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CIMOSA – Overview and status

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Abstract

Starting from the identification of the increased need for enterprise integration and real-time and up-to-date information, the paper briefly describes the CIMOSA concept, the enterprise modelling solution for identification of available information and its use in the operational processes of the manufacturing enterprise.

CIMOSA has been developed by the ESPRIT Consortium AMICE and has been validated together with the ESPRIT projects CIMPRES, CODE and VOICE in multiple case studies and pilot implementations. Validation results have been used to improve the technical specifications of CIMOSA.

Exploitation of CIMOSA has been started in the area of enterprise modelling, modelling tool developments and further enhancement of industrial pilot implementations of the Integrating Infrastructure. These efforts are being complemented by promotional activities aimed at increasing enterprise integration awareness and acceptance and support of standardisation activities on national, European and international level.

Enterprise integration has not yet become the common industrial goal, nor the specific day-to-day operational tool in the manufacturing community that it should be. Lean enterprises, business re-engineering, concurrent engineering, management of change – identified as current management concerns – should be viewed as subsets of enterprise integration. The engineering of the enterprise has to be become an engineering discipline in its own right in order to solve the many problems in the operation of enterprises of the future.

Keywords: Enterprise integration; Enterprise modelling; CIMOSA; CIM; Open System Architecture

1. Introduction

The manufacturing paradigm shift from economies of scale and manufacturing automation to flexible manufacturing and management of change creates new industrial environments and new challenges for the manufacturing industry. Even today manufacturing is experiencing continuous changes in customer demand, technology offerings and last, but not least, business constraints originating from society at large. To manage such changes in the enterprise operation in real-time requires not only access to sufficiently up-to-date information and knowledge on the operational processes, but also additional means to support handling and use of this information. Decision support is needed to visualise and evaluate the impact of these changes on the business across all phases of the product life cycle and to aid the implementation of corrective measures as well. This is especially apparent for small and medium enterprises (SMEs) which not only need better decision support for planning and investments, but even more require operational flexibility in their business processes.

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The most effective way to identify and obtain access to the needed information is via models of the enterprise operation. Process-based enterprise modelling not only identifies the enterprise information needed and produced in the course of the different business processes, but enables the description of the process functionality and dynamics, the resources needed and the relations to the enterprise organisation. Such models cover not only the business processes of the enterprise, but also identify their internal and external relations. Enterprise models provide transparency on the current operation with as sufficient level of detail as needed and defined by the user. They are also the base for evaluating operational alternatives and their capability to cope with the occurring changes. Simulating the proposed solutions provides answers with respect to their feasibility, as well as pointing to specific improvements of the operation, such as turn-around time, required stock level, resource productivity and many others. Such models with sufficient animation will also serve for information and retraining of the operational staff involved and may even be used for operational control and monitoring.

CIMOSA is an ESPRIT-supported pre-normative development aimed at process-based enterprise modelling and application of these models in the control and monitoring of enterprise operations. The ESPRIT [1] Consortium AMICE (European CIM Architecture – in reverse) has developed, validated, verified and introduced into industry and standardisation the CIMOSA (Open System Architecture for CIM) concept of enterprise engineering and model-driven enterprise operational control and monitoring. CIMOSA consists of an Enterprise Modelling Framework and an Integrating Infrastructure.

The CIMOSA concept has also been evaluated and validated by other ESPRIT projects (CIMPRES, CODE, VOICE), professional societies (IFIP/IFAC [2] and others), independent organisations in many countries (China, France, Germany, Hungary, Japan, Switzerland, and others) and last but not least by AMICE member organisations. National, European and international standardisation bodies (DIN, AFNOR, others, CEN and ISO) have started normative work to establish standards based on these concepts.

CIMOSA enterprise models may be used not only in decision support for engineering and evaluating enterprise operation alternatives, but also in model-driven operation monitoring and control. The latter is supported by the CIMOSA Integrating Infrastructure which provides a platform to execute CIMOSA process models in heterogenous manufacturing and IT environments.

In order to take advantage of enterprise modelling and simulation, enterprise models have to be kept up-to-date continuously. Since only the people directly involved in the business have the knowledge of the operational needs and required changes, model update and maintenance has to become a normal task in the daily business of the operational staff, rather than of modelling specialists. Therefore, enterprise modelling methods and tools have to be easily usable by manufacturing people. In addition, in order to achieve sufficient motivation for maintaining the models and keeping them really up-to-date, modelling has to become a tool not only for planning, but for operational support as well. To achieve this goal, model engineering has to be based on industry standards providing for industry-wide understandability and even more important, interchangeability.

2. CIMOSA modelling framework

The CIMOSA modelling framework shown in Fig. 1 structures the CIMOSA Reference Architecture into a generic and a partial modelling level, each one supporting different views on the particular enterprise model. This concept of views allows one to work with subsets of the model rather than with the complete model, providing especially the business user with reduced complexity for his particular area of concern. CIMOSA has defined four different modelling views (Function, Information, Resource and Organisation). However, this set of views may be extended if needed.

The CIMOSA Reference Architecture supports modelling of the complete life cycle of enterprise

[1] European Strategic Programme for Research and Development in Information Technology.

[2] IFIP = International Federation for Information Processing; IFAC = International Federation on Automatic Control.

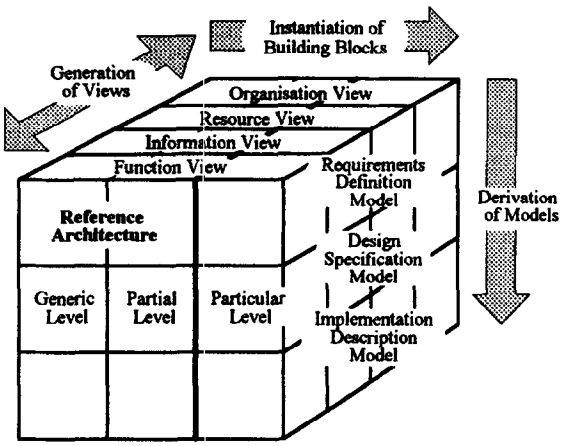

Fig. 1. CIMOSA modelling framework.

operations (Requirements Definition, Design Specification and Implementation Description). The sequence of modelling is optional. Modelling may start at any of the Enterprise System Life Cycle phases and may be iterative as well. Depending on the intention of model engineering, only some of the life cycle phases may be covered.

Enterprise operation should not be modelled as a large monolithic model, but rather as a set of co-operating processes. With a set of common modelling building blocks or a 'common modelling language', the CIMOSA Reference Architecture provides the base for evolutionary enterprise modelling. The common modelling language enables different people to model different areas of the enterprise, but ensures the integrity of the overall model. Fig. 2 shows the basic set of the CIMOSA building blocks for business modelling. Processes, Events and Enterprise Activities are the object classes which describe the functionality and behaviour (dynamics) of the enterprise operation. Inputs and outputs of Enterprise Activities define the information (Enterprise Objects) and resources needed. Organisational aspects are defined in terms of responsibilities and authorisation (Organisation Elements) for processes, functionalities, information, resources and organisation, and are structured in Organisational Units or Cells. CIMOSA object classes will be used recursively, enabling structuring of modelling entities into sub-sets and super-sets. CIMOSA also employs the object-oriented concepts of inheritance, which provides consistency between super-set and subset definitions.

3. CIMOSA – Process-based enterprise modelling

CIMOSA model engineering is demonstrated in Fig. 3, which shows three enterprise Domains (DM1–3), each one represented by its functionality – a set of Domain Processes (e.g. DP2.1–2.3). Domain Processes communicate with each other via

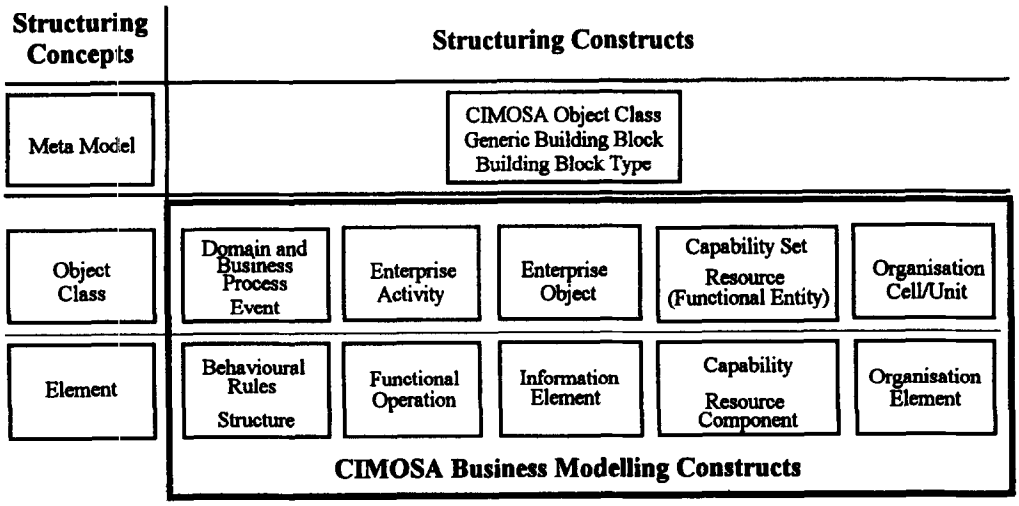

Fig. 2. CIMOSA constructs.

Events and Results. Decomposition of Domain Processes (DP2.1) via Business Processes (BP2.1.1 and 2.1.2) leads to identification of Enterprise Activities (EA1–5) and their connecting control flow represented by a set of Behavioural Rules (BRS). The network of these Enterprise Activities is the functional and dynamic representation of the Domain Process DP2.1. Events 1 and 2, which relate to Domain Process DP2.1, actually trigger EA1 and EA2 and Results a and b are produced by EA3 and EA5 respectively. The different Inputs and Outputs identified for each Enterprise Activity are shown in Fig. 3 as well. Resources and Control Inputs and Outputs identify the resources and control information needed for the execution of the Enterprise Activity and the corresponding information produced during the execution itself (resource and general EA status information to be used elsewhere in the enterprise operation). Responsibilities and authorisations are identified for all entities identified in the model (processes, information, resources and organisation itself), enabling exception handling in case of deviations from the modelled behaviour. For more information on CIMOSA-based enterprise modelling, please refer to CIMOSA references [1,2].

At the system design level, Enterprise Activities are further decomposed into Functional Operations

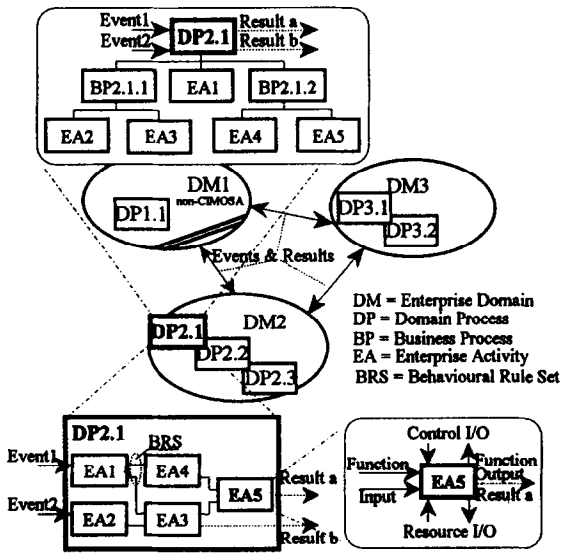

Fig. 3. Decomposition of Domain Process into a network of Enterprise Activities.

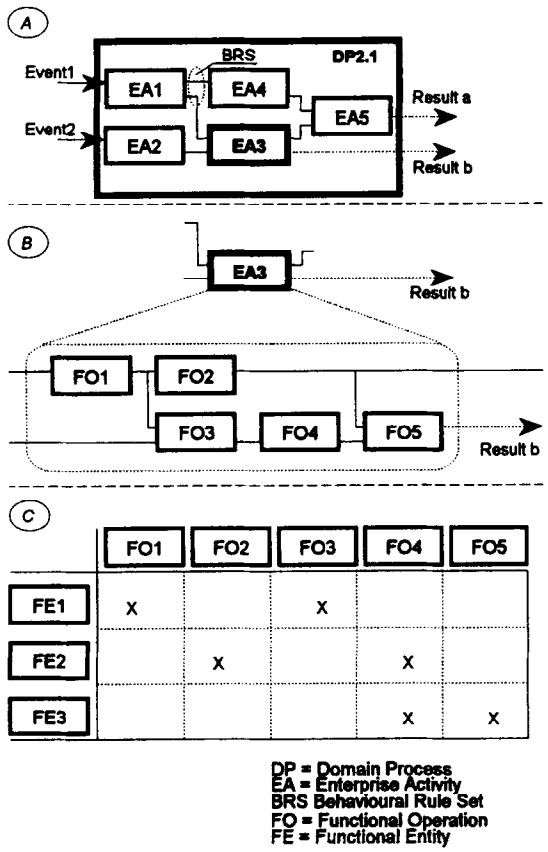

Fig. 4. Decomposition of Enterprise Activities and relation between Functional Operations and Functional Entities.

(Fig. 4B). Such CIMOSA Functional Operations are defined in relation to their executing resource types: the Functional Entities. Each Functional Operation will be completely executed by one Functional Entity, but a Functional Entity may be capable of executing more than one type of Functional Operation (Fig. 4C). CIMOSA Functional Entities are resources which are able to receive, send, process and (optional) store information.

4. CIMOSA integrating infrastructure

The Integrating Infrastructure provides a set of generic IT service entities for model engineering and model-driven enterprise operational control and monitoring especially in heterogeneous environments (see Fig. 5). Control of execution of the Implementation

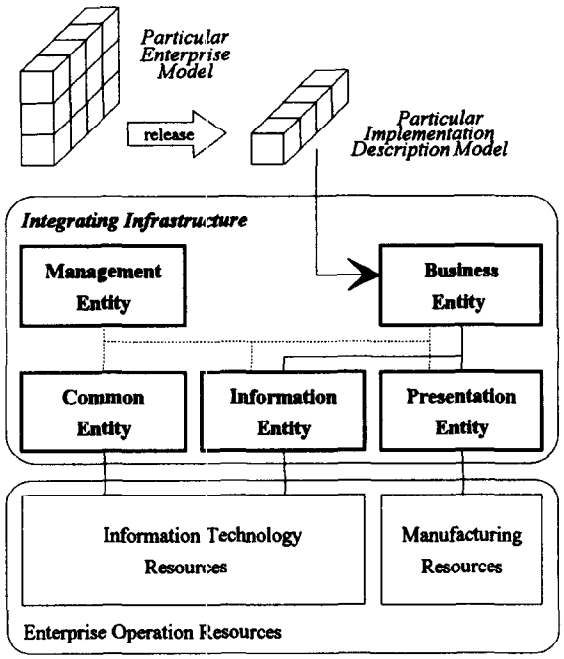

Fig. 5. Integrating Infrastructure.

Description Model is provided by the Business Entity, which receives the Events and creates occurrences of the related Domain Process and its contents, i.e. the set of Enterprise Activities.

Process Control, Resource Management and Activity Control (all part of the Business Entity) analyze the model contents, assign the resources, identify the required information and connect them to the necessary information technology and manufacturing resources via the Common, Information and Presentation Entities. The latter entity controls communications via networks (Common Entity), provides access to data bases (Information Entity) and communicates with people, machines and applications via the Human, Machine and Application Dialogue Services (part of the Presentation Entity). The Management Entity provides the necessary system services to configure and manage the Integrating Infrastructure itself.

5. CIMOSA and the real world

CIMOSA enterprise models may be used for decision support by simulating operation alternatives or different scenarios of existing operations, and for model-driven operational control and monitoring. For both areas of model application, CIMOSA distinguishes explicitly between engineering (model creation and modification) and operation (simulation and real operation), placing emphasis on the need for enterprise engineering as a discipline similar to product engineering. Therefore, the enterprise system life cycle phases for enterprise engineering include both model and implementation validation followed by an explicit release for operation.

The relations between the process of enterprise modelling and the different phases of the life cycle are shown in Fig. 6. Starting from the relevant Enterprise Objectives and Constraints and using the appropriate part of the CIMOSA Reference Architecture, the System Requirements for the part of the operation to be modelled are defined. The result is the Particular Requirement Definition Model, which includes the CIMOSA model of at least one domain and its relationship to the co-operating non-CIMOSA

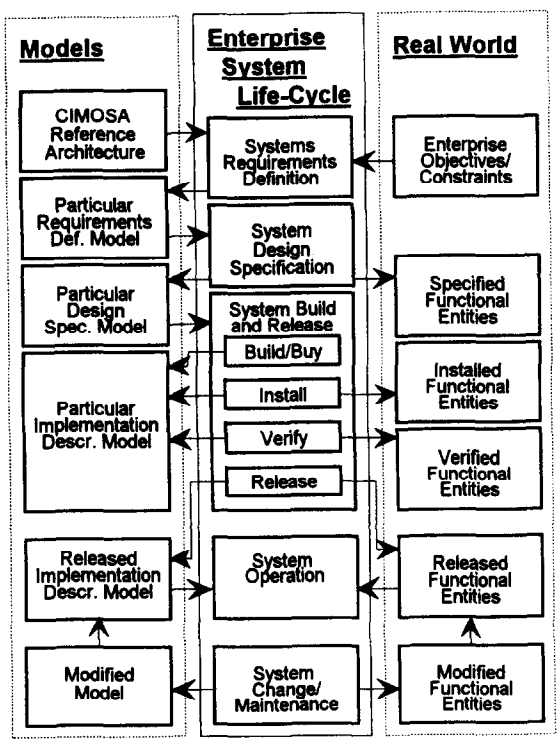

Fig. 6. CIMOSA modelling and enterprise system life-cycle.

domains (see Fig. 3). The Particular Requirements Definition Model is then the base for the system design specification. The information captured in the Requirements Definition Model is amended by using additional attributes in those modelling constructs already used for requirements definition modelling, or by using new constructs from the CIMOSA Reference Architecture. The system design specification itself will be done by system specialists, however, CIMOSA will always maintain a translation to the business user's constructs to enable him to use and to maintain his model.

The resulting Particular Design Specification Model and the contained Specified Functional Entities guide the system implementation phase (System Build and Release). The system design is realised, either through reuse of existing resources, or by buying or building of new ones. Installation and verification of their operation according to the design specification is the major part of the system implementation phase. Any deviation from the design specification is recorded in the Particular Implementation Description Model. The latter is both a further extension of the design model and its transformation into a format executable by the Integrating Infrastructure. As mentioned above, after successful verification CIMOSA asks for a formal model release prior to system transfer into operation. A formal model release is also defined for any model maintenance reflecting changes of business processes in the course of adaptation of the enterprise operation.

Fig. 7 summarises the use of CIMOSA in model engineering as well as in operational control and monitoring. Using the CIMOSA Reference Architecture, Particular Enterprise Models are engineered under control of the Enterprise Engineering Implementation Model. The latter will be implemented in CAE tools guiding the user through the engineering phases of the CIMOSA Enterprise System Life Cycle. The released Particular Implementation Model is then used to directly drive the operation, through monitoring and controlling the relevant product life cycles, or parts thereof, and their business process implementations. The Integrating Infrastructure links

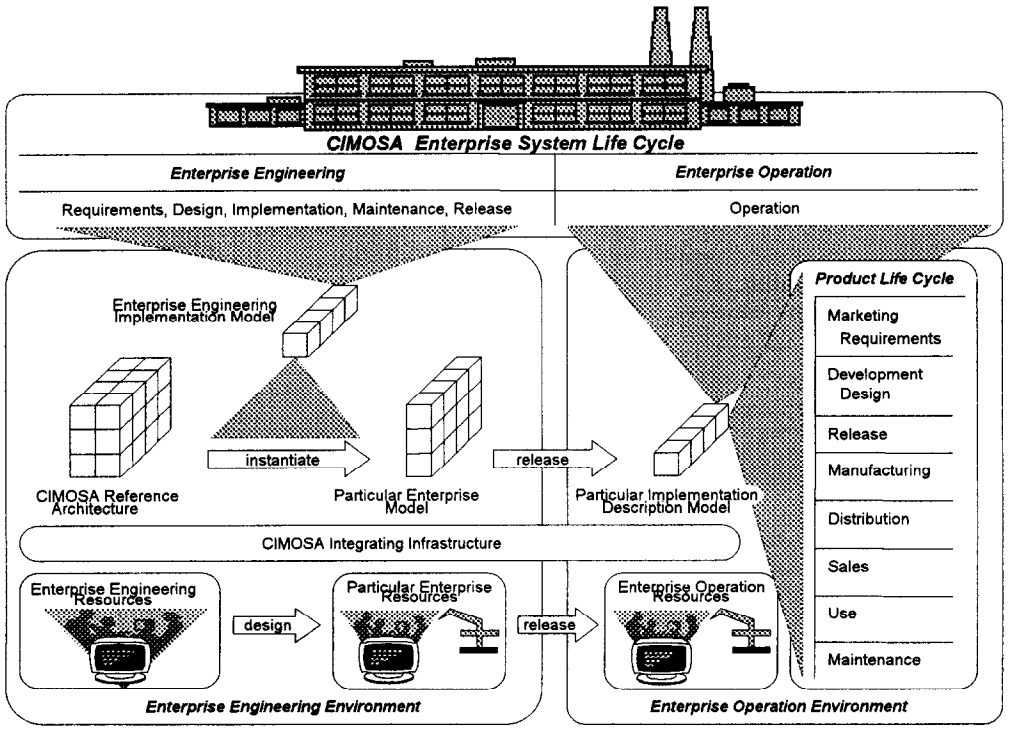

Fig. 7. CIMOSA concept and application.

to the enterprise resources. This link is required for model creation as well as for real-time model maintenance (updates and extensions).

6. CIMOSA validation, application and exploitation

The CIMOSA concept has been validated and verified in numerous case studies and a total of eight pilot implementations done by the ESPRIT projects AMICE, CIMPRES, CODE and VOICE covering both model engineering and model-based operational control and monitoring. CIMOSA has been applied in different industries as well (aerospace, automotive, process, tooling). Results have been presented to the public in many publications and presentations (see e.g. [3]) as well as in demonstrations at several project workshops supported by CIM Europe [4]. General descriptions of CIMOSA [1], user guides [1] and technical specification [2] have also been made publicly available.

CIMOSA models provide for a high flexibility in enterprise engineering, through fast modelling and evaluation, via simulation of operation alternatives and direct implementation of the final solution. This has been explicitly verified by the AMICE project in the FIAT model engineering pilot implementation, where CIMOSA has been used to model and evaluate operational alternatives in gearbox production and assembly. Compared with state-of-the-art methods currently applied by the FIAT Auto Division, the benefits of CIMOSA are in a considerably enhanced analysis capability (due to better structuring and more details on information, resources and organisation), much lower time to model the particular domain (standard building blocks lead to a time reduction by factor of three) and significantly improved re-usability of model parts (modelling time for similar application reduced by factor of eight) [5].

Exploitation of CIMOSA is mainly in the area of enterprise modelling. Applications external to the ESPRIT projects reach from business process re-engineering of a paper mill [6] to software selection in an enterprise operation [7]. Several adaptations of CASE tools to support CIMOSA modelling have been done supporting the different pilot implementations of the ESPRIT projects (e.g. [8]). This type of work will continue in the future. Additional tools have been identified which are either adaptable for CIMOSA type modelling like PROPLAN of WZL [3], Aachen [9]; or have been designed following CIMOSA principles e.g. SEW-CIMOSA (Software Engineering Workbench) of Loughborough University [10]. Product developments, especially for modelling tools, based on CIMOSA have been indicated by IT vendor companies.

Work in the area of Integrating Infrastructures or integrating platforms has indicated compatibility with CIMOSA. For instance, OSF-DCE (Open System Foundation – Distributed Computing Environment) has been used in the implementation of the CIMOSA Common Entity in the AMICE project pilot implementation of model-driven operational control and monitoring. Other platforms are being analyzed for their compatibility with CIMOSA, e.g. AMBAS (Adaptive Method Based Shell) of FAW [4] Ulm/Germany [11], or have been designed with some degree of CIMOSA compatibility ,e.g. CIM-BIOSYS (CIM Building Open Systems) of Loughborough University [12].

7. CIMOSA in standardisation

Standardisation efforts on enterprise integration are currently in progress on the ISO level (Framework for Enterprise Modelling), the CEN level (Modelling Constructs/Building Blocks and Framework for Integrating Infrastructure) and in various national organisations supporting European and international standardisation. At the international level, the ISO TC 184/SC5/WG1 – Committee Draft 14 258 "industrial automation systems – systems architecture – framework for enterprise modelling", has been placed for revision after a first ballot in 1994. The European Pre-Norm ENV 40 003 [5], which is

[3] WZL = Werkzeugmaschinenlabor (Machine Tool Laboratory).

[4] FAW = Forschungsinstitut für anwendungsorientierte Wissensverarbeitung (Research Institute for Application Oriented Knowledge Processing).

[5] ENV 40 003 = Computer Integrated Manufacturing – Systems Architecture – Framework for Enterprise Modelling.

based on CIMOSA, has recently been extended for two more years, either to be replaced by an international norm on the ISO level, or to become itself a European norm by 1996. An extensive report on the European standardisation activities on enterprise integration can be found in Ref. [13].

The German standardisation organisation, DIN, supports the QCIM (Quality CIM) activities, which are focused on quality in CIM with major efforts in modelling of products, production control, resources, enterprise integration and quality. Harmonisation of these efforts with CIMOSA has led to a joint paper on the subject of enterprise modelling constructs submitted to CEN/TC310/WG1 [14].

Although not formally a standardisation effort, there is also the work on Architectures for Enterprise Integration undertaken by the IFAC/IFIP Task Force [15]. The proposed Generic Enterprise Reference Architecture and Methodology (GERAM) is an attempt to define a framework beyond the current standardisation activity with its focus on modelling and systems integration. With GERAM's emphasis on enterprise system life cycle as the guiding concept of the reference architecture, and the identification of the subjects of enterprise integration methodology and modelling language, together with supporting tools, GERAM provides a good structuring concept and an identification of the needed support for enterprise integration. In particular, the clear distinction between the modelling methodology and the modelling language helps to clarify the current confusion in terminology. Many methodologies can and have been used in enterprise modelling, but only with a common modelling language can enterprise models become the unifying tool for the communications in and between enterprises. Today many concepts include both methodology and language, without a clear identification of the two. CIMOSA fits very well into this enhanced enterprise integration structuring concept, especially, with its emphasis on the modelling language (CIMOSA modelling constructs).

8. An outlook

Enterprise integration, in its general sense, is a subject which is recognised as being essential for the future of industrial enterprises. However, there is still a long way to go to establish enterprise integration as a common industrial goal, and enterprise engineering as a specific subject in the manufacturing community. Different terminology and emphasis on subsets of enterprise integration confuses the audience and fragments, and thereby lowers efficiency of relevant research, development, promotion and awareness, both in academia and industry.

Lean enterprises, business re-engineering, concurrent engineering, management of change and other such concepts have to be understood as subsets of enterprise integration. Even fractal manufacturing, the virtual enterprise, and other new forms of enterprise organisation, have to be parts of enterprise engineering in the large. The engineering of the enterprise has to be recognised as an engineering discipline in its own right, and at the same level as product and manufacturing engineering, in order to solve the many problems of enterprise operation. A sufficient framework for enterprise integration and a clear understanding of the position and role of the different players in the field has to be defined and accepted in order to establish and use enterprise integration in industry and to harvest all its potential benefits.

The efforts in standardisation stated above support this view of enterprise integration, even if they still focus on enterprise modelling, rather than enterprise integration as such. An effort which goes even further is the work on GERAM, which hopefully will help to clarify much of the current confusion of the user community, identify the overlaps and missing pieces of proposed solutions and thereby will advance promotion of enterprise integration, its acceptance and its use in industry. With CIMOSA identifying solutions for business modelling as well as for model-driven operational control and monitoring a generic framework like GERAM may become the unifying element in enterprise integration standardisation is looking for.

Nevertheless, the future of enterprises depends more and more on their ability to handle and use information efficiently and effectively and to implement the necessary operational modifications in real time. Providing the technical means which allow the enterprise to meet these challenges is still not sufficient to solve the problems. Creating awareness and

acceptance of enterprise integration and training the community of users is an even larger challenge. A challenge which requires all parties involved in academia, industry and government to join forces and to focus on the broad issue of enterprise integration, not only in research and development, but also in preparing the end user for the new industrial paradigm in information handling and use.

The CIMOSA Association (e.V.) has been established as a non-profit organisation to promote CIMOSA in the public domain and to support related exploitation activities. The Association will act as a focal point for an controlled evolution of the CIMOSA Technical Baseline [2] and can be contacted by any party interested in contributing or using CIMOSA in industrial applications as well as in enterprise integration related research and development.

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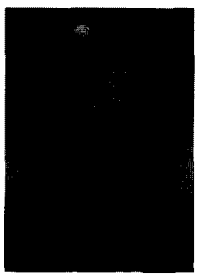

Kurt Kosanke received an Engineering degree in Physics from the Physikalisch Technische Lehranstalt in Lübeck, Germany. He joined the Development Laboratory of IBM Deutschland in Böblingen, Germany, working in advanced development projects on optical printers and large-scale displays using laser and light deflection technologies. After a 4 year assignment to IBM USA he joined the manufacturing research organisation of IBM Deutschland.

K. Kosanke worked and held management positions in the areas of instrument development, production control, material logistics and simulation. Since 1984 he has been responsible for the IBM Deutschland involvement in ESPRIT and similar programs. He has personally be involved in the ESPRIT AMICE project where he was responsible for the enterprise modelling part of the CIM Open Systems Architecture.

K. Kosanke has retired from IBM and is presently working as an independent consultant. As such he was Director of the AMICE project on behalf of the ESPRIT Consortium AMICE. He is currently Director of the CIMOSA Association (e.V.), involved in promoting CIMOSA and Enterprise Integration in industry, supporting its exploitation as well as being responsible for controlling the evolution of the CIMOSA technical specification (CIMOSA Technical Baseline).

He holds many patents in most of the working areas mentioned above and has published numerous papers in those fields as well.