FAULT DIAGNOSIS IN ORBITAL REFUELING OPERATIONS[1]

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Abstract

Usually, operation manuals are provided for helping astronauts during space operations. These manuals include normal and malfunction procedures. Transferring operation manual knowledge into a computerized form is not a trivial task. This knowledge is generally written by designers or operation engineers, and is often quite different from the user logic. The latter is usually a "compiled" version of the former. Experiments are in progress to assess the user logic. HORSES (Human - Orbital Refueling System - Expert System) is an attempt to include both of these logics in the same tool. It is designed to assist astronauts during monitoring and diagnosis tasks. Basically, HORSES includes a situation recognition level coupled to an analytical diagnoser, and a meta-level working on both of the previous levels. HORSES is a good tool for modeling task models and is also more broadly useful for knowledge design.

Keywords: On-Line Expert System, Man-Machine Interactions, Process Control, Diagnosis System, Knowledge Design, Task Models, Situation Recognition.

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[2] This work was completed when the author was a Research Associate at NASA-Ames Research Center, Aero-Space Human Factors Research Division, Mail Stop 239-3, Moffett Field, CA 94035, U.S.A..

[3] ONERA: Office National d'Etudes et de Recherches Aerospatiales ; CERT: Centre d'Etudes et de Recherches de Toulouse ; DERA: Departement d'Etudes et de Recherches en Automatique.

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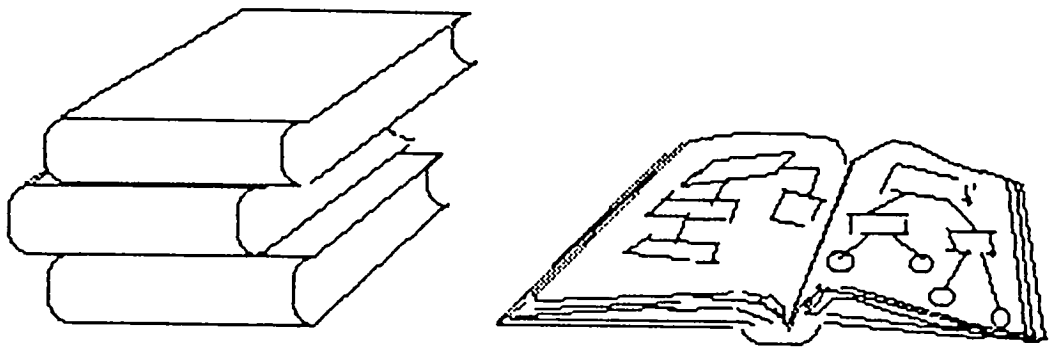
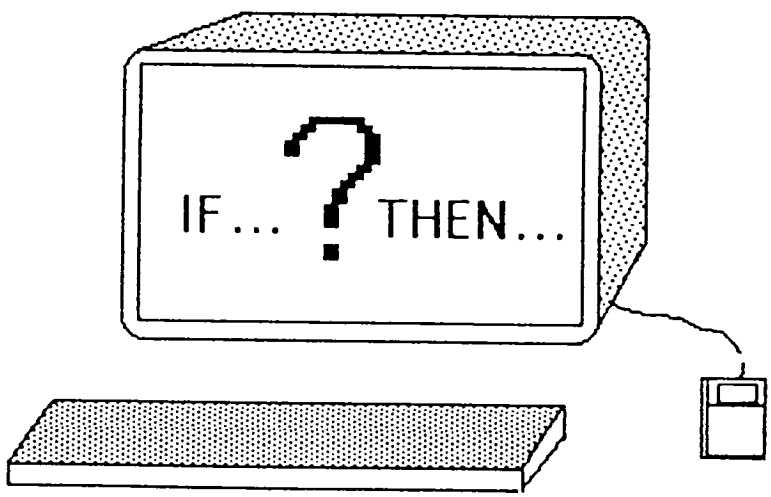
1. Problem Definition

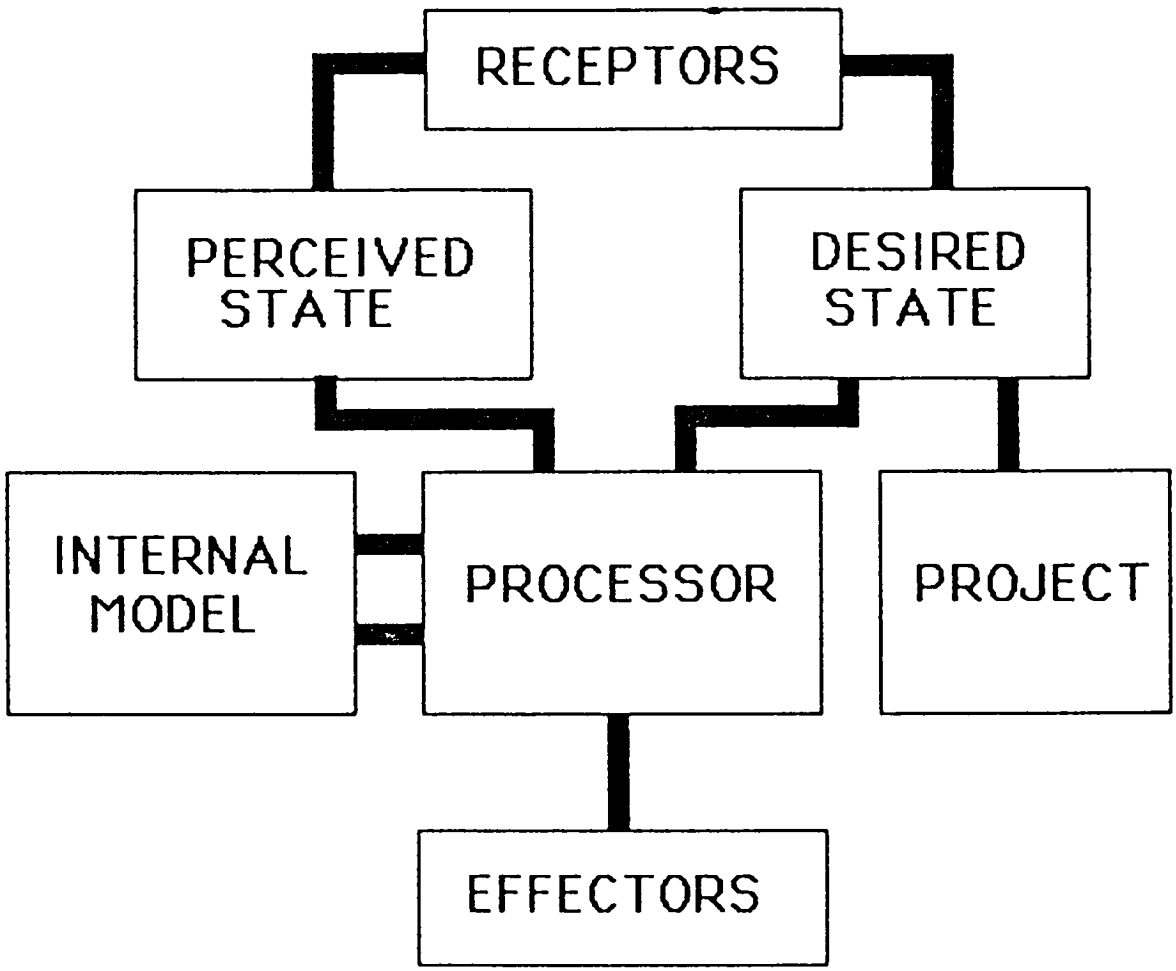
Human-Machine Interactions in Normal and Abnormal Situations

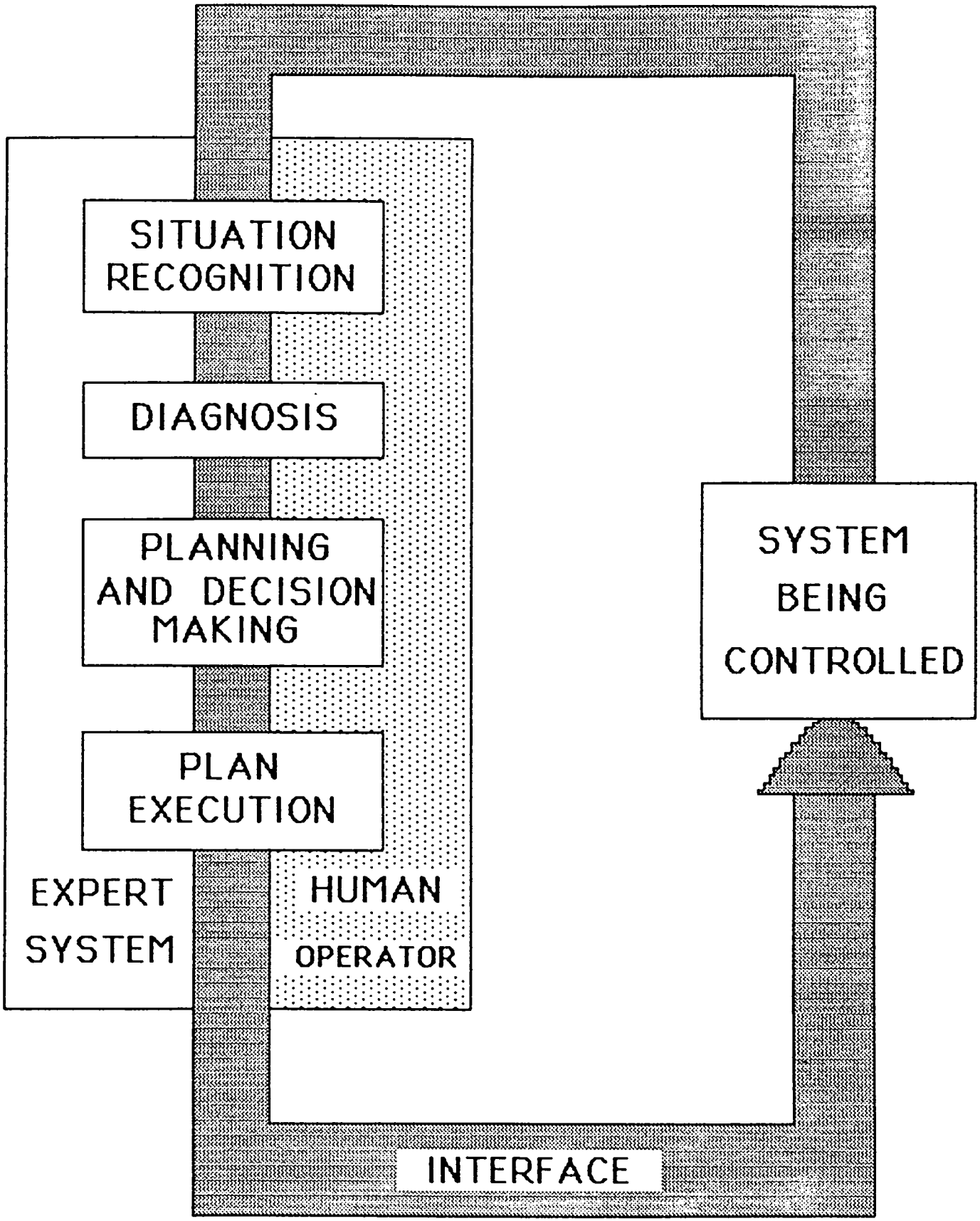
- Understanding the HMI Logic
  - Δ Human Operator Model
  - Δ System Logic vs. User Logic
- Need for, and Limitations of AI Tools in System Operations
  - Δ An Example : The ORS
- Building A User's Guide Expert System
  - Δ Operation Manual
  - Δ An AI Tool, why ? (modularity, flexibility, ...)
  - Δ Human vs. Automatic Diagnosis
  - Δ Human-Expert-System Interactions



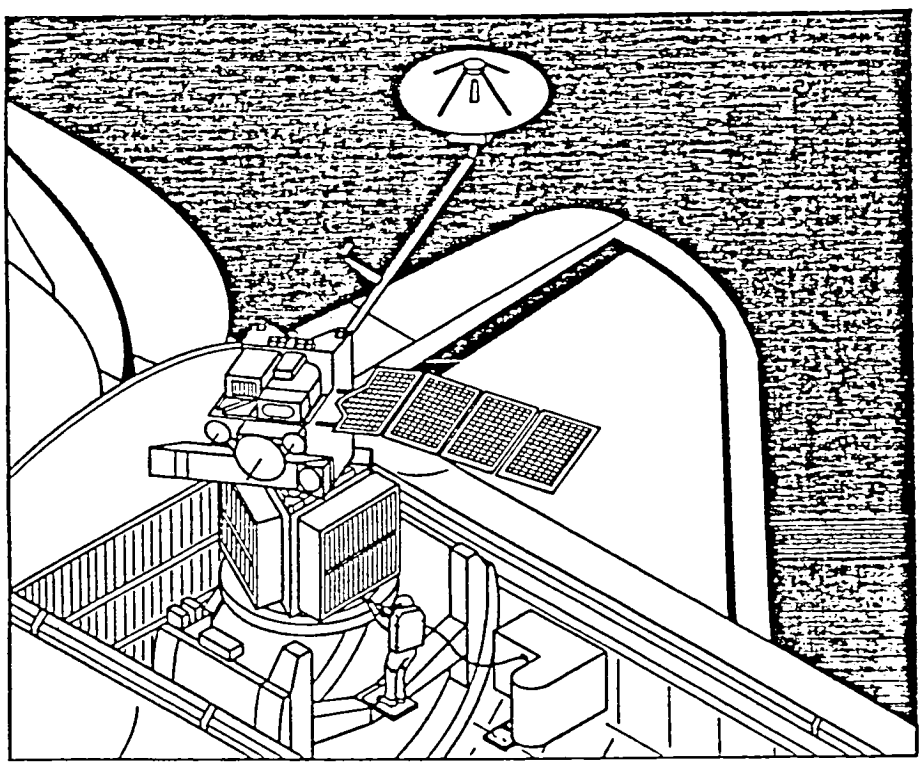
TIME ?
PROCEDURES ?
LEVELS OF AUTOMATION ?
EASY-TO-USE ?
EXPLANATION ?




RECEPTORS
PERCEIVED STATE
DESIRED STATE
INTERNAL MODEL
PROCESSOR
PROJECT
EFFECTORS

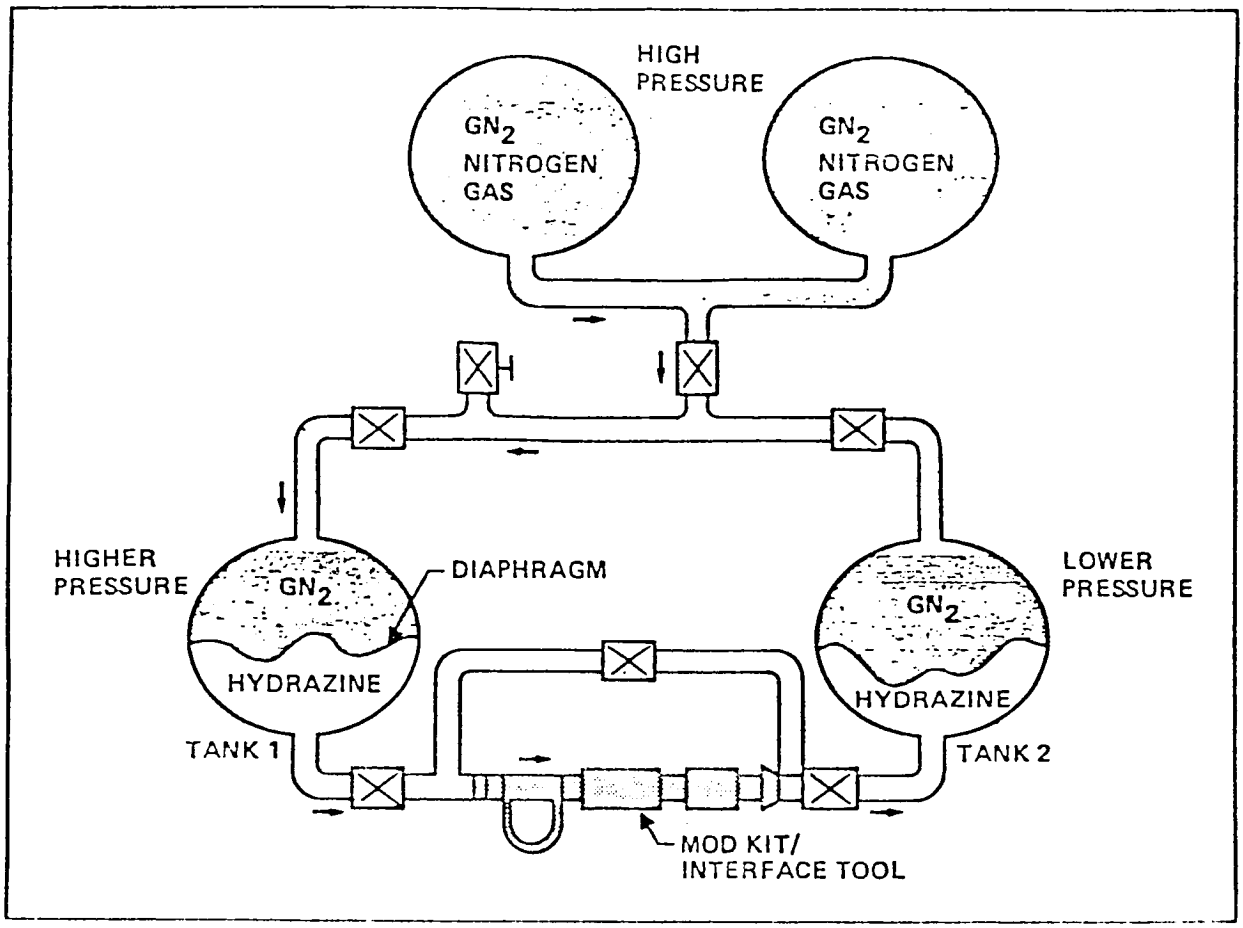

SITUATION RECOGNITION
DIAGNOSIS
PLANNING AND DECISION MAKING
PLAN EXECUTION
EXPERT SYSTEM
HUMAN OPERATOR
SYSTEM BEING CONTROLLED
INTERFACE

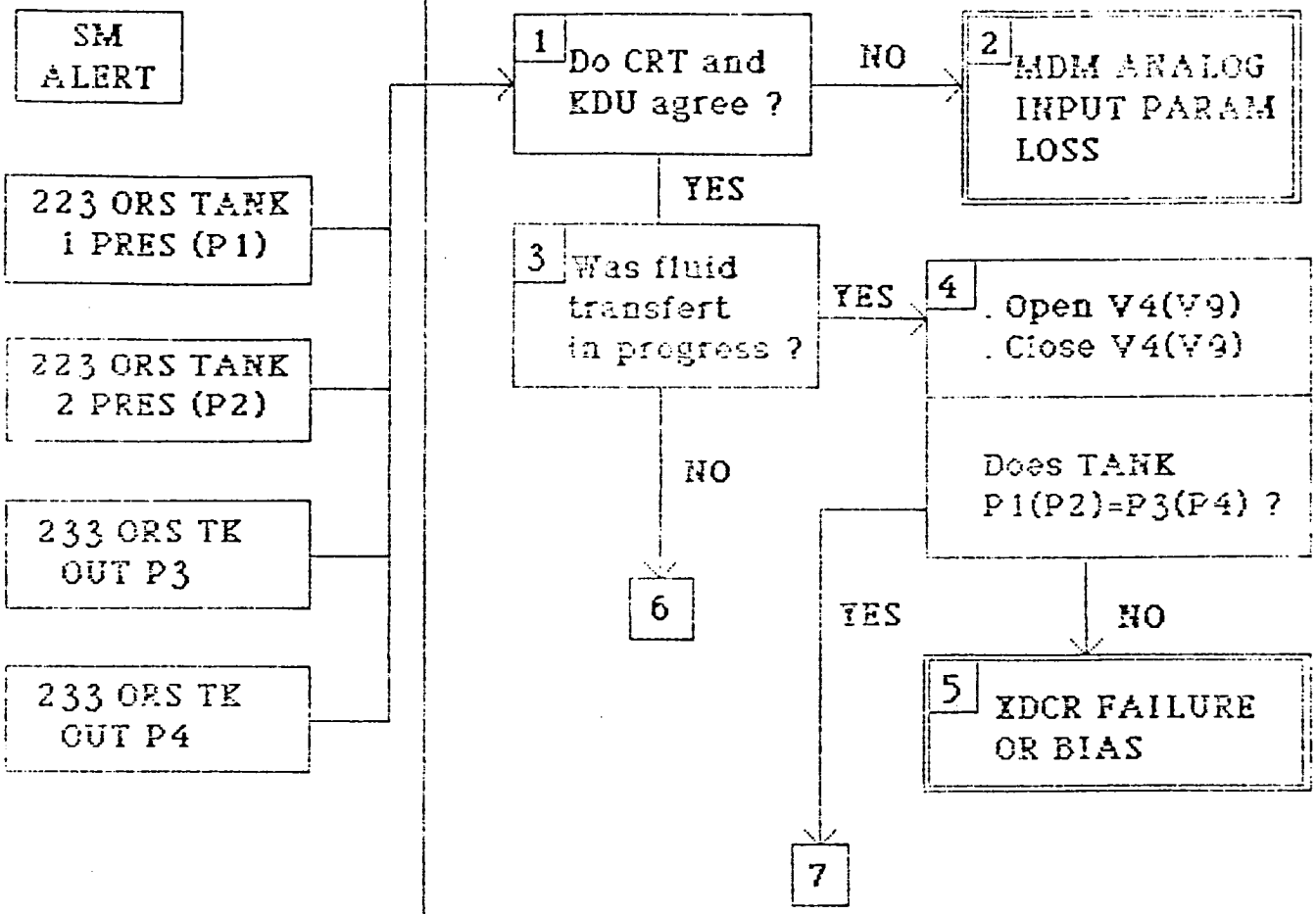
LANDSAT-D REFUELING



Landsat-D will utilize the ORS equipment and procedures for propellant replenishment.

ORS PROTOTYPE FLOW SCHEMATIC



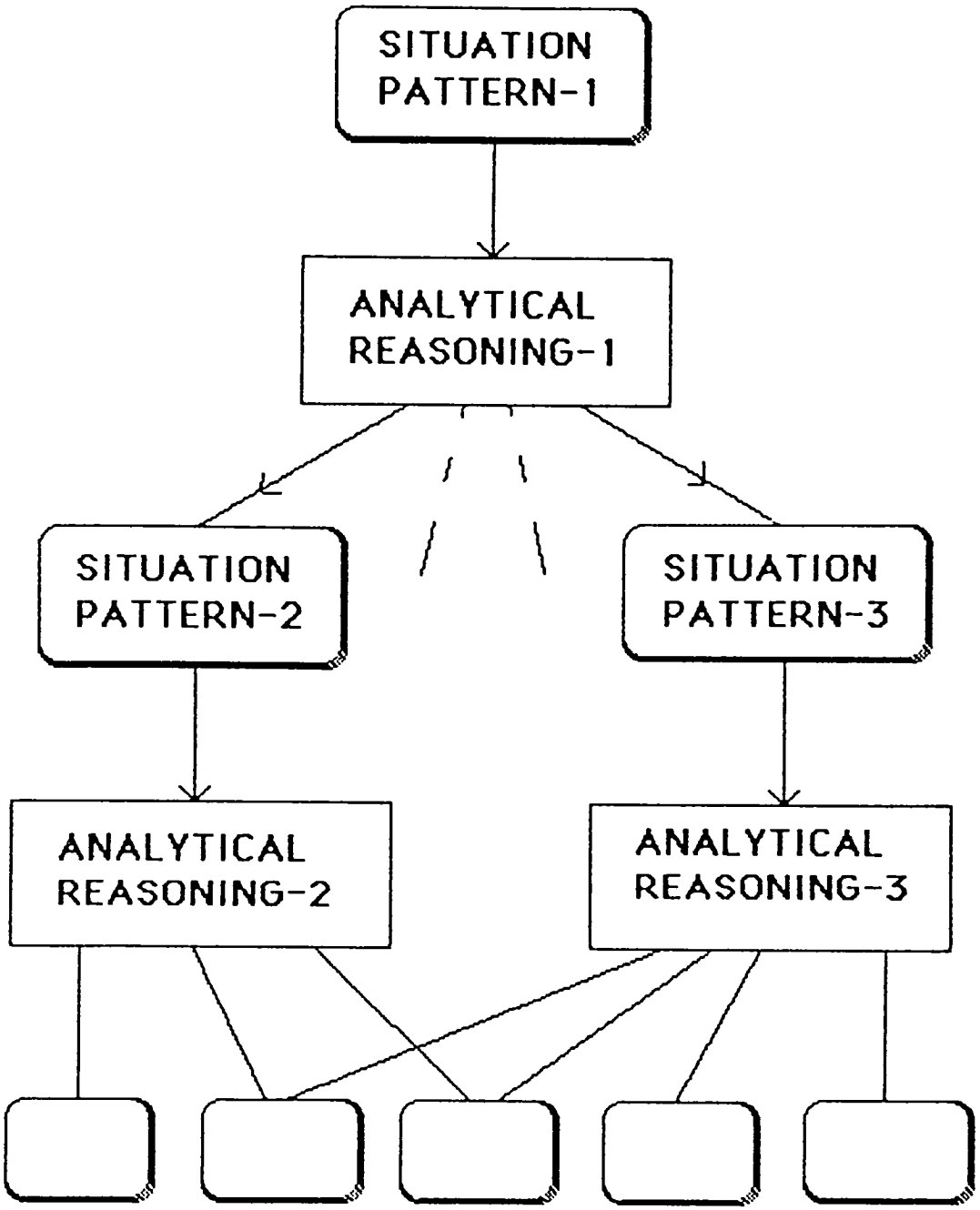


If ;

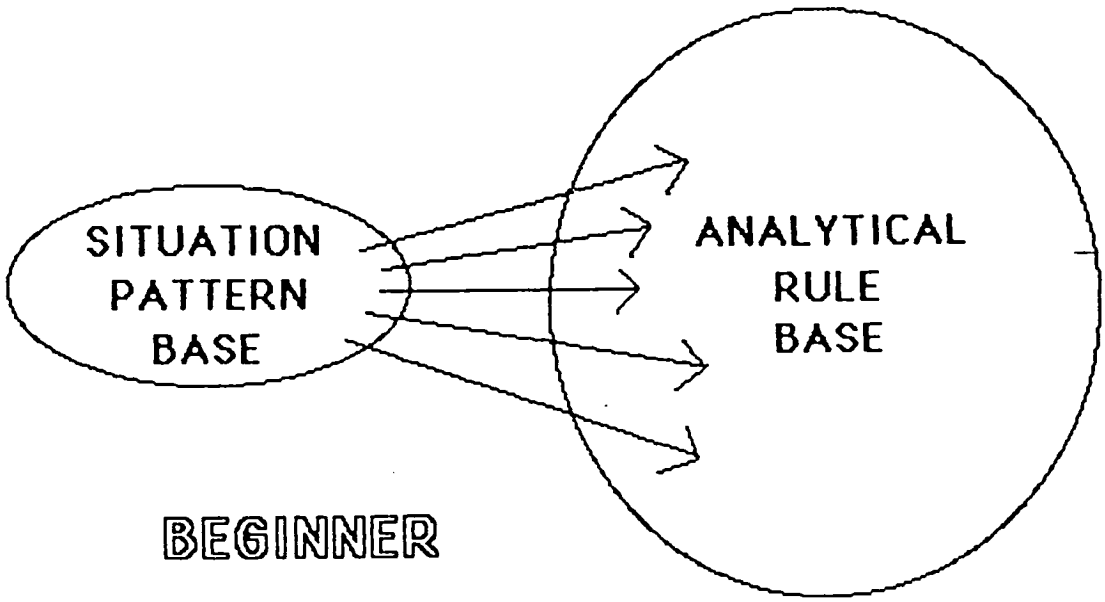
TANK 1(2) PRES
› 370 psia
‹ 20 psia

TK OUT P3(P4)
› 460 psia
‹ 20 psia

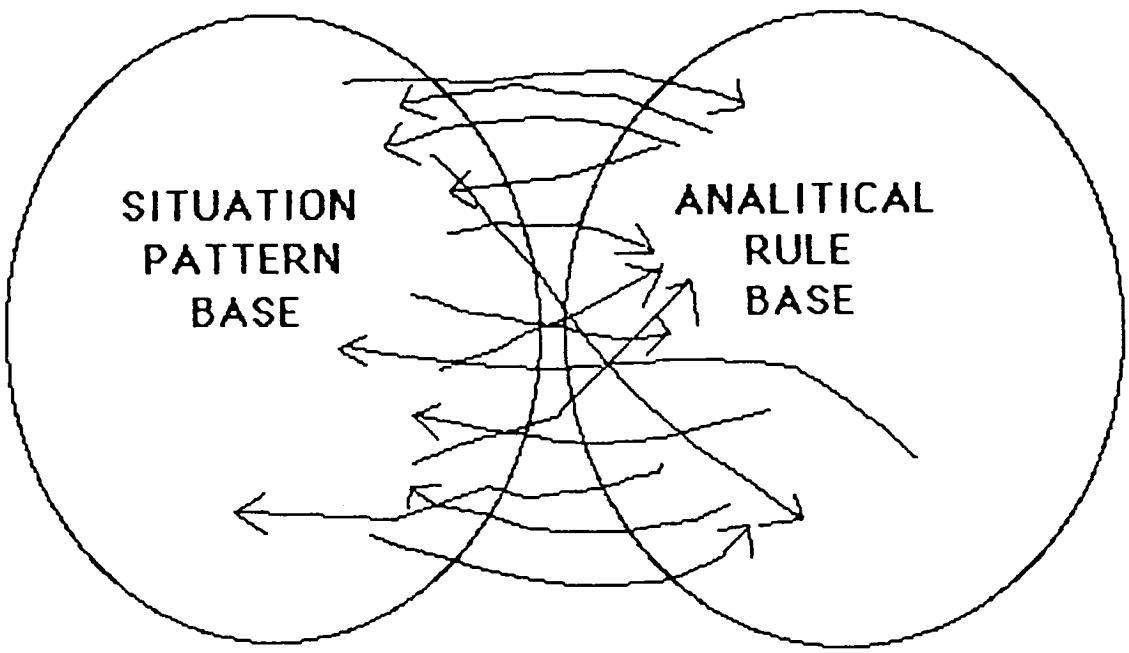
Example : Malfunction Procedure
1.4b ORS TANK 1(2) PRES
ORS TK OUT P3(P4)



SITUATIONAL AND ANALYTICAL PROCESSES



BEGINNER



EXPERT

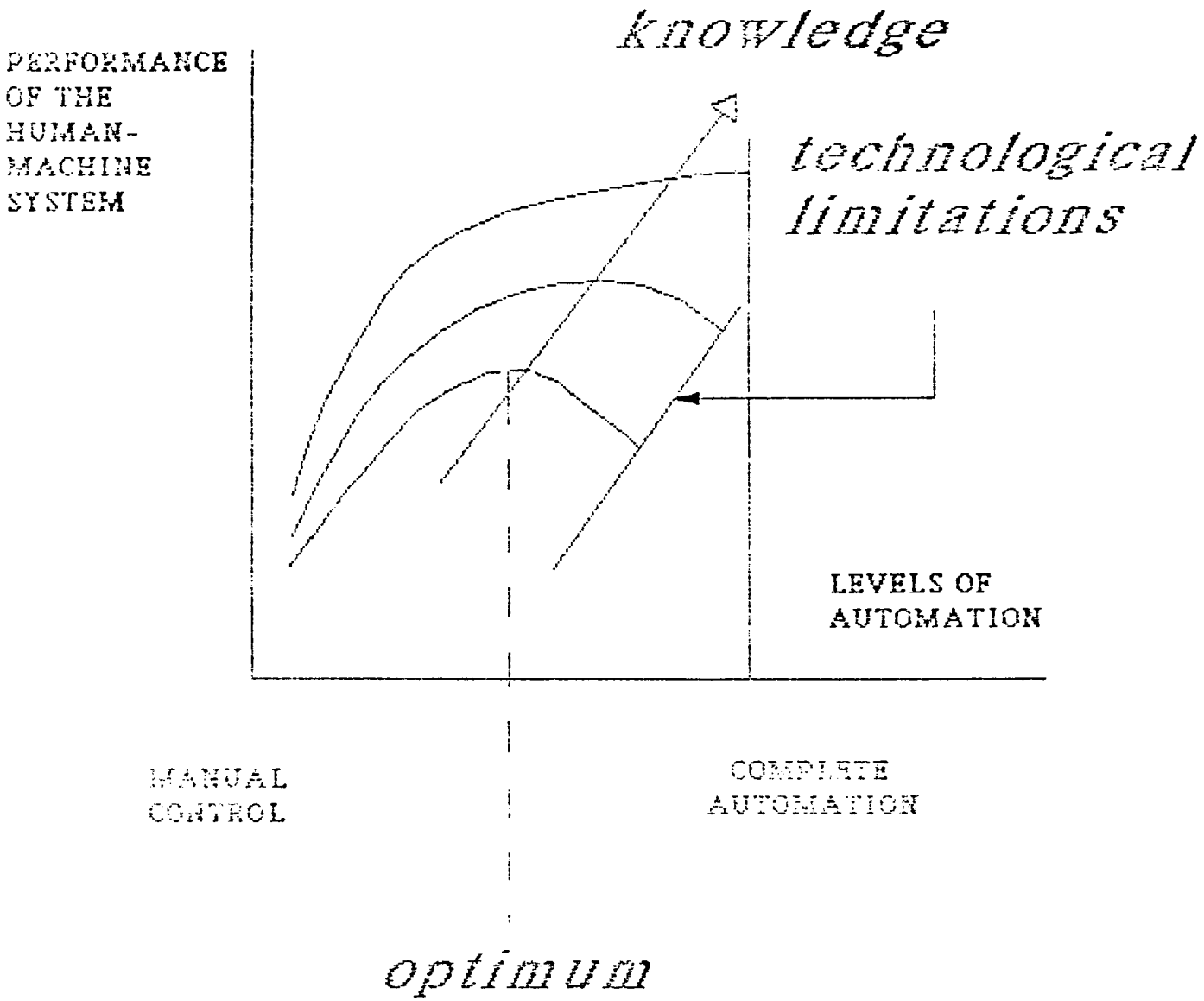
2. Building a User's Guide Expert System

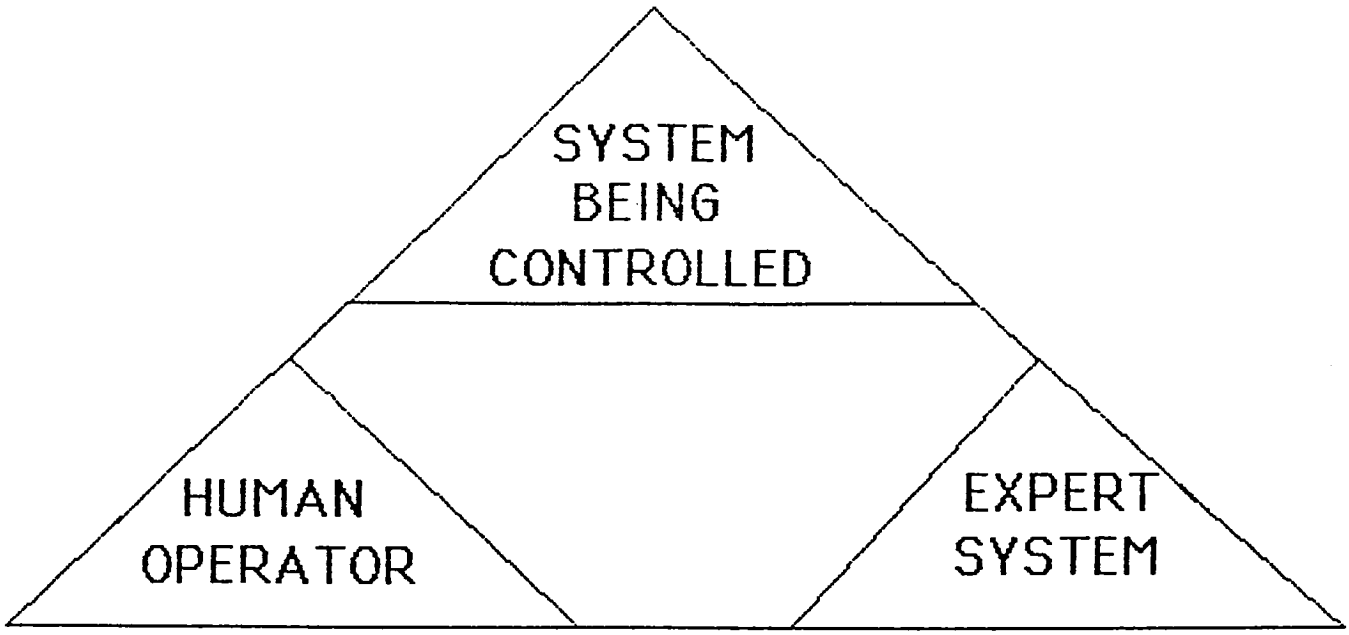
- Goals
  - Δ Optimal Level of Automation
  - Δ Explanation
  - Δ Easy-to-Use Interface

- Methods
  - Δ Modelling Approach
  - Δ Human Factors Studies
  - Δ Triangular Interactions

- Tasks
  - Δ Buiding an Expert System
  - Δ Experiments
  - Δ Theoretical Studies

- Product
  - Δ Tool to Design Procedures
  - Δ Diagnosis Aid


knowledge
PERFORMANCE OF THE HUMAN-MACHINE SYSTEM
technological limitations
LEVELS OF AUTOMATION
MANUAL CONTROL
COMPLETE AUTOMATION
optimum


SYSTEM
BEING
CONTROLLED
HUMAN
OPERATOR
EXPERT
SYSTEM

Human - ORS - Expert System

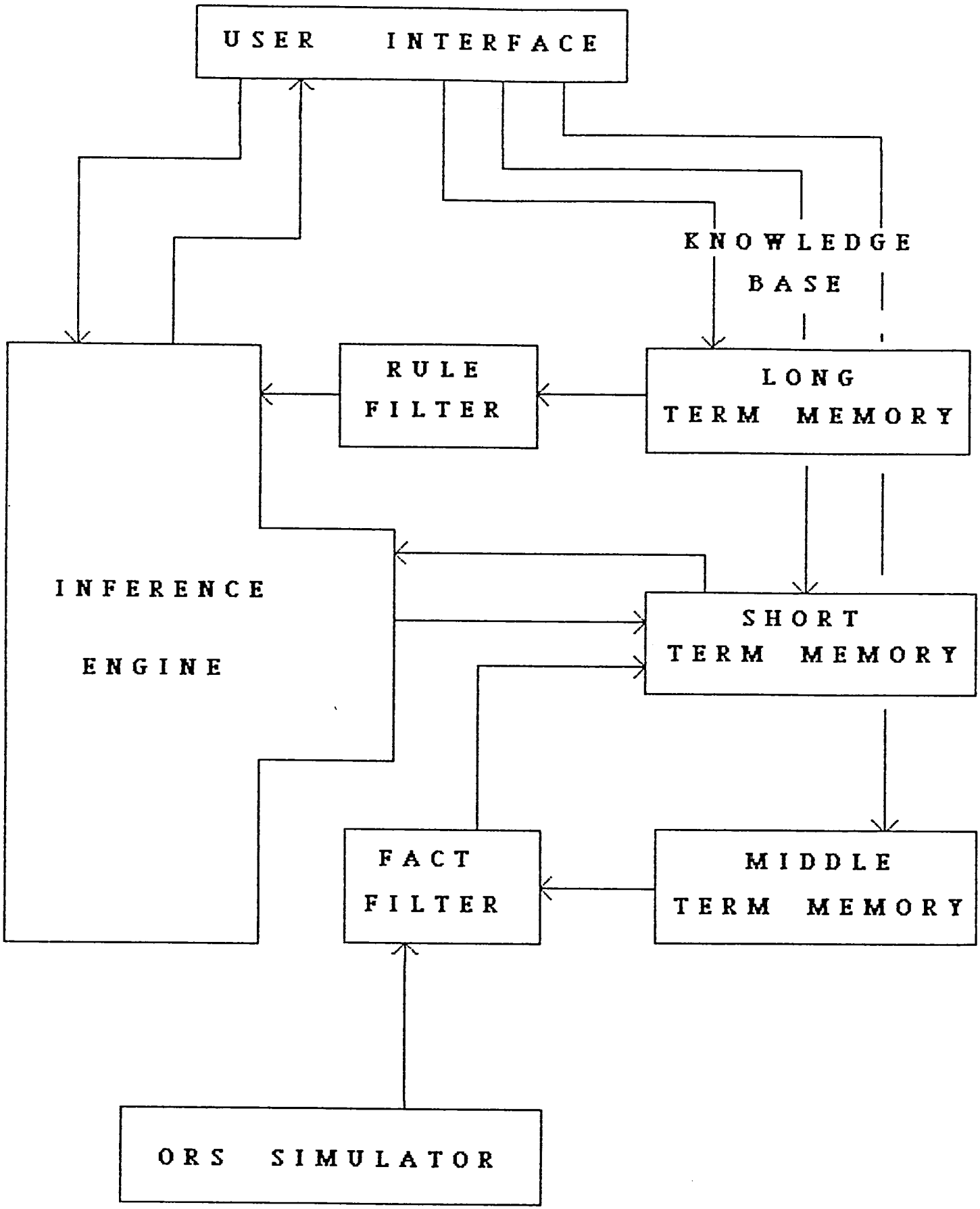
- Processor
  - Δ Situation Recognition (Monitoring)
  - Δ Diagnosis Inference Engine (2 levels)
- Knowledge Base
  - Δ Context Rules
  - Δ Regular Rules
  - Δ Meta Rules
  - Δ Predicates
  - Δ Tolerance Functions
  - Δ Objects
- Interfaces
  - Δ User Interface (Question-Answer, Menus)
  - Δ ORS Interface (Fact Filter, Fuzzy Models)

HORSES BACKGROUND

MESSAGE
(ONERA / Airbus Industrie)
(Certification, Workload & Performance Analyses)

SEAGOS
(ONERA / Matra)
(Satellite Malfunction Procedures)

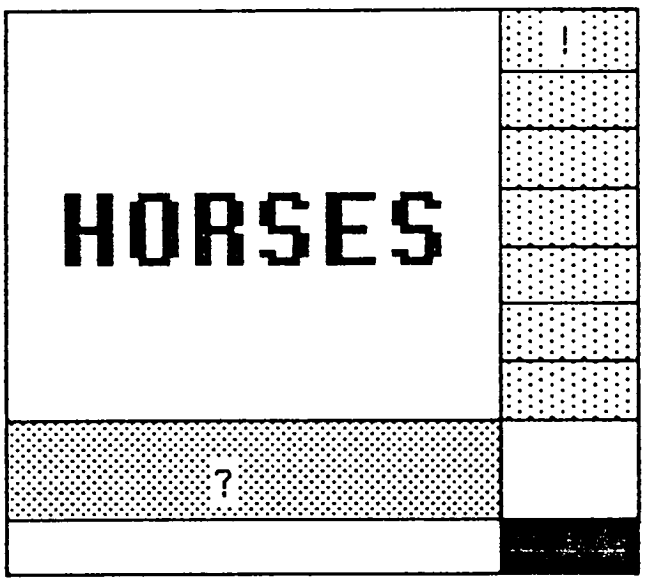
HORSES
(NASA / ONERA)
(ORS Malfunction Procedures)

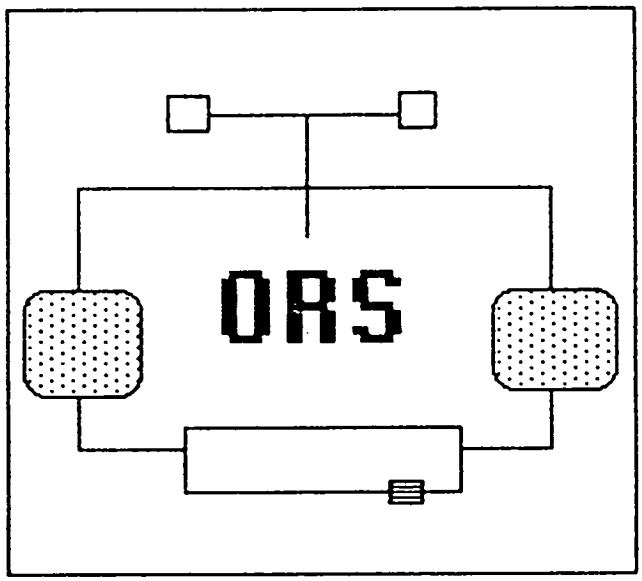

USER INTERFACE
KNOWLEDGE BASE
RULE FILTER
LONG TERM MEMORY
INFERENCE ENGINE
SHORT TERM MEMORY
FACT FILTER
MIDDLE TERM MEMORY
ORS SIMULATOR

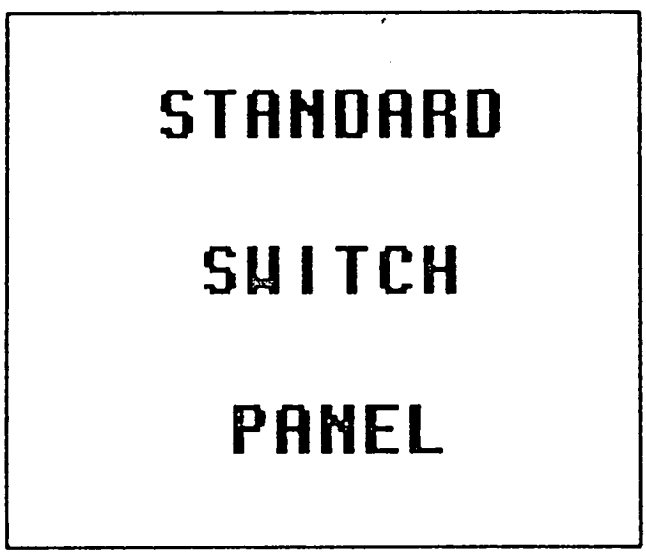
HORSES Current Version

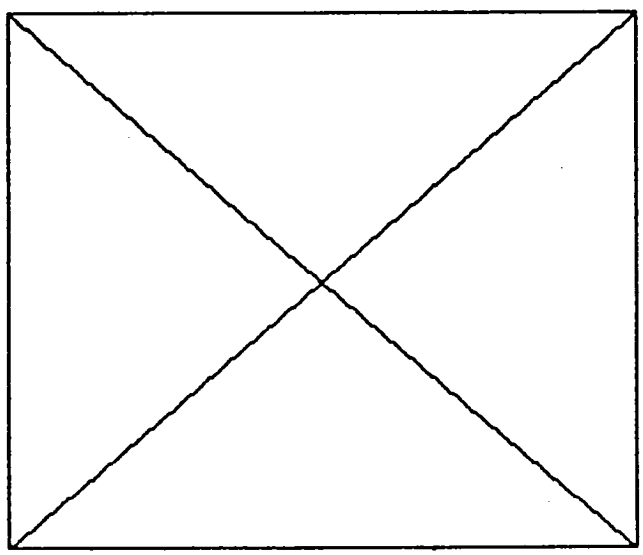
- ☐ Working in Lisp on MASSCOMP
- ☐ Connected to an ORS Fortran Simulation
- ☐ Graphic Interface (Windows, Color)

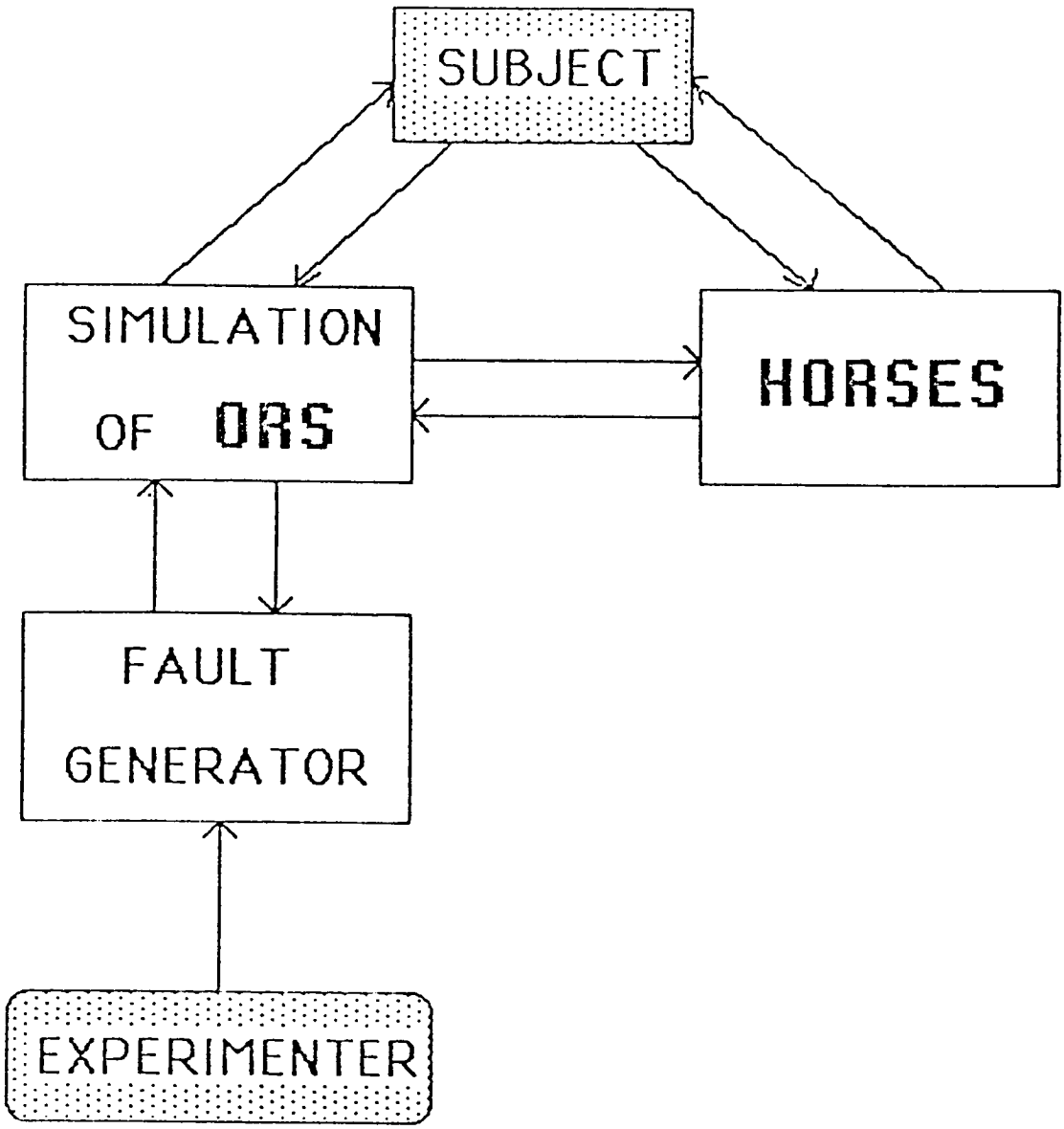
THE WINDOWS

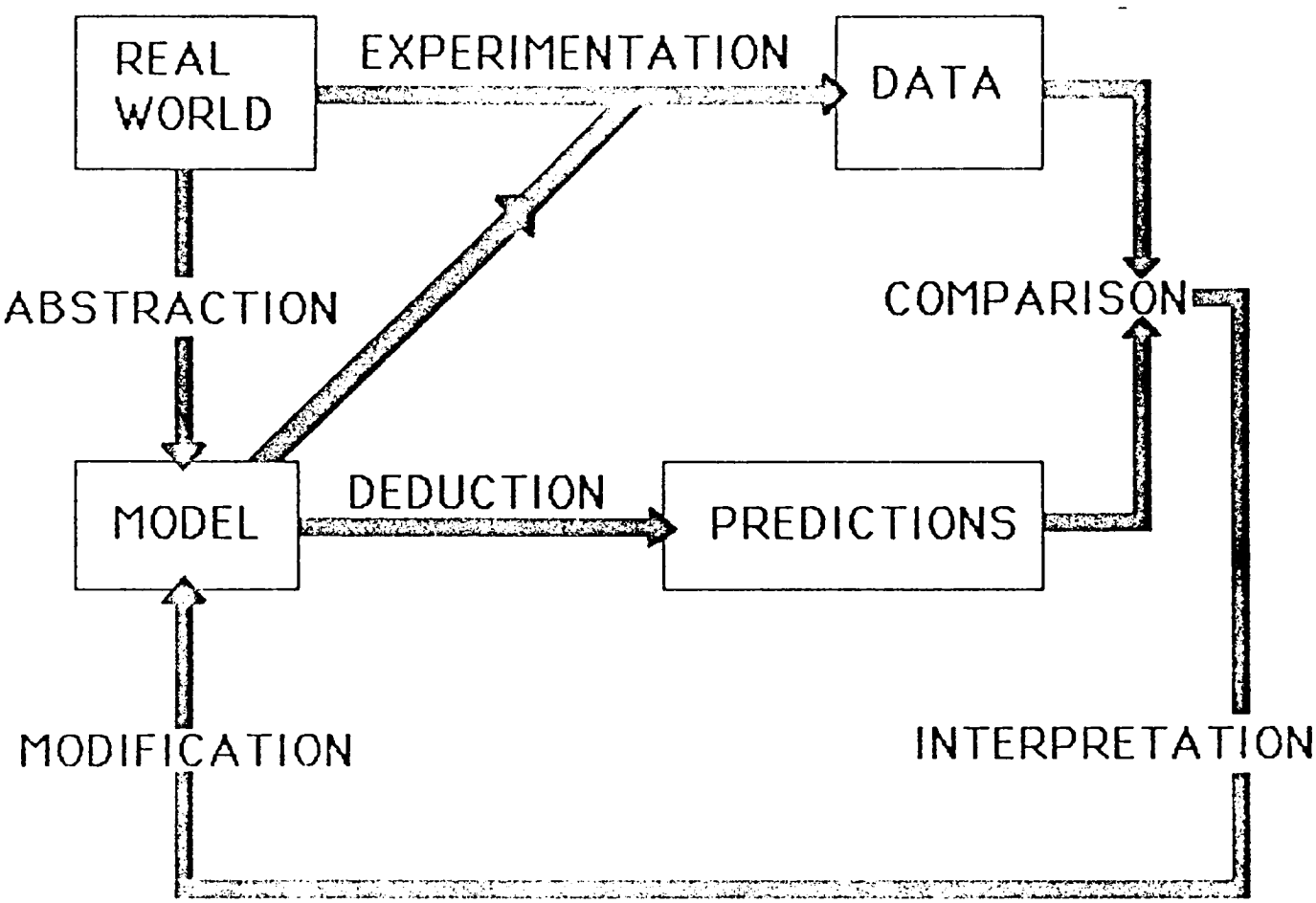









SUBJECT
SIMULATION
OF ORS
HORSES
FAULT
GENERATOR
EXPERIMENTER


REAL WORLD
EXPERIMENTATION
DATA
ABSTRACTION
COMPARISON
MODEL
DEDUCTION
PREDICTIONS
MODIFICATION
INTERPRETATION

Further Studies

- Experiments on Man-Machine Interactions
  - Δ Level 0 (Paper Manual)
  - Δ Level 1 (Expert System Guides and Advises)
  - Δ Level 2 (Automatic Diagnosis, Explanation)
- Situation Recognition
  - Δ Experiments on Qualitative Models
  - Δ Fuzzy Sets Approach
- Explanation
  - Δ Information on Time and at the Appropriate Level of Detail
  - Δ Graphic Displays
- Knowledge Editor
  - Δ Consistency
  - Δ Graphic Displays

Operator Assistant

- COMPUTERIZED OPERATION MANUAL
- SITUATION RECOGNITION SYSTEM
- COOPERATIVE DIAGNOSIS ADVISOR
- DIFFERENT LEVELS OF AUTOMATION
- DYNAMIC AND INTERACTIVE
- EASY-TO-USE

Tool for Implementing Task Models

- KNOWLEDGE DESIGN
- KNOWLEDGE PROCESSING
- VISUAL THINKING
- GRAPHICAL INTERFACE