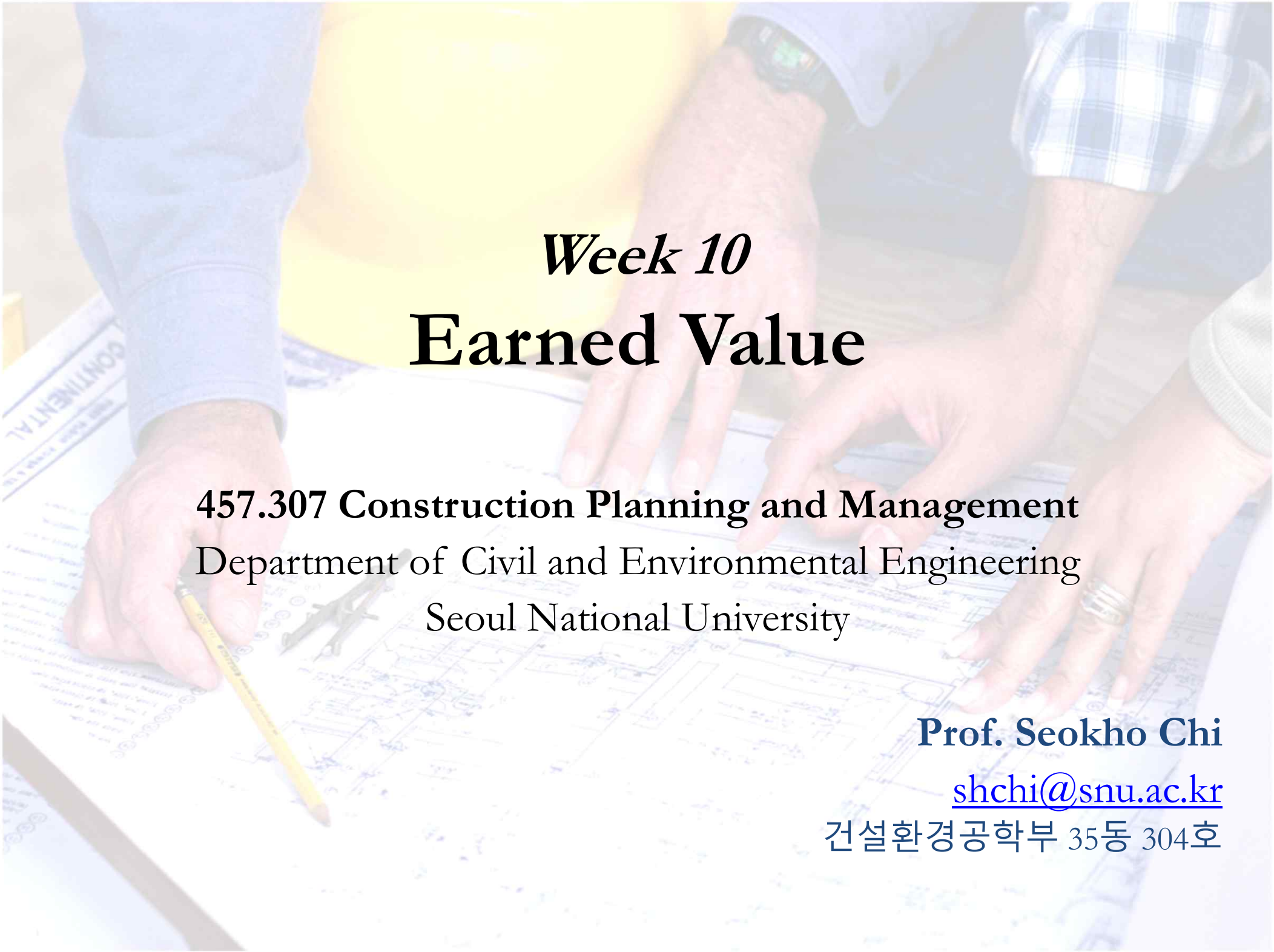


Week 10

Earned Value

457.307 Construction Planning and Management

Department of Civil and Environmental Engineering
Seoul National University

Prof. Seokho Chi

shchi@snu.ac.kr

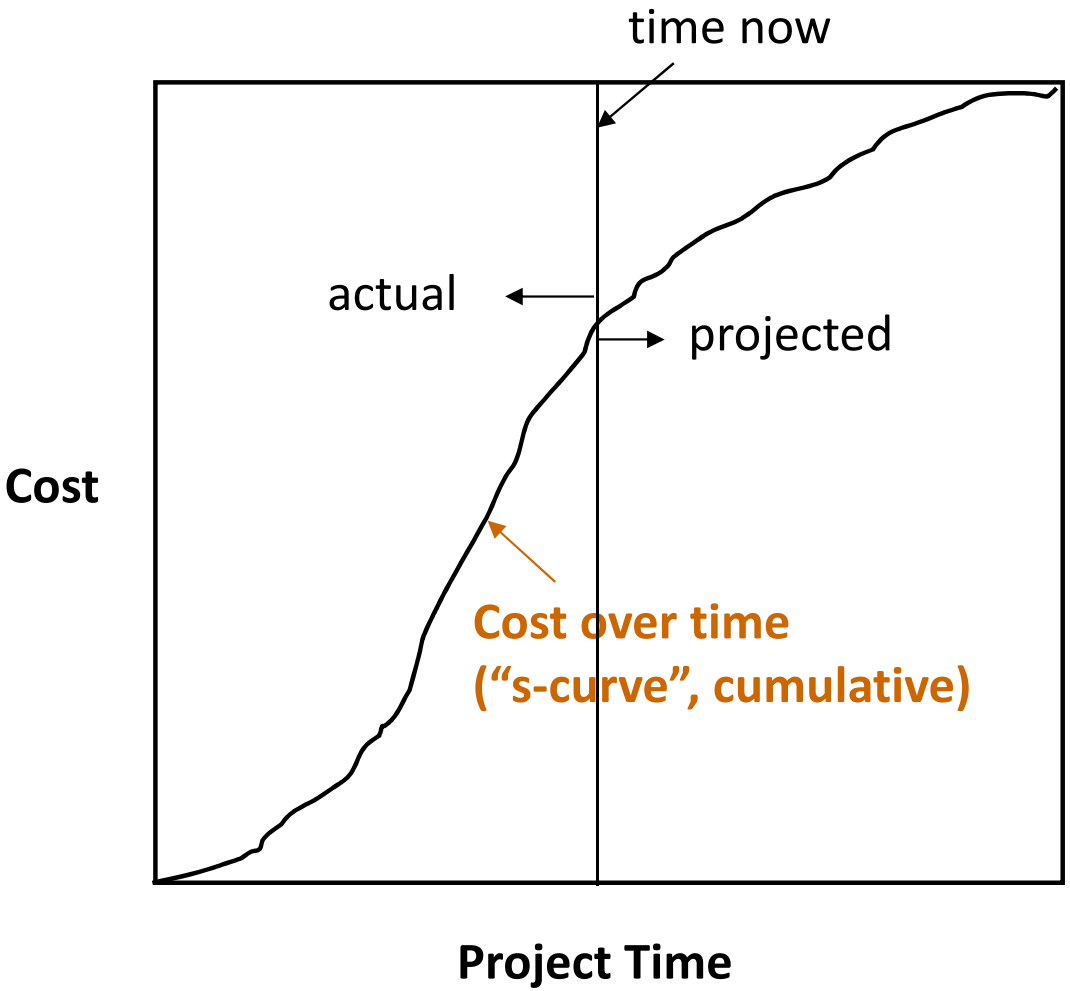
건설환경공학부 35동 304호

Earned Value Purpose

- **Monitor cost and schedule performance and progress in an integrated fashion**

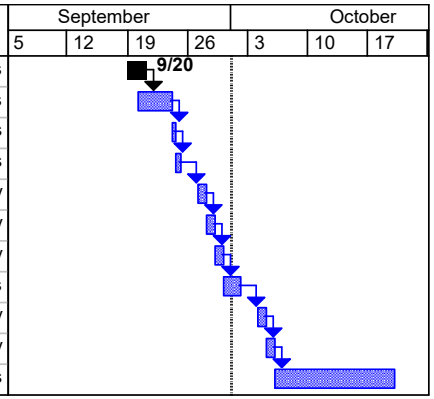
- **A contractor knows "earned" value: the *budgeted* value of completed work**
  - Budgeted: used to report to owner
  - Hence, earned value concept typically used as project control to track progress of those that work for you

Integrate Money and Time



Cost loaded schedule

ID	Task Name	Duration
1	Start Date	0 days
2	Clear & Grade Lot	4 days
3	Final Grade Check	0.5 days
4	Compaction Test	0.5 days
5	Stake Start	1 day
6	Plumbing Slab Start	1 day
7	Plumbing slab complete	1 day
8	Slab Setup	2 days
9	Slab Inspection	1 day
10	Slab pour / Finish	1 day
11	Frame	10 days

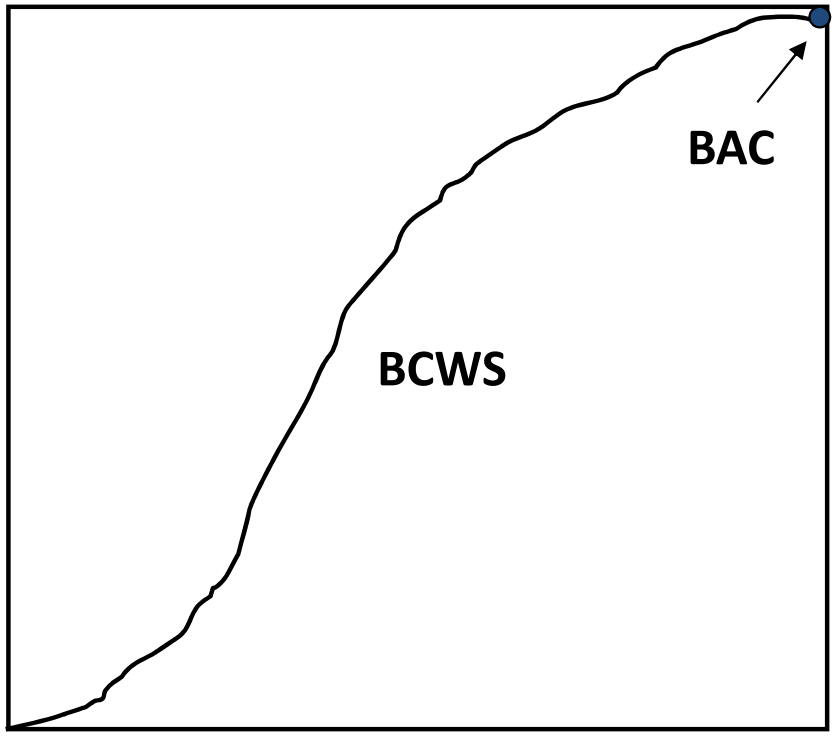


달성가치**(Earned Value):** 계획된 예산을 토대로 작업성과를 기간별로 측정하는 척도

Definitions (Metrics)

- **BCWS: Budgeted Cost o f Work Scheduled**
  - Cost loaded schedule used to generate cumulative cost curve

- **BAC: Budgeted Cost at Completion**
  - Original total estimated cost



Metrics (2)

- **BCWP: Budgeted Cost o f Work Performed**
  - Budgeted (not actual) cost of work performed to-date on project
  - BCWP = Earned Value (definition)

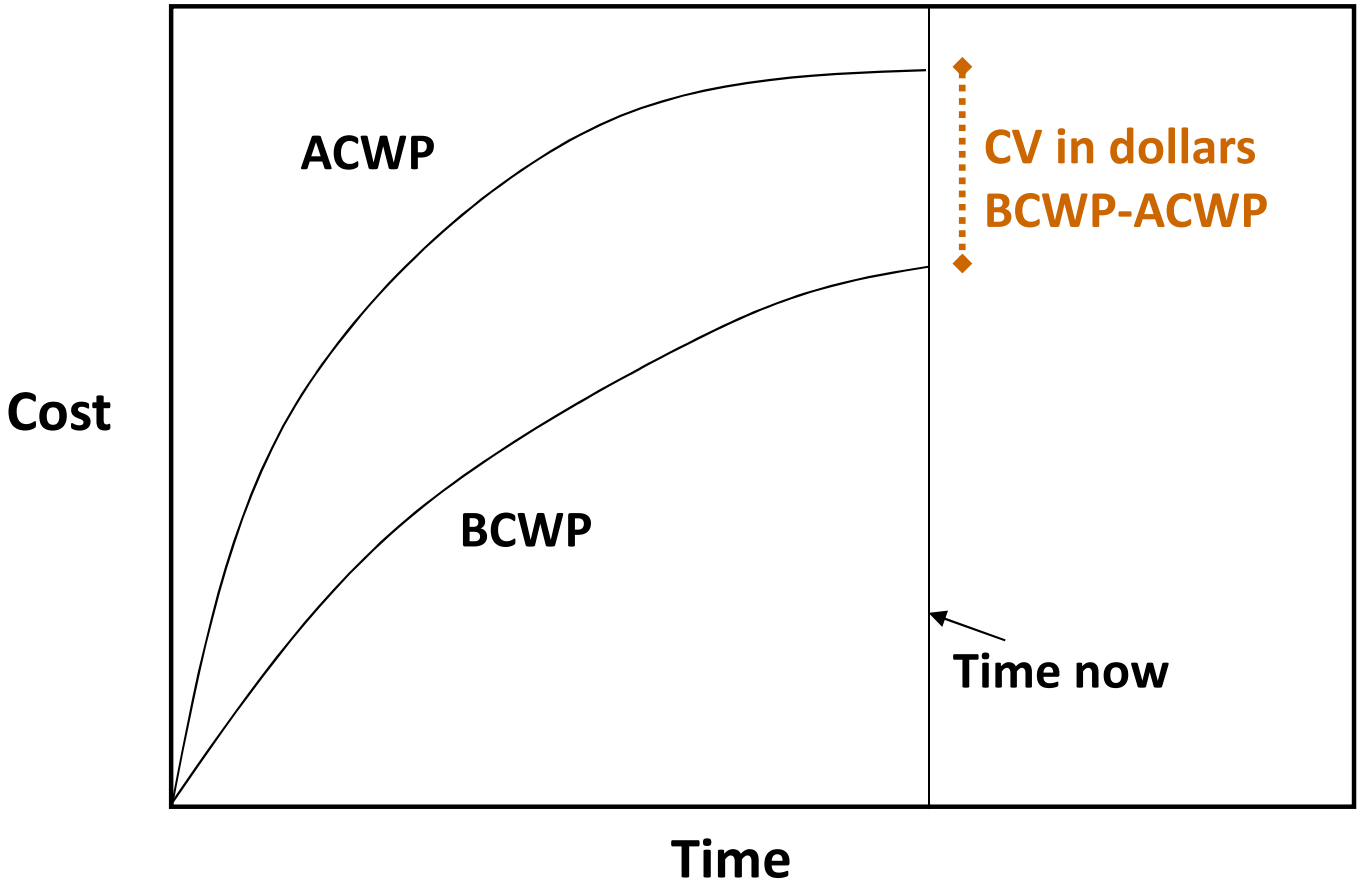
- **ACWP: Actual Cost o f Work Performed**
  - Actual (not budgeted) cost of work performed to-date on project
  - Monitor time and cost

Metrics (3) – CV

- **CV: Cost Variance = BCWP – ACWP**
  - Difference between budgeted and actual cost of work performed
  - Provided project cost status
  - CV > 0: project under budget
  - CV < 0: project over budget

- **%CV: % Cost Variance**
  - %CV = 100 x CV/BCWP

Metrics (4) – CV



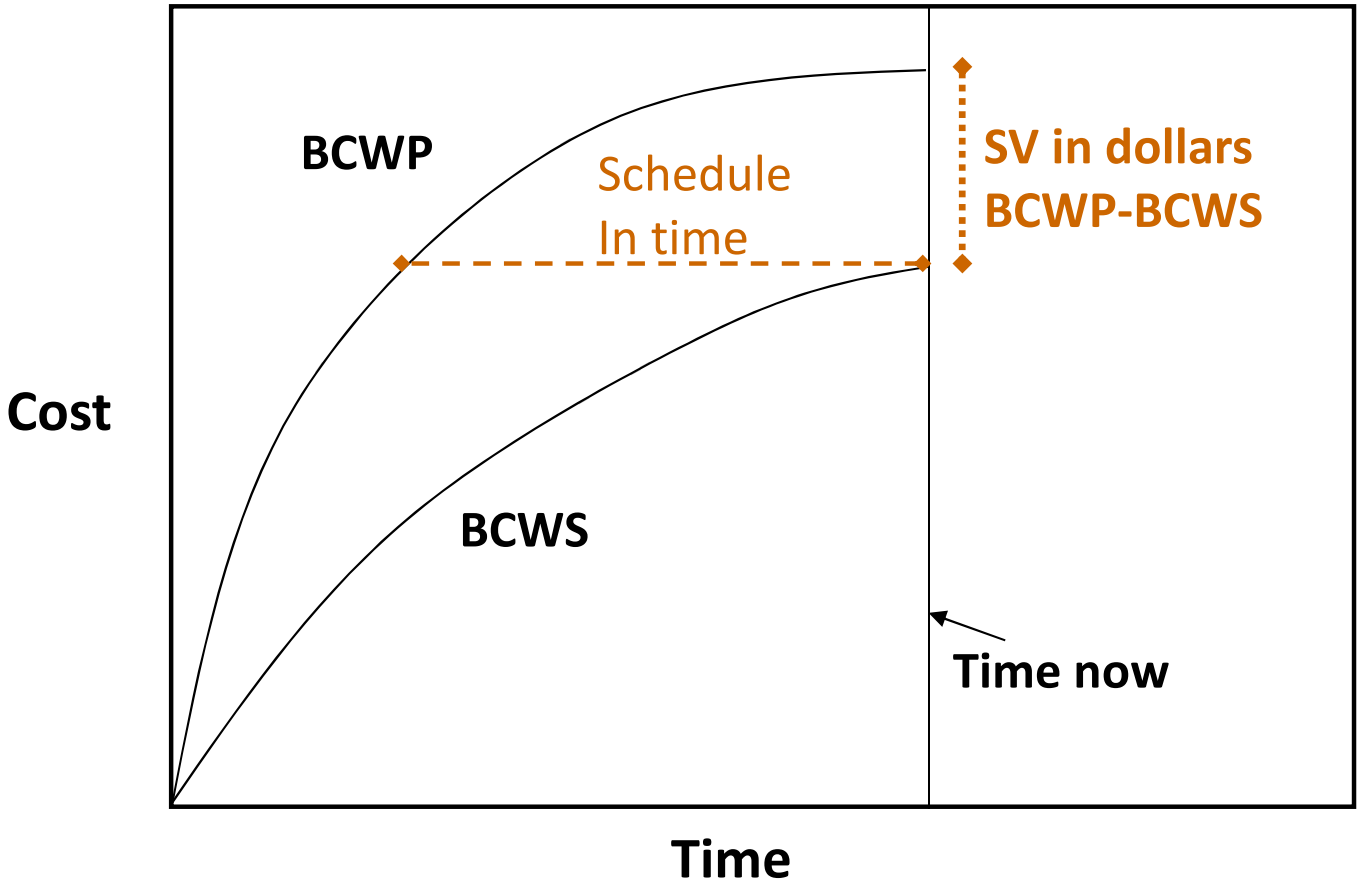
Is this project over or under budgeted cost?

Metrics (5) – SV

- **SV: Schedule Variance = BCWP – BCWS**
  - Use budgeted amount for both, so not looking at cost variance
  - Infer schedule performance from difference
  - SV > 0: ahead of schedule
  - SV < 0: behind schedule

- **%SV: % Schedule Variance**
  - %SV = 100 x SV/BCWS

Metrics (6) - SV



Is this project ahead of or behind schedule?

Metrics (7)

- **Related metrics:**
  - SPI: Schedule Performance Index (BCWP/ BCWS)
    - SPI > 1 – ahead of schedule
    - SPI < 1 – behind schedule
  - CPI: Cost Performance Index (BCWP/ ACWP)
    - CPI > 1 – under budget
    - CPI < 1 – over budget

Metrics (8)

- **PC: Percent Complete – BCWP/BAC**
  - Estimates of PC used to status each activity

- **EAC: Estimated cost at completion**
  - EAC = ACWP + (BAC – BCWP)
  - EAC = BAC + (ACWP – BCWP)
    - Is it reasonable if ACWP <> BCWP?
    - What is the assumption here?

There is no more changes.

    - What would you want to know to clarify?

Future change control

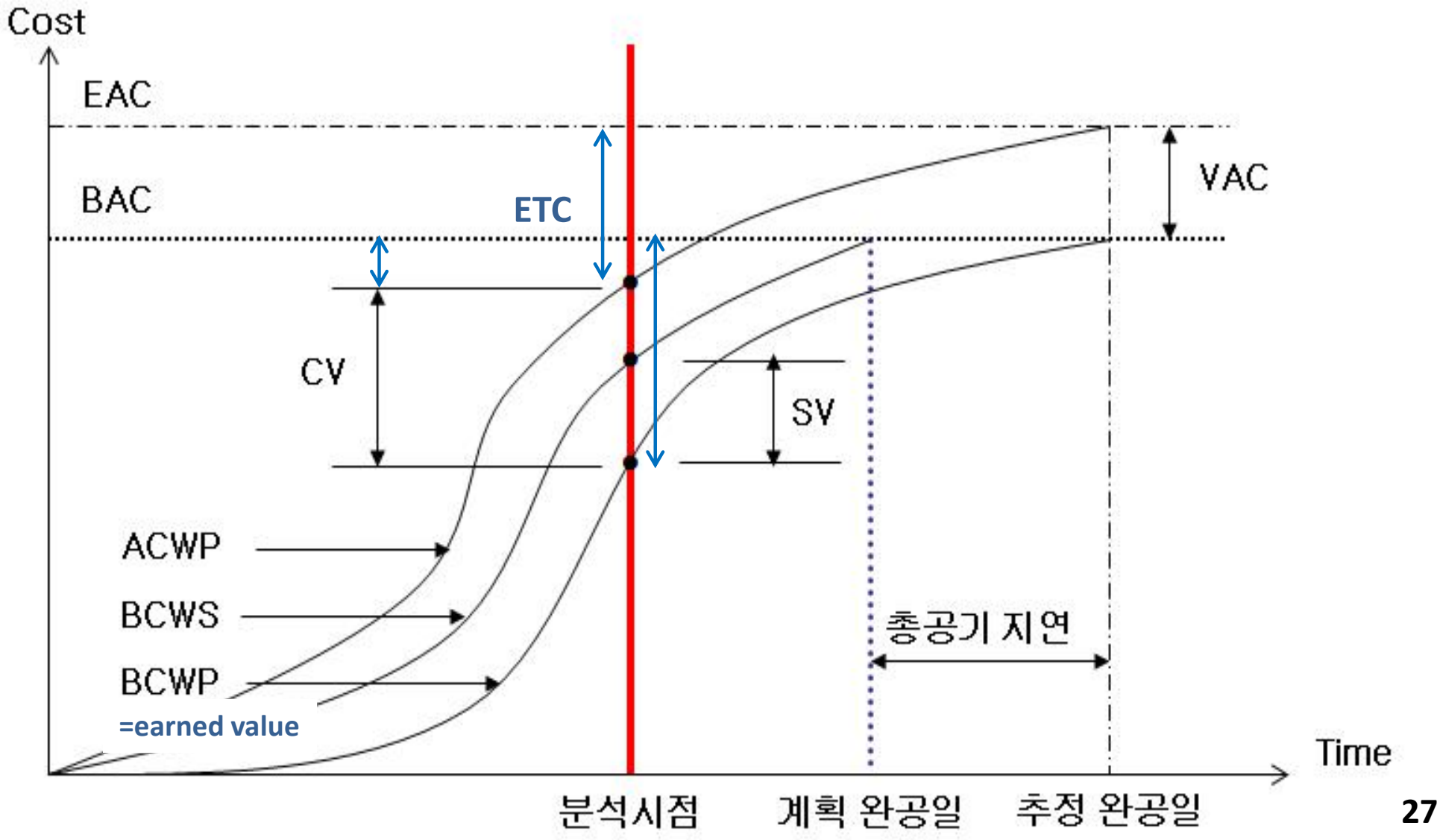
Metrics (9)

- **EAC: Estimated cost at completion**
  - $\text{EAC} = \text{ACWP} + \frac{(BAC - BCWP)}{CPI}$ **= BAC ÷ CPI**

    $= \text{BAC} \times \frac{ACWP}{BCWP}$

ETC: Estimated cost to completion

Earned Value Management



Example 1

Six month project
Current time 3.5 months
Current cost: $152,000
BAC: $257,000

Activity status
Sitework 100%
Excavation 100%
Foundation 100%
Fencing 100%
Rough electrical 100%
Framing 50%
Plumbing 75%
Paving 50%

Calculate:
ACWP, BCWP, BCWS, SV, %SV, SPI, CV, %CV, CPI, PC, EAC

Activity	Budget $	Mon1	Mon2	Mon3	Mon4	Mon5	Mon6
Sitework	$22,000						
Fencing	$10,000						
Paving	$18,000						
Excavation	$30,000						
Foundation	$50,000						
Framing	$40,000						
Rough Electric	$ 6,000						
Rough Plumbing	$16,000						
Drywall	$13,000						
Suspend Ceiling	$ 4,000						
Interior Finish	$34,000						
Carpeting	$14,000						

Example 1

- ACWP = **$152,000** (given)
- BCWS = $22,000 + $10,000 + $18,000 + $30,000 + $50,000
  + 0.5 x ($40,000 + $6,000 + $16,000) = **$161,000**
- BCWP = $22,000 + $30,000 + $50,000 + $10,000 + $6,000
  + 0.5 x ($40,000 + $18,000) + 0.75 x $16,000 = **$159,000**

- SV = BCWP – BCWS = $159,000 - $161,000 = **-$2,000**
- %SV = 100 x SV/BCWS = 100 x (-$2,000/$161,000) = **-1.2%**
- SPI = BCWP/BCWS = $159,000/$161,000 = **0.99**

Slightly behind schedule

Example 1

- ACWP = **$152,000** (given)
- BCWS = **$161,000**
- BCWP = **$159,000**

- CV = BCWP – ACWP = $159,000 - $152,000 = **$7,000**
- %CV = 100 x CV/BCWP = 100 x ($7,000/$159,000) = **4.4%**
- CPI = BCWP/ACWP = $159,000/$152,000 = **1.05**

Under budget

Example 1

- ACWP = **$152,000** (given)
- BCWS = **$161,000**
- BCWP = **$159,000**

- Percent Complete = BCWP/BAC x 100%
  = $159,000/$257,000 x 100% = **62% complete**
- EAC = BAC + (ACWP – BCWP)
  = $257,000 + ($152,000 + $159,000) = **$250,000**

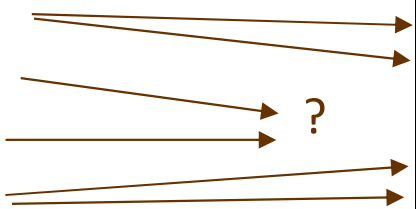
Although the project is slightly behind schedule, it is performing under budget. The project is currently at the 62% completion stage and is estimated to be completed for a revised estimated cost of $250,000, a decrease from the original estimate.

Cost Loading

- **Conceptually easy: add cost to activities**
- **Difficult because:**
  - Break apart estimates
  - Level of detail

1. One-to-many
2. No definite location
3. Where assign?

Grading 400 sf, $5k
Formwork, $8k
Rebar, $3k
Concrete, $12k



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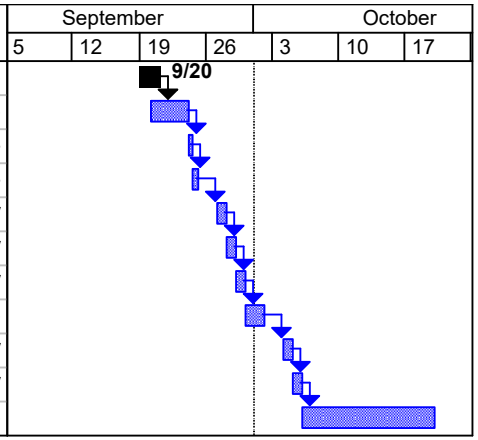
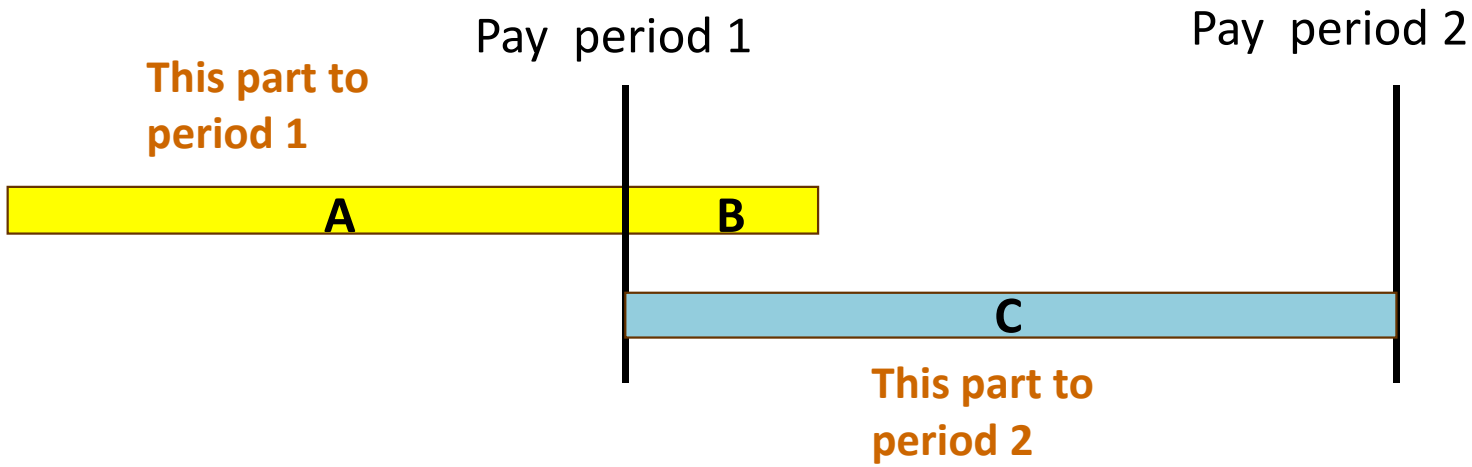
11	Frame	10 days



Calculating EV in the Real World

- In the real world, there are periodic payments (month, week)
- To account for these, apportion activity costs to pay period
  - Activity-based = A+B and C
  - Period-based = A and B+C



Key Skills

- Understand concept of Earned Value
- Know definition and use of several metrics related to earned value calculations
- Deploy metrics on project data to calculate values

Week 10

Change Management

457.307 Construction Planning and Management

Department of Civil and Environmental Engineering
Seoul National University

Prof. Seokho Chi

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Different Perspectives on Changes

"We commission hundreds of new build and refurbishment projects of various sizes every year. Many of them do not complete on time or within budget. As a result, we suffer significant losses in terms of both higher construction costs and delayed business opening."

<Client (Owner)>

"Many serious project delays can be traced to some seemingly insignificant delays that happened sometime ago somewhere upstream in the project delivery process."

<Project Manager>

<Contractor>

"We often have to delay the work on-site and even re-do the work because the drawings provided by the designers are either incomplete or inconsistent with the site conditions."

<Design Consultant>

"In many of our projects, we have to make late changes to the design because the client keeps changing their requirements. This results in a waste of staff time as high as 30% in a typical project."

<Source: Managing Changes in Construction Projects>

Construction Project Performance

- *"More than a third of major clients are dissatisfied with contractors' performance in keeping to the* ***quoted price*** *and to* ***time***, ***resolving defects***, *and delivering a final product of the* ***required quality***"

- **More than 50% of construction projects: delay, over-spending**
- **More than 30% of completed construction projects have quality defects**
- **About 30% of construction is rework**
  - Labor efficiency: 40 – 60%
  - At least 10% of materials are wasted
  - Direct costs caused by rework average 5% of total construction costs

Reasons for Change and Rework

- **Change in owner's requirements**
  - Owner will add or deduct portions of work (e.g., scope change to the contract)
  - A change order is almost always authorized for this kind of changes

- **Constructive Change**
  - The architect or owner representative causes the contractor to perform work outside the contract
  - Construction document errors, omissions

Reasons for Change and Rework

- **Differing Site Conditions**
  - Subsurface soil conditions
  - In renovation projects, the designer does not have all of the previous construction details and plans.

- **Jobsite Discovery of Hazardous Materials**
  - The contractor would notify the owner of any discovery of hazardous materials
  - The owner then needs to decide on the best way of handling the material (owner's responsibility).

Reasons for Change and Rework

- **Code Revisions by the Outside Agencies**
  - The local building code authority reviews the project after the construction contract has been awarded and requests code revisions.

**building code: a set of rules that specify the minimum acceptable level of safety for constructed objects*

e.g., code violation: this concrete block wall is penetrated by cable trays and cables. The hole should be firestopped to restore the fire-resistance rating of the wall. Instead it is filled with flammable polyurethane form.

Changes → Re-sequencing/Rework → More Time and Cost

Change Order

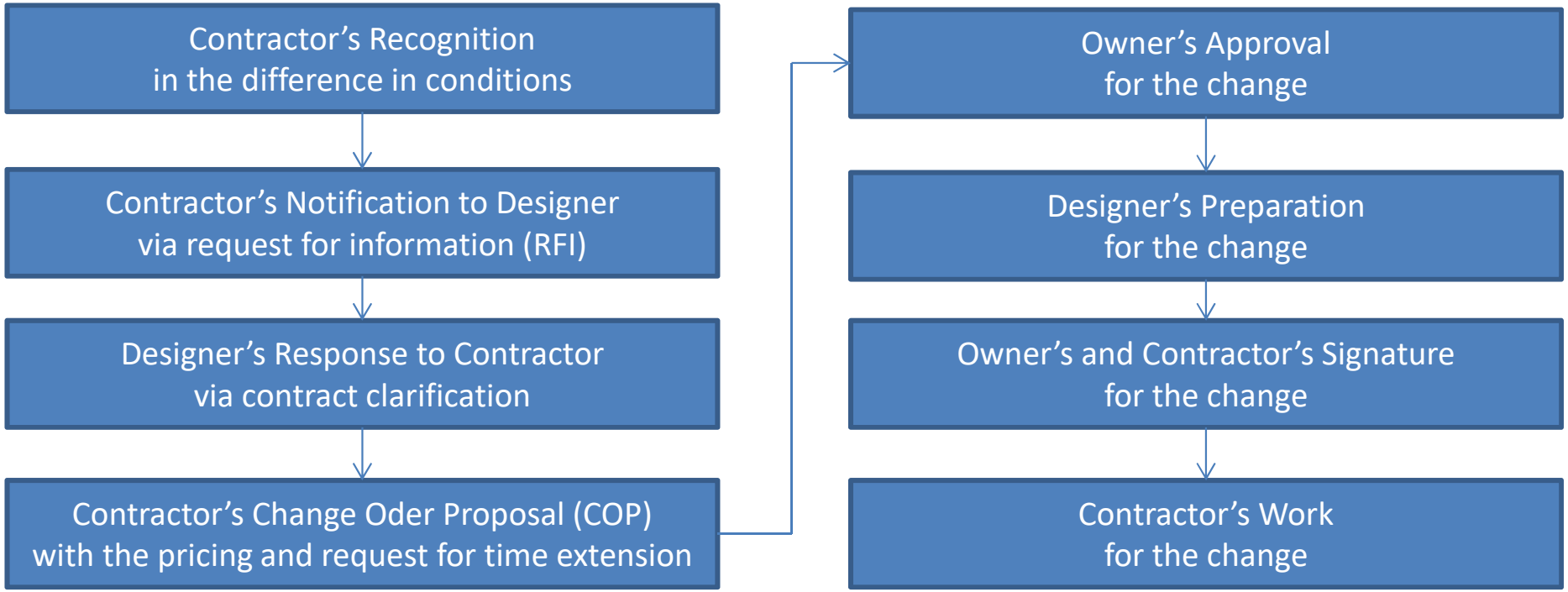
- **Change of scope or addition of work**
  - Construction contracts contain provisions allowing owners to make changes to the work by a written notice
  - Architects, engineers, and owners occasionally direct the contractor to alter the construction plan.

"The contractor's excavation subcontractor decided on using a Hydraulic Excavator for excavation of a sewer line trench. However, as construction proceeded, the owner requested that the contractor use a smaller piece of excavation equipment to minimize damage to the surrounding existing environment. Because the smaller piece of equipment was not owned by the excavating subcontractor, the rental rate exceeded the rate for the owned piece of equipment. The productivity of the smaller equipment was lower than the Hydraulic Excavator, requiring more time for the activity and resulting in higher labor costs. The excavating subcontractor requested a Change Order for an extra amount for a directed change in means and methods."

Item	Hydraulic Excavator	Rubber-tired Backhoe
Equipment	16 hrs @ $80/hr = $ 1280.	24 hrs @ $100/hr = $ 2400.
Labor	16 hrs @ $30/hr = $ 480.	24 hrs @ $ 30/hr = $ 720.
Equipment	16 hrs @ $20/hr = $ 320.	24 hrs @ $ 20/hr = $ 480.
Total Cost	$ 2080.	$ 3600.
Net Additional Cost		$ 1520.
Plus: 15% Allowable Overhead & Profit		$ 228.
Additional Cost Impact		$ 1748.

Change Order Process

- **Described in the contract document**
- **Typical change order process**
  - For different site conditions



FGH construction company

Change Order Proposal

To: _____ ***Date:*** _____

_____ ***Job No.:*** _____

_____

Subject: Notification of Change or Claim for: _____

Attn.: _____

Gentlemen:

The following ***Request for Information. No. 45*** has been determined by FGH Construction Company to be beyond the scope of our contract. You are hereby notified that this problem may create a suspension /delay of the work, increase scheduled time to complete the project, and/or cause additional cost to our work. We reserve the right to request additional time and costs for this work. This work could potentially have an adverse effect on other work being performed or that will be performed.

Description of Occurrence or Request for Information:

_____

_____

_____

_____

_____

Date of Occurrence ***On:*** _____

From: _____ ***To:*** _____

You are hereby notified of our intention to seek recovery of all extra costs, including but not limited to General Condition Expenses if this delay affects scheduled completion. It is our intent to minimize the effect of this change.

Please issue the appropriate paperwork to complete this change. Thank you.
Sincerely,

Bill Jones

Project Engineer

cc: ***Frank Canteen***

Project Manager

File CP - _____

Enclosures: _____

5390 Walnut Avenue, San Francisco,
California, 93422-0027
Phone: (415)555-2346,Fax: (415)555-2300

FGH construction company

Change Order Proposal

To: _____ ***No.*** _____

_____ ***Project:*** _____

_____ ***Date:*** _____

From: _____

_____

_____

FGH Construction Co., wishes to submit the following Change Order Proposal for the change in scope of the contract work as described:

_____

_____

_____

_____

Cost of the work:

Description :	Labor	Mat.	Equip.	Other	Sub	Total

Labor Burden _____ %
Subtotal
Bond Premium _____%
Liability Insurance _____%
Subtotal _____
Overhead _____
Profit _____

Grand Total: _____

Schedule Extension:

Calendar Days to be added to the contract time: _____

FGH Construction will proceed on this change when authorized by _____ in writing. This information is time sensitive and is valid for 10 days without review.

Signed: _____

Title: _____

5390 Walnut Avenue, San Francisco,
California, 93422-0027
Phone: (415)555-2346,Fax: (415)555-2300

CO Sample

2000 EDITION

AIA DOCUMENT G701-2000

Change Order

(Instructions on reverse side)

PROJECT: *(Name and address)*
Huna Office Building
9301 Glacier Highway
Juneau, Alaska 99801

CHANGE ORDER NUMBER: 1
DATE: November 15, 2000
ARCHITECT'S PROJECT NUMBER: 937
CONTRACT DATE: August 15, 2000
CONTRACT FOR: Construction of office building

OWNER ☒
ARCHITECT ☒
CONTRACTOR ☒
FIELD ☐
OTHER ☐

TO CONTRACTOR: *(Name and address)*
Northwest Construction Co.
1242 First Avenue
Cascade, Washington 98202

THE CONTRACT IS CHANGED AS FOLLOWS:
(Include, where applicable, any undisputed amount attributable to previously executed Construction Change Directives.)

Incorporate Change Order Proposals 1, 2, 3, 4, and 5 per attached Change Order Proposal Log

The original (~~Contract Sum~~) (Guaranteed Maximum Price) was $ 1,760,000.00

The net change by previously authorized Change Orders $ NA

The (~~Contract Sum~~) (Guaranteed Maximum Price) prior to this Change Order was $ 1,760,000.00

The (~~Contract Sum~~) (Guaranteed Maximum Price) will be (increased) (~~decreased~~)
(~~unchanged~~) by this Change Order in the amount of $ 4,623.00

The new (~~Contract Sum~~) (Guaranteed Maximum Price) including this Change Order will be $ 1,764,623.00

The Contract Time will be (~~increased~~) (~~decreased~~) (unchanged) by Zero (0) days.

The date of Substantial Completion as of the date of this Change Order therefore is June 3, 2001

NOTE: This Change Order does not include changes in the Contract Sum, Contract Time or Guaranteed Maximum Price which have been authorized by Construction Change Directive for which the cost or time are in dispute as described in Subparagraph 7.3.9 of AIA Document A201.

Not valid until signed by the Architect, Contractor and Owner.

Jensen Yorba Lott	Northwest Const.	Huna Totem
ARCHITECT *(Typed name)*	**CONTRACTOR** *(Typed name)*	**OWNER** *(Typed name)*
Norm Riley *(Signature)*	Sam Peters *(Signature)*	Robert Smith *(Signature)*
Norm Riley	Sam Peters	Robert Smith
BY	**BY**	**BY**
Nov. 15, 2000	Nov. 15, 2000	Nov. 15, 2000
DATE	**DATE**	**DATE**

The American Institute
of Architects
1735 New York Avenue, N.W.
Washington, D.C. 20006-5292

FIGURE 19–4 Change Order

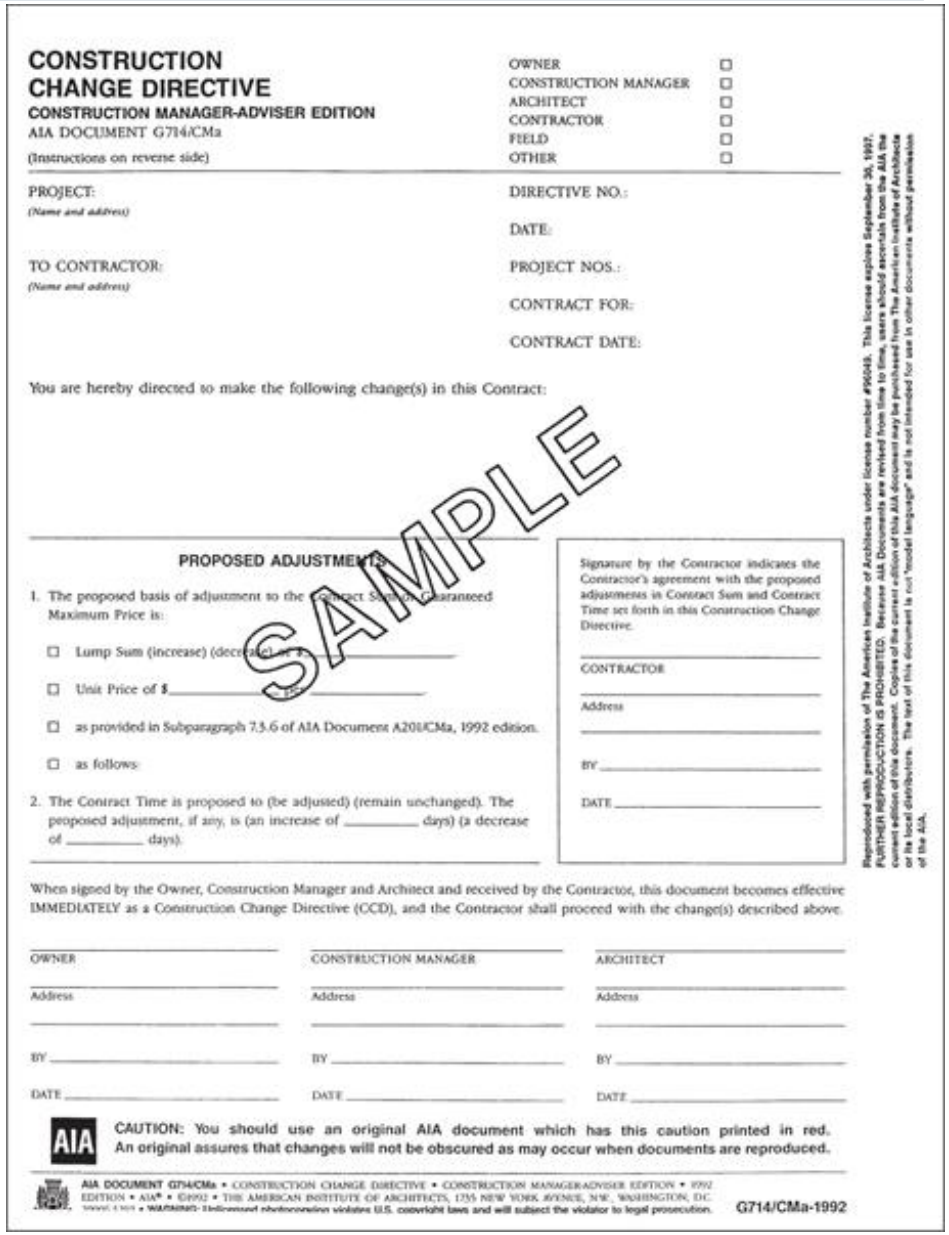
Change Order Process

- **Time is of the essence**
  - Usually takes a long time until authorization
  - All paperwork must be executed promptly and accurately
- **Changes can be initiated by any party involved**
- **If the owner and the designer disagree with the change order proposal submitted by the contractor**
  - Contractor options:
    - Revise the proposal
    - Withdraw the proposal
    - Pursue the proposal as submitted: Change proposal becomes a claim **But the contractor continuously works and the owner should pay.*

Change Order Process

- **Construction Change Directive (CCD)**
  - Written notice directing work change before a written change order
    - Used to keep work going
  - Clearly describes additional work

• Changes are needed, but the parties don't have the time to prepare the change order proposal and complete the review process;
• Changes are necessary, but the value can't be determined until a later date;
• The owner gives permission for the contractor to proceed and determine cost/schedule impacts at a later time.



CONSTRUCTION CHANGE DIRECTIVE
CONSTRUCTION MANAGER-ADVISER EDITION
AIA DOCUMENT G714/CMa
(Instructions on reverse side)

OWNER ☐
CONSTRUCTION MANAGER ☐
ARCHITECT ☐
CONTRACTOR ☐
FIELD ☐
OTHER ☐

PROJECT: (Name and address)
DIRECTIVE NO.:
DATE:
TO CONTRACTOR: (Name and address)
PROJECT NOS.:
CONTRACT FOR:
CONTRACT DATE:

You are hereby directed to make the following change(s) in this Contract:

SAMPLE

PROPOSED ADJUSTMENTS

1. The proposed basis of adjustment to the Contract Sum or Guaranteed Maximum Price is:
   - ☐ Lump Sum (increase) (decrease) of $
   - ☐ Unit Price of $ per
   - ☐ as provided in Subparagraph 7.3.6 of AIA Document A201/CMa, 1992 edition.
   - ☐ as follows:
2. The Contract Time is proposed to (be adjusted) (remain unchanged). The proposed adjustment, if any, is (an increase of _____ days) (a decrease of _____ days).

Signature by the Contractor indicates the Contractor's agreement with the proposed adjustments in Contract Sum and Contract Time set forth in this Construction Change Directive.

CONTRACTOR
Address
BY
DATE

When signed by the Owner, Construction Manager and Architect and received by the Contractor, this document becomes effective IMMEDIATELY as a Construction Change Directive (CCD), and the Contractor shall proceed with the change(s) described above.

OWNER	CONSTRUCTION MANAGER	ARCHITECT
Address	Address	Address
BY	BY	BY
DATE	DATE	DATE

AIA CAUTION: You should use an original AIA document which has this caution printed in red. An original assures that changes will not be obscured as may occur when documents are reproduced.

Documentation of Changes

- **Files should be established for every change**
  - Defined by COP: Includes all relevant documentation
  - Several change orders may be processing at the same time
    - Important to track proposals and orders
    - Change order log is used for recording

NORTHWEST CONSTRUCTION COMPANY
1242 First Avenue, Cascade, Washington 98202
(206) 239-1422

CHANGE ORDER PROPOSAL LOG

Project No.: *9821* Project Name: *Huna Office Building* Project Manager: *Ted Jones*

COP No.	Originating Document	Description	Originating Date	COP Date	Amount Requested	Date Approved	Approved Amount	CO No.	Comments
1	CCD #1	Permit documents	8/15/00	9/1/00	0	9/1/00	0	1	No impact
2		Over excavation for footings	9/15/00	10/1/00	1,500	10/10/00	1,250	1	
3	FQ #1/CCD #2	Pipe chase	10/12/00	10/27/00	4,351	11/1/00	4,351	1	in process
4	Submittal	Column rebar change	10/12/00	10/15/00	222	11/15/00	222	1	
5	Submittal	Carpet manufacture change	10/12/00	11/1/00	-1,200	11/1/00	-1,200	1	
6		Toilet accessory backing	11/1/00	11/15/00	475	NA	NA	NA	Rejected
7	FQ #3	Beam and duct conflict	11/1/00						
8	CCD #3	Low voltage light controls	11/15/00	12/1/00	3,500	12/1/00	3,600	2	

FIGURE 19–3 Change Order Proposal Log

Week 10

Project Closeout

457.307 Construction Planning and Management

Department of Civil and Environmental Engineering
Seoul National University

Prof. Seokho Chi

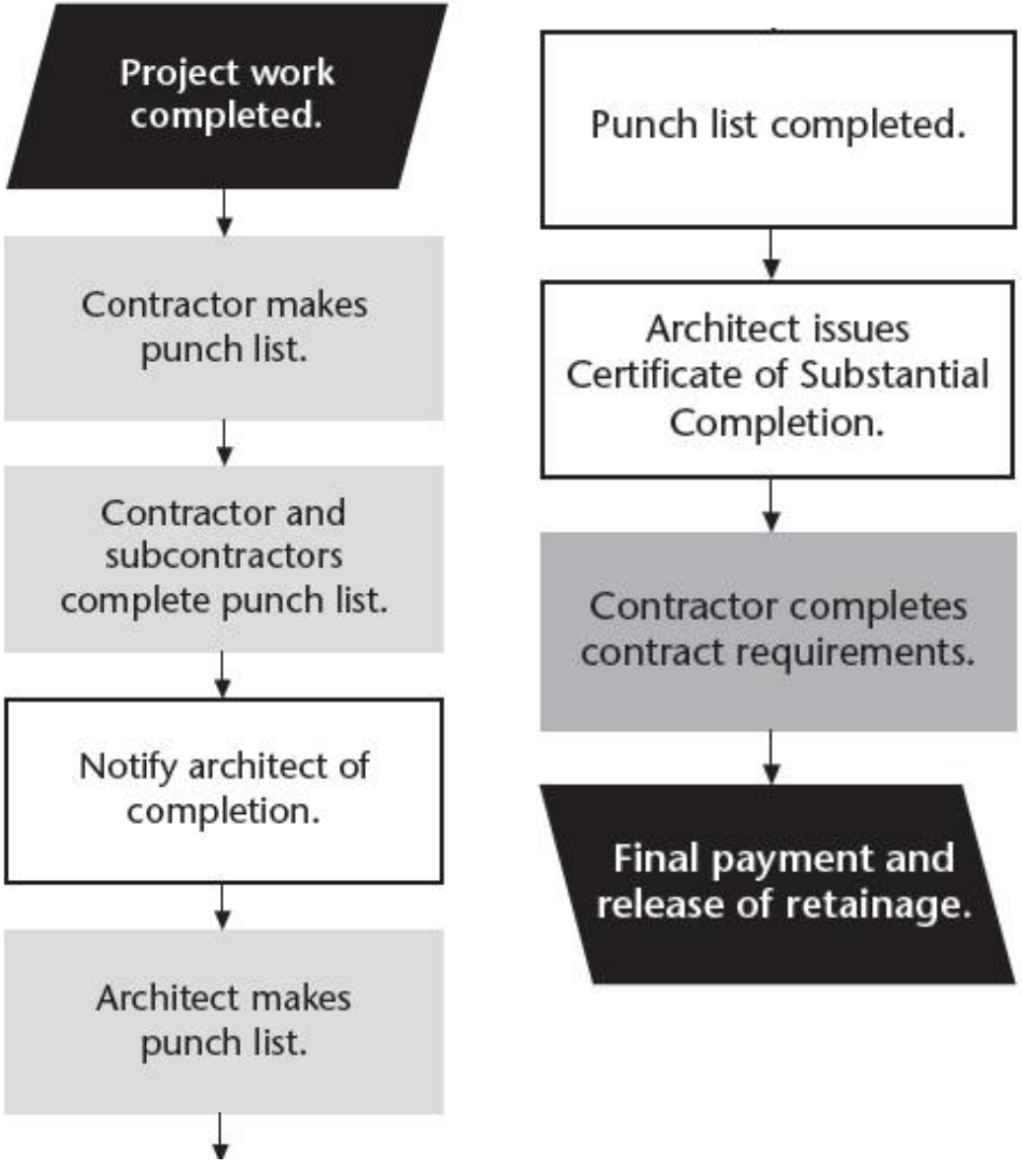
shchi@snu.ac.kr

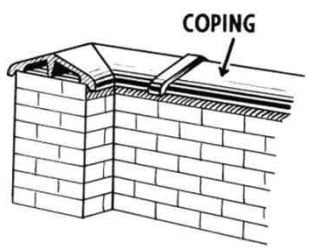
건설환경공학부 35동 304호

Project Closeout

- **Process of completing a construction project**
  - Contractual requirements, approvals, financial resolution, and documentation
    - Minor details
    - Late material and equipment delivery
    - Replacement of defective materials, equipment, etc.
    - Repairs
    - Testing and approval of building/infrastructure systems

Closeout Process





Punch List

- A sheet of paper posted on each door or in every room
- Managed by a log form

ROOM 1065
OFFICE
POSTED 6/27/10

Item	Gen. Cont. Complete	Architect Approval	Remarks
Rubber base	6/29/10	7/5/10 *MDA*	
Replace defective faucet @ sink	6/30/10	*7/6/10*	
Install Folding Door			Delivery scheduled for 7/10/10
Replace cracked outlet plate	6/29/10	7/6/10 *JLD*	
Touch-up paint, west wall	6/29/10		*Not acceptable 7/5/10 MDA*

Item #	Location	Item	Response	Completed Date	Completed Init	Approval Date	Approval By	Remarks
I A	General	Final clean	XYZ	7/5/10	RTZ	7/10/10	ALS	
I B	General	New filters	ABC Mech.	7/6/10	RTZ	7/10/10	ALS	
I C	General	Waste Rem.	XYZ	7/6/10	RTZ	7/10/10	ALS	
II A 1	West Ext.	Splash block	XYZ	7/6/10	RTZ	7/10/10	ALS	
II A 2	West Ext.	Caulking	A-1 Sealants	7/9/10	RTZ	7/10/10	ALS	
II B 1	North Ext.	Paint Coping	Steve's Painting	7/9/10	RTZ	7/10/10	ALS	
II C 1	East Ext.	Ovhd. door	Doors, Inc.					Scheduled: 7/13/10

Certificate of Substantial Completion

- ***Point when the designer has determined that the facility or a portion of the facility is acceptable for owner use and occupancy***
- **Contents**
  - Project identification
  - Description of the project completed
  - Definition of substantial completion
  - List of remaining responsibilities
  - List of warranty dates
  - Signature
  - List of agreements

Inspection

- **Final inspection must be issued prior to the owner occupying the facility**

- **Inspection agencies**
  - Plumbing
  - Electrical
  - HVAC equipment
  - Elevator
  - Public works (for roads)
  - Planning compliance
  - Fire protection systems
  - Fire alarm
  - Environmental/storm water drainage
  - Health department: sewage systems
  - ADA (the American with Disabilities Act) requirements: handicapped access

System Testing and Documentation

- **Building systems are tested for compliance to specifications**
  - Mechanical and electrical
- **Information to be documented**
  - Date and location of test
  - System or equipment tested
  - Method of testing
  - Results of the test
  - Witnesses to the test, signed by each
- **O&M manuals**

Test	System	Date	Method	Results	Tested by	Witnessed
Fire Protect.	Fire Alarm, Fire Sprinkler	6/3/10	Alarm, Smoke	OK	John Smith Fire Marshall	JLS
Plumbing Vents, Drains	Plumbing	3/23/10	Hydrostatic Pressure	OK	Fred Johnson Plumbing Inspector	FCJ
Pumps	Plumbing, Fire Sprinkler	5/2/10	Pressure, Flow	OK	Ole Olsen Pump Rep.	OO
Fans	HVAC	5/10/10	Speed, Blade angle	OK	N.T. Jones Fan Rep.	NTA
Temperature Controls	HVAC	5/13/10	Calibration, computer chk	OK	R.T. Andrews Temp. Cont. Rep.	RTA
Elevator	Elevator	4/2/10 5/8/10	Complete	No OK	O. McCarthy State Elevator Inspector	OJM