"*Delivering Military Advantage through multi-national geospatial interoperability*"

DGIWG 933

DGIWG Geospatial Reference Architecture (DGRA)

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Abstract: The DGIWG Geospatial Reference Architecture (DGRA) defines a framework for achieving interoperability in the military geospatial domain by showing the intended interrelationship between standards, implementation guides, and industry best practices when implemented in a national or coalition environment. Together these form a framework for achieving interoperability in the military geospatial domain. This is intended to enhance the exchange and use of geospatial data, services and products across an international network of independent military systems and equipment. The DGRA provides direction and defines the best practice(s) by which members can improve the interoperability of geospatial data and systems when developing solutions for new and emerging capabilities.

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Executive Summary

The DGIWG Geospatial Reference Architecture (DGRA) establishes a framework for achieving interoperability in the military geospatial domain when developing solutions for new and emerging capabilities. The DGRA defines how technical standards, implementation guides, and industry best practices work together to enable the interoperable exchange and use of geospatial data, services, and products across a national or coalition environment.

DGIWG and its partners have developed a well-established range of community standards and military profiles based on a Service-Orientated Architecture (SOA) that enables geospatial data dissemination and exploitation. As the military geospatial enterprise evolves, DGIWG will adopt new approaches and concepts, where appropriate, which support the changing needs of the geospatial community. These will be reflected in the dynamic DGRA.

The DGRA has been developed using a standards-based approach using the. ISO/IEC 10746 1-3 *“Information Technology - Open Distributed Processing - Reference Model”* [1]. This recommends the use of five viewpoints to describe the architecture. These are non-sequential and interrelated, and consist of:

- **Enterprise:** Defines the purpose, scope and policies of the system.
- **Information:** Describes the semantics of information used within the system, e.g. Vector, Imagery, Metadata, Portrayal, and their relevant standards.
- **Computational:** Describes the systems individual interfaces, e.g. the standards and the operations they use for each function.
- **Engineering:** Describes the system components, their relationships functions and standards.
- **Technology[1]:** Describes the technology choices available to realise systems in terms of their compliance to specifications described in other viewpoints.

The DGRA is dynamic with the current focus on standards-based interfaces between geospatial systems and their various components. Without the appropriate use of agreed standards, the interfaces they define are likely be developed on an ad hoc basis, resulting in stove-piped solutions that may not be fully interoperable. This reduces the ability of users to share data and services, thereby limiting the effectiveness of military operations.

At the heart of the DGRA is the Standards Model (DSM), illustrated in Figure 1. The DSM groups the DGRA standards into functions and shows their high-level relationship. The relationships are encapsulated within the logical flow of the geospatial data, from its collection by sensors to its exploitation by an end user. For example, sensors ***"collect"*** raw data. The raw data is then either published (Sensor Web Enablement (SWE)) directly as web services or ***"processed"*** (Web Processing Standard (WPS)) and ***"stored*"** in a geospatial database and ***"managed"*** by a data provider. A service provider generates data services (Web Map Service (WMS), Web Feature Service (WFS), etc.) to ***"disseminate"*** the data. The data and service content are described using metadata (DGIWG Metadata Foundation (DMF)). The metadata is published by a registry, which exposes it in a registry service (Catalogue Service

[1] **Note:** The Technology Architectural Viewpoint requires a robust testing and compliance process to provide a clear understanding of how technology can support the implementation. Although presently being developed by DGIWG, these processes are not yet established. As such, this version of the DGRA does not contain a Technology Viewpoint. Once this has been developed, the intention is to include it in future versions of the DGRA.

for the Web (CSW)). The end users utilise the metadata in the registry service to ***"discover"*** and ***"consume"*** appropriate data and services based on their understanding of the metadata.

The DGRA bridges the gap between standards and technology by using DSM and architectural viewpoints to link the standards to the functionality they support and the technical components that implement these. This relationship allows the military community to identify the appropriate standard(s) for their requirements and to correctly implement them in order to improve the interoperability of new geospatial capability.

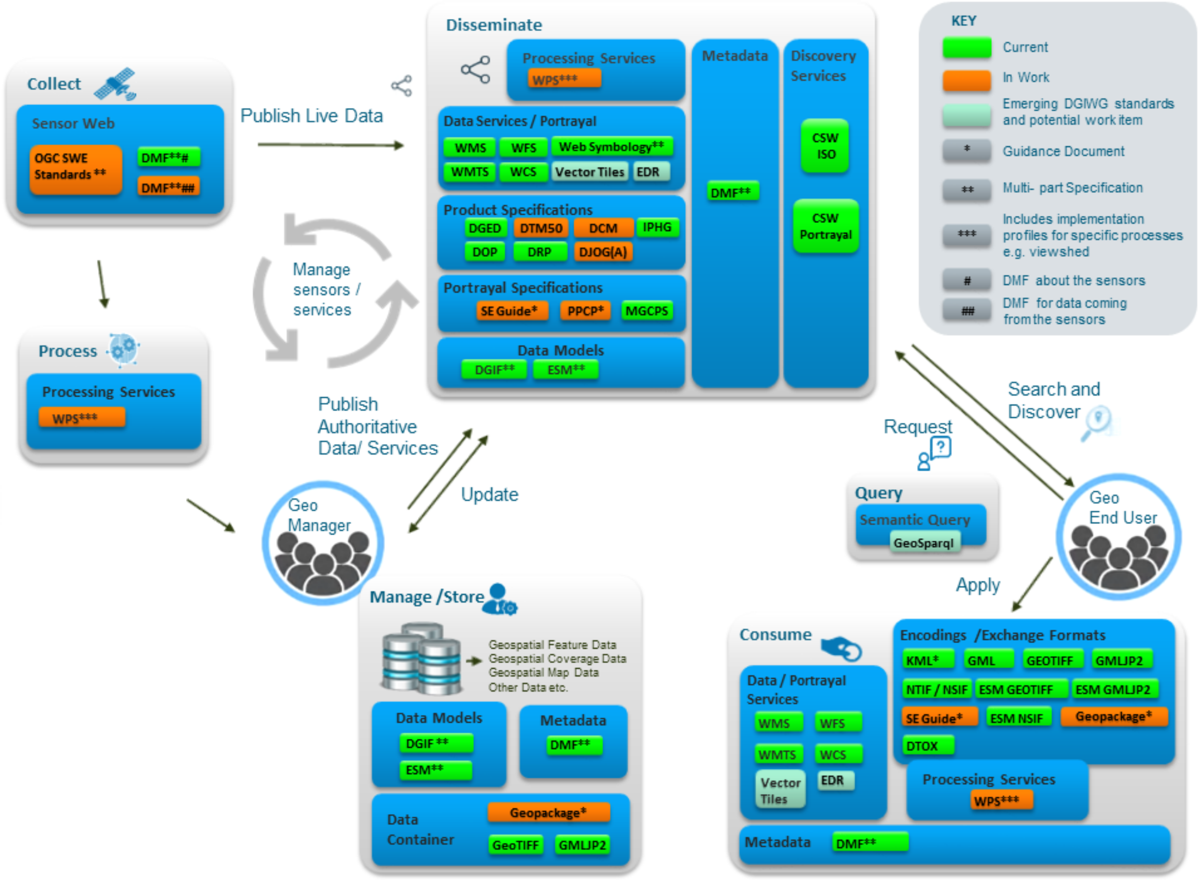

Figure 1: DGRA Standards Model (DSM) for geospatial functions and standards

ii. Contributing participants

Nation	Parent Organisation
GBR	UK Strategic Command Defence Intelligence Joint User for Geospatial Intelligence (JUIntCy JGI) Defence Science and Technology Laboratory (DSTL)
FRA	Délégation General pour l'Armement (DGA) Institut Géographique National (IGN)
USA	National Geospatial-Intelligence Agency
DEU	Bundeswehr Geoinformation Centre (BGIC)
CZE	Office of Military Geography and Hydrometeorology
CAN	The Department of National Defence

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28 Nov 22	0.9.2	Working Draft Document	Updated to reflect comments from additional P0 Review
22 Feb 23	0.9.4	Working Draft Document	Updated to reflect comments from DGIWG Ballot review process
115 May 23	1.0	Final Draft	Ready for Publication

1 Document Purpose

This document defines the DGIWG Geospatial Reference Architecture (DGRA). The DGRA defines standards, implementation guides, and industry practices as a framework for achieving interoperability by facilitating the consistent implementation of standards and industry best practice across the international and domestic military communities. The DGRA was constructed in accordance with the approach outlined in International Organization for Standardization (ISO)[2] 10746 *“Information Technology - Open Distributed Processing - Reference Model”,* which provides a robust framework for developing reference architectures. The DGRA does not attempt to provide detailed blueprints or propose specific technology solutions. Instead, the DGRA provides high-level descriptions of the various artefacts required to establish a flexible system, or system of systems, to support coalition interoperability in the geospatial domain. To achieve this, the DGRA uses multiple interrelated high-level viewpoints.

[2] **International Organization for Standardization (ISO):** is an independent, non-governmental international organization with a membership of 167 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges. http://www.iso.org/about-us.html

2 Introduction

2.1 DGIWG Background

DGIWG was established in 1983 as a multi-national body comprising individuals committed by participating nations to collectively advance the state of geospatial interoperability between defence organisations. It operates in accordance with a Memorandum of Understanding (MoU) between member nations. DGIWG undertakes its work on a requirements-driven basis based on prioritisation by member nations and by alliances and coalitions in which member nations participate, such as North Atlantic Treaty Organisation (NATO) and multinational co-production programs.

DGIWG addresses interoperability challenges between nations by creating the necessary standards, implementation guidance, and procedures to enable the exchange, delivery, and use of standardised geospatial information. Many of the standards developed by DGIWG are built upon open standards for geographic information as defined by the International Organization for Standardization (ISO) TC/211. DGIWG also leverages the web services and other standards that are developed by the Open Geospatial Consortium (OGC)[3] and other national and international third parties. DGIWG maintains formal partnerships with both ISO and OGC to ensure that the military perspective is considered in the development of their geospatial standards.

2.2 What is a Reference Architecture and why is it required?

Military operations are heavily reliant on geospatial information as it supports decision making, planning, and execution. Geospatial information is harvested from a variety of sources, and then assessed, stored; and made searchable and accessible in a timely and comprehensible manner with the aim of getting the right data to the right user in the right format at the right time. These functions or services are provided by a geospatial enterprise which is underpinned by standards that define how the data is handled.

A geospatial reference architecture, like the DGRA, provides guidance on which standards should be used within this geospatial enterprise. By using an agreed set of standards, implementation guides, and industry best practices, the systems of coalition partners become fully interoperable which is of critical operational importance. It also supports the development and procurement of national capabilities which provide or consume geospatial data and/or services by minimizing the risk that these capabilities will not be interoperable in a coalition setting.

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[3] **The Open Geospatial Consortium (OGC):** is an international not for profit organization committed to making quality open standards for the global geospatial community. These standards are made through a consensus process and are freely available for anyone to use to improve sharing of the world's geospatial data. http://www.ogc.org/

3 Architectural Approach

The ISO/IEC 10746 [1] standard was chosen as the foundation for the DGRA because:

- It is recognised and widely utilised by the international community; and
- It is less complicated than other similar approaches.

ISO/IEC 10746 recommends that a Reference Architecture (RA) be described using five architectural viewpoints. The viewpoints are non-sequential and usually interrelated. These are shown in Figure 2 and consist of.

- **Enterprise:** Defines the purpose, scope and policies of the system.
- **Information:** Describes the semantics of information used within the system, e.g. Vector, Imagery, Metadata, Portrayal, and their relevant standards.
- **Computational:** Describes the systems individual interfaces, e.g. the standards and the operations they use for each function.
- **Engineering:** Describes the system components, their relationships functions and standards.
- **Technology[4]:** Describes the technology choices available to realise systems in terms of their compliance to specifications described in other viewpoints.

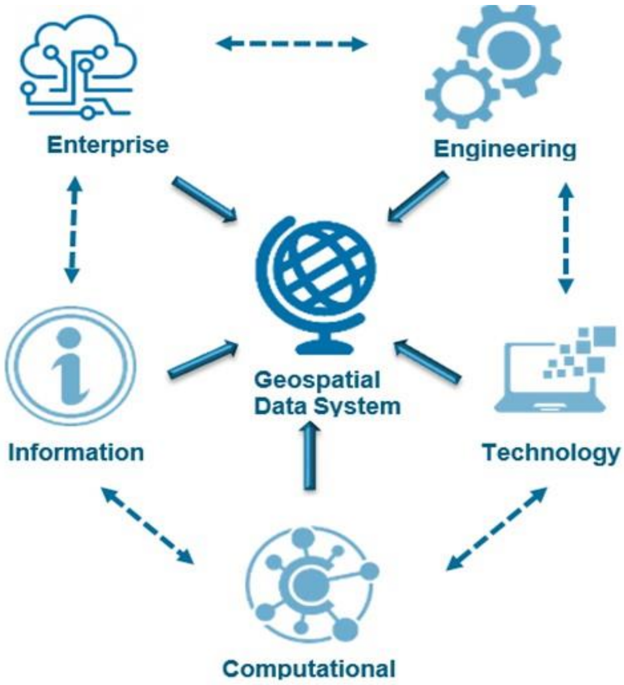

Figure 2: DGRA Architectural Viewpoints

[4] **Note:** The Technology Architectural Viewpoint requires a robust testing and compliance process to provide a clear understanding of how technology can support the implementation. Although presently being developed by DGIWG, these processes are not yet established. As such, this version of the DGRA does not contain a Technology Viewpoint. Once this has been developed, the intention is to include it in future versions of the DGRA.

The architectural viewpoints provide a coherent and unambiguous picture of how DGIWG specifications relate to each other and how they should be used to provide the interoperable functionality required by a geospatial system. The architectural viewpoints are not intended to provide detailed instructions for the implementation of standards within a geospatial capability. Such details are captured within the individual standards and specifications referenced by the DGRA.

The DGRA is a living document and as such it will be updated as required. Requests for updates or to participate in future maintenance or the development of the DGRA or any of its standards should be directed to a DGIWG Principal National Representative (PNR)[5] or Alternate PNR (Alt PNR), or through the http://www.dgiwg.org/contact_us page on the DGIWG website, and with a brief description of the query.

[5] **Principal National Representative (PNR)[5] or Alternate PNR (Alt PNR)**: principal point of contact (or alternate) for expressing the official position of that nation within the DGIWG community.

4 Enterprise Architectural Viewpoint

The aim of the Enterprise viewpoint is to define the following:

- The problem space which the DGRA is addressing;
- The DGRA's purpose and scope;
- The relationship between the standards and interfaces used in the DGRA;
- The key functions and roles needed to enable the DGRA.

4.1 The Problem Space

Geospatial information is a key enabler for military users who heavily depend on it to inform important decisions at all levels. Tactical level examples include identifying potential areas of interest, assessing potential threats, planning the deployment of combat systems and the movement of supplies, equipment and personnel. However, the complex nature of mission networks can make the sharing and analysis of geospatial information particularly challenging[6]. This is especially evident in coalition environments where data needs to be shared across an enterprise consisting of several member nations. There are a number of constraints typically associated with the discovery, dissemination and exploitation of geospatial information in a military environment. These will need to be considered as the DGIWG Standards and DGRA continue evolve to meet the users' needs. The key constraints include:

- **Access Control:** Data security is crucial and the capability to control who is allowed to access and use information and resources is vitally important [2]. Most military data has restrictive use controls associated with it and incorrectly labelled release caveated data may prevent users from getting timely and appropriate access.
- **Data Classification:** Data is classified and its use is restricted in accordance with its level of risk and sensitivity, and is typically stored on networks in accordance with its classification. Due to this approach, information may have to be manually transferred across air gaps that exist between networks and data stores at different classification levels, leading to additional effort and delay [3].
- **Trust:** Life or death decisions are regularly made in the military domain and as such data must be authoritative, reliable and trusted; underpinned by robust quality assurance. The data must therefore be accompanied by metadata which explicitly describes the data and its history to assure users that data is fit for purpose.
- **Variable Connectivity:** Military operations are often undertaken in hostile environments where users of geospatial information typically have limited bandwidth, sporadic connectivity or potentially no connection to the network. This is often characterised as a Denied, Disrupted, Intermittent, and Limited (DDIL) network environment. This can hinder the timely dissemination of information.

[6] This challenge is being addressed by several initiatives including NATO's Future Mission Network (FMN). The FMN is a capability aiming to support command and control and decision-making in future operations through improved information-sharing. It provides the agility, flexibility and scalability needed to manage the emerging requirements of any mission environment in future NATO operations

- **Lack of Compliance:** Legacy, and often highly bespoke or customised systems, are utilised across the military domain. These typically rely on out-of-date or proprietary formats resulting in difficult data sharing and poor interoperability.
- **Portrayal and Meaning:** Geospatial information plays an important role in all aspects of the military domain including intelligence, operations, logistics, and planning. Consistent and commonly understood portrayal of information is vital to avoid mis-interpretation of data and services.

4.2 DGRA Purpose

The purpose of the DGRA is to provide a best practice guide for enhancing interoperability in the military geospatial domain through the use of open standards. It provides high-level guidance on the appropriate use of open standards to overcome the constraints associated with the collection, discovery, dissemination and exploitation of geospatial information in a military environment. This will enable implementing nations to bridge the gap between standards and technology and to develop systems which address their own particular requirements while still providing the interoperability needed to share and exploit geospatial data in a coalition context.

This is enabled by using agreed open standards and implementation guides to deliver an interoperable SOA that provides functionality as a web service on a network rather than as processes within a monolithic software application. The rationale for SOA utilisation in DGRA includes:

- SOA provides the ability to develop focused solutions to meet specific interoperability issues in the defence geospatial domain that can be collected together, implemented with various technological solutions, to achieve interoperable results at the various touch points (ex. collection, storage, dissemination, etc.).
- SOA is a mature approach that has been proven to work effectively in operational settings, including in theatre.
- DGIWG and its partners have developed a well-established range of community standards and military profiles using a SOA that enables geospatial data dissemination and exploitation.

However, the military geospatial enterprise will continue to develop and where appropriate, DGIWG will adopt new approaches and concepts which support the changing needs of the geospatial community. The DGRA will evolve as these new approaches are adopted. For example, the OGC is developing new standards and services based on Web Application Programme Interfaces (APIs) (see Section 6.3), which could potentially benefit the military community. As these are adopted, the DGRA will evolve to guide their use.

The DGRA describes the key set of standards, components and roles required to enable:

- Users to access geospatial data and information in formats that meet their needs, at the right time from across the military enterprise.
- Users, both humans and systems, to discover and access geospatial data, information and services through a distributed architecture.

- The integration of disparate geospatial information to provide global, regional and local geospatial views.
- Improved ability to exchange interoperable geospatial information in Joint and multi-national operations

4.3 DGRA Scope

The DGRA promotes the interoperability of geospatial systems, services and data. To achieve this, it:

- Describes components and standards required to realise the purpose.
- Is targeted towards a wide audience: from senior leaders to operations-level commanders and operators; and from contracting and procurement officers to system developers.
- Is intended to be a practical guide to better enable geospatial information sharing, analysis, and exploitation by all consumers of geospatial data through the development, procurement, and operationalisation of interoperable standards-based capabilities.
- Is dynamic and will evolve as the need for more complex user requirements or use cases are included.
- Provides users and developers with a deeper understanding of the relationship between the standards DGIWG delivers and the functions that they enable.

The DGRA does not attempt to provide:

- Detailed blueprints or specific technology solutions.
- Guidance on the underlying technology infrastructure on which the DGRA would be implemented.
- Guidance on the specific software used to deliver the standards and functionality described by DGRA.

4.4 DGRA Standards and Interfaces

The DGRA Standards Model (DSM) (Figure 3) identifies the function of each standard and provides a view of the high-level connectivity between them in a logical flow of geospatial data from its collection to exploitation.

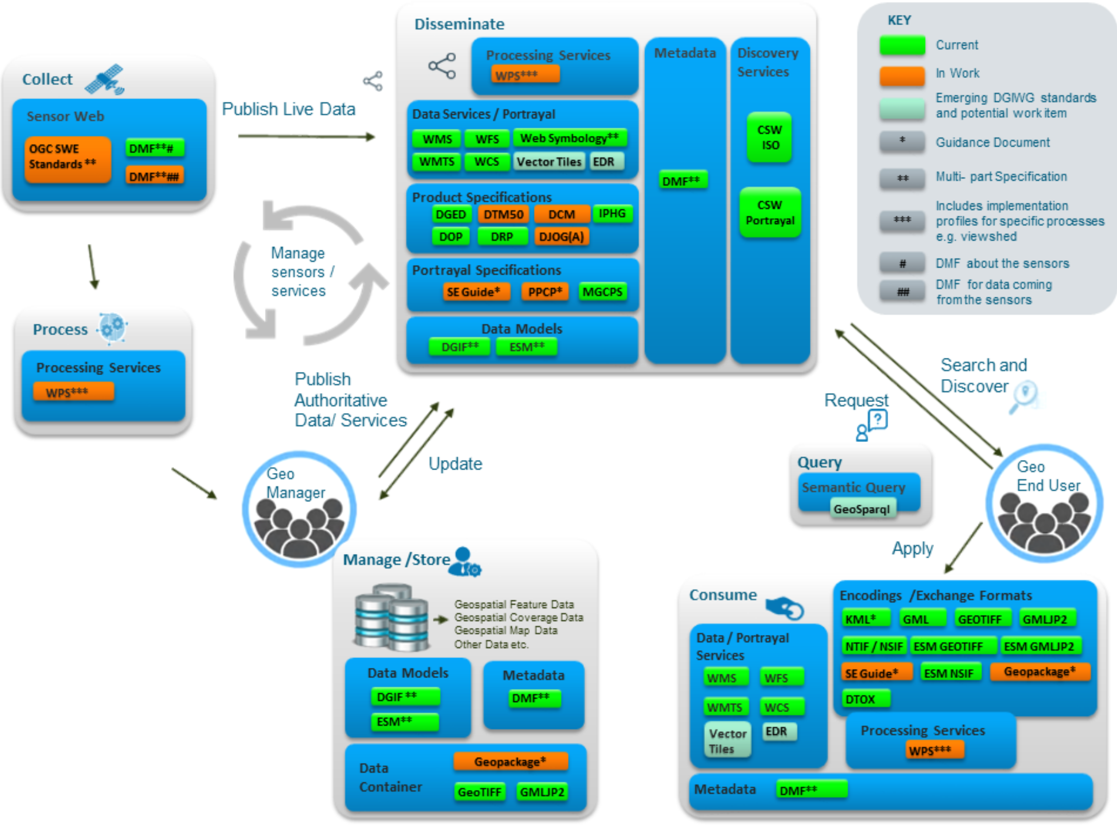

Figure 3: DGRA Standards Model (DSM) for geospatial functions and standards

The DSM includes both existing and planned DGIWG standards[7]. In order to provide a more complete architecture, encompassing more complex use cases, subsequent versions of the DGRA will also, where appropriate, reference standards from other recognised international standards bodies such as the ISO, the OGC, and the NATO Standardisation Office. DGIWG standards are usually profiles of existing ISO and OGC standards but there are some, such as DGIF, which have been developed specifically by DGIWG because a suitable core standard was not available.

The DSM groups the DGIWG standards into the following high-level functions:

- **Collect:** The collection of data using connected sensors, whether devices or human.
- **Process:** The modification of data and services, including by web services.
- **Manage / Store:** The management and storage of data and information using recognised data models, formats, catalogues, registries and services.
- **Disseminate:** The publishing and dissemination of data, information and services using catalogue services, to enable data discovery and distribution.
- **Consume:** The exploitation of data, information and services by end users.

[7] DGRA is based on the DGIWG standards as defined in the DGIWG Geospatial Standards Baseline (DGSB). The DGSB also looks beyond DGIWG standards and provides a view on the wider spectrum of geospatial standards, which are utilised across the geospatial community. More information on this can be found in section 9 of this document.

Visualising standards in this way shapes how DGIWG delivers standards by enabling it to better understand how emerging concepts may potentially affect future systems. It helps identify key gaps and determine where it should focus its limited resources.

The DSM is not intended to provide an exhaustive description of interface operations or their relationships to physical system components. These are summarised in the architectural viewpoints. However, when used with the architectural viewpoints, it helps link, the standards to the functionality they support and the technical components that implement these. This relationship allows the military community to identify the appropriate standard(s) for their requirements and to correctly implement them in order to improve the interoperability of new geospatial capability.

4.5 DGRA Key Roles

The DGRA includes a number of key roles to enable the successful collection, discovery, dissemination and exploitation of geospatial data and services. These are shown in Figure 4.

- **Data Provider:** Supplies the geospatial information for publishing within the geospatial enterprise.
- **End User (Human or System):** Discovers, accesses and exploits geospatial information.
- **Service Provider:** Publishes the services and associated metadata.
- **Registry Manager:** Manages the registries that enable discovery of geospatial services and data.
- **Domain Authority:** Endorses the common community policies and standards required by the geospatial enterprise.

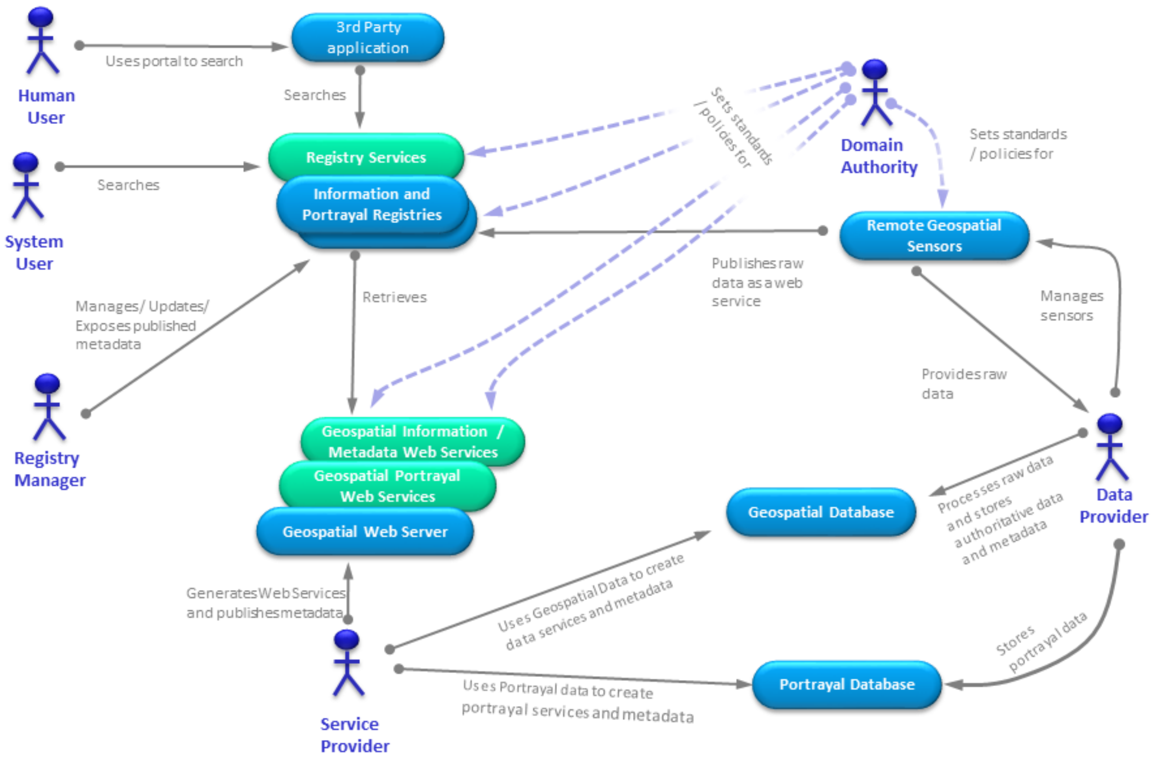

Figure 4: High-level user model for enabling a geospatial enterprise

5 Information Architectural Viewpoint

5.1 Information Overview

The Information Architecture Viewpoint provides high-level descriptions of the structure, information models, exchange formats and maintenance processes associated with the various types of data described throughout the DGRA. These include:

- **Vector Data:** A data structure, used to store spatial data. It consists of georeferenced points, curves, surfaces and volumes that represent physical locations or features in the real world [4].
- **Imagery and Gridded Data:** Any raster, pixelated, or gridded data where each pixel is associated with a specific geographical location and value. The value of a pixel[8] can be continuous (i.e. vary infinitely as used for elevation) or categorical (i.e. discrete as in specific land use types) [5].
- **Metadata:** A structured[9] description (data about the data) about a resource (data or service) that helps users understand or find it [6].
- **Portrayal Data:** Graphical illustrations that represent different features on a map. Also referred to as symbols, these give added meaning to vector or gridded data [7].

As the DGRA develops and matures, additional data types may be included in the architecture and as new standards for these are developed they may be adopted by DGIWG. As this occurs the guidance provided by the DGRA will be updated.

5.2 Vector Data

Vector-based data is precise geospatial data comprised of points, curves, and surfaces which represent geospatial features on the Earth's surface that are coincident in time and space. Vector data usually includes a relational link to tabular data containing further information about, or attributes of, the depicted feature. Examples include, but are not limited to: point of interest locations, road segments, boundaries of land use areas, building and structure footprints, and drainage patterns.

Defence organisations that create, share, or consume vector-based data should facilitate its effective exchange through adherence to standards-based semantics, syntax, and data structures that organize and configure vector data into precise formats and structures. Vector data should therefore conform to exchange and encoding schemas and/or data product specifications derived directly from defence community consensus standards such as DGIWG 200 *"The Defence Geospatial Information Framework (DGIF)"* [8].

Conformance to vector data standards established and maintained across the defence user community provides many benefits. These include:

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[8] The finite limit of a pixel value based on a files bit depth (ex. a value of 0-255 for an 8-bit panchromatic image

[9] Metadata can also be unstructured. However, the DGRA is focused on the provision of specifications that enable the structured collection, management and dissemination of metadata to support military use cases.

- **Data re-use:** Adherence to community-based standards positions the defence user community to exploit vector data for the missions and needs of today whilst ensuring that the data can also be re-used for future missions where applicable.
- **Data quality:** It supports efficient and lossless exchange of vector data, which is critical to maintaining data integrity.
- **Burden sharing:** Complex data production programs can more easily engage in burden-sharing for cooperative data development. Minimum standards of quality can be enforced, and data can be more rapidly exploited as little to no “data conditioning” is needed.
- **Simplified data processes:** The creation, management, sharing, and exploitation of vector-based data is greatly simplified by the application of agreed data standards.

5.2.1 DGRA Vector Data Models

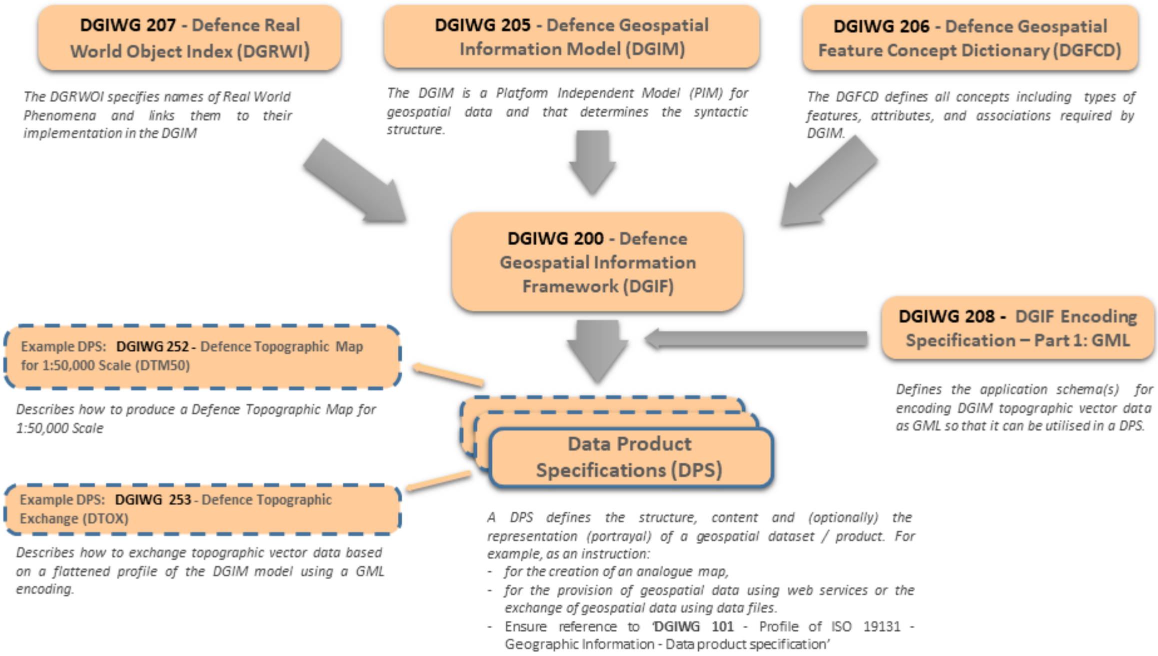

Figure 5: Key components of the DGIF

The DGIF is a suite of data standards encompassing different domains of geospatial information (for example land, maritime, aeronautical, human geography, etc.). It provides a model-based solution allowing for standardised information exchange and the creation of common geospatial product specifications. Figure 5 provides a detailed summary of the DGIF and its key components. A full overview is provided by DGIWG 200 *“DGIF”*. This establishes the purpose of DGIF and describes the overarching DGIWG approach to vector data standardization. DGIWG 205 *“DGIM”* [9], DGIWG 206 *“DGFCD”* [10], DGIWG 207 *“DGRWI”* [11] and DGIWG 208 *“DGIF Encoding Specification – Part1:GML”* [12] more thoroughly describe the components of the DGIF. DGIWG 205 (the Defence Geospatial Information Model, “DGIM”) describes the purpose and structure of the vector data model in detail.

The DGIM is not designed to be implemented directly. Instead, DGIM serves as the basis for multiple standards-conformant subsets of the parent model, with each subset representing a defined mission area or client requirement. The various components of DGIF provide standardised interoperability bridges between the data schemas of member nations which will guarantee consistent data products and services for the end-user of geospatial information. For example, DGIWG 253, *"Defence Topographic Exchange Model (DTOX)"* [13] establishes a subset profile and schema supporting the exchange of topographic data conforming to the DGIM data model. A similar subset is being developed to support the Multinational Geospatial Co-Production Program (MGCP)[10] and the MGCP Urban Vector Data (MUVD) program. This will enable the exchange of information between DGIF and the MGCP data models. Similar content has been developed for the International Program for Human Geography (IPHG)[11]. The DGIM profile for this is DGIWG 260 *"International Program for Human Geography (IPHG) Data Product Specification (DPS)"* [14]. Subsets of the DGIM also support the following Data Product Specifications which are being developed by DGIWG:

- The Defence Topographic Map 1:50,000 Scale (DTM50).
- The Defence City Map (DCM).
- The Defence Joint Operations Graphic (Air) (JOG(A)).

5.2.2 Exchange Formats

DGIWG supports vector data exchange using schemas that are compliant with OGC 10-129r1 *"Geography Markup Language (GML[12]) - Extended schemas and encoding rules* [15]. The DGIWG profile of this standard, DGIWG 208 *"DGIF Encoding Specification - Part 1: GML"* defines and explains how GML application schema(s) should be used for vector data within the DGIF.

DGIWG is also developing a profile of OGC 12-128r18 *"The GeoPackage Encoding Standard"* [16]. GeoPackage (GPKG) is a platform-independent, portable, self-describing, compact format for transferring geospatial information within a SQLite database. The primary role of a GPKG is to store multiple GIS data (layers) consisting of raster and vector data in a single file. The DGIWG GPKG profile has not yet been published but is expected to include both extensions of and restrictions to the underpinning OGC standard as well as system requirements in order to enable interoperability by appropriately configuring existing software. This will include descriptions for a set of conventions for storing the following data types:

  - Vector features and tiles.
  - Tiled matrix sets of imagery and raster maps at various scales.
  - Extensions.

[10] **The Multinational Geospatial Co-production Program (MGCP**): was created in April 2003 and has 35 participating members. The aim of the program is to collect geospatial data worldwide, concentrating on areas where little data exists. . MGCP Data is collected in 1 by 1 degree cells of geographic coordinates at scales 1:50,000 and 1:100,000.

[11] **The International Program for Human Geography (IPHG):** Is a co-production agreement between 12 member countries for the sharing of human geography data.

[12] **Geography Markup Language (GML):** is the XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical features. GML serves as a modelling language for geographic systems as well as an open interchange format for geographic transactions. http://www.w3.org/Mobile/posdep/GMLIntroduction.html

Additional standards-based encodings are also under consideration by DGIWG, driven by customer needs and community requirements. This includes encodings based on ecma[13]-404 *"The JSON[14] data interchange syntax*" [17].

5.2.3 Maintenance Strategy

DGIF and its components (DGIM, DRWOI, etc.) are revised regularly based on customer requirements and best-practice geospatial data modelling approaches. Within the DGIWG Vector Data Technical Panel, the Vectors Models and Schema Team (VMST) is the core DGIF maintenance body. The VMST is responsible for actively maintaining and evolving the DGIF content via a configuration management process that culminates in the production of three new data model content baselines per year. Change proposals can be developed to address shortfalls in the model and address user community requirements.

The DGIF specifications have been created using Unified Modelling Language (UML) which enables a highly developed model that captures the detailed information required for the defence community to describe geospatial features and enable informed decision making. The VMST manages this complex model utilising a specialised modelling environment, the DGIF Collaborative Environment (DCE), consisting of Sparx Systems Enterprise Architect[15] software implemented in an Amazon Cloud environment to enable DGIWG to edit and manage the model from different locations. Any changes to the DGIF specification or models are carried out in accordance to the processes found in DGIWG HBK-13-047 *"Change Management for the Defence Geospatial Information Framework (CM-DGIF)"* guidance document [18]. The process requires trained individuals to execute and manage it. DGIWG has developed an extensive training package to ensure members have appropriate level of expertise. These training sessions can be requested by members on an as-needed basis.

The full model maintenance process and future development strategy are described in DGIWG 910 *"Vector Panel Roadmap"* [19].

5.3 Imagery and Gridded data

Imagery and gridded data is any pixelated (or gridded) data where each pixel is associated with a specific geographical location. The value of a pixel can be continuous (e.g. elevation) or categorical (e.g. land use) [20]. It is produced or procured by defence agencies and used by military forces to provide situational awareness and is commonly used as an information base layer in systems providing a range of processes including command and control, intelligence or logistics etc.

The most commonly used imagery and gridded geospatial product types include:

- Orthoimagery (individual product or seamless orthoimagery database).
- Raster map, either rasterization of vector product or by scanning paper maps.

[13] **ecma International:** is an industry association dedicated to the standardization of information and communication systems

[14] **JSON (JavaScript Object Notation)** is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate http://www.json.org/json-en.html

[15] **Sparx Systems Enterprise Architect** helps individuals, groups and large organizations model and manage complex information. By integrating and connecting a wide range of structural and behavioral information in visual form, you can build a coherent, verifiable model of what-is or what-will-be. http://sparxsystems.com/

- Terrain or Surface elevation models, as elevation grids.
- Primary sensor imagery, with no georectification (i.e. in the geometry of the sensor), which may include: panchromatic, multi-spectral, or hyper-spectral imagery.
- Point clouds.
- Stereo imagery / perspective imagery.
- Meteorological and Oceanographic (METOC[16]) numerical grids.
- Thematic imagery, such as land use or land cover, where pixel values are categorical.

5.3.1 DGRA Imagery and Gridded Data Models

DGIWG recommends the use of DGIWG 116 *"Elevation Surface Model (ESM) Standardized Profile"* for the following elevation data types:

- Elevation rectified grid coverage, based on the ISO 19123-2 *"Geographic information - Schema for coverage geometry and functions - Part 2: Coverage implementation schema"* [21].
- Elevation point set, addressing elevation point clouds.
- Elevation Triangulated Irregular Network (TIN).

For orthoimagery and raster maps, DGIWG product specifications use the RectifiedGridCoverage model as described in OGC 09-146r6 "*Coverage Implementation Schema v1.1*" [22]. DGIWG has not developed a dedicated imagery model.

For primary sensor imagery, the data model is the ReferenceableGridCoverage described in the OGC 16-083r2 "*OGC Coverage Implementation Schema - ReferenceableGridCoverage*[17] *Extension"* [23]. An example of where this is used is OGC 08-085r8 *"OGC GML in JPEG 2000 (GMLJP2) Encoding Standard v2.1 "* [24], and DGIWG 104 (1-2) *"DGIWG Profile of JPEG 2000 for Georeferenced Imagery (Parts 1&2)"* [25].[18]

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[16] The METOC communities may have additional requirements (often more complex) that have not been addressed by the DGIWG. However, requirements on the usage of GeoTIFF profile (and more precisely usage of JPEG compression) for Meteorological data that have been incorporated in the DGIWG GeoTIFF profile; METOC communities may also use other standards for IGD data, incuding:

- **Network Common Data Form (NetCDF):** is a file format for storing multidimensional scientific data (variables) such as temperature, humidity, pressure, wind speed, and direction. Each of these variables can be displayed through a dimension (such as time) in ArcGIS by making a layer or table view from the netCDF file. http://pro.arcgis.com/en/pro-app/latest/help/data/multidimensional/what-is-netcdf-data.htm
- **GRIdded Binary or General Regularly-distributed Information in Binary form (GRIB):** is a file format for the storage and transport of gridded meteorological data, such as Numerical Weather Prediction model output. It is designed to be self-describing, compact and portable across computer architectures. The GRIB standard was designed and is maintained by the World Meteorological Organization http://weather.gc.ca/grib/what_is_GRIB_e.html
- **Bathymetric Attributed Grid (BAG):** is a hydrographic exchange data format developed and maintained by the ONS-WG (Open Navigation Surface Working Group) http://www.hydroffice.org/bag/main

[17] **A ReferenceableGridCoverage** is the Grid Coverage model that is applicable when the imagery is in the geometry of the acquisition process by the sensor, which can't be converted into a geodetic CRS by an affine function, but via a Sensor model or a more complex transformation function for the

[18] **Note:** accurate geolocation of each pixel. The usage of this ReferenceableGridCoverage is by the imagery producer for their primary products (when primary products are available).

5.3.2 Imagery and Gridded Data Exchange Formats

DGIWG recommends the use of three standardised encoding formats for raster imagery or elevation grids:

- **The Geographic Tagged Image File Format (GeoTIFF):** This is a format for packaging TIFF imagery with geospatial reference data and is used to store, transfer, and display large TIFF raster data files. The recommend profile is *DGIWG 108 "GeoTIFF profile"* [26]. This is based on the OGC *"GeoTIFF Standard"* [27].
- **GML JPEG 200 (GMLJP2):** This is a format for packaging GML data within JPEG 2000 data files which enables the JPEG2000 image to be distributed or stored as a georeferenced image. The recommended profile is DGIWG 104 *"Profile of JPEG 2000 for Georeferenced Imagery (Parts 1&2)*. This is based on the *"OGC GML in OGC® GML in JPEG 2000 (GMLJP2) Encoding Standard"* [28].
- **The National Imagery Transmission Format / NATO Secondary Imagery Format (NITF/NSIF):** NTIF is a U.S. government, imaging data format which contains a combination of text, graphics and metadata in a single file. It is used by the military for satellite imagery and aerial photos. NSIF is NATO's profile of NITF. They are used together for storing and transmitting government data. The recommended standard is the US Department of Defense *"National Imagery Transmission Format (NITF) (VERSION 2.1)*" [29].

For point clouds standards such as LAS 1.4 (OGC Community standard)[19] or HDF 5 (Hierarchical Data Format)[20] may be used. DGIWG has started to collect standardization needs on a point cloud exchange format.

5.3.3 DGRA Imagery and Gridded Data Products

DGIWG recommends the use of three data product standards for IGD as outlined below:

- DGIWG 250 *"Defence Gridded Elevation Data product (DGED)"* [30] for the whole range of elevation grids resolutions, based on the ESM Rectified Grid Coverage model.
- DGIWG 254 *"Defence Raster Product (DRP)"* [31] for the whole range of cartographic scales.
- DGIWG 255 *"Defence Orthoimagery product (DOP)"* [32] for the whole range of imagery resolutions.

5.3.4 Imagery and Gridded Data Maintenance Processes

DGIWG Imagery and Gridded Data (IGD) standards are managed by the DGIWG P2 panel with revisions based on new requirements or change requests. Requests or engagement should be addressed to the P2 IGD maintenance panel either via your DGIWG PNR or Alt PNR.

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[19] **The LAS file** is intended to contain LIDAR (or other) point cloud data records. http://www.ogc.org/standards/LAS

[20] **Hierarchical Data Format Version 5 (HDF5®)** is a data model, a programming interface, and a storage model for keeping and managing data http://www.ogc.org/standards/HDF5

5.4 Metadata

Organisations providing geospatial information must support its discovery, evaluation and use. Successful discovery depends on the descriptions provided by the metadata content of the geospatial information (dataset and data), and on the specific functions provided by the services.

Within the DGRA, metadata is used to describe resources in terms of certain well-defined attributes, such as resource topic category, resource title, or geographic extent of the resource. This description allows users to utilise keywords, dataset names and phrases in particular contexts or in structured searches. For example, an organisation's name might be associated with a specific role with regard to the data, such as 'responsible party' or 'distributor'. Such associations, combined with the use of 'controlled vocabularies' (i.e. standardised lists of terms, such as abbreviations for countries or code lists for categories) and standardised formats for values (e.g. for dates or geographic extents) can greatly improve the efficiency of discovery.

From the perspective of a military organisation, efficiency in retrieving relevant and accurate information is critical. Decision makers must have access to the best available information. To improve the exchange and use of geospatial information within and among allied nations, the metadata descriptions of the various resources must share a common form and meaning. With the increasing number of types and sources of geospatial information and the multitude of exploitation tools available, the defence community increasingly requires a single metadata vocabulary.

From a data producer perspective, metadata is used to locate the data and recall the context under which it was created and analysed.

From an architectural point of view, metadata is the entry point of the general architecture. Metadata describing data and services must be stored in a central Registry. This Registry allows a user to discover relevant data. High quality metadata enables timely access to required services and data; or provides details on how to request access. Metadata is also necessary to connect with different systems. Interoperability between different components of a spatial data infrastructure implies:

- A standard metadata structure.
- Standard interchange mechanisms.
- Well defined vocabularies.

Each spatial data infrastructure remains specific in terms of users, requirements, practices, cultures, and policies. The exchange of data between different spatial data infrastructures is particularly challenging and in this context the adoption of community agreed metadata standards is critical if this is to be achieved efficiently and without the loss or alteration of important information.

5.4.1 DGRA Metadata Model

DGIWG 114 *"DGIWG Metadata Foundation* (DMF)" [33] is DGIWG's metadata standard and underpins many of the DGRA functions. It is applicable to all datasets, series, products and services described in the DGRA. DMF defines an abstract model and code lists. The DMF metadata elements enable users to record different aspects of the resources including their identification, the related quality information, the spatial representation and the content description of the resource data.

Each aspect of the resource is dealt with by the definition of an identified element. DMF includes a mechanism for grouping similar metadata elements, thus enabling data producers to simplify the collection of metadata especially when dealing with a large number of metadata elements.

DMF offers two different implementations both based on ISO standards. One implementation is based on the old generation of ISO metadata standards (ISO 19115 and ISO 19139), and the second implementation is based on the current generation of ISO metadata standards (ISO 19115-1*"Geographic information - Metadata - Part 1"* [34] and ISO 19115-3 "*Geographic information - Metadata - Part 3: XML schema*" [35]). This double implementation allows compatibility with geospatial systems that use either approach whilst, keeping a common semantic thread that will enable interoperability between both systems.

The DMF is flexible and can be profiled using a subset of the optional elements described in the specification or by extending elements to cover a wider range of requirements.

5.4.2 Metadata Generation

The generation of metadata can be achieved with dedicated tools (e.g. ISO metadata editors) or integrated in the production line. Validation of the metadata is a key step to ensure that a sufficient level of interoperability will be reached. Basic validation can be done through the XSD[21] files. The DGIWG Metadata panel is considering the development of a DMF specific validator to validate metadata more accurately.

5.4.3 Exchange Formats

Metadata exchanges are based on the XML standard. XML standards define a text format and structure that allows the interoperable exchange of text-based information. The XML structure can be used to reflect the structure defined in the DMF and its ISO implementations. This format is independent, offering a neutral and an interoperable entry point to the architecture.

The XML should be compliant with either ISO 19139 or ISO 19115-3 depending on the implementation that has been chosen. DGIWG has extended ISO schemas to support the military domain, DGIWG 114 SD1 "*Metadata Foundation: XML Schemas*" [36] defines the rules and constraints for the XML and how it should be used in order to be compliant with DMF.

Regular maintenance (e.g. schemas updates) of the DMF is undertaken by a dedicated maintenance subgroup of the DGIWG Metadata Panel. To overcome any interoperability challenges of continual updates, DGIWG is developing a metadata registry to manage resources The processes for the management are defined in DGIWG 915 *"Register Maintenance Procedures"* [37].

When updating the DMF, the maintenance subgroup utilises use cases to ensure that the updates are correct and meet requirements. Use cases should also be identified and created when developing additional metadata specifications for new DGIWG Data Product Specifications (DPSs) or web service standards.

[21] **XML Schema Definition (XSD):** An XML Schema describes the structure of an XML document. The XML Schema language is also referred to as XML Schema Definition (XSD)

5.5 Portrayal Data

In the context of the DGRA, portrayal refers to how data is visually presented to the human user[22]. For example, in order to accurately depict geospatial features on a map, the system or provider must understand the shape and colour of the symbols used to represent features, as well as the associated rules required for displaying symbols (e.g., what zoom extent to display the symbol at or whether or not to include text labels, and so on). [38]. DGRA portrayal data encompasses both the rules and information needed to apply style elements (colour, size, pattern, symbols, labels, etc.) to geospatial data for the creation of maps, products or services. When combined with the underlying geospatial data, the portrayal provides a user with a common understanding of the geospatial features being presented.

5.5.1 DGIWG Portrayal Data Models

DGIWG is developing a structural framework in the form of a database that describes the informational elements needed for the development of community portrayal specifications. The aim of the database is to catalogue the symbols and relate these with the associated display rules. This information will allow for the standardized portrayal of geospatial data in a variety of hardcopy and digital (web map) cartographic products as defined in the suite of DPSs The database also supports the efficient management of portrayal information and enables the generation of reports and artefacts in a consistent and repeatable way. The generated artefacts are compliant with OGC 18-067r3 *"OGC Symbology Conceptual Model: Core Part 1 (SymCore)*" [39]. SymCore is a neutral model defining the elements needed for the portrayal of geographical data. This uses a modular design comprised of a minimal set of abstract classes that can be easily extended so that new capabilities can be efficiently defined and used.

The DGRA provides an implementation guide for general symbology styles and encoding. The aim of this guide is to provide advice and guidance on how to portray DGIWG symbols and services using a variety of approaches.

5.5.2 Portrayal Exchange Formats

Traditionally, geospatial products like digital maps were delivered to the end user as a completed artefact such as a digital raster file with the portrayal embedded into it. This required users to often rely on software to handle the portrayal of products. This resulted in the development of numerous software-specific formats for storing and sharing portrayal data, for example the ERSI layer format (.lyr). However, as the need to share the underlying data as well as the pre-packaged map products has grown so has the requirement to ensure that end-users can consistently visualise and display data.

Portrayal exchange formats used by the geospatial community define uniform styling for geospatial data while also storing a comprehensive model for that styling information. These exchange formats are referred to as Symbology/Style Encoding

[22] Simple analytical algorithms or complex AI systems also need to interact and interpret geospatial data. These will come with their own requirements for data format and presentation. The DGRA does not consider these and is currently only concerned with enabling “human” visual interaction with the data.

(SE)[23]. SEs can be applied by software at various points within the portrayal process from the styling of individual features to the portrayal of numerous features or layers within a map or project. Some of these SEs are open standards designed by the geospatial community to enable interoperability and are freely available to developers to integrate into their system. These include OGC 05-078r4 "*Styled Layer Descriptor (SLD*[24]*)"* [40] and the OSGeo Project "*Geospatial Data Abstraction Library (GDAL*[25]*) Feature Style specification"* [41]. Other SEs have been developed by commercial geospatial vendors to enable portrayal in their proprietary software applications. These include vendor-specific[26] formats such as the ESRI Cartographic Information Model (CIM)[27] and Mapbox GL[28] specifications. Despite the variety of SEs available to the community, there is limited interoperability between many of the individual SEs, although many of the encodings do leverage the same core elements.

SE formats work by encoding a full set of portrayal information using computer language such as XML or JSON to convey structured instructions to a system for applying a style to the data. These will often utilise other component formats to standardise elements of the portrayal, these include, but are not limited to:

- Colour models (Pantone, RGB, CMYK and HEX, etc.), whose application for cartographic screen display and hardcopy map/chart printing within the defence environment is described in the DGIWG Digital Printing Colour Profile.
- Text fonts (Arial, Sans Serif, etc.).
- Raster images (PNG, TIFF).
- Vector styling (SVG, EMF).

The complex nature of portrayal makes interoperable exchange difficult. To help overcome this DGIWG is producing an Implementation Guide for General Symbology Styles and Encoding, It will provide guidance on how to portray community symbol sets by utilising various SEs based on common vendor-specific and open standards approaches.

5.5.3 Portrayal Rules and Symbols

While there are a variety of SEs for enabling the sharing of symbols, the geospatial community also utilises DPSs and Symbol sets[29], to ensure that products and dataset are displayed consistently. These provide a system-agnostic set of rules and symbols

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[23] **Symbology Encoding (SE)** is a generic concept referring to composition of styling information for styling map data. The OGC SE Standard is defined as the language to formally encode the rules of how to portray features and coverages in an XML schema.

[24] **The Styled Layer Descriptor (SLD)** defines an encoding that extends the Web Map Service (WMS) standard to allow user-defined symbolization and coloring of geographic features and coverages. http://www.ogc.org/standards/sld

[25] **Geospatial Data Abstraction Library GDAL** - A translator library for raster and vector geospatial data formats that is released under an MIT style Open Source License by the Open Source Geospatial Foundation http://gdal.org/

[26] **Vendor specific** SE's are Portrayal exchange formats developed to work with in a specific vendor owned software

[27] **Esri Cartographic Information Model (CIM)** is a map content specification used to persist and transfer cartographic descriptions of GIS datasets http://www.esri.com/arcgis-blog/products/js-api-arcgis/mapping/create-points-lines-and-polygons-using-cimsymbols/#what-is-cim

[28] **Mapbox GL** is a suite of open-source libraries for embedding customizable and responsive client-side maps in web, mobile, and desktop applications. Mapbox GL maps render at a high frame rate.

[29] **Symbol Set**: Is a collection of symbols that cover a wide vocabulary. Most symbol sets are designed to follow a coherent set of design rules to provide consistency, which assists the decoding of meaning. http://www.widgit.com/about-symbols/intro_to_symbols/symbol_sets.htm

that can be utilised by the SEs to portray data according to specific requirements. The DGIWG community provides a number of these symbol sets:

Symbol Sets:

- DGIWG 109 "Multinational Geospatial Co-production Program (MGCP) Symbols" [42]: This standard defines the portrayal symbols and rulesets used to generate graphics from data collected in accordance MGCP technical reference documents.
- DGIWG 130 "Web Symbology" [43]: This document defines a common set of symbols which support the portrayal of feature data, as web services, across a full range of zoom levels.

5.5.4 Maintenance and Change Control Process for Portrayal Artefacts

Portrayal data artefacts within the DGRA are curated through the use of databases and libraries of graphics files that relate to DGIM. The DGIWG Portrayal Database creates traceability of symbol usage between specifications and is extendable to support additional symbols sets. DGIWG is developing a Database Maintenance Guide. This will document the database structure, outlines types of change requests and how they should be handled to maintain database and symbol library reference integrity. The database and accompanying symbol libraries will support traditional standards development and web deployment of portrayal information and symbols for download or potential direct use by systems through Uniform Resource Locators (URLs). A change control process based upon DGIWG 915 "*DGIWG Register Maintenance Procedures*" is being developed to ensure that the portrayal database can be appropriately managed.

In addition to the database, the DGRA also provides the methodology to host a portrayal registry that is remotely accessible and discoverable using a portrayal registry service. DGIWG 118 **"***Portrayal Registry Service Interface Specification*" [44] is based on the OGC 07-006r1 *"Catalogue Service for the Web (CSW*" [45]. Work is underway to retire and replace this specification.

6 Computational Architectural Viewpoint

6.1 Computational Overview

The purpose of this viewpoint is to describe how the individual components of the DGRA interact by decomposing the main system process into individual components and their interfaces.

6.2 DGRA Standards Interfaces

The interfaces recommended for use within the DGRA are based on the DGIWG web service standards. Table 1 provides a summary of the services, including mandatory operations, required to support interoperable geospatial data exchange for each interface.

Table 1: Summary of web service interfaces used in the DGRA

Specification Name	Version and Conformance	Mandatory Operations	Description	Profile of:
DGIWG 112 *"Profile of OGC Web **Map** Service 1.3 Revision"* [46]	v.3.0 Conformance Class - **DGIWG Basic WMS**	GetCapabilities GetMap	Provides a simple interface for requesting dynamically generated georeferenced map images from one or more distributed geospatial databases	ISO 19128:2005 Web Map Server Interface and the OpenGIS Web Map Server Implementation Specification 1.3.0 (OGC 06-042)
	v.3.0 Conformance Class - **DGIWG Queryable WMS**	GetCapabilities GetMap GetFeatureInfo	Extension of DGIWG 112 v.3.0 – Provides an additional interface for retrieving information about features in the pictures of maps that were returned by previous GetMap requests	
DGIWG 119 *" Profile of OGC Web **Coverage** Service 2.0"* [47]	v.1.0.0 Conformance Class - **Geo**	GetCapabilities, DescribeCoverage, GetCoverage	Provides an additional interface for retrieving and querying gridded coverage data from a distributed data store.	The Open Geospatial Consortium's Web Coverage Service 2.0.1 Interface Standard -Core (OGC 09-110r4)
DGIWG 122 *"Profile and of OGC Web **Feature** Service 2.0"* [48]	v2.0.2 Conformance Class - **DGIWG Basic WFS**	GetCapabilities DescribeFeatureType GetFeature GetPropertyValue ListStoredQueries DescribeStoredQueries	Provides an interface for retrieving and viewing geographical vector features from a distributed data store	ISO 19142:2010 - Web Feature Service (WFS) including changes made in the OpenGIS Web Feature Service 2.0 Interface Standard – Corrigendum (OGC 09-025r2) And Filter Encoding 2.0 Encoding Standard (same as ISO 19143:2010) OGC 09-026r2
	v2.0.2 Conformance Class - **DGIWG Locking (Transactional) WFS**	GetCapabilities DescribeFeatureType GetFeature GetPropertyValue ListStoredQueries DescribeStoredQueries Transaction LockFeature	Extension of DGIWG 122 - Provides an additional interface to enables clients to create, modify, replace and delete features in the Web Feature Service's data store. It also enables clients to lock the data store in order to maintain consistency when editing.	
DGIWG 124 *"Profile of OGC Web **Map Tile** Service 1.0"* [49]	v1.0 Conformance Class - **DGIWG Basic WMTS**	GetCapabilities GetTile Request	Provides an interface for serving map tiles of spatially referenced data using tile images with predefined content, extent, and resolution	Open Geospatial Consortium's Web Map Tile Service (WMTS) Implementation Standard, v.1.0.0(OGC 07-057r7) As above
	v1.0 Conformance Class - **DGIWG Queryable WMTS**	GetCapabilities GetTile Request GetFeatureInfo	Extension of DGIWG 124 - Provides additional interface to enable client to retrieve information about the features located at a particular pixel of a tile map	

Specification Name	Version and Conformance	Mandatory Operations	Description	Profile of:
DGIWG 125 *"Profile of OGC's* ***Catalogue*** *Service for the Web (CSW) 2.0"* [50]	v1.0.1 Conformance Class **- CSW Basic**	GetCapabilities DescribeRecord GetRecords GetRecordById GetDomain	Provides an interface for storing and managing metadata. This enables client application to discover and request geospatial services and data from a server.	The Open Geospatial Consortium's Catalogue Services Specification, CSW 2.0.2 (OGC 07-006r1), and Catalogue Services Specification 2.0.2 – ISO Metadata Application Profile, CSW ISO 1.0 (OGC 07-045).
	v1.0.1 Conformance Class **- CSW-T extension**	GetCapabilities DescribeRecord GetRecords GetRecordById GetDomain Harvest Transaction	Extension of the DGIWG 125 v1.0.1 – Provides an additional interface to enable the update and modification of the metadata catalogue	
NOT Published DGIWG Profile of OGC Web **Processing** Service 2.0	**NOT Published** DGIWG xxx Conformance Class	**NOT Published** GetCapabilities DescribeProcess Execute GetStatus GetResult	**NOT Published** Provides an interface for describing a service that enables processing functionalities to be executed in a web environment	**NOT Published** Open Geospatial Consortium's Web Processing Service 2.0 (OGC 14-065

The specifications described in Table 1 provide a HTTP(S) service architecture which enables client applications to interact with the server and to discover, process, visualise or access data, from distributed geospatial data stores. Figure 6 illustrates the service architecture alongside the operations that each service provides.

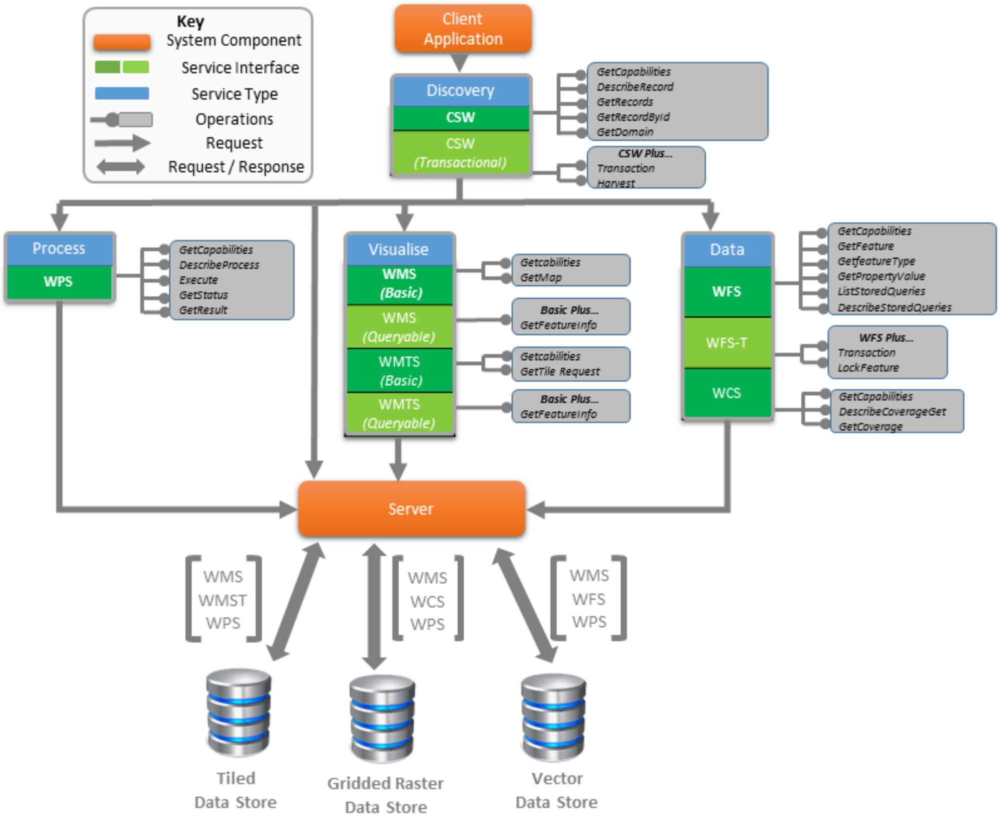

Figure 6: High-level web service interface architecture for the DGRA

The following sections describe in detail the key service interfaces and their operations.

6.2.1 Web Map Service (WMS)

Description: The DGIWG 112 *"WMS profile"* describes how to provide maps of spatially referenced data dynamically from geographic information. ISO 19128: 2005 defines a "map" to be a portrayal of geographic information as a digital image file suitable for display on a computer screen. The digital image is a visual representation of the data and is not the data itself. WMS-produced maps are generally rendered in a pictorial formats such as Portable Network Graphic (PNG), Graphics Interchange Format (GIF) or Joint Photographic Experts Group (JPEG).

Core Operations: The WMS Interface offers three Operations:

- **GetCapabilities:** Enables a client machine to obtain descriptive information (Metadata) about the service being requested. This includes information such as the operations supported by the service and descriptions of the data maplayers available in the service.
- **GetMap:** Returns a map image for a specified area and content to the client machine.

- **GetFeatureInfo:** Retrieves attribute information from features in the pictures of maps that were returned by previous GetMap requests.

The WMS Implementation Specification defines two conformance classes, "Basic WMS" and "Queryable WMS". The Basic WMS supports the mandatory GetCapabilities and GetMap operations (requests and responses) whereas the Queryable WMS supports all Basic WMS operations and the GetFeatureInfo operation. The DGIWG WMS profile mandates the implementation of the BasicWMS.

6.2.2 Web Coverage Service (WCS)

Description: The DGIWG 119 *"WCS profile"* describes how a client application can visualise and provide geospatial data from raster datasets on a web server. Raster files are defined as data that is represented as a matrix of cells in continuous space organized in rows and columns where each cells contains a value. Thus WCS services provide access to different types of gridded data representing various space/time-varying phenomena, such as Digital Elevation Models (DEMs), remote sensing imagery, etc. The WCS also allows the client application to select specific portions of a server's information holdings or data based on defined spatial constraints and other query data such as data format and data type. However, the WCS only provides access to the raw data and does not have transactional capabilities.

Unlike WMS, which returns spatial data to be portrayed as static maps (rendered as pictures by the server), the WCS provides available data together with their detailed descriptions; defines a rich syntax for requests against these data; and returns data with its original semantics (instead of pictures) which may be interpreted, extrapolated, etc., and not just portrayed.

Core Operations: Based on the WCS 2.0 Core conformance class, the DGIWG 119 profile supports the following operations:

- **GetCapabilities:** Allows a client application to retrieve the WCS service metadata. This includes information about the server's capability and coverages it offers.
- **DescribeCoverage:** Allows a client application to return the metadata for a specific coverage offered by the server.
- **GetCoverage:** Allows the Client application to request a coverage based on a selected range of properties for a selected spatial/temporal location. The server returns the selected coverage based on the clients query.

6.2.3 Web Feature Service (WFS)

Description: The DGIWG 122 *"WFS profile"* describes an interface for allowing requests for geospatial features across the web using platform-independent mechanisms and is independent of the underlying data store. Geospatial features can be regarded as the "source code" behind a map. Whereas the WMS interface return only an image, which end-users cannot edit or spatially analyse, the WFS provides GML as the default payload-encoding for transporting geospatial features. In other words, rather than sharing geographic information at the file level using File Transfer Protocol (FTP), for example, the WFS offers direct fine-grained access to geographic information at the feature and feature property level.

Core Operations: WFS standard defines several conformance classes for service implementations. These WFS implementations are hierarchical structured, meaning all capabilities within Simple are captured within Basic and so forth. The five conformance classes defining general WFS implementations are:

- **WFS Simple:** This only allows user viewpoint and search the data on the server.
- **WFS Basic:** Allows a client application to search and receive feature data from the data server.
- **Transactional WFS:** Allows a client application to modify a data source on the server side by creating updating or deleting a feature.
- **WFS Locking:** Allows a client application to initiate a lock request on one or more instances of a feature type for the duration of a transaction, to ensure that serializable transactions are supported.
- **Manage Stored Queries:** Allows a client application to create, drop, list and describe parameterized query expressions that are stored by the server, and can be repeatedly invoked using different parameter values.

DGIWG 122 defines two WFS profiles, these are:

- **DGIWG Basic WFS:** Allows Client Applications to view and query data. The operations allowed for this are as follows:
    - **GetCapabilities:** Generates a service metadata document describing the WFS service provided by a server.
    - **DescribeFeatureType:** Returns a schema description of the feature types offered by a WFS instance.
    - **GetFeature:** Returns a selection of features from a data source. A GetFeature element contains one or more Query elements that describe a query operation on one feature type. In response to a GetFeature request, a Web Feature Service must be able to generate a GML3 response that validates using a schema generated by the DescribeFeatureType request.
    - **GetPropertyValue:** Returns the value of a feature property or part of the value of a complex feature to be retrieved from the data source for a set of features identified using a query expression.
    - **ListStoredQueries:** Returns a list of all the stored queries available on the server.
    - **DescribeStoredQueries:** Provides detailed metadata about each stored query expression that the server offers.
- **DGIWG Locking (Transactional) WFS:** Allows Client applications to view, query and modify the data. The operations allowed for this are as follows:
    - DGIWG Basic WFS operations and
    - **Transaction:** Allows a client application to create, modify, replace and delete features in the Web Feature Service's data store.
    - **LockFeature:** Allows a client application to lock the data store in order to ensure consistency in data manipulation operations.

6.2.4 Web Map Tile Service (WMTS)

Description: The DGIWG 124 *"WMTS profile"* describes how to serve pre-rendered maps divided in individual tiles rather than creating a new image for each request as with the WMS. The tiles are organised into a discrete set of tile matrices called the tileMatrixSet. The service advertises the tiles available in the matrix through a standardized declaration in the ServiceMetadata document. This declaration defines the tiles available in each layer (i.e. each type of content), in each graphical representation style, in each format, in each coordinate reference system, at each scale, and over each geographic fragment of the total covered area. The main benefit of using this approach is that tiles can be rendered server-side and then cached client-side. This reduces waiting time and bandwidth limitations and improves user. The WMTS is an alternative to the WMS that provides accelerated and optimised map image rendering and delivery.

Core Operations: The WMTS Interface offers three Operations:

- **GetCapabilities:** Allows the client application to request metadata from the WMTS server in order to determine what the WMTS server can do and what operations the WMTS server can provide. The key parameter for this request is "request=GetCapabilities", which fetches the capabilities of the WMTS and responds in the form of XML data.
- **GetTile:** Allows the client application to request the server to return a map tile for as specific spatial location from the tileMatrixSet in a predefined image format.
- **GetFeatureInfo:** Allows a client application to retrieve attribute information about features in the map. The operation does this by allowing the WMTS clients to request information at a particular position of a particular tile for a particular queryable layer. A layer is queryable if the Contents section of the ServiceMetadata document specifies one or more InfoFormats for this layer.

The WMTS Implementation Specification defines two conformance classes, "Basic WMTS" and "Queryable WMTS". The Basic WMTS supports the mandatory GetCapabilities and GetTile operations (requests and responses) whereas the Queryable WMTS supports all Basic WMTS operations and the GetFeatureInfo operation. The DGIWG WMTS profile mandates the implementation of the Basic WMTS.

6.2.5 Catalogue Service for the Web (CSW)

Description: The DGIWG 125 *"CSW profile"* describes how organisations can publish and search collections of descriptive information (metadata) for data, services, and related information objects. The metadata published by catalogues summarise the attributes of a resource including title, abstract, geospatial extent etc. The metadata attributes can be queried through the CSW interface and the results can be displayed in a human or machine readable format.

The DGRA specifies the use of the DGIWG 122, a military implementation profile for the OGC 07-006r1 *"Catalogue Services specification"* [51] with the ISO 19115-3/19139 Metadata Application Profile to enable interoperable discovery of resources (e.g. geospatial datasets and services) within a multi-national coalition environment. The DGIWG CSW profile, requires support for the DGIWG Metadata Foundation (DMF) 2.0 DMF/Core.

The DGIWG CSW operations are divided in 2 conformance classes: The Basic and Transactional implementations. The Basic CSW enables the server to publish metadata and for users to search and retrieve information from it. Further to this the Transactional CSW also enables users to update and edit the content of the metadata catalogue.

The processes for managing a registry and its register(s) is described by DGIWG 915 *"The Register Maintenance Procedures"*.

The core operations of the Basic (Publish and Discover) CSW are as follows:

- **GetCapabilities:** This enables CSW clients to return the catalogue service metatdata from a CSW server. The, metadata describes the details of the CSW being queried**.** This includes:
    - *Service ID:* Metadata about this specific server.
    - *ServiceProvider:* Metadata about the organization operating the catalogue.
    - *OperationMetadata:* Metadata about an operations specified by this service, including the URL(s) for operation requests.
    - *Content:* Metadata about the type of resources catalogued by this server.
    - *Query Language:* Metadata about the query language supported by this server, specifying the query abilities that have been implemented.
- **DescribeRecord:** Allows a client to retrieve schema structure of the information model supported by the catalogue. It allows some or all of the information model to be described. The information model for the DGIWG 125 *"CSW profile"* is the DGIWG 114 *"DMF"*.
- **GetRecords:** The primary means of searching and retrieving information resources contained in the catalogue's information model. It allows the query of metadata records in the CSW.
    - Filtering is performed against the supported record schema using the advertised filtering/ querying capabilities. Constraints (logical, spatial, comparison) are typically specified against individual schema elements
- **GetRecordById**: Enables the user to request the complete set of DMF Metadata for a chosen record.
- **GetDomain**: This operation is used to get information about the values of elements of the information model. It retrieves information about the valid values of one or more named metadata properties.

The DGIWG CSW Transactional (CSW-T) extension is an optional component of the DGIWG CSW catalogue. It is required if end-users need to update or modify their catalogue. A compliant CSW-T must implement all the operations required for the DGIWG Basic CSW as well as the following operations:

- **Harvest:** Defines an interface for indirectly creating, modifying and deleting records from the catalogue. This achieved by using a CSW client-harvesting run on the server to a specified target. The Harvest operation can be enabled by an authorised user to run in either synchronous[30] or asynchronous[31] mode and can be executed just once or set to run periodically. This works by **pulling** the metadata from the server. This operation references the metadata that is to be inserted or updated into the catalogue, and it is the job of the catalogue service to resolve the reference, fetch that metadata, and process it into the catalogue.

- **Transaction:** Defines an interface for editing the catalogues metadata records and enables authorised users to create, modify and delete catalogue records. This works by **pushing** metadata into the catalogue.

6.2.6 The Defence Profile of the OGC Web Processing Service (WPS) 2.0 (DGIWG PROFILE NOT PUBLISHED)[32]

Description: The WPS Interface Standard provides rules for standardizing inputs and outputs (requests and responses) for geospatial processing services. The standard also defines how a client can request the execution of a process, and how the process output is handled. It defines an interface that facilitates the publishing of geospatial processes and clients' discovery of and binding to those processes. The data required by the WPS can be delivered across a network or it can be available at the server.

Core Operations: The WPS service model defines five operations:

- **GetCapabilities:** Returns service metadata.
- **DescribeProcess:** Returns the description of a specific process.
- **Execute:** Creates a job to run a specific process.
- **GetStatus:** Returns status information about a processing job.
- **GetResult:** Returns the result of a processing job.

6.3 Future DGRA Interfaces

The previous section describes a well-established range of community interface standards and military profiles that enable various functions within the military geospatial enterprise. However, as the enterprise continues to develop, DGIWG will consider and adopt new approaches which support the users changing needs. As these are adopted, the DGRA will evolve to guide their use.

Some of the key web service concepts and standards being considered by DGIWG include:

- **Sensor Web Enablement (SWE):** Is a suite of standards developed and maintained by Open Geospatial Consortium. SWE standards enable

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[30] **Synchronous mode:** The CSW receives a Harvest request from the client, processes it immediately, and sends the results to the client while the client waits *"OGC 04-039 - Geospatial Portal Reference Architecture"* [55]

[31] **Asynchronous Mode:** The server receives a Harvest request from the client, and sends the client an immediate acknowledgement that the request has been successfully received. [55]

[32] **Note:** The Defence Profile of the OGC Web Processing Service (WPS) 2.0 is being developed by DGIWG and is due to be published in autumn 2023

developers to make different sensors, transducers and sensor data repositories discoverable, accessible and usable via the Web. These are summarised in OGC 07-165r1 "*Sensor Web Enablement: Overview and High-Level Architecture"* [52]. DGIWG is working with NATO standards bodies to develop implementation guidance for their use within the military enterprise.

- **OGC APIs:** Are an interrelated suite of "building blocks" that can be used to assemble novel interfaces for web access to geospatial content. The API standards developed by OGC build upon the legacy of the Web Service interfaces summarised in section 6.1. These define resource-centric interfaces that take advantage of modern web development practices; this improves the ease of use by developers and better enables end users to exploit geospatial data on the web and integrate this data with other information. DGIWG is undertaking a review to understand how OGC APIs should be used by the military community and identify any interoperability requirements to ensure they are consistently employed within the military enterprise. This includes a detailed look at key APIs such as OGC 19-086r5 *"Environmental Data Retrieval (EDR[33]) API"* [53].

[33] **The Environmental Data Retrieval (EDR) API**: provides a family of lightweight interfaces to access Environmental Data resources. Each resource addressed by an EDR API maps to a defined query pattern. This specification identifies resources, captures compliance classes, and specifies requirements which are applicable to OGC Environmental Data Retrieval API's.

7 Engineering Architectural Viewpoint

The Engineering Architectural Viewpoint defines the various software components of the DGRA that are needed to enable the collection, discovery, dissemination and exploitation of geospatial information. The focus of this viewpoint is to summarise the technical approach and the specific components that are required to support interoperability.

7.1 Technological Approach

The SOA approach enables service providers to describe the web services using metadata. They then publish the service metadata through a register. The service clients (either human or system users of the services) search the registers to find data services. They then examine the metadata to identify the service and select a service based on their understanding of the metadata. Figure 7 provides an overview of how the SOA concept works.

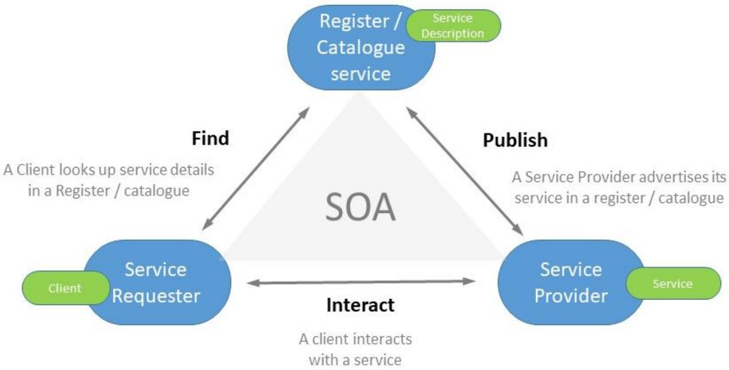

Figure 7: Service Orientated Approach

In order to enable a SOA, the providers must supply services that satisfy the clients requirements and underpin the system functions [54].

7.2 The DGRA Components

The DGRA components that enable the collection, dissemination, discovery and exploitation of geospatial data are summarised in

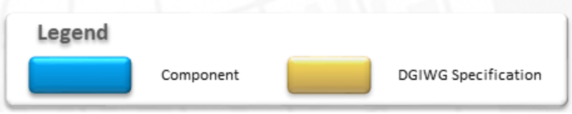

Figure 8. This figure describes the high-level view of the geospatial enterprise based on the DGRA and identifies the key components with specific functionality at different levels.

At the base level from the data provider's perspective there are the *"Data"* components. These enable the collection and storage of geospatial data and metadata. The "*Middleware"* components then provide the functionality to view download or process data through the generation of *"Web Services"*. For example, a web server generates geospatial services for viewing, downloading, collecting or processing data. The web service metadata is then published as a web service using a registry. The end users then access the web services via a *"Client"* software applications or a web portal. The *"Client"* software either uses the web service metadata to discover an appropriate web service or if the web service details are already known it can access the web service directly.

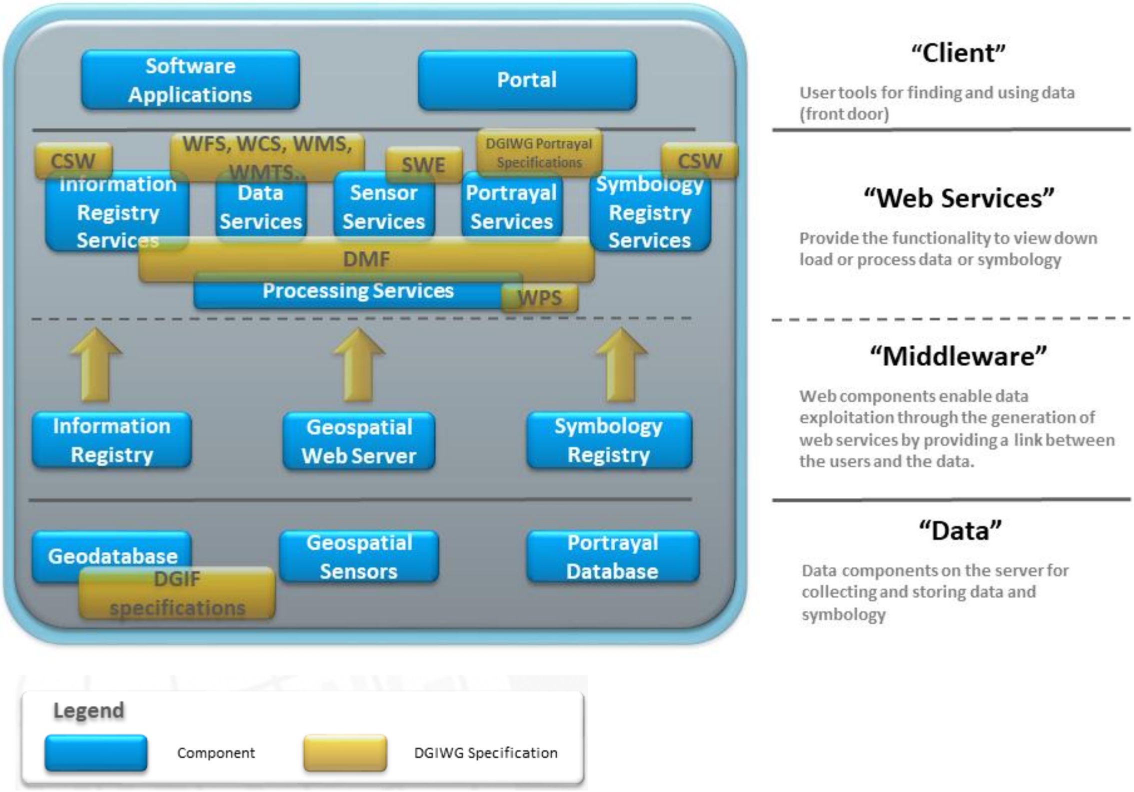

Figure 8: High-level view of the DGRA components

The key DGRA components and relevant enabling standards shown in Figure 8 are:

"Client" – User tools for finding and using data (front door):

- Portal: Portals are the front doors for users to access geospatial data and services. They are typically browser-based applications which provide a human-readable interface and employ a registry for finding, assessing and exploiting geospatial data.
- Software Applications: These are any application which are designed to consume geospatial data as a service. In the military context, this will most commonly be command and control (C2) systems and advanced GIS applications used by specialised technicians.

Typically, DGRA "Client" components consume web services based on the following DGIWG standards:

- Register service: DGIWG 125 "*CSW profile*".
- Data services: DGIWG 112 "*WMS profile*", DGIWG 122 "*WFS profile*", DGIWG 119 "*WCS profile*", and DGIWG 125 "*WMTS profile*".
- Portrayal Services: DGIWG 130 Web Symbology Specification.
- Metadata: DGIWG 114 "*DMF*".

These and other key standards are described in more detail elsewhere in the DGRA document (Computational and Information Architecture viewpoints). Additional specific guidance on their implementations are provided in the standards documents which can be found on the DGIWG website (http://dgiwg.org/documents/dgiwg-standards).

"Middleware" – Web components to enable data exploitation through the generation of web services by providing a link between the users and the data. These include:

- **Registry[34]:** This is a technology that enables the cataloguing, description, search and maintenance of resources (geospatial services, data or symbols etc.) available on a network. It achieves this by building a register driven by the metadata held and updated within the registry. The user can then search the register and select metadata for the appropriate product and data services [55]. To ensure the consistency of the data, there should be a single authoritative source of metadata within the register. The metadata used to populate registers in the DGRA is based on the DMF which is a profile of the ISO 19115-3/ ISO 19139. The registers are differentiated by their role in the system and can be used for grouping and managing different categories of resource including data services, processing services, sensor services or symbol library services etc. The DGRA recommends that registries are used to publish and discover geospatial resources within the digital enterprise. Depending on requirements, the number of registers needed may vary, according to the needs of the user. The DGRA describes two registers and are described as follows:
  - The Information Register: A collection of metadata entries that describe and point to geospatial datasets and web services. This is employed to enable users to discover the geospatial datasets and services available on a digital enterprise. The DGIWG 125 *"CSW profile"* standard provides more details on the implementation of an Information Registry.
  - The Symbology Register: A collection of metadata entries that describe collections of symbology and associated portrayal rulesets. DGIWG 118 *"Portrayal Registry Service Interface Specification"* provides more details on the querying model and operations required to discover and retrieve portrayal rules and symbols held in a Symbology Registry.

  In addition to publishing information about resources, a registry can also be used to manage key resources in a controlled manner. For example, a metadata registry and associated register could be used to store, maintain and manage metadata definitions[35].

  Whilst conceptually the DGRA recommends the use of multiple registers for specific purposes there is no reason that this functionality could not be provided using a single registry that hosts multiple registers. However, the ability to do this would be dependent on the capability of the underpinning hardware and associated registry software. For example, a complex registry for managing multiple registers would likely require a more

[34] **The Registry:** is the software component on which a register is maintained [ISO 19135 http://inspire-sandbox.jrc.ec.europa.eu/glossary/Registry . It supports the run-time discovery and evaluation of resources such as services, datasets, and application schemes. Open Geospatial Consortium (OGC) http://www.ogc.org/ogc/glossary/w

[35] **Metadata definitions:** The descriptions and rules outlining what specific metadata elements look like, how they are used and their relationships with other metadata elements.

robust setup, with hardware and software capable of being configured to handle multiple concurrent users accessing the registers.

- **Geospatial Web Servers:** The "Middleware" component that enables the generation and exposure of geospatial web services to clients. Through the generation of web services, they can facilitate access to the vector, raster, portrayal, and metadata information contained in the geodatabases. They can also generate a range of services, from managing remote sensors to processing and data analysis. The specific functionality of the web server is dictated by the underlying software. Given the varied nature and type of web services, implementers may choose to use separate web servers to deliver different functionality. For example a data web server for generating and managing data services or a processing web server for managing processing services etc.

  Geospatial web servers should be able to generate a range of various standards-based web services such as:

  - Data and Digital Map Services: (Implementing DGIWG 112 "*WMS profile*", DGIWG 122 *"WFS profile*", DGIWG 119 "*WCS profile*", and DGIWG 125 "*WMTS profile*" standards).
  - Portrayal Services (Offering SE files using symbols recommended in *DGWIG 130 "Web Symbology"*).
  - Processing Services: (Implementing the DGIWG Web Processing Service (WPS) standard.
  - Sensor Services: Implementing SWE standards.

  The ability to generate these different types of services is dependent on the capability of the underlying server software. As a result, a service provider may require multiple web servers to deliver the full range of different services.

"Data" - Components on the server that enable the collection and storage of data and symbology. These include:

- **Geospatial Databases:** Stores geospatial data held in a digital form, with data structures optimised to exploit the spatial characteristics of the information, be that metadata, vectors, raster (pixels) or other data such as text. Geospatial databases should be able to store data according to the structure laid out by various data models such as:
  - Vector data: DGIWG 205 *"DGIM*".
  - Metadata: DGIWG 114 *"DMF profile*".
- **Portrayal Database:** Stores map symbols in digital form, with data encodings and rulesets optimised to exploit symbology in portrayal services. A portrayal database should be able to store symbol data and support the Portrayal Registry information model as described in the DGIWG 918 *"Portrayal Registry Service Interface Specification*".
- **Geospatial Sensors:** Web enabled sensors that enable the remote collection and dissemination of raw geospatial data via web services. Sensors should be able to connect to and share data by using the SWE standards.

7.3 DGRA Configurability

The DGRA bridges the gap between standards and technology by using DSM and architectural viewpoints to link the standards to the functionality they support and the technical components that implement these. This relationship enables the military community to identify the correct components and supporting standards to meet their needs and to implement them to improve the interoperability of new geospatial capability. The principles and standards outlined in DGRA, when applied correctly, provide users with guidance for accessing a wide range of interoperable geospatial operations and services.

The DGRA is flexible, allowing different system configurations to meet specific requirements. For example,

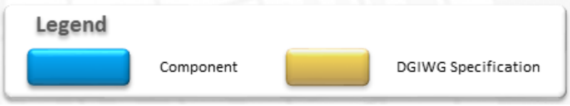

Figure 9 shows a simplified system for storing data and providing pre-built maps to the user. Although it uses only a few DGRA components, if the underlying network infrastructure and security requirements are met, this system can still connect and share information with other systems which follow the DRGA guidance. The DGRA's flexibility is achieved through consistent use of the DGIWG standards and principles. This allows implementers to select a subset of components to meet their needs, while maintaining interoperability with other systems using the DGRA.

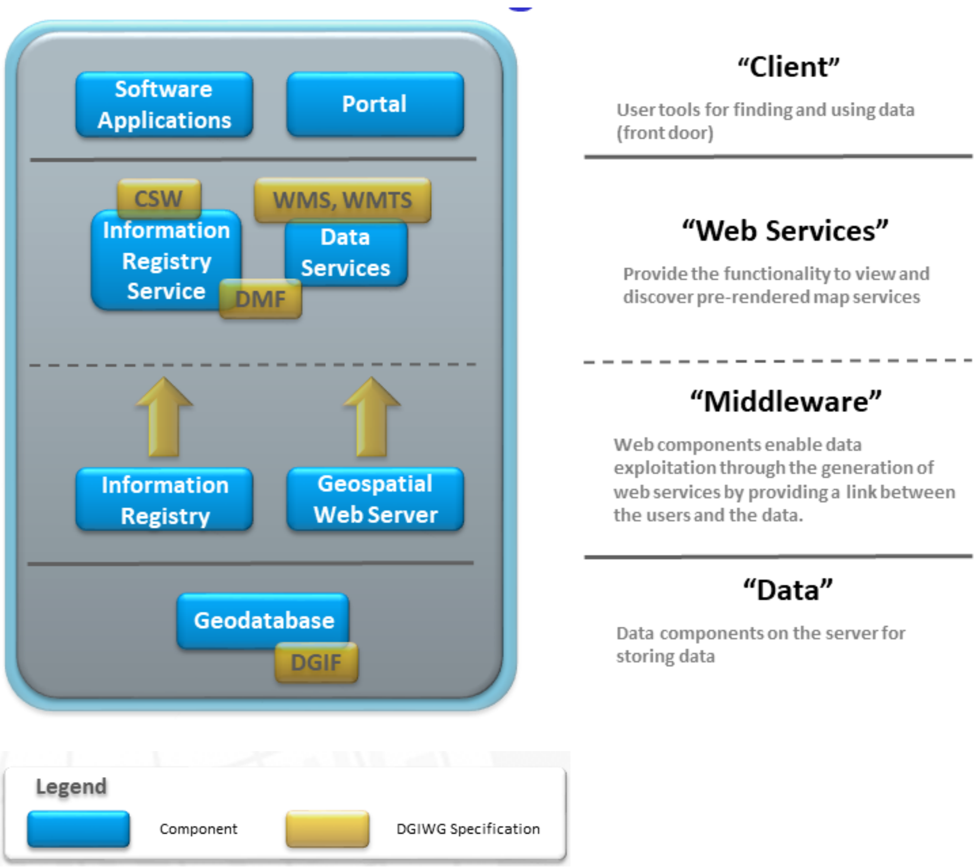

Figure 9: High-level view of a simplified DGRA system for disseminating pre-rendered raster maps

Figure 10 shows an example of a geospatial enterprise that is designed in according to the principles and standards outlined in the DGRA. This example provides a high-level logical overview of the relationship between interconnected DGRA components and the various system actors that interact with the system (described in Section 4.5). The steps in Figure 10 are as follows:

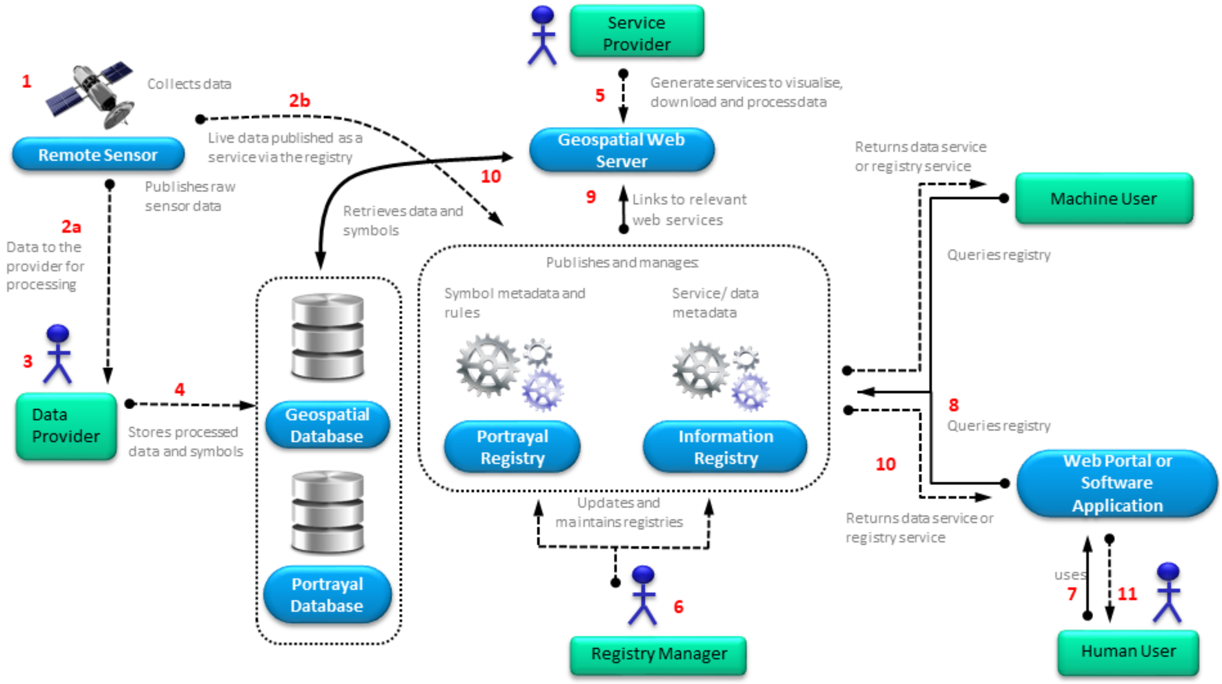

Figure 10: High-level logical view of the system components and key roles in an example DRGA based geospatial enterprise.

1. Vector Data is collected by the **Remote Sensor**.
2. The raw data is sent to the **Data Provider** via web services or published via the Registry as a live sensor service. This is enabled by OGC SWE standards.
3. The **Data Provider** processes the data and saves it in an appropriate data structure and generates appropriate Metadata. This is completed using geospatial software or pre-configured web processing services. The vector data and metadata are structured using principals described in DGIWG 205 *"DGIM*" and DGIWG 114 *"DMF profile"*, respectively.
4. The processed data is stored in a **Geospatial Database** along with associated metadata.
5. The **Service Provider** uses a **Geospatial Web Server** to generate geospatial data services with associated service metadata. DGIWG vector data is exposed as a WFS using DGIWG 122 *"WFS profile"* as guidance. Service metadata is generated using DGIWG 114 *"DMF profile*" as a guide.
6. The **Registry Manager** publishes the web service and dataset metadata using an Information Registry. The Registry service is then available for users to search for appropriate web services or datasets. The Registry service is published using, DGIWG 125 "*CSW* profile" as guidance.
7. A **Human User** uses the **Web Portal** to search for an appropriate web service.
8. The **Portal** queries the **Information Registry** and returns a **Register Service** with a human readable version of the register. The **Human User** selects an appropriate service from the register.
9. The **Information Registry** requests the appropriate service from the **Geospatial Web Server**.

10. The **Geospatial Web Server** returns the appropriate data as a resource through a web service that is discoverable through the **Information Registry**.
11. A **3rd Party application** consumes the web service and the **Human User** exploits the data service.

8 Current Work and Future Trends

The DGIWG continuously monitors the emergence of new trends and standards that may change and improve the use of geospatial data in the military domain. Each of the DGIWG technical panels have developed a technical roadmap that identifies future activities and trends that may potentially affect subsequent versions of the DGRA.

8.1 DGIWG Development Work

Current DGIWG activities supporting the DGRA are summarised in Table 2.

Table 2: Summary of DGIWG work on the development of key standards and guides

DGIWG Req. No.	Task Name	Task summary	Customer	Output (Standard, Profile Guidance note, White paper etc.)
56	Geo Package	Development of a DGIWG profile of the OGC Geo package Standard	MN	Profile
76	Web Processing Service (WPS) Profile	Development of a DGIWG profile of the OGC WPS standard	MN/ NATO	Profile
NA	DMF Implementation Guidelines	Give guidance to demonstrate how to use DMF for most common metadata use cases. (DMF cookbook).	MN	User Guide
NA	DGIWG Metadata Foundation (DMF) 2.0	Review and update of DGIWG Metadata Foundation	MN	Standard
NA	Urban Exchange Schema	Development exchange schema for all urban features within DGIF	NATO	Data Product Specification
70	Defence City Map (DCM)	Development of a product specification for the DCM subset of DGIF urban features	NATO	Data Product Specification
NA	Defence Joint Operations Graphic (Aeronautical) (DJOG(A))	Development of an “internationalized” product specification based on the US national Joint Operations Graphic (Aeronautical) product.	NATO	Data Product Specification
79	DGIF 3.0/NGIF 3.0	Development and formalization of the next version of NGIF/DGIF.	DGIWG/ NATO	Standard

85	OGC SWE	DGIWG Endorsement and Implementation Guide for OGC SWE	DGIWG/ NATO	Standard/ User Guide
91	Human Geography Points of Interest Exchange Schema	Enhancement of DGIF and development of exchange schema to satisfy requirements for the collection and exchange of specific human geography data types	IPHG	Data Product Specification
NA	Human Geography Statistics and Cultural Context	Enhancement of DGIF and development of exchange schema to satisfy requirements for the collection and exchange of specified human geography data types	IPHG	Data Product Specification
89	Defence Tactical Pilotage Chart (TPC)	Development of an “internationalized” product specification based on the US national TPC product.	NATO	Data Product Specification
TBA	OGC API	A review to understand how OGC APIs should be used by the military community and identify any interoperability requirements to ensure they are consistently employed within the military enterprise. This includes a detailed look at key APIs such as EDR	DGIWG	White paper

8.2 Future Trends

Future trends of interest to the DGIWG that may influence the direction of future versions of the DGRA are shown in Table 3.

Table 3: Summary of emerging trends and their potential impact on the DGRA

Trend Name	Trend Description	Potential Effect on the DGRA	Level of Maturity	Predicted Epoch for Trend	Link to DGIWG Roadmap
Application Programming Interface (API)	The OGC is developing resource-centric API standards that will eventually replace its traditional web service standards. These enable the use of modern web development practices making standards easier to implement and use. The OGCs API standards are being developed using OpenAPI[36].	The use of APIs is a fundamental shift in how standards are written and implemented. Their use will likely become the de facto approach to sharing geospatial data services and tools [56]. Therefore unless the military community adopts APIs its ability to share critical data and services may be significantly limited. This will affect likely affect all functional areas and standards in the DSM. Standards in the Disseminate and Consume functions are the most mature and should be developed first.	This is a mature trend and it is ready for adoption by the defence community.	Medium Term 3-5 years	DGIWG 909 *"Web Services Roadmap"* [57]
Blockchain	A blockchain is a digital ledger based system of sharing information that makes it impossible for potential hackers tamper with the data. [58] Geospatial Communities have been exploring the use of blockchain technology to improve the security of data management systems by enabling them to record and validate the spatial location of a transaction. [59]	The use of blockchain security features in the geospatial community will potentially affect several functional areas within the DSM, specifically Collection and Data Management. DGIWG will continue to monitor its development and identify if any appropriate courses of action as the need arises	Use in the Geospatial community is relatively immature	Long Term 6-10 years	DGIWG 909

[36] The OpenAPI Specification (OAS) (previously known as the Swagger) defines a standard, language-agnostic interface to RESTful APIs which allows both humans and computers to discover and understand the capabilities of the service without access to source code, documentation, or through network traffic inspection. http://swagger.io/specification/

Point Clouds	The emergence of LIDAR technologies for data acquisition has resulted in the development software solutions and formats for storing and exchanging LIDAR data. There is a need to standardise these to improve interoperability. For example, the use of Point Clouds is common approach for handling LIDAR. However Competing standards already exist.	Formats such as "LAS" have already been adopted by the OGC and this along with other formats will need to be considered by DGIWG. Point cloud dissemination is not directly handled by well-known OGC web services standards, (or their DGIWG profiles). Strategies for enabling this will also need to be considered. Further to this Point Clouds will also require agreed Metadata descriptions if they are to be exchanged and constantly understood. A questionnaire has been published on the DGIWG portal in order to collect use cases and standardization needs for the defence community: http://portal.dgiwg.org/files/?artifact_id=72195	This is a mature trend and it is ready for adoption by the defence community.	Medium Term 3-5 years	DGIWG 907 *"Imagery and Gridded Data Roadmap"* [60]
Feature level Metadata	Feature-level metadata (FLM) is used to store metadata about individual features. It enables users to better understand how data changes over time or to enable data-centric security[37] where protection is applied to the data itself.	Present approaches to handling record-level metadata are often too rigid for anything but the most basic of data discovery, management, and security. But analysing data is becoming an increasingly important aspect of military decision-making. Understanding subtle, fine-grained changes in data is very important. Feature-level metadata provides the specific information needed to understand these data changes at the (fine-grained) feature level, enabling secure and traceable management of information at that level. This will potentially affect all of the functional layers within the DSM.	This is a mature trend and it is ready for adoption by the defence community.	Medium Term 3-5 years	DGIWG 906 "Metadata Roadmap" [61]
Other Metadata Encoding Formats	The majority of Geospatial metadata is as a rule encoded using XML. However, XML can be large and verbose making which can make it slow to transfer and read by applications. Outside of the geo domain new lighter and simpler formats are being utilized. For example, JSON or Semantic Web technologies like DCAT[38], RDF[39], Triple stores[40], etc, could also be considered for metadata encoding	New encoding formats are less verbose and faster to read than traditional XML. It is these and other characteristics that have enabled new encoding formats such as JSON to be widely embraced by new technology. If the defence geospatial community is to leverage these benefits it will need to standardise their use and understand how they work with the existing suite of standards supported by the DGRA	This is a mature trend and it is ready for adoption by the defence community.	Medium Term 3-5 years	DGIWG 906

[37] **Data-centric security** is an approach to security that emphasizes the dependability of the data itself rather than the security of networks, servers, or applications. [63]

[38] **Data Catalog Vocabulary (DCAT)**: is an RDF vocabulary designed to facilitate interoperability between data catalogs published on the Web. http://www.w3.org/TR/vocab-dcat-2/

[39] **Resource Description Framework (RDF):** is a standard model for data interchange on the Web. http://www.w3.org/RDF/

[40] **A triple store** or RDF store is a purpose-built database for the storage and retrieval of triples through semantic queries. http://www.wikiwand.com/en/Triplestore

Linked Data	A key identified emerging technology is that of Linked Data. This involves the publishing of structured data that can be connected and linked together by machines. Instead of having all data stored locally in one dataset, there is significant potential in linking to the source that initially produced the data, and to those who will keep the data up-to-date.	It is not envisaged that DGIF would be evolved into a model to support a Linked Data construct, however, DGIF-compliant data may need to be able to integrate/link into such a construct. Research and an understanding of semantic technology and Linked Data standards such as Resource Description Framework (RDF), Web Ontology Language (OWL[41]), Friend of a Friend ontology (FOAF[42]) and SPARQL[43] Protocol and RDF Query Language (SPARQL) would be required to achieve this. The JSON-LD[44] and JSON-FG[45] candidate standards may identify further development trajectories that would affect how this technology impacts a Defence Geospatial Reference Architecture.	This is an evolving trend with element ready for adoption and other elements not yet ready for stabilization.	Medium-Term 3-5 Years	DGIWG 910

[41] **Web Ontology Language (OWL):** is a Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things. http://www.w3.org/OWL/

[42] **Friend Of A Friend (FOAF):** is a machine-readable ontology describing persons, their activities and their relations to other people and objects.

[43] **SPARQL:** SPARQL is an RDF query language and protocol produced by the W3C RDF Data Access Working Group (DAWG). It was released as a W3C Recommendation in January of 2008

[44] **JSON-LD**: is a lightweight Linked Data format. http://json-ld.org/

[45] **JSON-FG:** is an OGC Features and Geometries JSON standard, being developed, that build on GeoJSON overcome some of its limitations

9 The DGIWG Geospatial Standards Baseline (DGSB)

The DGIWG Geospatial Standards Baseline (DGSB) will represent DGIWG's perspective on which standards can be used to achieve interoperability across the military geospatial domain[46]. The DGSB describes over 200 standards that support a broad spectrum of use cases across the geospatial domain. These range from fairly general use cases involving the dissemination of geospatial data and services (including the standards referenced in the DGRA), to very specific use cases such as the creation of Joint Operation Graphics (JOGs) to support navigation during joint operations. In contrast, the DGRA focuses on a subset of the DGSB standards and provides additional guidance on their implementation, as well as the use of industry best practises required to enable the interoperable use of geospatial data from collection to exploitation within a military geospatial enterprise. The conceptual relationship between the DGRA and DGSB is illustrated in Figure 11.

Users with specific standardisation requirements beyond those outlined in the DGRA should look to the DGSB for guidance on which standards should be used to support their specific use case. For example the DGSB states that the maritime community should utilise the International Hydrographic offices' (IHOs) S-100[47] *"Universal Hydrographic Data Model"* [62] to structure their data and define data products. Although the DGRA does not provide guidance on this standard, it can be used to provide additional information to inform the community about the appropriate best practice and relevant standards required to improve interoperability data and capability throughout the military enterprise.

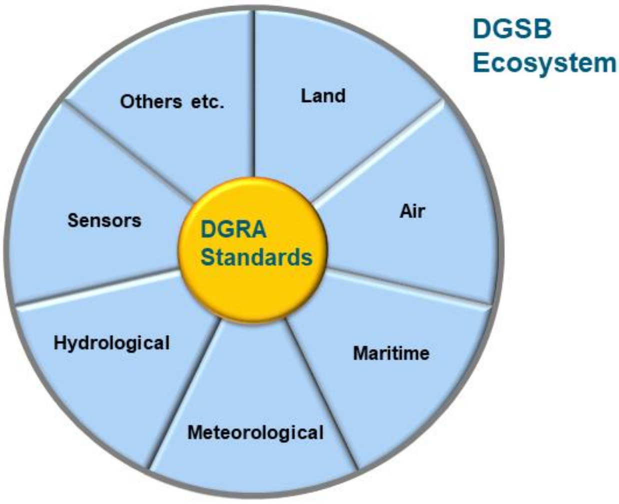

Figure 11: Conceptual view of how the DGRA standards relate to the wider geospatial domain standards described in the DGSB

[46] **Note**: DGIWG is preparing and issuing the DGSB for use by participating nations. It is intended to serve as a technical reference to guide and enable the interoperability of geospatial information and services amongst the respective defence organisations of participating nations. When complete, will be made available to the general public via the DGIWG website. More information about the DGSB is available at https://dgiwg.org/resources/dgsb/

[47] **100 Universal Hydrographic Data Model:** The IHO has developed the S-100 Universal Hydrographic Data Model to cater for future demands for digital products and services. The IHO Geospatial Information Registry contains several Registers containing managed lists of concepts, features attributes metadata, and other resources used to develop product specifications.

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11 Abbreviations and Acronyms

Acronym	Definition
Alt PNR	Alternate Principal National Representative
API	Application Programming Interface
BAG	Bathymetric Attributed Grid
BIIF	Basic Image Interchange Format
CIM	Cartographic Information Model
CMYK	Cyan, Magenta, Yellow, and Key (black)
CRS	Coordinate Reference System
CSW	Catalogue Service for the Web
DCAT	Data Catalog Vocabulary
DCE	DGIF Collaborative Environment
DCM	Defence City Map
DEM	Digital Elevation Model
DGED	Defence Gridded Elevation Data
DGIF	Defence Gospatial Information Framework
DGIM	DGIWG Geospatial Information Model
DGIWG	Defence Geospatial Information Working Group
DGRA	DGIWG Geospatial Reference Architecture
DGSB	DGIWG Geospatial Standards Baseline
DMF	DGIWG Metadata Foundation
DOP	Defence Orthoimagery Product
DPS	Data Product Specification
DRP	Defence Raster Product
DSM	DGRA Standards Model
DTOX	Defence Topographic Exchange Model
EDR	Environmental Data Retrieval
EMF	Enhanced MetaFile
ESM	Elevation Surface Model
ESRC	Economic and Social Research Council
FLM	Feature Level Metadata
FMN	Future Mission Network
FOAF	Friend Of A Friend
FTP	File Transfer Protocol
GDAL	Geospatial Data Abstraction Library
GEOINT	GEOspatial INTelligence
GIF	Graphics Interchange Format
GML	Geosgraphy Mark-up Language
GPKG	GeoPacKaGe
GRIB	GRIdded Binary or General Regularly-distributed Information in Binary form
HDF	Hierarchical Data Format
HEX	Hexadecimal
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGD	Imagery and Gridded

IHO	International Hydrographic Office
IMINT	IMagery INTelligence
IPHG	International Program for Human Geography
IPI	Image Processing and Interchange
ISO	International Organization for Standards
JOG	Joint Operations Graphic
JPEG	Joint Photographic Experts Group
JSON	JavaScript Object Notation
METOC	Meteorological and Oceanographic
MGCP	Multinational Geospatial Co-Production Program
MUVD	MGCP Urban Vector Data
NetCDF	Network Common Data Form
NATO	North Atlantic Treaty Organisation
NIST	National Institute of Standards and Technology
NITF	National Imagery Transmission Format
NSG	National System of Geospatial Intelligence (USA)
NSIF	NATO Secondary Imagery Format
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
PNG	Portable Network Graphic
PNR	Principal National Representative
PoW	Program of Work
RDF	Resource Description Framework
RGB	Red Green Blue
SDI	Spatial Data Infrastructure
SLD	Styled Layer Descriptor
SOA	Service Orientated Architecture
STANAG	NATO STANdardisation AGreement
SVG	Scalable Vector Graphics
SWE	Sensor Web Enablement
TIFF	Tag Image File Format
TIN	Triangulated Irregular Network
UML	Unified Modelling Language
URL	Uniform Resource Locator
VMST	Vector Models and Schema Team
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Map Tile Service
WPS	Web Processing Service
XML	eXtensible Mark-up Language
XSD	XML Schema Definition