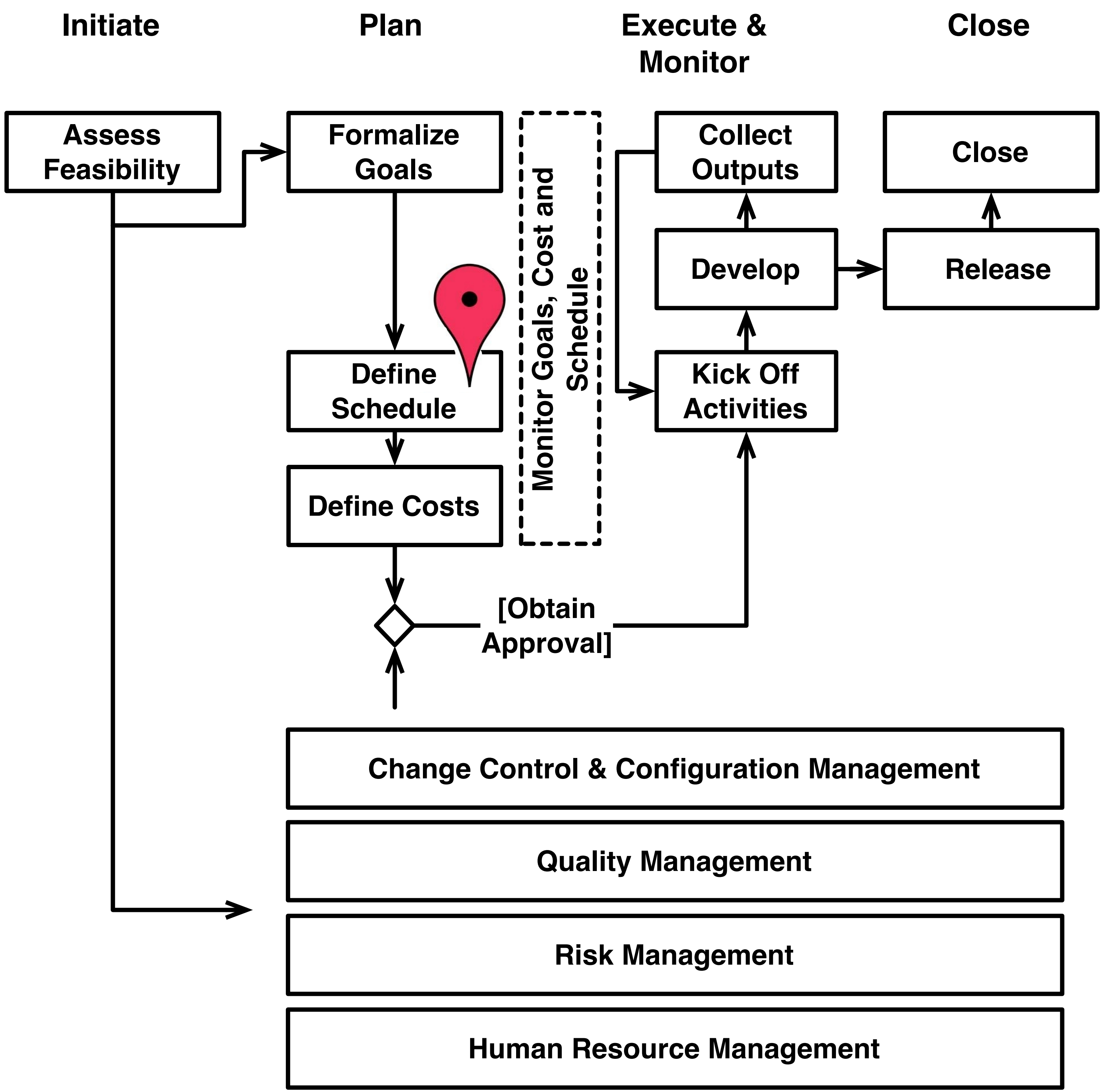
# Estimating

"It is difficult to make predictions, especially about the future" - Attributed to Yogi Berra
(… but also to Niels Bohr and others)

# Goals of the Unit

- Understand the fundamental (and simple) relation among Duration, Effort, and Manpower
- Understanding the perils of estimations in software development
- Learn the techniques commonly adopted to estimate effort in projects


Initiate
Plan
Execute & Monitor
Close
Assess Feasibility
Formalize Goals
Monitor Goals, Cost and Schedule
Collect Outputs
Close
Develop
Release
Define Schedule
Kick Off Activities
Define Costs
[Obtain Approval]
Change Control & Configuration Management
Quality Management
Risk Management
Human Resource Management

# Effort, Duration, and Resources

# Estimation

- **Effort (Work):** how much work will the activity need to be completed
- **Resources:** type and quantity of resources available the activity
- **Duration:** how long will the activity last for

# Effort

- The **amount of work** an activity requires to be completed. A very good starting point.
- Measured in (work-)days, (work-)weeks, (work-)months
- Often the term man-* is also used (e.g. 3 man-months = 1 person working for 3 months; 3 people working for one month)
- Mind you, though: the work required in a project includes direct and indirect activities (i.e., getting the stuff done, but also email, communication, reports, meetings, ...)

# Resources

- The resources needed to carry the work out. Typically a constraints (limited)
- Expressed as **manpower**, that is, number of people and percentage of availability
- For instance: 1 person full time; 2 people at 50%
- Certain tasks might require **material resources** (e.g. bricks & pipes) or **equipment** (e.g. a machine for DNA sequencing)
- Material resources are consumed by the execution of an activity; equipment can be reused
- In software development usually resources = manpower

# Duration

- How long the activity will last for
- Measured in **hours**, **days**, **months**, …
- Often:
  - 1 week = 5 days = 40 hours
  - 1 month = 20 days ... why?
- In some countries:
  - 1 week = 36 hours (7.12 hours/day)
- Calendar time differs from duration: calendar time includes non-working days, holidays, …

# A (simplistic) view

$$D = E / M$$

- Fix any two among D, E, and M (= manpower), and you get the third
- Typically effort and man power are the variables you will be working with (and derive duration from it)
- Notice also that manpower is

$$M = \sum_{i=1}^{N} p_i$$

$N$ = number of resources

$p_i$ = percentage of availability

# Some Examples

- 1 week = 40 hours

- Effort: 40 man-hours; Resources: 1 @ 100% → D = 40 man-hours / 1 man = 40 hours = 1 week
- Effort: 80 hours; Resources: 2 @ 100% → D = 80 man-hours / 2 man = 40 hours = 1 week
- Effort: 80 hours; Resources: 1 @ 50% → D = 80 / 50% = 160 hours = 4 weeks *(a person at 50% will be able to work 20 hours/week; it takes 4 weeks to get to the 80 hours needed for the activity)*

# Important Remark

- The equation is a simplification... good enough for various cases (do not take it to extremes)
- The hypothesis of “take any two variables” in D = E/M is not always reflected in practice (e.g. the variables are not completely independent)
- Estimating is hard: deciding how much effort a task requires is difficult ... in the next few lessons we will look at techniques and tools for estimation

# Uncertainty in Planning

# Uncertainty in planning

- Planning has a certain degree of uncertainty
- (In software and not only) we are over-optimistic
- “best guess” might also be a problem

# Uncertainty in planning

- Three practices (not necessarily good) to account for uncertainty
  - **Implicit padding:** each activity includes some contingency time
  - **Explicit padding:** the contingency time is explicitly modeled as an activity
  - **React and re-plan:** when a delays occurs, you re-plan and re-define a new realistic schedule
- Some suggestions:
  - Always evaluate the cost of delays
  - Choose a strategy and make it clear (with yourself and with your stakeholders, if possible)

# Implicit Padding

- Each activity includes some extra duration/effort to take into account delays
- Estimations become inaccurate and difficult to control
- Always being pessimistic (and always delivering earlier, according to a wrong pessimistic plan) is not necessarily good... the plan is still inaccurate
- Interaction with other projects might still be a problem (you deliver earlier and the next project needs to re-allocate resources in order to start an activity earlier)

# Explicit Padding

- The plan includes some extra activities or slack to take into account delays in finishing activities
- Contingency is not explicit in the plan. Data is accurate; no problems in budgeting/monitoring/...
- Might be difficult to have it accepted... the customer might think of padding as useless

# React and Re-plan

- When a delay occurs, it is dealt with and specific actions are decided. The actions are incorporated into the plan, which is revised
- **Flexible:** takes into account different strategies for dealing with contingencies (e.g. removing dependencies, adding resources)
- This is not a **planning practice**. It is a monitoring and executing practice.
- **The plan** does not show possible alternative courses of actions to the occurrence of a risk/contingency

# Estimation Techniques

# Approaches to Estimation

- **Expert Judgement** is “quick and dirty” and based on experience. It can be applied either top-down or bottom-up
- **PERT (Program Evaluation and Review Technique)** takes into account the probabilistic nature of estimations
- **Algorithmic Techniques** provide estimations by measuring specific qualities of a system and applying algorithms (Function Points, COCOMO, WebObjects

# Expert Judgement

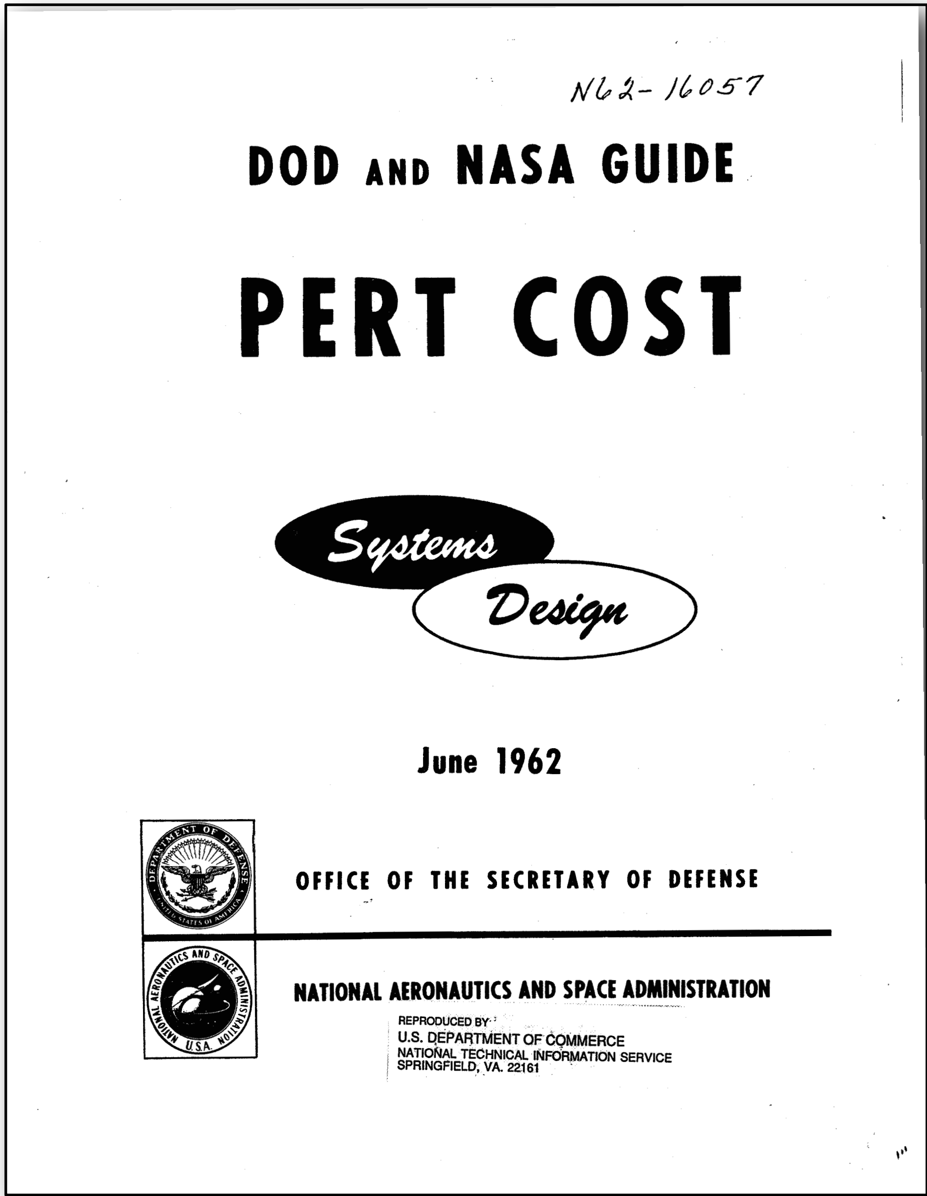
- Efficient and fast. Based on personal (rather than organizational) assets
- Underlying assumption: the project uses a product WBS
- Top-down
  - Start at the top of the WBS and break estimations as you move down
- Bottom-up
  - Start at the bottom of the WBS and sum as you move up

# PERT

# Program Evaluation and Review Technique

# PERT

- Program Evaluation and Review Technique
- Developed in the sixties
- It is a **methodology** to define and control projects
- Variations exists (e.g. PERT/COST developed by NASA/DOD)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DOD AND NASA GUIDE

PERT COST

Systems Design

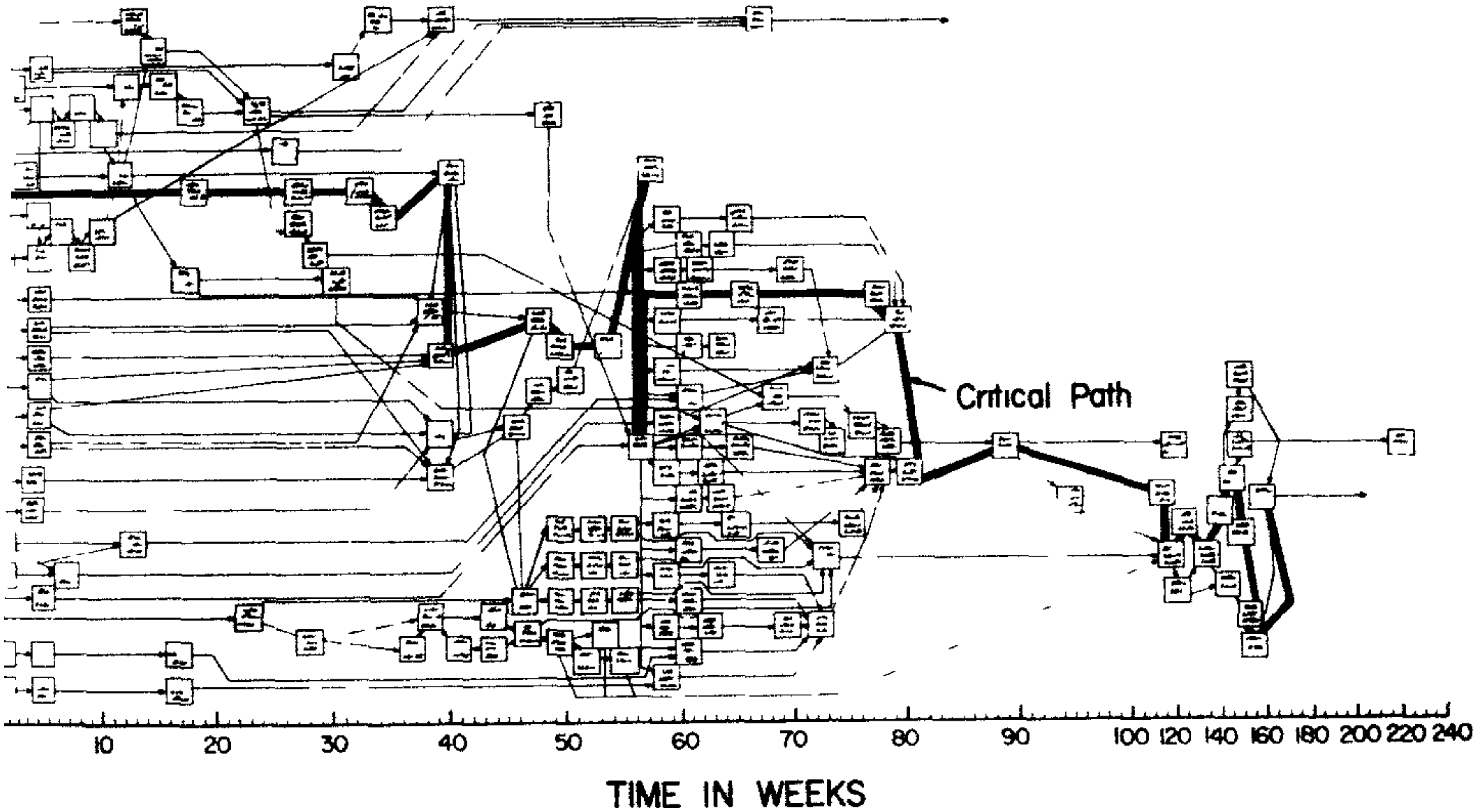
June 1962

OFFICE OF THE SECRETARY OF DEFENSE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

REPRODUCED BY:
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

# A Motivating Example



# PERT Formula

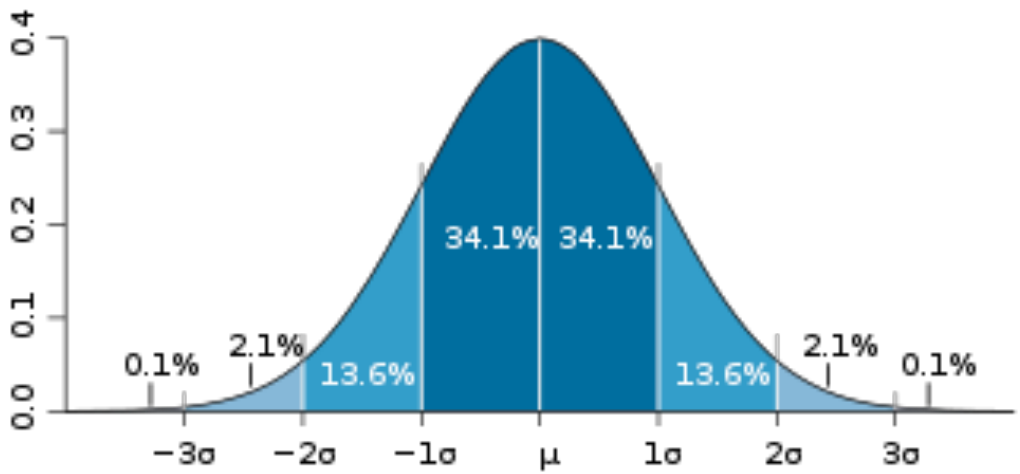
- Estimation in PERT is based on the idea that estimates are uncertain
  - Therefore uses duration ranges
  - And the probability of falling to a given range
- Uses an “expected value” (or weighted average) to determine durations

# PERT

- For each task, three estimates:
  - Optimistic
    - (would likely occur 1 time in 20)
  - Most likely
    - (modal value of the distribution)
  - Pessimistic
    - (would be exceeded only one time in 20)

# Variance and Standard Deviation

- Variance ($\sigma^2$) and standard deviation ($\sigma$) measure how spread a population is from the average
- Standard deviation ($\sigma$) is the square root of variance
- **Example: normal distribution**: a bell shaped probability distribution function




Source: http://en.wikipedia.org/wiki/Normal_distribution

# Beta Distributions

- Average is given by the formula:

$$t_e = \frac{(a + 4m + b)}{6}$$

- Variance ($\sigma^2$) and standard deviation ($\sigma$) are given by:

$$\sigma^2 = (\frac{b - a}{6})^2 \qquad \sigma = \frac{b - a}{6}$$

# PERT Formula

- Task duration is an average of three estimations:

$$t_e = \frac{(a + 4m + b)}{6}$$

*$t_e$ = expected time*

*$a$ = optimistic time estimate (1 in 20)*

*$m$ = most likely time estimate*

*$b$ = pessimistic time estimate (1 in 20)*

# Algorithmic Techniques

# Introduction

- Goal: find a way to systematically determine the effort (duration) required for an (arbitrary) task/project
- Ideally:
  - Identify a set of **measurable** characteristics of a project that determine the project's **effort/duration**
  - Define a function that, given the characteristics mentioned above, computes the **effort/duration**

$$f(x_1, \ldots, x_n) = e$$

Problem: how do you find $f$, $x_1$, ..., $x_n$?

# Solution

- Look at existing projects/datasets; each project is represented by a vector:

  $< a_1, \ldots, a_n, effort >$

- Find correlations between (some of the) variables in the datasets:

  $f(a_1, \ldots, a_k) \propto effort$

- Find appropriate measurement means for the variables at the beginning of a project (so that we can apply the function to a new project)

# Discussion

- Advantages:
  - Replicable
  - Objective
- Limitations of the models:
  - Size of the dataset used for defining the model and accuracy of the model
- Limitations of their application:
  - Resources needed to collect the data (time and expertise)
  - Applicability of the model to the system at hand
  - Accuracy of the data collected to estimate for a new system

# Main Techniques

- **Function Points (FP)**
  - **Function-based**, it estimates effort based on its functional characteristics
  - **Duration/Team** size computed through productivity metrics
  - It requires a critical analysis of the requirements
- **Constructive Cost Modeling (COCOMO)**
  - **Size-based**, it estimates effort, duration, and team size based on the (presumed) size of a system in source lines of code
  - Different families of models
- Sometime used in conjunction (FP to get the system size; COCOMO to do the rest)