Distributed Mission Training – How Distributed Should It Be?

Ms Ebb Smith, BSc
Defence Science and Technology Laboratory
Rm 126, Bldg 115
Bedford Technology Park
Thurleigh, Bedfordshire
MK41 6AE
United Kingdom
E-mail: mesmith@dstl.gov.uk

Ms Heather McIntyre, MSc
Defence Science and Technology Laboratory
Rm 126, Bldg 115
Bedford Technology Park
Thurleigh, Bedfordshire
MK41 6AE
United Kingdom
Email: hmmcintyre@dstl.gov.uk

Summary

The UK's MoD has funded a programme of applied research[1] to explore the benefits to be gained from using networks of simulator, or Synthetic Training Environments (STEs), for multi-role air mission training (i.e collective training[2]). Within the UK the use of networked simulation in this context has become known as Mission Training through Distributed Simulation (MTDS). Within the US it is known as Distributed Mission training (DMT). The Defence and Science Technology Laboratory (Dstl) and QinetiQ have undertaken the MoD sponsored research via a series of trials. The trials have been conducted under the banner heading of RAPTORS[3]. To date four trials have taken place; Ebb and Flow, SyCOE, VirtEgo and SyCLONE. All have been conducted using the synthetic Composite Air Operation (COMAO) test-bed created specifically to assess the potential of MTDS. Combat-ready, front-line aircrew and an expert White Force from the UK's Air Warfare Centre (AWC) Tactical Wing and Training have participated in all four trials. The research has indicated that there is, potentially, much to be gained from the use of networked simulation for MTDS. The question remains as to the extent that participants should or could be distributed during MTDS exercises. This is particularly pertinent if the aspiration is to use networked simulation for coalition training, because, of necessity this would require some training participants to be geographically dispersed. The last two trials therefore included a Wide Area Network (WAN) to link together research facilities in Canada, the UK and US. This paper will discuss the outcome of these trials with particular reference to SyCLONE.

Overview of VirtEgo and SyCLONE

Trial VirtEgo[4] took place in November 2001, whilst Trial SyCLONE[5] was undertaken in January 2003. The UK elements of the trials were funded by MoD and Strike Command, with the collaborative aspects carried out under the auspices of The Technical Co-operation Panel[6] (TTCP). As in the previous trials, VirtEgo and

[1] Under the sponsorship of the Director of Equipment Capability (Theatre Airspace)

[2] 'Collective mission training' is defined as two or more teams training to interoperate in an environment defined by a common set of collective mission training objectives, where each team fulfils a different military role. NATO SAS-013 Study

[3] Research into Aircrew Performance and Teamwork using Operationally Realistic Scenarios

4 VirtEgo - Virt stands for virtual and Ego a conscious thinking subject

5 SyCLONE - Synthetic CoaLition Operation in a Networked Environment

6 A long-term UK/US/CA collaborative project is being developed to take this research forward under the auspices of two groups of the Technical Co-operation Panel (TTCP); the Human Resources and Performance Group, Technical Panel 2 (HUM TP-2, Training Technology) and the Aerospace Systems Group, Technical Panel 1 (AER TP-1 Aerospace Operational Analysis and Simulation).

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SyCLONE were designed to execute emulation of a COMAO and incorporated all mission phases: tasking, brainstorming/planning, briefing, mission execution and debriefing [Ref 1]. The trials were modelled on live collective training exercise such as the NATO Tactical Leadership Programme (TLP) and UK Tactical Leadership Training (TLT) and the US Red Flag exercises. The major caveat being that the live collective training exercises have participants co-located. For elements of VirtEgo and SyCLONE, participants were geographically dispersed. This was a critical aspect of the research.

The synthetic environment created for the VirtEgo and SyCLONE enabled operational aircrew, based in the UK, Canada, and US to perform a COMAO based training exercise. For all missions, the rules of engagement (ROE), and special instructions (SPINS) were based on those of the theatre in question and the missions were designed to enable the aircrew to fly in accordance with coalition tactics and doctrine.

For all four of the RAPTORS trials, a team from the AWC Tactical Wing provided an expert White Force (WF). They provided a critical element of the exercise management function. They also provided expert assessment of collective performance throughout each mission day. This mirrors the role they perform in facilitating the UK's national air collective training exercises.

The manned participants in the trials formed part of a small package of aircraft flying a coalition mission within a shared synthetic battlespace. Other elements of the package, specifically Suppression of Enemy Air Defence (SEAD) assets, were represented during mission execution by computer generated forces (CGF). During planning the SEAD element lead was represented by a WF role player. For each mission day one of the participating aircrew was selected to be the Package Commander (PC) responsible for co-ordinating the package's efforts in order to achieve commander's intent.

The package formed part of a much bigger offensive air support operation, with other coalition missions being flown against hostile ground and air threats within the same timeframe. The added complexity of greater numbers of friendly and hostile forces was provided largely by CGF, with the addition of some manned air threats.

VirtEgo

Trial VirtEgo was the first trial to combine both training and research thrusts. VirtEgo was designed as a 'proof of concept' for preparing front-line Qualified Weapons Instructor (QWI) students for COMAOs in readiness for the two week operational phase (Ops Phase) of their CQWI training programme. An encrypted trans-atlantic WAN to Air Force Research Laboratory (AFRL) in Mesa, Arizona, US was also implemented to allow a coalition package to fly together in a shared synthetic battlespace. The WAN included a 'stealth' link between AFRL and Defence Research and Development (DRDC) Laboratories, Toronto, Canada. An initial distributed planning, briefing and debriefing was also provided. This capability utilised commercial-off-the shelf (COTS) technology and took the form of a video-teleconferencing (VTC) system and interactive whiteboards i.e. a SmartBoard™.

The SmartBoard™ provides a touch sensitive screen, of relatively large physical area, which is convenient for multiple users. The Smartboard™ technology allows users to write on the board as though it were a dry marker board; these inputs can then be transmitted via Microsoft NetMeeting to other networked SmartBoard™ . Electronic files created at one location can also be shared, thus for example, a PowerPoint presentation can be viewed simultaneously at different locations.

The findings from VirtEgo suggested that it was possible to combine training and research objectives within one trial, but that the technology must first be robust and proven. [Ref 2]. A perceived utility in pre-deployment training for ab-initio crews and general COMAO refresher training was also found. However, the ability of the STE to support mission training for dispersed participants was not proven. There were technical difficulties and front-line crews did not fly the AFRL simulators. This may have biased the findings.

SyCLONE

From the UK perspective, Trial SyCLONE was designed to explore the impact of distributed versus colocated mission training on the UK participants (aircrew and WF). In previous trials the UK players had been colocated[7] [Ref 3]. The coalition aspects of the research were maintained via long-haul transatlantic links to both AFRL in the US and Defence Research and Defence Canada, Toronto in Canada. The manned elements comprised:

For Trial SyCLONE the manned participants were:

- 1 x UK Ground Attack (GA) 4-ship (Jaguars)
- 1 x UK Air-to Air (A-A) 4-ship (Tornado F3s)
- 1 x US Swing role 4-ship (F-16Cs)
- 1 x Canadian GA 4-ship[8] (CF-18s).

The training research focus in SyCLONE was on the effects of distribution on planning and co-ordination and ultimately on execution of the mission itself. While simulation is deemed to be essential to explore the effectiveness of the mission plan, it was not the focus of training research in this trial. Aircrew may already have some experience of distributed briefing/debriefing in military exercises, such as Cope Thunder. Collaborative planning of complex missions is not something that aircrew normally carried out in a distributed way during operational training.

The importance of the planning phase can often be overlooked in simulation exercises when the emphasis tends to be on the mission and the time spent in the simulator. However, anecdotal evidence suggests that up to 80 to 90% of the benefit of participation in large scale, complex exercises, whether live or simulated, comes from involvement in the planning process. The stated objective of planning is to generate a product, namely the plan. Really one of the most important benefits of planning is the provision of a rigorous, structured way to learn about a problem space and therefore to develop judgement [Ref 4].

During trial SyCLONE, UK crews planned, briefed, debriefed their missions in separate locations but at the same site. As in VirtEgo they were using technology specifically provided for the purpose, namely VTC and SmartBoards™ to communicate with each other. The WF was also kept separate from the aircrews. This meant that in effect the distributed STE comprised five dispersed nodes: three at Bedford UK, one at AFRL US and one at DRDC Canada. A schematic is given in Figure 1.

[7] Little previous research has been done on the impact of distribution on teamwork and team effectiveness in real world task environments. A comprehensive review of teamwork research, estimated that of more than 4,000 team studies, 95% were to do with colocated teams performing tasks in laboratory conditions. From the remainder, very little can be deduced about the consequences of distribution for effective real world training.

[8] The CF-18 4-ship comprised two man-in-the loop players and 2 CGF wing-men.

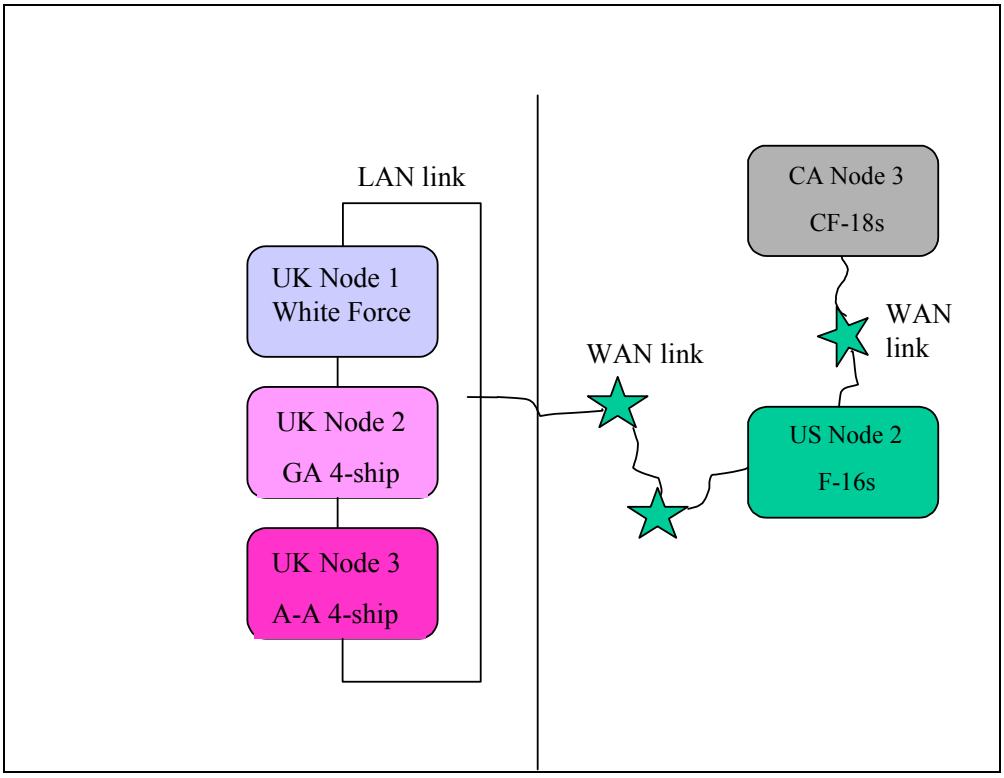

Figure 1: Experimental set-up with UK forces distributed

SyCLONE – findings

Analysis was conducted using a variety of assessment methods and tools. These included questionnaires, interviews and extensive use of subject matter expert opinion (the WF). A preliminary analysis of the data indicted that SyCLONE did not provide as fully optimised a training environment for the UK participants as did the previous three trials. There were a number of variables and confounding factors that contributed to this outcome. These included:

- Late mission days for UK crews
- Late tasking of aircrew to participate in the trial
- Current ops tempo placed an additional burden on WF
- Use of new technology, particularly for distributed planning, briefing and debriefing
- Some of the more specific findings and analysis are now discussed in turn.

Distributed planning, briefing and debriefing: The research team developed a very comprehensive concept of operation (conops) for distributed Planning, Briefing and Debriefing activities (PBD). The results of questionnaires given to aircrew indicated that they were happy with the instructions given on how to use the technology but did not feel the PBD system was user-friendly or robust.

The results also indicated that dispersion had impacted upon training value with the greatest effect being felt during the planning phase, resulting in a more 'simplistic' plan being produced. This is not necessarily a desirable outcome and certainly does not exploit some of the more obvious benefits of a complex MTDS environment. On the distributed days, problems were also experienced by the WF who felt unable to function as effectively when dispersed from crews. They believed that their ability to monitor and where appropriate guide the planning process was compromised.

The overall opinion by UK participants was that whilst the PBD technology was usable it detracted from the training benefits. The preference as in previous trials was for colocated synthetic COMAO training, irrespective of whether or not it is representative of real world operations.

To summarise:

- Distributed planning resulted in a simple and less integrated plan which did not fully exploit the capabilities of the other package elements
- The WF felt the Package Commander (PC) was not able to communicate effectively with other members of package
- The WF felt the technology too cumbersome for planning process
- Aircrew observed not as fully immersed in 'total experience' as in previous trials. No real 'buy in' to the synthetic experience, difficult to maintain suspension of disbelief through all phases, hence more critical of the simulation than in previous trials
- Low WF Situational Awareness (SA) on aircrew planning process, resulted in an inability to fully optimise the training environment.

As discussed, the UK crews did manage to have one day colocated where they were able to plan together. The WF provided an assessment of the aircrews performance during planning, briefing and debriefing for each of the four mission days. A summary of this is given below in Table 1 and clearly indicates that the day on which the crews were colocated (mission day four) produced a more comprehensive, well thought out and tactically considered plan.

Table 1: White Force assessment of Trial SyCLONE Planning Phases over Four Mission Days

Mission 1 (distributed)	Mission 2 (distributed)	Mission 3 (distributed but colocated for debrief)	Mission 4 (colocated)
Planning			
• Not able to assess planning phase adequately • PC not able to communicate effectively with other package members • Ist day was perceived as battle with unfamiliar technology	• Not able to assess planning process adequately • Inadequate technology to support overview of distributed planning • PC couldn't communicate effectively with other package members • Technology seemed to impact on ability of aircrew to conduct workup & produce sophisticated plans. Much frustration with the technology • Result is a simpler plan – Force Flow type approach - not able to develop an integrated detailed plan	• Not able to assess planning phase adequately • Same problems as previous days – very little SA on aircrew planning process but slight improvement – more bandwidth & better audio	• Able to assess planning for UK crews. UK planning resulted in better plan than on previous days – more detailed in plan, more tactical thought, using work rounds to overcome tech difficulties to distributed US & CA nodes. • Use of VTC & SmartBoards™ affected distributed planning process – technology too cumbersome to use in normal planning process

It is well understood that a good plan makes for a better mission. The WF view was borne out by subsequent, in-depth post-trial analysis of a number of key events that occurred during SyCLONE's final mission day[9]. Aircrew comments also indicated that this day was preferred to the previous three mission days.

These observations support the findings from previous trials. Previous experience of colocated trials shows that rapport begins to develop between colocated crews after two days together; this is accompanied by a measurable improvement in performance. The effects are illustrated in Figure 2; this figure shows some of the results from an earlier RAPTORS trial (trial SyCOE[10]) which took place in January 2001 [Ref 5]. The data shown are derived from an Assessment Criteria questionnaire, which asks for assessments on thirty-one criteria of effective mission performance. These criteria are shown in table 2.

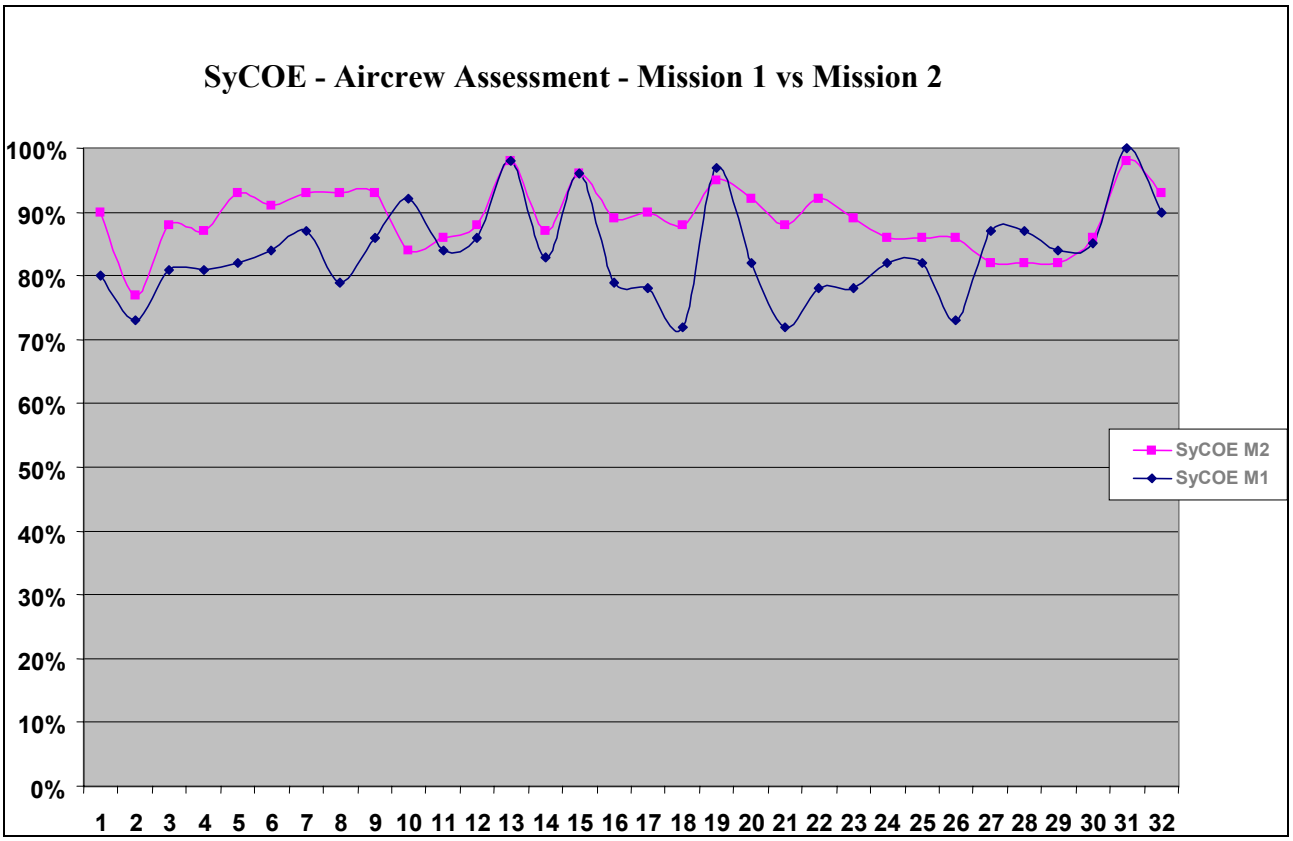

Figure 2: SyCOE aircrew assessment – mission 1 vs mission 2

Aircrew performance started from a good baseline in mission 1 and improved significantly in mission 2. This improvement was particularly marked for three areas:

- appropriate review of tactics as a result of lessons learnt in previous mission,

[9] This analysis is being undertaken by QinetiQ as part of an MoD funded study entitled *Quantifying the Effectiveness of Collective Training*.

[10] The training design of trial SyCOE provided a more appropriate comparison to SyCLONE than VirtEGO

- how well aircrew understood and implemented the briefed operational procedures
- 'between formation' awareness of other team's capabilities

Figure 3 shows results from trial SyCLONE.

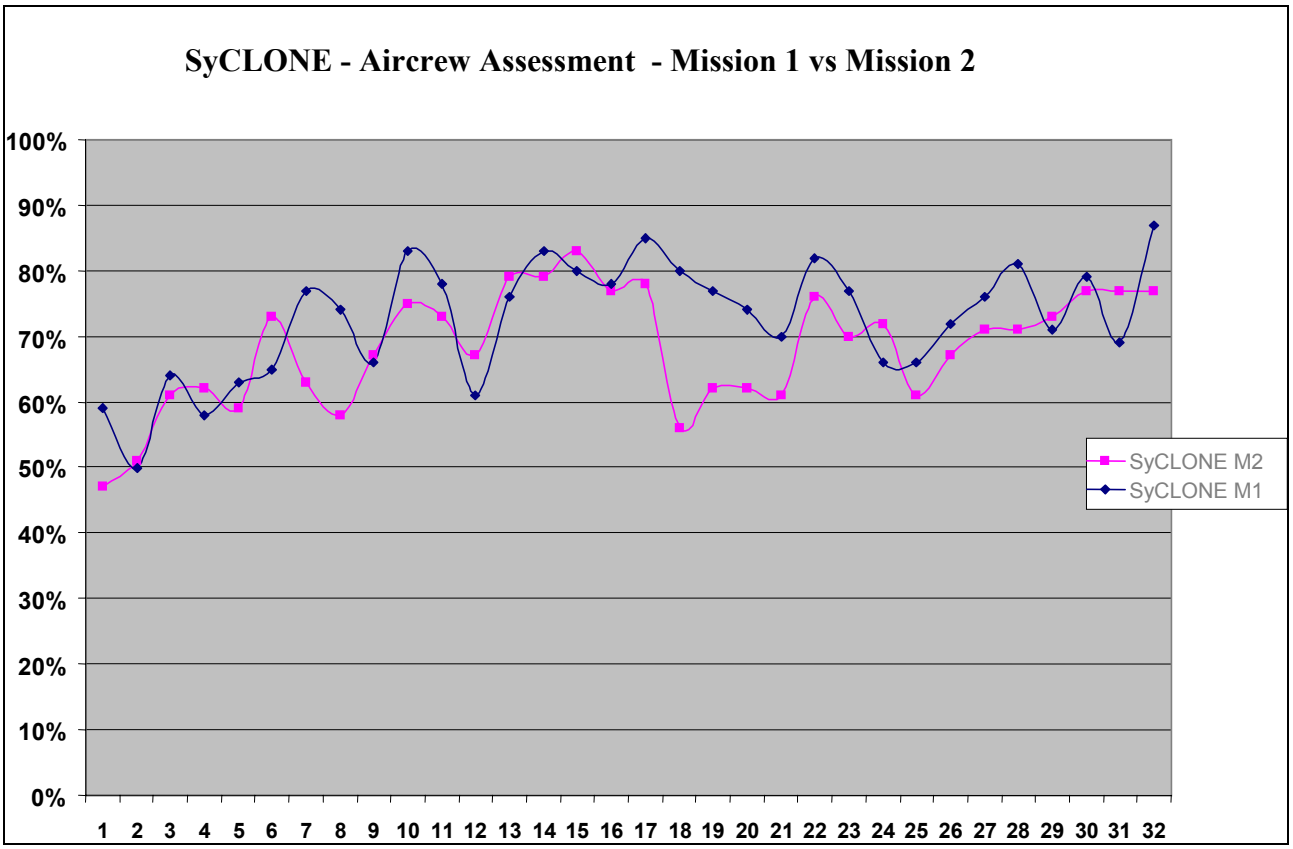

Figure 3: SyCLONE aircrew assessment – mission 1 vs mission 2

Aircrew performance during mission 1 was not given a particularly high rating, as compared to mission 1 in SyCOE. No obvious improvements in aircrew performance can be observed in SyCLONE mission 2. In fact there appears to be a decrement in performance in some areas, particularly:

- appropriate review of tactics as a result of lessons learnt,
- effectiveness of the plan,
- how well each role appeared to understand where they fitted into the 'bigger picture' of the COMAO

Table 2: Mission effectiveness - performance assessment criteria

Performance Assessment Criteria	
01	How effective was the plan?
02	How comprehensive was the brief ?
03	To what extent were all eventualities explored and addressed during the planning phase?
04	How effective were the tactics employed during the mission?
05	Were relevant lessons learnt and actions thoroughly debriefed?
06	How well was the expertise available during the planning phase, utilised by the PC?
07	How well were the needs, workload and time constraints of the other roles taken into account by the PC during planning?
08	How well did each role appear to understand where they fitted into the 'bigger picture' of the COMAO?
09	How effective were the responses to injects and self-generated problems during the mission?
10	How aware were the aircrew of relevant events and problems that could impinge on the mission
11	Given the knowledge available to them at the time how well did aircrew response to events & problems that could impinge upon the mission?
12	How well was formation integrity maintained throughout the mission?
13	How good was the comms discipline within the formations?
14	How effective were the formation leads in co-ordinating the assets within their formations?
15	How good was the comms discipline between formations?
16	How effective was the PC in co-ordinating the assets within the package?
17	How well were correct tactics employed against SAM or A-A threats?
18	How appropriate were any review of tactics made as a result of lessons learnt?
19	How well were the role-specific tasks demonstrated?
20	How well did the aircrew understand and implement the briefed operational procedures?
21	To what extent was the overall effectiveness of the group positively influenced by the PC leadership?
22	To what extent did the PC appear to benefit from the experience of command?
23	How appropriately did the others respond to the PC leadership style?
24	To what extent were the appropriate responses made to in-flight injects and self-generated problems?
25	To what extent was appropriate flexibility demonstrated?
26	How much confidence to individuals appear to have in their own capabilities?
27	Within formations, how much awareness did element leaders and their no. 2s appear to have of each others capabilities?
28	To what extent did formation members appear to be confident enough to rely on each others actions?
29	Between formations, how much awareness did teams appear to have of each others capabilities?
30	To what extent did the different formations appear to be confident enough to rely on each others actions?
31	To what extent were the overall objectives of the mission achieved?

Trust and confidence: Collective training exercises, whether live or synthetic, should endeavour to support the development of inter-role trust and confidence. This is an essential component of interoperability in theatre. To quote:

> *'The secret of a successful air campaign is interoperability*
> *and the most important component of interoperability is trust'*
> Air Cdre Stu Peach, Commandant Air Warfare Centre

An apparent inability of UK and US crews to develop trust via good inter-team cohesion and build rapport was observed during SyCLONE. A questionnaire given to UK aircrews asked them to provide trust and confidence ratings for the other roles that were participating in the trial. It also asked them to rate the level of confidence they had in the ability of these other players to contribute to mission success. Pre and post trial ratings of trust and confidence, made by UK aircrew, were analysed and are presented in Figures 4 and 5. Figure 4 shows pre and post trial ratings for trust while Figure 5 shows pre and post trial ratings for confidence.

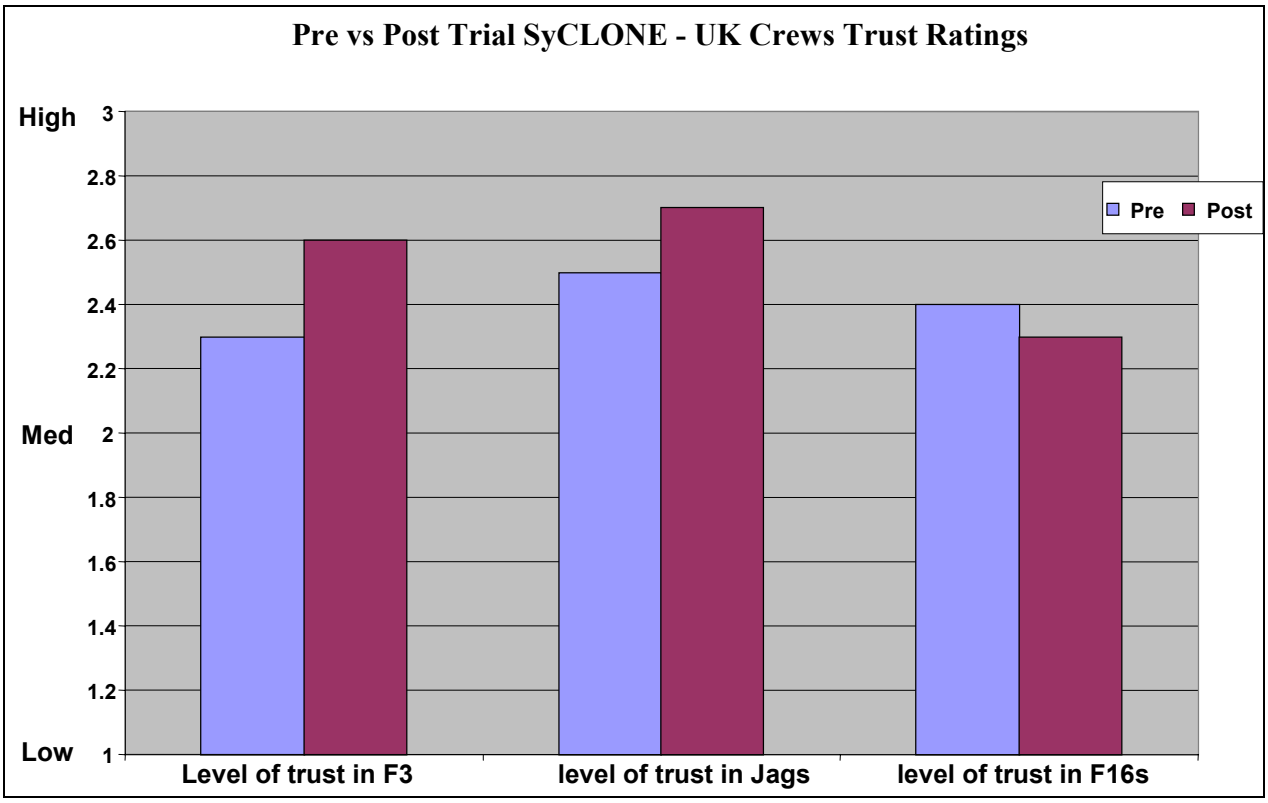

Figure 4: Pre v Post trial UK aircrew ratings for trust

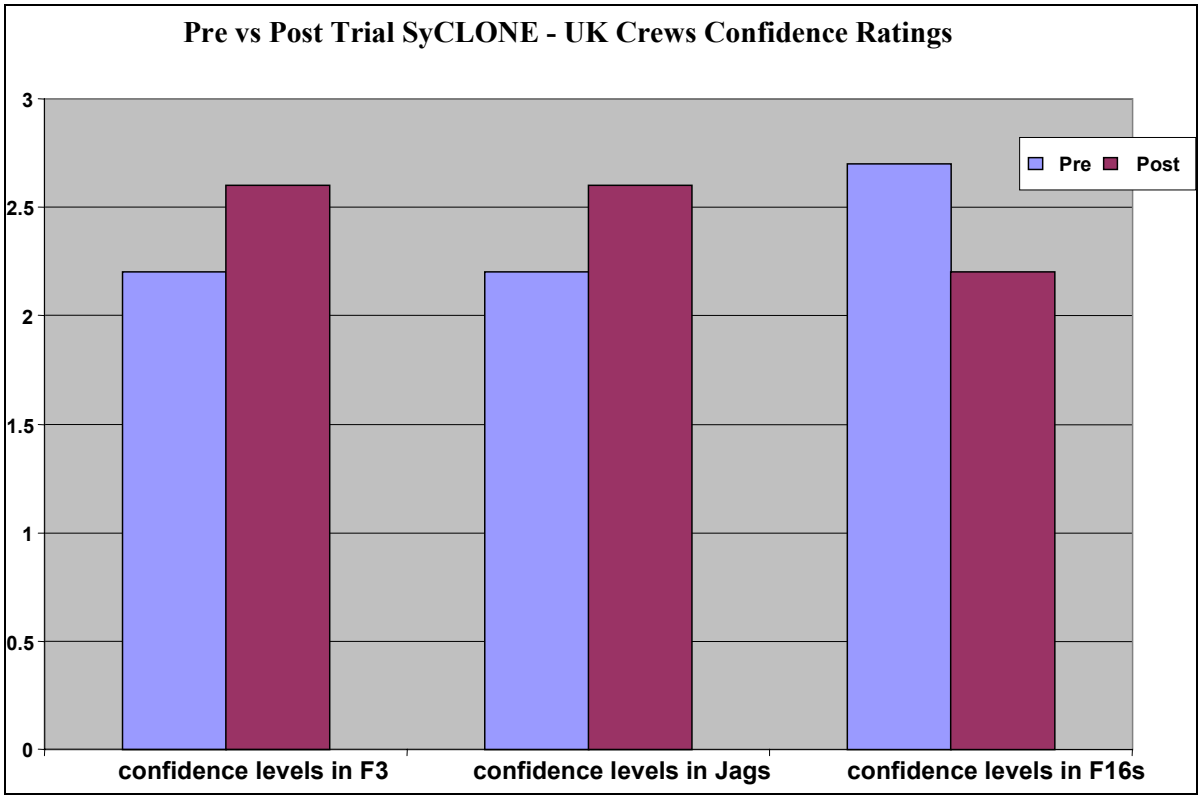

Figure 5: Pre v Post trial UK aircrew ratings for confidence

The results indicted that whilst trust and confidence had increased for the UK participants, it had reduced for the F16 role (the element that was dispersed for the complete duration of the trial). This effect deserves careful consideration.

Trust and confidence between the UK crews may have been able to develop through social interaction, even though attempts were made to keep the A-A and GA formations apart as much as possible. Thus aircrew were sharing the same hotel and took meals together during the trial day. It is also worth bearing in mind that the UK aircrew did manage to have one day colocated where they were able to plan together.

The reputation of the capability of F-16 as weapons platforms may have impacted upon pre-trial ratings. However the lack of social interaction and some of the problems encountered with the PBD technology meant that trust and confidence between the UK and US crews was starting to be eroded during the trial.

Exercise management: Trial SyCLONE provided a first opportunity to test an established, colocated, WF model in a distributed environment; this model has been developed within the research programme and used successfully in previous colocated trials.

SyCLONE has shown that the WF model used in previous, successful, networked trials cannot be applied if participants are distributed. Careful consideration needs to be given on whether or not an alternative exercise management model could be adopted for a real distributed collective training system. One option may be to have WF 'agents', or WF liaison officers (WFLOs), embedded with the aircrew. Each WFLO would liaise with the central WF team on the overall gameplan and general thrust of the mission. WFLOs would then monitor aircrew during the planning phase and guide planning direction, where and if appropriate, within the WF

Commander's directive. WFLOs could also pass on relevant information on aircrew performance to the central WF team.

To summarise, running a distributed training exercise is more difficult than running a colocated one. It is not possible to simply apply the model which has been used successfully in colocated trials to the distributed situation. Specifically, an appropriate exercise management model needs to be developed. A central exercise management team cannot have direct oversight of multiple dispersed sites. In order to maintain co-ordination there may be a requirement for WFLOs at each site but this needs to be tried and tested. As yet there is no evidence that the WFLO model would work in practice. However, it is planned to use WFLOs in the NATO SAS34 MTDS exercise, First WAVE, scheduled to take place in September 2004. This exercise should be monitored closely to learn as much as possible about the feasibility of using WFLOs in large scale distributed training exercises.

SyCLONE - overview of findings

There is a limit to the conclusions that can be safely drawn from this trial. SyCLONE was, after all, a single trial based on a small sample of aircrew. However, SyCLONE gave valuable insight into many of the issues associated with running a distributed training exercise. It is a much more difficult prospect than any encountered previously in the research and simply applying the RAPTORS model, known to work successfully in colocated trials, did not work for the distributed situation.

In simple terms the trial can be said to have been a success in that the available technology supported a distributed exercise, in which aircrew planned, briefed, flew and debriefed a complex mission. However the real issue is to understand how effective such an exercise could be in providing high value mission training. The difficulties aircrew experienced might be attributable to distribution, to artefacts of the technology chosen for the trial or simply to lack of experience in using such technology. Some of the observed adverse effects might be overcome by the application of simple expedients. The trial has however clearly demonstrated that it would be a mistake for MTDS protagonists to assume that it is simply a case of 'provide linking technology and all will be well.'

If there is a genuine causal link between poor mission performance and distribution then it is important to understand why this should be the case. One possibility is that the planning constraints already described had an adverse effect on the mission itself. It can be readily understood that these could influence the tactical nature of the plan with undoubted consequences for mission outcome. In order to test this hypothesis it would be necessary to eliminate the known planning constraints and observe the effect on overall performance.

Conclusions

The MoD sponsored research, coupled with military opinion, strongly suggests that there is much benefit in distributed mission training (i.e. MTDS). It has the potential to provide guaranteed COMAO training. The question is, what is an optimised MTDS configuration; all assets dispersed, all colocated or a compromise between the two? MTDS does not necessarily mean that the training systems have to be de-centralised. It is equally possible to conduct training with synthetic training devices all at the same site, linked together via a LAN. The devices would still all be distributed albeit on the same network. However, if the aspiration is to undertaken coalition mission training some elements of MTDS will have to be geographically dispersed. This would add additional levels of complexity due to interoperability issues that may severely impact upon the quality of training that could be undertaken. Research findings on the impact of distribution are not straightforward but a fully distributed MTDS solution would sacrifice some of the intrinsic advantages of colocation.

Irrespective of the final MTDS solution (colocated and/or comprising geographically dispersed elements) the requirement is first fully scope out the problem space in terms of the cost versus training requirement. This necessitates a thorough appreciation of both the technical and training interoperability issues associated with MTDS. It is imperative that there is inter-system and inter-team component compatibility and interoperability. Careful thought must be given to the most appropriate network architecture. In addition there are significant security implications for a military exercise being conducted in a dispersed STE. The optimal technical solution for a distributed mission training capability which fully supports the operational needs of the front-line, yet is cost-effective, and meets all the necessary doctrinal and security requirements has yet to be defined.

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