as the vector sum of the components of the direction vectors X, Y, and Z:

The actual waypoint ECEF vector is then computed as the sum of the ECEF relative position vector of the waypoint and the target position:

The latitude and longitude corresponding to this location are then computed. The position of this waypoint is then recomputed to account for the altitude of the waypoint in the user-desired AGL, TGT, or MSL units. If AGL, the waypoint altitude used is the value of WH added to the terrain elevation at the waypoints’ latitude and longitude. If MSL, the waypoint altitude used is the value of WH. If TGT, the waypoint altitude used is the value of WH added to the target elevation at the target’s latitude and longitude. This new position, the latitude, longitude, and profile waypoint altitude are all stored in the waypoint structure. The bit designating this waypoint as a profile point is then set. If the profile point is a hover waypoint, the waypoint on time is set to 0.0 and the off time is set to the profile hover point duration. If the profile point is not a hover waypoint, the waypoint on and off times are set to the default values of 0.0 and 99,999.0, respectively. Once all of this has been completed, this waypoint is added to the platform’s waypoint list, and the loop continues to the next profile waypoint, repeating the procedure until all profile waypoints have been inserted into the waypoint list.

* + 1. **State Vector Mode**

State Vectors provide the precise position, velocity, and orientation of an aircraft platform at a specific time. A State Vector consists of waypoint number, time, latitude, longitude, altitude, speed, heading, pitch, bank, and yaw. In addition to state vectors, waypoints are specified in the state vector mode of operation for weapon delivery.

The State Vector mode is defined by the user through Scenario Generation for airborne platforms. Inputs controlling platform movement in this mode are read from a file, which contains both waypoints and state vectors.

In the state vector mode, the first state vector defines the platform OnTime. Platforms move from one user-defined state to another in the order defined by the user. For platform movement between time steps input by the user, all state vector parameters are adjusted by means of a linear interpolation. When the last state is reached, the platform is deactivated and removed from the scenario.

In state vector mode, the waypoints and state vectors specified in the input file maintain complete control over the platform position, velocity, orientation, weapon delivery, etc. throughout the simulation. Any commands from the C3I model to vector to a new heading, begin drag maneuver, return to base, etc. for these platforms will be ignored in flight processing.

5.10 INTERCEPTOR MISSILE FLIGHT

The Interceptor Flight Model uses common algorithms with the general missile flight modeling described in Section 5.6.