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SHELIDON – SMART HELIBORNE FOR DISTRIBUTED OPERATIONS

C2 Experimentation / C2 Concepts and Organisation

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Abstract

SHELIDON is a pilot Air-Land Experiment that explores the concept of enhancing heliborne operations by enabling them to engage in dynamic heliborne-planning to land distributed and manoeuvre everywhere with reduced vulnerability and signature. The ability to land distributed would increase the probability of successful troop insertion. This becomes a strong enabler for the projection of ground forces to support the land battle, as insertion of forces is not more confined to large Landing Zone (LZ). Helicopter survivability is also improved as pilots and helicopter planning teams are now equipped with enhanced situation awareness to avoid surface threats during air-movement and empowered to decide en route to fly to other suitable Landing Sites (LS) should pre-planned LS be compromised. Traditional heliborne operation is rigid in terms of execution; it does not allow for changes while en route. If the pre-planned Landing Zones (LZ) are compromised, the mission will usually be aborted. Although this improves the survivability of the helicopters and the heliborne force, the land mission may be affected.

A virtual experiment was conducted from 14 - 15 Sep 2005 to evaluate the feasibility of the SHELIDON process and concept. This was followed by a field Experiment which was conducted from 8 - 11 Nov 2005. This paper examines the results of the experiments to address the critical issue of improving the SAF's current heliborne operations.

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INTRODUCTION

SHELIDON (**S**mart **HELI**borne for **D**istributed **O**peratio**N**) is a pilot Air-Land experiment that explores the concept as to how we can exploit IKC2 capabilities to enable heliborne operations to land distributed and manoeuvre everywhere with reduced vulnerability and signature thereby increasing the survivability of the helicopters and the heliborne force. SHELIDON forms part of the larger 3G SAF land warfare operations.

The use of helicopters would provide ground force commanders with the means to rapidly concentrate and deploy forces at the critical time and place to influence the tactical situation. The heliborne forces can bypass natural obstacles, enemy barriers and defences, and strike at the enemy in his depth and rear areas. Heliborne operations are therefore launched to isolate the battlefield, disrupt the integrity of the enemy's disposition, facilitate the manoeuvring of own forces or to secure key terrain.

However, in today's operational context, the deployment of heliborne forces is restricted by the fact that it has limited sustaining power and is vulnerable to both enemy attacks from the air and on the ground while en route and near the Landing Zones (LZs). In addition, the sheer size and numbers of helicopters involved would also cause heliborne operations to have a large signature. It is a predictable operation. Over and above, when a heliborne operation is launched, the manoeuvre unit being lifted does not have any situation awareness, as they need to switch off all radio and C2 system equipment. They are pretty much unaware of any changes to the operational plans while en route to the LZ.

Motivation for SHELIDON

With the imperative to make heliborne operations more survivable and the forces more aware of the continued changing situation in the battlefield, SHELIDON (**S**mart **HELI**borne for **D**istributed **O**peratio**N**) was conceived with the purpose of exploiting IKC2[1] capabilities to enable heliborne operations to insert and land forces in a distributed manner. It would also enable more confidence to the heliborne forces with better situation awareness, as well as for the helicopter squadron to work distributed so as to reduce vulnerability and signature while en route to the destination. This would also enable a greater throughput in day and night heliborne operations. These can be achieved in the following ways:

- Troop insertions need not be only at the LZs. With the ability to land at smaller Landing Sites (LS) / Landing Points (LP) (not necessarily within an LZ), it would be more difficult for the enemy to predict / pre-empt the troop insertion points.

[1] IKC2 – Integrated Knowledge-based Command and Control. The Singapore Armed Forces has conceptualised IKC2 as networked-enabled knowledge-based warfighting.

- With the proliferation of low-cost UAVs, it may no longer be necessary to send in traditional Terminal Air Guidance Teams (TAG Teams) to determine suitable LSs/LPs; planning can now be based on the video inputs provided by these UAV sensors.

- With smaller formations of helicopters, as well as the use of distinct flight routes, a smaller signature can be achieved.

- With the possibility of landing in many different LSs/LPs, landing is no longer confined to the standard Primary-Alternate LZs. This would increase the success of inserting a critical mass of fighting forces necessary to accomplish the ground mission.

- With the UAV video, situation awareness is greatly enhanced for the Heliborne Task Force Commander (HTFC) and/or the Air Mission Commander on-board the helicopter. If the enemy is detected, the Air Mission Commander and the HTFC can collaborate with UAV Planning Team (UPT) and Helicopter Planning Team (HPT) to divert the heliborne forces to another flight path through the use of appropriate planning and collaboration tools.

One of the key issues that arise from the insertion of heliborne forces in a distributed manner is that of troops may be disorientated after the insertion at the various LZs/LSs/LPs. There is, therefore, a need to ensure that the projected ground forces are able to link-up to achieve their mission.

- With ForceMate[2], the HTFC as well as his Troop Leaders, are able to maintain continuous situational awareness of the plans and have situational updates real-time. As such, they have visibility on the various troop insertion points, as well as any diversions while en route.

- Even while en route, the HTFC can do the necessary re-planning of his ground manoeuvre plan should there be a need to divert one or more helicopters from their pre-planned insertion points. The amended plans are then forwarded to the various Troop Leaders on-board the other helicopters for execution.

- In doing so, the inserted ground forces can then proceed to effect the ground movement plan immediately after being dropped off, instead of having to spend time to figure out their current location and how to get to the designated link-up point.

Previously, if the Primary and Alternative LZs are ‘Hot’, the mission may need to be aborted. Now with SHELIDON, the ability to land distributed, and dynamic planning of the ground manoeuvre plan by the HTFC on-board the helicopter allows the execution of the new plan to link up the ground forces immediately after the troops have been inserted. This flexibility afforded to the HTFC allows him to adapt easily to the situation to achieve his ground mission.

[2] ForceMate is the Command and Control System used for the experiment

MissionMate, ForceMate and the Joint Battle System (JBS)

MissionMate is an in-house developed CCKS (Command and Control Knowledge System) system that is built on a Service-oriented architecture where C2 applications (or services) can be accessed anywhere on the network via a browser. The key application used in both the SHELIDON virtual and field experiments is the Common Operating Picture (COP). Augmented with other communication tools such as the chat, MissionMate enables the various members of the Div CP (Division Command Post) to plan and collaborate effectively.

ForceMate is a 'scaled-down' version of MissionMate that has been specially designed for forces on-the-move. Using a Tablet PC, operators are able to make use of the built-in COP feature in ForceMate that allows real-time sharing of information and situational constructs of individual team members with fellow colleagues. The ForceMate was deployed to the Jump-seat pilots and the HTFC on-board the Super Puma helicopters. Figure 1 shows a screen-shot of MissionMate and ForceMate in use.

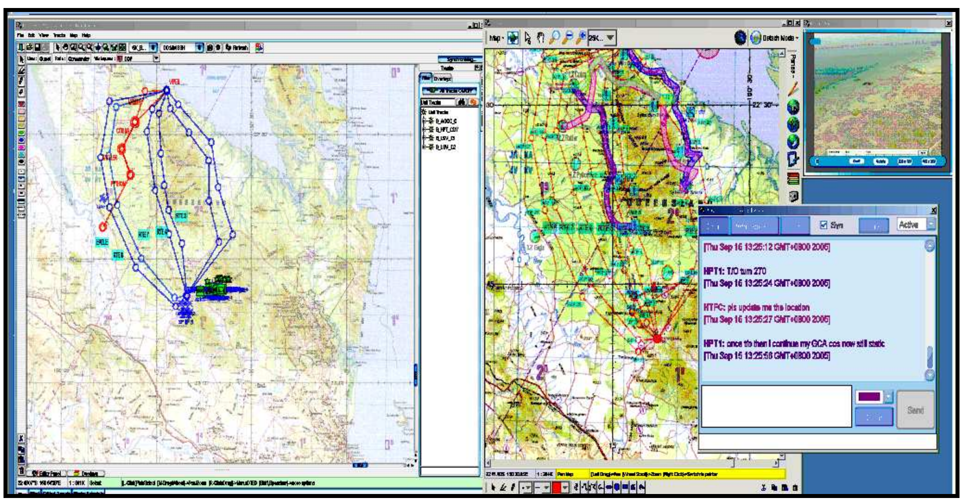


Figure 1: MissionMate (left) and ForceMate (right) in use, augmented with collaboration tools like the chat and video

The Joint Battle System (JBS) is an in-house developed virtual simulation system that allows experimental forces to conduct trials involving combat, command and control and tactical decision-making in a virtual battlefield. It is a HLA-compliant (High-Level Architecture) client-server network that runs a virtual entity-level wargame simulation, with operators being able to interact with the virtual wargame and exercise command and control over other players' and CGF (computer generated forces) during a simulated battle in the JBS.

Design Of SHELIDON For The Third Generation Singapore Armed Forces (3G SAF)

The SHELIDON experiment comprises of several phases as follows:

- *Phase 1*. This phase involved forces in a virtual environment conducted in Sep 05 at SCME. It provided greater confidence to the experiment team as well as finalised the various processes prior to the live experiment in Australia. This was carried out on 14 to 15 Sep 2005.

- *Phase 2*. This phase involved a live experiment in Shoalwater Bay Training Area (SWBTA), Australia from 8 to 11 Nov 2005, without manoeuvre troops. The scenarios and work processes used in this phase were similar to those of Phase 1.

- *Phase 3 and beyond*. Subsequent phases will involve forces with proper mission planning against enemy threats and targets that would test the survivability concept. Manoeuvre troops will also be involved, and possibly with fielded UAV communications. Prior to any live experiment in SWBTA, a virtual experiment will first be held in SCME to finalise the various work processes.

The focus of this paper is to summarise and discuss the results of Phases 1 and 2.

Experiment Hypothesis

The experiment sought to test the following hypotheses:

- With SHELIDON, the situational awareness of the pilots, Helicopter Planning Team (HPT) and Heliborne Task Force Commander (HTFC) will be increased with the aid of a Common Situation Picture, resulting in high self-synchronisation of forces.

- With SHELIDON, there will be an increase in decision agility to perform dynamic planning as and when significant changes to the ground dictate ad-hoc changes (as opposed to planned contingencies).

- With SHELIDON, the helicopters are now able to land distributed, resulting in the heliborne operations becoming more survivable.

METHOD

Experiment Participants

The key participants in the two phases of the SHELIDON Experiment were as follows:

Personnel	Phase 1 : Virtual Expt	Phase 2 : Field Expt
Division Command Post (Div CP) Officer	1 x Army Officer (Control)	1 x Army Officer (Control)
*Helicopter Planning Team (HPT)**	1 x Helicopter Pilot[3]	2 x Helicopter Pilots
*UAV Planning Team (UPT)**	1 x UAV Pilot	1 x UAV Pilot
*Helicopter Jumpseat Pilot**	2 x Helicopter Pilots	2 x Helicopter Pilots
Helicopter Pilot	2 x SCME Officers	2 x Helicopter Pilots
Heliborne Task Force Commander (HTFC)	1 x Army Officer	1 x Army Officer

* Indicates that these key personnel are the same for both Phases 1 and 2.

The roles of these personnel are as given below:

- *Division Comd Post (Div CP) Officer*. The Div CP Officer plays the role of the Div HQ, giving orders and instructions from the Div HQ for the entire heliborne operation. He also delivers the necessary injects during the experiment to 'force' the participants to engage in dynamic heliborne planning.

- *Helicopter Planning Team (HPT)*. The HPT plans the Air Movement Routes of the helicopters and monitors their flight progress to the designated LZ. In the event of enemy ADA detected or 'Hot' LZs, the HPT will relay the information to the Jump-seat pilots and instruct them to divert as appropriate. Depending on the scenario run, the HPT may also plan the necessary diversion route to avoid the enemy ADA area of influence. The HPT comprises active helicopter pilots who are trained, and have an average of more than 5 years of experience, in helicopter planning operations.

- *UAV Planning Team (UPT)*. The UPT plans the flight route for the UAV to clear the designated Air Movement Routes as well as possible LZs to ensure that the route and LZs do not pose any danger to the helicopters. The UAV planner is a trained UAV planner with more than 4 years of experience in commanding UAV operations.

- *Helicopter Jump-seat pilots*. The Helicopter Jump-seat pilots communicates with the HPT and monitors the developing situation through their ForceMate terminals. One of the Jump-seat pilot will act as the Air Mission Commander and engages in collaborative planning with the HPT, UPT and HTFC to divert the helicopters as necessary in the event of enemy forces detected. The use of Jump-seat pilots was necessary to fulfil the safety requirements imposed by the Air Force, so as not to disrupt the existing two-pilot configuration within the Super Puma cockpit. The Jump-seat pilots are themselves active helicopter pilots with an average of more than 8 years of piloting experience.

- *Helicopter Pilots*. For the Virtual Experiment, the pilots were played by officers

[3] Tactical Air Support Command

from SCME who piloted the helicopters based on the instructions of the Jump-seat pilots. This was done using the Joint Battle System (JBS) housed in SCME. For the field experiment, the actual operational helicopter crew were involved in the flying of the 2 x Super Puma helicopters. These helicopter pilots have an average of more than 7 years of piloting experience.

- *Heliborne Task Force Commander (HTFC)*. The HTFC is responsible for planning and executing the Ground Movement Plan to link up the Light Strike Vehicles (LSVs) of the ground forces that are to be inserted by the helicopters into the area of operations. For the Virtual Experiment, the HTFC has his Troop Leaders to carry out the ground manoeuvre plan on the JBS.

In addition to the technical support and observation team provided by SCME, the Air Force also supported the field experiment as follows:

- *2 x Super Puma Helicopters + Crew.* Providing the 2 x Super Puma Helicopters and necessary crew (including pilots and co-pilots) for the experiment runs.

- *1 x UAV + Crew.* Providing the UAV, Ground Control Station (GCS), Active Receiving Only Station (AROS) as well as the crew to support the experiment.

- *1 x Safety Officer.* Providing and assigning an Air Safety Officer to ensure that the various experiment runs are conducted safely under the given conditions, to prevent and minimise risk to life and property.

Experiment Scenario

For the virtual experiment, the mission objective is for 6 x Super Puma (SP) helicopters to pick-up a company of Light Strike Vehicles (LSVs), then fly to a designated Landing Zone (LZ), where the vehicles would be drop-off deep inside enemy territory. Two of these SPs are man-in-the-loop [MIL] controlled, while the other 4 are computer-generated forces [CGF]). These vehicles will then execute their ground movement plan to link up and secure an Air Head in order to prevent reserve enemy forces from advancing, as well as to halt the pull-back of enemy forces as the main force advances. The ground vehicles are commandeered by the HTFC who is on-board one of the helicopters.

Enemy forces, as well as Air Defence Artillery (ADA), will be planted along the planned Air Movement Routes and near the designated LZs. The key objective is to force the Helicopter Planning Team and/or the SP helicopter co-pilots to dynamically re-plan their routes and/or new LZs while en route. As such, the planted enemy forces are not actively played by an OPFOR. With the diversion, the HTFC will then need to make the necessary changes to his Ground Movement Plan to link up his LSVs.

For the field experiment, the mission objective is similar; however, only two Super Puma Helicopters were used. In addition, there are no live troops on the ground to execute the ground manoeuvre plan. The mission objective is deemed to be successful once the helicopters have diverted and arrive at the new Landing Sites based on the different scenarios and injects.

This scenario and the respective injects were planned in consultation with operational personnel from HQ Guards (for the virtual experiment) and the Helicopter Planning Team (HPT) (for the field experiment in SWBTA) to ensure that they are relevant and realistic to our operations.

Experiment Runs

For the virtual experiment, a total of 5 runs were conducted over a period of 1.5 days under different simulated network conditions. These consisted of 2 runs of good communications, 2 runs of degraded communications and a single run of poor communications. While more runs were initially proposed, the experiment team was not able to implement all the runs due to technical glitches in the system and participants' involvement in operational activities back at their unit. Nevertheless, the results obtained from the five runs allowed the experiment team to have a better understanding of the issues faced by the participants and to fine-tune the work processes. This has also provided the team with a greater confidence on how to conduct the live SHELIDON experiment in SWBTA later that year.

Figure 2 below shows a summary of the features available in ForceMate under the various network conditions, i.e. given the limited amount of bandwidth available. This is to simulate the conditions that will be experienced by the participants on-board the Super Puma helicopter:

- ***Voice*** – Refers to VHF communications used in actual operations. Walkie-talkies are used to simulate VHF Comms during the virtual experiment.

- ***Chat*** – Refers to the chat feature available in MissionMate / ForceMate.

- ***POLARS*** – Position Locating and Reporting System. It refers to the blue-force tracking implemented on the land platforms.

- ***Air Tracks*** – Refers to the air-tracks of the various platforms, i.e. UAV and helicopters.

- ***COP*** – Common Operating Picture. It refers to the GIS-based collaborative tool feature in MissionMate / ForceMate, where individuals are able to see and understand, as well as collaborate on the situational constructs of others in the team, thereby reducing the need to disseminate information, since the drawings made can be viewed real-time.

- ***Image*** – refers to images sent by the UAV, or image files sent by any user.

- ***Video*** – refers to the video feed from the UAV.

Series	Comms Condition	Voice	FORCEMATE						
			Chat	POLARS	Air Tracks	COP	Image	Video
S1	Good	✓	✓	✓	✓	✓	✓	✓
S2	Degraded	✓	✓	✓	✓	✓		
S3	Poor	✓	✓					

Figure 2: Experiment Conditions for SHELIDON Virtual Experiment

To simulate the desired network conditions in the LAN environment, the in-house developed BACES (BAttlespace Communications Emulator and Simulator) system was used to degrade the network bandwidth accordingly. This will result in the respective ForceMate terminals experiencing the emulated network conditions, e.g. network delays, dropped packets etc.

For the field experiment, a network infrastructure was set up in the experiment area of operations within the SWBTA. Commercial-Off-The-Shelf (COTS) wireless radios were integrated in tethered balloons, raised to a height of 60 metres, to realise an Aerial Comms Node (ACN). A total of 3 such nodes were created, providing wireless coverage (using 802.11) to the helicopters (which were each fitted with an antenna) over the entire area of operations. (Refer to Balloon Sites 2, 3, and 4 in Figure 3 below).

For the field experiment, apart from the waves launched to determine the technical performance of the C4 systems, 2 waves, each lasting about an hour, were launched for the actual SHELIDON experiment:

- For the first wave, a total of 4 runs were conducted, each covering a flight distance of approximately 8km. A single inject was issued during each of the runs. These injects were issued by the HPT (as this was the first time a live run was conducted) to test the ability of the Jump-seat pilots to react and re-plan based on the given situation. This experiment wave was not able to incorporate UAV video inputs as the Searcher experienced technical problems just prior to the commencement of the wave.

- For the second wave, a total of 3 runs were conducted. The flight distance covered was lengthened to approximately 18km (U-shaped route), and the number of injects issued during each run was increased to two. In this wave, the HPT and the UPT, like the Jump-seat pilots, were tested in their abilities to react and re-plan according to the various injects issued by the Div HQ.

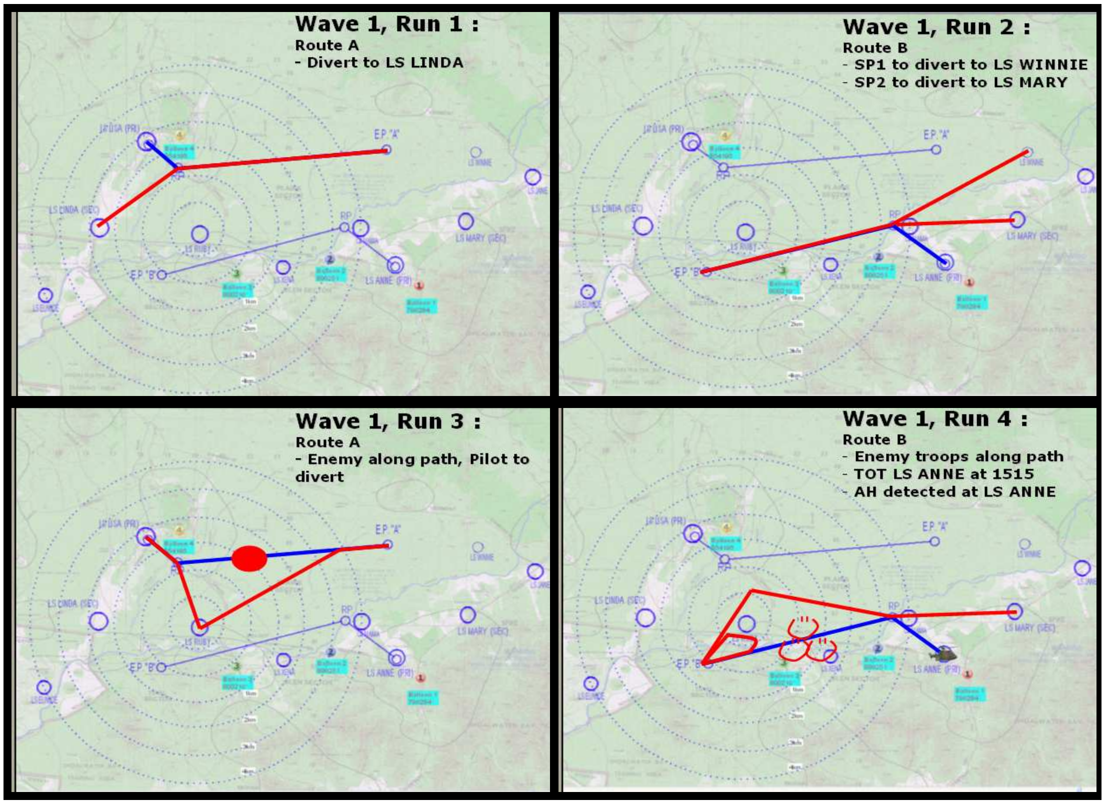
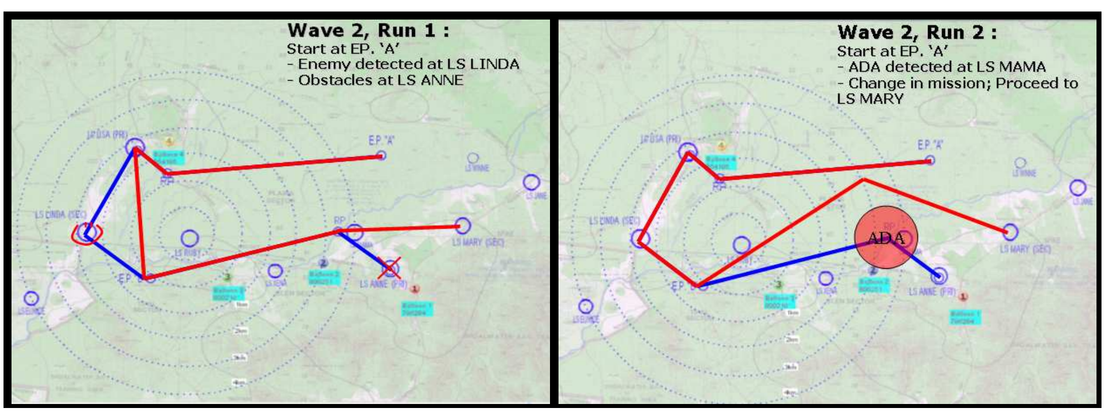


Figure 3: Actual Flight Routes for Wave 1



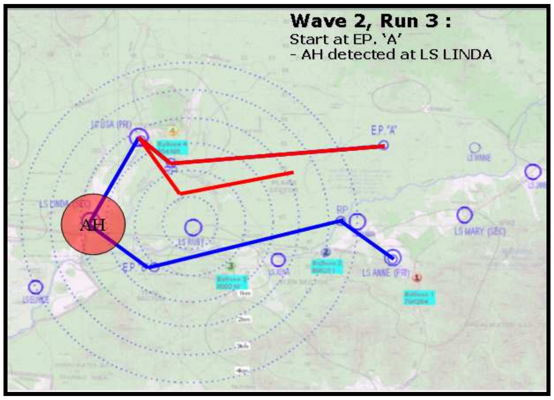


Figure 4: Actual Flight Routes for Wave 2

Experiment Setup

The setup of the SHELIDON Virtual Experiment is such that the participants in the Div CP (i.e. Div CP Officer, HPT and UPT) were seated in the Command Post of the Future (CPoF) Lab, whilst the rest of the participants (i.e. Helicopter Pilots and Jump-seat pilots, HTFC and his Troop Leaders as well as the UAV operator), were in the Battle Lab, at their respective simulator stations controlling the various platforms using the Joint Battle System (JBS). The seating arrangements in the CPoF Lab and BattleLab are as shown in Figure 5 below:

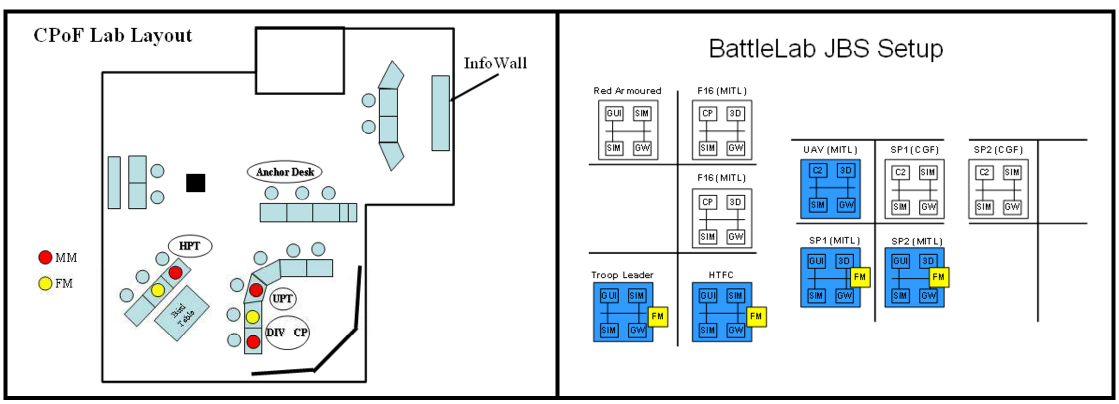


Figure 5: Participants' Seating Arrangement during SHELIDON Virtual Experiment

For the field experiment, the layout of the seating arrangement of the personnel on the ground and in the air is as given in Figure 6 below:

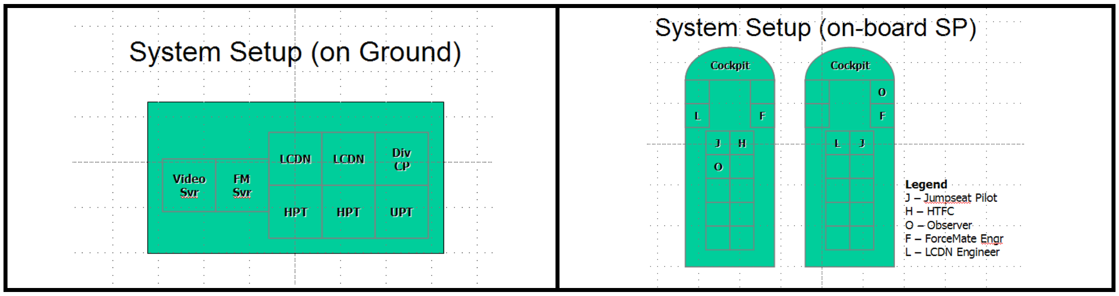


Figure 6: Participants' Seating Arrangement during SHELIDON Field Experiment

Experiment Measures

The following set of measures was developed to determine the effectiveness of SHELIDON:

	Phase 1 (Virtual Expt)	**Phase 2 (Field Expt)**
Social Network Analysis	Chat and video logs Screen logging of MissionMate / ForceMate terminals Observer inputs	Chat logs Screen Logging of the ForceMate Observer inputs
Situational Awareness (SA)	Administering of SAGAT questionnaire using online questionnaires and surveys for the participants after each run.	SAGAT questionnaire were administered for the participants. This was administered only at the end of each wave, due to the need to maximise the limited amount of flight time available for the experiment proper.
Improve Survivability - Ability of helicopters to engage in dynamic collaborative planning. - Ability of helicopters to avoid / bypass detected ADA areas while en route. - Ability of helicopters to divert from 'Hot' LZs and to land distributed.	Observe that the pilots were able to carry out their mission.	Observe that the pilots were able to carry out their mission.
Pilot Workload	-	Administration of the NASA-TLX (Team Loading Index). Like the questionnaire, this was administered only at the end of each wave.
Process Timings	The time taken to accomplish each stage of the heliborne process was measured and tabulated.	The time taken for the participants to re-plan and execute the new heliborne plan after each inject was provided was measured and tabulated.

Results

Social Network

The mode of communication among the experiment participants can be summarised as shown in Figure 7 as follows:

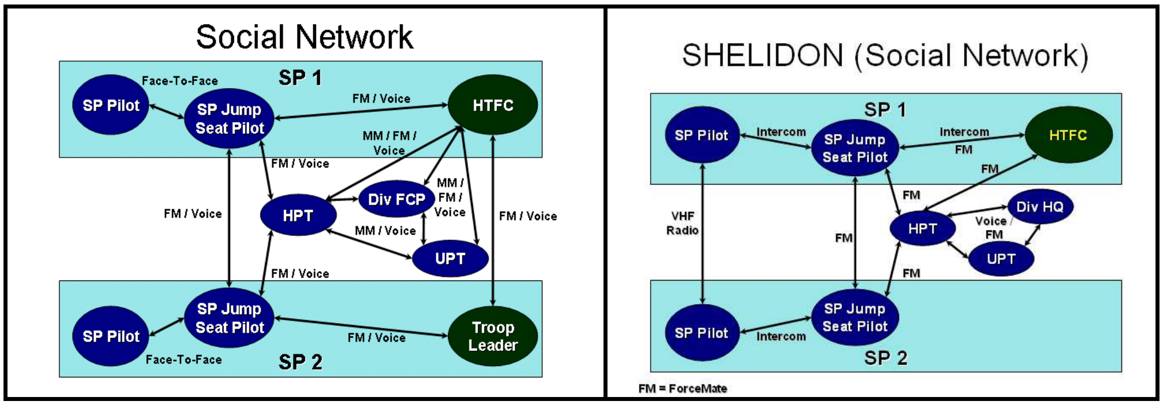


Figure 7: Social Network of the Participants during SHELIDON experiment

The participants' communication on the chat was monitored and analysed for their chat activity profile. Their communications patterns were also analysed and categorised into how many chat messages were spent on the following activities. Note that face-to-face communications between the participants, which forms a small part of the total amount of communications, was not captured and reported here:

- ***Dissemination of Information*** – defined as giving orders, instructions and issuing tasks;
- ***Collaboration*** – defined as exchanging ideas or clarifying; or
- ***Others*** – defined as engaging in other chatter, e.g. sending one another messages that are irrelevant to the experiment, performing comms test during the experiment run, etc.

Analysis of the chat logs revealed the following phenomena:

Number of Chat Messages exchanged. The amount of chat activity was kept to a minimum during the field experiment, as evidenced by the small numbers of messages exchanged by the various participants as compared to the virtual experiment. (An average of 23.25 and 37 messages were exchanged for each of the runs during Waves 1 and 2 of the field experiment as compared to 236.8 messages exchanged during each of the 5 runs of the virtual experiment.) The significantly higher number of messages exchanged during the virtual experiment can also be attributed to a longer run (Heli-insertion followed by link-up of the Light Strike Company) over a greater flight distance of approx 50km.

Content of Chat Messages exchanged. The content of the chat messages exchanged during the field experiment was short and concise. This was due to the participants' awareness of the need to keep the channel clear, and not to engage in idle chatter, especially when safety is of paramount concern. This was unlike the virtual experiment, when some of the participants sometimes engaged in small talk while waiting for the helicopters to fly from point-to-point or while waiting for the light-strike vehicles to link-up etc.

For both the virtual and field experiments, it was observed across the different runs that there was a greater amount of collaboration among all the participants compared to normal. In the traditional context, there would be minimal collaboration between the participants; with information being passed down (information dissemination) only from the HPT to the pilots on-board the helicopters. With ForceMate as an enabler, the various participants could now collaborate with the HPT in the Div CP and work together to achieve the mission objective. This was previously not possible as the pilots on-board the helicopter did not have the same situational picture as the HPT on the ground. A summary of the breakdown of the categorisation of the chat messages is as given in Figure 8 below.

Category	% of Messages Virtual Expt	% of Messages Field Expt – Wave 1	% of Messages Field Expt – Wave 2 (%)
Information Dissemination	32.2%	26.9%	18.9%
Collaboration	44.8%	58.1%	50.5%
Others	23.0%	15.0%	30.6%
Total	100%	100%	100%

Figure 8: Categorisation of chat

Situation Awareness (SA)

For the virtual experiment, the Situation Awareness of the participants is found to be generally high for both the good comms as well as the degraded comms run (~80%). In the case of poor comms, the SA of the participants in the Div HQ (i.e. HPT and UPT) remained high (since there was no comms degradation at the Div CP, which was in a LAN environment), while the SA of the participants on-board the helicopters (i.e. the Jump-seat pilots and the HTFC) were found to be lower (~40%). In the poor comms run, the pilots flew 'blind', with voice directioning provided by HPT. Their SA was judged to be much lower than in previous runs, especially since they were not able to receive the air tracks information. However, they were still able to fulfil their mission objectives to avoid the detected enemy ADA as well as divert from 'Hot' LZs.

The Jump-seat pilots and the HTFC's lower SA during the poor comms run can be attributed to the fact that there were problems with the chat feature during the run, resulting in them losing comms with the Div CP for approximately 10 mins; During this time, the ground situation had changed, e.g. enemy ADA was detected etc. Despite their lower SA scores, they were able to follow the HPT's instructions (through voice-directioning) to divert the helicopters safely away from the ADA area of influence.

The SA results from the field experiment (with poor comms) mirrored the results obtained for the poor comms run during the virtual experiment. The SA of the HPT (~90%) was found to be much higher than the Jump-seat pilots or the helicopter pilots (ranging from 25% - 50%). This is logical, as the HPT on the ground would have a better sense of the entire situation as it develops, as compared to the Jump-seat pilots or pilots.

A possible reason that may have contributed to the lower SA scores of the Jump-seat pilots and Pilots is the fact that the SAGAT questionnaires were issued only at the end of the wave, even though the flight route for the individual runs was the same. Furthermore, the participants were quizzed only after flying back to base (which was more than an hour after the completion of the experiment wave. This may have resulted in some confusion in trying to recall the different injects and situations for the various runs.

In addition, technical issues resulted in the occasional loss of COP for the Jump-seat pilots on-board the SPs, when their ForceMates were disconnected from the network. Furthermore, the pilots were dependent on their respective Jump-seat pilots for the latest information updates, e.g. own track location as well as given enemy locations. In the experiment, it was observed that the pilots flew using voice-directioning provided by their respective Jump-seat pilots. As such, if the Jump-seat pilot did not inform his/her Pilot on the reason for diversion, or the given enemy location, he/she would not know.

Improve Survivability

For the virtual experiment, depending on the availability of comms, the Jump-seat pilot may or may not have sufficient information to come up with the new heliborne plan to re-route the helicopters. In the cases of good and degraded comms, the runs were structured such that in more than one occasion, the Jump-seat pilot had to come up with the new heliborne plan (traditionally the job of the HPT). It was found that the Jump-seat pilot was able to engage in dynamic planning to come up with a new heliborne plan to divert from the ADA's area of influence as necessary as well as to land distributed (based on the instructions of the Div HQ and/or the HTFC).

For the field experiment, the flight profiles given in Figures 3 and 4 show the pre-planned and diversion routes that the helicopters took, evidence that the SPs were able to accomplish their given tasks based on the various injects. The Jump-seat pilots were able to engage in dynamic collaborative planning with the HPT to avoid / bypass detected enemy and ADA areas while en route. They were also able to divert from 'Hot' LS to other LS' as required. However, technical problems encountered resulted in the safety officer having to call off some of the runs, which would test the ability of the helicopters to operate distributed.

Pilot Workload

A summary of the workload is as shown in Figure 9:

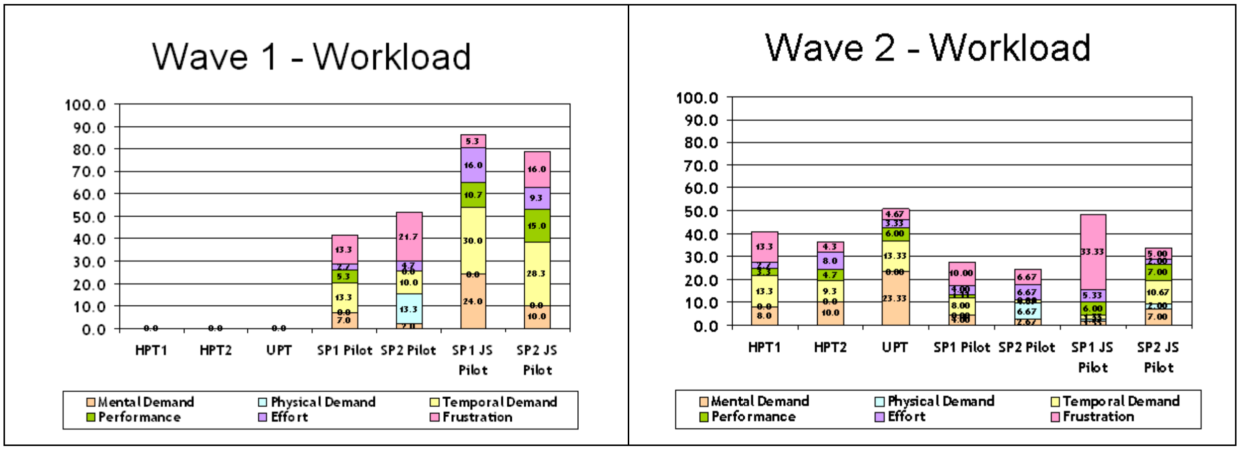


Figure 9 – Workload of participants during Field Experiment

Workload demand was not measured for the HPT during the first wave, as they were assisting the experiment team in the role of Control. Similarly, the UPT did not participate in the first wave, due to the technical problems encountered by the Searcher UAV.

The measured workload of the Jump-seat pilots and pilots were much lower during the second wave compared to the first. This could be attributed to the fact that by the second wave, the participants became much more familiar with the technology, processes and even the scenarios.

It was found that the workload of the Jump-seat pilots involved in self-synchronisation at the tactical level, in response to situation updates and mission changes, was considerably higher than that of their respective pilots. Post-mission feedback from the pilots also suggested that this was indeed the case. The following were observed to have possibly contributed to the higher workload of the Jump-seat pilots:

- <u>Employment of a 3-pilot configuration for the experiment.</u> The fact that the Jump-seat pilot, who was the one operating the ForceMate, had to relay verbal instructions to the 2 pilots in the cockpit increased the internal communications traffic. This, in effect, soaked up any spare mental capacity of the whole crew. It is ironic that the safety considerations of having a 3-pilot crew (which was necessary at this stage of the experiment) had probably resulted in a higher than normal crew workload. As the eventual configuration will be a 2-pilot cockpit crew, it is probably too premature at this point, and therefore not appropriate, to draw any conclusions from this experiment about the viability of the concept of operations due to work overload. It remains to be seen whether a reduction from 3 pilots to 2 pilots will result in a decrease in the workload.

- Chain of Command. A concern was raised that although the Jump-seat pilots now have the ability to communicate and collaborate with the various parties involved in the mission, this should not blur the line of having a proper chain of command, i.e. the pilots should still take 'orders' from the Air Mission Commander. It was proposed that the Air Mission Commander (who ought to be on the ground), should remain the 'interface' between the front-end operators (i.e. the helicopter crew) and the back-end mission planners and decision-makers (e.g. the HPT). In this way, collaboration at the back-end can still proceed as per normal, but where it involves the front-end operators, the number of parties in the net can be confined to those absolutely necessary to reduce 'chatter'.

- Chat Feature in ForceMate. Feedback from the Jump-seat pilots revealed that voice is generally preferred over chat, even though the usefulness of chat is apparent for the clarity and retention of critical alphanumeric messages. This is because chat requires the Jump-seat pilots to monitor the chat activity closely, regardless of its relevance. They felt that the attention focused on monitoring the chat will potentially compromise their other tasks in the cockpit in a 2-pilot configuration. In addition, it was observed that the number of chat messages exchanged was greatly reduced as compared to the virtual experiment. This can be attributed to the participants' consciously keeping the channel clear for important messages and not engage in 'chatter', which is critical in a live environment.

- UAV Video Feed. Feedback from the Jump-seat pilots revealed that they rarely referred to the raw UAV video feed sent to them on the ForceMate. This is due to the additional workload in interpreting the raw imagery. The usefulness of the raw imagery from the UAV to detect enemy activities in the vicinity of pre-planned LSs/LPs or to study the terrain of an ad-hoc LP (i.e. not previously identified in the directory of LPs) cannot be overstated. However, it may be more beneficial to let the UPT and other planners process the information first before pushing it to the pilots. In this way, pilot workload can be reduced.

- Technical Problems. The encountering of various technical problems as listed above resulted in the Jump-seat pilots not being able to receive real-time blue-force track updates (other than their own helicopter tracks), or collaborate effectively using the ForceMate (ForceMate gets disconnected, no COP) etc. The frustration in using the experimental technology that is still not able to fully support the process also resulted in an unnecessary increase in the workload of the pilots.

Process Timings

For the Virtual Experiment the process timings for the individual stages of the experiment run are shown in Figure 10. It was observed in general that across the runs, the Jump-seat pilots and the HTFC were able to react much faster, and the process of engaging in dynamic and collaborative planning was much smoother. For Run 5 (i.e. poor comms run), since the pilots flew 'blind' with voice-directioning given by the HPT, the Jump-seat pilots merely relayed the message sent from the HPT to fly in a given direction, or to divert in another direction as necessary. As such, the times at which the LZ was found by the Div HQ to be hot, and the HTFC initiating plans were not relevant, since the planning was done completely by the HPT.

It was observed that a large portion of time was taken during each stage for the UAV to ensure that the air movement route and possible LZs are safe. The Jump-seat pilots were frequently asked to hold and hover at certain locations while waiting for the UAV to search for possible enemy deployment along the route and at the LZs of interest.

Time	Run 1	Run 2	Run 3	Run 4	Run 5
Time Start	9:56 AM	2:01 PM	3:57 PM	09:28 AM	1:35 PM
SP Departs	+8 mins	+3 mins	+3 mins	+15 mins	+7 mins
Route Hot discovered	+7 mins	+16 mins	+15 mins	+12 mins	+6 mins
Pilot activates Detour	+1 min	+2 mins	+2 mins	+4 mins	+2 mins
LZ Hot	+17 mins	+14 mins	+12 mins	+7 mins	-
HFTC initiates plan	+4 mins	+5 mins	+4 mins	+3 mins	-
SP acts on the plan	+4 mins	+5 mins	+3 mins	+3 mins	-
SP landed	+8 mins	+7 mins	+6 mins	+11 mins	+27 mins
LSV link-up	+14 mins	-	+10 mins	-	-

Figure 10: Individual Process Timings for the SHELIDON Virtual Experiment

For the Field Experiment, the process timings for the various runs are shown in Figure 11 below. It is observed that depending on the scenario given, the HPT and/or the Jump-seat pilots were able to react quickly to the various injects issued. In fact, they were often able to establish and execute the new plan within 1 to 3 minutes after the individual inject was given.

Process Timings (Wave 1)

Time	Run 1	Run 2	Run 3	Run 4
Time Run Commenced	2:31 PM	2:45 PM	2:55 PM	3:02 PM
Inject #1 Given	+3 mins	+2 mins	+1 min	+2 mins
Plan Established	+2 mins	+1 min	+1 min	+3 mins
Pilot Executes Plan	+1 min	+2 min	+2 mins	+1 min
Inject #2 Given	-	-	-	+2 mins
Plan Established	-	-	-	+2 mins
Pilot Executes Plan	-	-	-	+1 min
Inject #3 Given	-	-	-	+2 mins
Plan Established	-	-	-	+2 mins
Pilot Executes Plan	-	-	-	+1 min
Mission Accomplished	+4 mins	+3 mins	+2 mins	+1 min
Time End	2:41 PM	2:53 PM	3:01 PM	3:19 PM

Process Timings (Wave 2)

Time	Run 1	Run 2	Run 3
Time Run Commenced	11:19 AM	11:54 AM	12:08 PM
Inject #1 Given	+2 mins	+2 mins	+3 mins
Plan Established	+1 min	+1 min	+2 mins
Pilot Executes Plan	+1 min	+1 min	+0 mins
Inject #2 Given	+10 mins	+5 mins	-
Plan Established	+0 mins	+1 min	-
Pilot Executes Plan	+1 min	+1 min	-
Mission Accomplished	-	-	-
Time End	11:35 PM	12:05 PM	12:15 PM

Figure 11: Process Timings of SHELIDON Experiment Waves

Key Observations

From the two phases of the SHELIDON experiment, the following key observations were made.

- *Enhanced Situation Awareness*. The participants (i.e. HPT, UPT, Jump-seat pilots and HTFC) agreed that their situation awareness has indeed increased. With the helicopter tracks now being updated real-time on ForceMate, it allows the planners on the ground as well as those on-board the helicopters (i.e. the Jump-seat pilots and the HTFC) to maintain continuous awareness of the helicopters' situation. The use of the Common Operating Picture and chat features available in ForceMate allowed those on-board the helicopters to communicate and engage in collaborative planning with the HPT (and the UPT) on the ground. Where traditionally, the HPT would mainly disseminate instructions and information to the helicopters, the experiment witnessed a more 'collaborative partnership'.

- *Decision Agility*. With this enhanced situation awareness, the HPT and/or Jump-seat pilots have become more agile in performing dynamic planning due to changes in the situation. During the experiments, the scenarios were structured such that in some runs, the HPT did the re-planning for the pilots to execute, while in others, the Jump-seat pilots on-board did their own planning. The key determinant as to which party was the most appropriate one to do the planning was one of time-criticality, i.e. if the location of the given threat vis-à-vis the helicopters did not permit the HPT to do the re-planning, then the Jump-seat pilots themselves would do the re-planning. Based on the given scenarios and injects, the experiment showed that the HPT and the Jump-seat pilots were able to react responsively to avoid the various threats, as well as to plan alternative flight routes and/or landing sites.

- *Workload of the Jump-seat pilot and HPT*. While the helicopters have become more agile, some of the participants express concern about the workload of the various parties in real-life situation. For the jump-seat pilot, these include the appreciation of the terrain, availability of fuel, which currently already take up most of the co-pilot's time. For the HPT, if the wave comprises more than 2 helicopters, would he be able to come up with a new heliborne plan in time? To address these concerns, we need to look into how technologies can be used to reduce the workload. For example, the ForceMate system can make some recommendations of an optimised new plan considering the terrain, fuel status, etc. These new plans will also take into consideration the ground manoeuvre plan after the troops have been inserted.

- *Usefulness of the UAV Video*. According to the Jump-seat pilots, the UAV video was not useful. This is probably due to the fact that there is no camera orientation, in that the operator (and the person viewing the video feed, e.g. Jump-seat pilot or HTFC) does not know the camera direction. In addition, the continuously moving video feed may cause the person viewing, who has no control over the UAV camera angle, to be disoriented. A possible enhancement would be to provide a continuously updated stitched image, rather than just a raw video feed, so that the relevant parties viewing the stitched image can make sense of it easily. A suggestion was to incorporate some video mosaic capability into the C2 system so that the pilots would be able to have an overall picture of the area of operation.

- *MMI for the Chat Feature*. Although the chat feature was useful, the downside to it is that all parties involved would need to constantly keep their eyes on the small dialog box so that they can keep up to date with the situation. This is especially true for the Jump-seat pilots. A concern was raised that if the co-pilot is expected to perform this role during real operations in the future, it may conflict with his other operational responsibilities, e.g. to maintain situation awareness, e.g. location and progress of the helicopter vis-à-vis Aerial-Check Points (ACPs) and Release Points (RPs), to ensure that the flight instrumentation are in order, etc. Some suggestions to improve the chat feature are to make it like the short message service (SMS) feature in the handphone, and to send only the critical information through the chat.

- *Training of participants*. Training is key to ensuring that personnel are familiar with the processes, and adept at harnessing and exploiting the available technology to increase their mission effectiveness. While technology remains a key enabler to support the development and application of new warfighting concepts, sufficient measures will need to be put in place to ensure that it does not become a single point of failure.

THE WAY AHEAD

The SHELIDON experiment conducted thus far have provided the operators, planners and experiment team with many valuable insights and learning points. The experiment did manage to prove the concept of dynamic heliborne planning through the increase in situation awareness to the pilots, as well as in decision agility.

Future phases of the experiment are being planned to increase the number of SPs, as well as to include live troops in Australia this year.

Discussions are already underway to integrate the Helicopter simulator with the ForceMate as well as with the simulation system in SCME. This will allow us to try out as many configurations and scenarios as possible in a virtual environment to establish the various processes, so that actual flight-tests are conducted only when absolutely necessary.

SHELIDON has brought about a new capability to the 3G SAF in terms of allowing the helicopters to engage in dynamic heliborne planning. The ability of the helicopters to land distributed with reduced vulnerability and signature will increase their survivability as well as that of the deep manoeuvre troops.

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