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Technical Performance Measures

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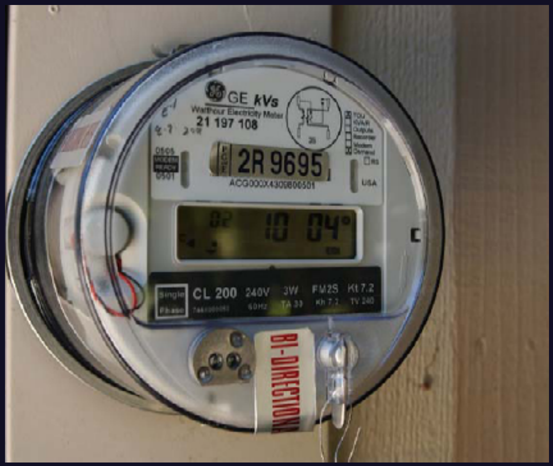
Definition

- Technical performance measures (TPMs) are tools that show how well a system is satisfying its requirements or meeting its goals
- TPMs provide assessments of the product and the process through design, implementation and test
- TPMs are used to:
  - forecast values to be achieved through planned technical effort
  - Provide visibility of actual versus planned performance
  - Provide early detection/prediction of problems requiring management attention
  - Support assessment of the impact of proposed changes
    - determine the impact of these differences
    - trigger optional design reviews

TPM examples

- Reliability
- Power required
- Weight
- Throughput
- Human Factors
- Response time
- Complexity
- Availability
- Accuracy
- Speed



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Requirements Criteria for TPMs creation

- High priority requirements that have an impact on
  - mission accomplishment
  - customer satisfaction
  - cost
  - system usefulness
- High risk requirements or those where the desired performance is not currently being met
  - the system uses new technology
  - new constraints have been added
  - the performance goal has been increased
  - but the performance is expected to improve with time
- Requirements where performance can be controlled
- Requirements where the program manager is able to rebalance cost, schedule and performance
- TPMs should meet all of these characteristics
- Less than 1% of requirements should have TPMs

TPM Characteristics

- Should be important and relevant
- Should be relatively easy to measure
- Performance should be expected to improve with time
- If the measure crosses its threshold, corrective action should be known
- The measured parameter should be controllable
- Management should be able to tradeoff cost, schedule and performance
- Should be documented
- Should be tailored for the project

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Collecting, Reporting and Displaying TPM data

- Systems Engineering Manager is responsible for collecting, analyzing, reporting and responding to TPM data
- TPMs should be presented to the person who can do something about it. Often this is the Chief Engineer
- Program Manager has oversight
- Measures Analysis Group might use them for process improvement suggestions
- TPM measures can be displayed with graphs, charts, diagrams, figures or frames
  - e. g. Statistical Process Control Charts, Run Charts, Flow Charts, Histograms, Pareto Diagrams, Scatter Diagrams, Check Sheets, PERT Charts, Gantt Charts, Line Graphs, Process Capability Charts and Pie Charts

TPM Measurement

- The measuring method will vary with life-cycle phase
- Start with legacy systems, blue sky guesses and approximations
- Derive data from models and simulations
- Collect data from prototypes
- Measure data on rudiments of the real system

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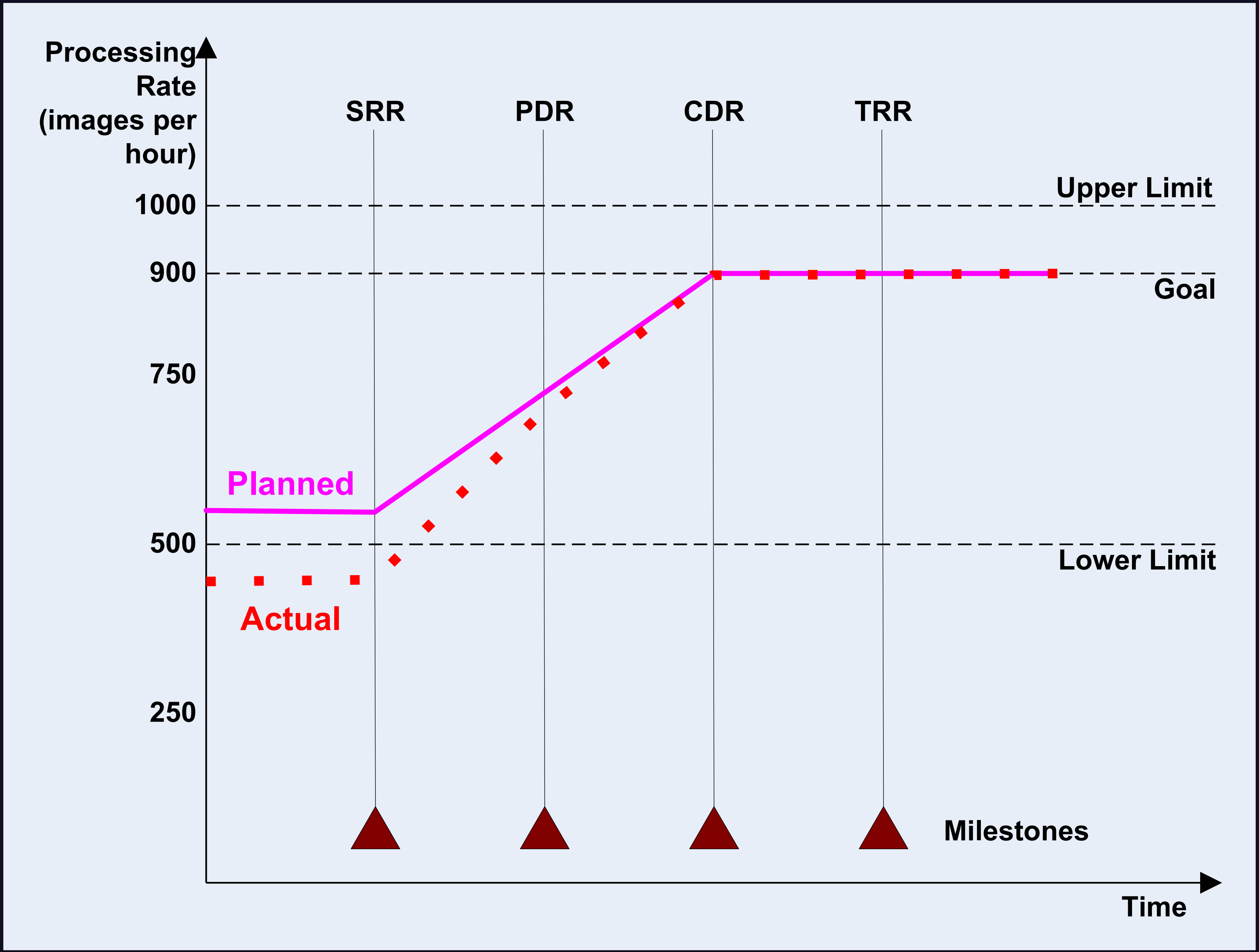
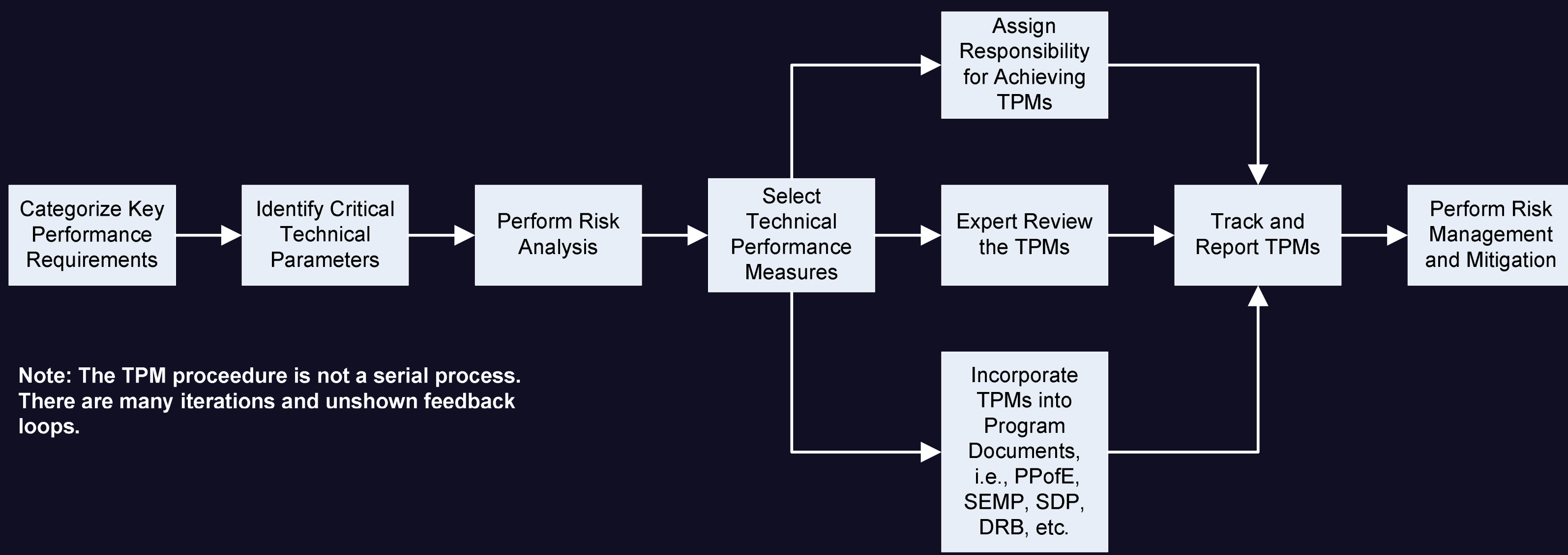
Typical TPM tracking chart



BAE NSS TPM Proceedure

- TPMs are established during the proposal process by the Chief Engineer for:
  - Key Requirements
    - Customer’s main requirement drivers
    - System requirements important to the Business
  - Key Functions
    - System level functions essential to the performance of the system
  - Critical Design Features
    - Represent uncertainty with respect to confidence in the design approach
    - Represent technical risk that is manifest as borderline performance
- TPMs are approved as a part of the Engineering Estimate Approval process
- TPMs are maintained in the program’s risk register
- The TPM Proceedure is PD0644

The BAE TPM Proceedure



Note: The TPM proceedure is not a serial process. There are many iterations and unshown feedback loops.

- **CMMI Requirements Development (RD) process area (SP 3.3-1) covers TPMs**
- **Related CMMI areas include Project Monitoring and Control (PMC) and Risk Management (RSKM)**

ID number	Process Step
1	Identify key performance requirements (refer to the Requirements Analysis process output). These are candidate TPMs.
2	Categorize key requirements within the requirements management tool (e.g., DOORS). Add TPM attributes as needed.
3	Identify critical technical parameters.
4	Perform risk analysis.
5	Select TPMs to be tracked throughout applicable program phase(s). Determine frequency of reporting.
6	Conduct expert review of selected TPMs. Feedback results and update.
7	For each TPM, establish upper and lower limits and performance growth values for discrete reporting points.
8	Assign responsibility for meeting TPMs.
9	Incorporate TPMs into appropriate program documents (e.g., PPofE, SEMP, SDP, DRB, etc.).
10	Use the project risk management process to track TPMs.
11	Schedule, collect and report TPM measurements.
12	Perform corrective action and risk mitigation on TPMs that do not meet performance growth values.

TPM Collection

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- TPMs require quantitative data to evaluate the likelihood of satisfying the system requirements
- Gathering such data can be expensive
- Because of the expense, not all requirements have TPMs, just the high priority requirements. As a rule of thumb, less than 1% of requirements should have TPMs.
- A TPM's values change with time, hopefully getting closer and closer to the goal
- TPMs are linked to a requirement, have quantitative values and a risk level

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Typical TPM ranking table

Technical Performance Measure (TPM)	Source Requirement	Quantitative Performance Requirement	Current TPM Value	Risk of Not Meeting TPM*
Image processing time (minutes)	ID # 123	Less than 5 minutes from time of request	10 minutes	1
MTBF of system	ID # 321	Greater than 1000 hours	750 hours	3
Availability (operational)	ID # 456	98% (minimum)	95%	2

*1= Very High
2= High
3= Moderate
4= Low
5= None

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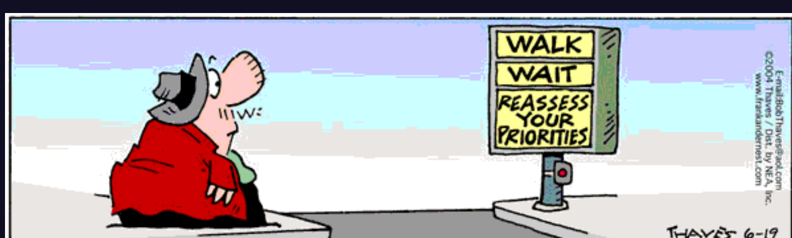
Prioritization

- Requirements are prioritized
- In addition, TPMs should be prioritized with relative importance to the customer
- BAE Systems NSS RF.PrioritizeRequirements documents process for requirements prioritization criteria and methods

TPM prioritization

TPM	Planned value	Current value	Relative importance
Image processing time (sec.)	30 sec. max	45 sec. for an SES simulation	10
Power required	10 KV max. UPS 2 hr. backup	12 KV UPS 1.5 hr. Vendor data	8
Weight	600 lbs. max man portable modules	625 lbs. six-modules CAD mockup	7



1 = least important
10 = most important

TPMs can be organized hierarchically

For example

- System lifetime
  - mechanical lifetime
  - electrical lifetime
    - power consumption
    - battery capacity
- The lower level TPMs (or measures) are used to derive values of higher level TPMs
- The top-level TPMs may be reported to Senior Management

Tracking TPMs

- The DOORS requirements module should have an attribute named TPM
- The name of each TPM should be entered in the attribute field of the appropriate DOORS requirement and this should be linked to the TPM module
- Each TPM should also be referenced in the project's Risk Register and be evaluated monthly

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Optional Independent Design Reviews

- TPMs can also be used to trigger optional independent design reviews
- Only eight design reviews are mandated
- If a TPM exceeds its thresholds, then an optional independent design review (IDR) will be added to the Engineering Plan

- PS0366 Plan and Conduct Independent Design Reviews
- PD0602 Plan Independent Design Reviews
- PD0603 Conduct Independent Design Reviews

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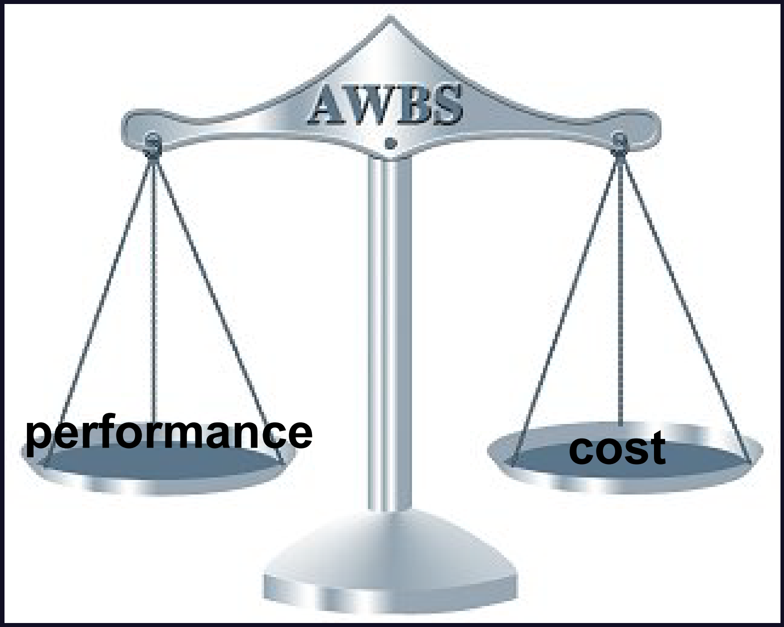
The big picture

- Program managers tradeoff cost, schedule and technical performance of a system
- Cost and schedule are often tracked with an earned value system
- TPMs give managers a way to track technical performance
- Managers can adjust cost and schedule per TPM forecasts



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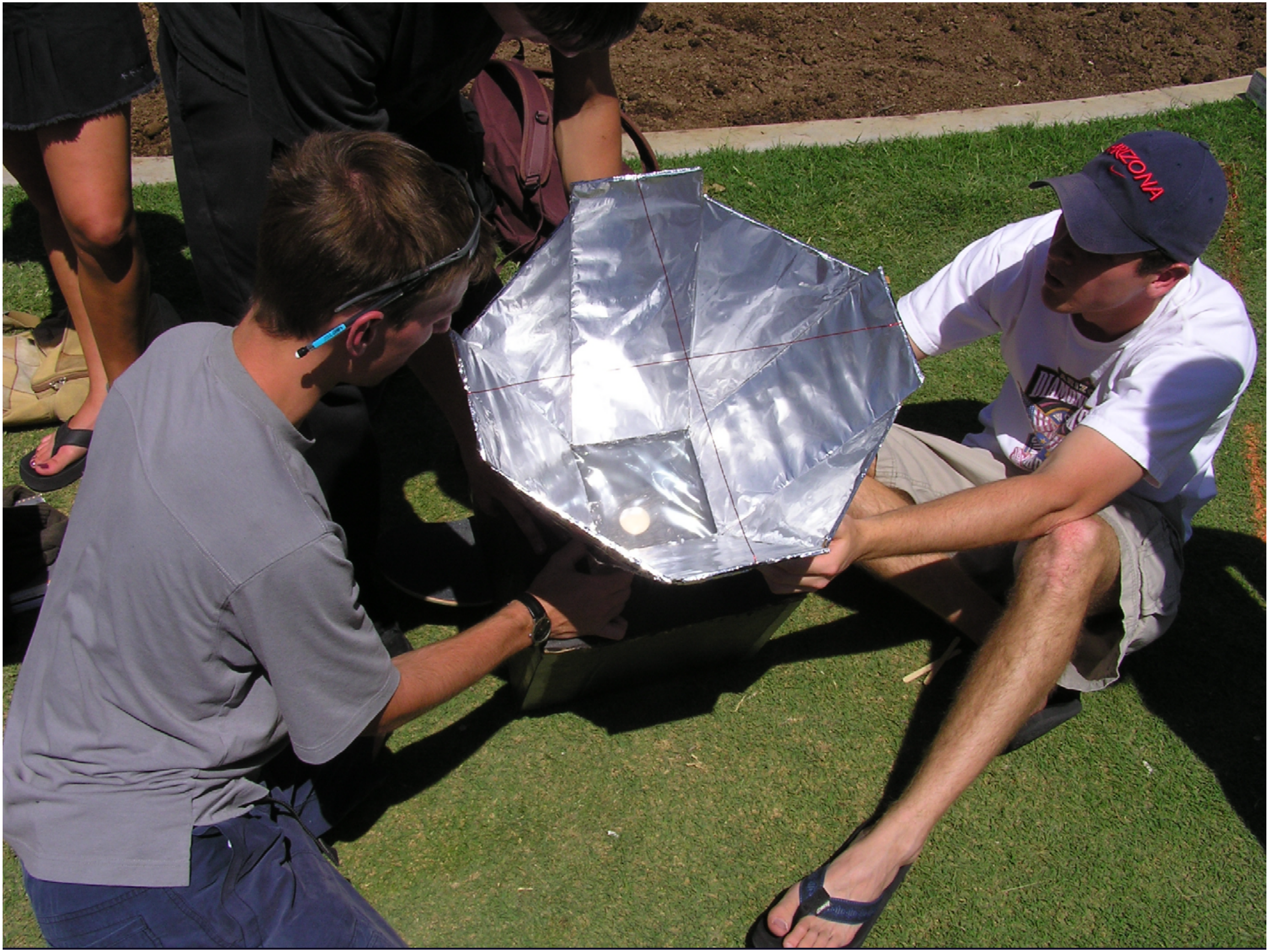
Solar Oven Case Study

- As an example of using a TPM, let us consider the design and manufacture of solar ovens
- In many societies people spend as much as 50% of their time acquiring wood for their cooking fires
- To address this, people have been designing and building solar ovens
- Let us examine the solar oven design and manufacturing process that we followed in a Freshman Engineering Design class (Engr-102) at the University of Arizona


ARIZONA

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Risk analysis$_1$

For each identified risk, students recorded the Risk Name, description, impact, probability, type and risk mitigation plan

For the solar oven project three risks were identified

Risk One

Name: High Cost

Description: Material for the ovens is provided. But some students paid $100 for special materials and told their parents that was required

Impact: medium

Probability: low

Type: monitor

Plan: Compute cost for every design

Risk analysis of solar oven$_2$

Risk Two

Name: Failure to Have Oven Ready for Testing

Description: Everyone must test at the same time on the same day. If a team is not ready, they cannot be tested fairly.

Impact: high

Probability: low

Type: manage

Plan: Require final design 7 days before scheduled test date and require preproduction unit 3 days in advance

Risk analysis of solar oven $_3$

Risk Three

Name: Insufficient Internal Oven Temperature

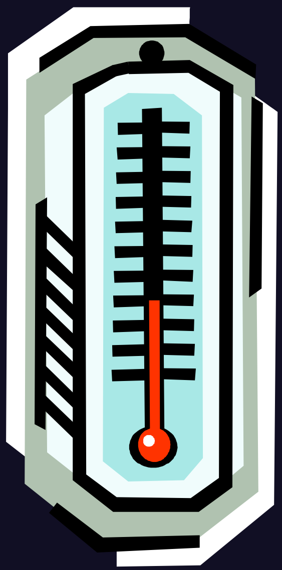
Description: The ovens must get hot enough to bake bread.

Impact: high

Probability: high

Type: resolve

Plan: Make it a technical performance measure



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Design the TPM

- When a loaf of bread is finished baking, its internal temperature should be 200°F
- To reach this internal temperature, commercial bakeries bake the loaf at 445°F
- As initial values for our oven temperature TPM, we chose a lower limit of 212°F, a goal of 445°F, and an upper limit of 520°F
- The tolerance band shrinks with time as shown in the upcoming figure

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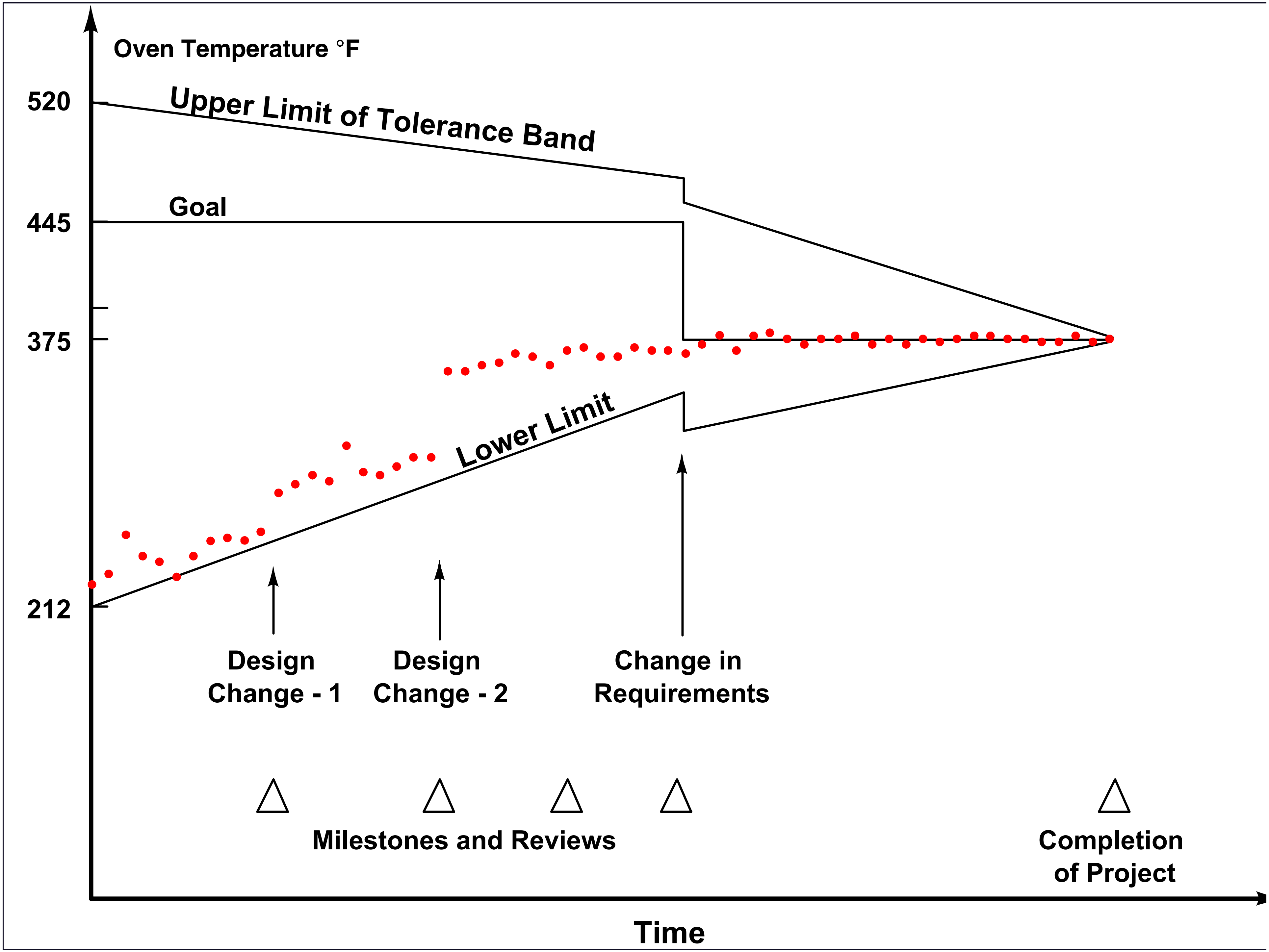
TPM template

- **Name:** Internal Oven Temperature
- **Purpose:** ensure that most ovens pass the scheduled test
- **Source requirement:** assignment for Engr-102
- **Risk level:** resolve
- **What should be measured?** internal oven temperature in degrees Fahrenheit
- **How should it be measured?** test
- **How often should it be measured?** daily
- **During which project phases should it be measured?** all
- **How should it be displayed?** see figure
- **To whom should it be presented?** Engr-102 instructor
- **Threshold above or below which action is necessary:** the lower limit shown in the figure
- **What action should be performed?** suggest new design or negotiate with the customer to relax the requirements
- **Who should perform this action?** Engr-102 instructor



Oven Temperature °F
520
445
375
212
Upper Limit of Tolerance Band
Goal
Lower Limit
Design Change - 1
Design Change - 2
Change in Requirements
Milestones and Reviews
Completion of Project
Time

Improvement$_1$

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- In the beginning our day-by-day measurement values increased because of:
  - finding better insulators,
  - finding better glazing materials (e.g., glass and Mylar),
  - sealing the cardboard box better,
  - aiming at the sun better, etc.
- At the time labeled “Design Change-1,” there was a jump in performance caused by adding a second layer of glazing to the window in the top of the oven
- This was followed by another period of gradual improvement as we learned to stabilize the two pieces of glazing material

Improvement$_2$

- At the time labeled "Design Change-2," there was another jump in performance caused incorporating reflectors to reflect sunlight onto the window in the oven top
- This was followed by another period of gradual improvement as we found better shapes and positions for the reflectors

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Study the requirement

- We might not attain our goal
- We reevaluated the process and requirements
- *Consequences of insufficient oven temperature:
  - Enzymes are not deactivated soon enough, and excessive gas expansion causes coarse grain and harsh texture
  - The crust is too thick, because of drying caused by the longer duration of baking
  - The bread becomes dry, because prolonged baking causes evaporation of moisture and volatile substances
  - Low temperatures cannot produce carmelization, and crust color lacks an appealing bloom

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Alternatives

- If the dough were made richer by adding sugar, eggs, butter and milk, we could get away with temperatures as low as 350°F
- But we decided to design our ovens to match the needs of our customers, rather than try to change our customers to match our ovens

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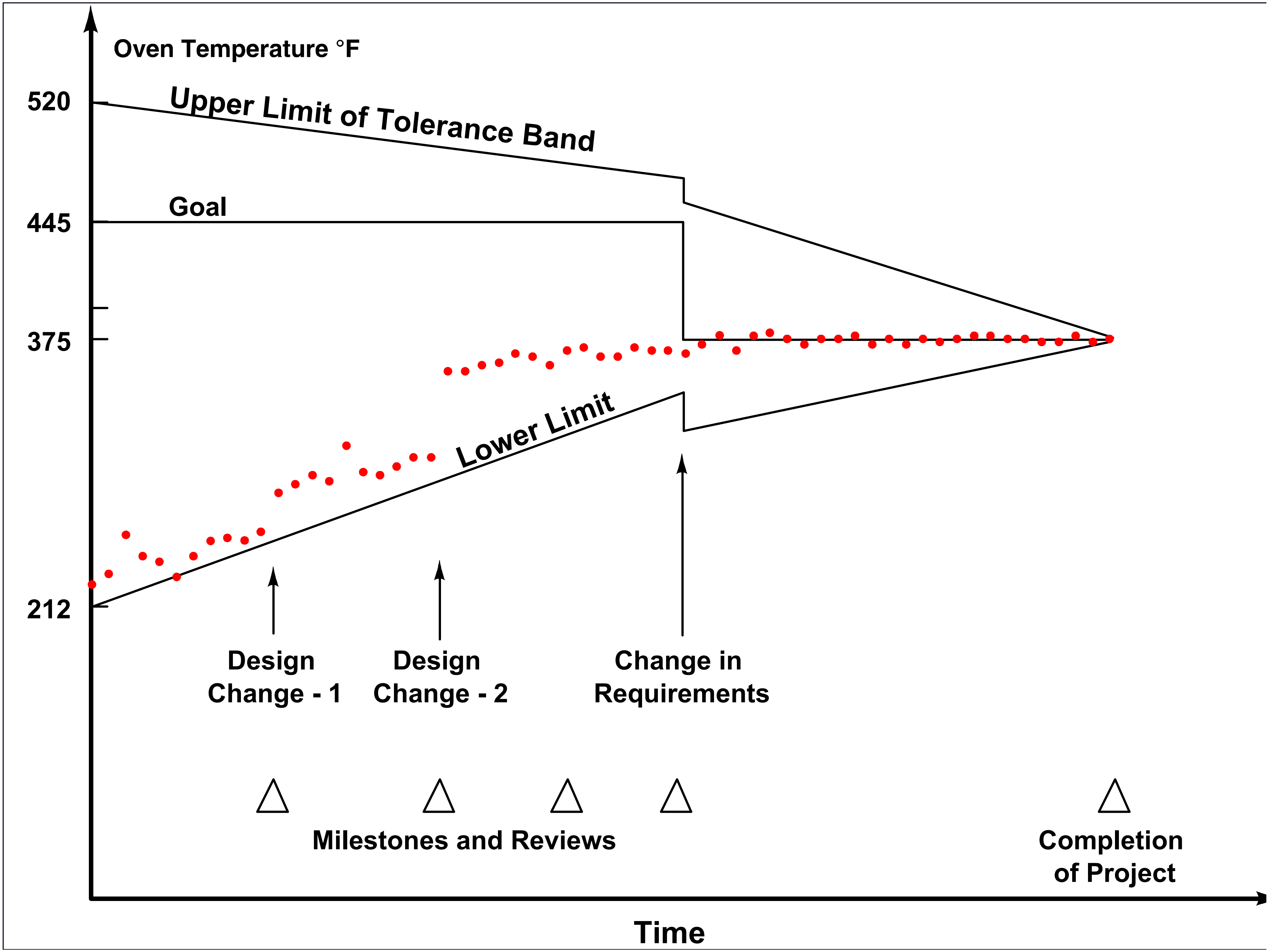
Change the requirement

- After consulting some bakers, our managers decided that 375°F would be sufficient to avoid the above problems
- Therefore, the requirements were changed at the indicated spot and our design was able to meet the goal of the TPM
- Of course, this change in requirements forced a review of ***all*** other requirements and a change in many other facets of the design
- For example, the baking duration versus weight tables had to be recomputed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Pilot at BAE Systems

- In 2005, a mature Archive and Dissemination development program piloted our TPM process
- This program has been running for seven years
- We used it on a new spiral that was to last seven months from funding to delivery
- TPMs were selected for less than 1% of the program's 7000+ system requirements
- The selected TPMs were related to image processing and data export (dissemination) rates
- Simulations done for the TPM process showed that dissemination of near-line data (information from tapes in a robot) and off-line data (information from tapes on a shelf) were significant risks
- The program continues to monitor these TPMs
- Modifications to the system/hardware design and architecture may be necessary to ensure satisfaction of the near-line and off-line dissemination requirements

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What might change?

- Only create TPMs for requirements where you can change something
- In the solar oven example the design was changed twice and the goal was also changed
- Obviously, cost and schedule can be changed to improve performance
- TPMs can be used to choose between alternative concepts. The alternatives that can be used to reduce blood pressure include drugs, exercise, diet and reducing alcohol consumption. If one technique is not working, then you can add or switch to another.

Subtleties

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Quantifying System Performance

- Evaluation criteria (which are also called figures of merit and measures of effectiveness) are used to quantify requirements and to help select amongst alternative designs in tradeoff studies
- Measures (which used to be called metrics) are used to help manage a company's processes
- Technical performance measures are used to mitigate risk during design and manufacturing

Examples of Measures, not TPMs

- Number of features implemented
- *Components designed
- Components implemented
- Components integrated and tested
- Requirements allocated
- Requirements tested
- Test cases completed
- Paths tested
- Problem reports resolved
- Reviews completed
- Changes implemented
- Hours between failures
- Failure Rate a.k.a. Failure Intensity

Most of these are process, not product related

Failure Rate

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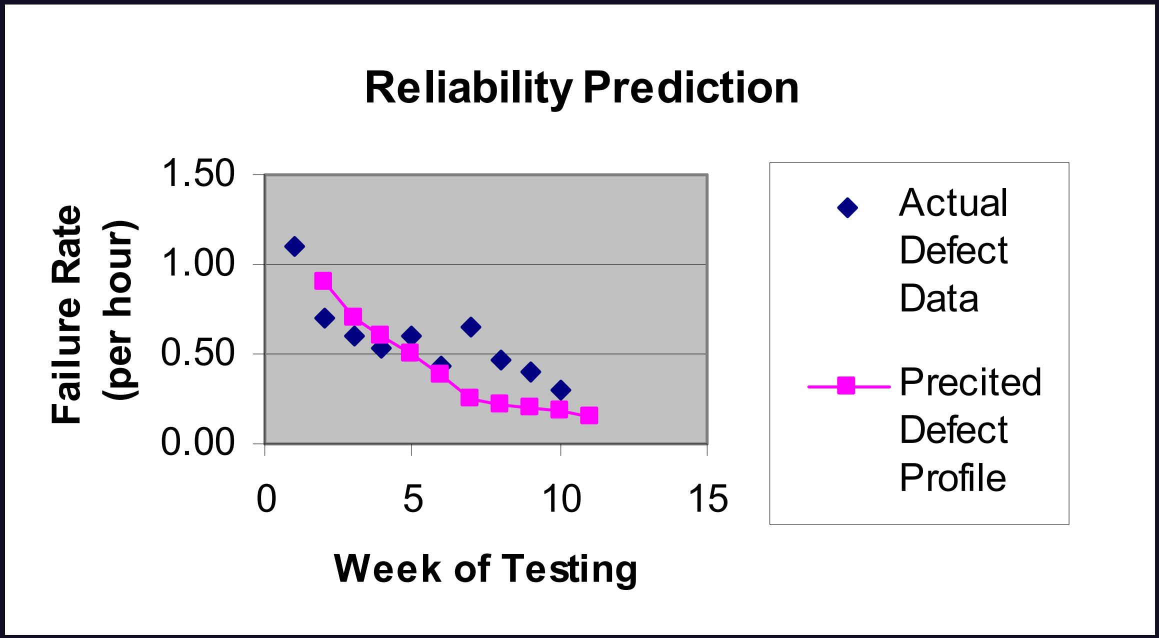

From David N. Card, Software Productivity Consortium

In this case the planned values are given with an equation

$$\lambda = \lambda_0 e^{-\theta t}$$

where λ is the failure rate, λ_0 is the initial failure rate, θ is the decay rate and t is time. This is the equation for a Poisson distribution

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Preventing deterioration

- We use TPMs for requirements where the desired performance is expect to improve with time
- Another use of TPMs would be to prevent unacceptable decreases in performance
- In the design and development process, adding bells and whistles might reduce processing time or increase weight
- TPMs could warn of such unwanted behavior

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TPM Summary$_1$

- TPMs are used to identify and track performance requirements that are program critical
- TPMs are used to establish the appropriate design emphasis, design criteria and identify levels of technical risk
- TPM measurements are collected and tracked against project design objectives in the project's risk register

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TPM Summary$_2$

Create TPMs for high priority requirements

- that impact
  - mission accomplishment
  - customer satisfaction
  - system usefulness
- where performance improves with time
- where performance can be controlled
- where management can tradeoff cost, schedule and performance