Instructions and Formulae for ATC-lab^{Advanced} Mathematical Spreadsheets

The University of Queensland
Selina Fothergill, Shayne Loft and Andrew Neal
July 2008

This document outlines how to use the mathematical spreadsheets to create aircraft events. There are two types of spreadsheets provided.

The first spreadsheet is called ***Cruising*** and is used for aircraft that are cruising (not changing flight level). Users can enter their required spatial and temporal characteristics of aircraft events and the hard-coded formulae contained in these spreadsheets will provide the starting *x* and *y* coordinates for the aircraft in the lateral plane.

The second spreadsheet is called ***Changing Level***. This is very similar to the Cruising spreadsheet. However, it also can also be used to determine the required starting flight level (altitude) of aircraft that are changing level. It also gives the user starting *x* and *y* coordinates for aircraft in the lateral plane.

Users enter values for the following fields depending on the required aircraft characteristics (e.g., flight levels, speeds, climb rates), the required spatial (angle, minimum separation, order) and temporal (time to minimum separation) characteristics of the aircraft event(s). Definitions for these fields are provided below.

An "*" means that values for these fields are only used for calculating the starting positions of aircraft that are changing level (the Changing Level spreadsheet).

- **FL1 and FL2:** The flight level (altitude in feet) of Aircraft 1 and Aircraft 2.
- **V1 and V2:** The speed (in nautical miles) of Aircraft 1 and Aircraft 2.
- **Climb rate*:** The rate that Aircraft 2 will climb in feet per minute.
- **Angle:** The angle of intersection.
- **Distance of Minimum Separation (Ldoms):** The distance between the aircraft when they are closest together laterally (the point at which they stop converging and begin diverging laterally). This determines whether the aircraft reach lateral conflict or not, depending on the minimum lateral separation employed (e.g., 5nm).
- **Distance of Minimum Vertical Separation (Vdoms).** The vertical distance between the aircraft when they are closest together laterally. This determines whether the aircraft reach vertical conflict or not when lateral minimum separation (Ldoms) is reached, depending on the minimum vertical separation employed (e.g., 1000ft).
- **Time to Minimum Separation (TTMS):** The time it takes from the beginning of the scripted scenario for the aircraft pair to reach the Ldoms and begin diverging (i.e., the aircraft have passed each other).
- **Order:** The order in which the two aircraft pass the intersection. A value of 1 denotes Aircraft 1 reaches the waypoint after Aircraft 2, and a value of 2 denotes vice versa.

So now the user has entered the values for the aforementioned fields into the spreadsheet. The spreadsheets contain a series of formulae that determine values in the remaining fields.
The fields generated (and the underlying excel formulae) are listed below.

- **v1m/sec and v2m/sec:** The distance in nautical miles that each aircraft will travel per second.
    - Formulae; V1/ 60/ 60 (same for aircraft 2 using V2)
- **Absolute Separation time (abs M) for a pair:** The absolute difference in time that aircraft reach the intersection point.
    - Formulae; DOMS*SQRT(A)/Y
        - Where $A = v_1^{\ 2} + v_2^{\ 2} - 2v_1v_2Cos\theta$ and $Y = v_1v_2Sin\theta$

- **Separation time (M) for a pair:** The time that Aircraft 2 reaches the waypoint relative to the time that Aircraft 1 reaches the waypoint. If the 'Order' is 1 this will be a negative number (i.e., Aircraft 2 reaches waypoint first). If the 'Order' is 2 this will be a positive number (this value is same as TCOP2 - TCOP1).
    - Formulae; IF(Order =1, -Abs M, Abs M)

- **TCOP1 and TCOP2:** How long from the present time each aircraft will take to reach the intersection point.
    - Formulae; TTMS – (v1m/sec*M*W)/A (then same for Aircraft 2 using v2m/sec)
        - Where $W = v_2 - v_1Cos\theta$

- **Dist1 and Dist2:** The required relative distance of each aircraft from the intersection point that will produce the specified spatial and temporal properties of the event.
    - Formulae; TCOP1* v1m/sec (then same for aircraft 2 using TCOP2 and v2m/sec)

- **Start FL*:** The flight level (altitude) that Aircraft 2 needs to start from (at Time = 0) in order to reach Vdoms at the time that Ldoms is reached.
    - Formulae; ((FL1 + (VDOMS/100))*100 – ((Climb rate/60)*TCOP2)

For the Cruising spreadsheet, the field that will be of most use is the distance (in nm) that the two aircraft need to start relative to each other from the intersection point (Dist 1 and Dist 2). You can then use these values to determine the starting *x* and *y* coordinates for aircraft in the lateral plane (depending on the specific flight paths in the sector you are using).

For the Changing Level spreadsheet, the Dist 1 and Dist 2 fields are also required to produce the specified properties of the event in the lateral plane. The spreadsheet will also produce the required starting flight level (altitude) of aircraft (Start FL) in order to allow the aircraft to reach Vdoms at the time that Ldoms is reached.