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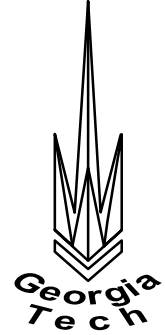
# **Accelerated Life Test of Mechanical Components Under Corrosive Condition**

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# Outline

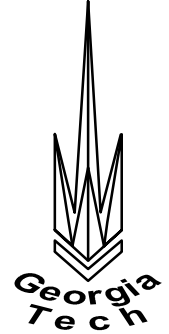
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- ❖ Objective
- ❖ Modeling
  - Model assumptions
  - Formulas and model parameters identification
- ❖ Experimental Investigation
  - Experimental Setup
  - Optimal Test Condition (Experimental Parameters)
  - Experimental Data
- ❖ ALT Package
  - Results of Modeling and Prediction
- ❖ Outcomes

# Objective

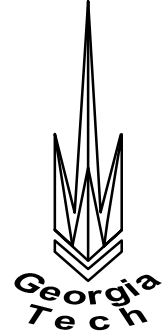
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- ❖ Develop a scientific, systematic, and reliable methodology to evaluate the life probability of mechanical components based on accelerated testing theory.
- ❖ Offer the attractive benefit of requiring relatively less investment in both time and resources for accelerated life testing of the mechanical component.

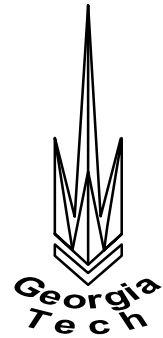
# *Model Assumptions*

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- ❖ Weibull distribution of Time-to-failure is applied.
- ❖ Life of bearing under salt water condition is an inverse power function of a non-thermal accelerating stress.
- ❖ The failure modes at accelerated stress are as same as those observed under use stress conditions.
- ❖ Each sample tested at a specified stress level is homogenous.
- ❖ Only the stress of acceleration is applied, all other stresses remain unchanged.

# The Inverse Power Law Model



**Characteristic life:**  $\eta(V) = \frac{1}{KV^n}$

**Reliability Function:**  $R(T;V) = e^{-\left[\frac{T}{\eta(V)}\right]^\beta}$

**Life Distribution:**  $f(T;V) = \frac{\beta}{\eta(V)} \left[\frac{T}{\eta(V)}\right]^{\beta-1} e^{-\left[\frac{T}{\eta(V)}\right]^\beta}$

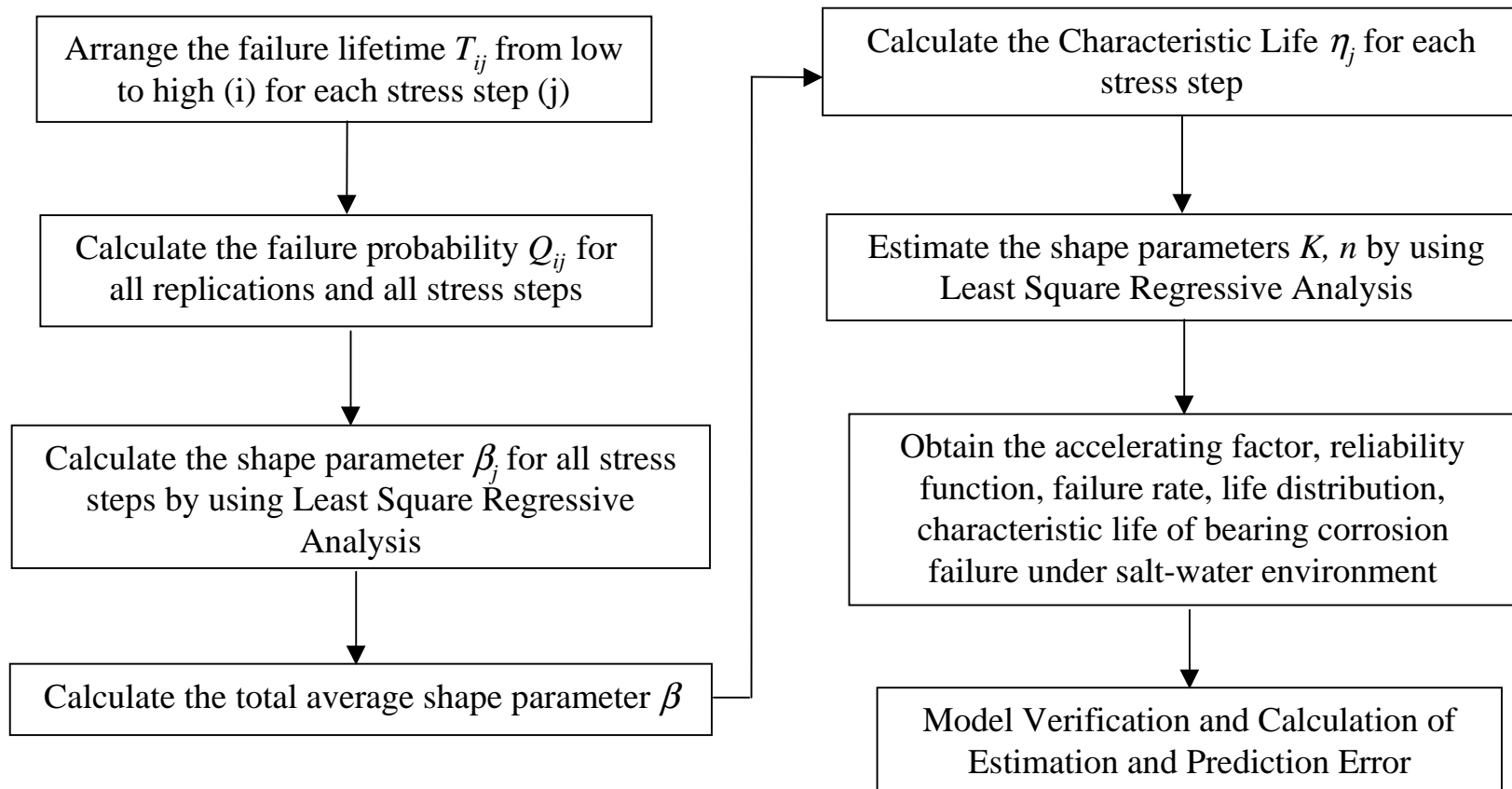
**Accelerated Factor (AF):**  $AF = \frac{\eta_U}{\eta_A} = \frac{T_{U-Q*100\%}}{T_{A-Q*100\%}} = \left[\frac{V_A}{V_U}\right]^n$

Where,  $\beta, K, n$  - shape parameters

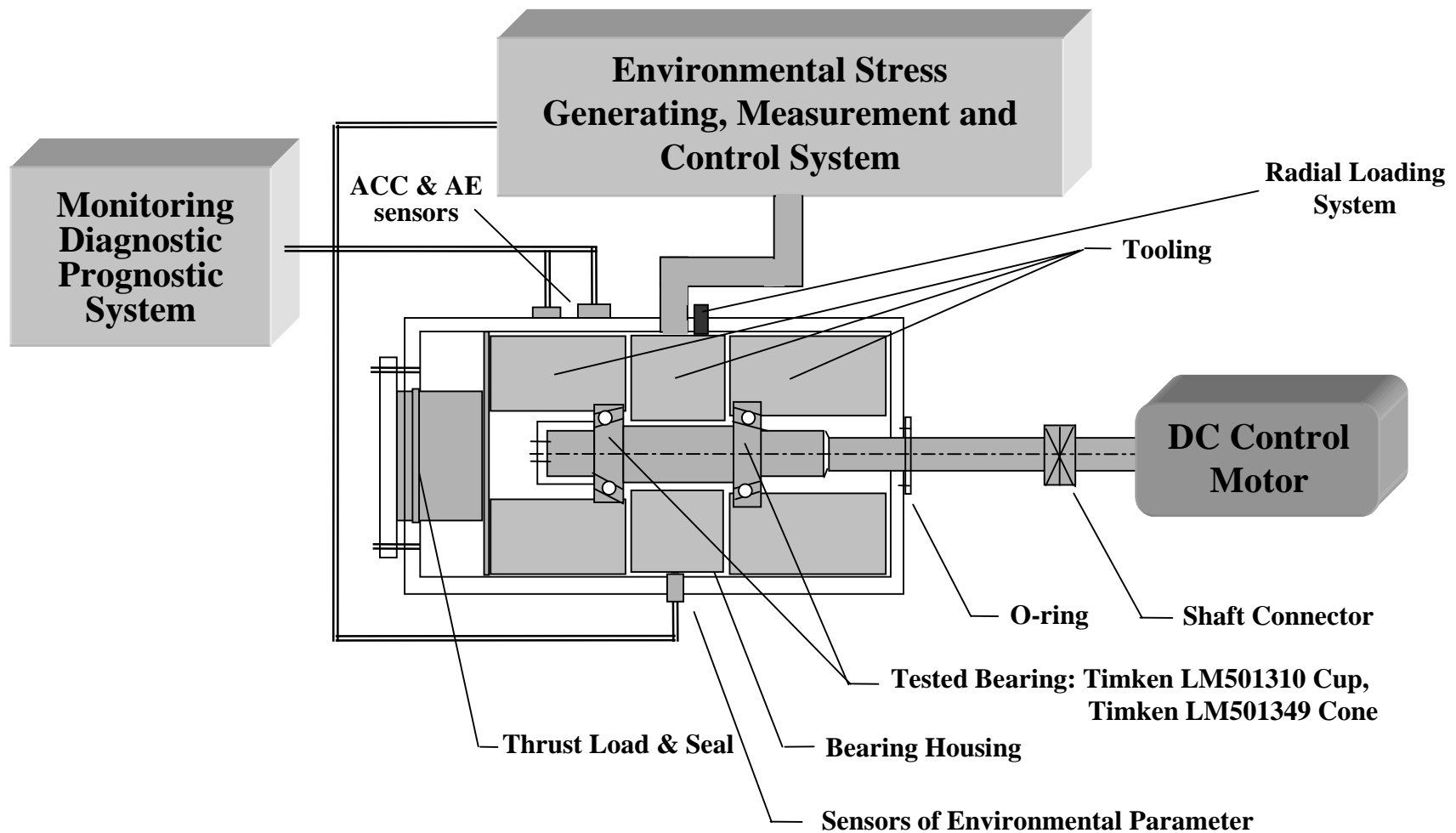
$T$  - failure lifetime

$V$  - stress

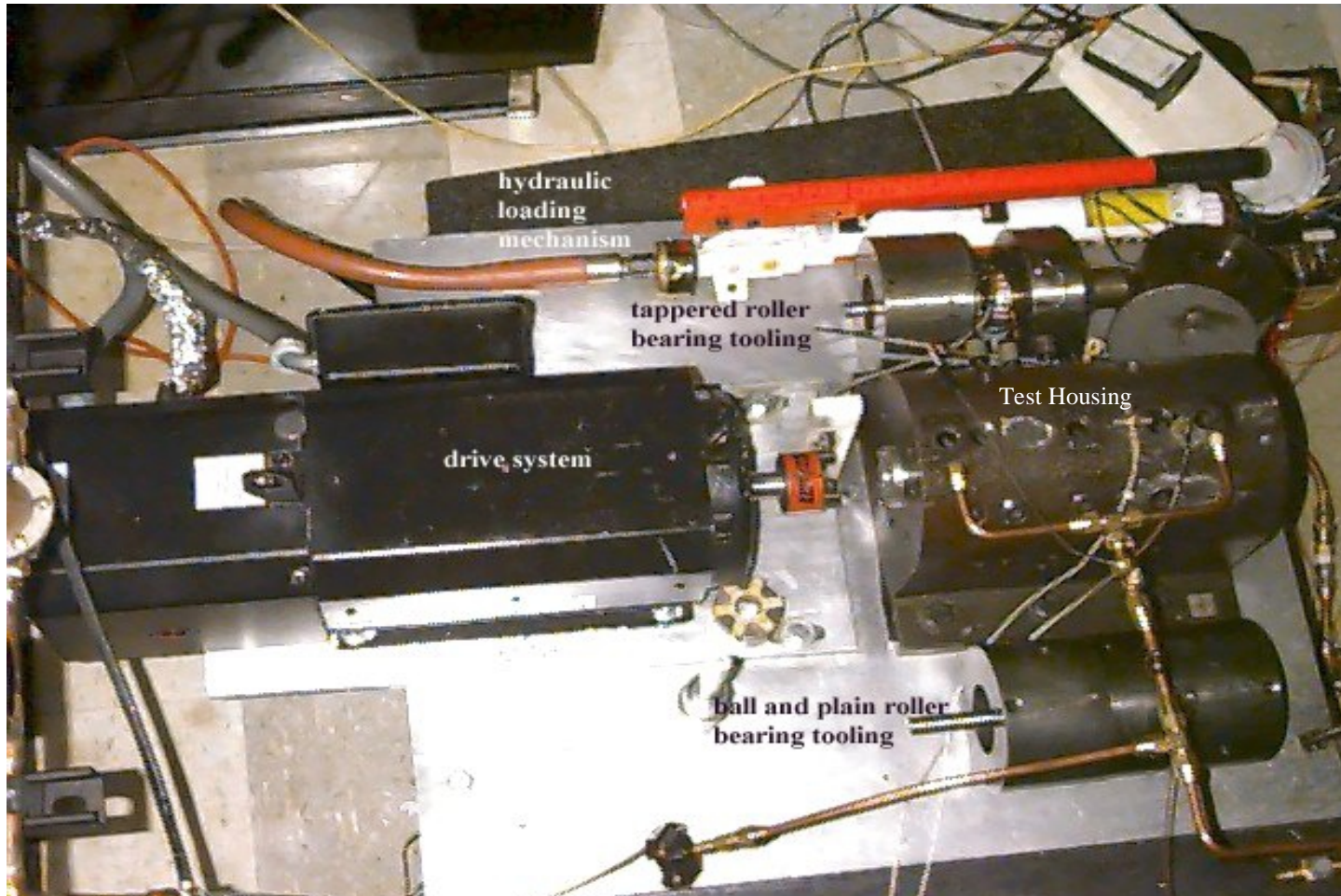
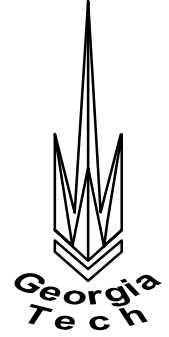
# Model Parameter Identification



# Experimental System



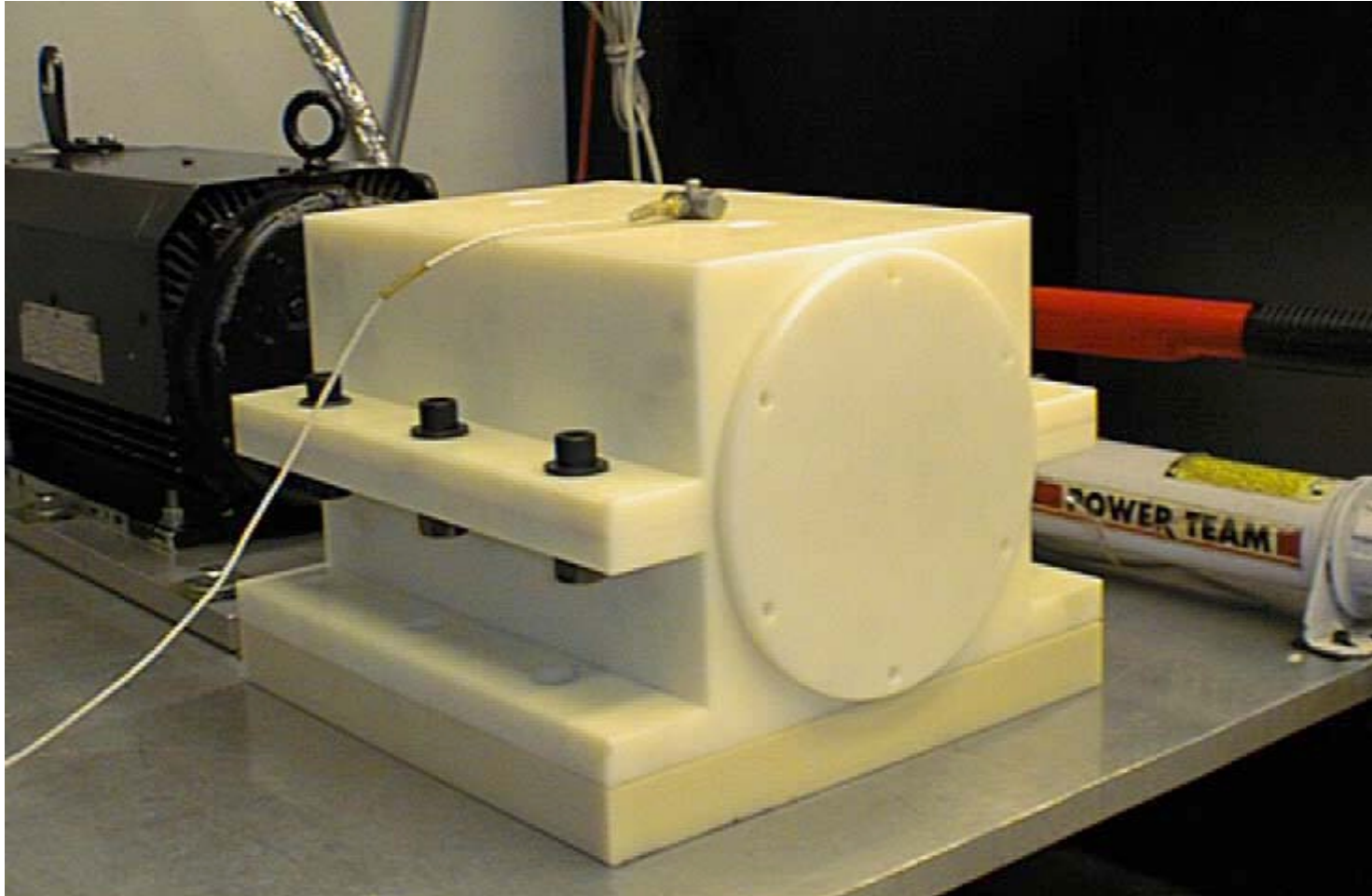
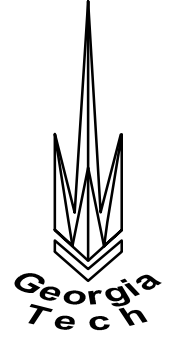
# Photo 1 - Overall Setup





# *Photo 2 - Testing Housing*

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# Photo 3 - Testing Components



# *Experimental Parameters of ALT*

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❖ **Main Stress Parameter is the Salt Content in water.**

❖ **Controlled Stress Steps**

- Five stress steps for testing and modeling analysis

1% salt water	8% salt water
16% salt water	26% salt water
36.1% salt water	

- Two stress steps for model verification

12% salt water	21% salt water
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\*  $(100 * \text{Salt Weight} / \text{Water Weight})$

❖ **Replication Number for each stress step is 2.**

# *Parameters of the Operating Condition*

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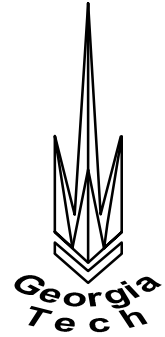
1. Rotational Speed: 600 rpm
2. Relative Humidity: The bearings were immersed in the salt water completely
3. Radial Load: 0 lb<sub>f</sub>
4. Thrust load: 288lb<sub>f</sub>
5. Temperature: Controlled with a variation range of 10°C
6. Lubrication: No (Except the salt water)

# Experimental ALT Data

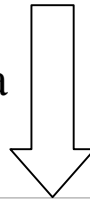


SAMPLES	MODEL IDENTIFICATION SAMPLES					MODEL VERIFICATION SAMPLES	
Stress Levels (Salt/Water %)	36.1	26	16	8	1	12	21
Failure Time 1 (Hour)	27.88	35.55	42.07	47.89	55.12	44.5	35.67
Failure Time 2 (Hour)	66.5	67.2	73.3	94.7	100.9	75.2	69.4

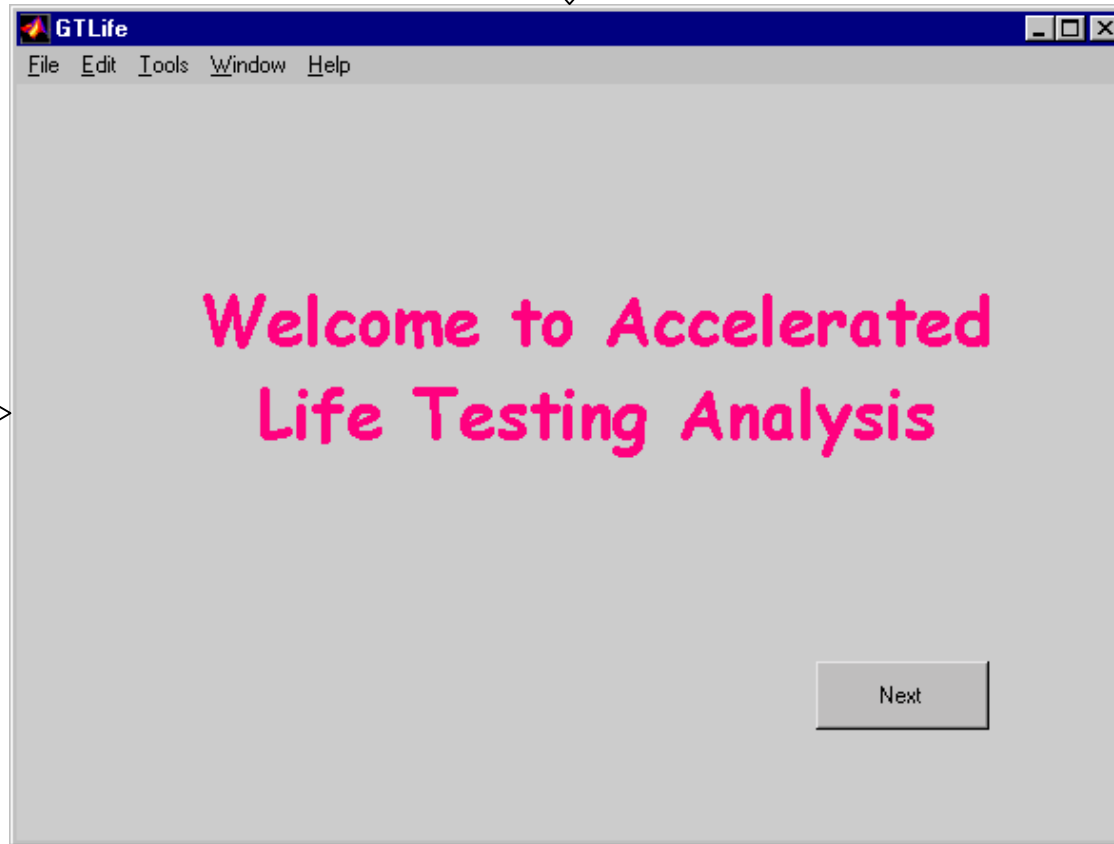
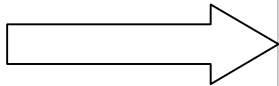
# ALT Package



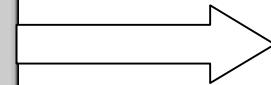
GT ALT Data



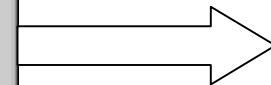
User's Data



Modeling



Prediction



# Weibull Plot of the Data (1)

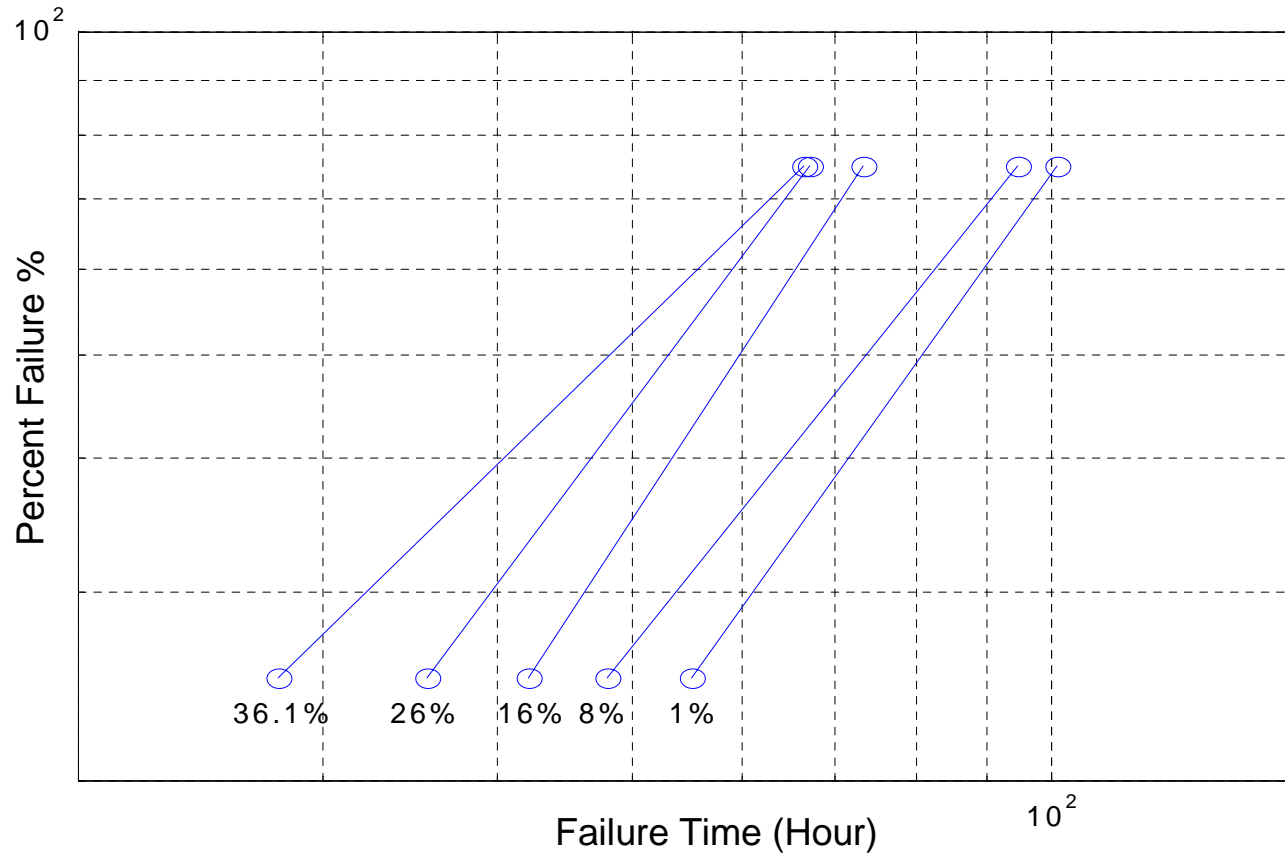
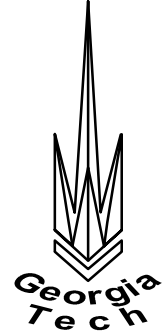
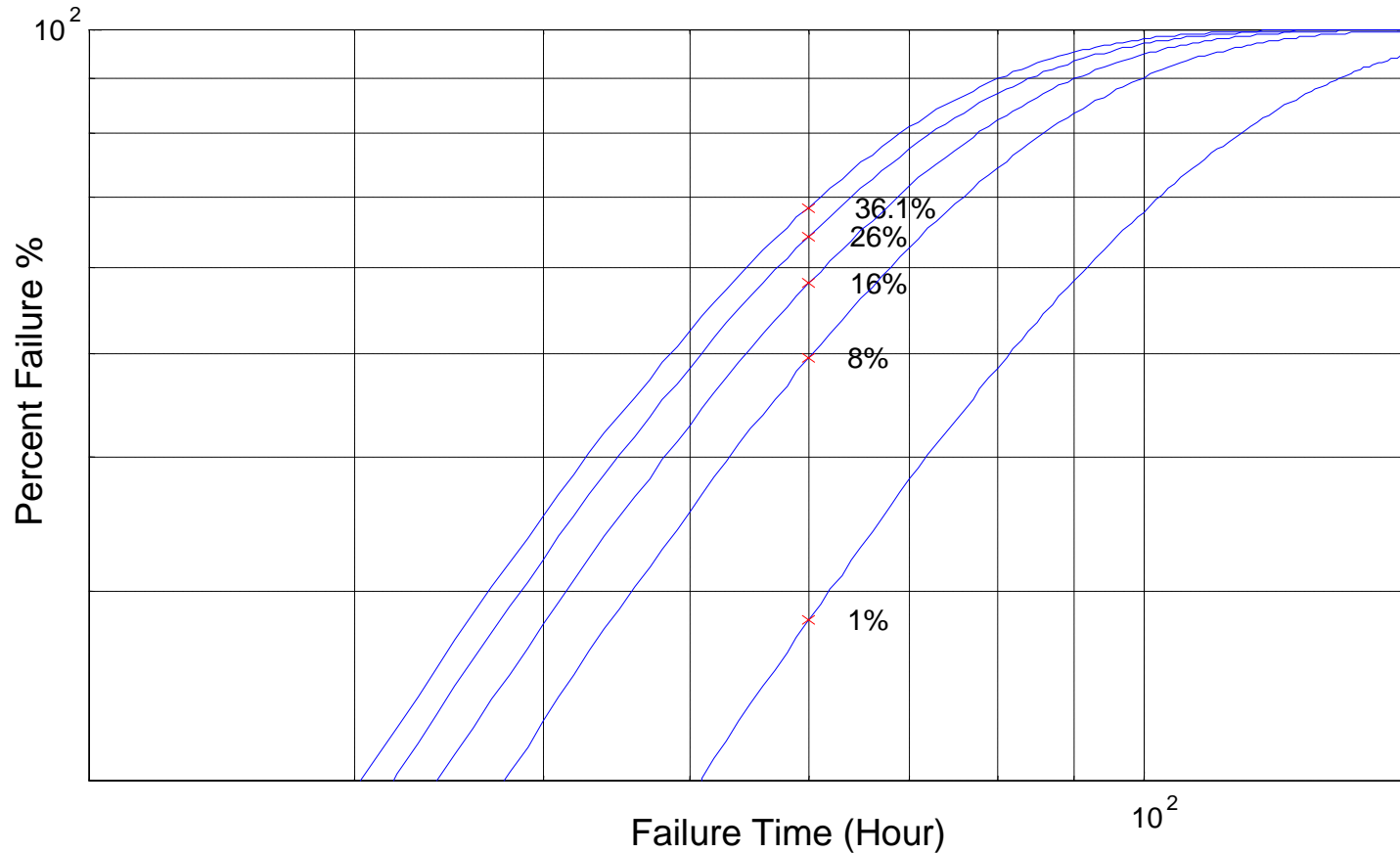


Figure 1. Relationship between Failure Time and Percent Failure

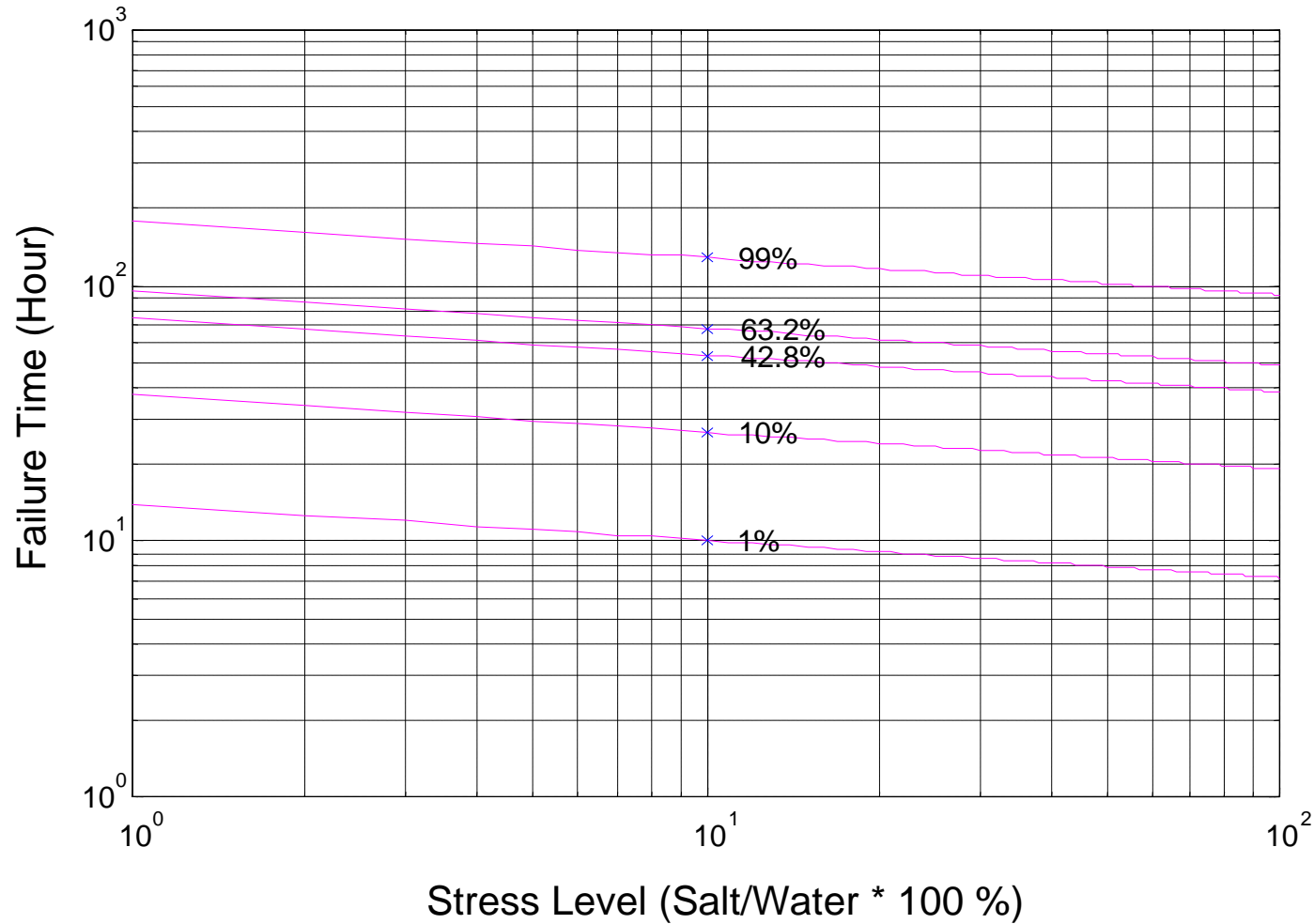
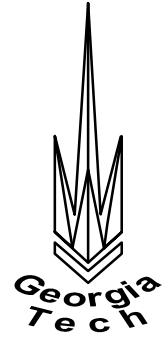
# Weibull Plot of the Data (2)



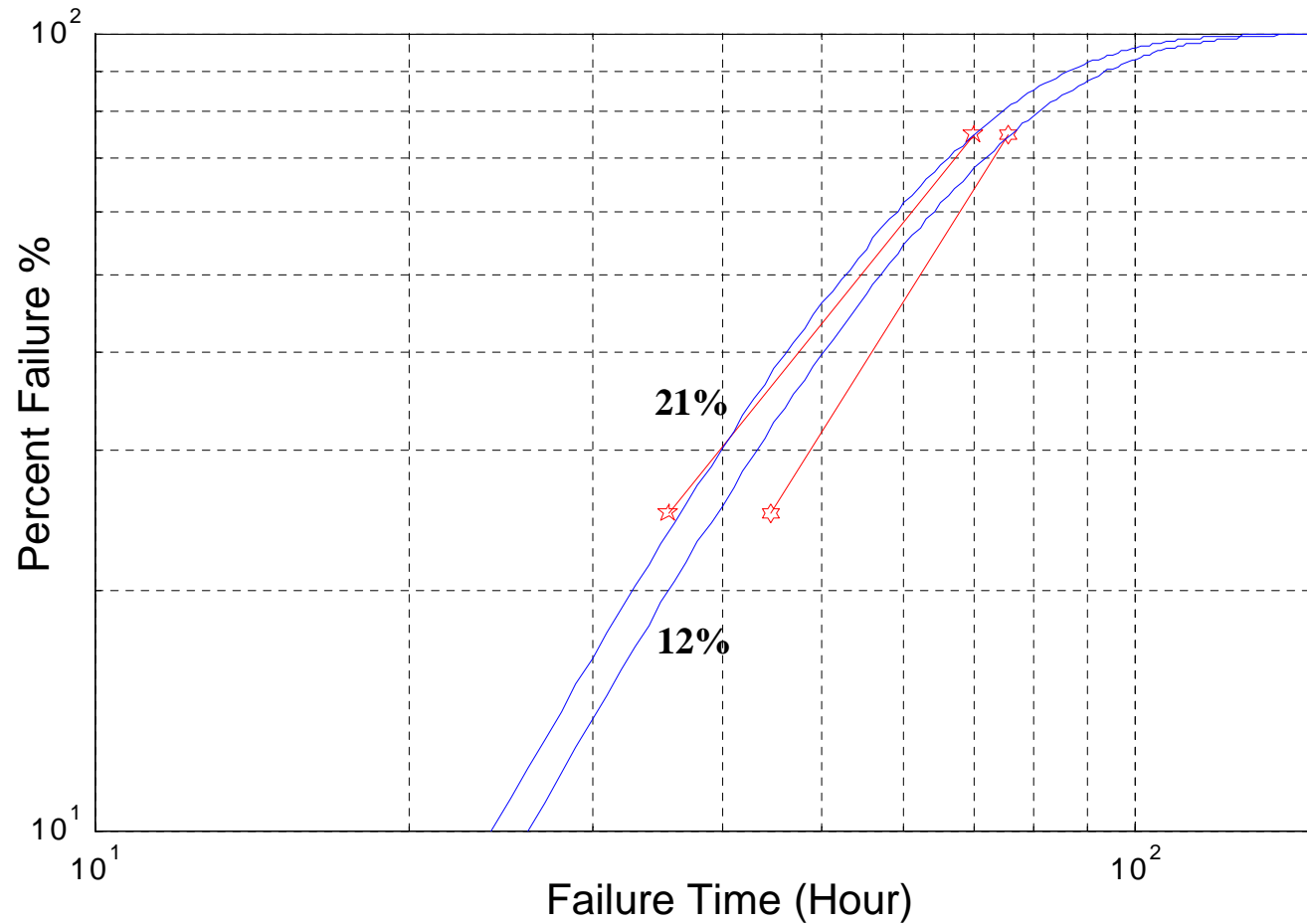
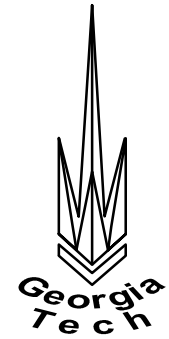
**Figure 2. Percent Failure versus Failure Time Based On  $\eta(V)$  Obtained from the Estimated Inverse Power Law**



# Failure Time Versus Stress Level Under Certain Failure Rate



# Model Verification



# Prediction Errors



Sample	ALT Data for Model Verification					
	12			21		
Stress Level (Salt / Water %)	Tested	Predicted	Errors	Tested	Predicted	Errors
Failure Time 1 (hours)	44.5	39.52	-4.98	35.67	36.45	0.78
Failure Time 2 (hours)	75.2	76.01	0.81	69.4	70.11	0.71
Mean Relative Error	4.2%					

# Outcomes

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- ❖ Develop a systematic and scientific methodology to assess the life probability of mechanical component.
- ❖ Optimize the accelerated life testing to achieve the maximum time/cost saving and the highest life prediction accuracy.
- ❖ Extend the methodology to any mechanical components with the same failure mode in nominal and in accelerated testing conditions.
- ❖ Pilot the case study of rolling element bearing testing to illustrate the fundamental basis and the implementation principles.