A CONCURRENT APPROACH TO TRANSDUCER AND SYSTEM DEVELOPMENT PROJECTS

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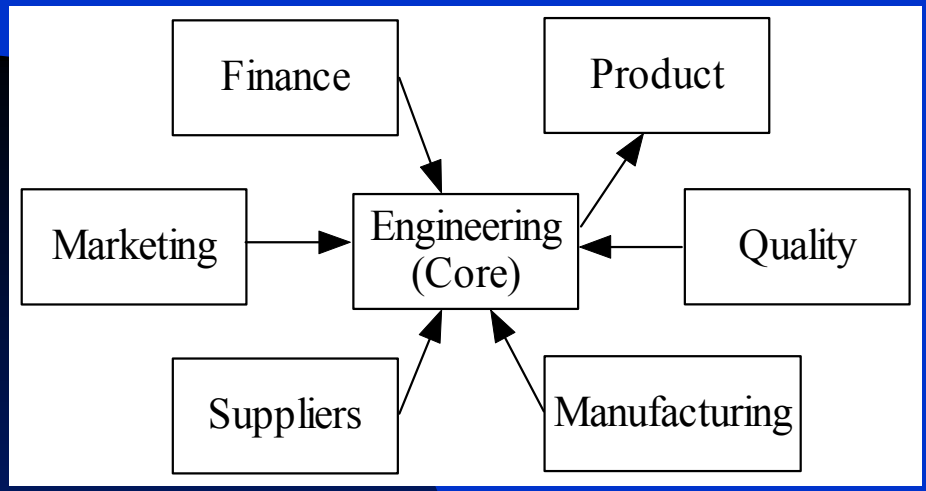
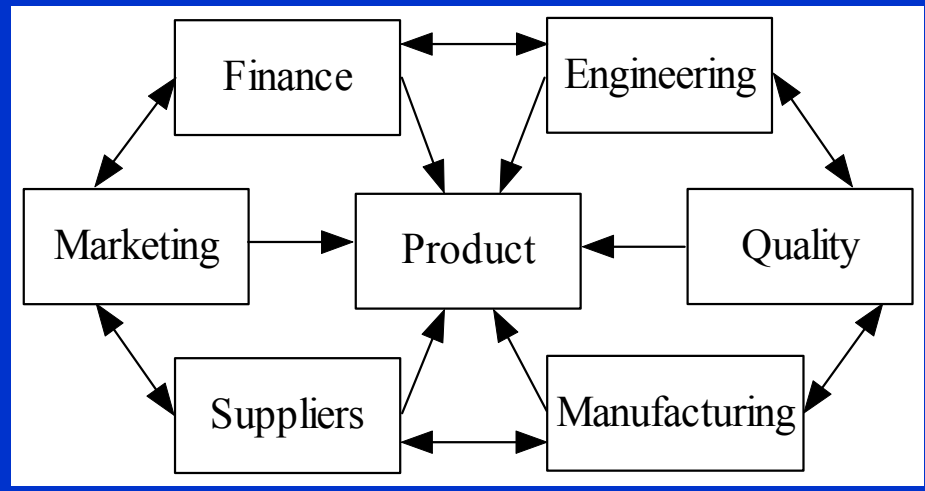
CONCURRENT PRODUCT DEVELOPMENT (CPD) HAS TWO BASIC SEGMENTS.

- **Concurrent Engineering (CE) is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developer, from the outset, to consider all elements of the product lifecycle from concept through disposal, including quality control, cost, scheduling and user requirements.**
- **Integrated Product Development (IPD) is a philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce an effective and efficient product that satisfies the customers' needs.**

A COMPARISON OF TWO DEVELOPMENT MODELS



Engineering owns the Project



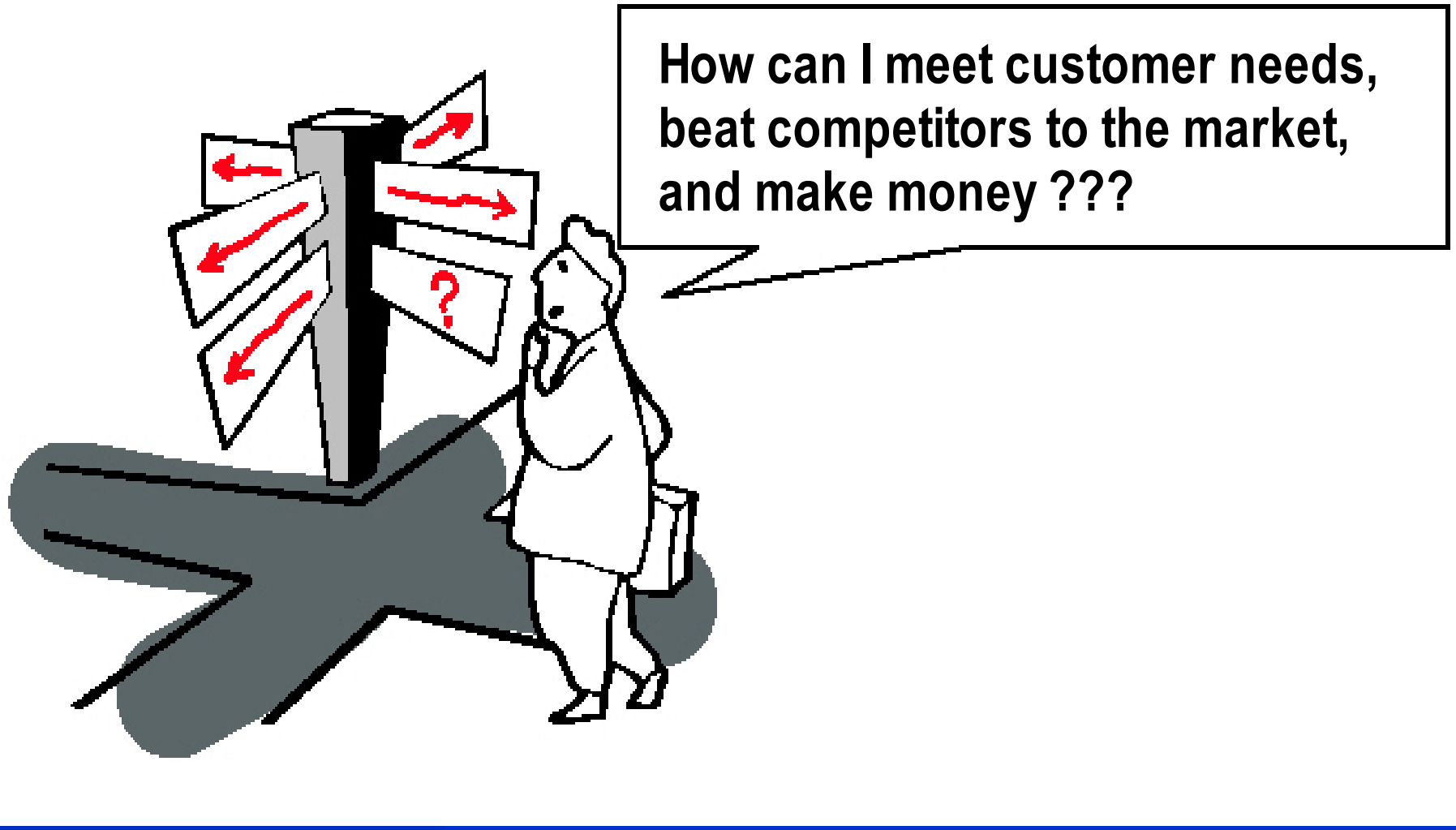
Everyone working together owns the Project

LIKELY CONSEQUENCES

- Functional silos
- Functional views
- The buck stops with Engineering
- Heavily serial activities
- Late, costly, and/or failing to meet customer needs

- Cross-functional input from start
- Holistic view of development
- The buck stops with the Team
- Parallel activities
- On time, within budget, and customer delighted

THE CHALLENGE OF 'CHEAPER, FASTER, AND BETTER' CAN BE MET!



Concurrent Product Development is the only way to get all three.

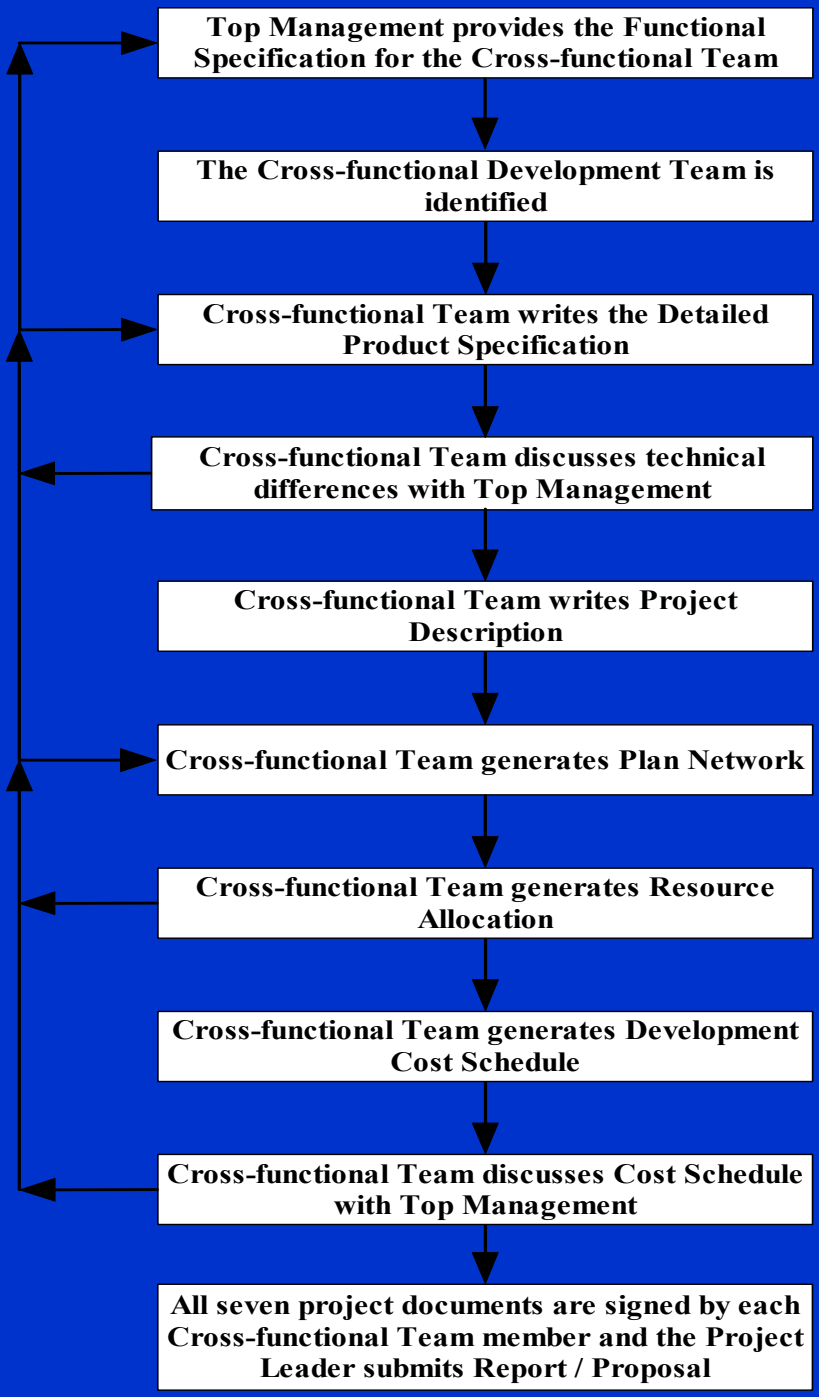
FOR WHAT SIZE AND/OR TYPE OF COMPANY WILL CPD TO BE MOST EFFECTIVE?

- CPD works with all sizes and types of companies. This has been proven over and over by several case studies in Europe and the USA, including CEPRA, PASE, the Society of Concurrent Product Development (SCPD), and the Quality Function Deployment (QFD) Institute.
- Benefits of CPD include 30% to 70% less development time, 65% to 90% fewer engineering changes, 20% to 90% less time to market, 200% to 600% higher quality, and 20% to 110% higher white collar productivity.
- There is no checklist for implementing CPD because there is no one solution.
- Each application will be unique.

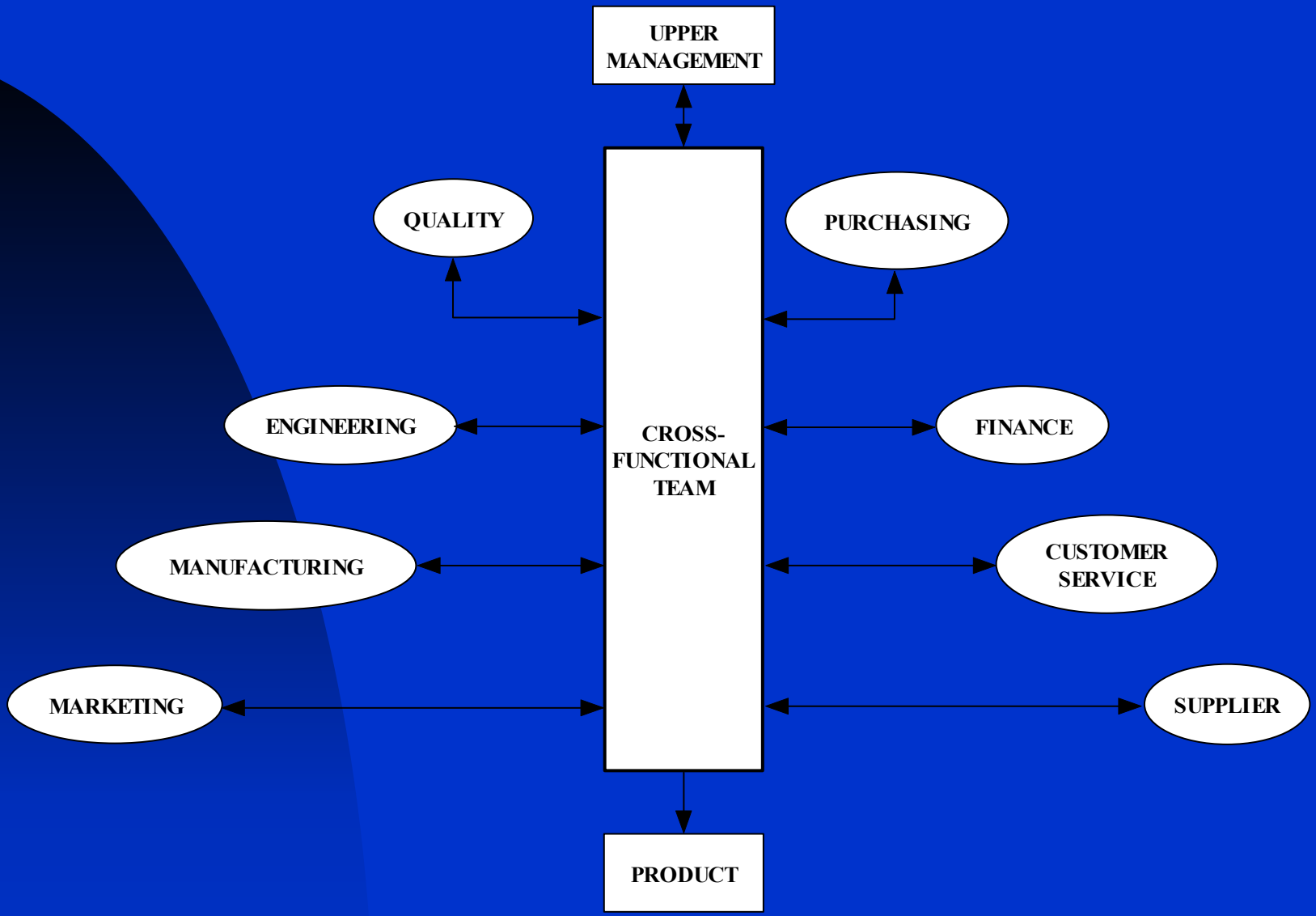
Strategy, People, Process, Tools, Technology, and Costs are essential elements of the business plans for all companies.

THE FLOWCHART OF CONCURRANCE

- Top management supplies the Functional Specification.
- The cross-functional team supplies the Detailed Product Specification.
- The cross-functional team supplies the Project Description.
- The cross-functional team supplies the Plan Network.
- The cross-functional team supplies the Resource Allocation.
- The cross-functional team supplies the Cost Schedule.
- The project leader or champion supplies the Report/Proposal.



CROSS-FUNCTIONAL TEAM NETWORK EXAMPLE



The Cross-functional Team should consist of 6 - 8 members.

THE FUNCTIONAL SPECIFICATION

- A written description of the transducer and/or system to be developed as it is viewed from the top level down.
- Typically presented to the cross-functional team from a higher supervisory level.
- Describes the functional characteristics of the product to be developed including the performance expectations and a cost target.

THE DETAILED PRODUCT SPECIFICATION

- Complete physical description of the transducer and/or system to be developed that is written by the cross-functional team.
- Must conform to the Functional Specification.
- The cross-functional team should study competitive products and customer needs.
- Brainstorming and Creativity

THE PROJECT DESCRIPTION

- The first two elements of the project plan, the Functional Specification and Detailed Product Specification, describe the product.
- The cross-functional team has fully described the transducer and/or system to be developed.
- The team ‘owns’ the project.
- The Project Description is a brief description of the project, typically inclusive of the project objectives that are written by the cross-functional team.
- Finalizing or ‘Hardening’ the specifications is a prerequisite for writing the Project Description, ‘Design-It-Once’ criteria.

Without hardening specifications early on in the project, the product is typically designed 5 times!

YOU WANT IT WHEN AND AT WHAT COST ?

Your plan and cost schedules should be based on previous experiences and sound mathematics.

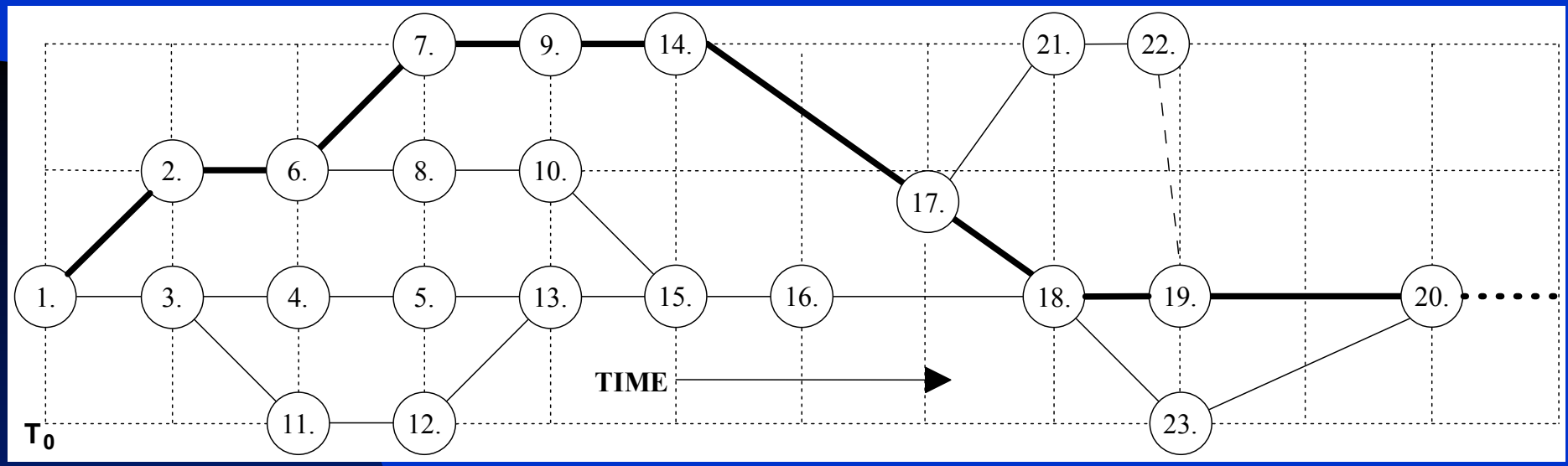
- t_m is the most likely time for previous similar activities.
- t_o is the optimistic time for previous similar activities at a 5% probability.
- t_p is the pessimistic time for previous similar activities at a 95% probability.
- $t_e = (t_o + 4t_m + t_p)/6$ and is the expected activity time at a 50% probability, with a variance, σ_e^2.
- $\sigma_e = (t_p - t_o)/6$ is the standard deviation.

ACTIVITY LIST WORKSHEET

No.	Activity	Person(s)	t_m	t_o	t_p	t_e	σ_e^2	Initials
1 - 2								
1 - 3								
2 - 6								
3 - 4								
3 -11								
4 - 5								
5 -13								
6 - 7								
6 - 8								
7 - 9								
8 -10								
9 -14								
10 -15								
11 -12								
12 -13								
13 -15								
14 -17								
15 -16								
16 -18								
17 -18								
18 -19								
...								

Each project plan should contain no less than 50 activities to effectively apply the Central Limit Theorem.

SEGMENT OF A PLAN NETWORK



The 'Critical Path' is the longest time path.

$$T_E = t_{e\,1\text{-}2} + t_{e\,2\text{-}6} + t_{e\,6\text{-}7} + t_{e\,7\text{-}9} + t_{e\,9\text{-}14} + t_{e\,14\text{-}17} + t_{e\,17\text{-}18} + t_{e\,18\text{-}19} + t_{e\,19\text{-}20} + \ldots$$

The probability of 'On-Time Completion' is only 50%.

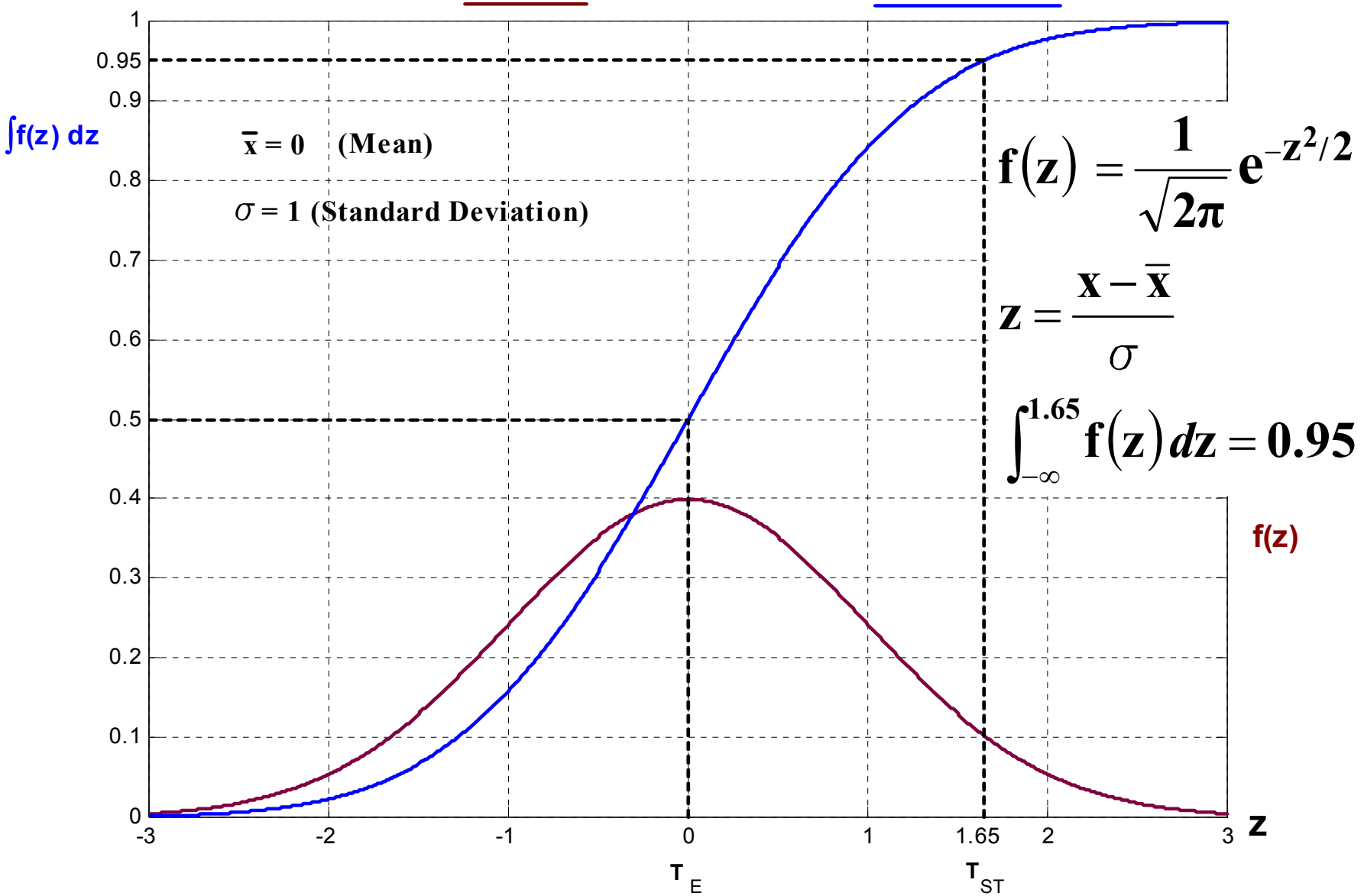
Let's include critical activity variance in the planning.

$$\sigma_E = \sqrt{\sigma^2_{e\,1\text{-}2} + \sigma^2_{e\,2\text{-}6} + \sigma^2_{e\,6\text{-}7} + \sigma^2_{e\,7\text{-}9} + \sigma^2_{e\,9\text{-}14} + \sigma^2_{e\,14\text{-}17} + \sigma^2_{e\,17\text{-}18} + \sigma^2_{e\,18\text{-}19} + \sigma^2_{e\,19\text{-}20} + \ldots}$$

$$T_{ST} = T_E + 1.65\sigma_E$$

The probability is now 95%!

NORMAL PROBABILITY DENSITY AND PROBABILITY DISTIBUTION FUNCTIONS

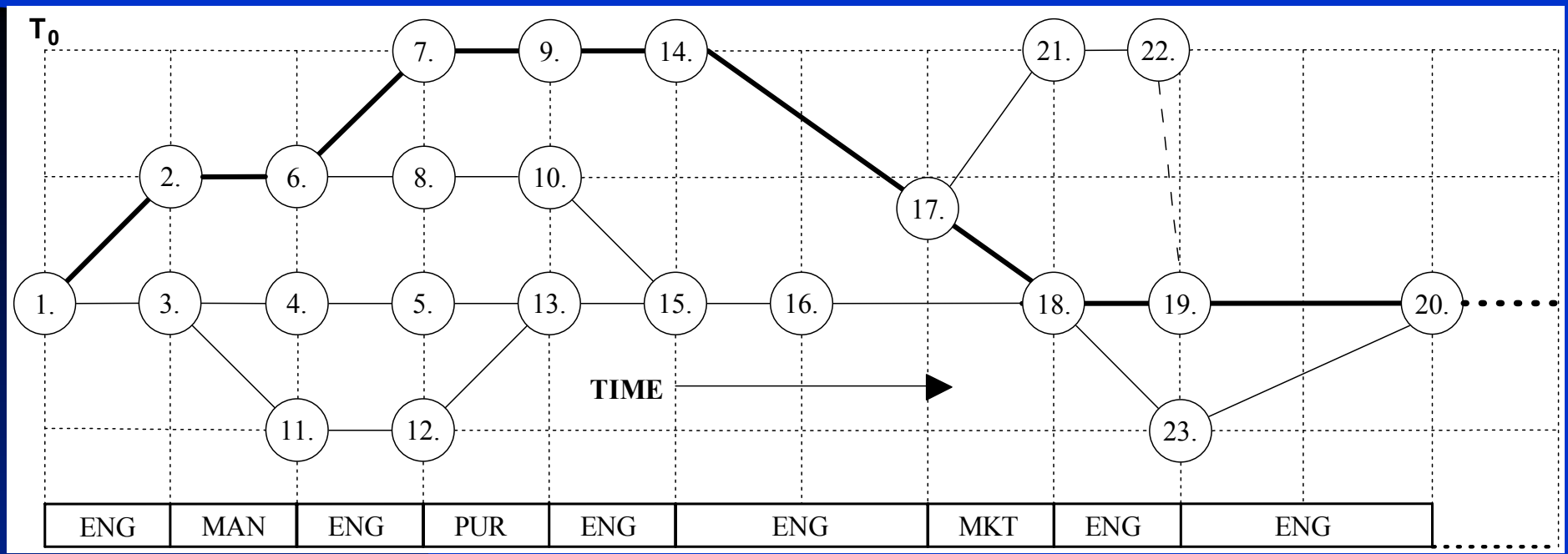


RESOURCE ALLOCATION

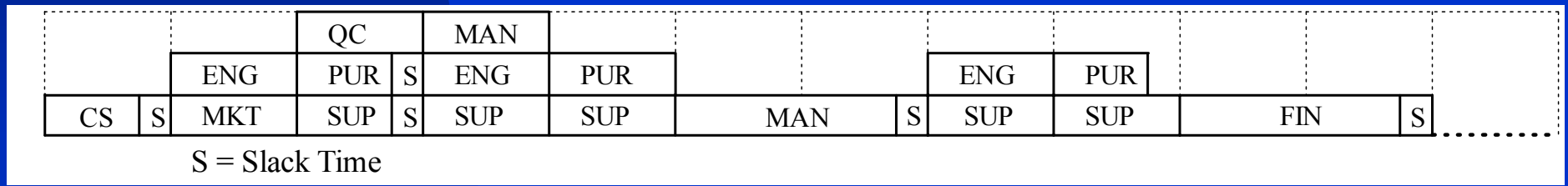
- Assign the appropriate talents to the corresponding project activities.
- Obtain approval for human resources from the source managers for scheduled allocations.
- Modify the Plan Network if necessary.
- Draw the Resource Allocation in the form of a histogram or vertical bar chart on the same time scale as the Plan Network.
- Draw separate histograms for critical and non-critical human resource allocations.
- All members of the cross-functional team must agree on the Resource Allocation.

Careful resource allocation helps to prevent schedule slippage.

PLAN NETWORK WITH CRITICAL HUMAN RESOURCE ALLOCATION



OTHER HUMAN RESOURCE ALLOCATION



Without sound planning and realistic scheduling before the project begins, it is impossible to achieve good control of the project later on.

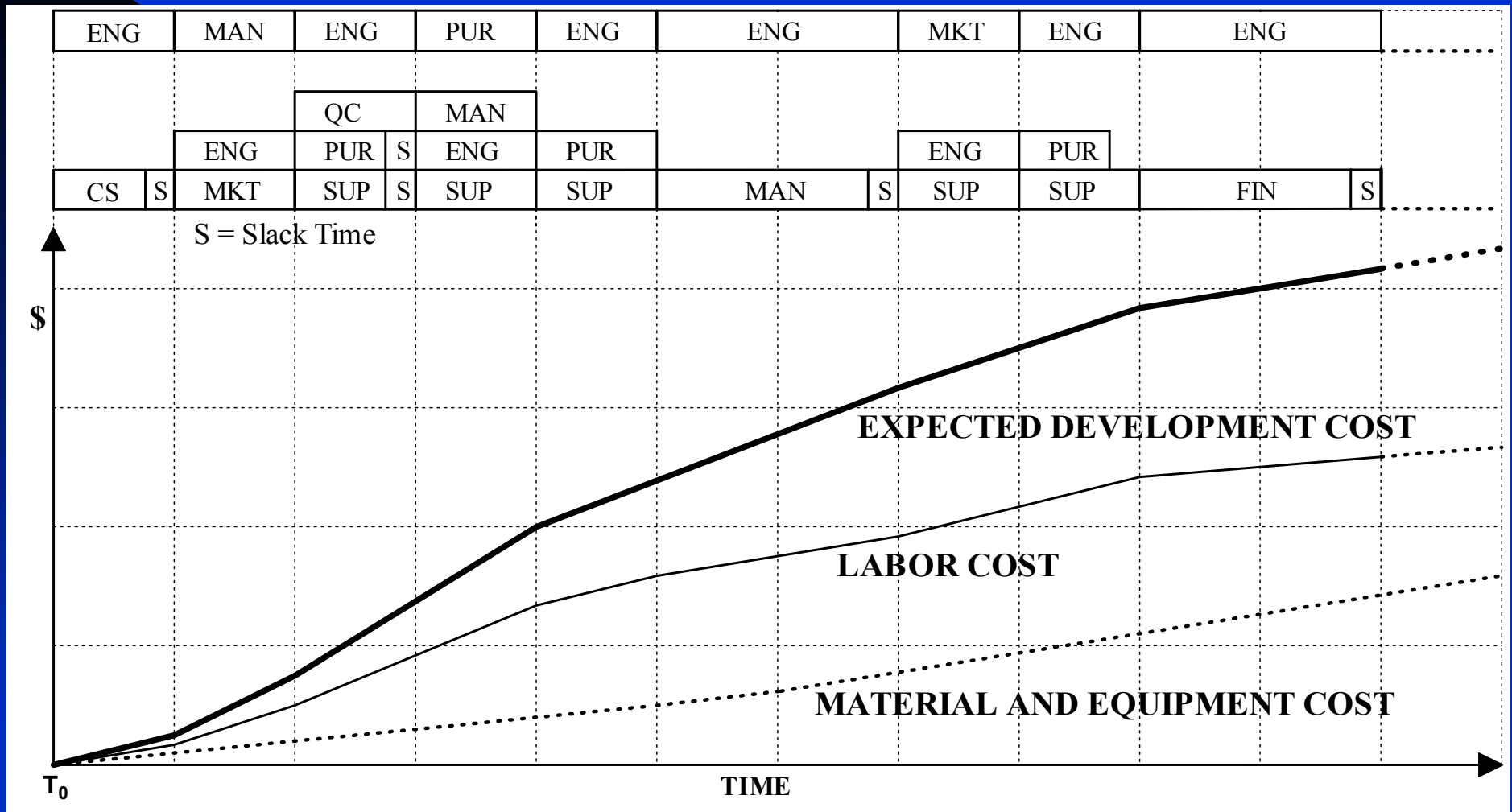
THE COST SCHEDULE WORKSHEET

No.	Activity	No. of People	x t_e (days)	x Cost / Person / Day ($)	= Cost ($)
1-2					
1-3					
2-6					
...					
				C_L = Total Labor Cost ($)	

No.	Activity	Material & Equipment	Cost ($)
1-2			
1-3			
2-6			
...			
		C_{ME} = Total Material and Equipment Cost ($)	

$C_{ED} = C_L + C_{ME}$ = Total Expected Development Cost ($)	
$C_{DT} = C_{ED} \times (T_{ST} / T_E)$ = Total Development Cost ($)	

THE COST CURVES ARE DRAWN ON THE SAME TIME SCALE THAT WAS USED FOR THE PLAN NETWORK AND THE RESOURCE HISTOGRAMS.



A more realistic Development Cost can be estimated.

Total Development Cost, $C_{DT} = (T_{ST}/T_E)\, C_{ED}$

THE PROJECT REPORT/PROPOSAL

- A request for approval of the development project by upper management and is a request for project funding.
- Consisting of two parts, an executive summary that contains no more than 200 words and the back-up documentation that gives credibility to this summary.
- Written by the Project Leader or Project Champion, typically the Project Engineer.
- All cross-functional team members must 'sign-off' on all project planning and costing documentation as a symbol of concurrence.
- The Project Leader presents the proposal to Upper Management.

Top managers must decide which projects to pursue. To do this effectively, they need realistic time, resource, and cost schedules.

QUALITY FUNCTION DEPLOYMENT (QFD)

- Links the needs of the customer and the end user with design, development, engineering, manufacturing, and service functions.
- Helps organizations seek out both spoken and unspoken customer needs, translating these into actions and designs.
- Listen to the 'Voice of the Customer.
- Assess customer affordability.
- Obtain customer feedback on requirements.
- Focus on customer needs.
- Perform functionality verses affordability analysis.
- Use QFD to help manage requirements and costs.

DESIGN FOR MANUFACTURABILITY & ASSEMBLY (DFMA)

Number of part types = N_t

Number of parts = N_p

Number of interfaces = N_i

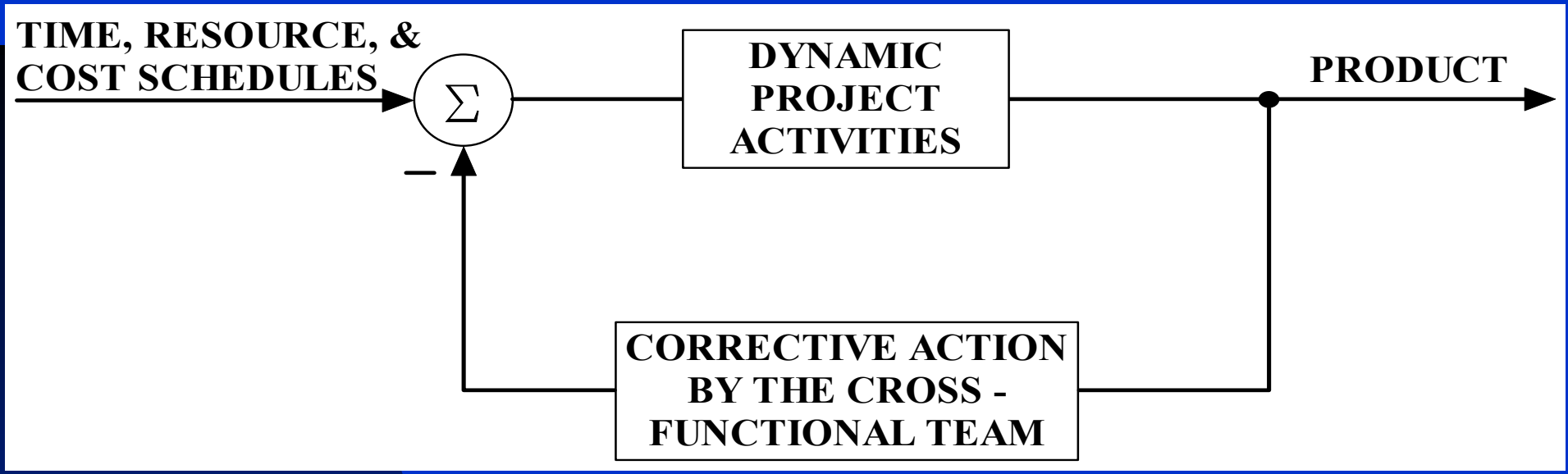
Complexity Factor = $\sqrt{N_t + N_p + N_i}$

- Simplify the design and reduce the number of parts.
- Standardize and use common parts and materials.
- Design for ease of part fabrication.
- Design within manufacturing process capabilities.
- Avoid unneeded surface finishes.
- Mistake-proof product assembly whenever possible.
- Design to minimize parts orientation and handling.
- Design for ease of assembly.
- Design for efficient joining and fastening.
- Design modular products and product families.

PROJECT COST MANAGEMENT

- The process of placing responsibility on the project designers, facilitators, and implementers to perform within their previously established budgets.
- Proactive development cost management by the cross-functional team, only future costs can be controlled.
- Establish a target costing program (Cost Function).
- Target cost and ‘Design to Cost’
- Supplier roles in Design to Cost
- Understand the cost drivers.
- Perform make-buy analysis.
- Analyze relationships between product costs, development costs, and production volume.
- ‘Life Cycle Costs’ vs. ‘Unit Production Costs’

CONCURRENT PROJECT CONTOL



- Concurrent Project Management requires closed-loop feedback control.
- Use the same documentation templates generated during the planning and scheduling phases for reporting the progress and cost of the project to date.
- The cross-functional team needs to know the current status of the project to effectively control it.
- The team should meet weekly for at least one-hour.

FAILURE MODE EFFECT ANALYSIS (FMEA)

- Develop product and/or processes that minimize the likelihood of failures, 'Design for Reliability'.
- Evaluate the requirements obtained from the customer and other participants in the design process to ensure that those requirements do not introduce failures.
- Identify design characteristics that contribute to failures and design them out of the design or at least minimize the resulting effects (Design Rules).
- Develop methods and procedures to test the product and processes to ensure that the failures have been successfully eliminated (Test Specification).
- Track and manage potential risks in the design. Tracking risks contributes to the success of future products by helping to build a 'Body of Knowledge'.
- Any failures must not seriously impact the customer.

FMEA WORKSHEET

DESCRIPTION	FUNCTION	FAILURE MODES	EFFECT	CAUSE	CORRECTIVE ACTION	PERSON RESPONSIBLE	SEVERITY	OCCURRENCE	DETECTION
							1 to 10	1 to 10	1 to 10

- Use FMEA for both product and process design.
- Rate the severity of failure modes.
- Identify corrective action to reduce occurence.
- Test adequacy of the controls' capability to detect.
- RPN is the Risk Priority Number, the lower the better.
- RPN = Severity x Occurrence x Detection

USE DESIGN OF EXPERIMENTS (DOE) FOR ROBUST DESIGNS AND MANUFACTURING PROCESSES.

$$\bar{y} = (y_1 + y_2)/2$$

$$R = |y_1 - y_2|$$

$$SUM_+ = \Sigma\, \bar{y}(+)$$

$$SUM_- = \Sigma\, \bar{y}(-)$$

$$Diff. = SUM_+ - SUM_-$$

$$Effect = \frac{Difference}{No.\ of\ '+'\ signs}$$

$$F = (\Sigma R+ / \Sigma R-)^2$$

$$\sigma' = \Sigma R / (Runs \times d_2)$$

$$\sigma'_{effect} = \sigma' \sqrt{4/N}$$

$$CL = \pm t\, \sigma'_{effect}$$

8-Run Plackett-Burman Screening Design with 2 Replicates, y_1 and y_2

Treatment Combination	A	B	C	D	E	F	G	y_1	y_2	$\bar{y}$	R
1	+	+	+	-	+	-	-				
2	-	+	+	+	-	+	-				
3	-	-	+	+	+	-	+				
4	+	-	-	+	+	+	-				
5	-	+	-	-	+	+	+				
6	+	-	+	-	-	+	+				
7	+	+	-	+	-	-	+				
8	-	-	-	-	-	-	-				
SUM_+											
SUM_-											
Difference											
Effect											
$\Sigma R+$											
$\Sigma R-$											
F, or if F< 1, 1/F											

N = 16

d_2 = 1.13

t = 2

UCL_F = 6.39

Significant Factors?

- ○ Affecting Performance:
- ○ Affecting Consistency:

Use Statistical Process Control (SPC) to know your process capabilities, $C_{pk}(\pm 3\sigma) > 1.0$?

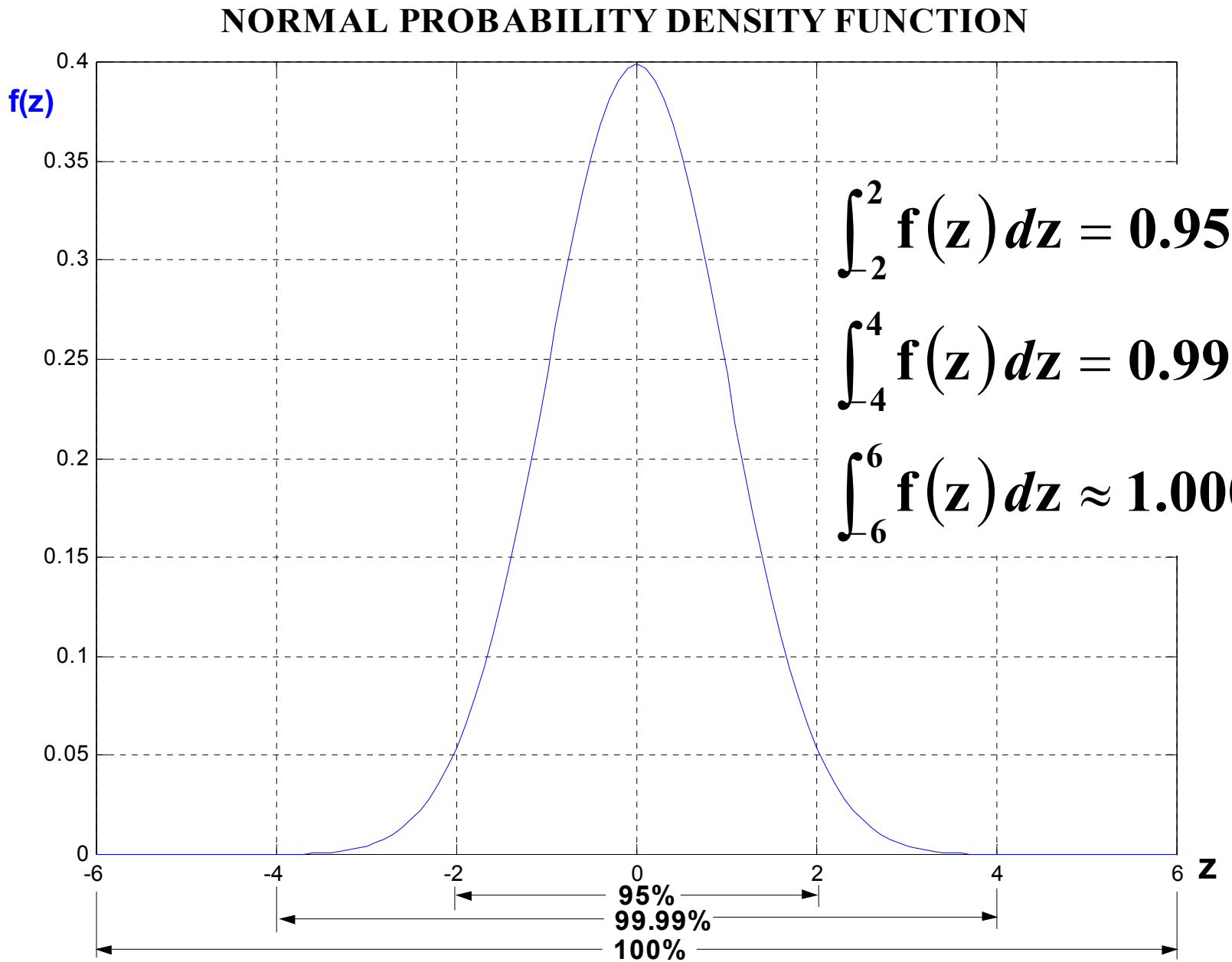
ELEMENTS OF DESIGN FOR SIX-SIGMA (DFSS)

- Concurrent Engineering (CE)
- Design for Manufacturability and Assembly (DFMA)
- Failure Mode and Effect Analysis (FMEA)
- Quality Function Deployment (QFD)
- Robust design and processes (DOE)

GE DEFINES THE PRINCIPALS OF DFSS AS:

- Disciplined critical to quality flow down (Leadership)
- Controlled design parameters (Hardened Specifications)
- Performance modeled and simulated (CAD/CAE)
- Designed for robust performance and producibility (DFMA / FMEA / DOE)
- Functionally integrated product development (CPD)
- Quality is 'designed in' (Cross-functional Teamwork)

A more realistic goal could be four-sigma production.



Six-sigma is <u>almost</u> the Zero Defect Product!

CONCLUSION

- This systematic concurrent approach to transducer and system product development utilizes simplified project scheduling documentation and powerful methodology.
- The procedures must be tailored to the specific company.
- Low cost commercial software and/or custom spreadsheets are available from SM Audio Engineering.
- Sound concurrent planning and budgeting are essential.
- One cannot use Statistical Process Control and supervision of artesian labor alone to control quality.
- Without 'Designing in Quality', no amount of process monitoring will result in four to six-sigma production.
- Quality is defined as the absence of variation about a quantitative target value and is the result of teamwork that starts at the project concept stage of development.

This Concludes the Presentation. Questions? Comments!