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A Conceptual Model for "Inherent Reliability" for Nuclear Weapons

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Outline

- Background
- Review of the bathtub curve model
- Inherent vs. estimated reliability
- Proposed new model for nuclear weapon reliability
- Considerations for the new model

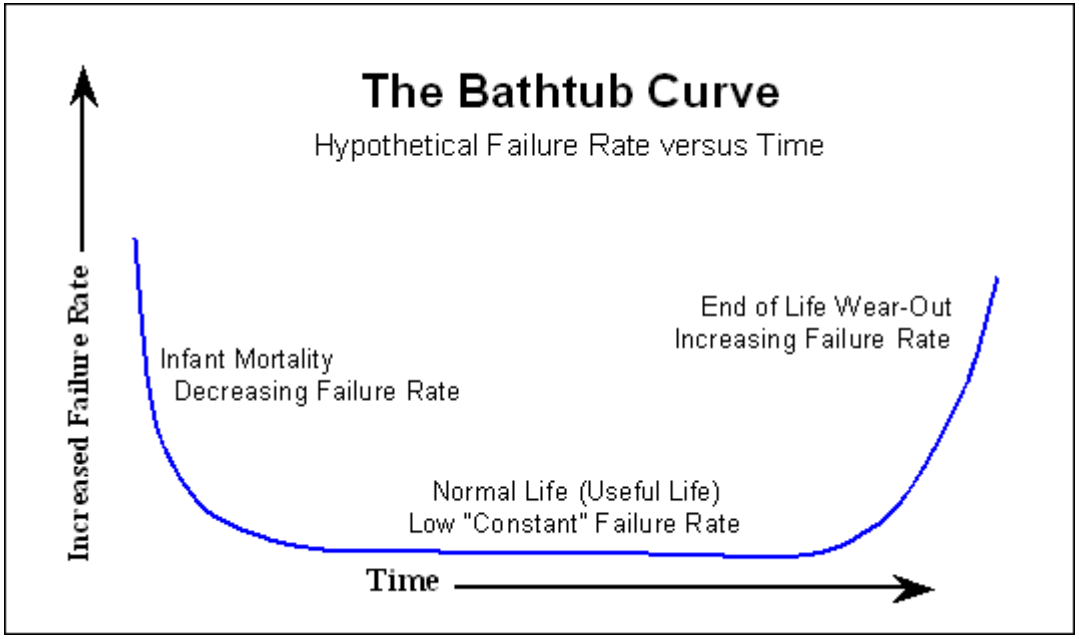
Background

- Nuclear weapons are generally considered as one-shot devices
  - Operational time (on the order of seconds) << dormant storage time (decades)
  - May have subsystems capable of multiple operations, but overall use characterized as “go/no-go” upon selection

Background

- Nuclear weapons characterized in terms of **failure probability** – what is the probability that a weapon will fail to achieve the specified nuclear output if functioned?
  - Percentage of failures observed in a given number of weapons operated
- Contrast with performance for continuously operating devices in terms of **failure rate**
  - Number of observed failures divided by the operating time

Bathtub Curve Model



http://www.weibull.com/hotwire/issue21/ht21_1.gif

Bathtub Curve and One-Shot Devices

- “Infant mortality” and “wear-out” refer to failures that are experienced during (and as a result of) operation
  - Not relevant to one-shot devices that spend most of their lives in dormant storage
- We can never infer from nuclear weapon testing when a defect has occurred – only that it occurred sometime between the present test and any prior applicable test

Bathtub Curve and One-Shot Devices

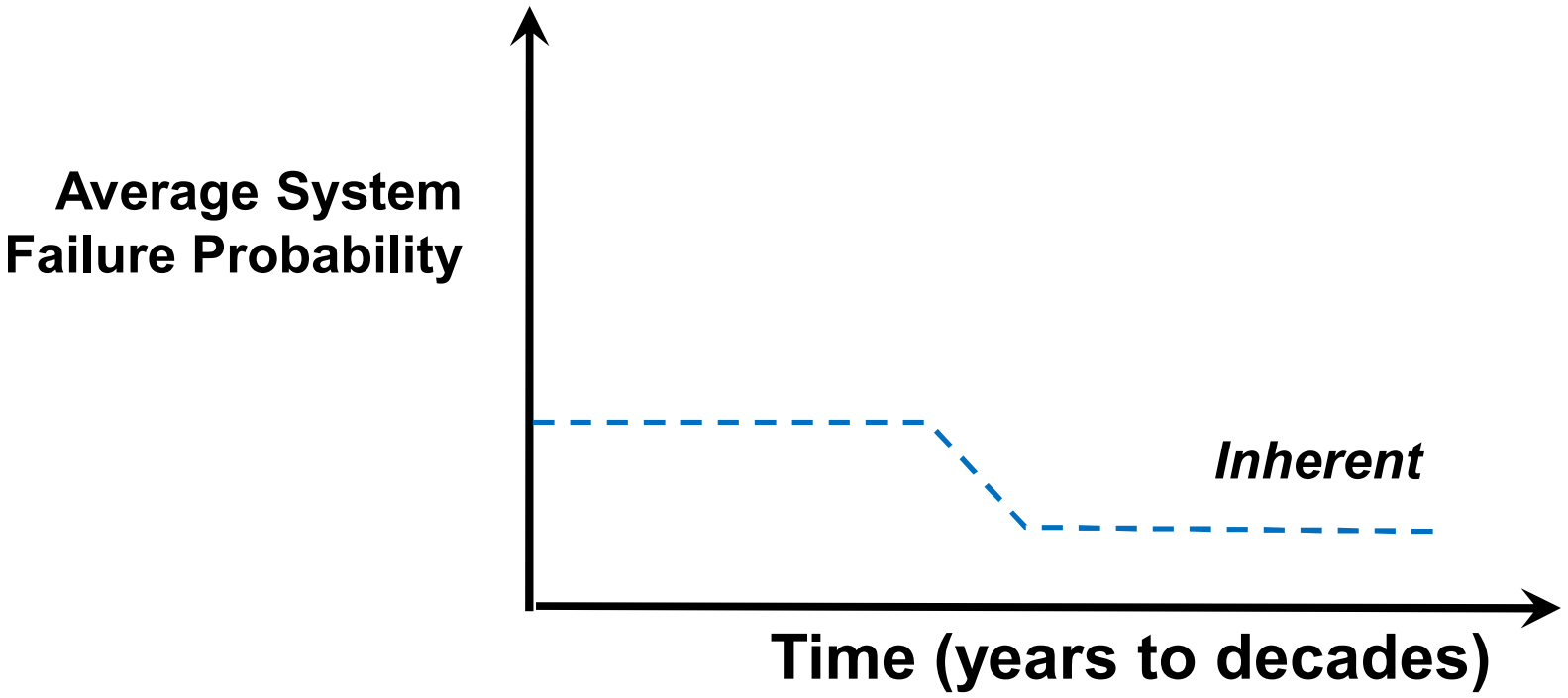
- Continuously operating systems allow for immediate detection and removal of defects when they occur
  - Infant mortality defects remove themselves from the population by failing during operation early on
- Not so for weapons…
  - Unknown defects may be present for long periods of time degrading reliability
  - Birth defects do not get removed unless sampling and testing is done to find them and then action taken to fix them

Inherent vs. Estimated Reliability

- Inherent reliability
  - "Is what it is" but is never known
- Estimated reliability
  - Estimate of inherent reliability based upon knowledge gained through experience, testing, and analysis

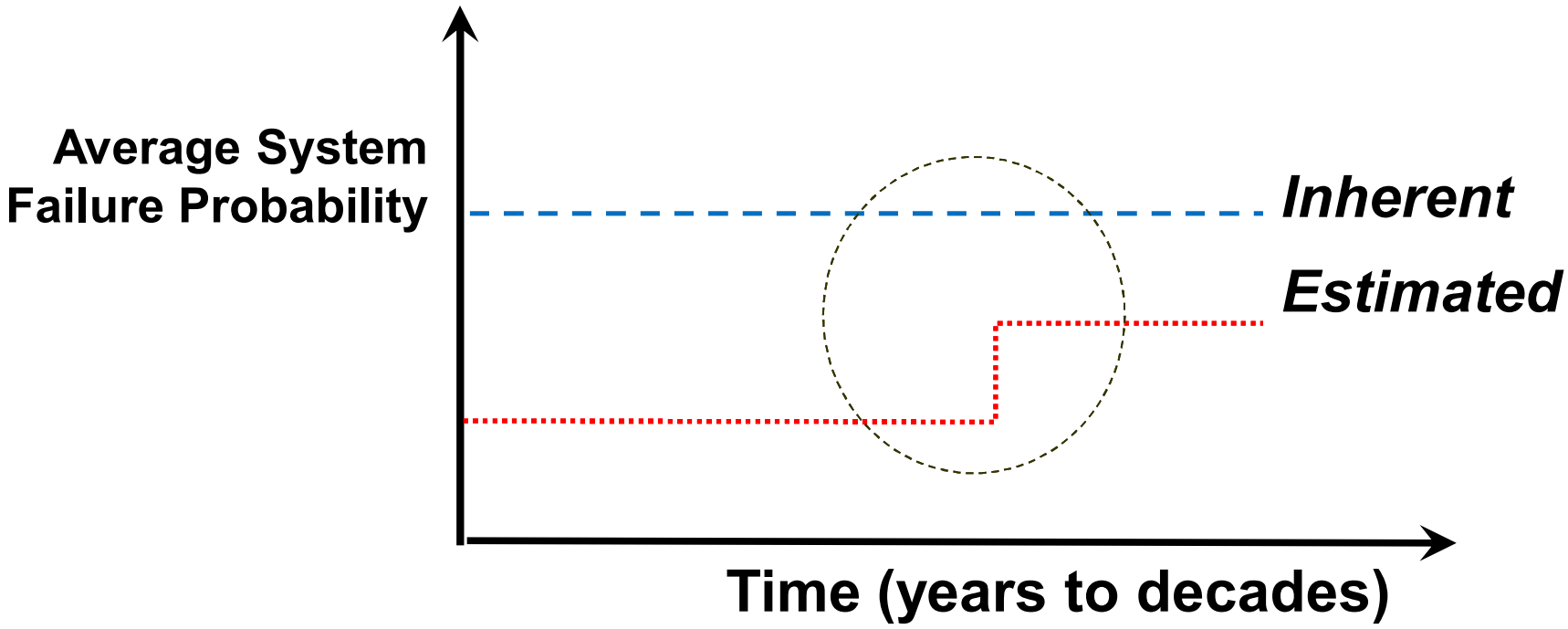
- *For nuclear weapons and other one-shot devices, the goal is to have these converge over time*

Example: Changing Inherent Reliability



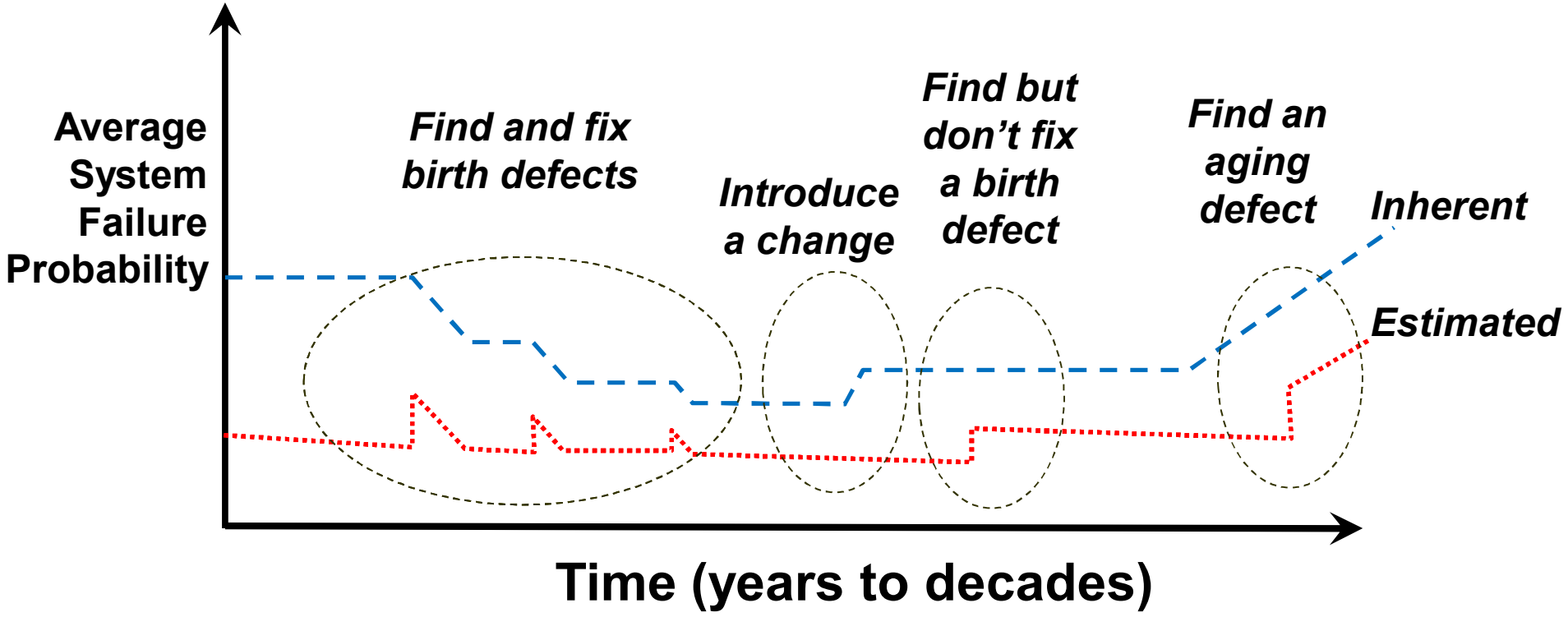
Fixing an existing stockpile defect

Example: Relationship of Inherent and Estimated Reliability



Finding and assessing an existing stockpile defect

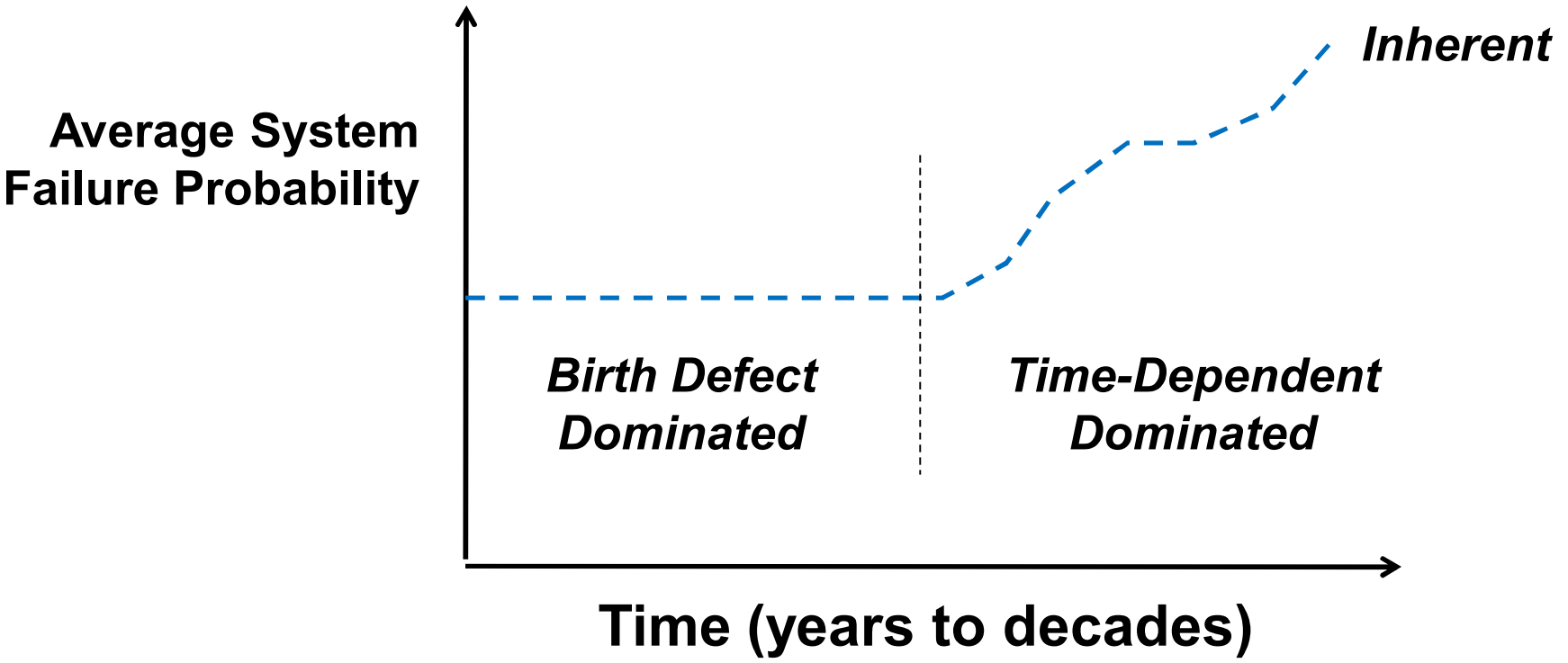
Example: Relationship of Inherent and Estimated Reliability



New Model for Nuclear Weapons

- Why a new model?
  - To combat a general belief that defects in one-shot devices will “reveal themselves” through infant mortality and wear-out
  - To underscore that the convergence of inherent reliability and estimated reliability depends upon an active, on-going search for defects
- Two regimes: Birth Defect Dominated and Time-Dependent Dominated

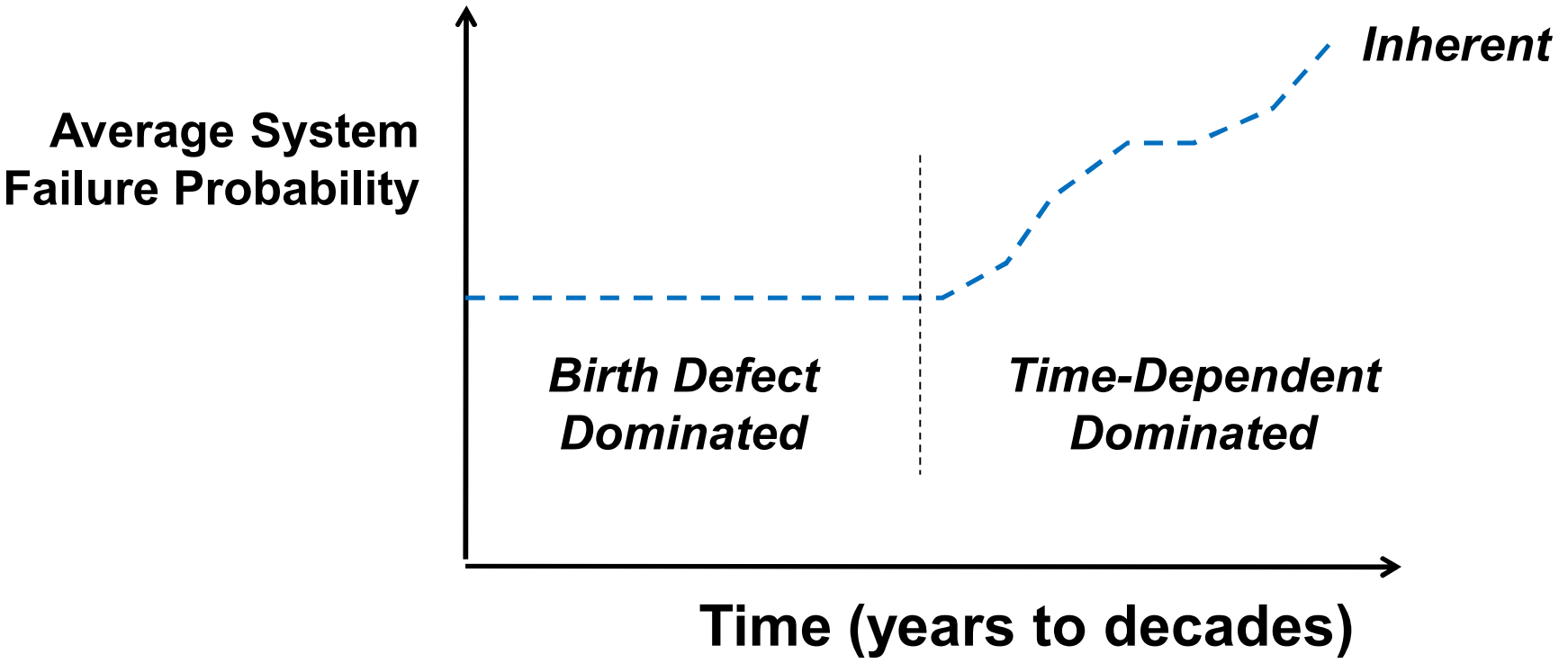
New Model for Nuclear Weapons



New Model for Nuclear Weapons

- Birth Defect Dominated:
  - Begins at production, characterized by defects that are in the weapons when they enter the stockpile
    - Design errors, production or assembly problems, or material flaws that were not detected during product acceptance testing
  - These defects are in the stockpile from Day 1 and will remain there unless fixed – and of course, fixing them requires them to be found first

New Model for Nuclear Weapons



New Model for Nuclear Weapons

- Time Dependent Dominated:
  - Begins when there is onset of time-dependent defects affecting reliability… but the transition point is unknown
  - To date, few time-dependent issues that affect performance
  - However, changes in materials/parameters indicate time-dependent behavior, even if it doesn't yet affect performance
- Defects are not due to wear, but arise during dormant storage as materials change with age
- As with birth defects, these will not be detectable without on-going evaluation

Why is the Bathtub Curve Inferred?

- Test program is “front-loaded” – more tests early in life
  - Consequence is that there are more opportunities to detect existing birth defects
- Basic statistics
  - Bigger problems tend to require fewer tests to find
- ***It is critical to avoid a false sense of security – few defects detected over time may indicate a deficient test program rather than a robust product***

Considerations for the New Model

- Explicit action required to achieve convergence of the estimated reliability with the inherent reliability for one-shot devices, through sampling, testing, and analysis
- Interpretation of defect detection history for one-shot devices must be done carefully with consideration of the underlying evaluation program
  - More tests will typically yield more defects
  - Normalizing with respect to test quantities may be helpful

Considerations for the New Model

- One must generally take action to improve reliability for one-shot devices when defects are found; this is different for the case of continuously operating systems where failed units essentially remove themselves from the population
- Testing continues to be important as systems age and potentially enter the regime of time-dependent change