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EUROCONTROL Guidance Material for Short Term Conflict Alert
Appendix D-1: Optimisation of STCA for ATCC Semmerzake

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Appendix D-1: Optimisation of STCA for ATCC Semmerzake

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Abstract

This document describes the analysis of STCA for ATCC Semmerzake. The specific military environment (military formation flights and a large number of primary tracks) creates a large number of nuisance alerts. This document describes the analysis of alerts, the tuning of parameters to the environment, and the modelling of a number of specific solutions to try to reduce the nuisance alert rate.

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Safety Nets
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CONTENTS

FOREWORD

ATCC Semmerzake is the Belgian Military ATC Unit. It is equipped with a modern ATC system that contains amongst others an STCA application. However, the specific military environment (military formation flights and a large number of primary tracks) creates a large number of nuisance alerts, rendering STCA ineffective.

In the period May 2006 to September 2006, ATCC Semmerzake and EUROCONTROL, supported by QinetiQ and Deep Blue, collaborated to develop specific solutions to reduce the nuisance alert rate.

This document is one of a set of two documents that describe the actions undertaken and the results achieved. The document set includes:

- Optimisation of STCA for ATCC Semmerzake [This document]
- Functional Hazard Assessment of STCA for ATCC Semmerzake

The document set forms a Case Study in applying the optimisation and safety assurance guidance material that supports the EUROCONTROL Specification for STCA, and as such is guidance material in its own right.

Note however that the developed specific solutions should not be adopted without performing similar analyses to determine the applicability in the target environment.

1. INTRODUCTION

1.1 Overview of the Study

The STCA system installed at ATCC Semmerzake (where Belgian military ATC is in operation) suffers from a number of known problems that severely restricts its usability, and frequently results in the controller switching the STCA function off at his working position. These problems are described in detail in chapter 2.

The purpose of this study was to find technical solutions that would overcome the identified problems and make the STCA system usable in Belgian military airspace.

The study was undertaken by taking system track recordings. These tracks were input into a fast-time STCA model that simulated the operational STCA system. In general terms, the approach to treating the problems was threefold:

1. Identification of the nature of the problems.

2. The introduction of novel algorithms in the model.

3. The introduction of reduced parameter values.

The analysis method is described in chapter 3, and the results of the various runs of the model are shown in chapter 4.

The results are summarised in the conclusions, in chapter 5, and a number of recommendations are made in chapter 6.

A list of abbreviations is included in chapter 7.

A selection of pertinent situations is shown in pictures in annex 1. Maps showing the TRA North and South aerobatic areas are shown in Annex 2. Example parameter and results files are shown in annex 3. Information related to an exercise performed by two F16s is in annex 4. Finally, new STCA algorithms for split track detection and military formation detection are described in annex 5.

2. STCA AT ATCC SEMMERZAKE

ATCC Semmerzake has participated in Eurocontrol's SPIN task force since its conception in 2005 and it has been keen to share its experience of safety nets, and in particular the difficulties it has found operating STCA in the military environment.

Picture 1 in annex 1 shows an outline map of Belgium and surrounding countries, with the large STCA playing area enclosing the aerobatic areas. More detailed pictures showing the aerobatic areas for TRA North and TRA South are shown in annex 2.

In the STCA system at ATCC Semmerzake all pairs of aircraft tracks qualify for STCA processing, providing that:

1. The aircraft are in the STCA playing area
2. At least one of the aircraft in the pair is assumed by the controller

The military operational environment is somewhat different to the civil environment in which STCA and other safety nets are more often deployed.

For example, military aircraft perform manoeuvres that civil aircraft do not, such as flying in formation, flying in radar trail, dog-fighting and executing very fast turns; this style of flying results in a large number of unwanted STCA alerts. Examples of the types of manoeuvres that routinely take place under ATCC Semmerzake control are shown in pictures 2 to 6 in annex 1.

It is usual practice for military aircraft to fly in formation across civil airspace, to enter one of the aerobatic areas in order to perform manoeuvres, then to rejoin formation again before re-entering civil airspace for the return home.

As examples of typical aircraft behaviour, picture 2 shows a pair of military aircraft flying in formation and picture 3 shows a pair of military aircraft performing the sort of tight turns that are normal in the aerobatic areas.

In addition, many split tracks are caused when aircraft are flying in formation, and the tracker is unable to correctly associate all the radar plots to existing system tracks. STCA alerts generated from split tracks are clearly false alerts, and can cause a severe nuisance to the controller. Picture 4 shows an example of a split track.

Furthermore, it was found in this study that pairs of split tracks and genuine military formations looked very similar and were sometimes difficult to tell apart, even when analysed in detail using display tools.

The aerobatic areas, where military aircraft perform manoeuvres are located close to civil airspace, resulting in a large number of nuisance alerts between manoeuvring military aircraft and normal civil traffic. Picture 5 shows one such situation.

There are also a significant number of primary (non-co-operative) tracks that are in the controlled airspace, for which STCA is expected to provide at least some level of protection. At ATCC Semmerzake, the STCA system provides alerts between aircraft if one or both of the aircraft in a pair has mode C. In the case that both aircraft have mode C, the STCA performs a vertical prediction to determine if the aircraft will violate the vertical threshold. On the other hand, if one of the aircraft does not have mode C then the aircraft is assumed to have any height, and a permanent vertical violation is assumed – this means that the calculation of a conflict is dependent entirely on the lateral characteristics.

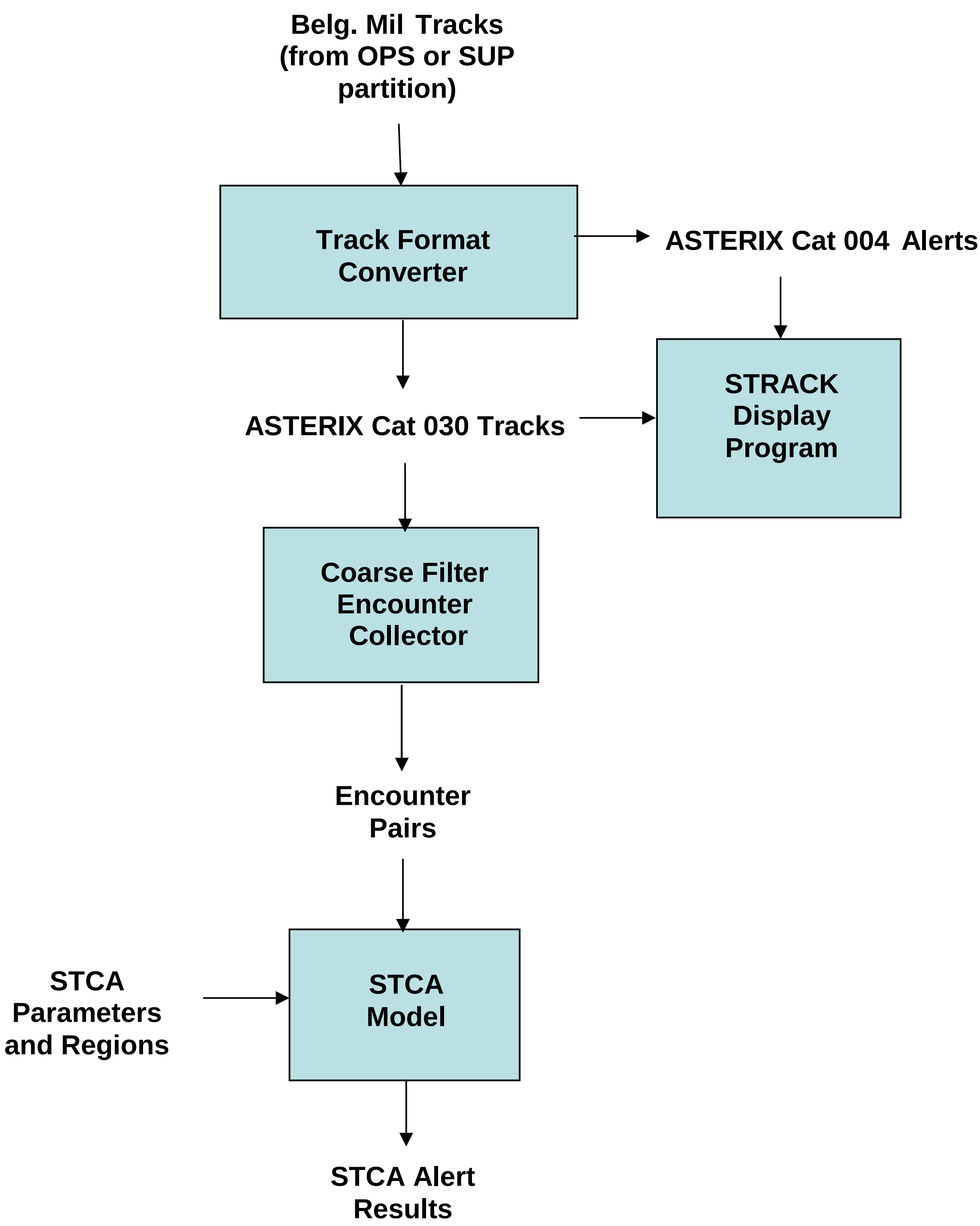
Picture 6 shows an example of STCA alerts between a military aircraft and two aircraft without mode C.

At ATCC Semmerzake, the problem of a high nuisance alert rate is exacerbated by a long prediction time used by the operational STCA system. In the operational system, the prediction time parameter is set to five minutes. Two minutes is generally considered the longest prediction that can be reliably made using surveillance data alone. In the military environment, considering the large amount of manoeuvring that is evident in the pictures, even a two-minute prediction could be considered over ambitious.

3. ANALYSIS METHOD

3.1 Description of the Analysis Process

The Analysis Process is summarised in the diagram below:



3.1.1 Track Format Conversion

The first stage of the analysis process was to take track files recorded at ATCC Semmezake and to convert these into a format that could be used with existing display facilities at QinetiQ in Malvern (i.e. STRACK). Usefully, the recorded tracks also contained a flag that indicated the STCA alert status (*alert*, *warning* or *none*). This data would allow the modelled STCA alerts to be compared to the recorded alerts as a check.

The data samples used for this study are described in section 3.2.

All the tools were written in the C programming language, running on a PC under the Fedora operating system. STRACK uses standard Motif/X-Windows libraries.

The Track Format Converter program converted the supplied track messages into ASTERIX Category 30 format. Each track that was in an STCA alert or warning state also prompted the generation of an ASTERIX Category 4 (Safety Nets) message. The output of the Track Format Converter was two files: one containing tracks in ASTERIX Category 30 format, the other containing STCA alerts in ASTERIX Category 4 format.

3.1.2 STRACK Display Program

The STRACK program is a dynamic display tool for visualising system tracks, radar plots and safety nets alerts on a number of display windows including plan view and vertical view. In the plan view window, useful map features, such as STCA areas can be shown.

In this study, the STRACK display program was used to visualise the tracks and STCA alerts for a number of purposes:

- To verify that the track format conversion was correct.
- To become familiar with the traffic and alerts of concern to ATCC Semmerzake.
- To analyse in detail specific situations, including problematic alerting situations such as split tracks and military formations.

3.1.3 Coarse Filter Encounter Collection

The ASTERIX tracks were input into the Coarse Filter Encounter Collector program. This program collected aircraft pairs that passed a coarse filter and organised these into an encounter-based structure that could be input into the STCA Model. The coarse filter emulated that in the ATCC Semerzake STCA system: when one aircraft in the pair was without mode C, a permanent vertical violation was assumed and only the lateral dimension was tested to pass the coarse filter conditions.

The benefit of the coarse filter process was that the output encounter file was considerably smaller than the original track file (and therefore much faster to process by the STCA Model). Furthermore, each encounter could be identified by a unique pair number for later analysis.

3.1.4 The STCA Model

The STCA model was also built specifically for this study, and was intended to represent the ATCC Semmerzake STCA system. The objective of the study was not to model the operational STCA system precisely (which would have taken considerable time and effort), but to find solutions to the identified problem areas, and help identify parameter settings effective in the specific airspace. In this respect, a limited comparison of modelled and recorded alerts was done and showed that the model was sufficiently close to the operational system to obtain valid results.

The model was based upon a linear prediction filter, which used cleared flight levels or block flight levels whenever these were available in the track data. Like the operational system, the model considered tracks both with and without mode C height for conflict detection. In the cases where mode C was not available for one of the tracks, the model tested only for a conflict in the horizontal dimension.

A flag in the recorded track data identified aircraft that were assumed by an ATCC Semmerzake controller (i.e. under Semmerzake control). To emulate the real system, the STCA model only applied STCA processing if at least one of the aircraft in a pair was assumed.

The STCA model was able to read a file containing STCA region definitions and the parameters to be applied in each region. An example region file is given in annex 3. In this study, the STCA model was run with various region definitions and a wide variety of parameter values, in order to find a good balance between nuisance alert rate and warning time.

3.1.5 STCA Results Files

An example STCA results file is given in annex 3. As can be seen, the file provides the number of STCA alerts, as well as pertinent information relating to the timing of each alert and the aircraft involved in the conflict.

3.2 Data Samples used for the Study

The data samples used for this study comprised periods of track recordings made at ATCC Semmerzake from either the OPS or SUP partition.

3.2.1 Opportunity Traffic Recordings

Opportunity track recordings were extracted around significant events identfied by ATCC Semmerzake, such as military formation flying or specific nuisance alerts. The encounters identified by ATCC Semmerzake are shown and described in pictures 7 to 13 (annex 1).

Generally, many of the nuisance alerts were due to military formations, or as a result of the long (5 minute) prediction time. All of the identified false alerts were due to split tracks, which were produced when aircraft came into close proximity whilst in military formations.

The total duration of opportunity traffic was 36 minutes.

3.2.2 F16 Flights

Further to the opportunity traffic samples, on 18 July, two F16s of the Belgian Air Force underwent an exercise in which they reconstructed a number of the known problem scenarios. The test card for this exercise and a screenshot of the ATC display showing the two F16's are shown in annex 4.

The purpose of this exercise was to obtain track data and STCA alert that contained a number of relevant events, including:

- military manoeuvres close to the edge of an aerobatic area
- the use of block flight levels to suppress nuisance alerts generated by military aircraft in aerobatic areas.

The duration of the traffic samples from this exercise amounted to 35 minutes in total. To give an indication of the types of encounters that occurred, pictures 14 to 25 (in annex 1) show a sample of the situations that were recorded from the exercise.

3.3 Steps in the Study

The analysis was undertaken as described in section 3.1. The coarse filter was run producing encounters for input into the STCA model.

For the next step, the STCA model was run with baseline parameters, and the resulting alerts were classified into various types (see section 3.4). Then, the objective was to try to improve the performance of the model by new parameter settings, new volume definitions, or by the introduction of new algorithms.

Improvements and test parameter values were introduced progressively, as shown in the table below, and the performance of STCA was assessed at each step.

The steps are summarised in the table below:

Step 1	Collection of coarse filter pairs
Step 2	Run of STCA model with baseline parameters
Step 3	Introduction of split track detection and military formation logic to suppress unwanted alerts
Step 4	Evaluation of the new logic
Step 5	Evaluation of various parameter values (applied to all aircraft tracks)
Step 6	Testing of various mode C / No mode C dependent parameter values
Step 7	Testing of various region dependent parameter values

3.4 Classification of Alerts

In order to classify the various alerting situations, tracks and STCA alerts were played back in STRACK. It was immediately noticeable that many unwanted alerts occurred between aircraft flying in formation.

Closer examination revealed that there were not only alerts between genuine aircraft tracks, but also alerts generated by split tracks for aircraft in close formation. Furthermore, there were many instances of one system track terminating, and a new track initiating immediately for the same aircraft.

Given that the aircraft were so close, this type of tracking behaviour was unavoidable. In categorising each encounter, the situation had to be checked very carefully in STRACK, and it became increasingly clear that it would be difficult for any new algorithm to differentiate between genuine military formations and split tracks. In other words, it would be likely that split track detection logic would suppress some military formations, and military formation detection logic would suppress some split tracks. This was not a problem, however, since both military formations and split tracks generated undesirable alerts, which needed to be suppressed.

A baseline run of the STCA model was made, with parameters set for a 300 second prediction time and a 5NM separation threshold. Following this run, each alerting situation was classified into one of six types, as described below:

- **Both Mode C** is all alerting track pairs, not in formation and not split, where both aircraft have mode C height.

- **One Mode C** is all alerting track pairs, not in formation and not split, where only one aircraft has mode C height.

- **Split Tracks** is all alerting track pairs that have been generated due to a split track. In this study, all the split tracks resulted when aircraft were in close formation.

- **Mil Formation** is all alerting track pairs that represent two real aircraft (not split tracks) flying in formation.

- **Joining Formation** is the alerting track pairs for aircraft joining a formation.

- **Leaving Formation** is the alerting track pair where the aircraft were just in the process of breaking the formation.

The number of alerts of each category is shown in section 4.1.

3.5 Development of New Algorithms

New algorithms were developed to suppress split tracks and military formations. The algorithms were based on the observed behaviour of the aircraft (in the case of military formations), and the tracker (in the case of split tracks). The algorithms are described in detail in annex 5.

3.5.1 Split Tracks

Split tracks originated when two military aircraft were flying in formation. In each military formation either one or both aircraft were squawking. The split track would have either a mode A code identical to that of one of the aircraft in the formation, or no mode A code (the mode A code field in the track was zero).

Another feature of split tracks is that they are created in immediate proximity to another aircraft. Since, after the coarse filter, STCA (and the STCA model) considers aircraft in pairs, the proximity of the pair of aircraft was considered at the time of track creation.

3.5.2 Military Formations

When in formation, two or more aircraft stay in close lateral and (usually) vertical proximity, matching each other's manoeuvres and maintaining a very similar speed and heading.

When examining military aircraft in STRACK, formations could be quite easily recognised by considering a number of factors, including:

The proximity of the aircraft

The difference in heading of the two aircraft

The difference in speed of the two aircraft

The height difference between the two aircraft

Although Mode A code assignments could not be relied on to identify military formations, there were certain mode A code combinations which were more prevalent in military formations, than in other situations. For example, two successive mode A codes (e.g. 1401 and 1402) often indicated a high likelihood that the pair were military aircraft. These may or may not have been in formation all the time, but a pair of such aircraft with formation-like geometry could be more positively identified as a military formation pair.

Furthermore, when one Mode A code was zero (i.e. the aircraft was not squawking), and the other was non-zero, this immediately identified the leader and wingman in the formation. Although it was seen that in tight turns, the wingman could be momentarily a fraction of a mile in front of the leader, the overwhelming rule was that the wingman followed the leader.

The military formation detection algorithm works in much the same way that a human would. It examines the various characteristics (proximity, headings, speeds) of the pair situation, assigning weighting to each one. The final decision takes all the characteristics into account.

The advantage of this approach (rather than a simpler Boolean logic) is that the final decision takes all characteristics into account. A military formation pair may look like a military formation in all respects but one. For example, on a turn, the difference in the aircraft headings may be slightly larger than is typical. Simple Boolean logic, with maximum thresholds for the various characteristics, could fail to detect a military formation, simply because one characteristic happened to fall just outside a threshold.

The military formation logic introduces a number of new parameters, which allow the user flexibility to give appropriate weightings for each situation, and to vary how cautiously the suppression logic is applied.

3.6 Test Runs of the STCA Model

3.6.1 Evaluation of the Split Track and Military Formation Logic

The first test runs of the STCA model were designed to evaluate the performance of the new logic.

The STCA model was run both with and without the split track logic and with and without the military formation logic. This allowed the effectiveness of each algorithm to be assessed.

The results of these test runs are shown in section 4.2.

3.6.2 Testing of various parameter values (applied to all aircraft tracks)

Having quite successfully treated the split tracks and military formations, the purpose of this stage of the study was to obtain a measurement of the probable alert rate with various parameter values. The intention was to measure the alert rate with the currently available parameters.

The STCA model was run ten times with different parameter values. The precise parameter values and the results of these runs is shown in section 4.3.1.

At the end of these ten test runs, a sample of situations were examined closely in STRACK, in order to try to identify the most suitable parameter set that could be employed immediately in the ATCC Semmerzake STCA system without need for modification for mode C or region dependent parameters.

3.6.3 Testing of various mode C / no mode C dependent parameter values

It was already known that situations where one aircraft was not transponding mode C contributed to a large proportion of the nuisance alerts.

Hence, for this part of the study new parameters were implemented in the STCA model that were applied when one aircraft in the pair had no mode C. (Note that at least one aircraft has to have mode C to generate an alert at ATCC Semmerzake and in the STCA model).

The STCA model was run four times with various narrower parameter values applied to the pairs involving tracks without mode C. The precise parameter values and the results of these four test runs is shown in the results in section 4.3.2.

3.7 Further Analysis of Alerts

At this stage, it was essential to understand which of the alerts were wanted, and which were unwanted. Consequently, further analysis was made of the alerting situations using the STRACK display program. While analysing the alerts, consideration was given as to whether each alert was wanted and if not, how the alert might be suppressed, either by appropriate parameter settings or by the introduction of further new logic.

As a result of this analysis, a number of common types of nuisance alerts were identified along with possible solutions to suppress each one. As a further task in the study, some of the suggested solutions, where practical, were included in the STCA model in order to check whether the solution would be effective in the operational system. Each type of nuisance alert situation is described in the table below, along with the suggested solution:

Type of situation	Suggested Solution	Modelled in STCA?
Nuisance alerts between aircraft in the aerobatic areas and aircraft in civil airways. Furthermore, possible wanted alerts occurred between aircraft in the airway and military aircraft leaving the aerobatic area.	The construction of an inner aerobatic volume, with shorter prediction time to prevent nuisance alerts with civil air traffic. Longer prediction times apply at the edge of the aerobatic areas to anticipate that the military aircraft may be about to enter the airway. See Picture 25.	Yes
Nuisance alerts when one aircraft had no mode C. The controller could immediately identify such aircraft as VFR traffic below (say) 9000ft, on the basis of mode A code (or lack of) and the slow speed of the aircraft. The other aircraft in the pair was invariable considerably higher than 9000ft.	The construction of a Mode A code list, specifying the minimum and maximum assumed flight level of slow moving aircraft, with various VFR mode A codes that have no mode C. The mode A code list is described in annex 3.	Yes
Nuisance alerts between VFR traffic below 4500ft. Aircraft below 4500ft are not under ATCC Semmerzake control.	The construction of a volume from 0 to 4500ft covering the whole area of interest in which much narrower parameters (3NM and 45 seconds) are applied.	Yes
Nuisance alerts between pairs of military aircraft dog-fighting or otherwise intentionally coming into proximity in a training area.	Set up specific military training areas (including aerobatic areas and TRAs) along with a list of “training” mode A codes for use in that area. STCA would not produce alerts between aircraft when both have “training” mode A codes in a specific area. This solution requires a change in the operational procedures at ATCC Semmerzake.	No
Nuisance alerts between	When a military formation is	No

a wingman in a formation (without mode C) and an unrelated nearby aircraft. This is a nuisance because the controller knows that the wingman's height is much the same as the leader, and is not in vertical conflict with the other aircraft.	identified, if the wingman has no mode C, assign the leaders height and vertical rate to the wingman, for use by STCA.	

The final two solutions in the above table were not modelled because they were outside the scope of this study. They would nevertheless be expected to work to effectively suppress a significant number of nuisance alerts.

A number of the typical nuisance alerts between aircraft in the aerobatic areas and those in the airways can be seen in pictures 5, 13, 15, 17, 18 and 21. Many of these are STCA warnings, which would disappear if a prediction time of less than 120 seconds were used.

Pictures 6, 10 and 22 show examples of nuisance alerts where one aircraft is without mode C. In pictures 6 and 22 the aircraft are identifiable as VFR due to their slow speed, and may be safely assumed to be no higher than FL90. In picture 10, the aircraft squawking 4651 is identified by its SSR code (46—block) and speed as a helicopter which may be safely assumed to be no higher than 4500ft. Picture 26 shows nuisance alerts between a pair of military aircraft performing exercises in a training area (in a TRA) just north east of Namur. These alerts could be suppressed by the use of specific “training” SSR codes for use strictly by aircraft undergoing military exercises.

Picture 27 shows an example of an nuisance alert between the wingman in a formation and another nearby aircraft (NAT009). NAT009 is at around FL270 and climbing, whereas the formation is at 2000ft. Assigning the leader's vertical position and rate to the wingman would suppress this alert, since the aircraft would be computed to not be in vertical conflict.

3.8 Further Improvements to the STCA model

Following the analysis of the alerts, the STCA model was modified to be able to apply different parameters depending on the region of airspace as described in section 3.9, and to be able to process the list of VFR mode A codes.

The VFR code list is described in annex 3. The solution in the STCA model was to assume that the aircraft without mode C is within the defined height band, and to compute the future vertical course of the aircraft with mode C (taking CFL or BFL's into account), to see if it will come within the vertical separation parameter of this height band.

3.9 Regions and Parameter Groups

In STCA, when aircraft are in the same region the selection of the correct parameters is usually straight forward. However, when aircraft are in different regions, an appropriate parameter set must be selected, based on the specific traffic environment. For example, if one aircraft is in an airway, and the other in the inner aerobatic area, then it has been identified that a short prediction time short should be applied to prevent nuisance alerts.

In consultation with ATCC Semmerzake, a number of region types were identified, as follows:

Aerobatic Area – Inner (One region as show in picture 25)

Aerobatic Area – Outer (including Balen, edge of Namur etc)

Airways – (all airspace outside the aerobatic areas above 4500ft)

VFR Traffic regions – all airspace below 4500ft.

Ten parameter groups were then set up in the STCA model. The selection of the parameter group in the model was dependent of the type of airspace in which each aircraft was positioned, as indicated in the table below:

Region Type combination	Parameter Group
Aerobatic Area Inner vs Aerobatic Area Inner	1
Aerobatic Area Inner vs Arerobatic Area Outer	2
Aerobatic Area Inner vs Airway	3
Aerobatic Area Inner vs VFR Traffic Region	4
Aerobatic Area Outer vs Aerobatic Area Outer	5
Aerobatic Area Outer vs Airway	6
Aerobatic Area Outer vs VFR	7
Airway vs Airway	8
Airway vs VFR	9
VFR vs VFR	10

This type of parameter group selection provided considerably more flexibility than assigning a group of parameters to specific regions.

3.10 Parameter Settings for each Parameter Group

A parameter file was built defining all the regions of interest, including the aerobatic areas, an inner aerobatic areas for TRA south (see picture 25), VFR airspace (below 4500ft) and the remaining civil airspace (4500ft to UNL).

Each region was assigned a region type:

Aerobatic areas inner : Region type 1

Aerobatic areas outer : Region type 2

Airway : Region type 3

VFR traffic region : Region type 4.

This would give rise to ten parameter groups as described above. A complete set of parameters was then defined for each parameter group. The main parameter settings assigned initially for each parameter group are shown in the table below:

Parameter Group	**Predicted Lateral Separation Threshold (NM) – both mode C**	**Warning Time (seconds) – both mode C**	**Predicted Lateral Separation Threshold (NM) – one mode C**	**Warning Time (seconds) – one mode C**
1	3.0	80	2.4	65
2	3.0	80	2.4	65
3	3.0	65	2.4	65
4	3.0	65	2.4	65
5	3.0	80	2.4	65
6	3.0	85	2.4	65
7	3.0	65	2.4	65
8	4.5	100	3.0	80
9	4.0	90	3.0	75
10	3.0	45	3.0	45

The rationale for choosing these initial parameter values was:

Lateral separation threshold parameters should be kept low for aircraft that were likely to be manoeuvring (i.e. those outside the airways), in order to keep the nuisance alerts to a minimum.

Lateral separation threshold parameters should be even lower when one aircraft has no mode C, in order to reduce nuisance alerts.

When an aircraft in the inner aerobatic area is in potential conflict with an aircraft in the airway or in the VFR traffic region the prediction time should be short: Parameter groups 3 and 4.

The prediction time should be extended slightly for aircraft that may be leaving the aerobatic areas: Parameter group 6.

The prediction time should be short in the VFR traffic region. (45 seconds).

It is important to note that this was just a initial guess at appropriate parameter values. It is strongly recommended that an optimisation process is carried out, in order to establish the most suitable parameters to be used in the operational STCA system.

3.11 Final Run of the STCA Model

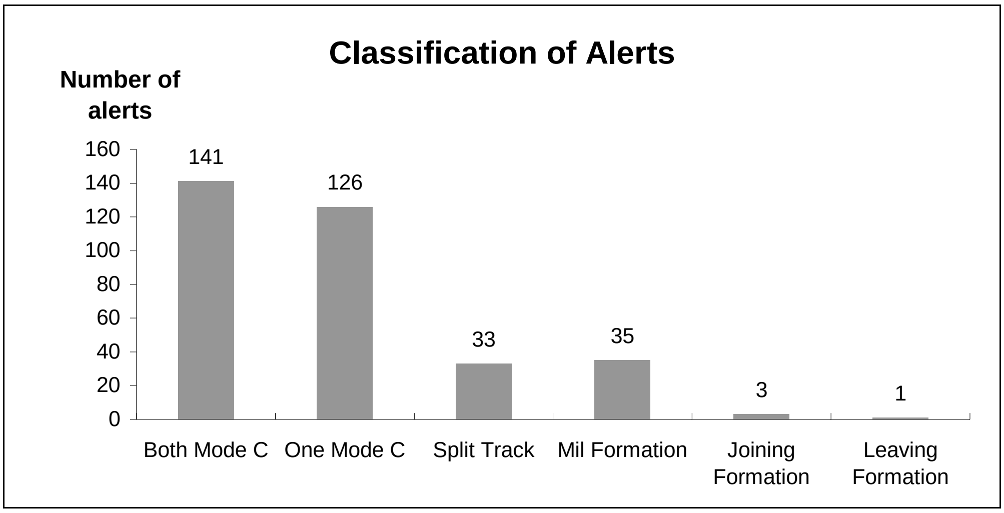
The STCA model was run using the region definitions and parameter groups as described above, along with the VFR mode A code list as described in annex 3.

In order to determine the effect on STCA alerting performance of the regions, the narrower parameters and the new logic, results from this run of the STCA model were compared with the results from run 2c (see section 3.6.3). For each alert from run 2c, it was established whether the situation still alerted in the latest run. If the alert was no longer present, the reason for the suppression was identified. Otherwise, it was determined whether it was desirable to suppress the alert by use of “training” SSR codes , or other wise would be likely to remain as either a wanted or unwanted alert. The results of this analysis are presented in section 4.3.3.

4. ANALYSIS RESULTS

4.1 Initial Classification of Alerts (Baseline Run)

The graph below shows the initial classification of alerts according to one of six categories:



The graph shows that there is a broad mix of different types of alerting situation. There are a significant number of alerts between aircraft where one of them has no mode C. The number of split tracks and military formation alerts is also significant. Both these types of alert would be particularly distracting for a controller, and military formation alerts could last for several minutes.

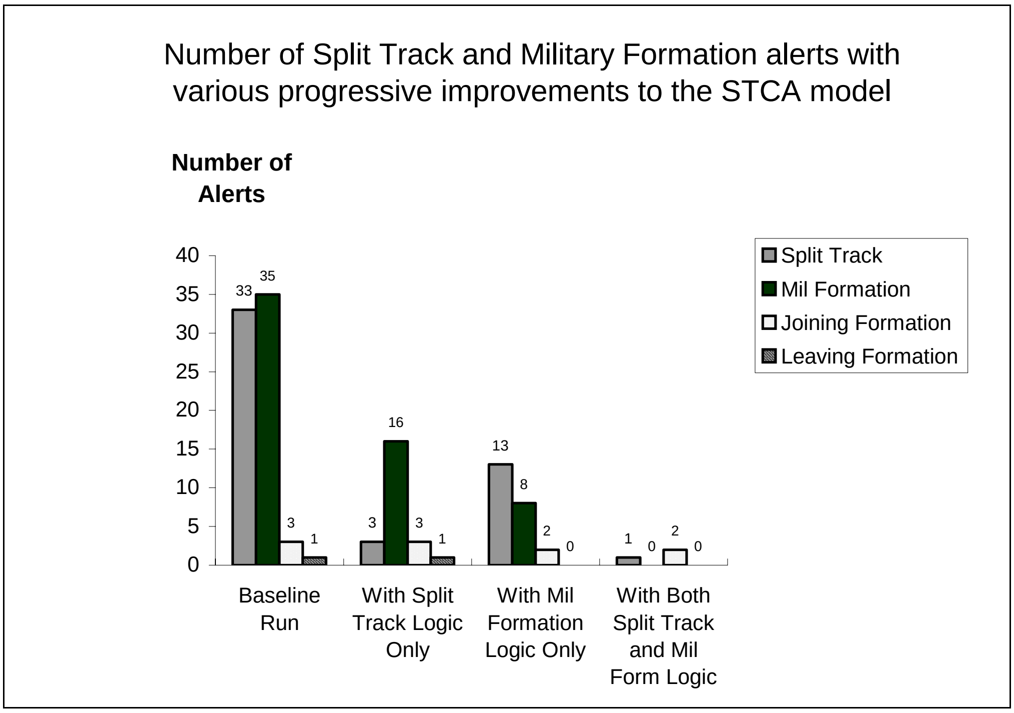
The majority of the alerts were between civil and military aircraft and were due to the long prediction time (5 minutes). The vast majority of these alerts were unwanted.

4.2 Progressive Improvement of the STCA model to treat Split Tracks and Military Formations

The first test runs of the STCA model were designed to evaluate the performance of the new logic. The following runs were made:

Run	Split Track Logic Included	Military Formation Logic Included
Baseline	No	No
A	Yes	No
B	No	Yes
C	Yes	Yes

The results of these runs are shown in the graph below:



The graph shows the number of split track and military formation type alerts for different runs of the STCA model (as described in section 3.6.1). The parameters were set so that alert was suppressed immediately that a split track or military formation was detected.

The graph shows quite clearly that each algorithm is most effective at suppressing the alerts for which it was specifically designed. Nevertheless, there is some overlap in the effect of the two algorithms (e.g. military formation processing manages to suppress 20 split tracks).

With either suppression algorithm applied, it was found that no other alerts were affected. That is, all non-split tracks and all non-military formations (those classified as Both Mode C and One Mode C) were completely unaffected by the suppression algorithms.

To give an indication of the effect of military formation alerts and split track alerts on the controller, the total duration of these alerts was tallied, both before the suppression logic was applied, and after. The table below shows the results:

Classification of alerts	Baseline Run (no suppression logic)	Both Split Track and Mil Formation suppression logic
Split Track	15 minutes, 10 seconds	10 seconds
Mil Formation	48 minutes, 10 seconds	0 seconds
Joining Formation	55 seconds	40 seconds
Leaving Formation	20 seconds	0 seconds

The total duration of the track recordings was 71 minutes. The table indicates clearly that there is currently a high likelihood of seeing a military formation or a split track in STCA alert at any given moment. The likelihood is reduced considerably by the introduction of both suppression algorithms.

4.3 Test Runs with various Parameter Settings

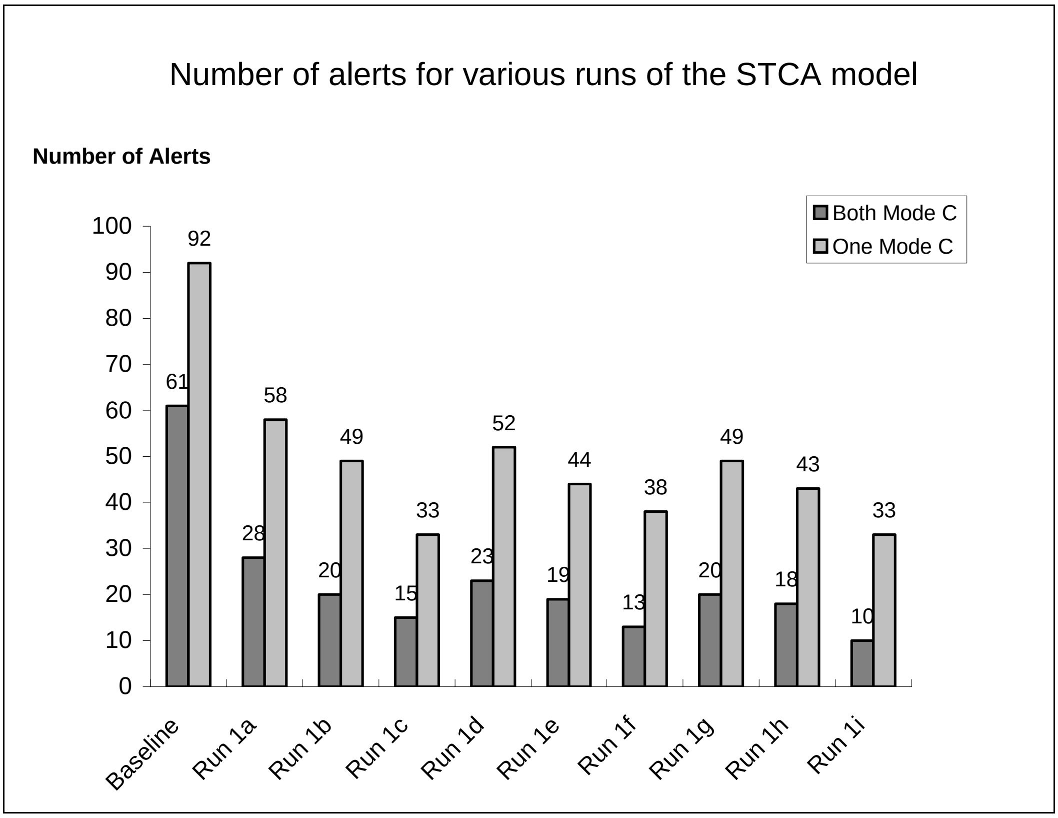
4.3.1 Test runs using various parameter values (applied to all aircraft tracks)

Having addressed the military formation and the split track problems, all subsequent runs of the model were done with the military formation and split track suppression logic applied. The intention was to measure the alert rate with the currently available parameters.

The STCA model was run a number of times with different parameter values as shown in the table below:

Test	Predicted Lateral Separation Threshold (NM)	Predicted Vertical Separation Threshold (feet)	Warning Time (seconds)
Baseline	5	1000	300
1a	5	800	120
1b	5	800	90
1c	5	800	60
1d	4.5	800	120
1e	4.5	800	90
1f	4.5	800	60
1g	4	800	120
1h	4	800	90
1i	4	800	60

The results from these runs are shown in the graph below:



4.3.2 Test runs using Mode C / no Mode C dependent parameter values

It was known that situations where one aircraft was not transponding mode C contributed to a large proportion of the nuisance alerts.

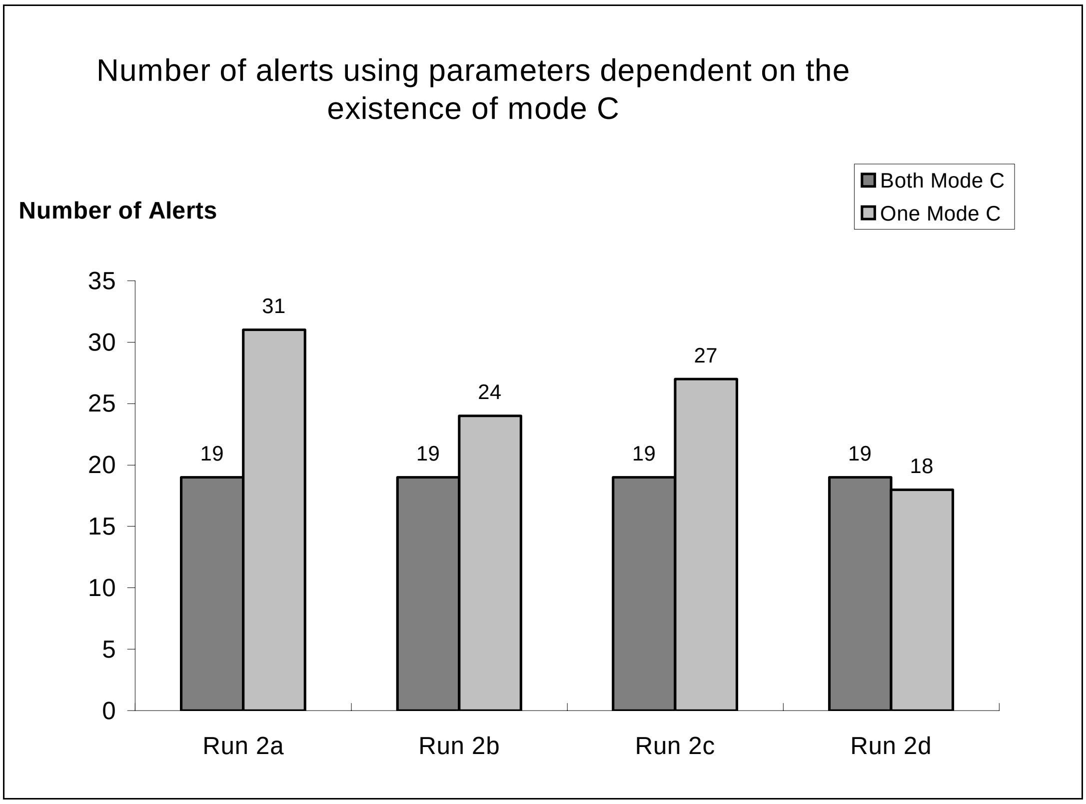
Hence, for this part of the study new parameters were implemented in the STCA model that were applied when one aircraft in the pair had no mode C.

The STCA model was run four times with various narrower parameter values applied to the pairs involving tracks without mode C.

The table below summarises the parameter values used.

Test	Predicted Lateral Separation Threshold (NM) – both mode C	Warning Time (seconds) – both mode C	Predicted Lateral Separation Threshold (NM) – one mode C	Warning TIme (seconds) – one mode C
2a	4.5	100	3	80
2b	4.5	100	2.4	80
2c	4.5	100	3	65
2d	4.5	100	2.4	65

The results of these runs are shown below:



4.3.3 Final run of the STCA model using Parameter Groups for different region combinations, and a VFR SSR code list to limit assumed aircraft height

The STCA model was run with narrower parameter values applied aerobatic areas, and even narrower parameters applied to aircraft without mode C. The full description of the regions and parameter values applied in each region is given in section 3.10. A VFR SSR code list was also used to limit the possible flight levels that aircraft without mode C were assumed to occupy in the STCA model.

This final run of the STCA model yielded 25 alerts, 14 of which involved an aircraft without mode C.

For comparison, run 2c, produced 46 alerts, of which 27 involved an aircraft without mode C.

It was established whether each alert situation in run2c still alerted in the latest run of the model. If the alert was suppressed, the reason for the suppression was identified. Otherwise, it was determined whether the alert could be suppressed by other means (such as use of “training” SSR codes, or would be likely to remain as either a wanted or unwanted alert. The table below presents a final analysis of the alerts from the latest run.

Unwanted alerts lost due to Aerobatic Area Inner	3
Unwanted alerts lost due to generally narrower parameters	4
Unwanted alerts lost due to VFR SSR code list	13
Unwanted alerts lost in VFR traffic region (<4500ft)	1
Unwanted alerts not lost, but would be suppressed by assigning the leaders vertical characteristics to the wingman	2
Unwanted alerts not lost, but would be suppressed by a list of “training” SSR codes	5
Alerts not lost, judged as a nuisance	11
Alerts not lost, judged as wanted	7

5. CONCLUSIONS

5.1 Identified Problems

Over the course of this study, a variety of types of nuisance alert have been identified. These include problem alerts due to split tracks and military formations, unwanted alerts between military aircraft in aerobatic areas and civil aircraft in neighbouring airways, and a large number of alerts involving aircraft without mode C.

Many alerts between civil and military aircraft were simply due to the long (5 minute) prediction time.

Some of the aircraft without mode C can be identified (by the controller and STCA) as VFR tracks, which may be safely assumed to be at a low level. Other aircraft without mode C may be wingmen in a formation, which provoke nuisance alerts with nearby aircraft that do have mode C.

There were also a number of unwanted alerts between military aircraft undergoing various training exercises such as dog-fighting, in specific training areas.

5.2 Effectiveness of Proposed Solutions

A number of solutions have been developed to try to overcome the various types of nuisance alerts. Many of the proposed solutions were included in the STCA model, in order to measure their effectiveness.

The split track and military formation logic proved to be very effective at suppressing the nuisance alerts they were designed to treat. All the military formation alerts were suppressed, and all but one of the split track alerts was suppressed. The logic was less effective at suppressing alerts due to military aircraft joining a formation, since these alerts look like any converging conflict between aircraft. None of the other alerts were affected by this logic, indicating that the probability of the logic unintentionally suppressing a wanted alert is very low.

Reducing the parameter values, such as the prediction time from five minutes to two minutes or less, was effective at eliminating many of the nuisance alerts, particularly those between tracks in the aerobatic areas and those in the airways. The use of region dependent parameters and the definition of an inner aerobatic area with a shorter prediction time were effective at reducing the nuisance alert rate further.

A significant number of nuisance alerts were eliminated in the STCA model by recognising certain tracks as VFR traffic, and then assuming the aircraft was in a predefined height band. Thirteen nuisance alerts were eliminated from run2c, by using this algorithm.

Two further solutions were identified but not modelled. It was found that a number of unwanted alerts could be removed by assigning military aircraft "training" mode A codes, and suppressing the STCA processing for pairs of these aircraft in pre-defined training areas. It was also identified that some nuisance alerts could be eliminated by identifying military aircraft in formation, and assigning the leader's vertical state (position and rate) to the wingman. This would eliminate nuisance alerts between wingmen and other nearby aircraft not in vertical conflict with the formation.

5.3 Effectiveness of the Analysis Method

This study demonstrates that effective solutions can be found for STCA in the military environment.

The method involved the use of display tools, and an STCA model which allowed each alerting situation to be studied in detail, and allowed potential solutions to be identified.

The STCA model was easily modifiable. This allowed different solutions to be tested and the effect on the alerting performance to be measured.

6. RECOMMENDATIONS

ATCC Semmerzake needs to be confident that the suggested solutions will be effective in their airspace without unforeseen negative side effects.

Appendix D-2 : Functional Hazard Assessment (FHA) of STCA for ATCC Semmerzake contains a number of means for mitigating a number of hazards which were identified as part of the FHA". As part of these mitigation means the document recommends the enhancement of both the split track detection logic and the military formation detection logic to detect when the respective conditions have terminated. That is, logic to detect the end of split tracks (in case two tracks were falsely detected as split) and logic to detect the end of military formations.

It is highly recommended that further track recordings should be analysed to increase confidence in the both the identified solutions, and in the means for mitigating the identified hazards. In particular, the effectiveness of the split track suppression and military formation detection algorithms in suppressing unwanted alerts, or any adverse effects on wanted alerts should be assessed further.

If desired, further work could also be carried out to measure the effectiveness of one of identified solutions that was not modelled in this study. For example, in the model, when a pair of aircraft is detected in a formation, the leader’s vertical state (position and rate) could be assigned to the wingman.

If the identified solutions prove robust, then these should be implemented in the system as a matter of priority, in order that the STCA system becomes usable by the controller.

It is strongly recommended that the STCA system parameters are optimised for the airspace in which they will be applied, by using aerobatic area regions, (inner and outer) and a VFR region. The parameter group solution used in the STCA model would allow sufficient flexibility.

The design of the regions and the parameters that apply should be carefully refined by using an STCA model and by checking how the model performs with various parameter sets.

Consideration should also be given to implementing regions which can be activated and deactivated in line with the use of the TRAs. The use of such regions could be tested first in an STCA model.

7. LIST OF ABBREVIATIONS

ASTERIX	All purpose Structured Eurocontrol surveillance Information eXchange
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
BFL	Block Flight Level
CFL	Cleared Flight Level
FL	Flight Level
SPIN	Safety nets : Planning, Implementation and eNhancement
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Alert
TRA	Temporary Reserved Area
VFR	Visual Flight Rules

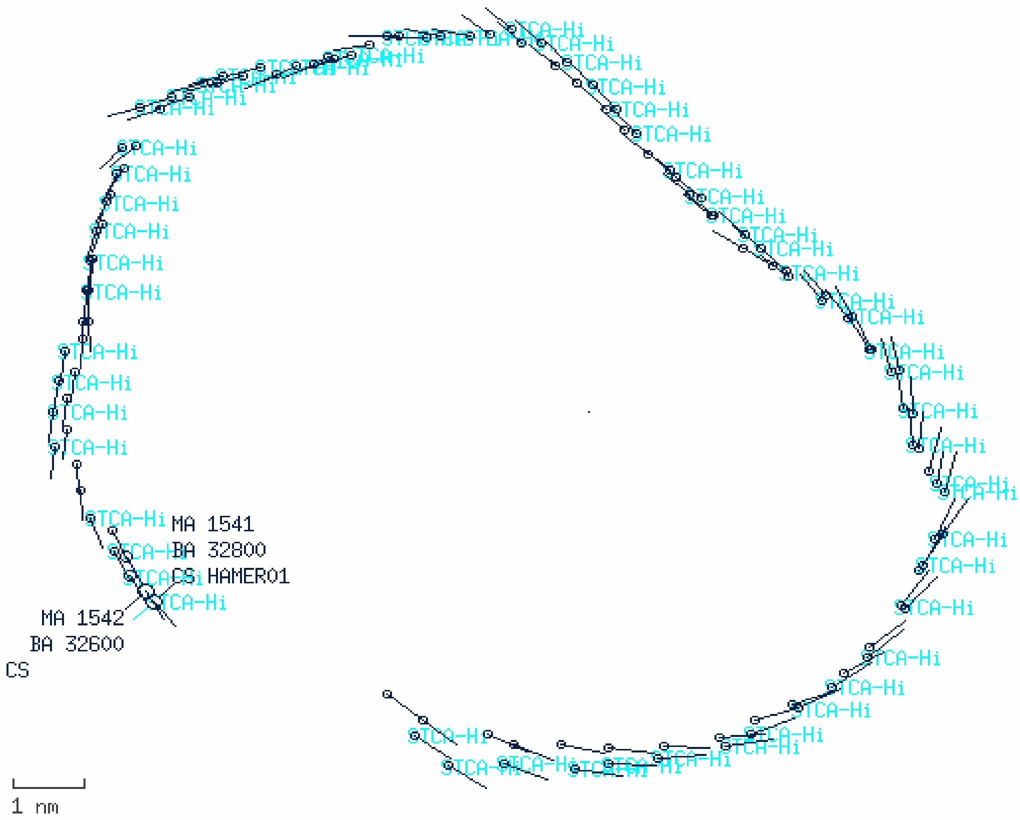
ANNEX 1 STRACK PICTURES

STRACK is a display program, able to show aircraft tracks and safety nets alerts in both plan view and vertical profile.

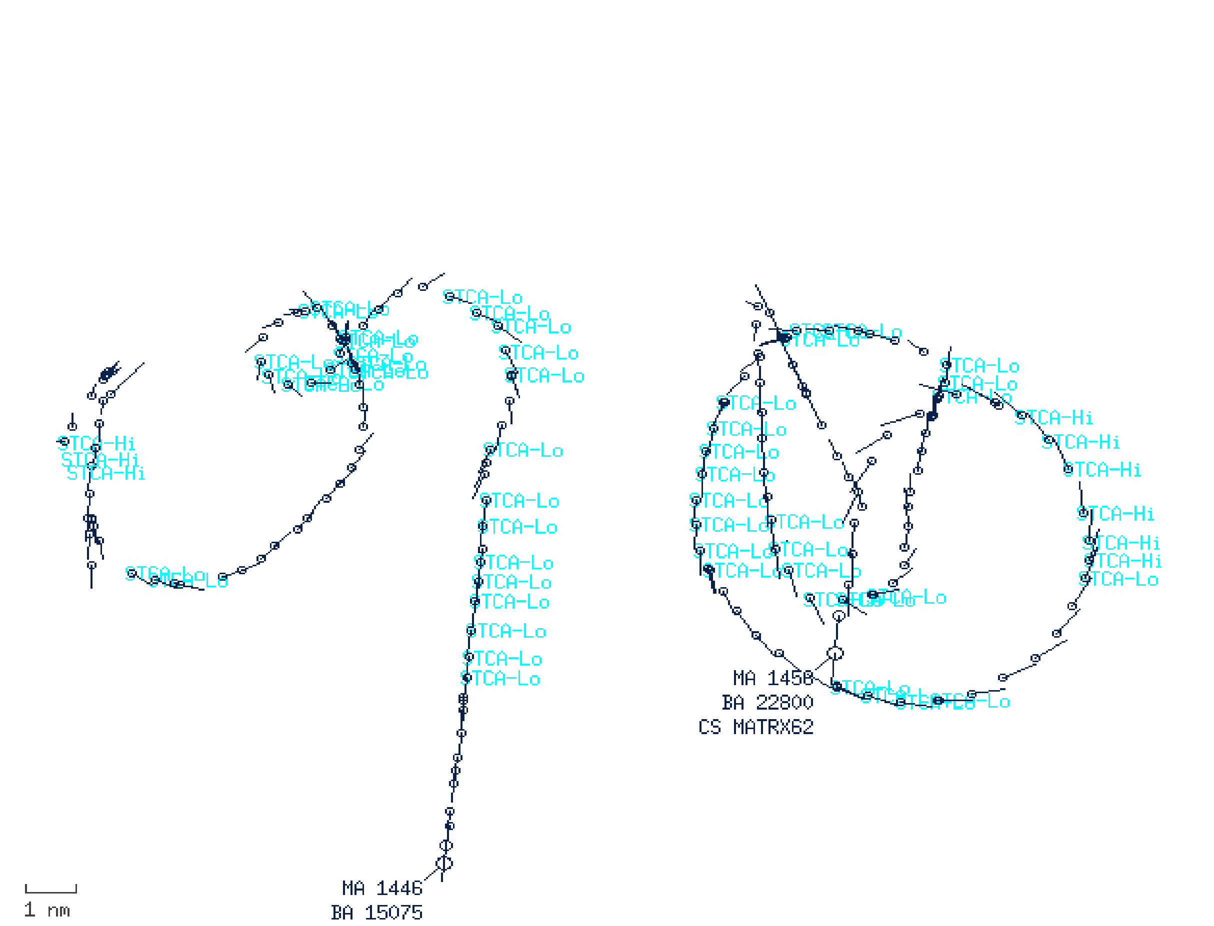
These pictures are useful in a variety of ways. Firstly, they help in understanding the Belgian Military ATC environment. Secondly, and more significantly for this study, the desirability of an STCA alert can be assessed for each encounter and the STCA system refined/tuned accordingly.

To save space each of the encounters is shown in plan view only. Where STCA alerts appear on the pictures (lightly coloured “STCA-Lo” or “STCA-Hi”) they are those recorded at ATCC Semmerzake (either OPS or SUP partition).

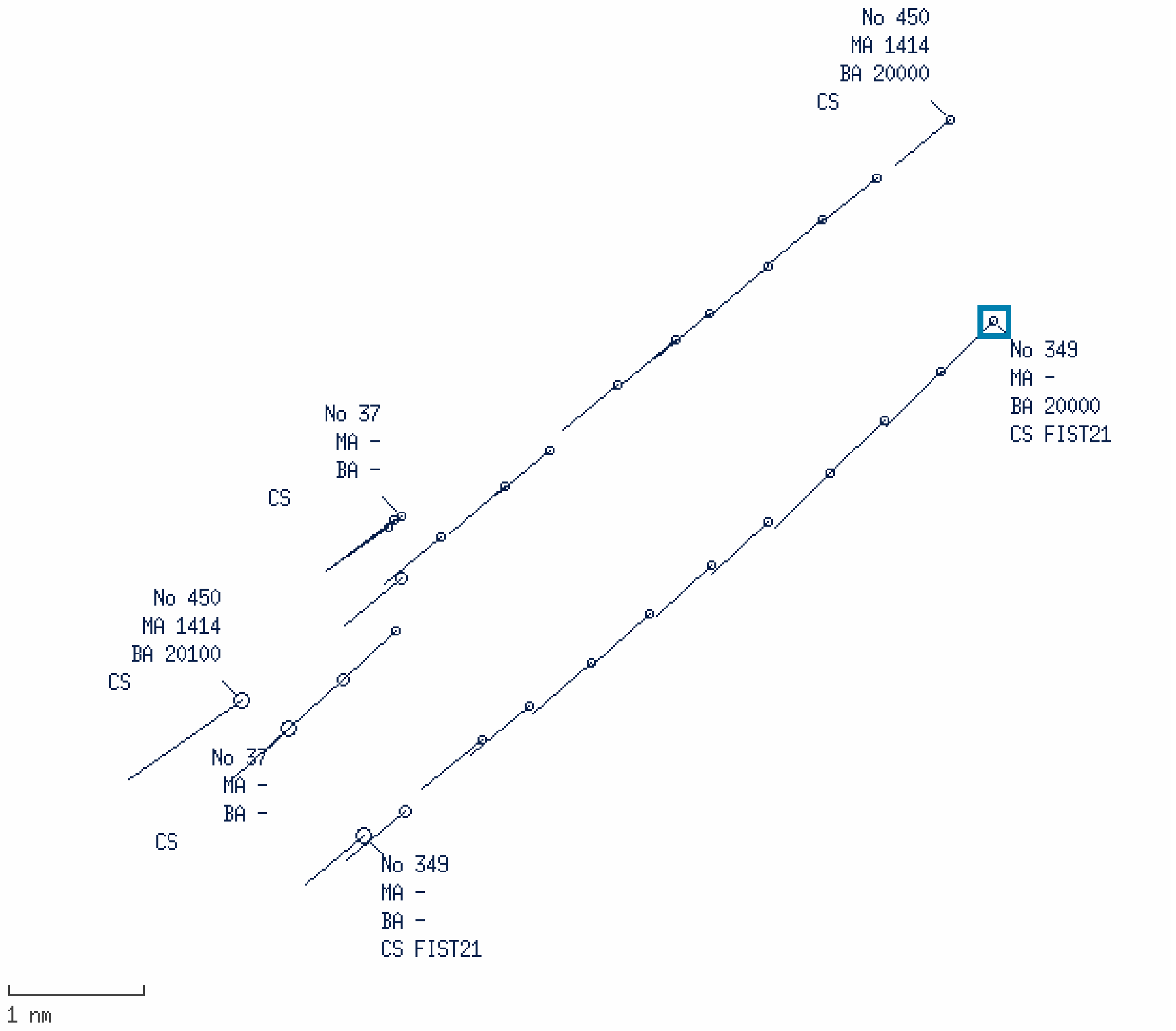
Picture 1: Map picture showing country borders and the STCA playing area enclosing the aerobatic areas.



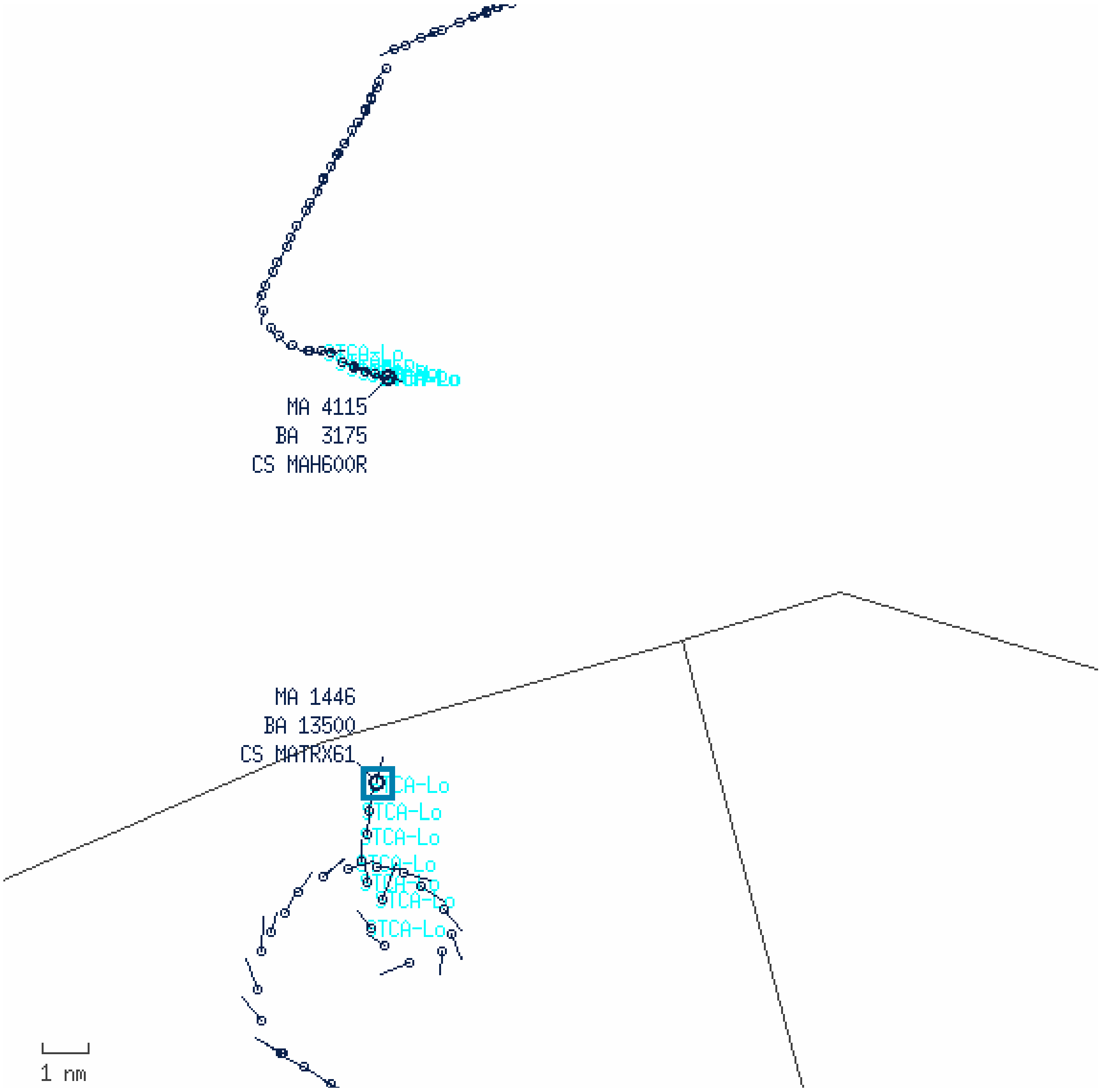
Picture 2: This example shows two military aircraft in formation. In this case both aircraft are transponding. In most other cases the leader only squawks. The recorded STCA alert is continuous, and is clearly a nuisance to the controller.



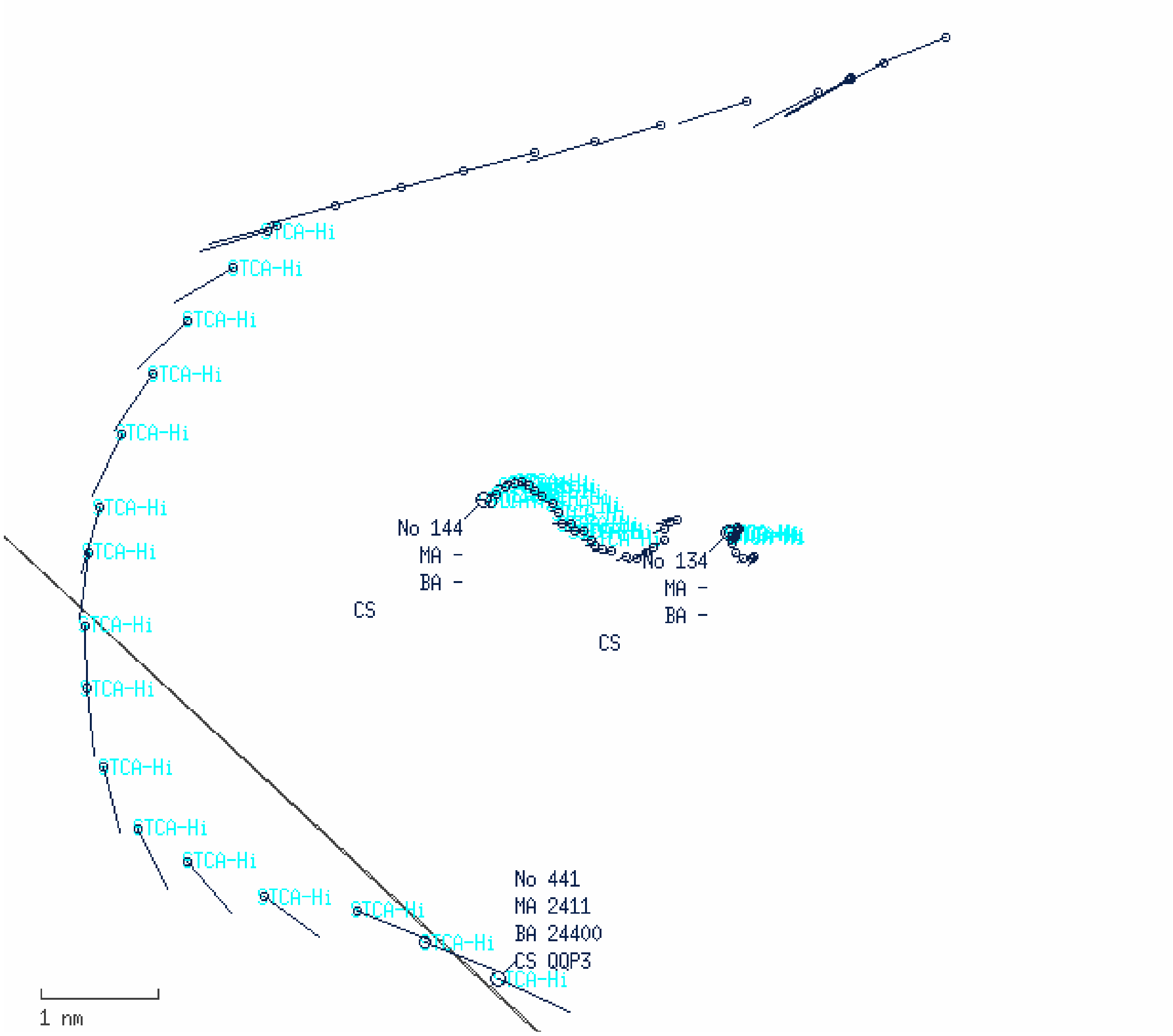
Picture 3: This example shows the typical tight turns and manoeuvres that frequently occur in the aerobatic areas, and the consequent STCA alerts.



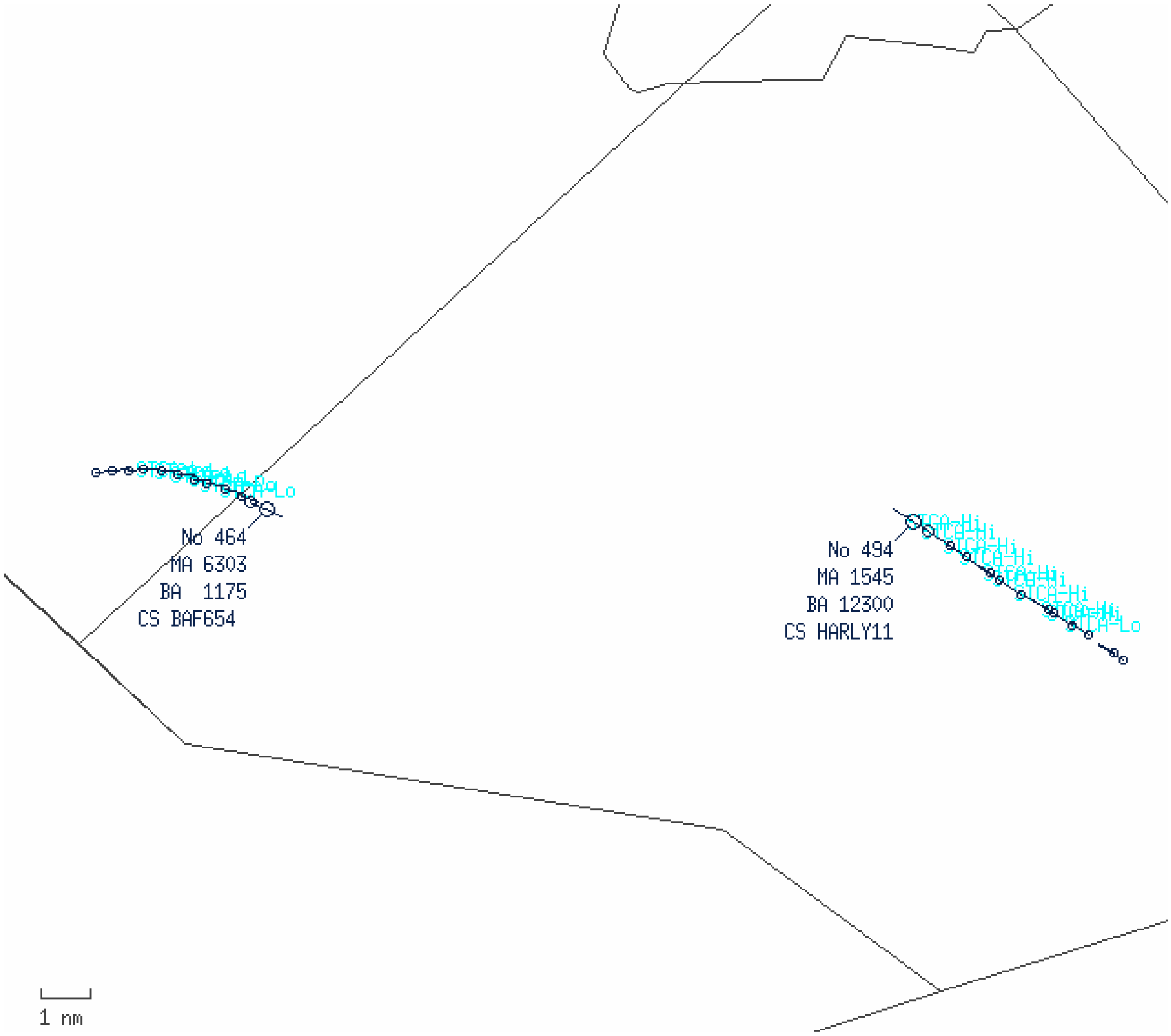
Picture 4: This example shows a split track (track No 37) whilst two aircraft (FIST21 and A1414) are flying in a loose military formation. At times, especially when the formation is tight, it can be difficult to distinguish between a split track and a genuine aircraft.



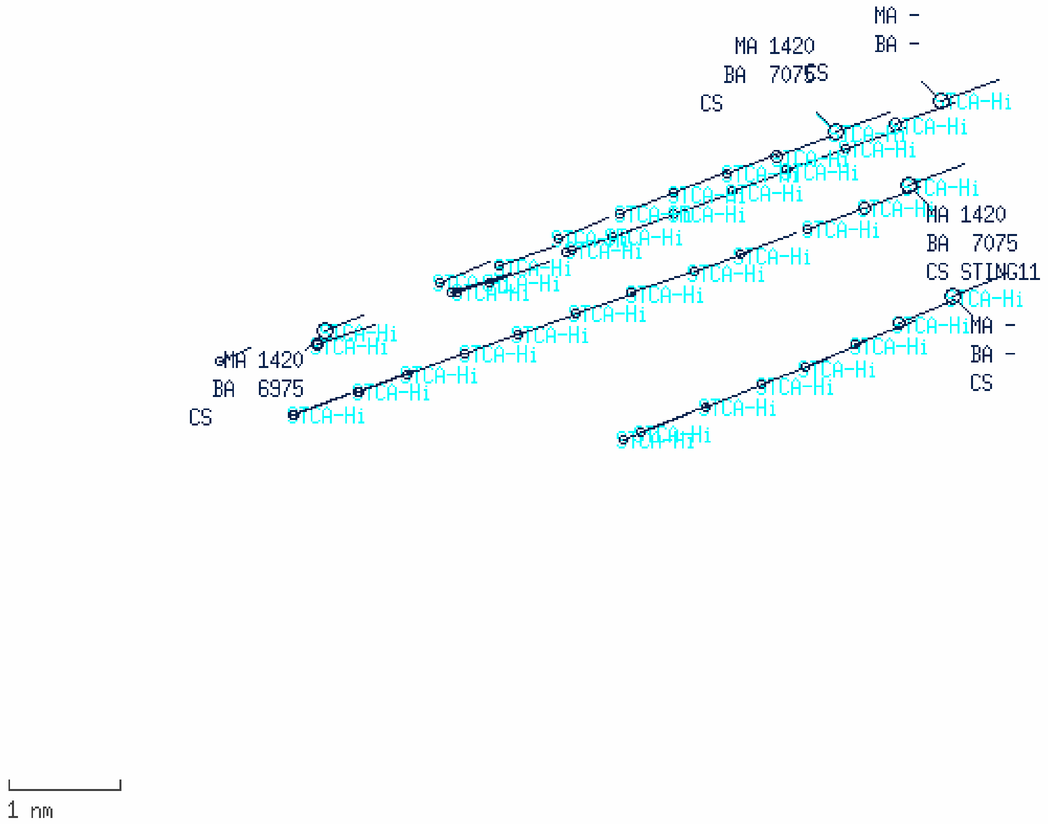
Picture 5: This example shows an STCA alert between a military aircraft in the Charleroi aerobatic area and a civil aircraft in the adjacent airway.



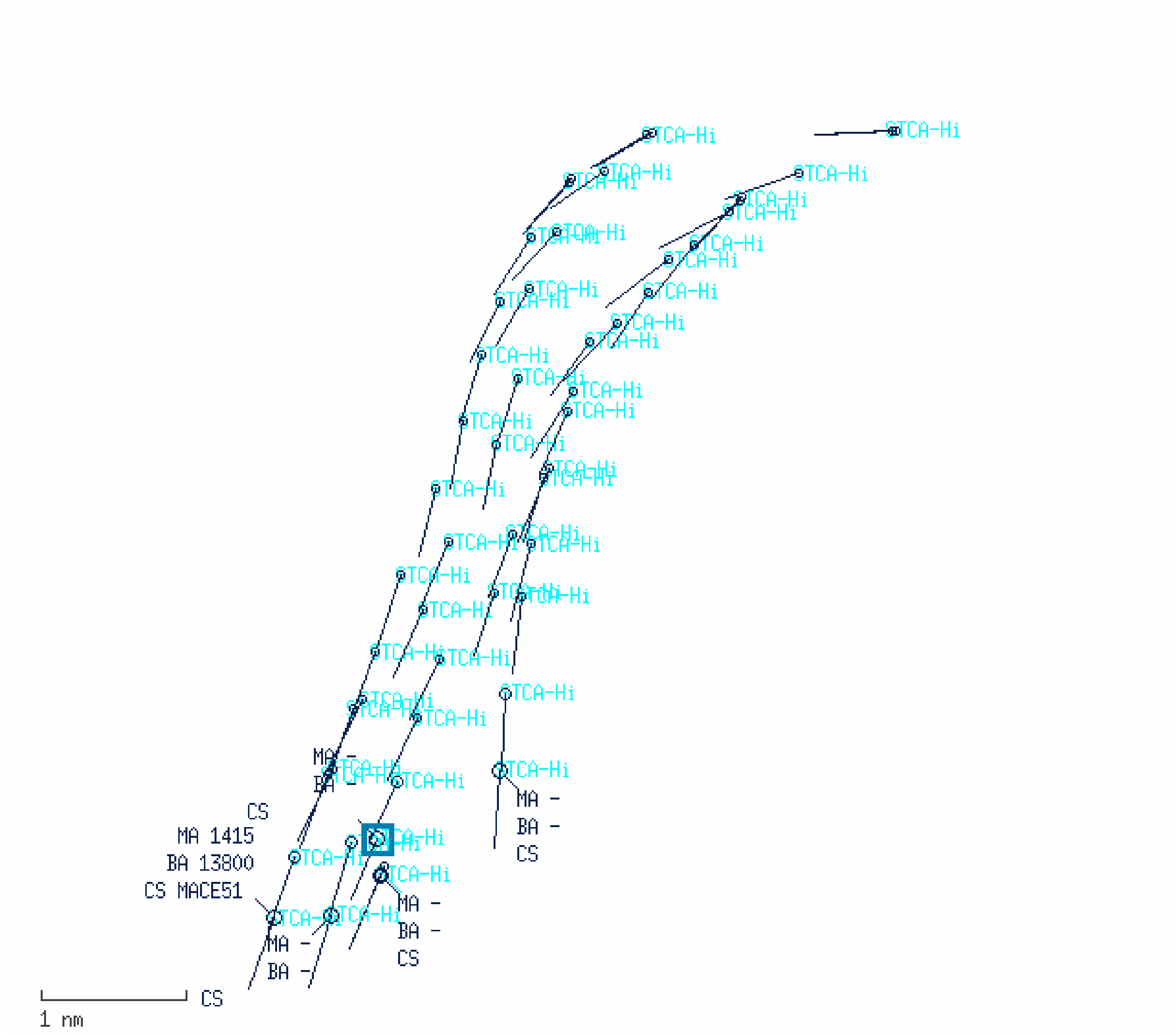
Picture 6: This example shows two STCA alert between a military aircraft (QQP3) and two primary tracks. Although the aircraft are laterally close, the vertical separation is unknown, and the need for the alert is impossible to assess after the event.



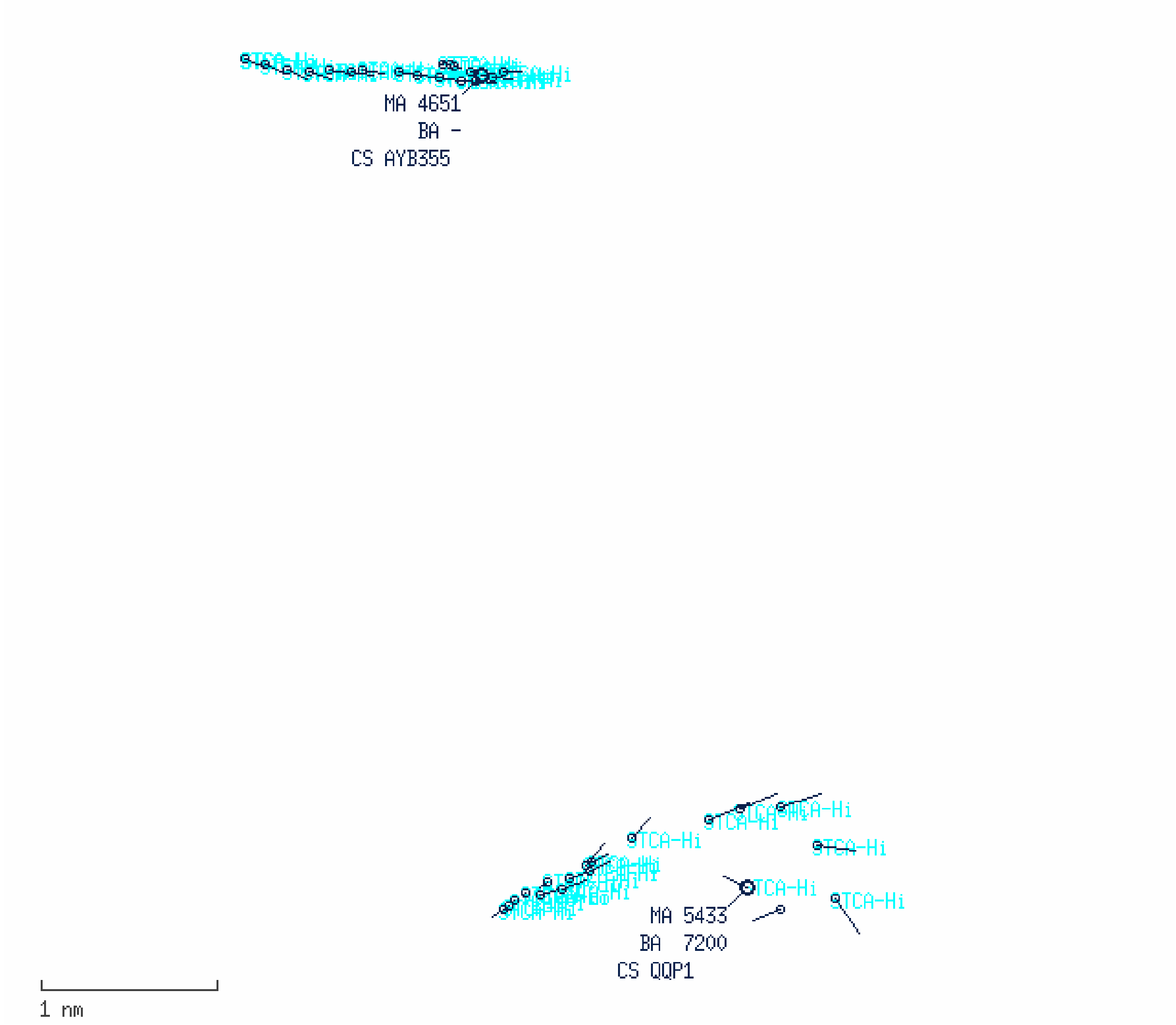
Picture 7: This example was identified by ATCC Semmerzake as an undesirable STCA alert.



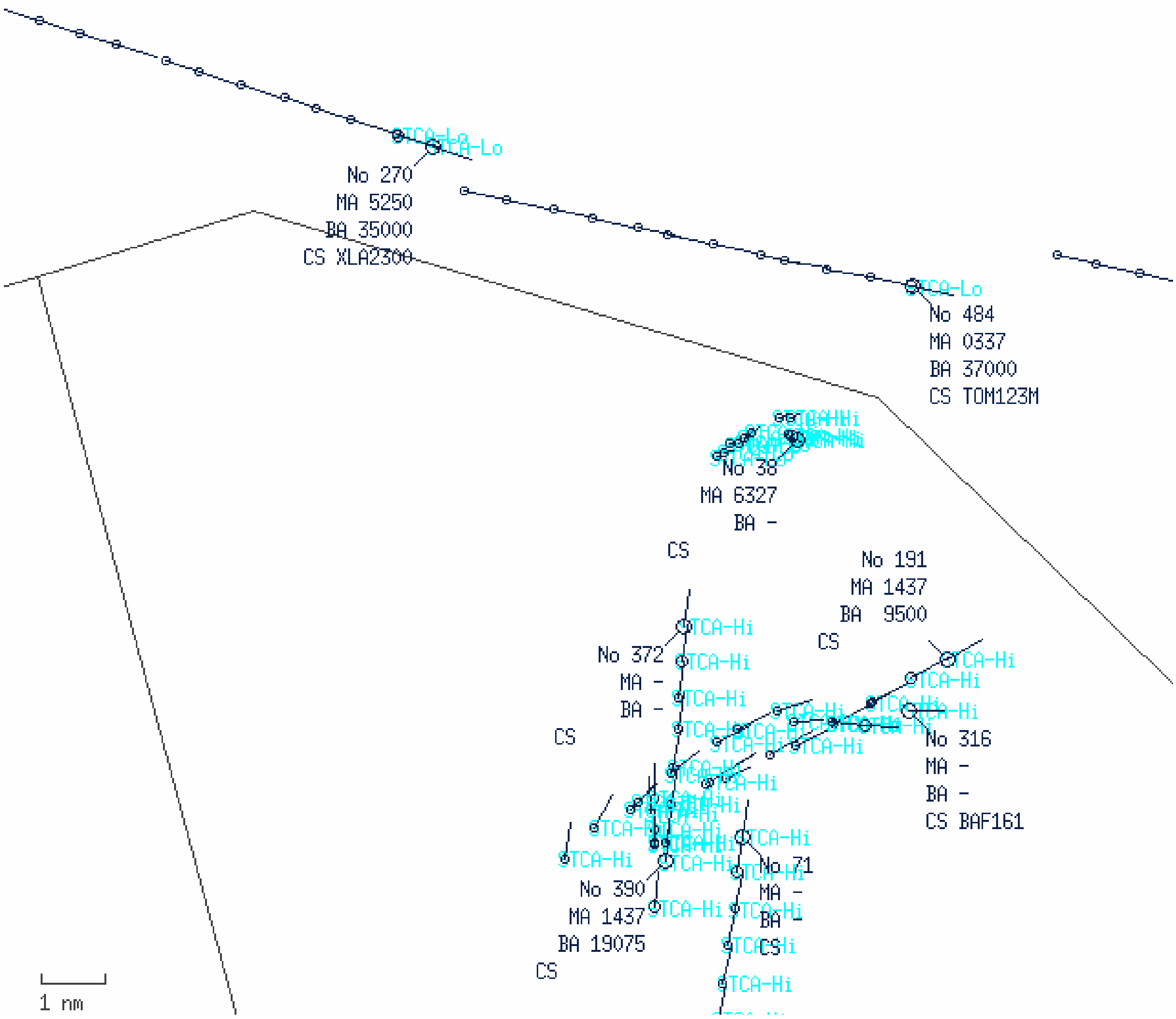
Picture 8: This example was identified by ATCC Semmerzake as a good example of aircraft flying in formation. Note that it is not entirely clear from this picture whether the uppermost aircraft in the picture is genuine, or is a split track.



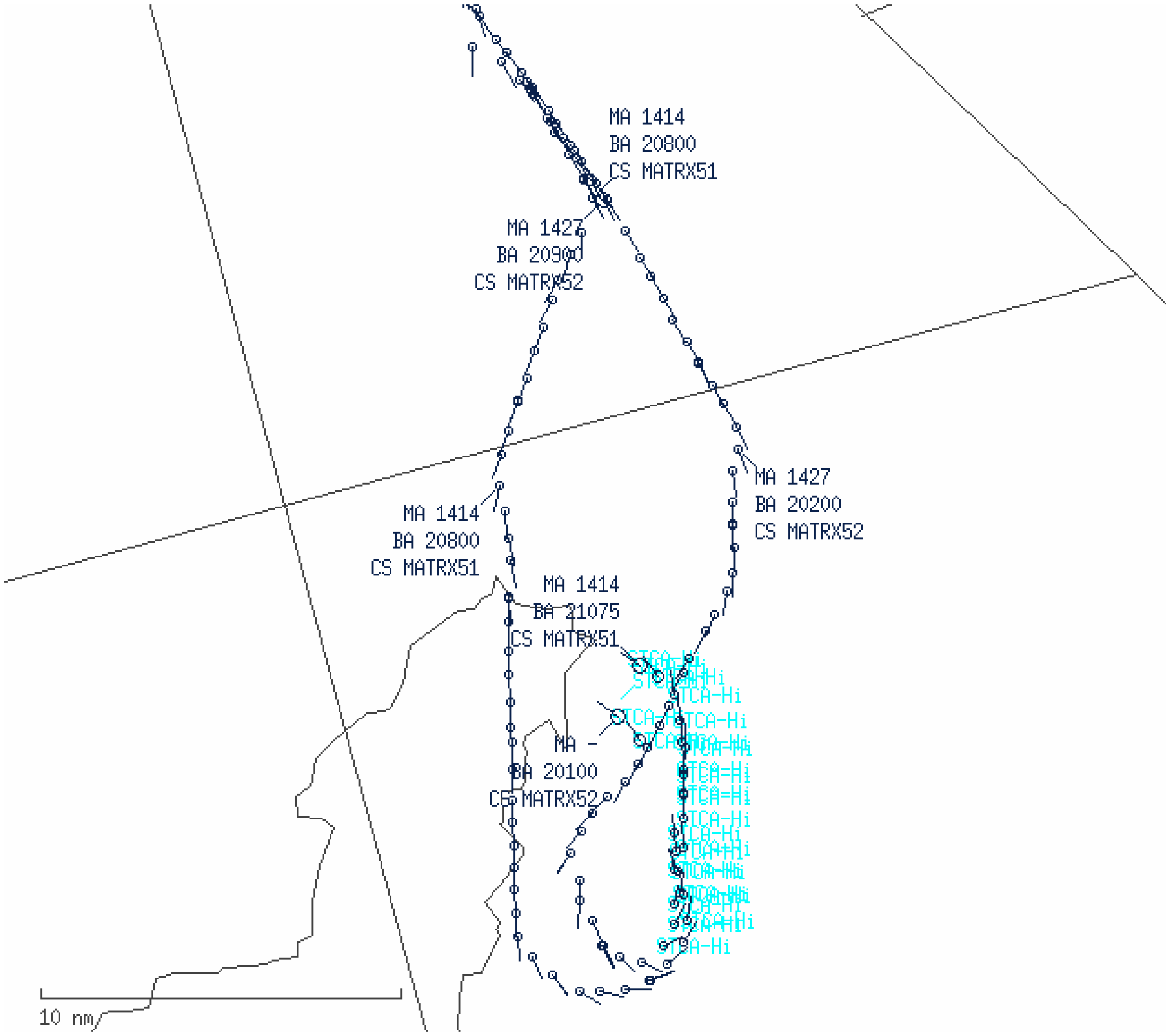
Picture 9: This is another example military formation identified by ATCC Semmerzake. Again, note that it is not entirely certain if all the tracks are from genuine aircraft, or if some of them are split tracks. In STRACK, the truth is normally apparent either before the formation joins, or after the formation splits, when the number of genuine aircraft can be seen on the display.



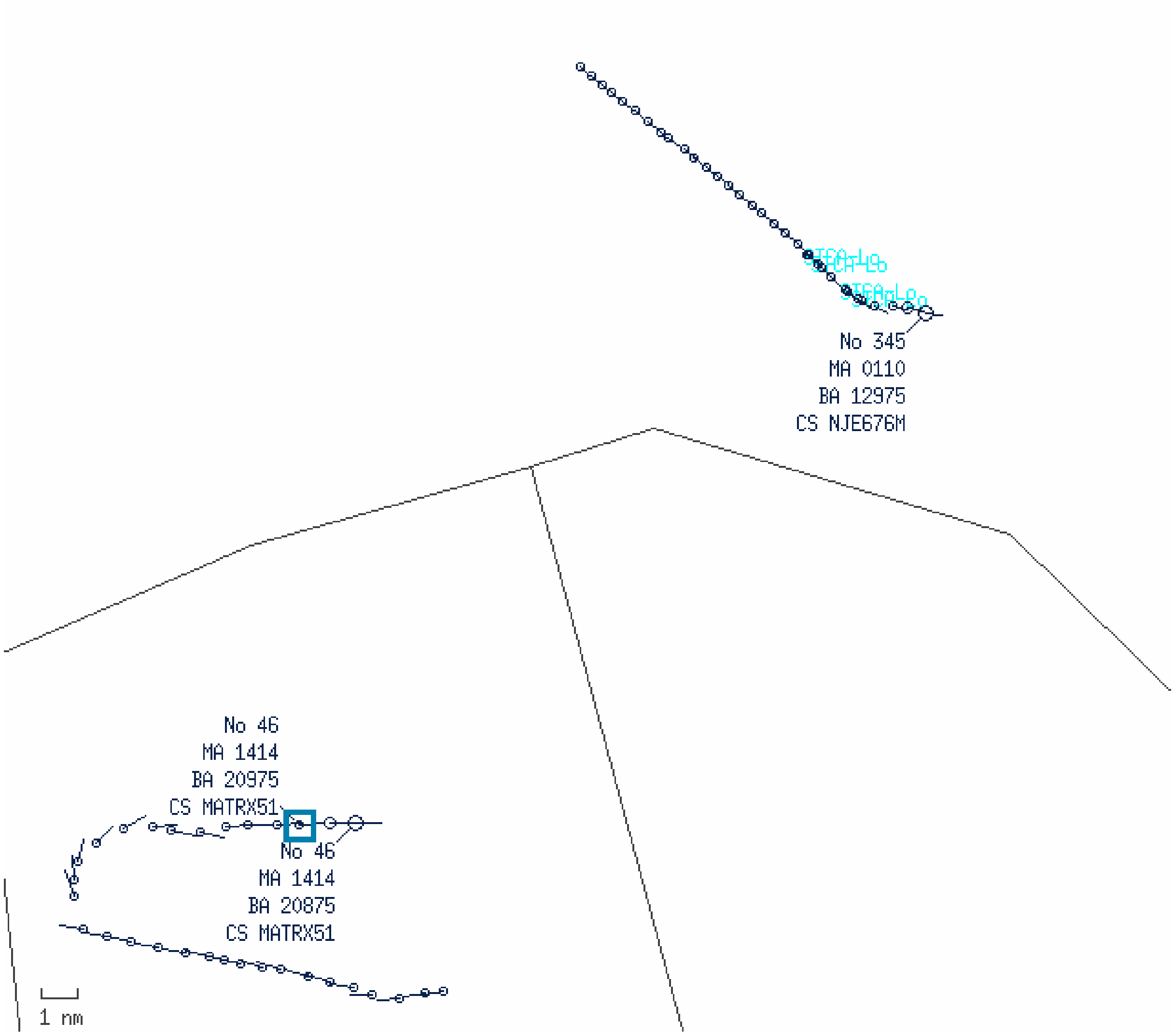
Picture 10: This example was identified by ATCC Semmerzake. QQP is manoeuvring in an aerobatic area and generates a nuisance STCA alert with AYB355 in the civil airway.



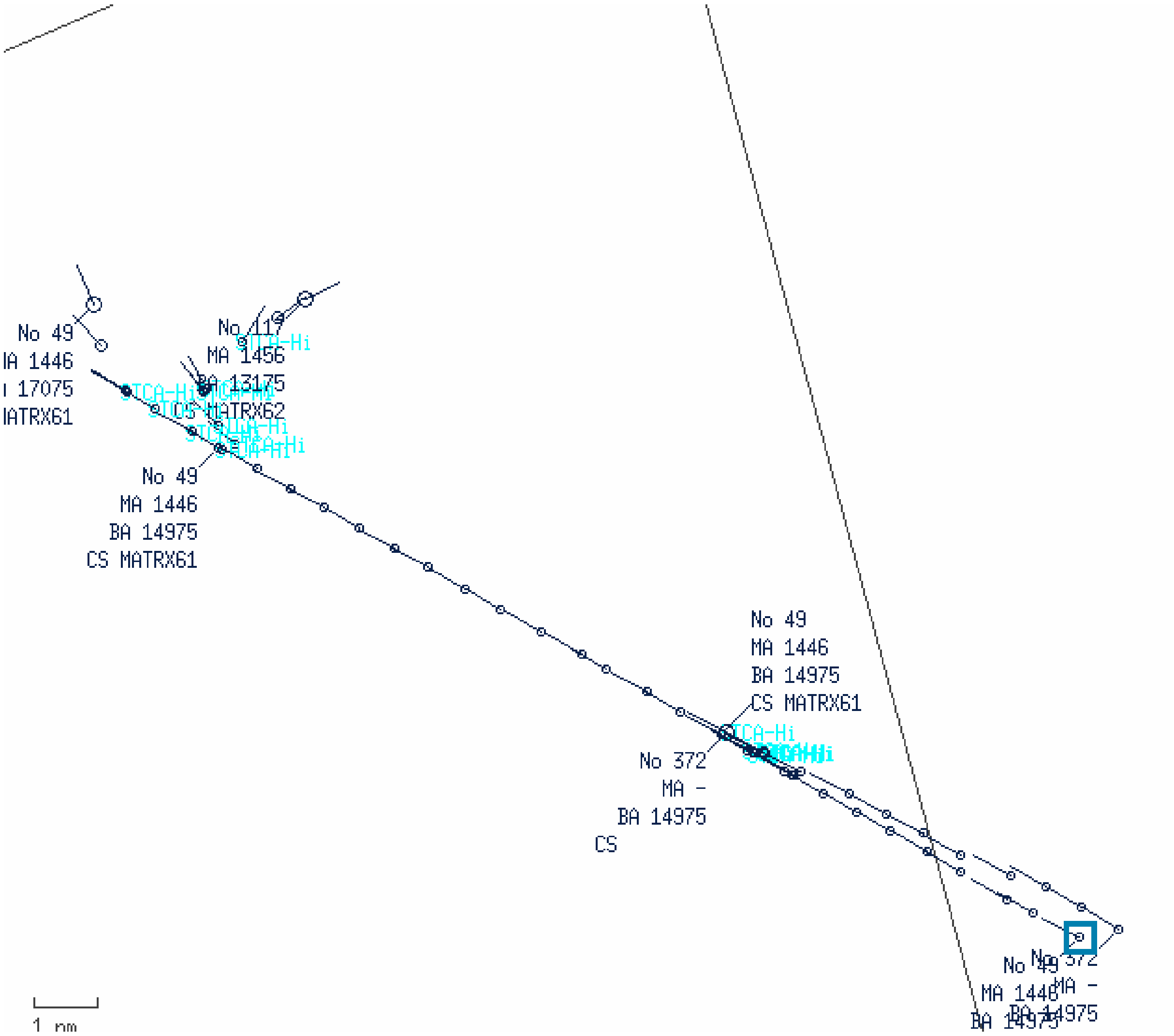
Picture 11: This example was identified by ATCC Semmerzake. Here, a military formation (A1437) generates multiple alerts with itself and surrounding traffic, including two civil aircraft (TOM123M and XLA2300) in the airway, and a track (A6327) without mode C.



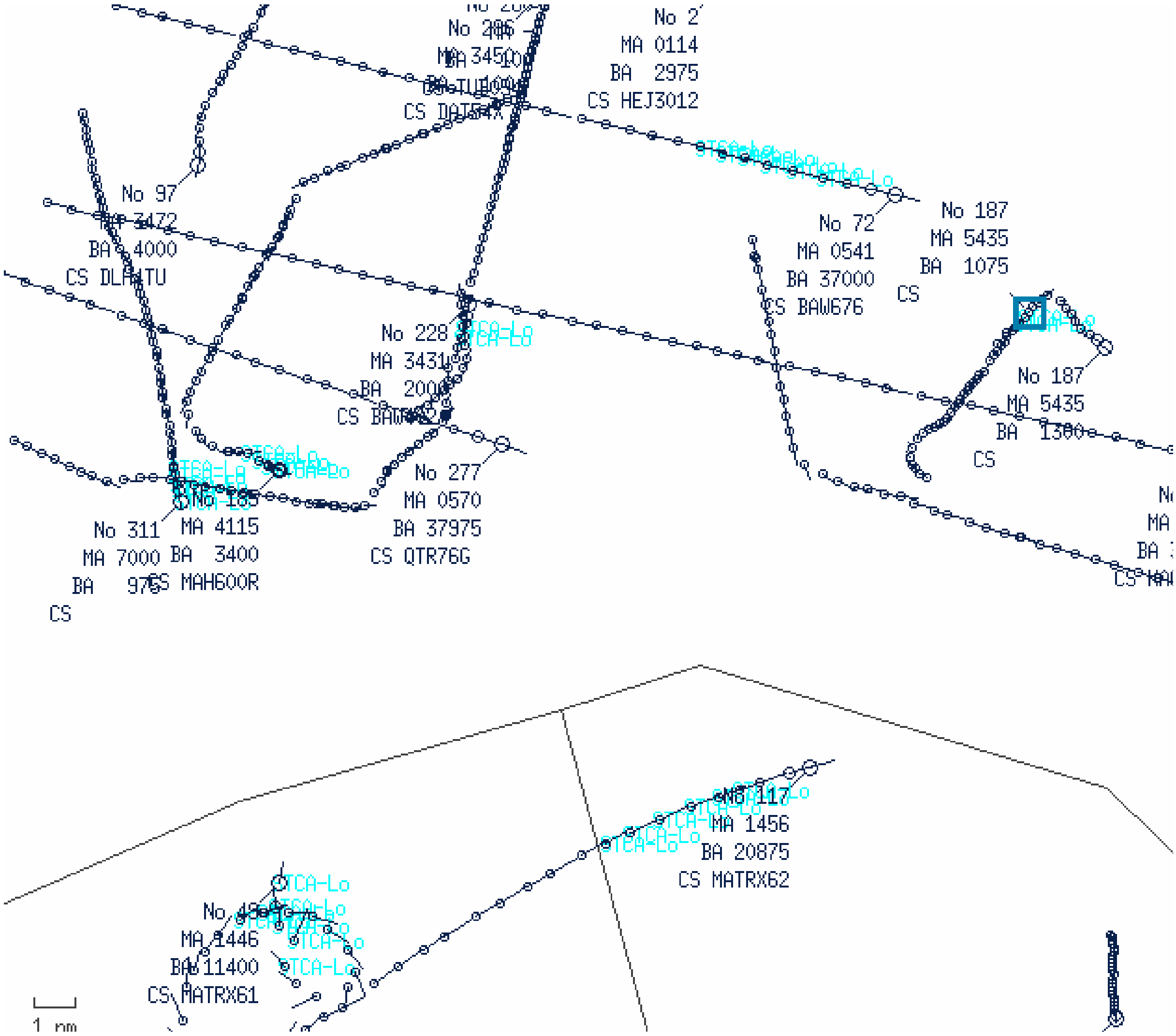
Picture 12: This was an example identified by ATCC Semmerzake as an example where a pair of aircraft (MATRX51 and MATRX52) starts in military formation, splits up and then rejoins.



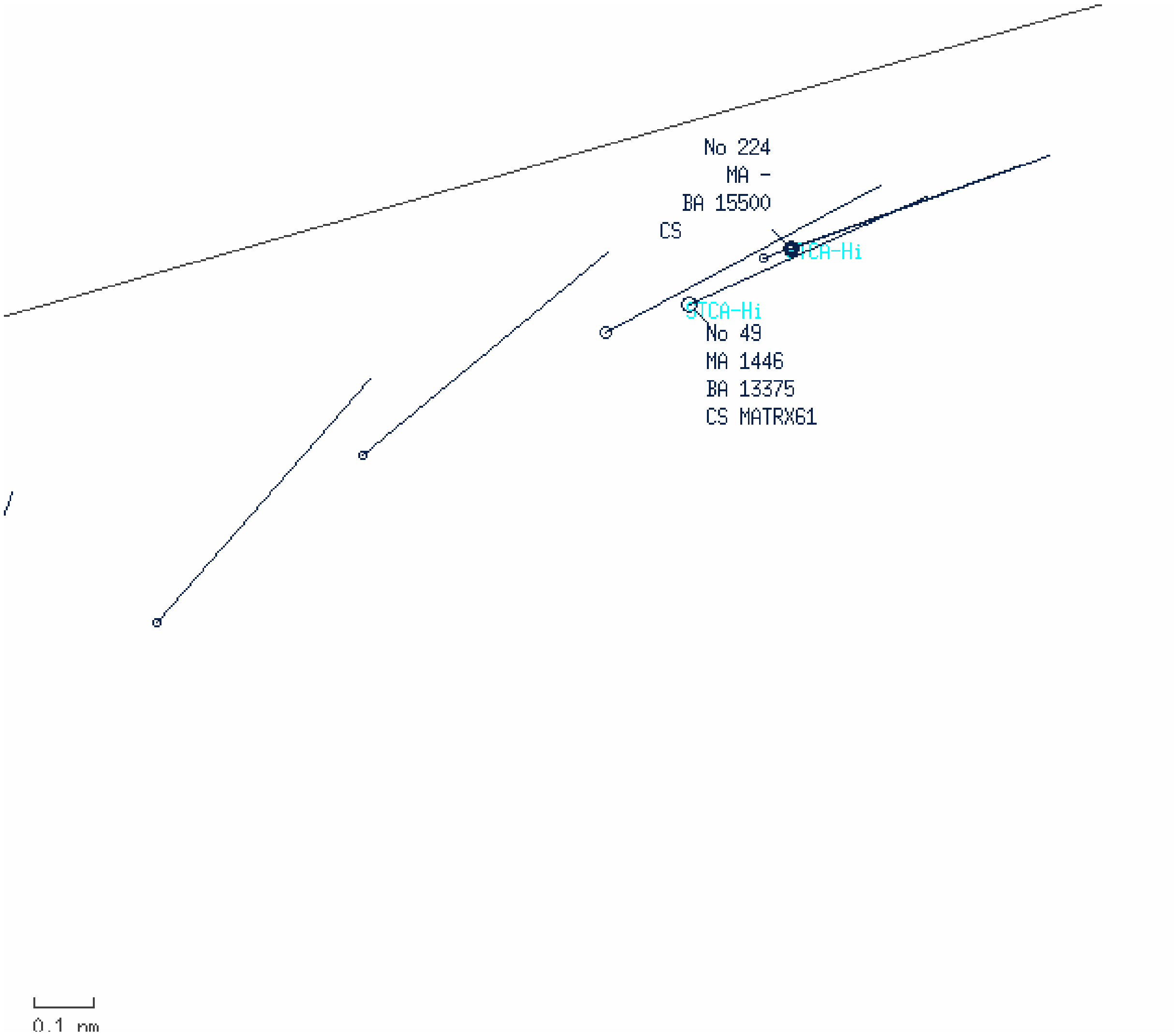
Picture 13: This example, identified by ATCC Semmerzake, shows a military aircraft (MATRX51) in an aerobatic area that produces an STCA alert with a civil aircraft (NJE676M) in the adjacent airway. This is a fairly typical nuisance alert.



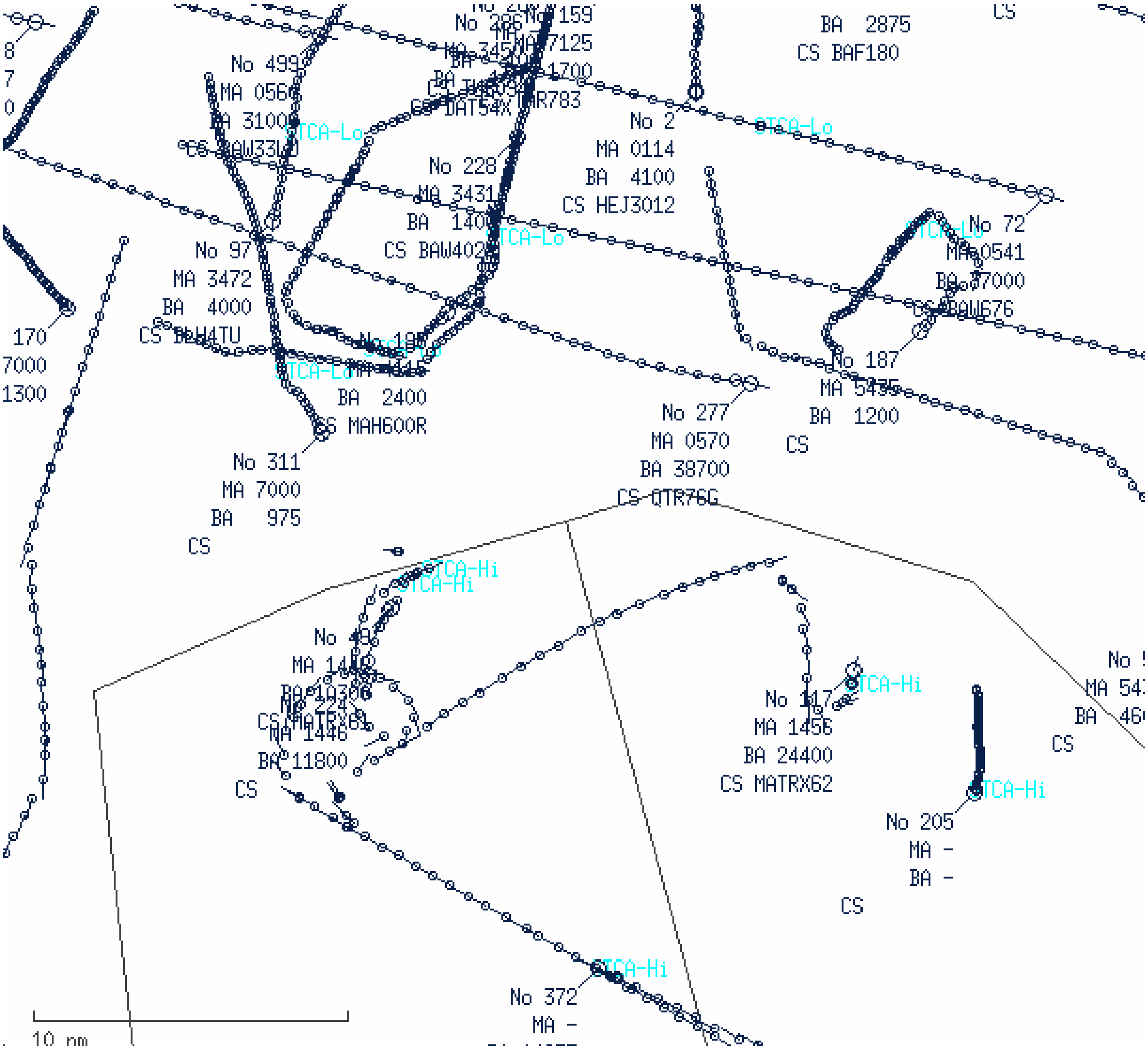
Picture 14: Example from F16 exercise. The two F16s, MATRIX61 and MATRX62 start in formation, then split at 10:44. Note that for 13 track updates (65 seconds) the tracker has not been able to resolve the two aircraft and produces just one track.



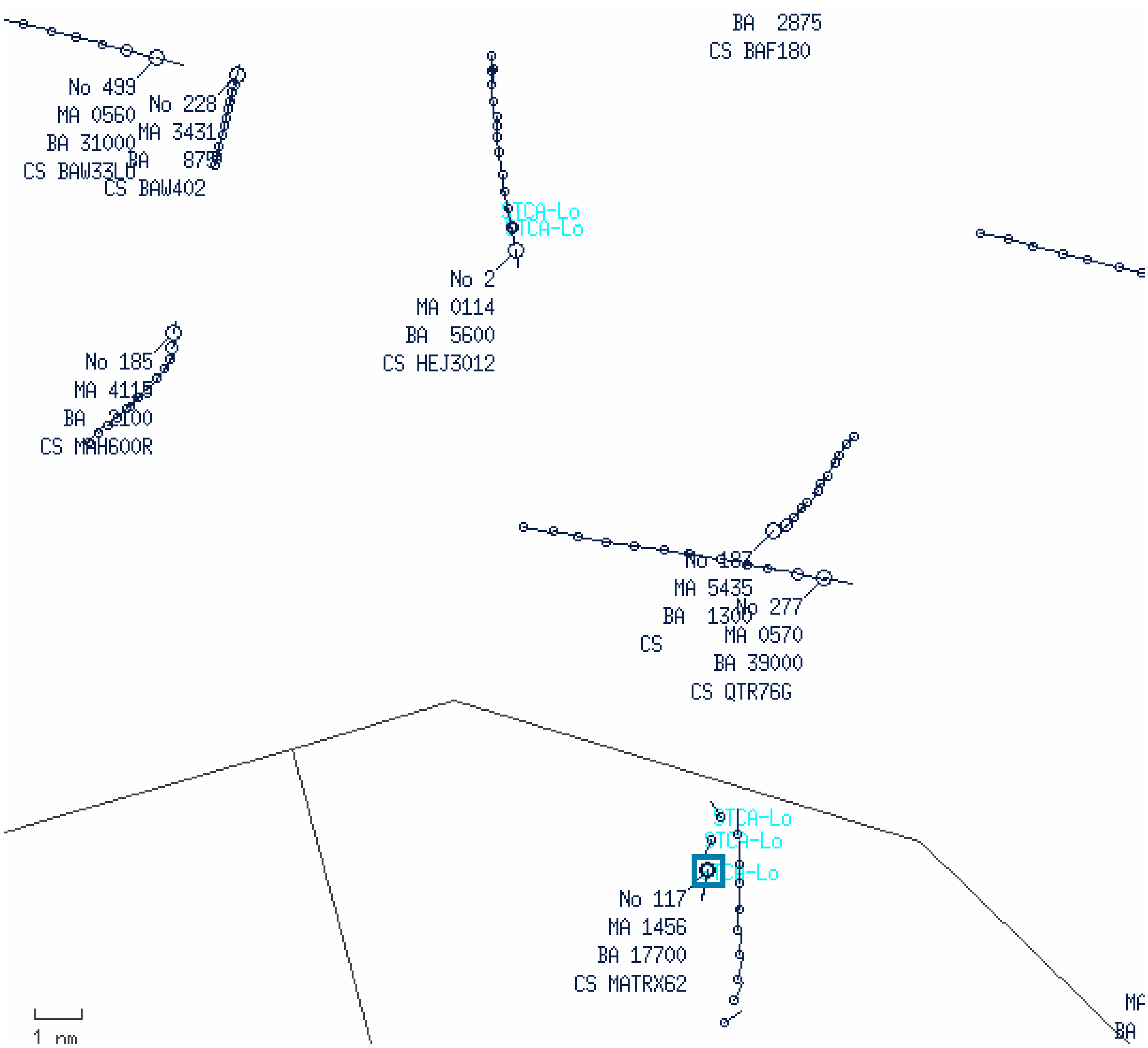
Picture 15: This is an example from F16 exercise showing multiple STCA warnings between MATRX61/MATRX62 and civil aircraft in the airway at 10:46. None of the civil aircraft are assumed by ATCC Semmerzake, so the all the alerts involve either MATRX61 or MATRX62.



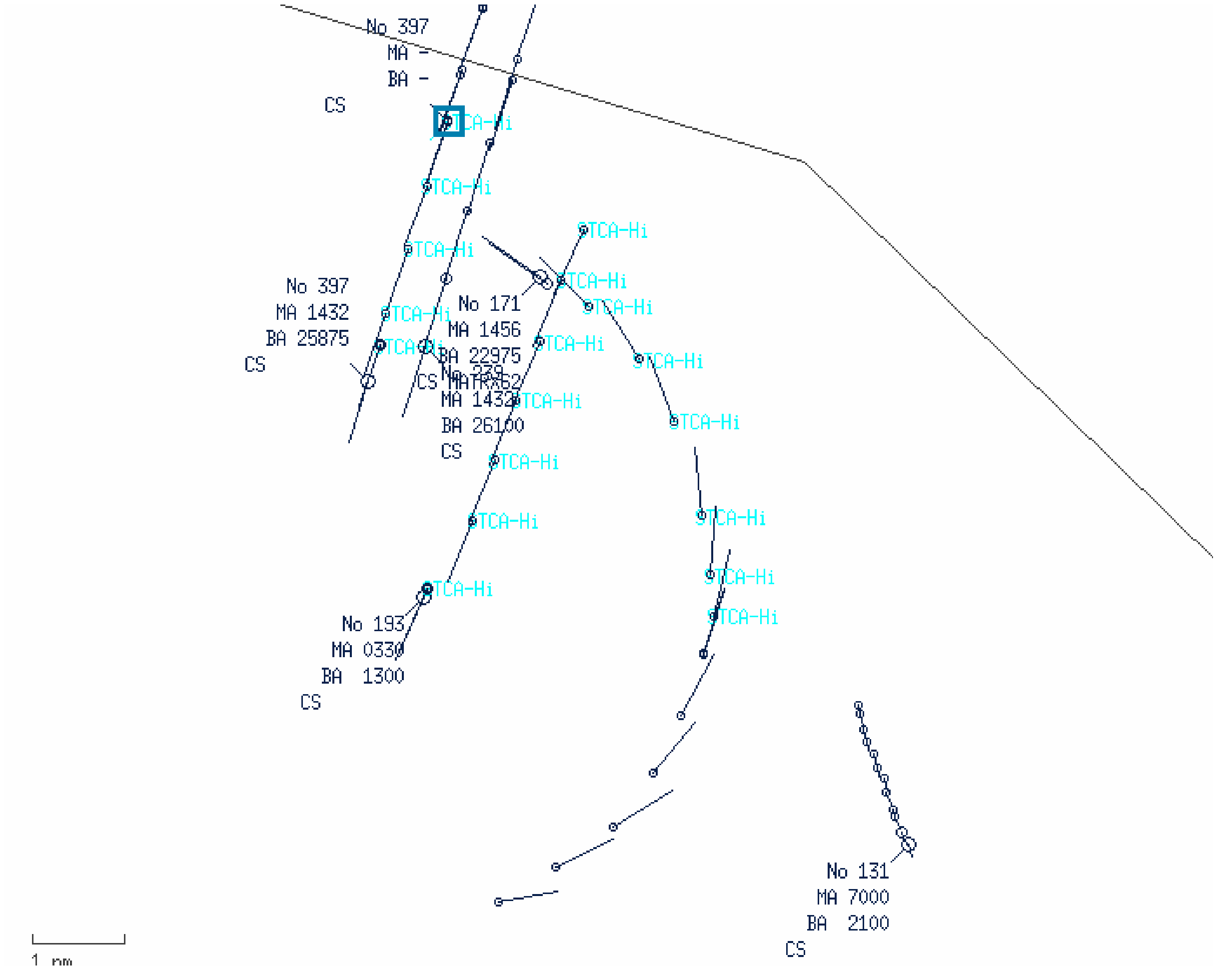
Picture 16: Example from F16 exercise. Split track (No 224) formed due to a tracker blunder. Unwanted STCA alert produced.



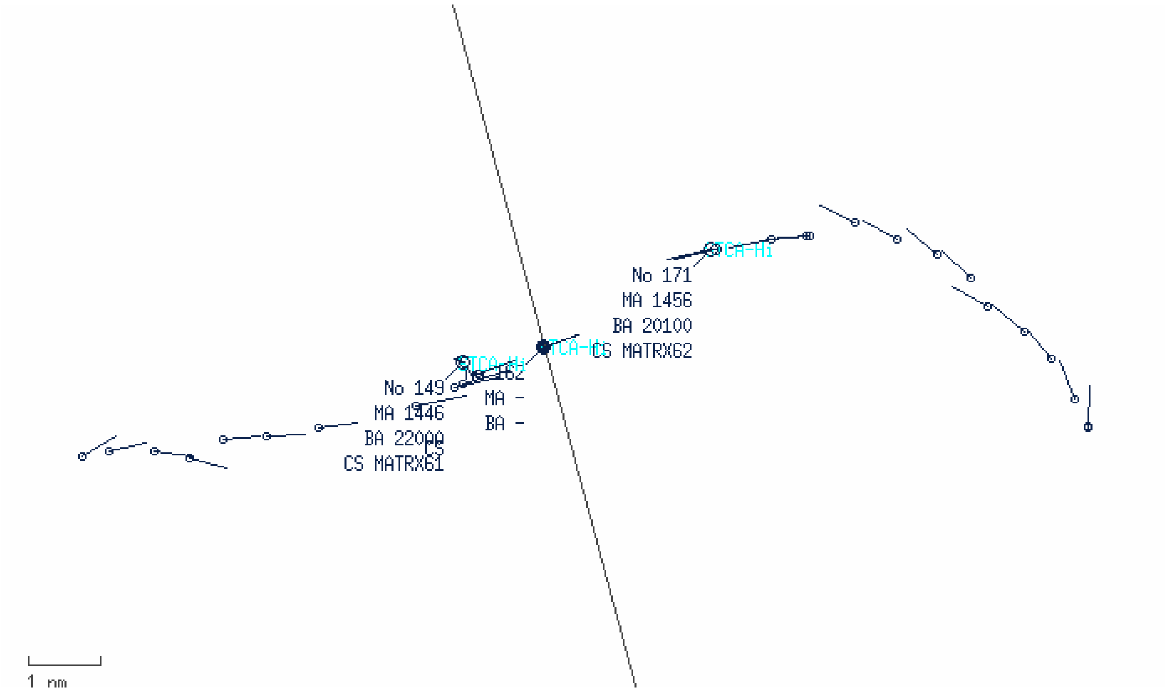
Picture 17: Example from F16 exercise. Snapshot of STCA alerts and warnings at 10:47:11. None of the civil aircraft are assumed by ATCC Semmerzake, so the all the alerts involve either MATRX61 or MATRX62.



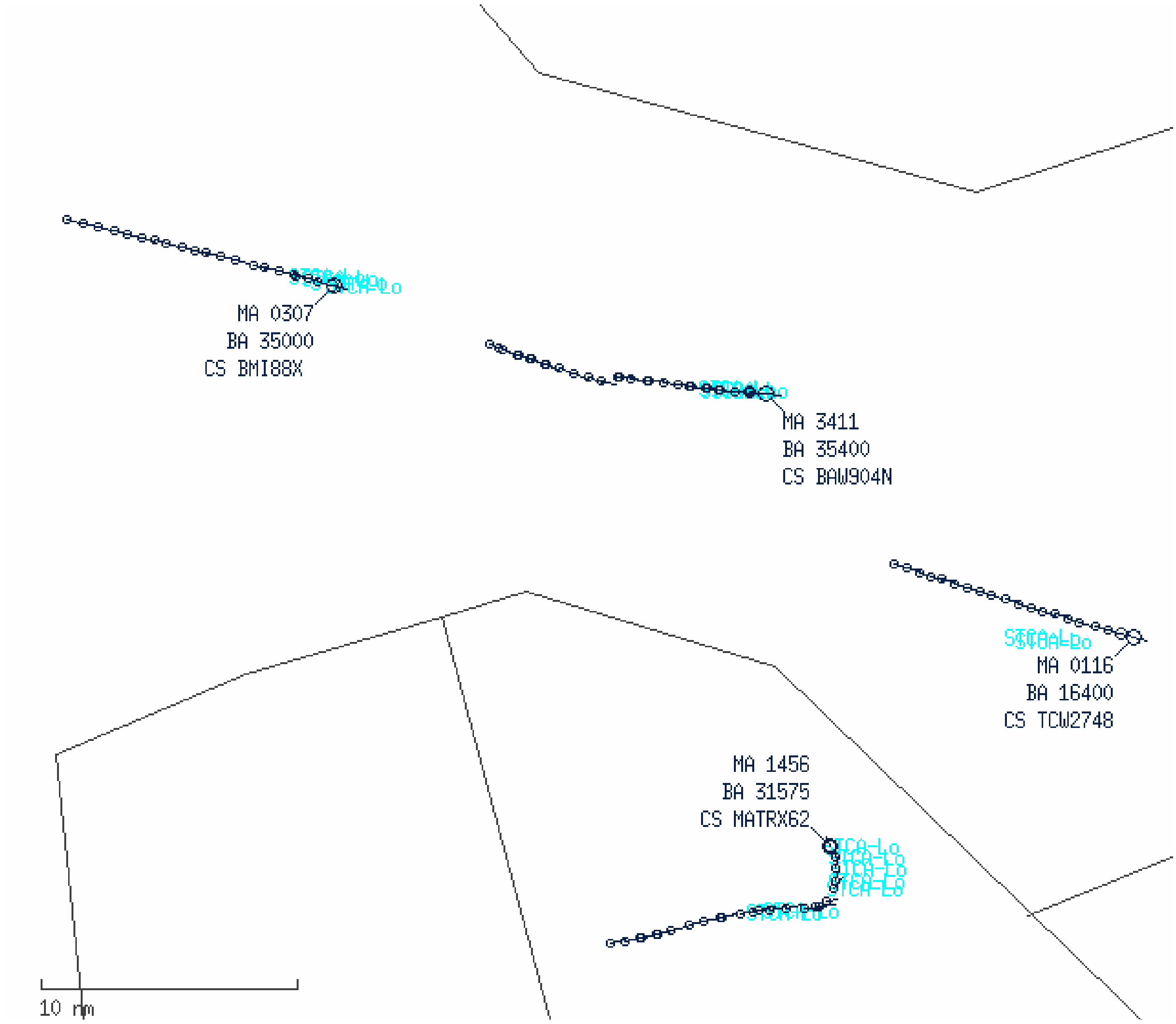
Picture 18: Example from F16 exercise. STCA Warning between MATRX62 (in Namur) and a civil aircraft HEJ3012 (in airway) at 10:47:45.



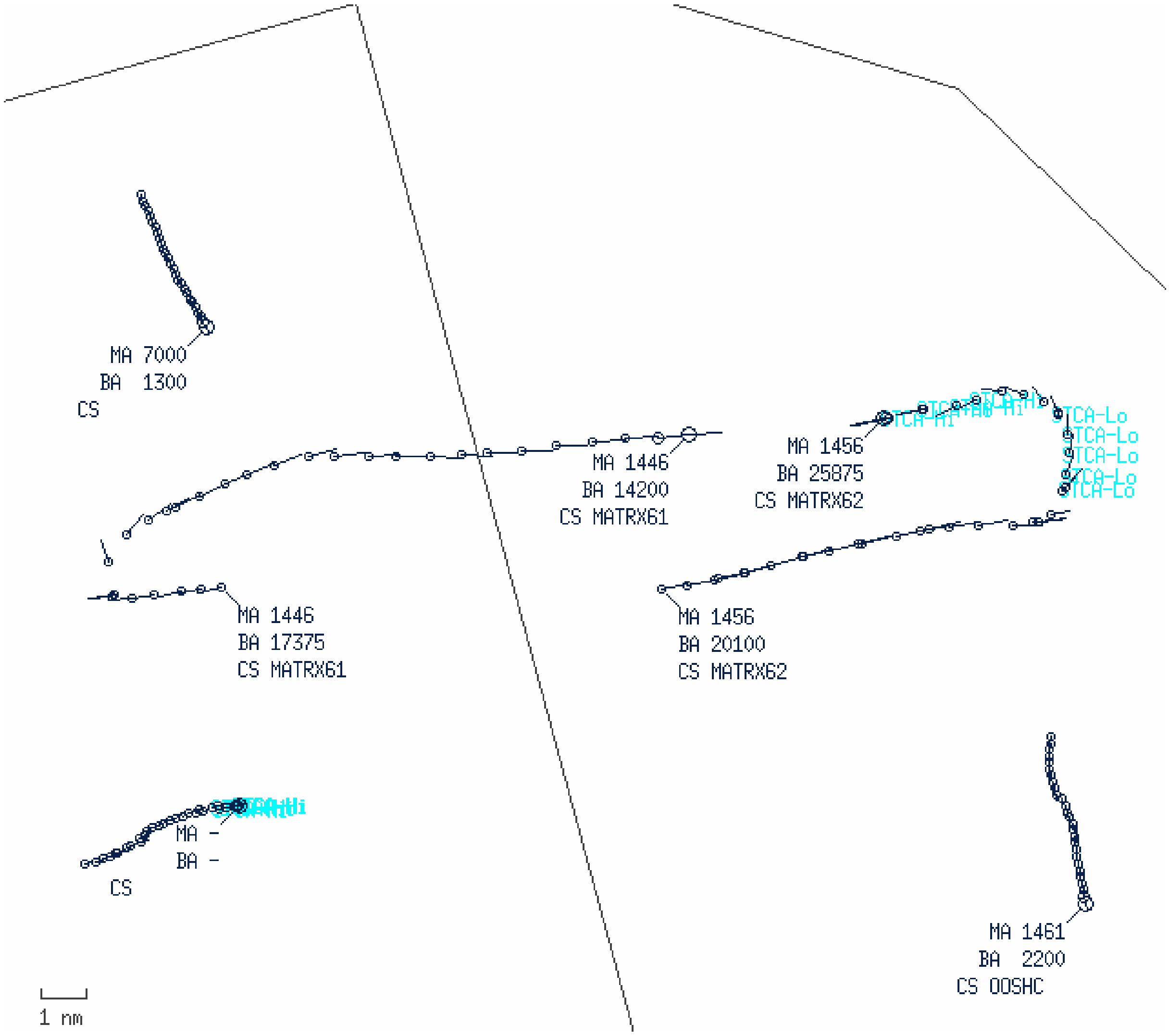
Picture 19: Example from F16 exercise. A wanted STCA alert between MATRX62 and A1432 (track number 397) in military formation.



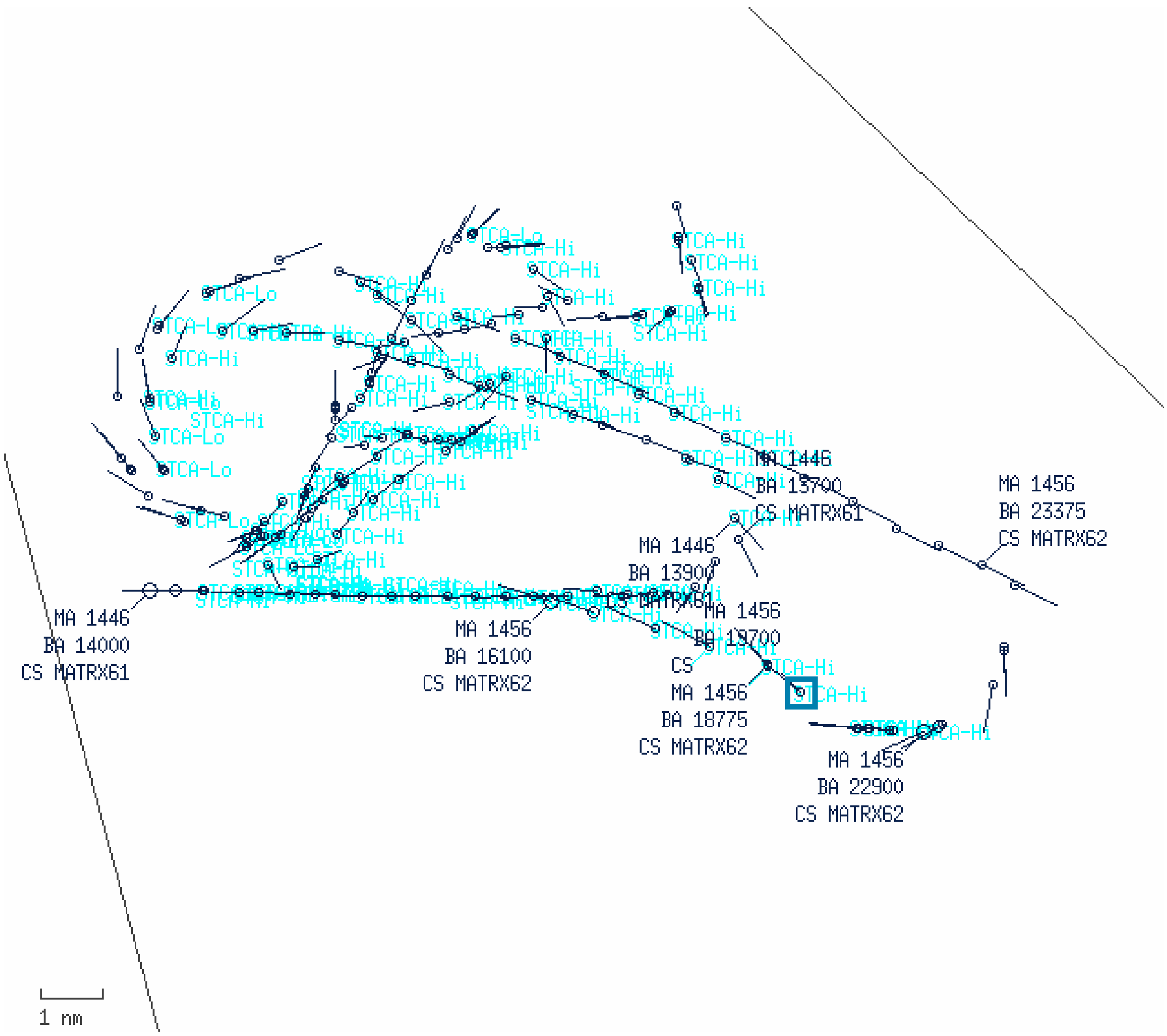
Picture 20: Example from F16 exercise showing a wanted STCA alert between MATRX61 and MATRX62.



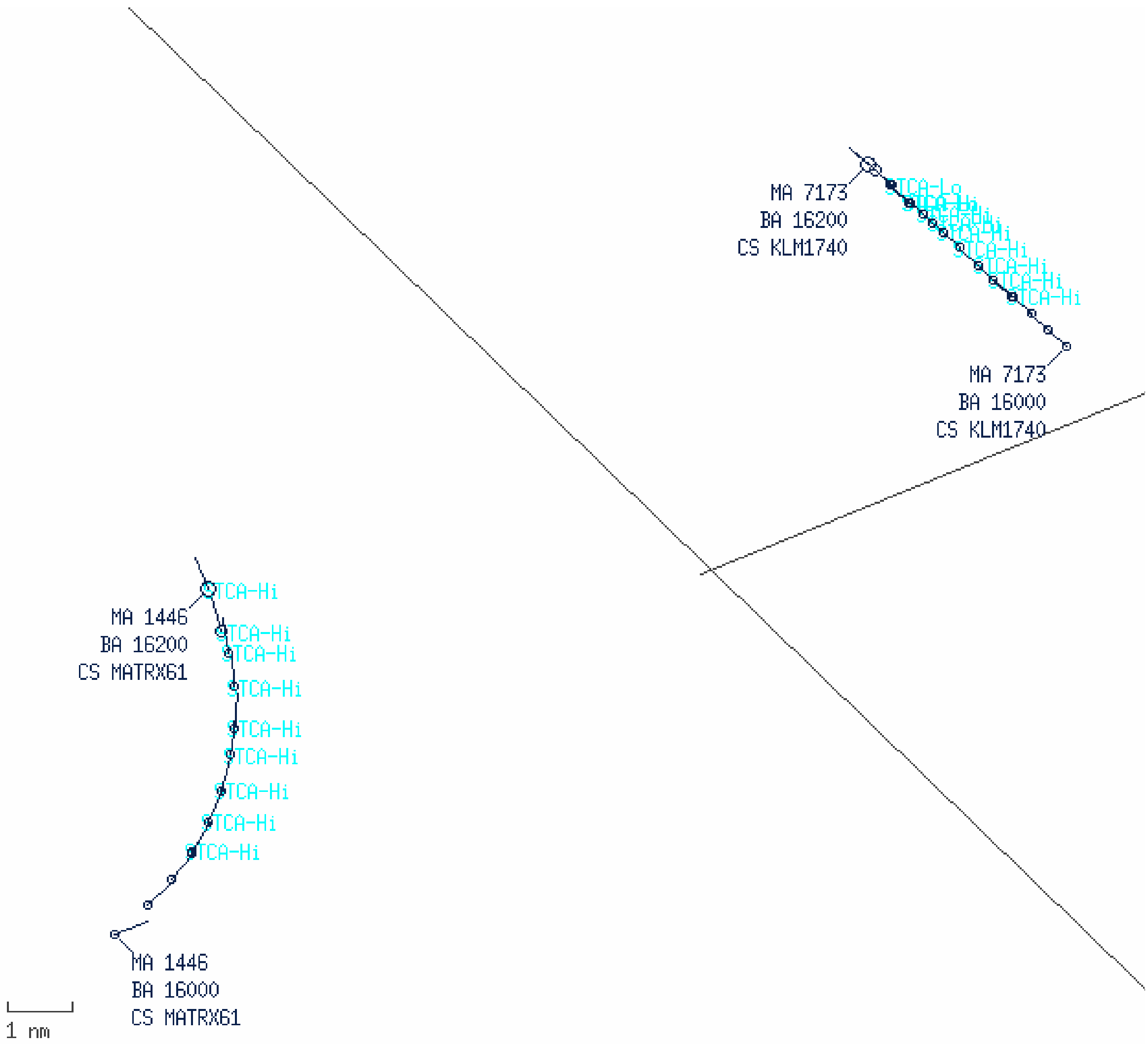
Picture 21: Example picture from F16 exercise. MATRX62 produces STCA warnings with three civil aircraft in the adjacent airway.



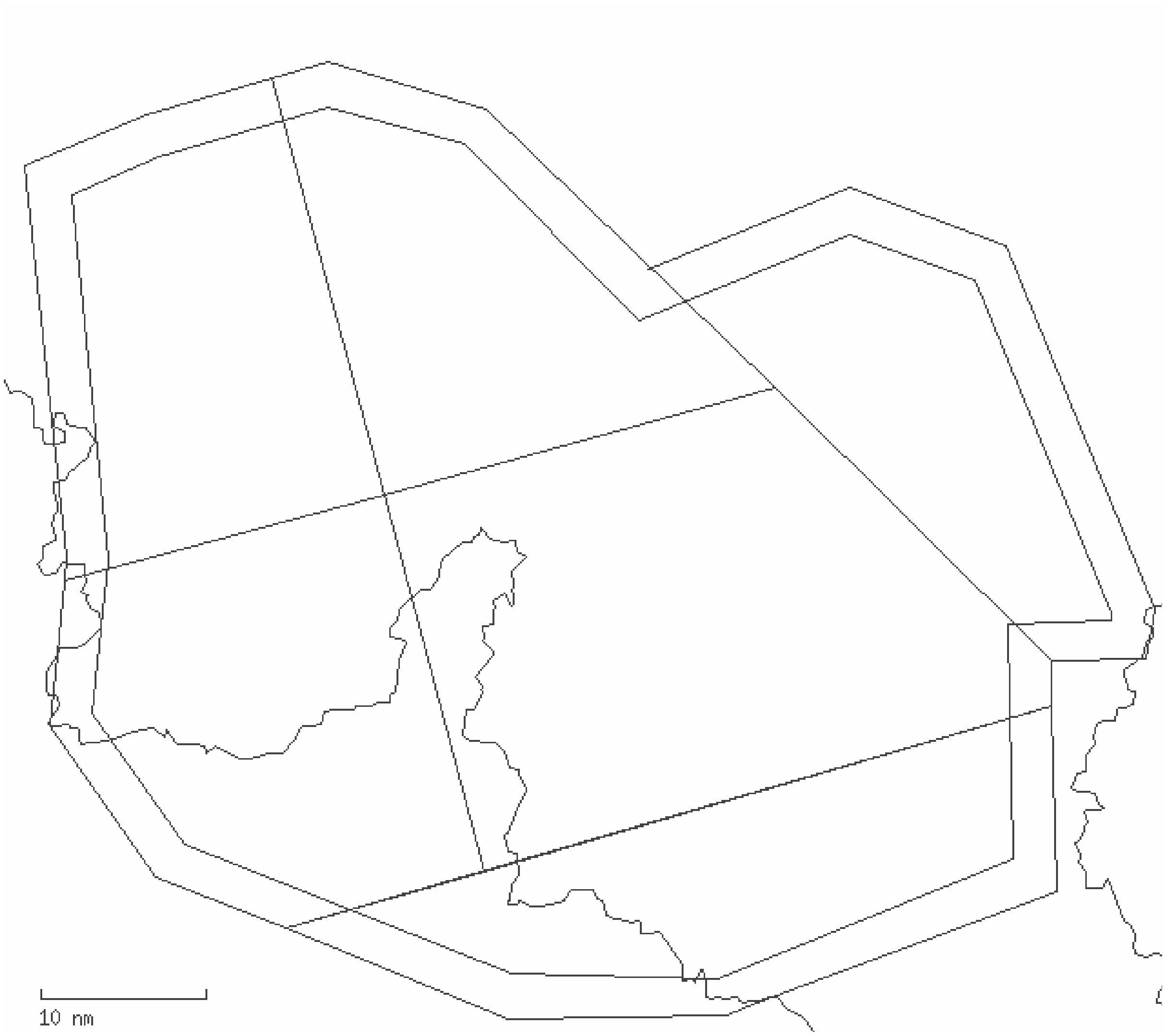
Picture 22: Example picture from F16 exercise. MATRX62 alerts with a primary track in the adjacent aerobatic area. There is no alert with MATRX61 because of the use of block flight levels.



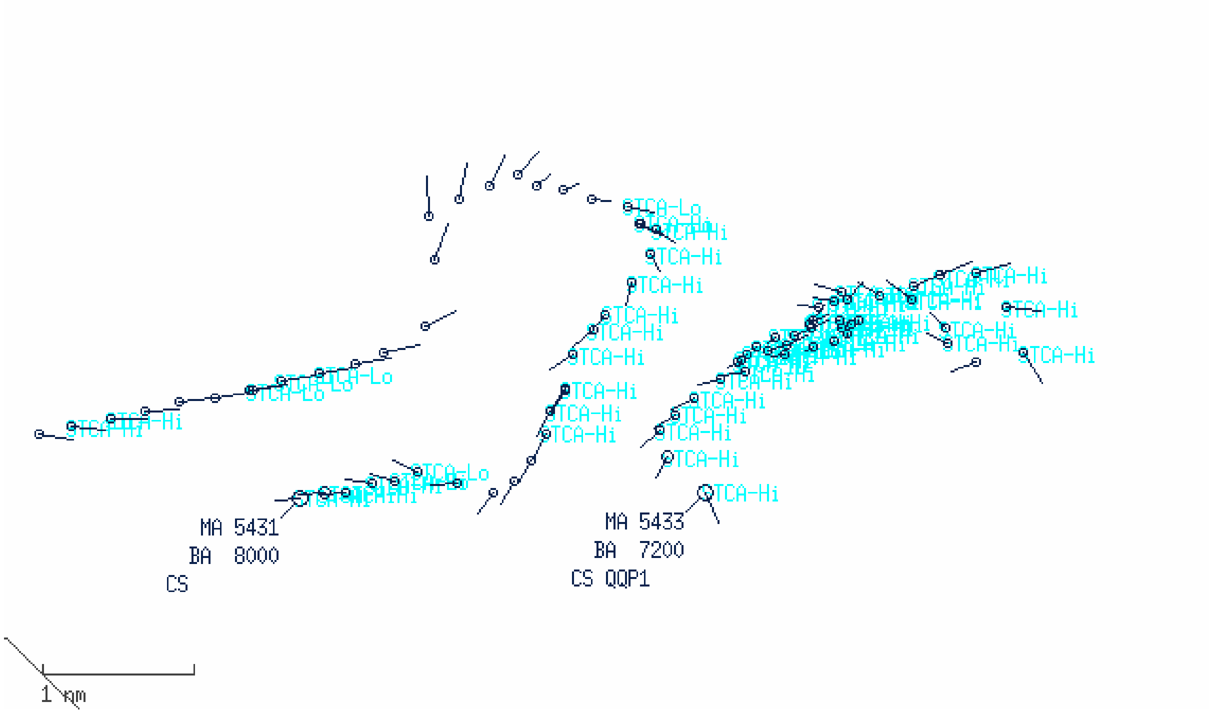
Picture 23: Example picture from F16 exercise. MATRX61 and MATRX62 rejoin into formation.



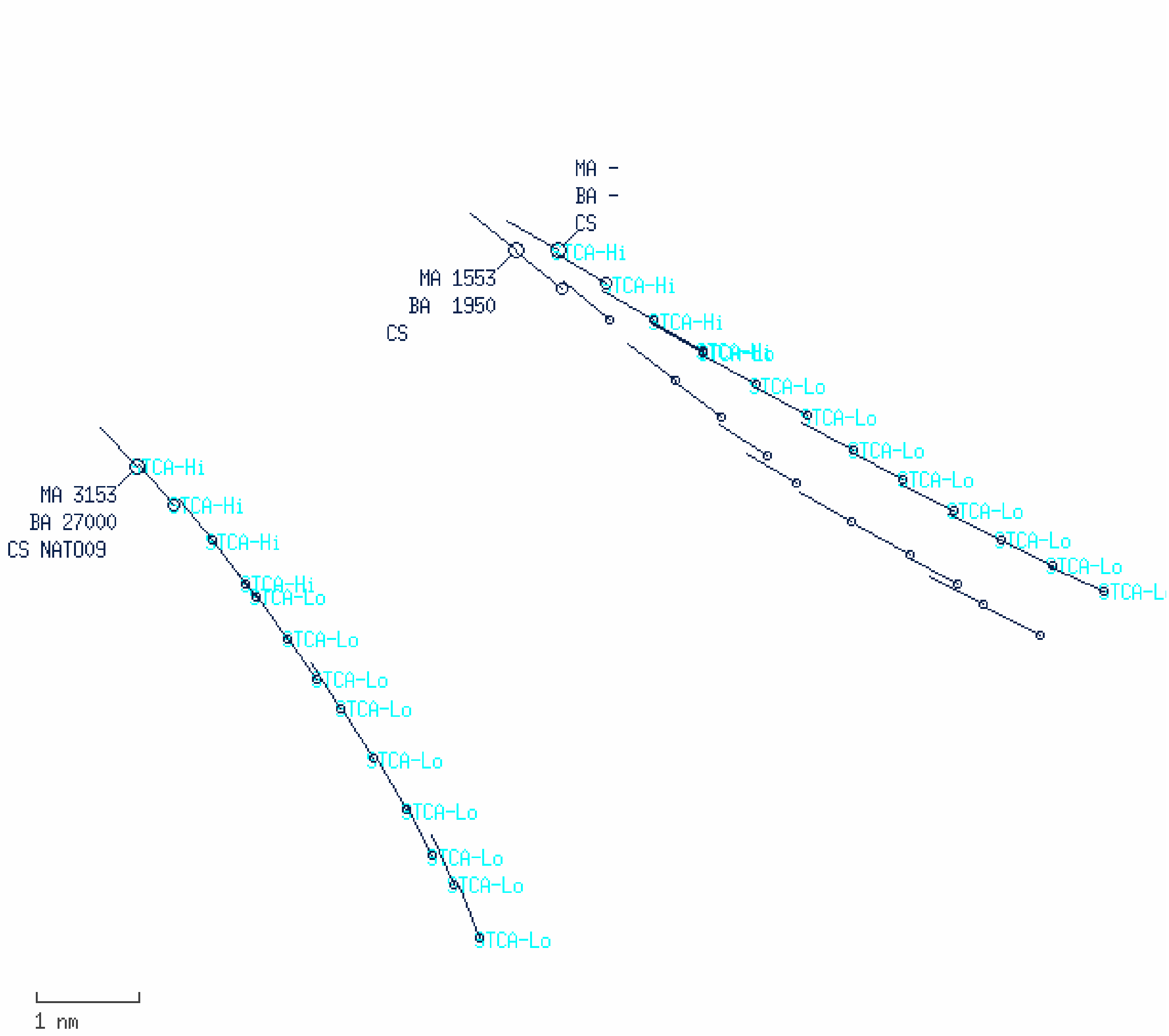
Picture 24: Example picture from F16 exercise. According to ATCC Semmerzake this may be considered a wanted alert, as the flight was coordinated with Belgocontrol to cross the airway at FL160. The Semmerzake controller took the action to climb the aircraft to FL170 in order to avoid a conflict. However, the Belgocontrol controller did the same thing. Finally, the Semmerzake decided not to cross the airway and turn MATRX61 away.



Picture 25: Map showing the southerly aerobatic areas (Namur, Charleroi, Givet, Beauraing, Durbuy, Neufchateau) and the inner aerobatic area.



Picture 26: A nuisance alert between a pair of military aircraft performing exercises in a training area just North East of Namur aerobatic area. This alert could be suppressed by the use of specific “training” SSR codes for use strictly by aircraft undergoing military exercises.



Picture 27: This picture shows a nuisance alert between a wingman in a formation and another nearby aircraft.

ANNEX 2 MAPS OF AEROBATIC AREAS

TRA South Aerobatic Areas

Namur: FL095 to UNL

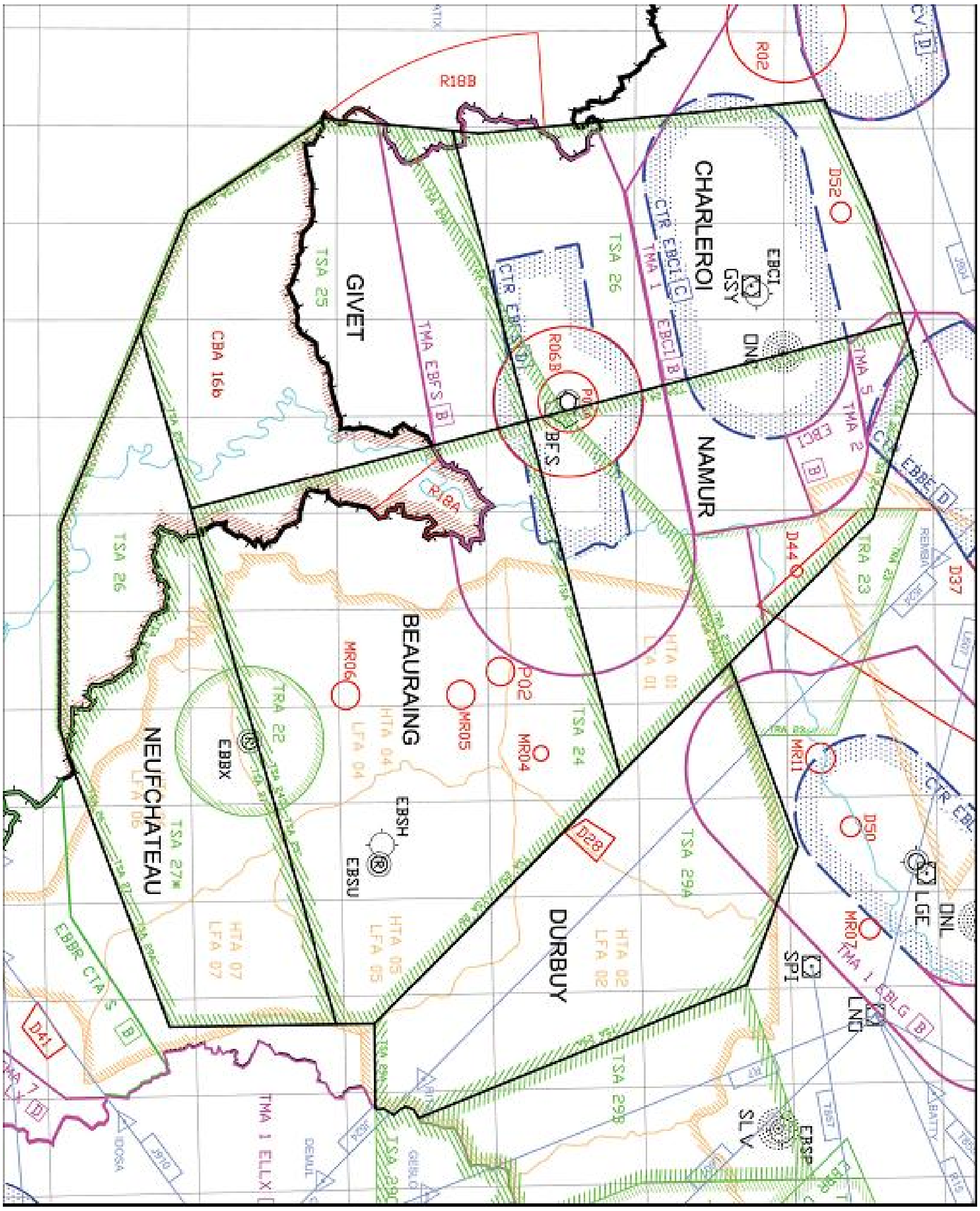
Givet: FL065 to UNL

Neufchateau: FL065 to UNL

Beauraing: FL065 to UNL

Charleroi: FL055 to UNL

Durbuy: FL055 to UNL

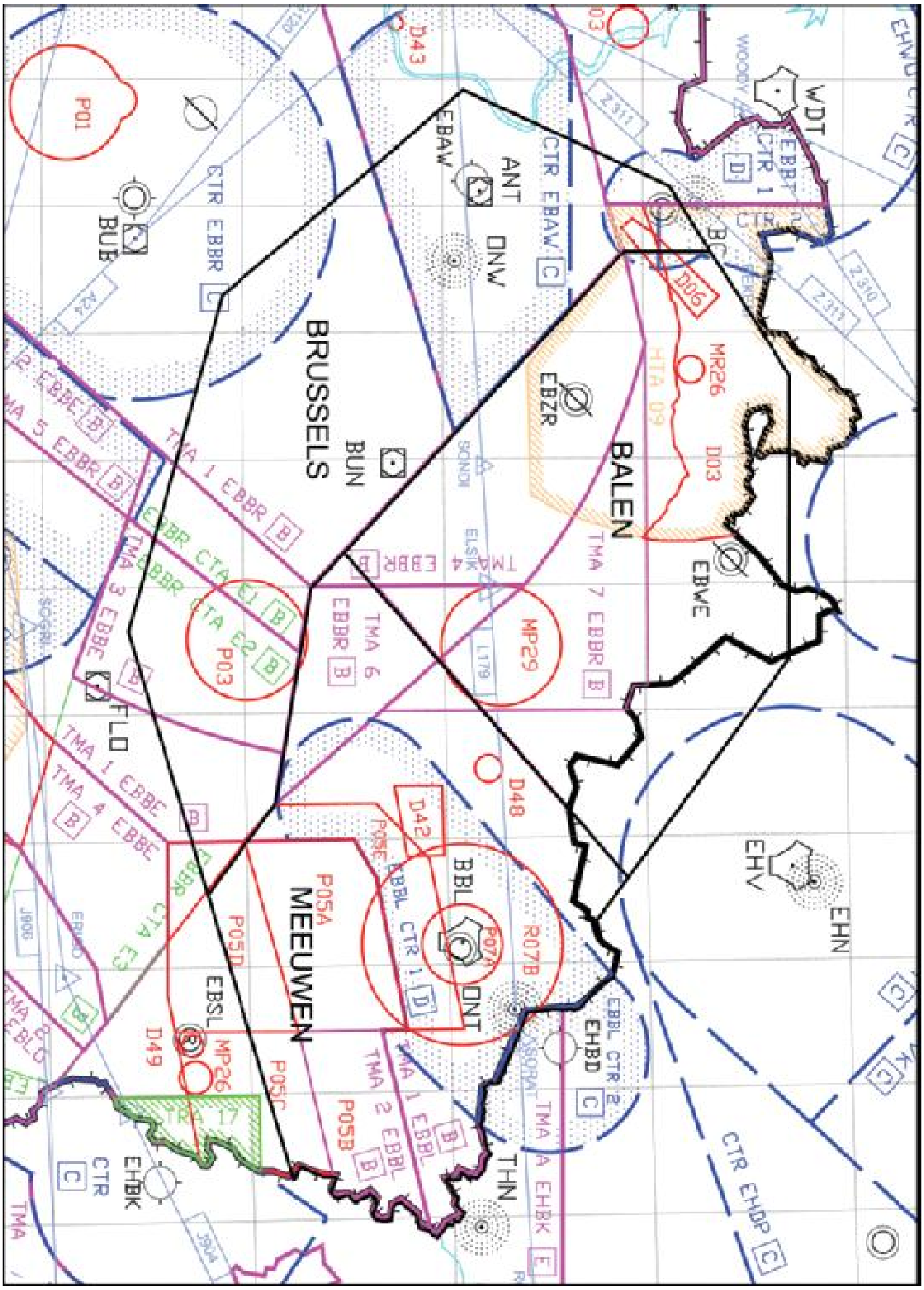


TRA North Aerobatic Areas

Brussels: FL195 to UNL

Balen: FL095 to UNL

Meeuwen: FL095 to UNL



ANNEX 3 STCA MODEL – EXAMPE INPUT AND OUTPUT FILES

Example Region / Parameter File

```
-- BelgoMil airspace

REGION_1

-- Floor (feet)

0

-- Ceiling (feet)

99000

-- LowerSeparationFlightLevel (feet)

28500

-- UpperSeparationFlightLevel (feet)

41000

-- CoarseFilterPredictionTime (seconds)

300

-- CoarseFilterLateralSeparation (NM)

6.0

-- CoarseFilterVerticalSeparation (feet)

100000

-- LinearPredictionTime (seconds)

300

-- LinearPredictionLateralSeparation (NM)

5.0

-- LinearPredictionStepTime (seconds)

60

-- LinearPredictionVerticalSeparationLower (feet)
```

```
1000
-- LinearPredictionVerticalSeparationRVSM (feet)
2000
-- LinearPredictionVerticalSeparationUpper (feet)
2000
-- UseCFLFlag (boolean)
1
-- LinearPredictionImminentTime (seconds)
300
-- LinearPredictionConflictCount (int)
2
-- LinearPredictionCycleCount (int)
3
-- LinearPredictionWarningTime (seconds)
300
-- LinearPredictionLatSepPSR (NM)
5.0
-- LinearPredictionWarningTimePSR (seconds)
300
--
POLYGON_POINTS
52.0000N|01.3000E
52.0000N|07.3000E
48.5000N|07.3000E
48.5000N|01.3000E
52.0000N|01.3000E
```

--

Example STCA Model Results File

Results of Reference STCA Model V0.1 for Belga Radar

Pairs File = ../CFCollector/Complex1.pair
Cycle Period = 5 seconds
Region File = STCATest1a.par

Number of Pairs = 59

Pair Numb	Categ	Track Num1	Track Num2	Mode A1	Mode A2	Height A/C1	Height A/C2	Time HH:MM:SS	Region Num	strt cycl	Durn Secs
8	0	00407	00405	3505	0000	9800.0	0.0	09:40:33	1	18	5
19	0	00484	00316	0337	0000	37000.0	0.0	09:43:13	1	46	70
23	0	00316	00038	1437	6327	20100.0	0.0	09:41:08	1	21	115
43	0	00316	00270	0000	5250	0.0	35000.0	09:43:18	1	23	>=85
46	0	00356	00316	4621	0000	1025.0	0.0	09:43:58	1	23	5
48	0	00163	00316	0556	0000	37000.0	0.0	09:44:03	1	22	>=40
52	0	00335	00316	7111	0000	6875.0	0.0	09:44:18	1	23	>=25
58	0	00356	00191	4621	1437	925.0	1550.0	09:44:48	1	21	>=15

Total Conflicts = 8
Total Pairs With Conflicts = 8

VFR SSR Code List

The VFR SSR code list is shown below. Each line in the list specifies a modeA code, a minimum and maximum speed and the minimum and maximum assumed height.

In the STCA model, if an aircraft has no mode C, has a mode A code in the list, and has a speed within the define range, then the aircraft is assumed to be within the defined height band.

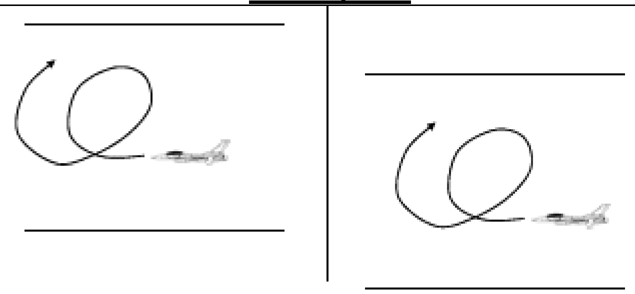
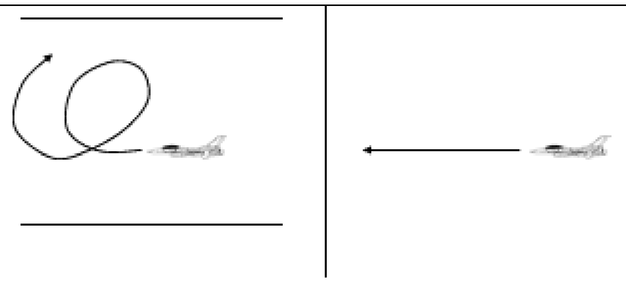
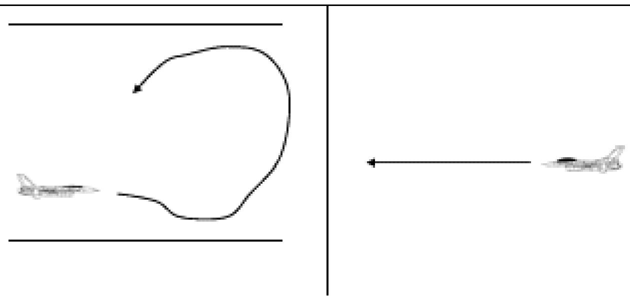
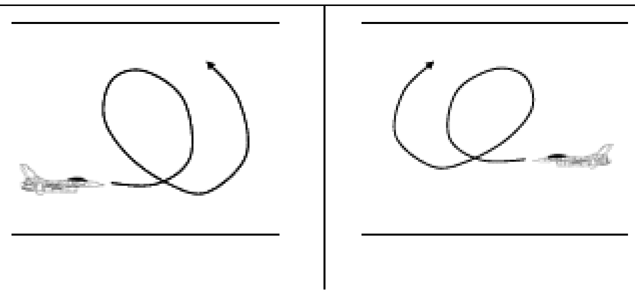
The list has been shortened here, rather than show an entry for every code in the 46 code block.

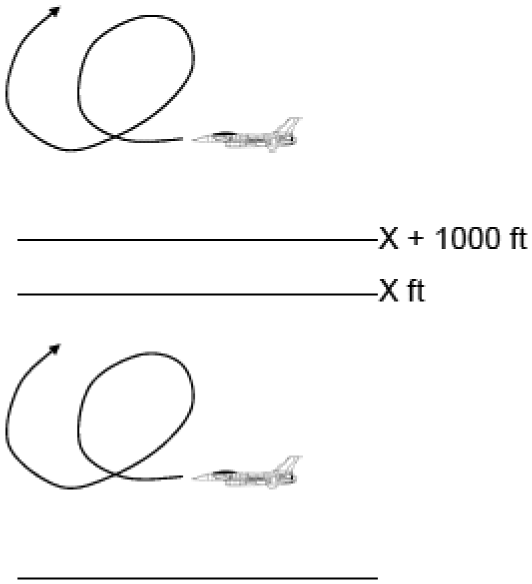
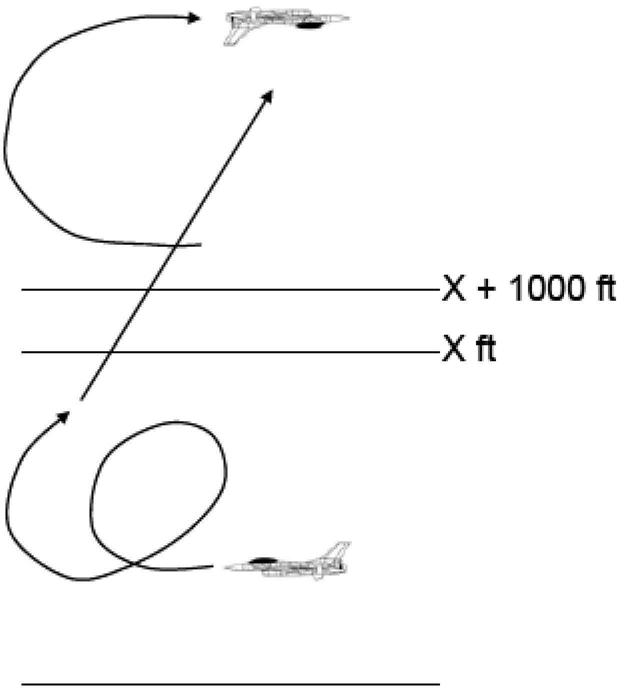
ModeA	Min Speed	MaxSpeed	MinHgt	MaxHgt
0000	0	240	0	9000
0021	0	240	0	9000
0033	0	240	0	9000
2000	0	240	0	9000
3331	0	240	0	9000
4601	0	240	0	4500
..	..	…	..	…
..	..	…	..	…
4677	0	240	0	4500
7000	0	240	0	9000

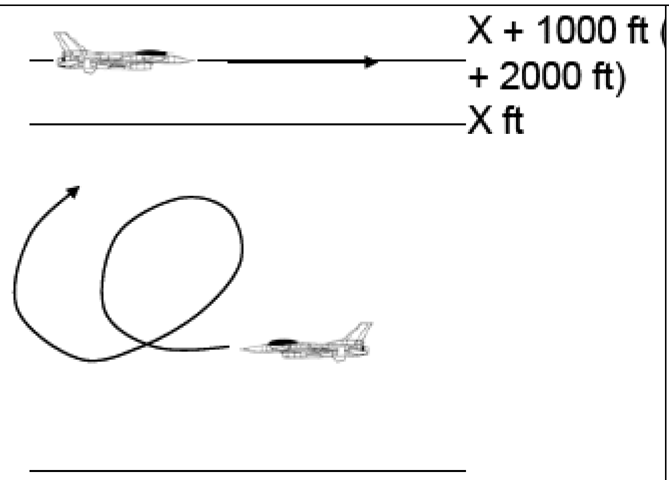
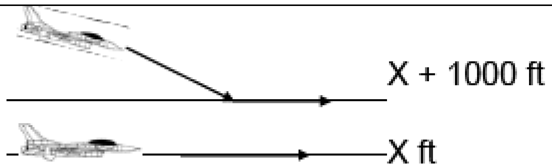
ANNEX 4 INFORMATION RELATING TO THE F16 EXERCISE

Test Card for the F16 exercise

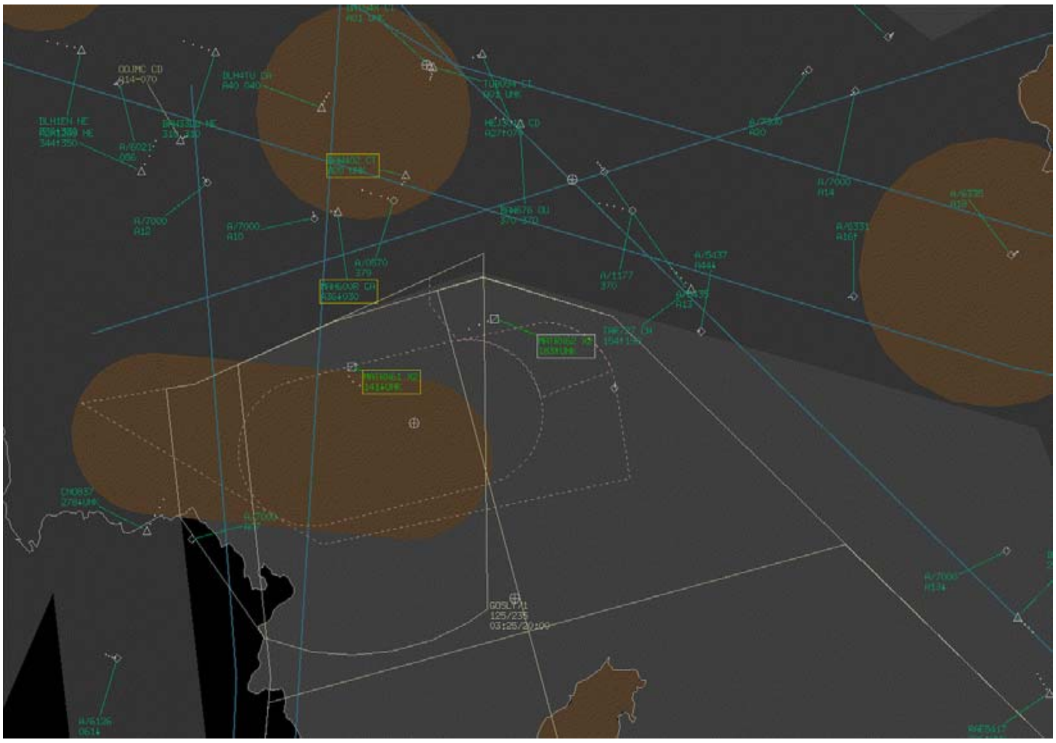
<u>F16 STCA Test Card</u>

Set Up	**Description**	**Remarks**
1 (Ref 4.2. 1)		- A and B in two separate areas adjacent to civil airways. - Blocks assigned by ATCC. - Aerobatics to be performed “close" to the border
2 (Ref 4.3. 1)		- A and B in two separate areas and remains inside their respective areas. - Blocks assigned by ATCC.
3 (Ref 4.3. 1)		- A and B in two separate areas and remains inside their respective areas. - Altitude of the straight and level jet to be crossed "close" to the border. - Blocks assigned by ATCC.
4 (Ref 4.3. 1)		- A and B in two separate areas. - Blocks assigned by ATCC (same block for A and B).

5 (Ref 4.4. 1)		- A and B in the same area. - Blocks assigned by ATCC (separate blocks for A and B).
6 (Ref 4.4. 1)		- A and B in the same area. - Blocks assigned by ATCC (separate blocks for A and B; below F 195) - A and B visual to cross the block

7 (Ref 4.5.2)		- A and B in the same area. - Block and altitude assigned by ATCC.
8 (Ref 4.5.4)		- A and B in the same area. - Altitude assigned by ATCC.
9 (Ref 4.6. 1)	- A and B joining up in close formation from heir respective areas - A and B crossing REMBA or LGE	- A and B initially in two separate areas. - Altitude assign by ATCC.
10 (Ref 4.6.2)	- A and B crossing REMBA or LGE - A and B splitting to their respective areas	- A and B initially in formation then splitting to two separate areas. - Altitude assign by ATCC.

Screen Shot from the Controller Workstation during the F16 exercise



ANNEX 5 NEW ALERT SUPRRESSION LOGIC

Split Track Detection

Split tracks originated when two military aircraft were flying in formation. In each military formation either one or both aircraft were squawking. The split track would have either a mode A code identical to that of one of the aircraft in the formation, or no mode A code (the mode A code field in the track was zero).

Another feature of split tracks is that they are created in immediate proximity to another aircraft. Since, after the coarse filter, STCA (and the model) considers aircraft in pairs, the proximity of the pair of aircraft at the time of track creation was considered.

The logic is described below.

We consider two tracks, referenced by indexes i and j as track[i] and track[j].

For track i, a flag track[i].created is set to TRUE if the track is in the creation state or was in the creation state in the last 5 seconds (i.e. within the last track update cycle). The same is done for track j.

For track i to be declared split:

1. (track[i].created == TRUE)

and

2. (track[i].modeA == 0)

   or (track[j].modeA == 0)

   or (track[i].modeA == track[j].modeA)

and

3. (Lateral Separation of Tracks < 2 nautical miles)

The same conditions are tested for track j.

If all three conditions are met, then the alert is suppressed for as long as the two tracks (i and j) form a pair by passing the coarse filter.

Military Formation Detection

When in formation, the two or more aircraft stay in close lateral and (usually) vertical proximity, matching each other's manoeuvres and maintaining a very similar speed and heading.

When examining military aircraft in STRACK, formations could be quite easily recognised by considering a number of factors, including:

The proximity of the aircraft

The difference in heading of the two aircraft

The difference in speed of the two aircraft

The height difference of the two aircraft

Although Mode A code assignments could not be relied on to identify military formations, there were certain mode A code combinations which were more prevalent in military formations, than in other situations. For example, two successive mode A codes (e.g. 1401 and 1402) often indicated a high likelihood that the pair were military aircraft. These may or may not have been in formation all the time, but a pair of such aircraft with formation-like geometry could be more positively identified as a military formation pair.

Furthermore, when one Mode A code was zero (i.e. the aircraft was not squawking), and the other was non-zero, this immediately identified the leader and wingman in the formation. Although it was seen that in tight turns, the wingman could be momentarily a fraction of a mile in front of the leader, the overwhelming rule was that the wingman followed the leader.

The military formation detection algorithm works in much the same way that a human would. It examines the various characteristics (proximity, headings, speeds) of the pair situation, assigning weighting to each one. The final decision takes all the characteristics into account.

The advantage of this approach (rather than a simpler Boolean logic) is that the final decision takes all characteristics into account. A military formation pair may look like a military formation in all respects but one. For example, on a turn, the difference in the aircraft headings may be slightly larger than is typical. Simple Boolean logic, with maximum thresholds for the various characteristics, could fail to detect a military formation, simply because one characteristic happened to fall just outside a threshold.

The military formation logic introduces a number of new parameters, which allow the user flexibility to give appropriate weightings for each situation, and to vary how cautiously the suppression logic is applied.

The new parameters are described in the table:

Parameter	**Description**	**Recommended Value**
MF_Suppress_Current_Cycle_Only	If set, suppress current cycle only, ignore suppression count	0
MF_Suppression_Count	Count at which alert is continuously suppressed	1
MF_Decision_Threshold	Decision threshold taking all factors (weights) into account	1.0
MF_ModeA_SSR_PSR	Weight assigned to pairs where one aircraft is without mode A.	1.2
MF_ModeA_SSR_Plus1	Weight assigned to pairs where mode A codes differ by one (e.g. 1401, 1402)	2.0
MF_ModeA_SSRSameBlock	Weight assigned to pairs of aircraft in the same code block (e.g. 1401 1435)	0.9
MF_ModeA_SameCode	Weight assigned to pairs of aircraft with identical mode A code (e.g. 1401, 1401)	2.0
MF_ModeA_Other	Weight assigned to all other Mode A code combinations	0.9
MF_L_lt1p3	Weight assigned to pairs of tracks within lateral distance of 1.3 NM	1.5
MF_L_lt2p6	Weight assigned to pairs of tracks within lateral distance of 2.6 NM	0.9
MF_L_lt3p9	Weight assigned to pairs of tracks within lateral distance of 3.9 NM	0.5
MF_L_gt3p9	Weight assigned to pairs of tracks with a lateral	0.25

	distance of 3.9 NM or more	
MF_Heading_lt20	Weight assigned to pairs of tracks with a heading difference less than 20 degrees	1.4
MF_Heading_lt45	Weight assigned to pairs of tracks with a heading difference less than 45 degrees	1.0
MF_Heading_gt45	Weight assigned to pairs of tracks with a heading difference of 45 degrees or more	0.5
MF_Speed_lt30	Weight assigned to pairs of aircraft with a speed difference of less than 30 knots	1.6
MF_Speed_lt60	Weight assigned to pairs of aircraft with a speed difference of less than 60 knots	1.1
MF_Speed_lt90	Weight assigned to pairs of aircraft with a speed difference of less than 90 knots	0.8
MF_Speed_gt90	Weight assigned to pairs of aircraft with a speed difference of 90 knots or more	0.4
MF_Height_lt25	Weight assigned to pairs of aircraft with a height difference of less than 25ft	1.6
MF_Height_lt150	Weight assigned to pairs of aircraft with a height difference of less than 150ft	1.2
MF_Height_lt1500	Weight assigned to pairs of aircraft with a height difference of less than 1500ft	0.7

MF_Height_gt1500	Weight assigned to pairs of aircraft with a height difference of 1500ft or more	0.4

The test for military formation conditions is made for each pair of aircraft on each track update cycle (or STCA cycle). Again, the tracks are identified as track i and track j.

Firstly, if the leader and wingman can be identified in the pair, then the first test checks that the wingman is not significantly in front of the leader. Some tolerance, 0.5NM, is given to allow for the wingman to momentarily progress ahead of the leader in a turn.

```
If ((track[i].modeA == 0) && (track[j].modeA > 0)

or (track[i].modeA > 0) && (track[j].modeA == 0))

{

        if (track[i].modeA > 0)     /* i is the leader */

        {

                Xleader = track[i].X

                Yleader = track[i].Y

                Headingleader = track[i].Heading

                Xwingman = track[j].X

                Ywingman = track[j].Y

        }

        else   /* j is the leader */

        {

                Xleader = track[j].X

                Yleader = track[j].Y

                Headingleader = track[j].Heading

                Xwingman = track[i].X

                Ywingman = track[i].Y
```

}

AngleToLeaderPostion = arctan (Xwingman – Xleader , Ywingman - Yleader)

OffsetAngle = AngleToLeaderPostion – HeadingLeader

AlongTrackOffset = LateralSeparation * cos(OffsetAngle)

If (AlongTrackOffset > 0.5) /* wingman is more than 0.5 miles in front of the leader – not a mil formation */

{

Stop military formation processing for this pair on this cycle and do not suppress the alert.

}

else continue military formation processing as described below.

}

Next the various weighting factors are computed, starting with the mode A code weighting, Weight_ModeA.

If (one track has mode A == 0)

Weight_ModeA = MF_ModeA_SSR_PSR

else if (mode A codes identical)

Weight_ModeA = MF_ModeA_SameCode

else if (mode A codes differ by one)

Weight_ModeA = MF_ModeA_SSRPlus1

else if (mode A codes in the same block)

Weight_ModeA = MF_ModeA_SSRSameBlock

else

Weight_ModeA = MF_ModeA_Other

Weight_L, the lateral separation weighting is computed as follows:

If (lateral separation < 1.3 NM)

    Weight_L = MF_L_lt1p3

else if (lateral separation < 2.6 NM)

    Weight_L = MF_L_lt2p6

else if (lateral separation < 3.9 NM)

    Weight_L = MF_L_lt3p9

else

    Weight_L = MF_L_gt3p9

The weighting factor for the heading difference between the two tracks is Weight_Head, and is computed as follows:

If (heading difference < 20 degrees)

    Weight_Head = MF_Heading_lt20

else if (heading difference < 45 degrees)

    Weight_Head = MF_Heading_lt45

else

    Weight_Head = MF_Heading_gt45

The weighting factor for the speed difference between the two tracks is Weight_Speed, and is computed as follows:

If (speed difference < 30 knots)

    Weight_Speed = MF_Speed_lt30

else if (speed difference < 60 knots)

    Weight_Speed = MF_Speed_lt60

else if (speed difference < 90 knots)

    Weight_Speed = MF_Speed_lt90

else

Weight_Speed = MF_Speed_gt90

The weighting factor for the height difference between the two tracks is Weight_dZ, and is computed as follows:

If (one track has no mode C)

Weight_dZ = 1.0

else if (height difference < 25 feet)

Weight_dZ = MF_Speed_lt25

else if (height difference < 150 feet)

Weight_dZ = MF_Speed_lt150

else if (height difference < 1500 feet)

Weight_dZ = MF_Speed_lt1500

else

Weight_dZ = MF_Speed_gt1500

Having computed each of the individual weighting factors, the overall weighting is calculated as follows:

OverallWeighting = Weight_ModeA x Weight_L x Weight_Head

x Weight_Speed x Weight_dZ

If the OverallWeighting is sufficient:

i.e. OverallWeighting >= MF_Decision_Threshold

then the pair is meets the military formation conditions on this cycle.

Finally, if MF_Suppress_Current_Cycle_Only is set to 1 then the STCA alert is suppressed on every cycle that the military formation conditions remains true.

Otherwise a confirmation count is incremented for the pair each time the military formation conditions are true. Once the confirmation count reaches MF_Suppression_Count, the STCA alert is suppressed continuously as long as the pair exists (i.e as long as it passes the coarse filter).

END OF DOCUMENT