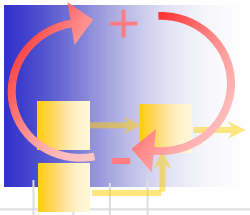
ESD.36J System & Project Management

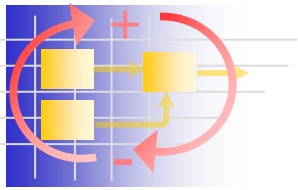
Lecture 4



Design Structure Matrix

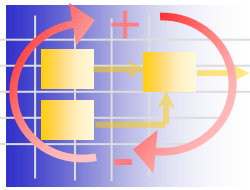
Instructor(s)

Prof. Olivier de Weck



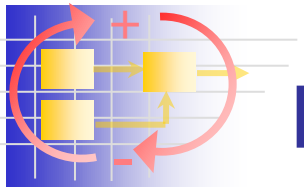
Reminder

- Term Project Proposals are due today !



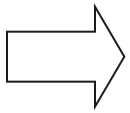
Today's Topic

- DSM Introduction
- Project Graphs --> Task-based DSMs
- DSM Operations
  - sequencing
  - partitioning
  - Tearing
- DSM Example
  - Humanitarian Logistics Project
- DSM Tools and References



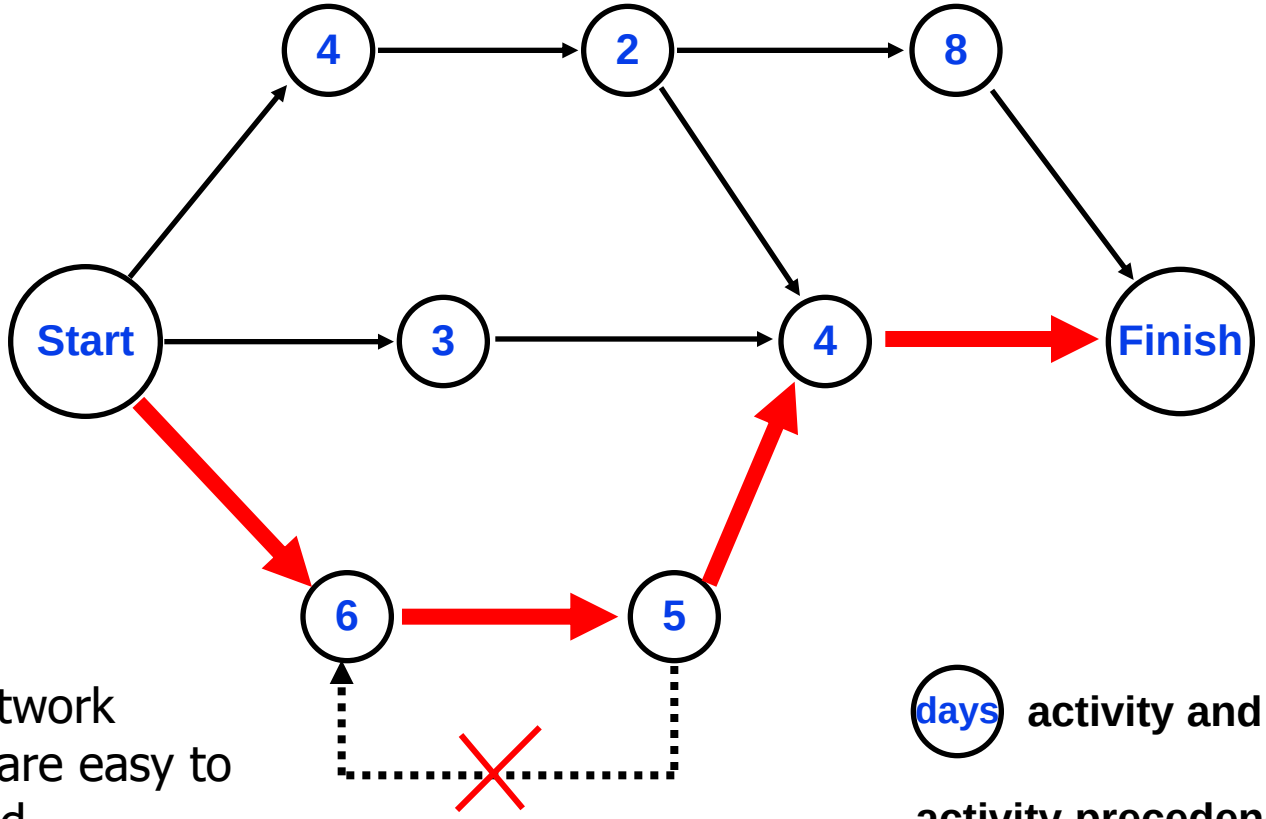
Lessons Learned from CPM

- +
  - Focuses attention on a subset of critical tasks
  - Determine effect of shortening/lengthening tasks
  - Links task durations to schedule
- -
  - 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

PERT and CPM Charts



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

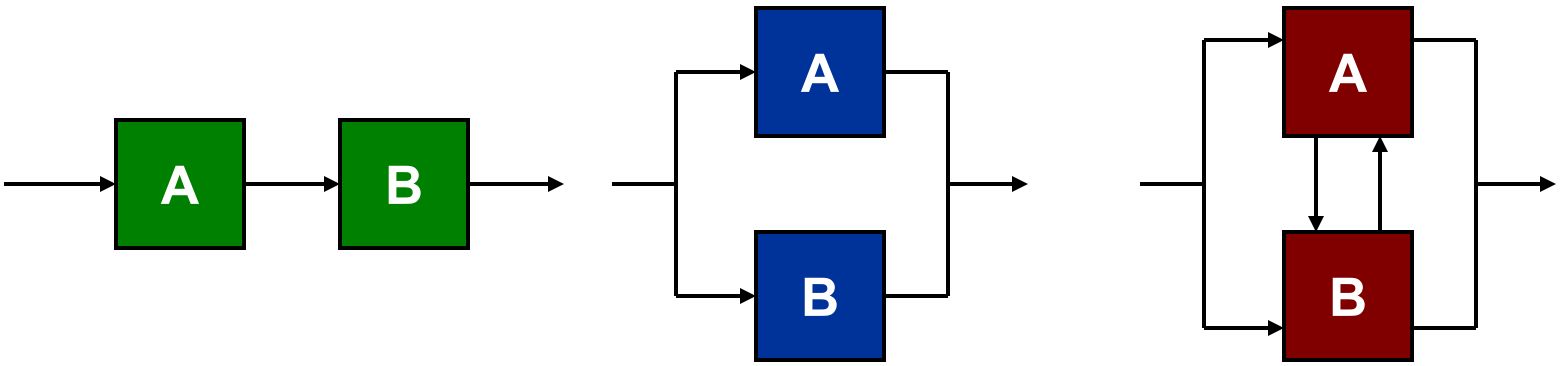
days activity and duration

activity precedence

critical path

Sequencing Tasks in Projects

Three Possible Sequences for Two Tasks



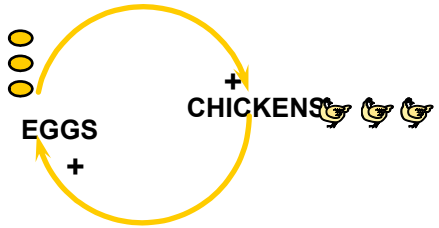
Dependent (Series) | **Independent (Parallel)** | **Interdependent (Coupled)**

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

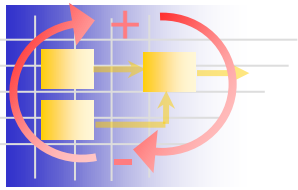
S/C total mass, total inertia: 800kg, 3000 kgm²

Adds mass inertia, ca. 50kg/wheel

Size reaction wheel assembly (RWA) torque and momentum capacity

Reaction Wheel Assembly

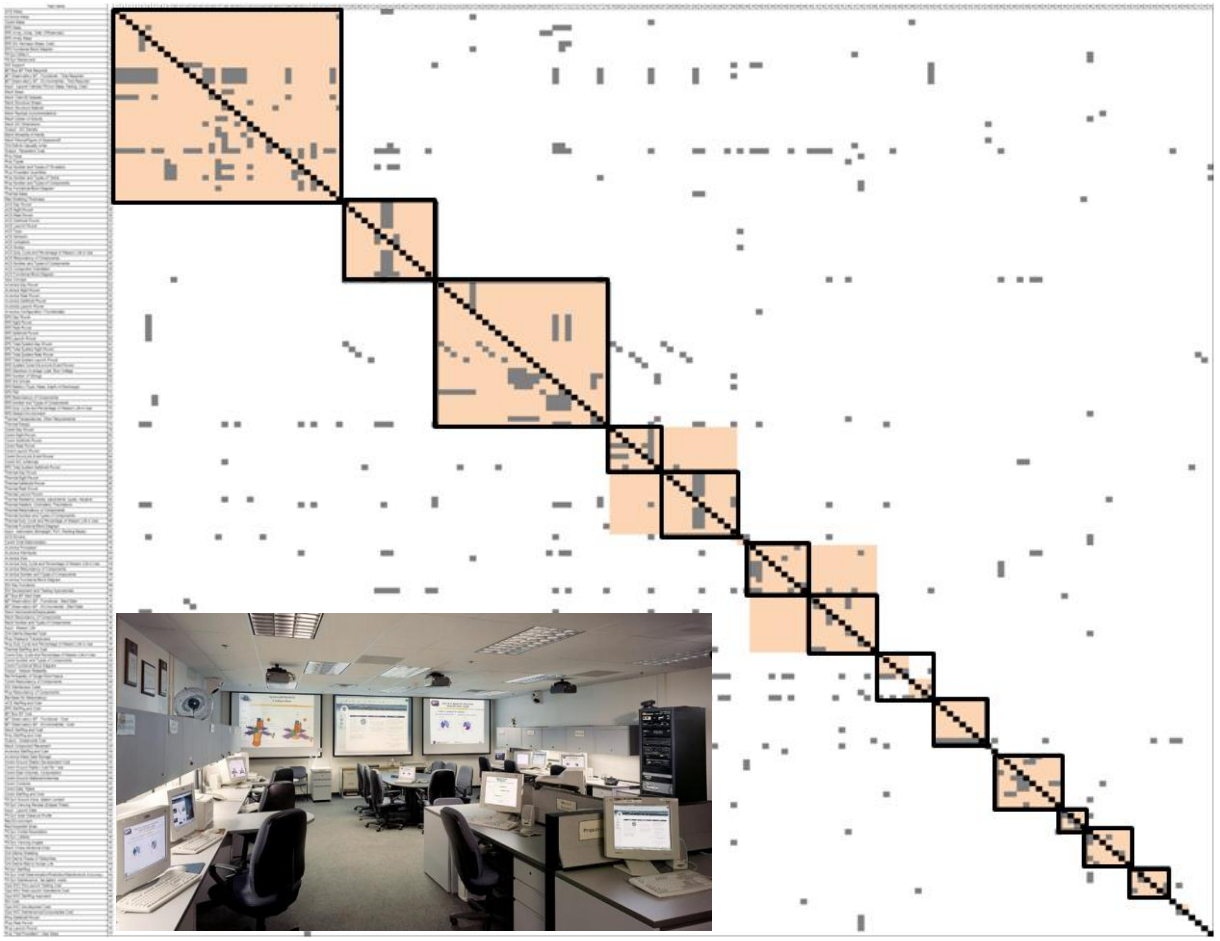
Courtesy of Olivier de Weck and Steve Eppinger. Used with permission.



Discussion Point

- What is your professional experience with iterations?
  - Technical examples
  - Drivers of iterations (rework, incomplete information)?
  - How viewed in the organization?
    - Encouraged, Discouraged, Acknoweldged…

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

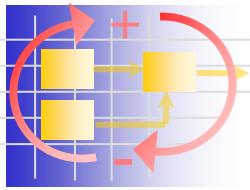
Data Cluster

Radiation Cluster

Orbit Life Cluster

Operations Cluster

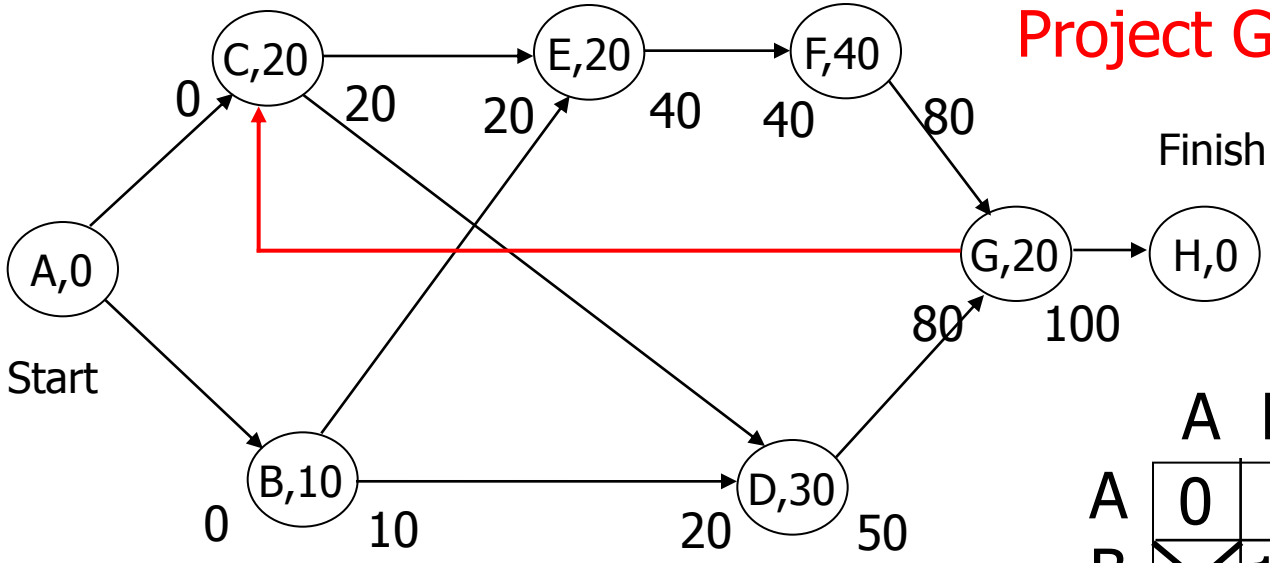
Source: Mark Avnet, ESD PhD
http://esd.mit.edu/people/dissertations/avnet.pdf



What is a DSM?

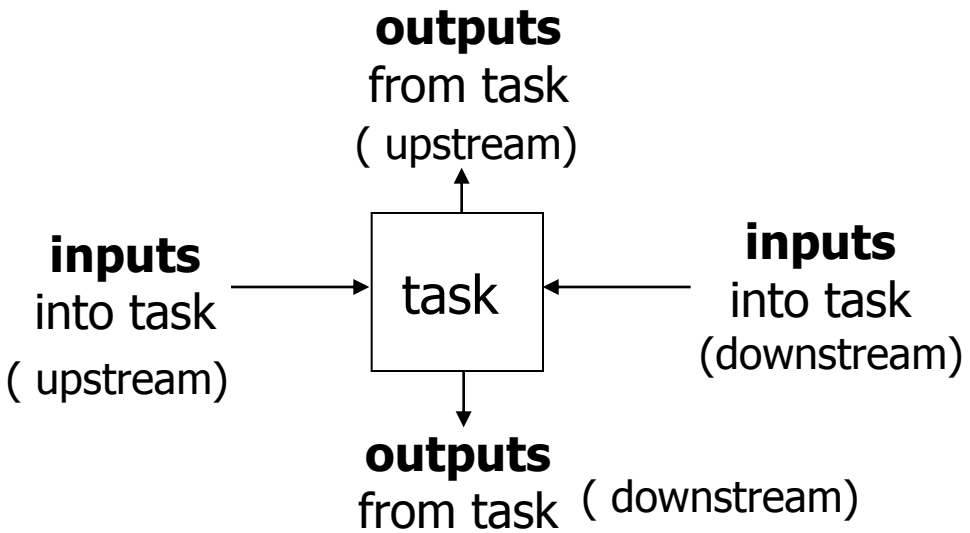
- Potential answer to first question:
  - How can iterations be represented?
- Design Structure Matrix (DSM)
  - A two-dimensional matrix representation of the structural or functional interrelationships of objects, tasks or teams
- Synonyms
  - Design Structure Matrix (DSM)
  - N^2-Diagram ("N-squared")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

Task-Based DSMs

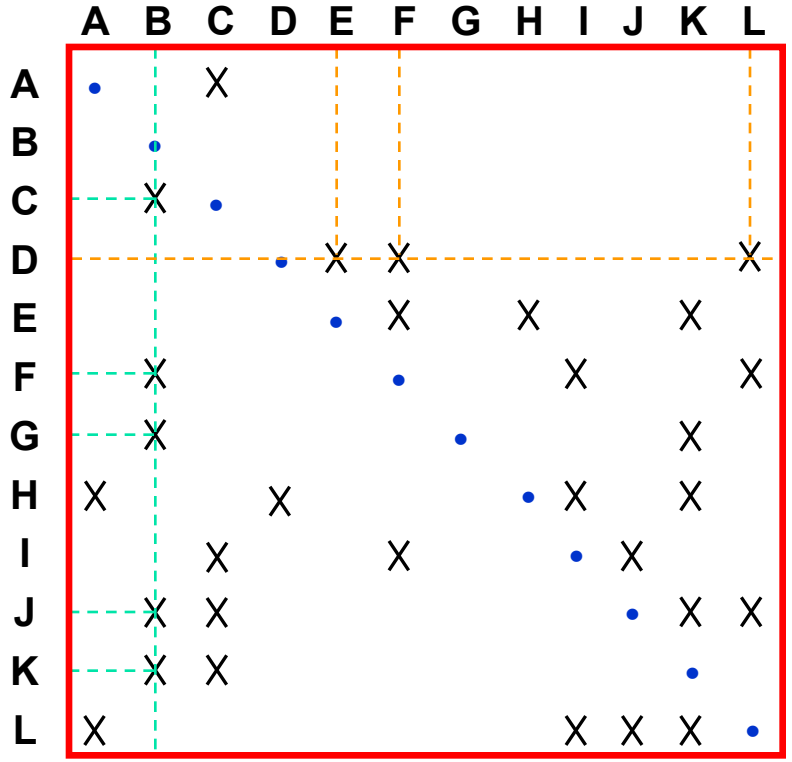


Project Graph → translate → DSM

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



The Design Structure Matrix:
An Information Exchange Model



Interpretation:

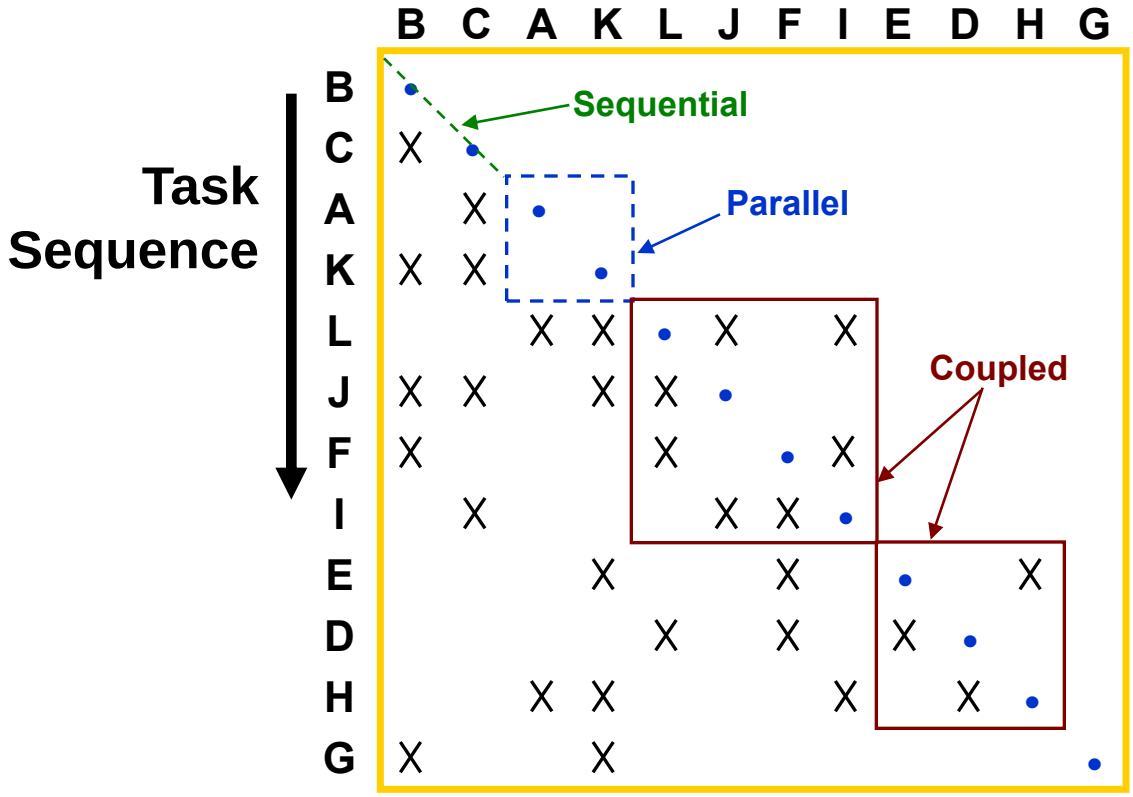
- Task D requires information from tasks E, F, and L.
- Task B transfers information to tasks C, F, G, J, and K.

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)

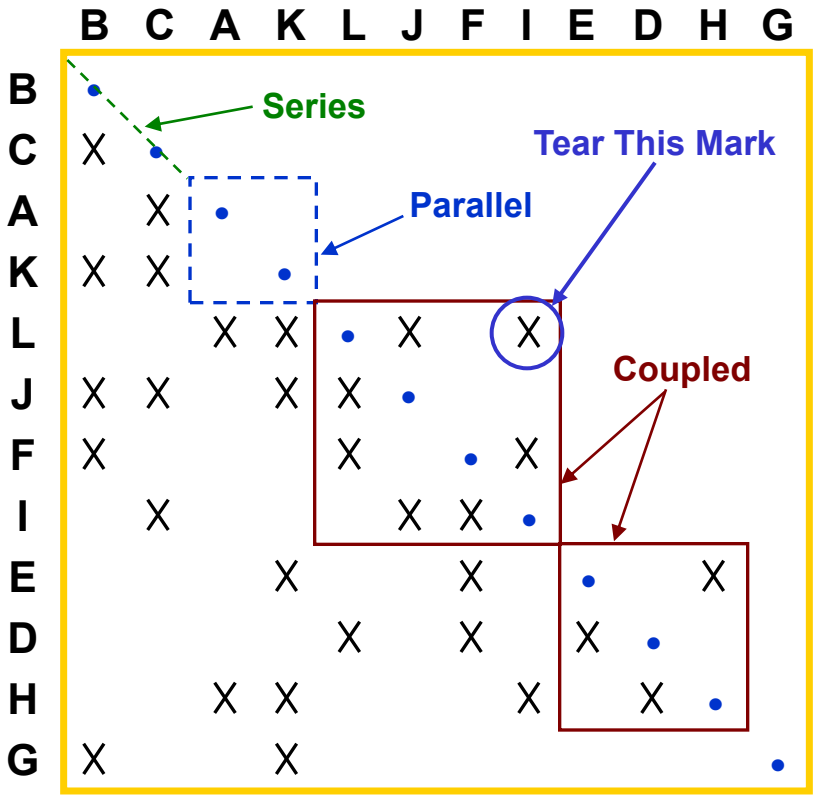


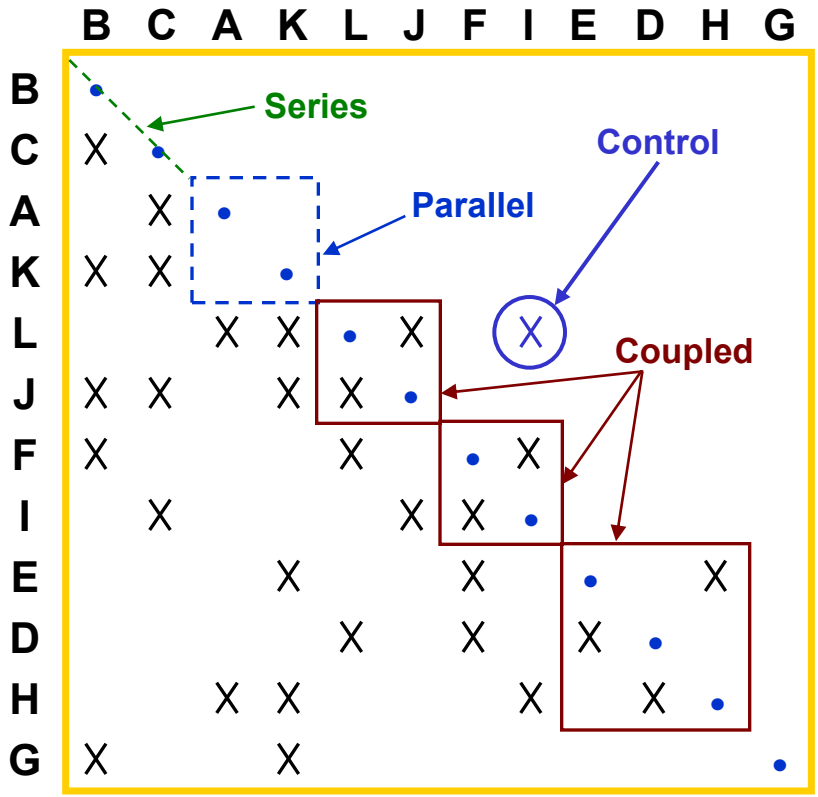
Note:

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

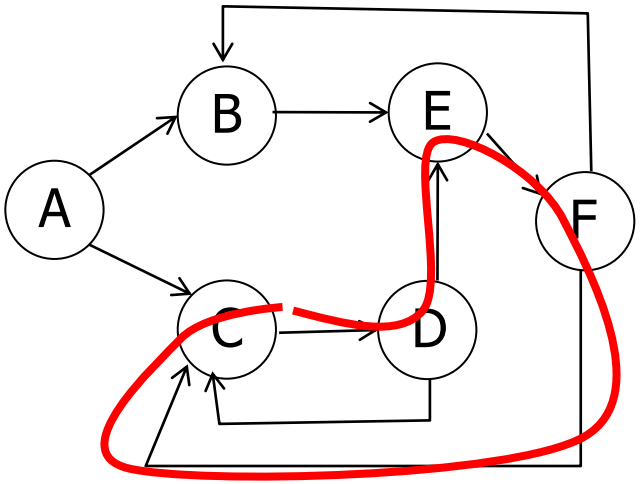
DSM Sequencing Exercise

	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	

Excel macro posted to the course site

Concept Question 1

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:

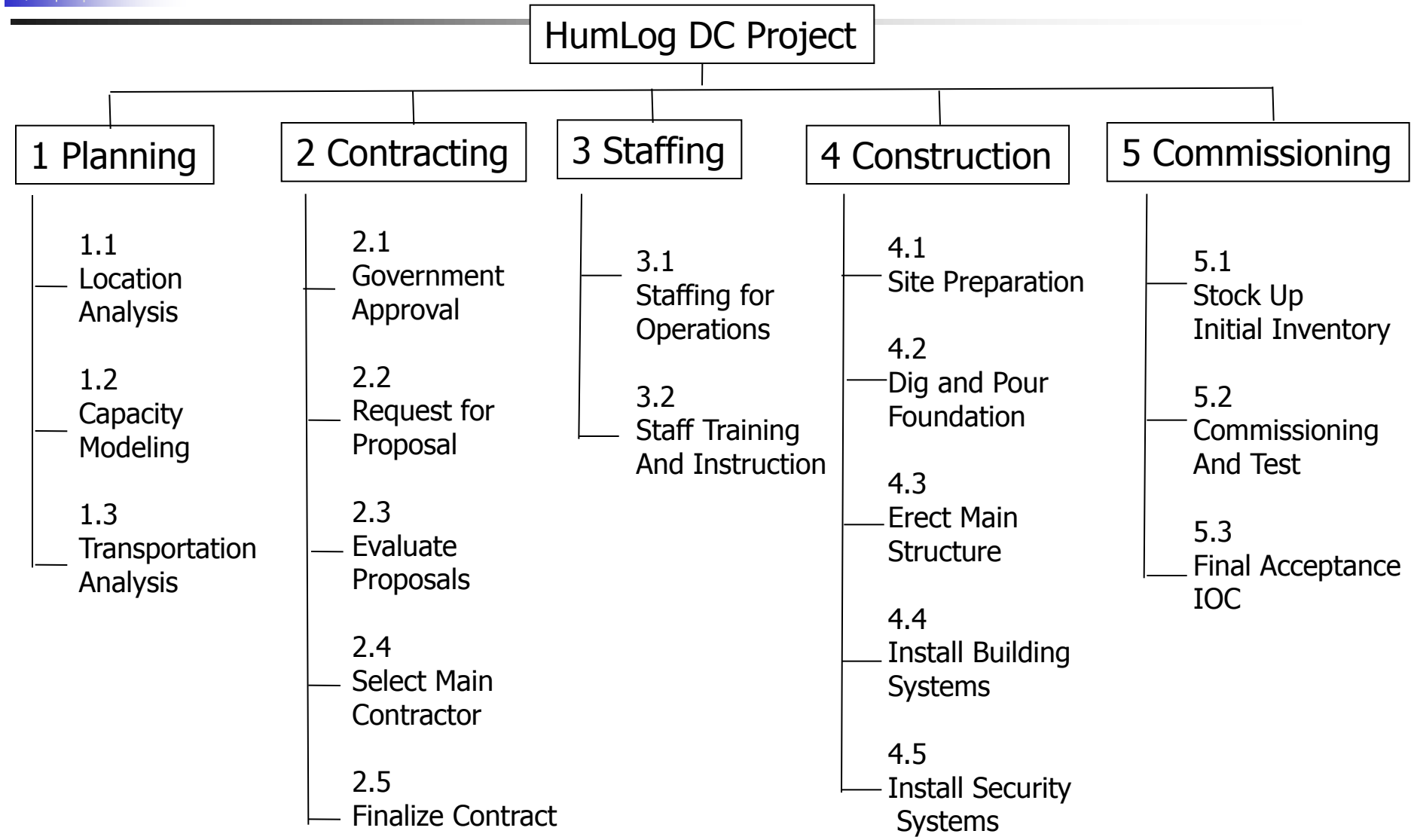
- ❑ There are no loops
- ❑ Length 2
- ❑ Length 3
- ❑ Length 4
- ❑ Length 5
- ❑ Length 6

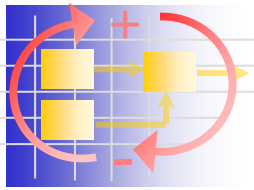
Sample Project HumLog

- 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

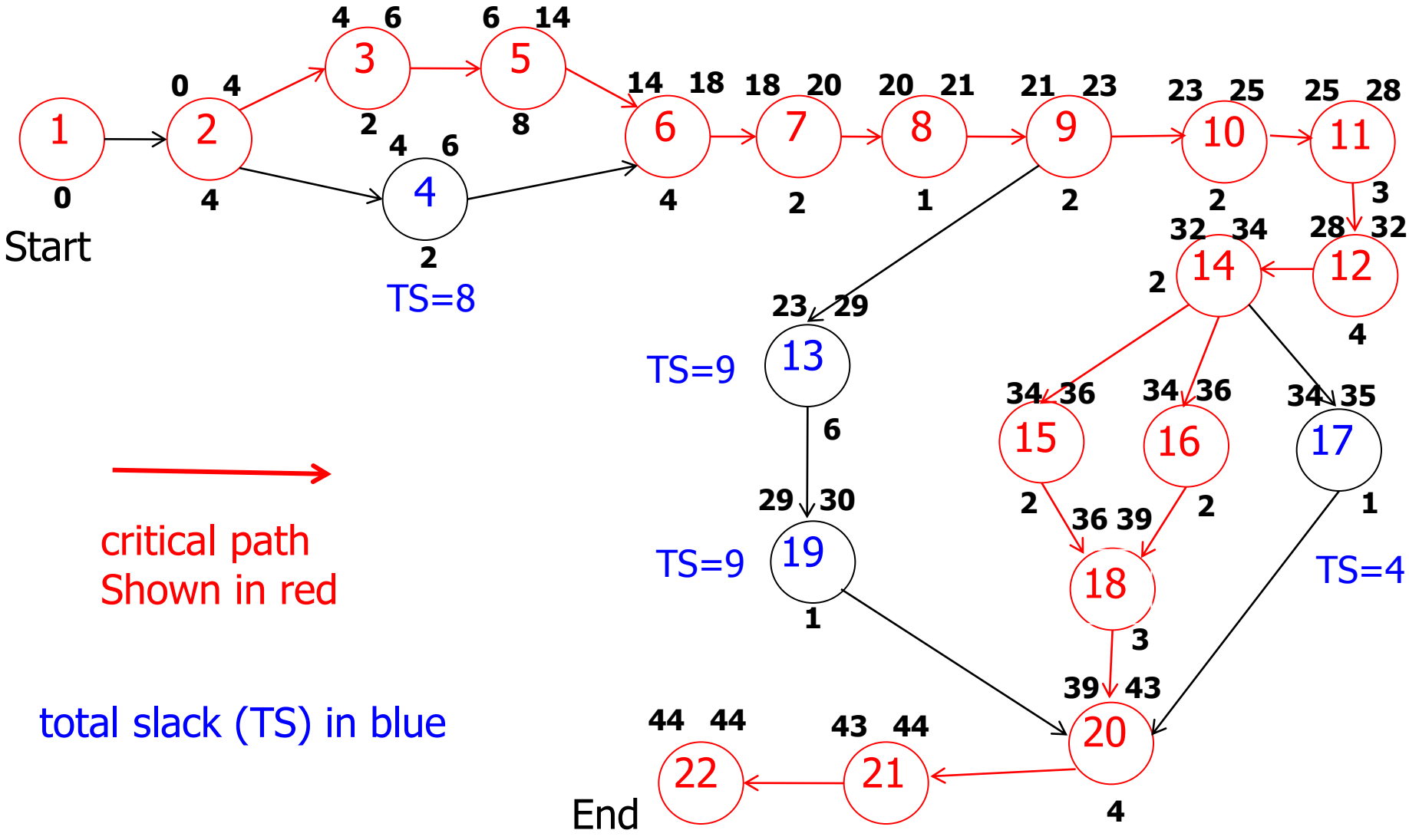




Task List – HumLog DC Project

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)



Baseline Project DSM (no iterations)

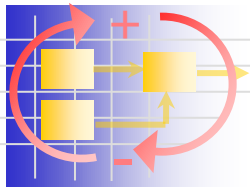
Psm32: Problem Solving Matrix 3.9j -Join- (c) 1996-2003 Problematics/Blitzkrieg Software

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	

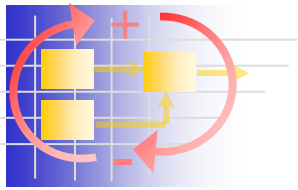
Using PSM32

Courtesy of Problematics (Donald Steward). Used with permission.



Possible Iterations

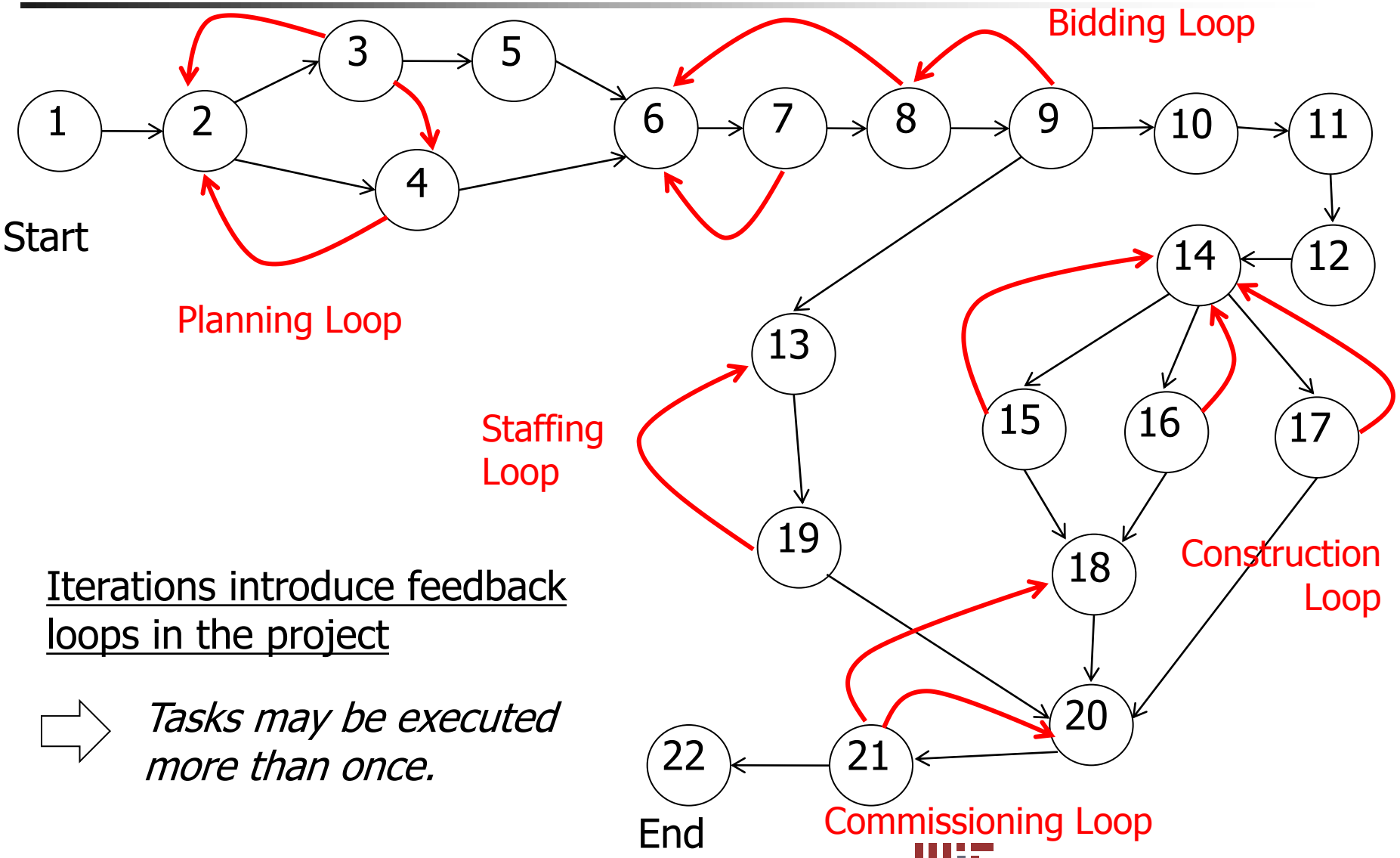
- Transportation analysis, demand, warehouse capacity and location are all coupled (=planning loop)
  - Add design iterations 3→2, 4→2, 3→4
- Initial proposals received from contractors may not be satisfactory, contract negotiations may fail (=bidding loop)
  - Add rework loops 8→6, 7→6, 9→8
- During 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?**

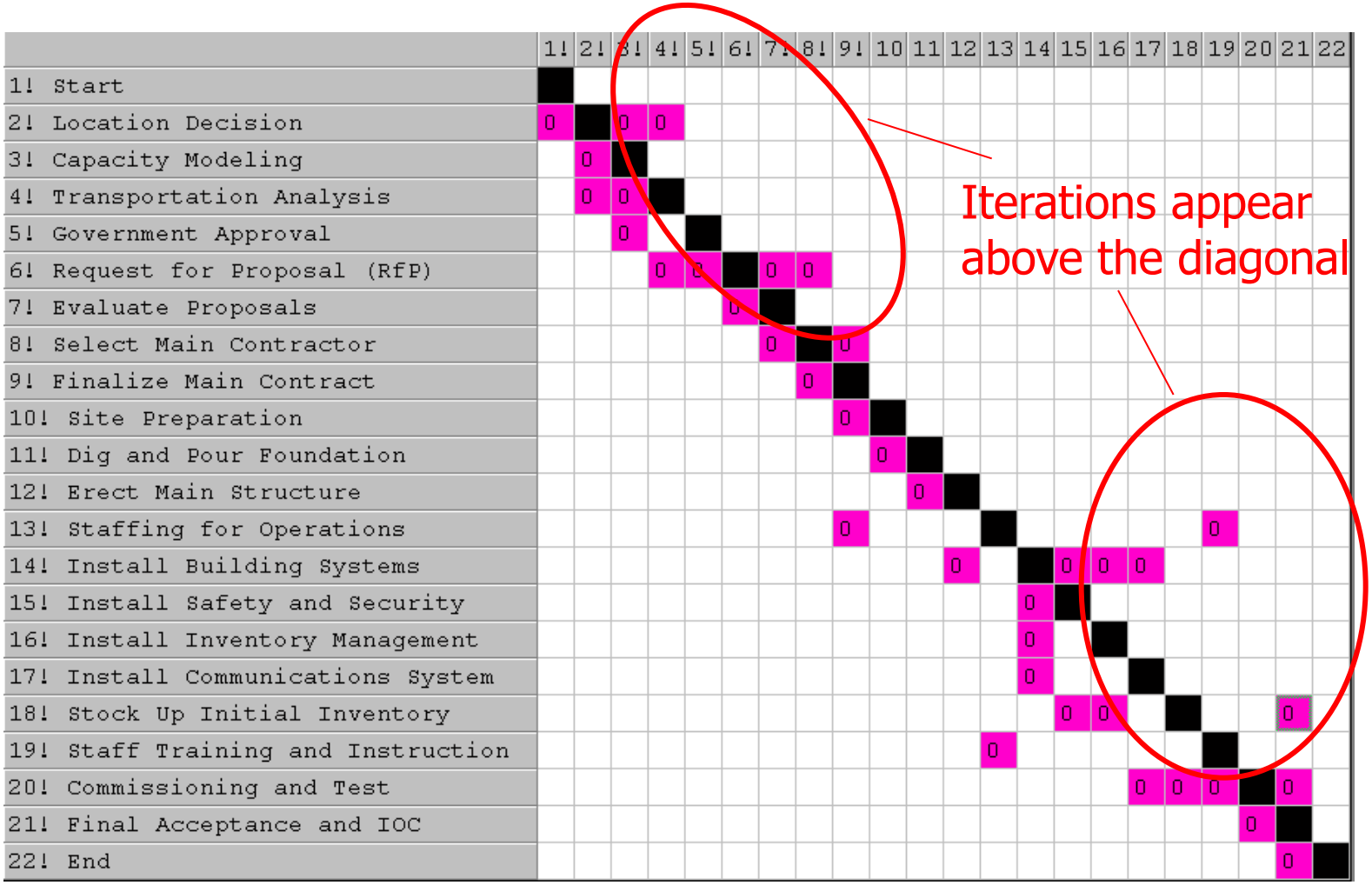
HumLog DC Project Graph



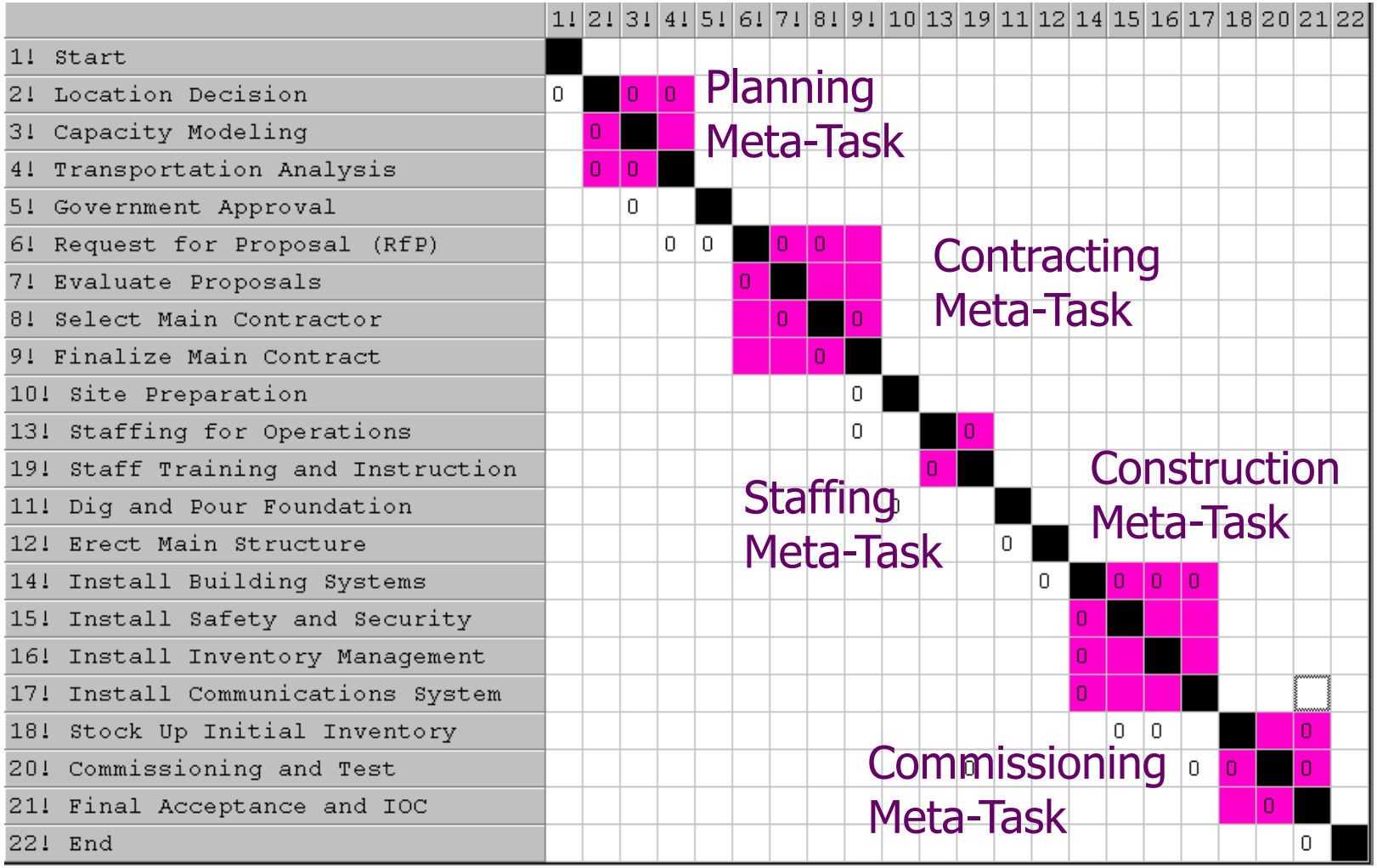
Iterations introduce feedback loops in the project

⇨ *Tasks may be executed more than once.*

DSM unstructured (with iterations added)



HumLog DC DSM Partitioned (PSM32)

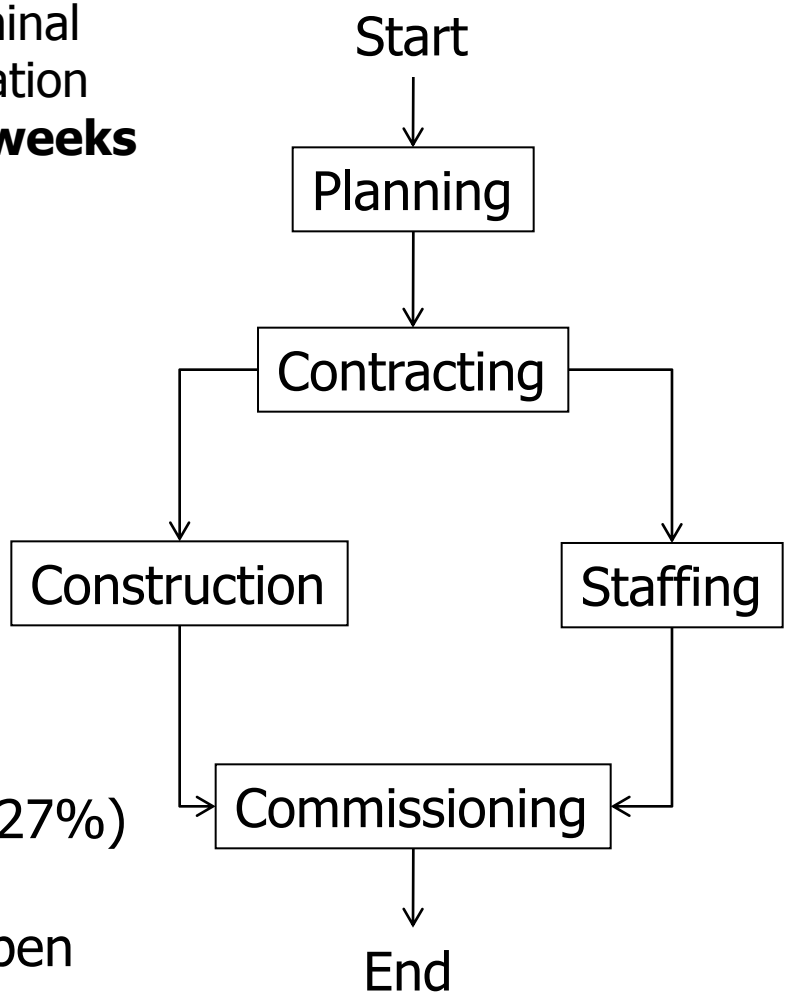


Simplified Project Structure

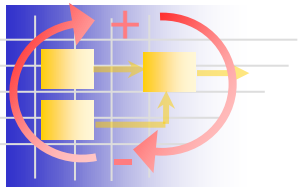
Simplified Project by creating Meta-Tasks

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

Nominal
Duration
44 weeks

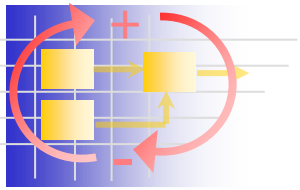


Average duration with loops **56 weeks** (+27%)
Predicted by simulation, but project
Durations 2-3 times that estimate can happen



Engineering *in the Small*

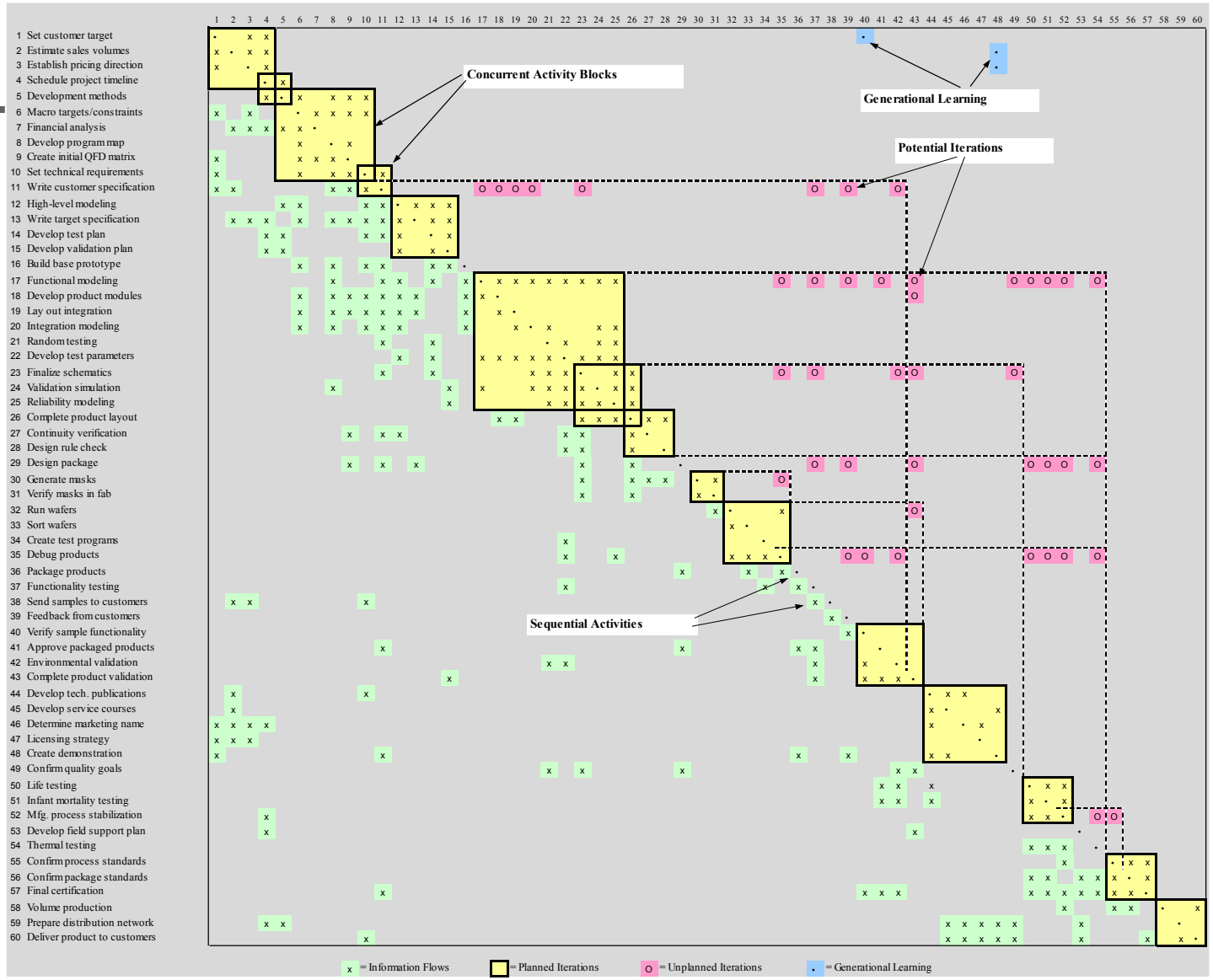
- Projects are executed by a cross-disciplinary team (5 to 20 people).
- Teams feature high-bandwidth technical communication.
- Tradeoffs are resolved by mutual understanding.
- "Design and production" issues are considered simultaneously.
- Might not need DSM



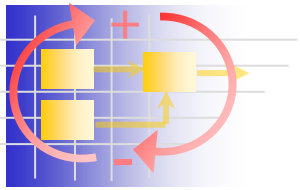
Engineering *in the Large*

- 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

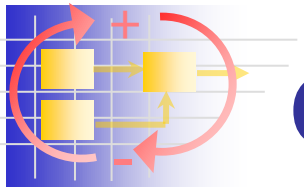


Courtesy of Steve D. Eppinger. Used with permission.



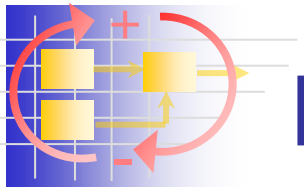
How to Create a Task-Based Design Structure Matrix Model

1. Select a project to model.
2. Identify the tasks of the project, who is responsible for each one, and the outputs created by each task.
3. Lay out the square matrix with the tasks in the order they are nominally executed.
4. Ask the process (task) experts what inputs are used for each task.
5. Insert marks representing the information inputs to each task.
6. Optional: Analyze the DSM model by re-sequencing the tasks to suggest a new process.
7. Draw solid boxes around the coupled tasks representing the planned iterations. **We call these the meta-tasks**.
8. Draw dashed boxes around groups of parallel (uncoupled) tasks.
9. Highlight the unplanned iterations.



Concept Question 2

- 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



Problematics DSM Software

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

Design Structure Matrix Web Site

- http://www.dsmweb.org/

•**Tutorial**

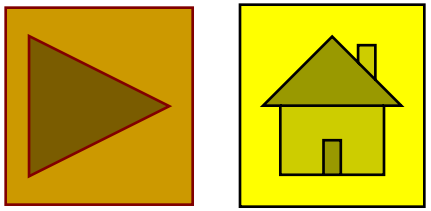
•**Publications**

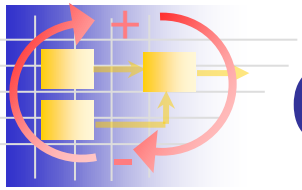
•**Examples**

•**Software**

•**Contacts**

•**Events**





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/PERT and DSM
  - CPM/PERT 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

ESD.36 System Project Management

Fall 2012