Introduction to Lean Construction

Lean Construction Institute
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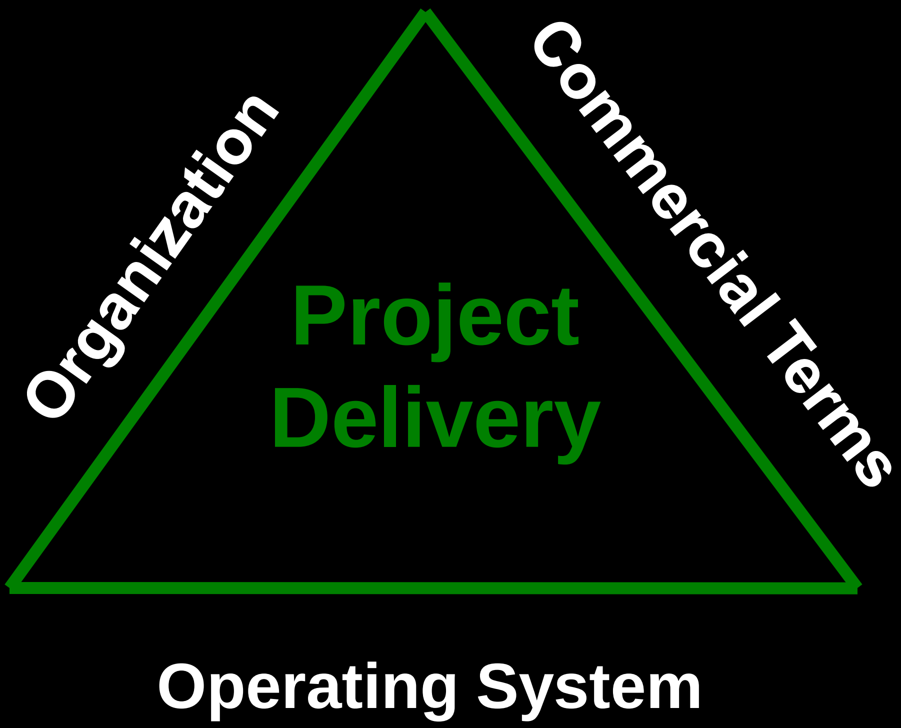
Workshop Objectives

- Understand Lean Project Delivery
  - Fundamental concepts, principles, key practices & basic vocabulary
  - How Lean Construction differs from current practice
- 3 Opportunities
  - Opportunity: Impeccable Coordination
  - Opportunity: Organizing the project as a production system
  - Opportunity: The Project as a Collective Enterprise
- Decide next steps

Putting the pieces together



Lean in the Construction Industry: Three Connected Opportunities

1. IMPECCABLE COORDINATION
2. ORGANIZING PROJECTS AS PRODUCTION SYSTEMS
3. THE PROJECT AS A COLLECTIVE ENTERPRISE

Parade of Trades Assumptions

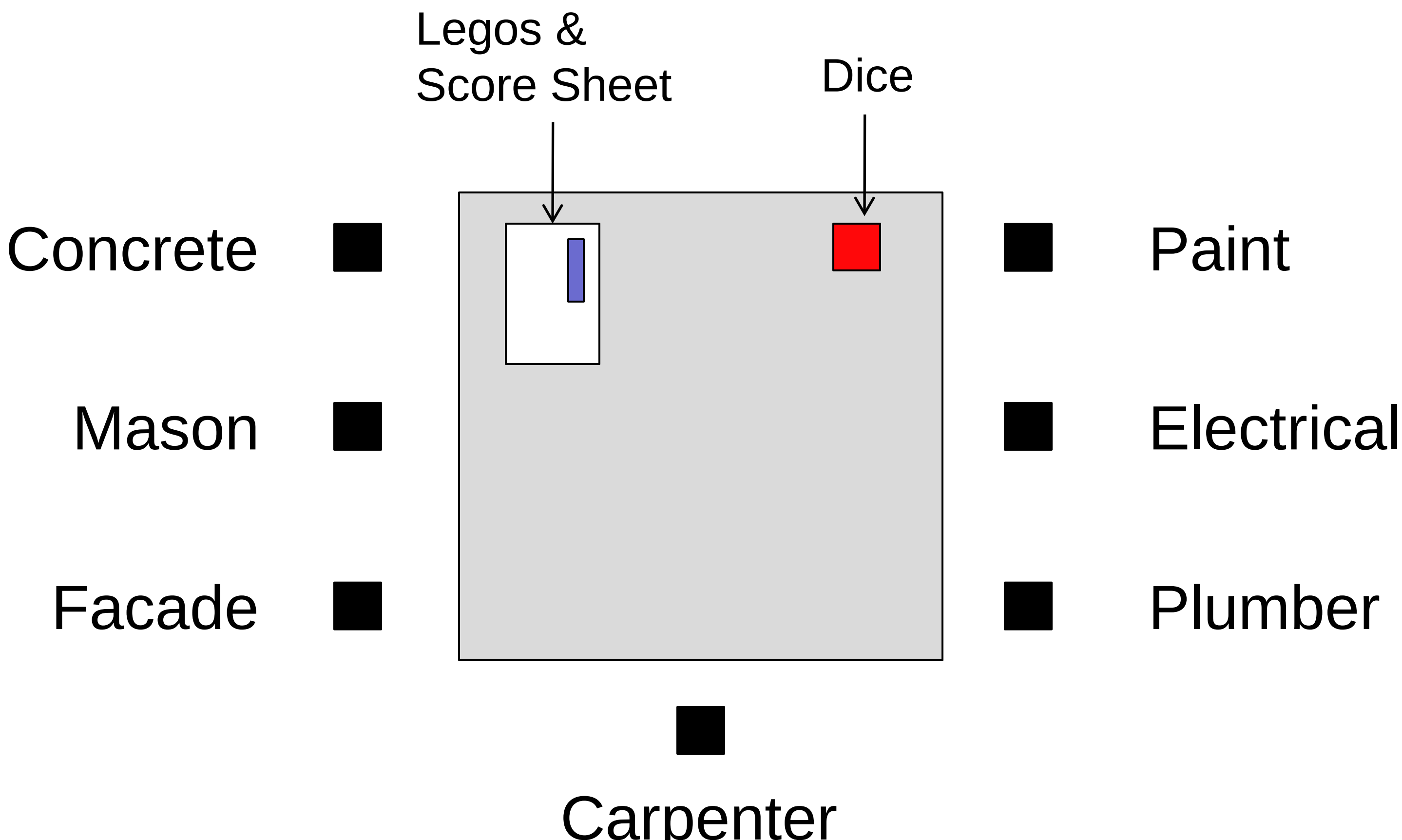
1. The project has 35 units of work to be processed.
2. There are seven trades, each of which must process all 35 units of work in order for the project to complete.
3. The trades come onto the project a week apart.
4. The trades work in sequence, with each following trade able to work only on what was produced in the previous week by the prior trade.
5. Work is done by rolling a dye (singular of ‘dice’) and passing the number of units rolled—up to the number of units the trade has to work on.
6. The number rolled represents the number of workers brought to the site that week by the trade rolling the dye. Each worker is able to process one unit of work in the week.

Parade of Trades

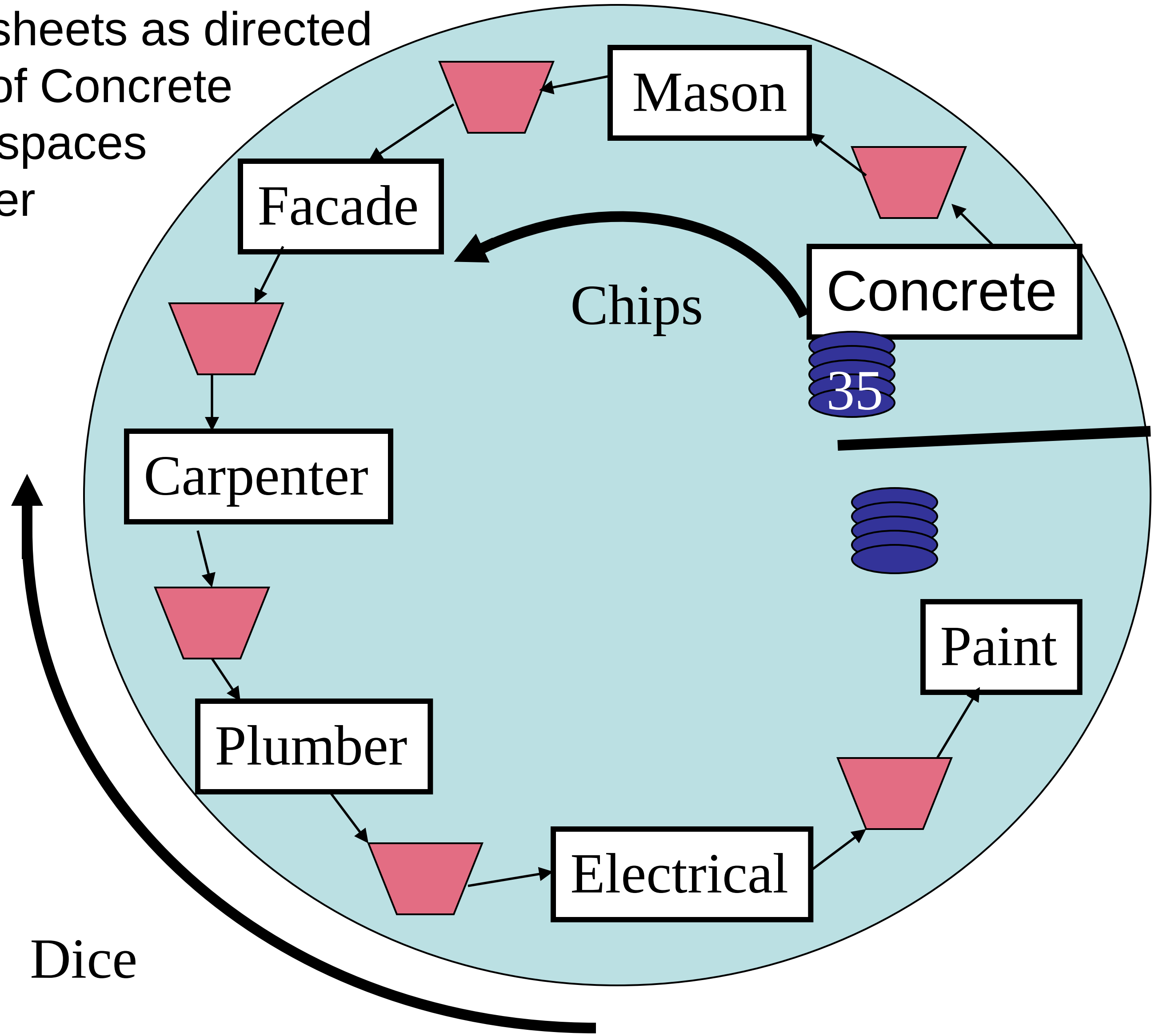
Move 35 pieces of work through 7 trades.

Work is completed at the end of the week and passed to next trade.

Place materials on table as shown.



1. Distribute score sheets as directed
2. Chips to the left of Concrete
3. Establish queue spaces
4. Give die to Painter

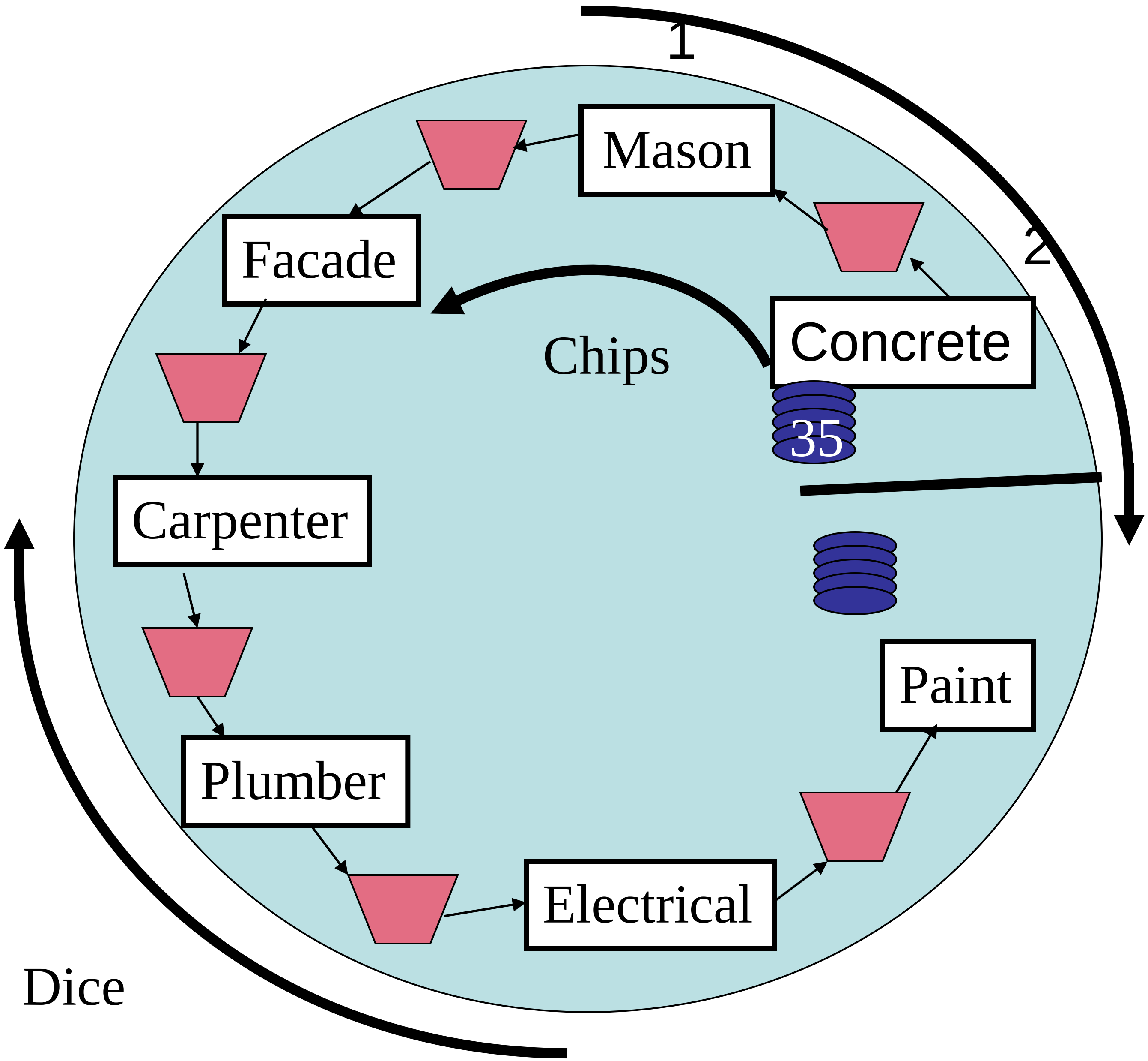


Week 1

Concrete

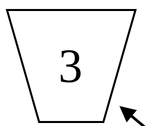
	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	32
2				
3				

Pass the Die to the Left!


1
2
Mason
Facade
Concrete
Chips
35
Carpenter
Paint
Plumber
Electrical
Dice

Week 2

Mason



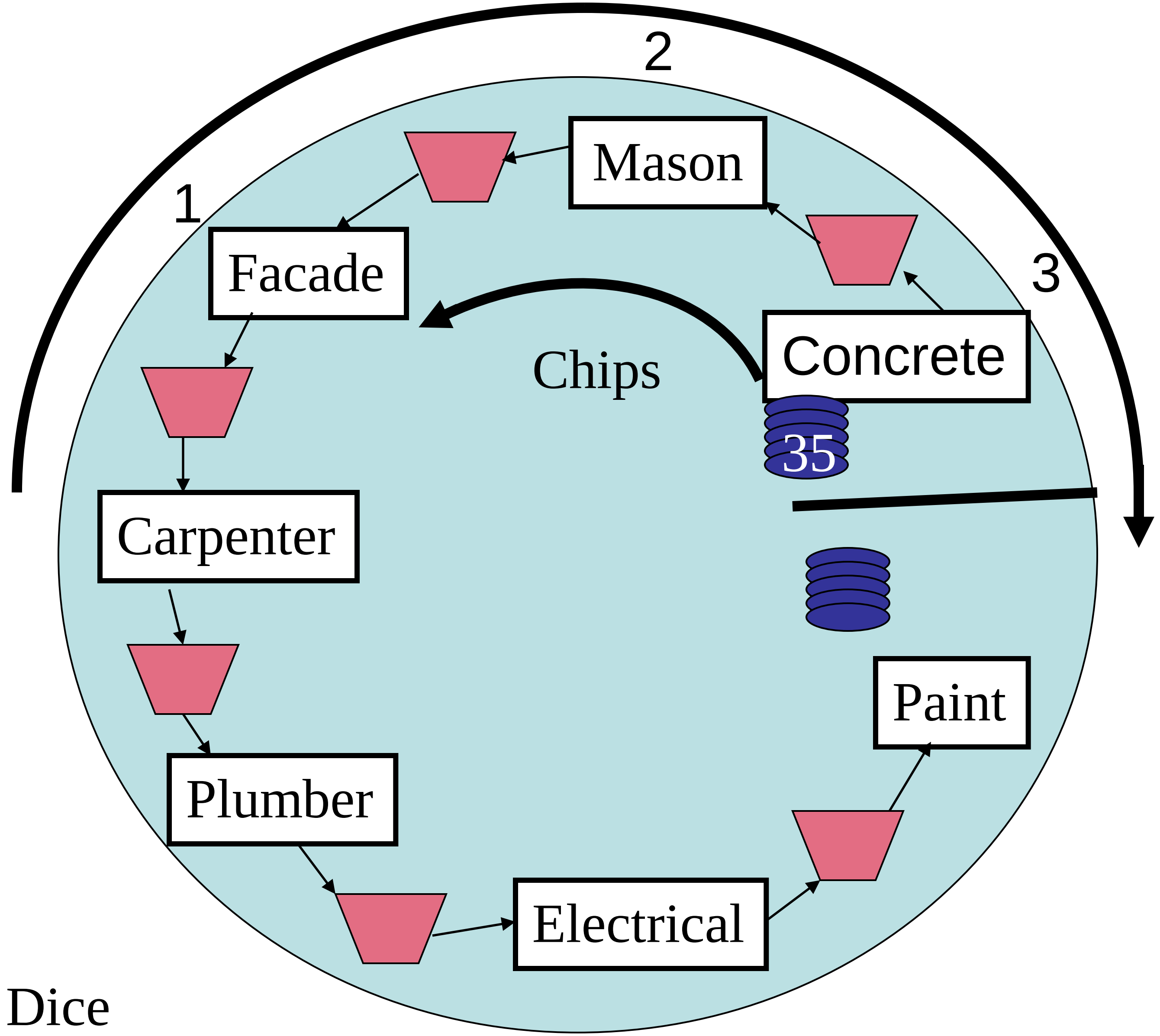
	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
2	2	2	0	1
3				

Pass the Die to the Left!

Concrete

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	32
2	2	2	0	30
3				

Pass the Die to the Left!


2
1
3
Mason
Facade
Concrete
Chips
35
Carpenter
Paint
Plumber
Electrical
Dice

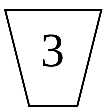
Facade

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
3	5	2	3	0

Pass the Die to the Left!

Mason

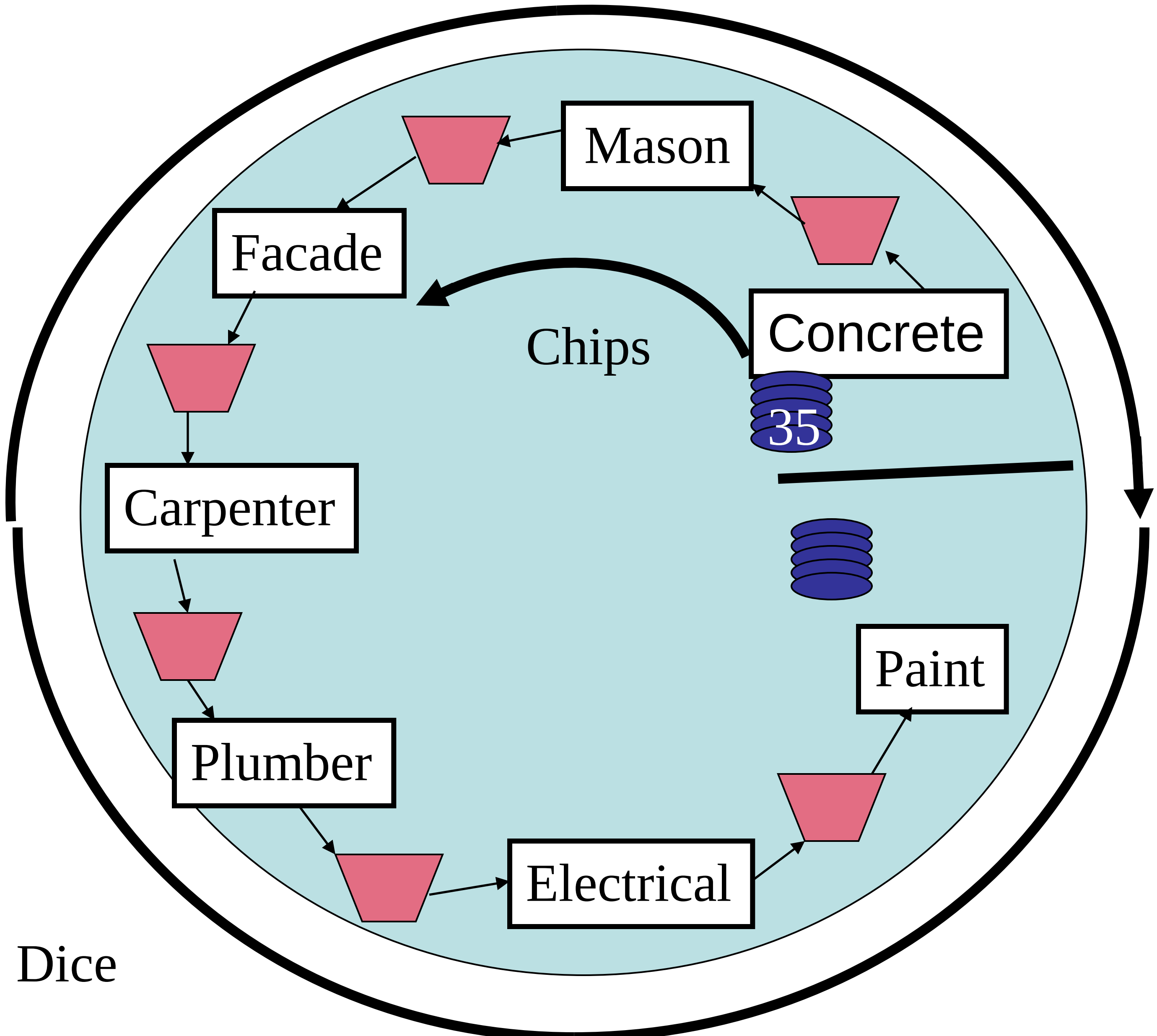
	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
2	2	2	0	1
3	5	3	2	0



Concrete

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	32
2	2	2	0	30
3	1	1	0	29

Keep passing the die to the left!



Keep passing the die to the left!

Scheduling and Estimating

Moving one chip through one station requires 1 “crew” work unit costing $1000. How much will it cost to complete the project?

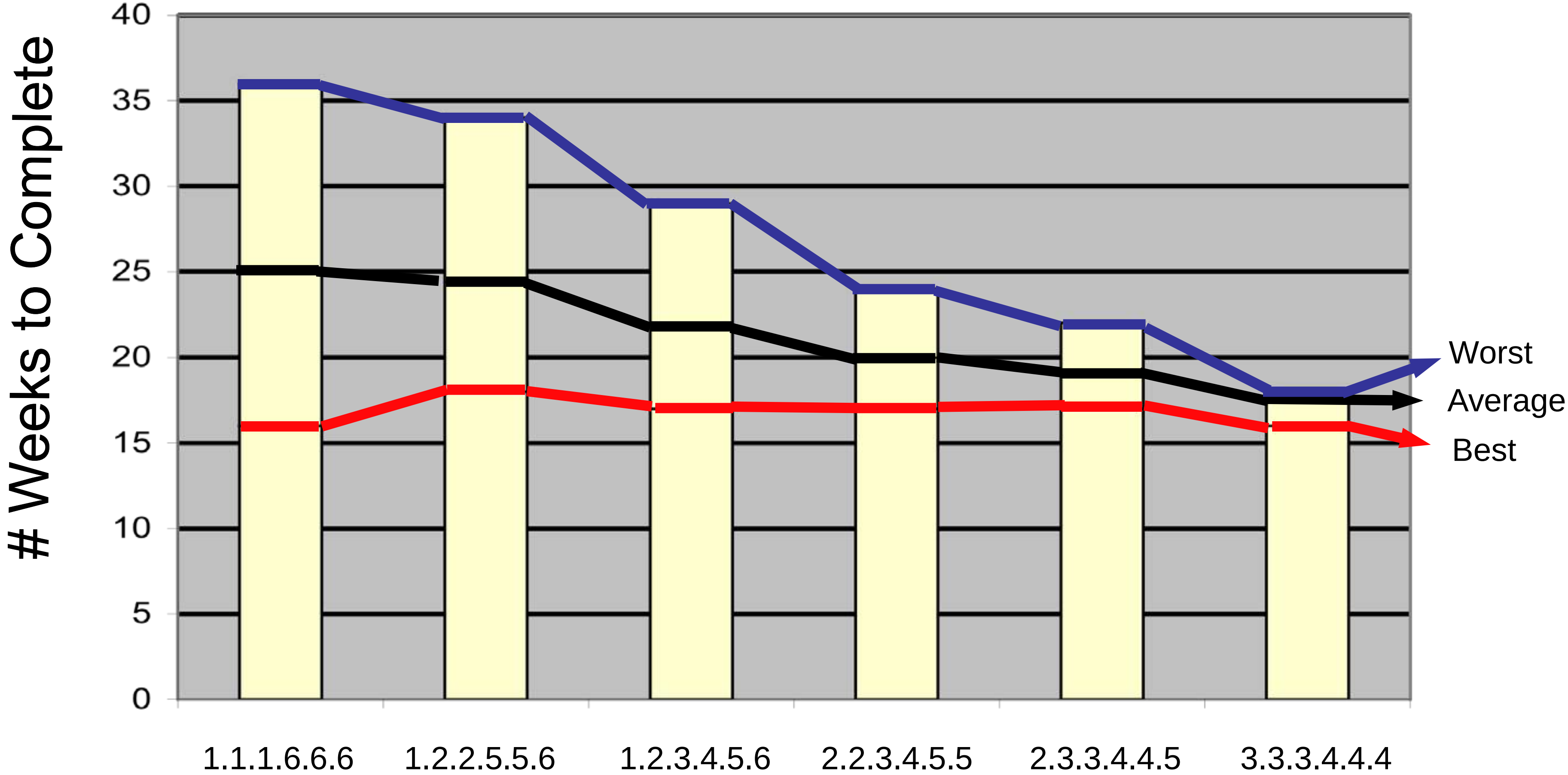
A die has an average production of 3.5 units per roll (week). How long will it take?

When work is complete….

Record the week each Trade finishes. Sum and record the Available Capacity for all Trades. Sum and record the total Remaining Inventory for all Trades except Concrete. Note the highest amount of Inventory in any week for each trade. Bring die and score sheet to the front.

Craft	Week Complete	Sum of Available Capacity Total Column 1	Sum of Remaining Inventory Total Column 4	Maximum Inventory in any week Column 4
Concrete				
Mason				
Façade				
Carpenter				
Plumber				
Electrical				
Paint				
Sums		Sum this Column	Sum this Column	

RESULTS



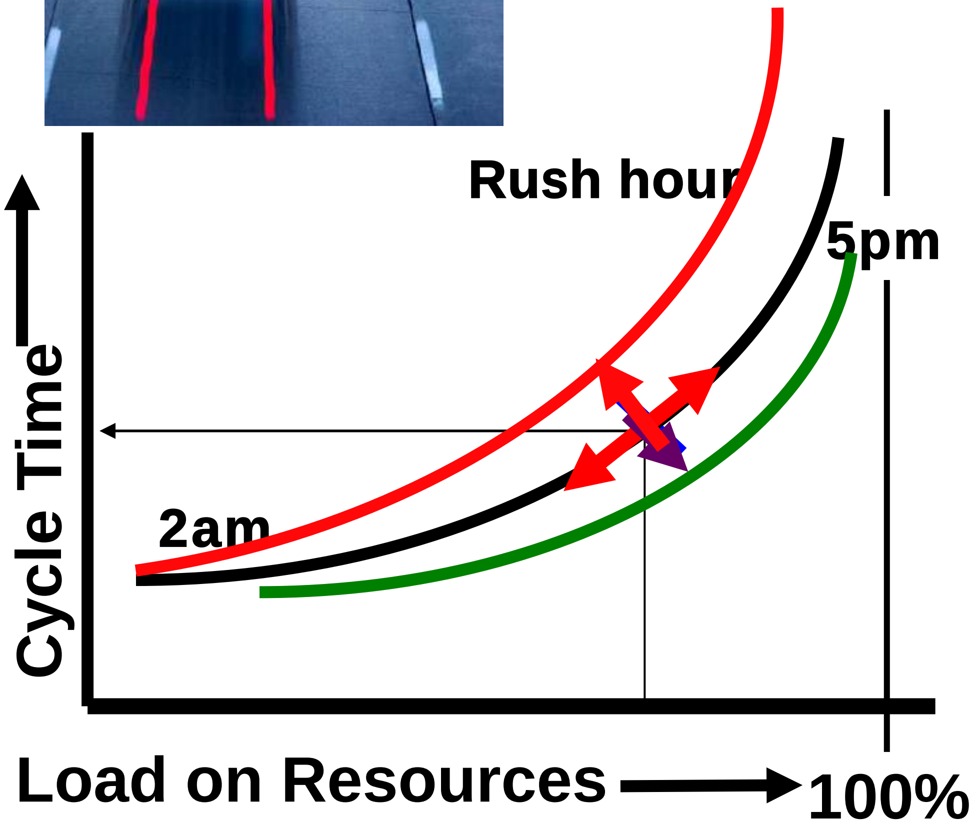
Average Loss	115.8	97.6	75.3	51.2	37	17.3

20 Most Recent

	Red 233445	Black 123456	Blue 122556	333333
Duration Weeks	19	21	23	18
Total Capacity $	294	332	361	252
Inventory Units	55	112	120	0

The gains are lost & the losses mount up

High Variability and Load on Resources (cars on the road) increases the travel (Cycle) time.



Key Points

- Reducing workflow variability
  - Improves total system performance
  - Makes project outcomes more predictable
  - Simplifies coordination
  - Reveals new opportunities for improvement
- Point speed and productivity of a single operation doesn't matter – throughput does.
- Strategy: Reduce variation then go for speed to increase throughput.

Problems with current practice

- Activity Focus ignores value creation and the flow of work.
  - Collaboration in design is limited
  - Fails to produce predictable work flow
- Command and Control planning cannot coordinate the arrival of the wherewithal or work of specialists.
  - Opportunities for trading ponies for horses are lost
  - Push systems are commitment free zones.
- Control begins with tracking cost and schedule.
  - Efforts to improve productivity leads to Unreliable Work Flow further reducing project performance.
  - Protecting activities leads to adversarial relations.

Question for Discussion

What would be the specific advantages of improved work flow reliability on your projects? For 10 minutes, discuss in 4 person teams. Select a spokesperson to report your findings if called upon.

Research Findings from early 1990's

Contractor 1	33 %
Contractor 2	52 %
Contractor 3	61 %
Contractor 4	70 %
Contractor 5	64 %
Contractor 6	57 %
Contractor 7	45 %
Average	54 %

Why Last Planner®?

- Without Last Planner®:
  - only half the tasks on weekly work plans are completed as planned.
  - so called ‘project control’ is after-the-fact identification of variances, not proactive steering toward objectives.
  - projects are a commitment-free zone; promises are neither requested nor made.

(If you can’t say ‘no’, you can’t make a promise.)

Last Planner Principles

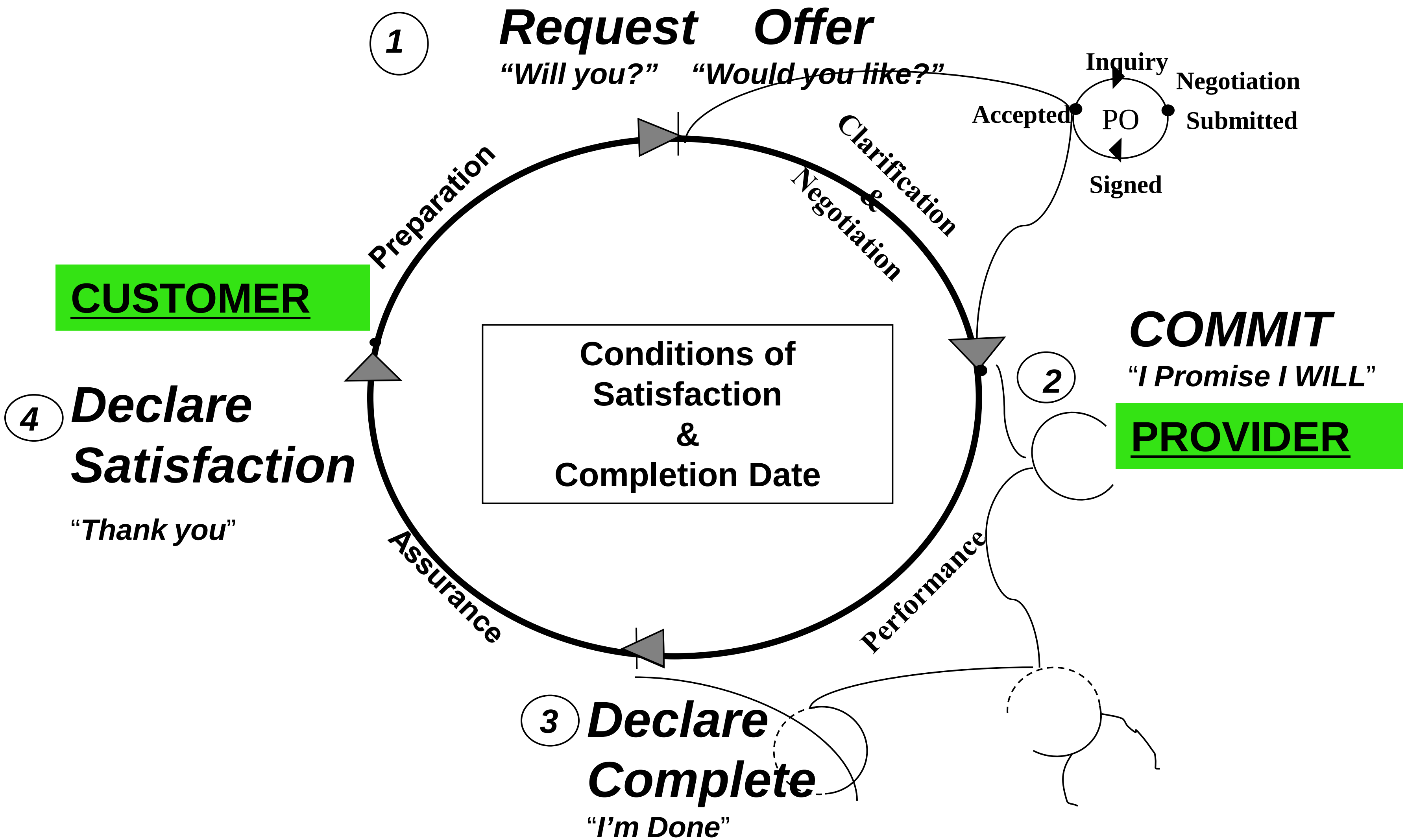
Starting Point: All plans are forecasts and all forecasts are wrong. The longer the forecast, the more wrong it is. The more detailed the forecast, the more wrong it is.

- Plan in greater detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make reliable promises.
- Learn from breakdowns.

Last Planner®:
Predictable workflow & rapid learning.

- Planning as Learning, Organizing and Promising
- Conversation centered: The right people talk about the right thing at the right level of detail at the right time.
  - Connects the big picture to details in progressively greater detail
- Runs on and improves Confidence and Judgment
  - Planning system performance metric
  - Increase trust, reduce contingency
- Designs and activates the Network of Commitments necessary to deliver project.

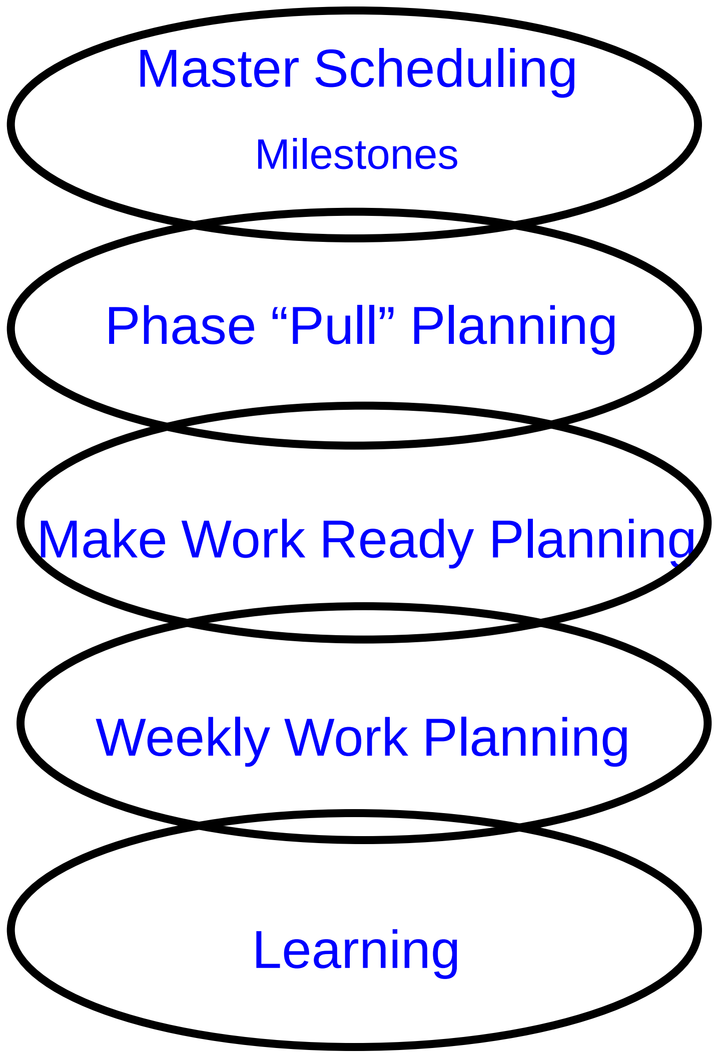
The "Physics" of Business and Coordination



Courtesy Chauncey Bell

The Last Planner® System of Production Control

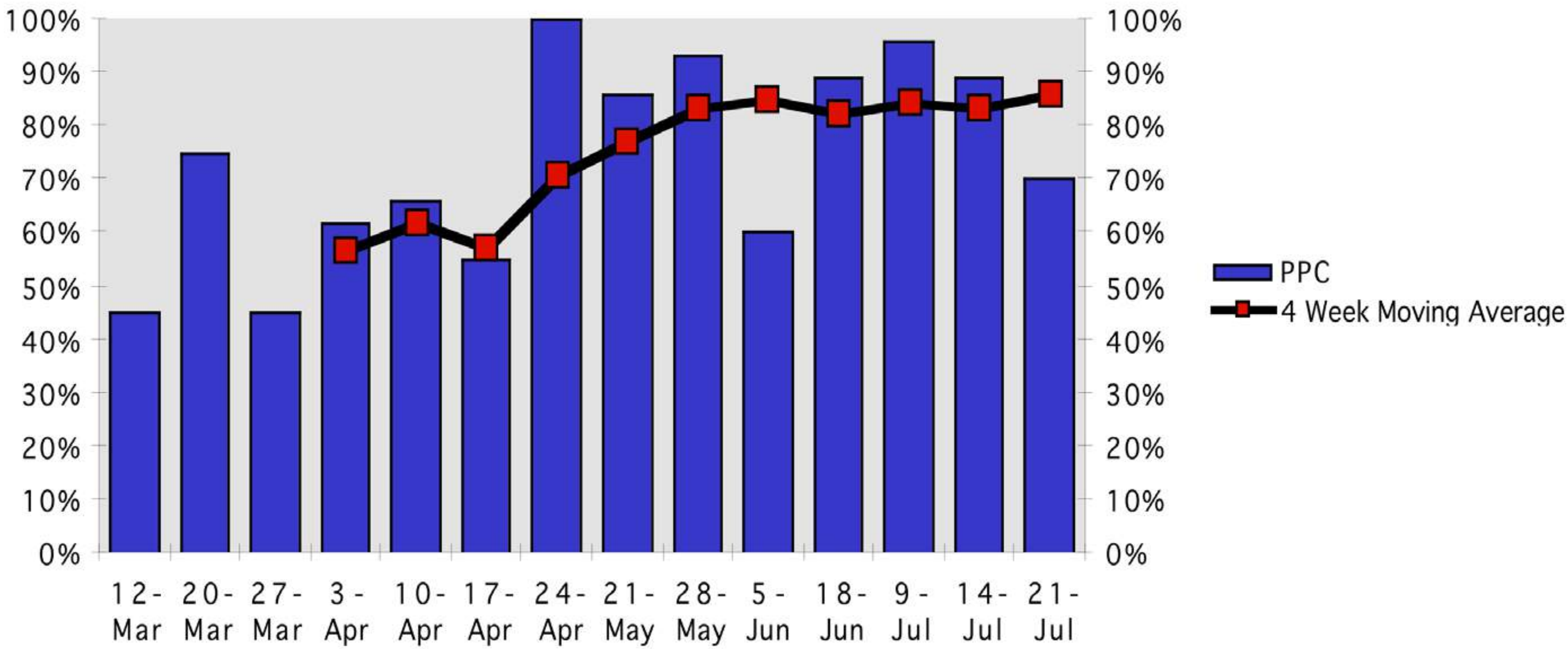
5 - Connected Conversations



SHOULD	Master Scheduling	Set milestones Set strategy Identify long lead items
	Phase “Pull” Planning	Specify handoffs Identify operational conflicts
CAN	Make Work Ready Planning	Make ready & Launch replanning when needed
WILL	Weekly Work Planning	Promise
DID	Learning	Measure PPC & Act on reasons for failure to keep promises

Percent Plan Complete (PPC) Chart

Rasacaven: Electrical Power Distribution



Quality Characteristics of Weekly Work Plans

- Definition
- Soundness
- Sequence
- Size
- Learning

1 WEEK PLAN

PROJECT: Pilot | **FOREMAN: PHILLIP**

ACTIVITY | **DATE: 9/20/96**

ACTIVITY	Est	Act	Mon	Tu	Wed	Thurs	Fri	Sat	Sun	PPC	REASON FOR VARIANCES
Gas/F.O. hangers O/H "K" (48 hangers)			XXXX Sylvano, Modesto, Terry	XXXX						No	Owner stopped work (changing elevations)
Gas/F.O. risers to O/H "K" (3 risers)					XXXX Sylvano, Mdesto, Terry	XXXX	XXXX	XXXX		No	Same as above-worked on backlog & boiler blowdown
36" cond water "K" 42' 2-45 deg 1-90 deg			XXXX Charlie, Rick, Ben	XXXX	XXXX					Yes	
Chiller risers (2 chillers wk.)						XXXX Charlie, Rick, Ben	XXXX	XXXX		No	Matl from shop rcvd late Thurs. Grooved couplings shipped late.
Hang H/W O/H "J" (240'-14")			XXXX Mark M., Mike	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Cooling Tower 10" tie-ins (steel) (2 towers per day)			XXXX Steve, Chris, Mark W.	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out CHW pump headers "J" mezz. (18)			XXXX Luke	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out cooling towers (12 towers)			XXXX Jeff	XXXX	XXXX	XXXX	XXXX	XXXX		No	Eye injury. Lost 2 days welding time
F.R.P. tie-in to E.T. (9 towers) 50%			XXXX Firt, Packy, Tom	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
WORKABLE BACKLOG Boiler blowdown-gas vents -rupture disks											

Pull Planning: Designing the Network of Commitments

- Produces the best possible plan by involving all with relevant expertise planning near action.
- Rehearsing together
  - Aligns understanding, reveals unexpected interactions, problems and value adding opportunities: Builds relationship.
  - Assures that everyone in a phase understands and supports the plan by the working as a team.
  - Assures the selection of value adding tasks that release other work by working backwards from the target completion date to produce a pull schedule.
  - Establishes the amount of time available for ‘contingency’ and how it should be allocated.


FINAL
COMP
BOOKS
SERVICE
UPDATES

Functions of Master Schedules

- Demonstrate the feasibility of completing the work within the available time
- Develop and display execution strategies
- Determine when long lead items will be needed
- Identify milestones important to client or stakeholders

Essential Planning Questions

Master Scheduling Milestones	Are we confident we can deliver the project within the set limits? Who holds the promise to make this happen?
Pull Scheduling Specify hand off	Do we understand how we are going to do the work? Have we designed the network of commitments to make it happen? Are we confident we can deliver the milestone?
Lookahead Planning Make ready & launch	Is the network of commitments active? Are reliable promises in place to make work ready in the right sequence and amounts to deliver the milestone? Are we confident the work will begin and end as planned?
Weekly Work Planning Promise	How will we coordinate and adjust? Have we promised our tasks will be done as planned or said no?
Learning Measure PPC, act on reasons for failure to keep promises	What have we learned, what needs changing so we can improve our performance?

Project Management Works

When Practices, Systems and Leadership produce **coherent commitments** connecting the **promise of the project** to the work of specialists, and coordinates their actions.

- Creating predictable workflow within and between workgroups
- Allowing decisions to be delayed to the last responsible moment.
- Adjusting appropriately in the moment to increase value and reduce waste.

What are your takeaways from what you have heard about coordination and control?

- ...

What questions have been provoked?

- …

Project Management Works

When Practices, Systems and Leadership produce **coherent commitments** connecting the **promise of the project** to the work of specialists, and coordinates their actions.

- Creating predictable workflow within and between workgroups
- Allowing decisions to be delayed to the last responsible moment.
- Adjusting appropriately in the moment to increase value and reduce waste.

Taking responsibility for the details of production at each level the place to start.

Subcontractor Case: BMW Constructors
BP Whiting Refinery Project

Courtesy of Strategic Project Solutions

COST CONTROL

	BP's APPROPRIATIONS BUDGET (SEE NOTES 1 & 2)	FORECAST ACTUAL @ COMPLETION (SEE NOTES 1, 2 & 3)	FORECAST SAVINGS @ COMPLETION (SEE NOTES 1,3 & 4)	
Direct Labor	$20,000,000	$15,400,000	$4,600,000	23%
Indirect Labor, Misc. Material & Supplies, Management & Support Staff Expense, Implementation Support	$22,000,000	$21,140,000	$860,000	4%
TOTAL COST	$42,000,000	$36,540,000	$5,460,000	13%

NOTES

1) Base Scope

2) Does NOT include Implementation Support Investment of $400,000

3) Includes actual Implementation Support Investment of ~ $400,000

4) at 85% Complete

Courtesy of Strategic Project Solutions

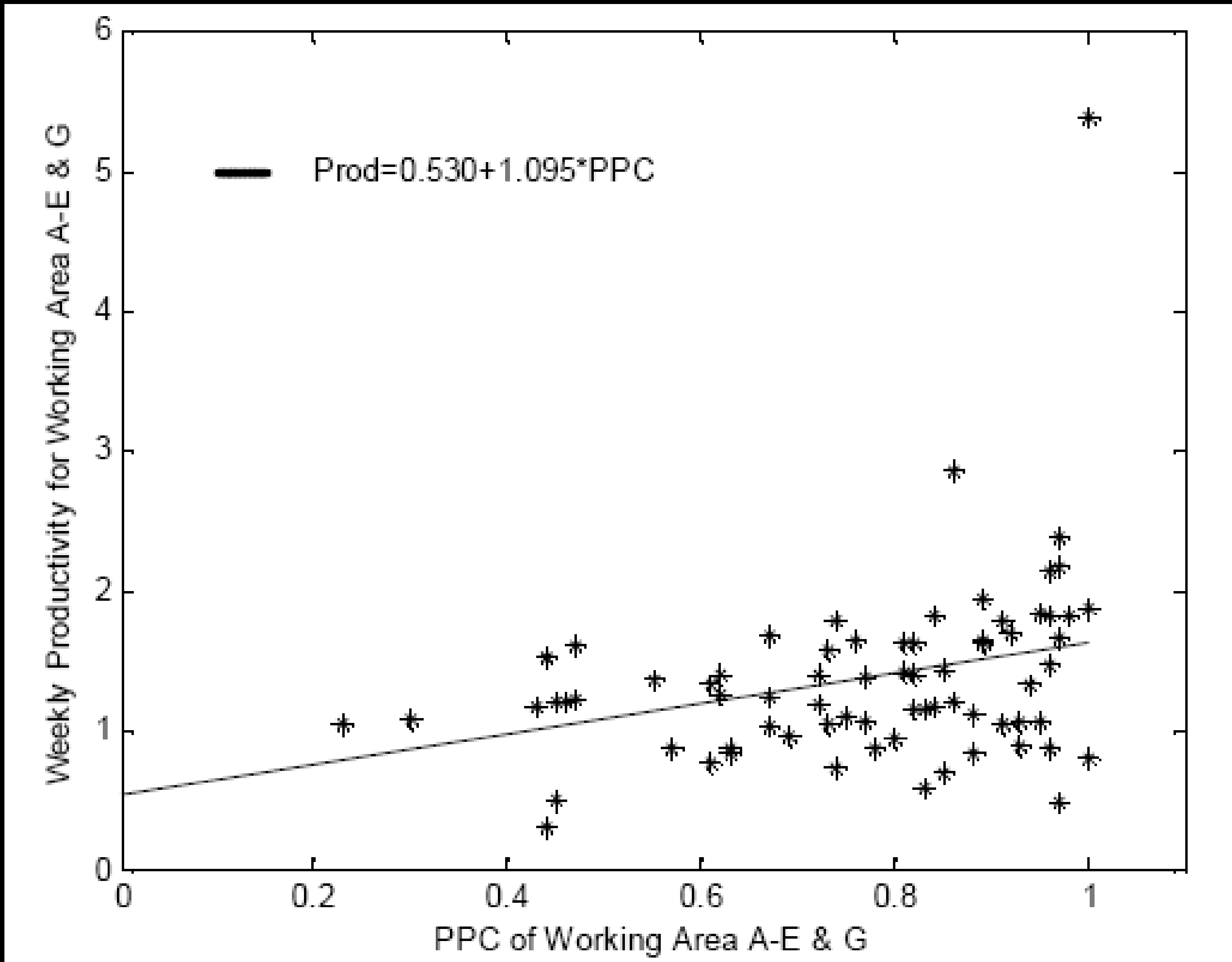
CRAFT BUY-IN and PRODUCTIVITY

LEVEL OF BUY-IN	CRAFT/SCOPE	DIRECT LABOR JOB-TO-DATE PRODUCTIVITY[1]	JOB-TO-DATE OR FORECAST SAVINGS/ OVERRUN
LOW	ELECTRICAL - ELECTRICAL SYSTEMS	**0.84**	**($0.50 MM)**
MEDIUM	CIVIL & STRUCTURAL - FOUNDATIONS & STRECTURAL STEEL	**1.06**	**$1.90 MM**
HIGH	MECHANICAL - PIPING	**1.31**	**$2.50 MM**
	TOTAL	**1.11**	**$3.90 MM**

NOTES 1) Budgeted productivity equals 1.00

Courtesy of Strategic Project Solutions

Correlation between PPC and Productivity



Lean in the Construction Industry: Three Connected Opportunities

1. IMPECCABLE COORDINATION

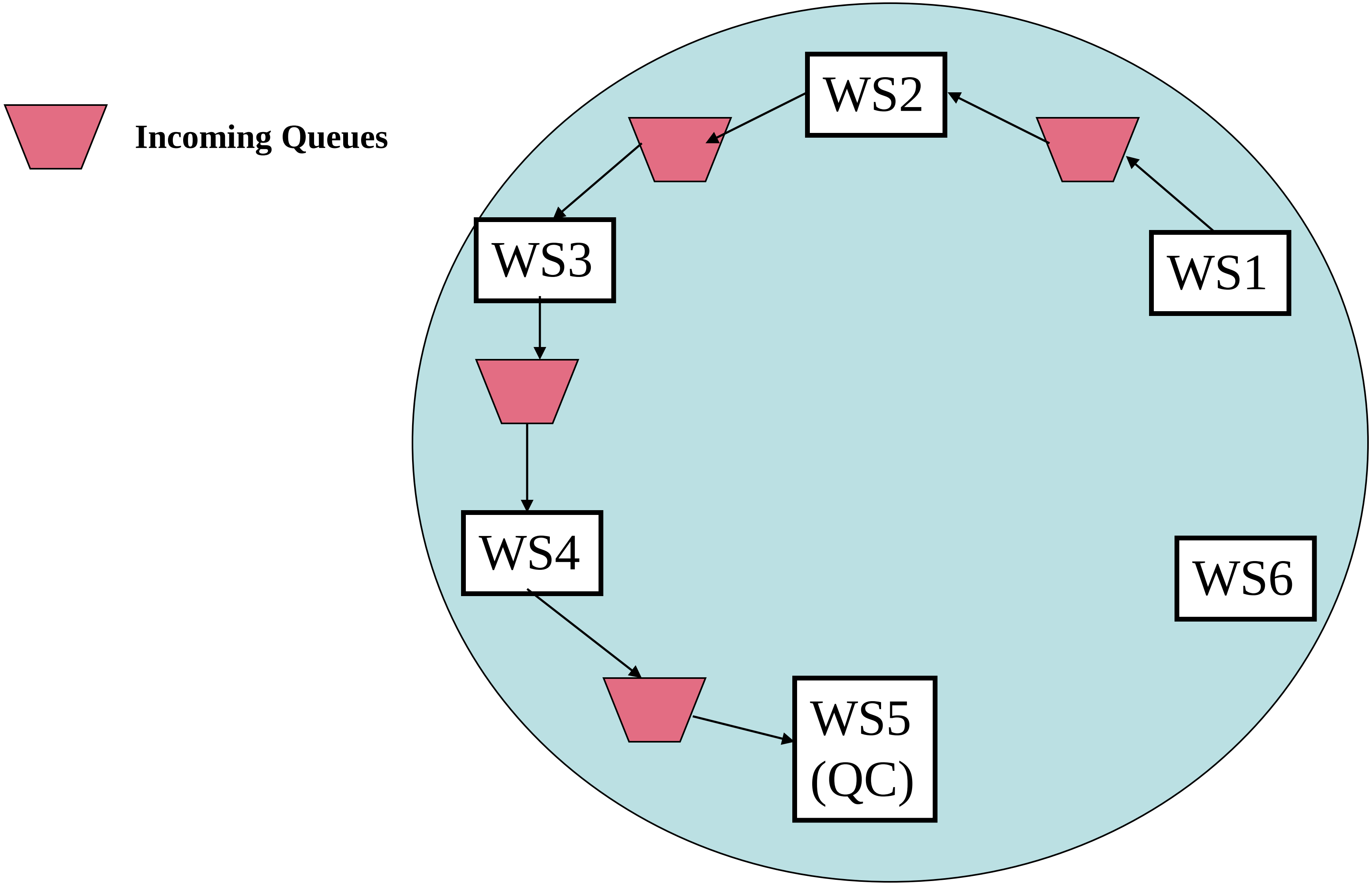
2. ORGANIZING PROJECTS AS PRODUCTION SYSTEMS

3. THE PROJECT AS A COLLECTIVE ENTERPRISE

Production System Design: The Structure and Management of Work

1. Assemble airplanes in 5 connected steps.
2. Three timed period separated by reflection, learning and improvement.
3. Assembly, inventory, batching, signaling, motivation, control and improvement.
4. The relationship between product and process design

Phase 1-3 Assembly Layout



Phase 1 Logistics

- Workstations in work flow sequence
- Materials located at workstation
- Workstations 2-5 have an incoming queue space
- Completed Batches of 5 placed in queue space of next station
- Batches remain together until final inspection

Phase 1 Policies

- **Workers perform only their assigned tasks - NO THINKING**
- **Maintain Batch integrity - BUILD IT IF YOU CAN and PASS IT ON IF YOU CAN'T.**
- **QC Problems only detected by Inspector - NO FEEDBACK - NO TALKING**
- **All QC problems set aside as rework - TURN UPSIDE DOWN**
- **QC Inspector announces first good plane.**
- **Assemblers are paid by the piece.**

Performance Metrics

- Planes: the number of good planes produced in each 6 minute phase.
- Time: the time it takes the first good plane to get through the system.
- Rework: the number of planes turned upside to indicate defects in configuration or fit.
- Work-in-Progress Inventory (WIP): the number of subassemblies on the table at the end of the 6 minute phase.

Your Hypotheses

- How many good planes will your team produce in Phase I?
- How long will it take for you to produce the first good plane?
- How much rework will you generate (planes turned upside down)?
- How much WIP will you generate (subassemblies left on the table)?

How could this system be redesigned for better performance?

Phase 2 Logistics

- Workers may have only one assembly at their workstation
- Only 1 assembly allowed in queue space between stations (Batch size of 1)
- Assembly can only be placed in queue when it is empty (pull mechanism).
- Workstations in Work Flow Sequence
- Materials located at station
- Stations 2-5 have an incoming queue space

Phase 2 Policies

- **QC Problems may be verbalized by any worker**
  - **SOME THINKING and TALKING ALLOWED**
- **All QC problems set aside as rework at station discovered.**
  - **TURN UPSIDE DOWN**
- **Everyone is paid hourly wages plus a bonus for team performance.**
- **Workers perform only their assigned tasks**
- **Workers cannot fix QC problems from upstream**
- **Inspector announces first good plane.**

Your Hypotheses

- How many good planes will your team produce in Phase II?
- How long will it take for you to produce the first good plane?
- How much rework will you generate (planes turned upside down)?
- How much WIP will you generate (subassemblies left on the table)?

Phase 3 Logistics

- Use Phase 3 Instruction Sheets.
- Workers may have only one assembly at their workstation
- Only 1 assembly allowed in queue space between stations (Batch size of 1)
- Components can only be placed in queue when it is empty (pull mechanism).
- Workstations in Work Flow Sequence
- Materials located at station
- Stations 2-5 have an incoming queue space

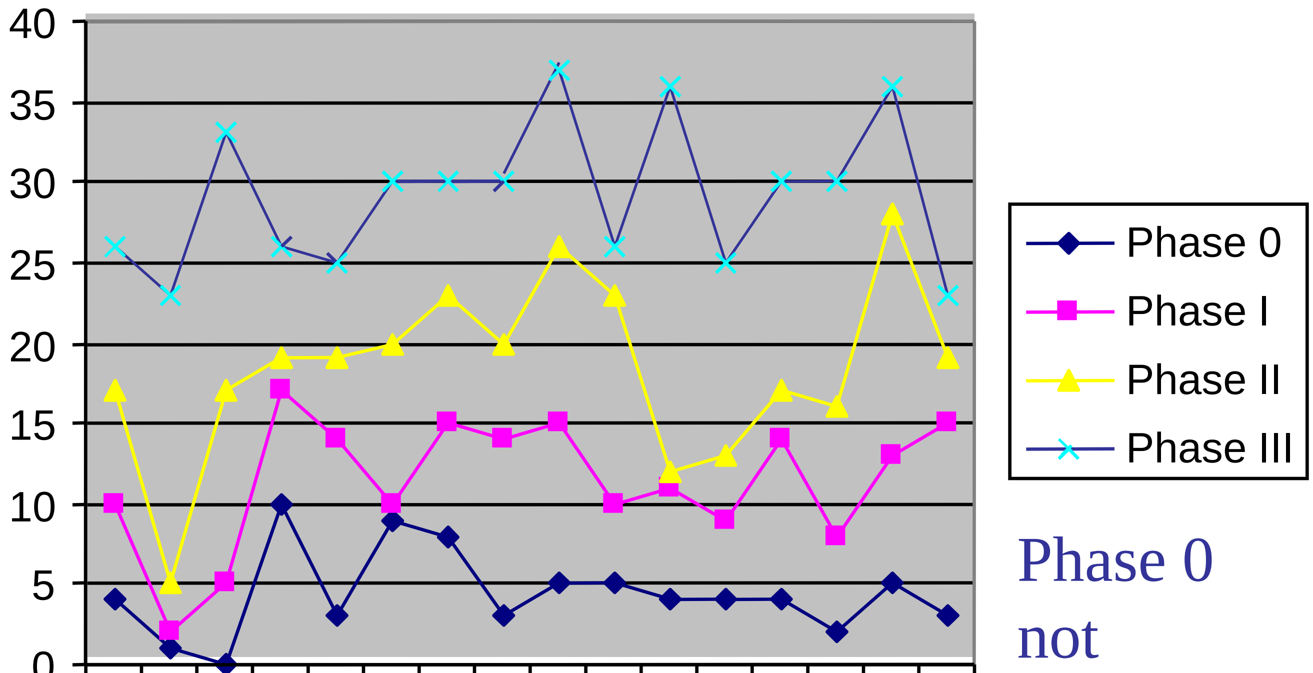
Phase 3 Policies

- Workers perform ANY step in the production process.
- QC problems can be fixed by <u>any</u> worker - Fix it when you find it.
- No restrictions on talking.
- Everyone is paid hourly wages plus a bonus for team performance.
- Inspector announces first good plane.

Your Hypotheses

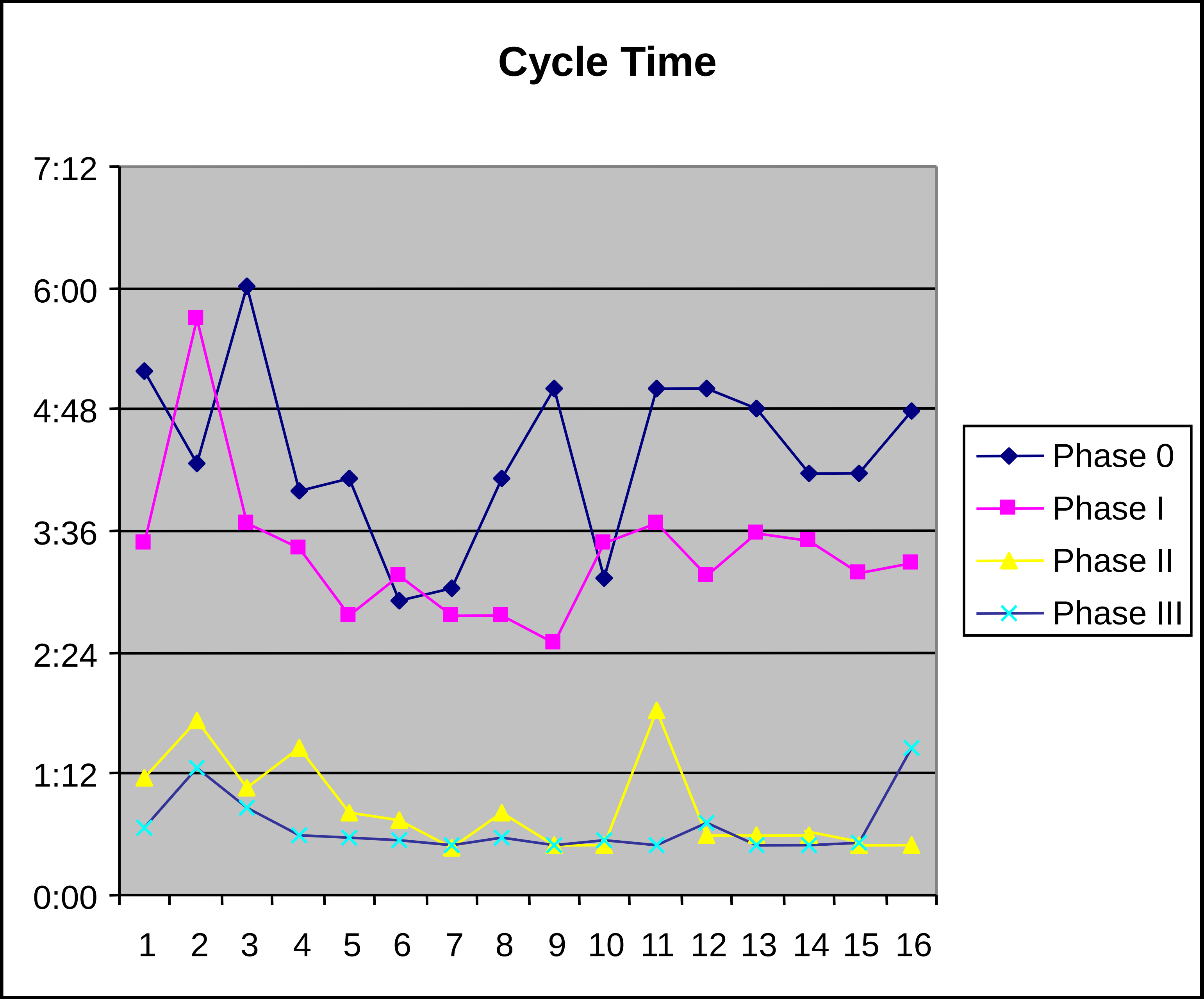
- How many good planes will your team produce in Phase III?
- How long will it take for you to produce the first good plane?
- How much rework will you generate (planes turned upside down)?
- How much WIP will you generate (subassemblies left on the table)?

Throughput



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Phase 0	4	1	0	10	3	9	8	3	5	5	4	4	4	2	5	3
Phase I	10	2	5	17	14	10	15	14	15	10	11	9	14	8	13	15
Phase II	17	5	17	19	19	20	23	20	26	23	12	13	17	16	28	19
Phase III	26	23	33	26	25	30	30	30	37	26	36	25	30	30	36	23

Phase 0 not played here


Cycle Time
7:12
6:00
4:48
3:36
2:24
1:12
0:00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Phase 0
Phase I
Phase II
Phase III

Learning to see

1. Minimize the movement of materials and workers by sequencing and positioning of workstations (layout) and by maintaining materials at the workstations.
2. **Release work (materials or information) from one workstation (specialist) to the next by pull versus push.**
3. **Minimize batch sizes to reduce cycle time.**
4. Make everyone responsible for product quality.
5. Balance the workload at connected workstations.
6. Encourage and enable specialists to help one another as needed to maintain steady work flow (multiskilling).
7. Stop the line rather than release bad product to your ‘customer’.
8. Minimize changeover (“setup”) time to allow one piece flow.
9. Make the process transparent so the state of the system can be seen by anyone from anywhere.

What batches are found in construction projects?

- Drawings for review and approval; e.g., Construction Documents, permit sets
- Requests for Information (RFIs)
- Requests from one specialist to another for more information than is needed at the time:
  - ‘I need your design for the chillers’ when what’s actually needed is footprint and weight.
  - ‘I need to know all penetrations through load bearing walls’ when what’s actually needed is to identify penetrations > 1 square meter.

What batches are found in construction projects?

- The spacing between ‘lessons learned’; end of project, end of phase—long feedback loops
- Spacing between trades
- Orders for materials
- ???

Where might we look for ‘pull’ or ‘push’?

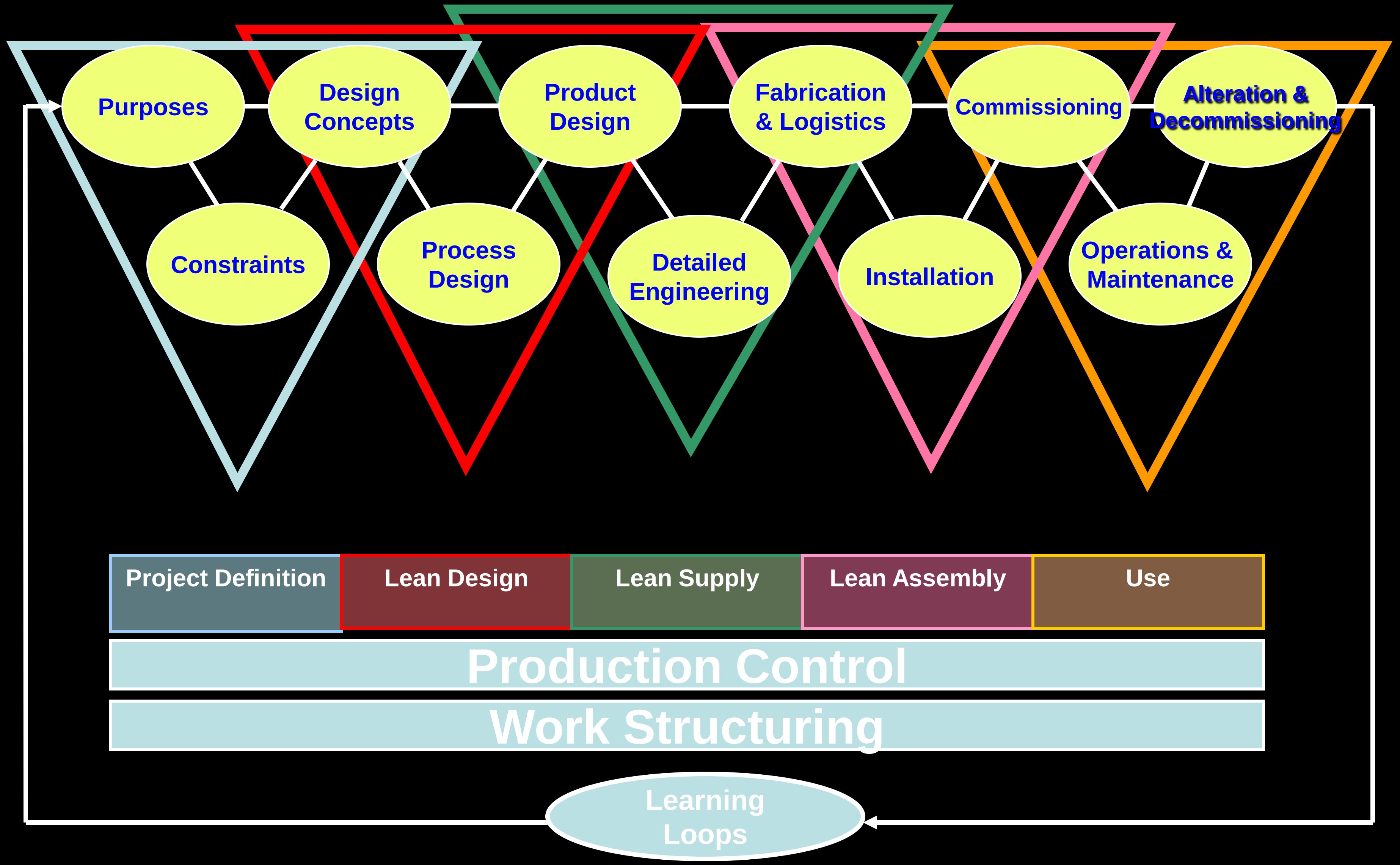
How does work product flow through networks of interdependent specialists…

- in design?
- in specification, fabrication and delivery of engineered-to-order products?
- in site assembly and commissioning?

How does each work group decide what work to do next?

The Airplane Game

1. What are the key points or lessons for you?
2. How might these apply to designing and making buildings? How could you use what you have learned on your projects?



Purposes
Design Concepts
Product Design
Fabrication & Logistics
Commissioning
Alteration & Decommissioning
Constraints
Process Design
Detailed Engineering
Installation
Operations & Maintenance
Project Definition
Lean Design
Lean Supply
Lean Assembly
Use
Production Control
Work Structuring
Learning Loops

Essential Features of the Toyota Production System

- Optimizing the system, not its parts
- Controlling processes
- Driving out variation
- Decentralizing decisions
- Rapid learning by everyone at every level every day


OUC

Site as it existed on Noven


EXIT

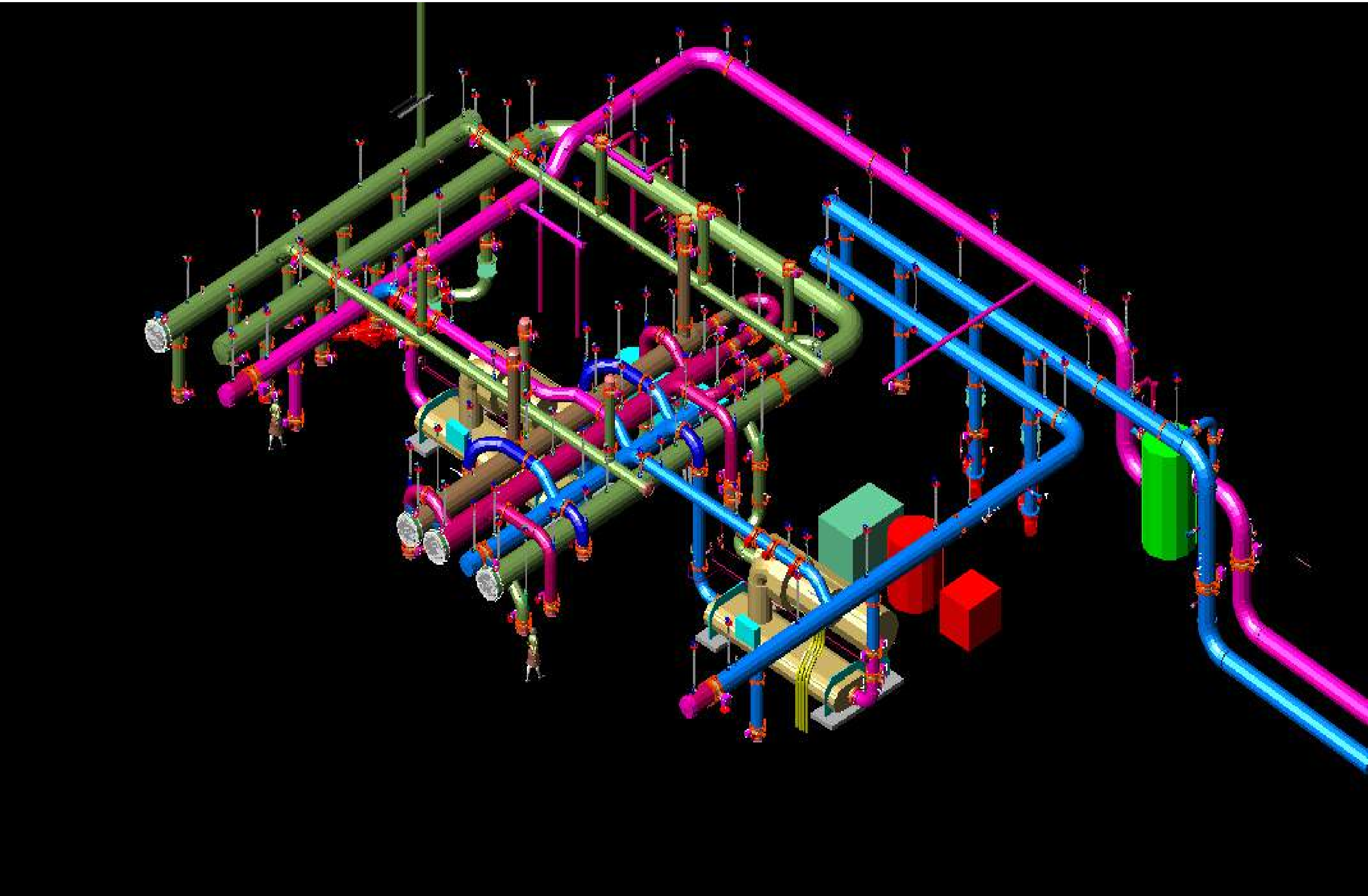
Vertical In-line Pumps

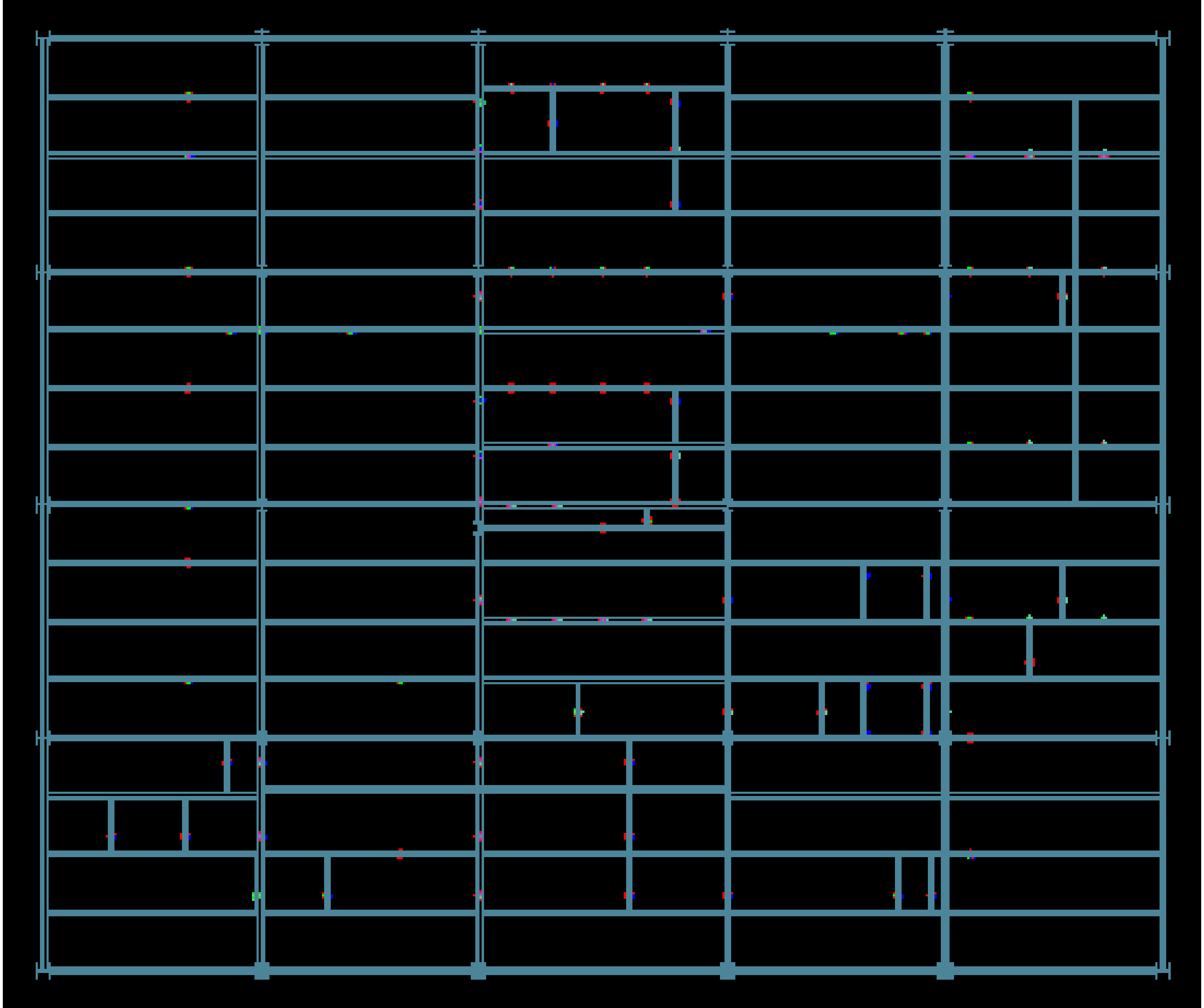
1,500 Ton Centrifugal Chiller

Planning Considerations

- Delay decisions to last responsible moment
- Create pull schedules
- Only do work that releases that needed by downstream crews (important also in design)
- Reliability of work flow

BFP-1






CAUTION
CAUTION
RENTAL
5. 18. 2004


Genie GS-2032
CAUTION
5.19. 2004


5. 22. 2004


5. 26. 2004


BOILER CO.
4. 28. 2004


4. 28. 2004


5. 7. 2004


5. 10. 2004


7/28/04

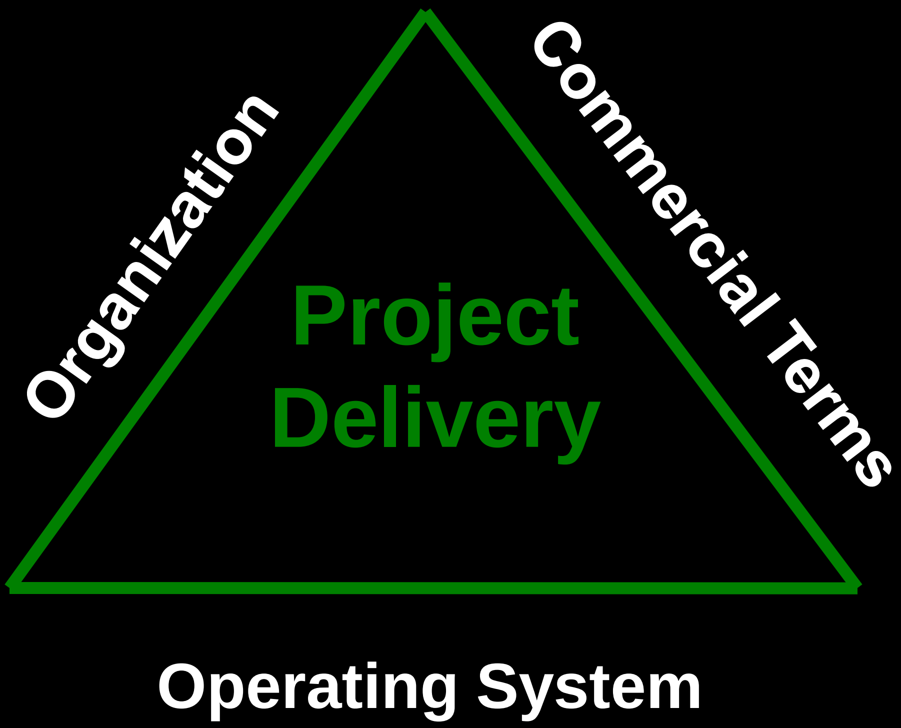
Schedule Considerations

- Delay decisions to last responsible moment
- Create pull schedules
- Only work to release downstream crews (important also in design)
- Reliability of work flow

SCHEDULE PERFORMANCE

Contract Date	12/30/03
DD Complete	1/26/04
Demolition Complete	1/7/04
Time lost to DDB	6 weeks
Permit Issued	4/14/04
Work Begins on Site	5/4/04
Plant Ready to Go	7/28/04

Putting the pieces together



Project management common sense

Operating System	Commercial Terms	Organization
CPM	Transactional	Command & Control
Lean	Relational	Collaborative

Optimizing the project not the piece

Lean in the Construction Industry: Three Connected Opportunities

1. THE PROJECT AS A COLLECTIVE ENTERPRISE

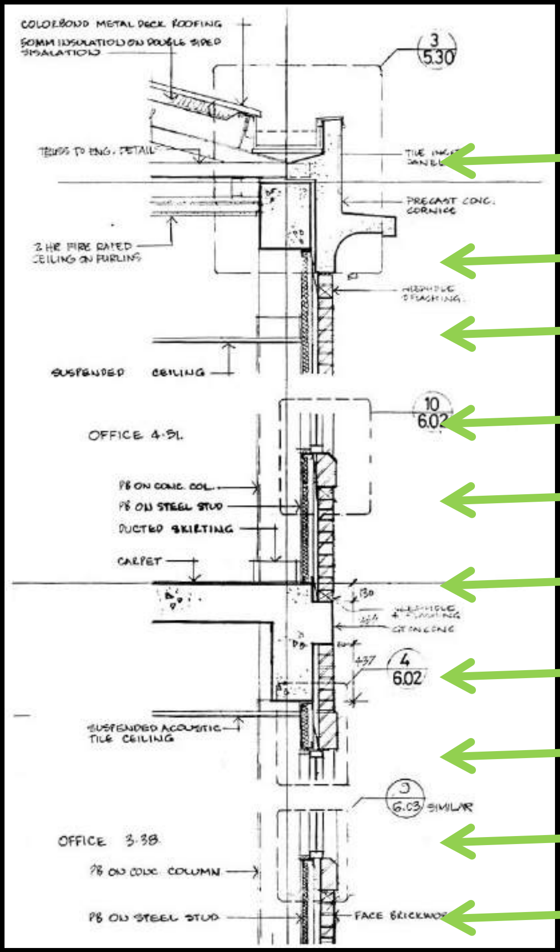
2. IMPECCABLE COORDINATION

3. ORGANIZING PROJECTS AS PRODUCTION SYSTEMS

The Big Questions

- What if every member of the team shared completely the responsibility for the entire project and set about correcting deficiencies or problems wherever they popped up without regard to who caused the problem or who is going to pay for it?
- What if all team members were friends looking out for the interest of the Client and each other, applauding the successes of each other and sharing the pain of each others failures?
- What if all of the design and construction entities on a project could be organized in such a way that they all functioned as if they truly were a single company with a single goal and with no competition amongst themselves for profit or recognition?

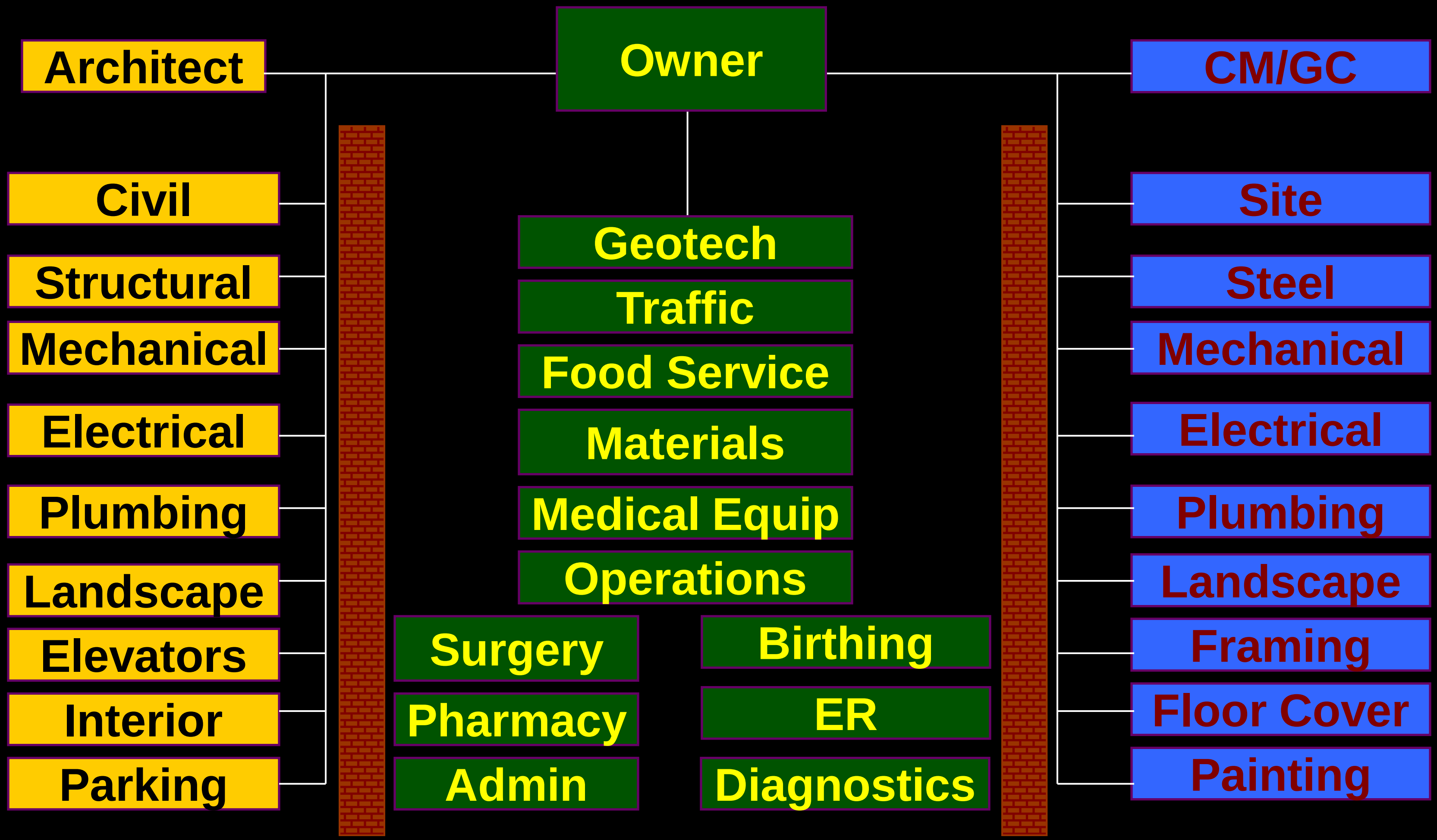
Buildings Leak at the Intersection of Contracts



- Roofing contractor
- Wall stud contractor
- Caulking contractor
- Window contractor
- Masonry contractor
- Waterproofing contractor
- Concrete contractor
- Structural steel contractor
- Foundation contractor
- Excavation contractor

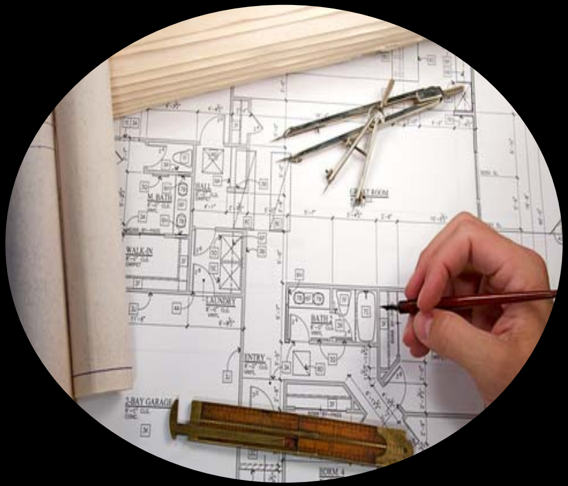
Graphic courtesy of Todd Zabelle, Strategic Project Solutions

Typical Organization



Why?

What?

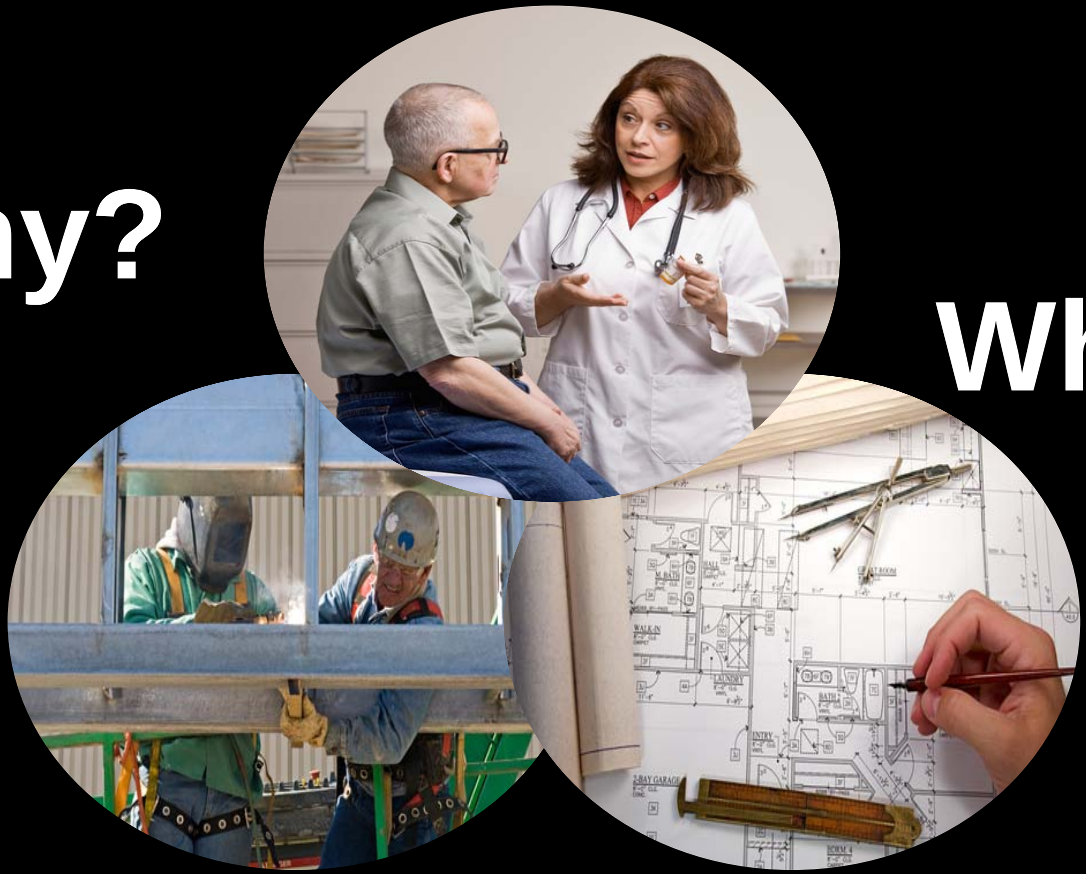


How?

"An Owner needs to decide what it's buying - a product - or a team to solve a problem that no one completely understands and that keeps changing."

- Jim Carroll, Washington Group

Why?



What?

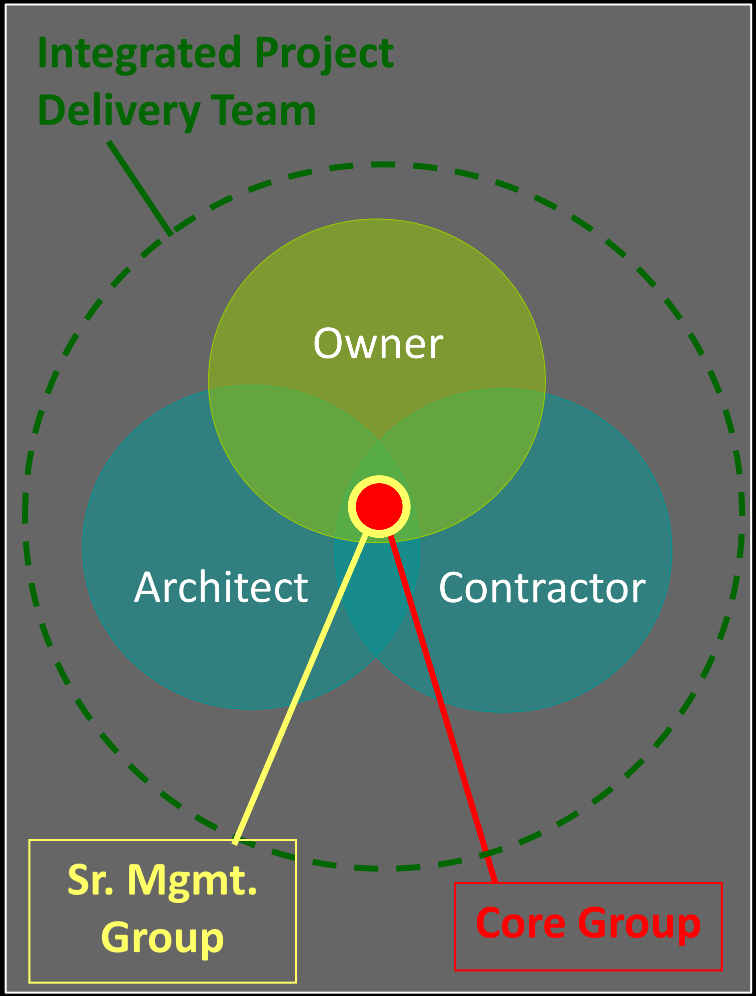
How?

What Underlies A Relational Contract?

Ian Macneil:

- Relations of significant duration
- Objects of “value” are not all easily measurable
- Many individuals, collective poles of interest
- Future cooperation anticipated
- Benefits and burdens shared
- Trouble is expected
- Relations will vary as unforeseeable future unfolds

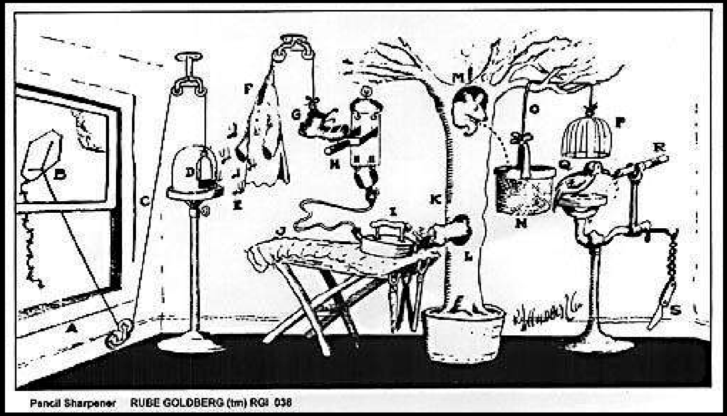
- One Agreement signed by O-A-C
- "Joined" by <u>jointly</u> selected team members
- No separate "general conditions"
- Provides for formation of:
  - Core Group
  - Integrated Project Delivery Team
  - Senior Management Group
- Incentives for team performance

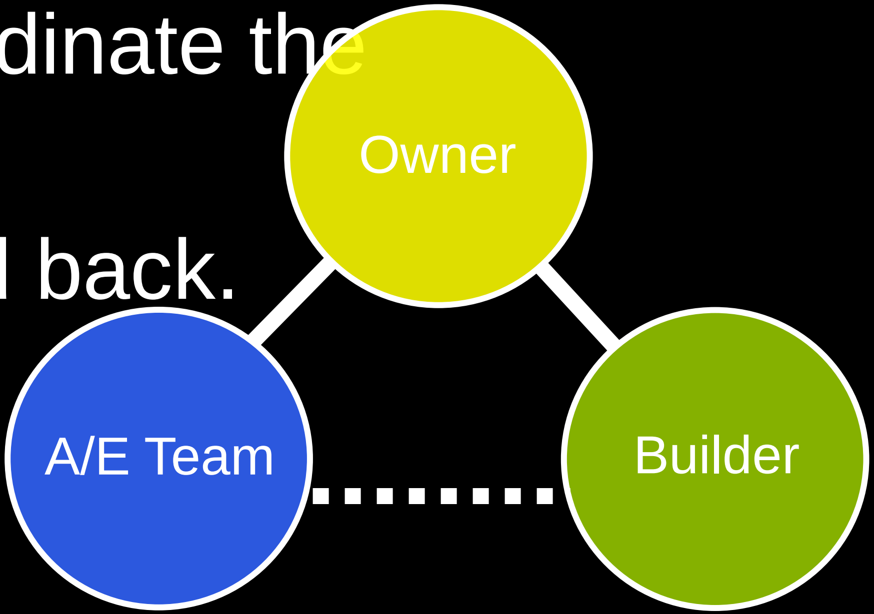


Source: McDonough Holland & Allen PC, Attorneys at Law

Traditional Project Delivery

- Traditional Contracting limits cooperation and innovation. Inability to fully coordinate the project.
- Good ideas are held back.

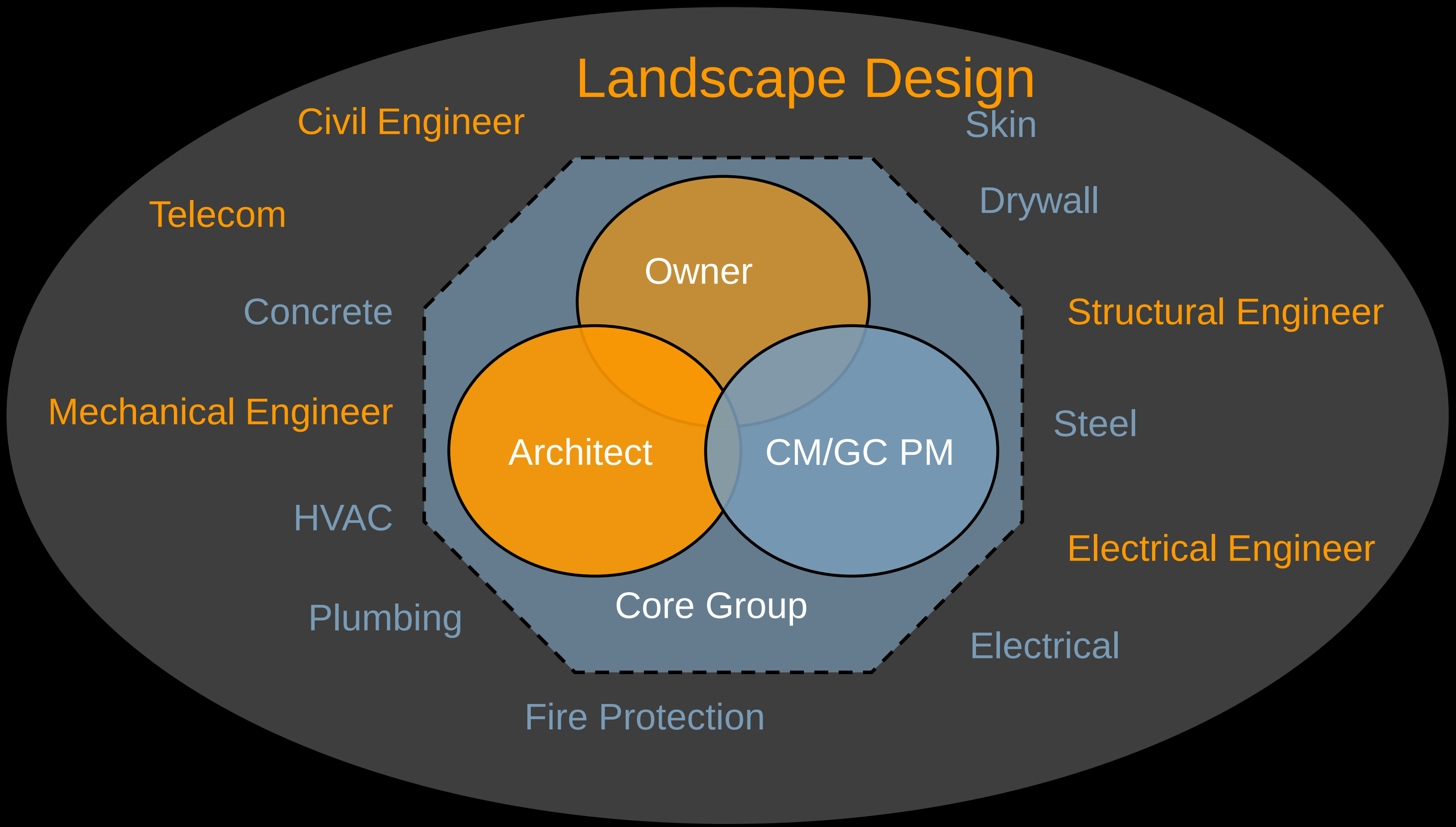




Source: McDonough Holland & Allen PC, Attorneys at Law

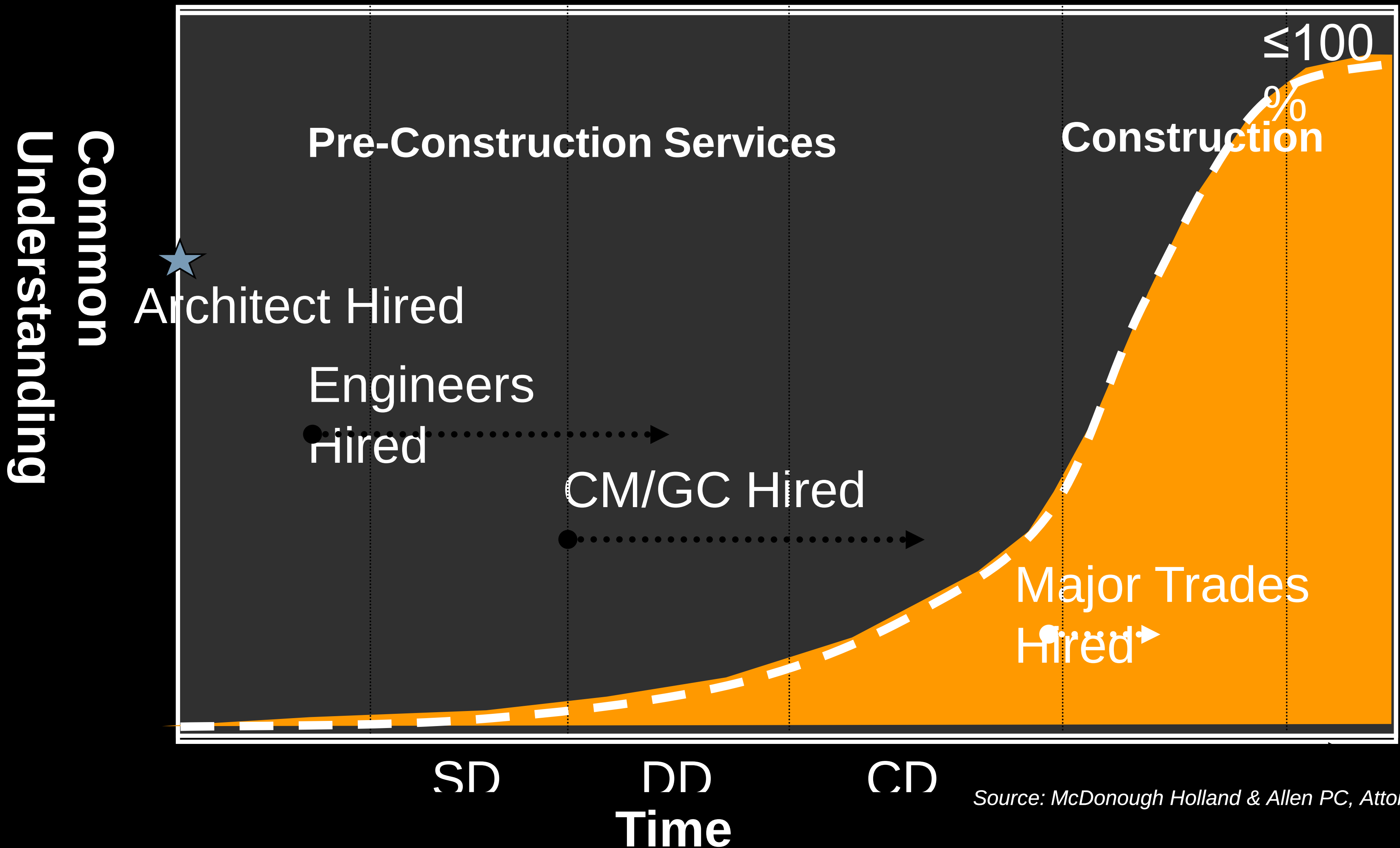
Integrated Project Delivery Team

Alignment / Integration / Collaboration



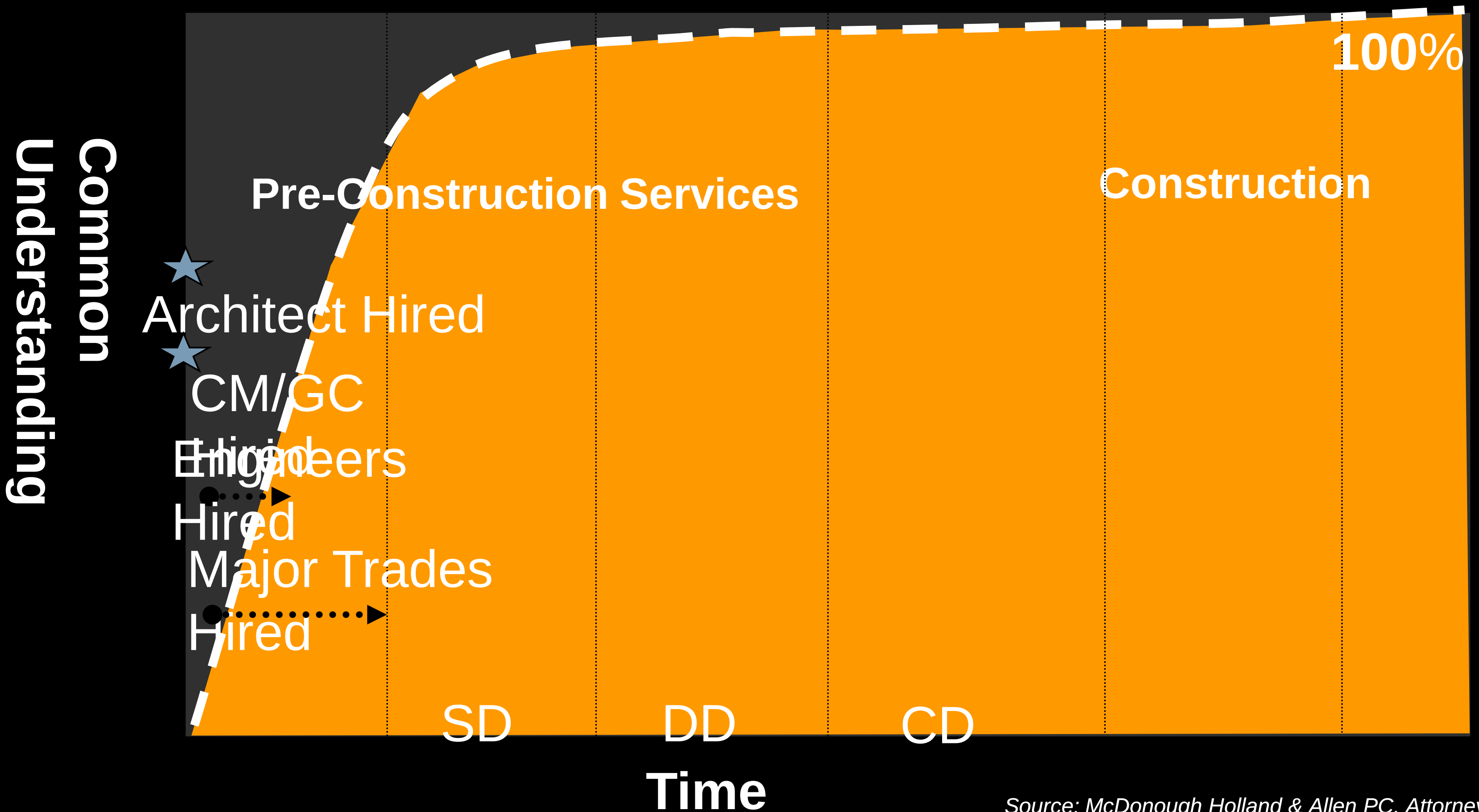
Source: McDonough Holland & Allen PC, Attorneys at Law

Level of Common Understanding



Source: McDonough Holland & Allen PC, Attorneys at Law

Integrated Project Delivery Level of Common Understanding

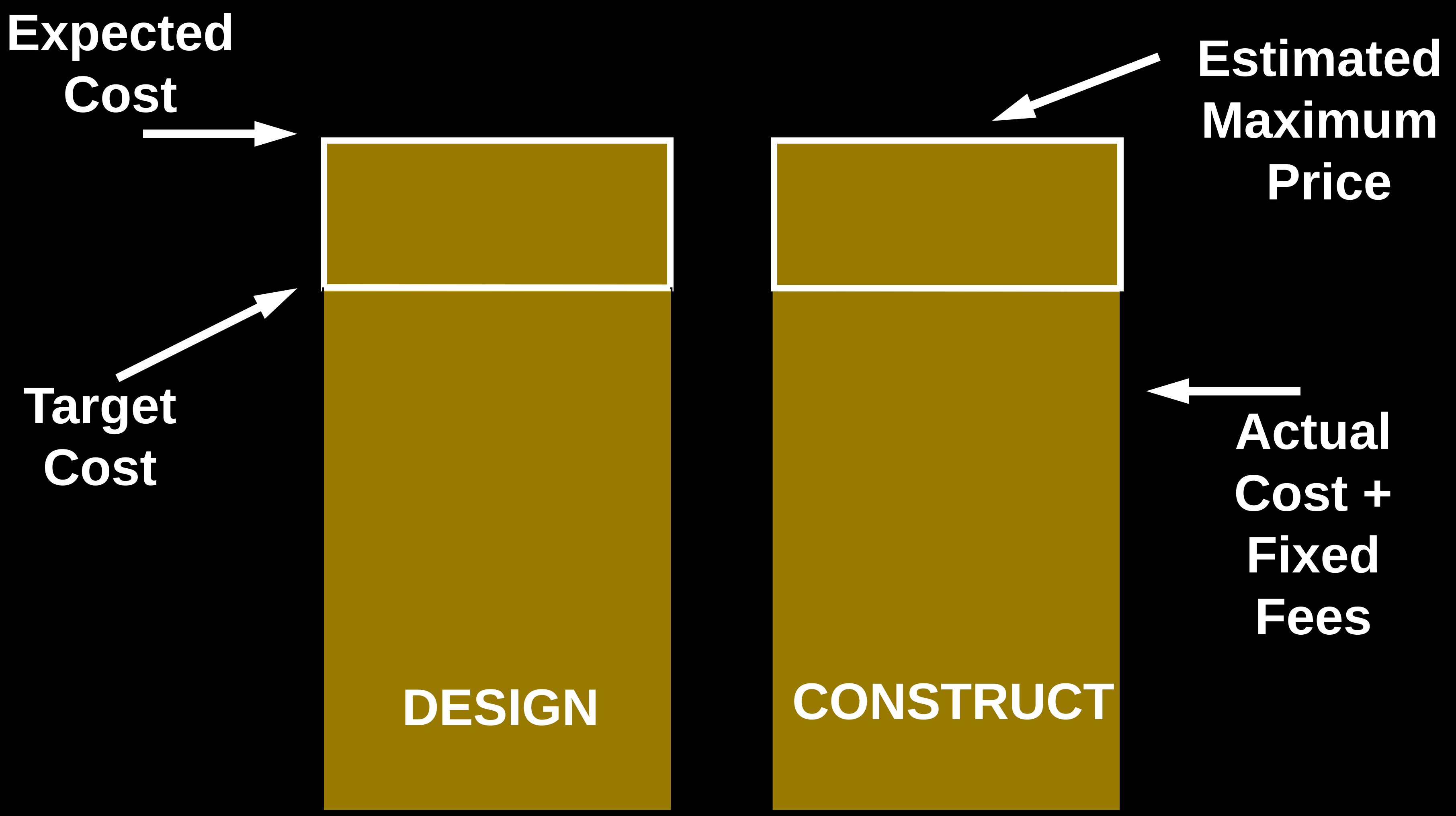


Source: McDonough Holland & Allen PC, Attorneys at Law

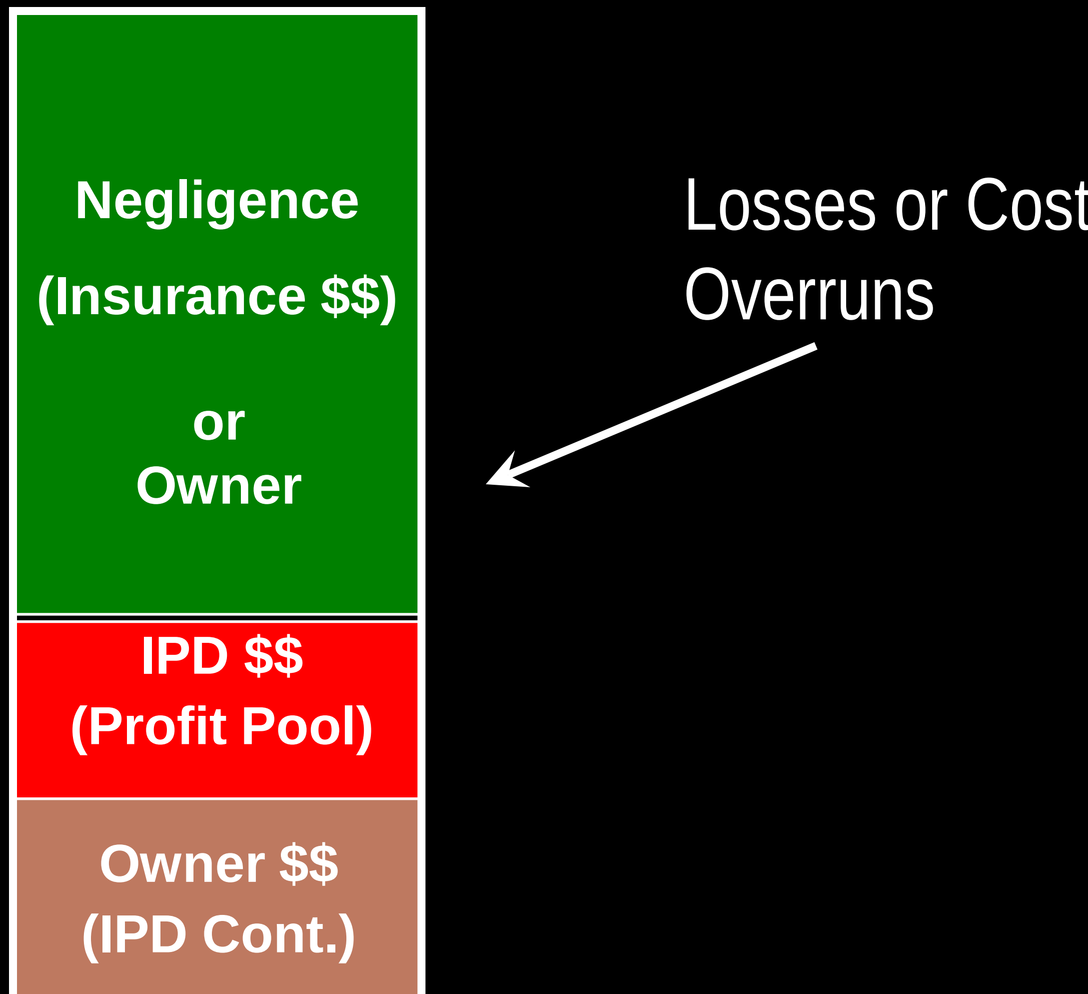
Commercial Opportunities

- Pool Contingencies
- Trade Contractors' Compensation
- Create Proper Incentives (Rewards)
- Create "Enterprise" Risk Sharing
- Eliminate trade-level GMPs
- Eliminate Project GMP

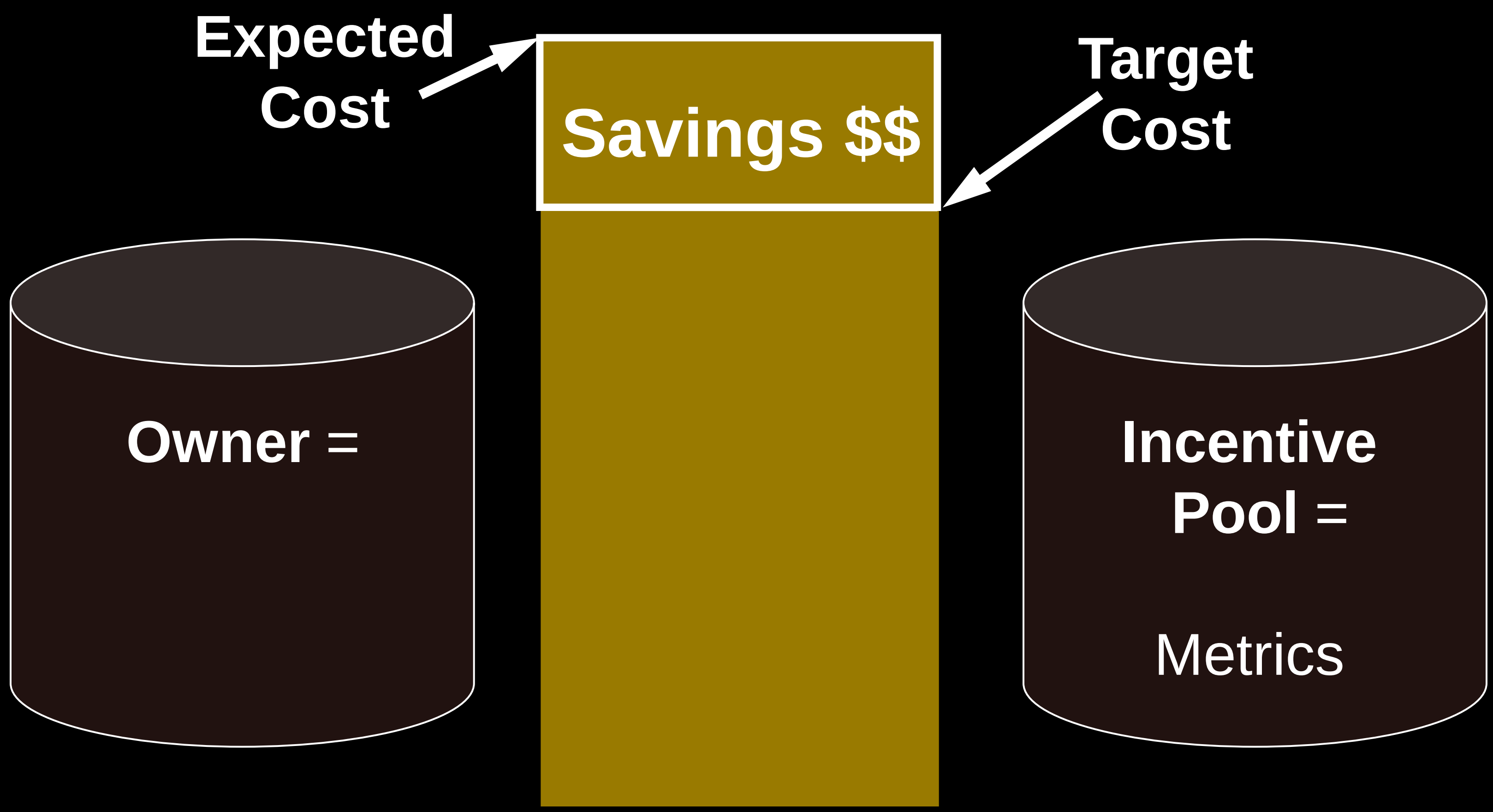
Basic Commercial Model



Sharing of Risk



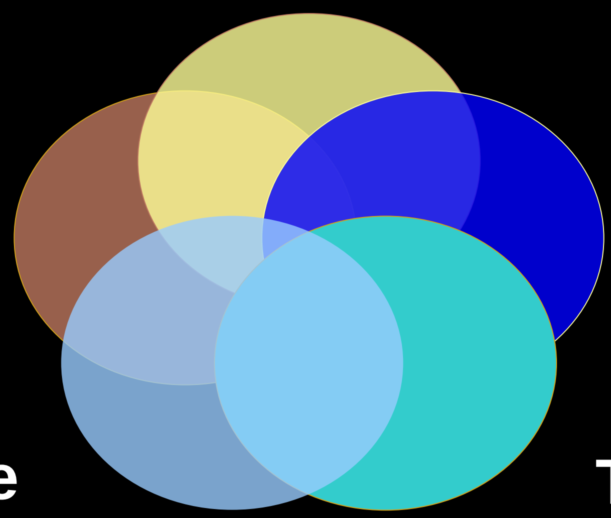
Sharing Project's Innovation



The 5 Big Ideas

Collaborate; Really Collaborate

Increase Relatedness

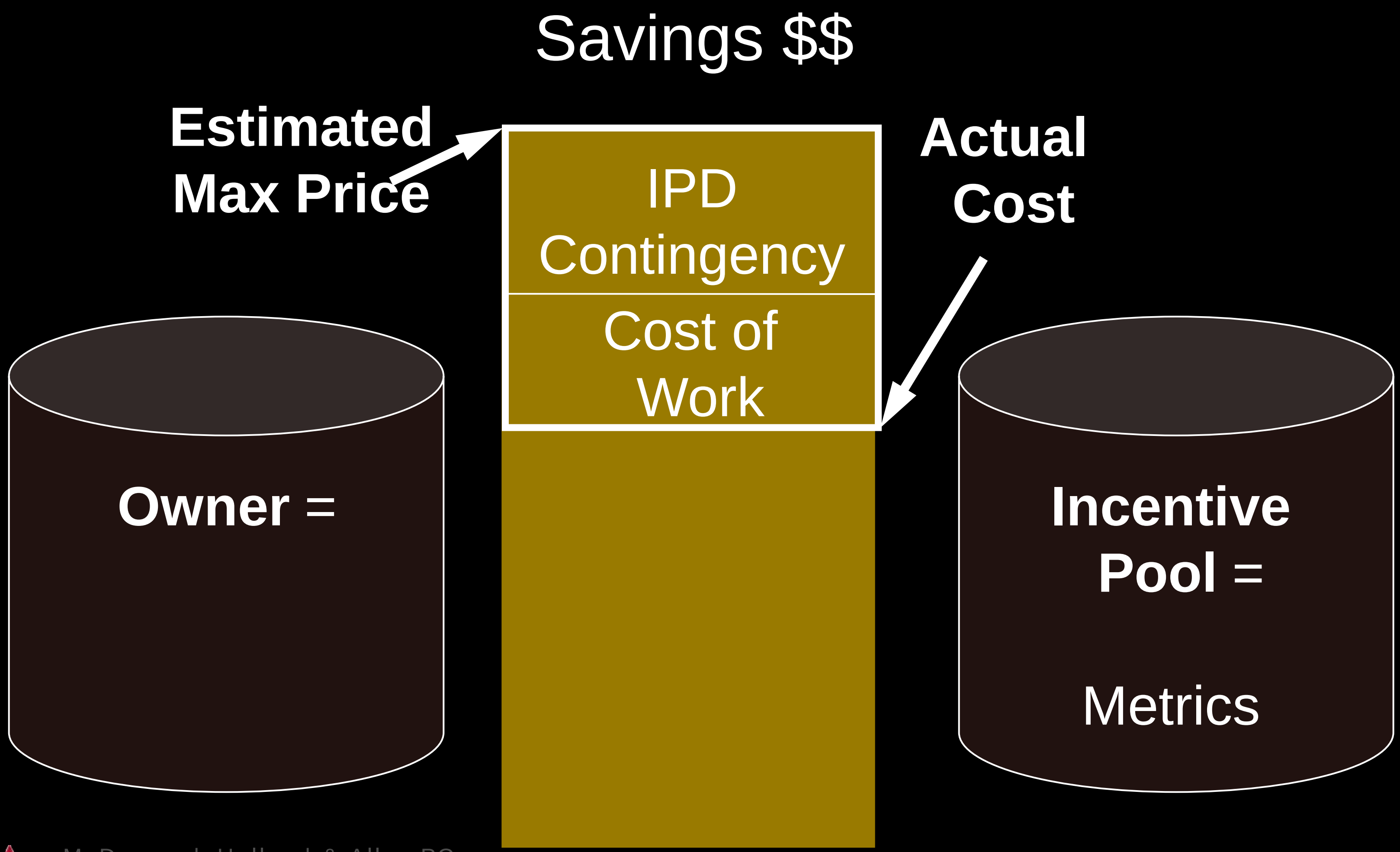


Networks of Commitment

Optimize The Whole

Tightly Couple Learning w/ Action

Sharing Project's Production Success

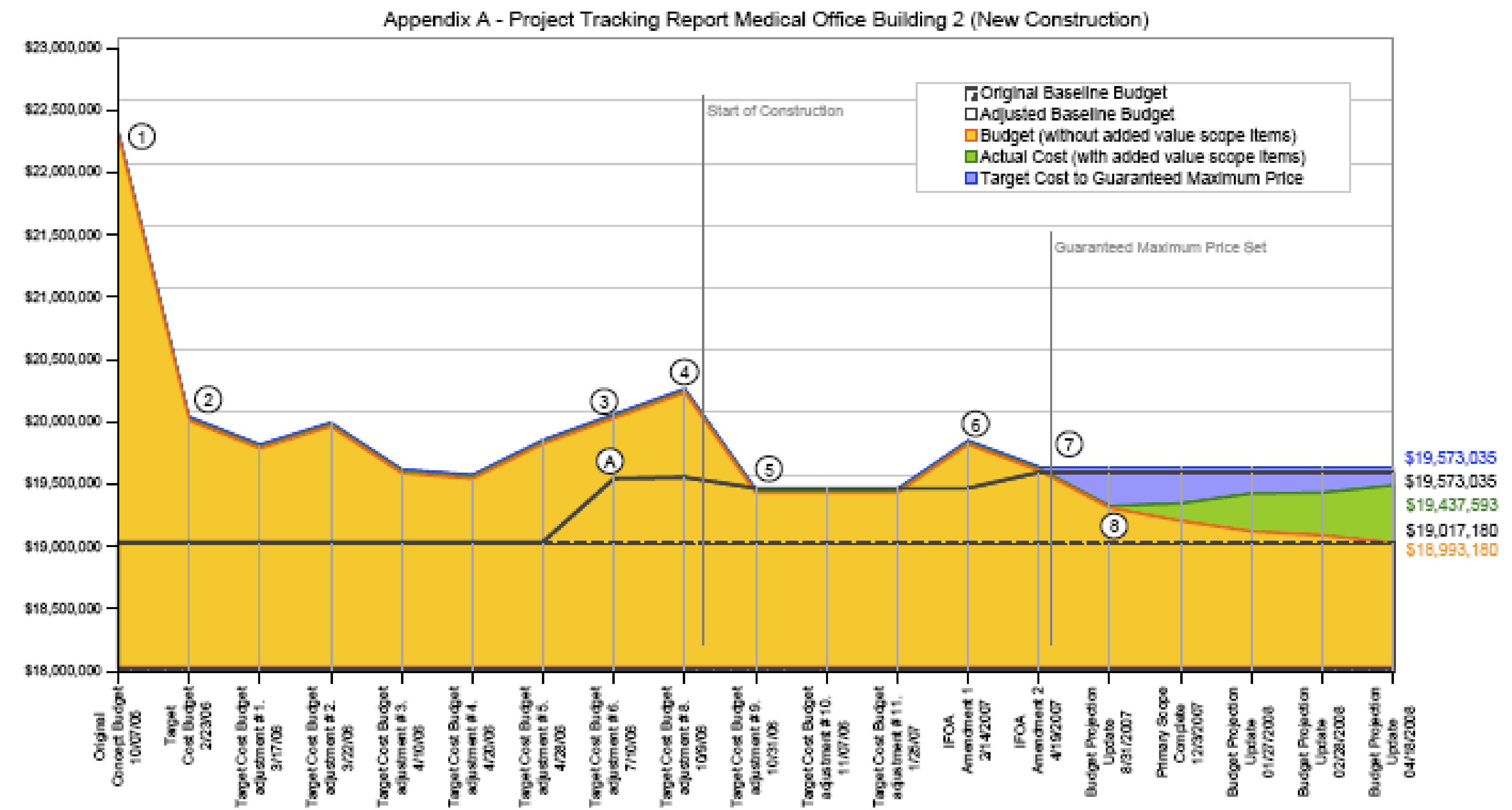


Owner Case: Sutter Fairfield MOB

The project was completed in 25 months, despite a 3 month delayed construction start.

The target cost ($18.9 million) was set 14.1% below the benchmark ($22.0 million). The actual cost ($17.9 million) for the original scope under ran the target by 5.3% and underran the benchmark by 18.6%.

Sutter Fairfield MOB



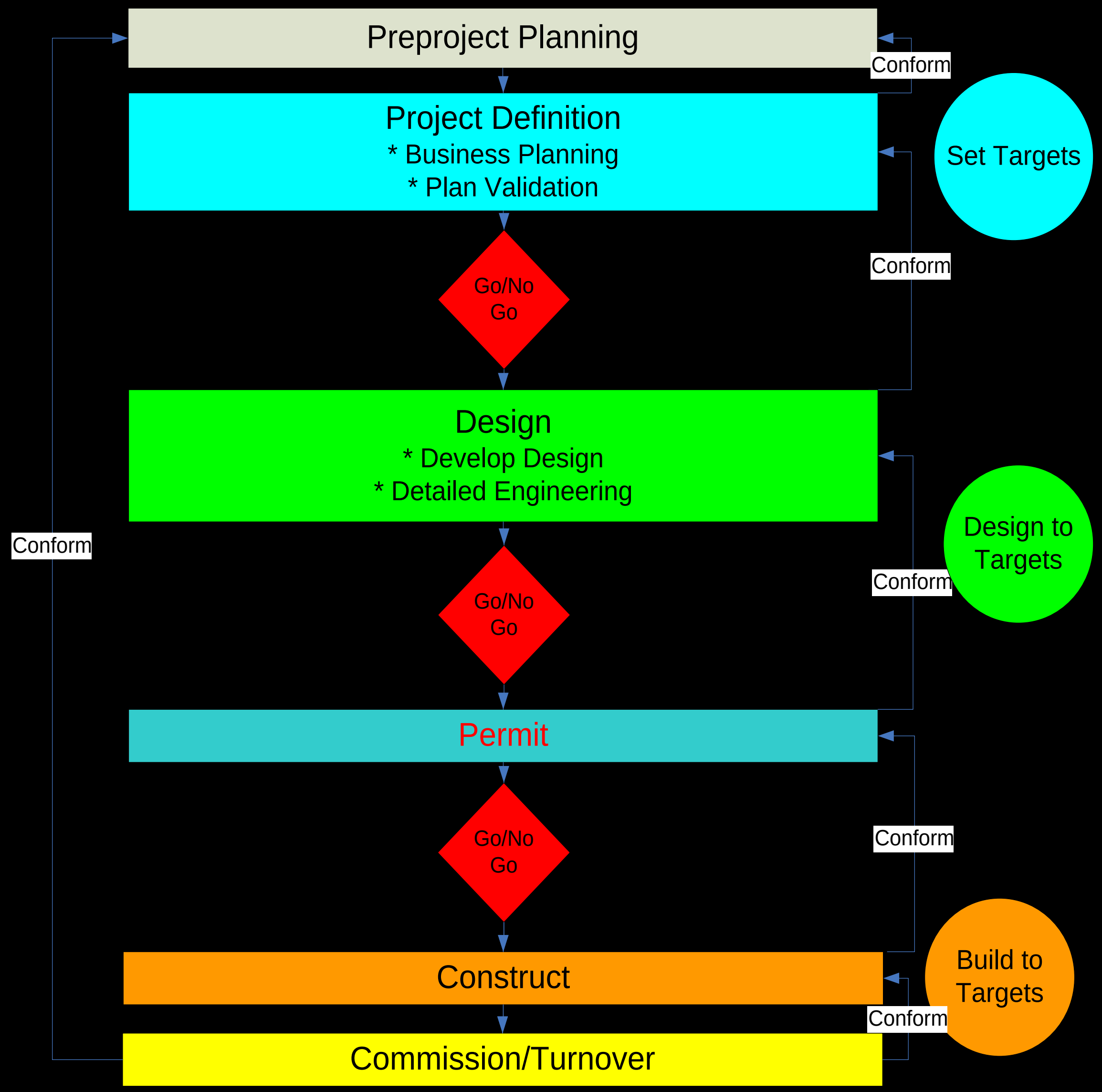
Dave Koester, BMW Senior Project Manager, on using Lean Production Management on the BP ULSD Project

- "Every large industrial project in Northwest Indiana and the south suburbs of Chicago has been over budget and has missed schedule for the last 20 years. This method broke the cycle."
- "We have been striving for employee involvement and empowerment; this method gave us a vehicle to achieve it."
- "We now utilize the entire bodies of our field crews, not just from the neck down."
- "If we didn't use the method on this project, I would have been begging for mercy [from the owner] months ago."

Key Features of Lean

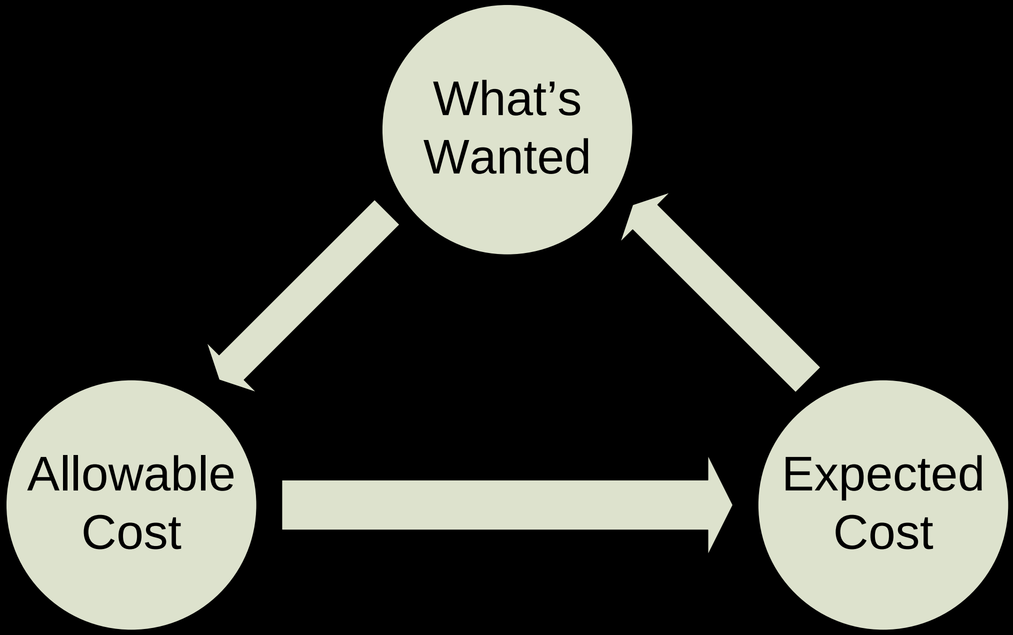
- The larger system is the focus of management attention, not local optimization
- Stakeholder interests are aligned through relational contracts
- All product life cycle stages are considered in design
- Product and process are designed together; indeed, all design criteria are considered when generating and selecting from design options
- Downstream players are involved in upstream work, and vice-versa
- Necessity, the mother of invention, is self-imposed to cause innovation and learning
- Variation is attacked and reduced —variation in work load, in process durations, in product quality, in plan reliability, …
- Inventory, capacity, schedule and financial buffers are sized and located to perform their function of absorbing variability that cannot yet be eliminated
- The rule followed for release of work between connected specialists is: Flow where you can, Pull where you can't, Push where you must
- Activities are performed at the last responsible moment

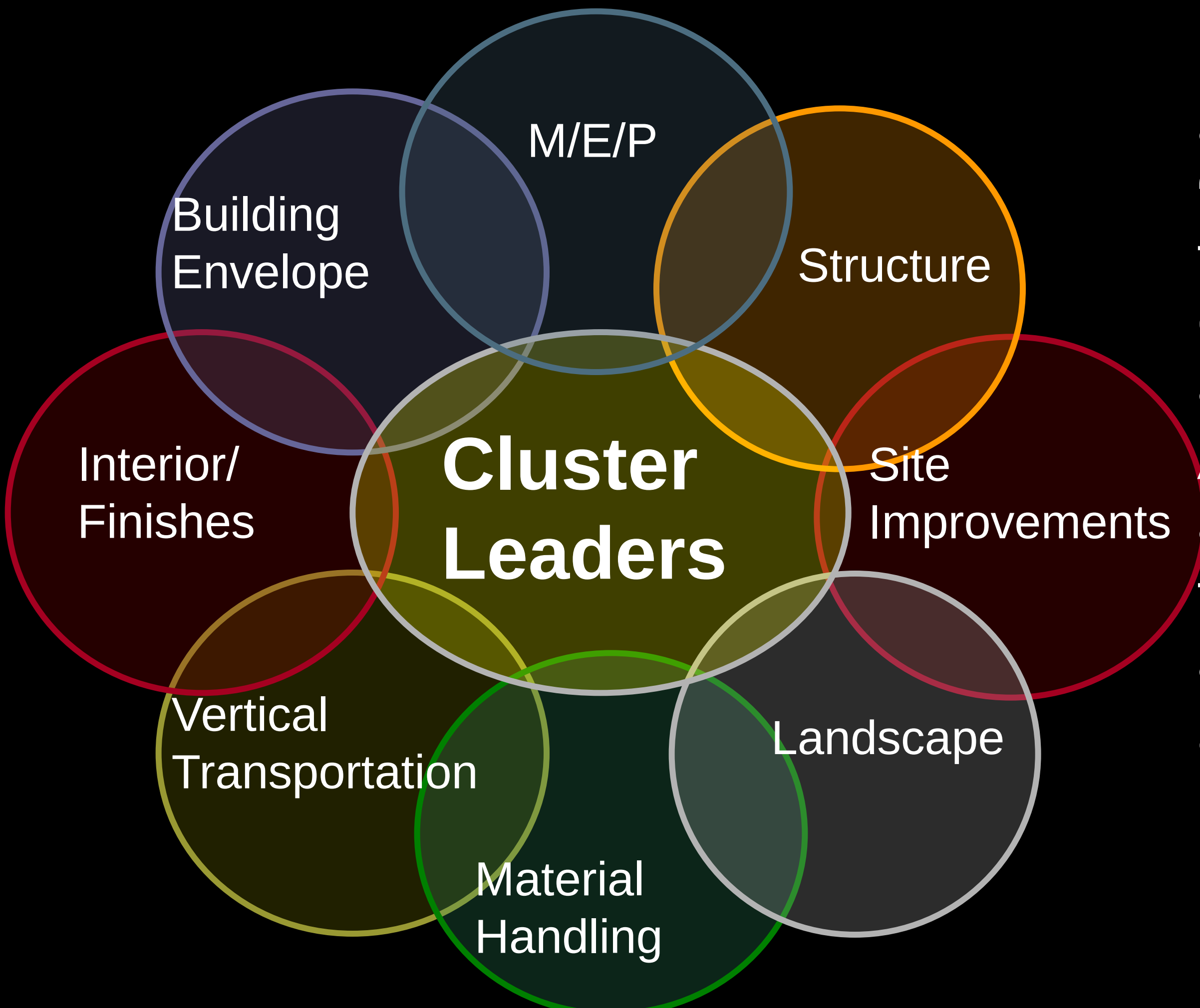
Project Phases and Target Costing



Target Costing

- Integrated team validates facility can be built for available funds
- Sets target cost at or below allowable cost
- Owner, architect and contractors work within market constraints





- Cardinal Rule: “The target cost of a facility can never be exceeded.”
- Teams composed of A/Es and contractors
- Each designs to a target cost
- Targets adjusted up and down to maintain project target cost

Target Cost Model

Legend:	Const TOTAL per SF	D-B TOTAL per SF
Worth (Target)		
Current Estimate	89.33	94.12

Project: Fieldhouse Expansion
Location: St. Olaf College Northfield MN
Phase of Design: Schematic Target
Date: June 21, 2001

Construction	+	Owner Reserves	+	Escalation	=	Construction TOTAL	Design-Build TOTAL
9,840,302		343,115				10,183,417	10,729,883

Incl Design at $504,886+41600

NOTES:
Bldg. Type: Recreational
Target (SQFT): 114,000
Floors: Single story plus mezzanines

SITE WORK	BUILDING
594,500	9,245,802

SITE WORK	SHELL	INTERIOR	MECHANICAL	ELECTRICAL	SPECIAL	GENERAL
Site GC OH&P	4,334,488	1,710,386	1,111,402	794,890	706,862	587,774
G10 Site Prep. Demo & Excav	A10 Foundation A20 Basement	C10 Interior Construction	D20 Plumbing	D5010 Service and Distribution	E10 Specialties & Equipment	Z1010 Project Administration
146,500	1,006,004	528,427	85,927	739,390	492,534	
G20 Site Improvements	B10 Superstructure	C20 Stairs	D30 HVAC	D5020 Lighting & Branch Wiring	E20 Furnishings Fixed/Movable	Z1030 General Conditions
373,000	1,218,797	62,639	824,160		34,000	
G30+40 All Utilities	B20 Exterior Closure	C30 Interior Finishes	D40 Fire Protection	D5030 Security Comm/Data	F10 Special Construction	Z1060 Fee
75,000	2,007,061	1,069,320	109,740		89,520	
G90 Other Site Structures	B30 Roofing	D10 Conveying	Testing and Special Mech	D5090 Other Electrical	F20 Selective Demolition	Z20 Risk and Contingency
	102,626	50,000	91,575	55,500	90,808	587,774

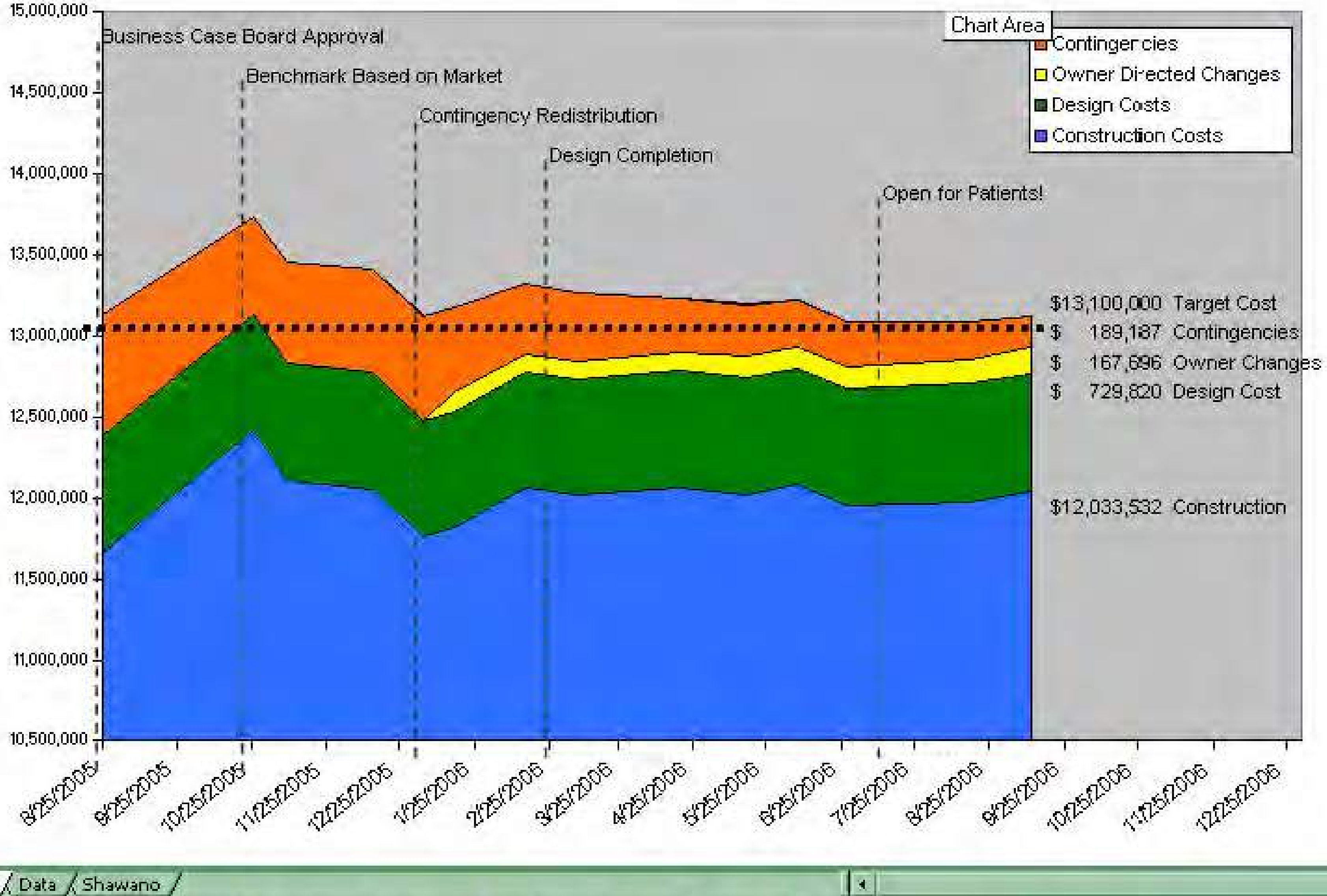
Target Costing vs. Conventional Project Management

	St. Olaf College Fieldhouse	Carleton College Recreation Center
Completion Date	August 2002	April 2000
Project Duration	14 months	24 months
Gross Square Feet	114,000	85,414
Total Cost (incl. A/E & CM fees)	$11,716,836	$13,533,179
Cost per square foot	$102.79	$158.44

Courtesy of the Boldt Companies

Attachment B

The Boldt Company
37359 ThedaCare Shawano Ambulatory Surgery Clinic
Project Final Costs Comparison
Thursday, November 2, 2006



Shawano Clinic

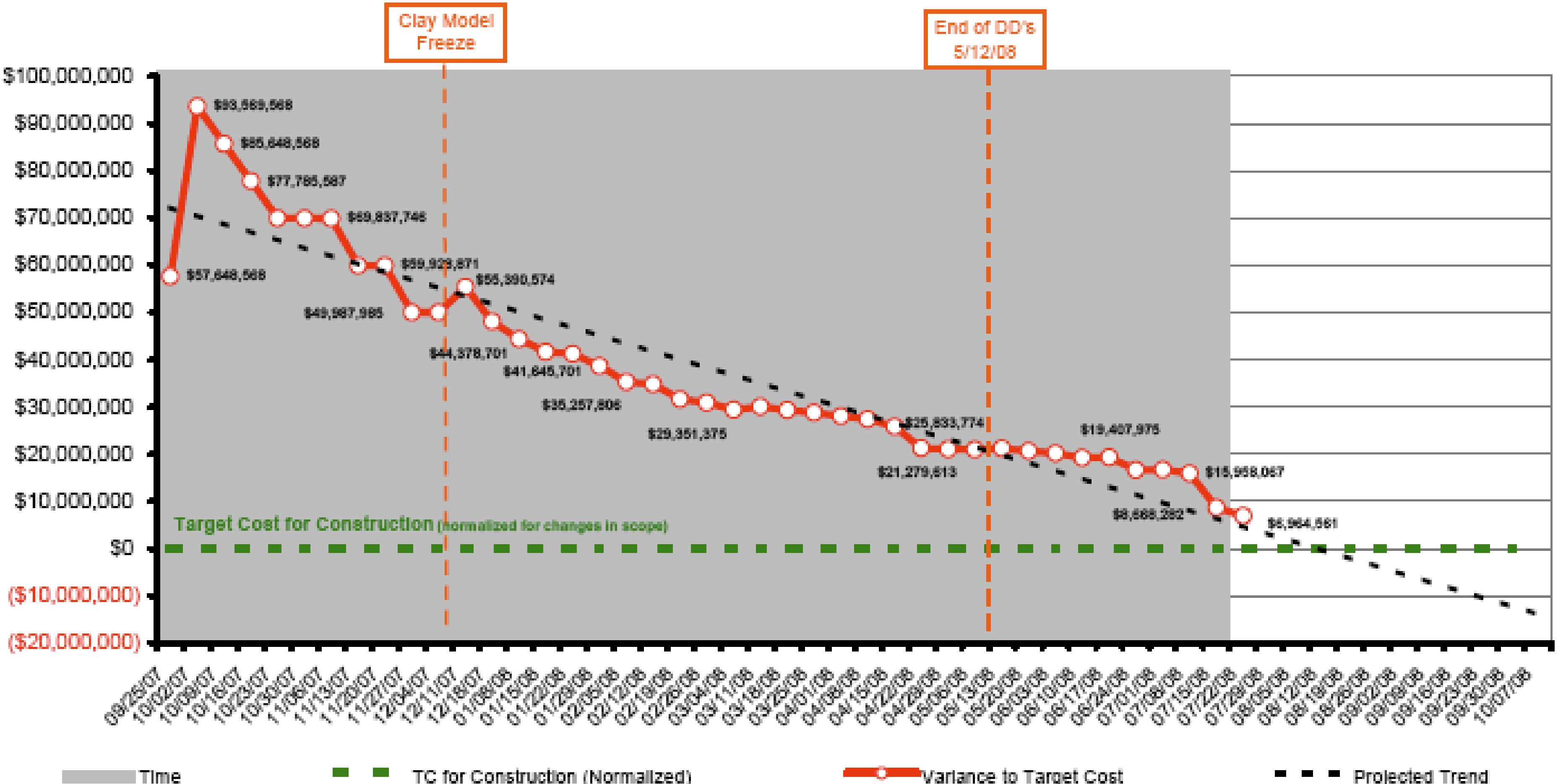
Under Budget and Ahead of Schedule

3.5 months ahead of schedule –70 additional days of clinic revenue translating into nearly $1 mil. in the expanded imaging service line functions and additional revenue in the 2006 year.

Below the budget in spite of additional equipment costs and added service line.

CPMC Cathedral Hill Hospital
TARGET VALUE DESIGN CLUSTER GROUP WEEKLY UPDATE

Construction Estimate Total - Gap Analysis to Target Cost for Construction



Set-Based Design

- “Preventing engineers from making premature design decisions is a big part of my job.” (Toyota’s Manager of Product Engineering)

Principles of Set-Based Design

1. Map the design space.
2. Integrate by intersection.
3. Establish feasibility before commitment.

Advantages of Set-Based Design

1. Enables reliable, efficient communication.
   - Vs point-based design, in which each change may invalidate all previous decisions.
2. Waste little time on detailed designs that can't be built.
3. Reduces the number and length of meetings.
4. Bases the most critical, early decisions on data.
5. Promotes institutional learning.
6. Helps delay decisions on variable values until they become essential for completion of the project.
7. Artificial conflicts and needless iterations of negotiations are avoided.
8. The initiator of a change retains responsibility for maintaining consistency.

Key Features of Lean

- The larger system is the focus of management attention, not local optimization
- Variation is attacked and reduced—variation in work load, in process durations, in product quality, in plan reliability, …
- Inventory, capacity, schedule and financial buffers are sized and located to perform their function of absorbing variability that cannot yet be eliminated
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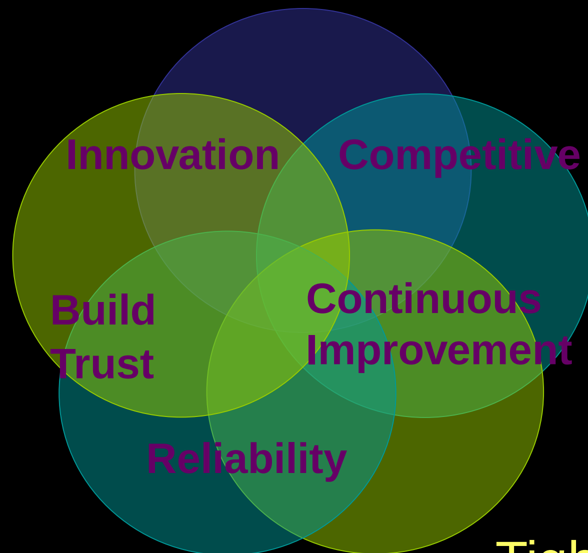

Projects as
Networks of
Commitment

Tightly Couple
Learning w/ Action

Next Steps?

1. …

Plus

- …

Delta

- …