

Two Decades' Experience in Developing Product Configurators

Mastered Challenges and Remaining Issues

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Siemens AG Austria
July 2008

Agenda

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Our Configurators

Experiences

S'UPREME

Demo

Future

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Future Issues and Research Topics



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Global presence

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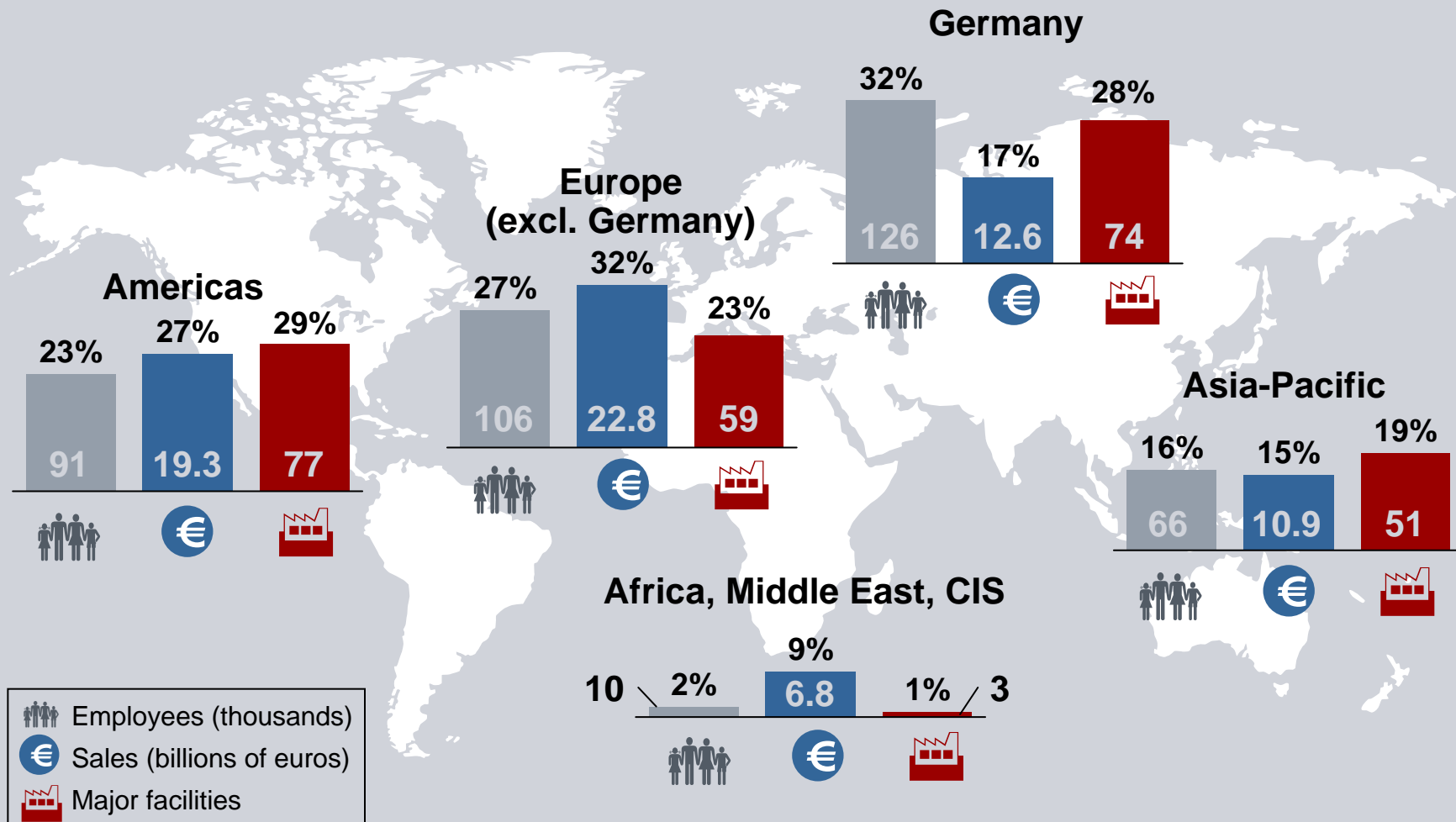
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As of September 30, 2007

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Innovation is our lifeblood

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Major R&D investments

- €3.4 billion in fiscal 2007
- 32,500 R&D employees worldwide
- 17,500 software engineers
- 150 R&D locations in over 30 countries around the world
- 7,900 inventions in 2007
- 50,700 active patents



Major innovations

Our patent positions (2006):

- Germany: No. 1
- Europe: No. 3
- U.S.: No. 11

Recent breakthroughs:

- **Somatom Definition**
(World's first dual source CT)
- **Combined cycle turbine**
(World's largest and most powerful turbine; reduces significantly pollutants)
- **Ostar-Lighting**
(Brightest LED at 1000 lumen won „Deutscher Zukunftspreis 2007“)

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Innovations have changed the world

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Industry



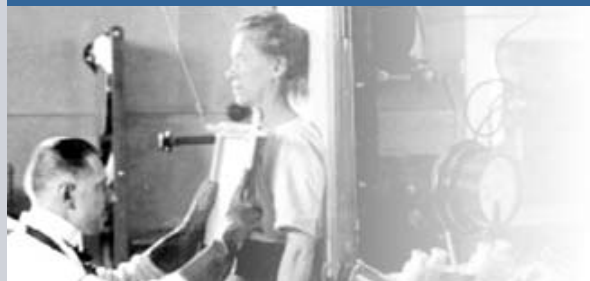
From the first electronic controls – to fully automated factories



Energy



From the invention of the dynamo – to the world's most efficient gas turbines



Healthcare



From the first views inside the body – to full-body 3D scans

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Sector Industry Automation and Drives

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Siemens A&D Mall



Selection of products and services
Configuration of systems
Pricing, Ordering
SAP IPC Solutions

Product Tree Siemens A&D

- Drive Technology
- Automation Systems
- Communication/Networks
- Low-Voltage Controls and Distribution
- Electrical Installation Technology
- Process automation
- Sensor, measuring and testing technology
- Power supplies
- Safety Systems - Safety Integrated
- System solutions and products for branches
- Service
- ... and everything else you need

Drive Technology

- 3RW soft starter
- Load Feeders (selection tool)
- Low-voltage Motors and Inverters
- SIDAC reactors
- SIMOVERT MASTERDRIVES
- SINAMICS S120 license bundle

Automation Systems

- 3SB3, 3SF5 Pushbutton Units and Indicator Lights
- 3VL Molded Case Circuit-Breakers
- HMI Selection Tool Software
- Load Feeders (selection tool)
- Proximity switches SIMATIC PXS
- Simatic Box PC 627B
- Simatic Box PC 827B
- Simatic Field PG M2
- SIMATIC HMI Selection Tool
- Simatic Microbox PC 427B
- SIMATIC Panel PC 477 embed
- SIMATIC Panel PC 577
- SIMATIC Panel PC 677
- SIMATIC Panel PC 677B
- SIMATIC Rack PC 547B
- SIMATIC Rack PC 847B
- SIMATIC Selection Tool
- SIMOTION Runtime licenses
- SIMOVERT MASTERDRIVES
- SINUMERIK solution line licenses

Communication/Networks

- 3RW soft starter
- 3SB3, 3SF5 Pushbutton Units and Indicator Lights
- 3SE5/3SF1 Position Switches
- Industrial Ethernet Switches SCALANCE X
- Load Feeders (selection tool)
- SIMOTION Runtime licenses
- SINUMERIK solution line licenses

Configurator for 6AV787

1. Welcome 2. Configuration 3. Order

Configuration

6AV787

- Front Panel** (Available from)
- Panel Options** w/ front USB
- Power supply** AC 110/230V industrial power supply, powercord Europe
- CPUs**
 - Celeron M 440, 1,86 GHz, 533 MHz FSB, 1 MB L2; 2x PCI
 - Cel M 440, 1,86 GHz, 533 MHz FSB, 1 MB L2; 1x PCIe 4x, 1x PCI
 - Core 2 Duo T5500, 1,86 GHz, 667 MHz FSB, 2 MB L2; 2xPCI
 - Core 2 Duo T5500, 1,86 GHz, 667 MHz FSB, 2 MB L2; 1x PCIe x4, 1x PCI
 - Core 2 Duo T7400, 2,16 GHz, 667 MHz FSB, 4 MB L2; 2x PCI
 - Core 2 Duo T7400, 2,16 GHz, 667 MHz FSB, 4 MB L2; 1x PCIe 4x, 1x PCI
- Memory**
- Hard disk drive:**
- Optical Drive**
- Communication Interfaces** Profibus/MP; 2x Gbit Ethernet; 512 kB NVRAM
- Operating System**
- Extension** without Extension

Legend:

- Choice expected
- Auto value, no change possible at the moment
- valid value, changes possible
- Selection error, set new or delete
- Product is a single component
- Product consists of several components
- Component completed
- Delete value



Sector Industry Industrial Solutions

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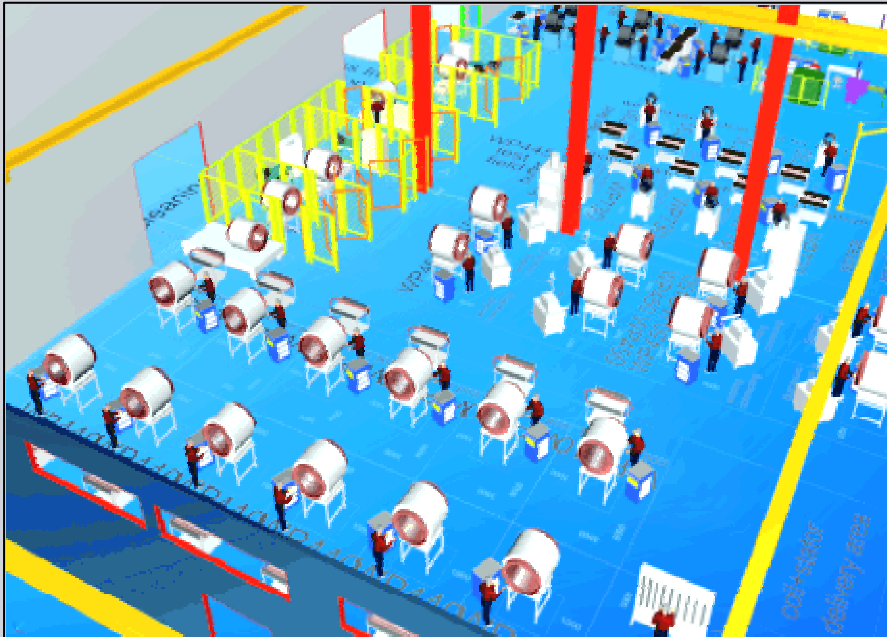
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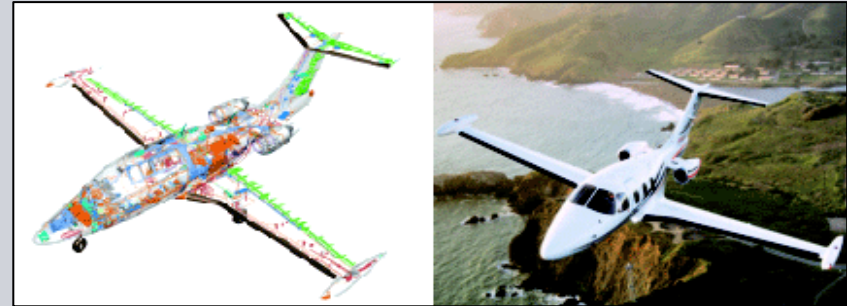


Digital Factory

Design
Simulation
Reality



Siemens PLM Software (UGS):
Teamcenter, Tecnomatix, SolidEdge, NX



Simatic Automation Designer



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Sector Industry Transportation Systems

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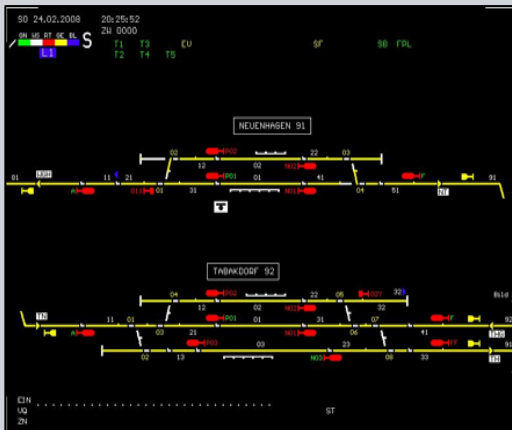
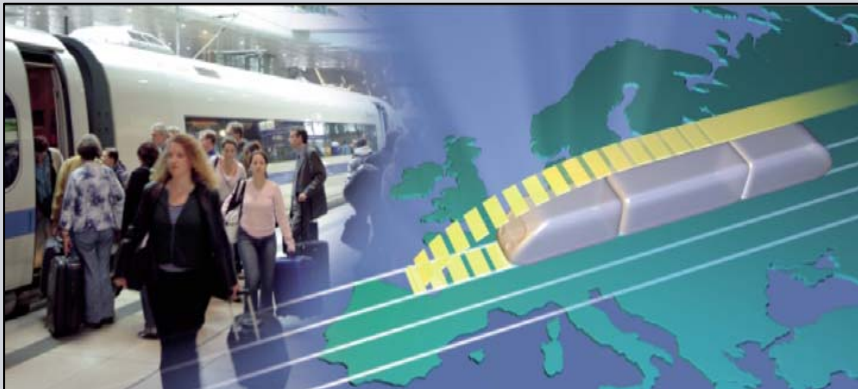
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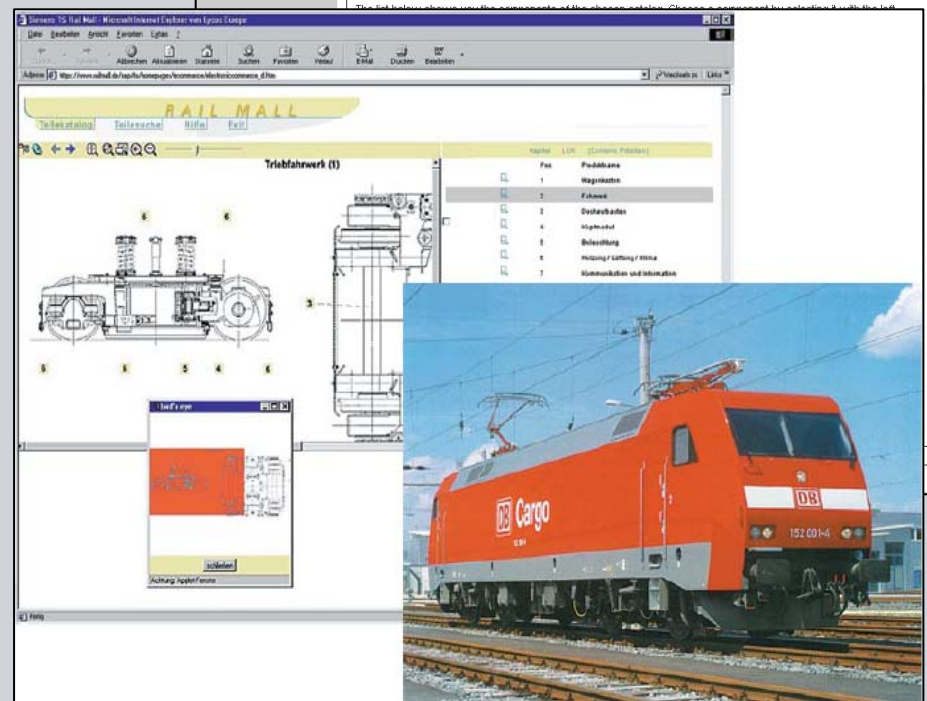
Rail Automation Systems
European Trainguard



Siemens PSE
Configurators

Docware
+ SAP

RailMall
- Spare
parts



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Sector Energy Power Generation

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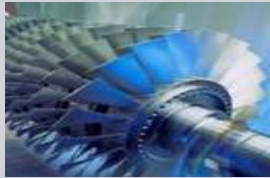
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Towards Sustainable Cities

Floating Wind Farms



Wind Turbines



Combined Cycle Power Plant



Gas Turbines



Challenge: Variant reduction and modularization
Sales (Tacton) - Engineering (Teamcenter) - Realization (SAP)

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Sector Energy Power Transmission & Distribution

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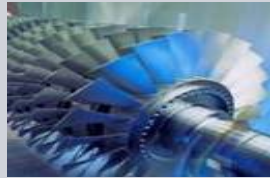
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Delivering Power
to the Planet



Energy Automation

SIPROTEC 7SJ602 Multifunction overcurrent and protection relay

Überblick

Details

Konfigurieren

Bestellnummer-
eingabe

Nennfrequenz f_n	
Nennstrom des Stromwandlers	
1 A	
1 A / I _e empf.	
5 A	
5 A / I _e empf.	

SIPROTEC 7SJ602 Multifunction overcurrent and protection relay

Überblick

Details

Konfigurieren

Bestellnummer-
eingabe

Systemschnittstellen- Protokoll	Systemschnittstelle Geräteunterseite
Ohne	Ohne
IEC 60870-5-103	Elektrisch RS 485
IEC 60870-5-103	Elektrisch RS 232
IEC 60870-5-103	Optisch ST-Stecker
Profibus DP Slave	Elektrisch RS 485
Profibus DP Slave	Optisch ST-Stecker
Modbus	Elektrisch RS 485
Modbus	Optisch ST-Stecker
Thermobox	Elektrisch RS 485

zurück

SIPROTEC 7SJ602 Multifunction overcurrent and protection relay

Überblick

Details

Konfigurieren

Preisinformation

Mit „Preisinformation / Bestellung“ gelangen Sie, ggf. über die Anmeldung, direkt zur Preisinformation für das soeben konfigurierte Produkt. Als angemeldeter Nutzer haben Sie die Möglichkeit, für ein breites Produkt- und Leistungsspektrum Preise einzusehen und die Online-Verkaufsfunktionalität zu nutzen. Sie können nähere Information auch über das Kontaktformular, das rechts unter dem Verweis „Ansprechpartner“ bereit gestellt ist, anfordern.

Preisinformation / Bestellung

Bestellnummer: 7SJ6025-4BB91-1FA1+L0B

Vorgangsnummer 1464336

Versionsnummer 0

Konfiguriert am 9. Juli 2008

ECCN N / AL_NR N

Produkt-Spezifikation

Verlagerungsspannung	---
Nennstrom des Stromwandlers	5 A
Nennfrequenz f_n	60/50 Hz
Bemessungs-Versorgungsspannung	60 / 110 V DC
Schwelle Binäreingabe	19 V
Gehäuseart	Aufbaugeschäse
Anschlussart	Doppelstockklemmen
Region Welt, 50/60 Hz, ANSI/IEC Kurven, Sprache	Mit
englisch, deutsch, französisch, spanisch, russisch	
Systemschnittstelle Geräteunterseite	Optisch ST-Stecker
Systemschnittstellen-Protokoll	Profibus DP Slave
Befehl ohne Prozessrückmeldung	Mit
Oszillographische Störschreibung	Mit
Erweiterte Messfunktion: Schleppzeiger Mittelwerte	Ohne

Concert Product Configurator -> SAP IPC

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Sector Healthcare Medical Solutions

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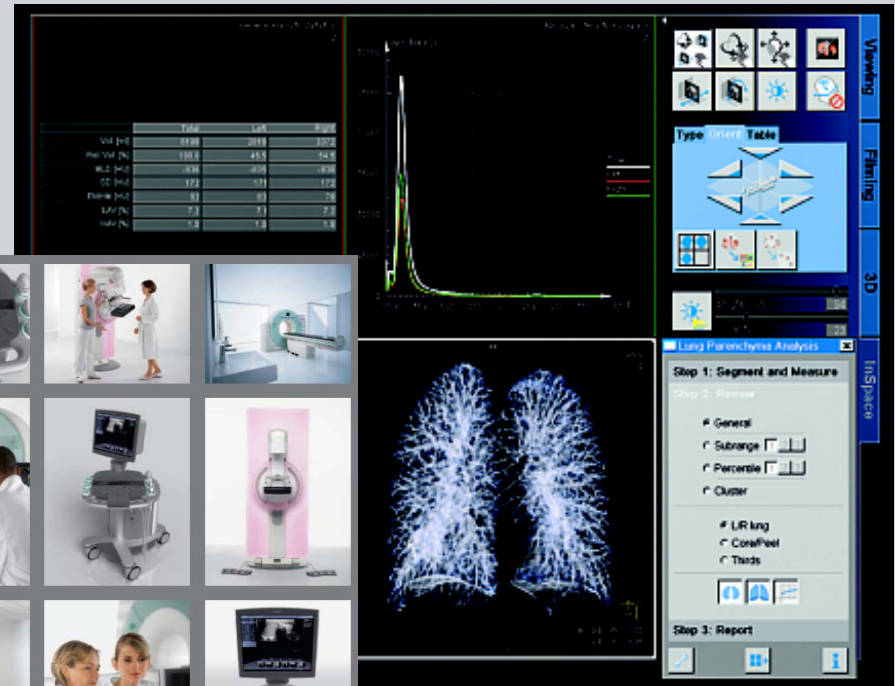
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Future



eHealth Applications
Patient Health Cards

Soarian Integrated Care: efficient workflow
throughout the entire care cycle



Digital Health
Digital Assistant Doctors





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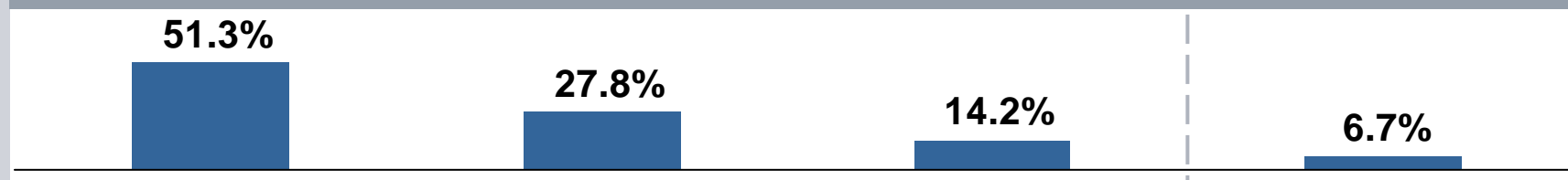
Siemens IT Solutions and Services Active in three Sectors

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Industry	Energy	Healthcare	Cross-Sector activities
			
Automation and Drives	Power Generation	Medical Solutions	Siemens IT Solutions and Services
Industrial Solutions and Services	Power Transmission and Distribution		Siemens Financial Services
Siemens Building Technologies			
Transportation Systems			
OSRAM			

External sales of Sectors excluding Other Operations (as of September 30, 2007)



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Siemens IT Solutions and Services PSE

Locations, facts & figures

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Total: FY 2006/2007

Revenues: €560 million

Headcount: approx. 6,000

21 locations worldwide:

Austria

China

Croatia

Czech Republic

Germany

Hungary

Romania

Slovakia

Turkey

USA (Representation via Siemens
Shared Services SSL USA)



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Segment PSE CVD IDB6 Portfolio



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Customization and development of configurator solutions, preferably using our problem solving engine & methodology S'UPREME or other configurator tools.

Expert know-how in knowledge-based systems and constraint technologies, proven in large-scale systems and challenging projects.

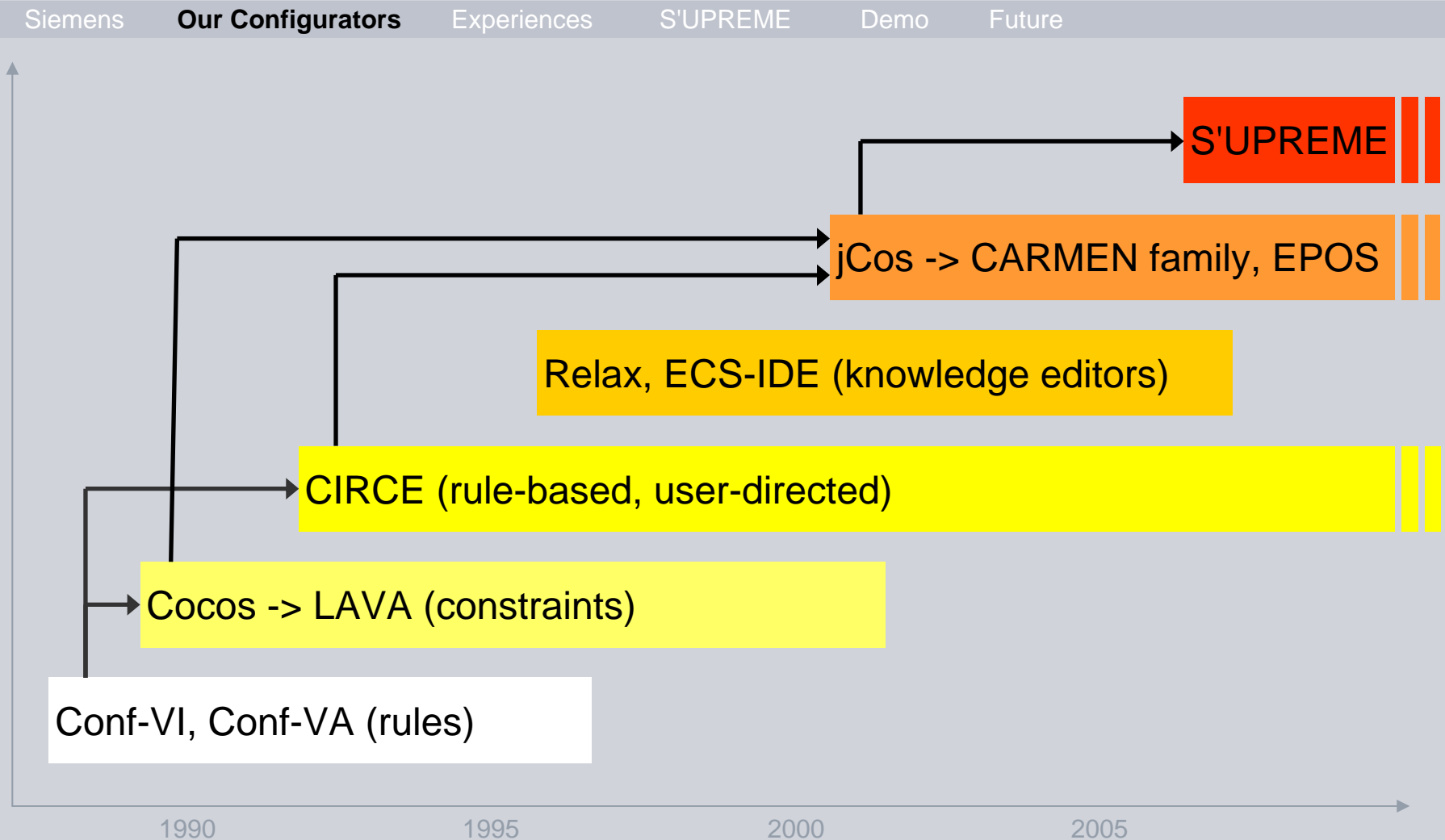
Consulting for product modeling, knowledge engineering, and mass customization.

Development of tools for knowledge base maintenance which support editing, modeling, and testing of knowledge bases for various configurators.

Segment PSE CVD IDB6

Timeline of main applications

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Configuration of railway interlocks

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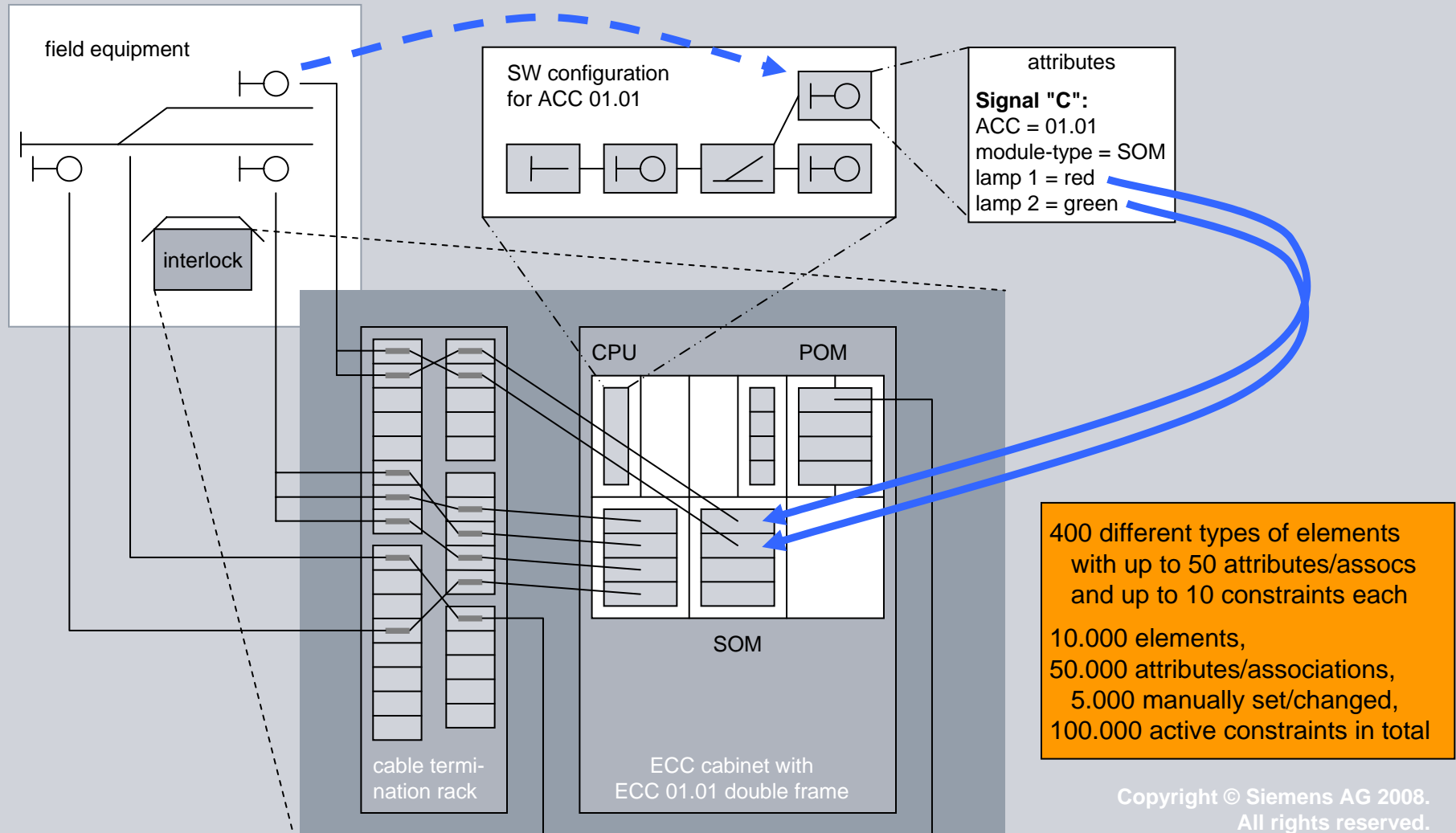
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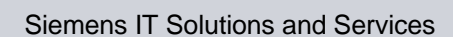
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Customer expectations

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Customers expect from configuration tools:

- fully automated configuration
- complete flexibility of manual changes / overriding
- fancy graphical user interface
- full integration into existing tools and processes
- short development time
- easy and quick changes / extensions / variants
- low costs

Challenge: **Efficient development of model and reasoning**



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Object-oriented model and UML-diagrams

- improved communication between developers and with domain experts
- facilitated development of versions and variants

Minimized redundant coding

- use constraints for filtering (UI), checking, explanations, repair, solving
- reduced knowledge base code by 40% (in CARMEN)

Tailor-made knowledge-base editor

- code generators accelerated coding and reduced errors
- reduced training time of new developers (knowledge engineers)
- constraints/rules written in a common language ensure high flexibility

Knowledge-base editor: jCosStudio

Explanation	Affected elements
All subelements of a class (attributes, associations and backlinks, tables, constraints, rules) must have a unique name.	ComIndElement: Superclass
No Cycles in the class-hierarchie	ComIndElement: Superclass
The value must be a Java-identifier sein: [_a-zA-Z][_a-zA-Z0-8]*	ComIndElement: Name

Example constraint code

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```
public class Room extends HouseConfigObject {  
    ...  
    /**  
    * @constraint Room's floor number must be between min and max of house  
    * @name constraintFloor  
    * @inConstraintNetwork Default  
    */  
    public void constraintFloor(IConstraint constraint) {  
        IIntVar varFloor = (IIntVar) getVar(Room.FLOOR, constraint);  
        IConfigObject house = getAssoc1(Room.HOUSE, constraint);  
        if (house==null || varFloor==null) return;  
        constraint.post(  
            varFloor.jcosGE(house.getIntAttr(House.MINFLOOR, constraint)));  
        constraint.post(  
            varFloor.jcosLE(house.getIntAttr(House.MAXFLOOR, constraint)));  
    }  
}
```

Challenge: Optimal User Interface



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Users and applications require specific user interfaces

- often necessary for sufficient usability (e.g. topology plans for railways)
- visualized constraints help the user to avoid mistakes and reduce integration cycles
- user-triggered rules creating objects / setting values improve productivity

General and generic views for common tasks

- workflow view (phases), constraint view, tree view, property editor
- customization of displayed objects, properties, texts, menus
- variants need no UI programming, only customization
- use of generic views reduced development time significantly

Challenge: Multiple input and output interfaces



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Effort for input/output higher than for knowledge engineering

- many different formats: ASCII, XML, MS-Office, PDF, CAD, API
- mapping of those formats to knowledge-base model
- standardized XML interface to 3rd-party tools reduced own effort

Output of consistent documentation

- different receivers: integration team, tester, assessor, customer
- high consistency due to one-step generation of complete output (SW configuration files, HW assembly plans, and customer documentation)

Input of "ground" data

- customer requirements available in various documents / preceding tools
- using such customer information as direct input source significantly reduced the amount of transcription errors and configuration editing time

Example for customer-specific input

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Signale																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Bezeichnung	km	Signaltyp	Sig. Teil von Nahbedienbereich	Tag/Nachtspannung (N=nur Nacht)	L01 (1geL)	L02 (gnL)	L03 (rtL)	L04 (1wsL)	L05 (2geL)	L06 (blL)	L07 (2wsL)	L08 (1gnB)	L09 (geB)	L10 (2gnB)	L11 (SA Z)	L12 (SA n)	L13 (SA X1)	L14 (SA X2)	L15 (SA X3)	L16 (SA X4)
A3	17	HS	PstA:A;PstB:A	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA3	18	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
RSA3	16	RS	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-
A4	15	HS	PstA:A;PstB:A	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA4	16	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A5	13	HS	PstC	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA5	14	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A6	11	HS	-	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA6	12	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A7	9	HS	-	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA7	10	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A8	7	HS	-	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA8	8	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A9	5	HS	-	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-
pA9	6	WVS	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
A10	3	HS	-	-	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-

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Challenge: Reconfiguration and Versions



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No or minimal changes to existing parts of the configuration

- in order to avoid unnecessary costs in the "real" world (e.g. HW)
- user is in full control of (incremental) configuration: triggers solver/rules
- reconfiguration is no special case because of cautious heuristics for the repair-based solving (e.g. do not change user-set values)

Upgrade mechanism, especially for long-living systems

- automated upgrade based on generic database schema
- tailor-made transformers for special cases (e.g. type changes)
- multi-step upgrade saved development time and user time

Versions of the knowledge-base

- consistent numbering of knowledge-base and database versions
- keep versions fully downward compatible because branches cause effort
- extensive regression tests to avoid unexpected side-effects of changes

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Challenge: Customization and Variants



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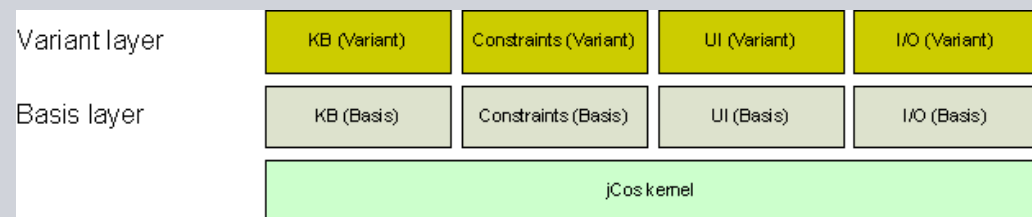
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Easy customization

- tables with alternatives (e.g. allowed values, component types)
- be aware of dependencies: UI texts, constraint code

Variants

- specialized applications based on inheritance
- CARMEN: 3 country clusters, >10 country variants



- fewer customization possibilities mean less costs
- e.g. fixed model and UI, I/O customized only by properties files
- EPOS: >20 country variants

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Selected previous papers

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- IEEE Intelligent Systems & applications (1998): Configuring Large Systems Using Generative Constraint Satisfaction
- AI EDAM Special Issue on Configuration (1998): Generative Constraint-Based Configuration of Large Technical Systems
- Configuration Workshop at IJCAI (2001): Configuration requirements from railway interlocking stations
- ÖVE e&i (2002): Constraints as key to industry configurator solutions (in German)
- Configuration Workshop at ECAI (2002): Ideas for Removing Constraint Violations with Heuristic Repair
- Configuration Workshop at IJCAI (2003): Modifying configurations with model finding
- ÖVE e&i (2005): Constraints on the user interface of configurator solutions (in German)
- **IMCM & PETO (2007): Benefits from Three Configurator Generations**
- Configuration Workshop at ECAI (2008): Solving Practical Configuration Problems Using UML

Summary of key challenges

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Configuration of large-scale technical systems:

- many significantly different component types
- large systems (>10.000 components)
- complex constraints and rules
- heterogeneous configuration tasks (SW, HW, ...)
- various input and output interfaces (XML, XLS, CAD, ...)
- versions and variants with a long lifespan (>10 years)
- reconfiguration occurs regularly
- users are technical engineers, not end-customers

Our Solution: S'UPREME

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Siemens' Configuration Problem Solving Engine & Methodology

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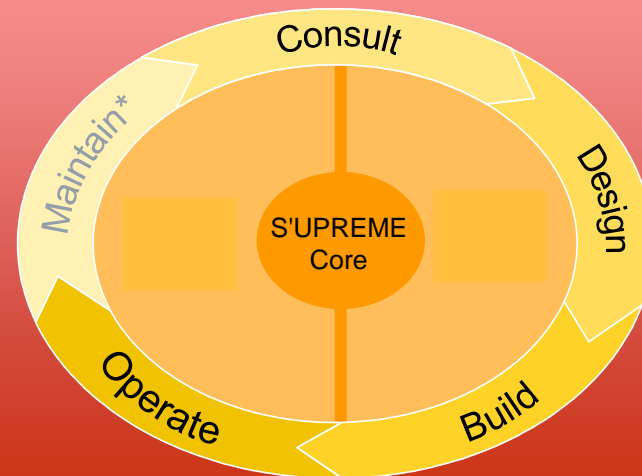
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Configuration Problem Solving Engine

- **Object-oriented** knowledge-base model
- Declarative **constraint language** with constraints and rules based on **Java**
- Proven for **large-scale systems**
- **Fast and reliable** in open search space
- **Generic solution**: Checking consistency, filtering of invalid options, automatic repair, automatic completion
- **Each constraint** reused for solving, checking, repairing and explaining
- **Extendable** by new solvers and strategies
- Integration into **different architectures** and environments possible

Modeling & Engineering Methodology

- **Modeling know-how** and support
- Methodology **proven** in big reference projects
- **Tool support** for modeling available



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What is a Configurator?

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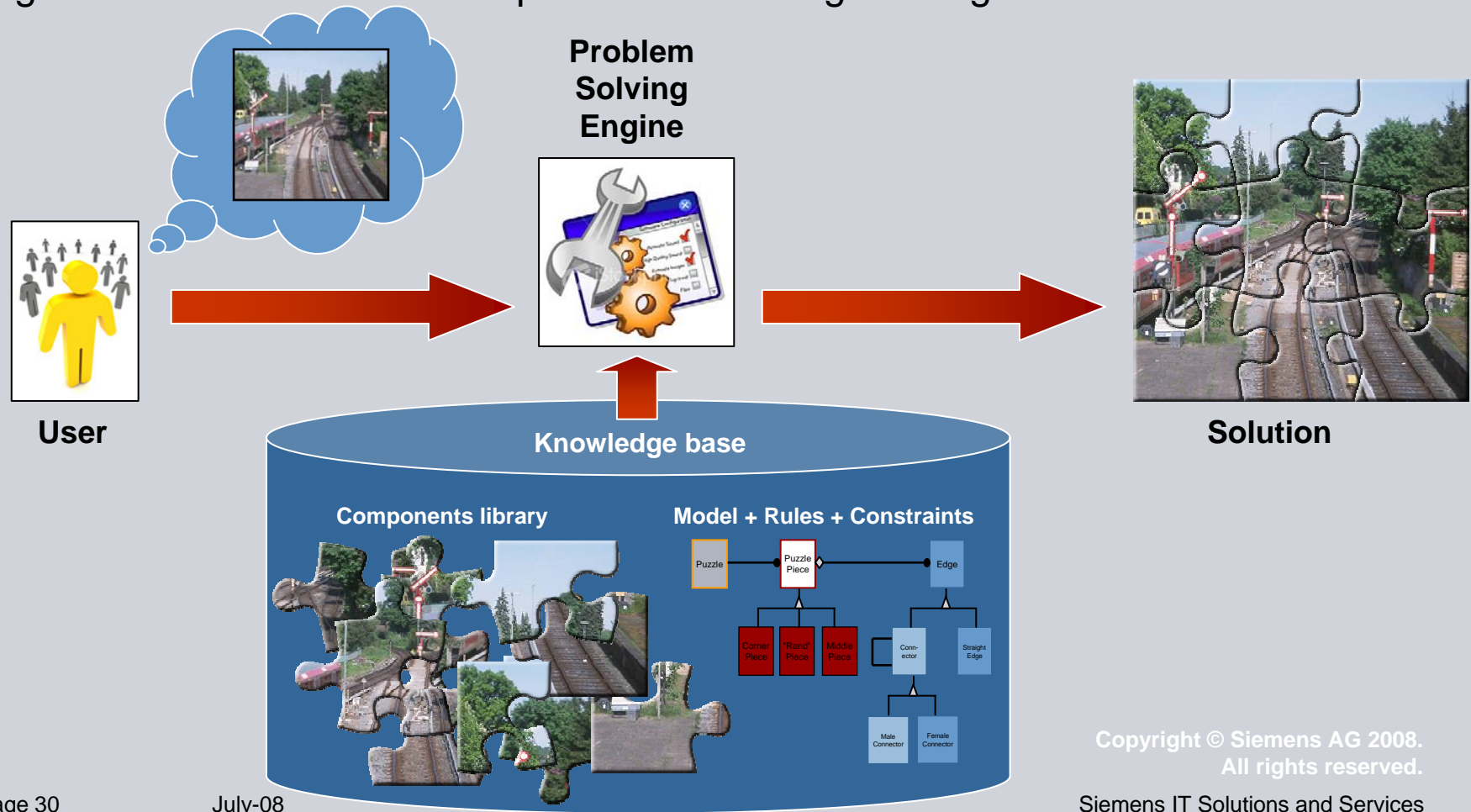
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A **configurator** is a software tool helping the user to construct the product which he imagines from a number of components according to the given constraints and rules.



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S'UPREME – Typical Architecture and Users

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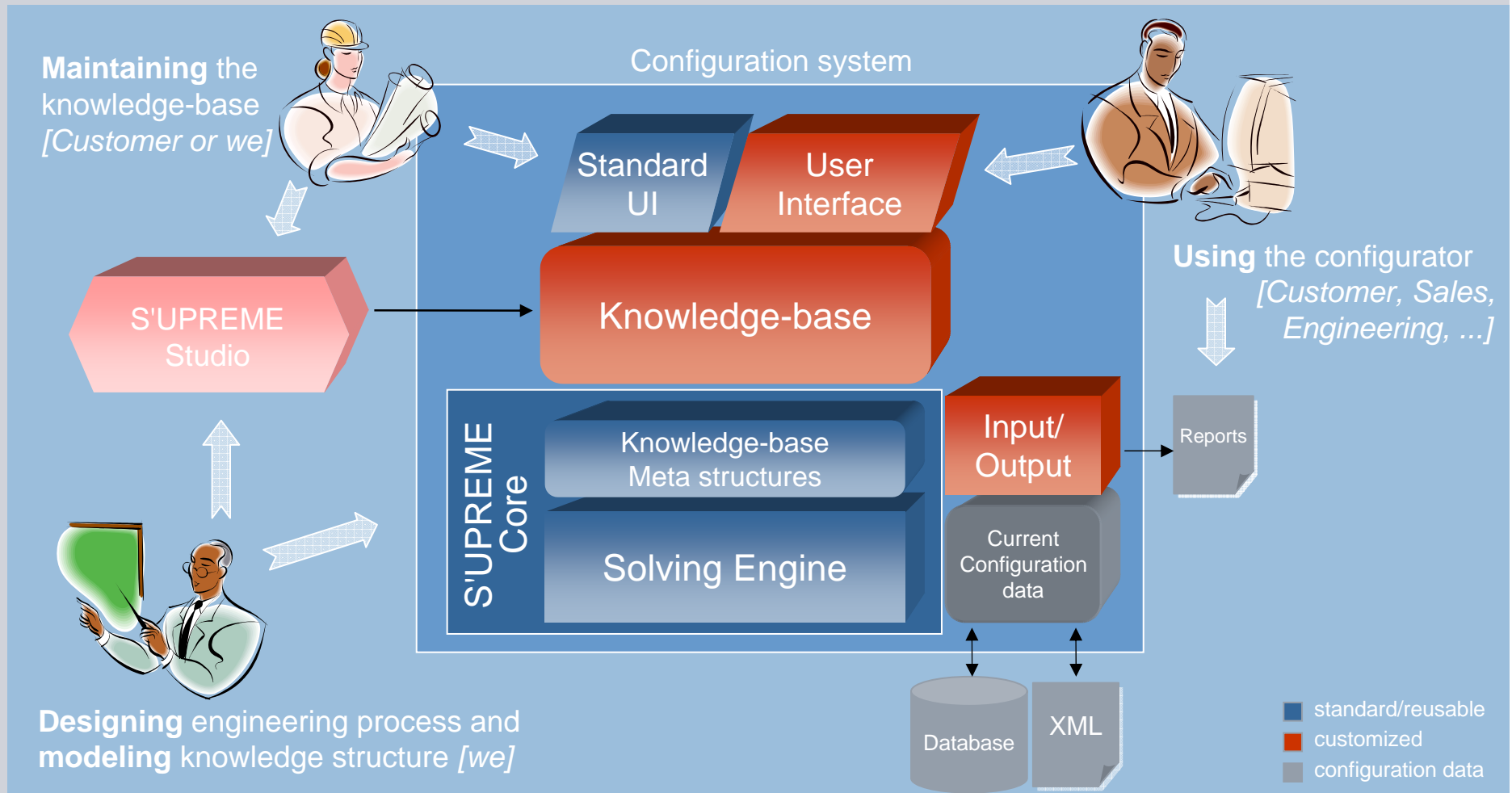
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Example for Demo Model and table

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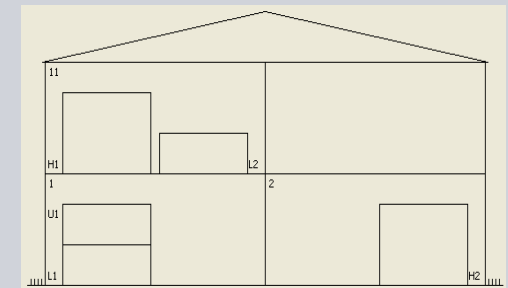
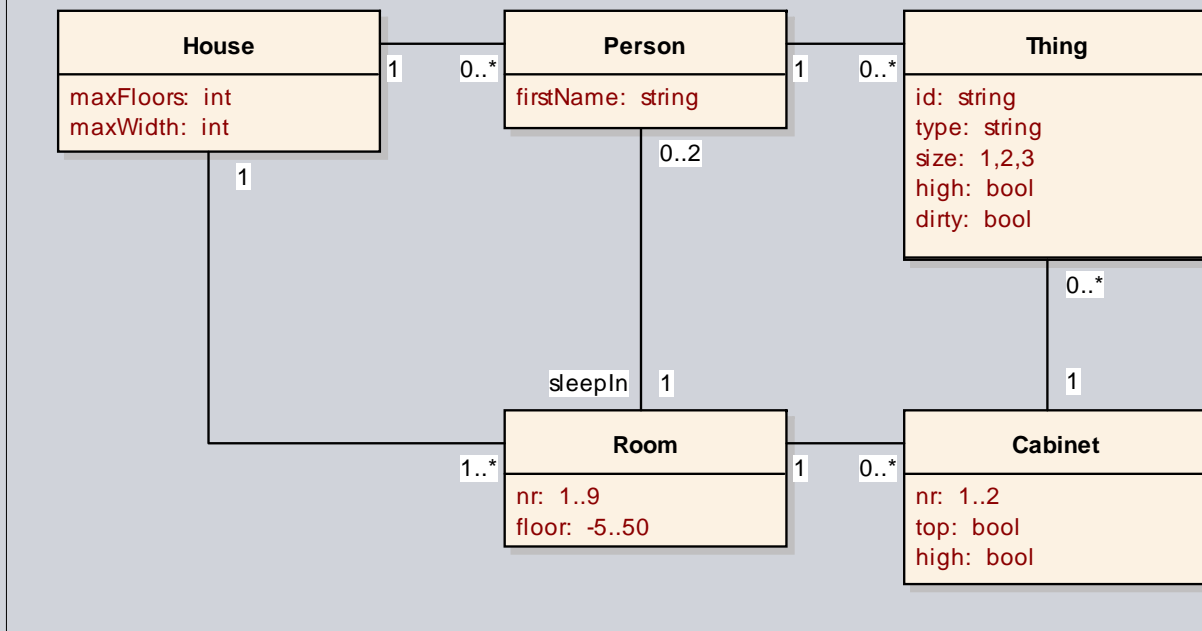
Demo

Future



<i>type</i>	<i>size</i>	<i>high</i>	<i>dirty</i>	<i>heavy</i>
toy-car	2	false	false	false
ball	1	false	true	false
flat-iron	1	false	false	false
tool	1	true	true	true
...	3	false	false	true

class model for house



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Example for Demo "House configuration"

Goal and constraints



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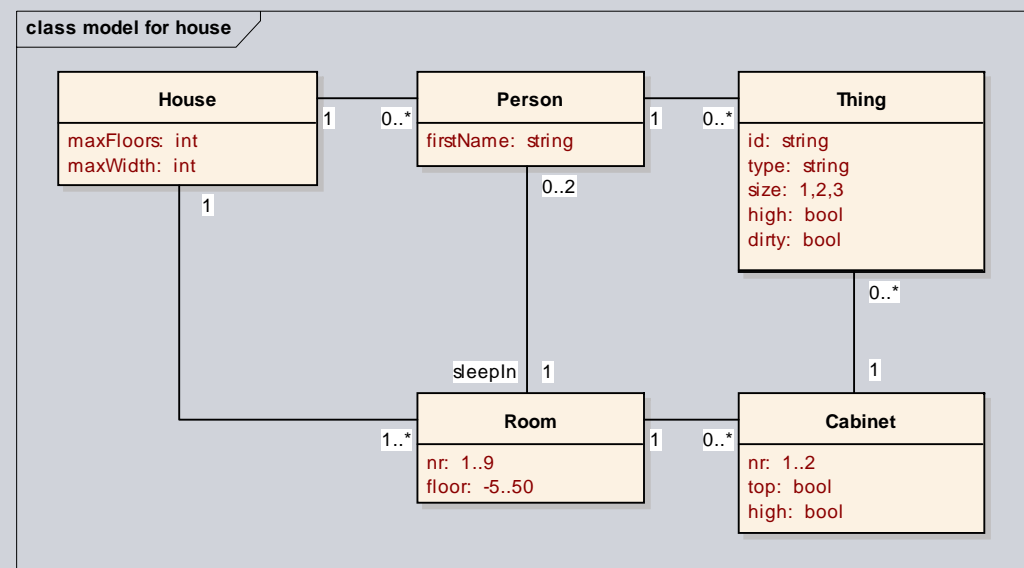
Future

Goal: Help a family build a house efficiently so that all their things fit in.

- persons and things are given
- how many rooms (and cabinets) do they need?

Some constraints:

- store things preferably in a cabinet in the owner's sleeping room
- do not mix dirty and clean things in one cabinet
- cabinets must not be overloaded
- cabinets must be placed in a room
- cabinet's name is computed by its room name and its position in the room
- all objects must have a unique name



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Example for Demo Screenshot

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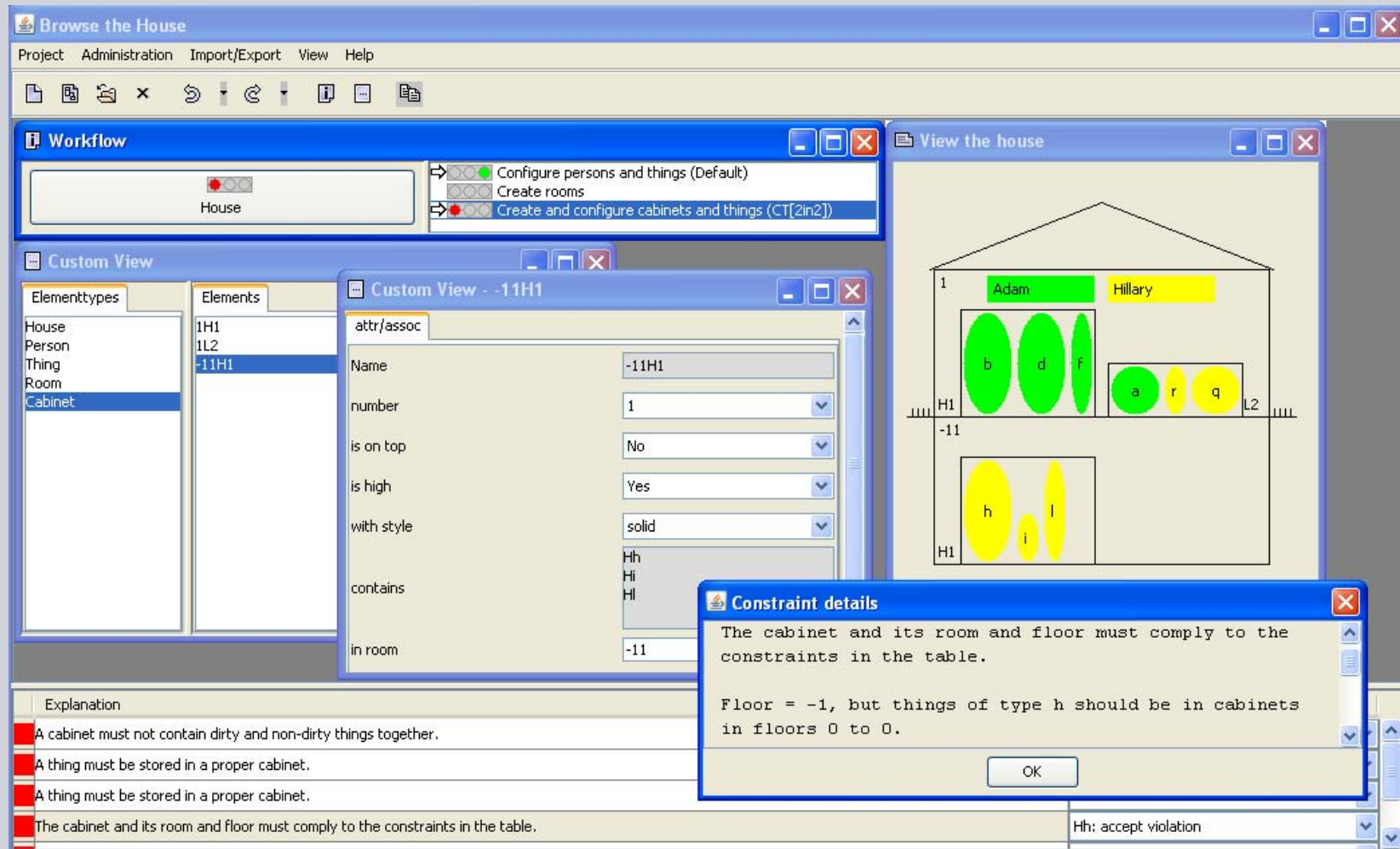
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S'UPREME – Answers to market challenges

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Handle **COMPLEXITY** 

- Dynamic generation of instances and solutions
- Object-oriented modeling on class level
- Mastering open solution space

Decrease **TIME to MARKET** 

- Reusing existing problem solving engine
- Using powerful constraint language
- Transfer expert knowledge using declarative way
- Support by our modeling experts available

Offer **CUSTOMIZATION** 

- Prepared for variant modeling (different countries)
- Custom development of interfaces (UI, I/O)
- Integration in custom application environments

Assure **RELIABILITY** 

- Automatic solving + checking of manual steps
- Engine handles explanation and repair
- Formal verification of model structure possible (objects, attributes, relations)

Future topics

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Future

Interfaces to CRM and other commercial systems

- SAP, Teamcenter

More focus on web applications

- configuration as a service

Improve usability

- explanations more user-friendly

From software development towards knowledge engineering

- knowledge-base editor as an Eclipse plug-in
- more (declarative) constraints instead of rules (extend language)
- keep Java as language for flexibility and performance
- how to support testing and other project-related tasks?

Research topics

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Specify the theoretical foundations for our approach

- user-set values
- 99%-rules (confirm violation)

Verification of the knowledge base

- contradicting constraints -> continue work with Prof. Salzer
- detect potential loops of the solver

Automatic learning

- adapt constraints/rules based on user decisions
- only for that user - as kind of user preferences
- for all users - as kind of learning previously unknown patterns (rules)

Contact

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Thank you for your attention!

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