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Multilateral Interoperability Programme — Advancements in MIP Baseline 3 —

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Abstract

Semantic interoperability of command and control information systems (C2ISs) is critical to combined and joint missions. Thus, in the *Multilateral Interoperability Programme* (*MIP*), 25 nations and NATO define a common interface for distributed, heterogeneous C2ISs.

A core feature of the MIP solution is the *Joint Command, Control, and Consultation Information Exchange Data Model* (*JC3IEDM*), which is developed in close cooperation with the NATO Data Administration Group (NDAG). In addition, MIP defines a *Data Exchange Mechanism* (*DEM*) to achieve interoperability on the technical and procedural level.

The MIP community improves its solution continually to meet new operational requirements and to take into account new technologies and lessons learned. Presently, MIP finalized its baseline 3, for which draft specifications are publicly available. Baseline 3 features the JC3IEDM 3.1, which has been extended significantly to cover, e.g., information exchange requirements from navy and air force and to support plans and orders. Moreover, MIP has revised its DEM to simplify the implementation and operation of its publish-subscribe mechanism and to make it more robust.

In this paper, we provide an overview of the Multilateral Interoperability Programme. In particular, we describe the major advancements of the JC3IEDM 3.1 and the DEM of the forthcoming MIP baseline 3.

Keywords: Multilateral Interoperability Programme, MIP, JC3IEDM, Data Exchange Mechanism, DEM, Command and Control Information Systems, C2IS

1 Introduction

In combined and joint missions, the semantic interoperability of command and control information systems (C2ISs) plays an important role. Therefore, 25 nations and NATO define a common interface for distributed, heterogeneous C2ISs in the *Multilateral Interoperability Programme* (MIP; see MIP, 2007a). The objective of MIP is "to achieve international interoperability of C2IS at all levels from corps to battalion, or lowest appropriate level, in order to support multinational (including NATO), combined and joint operations and the advancement of digitization in the international arena." (MIP, 2006a). MIP is a voluntary forum without common funding that is driven by national doctrine and requirements. It develops consensus-based, system-independent technical specifications for national C2ISs to achieve operational interoperability through automated information exchange.

A core feature of the MIP solution is the *Joint Command, Control, and Consultation Information Exchange Data Model* (JC3IEDM; see MIP, 2007b). It is developed in close cooperation with the NATO Data Administration Group (NDAG, 2007), which signed an agreement with MIP in February 2004. The JC3IEDM provides the basis for information exchange and specifies the semantics of militarily relevant objects, actions, etc., as well as the semantics of their relationships in an unambiguous way.

In addition to the data model, MIP also defines information exchange protocols and procedures. The MIP *Data Exchange Mechanism* (*DEM*) supports the partial replication of operational data depending on their affiliation to a particular *Operational Information Group* (*OIG*). For each category of OIG, MIP defines specific distribution rules.

MIP Schedule. The MIP community improves its solution continually to meet new operational requirements (e.g., the exchange of plans and orders according to STANAG 2014) and to respond to the lessons learned in preceding interoperability demonstrations (e.g., during the MIP technical and operational tests).

The MIP specifications, called *baselines*, are developed in an incremental manner based upon overlapping *blocks*. Each block comprises a development phase, in which the MIP members analyze operational requirements, develop concepts, make feasibility studies, define the MIP solution, implement it in their national systems, and finally perform interoperability tests. By the end of this phase, the baseline is finished and the baseline and MIP-compliant systems enter an in-service period. So far, the development phases have taken about three years, followed by a two-year in-service period. In the future, the spaces of time may be extended to reflect the maturity of the MIP specification.

For the forthcoming MIP baseline 3, initial draft specifications have been available on the public web site since December 2006 (MIP, 2007a). Interoperability tests will start in September 2007. Baseline 3 features the JC3IEDM 3.1, which has been extended significantly to cover, e.g., new requirements from navy and air force. Moreover, MIP has revised its DEM to simplify the implementation and operation of its publish-subscribe mechanism and to make it more robust and less bandwidth-consuming.

MIP Specifications. The MIP baseline comes as a set of specification documents addressing a varying audience (see figure 1). The end user of the MIP solution, i.e., the commander, will find useful information in the *MIP Tactical Interoperability Requirement* (*MTIR*), which describes the operational requirements underlying the MIP solution. For MIP baseline 3, joint information exchange requirements are described from a land component's view. The *MIP Operational Handbook* (*MOH*) tells the commander what functionality he can expect from a MIP-compliant system.

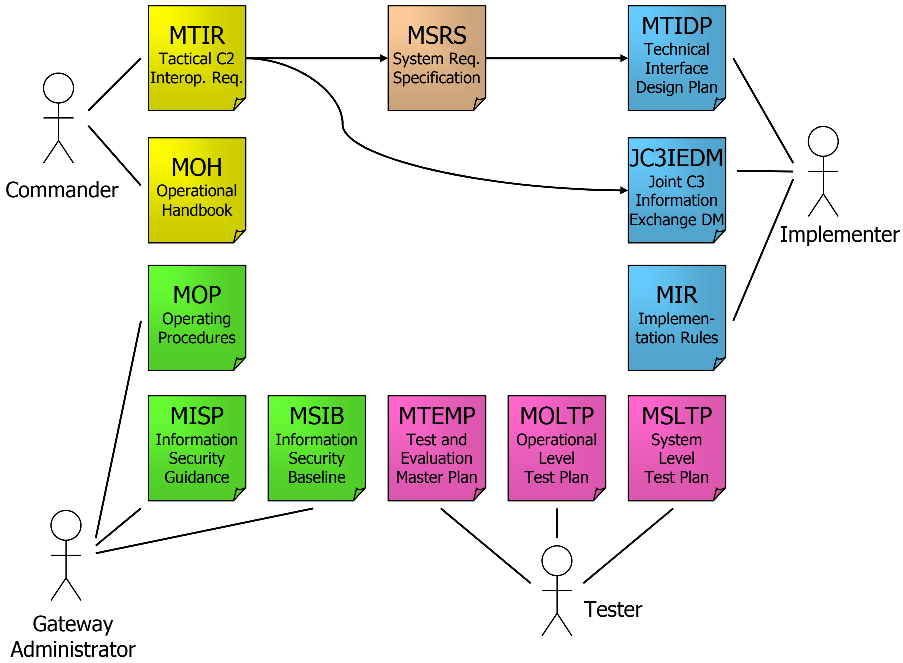

Figure 1: MIP Specifications

Based on the MTIR, the *MIP System Requirements Specification* (*MSRS*) is derived, which finally results in the *MIP Technical Interface Design Plan* (*MTIDP*). In order to implement the MIP solution, a system developer also has to consult the JC3IEDM and the *MIP Implementation Rules* (*MIR*).

The testing process is supported by another set of specifications that cover system-level tests (*MSLTP*) and as well as operational-level tests (*MOLTP*). The *Test and Evaluation Master Plan* (*MTEMP*) defines the overall test approach that is carried out within MIP in order to prove that national implementations are interoperable.

Finally, the MIP gateway administrator, i.e., the person configuring and running the MIP gateway, is supported by the *MIP Operating Procedures* (*MOP*). Security aspects are covered by the *MIP Information Security Guidance* (*MISG*) and the *MIP Information Security Baseline* (*MISB*), the latter defining information security requirements that are common to all nations and should be met in the MIP specification.

Guide Through This Paper. In this paper, we provide an overview of the MIP solution. The focus of our work will be on the major advancements achieved during MIP block 3. In section 2, we provide an overview of the JC3IEDM 3.1 and present new features on the entity level. In section 3, we describe the Data Exchange Mechanism of MIP baseline 3 and explicate the improvements by comparing it with the DEM of the preceding baseline. Finally, in section 4, a short summary and outlook is given.

The MIP specifications are the result of many people – military experts, data modelers, and system engineers – that come from all 25 MIP member nations and NATO. It is their merit that MIP is gaining increased acceptance in the C2 community.

As part of the German delegation, the authors are actively involved in the development of the MIP solution. For baseline 3, the FKIE Research Institute for Communication, Information Processing, and Ergonomics develops the MIP test reference system. It will allow the MIP community to check the conformance of their C2ISs with regard to the MIP specifications in an automated way.

2 The JC3IEDM 3.1

The MIP data model has a long history that dates back to the *Army Tactical Command and Control Information System* (*ATCCIS*) project in the 1980s. Over the years, the MIP data model has been renamed several times. What was known as the *Generic Hub* in ATCCIS, became the *Land Command and Control Information Exchange Data Model* (LC2IEDM) in MIP baseline 1. For MIP baseline 2, some joint aspects with relevance to the land component commander were added to the data model, and thus the prefix *Land* was dropped (⇒ C2IEDM). In baseline 3, the data model covers even more requirements of navy and air force, and thus it was renamed to *Joint Command, Control, and Consultation Information Exchange Data Model* (*JC3IEDM*). The most recent version of the JC3IEDM is 3.1a, the first bug fix release of the 3.1 series, which will be the basis for MIP baseline 3. Further minor bugs are expected to be discovered during the implementation and testing phase of MIP baseline 3. They will eventually result in a new version (i.e., 3.1b) of the data model.

The JC3IEDM is an Entity-Relationship (ER) model in IDEF1X notation (IEEE, 1998). It defines all military information in terms of entities (e.g., UNIT, HARBOUR, LOCATION), attributes (either optional or mandatory), and domains (e.g., codes with a finite set of predefined values). Moreover, MIP defines a large set of business rules that specify the proper use of the ER model. For instance, some types of capabilities can only be assigned to specific types of equipment. In baseline 3, many of these business rules are available in a formal representation, which greatly simplifies their implementation.

As shown in figure 2, the MIP data model has been extended significantly from one baseline to another. In comparison with the C2IEDM 6.15e, the logical view of the JC3IEDM 3.1 introduces 68 additional entities and 439 (!) additional attributes (this is an increase by 33% and 43% resp.). Moreover, several existing entities of the C2IEDM 6.15e have been refactored. Similarly, many new code values have been added on the domain level.

A comprehensive description of all changes in the JC3IEDM 3.1 is beyond the scope of this paper. In the following, we will focus on the most relevant changes on the entity level.

2.1 Capabilities

In the MIP data model, capabilities of military objects are not modeled as integral part of the respective entities but described in a separate submodel. This allows associating capabilities to

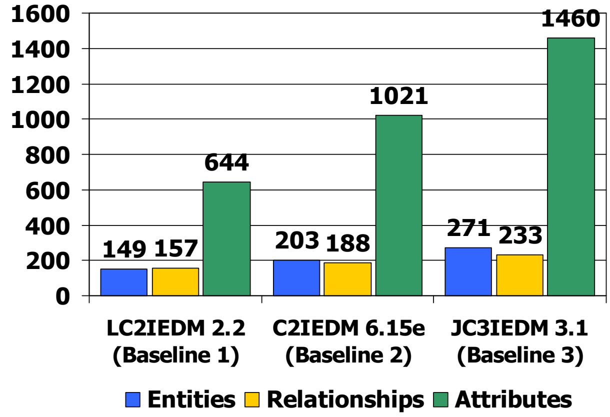

Figure 2: Evolution of the MIP Data Model

different entity types, which reduces redundancy in the model. Capabilities may be assigned to object items (like a concrete unit or equipment) but also as a norm to object types, e.g., to a specific *kind* of equipment. Moreover, capabilities can be specified as a prerequisite for a particular action.

In the JC3IEDM 3.1, the capability submodel has been extended by five new entity types. The motivation behind these extensions is partly of a technical kind. In the former model, specific capabilities were expressed by category-code and subcategory-code attributes. Since not every subcategory is applicable to every category, the valid combinations had to be defined by means of business rules. To overcome the complexity of this approach, MIP decided to enforce the proper use by introducing new subtypes.

The complete capability hierarchy is shown in figure 3, in which all new entities are marked with yellow. To enhance readability, the entity prefixes have been stripped from the attribute names in this and all following figures. For instance, the attribute object-item-capability-index in OBJECT-ITEM-CAPABILITY has been changed to simply index.

In total, the JC3IEDM 3.1 supports ten types of capabilities:

- *Storage* – the ability to hold a specific OBJECT-TYPE.
- *Engineering* – the ability to perform construction or destruction activities.
- *Fire* – the ability to discharge or launch a projectile or missile.
- *Mobility* – the nominal ability to move in space, air, on water, under water, or over a specific type of terrain.
- *Surveillance* – the nominal ability to observe aerospace, surface or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means.
- *Maintenance* – the ability to provide a range of activities required to restore or maintain operational usage.
- *Support* – the ability to provide supplies or services.

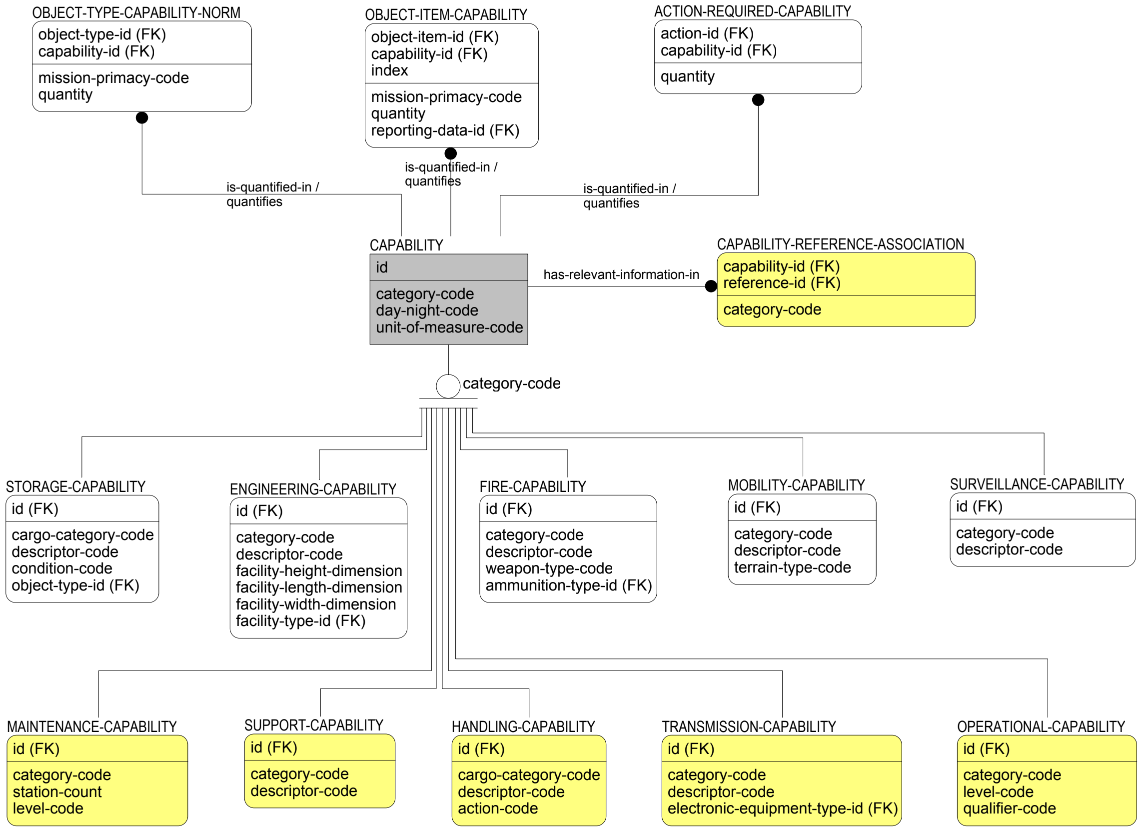

Figure 3: JC3IEDM 3.1 – Capability

- *Handling* – the ability to move materiels (raw materials, scrap, semi-finished, and finished) to, through, and from productive processes; in warehouses and storage; and in receiving and shipping areas.
- *Transmission* – the ability to generate, receive, or affect signals in the electromagnetic spectrum.
- *Operational* – the ability (as well as the training and the equipment) to perform an operation.

2.2 Air Force – Air Tasking Order

For the JC3IEDM 3.1, more air force requirements were considered. In particular, a lot of effort was put in the proper modeling of information that can be exchanged via message *Air Tasking Order* (*ATO*) of ADatP-3. This has led to numerous smaller changes to all parts of the data model (e.g., to PERSON/ORGANISATION-STATUS, ACTION-OBJECTIVE-TYPE, MISSION-CAPABILITY). In figure 4, some of the new entities are presented that are relevant to ATO and air force in general (again marked with yellow).

Beside the already existing entity AIRFIELD, two new FACILITY subtypes have been added:

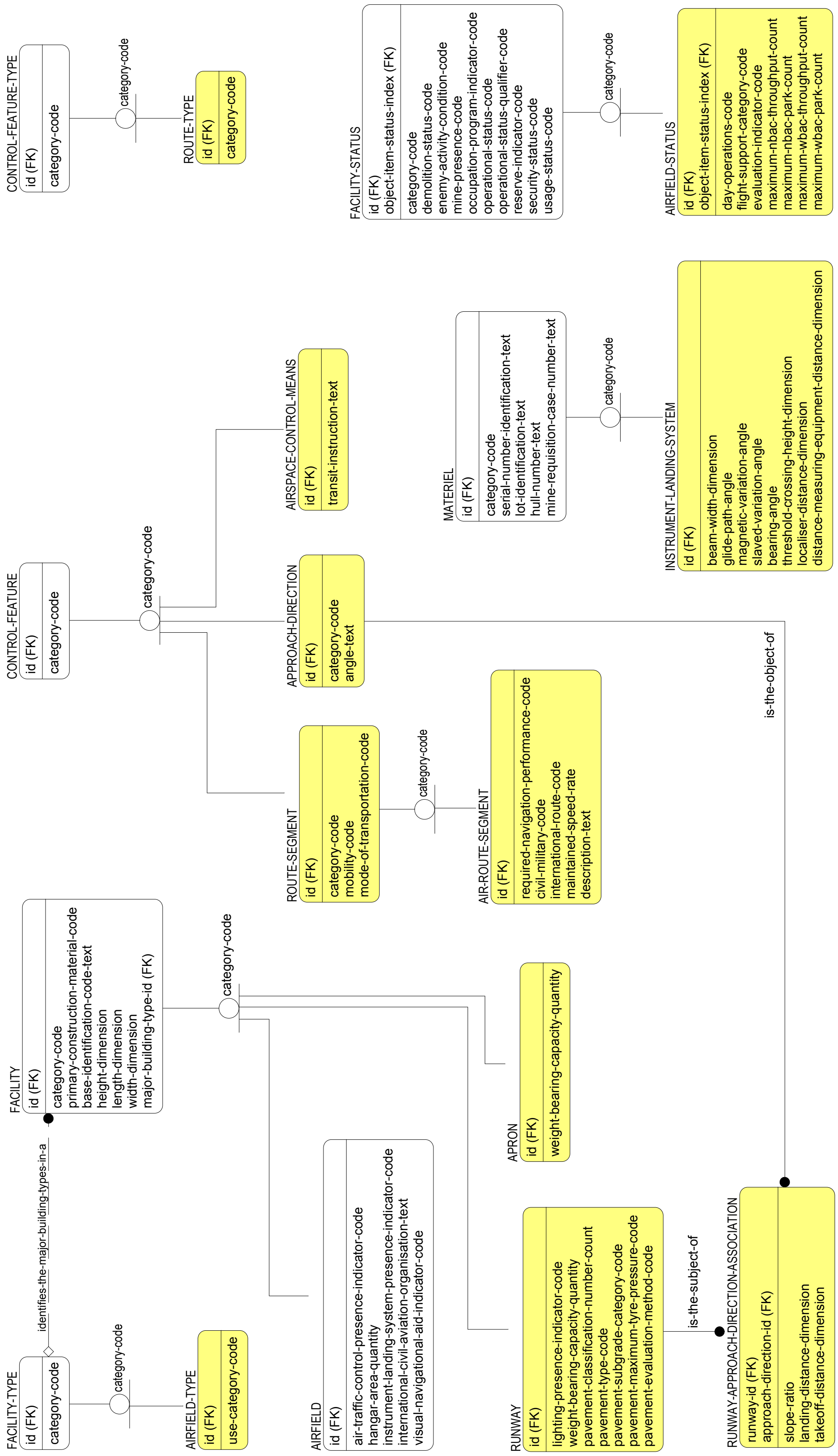

Figure 4: JC3IEDM 3.1 – Air Tasking Order

RUNWAY was introduced to cover scenarios, in which a runway is not located at an AIRFIELD but, e.g., on a carrier vessel. It was also added to model an AIRFIELD with more than one runway. RUNWAY can be associated with an APPROACH-DIRECTION for takeoff and landing by means of RUNWAY-APPROACH-DIRECTION-ASSOCIATION. The entity APRON is used to specify the surface type and bearing capacity of an area intended for parking, loading, unloading and/or servicing.

Several new control features were introduced. AIRSPACE-CONTROL-MEANS allows describing a reserved airspace for specific users and their transit instructions. Moreover, AIR-ROUTE-SEGMENT was added along with a corresponding ROUTE-TYPE to align the JC3IEDM with the NATO Corporate Data Model 4.0. AIR-ROUTE-SEGMENT is defined as a portion of a route to be flown usually without an intermediate stop. Possible ROUTE-TYPEs are *unmanned aerial vehicle route*, *main supply route*, *alternate supply route*, etc.

Finally, INSTRUMENT-LANDING-SYSTEM can be used to model materiel that provides aircrafts with horizontal and vertical guidance just before landing and during landing, and – at certain fixed points – indicates the distance to the reference point of landing.

2.3 CBRN – Chemical Biological Radioactive Nuclear

The C2IEDM 6.15e subsumed all weapons and events of mass destruction under the term *NBC – Nuclear, Biological, Chemical*. However, this terminology excluded radiological events, which involve radioactive material but neither fission nor fusion. Therefore, in the JC3IEDM 3.1, the NBC submodel was extended to the new *CBRN* submodel – *Chemical, Biological, Radiological, or Nuclear* (see figure 5).

With the JC3IEDM 3.1, it is now possible to describe radioactive concentration, radioactive dose, chemical and biological concentration time, etc. Furthermore, new weather attributes have been added to entities ATMOSPHERE and WIND to support information requirements for CBRN transport and dispersion prediction. Finally, some refactoring was made to prevent the use of nuclear attributes for chemical or biological events and vice versa.

The operational requirements for CBRN are derived from ADatP-3 B12.2 and NATO standard ATP-45 (Allied Technical Protocol-45), which defines current NATO and US command doctrine for nuclear, chemical, and biological hazard area templates.

As shown in figure 5, ten new entities have been introduced that replace the former NBC entities. The modifications affect three subtype hierarchies: CBRN-EQUIPMENT-TYPE is derived from EQUIPMENT-TYPE and models classes of equipment that are designed for specialized roles in detecting, decontaminating, or reconnoitring CBRN agents. Chemical, biological, and radioactive materiel types are subsumed under CONSUMABLE-MATERIEL-TYPE, which models expendable classes of supply. All CBRN events are modeled as subtypes of ACTION-EVENT, i.e., they are incidents, phenomenons, or occasions of military significance which have occurred or are occurring but for which planning is not known.

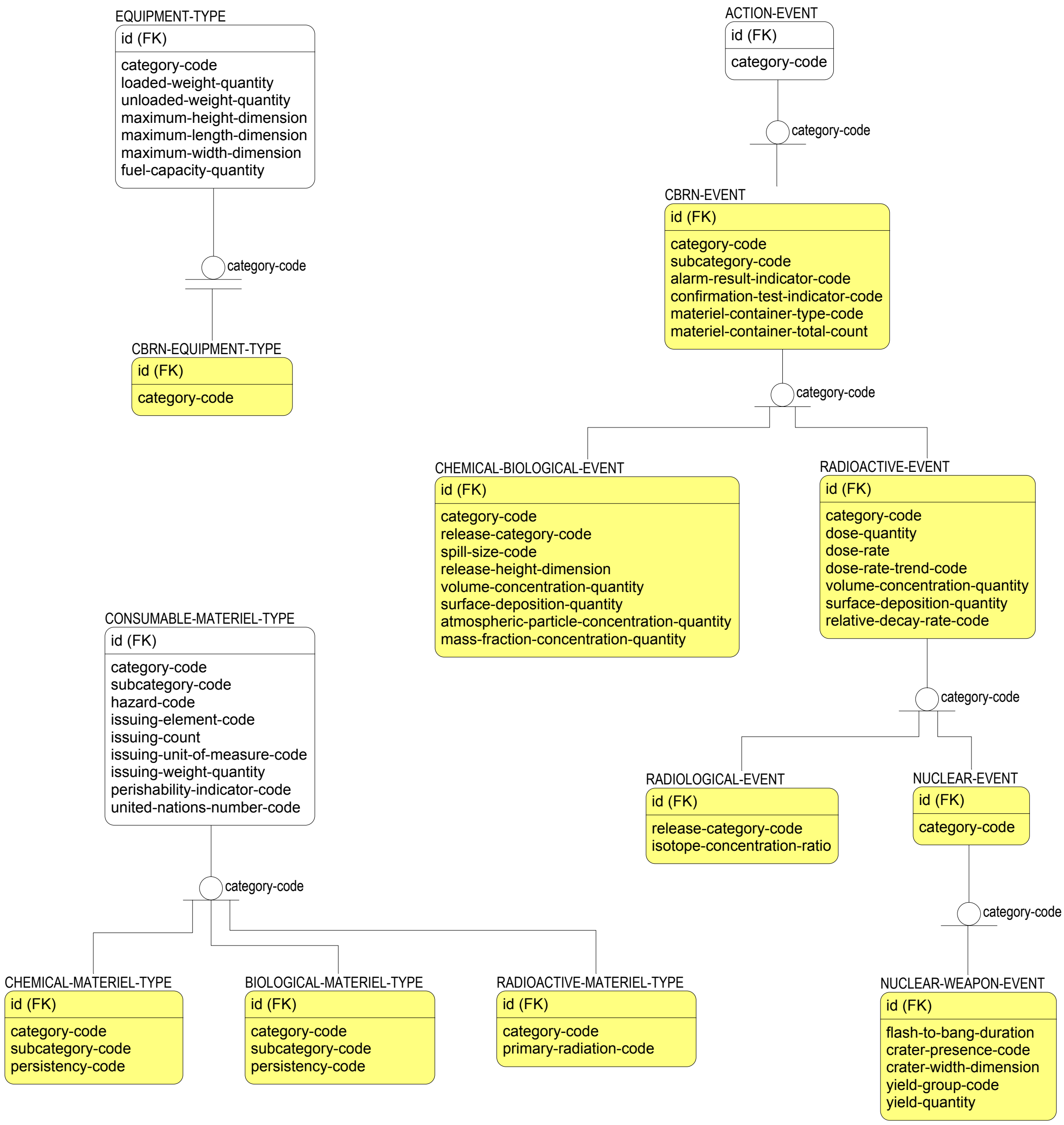

Figure 5: JC3IEDM 3.1 – CBRN

2.4 Harbors

In the C2IEDM 6.15e, the components of a harbor (quay, berth, jetty, dry dock, basin, slipway, and anchorage) were modeled as dependent entities of HARBOUR. From a modeling perspective, this made sense, because a quay cannot exist without a harbor. However, this approach made it impossible to associate individual harbor components with, e.g., a location, or to assign a facility status to them. Moreover, it was impossible to declare parts of a harbor as resources/objectives of an action. In the JC3IEDM 3.1, MIP follows the approach of the former NATO Corporate Data Model where the above-mentioned entities are sub-types of FACILITY.

Moreover, an analysis of the maritime information system MCCIS has shown that more information is needed to describe and define harbors. As a result, MIP has added several new attributes to the entities HARBOUR, BERTH, and DRY-DOCK. In addition, a new entity HARBOUR-TYPE was introduced as a subtype of FACILITY-TYPE in order to be able to describe the harbor category (canal or lake, coastal (breakwater, natural, or tide gateway), inland water way, etc.).

The new JC3IEDM 3.1 data structures are presented in figure 6.

2.5 Navy – Maritime Mine Warfare

As result of the MIP/NDAG merger, the JC3IEDM 3.1 supports navy requirements, in particular those related to maritime mine warfare. The modeling has resulted in several new entities that are depicted in figures 7 and 8 (new entities printed in yellow).

For instance, MINEFIELD has become the parent of a new subtype hierarchy for separating land-based specifics (MINEFIELD-LAND) from maritime-based specifics (MINEFIELD-MARITIME). MINEFIELD-MARITIME-SUSTAINED-THREAT-MEASURE-OF-EFFECTIVENESS determines the effectiveness of a specific MINEFIELD-MARITIME in terms of probability of mine function against a transit vessel over a given period. MINEFIELD-MARITIME-CASUALTY-ESTIMATE is an estimate of the average number of casualties for a given number of vessel transits.

Moreover, MARITIME-EQUIPMENT-TYPE has been introduced to model equipment like anchor, buoy, sonar, or sweep. GEOGRAPHIC-FEATURE-STATUS has been refined to SOLID-SURFACE-STATUS, LIQUID-SURFACE-STATUS, and LIQUID-BODY-STATUS.

2.6 Plans & Orders

Plans and orders are the formal means of a commander to communicate his intentions to subordinates. This makes the information contained in plans and orders crucial for the success of operations.

As of baseline 3, the MIP solution supports the exchange of plans and orders. For that purpose, the following main requirements have been taken into account and added to the MIP Tactical Interoperability Requirement (MTIR 3.6):

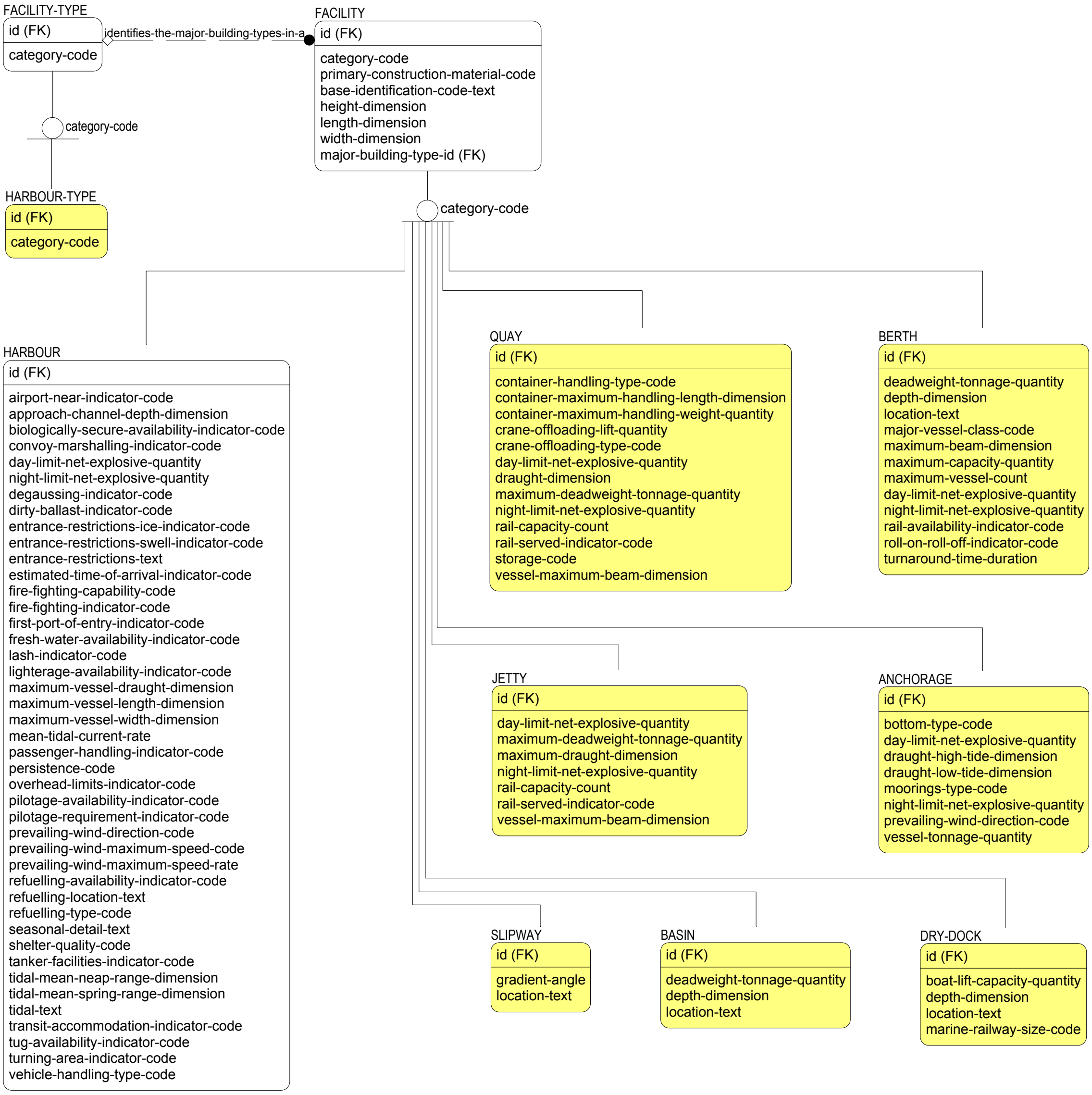

Figure 6: JC3IEDM 3.1 – Harbors

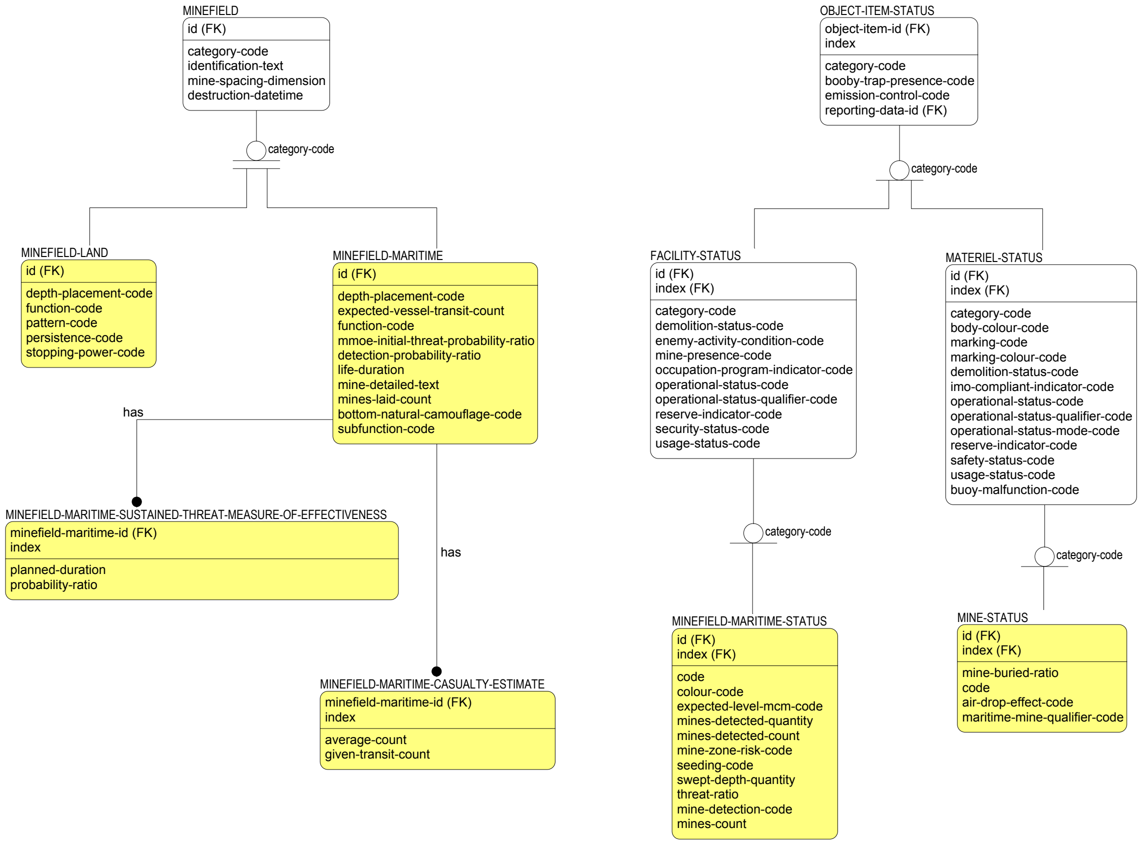

Figure 7: JC3IEDM 3.1 – Navy / Maritime Mine Warfare

- *STANAG 2014 Compliance*

  The *NATO Standardization Agreement 2014* (NATO, 2000) defines the format of plans and orders. It addresses the designation of days and hours as well as ground locations, areas and boundaries. In particular, the different types of plans and orders (operational plan/order, fragmentary order, warning order, administrative/logistics order, overlay order) are defined. STANAG 2014 prescribes the accurate sectioning of plans and orders by header information, a main body with paragraphs and subparagraphs, and additional annexes and their appendices. It also provides a clear nomenclature for the main elements in this hierarchy.

- *Content*

  The elements of a plan or order can be exchanged in the form of free text, task organizations, overlays (sketches, matrices, graphs, tables, imagery etc.) and action tasks. The content may be stored within the JC3IEDM. Alternatively, a reference to some external data source may be given.

- *Plan/Order States*

  During its life cycle, a plan/order can pass many states, which specify the progress in development. The self-explanatory names for these statuses are *NOT STARTED*, *IN*

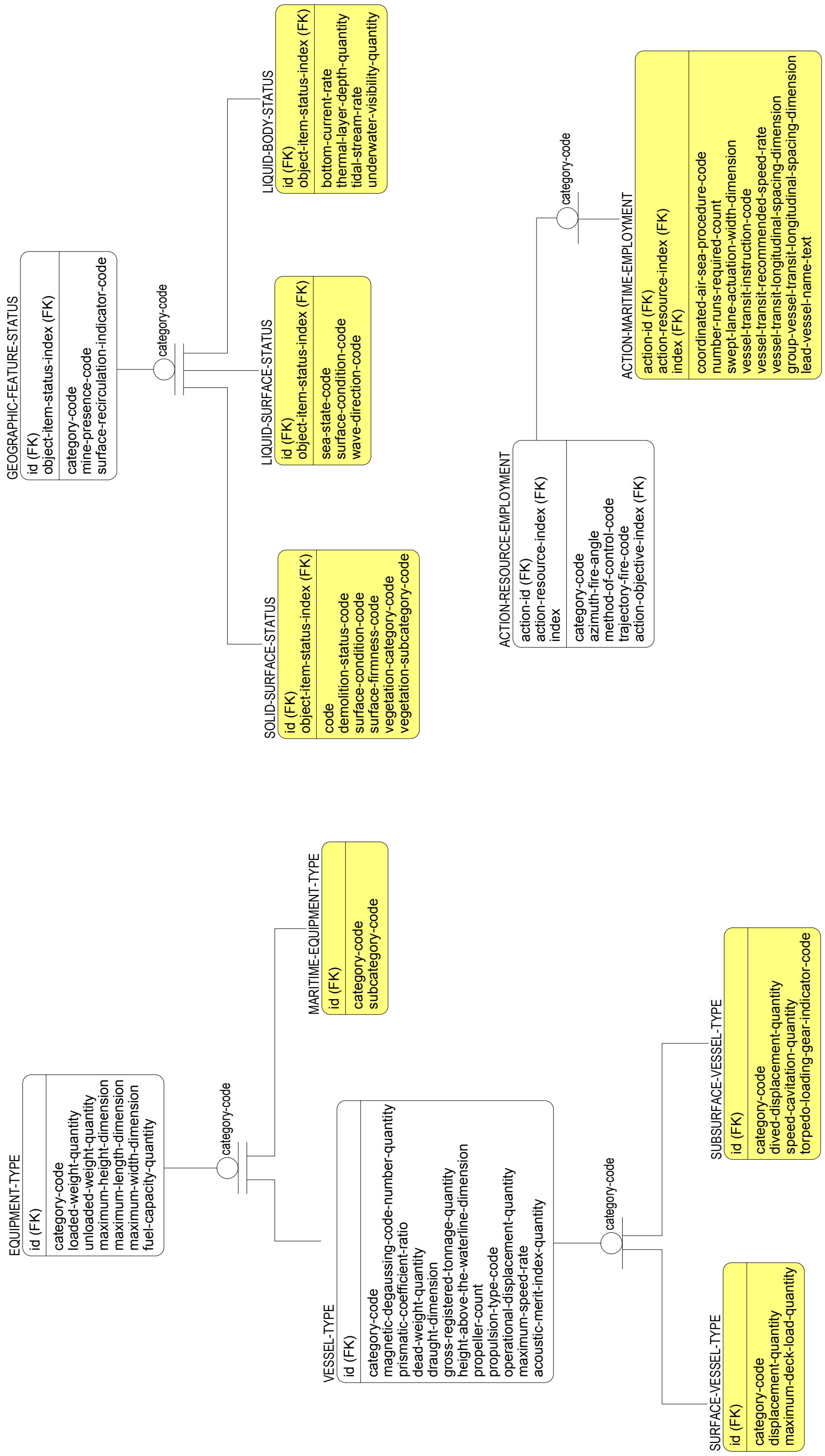

Figure 8: JC3IEDM 3.1 – Navy / Maritime Mine Warfare (continued)

PROGRESS, *NOT COMPLETE*, *COMPLETE*, and *STOP WORK*. In addition, the authorization state of a plan can be documented (*APPROVED*, *WITHDRAWN*, or *CANCELLED*). Both types of states can be assigned to the entire plan or an individual plan element (with the exception of APPROVED, which always applies to the complete plan). If the whole plan is APPROVED, it can be converted to an ISSUED order which may be STOPPED later.

- *Changes*

  Changes to plans and orders can be made in different ways. While the MIP solution supports continuous updates of a single plan, an issued order must be updated by an amending fragmentary order or must be superseded in its entirety by another order. Continuous updates of a plan affect the plan directly, but through versioning, it is possible to create different variants of a plan. Since fragmentary orders are also modeled as orders, an issued order can be amended by a chain of fragmentary orders.

- *Distribution*

  The MIP solution allows the exchange of one or multiple plans or orders with other MIP systems by distributing them either as a whole or as individual elements to different recipients. MIP defines a consistent behavior for handling content or status changes, and for conversions after the plan or order has been distributed.

A complex data model consisting of 19 additional entities has been incorporated into the JC3IEDM 3.1. The plans & orders submodel is shown in figure 9. It covers the requirements given above to the greatest possible extent. At the time of writing this paper, usage and business rules are being defined to fixate the use of the model, to resolve potential ambiguities and to disallow scenarios in which subtle problems may occur.

2.7 Miscellaneous

Various other changes have been made to the JC3IEDM. Examples are:

- Three more entities, namely ACTION, OBJECT-ITEM, and OBJECT-TYPE, can be associated with entity REFERENCE. The latter allows you to point to some external information not modeled within the JC3IEDM. Moreover, a REFERENCE can be declared as a supplement, modification, etc. of another REFERENCE.
- By means of OBJECT-ITEM-ALIAS, one can assign additional names to an OBJECT-ITEM.
- HOLDING is used to keep track of stockpiles of specific equipment and consumable materiel held by forces. The new entity HOLDING-TRANSFER allows adding and/or subtracting some quantity of equipment and material to/from a given HOLDING.

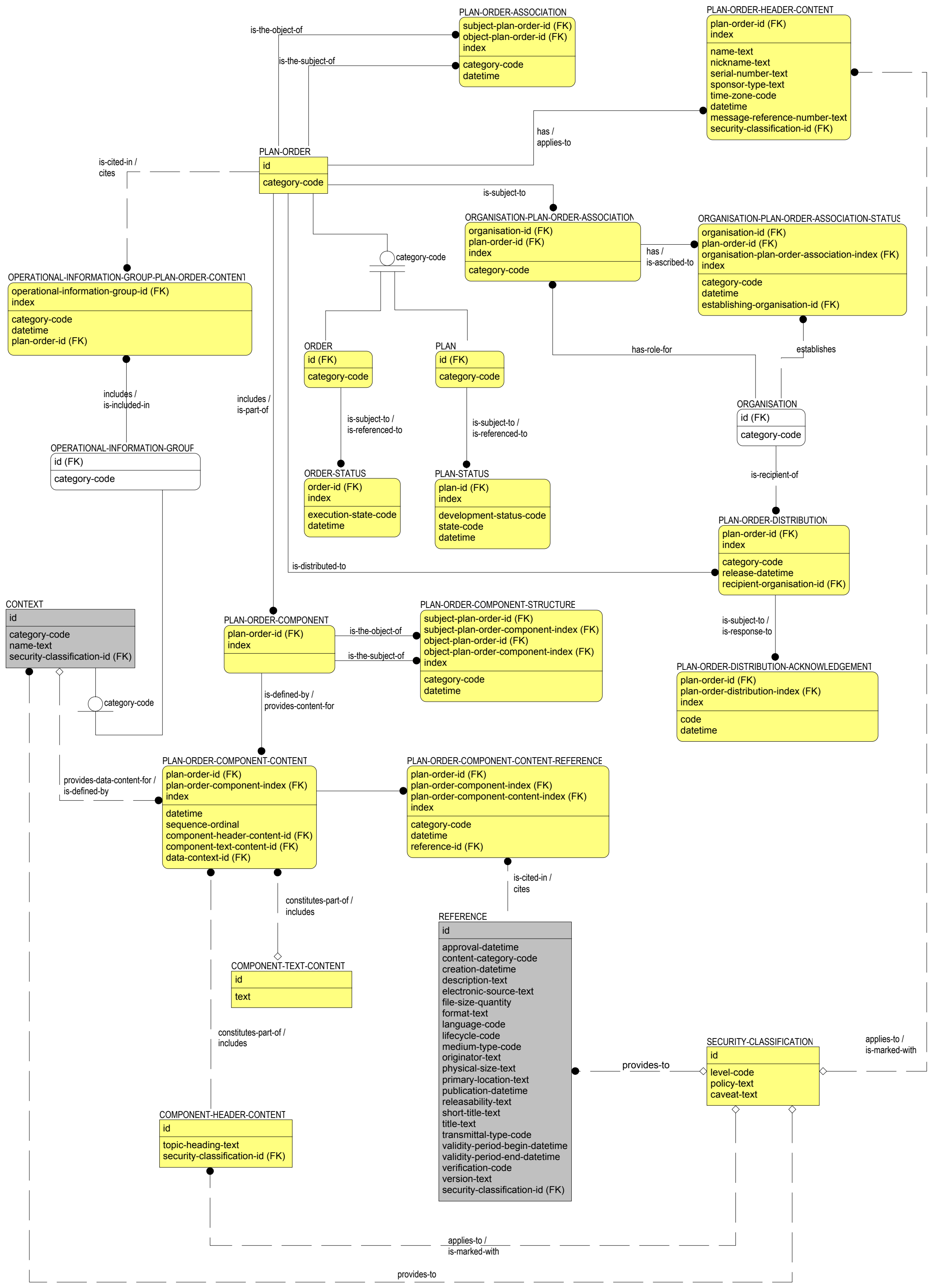

Figure 9: JC3IEDM 3.1 – Plans & Orders

3 The MIP Data Exchange Mechanism

Supplementary to the JC3IEDM, the *Data Exchange Mechanism* (*DEM*) is MIP's second means to achieve interoperability among heterogeneous C2 information systems. The DEM is a replication mechanism for the JC3IEDM. It uses a publish-subscribe method to distribute data, utilizing the concept of *Operational Information Groups* (*OIGs*). This concept separates the information space into operationally distinct groups, which can be delivered to different receivers. Within each of these groups, referential integrity and semantic completeness of information is ensured. Furthermore, the DEM checks for the compliance to additional business rules. For instance, if an organization is added to an OIG, the DEM takes care of transmitting the organization's status as well.

For MIP block 3, the DEM was redesigned based on the lessons learned in the previous block. Several goals have been addressed:

- Simplified technical implementation.
- Easier administration/operation of MIP gateways.
- Enhanced overall reliability and robustness.
- Reduced network bandwidth requirements.

To achieve these objectives, improvements have been made in several areas:

- Connection information is exchanged in an automatic manner.
- The DEM protocol stack has been completely revised and adjusted to the capabilities of the underlying TCP/IP layer.
- The number of optional features has been reduced.
- The responsibility for establishing contracts has been shifted from the data provider to the data receiver.
- New features to support backward compatibility for future baselines have been introduced.

In the following, we will describe the DEM improvements in detail.

3.1 DEM Initialization – Getting Into Contact

To allow the gateway operator to set up contracts, each MIP gateway on a MIP LAN needs to know all possible partner gateways. This information is gathered during the initialization phase of the DEM. Among others, the exchanged connection information comprises the node id of a MIP gateway, its IP address and TCP port, as well as its supported versions of the data model and the DEM. The latter is useful in case two gateways support different MIP baselines and the more recent gateway supports backward compatibility.

The DEM specifies three possible ways to exchange connection information:

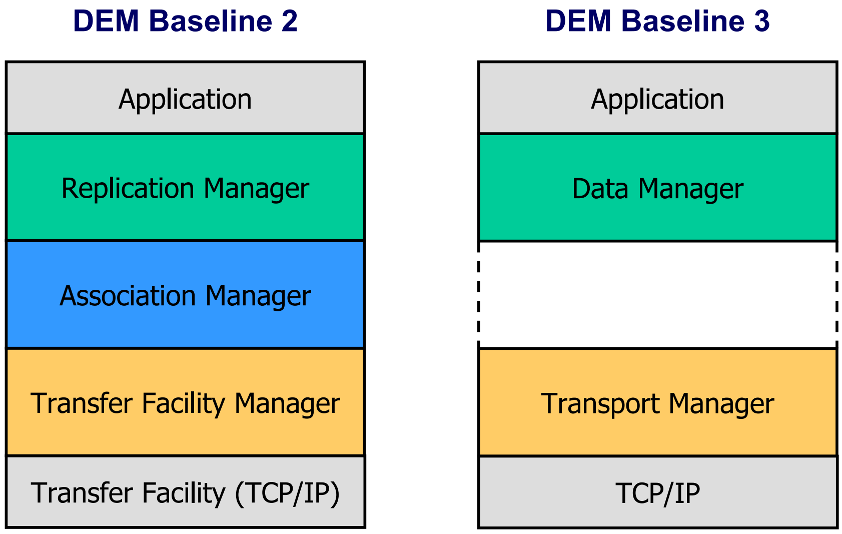

Figure 10: DEM Protocol Stacks

1. The gateway operator enters connection information manually.
2. The gateway operator loads connection information from a file (in XML format).
3. The MIP gateway receives and sends new connection information automatically.

The first two options were already available in baseline 2 and can be considered as off-line information exchange. The third way has been introduced in baseline 3. It uses an automated broadcast mechanism to exchange connection information. Whenever a MIP gateway connects to the MIP LAN, it sends its connection information to all nodes via a UDP broadcast to a fixed port. All nodes on the MIP LAN will respond with their own connection information by a unicast to the IP address provided in the newly received connection information.

To be able to distinguish between received broadcasts and unicasts, the connection information contains a field called *scope*, which can be either set to ANNOUNCE for broadcast or REPLY for unicast. Only upon receiving connection information with the scope set to ANNOUNCE, the MIP gateway replies with its own connection information.

For expandability and backwards compatibility, the XML connection information do not only include the supported versions of the data model and the DEM but also a field called *Extension*, which allows the exchange of additional information.

3.2 DEM Protocol Stack

To illustrate the simplifications of the DEM protocol stack in baseline 3, we first explain the structure of the baseline 2 solution as shown in figure 10.

The DEM protocol stack in baseline 2 consists of five layers:

1. The *Application Layer* provides means to create, read, update, and delete operational data and DEM meta data.

2. The *Replication Manager* replicates operational data, distributes the DEM management information, and synchronizes with the database.
3. The *Association Manager* is a connection-oriented transport layer which provides flow control for the upper layer while choosing an appropriate Transfer Facility Manager.
4. The *Transfer Facility Manager* provides an abstraction from different Transfer Facilities and ensures the correct transmission of replication messages, regardless of the underlying transport mechanism.
5. The *Transfer Facility* provides a point-to-point transfer service by utilizing TCP/IP or any other transfer protocol (in baseline 2, it was ruled to be TCP/IP only).

The baseline 3 protocol stack consists of four layers only, two of which are specified as part of the MIP solution (see MIP, 2006b, Annex A).

1. The *Application Layer* still creates, reads, updates, and deletes operational data, but it does not have to keep track of any DEM meta data. It will be informed automatically whenever the status of a subscription changes and new OIGs are available.
2. The *Data Manager* provides means for subscribing and unsubscribing to OIGs, for making OIGs available to other nodes, and for sending and receiving operational data within an OIG.
3. By utilizing the TCP/IP stack, the *Transport Manager* handles connections between two nodes. It supports sending and receiving primitives of the Data Manager and deals with error conditions on the connection level.
4. The *TCP/IP* layer provides a point-to-point transfer service.

State tables in the MTIDP, Annex A, specify the behavior of the Data Manager and the Transport Manager layers unambiguously. Distinct state tables are defined for the roles *data receiver* and *data provider*. Each MIP gateway may play both roles simultaneously. This means that for every connection to a gateway, up to two complete protocol stacks have to be used: one for sending own data to the partner and another one for receiving data from that particular node. The Data Manager state tables incorporate a mechanism that keeps track of all current subscriptions.

The new Data Manager protocol is designed to tolerate errors as much as possible while at the same time ensuring that no data corruption can occur. As long as an error can be identified within one OIG, the affected subscription is revoked and an error message is sent to the partner. Only in cases where an error affects more than one OIG (or no affected OIG can be identified), all subscriptions are canceled. Then, the data receiver sends an error message to inform the provider and closes the connection.

Furthermore, the state tables take into account that race conditions may occur due to asynchronous user interactions and TCP/IP message reception. These cases are identified when possible and the resulting error message is ignored deliberately.

To reduce bandwidth consumption, all operational data within PDUs must be compressed with the ZIP algorithm in baseline 3.

3.3 Managing of Contracts

In baseline 2, all management information — including information about all OIGs and contracts — was stored and distributed as part of a shared management model. The replication of the management model between nodes proved to be a powerful and flexible mechanism. Unfortunately, it was also difficult to implement and subject to inconsistencies among various partners. Furthermore, additional security checks were needed to prevent remote systems from changing one's own management information.

For baseline 3, the concept of a shared and distributed management model has been replaced by a much lighter mechanism. It solely relies on the exchange of protocol messages. While the new replication and subscription mechanism shifts the responsibility for subscription management towards the national implementations, the introduced simplifications allow for a much cleaner and more precise specification.

3.4 Flow of Control and Synchronization

In baseline 2, the data flow was controlled through several statuses:

1. The *Node Status* was used to specify whether a node was able to receive operational data at all.
2. The *Link Status* was a means by the receiver to indicate whether it was able to receive operational information from a specific provider.
3. The *Subscription Status* allowed the provider to indicate whether it sends operational information to the distinct receiver.
4. The *Contract Status* indicated whether data was collected for a specific contract.

These statuses could be used to keep sessions established while the network connection was interrupted and to suspend contracts while the connection was still active.

Unfortunately, most of these features were used rarely but added complexity to both implementation and administration. The lesson learned resulted in a simplified flow of control for baseline 3. It is based on a single concept: subscriptions based on OIG contracts.

If a node is subscribed to an OIG, the provider tries to send operational data contained within that OIG to the subscribed node. The DEM protocol specifies two messages, SUBSCRIBE and UNSUBSCRIBE, that allow the receiver to change the subscription status for a list of OIGs. A third message (AVAIL_OIGS) is used by a data provider to publish its list of available OIGs. Every protocol layer reacts to status changes of the underlying layer. This means that no situation can occur where data needs to be buffered until an underlying layer sets its status to active.

The baseline 3 version of the DEM uses a refined concept to reduce bandwidth usage. A synchronization point is assigned to each PDU that carries information of a particular OIG (each data PDU contains data of only one OIG). If transmission fails (e.g., due to a network problem), the data receiver is able to re-subscribe to the OIG later. When sending its subscription message, the data receiver can provide the synchronization point of the last PDU it was able to receive for that particular OIG. This synchronization point allows the sender to determine the data it has to send in order to update the receiver.

4 Summary and Outlook

In baseline 3, MIP has added a tremendous amount of new features to the JC3IEDM 3.1. Many of these changes were the result of the merger of MIP and NDAG that joint their forces to develop a common data model based on the C2IEDM and the NATO Corporate Data Model. In addition, various requirements from navy and air force, as well as plans and orders have been considered.

Moreover, MIP has revised its Data Exchange Mechanism. The new DEM will simplify the technical implementation, ease the administration/operation of MIP gateways, and enhance reliability and robustness.

Initial draft specifications of the MIP baseline 3 are available on the public MIP web site. Updates are expected in the forthcoming months as the nations gain experience with their national implementations.

Despite the many improvements in baseline 3, the efforts to improve the MIP solution will continue. Presently, the MIP members explore various directions in which the MIP solution may evolve in block 4. Points for discussion include the way the MIP solution supports the altering of operational data and the maintenance of time-sequenced operational data. The OIG concept may be subject to revision on both the operational and technical level. Moreover, new security considerations may be taken into account. Finally, the use of XML technologies and the alignment of the JC3IEDM with object-oriented modeling concepts are discussed.

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Nomenclature

C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command & Control Information System
DEM	Data Exchange Mechanism
IDEF1X	Integrated Definition Method 1 X
IP	Internet Protocol
JC3IEDM	Joint Command, Control, and Consultation Information Exchange Data Model
LC2IEDM	Land Command and Control Information Exchange Data Model
MIP	Multilateral Interoperability Programme
MTIDP	MIP Technical Interface Design Plan
MTIR	MIP Tactical Interoperability Requirement
NDAG	NATO Data Administration Group
OIG	Operational Information Group
PDU	Protocol Data Unit
STANAG	NATO Standardization Agreement
TCP	Transmission Control Protocol
UDP	User Datagram Protocol