# Grid Application Areas within DoD

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## 1 Introduction

We divide DoD applications into broad categories and describe the possible relevance of Grid technologies. We build on an earlier report [DoDescience] produced with DoD HPCMP support. The current state of the Grid is discussed in [Foster99A] [GGF-A] [Berman03A] and [GapAnalysis]. There are discussions of a service-oriented architecture for DoD applications [Lau04] [Birman05] and the major DoD Network centric computing and Global Information Grid activities. Currently a systematic examination of modern Grid technologies for DoD does not seem to be available. We note that the applications have many overlaps in possible relevant Grid technologies; this is to be expected as Grids and the Service architecture are meant to encourage re-use of services across both DoD domains and between DoD and non-DoD domains. One of our goals is to develop a more precise analysis of DoD requirements from a broad (unclassified) view so as to identify where DoD can take advantage of Grid and Web service activities.

## 2 Supercomputer Grids

### *2.1 Supercomputer Networks*

The NSF TeraGrid has an architecture similar to that of the HPCMP (DoD's High performance Computing and Modernization Program) with around 3-5 major facilities linked to several smaller sites (ETF or Extended Terascale Facility) by a high speed network [TeraGrid]. We see the analogs in NSF of MSRCs (Major Shared Resource Centers), distributed centers and the DREN (Defense Research and Engineering Network) within DoD. We note that the existing HPCMP Kerberos infrastructure and tools such as the Practical Supercomputing Toolkit [PST] already provide some of the computing grid core functionality of a TeraGrid style grid for the HPCMP production environment.

## *2.2 Code Coupling*

First we highlight the use of Grid technology to link applications together; this is code coupling whose importance is clear in CHSSI (Common High Performance Computing Software Support Initiative) portfolio projects (SOS, EBE, HIE, SPG, etc.). These will not always need Grid technology but we expect the most robust full featured application integration technologies to come from the Grid workflow field [workflow]. We can illustrate these possibilities with some of the computational technology areas (CTA) used in the HPCMP PET program; there are major large simulations in CFD (fluids), CSM (structures), CWO (weather and ocean), EQM (environment) and CCM (chemistry and materials). We get natural code coupling with multi-disciplinary simulations between CFD/CSM (numerous fluid/structure interactions), CWO/EQM (near shore ocean models), CSM/CCM (multi-scale fracture analysis, nano-materials), CCM/CFD (reactive combustor flow model). In this type of problem Grid technologies will also support rich data-sets, visualization and computational steering linked to the coupled applications. Portals use Grid technology to build problem solving environments providing users access to these capabilities. We expect Grid technology to be the preferred approach for building all Problem Solving Environments.

## *2.3 Seamless Access*

Seamless access to both computers and databases is a relatively simple but important application of Grid technology which involves use of standards for computing and data resources. This is not directly linking resources together but providing users a more uniform access and providing the first step towards more sophisticated Grids; resources with Web and Grid standard interfaces. This can be viewed as a special case of Portal technology described in section 2.

## *2.4 Computational Steering*

Computational Steering with users controlling simulations with remote portals is an area that has of course already been studied in depth outside the Grid arena. However Grid services (security, workflow, and notification) provide new approaches and indeed we expect visualization to be reworked to use Grid-based frameworks. The ARL ICE project features both visualization and code coupling and its innovative XML middleware would allow it to be straightforwardly reformulated as a set of Grid services [Clarke02A]. In the Grid approach pre and post processing of HPC jobs would be implemented as the linkage of services using workflow as described above for code coupling.

## 3 Portals

Essentially every DoD application needs user interfaces and these interfaces are typically both portals to a wide variety resources and offer some variant of a “problem solving environment” that involves customization of available capabilities and suites of tools that link capabilities together. Modern web service and Grid portals provide just such capabilities both as a component based user interface and as the workflow needed to link capabilities (services) together. Grid portals also provide user (client) profiles that allow a given electronic resource to be viewed from a mix of clients from hand-helds to desktops [Oh03a].

The Open Grid Computing Environment OGCE [OGCE] has demonstrated how collaborations can collect together Grid portlets (standard portal interfaces) aimed at the academic Grid community. A similar activity could be useful aimed at the special services needed by DoD [Gateway] [Thomas03A].

## 4 Distributed Modeling and Simulation

Here we discuss the use of distributed networks to support geographically distributed simulations and real-time instruments (vehicles) and HITL (Human-In-The-Loop). Key technologies include HLA (High Level Architecture) and RTI (Run Time Infrastructure) which have been developed by DMSO to support FMS simulations. This is supported by the Forces Modeling and Simulation (FMS) CTA within PET. HLA and RTI were very innovative distributed system ideas on their introduction some 5-10 years ago. However like Java CORBA and COM they probably need to be re-examined in light of the growing importance of Web services. In particular we see a new generation of distributed simulations that use web service technology instead of HLA and Web service messaging (SOAP) in place of RTI.

Extensions of this area include the integration of the distributed simulations with the information Grids described below. In fact all the categories can be federated using the Grid of Grids concept [GofG]. Relevant simulations can be event driven as in traditional HLA/RTI or involve components such as weather prediction that require parallel engines as discussed in Supercomputer Grids. The Virtual Proving Ground [VPG] would be a good candidate for Grid technologies and could use recent commercial initiatives such as that of the openGIS consortium which has issued request for technologies in the area of Web and Grid services for Geographic Information Systems [openGIS] [CrisisGrid].

The XMSF (Extensible Modeling and Simulation Framework) project [XMSF1] [XMSF2] [XMSF3] is building bridges between HLA/RTI and Web Service technology and there is related work from a groups in Europe [Wytzisk03] [Rycerz04] [Zajac04] and in Singapore [Xie04A] [Xie05A] [Xie05B] [Xie05C] [Zong04]. Although Web service wrappers for existing HLA systems are very important, it seems necessary to re-examine the whole distributed simulation framework.

## 5 Information, Knowledge, Collaboration and Real-time Grids

Here we discuss the class of Grids illustrated in Fig. 1 that emphasize the fusion and integration of data and provide decision support (command and control). These often involve real-time collaboration requirements.

From a HPCMP point of view, one could view the Online Knowledge Center OKC as a knowledge (high level information) Grid while FMS, IMT and SIP often require integration of real-time or archived data with simulations. In section 4.1, we give a commercial aircraft engine (Rolls Royce) example which uses Grids to link sensor nets to real-time system diagnostics to improve maintenance procedures; this appears generalizable to several IMT (HPCMP CTA for Integrated Modeling and Testing) applications. Generally data management, filtering, interoperability, fusion and

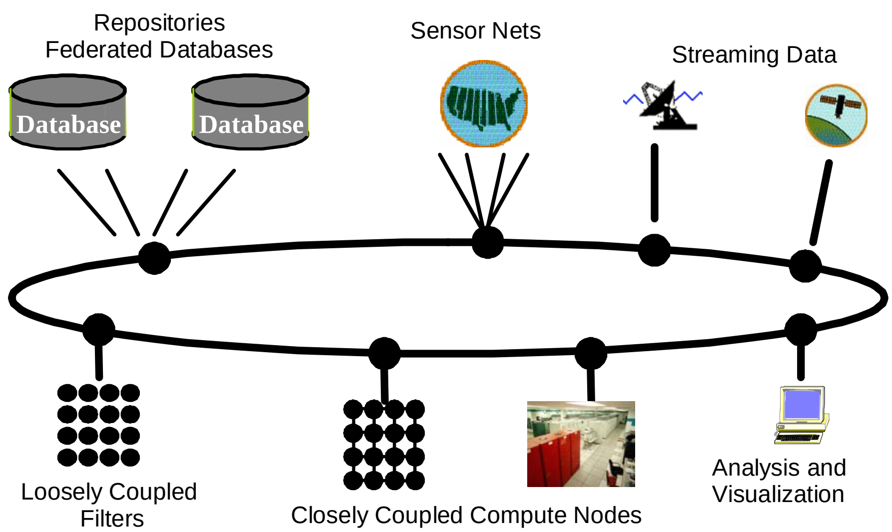


*Fig. 1: Information Grid with Sensors, Satellites, databases, high performance computers, clusters and filters (independent machines)*

provenance are possible intersections of DoD interests with Grids. Generic DoD areas amenable to Grid technology include Information Security, Systems of Systems, Information Superiority and Decision Dominance, Command and Control and Global Situational Awareness. The Coalition Agents Experiment [CoaxGrid] demonstrated real-time command systems built using peer-to-peer Grid infrastructure.

### *5.1 Sensor Nets*

Sensor Nets and their integration with large scale parallel simulation are a natural Grid application that already is in daily use (without perhaps the Grid vernacular) in the data assimilation approach to weather forecasting. Such integration of real-time data gathering and simulation is applicable to environmental science, solid earth [SERVOGrid] (shown in fig. 1) and structural problems where sensor nets can provide real time monitoring and control. There is a general expectation that sensor data will dramatically increase in volume. For instance NASA expects that weather data will grow from 400 megabytes to a petabyte of data gathered each day [ESS02A]. This "data deluge" could lead to new approaches to many fields with a growing importance of data assimilation methods applied to new areas.

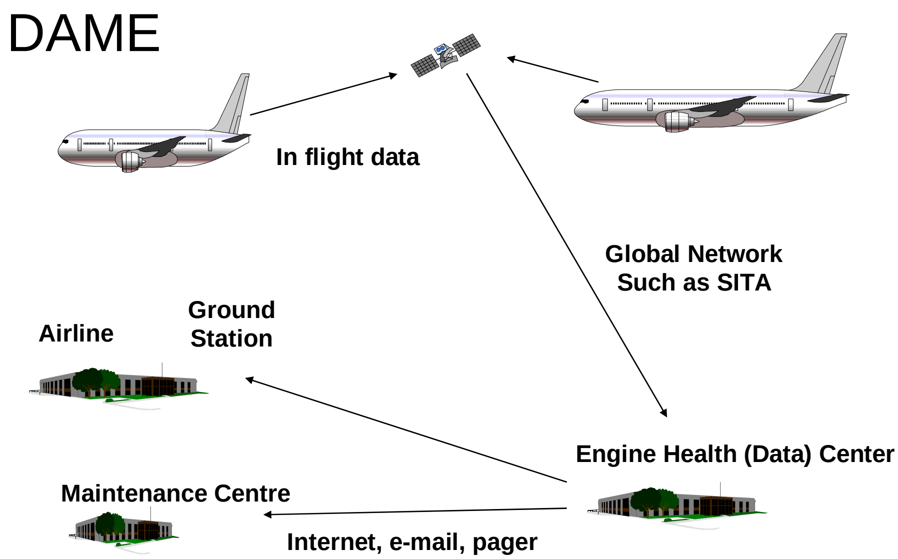


*Fig. 2: Distributed Aircraft Maintenance Environment*

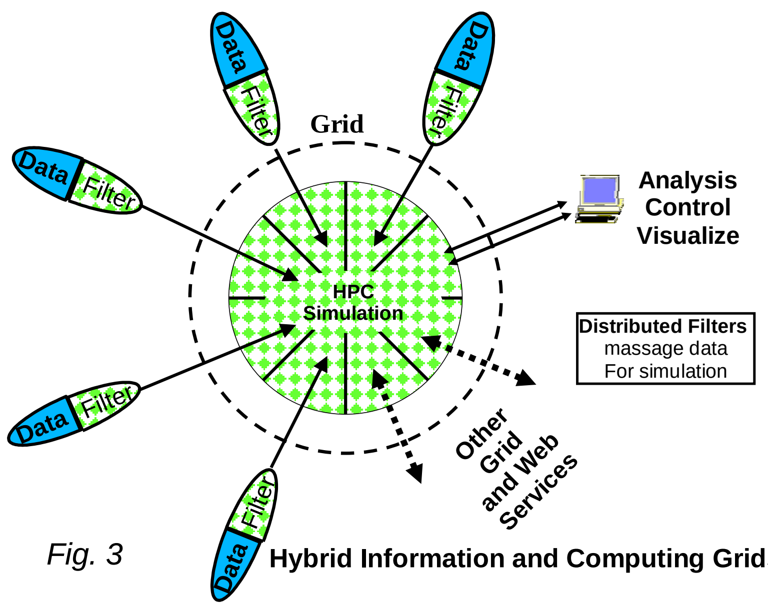


*Fig. 3*

An interesting commercial example of the integration of sensors is shown in Fig. 2 from a collaboration between Rolls-Royce and several UK companies and universities [DAME]. Real-time diagnostic data from aircraft engines (approximately a gigabyte per engine per transatlantic crossing) is fed into data centers. This is filtered through multiple data mining algorithms and compared with previous engine data. Anomalies are flagged and used to enhance the maintenance operations for the airlines using such engines. This uses directly the architecture of Fig. 1 and Fig. 3 with data mining being the central high performance algorithm. As noted before, such applications are intrinsically distributed and not sensitive to Grid latencies; data can certainly be pipelined as they flow from aircraft to satellites to ground station repositories and analysis stations.

This type of application can clearly be seen in DoD with instruments either gathering battlefield intelligence or simply monitoring the performance of a vehicle or warfighter.

## *5.2 Information Security*

Information Security is an urgent priority as we find continuing weaknesses in both the Internet and the core operating systems on which it is built. Systematic use of Grid security mechanisms combined with building robust resilient Grid and Web services appears to be part of any approach to information security. This allows us to bypass inevitable flaws in the core infrastructure by only allowing service interactions and engineering these in an Autonomic secure fashion.

## *5.3 Information Superiority and Decision Dominance*

Information Superiority and Decision Dominance are at the heart of new military thinking about the conduct of modern warfare. For example, Network-Centric Warfare [Netwarfare] notes that it derives its power from the effective linking or networking of the warfighting enterprise. Joint Vision 2020 [JV2020] emphasises the importance of collecting, processing and disseminating an uninterrupted flow of information while exploiting or denying an adversary’s ability to do the same. The UK has recently announced its Network Enabled Capability initiative with the aim of enhancing military capability through the better exploitation of information across the battlespace. As recent world events have shown, multi-national coalitions are playing an increasingly important role in military operations. Indeed, military coalitions are archetypal dynamic virtual organisations that have a limited lifetime, are formed from heterogeneous ‘come as you are’ elements at short notice, and need secure and partial sharing of information. A common requirement across these programs is the need to inter-operate and integrate heterogeneous distributed systems and to work with large volumes of information and high data rates. We described this earlier under the system of systems concept. In these respects, they could benefit substantially from Grid computing concepts. However, security, resilience, flexibility and cost effectiveness are key considerations for the deployment of military Grids. It is also likely that there will be the need for multiple Grids supporting different aspects of the military enterprise, e.g. ‘heavyweight’ Grids for imagery data and ‘lightweight’ ubiquitous Grids running on the PDAs of military commanders in a headquarters—these Grids will need to be interoperable. Currently, there are a number of US military programmes exploring Grid technologies in the context of Network-Centric Warfare, for example Joint Battlespace Infosphere [JBIGrid], Expeditionary Sensor Grid [ExpSensorGrid] and the Fleet Battle Experiments [FleetGrid].

## *5.4 Peer-to-Peer Grids*

The Coalition Agents Experiment [CoaxGrid] demonstrated how an agent-based Grid infrastructure could support the construction of a coherent command support system for coalition operations. This illustrates the relevance of peer-to-peer Grids to DoD applications [CoABS-A] [CoABS-B]. More generally we expect future DoD Grids to include the federation of dynamic Wireless Grids (in a war fighting vehicle for example) to provide more powerful command and control environments.

### 5.5 Command and Control with Collaboration Grids

Command and Control illustrates an information intensive DoD application where real-time collaboration is critically important as commanders, warfighters and other involved personnel and electronic resources gather data and make decisions in real time. The importance of collaboration technologies has been recognized by McQuay [McQuay04] with the collaborative enterprise environment CEE architecture [CEE00] implemented by Ball Aerospace as the KnowledgeKinetics project [KK].

The web service collaboration approach [GlobalMMCS] shows how one can replace specialized negotiation and framework specification protocols by a set of services with a syntax XGSP that captures [XGSP] [Wu04a] already the capabilities of H.323 and SIP. XGSP can be extended to express a rich set of roles for participants and complex “floor controls” to define the relationships between participants. One can also use the messaging substrate for Web services such as Message-oriented-middleware like NaradaBrokering [NaradaBrokering] with SOAP semantics [SOAP] [Fox05A] to provide Web service compatible security. This can naturally implement fast multicast key distribution algorithms [Wong98] [Sherman03].

### 5.6 Information Management

Content Management is a critical feature of many information Grids as one needs to support a wide variety of services on data, information and knowledge as well as the tools that transition between these forms. The DoD Infrastructure Operations Tool Access project [IOTA1] [IOTA2] is an example that needs to become consistent with a service architecture. Typical content management services include authoring, updating, data filtering and posting, persistent storage, retrieval and display, searching and the integration of all of this into a portal. A critical set of capabilities are associated with the generation (preferably automatically) of metadata for annotation to capture concepts like data provenance [myGrid-D] and curation [Curation-A]. We note the RDF-based [RDF-A] [RDF-B] Dublin Core [SemanticWeb] [DC] serving as a popular source of naming conventions for digital libraries. Dublin Core-style metadata is also compatible with the Intelligence Community Core Metadata Standard [ICCM]. The Semantic Grid [SemanticGrid] is an important focus group for Grid-related metadata activities.

Further publish-subscribe mechanisms are important for automated update and notification and the Web service technology is very strong here [WSE] [WSN]. The DoE chemistry and material science Grid [CMCS] [CMCSpaper] has produced interesting technology for annotation in SAM [SAM]. This is based on the Apache Slide implementation [Slide] of the WebDAV distributed authoring and versioning standard [WebDAV] [WebDAV-IETF]. There is a great deal of important DoD-relevant Grid activities connected to standardizing file operations [OGSA-DAI].

## *5.7 Global Situational Awareness*

Global Situational Awareness is a US defense program whose aim is to "monitor anywhere anytime" with a network of sensors, analysis stations and analysts. This is naturally architected as a Grid but has the constraint that we can't afford to build new weapon systems; rather we must evolve and integrate existing systems. Here one approach is to take each existing system and provide wrappers so that each forms a Grid; then the total DoD environment can be built by federating these existing Grids.

## *5.8 System of Systems*

The System of Systems slogan captures the concept that one cannot possibly construct elegant universal systems with clean single standards for every capability. Rather systems will be built leveraging and integrating previous with federation technology such as that pioneered in DoD's HLA approach to modeling and simulation. Grids will support such federation using the new OGSA (Open Grid Service Architecture) to provide interoperability between different existing systems [OGSA]. This federated architecture is important in Command and Control and the FMS and IMT CTA's in HPCMP. An example of core technology of this type is the new Grid DAI (Data Access and Integration) standard providing a common XML interoperability interface for file and database based repositories and supporting distributed query across multiple federated subsystems [OGSA-DAI]. There are many existing DoD frameworks, standards and architectures and gradually these must move to an XML specification and a service architecture. This migration will either use wrappers and/or the development of totally new specifications for data structures and services. We have already briefly discussed issue for HLA but it is also relevant for the Command, Control, Communications, Computer Intelligence Surveillance Reconnaissance (C4ISR) Core Architecture [C4ISRarch] and the Joint Battlespace Infosphere [JBI]. More broadly we believe the Global Information Grid [GiG] needs to come to terms with this issue. Both industry and academia are trying to set their standards through W3C, OASIS, DMTF and GGF. It seems useful for DoD to engage moré directly with these activities and independently work on their domain-specific standards.

We recently coined [GofG] the term "Grid of Grids" to emphasize that Grids have the same property as most systems of being composed from other Grids. This is discussed further in [Fox05C].