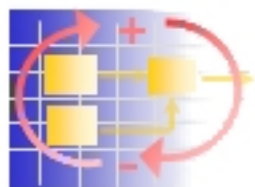


ESD.36J System & Project Management




Resource Consumption and Progress Tracking - Metrics

Instructor(s)

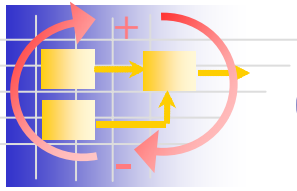
Pat Hale

Lecture 18

Nov. 4 - 2003

Massachusetts Institute of Technology 

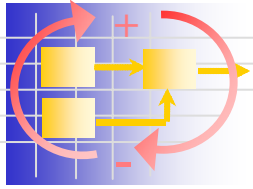
Courtesy of Pat Hale. Used with Permission



Outline

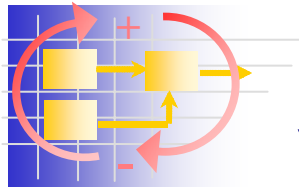
- Tracking of Resource Consumption and Progress
 - Creating Measurable Plans
 - Schedule, Cost Tracking
 - Scope/Progress Tracking
 - Risk Tracking - how?
- Industrial Practice
 - “Earned Value” and Cost Schedule Status Reporting (CSSR)
- Role of Metrics in Project Management
 - Process-related metrics
 - Product-related metrics

(We will stop at 3:50 for the Sheila Widnal's lecture in 1-190)



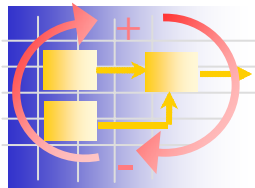
Project Tracking Challenges

- CPM/PERT, DSM, SD- our project planning tools are intended to help us establish a credible baseline for planned schedule, project and product cost- tracking should be easy, right? But...
 - Timely data suited to direct use for project tracking is difficult to access
 - Competing agendas in project resource organizations make the already difficult task of technical progress assessment even harder
 - Fitting the data into the proper context for project assessment requires time and judgment
- The fidelity of tracking can be no better than the corresponding plan- detailed and realistic planning requires extraordinary effort



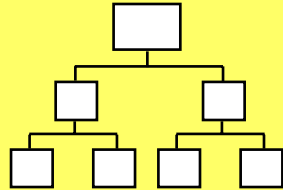
Source Notes

- Many following examples and methods draw upon DOD/aerospace practices
 - Methods originated in industry
 - Initial application found to be resource-intensive
 - DOD applied due to project size and complexity
- Commercial practices are converging with defense (movement in both directions) as IT infrastructure enables data acquisition and analyses
 - Practices are coming full circle
 - Stage-gate processes require tracking metrics
- Tailoring for your organization and project is essential
- Reference material will be posted to SloanSpace

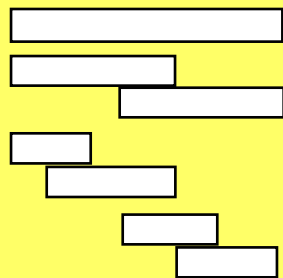


Creating Measurable Plans

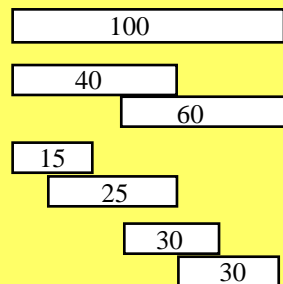
1. DEFINE THE WORK



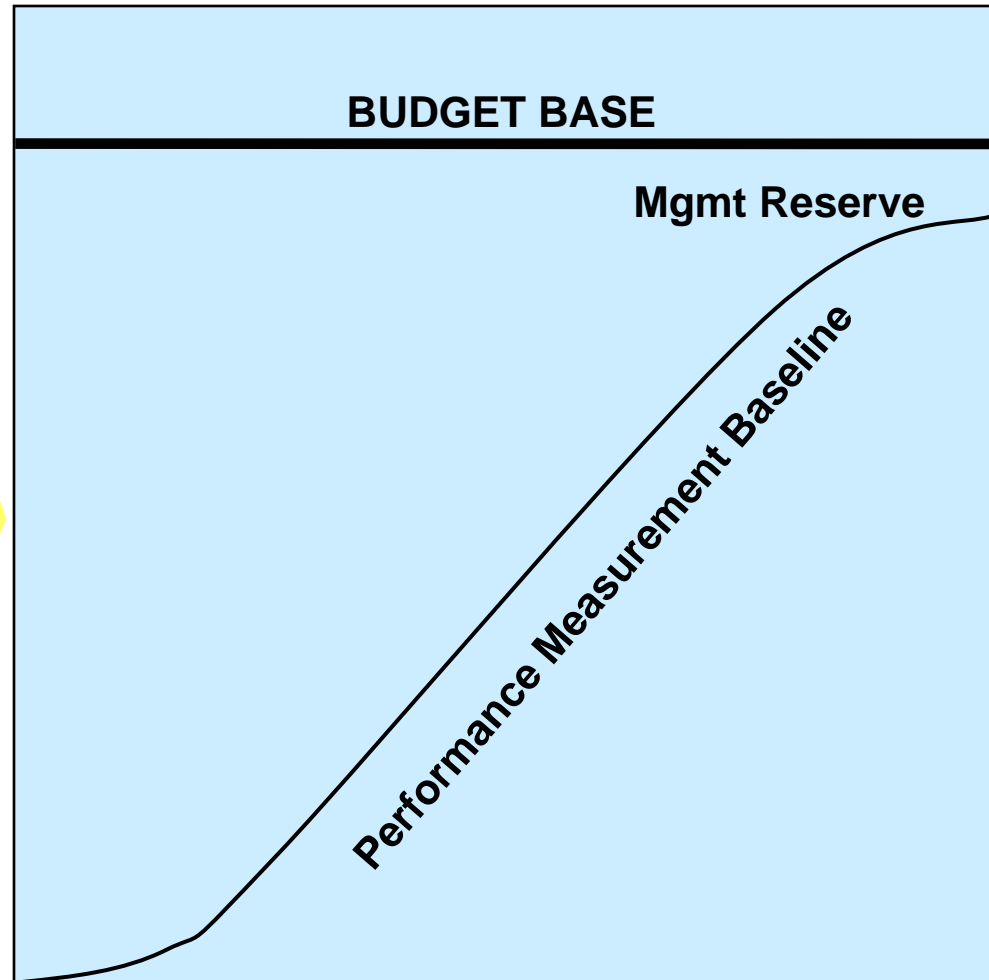
2. SCHEDULE THE WORK



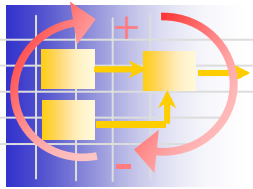
3. ALLOCATE BUDGETS



\$\$



Source: USAF www.acq.osd.mil/pm



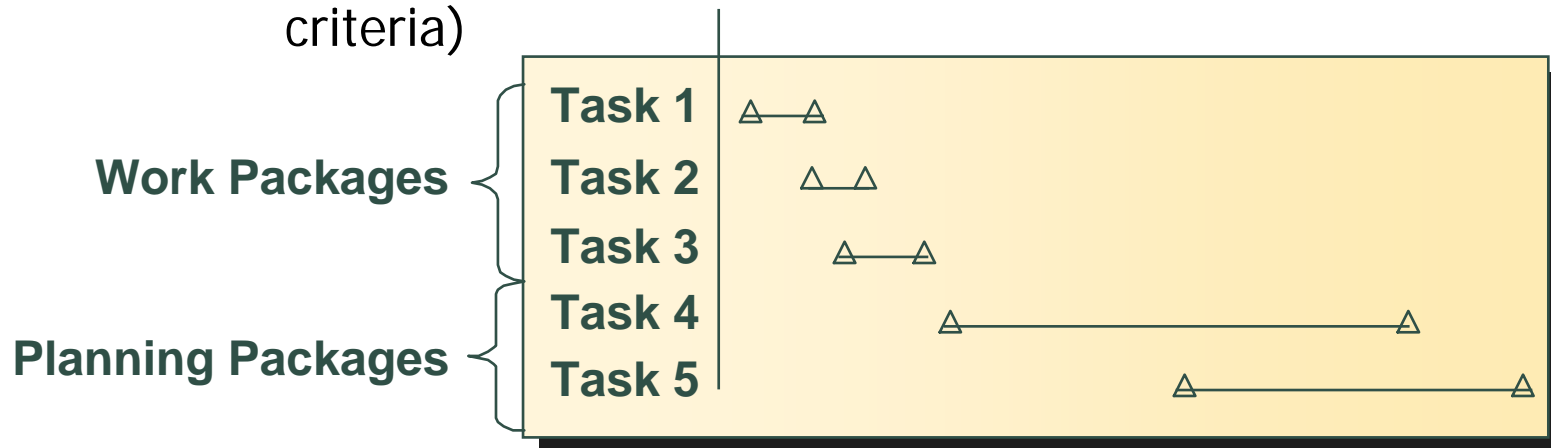
Planning Resolution & Timing

Work Packages

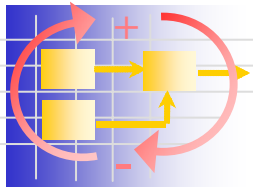
Detailed, short-span tasks, or material items, required to accomplish the CA objectives, typically in the near term (include costs & completion criteria)

Planning Packages

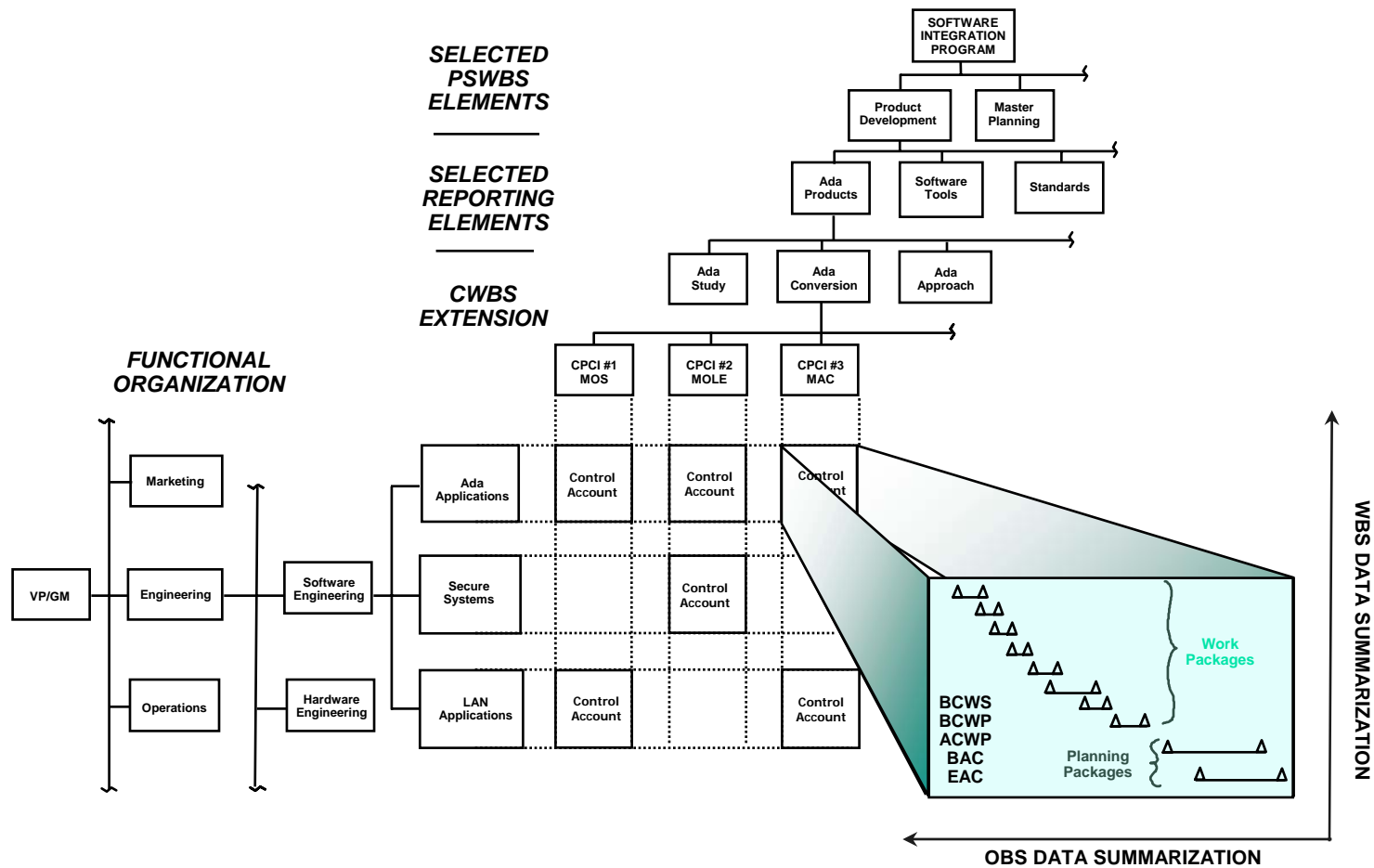
Future work that has not been detail planned as work packages. They are always scheduled to occur in the future.



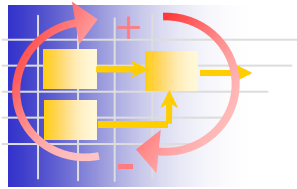
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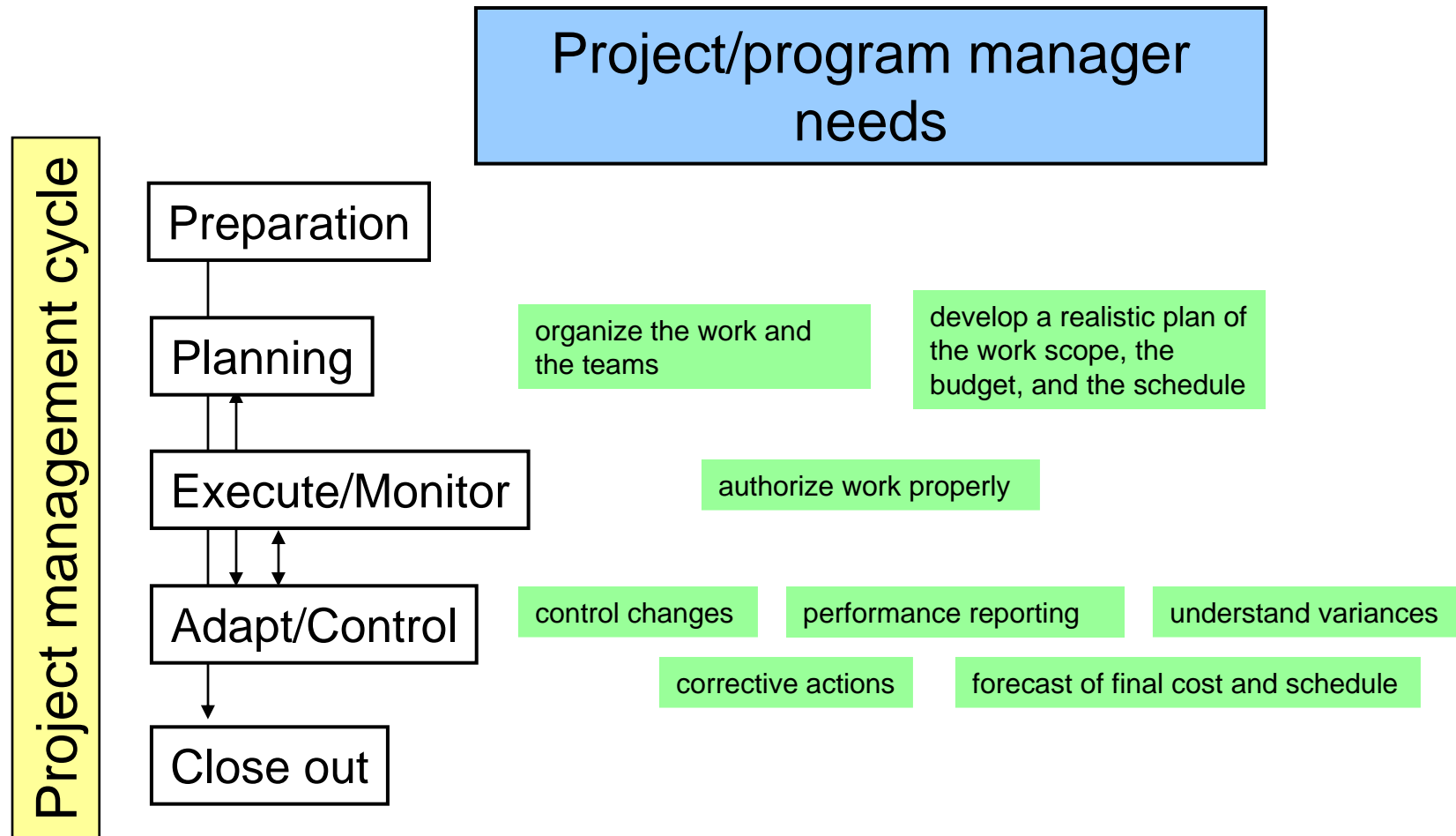
Mapping Work to Resources

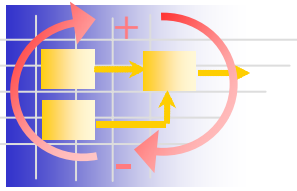


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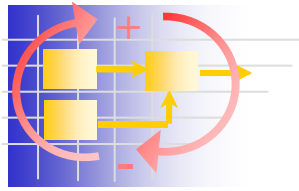
Project Planning & Control Context





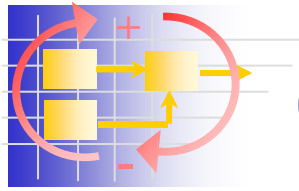
Data Sources for Project Tracking

- Project cost is usually tracked in development organization finance system
 - Data should be tracked on a 'per task, per resource' basis to be most useful
 - As outsourcing becomes a major strategy, similar costs must be gathered from suppliers
- Work completion is usually measured by milestone, but requires detailed planning and 'costed' tasks- this is often the most problematic measurement
 - 'Percent complete' measurements are notoriously unreliable
 - Milestone-based reporting is least ambiguous, but requires substantial planning effort



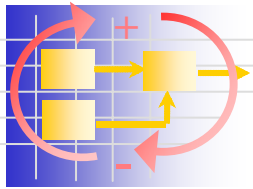
Risk Management

- All project measurement and control is driven by risk recognition and management
- Projects 'without risk' are generally not 'real world' examples- and, if real, are not aggressive enough!
- Several methodologies exist for estimating, tracking and mitigating risks



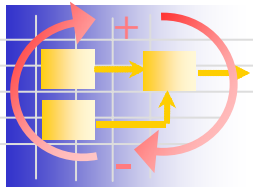
Guidelines/Principles

- Rank Risks as a Project Team
- Be Intellectually Honest
- Identify Risk Leads
 - Every Risk Needs A “belly button”
- Encourage Risk Identification
- Its Not So Much The Risk Level But The Risk Slope That Counts.....
- Satisfaction=Performance-Expectations
 - Manage Expectations!
- Risk Tracking \neq Risk Management

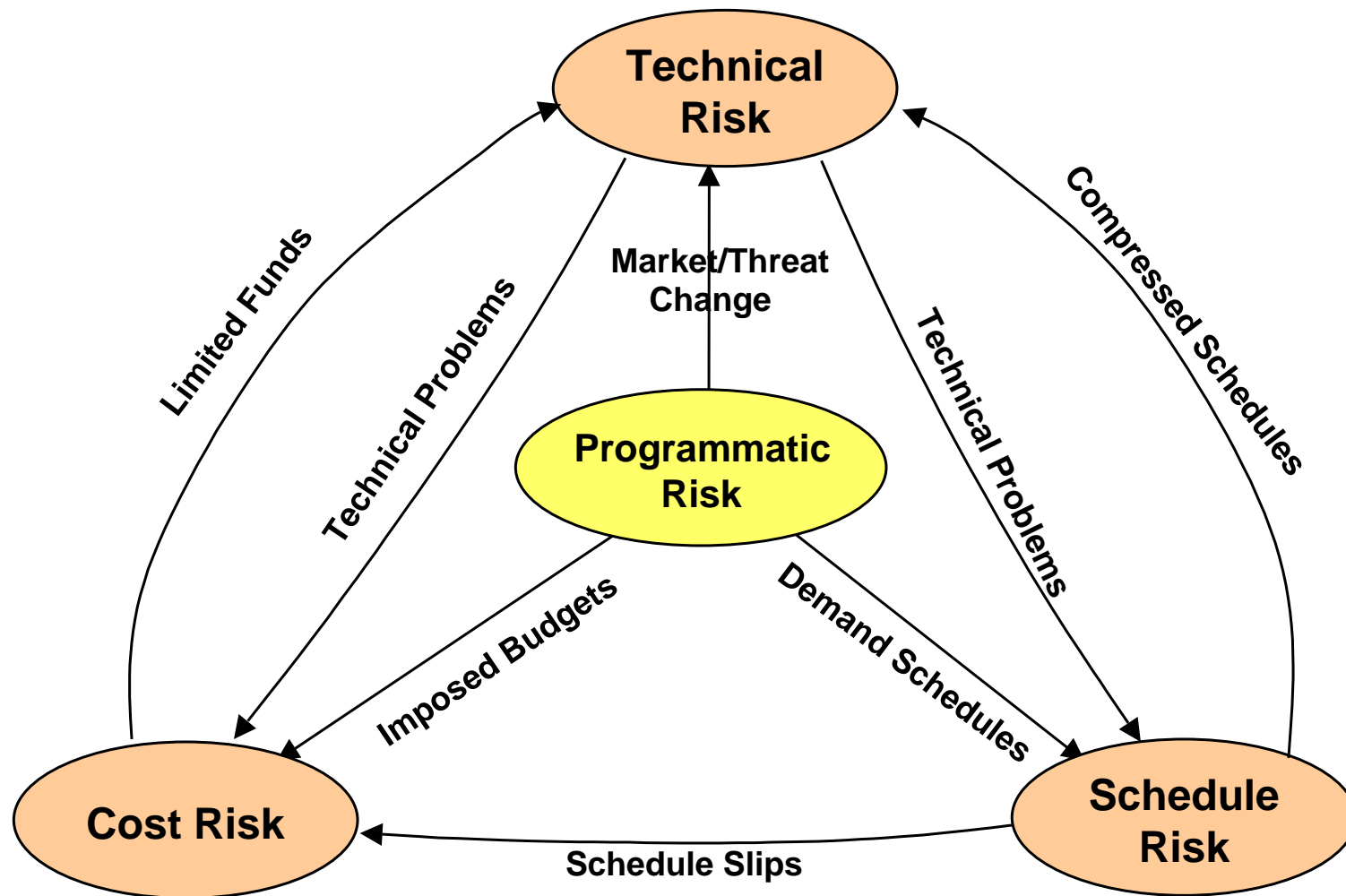


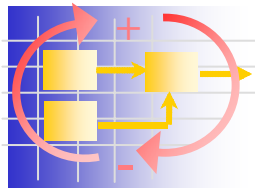
A Risk Management Framework



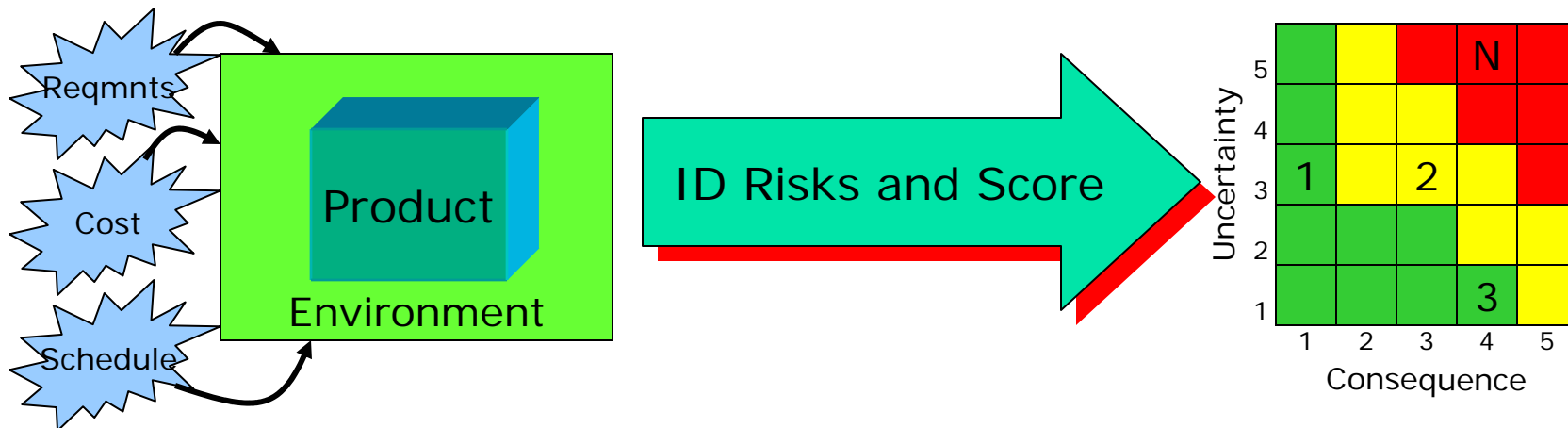


Risk Categories

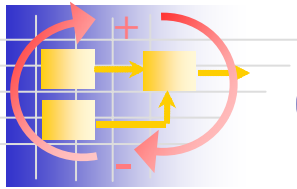




Risk ID/Assessment



- Brainstorm Technical Risks
 - Document Risk and Impact if Realized
- Aggregate Into Performance Categories
 - Rule of Thumb Limit @ $N \approx 20$
- Score (Based on Opinion & Data)
- Involve All Stakeholders



Quantitative Assessment

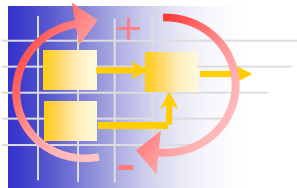
$$\text{Risk} = \text{Probability} * \text{Consequence}$$

PROBABILITY → CONSEQUENCES ↓	FREQUENT (HIGH)* $0.7 < P < 1.0$	PROBABLE (MEDIUM)* $0.4 < P < 0.7$	IMPROBABLE (LOW)* $0 < P < 0.4$	IMPOSSIBLE $P = 0$
CATASTROPHIC 1.0 - 0.9	0.9 HIGH	0.7	0.4	0.0
CRITICAL 0.8 - 0.7	0.8	0.6 MEDIUM	0.3	0.0 NONE
MARGINAL 0.6 - 0.4	0.6	0.4	0.2 LOW	0.0
NEGLIGABLE 0.3 - 0.0	0.3	0.2	0.1	0.0

* Additional terminology, not in US Air Force Guide on Software Risk Abatement

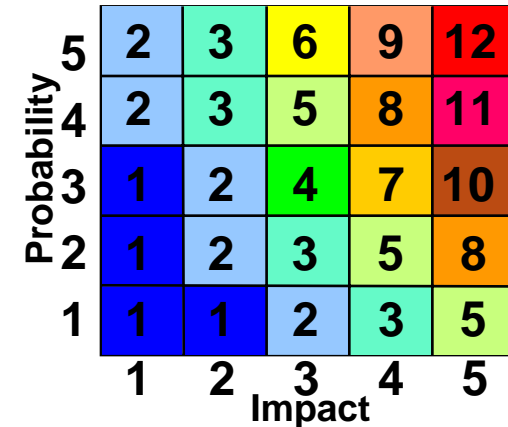
Note: Risk rating is consistent with $R = P * C$

Often used to track risk history over project

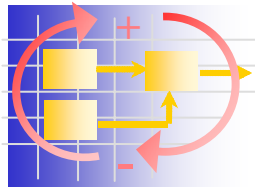


Risk Sector Plot (NASA Example)

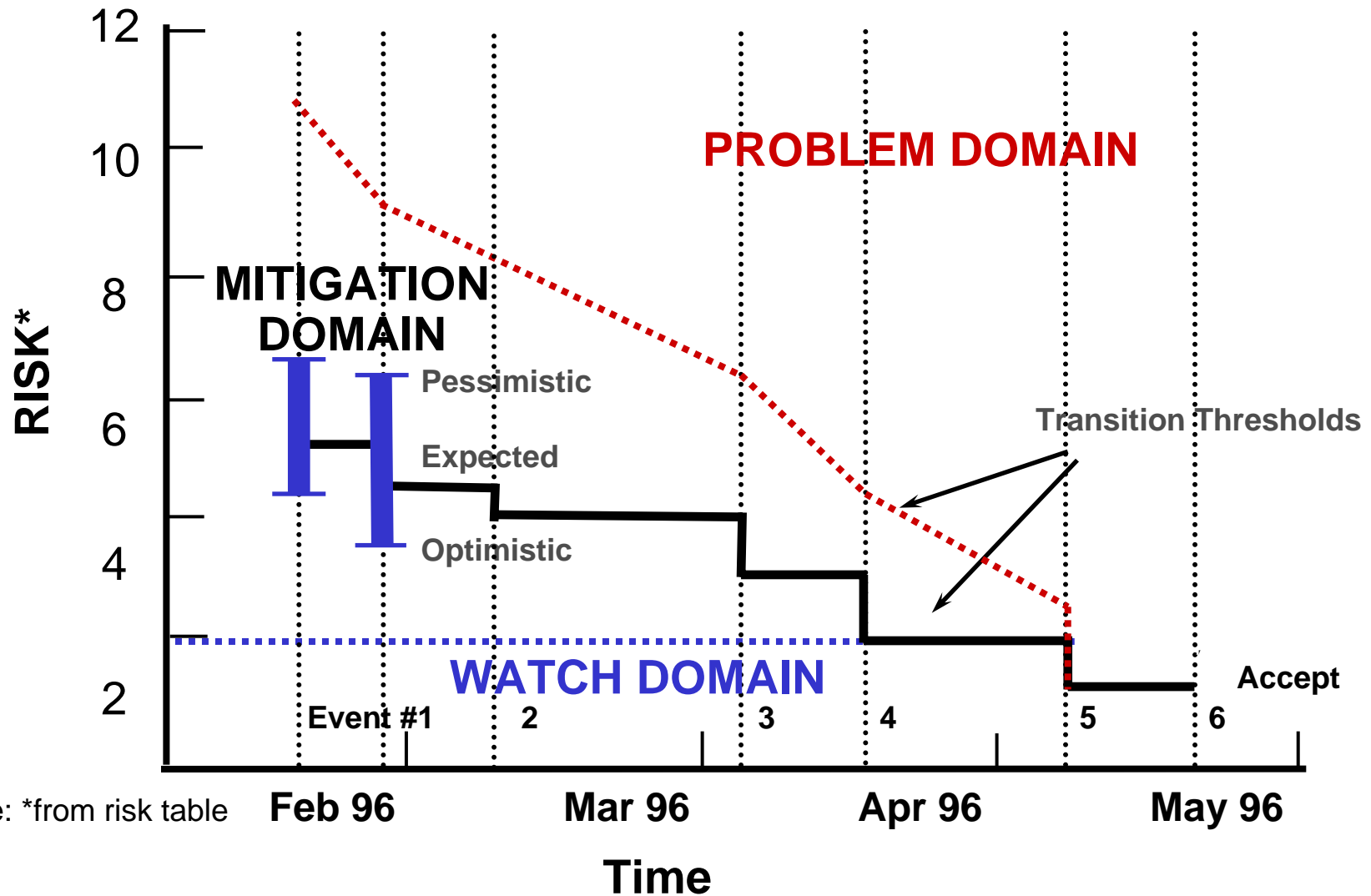
Attribute: Probability		
Level	Value	Criteria
5	Near certainty	Everything points to this becoming a problem, always has
4	Very likely	High chance of this becoming a problem
3	Likely (50/50)	There is an even chance this may turn into a problem
2	Unlikely	Risk like this may turn into a problem once in awhile
1	Improbable	Not much chance this will become problem



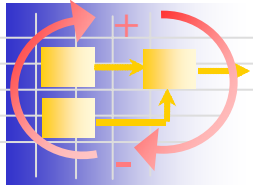
Attribute: Impact				
Level	Value	Technical Criteria	Cost Criteria	Schedule Criteria
5	Catastrophic	Can't control the vehicle OR Can't perform the mission	> \$10 Million	Slip to level I milestones
4	Critical	Loss of mission, but asset recoverable in time	$\$ 10 \text{ M} \leq X < \$ 5 \text{ Million}$	Slip to level II milestones
3	Moderate	Mission degraded below nominal specified	$\$ 5 \text{ M} \leq X < \$ 1 \text{ Million}$	Slip to level III milestones
2	Marginal	Mission performance margins reduced	$\$ 1 \text{ M} \leq X < \$ 100 \text{ K}$	Loss of more than one month schedule margin
1	Negligible	Minimum to no impact	Minimum to no impact	Minimum to no impact



Threshold Risk Metric (NASA)

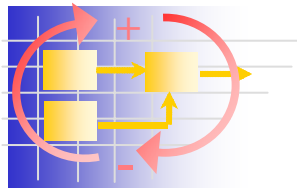


Note: *from risk table

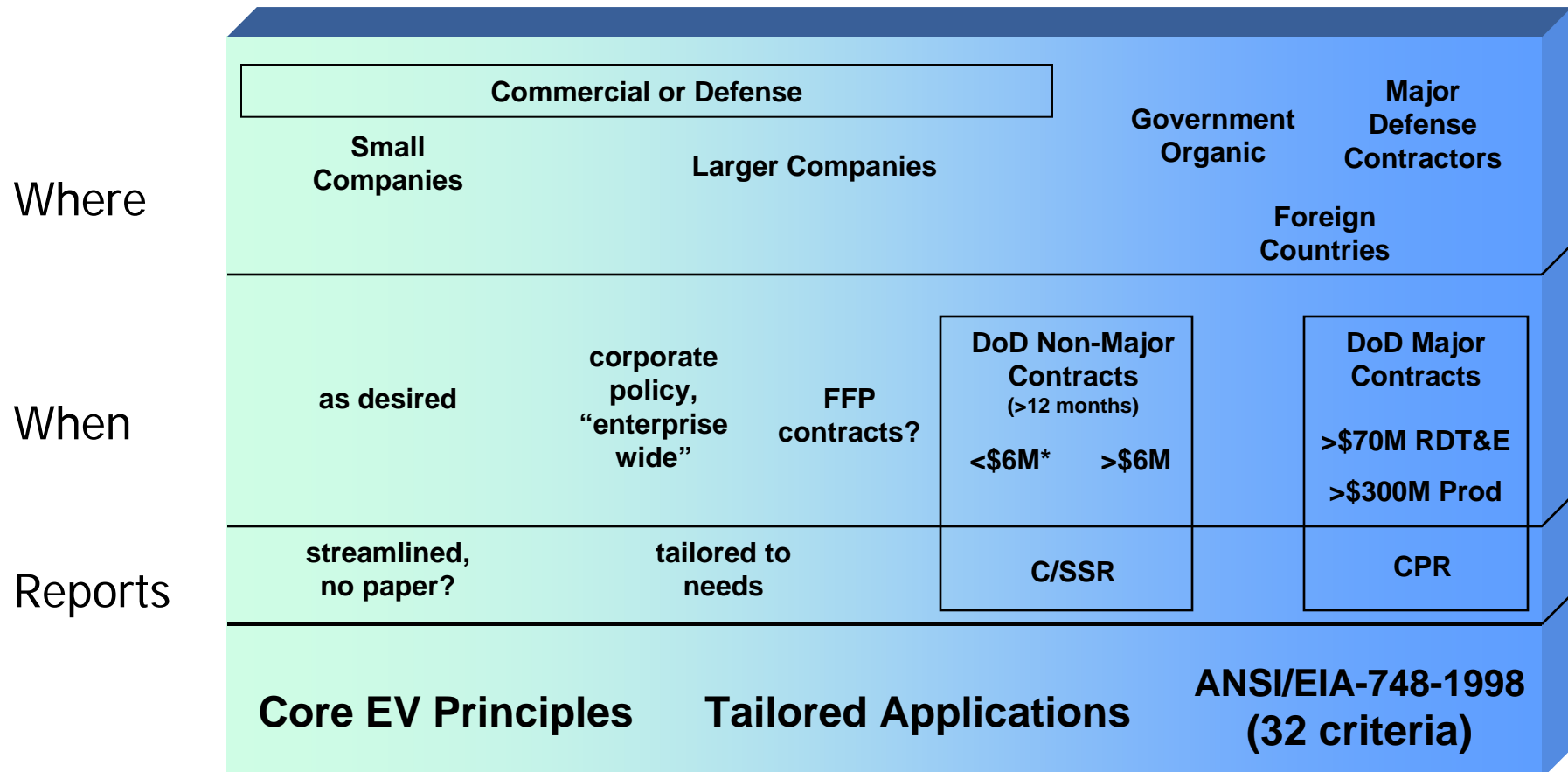


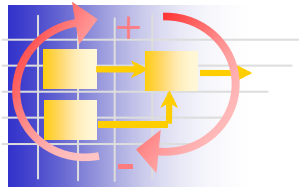
Earned Value Management

- Initially developed in industry (1970s)
- DOD adopted as CSSR, imposed on major contracts
- Has converged into current Earned Value Management System (EVMS) in both commercial and DOD use
 - ANSI/EIA-748-1998, Earned Value Management Systems
 - 32 project criteria
- If based on reasonable plan, excellent source of risk identification and project control metrics



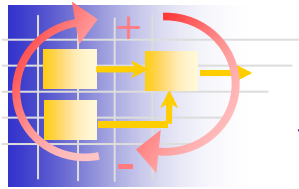
Implementation Spectrum





5 Key Elements

BCWS	Budgeted Cost of Work Scheduled
BCWP	Budgeted Cost of Work Performed
ACWP	Actual Cost of Work Performed
BAC	Budget at Completion
EAC	Estimate at Completion



Schedule Variance

BUDGET BASED

BC WS

of the work I scheduled to have done,
how much did I budget for it to cost?

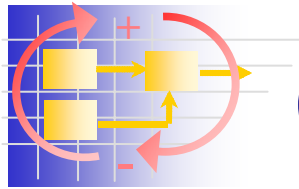
BC WP

of the work I actually performed,
how much did I budget for it to cost?

SCHEDULE VARIANCE is the difference between work scheduled and work performed (expressed in terms of budget dollars)

formula: $SV \$ = BCWP - BCWS$

example: $SV = BCWP - BCWS = \$1,000 - \$2,000$
 $SV = -\$1,000$ (negative = behind schedule)



Cost Variance

BC	WP
AC	WP

PERFORMANCE BASED

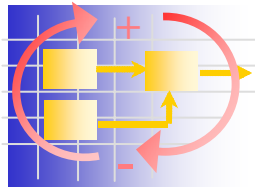
of the work I actually performed,
how much did I budget for it to cost?

of the work I actually performed,
how much did it actually cost?

COST VARIANCE is the difference between budgeted cost and actual cost

formula: $CV \$ = BCWP - ACWP$

example: $CV = BCWP - ACWP = \$1,000 - \$2,400$
 $CV = -\$1,400$ (negative = cost overrun)



Variance at Completion (VAC)

BAC

what the **total** job is supposed
to cost

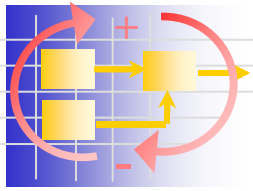
EAC

what the **total** job is expected
to cost

VARIANCE AT COMPLETION is the difference between what the total job is supposed to cost and what the total job is now expected to cost.

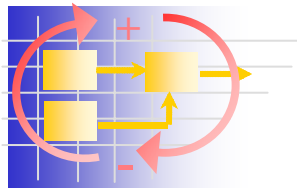
FORMULA: $VAC = BAC - EAC$

Example: $VAC = \$5,000 - \$7,500$
 $VAC = - \$2,500$ (negative = overrun)

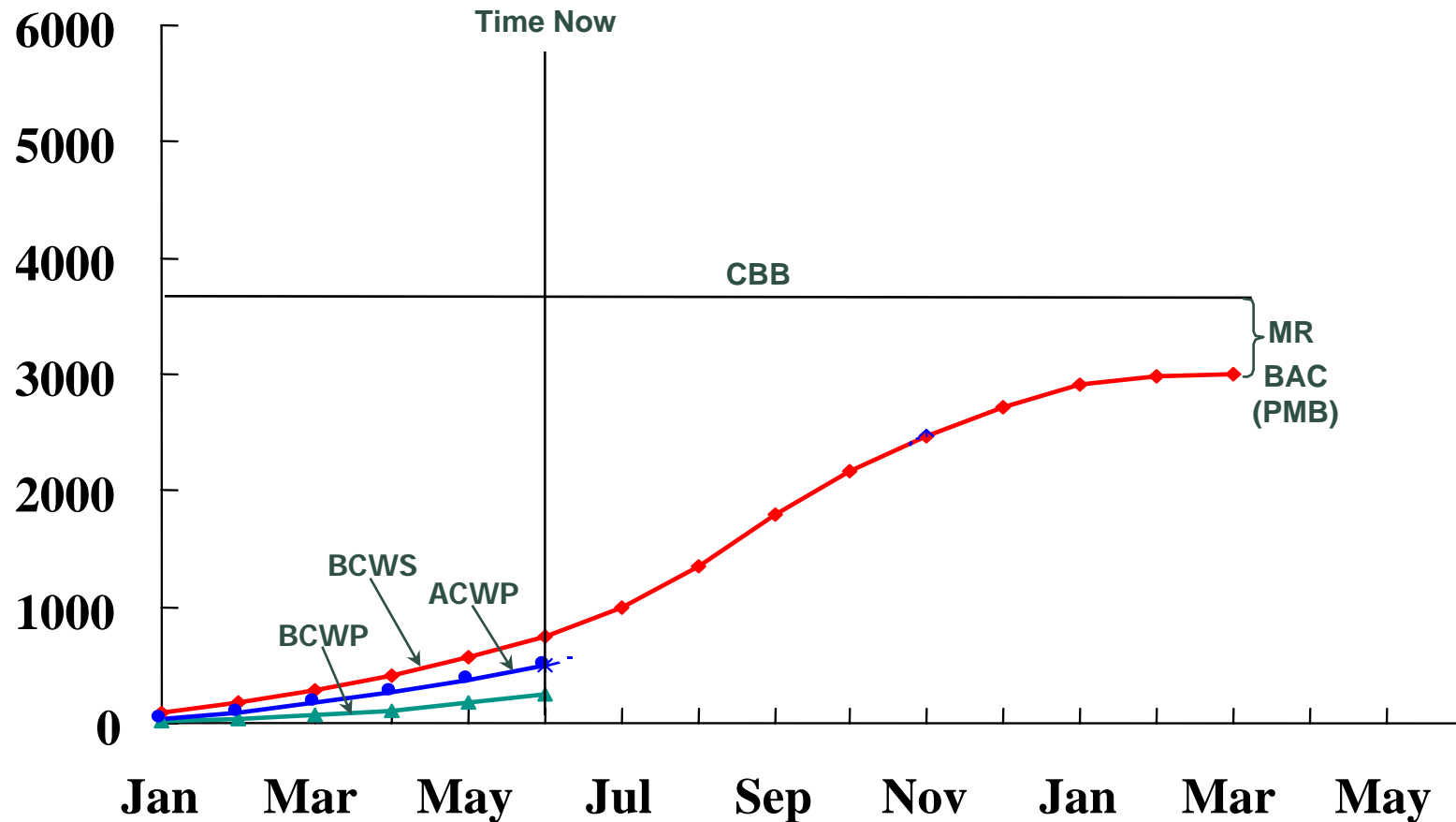


5 Basic Questions/Parameters

QUESTION	ANSWER	ACRONYM
How much work <u>should</u> be done?	Budgeted Cost for Work Scheduled	BCWS
How much work <u>is</u> done?	Budgeted Cost for Work Performed	BCWP
How much did the <u>is done</u> work cost?	Actual Cost of Work Performed	ACWP
What was the total job <u>supposed</u> to cost?	Budget at Completion	BAC
What do we <u>now expect</u> the total job to cost?	Estimate at Completion	EAC

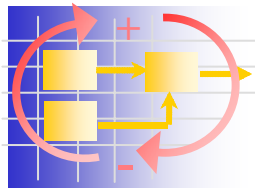


Earned Value Data Elements

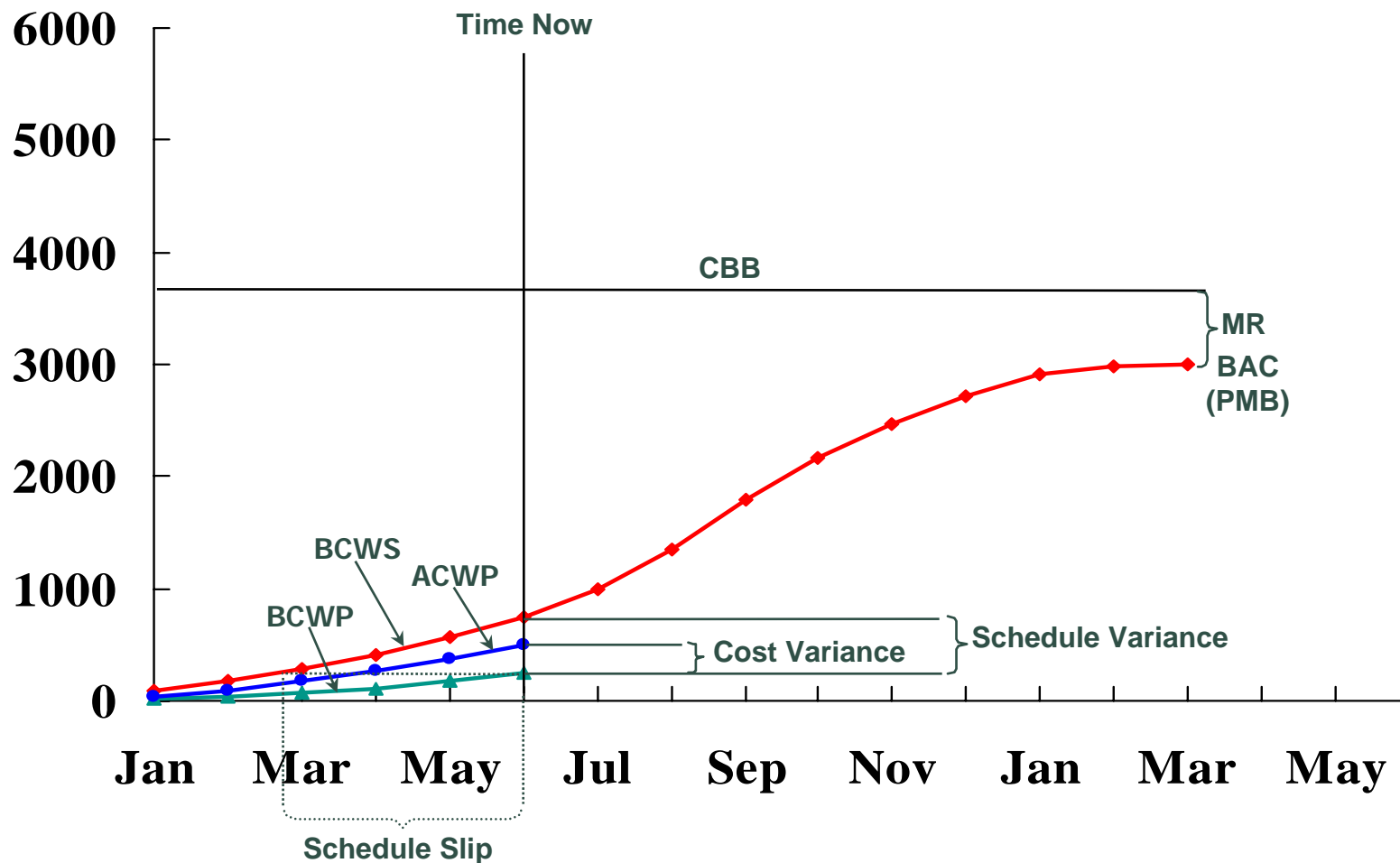


Source: MCG www.acq.osd.mil/pm

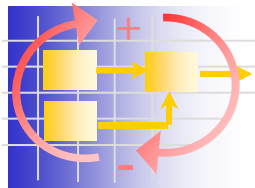
Nov 4 2003- ESD.36J SPM



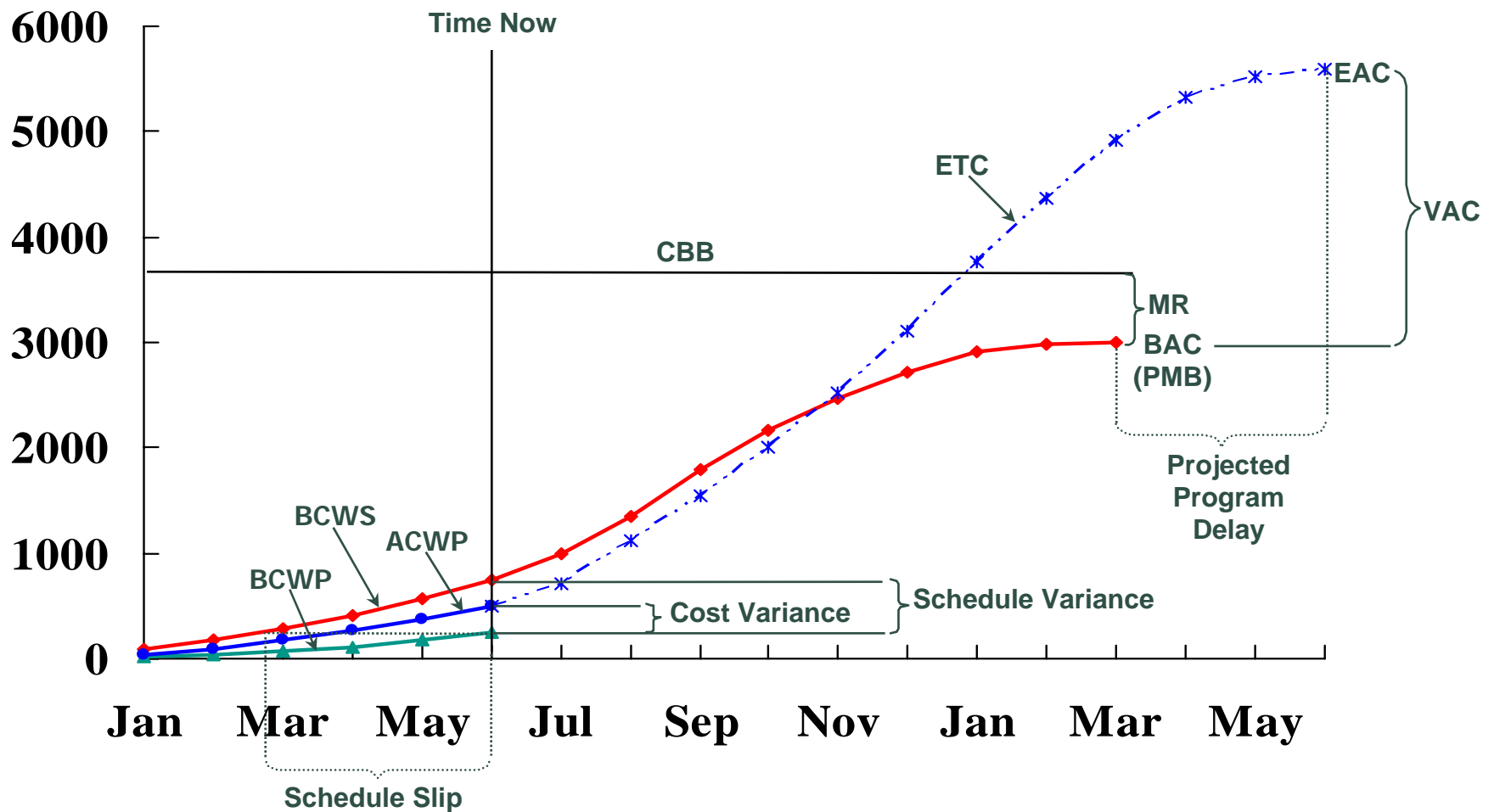
EV Data Elements- Variances



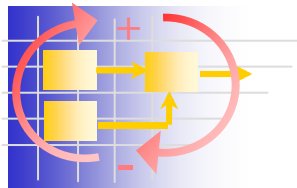
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EV Data Elements- Projections



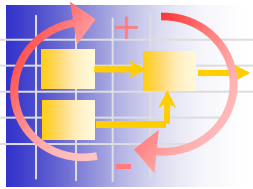
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Data Analysis Relationships

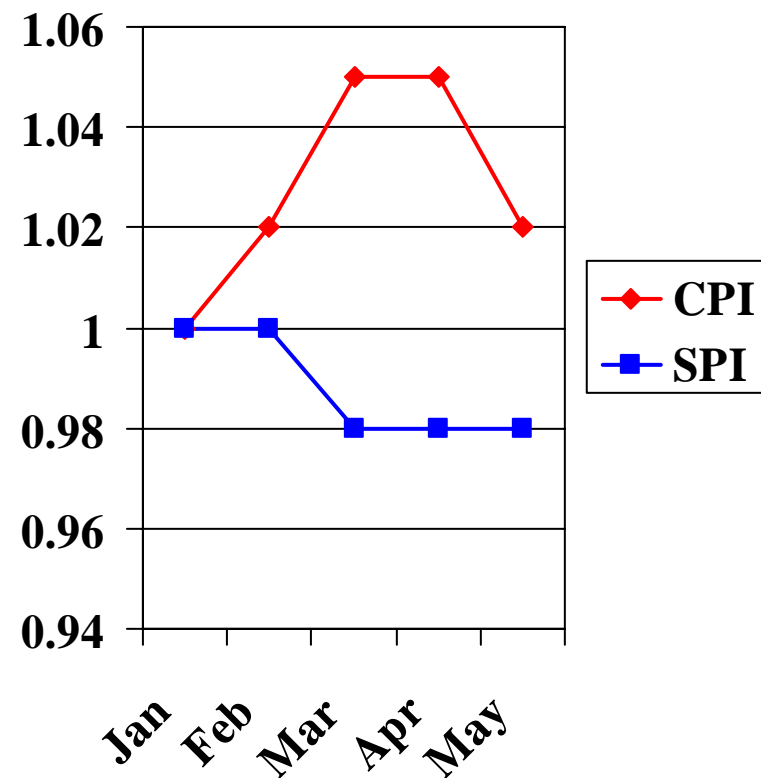
Term	Symbol	Formula	Checklist Actions
Percent Complete	% Done	$\frac{BCWP}{BAC}$	Ratio of work accomplished in terms of the total amount of work to do.
Cost Performance Index or Performance Factor	CPI or PF	$\frac{BCWP}{ACWP}$	Ratio of work accomplished against money spent (Efficiency Rating: Work Done for Resources Expended)
To Complete Performance Index or Verification Factor	TCPI or VF	$\frac{BAC - BCWP}{EAC - ACWP}$	Ratio of work remaining against money remaining (Efficiency which must be achieved to complete the remaining work with the expected remaining money)
Schedule Performance Index	SPI	$\frac{BCWP}{BCWS}$	Ratio of work accomplished against what should have been done (Efficiency Rating: Work done as compared to what should have been done)
Estimate At Completion	EAC	ETC + ACWP	Calculation of the estimate to complete plus the money spent
Estimate To Complete	ETC	$\frac{BAC - BCWP}{CPI}$	Calculation of the budgeted work remaining against the performance factor

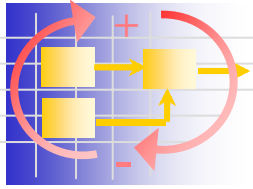
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Risk Indicators

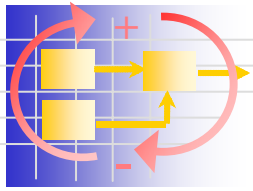
- EVM provides several metrics that can “flag” potential problems (risks) either as trends or thresholds.
- CPI: Good = ≥ 1.0
- SPI: Good = ≥ 1.0





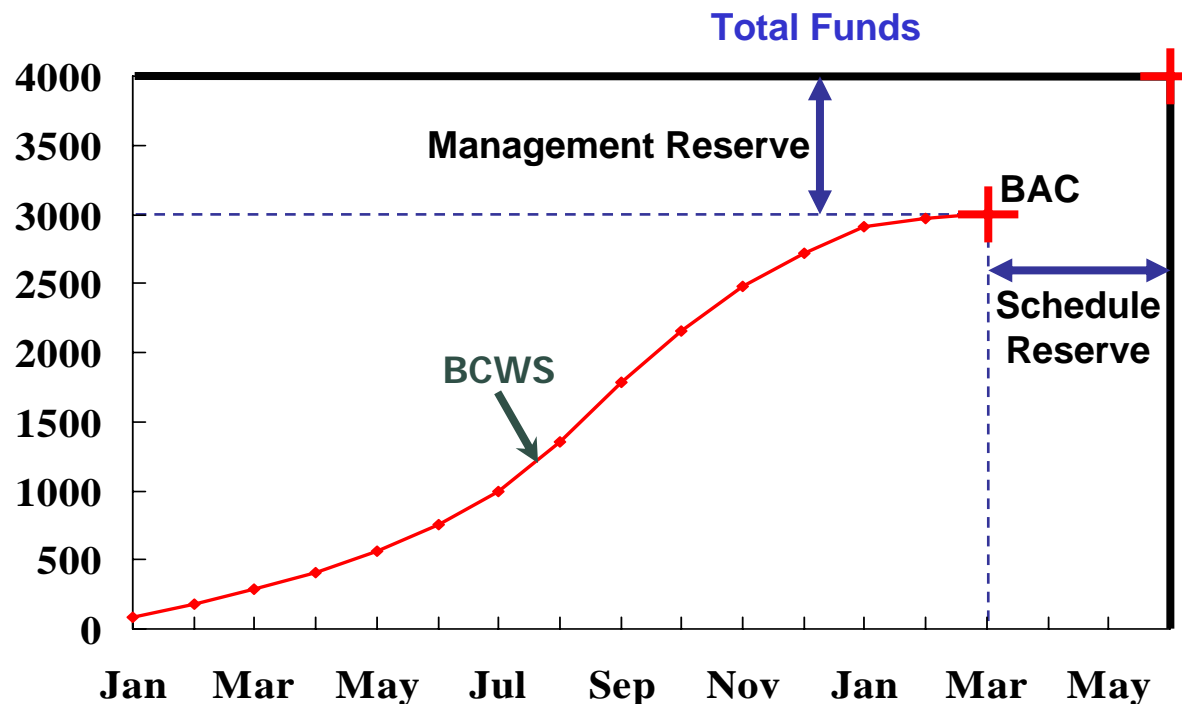
Planning 'Granularity'

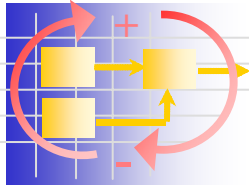
- To use EVMS with a reasonable amount of management resources, plan at the appropriate level of detail
- Avoid '% complete' estimation
- Plan work packages with short duration, estimated package cost, and clear deliverable
- Assign 'earned value' at discrete levels, e.g.:
 - Zero value until work package start
 - 50% value while executing
 - Full value when deliverable is complete



Management Reserve

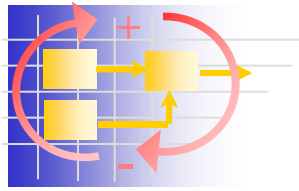
- Calculate total project management reserve required based on
 - statistical modeling
 - past experience





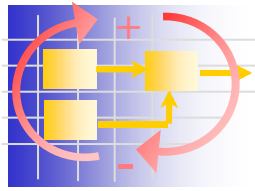
Project Control & Leverage

- Management reserve (cost and schedule) are important project management tools
 - Amounts based on statistical analyses, past experiences
 - Reserves should be planned and validated with the overall project plan
- The project manager owns management reserve and unallocated budget/schedule
 - Release of Management Reserve should be part of a formal, risk-driven process
 - Requests for reserve allocation should follow a quantitative template



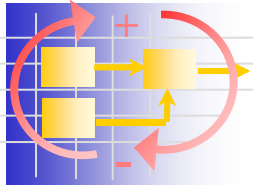
Metrics

- Source
- Formulation
- Use
- Approaches, problems



Source of Metrics

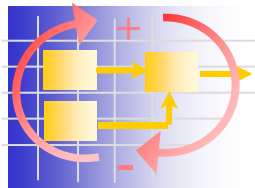
- Useful Goal = Metrics + Target Value
- Flow from goals - what the product's intent, what it does (process), what it is (form)
- Distinguished based on level of importance.
 - Live or die, vital, system success dependent (0.1)
 - Very important (0.2)
 - Desirements (0.3)
 - Nice to have (0.4), etc.
- Focus on one or two highest level



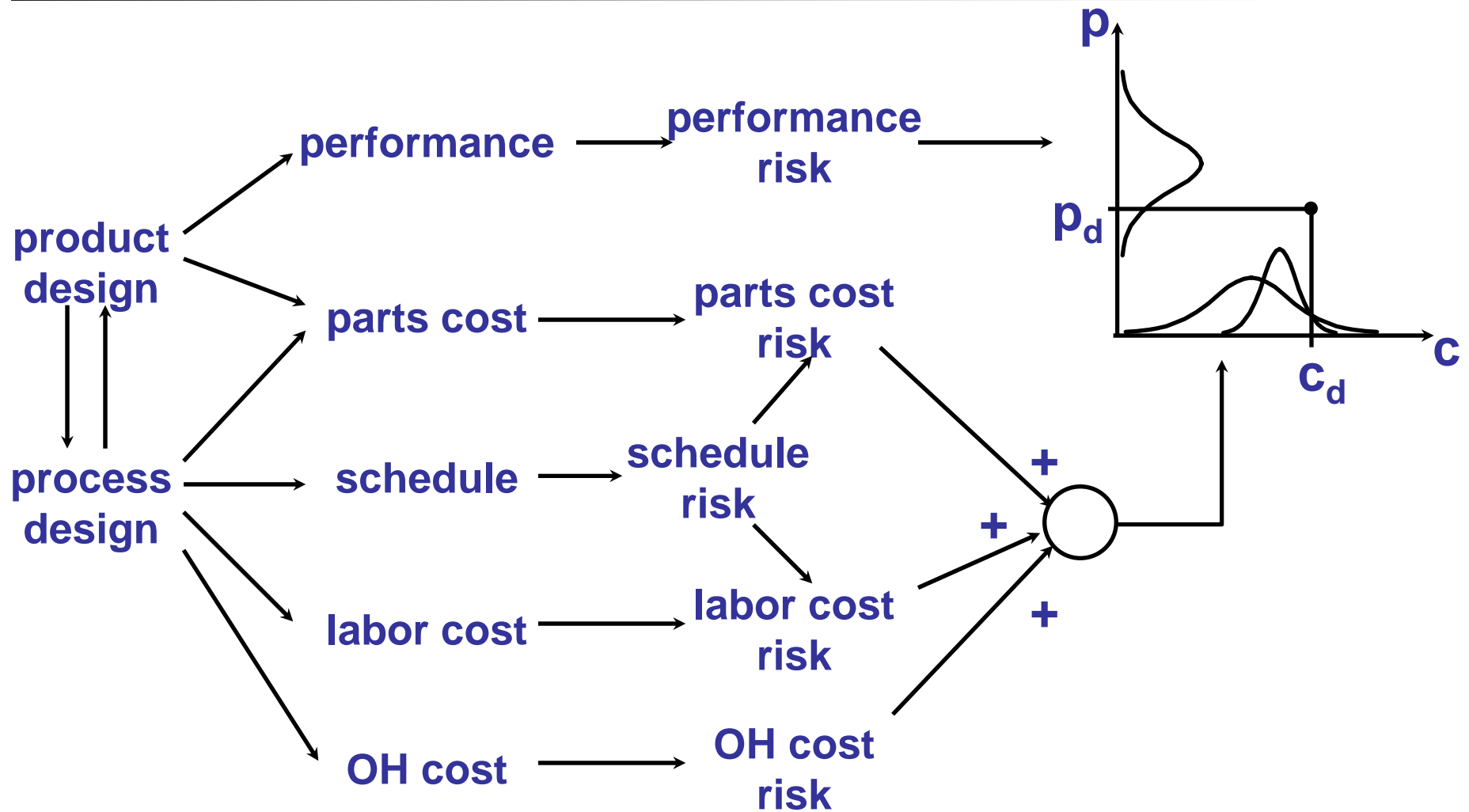
Formulation of Metrics

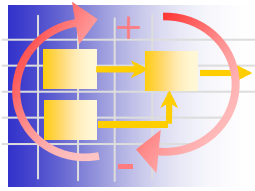
- May be marginal, absolute, probabilistic
 - = X% improvement in _____
 - = X value of _____
 - = X value of _____ with 90% confidence
- Tradition is metric based on benefit/performance (with cost*, schedule and risk assessed later)
- Current practice is metric based on benefit/performance and cost (with schedule and risk assessed later)
- “Ideal” would be metrics which include benefit/performance, schedule, cost and risk

* **cost can include liens on resources in addition to \$**



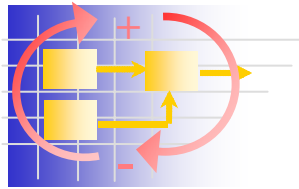
Notional "Ideal" Metric



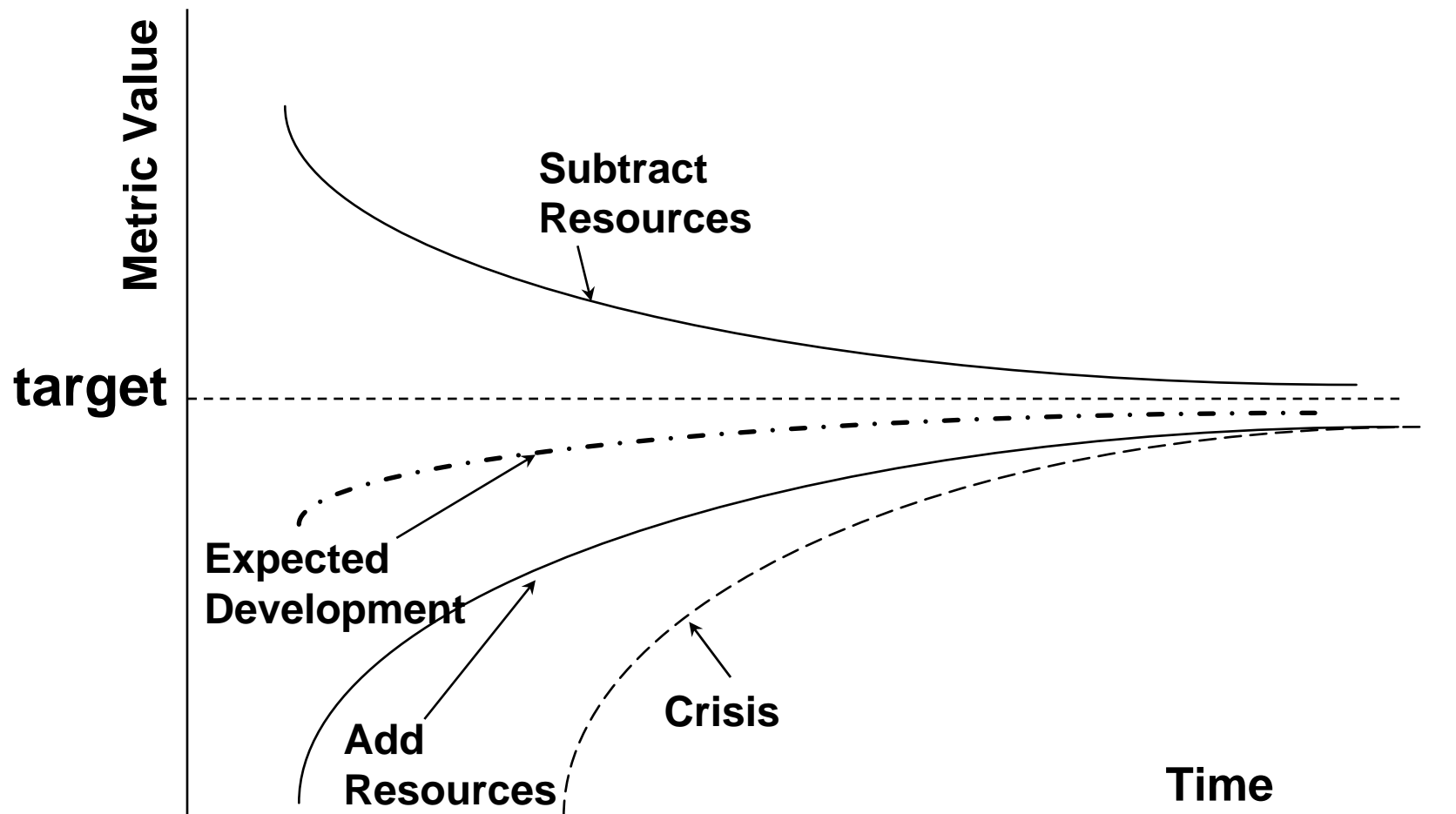


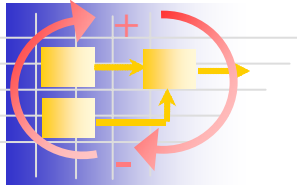
Use of Metrics

- System architecture
 - Selection of architecture usually done by quantitative comparison of metric - very sensitive to choice
- System Engineering - Tracking
 - High level metrics can and should be tracked during development
 - Progress towards target should have milestones
 - Discrepancies can be the basis of decisions (add resources, subtract resources, flag for “tiger team”)



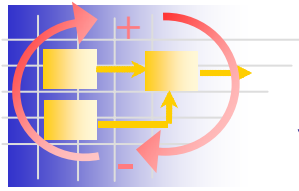
Metric Tracking





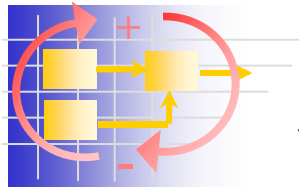
Problems with Metrics

- Identifying real and appropriate metrics is often one of the most difficult parts of engineering system design
 - customer often does not vocalize real metric
 - often have several metrics (must treat independently or combine)
- Metrics don't necessarily add linearly
 - mass does, cost doesn't (can push cost to another element easily)
 - hard to flow metrics down



Summary - Metrics

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