DIAMOND

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Andrew Caldwell graduated from Surrey University, England, with an honours degree in Materials Engineering and worked for three years as an operational researcher at British Steel Plc. He then joined the Centre for Defence Analysis (CDA), Farnborough as an analyst to provide operational analysis support to the current Conventional Forces in Europe (CFE) negotiations and to conduct scenario development work for the United Kingdom Ministry of Defence. For the last 18 months he has been involved in developing CDA's capability to model peace support operations and in particular the design and construction of the high level simulation model, DIAMOND.

ABSTRACT

DIAMOND (Diplomatic And Military Operations in a Non-warfighting Domain) is a campaign level simulation model for representing Peace Support Operations (PSO). DIAMOND is currently in development at the Centre for Defence Analysis (CDA), a sector of the UK's Defence Evaluation and Research Agency (DERA). This model is an experimental (but potentially high value) tool to be used for the analysis of the military contribution to PSO. The development has focused on providing an analytical capability for assessing force structure options and determining the requirement and utilisation for a variety of force elements deployed to PSO. To achieve as full a coverage of the issues associated with PSO as possible it has been necessary to mix hard and soft modelling techniques and develop new mechanisms for investigating and interpreting PSO. These include the assessment of coalition command and control structures, cross party negotiation for support, refugee movements and the modelling of military forces in non-warfighting roles. DIAMOND will be delivered to CDA in September 2000 and commissioned for study use by April 2001.

INTRODUCTION

THE CENTRE FOR DEFENCE ANALYSIS

The Centre for Defence Analysis (CDA) is the operational research (OR) arm of the Defence Evaluation and Research Agency (DERA). Most CDA study programmes support UK Ministry of Defence (MoD) planning processes on policy, procurement and operations.

Conventional combat has in the past been the core study area for CDA. To support this, a wide range of OR tools and techniques have been developed to support CDA's study programmes. However, since the end of the Cold War, greater emphasis has been placed on understanding operations that fall outside of conventional combat. In recent years, the ever-increasing commitment of the UK's armed forces to Peace Support Operations (PSO) has exposed a shortfall in high level modelling tools suitable for analysis of non-warfighting military tasks. As a consequence of this shortfall CDA is in the process of restructuring part of its tool-set to meet PSO OR requirements. DIAMOND (Diplomatic and Military Operations in a Non-warfighting Domain) is part of that programme.

THE PSO MODELLING JIGSAW

Modelling PSO is still a new and evolving area for the OR community. Rather understandably for such a young discipline there are many pieces to the 'jigsaw' but not yet the understanding of how they all fit together to provide the complete picture. In fact it could be argued that as a community we are still uncertain of which pieces we need to complete the jigsaw, let alone how they fit together. Figure 1 represents some aspects of this jigsaw and some of the pieces to which we have access.

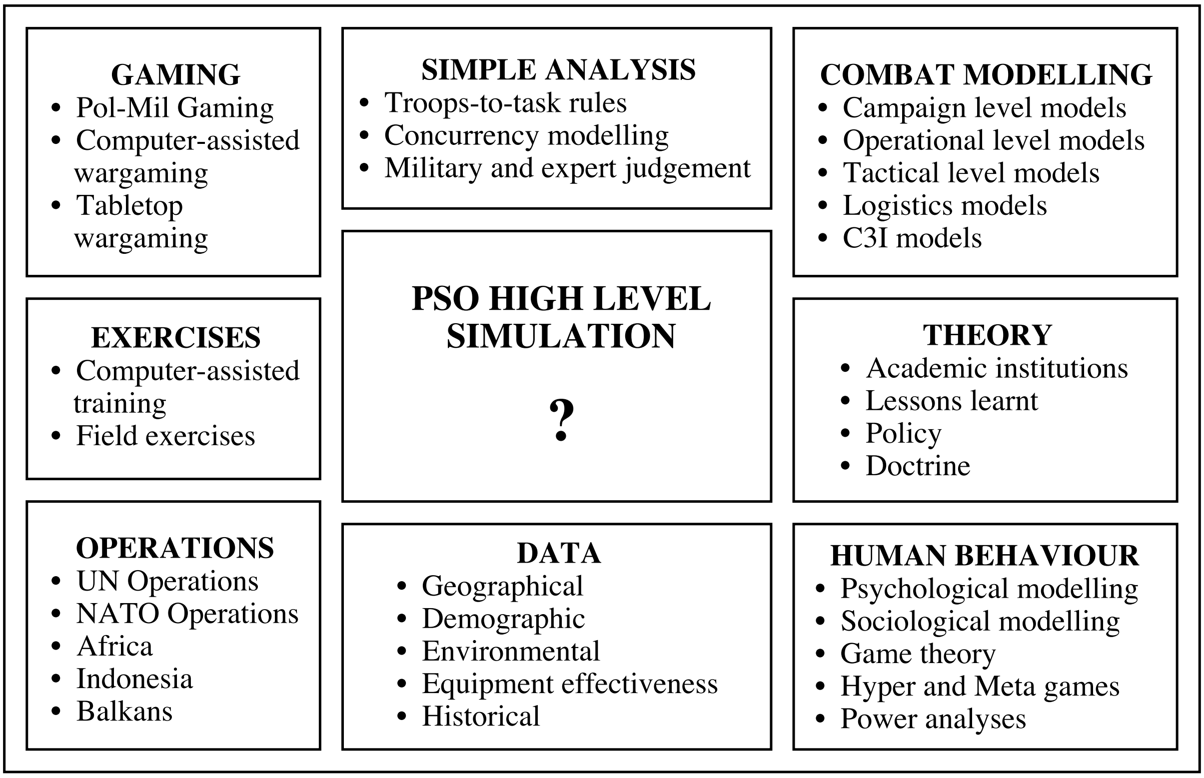

Figure 1: The PSO Modelling Jigsaw.

In answering any OR question on PSO it is important to examine the tools and techniques available to us and decide which of the pieces are most appropriate to answer that question. Some may be answered from a single source such as a database whereas others will require a combination of tools and techniques. Very complex questions, such as those concerning policy and force structures, require a wide selection of tools and sources and quickly become either too expensive to do or too complex to examine rapidly. One proven way to offset these disadvantages is to deploy simulation models that focus the data, techniques and understanding from other sources and provide an analytical environment in which to study complex questions. Figure 1 suggests that there is currently no tool available which fits the requirement for the high level simulation of PSO. DIAMOND, once completed will fill this requirement and provide a simulation model suitable to draw on the surrounding data, tools and techniques to which we already have access.

REQUIREMENT FOR DIAMOND

DIAMOND is under construction to address Force Development issues associated with peacekeeping, peace enforcement and humanitarian aid operations. Part of this requirement involves providing a tool to assist in answering the following types of question:

- Which force elements are essential to maintain the military mission?
- What is the utilisation of each force element[1]?
- Are force elements used in their primary role or do they substitute for high demand elements?
- Are such substitutions efficient?
- How robust is the force mix option in adapting to changing political and military circumstances in theatre?
- What is the ideal force mix to support an operation?
- What is the ideal force structure to support a wide variety of potentially concurrent operations?

One tool to answer these questions is a simulation model. In Figure 1, 'The PSO modelling jigsaw', High level simulation (ergo DIAMOND) is shown at the centre of the puzzle. This is not to suggest that DIAMOND is the 'final piece' in the PSO jigsaw but to show that DIAMOND links into all the pieces that surround it. For high level force development work this is the logical arrangement of the pieces but for other studies, such as procurement or balance of investment, DIAMOND may sit on the periphery or provide no significant contribution to an OR solution at all.

It is also important to state that the current design for DIAMOND is not intended to provide a 'single model' solution for analysing policy and force development PSO issues. Although many aspects of the other tools and techniques can be incorporated directly into DIAMOND (e.g. data and doctrine) the model will still require indirect support from other areas. For example, DIAMOND may rely on other models or wargaming to develop an initial concept of operations and scope the political constraints for any given scenario.

For any study there will inevitably still be pieces of the jigsaw missing but as our understanding of PSO deepens those pieces will be discovered and introduced into the

[1] Force element is defined as a company, battery or individual aircraft or ship.

picture. As DIAMOND is an evolutionary development, the model will be continually improved to take into account our increased understanding of the domain and the model itself. DIAMOND has already highlighted some areas where we have either very little or no suitable data with which to examine particular aspects of PSO operations (e.g. refugee movements) and thus its development can be used to focus other work on collecting and assimilating information for study use.

DEVELOPMENT PROGRAMME

The DIAMOND project began in August 1998 with a series of workshops to scope the requirement and focus the development on the core aspects of peacekeeping, peace enforcement and humanitarian aid. This resulted in the production of an outline requirement document establishing the boundaries and aims of the project (Caldwell, 1998). Following this a detailed requirement was written later that year (Caldwell and Christley, 1998) as the foundation for all future work. A further eight months development effort followed and resulted in the production of the functional specification which outlined how the requirements would be implemented to produce the DIAMOND model (Albano, Frankis, Hayes et al., 1999). In September 1999 further workshops were convened to complete the design and begin the process of coding the model. At the time of writing, a prototype containing part of the required functionality has been built and is undergoing testing and evaluation.

The project is on course to deliver a working version of the model by the end of August 2000 and for the model to be validated, commissioned and in use by March 2001. As the project is an evolutionary development it likely that further design and coding will occur in early 2002 to build on lessons learnt and incorporate research generated from the delivery of the first version of the model.

The model is being developed using the Rational Rose object-oriented modelling tool, Visual C++, Windows NT4, Microsoft Foundation Classes and DROMAS version 2.63. The target hardware requirement is Pentium II 300 with 64Mb of RAM and a 17-inch monitor. Given this hardware specification the model has been designed to complete a 100-day scenario in less than 10 minutes run time.

TECHNICAL SPECIFICATION

OVERVIEW

DIAMOND is a fast running, high level, stochastic, object-oriented simulation of peacekeeping, peace enforcement and humanitarian aid operations. The major aspects of the technical design are summarised below.

- A simple node and arc network provides a graphical representation of region and environment allowing the model to represent key areas of interest, areas of sea or lake and the airspace above. Key facilities, such as airports and civilian shelter can be represented. The model allows for the representation of key actors and contributors to peace support operations by use of Entities. These represent the capabilities and behaviours of military units, civilians, non-military organisations and the leaders or commanders for each. Entities interact with each other, the environment and create, exchange or consume key commodities such as food, fuel and ammunition.

- The model incorporates a mechanism to organise entities into common 'parties' that represent specific organisations or common groups in a scenario. Those parties have an appropriate command structure and communications network to facilitate the allocation of missions and flow of intelligence throughout the party. Parties have relationships with one another allowing them to interact with other parties.

- The model includes a mechanism to represent each party's concept of operations by nesting objectives in a series of plans and for those plans to consist of a series of missions that entities can prosecute during a campaign. Commanders within a party will allocate resources to achieve their objectives in line with the sequence of plans and the simulation will complete when a set number of parties achieve their end state conditions or when a predetermined period of time has elapsed.

- During a model run entities will gain information on their environment and other entities through sensing, interactions and communication. This information will be organised into a local picture which will allow those entities to make informed decisions on how they should prosecute their missions and activities delegated to them by their superior commanders. Finally, DIAMOND includes a mechanism (referred to as negotiation) to obtain access to an area denied to one party by another and to allow multi-party co-operation to achieve aims and objectives without having to rely entirely on their own resources.

ENVIRONMENT AND FACILITIES

A node and arc network provides the physical environment in DIAMOND. Nodes represent areas of operational interest, population centres and the locations of key infrastructure and terrain features. Arcs represent the routes between nodes.

Nodes can, depending upon the nature of the scenario, represent whole cities such as London or individual districts or regions within a city such as Chelsea, Lambeth, Westminster or East and West London. They can be used to represent individual villages but it is proposed that a more appropriate aggregation level would be collections of villages. Nodes are also used to mark areas of deep water, points along an air corridor, strategic junctions and key terrain features.

Arcs represent the routes between the nodes and each one has several channels which can include ground routes (road, rail and cross country aggregated), air corridors, inland waterway (canal, river, lake crossing aggregated), littoral waterway and deep waterway. The anticipated length of each arc is around 10 to 30 Km, although this may be much shorter where areas of interest are close to one another (e.g. the districts of a city).

The type of channel (and its capacity) determines which entities can move down that arc. For example, large ships cannot transit an arc connecting two water nodes with only an inland waterway channel (e.g. a canal), as they will be prohibited from using any channel that was not a deep-sea waterway.

When defining the node/arc network (Net), the user must take care to ensure that the Net is established with a level of granularity appropriate to the entity size, i.e. division sized entities on a Net where individual nodes represent single villages and settlements would be inappropriate. It is proposed that for an environment represented as cities, towns or districts with arcs between 10 to 30 Km then the appropriate entity size for military units is battlegroup, air package[2] and individual ship.

Nodes and Arcs both have a terrain type (called culture) which influences a variety of calculations; (e.g. effectiveness of sensors, rate of attrition between two units engaged in combat, movement rate etc.) These culture types are:

- Urban.
- Suburban.
- Open Flat.
- Open Rolling.
- Open Mountainous.
- Scrub.
- Lightly wooded.
- Densely wooded.
- Mountainous.
- Open Water.

Weather is also modelled and encapsulates factors with local, temporary effect. Weather on an arc shall default to the weather of the nearest node; ergo the midpoint of arcs shall be where weather types can change between different areas of interest. Weather conditions at all points on the net shall be known by all entities. Advance forecasting of weather will not be modelled in the first release of DIAMOND but may be introduced in later developments. Day and night will not be represented in the first version of the model but will be introduced in subsequent developments.

[2] Battlegroup approximately three to four companies, air package approximately one to four aircraft.

At each node it is possible for the user to define facilities, which are key attributes of that area that any entity can interact with. The facilities to be modelled in DIAMOND are:

- airports.
- hospitals.
- seaports.
- storage depots.
- shelter.
- bridges/tunnels.

Each facility has the following generic attributes:

- *Damage points:* The damage points for a facility will indicate how hard the target is to eliminate. Damage points will be represented by two fields: the maximum damage points a facility can sustain before it is eliminated (or at least ceases being targetable by weapon systems) and its current damage points. Note facilities may start a scenario already part damaged.

- *Capacity or Output:* Most facilities produce an output or service of one type or another. For example, shelter has the capacity to house people; hospitals have the capacity to treat a number of patients per day. The capacity or output will be different for each facility but the concept of capacity is generic across all facilities. The capacity can be degraded with damage. Therefore there will be two fields: Maximum capacity and current capacity. Both of these will be dynamically calculated at the start and/or throughout a run.

- *Damage point to Capacity point conversion factors:* As damage points inflicted affect the capacity of a facility the relationship between damage sustained and capacity reduction will be governed by the Damage point to Capacity point conversion factor.

- *Self-Repair capability and Self-Repair Threshold:* Although engineering and construction entities in the simulation perform repairs, all facilities are likely to have an intrinsic self-repair capability based on the manpower and/or specialist equipment at the site. For example, civilians can repair light damage to their homes by boarding up windows, replacing missing tiles or through other makeshift repairs. Plumbers, builders and other specialists within the community would repair heavier damage and would not necessarily be represented by a special entity. These effects are represented by the Self-Repair capability, which is the number of damage points that facility may repair itself per day. Only when damage is very heavy and widespread do these local services become ineffective. As such, the self-repair capability of any facility will be limited and may cease to operate if the damage is heavy. This is represented by the Self-Repair Threshold, which is the number of damage points above which the Self-Repair capability is available.

- *Residual Capacity and Residual Threshold*: Not all facilities can be totally destroyed and therefore even when fully damaged they may provide a residual capacity. For example, even if a hospital was destroyed some of the doctors could remain in the area and operate out of any acceptable premises. Consequently, a residual capacity is another general attribute of facilities. It is the minimum capability a facility will provide even if it has sustained maximum damage.

ENTITIES AND ACTIVITIES

The entities in the model can be considered to fall broadly into the four categories below.

1. *Peacekeepers:* Peacekeeping and Peace Enforcement forces with entities representing land, air, maritime and special forces units operating under a UN or other international mandate. Supplementary police forces to assist a failed state are also covered under this category.

2. *Factions:* The military and paramilitary forces of belligerent or warring factions who are not part of the peacekeeping or peace enforcement forces. The host nation's forces are also covered under the heading of factions. The entities include land, air, maritime and special forces units.

3. *Non-military organisations (NMOs):* NMOs include monitors and observers, commercial companies, governmental and international humanitarian agencies and non-governmental organisations.

4. *Civilians:* Civilians, including neutral civilians and those associated with individual factions, internally displaced persons, refugees and evacuees.

Each of these categories of actor can be represented in the model through use of an entity template. There are five types of template available. Three are for different levels of commander, one for civilians and the other is a generic template used to describe all land, sea, air and NMO entities. In summary the templates are:

1. Joint Theatre Commander.

2. Component Commander.

3. Intermediate Commander.

4. Civilian Entity.

5. Generic Entity.

Although three types of commander are specified it is implicit for both civilian and generic entities that they can command themselves if they have no direction from a superior. They have their own local picture, perceptions and are capable of making decisions for their own survival and to achieve their missions. The higher level commanders allow for additional considerations, such as deciding which stage of a campaign plan should be followed, allocating resources to missions and directing a number of subordinate entities to work together to achieve a common goal.

Each template allows the user to define a number of key descriptors for that actor in the simulation: movement rate, size, sensor package, combat ability, transport capability, civilian/military identifier, commodity consumption rates, communications networks, engineering capability and the missions the entity is eligible to perform.

The proposed aggregation levels for land, air and maritime units in DIAMOND are battlegroup, package and single ship respectively. Civilian populations will vary between several hundred and several million and NMOs are likely to be small units of variable size and attributes.

As commanders represent headquarters, local government, individuals and in some cases the intangible collective actions of a set of common entities (e.g. refugees) their size is entirely user defined.

To allow the model to calculate 'entities to tasks' all entities, regardless of their size will be standardised in terms of "components." For military land units a component represents a deployable company or squadron and for maritime and air forces a component represents a single ship, boat or airframe. This choice was made to allow components for land units in DIAMOND to map directly from lower level combat models and for combat outcomes from those models to populate lookup tables in DIAMOND.

Although no detailed work has been done on what is an appropriate component level for NMOs it is proposed that a size of components identical to their military counterparts be used in the first instance. Although this will mean some NMO entities will represent fractions of a component (a single land rover and two aid workers equals about 0.02 of a component), the entities to task rules can be written with this in mind and allow DIAMOND to substitute military and non-military entities between tasks (e.g. bridge repairs, food distribution).

SENSING AND COMMUNICATION

In DIAMOND sensing and communication cover the processes by which entities directly acquire information about other entities, events and the environment.

Sensing covers three processes:

- Direct observation.
- Use of a sensor such as radar.
- Experience of events, i.e. interactions with other entities and the environment.

The representation of sensors is to be kept as simple as possible for the first release of DIAMOND. Rather than have explicit representation of known sensors such as radar, optics etc. the user will be able to give names to generic sensor packages. A sensor package represents the collective sensor performance of that entity. For example, a British battlegroup will have numerous visual, IR, and radar sensors plus the eyes and ears of over 500 soldiers. In DIAMOND this would be represented as a single sensor package. A unique name and the component types it is capable of detecting will define each sensor package.

For the first release of DIAMOND 'cookie cutter' templates will represent the range of sensors. The surrounding culture type of any target entity, the size of that entity and the local weather conditions will modify these ranges. Any item that falls within this adjusted maximum range of the sensor package will be detected and all entities that fall outside will evade detection. Different ranges within the cookie cutter will determine the resolution (i.e. the detail) that the sensor information can provide (Figure 2).

For communications DIAMOND will represent a number of communications networks. Some nets (such as military networks) will be party-based, while others (such as commercial news stations) will be 'global.' Messages communicated include orders, status reports, requests for assistance, intelligence, local picture information, and media broadcasts.

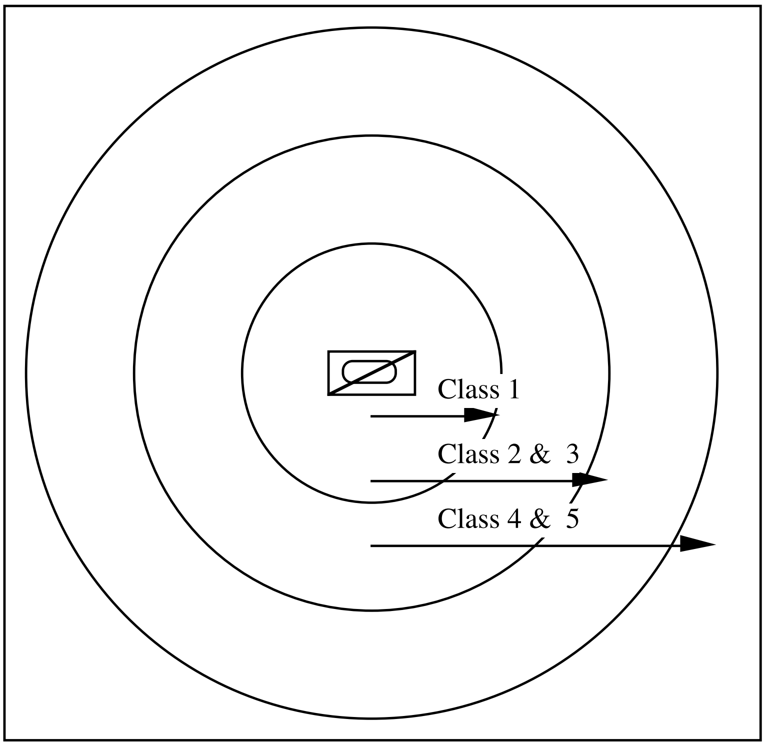

Figure 2: Example 'cookie cutter' sensor ranges with different classes of resolution.

An entity will always communicate with its superiors and subordinates. The user may also create special nets to allow communications that do not follow the command structure. For example, these might include media, the 'rumour' network and face-to-face communication. One occasion when this will occur dynamically is when an entity is assigned to operate for a commander (possibly in another party) that is not his direct superior. Under these circumstances the entity will report directly to its hierarchical commander and to the commander who has Operational Command (OpCom) of that unit.

Communications will be of four types:

1. *Regular (or event triggered) communication* between superiors and subordinates within a single party's communication network. This regular updating system is flexible and can include siblings and can be fully networked to represent digitised C2 architectures.

2. *Direct communication* between a commander and a subordinate entity from a different party who has been instructed to co-operate by its superior commander. This is a temporary (dynamic) link that will end when the mission they are co-operating on is complete.

3. *A global broadcast* that reaches all entities with a receive capability for that broadcast type.

4. *Negotiation* between two entities from different parties who are in the same 'peer group' (a user defined list of who is allowed to talk to who and about what). Examples include requests for escort, requests for supplies and requests for access. Negotiation is assumed to be supported by appropriate communications systems (e.g. radio if negotiating at distance, interpreters if negotiating face to face).

Broadcasts and directed messages are subject to delay at each level of command. Interoperability problems within a multinational force can be represented by additional delays in transferring information from one net to another when an entity has access to both. In DIAMOND entities from different parties may have 'receive' only links with other parties connected to the communications network to represent the sharing of intelligence.

All information received by an entity (whether that be through sensing or communication) will be assimilated into its local picture. The representation of local picture (and perceptions based upon it) is an important aspects of DIAMOND, as all entities decide what to do in the simulation on the basis of the information available to them. If this information is incomplete or out of date the entity's actions may be different, compared to their actions based on complete and current information.

The local picture in DIAMOND is defined as the aggregation of all information made available to that entity with perfect and efficient data fusion. Perception is the translation from what that perfect picture looks like into what the entity 'believes' it knows. For the first release of DIAMOND local picture will map 1:1 onto perception. In subsequent developments the perception function will be enhanced to allow for misinterpretation, double plotting and extrapolation of information in the local picture.

Each piece of information recorded in the local picture consists of four items. They are:

- Resolution classification.

- Credibility classification.

- Unique identifier.

- Timestamp.

1. *Resolution Class*. The resolution class determines the detail of the information available about that entity. In DIAMOND as soon as a level of detail is acquired about another object it is time stamped against the unique ID of that entity and the specific information gathered at that level is recorded to a temporary store. That information can then be recalled whenever an entity consults their local picture about that specific piece of information. There are 5 levels of resolution, ranging from the least detailed, detection, through to the most detailed, analysis.

2. *Credibility Class*. The credibility of the information (which is dependant upon the source of the information, previous credibility assigned to that information and the entity receiving the information) is also recorded. Credibility will influence whether entities use or discard that information when they make decisions based upon the information in their local picture. In the first version of DIAMOND the credibility may be detached from the other three data items (resolution class, timestamp and unique ID) to replace a lower credibility on a more accurate or up to date version of the same object (i.e. better resolution or timestamp). In subsequent versions of DIAMOND it will be possible to take two reports of the same object and combine them to provide an updated perception of that object. (And, as this is a perception function it will be possible to combine the worst credibility and detail by mistake and discard the good information!) There are five levels of credibility in the model, ranging from certain through to incredible.

3. *Unique Identifier*. The unique identifier records the individual identity of every object in the simulation. (This need not be the unique identifier the analyst uses, it could be a model generated identity number.) This information is required by the model to ensure the same object is not plotted twice in the local picture. As the local picture is defined as the most efficient fusion of data the model will always plot the most useful combination of information relating to that unique object. This effect is not true for the perception picture where errors may occur (i.e. the object is plotted twice, it is plotted in the wrong place, it is mislabelled, it is mis-identified, or it is ignored). However, as previously stated perception is not modelled to this level of detail for the first version of DIAMOND.

4. *Timestamp*. It is important to timestamp when the information was gathered. Certain decisions will only be made with up to date information and old information may be removed from a local picture entirely. Timestamp is also useful for determining whether to ignore a new piece of information. For example, if a poorly detailed and low credibility data item arrived it would not be worth replacing a higher quality report of the same object that was recorded only a few hours ago. However, if that existing data item was weeks old then the less detailed and less credible information would still be more useful and could replace the old information in the local picture.

MISSIONS AND DECISION MAKING

The activities of entities within the environment will be governed by the two criteria. Firstly, the missions (i.e. tasks) represented in the model that entities are eligible to perform and secondly, the decision making processes in each party that determines how and when those missions should be prosecuted.

There are 12 missions in the model. They are:

1. Transport.
2. Intelligence.
3. Move.
4. Engineering.
5. Defend.
6. Reserve.
7. Evacuate.
8. Escort.
9. Presence.
10. Strike.
11. Secure.
12. Deny movement.

The majority of the missions cover general tasks that any entity in the simulation could undertake (Transport, Intelligence, Move, Engineering, Defend and Reserve). The other missions are those that are likely to be specific to either the peacekeeping forces (Evacuate, Escort, Presence and Strike) or to the belligerent factions (Secure and Deny movement). This is not to prevent the missions being interchangeable between the different parties within DIAMOND but to indicate that the design has focused on providing specific tasks associated with the principal actors involved in PSO. Each of the missions is interpreted by the entities that perform them as a series of activities. For example, the transport mission consists of the sequence: Plan, move, commodity exchange (i.e. load), move, commodity exchange (i.e. unload), reserve (i.e. become available for a new task) and communicate (i.e. report to superior commander that the entity is now available for new missions).

The missions themselves are organised into concurrent and sequential packages, referred to as plans. For example, a plan may include a mission to secure an area after which several transport and presence missions may occur concurrently. The entities undertaking the missions within the plan report at regular intervals whether they are succeeding or failing and their superiors may allocate additional resources (if they have them) to move failing missions back towards success. The relationship between plans, missions and activities is shown below in Figure 3.

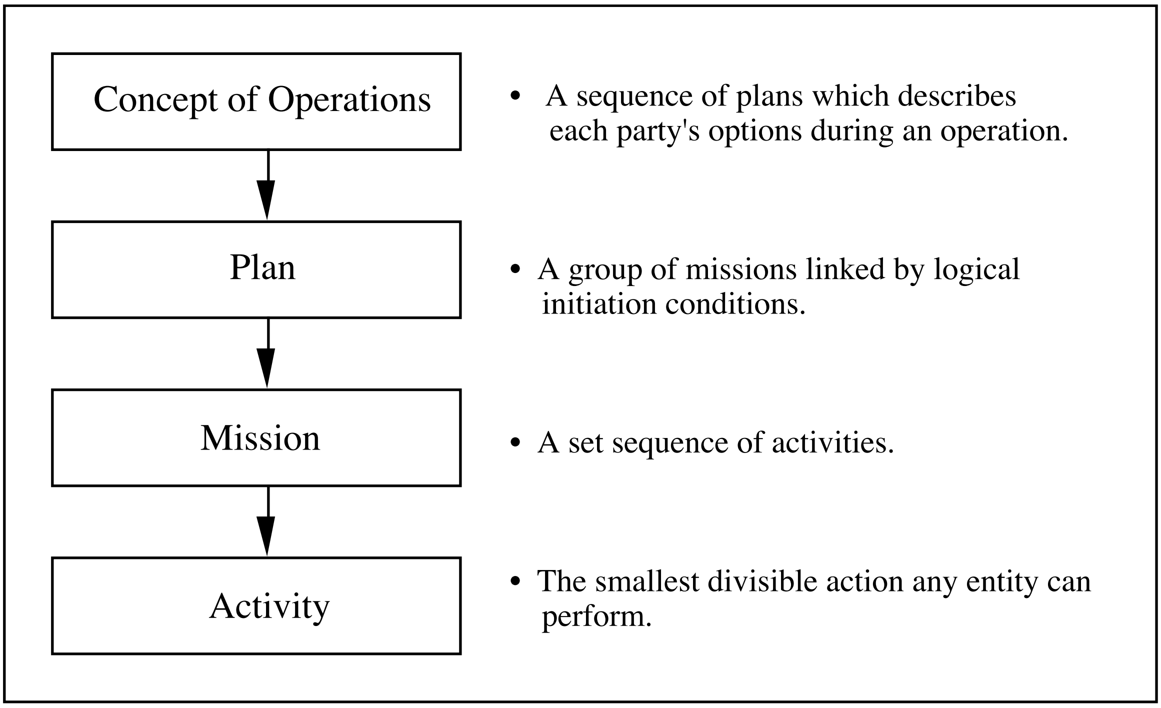

Figure 3: Relationship between plans, missions and activities.

Monitoring the overall progress of the plan will be the Joint Theatre Commander (JTC) or his NMO equivalent. The JTC's perceptions will include a function called the Campaign State Vector (CSV) and it is the CSV that will indicate to the JTC whether the plan is succeeding or failing. Each plan has an associated set of initiation conditions and end conditions, which may be time dependent and/or success dependent. If a plan is failing (or has completed) the JTC will decide which is the next most appropriate plan to follow. This is represented below in Figure 4.

In Figure 4 it can be seen that there are two additional boxes with success or failure in them. If either of these boxes is reached then the simulation will terminate and record the reason. If, during a run neither of these conditions are reached by any party then the run may terminate after a number of simulated days has elapsed. From the perspective of force development work the only failure and success conditions that would normally be of interest are those associated with the peacekeeping forces. However, Pol-mil gaming or other expert judgement that supports scenario construction within DIAMOND may identify other failure or success modes that relate to other parties. Reaching these may, or may not, end the simulation, as unlike war-fighting operations victory conditions in PSO for one party do not necessarily mirror the defeat conditions of another. For example, if a belligerent faction succeeded in ethnically cleansing an area it will not necessary follow that the peace enforcement forces will have failed (yet) in their mission to protect the civilians and return them to their homes.

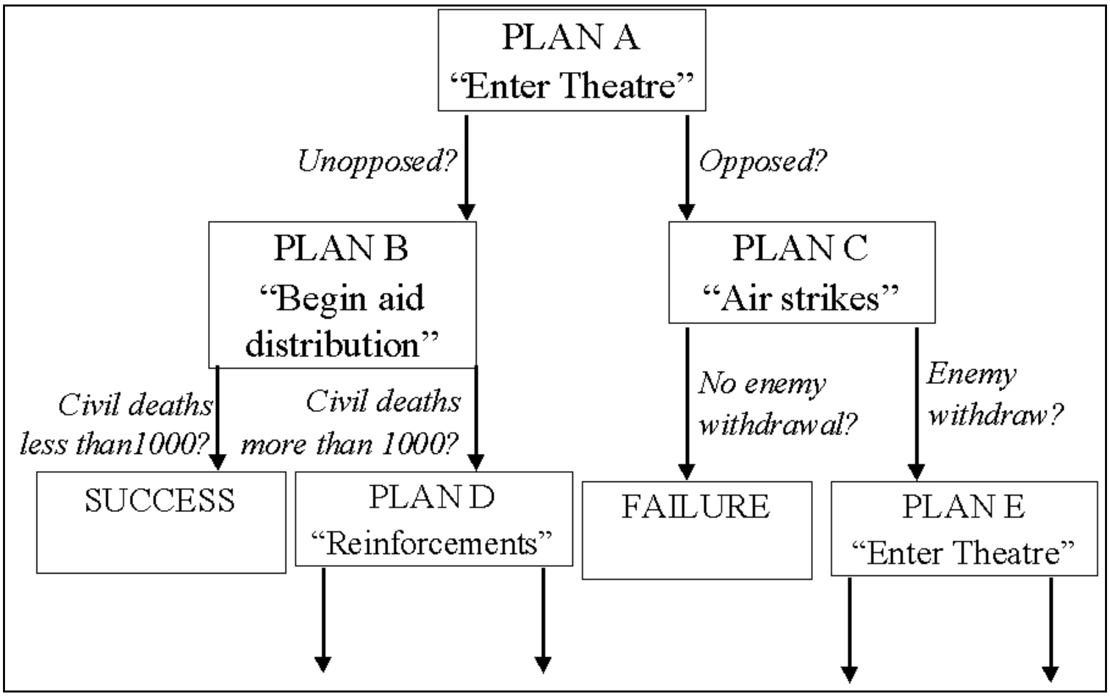

Figure 4: A Party's concept of operations (and its contingency planning) is expressed through the plan sequence.

The three types of commander in DIAMOND make decisions associated with the progress of plans or missions. The levels of commander are the Joint Theatre Commander (JTC), the Component Commanders (CC) and the Intermediate Commanders (IC). There is technically a fourth level of commander, the entities themselves (military units, NMOs and civilians). The types of decision each level of commander can make are shown in Figure 5.

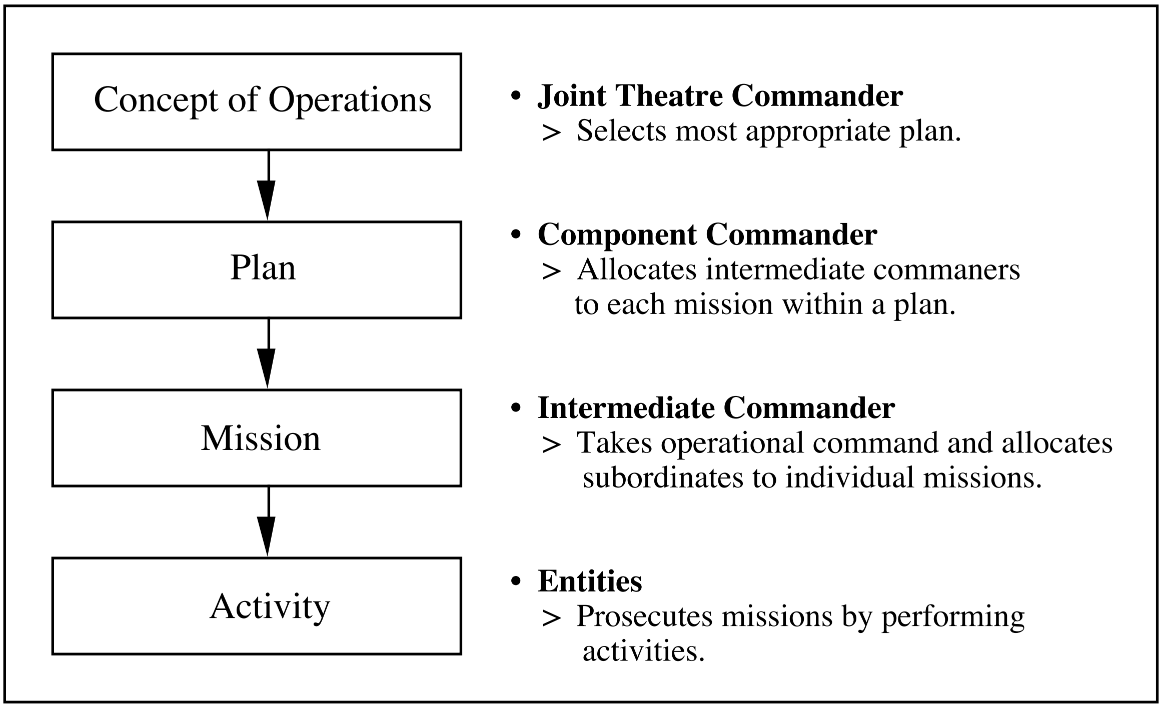

Figure 5: Commander decision profiles.

The JTC controls the progress of the campaign by deciding which plan to follow at any time. Beneath the JTC sit the component commanders. The component commanders represent land, sea and air forces or could represent national contingents within a coalition. They 'size' each of the missions within a plan and delegate operational command to an appropriate intermediate commander in the party's hierarchy. For example, if the mission were suitable for a division then the responsibility for conducting the mission would be applied at the divisional level.

It is the intermediate commanders that represent this command chain with multiple levels representing battalion commanders up to corps commanders. They act upon the reports of their subordinates and manage their assigned mission as best they can. Should additional resources be required beyond what the IC can provide then they need to be requested from a superior.

Below the intermediate commanders are the entities themselves. Their command attributes are limited to prosecuting the activities that make up a mission and taking local decisions to enhance their survival or chances of success.

It is the combination of all these processes that allows the simulation to run without user assistance once a scenario has been scoped and developed. It is the development and testing of plans and mission sequences that requires the greatest input from the user. The majority of the processes related to sizing of missions and managing resources will be based on doctrine or operational experience.

RELATIONSHIPS AND NEGOTIATION

In existing combat models it has been traditional to represent only two sides of any conflict. This is a suitable assumption for most conventional battles as, regardless of the number of participants, they tend to fall into the categories of friend or foe. In non-warfighting operations this assumption is not valid, as there are often a large number of participants, none of which can be classified purely as hostile to each other. For example, in Bosnia there were three main armed factions, their respective civilian populations and the peacekeeping forces. In Somalia there were upwards of twenty-four warlords vying for control, the embattled civilians, the multinational peacekeeping forces and United Nations personnel, all of which were of strategic importance to the operation at one time or another. Very quickly it becomes obvious that any successful attempt to model non-warfighting operations requires a multi-sided approach. It was decided that each side in the simulation would be identified as a separate party and that the relationships between those parties would be used to describe their affiliations, rather than aggregating like-minded parties into distinct sides.

In accepting that a multi-sided model is required it is necessary to identify the relationships that will be required to describe the affiliations of each party. Again, in traditional combat modelling only one type of relationship is modelled, that of hostility between parties. In non-warfighting models a greater range of relationships is required. Research at CDA has determined the minimum number of relationships required to represent basic inter-party behaviour is five:

- Hostile.
- Uncooperative.
- Neutral.
- Sympathetic (co-operative).
- Friendly.

Every entity within a party must share that party's relationships. For example, if a party of peacekeepers were neutral to the party of belligerents then every entity and commander within the peacekeeping party must share that view and see themselves as neutral also.

The exceptions are commanders (and their subordinate entities) that have maverick attributes. A maverick attribute allows the user to define a relationship different from that of the party. For example, that same belligerent faction may consider itself neutral to the peacekeepers but one intermediate commander may adopt an uncooperative relationship and frustrate the peacekeeping forces.

It was further recognised that a relationship between two parties does not have to be symmetric. For example, an NMO (Non Military Organisation) may consider its relationship with a belligerent faction as neutral whereas that faction may adopt an uncooperative or even hostile stance in return. In the first release of DIAMOND, for simplicity, a party will always know the stance of other parties towards them, even if it is an asymmetric relationship. This leads to the possible relationship pairings depicted in Figure 6 (those marked with an asterisk are probably unstable relationships and would decay quickly to another relationship on the list once interactions begin between the two parties). Furthermore, to initially simplify the command and control component of each party it will be mandatory for any party to have a hostile relationship to another before it can conduct combat operations against that party. This may of course be on a local (e.g. maverick commander) or temporary basis (e.g. a single punitive air strike) instead of a long term, party wide arrangement.

	Hostile	Uncooperative	Neutral	Sympathetic	Friendly
Hostile	♦	♦	♦	⌘	⌘
Uncooperative		♦	♦	♦	⌘
Neutral			♦	♦	♦
Sympathetic	Where ⌘ denotes an unstable relationship able to decay to an appropriate relationship			♦	♦
Friendly					♦

Figure 6: The 15 possible relationship pairings.

Relationship changes are user configured condition statements linking parties to events and the resulting relationship change. For example, if party A attacks party B the new relationship of A to B (and probably B to A) will become hostile. In a single DIAMOND run we would not anticipate relationships changing regularly. We would, however, expect to have one or two relationship changes per party linked to different phases identified from, for example, a Pol-mil game. Such relationship changes may relate to aggressive actions, peace talks or changes in policy.

There are, in PSO operations, many types of negotiation that occur through the life of any operation. Mediation to resolve local disputes, negotiation to obtain a cease-fire and negotiation to obtain access, are just a few. Each type of negotiation plays an important role in restoring normality or ensuring that potentially escalatory situations are resolved with the minimum amount of force by either side. As such aspects are an important part of PSO it is important that DIAMOND represents some elements of these interactions and their outcomes.

However, from the analytical community there has been very little related work on representing negotiation in a manner that is suitable for fast running simulation models. Consequently, DIAMOND will take a two path approach to representing some of the aspects of negotiation. The first path will be to use historical analysis and the second will provide a mechanism that will allow the user to enter into the model the insights from Pol-mil gaming so that they can be interpreted dynamically by the model.

These approaches will allow DIAMOND to become the first stage in an evolutionary process for modelling cross party negotiation in PSO. Should either or both techniques prove successful then further development will follow. The types of negotiation the model will be able to handle are:

- Negotiation for access.

- Negotiation for support.
  - Requests for humanitarian assistance.
  - Requests for escort.
  - Requests for supplies (including demands and theft).

Due to the time and expense incurred in conducting historical analysis only negotiation for access will be trialed with this approach. Roadblocks and other routeblocks are a major hindrance to peacekeeping operations, preventing and delaying free movement of peacekeepers, aid agencies and civilian traffic alike. They occur for a variety of needs, some through a genuine military reason to secure an area, some as a revenue source (tax and theft), and some simply because the protagonists are bored and see it as a means to exert their authority and pass time (Goodwin, 1999).

It is intended to conduct historical analysis on negotiation for access to identify the principal factors that affect the outcome. It is believed that current relationship, force ratio, rules of engagement and a unit's current mission are some of those factors. The input data to DIAMOND will be configured to match the important factors and referenced against a historical model derived from historical analysis. The output from this will be the time taken for a unit to negotiate and the probability of it successfully obtaining access. An example of what this model may look like is given below in Figure 7.

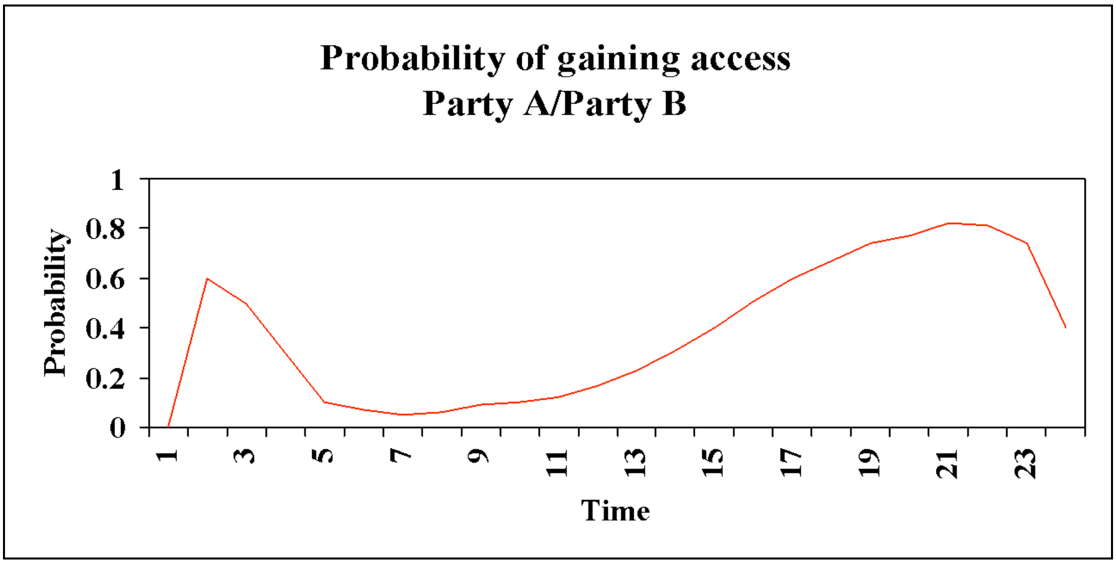

Figure 7: Negotiation for access, probability of passage by negotiation time.

There are some limitations in adopting this approach. The historical analysis conducted may be very region or context specific and may not allow for a fully generic approach. However, by ensuring that the historical analysis conducted focuses on areas or situations representative of the likely PSO contingencies there will be value in the data obtained for study use if not directly for DIAMOND itself.

The other types of negotiation that can be represented in the model will rely upon Pol-mil gaming or expert judgement to define the conditions on which such a negotiation may produce a result. In these cases the time taken to conclude any negotiations will be represented and the model will represent the effect of a successful negotiation. Negotiation is confined to the missions represented within the model. For example, a party could request a transport mission or intelligence from another party but it could not negotiate a local cease fire in this version of DIAMOND (as there is no specific mission associated with cease-fires).

These other types of negotiation can be generically referred to as 'negotiation for co-operation', although that co-operation may in itself be as a result of a threat or other aggressive activity. The user defines whether co-operation on any mission could occur with another party for each possible relationship pairing and should co-operation be possible the analyst defines which missions they would co-operate on.

CONCLUSIONS

In summary, DIAMOND has been designed specifically to tackle OR questions relating to high-level defence policy and force development issues. Once developed and populated DIAMOND will allow the OR community to examine these areas economically and quickly and act as a focus for the application of other tools, techniques and data collection. Where possible the design has been kept firmly rooted in accepted and validated modelling techniques and driven by known data sources. However, to obtain as full a coverage of the PSO domain as possible it has been necessary to develop new techniques and mechanisms and cite the requirement for new classes of data or algorithms to be developed. As our understanding of the PSO domain evolves so too will DIAMOND to take advantage of any new work and insights.

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GLOSSARY

C2	Command and Control.
CC	Component Commander.
CDA	Centre for Defence Analysis.
CFE	Conventional Forces in Europe (treaty of).
CSV	Campaign State Vector.
DERA	Defence Evaluation Research Agency.
DIAMOND	Diplomatic And Military Operations in a Non-warfighting Domain.
DROMAS	DERA Reusable Object Modelling System.
HMSO	Her Majesty's Stationary Office.
IC	Intermediate Commander.
ID	Identity.
IR	Infra-red.
JTC	Joint Theatre Commander.
MoD	Ministry of Defence.
NMO	Non Military Organisation.
OP Com	Operational Command.

OR	Operational Research.
Pol-Mil	Political Military.
PSO	Peace Support Operations.

PERMISSIONS