Using network-centric simulations to model C2 and the impact of information

Lorraine Dodd
Future ISTAR Group
DERA Malvern
St Andrews Road
WR14 3PS, UK

Sean Richardson
Future ISTAR Group
DERA Malvern
St Andrews Road
WR14 3PS, UK

Jim Moffat
CDA HLS
DERA
Farnborough
GU14 0LX

Steve Brooker
EDS Defence Ltd
Room B34/0
1-3 Bartley Way
RG27 9XA, UK

Abstract

This paper describes three DERA models, HiLOCA, CLARION+ and CISME, that are network-centric in design and are being used to explore the impact of ISTAR, picture compilation and C2 on operational outcome. CISME explicitly represents the functional units within HQs, ground stations, ISTAR platforms and network architecture. CISME outputs measures of performance (completeness, accuracy and timeliness) along with loading of processing nodes. HiLOCA uses the picture degradation factors and time delays derived from CISME to explore their operational impact in terms of combat dynamics and losses. CLARION+ is a testbed version of the CDA/HLS Land-Air model CLARION. HiLOCA and CLARION+ are agent-based simulations. Preliminary studies using HiLOCA show that small changes in sensor reporting rates and ground station positioning can greatly affect the model's operational outcome.

1. Introduction

Future ISTAR group at DERA Malvern is responsible for evaluating the performance and measuring the operational effectiveness (OE) of ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance) assets and architectures. Typical studies analyse all aspects of Land Tactical Operations: in particular, sensor tasking and intelligence collection, information fusion and Command and Control. The paper briefly describes HiLOCA, a model of High Level Operations using Cellular Automata [Dodd 1995] [Woodcock 1989], CLARION+ (a testbed version of CDA/HLS Land-Air model CLARION) [Moffat 2000] and CISME (Command Information Systems Modelling Environment). CISME evaluates the performance of particular network designs and ISTAR architectures. HiLOCA measures their effectiveness in terms of operational outcome. All three models use command agents and situation appraisal agents to represent the processes carried out within the HQs. The agents interact with one another within a network (normally a hierarchy). The basic architecture used is OACIS (Object Architecture for C2 in Simulations).

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2. HiLOCA

In HiLOCA, there are two separate domains: the Battlefield Domain, which represents all the physical activity of the conflict including the ISTAR interaction with the conflict situation; the Command Information Systems(CIS) Domain which represents all the J2 and C2 processes. The Battlespace and C2 entities are modelled adaptively so that they are able to react to the unpredictable. HiLOCA is a prototype test-bed for DERA's C2/ISTAR research. The C2 models use local perceived combat-strength ratios to determine a Course of Action (CoA) that defines the operational mode for the lower-level units.

HiLOCA can be briefly summarised as follows:

- Many-sided (up to nine 'sides') Land-Air tactical (Corps-Platoon) combat model;
- Explicit representation of sensors, data collection, information processing and C2;
- Fast (currently approximately 200 times real-time in interactive mode);
- Not scripted (C2 decisions are made locally according to simple rules, giving rise to globally complex behaviour);
- Stochastic (movement, attrition, detection).

HiLOCA has a physical domain and a CIS domain. The physical domain (a simulated battlespace) contains all physical elements of the model, such as functional 'automata' (combat units, combat support services, HQs and sensors), terrain, weather (also day/night) and culture. The CIS (Command Information System) domain is where all communication between automata takes place, including contact reports, sensor reports, situation appraisal and course of action selection. The new features in the CIS domain are:

- a Dynamic Linear Model (DLM) to smooth and track enemy and own force strengths;
- an extended concept of perceived combat power ratio (PCPR) to four 'PCPRs': 1st echelon combat (direct fire), C2W/EW, Air Defence, 2nd echelon forces (ind/fire);
- use of ORBAT knowledge and sensor-target performance data for multi-sensor fusion.

Necessary features not planned for the first release of version 3.0 are:

- non-linear effects of global C2 indicators and uncertainty on the C2 decision outcomes; (research is continuing under TG11 Corporate Research Programme)
- mission planning and encoding of enemy intent;
- ISTAR management and automatic sensor tasking.

Mission planning and encoding of enemy intent (as a consequence of the mission planning work) has been proposed as the main work item for the next phase of TG11 research. The non-linear effects of global indicators and uncertainty on C2 decisions are also being studied under TG11. Current work for ARP19e8 is focussed on the sensor tasking and collection management problem and provision has been made in the input specification for HiLOCA version 3.0 for NIIRS-based sensor-to-task allocation/matching process models.

Each automaton in the physical domain can be configured according to its functional needs and physical constituents (generic platforms). The different types of automata in version 3.0 are:

- Recce

- Combat
- Headquarters
- ASTOR
- UAV
- Comms ESM
- Non Comms ESM
- Air Recce
- ARTY
- AD
- Log maint
- Log med
- Log supply
- Atk heli
- Sup heli
- Off engr
- Def engr
- Bridging
- Comms
- Fighter
- Bomber

Each generic platform can also be configured according to functionality, PCP, weapons, sensors, personnel and supplies carried. The platforms are segregated into two classes: interdiction class and BSS (Battlefield Sensor Simulator) class.

Interdiction Class: selected from the following list:

- Tank
- Armored
- Soft Skin
- Infantry
- Helicopter
- Low Air
- High Air

BSS Class : selected from the following list that relates to the ISTAR Simulation Environment :

- Anti-Aircraft Artillery
- Armored Command Vehicle
- Armored Engineering Vehicle
- Ambulance
- Armored Personnel Carrier
- Artillery
- Armored Recovery Vehicle
- Anti-Tank Unit
- Box-Bodied Vehicle
- Bowser

- Bridging Equipment
- Helicopter
- Load Carrying Vehicle
- Main Battle Tank
- Motor Cycle
- Multiple Rocket Launcher
- Engineering Plant
- Surface to Air Missile
- Soft-Skinned Vehicle
- Railway Locomotive
- Trailer
- Truck Mounted Crane
- Van
- Car
- Fixed Wing Aircraft
- Self Propelled Gun
- Surface to Surface Missile

Sensor platform models in Version 3.0 are as follows:

- Ground-based ‘own forces in contact’ sensors;
- ASTOR (as a Divisional ISTAR asset) providing long-range MTI/SAR capability;
- Space-based IMINT/SAR;
- Forward ground recce platform (based on TRACER);
- Unmanned Air Vehicle (UAV).

Also planned: Ground-based ESM, long-range (airborne) SIGINT, a RAPTOR-based platform, ground-based radar (such as weapon-locating radar) and acoustic sensors. Sensor fusion and integration mimics the pragmatic approach used in CISME but current research into fusion algorithms will provide algorithmic enhancements.

3. CLARION+

CLARION+ is a testbed version of CDA/HLS Land-Air model CLARION [Moffat 2000], [Mason 1998]. CLARION+ is an agent-based simulation using OACIS architecture to capture the hierarchical network structure of interacting HQs processes. The lowest level of resolution used is the Bde level. At this level the missions assigned to units (command agents) must be translated into behaviours that the units are to perform in order to achieve the mission. For example, Bde-level command agent missions/postures are defined in terms of the existing CLARION CCE (Close Combat Entity) missions:

Mission	Behaviour
Secure	Move directly to the mission area. Engage any enemy entities which come within weapons range en route. Engage/ Intercept enemy entities in the mission area in priority order.
Fix	Move directly to the mission area. Engage any enemy entities which come within weapons range en route. Engage enemy entities in the mission area in priority order.
Defend Static	Move directly to the mission area. Engage any enemy entities which come within weapons range en route. Dig in at centre of mission area on arrival. Engage targets in priority order. Do not move.
Defend Mobile	Move directly to the mission area. Engage any enemy entities which come within weapons range en route. Engage/Intercept enemy entities in the mission area in priority order.
MoveTo	Move directly to the centre of the mission area. Engage enemy entities in contact.
Reserve	Move directly to the default position, perform low priority defend task: mission area based on class A sensor range.

Table 4.2.1 - CLARION CCE Missions

The command agent missions in terms of the CLARION CCE missions are as follows:

Advance - MoveTo, followed by Secure, followed by Defend Static.

Attack - Secure , followed by Defend Static.

Defend - Defend Static mission.

Delay - MoveTo, followed by Defend Mobile (the area defended is dependent upon the agent's current mission area).

Withdraw - MoveTo, followed by Defend Mobile (the area defended is dependent upon the agent's current mission area).

Note that the Delay and Withdraw missions/postures are structurally identical but differ in the area that is defended.

In this way, the military operations are driven from local PCPR-based decisions constrained by top-down mission directives when and if C2 conflicts occur. The C2 conflict resolution rules can be set so that differing degrees of local autonomy can be assigned to the HQs. The agent-based approach allows full representation of the command arrangements described in [Alberts 1995] from Control-free to Cyclic.

4. CISME

Command Information System Modelling Environment (CISME) is a suite of dynamic simulation models representing the command, control and operation of all the functional areas of the UK Army. CISME models are not conventional battle models and they do not predict military outcome. They are detailed (resource-limited) models of the command, control and operation processes conducted by an Army HQ network in the context of a time evolving operational scenario. The range of scenarios used typically includes both war fighting and peace enforcement. The resources represented in CISME models include men, machines, computers and communications systems.

CISME is funded by MOD ARP (Applied Research Package) 19e/8 (Future Way of Command). This package of work uses CISME to evaluate a range of future digitisation concept designs. An initial version of CISME-G2 was delivered and used for a study that reported in June 1999. The full version is under development for use in a study that is to report in June 2000. All of the CISME models are developed using the STARDIS distributed information system modelling toolkit which is available free of license fee to DERA, MOD and to third parties working for DERA or MOD.

The complete set of planned CISME models is as follows:

1. CISME-BGBMS (G1-G4)
2. CISME-G3 (Operations)
3. CISME-G4 (Logistics)
4. CISME-G6 (CIS and Comms Management)
5. CISME-G1 (Personnel)
6. CISME-Arty (Artillery)
7. CISME-Engr (Combat Engineer)
8. CISME-AD (Air Defence)

With the exception of the CISME-BGBMS model, all of the above are based on HQ's from 3* down to unit level. This is the regime of FBMS (The Formation Battle Management System). The CISME-BGBMS (Battle Group Battle Management System) model will encompass unit level down to individual platform level.

The CISME-G2 model represents the command, control and operation of the Army G2 process. The function of this process is the production of a tactical intelligence database (sometimes known as a tactical picture) which can be used by commanders at a variety of HQ levels and by other Army processes (e.g. Targeting).

The Army G2 process starts with the tasking of overwatch ISTAR assets to gather data in order to meet situational awareness RFIs (requests for information). Data from these sensors and from other sensors not under the control of the G2 process (e.g. Joint and Combined ISTAR assets) is then passed into a processing chain.

The processing chain includes the tasks of filtering, image exploitation (where necessary), target association and target fusion. The resulting information is then stored in a tactical intelligence database which will in general need to be replicated. The G2 process includes the preparation of reports and the onward dissemination of intelligence in order to meet the RFI's. The G2 process also includes the planning of Target Development RFI's and Target Maintenance RFI's. The outcomes of these types of RFI planning include; the immediate answering of the RFI from stored knowledge; the passing of the RFI to another HQ to deal with; the tasking of a asset under command, or the tasking of image exploitation. The G2 process also requires internal self management in order to meet a requirement for information that may exceed its own capabilities.

CISME Version 1.0 was restricted to Division and Brigade HQ and ISTAR assets:

1. ASTOR
2. RAPTOR
3. PHOENIX

4. TRACER

CISME Version 2.0 covers the HQ levels from 3* down to Battle Group and will encompass a full range of future ISTAR assets:

1. PICASSO
2. Strategic SIGINT
3. ASTOR
4. AWACS
5. INTERPRET
6. RAPTOR
7. SFOPs
8. AH
9. SENDER
10. SPECTATOR
11. SOOTHSAYER
12. TRACER
13. COBRA/MAMBA
14. Battlefield Surveillance Radar

The primary inputs to the CISME-G2 model are:

1. A range of G2 command, control and operation concepts to be assessed.
2. A time evolving scenario defining the locations and movements of all blue, red and neutral entities over time (supplied by HiLOCA).
3. A definition of the assets available to the blue forces in the scenario(s) including men, machines, computers and communications.
4. Performance data on each of the above, including the communications bearers.
5. Initial information requirements for all of the blue command levels in the scenario.
6. Concepts of use for each of the ISTAR assets.
7. Performance data for the ISTAR assets (including IMINT exploitation performance data).
8. Environmental and geographical data for the scenario in order to access the terrain, culture and other features that may affect the performance of the ISTAR assets

The primary outputs from the CISME-G2 model are quantified measures of performance for the Army G2 system including the following :-

1. Picture completeness;
2. Locational accuracy;
3. Level of confidence of information held in the tactical picture.

All of the above are time-varying and can be measured at any HQ (or any other component storing a tactical picture such as a Fusion Centre).

Also, in addition to the primary outputs:

1. Staff loading
2. Staff task queues
3. Computer loading
4. Computer access queues
5. Communications bearer loading

6. Communications bearer access queues

5. Preliminary ISTAR impact studies

The screenshots below show the impact of small changes in ISTAR specification.

Two runs of HiLOCA show that changes in the reporting times and update rates of the Airborne Stand-off Radar (ASTOR) cause large changes in the combat dynamics.
In the first simulation the ASTOR specification is:

- Track update period = 30mins. (time to build and maintain track)
- Reporting rate = once every 45mins.
- Staleness = 30mins (time to exploit information before sending to DivHQ).

In the second simulation the ASTOR specification is:

- Track update period = 5 minutes. (build and maintain track more quickly)
- Reporting rate = once every 5 minutes (report more frequently)
- Staleness = 10 minutes (site ground station at DIV HQ to reduce staleness).

No changes (other than the ASTOR timings above) were made to command agents or manoeuvre tactics. In the second run, Divisional HQ gets an early warning of the strength of the approaching enemy (Red) force and this clear early warning causes a series of events that trigger a cascade reaction to change the dynamics and hence the outcome of the operation. Figure 1 shows that in the first run (top screenshot) the incomplete tactical picture (that caused an abortive Divisional Attack order prior to the eventual Divisional Defence that changes the combat dynamics) causes the reserve Brigade to move too far south to be immediately effective. In the second run (lower screenshot) the more accurate, complete and timely tactical picture results in a decisive Divisional Defence posture and this allows the Brigade to carry out a flanking manoeuvre.

These preliminary results of simple single runs of a stochastic model can only show the general degree of potential change in combat outcome given small changes in the ISTAR system specification and should not be viewed seriously as study results. However, they serve to highlight the need for dynamic network-centric models that have fully user-configurable CIS/ISTAR architectures that are able to drive the C2 processes that in turn drive the combat dynamics.

HiLOCA and CISME are designed so that destruction or disruption of any CIS node has a direct impact on the C2 network of decision-making and hence a potential impact on operational outcome.

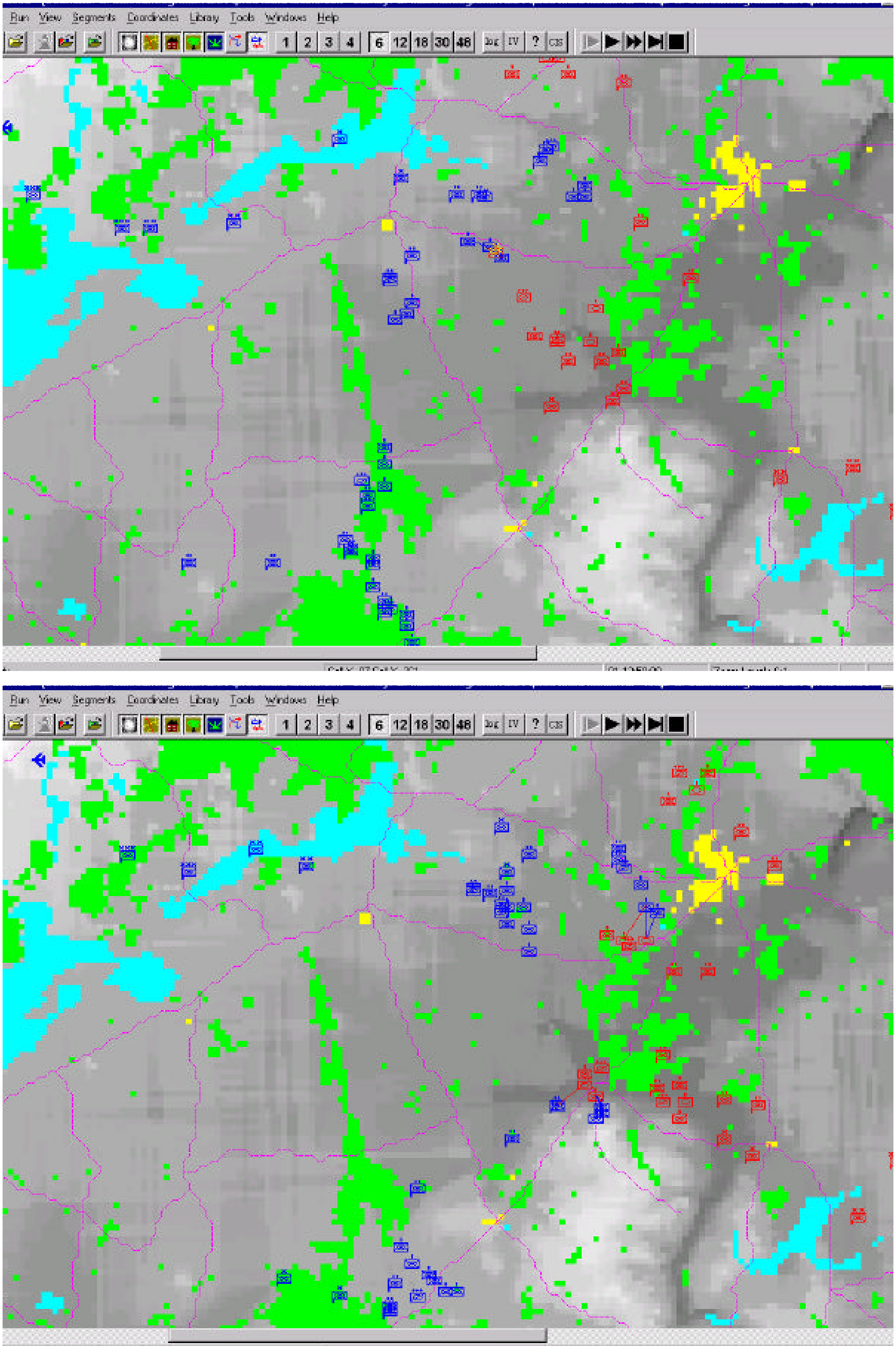

Figure 1: Change in combat dynamics resulting from change in ASTOR specification

6. References

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