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Abstract: Information needed to support ground mobility decision-making is critical to the success of ground operations. The ability to rapidly obtain and process relevant information in a network-centric environment will empower warfare planners. In addition, future network-centric operations that will include autonomous unmanned ground vehicles as envisioned in the Future Combat Systems program will increasingly require the exchange of well-structured information between human forces and robotic systems. Addressing this operational challenge begins with a clear understanding of the information content needed for ground mobility planning. The purpose of the Mobility Common Operational Picture (M-COP) project is to specify a standardized vocabulary and conceptual relationships for the expression and transfer of ground vehicle maneuver data, planned routes, trafficability assessments, and other parameters associated with Future Force assured mobility across Modeling and Simulation (M&S) systems and Battle Command (BC) systems. The scope of the project was limited to ground vehicle mobility and ground vehicle maneuver information. The project identified terms and concepts across relevant data representations that will enable the M-COP capability to be achieved in the current and emerging network-centric architecture.

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Preface

This report was prepared by Dr. Paul W. Richmond, Niki C. Goerger, and Burhman Q. Gates, all of the Geotechnical and Structures Laboratory (GSL), U.S. Army Engineer Research and Development Center (ERDC); Dr. Joyce A. Nagle, Cold Regions Research and Engineering Laboratory (CRREL), ERDC; Curtis L. Blais, Modeling, Virtual Environments, and Simulation Institute, Naval Postgraduate School; Robin K. Burk, Department of Electrical Engineering and Computer Science, U.S. Military Academy; John Willis, U.S. Army Training and Doctrine Command Analysis Center, Monterey, CA; and Robert Keeter, Department of Systems Engineering, U.S. Military Academy.

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The work was conducted under the general supervision of Wendell Gray, Chief, Mobility Systems Branch, GSL; Dr. Albert J. Bush III, Chief, Engineering Systems and Materials Division, GSL; and Dr. David W. Pittman, Director, GSL.

This report was prepared under the general supervision of Dr. Justin Berman, Chief, Force Projection and Sustainment Branch, CRREL; Lance Hansen, Deputy Director, CRREL; and Dr. Robert Davis, Director, CRREL.

The Commander and Executive Director of the Engineer Research and Development Center is COL Richard B. Jenkins. The Director is Dr. James R. Houston.

1 INTRODUCTION

In looking toward to the future of military operations, the U.S. Army Training and Doctrine Command (TRADOC) identifies force operating capabilities (FOC) necessary to meet future demands across the range of military operations (HQDA 2005b). The FOC-06-01, *Provide Assured Mobility*, serves as the impetus for this research, specifically calling for the establishment of the Mobility Common Operational Picture (M-COP). The assured mobility framework "includes all those actions that guarantee the force commander the ability to deploy, move, and maneuver, by ground or vertical means, where and when desired, without interruption or delay, to achieve the intent" (HQDA 2005b).

The capabilities resulting from this project are intended to be a standardized vocabulary and formalized definition of the conceptual relationships that will allow transfer of ground vehicle maneuver data, planned routes, trafficability assessments, and other parameters associated with assured mobility between Models and Simulations (M&S) and Battle Command (BC) systems. It also provides a preliminary step towards interoperability of future autonomously mobile equipment, as envisioned in the suite of Future Combat Systems vehicles, with BC and other systems. The COP is defined as "a single identical display of relevant information shared by more than one command" (Joint Publications 2001). Moreover, the COP is tailorable and facilitates collaborative planning. It thus "helps commanders make timely, accurate decisions about force sequence and direct resources and forces where needed by units in theater." Elements of the environment, friendly forces, and threat forces are included in the COP (HQDA 2001a). These are important considerations when determining elements of the M-COP. The M-COP is not intended to be a separate COP but is composed of components intending to convey data and information supporting assured mobility. It should also be pointed out that this project does not intend to suggest another data model, although it should serve as a point of reference for enhancements to existing data models. Additionally, the M-COP is not part of, or linked to, the Battle Management Language (Blais et al. 2005d), although again, this report maybe used to define future enhancements or extensions to it.

Several papers and reports grew out of the project execution and are shown, along with the project approach, flow, and products, in Figure 1. These earlier reports (Richmond et al. 2005a; Blais et al. 2005b) and papers (Blais et al. 2005a, 2005c; Goerger et al. 2006) relating to this project discuss the basis of the M-COP and the identification of components and attributes of a M-COP data representation. Research and development continued on the formalization of that representation in the final stage of the project and are discussed in this report. The first interim report (Richmond et al. 2005a) contained a review and analysis of doctrine, data structures, standards, and systems relevant to ground vehicle maneuver. An initial slate of data categories and features/ attributes for the M-COP was produced and presented, and a procedure for obtaining input from stakeholders was described. The second interim report (Blais et al. 2005b) described the conduct and findings of the stakeholders' analysis. From the data collected, this report presented the approach and design decisions in creating a description of the principal elements of a M-COP data model.

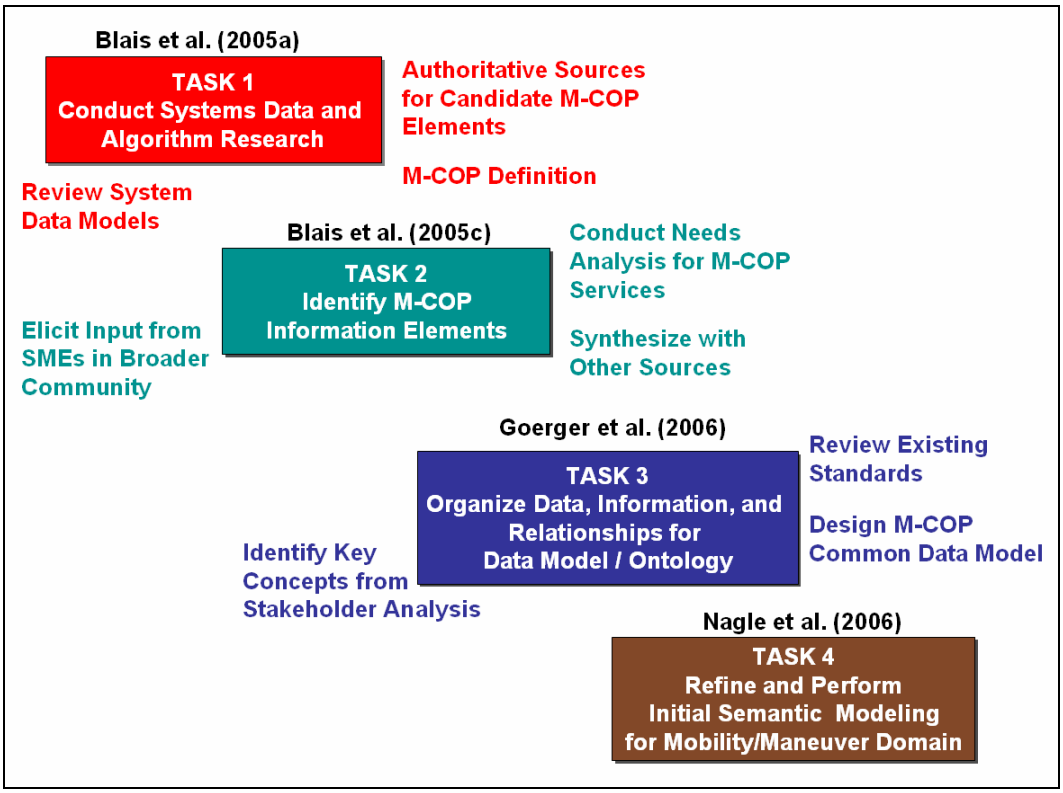

Figure 1. M-COP model development tasks, products, and documentation. The tasks are inside the four boxes. The products are color coded to match the tasks.

A third interim report (Richmond et al. 2006a) identified a number of Global Information Grid (GIG)-based services that will be needed to

obtain the M-COP in the distributed information architecture of the future. As described in Richmond et al. (2005a), the data model will be usable within the context of the GIG (Joint Forces Command 2001). The M-COP will be obtained through the creation of virtual links between the information requirements on the user side and information sources on the network side. The information requirements—i.e., the data and computational products needed to populate the user's view of the battlespace situation relating to mobility—are derived from the metadata description of the M-COP. In addition to basic data, the M-COP data representation must also support Community of Interest (COI) services* related to ground vehicle mobility and maneuver.

This report briefly reviews the earlier project efforts (Tasks 1 to 3) and provides details on the work done in the final stage of the effort (Task 4). Required M-COP terms and concepts were identified and defined. Comparisons of the M-COP information requirements were made between relevant data models, e.g., the OneSAF Objective System environmental data model (OOS EDM), and the Joint C3 Information Exchange Data Model (J3CIEDM). The amount of information to represent ground vehicle mobility and maneuver at a high level of fidelity is voluminous, as will be shown; however, by identifying these requirements across M&S and BC domains, we have taken the first step to achieve a M-COP. The report concludes with a summary of lessons learned and recommendations for future work.

In the following sections, the categories of the M-COP model are described by classes, subclasses, and attributes. By "class" we mean a collection of objects characterized by the same set of properties. A class can have subclasses that are more specific than the class to which they belong. The properties of a class are attributes. One instance of a class is a specific object in the collection. In this report, the following naming conventions are used: classes and subclasses are in uppercase (e.g., ROAD), attributes are in title case (e.g., Feature_Type), and at all levels, if the descriptor is multiple words, there is an underscore between words (e.g., CLOUD_COVER, Wind_Speed).

* A service is an abstract resource that represents a capability of performing tasks that form a coherent functionality from the point of view of the person or organization that is providing the resource and the person or organization that wishes to use the resource. The service is often a Web service. Source: http://www.w3.org/TR/ws-gloss/#service.

2 NOTIONAL USE CASE

A notional use case designed to demonstrate the M-COP context and utility was developed and presented in Burk et al. (2007) and is given below. The mission is a tactical scout reconnaissance mission at the platoon level.

> 1LT Griffin receives a mission from his higher headquarters (HQ) to conduct a route reconnaissance to facilitate the movement of humanitarian relief and unit logistic convoys in support of the unit's expanding operations into the fringes of a troubled region. The route will be used to support the movement of medical, food, and fuel supplies, as well as engineering equipment to facilitate the reconstruction of the road infrastructure and hospital facilities within the expanded area of operations. Knowing that there are several things he must consider in both planning his mission and conducting the reconnaissance to provide HQ with the necessary intelligence it needs to perform successful convoy operations along the intended route, 1LT Griffin starts to develop his reconnaissance plan to ensure he collects all relevant information. He receives a listing of check points (CPs) and 10 areas of interest from the unit's S2, intelligence officer, which he is specifically told to investigate for possible impediments to convoy movement.
>
> 1LT Griffin's platoon departs on time from Start Point (SP) Green. It moves in a V formation with two sections overwatching the route from key terrain along the route, while the headquarters section traverses the route collecting relevant data. Throughout the mission, the teams note any terrain that would be adversely affected by inclement weather, such as heavy rainfall.
>
> Shortly after crossing the Line of Departure (LD), Team C notes 30-ft poles with wire (probably electri-

cal lines) on both sides of the road, with wires occasionally drooping across the road. Owing to limited maintenance in this sector, they are not continuous. Some wires appear to be professionally installed while others look as if they are installed by some of the local inhabitants. The C Team Leader notes the location of these poles and wires, as they may come in contact with convoy vehicle antennae.

As the platoon passes CP 5, Team A observes a vehicle on the side of the road. The A Team Leader notifies Teams B and C of the vehicle's location so they are prepared to deal with it as they traverse the route. Initially they can only identify the object as a vehicle. Further investigation shows it is sitting completely off the road and unoccupied. Sensing a potential improvised explosive device (IED), 1LT Griffin notifies higher HQ and is told to bypass the vehicle and continue with the mission.

The route crosses a river at CP 6. The teams provide overwatch for each other as they cross the bridge. They note the load capacity and general condition of the bridge. This includes any potential sabotage or natural degradation from exposure to vehicle traffic and weather. Also, the potential for the bridge to become washed out during heavy rains or increased flow from upstream conditions is noted. The teams complete their assessment by making a careful check of potential fording sites in the area in the event the bridge is not available.

At CP 7, the platoon encounters a highway overpass. The teams check its height and condition. Additionally, Teams A and B scout alternative routes for oversized vehicles that may not make it under the overpass.

The majority of the road is concrete, but sections are worn away and consist of gravel or packed dirt. Team

C notes the location of extremely rough sections and road side areas that could be used for refueling or unscheduled maintenance needs. They also note choke points along the route. These include areas that are possibly too narrow for larger vehicles to pass, such as Heavy Equipment Transports or armored vehicles. They check the shoulder of the road for ease of entry or exit from the road network. The team also notes steep drop-offs or extremely rough surfaces that can impede rapid transition to off-road travel.

They also identify key terrain along the route, such as high ground surrounding the route where enemy or friendly forces could launch an attack or simply observe movement along the route. Conversely, they assess the fields of fire available to friendly troops that use the route as well as cover and concealment.

Prior to CP 8, a road intersection, the platoon comes upon a second smaller road intersection. 1LT Griffin believes this could be confusing to a convoy commander, especially at night, causing the convoy to turn too soon down the wrong road. He makes careful note to mark this location as a potential navigation challenge. He also sends the updated map information through the appropriate intelligence channels to have the new road added to overlays and future maps.

Near the end of the route, the road takes the platoon around a small village. Like the river crossing, the teams provide overwatch for each other as they pass the village. They note that there is some kind of festival going on in the center of town. Suddenly, they hear the distinct sound of AK-47 fire and immediately train their weapons in the direction of the sound. They watch carefully and realize that the celebration is a wedding party and the gunshots are simply shots in the air, common in this culture. They note the incident for future reference.

> Throughout the mission, the scout teams communicate with one another using tactical radio systems. They also maintain communication with their higher headquarters. Prior to departing, the unit signal officer advised them of potential "dead spots" for frequency modulation (FM) communications. They perform radio checks in these locations while conducting the reconnaissance to ensure that convoys will be able to maintain communications while on the route. If unable to maintain communications in these masked areas, the platoon must identify locations for retransmission stations to cover these dead spots.
>
> Upon completing the route, the teams return to their home base along the route. This trip is faster as they were already somewhat familiar with the route, but they did notice a culvert that ran under the road just outside the village that they had overlooked when the gunshots went off. They dismounted scouts to take a careful look at the entrances to the culvert as a possible place to hide explosives or launch enemy attacks upon the convoys. The scouts also identify if the culvert load classification would be able to handle an increased load from convoy traffic.
>
> When the platoon returned to its home base, it conducted a thorough debriefing with the squadron S2 (intelligence), S3 (operations), and S4 (logistics) officers. They relayed all that they had observed during the mission.

Although this reconnaissance was explained as an actual mission, it could just as easily have been part of a simulation training mission. For instance, a unit preparing to deploy may want to have its cavalry squadron rehearse route reconnaissance missions in a realistic training environment. This can readily be coded into a three-dimensional driving simulator that permits the platoon leader to "drive" the route while transmitting information to a squadron HQ for it to begin its analysis of the data before sending them to a higher HQ. This would permit multiple echelons to train in as realistic a scenario as possible. The information required for the real-world

mission would match that of the simulation mission. The M-COP will enable seamless transfer of the information between the real world and the simulation by standardizing the data model with terminology relevant to ground mobility and maneuver.

A well-defined data model and formalized ontology provide the means to share data and information gathered during the reconnaissance mission, as well as all the necessary mobility information that the scout platoon would require to perform that mission. An ontology is a "formal specification of a conceptualization" (Gruber 1993), a well-defined vocabulary identifying the concepts in a domain of interest, including description of the relationships among the concepts. From the tactical scout reconnaissance mission above, the example of the vehicle on the side of the road provides several insights. The first is that a vehicle can be classified as a mode of transportation as well as an obstacle or even a weapon. In Somalia, junked cars were pushed into intersections and lit on fire to act as barricades. They are currently employed in Iraq as IEDs: remotely detonated or detonated by a suicide bomber. These "new" uses of the vehicle necessitate a method of describing one in general terms (two-wheeled, four-wheel, tracked, etc.) as well as specific purpose (obstacle, mode of transportation, etc.) so that all parties receiving information about the vehicle conceptualize the same thing. The M-COP ontology captures our understanding of this non-standard but important use of the vehicle by describing a class of obstacles, where by "class" we mean a collection of objects characterized by the same set of attributes or properties. One instance of that class (that is, a specific object in the collection) may be a truck that has been disabled or abandoned and currently is being used to block or slow traffic on a route. If it is a friendly vehicle that simply needs maintenance assistance, then it will also eventually become a mode of transportation—i.e., it may be said to belong to the transportation vehicle class. This requires the instance to have multiple parent classes. Standard taxonomic hierarchies cannot capture this sort of relationship, but ontologies defined using one of the DOD-supported definition languages such as Web Ontology Language* (OWL) can. Additionally, as new uses for the vehicle are identified, the ontology can be updated and modified to address all the new attributes and functions of the new vehicle type (Goerger et al. 2006).

* http://www.w3.org/TR/owl-features/

3 TASK 1: SYSTEM DATA AND ALGORITHM RESEARCH

Task 1 presented an analysis of systems, data structures, format, and Army doctrine in the context of ground vehicle mobility and the COP (Richmond et al. 2005a; Blais et al. 2005a). An initial slate of categories and features/attributes for the M-COP was produced in a tabular format and a procedure developed for obtaining input and consensus from stakeholders. Emerging concepts and capabilities of the GIG, current and emerging standards, and tools were investigated and were used in follow-on work. When fully defined, numerous venues exist for posting and registering the M-COP ontology, and other products—such as the Department of Defense (DOD) Extensible Markup Language (XML) repository, Army Battlespace Environment (ABE) registry, and Command and Control Information Exchange Data Model (C2IEDM) enhancements—that will result from this work. The M-COP team developed this definition for the M-COP based on various authoritative definitions for the COP, including JP 3-0, *Doctrine for Joint Operations*, and Army FM 3-0, *Operations*:

> Mobility Common Operational Picture (M-COP): A subset of the COP consisting of relevant movement and maneuver data and information shared by more than one command. The M-COP can be tailored for various users and will include data and information for mobility of individual combatants, ground vehicles, and autonomous/robotic vehicles. — *M-COP Team*

As a review, the principal published documents used are listed below; Richmond et al. (2005a) should be consulted for specific information extracted from them.

Doctrine

- Army Force Operating Capabilities and Field Manuals.
- Joint Publications.
- Army Operations Order format and Intelligence Preparation of the Battlefield (IPB) process.
- Army Universal Task List (AUTL).

Data Structures and Specifications

- Environmental Data Coding Specification (EDCS).
- Military Scenario Development Language (MSDL).
- Battle Management Language (BML) and Command and Control Information Exchange Data Model (C2IEDM).
- DOD Discovery Metadata Specification (DDMS).
- Geospatial Standards, Specifications, and Data Dictionaries.

Existing Systems

- Army Battle Command System (ABCS).
- Force XXI Battle Command Brigade and Below (FBCB2) and Blue Force Tracker (BFT).
- Commercial Joint Map and Tool Kit (C/JMTK) with Battlespace Terrain Reasoning and Analysis (BTRA).

Emerging Systems

Global Information Grid (GIG).

4 TASK 2: INITIAL M-COP REQUIREMENTS

Task 2 consisted of a stakeholders' analysis to describe the top-level design of a common data model for the M-COP. The stakeholders' analysis proved to be a valuable method for prompting and collecting expert input for identifying theM-COP information requirements. The inputs provided an excellent foundation for identifying top-level data categories for designing the M-COP data model. Some key components of Task 2 work activities are described below. More thorough treatment of this task and related findings can be found in Blais et al. (2005b) and Goerger et al. (2006).

While an initial slate of potential M-COP elements was derived in Task 1, based on review of doctrine and authoritative sources, Task 2 involved identifying, expanding, and refining the M-COP information requirements by eliciting input from the broader community of stakeholders in the use of the M-COP, and synthesizing this with data and information identified from doctrinal sources in preceding work. The M-COP team identified stakeholders in the area of BC and M&S interoperability and assured mobility, and conducted several collaborative sessions to obtain their perspectives on M-COP requirements. Furthermore, stakeholders included, but were not limited to, active duty military representatives at the United States Military Academy (USMA) with current—e.g., Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF)—experience as well as those with earlier battle command, training, and doctrinal experience.

The problem definition phase of the Systems Engineering Management Process (SEMP), a robust, deliberate problem-solving methodology taught in the Department of Systems Engineering at the USMA, was applied for this task. The results of the problem definition phase were system definition, corresponding functional decomposition, and identification of M-COP required information elements and hierarchical relationships. The system under consideration was the battlefield operating system (BOS), or system of systems. The functions and subfunctions that the system must perform were scoped using the Army Universal Task List (AUTL) (HQDA 2003b) as the framework with which to map and augment information derived from the stakeholders' analysis and Task 1 research.

The brainstorming exercises were structured around a focus question: "What does the commander need to know to maneuver in the battlespace?" In addition, participants in different sessions were asked to brainstorm groupings for M-COP elements or comment on proposed groupings. There was no clear single theme that emerged for the groupings, instead there were several different ideas proposed to include the use of the BOS.

Table 1. M-COP top-level categories.

Categories from Functional Decomposition	Definitions
Terrain	Natural and manmade features and their attributes that may influence mobility or maneuver of ground vehicles.
Obstacles	Terrain features or other objects or conditions that disrupt or impede movement of ground vehicles.
Weather	Observed and forecasted weather conditions that affect mobility and maneuver.
Maneuver Analysis	Results of analysis related to ground vehicle movement relative to mission, command and control, local culture, and other considerations.
Route Finding	Results of and related information for finding a minimum-cost route in a maneuver search space.
Threat Analysis	Locations, capabilities, and other information (potential actions) relating to things that can threaten a mission. Note that this can include, in addition to enemy forces, local population, and cultural effects as they affect friendly maneuver (Melby and Glenn 2002).
Forces	Information relating to maneuver and transportation units and individual platform locations and capabilities as related to mobility and maneuver.
Utilities	Metadata that may be applicable to all elements of the M-COP.

In Task 2, the principal categories of information requirements of the M-COP were ultimately categorized as described in Table 1 and include elements of threat forces, friendly forces, and environment as indicated in FM 3-0 (HQDA 2001a). It is important to note, however, that the team recognizes there is no one definitive "answer" for the list of M-COP elements or their categorization. The goal is not to provide a "perfect" data model but to provide an actionable model that captures the majority of the identified ground vehicle mobility information requirements. It should also provide a solid basis for evolution of the data model over time as battlespace conditions and situations change and as autonomously mobile ground equipment and other intelligent systems are refined and integrated over time into battlespace forces.

In addition to spatial characteristics, objects described within the M-COP can have temporal properties, such as an obscurant or contaminated area

that disperses over time, or a physical feature, such as a river bed, that can be dry or flooded under certain conditions at different times of the year. In fact, all the principal components of the M-COP data model can be considered to have temporal characteristics, for example:

- *Terrain*: The surface condition of a road will change based on temperature and precipitation (dry to wet, snow or ice cover) affecting vehicle speeds.
- *Obstacles*: A minefield may be an obstacle at one point in time but no longer be an obstacle when a clearly marked lane has been made through it.
- *Weather*: Planning needs to be concerned with current and near-term weather conditions, as well as forecasted conditions at some future period of time in some particular geospatial region.
- *Maneuver Analysis*: Conditions considered in maneuver analysis for a mission in 24 hours can be considerably different from that for a mission in 72 hours.
- *Route Finding*: Routes planned under current conditions can be considerably different from routes planned under forecasted conditions.
- *Threat Analysis*: Threat conditions change over time as the enemy maneuvers, or as attrition or reinforcement occurs. Threat analysis has to deal with current perception as well as projected threat disposition.
- *Forces*: The ground vehicle mobility capabilities of the forces change as vehicles suffer battle and non-battle losses and as fuel supplies are expended. The future composition of a force can depend on forecasted threat and weather.

From this perspective, temporal considerations may be best applied in the Utilities component to apply to all the other components.

From a cardinality perspective, the M-COP data model needs to contain one or more geographical region providing the terrain data, and these regions may overlap or be distinct, and may or may not be adjacent regions in three-dimensional space.

This task also included evaluating data modeling techniques that provided insights into ontology development to guide model refinement in subsequent phases of the project. In addition, the evaluation indicated the software services that will be needed to support the M-COP generation in the future GIG environment. Figure 2 is a popular depiction of the spectrum of

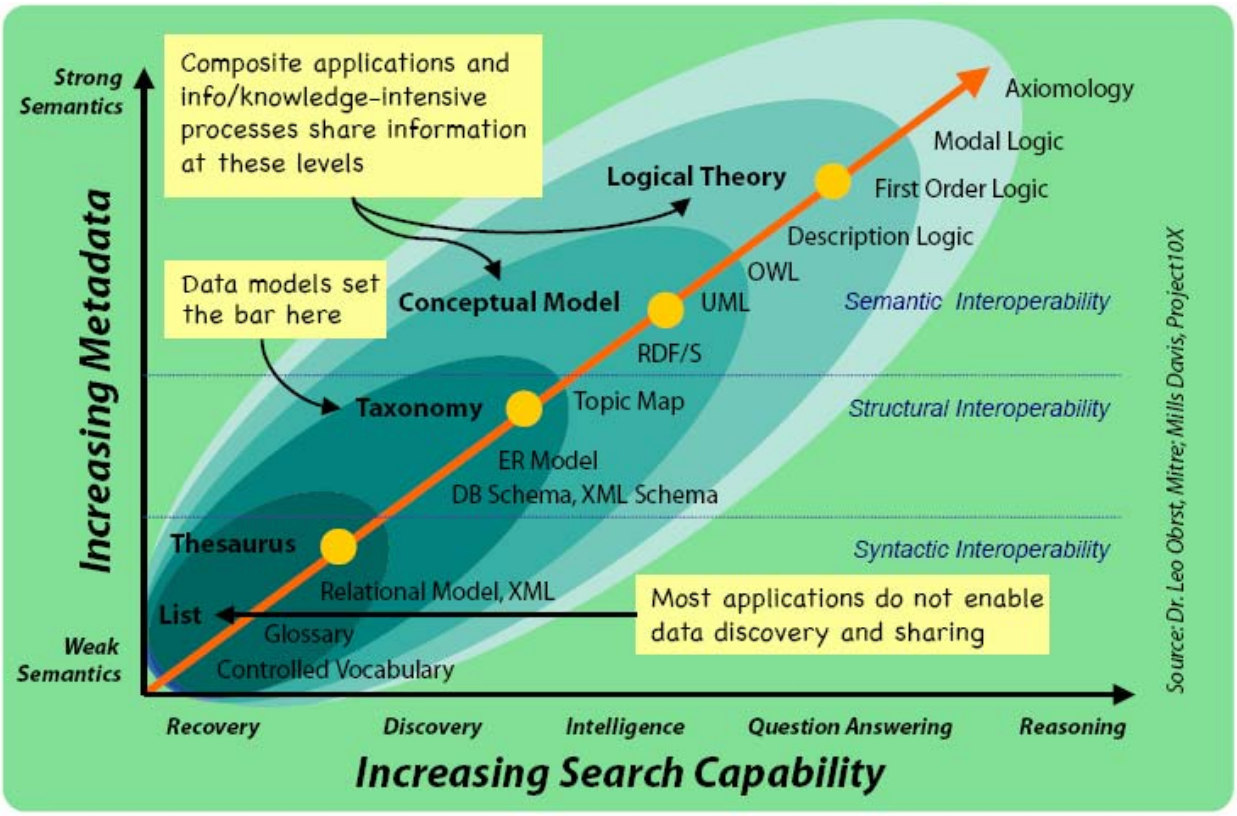

Figure 2. View of data/knowledge representations (Obrst and Davis 2006). UML is Unified Modeling Language, RDF/S is Research Description Framework/Schema, DB is database, OWL is Web Ontology Language, and XML is Extensible Markup Language.

data/knowledge representations used to help convey the idea of formalized semantics in data modeling. Long-established data modeling techniques are indicated at the lower left in the diagram, including the techniques of relational data base schema and entity-relationship (ER) diagrams.* Parallel data structuring techniques have emerged from the World Wide Web community involving the use of XML and XML schema. These techniques establish strong syntactic structures for exchange and processing of data, but lack the semantic content, readily understood by humans, needed to achieve greater autonomy in software processing. The current state of practice is largely entrenched in the lower left half of the spectrum. In recent years, many authors in the DOD BC and M&S communities have made strong arguments for the necessity of moving further up the spectrum to have any hope of achieving more effective interoperability across systems (Tolk and Muguira 2003). The World Wide Web Consortium and extremely active computer science and information technology research communities are creating new standards and tools to enable the expres-

* An entity in the context of a relationship diagram is anything about which data need to be stored.

sion of stronger semantic content in data models. The overarching initiative driving these developments is the Semantic Web:

> "The Semantic Web is specifically a web of machine-readable information whose meaning is well-defined by standards: it absolutely needs the interoperable infrastructure that only global standard protocols can provide." (Tim Berners-Lee, in Fensel et al. 2003.)

A major part of the foundation for the Semantic Web is the syntactic strength of XML, together with its flexibility to allow definition of new languages. The Semantic Web comprises layers of metadata for describing data in terms of concepts and interrelationships among concepts. Current and emerging Semantic Web standards—Research Description Framework (RDF), RDF/Scheme (RDF/S), Web Ontology Language (OWL), Semantic Web Rule Language, and others—enable developers to move up the spectrum from conceptual modeling to logical theory.

The M-COP project activities were conducted to achieve as high a level of representation of various components of the model as possible. Unfortunately, in the early stages of the project, it became apparent that much of the data needed to create the M-COP were not available at consistent levels of specification, resulting in more extensive effort to identify and define M-COP information components than originally expected. Still, we find that the work done on the M-COP project represents one of the few concerted efforts to establish a comprehensive data set supporting a specific command need—that of performing ground movement planning. The identification of top-level data categories in Task 2 helped to create better context for more detailed data modeling activities in Task 4.

5 TASK 3: DEVELOPMENT OF BASE CAPABILITIES IN DATA MAPPINGS AND PROCESSING SERVICES

Services related to the M-COP were identified from three perspectives:

- GIG Core Enterprise Services needed to support the M-COP.
- M-COP services that can be provided to other domains (each represented by a COI) on the GIG.
- Services provided by other domains that are needed to support the M-COP.

GIG Core Enterprise Services Supporting the M-COP

Services to be provided by the GIG Core Enterprise Services (CES) include (JROC 2005):

- *Enterprise Service Management*: "the ability to monitor, manage, and scale web services within a Service-Oriented Architecture (SOA) Foundation to ensure the service offerings are available to the DOD enterprise." As an activity expecting to contribute to the evolution of the GIG, the M-COP must employ GIG CES Enterprise Service Management to become registered and thereby become available to the enterprise through the Core and Environment Control Services (ECS).

- *Machine-to-Machine (M2M) Messaging*: "services to support synchronous and asynchronous information exchange." The M-COP will make use of GIG M2M messaging services for interactions with other systems and processes on the GIG. When provided as a Web service in the GIG environment, such messaging is likely to take the form of Simple Object Access Protocol (SOAP) messages over Hyper Text Transfer Protocol (HTTP), but other protocols may be employed as the GIG environment comes to realization.

- *Service Discovery*: "provides for the publishing and discovery of enterprise services." Implementation of M-COP services will require publishing of service descriptions in accordance with standards established for the GIG. Many of the policy issues relating to implementa-

tion of the M-COP on the GIG were described in Blais et al. (2005c). Particular attention must be given to requirements of the DOD Defense Discovery Metadata Specification (DDMS) (DOD 2005), providing the common set of descriptive metadata elements to be associated with each data asset. All data assets on the GIG must be described with metadata made visible to the GIG service discovery capability. In accordance with current Web service standards adopted for the GIG, the M-COP services will be described using the Web Services Description Language (WSDL) for use by other systems/ applications.

- *Identity Management (People and Device Discovery)*: "the federated set of capabilities for uniquely identifying, finding, and publishing white pages information on people and non-people identities within the GIG Web Services Environment." Users of the M-COP will be granted access to ground vehicle mobility services through establishment of roles, authentication, and authorization processes implemented on the GIG. Identity Management services will maintain necessary information on users. As a supporting service to other applications, the M-COP may not need to deal with Identity Management services directly, as those interactions will be coordinated by the using application.

- *Metadata Services*: "provides the ability for DOD Enterprise systems to discover (publish, make visible, and access) and manage various metadata artifacts critical to a system and/or person's access and ability to exchange and understand data components within the enterprise." The M-COP will use Metadata Services to make its own metadata artifacts known to the GIG enterprise. This will primarily occur through registration of data models and ontologies, as well as meeting the DDMS requirements indicated above. As the M-COP evolves, maintenance of metadata artifacts through these GIG services will be important to coherence of the services and data over time.

- *Mediation Services*: "the capability to transform data" including "simple transformations" such as transforming XML using Extensible Stylesheet Language (XSL), providing adaptors that transform data going to/from legacy applications or other non-standard interfaces, orchestrating the flow between services, and "data aggregation or fusion." M-COP capabilities depend upon information from a number of diverse sources. These are discussed in the M-COP project Second

Interim Report (Blais et al. 2005b) and indicated in the following discussion of services to be provided by M-COP and services needed by the M-COP that are to be provided by other GIG domains. In those areas where the M-COP is not dealing directly with the native data format of a particular system or application, it will make use of GIG Mediation services to make necessary data transformations. In addition, some M-COP capabilities will be obtained through coordinated sequences of service calls to other domains. The orchestration of those calls and data transformations that may occur within the chain will be coordinated through GIG Mediation services.

- *Service Security*: "provides security-related services," including "authentication, authorization, and attribute retrieval." Service Security services will ensure that only authorized users (and, by extension, other software applications) are able to access the M-COP data and services. Service Security services will operate across all GIG processes.

Use of GIG enterprise services by the M-COP is not expected to be unique in any way, but will reflect best practices (i.e., in accordance with policies enforced by ECS) for applications operating in the GIG environment that deploy services for use by other domains, while employing GIG CES and services from other domains.

Services Provided by the M-COP

The M-COP can be viewed as a general service that provides data mining mapping, mediation, and storage, where information from disparate sources in a variety of formats, some previously captured in other data models, is synthesized and interpreted with respect to mobility. For example, other users may need to find a supply route with a low probability of encountering improvised explosive devices. M-COP can be a source for this integrated product, performing a number of other information accesses on behalf of the requesting user (e.g., to access data from an "intelligence/threat" service as well as accessing a route finding service).

As a special service provider, specific products or sets of data for use by other services can be produced. Table 2 lists potential services that can be provided by or are supported by the M-COP. It should be noted that none of these products are static, but are dynamic, with changes based on the BOS, battlespace environment, etc.

One area for further study is the possibility of M-COP providing services that result in formulation of Military Scenario Definition Language (MSDL) files for use in initializing MSDL-capable systems (M&S or BC) (Surdu et al. 2005). The Simulation Interoperability Standards Organization (SISO) is currently in the process of advancing the MSDL specification to international standard status. If successful, MSDL use across M&S and BC systems is likely to grow in coming years. The M-COP can provide movement route information and other relevant ground vehicle mobility information to insert into MSDL files for a particular operational use. An extension to the M-COP services identified in Table 2 would be generation of movement orders from the planning activities. These orders could be expressed in the Battle Management Language (BML), a common language for plans and orders applicable to live, constructive, and robotic forces. BML is also undergoing standardization through SISO under the name Coalition Battle Management Language (C-BML) (Blais et al. 2005d).

Table 2. Services that can be provided by the M-COP.

Service Name	Description (sample input, output, other information requirements)
Ground Vehicle/Unit Route Finding Products	*Input*: Start and end points, way points, re-supply or refueling points, unit echelon, composition, or formation threat locations, threat range of influence, cultural considerations, criteria (mission, best speed, best cover and concealment, best communication availability, on-, off-road or combined, etc.). *Requires*: Maneuver Network Analysis Product (see below), Combat Service Support (CSS) data, and Intel data. *Note*: Can also be used by Intel for threat course of action analysis. Includes ability for modifying route finding cost functions (types of areas to avoid). Can be accessed for dynamic rerouting. *Output (example)*: Best routes based on user provided constraints (ála annotated map directions available on the World Wide Web), output as strip map or text based turn-by-turn direction, maneuver decision points, estimates of fuel consumption, movement timeline. Route trafficability analysis and classification, military load classes (MLC), capacity (tons/hr) performed against unit type. Used for planning (course of action, war gaming, and execution).
Obstacle Locations and Status Report	*Input*: Types of obstacles, area of interest, timeframe of interest (in case of planned missions that would create obstacles), vehicle types, breaching assets. *Requires*: Terrain data. *Output*: Obstacle locations and status (% completion or % breached, breachable, and required assets to breach), a reflection of standard military engineer obstacle analysis, or bypass.
Bridge Locations and Status Report	*Input*: Bridge identifier (need globally unique identifiers), or requesting bridge status and location information in an area of interest and timeframe (in case there are planned operations to do bridging, repair a bridge, or destroy a bridge). *Requires*: Terrain data, Intel (Battle Damage Assessment). *Output*: Text data relating to MLC, traffic conditions, security, Stability and Support Operations (SASO).

Table 2 (cont.). Services that can be provided by the M-COP.

Service Name	Description (sample input, output, other information requirements)
Choke Point Analysis Report	*Input*: Area of interest, timeframe, unit size and formation, mission, threat range of influence. *Requires*: Terrain data, weather data, obstacle report, and Intel data. *Note*: May be combined with Obstacle report, to plan, predict obstacle locations. *Output*: Those areas where maneuver operations are at risk of disruption (disruption from enemy, civilians, other friendly forces).
Key Terrain for Maneuver Report	*Inputs*: Area of interest, unit size, mission. *Requires*: Terrain data, weather data, and perhaps Obstacle, Bridge, and Choke point service output. *Output*: Specific areas, terrain features, and facilities that are key for maneuver (inverse for preventing maneuver).
Maneuver Network Analysis Product	*Input*: Area of Interest, timeframe, cover and concealment, key terrain, choke points, obstacles, bridge data, mission, SASO. *Requires*: Terrain data (features, soils, and ground state), weather—visibility, precipitation—vehicle speed predictions. *Note*: While a geospatial tool such as C/JMTK with a human-in-the-loop will be required to develop a maneuver network, once the product is made it should be available in a standard format. *Output*: A maneuver network or "graph."
Avenue of Approach Analysis Report	*Input*: Area and time of interest, unit size, objectives, choke points, obstacles, control measures (unit boundaries, other command, and cultural boundaries). *Requires*: Terrain data. *Output*: Coordinates for use in producing graphics depicting avenues of approach.
Command–Civilian–Cultural Weather Mobility Forecast Report	*Input*: Area and time of interest. *Requires*: Terrain data, Intel data (IED activity, civilian disposition, etc.), weather data, command road restrictions, and road closures. *Output*: Text based report (forecast) of estimated locations of heavy traffic, civilian crowds, and weather effects, takes into account market days, rush hour, neighborhood affiliations, hostile areas, etc.
Critical Maneuver Information Report	*Input*: Route plan, route finding constraints, forecasted weather, threat analysis. *Requires*: Maneuver Network analysis, terrain data, and Intel data. *Output*: A list of key data parameters or assumptions that, if determined to be incorrect, will adversely affect the maneuver plan.
Areas of Unrestricted, Restricted and Severely Restricted Movement Product	*Input*: Area and time of interest, unit size, vehicle types. *Requires*: Terrain data, mobility analysis. *Output*: Polygonal areas which can be depicted using standard graphical symbols.

Services Provided by Other COIs to Support the M-COP

Table 3 describes data and services that the M-COP will expect from other domains, categorized here by the BOS. Winters and Tolk (2005) discusses the development of some prototype services (Blue Force Tracking and Global Force Management) that can, in theory, provide some of the information described below. Both of those prototypes were based on the C2IEDM.

Table 3. Services from other domains required by the M-COP.

Battlefield Operating System (BOS)	Description of data, information required from services within the BOS by M-COP services*
Mobility / Countermobility/ Survivability	*Terrain products and data*: • Locations of terrain features and facilities, and their attributes. • Current and projected soil condition (temperatures, soil strength). • Line-of-sight, cover, and concealment ratings. • Elevation, slope, trafficability (vehicle speed predictions), vegetation. • Bridge conditions, road surface conditions, road load capacity. *Engineer products*: • Ability (time and resources required) to breach minefields and other obstacles, repair or emplace bridges, repair roads. • Ability (time and resources required) to emplace minefields and other obstacles. • Planned or in-process engineer operations.
Command and Control	• Friendly force locations, unit size. • Mission type, units involved. • Unit boundaries (area of unit operations/influence). • Control measures, objectives.
Air Defense	• Air defense coverage areas (where maneuver can be protected from air attack).
Maneuver	• None identified, the M-COP is a principal provider of maneuver services.
Intel	• Weather products (current and forecasted)—Visibility, precipitation snow, rain, icing, flooding current and projected, enemy locations, strengths, make-up, range of influence. • Location of obstacles. • Threat Analysis. • Known/suspected enemy locations, threat template. • Information on threat capabilities (What sorts of weapons do they have? How far can they see? What is their LOS capability from suspected vantage points?) • Estimated track (route) and enemy objective. • Information regarding who resides in what neighborhood, including neighborhood affiliations and hostile areas. • Last recon from given area.
Combat Service Support	• Resupply locations, times/schedules, and items. • Medical service locations. • Traffic Control Plans. • Junctions to other maneuver network types—Areal Points of Debarkation (APODs), Sea Ports of Debarkation (SPODs), rail heads, and inland ports.
Fire Support	• Planned missions.

* The data or products listed may depend on services and products from other BOS, which are not identified here (e.g., road condition data from terrain may require an Intel report or Engineer analysis).

6 TASK 4: COMMON REFERENCE MODEL REQUIREMENTS

The goal of the final task in the M-COP project was to review the status of command, control, communications, computers, and intelligence (C4I)-M&S Reference Object Model (CROM) efforts conducted over the past few years to align C4I and M&S data models, particularly those efforts that have described portions of a C4I object model using C2IEDM. The team compared mapping efforts from the M-COP data modeling efforts in the preceding tasks to CROM activities, as well as current work with the BML and C2IEDM, focusing on mobility-specific information. The team did initial semantic modeling of mobility information, moving beyond the CROM Unified Modeling Language (UML) representations to preliminary ontological representations using several semantic modeling techniques, including Formal Concept Analysis (FCA) and description logic expressions using the OWL. The work resulted in the beginning of an advanced knowledge model expressed in OWL for the mobility domain.

Additionally, M-COP data model components were mapped to the next-generation version of C2IEDM, called the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM) (MIP 2005b) to identify suggested extensions to this standard coalition data model. Deliverables for Task 4 (provided in subsequent sections of this report) include this mapping and preliminary OWL model.

Because the M-COP data model was not fully specified by the conclusion of Task 3, further definition and refinement of the model continued in Task 4. These efforts addressed the major information components identified for M-COP and are discussed below. While most of the actual data elements are defined in the appendices, these next sections define rationale and sources of those elements.

One issue that plagued the team was where to start (see Figure 2) and what tools and format to use in the development process, as numerous representations and mobility models currently exist. In fact, the intent of this project was not to invent yet another data model but to use existing models and formalisms to the extent possible. As the team investigated

existing models (and lack of them for some portions of the M-COP data model) and considered higher order representations, it became clear that a basic set of M-COP data or concepts was required. The following sections of the report expand the descriptions of the top-level M-COP data model categories and define the initial M-COP specification.

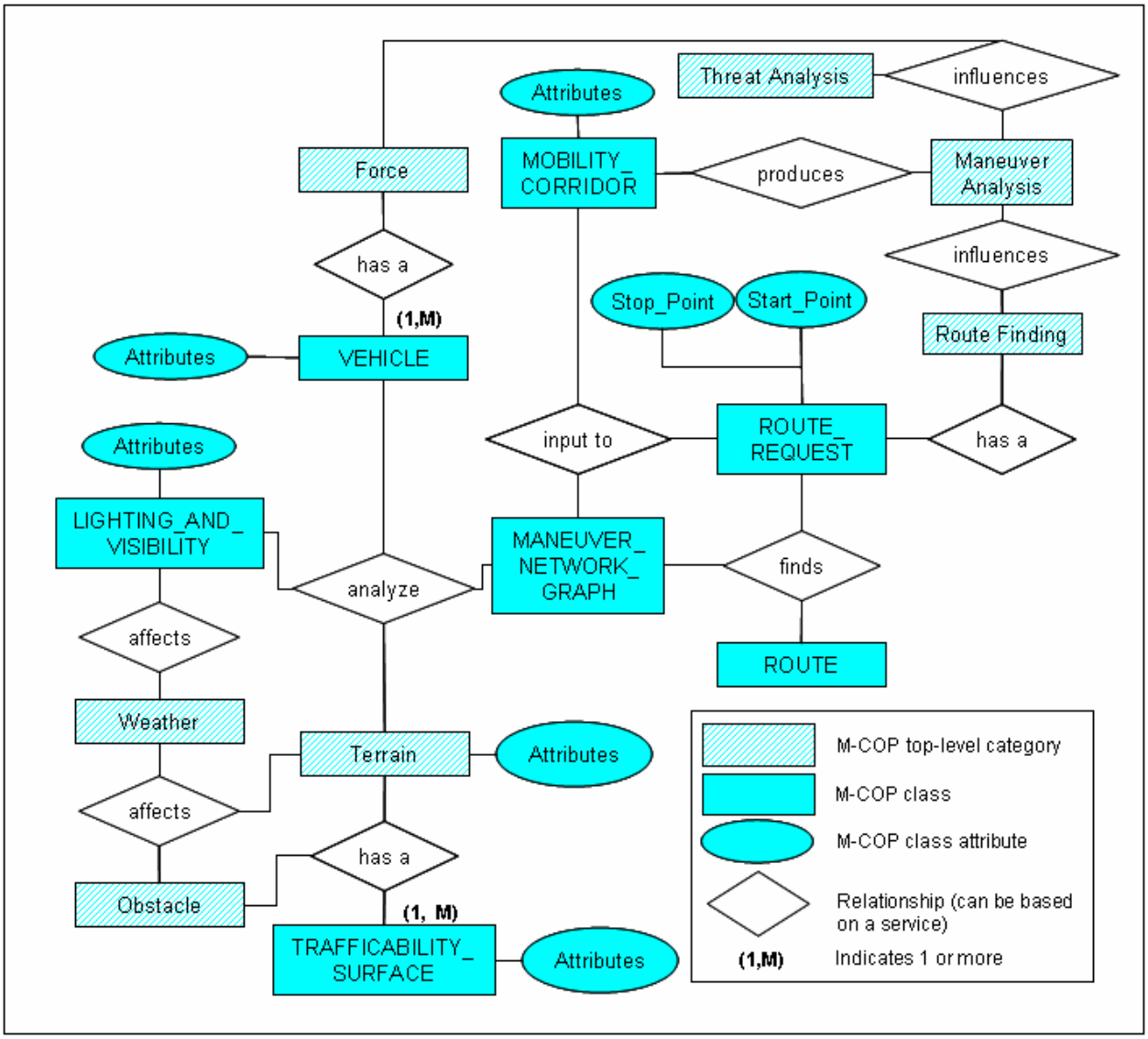

Figure 3. Example category–class–attributes relationships for M-COP structuring.

Figure 3 shows a diagram as a take-off from entity-relationship (ER) diagrams for the M-COP top-level categories, with example relationships to classes and attributes, as well as between categories in some cases. An ER diagram shows graphically "a list of entity types, the permissible relations between them, and some of the constraints on those relations" (Sowa 2000). Chen (1983) discusses the issues associated with developing these

diagrams and their relation to English sentence structure and database design. We did not follow these constructs exactly or strictly but used them as a guide for M-COP relationship designs. The ER-like approach is used here to help clarify relationships (represented as diamonds) between the M-COP top-level categories and those classes represented by other data models or BOS representations. In English, for example, *Route Request* has one or more constraints (such as fastest or shortest) along with attributes of *start point* and *stop point*. *Terrain* has zero or more *Obstacles* and *Terrain* has a *Trafficability Surface* with its own *attributes*. *Weather* affects *Terrain* (e.g., a snow storm will cover the terrain with snow). Maneuver Analysis supports the development of the Modified Combined Obstacle Overlay (MCOO) from which courses of action can be analyzed. Note, too, that *Threat Analysis* involves much of the activities in *Maneuver Analysis* and, as such, there is a relationship between these categories. The *Utilities* category is not shown, as it provides metadata and services supporting the other categories. Relationships in some cases are directly related to M-COP services described in the next section. This diagram is conceptual, and not meant to include every relationship; however, the diagram and relationships should be kept in mind as the M-COP is further described.

M-COP Top-Level Categories

The major categories of M-COP information identified from the earlier tasking are described in greater detail in this section. The discussion includes some of the design rationale and, where applicable, identifies existing data models that can be leveraged to satisfy portions of the M-COP model. Identifiying existing data models raises the question of how the M-COP data model can be populated in operational use. Determining these data sources in the operational (GIG) environment and detailing how the data will be accessed to populate the M-COP are beyond the scope of the current project and are recommended areas of work for follow-on efforts to realize the M-COP for operational employment.

Terrain

The Terrain category of the M-COP data model is defined as the natural and man-made features, or classes, and their attributes that may influence mobility or maneuver of ground vehicles. Terrain includes natural and manmade features; manmade features, or classes, include bridges, roads, etc. Man-made features are defined as things on, in, or over the terrain

and need to be distinguished from the underlying physical terrain (ground and water). They are also geometric in that they possess three-dimensional shapes but are located relative to the physical terrain region. The natural features can be abstracted as a geographic region having features and attributes at various postings (e.g., elevation, vegetation, soil characteristics).

Owing to the extensive past and present work in the area of terrain data modeling, representations are readily available that meet the M-COP purposes; however, a common mediation format is needed for more efficient design of data interchange across multiple systems (Dobey and Eirich 2005). A Visual Object Taxonomy (VOT) has been developed that provides "a detailed categorization of cultural and natural objects" (Bitters 2005). This work is creating distinct, mutually exclusive, unambiguous, and explicitly defined categories "formulated in a single language" (i.e., Webster's version of the English language). Of particular interest to the C4I and M&S communities, the taxonomy was developed with attention to the well-established (and heavily vetted) Synthetic Environment Data Representation and Interchange Specification (SEDRIS) Environment Data Coding Standard (EDCS)*, Feature and Attribute Coding Catalog (FACC), and the Digital Feature Analysis Data (DFAD). The VOT is a ready-made structure for a major portion of the M-COP data model. The main aspect lacking from the VOT is explicitly characterizing the relationship between the taxonomy categories and ground vehicle mobility (e.g., what characteristics make objects such as a Road effective for ground vehicle mobility while objects such as Rubble do not?).

Mobility analysis (calculation of maximum-ground-vehicle-capable speed, acceleration or deceleration on a given area) and terrain feature concepts can be classified as:

- *Off-road*: where issues associated with staying on a "path" can be ignored, i.e., curvature.
- *On-road*: where path curvature must be considered, and it can be assumed that there is no vegetation to be avoided, or over-run.
- *Obstacle crossing*: where wet and dry gaps, berms, craters, and rubble piles can require additional analysis in which ingress, egress, fording, and swimming effects must be considered.

* http://www.sedris.org

- *Obstacle breeching*: implies operation of engineer equipment such as bulldozers, or mine plows.
- *Amphibious operation*: assumes ground vehicle swimming; issues are current, wave heights, obstacles, ingress, egress, etc.

To develop a complete list of terrain features and their attributes required to support the M-COP, the OneSAF Objective System Environmental Data Model (OOS EDM) was used initially as a basis. The OOS EDM is based on the EDCS feature definitions and, by using their classification labels, the Terrain category was initially divided into the following five classes: REGION, TRACT, FACILITY, SITE, and WATERBODY.

In doing so, it became clear that the EDCS definitions that may have included these terms were not consistent, at least with respect to mobility and this context. Further consideration and sorting yielded the categories and definitions in Table 4. Note that some of them are hierarchical, but the intent was not to make them completely so.

Table 4. Terrain category classes.

Class	Definition
NATURAL_REGION	A NATURAL_REGION is an area of terrain that contains few manmade structures and is not maintained for some human use (e.g., cropland). Mobility analysis of NATURAL_REGIONs implies cross-country movement. Roads (including trails and railroads) may occur through regions or divide regions. SITEs may be found, but they do not disrupt movement and maneuver to the extent that they need to be accounted for in route planning.
OPEN_TRACT	OPEN_TRACTs are areas that may be used for some human purpose that has changed their character. It does not, in general, contain SITEs and off-road movement is generally assumed.
FACILITY	A FACILITY is an area that contains more than one structure used for a specific purpose or can be categorized as a group. These structures may be spread out enough so that there are roads, trails, or open space that allow ground vehicle movement within the FACILITY, possibly off-road, but normally on-road. Off-road route planning within a FACILITY will need to take into account individual structures.
SITE	A SITE is the area taken up by an individual structure; if it is a planned structure, the value of completion must be greater than zero. Ground vehicles are assumed to be incapable of normal travel through SITEs. (SITEs may be capable of being breached.)
WATERBODY	WATERBODYs are of concern for ground vehicle movement ingress, egress, fording, and swimming. WATERBODYs may contain SITEs and FACILITYs, which enhance or degrade mobility (swimming or fording).
ROAD	Terrain intended for ground vehicle travel between two locations. A ROAD may be a series of connected segments, each of which have differing attribute values.

In Appendix A, Table A1–Table A6 list enumerations of attributes associated with each of the classes defined in Table 4, which are required to support the M-COP. These enumerations should be considered allowable values of an attribute such as Feature_Type. These enumeration values are the same as their sources. For reader ease, the formats have been changed to the nomenclature chosen for this report. The intent for the M-COP is to use the OOS EDM values; the other sources are shown only for comparison. The terms *area*, *line*, *directed_line*, *3d_line*, and *point* denote the geometry type.

The OOS EDM was used as a basis, and feature types from the FACC (DGIWG 2000), along with those specified in FM 21-31 (HQDA 1961) are shown aligned (using corresponding terms). The Feature_Types from OOS EDM should be the chosen M-COP values. While the location and type of feature is required for Maneuver Analysis and Route Finding (e.g., where is a pass through the mountains?), additional information (attributes) is required for a complete mobility analysis.

The attributes associated with Terrain classes required for the M-COP are just as important as the features themselves. Again starting with OOS EDM and EDCS attributes, we identified eight subclasses to contain the information necessary to conduct mobility and maneuver analysis based upon vehicle–terrain interaction. Along with the EDCS attributes, inputs required by mobility models currently used by the U.S. Army (Ahlvin and Haley 1992; Baylot et al. 2005; Richmond et al. 2005b; Richmond et al. 2006c) were considered. The subclasses are:

- TRAFFICABILITY_SURFACE—a set of attributes associated with the terrain surface from which mobility calculations can be made; they specifically support the use of the NATO Reference Mobility Model (NRMM) and the Standard Mobility (STNDMob) Application Program Interface (API), but will support other models also (Table A7).
- TRAFFICABILITY_VEGETATION—attributes associated with vegetation features that can affect mobility (Table A8).
- TRAFFICABILITY_WETGAPS—attributes of water crossings and sites that can affect mobility (Table A9).
- TRAFFICABILITY_DRYGAPS—attributes of gaps (trenches and ditches) that can affect mobility (Table A10).
- TRAFFICABILITY_ROAD—a list of attributes associated with the M-COP ROAD class, from which mobility calculations can be made.

Specifically supports the use of the STNDMob API, but will support other models also, and must be used in conjunction with the TRAFFICABILITY_SURFACE subclass (Table A11).

- TRAFFICABILITY_BRIDGES_TUNNEL—a list of attributes associated with bridge and tunnels, from which mobility calculations can be made. Specifically supports the use of the STNDMob API, but will support other models also, and must be used in conjunction with the TRAFFICABILITY_ROADS subclass (Table A12).
- TRAFFICABILITY_RAILROAD—a list of attributes associated with railroads, from which mobility calculations can be made (Table A13). Currently, this list of attributes can stand alone, although it would be desirable to merge it with TRAFFICABILITY_ROAD and TRAFFICABILITY_SURFACE.
- MANEUVER_URBAN—a list of attributes for urban areas that should be considered for maneuver in urban areas (Table A14). Not required for trafficability analysis.

Table A7–Table 14 list and define the attributes of each of these subclasses, which should be associated with applicable Terrain classes.

FMI 2-91.4 (HQDA 2005a) specifies information about urban terrain that should be considered during maneuver planning. While no automated system to our knowledge takes this information into account, they are required as part of the M-COP. The EDCS contains attributes that describe this information by the type of urban terrain zone (UTZ) and street pattern. These two attributes currently make up the M-COP Terrain subclass MANEUVER_URBAN. As doctrine, simulations, and BC systems evolve to address urban operations, this category may need to be expanded.

To reduce the size of the OOS EDM, attributes associated with a particular feature are allowed only enumerations that are appropriate to the feature (e.g., a Treed_Tract has a vegetation type, but the allowable values are limited to types of trees). Additionally, not all of the OOS features have the complete set of M-COP attributes; however, those can be set to null or default values. Similarly, other applications interacting with the M-COP need to be aware of this requirement. For the M-COP Terrain attributes sets, this approach was not taken.

Slope effects also need to be considered; the determination of a slope implies directionality, and high-fidelity mobility models use the current

vehicle location and heading to determine a current vehicle pitch. Lower-fidelity models used for planning can use the average of the maximum, minimum, and level slope speeds to obtain an "Omni-speed" prediction. Other approaches can be imagined. In any case, if the terrain is represented initially as polygons, then the slope is inherent in the three-dimensional location of each vertex. The spatial location and extent of a feature or object are defined through the use of a "geometry." There are many geometry data models; refer to the Utilities category of the M-COP described later in this report.

Once speed (or acceleration/deceleration) has been determined for all terrain "types" in an area of interest, severely restricted, restricted, and unrestricted terrain can be identified, the Terrain category can be further classified, and a maneuver network created (see Route Finding category section).

Obstacles

The Obstacles category consists of those Terrain features (classes) or other objects or conditions that disrupt or impede movement of ground vehicles. As with the Terrain category, Obstacles may be natural (cliff, ravine, swamp) or manmade (minefield, log barricade, rubble). As indicated, some Terrain classes, whether manmade or natural, can also belong to the Obstacles category based on characteristics that cause these objects to disrupt or impede movement of ground vehicles. Even another vehicle can be an obstacle to ground vehicle mobility under certain circumstances. With an automated reasoner*, members of various classes can be automatically classified as Obstacles based on their properties; for example, a river with certain width, current, and depth property values can be classified as an Obstacle. If those property values change, say during a drought, then the river may cease to be an obstacle. Creating a lane through a minefield does not cause the minefield to no longer be a minefield, but it may cause it to no longer be an obstacle to ground vehicle mobility. The ability of software to perform these inferences based solely on the abstract description of the data model, rather than hard-coded in software specialized for the application, is one of the merits of a formalized ontology at the Logical Theory level of the ontology spectrum.

* Reasoner, something that can find new facts from existing data (a.k.a. reasoning) (http://en.wikipedia.org/wiki/Reasoner). See http://www.w3.org/2004/OWL/ for a list of available reasoners.

Like the Terrain category, Obstacles are also fully specified in existing data models that can be re-used for M-COP. Appendix B contains tables similar to those in Appendix A, except that here we specify these Obstacles as classes (Table B1) for the M-COP, because they have little in common with each other. The attributes of selected Obstacle category classes are in Table B2. By their nature, the kinds of obstacles identified in Appendix B were not included in the Terrain category. As with the Terrain category, the OOS EDM was used as a basis and obstacle types from the FACC (DGIWG 2000), along with those specified in FM 21-31 (HQDA 1961) are shown aligned (using corresponding terms) for comparison. The M-COP Obstacle category classes are those in the OOS EDM.

Weather

The Weather category classes developed for M-COP are shown in Table 5. The Weather category consists of current and forecasted weather conditions that affect mobility and maneuver (LIGHTING_AND_VISIBILITY*, PRECIPITATION). The Weather category has a similar abstract structure as the Terrain category, in that it is best characterized as a geographic region having certain physical and temporal characteristics. Existing Environmental Data Models (EDMs) provide detailed data representations that can meet M-COP data and information requirements.

Table 5. Weather category classes.

Class	Examples of Attributes	Appendix C
PRECIPITATION	Precipitation_Type, Precipitation_Rate, Snow_Accumulation_Depth, Accum_Precip	Table C1
ATMOSPHERE	2m_Air_Temperature, Maximum_Air_Temperature, Wind_Chill_Index, Lightning_Probability, Route_Weather_Type	Table C2
WIND	Wind_Direction, Wind_Speed, and Wind_Gust_Speed	Table C3
CLOUD_COVER	Information on clouds including Cloud_Type, base height, and amount of cover	Table C4
LIGHTING_AND_VISIBILITY	Information on visibility and lighting including distance, bearing, obscurants, time of sunrise, sunset, moonrise, moonset	Table C5
ICING	Probability_Of_Icing, Icing_Intensity, and Icing_Type	Table C6

The Weather category classes were developed by reviewing a series of models and field manuals to gather the pertinent features. Some of the

*The class LIGHTING_AND_VISIBILITY includes lighting. Even though it is not weather related it has a great effect on visibility.

field manuals from which the category classes and attributes were developed are given below:

- FM 5-33 *Terrain Analysis* (HQDA 1990).
- FM 34-81 *Weather Support for Army Tactical Operations* (HQDA 1989).
- FM 34-81-1 *Battlefield Weather Effects* (HQDA 1992).
- FM 34-130 *Intelligence Preparation of the Battlefield* (HQDA 1994).

The classes and attributes were also identified in the following models.

- SEDRIS EDCS.*
- OOS EDM-AOS components.
- Joint Meteorology and Oceanography (METOC) Conceptual Data Model (JMCDM).†
- Army Integrated Meteorological System (IMETS).
- MSDL.

Complete descriptions of the attributes of these classes are provided in Appendix C, Tables C1–C6.

Maneuver Analysis

As we have described, Maneuver Analysis includes analyses related to ground vehicle movement with respect to mission, command and control, flow of operations, local culture, and other considerations. It also includes some information versus raw data classes required for the analysis. The focus is on what the commander needs to know to conduct maneuvers in the battlespace and can apply to friendly and threat forces. In maneuver analysis, the need for assessment of higher-order effects resulting from characteristics at the data-level of the environment makes the Maneuver Analysis category different from the Terrain, Weather, and Obstacle categories. The Maneuver Analysis classes are not features of the terrain per se, but are representations of the effects of the terrain on ground vehicle mobility. This is also true for the Threat Analysis and Route Finding categories.

* http://www.sedris.org/edcs.htm

† The Joint METOC Conceptual Data Model (JMCDM) and its supporting encyclopedia are a subset of the DoD Enterprise Data Model. The JMBL schema provides an XML representation of the JMCDM and establishes a single interface for requesting and retrieving METOC data. http://pao.cnmoc.navy.mil/scripts/public_JMCDM/home_pwd.pl

Some researchers have observed that efforts to reach common terrain and environment models have been focused at the data level rather than at the information or knowledge level (Galvin et al. 2005). The distinction is important. Systems have primarily dealt directly with the raw data characterizing a geographic region, performing various processing to derive some battlefield effects (such as line-of-sight). Rather than having such information available directly, numerous systems spend processing resources to derive the higher-order effects, and often compute those results over and over again. Moreover, the raw data sets can be extremely large, making it very inefficient to distribute over a network. The ability to represent derived products could prove to be more efficient for system design.

In recognition of this, a parallel and complementary effort to M-COP has been started in the Engineer Research and Development Center (ERDC) Topographic Engineering Center (TEC) to define a data model for a Geospatial Battle Management Language (GeoBML). As described in Galvin et al. (2005):*

> ERDC seeks to abstract and represent terrain and dynamic environment through a rich set of discrete objects (spatial and temporal) and relationships to tactical entities and tasks. Instances of these objects and relationships can then be extracted from the current and future large terrain and dynamic environment datasets and databases—essentially reducing large terrain data sets to their tactical essence and expressing the reduction in an ontology for interoperability at the conceptual level.

Clearly, emerging ontology development for the GeoBML effort is of direct consequence to the Maneuver Analysis category of the M-COP data model. Several information-level "products" were identified in the stakeholders' analysis (e.g., avenues of approach, severely restricted areas, mobility corridors, and choke points). These are not features of the terrain per se, but representations of the effects of the terrain on ground vehicle mobility.

Maneuver Analysis is not a standard term found in military publications such as FM 1-02, *Operational Terms and Graphics* (HQDA 2003a), and

* The Coalition Battle Management Language (C-BML) Study Group Final Report included contributions from a number of researchers in the C4I and M&S communities. The particular contribution relating to a GeoBML was submitted by M. Powers of the ERDC TEC.

no existing data models were discovered. Likewise, there is no detailed discussion or standard operating procedure that neatly describes how to do a maneuver analysis. However, there are several processes and analyses the Army describes that are associated with the maneuver analysis category, and the team depended heavily on these to tease out concepts for maneuver analysis classes and associated attributes.

To identify the classes and attributes associated with the Maneuver Analysis category, we began by focusing on what the commander needs to know to maneuver in the battlespace, as was the subject of the stakeholder's analysis. The process was iterative and involved organizing potential elements (data and information) gathered from stakeholders, reading, and research into like concepts and interrelationships. The Intelligence Preparation of the Battlefield (IPB) process and terrain analysis procedures provided a good framework from which to identify and organize concepts. FM 3-0, *Operations* (HQDA 2001a), FM 3-90, *Tactics* (HQDA 2001b), and FM 7-15, *The Army Universal Task List* (HQDA 2003b) provided a bigger picture context in how the concepts apply.

The IPB process is an important component in determining where forces can and would want to maneuver to achieve a decisive advantage (define the battlefield environment and describe the battlefield's effects, noted as steps 1 and 2 of the IPB process). Terrain analysis involves interpreting the effects of terrain on military operations and is an integral part of the IPB process. There are field manuals dedicated to the subject of terrain analysis—e.g., FM 5-33, *Terrain Analysis* (HQDA 1990), and *Intelligence Preparation of the Battlefield*, FM 34-130 (HQDA 1994) and FM 2-91.4 (HQDA 2005a).

Before detailing the concepts and classes identified for the Maneuver Analysis category, it is important to discuss the means by which the team differentiated elements for Maneuver Analysis versus Threat Analysis. Many of the concepts pertaining to where the threat will be located or will try to engage friendly forces and so forth are represented as classes and subclasses in the Maneuver Analysis category rather than in the Threat Analysis category. The rationale used to determine classes of Maneuver Analysis versus Threat Analysis, as these are highly intertwined from an M-COP perspective, was based on the overarching steps of the IPB process. The first two steps of the IPB process are to define the battlefield environment and describe the battlefield's effects. These were used to guide

components of Maneuver Analysis. The Threat Analysis data model development was guided by the third and fourth steps of the IPB process: evaluate the threat and determine threat courses of action, with a focus on mobility-related components. There are natural linkages between the Maneuver Analysis and Threat Analysis categories.

The Modified Combined Obstacle Overlay (MCOO) is part of describing the battlefield's effects on threat and friendly forces, is a product of the IPB process, and includes maneuver analysis. An example is shown in Figure 4. The MCOO is developed for a geographic area and depicts avenues of approach (AA), mobility corridors (MC), mobility estimates as unrestricted, restricted, or severely restricted areas, identifies key terrain, potential engagement areas (EA), and obstacles, for example (FM 34-130, HQDA 1994). Many of these elements were noted during the collaborative brainstorming sessions with stakeholders as elements needed for determining where to maneuver in the battlespace.

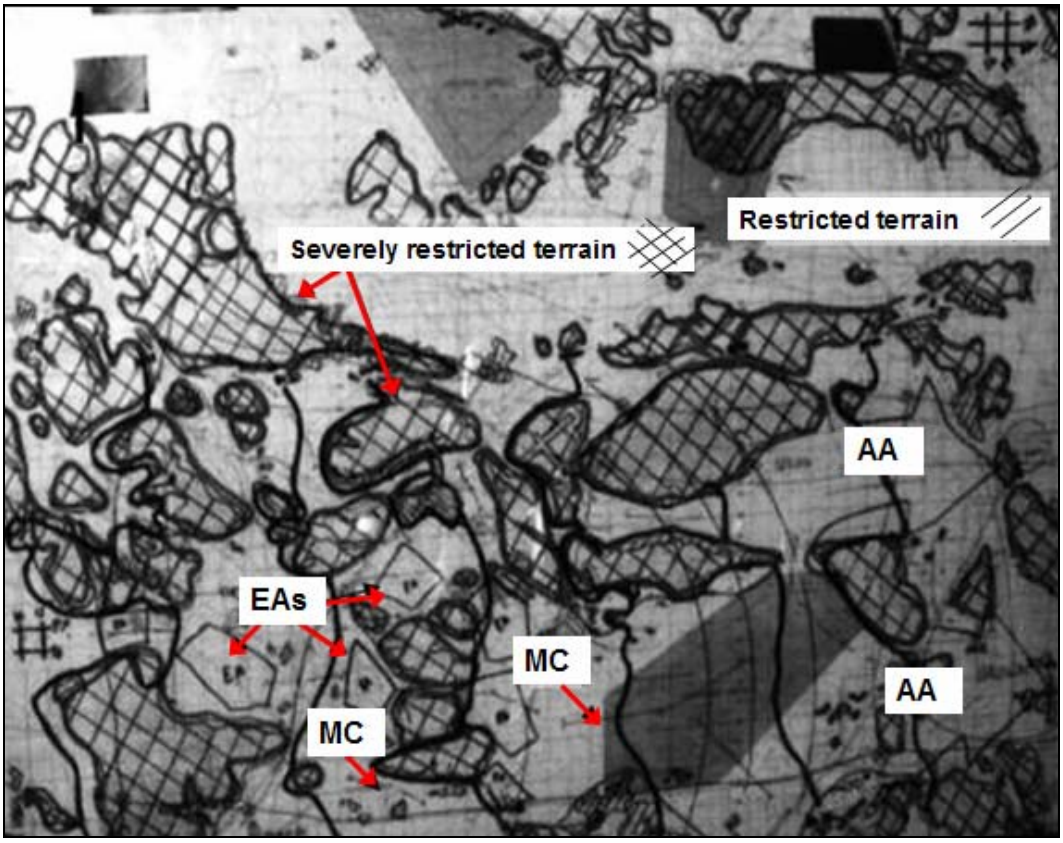

Figure 4. Modified Combined Obstacle Overlay developed during Mission Analysis Practical Exercise by officers at Fort Huachuca participating in the Military Intelligence Officer Advanced Course (March 1996).

Within the area of operations (AO), it is important to identify the obstacles, both military and natural, as these have an impact on mobility and maneuver. The obstacles are referenced in the Maneuver Analysis category but are obtained from the Obstacle category where the classes and attributes are organized and detailed.

Trafficability classifications are also key in analyzing maneuver in the AO. These are typically categorized as unrestricted, restricted, and severely restricted mobility, based on analysis of regions or sectors of the terrain. As taken from FM 34-130, unrestricted terrain does not restrict movement, and there is no need to enhance mobility through these areas. Thus, relatively flat, open terrain or improved roads would be characteristics of unrestricted terrain. Restricted terrain, as the term implies, offers impediments to movement. In such areas, movement may require more maneuvering around slower going areas or terrain may be more hilly and rough. Like restricted terrain, severely restricted terrain impedes movement, but to a more significant degree. This type of terrain can be characterized by steep slopes, soft soils, or the presence of several obstacles, or all three. Additionally, there are models such as the NATO Reference Mobility Model (NRMM) that can be applied to provide maximum speed potential estimates. In keeping with this, we developed a class called TRAFFICABILITY_SEGMENT (Table D2). Consider, in a maneuver analysis, analyzing the area of operations for terrain impediments. Conceptually, a human or a computer can break the terrain into sectors and assign trafficability estimates. This is also similar to the speed attribute assigned to the edge of a maneuver network (see the Route Finding category section). On examining Figure 4, one can see how determining severely restricted and restricted terrain influences movement and maneuver and is a key concept within maneuver analysis.

Avenues of approach (AA) for the ground are defined in FM 1-02 as "...ground route of an attacking force of a given size leading to its objective or to key terrain in its path" (HQDA 2003a). The AAs, then, are critical elements in maneuver analysis. The AAs are selected based on mission, objective, and trafficability, among other things. The corresponding proposed class is GROUND_AVENUE_OF_APPROACH (Table D3) and is associated with an AO. Figure 4 depicts AAs selected based on west to east movement toward objectives in the southern region of the AO (large, open arrows). One can see how the trafficability and obstacles influence AA determination.

Another important concept is mobility corridors. Mobility corridors (MC) are "Areas where a force will be canalized due to terrain restrictions. They allow military forces to capitalize on the principles of mass and speed and are therefore relatively free of obstacles" (HQDA 2004). The class MOBILITY_CORRIDOR (Table D4) is used to convey information about MCs associated with the AO. The MCs affect AAs and, as graphical symbols, convey information about the size of the force, or frontage, that can move through an area. The MCs are determined by analyzing the terrain for large obstacles and restricted or severely restricted areas. Thus, we also created a class called AVENUE_OF_APPROACH_CHANNELIZER (Table D5), which conveys data and information about the features associated with the MCs. Figure 4 shows MCs of different widths and restrictions.

Because some elements needed for maneuver analysis, such as cover and concealment, are characteristic of segments of the AA versus of the entire AA, we also created a class called AVENUE_OF_APPROACH_SEGMENT (Table D6). The segments are numbered and tied to a particular AA. Attributes associated with this class include intervisibility, cover, and concealment as estimated in percent. However, these can also be categorized as good, fair, poor or by some other method.

Key terrain is important to identify in maneuver analysis and is defined in FM 1-02 as "(DOD, NATO) any locality, or area, the seizure or retention of which affords a marked advantage to either combatant" (FM 1-02, HQDA 2003a). As noted above, key terrain can influence the placement of AAs. The associated class for the Maneuver Analysis category is KEY_TERRAIN (Table D7).

As part of determining where to maneuver, it is important to assess where you would want to engage the enemy, as well as where the enemy might have an opportunity to engage friendly forces (engagement area). As defined in FM 1-02, an engagement area (EA) is "an area where the commander intends to contain and destroy an enemy force with the massed effects of all available weapons and supporting systems" (HQDA 2003a). Characteristics of observation and fields of fire, which are influenced by terrain and elevation, affect potential engagement areas. This concept is reflected in the class ENGAGEMENT_AREA (Table D8). Several potential EAs are shown in Figure 4.

Maneuver analysis is also concerned with the progression of units over time. These are generally depicted as time phase lines (TPL), lines indicating the flow of the operation (based on a course of action), and the progression of units at particular time intervals relative to the start time for the movement. H-Hour typically indicates the start time and H+15 indicates progression after 15 minutes have elapsed, etc. (HQDA 2003a). This class is denoted as TIME_PHASE_LINES_H (Table D9). TPLs are named and are associated with an AO and AAs.

A summary of the classes for the Maneuver Analysis category is given in Table 6. The classes, attributes, definitions, and data types can be found in Appendix D, Table D1–Table D9.

Table 6. Maneuver Analysis category classes.

Class	Definition	Appendix D
AREA_OF_OPERATIONS	“An operational area defined by the joint force commander for land and naval forces.” (FM 1-02). Abbreviated as AO.	Table D1
TRAFFICABILITY_SEGMENT	An area of defined trafficability of a portion of the AREA_OF_OPERATIONS (e.g. severely restricted). Abbreviated as TS.	Table D2
GROUND_AVENUE_OF_APPROACH	"(DOD) ground route of an attacking force of a given size leading to its objective or to key terrain in its path.” (FM 1-02). Abbreviated as AA.	Table D3
MOBILITY_CORRIDOR	"(DOD) Areas where a force will be canalized due to terrain restrictions. They allow military forces to capitalize on the principles of mass and speed and are therefore relatively free of obstacles." (FM 1-02). Abbreviated as MC.	Table D4
AVENUE_OF_APPROACH_CHANNELIZER	Point or areal terrain feature of the AA that will cause channelization. This could be a severely restricted area, a forest, a river, etc. (FM 1-02)	Table D5
AVENUE_OF_APPROACH_SEGMENT	Segmented areas of the GROUND_AVENUE_OF_APPROACH.	Table D6
KEY_TERRAIN	“Any locality, or area, the seizure or retention of which affords a marked advantage to either combatant." (FM 1-02)	Table D7
ENGAGEMENT_AREA	"An area where the commander intends to contain and destroy an enemy force with the massed effects of all available weapons and supporting systems. Also called EA." (FM 1-02). Abbreviated as EA.	Table D8
TIME_PHASE_LINES_H	Lines indicating the flow of the operation (based on a course of action) and the progression of units at particular time intervals relative to the start time for the movement. H-Hour typically indicates the start time and H+15 indicates progression after 15 minutes have elapsed, etc. (FM 1-02). Abbreviated as TPL.	Table D9

Route Finding

Route Finding is the process of finding a minimum-cost route for a force from an origin to a destination in a maneuver search space that meets constraints specified in a route request. In this report, route requests are created during Maneuver Analysis; near-term route finding to avoid dynamic obstacles is not considered. Several concepts are involved in route finding. One is trafficability—the potential for movement of a force over a piece of terrain. As mobility and maneuver involve movement from one point to another, the idea of connectedness from one area to another in terms of trafficability is necessary. A maneuver network graph* with assessments of trafficability on each graph edge provides a context for maneuver potential in the area of operations. Edges represent contiguous trafficable terrain features. Impassable obstacles are represented by the absence of edges and negotiable obstacles are represented by edges attributed with the assessed trafficability of the obstacle. Nodes delimit changes in trafficability between adjacent edges. A graph composed of such edges and nodes provides a maneuver search space for determining a minimum-cost route for a group of vehicles as defined in the Force section. The context for determining a maneuverable route is built with elements from two sources. One source is the representation of maneuver considerations other than trafficability, such as concealment, in the maneuver network graph by additional edge attribution. Another source for maneuver considerations is maneuver analysis. These results are expressed in the form of constraints or "costs" on the route assessment calculations.

For a route to be suitable for a maneuver, it must not only be traversable, it must also comply with movement restrictions or constraints resulting from maneuver analysis. Examples of constraints include maximum range, proximity limits to specific terrain or terrain types, proximity limits to areas influenced by threat units, waypoints to visit, unit boundaries and other control measure limitations on operations, concealment requirements, obstacles unknown at network graph compilation time, and formations in which the force will travel. Often, one constraint cannot be met without violating another constraint. As constraints cannot always all be met simultaneously, each constraint must be weighted against other constraints during maneuver analysis. This weighting must be taken into

* Graph (data structure) Definition: A set of items connected by edges. Each item is called a vertex or node. Formally, a graph is a set of vertices and a binary relation between vertices, adjacency. http://www.nist.gov/dads/HTML/graph.html

account in finding a traversable route that best meets the constraints of the route request.

Another concept in route finding is that of a force. Because route finding is intended for traversal by some type of unit or force, it is important to know the type of vehicles in the force and the width of the formation in which the force will travel. Force attribution contains the type of vehicles, as well as the width of formations (see Force category in next section).

Development of the route finding data model mirrors the development of the M-COP data model. First, a set of questions intended to bound the model (Noy and McGuinness 2001) were answered. The initial inventory of terms used in the Route Finding data model is derived from the internal data model of the Battlespace Terrain Reasoning and Awareness (BTRA) software (Hall and Swann 2005). That inventory of terms was expanded with terms collected from previous M-COP literature, stakeholder sessions as described above, informal software documentation for OOS (Condon 2002), and a report on maneuver representation in simulations (SAIC 1999). These terms were included on the basis of their relevance to route finding. The terms were then compared to elements in the ER diagram in Figure 3. If a term still fit within the scope of route finding as bounded by the competency questions and was not a synonym of another term, it remained in the inventory. Finally, the terms were ordered into a hierarchy of classes and subclasses. Results are included in Appendix E, Table E1, and the proposed Route Finding classes are in Table 7.

Table 7. Route Finding category classes.

Class	Definition
ROUTE	"The prescribed course to be traveled from a specific point of origin to a specific destination." – FM 3-90
ROUTE_REQUEST	A request for a route through a maneuver network.
CONSTRAINT	A requirement that should be met by the route.
MANEUVER_NETWORK_GRAPH	A geometric representation of trafficability over terrain that can be used in mobility and maneuver analysis applications.
EDGE	A representation of contiguous stretches of terrain having like attributes—especially trafficability.
NODE	An endpoint of a graph edge.
FORCE	A group of ground vehicles.

Derivation of the routes depends on information from the other M-COP categories; for example, slope information from the Terrain category, minefield placement and status from the Obstacles category, precipitation

and temperature from the Weather category, positions of advantage from the Maneuver Analysis category, presence and capabilities of enemy forces from the Threat Analysis category, and mission and friendly force mobility assets from the Forces category. The BTRA software is a current decision aid doing this type of processing to generate route plans. Because the routes are products of such processing, there is a clear opportunity for identifying software services within the distributed GIG environment. Specification of M-COP in this regard will include not only the products, but should also characterize the processes through such standards as the WSDL. This will lead follow-on M-COP specification efforts toward another area of formalization, namely the use of OWL-S (Web Ontology Language for Services) to provide stronger semantics for discovering and orchestrating Web services in the GIG environment (Alesso and Smith 2005). Egenhofer (2002) argues for the development of a geospatial language for making requests in a geospatial web environment. The same type of language will be required for making geospatial requests in the GIG environment.

Forces

The Forces category describes information about maneuver and transportation units, and individual platform locations and capabilities as related to mobility and maneuver. Because representing military forces is a key element of C4I and M&S systems, there are numerous representations available for reuse in the M-COP data model. Clearly applicable are the XML Schema representation produced by the Unit Order of Battle Data Access Tool (UOB DAT) (DMSO 1999) and the XML Schema formalization of scenario data, including forces, in the MSDL (Surdu et al. 2005; Franceschini et al. 2004), which is based on MIL-STD-2525B, *Common Warfighting Symbology* (DISA 2005). MSDL is a leading candidate for use in the M-COP, as it is currently being standardized through the Simulation Interoperability Standards Organization (SISO). Moreover, MSDL is being used for scenario initialization and archival storage in the OOS. Taxonomies of military forces are also available in the DOD Meta-data Registry and Clearinghouse. Early efforts to create more formal ontologies for military unit behaviors are described in Lacy and Henninger (2003) and for other military M&S purposes in Lacy and Gerber (2004).

The stakeholders' analysis identified the following characteristics of the Forces category as being important to mobility planning (Blais et al. 2005b):

- Enemy forces:
    - Disposition.
    - Location.
    - Size.
    - Orientation.
    - Capabilities.
    - Weapon types.
    - Center of gravity.
    - Asymmetric or symmetric?
    - Information requirements.
    - Tactics, Techniques, and Procedures (TTP).
    - Known locations with date time group.
    - Location of last contacts and type weapons systems, etc.
    - Threat.
    - Composition.
    - Fire support assets in the area.
    - Historical data on recent activity and areas to avoid.
    - Pattern analysis of attacks over time.
    - Need additional information on enemy forces—Intent, Capability, Identification.
    - Movement—may need to know when the enemy may reach a certain location.
    - Fields of fire from suspected enemy forces.
    - Recent mortar activity and Observation Post (OP) locations.
    - Threat courses of action.
    - Avenues of approach available to enemy forces but not to friendly forces.
    - Recent operations in the area.
    - Historical data on IED attacks or ambushes.
- Friendly forces
    - Disposition.
    - Assets: Vehicle characteristics.
    - Fire support.
    - Friendly Forces Information Requirements (FFIR).
    - Information requirements.
    - Observer locations.
    - Fire support–counter battery assets–range fans.
    - Location of all friendly forces.
    - Force structure.
    - Battalion (BN) needs down to squad location.
    - Location of all Combat Service Support (CSS) and Combat Support (CS) assets.
    - Status of forces:
        - In urban operations, battalions will track down to platoon slants, individual and section (two-vehicle) status, which could also include infantry squads in nearby operation.

        - Brigades will usually want company slants as well (as opposed to red/amber/green reports).
    - Location of friendly bases with contact information (call sign, frequency, etc.).
    - Sectors, battlespace, retrans lines, medical evacuation (MEDEVAC) frequencies and units, etc., over long distances:
        - Possible congestion, choke points.
        - Timing of force movements.
    - Any air-to-ground attacks in area of operations (i.e., Joint Direct Attack Munitions [JDAMs], etc)—heads up for unexploded ordnance (UXO).
    - Recent operations in this area.
    - Force locations.
    - Center of gravity.
    - Communications footprint.
    - Available engineer mission packages (e.g., breaching assets available, countermine, bridging).
    - Unit experience in the environment (AO awareness).
    - State of training.
    - Maintenance readiness level.
    - Mission, tasks, and purposes for ongoing operations:
        - Offense–Defense.
        - Flanking movement, movement to contact, defense in depth, mobile defense, reserve, etc.
    - Logistics status (fuel capacity and sustainment).
    - Fatigue.
    - Food and water status.
    - MEDEVAC—location of nearest medical facilities.
    - Known times of CSS/CS convoys in area of operations and when US/Coalition soft targets will be present in the area of operations.
    - Update on left/right adjacent unit activities (could indicate forces coming into the area of operations).

- Non-military forces:
    - Refugees and local community.
    - Displaced civilians.
    - Non-governmental organizations.
    - Private volunteer organizations.
    - Local populace considerations.
    - Local populace disposition towards friendly forces.
    - Recent significant interactions and incidents between friendly forces and local populace.
    - Traffic control.
    - Civilian neutral elements' disposition (tendencies and trends of local populace).
    - Urban traffic patterns.
    - Cultural norms in traffic flows.

- Local gasoline situation.
- Types of local traffic.

After eliminating duplicate information and consolidating related information, the following organization of data results for the Forces category of the M-COP data model:

- FORCE_DISPOSITION (military/para-military, any side):
  - Identity.
  - Location.
  - Formation.
  - Formation spacing.
  - Orientation.
  - Center of gravity.
  - Fields of fire.
  - Mission/task/purpose.
  - Movement:
    - Direction.
    - Speed.
    - Plans (timing, locations).
  - Affiliation.
  - Communications footprint.
  - Equipment:
    - Nomenclature.
    - Type of equipment.
    - Maintenance readiness level.
    - Weapons: Fire support assets.
    - Vehicles:
      - Vehicle status.
      - Mobility characteristics.
  - Personnel:
    - Quantity.
    - Military occupation codes.
    - Experience in the area of operations.
    - State of training.
    - Fatigue.
  - Supplies:
    - Fuel.
    - Food.
    - Water.
  - Capability: TTPs.
  - Support:
    - Engineering (e.g., available mission packages for breaching, countermine, bridging).
    - CSS.
    - CS.

        - Fire.
        - Air.
        - Intelligence/reconnaissance.
        - MEDEVAC locations, frequencies.
    - Information requirements: Observer locations.
    - Force structure (command/subordinate relationships).
    - Bases:
        - Identification.
        - Location.
        - Affiliation.
    - Control measures:
        - Unit boundaries.
        - Adjacent units' dispositions.

Thus, the disposition of a force consists of its physical state on the battlefield and its historical and planned activities, including what it knows about other forces' dispositions. Note that the concept of affiliation or side is relative and not necessarily symmetrical. Also note that a particular side, say Blue, needs to know its own movement capabilities as well as those of other sides (including other Blue units) to project the state of the battlespace over time to determine the potential for certain "other-side" movements to adversely affect own-side planned movements.

Threat-specific information includes the following historical data:

- Location of last contacts.
- Disposition over time (where "disposition" includes the various data identified above under FORCE_DISPOSITION).
- Attacks over time.
- Enemy activities (recent operations) over time.
- Mortar activity OP locations.
- IED attacks or ambushes.

These data provide a basis for estimating or predicting current or future capabilities of the enemy force to disrupt or impede own-side ability to maneuver. This information would be accumulated from intelligence reports, contact reports, and other sources. The record of enemy activities becomes the raw material for performing threat analysis, together with FORCE_DISPOSITION data.

Some of the information dealing with enemy forces allocated from the stakeholders' analysis to the Forces category of the M-COP data model actually reflects inferences that can be made based on the above informa-

tion, and, therefore, make more sense being part of the Threat Analysis category (next section).

Non-military forces are not necessarily organized in the same sense as the forces described above, but create background traffic in the battlespace that can affect the ability of military forces to maneuver. The following set of information is retained from the earlier list produced in the stakeholders' analysis of local population:

- Refugees and local community.
- Displaced civilians.
- Non-governmental organizations.
- Private volunteer organizations.
- Local populace considerations.
- Local populace disposition towards friendly forces.
- Recent significant interactions and incidents between friendly forces and local populace.
- Traffic control.
- Civilian neutral elements' disposition (tendencies and trends of local populace).
- Urban traffic patterns.
- Cultural norms in traffic flows.
- Local gasoline situation.
- Types of local traffic.

This information is exclusive to civilians as they participate in an activity (or avoid an activity) that affects mobility, that activity is classified within the Forces category. For instance, if a villager takes down warning signs indicating that a field contains mines, they are acting as an agent and are no longer solely a civilian. Obviously, this can lead to debate about what constitutes participation versus normal activity that may affect operations. The entire purpose of the M-COP ontology is to assist with the sharing of information. There is the potential for significant overlap among the various categories in the ontology. This is especially true with regard to the civilian category. Therefore, it is important that you fully understand how we are defining the civilian class. Determining which category "receives credit" for activities is not as relevant as making sure the user records and labels all activities and objects *somewhere*. Thus, in ambiguous situations, the activity or object will go in a non-civilian category.

The following characteristics of civilians provide additional information to identify purely civilian effects on mobility. They consist primarily of

cultural activities such as holidays and religious customs. However, as the ontology develops over time, new characteristics are sure to emerge.

- Religious:
  - Customs (eye contact, entering holy sites, holidays, etc.).
  - Constraints (roles of men/women, clothing, etc.).
  - Distribution by denomination or sect (e.g., 1/3 Sect A, 2/3 Sect B).
  - "Holy ground or sites" (mosques, burial grounds, shrines/statues).
- Secular:
  - Language and standards (street signs, graffiti, metric vs. English).
  - Secular customs (attitudes, values, etc.).
  - Type of work (industrial, agricultural, etc.).
  - Local laws and regulations (drive on left side of road, size limitations of motor vehicles, etc.).
  - Economic factors.

Table 8 provides definitions of the two proposed classes for the Forces category subclasses, and attributes are discussed below.

Table 8. Forces category classes.

Class	Definition
FORCE_DISPOSITION	Information about the identity, affiliation, spatial characteristics, activities, plans, capabilities, assets, readiness, and structure of an organization operating in the battlespace.
LOCAL_POPULATION	Information about indigenous people, customs, behaviors, activities, and laws that affect ground vehicle mobility in an area of the battlespace.

While Forces data can identify the state of the local populace, threat analysis computations on these data provide edge weights for route finding algorithms to estimate the effects on ground vehicle mobility. There is a clear path for orchestrated services here, where a request to a service for route finding spawns a request to a service to perform threat analysis (specifically, mobility threat analysis) to obtain updated weighting of factors characterizing the edges of the maneuver network. The Threat Analysis service, in turn, requests M-COP data (Terrain, Weather, Obstacles, Forces, etc.) through an M-COP data service that is aware of the diverse sources of the relevant information.

The MSDL identifies information needed for scenario initialization, including the following (SISO 2005):

- *Options*: Identify how task organizations are specified (entity or aggregate based), the data standards being used by the scenario (coordinate systems and associated datum; enumeration standard and version) and any application-specific options that have been created by the Command and Control (C2) planning application or applications that created the scenario.
- *Environment*: Absolute scenario time (initial time), identification of the terrain (data source and terrain boundaries), synoptic weather (temperature range, moonrise and set times, sunrise and set times, nautical twilight, clouds/fog/haze visibility and ceiling information), and METOC graphics (from MIL-STD-2525B).
- *Force Structure*: Specifies the sides of the battle to which specific forces are aligned.
- *Task Organizations*: Identifies units and equipment, where equipment generally equates to entities in a simulation and follows MIL-STD-2525B classification.
- *Installations*: Identify military facilities.
- *Overlays*: Provide a mechanism for linking Tactical Graphics to specific Overlays or Layers to be placed on a tactical map display. Overlay types include Operations, Fire Support, Modified Combined Obstacles, Intelligence, Reconnaissance/Surveillance, Obstacle, Air Defense, Army Airspace Command and Control (A2C2), and User-Defined.
- *Tactical Graphics*: Define control measures (by referencing particular Overlay entries).
- *Military Operations Other Than War (MOOTW) Graphics*: MOOTW symbol modifiers as defined in MIL-STD-2525B.
- *Threats*: Specify non-military (threat) organizations, including characterizing the effects of threat-based actions and activities.
- *Plan*: Provide descriptive information on the scenario as well as executable courses of action. Information includes an executive summary of the Operations Order (OPORD), scenario objectives, references to doctrine, and planning documents.*

While the MSDL Environment component provides information that is relevant to several M-COP data categories, we are interested here in the components that carry information relevant to the Forces category of the M-COP. The MSDL components relevant to the Forces category are Plan, ForceStructure, TaskOrganizations, Installations, Overlays,

* Expression of orders will use the companion specification, C-BML, also undergoing standardization through the SISO at the time of this writing.

TacticalGraphics, MOOTWGraphics and Threats. Table 9 associates the M-COP Forces category data requirements for the class FORCE_DISPOSITION from the above synthesis with XML elements and attributes from the MSDL structure to show what parts of the M-COP Forces model are covered in M-COP and what parts are not. In Table 9, the location of the information in the MSDL structure is provided in XPath notation (W3C 1999) where feasible. Refer to the MSDL XML Schema files* for more detail.

Table 9. Association of the M-COP Forces category with MSDL data structures.

M-COP Forces Classes and Attributes	MSDL Data Structure
Force_Disposition†	Primarily found in /MilitaryScenario/TaskOrganizations but also in other parts of the MSDL data structure as will be seen below.
-Identity	/MilitaryScenario/TaskOrganizations/Units/Unit/Name (and/or …/Unit/ObjectHandle providing the Universal Unique Identifier [UUID] of the unit).
-Location	/MilitaryScenario/TaskOrganizations/Units/Unit/Location (in MGRS, UTM, GDC, or GCC).
-Formation	/MilitaryScenario/TaskOrganizations/Units/Unit/Position/Formation (indicating how subordinate units an echelon below will be positioned; this information is provided at the EquipmentItem level as well).
-Formation spacing	/MilitaryScenario/TaskOrganizations/Units/Unit/Position/Spacing.
-Orientation	/MilitaryScenario/TaskOrganizations/Units/Unit/Position/Orientation.
-Center of gravity	NOT PROVIDED—can be proposed as an extension to the MSDL specification of Unit, UnitLocation, or UnitPosition.
-Fields of fire	NOT PROVIDED—can be proposed as an extension to the MSDL /MilitaryScenario/TacticalGraphics constructs.
-Plan	/MilitaryScenario/Plan consists of Objectives and Courses of Action.
--Purpose	/MilitaryScenario/Plan/Course of Action (COA)/COA Purpose.
--Activity	/MilitaryScenario/Plan/COA/ActivityType (note: C2IEDM Action type).
--Task	/MilitaryScenario/Plan/COA/COAPhases/COAPhase/PhaseEvents/Event/ UnitActivities/Activity/ActivityData/Task/Enumeration, where the enumeration is taken from the Army Universal Task List.
-Movement	A Movement operation is one of the values of …/COA/COAPurpose. Therefore, a movement task is identified in the Plan structure described above.
--Direction	/MilitaryScenario/TaskOrganizations/Units/Unit/DirectionOfMovement
--Speed	NOT PROVIDED—as an initialization tool, MSDL considers all forces to be stationary; movement order processing is performed by the using simulation or BC application).

* Currently available through the SISO MSDL Product Development Group. See http://www.sisostds.org.

† Dashes and indentation indicate the hierarchical structure of the data.

Table 9 (cont.). Association of the M-COP Forces category with MSDL data structures.

M-COP Forces Classes and Attributes	MSDL Data Structure
--Movement Plans	See above, described as one of the types of activity that can be specified in a Plan.
-Affiliation	/MilitaryScenario/TaskOrganizations/Units/Unit/ForceRelation/ ForceSideHandle
-Communications footprint	MSDL provides the capability to describe communications connectivity (refer to /MilitaryScenario/TaskOrganizations/Units/Unit/ CommunicationNetInstances and /MilitaryScenario/TaskOrganizations/Equipment/EquipmentItem/ CommunicationNetReferences). The Communications Footprint will need to be computed by a tool/service accepting the communications equipment, locations, terrain, and environment data, at a desired level of resolution.
-Equipment	/MilitaryScenario/TaskOrganizations/Equipment/EquipmentItem.
--Nomenclature	/MilitaryScenario/TaskOrganizations/Equipment/EquipmentItem/Name (and/or .../EquipmentItem/ObjectHandle providing the UUID of the item of equipment).
--Type of equipment	/MilitaryScenario/TaskOrganizations/Equipment/EquipmentItem/ Enumeration.
--Quantity	/MilitaryScenario/Plan/TaskOrganizations/Equipment/EquipmentItem/ EquipmentSymbolModifiers/Quantity.
--Maintenance readiness level	NOT PROVIDED—can be proposed as an extension to the MSDL specification, possibly for the .../EquipmentItem/EquipmentSymbolModifiers/CombatEffective-ness entry.
--Weapons	Classification of an item of equipment as a weapon or vehicle needs to be determined from the Enumeration value and its mobility characteristics.
---Fire Support Assets	(as above).
--Vehicles	(as above).
---Mobility characteristics	(Refer to the NRMM/STNDMob discussion in the text).
-Personnel	NOT PROVIDED—should be added as extensions to Equipment Items in the MSDL specification ("Diver" is the only EquipmentEnumeration value of associated with a human!).
--Quantity	/MilitaryScenario/Plan/TaskOrganizations/Equipment/EquipmentItem/ EquipmentSymbolModifiers/Quantity.
--Military Occupation Specialties	NOT PROVIDED—can be proposed as an extension to the MSDL specification of EquipmentItem (consider the EnumerationSubType entry).
--Experience in the area of operations	NOT PROVIDED—can be proposed as an extension to the MSDL specification.
--State of training	NOT PROVIDED—can be proposed as an extension to the MSDL specification.
--Fatigue	NOT PROVIDED—MSDL does not provide an initial condition of the personnel for initialization of simulation or BC systems.
-Supplies	Supplies such as fuel, food, and water (and ammunition/ordnance) are not provided explicitly; i.e., there is no enumerated value for EquipmentEnumeration identifying these types of EquipmentItem.
-Capability (including TTPs and mission packages)	NOT PROVIDED—but one can imagine populating a MilitaryScenario document with identification of forces and courses of action down to individual tasks that could be *interpreted* as identification of tasks suitable to the identified Unit.

Table 9 (cont.). Association of the M-COP Forces category with MSDL data structures.

M-COP Forces Classes and Attributes	MSDL Data Structure
-Support	/MilitaryScenario/TaskOrganizations/Units/Unit/SupportRelations This is identified from the perspective of the unit providing support—see /MilitaryScenario/TaskOrganizations/Units/Unit/SupportRelations. The enumerations for SupportType are currently General Support (GS), Direct Support (DS), Regimental Support (RS), General Support—Reinforcing (GS-R), and NONE. Types of support of interest to M-COP—Engineering, Combat Service Support, Combat Support, Fire, Air, Intel/Recon, and MEDEVAC—an be inferred from the type of unit (from .../Unit/Enumeration).
-Information requirements (observer locations)	Not directly provided, but could possibly be inferred from .../Unit/Position information regarding Formation (especially down to the placement of each individual item of Equipment) or from supporting Intel/Recon forces.
-Force structure	Can be generated from the collection of entries for each unit in /MilitaryScenario/TaskOrganizations/Units/Unit/ForceRelation/ CommandRelation.
-Bases	/MilitaryScenario/Installations.
--Identification	/MilitaryScenario/Installations/Installation/Name (and/or .../Installation/ObjectHandle providing the UUID of the installation).
--Location	/MilitaryScenario/Installations/Installation/Location (also .../Orientation).
--Affiliation	/MilitaryScenario/Installations/Installation/ForceSideHandle.
-Control measures	Described in /MilitaryScenario/TacticalGraphics, referencing specific Overlays defined in /MilitaryScenario/Overlays. Types of Overlays currently identified in MSDL include Operations, Fire Support, Modified Combined Obstacles, Intel, Recon/Surveillance, Obstacle, Air Defense, Logistics, Army Airspace Command and Control (A2C2), and User-Defined. Location of control measures is described by a set of anchor points (.../TacticalGraphics/TacticalGraphic/AnchorPoints).
--Unit boundaries	Each TacticalGraphic may reference a MIL-STD-2525B Symbol Class, one of which is .../TacticalGraphic/MILSTD2525BSymbolClass/BoundarySymbol-Modifiers with indication of Echelon or Hostile aspects of the boundary.
--Adjacent units' dispositions	Once adjacent units are identified, their disposition is provided through the data identified above.

One of the XML Schema files making up MSDL is an enumeration of equipment types for items that can be possessed by units in the ForceStructure component (XML simple type EquipmentEnumeration). The EquipmentEnumeration data type uses a unique code for each item of equipment, with an annotation describing the type of equipment so designated. The annotations identify types, without going down to the level of individual equipment nomenclatures. For example, consider the XML fragment from the enumeration identifying the Tank subclass of equipment ("1.X.3.2.2.1.1" in the MSDL equipment taxonomy) in Figure 5.

An initial reaction is to wonder why the list does not go down to individual nomenclatures, such as the M1A1 Main Battle Tank, but there is an additional EnumerationSubType that may be intended for that purpose. While

```
<xs:enumeration value="1.X.3.2.2.1.1">
        <xs:annotation>
            <xs:documentation>Tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.1">
        <xs:annotation>
            <xs:documentation>Light tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.1.1">
        <xs:annotation>
            <xs:documentation>Recovery light tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.2">
        <xs:annotation>
            <xs:documentation>Medium tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.2.1">
        <xs:annotation>
            <xs:documentation>Recovery medium tank</xs:documentation>
</xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.3">
        <xs:annotation>
            <xs:documentation>Heavy tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
<xs:enumeration value="1.X.3.2.2.1.1.3.1">
        <xs:annotation>
            <xs:documentation>Recovery heavy tank</xs:documentation>
        </xs:annotation>
</xs:enumeration>
```

Figure 5. XML fragment of MSDL equipment taxonomy.

the MSDL representation provides a path for sharing scenario data across various applications, it is different from saying MSDL provides data interchange. Additional logic may be needed on the source or destination side (or both) to translate the MSDL classification of an item of Equipment into the classification needed in a particular application. Dealing with enumeration lists has been a long-standing problem in the BC and M&S domains. One of the most extensive lists for military systems can be found in the Distributed Interactive Simulation (DIS) standard (IEEE 1995).

The Standard Mobility (STNDMob) API is a candidate for implementation as a service on the GIG to provide vehicle speeds to vehicle routing services and planning aids. The NRMM is the Army Modeling and Simulation Office standard for single vehicle ground movement representation (Ahlvin and Haley 1992). A STNDMob API has been developed based on

the NRMM to incorporate terrain-limited vehicle speed determinations into M&S systems (Baylot et al. 2005). While the ultimate goal of the work is to create Aggregate, Tactical/Entity, and Engineering level resolution models, work to date has provided two levels of resolution for Tactical/Entity application: 1) a low resolution model based on preprocessed speed predictions from NRMM and some limited sensitivity to variations in terrain characteristics, and 2) a medium resolution model based on preprocessed tractive force relationships and the forces limiting movement in the environment.

This prior work fully meets the requirements for M-COP data with regard to vehicle mobility characteristics. An extensive XML Schema representation is available for general use, in addition to the STNDMob API software implementation, XML Schema, and XML data files. Version 2.0 of the NRMM Vehicle XML Schema is provided in Appendix F and Appendix G contains an example XML file storing NRMM vehicle data for the M1A1 Abrams tank in accordance with the schema.

Threat Analysis

The Threat Analysis category includes the locations, capabilities, and other information (potential actions) relating to things that can threaten a mission. Note that this can include, in addition to enemy forces, local population and cultural effects as they affect friendly maneuver (Melby and Glenn 2002). As discussed earlier concerning the Maneuver Analysis category, the IPB process offers a rich resource for framing the Threat Analysis category. Steps three and four of the traditional IPB process are evaluate the threat and determine threat courses of action, respectively (FM 34-130, HQDA 1994) and we used this to differentiate among elements included in the Maneuver Analysis category versus the Threat Analysis category. Likewise, there are attributes that were deliberately included in the Forces category that support the Threat Analysis category. For our analysis, we are specifically concerned with aspects of these that pertain to mobility and maneuver.

In considering concepts for the Threat Analysis category related to evaluating the threat and determining possible courses of action they might adopt, our focus was to consider what actions other forces (military or non-military) could take to undermine conditions that must hold for the movement plan to be successful. While an enemy cannot influence the weather to create poor road conditions, he can possibly attack a dam that

would flood an area and have the same effect. Or, if the movement depends highly on fuel reserves, an insurgent IED attack on the fuel transport could create a condition for mission failure. The challenge for the ontology design is to be able to express these often intertwined cause–effect relationships matching enemy capabilities to create certain effects to underlying conditions or assumptions that must hold to achieve mission success. This is an area where the M-COP work can complement BML ontology development work dealing with expression of plans and orders (Galvin et al. 2005).

The stakeholders' analysis categorized a number of effects under the Forces category that reflect threat information that is inferred from Forces data, including Threat Analysis:

- Enemy threat.
- Enemy intent.
- Asymmetric or symmetric threat.
- Pattern analysis of attacks over time.
- Areas to avoid because of history of enemy activities.
- Courses of action.
- Avenues of approach available to enemy forces but not to friendly forces.
- Possible congestion or choke points.

Some of these items are represented in the Maneuver Analysis category as discussed previously (e.g., avenues of approach, choke points). While some of these concepts could have been placed in the Forces category, they were included in Threat Analysis because we chose to have Forces describe the static and dynamic characteristics of forces in the battlespace, while the above set of inferences identify logical consequences of the presence and capabilities of those forces on ground vehicle mobility.

Classes pertaining to threat analysis not already represented in the Maneuver Analysis or Forces categories are given in Table 10. The two classes represent course of action, as denoted by the stakeholder and above, and situation template. Both of these are produced during the analysis. They are composed of several elements and involve the perceived mission and intent of the threat.

Table 10. Association of the M-COP Threat Analysis category with MSDL data structures.

Class	Definition	Appendix H
THREAT_COURSE_OF_ACTION	"A possible plan open to an individual or commander that would accomplish or is related to accomplishment of the mission. A COA is initially stated in broad terms with the details determined during staff wargaming. To develop COAs, the staff must focus on key information and intelligence necessary to make decisions. COAs include five elements: WHAT (the type of operation), WHEN (the time the action will begin), WHERE (boundaries, axis, etc.), HOW (the use of assets), and WHY (the purpose or desired end state)."— FM 34-130	Table H1
SITUATION_TEMPLATE	"(DOD) Depiction of assumed adversary dispositions, based on adversary doctrine and the effects of the battlespace if the adversary should adopt a particular course of action. In effect, the situation templates are the doctrinal templates depicting a particular operation modified to account for the effects of the battlespace environment and the adversary's current situation (training and experience levels, logistic status, losses, dispositions). Normally, the situation template depicts adversary units two levels of command below the friendly force, as well as the expected locations of high-value targets. Situation templates use time-phase lines to indicate movement of forces and the expected flow of the operation. Usually the situation template depicts a critical point in the course of action. Situation templates are one part of an adversary course of action model. Models may contain more than one situation template."— FM 101-5-1	Table H2

Of note, MSDL has an interesting portion of its structure dealing specifically with non-military threat organizations and threats to operations from environmental events. Figure 6 shows the top-level XML Schema structure of this portion of the MSDL data model. The ThreatActivity element provides a characterization of the threat activity or course of action as MOST_DANGEROUS, MOST_LIKELY, or OTHER, and provided information on the intensity (SEVERE, HIGH, MEDIUM, LOW, UNKNOWN), trend of intensity (INCREASING, DECREASING, STEADY, UNKNOWN), effect (e.g., BURN, CAPTURE_KIDNAP, DESTROY, FORCE_TO_WITHDRAW, IDENTIFY, ILLUMINATE, KILL, and others), and timing (DAYTIME, MORNING, EVENING, NIGHTTIME, TWILIGHT, ANYTIME, UNKNOWN) of the event. The data structure also allows identification of subsequent activities that can follow the threat activity.

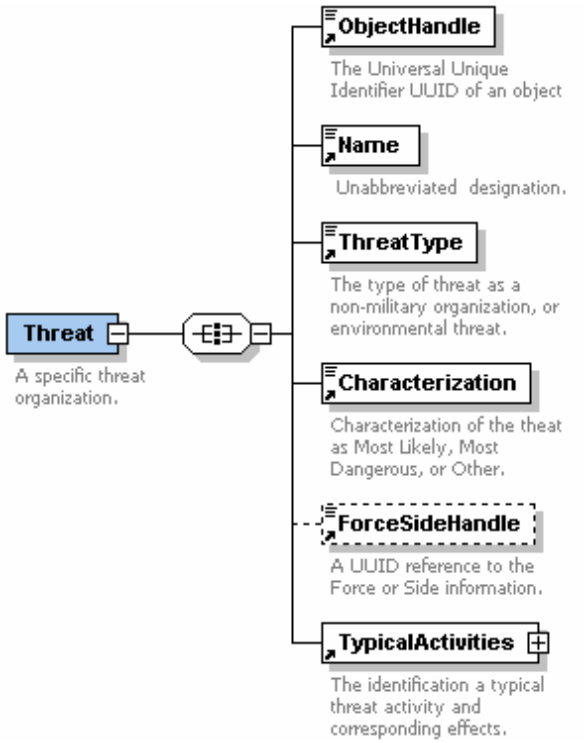

Figure 6. MSDL Threat Data Model (SISO 2005).

Clearly, more information is needed for such data to be useful to the M-COP. For one, the threat activity needs to more clearly specify the targeted object (e.g., a bridge) or capability (e.g., road movement by creating traffic problems) to determine possible effects on ground vehicle mobility. Also, the purpose of this data structure in MSDL appears to be for identifying events that can be injected into a simulation or C4I system (i.e., during a training exercise) by software or by a control team to create situations that will create specific training opportunities. Serving both live BC systems and M&S systems, M-COP requires information of this nature dynamically from events occurring in the battlespace and registered into the information system (e.g., through tactical or intelligence reports) for access and retrieval by M-COP implementations. Such information can include intelligence that indicates such threat activities that *may* occur in the future and need to be taken into account (as appropriate to the quality and reliability of the information) in movement planning.

Utilities

The Utilities category consists of classes and attributes for metadata and data model representations or geometry. The Utility category classes developed for the M-COP are shown in Table 11. Complete descriptions of the attributes of these classes are included in Table 11.

Table 11. Utilities category classes.

Classes	Definition
DATA_QUALITY	Descriptions of the quality of the data.
FEATURE	Representation of real world features.
FEATURE_TOPOLOGY	Information on connectivity and adjacency information in an environment.
FORMAT	Physical attributes of the asset including file size, bit rate, storage media.
GEOMETRY	Spatial representation of an object.
LOCATION	Information about the location of another object relative to this object.
RESOURCE	Maintenance, administration, and pedigree of the data set.
SECURITY_CLASSIFICATION	Security level assigned to national security information.
SOURCE	References to assets or resources from which the tagged data asset is derived.
SUMMARY_CONTENT	Concepts and topics.
TIME	Time/date, time/date formats.
USAGE	Information on the usage of certain objects.

Metadata is defined as data about data. As the M-COP is more of a specialized collection of information and services from the distributed data environment (i.e., it can be thought of as a virtual distributed database on the GIG) rather than a specific physical data structure on the network, the individual components making up the M-COP will be discoverable in their own right through adherence to the DOD Discovery Metadata Specification (DDMS) (DOD 2005). Therefore, the metadata associated with M-COP information components must, at a minimum, adhere to the DDMS. Metadata elements from EDCS and JMCDM are also included in Table 11.

The "obligation" requirement (DOD 2005) of each class is determined by the attributes contained within the class. Several of the metadata elements have a 'Mandatory' obligation, meaning the class or attribute must be supplied. A 'Mandatory Unless Not Applicable' obligation means that the class or attribute must be supplied if there is coverage information related to the data asset. A 'Conditional' obligation means that the usage of an element depends upon a particular condition. An 'Optional' obligation means that an element can be supplied, but is not required.

The M-COP classes FEATURE and FEATURE_TOPOLOGY, and GEOMETRY provide attributes for the M-COP representation in a real-world environment. The class GEOMETRY specifies the data necessary to produce both visual and non-visual representations of environments. The attributes include

Point, Line, and Polygon. The class FEATURE_TOPOLOGY provides connectivity and adjacency information in an environment. To represent a road as a "thing" with associated topological information, a data provider can represent it as a FEATURE, which by definition has associated topological information. A data provider might choose to represent the road in this example as a Linear_Feature, where each segment of the road is a separate FEATURE_TOPOLOGY instance, in this case a Feature_Edge. The topology relationships assist by providing explicit information, instead of performing calculations to derive the information.

Figure 7 shows a partial sample XML representation of the geospatial coverage and bounding geometry obtained from the DOD XML repository; note the reference to GML.*

```
< - <ddms:geospatialCoverage>
 ddms:GeospatialExtent>
 ddms:geographicIdentifier>
 ddms:name>Iraq</ddms:name>
 ddms:countryCode ddms:qualifier="http://metadata.dod.mil/mdr/ns/ExtStd/1.0/FIPS10-4-2.owl#IZ"
 />
</ddms:geographicIdentifier>
 <!--
 This boundingGeometry creates a box around Baghdad using the WGS-84 Coordinate Reference
 System. The "srsDimension" attribute indicates the length of coordinate sequence (the number
 of entries in the list), i.e. the number of components in the tuple, here 2. The "count"
 attribute specifies the number of direct positions in the list, here 5.
 -->
 ddms:boundingGeometry>
 gml:Polygon>
 gml:exterior>
 gml:LinearRing>
 gml:posList gml:srsName="WGS84" gml:srsDimension="2" gml:count="5">34.0 44.0 33.0 44.0 33.0 45.0
 34.0 45.0 34.0 44.0</gml:posList>
</gml:LinearRing>
</gml:exterior>
</gml:Polygon>
</ddms:boundingGeometry>
</ddms:GeospatialExtent>
</ddms:geospatialCoverage>
```

Figure 7. Representation of geospatial coverage and bounding geometry in XML.

* GML—OpenGIS Geography Markup Language—this specification provides objects for describing geography, including features, coordinate reference systems, geometry, topology, time, unit of measure, and generalized values. The Open Geospatial Consortium, Inc (OGC) (http://www.opengeospatial.org/) is an international, non-profit, voluntary organization that works to create open and Extensible software interfaces based on current technologies and standards. This organization is responsible for the GML Implementation Specification.

Mapping M-COP Categories to JC3IEDM (C2IEDM)

The C2IEDM is a common data model established by the Multilateral Interoperability Programme (MIP) for interchange of operations data across multinational command and control systems (MIP 2005b). The DOD has a number of initiatives underway to employ C2IEDM for data exchange with Coalition forces (DUSD 2004) and as a basis for data interchange (Koontz 2005). Additionally, the U.S. Army is standardizing on C2IEDM for data exchange, not just between command and control systems, but also between M&S systems and command and control systems. The C21EDM has been endorsed by the Army DCS, G-3/5/7, the Army CIO/G-6, and the Commander, Army Combined Arms Center, as the standard for information exchange in Battle Command systems. C2IEDM is a principal representation for the emerging C-BML standard coming out of the SISO (Galvin et al. 2005). XML Schema definitions for both physical and logical views of C2IEDM have been registered in the DOD Metadata Registry and Clearinghouse for broad use across the warfighting community (DOD 2005). As a common interchange format that will play an important role in the future GIG, it is important to consider the ability to express required M-COP information in C2IEDM. If gaps exist, in terms of M-COP data requirements that cannot be represented in C2IEDM, then extensions to the C2IEDM can be recommended for possible inclusion in future versions of the model. Short of international acceptance of the extensions, community acceptance and employment of specific extensions can still become standard practice in U.S. command and control and M&S communities to achieve M-COP objectives in ground movement planning.

At the time of the writing of this report, the MIP has specified a follow-on model to C2IEDM called the Joint C3 Information Exchange Data Model (JC3IEDM) (MIP 2005b). As this appears to be the next evolution of the data model, our mapping was done against the JC3IEDM specification. Information needed for the M-COP determined to be missing from the JC3IEDM can be recommended to the community as extensions. Simple extensions are considered to be additional values to existing enumerations. Straightforward extensions are identification of additional attributes to an existing entity. Structural extensions are identification of additional entities and their attributes to the model, likely to include addition of cross-reference tables relating the new entities to others. The level of complexity of the proposed extensions may affect acceptance and adoption, but should be proffered nonetheless to create community awareness of M-

COP requirements and cause appropriate consideration of the recommended extensions.

Relevant JC3IEDM Structure

JC3IEDM uses the name OBJECT-TYPE to refer to class objects and OBJECT-ITEM for individually identified instances. Implicit in the distinction between type and item is the assumption that data relating to OBJECT-TYPEs will tend to be relatively *static* or *persistent* (i.e., the values of the attributes are not likely to change very often over time), whereas the data characteristics related to OBJECT-ITEMs are likely to be more *dynamic*.

Item and type objects are subdivided into extensive hierarchies. There are five categories or *subtypes* to encompass any object within the scope of the model: facility, feature, materiel, organization, and person (Table 12). As may be expected, the two sets osf definitions are similar. The item and type objects have attributes and specific instances or enumerations.

Table 12. Definition of first-level JC3IEDM subtypings.

Entity	Entity Definition
FACILITY	An OBJECT-ITEM that is built, installed, or established to serve some particular purpose and is identified by the service it provides rather than by its content.
FACILITY-TYPE	An OBJECT-TYPE that is intended to be built, installed, or established to serve some particular purpose and is identified by the service it is intended to provide rather than by its content. Examples include a refueling port, a field hospital, and a command post.
FEATURE	An OBJECT-ITEM that encompasses meteorological, geographic, and control features of military significance.
FEATURE-TYPE	An OBJECT-TYPE that encompasses meteorological, geographic, and control features of military significance. Examples include a forest, an area of rain, a river, an area of responsibility.
MATERIEL	An OBJECT-ITEM that is equipment, apparatus, or supplies without distinction as to its application for administrative of combat purposes.
MATERIEL-TYPE	An OBJECT-TYPE that represents equipment, apparatus or supplies of military interest without distinction to its application for administrative or combat purposes. Examples include ships, tanks, self-propelled weapons, aircraft, etc., and related spares, repair parts, and support equipment, but excluding real property, installations, and utilities.
ORGANIZATION	An OBJECT-ITEM that is an administrative or functional structure.
ORGANIZATION-TYPE	An OBJECT-TYPE that represents administrative or functional structures.
PERSON	An OBJECT-ITEM that is a human being to whom military or civilian significance is attached.
PERSON-TYPE	An OBJECT-TYPE that represents human beings about whom information is to be held.

M-COP Terrain Category Relationships to the JC3IEDM

Table 13 shows a comparison between the M-COP Terrain category classes and subclasses, and the JC3IEDM representations. There is some alignment in regards to the J3CIEDM category codes for FEATURE and FACILITY, and their attributes provide additional information, much like other data models; however, there are only a few JC3IEDM entities that have more than basic attribute information, and they do not contain the information required for the M-COP.

Table 13. Association of M-COP Terrain category with JC3IEDM entities and attributes.

M-COP Terrain Class or Subclass	Corresponding JC3IEDM Entity or Attribute
NATURAL_REGION OPEN_TRACT FACILITY SITE WATERBODY ROAD	Terrain can be represented as an OBJECT-TYPE, FEATURE-TYPE, GEOGRAPHIC-FEATURE-TYPE with an attribute of geographic-feature-type-category-code As an OBJECT-ITEM, FEATURE, GEOGRAPHIC-FEATURE with attributes of geographic-feature-solid-surface-composition-code geographic-feature-surface-category-code geographic-feature-terrain-code geographic-feature-vegetation-code Facilities can be represented as an OBJECT-TYPE, FACILITY-TYPE which has an attribute of facility-type-category-code and as an OBJECT-ITEM, FACILITY with attributes of facility-category-code The J3CIEDM codes align with some of the M-COP FEATURE-TYPE are indicated in the first column of Tables A1–A6.
TRAFFICABILITY_SURFACE TRAFFICABILITY_VEGETATION TRAFFICABILITY_WETGAPS TRAFFICABILITY_DRYGAPS MANEUVER_URBAN	The object-item-status-category-code, GEOGRAPHIC-FEATURE-STATUS is a record of condition of a specific geographic feature. The geographic-feature-surface-category-code has sub-attributes related to liquid, and solid surfaces, including firmness code related to trafficability, but it is not sufficient for the M-COP. Additional surface status information relates to: solid-surface-status-code Cleared Contaminated Destroyed Heavily damaged Lightly damaged Moderately damaged Obstructed Not known solid-surface-status-surface-condition-code Dust Earth Flood Ice Sand Snow Not known Not otherwise specified Additionally, facilities also have a FACILITY-STATUS, which adds a little more of the required attribution, it is not sufficient for the M-COP.

Table 13 (cont.). Association of M-COP Terrain category with JC3IEDM entities and attributes.

M-COP Terrain Class or Subclass	Corresponding JC3IEDM Entity or Attribute
TRAFFICABILITY_ROADS	The FACILITY entity ROAD has the following attributes: road-id road-category-code road-shoulder-width-code road-traffic-density-count road-weather-condition-category-code road-quality-code These attributes only partially meet the needs of the M-COP.
TRAFFICABILITY_BRIDGES_TUNNEL	The FACILITY entity BRIDGE has the following attributes: bridge-id bridge-longest-span-length-dimension bridge-span-count bridge-usage-code bridge-type-id bridge-type-design-type-code These attributes only partially meet the needs of the M-COP, and there are no attributes for tunnels.
TRAFFICABILITY_RAILROAD	The FACILITY entity RAILWAY has the following attributes: railway-id railway-track-gauge-code railway-track-count railway-train-density-count railway-block-distance-dimension railway-sleeper-density-dimension railway-gross-trailing-load-quantity railway-maximum-speed-rate railway-traction-system-code railway-signal-system-code railway-signal-system-efficiency-code These attributes only partially meet the needs of the M-COP.

Comparing the GEOGRAPHIC-FEATURE-STATUS to the M-COP subclasses, we see that the M-COP subclasses can be represented in the JC3IEDM respectively:

- GEOGRAPHIC-FEATURE-TRAFFICABLITIY-SURFACE-STATUS
- GEOGRAPHIC-FEATURE-TRAFFICABLITIY-VEGETATION-STATUS
- GEOGRAPHIC-FEATURE-TRAFFICABLITIY-GAP-STATUS

with the corresponding attributes as specified in Tables A7–A10. The trafficability attributes associated with roads, railroads, bridges, and tunnels will need to be split up among the JC3IEDM FACILITY-TYPE, FACILITY, and FACILITY-STATUS. With these extensions, the M-COP Terrain cate-

gory can be represented within the JC3IEDM, although some further formalization and analysis remains to be done.

M-COP Obstacle Category Relationships to the JC3IEDM

Several classes (entities) of obstacles are identified in JC3IEDM; trenches, wire, and berms are described through use of the military-obstacle-type-category-code, but provide only the type, with no additional attributes (such as depth or height) required for the M-COP. The JC3IEDM entity/attributes that seem to align with the M-COP obstacles are indicated in Table B1. Minefields are very well described, but they lack information on trafficability over the terrain and complete alignment with allowable attribute values, as shown in Table 14. The JC3IEDM allows instances of OBJECT-ITEMs to have a relationship or association to other instances of an OBJECT-ITEM. This association allows a FACILITY, such as a Military-Obstacle, to be associated to Feature as in, for example, "Is situated in." Thus, the underlying terrain attributes required for trafficability can be "connected" with the JC3IEDM obstacles. However, further attribution is still needed for the non-minefield type obstacles, and these specific attributions will need to be individually formalized, based on the type of obstacle.

Table 14. Association of M-COP MINEFIELD class and the JC3IEDM.

M-COP MINEFIELD Class Attributes	Corresponding J3CIEDM Entity and Attribute Names
TRAFFICABILITY_SURFACE	See Terrain discussion above and Table 15.
Case_Burial_Fraction	MINEFIELD-LAND minefield-land-depth-placement-code Comment: there is not a direct and complete mapping between the allowable values.
Completion_Precentage	OBJECT-ITEM, FACILITY-STATUS operational-status-qualifier-code Comment: there is not a direct and complete mapping between the allowable values.
Prepared_Explosive_ Destruction_Completion_Fraction General_Damage_Fraction	OBJECT-ITEM, FACILITY-STATUS facility-status-demolition-status-code Comment: there is not a direct and complete mapping between the allowable values.

Table 14 (cont.). Association of M-COP MINEFIELD class and the JC3IEDM.

M-COP MINEFIELD Class Attributes	Corresponding J3CIEDM Entity and Attribute Names
Explosive_Mine_Type	OBJECT-TYPE, MILITARY-OBSTACLE-TYPE military-obstacle-type-category-code OBJECT-ITEM, MINEFIELD minefield-category-code OBJECT-ITEM, MINEFIELD-LAND minefield-land-function-code OBJECT-ITEM, MINEFIELD-MARITIME minefield-maritime-depth-placement-code Comment: Requires several different J3IEDM attributes to map to the M-COP attribute values
Duration_Overview	OBJECT-ITEM, MINEFIELD-LAND Minefield-land-persistence-code
Minefield_Marking_Type	Not found
Numeric_Object_Identifier	OBJECT-ITEM, MILITARY-OBSTACLE-TYPE military-obstacle-type-id
Force_Identifier Mine_Allegiance	An OBJECT-ITEM, ORGANISATION can be associated with the FACILITY-MINEFIELD, and the object-item-status-hostility-code contains the Mine_Allegiance information.

M-COP Weather Category Relationships to the JC3IEDM

Table 15 shows a comparison between the M-COP Weather category classes and the JC3IEDM representations. The JC3IEDM entity METEOROLOGIC-FEATURE has seven classes: ATMOSPHERE, CLOUD-COVER, ICING, LIGHT, PRECIPITATION, VISIBILITY, and WIND. Each instance of METEOROLOGIC-FEATURE describes a single meteorological condition at a specific location and time, and each condition is either observed or forecasted.

There is good alignment between the M-COP classes and the JC3IEDM entity METEOROLOGIC-FEATURE. In the case of the M-COP Weather classes ATMOSPHERE, PRECIPITATION, CLOUD_COVER, ICING, LIGHTING_AND_VISIBILITY, and WIND, not all of the M-COP attributes map to JC3IEDM.

Table 15. Association of M-COP Weather category with JC3IEDM entities and attributes.

M-COP Weather Class	Corresponding JC3IEDM Entity or Attribute
PRECIPITATION	An entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for PRECIPITATION are: precipitation-category-code precipitation-rate These attributes only partially meet the needs of the M-COP. There are no attributes for precipitation accumulation, precipitation intensity, snow depth, precipitation or thunderstorm probability.
ATMOSPHERE	ATMOSPHERE is an entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for ATMOSPHERE are: atmosphere-humidity-ratio atmosphere-inversion-layer-code atmosphere-pressure-rate atmosphere-pressure-system-category-code atmosphere-temperature atmosphere-temperature-gradient-code These attributes only partially meet the needs of the M-COP. There are no attributes for dew point, lightning, or climatology.
WIND	An entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for WIND are: wind-category-code wind-air-stability-category-code wind-altitude-layer-code wind-direction-angle wind-effective-downwind-direction-angle wind-speed-rate wind-nuclear-yield-qualifier-code These attributes only partially meet the needs of the M-COP. There are no attributes for wind speed *u*, *v* components or climatology.
CLOUD_COVER	CLOUD-COVER is an entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for CLOUD-COVER are: cloud-cover-category-code cloud-cover-base-dimension cloud-cover-top-dimension cloud-cover-average-coverage-code cloud-cover-light-refraction-ratio These attributes only partially meet the needs of the M-COP. There are no attributes for cloud type, high, medium, or low clouds.

Table 15 (cont.). Association of M-COP Weather category with JC3IEDM entities and attributes.

M-COP Weather Class	Corresponding JC3IEDM Entity or Attribute
LIGHTING_AND_VISIBILITY	VISIBILITY is an entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for VISIBILITY are: visibility-category-code visibility-direction-code visibility-range-dimension LIGHT is an entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for LIGHT are: light-category-code light-up-datetime light-down-datetime light-moon-phase-code
ICING	An entity of METEOROLOGIC-FEATURE meteorologic-feature-category-code. The attributes for ICING are: icing-category-code icing-severity-qualifier-code These attributes only partially meet the needs of the M-COP. There are no attributes for probability of icing.

M-COP Maneuver Analysis Category Relationships to the JC3IEDM

Only a few classes (entities) from the Maneuver Analysis category are represented directly in JC3IEDM; additionally, there are other categories that are not found explicitly but can be constructed through relationships and associations. Also, there are a few items that would likely need to be added. Table 16 contains a summary of the M-COP Maneuver Analysis classes and attributes, along with corresponding JC3IEDM representations and notes.

Areas of operations, key terrain, and engagement areas seem to be sufficiently described. On the other hand, trafficability segments, avenue of approach segments, and time phase lines can be derived by relationships and associations. Further attribution is needed in most cases for all classes. Classes for trafficability sector, mobility corridor, and avenue of approach channelizer were not found and would need to be developed, along with their attributes, as extensions to the JC3IEDM.

Table 16. Association of M-COP Maneuver Analysis category with JC3IEDM entities and attributes.

M-COP Maneuver Analysis Classes and Attributes	Corresponding JC3IEDM Entity or Attribute
AREA_OF_OPERATIONS (AO)	Is a control-feature-type-category-code (attribute of an OBJECT-ITEM)
Name	OBJECT-ITEM name
Commander	An ORGANIZATION can have an association (Is under command of) with a PERSON
Unit	OBJECT-ITEMs can have an associated UNIT, alternatively an ORGANIZATION can have an association (Controls, bounded by, etc) with a control measure
GEOMETRY*	OBJECT-ITEMs have a LOCATION which can be a POLYGON AREA
TRAFFICABILITY_SECTOR (TS)	Not found, although control feature category codes: no-go area and slow-go area can be identified, they are not sufficient to meet the needs of this M-COP class
Name	OBJECT-ITEM name
AO_Name	OBJECT-ITEM name
Unit	As above
Trafficability_Estimate	Not found
Speed	Not found
FORCE_DISPOSITION Affliation	An ORGANIZATION can be associated with a CONTROL FEATURE
GROUND_AVENUE_OF_APPROACH (AA)	Is similar to Axis of Advance,† a control-feature-type-category-code (which is an OBJECT-ITEM)
Name	OBJECT-ITEM name
AO_Name	OBJECT-ITEMs can be related to each other using the JC3IEDM business rules, in this case the OBJECT-ITEM CONTROL FEATURE Area of Operations “Encloses” the Axis of Advance, where “Encloses” is the object-item association-category-code
Number _Of_AA_Segments	Not found
Number_Of_Mobility_Corridors	Not found

* All of the classes in this table require a geometry, this class is not repeated in this table.

† While the U.S. Army differentiates between an Avenue of Approach and Axis of Advance, the J3CIEDM definition for Axis of Advance “A general route of advance, assigned for control, which extends towards the enemy. An axis of advance symbol graphically portrays a commander's intention, such as avoidance of built-up areas or envelopment of an enemy force. It follows terrain suitable for the size of the force to which the axis was assigned, and is often a road, a group of roads, or a designated series of locations. An axis of advance is not used to direct the control of terrain or the clearance of enemy forces from specific locations. Intermediate objectives are normally assigned for these purposes.” This definition seems to describe the U.S. usage of the term Avenue of Approach.

Table 16 (cont.). Association of M-COP Maneuver Analysis category with JC3IEDM entities and attributes.

M-COP Maneuver Analysis Classes and Attributes	Corresponding JC3IEDM Entity or Attribute
Force_Size	An ORGANIZATION can be associated with a CONTROL FEATURE
FORCE_DISPOSITION Affliation	As above
General_Direction	Not found
MOBILITY_CORRIDOR (MC)	Not found
Name	OBJECT-ITEM name
AA_Name	OBJECT-ITEM name, can be associated
Force_Size	An ORGANIZATION can be associated with a CONTROL FEATURE
Restriction	Not found
Characteristic_Width	Not found
Trafficability_Estimate	Not found
Reason	Not found
AVENUE_OF_APPROACH_CHANNELIZER	Not found
Name	OBJECT-ITEM name
AA_Name	OBJECT-ITEM name, can be associated
AA_Segment_Mobility_Corridor_1	Not found
AA_Segment_Mobility_Corridor_2	Not found
AVENUE_OF_APPROACH_SEGMENT	CONTROL FEATURES can be linked together using the object-item-association-category-code (is part of); alternatively, if the attributes are all the same the POLYGON AREA can represent the segmented of the AA
AA_Name	OBJECT-ITEM name
Segment_Number	Not found
Segment_Width	Not found
Segment_Visual_Obstructions	Not found
Segment_Concealment	Not found
Segment_Cover	Not found
KEY_TERRAIN	Is a control-feature-type-category-code (which is an OBJECT-ITEM)
Name	OBJECT-ITEM name
AO_Name	OBJECT-ITEM name, can be associated
Key_Terrain_Type	This OBJECT-ITEM can be associated with a specific Geographic-Feature Object-item

Table 16 (cont.). Association of M-COP Maneuver Analysis category with JC3IEDM entities and attributes.

M-COP Maneuver Analysis Classes and Attributes	Corresponding JC3IEDM Entity or Attribute
Reason	Not found, however by association with an organization the reason may be apparent
FORCE_DISPOSITION Affliation	As above
ENGAGEMENT_AREA (EA)	Is a control-feature-type-category-code (which is an OBJECT-ITEM)
Name	OBJECT-ITEM name
AO_Name	OBJECT-ITEM name, can be associated
AA_Name	OBJECT-ITEM name, can be associated
Unit	Can be associated (as above in this table)
Fire_Type	Can be associated through use of a JC3IEDM ACTION
Enemy_Unit	Associated as above (in this table) along with specifying the unit is hostile (see Threat Analysis below)
Enemy_Fire_Type	Associated as in THREAT_COURSE_OF_ACTION below
Initiator	Specified by associating an ACTION
TIME_PHASE_LINE_H (TPL)	Phase Line is a control-feature-type-category-code (which is an OBJECT-ITEM) to associate it with a time requires association with an ORGANIZATION with an ACTION
Name	OBJECT-ITEM name
AO_Name	OBJECT-ITEM name, can be associated
Time_Increments	See Phase Line above in this table
TPL_PT_1	See Phase Line above in this table
TPL_PT_2	See Phase Line above in this table
FORCE_DISPOSITION Identity Affliation	Organization can be associated

M-COP Route Finding Category Relationships to the JC3IEDM

Table 17 contains a summary of the M-COP Route Finding classes and attributes, along with corresponding JC3IEDM representations and notes. There are three changes to JC3IEDM that would go far in accommodating information from the Route Finding category. One is the generalization of the JC3IEDM NETWORK entity. As specified, a NETWORK entity represents an electronic communications network FACILITY. If the NETWORK entity were generalized to be a graph construct, a maneuver network graph could be represented as well as other types of graphs—including electron-

ics communication networks. Other potential networks include main supply ROUTEs and alternate supply ROUTEs, AIR-ROUTE-SEGMENT networks, or a network showing intersections between CONTROL-FEATUREs. Additionally, the notion of a "general-vehicle-type," would, like the existing unit-type-general-mobility-code, allow characterization of trafficability without specific vehicle-types. Lastly, addition of a construct to allow the expression of the M-COP class CONSTRAINTs for Route Finding would enhance JC3IEDM as a model for accommodating route requests. Considerations for routing are legion, and the need for routing as a GIG service is obvious. However, the current JC3IEDM is missing this important aspect of joint operations information. Other comparisons to JC3IEDM are made in Table 17.

Table 17. Association of M-COP Route Finding category with JC3IEDM entities and attributes.

M-COP Route Finding Classes and Attributes	Corresponding JC3IEDM Entity or Attribute
ROUTE	ROUTE
Route_Purpose	Not found
Route_Classification	Not found
Start_Point	POINT
Stop_Point	POINT
Edge_List	Not found
ROUTE_REQUEST	REQUEST
Start_Point	POINT
Stop_Point	POINT
Way_Point	POINT
Datetime	Not found
Constraint_List	Not found
Constraint_Weight_List	Not found
CONSTRAINT	Not found
Force	Not found
Constraint_Type	Not found
Control_Measure	CONTROL_FEATURE
Geometry	LOCATION – can be a POLYGON AREA, LINE, or POINT
Feature	FEATURE
Feature_Type	FEATURE_TYPE
Obstacle	OBSTACLE
Obstacle_Type	OBSTACLE_TYPE

Table 17 (cont.). Association of M-COP Route Finding category with JC3IEDM entities and attributes.

M-COP Route Finding Classes and Attributes	Corresponding JC3IEDM Entity or Attribute
MANEUVER_NETWORK_GRAPH	Not found
Edge_List	Not found
Node_List	Not found
Maneuver_Network_Type	Not found
Network_Junction	Not found
EDGE	Not found
NodeA	Not found
NodeB	Not found
Feature	FEATURE
Width	Not found
Off_Road_Shortest	MOBILITY-CAPABILITY
On_Road_Shortest	MOBILITY-CAPABILITY
Military_Load_Classification	MOBILITY-CAPABILITY
General_Vehicle_Speed	MOBILITY-CAPABILITY
General_Vehicle_Type_Time	MOBILITY-CAPABILITY
General_Vehicle_Type_Off_Road_Fastest	MOBILITY-CAPABILITY
General_Vehicle_Type_On_Road_Fastest	MOBILITY-CAPABILITY
Concealment	Not found
Radius_of_Curvature	Not found
NODE	Not found
Geometry	POINT
Edge	Not found
FORCE	MILITARY-ORGANISATION-TYPE
Width	unit-type-size-code
Formation_Type	TASK-FORMATION-TYPE
Vehicle_Type	VEHICLE-TYPE
General_Vehicle_Type	VEHICLE-TYPE

M-COP Threat Analysis Category Relationships to the JC3IEDM

Recall that many of the classes associated with the Threat Analysis category are subsumed in the Maneuver Analysis category. The reader can refer to that section for maneuver analysis classes and concepts associated with analyzing the maneuver potential of the threat. The two classes and associated attributes identified to meet the needs of the M-COP in regards to Threat Analysis are summarized in Table 18. The table also contains the

corresponding JC3IEDM entities or further notes. For this category, there is good correlation between M-COP categories and JC3IEDM representations.

Table 18. Association of M-COP Threat Analysis category with JC3IEDM entities and attributes.

M-COP Threat Analysis Classes and Attributes (indented)	Corresponding JC3IEDM Entities and Attributes
THREAT_COURSE_OF_ACTION	THREAT_COURSE_OF_ACTION can be represented by specifying an ACTION and CONTEXT with a value of "prediction" for a hostile unit
Course_Of_Action_Name	ACTION has a name
Threat_Unit_Name	A unit name with an object-item-status-hostility-code of hostile
Threat_Unit_Objective_Location	OBJECT-ITEM CONTROL-FEATURE type—objective area, associated with the threat unit
Threat_Unit_What	Specified with ACTION-EFFECT
Threat_Unit_When	Specified with ACTION-TEMPORAL-ASSOCIATION
Threat_Unit_Where	Specified with LOCATION
SITUATION_TEMPLATE	A template per se does not appear to exist; however, objects and relationships are available to create one
Unit_Type	See Forces below
Unit_Name	See Forces below
Unit_Locations	See Forces below
Time_Phase_Line_H	Phase lines exist as a control-feature-type-category-code
High_Value_Target_X_Location	Represented within the context of CANDIDATE-TARGET-LIST

Each OBJECT-ITEM within the J3CIEDM can have an object-item-status-hostility-code, which provides a value that specifies its perceived level of threat; the allowable values are:

- Assumed friend — An OBJECT-ITEM that is assumed to be a friend because of its characteristics, behavior or origin.
- Assumed hostile — An indication that the OBJECT-ITEM in question is likely to belong to enemy forces.
- Assumed involved — An indication that the OBJECT-ITEM in question is likely to belong to involved forces different from own, allied and enemy forces.

- Assumed neutral — An indication that the OBJECT-ITEM in question is likely to belong to neither own, allied, enemy, or otherwise involved forces.
- Faker — An OBJECT-ITEM that is a friendly aircraft simulating a hostile aircraft in an air defense exercise.
- Friend — An OBJECT-ITEM that belongs to a declared friendly nation.
- Hostile — An OBJECT-ITEM that is positively identified as enemy.
- Involved — An indication that the OBJECT-ITEM in question belongs to involved forces different from own, allied and enemy forces.
- Joker — An OBJECT-ITEM that is acting as a suspect track for exercise purposes only.
- Neutral — An OBJECT-ITEM whose characteristics, behavior, origin, or nationality indicate that it is neither supporting friendly nor opposing forces.
- Pending — An OBJECT-ITEM for which identification is to be determined.
- Suspect — An OBJECT-ITEM that is potentially hostile because of its characteristics, behavior or origin.
- Unknown — An OBJECT-ITEM for which hostility status information is not available.

M-COP Forces Category Relationships to the JC3IEDM

Earlier in this report (Table 9), the data elements identified for the Forces category of the M-COP data model were mapped to elements of the MSDL. The developers of MSDL have been keenly aware of the history and application of C2IEDM (and the new JC3IEDM) for data interchange across BC and M&S systems, and have incorporated a small set of C2IEDM enumerations into the current MSDL schema (specifically, enumerations for ActivityType). Given the widespread and growing international adoption of C2IEDM and the upcoming JC3IEDM, ongoing standardization work in SISO on MSDL and the related C-BML is certain to create more complete linkages with JC3IEDM data and data structures.

Information identified in Table 9 describing FORCE_DISPOSITION is largely available in JC3IEDM in the OBJECT-ITEM data structure, with related LOCATION information that will describe the physical geometry of the force on the battlespace. Specific classes of vehicles are identified in

the OBJECT-TYPE / MATERIEL-TYPE / EQUIPMENT-TYPE / VEHICLE-TYPE hierarchy (similar hierarchy under OBJECT-ITEM for individual vehicles), but VEHICLE characteristics at the class level only include a type identifier and vehicle type category code, with additional features regarding physical dimensions and logistical information about the vehicle inherited from the higher levels of the data structure. Additional details about vehicle characteristics that are provided in NRMM and the STNDMob API need to be added as an extension to JC3IEDM.

Planned missions of a force are described under the ACTION hierarchy, where an ACTION is defined in the JC3IEDM specification as "an activity, or the occurrence of an activity, that may utilize resources and may be focused against an objective." The data model provides a rich set of temporal descriptors allowing planned actions to be placed in temporal relation to each other, so that actions can be specified to occur some time before or some time after some other action, among other options.

Table 9 provided an association of the data identified for the M-COP Forces category with information in the MSDL. Similarly, Table 19 provides a mapping of the Forces data requirements with JC3IEDM entities and attributes, either existing or as potential extensions to the JC3IEDM. The effort here does not intend to provide precise mapping of JC3IEDM to the Forces concepts, but to provide a summary of the potential for representation of the M-COP Forces category with JC3IEDM data structures.

Table 19. Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
FORCE_DISPOSITION*	Static characteristic data at an organizational level is found in OBJECT-TYPE with object-type-category-code of ORGANISATION-TYPE. This is further partitioned by organization-type-category-code to CIVILIAN-POST-TYPE, GOVERNMENT-ORGANISATION-TYPE, GROUP-ORGANISATION-TYPE, PRIVATE-SECTOR-ORGANISATION-TYPE. GOVERNMENT-ORGANISATION-TYPE is further refined by MILITARY-ORGANISATION-TYPE, with military-organisation-type-category-code of UNIT-TYPE, EXECUTIVE-MILITARY-ORGANISATION-TYPE, MILITARY-POST-TYPE, and TASK-FORMATION-TYPE. Specific organizations (instances) of these OBJECT-TYPEs are described in a parallel structure in OBJECT-ITEM, with the association of OBJECT-ITEM and OBJECT-TYPE provided in the OBJECT-ITEM-TYPE relation.

* As in Table 9, dashes and indentation in Table 19 indicate the hierarchical structure of the data.

Table 19 (cont.). Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
-Identity	OBJECT-ITEM/object-item-id and object-item-name-text. Also, OBJECT-ITEM/object-item-category-code=ORGANISATION/organization-category-code=UNIT/unit-id, unit-formal-abbreviated-name-text, and unit-identification-text. Similarly, for organization-category-code=CONVOY, identity is give by attribute convoy-id. In addition to organizations, OBJECT-ITEMs for individual persons and equipment (vehicles) can be specified in JC3IEDM.
-Location	Provided by LOCATION and associated with an OBJECT-ITEM through the OBJECT-ITEM-LOCATION relation. The location-category-code attribute of LOCATION provides description as GEOMETRIC-VOLUME, POINT, LINE, or SURFACE, allowing extensive variety of descriptions of the geometry of the OBJECT-ITEM in the further subtypes of these selections.
-Formation	Formation is the geometric arrangement of materiel or, in the aggregate, several forces on the battlefield. Common ground combat formations include line, vee, wedge, echelon left and echelon right. JC3IEDM uses the term "formation" differently, where TASK-FORMATION-TYPE is defined as "A MILITARY-ORGANISATION-TYPE that is constituted on a temporary or semi-permanent basis for the purpose of carrying out a specific operation, mission or task." The desired description of "formation" for ground maneuver can be described in JC3IEDM using LOCATION, OBJECT-ITEM-LOCATION, and OBJECT-REFERENCE (special case of RELATIVE-COORDINATE-SYSTEM) to create a relative geometry for the arrangement of OBJECT-ITEMs on the battlefield. Some enumeration of formations (line, wedge, etc.) needs to be added to JC3IEDM.
-Formation spacing	As above, defined by the relative geometry of OBJECT-ITEMs using LOCATION, OBJECT-ITEM-LOCATION, and OBJECT-REFERENCE.
-Orientation	Attribute object-item-location-bearing-angle of an OBJECT-ITEM-LOCATION.
-Size	Attribute unit-type-size-code represents the relative size of the unit (e.g., Battalion; Brigade; Company, Platoon, Squad, Section, Team).
-Center of gravity	Not currently specified as such, but can be expressed through the LOCATION and OBJECT-ITEM-LOCATION structures.
-Fields of fire	In LOCATION/location-category-code=SURFACE-AREA, fields of fire can be represented as one or more FAN-AREAs.
-Plan	Set of ACTION-TASKs.
--Purpose	ACTION/ACTION-EFFECT; also can be recorded in narrative form in attribute action-task-detailed-text of ACTION-TASK.
--Activity	Attribute action-task-activity-code of ACTION/ACTION-TASK (e.g., Block, Breach, Capture, Constitute a flank guard, Cross, Defend, Delay, Evacuate, Guard, Intercept, Interdict, Jam, Move, Occupy, Plan, Reconnaissance, Redeploy, Reinforce, Reorganise, Repair, Resupply, Screen, Secure, Set up, Suppress, Withdraw).
--Task	ACTION-TASK structure.
-Movement	A Movement operation is a specific selection from the action-task-activity-code of ACTION-TASK, as described above. UNIT-TYPE as a subtype of MILITARY-ORGANISATION-TYPE has a unit-type-general-mobility-code that represents the general mobility of a unit, seen as a whole. Example values are Air, fixed wing; Amphibious; Land, tracked.

Table 19 (cont.). Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
--Direction	Attribute object-item-location-bearing-angle of an OBJECT-ITEM-LOCATION
--Speed	Attribute object-item-location-speed-rate of an OBJECT-ITEM-LOCATION
--Movement Plans	See above, described as one of the activity types that can be specified in a Plan. Also, ROUTE and ROUTE-SEGMENT are subtypes of CONTROL-FEATURE and have attributes for route-mobility-code and route-segment-mobility-code, respectively, to indicate the suitability of a particular ROUTE-SEGMENT for movement (Foot, Tracked, Wheeled, all road; Wheeled, general; Wheeled and tracked; Not known).
-Affiliation	AFFILIATION structure, associated with OBJECT-TYPE through the OBJECT-TYPE-AFFILIATION relation or with a specific OBJECT-ITEM through the OBJECT-ITEM-AFFILIATION relation. The affiliation-category-code values permit representation of AFFILIATION-ETHNIC-GROUP, AFFILIATION-FUNCTIONAL-GROUP, AFFILIATION-GEOPOLITICAL, and AFFILIATION-RELIGION. Extensive lists of allowable values exist for ethnicity, geopolitical and religious, function is limited to: Criminal, Exercise, Multinational, Terrorist, Not known, or Not specified. What can't be obtained from these attributes is whether or not the force is hostile. However, each OBJECT-ITEM has an object-item-status-hostility-code attribute (refer to the section on Threat Analysis).
-Communications footprint	NETWORK is a particular facility-category-code attribute value for FACILITY, which is a selection under object-item-category-code for OBJECT-ITEM. A communications network can be described as a NETWORK OBJECT-ITEM and its footprint can be described by geometry structures in LOCATION and associated to the OBJECT-ITEM through the OBJECT-ITEM-LOCATION relation.
-Equipment	Described by type in OBJECT-TYPE/MATERIEL-TYPE/EQUIPMENT-TYPE or individually as OBJECT-ITEM/MATERIEL. The HOLDING relation provides the association of a specific object (OBJECT-ITEM) with a class of objects (OBJECT-TYPEs).
--Nomenclature	Attribute equipment-type-id for EQUIPMENT-TYPE in OBJECT-TYPE (object-type-category-code=MATERIEL-TYPE; materiel-type-category-code=EQUIPMENT-TYPE). By individual item, OBJECT-ITEM attributes object-item-name-text, object-item-id, materiel-id, materiel-serial-number-identification-text, materiel-lot-identification-text, and materiel-hull-number-text provide detailed identification of an item of equipment.
--Type of equipment	OBJECT-TYPE/EQUIPMENT-TYPE, with attributes equipment-type-id and equipment-type-category-code, which includes ENGINEERING-EQUIPMENT-TYPE, VEHICLE-TYPE and WEAPON-TYPE. The next level of the type structure provides additional detailed specification of type through attributes engineering-equipment-type-id and engineering-equipment-type-category-code for ENGINEERING-EQUIPMENT-TYPE, vehicle-type-id and vehicle-type-category-code for VEHICLE-TYPE, and weapon-type-id, weapon-type-category-code, and weapon-type-subcategory-code for WEAPON-TYPE.
--Quantity	HOLDING associates OBJECT-TYPEs (EQUIPMENT-TYPE) with an OBJECT-ITEM (e.g., a unit), providing quantities in holding-operational-count and holding-total-count attributes.

Table 19 (cont.). Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
--Maintenance readiness level	Attribute materiel-status-category-code of OBJECT-ITEM/OBJECT-ITEM-STATUS/MATERIEL-STATUS. Materiel can suffer mobility damage (materiel-status-operational-status-mode-code).
--Weapons	Type described in OBJECT-TYPE/MATERIEL/EQUIPMENT/WEAPON-TYPE structure; individual item in OBJECT-ITEM/MATERIEL.
---Fire Support Assets	Attribute capability-subcategory-code of CAPABILITY provides information such as maximum range, sustained fire rate, etc. Additional capability information described in CAPABILITY/FIRE-CAPABILITY.
--Vehicles	Type described in OBJECT-TYPE/MATERIEL/EQUIPMENT/VEHICLE-TYPE structure; individual item in OBJECT-ITEM/MATERIEL.
---Mobility characteristics	Attribute capability-subcategory-code of CAPABILITY provides information such as maximum speed or planning speed (with designation of day or night, or both, capability). Also CAPABILITY/MOBILITY-CAPABILITY specifies the kind of mobility (e.g., Air, fixed wing; Air, rotary wing; Amphibious; Dismounted; Land, tracked; Land, wheeled; etc.) and, in certain cases, the conditions for which the maneuver capability is defined (e.g., the type of terrain that is being traversed, such as Cross-country; Road; Snow; Terrain independent; etc.). JC3IEDM needs to be extended to include the detailed data identified in the NRMM/STNDMob discussion in the text.
--Engineering Equipment	Type described in OBJECT-TYPE/MATERIEL/EQUIPMENT/ENGINEERING-EQUIPMENT-TYPE structure (with attribute engineering-equipment-type-category-code with values including, for example, Bridge vehicle; Earthmover; Mine clearer; Minefield marking; Tactical floating bridge); individual item in OBJECT-ITEM/MATERIEL. Attribute capability-subcategory-code of CAPABILITY provides information such as breaching time, demolition time, etc. Also, additional capabilities are described in CAPABILITY/ENGINEERING-CAPABILITY.
-Personnel	PERSON-TYPE in OBJECT-TYPE; individuals are identified by PERSON in OBJECT-ITEM.
--Quantity	HOLDING associates OBJECT-TYPEs (PERSON-TYPE) with an OBJECT-ITEM (e.g., a unit), providing quantities in holding-operational-count and holding-total-count attributes.
--Military Occupation Specialties	NOT PROVIDED – can be proposed as an extension to the JC3IEDM attributes to PERSON-TYPE under OBJECT-TYPE. An alternative may be to use the CAPABILITY structure, where CAPABILITY is defined as “The potential ability to do work, perform a function or mission, achieve an objective, or provide a service.”
--Experience in the area of operations	NOT PROVIDED—can be proposed as an extension to the JC3IEDM specification, possibly associated with particular TASKs associated with an individual PERSON (OBJECT-ITEM) or through the CAPABILITY structure.
--State of training	Attribute organization-status-training-code of ORGANISATION-STATUS under OBJECT-ITEM-STATUS. Can also relate to MISSION-CAPABILITY (e.g., mission-capability-category-code attribute has values Air assault; Airborne; Civilian law enforcement; Engineer, combat; Joint intelligence; medical evacuation; etc.).

Table 19 (cont.). Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
--Fatigue	NOT SPECIFICALLY PROVIDED—person-status-physical-status-code has values for Fit; Incapacitated, not walking; Incapacitated, walking; Slightly incapacitated; Not known. Also the person-status-physical-status-qualifier-code with values for Injured; Ill, Contagious; Pregnant; Wounded. Can be proposed as an extension to JC3IEDM values.
-Supplies	MATERIEL-TYPE/materiel-type-category-code=CONSUMABLE-MATERIEL-TYPE. Subtypes of CONSUMABLE-MATERIEL-TYPE distinguish food, fuel, water, etc. The quantity of the supply type in a unit is provided in the HOLDING relation.
-Capability (including TTPs and mission packages)	Represented using the CAPABILITY structure.
-Support	The support role for a particular operation is indicated by the ACTION-OBJECTIVE-ITEM, "a battlespace object (FACILITY, FEATURE, MATERIEL, ORGANISATION, or PERSON) which is the focus of a specific ACTION." The desired ACTION is defined in an ACTION-TASK to be performed. The unit providing the support is identified in the ACTION/ACTION-RESOURCE/ACTION-RESOURCE-ITEM structure.
-Information requirements (observer locations)	Not directly provided, but described in the JC3IEDM specification (Edition 3.00) under the section titled Intelligence extension. A request for intelligence information is modeled as a subtype of ACTION-TASK. A response to a request for intelligence information is modeled as a REQUEST-ANSWER.
-Force structure	Force structures are described by OBJECT-ITEM-ASSOCIATIONs: "Every instance of OBJECT-ITEM can have some type of relationship to another instance of OBJECT-ITEM in the sense of belonging, using, controlling, being constrained by, occupying and so on."
-Bases	OBJECT-ITEM/object-item-category-code=FACILITY.
--Identification	Provided by OBJECT-ITEM object-item-id attribute or the FACILITY facility-id or facility-base-identification-code-text attributes.
--Location	Refer to earlier description of Location above (in this table).
--Affiliation	Refer to earlier description of Affiliation above (in this table).
-Control measures	As a type, represented in OBJECT-TYPE/FEATURE-TYPE/CONTROL-FEATURE-TYPE (includes ROUTE-TYPE for specifying movement routes). Examples of CONTROL-FEATURE-TYPE include Airspace coordination area; Area of interest; Area of responsibility; Artillery area; Crossing site; Decision point; Drop zone; Fire support coordination line; Forward line of troops; Landing zone; ROUTE-TYPE; Strong point; Supply area; etc. Specific measures are described by OBJECT-ITEM/FEATURE/CONTROL-FEATURE, with subtypes for APPROACH-DIRECTION, ROUTE-SEGMENT, AIRSPACE-CONTROL-MEANS, and ROUTE. As with force structures described above, control measures are related to specific forces using OBJECT-ITEM-ASSOCIATION. The full set of Tactical Graphics (partitioned into Tasks, Command and Control and General Maneuver, Mobility/Survivability, Fire Support, Combat Service Support, and Other) is defined in MIL-STD-2525B.

Table 19 (cont.). Association of M-COP Forces category with JC3IEDM entities and attributes.

M-COP Forces Classes and Attributes	Corresponding JC3IEDM Entities and Attributes
--Unit boundaries	Not specifically addressed, but readily constructed from the LOCATION geometry and FEATURE/CONTROL-FEATURE. Can be added to the selections for CONTROL-FEATURE-TYPE, together with any other control measures that are deemed necessary for explicit representation in JC3IEDM.
--Adjacent units' dispositions	Adjacent units can be identified through the OBJECT-ITEM-ASSOCIATION relation. Their disposition is provided through the data identified above for forces in general.

M-COP Utilities Category Relationships to the JC3IEDM

Table 20 shows a comparison between the M-COP Utilities category classes and the JC3IEDM representations.

The JC3IEDM data structure LOCATION is the overall structure for specifying location and geometry. The basic element is a point. It plays a role in generating every other geometric construct in JC3IEDM. All geometric constructs are defined either totally or partially in terms of the POINT structure. Lines are generated from a series of points that are connected in a specified order. Surfaces are built either directly from lines or the points provide part of the specification. For example, a polygon area is defined by a closed boundary line. There is some alignment between JC3IEDM and FEATURE and FEATURE_TOPOLOGY is included under JC3IEDM entity LOCATION.

The JC3IEDM does not contain adequate information for metadata entities for the M-COP. There is some alignment with the RESOURCE, SECURITY_CLASSIFICATION, and SOURCE classes.

The M-COP TIME class is not aligned with the JC3IEDM, which does not include information about time format.

Table 20. Association of M-COP Utilities category with JC3IEDM entities and attributes.

M-COP Utility Class	Corresponding JC3IEDM Entity or Attribute
DATA_QUALITY	REPORTING-DATA is the specification of source, quality and timing that applies to reported data. reporting-data-accuracy-code reporting-data-credibility-code reporting-data-reliability-code OBJECT-ITEM-LOCATION is an association of an OBJECT-ITEM with a LOCATION that enables the geographic position of the OBJECT-ITEM to be specified. The operational meaning of geometry may also be specified. object-item-location-horizontal-accuracy-dimension object-item-location-vertical-accuracy-dimension
FEATURE	Included under JC3IEDM entity LOCATION.
FEATURE_TOPOLOGY	LINE-POINT is a specification of one of an ordered sequence of POINTs used to define the specific LINE. line-id line-point-index line-point-sequence-ordinal line-point-point-id
FORMAT	ACTION-OBJECTIVE-TYPE-IMAGERY-PRODUCT is the intended characteristics of a specific ACTION-OBJECTIVE-TYPE-IMAGERY-PRODUCT that is an instance of MATERIEL-TYPE. action-objective-type-imagery-product-image-type-code
GEOMETRY	In JC3IEDM the entity LOCATION defines all locations and geometry. The LOCATION attribute location-category-code (point, line, surface, or volume) corresponds to M-COP's FEATURE class. The entity POINT is a zero dimensional LOCATION. point-category-code (declares either absolute of relative reference system) The entity LINE is defined by two or more POINTs connected by 1D line segments used to define specific LINE. line-point-sequence-ordinal (order of line segments) The entity SURFACE is a two-dimensional LOCATION; surface-category-code (ellipse, polygon-area, fan-area, corridor-area, etc.) The LOCATION entity defines all of M-COP's GEOMETRY class attributes and names the attributes in the FEATURE class.

Table 20 (cont.). Association of M-COP Utilities category with JC3IEDM entities and attributes.

M-COP Utility Class	Corresponding JC3IEDM Entity or Attribute
LOCATION	The entity LOCATION is a specification of position and geometry with respect to a specified horizontal frame of reference and a vertical distance measured from a specified datum. location-id is an attribute of both LOCATION and OBJECT-ITEM-LOCATION location-category-code (point, line, surface, or volume) corresponds to M-COP FEATURE and GEOMETRY classes OBJECT-REFERENCE is a RELATIVE-COORDINATE-SYSTEM that has its frame of reference defined by using the position and orientation of a specific OBJECT-ITEM at a given point in time. POINT-REFERENCE is a RELATIVE-COORDINATE-SYSTEM that uses three specific POINTs to establish its frame of reference. RELATIVE-COORDINATE-SYSTEM is a rectangular frame of reference defined by an origin, *x* and *y* axes in the horizontal plane, and a *z*-axis.
RESOURCE	REFERENCE is the identification of a record of information. reference-approval-datetime reference-content-category-code reference-creation-datetime reference-description-text reference-electronic-source-text reference-file-size-quantity reference-format-text reference-language-code reference-lifecycle-code reference-medium-type-code reference-originator-text reference-physical-size-text reference-primary-location-text reference-publication-datetime reference-releasability-text reference-security-classification-code reference-short-title-text reference-title-text reference-transmittal-type-code reference-validity-period-begin-datetime reference-validity-period-end-datetime reference-verification-code reference-version-text ORGANISATION is an OBJECT-ITEM that is an administrative or functional structure. ORGANISATION-ACTION-ASSOCIATION is a relationship indicating the role of a specific ORGANISATION with respect to a specific ACTION. ORGANISATION-TYPE is an OBJECT-TYPE that represents administrative or functional structures. organisation-type-category-code organisation-type-description-text

Table 20 (cont.). Association of M-COP Utilities category with JC3IEDM entities and attributes.

M-COP Utility Class	Corresponding JC3IEDM Entity or Attribute
RESOURCE (continued)	ADDRESS address-category-code (electronic or physical) address-place-name-text PHYSICAL-ADDRESS physical-address-category-code physical-address-residence-text physical-address-street-text physical-address-street-additional-text physical-address-postal-box-text physical-address-postbox-identifier-text physical-address-city-text physical-address-geographic-text physical-address-postal-code-text
SECURITY_CLASSIFICATION	CONTEXT is a collection of information that provides in its entirety the circumstances, conditions, environment, or perspective for a situation. security-classification-code is the specific value that represents the level of NATO security classification. (cosmic top secret, NATO confidential, NATO restricted, NATO secret, NATO unclassified) REFERENCE identifies a record of information. reference-security-classification-code is the specific value that represents the security classification of the artifact cited in a specific REFERENCE.
SOURCE	REPORTING-DATA reporting-data-reliability-code reporting-data-reporting-organisation-id reporting-data-reporting-datetime REPORTING-DATA-ABSOLUTE-TIMING reporting-data-absolute-timing-effective-start-datetime reporting-data-absolute-timing-effective-end-datetime REPORTING-DATA-RELATIVE-TIMING reporting-data-relative-timing-offset-duration reporting-data-relative-timing-reference-action-task-id
SUMMARY_CONTENT	Similar to SOURCE and RESOURCE.
TIME	The information needed for M-COP is not found in JC3IEDM.
USAGE	ACTION-TASK action-task-planned-end-datetime action-task-planned-start-datetime CONTEXT-ASSESSMENT context-assessment-effective-datetime ACTION-CONTEXT-STATUS is a point in time that designates the beginning of the period of effectiveness action-context-status-effective-datetime

Summary of M-COP Category Relationships to the JC3IEDM

Terrain Category

Most of the M-COP required terrain features and facilities are found in the JC3IEDM, and it appears that those missing could easily be added as JC3IEDM geographic-feature-type-category-codes or facility-category-codes. What is more significant is the lack of detail in the attributes associated with these JC3IEDM OBJECT-ITEMs (FEATURE and FACILITY), and which are required for the M-COP. The addition of some of the M-COP Terrain subclasses (TRAFFICABILITY_SURFACE, _VEGETATION, and _WETGAPS, and _DRYGAPS) to the JC3IEDM as additional STATUS entities seems straightforward. Adding attribution associated with the M-COP Terrain ROAD class will take some careful analysis and merging with existing J3CIEDM attributes.

Obstacle Category

While most of the M-COP Obstacle category classes can be found in the JC3IEDM, they lack sufficient attribution to meet the needs of the M-COP. Each Obstacle will need to have a set of attributes developed within the JC3IEDM, similar to what is available for LANDMINES, the attributes of which also need to be enhanced or merged with M-COP attributes and allowable values.

Weather Category

There is good alignment between the M-COP classes and the JC3IEDM entity METEOROLOGIC-FEATURE. In the case of the M-COP Weather classes ATMOSPHERE, PRECIPITATION, CLOUD_COVER, ICING, LIGHTING_AND_VISIBILITY, and WIND, not all of the M-COP attributes map to JC3IEDM.

Maneuver Analysis Category

While the JC3IEDM offers much of the context required for doing maneuver analysis, significant gaps exist. The missing attributes, for the most part, are related to analysis of maneuver/trafficablity, tasks typically done during terrain analysis, and the generation of the graphical control measures.

Route Finding Category

JC3IEDM does not represent route finding well. However, three changes to JC3IEDM would accommodate most Route Finding information. The changes include addition of a mathematical GRAPH construct, representation of General Vehicle Types, and addition of constructs to represent the M-COP Route Finding category class CONSTRAINTs for the route being sought.

Threat Analysis Category

The analysis done for this report showed that the M-COP Threat Analysis category is represented in JC3IEDM. Some information, related to threat, is in the Forces Category and discussed there.

Forces Category

Most of the information required for the M-COP is found in the current specification of the JC3IEDM. The key information that needs to be added is more complete technical data for vehicles as provided in the NRMM and STNDMob API.

Utilities Category

The JC3IEDM contains adequate information for the M-COP Utilities category classes FEATURE and GEOMETRY. There are insufficient data structures for FEATURE_TOPOLOGY. The JC3IEDM does not contain adequate information for metadata entities for the M-COP. The key information for M-COP is found in the DMMS. There is some alignment in the JC3IEDM with the M-COP RESOURCE, SECURITY_CLASSIFICATION, and SOURCE classes.

7 M-COP WEB ONTOLOGY LANGUAGE (OWL) IMPLEMENTATION

The second interim report (Blais et al. 2005b) discussed the development and design of a preliminary ontology for M-COP. Here, we further present the M-COP ontology by expressing a preliminary version using the Protégé ontology editing tool provided by Stanford University.* This editing tool allows us to define classes, subclasses, and properties as OWL expressions. Figure 8 shows (partially) the relationships between the Terrain category (Table 4) and its classes and subclasses, along with some classes of Route Finding. The arrows connecting elements can be read as "is a" relationships in a left-to-right manner (e.g., an area "is a" geometry). The darker-colored classes indicate that they are defined by properties relating them to other classes (for example, terrain must have a geometry). These types of relationships between classes are relatively easy to define; what becomes difficult is defining relationships that require computations (those relationships that were recognized as services in Figure 2). The challenge is to develop classes, subclasses, and properties within the ontology that can be instantiated, based on a service, and also based on as much knowledge that can be "built-in" to the ontology as possible.

The M-COP ontology design and development work remains very preliminary at this time. However, ontology development work is ongoing in a number of related areas, including the synthetic environment (Bhatt et al. 2004) and plans and orders (Blais et al. 2006), that can be leveraged for M-COP ontology development.

* http://protege.stanford.edu

Figure 8. Segment of the M-COP ontology showing partially the Route Finding, Obstacles, and Terrain categories.

8 LESSONS LEARNED

In the course of this effort, it was disappointing to find so few fully specified, application-independent components that would serve the needs of the M-COP model. This forced the team to work with more primitive (as in "weaker semantics" as identified in Figure 2) data structures than was anticipated at the outset. While constraining the achievement of some of the original goals of the effort, this lack of formal models in itself was an important finding, resulting in a comprehensive effort to identify and define necessary ground vehicle mobility data to support movement planning. The resulting model description in this report is perhaps less encumbered by pre-existing biases.

As stated previously, it was not the intent of this project to develop a formal data model, though we found ourselves drawn in that direction, as we tried to understand existing data models, system data representations, and potential applications. The lack of specific target applications, while keeping us from a point-to-point solution or multiple-point solutions, also kept us from a definitive M-COP solution.

While numerous methods of storing a data model exist (Microsoft Access, Oracle, MySQL), these in themselves become an application, so we settled on MS Word document tables, which are easy to examine, but difficult to cross check for consistency across tables, and nor can they be considered an implementation. The use of Protégé for the development of a M-COP ontology appears promising, but linking relationships that require complex computations appears problematic.

9 RECOMMENDATIONS FOR FUTURE WORK

- For broadest applicability of the M-COP representation, we recommend establishing a Working Group to fully specify the M-COP information model in the context of the JC3IEDM. This is being done in other critical data modeling areas, such as for exchange of Chemical, Biological, Radiological, and Nuclear (CBRN) data (Johnson 2004; Johnson and Vachher 2005). It would become the responsibility of the Working Group to evaluate the JC3IEDM, with existing and planned extensions, to specify M-COP information requirements in that context and to prepare necessary proposals for extensions to JC3IEDM to provide required M-COP data.

- Working through the JC3IEDM also provides a path toward stronger semantic representations as various initiatives arise to create a formal ontology of command and control information.* We recommend that personnel familiar with M-COP objectives and the current M-COP representation participate in such efforts to ensure that ground vehicle mobility information is fully characterized, particularly in areas where significant reasoning is currently hidden in software rather than exposed through data, such as for maneuver analysis, terrain reasoning, threat analysis, route finding, and identification of obstacles that can impede movement. Some relevant references to this type of work follow:

  - An evaluation of the C2IEDM as an ontology: http://www.vmasc.odu.edu/pubs/tolk-evaluation01.pdf
  - OWL ontology for a subset of C2IEDM: http://www.dodccrp.org/events/2005/10th/papers/239.pdf
  - (Blais et al., 2005d) SISO Study Group Report on C-BML and C2IEDM: http://www.movesinstitute.org/~blais/CoalitionBMLStudyGroup.htm
  - Ontologies on top of C2IEDM: http://discussions.sisostds.org/default.asp?action=9&fid=46&read=38351

* There has been interest expressed in the Modeling, Simulation and Demonstration (MSD) Working Group of the Network Centric Operations Industry Consortium (**http://www.NCOIC.org**) to initiate an effort to develop an ontology formalization of the JC3IEDM.

including the Suggested Upper Merged Ontology (SUMO) and http://ontology.teknowledge.com/arch.html

- An FCA of the M-COP data model should be conducted as a metric to assess appropriateness of the model. As the model is refined, the initial FCA can be used to guide improvements.

- The M-COP ontology should be developed further and submitted to the DOD Metadata Registry and Clearinghouse for review and feedback.

- The NRMM and STNDMob API XML schema and data files should be assigned to an appropriate XML Namespace and submitted to the DOD Metadata Registry and Clearinghouse for broad re-use.

- The STNDMob API should be configured to operate as a Web service and offered for use in the Defense Information Systems Agency (DISA) GIG prototype efforts.

- As part of an effort by a related ERDC project, *Common Maneuver Networks for Embedded Training, Mission Planning and Rehearsal*, a demonstration service should be developed. This would explore the use of the M-COP service descriptions and emerging ontology with OOS as a route-finding client and BTRA maneuver network products serving as a basis for routing calculations. The routing will initially require way-points and vehicle types as input, but should be extended, where possible, to include OOS entity behavior needs as routing constraints. Results from this work will inform further refinement of M-COP service description and continued development of the M-COP taxonomy. Figure 9 depicts the demonstration concept.

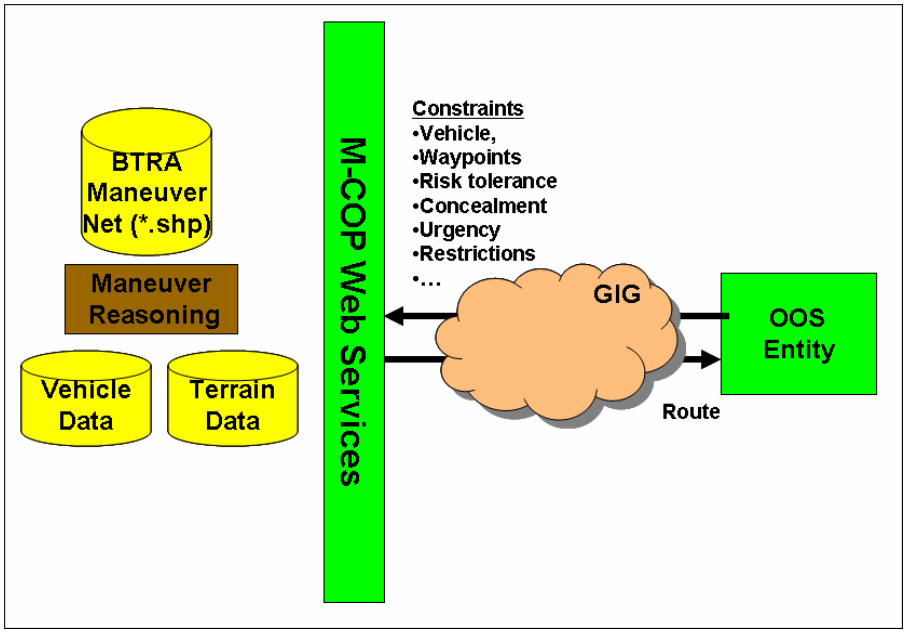

Figure 9. Demonstration application of M-COP Web Services.

10 SUMMARY

The amount of information to represent ground vehicle mobility and maneuver at a high level of fidelity is voluminous, particularly in the area of terrain attribution. The linkages and analysis required between terrain information and maneuver performance can be complex; however, by identifying these requirements we have taken the first step to achieve an M-COP for BC and M&S. For the first time, a body of knowledge is specified for this domain that indicates both the raw data necessary for movement planning as well as the logic products needed to support movement planning through software services or as decision support tools.

The M-COP data model as presented here can neither be called a definitive work nor a complete work. It is, however, one of the “80% solutions” that are critical to advances in military technology and capability. Taking the lead from the long-standing, practical, multi-national, multi-service C2IEDM/JC3IEDM development, this M-COP data model provides a core set of information requirements for ground vehicle mobility that can be extended and refined as the concepts are employed.

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ACRONYMS

A2C2	Army Airspace Command and Control
AA	Avenues of Approach
ABCS	Army Battle Command System
ABE	Army Battlespace Environment
AMSO	Army Modeling and Simulation Office
AO	Area of Operations
API	Application Program Interface
APOD	Aerial Port of Debarkation
AUTL	Army Universal Task List
BC	Battle Command
BCSE	Battle Command Simulation and Experimentation
BFT	Blue Force Tracker
BML	Battle Management Language
BN	Battalion
BOS	Battlefield Operating Systems
BTRA	Battlespace Terrain Reasoning and Analysis
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
C2IEDM	Command and Control Information Exchange Data Model
C-BML	Coalition Battle Management Language
CBRN	Chemical, Biological, Radiological, and Nuclear
CES	Core Enterprise Services
C/JMTK	Commercial Joint Mapping Toolkit
CIO	Chief Information Officer
COA	Course of Action

COI	Community of Interest
COP	Common Operational Picture
CP	Checkpoint
CROM	C4I-M&S Reference Object Model
CS	Combat Support
CSS	Combat Service Support
DCS	Deputy Chief of Staff
DDMS	DOD Discovery Metadata Specification
DFAD	Digital Feature Analysis Data
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DNS	Domain Name System
DS	Direct Support
EA	Engagement Areas
ECS	Environment Control Service
EDCS	Environmental Data Coding Specification
EDM-AOS	Environmental Data Model—Atmosphere Ocean and Space
ERDC	Engineer Research and Development Center
FACC	Feature and Attribute Coding Catalog
FBCB2	Force XXI Battle Command Brigade and Below
FCA	Formal Concepts Analysis
FFIR	Friendly Forces Information Requirements
FM	Frequency Modulation
FOC	Force Operating Capabilities
GCC	Geocentric Coordinates
GDC	Geodetic Coordinates
GeoBML	Geospatial Battle Management Language
GIG	Global Information Grid
GML	OpenGIS Geography Markup Language

GS	General Support
GS-R	General Support - Reinforcing
HET	Heavy Equipment Transporter
HTTP	Hyper Text Transfer Protocol
HQ	Headquarters
IED	Improvised Explosive Device
IMETS	Integrated Meteorological System
IPB	Intelligence Preparation of the Battlefield
JC2	Joint Command and Control
JC3IEDM	Joint Consultation, Command, and Control Information Exchange Data Model
JDAM	Joint Direct Attack Munition
JMCDM	Joint METOC Conceptual Data Model
LOS	Line of Sight
M2M	Machine-to-Machine Messaging
M&S	Modeling and Simulation
M-COP	Mobility Common Operational Picture
MC	Mobility Corridors
MCOO	Modified Combined Obstacle Overlay
MEDEVAC	Medical Evacuation
METOC	Meteorology and Oceanography
MGRS	Military Grid Reference System
MIP	Multilateral Interoperability Programme
MLC	Military Load Class
MOOTW	Military Operations Other Than War
MSD	Modeling, Simulation, and Demonstration
MSDL	Military Scenario Definition Language
NATO	North Atlantic Treaty Organization
NCOIC	Network Centric Operations Industry Consortium
NCOW RM	Net-Centric Operations and Warfare Reference Model

NRMM	NATO Reference Mobility Model
OOS	OneSAF Objective System
OOS EDM	OneSAF Objective System Environmental Data Model
OP	Observation Post
OPORD	Operations Order
OWL	Web Ontology Language
OWL-S	Web Ontology Language for Services
RS	Regimental Support
SAF	Semi-Automated Force
SASO	Stability and Support Operations
SEDRIS	Synthetic Environment Data Representation and Interchange Specification
SEMP	Systems Engineering Management Process
SISO	Simulation Interoperability Standards Organization
SIW	Simulation Interoperability Workshop
SME	Subject Matter Expert
SMTP	Simple Mail Transfer Protocol
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SPOD	Seaport of Debarkation
STNDMob	Standard Mobility
SUMO	Suggested Upper Merged Ontology
TEC	Topographic Engineering Center
TPL	Time Phase Lines
TTP	Tactics, Techniques, and Procedures
TRADOC	US Army Training and Doctrine Command
UML	Unified Modeling Language
UOB DAT	Unit Order of Battle Data Access Tool
UTM	Universal Transverse Mercator
UUID	Universal Unique Identifier

UXO	Unexploded Ordnance
VOT	Visual Object Taxonomy
WSDL	Web Services Description Language
XML	Extensible Markup Language
XSL	Extensible Stylesheet Language

GLOSSARY

Term	Definition
Army Universal Task List (AUTL)	The AUTL provides a common, doctrinal structure for collective tasks that support Army tactical missions and operations performed by Army units and staffs. Articulates what tasks the Army performs to accomplish missions.
Attribute	A property or characteristic that is common to some or all of the instances of an entity. An attribute represents the use of a domain in the context of an entity.
Battle Management Language (BML)	The unambiguous language used to: 1) command and control forces and equipment conducting military operations and, 2) provide for situational awareness and a shared, common operational picture. It can be seen as a representation of a digitized commander's intent to be used for real troops, for simulated troops, and for future robotic forces.
Battlefield Operating System (BOS)	The BOS are the physical means (soldiers, organizations, and equipment) that commanders use to accomplish missions.
Cardinality	The number of entity instances that can be associated with each other in a relationship.
Class	A class defines a group of individuals that belong together because they share some properties.
Coalition Battle Management Language (C-BML)	Unambiguous language to describe commander's intent, to be understood by both live forces and automated systems, for simulated and real world operations.
Command and Control Information Exchange Data Model (C2IEDM)	A data model that is managed by the Multilateral Interoperability Programme (MIP). The C2IEDM serves as a common baseline for information exchange that is designed to support common, or generic, information exchange terms.
Core Enterprise Services (CES)	Generic information services that apply to any COI, provide the basic ability to search the enterprise for desired information, and then establish a connection to the desired service.
Database	A collection of interrelated data, often with controlled redundancy, organized according to a schema to serve one or more applications.
Data model	A graphical and textual representation of analysis that identifies the data needed by an organization to achieve its mission, functions, goals, objectives, and strategies and to manage and rate the organization. A data model identifies the entities, domains (attributes), and relationships (or associations) with other data, and provides the conceptual view of the data and the relationships among data.
Data type	A categorization of an abstract set of possible values, characteristics, and set of operations for an attribute. Integers, real numbers, character strings, and enumerations are examples of data types.

Term	Definition
Defense Discovery Metadata Specification (DDMS)	Defines discovery metadata elements for resources posted to community and organizational shared spaces.
Edge	A connection between two vertices or nodes
Entity	The representation of a set of real or abstract things (people, objects, places, events, ideas, combination of things, etc.) that are recognized as the same type because they share the same characteristics and can participate in the same relationships.
Entity Relationship Diagram	An ER diagram represents graphically a list of entity types, the permissible relations between them, and some of the constraints on those relations.
Environment Data Coding Standard (EDCS)	Stand alone data coding standard that characterizes environmental objects according to their semantic identification.
Extensible Markup Language (XML)	A general-purpose markup language for creating special-purpose markup languages, capable of describing many different kinds of data. Its primary purpose is to facilitate the sharing of data across different systems. (http://www.w3.org/TR/REC-xml/)
Extensible Stylesheet Language (XSL)	A set of language technologies for defining XML document transformation and presentation.
Formal Concept Analysis (FCA)	A theory of data analysis that identifies conceptual structures among data sets. These structures can be graphically represented as conceptual hierarchies, allowing the analysis of complex structures and the discovery of dependencies within the data. FCA is increasingly applied in conceptual clustering, data analysis, information retrieval, knowledge discovery, and ontology engineering.
GeoBML	GeoBML is an extension of BML into the domain of actionable geospatial information; provides a semantic and syntactic bridge between the Warfighter's decision making and situational awareness needs and the terrain experts' realm. It is NOT a geo-spatial database.
Geography Markup Language (GML)	OpenGIS Consortium specification that provides objects for describing geography including features, coordinate reference systems, geometry, topology, time, unit of measure, and generalized values.
Global Information Grid (GIG)	The globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policymakers, and support personnel. The GIG includes all owned and leased communications and computing systems and services, software (including applications), system data, security services, and other associated services necessary to achieve information superiority for the U.S. military. It is the physical manifestation of the network-centric warfare doctrine.
Instance	One of a set of real or abstract things represented by an entity.
Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM)	An information exchange data model. The next version of C2IEDM. This data model extends and enhances the C2IEDM in a consistent manner and will support XML information exchanged.
Joint METOC Broker Language (JMBL)	The JMBL schema provides an XML representation of the JMCDM and establishes a single interface for requesting and retrieving METOC data.

Term	Definition
Joint METOC Conceptual Data Model (JMCDM)	JMCDM, a logical data model, was created in 1995 to integrate the geophysical data requirements of all DOD components. JMCDM and its supporting encyclopedia are a subset of the DOD Enterprise Data Model.
M-COP	The definition set by this team is “A subset of the COP consisting of relevant movement and maneuver data and information shared by more than one command. The M-COP can be tailored for various users and will include data and information for mobility of individual combatants, ground vehicles, and autonomous/robotic vehicles.”
Markup language	A markup language combines text and extra information about the text. The extra information, for example about the text's structure or presentation, is expressed using markup, which is intermingled with the primary text.
Military Scenario Definition Language (MSDL)	An XML based data interchange format that enables C2 planning applications to interchange the military portions of scenarios with simulations and other applications.
Ontology	An explicit, formal, machine-readable semantic model defining the classes (or concepts) and their possible inter-relations pertinent to a specific domain.
Web Ontology Language (OWL)	A markup language for publishing and sharing data using ontologies on the Internet. (http://www.w3.org/TR/owl-features/)
Web Ontology Language for Services (OWL-S)	OWL-S is an OWL-based Web service ontology, which supplies Web service providers with a core set of markup language constructs for describing the properties and capabilities of their Web services in unambiguous, computer-interpretable form. OWL-S markup of Web services will facilitate the automation of Web service tasks, including automated Web service discovery, execution, composition, and interoperation.
Reasoner	Software tool that can derive new formally annotated facts from a set of predefined formally annotated facts.
Relationship	An association between two entities or between instances of the same entity.
Semantics	The meaning of the syntactic components of a language.
Semantic Web	A project that intends to create a universal medium for information exchange by putting documents with computer-processable meaning (semantics) on the World Wide Web. The Semantic Web comprises the standards and tools of XML, XML Schema, RDF, RDF Schema and OWL.
Service	A service is an abstract resource that represents a capability of performing tasks that form a coherent functionality from the point of view of providers’ entities and requesters’ entities. To be used, a service must be realized by a concrete provider agent.
Service-Oriented Architecture (SOA)	A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with, and use capabilities to produce desired effects consistent with measurable preconditions and expectations.

Term	Definition
Simple Object Access Protocol (SOAP)	A protocol for exchanging XML-based messages over a computer network, normally using HTTP. SOAP forms the foundation layer of the Web services stack, providing a basic messaging framework upon which more abstract layers can build.
Web Services Description Language (WSDL)	An XML-based service description on how to communicate using the web service, namely, the protocol bindings and message formats required to interact with the web services listed in its directory.

APPENDIX A: M-COP TERRAIN CATEGORY

Tables A1–A6 present the enumeration values for a Feature_Type attribute of each of the Terrain classes. These enumeration values are the same as their sources. For reader ease, the formats have been changed to the nomenclature chosen for this report. The intent for the M-COP is to use the OOS EDM values; the other sources are shown only for comparison. The terms *area*, *line*, *directed_line*, *3d_line*, and *point* denote the geometry type.

Table A1. Enumeration values for Feature_Type attribute, Terrain class NATURAL_REGION.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
		alkali_flats	
		animal_sanctuary	
	asphalt_lake *area*	asphalt_lake	asphalt_lake
	barrier *area*		
x	bog *area*	bog, marsh, marsh_or_swamp, swamp	marsh, swamp, coastal_marsh_in_nontidal_waters, coastal_marsh_in_tidal_waters, cranberry_bog, peat_bogs, marshy_areas_in_northern_latitudes
	boulder_field *area*		boulder_strewn_beach, glacial_moraine
	brush_land *area*	bamboo, cane	woods, brushwood
	butte *area*		
	cave *area*		cave
		cay	
		crevice, crevasse	crevasse, crevice
	dry_lake *area*		
x	escarpment *directed_line*	bluff, cliff, escarpment	abrupt_slope, abrupt_scarp, high_cliff
	esker *line*	esker	
x	exposed_bedrock *area*	exposed_bedrock	
		fan	
	geologic_fault *line*	fault	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	foreshore *area*	foreshore, beach, shoreline, foreshore (precise_iho), coastline	sand, sand_beach, shoreline, wet_sand, gravel_beach
	frozen_precipitation_field *area*	snow_field, ice_field, permanent_snowfield	glacier, icefield, snowfield
	glacier *area*	glacier	
x	grass_land *area*	grassland, grass, scrub, brush	tropical_grass
	ground_surface_ element *area*	ground_surface_element, land_area, land_region, barren_ground	
x	gully *area*, gully *line*	us_gully, us_gorge uk_gullies	perennial_ditch
	jungle *area*		
x		hill	
		hummock	hummocks_and_ridges_in_swamps, hummocks_and_ridges_in_marshes
	ice_cliff *directed_line*	ice_cliff	high_ice_cliff, low_ice_cliff
		ice_peak, nunatak	
		ice_shelf	
x		island	
	land_flooding_ periodically *area*	land_subject_to inundation	land_subject_to_inundation
		large_isolated_rock, boulder, or rocky_formation_surrounded_by_water	
	mesa *area*		
		ledge	
	mixed_vegetation_land *area*	miscellaneous_vegetation, scrub, brush, bush	scattered_trees
	moraine *area*	moraine	
x	mountain_pass *line*	mountain_pass	mountain_pass
		oasis	
x	pack_ice *area*	pack_ice	
		pingo	
	polar_ice *area*	polar_ice	
x	rocky_outcrop *area*, rocky_outcrop *line*	rock_strata, rock_formation	
	salt_pan *area*	salt_pan	
	sand_bar *line*		
x	sand_dune_region *area*	sand_dune, sand_hills	crescent_dunes, lateral_dunes
	sebkha *area*	sebkha	
	surface_fissure *line*		

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	terrain_depression *area*	depression	depression
x	treed_tract *area*	forest	mangrove, nipa
	tundra *area*	tundra	
	valley_region *area*		
	vegetated_saturated_land *area*		
	volcanic_dyke *line*	volcanic_dike	
		volcano	
	wadi *area*		wide_wash or dry_river_bed, narrow_wash or dry_stream
	wadi *directed_line*		
	waterbody_bank *line*	river_bank, inland_shoreline	
x	woody_grass_land *area*		scrub

Table A2. Enumeration values for Feature_Type attribute, Terrain class OPEN_TRACTS.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	aerodrome *area*	airport_area, us_airfield, uk_airstrip, us_airport, uk_airport, airfield, airstrip, landing_place	airport, airfield, landing_ground
x	aircraft_parking_ facility *area*	us_apron, us_hardstand, uk_apron, uk_hardstanding	
	animal_park *area*	zoo, safari_park	
	athletic_field *area*	us_athletic_field, uk_athletic_field, uk_sports_field, us_playing_field	
x	campground *area*	campground, campsite	
x	crop_land *area*	cropland	
		drove	
	flood_basin *area*		
	golf_course *area*	golf_course	
		golf_driving_range	
		greenspace	
x	helicopter_landing_ pad *point*	helicopter_landing_pad	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	hop_field *area*	hops	
x	man_made_clearing *area*	land_devoid_of_vegetation, disturbed_soil	
	man_made_clearing *line*	us_cleared_way, us_cut_line, us_firebreak, uk_cleared_way, uk_firebreak	
x	petroleum_field *area*		
	prepared_defensive_ region *area*		
	rice_field *area*	rice_field	rice_paddy
x	runway *area* runway *line*	runway	
	runway_stopway *line*	overrun, stopway	
	shoreline_landing_ place *area*		
	shoreline_landing_ place *point*		
x	systematic_tree_ planting *area*	nursery, orchard, plantation	orchard or plantation
	taxiway *line*		
		training_area	
		touchdown_zone	
	tree_blowdown *area*		
x	vehicle_lot *area*	us_vehicle_storage, us_parking_area, uk_vehicle_storage, uk_parking_area, uk_car_park, uk_boat_park	
	vineyard *area*	vineyards	vineyard

Table A3. Enumeration values for Feature_Type attribute, Terrain class FACILITY.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	amusement_park *area*	amusement_park	
		archeological_site	
	assembly_plant_*area*	assembly_plant, works	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
		us_boardwalk, uk_wooden_causeway	
		botanical_garden	
x	built_up_region *area*	built_up_area, settlement	built_up_area, town, village, settlement
	built_up_terrain *directed_line*		
		camp	
	cave_3d *line*		
x	cemetery *area*	us_cemetery, uk_cemetery, uk_graveyard	cemetery
		circular_irrigation_system	
x	communication_station *area*		
	courtyard *area*		
	crib *area*	crib	
	culvert *line*	culvert	
	dam *area*	dam, weir	large_masonry_dam, diversion_dam
x	dam *line*		small_dam
		decontamination_pad	
x	defensive_position *area*		fort
	disposal_site *area*	us_disposal_site, us_waste_pile, uk_refuse_tip, uk_slag_heap	
	drive_in_theatre *area*	us_drive_in_theater, uk_drive_in theatre	
		us_drive_in_theater_screen, uk_drive_in_theatre_ screen	
	electrical_signal_line *line*	telephone_line, telegraph_line, overhead_cable	
		exhibition_grounds	
	extraction_mine *area*		mine_dump, strip_mine, tailings_pile
	fairground *area*	us_fairgrounds, uk_fairgrounds	
		feed_lot, stockyard, holding_pen	
	ferry_crossing *line*	ferry_crossing	ferry
		filtration_beds, aeration_beds	
		firing_range, gunnery_range	
	fish_hatchery *area*	fish_hatchery, fish_farm, marine_farm	
		fishing_pier, promenade_pier	
		heating_plant	
	fortification *area*		
	grain_elevator *line*		

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	grain_storage_structure *line*		
x	heliport *area*	heliport	heliport
		historical_built_up_area	historical_battlefield
	hydrographic_lock *area*		
	hydrographic_lock *line*		
	irrigation_ditch *area*		
		landing_stairs	
		lookout	
	land_fish_hatchery *area*		
	levee *line*	dyke_crown	small_levee
	livestock_pen *area*		
	marine_wreck *area*	wreck	
x	military_facility *area*	military_base	
x	missile_site *area*	missile_site	
	mobile_home_park *area*	us_mobile_home, us_mobile _home_park, uk_caravan, uk_caravan_park, uk_mobile_home, uk_mobile_home_park	
	native_settlement *area*	native_settlement	native_settlement
x	nuclear_weapons_ facility *point*		
	offshore_loading_ facility *area*	us_offshore_loading_facility, uk_single_point_mooring	
		oil_ facilities, gas_facilities	
		oil_field, gas_field	
	park *area*	park	
	parking_garage *point*		
	particle_accelerator *area*	particle_accelerator	
x	petroleum_facility *area*		
x	pipeline *line*	pipeline, pipe	pipeline, elevated_conduit_of_any_type
	plant_nursery *area*		
x	power_plant *point*	us_power_plant, uk_power_station	
	power_substation *area*	substation, transformer_yard	
		picnic_site	
		pit	
		port_facility	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	power_transmission *line*	power_transmission_line	power_lines, telephone_lines, telegraph_lines
	prepared_defensive_ position_site *area*		
		prepared_raft_bridge_site, prepared_float_bridge_site	
x	processing_facility *area*	processing_plant, treatment_plant, waste_processing_facility	
		production_installation	
	public_square *area*	plaza_square, city_square	
x	pumping_station *point*	pumping_station	
x	quarry *area* , quarry *line*	quarry, mine, quarry_shear_wall, mine_shear_wall	quarry, open_pit_mine
	race_track *area*	us_race_track, uk_race_track, uk_race_course	race_track
	radar_station *point*		
	railroad_turntable *area*	us_railroad_turntable, uk_railway_turntable	turntable
x	railroad_yard *area*	us_railroad_yard, us_marshalling_yard, uk_railway_yard, uk_marshalling_yard, railhead	railroad_yard, railroad_siding
	roadside_rest_stop *point*	us_vehicle_stopping, us_vehicle_area, us_vehicle_rest_area, uk_vehicle_stopping_area, uk_vehicle_rest_area, uk_vehicle_lay_by	
	rubble *area*		
		ramp	
		ramp_maritime	
x	ruins *area*	ruins	ruined_or_destroyed_area
	scrapyard *area*	wrecking_yard, scrap_yard	
	seaplane_base *area*	seaplane_base	seaplane_base
	settlement *area*		
	shore_protection_ structure *area*		
	sidewalk *line*		
x	storage_depot *area*		
		ski_track	
x		slipway, patent_slip	
		small_craft_facility	
	taxiway *area*	taxiway	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
		test_area	
		timber_yard	
	treeline *line*		
x	tunnel_shelter *area*		
	water_treatment_bed *area*		
x	weapon_fighting_ position *point*		
	weapon_full_ defilade_position *point*		
	weapon_hull_defilade_position *point*		
	weapon_turret_ defilade_position *point*		
	weapons_range *area*		
x	wharf *line*	us_pier, us_wharf, us_quay, uk_pier, uk_wharf, uk_quay, uk_jetty	wharf, pier, dock

Table A4. Enumeration values for Feature_Type attribute, Terrain class SITES.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	aircraft_hangar *point*		
		bastion, rampart, fortification	
	blast_furnace *point*	blast_furnace	
x	building *area* building *point*	building, cabin, building_superstructure_addition, hut, cliff_dwelling, arcade, amusement_park_attraction, shed, us_steeple, uk_steeple, uk_spire, station_miscellaneous	buildings_in_general, structures_similar_to_buildings, school, church, non_christian_house_of_worship, mosque, pagoda, greenhouse, landmark_building, railroad_station
x	bunker *point*	fortification	
	catalytic_cracker *point*	catalytic_cracker	
x	communication_station *point*	communication_building	
x	control_tower *point*	control_tower	
x	dry_dock *point*	us_drydock, uk_dry_dock	drydock

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	early_warning_radar_site *point*	early_warning_radar_site	
	fortification_wall *point*		
	grain_elevator *point*	grain_elevator	
	grain_storage_structure *point*	grain_bin, grain_silo	
	grandstand *area*	grandstand	
	grandstand *point*		
	hardened_aircraft_ shelter *point*	revetment (airfield/equipment/facilities)	
		historic_site, historic_point_of_interest	historical_site
x	individual_fighting_ position *point*		
x	infantry_trench *line*		
x	irrigation_ditch *directed_line*	ditch, trench	
x	jetty *line*	groin, breakwater, breakwater_or_groyne, us_jetty, uk_training_wall	jetty
x	lighthouse *point*	lighthouse	lighthouse_or_light
	main_telecom_ exchange *point*		
	marine_mole *line*	mole	
	marine_signal_station *point*	maritime_station, maritime_signal_station	
x	nuclear_reactor *point*	nuclear_reactor	
	protection_shed *line*	snow_shed, rock_shed	railroad_snowshed
	rampart *line*		
	rig *point*	rig, superstructure	
	rubble *point*		
x	ruins *point*		ruins
	seawall *line*	seawall	large_seawall, narrow_seawall_or_revetment, large_revetment
			christian_shrine, non_christian_shrine, moslem_shrine
	shore_protection_ structure *line*	revetment_shore_protection, rip_rap	small_breakwater, large_breakwater
		shoreline_construction, mooring_facility, warping_facility	
	sports_arena *area*	us_stadium, us_amphitheater, uk_stadium, uk_ampitheatre	
	sports_arena *point*		
	step_flight *line*	flight_of_steps	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	storage_bunker *point*	storage_bunker, storage_mound	
	storage_tank *point*	tank	tank
	swimming_pool *area* swimming_pool *point*	swimming_pool	swimming_pool
	telecom_switching_ station *point*		
x	underground_bunker *point*	underground_bunker	
x	wall *line*		prominent_wall
	warehouse *point*	depot_storage	
x	water_tower *point*	water_tower, tower_general	
x	windmill *point*	windmill	windmill_or_windpump

Table A5. Enumeration values for Feature_Type attribute, Terrain class WATERBODY.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x		anchor_berth	
x		anchorage	
		anchorage_complex_feature	
	aqueduct *area*	aqueduct	
	aqueduct *directed_line*		aqueduct_tunnel
		backshore_precise_iho	
x		basin	
x		berth	
		boat_turning_basin	
		bottom_feature	
	breaker_region *area*	breakers	
x	canal *area*	canal	abandoned_canal, abandoned_canal_containing_water
x	canal *directed_line*	canal_route	navigable_canal_in_operation
		channel	
		common_open_water	
		eddies	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
		flooded_area	
		flume	flume
x	ford *line*	ford	ford
		inland_water	
	lagoon *area*	lagoon, reef_pool	
x	lake *area*	lake, pond	perinneal_lake_or_pond, dry_or_cyclical_lake_or_pond, fish_ponds, intermittent_lake_or_pond
		lock_basin	
	marine_foul_ground *area*	us_foul_ground, uk_foul	
	marine_region *area*	maritime_area, depth_area	
	marine_region *line*		
	marine_region *point*		
	marine_route *area*	route_maritime	
	marine_route *line*	deep_water_route	
	marine_route *point*		
		miscellaneous_surface_drainage_feature	intermittent_ditch
		miscellaneous_underwater_feature	disappearing_stream
	moat *area*	moat	
		nearshore_precise_iho	
		overfalls, tide_rips	
	rapid *line*	rapids	small_rapids, large_rapids
	reef *area*, reef *line*	reef	
x	reservoir *area*	reservoir	reservoir_with_natural_shoreline
x	river *area*	river_navigation_route	wide_perennial_stream, narrow_perennial_stream, braided_stream, unclassified_stream, intermittent_stream
x	river *directed_line*	river, stream	
	safety_fairway *area* , safety_fairway *line*	safety_fairway	
	salt_evaporator *area*	salt_evaporator	salt_evaporator
		seaplane_landing, seaplane_takeoff_area	seaplane_anchorage
	settling_pond *area*	settling_basin, sludge_pond	
		spillway	
	snag *area*	us_snags, us_stumps, uk_snags, us_submerged_stumps	

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	swept_region *area*, swept_region *line*	swept_area	
		tideway	
		us_current_flow, uk_current_flow, uk_tidal_stream_direction	
		us_harbor, uk_harbour	
		us_harbor_complex, uk_harbour_complex	
	underwater_hazard *area*		
	underwater_hazard *line*		
	waterbody_floor *area*		
x	water_except_inland *area*	water_except_inland	
		water_turbulence	
	waterfall *line*	waterfall	large_falls, small_falls
	watering_hole *point*		

Table A6. Enumeration values for Feature_Type attribute, Terrain class ROAD.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
	breach *line*		
x	bridge *line*	bridge, overpass, viaduct	highway_bridge_or_viaduct, highway_drawbridge, railroad_bridge_or_viaduct, railroad_drawbridge
	cart_track *line*	cart_track	
	causeway *line*	causeway	small_levee_carrying_railroad, small_levee_carrying_road
		constriction, expansion	
	driveway *line*		
	engineer_bridge *line*		
	overpass *line*		overpass_or_underpass
			point_of_change_in_the_gage_or_number_of_tracks
			point_of_change_in_number_of_lanes_of_extra_width_road

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	railroad *line*	us_railroad, uk_railway, us_railroad_switch, uk_railway_points	single_track_railroad_in_operation, single_track_railroad_nonoperating, double _or_multiple_track _railroad_in_operation, double_or_multiple_track- _railroad_nonoperating, rail- road_in_street_or_wharf
	railroad_sidetrack *line*	us_railroad_siding, us_railroad_spur, uk_railway_siding, uk_railway_spur	
x	road *line* road_lane *directed_line*	road, us_sharp_curve, uk_sharp_bend	hard_surface_heavy_duty_road, hard_surface_medium_duty_road, improved_light_duty_road, unimproved_dirt_road, hard_surface_all_weather_road_two_ or_more_lanes_wide, hard_surface_all_weather_road_one_ lane_wide,_loose_or_light_surface_all _weather_road_two_or_more_lanes_ wide, loose_or_light_surface_all_weather_ road_one_lane_wide, loose_surface_fair_or_dry_weather_ road, dual_or_super_highway, main_road, secondary_road, other_road, road_under_construction, streets_in_developed_areas, street_ending_at_barrier_or_embank ment, dam_carrying_road
x	road_interchange *line*	us_interchange, uk_interchange, uk_complex_junction	interchange, cloverleaf, traffic_circle, grade_crossing
	trail *line*		trail, track
		shoulder	
		steep_grade	steep_gradients_on_roads
x	tunnel 3d *line*	tunnel	road_tunnel, railroad_tunnel
	underground_railroad 3d *line*	us_subway, uk_underground_railway, uk_metro	
	weapon_fighting_position_access_ro ute *line*		

Table A7. Attributes of Terrain subclass TRAFFICABILITY_SURFACE.*

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Area	The absolute area within the area of an object.	1	float	m^2
Name	The textual identifier or code used for an object; the name.	0	string	none (name may be "missing")
Frozen_Soil_Layer_ Bottom_Depth	The depth from the terrain to the base of a layer of frozen soil.	1	float	meters
Frozen_Soil_Layer_ Top_Depth	The depth from the terrain to the top of a layer of frozen soil.	1	float	meters
Frozen_Water_Type	The type of frozen water present.	1	integer	0001 ice 0002 melting_snow_or_ice 0003 mixed_snow_and_ice 0004 none_present 0005 slush 0006 snow 0007 snow_over_ice
Maximun_Standing _Water_ Depth	The maximum depth of non-flowing/standing water within the region delineated by an object.	0	float	meters
Snow_Density	The density of accumulated snow on an object.	0	float	(specific gravity) or g/cc
Snow_Depth	The depth of snow and/or ice on the terrain.	0	float	meters
Snow_Only_Depth	The depth of the snow, which may be over terrain, ice, or floating ice.	0	float	meters
Soil_Cone_Index_QB§_ Measurement _Depth	Soil cone index at measurement depth: [0,15], [15,30] where measurement depths (cm).	1	integer	kPa
Soil_Density_Dry	The average density of the soil between the surface and the bedrock after it has been dried to a constant mass at 105°C.	0	float	(specific gravity) or g/cc

* Subclass: TRAFFICABILITY_SURFACE - a set of attributes associated with the terrain surface from which mobility calculations can be made, specifically supports the use of the STNDMob API, but will support other models also.

† Some precipitation and state-of-the-ground attributes will also be found in the Weather category; within the Terrain category, these values are related to specific instance of the class, within the Weather category they are related to a regional area. In most cases the values will be the same, however not always, e.g. the snow cover depth based on the Weather category may be 10 cm, for a region, for a specific road within that region the snow depth could be zero because it had been plowed. Mobility analysis would be based on the Terrain category attributes, which must be dynamically updated based on the Weather category information, reconnaissance reports or other services.

‡ The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

§ QB – “qualified by”

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Soil_Depth	The general depth of soil, or unconsolidated material, from terrain to bedrock.	0	float	meters
Soil_Type	The Unified Soil Classification System (USCS) Soil_Type.	0	integer	0007 ch 0008 cl 0009 evaporites 0010 gc 0011 gm 0012 gp 0013 gw 0014 mh 0015 ml 0016 ml_and_cl 0018 oh 0019 ol 0020 pt 0021 sc 0022 sm 0023 sm_and_sc 0024 sp 0025 sw unknown
Soil_Water_Volume	The water lost from the soil upon drying to constant mass at 105°C, expressed as the fractional volume of water per unit bulk volume of wet soil.	0	float	none
Soil_Wetness	The categorical (coded) soil water content, whether liquid or solid.	0	integer	0002 average 0003 dry 0005 frozen_or_permafrost 0006 moist 0001 perenially_dry 0008 saturated 0009 waterlogged 0010 wet
Surface_Slippery	Indication that a surface is slippery. Examples: wet grass, and wet clay soil.	1	boolean	none
Terrain _Roughness_Root_ Mean_Square	The roughness of terrain based on elevation variations, calculated using the root-mean-square (RMS) value of the detrended terrain elevation measured at a spatial frequency of approximately 0.3 m.	0	float	meters
Terrain_Trafficability_Fine	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a fine resolution estimate of trafficability.	0	integer	0650 ID_683 ....

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Terrain_Trafficability_Medium	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a medium resolution estimate of trafficability.	0	integer	0001 ID_001
Terrain _Trafficabilty_Coarse	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a coarse resolution estimate of trafficability.	0	integer	0005 Default
Terrain_Transportation_ Route_Surface_Type	The physical surface composition of a road, runway or other surface intended to support the movement of vehicles.	0	integer	0001 asphalt 0002 bituminous 0003 brick 0004 clay 0005 composite_non_permanent hard 0006 composite_permanent 0007 concrete 0008 coral 0009 corduroy 0010 graded_soil 0011 gravel 0012 hard 0013 ice 0014 laterite 0015 loose 0016 macadam 0017 membrane 0018 mix_in_place 0019 mixed_concrete_asphalt 0020 natural 0021 permanent 0022 sand 0023 snow 0024 sod 0025 steel_grating 0026 steel_planking 0027 temporary 0028 ungraded 0029 unpaved 0030 wood

Table A8. Attributes of Terrain subclass TRAFFICABILITY_VEGETATION.*

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Brush_Density	The fraction of ground covered by undergrowth (e.g., scrub, brush, or bush) within the area of an object.	1	float	none
Maximum_Visibility_Range	The maximum range of visibility into an object, e.g., a forest.	1	integer	meters
Mean_Stem_Diameter	The mean vegetation stem diameter within the area of an object, measured at a height of 1.4 m above the terrain.	0	float	meters
Mean_Stem_Spacing_ QB_Stem_Diameter	Mean_Stem_Spacing of all stems of stem diameter: (0.0, open‡), (2.5, open), (6.0, open), (10.0, open), (14.0, open), (18.0, open), (22.0, open), (25.0, open)	0	float	meters
Vegetation_Type	The type of vegetation.	0	integer	0001 agri_scattered_forests 0002 agri_scattered_trees 0003 almond 0004 apple 0005 artemisia 0006 ash 0007 bamboo 0008 beech 0009 birch 0010 black_spruce 0011 bog 0012 brushland_medium_to_dense 0013 brushland_open_to_medium 0014 carob 0015 casuarina 0016 chestnut 0017 citrus 0018 conifer 0019 cork_oak 0020 corn 0021 cranberry

* Subclass: TRAFFICABILITY_VEGETATION - a generic list of attributes associated with vegetation from which mobility calculations can be made, specifically supports the use of the STNDMob API, but will support other models also.

† The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

‡ The term “open” implies and greater.

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
				0022 cypress 0023 deciduous_unspecified 0024 dry_crops 0025 elm 0026 eucalyptus 0027 evergreen_unspecified 0028 filao 0029 fir 0030 forest_clearing 0031 garden 0032 grass 0033 grassland 0034 grasland_scattered_trees 0035 grove 0036 hardwood 0037 hazel 0038 heath 0039 ilex 0040 joshua_tree 0041 kelp 0042 larch 0043 mangrove 0044 maple 0045 marsh 0046 mixed_crops 0047 mixed_deciduous 0048 mixed_trees 0049 moss 0050 nipa_palm 0051 non_treed 0052 oak 0053 olive 0054 palm 0055 peach 0056 peat 0057 pine 0063 poplar 0064 reed 0065 rhanterium 0066 rice_paddies 0067 sargasso 0068 sea_grass 0069 sea_weed 0070 swamp 0071 swamp_deciduous 0072 swamp_evergreen

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
				0073 swamp_mangrove 0074 swamp_mixed 0075 tropical_grass 0081 vineyards_hops_genseng 0082 walnut 0083 wet_crops 0084 wheat 0085 with_trees 0086 without_trees 3006 undesignated

Table A9. Attributes of Terrain subclass TRAFFICABILITY_WETGAPS.*

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Height_Above_Surface_Level	The height measured vertically from the terrain or WATERBODY surface. For physical objects, measured from the lowest point of the object base (downhill side/downstream side) to the highest point of the object.	1	float	meters
Hydrologic_Permanence	The persistence, over time, of a hydrologic object.	1	integer	0001 dry 3003 missing (unknown) 0002 non_perennial 0004 perennial_or_permanent
Ice_Layer_Thickness	The thickness of the layer of ice that covers a WATERBODY.	1	float	meters
Left_Above_Bank_Slope	The slope (rise/run) of the left bank (facing downstream) of a watercourse above the mean water level.	1	float	none

* Subclass: TRAFFICABILITY_WETGAPS—a generic list of attributes associated with water features from which ground vehicle mobility calculations can be made, specifically supports the use of STNDMob API, but will support other models also.

† Some precipitation and state-of-the-ground attributes will also be found in the Weather category; within the Terrain Category, these values are related to specific instance of the class, within the Weather category they are related to a regional area. In most cases the values will be the same, however not always, e.g. the Snow_Depth based on the Weather category may be 10 cm, for a region, for a specific road within that region the Snow_Depth could be zero because it had been plowed. Mobility Analysis would be based on the Terrain category attribution, which must be dynamically updated based on the Weather category information, reconnaissance reports or other services.

‡ The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Left_Bank_Height	The height of the left bank (facing downstream) of a watercourse, measured from mean water level to the first break in slope above the mean water level.	1	float	meters
Left_Bank_Soil_Cone_ Index	The soil cone index of the left WATERBODY bank.	1	float	kPa
Maximum_Water_Depth	The maximum WATER_DEPTH within the region delineated by an object.	1	float	meters
Mean_Water_Depth	The mean depth of the water from a specified surface datum to a WATERBODY floor, as a positive number.	1	float	meters
Mean_Water_Speed	The mean rate of horizontal motion of a water parcel, estimated within the delineation of a WATERBODY, exclusive of high water current due to runoff or low water current due to drought	1	float	meters per second
Right_Above_Bank_ Slope	The slope (rise/run) of the right bank (facing downstream) of a watercourse above the mean water level.	1	float	none
Right_Bank_Height	The height of the right bank (facing downstream) of a watercourse, measured from mean water level to the first break in slope above the mean water level.	1	float	meters
Right_Bank_Soil_Cone_ Index	The soil cone index of the right WATERBODY bank.	1	float	kPa
Waterbody_Floor_Clutter_De nsity	The spatial density of objects on a WATERBODY floor, within a delineated region, which appear to acoustic sensors to be, but are not, explosive mines.	1	float	
Waterbody_Floor_Material_T ype	The predominant type of material composition of the WATERBODY floor.	1		0001 bedrock sand_and_gravel 0002 clay_and_silt 0003 coral 0004 gravel_and_cobble 0005 mixed_qualities 0006 paved 0007 peat 0008 rocks_and_boulders 0009 rocky_outcrop 0010 sand 0011 sand_and_gravel 0012 sand_and_mud 0013 silty_sands 0014 slash
Waterbody_Surface_Ice_Fra ction	The fraction of a WATERBODY surface covered by ice.	1	float	

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Frozen_Water_Type	The type of frozen water present.	1	integer	0001 ice 0002 melting_snow_or_ice 0003 mixed_snow_and_ice 0004 none_present 0005 slush 0006 snow 0007 snow_over_ice
Snow_Density	The density of accumulated snow on an object.	0	float	(specific gravity) or g/cc
Snow_Depth	The depth of snow and/or ice on the terrain.	0	float	meters
Snow_Only_Depth	The depth of the snow, which may be over terrain, ice, or floating ice.	0	float	meters

Table A10. Attributes of Terrain subclass TRAFFICABILITY_DRYGAPS.*

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Depth_Below_Surface_ Level	The distance measured from the highest point at surface level to the lowest point of an object below the surface, as a positive number.	1	float	meters
Surface_Slope	The maximum slope (rise/run) of the surface of an object.	1	float	none
Height_Above_Surface_ Level	The height measured vertically from the terrain or WATERBODYsurface. For physical objects, measured from the lowest point of the object base (downhill side/downstream side) to the highest point of the object.	1	float	meters
Left_Above_Bank_Slope	The slope (rise/run) of the left bank (facing downstream) of a watercourse above the mean water level.	1	float	none
Left_Bank_Height	The height of the left bank (facing downstream) of a watercourse, measured from mean water level to the first break in slope above the mean water level.	1	float	meters

* Subclass: TRAFFICABILITY_DRYGAPS—a generic list of attributes associated with gap crossing (dry ditches, trenches craters) from which ground mobility calculations can be made, specifically supports the use of the STNDMob API, but will support other models also.

† The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Left_Bank_Soil_Cone_ Index	The soil cone index of the left WATERBODY bank.	1	float	kPa
Right_Above_Bank_Slope	The slope (rise/run) of the right bank (facing downstream) of a watercourse above the mean water level.	1	float	none
Right_Bank_Height	The height of the right bank (facing downstream) of a watercourse, measured from mean water level to the first break in slope above the mean water level.	1	float	meters
Right_Bank_Soil_Cone_ Index	The soil cone index of the right WATERBODY bank.	1	float	kPa

Table A11. Attributes of Terrain subclass TRAFFICABILITY_ROAD.*

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Bed_Height	The height of the bed of a terrain transportation route above the surrounding terrain.	0	float	meters
Existence_Status	The status or existence condition of an object.	0	integer	0001 abandoned 0012 destroyed 0043 operational 0063 under_construction
Median_Width	The width of the divider between multiple road lanes, or railroad tracks.	0	float	meters
Multipass_Surface_ Degradation	The qualitative degree to which terrain or a terrain transportation route has been degraded by the passage of vehicles.	0	integer	0001 heavy 0002 moderate 0003 none_present
Path_Count	The number of independent, parallel paths within a terrain transportation route (e.g., tracks or lanes), including both directions.	1	integer	

* Subclass: TRAFFICABILITY_ROAD—a list of attributes associated with M-COP road features, from which mobility calculations can be made, specifically supports the use of the STNDMob API, but will support other models also, must be used in conjunction with the TRAFFICABILITY_SURFACE subclass.

† The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Road_Lighting_Present	Indication that a road is illuminated by street lights.	0	boolean	
Road_Minimum_Width	The minimum width of a road traveled way, determined by the sum of the widths of includedroad lanes, excluding adjacent hard paved shoulders, sidewalks, and other pathways.	1	float	meters
Sharp_Curve_Radius	The radius of curvature of a sharpe curve in a land transportation route.	1	float	meters
Superelevation	The lateral slope (rise/run) of a terrain transportation route.	1	float	
Terrain_Route_Type	The type of a terrain transportation route.	1	integer	0001 primary_road 0002 secondary_road 0003 super_highway 0004 trail
Terrain_Route_Usable_ Weather_Type	The type of weather conditions under which a terrain transportation route is usable.	1	integer	0001 all 0003 fair_and_dry_only 3002 missing 0004 winter_only
Transportation_Use	The type of primary user, function, or authority of a transportation system.	1	integer	0011 caravan_route 0025 road 0027 road_and_railroad 0034 street 0035 through_routes
Usage	The primary user, function, or controlling authority, of an object.	1	integer	0067 international 0068 interstate 0088 national 0093 non_military 0105 primary 0107 private 0130 secondary 0134 state
Vehicle_Traffic_Flow	The type of flow-pattern of vehicle traffic.	1	integer	0002 one_way 0004 two_way
Vehicular_Speed_Limit	The maximum speed legally permitted on a given stretch of a terrain transportation route.	1	integer	kph
Width	The length of the shorter of two orthogonal linear axes of an object, measured in the horizontal plane. For a square object, measure either axis. For a round object, width is equal to length. For a bridge, the width is the measurement perpendicular to the axis between the bridge piers.	1	float	meters

Table A12. Attributes of Terrain subclass TRAFFICABILITY_BRIDGE_TUNNEL.*

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Blockage_Present	Indication that a passageway is blocked to the movement of vehicles and/or personnel.	1	boolean	
Bridge_Design	The structural design characteristics of a bridge or bridge span.	1	integer	0001 arch 0002 bailey 0003 cantilever 0004 deck 0005 floating 0008 medium_girder 0009 mltry_armour_veh_launched 0010 mltry_heavy_assault 0011 mltry_m4t6 0012 mltry_pmp 0013 mltry_tactical 0014 mltry_tmm 0015 mobile_assault 0017 ribbon 0018 slab 0020 stringer_beam 0021 suspension 0022 transporter_ferry 0023 truss 0025 pontoon 3002 missing 3006 undesignated
Bridge_Level_Count	The number of levels of a bridge which carry vehicle and/or personnel traffic.	1	integer	
Bridge_Span_Count	The number of spans in a bridge or aqueduct.	1	integer	
Completion_Percentage	The extent of completion for an object in terms of fractional ascension from start of construction to completion of construction.	1	float	
Force_Identifier	A textual identify of a military or civilian force.	0	String	

* Subclass: TRAFFICABILITY_BRIDGE_TUNNEL—a list of attributes associated with M-COP Bridge and tunnel features, from which mobility calculations can be made, specifically supports the use of the STNDMob API, but will support other models also, must be used in conjunction with the TRAFFICABILITY_ROAD subclass.

† The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Length	The length of the longer of two orthogonal linear axes of an object, measured in the horizontal plane. For a square object, measure either axis. For a round object, measure the diameter. For a bridge, the length is the distance between the bridge piers.	1	float	meters
Load_Class_One_Way_Tracked	The weight bearing capacity of a bridge or bridge span for one way tracked traffic; also known as the military load classification, Type 3.	1	integer	
Load_Class_One_Way_Wheeled	The weight bearing capacity of a bridge or bridge span for oneway wheeled traffic; also known as the military load classification, Type 1.	1	integer	
Load_Class_Two_Way_Tracked	The weight bearing capacity of a bridge or bridge span for two way tracked traffic; also known as the military load classification, Type 4.	1	integer	
Load_Class_Two_Way_Wheeled	The weight bearing capacity of a bridge or bridge span for two way wheeled traffic; also known as the military load classification, Type 2.	1	integer	
Overall_Bridge_Height	The vertical distance measured from the lowest point at terrain or WATERBODY level to the highest portion of bridge (including any bridge superstructure).	1	float	
Overhead_Clearance	The least distance between a terrain transportation route and any obstruction vertically above it; the overhead clearance.	1	float	
Primary_Material_Type	The type of primary material composition of an object.	0	integer	0002 aluminum 0006 basalt_masonry 0025 concrete 0036 earthen 0080 masonry 0109 rock 0136 steel 3002 missing 3006 undesignated

Attribute Name (from EDCS)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units†
Transportation_Use	The type of primary user, function, or authority of a transportation system.	1	integer	0013 highway_road 0021 pedestrian 0024 railroad 0025 road 0026 road_and_pedestrian 0027 road_and_railroad 3002 missing 3006 undesignated
Tunnel_Cross_Section	The characteristic cross-sectional shape of a tunnel, viewed from the ends.			0001 arch 0002 box 0003 circular
Underbridge_Clearance	The clearance below a bridge, measured from the bridged lowest surface level to the base of the lower of either a cross beam or the lowest bridge deck; the underbridge clearance.	1	integer	meters

Table A13. Attributes of Terrain subclass TRAFFICABILITY_RAILROAD.*

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Bed_Height	The height of the bed of a terrain transporation route above the surrounding terrain.	1	float	meters
Existence_Status	The status or existance condition of an object.	1	integer	0001 abandoned 0012 destroyed 0013 dismantled 0043 operational 0063 under_construction

* Subclass: TRAFFICABILITY_RAILROAD—a list of attributes associated with M-COP railroad features, from which mobility calculations can be made. Currently, this list of attributes can stand alone, although if would be desirable to merge it with TRAFFICALBILITY_ROAD AND TRAFFICALBILITY_SURFACE.

† Some precipitation and state-of-the-ground attributes will also be found in the Weather category; within the Terrain category, these values are related to specific instance of the class, within the Weather category they are related to a regional area. In most cases the values will be the same, however not always, e.g. the snow cover depth based on the Weather category may be 10 cm, for a region, for a specific road within that region the snow depth could be zero because it had been plowed. Mobility Analysis would be based on the Terrain category attribution, which must be dynamically updated based on the Weather category information, reconnaissance reports or other services.

‡ The OOS EDM does not specify units of measure for these attributes. Each attribute needs a subclass "UnitsOfMeasure" values stated are recommended.

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Frozen_Water_Type	The type of frozen water present.	1	integer	0001 ice 0002 melting_snow_or_ice 0003 mixed_snow_and_ice 0004 none_present 0005 slush 0006 snow 0007 snow_over_ice
Maximum_Standing_Water_Depth	The maximum depth of non-flowing/standing water within the region delineated by an object.	1	float	meters
Multipass_Surface_Degradation	The qualitative degree to which terrain or a terrain transportation route has been degraded by the passage of vehicles.	1	integer	0001 heavy 0002 moderate 0003 none_present
Name	The textual identifier or code used for an object.	0	string	
Path_Count	The number of independent, parallel paths within a terrain transportation route (e.g., tracks or lanes), including both directions.	1	integer	
Primary_Material_Type	The type of primary material composition of an object.	1	integer	0025 concrete_steel 0136 steel 0155 wood
Railroad_Gauge	The gauge of a railroad.	1	integer	0002 broad 3002 missing 0003 narrow 0004 normal_country_specific 0005 us_standard
Railroad_Power_Source	The source of electrical power for a railroad.	1	integer	0001 electrified_track 3002 missing 0002 non_electrified 0003 overhead_electrified_ non_electrified
Railroad_Type	The type of railroad system used to support various transportation uses.	1	integer	0001 abandoned 0002 branch_line 0003 car_line 0004 inclined 0005 logging 0006 main_line 0007 marine 3002 missing 0009 monorail 0010 railroad_in_road 0012 subway 0013 tramway

Attribute Name (from EDCS†)	Attribute Definition	Cardinality	Data Type	Enumeration Values or Units‡
Relative_Location	The location of an object relative to the surrounding region.	1	integer	0001 above_srf 0007 below_wtr_body_surface 3002 missing 0030 on_terrain
Snow_Density	The density of accumulated snow on an object.	0	float	(specific gravity) or g/cc
Snow_Depth	The depth of snow and/or ice on the terrain.	0	float	meters
Snow_Only_Depth	The depth of the snow, which may be over terrain, ice, or floating ice.	0	float	meters
Surface_Material_Type	The surface material composition of an object, excluding internal structural material.	1	integer	0024 concrete_steel 0137 steel 0155 wood
Surface_Slippery	Indication that a surface is slippery. Examples: wet grass, and wet clay soil.	1	boolean	
Terrain_Roughness_Root_Mean_Square	The roughness of terrain based on elevation variations, calculated using the root-mean-square (RMS) value of the detrended terrain elevations measured at a spatial frequency of approximately 0.3 m.	0	float	meters
Terrain_Trafficability_Fine	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a fine resolution estimate of trafficability.	0	integer	0696 id_724
Terrain_Trafficability_Medium	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a medium resolution estimate of trafficability.	0	integer	0001 id_000
Terrain_Trafficabilty_Coarse	The categorized character of the terrain as it affects the movement of ground forces (e.g., military units, vehicles, or infantry) in terms of a coarse resolution estimate of trafficability.	0	integer	0005 default

Table A14. Attributes of Terrain subclass MANEUVER_URBAN.*

Attribute Name (from EDCS)	Enumeration Values	Enumeration Definitions
Urban_Terrain_Zone_Type†	attached_1	Center of older cities with high concentrations of buildings with multiple floor levels (5 to 50). Buildings occupy nearly all of their lots and are flush to sidewalks and they either attach or about neighbors. Usually bordered by attached_1 and discrete_clust_1 zones.
	attached_2	Buildings fill lots to their perimeters, but are not as tall as those in attached_1. Buildings are attached or abutted to neighbors, are flush to streets, and are typically 5 to 10 floor levels. Land use is mainly apartment houses with some hotels and offices.
	attached_3	Attached or abutted individual buildings (for example: row houses), typically of 1 to 4 floor levels and most often residential. Buildings have little or no setback from sidewalk and they usually have a narrow back yard.
	attached_4	Attached or abutted buildings, 2 to 10 floor levels, flush to the street with no setback or side set. Buildings have industrial or storage functions with little space for parking. Non-built-upon space is primarily for storage of material.
	attached_5	Attached or abutted buildings, along commercial ribbon streets. Typically 1 to 5 floor levels, and old in age (newer types are typically of the discrete_clust_5 zone), with no setback from sidewalks. The buildings often have a commercial function on the ground floor, with apartments above.
	attached_6	Attached building or buildings, 1 to 7 floor levels; often a single institutional land use along a street otherwise occupied by office buildings or stores, e.g., a church, government building, or a hospital. This is in effect a single instance of a differing building rather than a zone of multiple buildings.
	attached_buildings	Attached buildings of an unknown type or function.
	close_set_buildings	Close-set buildings of an unknown type or function.
	discrete_clust_1	Newer (post 1950) high-rise buildings (20 to 50 floor levels) that often have "skins" of some decorative material (for example: glass). Typical use is for office buildings, while some are hotels. Buildings are spaced at approximately 13 m.
	discrete_clust_2	Close-set apartment buildings (3 to 10 floor levels) with some set back from the lot boundary. Buildings are usually long and narrow with the narrow end to the street. Maximum spacing of the buildings is 13 m.
	discrete_clust_3	Common single family detached structures occupying a minimum amount of land. Houses are set back from the street, but have narrow separations between them, and narrow back yards. Maximum spacing of the buildings is 13 m, and buildings are typically 1 to 3 floor levels.
	discrete_clust_4	Narrow, close-set buildings (2 to 10 floor levels) adjoining

* Subclass MANEUVER_URBAN: A group of attributes for Built-Up area features, used for Maneuver Analysis in urban Terrain, these attributes are from the EDCS, the urban zone types (UTZ) are based on Liu and Ellefsen (1996), and the street patterns from FACC (DGIWG 2000).

† Definition: The type of an UTZ based on the characterization of buildings and their density.

Attribute Name (from EDCS)	Enumeration Values	Enumeration Definitions
		railway tracks with docks for access by ground vehicles. Buildings are often long and narrow, with the narrow end abutting the railway tracks. Maximum spacing of the buildings is 13 m.
	discrete_clust_5	Detached buildings (1 to 5 floor levels) set back from the street to provide parking and access. These buildings often exhibit store windows at front. The majority of the terrain is used for parking ground vehicles. Maximum spacing of the buildings is 13 m.
	discrete_clust_6	Master planned development with specifically set buildings of 1 to 7 floor levels, and vegetated sites that provide elegantly designed facilities and a sense of openness. Uses include schools, colleges, hospitals, or churches. Maximum spacing of the buildings is 13 m.
	discrete_clust_8	Outer city.
	discrete_open_1	Large buildings (1 to 4 floor levels) with a distinctive lack of exterior windows, internally partitioned into individual retail facilitys, and surrounded by extensive vehicle lots. The main building is normally located in the center or at the rear of the vehicle lot, with vehicle lots consuming approximately 70 % of the terrain. Typical use is for shopping malls, professional/business parks. Spacing between buildings is 13 m or greater.
	discrete_open_2	Evenly spaced buildings in planned settings supporting fairly high population densities yet providing collective open space between buildings. Intervening ground space is landscaped or vehicle lots. Typical spacing between buildings is 13 m with buildings being 2 to 40 floor levels.
	discrete_open_3	Single family detached buildings occupying a minimum amount of land. Buildings are set back on all sides. This zone is similar to discrete_clust_3 with the difference being that discrete_open_3 signifies more space between buildings, and often more vegetation. Spacing between buildings is 13 m or greater, with buildings being 1 to 3 floor levels.
	discrete_open_4	Modern industrial space with access for trucks and parking space, typically used for industry or storage. Buildings are widely separated and have paved surfaces around them. Spacing between buildings s is 13 m or greater, and buildings are 1 to 4 floor levels.
	discrete_open_5	Modern, large, commercial buildings (1 to 5 floor levels) with large vehicle lots and located along wide streets; Discrete-open-5. Typically used for large retail facilitys, equipment, automobile dealerships, and restaurants. Space between the buildings is 13 m or greater.
	discrete_open_6	Sizeable, master planned development with large buildings and maintained heavily vegetated sites that provide elegantly designed facilities and a sense of openness. Often used for schools, colleges, hospitals, churches, and administrative facilities. Spacing between buildings is 13 m or greater, and buildings are typically 1 to 7 floor levels.
	does_not_conform	Configuration does not conform to any urban terrain zone.
	widely_spaced_buildings	Widely separated detached buildings of an unknown type or function.

Attribute Name (from EDCS)	Enumeration Values	Enumeration Definitions
Urban_Street_Pattern*	curvilinear_cluster	Curvilinear cluster with limited access from outside.
	irreg_grid	Rectangular or irregular grid.
	irreg_radial	Concentric or radial irregular.
	linear_strip	Linear strip.
	mixed_cluster	Mixed curvilinear_cluster and rectangular grid.
	mixed_grid	Mixed concentric or radial and rectangular grid.
	mixed_radial	Mixed curvilinear_cluster and concentric or radial.
	reg_grid	Rectangular or regular grid.
	reg_radial	Concentric or radial regular.

* Definition: The predominant geometric configuration of streets found within a delineated terrain surface region.

APPENDIX B: M-COP OBSTACLE CATEGORY

Table B1 presents the enumeration values for a Feature_Type attribute of each of the Obstacle classes. These enumeration values are the same as their sources. For reader ease the formats have been changed to the nomenclature chosen for this report. The intent for the M-COP is to use the OOS EDM values; the other sources are shown only for comparison. The terms *area*, *line*, *directed_line*, *3d_line*, and *point* denote the geometry type.

Table B1. Enumeration values for Feature_Type attribute of each of the Obstacle classes.

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x			abatis
x			antitank_wall
x	barrier *line*	barrier	
			biologically_contaminated_area
			chemically_contaminated_area
x	cross_country_barrier *line*		belt_obstacle
x	dragon_teeth *line*, dragon_teeth *point*	dragon_teeth	fixed_and_prefabricated_antitank_ obstacles, tetrahedrons, dragon_teeth_and_other_similar_obstacles,
x			moveable_antitank_obstacles, tetrahedrons, dragon_teeth_and_other_similar_obstacles
x	engineer_trench *directed_line*	trench	completed_antitiank_ditch, antitank_ditch_under_construction, antitank_ditch_reinforced_with_antitank_mines
x	fence *line*	fence	unspecified, single_fence, double_fence, double_apron_fence, low_wire_fence, high_wire_fence, single_strand_concertina, double_strand_concertina, triple_strand_concertina,
	field_expedient_obstacle *point*		
	hedgerow *line*	hedgerow	
	log_obstacle *point*		

JC3IEDM geographic or facility category code	OOS EDM (version 1.7)	FACC (DGIWG 2000)	FM 21-31 (HQDA 1961)
x	minefield *area*		booby_trap, antipersonnel_mines, antitank_mine, antitank_mine_with_anti_handling_device, unspecified_mine, mine_cluster, wide_area_mine, completed_minefield, planned_minefield, antipersonnel_minefield, antitank_minefield, antitank_minefield_with_gap, scatterable_mines_minefield_with_self_destruct, antipersonnel_ minefield_reinforced_with_scatterable_mines, scatterable_ minefield_(antitank_mines)_with_self_ destruct, mined_area, executed _volcano_antitank_minefield
		miscellaneous_obstacle	
			obstacle_line
			obstacle_zone
			obstacle_restricted_area
			radioactive_area
x	rock_drop *point*		
	terrain_crater *point*		
x	terrain_cut *directed_line*		
			unexploded_ordnance_area
x	vehicle_barrier *point*		
x	wire_obstacle *line*		

Table B2. Attributes of selected Obstacle category classes.

Class (from EDCS)	Attribute Name	Attribute Description	Enumeration Values
BARRIER	Completion_Percentage	The extent of completion for an object in terms of fractional ascension from start of construction to completion of construction.	
	General_Damage_Fraction	The extent of physical injury/damage to an object in terms of fractional degradation from a healthy state.	1/4: Slight Injury/Damage 2/4: Moderate Injury/Damage 3/4: Heavy Injury/Damage 4/4: Fatally Injured or Completely Destroyed
	Height_Above_Surface_Level	The distance measured from the highest point at surface level to the lowest point of an object below the surface, as a positive number.	
	Numeric_Object_Identifier	The numeric identifier of an object.	

Class (from EDCS)	Attribute Name	Attribute Description	Enumeration Values
	Prepared_Explosive_ Destruction_ Completion_Fraction	The extent to which an object (e.g., a structure or terrain obstacle), has been prepared for destruction by explosives in terms of fractional completion.	1/4: Partially Prepared 2/4: Half Prepared 3/4: Mostly Prepared 4/4: Completely Prepared
	Surface_Slope	The maximum slope (rise/run) of the surface of an object.	
CROSS_COUNTRY_ BARRIER LINE	Completion_Percentage	The extent of completion for an object in terms of fractional ascension from start of construction to completion of construction.	
	Depth_Below_Surface_Level	The distance measured from the highest point at surface level to the lowest point of an object below the surface, as a positive number.	
	Force_Identifier	A textual identify of a military or civilian force.	
	General_Damage_Fraction	The extent of physical injury/damage to an object in terms of fractional degradation from a healthy state.	1/4: Slight Injury/Damage 2/4: Moderate Injury/Damage 3/4: Heavy Injury/Damage 4/4: Fatally Injured or Completely Destroyed
	Height_Above_Surface_Level	The height measured vertically from the terrain or WATERBODY surface. For physical objects, measured from the lowest point of the object base (downhill side/downstream side) to the highest point of the object.	
	Prepared_Explosive_ Destruction_Completion_Fraction	The extent to which an object (e.g., a structure or terrain obstacle), has been prepared for destruction by explosives in terms of fractional completion.	1/4: Partially Prepared 2/4: Half Prepared 3/4: Mostly Prepared 4/4: Completely Prepared
	Terrain_Obstacle_Type	The type of a terrain obstacle.	0001 abatis 0002 antipersonnel_wire 0003 antitank_ditch 0004 antivehicle_wire 0007 craters 0014 dragon_teeth 0018 hedge_hogs 0019 linear_concrete_barrier 3002 missing 0024 road_block_or_crib 0025 rubble_missing 0027 tetrahedrons 3006 undesignated
	Surface_Slope	The maximum slope (rise/run) of the surface of an object.	

Class (from EDCS)	Attribute Name	Attribute Description	Enumeration Values
	Width	The length of the shorter of two orthogonal linear axes of an object, measured in the horizontal plane. For a square object, measure either axis. For a round object, width is equal to length. For a bridge, the width is the measurement perpendicular to the axis between the bridge piers.	
ENGINEER_TRENCH *directed_line*	Trafficablity_Surface	From Terrain category.	
	Trafficability_Drygap	From Terrain category.	
	Completion_Percentage	The extent of completion for an object in terms of fractional ascension from start of construction to completion of construction.	
	Overall_Vertical_Dimension	The overall vertical dimension that includes both above and below.	
	Terrain_Gap_Width	The minimum horizontal bridging distance between the banks of a localized terrain depression, as measured perpendicular to the center line of its length along the terrain depression.	
	Terrain_Obstacle_Type	The type of a terrain obstacle.	0003 antitank_ditch 0011 ditch 0012 ditch_with_berm 0016 emplaced_boulder
	Width	The length of the shorter of two orthogonal linear axes of an object, measured in the horizontal plane. For a square object, measure either axis. For a round object, width is equal to length. For a bridge, the width is the measurement perpendicular to the axis between the bridge piers.	
MINEFIELD	Trafficablity_Surface	From Terrain category.	
	Case_Burial_Fraction	The fraction of an equipment case that is buried beneath the terrain or WATERBODY floor.	0/4: On-surface 2/4: Half-buried 4/4: Completely buried
	Completion_Percentage	The extent of completion for an object in terms of fractional ascension from start of construction to completion of construction.	
	Duration_Overview	The quantity of time in a gross sense that the object may be assumed to be active.	0001 infinite 0002 long 0003 medium 0005 none 0099 other 0004 short

Class (from EDCS)	Attribute Name	Attribute Description	Enumeration Values
	Explosive_Mine_Type	The type of an explosive mine.	0002 antipersonnel 0003 antitank 0004 antitank_smart 0006 aquatic_bottom 0007 aquatic_buried 0009 aquatic_floating 0011 aquatic_moored 0012 aquatic_proud 0015 decoy 3002 missing 0019 mixed 3006 undesignated
	Force_Identifier	A textual identify of a military or civilian force.	
	General_Damage_Fraction	The extent of physical injury/damage to an object in terms of fractional degradation from a healthy state.	1/4: Slight Injury/Damage 2/4: Moderate Injury/Damage 3/4: Heavy Injury/Damage 4/4: Fatally Injured or Completely Destroyed
	Mine_Allegiance	The military allegiance of the force responsible for the creation or maintenance of an EXPLOSIVE_MINE.	0001 alternate_1 0002 alternate_2 0003 alternate_3 0004 alternate_4 0005 alternate_5 0006 alternate_6 0007 alternate_7 0008 alternate_8 0009 alternate_9 0010 friend 0011 hostile 3002 missing 0012 neutral
	Mine_Density	The areal density of explosive mines within a minefield. Units of 1 mine/m^2.	
	Minefield_Marking_Type	Specifies by whom and how the MINEFIELD is marked.	0003 all_sides 0997 data_withheld 0002 marked 0998 not_applicable 0999 other 0001 unmarked
	Numeric_Object_Identifier	The numeric identifier of an object.	
	Prepared_Explosive_ Destruction_Completion_Fraction	The extent to which an object (e.g., a structure or terrain obstacle), has been prepared for destruction by explosives in terms of fractional completion.	1/4: Partially Prepared 2/4: Half Prepared 3/4: Mostly Prepared 4/4: Completely Prepared

APPENDIX C: M-COP WEATHER CATEGORY

Table C1. Weather class: PRECIPITATION.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Accum_Precip	The depth of PRECIPITATION (water-equivalent) that accumulated over a measurement period of time.				IMETS, EDCS
Accum_Precip_6_Hour	The depth of PRECIPITATION (water-equivalent) that accumulated over a 6-hr period.				IMETS, EDCS
Accum_Precip_3_Hour	The depth of PRECIPITATION (water-equivalent) that accumulated over a 3-hr period.				IMETS, EDCS
Accum_Precip_6_Hour	The depth of PRECIPITATION (water-equivalent) that accumulated over a 6-hr period.				IMETS, EDCS
Accum _Precip_24_Hour	The depth of PRECIPITATION (water-equivalent) that accumulated over a 24-hr period.				IMETS, EDCS
Hail_Size	The diameter of the largest hailstone observed.				JMCDM
Precipitation_Intensity	Intensity of PRECIPITATION.	0	none	No PRECIPITATION is present.	IMETS, EDCS
		1	light	For rain and ice_pellets: up to 2.54 mm per hr or up to 0.254 mm in 6 min. For snow and drizzle: visibility greater than 800 m.	IMETS, EDCS
		2	moderate	For rain and ice_pellets: more than 2.54 mm up to 7.62 mm per hr or more than 0.254 mm up to 0.762 mm in 6 min. For snow and drizzle: visibility moderate.	IMETS, EDCS
		3	heavy	For rain and ice_pellets: more than 7.62 mm per hr or more than 0.7 62 mm in 6 min. For snow and drizzle: visibility less than or equal to 400 m.	IMETS, EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Precipitation_Phase	The state (liquid/solid disposition) of precipitable water.	1	liquid	Composed of only liquid components.	EDCS
		2	mixed	Composed of both liquid and solid components.	EDCS
		3	solid	Composed of frozen components.	EDCS
Precipitation_Rate	The rate of PRECIPITATION.				IMETS, EDM-AOS, EDCS
Precipitation_Type	The type of PRECIPITATION.	1	diamond_ dust	solid_precipitation that falls from a clear sky in very small crystals of ice, often so tiny that they appear to be suspended in the air.	EDCS
		2	drizzle	Fairly uniform PRECIPITATION in very fine droplets (outside diameter less than 0.5 mm) that are located very close to one another and are falling from a cloud.	EDCS, IMETS
		3	freezing_ drizzle	drizzle that falls in liquid form but freezes upon impact to form a coating of ice_glaze on the land and on exposed objects.	EDCS
		4	freezing_ rain	rain that falls in liquid form but freezes upon impact to form a coating of ice_glaze on the land and on exposed objects.	EDCS, IMETS
		5	graupel	A form of frozen PRECIPITATION consisting of snowflakes or ice_crystals and supercooled water droplets frozen together.	EDCS
		6	hail	solid_precipitation of either transparent or partly or completely opaque particles of ice (hailstones), usually spherical, conical, or irregular in form and of outside diameter generally between 5 and 50 mm, that falls from a cloud either separately or agglomerated into irregular lumps.	EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		7	ice_ crystals	A fall of any one of a number of macroscopic crystalline forms of ice, including hexagonal columns and platelets, dentritic crystals, needles or a combination of these forms.	EDCS
		8	ice_pellets	solid_precipitation of transparent or translucent particles of ice that are spherical or irregular, rarely conical, and that have an outside diameter of 5 mm or less.	EDCS
		9	liquid_ precip_ freezing	Liquid PRECIPITATION that freezes upon contact to form a coating of ice_glaze upon the land and exposed objects.	EDCS, IMETS
		10	liquid _precip_ not_freez- ing	Liquid PRECIPITATION that does not freeze upon contact.	EDCS, IMETS
		11	no_precip	No PRECIPITATION.	EDCS, IMETS
		12	precip	Unspecified PRECIPITATION.	EDCS
		13	rain	PRECIPITATION of particles of liquid water either in the form of drops of more than 5 mm in outer diameter or in the form of widely scattered drops.	EDCS, IMETS
		14	rain_and_ drizzle	PRECIPITATION consisting of a mixture of rain and drizzle.	EDCS
		15	rain_and_ hail	PRECIPITATION consisting of a mixture of rain and hail.	EDCS
		16	rain_and_ snow	PRECIPITATION consisting of a mixture of rain and snow.	EDCS
		17	sleet	snow that has partially melted on its fall to the ground.	EDCS
		18	small_hail	hail with an outside diameter less than 0.64 cm which is a form of ice_pellets.	EDCS
		19	snow	solid_precipitation composed of white or translucent crystals of ice that are chiefly in complex branch hexagonal form and are often agglomerated into snowflakes or the layer formed by them on the land.	EDCS, IMETS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		20	snow_ grains	solid_precipitation of very small opaque white particles of ice that fall from a cloud and are fairly flat or elongated with outside diameters generally less than 1 mm; the solid equivalent of drizzle.	EDCS
		21	snow_ pellets	PRECIPITATION of white and opaque particles of ice, which fall from a cloud and which are generally conical or rounded, with diameters attaining as much as 5 mm.	EDCS
		22	solid_ precip	PRECIPITATION of ice.	EDCS, IMETS
Snow_Accumulation _Depth	The frozen or freezing PRECIPITATION that accumulates during a period of time.				EDCS, JMCDM
Snow_Accumulation _Condition_Code	The code that denotes specific conditions associated with the measurement of the depth of snow accumulation.	0	none		JMCDM
		1	measurement_ impossible _or_ inaccurate		JMCDM
		2	snow_ cover_not _ continuous		JMCDM
		3	trace		JMCDM
		4	measurable		JMCDM
Snow_Age	The time difference between the reference date and the date of the last measurable snow precipitation.				EDCS
Snow_Density	The density of accumulated snow precipitation on an object.				edcs

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Snow_Depth*	A frozen accumulation of PRECIPITATION on the ground.				IMETS, EDM-AOS, EDCS, JMCDM
Snow_Depth_Category	The categorical (coded) amount of snow that has accumulated.	1	none_ present	No snow present.	EDCS
		2	trace	Light (trace) dusting of snow in which the visual appearance of the original landscape predominates, less than 1 cm accumulation.	EDCS
		3	slight	Dusting of snow in which the white color of the snow predominates but the visual appearance of the original landscape is still evident; 1–2 cm accumulation.	EDCS
		4	moderate	Snow_Depth_Dimension of 2 to 5 cm.	EDCS
		5	moderate_ to_ heavy	Snow_Depth_Dimension of 5 to 20 cm.	EDCS
		6	heavy	Snow_Depth_Dimension greater than 20 cm.	EDCS
Snow_Depth_ Condition_Code	The code that denotes specific conditions associated with the measurement of snow in a PRECIPITATION observation.	0	none		JMCDM
		1	measurement_ impossible_ or_ inaccurate		JMCDM
		2	snow_ cover_not _continu-ous		JMCDM
		3	trace		JMCDM
		4	measurea ble		JMCDM
Snow_Depth_Dimen-sion	Depth of snow and ice on the ground.				JMCDM

* Snow_Depth pertaining to meteorological conditions.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Snow_Depth_ Equivalent_Water_Depth_ Dimension	The depth of the liquid content of solid PRECIPITATION that has accumulated on the ground.				JMCDM
Snow_Drift_Height_ Dimension	Maximum height of snow drifts.				JMCDM
Snow_Melting_Rate	Estimated melting rate of snow on the ground.				JMCDM
Thunderstorm_Intensity	The intensity of a thunderstorm as determined by its Precipitation_Rate.	1	light	Up to 2.54 mm per hr; maximum 0.254 mm in 6 min.	EDCS
		2	moderate	More than 2.54 mm up to 7.62 mm per hr; more than 0.254 mm up to 0.762 mm in 6 min.	EDCS
		3	heavy	More than 7.62 mm per hr; more than 0.762 mm in 6 min.	EDCS
Thunderstorm_Present	An indication that a thunder storm is present.	0	not_ present		EDCS
		1	present		EDCS
Thunderstorm_Probability	The probability of the occurrence of a thunderstorm.				EDCS, JMCDM

Table C2. Weather class: ATMOSPHERE.

Subclass	Attribute Name	Attribute Definition	Source
AIR_TEMPERATURE	2m_Air_Temperature	The temperature of the air at 2 m.	IMETS, JMCDM
	Height_Of_Measurement	Height AIR_TEMPERATURE was taken.	JMCDM
	Maximum_Air_Temperature	The maximum AIR_TEMPERATURE that occurred at a given LOCATION during a specific Time_Period.	EDCS, JMCDM
	Maximum_Air_Temperature_Period	The Time_Quantity for which a Maximum_Air_Temperature was recorded.	EDCS, JMCDM
	Mean_Air_Temp	The mean AIR_TEMPERATURE.	EDCS, JMCDM
	Mean_Air_Temp_Clim	The mean historical (climatology) AIR_TEMPERATURE.	EDCS
	Mean_Air_Temp_Clim_Std_Dev	The standard deviation of Mean_Air_Temp_Clim measurements.	EDCS
	Mean_Air_Temp_Difference_Clim	The historical (climatology) quantity of mean difference between the Mean_Air_Temperature at an initial time and the Mean_Air_Temperature at an offset from that time.	EDCS

Subclass	Attribute Name	Attribute Definition	Source
	Mean_Air_Temp_Min_Difference_Clim	The historical (climatology) quantity of maximum difference between the Mean_Air_Temperature at an initial time and the Mean_Air_Temperature at an offset from that time.	EDCS
	Minimum_Air_Temperature	The lowest AIR_TEMPERATURE attained during a Time_Quantity.	EDCS, JMCDM
	Minimum_Air_Temperature_Period	The Time_Quantity for which a Minimum_Air_Temperature was recorded.	EDCS, JMCDM
	Surface_Air_Temperature	AIR_TEMPERATURE at the surface.	IMETS, JMCDM
	Wind_Chill_Index	The temperature with nearly still air that (ideally) produces the same rate of heat loss from the human body as the given combination of temperature and wind speed.	EDCS
	Wind_Chill_Temperature_Index	A means of quantifying the combined effect of low AIR_TEMPERATURE and Wind_Speed on the body temperature of humans that may result in hypothermia.	EDCS
DEW_POINT	Dew_Point_Depression	The difference between AIR_TEMPERATURE at a location and the Dew_Point_Temperature at that location.	EDCS
	Dew_Point_Temperature	The temperature to which a given parcel of air must be cooled at constant atmospheric pressure and water vapor content for saturation to occur.	EDCS, JMCDM
	Mean_Dew_Point_Temperature	The mean Dew_Point_Temperature.	EDCS, JMCDM
HUMIDITY	Absolute_Humidity	The ratio of the mass of water vapor to the volume occupied by the mixture of water vapor and dry air.	EDCS
	Relative_Humidity	The ratio of vapor pressure to saturation vapor pressure, where vapor pressure is the pressure exerted by the molecules of water vapor and saturation vapor pressure is the pressure exerted by molecules of water vapor in air that has attained saturation	EDCS
	Specific_Humidity	The ratio of the mass of water vapor to the total mass of a volume of moist air.	EDCS
	Relative_Humidity_Minimum_Temperature	The Relative_Humidity at the time of the lowest AIR_TEMPERATURE.	EDCS
LIGHTNING	Lightning_Loc_Err_Ellps_Angle	The Geodetic_Azimuth of the semi-major axis of the error ellipse of the LOCATION of a stroke of LIGHTNING.	EDCS

Subclass	Attribute Name	Attribute Definition	Source
	Lightning_Loc_Err_Major_Axis	The length of the semi-major axis of the error ellipse at the LOCATION of a stroke of LIGHTNING.	EDCS
	Lightning_Loc_Err_Minor_Axis	The length of the semi-minor axis of the error ellipse at the LOCATION of a stroke of LIGHTNING.	EDCS
	Lightning_Probability	The probability that LIGHTNING will occur.	EDCS
	Route_Weather_Type	The weather conditions under which a land transportation route is passable or remains open (has enumerations).	EDCS

Table C3. Weather class: WIND.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Dust_Production_Rate	A number between 0 and 1 inclusive representing the linearly scaled fraction of the production of dust at an object that has been induced by ground movement or surface wind.				EDCS
Maximum _Wind_Gust_Spread	The maximum Wind_Gust_Spread.				EDCS, JMCDM
Maximum_Wind_Speed	The maximum or peak Wind_Speed including gusts.				EDCS, JMCDM
Mean_Wind_Speed	The mean Wind_Speed.				EDCS, JMCDM
Mean_Wind_Speek_Std_ Dev	The standard deviation of Mean_Wind_Speed measurements.				EDCS
Surface_Wind_Speed	The Wind_Speed 10 m above the earth.				EDCS
Wind_Calm_Fraction _Climatology	The historical (climatology) fraction of calm Wind_Speeds (less than 2.575 m/s).				EDCS
Wind_Category	A categorization of wind based on Wind_Speed and its variabilitiy.	1	calm	The absence of air motion or Wind_Speeds is less than 1.582 kph.	EDCS, JMCDM
		2	no_ gusts	No gusts.	EDCS, JMCDM
		3	squall	An abrupt and large increase in Wind_Speed with a duration on the order of minutes which diminishes rather suddenly.	EDCS, JMCDM
		4	variable	Wind that changes direction frequently.	EDCS, JMCDM
Wind_Direction	The Geodetic_Azimuth of the direction from which the wind is blowing.				EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Wind_Direction_Climatology	The mean historical (climatology) Wind_Direction.				EDCS, JMCDM
Wind_Direction_Octant_Climatology	The historical (climatology) Wind_Direction categorized by cardinal vector octant (45 arc degree sector centered on a cardinal direction).	1	north		EDCS
		2	north_east		EDCS
		3	east		EDCS
		4	south_east		EDCS
		5	south		EDCS
		6	south_west		EDCS
		7	west		EDCS
		8	north_west		EDCS
Wind_Direction_Octant_Fraction	A number between 0 and 1 inclusive representing the linearly scaled fraction of observations reporting Wind_Directions within a cardinal vector octant (a 45 arc degree sector centered on a cardinal direction).				EDCS, JMCDM
Wind_Direction_Variability	The angular range of the Wind_Direction during a relatively short reporting period.				EDCS
Wind_Gale_Force_Rate_Climatology	The fraction of historical (climatology) gale force Wind_Speeds (greater than or equal to 17.49 m/s).				EDCS
Wind_Gust_Speed	The speed of a sudden, brief increase in Wind_Speed.				EDCS, JMCDM
Wind_Gust_Spread	The difference between adjacent peaks and lulls in Wind_Speed.				EDCS, JMCDM
Wind_Speed	Ratio of distance covered by air to the time taken to cover it.				EDCS, JMCDM
Wind_Speed_20_Percentile_Climatology	The minimum Wind_Speed that is greater than 20 percent of the Wind_Speed_Climatology.				EDCS, JMCDM
Wind_Speed_50_Percentile_Climatology	The minimum Wind_Speed that is greater than 50 percent of the Wind_Speed_Climatology.				EDCS, JMCDM
Wind_Speed_80_Percentile_Climatology	The minimum Wind_Speed that is greater than 80 percent of the Wind_Speed_Climatology.				EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Wind_Speed_Climatology	The mean historical (climatology) Wind_Speed.				EDCS, JMCDM
Wind_Speed_Climatology _Std_Dev	The standard deviation of Wind_Speed_Climatology measurements.				EDCS
Wind_Speed_East	The Wind_Speed in the east-west direction, where east is positive.				EDCS
Wind_Speed_East_ Climatology	The mean historical (climatology) Wind_Speed_East.				EDCS, JMCDM
Wind_Speed_East_ Clim_Std_Dev	The standard deviation of the Wind_Speed_East_Climatology.				EDCS
Wind_Speed_North	The Wind_Speed in the north-south direction, where north is positive.				EDCS
Wind_Speed_North_ Climatology	The mean historical (climatology) Wind_Speed_North.				EDCS, JMCDM
Wind_Speed_North_ Clim_Std_Dev	The standard deviation of the Wind_Speed_North_Climatology.				EDCS
Wind_Speed_East	The Wind_Speed in the east-west direction, where east is positive.				EDCS
Wind_Speed_East_ Climatology	The mean historical (climatology) Wind_Speed_East.				EDCS
Wind_Speed_East_Clim_ Std_Dev	The standard deviation of the Wind_Speed_East_Climatology.				EDCS
Wind_Speed_Octant_ Fraction	A number between 0 and 1 inclusive representing the linearly scaled fraction of observations reporting Wind_Speeds within a cardinal vector octant (a 45 arc degree sector centered on a cardinal direction).				EDCS, JMCDM
Wind_Speed_U	The component of Wind_Speed in the *x* direction of a projected coordinate system.				EDCS
Wind_Speed_V	The component of Wind_Speed in the *y* direction of a projected coordinate system.				EDCS
Wind_Speed_W	The component of Wind_Speed in the *z* direction of a projected coordinate system.				EDCS
Wind_Type	Type of a wind.	1	calm	Wind speeds less than 9.260 kph.	EDCS, JMCDM
		2	normal	Normal	EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		3	squall	Strong wind characterized by a sudden onset in which the Wind_Speed increases at least 29.632 km (16 nautical miles) per hour and is sustained at 40.744 km (22 nautical miles) per hour or more for at least 1 minute.	EDCS, JMCDM
		4	variable	Variable	EDCS, JMCDM
Thunderstorm_Maximum _Wind_ Speed	The maximum Wind_Speed measured within a thunderstorm.				EDCS

Table C4. Weather class: CLOUD_COVER.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Below_Station_ Cloud_Coverage	Cloud coverage of the sky below an observation station located in the mountains on earth.	1	none_present		EDCS, JMCDM
		2	one_okta		EDCS, JMCDM
		3	two_okta		EDCS, JMCDM
		4	three_okta		EDCS, JMCDM
		5	four_okta		EDCS, JMCDM
		6	five_okta		EDCS, JMCDM
		7	six_okta		EDCS, JMCDM
		8	seven_okta		EDCS, JMCDM
		9	eight_okta		EDCS, JMCDM
		10	sky_obscured		EDCS, JMCDM
		11	partial_obscuration		EDCS, JMCDM
		12	scattered		EDCS, JMCDM
		13	broken		EDCS, JMCDM
		14	few		EDCS, JMCDM
		15	indiscernable		EDCS, JMCDM
Below_Station _Cloud_Top_Altitude	The highest surface of a Cloud_Top or a Cloud_Layer relative an atmospheric vertical reference below an observation station located in the mountains on earth.				EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Below_Station _Cloud_Top_ Characteristics	The characteristics of the Cloud_Top or a Cloud_Layer below an observation station located in the mountains on earth.	1	fragmented	Isolated clouds or fragments of clouds.	EDCS, JMCDM
		2	cont_flat_tops	Continuous clouds with flat Cloud_Tops.	EDCS, JMCDM
		3	sml_breaks_flat_ tops	Clouds with small breaks and flat Cloud_Tops.	EDCS, JMCDM
		4	lrg_breaks_flat _tops	Clouds with small breaks and flat Cloud_Tops.	EDCS, JMCDM
		5	cont_undulating_ tops	Continuous clouds with undulating Cloud_Top.	EDCS, JMCDM
		6	lrg_breaks_undu-lating_tops	Clouds with large breaks and undulating Cloud_Tops.	EDCS, JMCDM
		7	sml_breaks_un-dulating_tops	Clouds with small breaks and undulating Cloud_Tops.	EDCS, JMCDM
		8	cont_towering_ tops	Continuous or almost continous clouds with towering Cloud_Tops above the Cloud_Layer.	EDCS, JMCDM
		9	wave_groups_ with_towering	Groups of waves of clouds with towering Cloud_Tops above the Cloud_Layer.	EDCS, JMCDM
		10	multiple_layers_ and _levels	Two or more Cloud_Layers at different levels.	EDCS, JMCDM
		11	cloud_not_visible	Clouds are not visible due to darkness and or fog, blowing dust, blowing sand or other obscuring phenomena.	EDCS, JMCDM
Below_Station_ Cloud_Type		1	cirrus	Detached clouds in a form of white delicate filaments and/or white or mostly white patches or narrow bands.	EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		2	cirrocumulus	A thin and white patch, sheet and/or Cloud_Layer without shading that is composed of very small elements in the form of grains and/or ripples that are merged or separated and more or less regularly arranged.	EDCS, JMCDM
		3	cirrostratus	A transparent, whitish veil of clouds of fibrous or smooth appearance that totally or partially covers the sky and generally produces halo phenomena.	EDCS, JMCDM
		4	altocumulus	A white or grey or both white and grey patch, sheet, and/or Cloud_Layer, generally with shading, composed of laminae, rounded masses, or rolls, which are fibrous or diffuse and which may or may not be merged. Most of the regularly arranged, small elements usually have an apparent width between 1 and 5 arc degrees as observed from the earth.	EDCS, JMCDM
		5	altostratus	A gray and/or bluish cloud sheet and/or Cloud_Layer of striated, fibrous, or uniform appearance that totally or partially covers the sky and has parts thin enough to reveal the sun at least vaguely, as through ground glass, and does not show halo phenomena	EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		6	nimbostratus	A grey Cloud_Layer that is often dark with an appearance rendered diffuse by more or less continuously falling rain and/or snow, which in most cases reaches the earth, and thick enough throughout to blot out the sun.	EDCS, JMCDM
		7	stratocumulus	A grey or whitish or both grey and whitish patch, sheet, and/or Cloud_Layer that almost always has dark parts composed of tessellations, rounded masses, or rolls, that are non-fibrous (except for virga) and which may or may not be merged. Most of the regularly arranged, small elements have an apparent width of more than 5 arc degrees as observed from the earth.	EDCS, JMCDM
		8	stratus	A generally grey Cloud_Layer with a fairly uniform base that may give drizzle, ice prisms, or snow grains. When the sun is visible through the Cloud_Layer, its outline is clearly discernible and does not show halo phenomena except possibly at very low AIR_TEMPERATUREs.	EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		9	cumulus	Detached clouds that are generally dense with sharp outlines and develop vertically in the form of rising mounds, domes, and/or towers, the bulging upper part of which often resembles a cauliflower. The sunlit parts of these clouds are mostly brilliant white and the bases are relatively dark and nearly horizontal.	EDCS, JMCDM
		10	cumulonimbus	A heavy and dense cloud with considerable vertical extent in the form of a mountain or a set of huge towers. At least part of its upper portion is usually smooth, fibrous, or striated, and nearly always flattened. This portion often spreads out in the shape of an anvil or vast plume.	EDCS, JMCDM
		11	not_visible	Clouds are not visible due to darkness and or fog, blowing dust, blowing sand or other obscuring phenomena.	EDCS, JMCDM
		12	no_clouds	No clouds are present.	EDCS, JMCDM
Cloud_Base	The lowest level in a specific cloud or Cloud_Layer where the atmosphere contains a perceptible quantity of particles of the cloud.				EDCS
Cloud_Base_Level	The vertical displacement of a Cloud_Base from a surface datum identified by an atmospheric vertical reference.				EDCS, JMCDM
Cloud_Ceiling_Altitude	The altitude of the lowest cloud. The altitude is AGL below 3,048 m (10,000 feet), and then becomes MSL at and above 3,048 m (10,000 feet).				EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Cloud_Layer	An arrangement of clouds, continuous or composed of separated components, where the Cloud_Base_Levels are the same and the Cloud_Thicknesses are approximately the same.				EDCS
Cloud_Liquid_ Water_Content	The liquid water content of a unit volume of cloud.				EDCS
Cloud_Phase	The phase (liquid/solid disposition) of the water content of a cloud.	1	liquid	Composed of liquid (non-frozen) water.	EDCS
		2	mixed	Mixed liquid and solid.	EDCS
		3	solid	Composed of frozen water.	EDCS
Cloud_Sky_Cover_Layer_ Type	The type of cloud that comprises a sky cover layer.	1	cirrus	Detached clouds in a form of white delicate filaments and/or white or mostly white patches or narrow bands.	EDCS, IMETS, JMCDM
		2	cirrocumulus	A thin and white patch, sheet and/or Cloud_Layer without shading that is composed of very small elements in the form of grains and/or ripples that are merged or separated and more or less regularly arranged.	EDCS, IMETS, JMCDM
		3	cirrostratus	A transparent, whitish veil of clouds of fibrous or smooth appearance that totally or partially covers the sky and generally produces halo phenomena.	EDCS, IMETS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		4	altocumulus	A white or grey or both white and grey patch, sheet, and/or Cloud_Layer, generally with shading, composed of laminae, rounded masses, or rolls, which are fibrous or diffuse and which may or may not be merged. Most of the regularly arranged, small elements usually have an apparent width between 1 and 5 arc degrees as observed from the earth.	EDCS, IMETS, JMCDM
		5	altostratus	A gray and/or bluish cloud sheet and/or Cloud_Layer of striated, fibrous, or uniform appearance that totally or partially covers the sky and has parts thin enough to reveal the sun at least vaguely, as through ground glass, and does not show halo phenomena	EDCS, IMETS, JMCDM
		6	nimbostratus	A grey Cloud_Layer that is often dark with an appearance rendered diffuse by more or less continuously falling rain and/or snow, which in most cases reaches the earth, and thick enough throughout to blot out the sun.	EDCS, IMETS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		7	stratocumulus	A grey or whitish or both grey and whitish patch, sheet, and/or Cloud_Layer that almost always has dark parts composed of tessellations, rounded masses, or rolls, that are non-fibrous (except for virga) and which may or may not be merged. Most of the regularly arranged, small elements have an apparent width of more than 5 arc degrees as observed from the earth.	EDCS, IMETS, JMCDM
		8	stratus	A generally grey Cloud_Layer with a fairly uniform base that may give drizzle, ice prisms, or snow grains. When the sun is visible through the Cloud_Layer, its outline is clearly discernible and does not show halo phenomena except possibly at very low AIR_TEMPERATUREs.	EDCS, IMETS, JMCDM
		9	cumulus	Detached clouds that are generally dense with sharp outlines and develop vertically in the form of rising mounds, domes, and/or towers, the bulging upper part of which often resembles a cauliflower. The sunlit parts of these clouds are mostly brilliant white and the bases are relatively dark and nearly horizontal.	EDCS, IMETS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		10	cumulonimbus	A heavy and dense cloud with considerable vertical extent in the form of a mountain or a set of huge towers. At least part of its upper portion is usually smooth, fibrous, or striated, and nearly always flattened. This portion often spreads out in the shape of an anvil or vast plume.	EDCS, IMETS, JMCDM
		11	not_visible	Clouds are not visible due to darkness and or fog, blowing dust, blowing sand or other obscuring phenomena.	EDCS, IMETS, JMCDM
Cloud_Thickness	The vertical distance between the Cloud_Base and the Cloud_Top.				EDCS
Cloud_Top	The highest level in a specific cloud or Cloud_Layer where the atmosphere contains a perceptible quantity of particles of the cloud.				EDCS
Cloud_Top_Level	The vertical displacement of a Cloud_Top from a surface datum identified by an atmospheric vertical reference.				EDCS
Convective_Cloud_Layer	A number between 0 and 1 inclusive represents the linearly-scaled fraction of the sky that is covered by convective (cumuliform) clouds.				EDCS
High_Cloud	A cloud of the genus cirrus, cirrocumulus, or cirrostratus. Also the top of a cloud of the genus cumulonimbus or, occasionally, altostratus.				EDCS
High_Cloud_Base_Level	The Cloud_Base_Level of a High_Cloud.				EDCS
High_Cloud_Coverage	The fraction of the sky covered by High_Clouds.				EDCS, IMET

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
High_Cloud_Genus		1	cirrocumulus	A thin and white patch, sheet and/or Cloud_Layer without shading that is composed of very small elements in the form of grains and/or ripples that are merged or separated and more or less regularly arranged.	EDCS, IMETS, JMCDM
		2	cirrostratus	A transparent, whitish veil of clouds of fibrous or smooth appearance that totally or partially covers the sky and generally produces halo phenomena.	EDCS, IMETS, JMCDM
		3	cirrus	Detached clouds in a form of white delicate filaments and/or white or mostly white patches or narrow bands.	EDCS, IMETS, JMCDM
		4	none_present	No High_Clouds present.	EDCS, IMETS, JMCDM
High_Cloud_Top_Level	The Cloud_Top_Level of a High_Cloud.				EDCS
Historical _Cloud_Free_Line_Of_ Sight_Climatology	The historical (climatology) probability of a line of sight free of clouds.				EDCS
Low_Cloud	A cloud of the genus stratocumulus or stratus. Also the base of a cloud of the genus cumulus.				EDCS
Lowest _Cloud_Base_Level	The Cloud_Base_Level of the lowest cloud.				EDCS, IMETS, JMCDM
Low_Cloud_Coverage	The fraction of sky covered by Low_Clouds.				EDCS, IMETS
Low_Cloud_Genus		1	cumulonimbus	A heavy and dense cloud with considerable vertical extent in the form of a mountain or a set of huge towers. At least part of its upper portion is usually smooth, fibrous, or striated, and nearly always flattened. This portion often spreads out in the shape of an anvil or vast plume.	EDCS, IMETS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		2	cumulus	Detached clouds that are generally dense with sharp outlines and develop vertically in the form of rising mounds, domes, and/or towers, the bulging upper part of which often resembles a cauliflower. The sunlit parts of these clouds are mostly brilliant white and the bases are relatively dark and nearly horizontal.	EDCS, IMETS, JMCDM
		3	none_present	No Low_Clouds are present.	EDCS, IMETS, JMCDM
		4	stratocumulus	A grey or whitish or both grey and whitish patch, sheet, and/or Cloud_Layer that almost always has dark parts composed of tessellations, rounded masses, or rolls, that are non-fibrous (except for virga) and which may or may not be merged. Most of the regularly arranged, small elements have an apparent width of more than 5 arc degrees as observed from the earth.	EDCS, IMETS, JMCDM
		5	stratus	A generally grey Cloud_Layer with a fairly uniform base that may give drizzle, ice prisms, or snow grains. When the sun is visible through the Cloud_Layer, its outline is clearly discernible and does not show halo phenomena except possibly at very low AIR_TEMPERATUREs.	EDCS, IMETS, JMCDM
Low_Cloud_Top_Level	The Cloud_Top_Level of a Low_Cloud.				EDCS, JMCDM
Lowest _Cloud_Base_Level	The Cloud_Base_Level of the lowest cloud.				EDCS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Lowest_Cloud_ Cover_Category	A category indicating the fraction of the sky covered by Low_Clouds, if no Low_Clouds are present, the fraction of sky covered by the Middle_Clouds.	1	none_present		EDCS, IMETS, JMCDM
		2	one_okta		EDCS, IMETS, JMCDM
		3	two_okta		EDCS, IMETS, JMCDM
		4	three_okta		EDCS, IMETS, JMCDM
		5	four_okta		EDCS, IMETS, JMCDM
		6	five_okta		EDCS, IMETS, JMCDM
		7	six_okta		EDCS, IMETS, JMCDM
		8	seven_okta		EDCS, IMETS, JMCDM
		9	eight_okta		EDCS, IMETS, JMCDM
		10	partial_obscuration		EDCS, IMETS, JMCDM
		11	sky_obscured		EDCS, IMETS, JMCDM
Middle_Cloud	A cloud of the genus altocumulus, altostratus, or nimbostratus. Also portions of a cloud of the genus cumulus or cumulonimbus.				
Middle_Cloud _Base_Level	The Cloud_Base_Level of a Middle_Cloud.				
Middle_Cloud_Coverage	The fraction of the sky covered by Middle_Clouds.				

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Middle_Cloud_Genus		1	altocumulus	A white or grey or both white and grey patch, sheet, and/or Cloud_Layer, generally with shading, composed of laminae, rounded masses, or rolls, which are fibrous or diffuse and which may or may not be merged. Most of the regularly arranged, small elements usually have an apparent width between 1 and 5 arc degrees as observed from the earth.	EDCS, IMETS, JMCDM
		2	altostratus	A gray and/or bluish cloud sheet and/or Cloud_Layer of striated, fibrous, or uniform appearance that totally or partially covers the sky and has parts thin enough to reveal the sun at least vaguely, as through ground glass, and does not show halo phenomena.	EDCS, IMETS, JMCDM
		3	nimbostratus	A grey Cloud_Layer that is often dark with an appearance rendered diffuse by more or less continuously falling rain and/or snow, which in most cases reaches the earth, and thick enough throughout to blot out the sun.	EDCS, IMETS, JMCDM
		4	none_present	No Middle_Clouds present.	EDCS, IMETS, JMCDM
Middle_Cloud_Top_Level	The Cloud_Top_Level of a Middle_Cloud.				EDCS
Total_Cloud_Coverage	The fraction of the sky hidden by all clouds.				EDCS, JMCDM
Total_Cloud _Coverage_Category	A category describing the Total_Cloud_Coverage.	1	none_present		EDCS, IMETS, JMCDM
		2	one_okta		EDCS, IMETS, JMCDM
		3	two_okta		EDCS, IMETS, JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		4	three_okta		EDCS, IMETS, JMCDM
		5	four_okta		EDCS, IMETS, JMCDM
		6	five_okta		EDCS, IMETS, JMCDM
		7	six_okta		EDCS, IMETS, JMCDM
		8	seven_okta		EDCS, IMETS, JMCDM
		9	eight_okta		EDCS, IMETS, JMCDM
		10	sky_obscured		EDCS, IMETS, JMCDM
		11	partial_obscuration		EDCS, IMETS, JMCDM
		12	scattered		EDCS, IMETS, JMCDM
		13	broken		EDCS, IMETS, JMCDM
		14	few		EDCS, IMETS, JMCDM
		15	indiscernable		EDCS, IMETS, JMCDM

Table C5. Weather class: LIGHTING_AND_VISIBILITY.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Blackout_Brake_ Light_Intensity	A number between 0 and 1 inclusive represents the linearly scaled fractional intensity of external lighting that is designed for use under military blackout conditions to prevent collision with/between vehicles.				EDCS
Blackout_Light_Intensity	A number between 0 and 1 inclusive represents the linearly scaled fractional intensity of internal lighting that is designed for use under military blackout conditions.				EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Bmnt	Begin Morning Nautical Twilight. The start of that period where, in good conditions and in the absence of other illumination, enough light is available to identify the general outlines of ground objects and conduct limited military operations. Light intensification devices are still effective and may have enhanced capabilities. At this time, the sun is 12 degrees below the eastern horizon.				JP 1-02 DOD Dictionary of Military Terms
Ceiling_And_Visibility_Ok	An indication that CAVOK conditions prevail.	0	false		
		1	true	(1) VISIBILITY is 10 km or more; (2) there are no CLOUDs below 1.5 km or below the highest minimum sector altitude, whichever is greater; and (3) there are no cumulonimbus CLOUDs, PRECIPITATION, thunderstorms, shallow fog, or low drifting snow ground cover present.	EDCS
Cloud_Free_ Line_Of_Sight	The fraction of all lines of sight that are unhampered by clouds.				EDCS
Eent	End of Evening Nautical Twilight. It is the time when the sun has set but enough light is still available to identify the general outlines of ground objects and conduct limited military operations. Light intensification devices are still effective and may have enhanced capabilities. At this time, the sun is 12 degrees below the western horizon.				Inferred from JP 1-02 DOD Dictionary of Military Terms
Fog_Coverage_Fraction	A number between 0 and 1 inclusive represents the linearly-scaled fractional area of a region of a planetary surface that is covered by fog, as seen from above.	0	no_coverage		EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		1	complete _coverage		EDCS
Fog_Detector_ Light_Present	An indication that an object has an associated detector light for fog.				EDCS
Fog_Extinction _Coefficient	The extinction coefficient due to fog.				EDCS
Fog_Present	An indication that fog is present.				EDCS
Fog_Probability	The probability of the occurrence of fog.				EDCS
Fog_Probability_Rate	Estimated rate of fog_probability.				JMCDM
Fog_Region	A region of fog at or near a planetary surface.				EDCS
Fog_Thickness	The height of a bank of fog relative to the local terrain where the base of the fog is assumed to be at ground level.				EDCS
Geographic_Light_Range	The maximum distance at which the curvature of the earth and refraction due to the ATMOSPHERE permit a light to be seen from a particular height of eye without regard to the luminous intensity of the light.				EDCS
Light_Elevation	The elevation of a light.				EDCS
Light_Exhibition _Condition	The condition of a light.	1	constant		EDCS
		2	daytime		EDCS
		3	night_time		EDCS
		4	reduced_visibility		EDCS
Light_Function	The function of a light.	18 enumerations			EDCS
Light_Multiplicity	The number of lights of the same kind at a location.				EDCS
Light_Pattern	The type of sequence, grouping, and/or distinctive character of a light.	41 enumerations			EDCS
Light_Period	The Time_Quantity occupied by an entire cycle of intervals of light and dark of a light.				EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Light_Relative_Location	The relative horizontal location of a light in a range of two or three lights.	4 enumerations			EDCS
Light_Sector_Angle	The horizontal angular sector limts of the visibility of a light.				EDCS
Light_Type	The type of light.	1	display		EDCS
		2	spotlight		EDCS
		3	street_light		EDCS
Light_Visibility	The type of specific visibility of a light, with respect to the intensity of the light and ease of recognition.	1	deliberately_restricted		EDCS
		2	faint		EDCS
		3	high_intensity		EDCS
		4	intensified		EDCS
		5	low_intensity		EDCS
		6	obscured		EDCS
		7	partially_obscured		EDCS
		8	unintensified		EDCS
Low_Visibility_Ranges	A set of two numbers defining the range of visibility at a light in nautical miles.				EDCS
Low_Visibility_Region	An ATMOSPHERE region of reduced visibility near a planetary surface.				EDCS
Lighting_Characterization	The qualitative characterization of lighting intensity.	1	brightly_lit		EDCS
		2	dimly_lit		EDCS
		3	lights_off		EDCS
Luminous_Light_Range	The maximum distance at which a light can be seen under existing visibility conditions taking no account of the height of the light, the height of the observer, or interference from background lighting.				EDCS
Maximum_Visibility_Range	The maximum range of visibility into an object (i.e., a forest).				EDCS
Mean_Visibility_Distance	Mean_Visibility_Distance derived from successive visibility measurements.				JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Meteorological_Range	The distance at which an ideal observer can detect a high-contrast target assuming a detection contrast threshold of 0.02 and a target inherent contrast of 1.0.				EDCS
Moon_Phase	The phase of the moon.	1	new_moon		EDCS
		2	waxing_crescent		EDCS
		3	first_quarter		EDCS
		4	waxing_gibbous		EDCS
		5	full_moon		EDCS
		6	waning_gibbous		EDCS
		7	last_quarter		EDCS
		8	waning_crescent		EDCS
Moon_Phase_Time	The time at which a Moon_Phase occurs.				EDCS
Moonrise_Time	The time of day of moonrise.				EDCS
Moonset_Time	The time of day of moonset.				EDCS
Nominal_Light_Range	The maximum distance at which a light can be seen in clear weather as defined by the International Visibility Code.				
Obscurant_Type	The type of obscurant present in an atmosphere.	1	advection_fog	Fog caused by advection of most air over a cold surface.	EDM-AOS, EDCS
		2	blowing_snow	Snow lifted over the surface by wind to a height of 2 m or more.	EDM-AOS, EDCS
		3	desert_haze		EDM-AOS, EDCS
		6	duststorm	Strong wind and dust suspension over an extensive region.	EDM-AOS, EDCS
		7	haze	Suspension in the atmosphere of extremely small, dry particles that are invisible to the naked eye but numerous enough to give the sky an opalescent appearance.	EDM-AOS, EDCS
		9	none_present		EDM-AOS, EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		10	radiation_fog	Fog produced over a tract when radiational cooling reduces the AIR_TEMPERATURE to or below its DEW_POINT.	EDM-AOS, EDCS
		11	rural_haze		EDM-AOS, EDCS
		12	snow	Obscuration caused by the presence of snow PRECIPITATION suspended in the ATMOSPHERE.	EDM-AOS, EDCS
		13	temperate_summer_day	Condition present during the sumer and dependent on the AIR_TEMPERATURE during the day.	EDM-AOS, EDCS
		14	temperate_ summer_night	Condition present during the sumer and dependent on the AIR_TEMPERATURE during the night.	EDM-AOS, EDCS
		15	temperate_winter	Condition present during the winter season and dependent on the AIR_TEMPERATURE at the time.	EDM-AOS, EDCS
		17	urban_haze	Haze caused by or present in urban environment.	EDM-AOS, EDCS
Observed _Visibility_Report_Type	The type of report of observed visibility	1	minimum		EDCS
		2	prvl		EDCS
		3	prvl_var_high		EDCS
		4	prvl_var_low		EDCS
		5	sector		EDCS
		6	tower		EDCS
		7	tower_var_high		EDCS
		8	tower_var_low		EDCS

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Opacity	A number between 0 and 1 representing a linearly-scaled fraction specifying the degree of light of sight blockage. The value is, on average, the fraction of the cross-sectional Area of a non-homogeneous object that completely blocks the line of sight.				EDCS
Period_Interval	The interval of time between successive measurements.				JMCDM
Period_Quantity	The Time_Quantity over which visibility measurements are sampled.				JMCDM
Received_Ambient _Light_Scaled_Intensity	A number between 0 and 1 inclusive representing the linearly scaled fractional light intensity received by an object from all unlocalized sources.				EDCS
Road_Lane_Light_State	The state of the traffic light at the end of a route lane.	7 enum merati ons			EDCS
Road_Lighting_Present	An indication that a road is illuminated by street lamps.				EDCS
Sky_Obscuration _Fraction	The fraction of the sky that is covered by fog or other low-altitude atmospheric phenomena.				EDCS
Sunshine_Period	The Time_Quantity that solar irradiation occurred.				EDCS
Sunrise_Time	The time of day of sunrise.				EDCS
Sunset_Time	The time of day of sunset.				EDCS
Urban_Street_ Light_Intensity	A number between 0 and 1 inclusive representing the linearly-scaled fractional intensity of the lighting on an urban street. Zero means unlit and one means maximum intensity.				EDCS
Visibility_Bearing	Direction a visibility is observed.	E	east		JMCDM
		N	north		JMCDM
		NE	northeast		JMCDM
		NW	northwest		JMCDM
		S	south		JMCDM
		SE	southeast		JMCDM
		SW	southwest		JMCDM

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
		W	west		JMCDM
Visibility_Distance	The greatest distance in a given direction at which it is just possible to see and identify with the unaided eye either: (1) in the daytime, a prominent dark object against the sky at the horizon or (2) at night, a known, preferably unfocused, moderately intense light.				EDCS, JMCDM

Table C6. Weather class: ICING.

Attribute		Enumeration			Source
Name	Definition	Value	Label	Definition	
Icing_Intensity	The code that denotes the intensity of ICING on the surface.	0	none		JMCDM
		1	light		JMCDM
		2	moderate		JMCDM
		3	severe_or_heavy		JMCDM
		4	trace		JMCDM
		5	unknown		JMCDM
Icing_Type	The type of ice.	1	clear_ice		EDCS
		2	hard_rime		EDCS
		3	hoar_frost		EDCS
		4	ice_glaze		EDCS
		5	rime		EDCS
		6	soft_rime		EDCS
Probability_Of_Icing	The probability that ICING will occur in a designated Time_Period.				IMETS

APPENDIX D: M-COP MANEUVER ANALYSIS CATEGORY

Table D1. Maneuver Analysis class: AREA_OF_OPERATIONS.*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier of this AO.	1	string	
Commander	Commander of highest echelon unit assigned this AO.	1	string	This can be used for coordination purposes.
Unit	Highest echelon unit assigned this AO.	1	string	e.g., Corps, Division, Brigade, Battalion; since doctrine is evolving with transformation of the force, recommend leaving as a string until terminology is established. Should agree with Forces category attribute.
GEOMETRY	A spatial representation of the class; note this is from a class in the utilities category.	1	float	A polygon.

Table D2. Maneuver Analysis class: TRAFFICABILITY_SEGMENT (AO).†

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier or number of this TRAFFICABILITY_SECTOR within the Area of Operations (AO).	1	string	This could also be a numeric data type, depending on the implemention within the system.
AO_Name	Unique identifier of the AO associated with the TRAFFICABILITY_SECTOR.	1	string	Name given the AO.
Unit	Type of unit or platform for which trafficability is estimated.	1	string	Trafficability can vary by type of unit (generally based on equipment).
Trafficability_Estimate	Trafficability for the given unit or platform.	1	integer	0 – unrestricted 1 – restricted 2 - severely restricted
Speed	Maximum speed for this unit in the TRAFFICABILITY_SECTOR.	1	float	kph

* AREA_OF_OPERATIONS—(DOD) An operational area defined by the joint force commander for land and naval forces. Areas of operations do not typically encompass the entire operational area of the joint force commander, but should be large enough for component commanders to accomplish their missions and protect their forces. Also called AO. See also area of interest; area of responsibility; battlespace; joint operations area; joint special operations area. See FM 3-0 (HQDA 2001a). (Ref. FM 1-02.)

† TRAFFICABILITY_SEGMENT describes the trafficability of a portion of the AO.

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
GEOMETRY	A spatial representation of the TRAFFICABILITY_SECTOR; note this is from a class in the Utilities category.	1	float	A polygon.
FORCE_DISPOSITION Affliation	The forces side associated with the trafficability estimate in the TRAFFICABILITY_SECTOR, FORCE_DISPOSITION is a class in the Forces category.	1		As represented by Forces category.

Table D3. Maneuver Analysis class: GROUND_AVENUE_OF_APPROACH (AA).*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier for this AA.	1	string	
AO_Name	Name identifier for the AO with which this AA is associated.	1	string	
Number_Of_AA_Segments	Total number count of segments composing the AA.	1	integer	
Number_Of_Mobility_Corridors	Total number count of mobility corridors within the AA.	1	integer	
Force_Size	Size of unit using this AA.	1	string	e.g., battalion; since doctrine is evolving with transformation, recommend leaving as a string until terminology is established. Should align with a Forces category attribute.
General_Direction	Compass direction of approach (start to end).	1	string	"ENE", "NNW", etc.
FORCE_DISPOSITION Affliation	Side associated with this AA; FORCE_DISPOSITION is a class in the Forces category.	1		As represented by Forces category.
GEOMETRY	Spatial representation of the EA; note this is from a class in the Utilities category.	1	float	A polygon.

* GROUND_AVENUE_OF_APPROACH—"(DOD) ground route of an attacking force of a given size leading to its objective or to key terrain in its path. Also called AA." FM 1-02 (HQDA 2003a). Assumes an AA is contained within a single AREA_OF_OPERATIONS; an AA is made up of distinct segments described as straight lines with segment width.

Table D4. Maneuver Analysis class: MOBILITY_CORRIDOR (MC).*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	A unique identifier for this MOBILITY_CORRIDOR.	1	string	
AA_Name	The identifier for the AVENUE_OF_APPROACH (AA) with which this MOBILITY_CORRIDOR is associated.	1	string	
Force_Size	The size of force that can pass through the MOBILITY_CORRIDOR.	1	string	E.g., battalion; since doctrine is evolving with transformation, recommend leaving as a string until terminology is established. Should align with Forces category attributes.
Restriction	Identifier of the restriction being bypassed in this MOBILITY_CORRIDOR.	1	string	Obstacle will have associated location information (from Obstacle category).
Characteristic_Width	Characteristic width of the MOBILITY_CORRIDOR as determined by the direction of travel of the platform or force.	1	float	The most limiting dimension of the MC given the direction of travel.
Trafficability_Estimate	Category of trafficability for the given unit.	1	integer	0 – unrestricted 1 – restricted 2 - severely restricted
Reason	Why choose this route around the obstacle.	1	string	
GEOMETRY	Spatial representation of the MOBILITY_CORRIDOR; note this is from a class in the Utilities category.	1	float	A polygon.

* MOBILITY_CORRIDOR--"(DOD) Areas where a force will be canalized due to terrain restrictions. They allow military forces to capitalize on the principles of mass and speed and are therefore relatively free of obstacles." (FM 1-02; HQDA 2003a.)

Table D5. Maneuver Analysis class: AVENUE_OF_APPROACH_CHANNELIZER.*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier for obstacle or area that channelizes movement within the AA.	1	string	
AA_Name	Unique name identifier for AA with which the channelizer (object) is associated.	1	string	
Type	Obstacle category. An obstacle could be a minefield whereas a severly restricted area could be a river or a marsh. Obstacles come from the Obstacle categoy and have associated geometries and characteristics.	1	integer	0 = severly restricted area 1 = restricted area 2 = obstacle
AA_Segment_ Mobility_Corridor_1	First corridor around the obstacle.	1	string	Unique MC identifier; should correspond to a particular MOBILITY_CORRIDOR_NAME in MOBILITY_CORRIDOR (MC) subclass.
AA_Segment_ Mobility_Corridor_2	Second corridor around the obstacle, if it exists.	1	string	Null if no second MC.
GEOMETRY	A spatial representation of the obstacle; note this is from a class in the Utilities category.	1	float	A polygon.

* AVENUE_OF_APPROACH_CHANNELIZER—Point or areal terrain feature of the AA that will cause channelization. This could be a severly restricted area, a forest, a river, etc.

Table D6. Maneuver Analysis class: AVENUE_OF_APPROACH_SEGMENT.*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
AA_Name	Unique name identifier for AA of which this segment is a part.	1	string	
Segment_Number	The unique identifier for this segment of the AA.	1	integer	0 = start and is associated with the segment at the start point of the AA, increment by 1
Segement_Width	Characteristic width of AA segment perpendicular to the intended direction of travel.	1	float	meters
Segment_Visual_Obstruction	Degree of visual obstruction in this segment.	1	float	0..1 where 0 - 0% visibility and 1 = 100% visibility (100 meters or more); could also use MAXIMUM_VISIBILITY_ RANGE from Terrain category or visibility distance from Weather category.
Segment_Concealment	Degree of concealment provided for the unit by the terrain in that AA segment.	1	float	0..1 where 0 - 0% and 1 = 100%
Segment_Cover	Degree of cover provided by the terrain for unit in that AA segment.	1	float	0..1 where 0 - 0% and 1 = 100%
GEOMETRY	Spatial representation of the AA segment; note this is from a class in the Utilities category.	1	float	A polygon.

Table D7. Maneuver Analysis class: KEY_TERRAIN.†

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier for this KEY_TERRAIN.	1	string	
AO_Name	Unique identifier of this AO associated with this KEY_TERRAIN.	1	string	
Key_Terrain_Type	Description of the KEY_TERRAIN (e.g., building, knoll).	1	string	Could be parsed into preset categories and made integer.
Reason	Reason this is considered KEY_TERRAIN.	1	string	
FORCE_DISPOSITION Affliation	The side associated with with this key terrain; FORCE_DISPOSITION is a class in the Forces category who owns this KEY_TERRAIN.	1		As represented by Forces category.

* AVENUE_OF_APPROACH_SEGMENT—Assumes an AA is made up of distinct segments described as straight lines with segment width.

† KEY_TERRAIN—"(DOD, NATO) Any locality, or area, the seizure or retention of which affords a marked advantage to either combatant." (FM 1-02; HQDA 2003a.)

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
GEOMETRY	Spatial representation of the KEY_TERRAIN; note this is from a class in the Utilities category.	1	float	KEY_TERRAIN can typically be represented as a polygon.

Table D8. Maneuver Analysis class: ENGAGEMENT_AREA (EA).*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
Name	Unique name identifier for the ENGAGEMENT_AREA (EA).	1	string	
AO_Name	Unique identifier of this AO.	1	string	
AA_Name	Unique name identifier for AA.	1	string	
Fire_Type	Type of fire to employ.	1	string	
Enemy_Unit	Enemy unit to engage.	1	string	
Enemy_Fire_Type	Expected enemy Fire_Type.	1	string	
Initiator	Who will initiate engagement?	1	integer	0 = friendly unit 1 = enemy unit
FORCE_DISPOSITION Identity	Identity of the friendly unit which will engage in this area; FORCE_DISPOSITION is a class in the Forces category who owns this KEY_TERRAIN.	1		As represented by Forces category.
GEOMETRY	Spatial representation of the EA; note this is from a class in the Utilities category.	1	float	A polygon.

* ENGAGEMENT_AREA —"An area where the commander intends to contain and destroy an enemy force with the massed effects of all available weapons and supporting systems. Also called EA." (FM 1-02; HQDA 2003a.)

Table D9. Maneuver Analysis class: TIME_PHASE_LINE_H (TPL).*

Attribute or Associated Class	Definition	Cardinality	Data Type	Units of Measure / other notes
AO_Name	The unique identifier of this AO.	1	string	
Time_Increment	Time lapsed relative to start time for the movement.	1	float	Time in minutes; range >=0 (note, this is for tactical level; for a campaign days can be the unit of measure).
TPL_PT_1	Defines the line segement for the time phase line at a particular time increment.	1	float	
TPL_PT_2	Defines the line segement for the time phase line at a particular time increment.	1	float	This can be carried out to n TPL_PT_n.
GEOMETRY	Spatial representation of the EA; note this is from a class in the Utilities category.	1	float	Can be represented as a line.
FORCE_DISPOSITION Identity Affliation	Identity and Side associated with this TPL; FORCE_DISPOSITION is a class in the Forces category who owns this KEY_TERRAIN.	1		As represented by Forces category.

* TIME_PHASE_LINE_H—Lines indicated the flow of the operation (based on a course of action) and the progression of units at particular time intervals relative to the start time for the movement. H-Hour inidicates start typically and H+15 indicate progression after 15 minutes have elapsed, etc. (FM 1-02; HQDA 2003a.)

APPENDIX E: M-COP ROUTE FINDING CATEGORY

Table E1. Route Finding category classes.

Class	Class Definition	Attributes	Attribute Definition	Units	Cardinality	Source
ROUTE	Prescribed course to be traveled from a specific point of origin to a specific destination.					FM 3-90
		Route_Purpose	Usage ROUTE will support (i.e. MSR, passing route).		(0,M)	FM 3-90
		Route_ Classification	Classification assigned to a route using factors of minimum width and worst ROUTE type, least bridge, raft or culvert military load.		(0,1)	FM 5-100
		Start_Point	Start point of ROUTE.		(1,1)	BTRA
		Stop_Point	End point of ROUTE.		(1,1)	BTRA
		Edge_List	An ordered list of EDGEs included in this ROUTE.		(1,1)	M-COP Maneuver Analysis
ROUTE_ REQUEST	A request for a ROUTE through a maneuver network.					M-COP Route Finding
		Start_Point	Point to begin ROUTE search.		(1,1)	BTRA
		Stop_Point	Point to end ROUTE search.		(1,1)	BTRA
		Way_Point	Point ROUTE should pass near or visit.		(0,M)	M-COP Route Finding
		Datetime	A point in time that designates the beginning of the period of effectiveness for the trafficability assessments of EDGEs in which to search for the ROUTE.		(0,1)	BTRA
		Constraint_List	CONSTRAINTs included in ROUTE_REQUEST.		(0,M)	M-COP Route Finding
		Constraint_ Weight_List	Weights of CONSTRAINTs.		(0,M)	M-COP Route Finding
CONSTRAINT	A requirement that should be met by					M-COP Route

Class	Class Definition	Attributes	Attribute Definition	Units	Cardinality	Source
	ROUTE.					Finding
		Force	Force ROUTE should accommodate. This would imply such requirements as overhead clearance, minimum turning radius, width, movement technique, etc.		(0,1)	BTRA
		Constraint_Type	Whether this CONSTRAINT is on time, distance, control-measure, GEOMETRY, Feature, or Feature-Type.		(1,1)	M-COP Route Finding
		Control_Measure	Unit boundaries, ENGAGEMENT_AREAS, phase lines, etc used to bound or otherwise constrain ROUTE search.		(0,M)	M-COP Maneuver Analysis
		Geometry	A geospatial object used to bound or otherwise constrain ROUTE search.		(0,M)	M-COP Route Finding
		Feature	Feature(s) specified for bounding or otherwise constraining ROUTE search.		(0,M)	M-COP Route Finding
		Feature_Type	Feature_Types(s) specified for bounding or otherwise constraining ROUTE search.		(0,M)	M-COP Route Finding
		Obstacle	Obstacle(s) specified for bounding or otherwise constraining ROUTE search.		(0,M)	M-COP Route Finding
		Obstacle_Type	Obstacle_Types(s) specified for bounding or otherwise constraining ROUTE search.		(0,M)	M-COP Route Finding
MANEUVER_ NETWORK_ GRAPH	A geometric representation of trafficability over terrain that can be used in mobility and maneuver analysis applications.				(1,M)	BTRA
		Edge_List	List of EDGEs.		(1,M)	BTRA
		Node_List	List of NODEs.		(2,M)	BTRA
		Maneuver_ Network_Type	Describes the nature of this maneuver network graph whether for composed of main supply routes, on-road only, off-road only, etc.		(1,1)	BTRA
		Network_Junction	A NODE with connecting EDGEs from more than maneuver network graph.		(0,M)	BTRA
EDGE	A graph					BTRA

Class	Class Definition	Attributes	Attribute Definition	Units	Cardinality	Source
	representation of contiguous stretches of terrain having like attributes — especially trafficability.					
		NodeA	NODE where EDGE end designated as “A” terminates (A,B designation is arbitrary).		(1,1)	BTRA
		NodeB	NODE where EDGE end designated as “B” terminates (A,B designation is arbitrary).		(1,1)	BTRA
		Feature	Feature represented by this EDGE.		(1,1)	M-COP Terrain
		Width	Width of trafficable terrain.	m	(1,1)	BTRA
		Off_Road_Shortest	Weighted cost favoring short off-road features.		(1,1)	BTRA
		On_Road_Shortest	Weighted cost favoring short road features.		(1,1)	BTRA
		Military_Load _Classification				
		General_Vehicle_ Type_Speed	Assessed speed of a General_Vehicle_Type over this EDGE.	m / s	(12,M)	BTRA
		General_Vehicle_ Type_Time	Weighted cost reflecting time required for a General_Vehicle_Type to traverse this EDGE.		(12,M)	BTRA
		General_Vehicle_ Type_Off_Road_ Fastest	Weighted cost favoring fastest off-road EDGEs for a General_Vehicle_Type.		(12,M)	BTRA
		General_Vehicle_ Type_On_Road_ Fastest	Weighted cost favoring fastest on-road EDGEs for a General_Vehicle_Type.		(1,1)	BTRA
		Concealment	Weighting of concealment.		(1,1)	BTRA
		Radius _of_Curvature	Most narrow curve along EDGE.	m	(1,1)	URBAN
		Assessment_ Effective_Datetime	The character string representing a point in time that designates the beginning of the period of effectiveness for a specific EDGE.		(1,1)	BTRA
NODE	An endpoint of a graph EDGE.					BTRA
		Geometry	A geometric representation of the NODE.			M-COP Utility
		Edge	EDGE terminating at this NODE.		(1,M)	BTRA
FORCE	A group of ground					M-COP

Class	Class Definition	Attributes	Attribute Definition	Units	Cardinality	Source
	vehicles.					
		Width	Width of FORCE while traveling.	m	(0,1)	BTRA
		Formation_Type			(0,1)	M-COP Force
		Vehicle_Type			(0,M)	BTRA
		General_Vehicle_ Type			(0,M)	BTRA

APPENDIX F: NATO REFERENCE MOBILITY MODEL (NRMM) VEHICLE SCHEME 2.0 (June 2003)

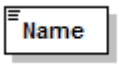
The NATO Reference Mobility Model (NRMM) is the Army Modeling and Simulation Office standard for single vehicle ground movement representation (Ahlvin and Haley 1992). A Standard Mobility (STNDMob) Application Program Interface (API) has been developed based on the NRMM to incorporate terrain-limited vehicle speed determinations into M&S systems (Baylot et al. 2005). An extensive XML schema representation of the NRMM is available for general use, in addition to the STNDMob API software implementation, XML schema, and XML data files. An overview of Version 2.0 of the NRMM vehicle XML schema is provided below. Appendix G contains an example XML file storing NRMM vehicle data for the M1A1 Abrams tank in accordance with this schema.

schema location:	NRMMVehicleSchema_2.0.xsd	
attribute form default:		
element form default:	qualified	
Elements	Complex types	Simple types
Comment	AssemblyType	DescriptionType
Name	ConfigurationType	Name60LettersType
PreComment	FloatArrayType	unitAngle
SourceReference	FloatValueType	unitArea
Vehicle	IntegerArrayType	unitCorneringStiffness
	IntegerValueType	unitDisplacement
	StringArrayType	unitForce
	StringValueType	unitLength
	TrackSetAssemblyType	unitPower
	UnknownAssemblyType	unitPressure
	WheeledAxleAssemblyType	unitRevPerDistance
		unitRMSDistance
		unitSpeed
		unitStiffness
		unitTorque
		unitWeight

element Comment

diagram	
type	xsd:string
properties	content simple

element Name

diagram	
type	xsd:string
properties	content simple

element PreComment

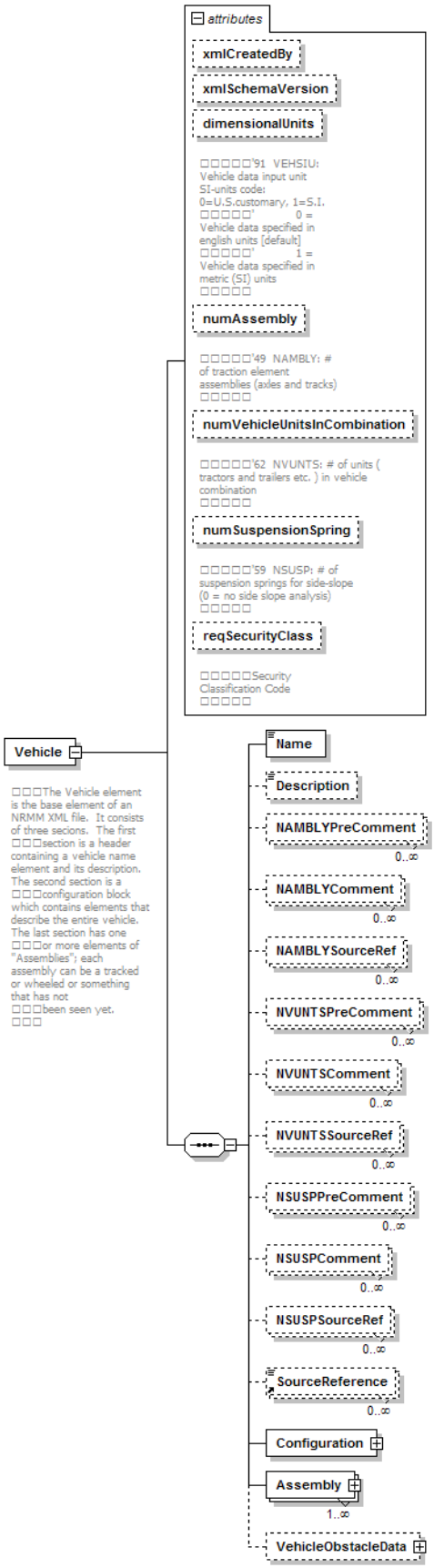
diagram	
type	xsd:string
properties	content simple

element SourceReference

diagram	
type	xsd:string
properties	content simple

element
Vehicle

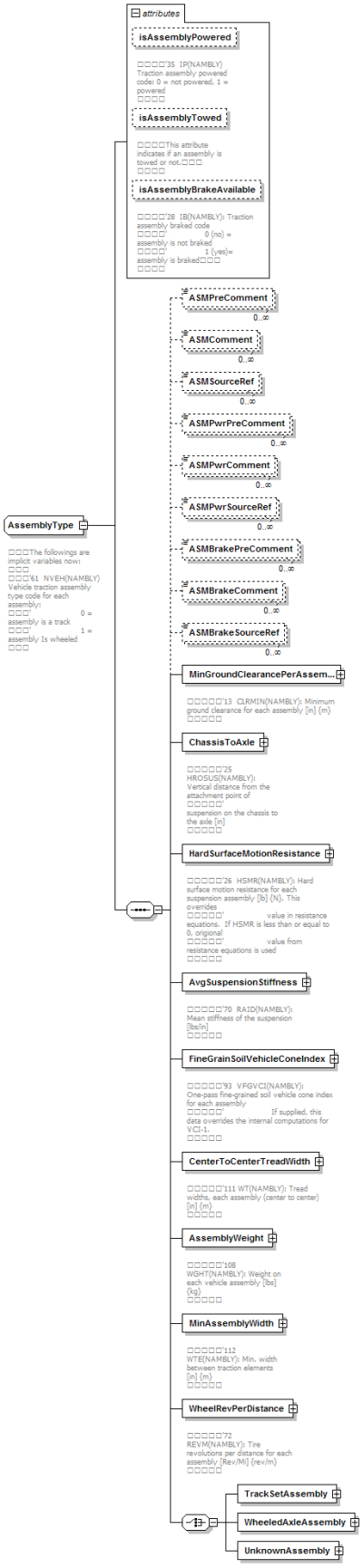
diagram



Properties	content complex					
children	**Name Description NAMBLYPreComment NAMBLYComment NAMBLYSourceRef NVUNTSPreComment NVUNTSComment NVUNTSSourceRef NSUSPPreComment NSUSPComment NSUSPSourceRef SourceReference Configuration Assembly VehicleObstacleData**					
attributes	Name	Type	Use	Default	Fixed	Annotation
	xmlCreatedBy	**xsd:string**				
	xmlSchemaVersion	**xsd:string**				
	dimensionalUnits	**derived by: xsd:string**		English		documentation '91 VEHSIU: Vehicle data input unit SI-units code: 0=U.S.customary, 1=S.I. 0 = Vehicle data specified in english units [default] 1 = Vehicle data specified in metric (SI) units
	numAssembly	**xsd:int**				documentation '49 NAMBLY: # of traction element assemblies (axles and tracks)
	numVehicleUnitsInCombination	**xsd:int**		1		documentation '62 NVUNTS: # of units (tractors and trailers etc.) in vehicle combination
	numSuspensionSpring	**xsd:int**				documentation '59 NSUSP: # of suspension springs for side-slope (0 = no side slope analysis)
	reqSecurityClass	**derived by: xsd:string**		U		documentation Security Classification Code
annotation	documentation The Vehicle element is the base element of an NRMM XML file. It consists of three sections. The first section is a header containing a vehicle name element and its description. The second section is a configuration block which contains elements that describe the entire vehicle. The last section has one or more elements of "Assemblies"; each assembly can be a tracked or wheeled or something that has not been seen yet.					

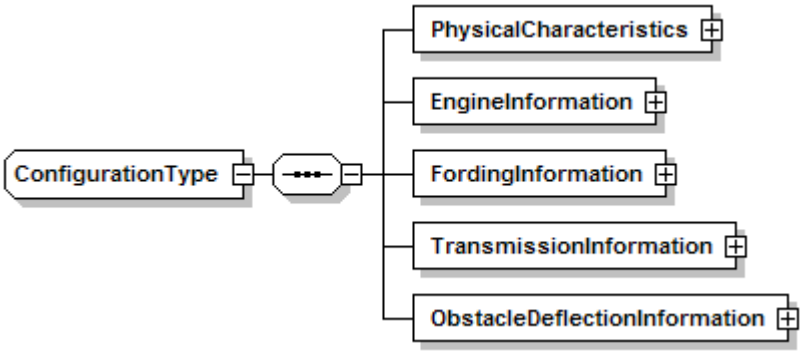
complexType
AssemblyType

diagram

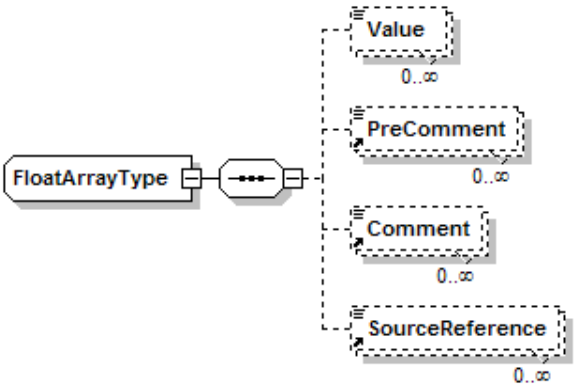


children	**ASMPreComment ASMComment ASMSourceRef ASMPwrPreComment ASMPwrComment ASMPwrSourceRef ASMBrakePreComment ASMBrakeComment ASMBrakeSourceRef MinGroundClearancePerAssembly ChassisToAxle HardSurfaceMotionResistance AvgSuspensionStiffness FineGrainSoilVehicleConeIndex CenterToCenterTreadWidth AssemblyWeight MinAssemblyWidth WheelRevPerDistance TrackSetAssembly WheeledAxleAssembly UnknownAssembly**
attributes	Name / Type / Use / Default / Fixed / Annotation isAssemblyPowered — **derived by: xsd:string** — documentation: '35 IP(NAMBLY) Traction assembly powered code: 0 = not powered, 1 = powered isAssemblyTowed — **derived by: xsd:string** — documentation: This attribute indicates if an assembly is towed or not. isAssemblyBrakeAvailable — **derived by: xsd:string** — documentation: '28 IB(NAMBLY): Traction assembly braked code 0 (no) = assembly is not braked 1 (yes)= assembly is braked
annotation	documentation The followings are implicit variables now: '61 NVEH(NAMBLY) Vehicle traction assembly type code for each assembly: ' 0 = assembly is a track ' 1 = assembly Is wheeled

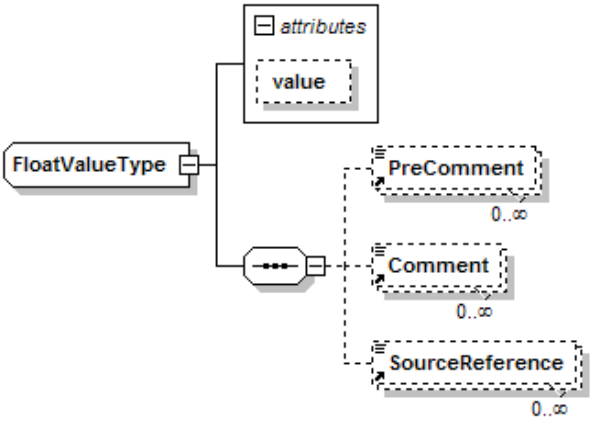
complexType ConfigurationType

diagram	
children	PhysicalCharacteristics EngineInformation FordingInformation TransmissionInformation ObstacleDeflectionInformation

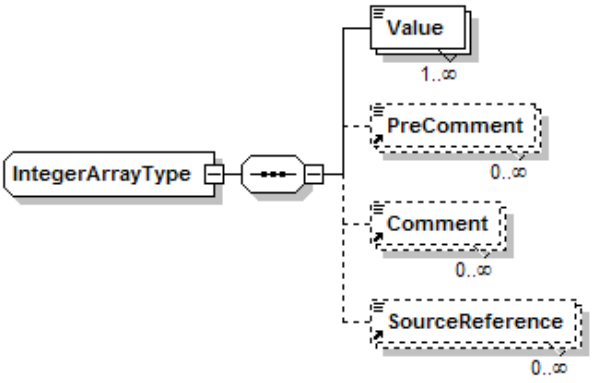
complexType FloatArrayType

diagram	
children	**Value PreComment Comment SourceReference**

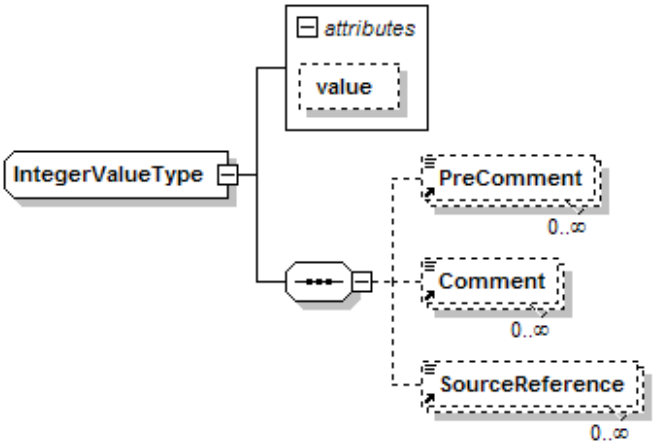
complexType FloatValueType

diagram						
children	**PreComment Comment SourceReference**					
attributes	Name	Type	Use	Default	Fixed	Annotation
	value	**xsd:float**				

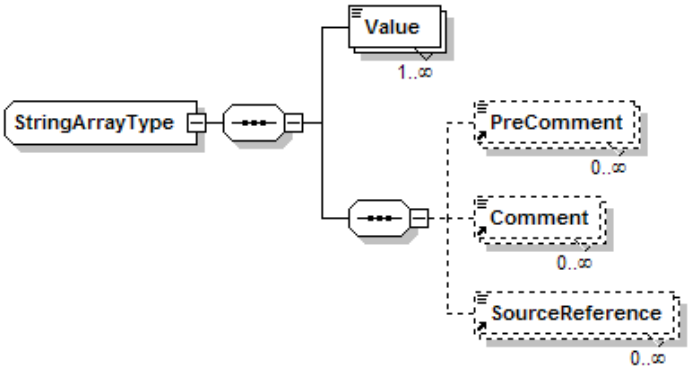
complexType IntegerArrayType

diagram	
children	**Value PreComment Comment SourceReference**

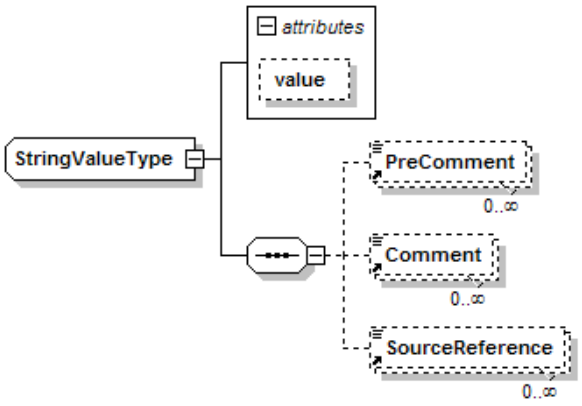
complexType IntegerValueType

diagram	
children	PreComment Comment SourceReference
attributes	Name Type Use Default Fixed Annotation value xsd:int

complexType StringArrayType

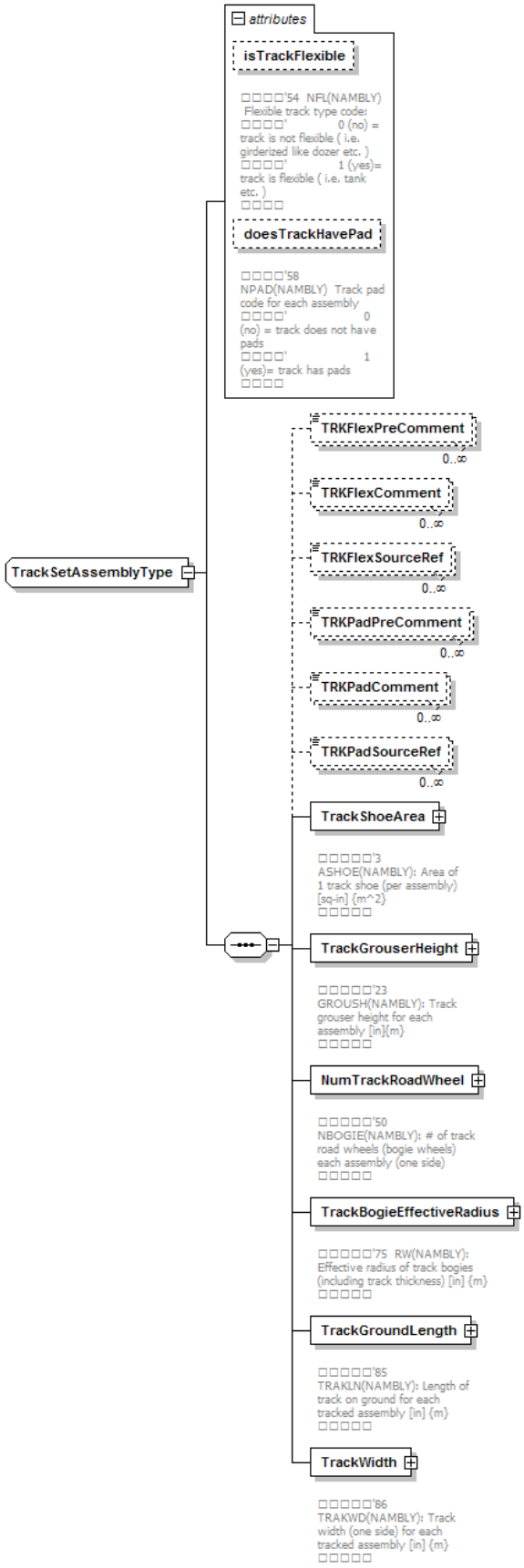
diagram	
children	Value PreComment Comment SourceReference

complexType StringValueType

diagram						
children	**PreComment Comment SourceReference**					
attributes	Name	Type	Use	Default	Fixed	Annotation
	value	**xsd:string**				

complexType
TrackSetAssemblyType

diagram

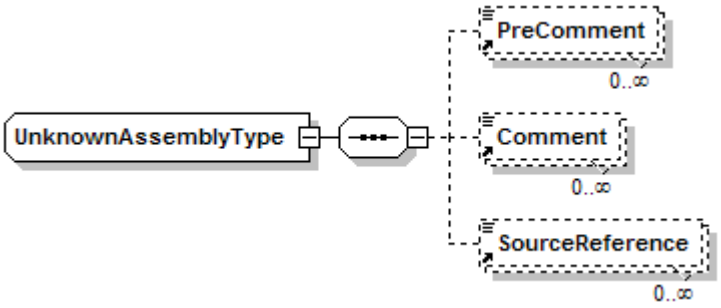


children	**TRKFlexPreComment TRKFlexComment TRKFlexSourceRef TRKPadPreComment TRKPadComment TRKPadSourceRef TrackShoeArea TrackGrouserHeight NumTrackRoadWheel TrackBogieEffectiveRadius TrackGroundLength TrackWidth**

attributes

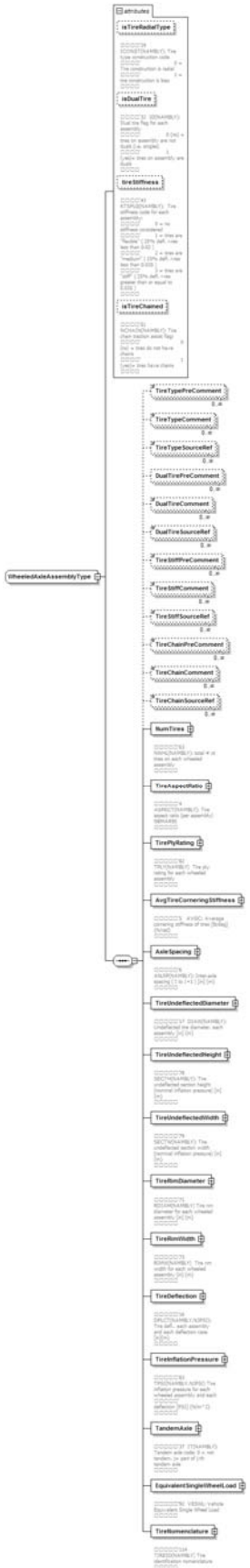
Name	Type	Use	Default	Fixed	Annotation
isTrackFlexible	**derived by: xsd:string**				documentation '54 NFL(NAMBLY) Flexible track type code: 0 (no) = track is not flexible (i.e. girderized like dozer etc.) 1 (yes) = track is flexible (i.e. tank etc.)
doesTrackHavePad	**derived by: xsd:string**				documentation '58 NPAD(NAMBLY) Track pad code for each assembly 0 (no) = track does not have pads 1 (yes)= track has pads

complexType UnknownAssemblyType

diagram	
children	**PreComment Comment SourceReference**

complexType
WheeledAxleAssemblyType

diagram



children	**TireTypePreComment TireTypeComment TireTypeSourceRef DualTirePreComment DualTireComment DualTireSourceRef TireStiffPreComment TireStiffComment TireStiffSourceRef TireChainPreComment TireChainComment TireChainSourceRef NumTires TireAspectRatio TirePlyRating AvgTireCorneringStiffness AxleSpacing TireUndeflectedDiameter TireUndeflectedHeight TireUndeflectedWidth TireRimDiameter TireRimWidth TireDeflection TireInflationPressure TandemAxle EquivalentSingleWheelLoad TireNomenclature**
attributes	Name / Type / Use / Default / Fixed / Annotation isTireRadialType — **derived by: xsd:string** — documentation: '29 ICONST(NAMBLY): Tire type construction code 0 = Tire construction is radial 1 = tire construction is bias isDualTire — **derived by: xsd:string** — documentation: '32 ID(NAMBLY): Dual tire flag for each assembly 0 (no) = tires on assembly are not duals (i.e. singles) 1 (yes)= tires on assembly are duals tireStiffness — **derived by: xsd:string** — documentation: '43 KTSFLG(NAMBLY): Tire stiffness code for each assembly: 0 = no stiffness considered 1 = tires are "flexible" (25% defl. r-res less than 0.02) 2 = tires are "medium" (25% defl. r-res less than 0.035) 3 = tires are "stiff" (25% defl. r-res greater than or equal to 0.035) isTireChained — **derived by: xsd:string** — documentation: '51 NCHAIN(NAMBLY): Tire chain traction assist flag: 0 (no) = tires do not

	have chains 1 (yes)= tires have chains

simpleType DescriptionType

type	xsd:string
annotation	documentation The Desccription element type can have unlimited number of charaters to describe a vehicle in detail.

simpleType Name60LettersType

type	restriction of xsd:string
facets	minLength 1 maxLength 60
annotation	documentation By rule, the first line of NRMM file only can hold no more than 60 characters to describe a vehicle name.

simpleType unitAngle

type	restriction of xsd:string
facets	enumeration deg enumeration rad

simpleType unitArea

type	restriction of xsd:string
facets	enumeration in^2 enumeration ft^2 enumeration cm^2 enumeration m^2

simpleType unitCorneringStiffness

type	restriction of xsd:string
facets	enumeration lb/deg enumeration N/rad

simpleType unitDisplacement

type	restriction of **xsd:string**	
facets	enumeration	in^3
	enumeration	ft^3
	enumeration	cm^3
	enumeration	m^3

simpleType unitForce

type	restriction of **xsd:string**	
facets	enumeration	lb
	enumeration	N

simpleType unitLength

type	restriction of **xsd:string**	
facets	enumeration	in
	enumeration	ft
	enumeration	cm
	enumeration	m

simpleType unitPower

type	restriction of **xsd:string**	
facets	enumeration	watts
	enumeration	HP

simpleType unitPressure

type	restriction of **xsd:string**	
facets	enumeration	psi
	enumeration	N/m^2

simpleType unitRevPerDistance

type	restriction of **xsd:string**	
facets	enumeration	rev/Mi
	enumeration	rev/m

simpleType unitRMSDistance

type	restriction of **xsd:string**	
facets	enumeration	RMS-in
	enumeration	RMS-m

simpleType unitSpeed

type	restriction of **xsd:string**	
facets	enumeration	fps
	enumeration	MPH
	enumeration	mps
	enumeration	KPH

simpleType unitStiffness

type	restriction of **xsd:string**	
facets	enumeration	lb/in
	enumeration	N/m

simpleType unitTorque

type	restriction of **xsd:string**	
facets	enumeration	ft-lb
	enumeration	N-m

simpleType unitWeight

type	restriction of **xsd:string**	
facets	enumeration	lb
	enumeration	kg

APPENDIX G: M1A1 DATA USING THE NATO REFERENCE MOBILITY MODEL (NRMM) VEHICLE SCHEMA 2.0 (June 2003)

The NATO Reference Mobility Model (NRMM) is the Army Modeling and Simulation Office standard for single vehicle ground movement representation (Ahlvin and Haley 1992). A Standard Mobility (STNDMob) Application Program Interface (API) has been developed based on the NRMM to incorporate terrain-limited vehicle speed determinations into M&S systems (Baylot et al. 2005). An extensive XML schema representation of the NRMM is available for general use, in addition to the STNDMob API software implementation, XML schema, and XML data files. An overview of Version 2.0 of the NRMM vehicle XML schema is provided in Appendix F. An example XML file storing NRMM vehicle data for the M1A1 Abrams tank in accordance with this schema is provided below

```
<?xml version="1.0" encoding="utf-8" ?>
<?xml-stylesheet type="text/xsl" href="NRMMVehicleXSL_2.0.xsl" ?>
<!--
Agency: Army Materiel Systems Analysis Activity
U.S. Government employees and contractors generated this product, and the overnment has format and data rights therein for government purposes.
Should the contractor obtain a copyright in the product, those sections developed solely by government employees should be designated so that one is
on notice that no copyright exists for those portions of the product generated solely by government employees.
-->
<Vehicle xmlCreatedBy="AMSAA" xmlSchemaVersion="2.0" dimensionalUnits="English" numAssembly="1" numVehicleUnitsInCombination="1" numSuspensionSpring="0"
reqSecurityClass="U">
        <Name><![CDATA[M1A1 ABRAMS TANK (WES Standard) JHL]]></Name>
        <Description><![CDATA[Project: Standard vehicle
Date entered: 7 Dec '93 RBA & NRMM-mgr
Date updated: 10 Feb '94 RBA, NRMM-mgr
File name: M1A1.STD
Description:
M1A1            ABRAMS TANK (WES Standard)
]]>
        </Description>
        <NAMBLYSourceRef><![CDATA[just test ]]></NAMBLYSourceRef>
        <NSUSPComment><![CDATA[ to be derived from VEHDYN data]]></NSUSPComment>
        <Configuration>
                <PhysicalCharacteristics>
                        <AerodynamicDragCoefficient value="1.2">
                                <PreComment><![CDATA[  ACD    =   0.8  ! WES, unknown origin]]></PreComment>
                                <Comment><![CDATA[ (worst case rectangular plate)]]></Comment>
                        </AerodynamicDragCoefficient>
                        <CGToGround value="53.04" unitInfo="in">
                                <PreComment><![CDATA[  CGH    =   52.1 ! WES, PM ofc 26Jun89]]></PreComment>
                                <PreComment><![CDATA[  CGH    =   52.0 ! TM55-2350-255-14, '79]]></PreComment>
                                <Comment><![CDATA[ PM ofc, 1991]]></Comment>
                        </CGToGround>
                        <CGToCenterLine value="1.82" unitInfo="in">
                                <PreComment><![CDATA[  CGLAT  =    0.0 ! WES, unknown origin]]></PreComment>
                                <PreComment><![CDATA[  CGLAT  =    1.2 ! TM55-2350-255-14 '79]]></PreComment>
                                <Comment><![CDATA[ PM ofc, 1991]]></Comment>
                        </CGToCenterLine>
                        <CGToRearAxle value="100.55" unitInfo="in">
                                <PreComment><![CDATA[  CGR    =  100.3 ! WES, unknown origin]]></PreComment>
                                <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
                        </CGToRearAxle>
                        <MinGroundClearance value="17" unitInfo="in">
                                <PreComment><![CDATA[  CGR; PM ofc, 1991, 126.01in = H-dist C-G to final drive (rear sprocket)]]></PreComment>
```

```
            <PreComment><![CDATA[  CL     =   19.0 ! TM55-2350-255-14 '79]]></PreComment>
            <Comment><![CDATA[ JANE'S 1990-91 & PM ofc 1991]]></Comment>
</MinGroundClearance>
<DriverEyeHeight value="59" unitInfo="in">
            <PreComment><![CDATA[  EYEHGT =    60 ! WES, unknown origin]]></PreComment>
            <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
</DriverEyeHeight>
<FrontalArea value="78" unitInfo="in^2">
            <PreComment><![CDATA[  PFA    =    76  ! WES, unknown origin]]></PreComment>
            <PreComment><![CDATA[  PFA    =    80  ! TM55-2350-255-14 '79]]></PreComment>
            <Comment><![CDATA[ PM ofc, 1991]]></Comment>
</FrontalArea>
<MaxPushBarForce value="252000" unitInfo="lb">
            <Comment><![CDATA[ estimated as 2*GVW]]></Comment>
</MaxPushBarForce>
<PushBarHeight value="46.8" unitInfo="in">
            <PreComment><![CDATA[  PBHT   =   44.5 ! WES, unknown origin]]></PreComment>
            <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
</PushBarHeight>
<ApproachAngle value="22" unitInfo="deg">
            <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
</ApproachAngle>
<RideTolerance value="0" unitInfo="G" />
<MaxDepartureAngle value="36" unitInfo="deg">
            <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
</MaxDepartureAngle>
<MilitaryLoadClass value="0" />
<MaxSpeedOnVegetatedSlopeBeforeSliding value="0" unitInfo="MPH" />
<MaxSpeedOnVegetatedSlopeBeforeTipping value="0" unitInfo="MPH" />
<WinchCapacity value="0" unitInfo="lb">
            <Comment><![CDATA[ TARDEC, unknown origin]]></Comment>
</WinchCapacity>
<MaxVehicleWidth value="143.76" unitInfo="in">
            <PreComment><![CDATA[  WDTH   =    144 ! JANE'S 1990-91 & PM ofc 1991]]></PreComment>
            <PreComment><![CDATA[  WDTH   = 143.80 ! FSP83-025, Apr'83]]></PreComment>
            <Comment><![CDATA[ TM55-2350-255-14 '79]]></Comment>
</MaxVehicleWidth>
<CombinationVehicleBrakingCoefficient value=".55">
            <PreComment><![CDATA[  XBRCOF= 0.40  ! WES, unknown origin]]></PreComment>
            <PreComment><![CDATA[  XBRCOF= 0.80  ! NRMM-mgr M1A2 Jul'93]]></PreComment>
            <Comment><![CDATA[ APG REPORT # 91-LR(F)-3, test results for M1E1]]></Comment>
</CombinationVehicleBrakingCoefficient>
<FirstWheelCenterToLastWheelCenter value="180.08" unitInfo="in">
```

```
                <PreComment><![CDATA[  TL     = 180.1  ! WES, FSP83-025, Apr'83 (rounded off)]]></PreComment>
                <PreComment><![CDATA[  TL     = 180.0  ! TM55-2350-255-14 '79]]></PreComment>
                <Comment><![CDATA[ FSP83-025, Apr'83]]></Comment>
        </FirstWheelCenterToLastWheelCenter>
        <VehicleLength unitInfo="in">
                <Value>311.68</Value>
                <PreComment><![CDATA[  VULEN  =    190 ! Old WES, unknown origin]]></PreComment>
                <PreComment><![CDATA[  VULEN(1)=   312 ! JANE'S 1990-91]]></PreComment>
                <Comment><![CDATA[ FSP83-025, Apr'83]]></Comment>
        </VehicleLength>
</PhysicalCharacteristics>
<EngineInformation>
        <Engines numEng="1" powerUnit="HP" torqueUnit="ft-lb" displacementUnit="in^3">
                <EachEngine netEngPower="1500" maxEngTorque="3825" engDisplacement="1500" engType="turbine" numEngCylinder="8" />
                <PowerComment><![CDATA[ gross HP, PM ofc 1991]]></PowerComment>
                <MaxTorquePreComment><![CDATA[  QMAX(1)  = 3940  ! WES & PM ofc 1991]]></MaxTorquePreComment>
                <MaxTorqueComment><![CDATA[ Allison SCAAN Jan 16 '91]]></MaxTorqueComment>
                <DisplacementPreComment><![CDATA[  CID    = 1360 ! TARDEC Diesel equivalent, unknown origin]]></DisplacementPreComment>
                <DisplacementComment><![CDATA[ WES, Use rated horsepower for turbine engine]]></DisplacementComment>
                <EngTypeComment><![CDATA[ 1=Gas,4-stroke diesel, 2=2-stroke diesel, 3=turbine(M1)]]></EngTypeComment>
                <NumCylinderPreComment><![CDATA[  HPNET =1152  ! Allison SCAAN Jan 16 '91]]></NumCylinderPreComment>
                <NumCylinderPreComment><![CDATA[  NCYL  =  1  ! WES, unknown origin]]></NumCylinderPreComment>
                <NumCylinderPreComment><![CDATA[  NCYL  =  12  ! TARDEC, unknown origin]]></NumCylinderPreComment>
                <NumCylinderComment><![CDATA[ Correct number for M1 gas turbine (i.e. IDIESL=3)]]></NumCylinderComment>
        </Engines>
        <EngSpeedVsEngTorque numPairsEngSpeedVsEngTorque="11" engSpeedUnit="RPM" engTorqueUnit="ft-lb">
                <Pair engSpeed="800" engTorque="1350" />
                <Pair engSpeed="1000" engTorque="1650" />
                <Pair engSpeed="1200" engTorque="2000" />
                <Pair engSpeed="1400" engTorque="2300" />
                <Pair engSpeed="1500" engTorque="2450" />
                <Pair engSpeed="1500" engTorque="3920" />
                <Pair engSpeed="1600" engTorque="3850" />
                <Pair engSpeed="2000" engTorque="3550" />
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SCAAN]]></IPOWERPreComment>
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APPENDIX H: M-COP THREAT ANALYSIS CATEGORY

Table H1. Threat Analysis class: THREAT_COURSE_OF_ACTION.*

Attribute	Definition	Cardinality	Data Type	Units of Measure / other notes
Course_Of_Action_Name	Identifier for the THREAT_COURSE_OF_ACTION.	1	string	There are usually 3 or more developed courses of action (COAs) for consideration.
Threat_Unit_Name	Name of the unit associated with the THREAT_COURSE_OF_ACTION.	1	string	
Threat_Unit_Objective_Location	Location (x,y,z) of the assumed objective for the threat unit.		float	Also known as the "Why".
Threat_Unit_What	"...the type of operation, such as attack, defend, reinforce, or conduct retrograde." - FM 34-130	1	string	
Threat_Unit_When	"...the time the action will begin." - FM 34-130	1	float	
Threat_Unit_Where	"...the sectors, zones, axis of attack, avenues of approach, and objectives that makes up the COA." - FM 34-130	>1	string	

* "A possible plan open to an individual or commander that would accomplish or is related to accomplishment of the mission. A COA is initially stated in broad terms with the details determined during staff wargaming. To develop COAs, the staff must focus on key information and intelligence necessary to make decisions. COAs include five elements: **WHAT** (the type of operation), **WHEN** (the time the action will begin), **WHERE** (boundaries, axis, etc.), **HOW** (the use of assets), and **WHY** (the purpose or desired end state)." – FM 34-130 (HQDA 1994).

Table H2. Threat Analysis class: SITUATION_TEMPLATE.*

Attribute	Definition	Cardinality	Data Type	Units of Measure / other notes
Unit_Type	Type of unit being assessed.	1	string	
Unit_Name	Name of unit.	1	string	
Unit_Locations	Location of the unit within the battlespace area of interest.	1	float	
Time_Phase_Line_H	See Appendix D.	1...N	float	Class in Maneuver Analysis category.
High_Value_Target _X_Location	Location of the particular high value target.	>= 1	float	

* "A depiction of assumed adversary dispositions, based on adversary doctrine and the effects of the battlespace if the adversary should adopt a particular course of action. In effect, situation templates are the doctrinal templates depicting a particular operation modified to account for the effects of the battlespace environment and the adversary's current situation (training and experience levels, logistic status, losses, dispositions). Normally, the situation template depicts adversary units two levels of command below the friendly force, as well as the expected locations of high-value targets. Situation templates use time-phase lines to indicate movement of forces and the expected flow of the operation. Usually, the situation template depicts a critical point in the course of action. Situation templates are one part of an adversary course of action model. Models may contain more than one situation template." (JP 2-03.1) - FM 3-06.

APPENDIX I: M-COP UTILITIES CATEGORY

Table I1. Utilities category classes and attributes.

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
DATA_ QUALITY	Metadata describing the quality of the data.	Completeness	Information about omissions, selection criteria, generalization, definitions used, and other rules used to derive the data.			DDMS, EDCS
		Existence_Certainty	The certainty of existence of an object.	1–5		EDCS
		Existence_Status	The status or existence condition of an object.	1–65		EDCS
		Horizontal_Positional_ Accuracy	An explanation of the accuracy of the horizontal positions (coordinates) of spatial objects.			DDMS, EDCS
		Vertical_Positional_ Accuracy	An explanation of the accuracy of the vertical positions (coordinates) of spatial objects.			DDMS, EDCS
FEATURE	Representation of real world features.	Areal_Feature				SEDRIS DRM
		Linear_Feature				SEDRIS DRM
		Point_Feature				SEDRIS DRM
		Volumetric_Feature				SEDRIS DRM
FEATURE_ TOPOLOGY	Topology of the real world features.	Feature_Edge				SEDRIS DRM
		Edge_Direction				SEDRIS DRM
		Feature_Face				SEDRIS DRM
		Face_Direction				SEDRIS DRM
		Feature_Node				SEDRIS DRM
		Feature_Volume				SEDRIS DRM

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
FORMAT	Physical attributes of the asset.	Format	The physical or digital manifestation of the resource.		media_format	DDMS
					extent_qualifier	DDMS
					extent	DDMS
					medium	DDMS
		Meida_Type	Type of media (i.e., CD, tape, etc.)	Multipl e		EDCS, JMCDM
GEOMETRY	Spatial representation of an object.	Arc				SEDRIS DRM
		Line				SEDRIS DRM
		Ellipse				SEDRIS DRM
		Polygon				SEDRIS DRM
		Point				SEDRIS DRM
LOCATION	Information about the location of another object relative to this object.	Geodetic_Azimuth	The vector azimuth geodetic in the horizontal plane at the observer's LOCATION, to either a Line passing through the observer, or a vector relative to the observer, or the direction from the observer to an object of LOCATION.			EDCS
		Geodetic_Datum	The datum describing the relationship of a coordinate system to the earth.			EDCS
		Geodetic_Datum_ Identifier	The designation of a Geodetic_Datum.	1–307		EDCS
		Geographic_ Information	A LOCATION or region where geographic information or statistics may apply.			EDCS
		Horizontal_ Reference_Datum	A frame of reference for geodetic latitude and longitude.			
		Location_Property _Set	A property set describing properties of a location. Includes LOCATION name.			EDCS
		Point_Identifier	The identifier that represents a specific LOCATION.			JMCDM

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
		Vertical_Reference _Datum	The code that represents a Vertical_Reference_Datum.	1–46		JMCDM, EDCS*
RESOURCE	Maintenance and administration information.	Contributor	Information about an organization, person, or entity that contributed intellectual content to a resource, other than the publishing organization.		contributor	DDMS
		Creator	Information about the entity responsible for generating the resource.		creator	DDMS
		Date	A calendar date associated with an event in the life cycle of the resource.		date_created	DDMS
					date_posted	DDMS
					date_valid_til	DDMS
					date_info_cut_off	DDMS
		Identifier	An unambiguous reference to a resource within a given context.			DDMS
		Interest_Type	The reason an object is of interest.			EDCS
		Keyword	Keywords describing data set.			JMCDM
		Language	The primary language of the intellectual content of the resource.		language_qualifier	DDMS
					language_value	DDMS
		Organization	Information about an organization.		name	DDMS
					phone_number	DDMS
					email_address	DDMS
		Person	Information about a person.		surname	DDMS
					name	DDMS
					user_id	DDMS
					organization	DDMS
					phone_number	DDMS
					email_address	DDMS

* Only at attribute level; not enumerations.

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
		Publisher	This category is used to tag the identification of the entity responsible for releasing the data asset—the entity primarily responsible for the intellectual content of the product. It is intended that this category apply whenever applicable to an organization, as opposed to a person.		publisher	DDMS
		Reference_Citation				JMCDM, EDCS
		Rights	Information about rights held in and over the resource.		privacy_act	DDMS
					intellectual_property_rights	DDMS
					copyright	DDMS
		Title	A name, or names, given to the resource.			DDMS
		Type	The nature, genre, or discipline, of the content of the resource.		type_qualifier	DDMS
					type_value	DDMS
		Web_Service	Information about a Web_Service.		name	DDMS
					phone_number	DDMS
					email_address	DDMS
SECURITY_CLASSIFICA-TION	The level assigned to national security information and material that denotes the degree of damage that its unauthorized disclosure would cause to national defense or foreign relations of the United States and the degree of protection required.	Security_Classification_Description_Text	The text that describes a security classification.			DDMS, EDCS, JMCDM

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
		Security_Level	The highest level of security associated with an object.	1–5		DDMS, EDCS, JMCDM
SOURCE	References to assets or resources from which the tagged data asset is derived.	Source				DDMS, EDCS, JMCDM
		Source_Data_Set_Compile_Date				EDCS
		Source_Data_Set_Edition				EDCS
		Source_Data_Set_General_Information				EDCS
		Source_Data_Set_Name				EDCS
		Source_Data_Set_Print_Date				EDCS
		Source_Data_Set_Revision_Date				EDCS
SUMMARY_CONTENT	Concepts and topics	Subject	Subject keyword(s) that characterize the subject matter of a resource.		category_qualifier	DDMS
					category_code	DDMS
					category_label	DDMS
					keyword	DDMS
		Geospatial_Coverage (M-A*)	Geographic place names or coordinates that relate to the resource, such as a jurisdiction, point, area, or volume on land, in space, or at sea.		geographic_identifier	DDMS
					geographic_bounding_box	DDMS
					geographic_bounding_geometry	DDMS
					postal_address	DDMS
					vertical_extent	DDMS
					facility_be_number	DDMS
					facility_suffix	DDMS
					region	DDMS

* If applicable, an attribute must be supplied, for a given class.

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
					name	DDMS
					westbound_longitude	DDMS
					eastbound_longitude	DDMS
					northbound_latitude	DDMS
					southbound_latitude	DDMS
					street	DDMS
					city	DDMS
					state	DDMS
					postal_code	DDMS
					country_code_qualifier	DDMS
					country_code	DDMS
					province	DDMS
					minimum_vertical_extent	DDMS
					maximum_vertical_extent	DDMS
		Temporal_Coverage (M-A)	Subject matter coverage expressed in terms of one or more periods of time.		date_start (M-A)	DDMS
					date_end (M-A)	DDMS
					time_period (M-A)	DDMS
		Virtual_Coverage	The subject-matter coverage of a publication in terms of one or more virtual addresses.		virtual_address	DDMS
					network_protocol	DDMS
		Description	An account of the content of the resource.		description	DDMS
TIME		Date_Format	The format of a date.	1–46	calendar_date	EDCS
		Hour_Within_Day	The ordinal index of the hour within the day, starting with the number "0" at midnight.			EDCS
		Julian_Date_Terrestial_Time	The Julian_Day number for the preceding noon plus the fraction of the day since that instant.			EDCS
		Julian_Day	The Julian_Day number associated with the solar day.			EDCS

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
		Minute_Within_Day	The ordinal index of a minute within the day, starting with the number "0" at midnight.			EDCS
		Minute_Within_Hour	The ordinal index of a minute within the hour. The index starts with the number "0" at the beginning of the hour.			EDCS
		Month	The Month of the year in the Gregorian calendar.	1–12		
		Periodic_Cycle_Time	The Time_Quantity within a within a cyclic repeating phenomenon, typically the intervals of light and eclipse of a lighthouse.			EDCS
		Periodic_End_Date	The end of the active period for a seasonal object.			EDCS
		Periodic_Restriction_ End	The Month in which restrictions end on the use of an object due to climate or other limitations.	1–12		EDCS
		Periodic_Restriction_Start	The Month in which restrictions begins on the use of an object due to climate or other limitations.	1–12		EDCS
		Periodic_Start_Date	The start of the active period for a seasonal object.			EDCS
		Permanent	An indication that an object is permanent (as opposed to temporary).			EDCS
		Time_Coordinate	The coordinate value for a defined temporal reference frame.			EDCS
		Time_Division_Within_Day	The division of the day (one of several) marked by the passage of the sun through its diurnal cycle.	1	sunrise	EDCS
				2	daytime	EDCS
				3	sunset	EDCS
				4	night_time	EDCS
				5	continuous	EDCS
		Time_Format	The format of a time of the day.	1–22		EDCS
		Time_Of_Day	A time of the day formatted as a Time_Format.			EDCS
		Time_Period	A period of time; formatted as specified by Time_Period_Format.			EDCS

Class		Attribute		Enumeration		Source
Name	Definition	Name	Definition	Value	Label	
		Time_Period_ Format	The format of a period of time.	1	iso	EDCS
				2	period_start_end	EDCS
				3	duration	EDCS
				4	period_start_ duration	EDCS
				5	period_duration_ end	EDCS
				6	reduced	EDCS
		Time_Quantity	A quantity of time (period).			
		Season	Season of the year.	1–4		EDCS
		Year_Common_ Era	The Time_Quantity as measured by the Gregorian calendar in whole years since the beginning of the Common Era.			
USAGE	Information on the usage of certain objects.					EDCS
		Operating_Time	The times during which the use of an object is unrestricted.			EDCS
		Operating_ Restrictions_Type	The conditions during which the use of an object is restricted.	1-7		EDCS

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14. ABSTRACT

Information needed to support ground mobility decision-making is critical to the success of ground operations. The ability to rapidly obtain and process relevant information in a network-centric environment will empower warfare planners. In addition, future network-centric operations that will include autonomous unmanned ground vehicles as envisioned in the Future Combat Systems program will increasingly require the exchange of well-structured information between human forces and robotic systems. Addressing this operational challenge begins with a clear understanding of the information content needed for ground mobility planning. The purpose of the Mobility Common Operational Picture (M-COP) project is to specify a standardized vocabulary and conceptual relationships for the expression and transfer of ground vehicle maneuver data, planned routes, trafficability assessments, and other parameters associated with Future Force assured mobility across Modeling and Simulation (M&S) systems and Battle Command (BC) systems. The scope of the project was limited to ground vehicle mobility and ground vehicle maneuver information. The project identified terms and concepts across relevant data representations that will enable the M-COP capability to be achieved in the current and emerging network-centric architecture.

15. SUBJECT TERMS

Battle command
Battle management language
Common operational pictire
Force operating capabilities
Mission analysis
Mobility
Modeling and simulation
Ontology

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