Designing for Reliability: Thin-Film Building Integrated Photovoltaic Modules

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Purpose

- Review Reliability Challenges for PV, Thin Film and BIPV
- Emphasize Importance of Reliability
- Purpose a Reliability Methodology and Process
  - Design for Reliability Process
  - Reliability Best Practices
- Introduce a Staged Approach to Reliability Assurance
- Provide a Quantitative Example – Temp Humidity Test
- Gather Feedback and Consensus

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Reliability Challenges for PV

1. Incorporation of reliability methodologies in the product development process
2. Assuming current qualification testing is a reliability prediction
3. Instituting test to failure
4. Failure Modes and Effects Analyses that adequately capture field experience
5. Accelerated test models
6. Increased acceleration factors – without compromising prediction
7. Combined simultaneous stress effects
8. Quantitative reliability analysis tools/techniques

Reliability Challenges for Thin Film and BIPV

- Thin Film Reliability Challenges
  - Potential for New Failure Modes and Mechanisms
  - Acceleration Factors for Accelerated Tests Largely Unknown
  - Limited, Long Term Field Data to Develop Correlations with Accelerated Testing
  - Metastable Effects (e.g. light, thermal, bias induced)
- BIPV Reliability Challenges
  - Multifunctional Design – additional interfaces and requirements
  - Roof Functionality (wind, hail, rain)
  - Retention of Aesthetics

Importance of Reliability

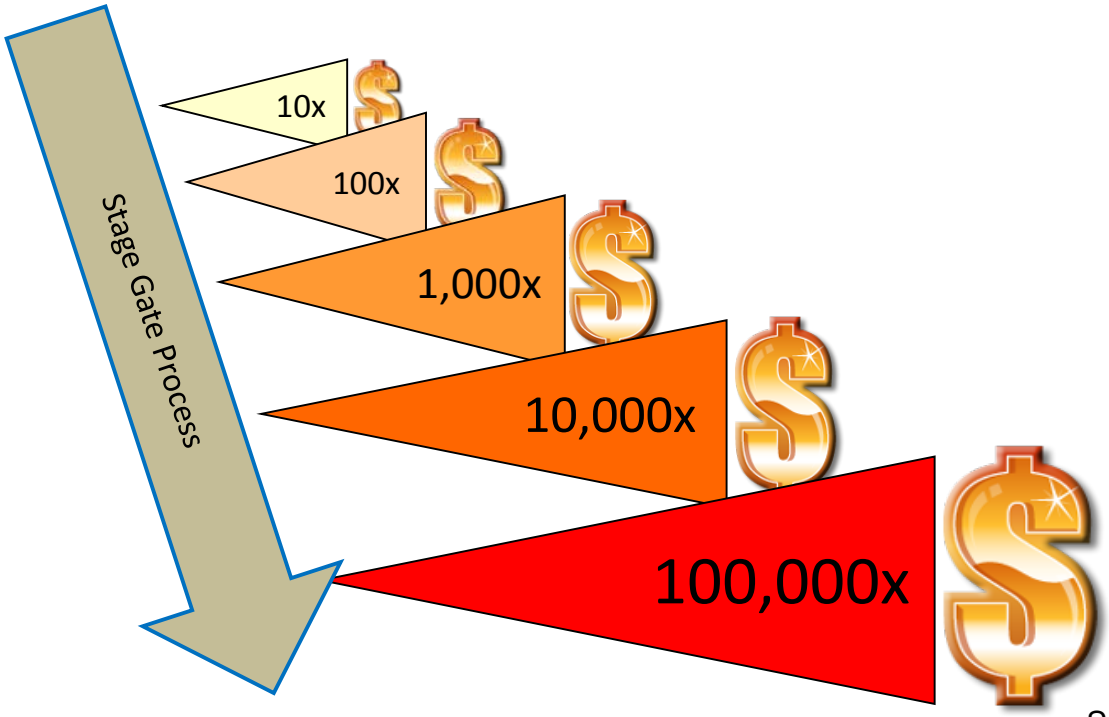
- Customer Expectations
  - Long Operational Life (20+ years)
  - “Trouble-Free” Operation
  - Predictable Financial Return
- Impact of Reliability Failures – Company Level
  - Destruction of Brand Integrity
  - Product Claims
  - Reduced Sales
- Impact of Reliability Failures – Industry Level
  - Negative Perception of PV
  - Reduced Future PV Market Size

Pay Now or Pay Later

Factor of 10 Rule

If you discover a reliability problem in this stage…

…it will cost you this much



TOYOTA

Source: Reliasoft

Product recalls and field repairs can be extremely expensive, for example, it is reported that Xbox field issues have cost Microsoft more than a billion dollars

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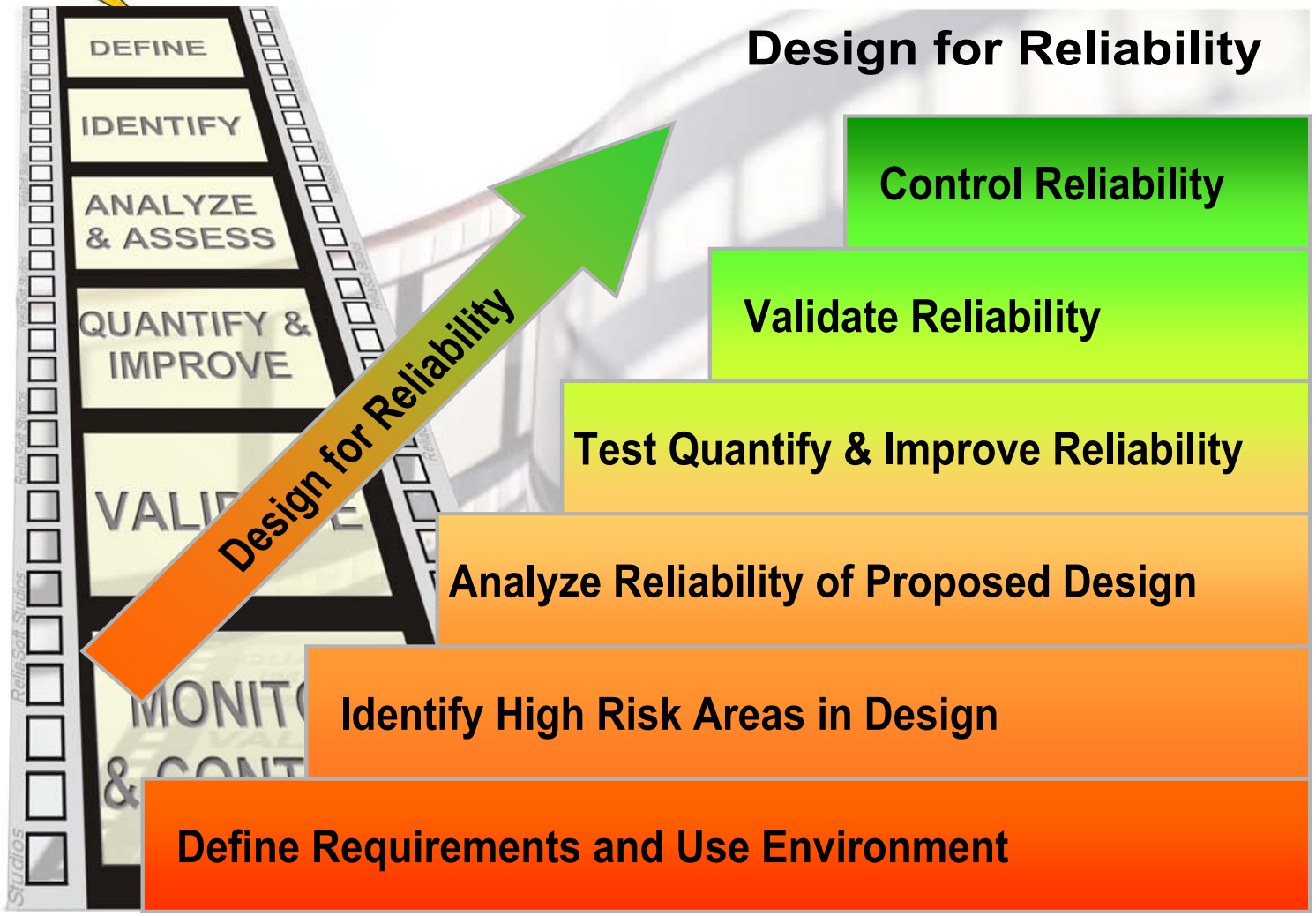
Taub, E., "Microsoft to Spend $1.15 Billion for Xbox Repairs", The New York Times, July 6 (2007).

Design for Reliability Process



Source: Reliasoft

Reliability Best Practices

Concept Stage
- System Operating Conditions
- System Reliability Requirements
- Flow Down of Requirements to Subsystems and Components
- Identify Reliability Critical Components

Design Stage
- Design Margin Analysis
- Failure Modes and Effects (FMEA)
- Virtual Modeling (FEA)
- Physics of Failure (POF)
- Highly Accelerated Testing (HALT)

Assurance Stage
- Accelerated Life Testing Methods
- System Reliability Model
- Supplier Reliability
- Reliability Growth

Manufacturing Stage
- Manufacturing Control (SPC, QA/QC)
- Field Test Plans
- Preventative Maintenance
- Verification of Reliability

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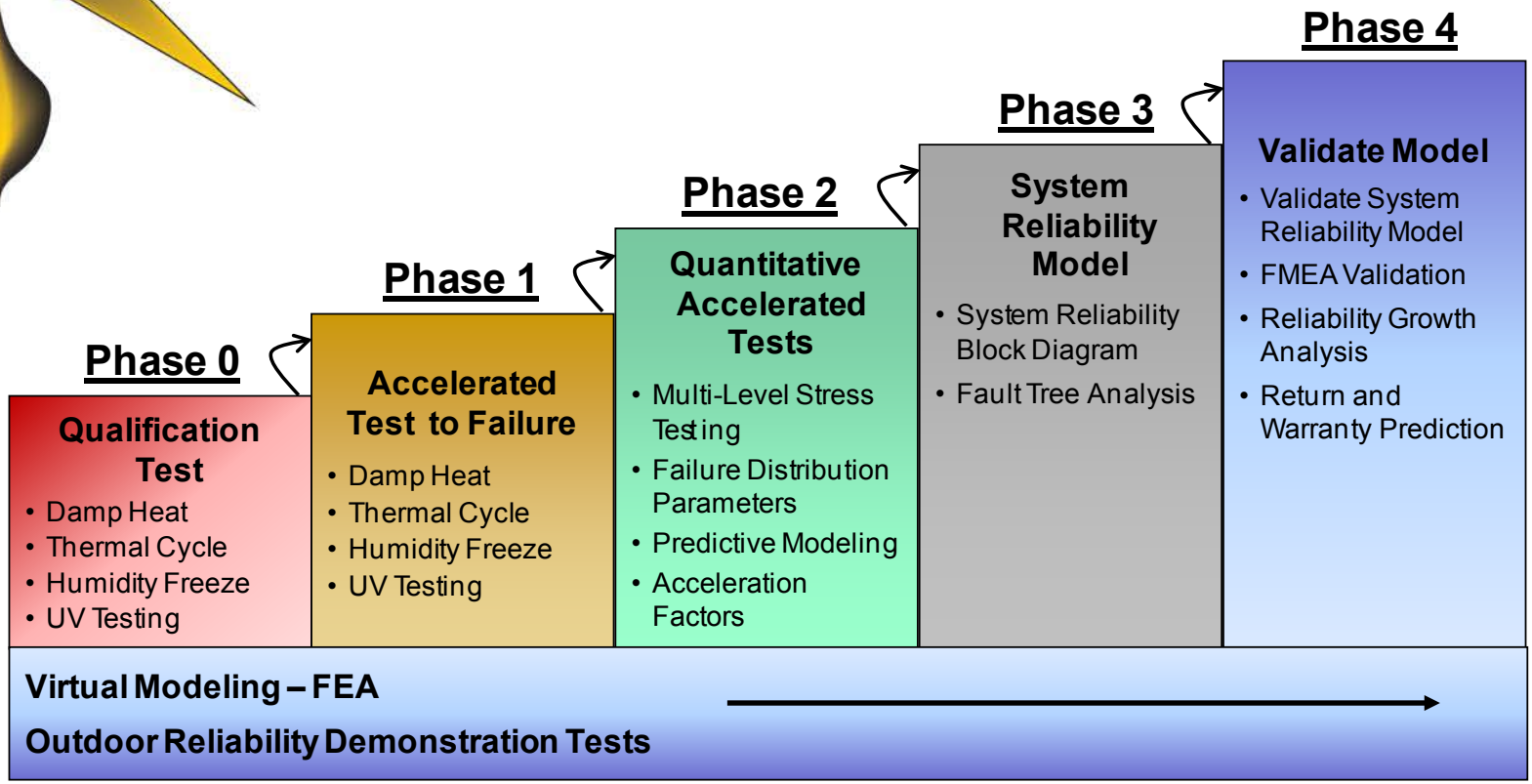
Dow's Approach to a Staged Reliability Assurance Process



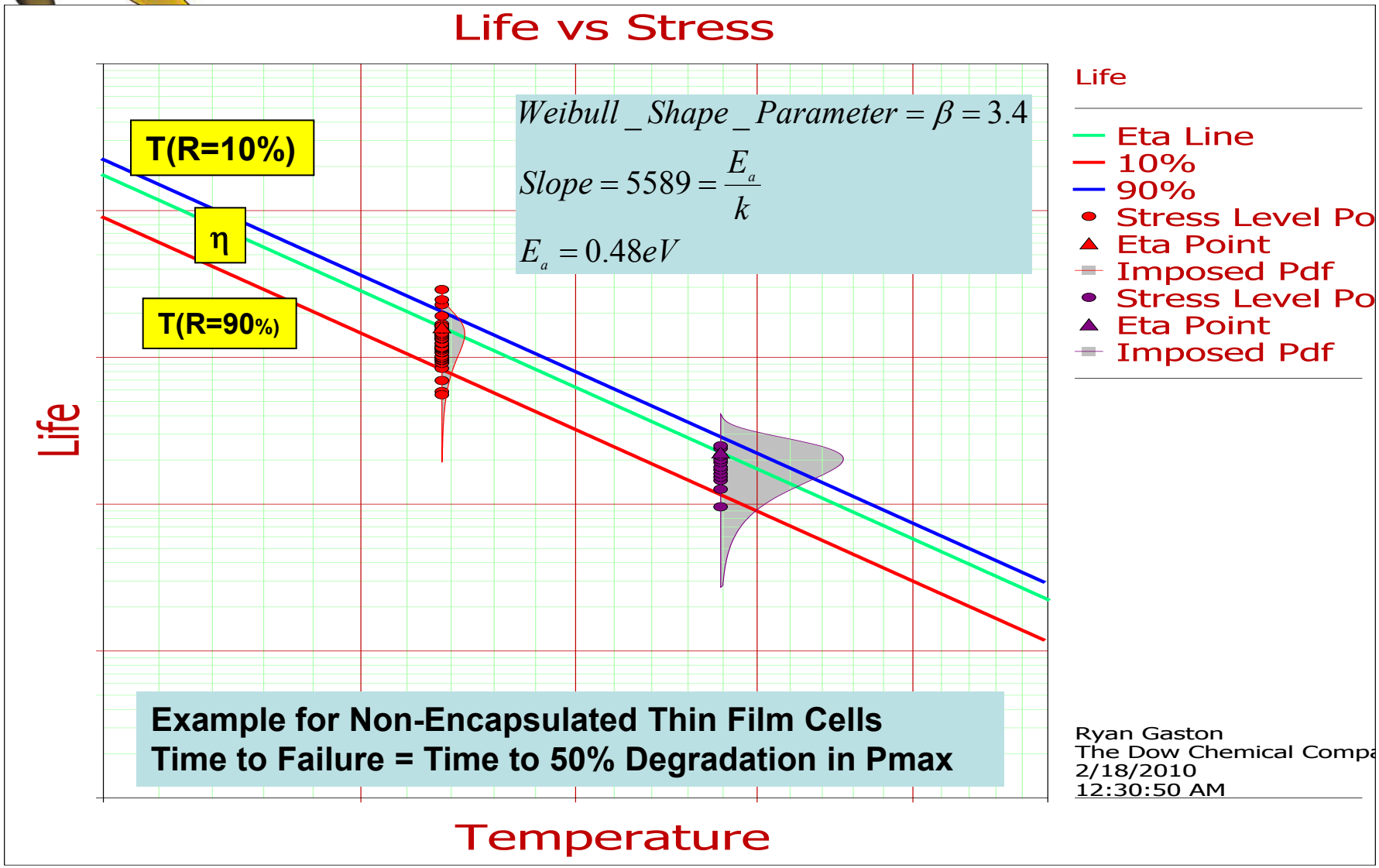
Objectives:

- Maximize results while minimizing resource requirements
- Screening and qualification of new materials, designs, and process changes
- Quantify impact to reliability and assess risk to business

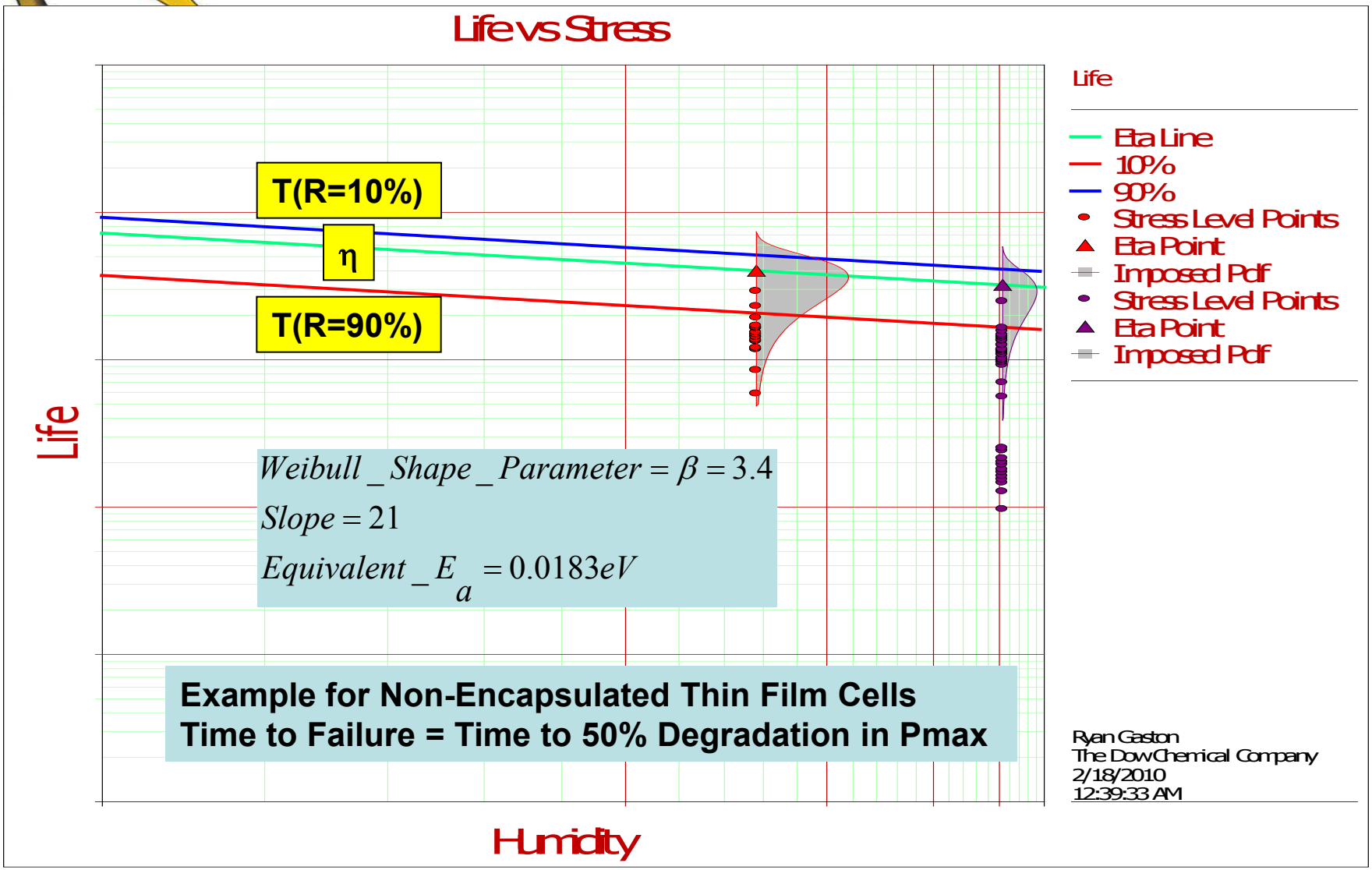
Phase 2 Example: Quantitative Temp-Humidity Test

- Two Stress Test Plan Development (Damp Heat Example)
  - Two Stresses (Temperature and Relative Humidity)
    - Stress Life Relationship Assumed – Modified Eyring Model
    - Highest Stress Level and Use Stress Level Set
    - Failure Distribution Function (Weibull/LogNormal)
    - Probability of Failure Estimate
    - Desired Reliability and Confidence Interval
- Test Plan Output → Test Conditions and # of Samples
- Conduct Tests → Degradation in Performance vs Time Interval
- Critical Degradation Level Set
  - Time to Failure Calculated
- Failure Distributions Estimated from Time to Failure Data
- Acceleration Factors Calculated for Each Stress Type
- Reliability/Unreliabilty at Use Stress Predicted
  - Confidence Bounds Estimated

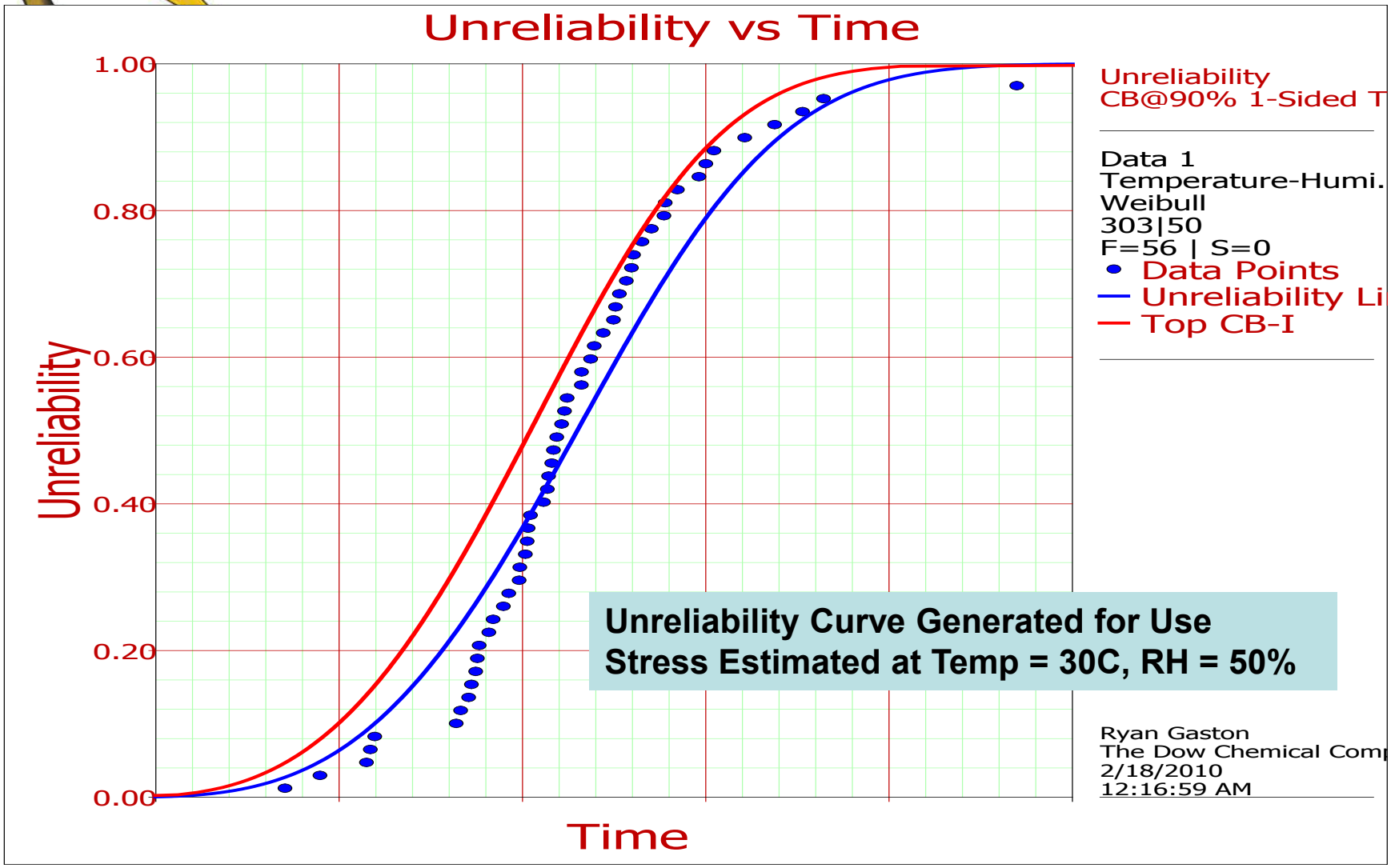
Phase 2 Example: Life vs Temp Profile



Phase 2 Example: Life vs Humidity Profile



Phase 2 Example: Unreliability vs Time



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Summary

- Incorporating reliability methodologies into PV design and manufacturing is an ongoing opportunity
- Reducing reliability issues early in the product development process saves time and money
- Reliability is more than testing – touching on all aspects of development (Design for Reliability)
- A Staged Reliability Assurance approach can maximize results, while minimizing resource requirements
- Dow has successfully implemented a Reliability program for estimating product lifetimes for Thin Film BIPV Modules and Systems

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