Reliability Engineering - Discussions and Clarifications

Reliability Engineering VS. Probabilistic Risk Assessment (PRA)
Reliability Prediction VS. Reliability Demonstration
Design Reliability VS. Process Reliability

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Agenda

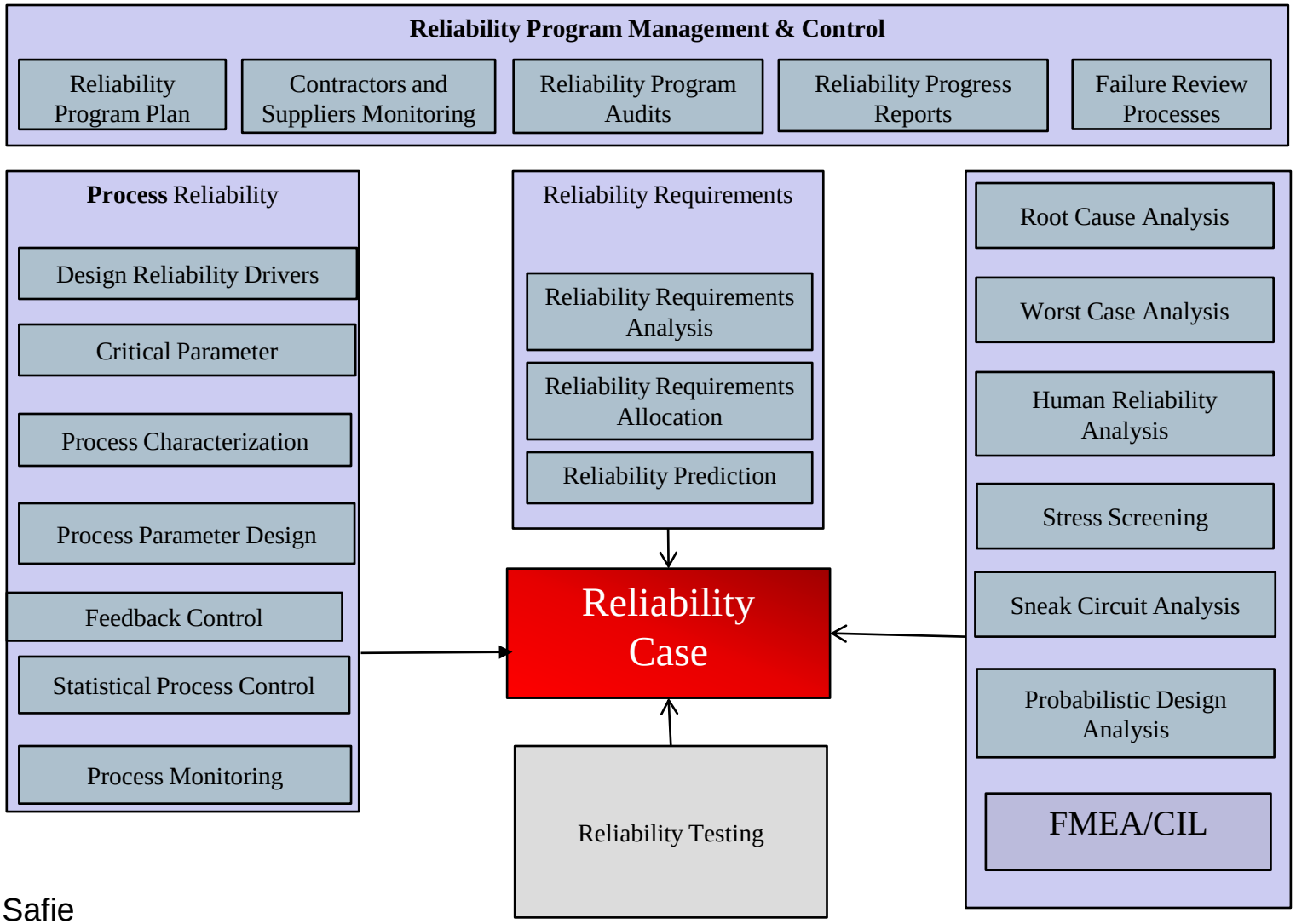
- **Reliability Engineering Overview**
  - Reliability Engineering Definitions
  - The Reliability Engineering Case
  - The Relationship to Safety, Mission Success, and Affordability
- **Discussions and Clarifications**
  - Reliability VS. Probabilistic Risk Assessment (PRA)
  - Reliability Prediction VS. Reliability Demonstration
  - Design Reliability VS. Process Reliability
- **Concluding Remarks**

Reliability Engineering Overview

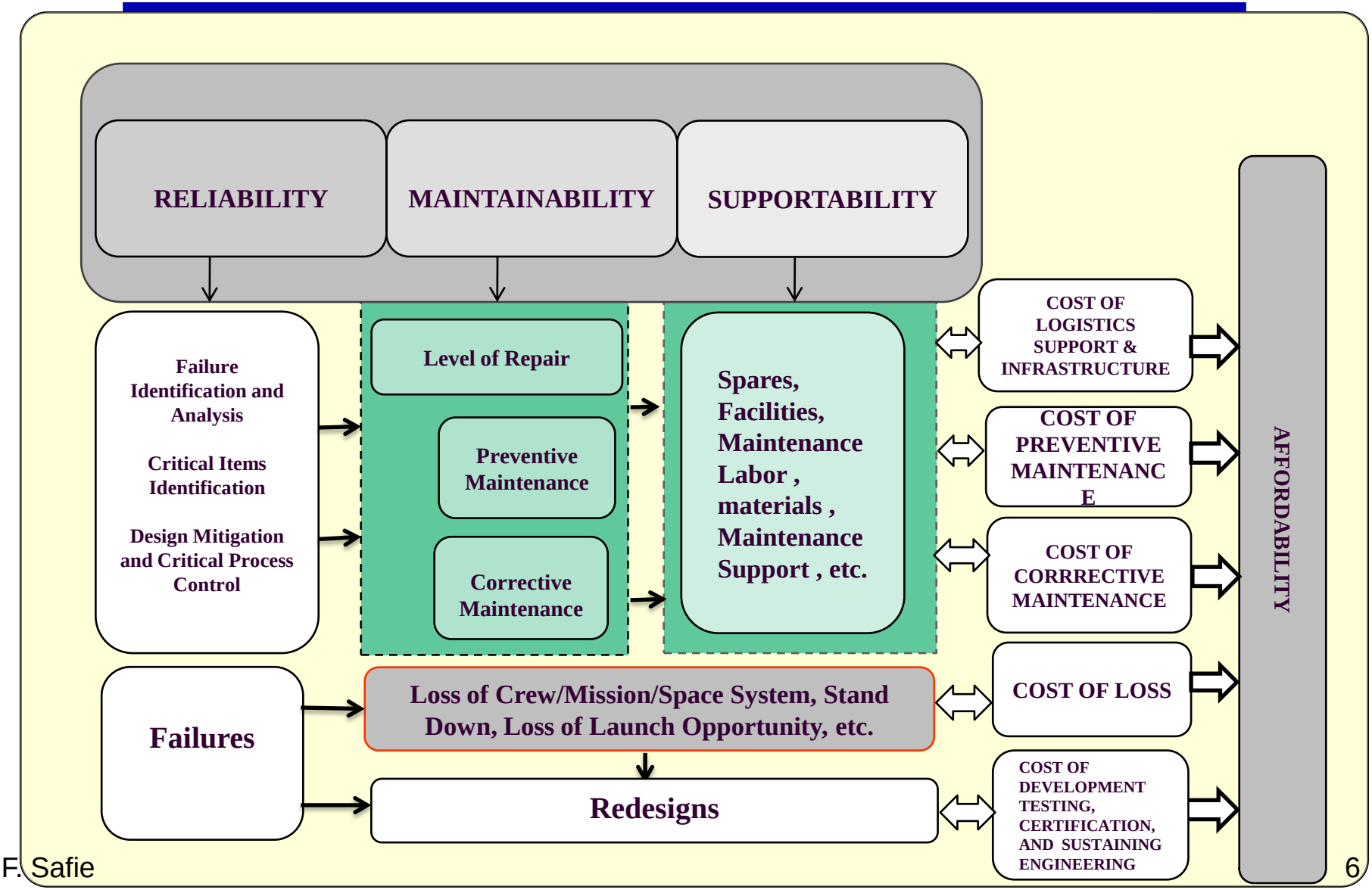
Reliability Engineering

- **Reliability Engineering as a Discipline:**
  - The application of engineering and scientific principles to the design and processing of products, both hardware and software, for the purpose of meeting product reliability requirements or goals.
- **Reliability as a Figure of Merit is:**
  - The probability that an item will perform its intended function for a specified mission profile.
- Reliability is a very broad design-support discipline. It has important interfaces with most engineering disciplines
- Reliability analysis is critical for understanding component failure mechanisms and identifying reliability critical design and process drivers**.**

The Reliability Engineering Case



The Relationship to Safety, Mission Success, and Affordability



Reliability Discussions and Clarifications

Probabilistic Risk Assessment (PRA)

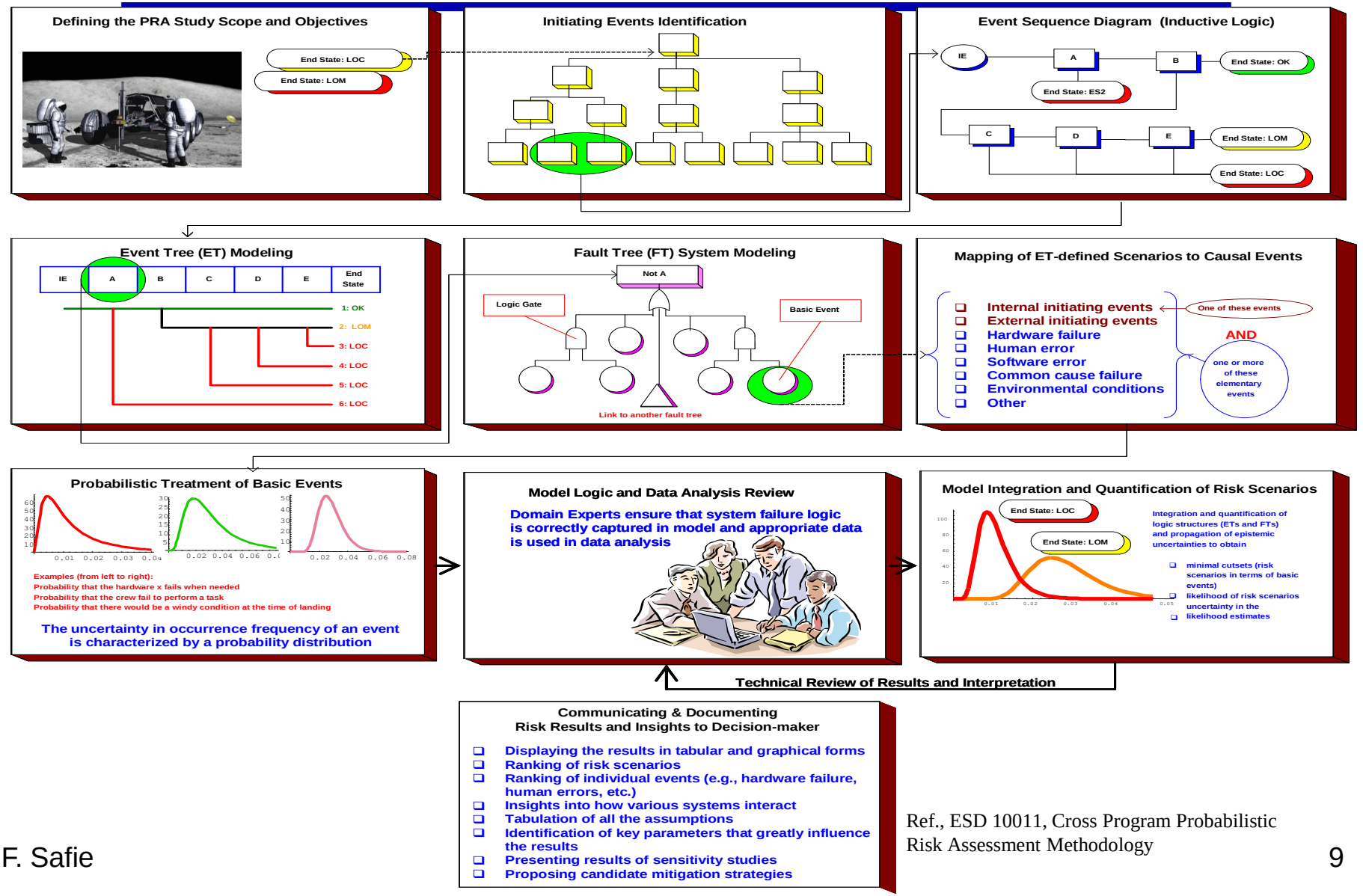
- **Reliability: The probability that an item will perform its intended function for a specified mission profile.**
- **Risk: The chance of occurrence of an undesired event and the severity of the resulting consequences.**
- **Probabilistic Risk assessment (PRA) is the systematic process of analyzing a system, a process, or an activity to answer three basic questions:**
  - What can go wrong that would lead to loss or degraded performance (i.e., scenarios involving undesired consequences of interest)?
  - How likely is it (probabilities)?
  - What is the severity of the degradation (consequences)?

Scenario	Likelihood (Probability)	Consequence
S_1	p_1	C_1
S_2	p_2	C_2
S_3	p_3	C_3
⋮	⋮	⋮
S_N	p_N	C_N

Risk assessment is the task of generating the triplet set

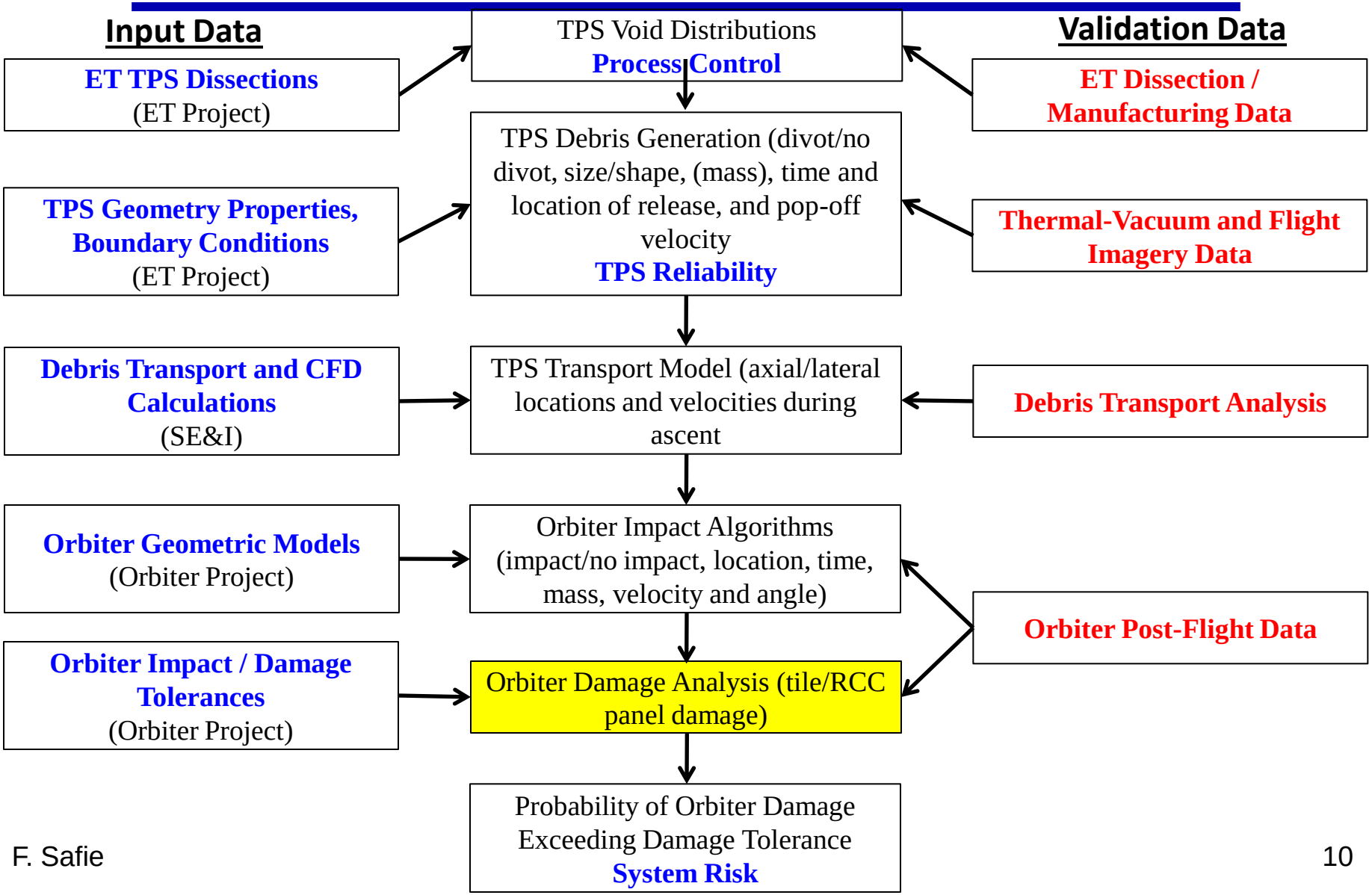
$$R \equiv \text{RISK} \equiv \{\langle S_i, P_i, C_i \rangle\}$$

The PRA Process



Ref., ESD 10011, Cross Program Probabilistic Risk Assessment Methodology

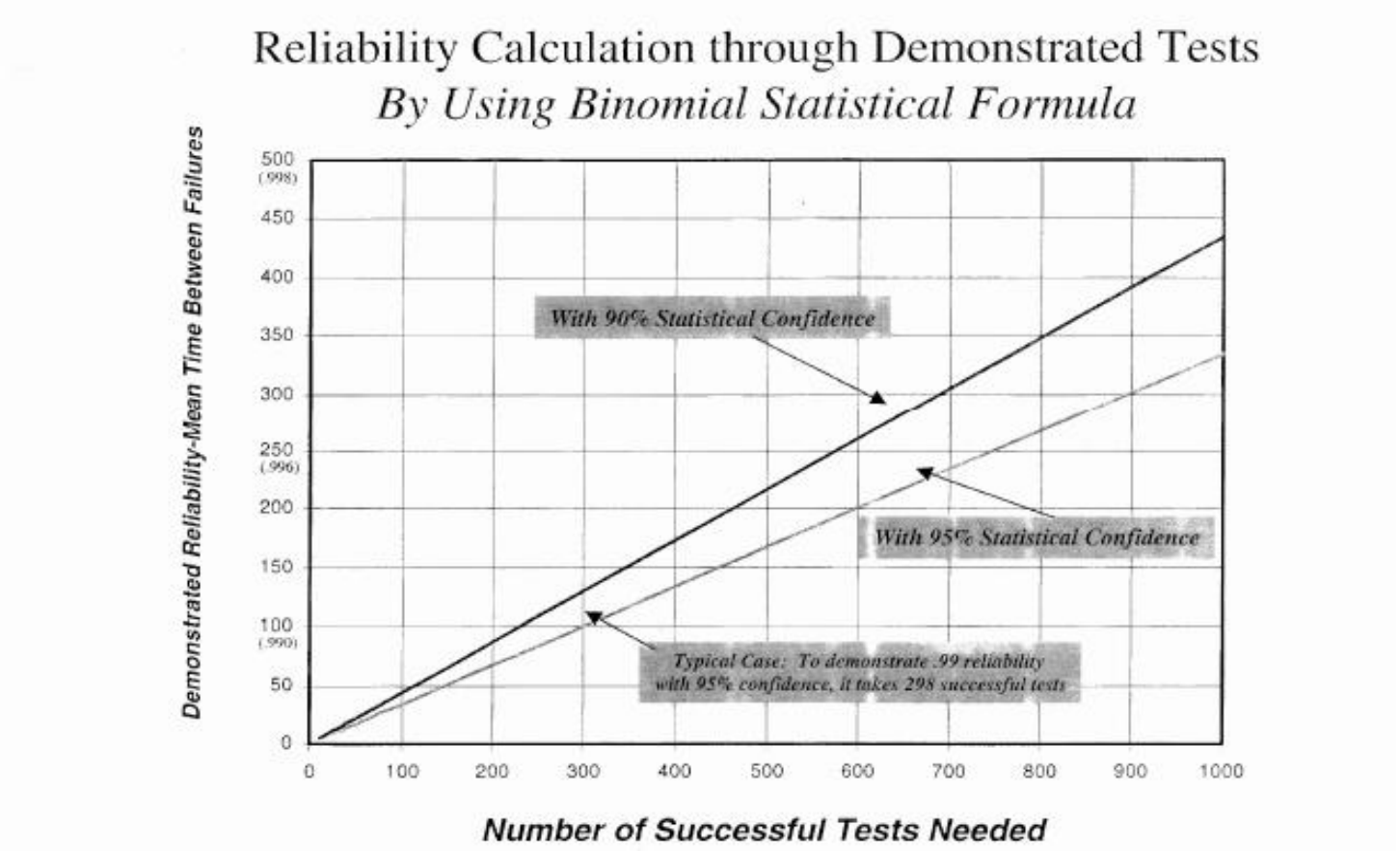
The ET Foam Probabilistic Risk Assessment



Reliability Demonstration

- Reliability Demonstration is the process of quantitatively estimating the reliability of a system using objective data at the level intended for demonstration.
- statistical formulas are used to calculate the demonstrated reliability at some confidence level.
- Models and techniques used in reliability demonstration include Binomial, Exponential, Weibull models, etc..
- Due to high cost and schedule impact of reliability demonstration, programs employed this method only to demonstrate a certain reliability comfort level. For example, a reliability goal of .99 at 95% confidence level is demonstrated by conducting 298 successful tests.

Statistical Confidence

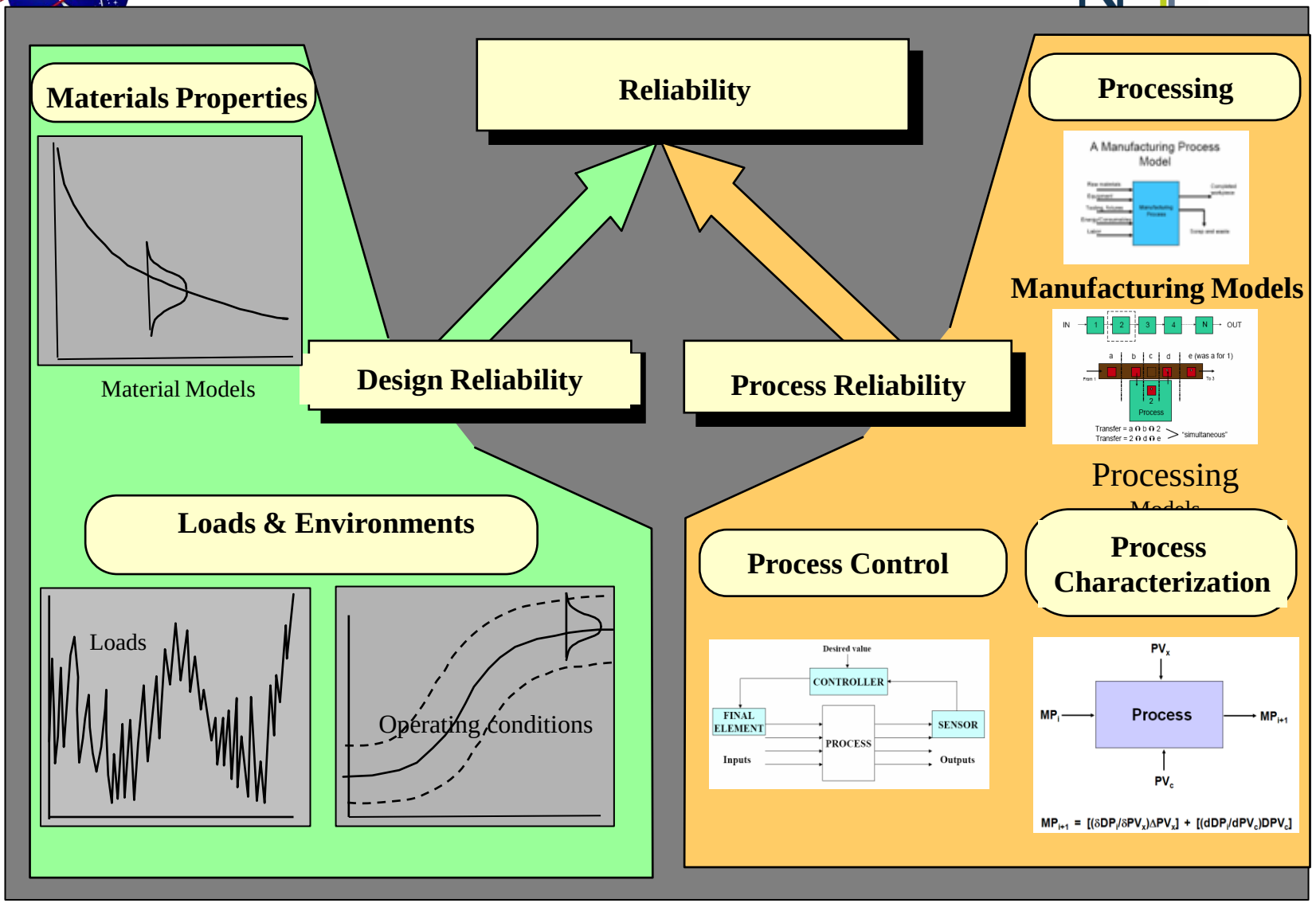


Reliability Predictions

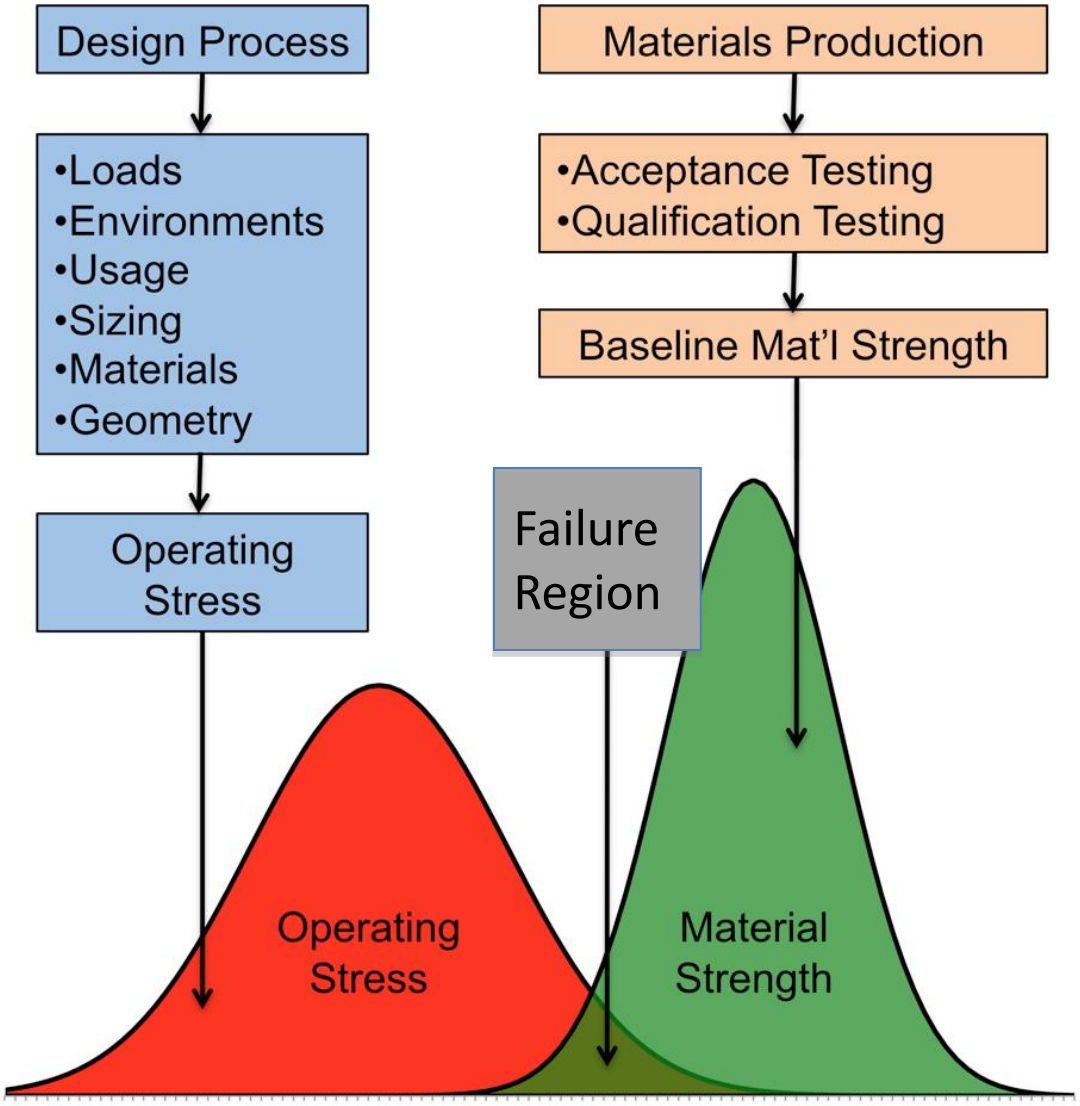
- **Reliability prediction is the process of quantitatively estimating the reliability of a system using both objective and subjective data.**
- **Reliability prediction is performed to the lowest level for which data is available. The sub-level reliabilities are then combined to derive the system level prediction.**
- **Reliability prediction techniques are dependent on the degree of the design definition and the availability of historical data. Examples are:**
  - Similarity analysis techniques: Reliability of a new design is predicted using reliability of similar parts; where failure rates are adjusted for the operating environment, geometry, material change, etc.
  - **Physics-based techniques: Reliability is predicted using probabilistic engineering models expressed as loads and environment vs. capability**
  - Techniques that utilize generic failure rates such as MIL-HDBK 217, Reliability Prediction of Electronic Equipment.

Design VS. Process Reliability

"Design it Right and Built it Right



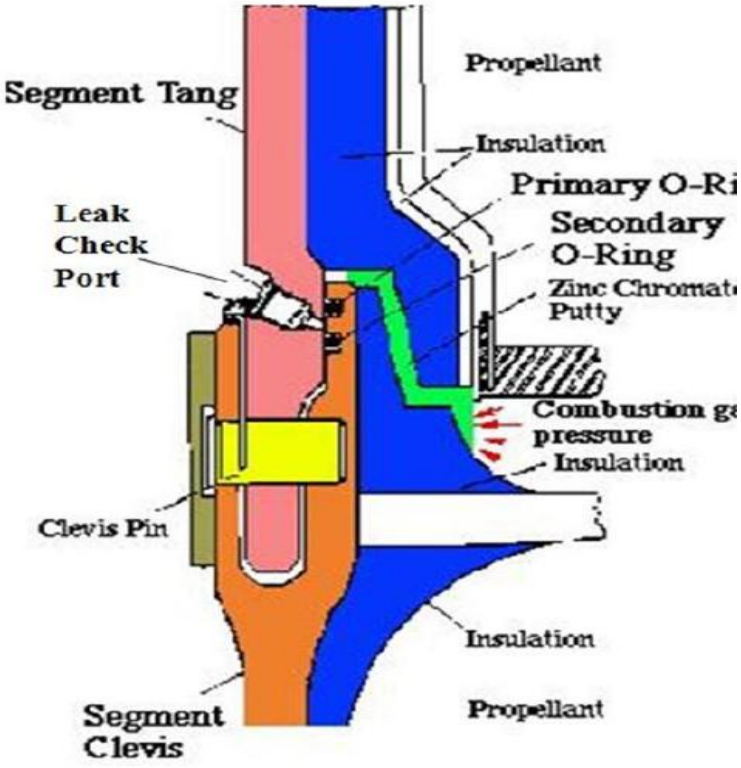
Design Reliability



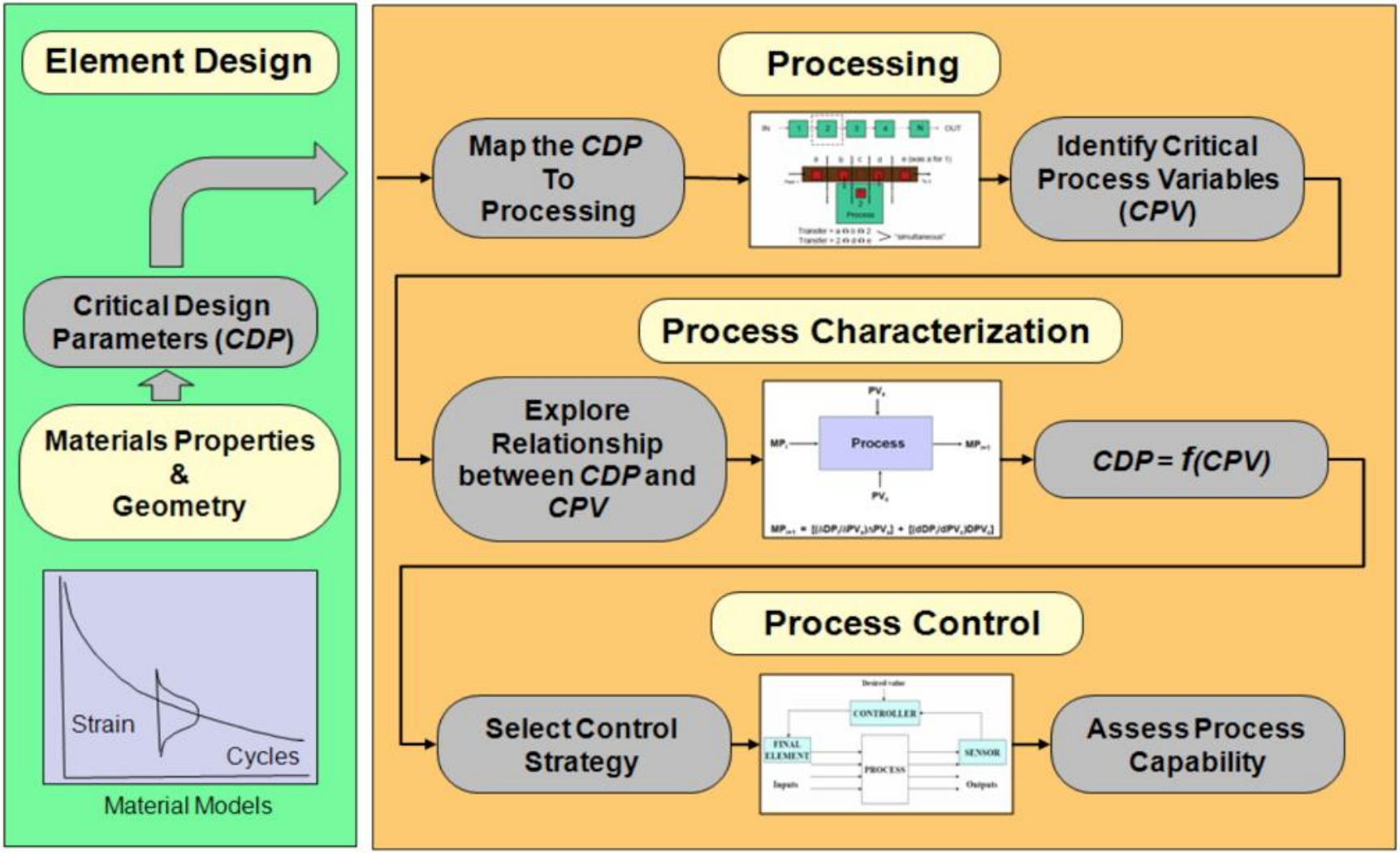
Design Reliability

The Challenger Accident

- **Causes and Contributing Factors**
  - The zinc chromate putty frequently failed and permitted the gas to erode the primary O-rings.
  - The particular material used in the manufacture of the shuttle O-rings was the wrong material to use at low temperatures.
  - Elastomers become brittle at low temperatures.



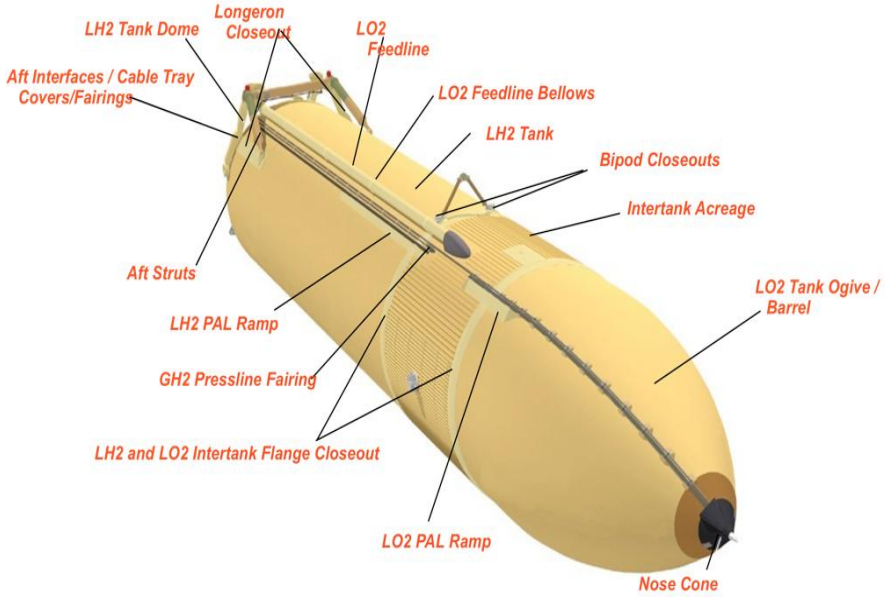
Process Reliability



Process Reliability

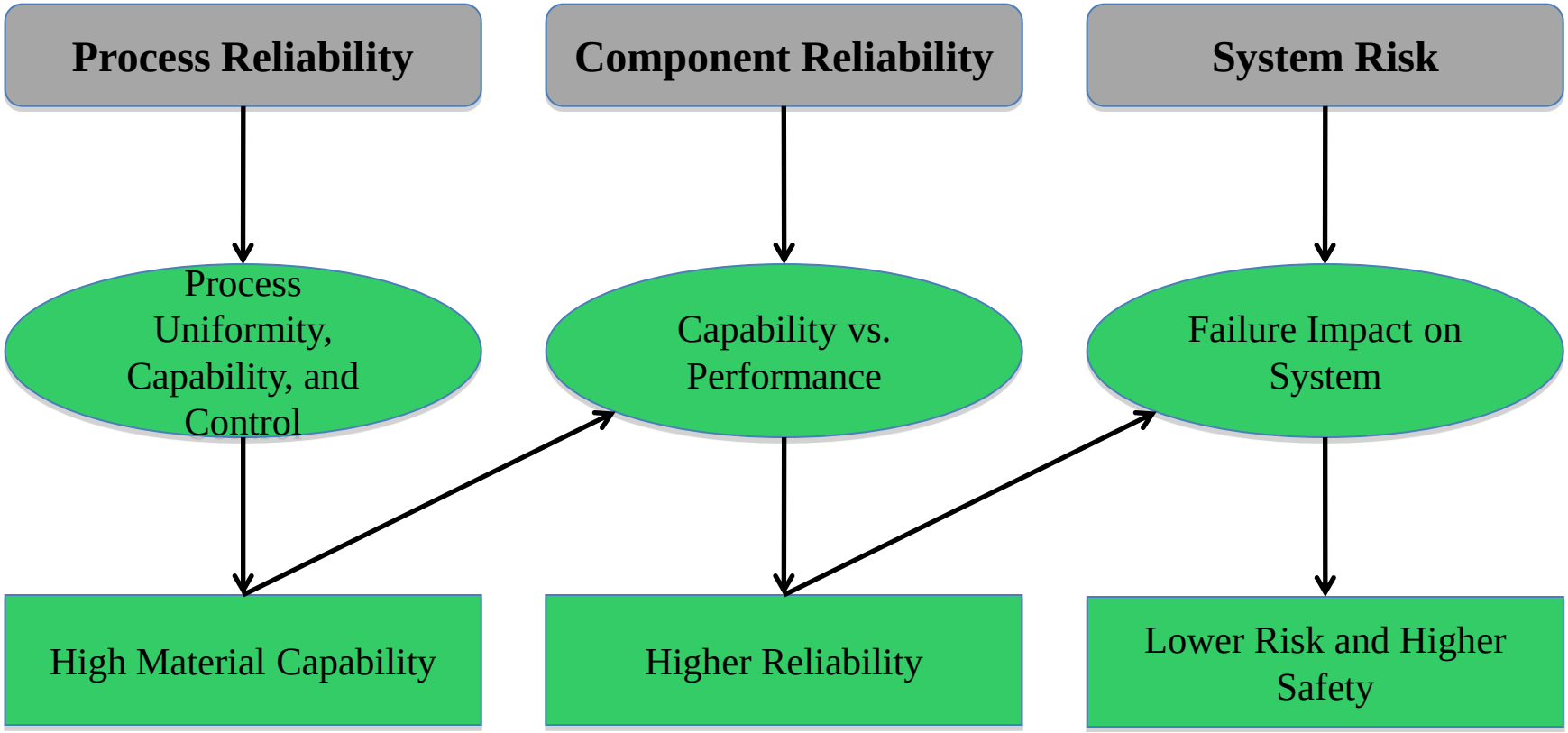
The Columbia Shuttle Accident

- The ET thermal protection system is a foam-type material applied to the external tank to maintain cryogenic propellant quality, minimize ice and frost formation, and protect the structure from ascent, plume, and re-entry heating.
- The TPS during re-entry is needed because after ET/Orbiter separation, premature structural overheating due to loss of TPS could result in a premature ET breakup with debris landing outside the predicted footprint.



Process Reliability

The Quality, Reliability, and Risk Relationship



Concluding Remarks

- Reliability engineering is a discipline while PRA is a process
- Reliability deals with failure analysis focusing on understanding failure mechanisms that could lead to loss of function ; while PRA deals with system risk focusing on understanding the system risk scenarios that could lead to loss of mission or loss of crew.
- Reliability prediction, which is based on objective and subjective data, is intended to help the design process by identifying component, subsystem, and system reliability drivers; while demonstrated reliability, which is based on objective data, is intended to demonstrate certain comfort reliability level in support of reliability prediction.
- Physics based design reliability and process reliability, which are performed on selected failure modes, are critical input to reliability prediction.
- Both reliability prediction and reliability demonstration are critical data source for PRA.