



# RESILIENCE FOR PERMANENT EXTRATERRESTRIAL HABITATS



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## Introduction

In the context of long-term extraterrestrial habitation, **safety** and **resilience** should be given consideration early on: a *planned design of habitats to consider degradation and vulnerability to disasters, and minimize disruptions affecting normal functions.*

We are developing a **System Resilience Framework** to counter these challenges and design sustainable, long-term extraterrestrial habitat systems. This framework addresses the following questions:

- What can go wrong?
- What is the likelihood?
- What are the consequences?
- What should be the level of preparedness?
- What is the recovery time?

### System Resilience ...

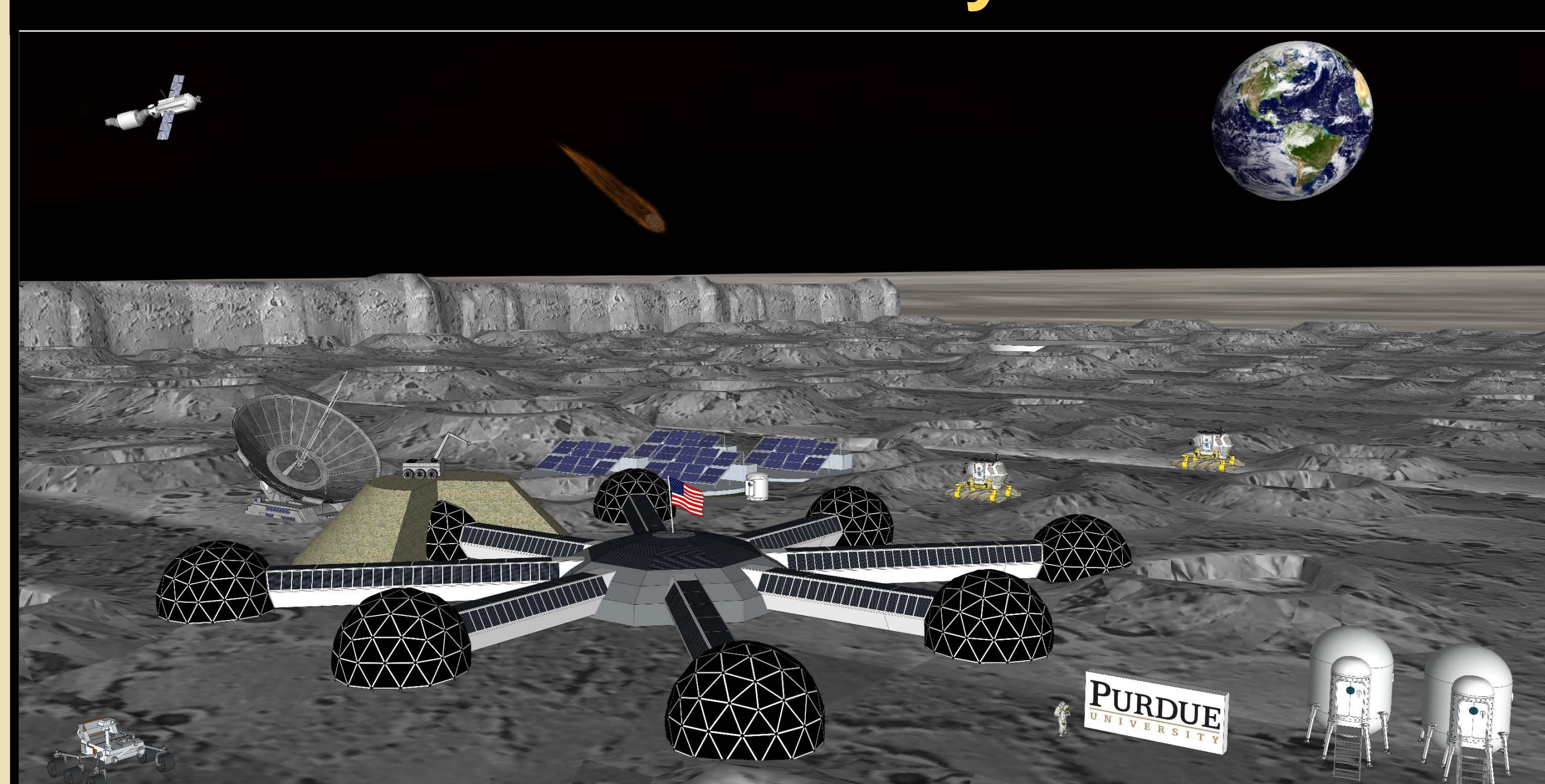
Resilience is the ability of a system to **adapt**, **absorb** and **recover** quickly from a disruption, expected or unexpected, without fundamental changes in function or sacrifices in safety. Resilience is an umbrella under which other factors can be found:

- reconfigurability
- robustness
- scalability
- rapidity

### System Design Criteria ...

- function, as intended, under **continuous disruptive conditions**, such as wild temperature fluctuations, galactic cosmic rays, as well as **discrete disruptive events**, such as meteoroid impacts, vibrations, solar particle events, and equipment failures; and
- meet design objectives under limited in-situ resources.

## Case Study



## Approach

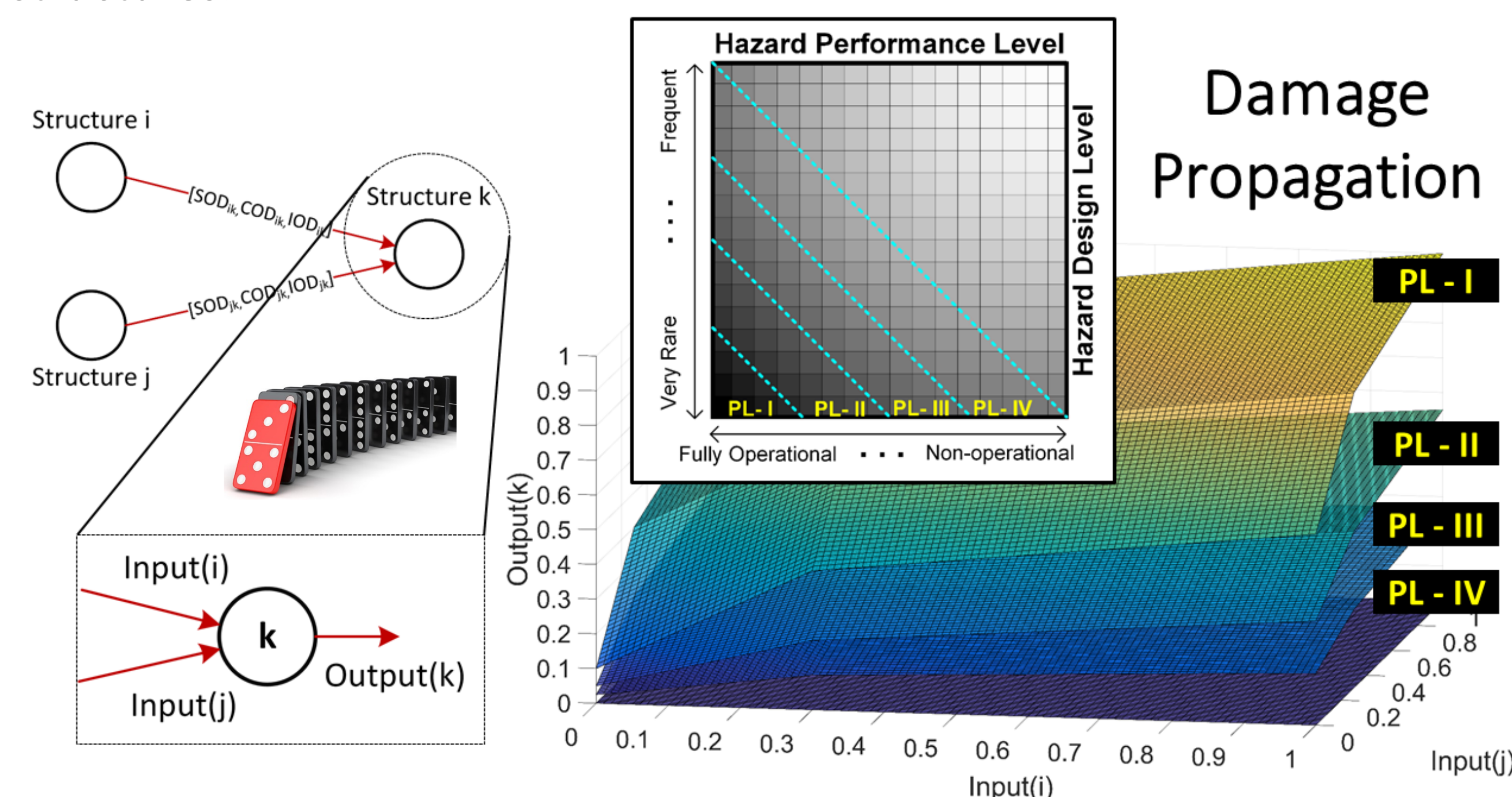
The **civil engineering** community has learned from past natural disasters and the impacts of failures driven by **interdependencies among infrastructure sectors** (Hurricane Katrina and Fukushima nuclear disaster).

The design for structures has evolved/matured, leading to

- **performance-based design (PBD)**
- **consequence-based design (CBD).**



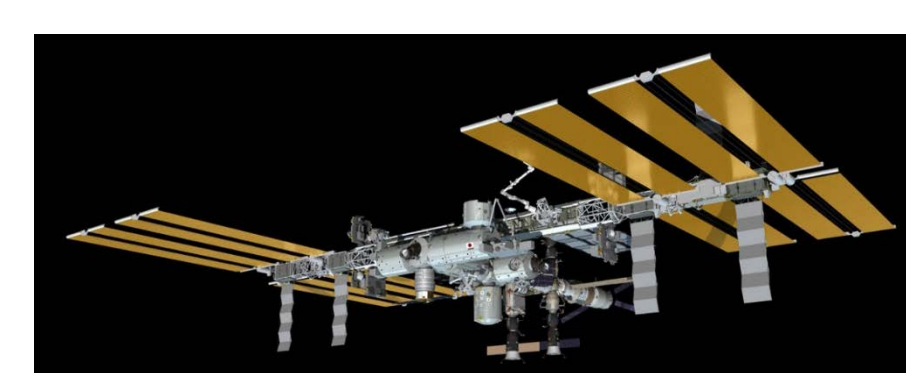
System interdependencies are modeled based on **Systems Operational Dependency Analysis (SODA)**. **Strength of dependency** accounts for the functional dependencies of the structures. **Criticality of dependency** and **Impact of dependency** quantify the functional degradation of a structure due to failure in other structures.



Civil Engineering

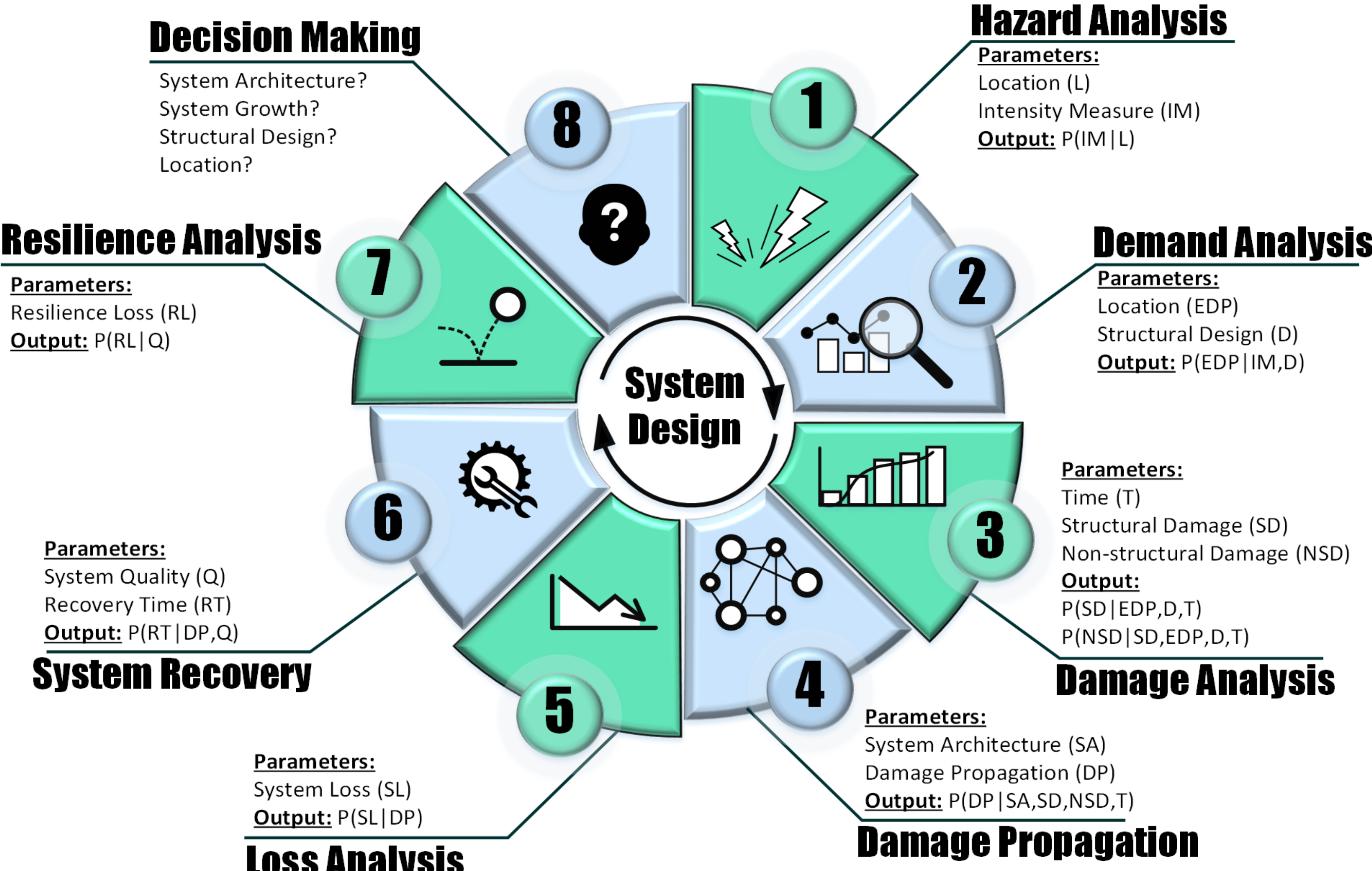
Aerospace Engineering

In our framework, **Probabilistic Risk Assessment (PRA)** is used to obtain the probability of a major accident as a function of the probabilities of subsystem failures.



Our framework considers not only the identification of potentially major accidents and their causes but also the habitat system's

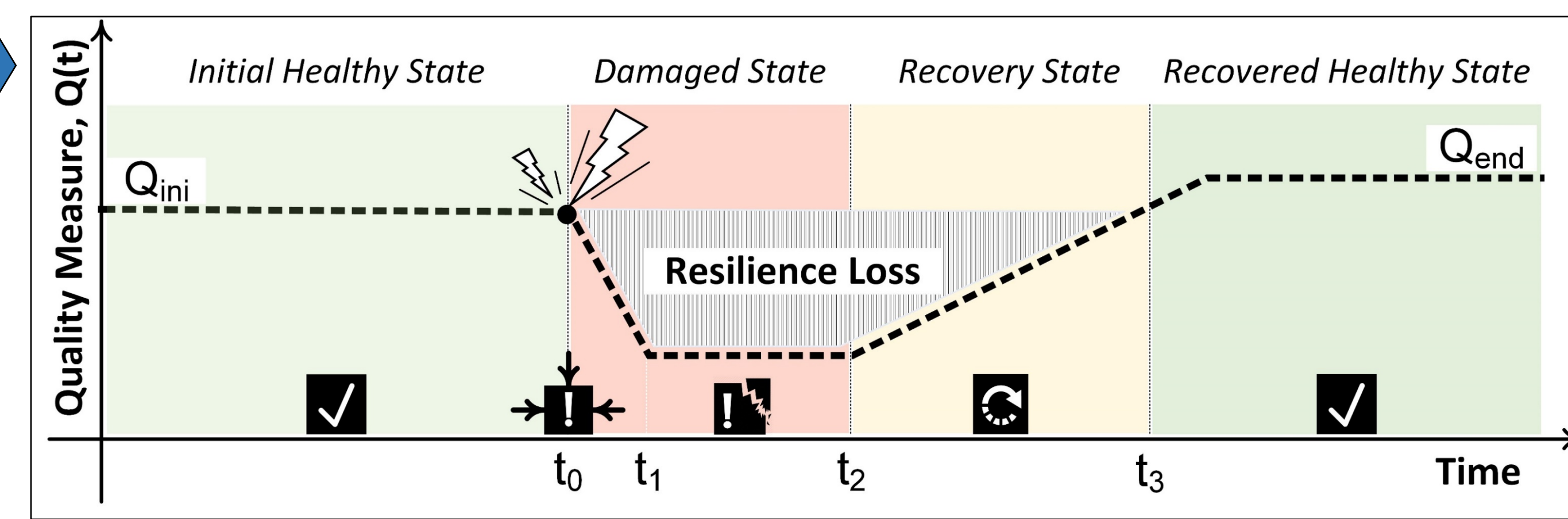
- response
- performance level
- loss
- recovery



Systems Engineering

System Resilience Framework

### System Resilience Framework



Initial Design

Analysis

Evaluation

Decision

Design Iteration