

Cognitive Engineering at Hydro-Québec

Human-Computer Interaction, ECE 304-424,
Electrical and Computer Engineering, McGill University,
January 12th 2011, Jeremy Cooperstock

André Gascon
Contrôle et Exploitation du Réseau

Objectives

- That you get a flavour of cognitive engineering (CE) in industry :
 - Describe how it fits, what it is like in practice;
 - Show an example of CE applied to an industrial problem.
- That you understand the necessary attitude

(Find the real user needs; only then can you look for solutions. Don't rely on your own impressions.)
(it isn't natural, it has to be learned **hammered** in)

 - Illustrate some aspects of the design process using an advance exercise

Outline

- Cognitive Systems Engineering
- Advance exercise
 - Context
 - Results
 - Recommendations
 - Actual design
- Lessons learned - Suggestions - Problems encountered
- Examples of CE projects (if time permits)
- Questions during the lecture are OK.
- If needed, I'll be glad to answer questions after the lecture.

How I got to CE

- Physicist
- Programmer-analyst (real-time software)
- Project leader (automation software)
- Requirements specification, automation of the Beauharnois hydroelectric power plant
- Cognitive Engineering to define needs

Elements of a successful TI project

Four essential ingredients for a successful project

- Strategic alignment
- **Interaction design** (appearance et behaviour)
- Technical design
- Project management

Definition of needs (functionnal)

- Demands **≠** needs
- Needs **=** Interaction design
- It is essential to **validate** the design
- Tasks et processes

< **Expert users** >

< **Interactive systems** >

< **Objective = profitability** >

Cognitive Systems Engineering

- Industrial engineering = performance and efficiency
- Better tools → better performance in task (speed, errors, quality, ...)
- Applied to software (considered as a tool) = performance and efficiency of the Human-machine system (HMS)
 - Human beings are part of the system, so part of the problem must be solved using applied psychology (cognitive ergonomics)
- Design method, validation method

Specific expertise

- Methodology; integration with requirements engineering and software engineering methodologies.
- Techniques to find the necessary information
 - Interviews, task analysis, usability testing, ...
 - < how to get access to the user expertise {in their task} >
- Human being :
 - Vision, perception, decision making, mental load, nature of expertise, human error, ...
- HMI design, interaction design

CE : fundamental concepts

Definition of needs

Through the design and the validation of the HMI.

Design

Based on task analysis and usability testing.

< ie.: based on the users' expertise in their task >

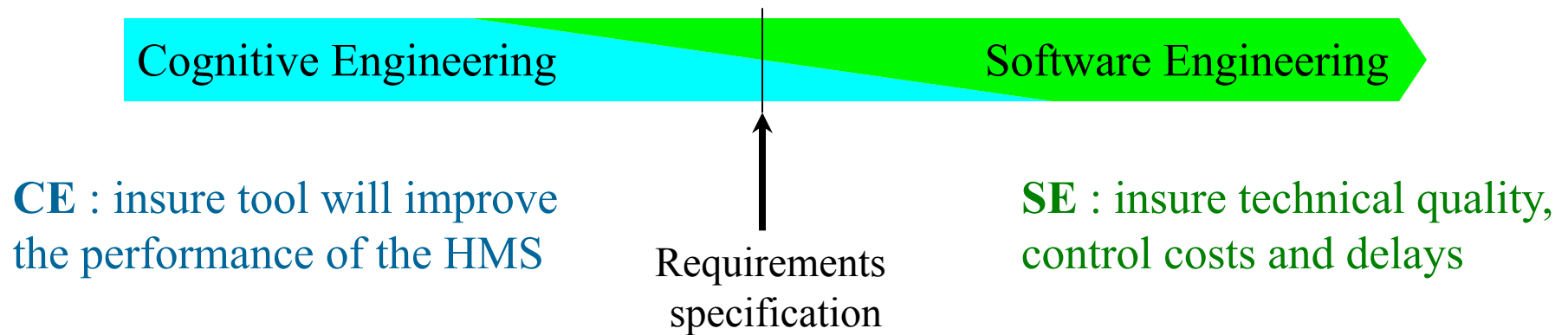
With technical optimization.

The design is expressed as a **mockup which is also the basic tool for usability testing.**

Interaction design → Functional requirements specification

N.B. : Standards, guidelines and good practices are necessary, but grossly insufficient to get a good product.

Role of CE



More than the Human-Machine Interface (HMI)

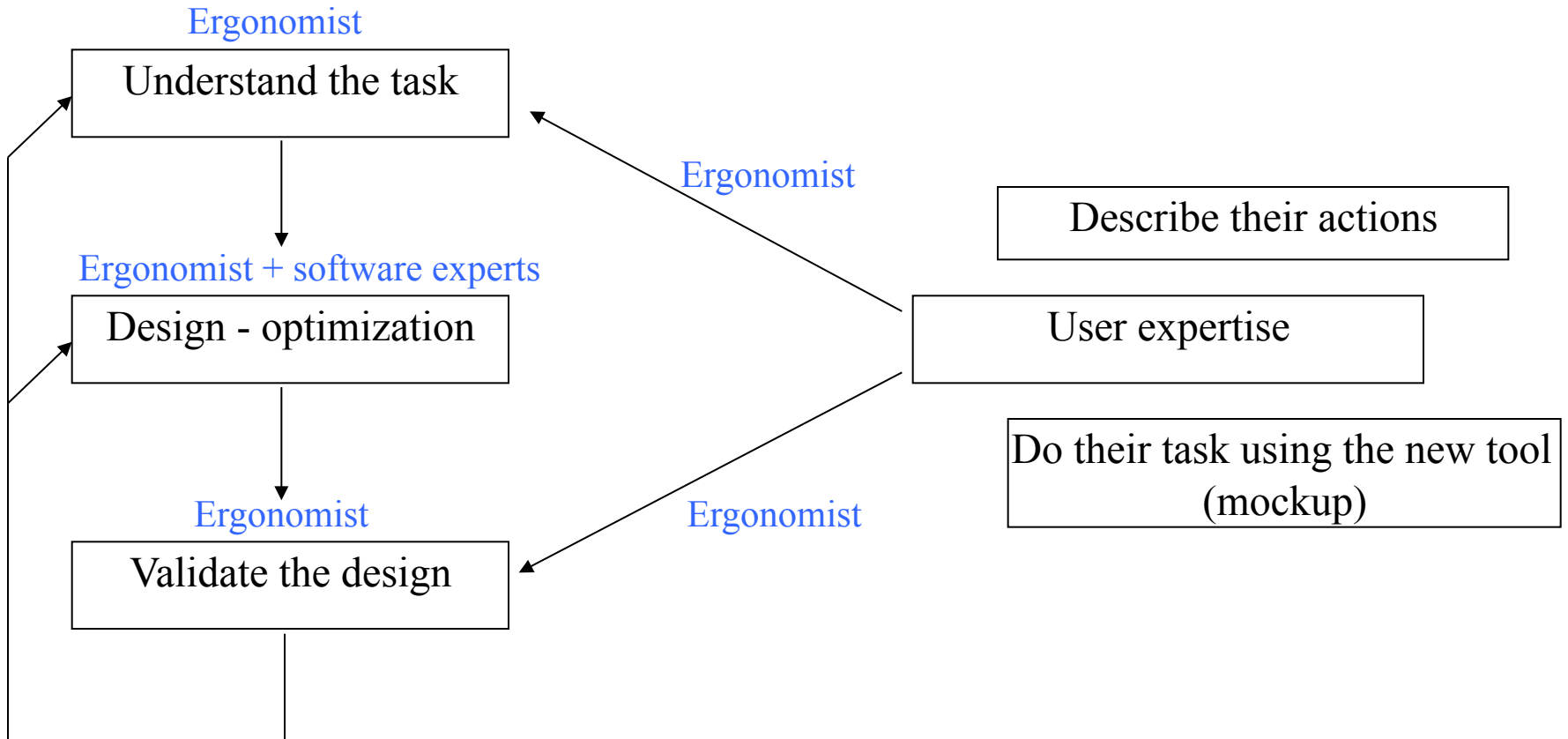
Task Design

Functions, services, data base

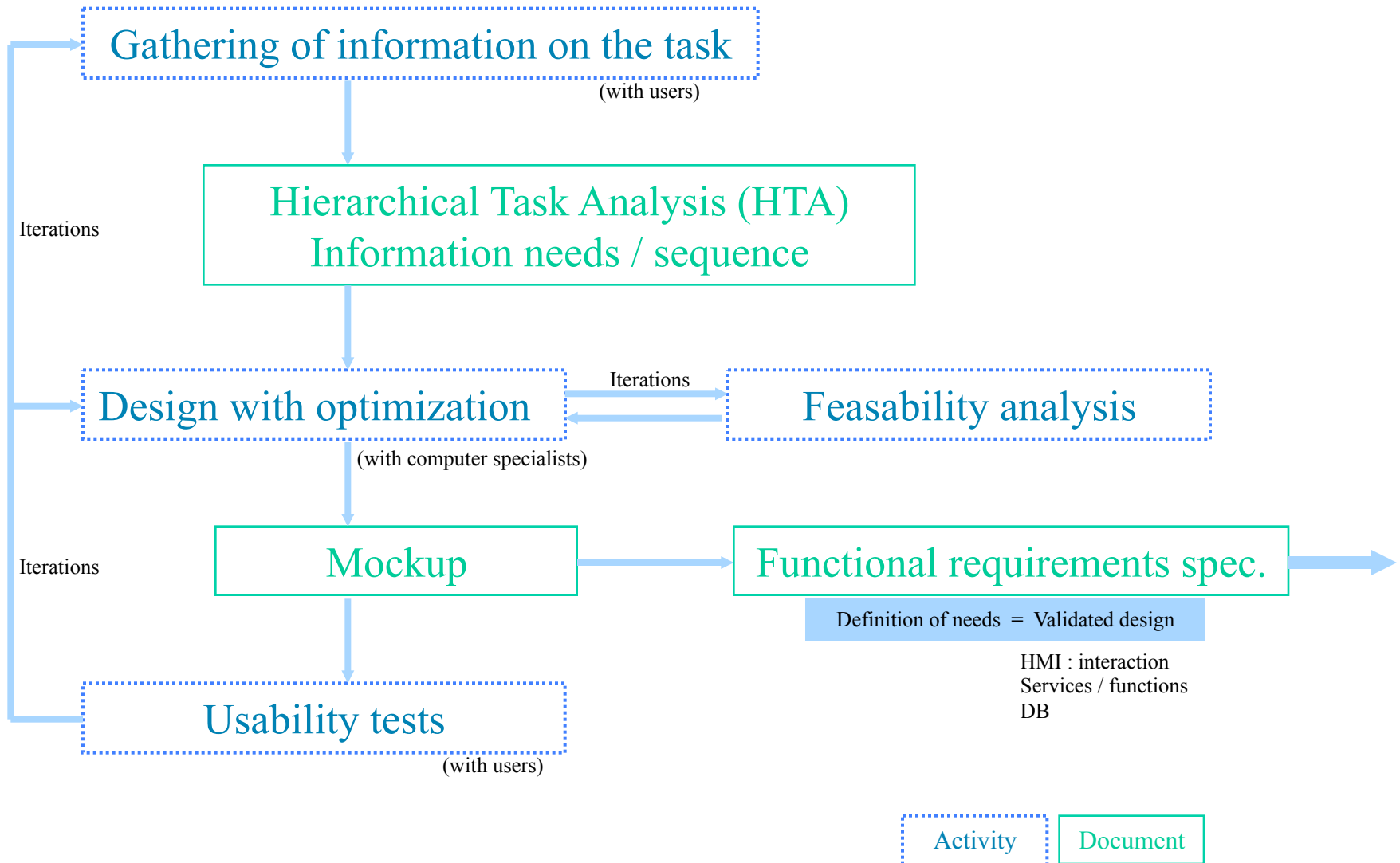
Help the clients define their needs.

Functional requirement specification : interaction, security, adaptability and « pérennité ».

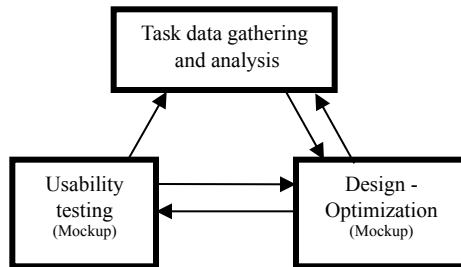
Methodology



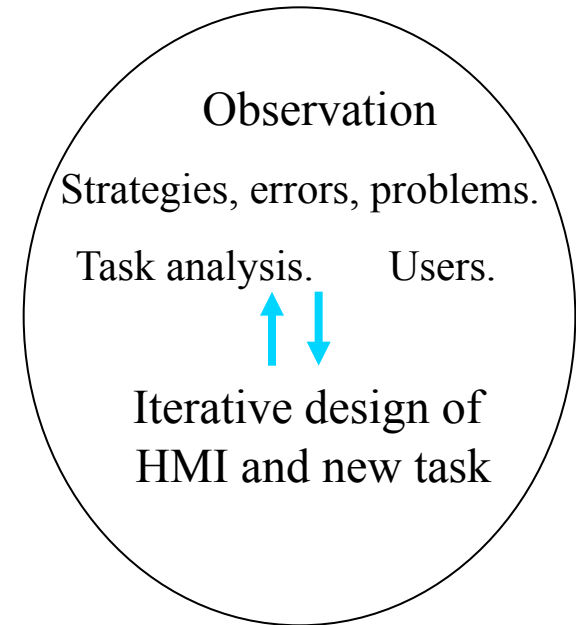
Methodology



Methodology



Objectives set for human-machine system (performance centered)



Design

The study of the task (analysis et synthesis) guides the design

Process

The mockup supports the creative process, gives it a representation necessary to make progress (in the design)

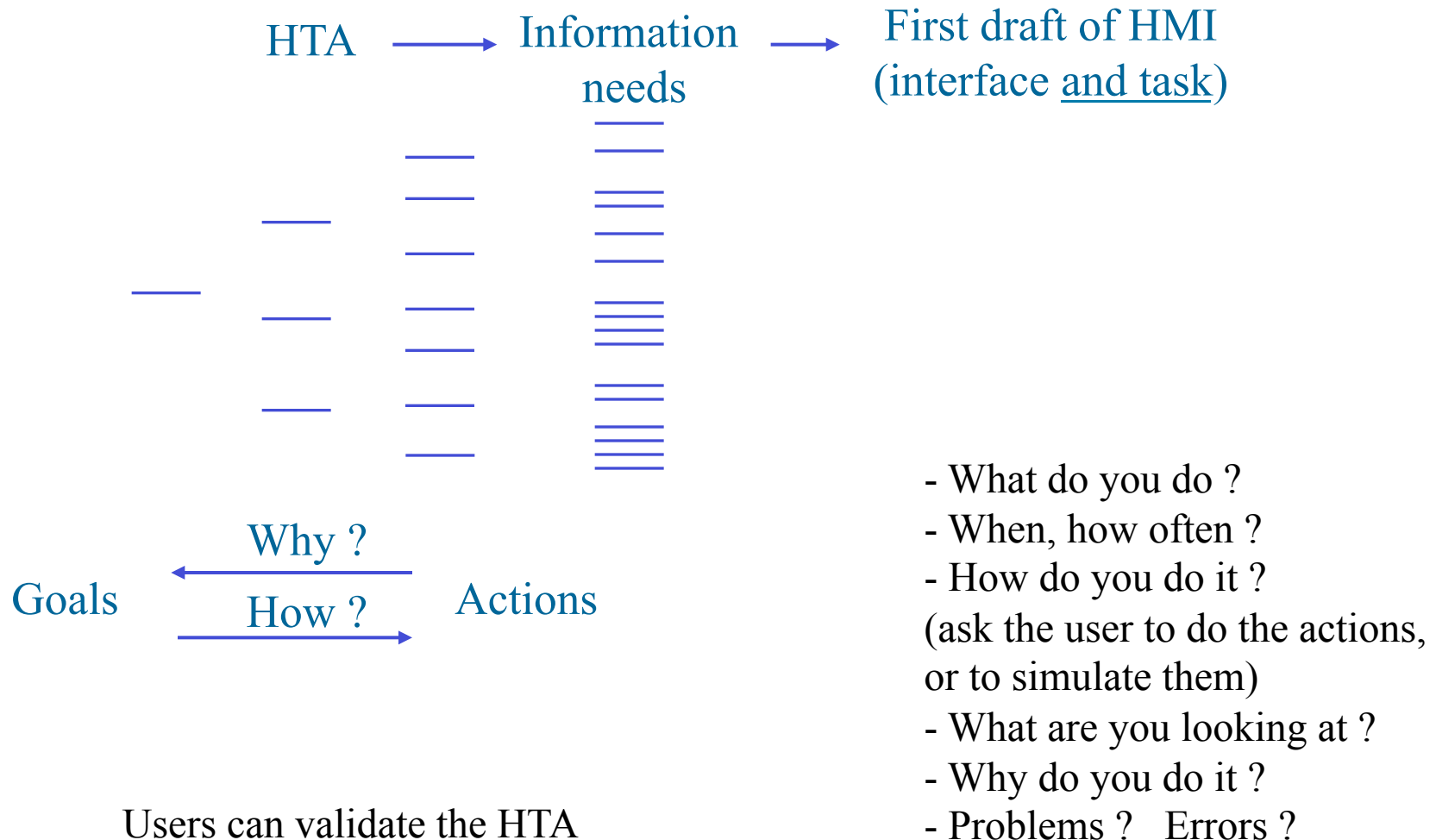
Usability tests enable the designer to check his design, to uncover design errors, to continue to make progress

Iterations are necessary because we **never** get it right the first time

Techniques

Observation	At workplace, performing (or simulating) actual work, one user at a time Notes, screen captures, video camera (with sound), photos
Analysis	Hierarchical Task Analysis (HTA), strategies, problems, errors HTA (goals, data) --> Data, grouping, sequence
Design	Optimize design with software experts Look everywhere for ideas Heuristic evaluation
Usability tests	Use the mock-up to do real task examples Iterate

Techniques



Techniques

First mock-up Paper and PostIt, or Visual Basic used as a drawing tool
Styrofoam and paper for physical aspects

Evolution Usually Visual Basic used as a drawing tool, adding just
enough fonctionnality to properly test specific sub-tasks
Other mockup tools : PowerPoint, Excel, DHTML
(Excel is excellent for web site mockups)

Mock-up \neq Prototype* Never (almost) demo the mock-up to users **;
ask the user to use it to do actual work

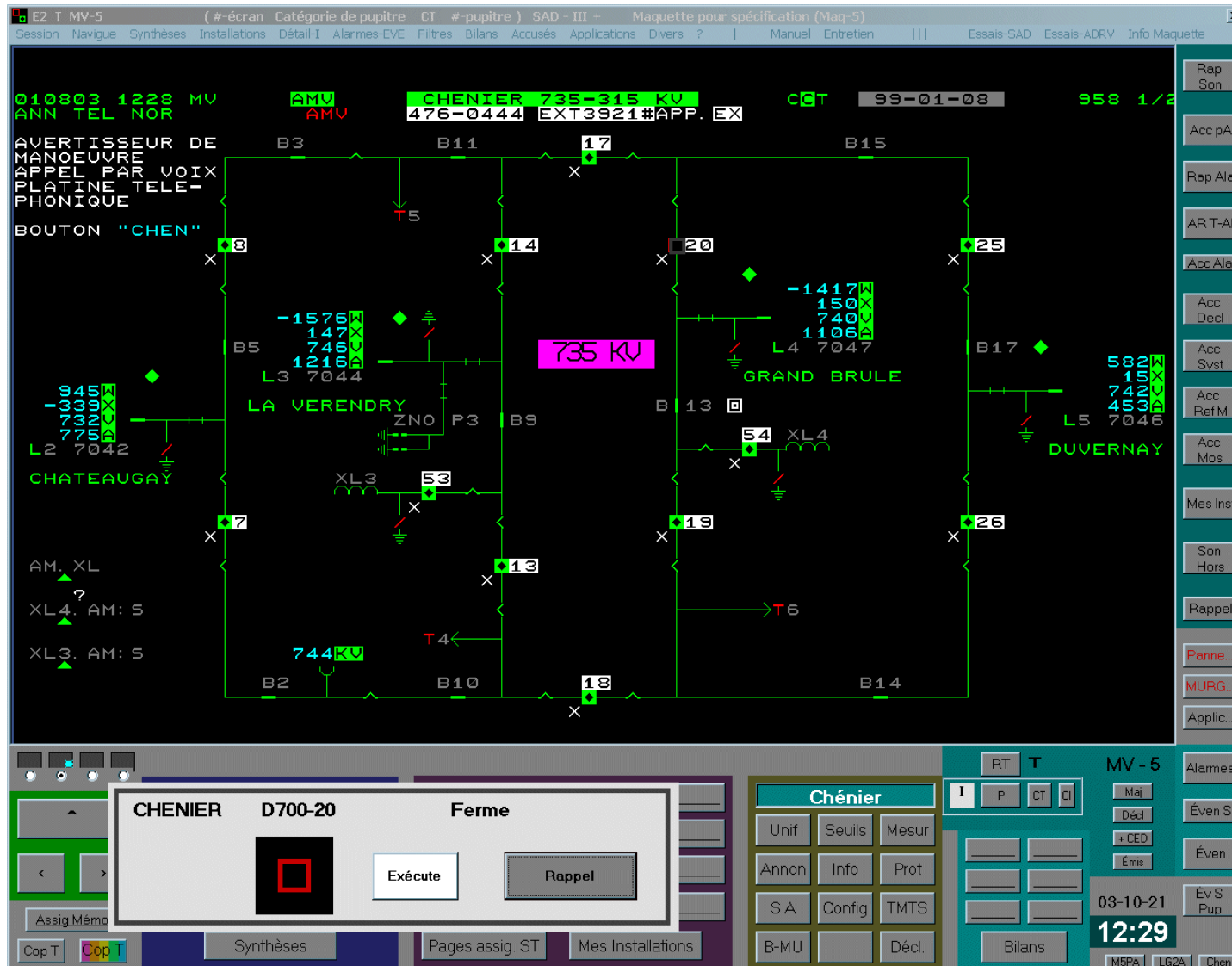
The mock-up is the best communication tool between user, client, designer and programmer

Designing the mock-up and doing usability tests enables one
to push the interaction design much further

* : a partial prototype may be needed in some cases

** : however, a demo may be useful for clients

Mockup example (SCADA HMI)



SAD+A

SCADA : Supervisory Control And Data Acquisition

Example : Alarm annunciator

From diagnostic

to situation assessment.

(circa 1995, but the lessons remain valid)

Electric power supply and control

1 provincial control center (CCR)

7 regional control centers (PA)

5 distribution control centers (CED)

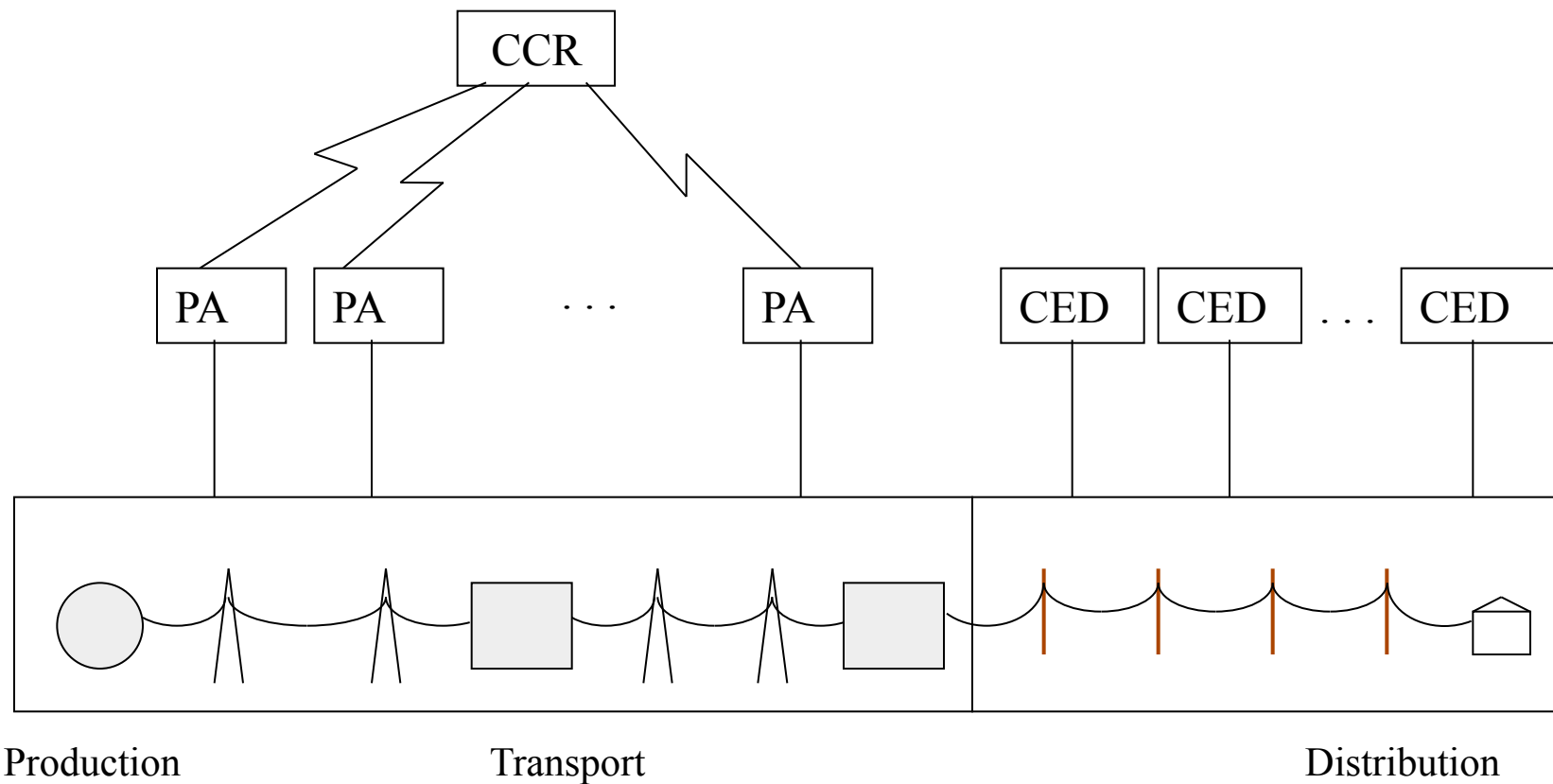
63 power plants (Production)

> 500 substations (Transport)

CCR : Centre de conduite du réseau

PA : Place d'affaire téléconduite (salle de téléconduite)

CED : Centre d'exploitation de distribution



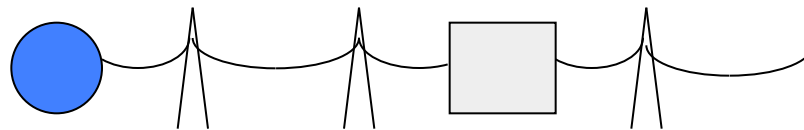
Electrical power network : Production



Pagan power station



50 hydroelectric power plants



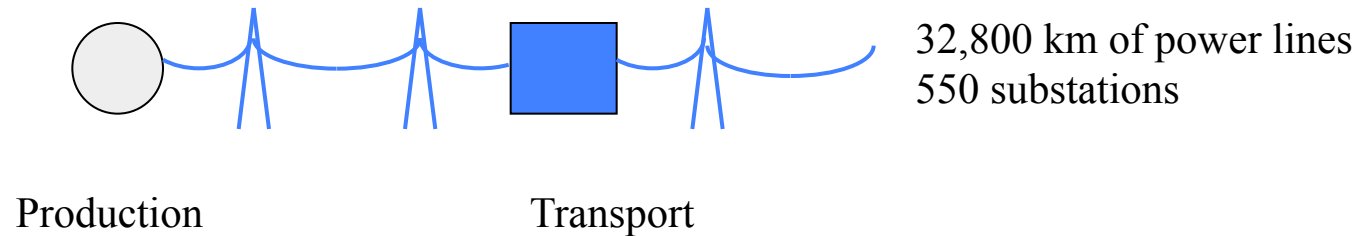
Electrical power network : Transport



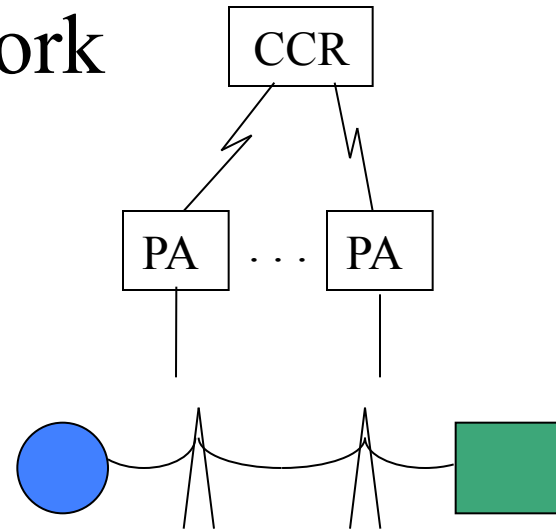
Power lines



Duvernay substation



Electrical network control : local



Boucherville substation HMI



Beauharnois power plant HMI





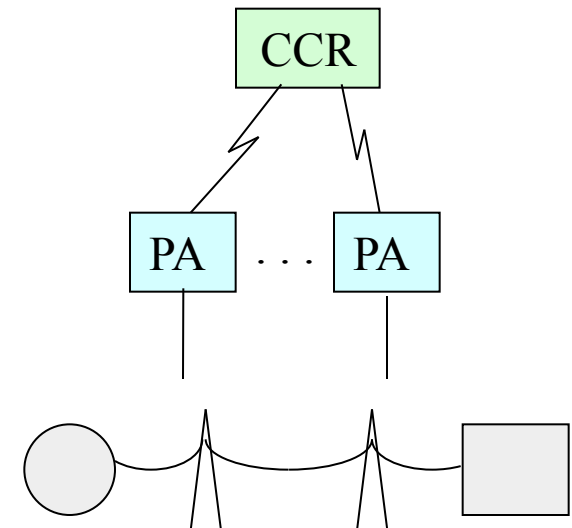
Electrical network control : remote

- 1 provincial center (CCR)
- 7 regional control centers (PA)
- 5 distribution control centers (CED)

Provincial control center HMI (CCR)



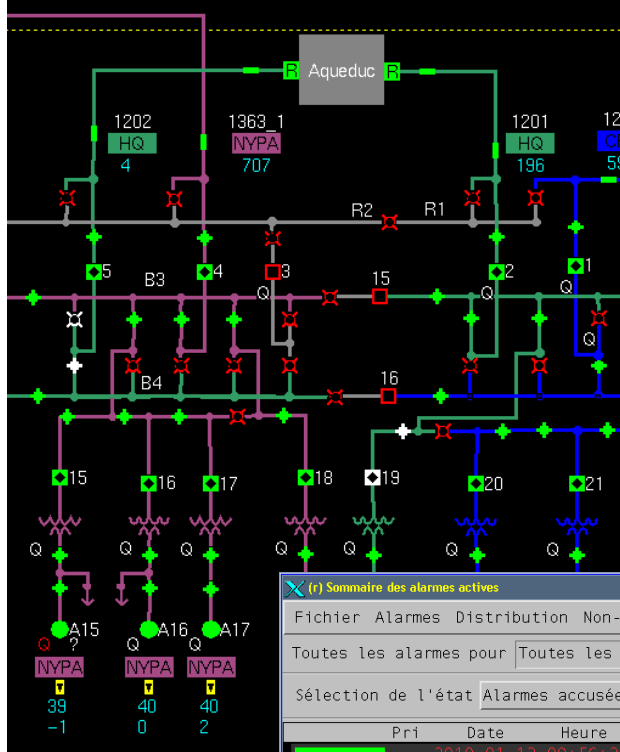
St-Jérôme regional control center HMI (PA)



Typical displays (SCADA HMI)

SAD

ADR



(r) Sommaire des alarmes actives

Fichier Alarmes Distribution Non-statut-par-défaut Filtre Tri Actions Aide

Toutes les alarmes pour Toutes les installations

Sélection de l'état Alarmes accusées ou non Toutes Figurer

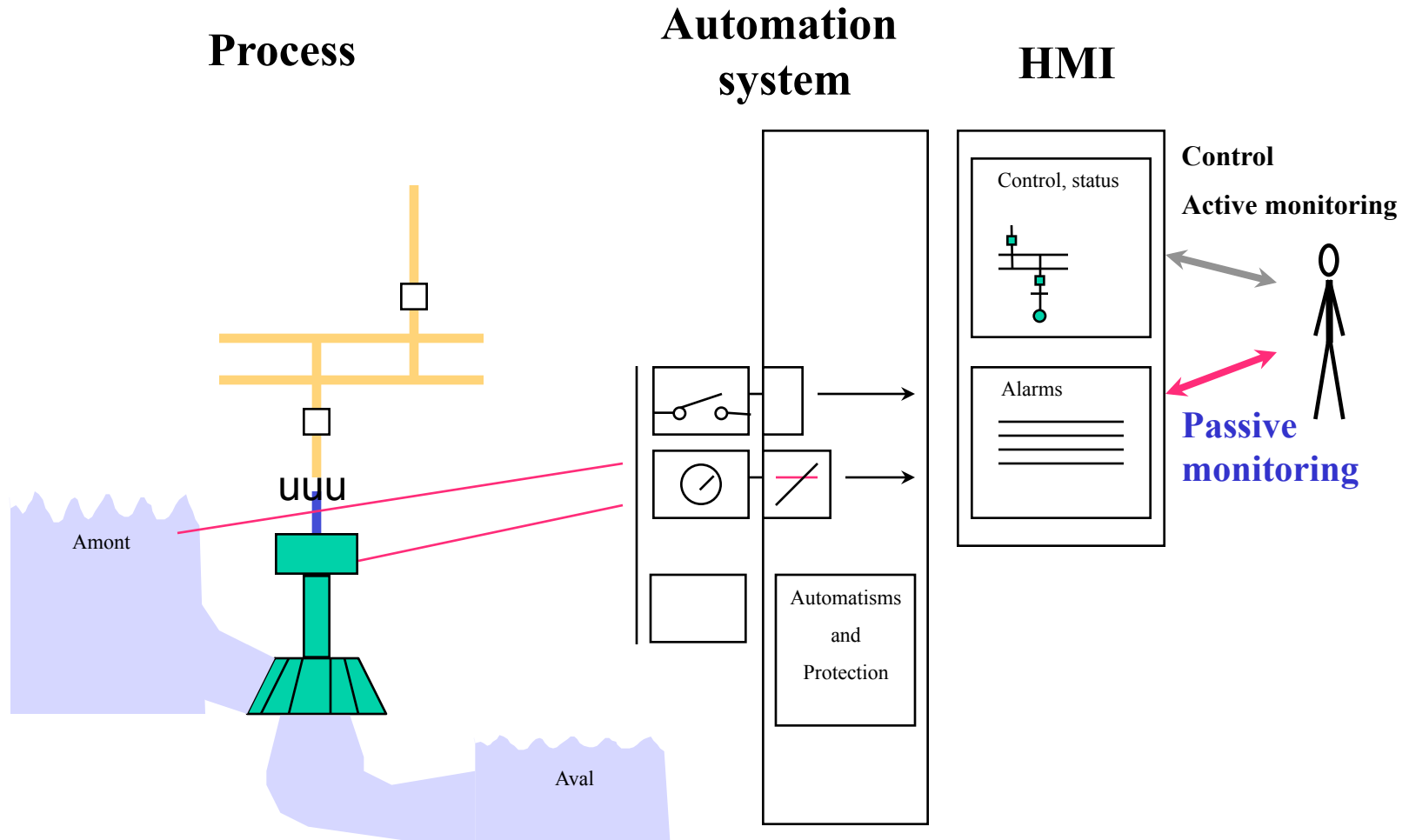
Pri	Date	Heure	Inst.	Code	Message
	2010-01-13	09:56:25	DELSON	SE1.35179	POSTE DEMARRE
N-3	2010-01-13	09:55:54	DELSON	T5	0 V0Bn
N-3	2010-01-13	09:55:54	DELSON	T5	0 V0Bn
N-3	2010-01-13	09:55:48	DELSON	T5	0 V0Cn
N-3	2010-01-13	09:55:46	DELSON	T5	0 V0Cn
R-4	2010-01-13	09:55:07	BELANGER	CC129...27	0106 MALT SERV AUX 129V
R-4	2010-01-13	09:55:07	BELANGER	CC129...27	0105 BAS TENS 129VCC
R-4	2010-01-13	09:55:07	BELANGER	CC129...27	0105 BAS TENS 129VCC
R-4	2010-01-13	09:55:04	PRAIRIE	120-18.71<	0315 BAS PRESS SF6 SEUI
R-7	2010-01-13	09:53:30	+MAXIME	L253..PR85	0808 PANNE COM CEPA L25
N-8	2010-01-13	09:51:36	HUNTI	T2	121 V0An
N-8	2010-01-13	09:51:36	HUNTI	T2	121 V0An
N-7	2010-01-13	09:50:29	+THERE 0	25-50CHFCA	0162 PERT ALIM CA OU CH
N-8	2010-01-13	09:50:09	ROUSS	T2	120 V0An
N-8	2010-01-13	09:48:25	ROUSS	T2	121 V0An
N-8	2010-01-13	09:48:25	HADLEY	T23	119 V0An

1330 items 154nouvelles non accusées 351 retours non accusés 825 accusées Temps réel

Accuser réception Localiser Info numérique/Analogique Supprimer Silence

ALB

SCADA : two channels



Chronological annunciator (ALCID-SICC-I)

Annunciateur traditionnel en liste chronologique

D 980617 16:12:57 CENTRALE BEAUHARNOIS ALARMES ANN LOC DESAC 00 TELE HORS

DATE	HEURE	CODE	DESCRIPTION	N/R
980617	19:11:32	A24.PT.38>	Haute temp regule palier turbine	N
980617	19:11:41	A24..86-1*	Decl prot mecanique alt	N
980617	19:11:41	A24RUR71H<	Bas niv huile bassin recup s oleo	N
980617	19:11:41	A24RVO.PO-	Arret pompe oleo bas niv recup	N
980617	19:11:41	A26RUR71H<	Bas niv huile bassin recup s oleo	N
980617	19:11:41	A26RVO.PO-	Arret pompe oleo bas niv recup	N
980617	19:11:41	A25RVO.PO-	Arret pompe oleo bas niv recup	N
980617	19:11:41	A25RUR71H<	Bas niv huile bassin recup s oleo	N
980617	19:11:42	D2-4B...27	Perte tens permut 2.4kV disj 2-4B	N
980617	19:11:43	D2-4B...27	Perte tens permut 2.4kV disj 2-4B	R
980617	19:11:44	A26RVO.PO-	Arret pompe oleo bas niv recup	R
980617	19:11:44	A26RUR71H<	Bas niv huile bassin recup s oleo	R
980617	19:11:44	A24RVO.PO-	Arret pompe oleo bas niv recup	R
980617	19:11:44	A24RUR71H<	Bas niv huile bassin recup s oleo	R
980617	19:11:45	A25RUR71H<	Bas niv huile bassin recup s oleo	R
980617	19:11:45	A25RVO.PO-	Arret pompe oleo bas niv recup	R
980617	19:11:46	L2.4KV..27	Perte tension ligne 2.4kV	N
980617	19:11:46	L2.4KV..27	Perte tension ligne 2.4kV	R

980617 19:11:44 A26RVO.PO- Arret pompe oleo bas niv recup R v

son acq acq p rap sens song acq T son hors

Still in use

Regional control center example (SAD)

011120 1240 LE		PUPITRE			TABLEAU D'ALARMS ET DE SEUILS			TELE
DATE	HEURE	ST	CODE	DESCRIPTION				
				IL N'EXISTE PAS D'ALARME PLUS ANCIENNE				
011106	044453	DESAU	PUI@... 71	HAUT NIVEAU EAU DANS UN DES PUIITS				047 N
011117	231549	LG 2 A	D24.CA... 27	PERTE TENS CA DISJ				017 N
011118	134215	NEMISCAU	S2... 27*	DECL PERTE TENS S2				354 N
011119	110052	RAD TERM	S0;85&86..	COND ANOR (GTCOMS) A/B				790 N
011119	132607	NEMISCAU	AS/A.CHE85	COND ANORM UNIT TON CHENIER SYS A				972 N
011119	134124	RAP HILE	L1.TPR..HO	POST HORS CIRC TELEPROT LIGNE 1325				004 N
011120	111733	FIGUERY	DIR... 69	PRESS SYST AIR ANORM				285 N
011120	112909	FIGUERY	CP1@... 74	COND ANORM COMPR 1 ET/OU 2				284 N
011120	121254	LG 2	BB15.SR. 74	COND ANOR MINEUR SYST REFROID BB15				059 N
011120	124008	LG 2	2... 71	NIV ANORM BARRAGE PRINCIPAL				145 N
011120	124008	LG 2	2... 71	NIV ANORM BARRAGE PRINCIPAL				145 R

In use up to october 2007

Regional control center example (Gen-4)

The screenshot shows a software window titled "(r) Sommaire des alarmes actives". The window contains a menu bar with options: Fichier, Alarmes, Distribution, Non-statut-par-défaut, Filtre, Tri, Actions, and Aide. Below the menu bar, there are search filters: "Toutes les alarmes pour" (set to "Toutes les installations") and "Sélection de l'état" (set to "Alarmes accusées ou non" and "Toutes"). A "Figer" button is also present. The main area is a table of active alarms with the following columns: Pri, Date, Heure, Inst., Code, and Message. The table contains 13 rows of data, with some rows highlighted in green, red, or yellow. The status bar at the bottom indicates "1330 items 154 nouvelles non accusées 351 retours non accusés 825 accusées" and "Temps réel". There are five buttons at the bottom: "Accuser réception", "Localiser", "nu numérique/analogiq", "Supprimer", and "Silence".

Pri	Date	Heure	Inst.	Code	Message
	2010-01-13	09:56:25	DELSON	SEI.35179	POSTE DEMARRE
N-3	2010-01-13	09:55:54	DELSON	T5	0 VØBn
N-3	2010-01-13	09:55:54	DELSON	T5	0 VØBn
N-3	2010-01-13	09:55:48	DELSON	T5	0 VØCn
N-3	2010-01-13	09:55:46	DELSON	T5	0 VØCn
R-4	2010-01-13	09:55:07	BELANGER	CC.....64	0106 MALT SERV AUX 129V
R-4	2010-01-13	09:55:07	BELANGER	CC129...27	0105 BAS TENS 129VCC
R-4	2010-01-13	09:55:07	BELANGER	CC129...27	0105 BAS TENS 129VCC
R-4	2010-01-13	09:55:04	PRAIRIE	120-18.Z1<	0315 BAS PRESS SF6 SEUI
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N-8	2010-01-13	09:51:36	HUNTI	T2	121 VØAn
N-7	2010-01-13	09:50:29	+THERE 0	25-50CHFCA	0162 PERT ALIM CA OU CH
N-8	2010-01-13	09:50:09	ROUSS	T2	120 VØAn
N-8	2010-01-13	09:48:25	ROUSS	T2	121 VØAn
N-8	2010-01-13	09:48:25	HADLEY	T23	119 VØAn

Color rectangles are flashing

In use

Example : Field

- Complex HMS
- Expert users
- Process control
 - Multiple interdependent variables
 - Dynamic - Risk - Conflicting objectives
 - Typical task : information → decision
- Hydroelectric power generation and transport
 - Multiple processes; most of them small
 - Complex configuration
 - Expert users

Present status

- Automation :
 - Smaller number of operators
 - More alarm points (for example 18,000 points in Beauharnois power plant)
 - From 20 to 30 (up to 70) installations for a tele-control desk
 - Up to 3000 alarms a day for one desk
- Cascades of up to 200 (up to 400) alarms at the beginning of a perturbation.

Present solutions : observations

- Acknowledge - reset without prior reading of alarm messages (loses historical information, gets the present state)
- In a power plant, the operators go directly to the control panel, without first looking at the alarm list on the CRT
- High proportion (operators opinion) of one by one judgment about pertinence of alarms
- From 70% to 80% (operators opinion) of alarms are not pertinent
- In important events, a high proportion of the alarms are momentary
- In some cases, it is difficult to understand the new state of the plant immediately after a complex event. The annunciator doesn't seem to help.
- Small or no pattern recognition in the regional control center *, only reading of alarm messages

* : except on the mosaic overview display : changes of state

Literature and products

- Intelligent filtering (to reduce the number of alarms) is difficult to implement and maintain
- Almost nothing on presentation
- No tests with experts
- Situation awareness thought to be important
- Products : design is neglected (ex.: date-time on the left; looks as if design was done for diagnosis)

Avenues of solution

- **Conjecture**

(after an event, first re-establish situation awareness; diagnosis is secondary)

(after a perturbation, one needs to update his mental model of the process before making decisions)

"The other important aspect of cognitive skills in on-line decision making is that decisions are made within the context of the operator's knowledge of the current state of the process."

Lisanne Bainbridge 1983

Avenues of solution

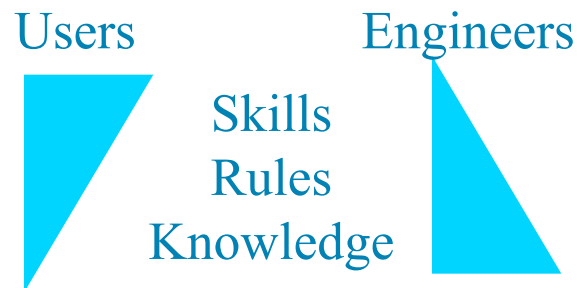
- We need to work on the presentation of information to help current state perception
- Pattern recognition is probably the best way (if not the only one)
 - Hint for the designer : my guess is that knowledge of Gestalt and characteristics of perception via peripheral vision might prove useful ...

Necessary attitude

“ The best attitude for today's designer to adopt is to think of the user as a different species that one knows nothing about; the user must be investigated scientifically to determine the optimal design features to facilitate the use of interactive systems ”
Deborah Mayhew

Be very careful with your own impressions,
concentrate on user reactions,
try to understand their goals, know the context.

You are building a tool for somebody else
who is doing a job you don't really know about (at least not at the skill level).
(Most of the time, you know too much about computers to rely on your own impressions to design an HMI)



Necessary attitude

“ Most (75%) of the ergonomist’s work is to describe and understand what already exists. ”

“ ... then everything will fall in place ... ”

Jean-Marc Robert

Any idea, however brilliant it looks, has to be tested.

Good usability tests are essential.

Design

First priority after an important event :
understand the new state of the plant

First objective after perturbation :
safeguarding the network

HMI has to be designed for the perturbed situations,
and must also work in normal operation

Density vs Structure

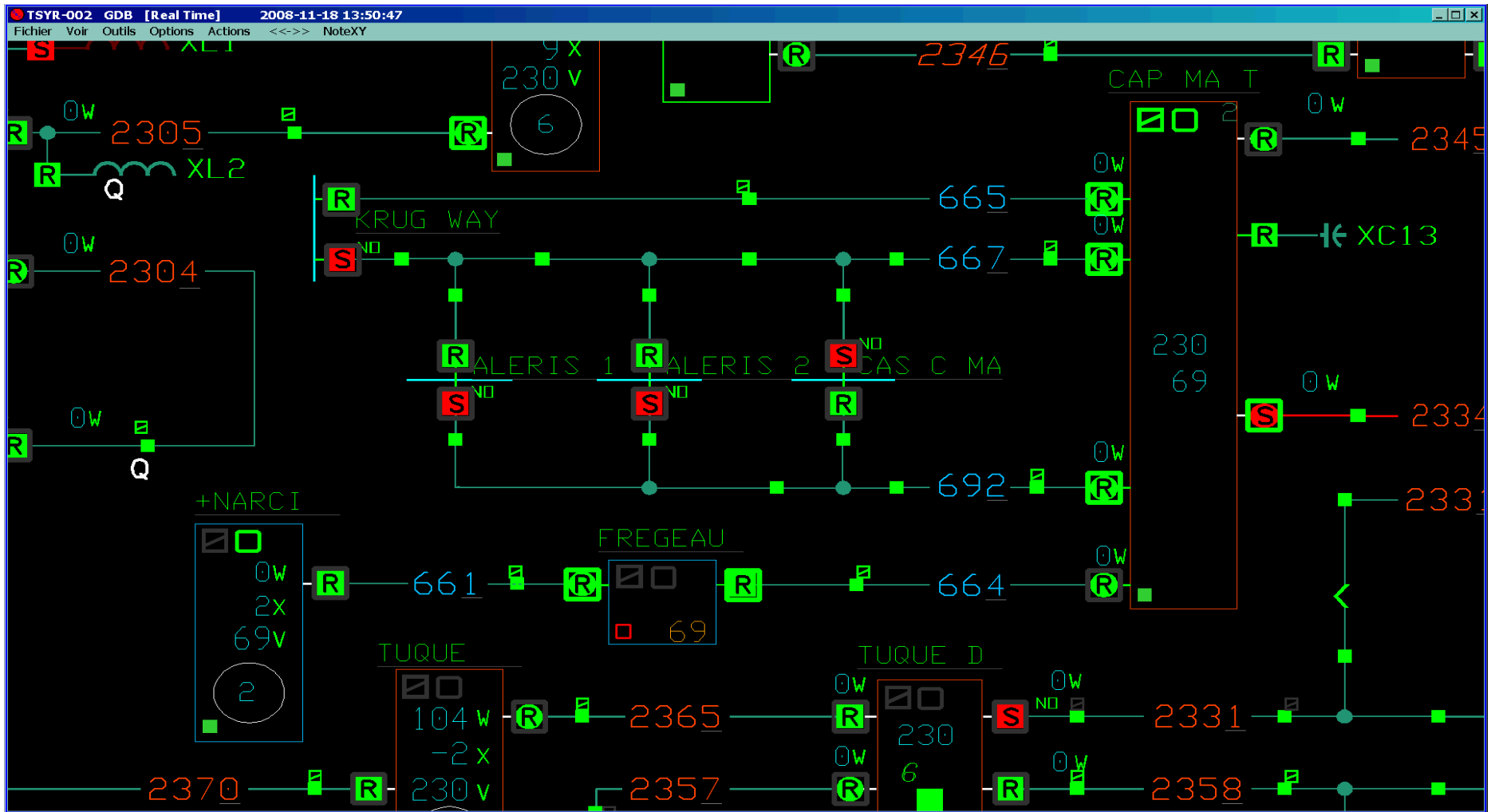
Diagnosis is a different task, done after the fact : it requires a
different tool, with filters, search, separate event for new alarm
and return to normal, date and time, ...

Overview display



Summer 2007

Overview display with alarms



Major lessons learned

- Demands \neq Needs
- Task mode : to extract information useful for design
- Mockup : as a design tool, as a medium for usability testing, and as a communication tool
- Objective : performance of HMS
- Usability testing and iterations are absolutely necessary

Lessons learned

- Analyze work activities (and use HTA to design the first draft of the HMI)
 - Don't consider demands as needs; try instead to uncover the real needs
 - Beware of needs expressed as solutions
- Task Mode
- Don't ask users to validate the requirements specification
 - Insure that the user is in « task mode » to obtain the right information
 - Beware of the pitfalls of participative design
 - Keep contact with the field by regular visits
- Objectives
- Evaluate the HMI according to the task logic and the performance of the human-machine system
 - Do not aim for conviviality as a primary objective
- Mockup
- **Build mockups**
 - Do the complete CE cycle
 - Explain the design process (tell the story) to the decision makers to convince them of the merits of the recommended design.

Difficulties

- Solutions becoming needs, or needs expressed in the form of solutions
 - Technical « trips »
- CE results difficult to explain to software developers (in fact to anybody who didn't spend much time observing users at work)
- Difficult to convince project leaders to accept the time and cost of CE
- Usability testing limits with experts

- One way to help convince project leaders, expert consultants, client representatives, ..., is to tell stories about users performing their tasks. Seeing a video of users in their activities may also be useful.
 - video and video editing
 - describe observations and the actual design process

Suggestions

- When a client demands something, find out why, find out what are the task objectives.
- Pay regular visits to users; be there also when the software is installed
- Always check with users (3-4 at least, if possible); but don't let them do the design; don't rely on your own opinion.
- Never (almost) do demos to users, ask them to use the product to do actual work
- Be rigorous (complete CE cycle), not necessarily formal
- < + citations.doc >

CE future (my opinion)

Compatibility with human being

Better representations : better adapted to human beings

Better interaction means : better adapted to human beings

User aware of what the computer is doing {Human-Computer Cooperation (Norman)}

Compatibility with task

Still far from complete generic solutions → bottom-up analysis is essential

Importance of details

Nature of expertise

Monitoring → better situation awareness, without saturation (especially the rapid restoration of situation awareness following a complex event)

(up to date mental model of the process + computer)

**Process Control
Tasks**

95% = acquisition of information, judgment on the quality of the information; importance of presentation

5% = decision

Intervention examples

→ `\pro-ics\IPM-AS\ICS\Pres-ICS-IdT-2005\ Exemples-realisations-ICS.ppt`

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