

Rapid Data Generation for Modeling and Simulation

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ABSTRACT

Preparing data for use in models and simulations is a process that often consumes a significant amount of resources and has significant schedule impacts during the preparation for events enabled by modeling and simulation (M&S). The processes for data preparation vary widely across organizations and activities, with many individual simulations and federations creating unique processes and semi-automated solutions for database generation. For M&S application, data is typically drawn from multiple sources and integrated to form a common scenario-based data initialization baseline. Database generation is required for many types of data including natural and manmade environments, unit and electronic order of battle, logistics, and command and control information. Effective reuse of data across M&S environments and organizations is severely lacking.

The US Department of Defense (DoD) M&S Steering Committee has established a Rapid Data Generation (RDG) project to reduce the time required to discover, integrate, and correlate M&S data and promote data sharing through common metadata and services. The RDG project is leveraging multiple past and current efforts that address data generation. The RDG project is in its first year of implementation, focusing on establishing a common architecture and demonstrating data reuse across multiple communities. Eventually, RDG will span the full breadth of communities employing M&S including training, planning, testing, analysis, experimentation, intelligence, and acquisition. This paper will describe the background that led to the establishment of the RDG project, the elements of the RDG project, and the concept of operations for an M&S Common Data Production Environment. We will discuss the service oriented architecture-based approach to data discovery and access and the use of common metadata, which will result in a common set of data services to support the M&S user community and the reuse of data across M&S environments.

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INTRODUCTION

In the US Department of Defense (DoD) modeling and simulation (M&S) enterprise, challenges to data preparation and the effective reuse of data have existed for many years. The communities enabled by M&S do not have the ability to obtain easy access to authoritative data by means of a common capability that supports the entire DoD. Processes and tools tend to be specific to individual communities (e.g., training, analysis, experimentation, etc.), although there would be significant benefit from sharing data across these communities. Discovery and use of data sources is made difficult by the fact that data producers do not regularly register and update discovery metadata through common methods such as card catalog-level descriptions of their data holdings. Metadata catalogs typically have numerous obsolete entries, and metadata on many sources is missing or nonexistent. In addition, access to structural (format) metadata, critical for making decisions to use a particular source and to integrate data from multiple sources, often is not readily available. Data sources use a variety of formats, data element definitions, and data models. Complete and current discovery and structural metadata are essential for users to find and access what they need, and to integrate data from multiple sources.

Work performed to date in the Rapid Data Generation (RDG) project illustrates the impact of these problems. A data source usage questionnaire (ORNL, 2010) sent to M&S data subject matter experts produced a surprising result—that users very often obtain data from sources such as models that consolidate multiple sources rather than using the original sources

themselves, even when these models are not intended to be used as data sources. This result indicates that users will abandon the search for the best data to meet their needs for the convenience of easy access, providing evidence that discovery and data retrieval from authoritative data sources is currently more difficult than it should be. Another observation from ongoing RDG work is that often no automated authoritative source for particular M&S data elements can be found, requiring manual data entry and the use of open sources, expert opinion, or estimates to fill in missing values. Overall, solving these longstanding problems is becoming more important as the various communities expand the use and integration of models and simulations.

BACKGROUND

Current State of M&S Data Generation

M&S subject matter experts (developers, technicians, and operators) currently spend considerable time and resources on the mundane tasks of obtaining, correcting, correlating, and maintaining reference and scenario-specific data. Individual simulations are typically developed with the capabilities to manually build scenario-specific data by allowing a technician to enter data into the simulation graphical user interface (GUI). Some technicians will “cut-and-paste” data into the GUI from external data sources. Some simulation software developers have added the capability to “ingest” data from an external data file in particular formats (spreadsheet, comma delimited, XML, etc.), from which the technician can manually edit the data for a particular scenario before the start of a simulation

or federation execution. Many individual simulations today continue to generate and initialize through a manual or semi-manual process.

As individual simulations were “federated” on networks to form a federation of simulations, a new requirement emerged to synchronize the scenario data among the “federates”. Ad-hoc local M&S federation site procedures and semi-manual processes and tools were developed to build and synchronize the scenario data that was common to all of the federates and to “initialize” the federation before the start of federation execution.

Today, many of the communities enabled by M&S are investing in semi-automated federation-, community- and DoD component-level M&S scenario data generation and data management environments. Each is designed to meet specific community or DoD component M&S scenario data requirements in support of multiple M&S live-virtual-constructive federates and, in some cases, federations. Some of these M&S environment/systems can access data from multiple data sources and integrate, fuse, and correlate data to produce a standard M&S XML data interchange format (e.g., Order of Battle Service [OBS], Military Scenario Definition Language [MSDL], C2 Core, Synthetic Environment Data Representation and Interchange Specification [SEDRIS], etc.) that can be ingested by multiple simulations and federations. However, this process is still very time-intensive, relying on subject matter experts in the loop to establish and maintain data repositories and scenario-specific datasets.

In the development of these M&S environments, the various communities have realized that, although there are some community-unique data requirements, many of their M&S data requirements are common or “overlap”. However, despite the commonality of M&S data requirements, their scenario generation requirements, discovery and structural metadata, data interchange formats, and “run-time” data file formats can be quite different. Currently, each of these federation, community, or DoD component-level M&S scenario data generation/data management environments accesses many of the same data sources and performs the same or similar data integration, fusion, and correlation processes.

DoD Net-Centric Data and Services Strategies

The DoD Chief Information Officer (CIO) has established clear direction on how data should be shared across the DoD in the form of the Net-Centric Data Strategy (NCDS) (DoD CIO, 2003) and the Net-Centric Services Strategy (NCSS) (DoD CIO, 2007).

In combination, these strategies define a shift from application and system-centric data sharing to a net-centric model of sharing data, using service oriented architectures (SOAs).

The NCDS provides a key enabler of the DoD’s Transformation by establishing the foundation for managing the DoD’s data in a net-centric environment. The key attributes of the NCDS include: 1) ensuring that data are visible, available, and usable when needed and where needed to accelerate decision-making; 2) “tagging” of all data (intelligence, non-intelligence, raw, and processed) with metadata to enable discovery of data by users; 3) posting of all data to shared spaces to provide access to all users except when limited by security, policy, or regulations; and 4) advancing the DoD from defining interoperability through point-to-point interfaces to enabling the “many-to-many” exchanges typical of a net-centric data environment.

The NCSS describes the DoD’s vision for establishing a Net-Centric Environment (NCE) that increasingly leverages shared services and SOA. The NCSS expands upon the NCDS by connecting services to the Data Strategy goals. The goals of the NCSS are to: 1) provide services by making information and functional capabilities available as appropriately secure services on the network; 2) use existing services to satisfy mission needs before creating duplicative capabilities; 3) establish the policies and processes for a single set of common standards, rules, and shared secure infrastructure and services throughout the DoD Enterprise to ensure interoperability; and, 4) monitor and manage services to ensure situational awareness of the NCE.

DoD M&S Enterprise Data Strategy

A DoD M&S Enterprise Data Strategy (McGroder, 2011) is being prepared to address the DoD-wide treatment of M&S data to provide efficiencies for M&S through data production, discovery, and sharing across the enterprise, and to foster the important strategic M&S objectives of interoperability and reuse. The strategy is based upon the DoD NCDS, DoD Directive 8320.02, “Data Sharing in a Net-Centric Department of Defense” (CIO, 2004); and DoD issuance 8320.02-G, “Guidance for Implementing Net-Centric Data Sharing” (CIO 2006).

The strategy document will advance the M&S Enterprise towards a more efficient use of M&S data. Efficiencies should be achieved through better and faster M&S data production, easier discovery of M&S data assets, and increased sharing of M&S data across the enterprise to fulfill the important strategic

objectives of interoperability and reuse. Examples of the strategic goals identified include: 1) reducing similar or duplicative M&S data sets and reducing the time and cost currently required to generate them; and 2) making existing M&S data discoverable to a broad range of M&S practitioners via standardized metadata tagging and development of advanced metadata discovery tools and web services.

Another important element of the M&S Enterprise Data Strategy is to maximize the use of the M&S Community of Interest (COI) to make M&S data and data-related tools and services viable and visible to M&S communities and components; align M&S with the DoD NCDS; and provide a collaborative forum to influence, advise, and educate the global community with regard to M&S Enterprise Data issues. The M&S COI provides technical guidance to senior leaders throughout the DoD Enterprise, and facilitates cross-domain collaboration with other active and effective COIs related to M&S, including the Command and Control (C2) Interoperability, Global Force Management, Geospatial Intelligence (GEOINT) Standards, and Logistics COIs.

As we will see in the remainder of this paper, the RDG project represents an implementation of the Net-Centric Data and Services Strategies for the M&S Enterprise, and is the DoD M&S Steering Committee's flagship project to implement the DoD M&S Enterprise Data Strategy.

RAPID DATA GENERATION PROJECT

Project Objectives

The overarching objective of the RDG project is to reduce the time required to integrate and initiate data, eliminate or reduce duplicative data efforts, and promote data commonality across the communities enabled by M&S. RDG will accomplish this by fostering the reuse of data, enabling data access, and providing access to services to prepare data for M&S federates and federations using net-centric data and services concepts.

Elements of the RDG Solution

While technology has a place in solving the challenges that RDG is addressing, a successful solution must have additional components. The technical solutions portion of RDG, the Common Data Production Environment (CDPE), is described in detail later in this paper. In addition to the CDPE, the RDG project has developed a five-year Implementation Plan (described in the next section) and a Business Plan. This Business

Plan defines the options for life-cycle support of RDG enduring capabilities (including hardware, software, and infrastructure components of RDG), offers an initial set of criteria to evaluate the options, and provides a recommended approach for life-cycle support based on those criteria. The business plan addresses fiscal issues including who bears the cost for integrating existing systems into the RDG solution and the cost for maintaining metadata. It also identifies the other factors necessary to make an RDG solution viable, such as the need for outreach to the community, needed policy, and incentives. Without an effective business plan, the RDG project runs the risk of providing a non-sustainable solution.

The RDG solution relies on integrating existing data-preparation activities. To support this integration, the RDG project will follow a rigorous systems engineering approach that will produce the following key documentation:

- RDG M&S CDEP Concept of Operations (CONOPS) Document that describes the system characteristics for a proposed system from the user's viewpoint. Consistent with the Institute of Electrical and Electronics Engineers guide for CONOPS (IEEE, 1998), the RDG CONOPS document is used to communicate overall quantitative and qualitative system characteristics to the user, developer, and other stakeholders.
- RDG M&S CDPE Requirements Document that identifies the common data and tools across the communities and services to provide focus for development of enterprise capability.
- RDG M&S CDPE Standards Document that specifies which standards will be used to enable secure DoD net-centric interfaces, discovery, sharing, and reuse.
- RDG M&S CDPE Data Integration Framework Design Document that supports cross-community data discovery, sharing, re-use, and exchange.
- RDG M&S CDPE Discovery Metadata Specification that defines the metadata that enables data asset discovery. This will be an extension of the M&S COI Discovery Metadata Specification.
- RDG CDPE M&S Data and Tool Implementation Architecture Design Document. This document will articulate the CDPE design to define the SOA infrastructure, hardware, software, and business rules necessary to host the CDPE Data Services.

The M&S COI is another key component in the RDG solution. The M&S COI has established a Data

Management Working Group, which is being used to vet the systems engineering artifacts described above with key stakeholders in the DoD M&S Enterprise.

RDG Implementation Plan

The RDG Team produced an RDG Roadmap document and detailed plan of action and milestones. The purpose of this RDG Roadmap document is to describe an iterative approach toward realizing the goals and objectives of the RDG project. Rather than attempting to solve all data problems across the M&S Enterprise simultaneously, the RDG Roadmap takes an incremental approach. As shown in Figure 1, a series of overlapping two-year development cycles will incrementally address order of battle (forces and units data), geospatial data, logistics data, and command and control information. Each cycle will follow the systems engineering process defined earlier, and will produce annexes to the documents identified that address the specifics related to a specific type of data.

Relationship to Prior Efforts

Rapid data generation is not a new term or concept. The Joint Training Functional Capabilities Board, Joint Capabilities Board, and Joint Requirements Oversight Council validated the requirement for RDG capability and documented it in JROCM 239-05, which approved the Initial Capabilities Document (ICD) for the Joint Rapid Distributed Database Development Capability (JRD3C—since renamed the Joint Rapid Scenario Generation (JRSG) Capability) (JROC, 2005). The RDG project is built upon the accomplishments of

these and other, similar initiatives, including but not limited to Joint Data Alternative (JDA) (MITRE, 2007), JRSG pilots developed by US Joint Forces Command, a series of pilot tasks executed within RDG in FY09 and FY10, and other DoD M&S Steering-Committee-sponsored projects.

While prior efforts have not delivered the desired RDG capabilities, the requirements documented in JROCM 239-05 and other efforts have clarified the goals for this activity. In addition to benefiting from the lessons learned from the RDG pilot projects and other previous efforts, the RDG project benefits from recent advancements in DoD information technology policies.

The RDG strategy to addressing M&S data challenges is different from prior efforts in that it establishes a community-driven approach for an enduring enterprise capability that starts with a business plan; implements the DoD Net-Centric Data and Services Strategies for the M&S COI; facilitates reinforcement of tool, data, and services reuse; promotes interoperability between M&S and operational systems; lays out a five-year incremental capability-development approach; and most importantly, engages senior leaders within the DoD M&S Steering Committee.

RDG Use of Operational Data and Data Standards

Although there are M&S-unique categories of data, most of the data required by federation, community, or DoD component-level M&S scenario data generation environments is operational data. The DoD operational communities are also implementing the Net-Centric Data and Services Strategies and registering data

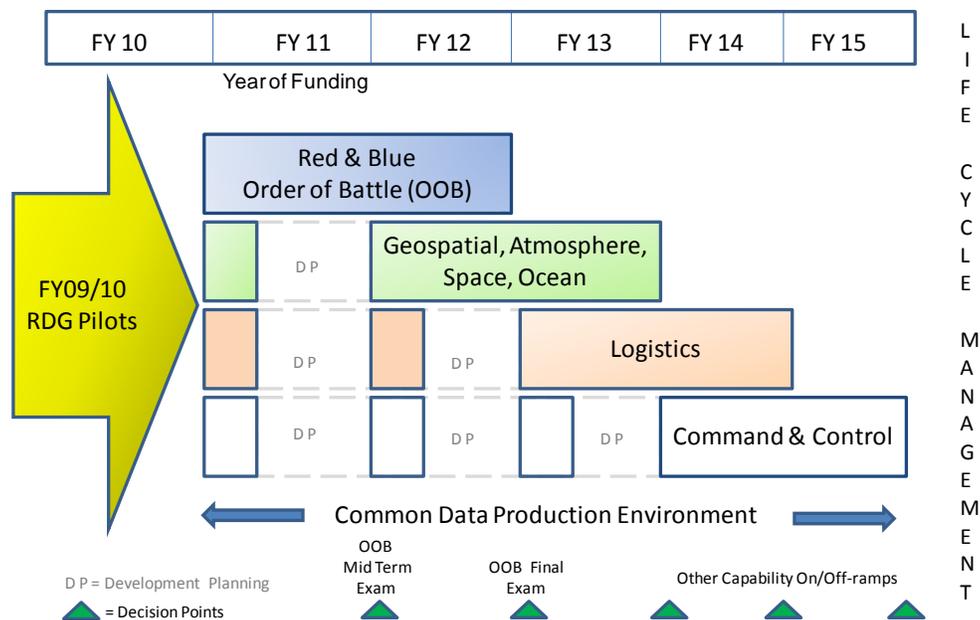


Figure 1. RDG Implementation Plan

services to provide data to anticipated and unanticipated users (with the proper permissions). These operational data sources are usually considered the “authoritative data sources,” although data often must be augmented to be suitable for M&S use. For many simulation federations, data must be synchronized between the simulation federates and the operational Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems that interface with the M&S federation. For these reasons, RDG will interface with operational data repositories and operational data services to include this data in the production process (obtain source data, integrate/correlate data from multiple sources, and translate to standard/native M&S formats).

The development of RDG will reuse and extend as necessary core operational discovery and structural metadata specifications and standard information exchange data models such as the DoD Discovery Metadata Specification (CIO, 2011), Universal Core, and C2 Core. The RDG implementation will use web service interfaces to access operational data repositories and web service applications.

The RDG team will interface through the M&S COI to coordinate with operational programs and COIs to ensure that RDG web service interface specifications, design patterns, information exchange data models, schemas, etc., are common, compatible, and in compliance with DoD directives, instructions, and

guidelines.

RDG COMMON DATA PRODUCTION ENVIRONMENT (CDPE)

Capabilities of the Common Data Production Environment

The RDG overarching objective to reduce the time required to integrate and initiate data, eliminate or reduce duplicative data efforts, and promote data commonality across the communities enabled by M&S is supported by the development of an M&S CDPE. The M&S CDPE will

- provide users a capability to discover data to meet M&S requirements—both existing datasets built by M&S data integrators and data from Authoritative Data Sources;
- provide users a capability to view metadata and instance data with data-specific viewers;
- provide users a capability to retrieve data in intermediate M&S data exchange formats;
- provide users a capability to manipulate/fuse/correlate data; and
- provide access to these capabilities through a web-based CDPE portal and/or web service (SOA) interfaces (to allow integration and use of CDPE capabilities in user-developed applications).

Elements of the CDPE

Figure 2 depicts the high-level design for the RDG

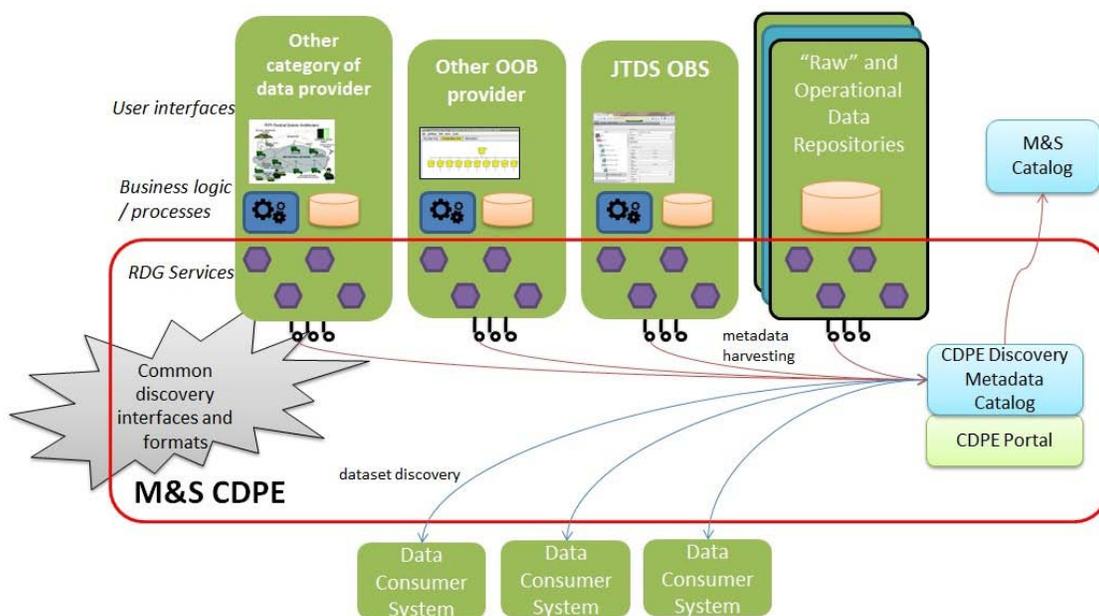


Figure 2. RDG M&S CDPE Data Discovery

M&S CDPE data discovery capabilities. Existing M&S data integration programs will implement the CDPE architecture, becoming CDPE data providers. As shown in Figure 2, the Joint Training Data Services (JTDS) Order of Battle Service (OBS) capability has been selected as the initial order of battle data provider. Discussions are ongoing with other data providers for potential integration into the CDPE. In the second RDG focus area (geospatial, atmosphere, and ocean data), the analysis has begun on how to integrate the following geospatial capabilities via RDG to foster data sharing across these efforts and improve the capabilities for their data customers to find and obtain data:

- US Army Synthetic Environment Core (SE Core)
- Naval Air Systems Command (NAVAIR) Portable Source Initiative (NPSI)
- USAF Simulator Database Facility (SDBF)
- Air and Space Natural Environment (ASNE) M&S Executive Agent (MSEA) Environmental Data Cube Support System (EDCSS)
- US Special Operations Command (USSOCOM) Special Operations Forces Planning, Rehearsal, and Execution Preparation (SOFPREP)

Each RDG provider will produce and maintain standard discovery metacards for individual datasets based on the M&S COI Discovery Metadata Specification (M&S CO, 2010), with additional data-type-specific extensions. Automated tools will add metacards when new datasets are available or update

metacards when data has changed within a dataset. A CDPE discovery metadata catalog will “harvest” metacards from each CDPE data provider repository. The resulting “cached” version of discovery metadata will be passed to the DoD M&S Catalog to enable higher-level discovery of CDPE data.

CDPE providers will implement discovery mechanisms as web services, which end users can access via their own applications. In addition, the CDPE will provide a web-based portal to access these data discovery services. The CDPE Portal will include specialized tools to query and visualize discovery metadata based on the type of data (e.g., displaying geospatial data holdings on a map). The CDPE portal will also allow the user to gain the proper permissions to access the appropriate repositories and select and download individual datasets in available standard M&S data interchange formats. These “reused” datasets can then be edited, tailored, and translated in the community or DoD-component-level M&S scenario data generation environment/system to meet the specific needs and formats of the community’s M&S live-virtual-constructive federations.

Figure 3 depicts the high-level design concept for the RDG M&S CDPE data retrieval. After the discovery metadata is queried, reviewed, and assessed, the user of the CDPE Portal or any application that is developed to access the CDPE web services interface will be able to select a particular dataset, and download the file in a

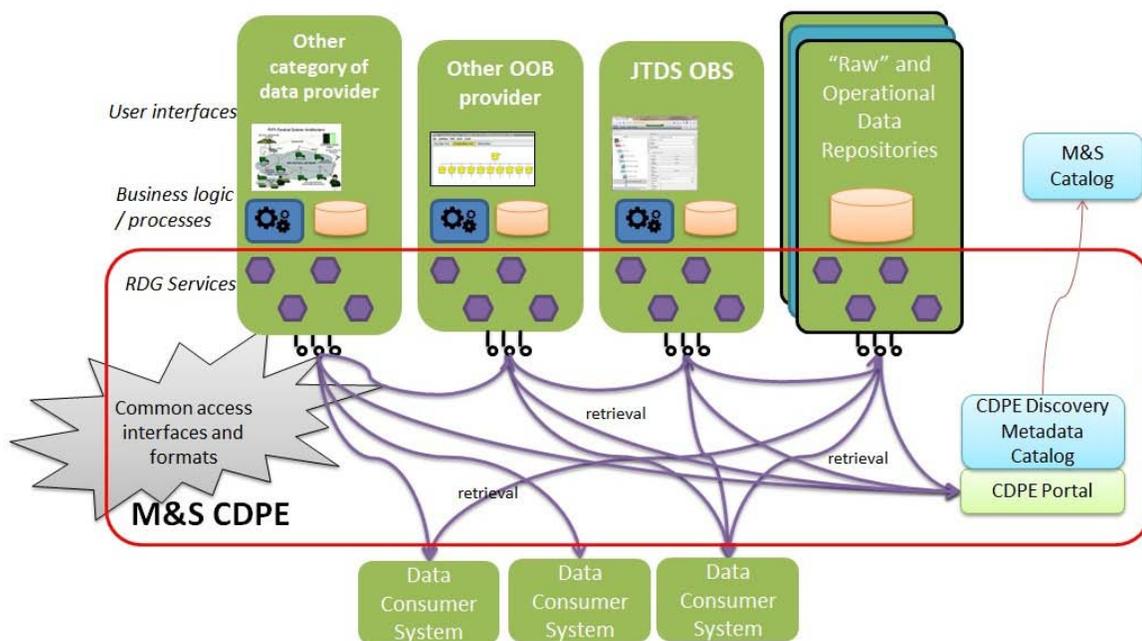


Figure 3. RDG M&S CDPE Data Access

selected standard data interchange format. This high-level concept of data retrieval may vary for different categories of data. For example, geospatial terrain data files may be too large to download over the network and the CDPE data web service would require more of an interaction to provide the data by CD/DVD or hard drive.

The initial CDPE data web service capabilities will be limited to data discovery and retrieval; however, other more complex interactive CDPE data web service applications will be developed to allow the user to request specific data integration, fusion, correlation, translations, or other data manipulation functions. The resulting output file may be immediately available for download, or the user may be notified when a job order is complete for downloading. Other CDPE data web service applications may be developed to allow the user to visualize and/or edit the dataset before downloading, or allow the user to re-post the data to a CDPE data repository—along with the appropriate metadata—to be discovered and reused by others. A CDPE repository may also be available for community systems that lack persistent data storage. The requirements for such CDPE data web service applications will be addressed during the RDG M&S CDPE requirements identification and analysis systems engineering process. Tools may already be available within community or DoD component-level scenario data generation environments that can be web-enabled and reused across the M&S enterprise.

Integrating Systems into the CDPE

Figure 4 depicts a view of a typical RDG M&S CDPE data provider. A program that has invested in processes and tools to establish and maintain a repository of a category of data will be selected to “host” RDG M&S CDPE web services. The program is likely to include processes and tools to integrate, fuse, and correlate data from multiple data sources.

RDG will provide resources and technical expertise to assist the host program to expose their data to other communities through the establishment of standard discovery metadata. If necessary, RDG will also assist the program to develop standard DoD web service interfaces with authoritative data sources; standardize discovery/structural metadata; and build more automated tools to integrate, fuse, and correlate data that is common to multiple M&S federations in multiple communities. CDPE web services will provide enhanced and correlated data to a consumer that may be an M&S system “end-user” or another CDPE data provider. By using these web services, and “chaining” them together where needed, data production processes that currently require manual intervention to transfer and manipulate data can be automated. The existing program will benefit from the net-centric improvements to obtain and enhance data to meet its normal customer data requirements, and the other communities will benefit from the reuse of the enhanced data.

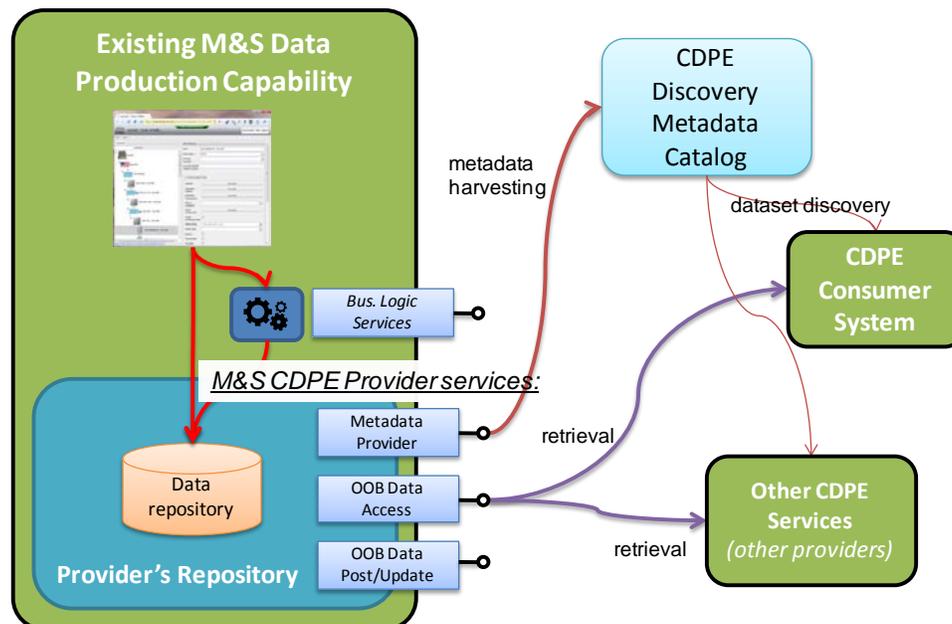


Figure 4. RDG M&S CDPE Data Provider

CONCLUSION

The RDG project holds the promise of bringing substantial cost and time savings across the DoD M&S Enterprise by providing a net-centric solution to data sharing and data integration capabilities across the communities and Services. Long-term success will depend on the willingness and ability of current data providers/integrators to implement the NCDS through RDG and share their data across the M&S enterprise as well as the willingness of M&S users to use the RDG data and services.

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REFERENCES

- Department of Defense Chief Information Officer (DoD CIO), "DoD Net-Centric Data Strategy," May 9, 2003
- DoD CIO, "DoD Net-Centric Services Strategy: Strategy for a Net-Centric Service Oriented DoD Enterprise," May 4, 2007.
- DoD CIO, "DoD Directive 8320.02, Data Sharing in a Net-Centric Department of Defense," December 2, 2004.
- DoD CIO, "DoD 8320.02-G, Guidance for Implementing Net-Centric Data Sharing," April 12, 2006.
- DoD CIO, "Department of Defense Discovery Metadata Specification (DDMS), Version 3.0.1," March 2, 2011.
- DoD Modeling and Simulation Coordination Office (M&S CO), "Modeling and Simulation (M&S) Community of Interest (COI) Discovery Metadata Specification (MSC-DMS), Version 1.3.1," March 22, 2010.
- Institute of Electrical and Electronics Engineers (IEEE), "IEEE Guide for Information Technology – System Definition – Concept of Operations Document," December 22, 1998.
- Joint Requirements Oversight Council (JROC), "Joint Rapid Distributed Database Development Capability (JRD3C), Initial Capabilities Document (ICD)," May 9, 2005.
- McGroder, D., Lashlee, J., "An Emerging DoD M&S Enterprise Data Strategy," Proceedings of the Spring 2011 Simulation Interoperability Workshop, April 2011.
- MITRE, "Joint Data Alternatives Study, Final Project Report, MITRE Technical Report MTR070236," July 2007.
- Oak Ridge National Laboratory National (ORNL) Transportation Research Center, "Analysis of Adaptive Planning (AP) Rapid Data Generation (RDG) Questionnaire Results," February 5, 2010.