DG12 File

SCIENCE AND ENGINEERING RESEARCH COUNCIL
RUTHERFORD APPLETON LABORATORY

INFORMATICS DEPARTMENT

SYSTEMS ENGINEERING DIVISION NOTE 27

Visit to ISPRA
February 1989

issued by
R W Witty
9 February 1989

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M R Jane
K F Hartley
D A Duce
C P Wadsworth

(see next page)

1. INTRODUCTION

ISPRA is the biggest lab of DG12, the Joint Research Centre. The JRC consists of

1. ISPRA
2. Patten - high flux reactor
3. Karlsruhe - transuranium elements
4. Geel - nuclear measurement

Jean Pierre Contzen is deputy DG of DG12 and DG of the JRC. He is based in Brussels. George Bishop is head of ISPRA, but is about to be pensioned off. JRC is being split up into 9 Institutes. Institutes are not necessarily single site. Some subcontract to each other.

ISPRA has a very similar look and feel to RAL - big, geographically isolated, full of old physicists!

Institutes are

1. Systems Engineering

   IKBS for nuclear safety and new areas, eg transport.
   Nuclear Fusion
   - safety aspects
   - collaborate with USSR and Japan
   - IGNATUR (Italian project)

2. Safety Technology

   Nuclear (fission) reactor safety
   looking to broaden into non nuclear, eg chemistry.

3. IT and Electronics

   central computing dept for site
   R&D programme. (ESPRIT help) (like CCD and Inf)

4. Prospective Studies

   bootstrap work
   5 people
   brand new institute
   no objectives yet.

5-9. Not listed.

ISPRA has 1500 staff on site (Mitchinson says 50% over age 50!) All old staff on permanent contracts. All new staff on 3-5 year fixed term.

Budget over 4 years.

	MECU	Staff
DG12 framework	700	1683
Other DGs	120	262
outside work	130	235
win new work	250	497
	900	2180

Cost of physical security for nuclear installations is very expensive therefore high overheads.

Staff

Geel	200
Patten	160 (increasing)
Karlsruhe	200
ISPRA	1600

DG Agriculture is biggest customer (remote sensing, land use survey etc) also DG Nuclear Safeguards (research and inspector training), DG Energy (technical support).

DG Environment (protection of consumers, food and drug, increasing because 'green' is fashionable).

ISPRA strategy to diversify into

1. Environment (growth area!)

2. Internal market (a la ESPRIT)

3. Infrastructure (a la Arpanet).

ISPRA got lots of money for PhD students and sabbatical visitors.

ISPRA has admin problem about getting money from ESPRIT (just like RG2s!). Keen to collaborate with outsiders because been isolated for too long.

Institute of IT and Electronics

Has two sides just like CCD and ID. CCD side runs site computers. Big Amdahl and carousel type square tape cartridges. Staff shortages!

ID side does R&D

1. parallel processing (transputers!)

2. image processing (satellites, robots)

3. IKBS

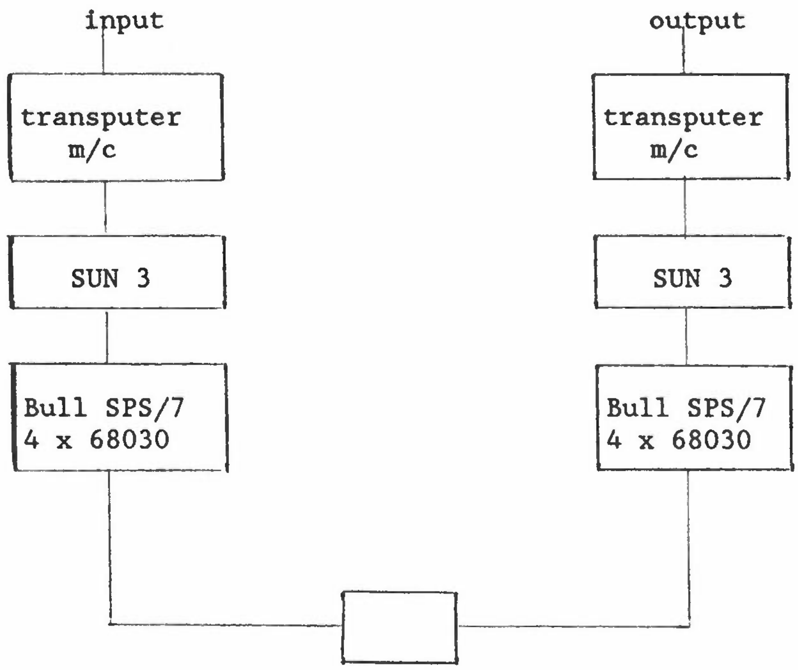
4. electronics for plant monitoring.

Looking to get new work being 'shop window' for ESPRIT products! eg Supernode.

ERCOFTAC collaboration includes Harwell on combusion (CFD?)

Transputers

Going to buy kit for image processing



Looking to buy Supernode and Meiko or MF(?). This is the 'French' clique. Interested in being European Transputer Centre (meeting with MRJ 22 February 1989). Also existing other image processing project run by German, who is running Transputer Workshop at ISPRA Summer 89.

Networking

Unclear if setting up WAN or just arm waving.

Done own 140 Mbit/sec optical fibre LAN. (Plessey involved - now "obsolete").

Burotics

Got lots of admin s/w (700K lines Cobol) and maintenance problem!

Burotics is Anglicisation of French for ofice automation (cf Informatics!)

IKBS

Wargame system for nuclear safety

CD-ROM + hypertext (with Maxwell UK) uses Apple Hyper Card.

Financial adviser for Finance Admin.

Image database for JET. (pictures of inside of JET for robot maintenance in future).

90 people in CCD bit, 30 in ID bit staff shortages! Target 200.

Institute of Systems Engineering

10 years old.

1. Nuclear Safety

   Databases of accidents
   Looking to do fuzzy reasoning

2. HCI

   trying to do cognitive modelling of nuclear plant operator so can stop him doing silly things in accident situation.

3. Probabistic safety analysis

   fault tree analysis software
   tools/workbench
   Eureka FORMENTOR project with aerospace companies.

HCI/Cognitive is MOHAWC (ESPRIT BRA) includes Manchester (UK) pshycology department. Prof James Reason.
Uses Symbolics + Key + Lisp (operator model) and SUN (plant model).
Ultimate payback is redcution on insurance premiums!

Conclusions

Follow up actions in Computing were

1. Networking (CCD)
2. Cray time (CCD)
3. Transputers (ID). Meeting at RAL with MRJ 22/2/89.

Visit of Dr P R Williams, Director of Rutherford Appleton Laboratory,
accompanied by
Dr D Llewellyn-Jones, Dr B Davies, Dr R Witty and Mr B Toner

on February 1st and 2nd 1989

P R O G R A M M E

<u>Wednesday, February 1st</u>

09.00	Departure from Hotel Crystal, Varese
09.30	Arrival at the Ispra Establishment Welcoming address and introduction to the JRC activities and their evolution by Mr J P CONTZEN, JRC General Director (Conference room n° 6, Bldg. 6)
11.00	Institute for Remote Sensing Applications - Application of Laser Mr R KLERSY (Bldgs. 67 and 44)
13.00	Lunch at the "Piccola Mensa"
14.30	Presentation of the Rutherford Appleton Laboratory's activities by Dr P R WILLIAMS (Conference room n° 6, Bldg. 6)
15.30	Centre for Information Technologies and Electronics Mr P BONNAURE (Bldg. 36)
17.30	Return to Hotel
20.00	Dinner

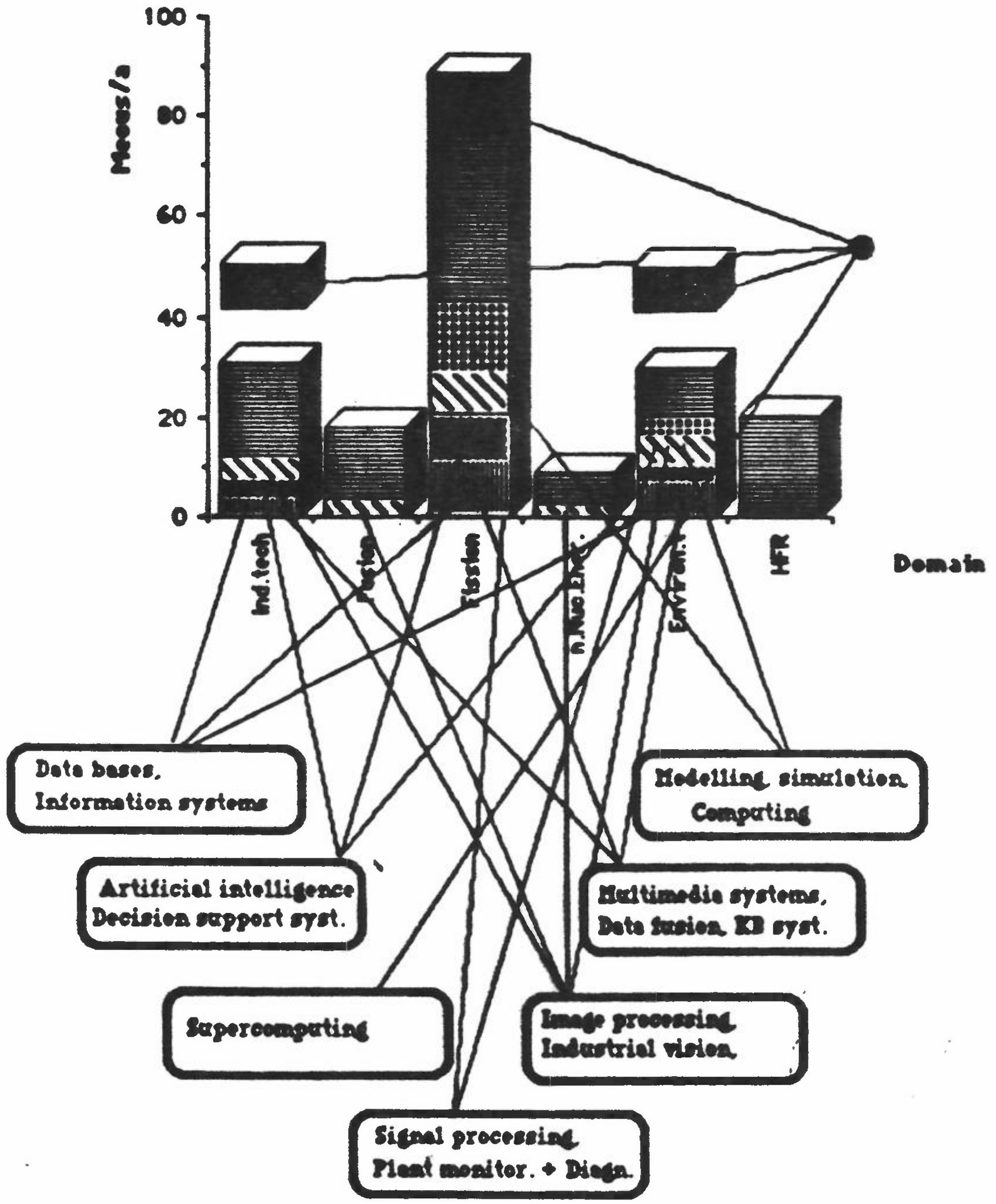
Thursday, 2nd February

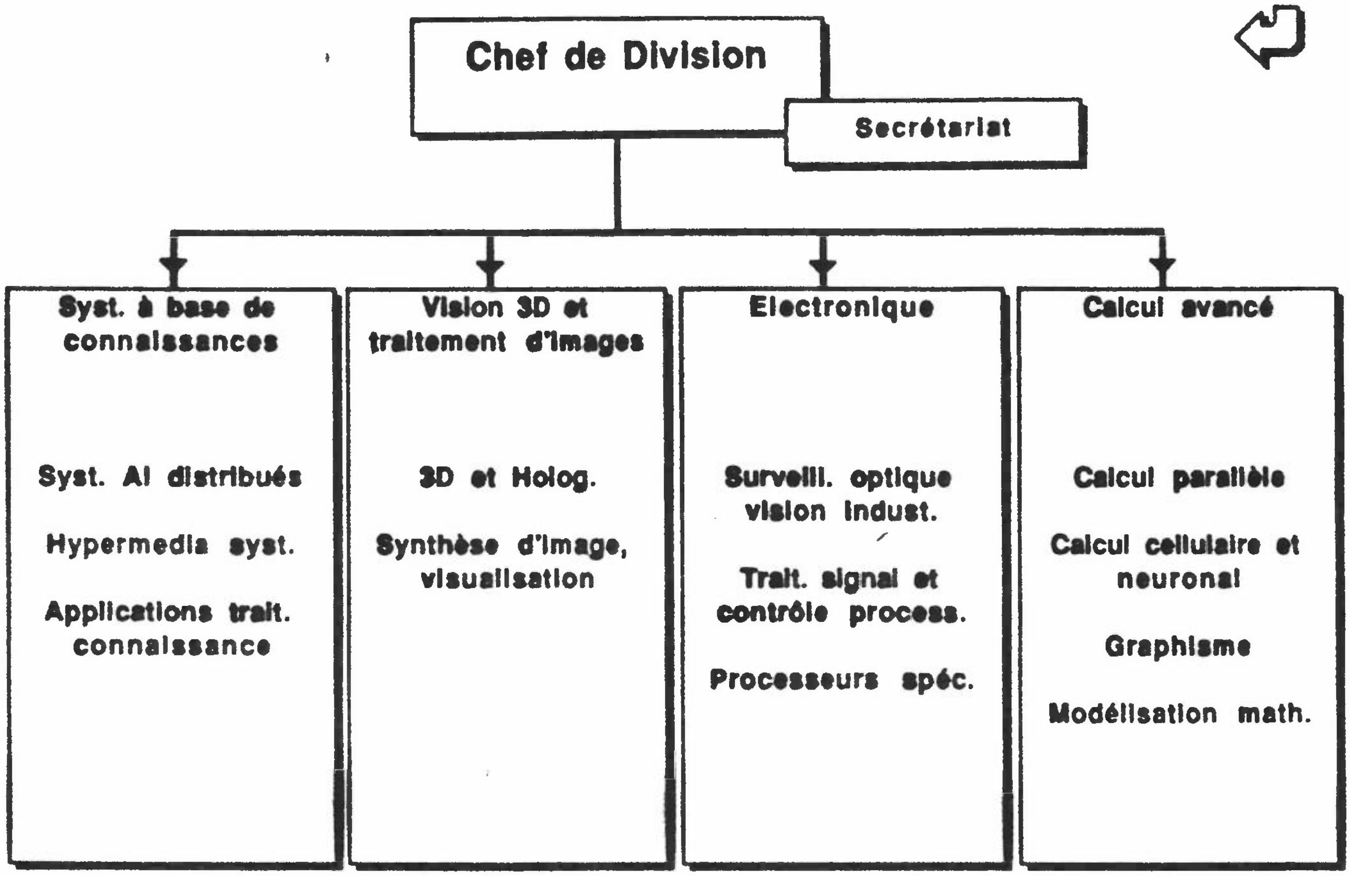
09.00 hrs	Institute for Advanced Materials	
	- Laser Foundry	L. Manes (Bldg 75)
10.00 hrs	Institute for Systems Engineering	G. Volta (Bldg 21)
12.00 hrs	Conclusions	G.R.Bishop Conference Room (Bldg 6)
12.30 hrs	Departure for Linate	

Alternative

10.00 hrs	Lasers in Remote Sensing	G. Bertolini (Bldg 27B) (receiving Mr TONER)
	Atmospheric Chemistry	G. Restelli (Bldg 27B) (receiving Mr LLEWELLYN-JONES)

Contribution of Information Technologies

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Hypermedia syst.
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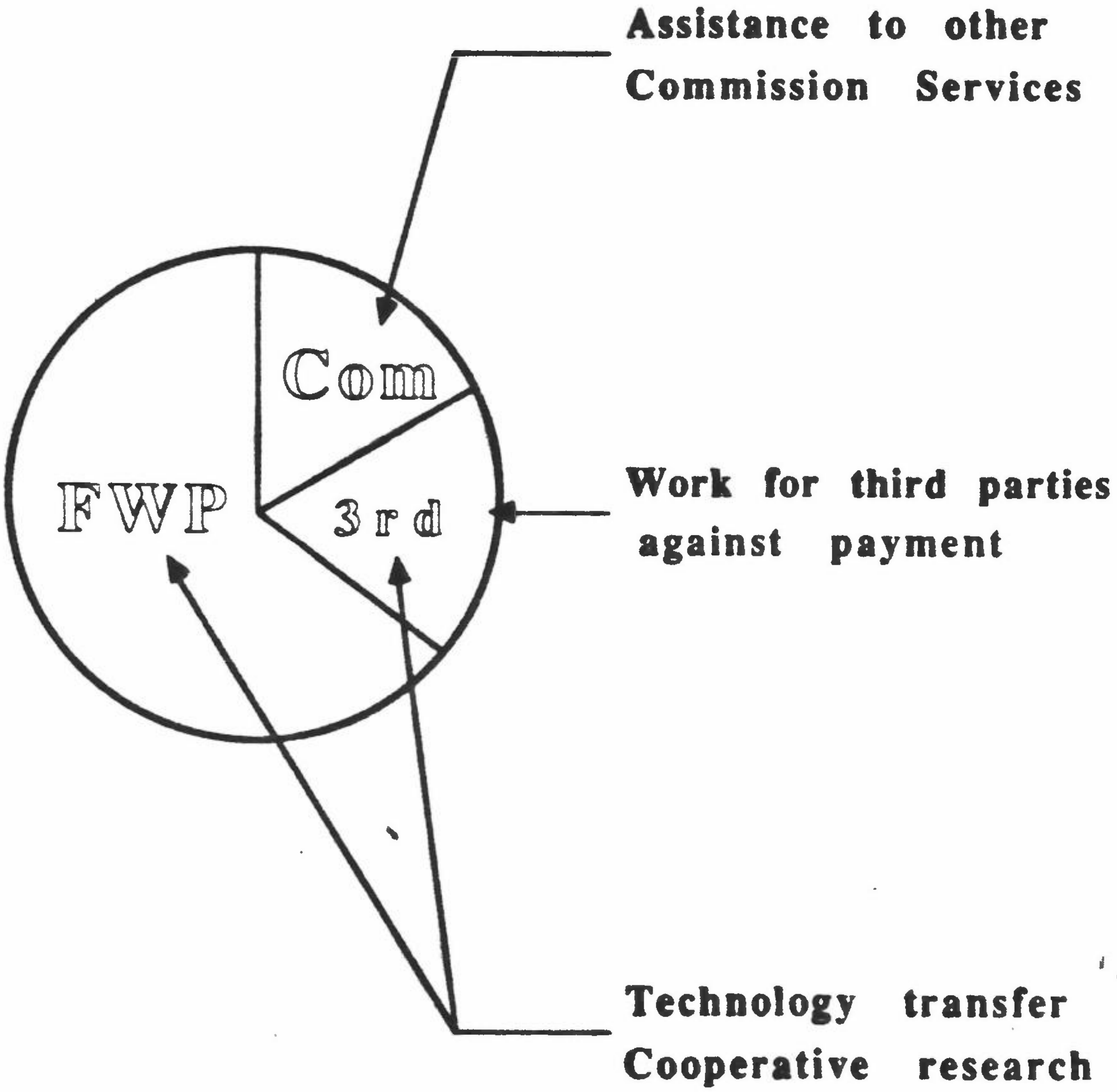
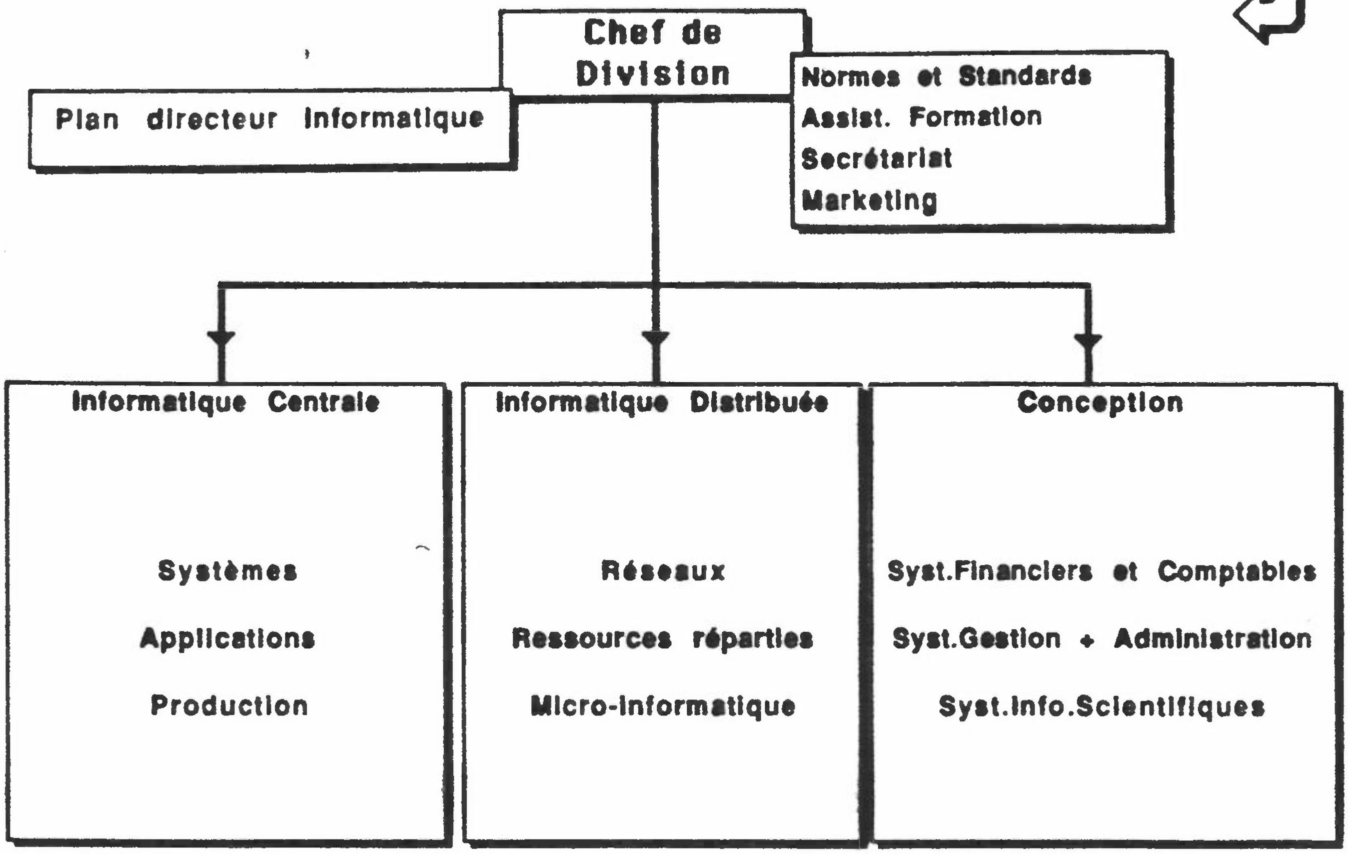
Vision 3D et traitement d'images
3D et Holog.
Synthèse d'image, visualisation
Electronique
Surveill. optique vision indust.
Trait. signal et contrôle process.
Processeurs spéc.
Calcul avancé
Calcul parallèle
Calcul cellulaire et neuronal
Graphisme
Modélisation math.

C.I.T.E

towards industry and final user

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Conception
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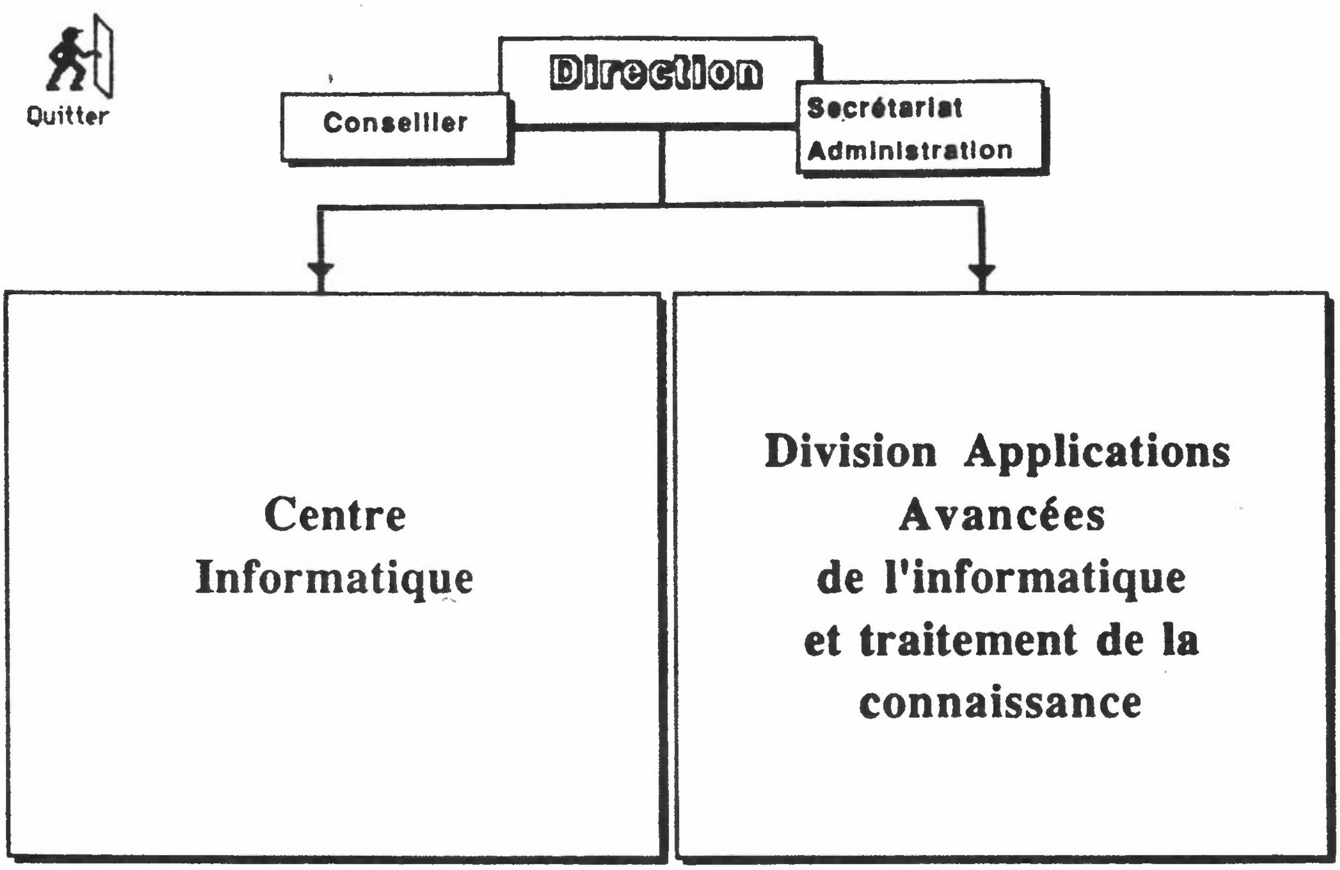
Syst.Gestion + Administration
Syst.Info.Scientifiques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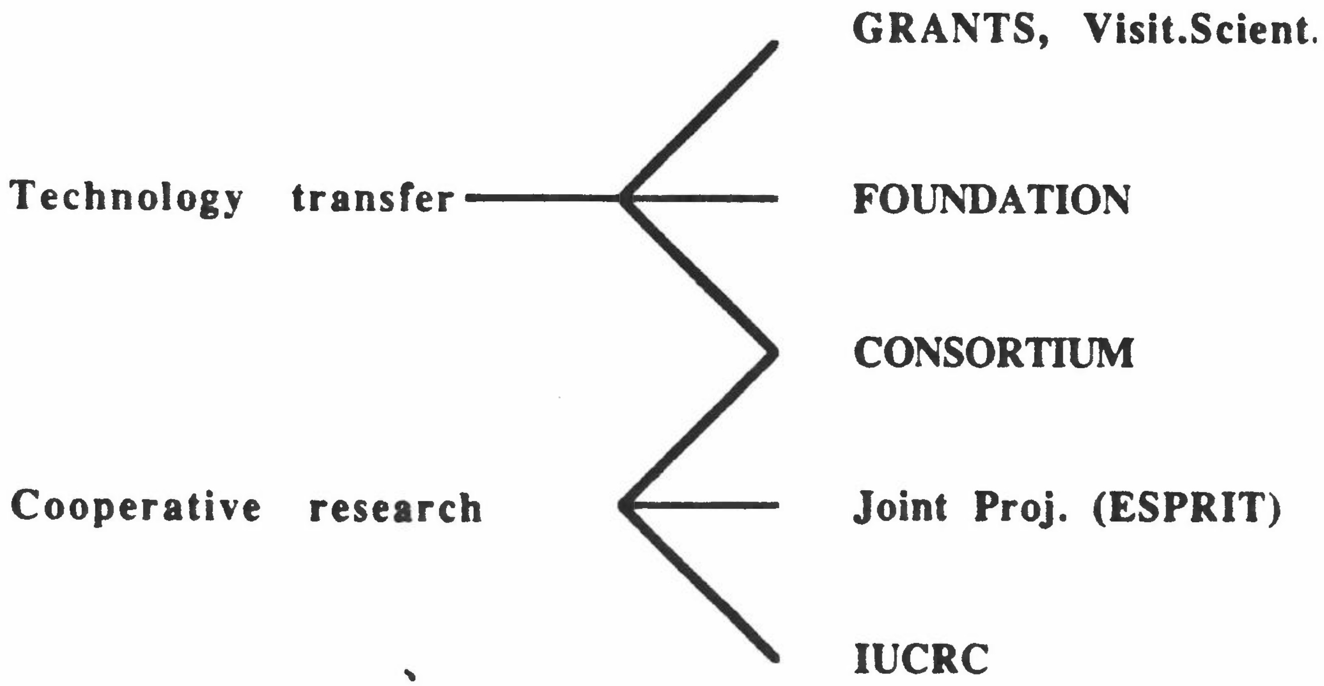
C.I.T.E

towards industry and final user



C.I.T.E.

Corporate management tools

Administration :

- Financial system
- Personnel management and wages
- Inventory
- Access
- Medical service

Communication :

- Inter-Establishment networking
- Campus networks
- DUAL backbone network
- ERCOFTAC network (with DG XIII)

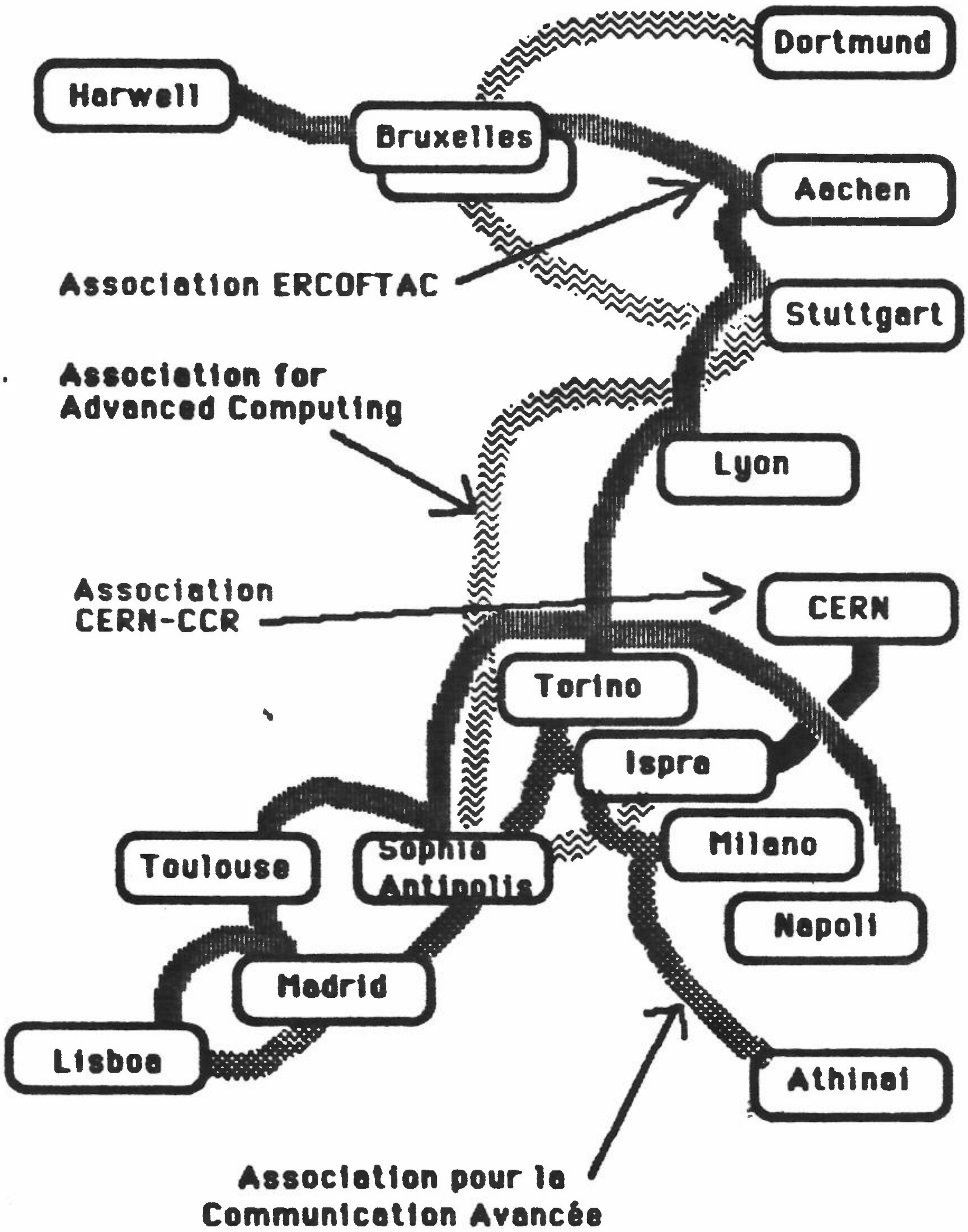
Knowledge based and multi-media information systems :

- Expert systems for AIEA inspections
- CD-ROM + hypertext for ACTA
- FARSCAN pilot for Financial Control
- HIWAY project for S.ta.Autostrade
- Image base for JET

ESPRIT II projects :

- ARCHON, with KRUPP (multipurpose
- KWICK with BULL (adv. burotics)

JRC and Research Networks



C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :

Informatic Center

Consortium

Division 2:

Advanced Applications

Foundation

-to compensate for the lack of local resources,
-to complement existing mobility measures for researchers,
-to participate into joint research projects in supercomputing with ERCOFTAC, CERN, CERFACS , ...
-to open services to region , industries, SMCs,
-to help promote applications of ESPRIT products, such as Supernode,
-to prepare future activities for the JRC

C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :

Informatic Center

Consortium

Joint venture,
to share the cost
of a supercomputing
center with varied
machines , up to a
CRAY 3

Division 2:

Advanced Applications

Foundation

+20 grants JRC
+20 grants Industry
+ X grants DG XIII
+10 people detached
from JRC

C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :

Informatic Center

Offers:

-Scalar/vector computing with IBM compatible mainframes, UNIX minis and mini-supers.
-Access to remote CRAYs.
-Networks and distributed services : CAD/CAM, burotics
-Data base and corporate information systems developpement, administration and service (host).
-Program library, user support, training and education.

Division 2:

Advanced Applications

Offers:

-Advanced computing : massively parallell, neural, cellular, connectionist
-Image processing, pattern recognition, industrial and robotic vision, image bases
-Knowledge based, multimedia information systems and decision support systems; cooperating expert systems; advanced burotics. CD-ROM mastering
-Electronics, signal processing, plant monitors
-Industrial vision, optronics
-VLSI custom chip design.

C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :	Division 2:
Informatic Center	**Advanced Applications**

Service oriented.
Delivers both hardware, software and study services.
In charge of networks, connectivity and procurement policy for the whole JRC.

Research and development oriented.

C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :	Division 2:
Informatic Center	**Advanced Applications**

C.I.T.E.

Center for Information Technologies and Electronics

Division 1 :

Informatic Center

Consortium

Joint venture, to share the cost of a supercomputing center with varied machines , up to a CRAY 3

Division 2:

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+20 grants JRC
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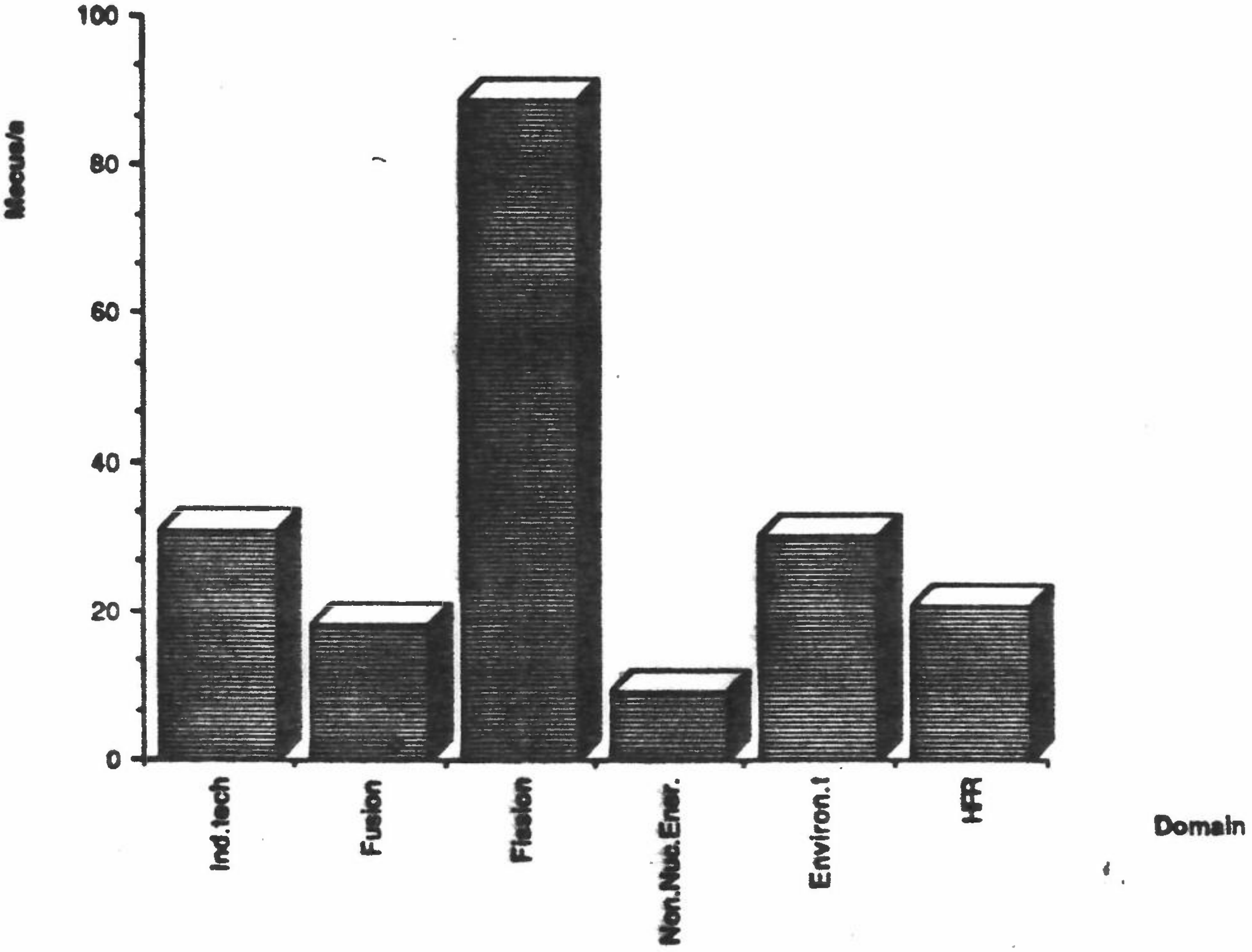
+10 people detached from JRC

JRC activity break-down



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A COGNITIVE MODEL OF HUMAN BEHAVIOUR FOR SIMULATING OPERATORS OF COMPLEX PLANTS

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Joint Research Centre Ispra
21020 Ispra (Va), Italy

To be presented at: *International Seminar on Human Interface*
Kyoto, Japan, 22 -23 February 1988.

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ABSTRACT

This paper discusses the need of a "deterministic" representation of the operator's reasoning and sensory-motor behaviour in order to approach correctly the overall problem of Man-Machine Interaction (MMI). Such type of modelling represents a fundamental complement to the merely probabilistic quantification of operator performances for safety as well as for design purposes.

A cognitive model, formally based on a hierarchical goal-oriented approach and driven by fuzzy logic methodology, is then presented and briefly discussed, including the psychological criteria by which the content of operators' knowledge is exploited for instantiation of strategies during emergencies.

Finally the potential applications of such methodology are reviewed identifying limits and advantages in comparison to more classical and mechanicistic approaches.

1. INTRODUCTION

The study and the consideration of Human Factors (HF) and the evaluation of engineered systems by means of Man-Machine Interaction (MMI) approaches have become, in the past years, key issues in most fields of modern technology. This is mainly the result of the complexity of the work environment, the removal of the operator from the contact with the process, the multiple decision making level required to control complex plants, the use of decision support systems, etc., as discussed by many authors like Sheridan [1], Decker [2], Norman [3] and Rasmussen [4]. In such a scenario, it results necessary to consider the operator mainly as a supervisor and a decision-maker rather than a manipulator of control mechanisms for compensating disturbances of a plant. This leads to a need to include the analysis of the mental mechanisms of decision making when designing the plant control system and the safety devices. The recognition of the role played by the human being in managing transients and unexpected events, has enhanced the research in the field of modelling the performance of operators, accounting for cognitive as well as motor activities and combining psychological consideration, logic formalisms and decision making theories, as discussed in Rasmussen [5], Rouse [6], Mancini [7] or Cacciabue and Bersini [8]. These models represent a step forwards in that they attempt to model the behaviour of operators in a "deterministic" way, as opposed to the "behaviouristic" approaches, where only the sensory-motor activities of operators are accounted for. This distinction is similar to what occurs in plant analysis, where two main lines of development have been followed, on the one hand, by the simulation of the physical phenomena evolving within the plant, and, on 'the other hand, by analysing probabilistically the behaviour of components independently of the transient within which they operate.

In this paper, a model of behaviour of plant operator is proposed, where the cognitive processes leading to decisions as well as the execution of strategies are simulated in details for the management of a plant in transient conditions. In the following sections the general architecture and the rationale of the model are discussed and then the details of the methodologies applied for the different parts of the model are presented. Finally some conclusive remarks, including the directives for future research, are briefly discussed.

2. COGNITIVE MODEL OF OPERATOR'S BEHAVIOUR

Following the above discussion, simulating the behaviour of an operator in a modern complex plant requires primarily the modelling of the primitive cognitive processes performed by the operators, accounting for the environmental constraints in which they are activated. Many existing techniques focus separately on models of detection, planning, diagnosis or execution with adequately different formalisms, as described by Rasmussen [5] and by Rouse [6]. In the present model, instead, the tendency is towards an integrated simulation, allowing to tackle all the activities of the operator in the same modelling context. A conceptual framework has been developed whereby the models of the plant and of the operator act as interactive counterparts of the man-machine system simulation (fig. 1). Two cognitive levels of reasoning and decision making are foreseen, " High Level Decision Making " (HLDM) and " Low Level Decision Making " (LLDM). The HLDM model accounts only for pure mind-work implying long term planning as well as the analysis of the plant as a whole and possibly the reasoning about the evolution of physical phenomena. No direct interaction with the actual control system is foreseen, in that information on the plant behaviour is passed to the operator for his diagnosis and formulation of strategy of actions. These actions are actually carried over in the LLDM model, where the interaction with the machine is dual in the sense that plant behaviour data and operator actions of optimization or regulation develop on a short time scale and on localized part of the plant such as control panels or manually operated components. Errors can be made at any time of the sequence under study or at any level of the human behaviour model, and the detection and recovery processes are implicitly considered as feedbacks or results of the various ongoing processes within the HLDM and LLDM levels.

2.1. High Level Decision Making

In the HLDM model the formulation of sequences of intentions or goals and the ordering of such goals in a hierarchical goal-oriented structure, as in Bainbridge [9] and Rasmussen [10], is proposed as the general framework within which the strategies of operators are developed and carried over. Here intentionality is considered a fundamental aspect of cognitive processes, in accordance with Searle [11].

The cognitive system is organized in a Knowledge Base (KB), where the entire knowledge of the operator is contained, and a Working Memory (WM), where the mental schema are processed (fig. 2). The knowledge base contains two kinds of internalized frames: Rule Frames (RF) and Knowledge Frames (KF).

1 The Rule Frames are packets of preprogrammed instructions for diagnosing and recovering a particular emergency. They are characterized by:

* "state labels", "attributes" and "frequency tags", which relate to a specific event, its diagnosticity signs and to the frequency of encounter;
* a hierarchical structure of subsequent interlinked goals to be accomplished in order to control the transient (fig. 3); and
* parts of frames, such as the elementary goals of a structure or more complex sequences of a task, which are considered as "content-addressable" and thus can be "called" into play in the working memory of the operator at any time.

2 The Knowledge Frames contain only general principles regarding the operation of the plant and a wide range of pointers to "content-addressable" actions, but no precompiled structures of interconnected sequence of goals. The formulation of a strategy is developed by KFs using a slow and intermittent interaction process with the plant transient.

The access to KB, in order to select possible candidates for the formulation of the strategy to be instantiated in the Working Memory, is granted by three basic mechanisms: two of them, "similarity matching" and "frequency gambling", represent the parallel, rapid and efficient component of the retrieval process, the third one, "directed inference", accounts for the serial, slow and conscious component, as thoroughly discussed by Reason in recent works [13,14].

The plant dynamics and the HLDM model interact through the combination of the "cues", transferred from the plant to the operator, and the "attributes" associated with a frame. The perception of a cue is indeed dependent on its "diagnosticity" and "accessibility" and on the "Currently Instantiated Frame", i.e. the frame present in the mind of the operator at the time of the initiating event. The values associated with these quantities depend on the operator expertise and plant design. The number of cues that will reach the operator's attention will be a small subset of the available ones, and consequently more than one RF is likely to be selected by the mechanism of "similarity matching" which operates between external perceived cues and internal attributes of frames. The technique implemented in order to match like-with-like is fuzzy pattern matching, which is coherent with the intervals associated to cues and attributes. Indeed, these are rarely associated to crisp entities but rather to intervals which allow to represent the approximate and imprecise knowledge of the operator and thus the use of fuzzy logic as driving methodology of reasoning. The selection amongs partially matched RFs will be performed on the bases of frequency of encounter, i.e. the "frequency gambling" mechanism. When no matching with RFs is obtained the switch to a knowledge frame is performed and the search for an appropriate strategy to be carried over will be started by the retrieval process of direct inference. This requires the interaction of some higher order principles and some rules of thumb of the operator with the actual plant dynamics. In this case the role played by the task analysis in the case of RFs is taken by a general mental model of the plant which the operator has developed during training, experience and theoretical background. This type of mental representation is based on qualitative modelling approach [15].

2.2. Low Level Decision Making Model

The tree of goals selected by the HLDM model is actually carried over within the LLDM model which interacts with the simulation of the plant and its interfaces. The dynamic allocation of goals in the working memory and the simulation of the attainment of a goal during the flow of events is based on fuzzy logic, which is a well suited theory for representing the approximate operator's knowledge and allows to create a semantic interface between the system simulation and the operator cognitive model, as in Dubois and Prade [12]. Each goal is associated with a certain number of executional parameters which identify uniquely the goal and regulate the navigation through the network. There are four main parameters, the *degree of priority* (GDP), the *degree of membership* (GDM), the *degree of satisfaction* (GDS), and the *degree of cenainty* (GDC): GDP, assigned by HLDM, expresses the measure of hierarchical sequence between goals; GDM, also assigned by HLDM, defines the measure of the dependency between a goal and its directly superior goals; GDS, evaluated in LLDM, represents the correlation between the result of a goal and the operator's expectancy; and finally GDC represents the measure of the attainment of a goal.

The navigation through the network is regulated by the values assumed by the parameters of the goals. At any level the operator attends to the goal of highest priority. The attainment of a goal is measured by the GDS and GDC parameters, which are governed by the "fuzzy feedback mechanism". The following steps are performed.
GDS is evaluated as the result of matching the goal expectancy and the real behaviour of the related indicators, expressed by means of a trapezoidal membership function:

$$GDS(goal) = f_{trapez}(x,a,b,c,d) = \begin{cases} 0 & \text{for } x< a \\ \frac{(x-a)}{(b-a)} & \text{for } a< x< b \\ 1 & \text{for } b< x< c \\ \frac{(d-x)}{(d-c)} & \text{for } c< x< d \\ 0 & \text{for } x> d \end{cases} \qquad (1)$$

in case of static estimations; and :

$$GDS(goal) = f_{trapez}(dx/dt,a,b,c,d)$$

in case of dynamic estimations.

When GDS is greater than a pre-established threshold the goal is considered as attained and the next goal in the tree structure is tackled, in order of priority. If GDS is below the pre-established threshold value, then GDC is evaluated in terms of GDS of the goal itself and GDC and GDM of the connected sub-goals. Assigning two weighting factors, x to GDS and y to the sub-goals GDC and GDM, and using the fuzzy logic dual concepts of *necessity* (N) and *possibility* (Π), the expression of GDC of a goal is:

$$\Pi = \max[\min(x,GDS(goal)), \min(y,GDC^{*}(sub-goals))] \qquad (2)$$

$$N = \min[\max(1-x,GDS(goal)), \max(1-y,GDC^{*}(sub-goals))] \qquad (3)$$

$$N \leq GDC(goal) \leq \Pi \qquad (4)$$

where :

$$GDC^{*}(sub-goals) = \max_{j=1,k} \{ \min[GDC(sub-goal_j), GDM(sub-goal_j)] \} \qquad (5)$$

in case of an "or" gate connecting the goal with its sub-goals; or :

$$GDC^*(sub-goals) = \min_{j=1,k} \{ \max[GDC(sub-goal_j), 1-GDM(sub-goal_j)] \} \quad (6)$$

in case of an "and" gate connecting the goal with its sub-goals.

By this approach it is possible to model various degrees of confidence experienced by the operator during the management of the accidental sequence. As an example, figure 4 presents the dynamic evolution of GDC of the operator, in terms of N and Π, for a case of contradictory information, as in Bersini, Cacciabue and Mancini [16], which leads to complete inactivity (step 4-5) until new information is collected and a more clear understanding of the situation is obtained.

3. CONCLUSIONS

In this paper the methods used for developing a model of human behaviour based on cognitive sciences as well as on mathematic formalisms have been described. Such research, although in its early stages has already shown some encouraging results when the model has been applied to simple test case and only for "normative" operator behaviour. In particular, the following qualities of a cognitive approach can be summarized in:

1 the model is fully adaptive to whichever configuration the components of the system might take, at any time of the transient.

2 the dynamic aspect of the plant evolution does not represent a serious problem to the man-machine simulation; and

3 the cognitive attitude of the operator and his internal errors can be fully accounted for by the theoretical prethought simulation, i.e. behaviouristic aspect of the operator's error is not evaluated by an a-priory function but rather it results from the entire evolution of the man-machine interaction.

The future research will concentrate on the validation of the model by its application to more realistic and complex cases and on the consideration of degraded ("descriptive") knowledge in order to include errors and inappropriate behaviour of operators, also in presence of faulty and incomplete information.

It must be recognized, however, that the complexity of a cognitive model represents a major drawback for its extensive use in broad studies like those required for PSA for a Nuclear Power Plant. For this reason it can argued that there exist in reality distinct fields of applications which require different types of approaches. It is up to the designer or the plant analyst to recognize the needs of a deeper evaluation of the cases under study and to decide whether it is necessary or not to substitute a behaviouristic analysis with a more sound model of the operator cognitive activity in the interest of the overall safety of the plant.

REFERENCES

[1] T.B. Sheridan, Forty-five years of Man-Machine systems: history and trends. Keynote Address. Proceedings of *2nd IFAC Conf. on Analysis, Design and Evaluation of Man-Machine Systems*, Varese, Italy, 10-12 September 1985 (Pergamon Press, Oxford 1986).

[2] K.S. Decker, Distributed problem solving techniques: a survey, *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-17, 5, (1987) 729-740.

[3] D.A. Norman, New views of information processing : Implications for intelligent decision support systems. In *Intelligent Decision Aids in Process Environments*, E.

Hollnagel, G. Mancini & D. Woods (Eds.), NATO ASI Series, (Springer-Verlag, Berlin, 1986).

[4] J. Rasmussen, Mental models and the control of actions in complex environments, 6th Workshop on Informatics and Psychology: Mental Models and Human-Computer Interaction, Schaerding, Austria, June 1987, RISO-M-2656 (July 1987).

[5] J. Rasmussen, Simulation of Operators' Response in Emergencies. RISO-M-2616 (1986).

[6] W. Rouse, Models of human problem solving: detection, diagnosis and compensation for system failures. *Automatica* 19, 6 (1983) 613-625.

[7] G. Mancini, Modelling humans and machines. In *Intelligent Decision Support in Process Environments*, E. Hollnagel, G. Mancini and D. D. Woods (Eds.), NATO ASI Series, (Springer-Verlag, Berlin, 1986).

[8] P.C. Cacciabue and U. Bersini, Modelling Human Behaviour in the Context of a Simulation of Man-Machine Systems. In *Human Decision Making and Control*, J. Patrick and K. Duncan (Eds.) (North-Holland, Elsevier, Amsterdam), to appear.

[9] L. Bainbridge, What should a good model of the NPP operator contain? Proceedings of *Int. Topical Meeting on Advances in Human Factors in Nuclear Power Systems*, April 1986, Knoxville, Tennessee, USA.

[10] J. Rasmussen, The role of hierarchical knowledge representation in decision making and system management. *IEEE Trans. on Syst. Man, and Cybern.*, SMC-15, 2, (1985), 234-243.

[11] J.R. Searle, The intentionality of intention and action. *Cognitive Science* 4 (1980) 47-70.

[12] D. Dubois and H. Prade, On several representation of an uncertain body of evidence. In M.M. Gupta and E. Sanchez (Eds.), *Fuzzy Information and Decision Process* (North Holland, Amsterdam, 1980).

[13] J. Reason, Modelling the Basic Error Tendencies of Human Operators. 9nt SMiRT Post-Conference Seminar on Accident Sequence Modelling: Human Actions, System Response, Intelligent Decision Support. Munchen, FRG, August 24-25, 1987. To appear in *Reliability Engineering and System Safety*.

[14] J. Reason, papers in J. Rasmussen, K. Duncan and J. Leplat (Eds.) *New Technology and Human Errors* (J. Wiley and Sons, 1987) pp. 5-14, 15-22, 45-52, 63-86.

[15] D.G. Bobrow (Ed.), *Qualitative Reasoning about Physical Systems*. Reprinted from *Artificial Intelligence*, volume 24, 1984 (North-Holland, Amsterdam, 1985).

[16] U. Bersini, P.C. Cacciabue and G. Mancini. (1987). Cognitive Modelling: A Basic Complement of Human Reliability Analysis. 9nt SMiRT Post-Conference Seminar on Accident Sequence Modelling: Human Actions, System Response, Intelligent Decision Support. Munchen, FRG, August 24-25, 1987. To be published in *Engineering Reliability*.

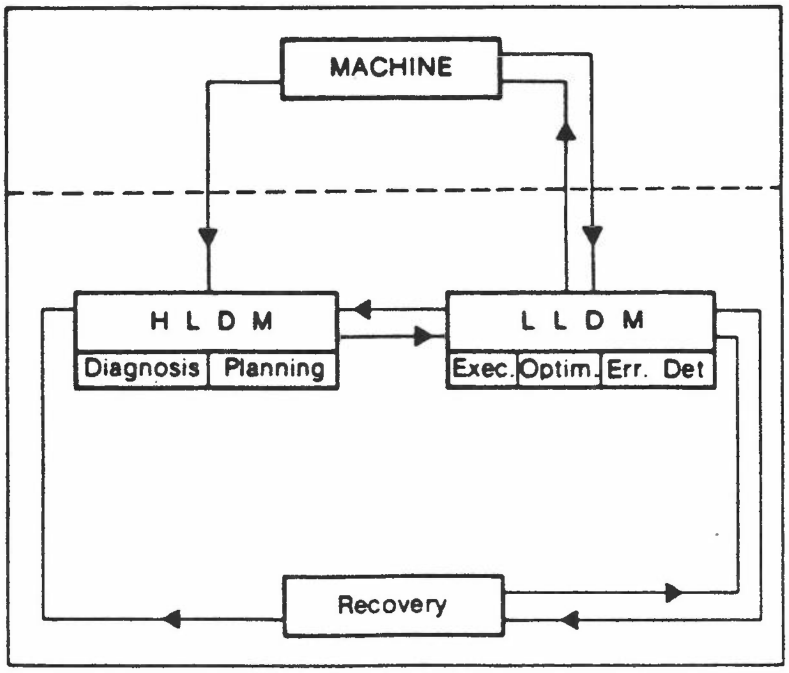
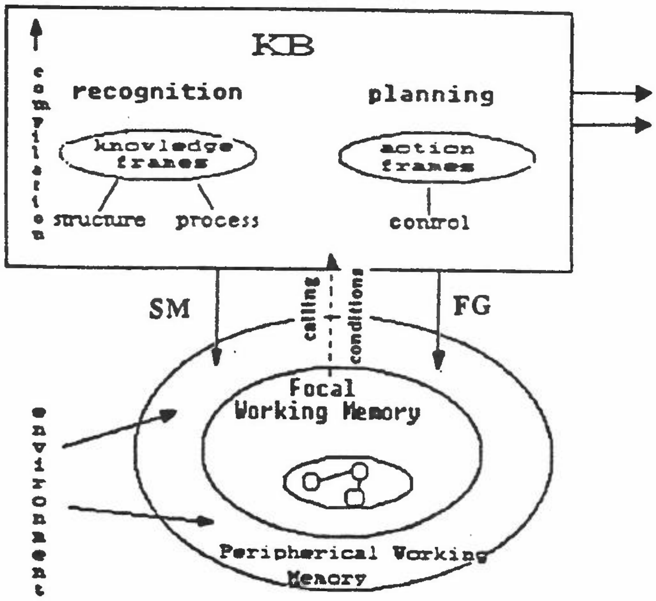


Fig. 1. General framework of the human behaviour model.



KB: Knowledge Base; **FWM**: Focal Working Memory;
PWM: Peripherical Working Memory
SM: Similarity Matching; **FG**: Frequency Gambling.

Fig. 2. Architecture of HLDM model

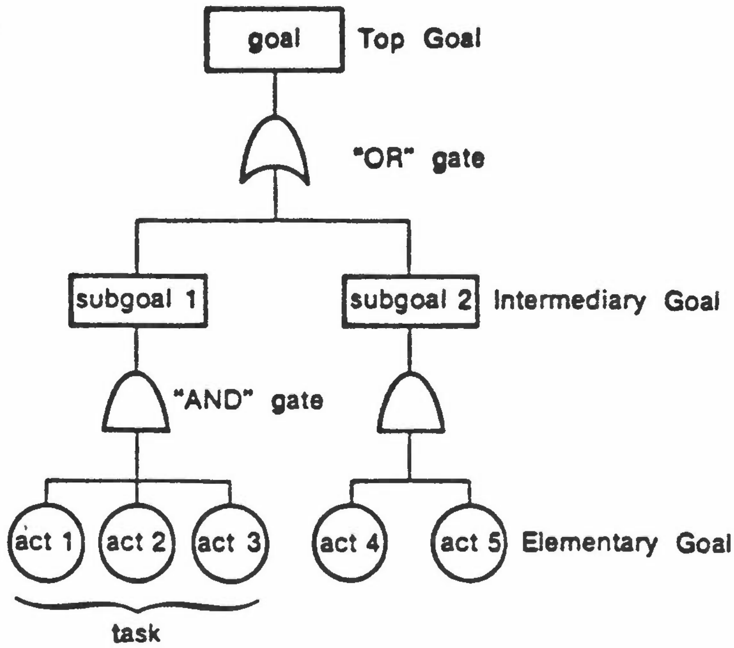


Fig. 3. Goal, task and act concept.

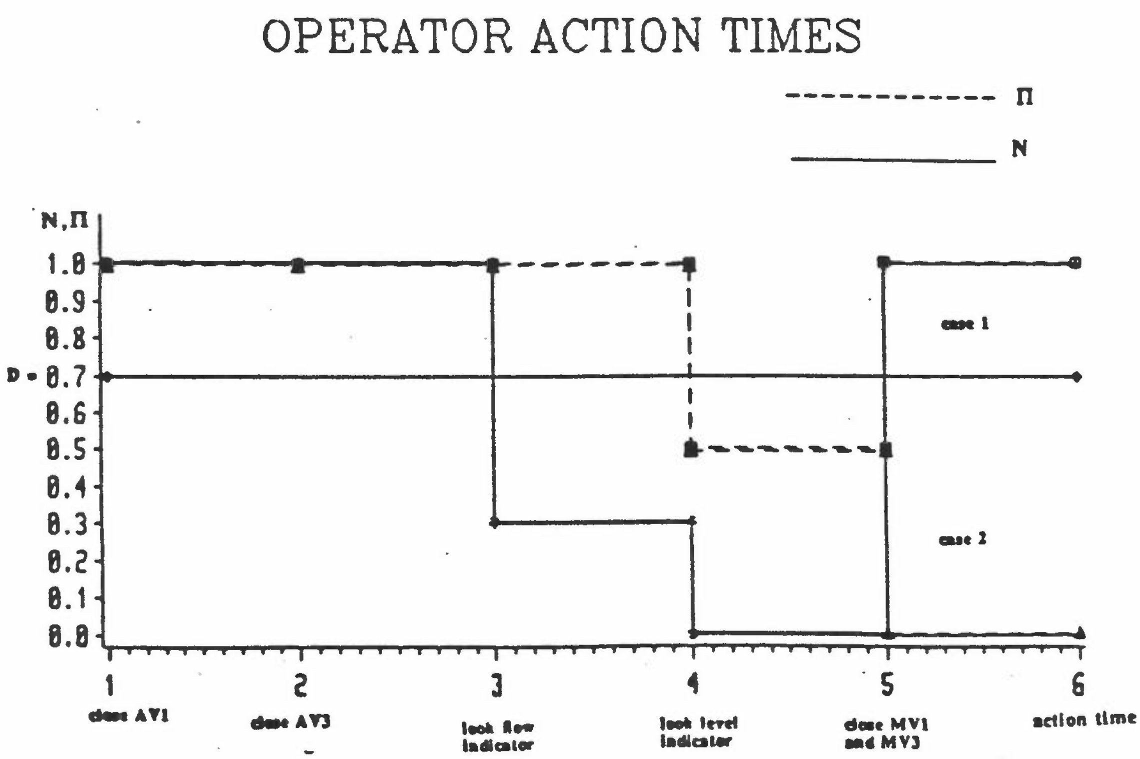


Fig. 4. Example of "operator action time" as resulting from the cognitive model.