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FLEXIBLE STRUCTURE CONTROL EXPERIMENTS USING A REAL-TIME WORKSTATION FOR COMPUTER-AIDED CONTROL ENGINEERING

By

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ABSTRACT

A Real-Time Workstation for Computer-Aided Control Engineering has been developed jointly by the Communications Research Centre (CRC) and Ruhr-Universitaet Bochum (RUB), West Germany. The system is presently used for the development and experimental verification of control techniques for large space systems with significant structural flexibility.

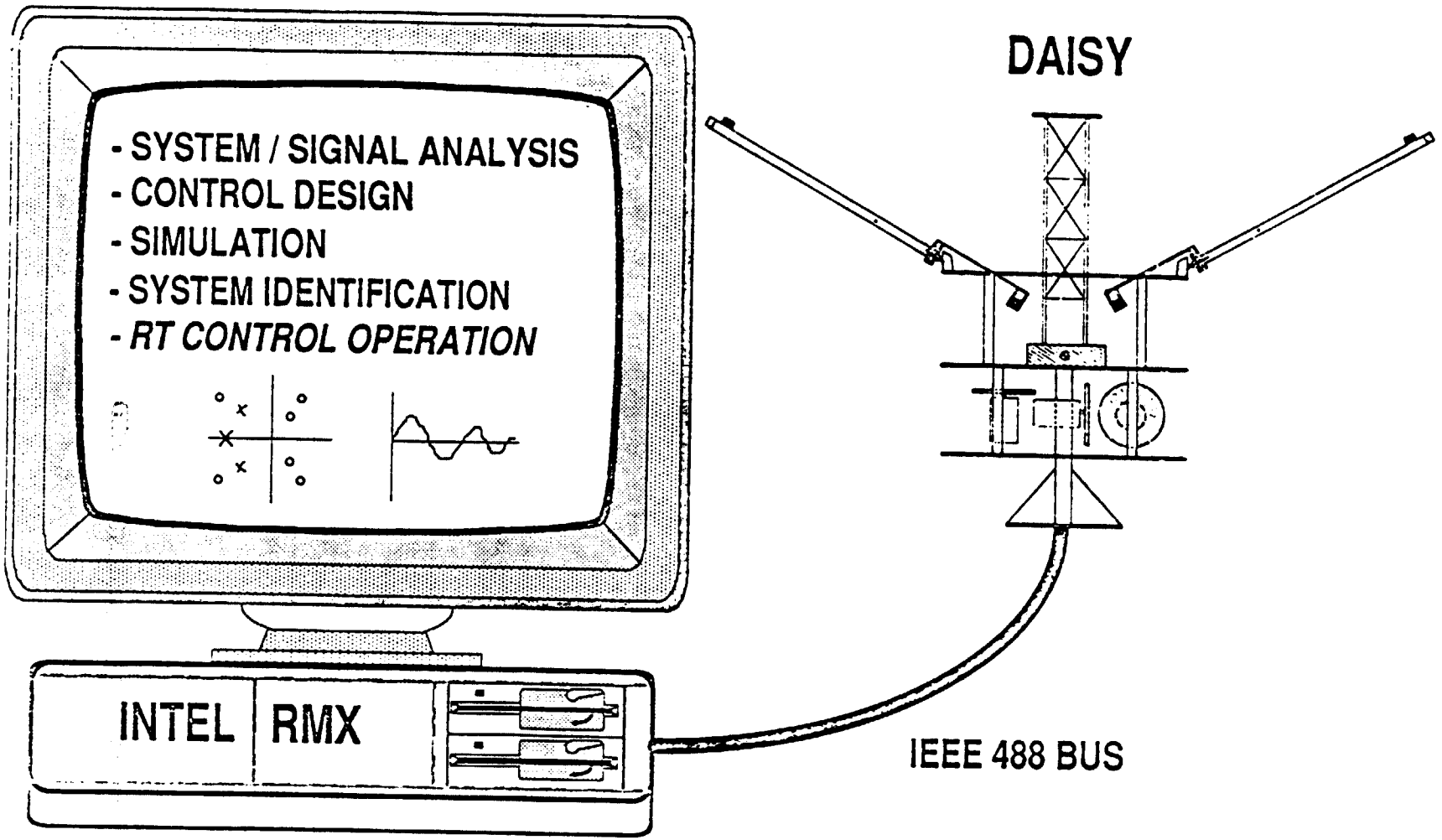
The Real-Time Workstation (cf. Attachment 1) essentially is an implementation of RUB's extensive Computer-Aided Control Engineering package "KEDDC" on an INTEL micro-computer running under the RMS real-time operating system. The portable system supports system identification, analysis, control design and simulation, as well as the immediate implementation and test of control systems. A wealth of classical and modern control analysis and design methods are available to the user who interacts with KEDDC through a friendly dialog. The workstation can be configured both with analog and digital interfaces to the "real world" for data acquisition and control.

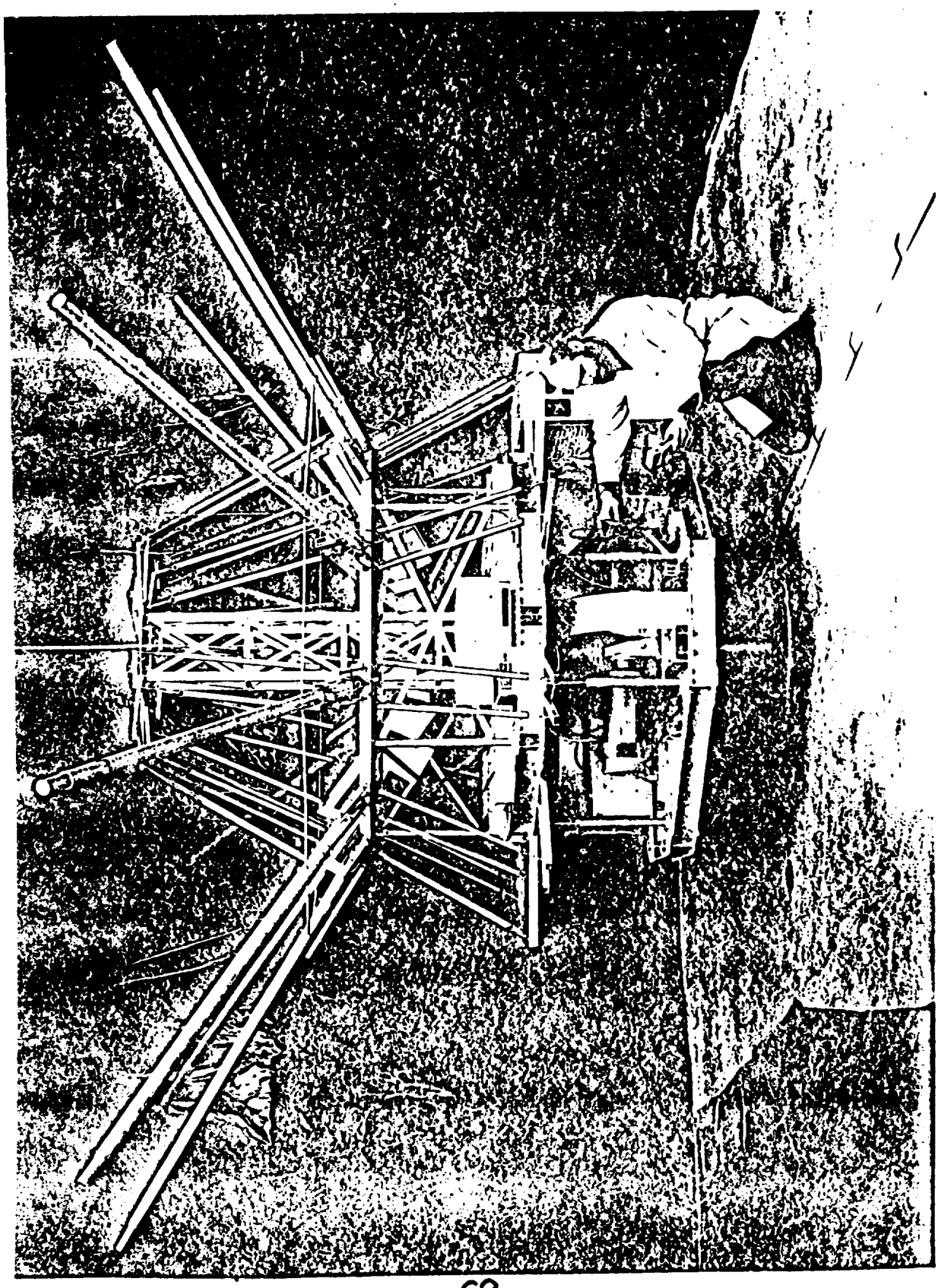
The Real-Time Workstation is currently being used by CRC to study control/structure interaction on a ground-based structure called "DAISY" (cf. Attachment 2), whose design was inspired by a reflector antenna. DAISY emulates the dynamics of a large flexible spacecraft with the following characteristics: rigid body modes, many clustered vibration modes with low frequencies and extremely low damping. DAISY presently has seven control actuators and eight sensors which are all "spacecraft-like."

The class of control algorithms currently investigated by experiments is "robust LQG" control. The Real-Time Workstation was found to be a very powerful tool for experimental studies, supporting control design and simulation, and conducting and evaluating tests within one integrated environment. It has dramatically increased the flexibility and turnaround of the experiments. As the Workstation all but eliminates the barriers between ideas on control systems and their experimental evaluation, analytical and experimental development can take place essentially simultaneously.

REAL-TIME WORKSTATION FOR

COMPUTER-AIDED CONTROL ENGINEERING





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OUTLINE

1. INTRODUCTION

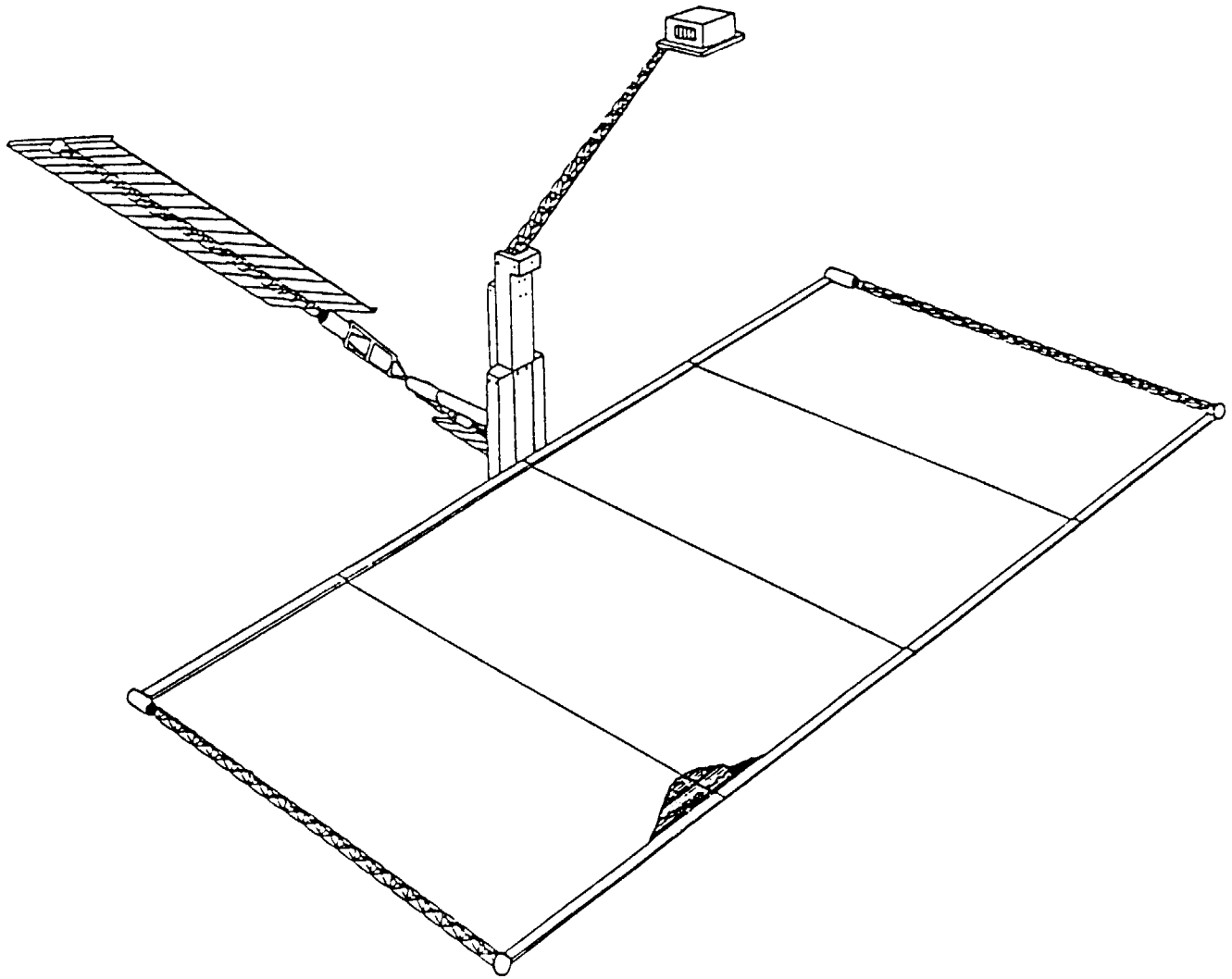
2. REAL-TIME WORKSTATION
   - CAPABILITIES
   - HOST ENVIRONMENT

3. FLEXIBLE STRUCTURE CONTROL EXPERIMENT
   - CHARACTERISTICS
   - APPLICATION OF REAL-TIME WORKSTATION

4. SUMMARY & CONCLUSIONS

SPACE-BASED RADAR

SPACE-FED PHASED ARRAY ANTENNA CONCEPT



TECHNOLOGY DEVELOPMENT FOR CONTROL OF FLEXIBLE SPACE STRUCTURES

- **ANALYTICAL STUDIES**
  DEVELOPMENT OF NEW TECHNIQES
  APPLICATION TO STRAWMAN PROBLEMS (SIMULATIONS)

- **GROUND-BASED EXPERIMENTS**
  VALIDATION AND DEMONSTRATION OF ANALYTICAL RESULTS

- **FLIGHT TEST**

SUPPORT BY CAD SYSTEMS ?

HOW DO CAD PACKAGES SUPPORT

CONTROL SYSTEM TECHNOLOGY DEVELOPMENT ?

MANY SUPPORT ANALYTICAL STUDIES

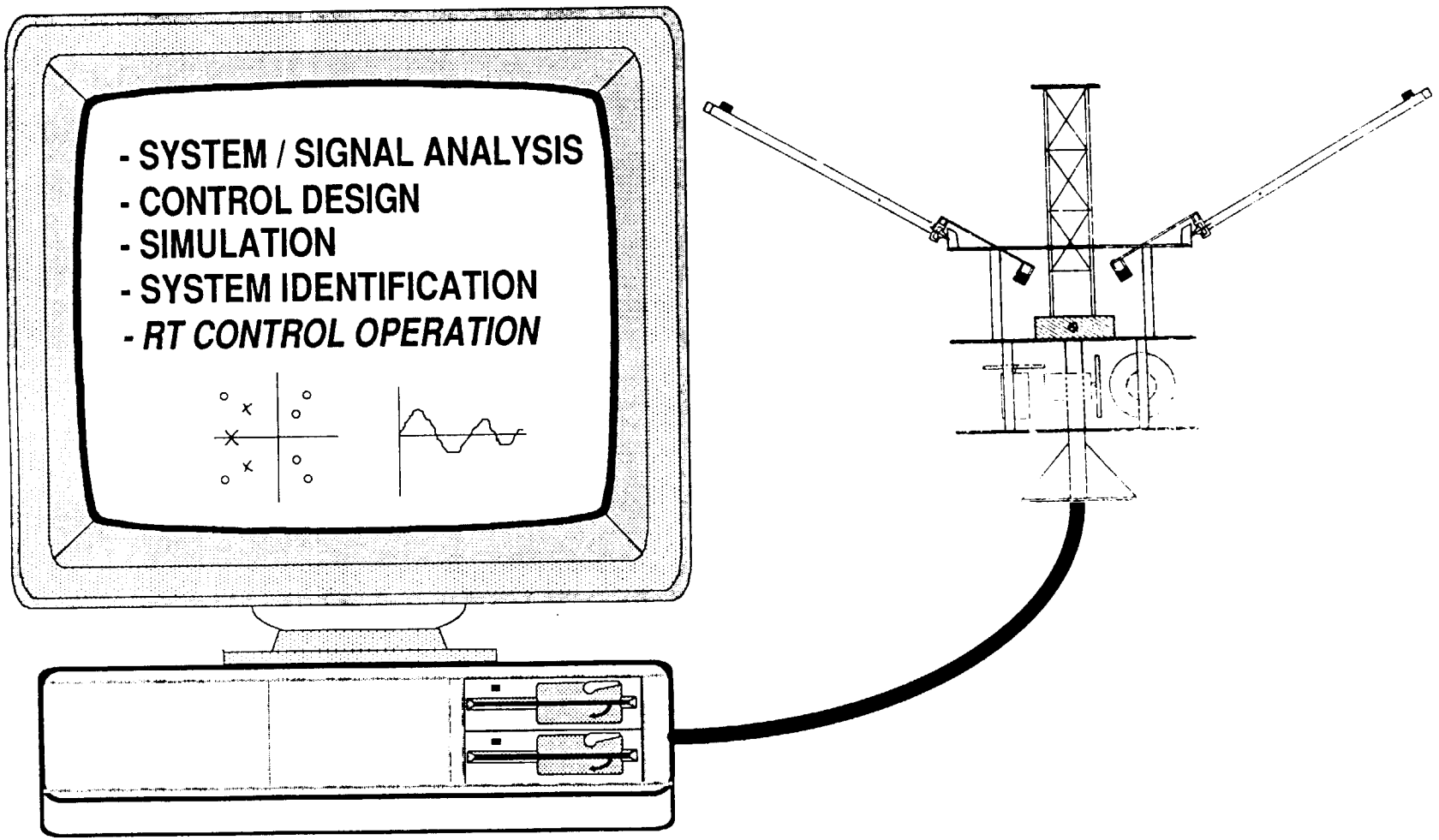
- NUMERICAL ANALYSIS
- GRAPHICS

FEW DIRECTLY SUPPORT EXPERIMENTAL STUDIES, WHICH REQUIRES:

- INTERFACE TO THE REAL WORLD
- DATA ACQUISITION
- IMPLEMENTATION & TEST OF REAL-TIME CONTROL SYSTEMS

REAL-TIME WORKSTATION

FLEXIBLE STRUCTURE CONTROL EXPERIMENT



REAL-TIME WORKSTATION SOFTWARE

UNDERLYING CAD PACKAGE: *KEDDC*

- DEVELOPED BY DR. CHRISTIAN SCHMID
- AT RUHR-UNIVERSITY, BOCHUM, WEST GERMANY
- RT WORKSTATION A JOINT PROJECT OF RUHR-U. AND CRC

FEATURES

- MATURE
- COMPREHENSIVE
- PORTABLE (RUNNING UNDER 12 OPERATING SYSTEMS)
- MODULAR, OPEN SYSTEM

KEDDC

CORE MODULES

- MATRIX MANAGER
- SYSTEM MANAGER
- FREQUENCY MANAGER
- SIGNAL MANAGER
- POLYNOMIAL MATRIX MANAGER
- GRAPHICS MANAGER

CAPABILITY OF CORE PACKAGE

- INTERACTIVE 'CALCULATOR' -TYPE ENVIRONMENT
- 250 COMMANDS
- EXTENDED BY APPLICATIONS MODULES

HOST ENVIRONMENT

REQUIREMENTS FOR SELECTION

- REAL-TIME MULTI-TASKING OPERATING SYSTEM
- PORTABLE COMPUTER
- COMPATIBLE WITH FUTURE MICRO-PROCESSORS

SYSTEM CHOSEN (IN 1985): INTEL 286/310

- OPEN SYSTEM (MULTIBUS 1)
- CPU: INTEL 80286/80287
- OPERATING SYSTEM: INTEL RMX86
- UPGRADE TO 386-BASED RMX286 SYSTEM PLANNED

HOST ENVIRONMENT (CONT'D)

PERIPHERALS

- **GRAPHICS TERMINAL** (780 X 1024 RESOLUTION)
- **DOT MATRIX PRINTER**

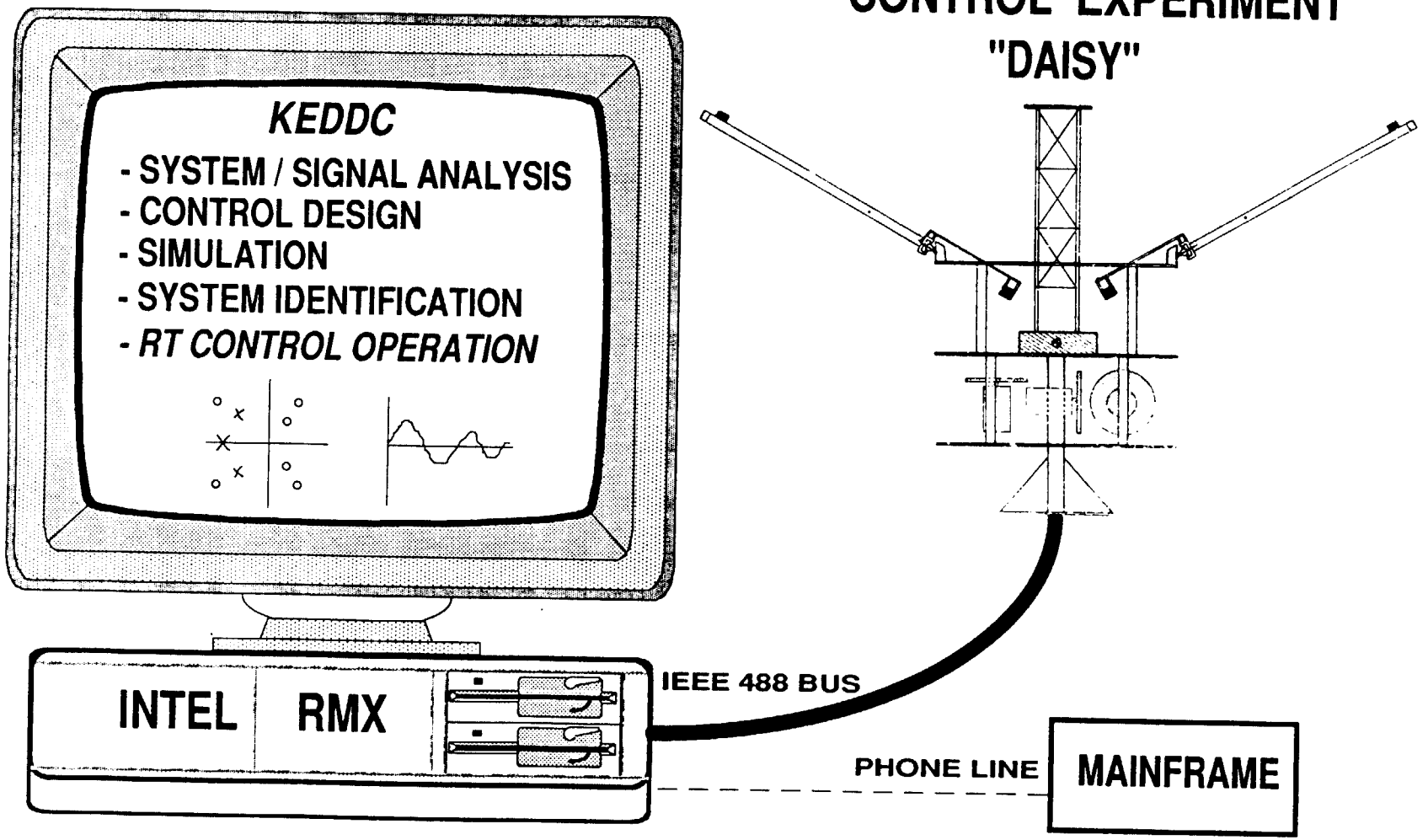
REAL-TIME SIGNAL INTERFACE FOR DATA ACQ. AND CONTROL

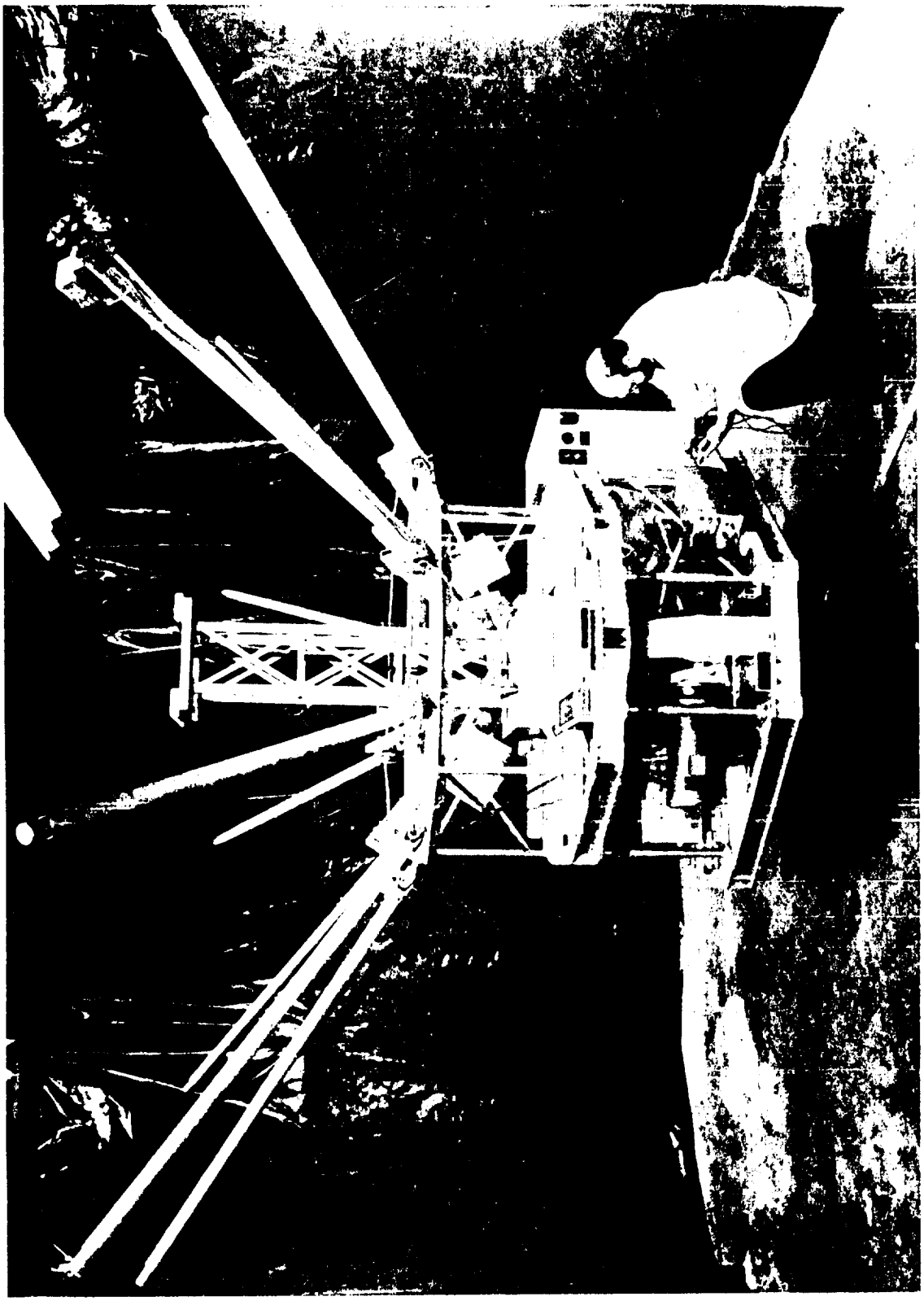
- **IEEE 488 GPIB** (USED IN FLEXIBLE STRUCTURE CONTROL EXPERIMENT)
- **ANALOG SIGNALS**

DATA LINK TO REMOTE MAINFRAME

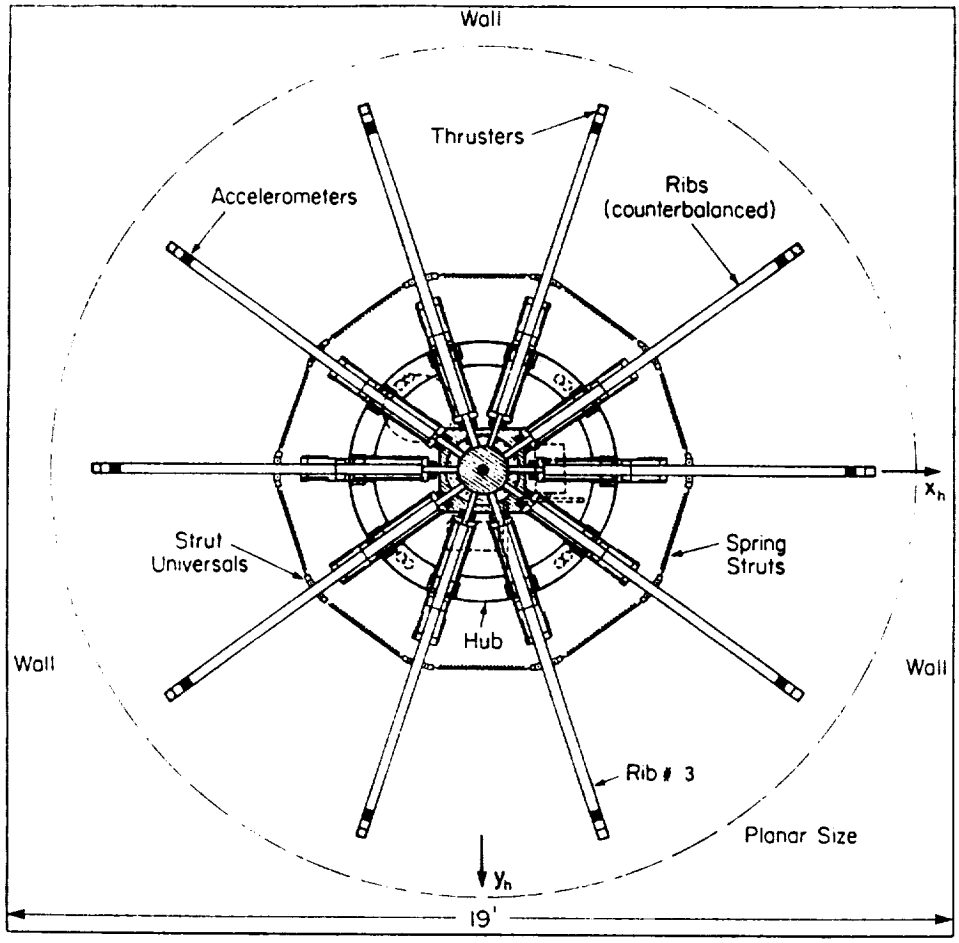
REAL-TIME WORKSTATION

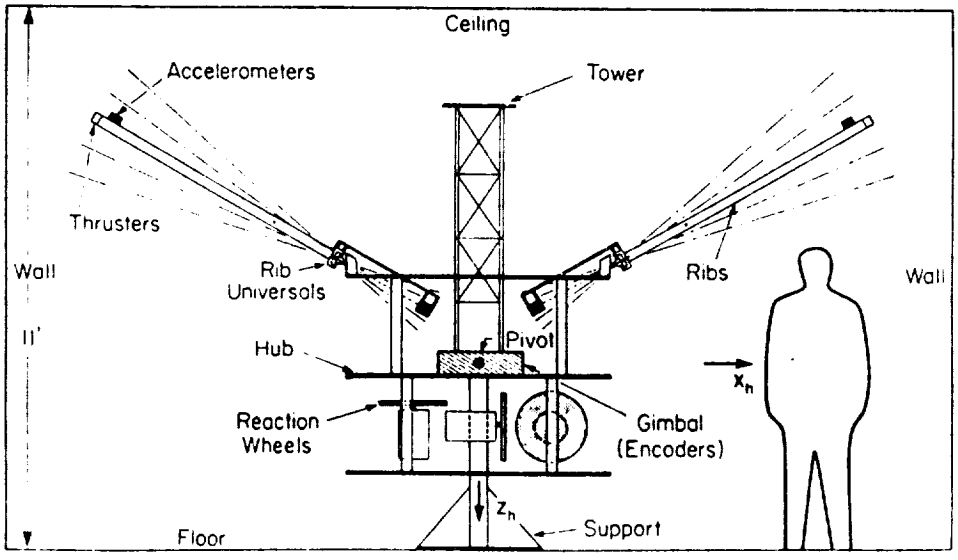
FLEXIBLE STRUCTURE CONTROL EXPERIMENT "DAISY"





DAISY: A FLEXIBLE SPACECRAFT EMULATOR





DAISY

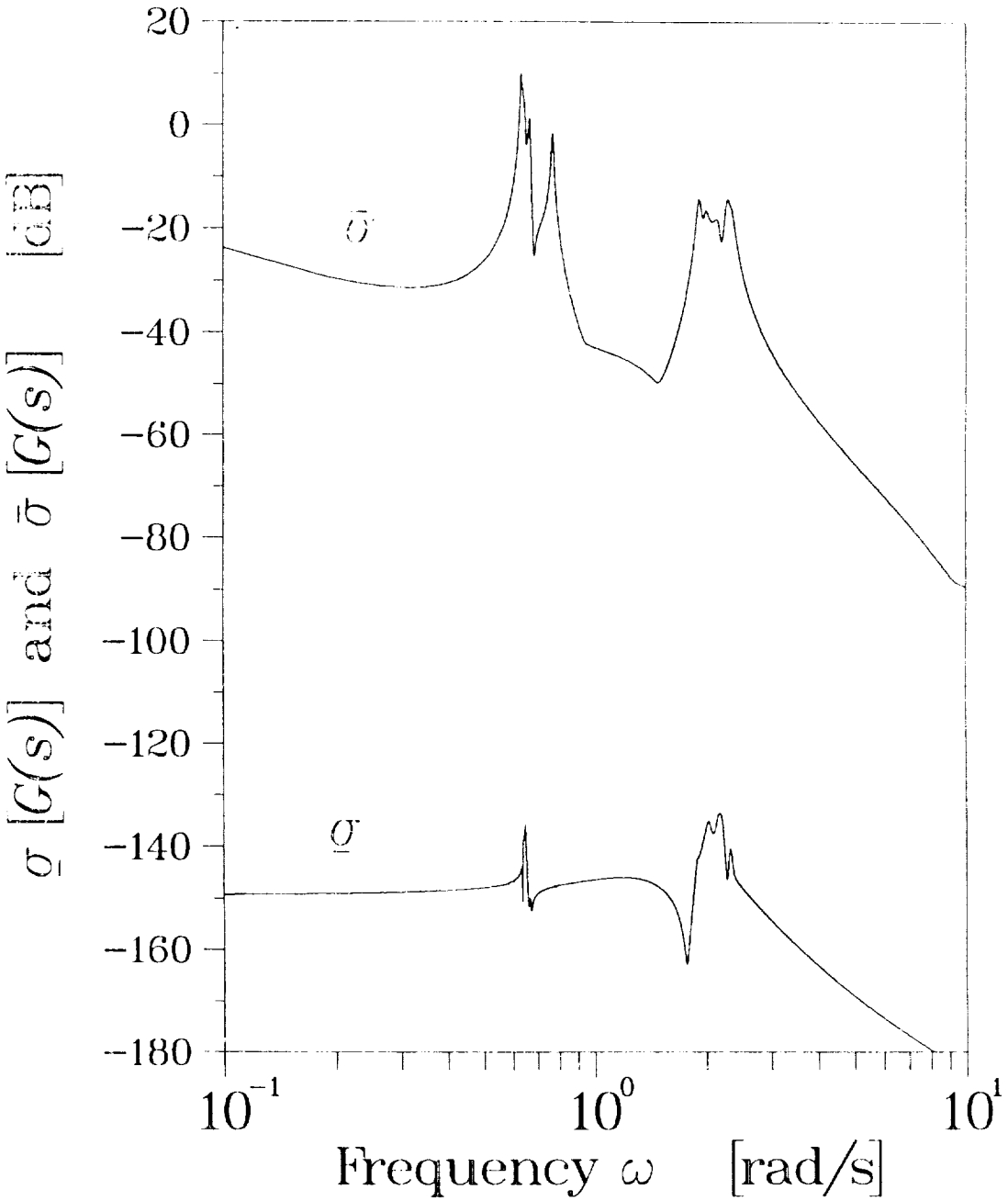
EMULATES DYNAMICS OF A LARGE FLEXIBLE SPACE STRUCTURE

- **3 RIGID-BODY MODES**
  (SLIGHT PENDULOSITY IN 2 RIGID-BODY MODES)
- **20 FLEXIBLE BODY MODES,**
  LOW FREQUENCIES: 0.07 ... 0.11 Hz, IN CLUSTERS
- **LOW DAMPING RATIO ACHIEVED**
  RIBS: 0.008, HUB: 0.01 ... 0.05

SPACECRAFT - LIKE SENSORS AND ACTUATORS

- **3 REACTION WHEELS ON HUB**
- **THRUSTERS ON RIB(S)**
- **ENCODERS ON HUB GIMBAL**
- **ACCELEROMETERS ON RIB(S)**

Principal Gains of DAISY



EXPERIMENTAL RESEARCH USING DAISY

PRESENT OBJECTIVE

DEVELOPMENT AND DEMONSTRATION OF

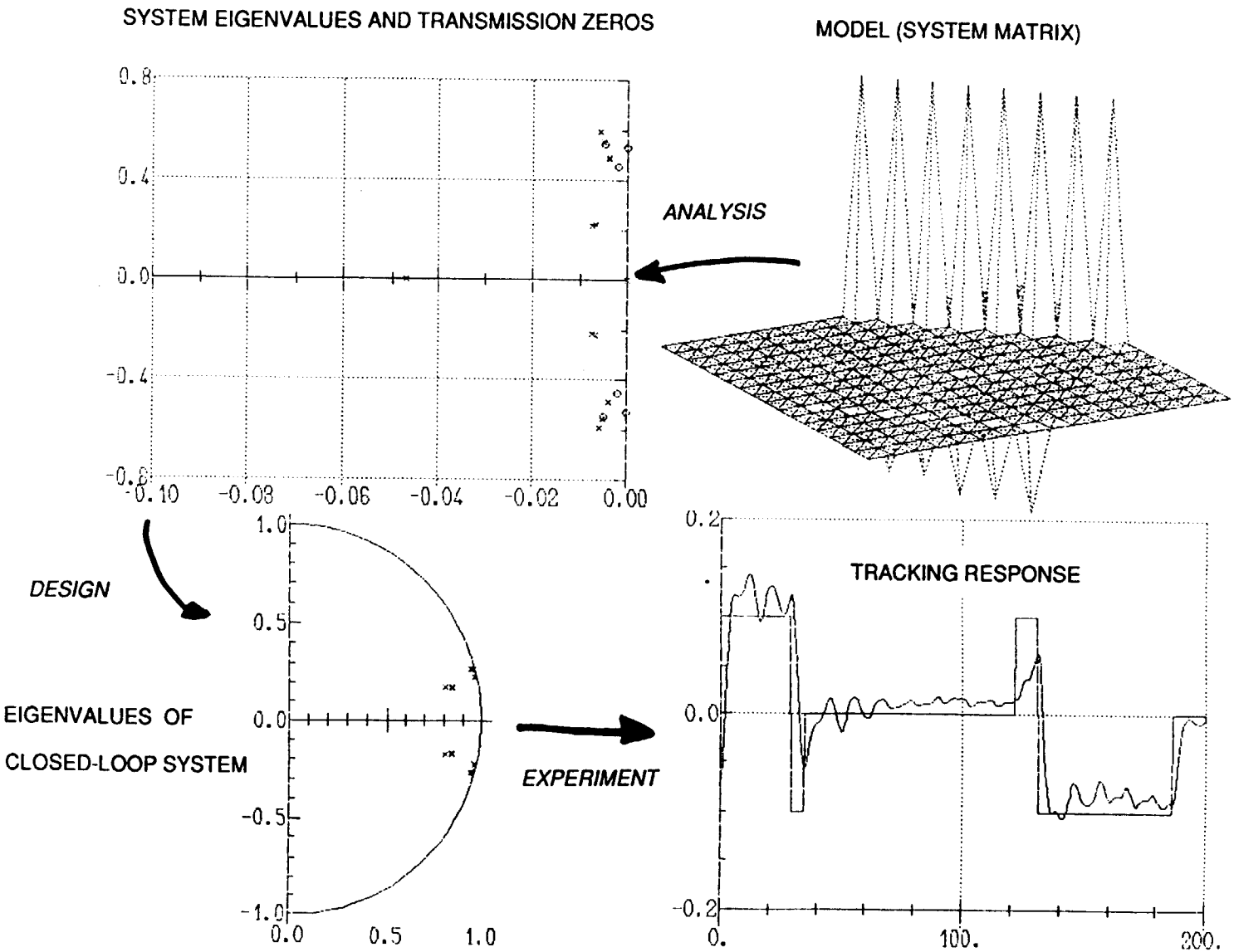
ROBUST CONTROL ALGORITHMS FOR FLEXIBLE STRUCTURES

STEPS (NOT NECESSARILY IN THIS ORDER)

- **GIVEN: ANALYTICAL DYNAMICS MODEL**
- **SYSTEM-ORDER REDUCTION**
- **MODEL DISCRETIZATION**
- **SYNTHESIS OF CONTROL ALGORITHM**
- **SIMULATION**
- **EXPERIMENT**
- **EVALUATION OF ALGORITHM**

TURNAROUND: 40 MIN

DESIGN EXAMPLE



REAL-TIME CONTROL OPERATION

INTERACTIVE MONITOR

- **INTERFACE BETWEEN USER AND REAL-TIME CONTROL ALGORITHM**
- **CONFIGURATION AND CONTROL OF REAL-TIME ALGORITHM**
- **DISPLAY AND RECORDING OF EXPERIMENTAL RESULTS**
  SIGNALS: PLANT INPUT/OUTPUT, SETPOINTS, OBSERVER STATES, ...
- **COMPLETE ENVIRONMENT FOR EFFICIENT EXPERIMENTATION**

REAL-TIME CONTROL ALGORITHM

- **EXECUTION TIME**

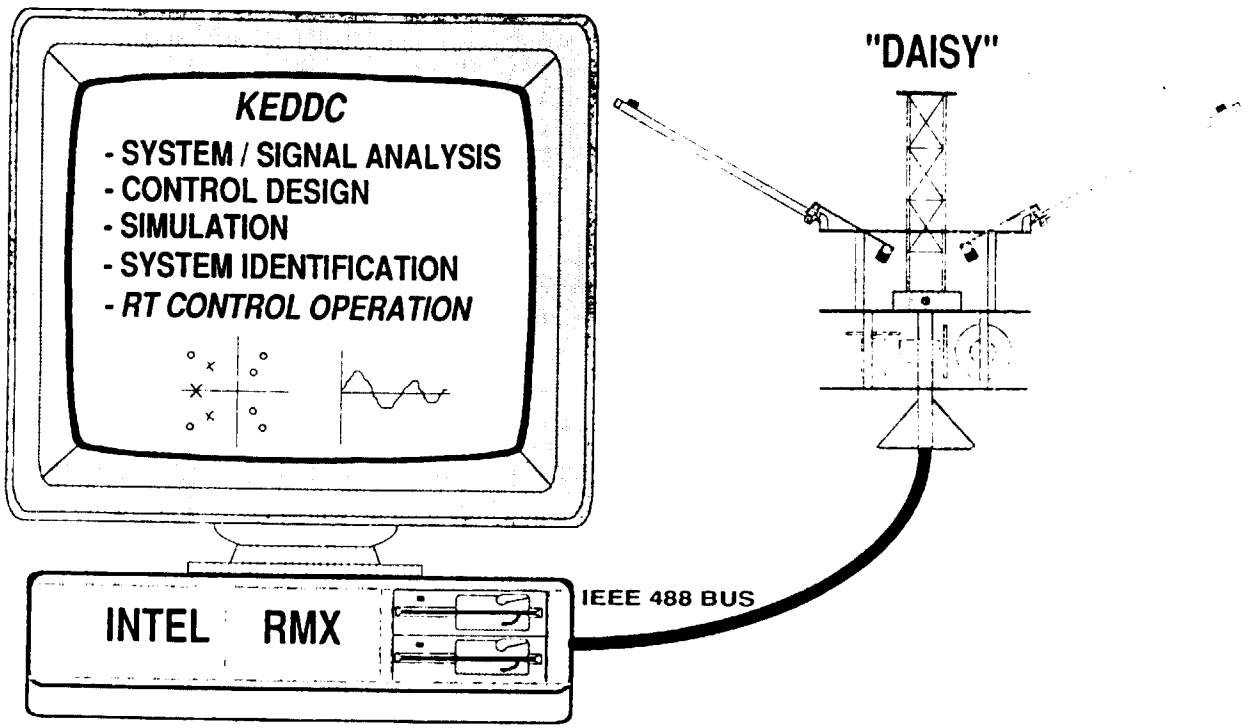
  EXTREMES: 5 MILLISEC WITH 5^{TH}-ORDER OBSERVER
  1.2 SEC WITH 50^{TH}-ORDER OBSERVER, 10 INPUTS, 10 OUTPUTS

  TYPICAL FOR DAISY APPLICATION (20^{TH}-ORDER, 5 INP, 5 OUTP): 20 MILLISEC

- **HOST FAST ENOUGH FOR REAL-TIME CONTROL OF DAISY**
  SAMPLING INTERVAL: 0.2 SEC ... 1 SEC

SUMMARY

EXPERIMENTAL RESEARCH ON CONTROL OF FLEXIBLE STRUCTURES



CONCLUSION

REAL-TIME WORKSTATION BRIDGES GAP BETWEEN THEORY AND EXPERIMENT!