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Extra-terrestrial Habitat Systems: Safety, Reliability, and Resilience

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Background & Motivation

Grand challenge to design resilient extraterrestrial habitats

Envision first Earth-independent human settlement

Current risk-based techniques lack resilience

Critiquing conventional reliability-based design

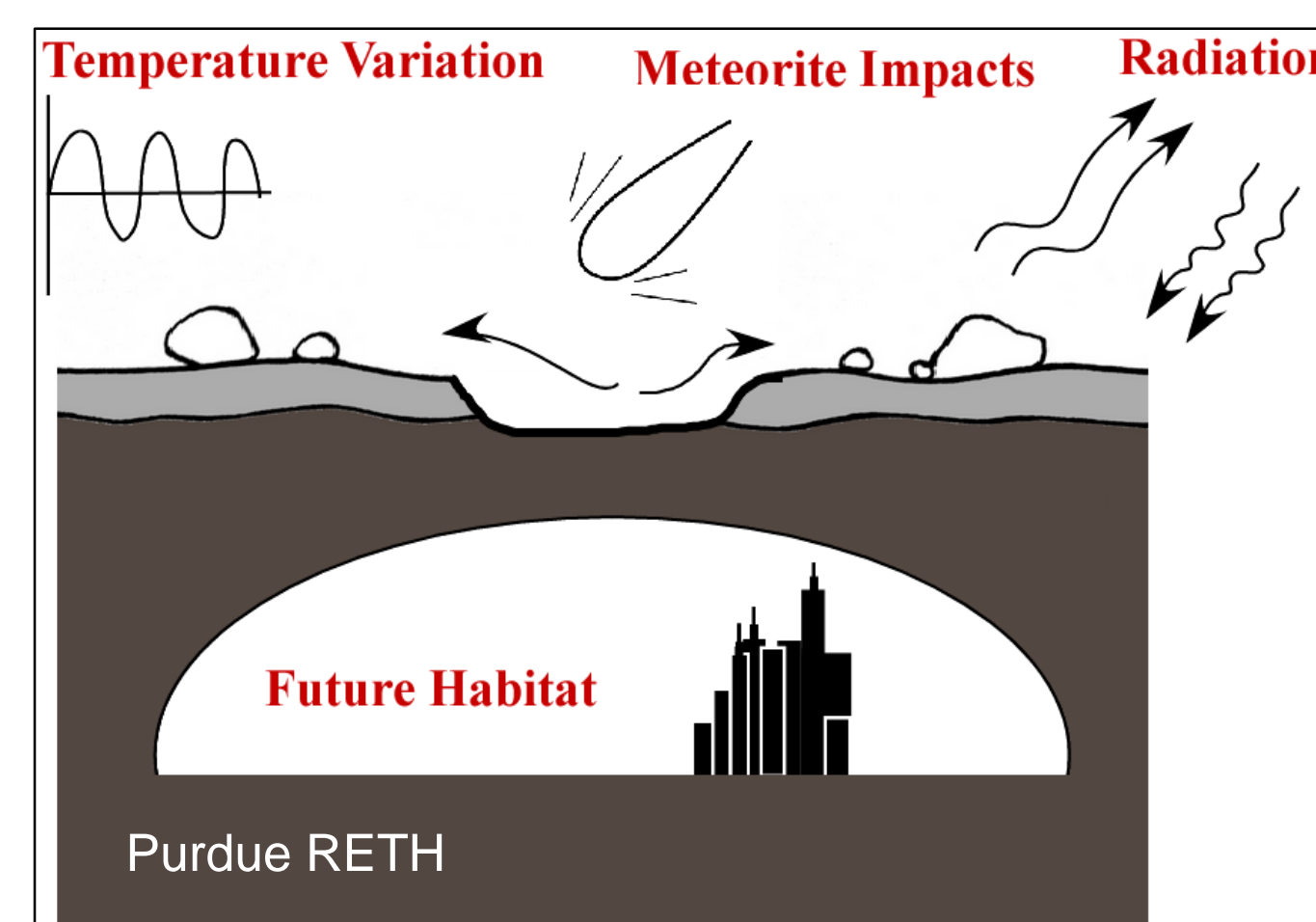
Avoid catastrophic disasters

Apollo 1 fire

Space Shuttle failures

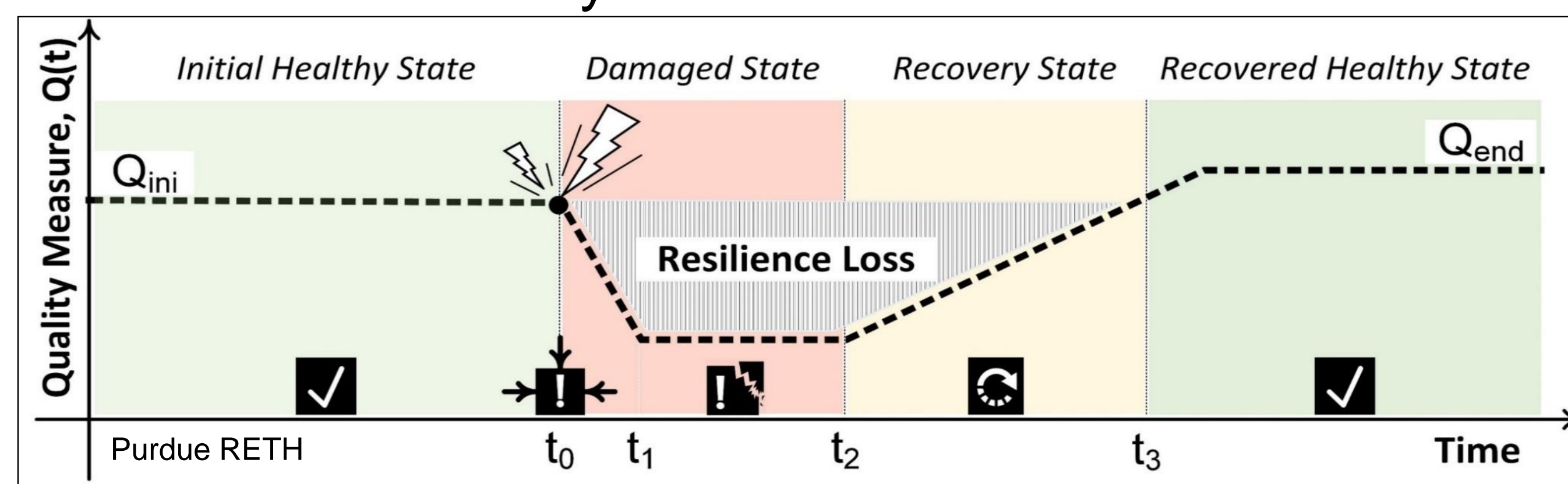
Environmental Hazards

- Temperature extremes
- Hypervelocity Meteoroids
- Radiation
- Moon-quakes
- Atmospheric Vacuum



Proposed Approach: Resilience-based Design

ability for system to absorb, recover, and adapt quickly from disruption without fundamental changes in function or sacrifices in safety



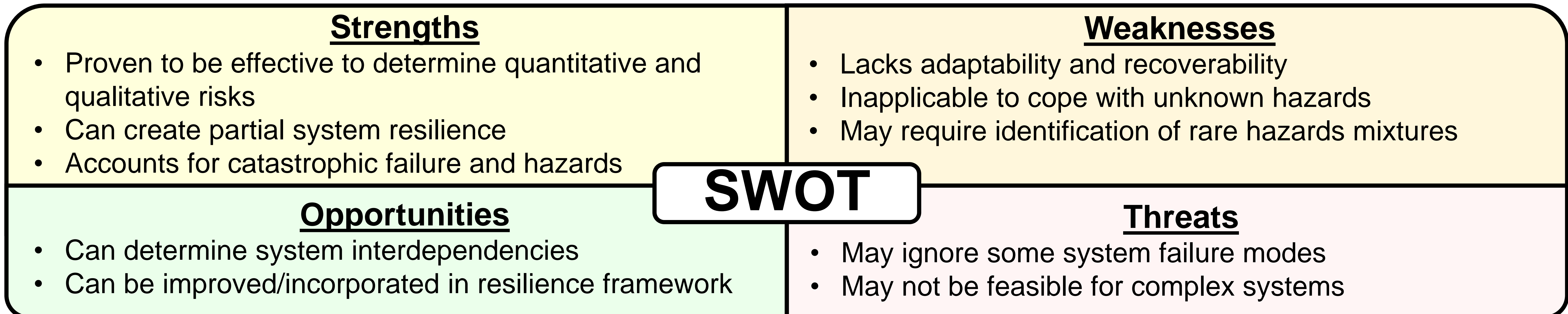
Reliability-Based Approaches

Failure Modes, Effects, and Criticality Analysis (FMECA)

- Occurrence (O), Severity (S), Detection (D)
- Risk Priority Number (RPN = O*S*D)
- Criticality Number: identify and rank importance
- Helps tell which failures to fix and data to acquire

Probabilistic Risk Assessment (PRA)

- Includes FMECA or FMEA
- Fault Tree Analysis (FTA)
- Event-sequence Diagram (ESD)
- Uses FMECA
- Determines more failures and combinations
- May include *partial* or full FMECA
- Quantitative and qualitative



Identification Number	Component Name	Component Function	Failure Mode(s)	Mission Mode	Failure Cause(s)	Failure Effects
1	Parachute	Landing	Deployment failure	Landing	Stuck / jammed	Unrecoverable rocket

Failure Detection Method	Occurrence Index (O)	Severity Index (S)	Detection Index (D)	Risk Priority Number (O)*(S)*(D)	Data Source	Damage Mode	Damage Effects
None	4	5	5	100	Estimate	Use	More probable

Failure Effect Probability (β)	Failure Mode Ratio (α)	Failure Rate (λ _p)	Conditional Probability of Detection	Operating Time (t)	Criticality Number	Item Criticality	Remarks
1.000	0.900	0.0100	1.000	1	0.009	0.024	Need backup

Case Study

