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Recording Storage Environments to Predict COTS Parts Lifetimes

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Assessment of the Military Use of COTS

Project Goal: Determine if Components will Meet the Design Life

- **Objective**: Assure the long term reliability of Commercial Off the Shelf (COTS) electronic components and new COTS fabrication technologies in weapons applications.

- **Approach**: Develop and validate procurement / qualification methodology as well as life predictive models of COTS components and assemblies under a variety of environmental conditions. These include temperature, humidity, thermal cycling, and material finishes.

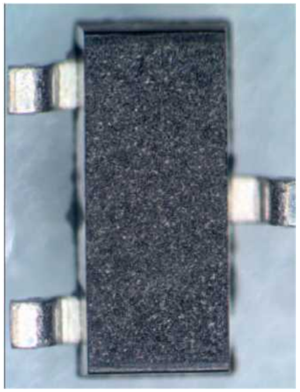
- **Status**: We have implemented a monitored long term dormant storage test to compare with life predictions made by model using highly accelerated test and in-use conditions. First group of parts are in 3rd year of storage and second group of parts in 1st year of deployment.

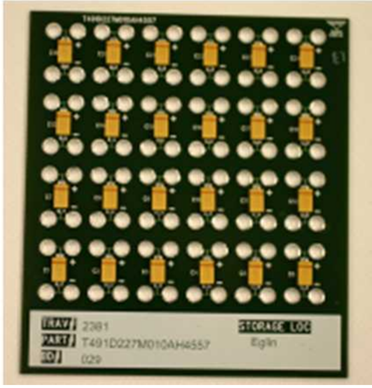
Long Term Dormant Experiment: 40,000 Parts Total

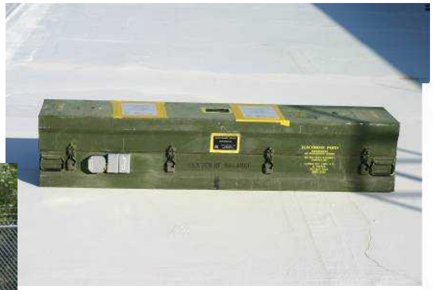
- **Accelerated Stress**
  - **HAST;**
  - **Temperature Cycling;**
  - **Thermal Shock.**

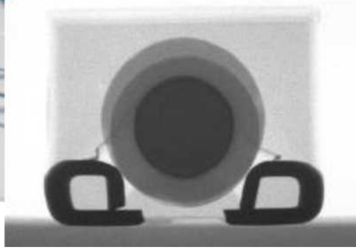
- **Inspections:**
  - **Electrical Testing;**
  - **Scanning Acoustic Microscopy;**
  - **Failure Analysis.**

- **Locations:**
  - **SNL, Albuquerque NM,**
  - **Yuma Arizona;**
  - **Eglin AFB, Florida**
  - **Redstone Arsenal, Huntsville Alabama**
  - **Fort Greeley, Alaska**









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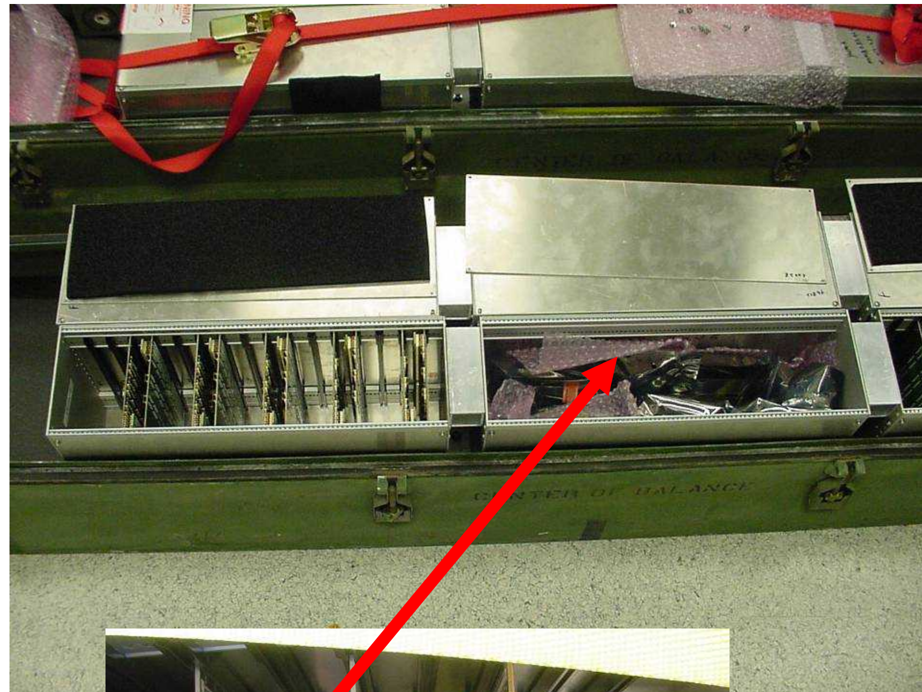
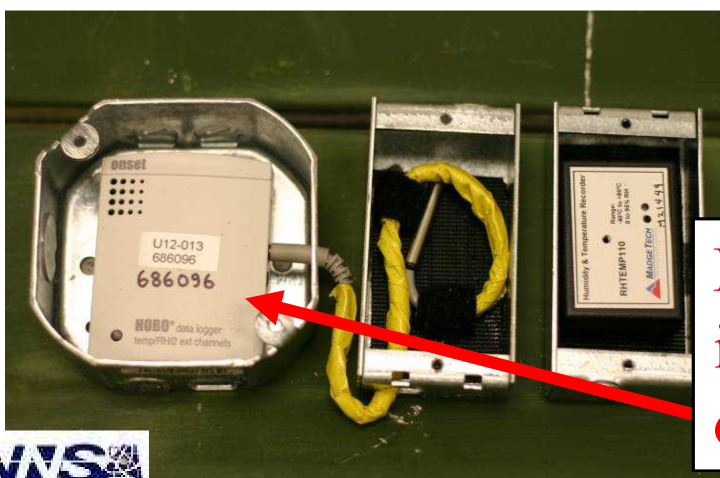
Recording Environment Inside and Outside of Hellfire Storage Container

Boxes Installed Inside Container





Dataloggers inside and outside

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Lifetime Prediction

- Assume that lifetime at use conditions is related to lifetime at accelerated test conditions by an ***Acceleration Factor***.
  - Form of the time to failure distribution function is the same at accelerated test and use conditions.
- Utilize an acceleration factor which contains only a small number of parameters for a given failure mechanism.
- Treat the parameters as random variables characterized by distribution functions.
- Use Monte Carlo technique to calculate time to failure distribution function at use conditions.

$$dt_{use} = AF\left(s(t), s_0\right) \times dt_{accel}$$

Two Failure Mechanisms

$$t_f = AF \times t_{f0}$$

- **PEMs temperature and humidity aging**

$$AF\left(T, RH, T_0, RH_0 \middle| E_a, n\right) = \exp\left[\frac{E_a}{k_B}\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]\left(\frac{RH_0}{RH}\right)^n$$

  - **High storage temperature and humidity values result in low acceleration factors and short predicted lifetimes at use conditions.**

- **PEMs temperature cycling aging**
  - **High storage temperature maxima and changes result in low acceleration factors and short predicted lifetimes at use conditions.**

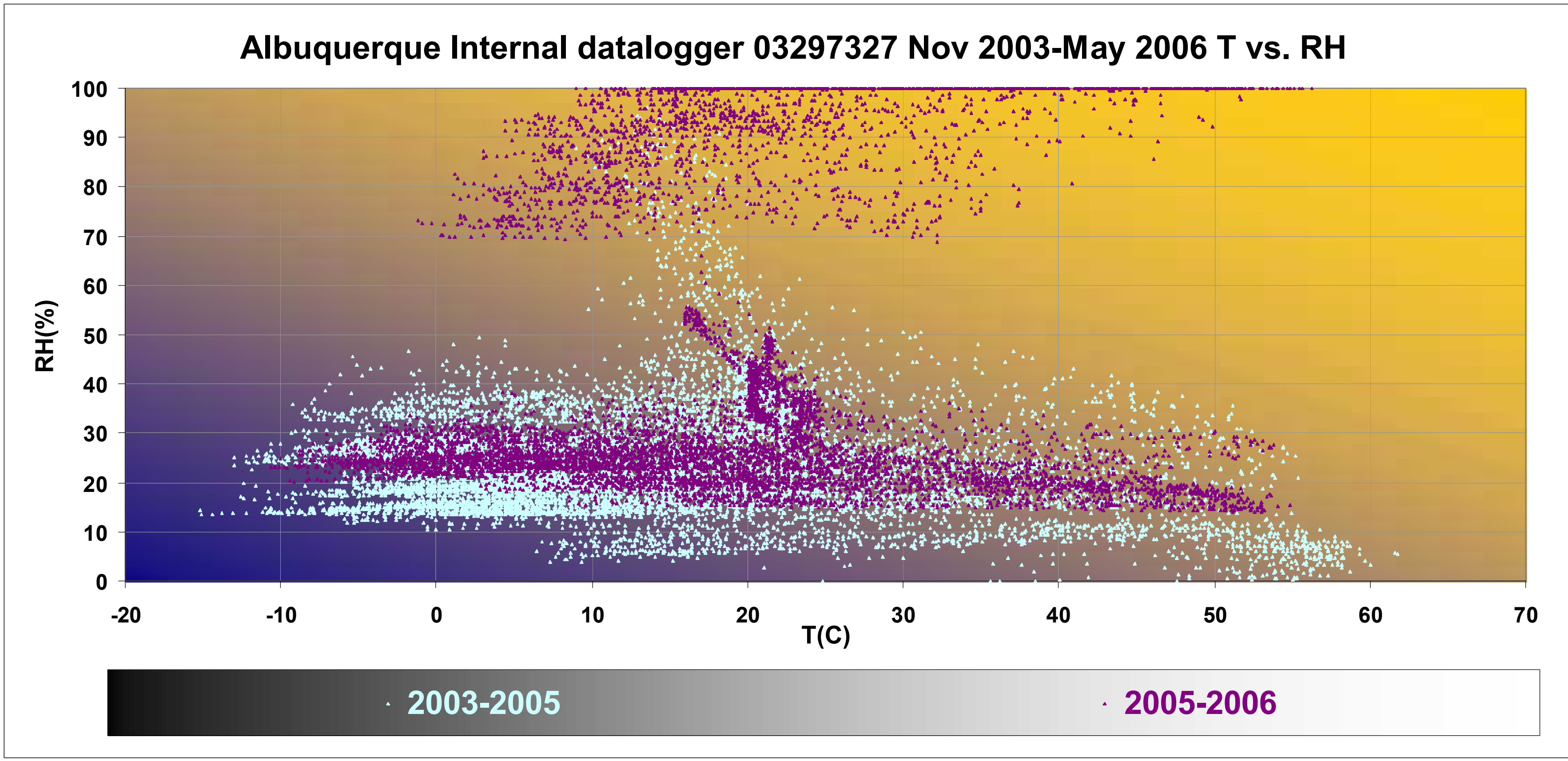
$$AF\left(s, s_0 \middle| m, p, Q_a\right) = \left(\frac{\Delta T_0}{\Delta T}\right)^m \left(\frac{f}{f_0}\right)^p \exp\left[\frac{Q_a}{k_B}\left(\frac{1}{T_h} - \frac{1}{T_{h0}}\right)\right]$$

Datalogger Verses Weather Station Data

- Lifetime prediction models need temperature and humidity field data.
- Is it necessary to record data inside the container where the parts are located?
- Is it sufficient to acquire data from the facility monitoring station or the NWS?
- Use data collected inside and outside of the container to run the prediction models and compare results.

Temperature and Humidity Data

Dot plot representation of storage site environment data with temperature along horizontal axis and humidity along vertical axis.



Severe environments leading to short predicted lifetimes correspond to data points in upper right corner. Benign environments/long lifetimes correspond to lower left corner.

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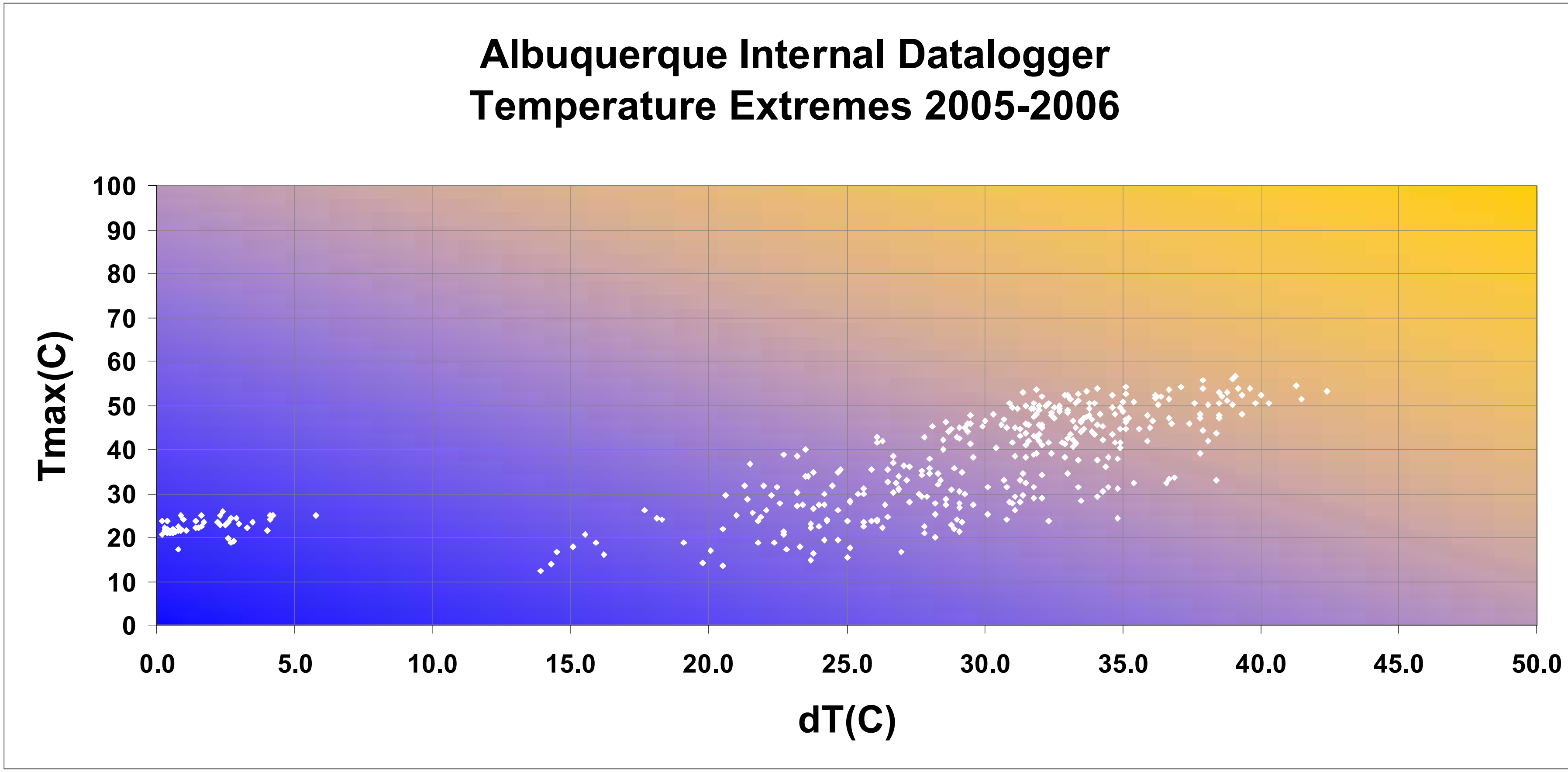
Temperature Cycling Data

Dot plot representation of storage site environment data with daily temperature extremes along horizontal axis and daily maximum temperature along vertical axis.



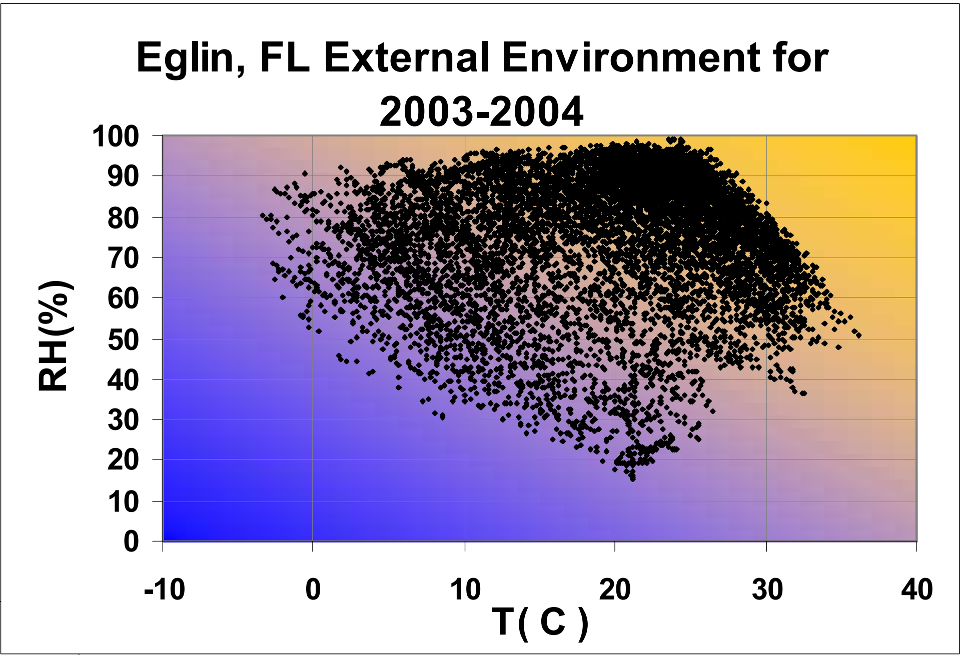
Severe environments leading to short predicted lifetimes correspond to data points in upper right corner. Benign environments/long lifetimes correspond to lower left corner.

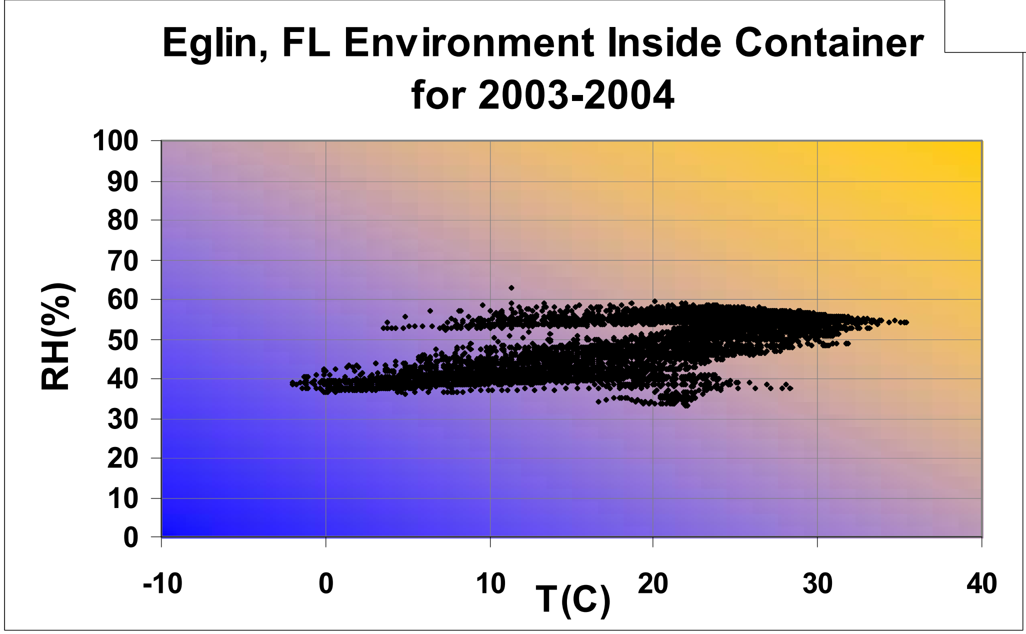
OP400 at Eglin, FL in a Tightly Sealed Box

$$AF\left(s,s_0|Q_a,n\right)=\exp\left[\frac{Q_a}{k_B}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]\left(\frac{RH_0}{RH}\right)^n$$

Observations:

- Environment outside of box had high concurrent humidity and temperature.
- Humidity inside box stable.
- On average the predicted lifetimes inside the box are around twice that predicted for parts placed outside.
- ***Lifetime longer inside box.***





Predicted Lifetime*

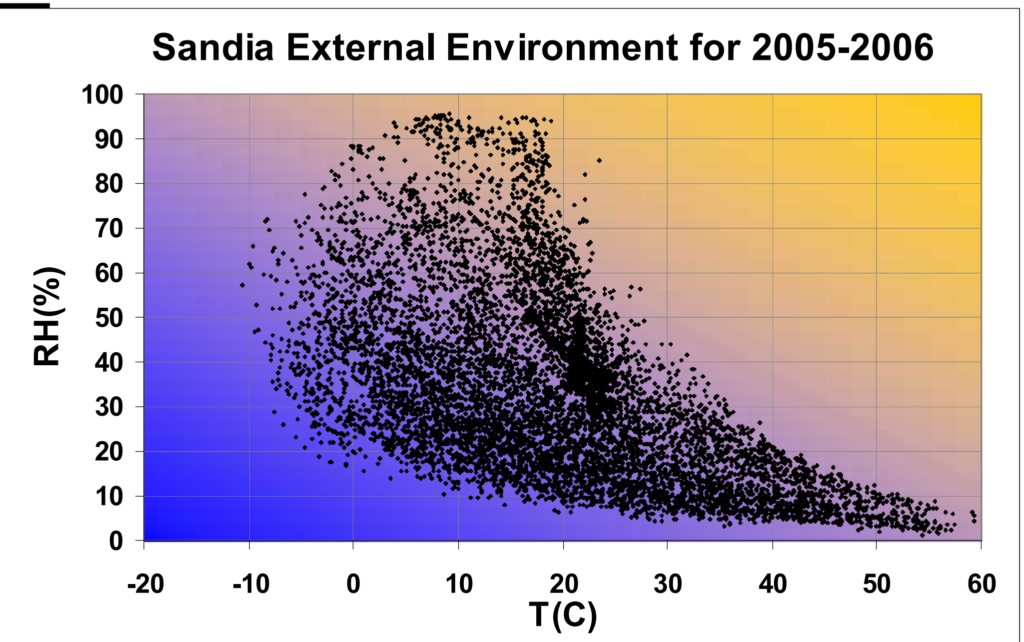
External to box: 40 years
Internal to box: 93 years

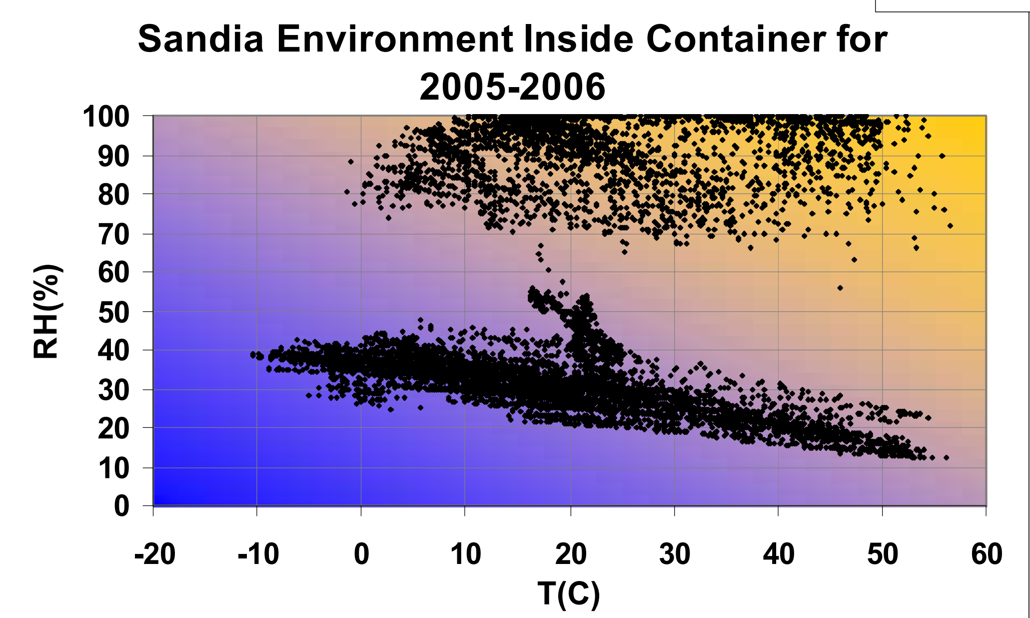
*Temperature and RH Model

OP400 at Albuquerque, NM in a Leaky Box Stored Outside

Observations:

- Environment inside of box had high concurrent humidity and temperature.
- External environment reflects cool humid mornings and dry hot afternoons.
- Average predicted lifetime for parts inside container is around 1/6 the lifetime outside the box.
- ***Lifetime longer outside box.***





$$AF\left(s,s_0\,|Q_a,n\right)=\exp\left[\frac{Q_a}{k_B}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]\left(\frac{RH_0}{RH}\right)^n$$

Predicted Lifetime*

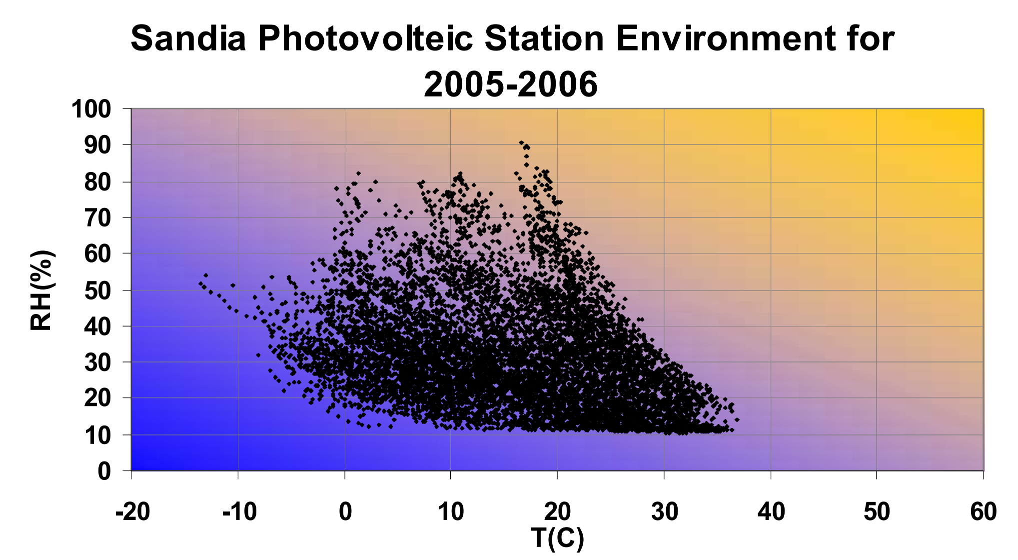
External to box: 295 years

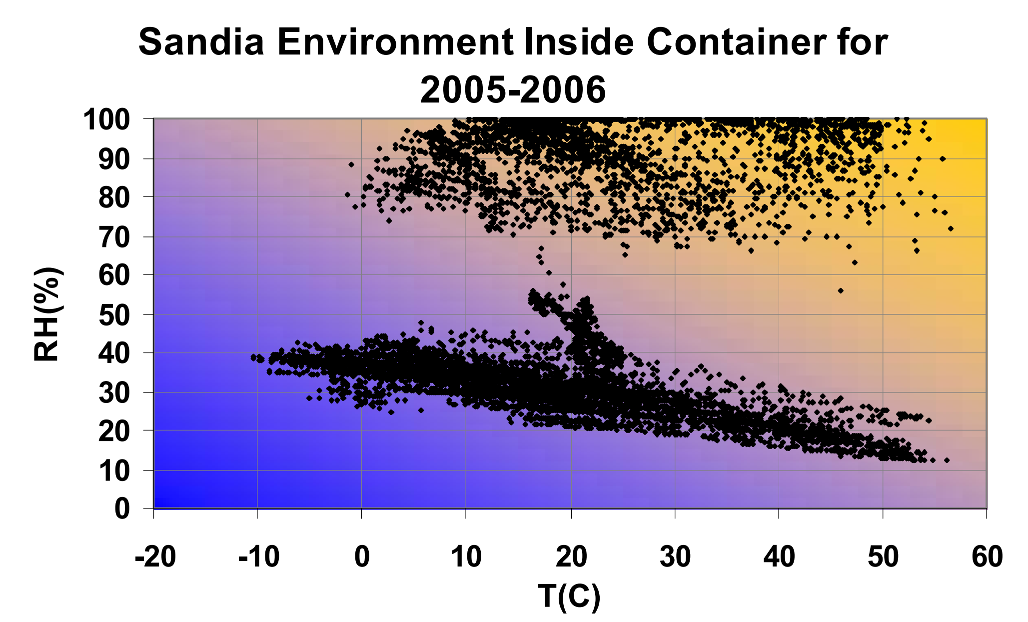
Internal to box: 43 years

*Temperature and RH Model

OP400 at Albuquerque, NM

- **Observations**:
- Environment inside of box had high concurrent humidity and temperature.
- External environment reflects relatively mild condition at weather station.
- If station data used, parts predicted to live over 8 times longer than if datalogger data used.
- ***Lifetime predicted using weather station data is too optimistic.***





$$AF\left(s,s_0\,|Q_a,n\right)=\exp\left[\frac{Q_a}{k_B}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]\left(\frac{RH_0}{RH}\right)^n$$

Predicted Lifetime*

External to box: 295 years

Internal to box: 43 years

Weather Station: 365 years

*Temperature and RH Model

OP400 at Albuquerque, NM, Solar Cycling

$$AF\left(s,s_0 \middle| m,p,Q_a\right)=\left(\frac{\Delta T_0}{\Delta T}\right)^m\left(\frac{f}{f_0}\right)^p \exp\left[\frac{Q_a}{k_B}\left(\frac{1}{T_h}-\frac{1}{T_{h0}}\right)\right]$$

Predicted Lifetime*

External to box: 162 years

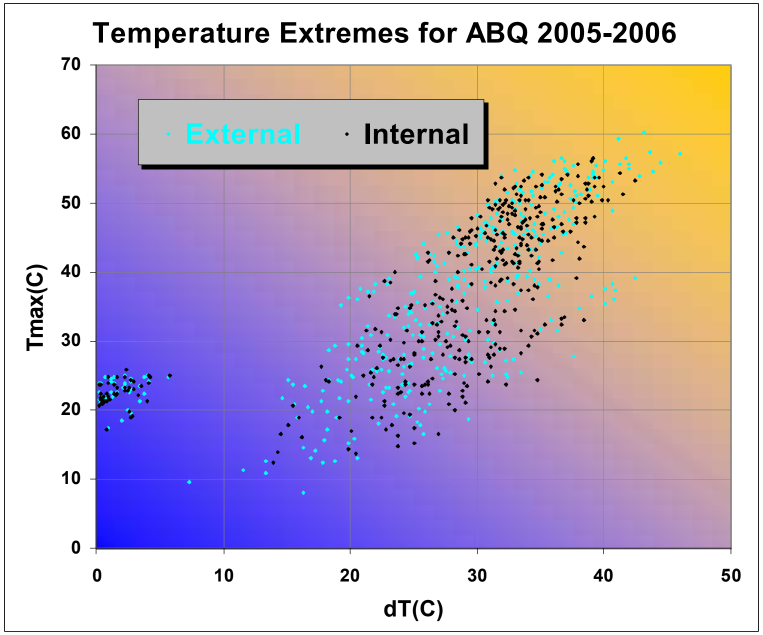
Internal to box: 161 years

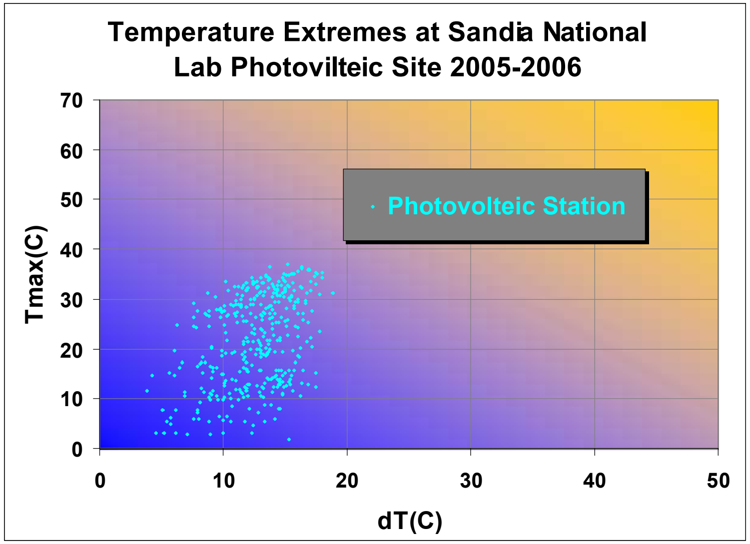
Weather Station: 1755 years

***Results from temperature cycle model**

Observations:

- Weather station conditions very mild compared to storage site. Lower recorded temperature and humidity.
- Average predicted lifetime for parts inside container is around ten time the lifetime at the storage site.
- ***Lifetime predicted using weather station data is too optimistic.***

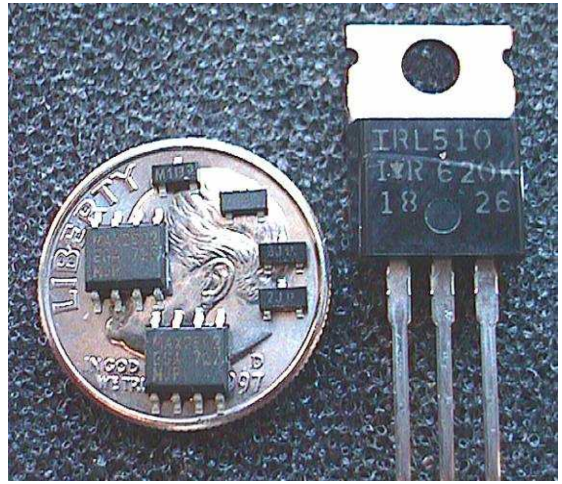


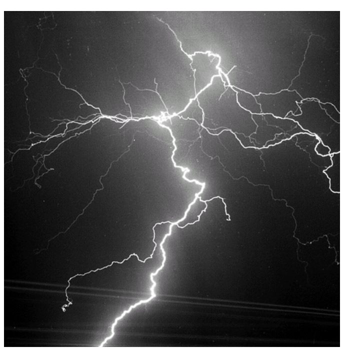


Conclusions

- Using weather station data in lifetime prediction models will lead to:
  - optimistic predicted lifetimes if the parts container is not well sealed from the external environment.
  - shorter predicted lifetimes if the parts container shields it's contents from the extremes of the external environment.
- It is absolutely necessary that the environmental conditions that the test parts are exposed to inside their containers are recorded for use in prediction models.
- The use of data recorded outside of the parts' containers will lead to false lifetime predictions.

Questions?





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