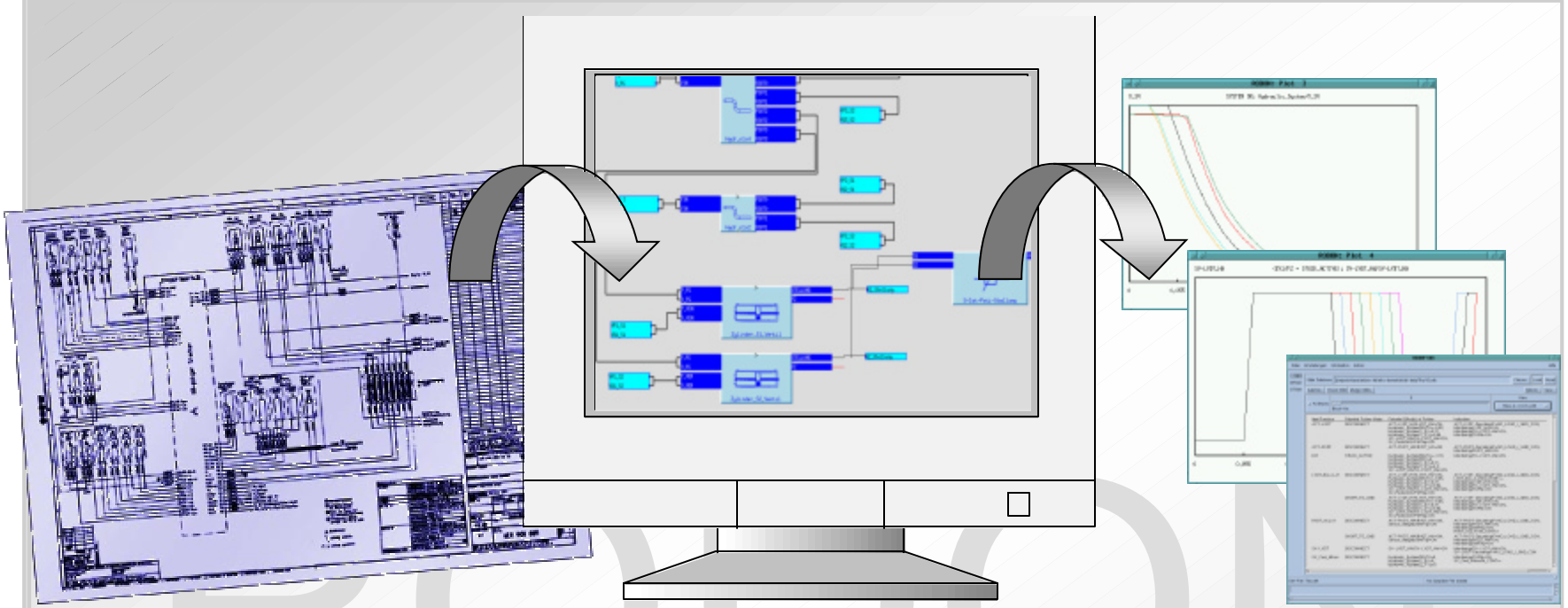


RODON®

Tolerance Based Simulation & Automated FMEA generation in Aircraft Elevators

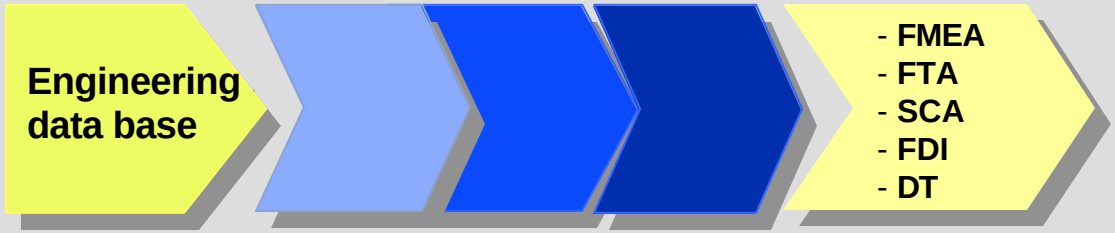
4th Annual Systems Engineering Conference

Dallas, October 22 - 25, 2001

How to improve supportability, affordable readiness & RTOC ?

Our basic approach:

- **Seamless math-based data flow** from Engineering data to FMEA and Service Information



This leads to:

- **Reduced costs**
  - Lower development costs for FMEA & Service Information (FDI) generation
- **Improved Quality**
  - More complete and accurate FMEAs & Troubleshooting Procedures
- **Reduced Lead times**
  - Design validation early on in the development process
  - Early Availability of Service Information (FDI)

How can a math- based seamless data flow be achieved?

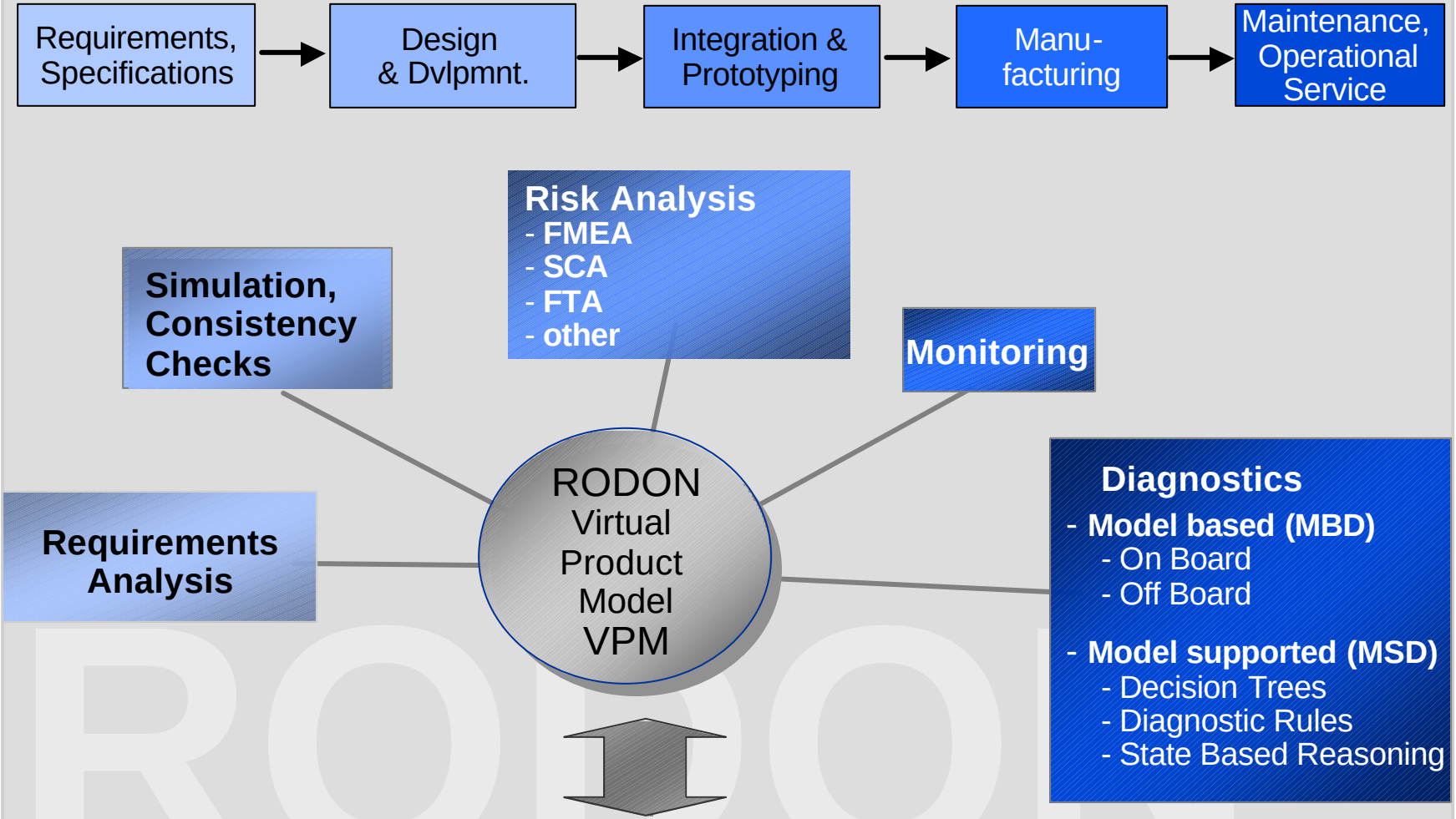
By using a software tool which allows

- To create a simulation model of a system based on its
  - Functional behavior
- To have analysis capabilities available for
  - Validation of functional design & Risk analysis
  - Diagnostics (FDI)
  - Non-functional attributes
    - like cost, mass for early on requirements analyses
    - Failure probability on component level for FTA

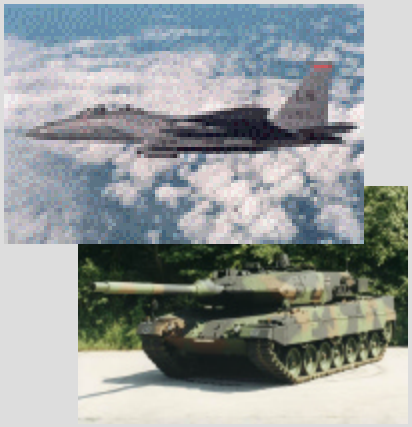
=> Both requirements are fulfilled by the model-based software tool **RODON**

RODON - Application Areas

RODON is a Software-Tool for System Integration based on the analysis of the functional behavior of the components



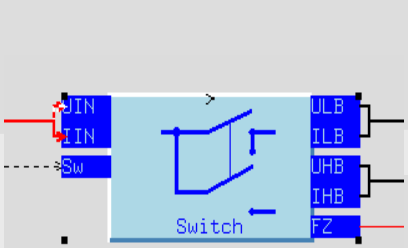
RODON
Modeling I - Components

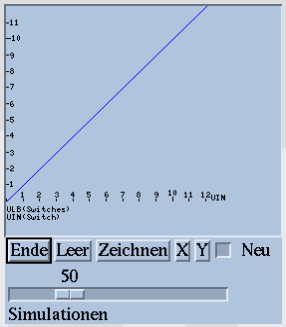


- Electrical
  - Cable
  - Switches
    - On/Off Switch
  - Relays
  - ECU's
- Hydraulics
- Pneumatics
- Mechanics

Model Description - Transfer Functions

Model Visualization



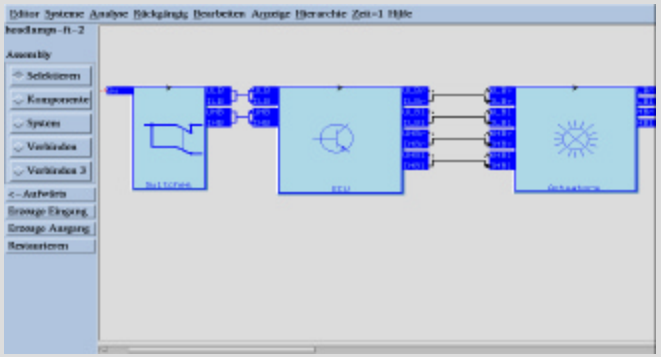


RODON

Modeling II - Connectivity, Assemblies and Systems

Connectivity on Component and Assembly Level

Modeling I



Highlights & Features:

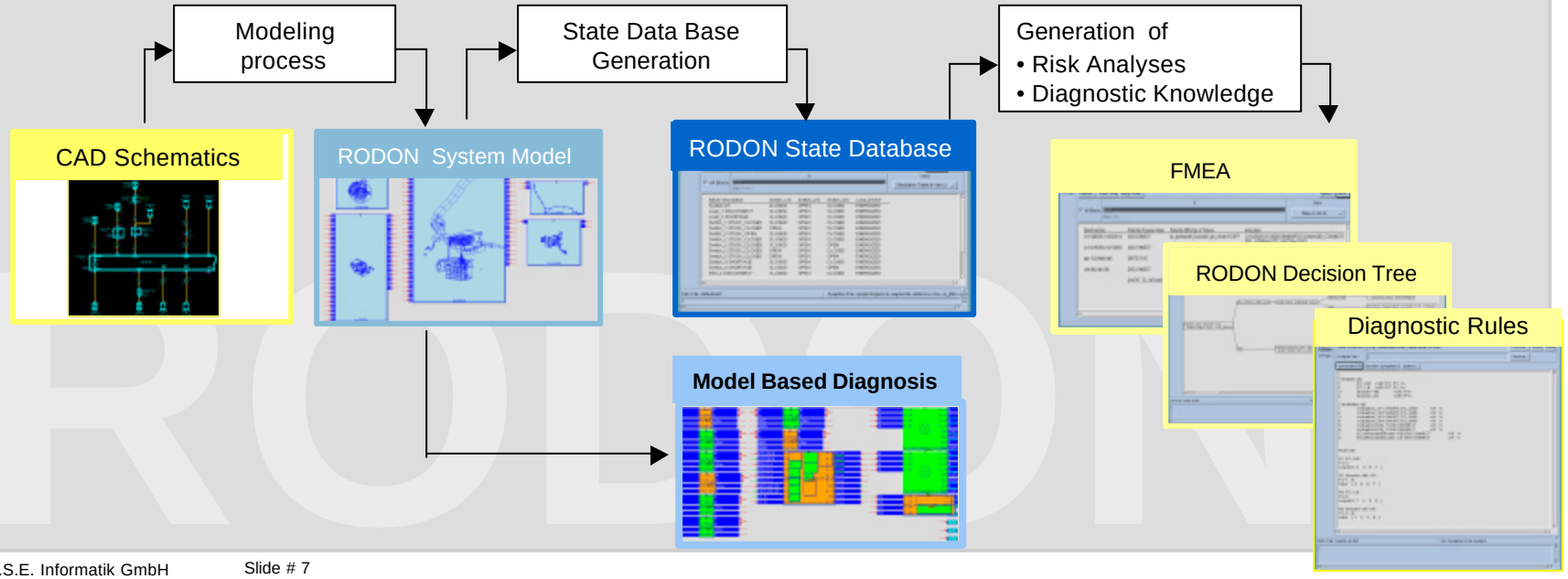
- Description of **Nominal Behavior**
- Hierarchical Model Structure based upon BOM
- **Multidirectional Determination** of all Values of the System
- Qualitative and quantitative Values
- Representation of **Tolerances** as Intervals
- Steady State and Dynamic Analyses
- **Top-Down** and **Bottom-Up** Approach
- Definition of **Failure Modes** on Component Level
- Straight Forward Variant Handling

Execution of Analyses

Rqmts Analysis | **Simulation** | **Risk Analysis** | **Monitoring** | **Diagnosis**

The RODON Process

- Generates Models Automatically from Design Data
- Generates all Analyses by calculation from one Model

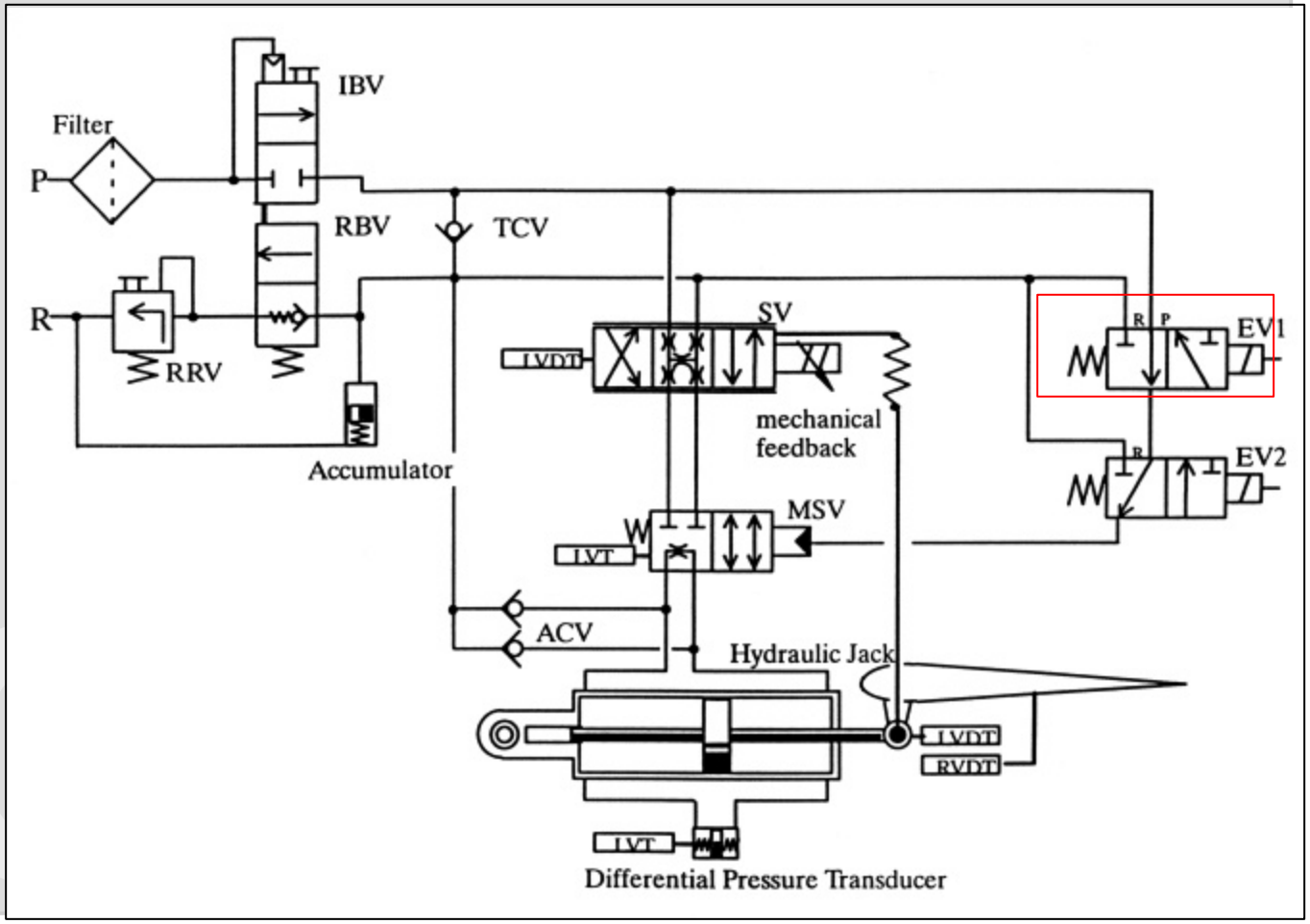


Example: Project with Aircraft Manufacturer

Aircraft Elevator - Fly by wire system

System consists of:

- **Hydraulic** control loop
- Controller **Logic**
- **Electrical** Wiring



Example: Aircraft Elevator - Fly by wire system

Tasks:

- Simulate maximum deviation of actual value from set point depending on tolerances & offsets of inputs
- Investigate impact of tolerances & offsets on behavior of monitors
- Investigate impact of failure modes on behavior of monitors

Methodology:

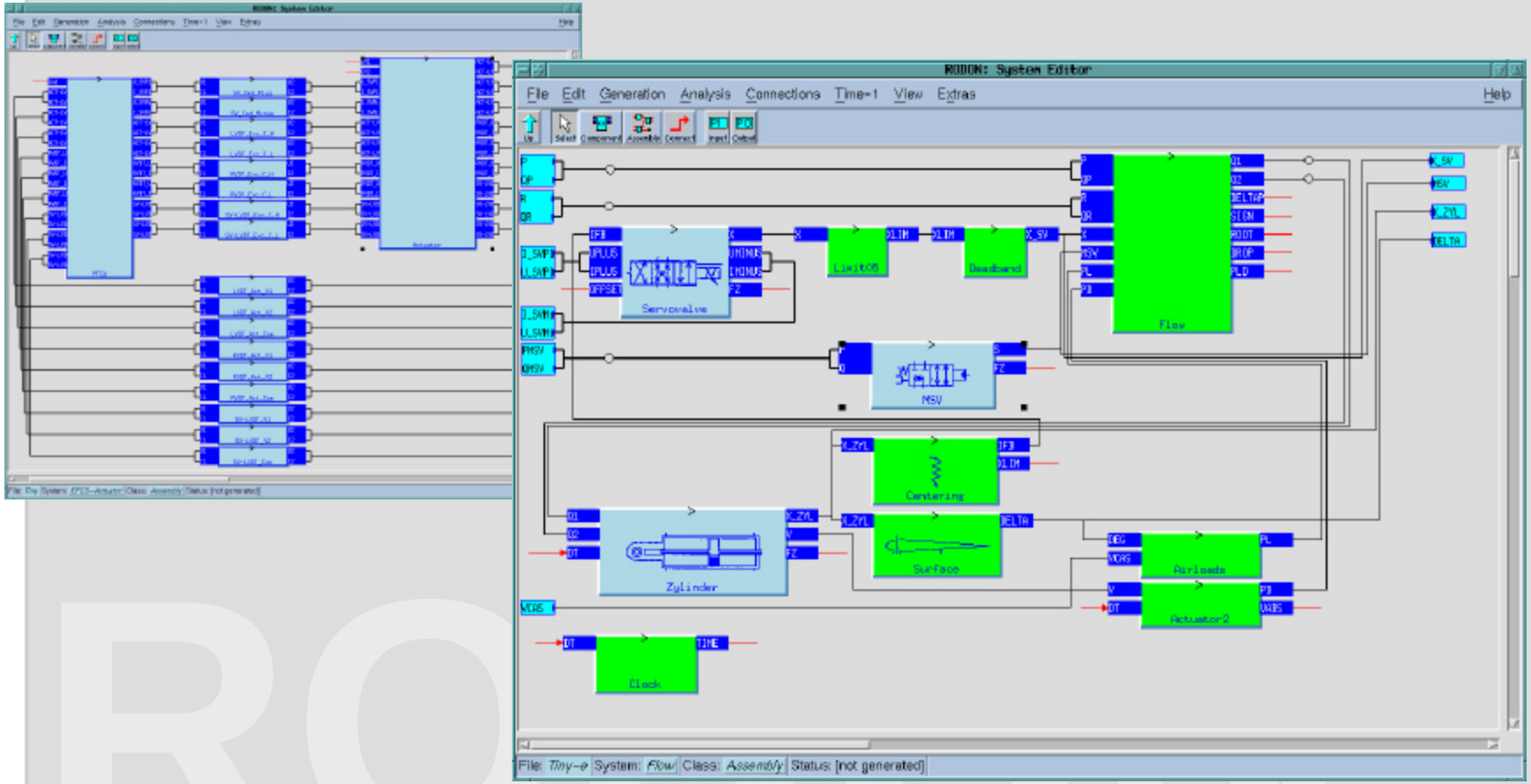
- Create RODON Virtual Product Model
- Simulation with Tolerances for time-dependent systems
- Failure-Mode-Simulations for time-dependent systems

Additional benefits concurrently to the simulations:

- Automated FMEA generation for dynamic systems
- Generation of Troubleshooting Procedures

Example: Aircraft Elevator - Fly by wire system

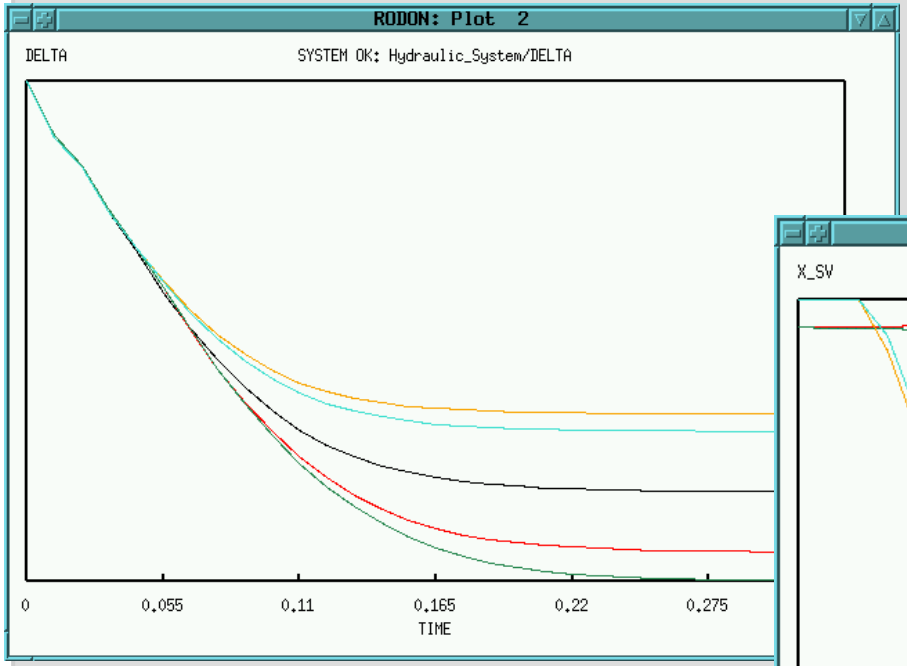
Create RODON Virtual Product Model



Example: Aircraft Elevator - Fly by wire system

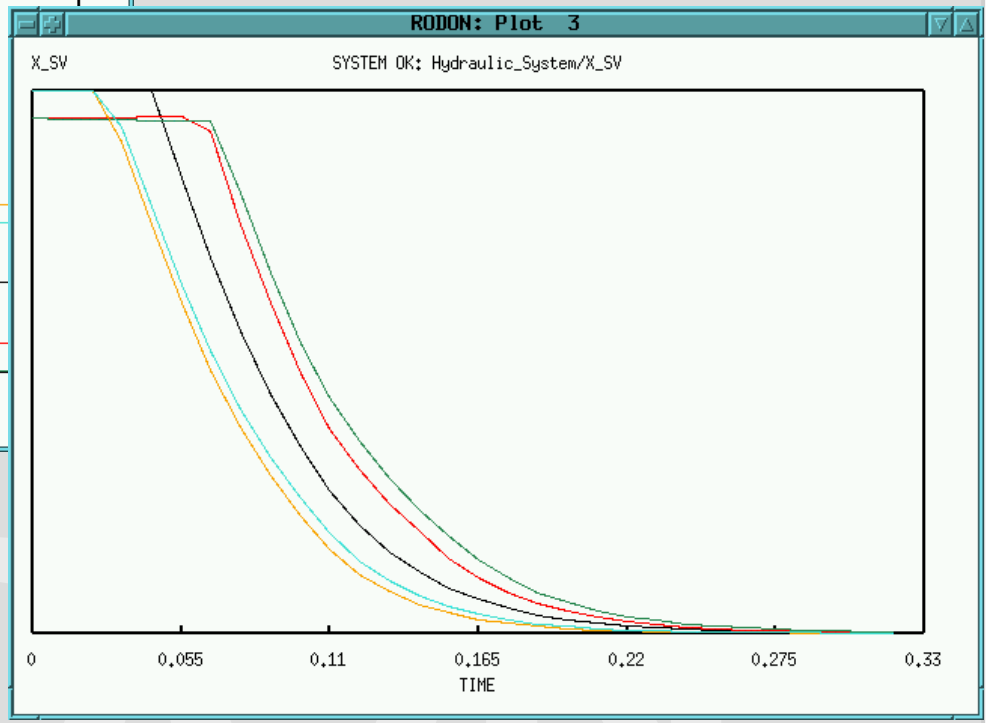
Tolerance-Simulations with RODON

- Sensor-tolerances
- Offsets



Elevator position versus time after stimulation with a step function.

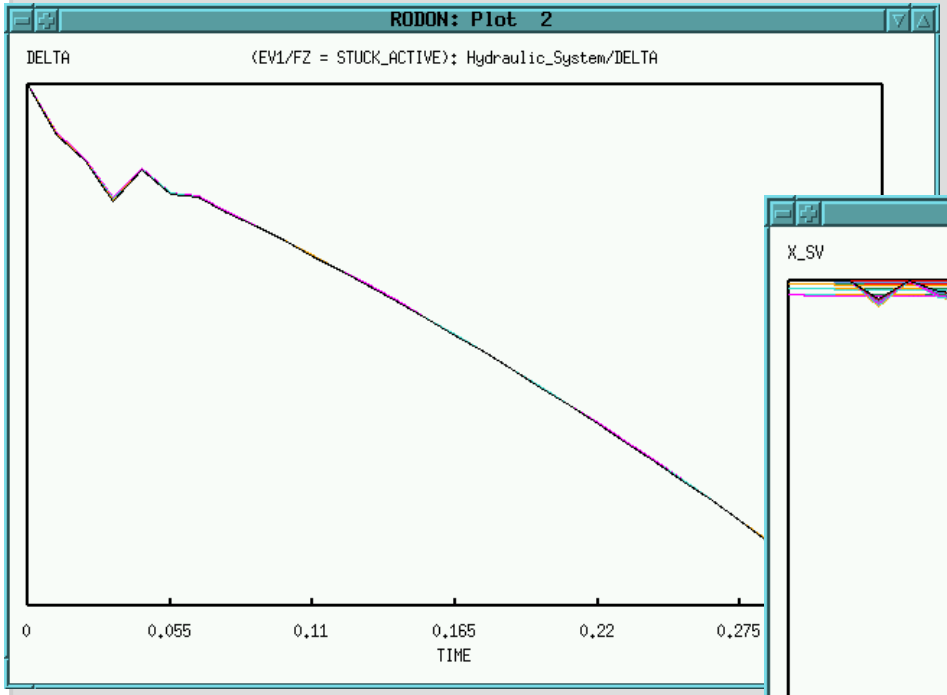
Black: no offsets & tolerances
Yellow / cyan:
upper boundary of tolerances & offsets
Red / green:
lower boundary of offsets and tolerances

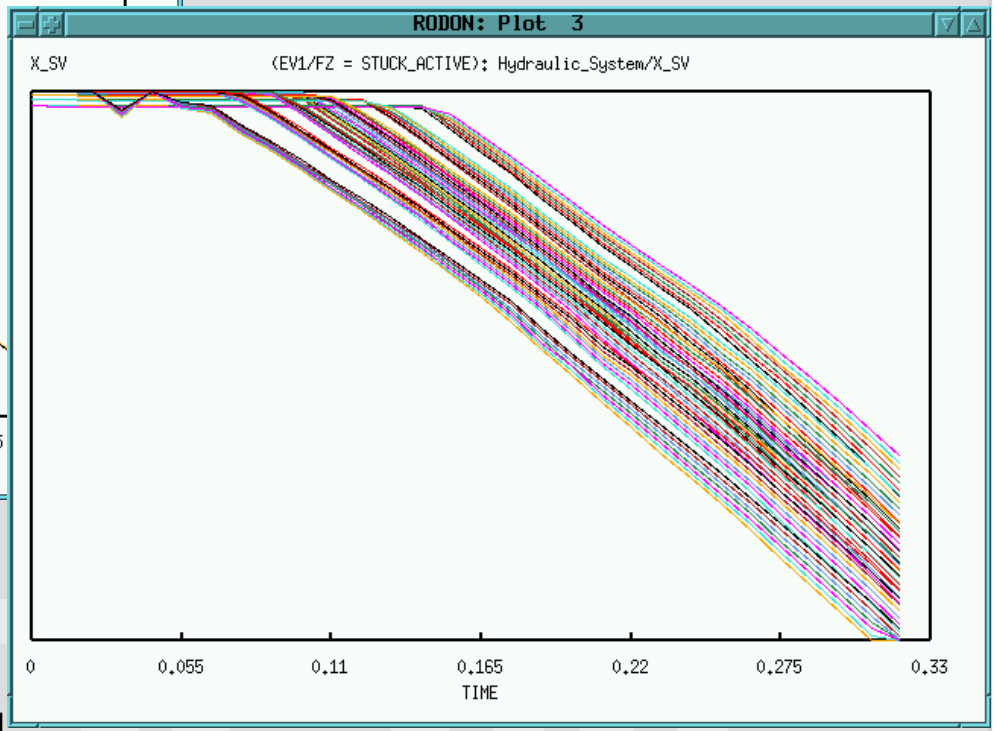


Servo-valve position versus time, controlling the elevator position.

Example: Aircraft Elevator - Fly by wire system

Failure Mode Simulations



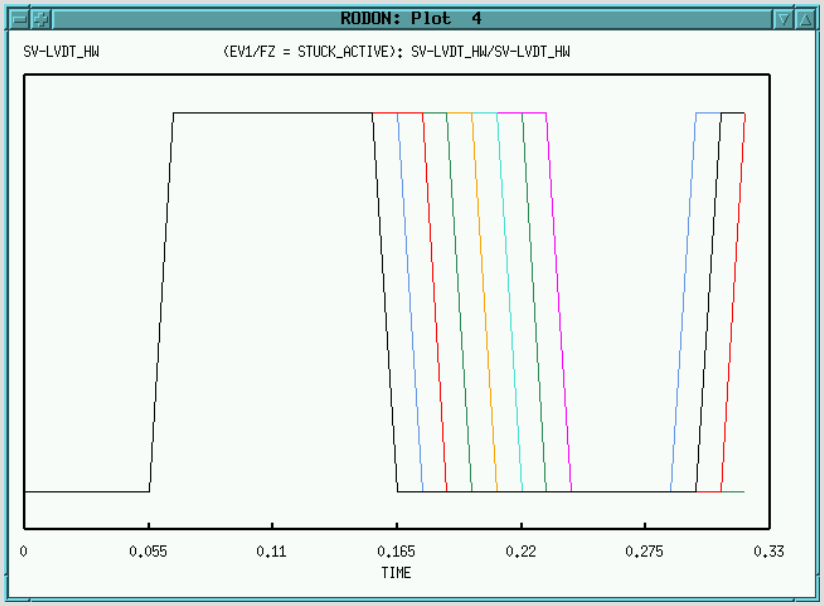


Elevator position versus time. „Run-away“ situation.
Failure-mode is Enabling Valve EV1 „STUCK_ACTIVE“.
Effect: Main Servo Valve is closed; no control possible. Elevator runs away due to air loads.

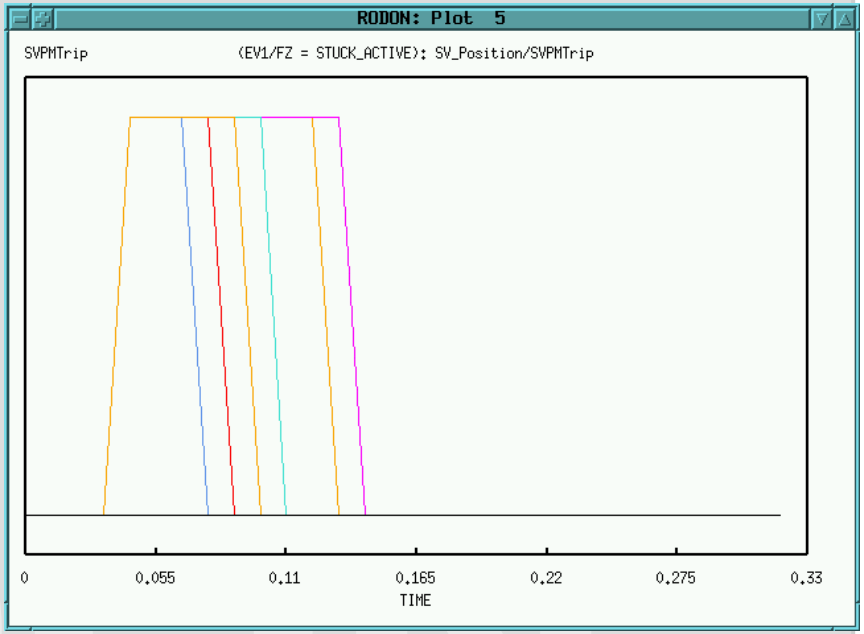
Servo Valve position versus time for all offsets and tolerances. Position of Servo Valve has no influence on elevator due to closed Main Servo Valve.

Example: Aircraft Elevator - Fly by wire system

Excitation of Monitors



Sensor-Monitoring of sensor LVDT of Servo Valve SV. Monitoring behavior as expected.



Position-Monitoring of Servo Valve SV.
Monitor activated due to offsets and tolerances.
Unexpected Monitoring behavior!

Black curve: Simulation with no offsets and tolerances.
Colored curves: Simulations with offsets and tolerances.

Example: Aircraft Elevator - Fly by wire system

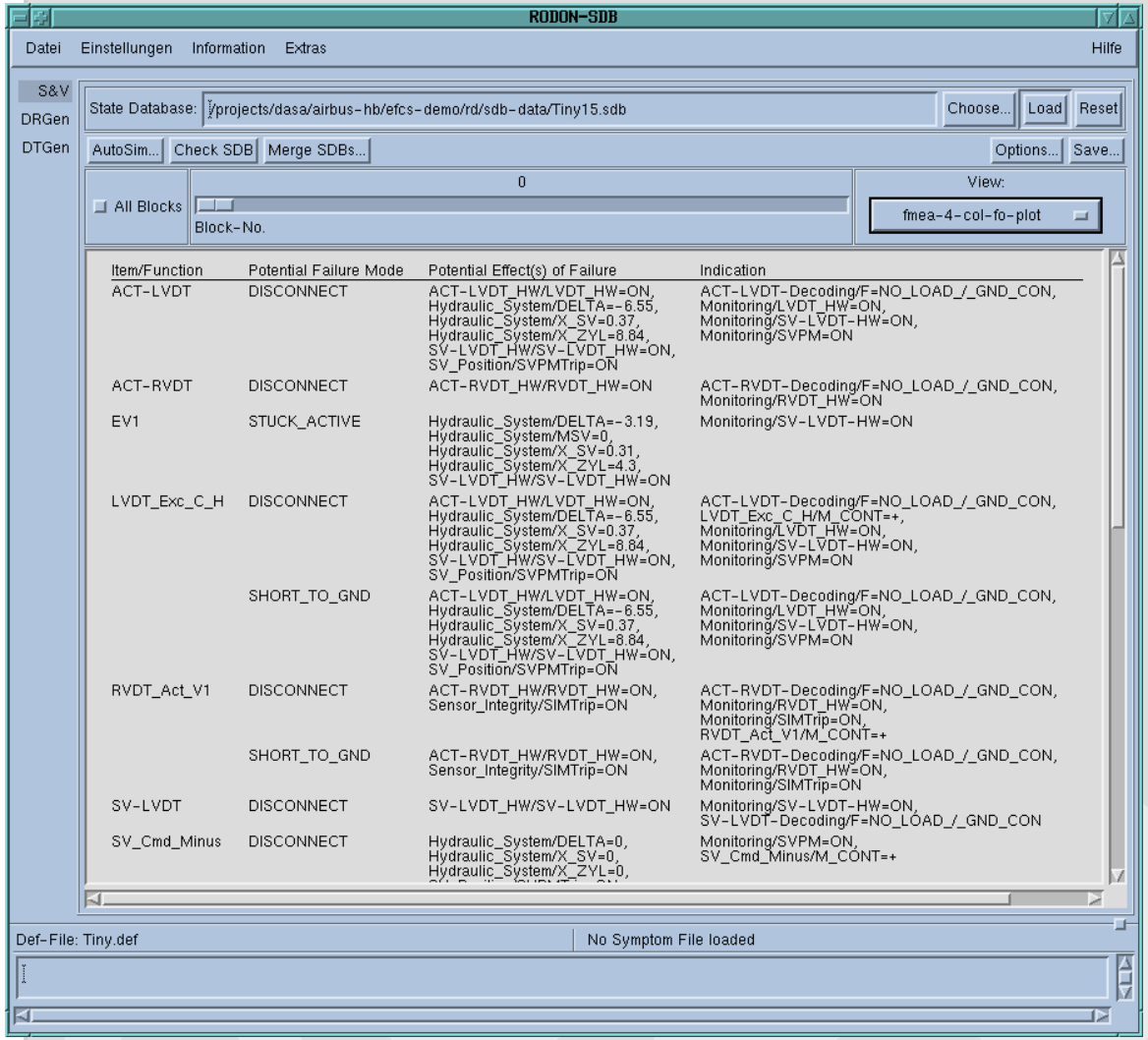
Results of the analysis

- Maximum deviation of actual value from set point due to the offsets and tolerances were larger than specified

- Offsets & Tolerances have significant impact on Monitoring for both
  - the nominal behavior mode
  - failure modes

Example: Aircraft Elevator - Fly by wire system

Additional benefits - **FMEA**



System **FMEA** for **dynamic- and tolerance-** based systems; generated automatically out of the same RODON Virtual Product Model.

FMEA was used to **check** the **controller's self diagnostics** and **monitors** for about 300 failure modes.

Potential Effects:

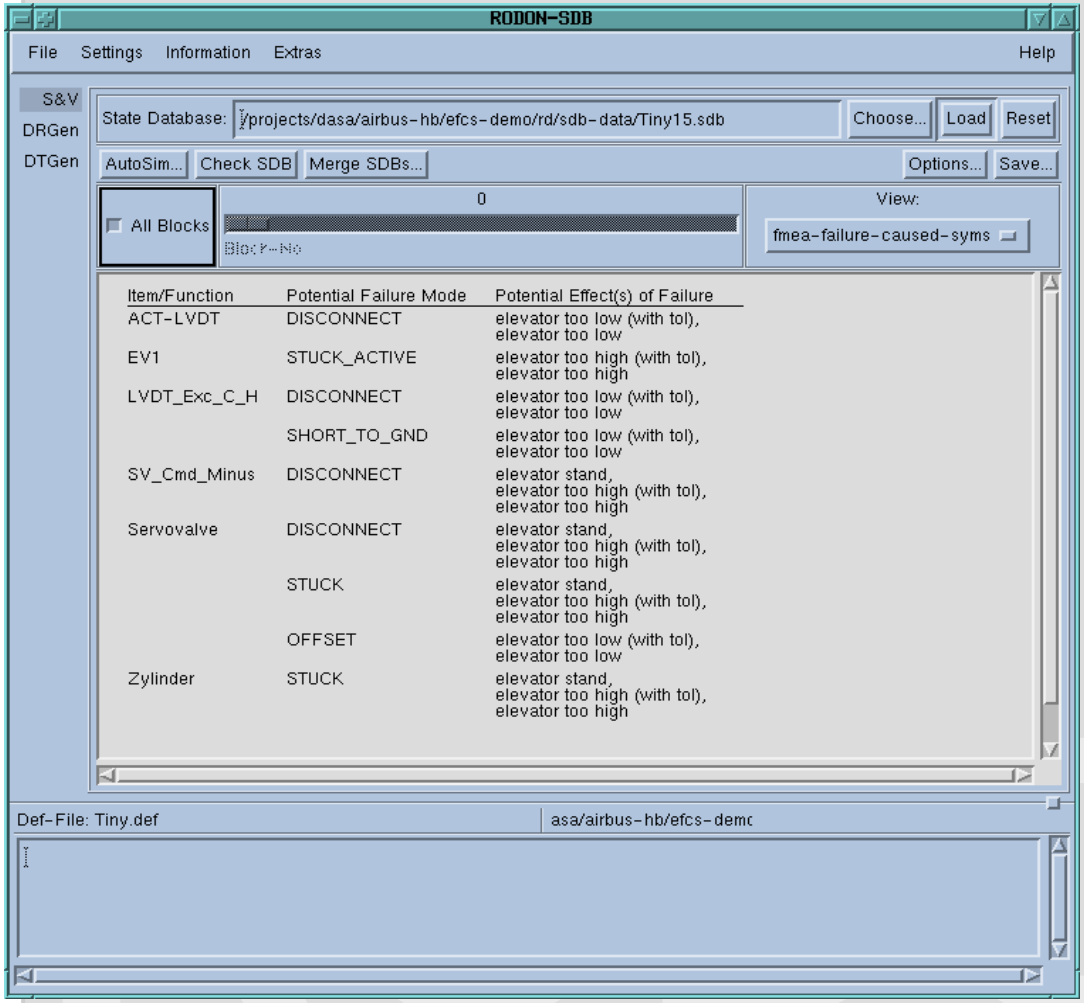
- Observable and measurable variables of the hydraulic system

Indications:

- Monitors
- Diagnostic Trouble Codes

Example: Aircraft Elevator - Fly by wire system

Additional benefits - **Simplified Fault Trees**



Simplified Fault Trees:
Symptom -> possible causes relationship

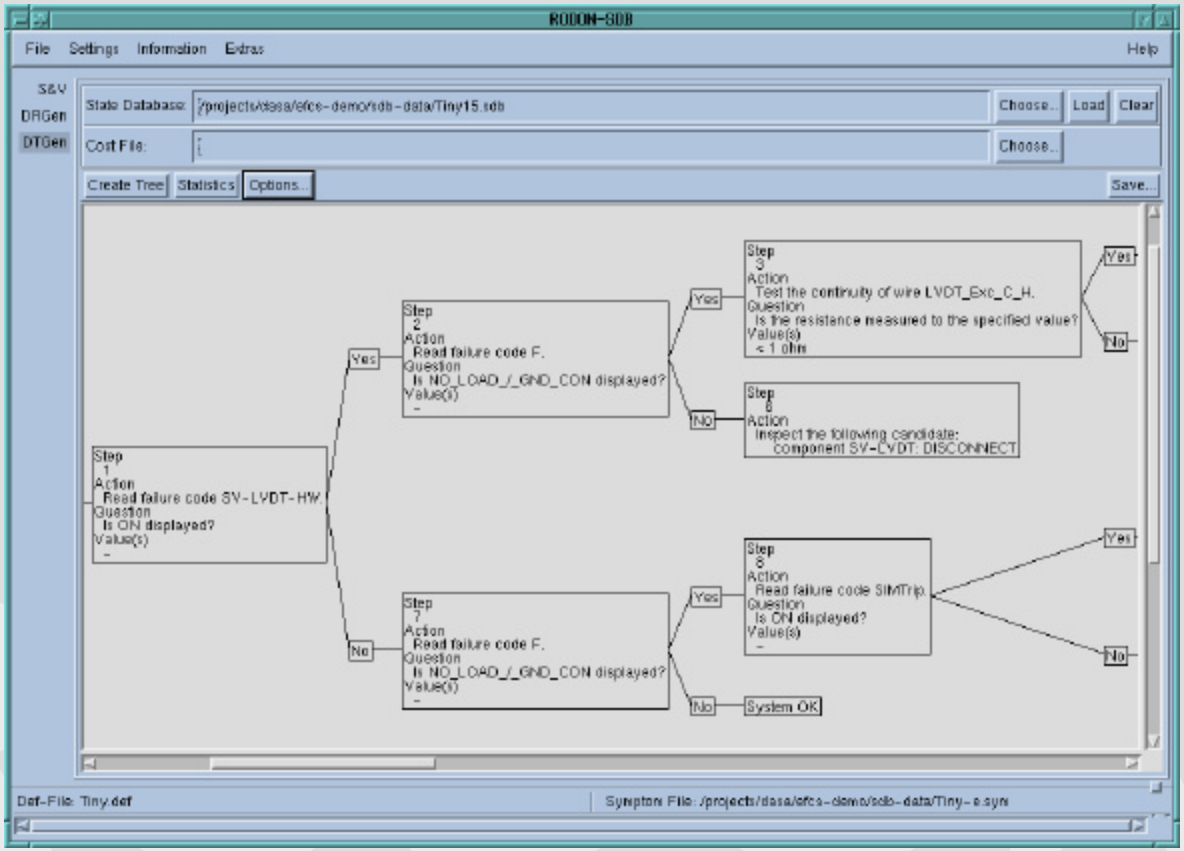
Selected Symptoms

- Elevator too high
- Elevator too low
- Elevator stuck

Example: Aircraft Elevator - Fly by wire system

Additional benefits - **Troubleshooting Procedures**

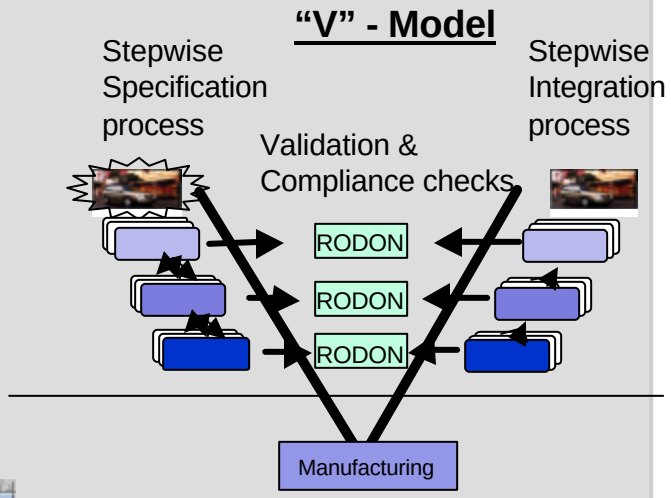
Automated generation of **Troubleshooting Procedures** (Decision Trees) out of the same RODON Virtual Product Model.



Additional benefit -

Compliance checks for integration and test phases

Compliance checks between specifications and the real, physical system according to the “V”-Model can be performed by using RODON’s Model-Based Diagnosis (MBD) - Function.



Summary I

RODON-Support to Product Design, Integration & Maintenance

RODON supports the following tasks using the same RODON Virtual Product Model:

- Analysis of the design
- Automated Risk Analysis: FMEA, simplified FTA, Sneak Circuit Analysis (SCA)
- Automated generation of troubleshooting procedures and diagnostic rules

- FDI analysis of the design
- Coverage analysis in the design stage
- Subsystems' integratability tests by Virtual Prototyping
- Identification of fault conditions for ECU
- "Executable" FMEA with Math Based Model

Summary II

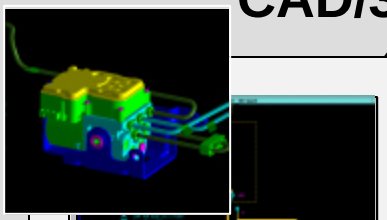
Benefits

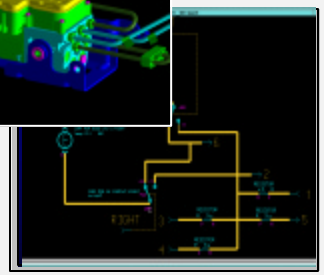
- **Reduces Effort**
  - To generate FMEA, FTA and diagnostic Information
  - Creates **“Technical Memory”** over successive programs
- **Improves Quality:**
  - More complete and accurate results
    by using math based process
- **Reduces lead times** by early analysis of design
  - Getting Errors out Early
  - Early Availability:
    Diagnostic Information available at Integration & Test phase

RODON

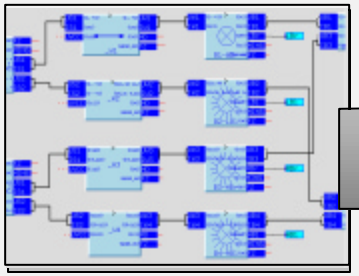
Overall Applications

CAD/3-D

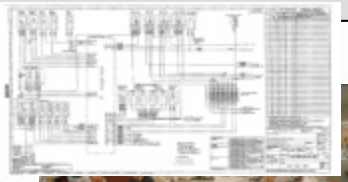




RODON

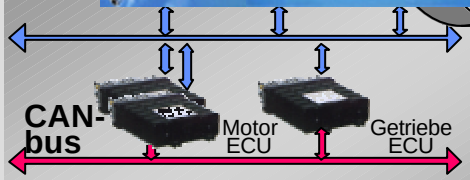


Engineering
Risk analyses
FTA, FMEA…



Integration &
System tests

Manufacturing



-Component Behavior
-ECU-Communication

Maintenance
Troubleshooting
Procedures
for
Fault Isolation

R.O.S.E. Informatik GmbH
Major Customers

Automotive Industry

- General Motors (GM)
- DaimlerChrysler
- Volkswagen

Aerospace Industry

- NASA Ames Research Center
- EADS Airbus
- ASTRIUM Space Infrastructure

Military

- Krauss-Maffei Wegmann

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