N91-10952

FAULT RECOVERY RECOMMENDATION
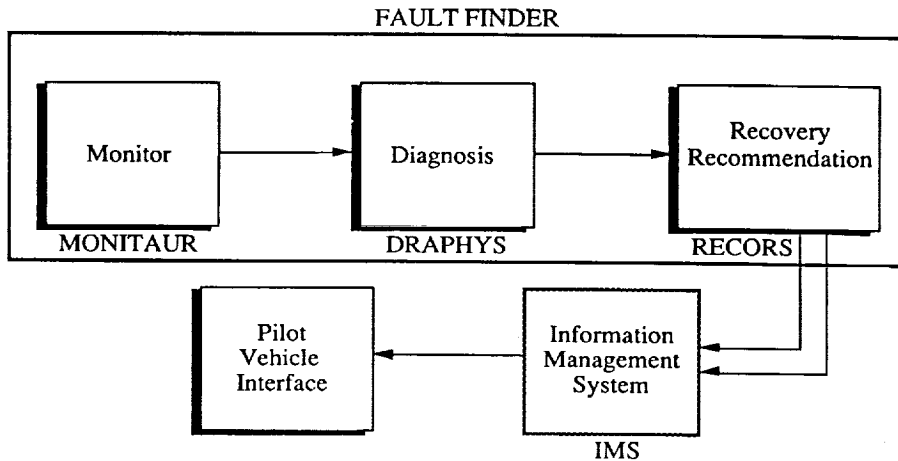
Eva Hudlicka
and
Kevin Corker
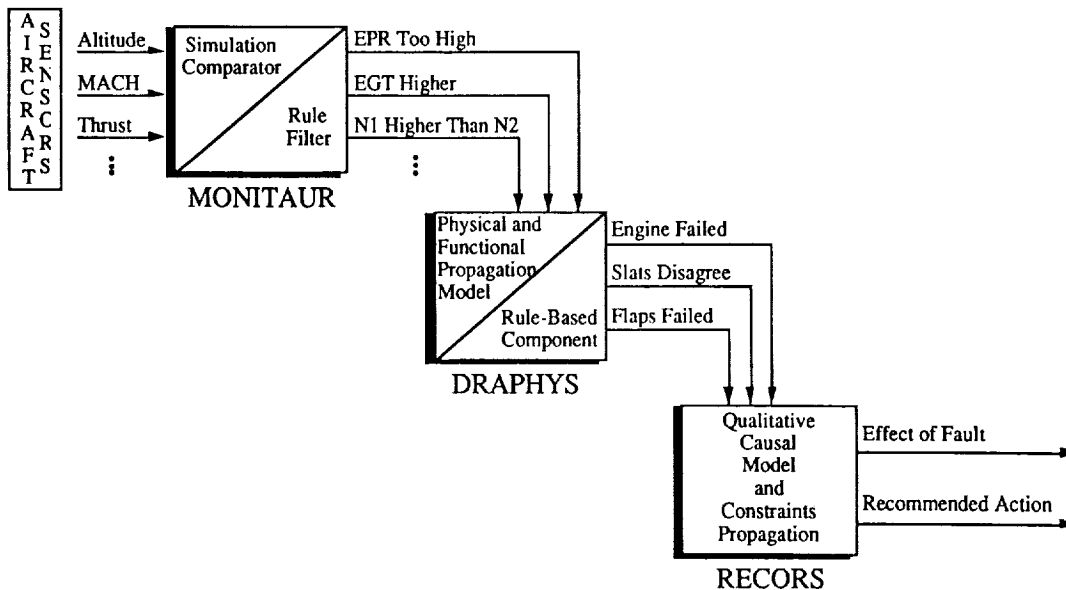## BBN Systems and Technologies Corporation

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SYSTEM INTEGRATION CONTEXT
FOR THE
RECOVERY RECOMMENDATION SYSTEM
(RECORS)

System Goal: To provide intelligent aiding for monitoring, diagnosis and response to aircraft system failures.

FAULT FINDER

```
┌──────────────────────────────────────────────────────────────────┐
│  ┌──────────┐         ┌──────────┐         ┌──────────────┐        │
│  │          │         │          │         │   Recovery   │        │
│  │ Monitor  │────────▶│Diagnosis │────────▶│Recommendation│        │
│  │          │         │          │         │              │        │
│  └──────────┘         └──────────┘         └──────────────┘        │
│   MONITAUR             DRAPHYS               RECORS                 │
└──────────────────────────────────────────────────────────────────┘
```

```
┌──────────┐         ┌──────────────┐
│  Pilot   │         │ Information  │
│ Vehicle  │◀────────│ Management   │
│Interface │         │   System     │
└──────────┘         └──────────────┘
                          IMS
```

DATA FLOW CONTEXT FOR RECORS

```
AIRCRAFT          Altitude   ┌──────────────┐ EPR Too High
SENSORS           MACH ─────▶│ Simulation   │ EGT Higher
                  Thrust ───▶│ Comparator   │ N1 Higher Than N2
                             │       Rule   │
                             │       Filter │
                             └──────────────┘
                                 MONITAUR
```

```
        ┌──────────────────┐ Engine Failed
        │ Physical and     │ Slats Disagree
        │ Functional       │ Flaps Failed
        │ Propagation      │
        │ Model            │
        │      Rule-Based  │
        │      Component   │
        └──────────────────┘
             DRAPHYS
```

```
        ┌──────────────────┐ Effect of Fault ───▶
        │ Qualitative      │
        │ Causal           │ Recommended Action ───▶
        │ Model            │
        │ and              │
        │ Constraints      │
        │ Propagation      │
        └──────────────────┘
             RECORS
```

GOALS OF RECOVERY RECOMMENDATION SYSTEM (RECORS) ARE SITUATION ASSESSMENT AND RESPONSE AIDING DURING EMERGENCIES

Method:

- Predict effects of faults on future system behavior

- Perform reasoning to aid the time-stressed and/or capacity limited flight-crew to suggest response to faults

- Predict consequences of recommended actions and advise crew

RECORS:
MODEL-BASED
SITUATION ASSESSMENT/RESPONSE AIDING

Current Status:

- Functions in a help mode, rather than autonomous mode

  - pilot is in the Loop

  - pilot has Final Authority

  - explanation of Reasoning and Displays are Important

- Uses a causal model of the aircraft and the flight domain

- Reasons at multiple levels of abstraction

- Predicts the effects of aircraft system failures on flight profile

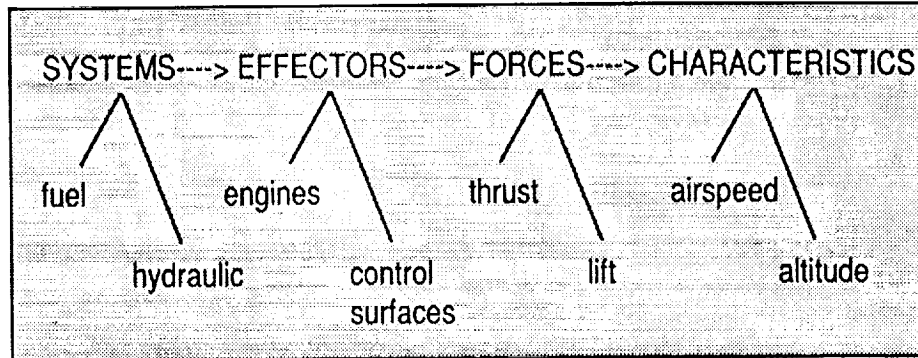- Suggests responses in emergencies

. . . RECORS

Planned Development:

- Help identify faults based on their effects on the system

- Help make up for lack of sensor data by inferencing

- Predict long-term effects of actions to help in response selection

RECORS: CAUSAL MODEL

- Model implemented within Object-Oriented,
  Frame-Based representation formalism

- Model consists of objects representing:

    - aircraft sub-systems

    - effectors

    - forces acting on the aircraft

    - flight characteristics

CAUSAL MODEL (cont)

- **Represents both the taxonomic and the causal relationships among the objects**


```
SYSTEMS---> EFFECTORS---> FORCES---> CHARACTERISTICS
        /\            /\          /\            /\
       /  \          /  \        /  \          /  \
  fuel      engines        thrust      airspeed
        \            \            \            \
      hydraulic    control        lift       altitude
                   surfaces
```

RECORS:
MULTIPLE LEVELS OF ABSTRACTION

- Two orthogonal types of abstraction exist in the model: taxonomic and causal

  - Taxonomic ("IS-A" relationship)

    Taxonomic abstraction consist of the different levels of the model hierarchy

  - Causal: causal relationships among model objects expressed at binary and qualitative levels (AFFECTS and AFFECTED-BY relationships)

    Causal relationships are represented at both binary and qualitative levels at each level in the object taxonomy

- Other planned abstractions include partonomy and physical location relations

MULTIPLE LEVELS OF ABSTRACTION

BINARY   normal/abnormal

QUALITATIVE   low/normal/high
                decreasing/stable/increasing

QUANTITATIVE   differential equations

knowledge of   amount of   time   specificity
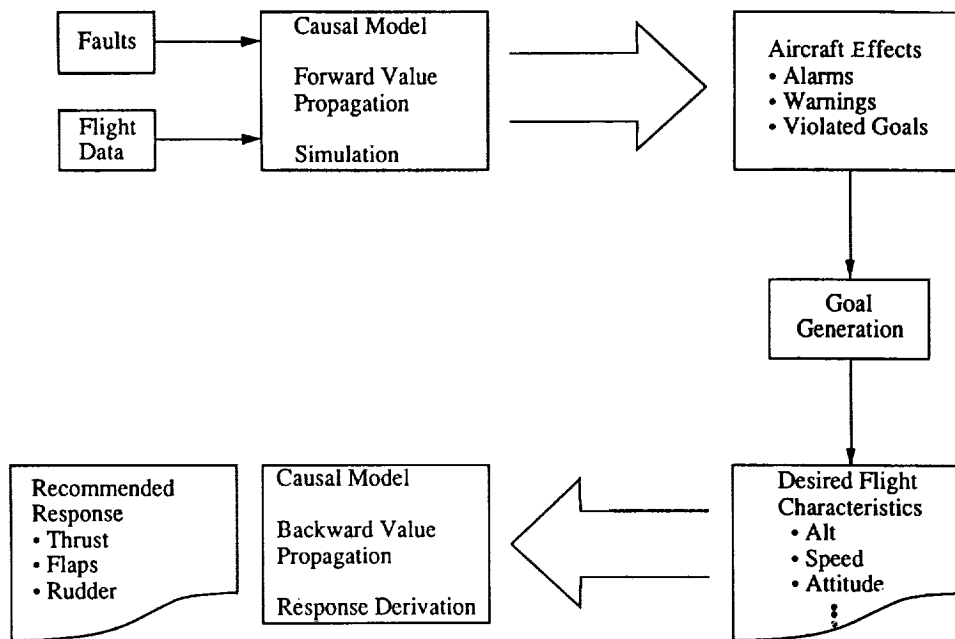domain   data   required   of results
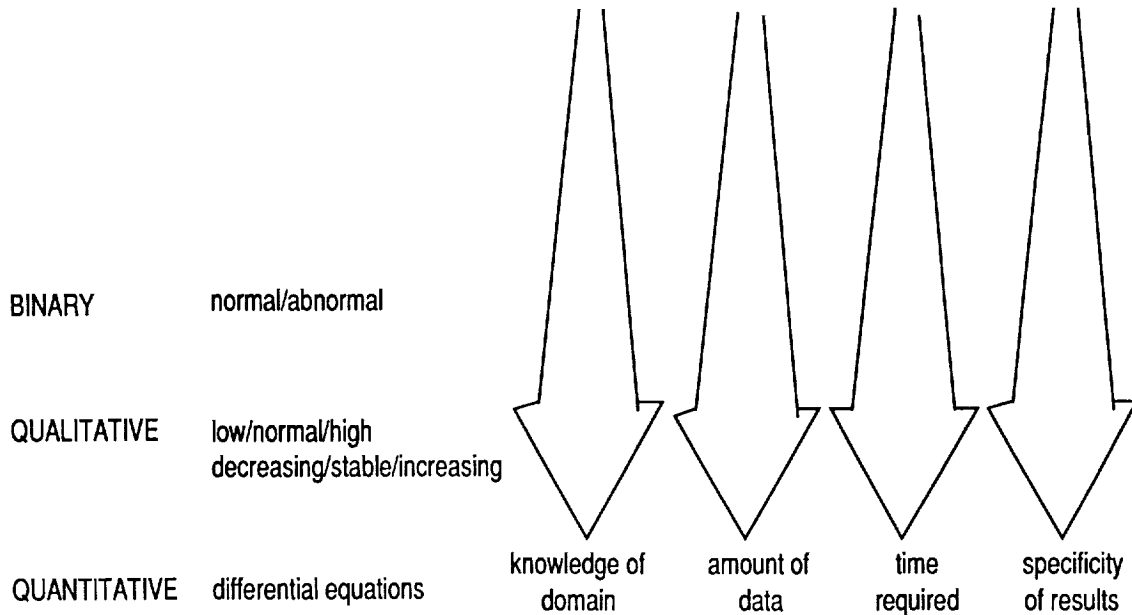
RECENT DEVELOPMENTS

• Causal Model Editor

• Subsystem Modeling

  - Requires the Representation of various types of Causal Relations
  - Different Temporal Propagation Delays Exist Along the Causal Links
  - Requires Use of Different Causal Contexts
  - Specialized "Device" Models

• Representational Formalism Modified to Reflect these Requirements

• Simulation Algorithm Modified to Reflect These Requirements

• Time Representation Included in terms of Delays Along Causal Links

• Reconfigurable Interface

FUTURE DIRECTIONS

- **Explanation**

  - **Display Format for Recommendations and Aircraft Effects**
  - **Visual and Textual Explanation of RECORS' Reasoning**

- **Verification and Validation**

  - **Determine How System Effectiveness Varies with**
    - **fault type**
    - **emergency type**
    - **display design**
    - **crew experience**

  - **Verify Model Function**
  - **Validate Against Known Accident Responses**

- **Evaluation**

 - **Test Pilot Acceptance in Cockpit Simulation**

RECORS INFERENCING CYCLE

```
  ┌────────┐      ┌──────────────────┐                    ┌────────────────┐
  │ Faults │─────▶│ Causal Model     │                    │ Aircraft Effects│
  └────────┘      │                  │        ▶           │ • Alarms        │
                  │ Forward Value    │                    │ • Warnings      │
  ┌────────┐      │ Propagation      │                    │ • Violated Goals│
  │ Flight │─────▶│                  │                    └────────────────┘
  │ Data   │      │ Simulation       │                            │
  └────────┘      └──────────────────┘                            ▼
                                                          ┌────────────────┐
                                                          │ Goal           │
                                                          │ Generation     │
                                                          └────────────────┘
                                                                  │
  ┌────────────┐  ┌──────────────────┐                           ▼
  │ Recommended│  │ Causal Model     │                    ┌────────────────┐
  │ Response   │  │                  │        ◀           │ Desired Flight │
  │ • Thrust   │  │ Backward Value   │                    │ Characteristics│
  │ • Flaps    │  │ Propagation      │                    │ • Alt          │
  │ • Rudder   │  │                  │                    │ • Speed        │
  └────────────┘  │ Response Derivation│                  │ • Attitude     │
                  └──────────────────┘                    └────────────────┘
```
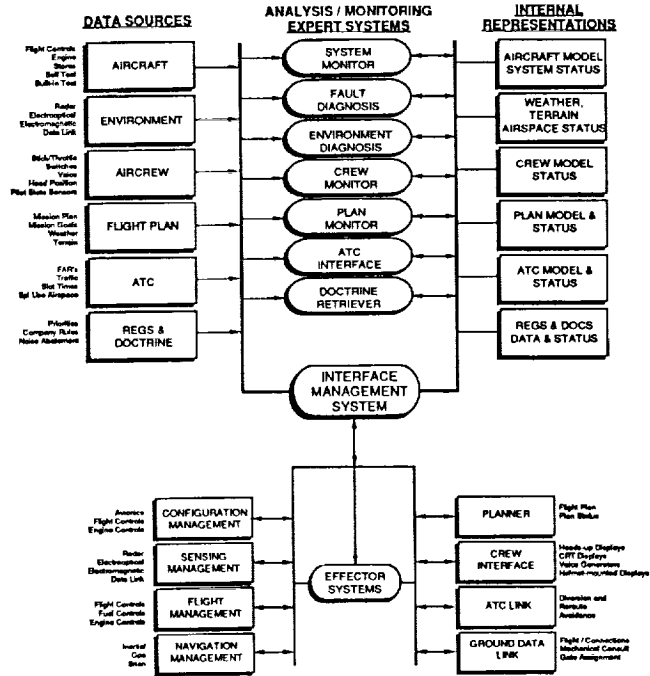
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RECORS IMPLEMENTATION

- Version I: Implemented in the KEE development environment on a Symbolics 3600

- Version II: Implemented in Zeta LISP Using an Object-Oriented, Frame-Based Language on a Symbolics XL400
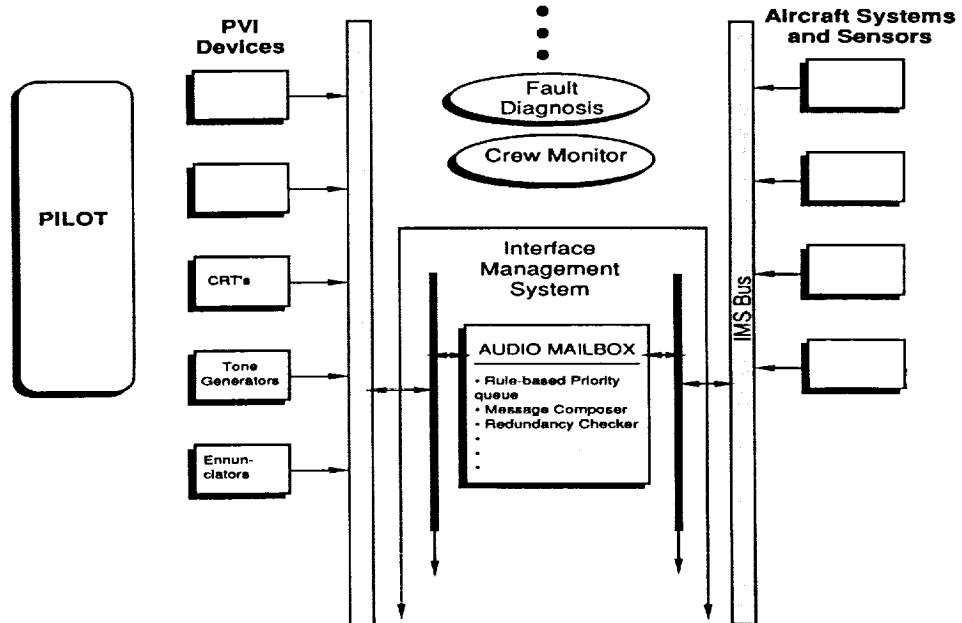
THE INTERFACE MANAGEMENT SYSTEM MANAGES THE FLOW OF INFORMATION AND THE DIALOGS BETWEEN THE SYSTEMS AND THE PILOT
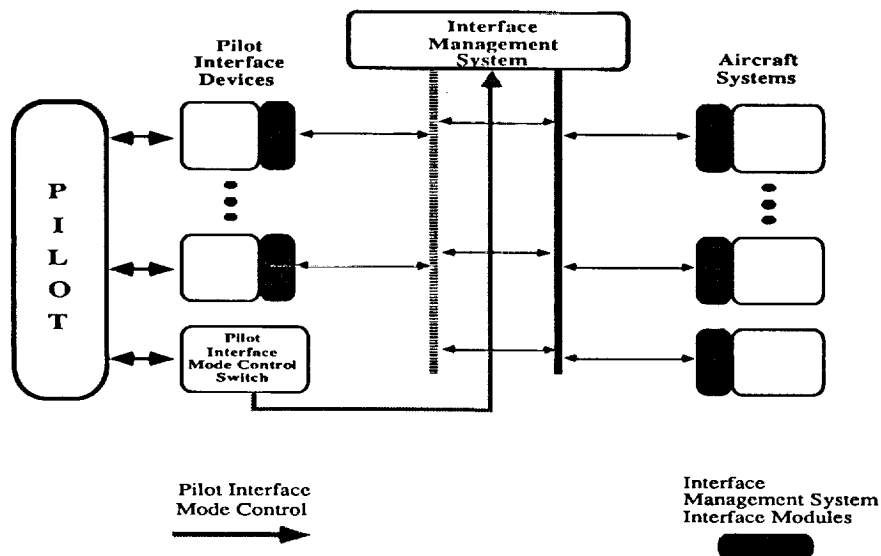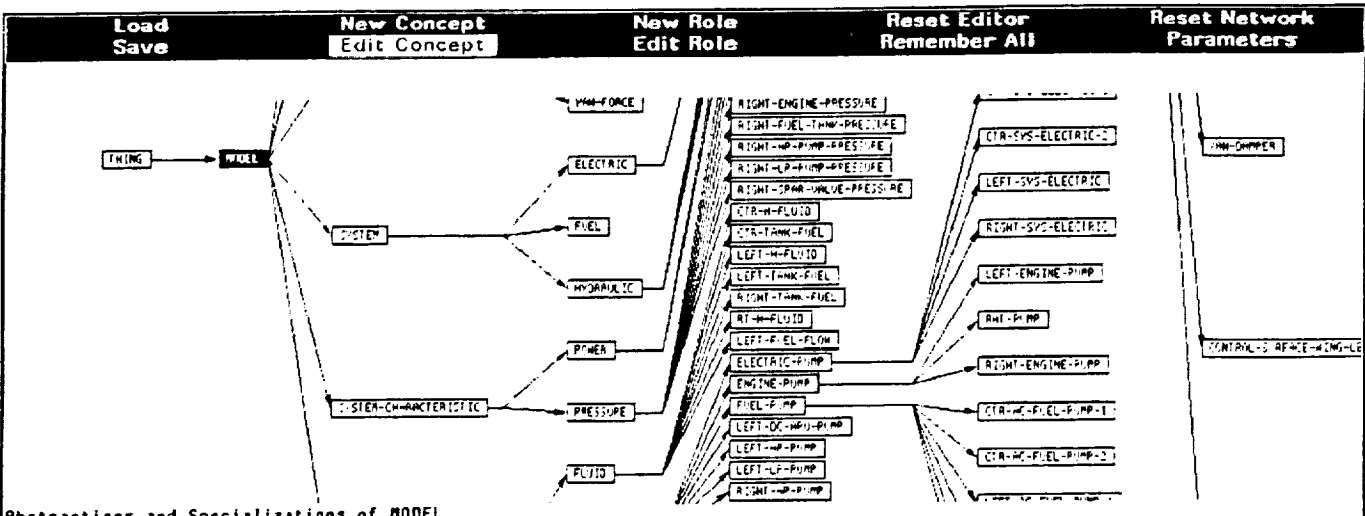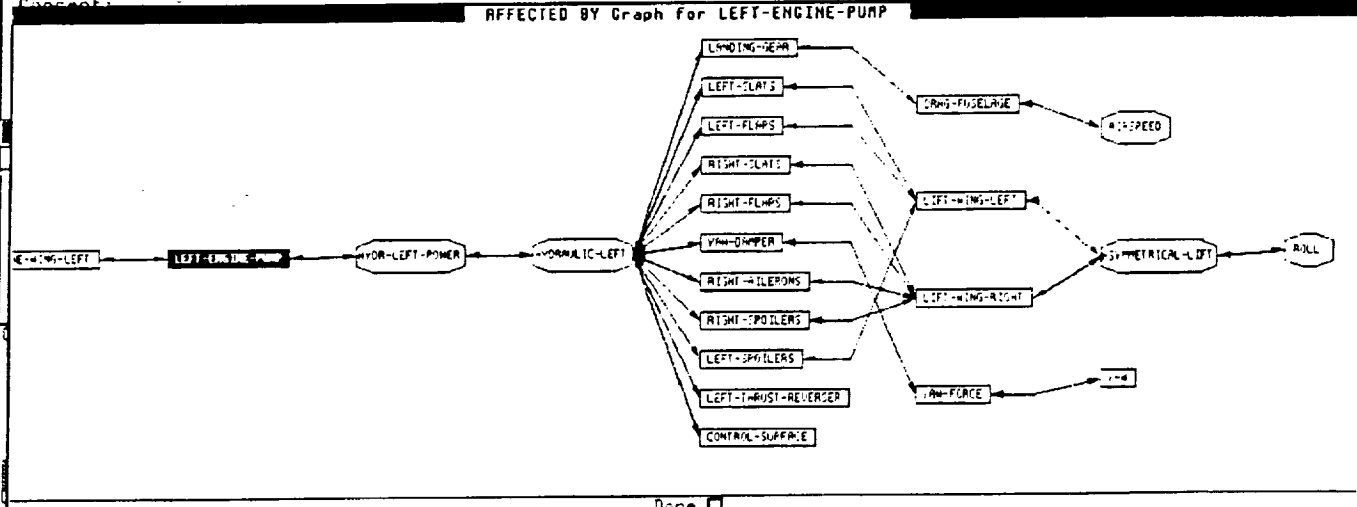
OVERALL A3 ARCHITECTURE

AUDIO MAILBOX ARCHITECTURE
AND INTERACTIONS WITH IMS

Abstractions and Specializations of MODEL

Flavorize Copy New Child View Kill Pop Stack Revert Remember

AFFECTED BY Graph for LEFT-ENGINE-PUMP

Done ☐

Left and hold: pan; Middle: speed pan; Right: menu of other graph operations.
To see other commands, press Control, Meta or Shift.

[Fri 29 Sep 5:04:25] Eva   CL FF: User Input   strunk

ORIGINAL PAGE IS
OF POOR QUALITY