

Functional Monitoring & Diagnosis (FMD)

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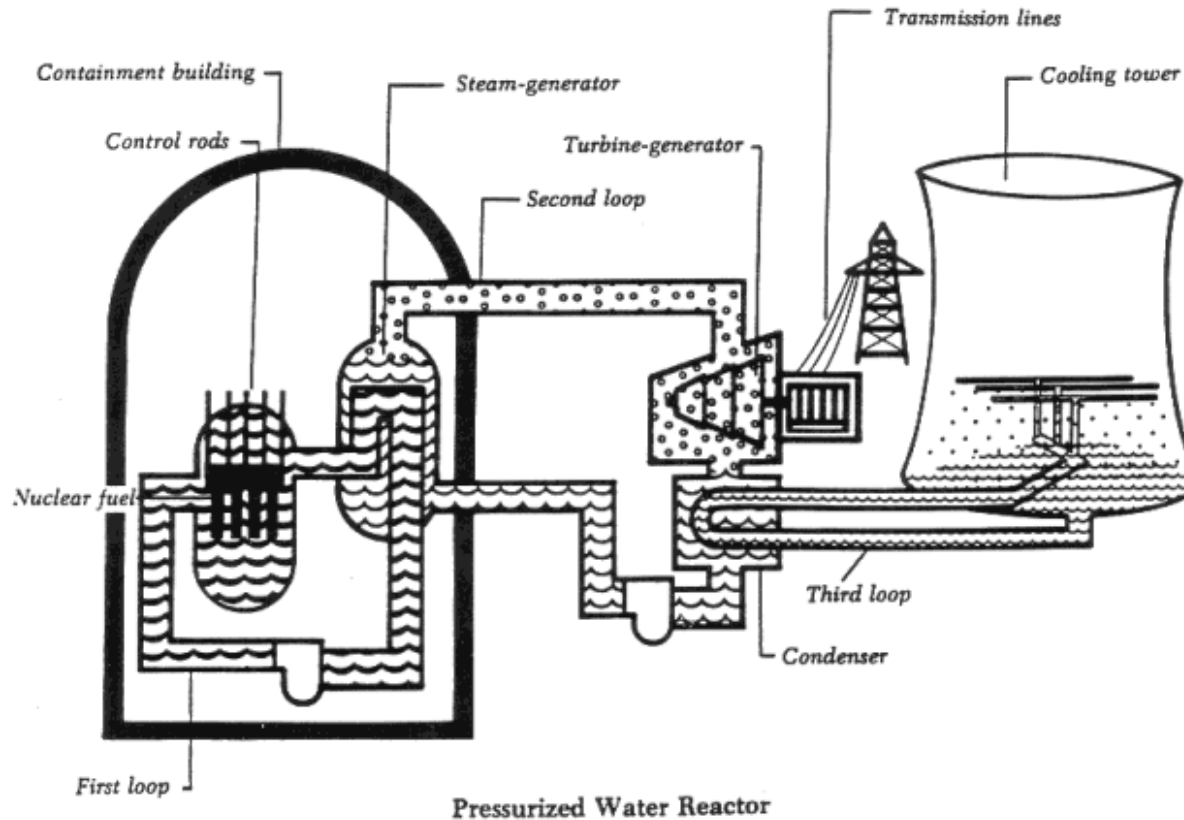
Requirement

- Current tools for Monitoring & Diagnosis have major limitations
 - Poor Effectiveness
 - False Positives
 - False Negatives
 - Tuning makes one better at the expense of the other
 - Poor Coverage
 - Detect anomalies
 - Diagnose/Isolate them correctly
 - Expensive
 - Not affordable to achieve high coverage
 - Not affordable to maintain as the monitored system evolves

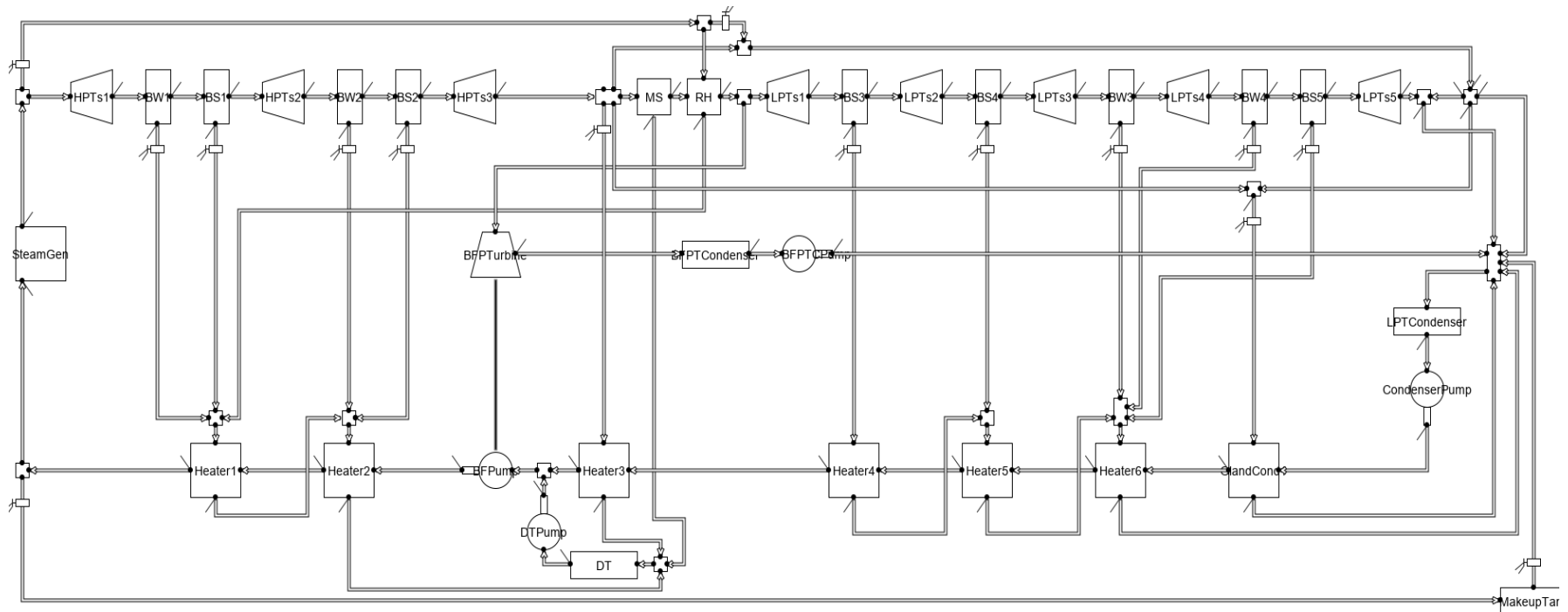
Strategy

- Empirical
 - EG Machine Learning, Neural Nets
 - Easily discovers patterns from data sets
 - But:
 - Many patterns are trivial
 - Most patterns are not predictive
 - Contact with the real world is always problematic
- Models
 - Non-trivial patterns that are testably predictive are called models
 - Desire to fully exploit the entire operational math model of the system
 - Highly scalable
 - Even as big as a nuclear power plant (1k-10k sensors)

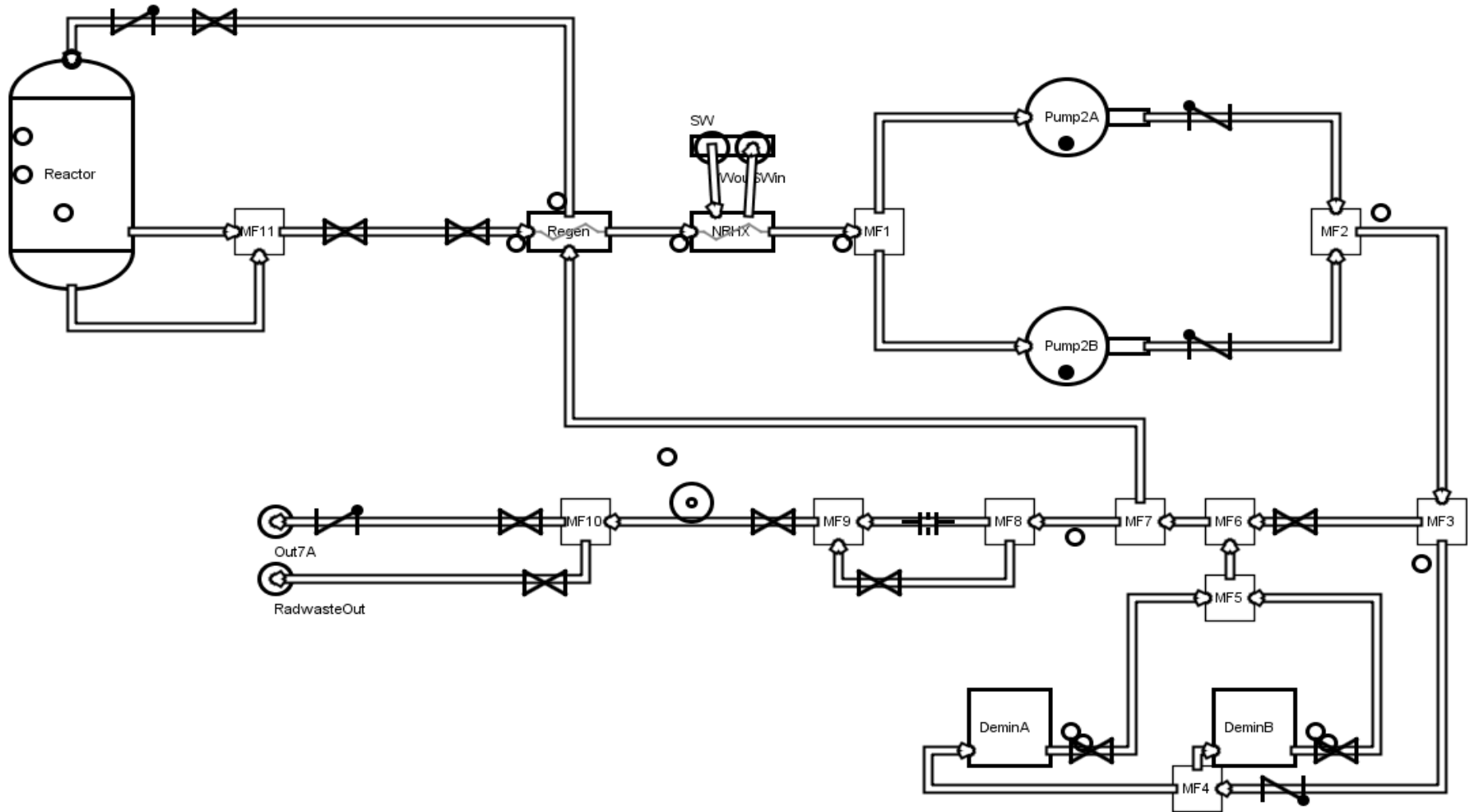
Nuclear Power Plant (Pressurized Water Reactor)



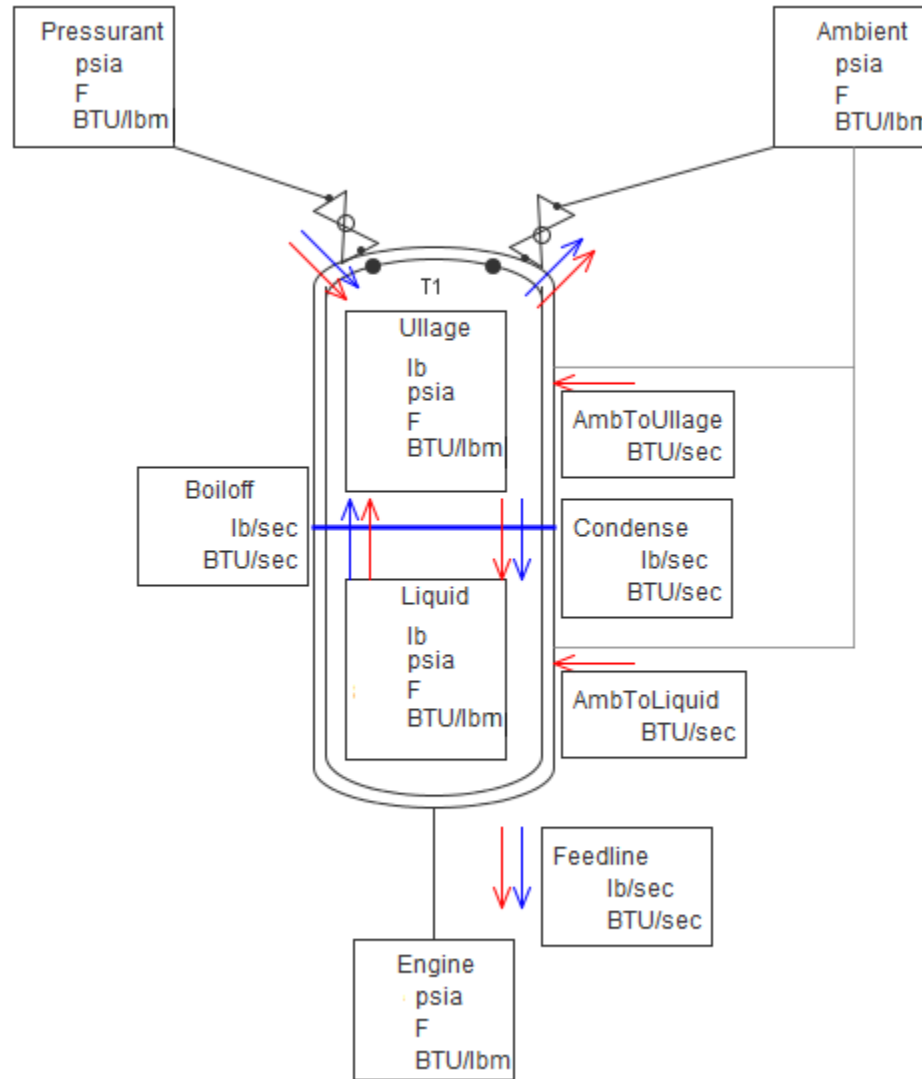
Nuclear Power Plant (PWR) – Balance of Plant (BoP)



Nuclear Power Plant (Pressurized Water Reactor) Reactor Water Cleanup System



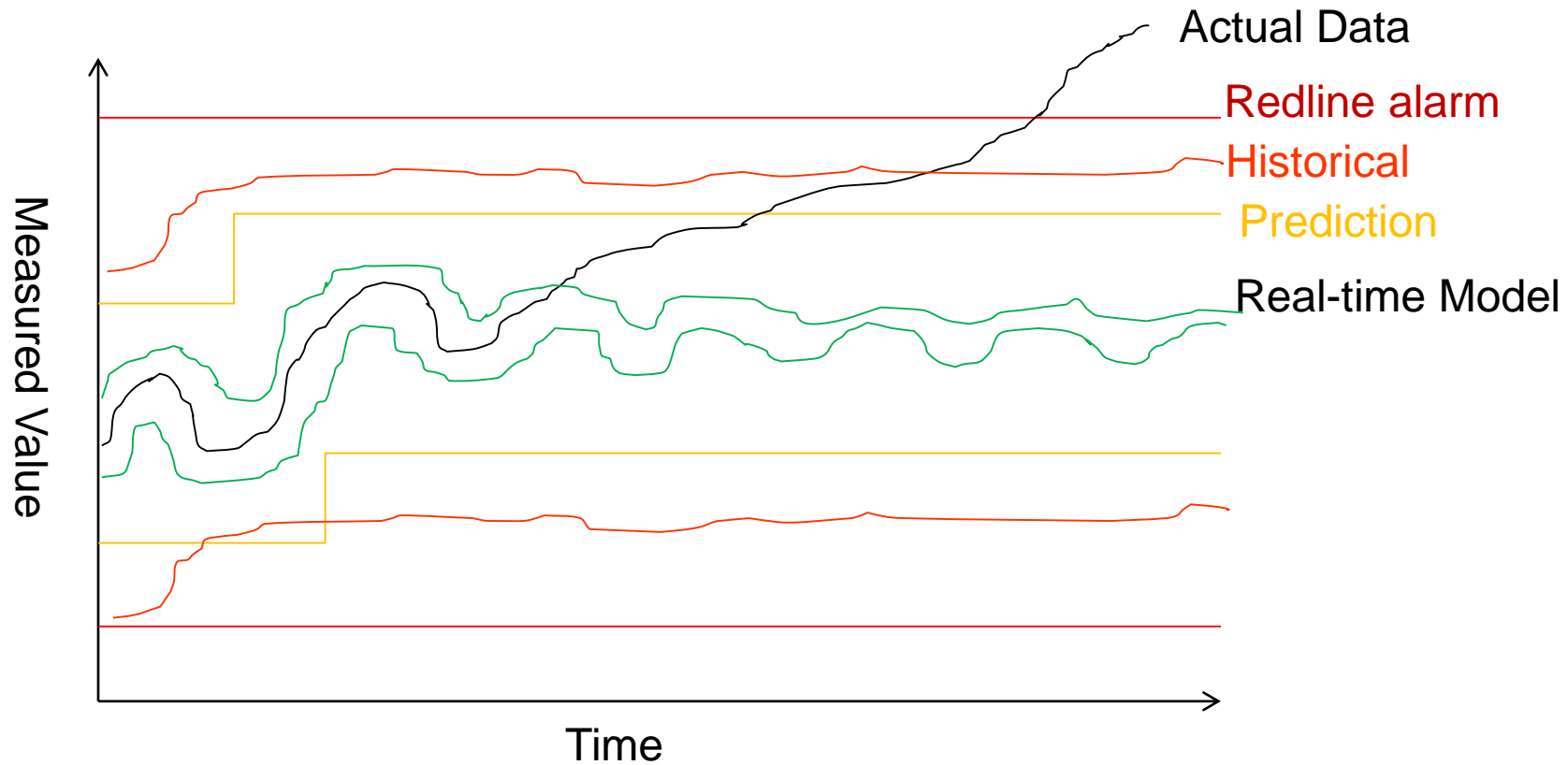
Rocket Engine Propellant



Benefits

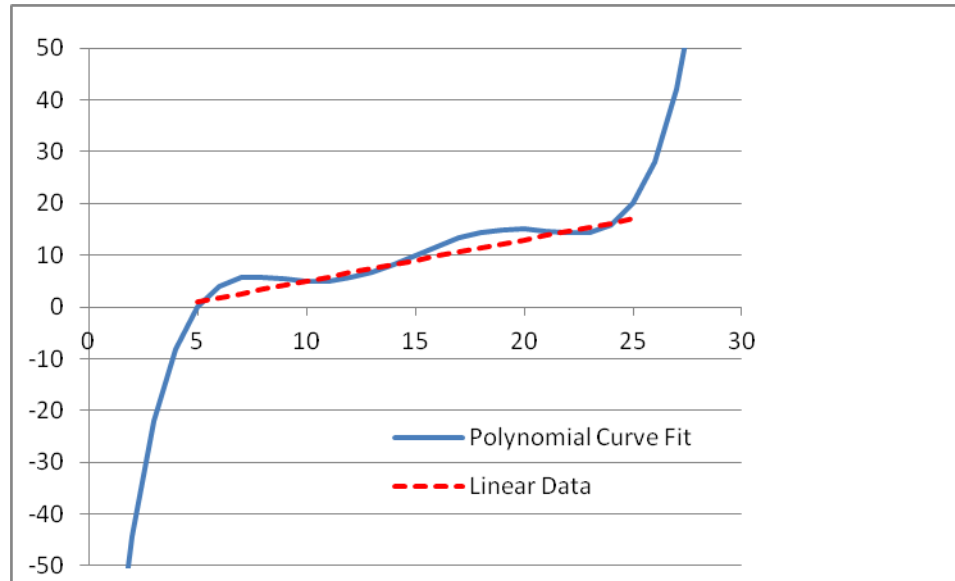
- Labor
 - Use existing process engineers
 - Not “AI experts”
 - Affordable to both set up & maintain as the target system evolves
- Effective
 - Minimize False Positives
 - Minimize False Negatives
 - Diagnostic limitations
 - Typically result from the limitations of the sensor suite
 - Not the software or the model

Real-time Detection of Failure



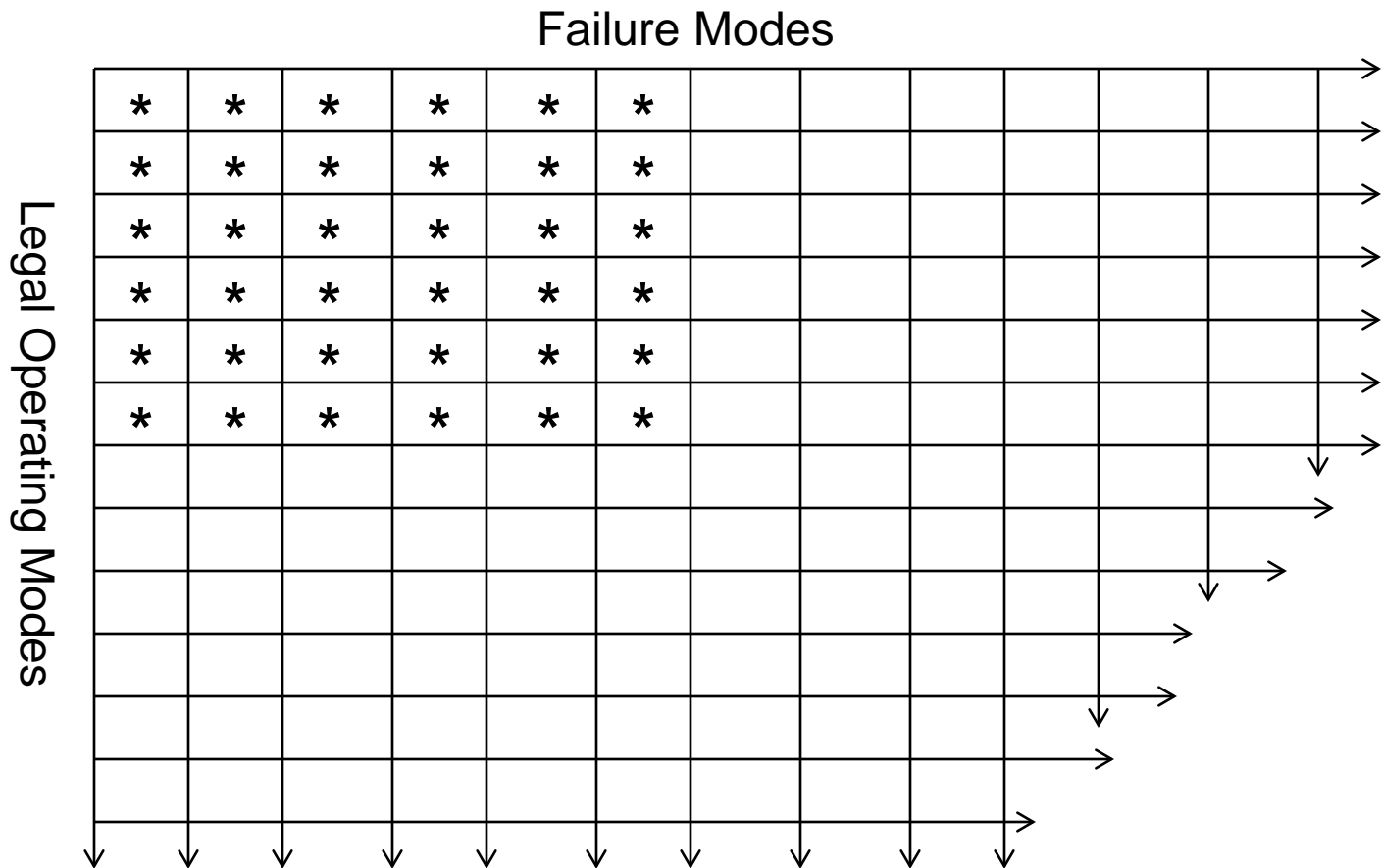
- Using an operating model enables detecting failures earlier than they might otherwise be detected, affording more time to manage them

Existing Technologies: Empirical



- Goodness of Fit (Overfitting)
 - Curve-fitting tools are notorious for fitting high-order polynomials to low-order phenomenon, such as for log and square-root functions, or even just simple linear equations that are slightly obscured by noise.
 - While by adding enough high-order terms, there can eventually be a fit, to some criteria, within the data domain of the exemplars, but as soon as the equations are used outside the range of the training exemplars the fit can be extremely bad

Combinatorial Space of Symptoms



* Defined symptom-fault relation

Technicians & Engineers

- The empirical techniques are comparable to using technicians to diagnose equipment
 - Most all the time the technician immediately knows what is wrong – because he has seen it before in actual practice or in training
 - The balance of the time the technician struggles because he doesn't know how to diagnose from first principles
- An engineer can diagnose anything if he has a schematic and some time
 - He is well-versed in the first principles and in reasoning about models
- The downside to using engineers is that they must be kept on call and they do require some time to think about the problem
- FMD software performs essentially the same analysis that an engineer would perform
 - But it is practical to keep the FMD software online 24/7
 - It is able to perform the analysis in less than a second

Technique Summary

	Handcode	Empirical	Models
Availability of	Expert/Model	Data	Model
Goodness of Fit	Varies	Overfit	As good as it gets
Combinatorics	Limited	Limited	Virtually unlimited
Reliability	Good	Limited	Best
Range of Scenarios	Considered scenarios	Scenarios in exemplar set	Limited only by # of elements in Model