A Hybrid Technique for Organizational Safety Risk Analysis

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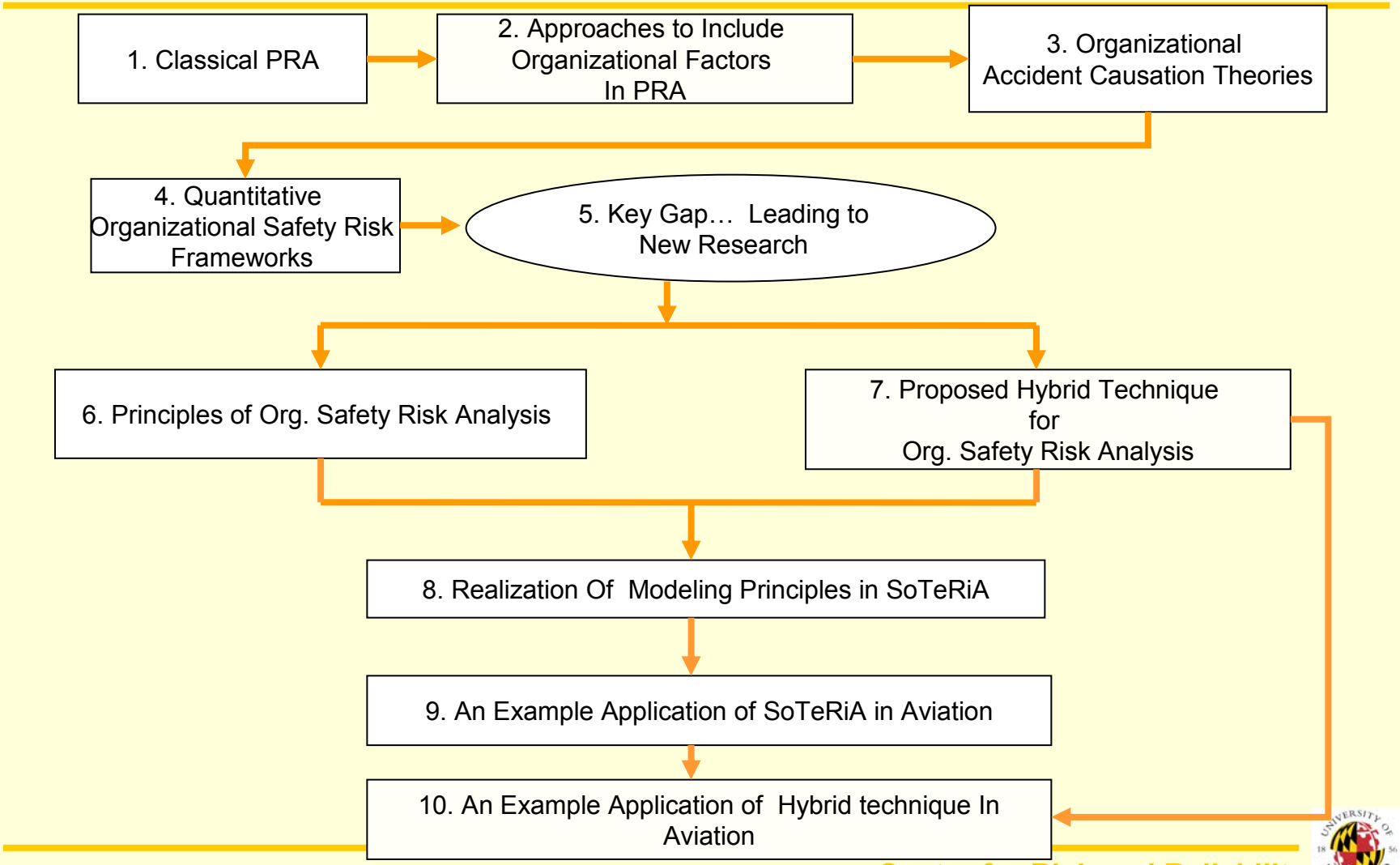
Motivation

- Major system failures with significant contributions from human & organizational factors
  - Chernobyl
  - Columbia and Challenger space shuttle accidents
- In the quest to achieve 80% reduction in aviation accidents, US FAA has recognized "organizational factors" as one of the most critical components

Key Questions

- What are the organizational “factors” that affect system risk?
- How?
- To what degree?

The Research Approach



Quantitative Approaches

- Static : Variations of Influence Diagrams (e. g., BBN), Process Models and Logic Models
  - MACHINE (Embrey, 1992)
  - SAM (Pate-Cornell, 1996)
  - Omega Factor Model (Mosleh & Golfeiz, 1999),
  - ASRM (Luxhoj, 2004)
  - "Causal Modeling of Air Safety" (Roelen et al., 2003)
- Dynamic: e.g, use of "System Dynamics"
  - Mousang (2004)

Key Gap

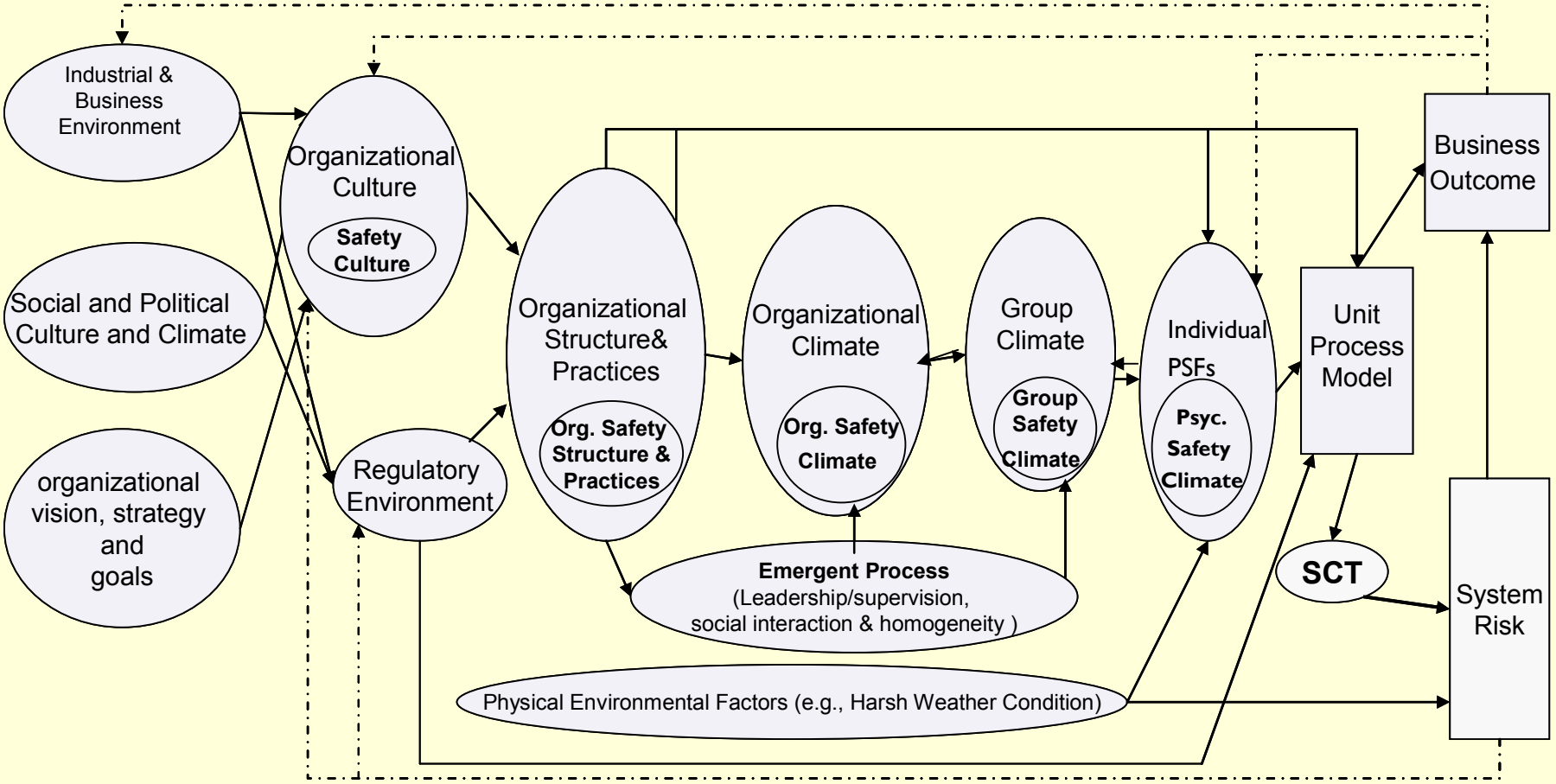
- In the absence of a comprehensive theory, or at least a set of principles rooted in theory, all models look equally good, or equally poor, with very little basis to discriminate, and build confidence.

- This research focused on improving the theoretical understanding of relation between characteristics of organizations and their (system) safety outputs

Modeling Principles

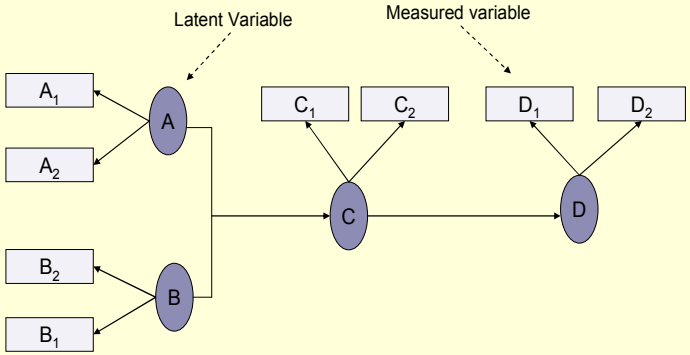
Problem Definition, Metrics & Scope	*(A) Defining the Unknown of Interest* *(B) Safety & other Org. Performance* *(C) Safety Performance & Deviation*
Level of Analysis	*(D) Multilevel framing*
Factors / Elements	*(E) Basic building block* *(F) Factor Level* *(G) Factor Selection* *(H) Measurement methods* *(I) Role of Perception* *(J) Factor Interdependencies* *(K) Multidimensional measurement perspective*
Relations	• *Multidimensional links* • *Dynamic characteristics*
Boundaries & Assumptions	*(N) Depth of causality and level of detail* *(O) Generalizablity*
Characteristics	

SoTeRiA (Socio-Technical Risk Analysis)

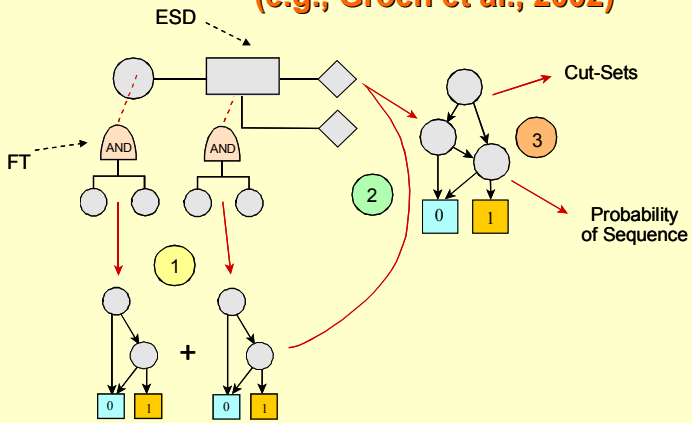


Menu of Modeling Techniques

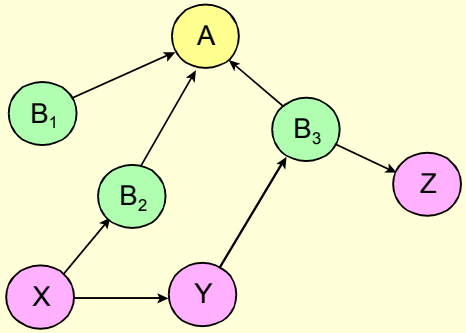
Regression-based Causal Modeling
(e.g., Bollen, 1989)



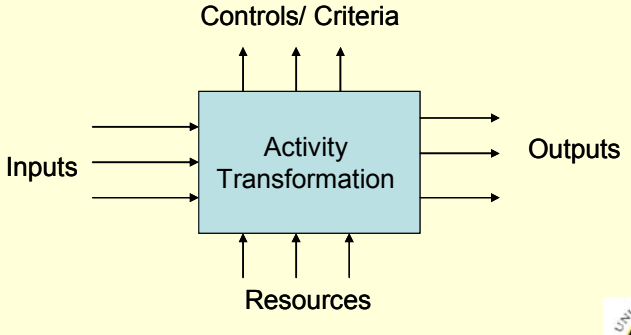
Techniques for Technical System
(e.g., Groen et al., 2002)



Bayesian Belief Network(BBN)

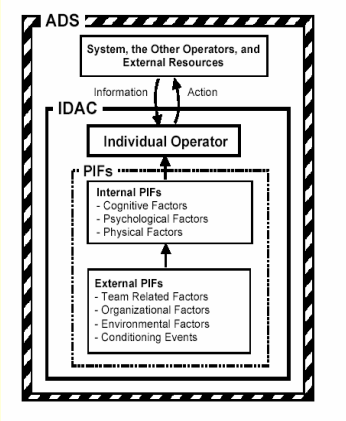


Process Modeling Techniques
(e.g., Heins, 1993)



Menu of Modeling Techniques

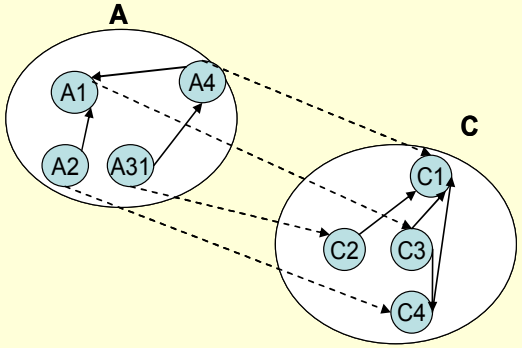
Human Reliability Techniques (e.g., Chang & Mosleh , 2004)



- ***THERP***
- ***IDAC***
- ***NARA***

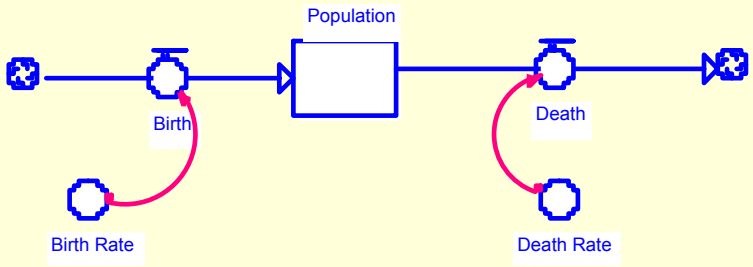
***Configurational* approach**

(e.g. Meyer et al., 1993)



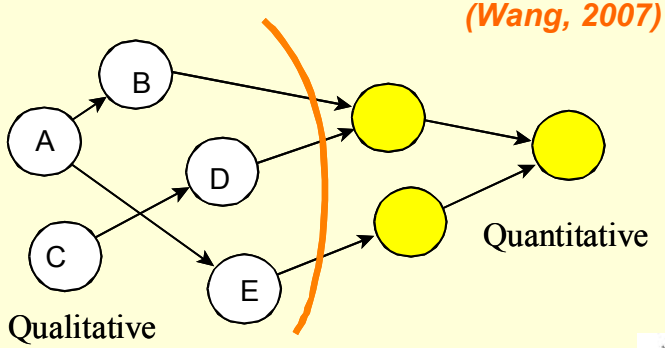
System Dynamics

(e.g. Sterman, 2000)



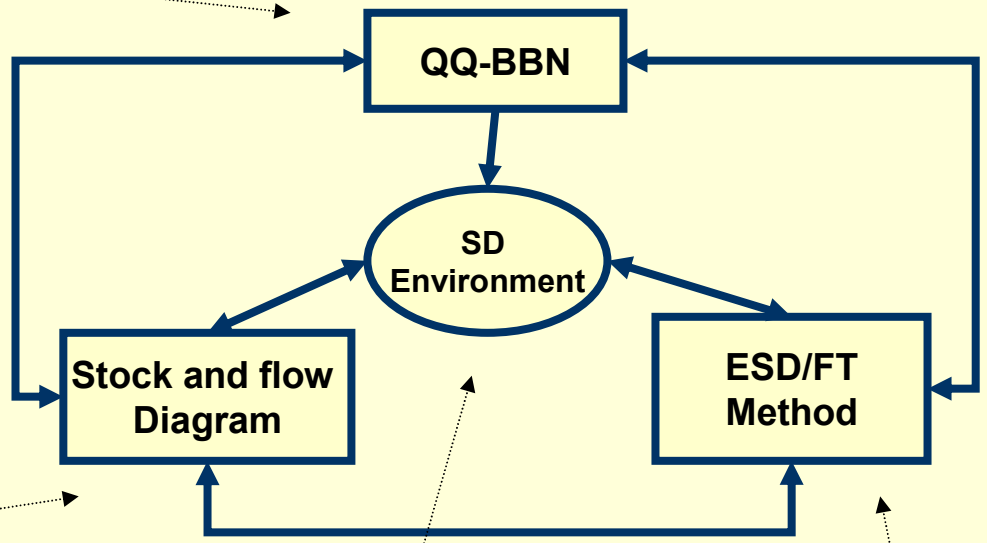
QQ-BBN

(Wang, 2007)



Hybrid Technique for Organizational Safety Risk

- *process modeling*
- regression-based models
- *configurational* characteristics
- human model



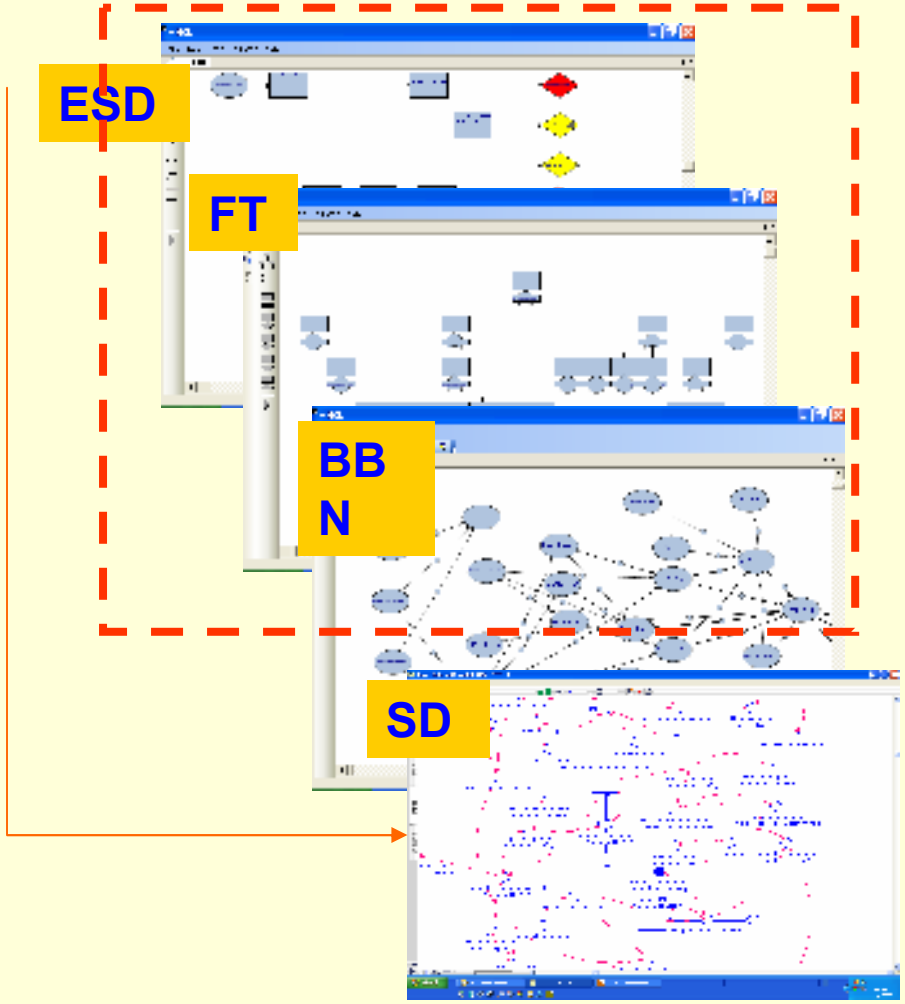
HCL (Mosleh et al. , 2005)

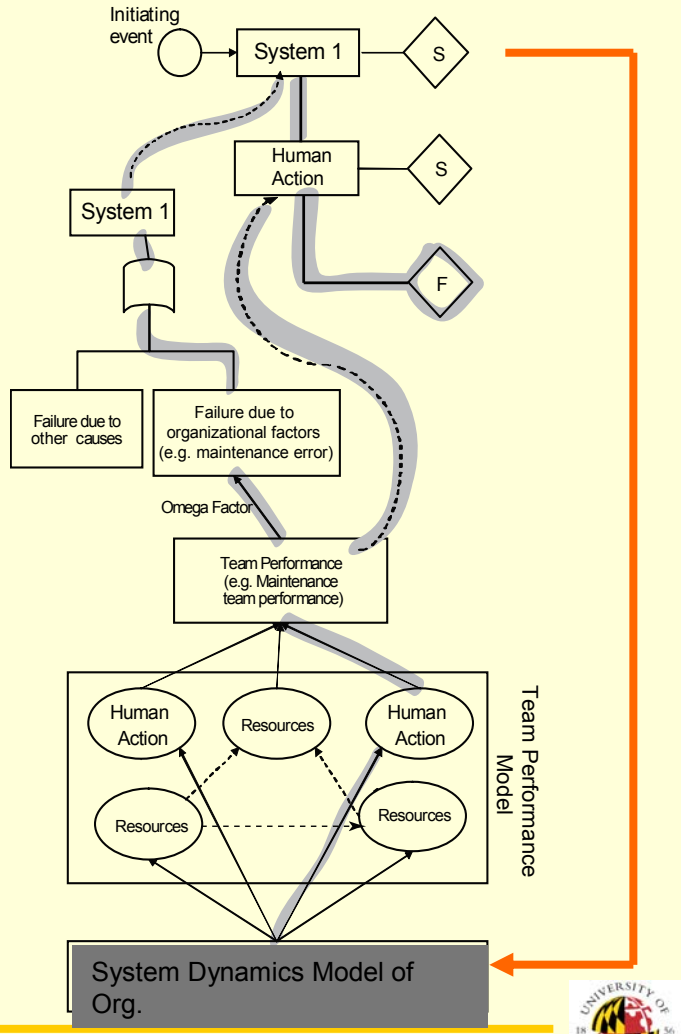
deterministic relations

dynamic integration

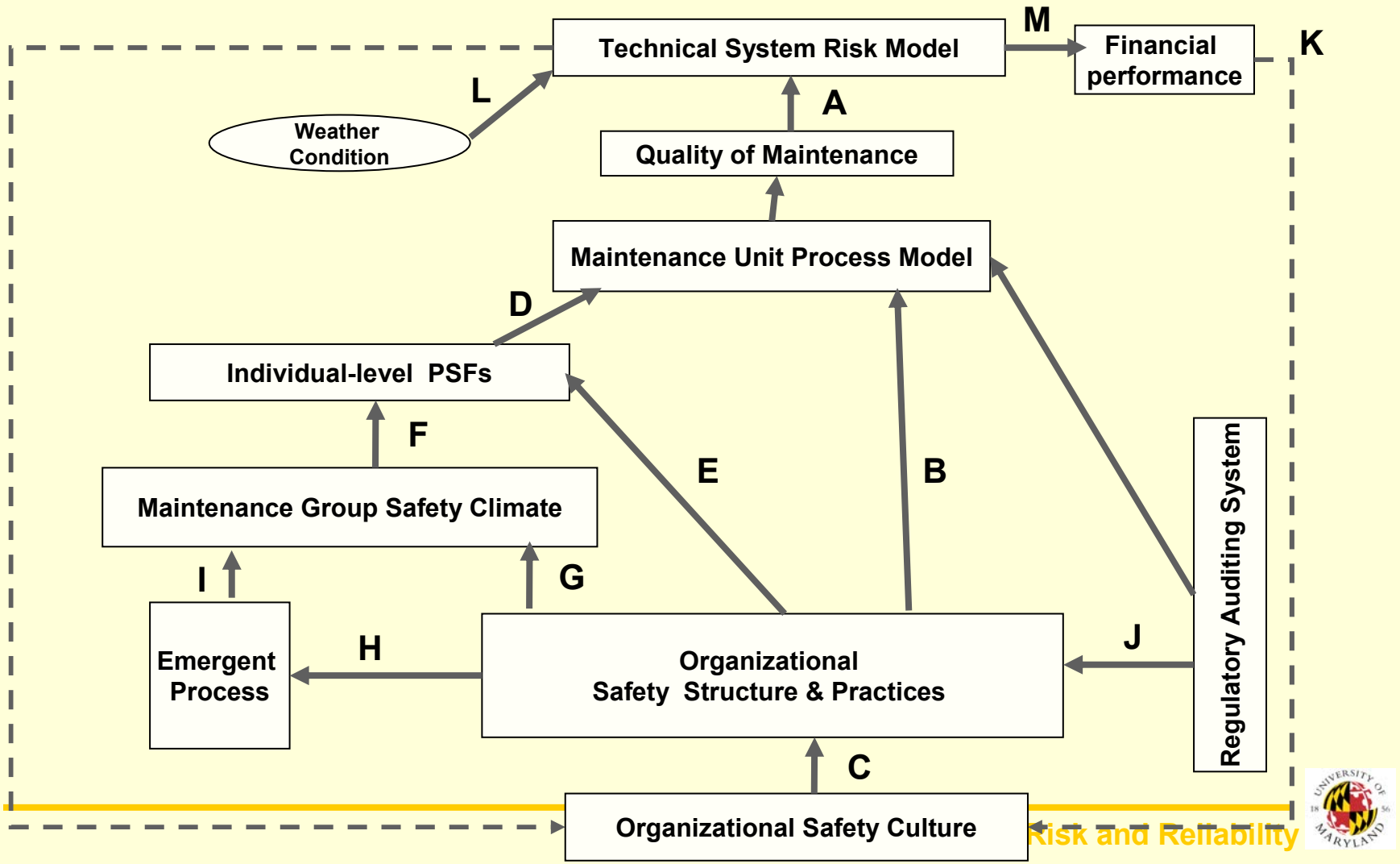
technical systems

Hybrid Technique for Organizational Safety Risk

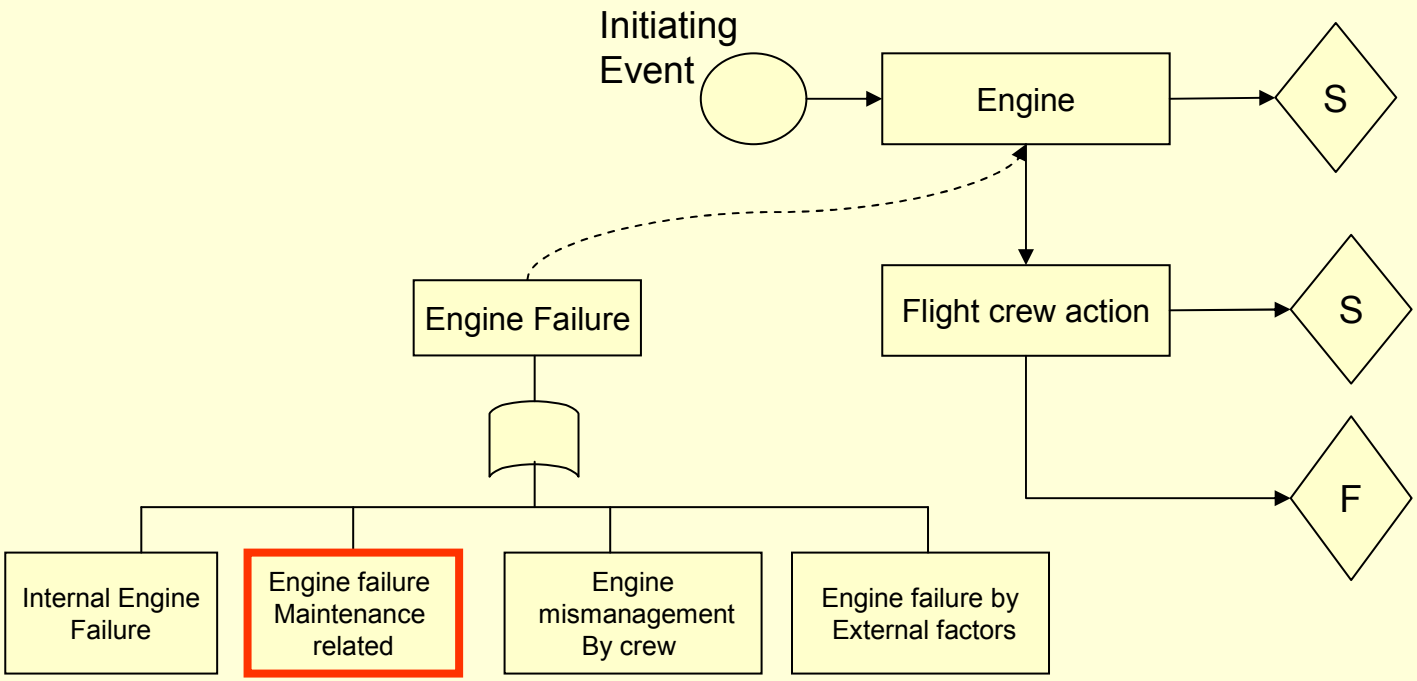




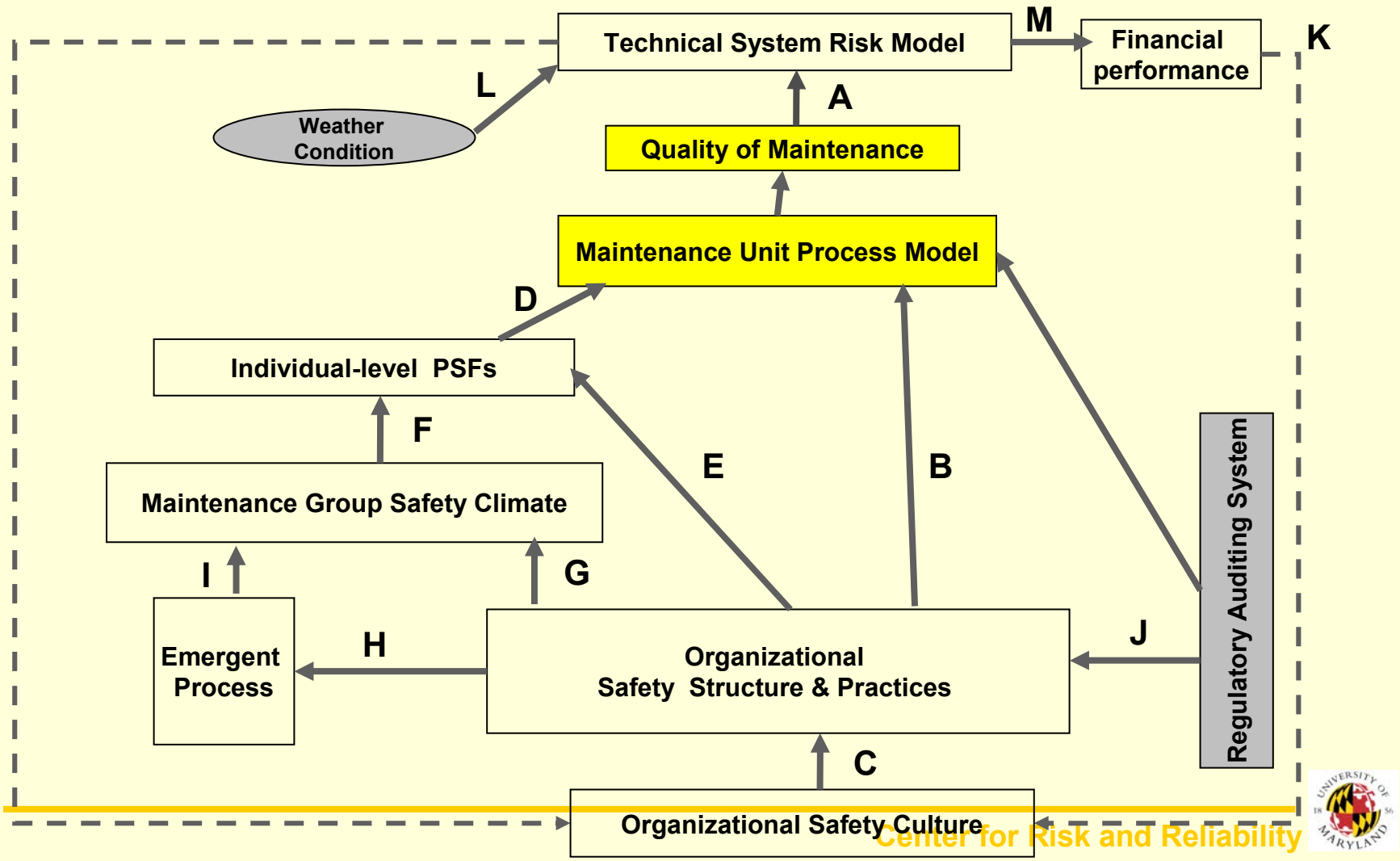
SoTeRiA –based Aviation Maintenance Model



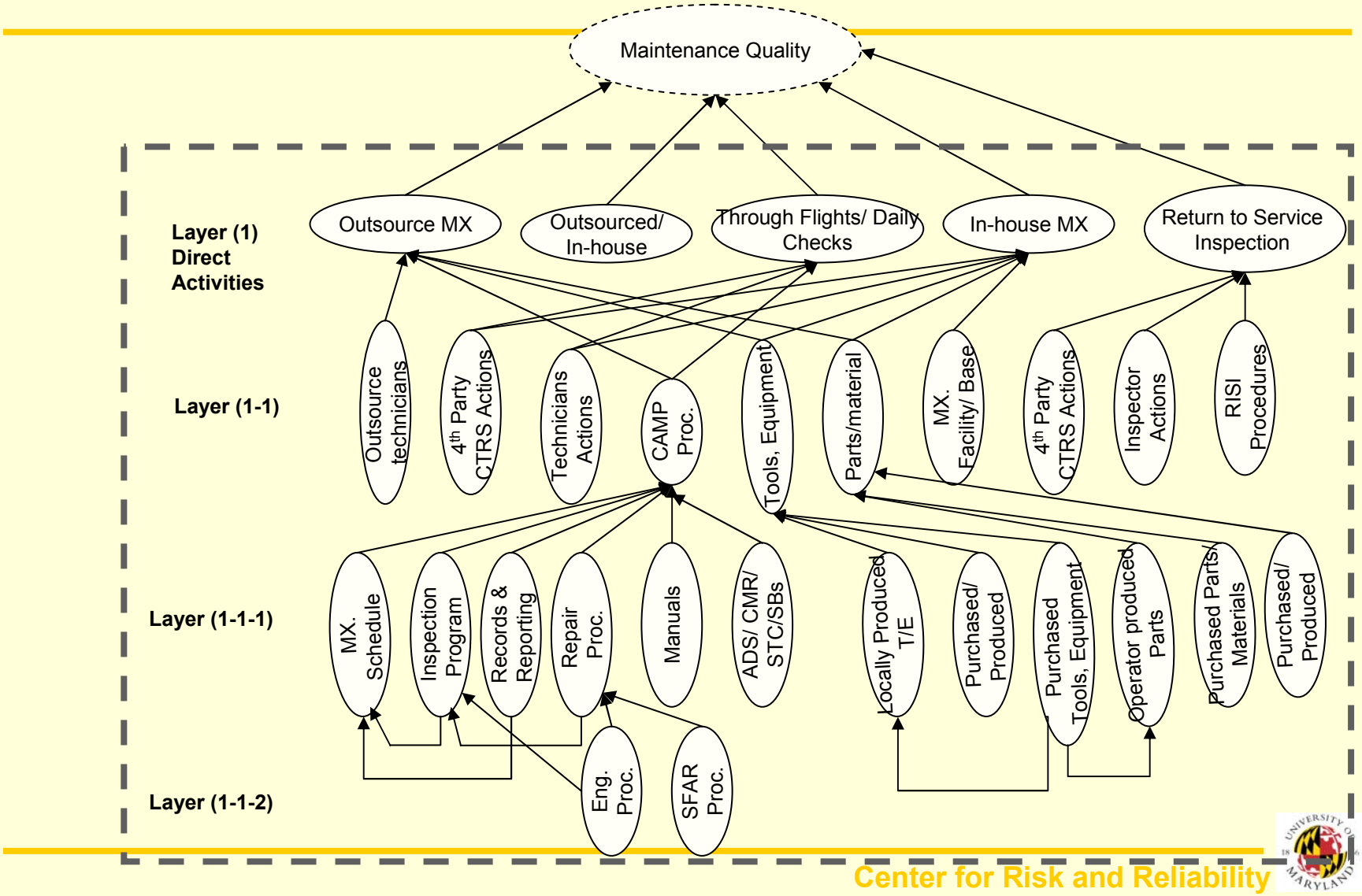
Technical System Risk



Implementing SoTeRiA in Aviation Maintenance



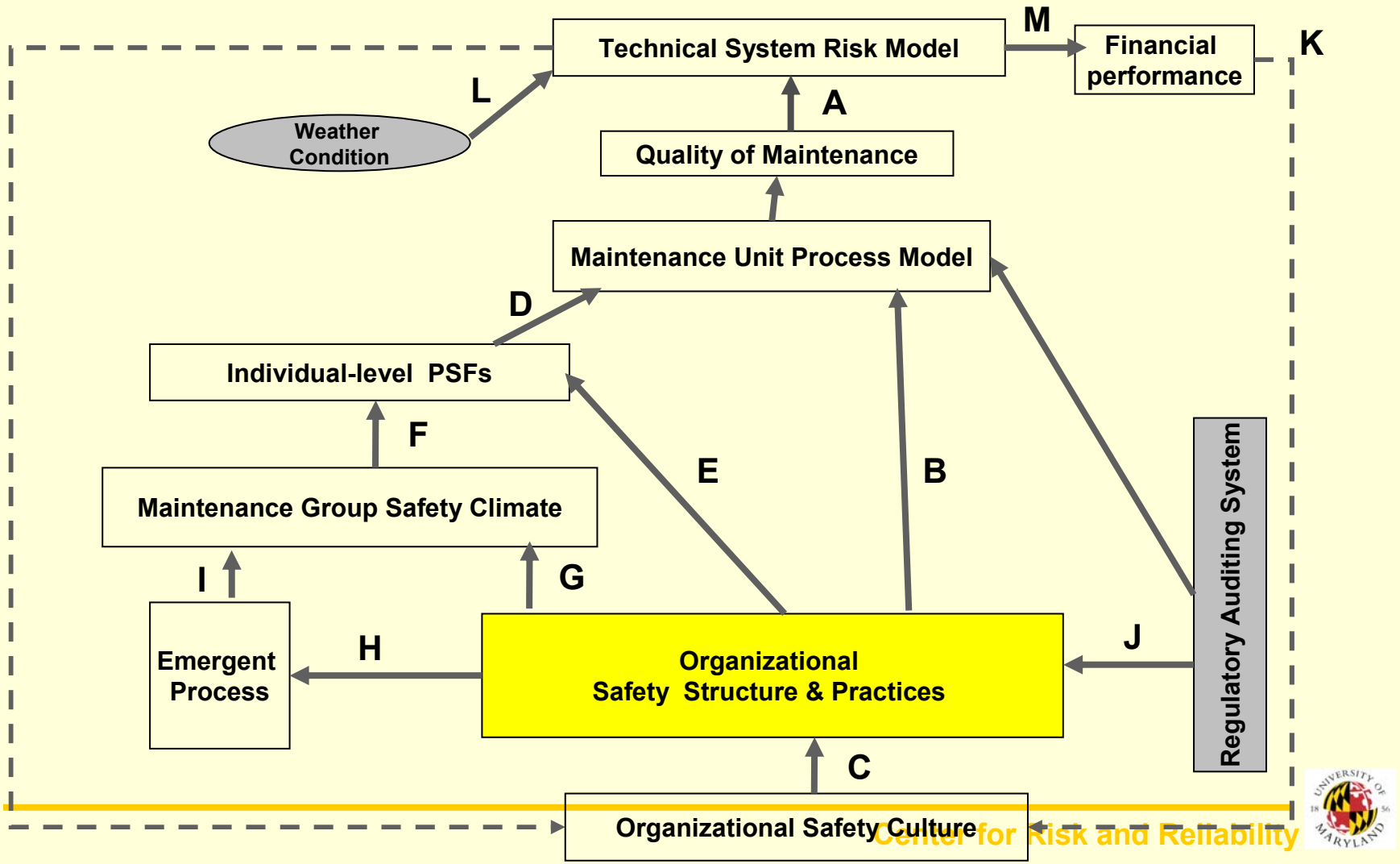
Maintenance Unit Process Model



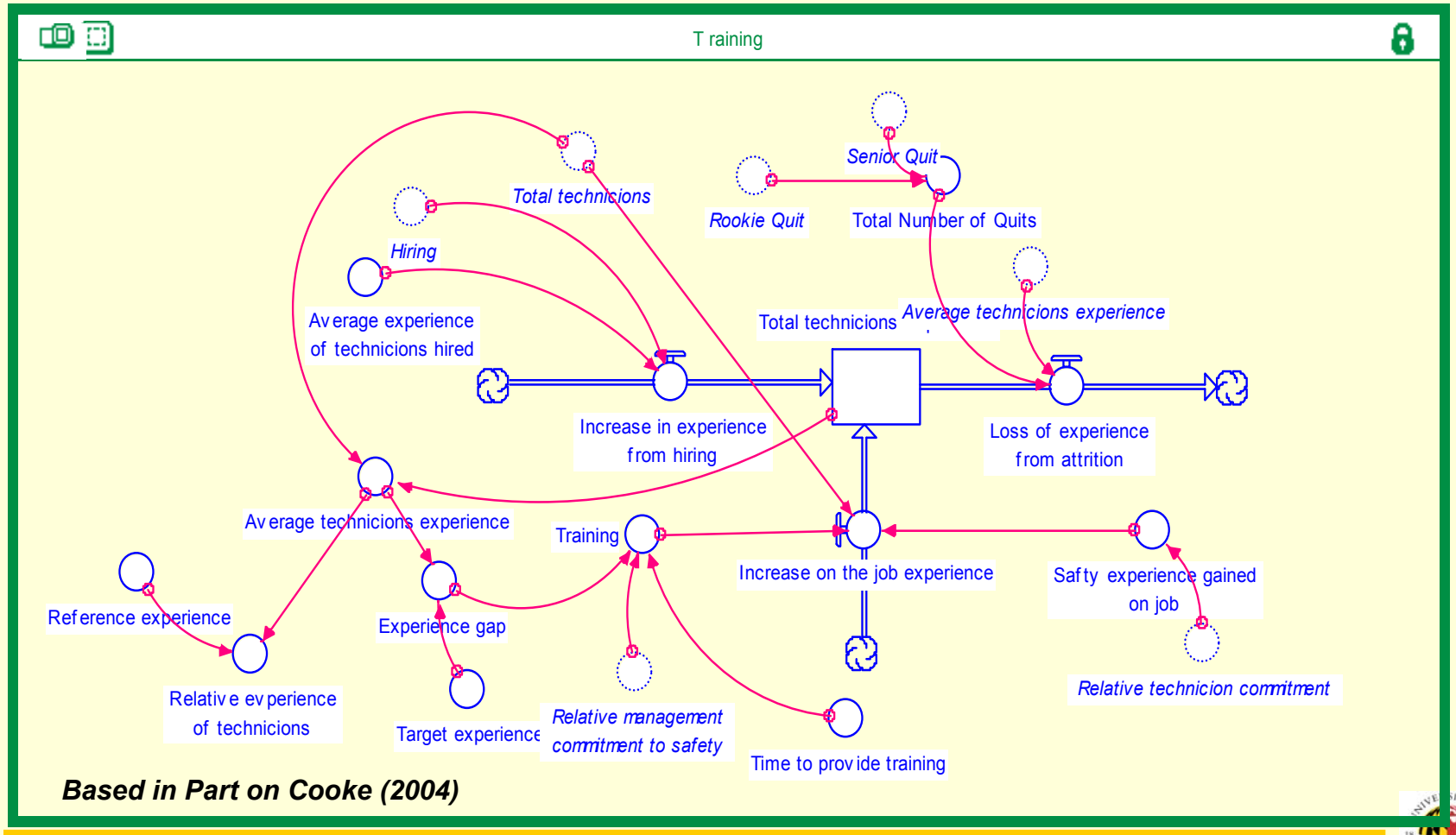
Center for Risk and Reliability

Adapted from Eghbali (2006)

Implementing SoTeRiA in Aviation Maintenance

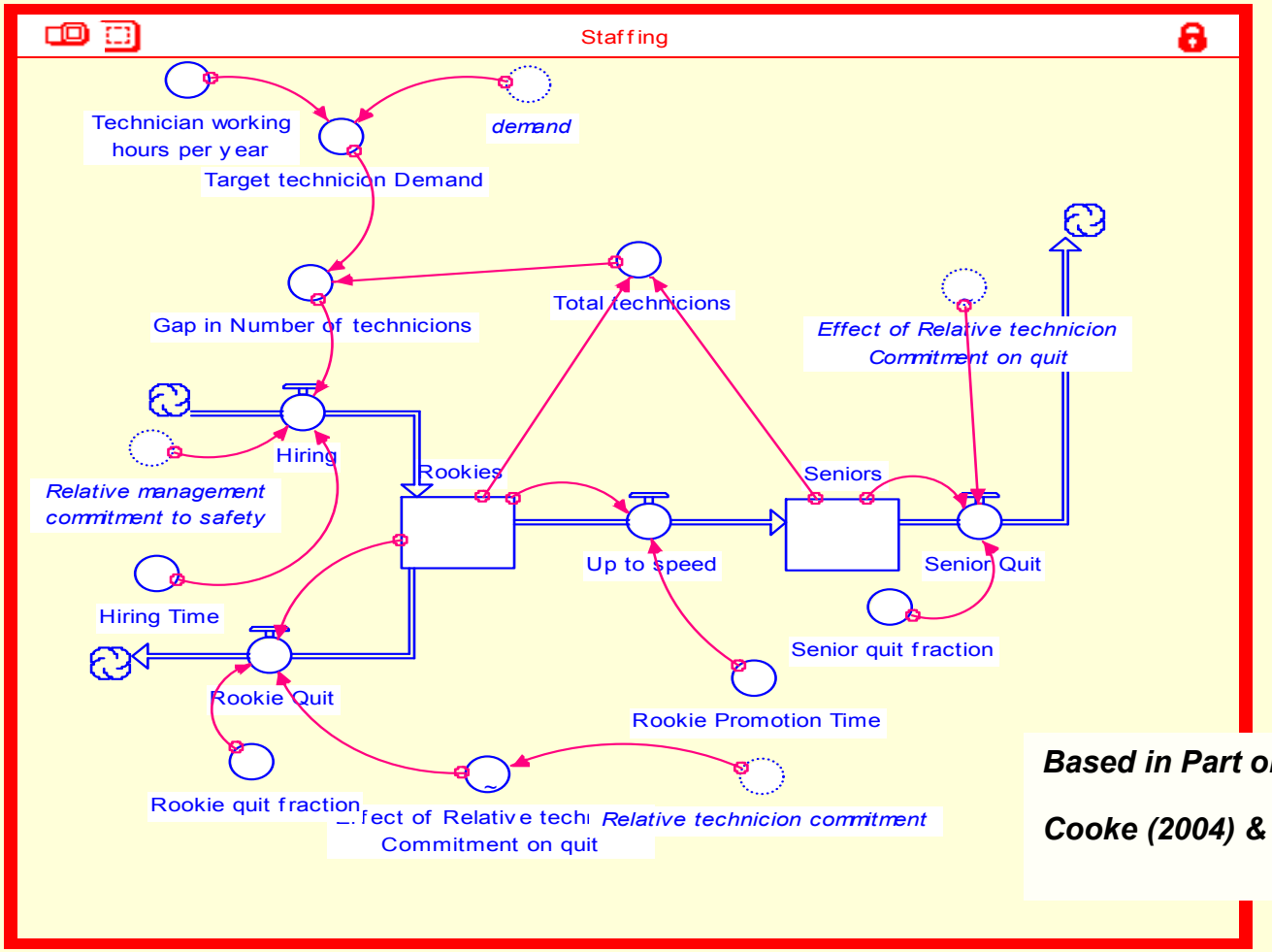


“Training” in System Dynamics Environment



Based in Part on Cooke (2004)

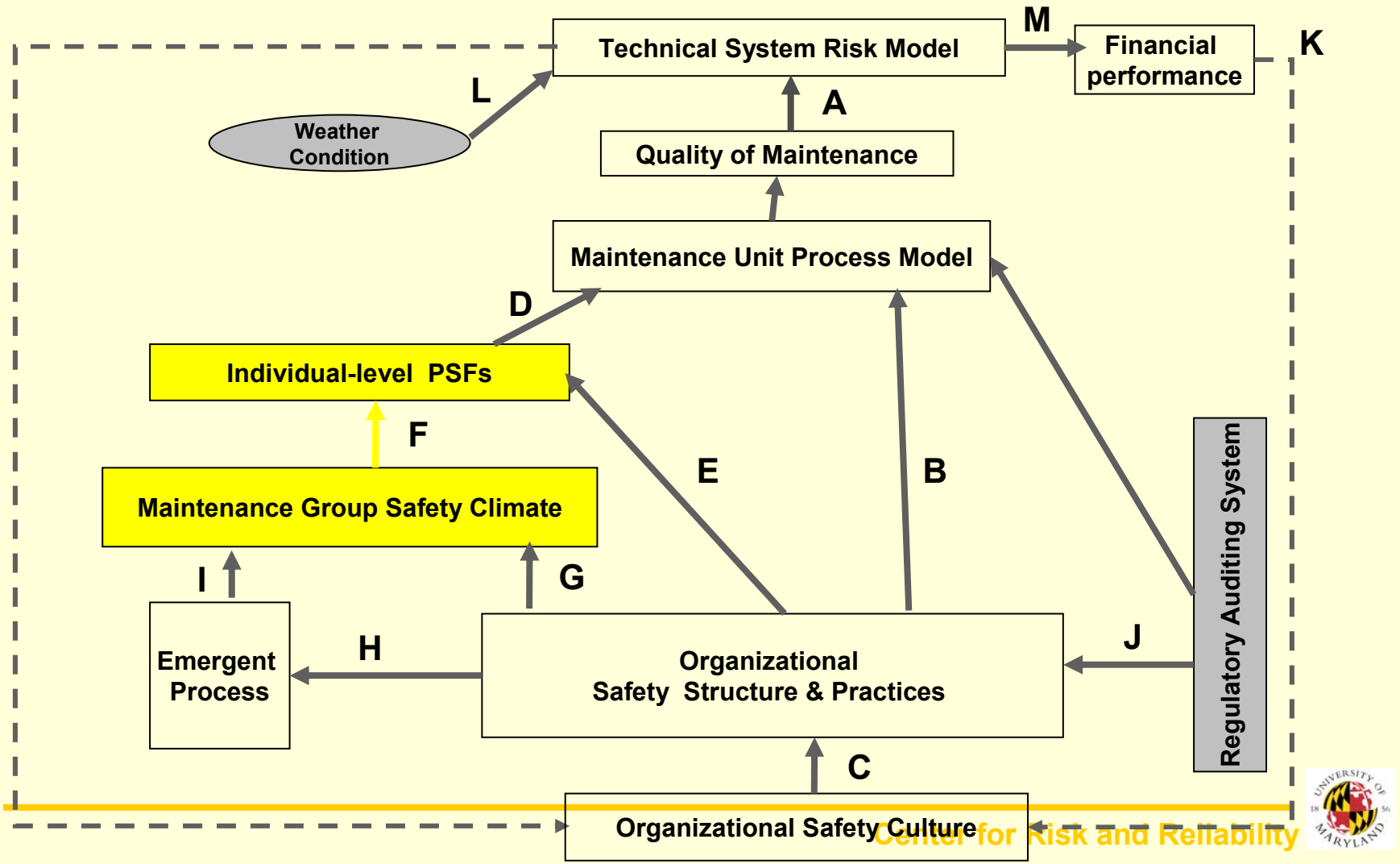
“Hiring Model” (System Dynamics Environment)



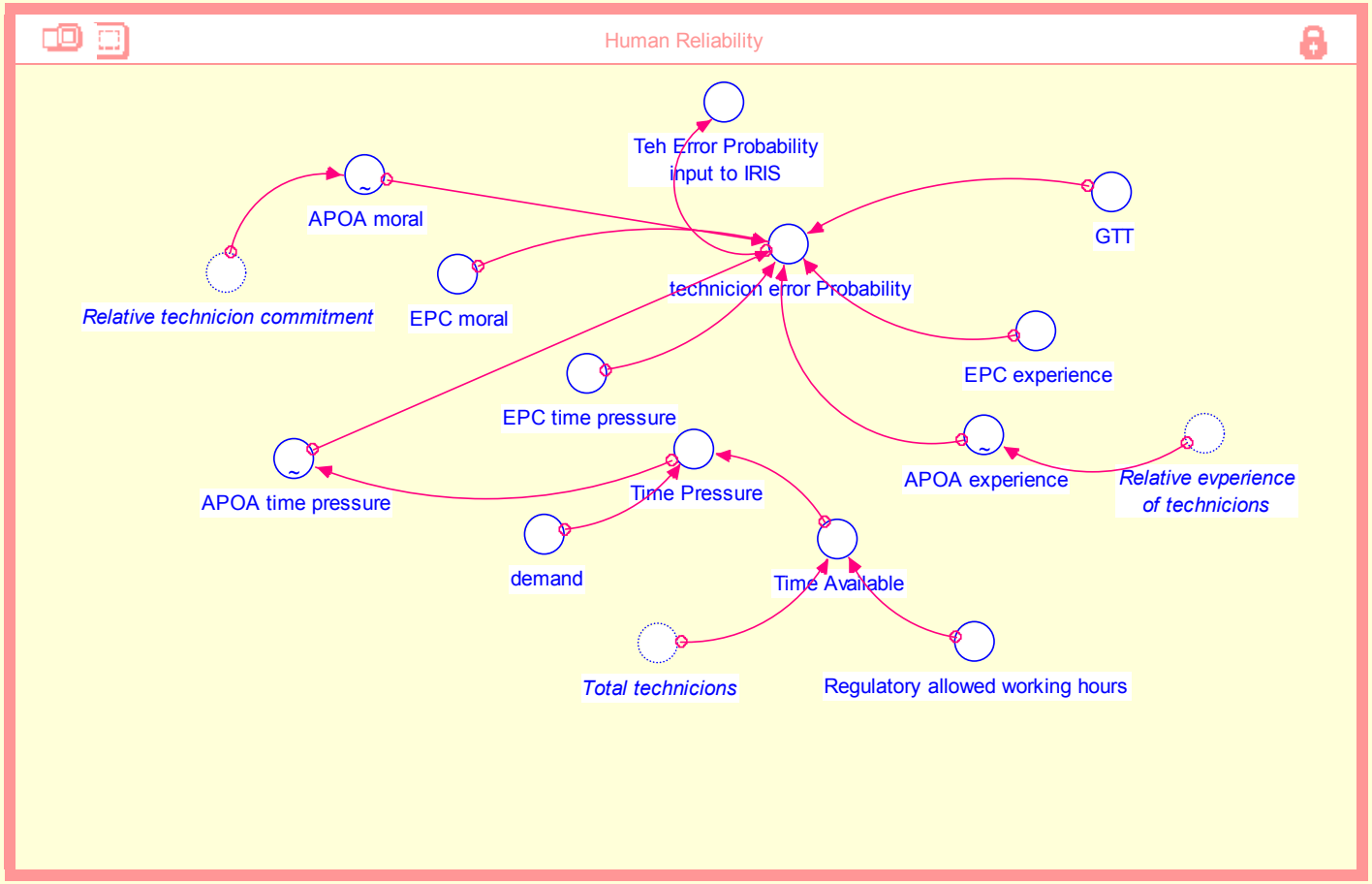
Based in Part on

Cooke (2004) & Cabe(1998)

Implementing SoTeRiA in Aviation Maintenance



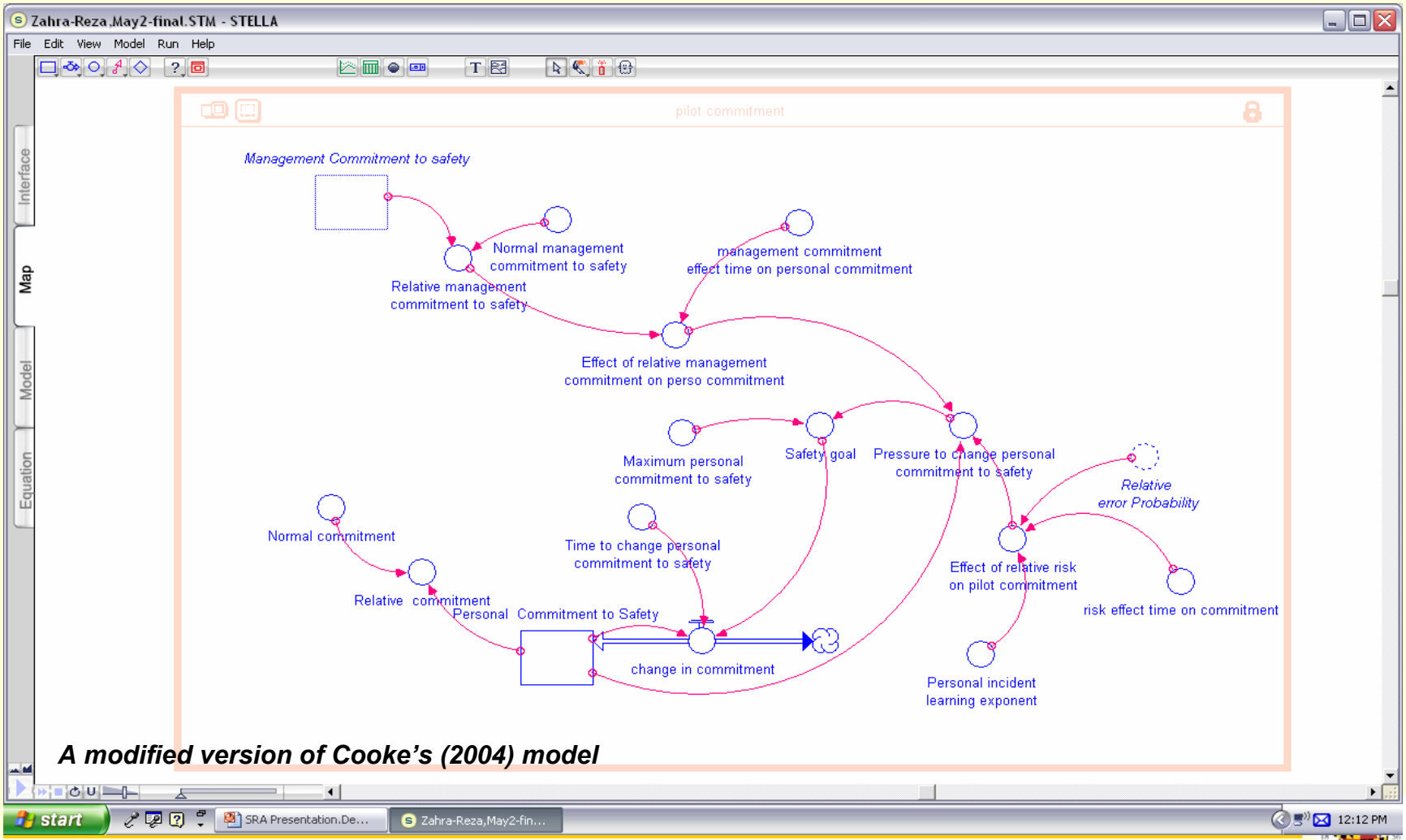
Human Reliability Model
(in System Dynamics Environment)



Center for Risk and Reliability

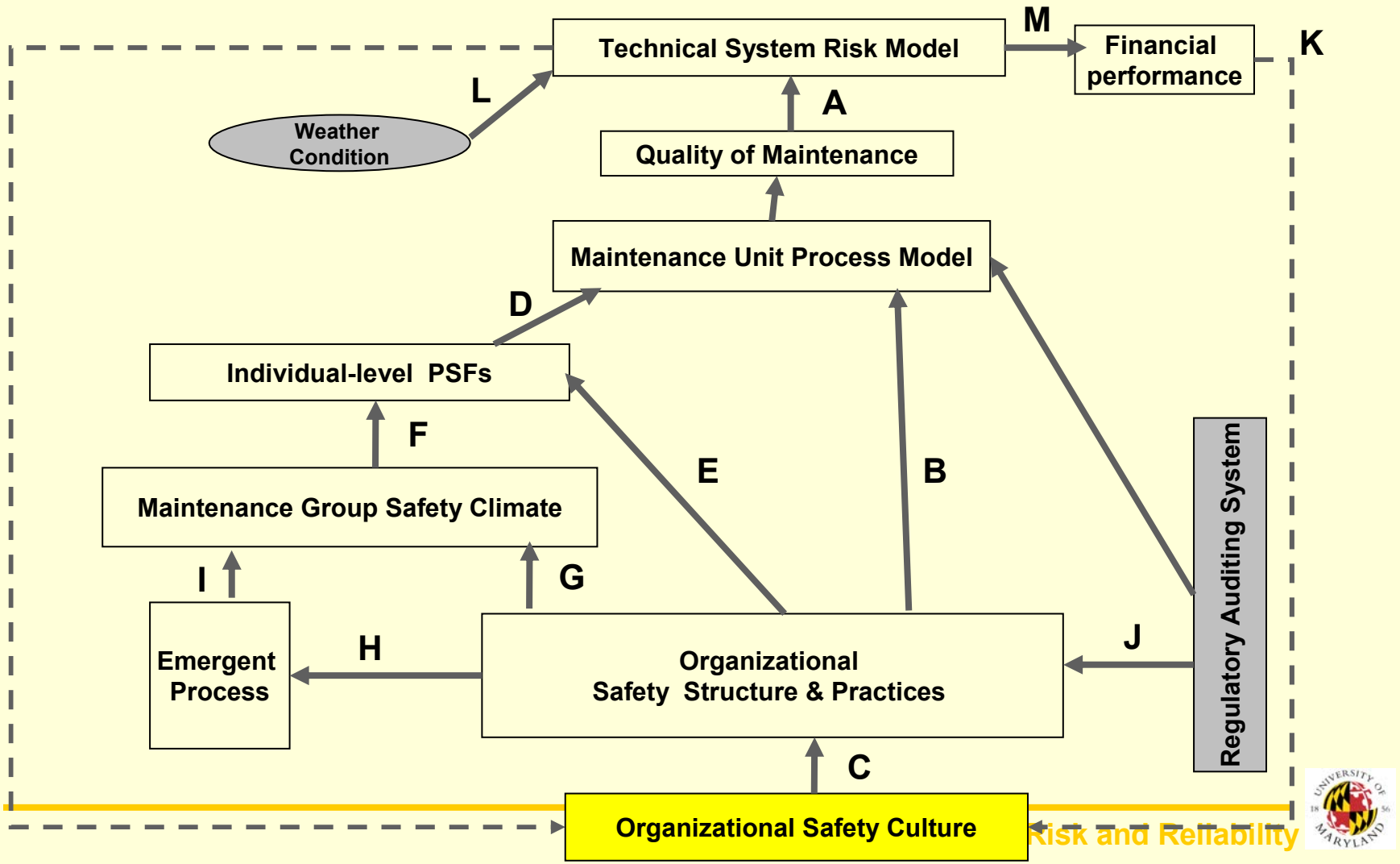
The module is built partially based on Nuclear Action Reliability Assessment (NARA) (Kirwan, et.al., 2004)

Technician Commitment
(in System Dynamics Environment)



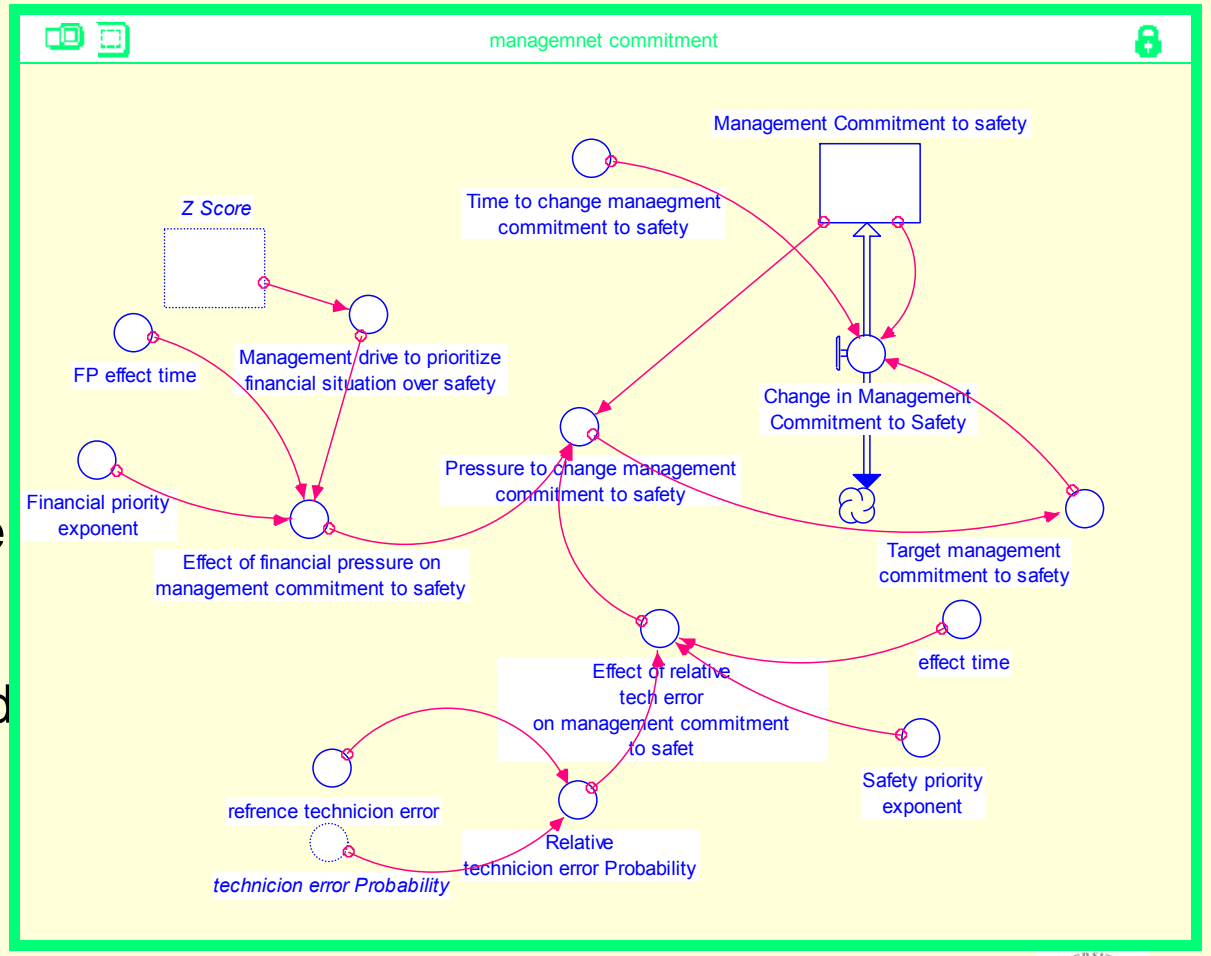
A modified version of Cooke's (2004) model

SoTeRiA in Aviation Maintenance



Management Commitment Model
(in System Dynamics Environment)

- The basic modeling follows Sterman 2000
- Describes the process of groping toward a proper quantity
- Assumes an initial leve of commitment which later changes according to safety and financial pressures applied to organization



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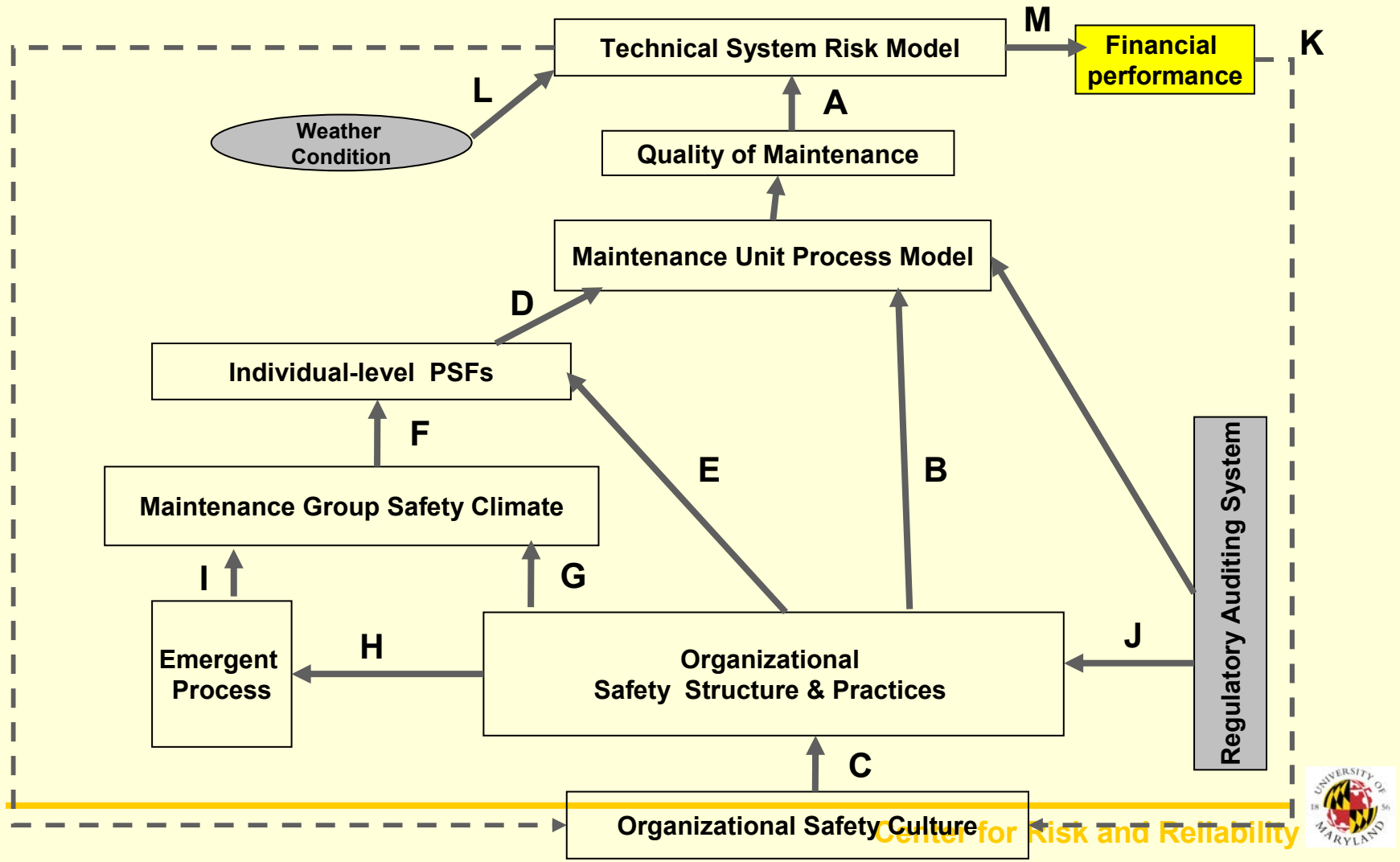
Partially referred to Cooke (2004)

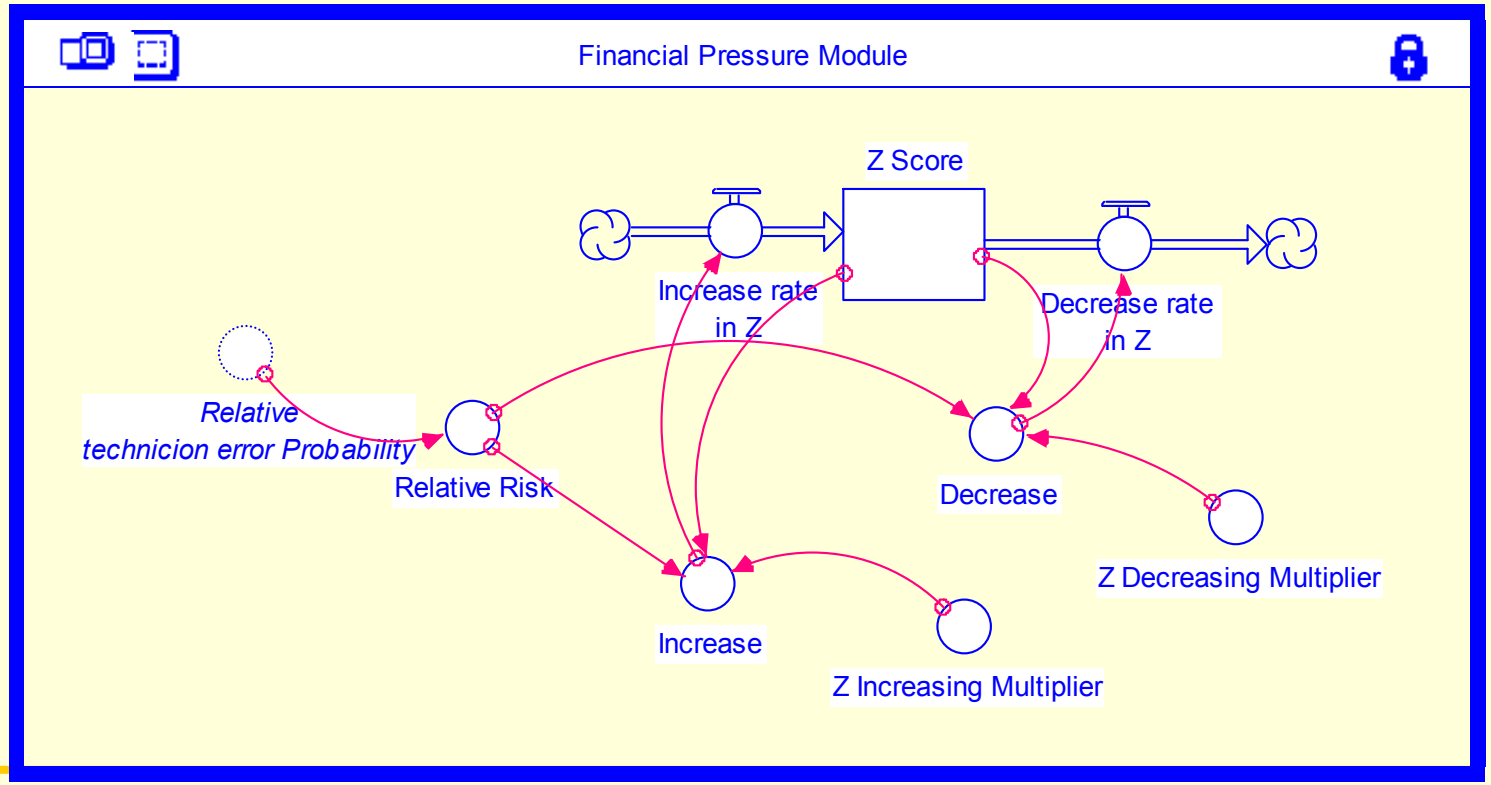
SoTeRiA in Aviation Maintenance



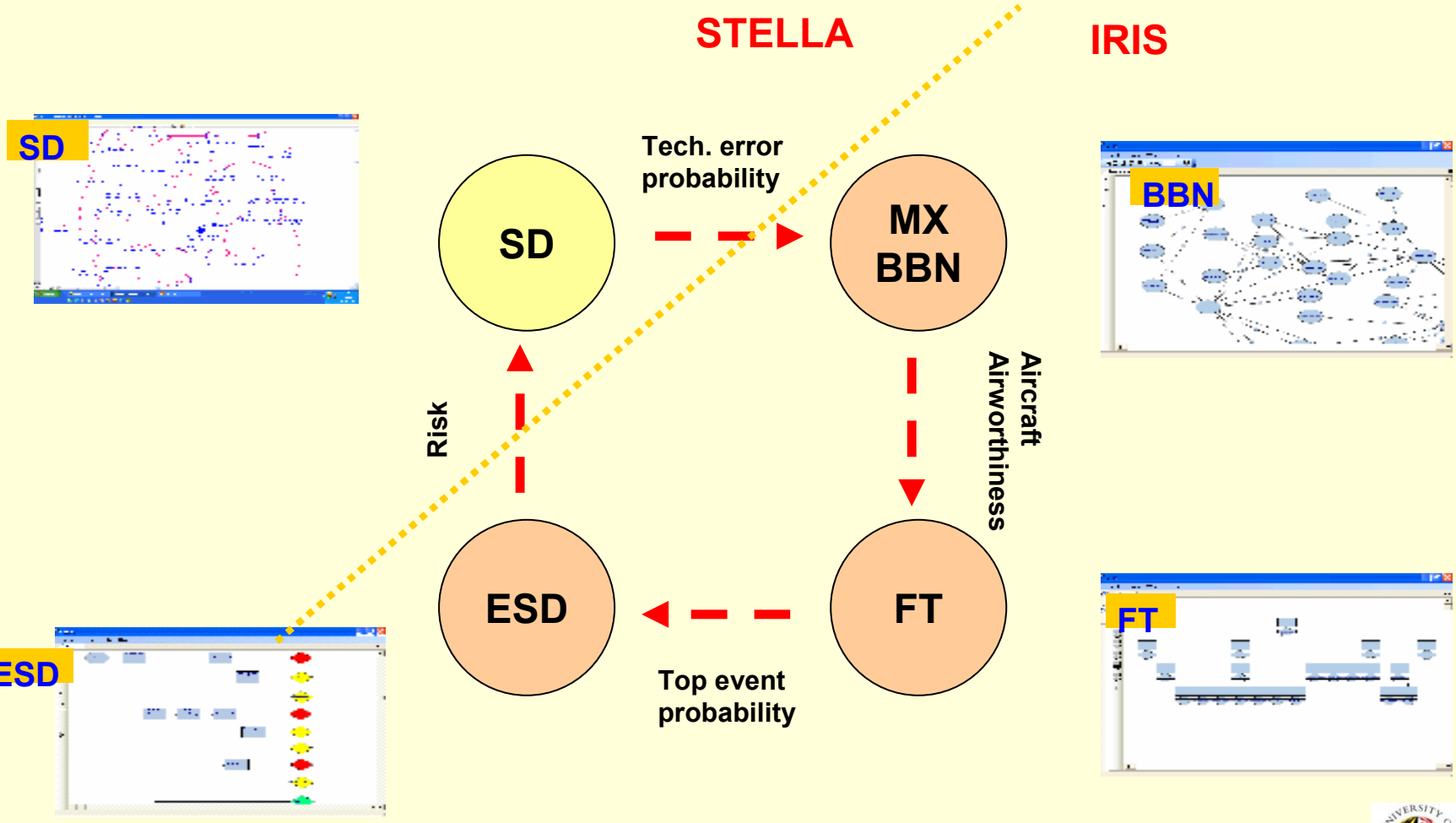
Financial Stress Model

(in System Dynamics Environment)

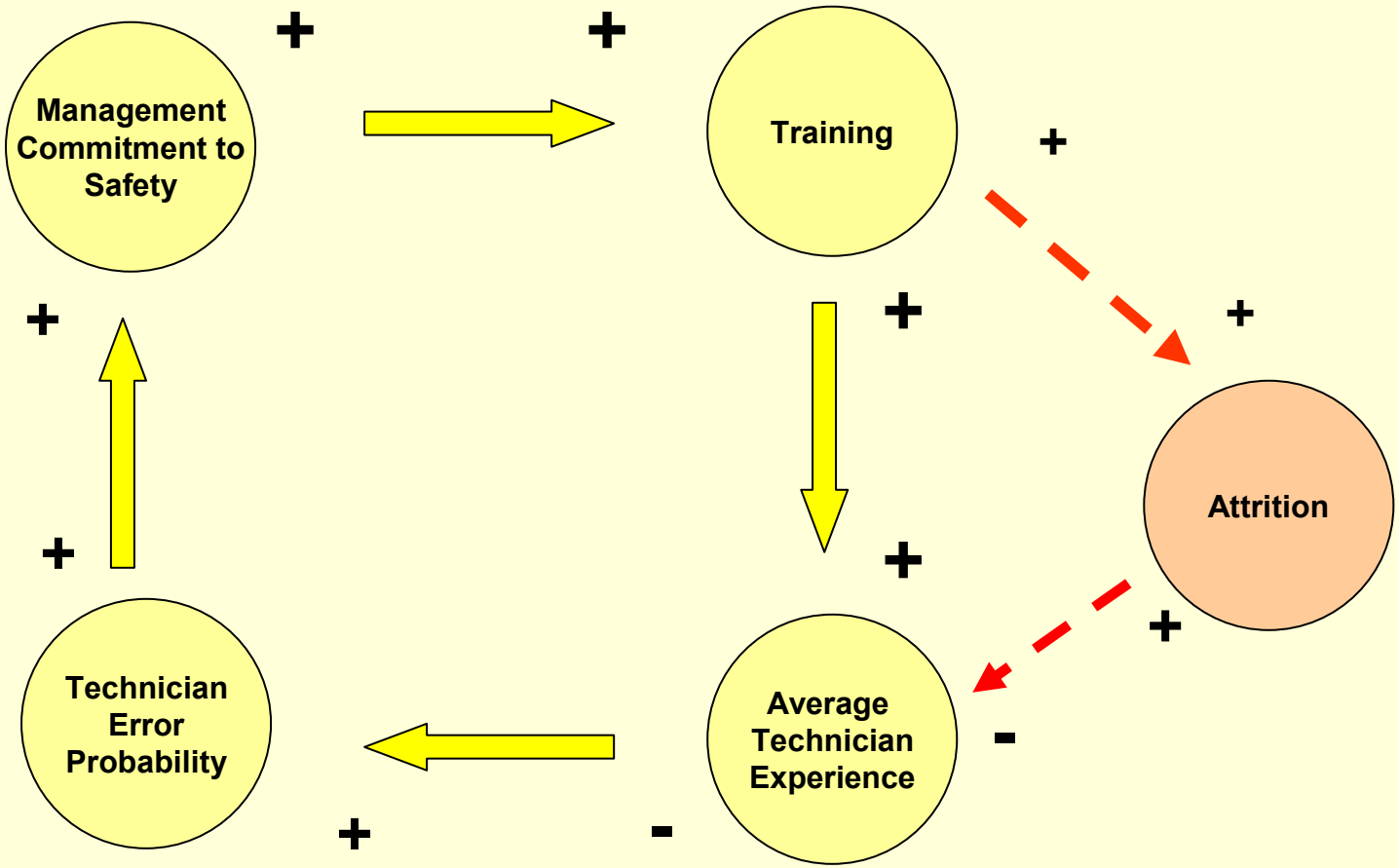
- "Altman's score" model has been employed As a measure of financial distress
- "Z score" is a linear combination of some financial ratios available on a firm's balance sheet



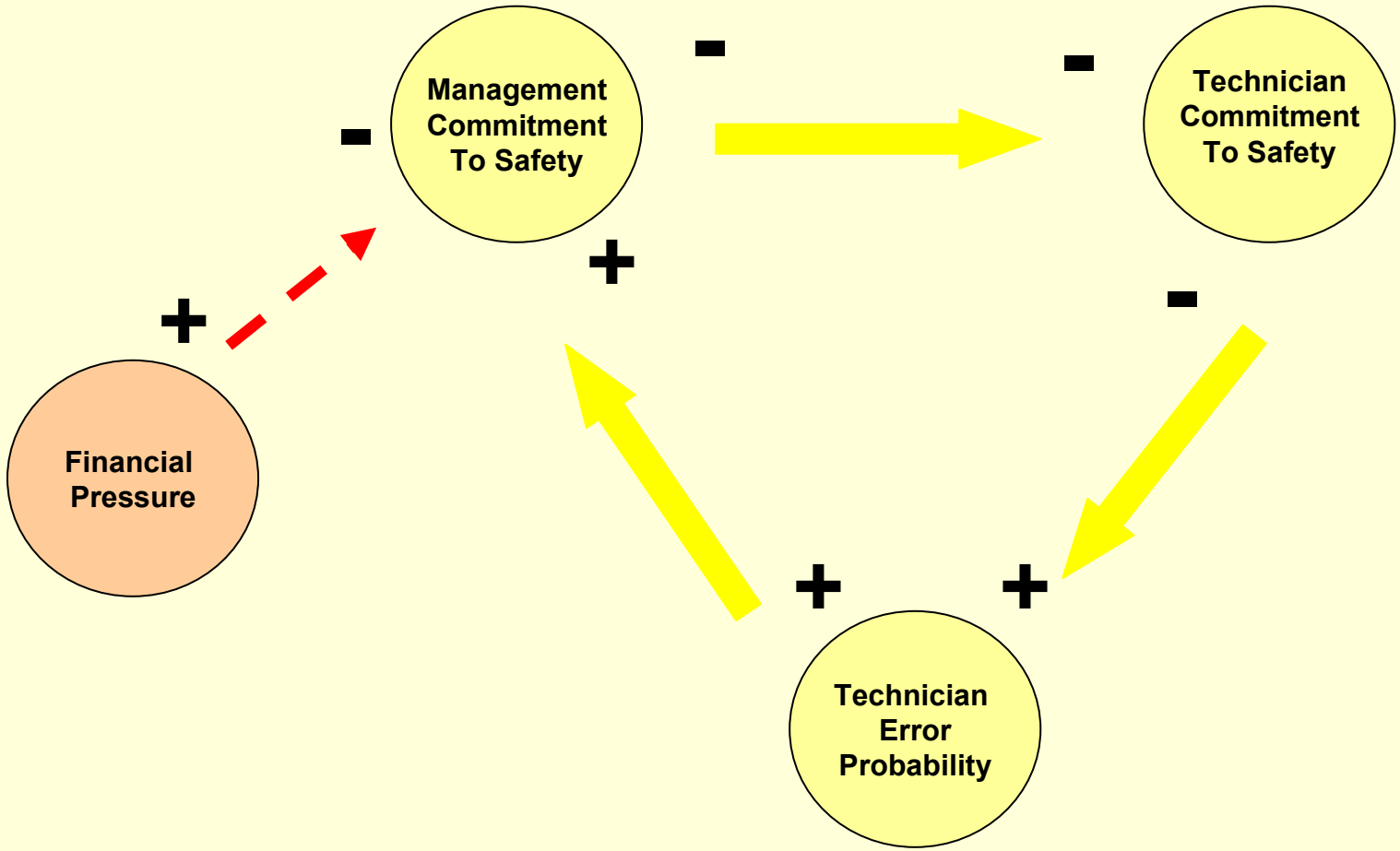
Integration of Software Tools



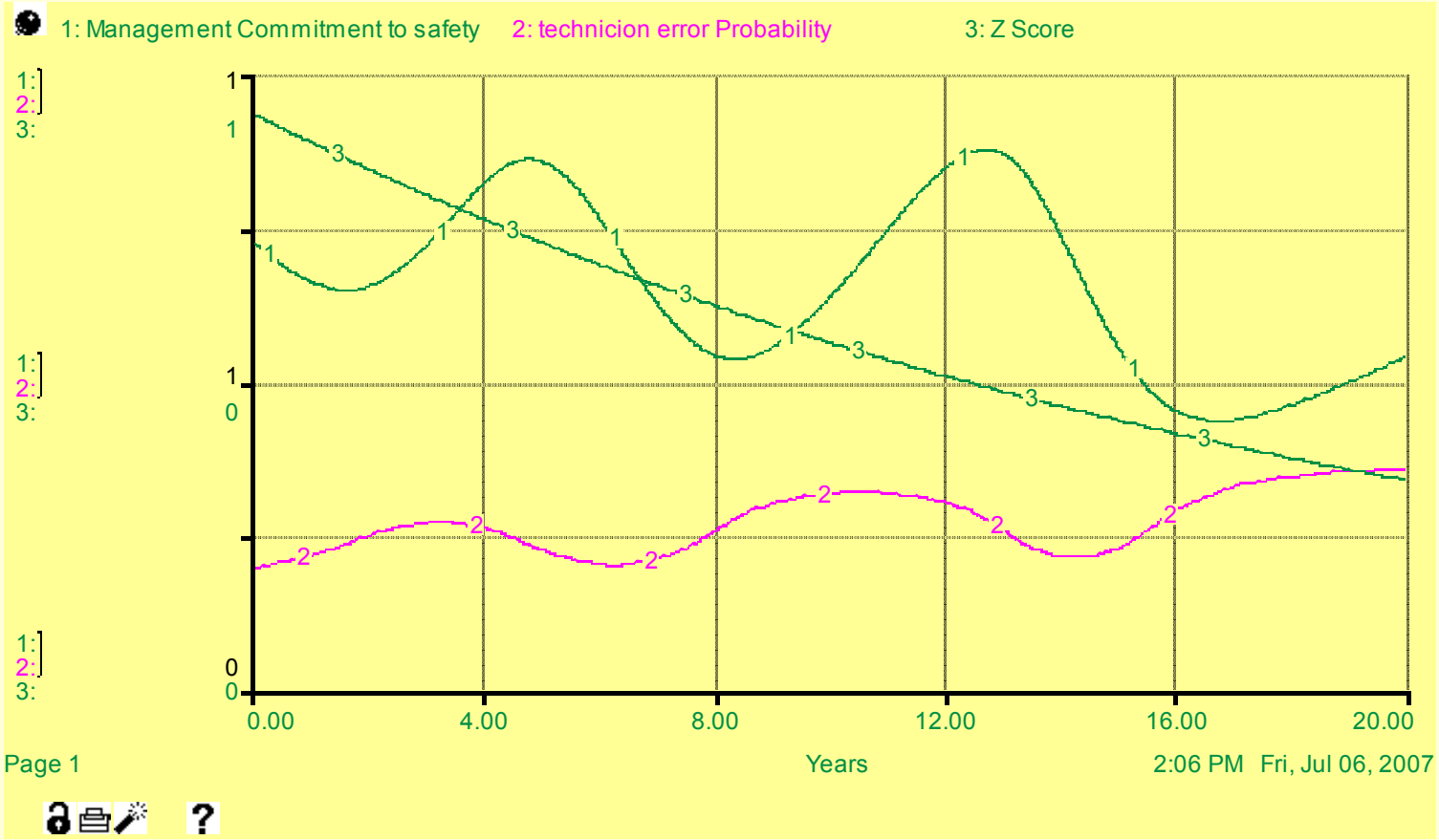
Example Causal Loop



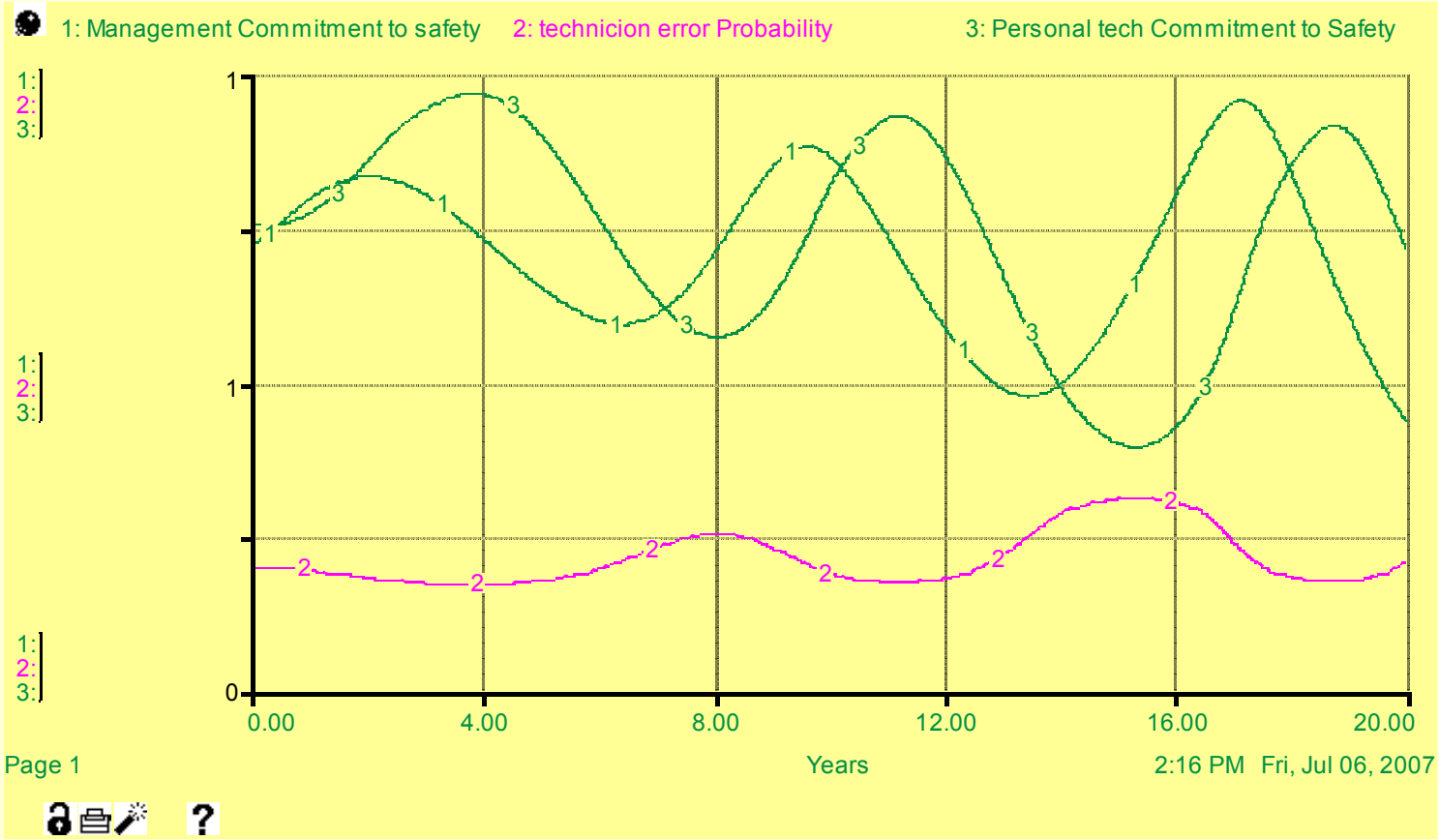
Example Causal Loop: Safety & Profitability



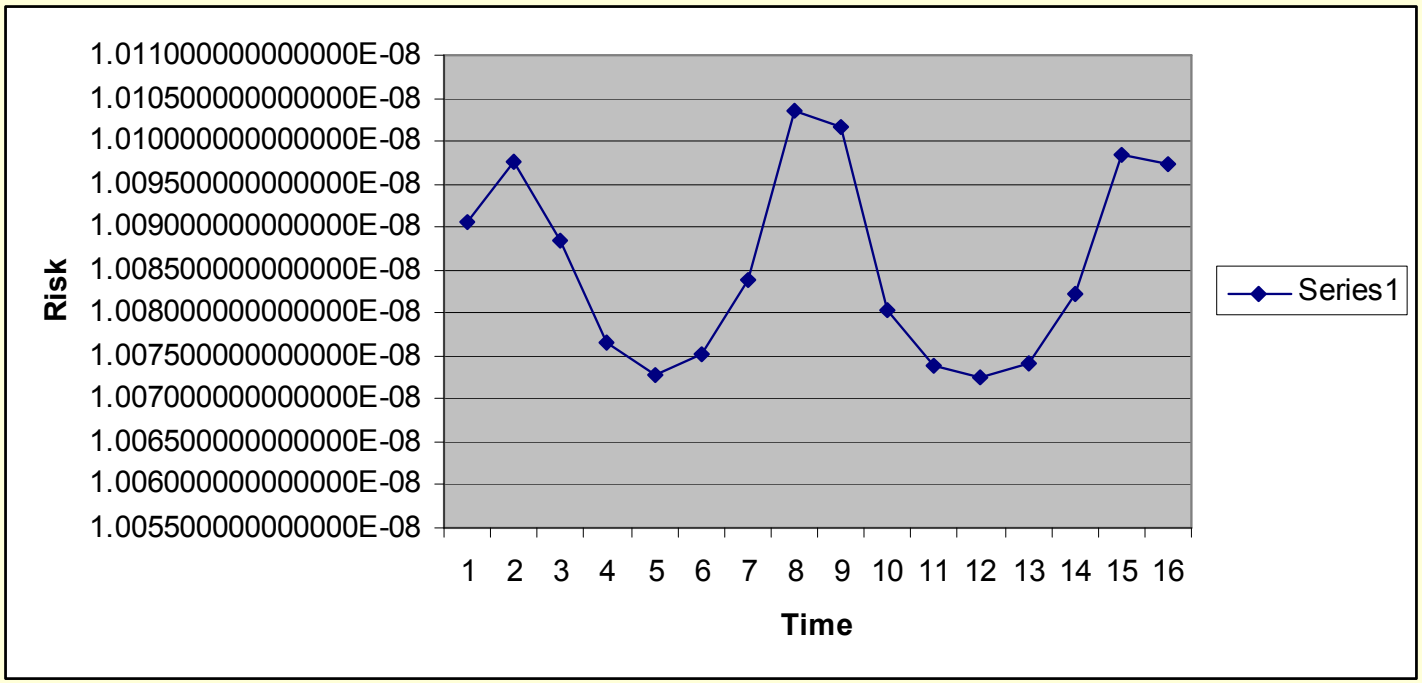
Typical Output: Financial Stress as a Trigger Point



Typical Output : A period of Low-error Stability



Typical Output: Total Risk Over 15 Years



Concluding Remarks

- Introduced a 4-layer hybrid dynamic framework for causal modelling of organizational safety risk
- Integration of *deterministic* (e.g. SD) and *probabilistic* (e.g., BBN, ESD, and FT) modelling methods
- Flexible risk-informed decision making tool with explicit consideration of
  - Dynamic effects, such as time lags between decisions and outcomes, and feedbacks such as the impact of incidents on worker awareness and attention to safety
  - The uncertain nature of the impact of organizational factors on human performance
  - The impact of human performance on the systems and evolution of risk scenarios

Acknowledgment

- The work described in this paper was in part supported by the US Federal Aviation Administration.

Example Causal Loops: