Towards an FDIR Software Fault Tree Library for Onboard Computers

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Outline

- FDIR Analysis with Fault Trees
- Problem Statement
- FDIR Software Fault Tree Library
- Dependability Quality Model
- Use Case: MMX
- Results
- Conclusion

Fault Detection, Isolation and Recovery

FDIR

Even well designed systems cannot avoid the existence of faults

- But not every fault is a **failure**
- FDIR tries to prevent faults from turning into failures

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Fault → Detection → (Isolation) → Recovery

Detection
- Fault detected?

(Isolation)
- Where?
- Why?

Recovery
- Can we recover?
- How?

High Performance On-Board Computers and FDIR

On-Board Computing in Space

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Need FDIR to provide stable operation

How to plan and assess the FDIR concept in the **design phase**?

Modeling the F in FDIR

Fault Model

Relationship between basic faults and how they lead to failures

- Failure Modes and Effects Analysis (FMECA)
- Reliability Block Diagrams
- Markov Modeling
- **Fault Tree Analysis (FTA)**
- ... and many more

Basics of Fault Trees

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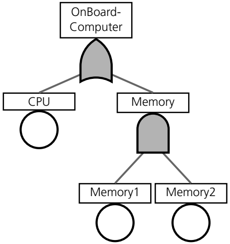

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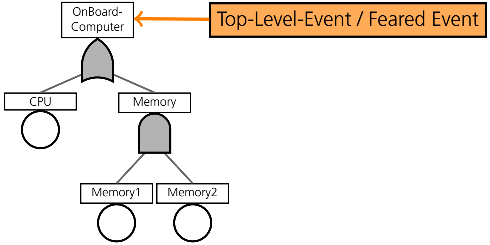

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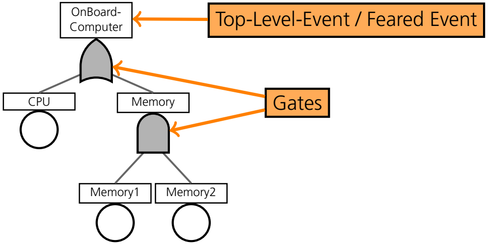

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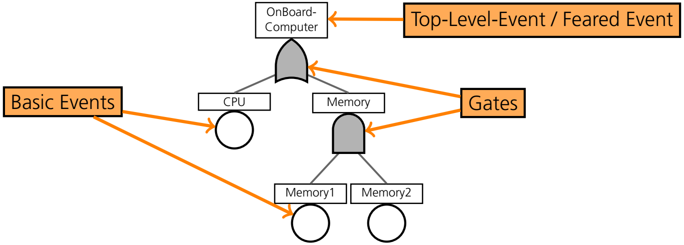

Fault Trees and RAMS

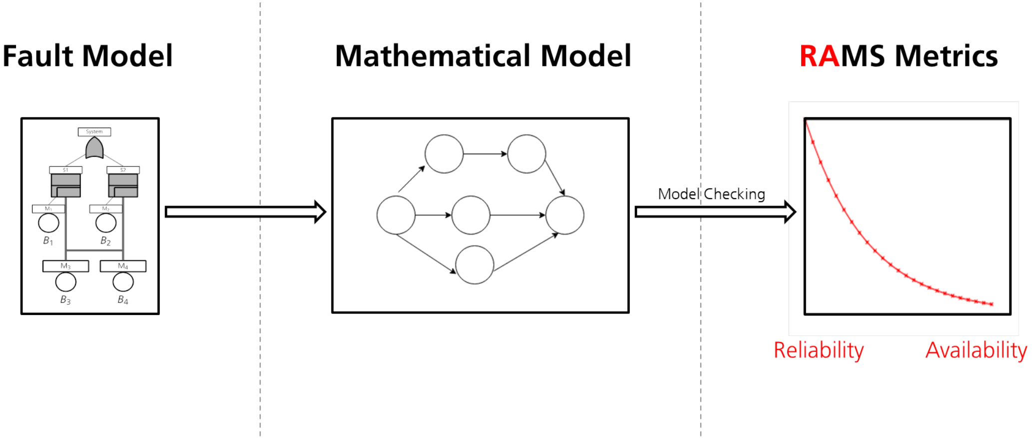

Figure: Fault Tree Evaluation

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Fault trees provide great analysis benefits but...

- also require a lot of modeling effort!
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Can we develop..

- a generic FDIR software library
- **generic fault tree models for FDIR Software library?**
- **a methodology to easily generate fault trees incorporating calls to the library?**

FDIR Software Library

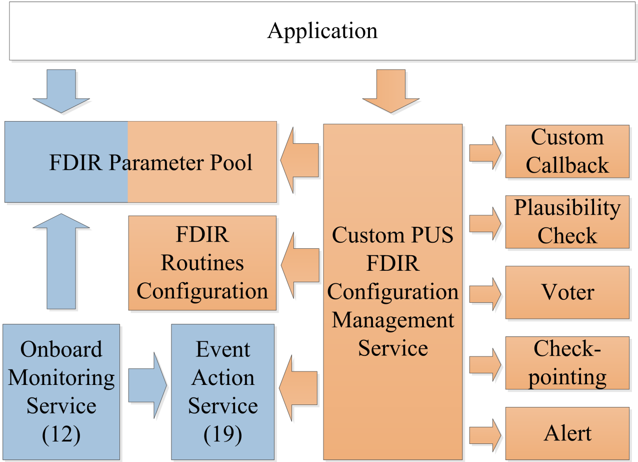


Figure: FDIR C++ Library Architecture

Fault Tree Generation

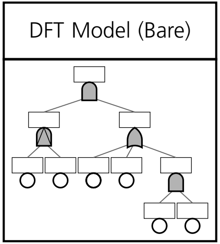
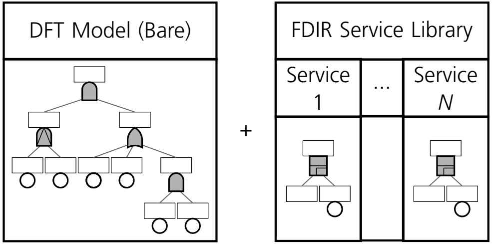


Figure: Generation process with DFT model and service library models.

Fault Tree Generation



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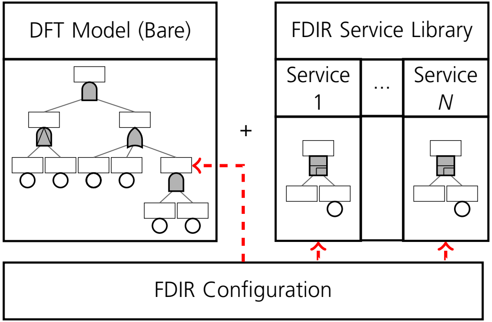

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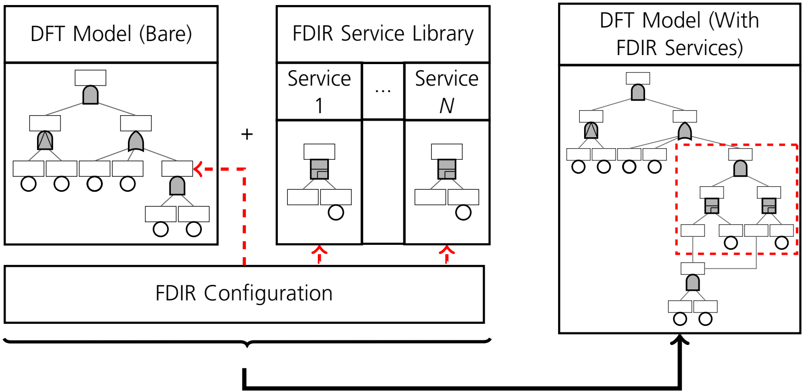

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Quality Model

Characteristic	Sub Characteristic	Metric	Threshold
Reliability	Reliability Evidence	Reliability after t	> 95% in 50 d
		Structural Coverage	100%*
Maintain-ability	Complexity	Cyclomatic Complexity	< 12*
	Modularity	Modular Coupling	< 4*
Availabilty	Availability Evidence	MTTF	> 50 d

Figure: Quality mode using factor-criteria-metric model (Based on ECSS)

Implementation - Virtual Satellite 4 FDIR

Virtual Satellite

- Model Based Systems Engineering tool
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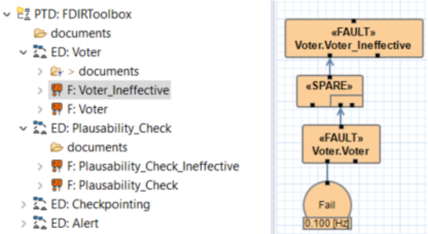

Figure: Excerpt of the library in VirSat

MMX

Mission

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- Carries rover exploration with various payloads
- Limited communication windows and delays: High degree of autonomy required
- Single OBC based on COTS components

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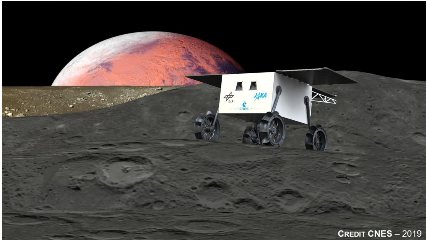

Figure: Artist impression of the MMX rover on Phobos (credit: CNES)

Services

Feared Events

- Loss of Position Service
- Loss of Obstacle Detection Service

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Applications

- **Rectification:** Reverses lens distortions
- **Depth Image Computation:** Computes disparity image and depth image
- **Visual Odometry:** Measures rover's egomotion
- **Obstacle Detection Algorithm:** Utilizes camera images and depth images to detects obstacles and terrain featuress

Basic Events

Main Events

- Short mission duration (50 days): Focus on short-term effects rather than long-term accumulation effects
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Main Hardware Components for Analysis

- Processing Logic (PL):
  - Sub-Components: BRAM, CRAM
  - SEE/day: 3.21
- Processing System (PL):
  - Sub-Components: OCM, D-CACHE, ALU, FPU, Peripheral
  - SEE/day: 8.22E-02

Bare Fault Tree Model

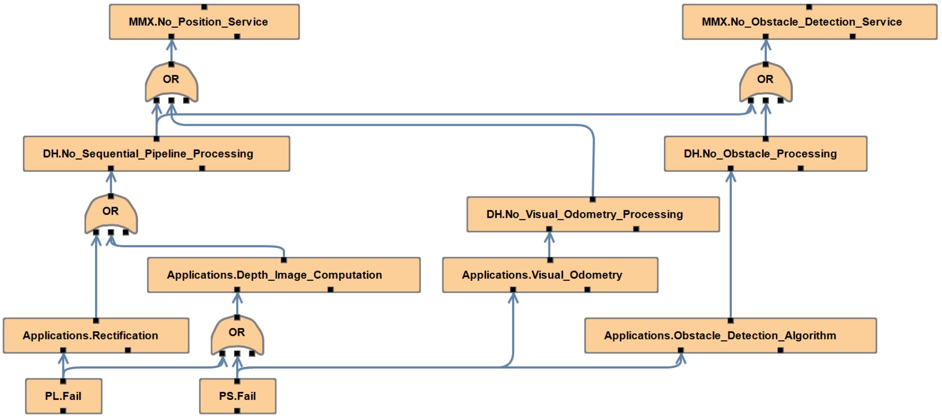

Figure: Bare fault tree model without FDIR

Summary of Evaluation Results

Experiment Setup

- Defined (sensible) configurations of increasing complexity
- FT size, configuration costs, MTTF, and reliability after 50 days

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Results

- Could answer the question if simpler configurations would suffice (sadly: No)
- Generated fault trees with ∼100 nodes
- Reduced modeling effort by 80% for most complex configuration

Conclusion

Recap

- Separated software fault model (Bare model) and mitigation fault models (Fault Tree Library)
- Reusable
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Towards the future

- Automatic optimization of configurations? Constraints defining what a "sensible" configuration is?
- Coupling with code generation

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Thank You!! Questions?