1 What is AKM Technology?

Many scientists argue that the main reason why humans have excelled as species is our ability to represent, reuse and transfer knowledge across time and space. Based on mental models we grow our knowledge and wisdom through experiences and participative learning. Whereas in most areas of human conduct, primarily standard one-dimensional natural languages are used to express and share knowledge, we see the need for and use of two and many-dimensional representational forms to be on the rise. One such technique is traditionally termed *enterprise modeling.*

Visual modeling is today used for many purposes in most industrial sectors and application areas. For instance the automotive industry has used visual process and product modelling since the late 1990s. In 2006 automotive industry started developing visual knowledge models to build configurable product platforms, aiming to realize integrated life-cycle operations. In new approaches to Holistic Design, Product Family Design, Systems Engineering and IT the trend is towards model-based IT solutions using visual languages such as UML, BPMN and IRTV.

Industry still lack adequate IT support for the early project phases such as IT support for effective holistic design, involving capabilities for iterations, knowledge sharing, proactive team-learning, visual collaboration, and traceability. The trend is towards configurable product platforms for more effective innovation, for product variants supporting customized product design and manufacture. However, in 2008 idea-generation, initial studies and analyses, and conceptual design are still manual work, and documented using tools such as Word, Excel and Powerpoint. The tasks performed, the data defined, and the issues swirling in designers minds are lost. This knowledge is part of the logic expressing the design intent, design rationale and the core product concepts. There will never be support in IT application systems for growing and sharing design data in role-specific reflective views of emerging product structures and process task-patterns. Designers and engineers must be able to take ownership of their data and knowledge by defining data, by giving meaning through reflective views, determining value-ranges and customer specific values. To perform these tasks designers and engineers must have access to workplaces and services that evolve with the knowledge created and ag-

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gregated. This implies that data and knowledge has to be stored in and reactivated from what we call an *Active Knowledge Architecture (AKA)*. Active implies that its contents of roles, task-patterns, information structures and reflective views will automatically configure the workplaces. Work-centric data created by execution on the workplaces are directly folded back into the architecture, thus closing the learning loop. This behavior is instrumental to collaborative design and engineering.

AKM cooperates with industry projects to develop their *active knowledge architectures and configured workplaces* for effectively sharing and refining knowledge, and for defining new design project roles, properties, tasks and views. Collaboration, concurrent design and pro-active learning is supported by the active knowledge architecture with services to build knowledge structures, capture contents, build workplaces, and contextualize and configure workplace views. Applying AKM methodologies industry has started developing new approaches and methods to concurrently design products, work processes, systems, and smart service-team organizations. *This is the AKM meaning of holistic design.*

The industrial community has not been offered much new in terms of Systems Engineering approaches, work methodologies, and IT solutions over the last twenty years. The few exceptions that spring to mind are enterprise modeling, industrial information portals and more recently Web Services (WS) and Service-Oriented Architecture (SOA). This has left industry with a long list of unsolved needs and problems. The situation was analyzed and described in the IDEAS EU- project, and elaborated in the Athena Integrated Project (ATHENA 2007). The needs and challenges of these projects are synthesized and described in these twelve points:

1. Aligning business, ICT and Knowledge Management (KM),
2. Reducing costs for application portfolio management and integration,
3. Achieving more effective solutions development, delivery, deployment and integration,
4. Achieving predictability, accountability, interoperability, adaptability and trust in networked organizations,
5. Achieving ease of re-engineering, reuse and management of solutions,
6. Supporting concurrency, context-sensitivity, and multiple simultaneous projects and business processes,
7. Supporting multi-dimensional, collaborative product design and lifecycle innovation and knowledge capture,
8. Providing self-organizing, self-managing and re-generating solutions,

9. Semi-automating information and knowledge reuse and management,
10. Supporting learning-by-doing, enabling users to acquire and activate new knowledge as work is performed,
11. Achieving independence of system and IT experts,
12. Designing personal workplaces and harmonizing work environments.

Industrial needs and challenges are further discussed in Chap. 2. AKM is developing methodologies and web-platforms to offer solutions to most of these challenges. Dynamic, continuously improving, industrial computing solutions are required to meet the requirements and on-demand business opportunities of the new global networked economy. The customer solutions must be more effective and user-manageable, and must offer capabilities not achievable by current IT systems. A holistic approach is required, involving most key roles of innovation, capturing dependencies and changes in the many enterprise knowledge dimensions. This means developing and aligning the mental models of people involved, and taking multi-dimensional knowledge spaces and aspects into account. Building a project-specific active knowledge architecture would allow early prototyping of workplaces, thus involving key users in creating their own work processes, emphasizing collaboration and cooperation.

Enterprise Modeling (EM) grew out of modeling techniques motivated by more effective IT engineering and use. The four IT inspired modeling origins were the initiatives for CASE tools, modeling processes, product structures, and information structures. Enterprise Modeling has been defined as the art of externalizing enterprise knowledge, i.e. representing the core knowledge of the enterprise (Vernadat 1996). Although useful in product design and systems development, for modeling and model-based approaches to have a more profound effect, we propose a shift in modeling approaches and methodologies. Model-based approaches and methods must enable *regular industrial users to be active modelers***,** both when performing their work, expressing and sharing their results and values created, and when adapting and composing the services they are using to support their work. Modeling should become as natural as drawing, sketching and scribbling, and should provide powerful services to capture work-centric, work-supporting and generative knowledge, for preserving context and ensuring reuse. A solution is the application of what we term Active Knowledge Modeling (AKM). Although active knowledge modeling have potentially value and usage across a large range of knowledge creation and knowledge representation tasks, our focus is the use of these techniques in providing IT-support for performing creative and innovative work.

New Systems Engineering (SE) approaches and IT solutions based on active knowledge architectures will emerge, offering capabilities that will reduce lead-times and budgets for developing, deploying, operating and managing field extendable solutions by units of time and cost.

1.1 Definition of Active Knowledge Modeling

The Active Knowledge Modeling (AKM) technology (Lillehagen 2003) is about discovering, externalizing, expressing, representing, sharing, exploring, configuring, activating, growing and managing enterprise knowledge. An AKM-solution is about exploiting the web as a knowledge-engineering medium, developing knowledge-model-based families of platforms, model-configured workplaces and services. Working in these environments means augmenting the mental models of the human mind.

Coherent and consistent knowledge elements, created by the different kinds of models built, are structured and managed in one or more *Active Knowledge Architectures (AKA)*. Active knowledge architectures will enable the capabilities of what earlier research on "Corporate Memory" failed to achieve and much more. Situated knowledge can not be managed by traditional software tools on top of a static data model alone.

The AKM approach and integrated methodologies, captured in the AKA, will allow humans to exploit more than the 7% of the capacity of the left hemisphere of the brain, and to express and share internal knowledge resulting from performing work and actions. Most work-centric knowledge would otherwise remain tacit. So AKM enables us to capture, share and benefit from situated, work-generative knowledge that otherwise would remain tacit in the minds of those involved. Team collaboration in visual scenes amplifies individual knowledge capture and learning.

Active and work-centric knowledge has some very important intrinsic properties found in mental models of the human mind, such as reflective views, recursive tasks, repetitive roles, and replicable knowledge architecture elements. The best way to benefit from these intrinsic properties is by enabling users to perform knowledge modeling using the AKM platform services to model methods, and execute work using role-specific, model-configured workplaces. So active knowledge modeling must become as easy for designers and engineers as scribbling in order for them to express their knowledge while performing work, learning and excelling in their

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roles. This will also enable users to capture contextual dependencies between roles, tasks, information elements and the views required for performing work. So modeling roles and tasks in sufficient detail and granularity, as discovered by the CIMOSA project (Vernadat 1998), is crucial for preserving context and the meaning of data for various roles.

The multi-dimensional evolution from ideas, to design concepts and to engineered products and systems must be captured to facilitate iterations and model-driven workplace updating. Designers designing on a model-configured workplace will simultaneously create their product concepts, the languages to express the concepts, and the tasks and views to enhance their workplaces. Each time a designer or engineer performs a project service a cascaded task-structure may be triggered to automatically execute more background routine services, such as change notification.

The AKM technology reforms and extends the roles for enterprise modeling to address important issues, such as:

- Modeling specific roles, tasks, information and views to capture context, and to configure and generate role-specific workplaces,
- Modeling products, organizational resources, processes and systems to support core industrial design and engineering knowledge,
- Modeling properties and parameter-trees and their values and value-ranges as separate structures, independent of objects,
- Managing corporate modeling elements and workplace contents in an active knowledge architecture,
- Managing contextual descriptions of work, and workplace configurations to support extensive reuse of knowledge and data,
- Enabling industrial users to build and manage their own working environments, workplaces and services,
- Enabling life-cycle data and knowledge management, capturing and sharing experiences, unresolved issues and lessons learned,
- Expressing knowledge readily reflected as updated menus and views in model-configured workplaces,
- Building knowledge models and architectures of methodologies, information libraries and reference models, currently only available on paper,
- Building collaboration spaces and visual scenes for design, engineering, work process experimentation, validation and pro-active learning.

To be an *active model* a visual model must first and foremost be available to the users of the operational information system at execution time. Second, the model must automatically influence the behavior of the computerized work support system or workplace. Third, the model must be dynamically extended and adapted, users must be supported in changing the model to fit their local needs, enabling tailoring of the work environment's behavior. Industrial users should therefore be able to manipulate and use active knowledge models as part of their day-to-day work (Jørgensen 2001, Jørgensen 2004).

Recent platform developments (AKModeling 2007, Intalio 2007) support integrated modeling and execution in one common platform, enabling what in cognitive psychology is denoted as "closing the learning cycle". This implies that knowledge modeling, expressing and architecting work-centric knowledge, will be performed by users executing workplace services and thus allowing:

- Discovery of the powers of visual models, visualizing data and information. Examples are application demands for operative architectures, visible inventory and visible project management.
- Models to contain actual project knowledge, situated knowledge, and work-generative data, avoiding redundant models,
- Viewing of critical data at runtime for monitoring processes and collaborative work, satisfying the cry for so-called dashboards in IT Governance and Collaborative Supplier Management
- The demand from some markets for active or living pragmatic knowledge capture, being able to collaborate on performing complex tasks, and supporting the fulfillment of four of the "12 I"s; - involvement, interaction, integration and interoperability.

Active knowledge modeling is capturing knowledge involved in building workplaces, in supporting work execution, and knowledge generated by work execution. There are many definitions of knowledge, as we will discuss in Chap. 12, dependent on the roles expressing the knowledge and their proximity to the action or the work performed. AKM can accommodate all of them, but focus is on capturing work-generative and –supportive data and knowledge, tacit knowledge, and closing the value-cycle integrating the reflective views of these knowledge aspects.

Introducing AKM to support product, process and system design and development will enable new approaches and ways of working that will have a huge impact on industrial use of IT, on Systems Engineering and on many other technologies and sciences.

1.2 State-of-the-art overview

It is possible to track modeling back to the late 50-ties, with the work of (Young and Kent 1958). Modeling approaches as we know them today within the information system field were introduced in large scale in connection around 30 years ago, with developments of such techniques as DFDs (Demarco 1979) and ER-diagrams (Chen 1976). In the beginning, focus was on developing conceptual modeling languages that would highlight *the* important concepts of the world, typically containing a few, general concepts, depicted with simple and abstract visual icons. The languages were developed for IT-experts to do the model building as a consultancy service, although intended used as a communication-artifact towards different types of 'domain experts'. In the eighties, there were a large number of proposals for *the* right modeling notation. The understanding that language appropriateness depends on the situation and the objectives of modeling grew in the late 1980s. To address this situation, meta-modeling approaches started to appear around 1990 (Kelly, Lyytinen and Rossi 1996), making it possible for projects and organizations to extend existing modeling languages and notations, or creating entirely new modeling languages from scratch. Still the main users of these techniques are intermediaries (e.g. analysts, designers) and the models built are meant to document the knowledge as held by different stakeholders for further use, rather than for workers themselves to use as services for knowledge representation, creation and reuse tailored for their own needs.

Whereas the first modeling approaches where focused on software development, the area of enterprise modeling provided in the eighties similar techniques to a wider organizational scope than IT-systems. On the other hand, after fifteen years of industrial enterprise modeling, visual models are still primarily consultancy tools for providing help in understanding and resolving complexity. State-of-practice in EM has progressed furthest in certain manufacturing industries, and in particular with respect to these four areas:

- Enterprise Architecture (Vernadat 1996) is currently the most vivid and fastest growing market particularly in the US.
- Business Process Modeling (Havey 2005) looked like a fast growing market already around 1998, but new requirements for web-service security and safety have slowed it down. As for BPM (Business Process Management), the area appears to be on the rise.
- Business Intelligence or Enterprise Performance Analyses is another promising market that has as yet to really take off.

- Model-based Systems Engineering (MBSE) (Stahl and Völter 2006) is rapidly gaining momentum, but industrial large-scale references are still scarce.

We believe that the major reasons for this slow acceptance and modest market penetration are mainly the fact that EM is still a tool-based effort for experts, lacking scientifically and practically founded methodologies, and dynamic visual languages and services to support pragmatic industrial work. In summary the characteristics of the EM languages, approaches and usage of models by industry are:

- Enterprise knowledge can only be represented in predefined, vendor proprietary or prematurely standardized modeling languages,
- The modeling approach, roles to engage, tasks to support and views to create are predetermined and cannot be adapted to the case in hand,
- Modeling is not an integral part of engineering or product development, but performed in isolation by specialists,
- The user interface is static and systems engineer oriented, and supports just one style of modeling,
- There is limited support for knowledge externalization, sharing, reuse and management,
- Most models are collections of static views and diagrams and give no support for adaptation and extension of meta-models,
- Models and modeling environments are detached from solution execution platforms,
- The leading concepts for modeling languages, view management and parameter definition are restricted to object-oriented thinking.

A comprehensive source on EM can be found in the ATHENA project (ATHENA 2007), and we will go in some more detail on some of these approaches. It is fair to state that so far EM is just another technology island in the non-interoperable industrial tools and systems landscape. Current standardization activities have little effect on industry. Although many such activities are going on, present standards (e.g. ENV 12204 or DIS 19439) are rarely used within industry. Now, this situation is about to change. The goal of AKM technology is to make explicit and exploit knowledge that add value to the enterprise and can be shared by business services and users for improving the agility and performance of the enterprise, and for getting much more value from IT and web technologies.

1.3 Discoveries and Core Concepts

The ten founding discoveries of the AKM technology dates back to 1990 when a team, headed by Frank Lillehagen, was engaged in innovative car projects with Volvo Cars, Gothenburg. The ten discoveries made in the early 1990s are in current language described to be:

1. Enterprise knowledge exists in *nested multi-dimensional bounded spaces*, and in delimited layers and domains,
2. The spaces and dimensions involved in enterprising and product design are not linear nor orthogonal, they reflect *human mental models with perspective views,*
3. Most enterprise *aspects and views are mutually inclusive* – as a consequence of the nested knowledge spaces, ref., the war-room thinking (Zakis 2007).
4. The world is *both perspective view (method) and object oriented* – we need to integrate mental and object-oriented computer models and views, producing work sensitive models,
5. *Mental models in the human brain*, with perspective and computed views, content and context contributed by specific roles, is poorly understood and currently not exploited by IT people.
6. Existing models are based on and bounded by diagrams, charts and mathematical formalisms, there is no capture of situated knowledge, exploiting the intrinsic knowledge properties,
7. Process- and work- flow, and time-dimension phase dependencies must be relaxed/expanded, and minimized by providing intelligent working environments,
8. Present systems engineering approaches will never adequately handle properties, parameter trees and multiple value-sets,
9. Learning, design and problem-solving are intimately related, use similar methods, and have similar service and viewing needs,
10. Deployed legacy systems are a challenge, but small compared to the prevailing *legacy thinking*. Vaults of information documents describing design rules, materials, reference models, and more should become sharable active knowledge.

The discoveries imply that knowledge exists as both object-oriented IT structures and as perspective method-oriented structures, such as the life-cycle view, where different roles perform tasks to add methods, content and context in some common views as well as in role-specific views.

These discoveries would not have been possible without the intimate cooperation of industrial practitioners, engineers and IT experts. The sources and foundations of these discoveries are further described in Chap. 12, and their future outlook as collaborative visual scenes are discussed in Chap. 11.

1.4 State-of-Practice - An Example

The first industrial piloting of visual model-configured workplace solutions were started at Kongsberg Automotive in the Autumn of 2006 as one of three industrial scenarios of the EU project MAPPER, IST 015 627. The objectives at Kongsberg are improved seat heating design, better product quality, less data errors, and improved ways of working. Better work processes for interpreting and fulfilling customer requirements and producing supplier specifications will be developed. The needs of Kongsberg are close to identical with the needs expressed by companies in other industrial sectors, such as aerospace, construction and energy systems.

Short term Kongsberg's needs and goals are to:

- Capture and correctly interpret customer requirements,
- Create role-specific, simple to use and re-configurable workplaces,
- Create effective workplace views and services for data handling,
- Improve the quality of specifications for customers and suppliers,
- Improve communications and coordination among stakeholders,
- Find a sound methodology for product parameterization, automating most of the tasks for product model customized engineering.

To fulfill these goals they are applying the AKM approach, adapting several methodologies and building knowledge model-based workplaces.

With time Kongsberg Automotive has focused more on developing an active knowledge architecture supporting parameterized seat heat product family design. Sofar five workplaces have been model-designed, -configured and –generated;

- the material specification workplace, as illustrated in Fig. 1.1. It shows the workplace for the designer responsible for material specification entering the parameters in the model generated environment. This case will be further explained at the end of Chap. 9.
- the customer product specification workplace,
- the customer solution configuration workplace
- two workplaces for designing configurable product components.

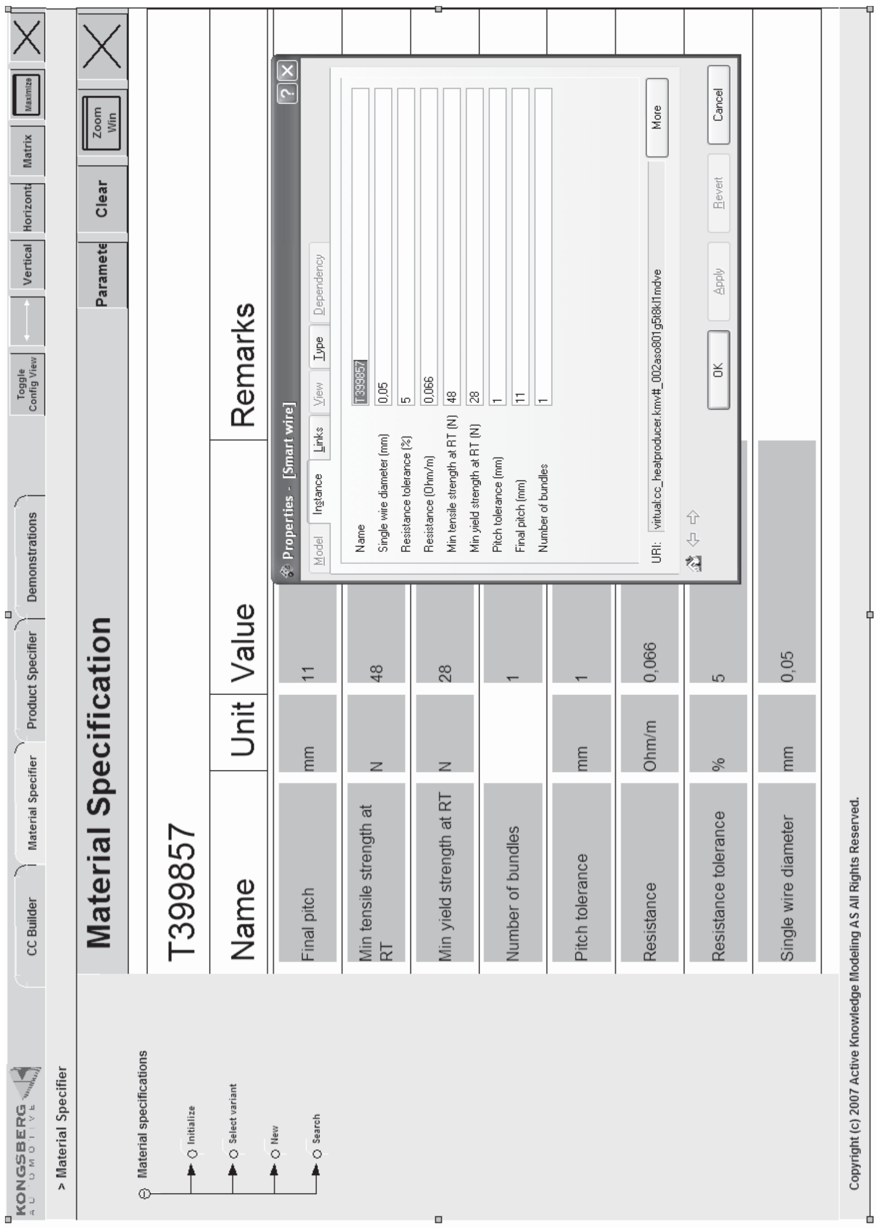

Fig. 1.1. Model-configured workplaces for material specification of heating wire

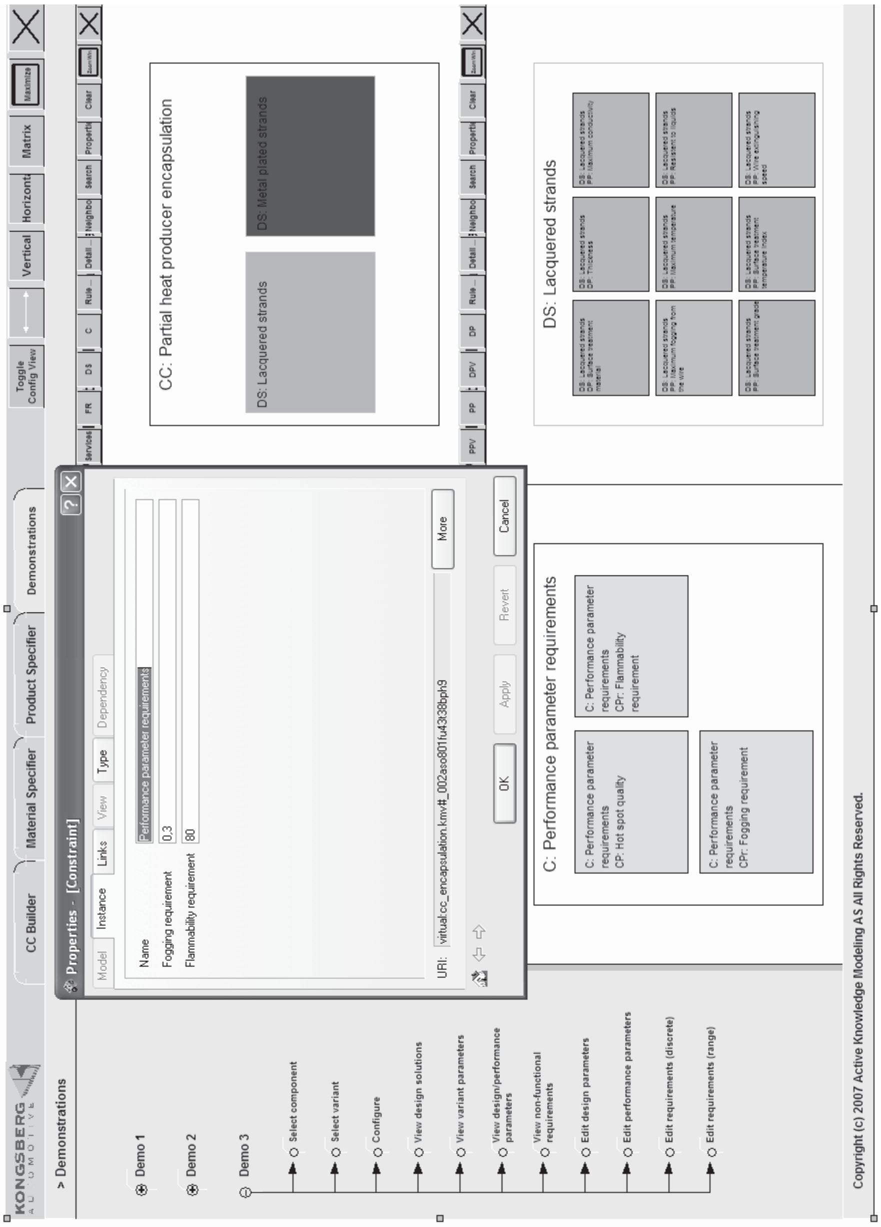

Fig. 1.2. The seat heating design workplace for configurable components

Each workplace is built by configuring knowledge architecture elements captured in three or more different kinds of knowledge models. The different kinds of models used to design and model-configure and model-generate workplaces are explained in Chap. 6 on new approaches to industrial solutions.

The dynamic evolution and adaptation of work-generative content and context, the workplace composition and the user preferences are impossible to support by programming and compiling the logic. This is simply because any extension or adaptation of contents in one solution model and its views need to be reflected in other models and views that will be used to model-configure other workplaces. The tasks to be executed are totally dependent on the context created by inter-relating workplace contents and configuration models, Experiences verify that product and material requirements handling and supplier specifications of the Kongsberg seat comfort product line has been improved in data quality and reliability.

The materials specification workplace is accepted by the users, but will get additional services to manage and communicate design issues among customers and suppliers The customer product specifications workplace will be further developed and related to three or more role-specific workplaces for product design;- the product family responsible, the customer product configuration responsible and the product portfolio responsible.

In the customer product specifications workplace colors are used to indicate the degree of requirements satisfaction, parameter consistency and the solution fit to meet the requirements. The more role-specific the workplaces, their tasks, views and data are modeled, the bigger the potential to further exploit the resulting knowledge architecture elements, and reuse the reflective views and task-structures.

The Kongsberg seat heat solution is modeled by a team composed of Kongsberg product designers and engineers, and AKM knowledge architects and model and workplace builders, concurrently developing and adapting the many kinds of models required for the workplace solutions. The first version of the AKM platform and the first prototype components of the Collaborative Product and Process Design (CPPD) methodology are developed in this use-case. This is producing some extra challenges for the model building team. The CPPD methodology is providing the methods, meta-data and services to enhance the AKM platform with configurable components for building customer product architectures.

1.5 The AKM Products

The people behind the AKM company (AKM AS 2007) founded in September 2006, started developing the AKM technology and products as far back as 1998 with the definition of a series of EU financed projects. AKM has defined four main product lines:

- The AKM Approach providing delivery services to customers
- The core AKM Platform tools, workplaces and services (Described in more detail in Chap. 8)
- The Visual Solutions Development (VSD) methodology using the C3S3P steps (Described in more detail in Chap. 7)
- The Collaborative Product and Process Design (CPPD) methodology (Described in more detail in Chap. 9)

The approach has been refined many times over the last years, and the customer delivery of role-specific workplaces, work processes, services and views, are starting to solidify. The delivery process roles and workplaces development will accelerate with more challenging customer projects. The AKM Platform has proven its capabilities, and will guided by industrial project experiences, be extended with the necessary systems integration capabilities. The CPPD methodology, targeting the design of product design platforms, collaborative engineering, and systems integration consists of twelve or more components. Some of the components need more industrial project development and validation, but the configurable product component, the configurable workplace, and four more components have been through solid development and testing in three industrial projects addressing different products and sectors.

1.6 Enterprise Knowledge Spaces

The first enterprise knowledge space, defined by the Product-Organization- Process and Systems (POPS) dimensions, was discovered as early as 1992. Its integrating capabilities were confirmed in EU projects during the late 1990s, and a uniform modeling language was developed in the ATHENA project in 2005 (Ziemann et al 2006). A major contributor to the discovery was work performed in the automotive industry on war-room or multi-dimensional thinking and Doug Engelbart's bootstrap approach. The existence of the other knowledge spaces of enterprises matured from 1998 to 2003, but the exploitation has not been possible until recently due to lack of expressiveness and dynamic extensi-

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bility of visual modeling languages by supportive active knowledge architectures, tools and services. The last piece to fall into place was the understanding of how fundamental the personal and role-specific knowledge spaces and workplaces are in being able to execute work, capture context and access and maintain knowledge architecture content. This understanding has enabled the implementation and operation of Active Knowledge Architectures (AKA)™, enabling industrial users to define and manage their own detailed knowledge elements, local data, views and model-configured services.

The four categories of generic work-sensitive knowledge spaces we have discovered and modeled are defined and identified by simple names on the four key knowledge dimensions defining each space:

1. The role-specific knowledge space, defined by Information, Role, Task, and View, abbreviated and referenced as IRTV,
2. The innovation space, defined by Product, Organization, Process and System, and abbreviated and referenced as POPS,
3. The business space, defined by Services, Networking assets, Projects and Platforms, and abbreviated and referenced as SNPP,
4. The community space, defined by Values, Resources, Initiatives and Infrastructures, and abbreviated and referenced as VRII.

These knowledge spaces exist in all enterprises from two people collaborating to global value-chains. The spaces are bounded by identifiable but fuzzy borders. Now, whether the borders are a result of pragmatic boundaries, such as gateways between project phases and the isolated roles of engineering disciplines and so forth, or whether they are caused by limitations inherent in the mental models of our brains remains a research issue. Enterprise knowledge spaces are further discussed in Chap. 13.

As we started discovering in 1991 at Volvo, object-oriented thinking is powerful once you have performed design of an artifact, but it does not provide direct support for design and creative work as object classes represent rule-constrained knowledge.

Product and system design starts with defining conceptual artifacts, concepts of objects, properties and task-structures, with no predefined types or flows, and then the concepts undergo functional system design with capabilities to define parameters and rules for embedding properties as parameter-trees. One may say that the IT world we have designed and manufactured so far is object-oriented, but what we need to deliver in the future must combine the best of object-oriented and mental-model knowledge representation principles.

1.7 Active Knowledge Architectures

An Active Knowledge Architecture (AKA) is a project or sector specific ”knowledge landscape”, built using sector and project specific IRTV languages to capture contents from the customer, such as innovative and project knowledge spaces, creating the POPS, SNPP and VRII languages, for including other customer knowledge dimensions and aspects. The purpose of any AKA is to give product designers, engineers, architects and other stakeholders involved common languages and workplace contents for building interoperable, collaborative and reusable customer platforms, enabling re-configurable workplaces, collaboration spaces, services, and knowledge elements. AKA structures and contents are built and maintained by customer engineers, working in project teams with partners and suppliers. The resulting AKA will therefore have reflective knowledge layers supporting the various enterprise teams.

Building an AKA starts by modeling a customer scenario using what AKM calls the Enterprise Knowledge Architecture (EKA) as a model template. The EKA is a generic knowledge model, able to represent any AKA content as information, roles, tasks, and views (reflecting the IRTV language). This methodology should not to be confused with the goal-information-task approach of the International Society for Performance Improvement. Roles can range from task and work process roles, to personal, team roles, and roles for entire enterprises. The purpose of the EKA is to give knowledge model designers and engineers a common language for building interoperable, collaborative and agile active knowledge models and architectures, supporting community wide reusable, re-configurable knowledge elements.

The EKA is the most abstract and general enterprise model of the entire family of enterprise models, acting as a family reference model for all other kinds and variants of enterprise models. An AKA, built using the EKA template, integrates all other enterprise architectures, such as product architectures and system architectures. An enterprise specific AKA will support simultaneous modeling, meta-modeling, model management and work execution, using model-configured and -generated workplaces (MGWP), see section 1.7.2. Relationships between AKA, EKA, and ICT infrastructure is depicted in Fig. 1.3.

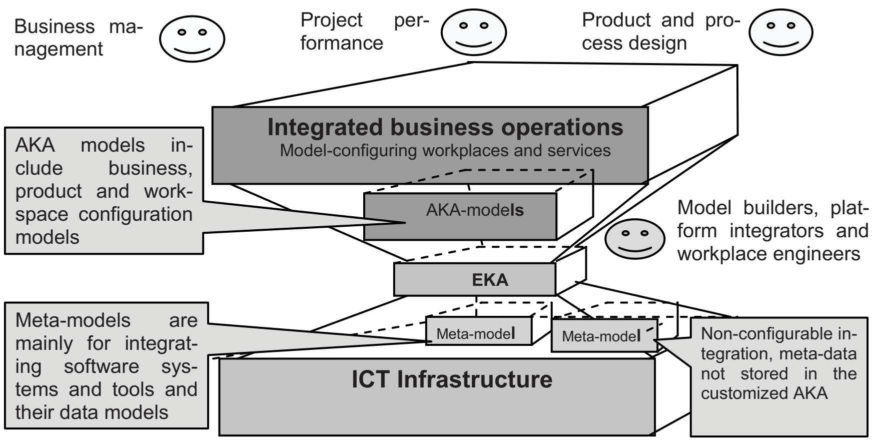

Fig. 1.3. Active Knowledge Architectures integrate enterprises

Intelligence is normally attributed to the associative and creative capacities and capabilities of the human brain, and just as knowledge is externalized and represented in the AKA so is intelligence. In this context we define intelligence as: "*The ability to interactively reuse knowledge to perform actions, and to automatically update knowledge elements and structures when performing actions.*" Knowledge elements, structures and views are adapted, extended, coordinated and managed by role-specific services, that for quality assurance should be implemented as recursive and repeatable work processes (what we term task-patterns). The task trees, supporting these work processes, are themselves part of the AKA. Any task can be model-configured, invoked and executed as need arises, supporting unpredictable situations. Execution of most tasks may vary between automatic and highly interactive depending on the context. This means that self-adaptive, self-organizing solutions are possible, whenever situated knowledge models are built, workplaces are model-updated and activated.

1.7.1 How to Represent Enterprise Knowledge

An AKA is sets of role-, task- and information-specific, inter-dependent structures of views, both computer and mentally captured and managed. AKM therefore has a new definition of knowledge; *"Knowledge is a continuous flux of reflective views between human minds and external media"* To possess knowledge you must therefore acquire three or more views of any artifact or scene of action. Consequently, knowledge management is best performed by making sure that adequate role-specific views are created and configured, and by associating the views to the task-patterns defining, updating and managing them.

The AKA contents may come from many sources and knowledge spaces, dimensions and domains externalized and captured by knowledge modeling and work execution. The main source for designers is of course their own mental model of associative perspective views. To support designing, externalizing, sharing and representing role-specific knowledge elements, AKM has developed the EKA, the generic knowledge architecture model and reference template. The EKA defines the most abstract, general and accommodating modeling language, allowing modeling teams to inter-relate all kinds of enterprise knowledge elements, and to define and manage the elements de-coupled from software systems and components. The EKA supports adaptable visual languages by inter-relating similar knowledge elements without having to classify them, and automatically yields interoperable Active Knowledge Architectures.

The approach to building and representing an AKA involves modeling these knowledge models and storing their elements in the AKA:

- use-case scenarios, focused on role-and task-specific data and views
- integrated and use-case adapted methodologies
- platform integration, and workplace configuration models
- workplace setup and behavior rules

Building and storing these models and their elements transforms the EKA or any existing AKA to an operational scenario-specific AKA.

These enterprise knowledge architectures are vital for the formation, integration and operation of intelligent enterprises and smart organizations, and should be visually editable and manageable in a web environment to harvest the full benefits of visual knowledge architectures. The AKA should also offer meta-modeling capabilities to function as an industrial system engineering platform, providing an environment to integrate and perform IT applications and web services. Application services are work processes, single or cascaded tasks, configured and stored in the AKA for re-activation and repetitive execution. The services that will be provided in workplaces, supported by the AKA, are services to build knowledge models, to build collaboration spaces, to configure workplaces, to monitor project execution, to do work management, and finally services to perform work. Persistent storage of the AKA can be partially hidden from users, by implementing task-patterns to automate the communication between the web-based AKA and any knowledge repository.

Most existing architecture modeling frameworks like (Zachman 2007), CIMOSA (Vernadat 1998), TOGAF (Open Group 2000) and GERAM (1999) represent useful methodology views, but all of them are lacking in granularity, in reflective views and meta-views, in support for meta-modeling languages, and in model activation and management structures. These are crucial knowledge constructs and structures for enterprise integration at all layers, and for linking to execution engines.

No other known technology is aware of the key intrinsic properties of situated knowledge, the nested knowledge spaces, and of the integrating properties of a logically consistent, dynamically coherent AKA layer. All AKAs are created from a generic Enterprise Knowledge Architecture – EKA template. The EKA is the base for interoperable families of AKAs. The AKA must be designed for each enterprise, but the design is based on extensive reuse of constructs and structures across sectors and projects, and on re-activation of generic tasks as design services.

1.7.2 Model-Generated Workplaces (MGWP)

A model-generated workplace is a working environment for the business users involved in running the business operations of the enterprise. It is a model-generated user platform that provides the graphical front-end for human users to interact with services, views, data and knowledge elements, supporting their day-to-day business activities. At Kongsberg Automotive Mullsjø Works three models are concurrently developed and adapted to ensure knowledge and workplace consistency:

- the model of the seat heat design roles, and the information, tasks and views that Kongsberg designers assisted by AKM expert model builders have built to capture future innovative seat heat principles, ideas and any product family evolution,
- the configuration model of each role-specific workplace, capturing its tasks, views and information elements and data, and finally
- the solution and workplace builder workplace model allowing the AKM workplace developer to add new capabilities and contents to the knowledge architecture and the generated workplaces.

A workplace can be tailored to meet the specific requirements of different roles or persons within an enterprise, providing customized presentation and operation views. This is achieved through Model-configured and User-comPoSable services (MUPS). These services make use of knowledge models to generate business-oriented and context-aware graphical user interfaces.

This manuscript is published by Springer as 978-3-540-79416-5. Available at http://link.springer.com/book/10.1007/978-3-540-79416-5/page/1

Figures 1.1 and 1.2, from the Kongsberg seat heat use-case, depict practical examples of model-generated workplaces. The figures illustrate that persons filling the same general roles, accessing the same IT services and knowledge assets, actually may still prefer and use different views. For project monitoring some people would use Gantt-charts while others might prefer role swim-lanes with assigned tasks. For activity reporting, bar graphs visualizing budget spending, and Web documents reporting on activities are views supporting important methods even though inherited from the paper world. The different views may reflect the same knowledge asset in a different form or manner that best suit the role or person using that asset in a given context. Information represented in the different views is based on contents of the same active knowledge architecture and models and therefore ensure information consistency. Many MGWPs are implemented on Web portals for security mostly. MUPS services specify and generate the Web elements in the portals.

1.7.3 Model-based Holistic Design

Design theories and practices exist in abundance, but common to them all is that they are based on distinctly defined project phased structures and lack layers of abstraction and generalization of common product artifacts. Few industries have common conceptual views or an architecture of their products, and no common integrated product description exists. Product design and engineering disciplines have since the industrial revolution developed phased and discipline-oriented product structures, or rather isolated product structure views. This has resulted in many non-cohesive and disjoint product structures with predefined object types, parameter sets and values, and phased sequential information flows. Actually studying most available sources on design theory you are made to believe that this is pragmatic reality. These disjoint, delimited, product structures are the cause of many of the industrial challenges we will discuss in Chap. 2. To more effectively support design AKM provides visual language definition services to enable industrial designers to dynamically define evolving product artifacts, combining object instances, properties and task-patterns by capturing the designer actions as an integrating task-pattern.

The fact that industry can now develop languages and methods to express conceptual artifacts, capture innovative situated knowledge, and integrate the disjoint product structures into coherent product family model representations will open up for product mass-customization. Integrated product architectures are key structures and contents of the AKA, capturing new aspects of design, such as experience aggregation. This will support collaborative design, concurrent engineering and global teambuilding, which is what we call holistic design. It promises to revolutionize industrial product design, engineering, and manufacturing including Systems Engineering (SE).

1.7.4 Model-based Systems Engineering

Systems engineering has not seen much new since the introduction of databases and database schema design using ER techniques and more recently object-oriented modeling methods. Systems Engineering (SE) as practiced in many communities are still based on monolithic, strictly sequential, single role and single view waterfall processes. Although new methods, such as agile modeling (Ambler 2002), is trying to attack this differently, the majority of agile approaches are still code-oriented, not active knowledge modeling oriented. This is very different from the current industrial approaches to product design, but as stated, product design also has big needs for improvements in how to express and represent product knowledge. The two disciplines could actually both do with a new holistic and common model-based approach and model-designed, integrated methodologies.

Industrial conceptual design is for a large part data-modeling. Design data and the context giving meaning to data and values is captured in the AKA. The database schema could therefore be automatically derived from role-specific elements and data in the AKA. The database schema is today defined by IT people to precisely accommodate and identify data, but could be generalized to accommodate all data definitions and contexts as captured in the AKA. No matter what IT systems offer in terms of services, the layers of compiled code on top of the data-model have made them inaccessible and non-manageable by industrial users.

1.8 The Core Modeling Languages

In connection to the ATHENA project (Ziemann et al 2006) we have, based on the innovation space – POPS, developed a first version of a unified enterprise modeling language to enable the exchange of enterprise models independent of tools. The partners have provided new solutions for open, tool-independent visual languages to model enterprise core knowledge aspects. These languages offer consistent and coherent enterprise descriptions, and represent a scientific basis for enterprise modeling, but integrated operations require that the POPS languages are defined and adapted by model-configuring them using the IRTV languages. The core business knowledge of any enterprise is the four inseparable dimensions of product, organization, process and system (POPS). The POPS dimensions have several intrinsic properties, such as reflective views, recursive work processes, repetitive roles and tasks, and replicable solutions. In order to create contextual, re-configurable knowledge model-based solutions, and replicable meta-models and templates we must add the IRTV methodology for improved language granularity and context preservation.

Business and other aspects and views are derived from these core enterprise knowledge dimensions, enabling us to define, calculate and manage parameters and balance attributes and value-sets across disciplines. Any EM language must be a derivation from this core, otherwise it will not be able to produce quality, manageable models and solutions. Implementing the IRTV and POPS languages has to do with the definition of the “grammar” for descriptiveness and expressiveness, for representation, for extensions and adaptations and for lifecycle reuse and management.

1.9 Towards Enterprise Visual Scenes

Enterprise Visual Scenes (EVS) can provide users with modeling approaches, user environments and solutions for knowledge creation, sharing, engineering and management, meeting most of the industrial challenges discussed in Chap. 2.

The most advanced EM approaches and tools contribute to solving interoperability problems by increasing the shared understanding of the enterprise structures, rules and behavior. EM provides methodologies for the identification of connected roles, objects and processes between enterprises from different perspectives. Sets of software applications used in the enterprises and their relationships can be identified with EM, and their degree of interoperability can be analyzed. Many languages and tools (more than 350) exists that support some form of EM with partially overlapping approaches. Today, several attempts to combine languages are being pursued. For example, the Unified Enterprise Modeling Language project has prototyped an integrated approach for exchange of enterprise models among EM tools, work that was continued within the EU NoE INTEROP (2007) and in the ATHENA project as described above.

As indicated above, traditional enterprise modeling shows various inadequacies in a number of areas: representing enterprise knowledge, combining enterprise models, maintaining enterprise models, developing manageable structures of meta-models, enabling model generated solutions, supporting dynamic user environments, and creating the link with software execution platforms. The solution of EM tool fallacies is to develop common core languages, services, modeling constructs, models and meta-model structures based on a common infrastructure (Karlsen et al 2003). The core components of an AKM built platform are:

- its core modeling languages: POPS – Product, Organization, Process, System, and IRTV – Information, Roles, Tasks and Views,
- its approach (C3S3P – Concept Testing, Scaffolding, Scenario Modeling, Solutions Modeling, Platform Configuration, Platform Delivery and Practicing, Performance Improvement and Operations),
- its methodologies (CPPD – Collaborative Product and Process Design),
- its enterprise knowledge spaces and the generic Enterprise Knowledge Architecture – EKA (the enterprise of all enterprises),
- its customer specific Active Knowledge Architecture – AKA,
- its re-configurable user-composable services – MUPS

1.9.1 Visual Scenes and Collaboration Spaces

An enterprise has many Knowledge Spaces. These spaces can be implemented as Enterprise Visual Scenes (EVS), modeled in the AKA. Visual scenes are ensembled views to interrelated active knowledge models supporting archetypical work in an organization.

We see four major enterprise visual scenes required to continuously innovate, operate, evolve and transform, and govern and manage future enterprises. In addition there will be a multitude of smaller, more project and task specific scenes to support situated project work. The four Visual Scenes for future enterprising are defined as:

- *The Innovative scene* where focus is to invent, reuse, design and learn. The main concept is the industrial War-room, implemented as application of the POPS modeling methodologies. The innovative scene manages continuous change in product, process and organizational structures and rules of the Active Knowledge Architecture.
- *The Operations scene* where focus is to operate, generate, adapt, extend, manage and terminate; The main concepts are Collaborative Business Solutions (CBSs) generation and C3S3P delivery approach, supported by multiple life-cycle management (adapting and extending the common infrastructure), Proof of concept has been provided in earlier projects (EXTERNAL) supporting solutions generation and user deployment (Elvekrok et al 2003).

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- *The Governance scene* where focus is to govern, plan, decide, assign, measure and strategize; The main concept is related to aggregation and propagation of parameters, attributes and values, realizing the "real-time enterprise",
- *The Evolutions scene* where the focus is to analyze, configure, change, transform, align, and manifest; The main concept is continuous Collaborative Business Management (CBM). To be supported by continuously adapting and extending the EKA by infrastructure services.

1.9.2 The Powers of Visual Scenes

There is a need to enhance the way people think about computing, and there is a need to extend enterprise modeling from being a tool-based exercise for experts, isolated from operational business solutions, to become visual environments for a new style of computing supported by a common infrastructure. Visual patterns, scenes and languages, have at least six properties that natural language and current software methods will never acquire. We believe these properties are fundamental in driving a new approach to Systems Engineering, and for solving the challenges facing industry and IT provider:

1. Being able to collapse life-cycle stow-piping, i.e. play with abstractions of the time-dimension, removing the phases of material and information flows as documents and files,
2. Providing methods for concurrently evolving concepts, content, context and actions,
3. Correlation of conceptual views (meta-views), several content and functional views, and finally contextual views, and all dependencies,
4. Defining and applying business and working services and rules that are valid in given contexts and for limited parameter value sets,
5. Performing innovative work, and being able to create meta-models by executing tasks,
6. Supporting pro-active learning in visual scenes by role-playing, dry-runs and experimentation.

When we are able to support these properties then we are closer to truly supporting holistic design, problem-solving and organizational team learning.

1.10 Implications and Impacts

The demand for AKM technology will explode once western industry faces head on competition from India and China. Global networking will require full integration of enterprise teams across cultures, collaborative design and global team-composition. The role of learning is enhanced and there will be a need to support on-the-job learning. Active or living knowledge capture, supporting customized working environments, will enable new approaches to industrial computing, exploiting the web as a knowledge-sharing medium for improved collaboration and coordination

Involvement of stakeholders in sharing knowledge and data, is a key issue. Inter-relating all stakeholder perspectives and life-cycle views from requirements, expectations and constraints on design to maintenance and decommissioning or re-engineering. Being able to interrelate and analyze, building the "big picture" and making parts of it active so that it drives execution, depends mainly on parallel team-working:

1. Use-case designers and engineers must work with solution model builders on real customer product deliveries, and
2. Product and process methodologies are designed/modeled and applied (executing tasks) in concert with the use-case team.

This implies closing the gap between modeling and execution, supporting these capabilities

- Interaction of users in developing common approaches, pragmatic best-practices and matching solutions,
- Integration of systems to create effective, well-balanced solutions.
- Interoperability of enterprises in performing networked collaborative business
- The discovery of multi-dimensional knowledge spaces and views
- The socialization, discovery and externalization of what would otherwise be tacit human knowledge
- The recognition that software is nothing else but knowledge.

A good metaphor is to think of the web as an intelligent mirror, a mirror "painted" on its back with software components, enabling us to inter-relate the mental models of humans and the object-oriented models of computers. This intelligent mirror has memory, and behavior, and can mimic more and more of what humans think and do.

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