Project Scheduling Management

Lecture 3

PERT, DSM, & Project Simulation

Instructor

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Today's Topic

- PERT
- DSM Introduction
- Project Graphs --> Task-based DSMs
- DSM Operations
  - sequencing
  - partitioning
  - tearing
- Project Simulation
  - Signal Flow Graph Method
- Introduce HW2
- DSM Tools and References

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Lessons Learned from CPM

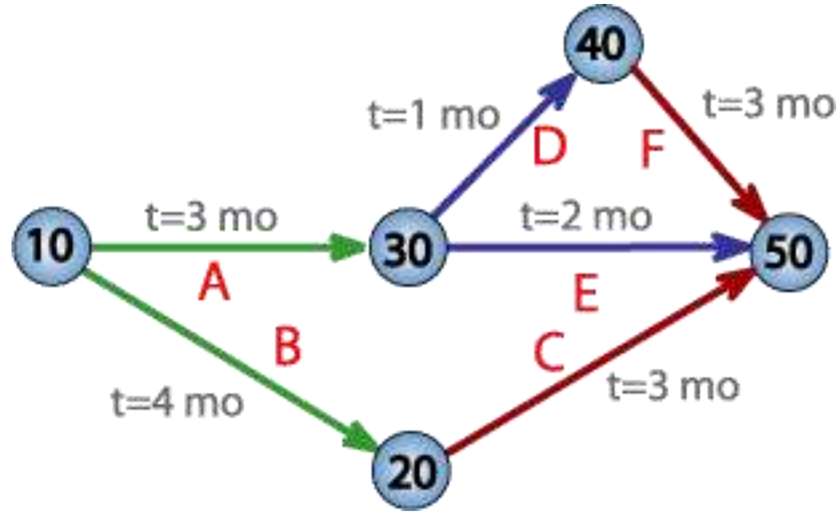
- +
  - Focuses attention on a subset of critical tasks
  - Determine effect of shortening/lengthening tasks
  - Links task durations to schedule
- -
  - Deterministic vs. Stochastic
  - Doesn't capture task iterations, in fact …
  - Prohibits iterations = called "cycle error"

CPM vs PERT

- Difference how "task duration" is treated
- CPM assumes time estimates are <u>deterministic</u>
  - Obtain task duration from previous projects
  - Suitable for "implementation"-type projects
- PERT treats durations as <u>probabilistic</u>
  - PERT = CPM + probabilistic task times
  - Better for "uncertain" and new projects
  - Limited previous data to estimate time durations
  - Captures schedule (and implicitly some cost) risk

PERT

- PERT invented in 1958 for U.S Navy Polaris Project (BAH)
- Similar to CPM
- Treats task times probabilistically

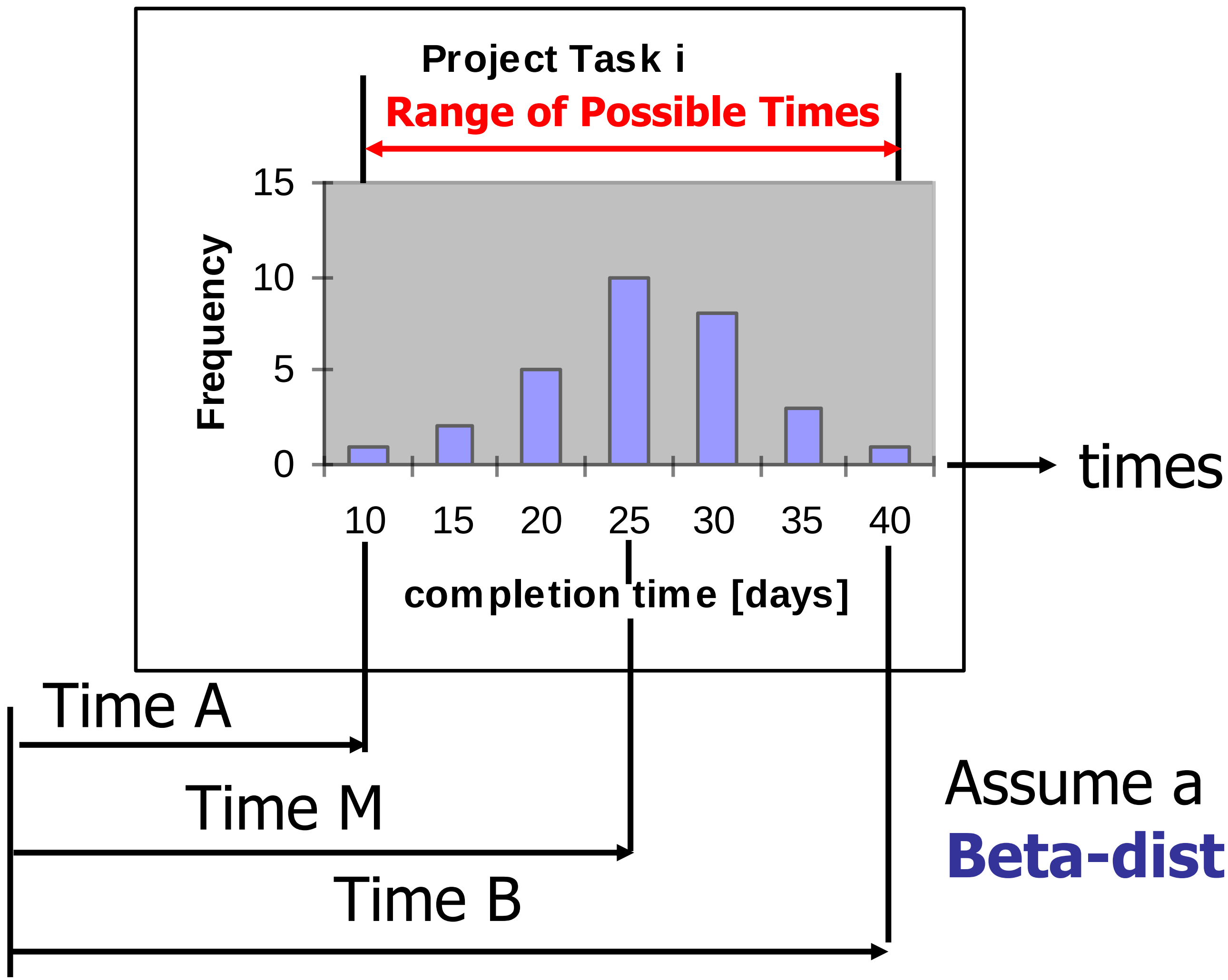


Original PERT chart used "activity-on-arc" convention

PERT

- Project Evaluation and Review Technique
- Task time durations are treated as uncertain
  - **A** - optimistic time estimate
    - minimum time in which the task could be completed
    - everything has to go right
  - **M** - most likely task duration
    - task duration under "normal" working conditions
    - most frequent task duration based on past experience
  - **B** - pessimistic time estimate
    - time required under particularly "bad" circumstances
    - most difficult to estimate, includes unexpected delays
    - should be exceeded no more than 1% of the time

A-M-B Time Estimates



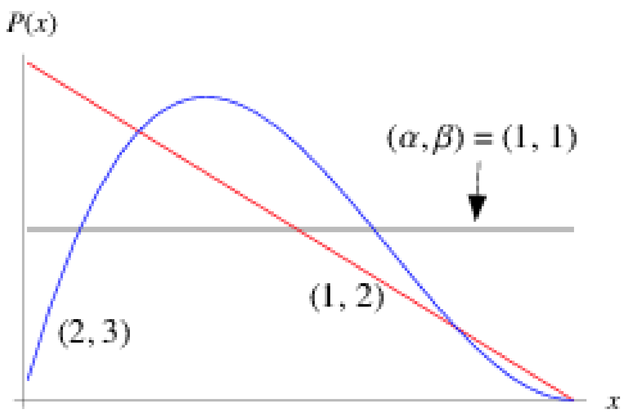
Assume a **Beta-distribution**

Beta-Distribution

- All values are enclosed within interval $t \in [A, B]$
- As classes get finer - arrive at β-distribution
- Statistical distribution

pdf:

$$P(x) = \frac{(1-x)^{\beta-1} x^{\alpha-1}}{B(\alpha,\beta)} = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}(1-x)^{\beta-1}x^{\alpha-1}$$



$$x \in [0,1]$$

Beta function:

$$B(p,q) = \frac{\Gamma(p)\Gamma(q)}{\Gamma(p+q)} = \frac{(p-1)!(q-1)!}{(p+q-1)!}.$$

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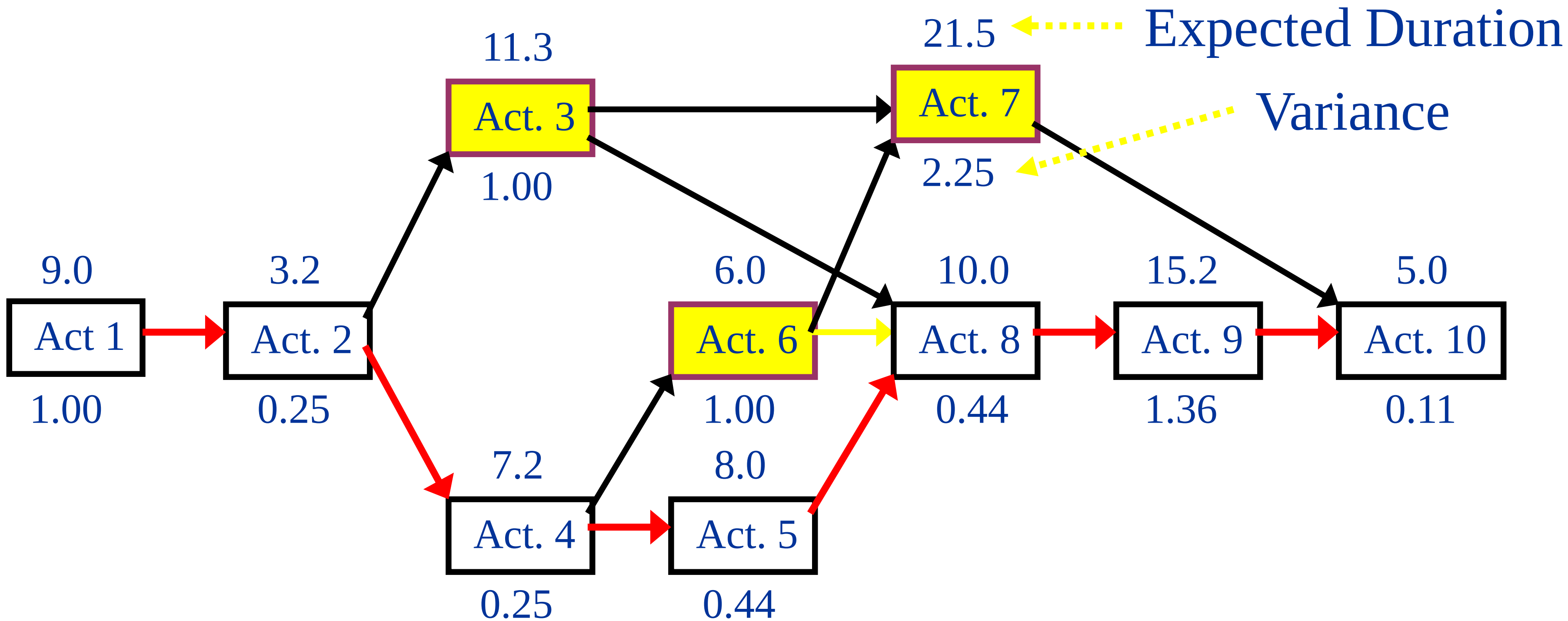
Expected Time & Variance

- Mean expected Time (**TE**) $$TE = \frac{A + 4M + B}{6}$$
- Time Variance (**TV**) $$TV = \sigma_t^2 = \left(\frac{B - A}{6}\right)^2$$
- Early Finish (**EF**) and Late Finish (**LF**) computed as for CPM with **TE**
- Set **T**=**F** for the end of the project
- Example: A=3 weeks, B=7 weeks, M=5 weeks --> then **TE**=5 weeks

PERT Analysis Example



Variance of CP = sum variances of activities on CP = 3.85

Standard Deviation of CP = SQRT(3.85) = 1.96

Project Duration = NORMAL (57.6 ; 1.96)

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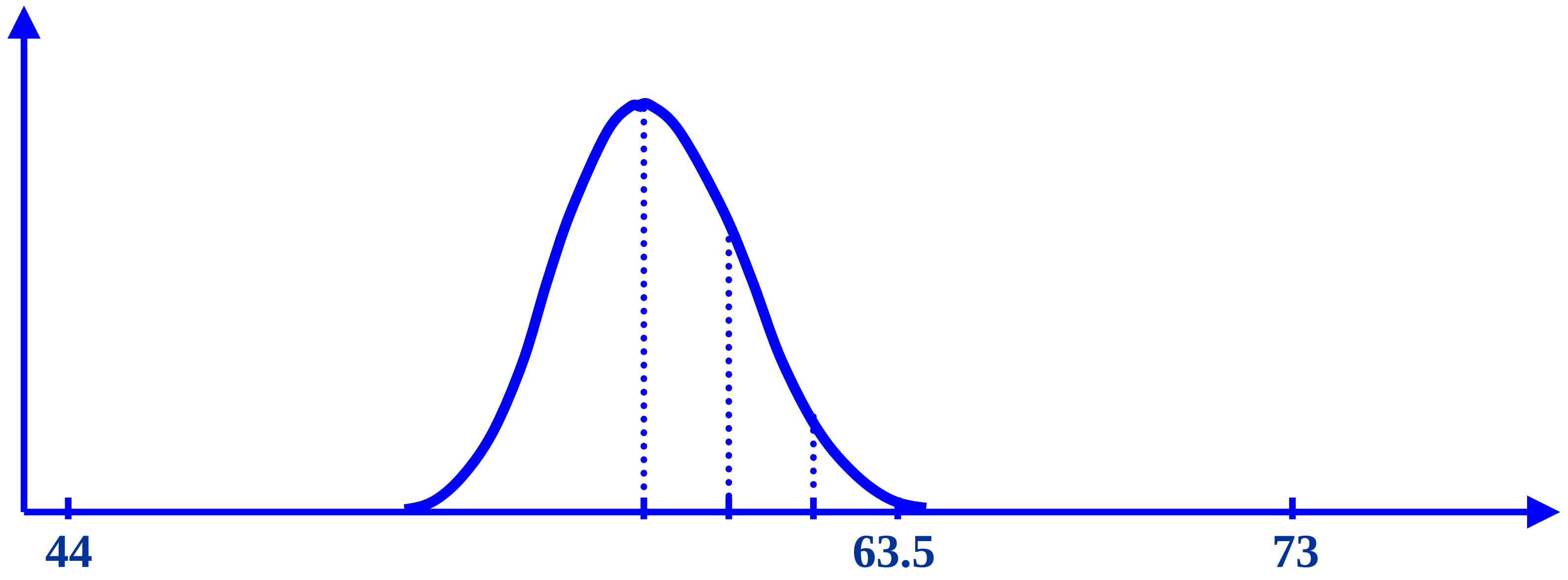
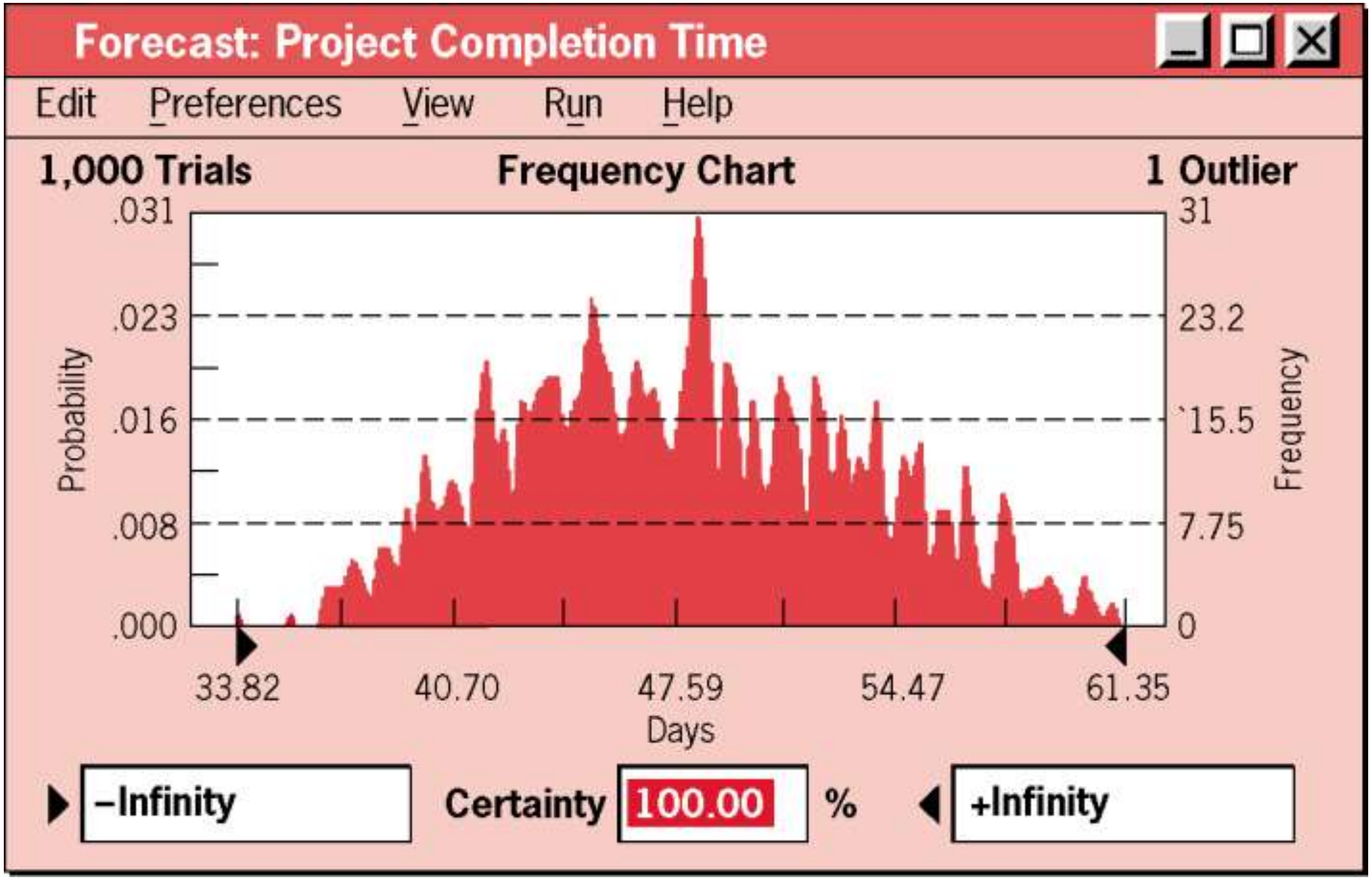
PERT Analysis

- Expected project duration: 57.6 days
- Probability that it will take more than 57.6 days = 50% !
- Confident it will take less than 63.5 days (3 standard deviations)
- Probability of meeting deadline (10 weeks) working Sat. (60 days) = 89%
- Critical activities: 1, 2, 4, 5, 8, 9, 10



Monte-Carlo Simulation



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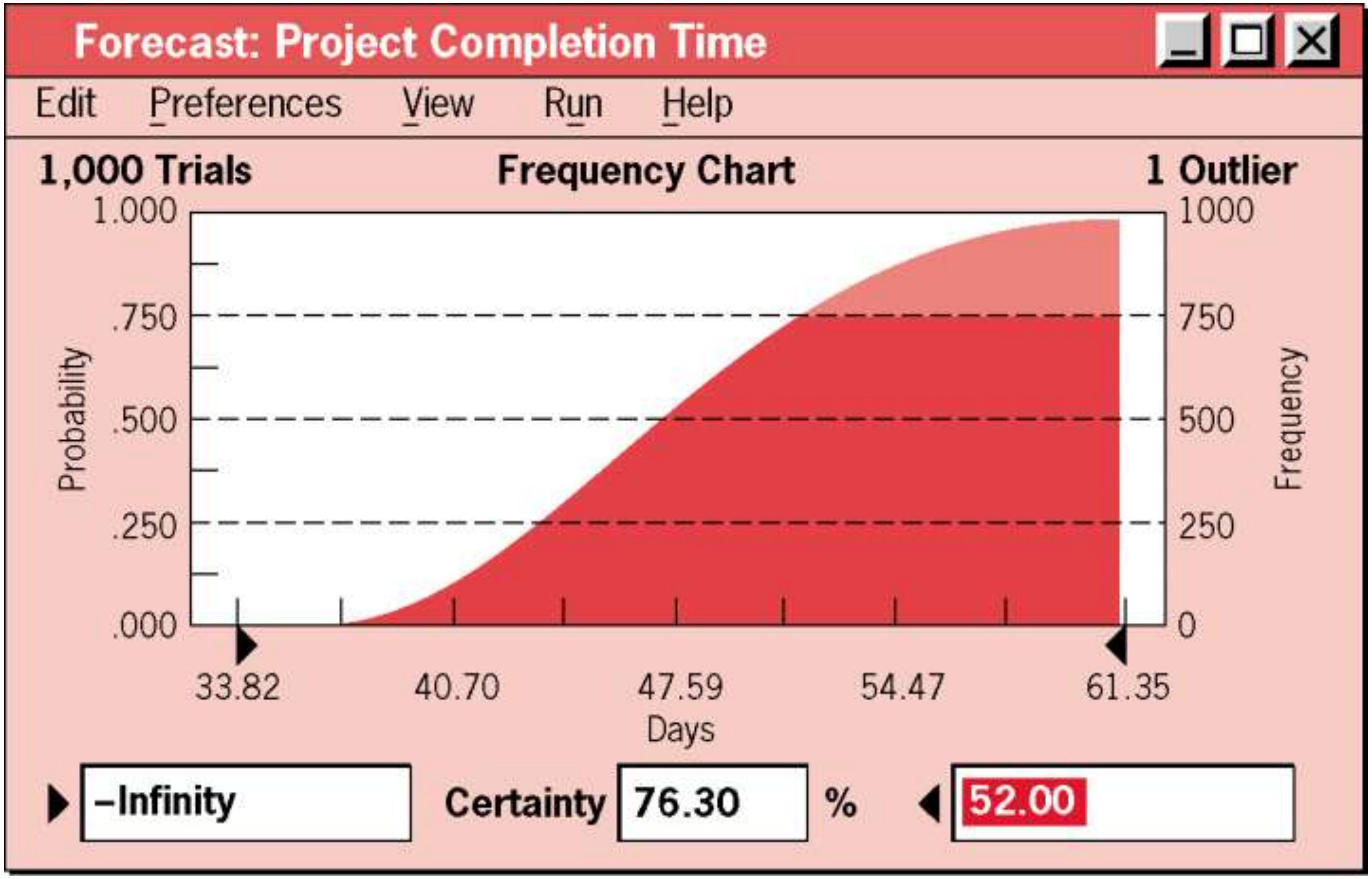
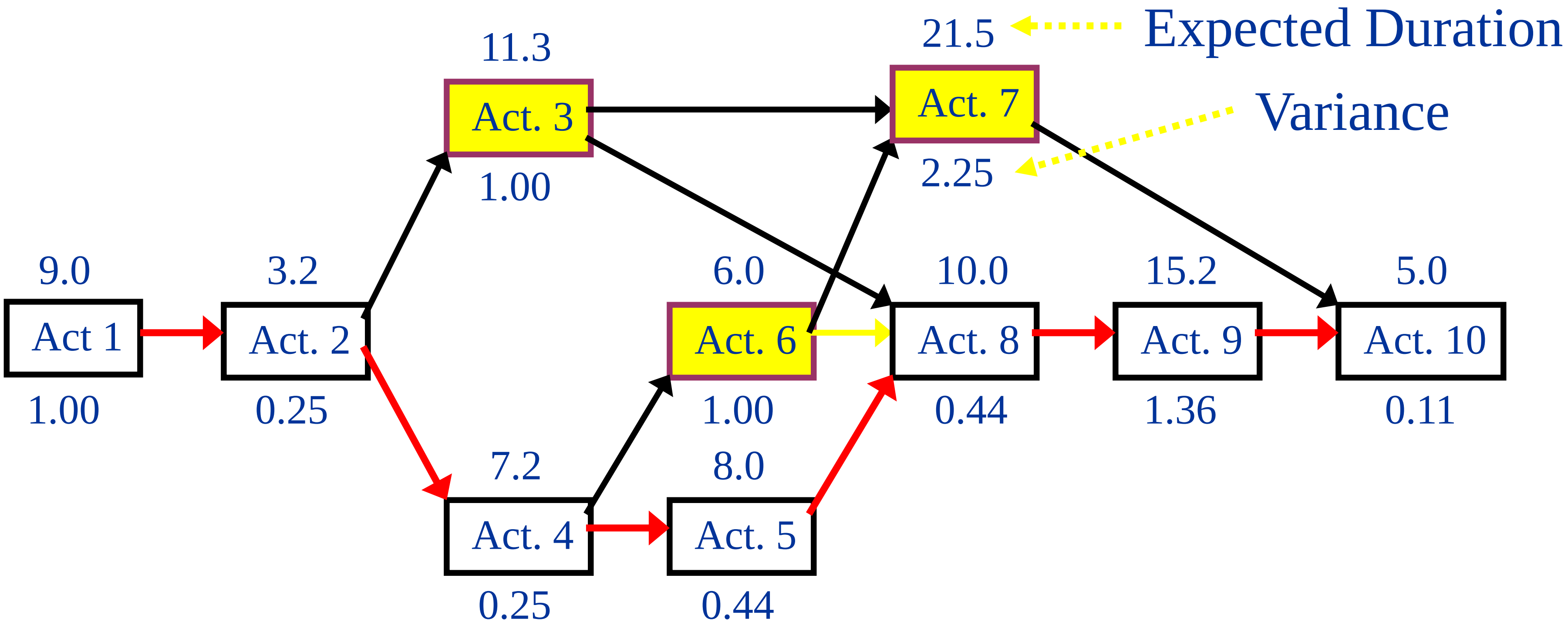
Cumulative Probability



Recall Example



Variance of CP = sum variances of activities on CP = 3.85

Standard Deviation of CP = SQRT(3.85) = 1.96

Project Duration = NORMAL (57.6 ; 1.96)

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Simulation Results

- Estimated project completion: 58.1 days (PERT: 57.6 days)
  - range: [51.1,65.4]
  - probability meeting deadline (10 weeks) by working Saturdays (60 days): 78% (PERT: 88%)
  - 95% confident project will be completed in 62 days (PERT: 60.8), so 2 days of crashing required
- Critical activities (Criticality Index)
  - 1,2,10 : 100% (PERT: 100%)
  - 4 : 99% (PERT: 100%)
  - 8,9 : 96% (PERT: 100%)
  - 5 : 87% (PERT: 100%)
  - 6 : 12% (PERT: 0%)
  - 7 : 4% (PERT: 0%)
  - 3 : 1% (PERT: 0%)

Lessons Learned from CPM

- +
  - Focuses attention on a subset of critical tasks
  - Determine effect of shortening/lengthening tasks
  - Links task durations to schedule
- -
  - Deterministic vs. Stochastic
  - Doesn't capture task iterations, in fact …
  - Prohibits iterations = called "cycle error"

⇨ However, iterations are one of the **essential features** of design and development projects

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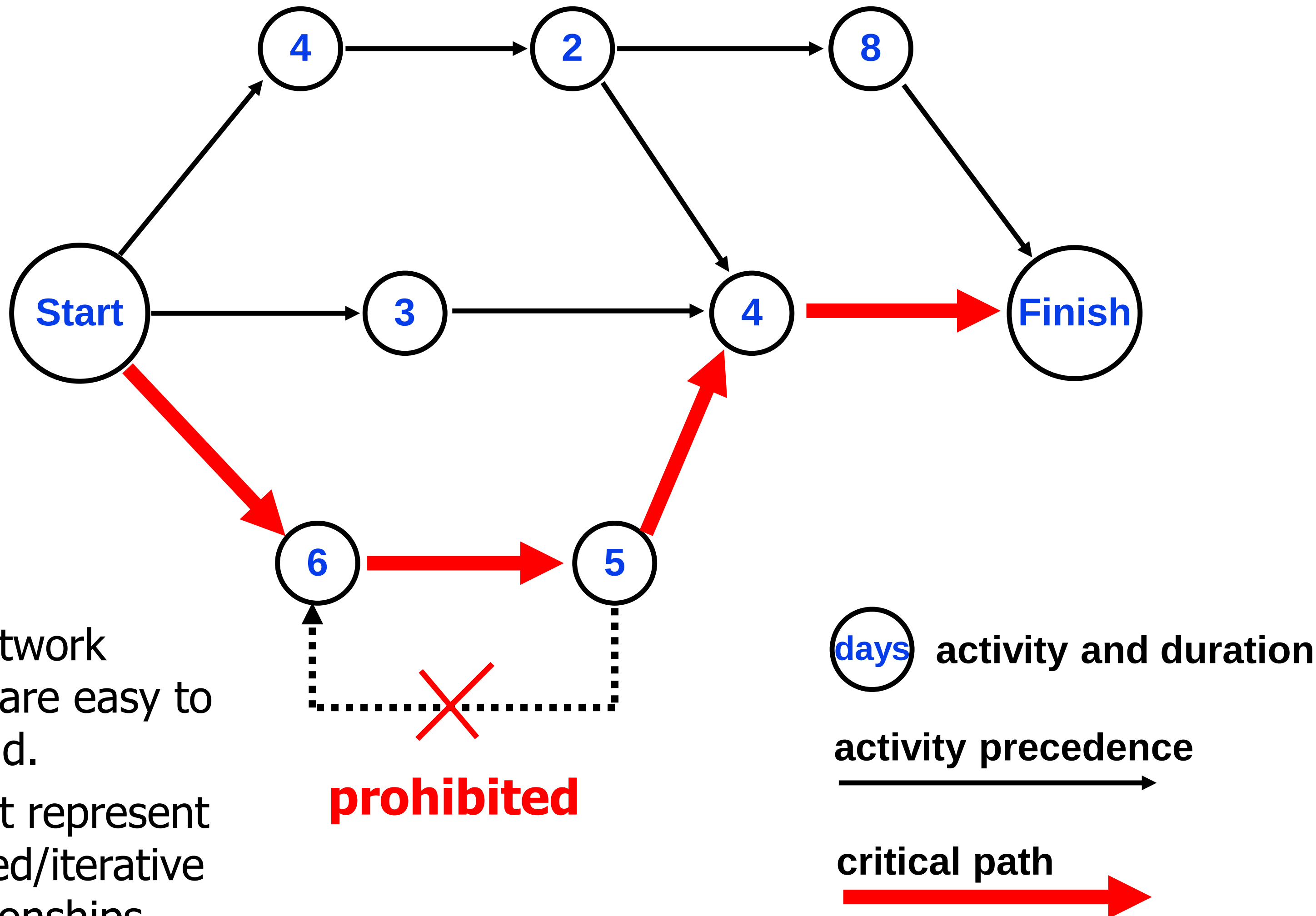
CPM Charts



- Simple network diagrams are easy to understand.
- We cannot represent the coupled/iterative task relationships.

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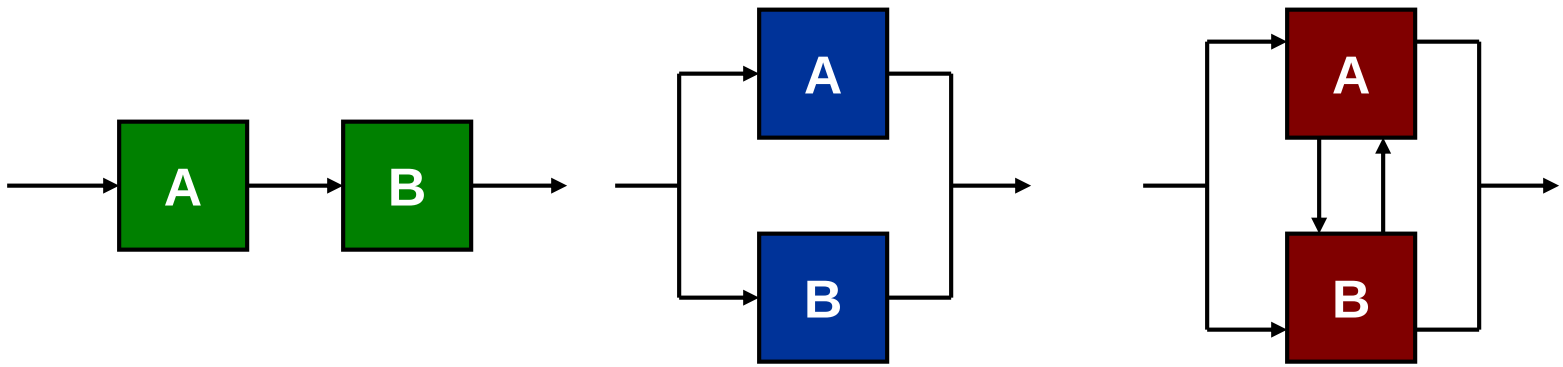
Sequencing Tasks in Projects

Three Possible Sequences for Two Tasks



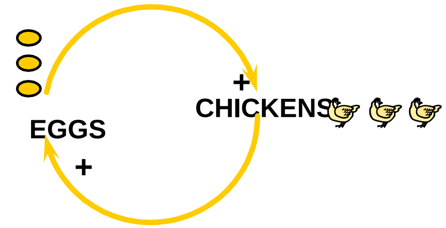
Dependent (Series) | **Independent (Parallel)** | **Interdependent (Coupled)**

Discussed so far

New !

Interdependent Tasks

- Sometimes iterative tasks are referred to as "chicken-and-egg" problems in design



- Example from Spacecraft Design
  - Inertia and Attitude Control Coupling

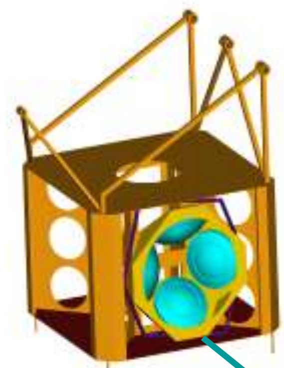
External Disturbances
Slew Rate Requirement
Desaturation Interval

Nexus Spacecraft

Define s/c size, mass inertia matrix

S/C total mass, total inertia: 800kg, 3000 kgm²

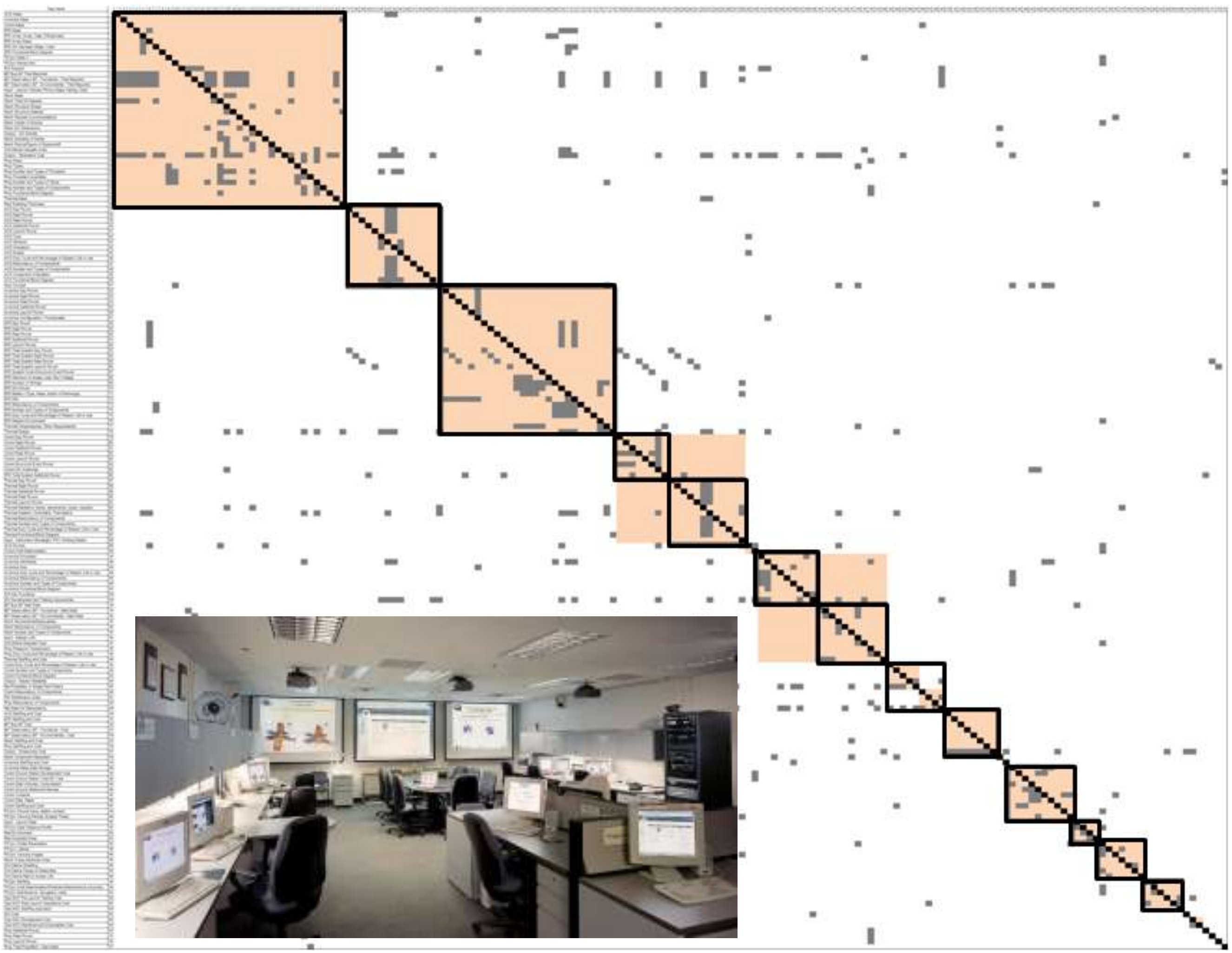
Adds mass inertia, ca. 50kg/wheel



Size reaction wheel assembly (RWA) torque and momentum capacity

Reaction Wheel Assembly

Spacecraft Mission Design



NASA GSFC MDL

Spacecraft Bus Cluster

Attitude Control Cluster

Spacecraft Power Cluster

Communications Power Cluster

Thermal Cluster

Computing Cluster

Spacecraft Integration Cluster

Reliability Cluster

Costing Cluster

Data Cluster

Radiation Cluster

Orbit Life Cluster

Operations Cluster

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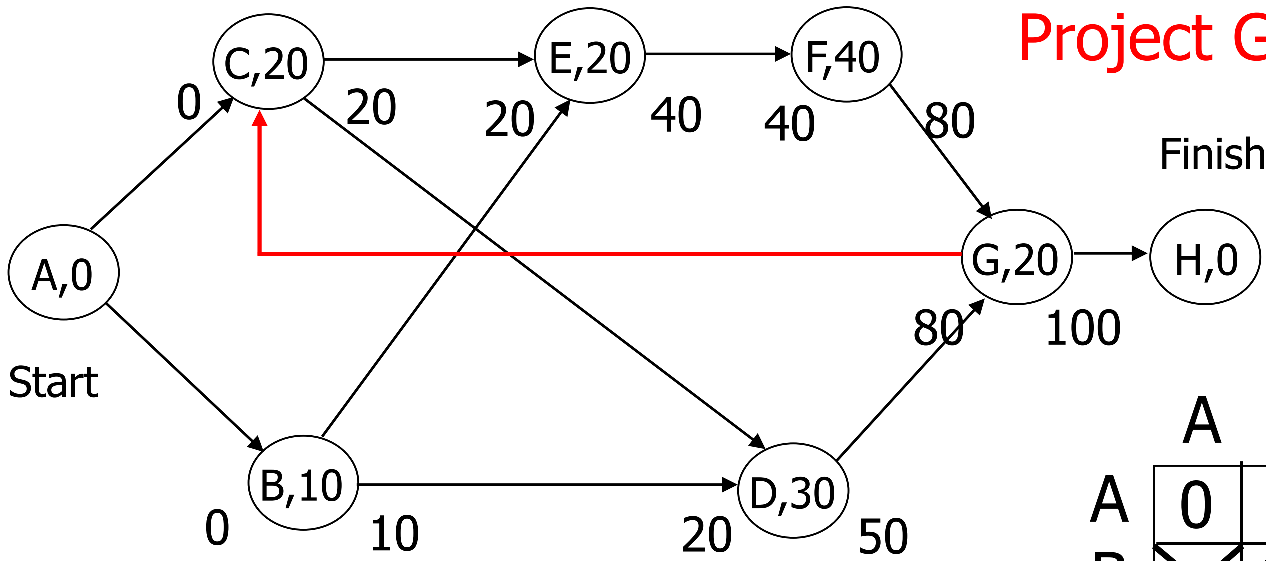
Source: Mark Avnet, ESD PhD

http://esd.mit.edu/people/dissertations/avnet.pdf

What is a DSM?

- Potential answer to first question:
  - How can iterations be represented?
- Design Structure Matrix (DSM)
  - A two-dimensional matrix representation of the structural or functional interrelationships of objects, tasks or teams
- Synonyms
  - Design Structure Matrix (DSM)
  - N^2-Diagram ("N-squared")
  - Dependency Structure Matrix
  - others …
- Types of DSMs
  - Object-based, Team-based, Parameter-based, Task-based

Task-Based DSMs

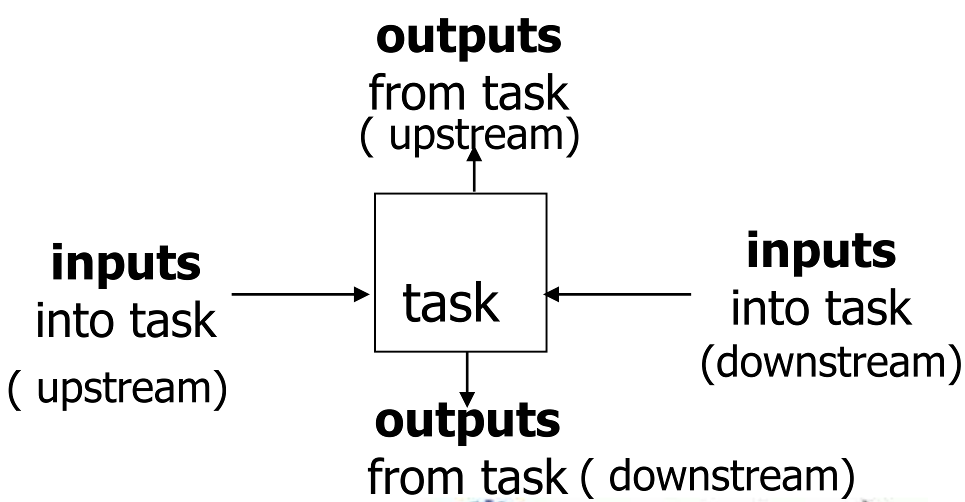


Project Graph

translate

DSM

	A	B	C	D	E	F	G	H
A	0							
B	X	10						
C	X		20				X	
D		X	X	30				
E		X	X		20			
F					X	40		
G				X		X	20	
H							X	0



The Design Structure Matrix:
An Information Exchange Model

	A	B	C	D	E	F	G	H	I	J	K	L
A	•		X									
B		•										
C		X	•									
D				•	X	X						X
E					•	X		X			X	
F		X				•			X			X
G		X					•				X	
H	X			X				•	X		X	
I			X			X			•	X		
J		X	X							•	X	X
K		X	X								•	
L	X								X	X	X	•

Interpretation:

- Task D requires information from tasks E, F, and L.
- Task B transfers information to tasks C, F, G, J, and K.

Note:

- Information flows are easier to capture than work flows.
- Inputs are easier to capture than outputs.

Donald V. Steward, Aug. 1981
IEEE Trans. on Eng'g Mgmt.

The Design Structure Matrix
(Partitioned, or Sequenced)

Task Sequence

	B	C	A	K	L	J	F	I	E	D	H	G
B	•											
C	X	•										
A		X	•									
K	X	X		•								
L			X	X	•	X		X				
J	X	X		X	X	•						
F	X				X		•	X				
I		X				X	X	•				
E				X			X		•		X	
D					X		X		X	•		
H			X	X				X		X	•	
G	X			X								•

Sequential

Parallel

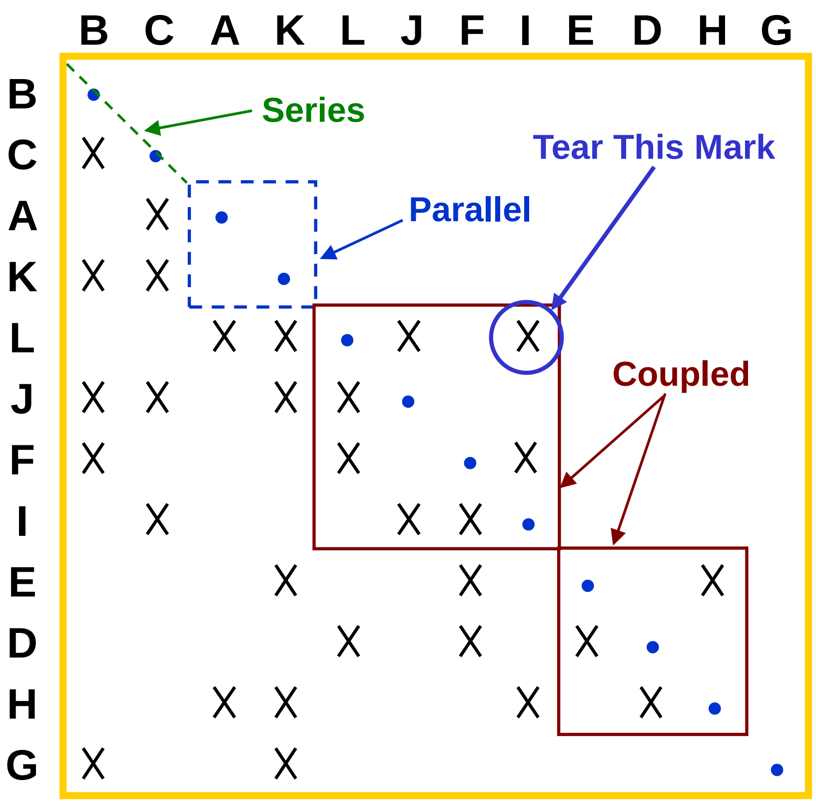
Coupled

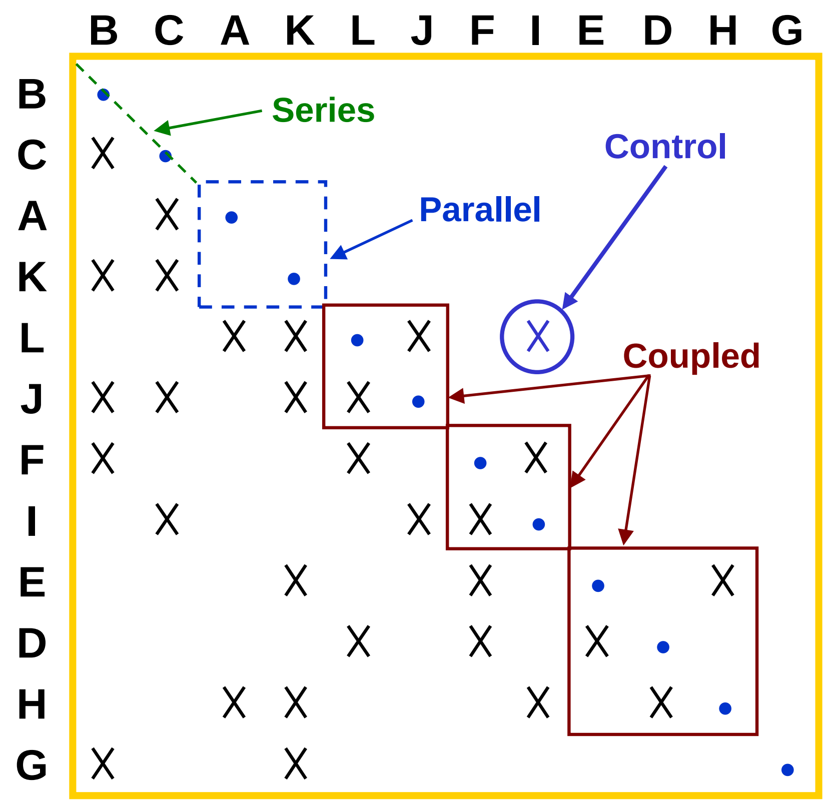
Note:

Coupled tasks can be identified uniquely.

The display of the matrix can be manipulated to emphasize certain features of the process flow.

Tearing Marks in the DSM





Tear the marks which break the coupled block into smaller ones or make it sequential.

Torn marks may become

- Assumptions
- Feedbacks
- Controls for the process

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DSM Sequencing Algorithm

1. Find any empty rows. Move these up to the front."
2. Find any empty columns. Move these to the end."
3. Find any loop, collapse it and schedule it as above if possible."
4. Repeat steps 1-3 until all tasks and loops are sequenced.

DSM Example
for Manual Sequencing"

	A	B	C	D	E	F	G	H	I	J	
A	A		X		X					X	A
B	X	B	X					X	X		B
C			C								C
D				D	X		X			X	D
E	X				E					X	E
F	X	X	X	X		F	X				F
G				X			G			X	G
H		X			X			H		X	H
I	X	X	X						I		I
J			X		X					J	J
	A	B	C	D	E	F	G	H	I	J	

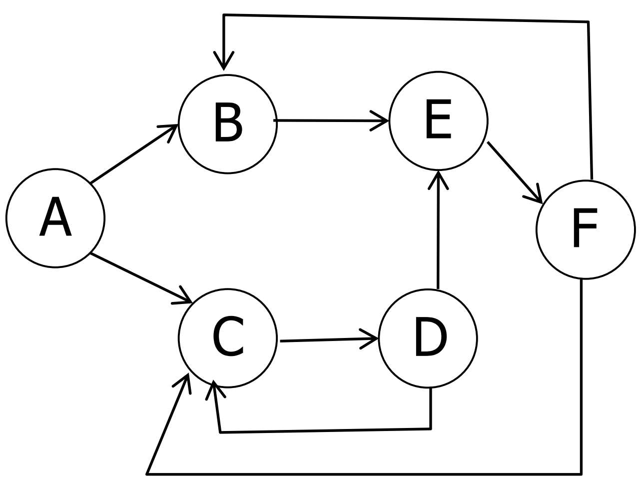
DSM Sequencing Exercise

	A	B	C	D	E	F	G	H	I	J	
A	A		X		X					X	A
B	X	B	X					X	X		B
C			C								C
D				D	X		X			X	D
E	X				E					X	E
F	X	X	X	X		F	X				F
G				X			G			X	G
H		X			X			H		X	H
I	X	X	X						I		I
J			X		X					J	J
	A	B	C	D	E	F	G	H	I	J	

Concept Question 1

https://www.diaochapai.com/survey2891339

A					
x	**B**				x
x		**C**	x		x
		x	**D**		
	x		x	**E**	
				x	**F**



What is the length of the longest cycle in this DSM?

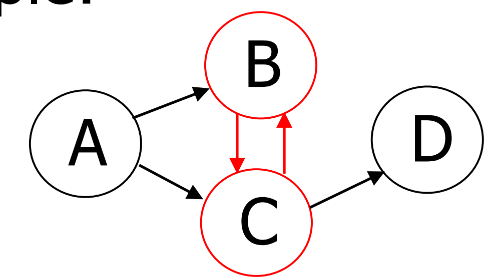
Possible Answers:

- ❑ There are no loops
- ❑ Length 2
- ❑ Length 3
- ❑ Length 4
- ❑ Length 5
- ❑ Length 6

Discover Loops (Length 2)

- Turn DSM into a binary matrix
  - Replace “X” and “ “ with 1 and 0
  - Square binary matrix
  - Find non-zero diagonals

Example:



A			
X	B	X	
X	X	C	
		X	D

{0,1}

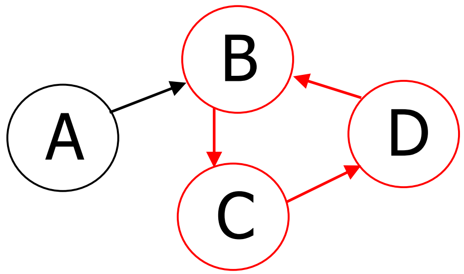
0	0	0	0
1	0	1	0
1	1	0	0
0	0	1	0

^2

0	0	0	0
1	1	0	0
1	0	1	0
1	1	0	0

Discover Loops (Length 3)

Example:



A			
X	B		X
	X	C	
		X	D

0	0	0	0
1	0	0	1
0	1	0	0
0	0	1	0

^3 ⇒

0	0	0	0
0	1	0	0
0	0	1	0
1	0	0	1

Discover Loops

- This reveals how many iterations of length n (**n-task** loops) each task is involved in. Which specific tasks are involved in each loop, however, is not immediately known (you must look back at the project graph).
- The method only allows for determination of the existence, but not the detailed identification of feedback loops.

	A	B	C	D
A	0	1	0	0
B	1	0	1	0
C	1	0	0	1
D	1	0	0	0

DSM

	A	B	C	D
A	1	0	1	0
B	1	1	0	1
C	1	1	0	0
D	0	1	0	0

Square

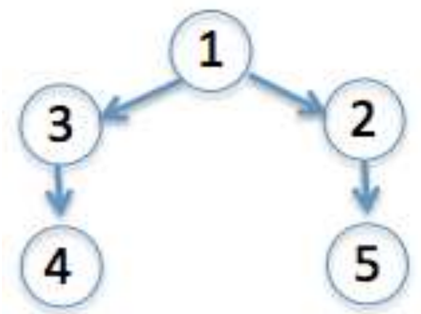
	A	B	C	D
A	1	1	0	1
B	2	1	1	0
C	1	1	1	0
D	1	0	1	0

Cube

	A	B	C	D
A	2	1	1	0
B	2	2	1	1
C	2	1	1	1
D	1	1	0	1

Power 4

Visibility Matrix



$$V=\sum_{n=1}^{4}A^n=\begin{bmatrix}0&0&0&0&0\\1&0&0&0&0\\1&0&0&0&0\\1&0&1&0&0\\1&1&0&0&0\end{bmatrix}$$

$$A=\begin{bmatrix}0&0&0&0&0\\1&0&0&0&0\\1&0&0&0&0\\0&0&1&0&0\\0&1&0&0&0\end{bmatrix}\quad A^2=\begin{bmatrix}0&0&0&0&0\\0&0&0&0&0\\0&0&0&0&0\\1&0&0&0&0\\1&0&0&0&0\end{bmatrix}\quad A^3=\begin{bmatrix}0&0&0&0&0\\0&0&0&0&0\\0&0&0&0&0\\0&0&0&0&0\\0&0&0&0&0\end{bmatrix}$$

Visibility Matrix is a way to find loops and most influential tasks

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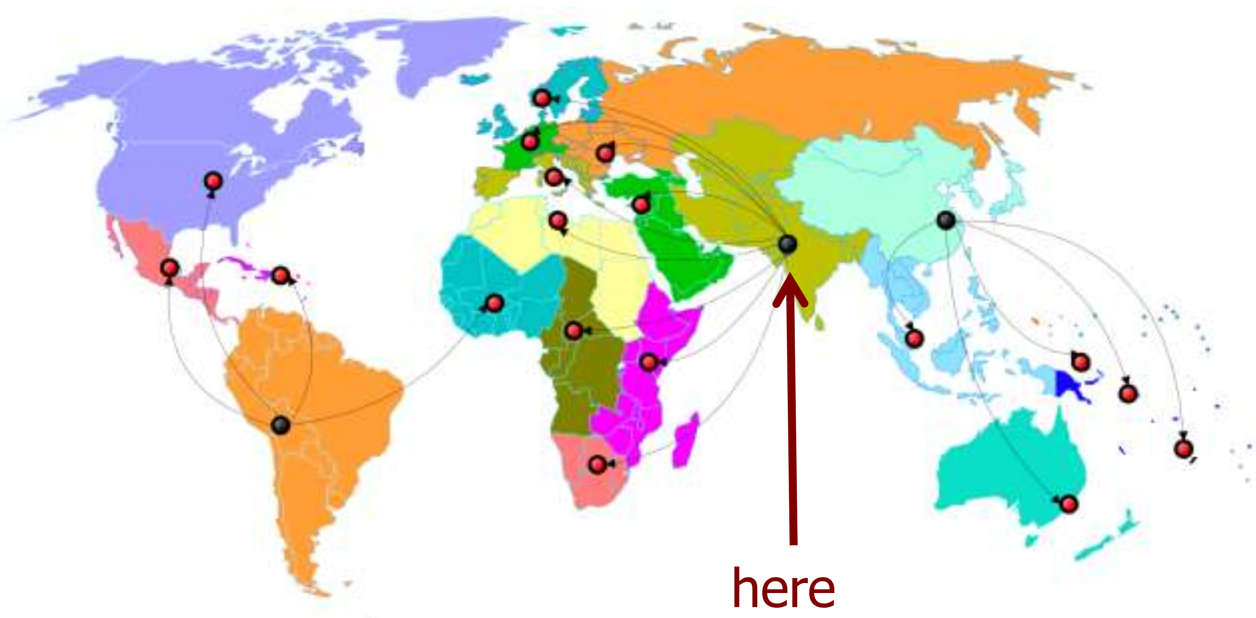
Sample Project HumLog

- Establish a Regional Distribution Center for Humanitarian Logistics (HumLog DC)
  - Location: South-Central Asia
  - Reference: Akkihal, A.R., "Inventory Pre-positioning for Humanitarian Operations", S.M. Thesis, Master of Engineering in Logistics, MIT, June 2006
  - Function: Pre-position Inventory for Disaster Relief



WBS for HumLog DC

Set up a Regional Logistics Distribution Center in Asia

HumLog DC Project

- 1 Planning
  - 1.1 Location Analysis
  - 1.2 Capacity Modeling
  - 1.3 Transportation Analysis
- 2 Contracting
  - 2.1 Government Approval
  - 2.2 Request for Proposal
  - 2.3 Evaluate Proposals
  - 2.4 Select Main Contractor
  - 2.5 Finalize Contract
- 3 Staffing
  - 3.1 Staffing for Operations
  - 3.2 Staff Training And Instruction
- 4 Construction
  - 4.1 Site Preparation
  - 4.2 Dig and Pour Foundation
  - 4.3 Erect Main Structure
  - 4.4 Install Building Systems
  - 4.5 Install Security Systems
  - …
- 5 Commissioning
  - 5.1 Stock Up Initial Inventory
  - 5.2 Commissioning And Test
  - 5.3 Final Acceptance IOC

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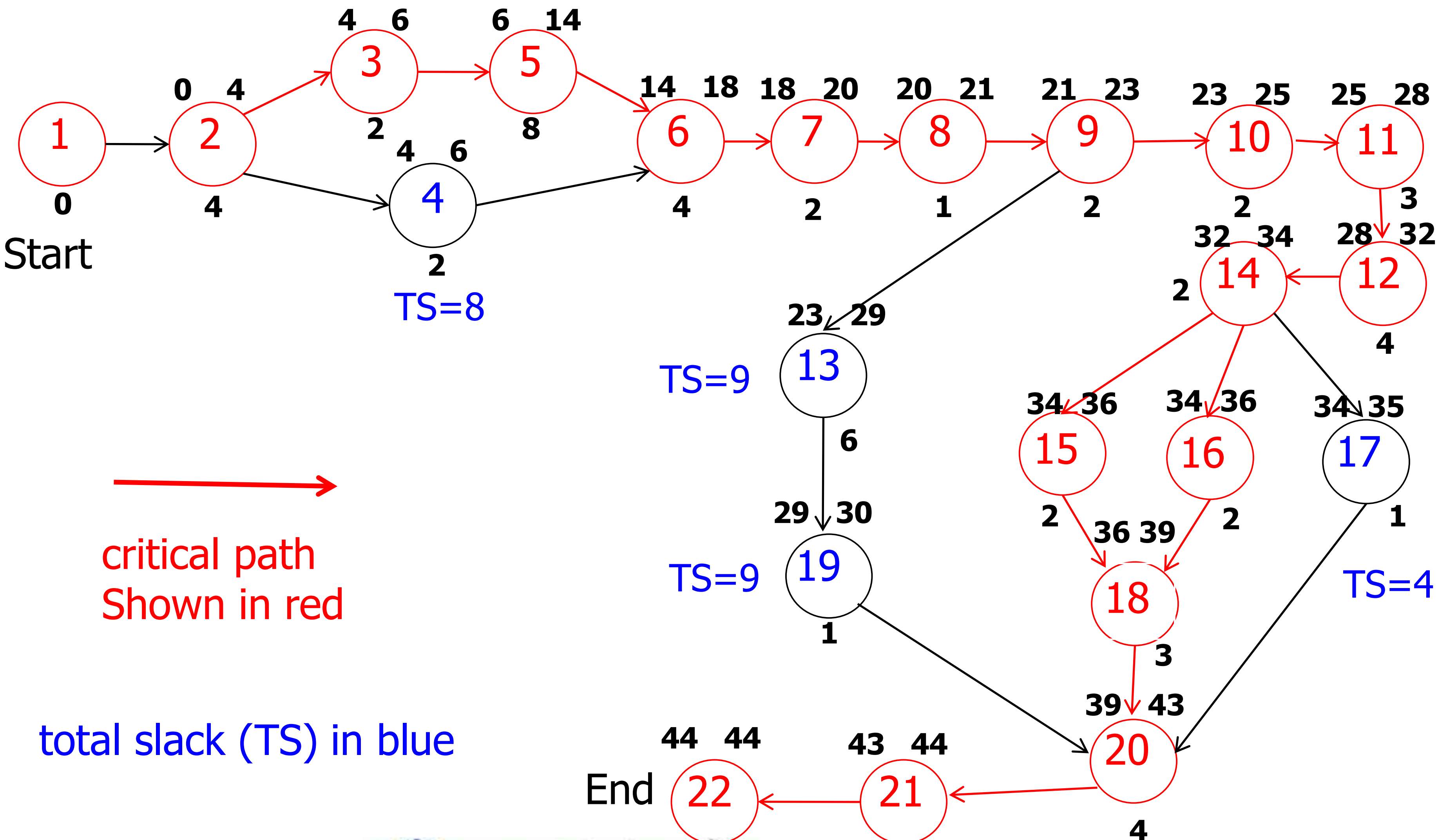
Task List – HumLog DC Project

ID	WBS	Task Description	Predecessor	Duration (wks)
1		Start – Project Kickoff		0
2	1.1	Location Decision	1	4
3	1.2	Capacity Modeling	2	2
4	1.3	Transportation Analysis	2	2
5	2.1	Obtain Government Approval	3	8
6	2.2	Request for Proposal	4,5	4
7	2.3	Evaluate Proposals	6	2
8	2.4	Select Main Contractor	7	1
9	2.5	Finalize Main Construction Contract/Negotiations	8	2
10	4.1	Site Preparation	9	2
11	4.2	Dig and Pour Foundation	10	3
12	4.3	Erect Main Structure	11	4
13	3.1	Staffing for Operations	9	6
14	4.4	Install Building Systems (Electrical)	12	2
15	4.5	Install Safety and Security Systems	14	2
16	4.6	Install Inventory Management System (RFID)	14	2
17	4.7	Install Communications System	14	1
18	5.1	Stock Up on Initial Inventory	15, 16	3
19	3.2	Staff Training and Instruction	13	1
20	5.2	Commissioning and Test	19, 18, 17	4
21	5.3	Final Acceptance and IOC	20	1
22		End – Project Finish	21	0

Application of DSM to Example

(Creating a Warehouse for Humanitarian Logistics)



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Baseline Project DSM (no iterations)

Psm32: Problem Solving Matrix 3.9j -Join- (c) 1996-2003 Problematics/Blitzkrieg Software

File Edit View Data Compute Tools Help

	1!	2!	3!	4!	5!	6!	7!	8!	9!	10	11	12	13	14	15	16	17	18	19	20	21	22
1! Start																						
2! Location Decision	0																					
3! Capacity Modeling		0																				
4! Transportation Analysis		0																				
5! Government Approval			0																			
6! Request for Proposal (RfP)				0	0																	
7! Evaluate Proposals						0																
8! Select Main Contractor							0															
9! Finalize Main Contract								0														
10! Site Preparation									0													
11! Dig and Pour Foundation										0												
12! Erect Main Structure											0											
13! Staffing for Operations									0													
14! Install Building Systems												0										
15! Install Safety and Security														0								
16! Install Inventory Management														0								
17! Install Communications System														0								
18! Stock Up Initial Inventory															0	0						
19! Staff Training and Instruction													0									
20! Commissioning and Test																	0	0	0			
21! Final Acceptance and IOC																				0		
22! End																					0	

Possible Iterations

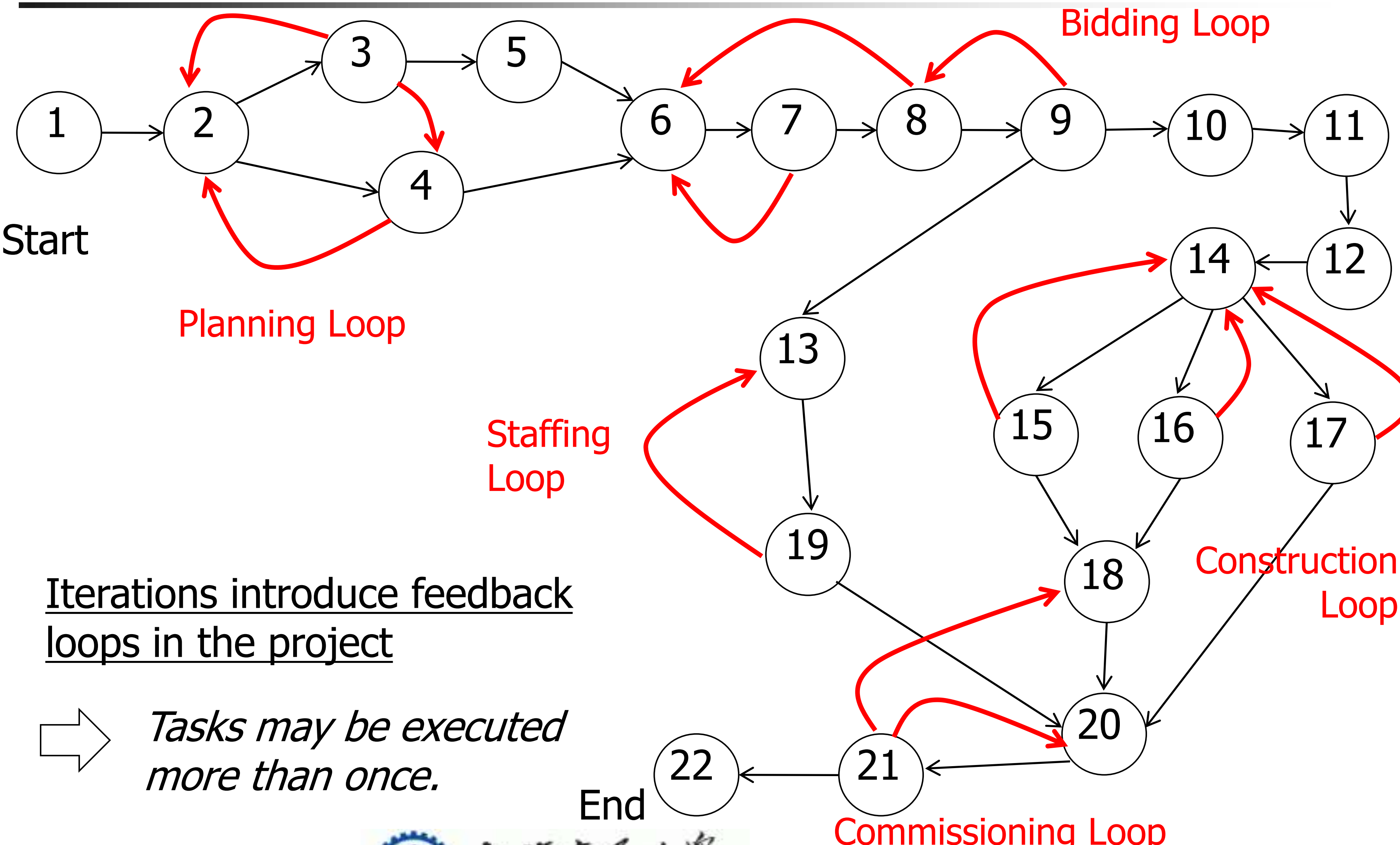
- Transportation analysis, demand, warehouse capacity and location are all coupled (=planning loop)
  - Add design iterations 3→2, 4→2, 3→4
- Initial proposals received from contractors may not be satisfactory, contract negotiations may fail (=bidding loop)
  - Add rework loops 8→6, 7→6, 9→8
- During training and instruction, it turns out that staff is inadquate in terms of quality and quantity (=staffing loop)
  - Add hiring loop from 19→13

Possible Iterations (cont.)

- During Construction and Installation, there are a number of technical problems that need to be addressed, e.g. poor layout (=construction loop)
  - Add construction rework from 15→14, 16→14, 17→14
- During Commissioning and Testing the initial operations of the distribution center need to be refined, e.g. inventory management (=commissioning loop)
  - Add rework loops from 21→20, 21->18

- **What is the effect of these iterations?**

HumLog DC Project Graph



<u>Iterations introduce feedback loops in the project</u>

⇨ *Tasks may be executed more than once.*

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DSM unstructured (with iterations added)

	1!	2!	3!	4!	5!	6!	7!	8!	9!	10	11	12	13	14	15	16	17	18	19	20	21	22
1! Start																						
2! Location Decision	0		0	0																		
3! Capacity Modeling		0																				
4! Transportation Analysis		0	0																			
5! Government Approval			0																			
6! Request for Proposal (RfP)				0	0		0	0														
7! Evaluate Proposals						0																
8! Select Main Contractor							0		0													
9! Finalize Main Contract								0														
10! Site Preparation									0													
11! Dig and Pour Foundation										0												
12! Erect Main Structure											0											
13! Staffing for Operations									0										0			
14! Install Building Systems												0			0	0	0					
15! Install Safety and Security														0								
16! Install Inventory Management														0								
17! Install Communications System														0								
18! Stock Up Initial Inventory															0	0					0	
19! Staff Training and Instruction													0									
20! Commissioning and Test																	0	0	0		0	
21! Final Acceptance and IOC																				0		
22! End																					0	

Iterations appear above the diagonal

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HumLog DC DSM Partitioned

(PSM32)

	1!	2!	3!	4!	5!	6!	7!	8!	9!	10	13	19	11	12	14	15	16	17	18	20	21	22
1! Start																						
2! Location Decision	0		0	0																		
3! Capacity Modeling		0																				
4! Transportation Analysis		0	0																			
5! Government Approval			0																			
6! Request for Proposal (RfP)				0	0		0	0														
7! Evaluate Proposals						0																
8! Select Main Contractor							0		0													
9! Finalize Main Contract								0														
10! Site Preparation									0													
13! Staffing for Operations									0			0										
19! Staff Training and Instruction											0											
11! Dig and Pour Foundation										0												
12! Erect Main Structure													0									
14! Install Building Systems														0		0	0	0				
15! Install Safety and Security															0							
16! Install Inventory Management															0							
17! Install Communications System															0							
18! Stock Up Initial Inventory																0	0				0	
20! Commissioning and Test												0						0	0		0	
21! Final Acceptance and IOC																				0		
22! End																					0	

Planning Meta-Task

Contracting Meta-Task

Staffing Meta-Task

Construction Meta-Task

Commissioning Meta-Task

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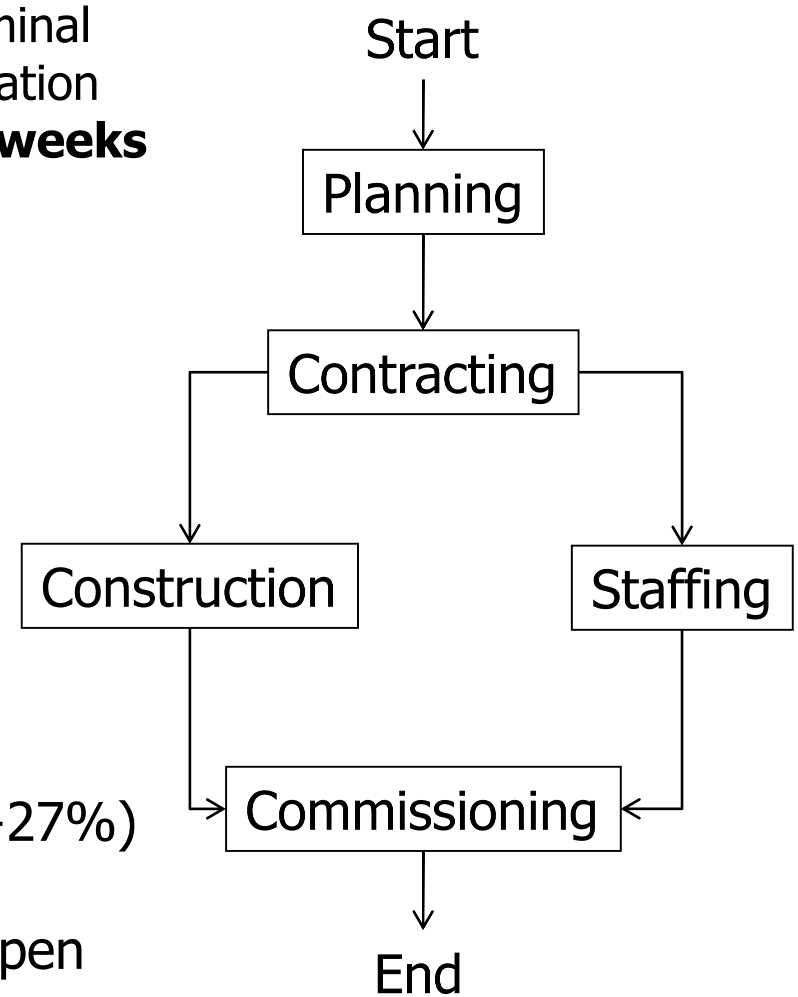
Simplified Project Structure

Simplified Project by creating Meta-Tasks

Nominal
Duration
44 weeks

Need to adjust
time durations of meta-tasks
due to iterations
(e.g. through simulation)



Average duration with loops **56 weeks** (+27%)
Predicted by simulation, but project
Durations 2-3 times that estimate can happen

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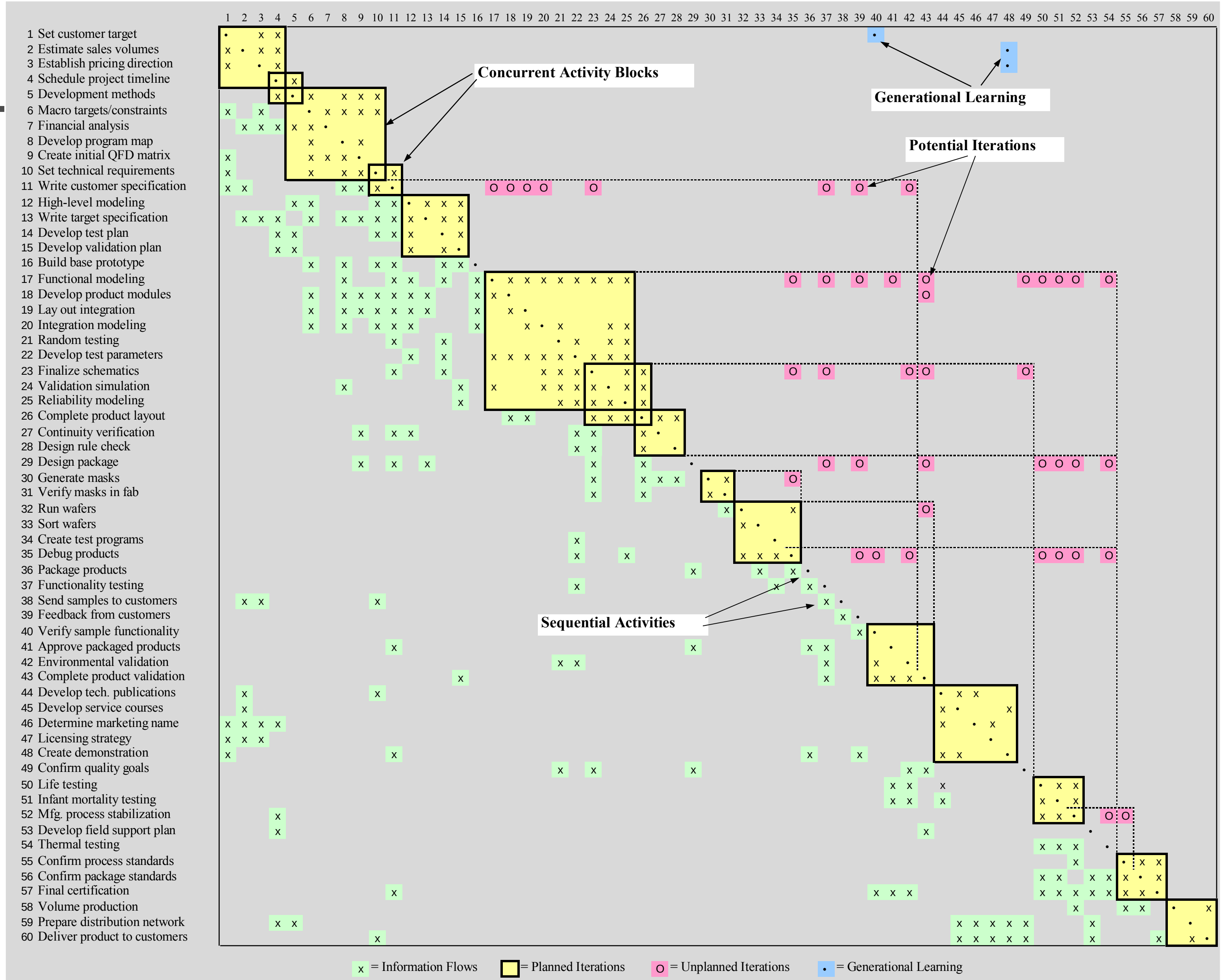
Concurrent Engineering *in the Small*

- Projects are executed by a cross-disciplinary team (5 to 20 people).
- Teams feature high-bandwidth technical communication.
- Tradeoffs are resolved by mutual understanding.
- "Design and production" issues are considered simultaneously.
- Might not need DSM

Concurrent Engineering *in the Large*

- Large projects are organized as a network of teams (100s to 1000 people).
- Large projects are decomposed into many smaller projects and tasks.
- Large projects may involve development activities dispersed over multiple sites.
- The essential challenge is to integrate the separate pieces into a *system* solution.
- The needs for integration depend upon the technical interactions among the sub-problems → DSM can be helpful

Semiconductor Development Example



inside intel

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Concept Question 2

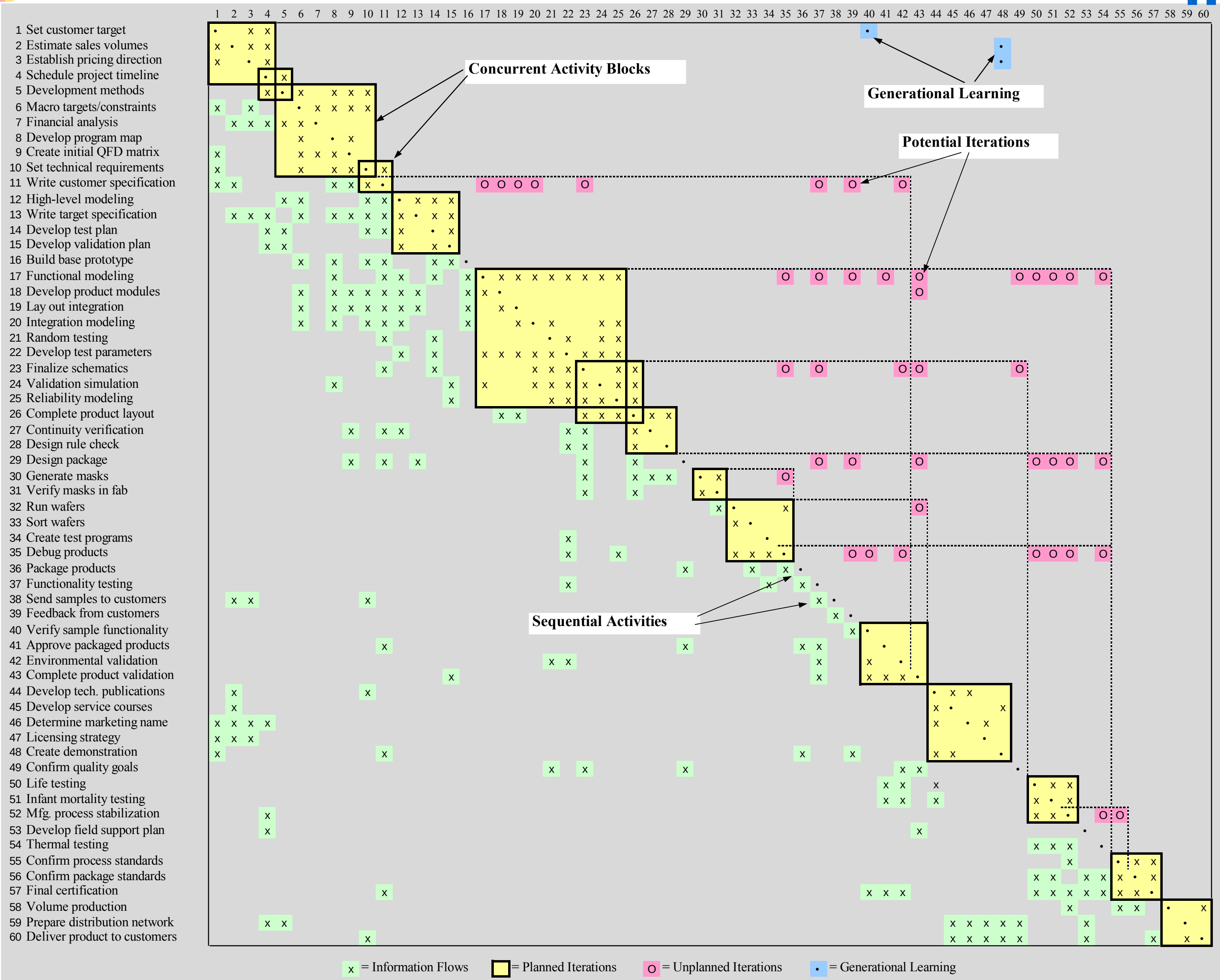
https://www.diaochapai.com/survey1673032

- The main benefits of the Design Structure Matrix (DSM) method for modeling projects are:
  - A – highlight the iterations in the project
  - B – aggregate coupled tasks into blocks
  - C – better understand information flows
  - D – create a more precise schedule
  - B,C and D
  - A,B and C
  - All of the above

Short Conclusions

- Iterations are an essential part of design
  - Some iterations are desirable
    - improve quality
  - Some iterations are undesirable (rework)
    - can cause delay and cost increases
- Differences between CPM and DSM
  - CPM is work-flow oriented
    - time and schedule flow
    - useful for planning and tracking detailed execution of project
  - DSM is information-flow oriented
    - DSM captures iterations
    - DSM shows blocks , i.e. the macro-tasks
    - useful for analyzing and improving design processes

Semiconductor Development Example



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Two Types of Iteration

Planned Iteration

- Caused by needs to "get it right the first time."
- We know where these iterations occur, but not necessarily how much.
- Planned iterations should be facilitated by good design methods, tools, and coordination.

Unplanned Iteration

- Caused by errors and/or unforeseen problems.
- We generally cannot predict which unplanned iterations will occur.
- Unplanned iterations should be minimized using risk management methods.

Design Iteration

- Product development is fundamentally iterative — yet iterations are hidden.
- Iteration is the repetition of tasks due to the availability of new information.
  - changes in input information (upstream)
  - update of shared assumptions (concurrent)
  - discovery of errors (downstream)
- Engineering activities are repeated to improve product quality and/or to reduce cost.
- To understand and accelerate iterations requires
  - visibility of iterative information flows
  - understanding of the inherent process coupling

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Instrument Cluster Development

Supplier A

Casing Design	•	X	X			O
Wiring Layout	X	•	X			O
Lighting Details	X	X	•			O
Tooling	X	X	X	•		O
Hard Prototype				X	•	
Testing					X	•

Supplier B

Casing Design	•	X					
Lighting Details	X	•					
Wiring Layout	X	X	•				
Soft Prototype	X	X	X	•			
Testing				X	•		
Revision					X	•	
Hard Tooling	X	X	X		X	X	•

Slower Design Process

Several planned iterations

Usually one unplanned iteration

Faster Design Process

Fewer planned iterations

Planned revision cycle

No unplanned iterations

Use of “Soft” Prototype

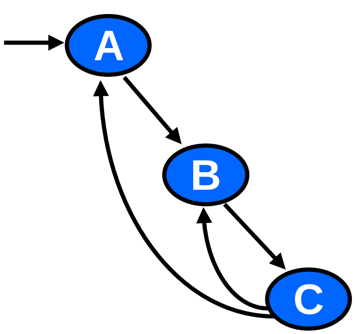
Two Iteration Styles

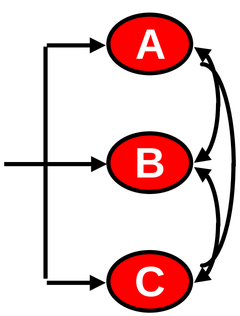
Sequential Iteration

- One activity is executed at a time.
- Models assume that probabilities determine the next actions.
- Signal Flow Graph Model

Parallel Iteration

- Several activities are executed at the same time.
- Models assume that rework is created for other coupled activities.
- Work Transformation Model





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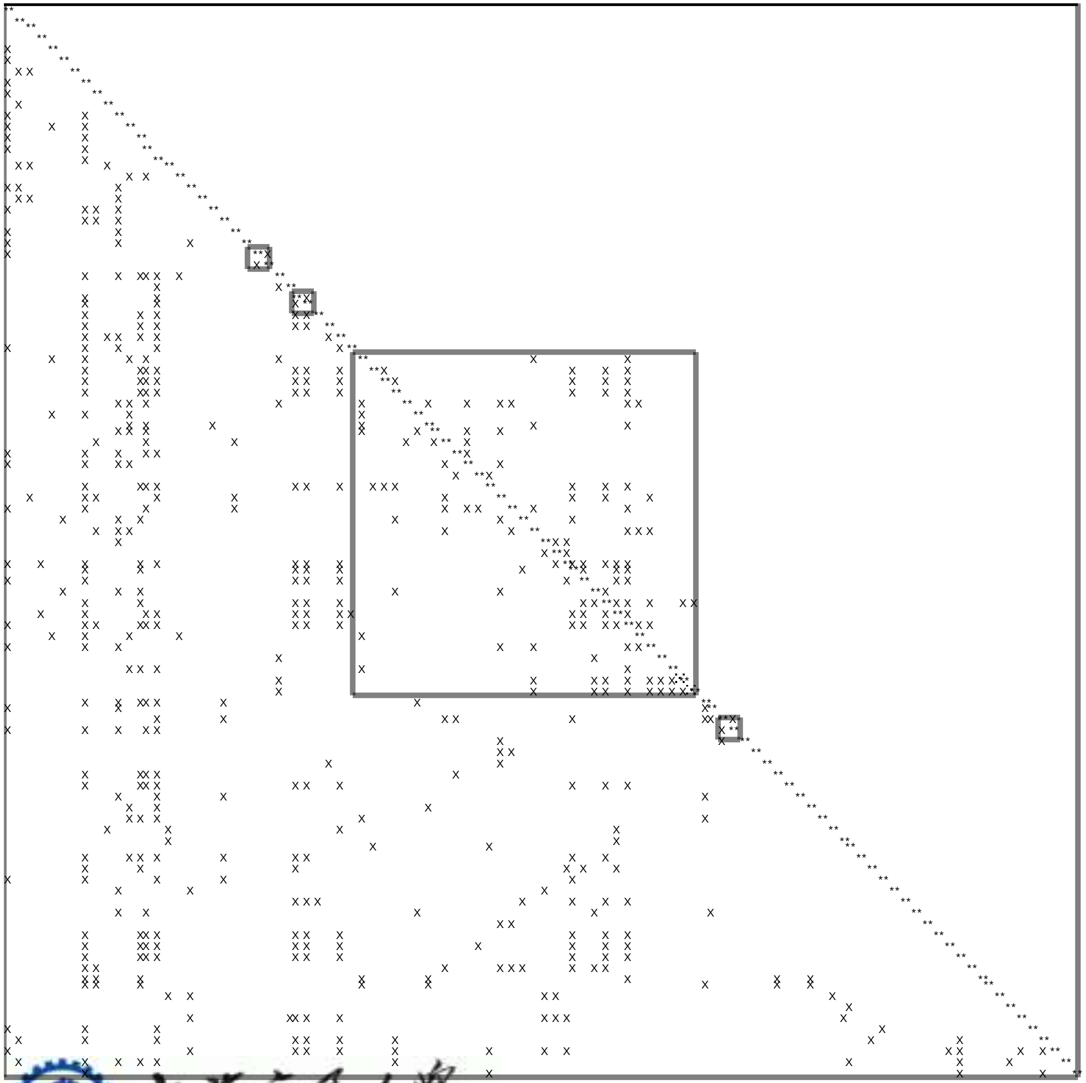
Brake System Design Example

Work
Transformation
Model



105
parameters

Brake System Coupled Block

		33	34	35	37	40	44	45	46	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	04
33	Knuckle envelope & attach pts	**																•									•		
34	Pressure at rear wheel lock up		**	x																		X			•		•		
35	Brake torque vs. skidpoint			**	x																	x			x		x		
37	Line pressure vs. brake torque				**																	•			x		•		
40	Splash shield geometry椇ront	•				**		•				•			x	x											•	x	
44	Drum envelope & attach pts	•					**																						
45	Bearing envelope & attach pts	•						**										•									•		
46	Splash shield geometry椖ear	•					•		**			•			•														
48	Air flow under car/wheel space					x			x	**		x																	
49	Wheel material										**	x																	
50	Wheel design									•		**			•														
51	Tire type/material										•		**	•															
52	Vehicle deceleration rate		X	X	X									**								•			x		•		
53	Temperature at components									x					**							•			x				•
54	Rotor cooling coeficient									x		x	•			**		x									x		
55	Lining椖ear vol and area				x										•		**					x							
56	Rotor width									x						x		**									x	x	•
57	Pedal attach pts																		**	x	•								
58	Dash deflection																		x	**	x								
59	Pedal force (required)																			x	**	•	x		X	x	•		
60	Lining material椖ear																•					**	•			x	•		
61	Pedal mechanical advantage																				x		**			x	•		
62	Lining椇ront vol & swept area				x										x									**	•				
63	Lining material椇ront																						x	•	**	X	x		x
64	Booster reaction ratio																					•	x		x	**	•		
65	Rotor diameter																					•	•		•	•	**	x	•
66	Rotor envelope & attach pts	x																										**	
104	Rotor material														x			•									•	•	**

•	Weak
x	Medium
X	Strong

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The Work Transformation Model (Parallel Iteration Model)

$$u_{t+1} = A u_t$$

work vector

work transformation matrix

Assumptions

- All coupled tasks are attempted simultaneously.
- Off-diagonal elements correspond to fractions of each task's work which must be repeated during subsequent iterations.
- Objective is to characterize the nature of design iteration.

Work Transformation Model Mathematics

$$u_{t+1} = Au_t$$ **work transformation equation**

$$U = \sum_{t=0}^{\infty} u_t = (\sum_{t=0}^{\infty} A^t)u_0$$ **total work vector**

$$A = S\mathrm{L}S^{-1}$$ **eigenvalue decomposition**

$$\mathrm{U{=}S}\left(\sum_{\mathrm{t=0}}^{\infty} \mathrm{L}^{\mathrm{t}}\right) S^{-1}u_0$$ **substitution**

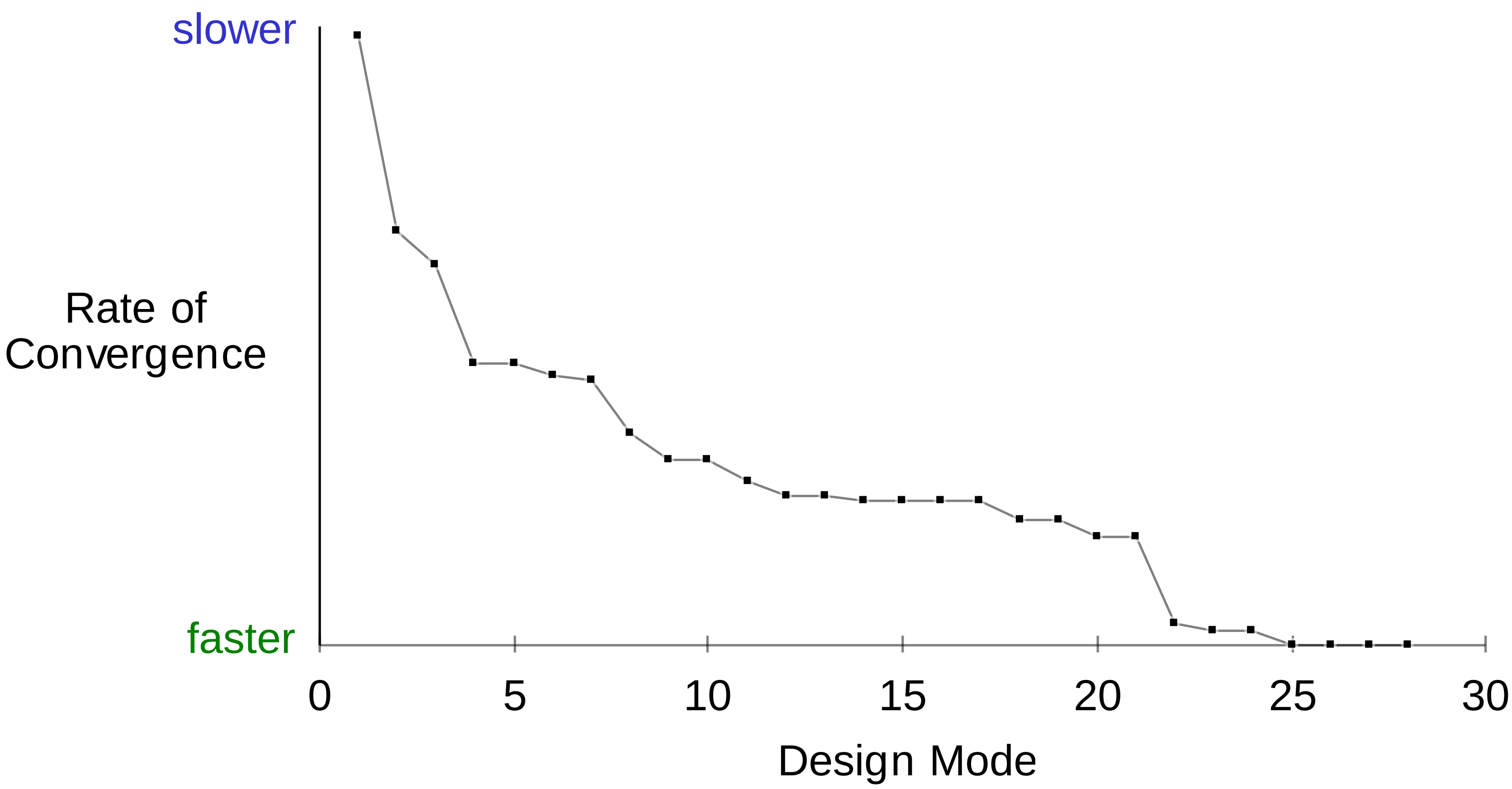
$$\left(\sum_{\mathrm{t=0}}^{\infty} \mathrm{L}^{\mathrm{t}}\right) = (I - \mathrm{L})^{-1}$$ **diagonal matrix of $\frac{1}{1-\lambda}$ terms**

$$U = S\underbrace{\left[(I - \mathrm{L})^{-1} S^{-1} u_0\right]}_{\text{scaling vector}}$$

total work **eigenvector matrix**

Total work is a scaling of the eigenvectors.

Brake System "Design Modes"



Brake System "Design Modes"

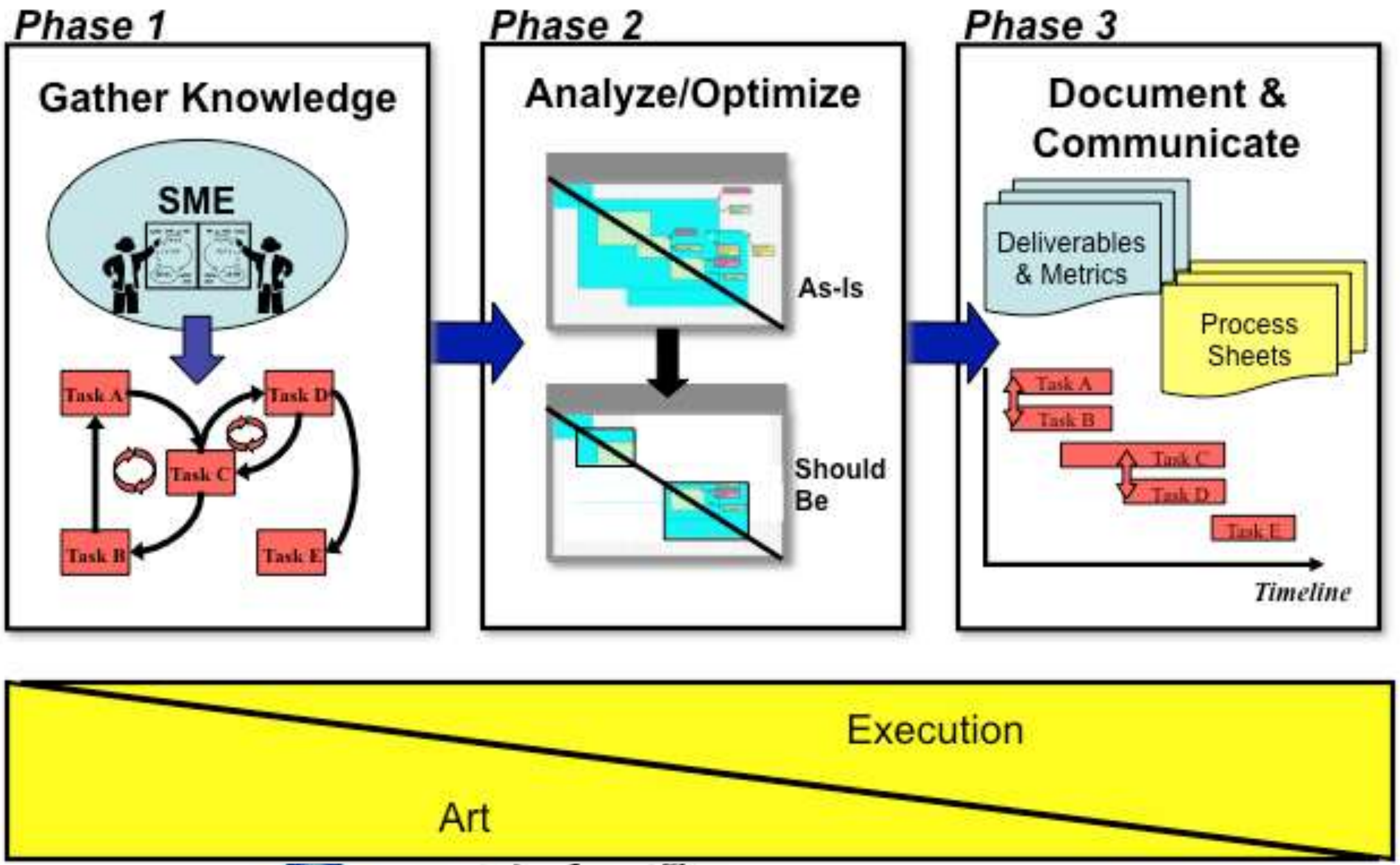
	First	Second
Knuckle envelope & attach pts	0.0157	0.1215
Pressure at rear wheel lock up	**0.4808**	0.0075
Brake torque vs. skidpoint	**0.4254**	0.0435
Line pressure vs. brake torque	0.1979	0.0228
Splash shield geometry—front	0.1109	**0.8328**
Drum envelope & attach pts	0.0011	0.0141
Bearing envelope & attach pts	0.0168	0.1356
Splash shield geometry—rear	0.0143	0.0654
Air flow under car/wheel space	0.0512	**0.5824**
Wheel material	0.0057	0.0610
Wheel design	0.0156	0.1051
Tire type/material	0.0731	0.0177
Vehicle deceleration rate	**1.0000**	0.0910
Temperature at components	0.1641	**0.3224**
Rotor cooling coefficient	0.1035	**0.9598**
Lining—rear vol and area	0.1479	0.0166
Rotor width	0.1043	**1.0000**
Pedal attach pts	0.1843	0.1584
Dash deflection	**0.3510**	0.2265
Pedal force (required)	**0.7818**	0.2317
Lining material—rear	0.1765	0.0587
Pedal mechanical advantage	**0.4193**	0.1749
Lining—front vol & swept area	0.1669	0.2052
Lining material—front	**0.4870**	0.0417
Booster reaction ratio	**0.3502**	0.0787
Rotor diameter	0.1117	0.0463
Rotor envelope & attach pts	0.0057	0.0705
Rotor material	0.0757	**0.3168**

Stopping Performance Design Mode

Thermal Design Mode

Application of DSM at Ford

Three-Phased Approach



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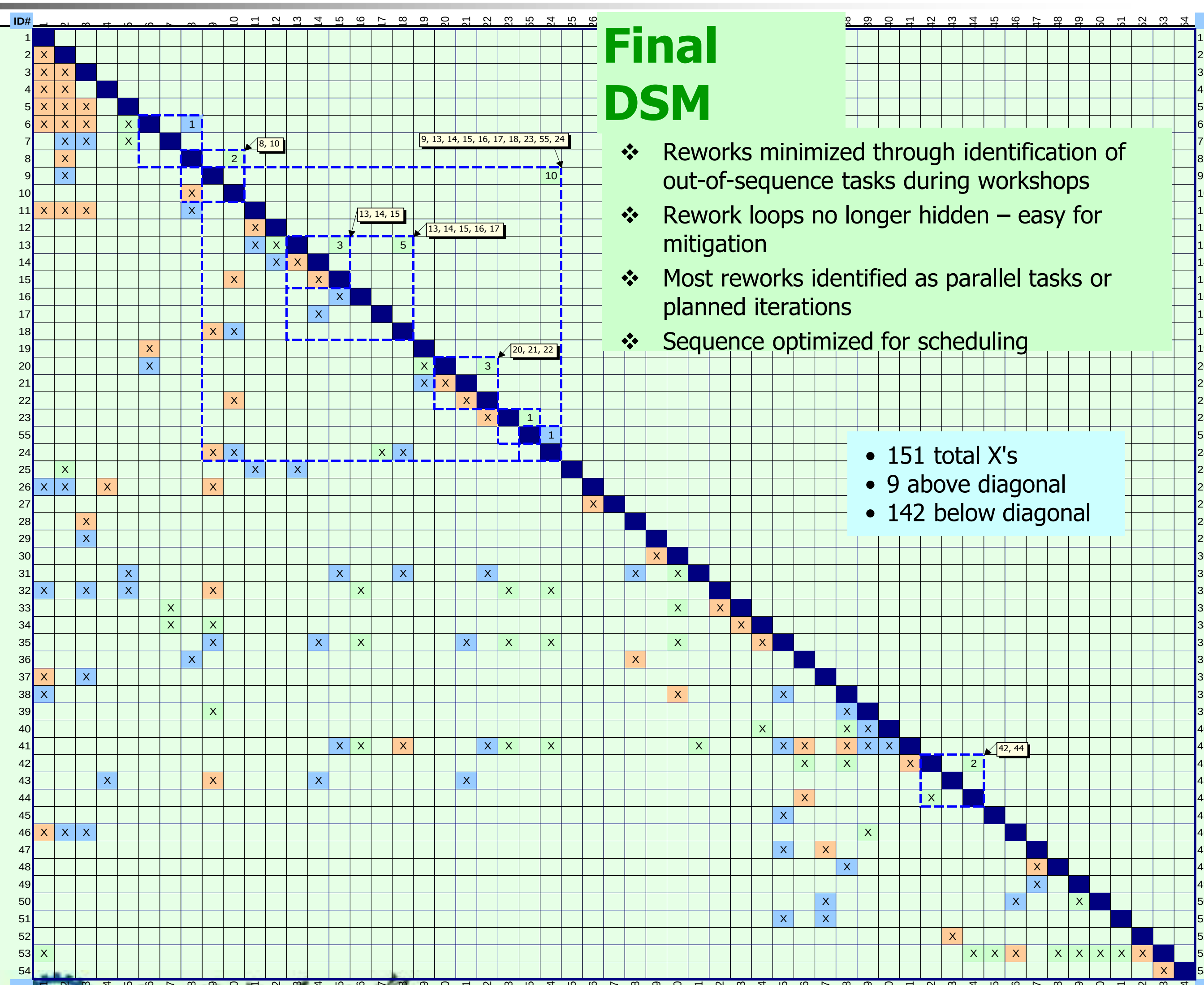
Application of DSM at BP

Task
001. Define and agree overall project accountability and mgmt strategy
002. Data setup - define, communicate, and agree ops data requirements
003. Data setup - define, communicate, and agree site data rqts&roles
004. Define ops data schedule
005. Define data priority (Cat A+B, mandatory doc rqts for MC/comm)
006. Define and agree standards with third party
007. Mandatory field check per tag type to allow CSS verification (RS3+)
008. Setup detailed requirement issue for data by tag type
009. Load Propid with eng data
010. Produce Toxis setup matrix
011. Define and agree standards with suppliers and package engineers
012. Pre-allocate tags to suppliers
013. Provide supplier DCT feeder docs on SDC
014. Load supplier DCT feeder docs on SDC
015. Produce supplier data TOXIS detailed reports
016. Monitor supplier data completeness (Toxis Summary)
017. Remove unused tags from Propid (supplier)
018. Produce eng data TOXIS reports
019. Pre-allocate tags to third party
020. Receive third party docs into KBR dctm/ipms
021. Load third party DCT feeder docs on IDC
022. Produce third party TOXIS detailed reports
023. Monitor third party data completeness
055. Remove unused tags from Propid (third party)
024. Monitor eng data completeness
025. Get information on spares electronically
026. Ops eWarehouse initial load
027. Ops eWarehouse data update (weekly task)
028. Commissioning schedule published
029. CSS markup on PIDs (manual, C2 P&ID's)
030. CSS markup on PIDs (PEGS)
031. Prioritise data for handover and completeness
032. Site verification of initial Propid data
033. CMS initial load of Propid data and CSS assignment
034. Site Verification of new Propid data and CSS assignment
035. CMS data update from Propid (regular, every 2 weeks)
036. CMS, CSS/SH1 skyline published and uploaded into Propid
037. Offshore - Agree offshore process
038. CMS update of CSS (reverse load) (regular, every 2 weeks)
039. Reconcile CMS new tags with those in Propid
040. Monitor tag assignment to CSS from CMS
041. Data ready for first MC. Cat A 80% per CSS
042. Data ready for SH1 commissioning Cat A 95% per CSS
043. Ex, SRD, SCE, LO/LC, and Alarm Trip registers received at site
044. CMS CSS/SH1 skyline update (weekly) and Propid load
045. CMS reverse load of PC ITR date for ops
046. As built eng data feedback from sites
047. Offshore - CMS data update
048. Offshore - CMS reverse load for CSS and ITR date
049. Offshore - Site verification of new data
050. Offshore - As built data on SEQ
051. Offshore - Feed skyline back to KBR
052. As built register update to KBR from site (Ex, SRD, etc.)
053. Data ops tag handover
054. Data ops tag acceptance



Final DSM

- Reworks minimized through identification of out-of-sequence tasks during workshops
- Rework loops no longer hidden – easy for mitigation
- Most reworks identified as parallel tasks or planned iterations
- Sequence optimized for scheduling

- 151 total X's
- 9 above diagonal
- 142 below diagonal

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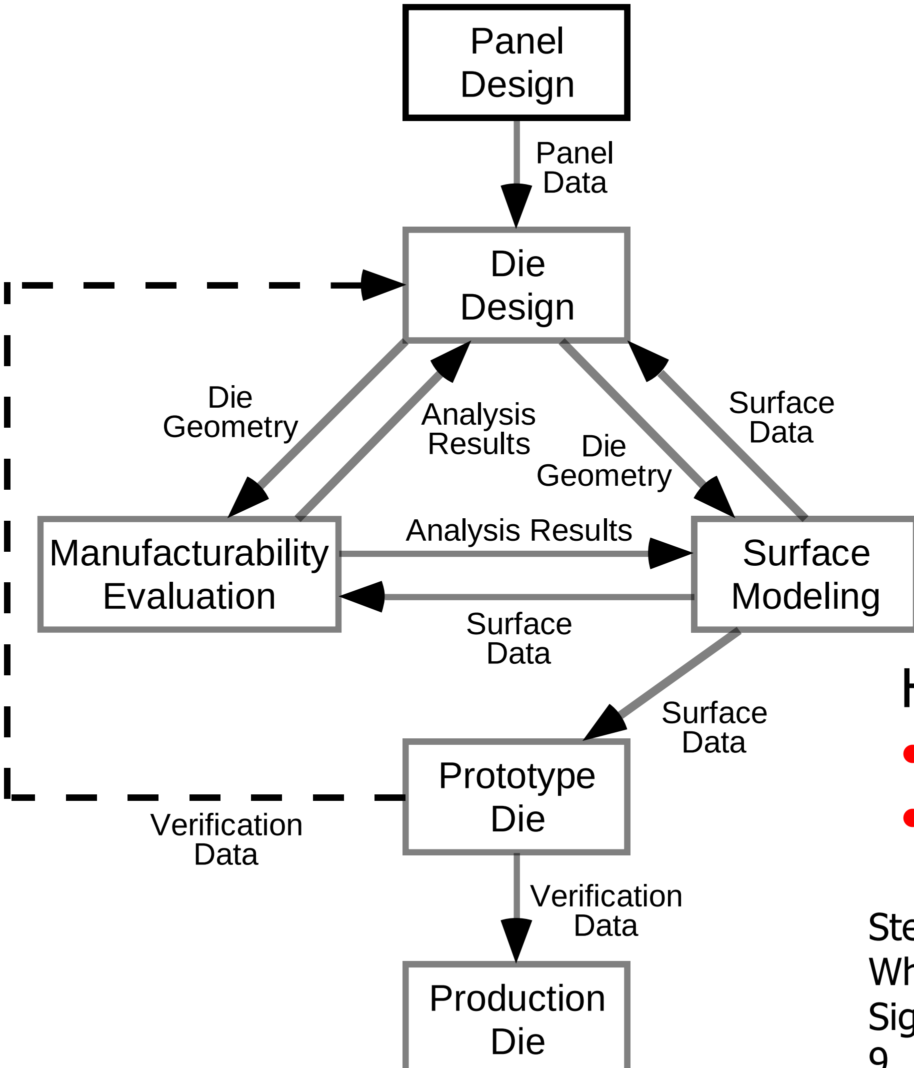
Summary: Iterations

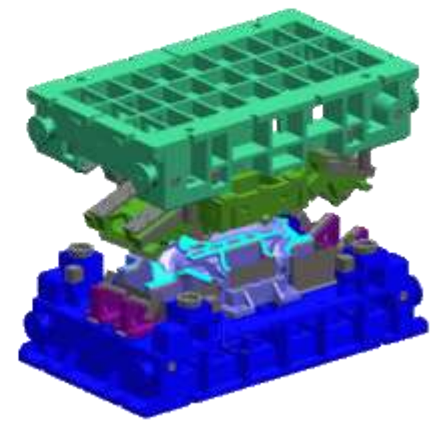
- Development projects are inherently iterative.
- An understanding of the coupling is essential.
- Iteration results in improved quality.
- Iteration can be accelerated through:
  - information technology (faster iterations)
  - coordination techniques (faster iterations)
  - decreased coupling (fewer iterations) → modular design?
- There are two fundamental types of iteration:
  - planned iterations (getting it right the first time)
  - unplanned iterations (fixing it when it's not right)
- Mature processes have more planned and fewer unplanned iterations.

Always ask as a project manager: Where do we expect iterations?

Project Simulation (Manufacturing Example)



Source:http://www.tescoeng.com/images/stamp-dies.gif



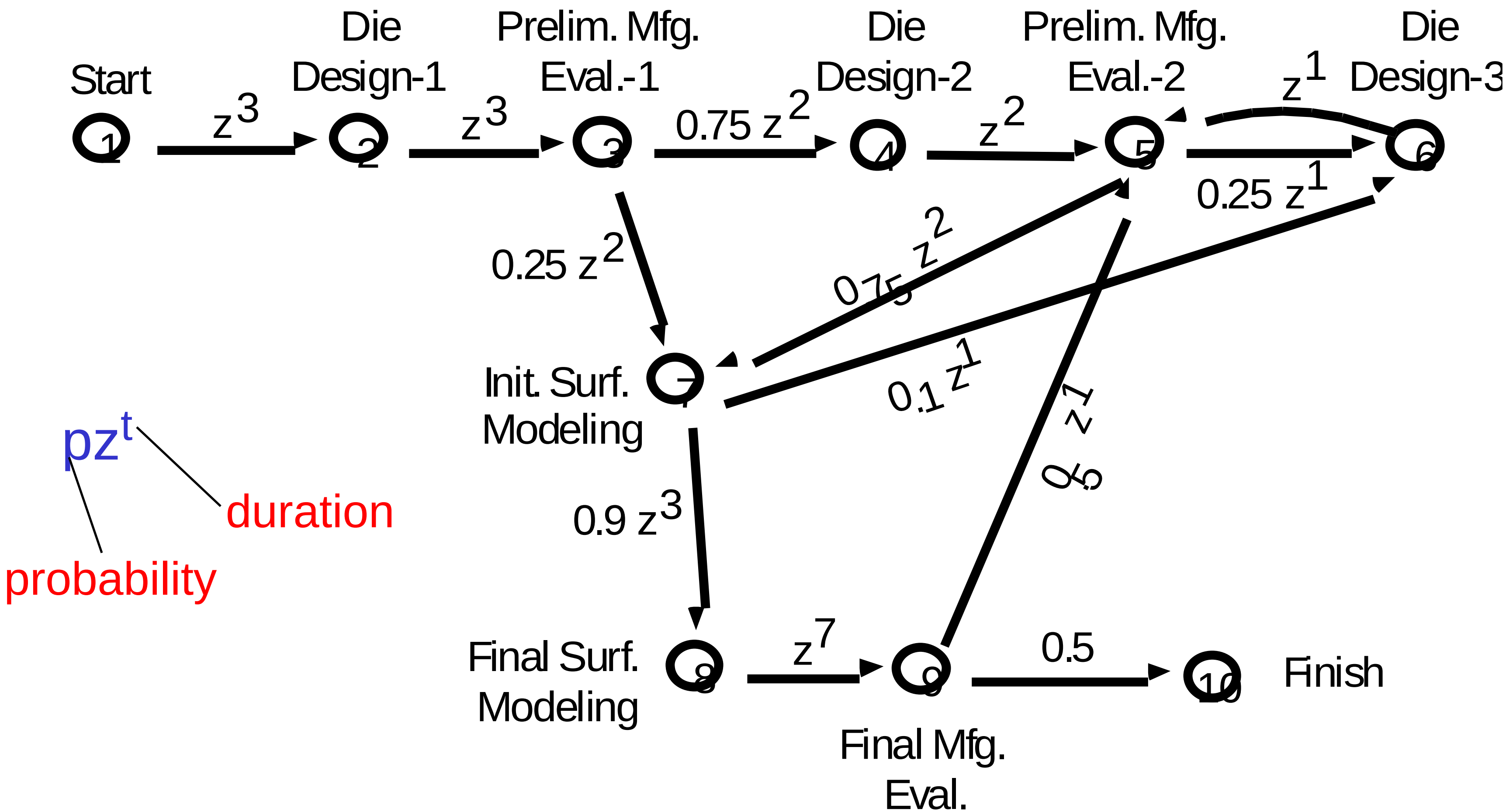
Die Design and Manufacturing

Highly Iterative Process

- how often is each task carried out ?
- how long to complete?

Steven D. Eppinger, Murthy V. Nukala, and Daniel E. Whitney. "Generalised Models of Design Iteration Using Signal Flow Graphs", Research in Engineering Design. vol. 9, no. 2, pp. 112-123, 1997.

Signal Flow Graph Model: Stamping Die Development

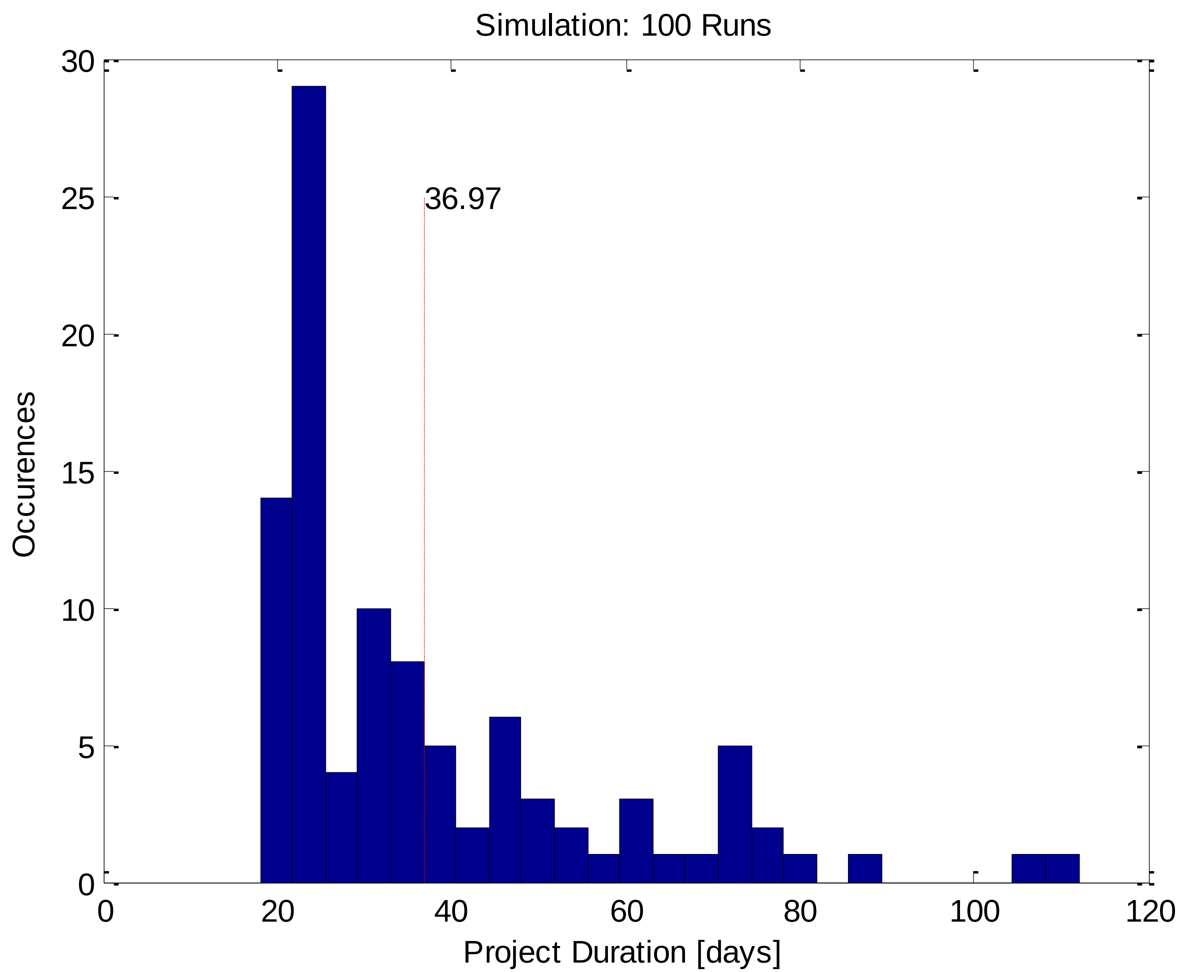


Matlab Simulation

- Review Signal Flow Simulation
  - State Transition Probability Matrix: P
  - State Transition Duration Matrix: T

- Implementation (die_sim.m)
  - while state<10
  - newstate= find(P(:,state));
  - cumprob= cumsum(P(newstate,state));
  - event=rand;
  - newind=max(find(event>[0 cumprob']));
  - % state transition
  - time(ind)=time(ind)+T(newstate(newind),state);
  - state=newstate(newind);
  - end

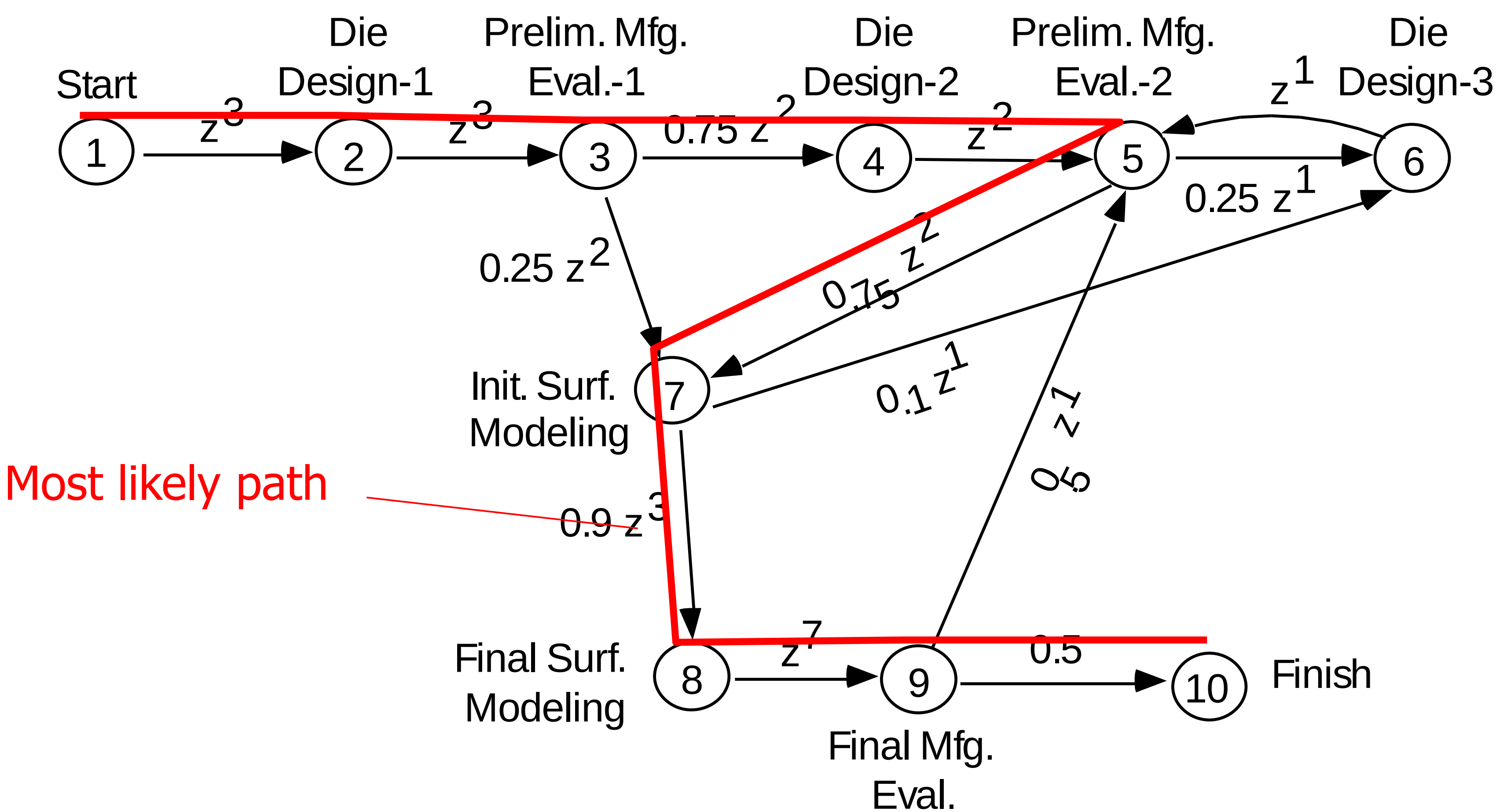
Computed Distribution of Die Development Timing



Estimate likely completion time

What else can we do with the simulation?

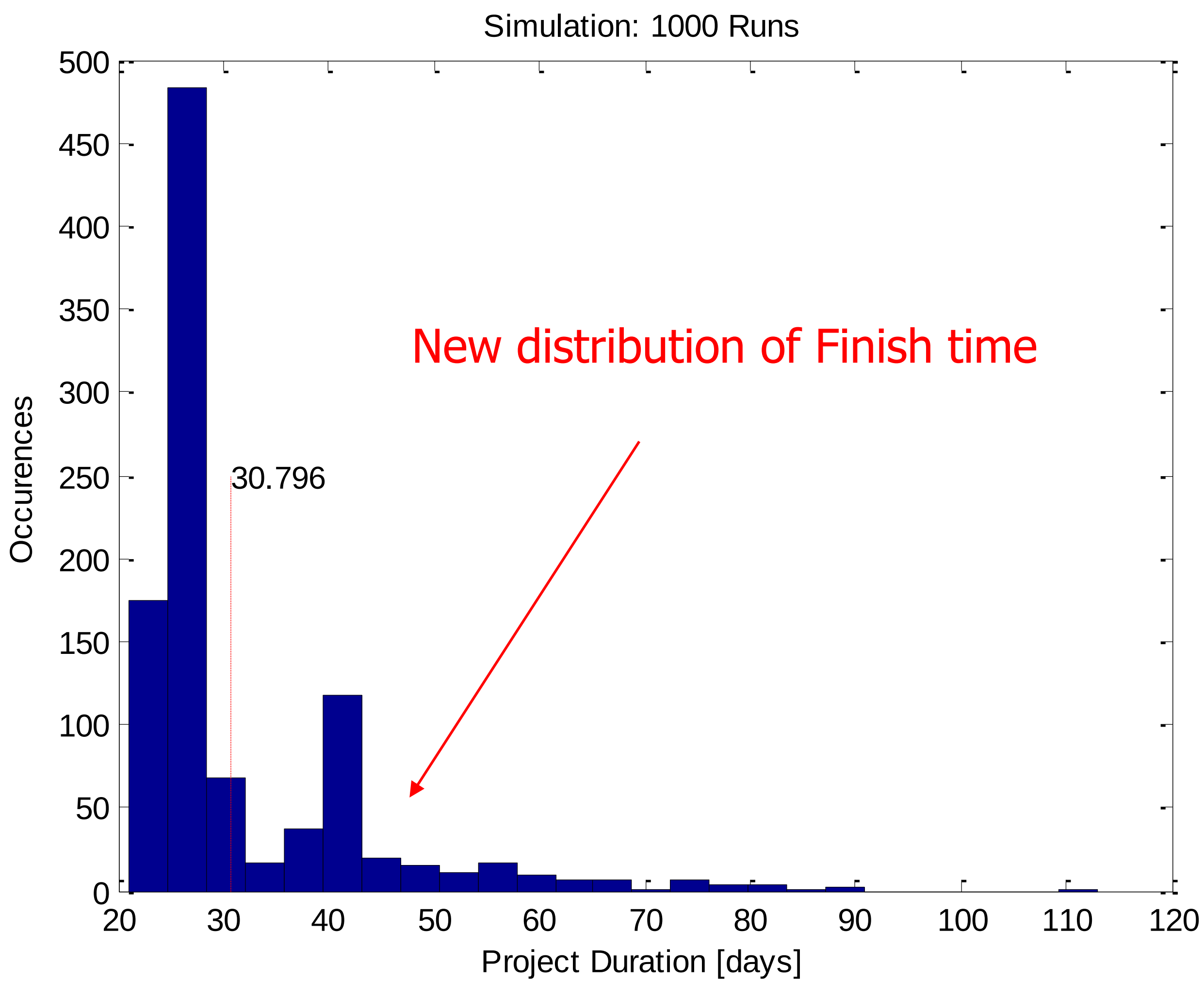
Process Redesign/Refinement



What-if analysis

- Spend more time on die design (1):
  - Increase time spent on initial die design (1) from 3 to 6 days
  - Increase likelihood of going to Initial Surface Modeling (7) from 0.25 to 0.75
    - Is this worthwhile doing?
    - Original E[F]=37 days
    - New E[F]= 37 days – no real effect ! Why?
- Spend more time on final surface modeling (8):
  - Increase time for that task from 7 to 10 days
  - Increase likelihood of Finishing from 0.5 to 0.75
    - New E[F] = 30.8 days
    - Why is this happening?

New Project Duration



Concept Question 3

- In the Die Design Project, why did spending more time on final surface modeling (step 8) help reduce average completion time when spending more time on early die design (step 1) did not? Because …
  - The project avoids iterations altogether
  - The early die design cycle has been shortened by 20%
  - Fewer very long loops reduce the tail of the distribution
  - There is an increase in planned iterations which helps
  - It is a random result
  - I don’t know

https://www.diaochapai.com/survey1677621

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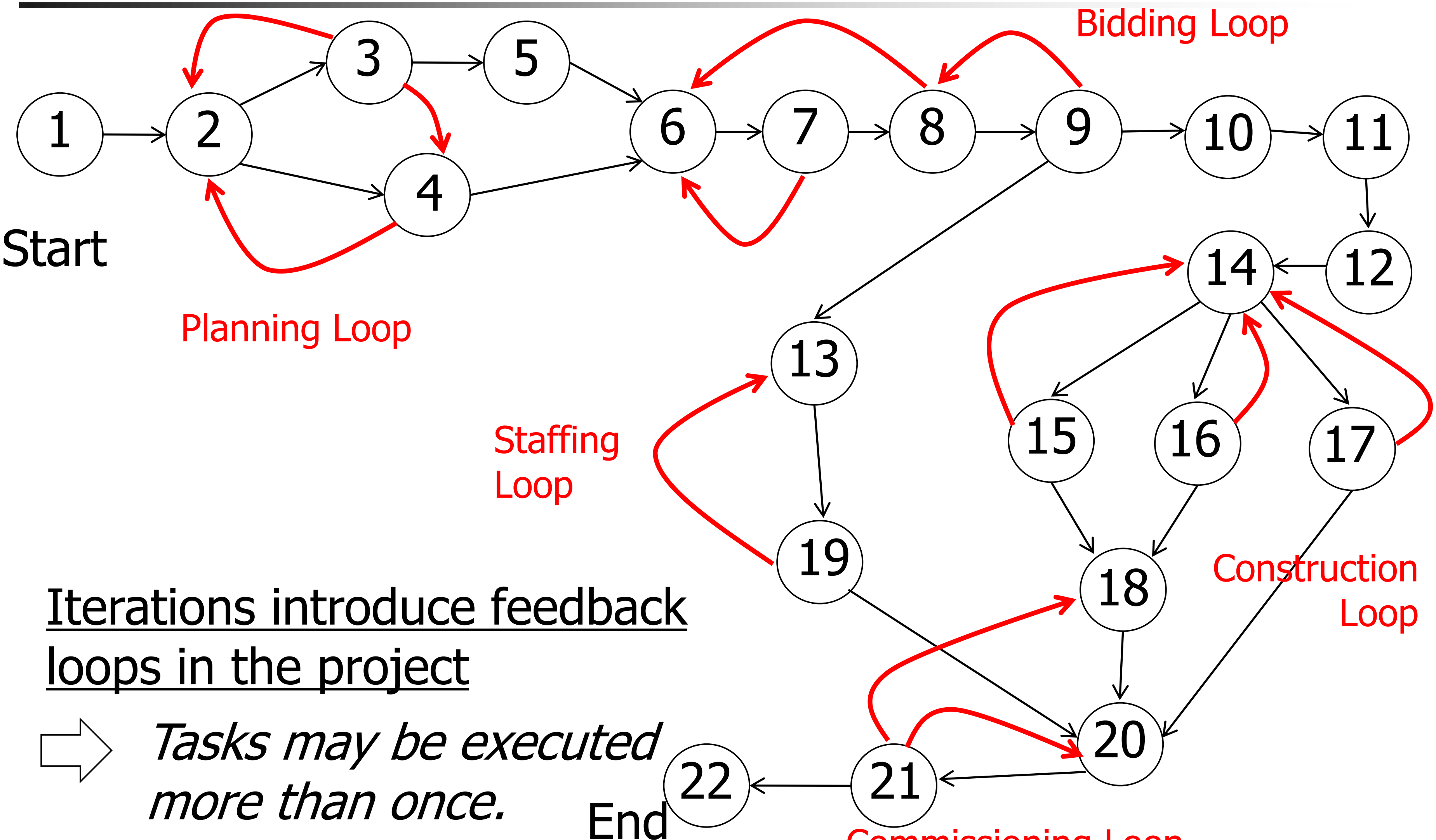
Warehouse in Ethiopia, 2007, courtesy F. Keig (PSI)

HumLog DC Project Graph



Iterations introduce feedback loops in the project

Tasks may be executed more than once.

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HumLog DC DSM Partitioned
(PSM32)

	1	2	3	4	5	6	7	8	9	10	13	19	11	12	14	15	16	17	18	20	21	22
1 Start																						
2 Location Decision	0		0	0																		
3 Capacity Modeling		0																				
4 Transportation Analysis		0	0																			
5 Government Approval			0																			
6 Request for Proposal (RfP)				0	0		0	0														
7 Evaluate Proposals						0																
8 Select Main Contractor							0		0													
9 Finalize Main Contract								0														
10 Site Preparation									0													
13 Staffing for Operations									0			0										
19 Staff Training and Instruction											0											
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12 Erect Main Structure													0									
14 Install Building Systems														0		0	0	0				
15 Install Safety and Security															0							
16 Install Inventory Management															0							
17 Install Communications System															0							
18 Stock Up Initial Inventory																0	0				0	
20 Commissioning and Test												0						0	0		0	
21 Final Acceptance and IOC																				0		
22 End																					0	

Planning Meta-Task

Contracting Meta-Task

Staffing Meta-Task

Construction Meta-Task

Commissioning Meta-Task

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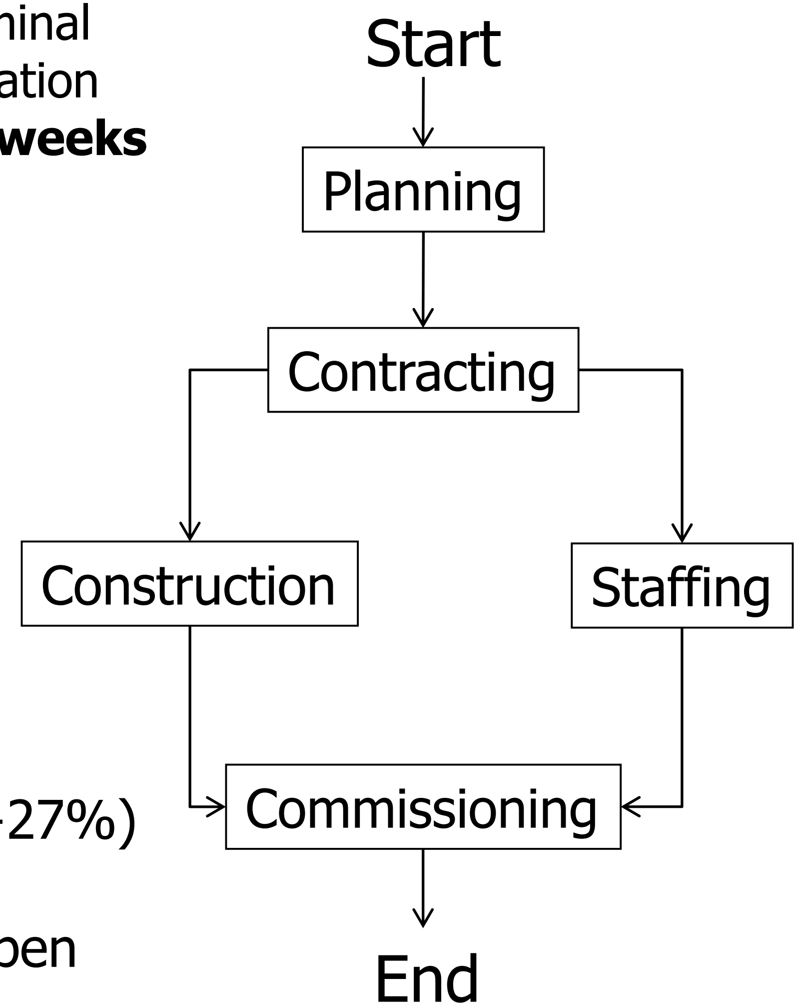
Simplified Project Structure

Simplified Project by creating Meta-Tasks

Nominal Duration
44 weeks



Need to adjust
time durations of meta-tasks
due to iterations
(e.g. through simulation)

Average duration with loops **56 weeks** (+27%)
predicted by simulation, but project
durations 2-3 times that estimate can happen

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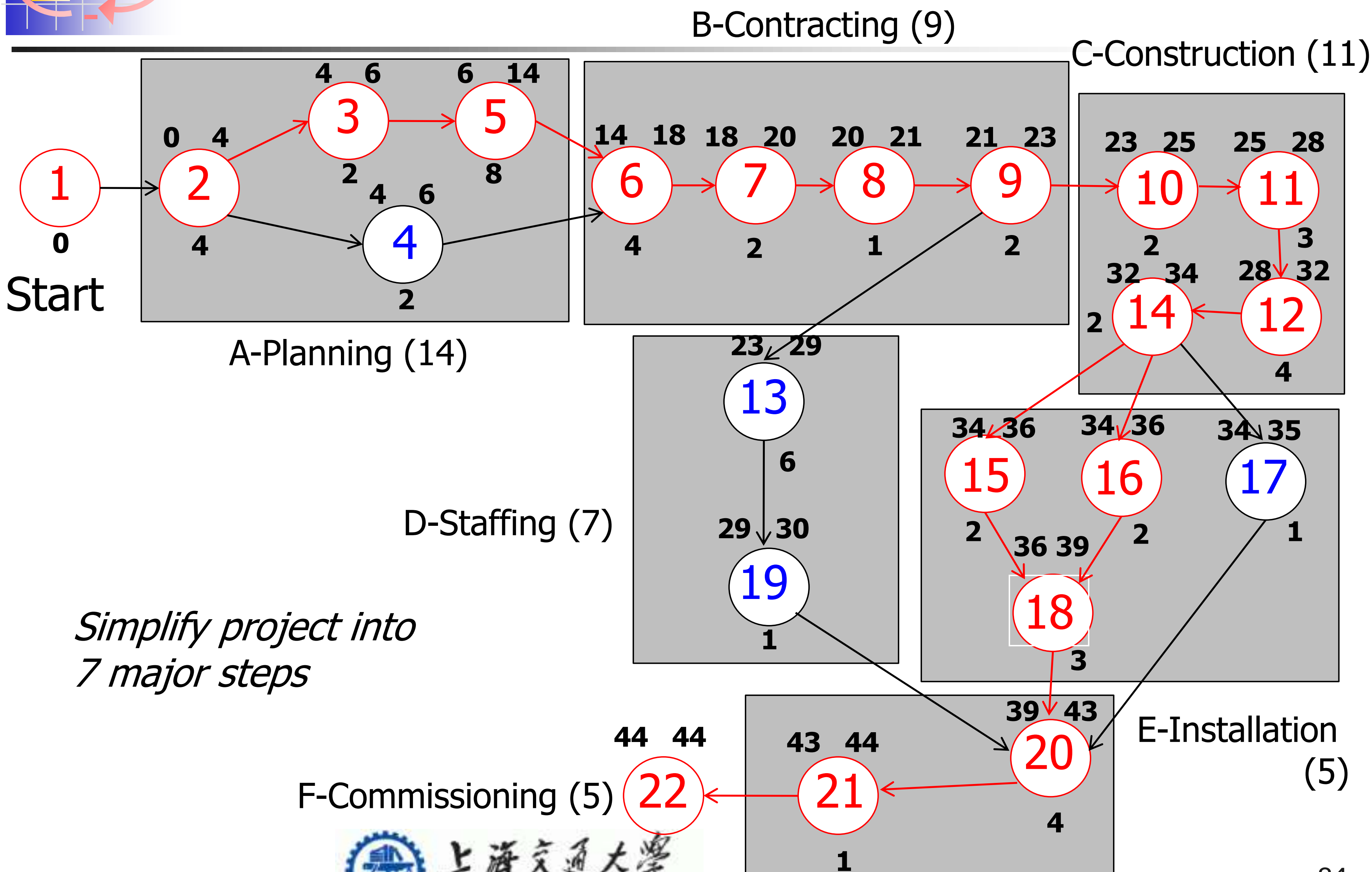
Simulation Application to HumLog DC



Simplify project into 7 major steps

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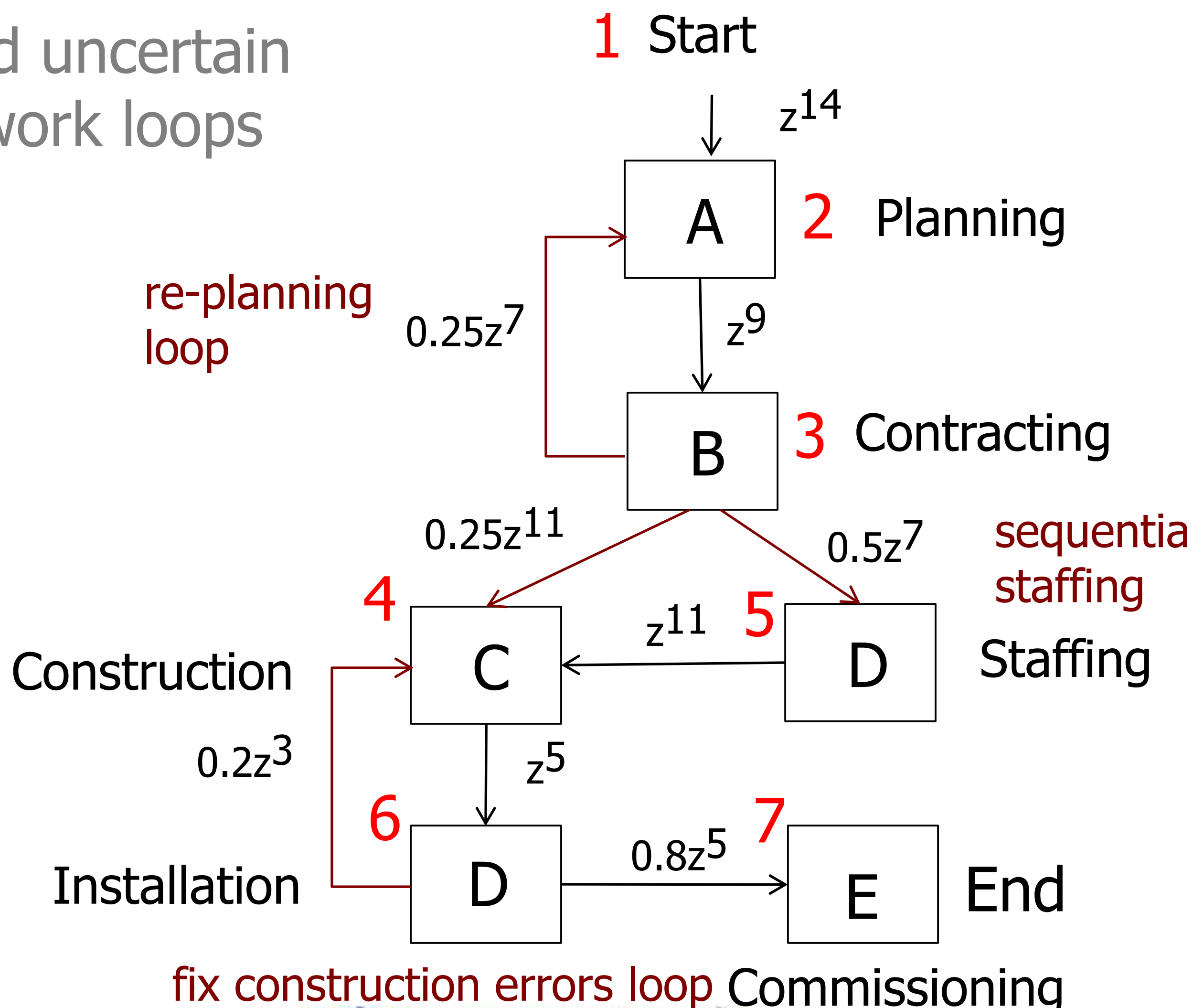
Signal Flow Graph (with iterations)

Add uncertain rework loops

state in red



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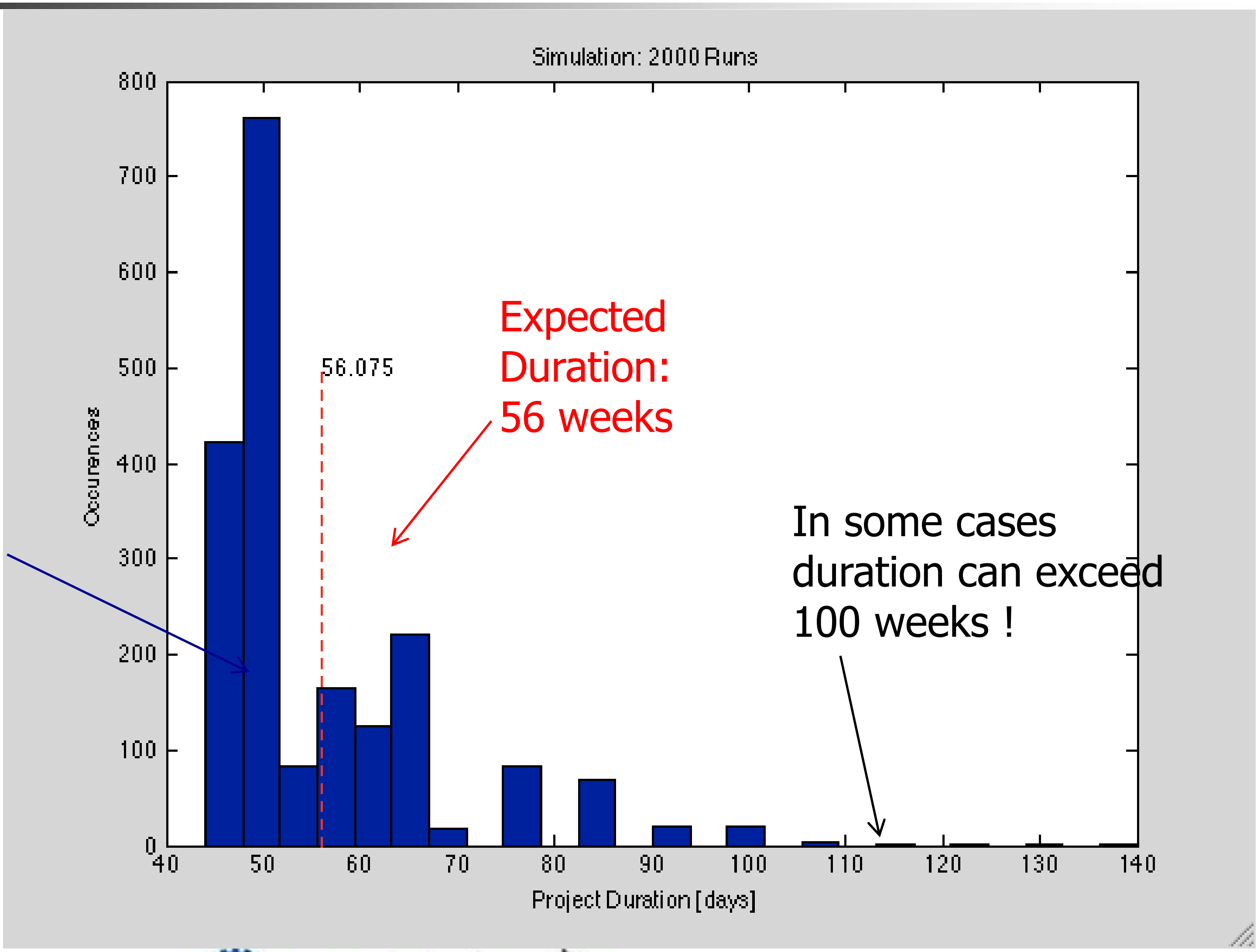
HumLog Simulation Results



Shortest Duration: 44 weeks

Expected Duration: 56 weeks

In some cases duration can exceed 100 weeks !

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Usefulness of PERT and Simulation

- Account for task duration uncertainties
  - Optimistic Schedule
  - Expected Schedule
  - Pessimistic Schedule
- Helps set time reserves (buffers)
- Compute probability of meeting target dates when talking to management, donors
- Identify and carefully manage critical parts of the schedule

HW2: DSM Model of UAV project

- Still NMA-X1 Project Manager Role
- Translate CPM → DSM
  - Network Graph → Matrix
- Add Iterations
- Find Loops
- Reorganize DSM
  - Sequence (reorder tasks)
  - Partition (cluster coupled tasks)
  - Tearing (break loops)

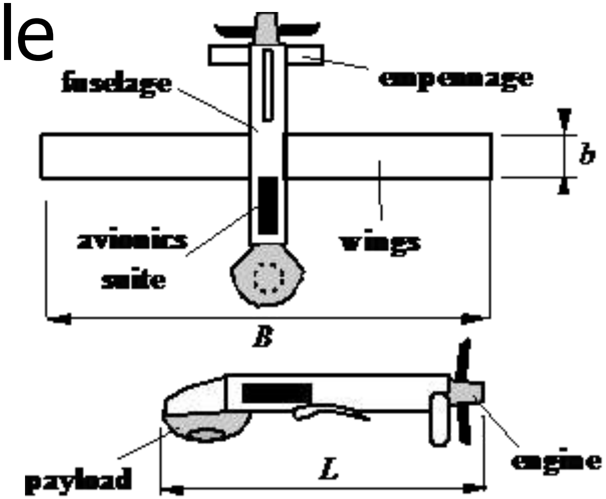

Fig 1. UAV concept, Specifications:
L=2000 mm, B=3500 mm, b=500 mm

Problematics DSM Software

- Download the latest version of the PSM32 program at:
- http://www.problematics.com
- 30 day free trial version
- 40 tasks maximum
- Contact: Donald Steward steward@problematics.com

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Design Structure Matrix Web Site

- http://www.dsmweb.org/

•Tutorial

•Publications

•Examples

•Software

•Contacts

•Events

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Readings for Next Class

- Book Chapter: "Introduction to Project Dynamics". Chapter SD1.
- Book Chapter: "Causes of Project Dynamics". Chapter SD2.