Project Scheduling and Earned Value 101

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What is Project Scheduling

- A schedule is fundamentally the decomposition of a project Work Breakdown Structure (**WBS**).
- The most widely used scheduling technique is the critical path method (**CPM**).
- CPM is mathematical analysis, which can be used on all types of projects that can be represented as ***a list of activities, each with an estimated duration, single or three-point***.
- In addition, the dependencies between activities need to be defined, as do the resources required to deliver the scope of each activity.

History of Project Scheduling

- CPM was developed in the late 1950s by Morgan R. Walker of DuPont and James E. Kelley Jr. of Remington Rand.
- Kelley attributed the term “Critical Path" to the developers of the Program Evaluation and Review Technique (PERT). This was developed at about the same time by Booz Allen Hamilton and the U.S. Navy.
- The precursors of what came to be known as Critical Path were developed and put into practice by DuPont between 1940 and 1943 and contributed to the success of the Manhattan Project.

What is a WBS

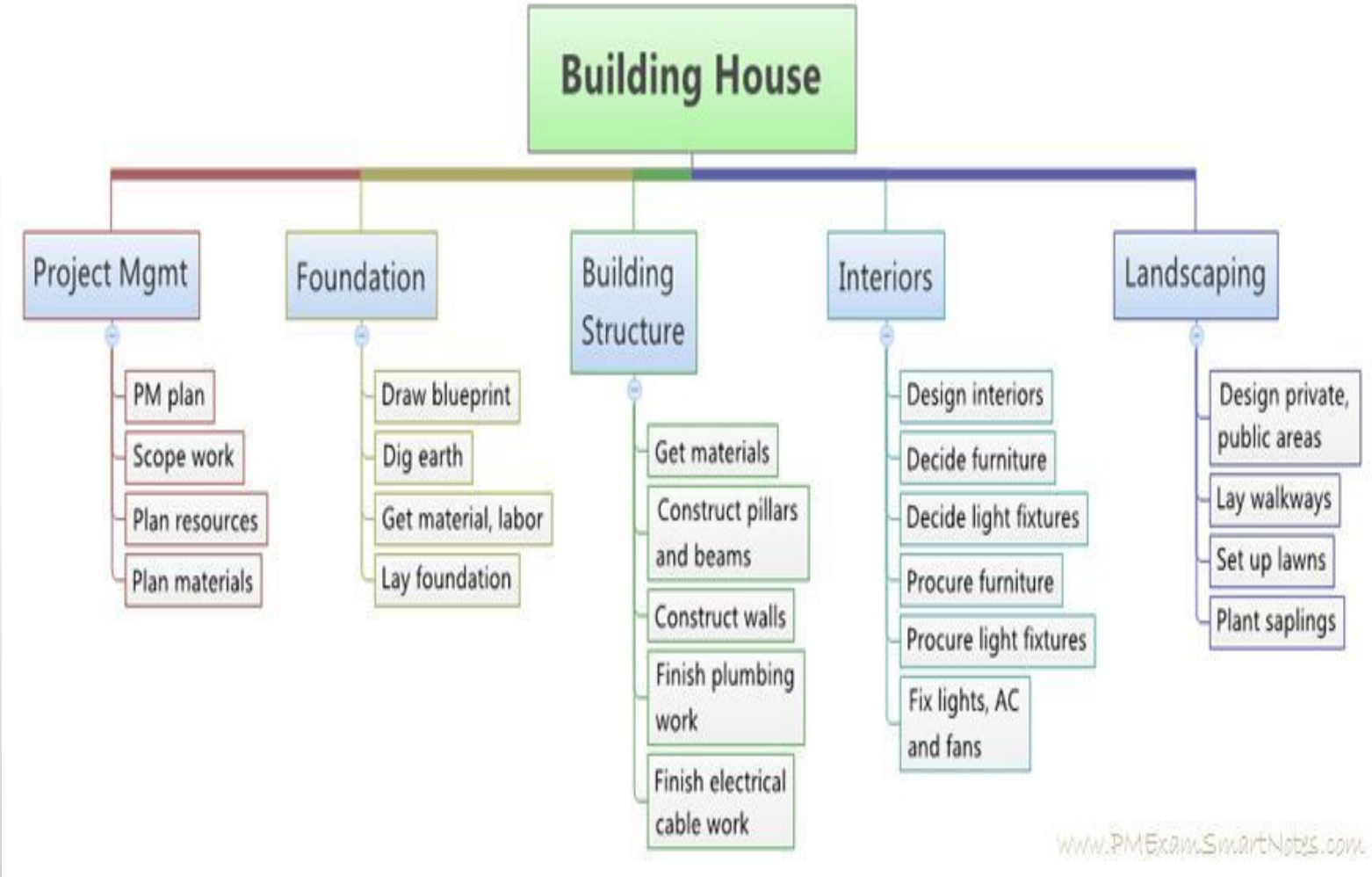
- The WBS identifies the major functional deliverables

- These deliverables are subdivided into smaller systems and sub-deliverables.

- The Project Management Body of Knowledge (PMBOK), an internationally recognized collection of processes and knowledge areas, defines ***the WBS as a "deliverable oriented hierarchical decomposition of the work to be executed by the project team***."

  The WBS visually defines the scope into manageable chunks that a project team can understand, as each level of the WBS provides further definition and detail.

What is a WBS


Building House
Project Mgmt
PM plan
Scope work
Plan resources
Plan materials
Foundation
Draw blueprint
Dig earth
Get material, labor
Lay foundation
Building Structure
Get materials
Construct pillars and beams
Construct walls
Finish plumbing work
Finish electrical cable work
Interiors
Design interiors
Decide furniture
Decide light fixtures
Procure furniture
Procure light fixtures
Fix lights, AC and fans
Landscaping
Design private, public areas
Lay walkways
Set up lawns
Plant saplings
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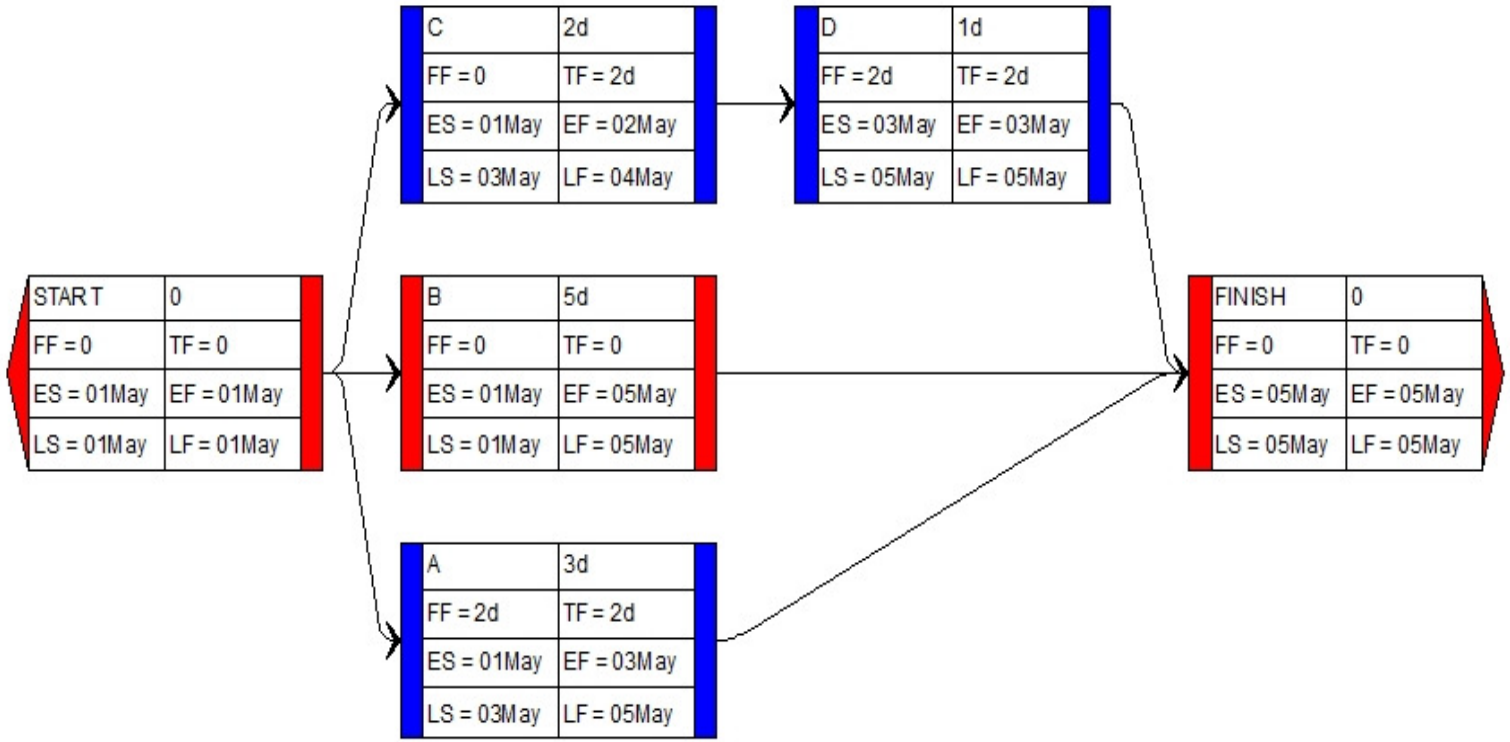
Project Critical Path

- The Project Management Body of Knowledge defines the critical path calculated using ***CPM as "the sequence of scheduled activities that determines the duration of the project***."
- ***It is the longest sequence of tasks in a project plan***. If there is a delay in any task on the critical path, then the project will be delayed.
- ***Total Float is the amount of time*** that an activity can be delayed from its early start date ***without delaying the project finish date***.
- *Free Float is the amount of time* that an activity can be delayed ***without delaying the early start date of any successor activity***.

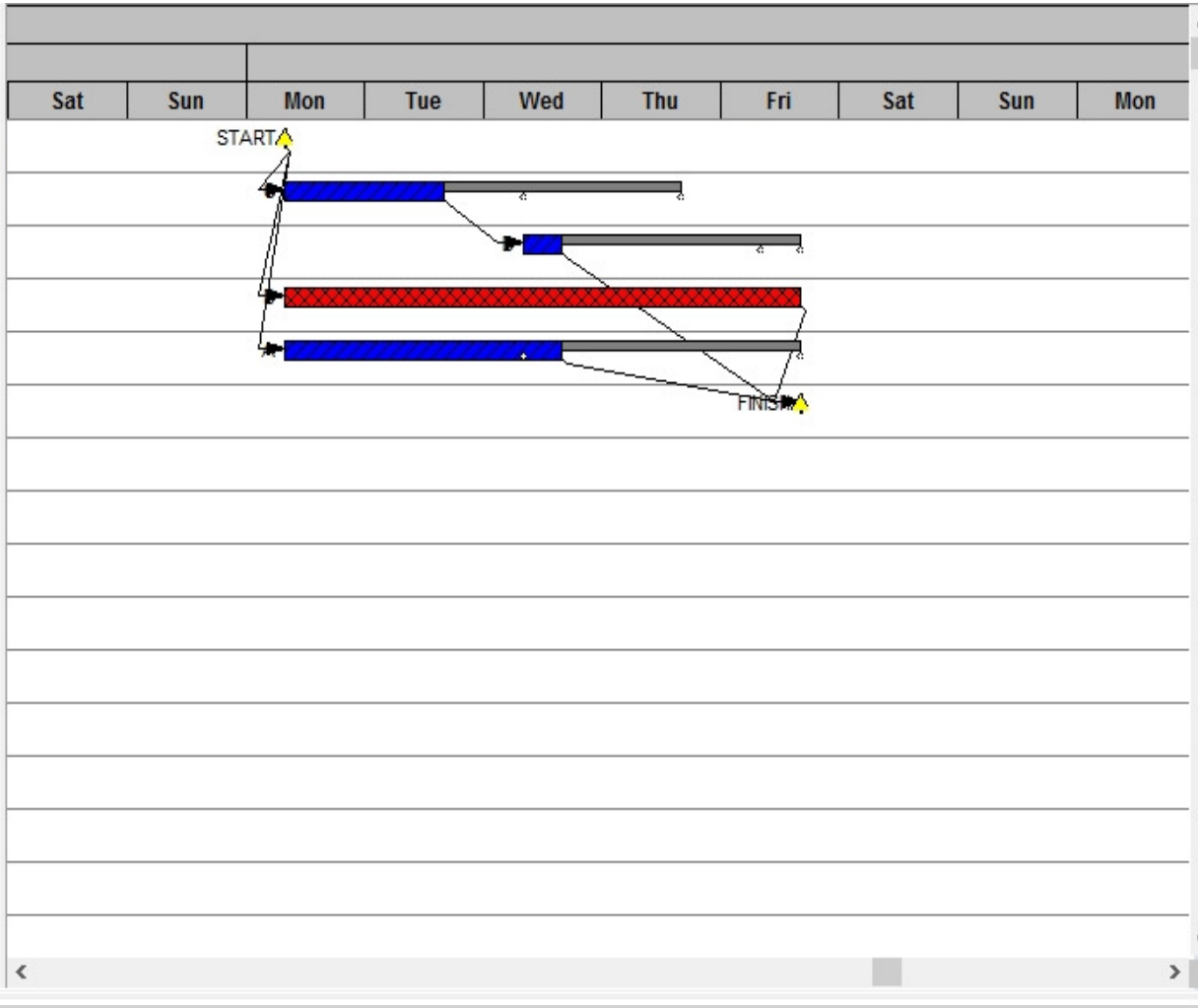
Project Critical Path



Project Critical Path

START

Activity ID	Duration	Free Float	Total Float	Early Start	Late Start	Late Finish	Early Finish
START	0	0	0	01May17	01May17	01May17	01May17
C	2d	0	2d	01May17	03May17	04May17	02May17
D	1d	2d	2d	03May17	05May17	05May17	03May17
B	5d	0	0	01May17	01May17	05May17	05May17
A	3d	2d	2d	01May17	03May17	05May17	03May17
FINISH	0	0	0	05May17	05May17	05May17	05May17



Project Schedule Dependencies

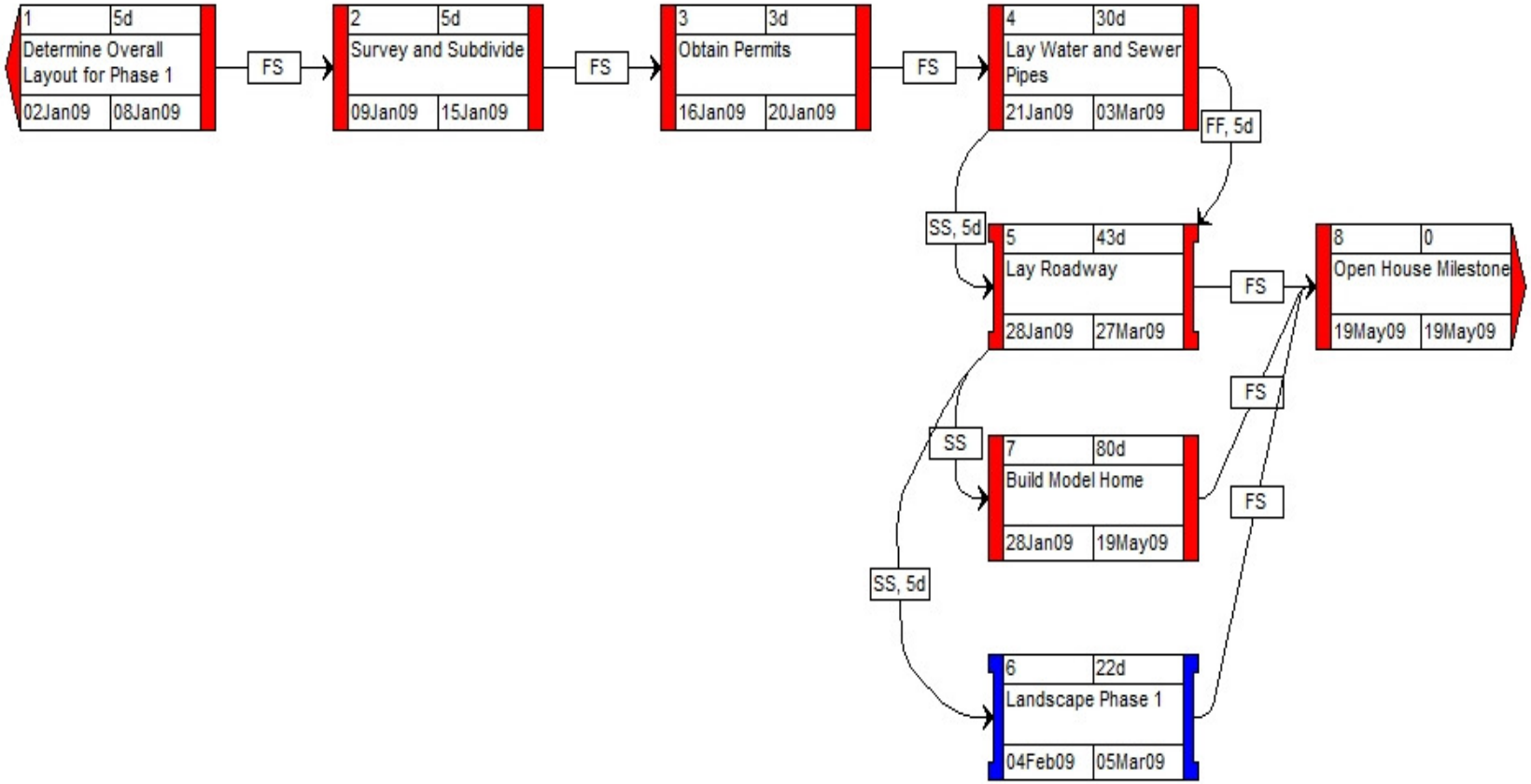
- **Finish to Start (FS)** - Predecessor must finish before Successor can start. [Can't lay water and sewer pipes until permits have been obtained]

- **Start to Start (SS)** - Predecessor must start before Successor can start. [Can't start laying roadway until laying of water and sewer pipes has started]

- **Finish to Finish (FF)** - Predecessor must finish before Successor can finish. [Can't finish laying roadway until laying of water and sewer pipes has finished']

- **Start to Finish (SF)** Predecessor must start before Successor can finish. [A baby sitter can't finish minding the child until a parent returns and starts minding the child]

Project Schedule Dependencies



Project Schedule Constraints

- ***Can apply to either an activity start or finish***. Constraint types include:
  - Start Not Earlier Than
  - Start Not Earlier Than
  - Start On

  - Finish Not Later Than
  - Finish Not Earlier Than
  - Finish On
- CPM is deigned to calculate a Critical Path using activity estimated durations and dependencies.
- The use of constraints may impact the integrity of the CPM calculations, ***as well as generate negative float***.

Project Schedule Resources

- The ***calculation of the Critical Path does not take into account the resources required*** to delver the scope of each activity defined in the schedule.

- Resources can be typically categorised as:

  - **Labour**
  - **Material**
  - **Subcontract**
  - **Other Directs Costs**

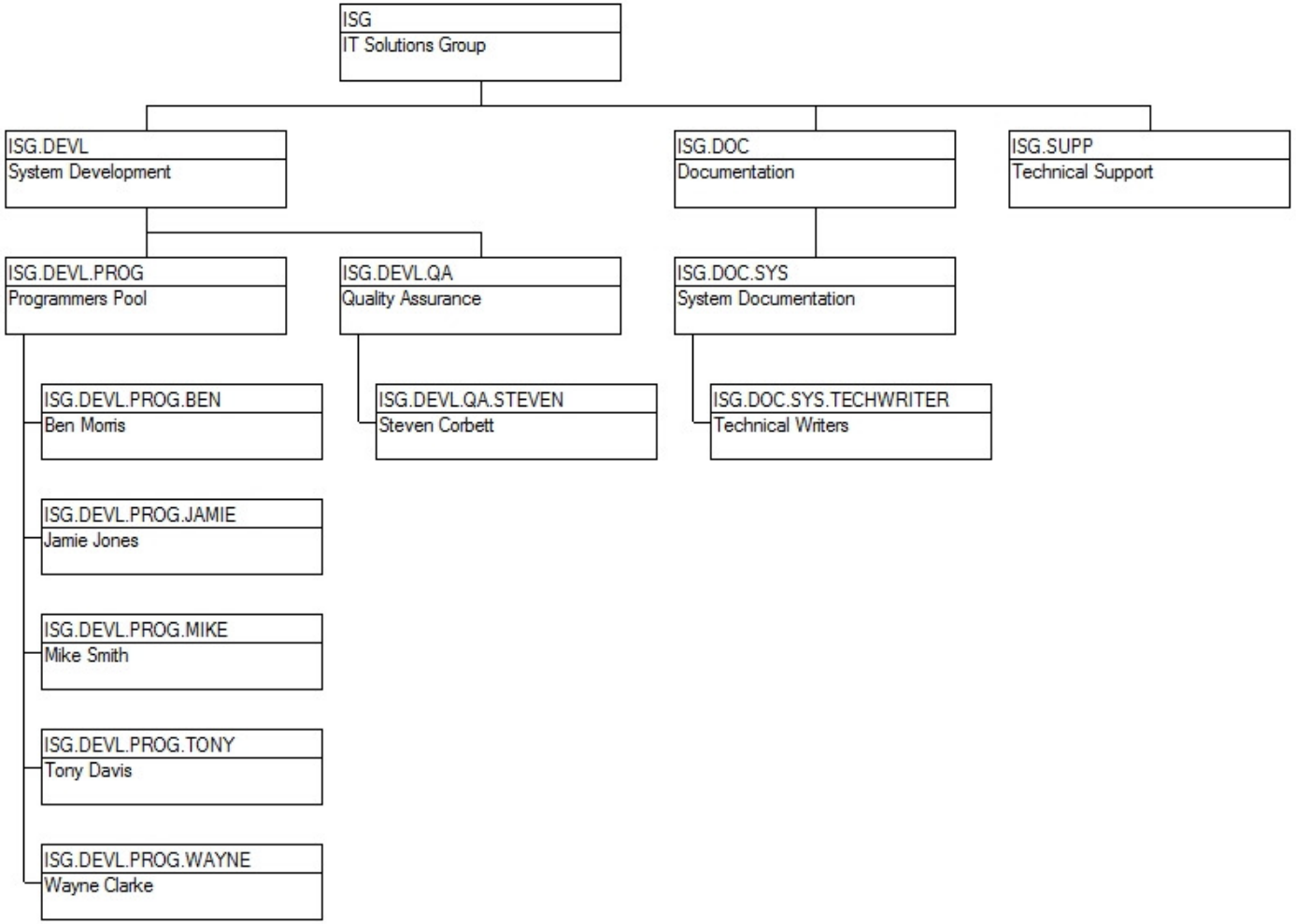
- The development of a project schedule requires the allocation of resources to all activities which will deliver an output. Milestone activities would not ordinarily have resources allocated as they are activities of zero duration that represent an event.

- ***A "Payment" type milestone may have budget allocated to it***, which would be assigned as a resource.

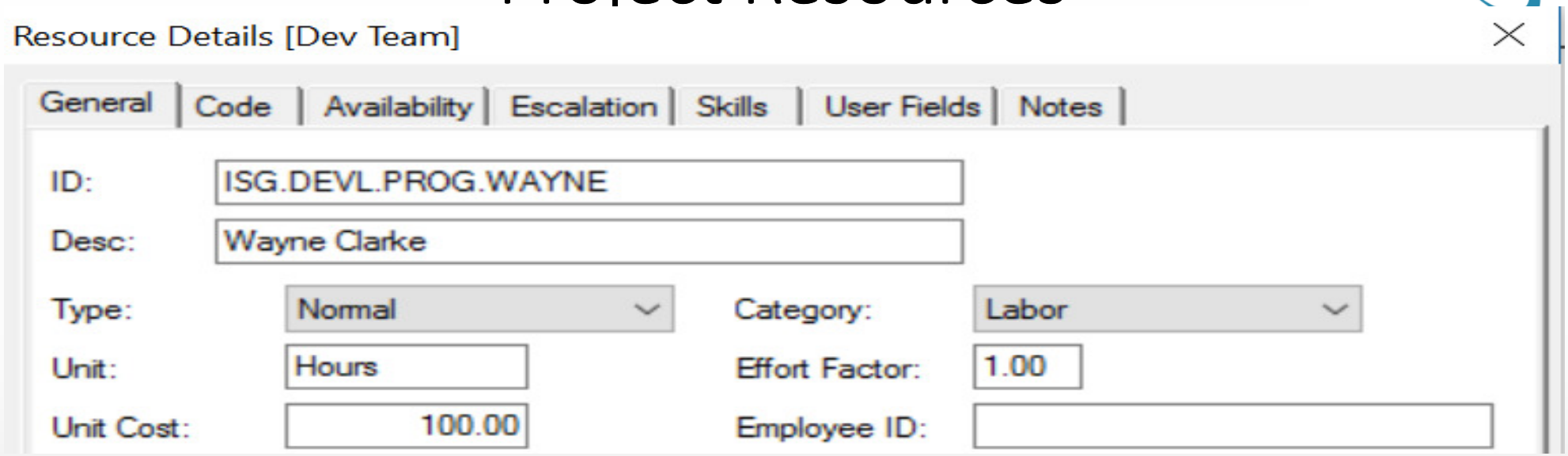
Project Schedule Resources

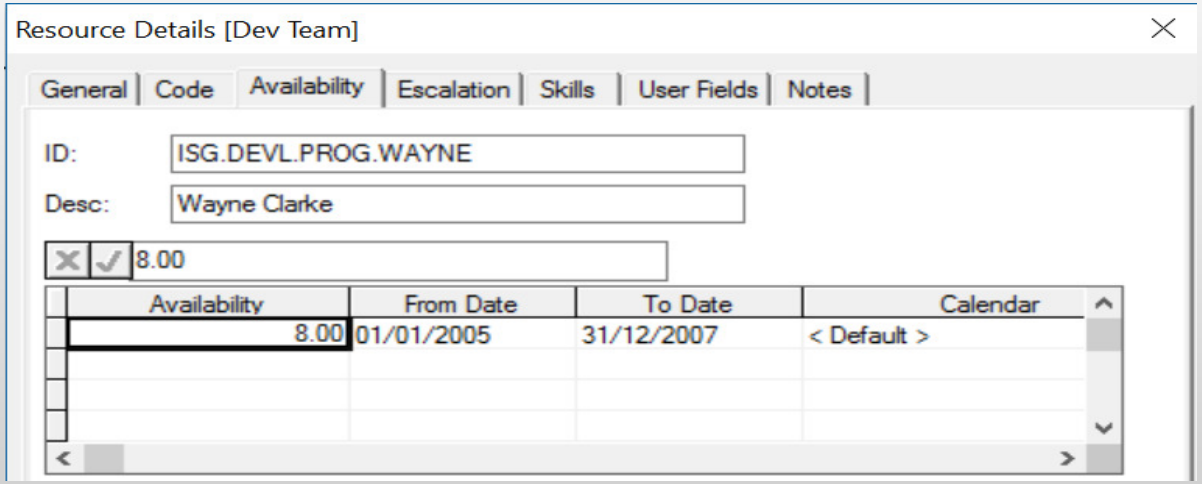
- Once the allocation of resources is complete, they are aggregated on a periodic basis which may be daily, weekly or monthly, as appropriate.
- The aggregated data is often presented in a histogram that illustrates the fluctuating use of resources against time.
- It is at this stage of the development of the schedule that a ***detailed comparison of resources required to complete the project scope, versus the resources available is undertaken***.
- The analysis may show that during the project lifecycle, there are periods where there are ***insufficient resources available to start all activities on or before their Late Start Date***.

Project Resources



Project Resources

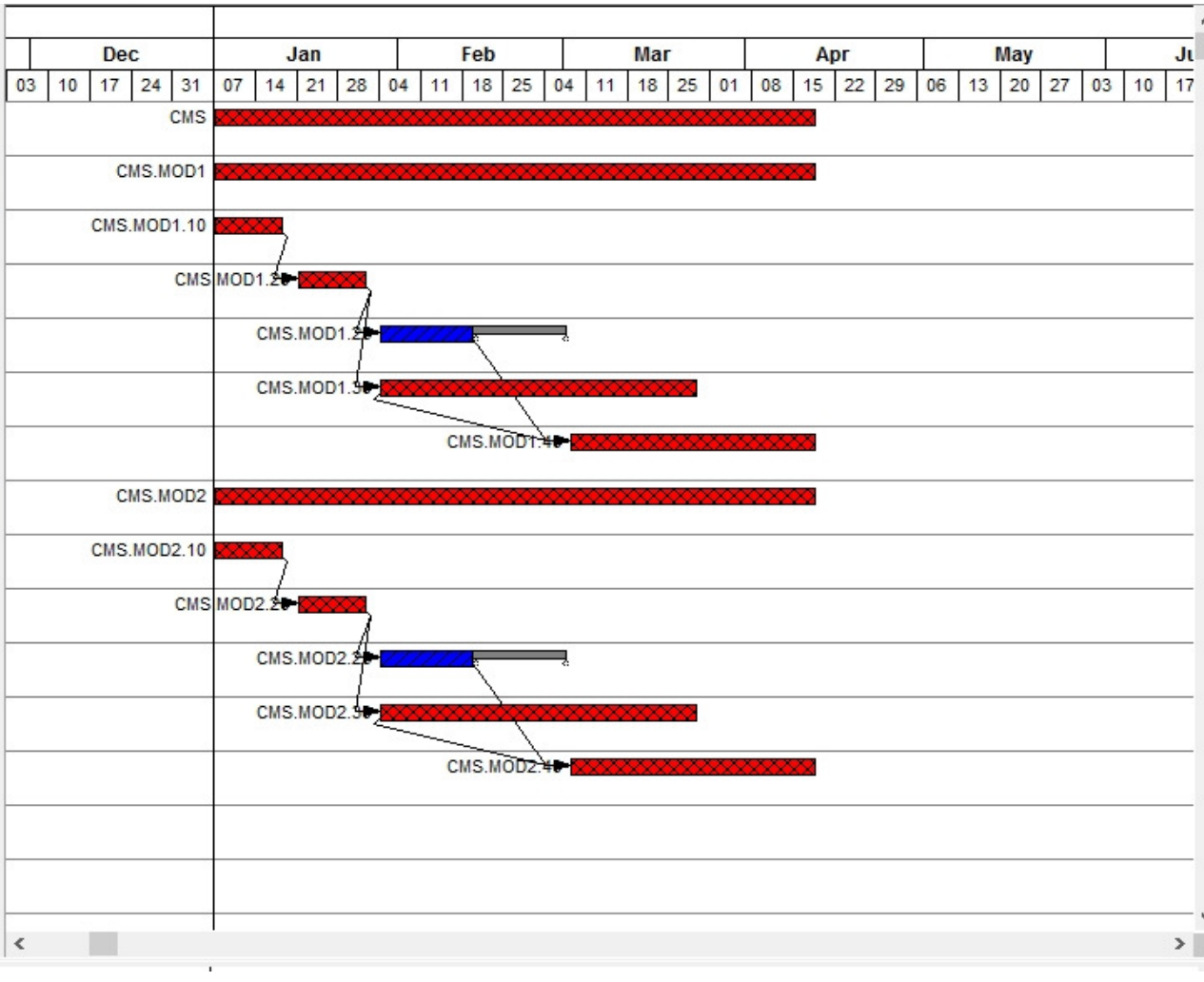




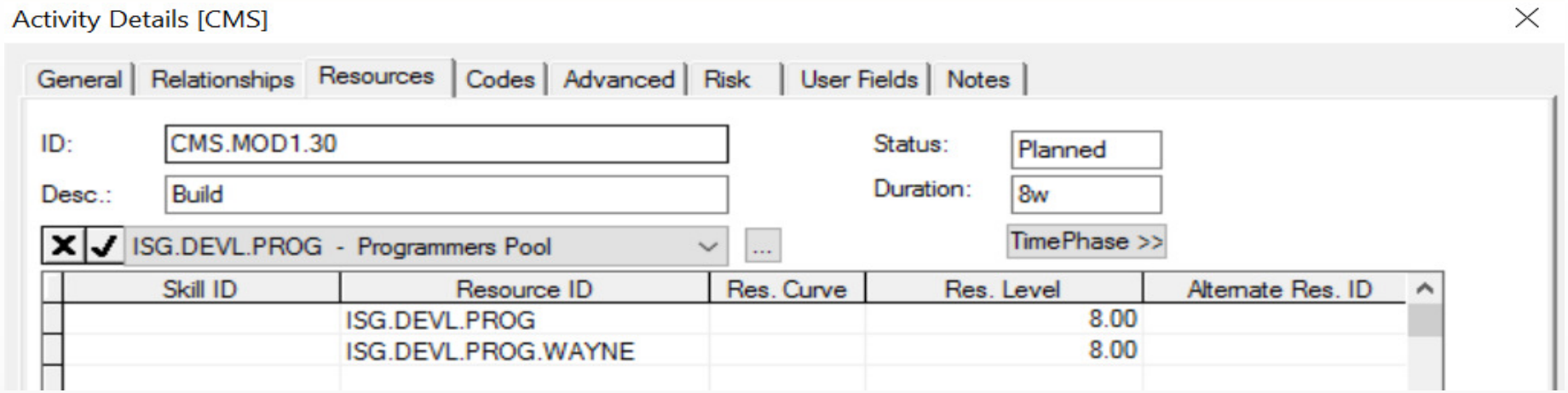
Project Schedule

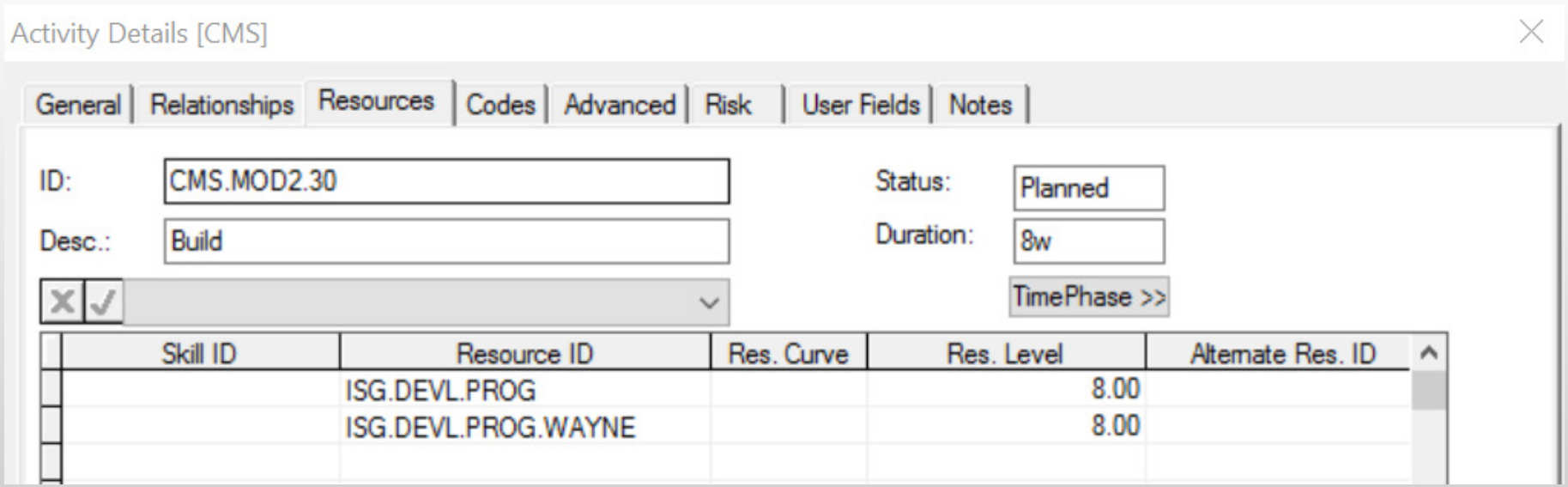
13Feb07

Activity ID	Activity Description	Duration	Total Float	Early Start	Early Finish
CMS	Contact Management System	74d	0	01Jan07	12Apr07
CMS.MOD1	Module 1	74d	0	01Jan07	12Apr07
CMS.MOD1.10	Requirements Analysis	2w	0	01Jan07	12Jan07
CMS.MOD1.20	System Specification	2w	0	15Jan07	26Jan07
CMS.MOD1.25	Sales Literature	12d	12d	29Jan07	13Feb07
CMS.MOD1.30	Build	8w	0	29Jan07	23Mar07
CMS.MOD1.40	Documentation	30d	0	02Mar07	12Apr07
CMS.MOD2	Module 2	74d	0	01Jan07	12Apr07
CMS.MOD2.10	Requirements Analysis	2w	0	01Jan07	12Jan07
CMS.MOD2.20	System Specification	2w	0	15Jan07	26Jan07
CMS.MOD2.25	Sales Literature	12d	12d	29Jan07	13Feb07
CMS.MOD2.30	Build	8w	0	29Jan07	23Mar07
CMS.MOD2.40	Documentation	30d	0	02Mar07	12Apr07

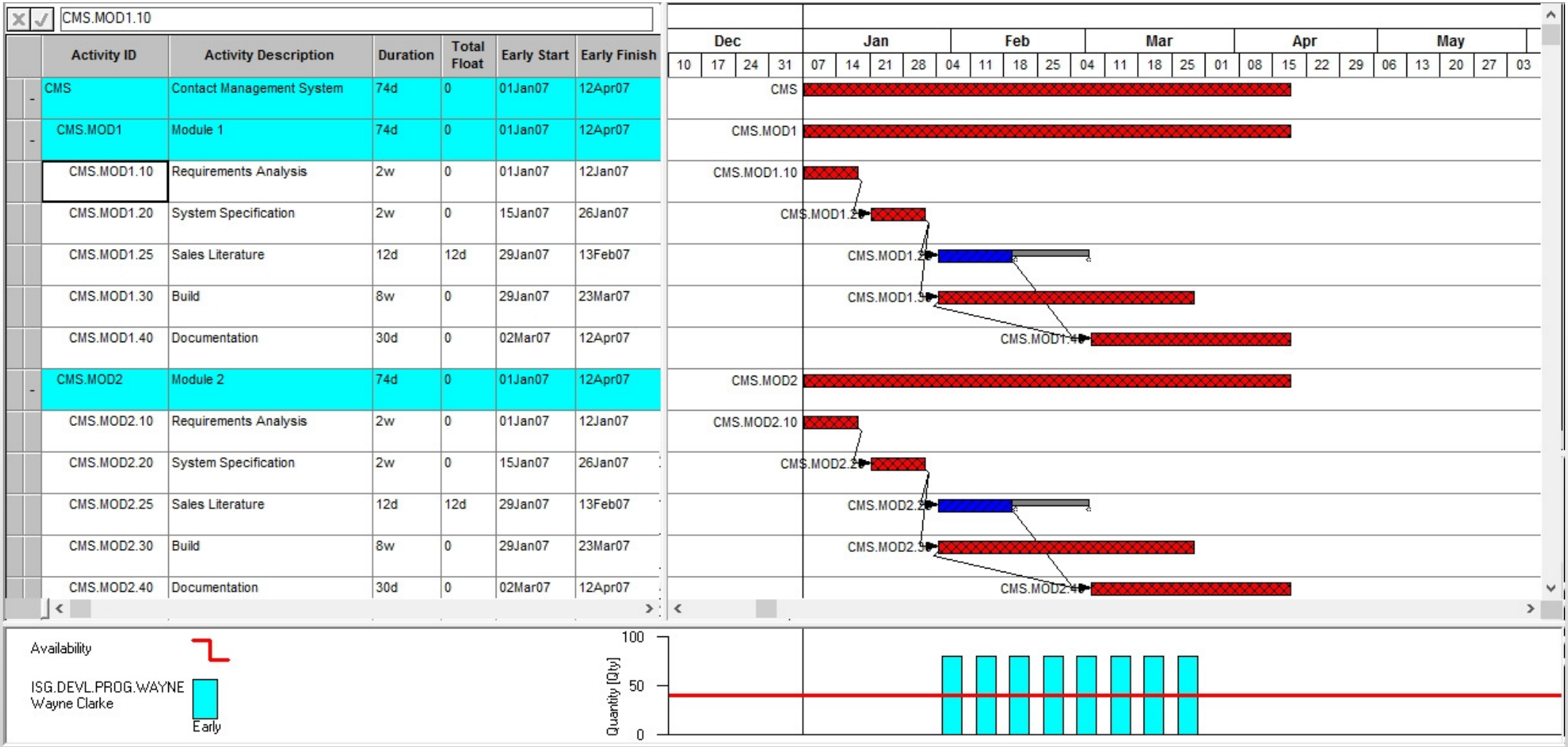


Project Schedule Resource Allocations





Project Schedule Resource Aggregation



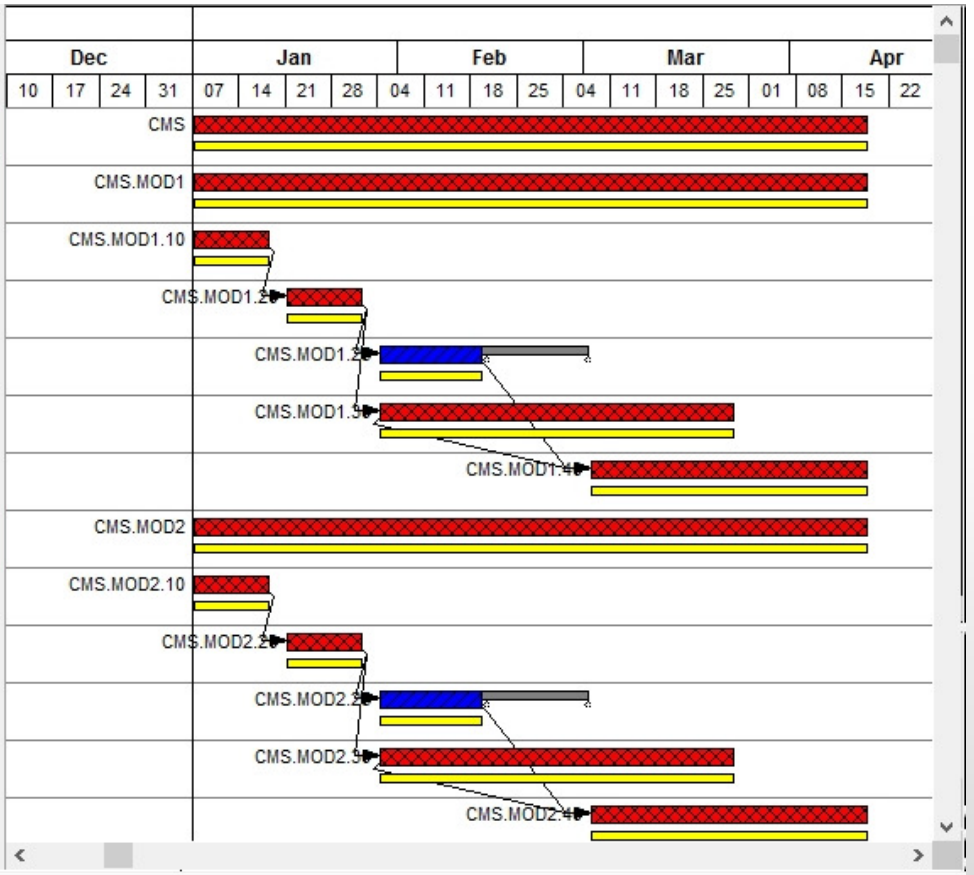
Project Resource Scheduling Methods

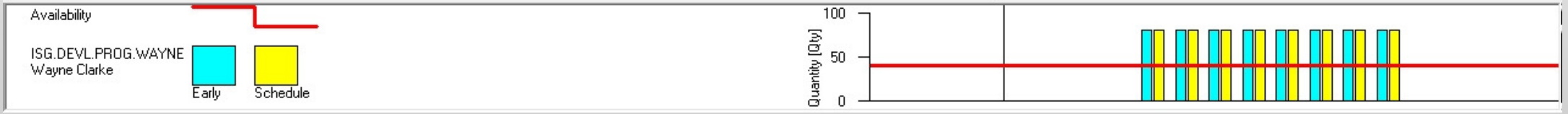
- **Time Limited**
  - ***Places a priority on maintaining the project completion date***, while attempting to minimise the extent to which any resource is over-utilised.
  - Constraints on resource availabilities will not delay the completion date of the project. As a result, ***resources may be overloaded*** if doing so prevents an activity from finishing after its late finish date.
  - Time-limited resource scheduling places all scheduled dates between the early and late dates of activities. Thus***, only activities not on the project critical path can be delayed by resource constraints***.
- **Resource Limited**
  - ***Places a priority on preventing the over-utilisation of resources***, even if that means exceeding the project completion date.
  - The results of Resource-limited scheduling would ordinarily be analysed (***and acted on***) prior to any commitment being made with regard to the projected project completion date.

Project Resource Scheduling–Time Limited

CMS.MOD1.20

Activity ID	Activity Description	Duration	Total Float	Early Start	Early Finish	Scheduled Start	Scheduled. Finish
CMS	Contact Management System	74d	0	01Jan07	12Apr07	01Jan07	12Apr07
CMS.MOD1	Module 1	74d	0	01Jan07	12Apr07	01Jan07	12Apr07
CMS.MOD1.10	Requirements Analysis	2w	0	01Jan07	12Jan07	01Jan07	12Jan07
CMS.MOD1.20	System Specification	2w	0	15Jan07	26Jan07	15Jan07	26Jan07
CMS.MOD1.25	Sales Literature	12d	12d	29Jan07	13Feb07	29Jan07	13Feb07
CMS.MOD1.30	Build	8w	0	29Jan07	23Mar07	29Jan07	23Mar07
CMS.MOD1.40	Documentation	30d	0	02Mar07	12Apr07	02Mar07	12Apr07
CMS.MOD2	Module 2	74d	0	01Jan07	12Apr07	01Jan07	12Apr07
CMS.MOD2.10	Requirements Analysis	2w	0	01Jan07	12Jan07	01Jan07	12Jan07
CMS.MOD2.20	System Specification	2w	0	15Jan07	26Jan07	15Jan07	26Jan07
CMS.MOD2.25	Sales Literature	12d	12d	29Jan07	13Feb07	29Jan07	13Feb07
CMS.MOD2.30	Build	8w	0	29Jan07	23Mar07	29Jan07	23Mar07
CMS.MOD2.40	Documentation	30d	0	02Mar07	12Apr07	02Mar07	12Apr07

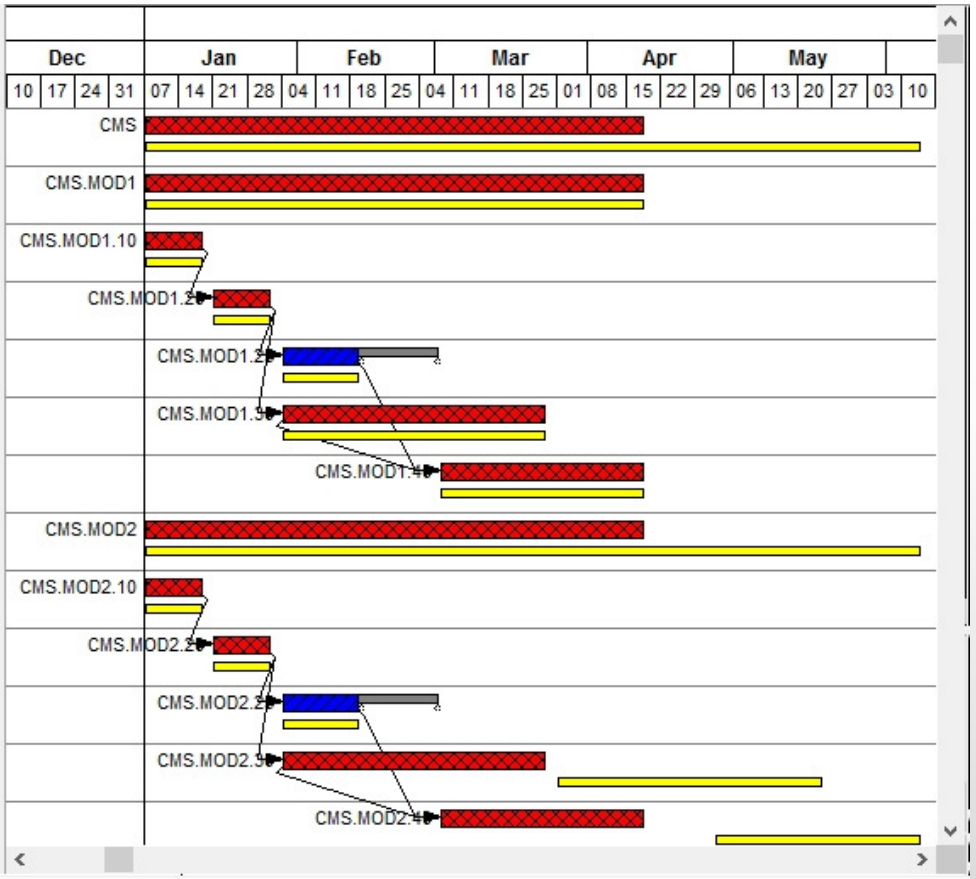


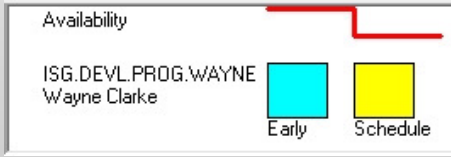


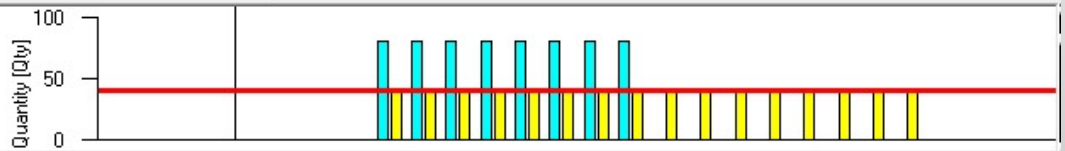
Project Resource Scheduling–Resource Limited

CMS.MOD1.20

Activity ID	Activity Description	Duration	Total Float	Early Start	Early Finish	Scheduled Start	Scheduled. Finish
CMS	Contact Management System	74d	0	01Jan07	12Apr07	01Jan07	07Jun07
CMS.MOD1	Module 1	74d	0	01Jan07	12Apr07	01Jan07	12Apr07
CMS.MOD1.10	Requirements Analysis	2w	0	01Jan07	12Jan07	01Jan07	12Jan07
CMS.MOD1.20	System Specification	2w	0	15Jan07	26Jan07	15Jan07	26Jan07
CMS.MOD1.25	Sales Literature	12d	12d	29Jan07	13Feb07	29Jan07	13Feb07
CMS.MOD1.30	Build	8w	0	29Jan07	23Mar07	29Jan07	23Mar07
CMS.MOD1.40	Documentation	30d	0	02Mar07	12Apr07	02Mar07	12Apr07
CMS.MOD2	Module 2	74d	0	01Jan07	12Apr07	01Jan07	07Jun07
CMS.MOD2.10	Requirements Analysis	2w	0	01Jan07	12Jan07	01Jan07	12Jan07
CMS.MOD2.20	System Specification	2w	0	15Jan07	26Jan07	15Jan07	26Jan07
CMS.MOD2.25	Sales Literature	12d	12d	29Jan07	13Feb07	29Jan07	13Feb07
CMS.MOD2.30	Build	8w	0	29Jan07	23Mar07	26Mar07	18May07
CMS.MOD2.40	Documentation	30d	0	02Mar07	12Apr07	27Apr07	07Jun07







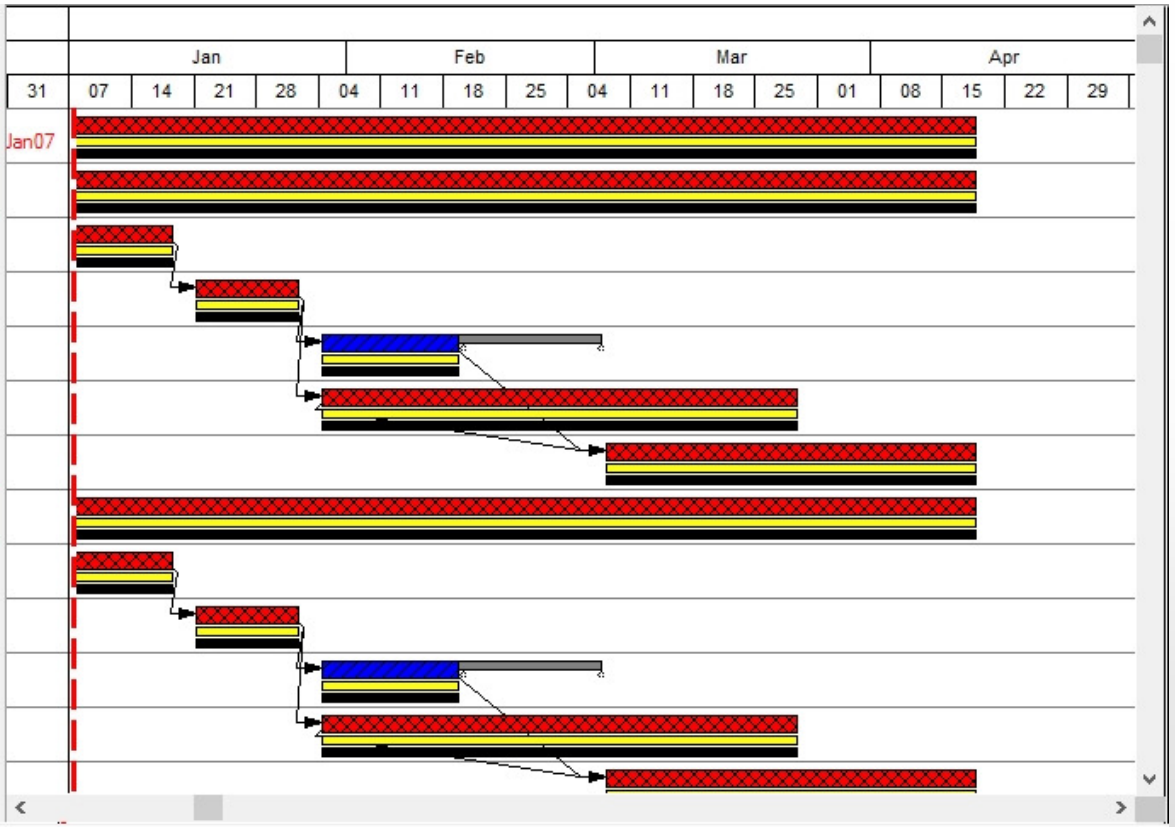
Project Schedule Baseline

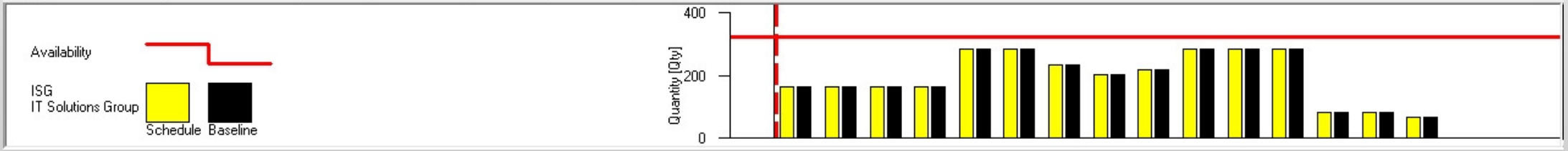
- ***The approved version of a schedule model*** that can be changed only through formal change control procedures, e.g. ***Baseline Change Request (BCR***).
- The project's baseline is used for ***variance analysis purposes***, i.e. how performance deviates from the Baseline schedule.
- Variance analysis will only be meaningful if the ***Baseline is an accurate representation of the original scope, cost and schedule***.
- Project management involves the ***planning of activities for which there may be a dearth of validated metrics and data***, upon which to base estimates of scope delivery time.
- ***The subjective knowledge of the project planners plays an important role in assessing uncertainties of scope delivery time estimates***. Generally, we are concerned with quantifying the uncertainty associated with an estimate of the duration of an activity.

Project Schedule Baseline

13Feb07

Activity ID	Activity Desc.	Duration	Scheduled Start	Baseline Start	Scheduled Finish	Baseline Finish
CMS	Contact Management System	0	01Jan07	01Jan07	12Apr07	12Apr07
CMS.MOD1	Module 1	0	01Jan07	01Jan07	12Apr07	12Apr07
CMS.MOD1.10	Requirements Analysis	0	01Jan07	01Jan07	12Jan07	12Jan07
CMS.MOD1.20	System Specification	0	15Jan07	15Jan07	26Jan07	26Jan07
CMS.MOD1.25	Sales Literature	0	29Jan07	29Jan07	13Feb07	13Feb07
CMS.MOD1.30	Build	6w	29Jan07	29Jan07	23Mar07	23Mar07
CMS.MOD1.40	Documentation	0	02Mar07	02Mar07	12Apr07	12Apr07
CMS.MOD2	Module 2	0	01Jan07	01Jan07	12Apr07	12Apr07
CMS.MOD2.10	Requirements Analysis	0	01Jan07	01Jan07	12Jan07	12Jan07
CMS.MOD2.20	System Specification	0	15Jan07	15Jan07	26Jan07	26Jan07
CMS.MOD2.25	Sales Literature	0	29Jan07	29Jan07	13Feb07	13Feb07
CMS.MOD2.30	Build	7w	29Jan07	29Jan07	23Mar07	23Mar07
CMS.MOD2.40	Documentation	0	02Mar07	02Mar07	12Apr07	12Apr07





Project Schedule Progress

- A great deal of effort is expended in creating a project schedule, yet ***the same level of vigour and discipline is not always applied in maintaining it during the execution phase of the project***.

- It is critical that throughout the project lifecycle, the ***project schedule is an accurate representation of the remaining work required to complete the approved (current) scope***.

- Project-based organisations typically have ***well-defined procedures*** for collecting progress on a periodic basis and using it to update their project controls systems.

Project Schedule Progress

- Work has started on the project. You are receiving (hopefully!) status information on the activities and resources. Management wants to know how that status compares.
  - Has the activity started? If so, when?
  - Has the activity ended? If so, when?
  - ***If the activity has started but not yet ended, what is the estimated remaining activity duration and resource remaining requirement?***
- Types of activity progress
  - **Actual Start** — The actual start date for the activity.
  - **Actual Finish** — The date on which the activity actually finished.

Project Schedule Progress

- Types of activity progress
  - **Remaining Duration** — This field represents the duration remaining for the activity. This value is used to calculate the values in the Elapsed Duration and Percent Complete fields.
  - **Elapsed Duration** — Represents the amount of the original duration that has elapsed. This value is used to calculate the values in the Remaining Duration and Percent Complete fields.
  - **Percent Complete** — The percent of the original activity duration that is complete. Any value you enter in this field is used to calculate the values in the Remaining Duration and Elapsed Duration fields.
- ***Which is best?***

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Project Schedule Progress

Activity ID	Actual Start	Actual Finish	Progress Type	Progress Value
CMS.MOD1.10	01Jan07	12Jan07	Complete	100%
CMS.MOD1.20	15Jan07		Remaining Duration	7d
CMS.MOD2.10	01Jan07		Remaining Duration	5d
CMS.MOD2.20	18Jan07 ← Out of Sequence		Remaining Duration	8d
CMS.MOD1.25			Planned	0
CMS.MOD1.30			Planned	0
CMS.MOD1.40			Planned	0
CMS.MOD2.25			Planned	0
CMS.MOD2.30			Planned	0
CMS.MOD2.40			Planned	0

Slide 27

TS1 Tony Scuteri, 2/05/2017

Project Schedule Estimated Durations

- Project management involves the planning and coordination of activities for which there are often a ***dearth of validated metrics and data, upon which to base estimates of scope delivery time***.

- As a result, there may be considerable uncertainty in the accuracy of the activity durations specified in the project schedule. ***An alternative to the use of a single-point activity estimated duration, is to attempt to quantify the uncertainty by allowing the definition of a three-point activity duration estimate***.

- This is comprised of a ***best-case, most-likely case, and a worst-case estimate of the activity duration***. In addition to specifying a three-point activity duration, a probability duration shape is specified.

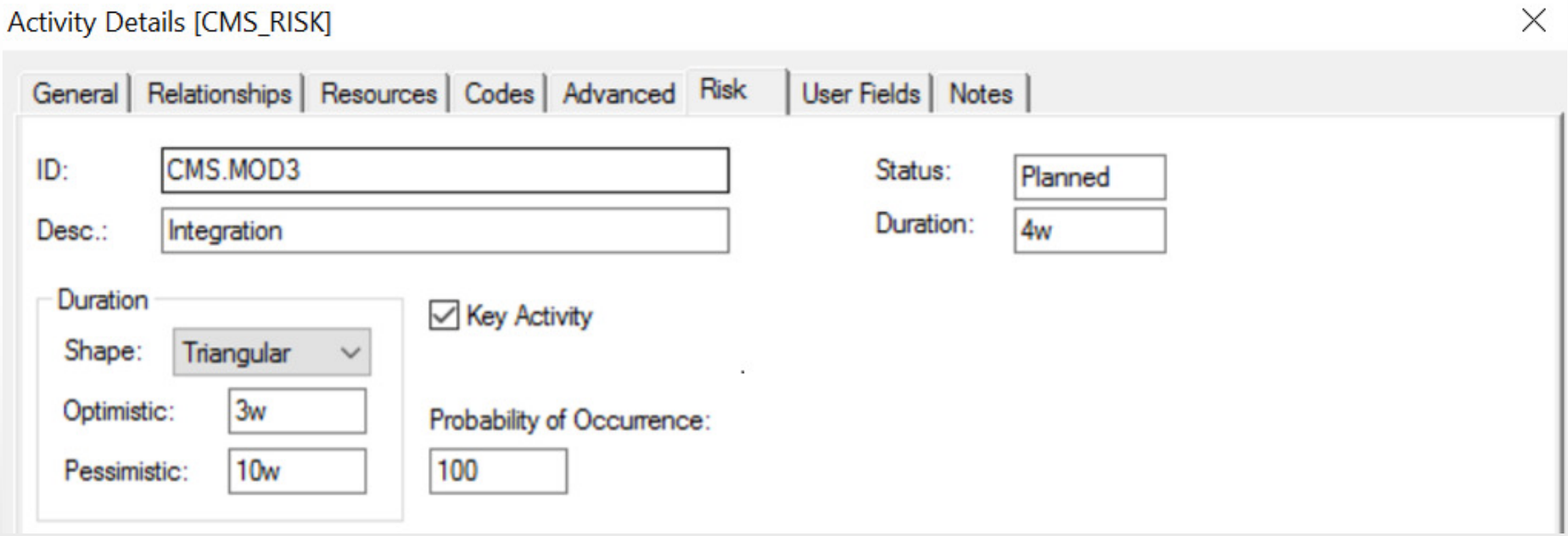
Project Schedule Estimated Durations

- Using a method known as ***Monte Carlo Analysis***, we can model the impact of activity duration uncertainty on the project completion date.

- ***Instead of running Critical Path Analysis once based on a single point activity duration for each activity, we simulate the project several hundred or several thousand times***. Each time, we use a different activity duration sampled from the probability distributions of these uncertain values.

- The sampling is done so that the probability of selecting a particular duration in the simulation is the same as our subjective estimate of the probability of that value actually occurring. ***With definite values for activity duration, such things as project completion date can be calculated for each trial***.

Project Schedule Risk



- **Duration -** This value corresponds to the mode for the probability distribution of the duration.
- **Optimistic -** This is the minimum estimated duration for the activity.
- **Pessimistic -** This is the maximum estimated duration for the activity.

Project Schedule Risk

- **Probability Shapes**
  - **Beta** — probable outcomes cluster around the mode value of the distribution. Outcomes at the extreme values of the distribution are very unlikely.
  - **Normal** — probable outcomes cluster symmetrically around the centre of the distribution.
  - **Triangular** — probable outcomes cluster around the mode value of the distribution. Outcomes close to minimum and maximum values of the distribution still possess a significant probability.
  - **Uniform** — each outcome is equally likely.
- There is little in nature that has a triangular distribution but it is a good approximation to the day-to-day events that occur in projects.
- As regards to the choice of the probability distribution shape for the activity duration, ***the asymmetric triangular distribution is often the most appropriate – Why?***

Project Schedule Risk

CMS.MOD3

Activity ID	Activity Desc.	Duration Distribution Type	Optimistic Duration	Original Duration	Pessimistic Duration	Mean Early Start	Early Finish	Early Finish 5%	Mean Early Finish	Early Finish 95%	Std. Dev. of Early Finish
- CMS	Warfare System	None	0	94d	0	01Jan07	10May07	01May07	23May07	14Jun07	8d
- CMS.MOD1	SubSystem 1	None	0	74d	0	01Jan07	12Apr07	12Apr07	12Apr07	12Apr07	0
CMS.MOD1.10	Requirements Analysis	None	0	2w	0	01Jan07	12Jan07	12Jan07	12Jan07	12Jan07	0
CMS.MOD1.20	System Specification	None	0	2w	0	15Jan07	26Jan07	26Jan07	26Jan07	26Jan07	0
CMS.MOD1.25	System Documentation	None	0	12d	0	29Jan07	13Feb07	13Feb07	13Feb07	13Feb07	0
CMS.MOD1.30	Build	None	6w	8w	10w	29Jan07	23Mar07	23Mar07	23Mar07	23Mar07	0
CMS.MOD1.40	Integration API	None	0	30d	0	02Mar07	12Apr07	12Apr07	12Apr07	12Apr07	0
CMS.MOD1.50	M1 Complete	None	0	0	0	13Apr07	12Apr07	12Apr07	12Apr07	12Apr07	0
- CMS.MOD2	SubSystem 2	None	0	74d	0	01Jan07	12Apr07	12Apr07	12Apr07	12Apr07	0
CMS.MOD2.10	Requirements Analysis	None	0	2w	0	01Jan07	12Jan07	12Jan07	12Jan07	12Jan07	0
CMS.MOD2.20	System Specification	None	0	2w	0	15Jan07	26Jan07	26Jan07	26Jan07	26Jan07	0
CMS.MOD2.25	System Documentation	None	0	12d	0	29Jan07	13Feb07	13Feb07	13Feb07	13Feb07	0
CMS.MOD2.30	Build	None	7w	8w	12w	29Jan07	23Mar07	23Mar07	23Mar07	23Mar07	0
CMS.MOD2.40	Integration API	None	0	30d	0	02Mar07	12Apr07	12Apr07	12Apr07	12Apr07	0
CMS.MOD2.50	M2 complete	None	0	0	0	13Apr07	12Apr07	12Apr07	12Apr07	12Apr07	0
CMS.MOD3	Integration	Triangular	3w	4w	10w	13Apr07	10May07	01May07	23May07	14Jun07	8d
CMS COMPLETE	System Complete	None	0	0	0	23May07	10May07	01May07	23May07	14Jun07	8d

Project Schedule Risk

- You will notice that the Duration Distribution Type for activity CMS.MOD3 -***Integration*** is Triangular, with a three-point estimated duration as follows:

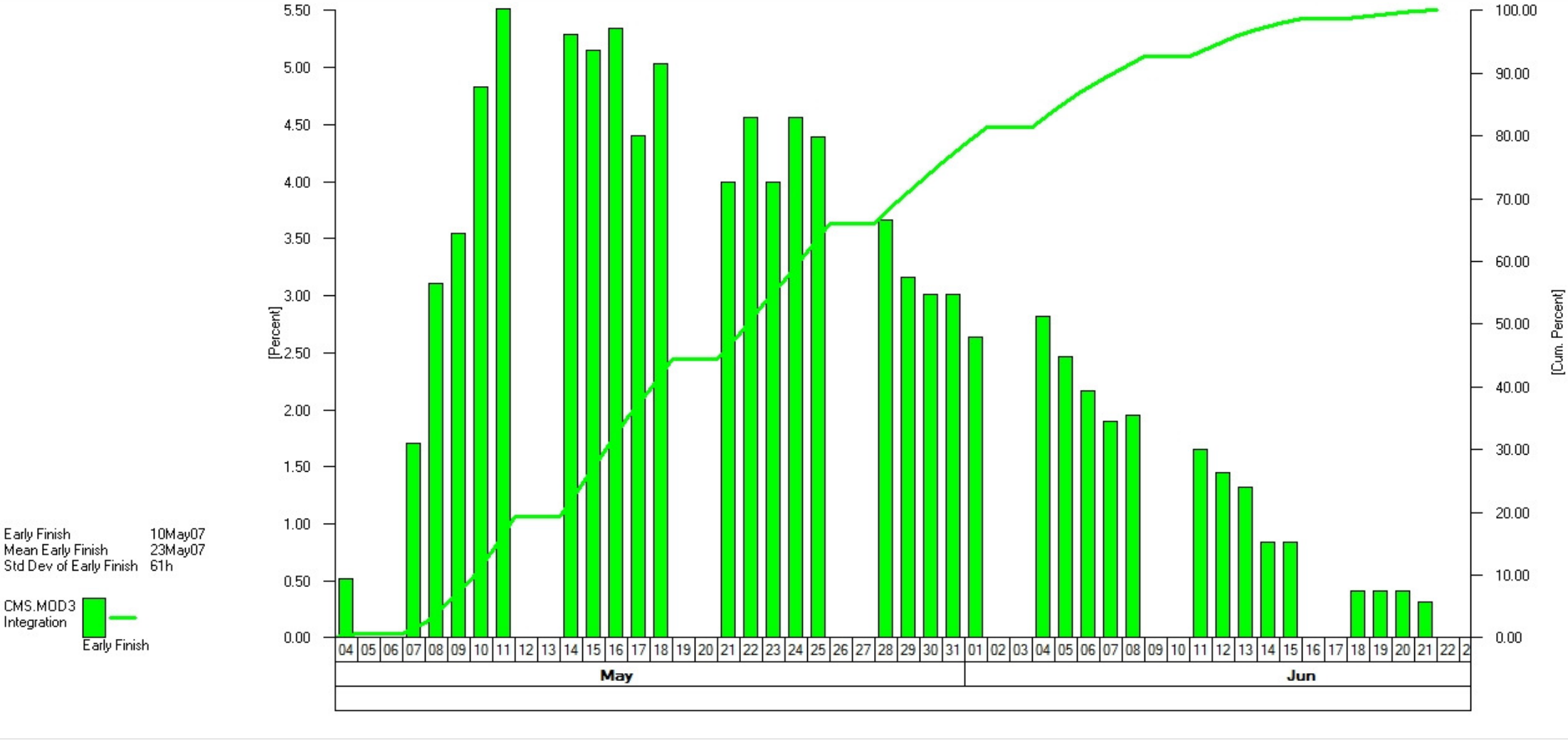
  Optimistic: 3w | Original Duration: 4w | Pessimistic Duration: 10w

- The ***standard deviation*** of a probability distribution, as represented above in the column titled “Std. Dev. of Early Finish”, ***measures the degree of variation from the Mean*** without regard for the direction in which the variation occurs.

- As a very rough guide, it turns out that there is about a two-thirds chance of any particular outcome falling within one standard deviation of the mean value and about ***a 95% chance of the outcome falling within two standard deviations of the mean***.

  In the case of the latter, this variation can occur in either direction from the mean and is usually referred to as a ***95% confidence interval***.

Project Schedule Risk



Project Schedule Risk

- Generally, we are concerned with quantifying the uncertainty associated with an estimate of the duration of an activity.

- When analysing the risks of a project combining thousands of activities, the estimate of the uncertainty is, in the end, a ***statement more about the state of knowledge of the estimator***.

- The concept of probability and risk analysis in this environment is not easy to grasp. Indeed, ***some project managers may feel that it is without foundation***. We will, nevertheless, maintain that it is possible to make a subjective estimate of the probability distribution associated with our forecasts about the future.

- Perhaps more importantly, ***it is necessary to make such an estimate since the failure to do so merely asserts that there is no uncertainty associated with these forecasts***.

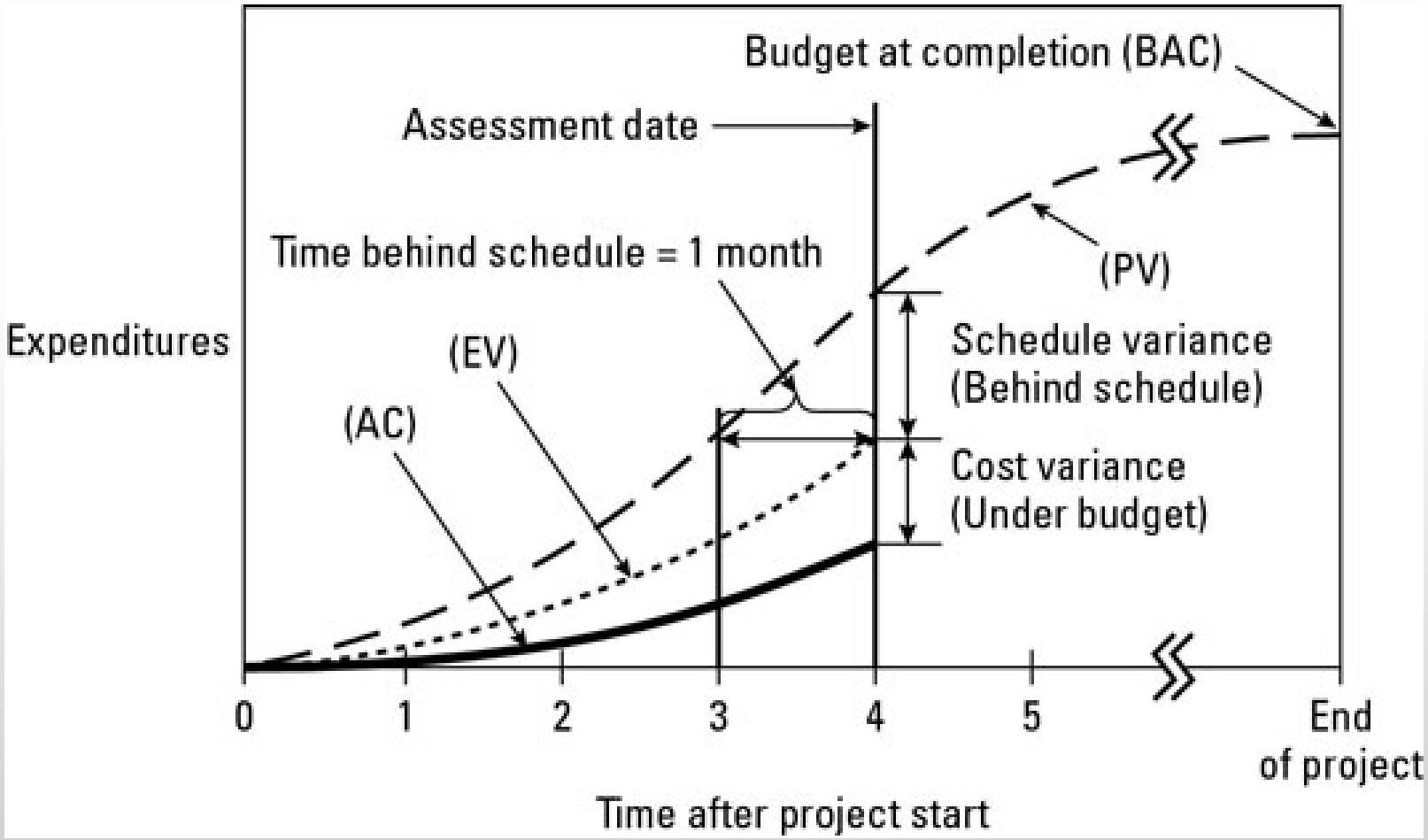
Earned Value Management (EVM)

- **EVM** is the ***measurement of work performed, relative to the Baseline value of the work***, typically expressed in dollars or labour units. The following information is used to assess your schedule and cost performance throughout your project.
- **Planned value (PV) -** The approved budget for the work scheduled to be completed by a specified date; also referred to as the budgeted cost of work scheduled (BCWS).
- **Earned value (EV):** The approved budget for the work actually completed by the specified date; also referred to as the budgeted cost of work performed (BCWP).
- **Actual cost (AC):** The costs actually incurred for the work completed by the specified date; also referred to as the actual cost of work performed (ACWP).

Earned Value Management (EVM) – Key Formulas

- **BAC** – Budget at completion
- **CV = EV - AC**
- **CPI = EV/AC**
  - An index of 1 or greater indicates that work is being accomplished at a cost equal to or below what was planned. An index of less than 1 suggests work is accomplished at a cost greater than planned.
- **SV = EV - PV**
- **SPI - EV/PV**
  - An index of 1 or greater indicates that work is being accomplished at a rate on or ahead of what was planned. An index of less than 1 suggests work is being accomplished at a rate below the planned schedule.
- **PF** – Performance Factor, an example of which is 1/CPI.
- **EAC = AC + PF*(BAC-EV)**

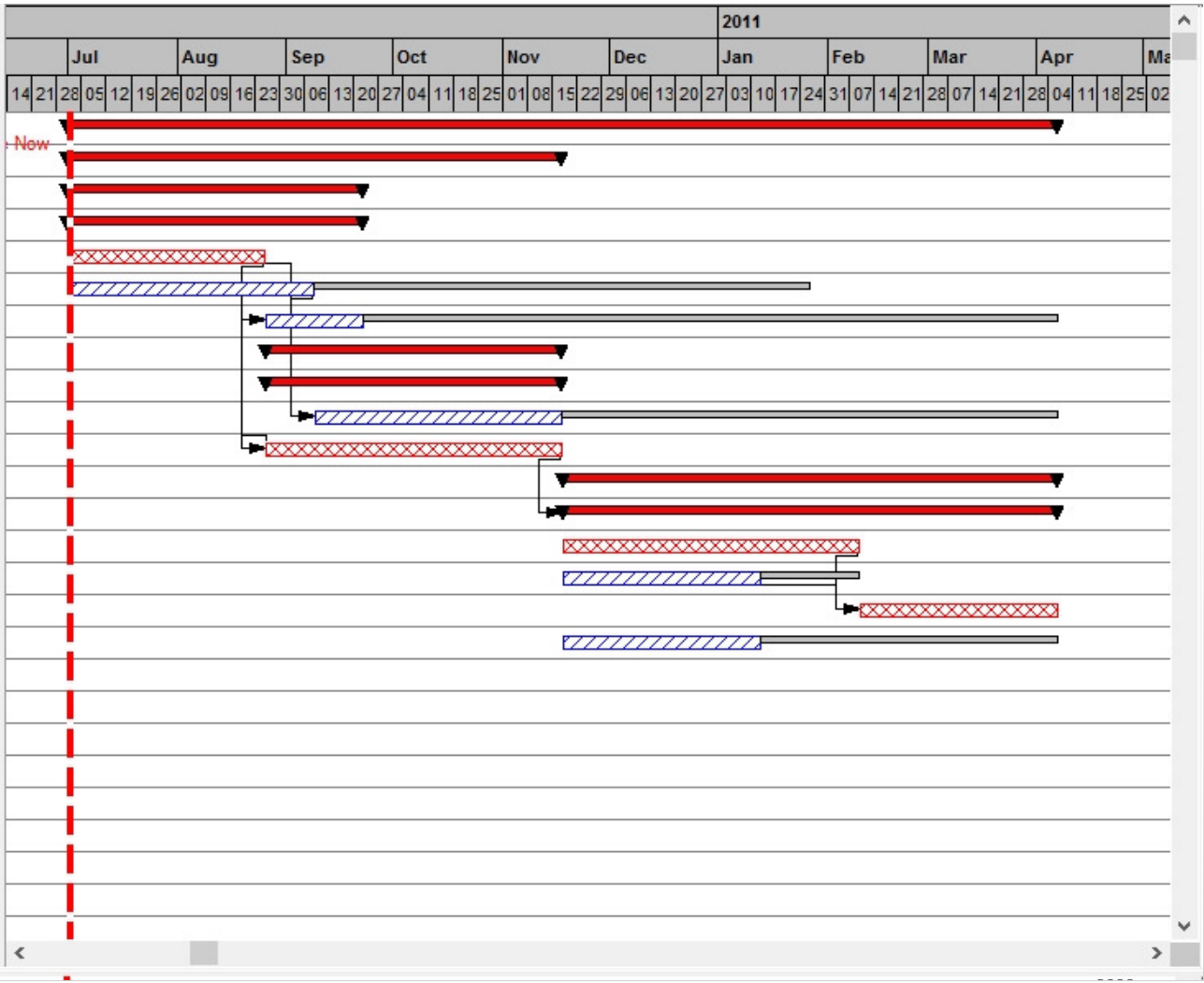
Earned Value Management (EVM)



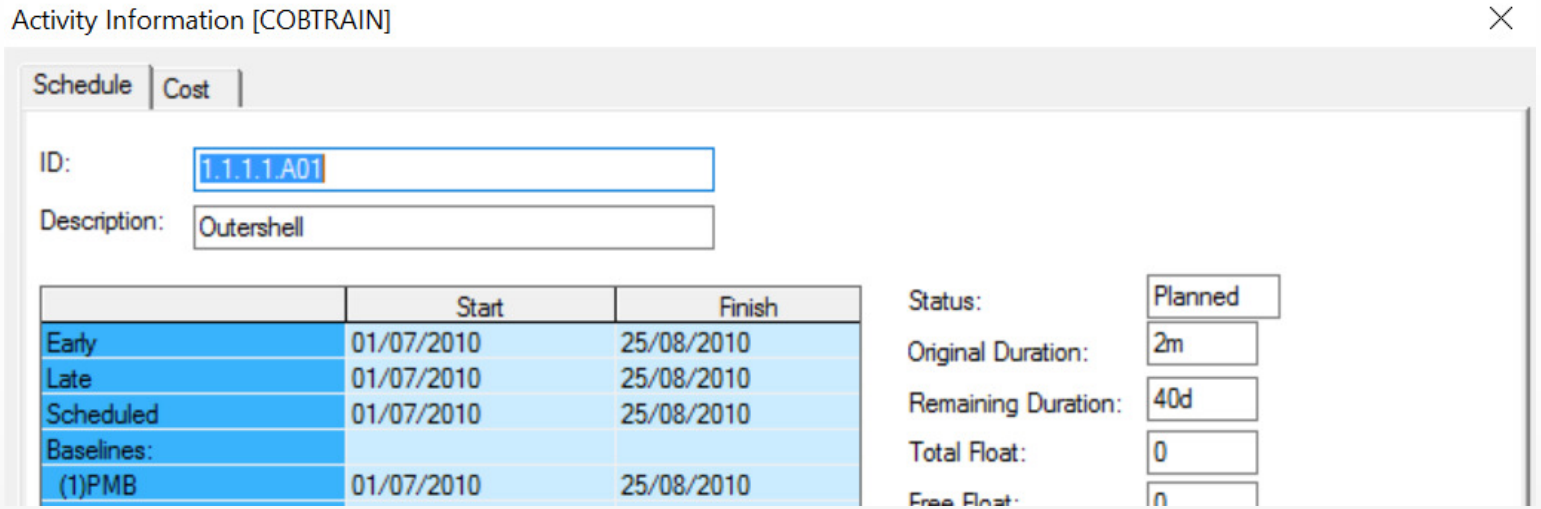
Project Schedule and EVM Integration

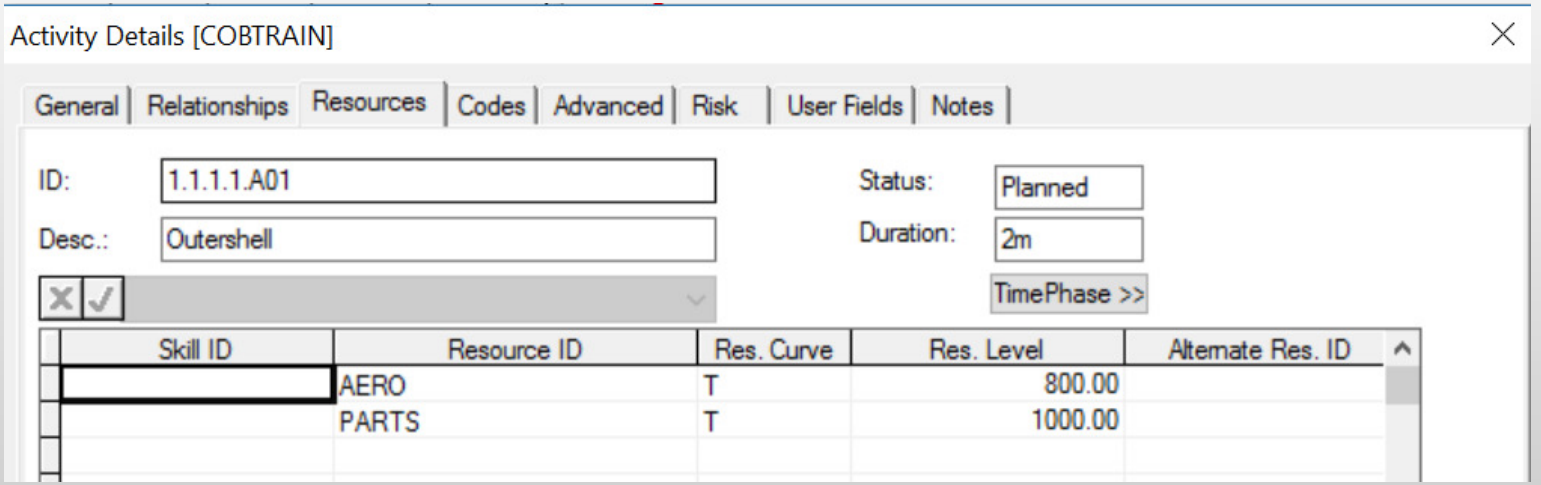
Connexion SYSTEMS

Activity ID	Activity Desc.	Duration	WBS	OBS	Start	Finish
1	Inter-Planet Shuttle	200d			01/07/10	06/04/11
1.1	Design	100d			01/07/10	17/11/10
1.1.1	Fuselage	60d			01/07/10	22/09/10
1.1.1.1	Body	60d			01/07/10	22/09/10
1.1.1.1.A01	Outershell	40d	1.1.1.1	AERO	01/07/10	25/08/10
1.1.1.1.A02	Hydraulics	50d	1.1.1.1	AERO	01/07/10	08/09/10
1.1.1.1.A03	Quality Inspection	20d	1.1.1.1	AERO	26/08/10	22/09/10
1.1.2	Engine	60d			26/08/10	17/11/10
1.1.2.1	Internal Design	60d			26/08/10	17/11/10
1.1.2.1.B01	Control Bay	50d	1.1.2.1	MECH	09/09/10	17/11/10
1.1.2.1.B02	Engine Room	60d	1.1.2.1	MECH	26/08/10	17/11/10
1.2	Avionics	100d			18/11/10	06/04/11
1.2.3	Control Panel	100d			18/11/10	06/04/11
1.2.3.C01	System Controls	60d	1.2.3	CNTRL	18/11/10	09/02/11
1.2.3.C02	Auto Controls	40d	1.2.3	CNTRL	18/11/10	12/01/11
1.2.3.C03	Validate Auto Cntrls	40d	1.2.3	CNTRL	10/02/11	06/04/11
1.2.3.C04	Supervise System and A	40d	1.2.3	CNTRL	18/11/10	12/01/11

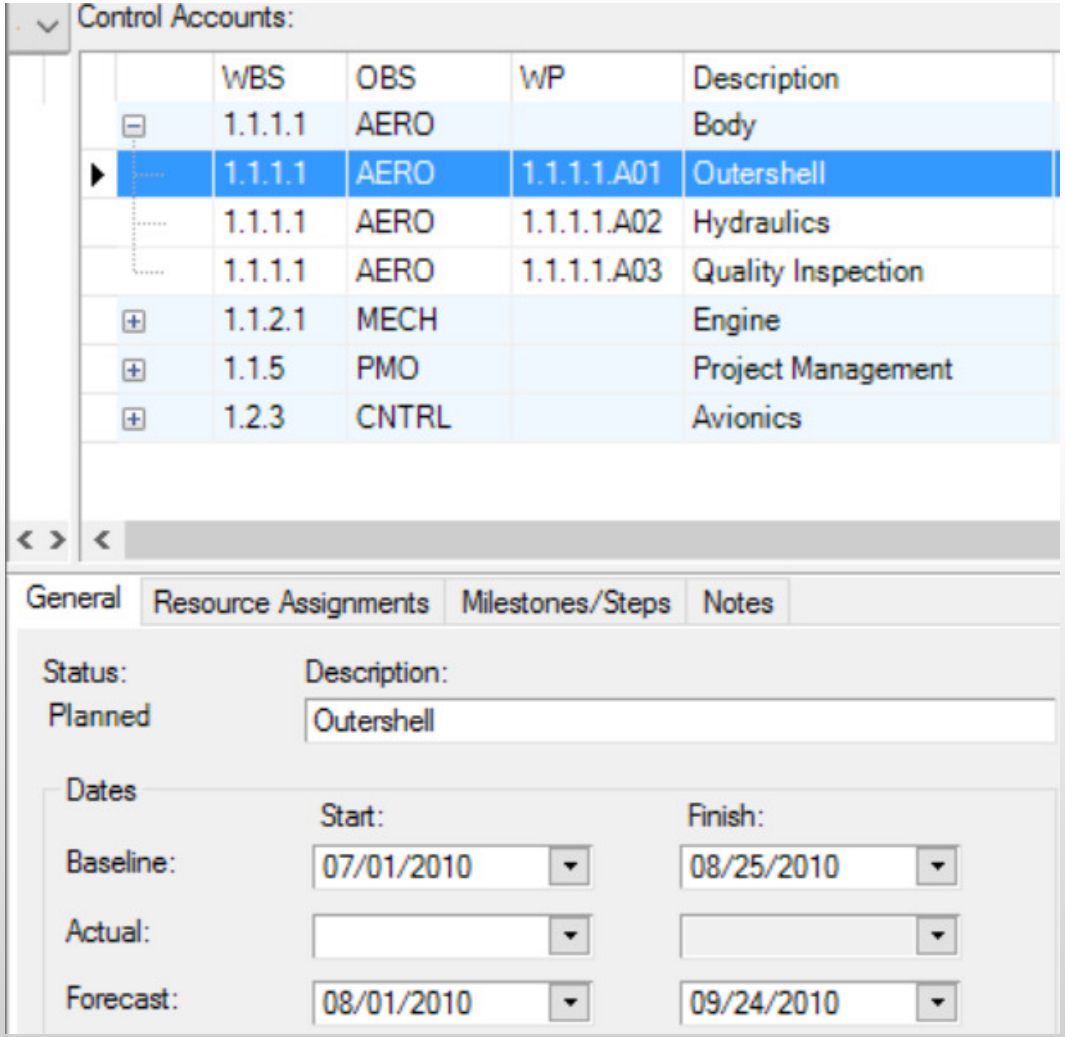


Project Schedule and EVM Integration

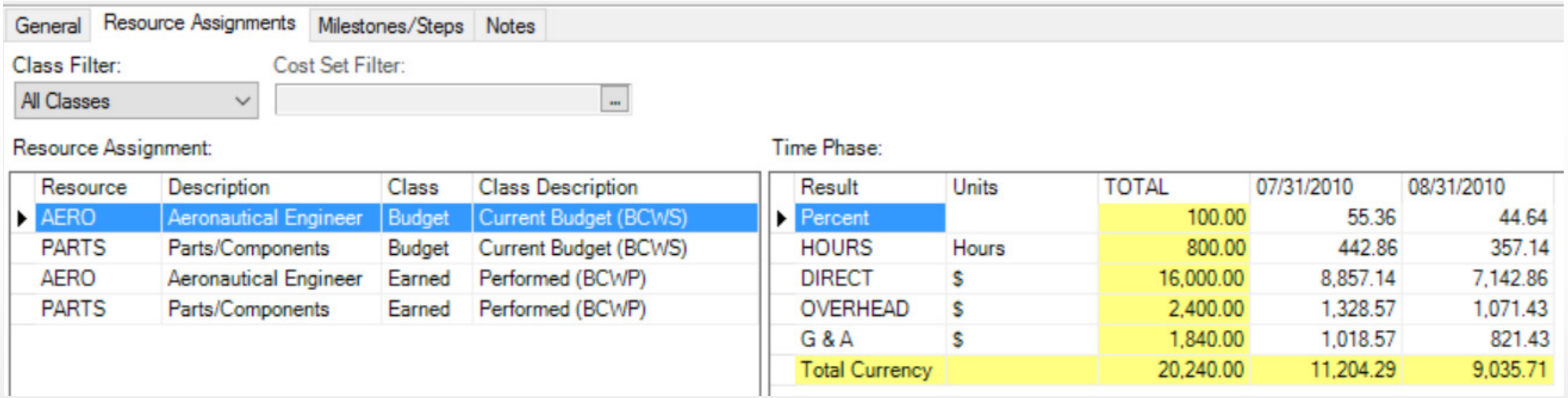




Project Schedule and EVM Integration



Project Schedule and EVM Integration



Resource	Description	Class	Class Description
AERO	Aeronautical Engineer	Budget	Current Budget (BCWS)
PARTS	Parts/Components	Budget	Current Budget (BCWS)
AERO	Aeronautical Engineer	Earned	Performed (BCWP)
PARTS	Parts/Components	Earned	Performed (BCWP)

Result	Units	TOTAL	07/31/2010	08/31/2010
Percent		100.00	55.36	44.64
HOURS	Hours	800.00	442.86	357.14
DIRECT	$	16,000.00	8,857.14	7,142.86
OVERHEAD	$	2,400.00	1,328.57	1,071.43
G & A	$	1,840.00	1,018.57	821.43
Total Currency		20,240.00	11,204.29	9,035.71

- EVM requires planning, scheduling, and establishing the time phased budgets for activities
- The schedule must be resource loaded to determine the budget for the work as scheduled. The resource loaded schedule is the basis for the monthly budget, or PV, for each task and thus the project.
- This time phased budget is the performance measurement baseline (PMB).

Project Scheduling and Earned Value 101

Thank You!