

IFIP IFAC Task Force on Architectures for Enterprise Integration

Final Report

May 2002

Introduction

In 1992 IFIP and IFAC established a joint Task Force to review existing approaches to Enterprise Integration and to make recommendations to the industrial and research community.

The IFIP constituent is the Task Force is operating under WG 5.12 of TC5, the IFAC constituent is operating under the Coordinating Committee 'Manufacturing and Instrumentation, TC-MIA.

The Task Force was chaired by Prof Emeritus T.J.Williams (Purdue University) from 1992 till 1996, and by A/Prof Peter Bernus (Griffith University) from 1996 till 2002.

Members comprised representatives from the industrial and research communities, with several researchers coming from previously held management or consultant positions in industry.

Enterprise Integration has steadily evolved from the nineteen-seventies with increasing needs of integrating the information and material flow throughout the enterprise. Separate achievements have been accomplished in the area of manufacturing both in design and production (NC and CAD/CAM systems, CIM systems, Manufacturing Cells, Material Requirements Planning and Production Scheduling Systems), and in the area of business support (Accounting, Financial Planning, Human Resource Management, Decision Support Systems, etc).

By the mid-eighties it has become clear, that isolated efforts lead to systems that can not easily communicate and thus elaborate islands of automation had to be maintained, where the integration of these proved to be difficult. Today industry still feels the problems arising from this, with many isolated 'legacy' applications being still in use (although the renewal programs associated with the Year 2000 problem have considerably eased the pain).

At the same time, in the mid-eighties, it transpired that considering the automated parts of material and information processing is no longer tenable, because the human element in the enterprise is still the most important part, and thus an approach is needed that deals at the same time with the human and automated parts of the enterprise. Thus the complete enterprise, as any other human made system, needs to be properly designed, and there is a need for methods to do so.

Two approaches have emerged.

The first approach was based on generic models, or designs, (called 'architectures') that could subsequently be implemented as information systems products (or families of products), incorporating most or all information processing tasks in the enterprise (especially its management). The resulting systems were called Enterprise Resource Planning (ERP) systems. Also, specifically for CIM systems, a number of CIM Reference Models were developed, that tried to systematise the functional building blocks of a CIM system. The problem was, however, that the number of competing models was in the order of several dozens, with all of these failing to achieve an industry-wide acceptance, or standard status. The appeal of this approach was that it could easily be turned into products (software systems).

The second approach was based on the recognition that similarly to many engineering disciplines (such as chemical engineering, manufacturing engineering, software engineering, civil engineering, etc) 'enterprise engineering' should also be based on the so-called life-cycle approach. According to this approach, in order to create an integrated enterprise the enterprise creation activities (and thus methodologies) must extend to the whole of life of the enterprise from its inception till it is no longer

operated (i.e. when it is decommissioned). Several such architectures were developed - some by groups with manufacturing systems background, and some with information systems background.

The First Mandate (1990-1994)

The first mandate of the Task Force was to overview the available approaches and make recommendations regarding what the research, industrial and standards communities should do in order to overcome the complexity arising from the situation described in the Introduction.

The first results were published as a Task Force Report (Williams *et al.*, 1994) and presented to both IFIP and IFAC. The Task Force's report was published as a book, with the title 'Architectures for Enterprise Integration'. The book contained contributions from several Task Force members, and summarised the findings and recommendations of the Task Force (Bernus *et al.*, 1996).

The major findings were the following:

1. There are two types of 'architectures' available to support enterprise integration. Type I architectures, that are models (blueprints) of the information system that integrates the information flow of the enterprise. As mentioned in the Introduction, unfortunately these models are a) very high level, b) they gave rise to many incompatible solutions. Type II architectures, that are life-cycle models of the enterprise, thus systematising the activities that are needed in order to create integrated enterprises. Such (type II, or life-cycle) architectures allow the enterprise to introduce all necessary methodological processes (including management and technical tasks) so as to evolve the enterprise in the desired direction.

There were three such major type II architectures identified (PERA, CIMOSA and GIM). The conclusion of the Task Force was that these three architectures were all containing components that were necessary, but were not found at the time in each of these. Thus there was a need for the *generalisation* of these. Such generalisation would then allow each architecture to further develop to be complete. The first attempt at such a generalisation (called GERAM) was proposed in (Bernus and Nemes, 1994). The Task Force decided to base its further work on that proposal and bring the specification of GERAM to its completion.

It is to be noted, that the aim was not to develop a fourth architecture to replace the existing ones, but to create a generalisation that allowed users of the existing architectures to make their architectures more complete, and also demonstrate that they all satisfy the GERAM requirements.

In a sense GERAM was to be an ontology of enterprise architecture, defining what enterprise architectures need to contain, and though it create a vehicle for communication between different practitioners' groups, as well as choose elements of one architecture and incorporate them into the other, should the definition of one architecture have more useful detail than the other in some respect.

It was also recognised that the Task Force must form links with standardisation bodies that address the integration problem, and thus the Task Force became a category A liaison to ISO TC184/SC5/WG1 'Industrial Automation Systems and Integration / Architecture, Communications, and Integration Frameworks / Modelling and Architecture'. WG1 was keen to develop standards in the area and endeavoured to follow up the possibility of incorporating the GERAM requirements in an international standard.

The Second Mandate (1995-1999)

The second mandate of the Task Force was a continuation of the first, and based on the recommendations developed there GERAM was fully developed during this period, and the current version is GERAM V1.6.3 (1999) - available from <http://www.cit.gu.edu.au/~bernus/>

During this period the Task Force held the majority of its meetings jointly with the ISO Working Group ISOTC184/SC5/WG1, under the convenership of Mr Jim Nell (NIST).

The task was two-fold: a) Complete the definition of GERAM, b) Develop an international standard that specifies the requirements that an Enterprise Reference Architecture must satisfy.

With sixteen meetings during this period and numerous discussions over email GERAM V 1.6.3 (1999) was developed. IS 15704 'Requirements for Generalised Enterprise Reference Architectures and Methodologies' (ISO 15704, 2000) was then developed on this basis (with the GERAM document as an appendix to the standard).

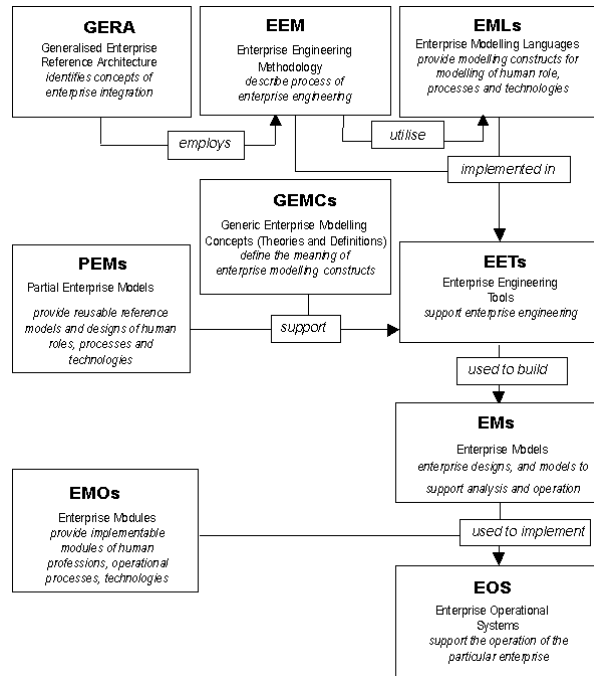


Fig 1. The GERAM Framework

Some important features of GERAM

The most detailed component of GERAM is GERA, the Generalised Enterprise Reference Architecture. GERA defines the concept of Enterprise Entity, which has a much wider domain of applicability than the manufacturing enterprise itself. Enterprise entities include any type of enterprise, incorporated or virtual, any project or product. Thus the life-cycle of any of these entities can be dealt with using the same framework. Particular architectures may detail life-cycle processes to different levels of detail, nevertheless they should cover the entire scope as defined in GERA.

GERA also defines the concept of life-history, which - as opposed to life-cycle - represents the time dimension. Through this GERAM clarifies the role of the often misunderstood 'waterfall diagram' and relegates it to the dimension of functional decomposition, while characterising various typical development approaches (such as rapid prototyping, top-down development, 'spiral life-cycle') as types of life histories. Life histories are represented somewhat similar to GANTT charts, but can also represent multiple change processes for any entity (enterprise, project or product).

The definition of GERA includes a modelling framework, which extends the scope of many particular frameworks, defining the complete scope of modelling. Importantly (derived from CIMOSA and PERA) the modelling framework includes to an equal extent the coverage of the human element and of any automated elements of any enterprise entity, and it also represents the models of particular enterprises as well as Reference Models and Ontologies (Generic Concepts) that underlie all modelling languages used to represent enterprise entities. Furthermore, the scope includes the modelling of functional entities (like humans and technological systems) as well as their controlled state (such as software and controllable configuration).

The recursive nature of the definitions is consistent with systems engineering and software engineering principles and standards, opening up the possibility to use these in a wider context than originally intended. This development was an important factor in the work of the Task Force during its third mandate, discussed below.

The three major reference architectures (PERA, CIMOSA and GIM) have been mapped to GERAM, and through this a) GERAM had an effect on the development of each of these, whereby the respective architecture groups have worked to make their architectures complete with respect to the GERAM requirements, b) GERAM offered the possibility of assessing other previously not reviewed or new reference architectures and is a potential enabler to their further development. Two important examples of such frameworks are the Zachman Framework and C4ISR (DoDAF).

During this period the IFIP-IFAC Task Force, through its IFIP, arm co-sponsored the International Conference on Enterprise Integration and Modelling Technologies in Torino (Nell and Kosanke, 1997), and several members contributed to the strategy making workshops organised around the conference as well as to the conference itself. ICEIMT, organised due to the efforts of Jim Nell (NIST) and Kurt Kosanke (CIMOSA Association) and supported by NIST and the European Community has become a forum for stating strategically important development directions in enterprise integration.

Two workshops were also organised, *Enterprise Integration Architectures: The Application Experience* (Detroit, 1997) hosted by Gus Olling, Chrysler, and *Strategic Workshop on Enterprise Integration and Enterprise Computing* (Sanctuary Cove, 1998) hosted by Peter Bernus (Griffith U) - see the TF website <http://www.cit.gu.edu.au/~bernus> with the participation of two standards groups, ISO TC184/SC5/WG1 and ISO/IEC JTC1 SC7.

The Third Mandate (2000-2002)

The ICEIMT process defined some major directions as priority areas

1. The need to develop Reference Models for dynamically creating and sustaining Virtual Enterprises, and
2. The need to develop a Unified Enterprise Modelling Language (UEML).

Both of these have been accepted as the basis of two special interest groups within the Task Force, (1) led by A/Prof Peter Bernus (Griffith U) the chair of the TF, and (2) led by Prof Francios Vernadat (U of Metz) the vice-chair of the TF, and later Dr Jochem Roland (IPK Berlin).

In addition the Task Force assumed a participatory role in the development of ISO 15288, 'System Life Cycle Processes' - a standard developed during this period by ISO/ IEC JTC1 SC7. The role of the Task Force was to ensure the harmonisation of ISO 15704 and ISO 15288, and further potential exists in the development of new software engineering standards. As a result ISO 15288 may be considered as a reference model (or 'partial model') of processes and their outcomes as exercised in systems engineering. The concepts of the two standard are harmonious, thus when a company attempts a major system development project, for example, GERAM or any GERAM compliant architecture (PERA, CIMOSA, GIM) may be used to plan the project, while individual processes may be defined on the basis of the 15288 standard. Similar possibilities exist in the application of ISO 15504 and other software engineering standards.

The Task Force's activity during this period was less intensive than originally planned, however, by 2002 the UEML group has been vitalised and held meetings in Europe several times. The development of virtual enterprise reference models has gained impetus through the application of GERAM concepts by a number of groups, with results published in ICEIMT2002 (Nell and Kosanke, 2002) (co-sponsored by the IFIP arm of the TF) and PROVE2002 conferences.

Members of the Task Force have been very active throughout this period in participating in the development of several other standards, such as a new joint standard prEN/ISO 19439 'Framework for Enterprise Modelling' replacing ENV 40003 and a new ENV 12204 on Enterprise Modelling Constructs (in preparation). The GERA modelling framework, since it is a logical generalisation of CIMOSA has been adopted by the European Standards Organisation (ENV) and ISO in prEN/ISO

19439. The advantage of this development is that CIMOSA users and developers need not take a new direction in their efforts, because GERA extends the life-cycle dimension of CIMOSA.

It is to be noted that the work on a new ENV on Enterprise Modelling Constructs is based on the original CIMOSA languages, but with some extensions to allow decisional modelling proposed by the GRAI architecture community, and more formal definitions.

Assessment of the outcomes

During its three mandate periods the IFIP IFAC Task Force on Architectures for Enterprise Integration successfully completed its task of reviewing the field of Enterprise Integration and proposing a solution to organise the field. The major outcome of this work has been the development of the Generalised Enterprise Reference Architecture and Methodology (GERAM) which has become the basis of the ISO 15704 standard.

The work had strong impact on enterprise integration projects world-wide, for example the Globemen consortium organised its 'Concept' around the GERAM framework, specialising it for the case of developing Enterprise Networks and Virtual Project Enterprises (the result is called VERAM) which included industry partners from Japan, Finland, Denmark, Norway, Germany, Switzerland, the Netherlands, Greece and Australia. Other applications emerged in Networks of SMEs (Mexico) and Defence Logistics (Australia). While in the beginning the existence of the Task Force helped emerging applications we feel that the continuation of the exploitation of the results is no longer in need of the Task Force.

Work on UEML (the Unified Enterprise Modelling Language) started strongly in 2002, and we feel that this project would benefit from the formation of a new Task Force in its own right. Since UEML has now become an international project (in a consortium supported by the European Community) it transpired at the Sesimbra (May, 2002) meeting held in conjunction of the meeting of IFIP TC5 that there is a need for over-viewing similar attempts at unifying Enterprise Modelling as they are developing around the world. From IFIP's perspective the Task Force belongs to operate under the umbrella of IFIP WG5.12 (Enterprise Integration).

Discussion of the options, with the proposed chair of this Task Force, Dr Roland Jochem (IPK, Berlin) and the incoming chair of IFAC TC-MIA, Dr Arturo Molina (U Monterrey, Mexico) and Dr Peter Bernus chair IFIP WG5.12 revealed that there is equal interest in establishing this new TF from TC-MIA's point of view.

Proposal to establish a new IFIP-IFAC Task Force

The discussion was held on 3 May, in Sesimbra, Portugal with the participation of IFIP-IFAC Task Force members Guy Doumenqts (also leader of the EU UEML project), Kurt Kosanke (CIMOSA Association), Jim Nell (NIST), Arturo Molina (incoming chair of IFAC TC-MIA), Jochem Roland (Fraunhofer Institute, IPK Berlin), Peter Bernus (chair IFIP-IFAC Task Force, IFIP WG5.12 and IFAC TC-MIA) and IFIP TC5 members G. Olling (Daimler-Chrysler, IFIP TC5 Chair), L. Camarinha-Matos (New University of Lisbon, IFIP WG5.5 Chair), R. Denzer (Germany, IFIP WG 5.11 Chair), Rae Earnshaw (U Bradford, IFIP WG 5.10 Chair), E. Myriam Gelle (IFIP Swiss representative), G. Halevi (Technion), Ron Waxman (IFIP TC5 Pub & Events Officer).

Peter Bernus, after reporting to TC5 the completion of the present IFIP-IFAC Task Force on Architectures for Enterprise Integration, proposed that the present Task Force should be declared to have completed its mission. However, he also proposed that given the very active international development efforts on furthering the field of Enterprise Modelling, with various interest groups, standards organisations and research establishments proposing solutions, IFIP and IFAC should create a new Task Force to overview the field and make recommendations to harmonise the results. To this effect the new 'IFIP-IFAC Task Force on Enterprise Modelling' should actively seek the collaboration

of any and all relevant groups, preferably securing both institutional intent and personal participation in the work on behalf of major players in the area.

Based on the above discussion it has been accepted at this meeting that

1. IFIP and IFAC should acknowledge the successful completion of the Task Force project on Architectures for Enterprise Integration.
2. A new IFIP IFAC Task Force on Enterprise Modelling be established
3. The TF be established on a temporary basis, to allow the new chair Dr Jochem Roland to obtain clearance from his home institution IPK Berlin to undertake this role, and to develop a statement of aims and scope for the new Task Force, by the end of November 2002. TC5 chair Dr Gus Olling will write a letter to the director of IPK Berlin to this effect.
4. IFAC TC-MIA will propose this resolution to be adopted by the respective IFAC Technical Committee, Co-ordinating Committee and IFAC Technical Board at its Barcelona meeting in July 2002.
5. The chair of the new Task Force should submit to both IFIP WG5.12 and IFAC TC-MIA the proposed scope and aims for the provisional TF to be approved, and be operated for an initial three year period (2002-2005). Results should be reported to both IFAC and IFIP at the end of this period, while usual yearly reports would be submitted to IFIP WG5.12 and IFAC TC-MIA.

Acknowledgements

The work of the IFIP Task Force on Architectures for Enterprise Integration was supported by a large number of members.

Special thanks should go to Jim Nevins (USA) who originally proposed the establishment of this TF. Prof T.J.Williams (Purdue University) has lead the TF with great energy from the TF's inception till 1996, and his efforts and leadership were invaluable to this group. The list of active members who attended the numerous meetings is long, and it is hard to make sure that there are no omissions made when we commend the efforts of Kurt Kosanke (CIMOSA Association), Jim Nell (NIST), Guy Doumeings and David Chen (Bordeaux U), Francois Vernadat (U Metz), Richard Weston (U Loughborough), David Shorter (ITFocus), Yoshiro Fukuda (Hosei U), Laszlo Nemes (CSIRO), Jacob Vlietstra (formerly AT&T), Gus Olling (Daimler Chrysler), Michael J Rodd (UC Swansea), Ljubo Vlacic (Griffith U), Johan Vesterager (TU Denmark), Michael Petit (U Namour), Hong Li (Waterlogic), Atsui Inamoto (Mitsubishi E), Ziquiong Deng (Narvik Inst T), Zenjin Han (Tsinghua U), Yuilu Chen (Tsinghua U), Arturo Molina (U Monterrey), Bruce Gutheridge (Systemhouse), Michael Gruninger (U Toronto/NIST), Luis Basanez (UP Catalunya), Marco Garetti (U Milan), Mark Fox (U Toronto), Pinto Ferreira (U Porto), John Edwards (Loughborough U), Jochem Roland (IPK Berlin), Christopher Bussler (Oracle), Jim Brown (UC Galway), Gunter Schmidt (U Saarlandes), Sam Bansal (SAP), Cheng Leong Ang (Gintic), Brane Kalpic (ETI), Yusaku Shibata (Nagoya U), James Brosvic (Honeywell), Bruno Vallespir (Bordeaux U) and Dick Zoetekouw (AT&T), F Gh Filip (ICI Inst.), Geza Haidegger and Gyorgy Kovacs (SzTAKI), Peter Kopacek (TU Wien), Angel Ortiz (U Valencia), Ajit Pardasani (NRC Canada), Norbert Rozenich (BMf Wien), . We also thank other members of the Task Force who supported our work but have not been able to participate the meetings: S.K. Banerjee (U Strathclyde), V Charpulat (EERIE), F Fadel, Joel Favrel (AIPRAO Lyon), M Jarke (GMD), HJ Molstad (Standards Denmark), J Mylopoulos (U Toronto), Mihai Avram (IPA-SA), Leo Obrst (MITRE). If this list is incomplete, the chair offers his sincere apologies for any omissions that may have slipped in.

Submitted to IFIP and IFAC by A/Prof Peter Bernus
chair IFIP-IFAC Task Force on
Architectures for Enterprise Integration

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