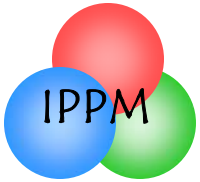

Integrated Project
Performance Management

…….EMERGING PRACTICE…….

Earned Schedule

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Required Legal Notices

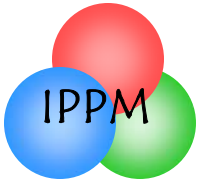
CAUTION

…….*EMERGING PRACTICE*…….

Use with caution until validated by research.

Do not substitute for analysis of integrated master schedule.

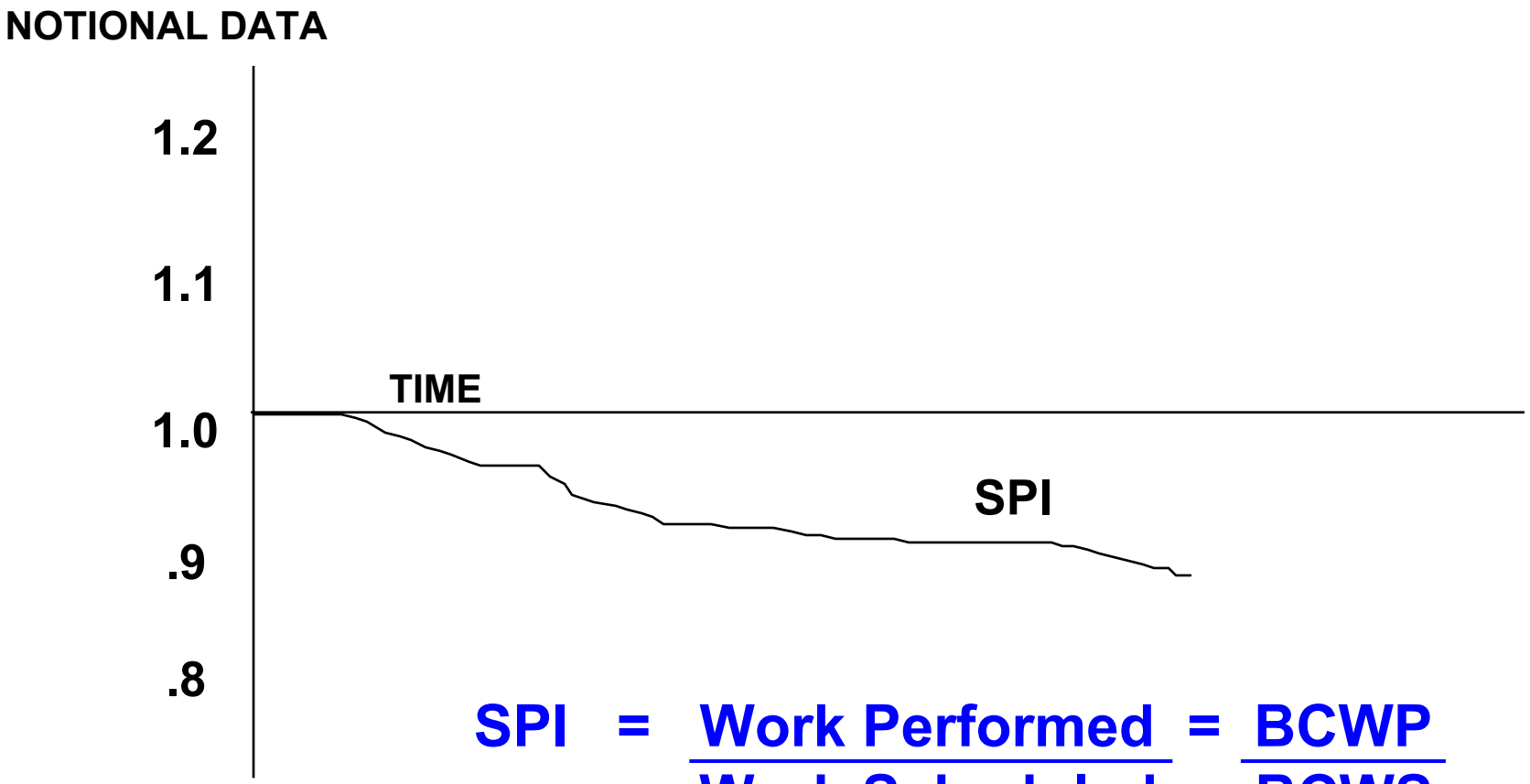
Not valid in Guam or New Zealand. Contents may be hot. Do not use while sleeping.
Do not use electrical device in bathtub. Only one offer per household. Chances in winning: 1:62,000,000.
Not for use by unsupervised children under 11 years. APR 21.00*** except in Arkansas.



Overview

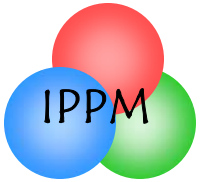
- Traditional EVM schedule metrics
- Earned Schedule
  - Basic concepts
  - Baseline
  - Status
  - Predicting the project duration
  - Comparison of efficiencies
- Earned schedule metrics & IMS
- Analysis
- Considerations
- Summary

Traditional Definition
Schedule Performance Index



$$SPI = \frac{\text{Work Performed}}{\text{Work Scheduled}} = \frac{BCWP}{BCWS}$$

calculated from budgeted cost



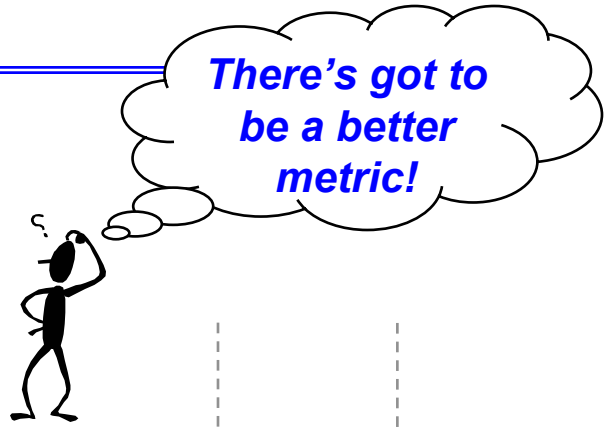
So, what's the problem?

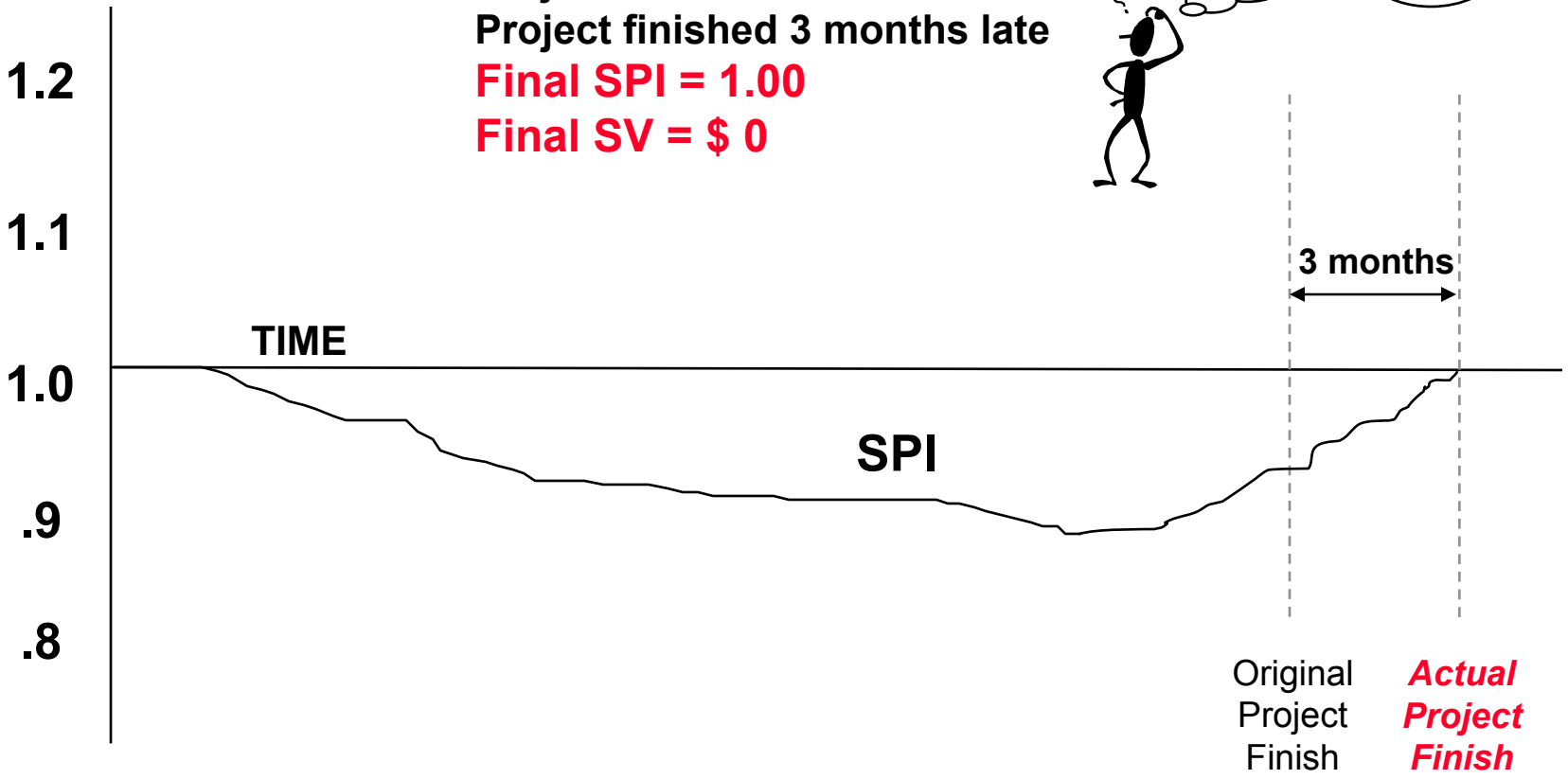
- Traditional schedule EVM metrics are good at beginning of project
  - Show schedule performance trends
- But the metrics don't reflect real schedule performance at end
  - Eventually, all "budget" will be earned as the work is completed, no matter how late you finish
    - SPI improves and ends up at 1.00 at end of project
    - SV improves and ends up at $0 variance at end of project
  - Traditional schedule metrics lose their predictive ability over the last third of project
    - Impacts schedule predictions, EAC predictions
- **Project managers don't understand schedule performance in terms of budget**
  - Like most of us!

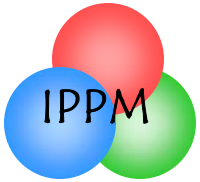
SPI at the End of the Project

NOTIONAL DATA

Project status:
Project finished 3 months late
Final SPI = 1.00
Final SV = $ 0







Basic Concepts of Earned Schedule

Earned Schedule Concepts

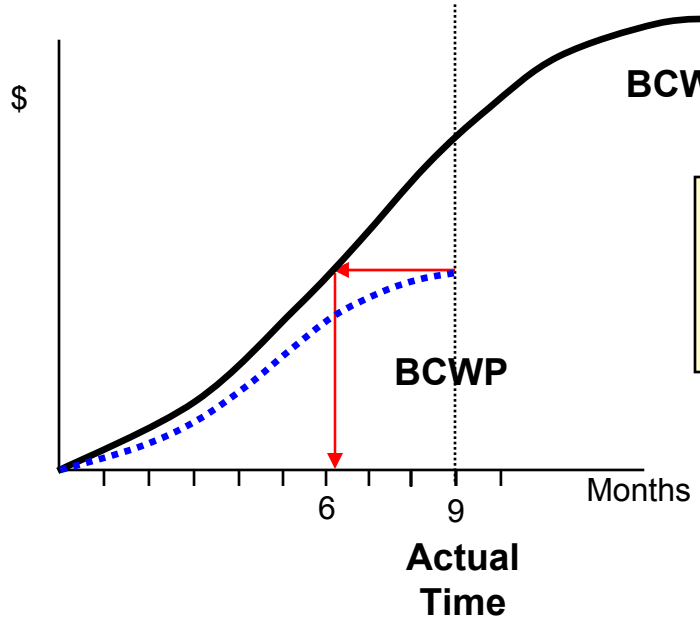
- Analogous to Earned Value
  - **Based on time-phased earned value data (BCWS, BCWP)**
- However, schedule performance is determined with **time based** metrics, not **cost**
  - **Key concept: how much schedule did I earn on the BCWS curve?**
  - **Resulting metrics and variances are expressed in time units**
  - **Works for both conditions (ahead or behind schedule)**
- Bridge between traditional EVM and integrated scheduling
  - **Correlation requires certain data from integrated master schedule**

Determining Earned Schedule

How Much Schedule Did I Earn?

- **Earned Schedule** = cumulative **earned value** in **time units** as established by the value of cumulative BCWP on the BCWS curve
  - Partial units of time are calculated
- Can be calculated graphically or with tabular data

EARNED SCHEDULE = ~6.1 months



- **Actual time is 9 months**
- **The earned schedule is 6.1 months**

Earned Schedule Metrics

NOTIONAL DATA

SV(t) = Schedule Variance (time)

= Earned Schedule – Actual Time

= 6.1 months – 9 months

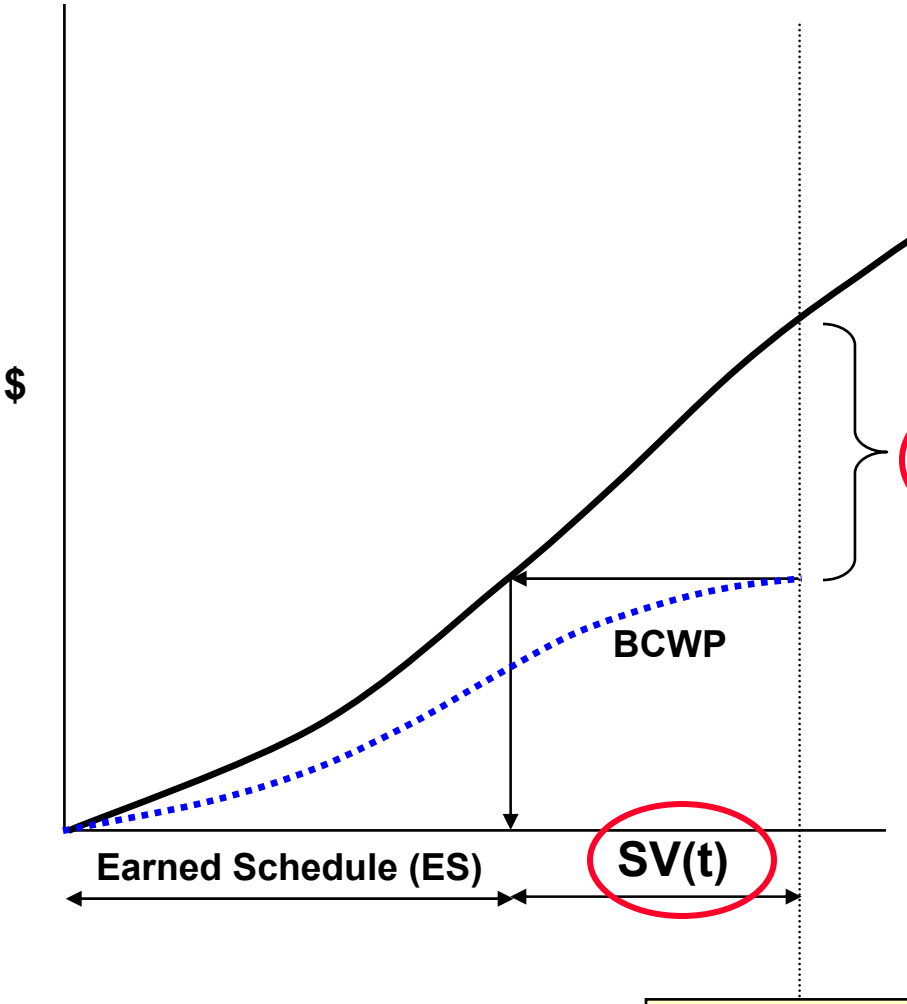
= **-2.9 months**

I should have earned 9 months, but have only earned 6.1 months

SPI(t) = Schedule Performance Index (time)

$$= \frac{\text{Earned Schedule}}{\text{Actual Time}} = \frac{6.1}{9} = .68$$

SV ($) versus SV(t)



- Earned schedule metrics relate work performed to actual time, not work scheduled
- Retain utility over time
  - never return to 0 or 1.00

Earned Schedule (tabular)

Earned Schedule = whole + partial months

= whole months (where BCWP ≥ BCWS) + partial month

= month X + $(BCWP_{cum} - BCWS_x) / (BCWS_y - BCWS_x)$

Month		BCWP	BCWS
1	Feb 03	804	782
2	Mar 03	1,423	1,411
3	Apr 03	1,687	1,923
4	May 03	1,886	2,510
5	Jun 03	2,304	3,215
6	Jul 03	2,751	4,127
7	Aug 03	3,198	5,122
8	Sep 03	3,801	6,229
9	Oct 03	4,257	7,279

Note: ES becomes more accurate if weekly EVM is used

Earned Schedule = 6.? months

= whole months + partial month

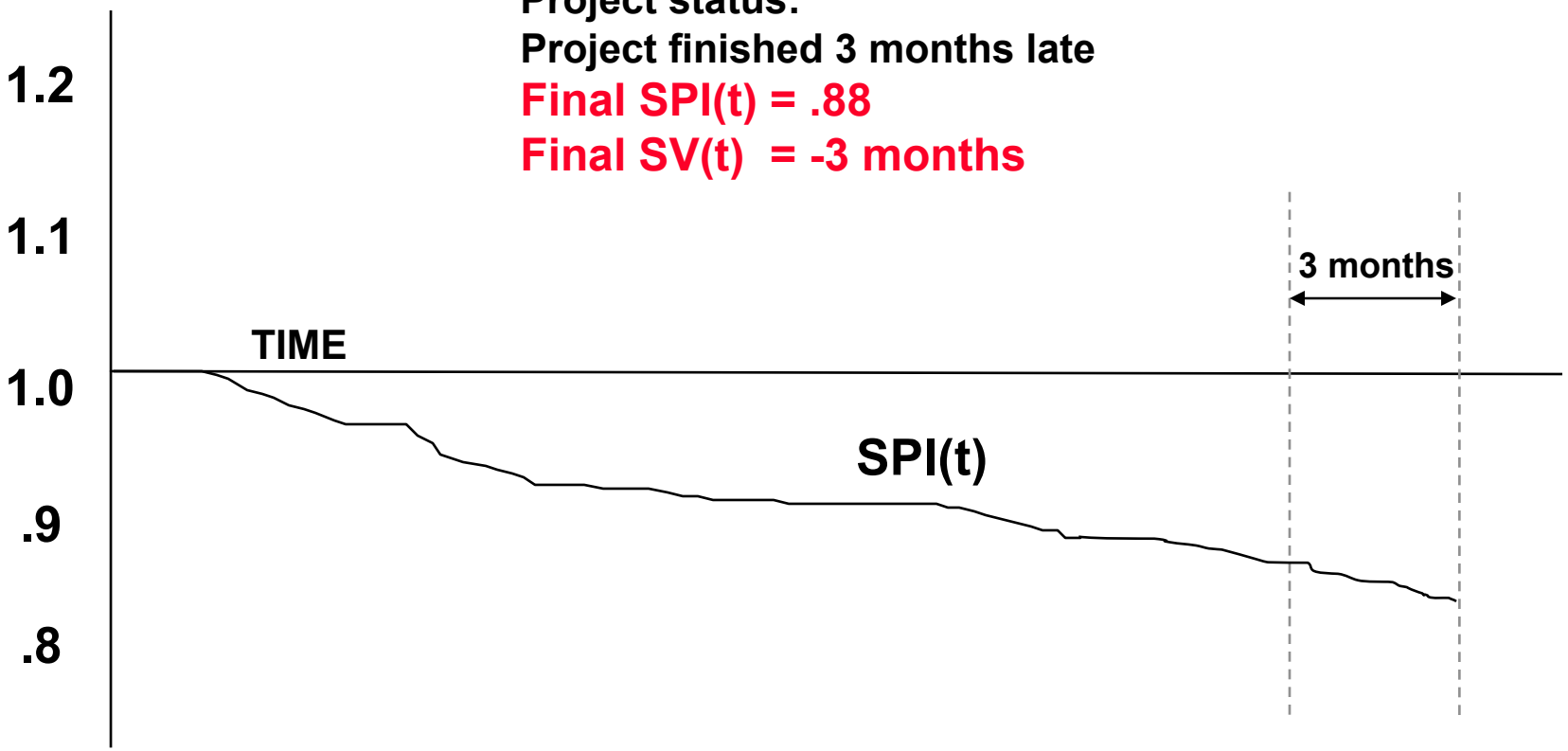
= 6 + (4,257 – 4,127) / (5,122 – 4,127)

= 6 + .1

= 6.1 months

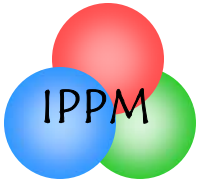
SPI(t) at the End of the Project

Project status:
Project finished 3 months late
Final SPI(t) = .88
Final SV(t) = -3 months



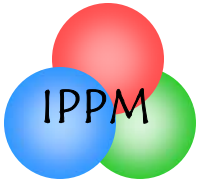
Benefits of Earned Schedule

- **Makes common sense!**
- **Easier concept to grasp**
  - Schedule variance metrics in terms of time rather than $
- **More stable metric**
  - Retains trend until end of project
  - Retains predictive utility
    - Use to predict duration
    - Can be used to improve EAC predictions
  - Check of contractor's schedule realism
- **Bridge between EVM and the integrated master schedule**



Earned Schedule

Baseline Terminology



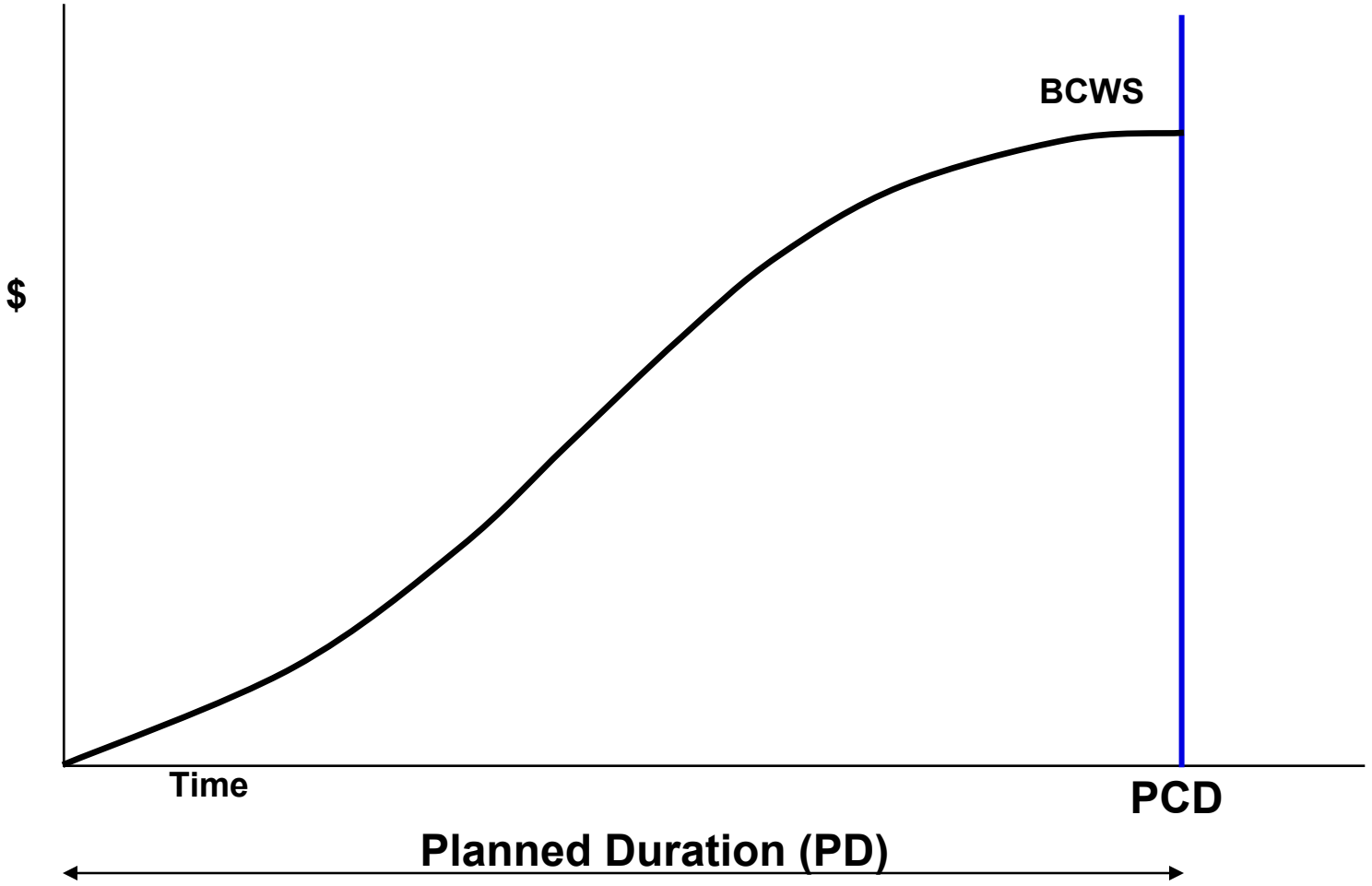
Baseline Terms

NOTIONAL DATA

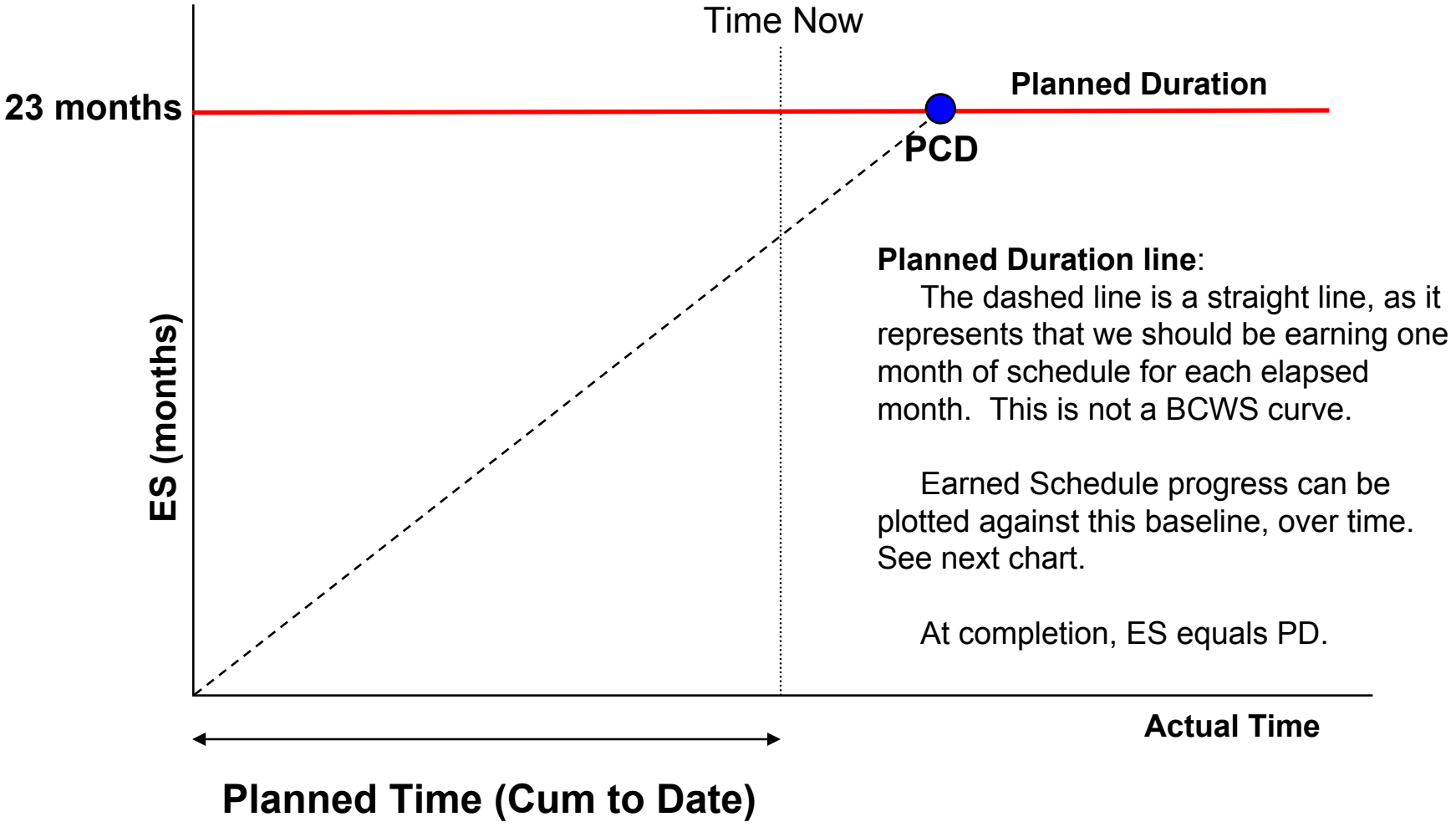
New Acronym	New Earned Schedule Term	Example	EVM Equivalent Term
PD	**Planned Duration** total **baseline** duration in units of time	23 months	BAC
PCD	**Planned Completion Date**	Dec 04	

Note: terms and formulas are illustrated with an example that is consistent throughout the presentation. All data is notional.

Project Baseline



Planned Duration Line



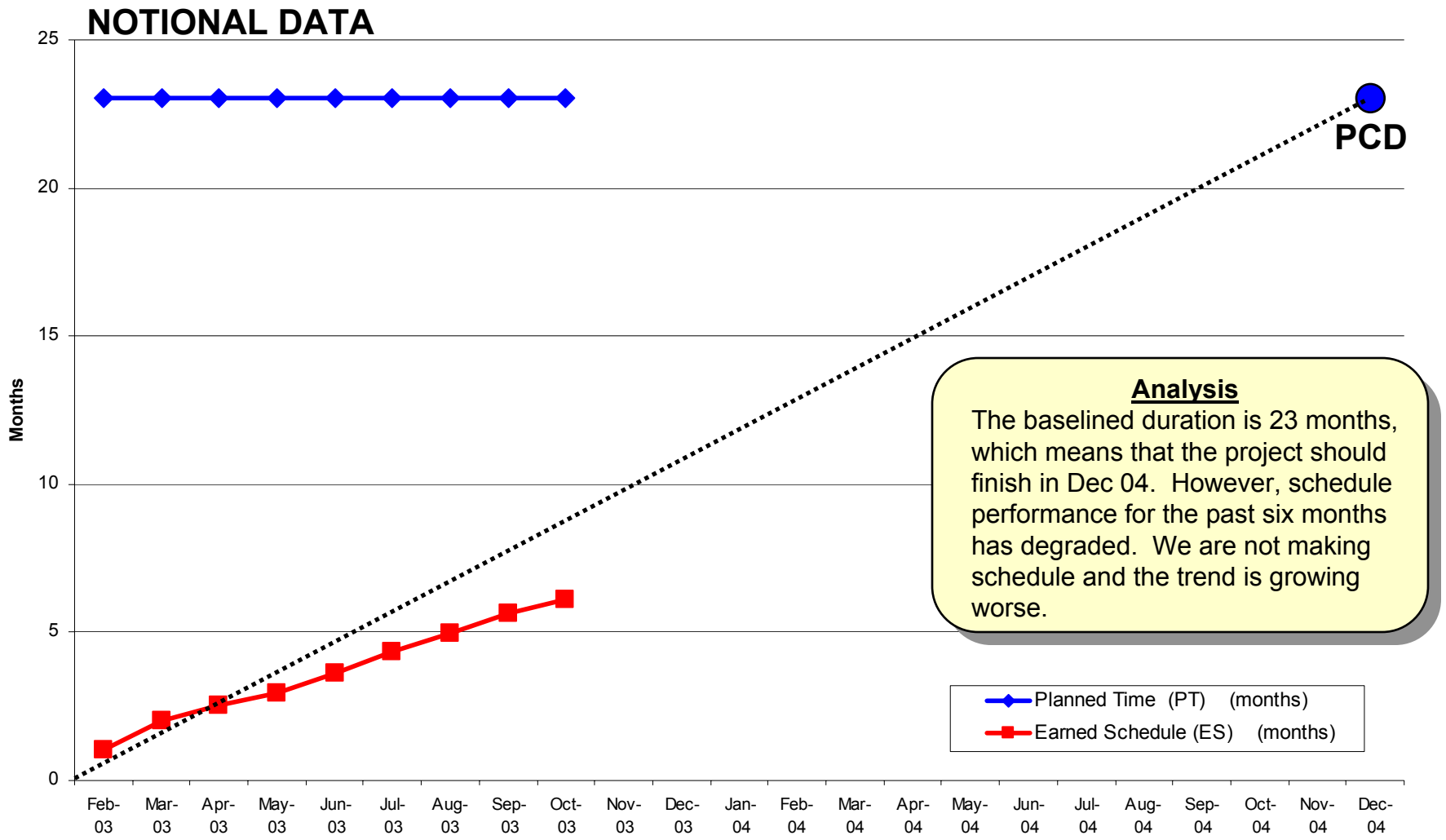
Planned Duration line:

The dashed line is a straight line, as it represents that we should be earning one month of schedule for each elapsed month. This is not a BCWS curve.

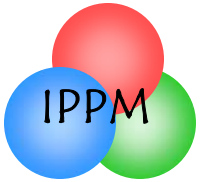
Earned Schedule progress can be plotted against this baseline, over time. See next chart.

At completion, ES equals PD.

Earned Schedule vs. Planned Duration



NOTE: the dashed line is a straight line, as it represents that we should be earning one month of schedule for each elapsed month. This is not a BCWS curve.



Earned Schedule

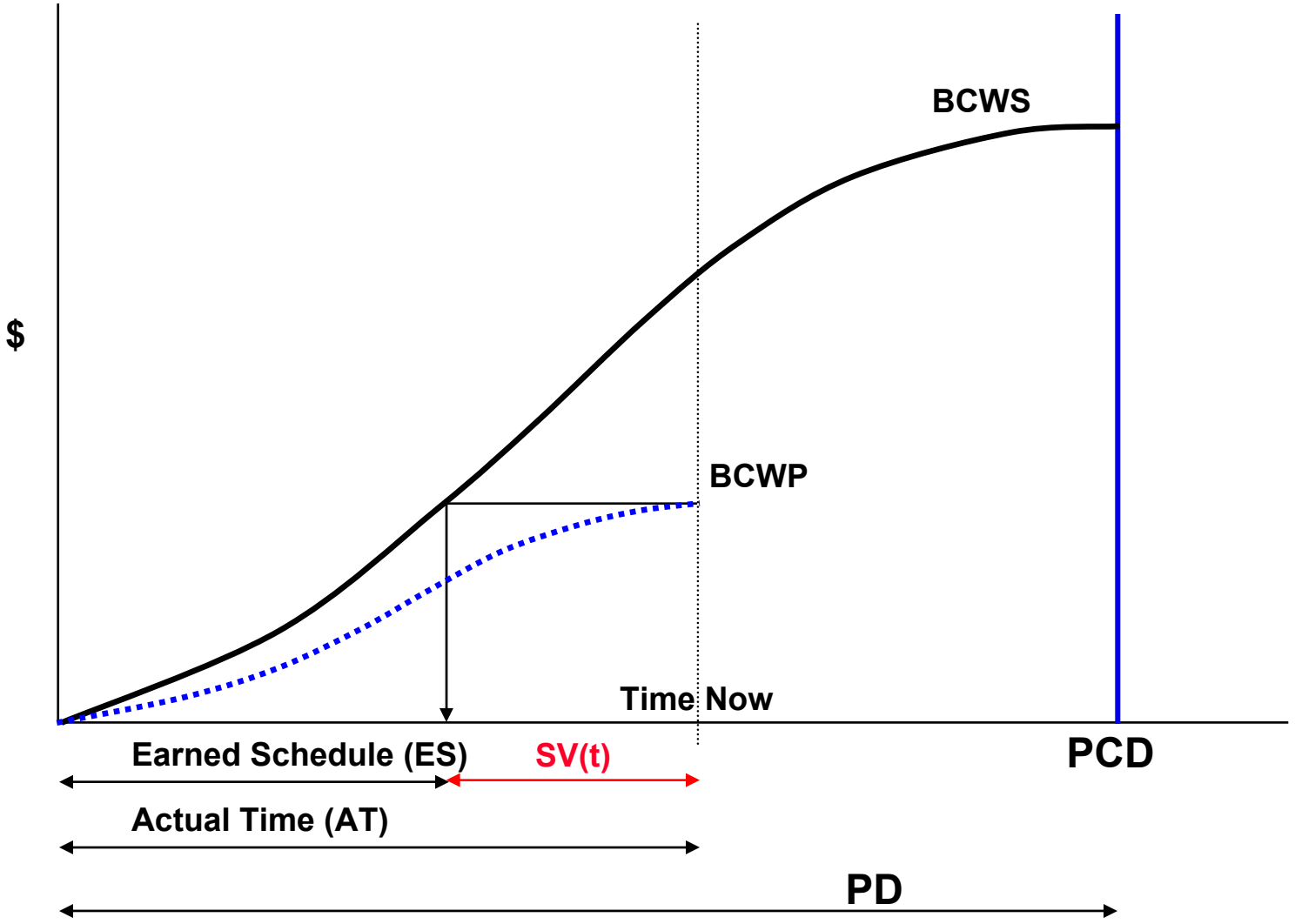
Status

Status Terms

NOTIONAL DATA

New Acronym	New Earned Schedule Term	Example	EVM Equivalent Term
ES	**Earned Schedule** cumulative **earned value** in **time units** as established by the value of cumulative BCWP on the BCWS curve	6.1 months	BCWP
AT	**Actual Time** how much time has elapsed = time now – start time	9 months	ACWP
PT_{cum}	**Planned Time, cumulative** = planned months from start to time now = equivalent to Actual Time **only** until PD occurs, then PT_{cum} will always = PD	9 months	BCWS
SV(t)	**Schedule Variance (time)** = ES – AT (time units)	= 6.1 – 9 = -2.9 months	SV
SV(t)%	**Schedule Variance (time) (%)** = SV(t) / PT_{cum}	= -2.9 / 9 = -32%	SV%
SPI(t)	**Schedule Performance Index (time)** = ES / AT	= 6.1 / 9 = .68	SPI

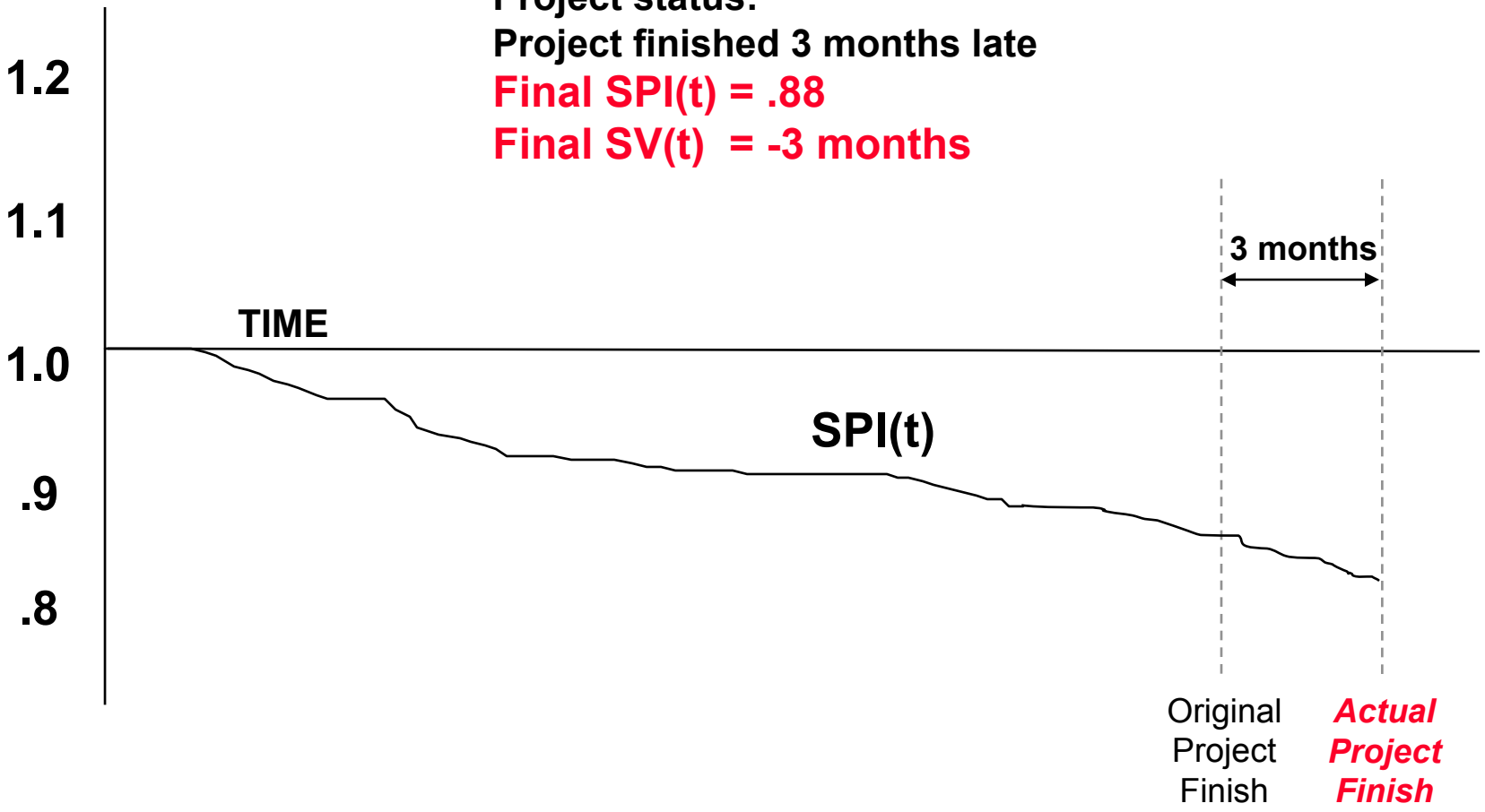
Earned Schedule
Project Status

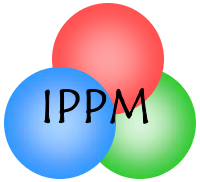


SPI(t) at the End of the Project

NOTIONAL DATA

Project status:
Project finished 3 months late
Final SPI(t) = .88
Final SV(t) = -3 months



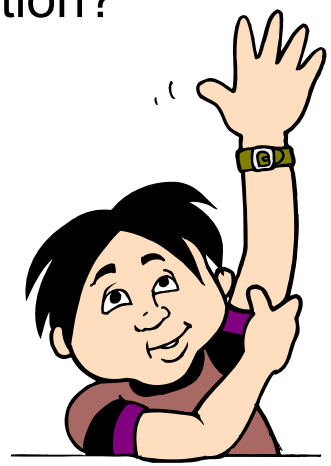


Earned Schedule

Predicting the Project's Duration

Predicting Durations?

- EVM
  - CPI has proven to be stable metric
    - Used to predict estimated final costs
  - SPI based on dollars rarely used to predict duration
- Earned Schedule
  - Early work by Kym Henderson indicates stability of SPI(t)
  - How can SPI(t) be used to predict duration?



Predicting the Duration

NOTIONAL DATA

IEAC(t) = Independent Estimate at Completion (time)

$$= \frac{\text{Planned Time}}{\text{SPI(t)}} = \frac{23 \text{ months}}{.68}$$

$$= 33.8 \text{ months}$$

Parallels EAC formula based on CPI

Assumes schedule performance will remain at same efficiency

Use this as crosscheck against baseline or revised estimate of schedule

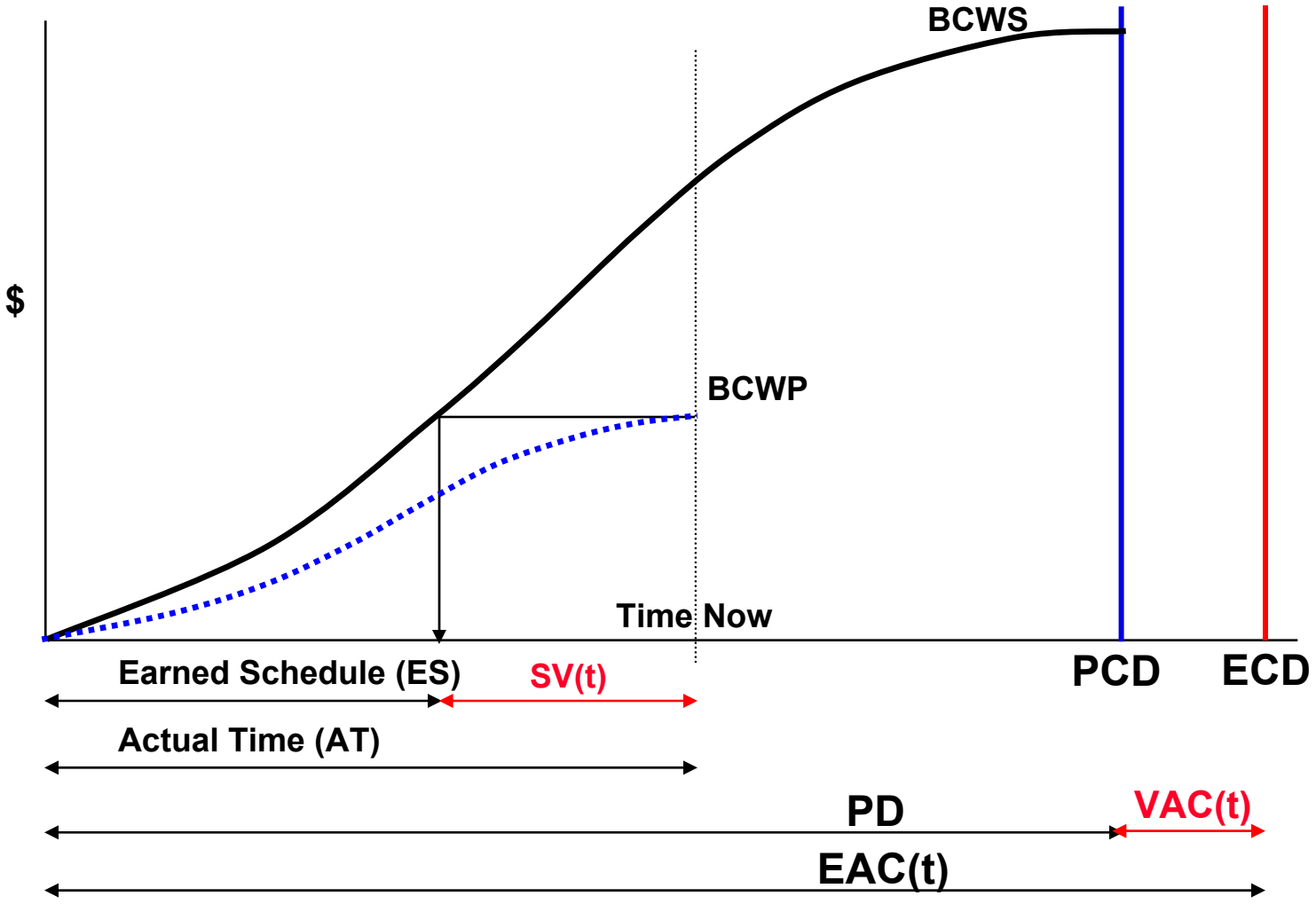
At Completion Metrics

NOTIONAL DATA

New Acronym	New Earned Schedule Term	Example	EVM Equivalent Term
PDWR	**Planned Duration for Work Remaining** = PD – ES (time units)	= 23 – 6.1 = 16.9 months	BCWR
EAC(t)	**Estimate at Completion (time) (supplier)** revised estimate of project length (time units)	25 months	EAC
ETC(t)	**Estimate to Complete (time)** = EAC(t) – AT (time units)	= 25 – 9 = 16 months	ETC
ECD	**Estimated Completion Date (supplier)**	28 Feb 05	
VAC(t)	**Schedule Variance at Completion** = PD – EAC(t) (time units)	= 23 – 25 = - 2 months	VAC
IEAC(t)	**Independent EAC(t) (customer)** = PD / SPI(t) (see other formulas on chart 27)	= 23 / .68 = 33.8 months	IEAC
IECD	**Independent Estimated Completion Date**	= 24 Nov 05	

Earned Schedule
Project Status

NOTIONAL DATA



Predicting the Duration

IEAC(t) = Independent Estimate at Completion (time)

$$= \text{Actual Time} + \frac{\text{Planned Duration for Work Remaining}}{\text{performance factor}}$$

If SPI(t) is used as the performance factor, the formula resolves to:

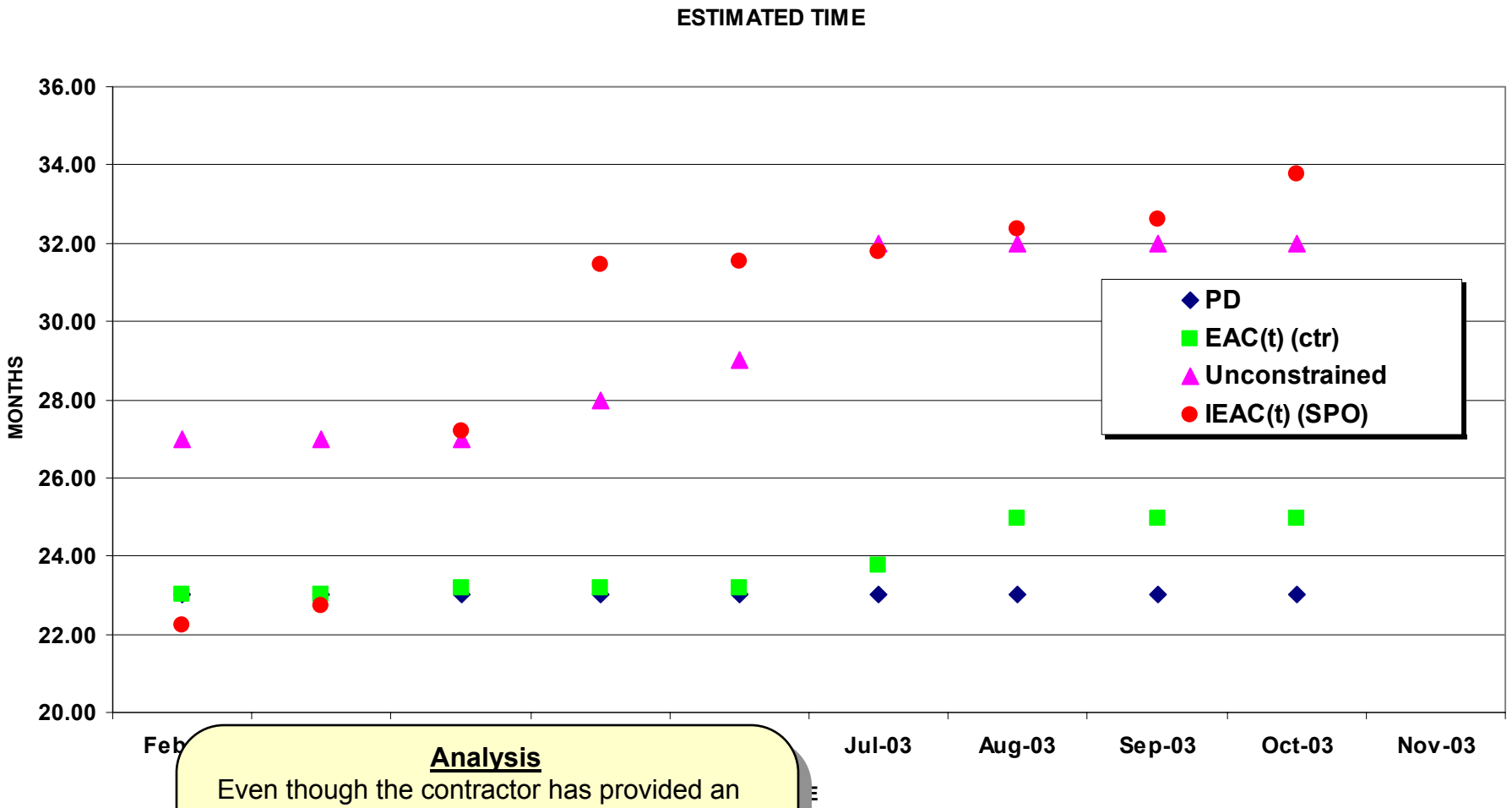
$$= \frac{\text{Planned Duration}}{\text{SPI(t)}}$$

Other IEAC(t) Formulas

IEAC(t) =	Assumptions
AT + PDWR	Remaining schedule will finish at planned duration
AT + PDWR + Total Float*	Remaining schedule will finish at planned duration, plus all float will be consumed
PD / SPI(t)	Work will finish at existing level of schedule efficiency
(PD / SPI(t)) + Total Float*	Work will finish at existing level of schedule efficiency, plus float will be consumed
(PD + TF) / SPI(t)*	Work will finish at existing level of schedule efficiency, plus float will be consumed at same level of efficiency
AT + (PDWR / USE)	Assumes remaining work will finish at unconstrained schedule efficiency (USE) (see slide 45)

***Use only if baseline was planned to early finish date**

NOTIONAL DATA



Analysis

Even though the contractor has provided an updated schedule estimate, it appears that it is unachievable. The independent calculation by the SPO results in an estimated duration of just under 34 months, compared to the contractor's estimate of 25 months.

Recommend calculation of a range of durations

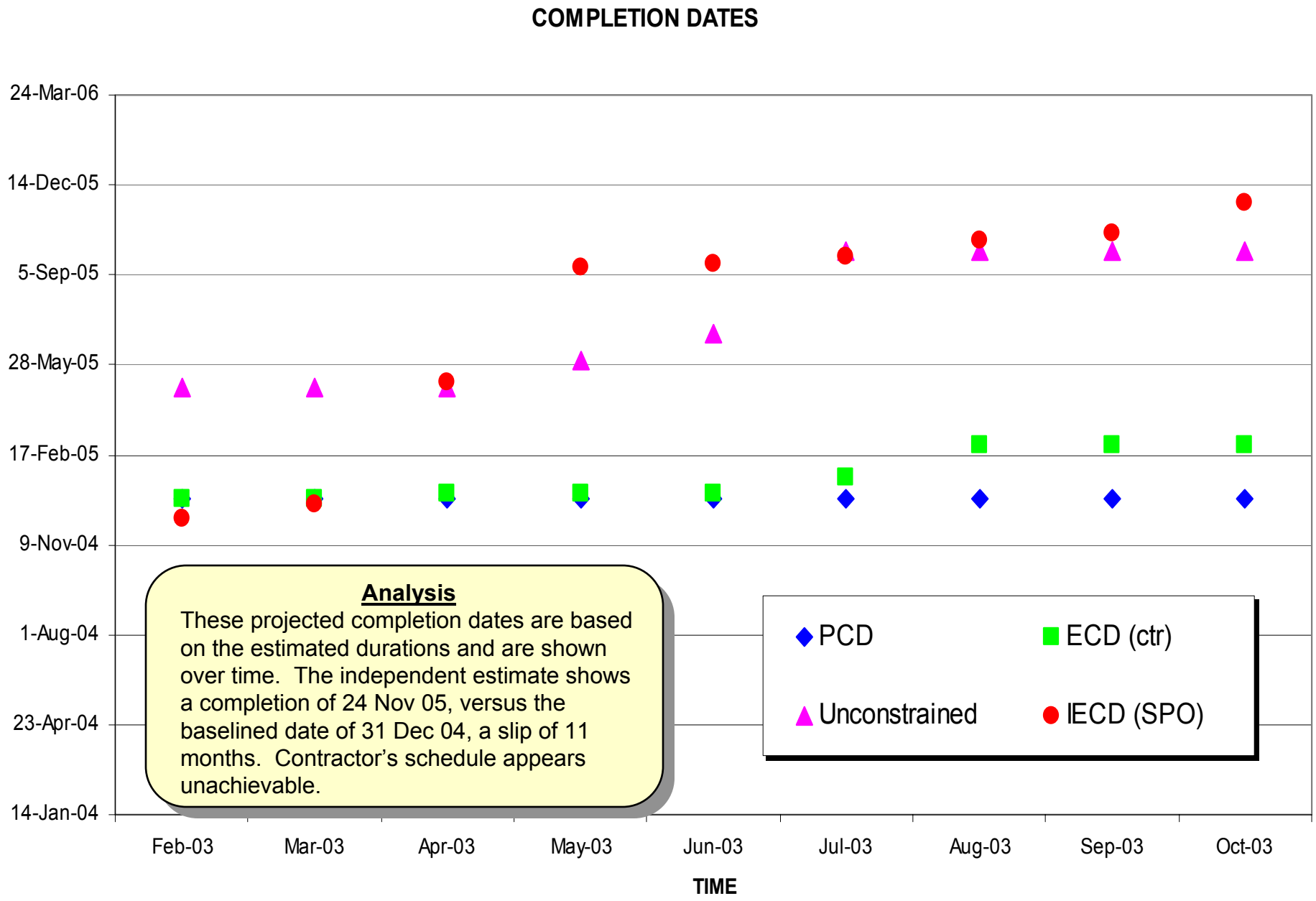
Independent Estimated Completion Date

IECD = Independent Estimated Completion Date

= Start date + IEAC(t)

use this as crosscheck against contract schedule

NOTIONAL DATA



What is the Final SPI(t)?

Cum to Date

$$SPI(t) = \frac{ES}{AT}$$

During project execution phase

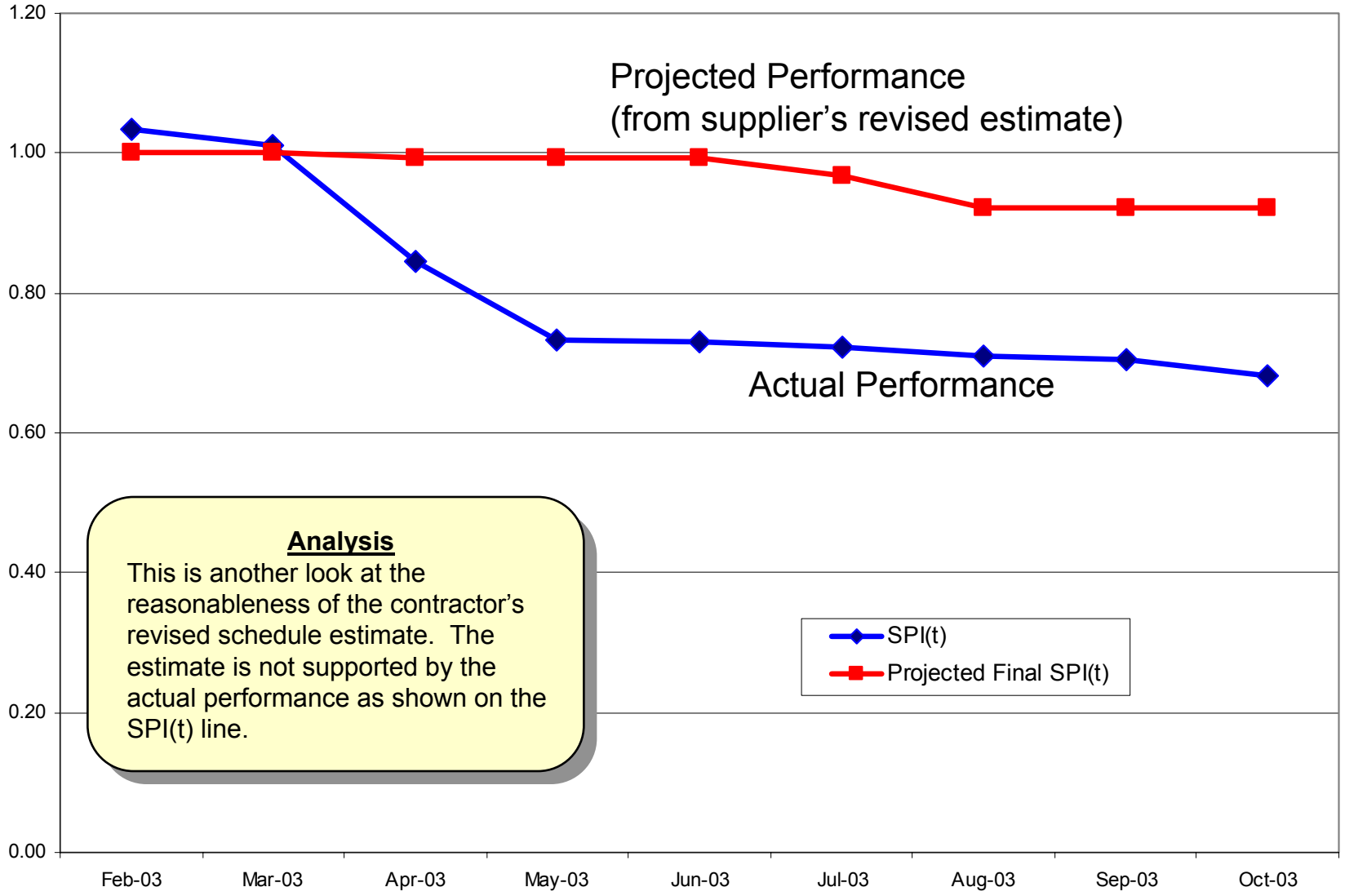
Projected Final SPI(t) = $\frac{PD}{EAC(t)}$

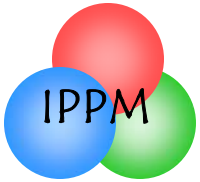
Final SPI(t) = $\frac{PD}{\text{final AT}}$

Project complete

NOTIONAL DATA

SPI(t) (past) vs. Projected Final SPI(t)





Earned Schedule

Comparison of Efficiencies

Work Remaining Metrics

New Acronym	New Earned Schedule Term	Example	EVM Equivalent Term
PDWR	**Planned Duration for Work Remaining** = PD – ES (time units)	= 23 – 6.1 = 16.9 months	BCWR
ETC(t)	**Estimate to Complete (time)** = EAC(t) – AT (time units)	= 25 – 9 = 16 months	ETC
TSPI(t)	**To Complete Schedule Performance Index (time)** = PDWR / ETC(t)	= 16.9 / 16 = 1.06	TCPI-EAC or TCPI

Compare Past to Future Efficiency

Past Schedule Efficiency = SPI(t)

$$= \frac{\text{Earned Schedule}}{\text{Actual Time}}$$

.68

COMPARE

Future Schedule Efficiency = TSPI(t)

$$= \frac{\textbf{Planned Time for Work Remaining}}{\textbf{Estimate to Complete (time)}}$$

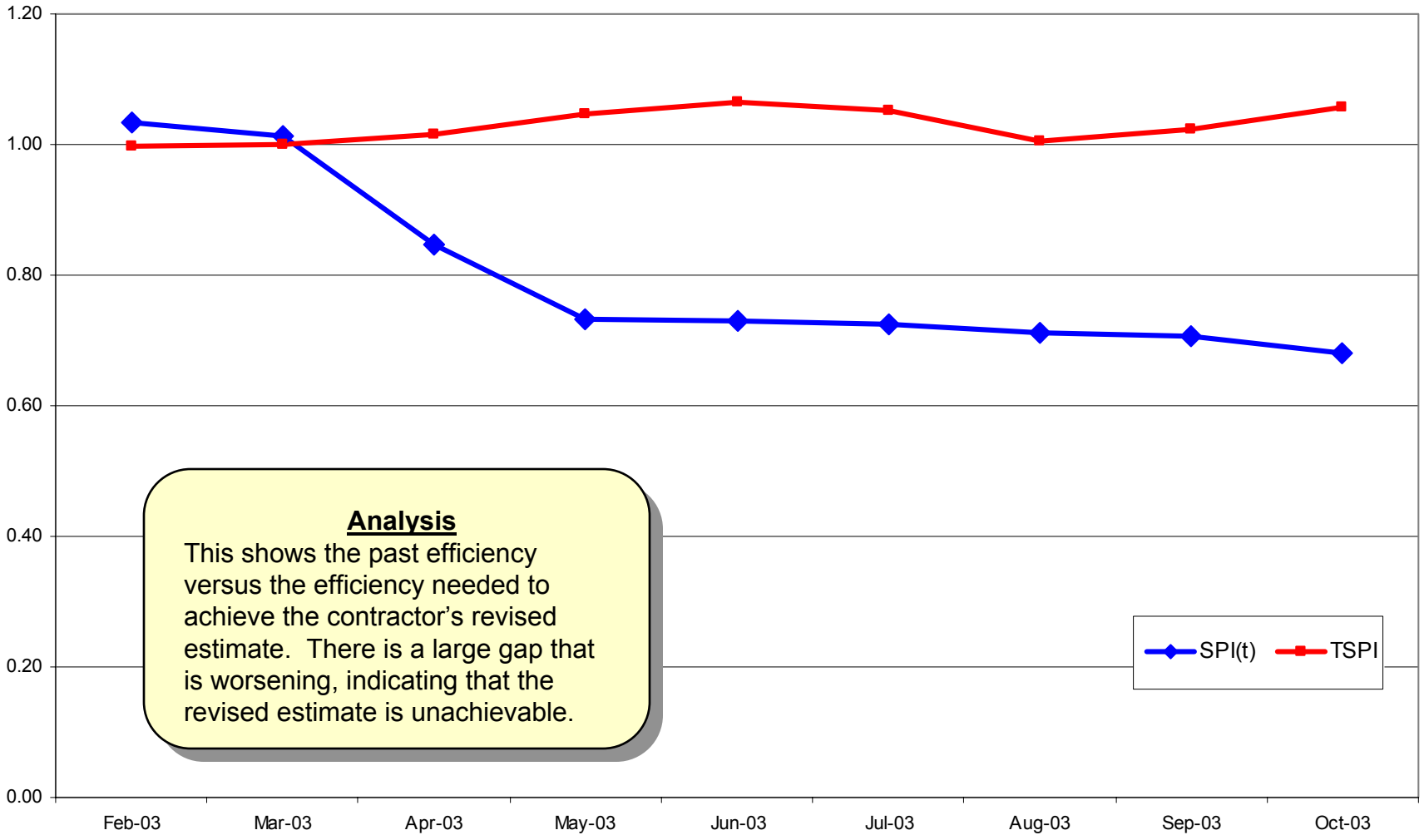
1.06

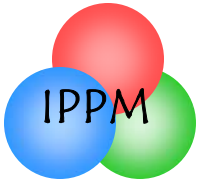
Future efficiency needed to achieve revised estimate of duration

May also be calculated for IEAC(t)

SPI(t) (past efficiency) vs. TSPI(t) (future efficiency)

NOTIONAL DATA





Earned Schedule Metrics and the Integrated Master Schedule

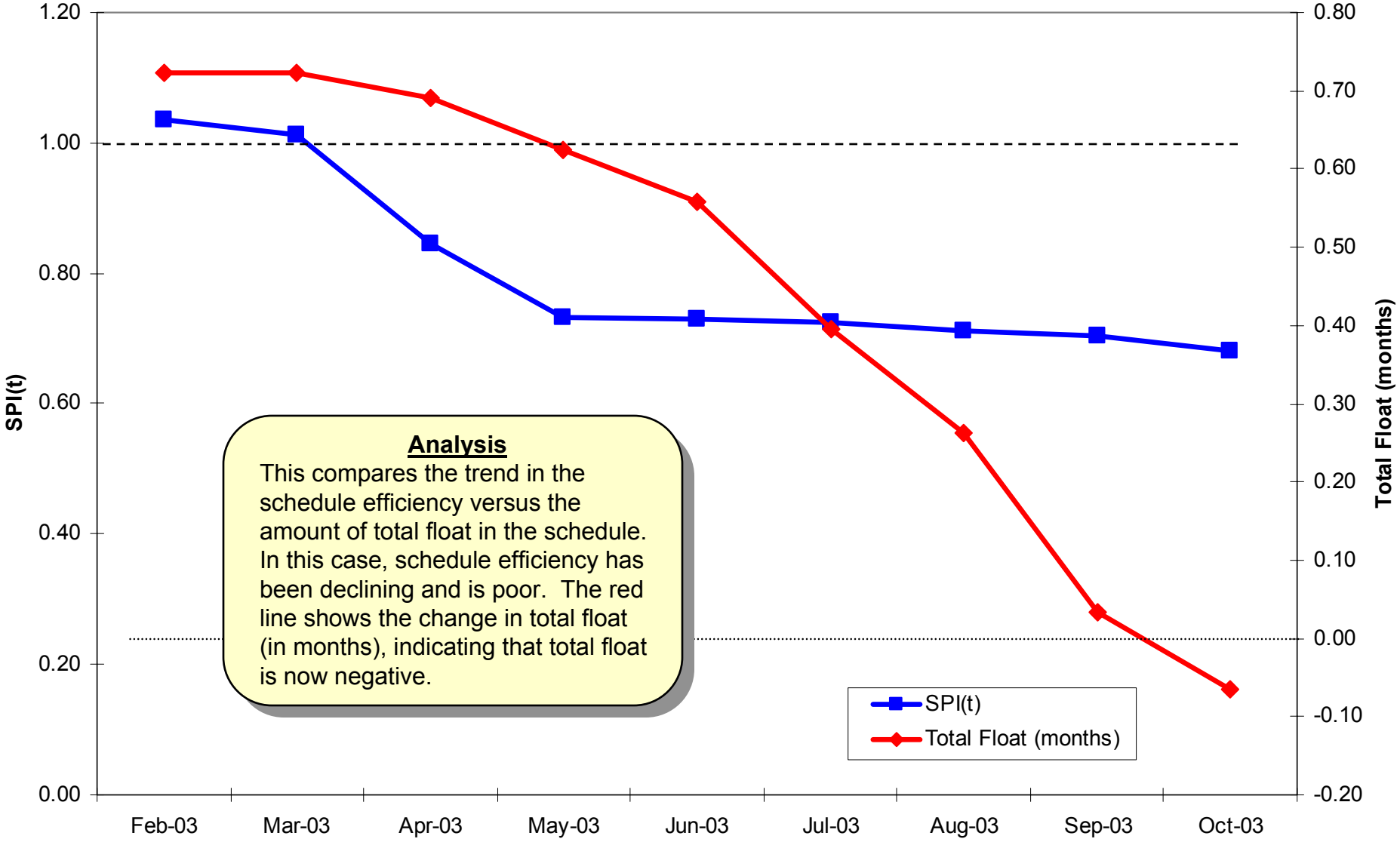
Compare Total Float to SPI(t)

SPI(t)	TF	
>1	**>0**	Ahead of schedule
<1	**<0**	Behind schedule
>1	**<0**	Critical activities behind, but total work ahead (priority problem)
<1	**>0**	Critical activities ahead, but total work behind (future trouble)

Adapted from Humphreys & Associates, Project Management Using Earned Value

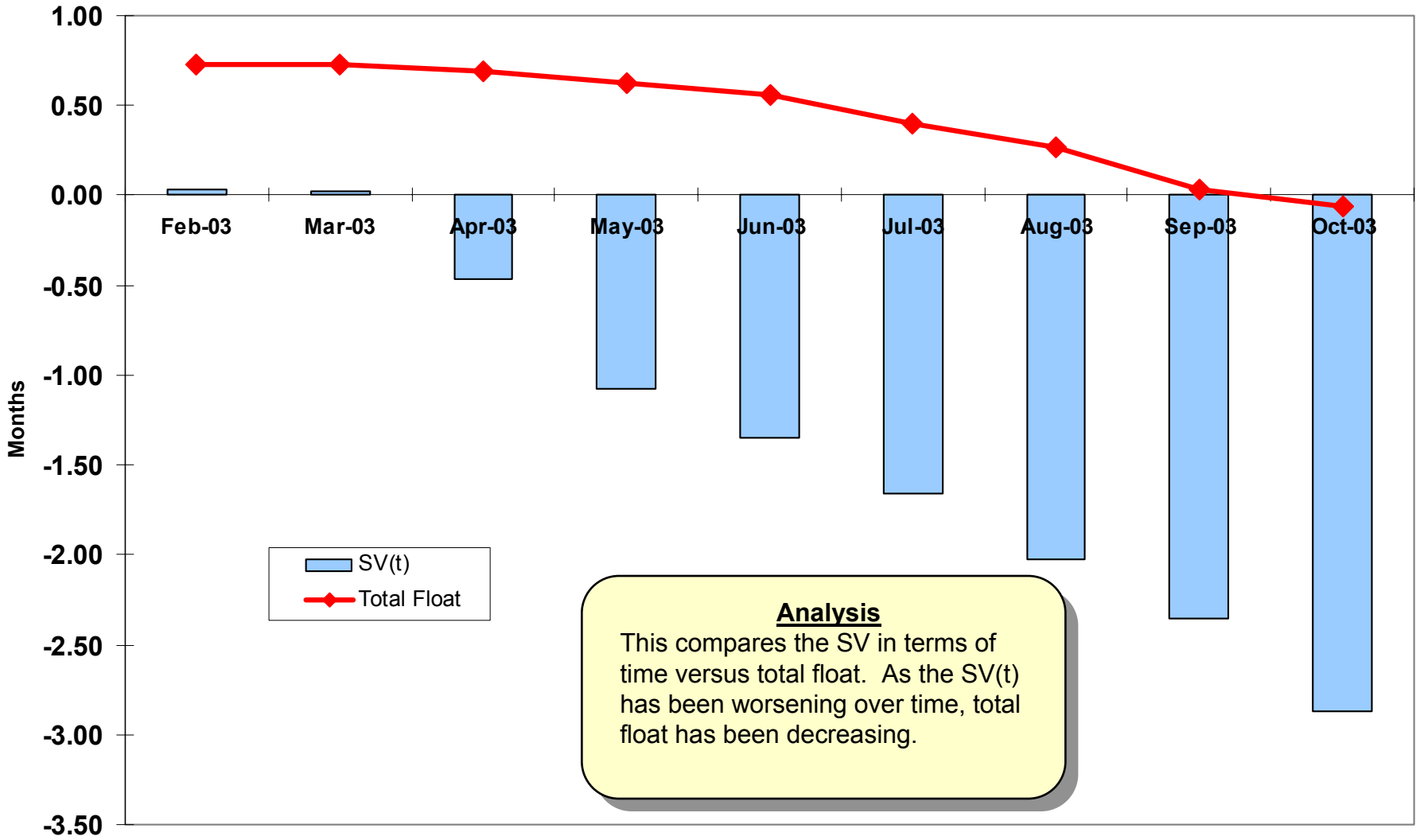
NOTIONAL DATA

SPI(t) versus Total Float



NOTIONAL DATA

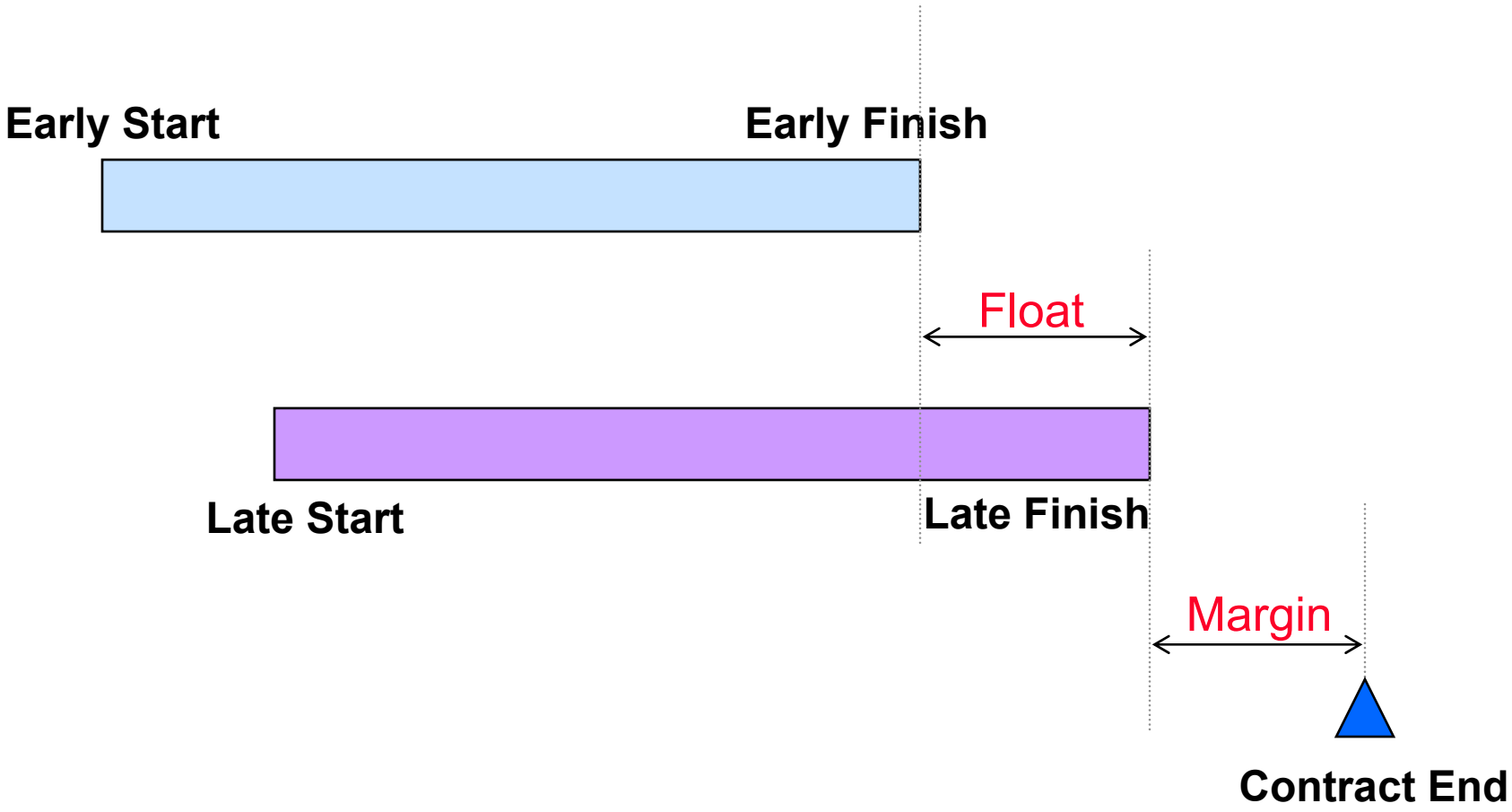
Schedule Variance and Total Float



Constrained vs. Actual Schedule Efficiencies

- **Very rarely do projects get baselined to completely unconstrained schedule**
- **Reality**:
  - Constrained to imposed end date or milestones in contract
  - Baselined schedule may even use early start dates
    - Many baselined schedules end prior to Late Finish or contract end date
    - Difference is total float or margin
  - Result: most schedules are doubly constrained and unlikely to be realized
- **Definitions**:
  - **Planned duration (PD)**
    - Duration of planned schedule baseline
    - If planned to Early Finish date, does not include total float
    - If planned to Late Finish date, includes total float
  - **Contract duration (CD)**
    - Duration of contract (from start to final milestone), with total float and margin
  - **Unconstrained duration (UD) "90%"**
    - Duration of schedule when all constraining dates in networked schedule are removed
    - Must have logically networked schedule to calculate unconstrained end date
    - Use higher durations from Schedule Risk Assessment

Float and Margin



Constrained vs. Actual Schedule Efficiencies

NOTIONAL DATA

- **Contract Schedule Efficiency (CSE)** = minimum efficiency needed to meet baselined schedule
  - CSE = planned duration / contract duratin
  - Example

    Planned duration = 23 months (assumes baseline was planned to Early Finish)

    Contract duration = 24 months

    CSE = 23 / 24 months = .96
  - If SPI(t) falls below this efficiency, it is probable that the planned duration will be exceeded and total float is now being consumed
- **Unconstrained Schedule Efficiency (USE)** = level of efficiency that indicates that the unconstrained schedule will be realized
  - USE = planned duration / unconstrained duration
  - Example

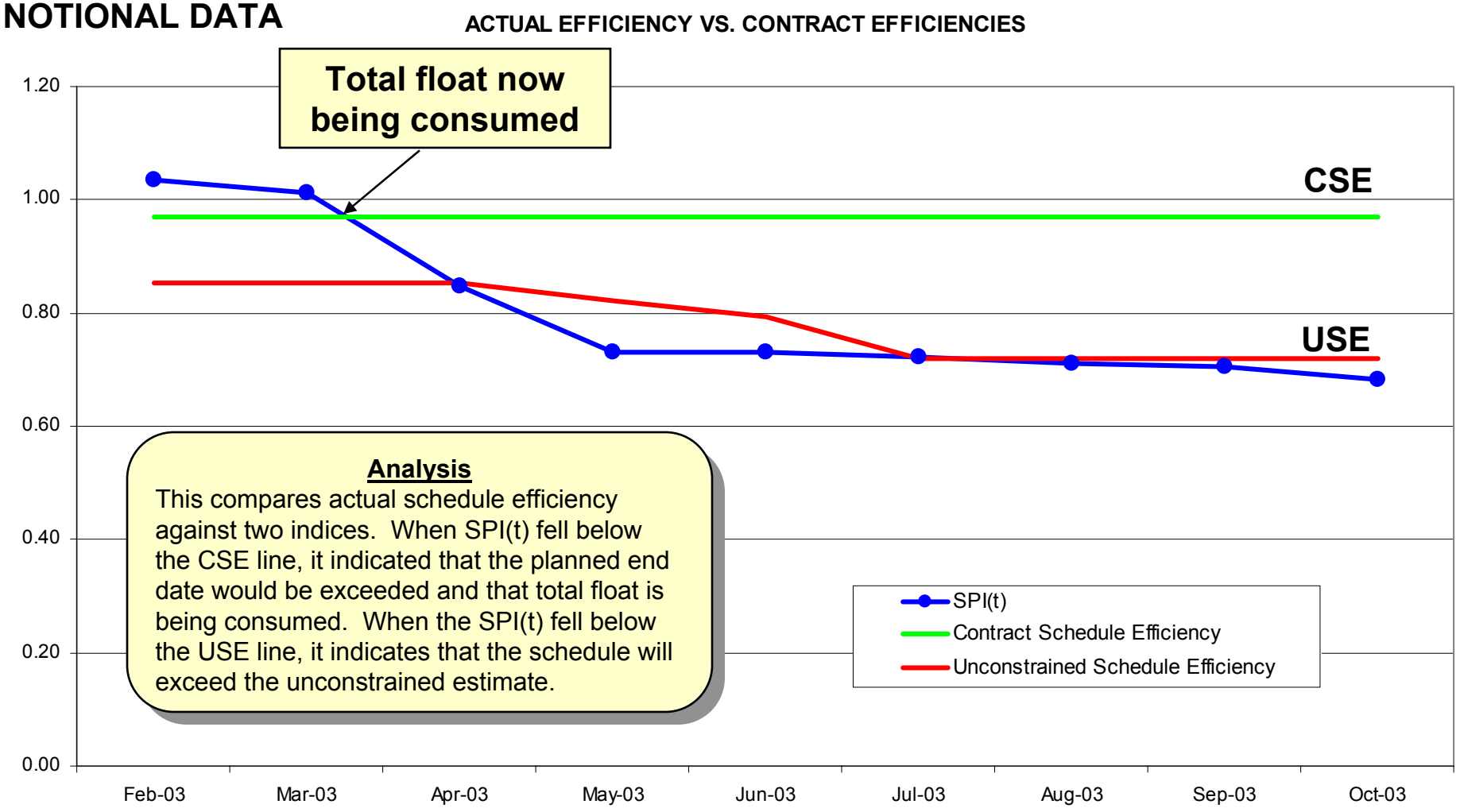
    Planned duration = 23 months

    Unconstrained duration = 32 months

    USE = 23 / 32 months = .72
  - If SPI(t) falls below this efficiency, it is almost certain that the planned time will be exceeded and that the final time will be the unconstrained time

Comparison of Efficiencies

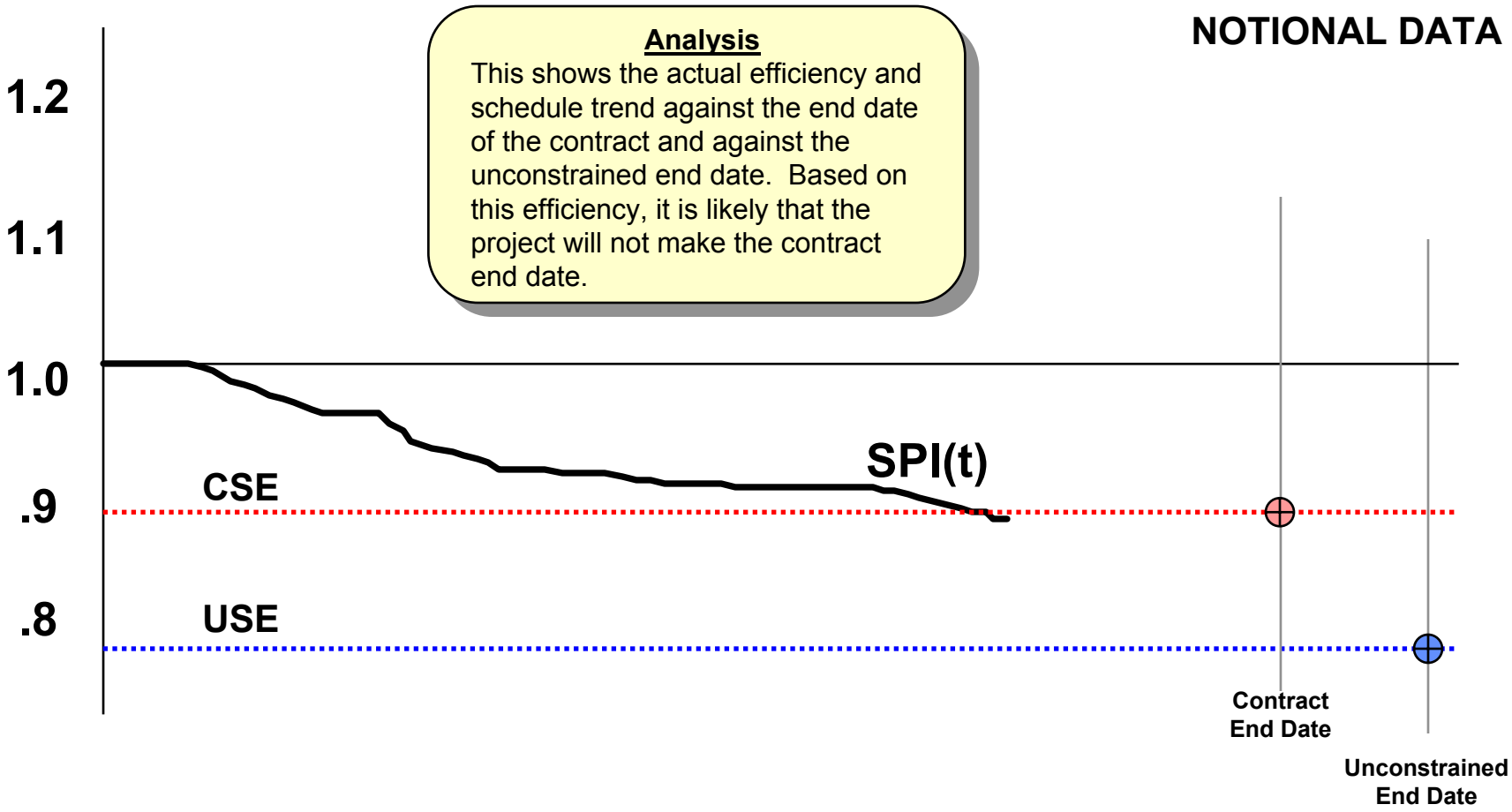
NOTIONAL DATA

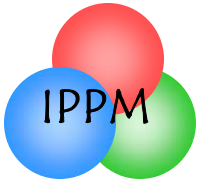


Analysis

This compares actual schedule efficiency against two indices. When SPI(t) fell below the CSE line, it indicated that the planned end date would be exceeded and that total float is being consumed. When the SPI(t) fell below the USE line, it indicates that the schedule will exceed the unconstrained estimate.

Efficiencies vs. Completion Dates





Analysis Process

Data Needed for ES Analysis

- EVM data
  - BCWP cum to date
  - BCWS cum to date (from beginning to time now)
- Integrated Master Schedule data
  - Start date
  - Planned completion date (baseline)
  - Planned duration (without total float)
  - Total float (days)
  - Estimated completion date
  - Optional:
    - Unconstrained completion date

Steps for ES Analysis

- Gather required data
- Analyze status to date
  - Calculate
    - ES
    - AT
    - SV(t)
    - SPI(t)
- Project performance
  - Calculate
    - VAC(t)
    - IEAC(t) (use various formulas)
    - IECD
    - Projected final SPI(t)
- Compare
  - Calculate
    - PDWR
    - ETC(t)
    - TSPI(t)
    - CSE
    - USE
- Construct graphs and analyze trends

Potential Graphs

- SV(t)
- SV(t) vs. Float
- SPI(t), projected final SPI(t)
- SV(t), CV$
- ES vs. AT
- SPI(t), CPI
- PCD, ECD, IECD over time
- range of IECDs
- SPI(t) vs. TSPI(t)
- SPI(t) vs. CSE vs. USE

Earned Schedule Excel worksheet

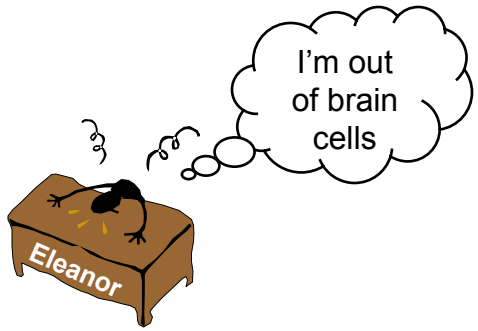
Contains logic, formulas, generates charts

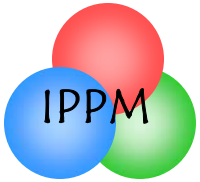
NOTIONAL DATA

Month	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03
BCWScum ($)	782	1,411	1,923	2,510	3,215	4,127	5,122	6,229	7,279
BCWPcum ($)	804	1,423	1,687	1,886	2,304	2,751	3,198	3,801	4,257
Status to Date									
Actual Time (AT) (months)	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
Earned Schedule (ES) (months)	1.03	2.02	2.54	2.93	3.65	4.34	4.98	5.64	6.13
Planned Duration for Work Remaining (PDWR)	21.98	20.99	20.47	20.09	19.36	18.67	18.04	17.37	16.88
SV(t) (months)	0.03	0.02	-0.46	-1.07	-1.35	-1.66	-2.02	-2.36	-2.87
Planned Time (cum)	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
SV(t) %	3%	1%	-15%	-27%	-27%	-28%	-29%	-29%	-32%
SPI(t)	1.03	1.01	0.85	0.73	0.73	0.72	0.71	0.71	0.68
At Completion			BLUE FONT INDICATES DATA ENTRY CELLS						
Project Start	1-Feb-03								
Planned Completion Date (PCD)	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04	31-Dec-04
Estimated Completion Date (ECD)	31-Dec-04	31-Dec-04	5-Jan-05	5-Jan-05	5-Jan-05	23-Jan-05	28-Feb-05	28-Feb-05	28-Feb-05
Contract Completion Date	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05	22-Jan-05
Total Float (days)	22	22	21	19	17	12	8	1	-2
Total Float (months)	0.72	0.72	0.69	0.62	0.56	0.39	0.26	0.03	-0.07
Unconstrained Duration (months)	27.00	27.00	27.00	28.00	29.00				
Unconstrained Schedule Efficiency (USE)	0.85	0.85	0.85	0.82	0.79				
Unconstrained Completion Date	2-May-05	2-May-05	2-May-05	1-Jun-05	2-Jul-05				
Planned Duration (PD) (months)	23.01	23.01	23.01	23.01	23.01				
Estimate at Completion (time) EAC(t) (months)	23.01	23.01	23.18	23.18	23.18				
Estimate to Completion (time) ETC(t) (months)	22.01	21.01	20.18	19.18	18.18				
Variance at Completion (time) VAC(t) (months)	0.00	0.00	-0.16	-0.16	-0.16				
Independent Estimate at Completion (time) IEAC(t)									
AT + PDWR	22.98	22.99	23.47	24.09	24.36				
AT + PDWR + Total Float	23.70	23.71	24.17	24.71	24.92	25.07	25.30	25.40	25.88
PD / SPI(t)	22.24	22.75	27.19	31.44	31.53	31.80	32.38	32.63	33.78
PD / SPI(t) + Total Float	22.96	23.47	27.88	32.07	32.09	32.20	32.64	32.66	33.78
(PD + TF) / SPI(t)	22.93	23.46	28.01	32.30	32.30	32.35	32.75	32.68	33.78
AT + (PDWR / USE)	26.79	26.63	27.02	28.44	29.40	31.96	32.08	32.15	32.48
Independent Estimated Completion Date (using SPI(t))	8-Dec-04	23-Dec-04	8-May-05	14-Sep-05	17-Sep-05	25-Sep-05	12-Oct-05	20-Oct-05	24-Nov-05
Comparison of Indices									
SPI(t)	1.03	1.01	0.85	0.73	0.73	0.72	0.71	0.71	0.68
TSPI(t)	1.00	1.00	1.01	1.05	1.07	1.05	1.00	1.02	1.06
Projected Final SPI(t)	1.00	1.00	0.99	0.99	0.99	0.97	0.92	0.92	0.92
Contract Efficiencies									
Contract Duration	23.74	23.74	23.74	23.74	23.74	23.74	23.74	23.74	23.74
Contract Schedule Efficiency	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

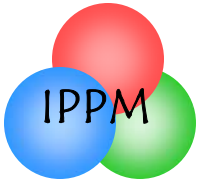
EARNED SCHEDULE
= (HLOOKUP(J5,$B$3:$X$5,2))+(J5-(HLOOKUP(J5,$B$3:$X$5,1)))/((HLOOKUP((HLOOKUP(J5,$B$3:$X$5,2))+1),$B$7:$X$8,2)-(HLOOKUP(J5,$B$3:$X$5,1))))

available upon request for use or evaluation



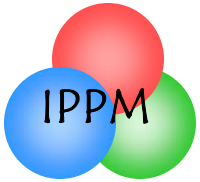


Considerations



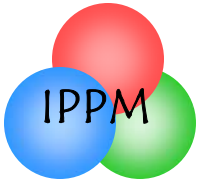
Things to Consider

- Depends on valid BCWP
  - Should represent completed work
- Replanning of schedule or adjustment of EVM variances
  - May affect $BCWS_{cum}$
  - May impact metrics and projections
  - Analyst should closely follow stability of baseline
    - Adjustments to prior or future baseline
- Other areas to explore
  - Lower level analysis of schedule activities or by IPT

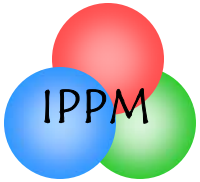


Impact to EAC Formulas

- Performance based EAC formulas
  - Two formulas rely on SPI ($)
    - But, predictive ability is lost during late stage of project
  - Need to determine applicability of using SPI(t) in EAC formulas
    - Weighted performance factor: .5*CPI + .5*SPI(t)
    - Composite performance factor: CPI*SPI(t)
  - Analysts should use with caution until research confirms utility
- Burn rate analysis
  - Use average burn rates (actual cost) against estimates of duration
  - Should improve EAC projections

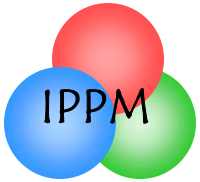


Summary



Way Ahead

- Collaborate and gain consensus on terms
- Need continuing research on completed projects to confirm predictive utility of metrics
  - AFIT graduate thesis underway
    - Determine if SPI(t) is a valid predictor of final duration
- Software tools need to incorporate new metrics
- Widespread education and adoption
- Incorporate into
  - PMI Guide to Project Management Body of Knowledge
  - CPM Professional Education Program
  - PMI-CPM Practice Standard for EVM



Research Topics

- Determine if SPI(t) is a valid predictor of final duration (ongoing)
- Validate use of SPI(t) in EAC formulas
- Determine if earned schedule metrics are better at portraying schedule performance than traditional EVM metrics
- Compare predicted IEAC(t) durations against predicted critical path
- Compare predicted IEAC(t) durations against range of durations from schedule risk assessment

Conclusions

- ***Earned Schedule***
  - a powerful new dimension to Integrated Project Performance Management (IPPM)
  - a breakthrough in theory and application

the first scheduling system

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