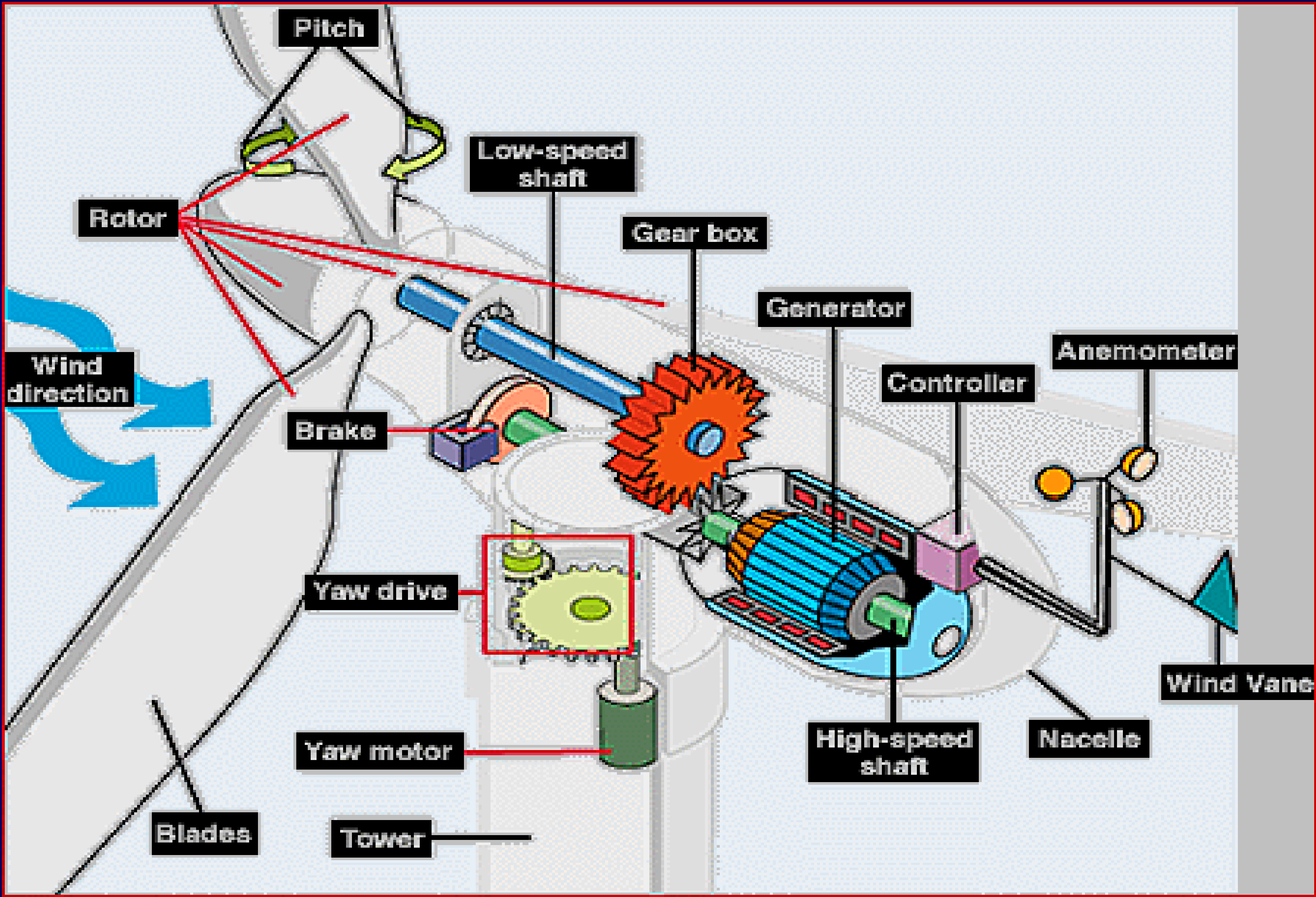
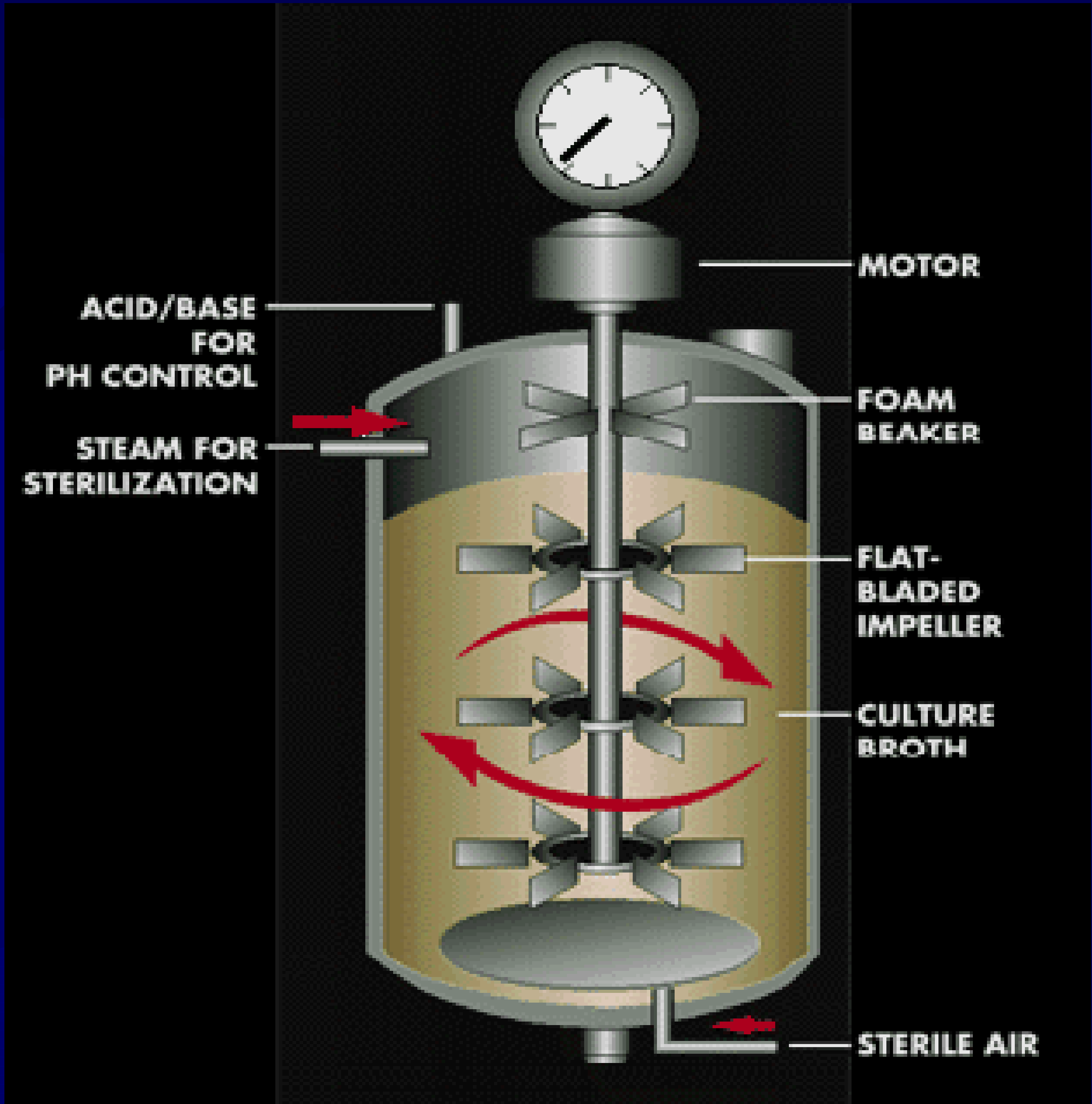
Emerging Technologies

Insuring What Has Not Been Insured Before

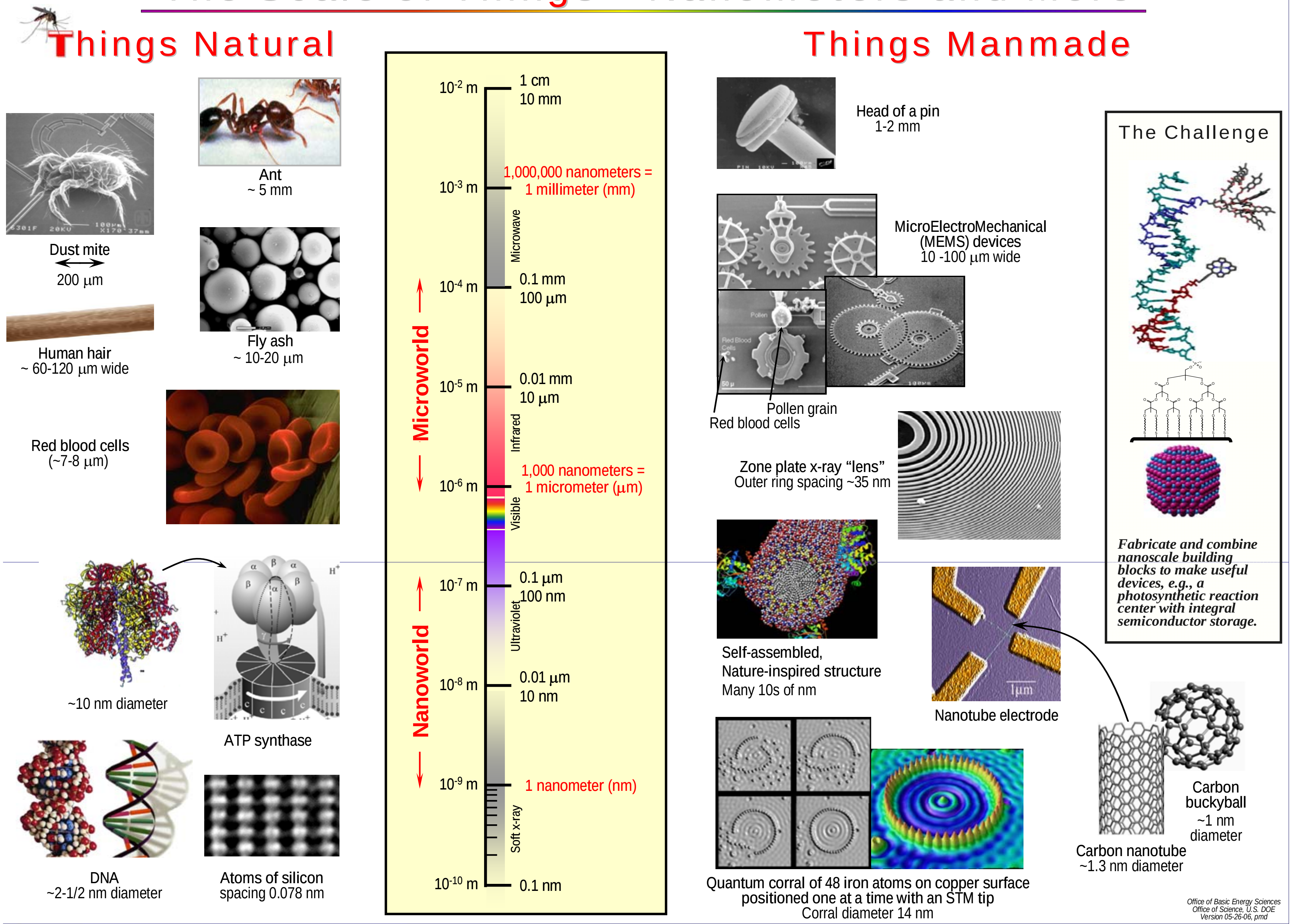


U.S. Dept. of Energy


MOTOR
ACID/BASE
FOR
PH CONTROL
FOAM
BEAKER
STEAM FOR
STERILIZATION
FLAT-
BLADED
IMPELLER
CULTURE
BROTH
STERILE AIR

Genentech

The Scale of Things – Nanometers and More



Issues in Insuring Emerging Technologies

- Lack of loss experience
  - Lack of data / lack of expertise / rapid change
- Systems risks
  - Technological risk
    - Quality, Reliability, Cost
    - Competing technologies
  - Regulatory & political risk
    - including loss of government subsidy

Some Relevant Tools

- Risk models
  - for pricing insurance
  - for modeling portfolio risk
- Models that combine data and expert opinion
- Procedures for efficiently updating models as new data becomes available
- Techniques for incorporating systems risk into models

Some Potentially Insurable Losses

- Property damage
- Business interruption & extra expense
- Products & Operations liability
- Systems performance shortfall
- Other revenue losses & cost increases
- Equipment Breakdown: PD and resulting BI & EE

Equipment Breakdown - Basic Model Elements

- External hazards & environmental influences
- Vulnerabilities and failure modes
- Loss frequency distributions
- Loss severity distributions

External Hazards for EB

- May cause losses or may simply increase the probability of losses
- Weather: temperature, humidity, dust
- If all risk coverage: wind, flood, lightning, quake etc.
- Power outage & power quality disturbances
- Computer & communications network disturbances

EB Failure Modes - New Technologies

- First step: identify, don't quantify
- Using components with known failure modes? Identify how component failures can interact to cause system failures
- Using novel components? Look at basic failure mechanisms

Some Basic Failure Mechanisms

- Chemical
  - Fire, chemical explosion, oxidation, corrosion, migration, deposition, cross-linking
- Mechanical
  - Cracking, deforming, scoring, erosion, melting, annealing
- Programming Error

Loss Frequency Distributions

- Frequencies of failure by component & failure mode
- Choice of exposure unit
- Hypothetical data for illustration only: new 1.5 MW wind turbine

Component	Failure Mode	Failure Rate per Unit per Year
gearbox	mechanical failure	.01
entire unit	lightning strike causing electrical fire	.002

Loss Frequency Model

- Depends on characteristics of the unit - a multivariate frequency model
- Hypothetical example: gearbox failure rate (model A2 is a new design with no gearbox)

Model	Maintenance	Failure Rate
A1	Good	0.01
A2	Good	0.00
B1	Good	0.02
A1	Poor	0.03
A2	Poor	0.00
B1	Poor	0.06

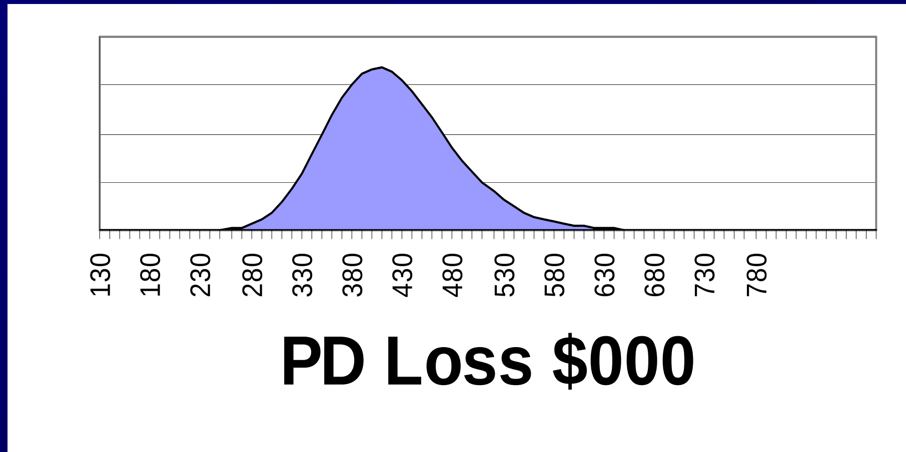
Loss Frequency Model (continued)

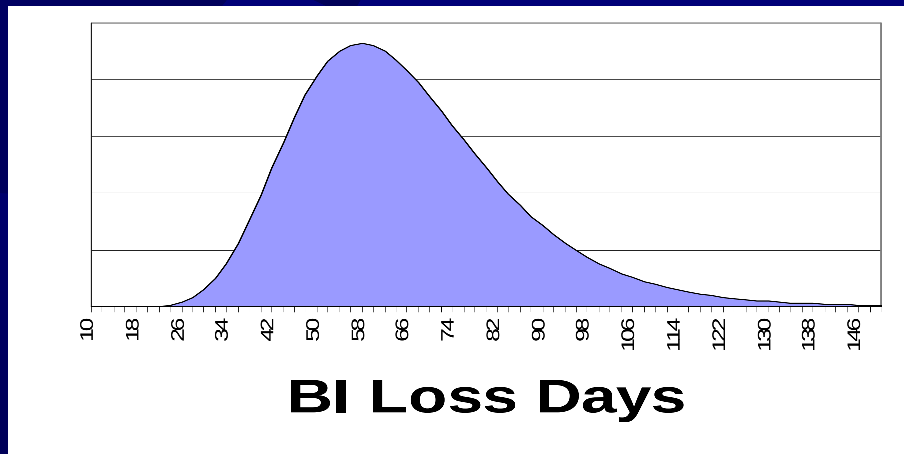
- Hypothetical example: electrical fire from lightning strike

Model	Lightning Strike Frequency at Location of Unit	Failure Rate
A1	High	0.020
A2	High	0.020
B1	High	0.030
A1	Medium	0.004
A2	Medium	0.004
B1	Medium	0.006
A1	Low	0.002
A2	Low	0.002
B1	Low	0.003

Loss Severity Distributions

- Severity distributions by component & failure mode
- Hypothetical example: gearbox failure, model A1:





Pure Premium

- Pure Premium = expected loss per exposure unit (such as a unit-year)
- May include certain allocated expenses
- Does not include unallocated expenses
- Does not include profit
- Does not incorporate risk loads

Pure Premium Calculation for a Specified Unit

- For each failure mode, multiply expected frequency and expected severity to obtain the pure premium for that failure mode
- Add up the pure premium for each failure mode to get the pure premium for the unit
- The pure premium for the unit depends on the unit's characteristics and exposures

Portfolio Risk for a Collection of Units

- Add up the pure premium for each exposure unit to get the pure premium for the portfolio
- Two portfolios may have the same pure premium but very different likelihoods of high portfolio losses
- Positive correlations increase the likelihood of high portfolio losses
  - Correlated failure modes within a unit
  - Correlated failure modes between units (more important)

Correlations for the Hypothetical Wind Turbine Example

- If we are fairly certain about the technology and its implementation then:
- Gearbox failures are statistically uncorrelated between units (approximately)
- Electrical failures due to lightning are correlated between units
  - A single thunderstorm at a wind farm may cause multiple failures
  - A year with a large number of thunderstorms will produce more portfolio failures, on average

More Correlations

- If we are uncertain about the technology and its implementation then:
- Gearbox failures are now positively correlated between units
  - The pure premium remains the same but our losses will be higher than expected if:
    - our portfolio consists of poorly maintained units
    - our portfolio consists of non-robustly designed units
  - If the opposite is true, losses will be lower than expected - but we don’t know which will be the case

A Hypothetical Portfolio of Identical Units

- The design may be robust or non-robust
- We don't know which is true
- If Design is Robust then Pure Premium = $10M, Profit = $2M
- If Design is Non-Robust then Pure Premium = $30M, Loss = $18M
- If our best estimate of the probability of a robust design is 95%, then the pure premium = .95*10 + .05*20 = $11M and expected profit = $1M

Hypothetical Portfolio (continued)

- The portfolio is profitable
- However, there is a 5% chance of an $18M loss
- The portfolio is not diversified due to the equipment design risk common to all units in the portfolio

Quantifying the Value of Information

- The quantified Value of Information is
  - the expected payoff using the best strategy with information
- Minus
  - the expected payoff using the best strategy without information

Value of Information Example

- For the hypothetical portfolio:
- Best strategy without knowing design robustness is to write the business (expected profit = $1M)
- Best strategy with knowledge of design robustness is
  - Write the business if the design is found to be robust (expected profit = $2M)
  - Don't write the business otherwise (expected profit = $0)
- There is a 95% probability that the design is robust, so the expected payoff with information is .95*2+.05*0 = $1.9M
- The difference, $1.9M - $1M = $0.9M, is the value in this context of finding out whether the design is robust

Developing Risk Models for New Technology

- How to develop risk models?
- For a well understood physical system - Physical Models
- For a stable process with an extensive quantified history - Statistical Models
- For new technology, may have lack of physical model and data - turn to experts?

The Role of Expert Opinion

- More important in the absence of physical models and data
- Should be given progressively less weight as relevant data accumulates
- Should be given less weight as accepted physical models become available
- Needs to be quantified to produce frequency and severity models
- A probability framework is essential

The Importance of Quantifying Expert Uncertainty

- Two sorts of uncertainty: uncertainty in the mind of each expert and lack of agreement between experts
- Quantifying uncertainty helps us balance the value of more information-gathering against the value of immediate action
- It helps us to determine the weight to be given to accumulating data. More expert uncertainty requires more sensitivity to incoming data signals but also more sensitivity to incoming data noise

Tools for Quantifying Expert Uncertainty

- Ask for confidence intervals from individual experts
- Use a betting framework (with notional money)
- Use tools to develop underlying structure from the response a series of questions and quantify the level of uncertainty (and inconsistency) within an expert
  - AHP - mathematical technique for developing underlying dimensions from a collection of expert's pairwise comparisons

Multiple Experts

- Risky not to elicit from multiple experts
- Best to elicit separately at first to avoid one expert influencing another, groupthink and clashes of ego
- May be useful to follow up with group discussions
- Standard statistical tools can be use to quantify the disagreement between experts

Why Might Experts Disagree

- Different interpretations of the question. Questions need to be well-defined. Avoid vague or fuzzy concepts.
- Lack of understanding or rejection of probability framework
- Differing experiences

Finding Hidden Data

- A useful step is to consider the basis for the expert's opinion
- Is it based on a formal or informal analysis of data? Can this data be obtained? If so, use this data to help build the risk model
- Is it based on a document that can be obtained?
- If the expert's opinion is based on a synthesis of a wide variety of facts, use the expert

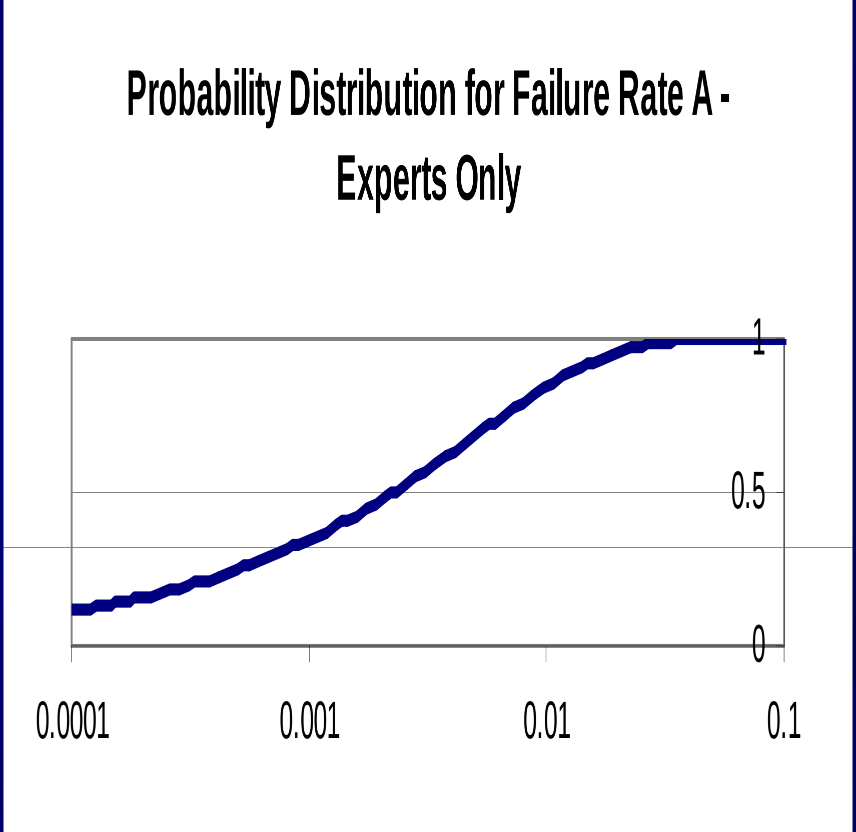
Combining Expert Opinion and Data

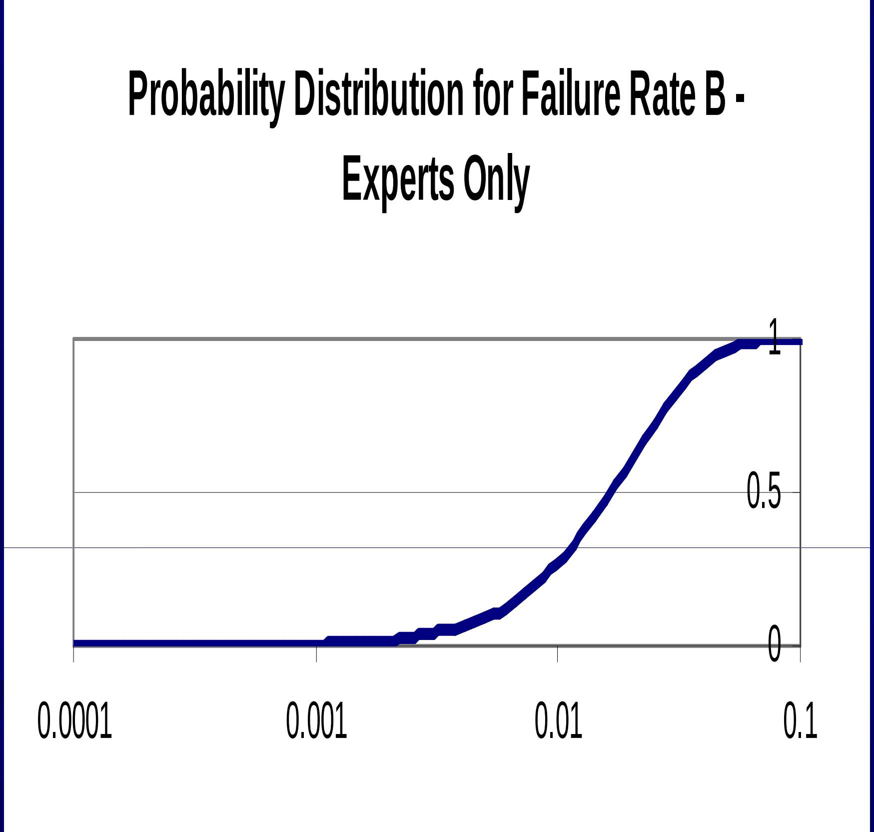
- Informal procedures
  - switch to data-based model when “enough” data
- Formal procedures
  - Bayesian updating
    - well-established mathematics
    - guaranteed logical consistency
    - make require heavy computing

Simplified Example of Bayesian Updating

- Two failure modes
- Want failure rate for each mode
- Start with expert elicitation, no data
- After 3 months of exposure for a portfolio of units, update failure probabilities based on portfolio losses

Results from Expert Elicitation

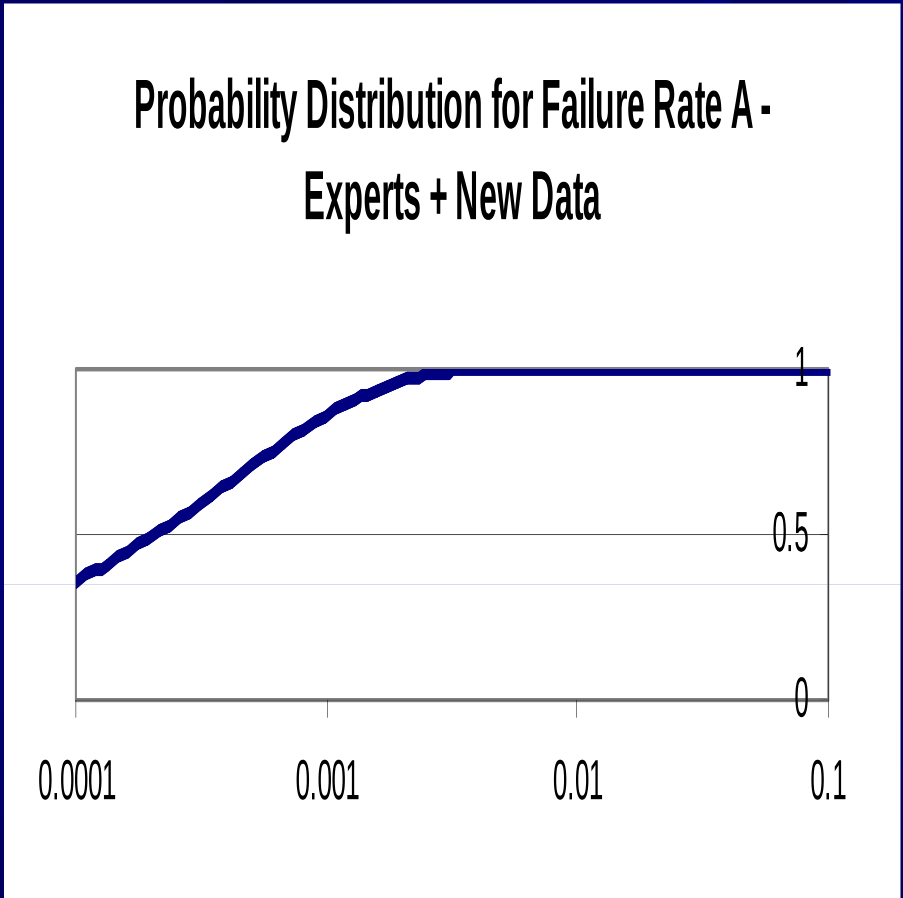


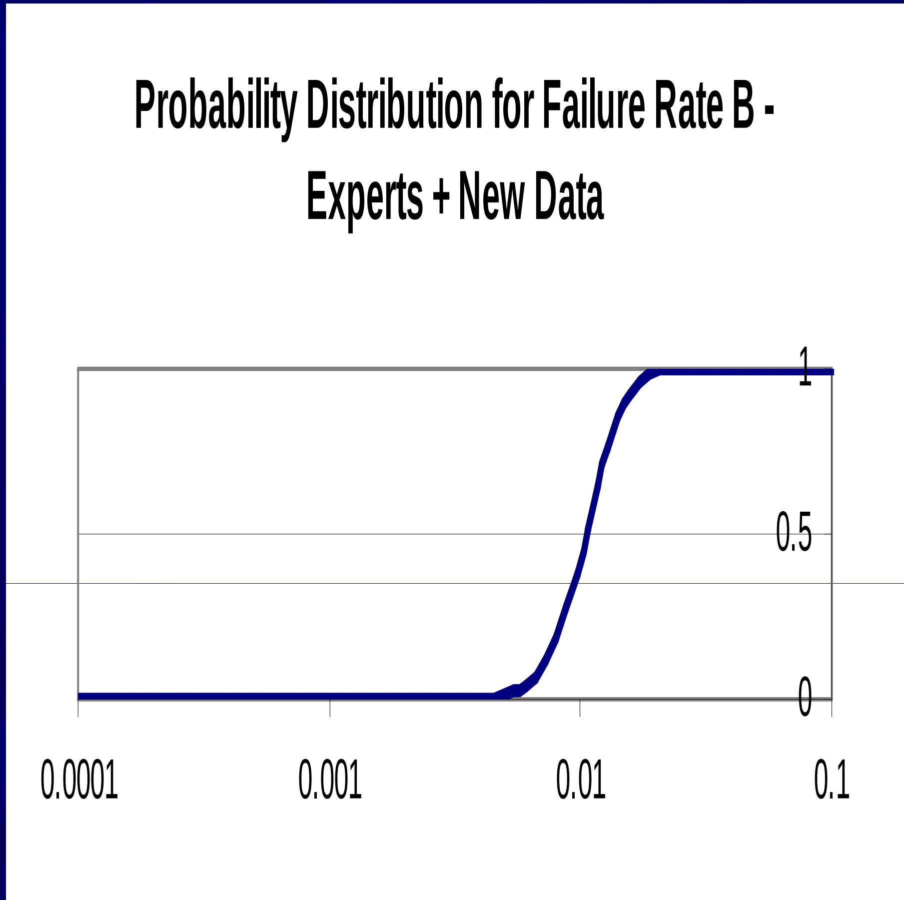


New Data After 3 Months

- 1000 Exposure Units
- 0 losses for failure mode A
- 10 losses for failure mode B

Results after Bayesian Update with New Data





Conclusions

- Importance of eliciting expert opinion and quantifying uncertainties
- Quantifying the value of information
- Importance of efficient and rapid update with new data as it becomes available
- Importance of quantifying portfolio risk – correlated losses, equipment design risk