Intelligent Structural Health Management of Safety-Critical Structures

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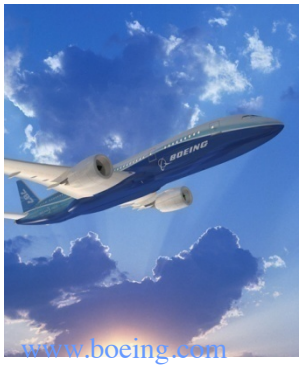


McCormick

Northwestern Engineering

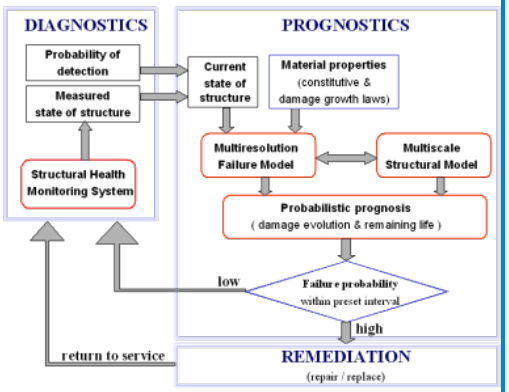
Center for Quality Engineering & Failure Prevention

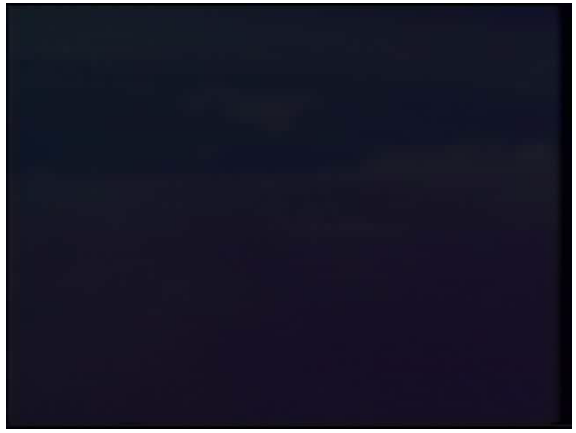
Mission: *The center's mission is to be at the global forefront of cross-disciplinary research and education in the area of* ***Intelligent Structural Health Management*** *of aerospace, civil and mechanical structures.*

Research Theme

Intelligent Structural Health Management (ISHM) systems facilitate prevention of catastrophic structural failure by incorporating smart multifunctional structures and closed-loop diagnostics-prognostics. The Center's focus on ISHM involves cross-disciplinary integration of several emerging and some mature subfields of science and engineering:

- **sensors and smart structures**
- **multifunctional materials**
- **self-assembled sensors**
- **structural health monitoring**
- **nondestructive evaluation**
- **damage and failure mechanics**
- **structural reliability analysis.**





Center Facts

- CQE is an interdisciplinary unit of the McCormick School with faculty from ME, CEE, and MSE.
- Center funding from FAA, NIST, ONR, AFOSR, DOT, Honeywell, GE etc averaging in excess of $1M per year for the past 17 years.
- Active international partnerships with China, Korea, India, Hong Kong

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www.cqe.northwestern.edu
ishm.northwestern.edu

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Crude by Rail

The Risks:

Edmonton Journal

Technological solution:

Safer Tracks

Safer Trains

Structural Reliability

Why do structures fail?

Genetic: faulty construction
Disease/**accidents**: collisions, earthquakes
Aging: fatigue, environmental degradation

How can we prevent structural failure?

- Routine physical exam
- (**scheduled maintenance**)

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Track Inspection Rules

Department of Transportation

Federal Railroad Administration

49 CFR Part 213

Track Safety Standards; Improving Rail Integrity; Final Rule

Scheduled Maintenance

The final rule also requires that internal rail inspections on Class 4 and 5 track, and Class 3 track with regularly-scheduled passenger trains or that is a hazardous materials route, not exceed a time interval of 370 days between inspections or a tonnage interval of 30 mgt between inspections, whichever is shorter. Internal rail inspections on Class 3 track without regularly-scheduled passenger trains and that is not a hazardous materials route must be inspected at least once each calendar year, with no more than 18 months between inspections, or at least once every 30 mgt, whichever interval is longer, but in no case may inspections be more than 5 years apart.

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Materials Assessment During Component Life Cycle: Conventional Approach

- **Materials assessment during fabrication**:
  - *initial* material properties assessment
  - process monitoring

- **Materials assessment during maintenance**:
  - material degradation due to service / environment
  - intrusive NDI ***scheduled regularly***

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Materials Assessment During Component Life Cycle: Evolving Approach

- **Materials assessment during fabrication**:
  - *initial* material properties assessment
  - process monitoring

- **Materials assessment during service**:
  - *in-situ* real-time structural integrity assessment
  - **structural health monitoring**

- **Materials assessment during maintenance**:
  - material degradation due to service / environment
  - intrusive NDI ***scheduled as required***

Structural Reliability

Why do structures fail?

Genetic: faulty construction
Disease/accidents: collisions, earthquakes
Aging: fatigue, environmental degradation

How can we prevent structural failure?

- Routine physical exam
- (**scheduled maintenance**)
- consult doctor as needed because of fever, pain…
- (***maintenance on demand***)

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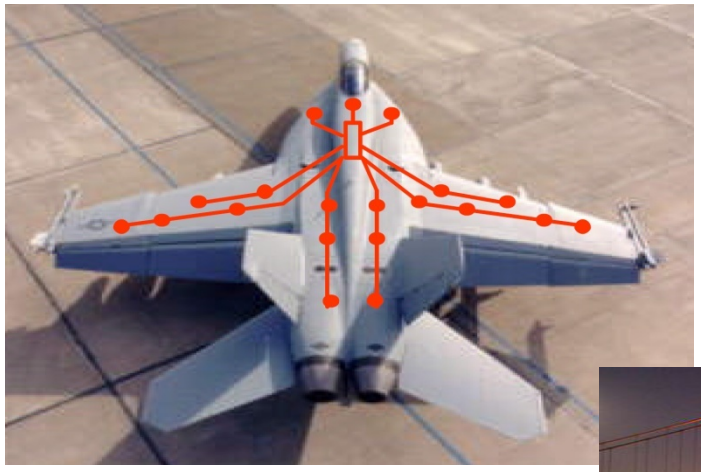
Structural Health Monitoring

Structure senses and reports on its condition:
overload / fatigue / corrosion / erosion
collisions /bird impact / earthquakes /



Optical fiber sensors
Guided-wave ultrasonic sensors
Wireless acoustic emission sensors

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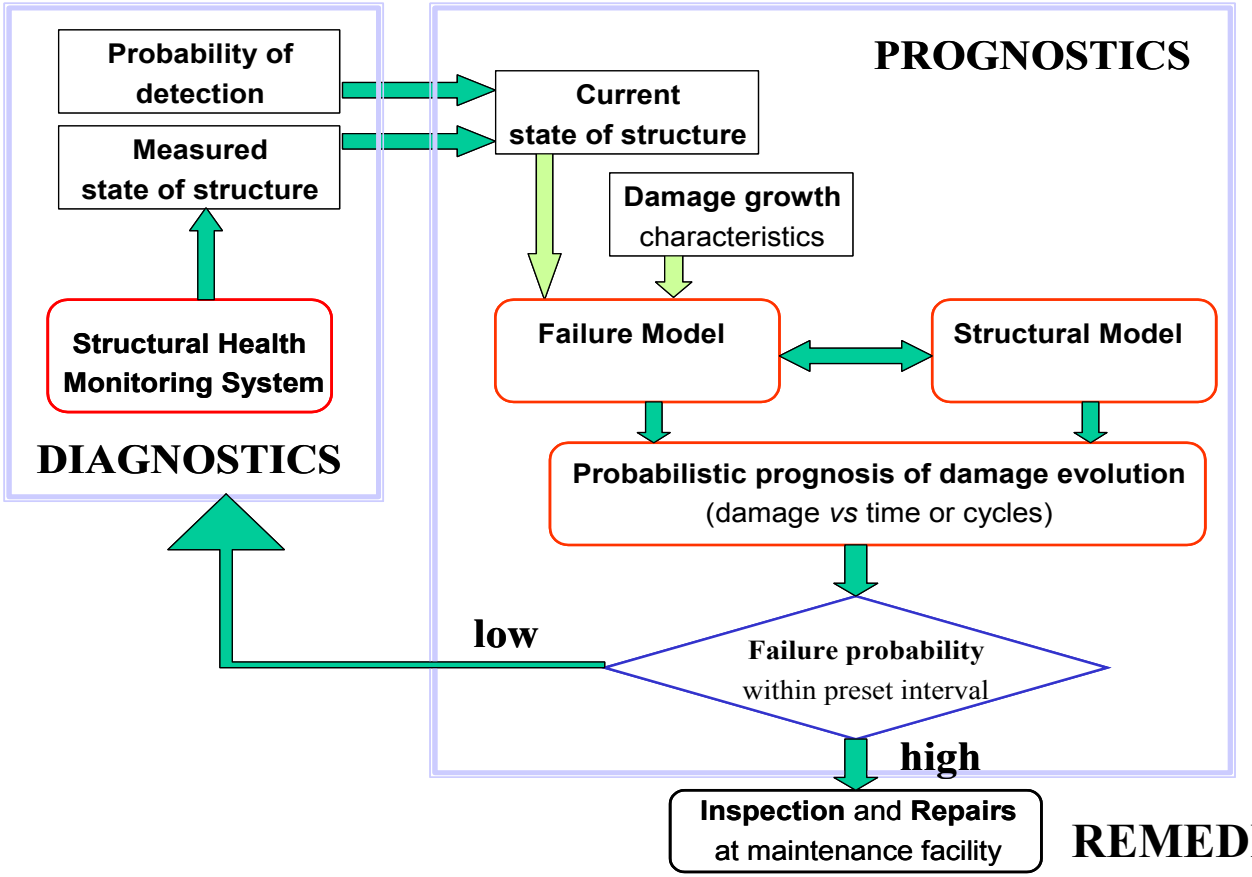
Intelligent Structural Health Management of Safety-Critical Structures

Intelligent Structural Health Management systems facilitate taking timely remedial actions in order to prevent catastrophic structural failure by incorporating real-time diagnostic sensor data for **closed-loop prognosis** of remaining structural integrity.



- sensor technology
- smart structures
- materials science
- nondestructive characterization
- structural analysis
- failure models
- probabilistic prognosis of remaining lifetime
- decision-making
- remediation

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Structural Health Monitoring of Trains and Tracks

www.youtube.com/watch?v=zAKQYkMdLfQ

Distributed fiber-optic **sensors**, guided acoustic wave sensors etc can provide **real-time information** about:

- the state of the **tracks** ahead
- the state of **bridges**
- the state of the **train** (wheels, axles etc)
- presence of **other trains**

to make a real-time assessment of the safety and structural integrity of the train and the tracks ahead.

An example from China:
https://youtu.be/4R9BImwH0rI

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Crude by Rail