Managing Scientific Projects

Part ②

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ESIPAP 2014

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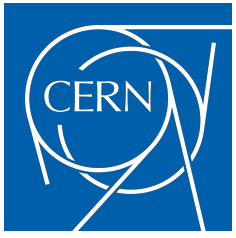

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Project Planning

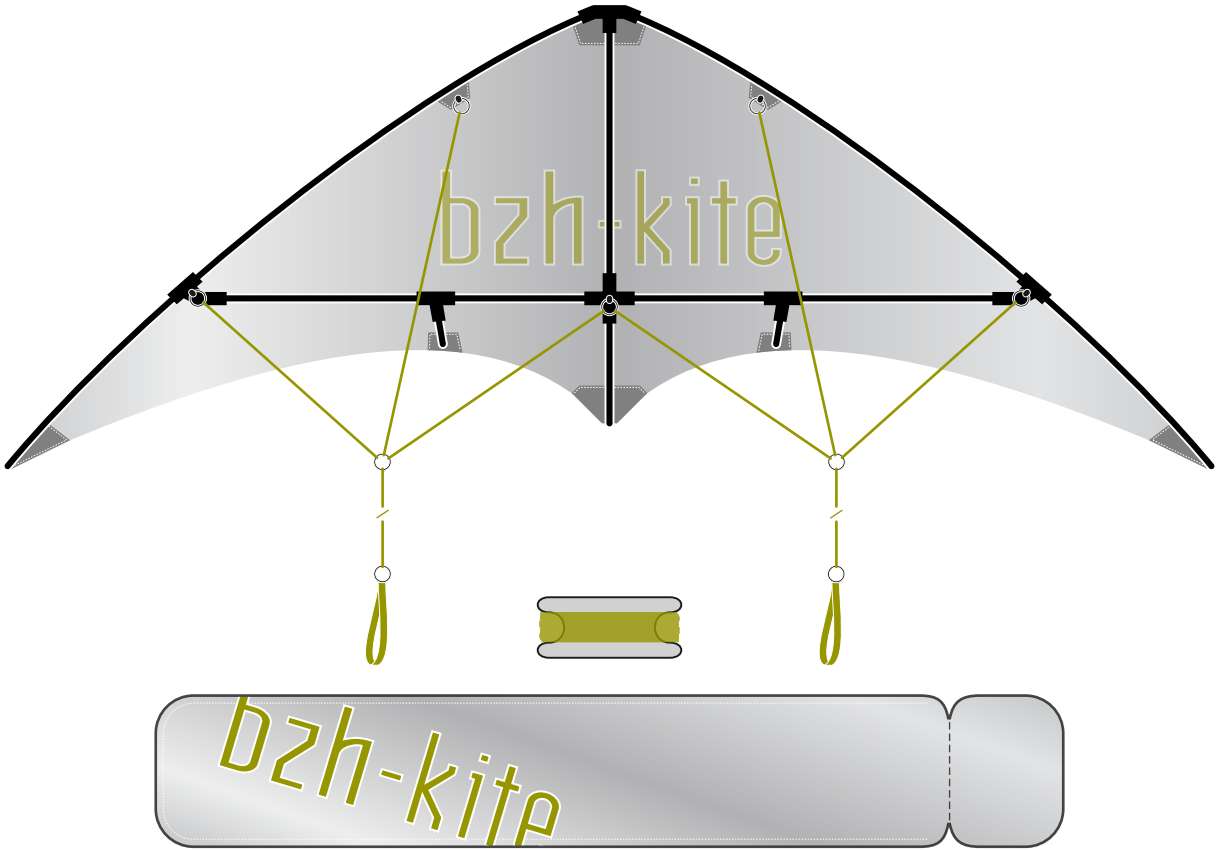
The US approach to WBS making.

1. Break down the project into key phases
2. Break down the deliverable into systems
3. Continue further down to sub-systems,
   then to sub-sub-systems, then to sub-sub-sub-systems,
   then to sub-sub-sub-sub-systems, then to sub-sub-sub-sub-sub-systems...
4. Then identify activities, that can also be called
   Work Packages (WP) or Work Units (WU)
   at project coordination level.

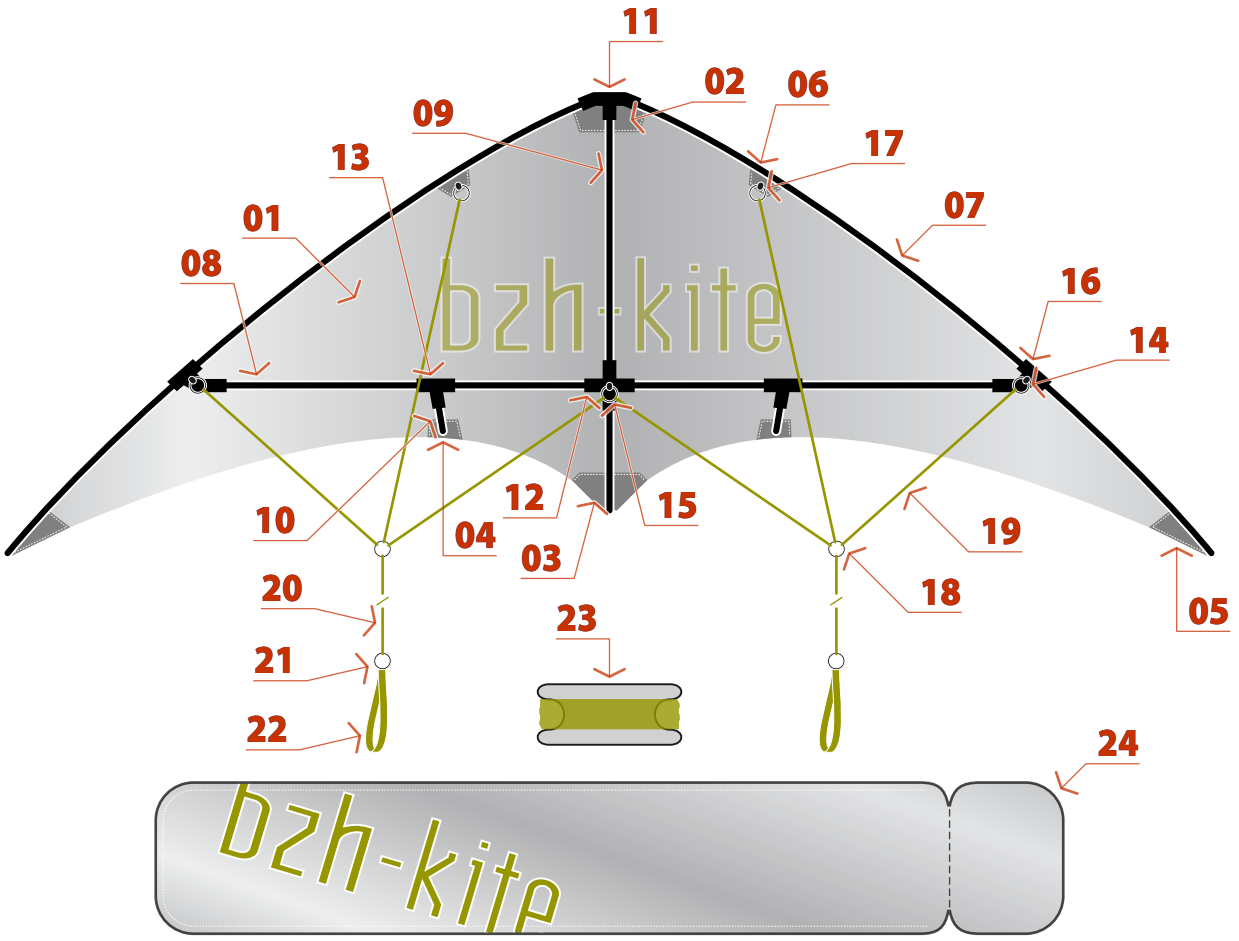
The EU approach to WBS making.

1. Break down the project expected outcome into sub-systems, components… down to **elementary components**
   ⇢ **PBS** (Product Breakdown Structure)
2. Derive the **higher levels** of the **WBS** (Work Breakdown Structure) from this PBS (that can be slightly refurbished)
   ⇢ **WBS - top nodes**
3. Matrix the higher levels of the WBS with a list of **generic activities** to dimension a portfolio of Activities / Work Packages / Work Units
   ⇢ **WBS - matrix**
4. Give a **unique label** to each of the Activities identified that way
   ⇢ **Activity list** / **Work Unit Portfolio** / Dictionary of activities.

Breizh-Sports → *bzh-kite* development project.



Breizh-Sports *bzh-kite* development project.



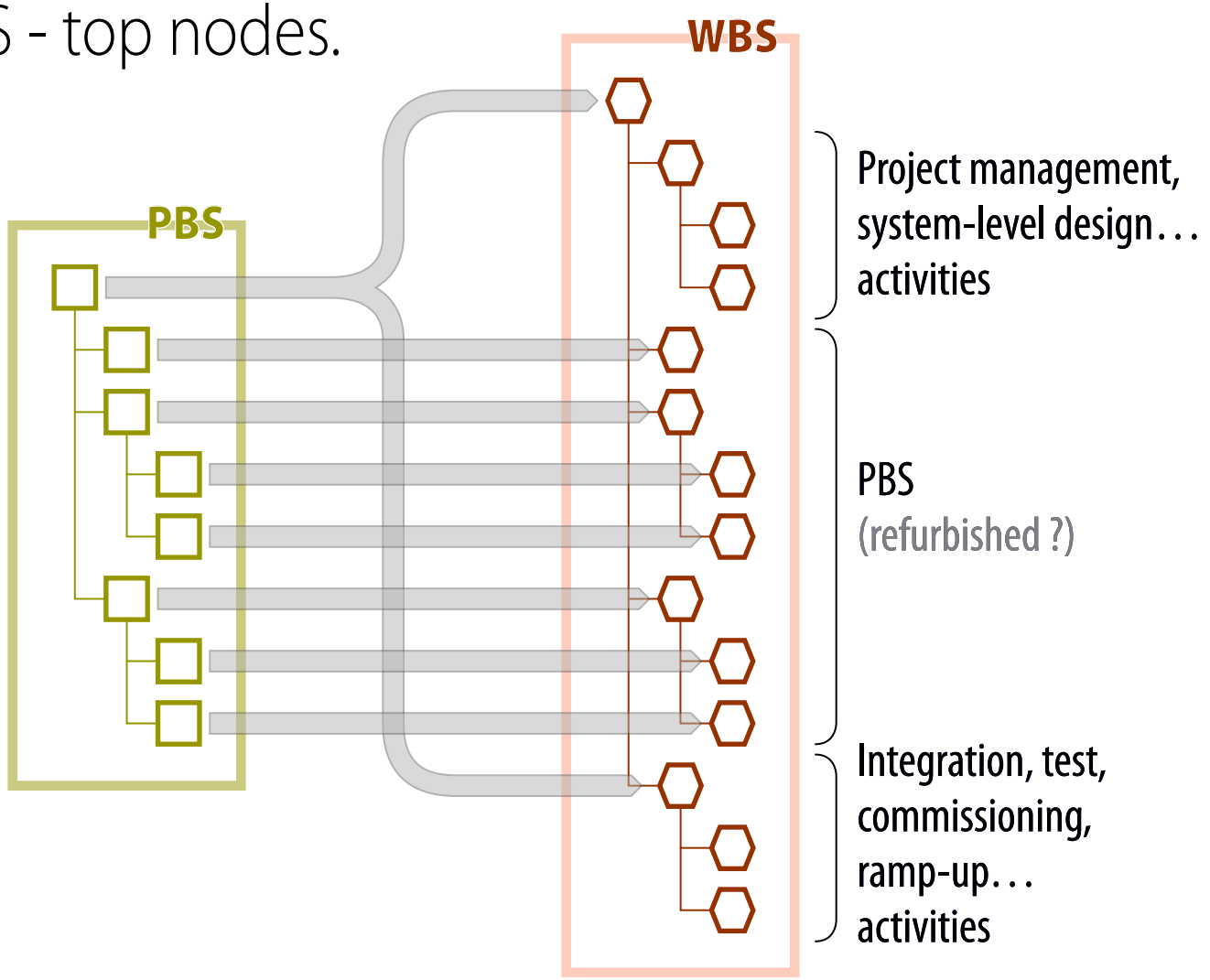
ID	Component description	Qty	Component specification
01	Wing surface (canopy)	1	1800 mm × 700 mm ; 0.5 m^2 ; Polyamide 5.5 nylon
02	Nose reinforcement piece	1	Reinforced polyamide nylon
03	Tail reinforcement piece	1	Reinforced polyamide nylon
04	Wisker reinforcement piece	2	Reinforced polyamide nylon
05	Wing end reinforcement piece	2	Reinforced polyamide nylon
06	Wing side reinforcement piece	2	Reinforced polyamide nylon
07	Wing side yard	2	Ø6 mm × 1100 mm ; carbon rod
08	Rear yard	2	Ø6 mm × 600 mm ; carbon rod
09	Longitudinal yard	1	Ø6 mm × 550 mm ; carbon rod
10	Wisker	2	Ø6 mm × 120 mm ; carbon rod
11	Nose yard junction tee	1	Cycolac ABS
12	Central cross	1	Cycolac ABS
13	Wisker junction tee	2	Cycolac ABS
14	Wing side junction tee	2	Cycolac ABS
15	Central tying ring	1	Ø10 mm × 0.4 mm^2 ; stainless steel
16	Wing end tying ring	2	Ø10 mm × 0.4 mm^2 ; stainless steel
17	Wing side tying ring	2	Ø10 mm × 0.4 mm^2 ; stainless steel
18	Line attachment ring	2	Ø10 mm × 0.4 mm^2 ; stainless steel
19	Tie	6	0.1 mm^2 × ca. 800 mm ; nylon rope
20	Line	2	0.15 mm^2 × ca. 800 mm ; nylon rope
21	Handle ring	2	Ø20 mm × 1 mm^2 ; stainless steel
22	Handle	2	20 mm width nylon strap
23	Line winder	1	Cycolac ABS
24	Storage bag	1	Transparent nylon

ID	Component description		Qty	Component specification
01	Wing surface (canopy)	Fabrics	1	1800 mm × 700 mm ; 0.5 m^2 ; Polyamide 5.5 nylon
02	Nose reinforcement piece		1	Reinforced polyamide nylon
03	Tail reinforcement piece		1	Reinforced polyamide nylon
04	Wisker reinforcement piece		2	Reinforced polyamide nylon
05	Wing end reinforcement piece		2	Reinforced polyamide nylon
06	Wing side reinforcement piece		2	Reinforced polyamide nylon
07	Wing side yard	Carbon rods	2	Ø6 mm × 1100 mm ; carbon rod
08	Rear yard		2	Ø6 mm × 600 mm ; carbon rod
09	Longitudinal yard		1	Ø6 mm × 550 mm ; carbon rod
10	Wisker		2	Ø6 mm × 120 mm ; carbon rod
11	Nose yard junction tee	Moulded ABS parts	1	Cycolac ABS
12	Central cross		1	Cycolac ABS
13	Wisker junction tee		2	Cycolac ABS
14	Wing side junction tee		2	Cycolac ABS
15	Central tying ring	Rings (COTS)	1	Ø10 mm × 0.4 mm^2 ; stainless steel
16	Wing end tying ring		2	Ø10 mm × 0.4 mm^2 ; stainless steel
17	Wing side tying ring		2	Ø10 mm × 0.4 mm^2 ; stainless steel
18	Line attachment ring		2	Ø10 mm × 0.4 mm^2 ; stainless steel
19	Tie	Rope & strap	6	0.1 mm^2 × ca. 800 mm ; nylon rope
20	Line		2	0.15 mm^2 × ca. 800 mm ; nylon rope
21	Handle ring		2	Ø20 mm × 1 mm^2 ; stainless steel
22	Handle		2	20 mm width nylon strap
23	Line winder		1	Cycolac ABS
24	Storage bag	Storage bag	1	Transparent nylon

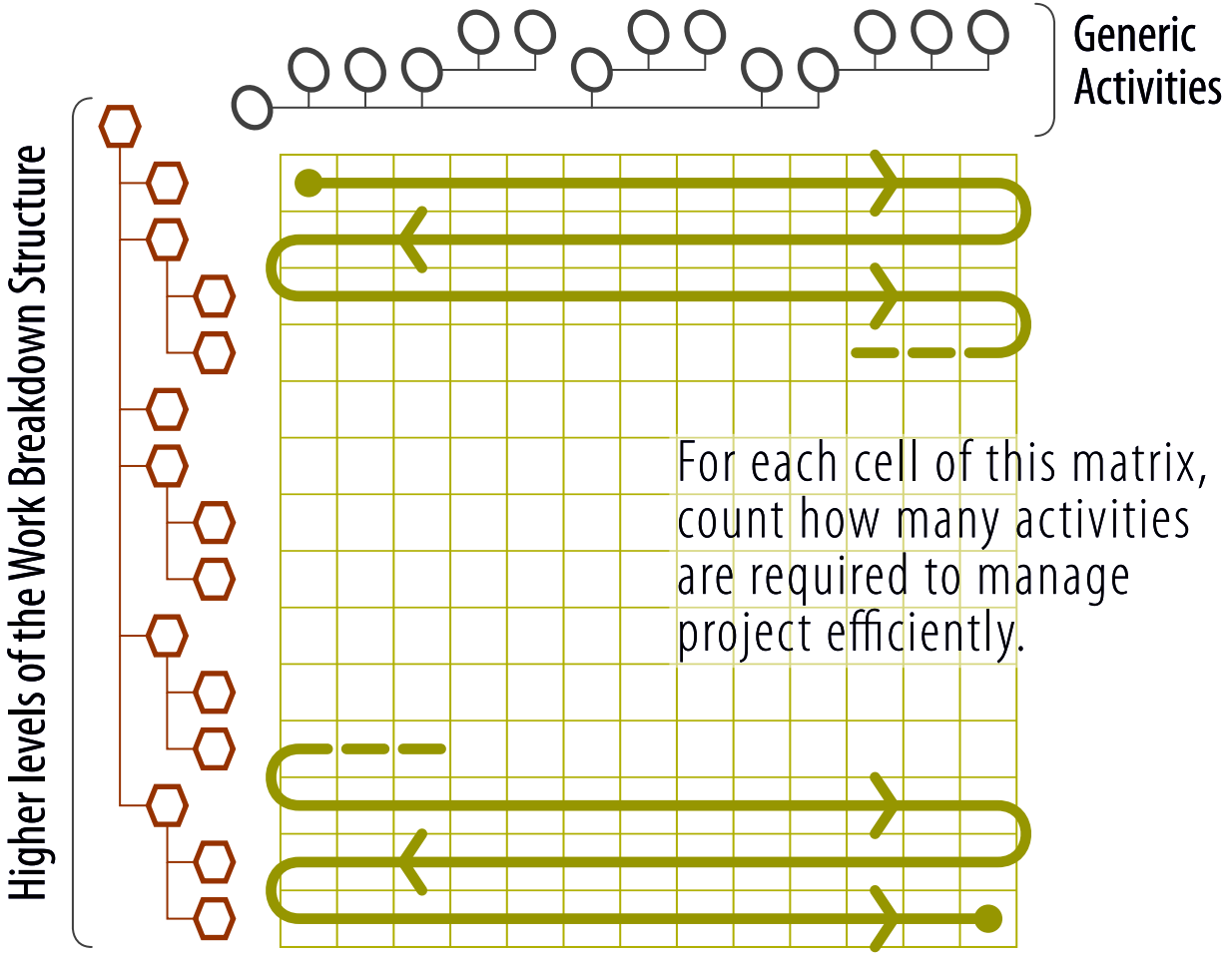
Breizh-Sports → *bzh-kite* PBS.

- ***bzh-kite***
  - Fabrics
  - Carbon rods
  - Moulded ABS parts
  - Rings (COTS)
  - Rope & strap
  - Storage bag
  - User's guide & safety instructions

PBS → WBS - top nodes.

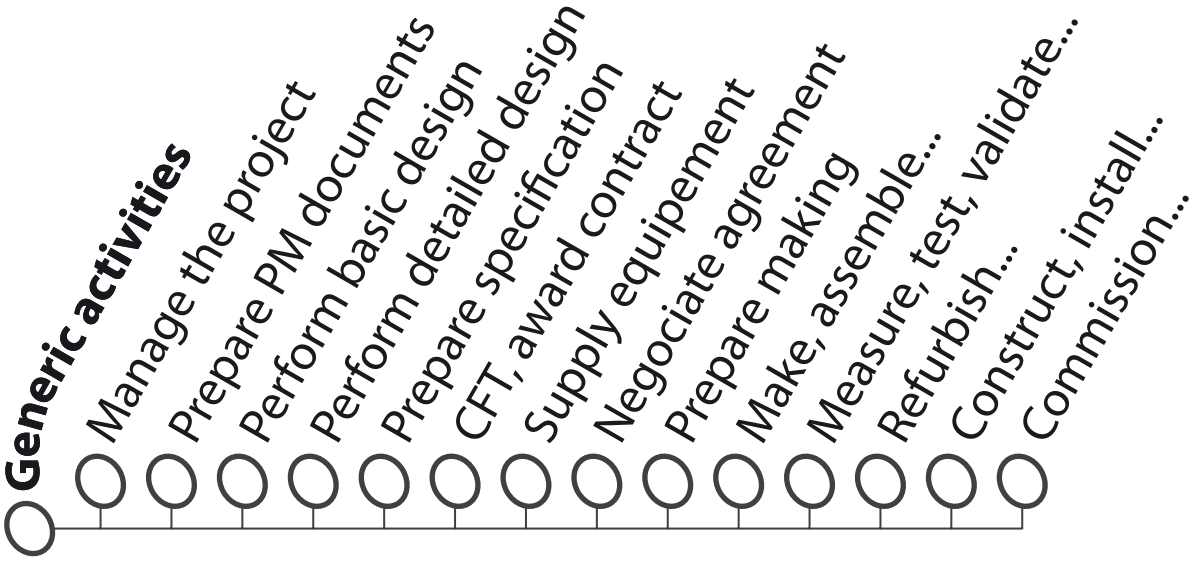


WBS matrix.


Generic Activities
Higher levels of the Work Breakdown Structure
For each cell of this matrix, count how many activities are required to manage project efficiently.

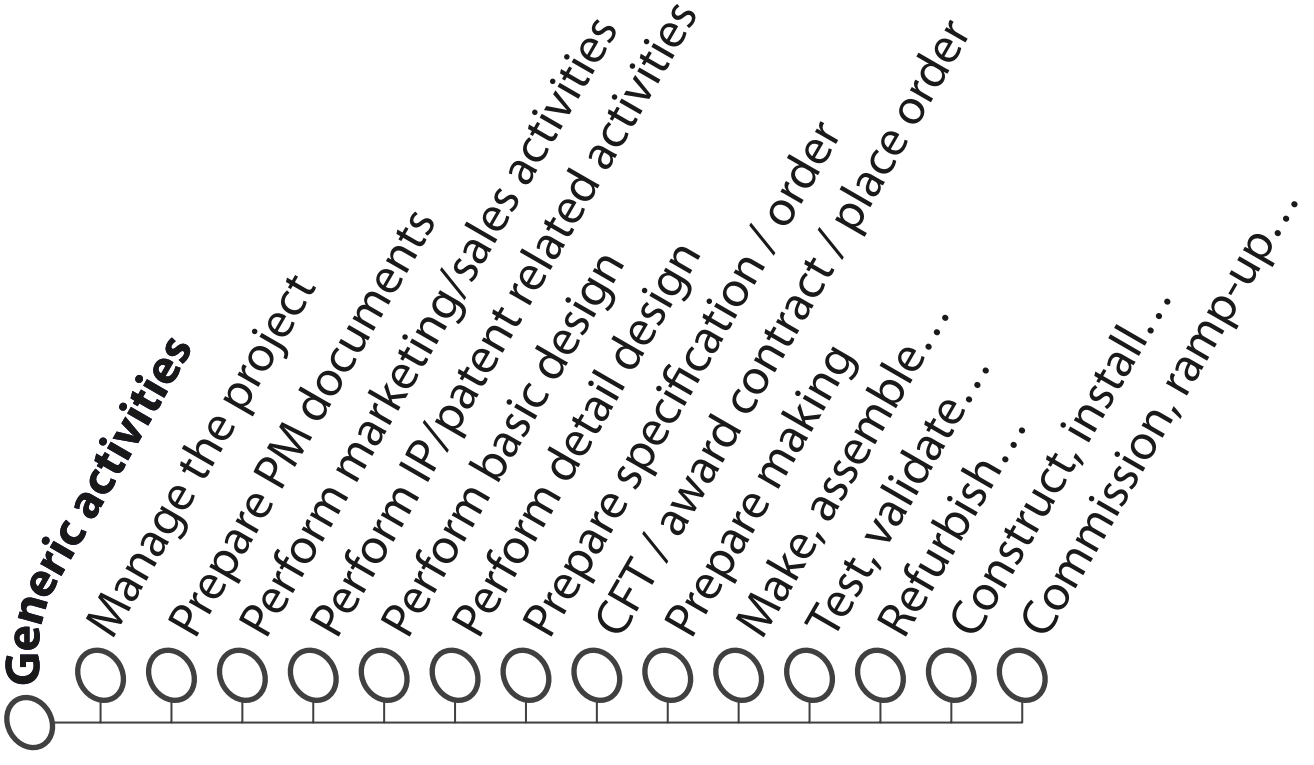
Generic activities.

Example of generic activities suited to a construction project.



Generic activities.

Example of generic activities suited to a NPD project.



Generic activities ⇢ Perform marketing/sales activities.

- Refine/update/simulate product planning
- Develop marketing/sales/ASS plans
- Design and develop launch materials, promotion materials
- Facilitate field testing
- …

Generic activities ⇢ *Perform basic (system-level) design.*

- Define major sub-systems and interfaces ⇢ engineering specs
- Performs calculations at system, sub-systems level
- Refine industrial design
- …

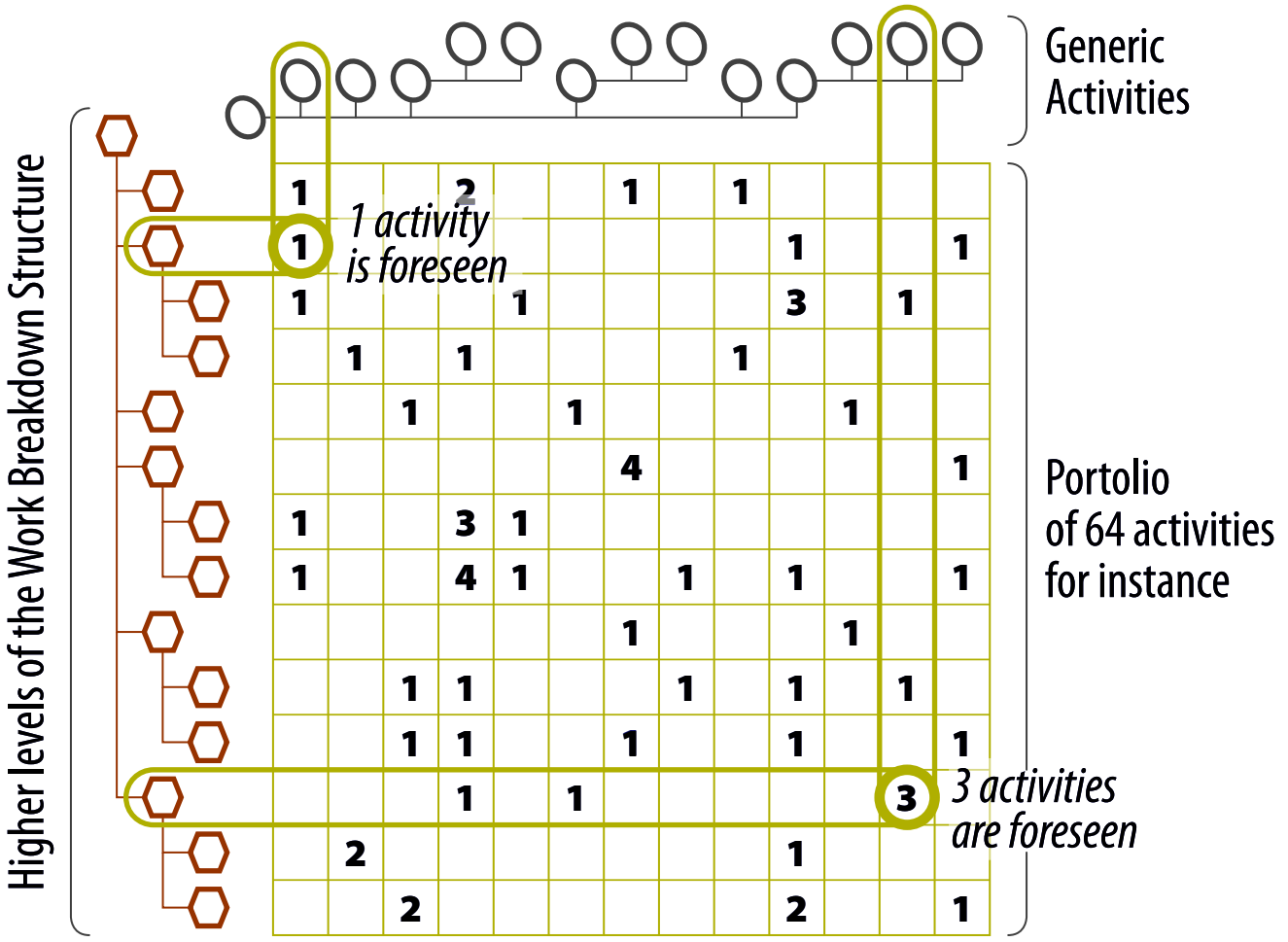
- Identify suppliers for key components, define the supply-chain
- Perform make-buy analysis, set target costs
- Define manufacturing/assembly scheme ⇢ process diagram
- Design manufacturing/assembly ⇢ plant layout
- …

Generic activities ⇢ *Perform detail (component-level) design.*

- Define geometry, manufacturing/assembly tolerances
  ⇢ engineering drawings
- Choose materials
- Design electronics
- …

- Define/design equipment, fixture, tooling
- Define manufacturing/assembly quality assurance/control systems
- …

WBS matrix.


Generic Activities
Higher levels of the Work Breakdown Structure
1 activity is foreseen
Portolio of 64 activities for instance
3 activities are foreseen

WBS matrix.

Why such an approach to set up the activity portfolio of the project?

- ***Reason #1.*** Because lessons learned has shown that, whatever its size (NPD projects for simple and cheap consumer goods, or for complex and expensive products), this portfolio should not be made of more than 300 or 400 activities (at coordination level).
- ***Reason #2.*** Because several key contributor should be involved in the definition of the activities they will be responsible of, and small drifts lead rather quickly to poorly balanced portfolio of activities, jeopardizing the efficiency of the project management system.

What's an Activity or preferably a Work Unit?

A **Work Unit** (WU) is an *elementary activity* that:

- consumes time
- consumes resources
- has a start and a finish dates
- is assignable to one person
- produces Deliverable(s)
- is measurable (to assess progress).

What's a Work Unit?

A **Work Unit** is not a **Deliverable**.
To avoid confusion, clever professional practices and several textbooks suggest to label Work Units as follow:

Verb (infinitive tense) **+ Substantive**

What's a Work Unit?

Examples:

- Manage the project
- Prepare PM documents
- Perform detail design of wing surface
- Supply rope & straps
- CFT for moulded ABS parts
- ...

What's a Work Unit?

A **Work Unit** (WU) is an *elementary activity* that:

- consumes time *yes, but within certain limits!*

What is the maximum duration?

- No definitive answer!
- No more than **5% - 10%** of the project duration
- No more than **13 weeks** (long lead projects)
- Some so-called **Level-of-Effort Work Units** (LoE-WU) allowed one such LoE-WU, or up to 1% of the WUs can be LoE-WUs.

Work Unit vs. Planned Unit.

The **ANSI #748** project management standard for reporting distinguishes two types of activities:

- **Work Units** as defined here before ⇢ on the short/medium term
- **Planned Units** defined more roughly ⇢ on the longer term.

As the project progresses, Planned Units arrive on the shorter term and are split up in Work Units.

How many Work Units?

What should be the **size** of a NPD project's Work Unit Portfolio?

- No definitive answer!
- That depends of the size and complexity of the project
- But more than 300 or 400 WUs* is known to be difficult to manage
- 100 WUs* sounds reasonable for a project spanning over 1 year.

* WUs + PUs remaining to do.

What's a Deliverable?

A Deliverable is not a Product (in the sense of the PBS).

Why defining Deliverables is so important?

- For measuring progress!
- Many projects have failed to achieve their objectives because of weaknesses of their progress monitoring system
  - *90% syndrome*.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		*Level*	Manage the project	Prepare PM documents	Perform marketing/sales activities	Perform IP/patent related activities	Perform basic design	Perform detail design	Prepare specification / order	CFT / award contract / place order	Prepare making	Make, assemble…	Test, validate…	Refurbish…	Construct, install…	Commission, ramp-up…
2	*bzh-kite*	1	1	1	7		6	1					3		1	2
3	Fabrics	2						4	2	2	1	1				
4	Carbon rods	2						3	2	2	1	1				
5	Moulded ABS parts	2						2	1	1						
6	Rings (COTS)	2							1							
7	Rope & strap	2						1	2		1	1				
8	Storage bag	2						2	1	1						
9	UG & SI	2						2	1	1						

Σ = 59 WUs

	A	B	C
1	*WU ID*	*PU ID*	*Work Unit or Planned Unit Label*
2	100		Manage bzh-kite project
3	101		Prepare bzh-kite project management documents
4	102		Refine Breizh-Sports product planning
5	103		Develop marketing plan for bzh-kite
6		010	Develop sales plan for bzh-kite
7	104		Develop after-sale support plan for bzh-kite
8		011	Design and release launch materials
9		012	Design and release promotion materials
10		013	Facilitate field testing
11	106		Refine industrial design of bzh-kite
12	107		Perform basic design for bzh-kite
13		014	Manufacture and assemble pre-series bzh-kite
14	108		Define the supply-chain for all bzh-kite components
15	109		Define bzh-kite manufacturing/assembly scheme f process diagram
16	110		Design bzh-kite manufacturing/assembly facility f plant layout

	A	B	C
1	*WU ID*	*PU ID*	*Work Unit or Planned Unit Label*
17	111		Perform detail design for bzh-kite fabrics f engineering drawings
18	112		Choose materials for bzh-kite fabrics
19	113		Identify suppliers for bzh-kite fabrics
20	114		Prepare specifications for bzh-kite fabrics
21	115		CFT/award contract for bzh-kite fabrics
22		015	Define/design equipment for bzh-kite fabrics related processes
23		016	Prepare specifications for bzh-kite fabrics equipment
24		017	CFT/award contract for bzh-kite fabrics equipment
25		018	Prepare making for bzh-kite fabrics equipment
26		019	Make/assemble bzh-kite fabrics equipment
27	116		Choose materials for bzh-kite carbon roads
28	117		Identify suppliers for bzh-kite carbon roads
29	118		Prepare specifications for bzh-kite carbon roads
30	119		CFT/award contract for bzh-kite carbon roads
31		020	Define/design equipment for bzh-kite carbon roads related processes

	A	B	C
1	*WU ID*	*PU ID*	*Work Unit or Planned Unit Label*
32		021	Prepare specifications for bzh-kite carbon roads equipment
33		022	CFT/award contract for bzh-kite carbon roads equipment
34		023	Prepare making for bzh-kite carbon roads equipment
35		024	Make/assemble bzh-kite carbon roads equipment
36	120		Perform detail design for bzh-kite moulded ABS parts
37	121		Identify suppliers for bzh-kite moulded ABS parts
38	122		Prepare specification for bzh-kite moulded ABS parts
39	123		CFT/award contract for bzh-kite moulded ABS parts
40	124		Prepare/place order for bzh-kite rings
41	125		Prepare/place order for bzh-kite rope & strap
42		025	Define/design fixtures for bzh-kite rope & strap related processes
43		026	Prepare/place order for bzh-kite components for rope & strap fixture
44		027	Prepare making for bzh-kite rope & strap fixtures
45		028	Make/assemble bzh-kite rope & strap fixtures
46	126		Design storage bag for bzh-kite

	A	B	C
1	*WU ID*	*PU ID*	*Work Unit or Planned Unit Label*
47	127		Identify suppliers for bzh-kite storage bags
48	128		Prepare specification for bzh-kite storage bags
49	129		CFT/award contract for bzh-kite storage bags
50	130		Design UG & SI for bzh-kite
51	131		Identify suppliers for bzh-kite UG & SI publishing
52	132		Prepare specification for bzh-kite UG & SI publishing
53	133		CFT/award contract for bzh-kite UG & SI publishing
54		029	Perform tests of pre-series bzh-kite
55		030	Define/design equipment for bzh-kite final assembly processes
56		031	Install bzh-kite manufacturing/assembly facility equipment
57		032	Refine bzh-kite manufacturing/assembly processes
58		033	Refine bzh-kite manufacturing/assembly quality assurance processes
59	134		Train bzh-kite manufacturing/assembly facility work force
60		034	Commission bzh-kite manufacturing/assembly facility
61			

8

Project Costing

Costing the Project

Resource Estimating, Budgeting and Controlling

openSE

- Estimating the resources required to perform the project
- Budgeting the resources allocated to the project
- Controlling the resources that are spent as the project progresses

Costing the Project

Resource Estimating, Budgeting and Controlling

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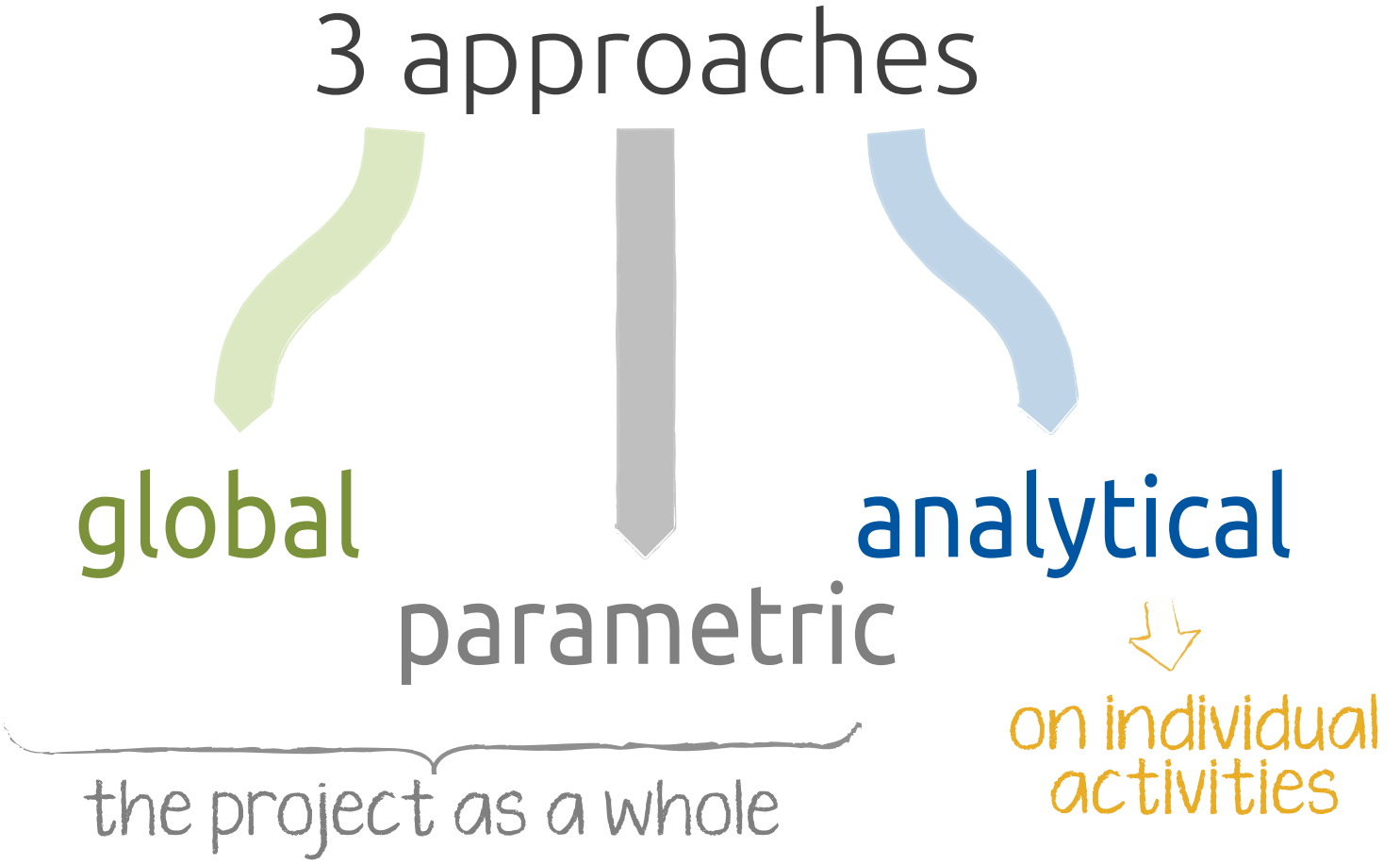

Costing the Project

Resource Estimating, Budgeting and Controlling

openSE

1. Define the Project Resource Currency
   - monetary currency (EUR, CHF, GBP, USD, JPY, etc.)
   - workload currency (person·days, person·weeks, etc.)
2. Identify the resources to consider:
   - Project Participants (internal + external)
   - materials and equipment
   - services and facilities
   - works and storage spaces
   - energy and utility, etc.

Result of the exercise

Costing the Project

Resource Estimating, Budgeting and Controlling

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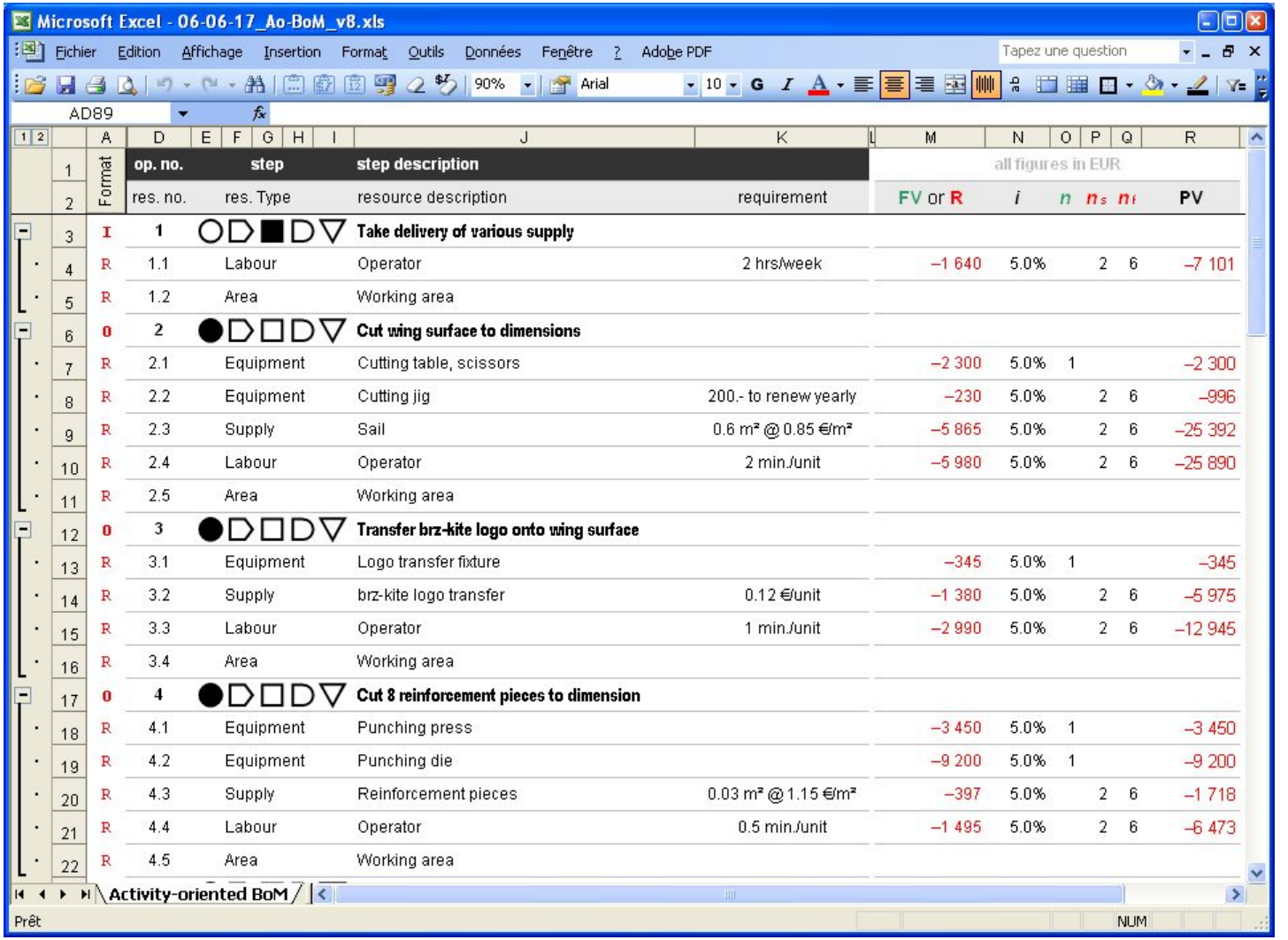


Microsoft Excel - 06-06-17_Ao-BoM_v8.xls

Fichier Edition Affichage Insertion Format Outils Données Fenêtre ? Adobe PDF — Tapez une question

90% — Arial — 10

AD89

	Format	op. no.	step	step description		all figures in EUR					
		res. no.	res. Type	resource description	requirement	FV or R	*i*	*n*	n_s	n_t	PV
3	I	1		**Take delivery of various supply**							
4	R	1.1	Labour	Operator	2 hrs/week	–1 640	5.0%		2	6	–7 101
5	R	1.2	Area	Working area							
6	O	2		**Cut wing surface to dimensions**							
7	R	2.1	Equipment	Cutting table, scissors		–2 300	5.0%	1			–2 300
8	R	2.2	Equipment	Cutting jig	200.- to renew yearly	–230	5.0%		2	6	–996
9	R	2.3	Supply	Sail	0.6 m² @ 0.85 €/m²	–5 865	5.0%		2	6	–25 392
10	R	2.4	Labour	Operator	2 min./unit	–5 980	5.0%		2	6	–25 890
11	R	2.5	Area	Working area							
12	O	3		**Transfer brz-kite logo onto wing surface**							
13	R	3.1	Equipment	Logo transfer fixture		–345	5.0%	1			–345
14	R	3.2	Supply	brz-kite logo transfer	0.12 €/unit	–1 380	5.0%		2	6	–5 975
15	R	3.3	Labour	Operator	1 min./unit	–2 990	5.0%		2	6	–12 945
16	R	3.4	Area	Working area							
17	O	4		**Cut 8 reinforcement pieces to dimension**							
18	R	4.1	Equipment	Punching press		–3 450	5.0%	1			–3 450
19	R	4.2	Equipment	Punching die		–9 200	5.0%	1			–9 200
20	R	4.3	Supply	Reinforcement pieces	0.03 m² @ 1.15 €/m²	–397	5.0%		2	6	–1 718
21	R	4.4	Labour	Operator	0.5 min./unit	–1 495	5.0%		2	6	–6 473
22	R	4.5	Area	Working area							

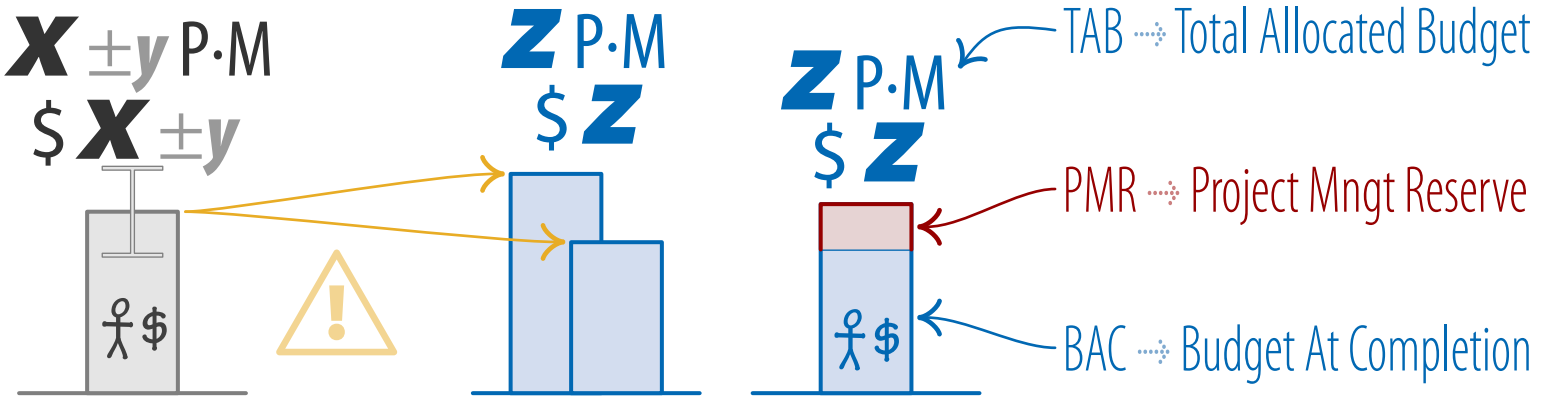
Activity-oriented BoM

Prêt — NUM

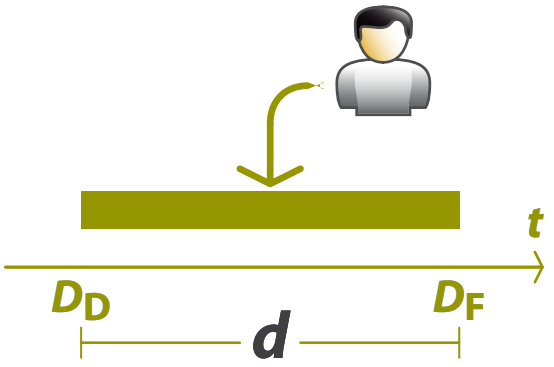
Costing the Project

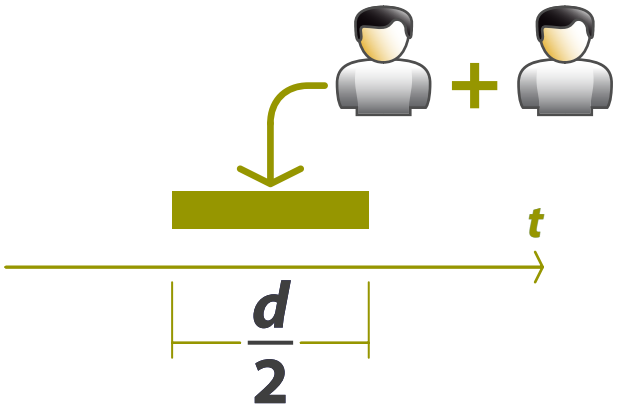
Resource Estimating, Budgeting and Controlling

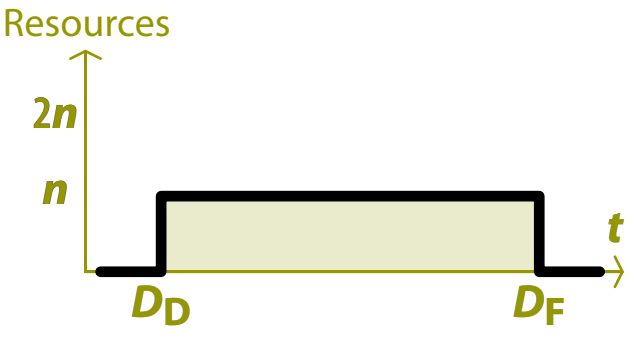
openSE

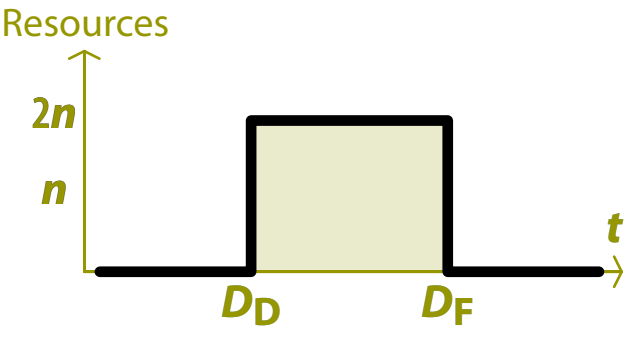


Work Unit Duration.





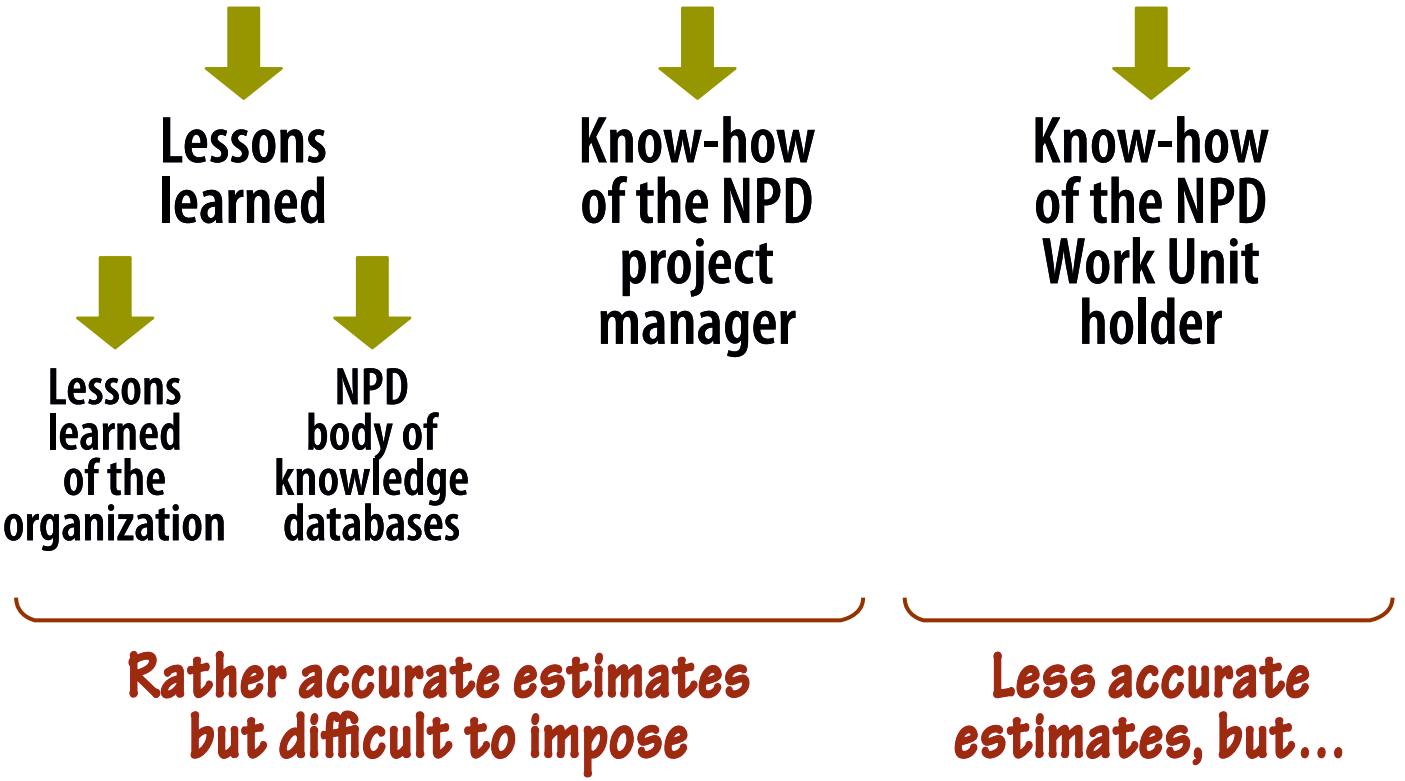




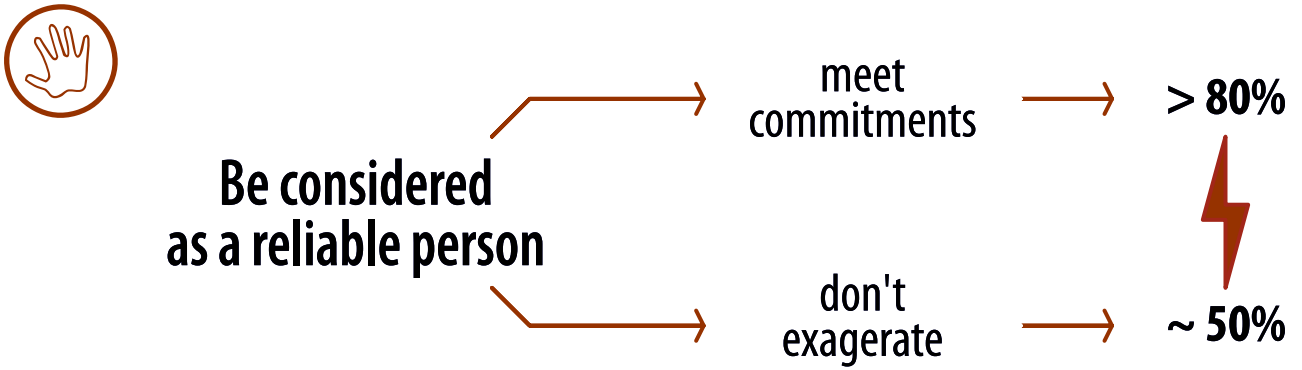
Work load = $d \times n \sim A$

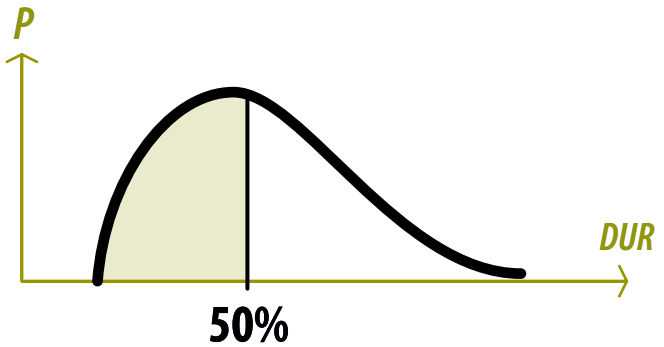
Work load = $\frac{d}{2} \times 2n = d \times n$

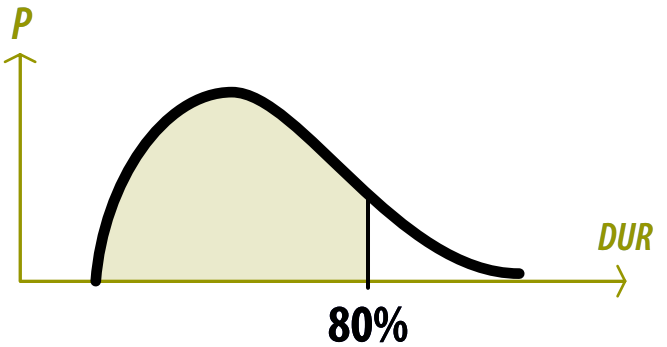
Duration estimates.



Goldratt's dilema.







9

Project Scheduling

A first formulation of the problem.

- A project made of Activities, for which **duration** have been estimated.
- Some activities cannot be carried until other are finished.

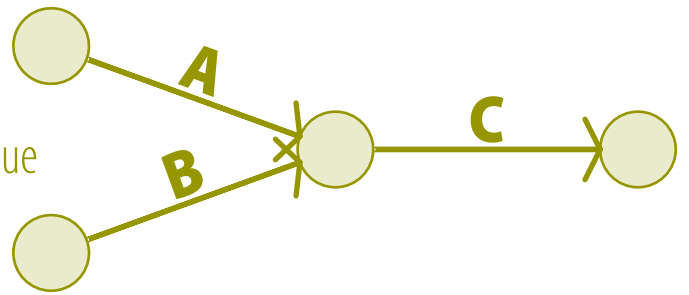
Three approaches to solve out such a problem:

- **CPM/PERT** (Critical Path Method) ⇢ activity-on-arrow diagram
- **PDM** (Precedence Diagramming Method) ⇢ activity-on-node diagram
- **LP** (Linear Programming) ⇢ Simplexe.

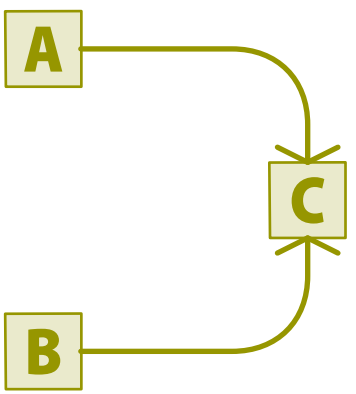
CPM/PERT vs. PDM.

a_i	Γ_i^{-1}
A	–
B	–
C	A,B

CPM/PERT
Critical Path Method
Program Evaluation & Review Technique
Activity-on-arrow



PDM
Precedence Diagramming Method
Activity-on-node



PDM conventions.

a_j	DUR_j
ES_j	EF_j
LS_j	LF_j
FF_j	TF_j

α	ω
E_α	E_ω
L_α	L_ω

a_j Activity ID

DUR_j Duration

ES_j Earliest start date

EF_j Earliest finish date

LS_j Latest start date

LF_j Latest finish date

FF_j Free float

TF_j Total float

α Project start node

ω Project finish node

E_α , E_ω Earliest dates

L_α , L_ω Latest dates

Total float, free float.

- **Total Float** (TF). The total amount of time that a schedule activity may be delayed from its early start date without delaying the project finish date, or violating a schedule constraint.
- **Free Float** (FF). The amount of time that a schedule activity can be delayed without delaying the early start of any immediately following schedule activities.

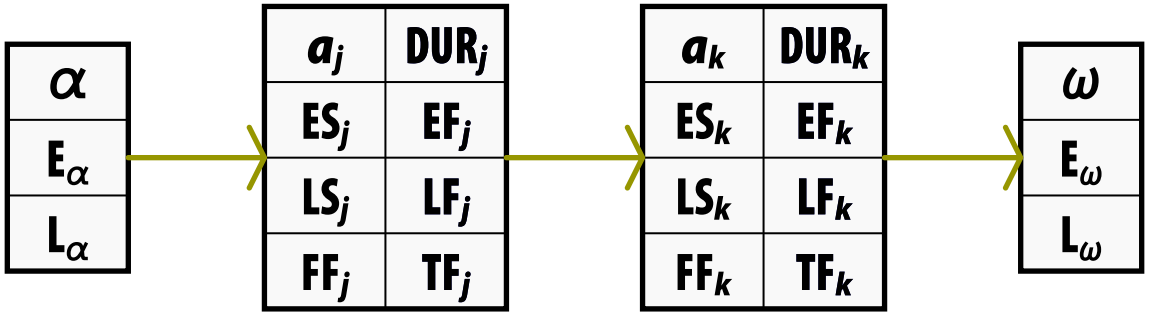
PMI Standard Committee (2000) *A guide to the project management body of knowledge*. (4th ed.) Newton Square PA: Project Management Institute. 216 p. ISBN 1880410230.

Critical path, critical activity.

- **Critical Path**. Generally, but not always, the sequence of schedule activities that determines the duration of the project. Generally, it is the longest path through the project. However, a critical path can end, as an example, on a schedule milestone that is in the middle of the project schedule and that has a finish-no-later-than imposed date schedule constraint.
- **Critical Activity**. Any schedule activity on a critical path in a project schedule.

PMI Standard Committee (2000) *A guide to the project management body of knowledge*. (4th ed.) Newton Square PA: Project Management Institute. 216 p. ISBN 1880410230.

Activity network calculations ⇢ PDM.



FORWARD PASS

E_α : given

$ES_j = E_\alpha$

$EF_j = ES_j + DUR_j$

$ES_k = EF_j$

$EF_k = ES_k + DUR_k$

$E_\omega = EF_k$

BACKWARD PASS

$L_\omega = E_\omega$

$LF_k = L_\omega$

$LS_k = LF_k - DUR_k$

$LF_j = LS_k$

$LS_j = LF_j - DUR_j$

$L_\alpha = LS_j$

FLOATS

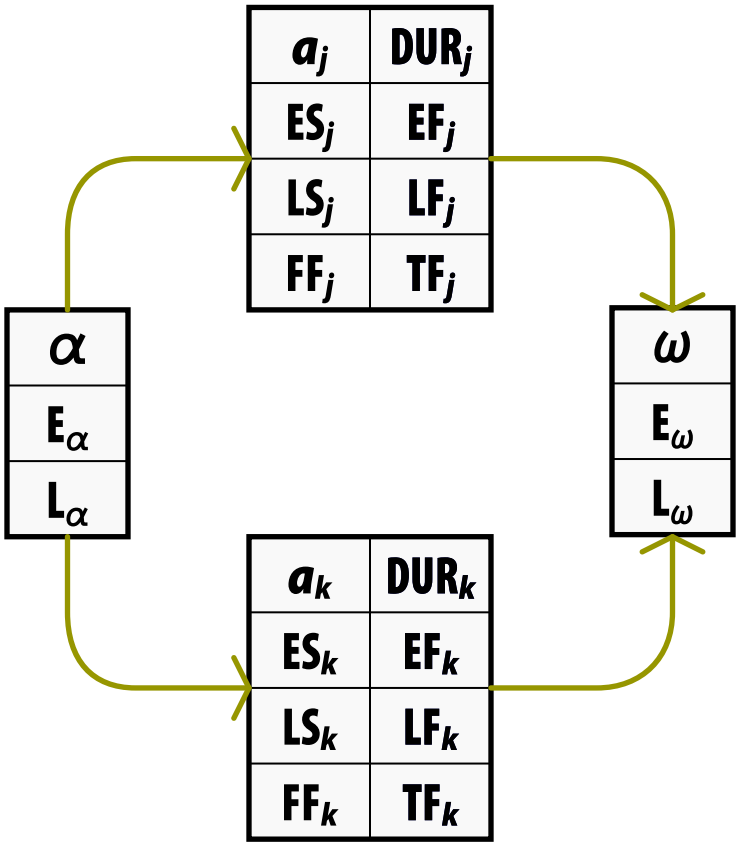
$TF_j = LF_j - EF_j$

$FF_j = ES_k - EF_j$

$TF_k = LF_k - EF_k$

$FF_k = E_\omega - EF_k$

Activity network calculations ⇢ PDM.



FORWARD PASS

E_α : given
$ES_j = E_\alpha$
$EF_j = ES_j + DUR_j$
$ES_k = E_\alpha$
$EF_k = ES_k + DUR_k$
$E_\omega = \max(EF_j , EF_k)$

BACKWARD PASS

$L_\omega = E_\omega$
$LF_j = L_\omega$
$LS_j = LF_j - DUR_j$
$LF_k = L_\omega$
$LS_k = LF_k - DUR_k$
$L_\alpha = \min(LS_j , LS_k)$

FLOATS

$TF_j = LF_j - EF_j$
$FF_j = E_\omega - EF_j$
$TF_k = LF_k - EF_k$
$FF_k = E_\omega - EF_k$

PDM (simplified) algorithm.

$\mathbf{E}_{\alpha} \leftarrow$ Project start date

Order $\{ \boldsymbol{a}_j \}$ so that $\boldsymbol{a}_i \prec \boldsymbol{a}_k \; \forall \; \boldsymbol{i} < \boldsymbol{k}$

For $\boldsymbol{j} = 1$ to $\left| \{ \boldsymbol{a}_j \} \right|$ repeat:

$$\mathbf{ES}_j \leftarrow \begin{cases} \mathbf{E}_{\alpha} \text{ if } \Gamma_j^{-1} = \emptyset \\ \max_{\boldsymbol{k} \in \Gamma_j^{-1}} \{ \mathbf{ES}_k + \mathbf{DUR}_k \} \text{ otherwise} \end{cases}$$

$\mathbf{L}_{\omega} \leftarrow \mathbf{E}_{\omega}$

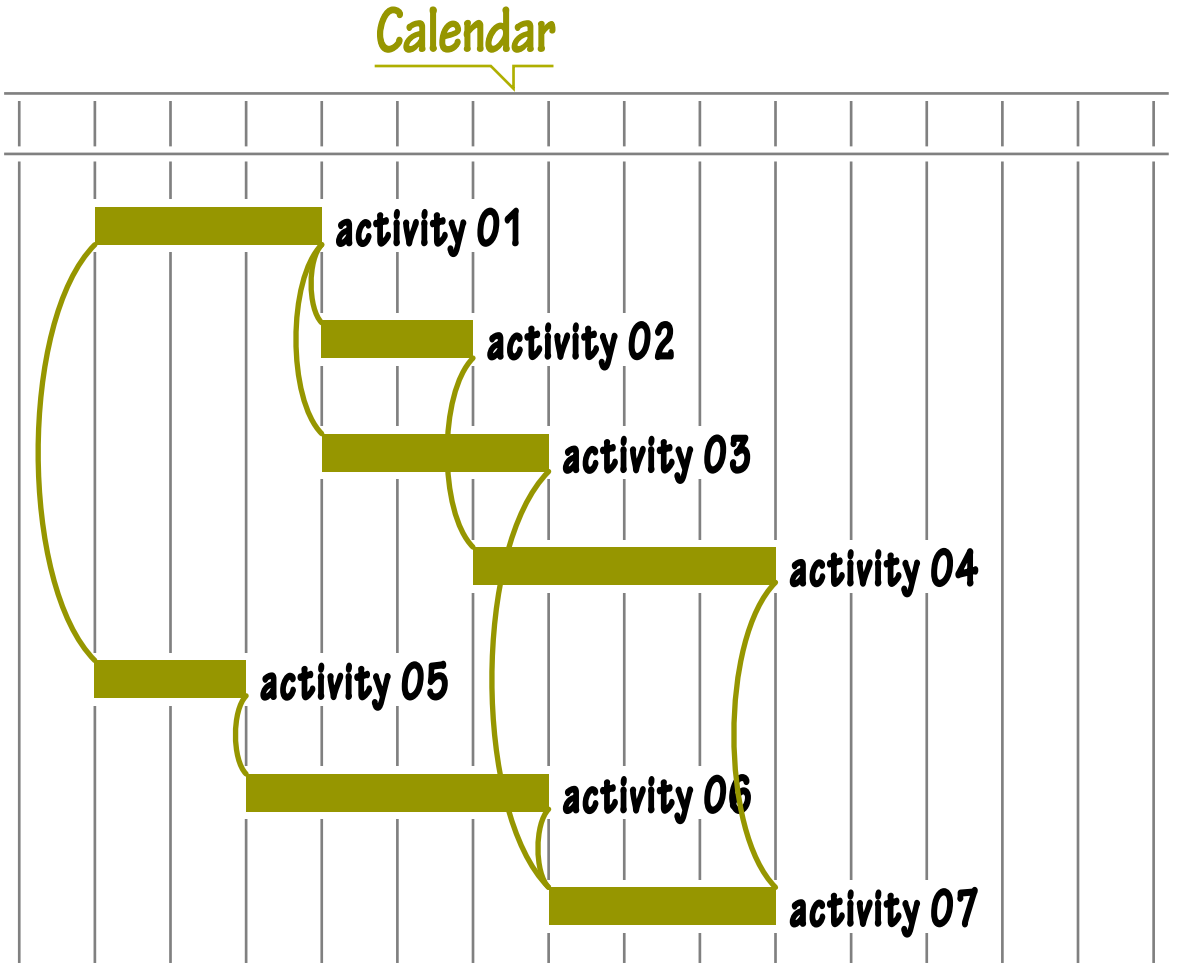
For $\boldsymbol{j} = \left| \{ \boldsymbol{a}_j \} \right|$ to 1 repeat:

$$\mathbf{LF}_j \leftarrow \begin{cases} \mathbf{L}_{\omega} \text{ if } \Gamma_j = \emptyset \\ \min_{\boldsymbol{k} \in \Gamma_j} \{ \mathbf{LF}_k - \mathbf{DUR}_k \} \text{ otherwise} \end{cases}$$

$\mathbf{TF}_j \leftarrow \mathbf{LF}_j - \mathbf{EF}_j$

$\mathbf{FF}_j \leftarrow \min_{\boldsymbol{k} \in \Gamma_j} \{ \mathbf{ES}_k \} - \mathbf{EF}_j$

Gantt chart.


Calendar
activity 01
activity 02
activity 03
activity 04
activity 05
activity 06
activity 07

A second formulation of the problem.

- A project made of Activities, for which **duration** have been estimated.
- Some activities cannot be carried until other are finished;
  others can be stated as soon as some activities are started;
  others cannot be finished until other activities are not finished…

Two approaches to solve out such a problem:

- **PDM** (Precedence Diagramming Method)
- **LP** (Linear Programming).

Typology of constraints.

	finish-start	start-start	start-finish	finish-finish
without lag	→	SS →	SF →	FF →
with LAG	FS+LAG →	SS+LAG →	SF+LAG →	FF+LAG →

PDM algorithm.

$\mathbf{E}_\alpha \leftarrow$ Project start date

Order $\{\boldsymbol{a}_j\}$ so that $\boldsymbol{a}_i \prec \boldsymbol{a}_k \; \forall \; \boldsymbol{i}<\boldsymbol{k}$

For $\boldsymbol{j}=1$ to $|\{\boldsymbol{a}_j\}|$ repeat:

$$\mathbf{ES}_j \leftarrow \begin{cases} \mathbf{E}_\alpha \text{ if } \Gamma_j^{-1}=\emptyset \\ \max_{k\in\Gamma_j^{-1}}\{\ \} \text{ otherwise} \end{cases}$$

$\mathbf{ES}_k+\mathbf{DUR}_k+\mathbf{LAG}_{kj}$ if $\sigma_{kj}=$"FS"

$\mathbf{ES}_k+\mathbf{LAG}_{kj}$ if $\sigma_{kj}=$"SS"

$\mathbf{ES}_k-\mathbf{DUR}_j+\mathbf{LAG}_{kj}$ if $\sigma_{kj}=$"SF"

$\mathbf{ES}_k+\mathbf{DUR}_k-\mathbf{DUR}_j+\mathbf{LAG}_{kj}$ if $\sigma_{kj}=$"FF"

$\mathbf{L}_\omega \leftarrow \mathbf{E}_\omega$

For $\boldsymbol{j}=|\{\boldsymbol{a}_j\}|$ to 1 repeat:

$$\mathbf{LF}_j \leftarrow \begin{cases} \mathbf{L}_\omega \text{ if } \Gamma_j=\emptyset \\ \min_{k\in\Gamma_j}\{\ \} \text{ otherwise} \end{cases}$$

$\mathbf{LF}_k-\mathbf{DUR}_k-\mathbf{LAG}_{kj}$ if $\sigma_{jk}=$"FS"

$\mathbf{LF}_k-\mathbf{DUR}_k+\mathbf{DUR}_j-\mathbf{LAG}_{kj}$ if $\sigma_{jk}=$"SS"

$\mathbf{LF}_k+\mathbf{DUR}_j-\mathbf{LAG}_{kj}$ if $\sigma_{jk}=$"SF"

$\mathbf{LF}_k-\mathbf{LAG}_{kj}$ if $\sigma_{jk}=$"FF"

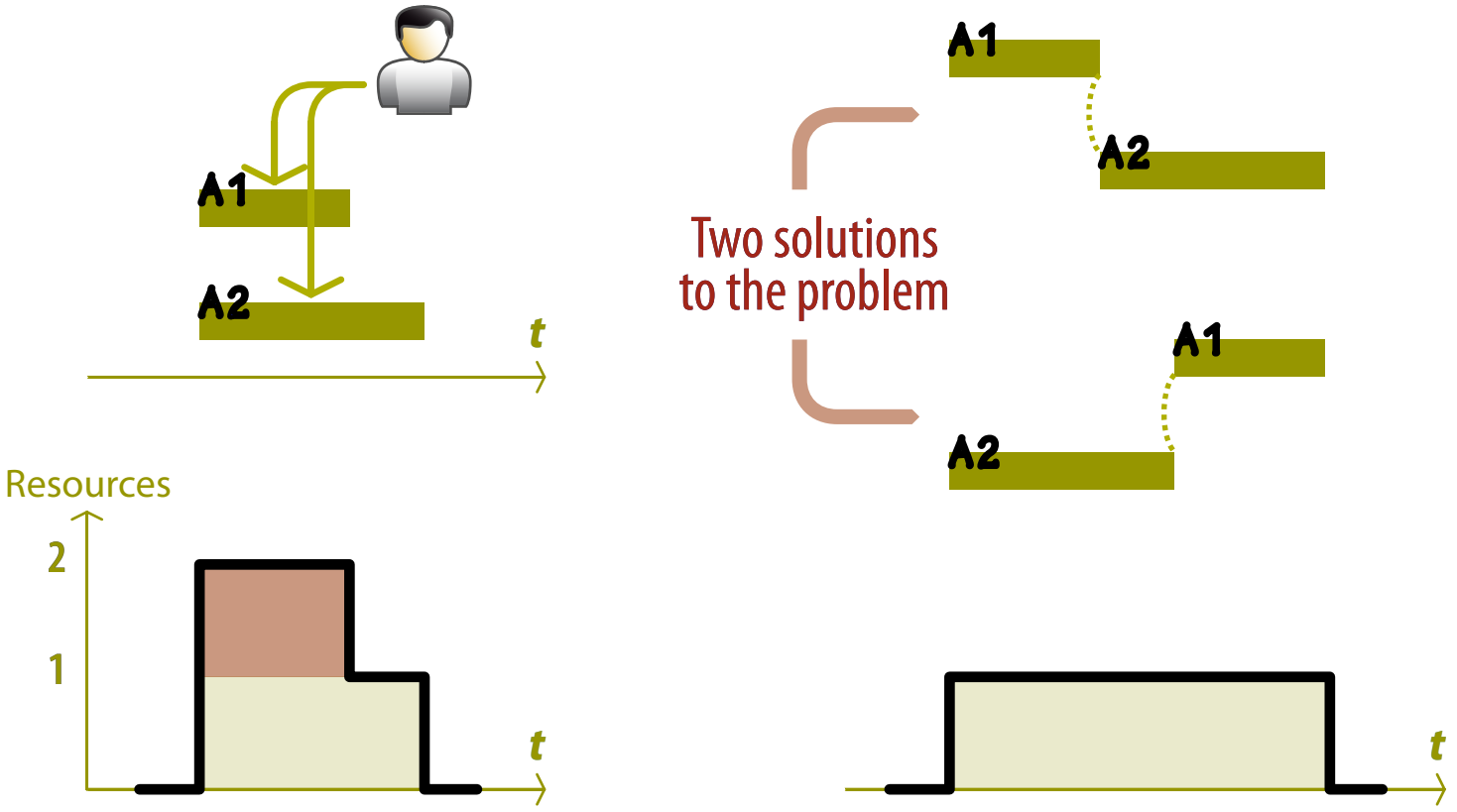
$\mathbf{TF}_j \leftarrow \mathbf{LF}_j-\mathbf{EF}_j$

$\mathbf{FF}_j \leftarrow \min_{k\in\Gamma_j}\{\mathbf{ES}_k\}-\mathbf{EF}_j$

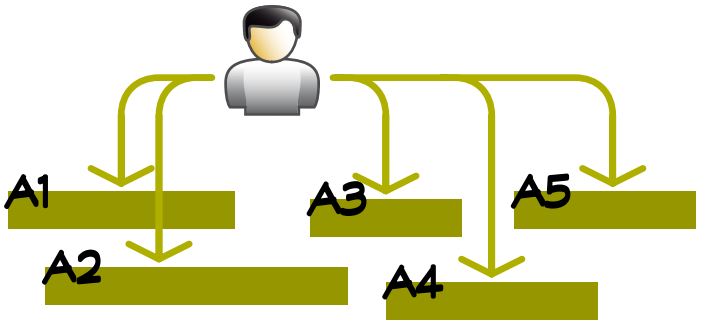
A third formulation of the problem.

- A project made of Activities, for which **duration** have been estimated.
- Some activities cannot be carried until other are finished […]
- And (renewable) **resources** are needed to do the work!

Resource-constrained project scheduling problem.



RC-PSP.



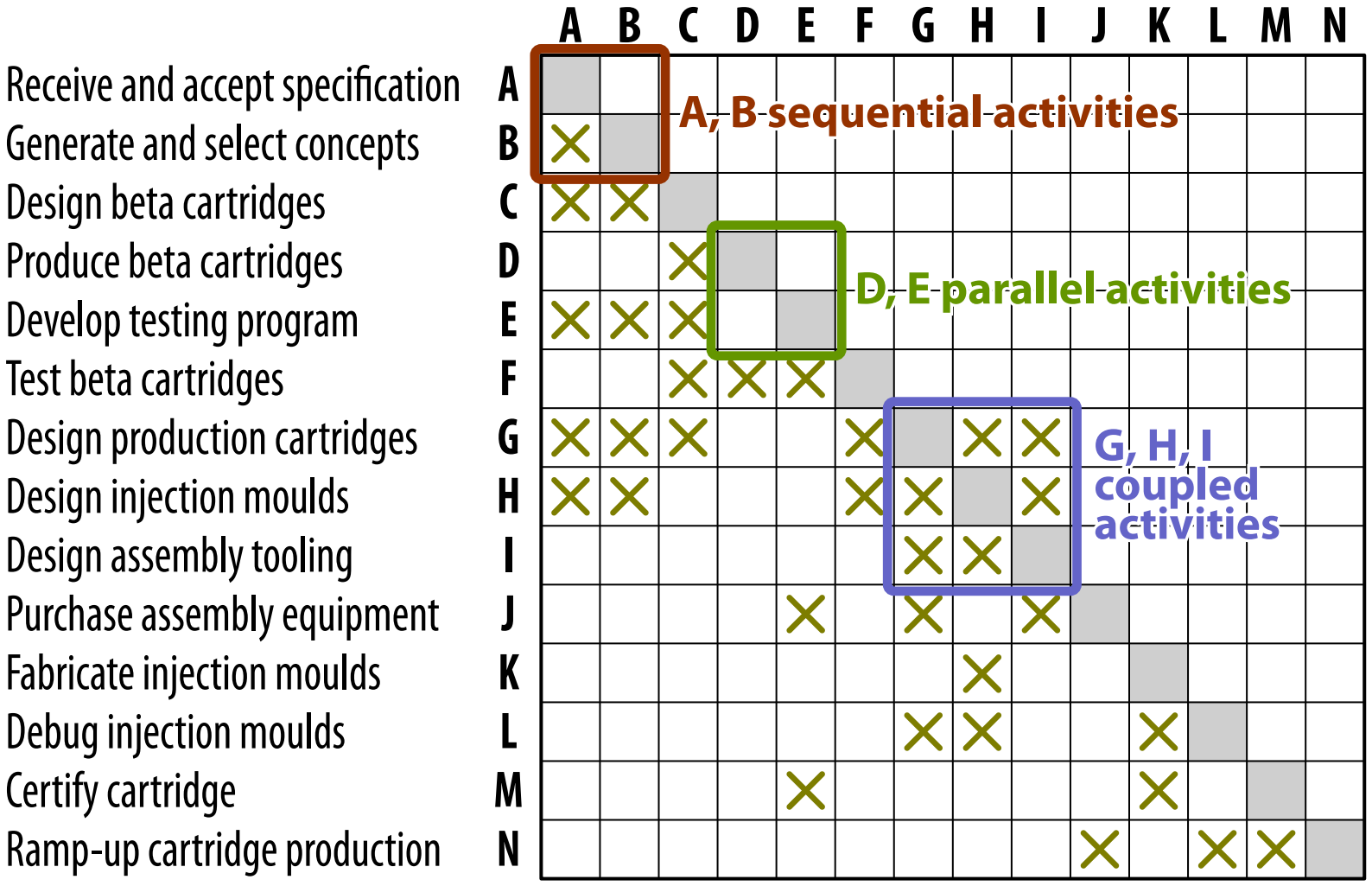
2 activities	**1** resource	⇢	**2** combinations
3 activities	**1** resource	⇢	**6** combinations
4 activities	**1** resource	⇢	**24** combinations
5 activities	**1** resource	⇢	**120** combinations
			720 combinations
			5040 combinations
			40320 combinations
			362880 combinations
			3628800 combinations

Project scheduling.

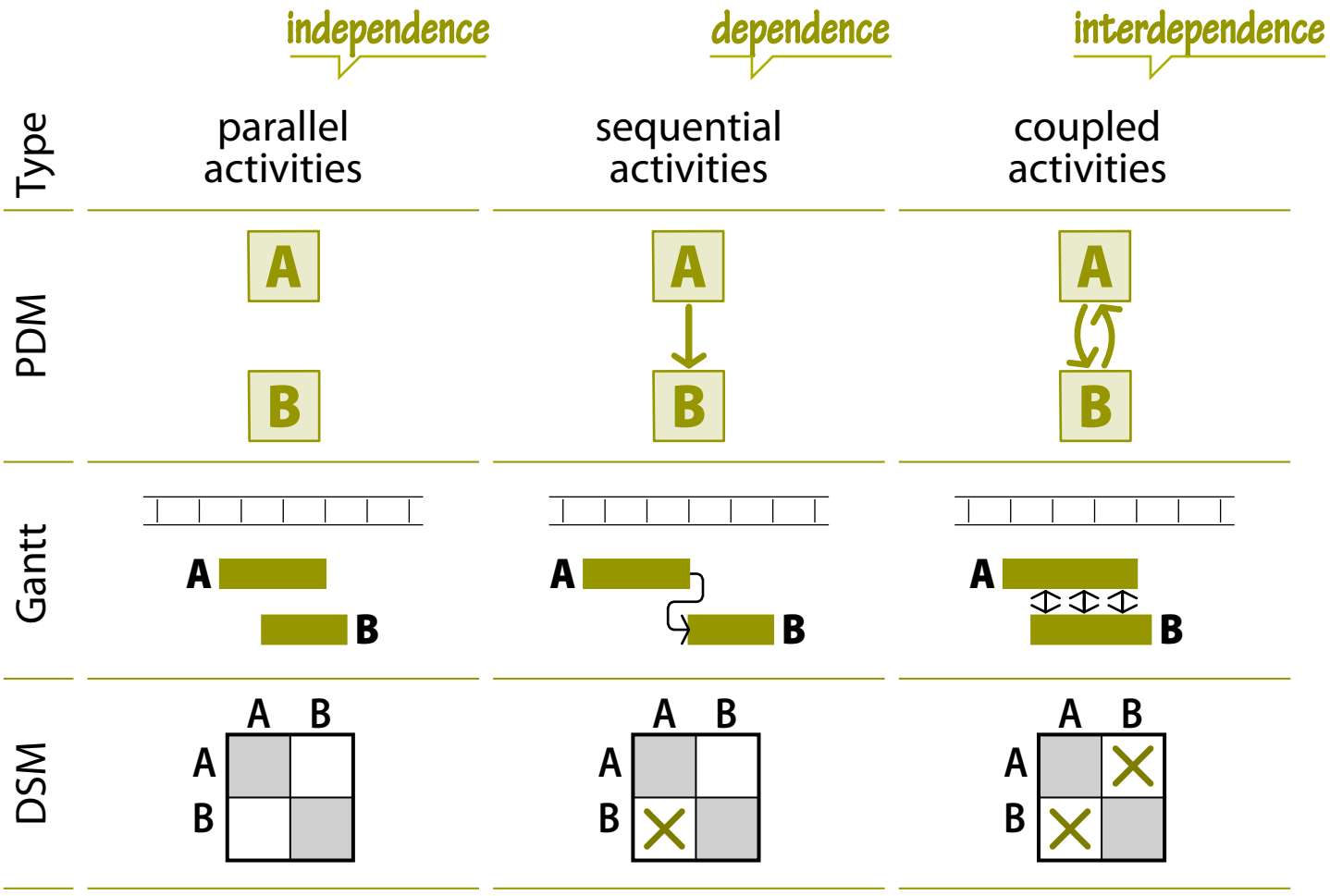
- 200+ Activities
- Many constraints
- Several resources
- Gregorian calendar

A project scheduling software is mandatory.

Precedence relationships.



DSM.

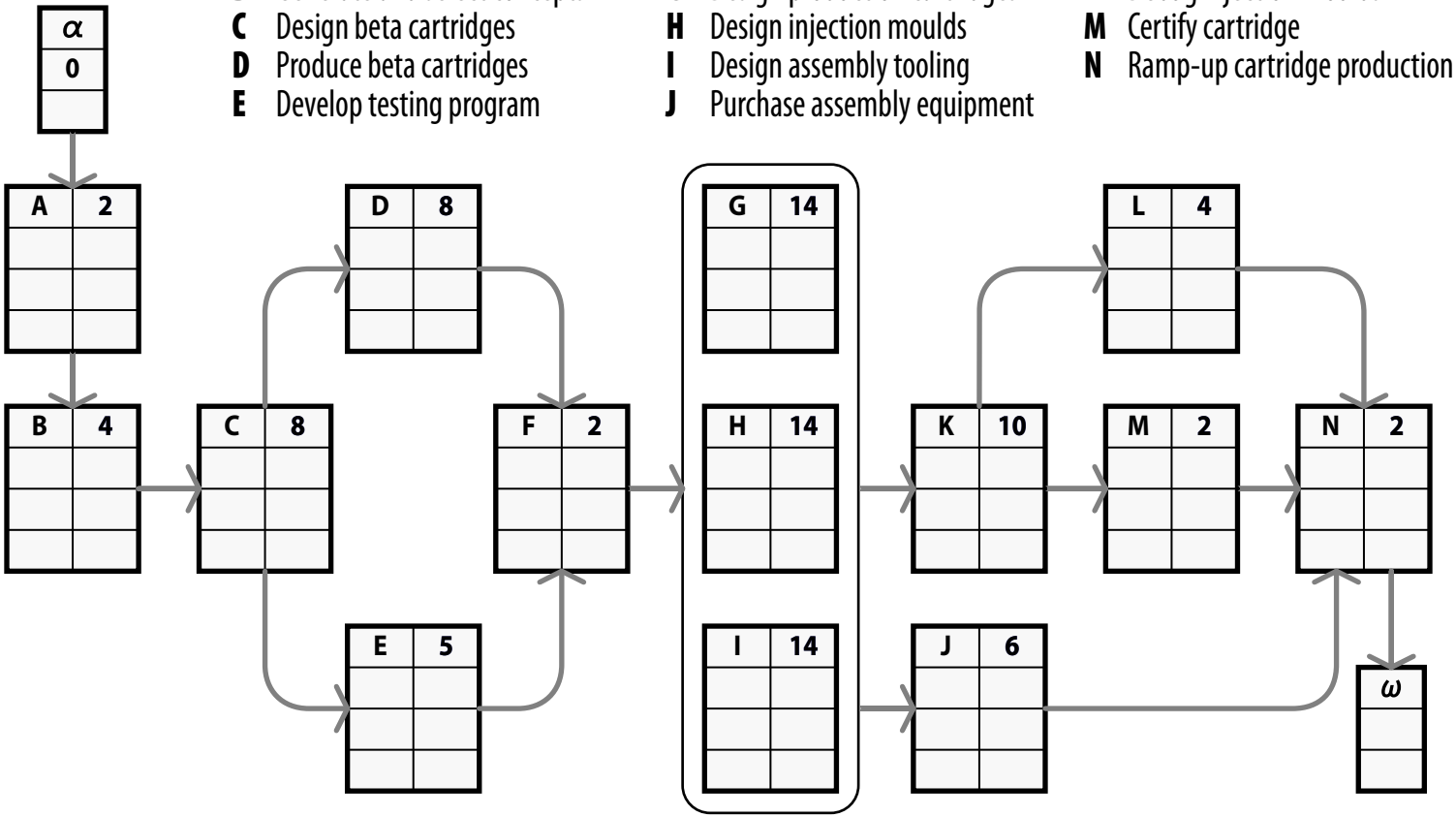

independence
dependence
interdependence
Type
parallel activities
sequential activities
coupled activities
PDM
A
B
Gantt
DSM

BONNAL & ASSOCIÉS

Kodak Cheetah Project

PDM network

A Receive and accept specification
B Generate and select concepts
C Design beta cartridges
D Produce beta cartridges
E Develop testing program
F Test beta cartridges
G Design production cartridges
H Design injection moulds
I Design assembly tooling
J Purchase assembly equipment
K Fabricate injection moulds
L Debug injection moulds
M Certify cartridge
N Ramp-up cartridge production



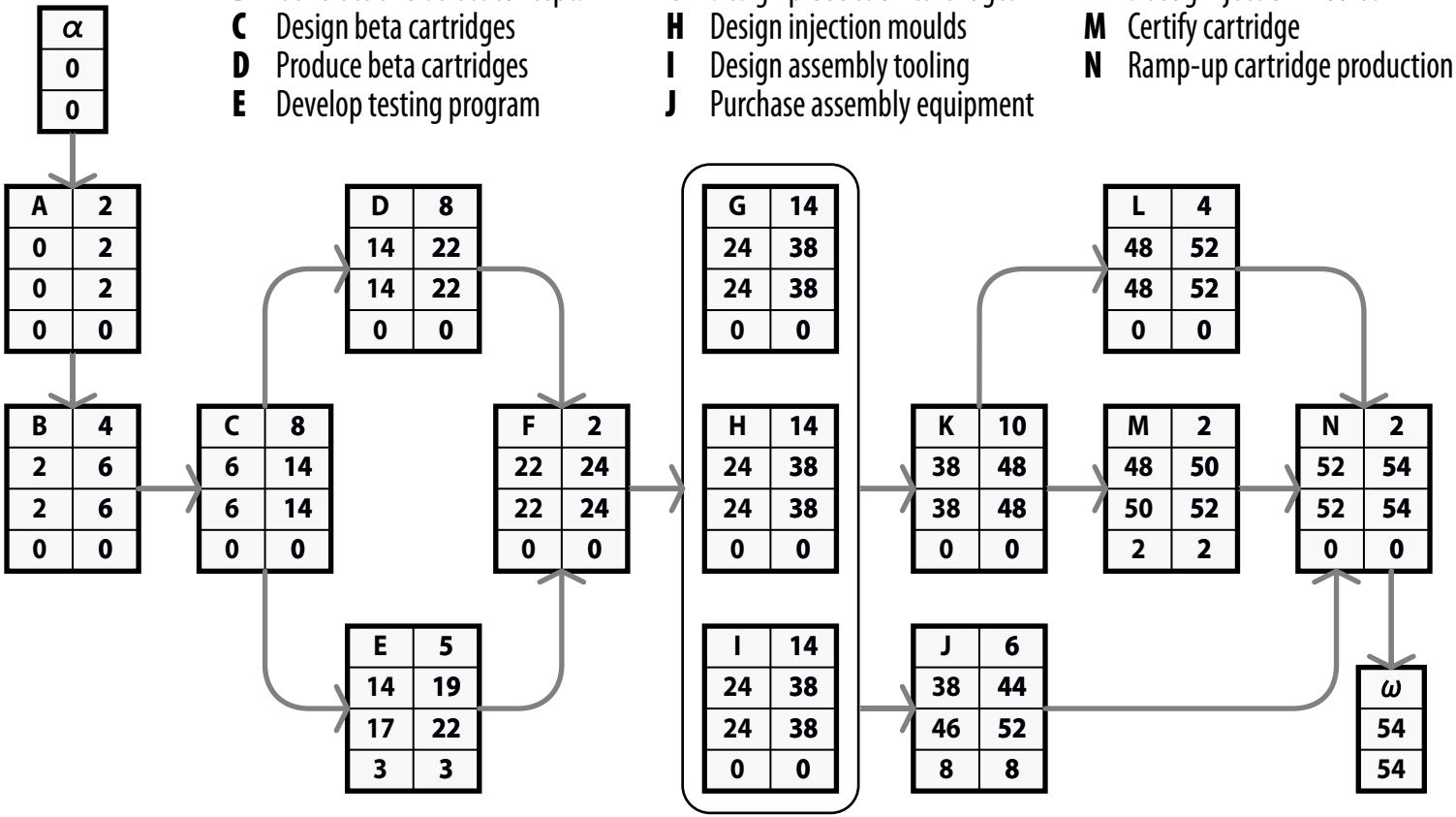
PDMNet v1

BONNAL & ASSOCIÉS

Kodak Cheetah Project

PDM network

A Receive and accept specification
B Generate and select concepts
C Design beta cartridges
D Produce beta cartridges
E Develop testing program
F Test beta cartridges
G Design production cartridges
H Design injection moulds
I Design assembly tooling
J Purchase assembly equipment
K Fabricate injection moulds
L Debug injection moulds
M Certify cartridge
N Ramp-up cartridge production

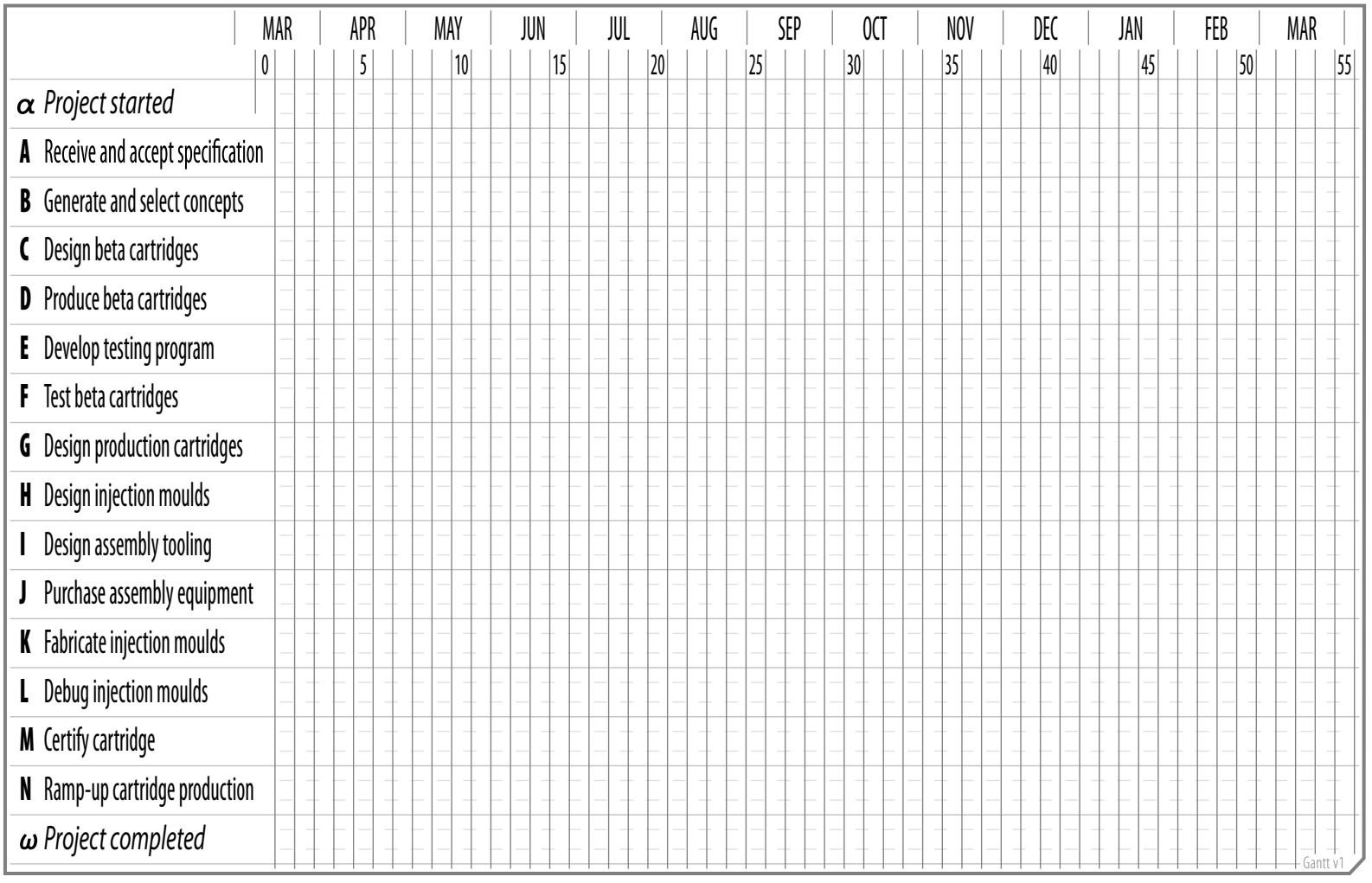


PDMNet v1

BONNAL & ASSOCIÉS

Kodak Cheetah Project

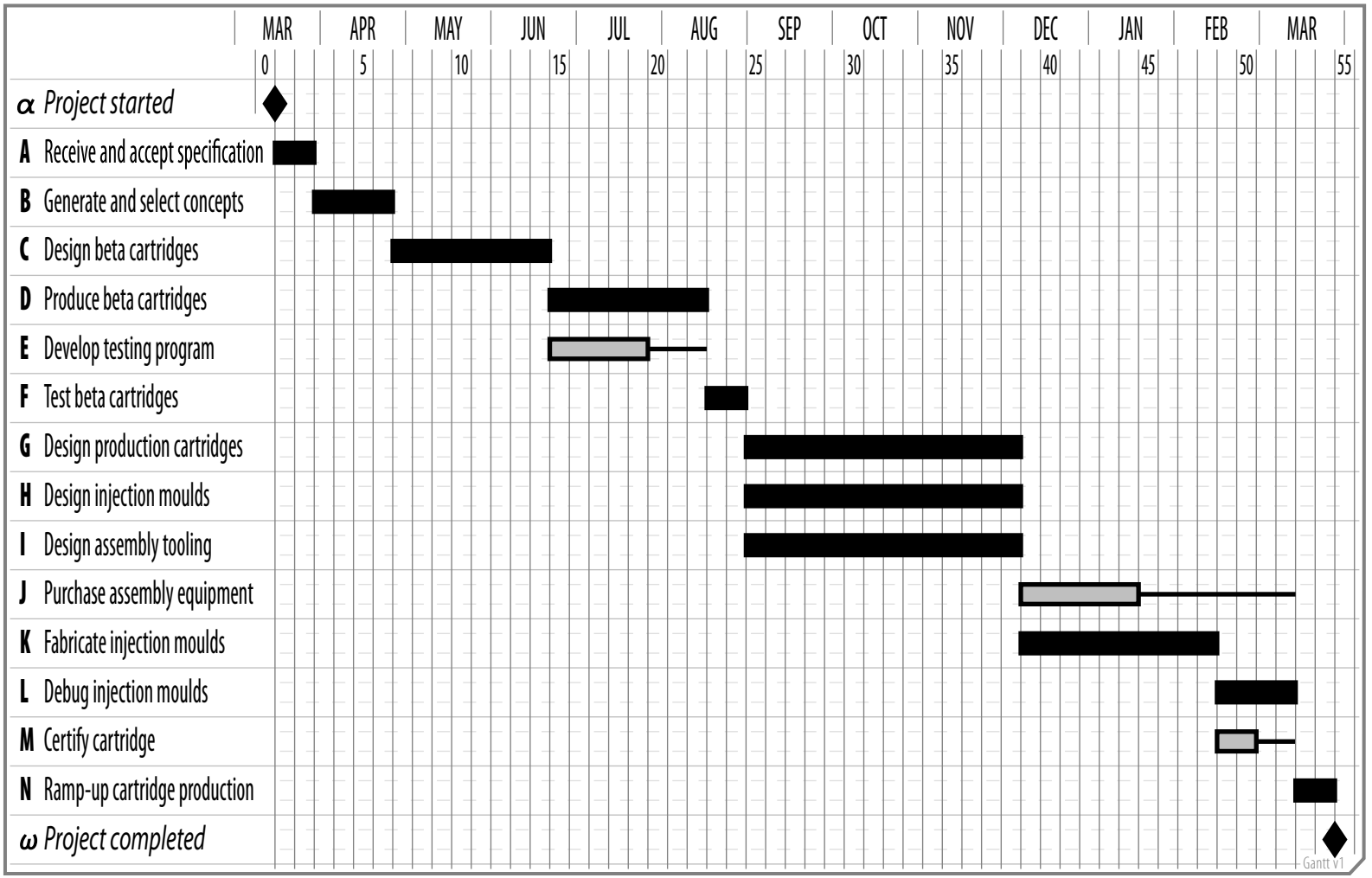
Gantt chart



BONNAL & ASSOCIÉS

Kodak Cheetah Project

Gantt chart



10

Project Risk Management

PRM → Six steps.

Step 1. Strategy & risk planning

Step 2. Risk identification

Step 3. Risk evaluation

Step 4. Risk quantification

Step 5. Risk handling

Step 6. Risk follow-up.

PMI Standard Committee (2000) *A guide to the project management body of knowledge*. (4th ed.) Newton Square PA: Project Management Institute. 216 p. ISBN 1880410230.

Risk management strategy | Process.

INPUTS:

- Project charter
- NPD project mission statement
- Organizational policy ⇢ PRM
- Identification of the contributors (incl. their tolerance towards risks)
- Framework for editing a PRM Plan
- Work Breakdown Structure (WBS) of the project

TOOLS & TECHNIQUES:

- Some meetings

OUTPUTS:

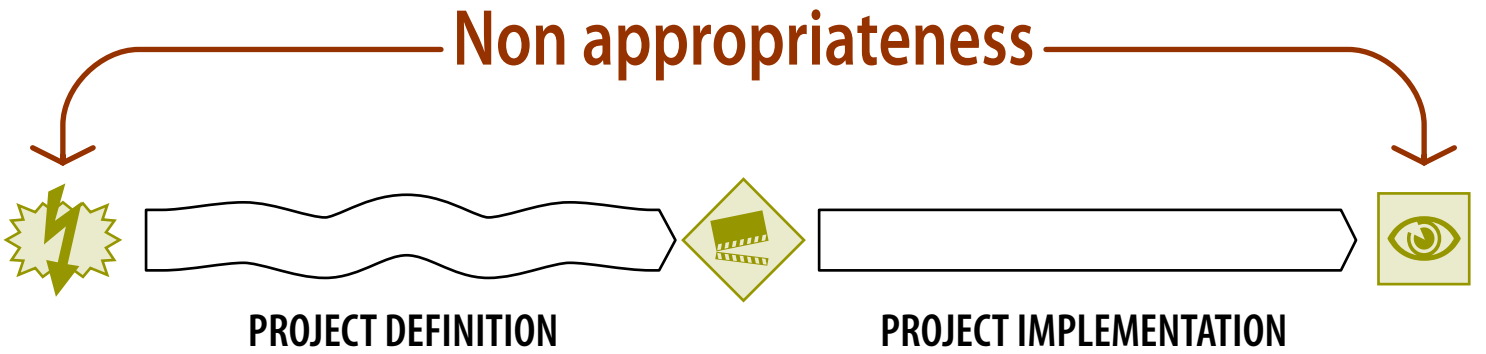
- Project Risk Management Plan.

PRM Plan ⇢ Table of contents.

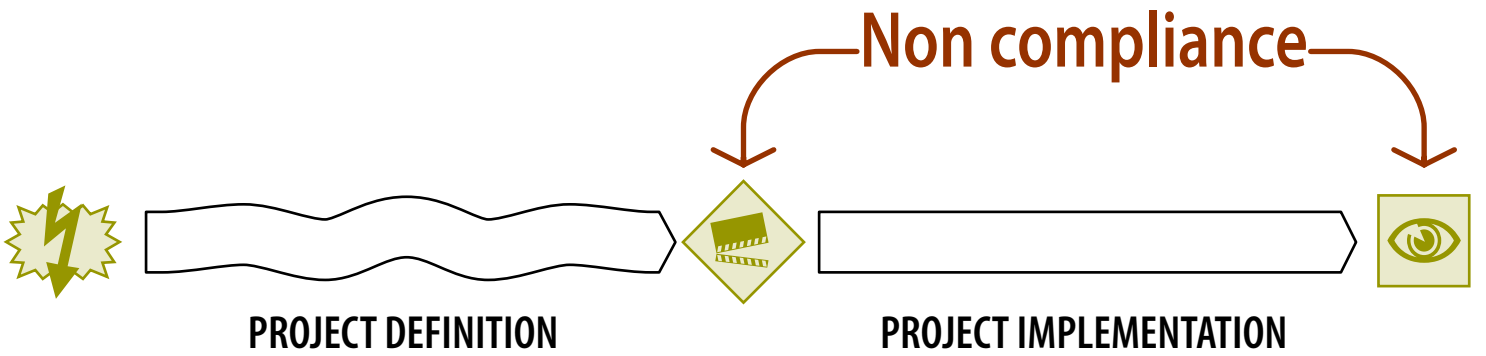
Risk categories → first scheme.

- **Technical** risks → related to the product being designed and developed
- **Programmatic** risks → related to the project itself: on schedule, on budget…
- **External** risks → for which the NPD project team has no control.

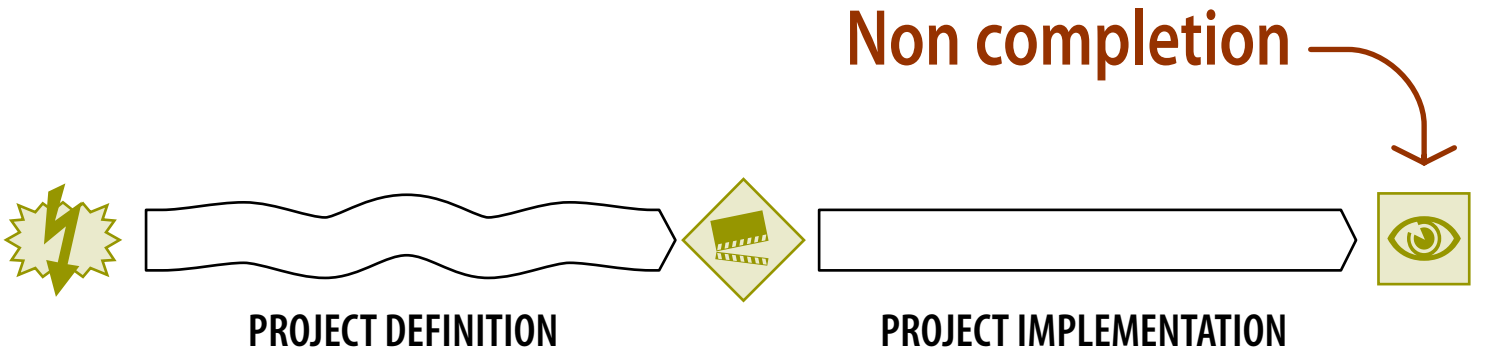
Risk categories ⇢ second scheme.



Risk categories ⇢ second scheme.



Risk categories ⇢ second scheme.



Risk identification | Process.

INPUTS:

- PRM Plan
- Outputs of the project planning phase ⇢ PBS, WBS, Gantt Chart…
- Lessons learned in matter of PRM on former NPD projects
- Databases, check lists, *vade-mecum*…
- Organizational policy ⇢ PRM
- Names of NPD PRM experts ⇢ interviews

TOOLS & TECHNIQUES:

- Project document screening
- Brainstorming sessions, Six-hats, Delphi method…
- Interviews
- SWOT analysis, Ishikawa diagrams…

Risk identification | Process.

OUTPUTS:

- **Project Risk Register**
- List of feared events
- Recommendations.

Risk evaluation | Process.

INPUTS:

- PRM Plan
- Project Risk Register

TOOLS & TECHNIQUES:

- Risk Level Matrix
- Failure Mode Analysis and Consequences (FMAC)

OUTPUTS:

- Project Risk Register
- Preliminary **Risk Assessment Forms**.

Risk Level Matrix.

Probability	***P***
Very unlikely	.1
Rather unlikely	.3
Possible, plausible	.5
Rather likely	.7
Very likely, quite certain	.9

Consequences	***C***
Negligible	.05
Marginal	.1
Significant	.2
Major, critical	.4
Catastrophic, crisis	.8

Risk Level Matrix.

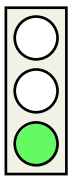
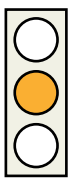
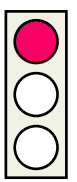
Consequences	**c**	on budget	on schedule
Negligible	.05	$\Delta C \approx 0$	$\Delta D \approx 0$
Marginal	.1	$1\% < \Delta C \leq 5\%$	$1\% < \Delta D \leq 5\%$
Significant	.2	$5\% < \Delta C \leq 10\%$	$5\% < \Delta D \leq 10\%$
Major, critical	.4	$10\% < \Delta C \leq 20\%$	$10\% < \Delta D \leq 20\%$
Catastrophic, crisis	.8	$\Delta C > 20\%$	$\Delta D > 20\%$

Risk Level Matrix.

Consequences	***C***	on the project performance
Negligible	.05	Minimal or no consequence
Marginal	.1	Small reduction of the performance
Significant	.2	Significant degradation of the performance
Major, critical	.4	Technical goals cannot be achieved
Catastrophic, crisis	.8	Project cannot be completed

Risk Level Matrix.

$$S = P \times C$$

$S < 0.05$		low risk
$0.05 \leq S < 0.20$		medium risk
$S \geq 0.20$		high risk

Risk Level Matrix.

P \ C	.05	.1	.2	.4	.8
.9	.05	.09	.18	.36	.72
.7	.04	.07	.14	.28	.56
.5	.03	.05	.10	.20	.40
.3	.02	.03	.06	.12	.24
.1	.01	.01	.02	.04	.08

Risk quantification.

Four approaches for dealing with probabilities:

- **Classical** approach
- **Mathematical** approach
- **Frequentist** approach
- **Bayesian** approach.

Risk quantification.

Four approaches for dealing with probabilities:

- **Classical** approach:

The probability P(*A*) of an event *A* is the property that determines its frequency of occurrence.

E.g.:
P(head) = P(tail) = 1/2
P(⚀) = P(⚃) = 1/6
P(⚃ and ⚃) = 1/36.

Risk quantification.

Four approaches for dealing with probabilities:

- **Mathematical** approach:

P(A) is a number that obeys the many axioms of the theory built up by A. Kolmogorov in the '30s:

$0 \leq P(A) \leq 1$
$P(A \vee B) = P(A) + P(B)$
$\sum P(A_i) = 1$
…

Risk quantification.

Four approaches for dealing with probabilities:

- **Frequentist** approach:

P(*A*) is a limit over a set, when the number of elements of this set tends to ∞.

Risk quantification.

Four approaches for dealing with probabilities:

- **Bayesian** approach:

P(*A*) is the degree of belief in the occurrence of an event.

Risk quantification | Process.

INPUTS:

- PRM Plan
- Project Risk Register
- Risk Assessment Forms
- Outputs of the project planning phase ⇢ PBS, WBS, Gantt Chart…
- Lessons learned in matter of PRM on former NPD projects
- Names of NPD PRM experts ⇢ interviews

TOOLS & TECHNIQUES:

- Math toolbox ⇢ probability, combinatory…
- Decision trees
- Monte-Carlo simulations

Risk quantification | Process.

OUTPUTS:

- Project Risk Register
- Risk Assessment Forms
- Quantitative risk analysis calculation notes…

Risk handling.

Four strategies:

- **mitigate**
- **accept**
- **avoid**
- **transfer**.

Risk handling | Process.

INPUTS:

- PRM Plan
- Project Risk Register
- Risk Assessment Forms
- Lessons learned in matter of PRM on former NPD projects
- Names of NPD PRM experts ⇢ interviews

TOOLS & TECHNIQUES:

- Brainstorming sessions, Six-hats, Delphi method…
- Interviews

Risk handling | Process.

OUTPUTS:

- Project Risk Register
- Risk Assessment Forms
- **Response Plans**
- **Contingency Plans**.

Risk follow-up.

Consists of:

- Following up the risks identified of the Project Risk Register
- Detecting the emergence of residual risks, and engaging the appropriate Contingency Plans
- Following up the implementation of the Contingency Plans and appraising their efficiency
- Scrutinizing the emergence of **new risks** (i.e. risks that weren't identified during the Planning phase of the project) and applying to them all the methodology presented here before.

Risk follow-up | Process.

INPUTS:

- All PRM documents
- Project performance indices ⇢ EVM…
- Checklists

TOOLS & TECHNIQUES:

- Project audits and reviews focused on PRM

OUTPUTS:

- Updated PRM documents.

11

Controlling the Progress

Earned Value Management.

The **Earned Value Criteria** is a methodology developed by the US DoD in the late '60s for project reporting.

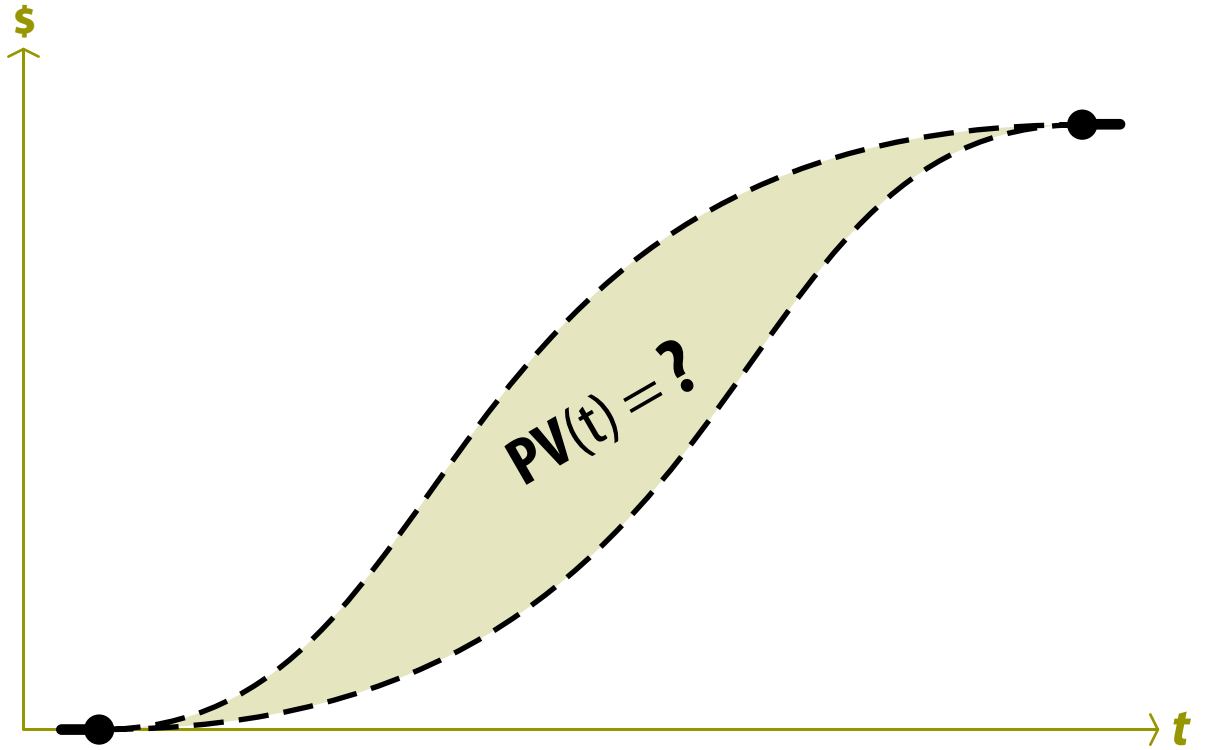
At that time, this methodology was known as the **C/SCSC** (Cost/Schedule Control System Criteria).

As of 1996, it is managed by the ANSI, under standard **#748**.

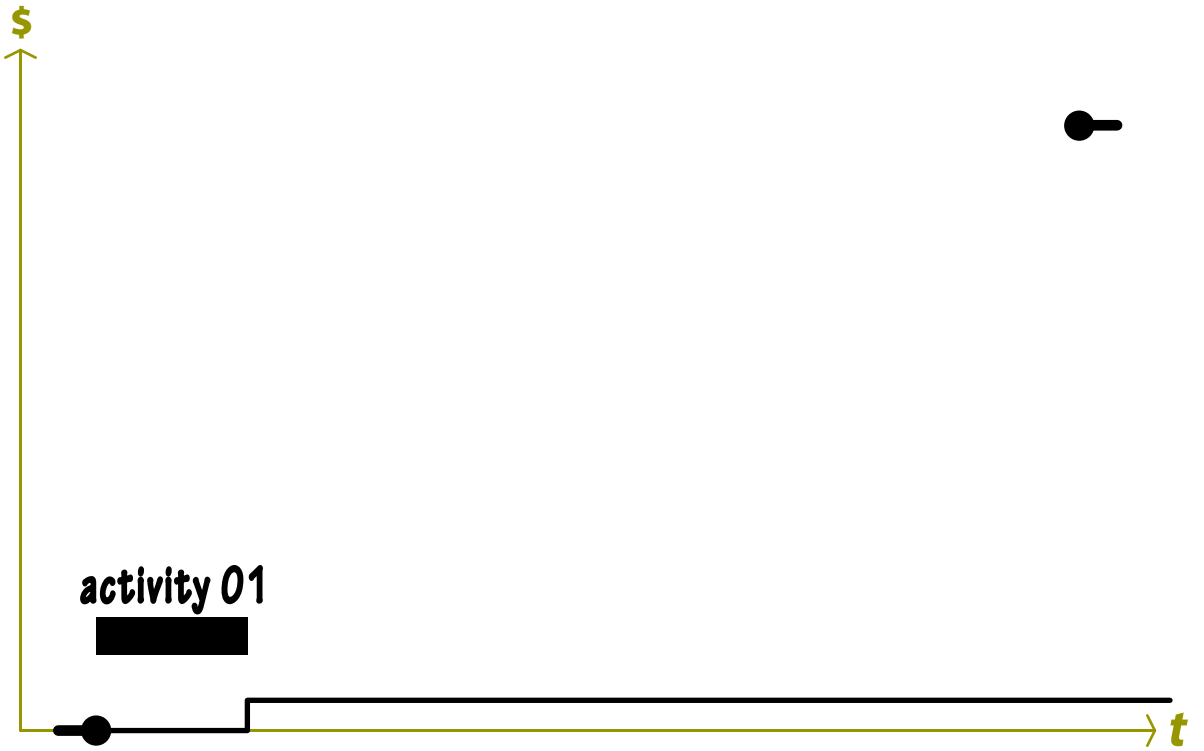
From then on, it is known as:

- **EVM**, standing for Earned Value Management (in the US)
- **EVA**, standing for Earned Value Analysis (in the UK).

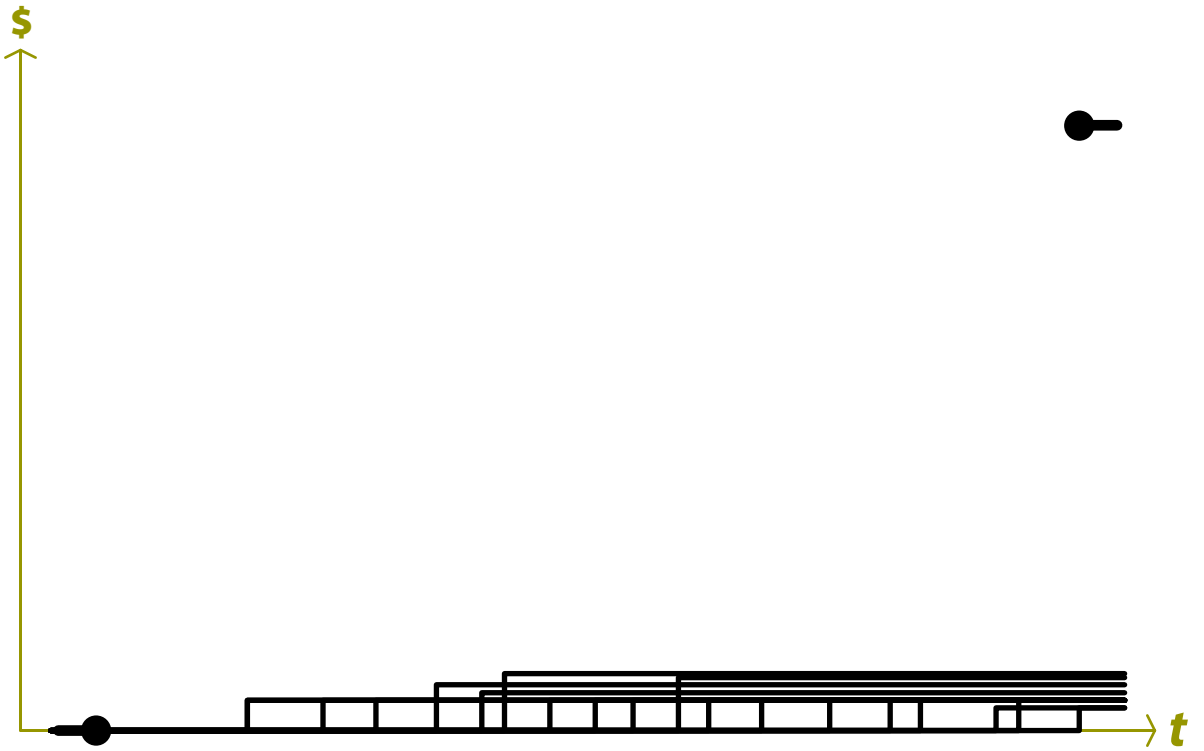
EVM Basics.



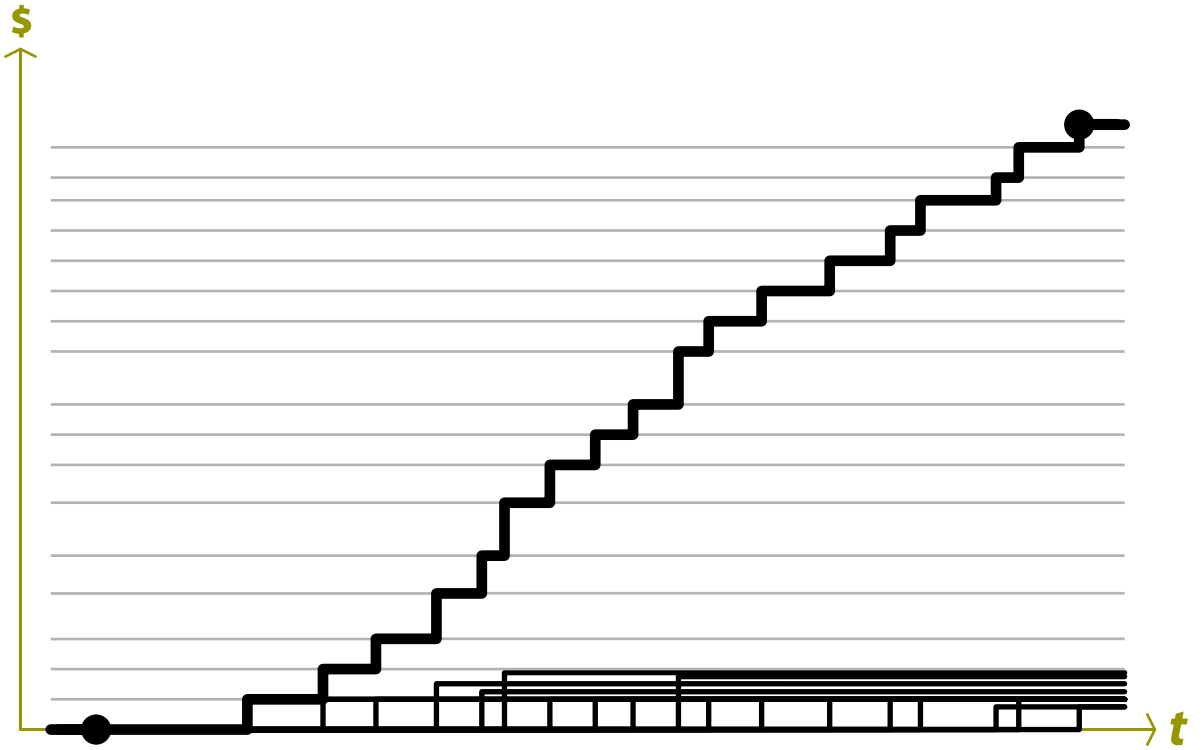
EVM Basics.



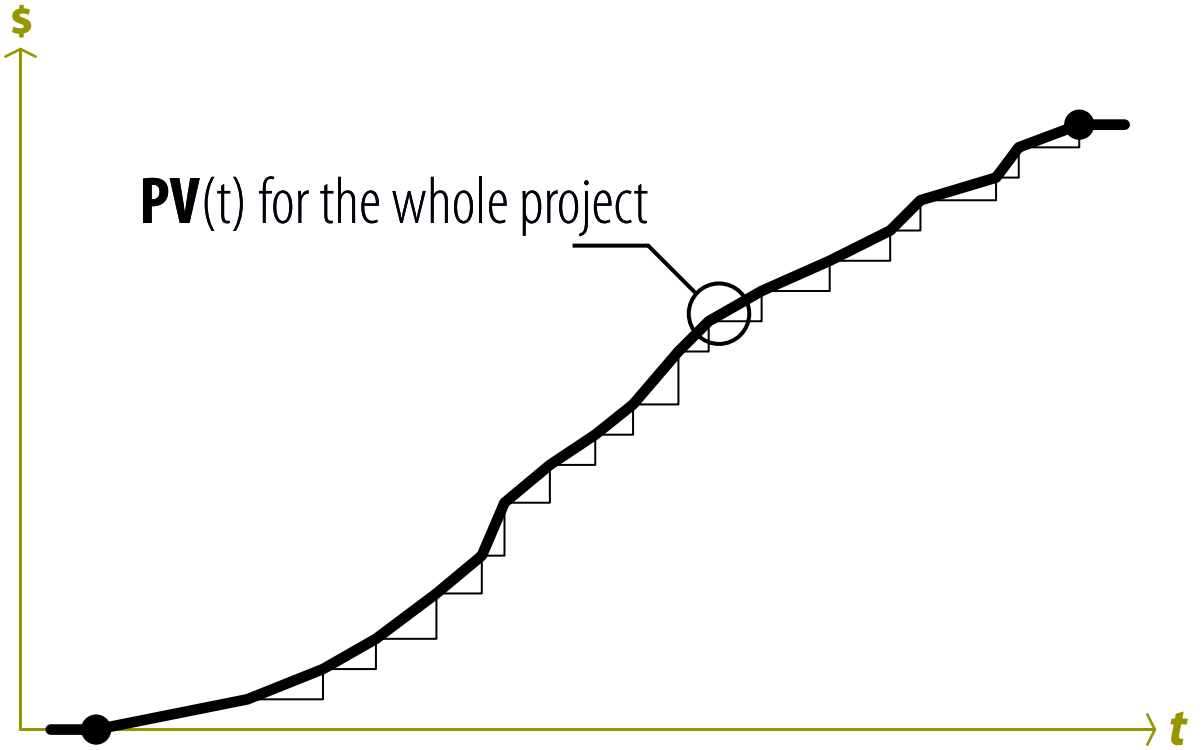
EVM Basics.



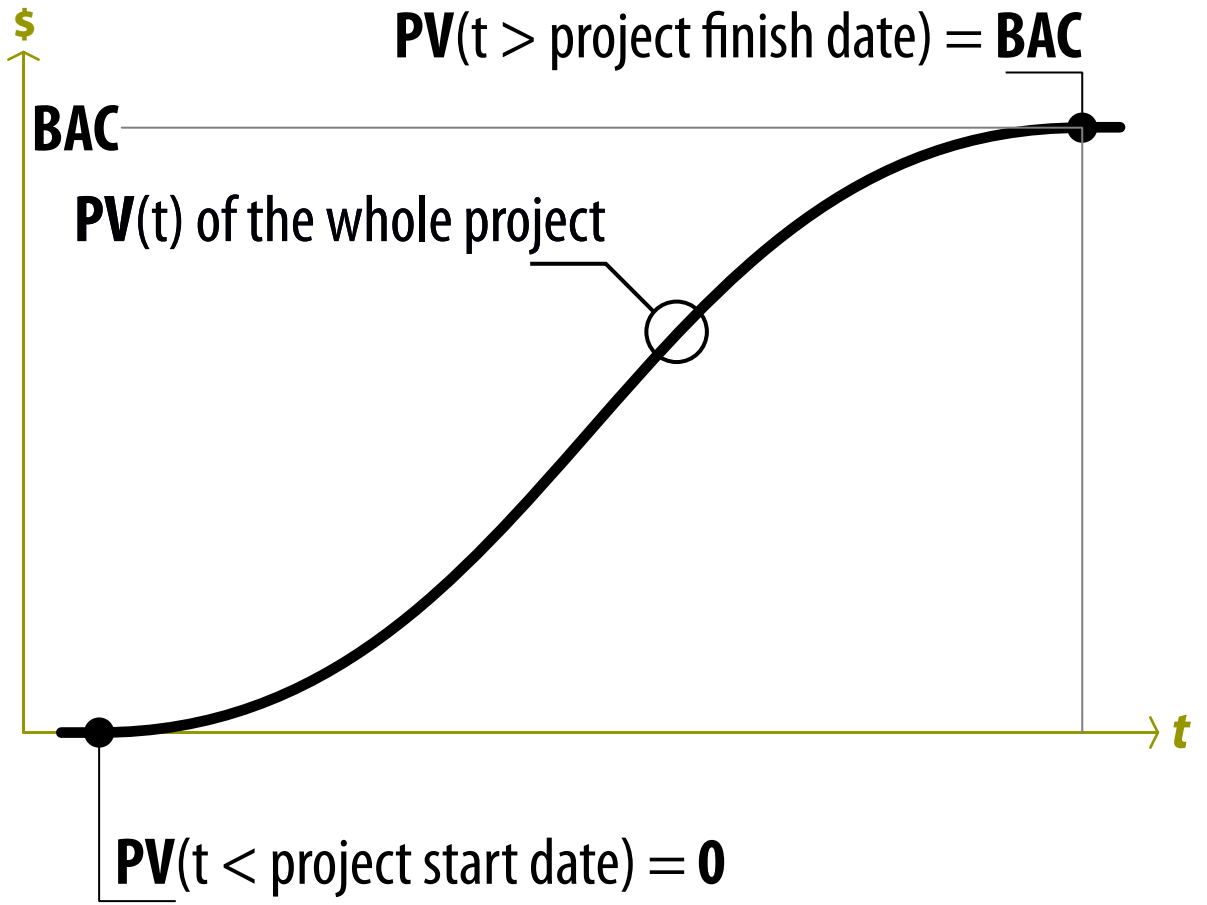
EVM Basics.



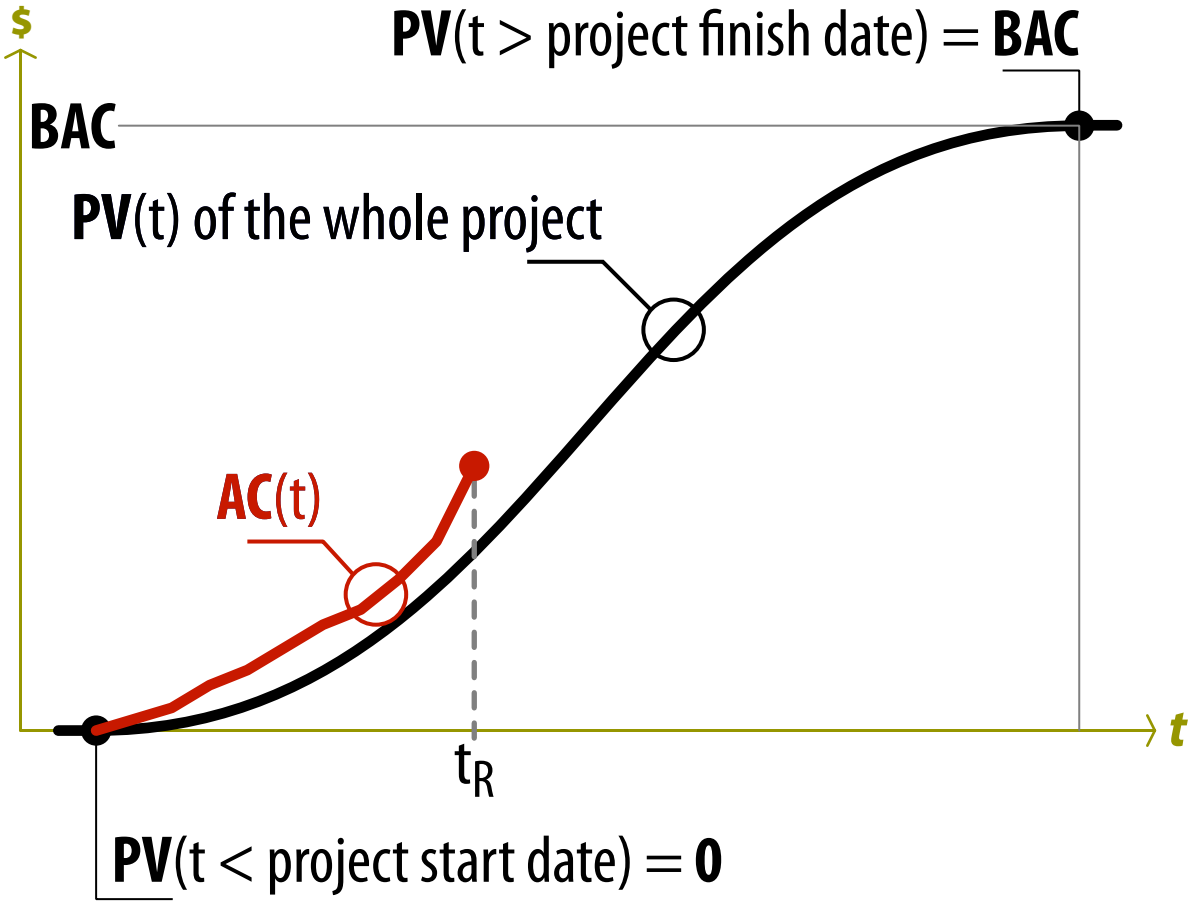
EVM Basics.



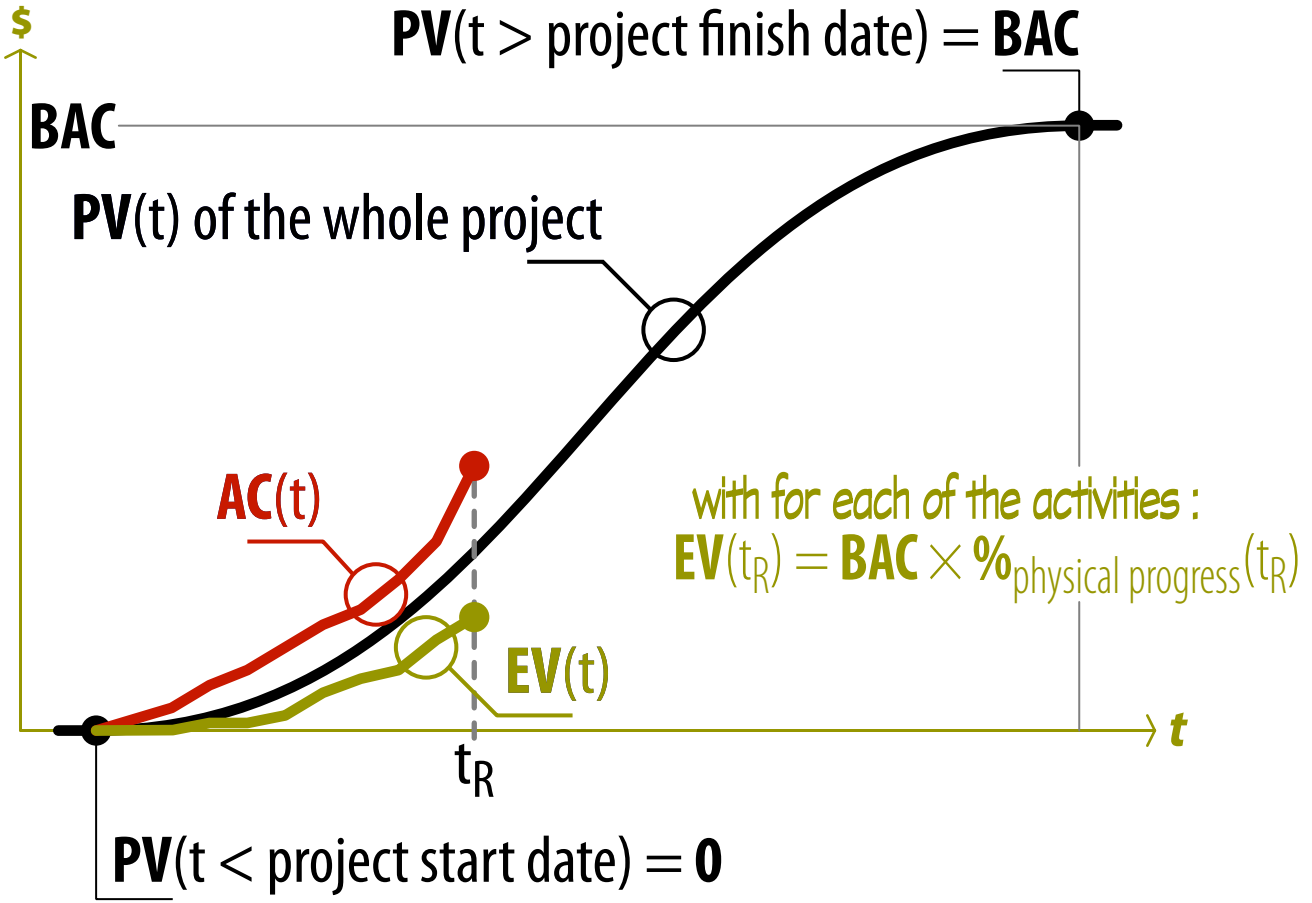
EVM Basics ⇢ PV, Planned Value.



EVM Basics ⇢ AC, Actual Costs.



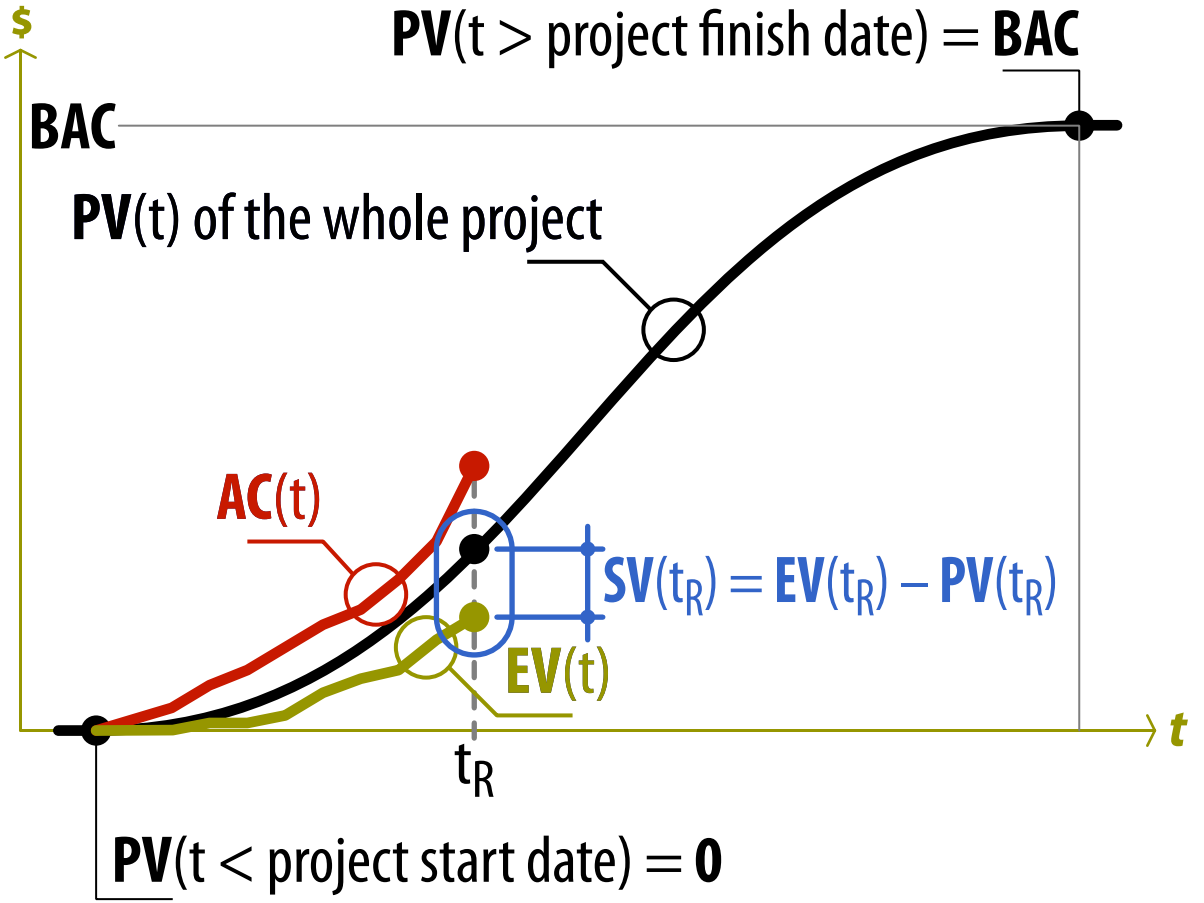
EVM Basics ⇢ EV, Earned Value.



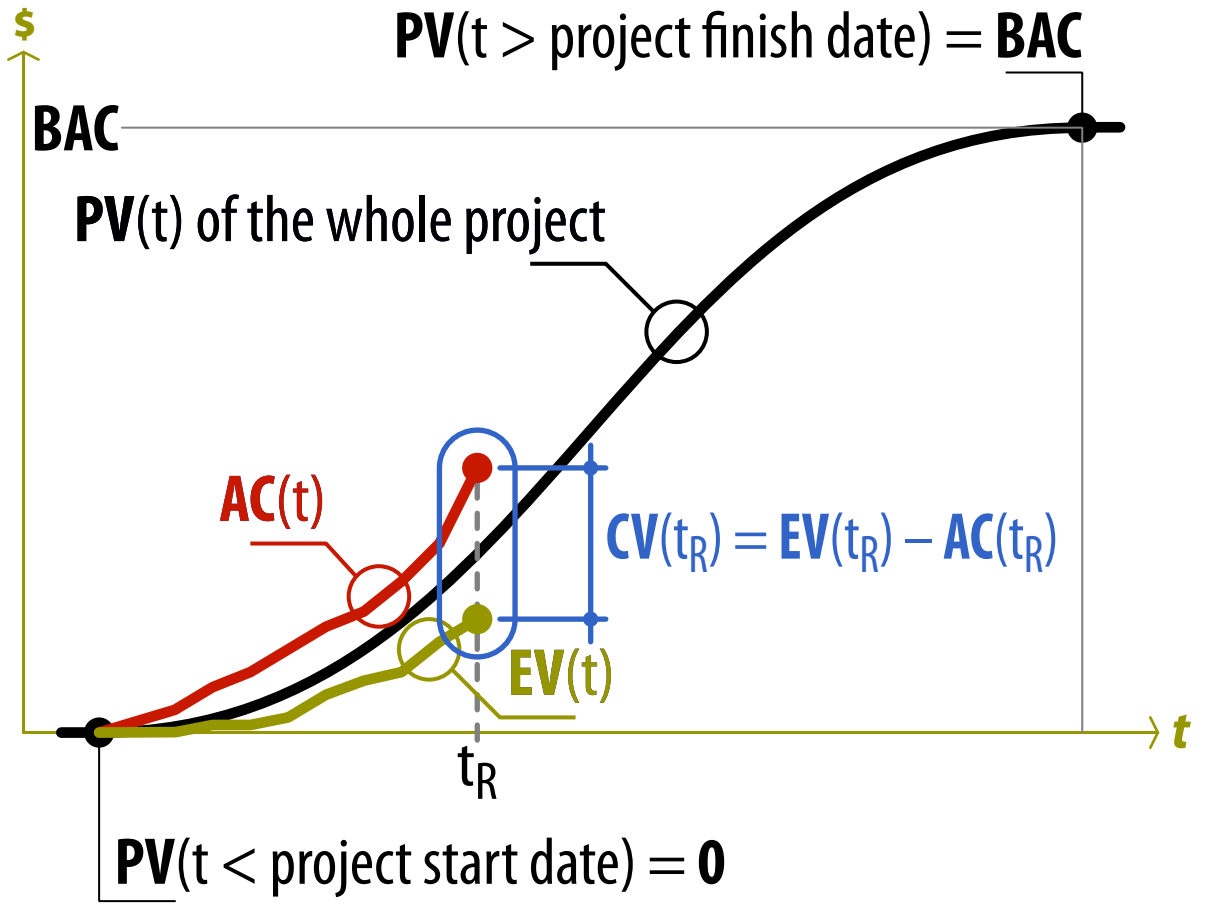
EVM Basics.

AFITEP	C/SCSC	ANSI #748
CBTP Coût budgété du travail prévu	**BCWS** Budgeted Cost of the Work Scheduled	**PV** Planned Value
CRTE Coût réel du travail effectué	**ACWP** Actual Cost of the Work Performed	**AC** Actual Cost
CBTE Coût budgété du travail effectué	**BCWP** Budgeted Cost of the Work Performed	**EV** Earned Value
CTB Coût total budgété	**BAC** Budget at Completion	**BAC** Budget at Completion

EVM Basics ⇢ SV, Schedule Variance.



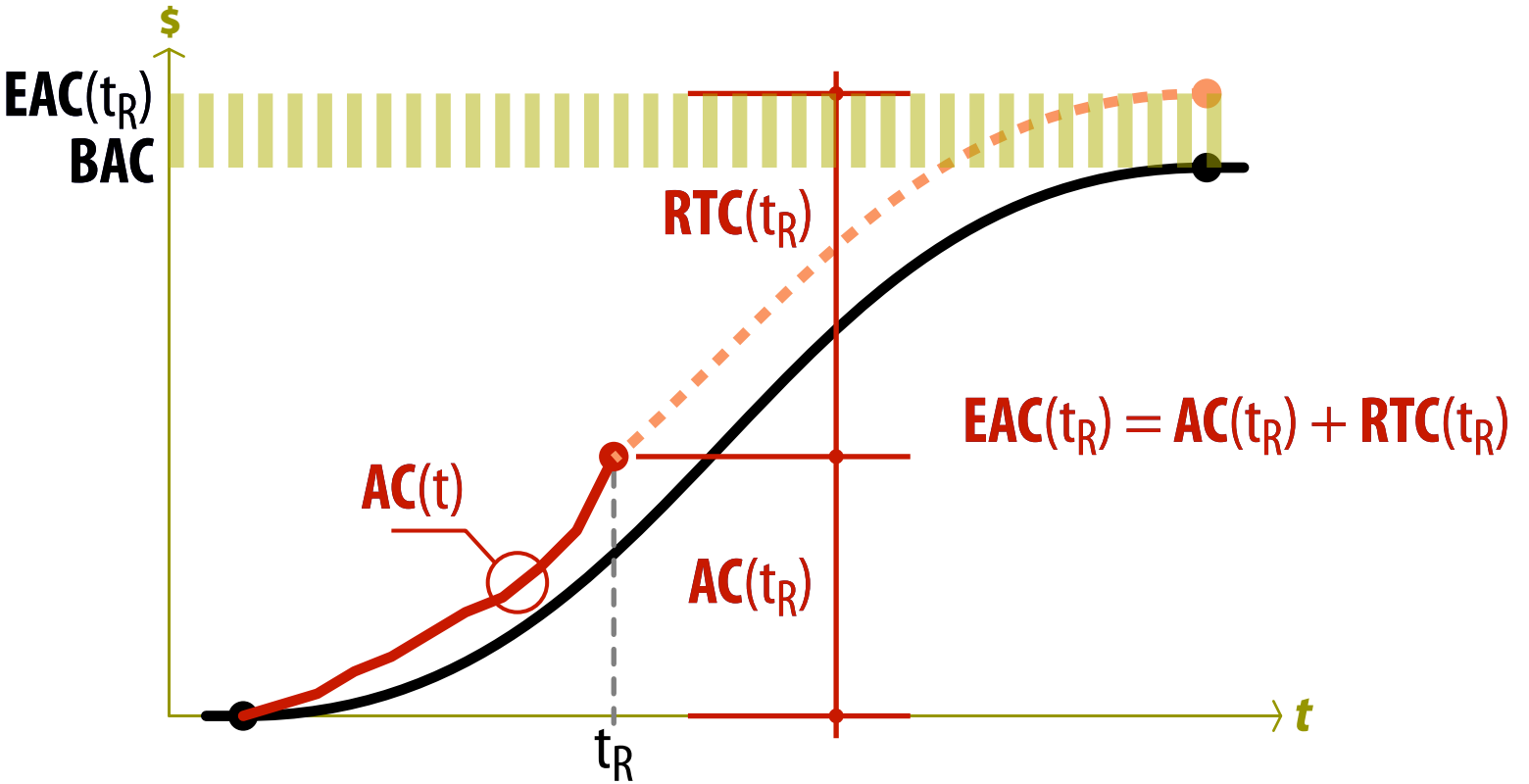
EVM Basics ⇢ CV, Cost Variance.



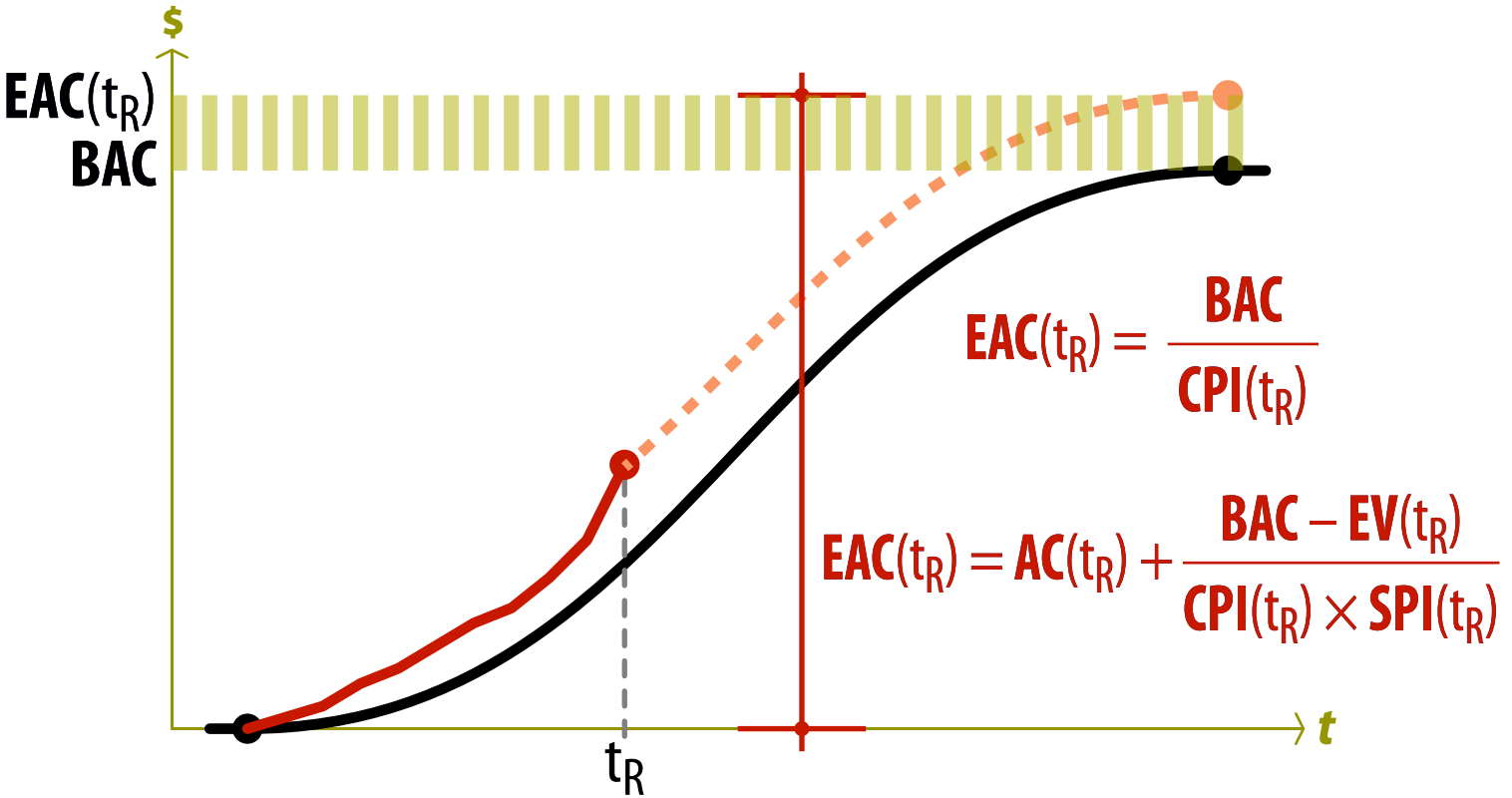
EVM Basics.

Schedule Variance $\mathbf{SV}(t_R) = \mathbf{EV}(t_R) - \mathbf{PV}(t_R)$	**Cost Variance** $\mathbf{CV}(t_R) = \mathbf{EV}(t_R) - \mathbf{AC}(t_R)$
Schedule Performance Index $\mathbf{SPI}(t_R) = \dfrac{\mathbf{EV}(t_R)}{\mathbf{PV}(t_R)}$ $\mathbf{SPI}(t_R) > 1$ ☺ $\mathbf{SPI}(t_R) < 1$ ☹	**Cost Performance Index** $\mathbf{CPI}(t_R) = \dfrac{\mathbf{EV}(t_R)}{\mathbf{AC}(t_R)}$ $\mathbf{CPI}(t_R) > 1$ ☺ $\mathbf{CPI}(t_R) < 1$ ☹
Critical Ratio $\mathbf{CR}(t_R) = \mathbf{SPI}(t_R) \times \mathbf{CPI}(t_R)$	**Physical Progress** $\varphi(t_R) = \dfrac{\mathbf{EV}(t_R)}{\mathbf{BAC}}$

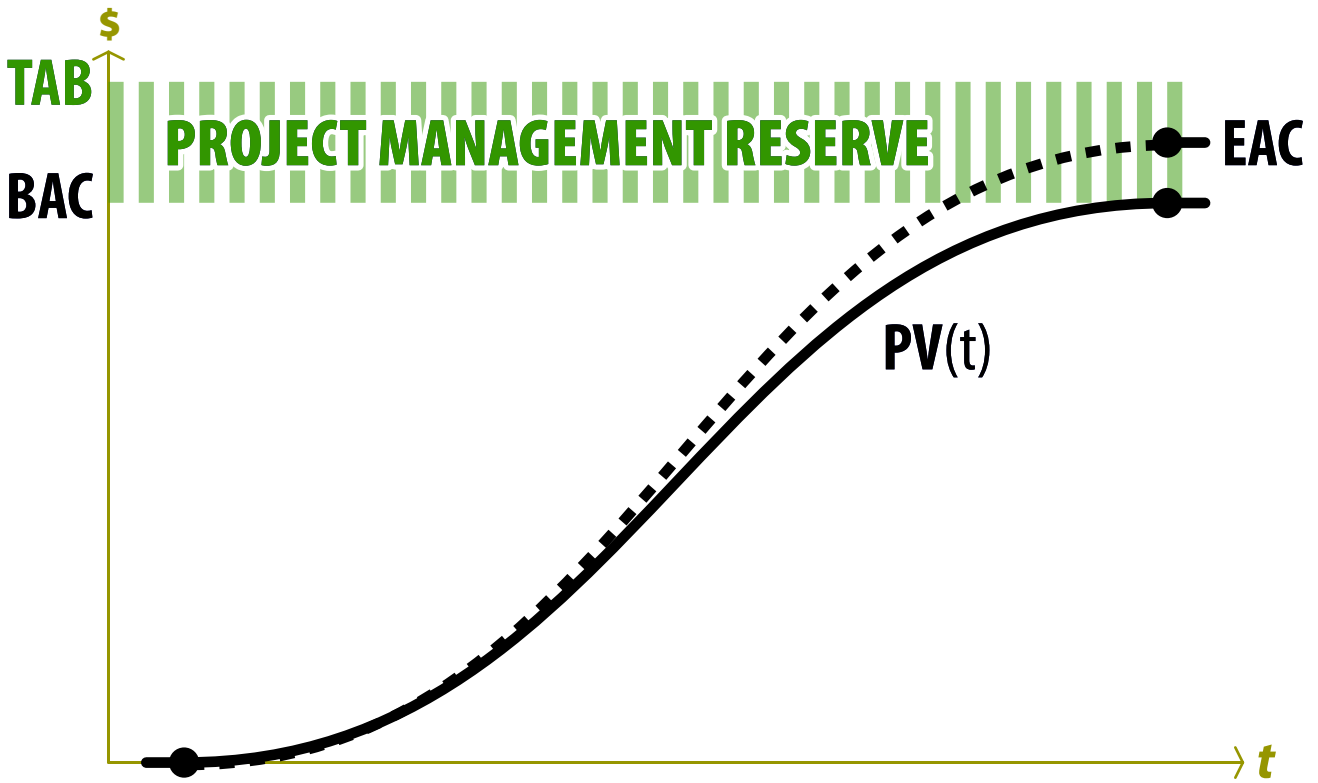
EVM Basics ⇢ EAC, Estimate at Completion.



EVM Basics ⇢ EAC, Estimate at Completion.



EVM Basics ⇢ TAB, Total Allocated Budget.



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