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Development of GERAM, A Generic Enterprise Reference Architecture and Enterprise Integration Methodology

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Abstract
The IFAC/IFIP Task Force on Architectures for Enterprise Integration has developed an initial proposal for its **G**eneric **E**nterprise **R**eference **A**rchitecture and **M**ethodology (GERAM). The report briefly describes GERAM and the plans of the Task Force for its further development.

Keywords
Enterprise Integration, Reference Architecture, Integration Methodology, Modeling Tools, Modeling Languages, Glossary

1 THE TASK FORCE AND ITS WORK

The IFAC/IFIP Task Force on Architectures for Enterprise Integration was formed at the IFAC World Congress in Tallinn, Estonia, in August 1990. It's mission was to study the field of enterprise reference architectures for the purpose of picking a best one for future use from those already available. Failing this, the Task Force should recommend a method of development of a better one than those it had studied.

At the 1993 Congress in Sydney, Australia, the Task Force reported (Williams, et al, 1993) on its extensive analysis of the three major enterprise integration architectures available at that time: CIMOSA (AMICE Consortium, 1992), GRAI-GIM (Doumeingts, et al, 1992), and PERA (Williams, 1992). While each of these could be developed into a complete and satisfactory Reference Architecture and associated Integration Methodology, the group recommended that the synergy of the consolidation of the best features of each should be developed. This should give the best possible system for future enterprise integration programs.

Our first major proposal for such a consolidated architecture was authored by Peter Bernus and Laszlo Nemes, both Task Force Members, and presented at the Vienna Workshop Meeting of the Task Force in June 1994 (Bernus and Nemes, 1994). They applied the title GERAM (**G**eneric **E**nterprise **R**eference **A**rchitecture and **M**ethodology) to this more complete and usable architecture as suggested earlier by the Task Force.

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2 WHAT IS GERAM?

As had been recommended in the previous report of the Task Force, the proposal by Bernus and Nemes builds upon the work carried out earlier by CIMOSA (AMICE Consortium, 1992), GRAI-GIM (Doumeingts, et al, 1992) and PERA (Williams, 1992) to organize the development and use of the modeling techniques, tools and methodologies needed by the potential user to consolidate and use the data required for integrating their own enterprise. The proposed system would also help the work of industrial consultants in aiding the user. It would help coordinate the products of tool and methodology developers to prepare suitable additional products to further enhance the developing system. Finally, it would outline the needs of further theory and concept development to be carried out by the researcher in this area.

As proposed by Bernus and Nemes, GERAM itself is a framework of six major components as follows:

1. Generic Enterprise Reference Architecture (GERA);
   This is the definition of enterprise related concepts, with the primary focus on the life-cycle of the enterprise. Since the life-cycle can be considered as a design process the architecture will also have to identify the intermediary results and components of this design process. It can be considered the model of the life cycle.
2. Generic Enterprise Engineering Methodology (GEEM);
   This is the description, on a generic level, of the processes of enterprise integration. In other words, the methodology is a detailed process-model, with instructions for each step of the integration project.
3. Generic Enterprise Modeling Tools and Languages (GEMT&L);
   The engineering of the integrated enterprise is a highly sophisticated, multidisciplinary management, design and implementation exercise during which various forms of descriptions and models of the target enterprise need to be created. To express these models more than one modeling language may be needed.
4. Generic Enterprise Models (GEMs);
   Generic enterprise models capture concepts which are common to all enterprises. Therefore the enterprise engineering process can use them as tested components for building any specific enterprise model.
5. Generic Enterprise Modules (GMs);
   Modules are **products**, which are standard implementations of components that are likely to be used in enterprise integration — either by the enterprise integration project or by the enterprise itself. Generic modules can be configured to form more complex modules for the use of an individual enterprise.
6. Generic Enterprise Theories (GTs);
   Theories which describe the most generic aspects of enterprise-related concepts. Generally called ontological theories. They may also be considered "meta models" because they consider facts and rules **about** the facts and rules of enterprise models.

The Bernus and Nemes Proposal also pointed out an interesting aspect of the generic integration process. This is that it is recursive in that the same Generalized Enterprise Reference Architecture and Methodology (GERAM) can be used to describe not only the manufacturing enterprise itself, but also three other recursively related enterprises as well. These are all as follows:

1. The design development and production of a product to be produced by a manufacturing enterprise. The product so produced will be labeled Entity 4.

2. The life history (concept, design, construction and operation) of the manufacturing enterprise itself. The manufacturing enterprise is Entity 3.
3. The life history of the engineering enterprise which developed the subject enterprise in question. The engineering design enterprise is Entity 2.
4. The strategic enterprise management process (life cycle) which developed the need and concept for the subject manufacturing enterprise in the first place as well as the engineering enterprise that produced this subject enterprise. The strategic enterprise is Entity 1.

That is: Entity 1 (The Strategic Enterprise) developed Entity 2 (The Engineering Enterprise), which further develops Entity 3 (the Manufacturing Enterprise) which then develops and produces the product (Entity 4) for the final customer user. This scenario with suitable adjustments would describe the relationship of any similar set of enterprises and their final products in any industrial interaction or indeed in any multi-enterprise endeavor of any type.

Bernus and Nemes proposed that this process of recursivity is limited to the above four stages and that there are no further stages in either direction from them.

Such a concept of universal usage of the principles of enterprise reference architecture applicability in all areas of human endeavor today (not just manufacturing as commonly assumed by many involved in our field) has major ramifications on the importance and potential future use of the results of the Task Force's work.

3 WHAT MUST GERAM ACCOMPLISH?

A generic enterprise reference architecture, such as GERAM will become, has many requirements that it should satisfy. Some of these are:

1. Give the best possible treatment of the scope of the enterprise from the systems point of view;
   It is necessary that all activities which are involved directly or indirectly in designing and operating or improving the enterprise should be covered by the architecture.
2. Provide a consistent modeling environment which will lead eventually to executable code for computer usage;
   The modeling views offered should cover a minimal necessary set but this set should be expandable. The ideal modeling environment should be modular so that alternative methodologies can be based upon it.
3. There should be a detailed methodology for use which development personnel of enterprises of all types can readily follow;
   This methodology must be technically correct as well as readily understandable and easy to use. It must be executable by real teams within acceptable cost, time and resource constraints.
4. It should promote good engineering practice for building reusable, tested and standard models;
   The apparent complexity must be kept low. Intricate details should be encapsulated in reusable engineering building blocks.
5. It should provide a unifying perspective for products, processes, management, enterprise development and strategic management;
   The architecture should tie and relate all aspects of enterprise integration and the related enterprise engineering to the rest of the activities of the enterprise.

4 A DESCRIPTION OF GERAM

GERAM as proposed (Bernus and Nemes, 1994) is based upon a so-called matrix graphical model of the life-cycle of an enterprise as developed by those authors and others for use in the Task Force Major Report (Williams, et al, 1993) as a basis for a comparison and evaluation of the capabilities of each of the candidate architectures studied there. This model has been structured to include a representation of the capabilities and strong points of each of these architectures.

Since our stated goal is to develop an architecture combining the best features of the earlier architectures to produce a synergistically superior product, the evaluation matrix also becomes a model of GERAM itself. The matrix is shown in Figure 1.

The other major contributions of the authors in describing GERAM beyond the earlier recommendations of the Task Force in its report are as follows:

1. The definition of the three major classes of users of GERAM;
   a) Those who would use GERAM as the basis for developing enterprise integration programs for their own companies or manufacturing plants. This would also include consultant engineering companies who help final user groups prepare and carry out these programs.
   b) Those entities, individuals, groups or companies, carrying out the development of new and improved tools and methodologies for carrying out the work of the personnel of Item 1a above.
   c) Researchers, academics, and others developing new modeling theories and ontologies to provide a theoretical underpinning for the work described for both groups above.
   It was noted by the authors that the matrix representation would probably be too complex for ready use by Group 1a above and maybe even 1b as well. Thus it was recommended by them that initially the PERA diagram of Figure 2 (Williams, 1992) should be used. The Matrix form of Figure 1 would be used by the research group and possibly the tool developers as well.
2. The definition of the six major components of GERAM as described in Section 2 above.
3. The discovery and promulgation of the recursivity of the Matrix diagram, and the PERA diagram as well, as also described in Section 2 above in the representation of all types of enterprise entities as noted there. This latter finding is a major factor in showing the correctness and probably the universal applicability of these architectural forms.
4. Following the Task Force recommendations, Bernus and Nemes also emphasized the need for a complete descriptive methodology to teach and guide users in preparing the enterprise integration programs. As the most complete at present, the Purdue Methodology (Williams, 1994) was presented as the initial choice.

5 CURRENT STATUS OF THE GERAM PROJECT

The Task Force Members have in general whole-heartedly welcomed the Bernus-Nemes Proposal as a solid step toward our eventual goal of a single, well-accepted, and standardized architecture with its associated tools and methodology. However, it is also very clear at this point that this is being considered only as a first step which will require much additional clarification, and development, and hopefully competition with other near future proposals which may emerge by others.

Bernus and Nemes thus proposed the following to develop the six components of GERAM:

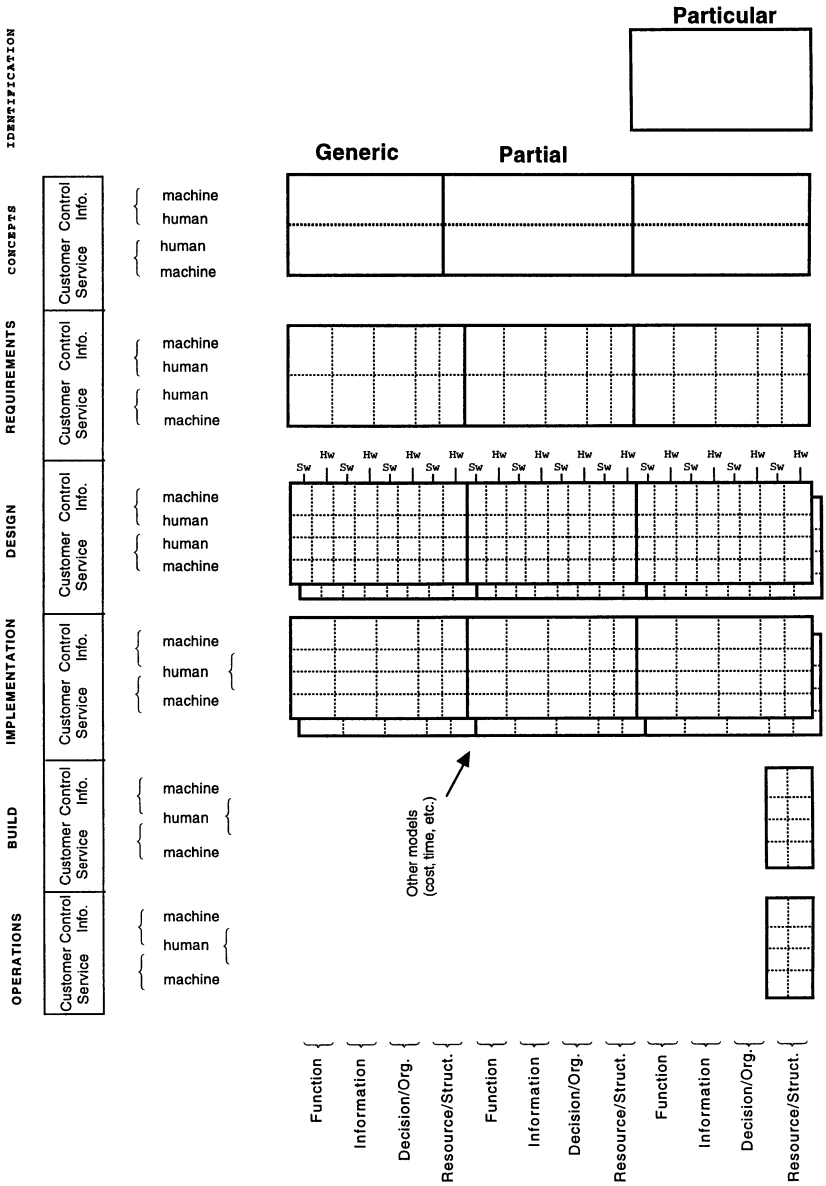

Figure 1 Matrix representation of the life-cycle of any entity.

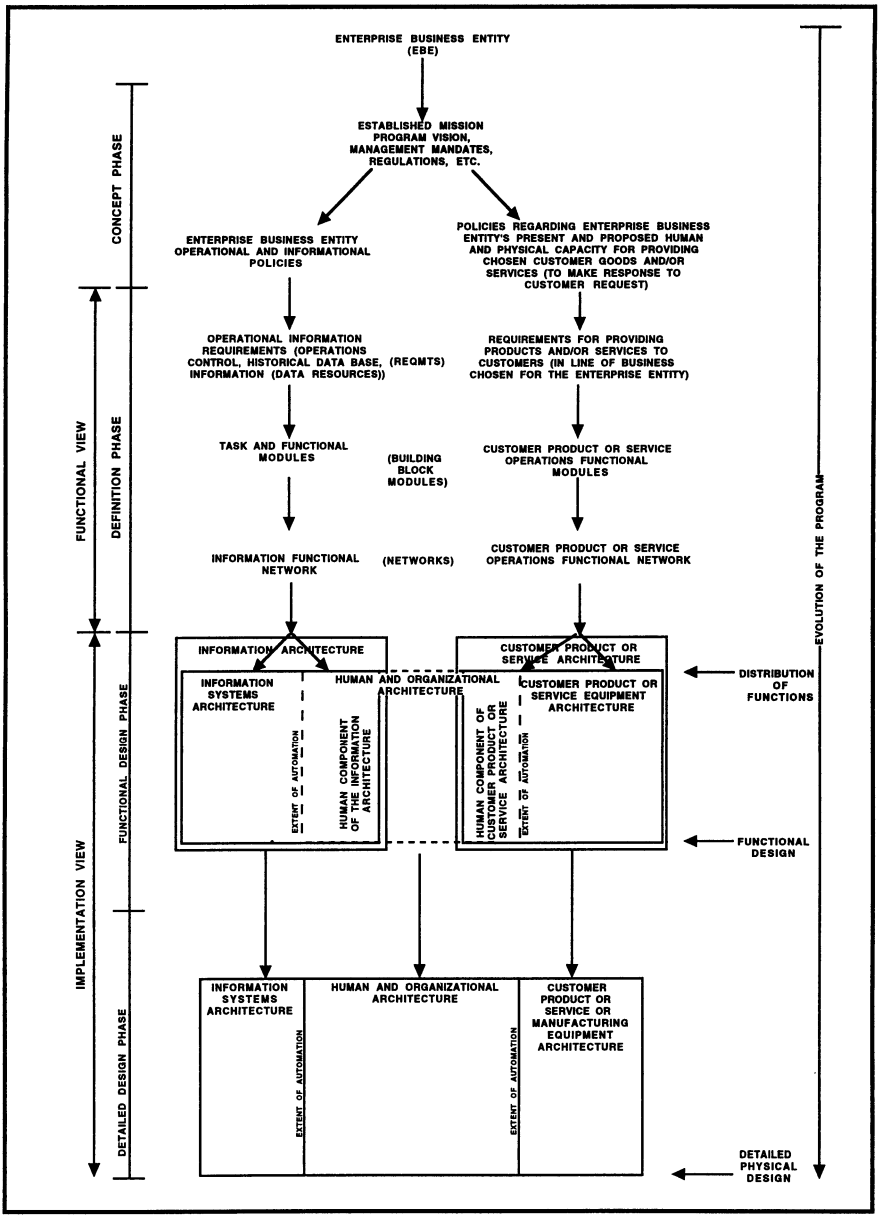

Figure 2 Detailing the development of an enterprise integration program.

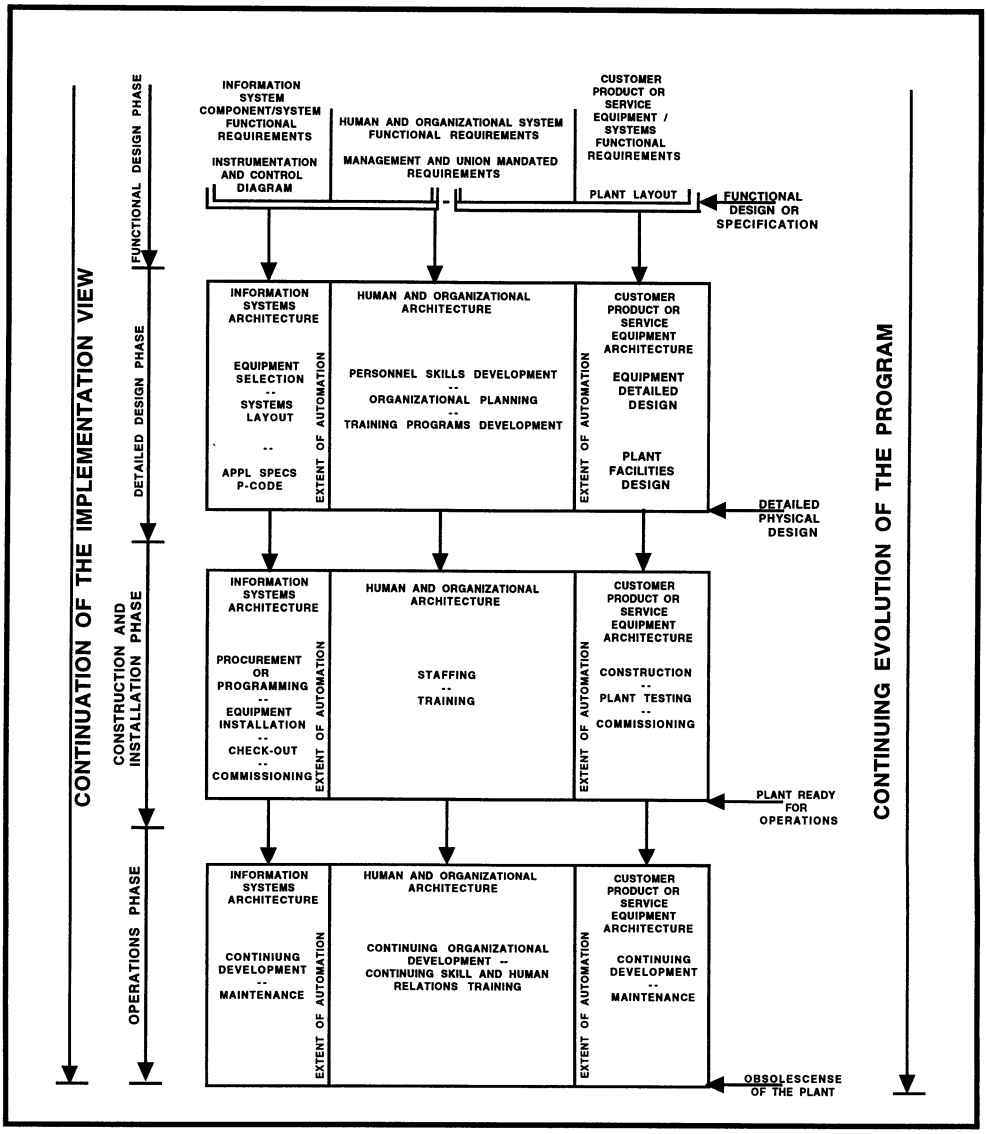

Figure 2 (cont.) The later phases in the detailing of the enterprise integration system evolution and its tasks.

1. Milestones to develop GERA:
   a) Take the Purdue Enterprise Reference Architecture, PERA, as the most complete in scope and add to it the areas discovered in the study of the four recursive matrices and their associated entities. This will include the development of the complete specification of GERA (i.e. including the concept, identification, and requirements and design of GERA). The specifications will also have to include the definitions of the other deliverables.
   b) Develop two presentation forms:
      1) Presentation of GERA for the user community:
         For the user community, preferably use the two tiered diagram format of PERA (Figure 2) (now presenting four such diagrams according to the four entities of Section 2). The two tiered diagram format will **group** together those "subject matter" areas which will belong together in the methodology. This presentation can be prepared on the basis of the PERA document by adding further chapters.
      2) Presentation of GERA for the developer and researcher (tools and theoretical aspects) community:
         The second presentation is for the methodology, modeling, research, and standardization community, preferably in the form of the four recursive matrices of Figure 1. The matrix presentation will be seen as a further development of the CIMOSA cube. The matrix presentation will use a refined subject matter presentation drawing on the one hand from the corresponding CIMOSA definitions and on the above subject matter groups (as developed for the user community).
2. Milestones to develop GEEM:
   a) Determine, given GERA, the areas which should be but are not yet covered by the Purdue Methodology (Williams, 1994).
   b) Extend the methodology regarding the specification and design of the decision system of the enterprise, based on GIM where these details are highly developed and tried.
   c) Based on the extensions to the CIMOSA modeling framework (GEMT) illustrate, with examples and specific instructions, the steps of the methodology.
3. Milestones to develop GEMT&L, GEM and GMs;
   Given the above uncertainties these milestones need to be re-evaluated in light of the feasibility of the first few steps.
   a) Determine which modeling tasks are not currently addressed by CIMOSA or GIM.
   b) Identify the complementing set of languages as needed. Draw on the IDEFX set of languages.
   c) Feed the result into the definition of the Generic Enterprise Engineering Methodology (GEEM) project. This ensures that the existing set of modeling constructs will be met by a compatible presentation of the Enterprise Engineering Methodology.
      Up to this point this is a feasible engineering project. The following tasks, however, need to be addressed by research.
4. Milestones to develop GTs;
   a) Integrate these languages (as described above) on the meta level — possibly using ontological theories such as developed in TOVIE (Fox, 1992) or IDEFX. Since the core CIMOSA languages are already based on one integrated meta-model this is not a project from scratch.
   b) Express the languages as views of an underlying ontology.

Comments by Task Force Members on this proposal as initially presented by Bernus and Nemes have concentrated on four major points:

1. The need on the part of final enterprise integration users for the simplest and most easily understandable and usable system of methodology, tools and illustrating architecture.
2. Means for allowing methodology and tool initiating and producing individuals and organizations to readily develop their offerings in this area and as equally readily incorporate them into the user's potential work package.
3. Means by which individuals and groups doing research and development in this field could easily contribute their findings to Item 2 above and eventually to Item 1.
4. The vital need for development and use by the Task Force of one agreed-upon Glossary. Even the most common terms in our field are used in different ways by each of the individual development groups in our Task Force, let alone others in the field.

Most prominent in the comments was the often expressed call for major help to potential users by developing a simple, easy-to-use, robust methodology with its associated tools and descriptive architecture. Excessive complexity was cited often as the principal impediment in the use of these technologies in industry today. In these times of drastically reduced engineering and research staffs in most companies, those companies simply do not have the personnel to devote the time necessary to learn and use the currently available systems in view of the present complexity and difficulty of understanding.

Bernus and Nemes had anticipated this message by proposing a two level system with the PERA two-tier diagram (Williams, 1992) (Figure 2) and the Purdue Methodology (Williams, 1994) as an initial recommendation for users applications. This would be supported by the second, or so-called matrix form of the architecture (Figure 1) to assist tool and methodology developers in their work. Finally they proposed the development of ontological models and theories as suitable and needed research tasks for academicians and other theoretical workers in the field.

The issue of a Glossary surfaced often during the Vienna meeting discussion (June 1994) and must be a priority topic in future meetings as even the most common terms have obviously different meanings when used by different individuals. An initial version of such a Glossary is included in the Purdue Methodology (Williams, 1994).

6 THE PATH AHEAD

The Task Force will thoroughly discuss the above results in its future meetings. The Task Force is committed to make a major report of its findings to date at the Triennial Congresses of its parent bodies: IFAC, the International Federation of Automatic Control and IFIP, the International Federation for Information Processing, both of which will be held in 1996.

The Task Force has committed itself to produce the following deliverables in its continuing program for the next two years of its current term:

1. A trade journal version of the GERAM definition article (Bernus and Nemes, 1994). This article will be produced in the near future to publicize the work of the Task Force.
2. A thorough review and early publication of the Purdue Methodology document (Williams, 1994) as the initial version of GEEM.
3. An investigation of the potential for developing a Hypertext version of Item 2 above.
4. Investigation of the need for specializing the Methodology of Items 2 and 3 for use by specific industries.
5. Development of a report and instructional guide for the use of CIMOSA Constructs with the PERA diagram and Methodology.
6. A teachable book for university and industrial classes on the CIMOSA architecture, tools, models and languages.

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8 BIOGRAPHY

Professor Theodore J. Williams is Professor Emeritus of Engineering and Director Emeritus of the Purdue Laboratory for Applied Industrial Control having retired in December 1994 after thirty years of service at Purdue University. He has been Chairman of the IFAC/IFIP Task Force since 1990. He is a Past President of the Instrument Society of America, of the American Automatic Control Council, and of the American Federation of Information Processing Societies.