A Quick Overview of GTST Functional Modeling

Seminar Presentation at the Technical University of Denmark, DTU

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College Park, MD, 20742, USA

About CRR

Our Mission

Our mission is to advance reliability and risk analysis for complex engineering systems through innovative research, education, and collaboration with industry partners.

Our Approach

We research why systems fail, how they fail, when they fail, how to prevent failure, and how to mitigate consequences.
We educate through coursework, research, and stakeholder engagement. We engineer solutions.

Our Impact

We prevent losses and protect life, property, and the environment. Our work improves systems and processes in energy, transportation, defense, space, information systems, and civil infrastructures.

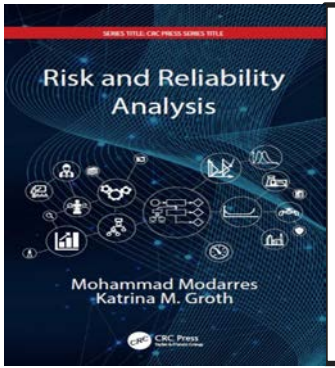
Facts About CRR

20+
Core, Affiliate, and Adjunct Faculty

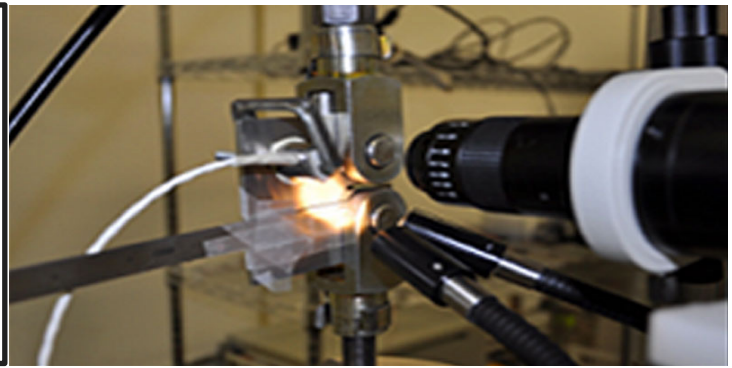
6
Cutting-Edge Research Laboratories

4
Degrees Offered (Certificate, MS, M.Eng, Ph.D.)

500+
Graduates since 1991



- SyRRA (Systems Risk and Reliability Analysis) Lab
- Probabilistic Physics of Failure and Fracture
- Cybersecurity Quantification Lab
- Hybrid Systems Integration and Simulation
- Design Decision Support Lab
- Laboratory for Reliable Nanoelectronics



The **#5** Reliability and Quality Engineering in the World
(source: EduRank.org, May 2023 rankings)

#1 Reliability Engineering degree program in the U.S.,

#2 internationally (Microsoft Academic Rankings, 2020)

Educational Programs

M.S. Reliability Engineering

Thesis and Non-thesis Research

Ph.D. in Reliability Engineering

A snippet of Courses Offered:

1 Reliability Engineering Fundamentals

The course introduces students to the fundamental concepts and methods used in reliability data analysis and engineering, including reliability modelling, probability theory, and statistical analysis

2 Design for Reliability

Students learn how to design systems that are reliable, maintainable, and cost-effective over the entire product lifecycle.

3 Probabilistic Risk Assessment

The course covers methods for risk scenario development, simulation approaches, risk model integration and quantification etc. to identify and assess potential risks in complex systems and develop effective mitigation and maintenance plans.

4 Advanced Research in Reliability Engineering

Students explore the latest research and developments in the field of reliability engineering and engage in hands-on projects to apply these concepts in real-world scenarios.

*All annual courses are available on campus and online

Our alumni are making impact

CENTER FOR RISK AND RELIABILITY

Government

U.S. FOOD & DRUG ADMINISTRATION

U.S.NRC

Australian Government Defence

Office of Naval Research ONR Science & Technology

DEPARTMENT OF DEFENSE

NAVAL AIR SYSTEMS COMMAND

NASA

NIH National Institutes of Health

Industry & Tech

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JOHNS HOPKINS APPLIED PHYSICS LABORATORY

COLORADO STATE UNIVERSITY

RUTGERS

UNIVERSITY OF MARYLAND

UCLA

CHINA UNIVERSITY OF PETROLEUM

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Research sponsors

The Impetus for My Work on Functional Modeling: GTST Modeling

- U.S. Department of Energy funded a comprehensive study (Post TMI Accident) on an Integrated Model of Safe, Reliable, and Economic Nuclear Power during 1983-1986.
- There was concern over nuclear workforce depletion and retirement and how to capture and model nuclear plant and use it for knowledge management
- Functional Modeling was proposed and determined as the ideal framework to model nuclear plant knowledge
- The Concept of Goal Tree- Success Tree (GTST) was introduced in 1984
- The Success tree part was later extended to Master Plant Logic Diagram (MPLD) model

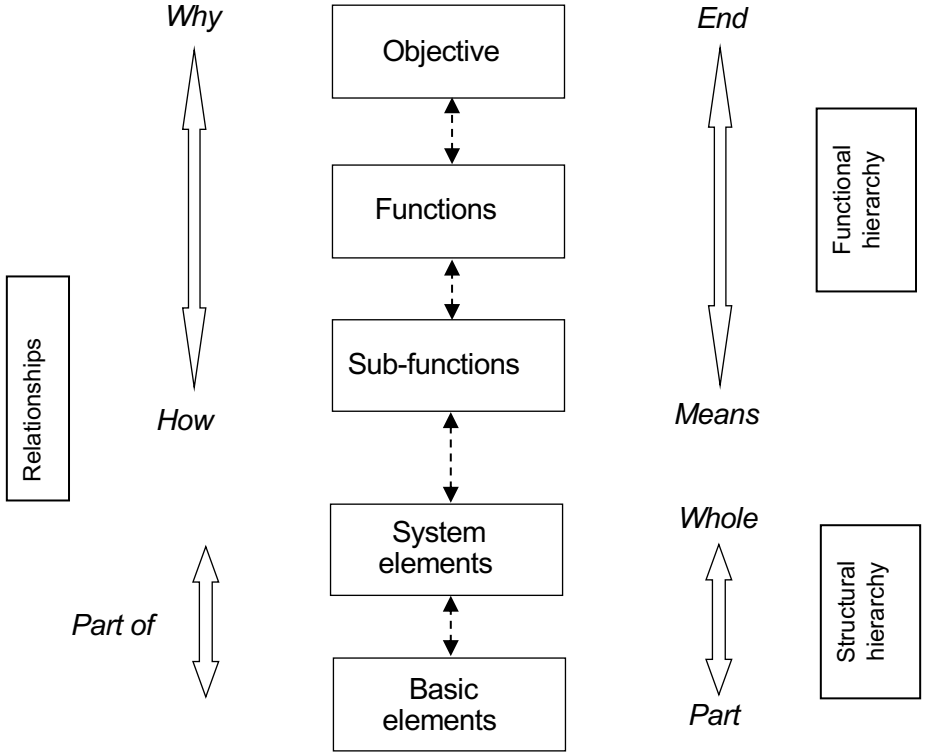
Integrated Economic Risk Management in a Nuclear Power Plant Hardware Protection, Hunt & Modarres, October 1984, DOI:10.1007/978-1-4684-5317-1_34
Conference: 1984 Annual Meeting of Society for Risk Analysis

A Conceptual Goal Tree- Success Tree Diagram

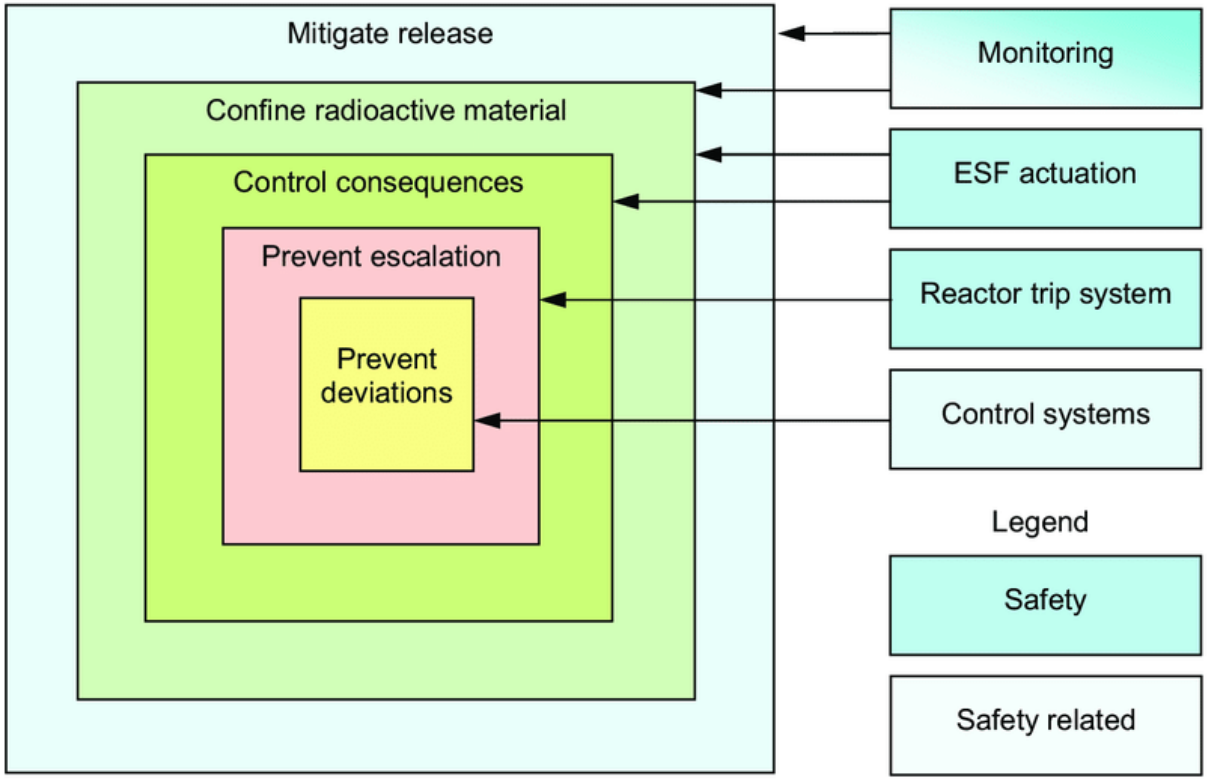
GTST meant to model extremely large systems

These systems are:

- Evolving
- Integrated (Nonlinear and tightly and diversly coupled)
- Dynamic
- Large Scale (over space and time)

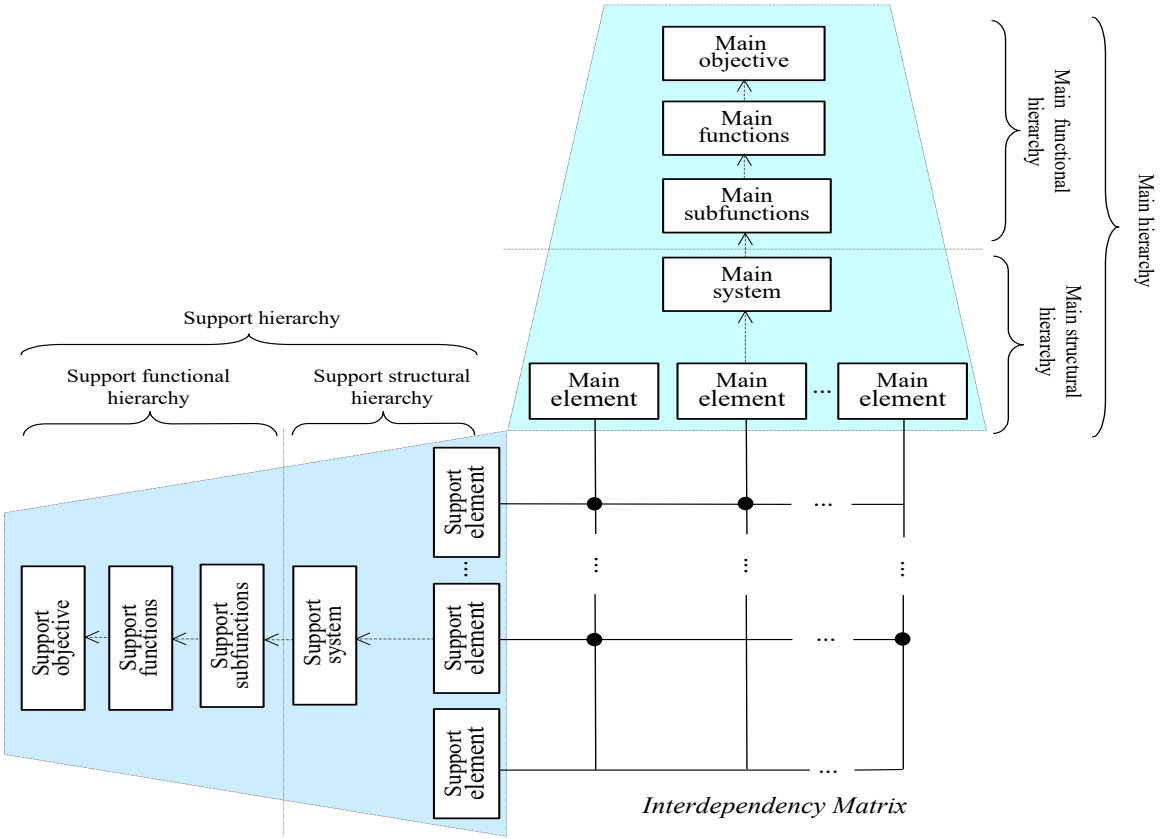


Application of GTST to Nuclear Plants

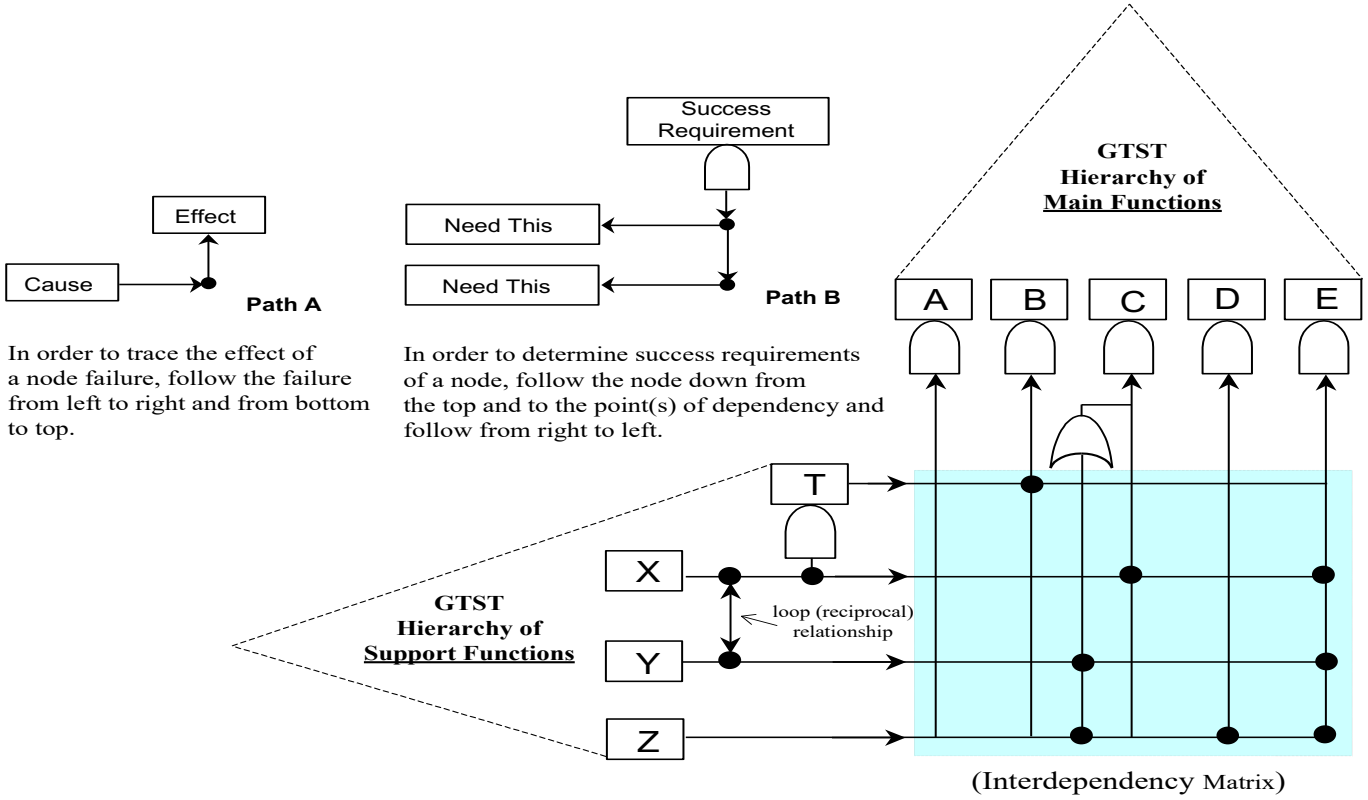


Source: Core Knowledge on Instrumentation and Control Systems in Nuclear Power Plants, Altkind, et al., IAEA Nuclear Energy Series, No. NP-T-3.12, Jan 2011,

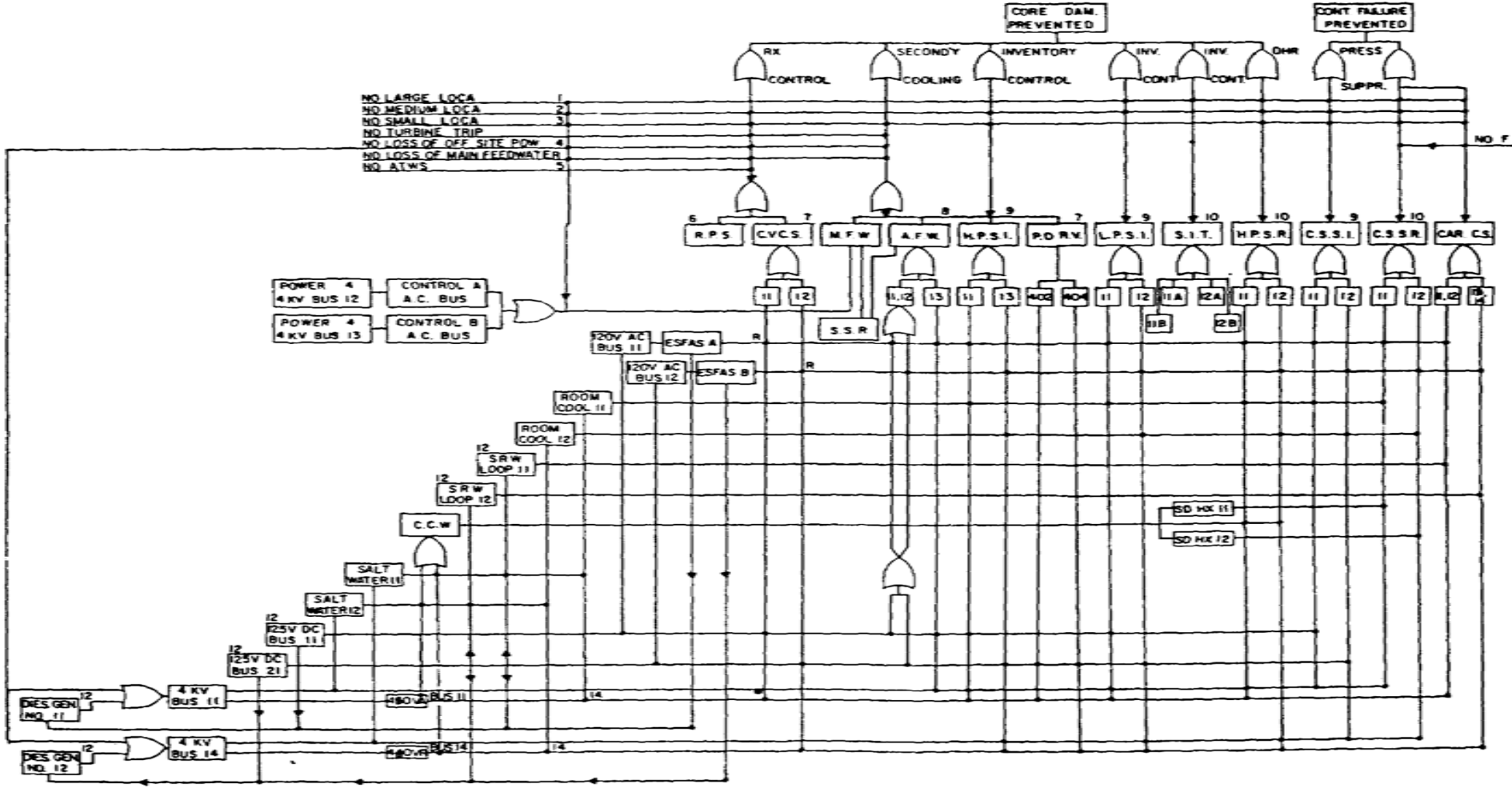
Extending Success Tree: The Master Plant Logic Diagram (MPLD) and GT-MPLD



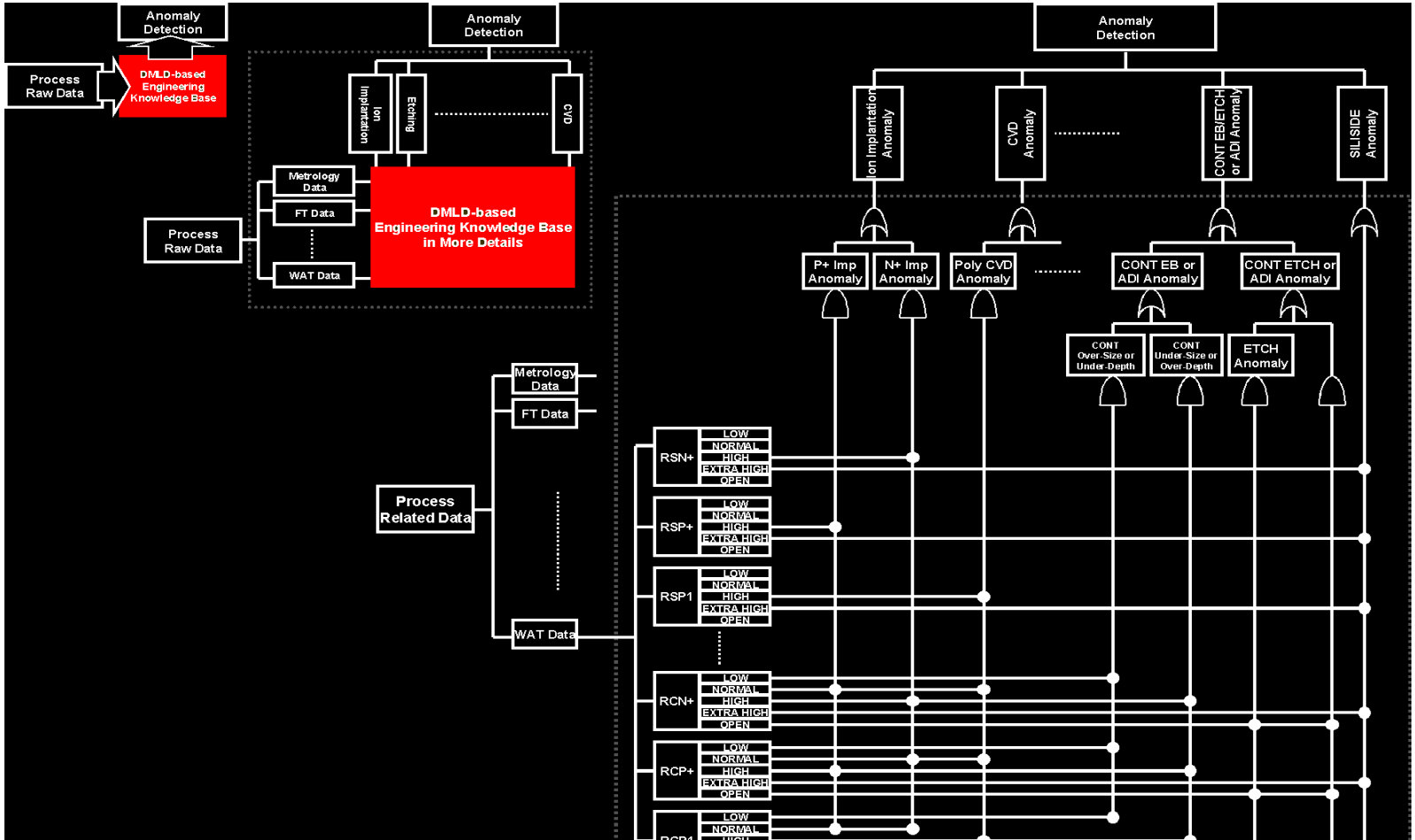
USE of GTST-MPLD as a Searchable Knowledge Base



Full Scale Simplified MPLD of a PWR Nuclear Plant

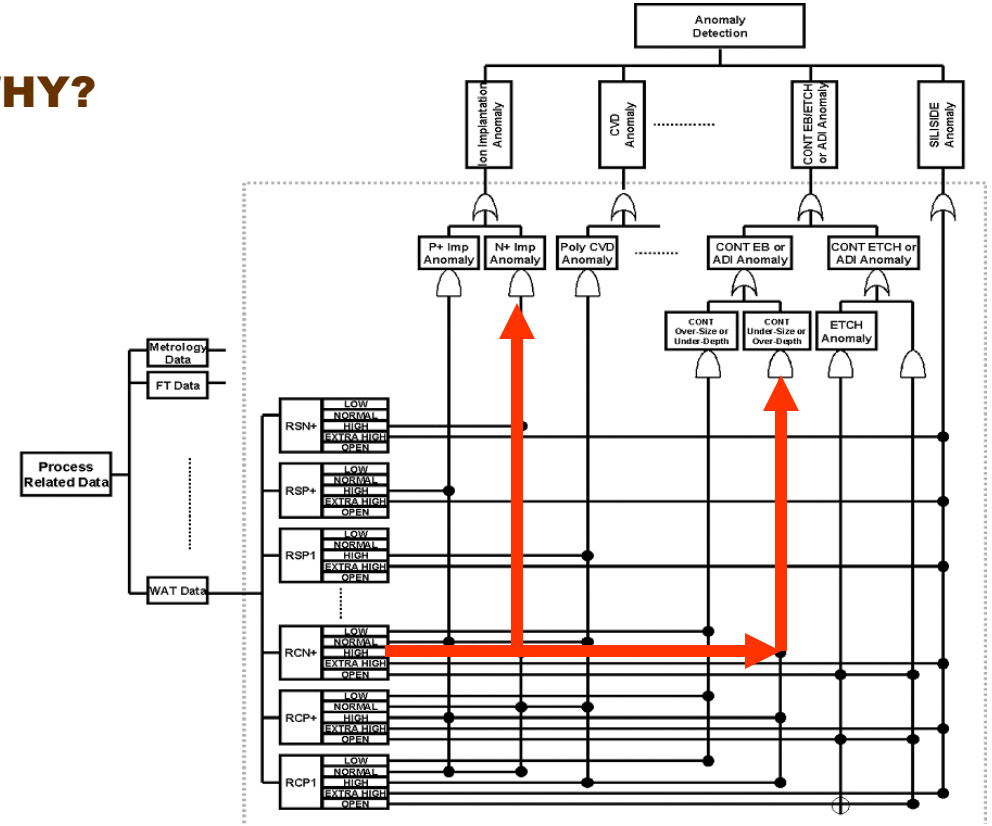


GTST-DMLD Applications to Many Other Systems



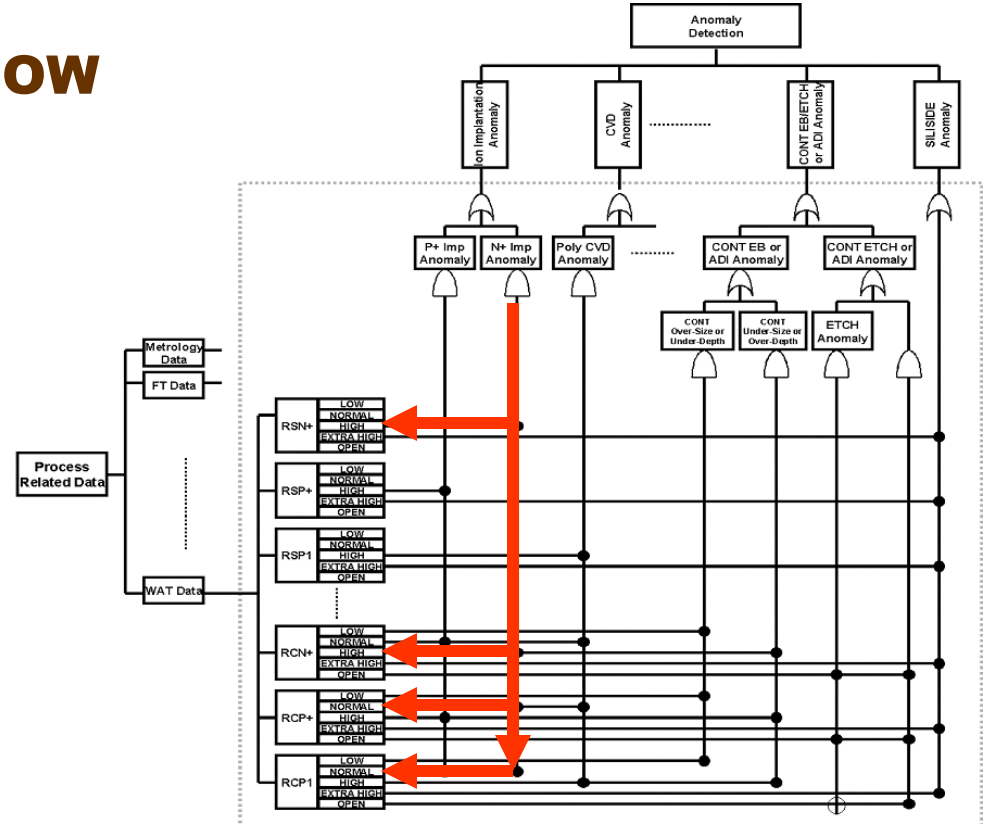
USE of GTST-MPLD as a Searchable Knowledge Base (Cont.)

WHY?

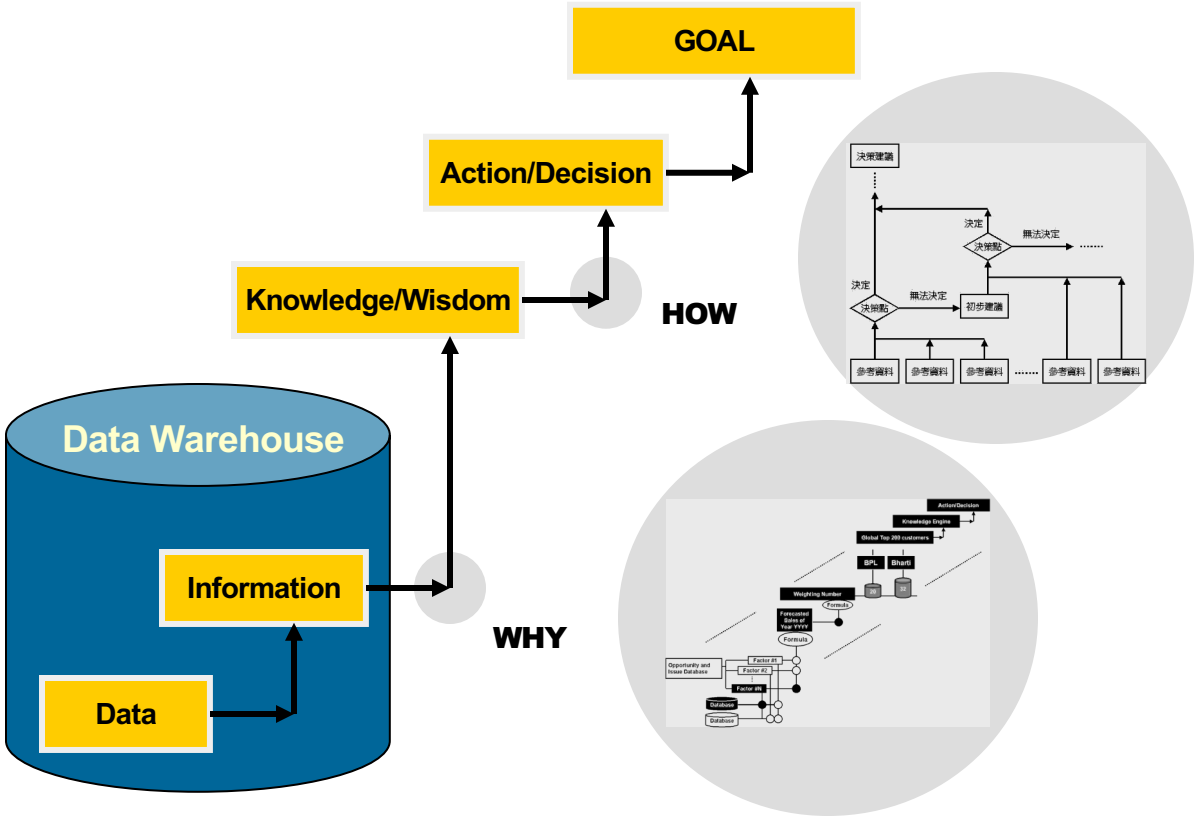


USE of GTST-MPLD as a Searchable Knowledge Base (Cont.)

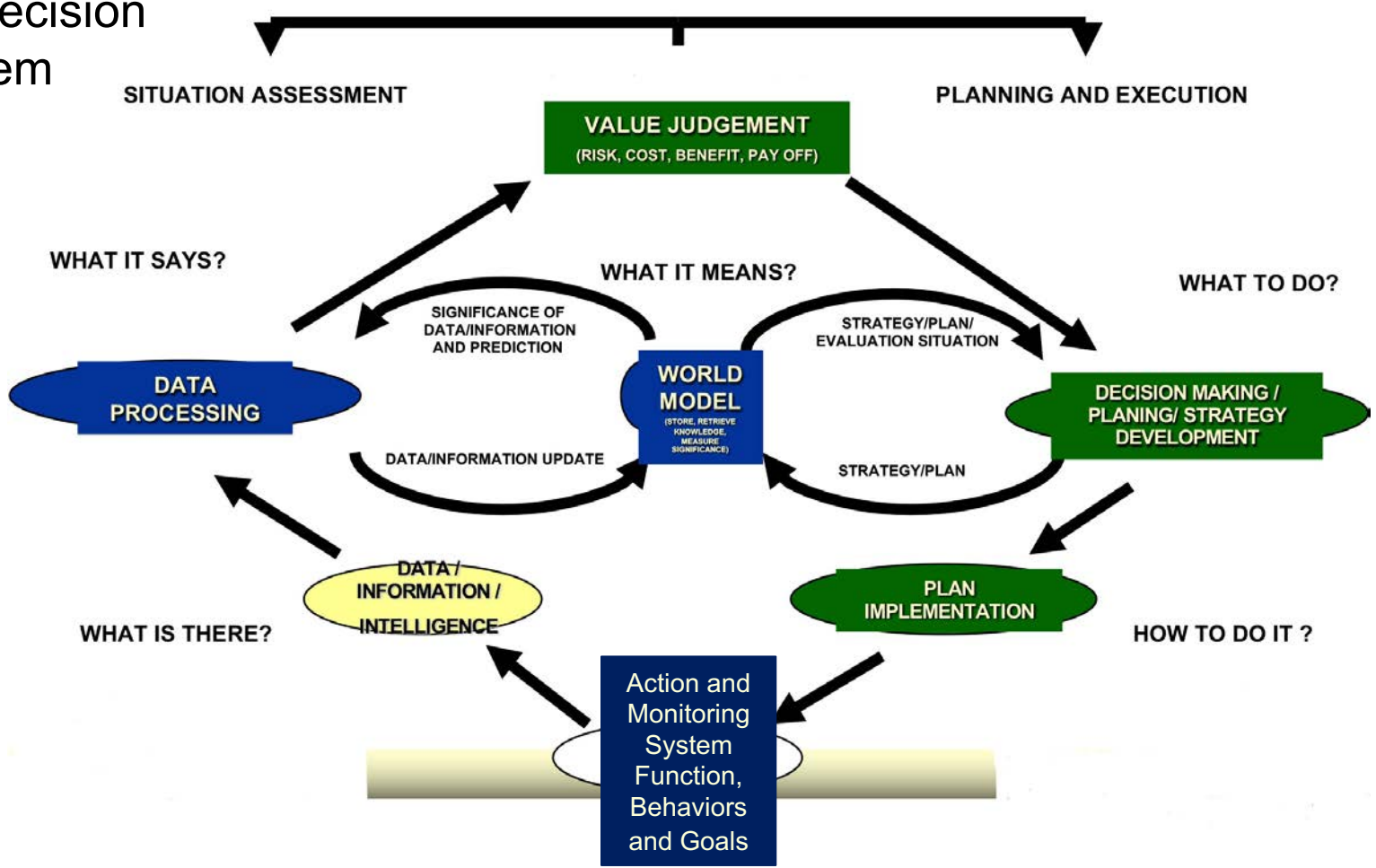
HOW



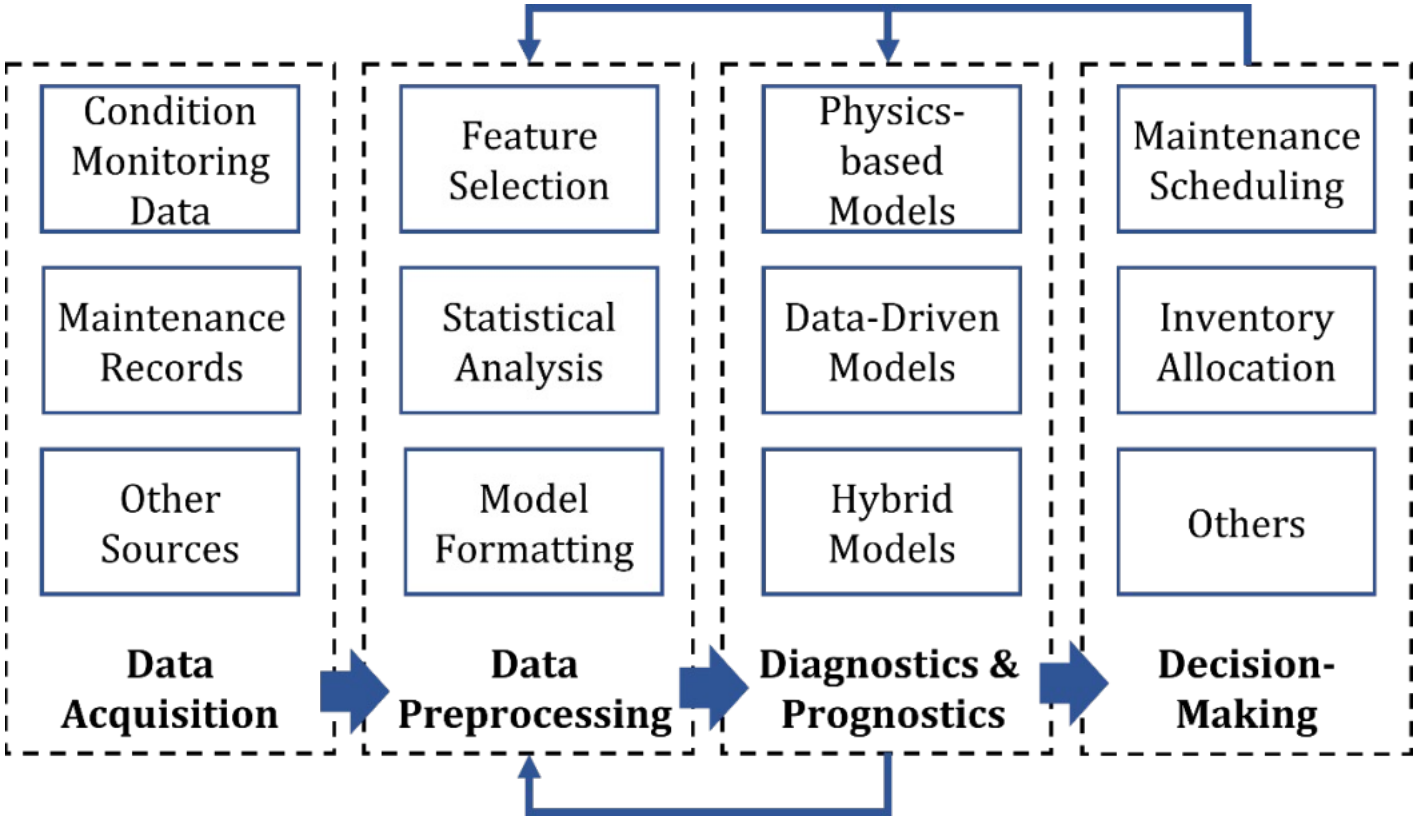
More Recent Work Connects GTST-MPLD (more recently GTST-DMLD) to Intelligent ML Applications



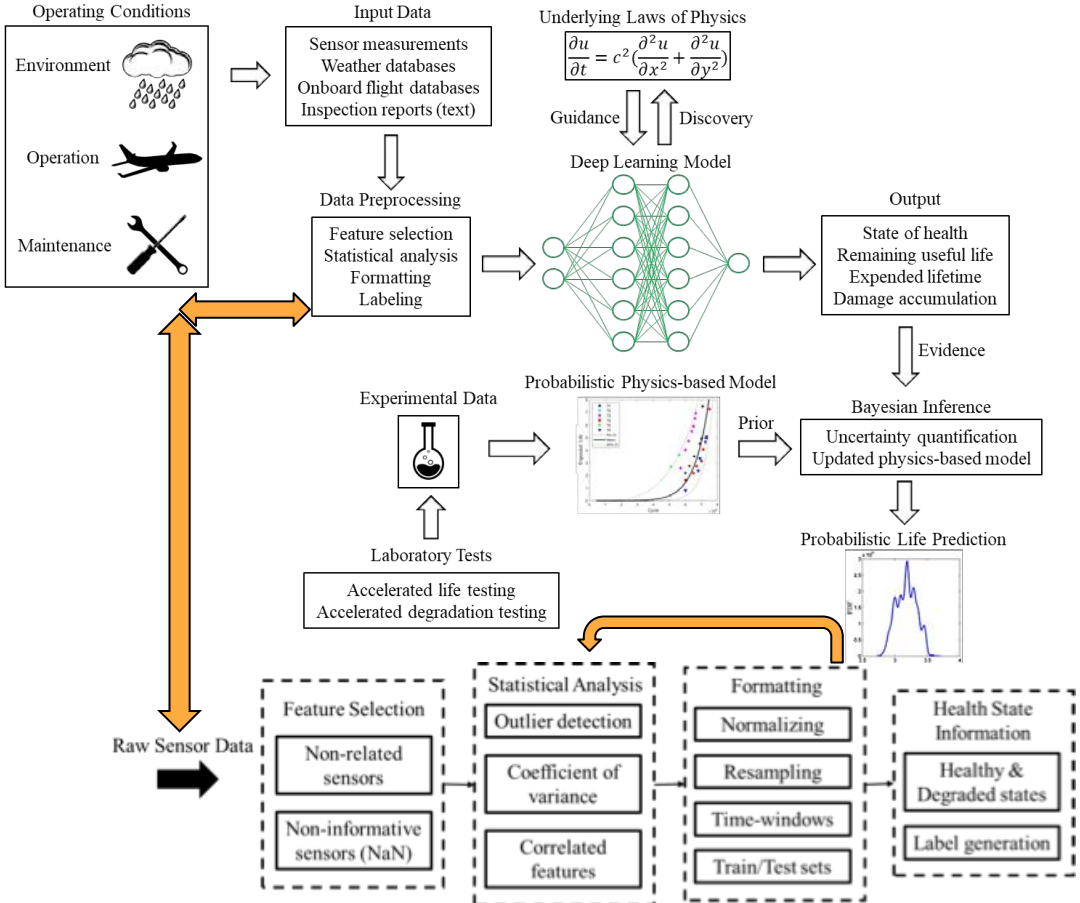
GTST As a Decision Support System



Our Recent Work on Data Processing for GTST ML-Based Decision Making

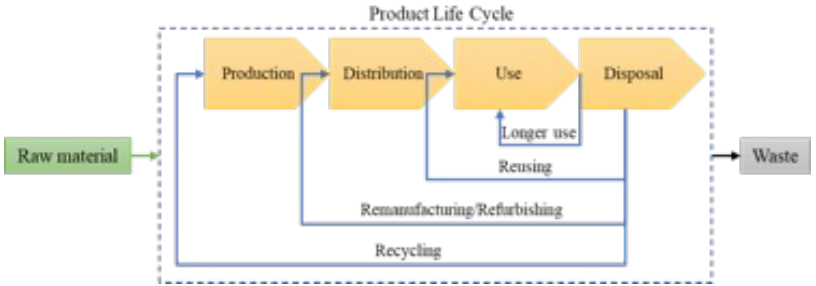


Hybrid Deep-Learning Physics Discovery & Physics of Failure Model



Application of GTST to Climate Change and Decarbonizing Human Activities

- Reduce/control Human-Induced climate change Rate
  - Minimize Production of human-made greenhouse gases
    - HFC
    - PFC
    - SF_6
  - Minimize Production of Nitrous Oxides (N_2O)
    - Organic Fertilizers
    - Fossil Fuel Combustion
    - Nitic-Acid (HNO_3) Production
    - Biomass Burning
  - Minimize Release of the Methane gas (CH_4)
    - Cattle Farming
    - Landfill waste
    - Rice Farming
    - Fossil Fuel Production
  - Maximize Absorption of CO_2
    - Avoid Deforestation
    - Minimize CO_2 capture
    - Minimize Land use changes
    - Maintain conditions for ocean floor of CO_2 absorption
  - Minimize Generation of CO_2
    - Minimize Burning Fossil Fuel
      - Energy (Electricity Production)
      - Transportation
      - Space Heat/cooling
    - Industrial Processes
      - Cement Production
    - Human Consumed Products
      - Product A
        - Reduce use of raw materials
      - Product B
        - Reduce generation of waste
      - Minimize consumption of e-products
        - Reduce use of Raw materials in electronic products
        - Reduce Generation of e-waste



Circular economy and the concept of Product Durability

A Functional Description of Product Durability

Goal: Offer promise of Life

Function: Prevent/Predict/Minimize/Assure Product Failure

- Minimize degradation
- Minimize performance reduction
- Maximize endurance to over-stress
- Maximize warranty

Goal: Offer assurance of readiness to work

Function: Maximize product availability and capability

- Assure ease of repair
- Assure ease of maintenance
- Maximize ability to upgrade

Conclusions

- Functional modeling stands on a strong philosophical foundation
- Functional Modeling has served well and can naturally work with modern ML approached for decision making
- The full potential of the FM concepts are yet to be realized
- Collaboration and exchange of ideas will be critical for further expansion of FM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ngiyabonga
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спасибо
dank je
thank you
gracias
tapadh leat
hvala
mauruuru
bedankt
mochchakkeram
dziękuję
go raibh maith agat
sagolun
sukriya
kop khun krap
obrigado
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