SOME TOOLS FOR USE IN PROGRAM/PROJECT MANAGEMENT AND SYSTEMS ENGINEERING INTEGRATION

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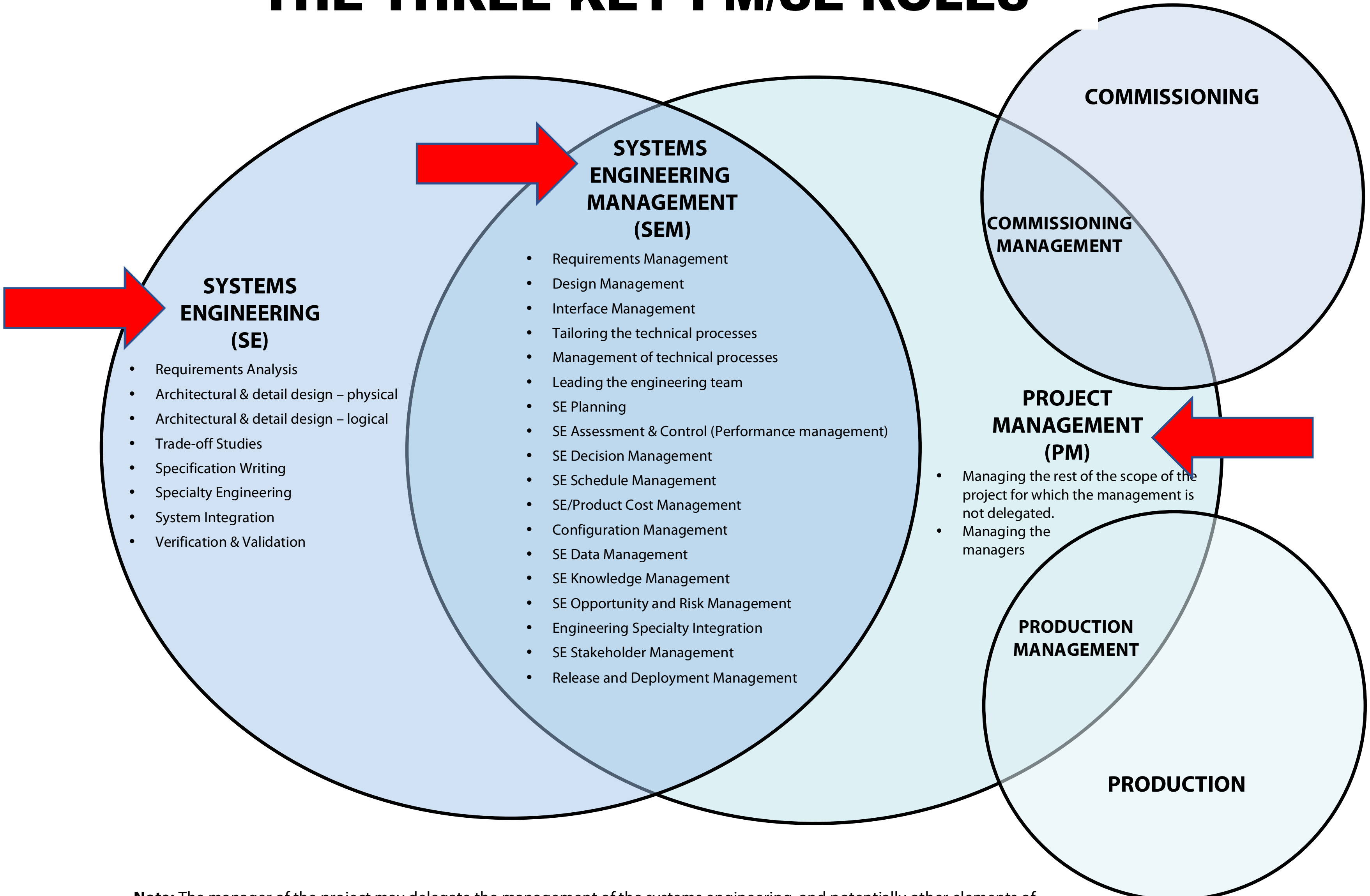
THE THREE KEY PM/SE ROLES



Note: The manager of the project may delegate the management of the systems engineering, and potentially other elements of project scope, e.g., production, commissioning, contract.

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THE THREE KEY PM/SE ROLES MUST ALL BE CONVINCED OF THE VALUE OF SYSTEMS ENGINEERING!

SEI/AESS/NDIA 2012 STUDY RESULTS

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Driver	Relationship to Performance (Gamma)		
	All Projects	Lower challenge	Higher challenge
SEC-Total – total deployed SE	+0.49	+0.34	+0.62
SEC-PP – project planning	+0.46	+0.16	+0.65
SEC-REQ – reqts. developt. & mgmt.	+0.44	+0.36	+0.50
SEC-VER – verification	+0.43	+0.27	+0.60
SEC-ARCH – product architecture	+0.41	+0.31	+0.49
SEC-CM – configuration management	+0.38	+0.22	+0.53
SEC-TRD – trade studies	+0.38	+0.29	+0.43
SEC-PMC – project monitor & control	+0.38	+0.27	+0.53
SEC-VAL – validation	+0.33	+0.23	+0.48
SEC-PI – product integration	+0.33	+0.23	+0.42
SEC-RSKM – risk management	+0.21	+0.18	+0.24
SEC-IPT – integrated product teams	+0.18	-0.12	+0.40

Gamma	Relationship
-0.2 <| *Gamma* | ≤ 0	Weak negative
0 ≤ | *Gamma* | < 0.2	Weak positive
0.2 ≤ | *Gamma* | < 0.3	Moderate
0.3 ≤ | *Gamma* | < 0.4	Strong
0.4 ≤ | *Gamma* |	Very strong

http://resources.sei.cmu.edu/asset_files/specialreport/2012_003_001_34067.pdf

Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

SEI/AESS/NDIA 2012 STUDY RESULTS

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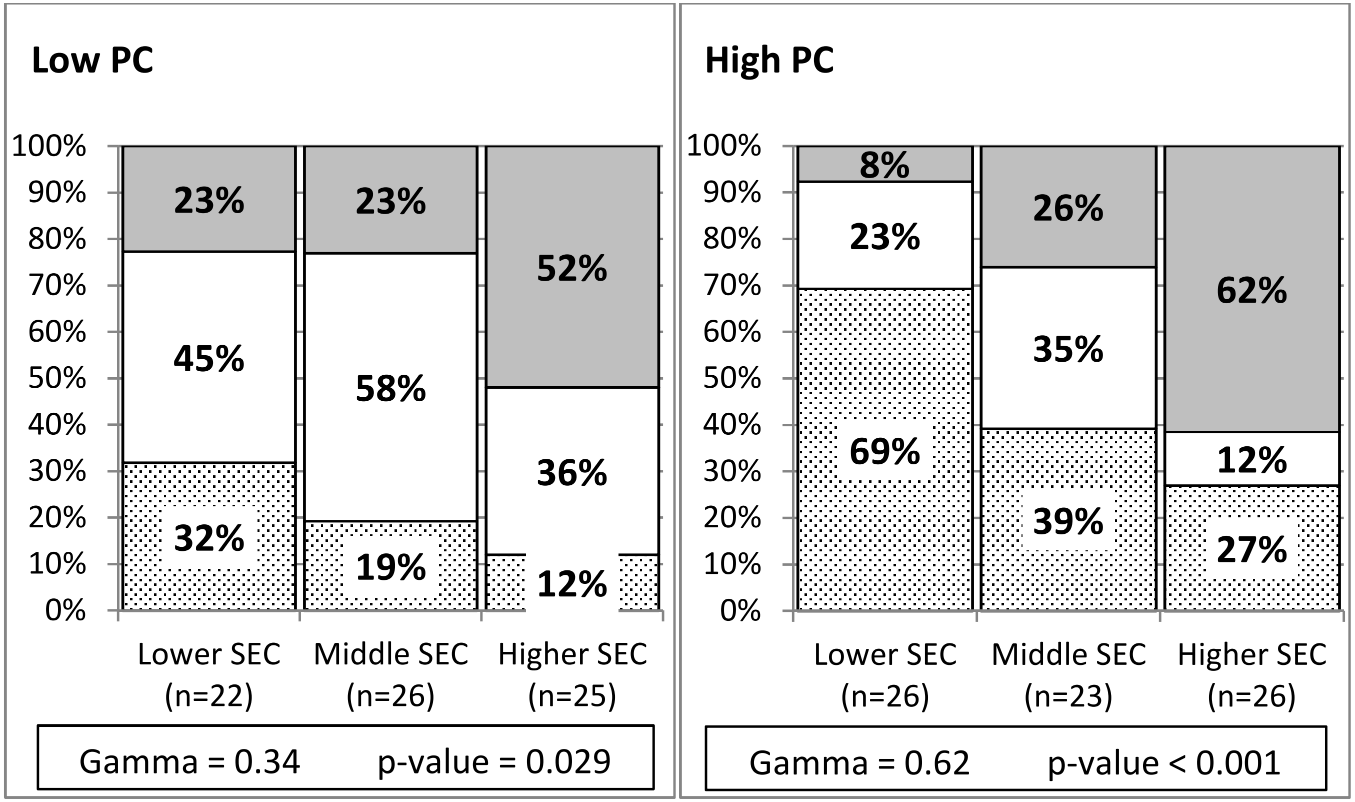

Legend: PC Project Challenge

Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

PMs ARE (OR SHOULD BE) SEs

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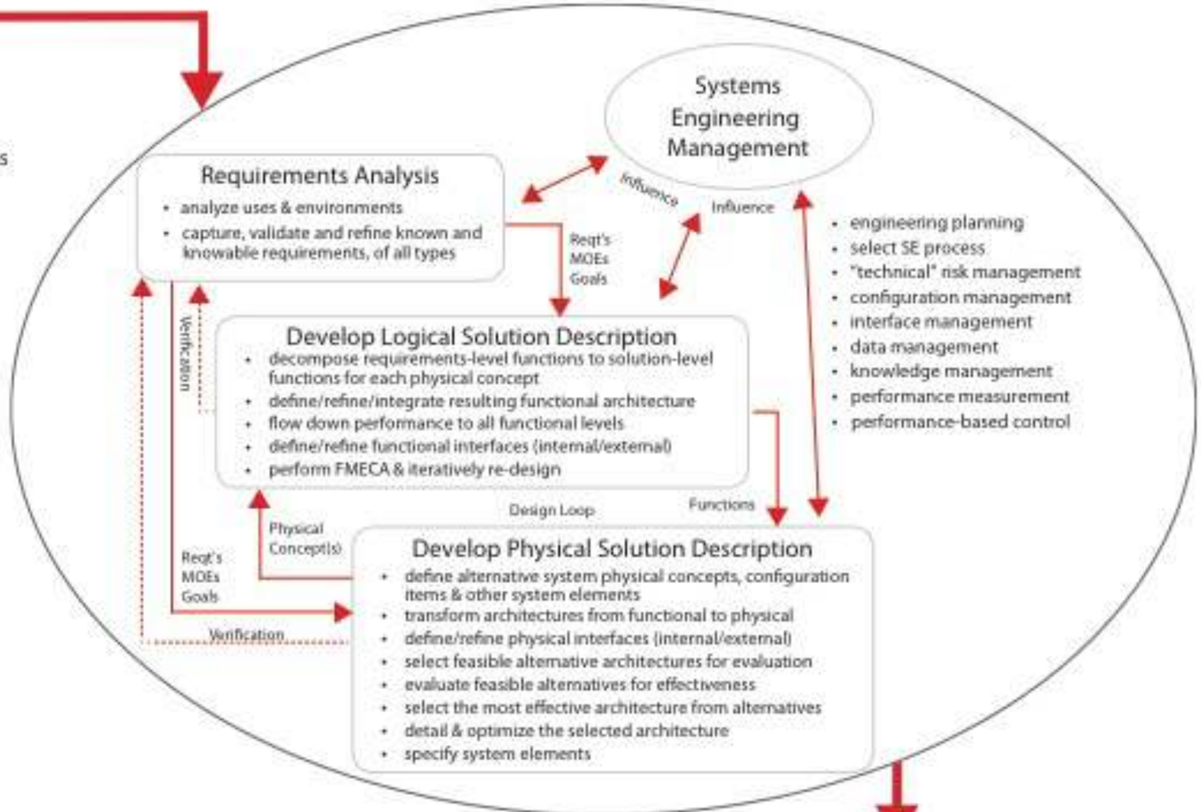
PROCESS INPUT

- problem domain info
  - user/customer/other stakeholder needs/ desires/wants/goals/ requirements/expectations
  - uses/missions
  - measures of effectiveness
  - value information
  - environments
  - other constraints
- technology base
- concurrent engineering – related inputs



PROCESS OUTPUT

- **identification & specification of each system element, including build instructions**
- requirements traceability information
- system & system element verification requirements
- design traceability information (decision data base)
  - system functional & physical architecture and detail descriptions
  - design decision support data
  - design decision rationale data
- concurrent engineering-related outputs
- prototypes, where applicable

Note 1: The Systems Engineering Process is applied repeatedly to each design object, starting at, for example, the Capability, Mission or Use System, then to, for example, the Prime Mission or Use Product, Maintenance System, Production System, Operational Infrastructure, etc., then to subsystems of these systems.

Note 2: Also, where applicable, validate data products (not shown diagramatically).

Note 3: The process also performs the integration of the system elements to build the system for the first time (system integration).

Note 4: The process also includes the conduct of verification of the produced system against the requirements for that system, thereby verifying both the system, and the design of the system.

Note 5: The process also includes the conduct of validation of the produced system against the need.

A Systems Engineering Process View

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SOME TOOLS TOWARDS PM/SE INTEGRATION

- Project/Work Breakdown Structure (PBS/WBS)
- Use of Integrated Product Teams with Vertical Integtation
- Give Engineers Responsibility, Authority and Accountability For Cost And Schedule
- Build, Communicate and Use a Project Effectiveness Model
- Technical Performance Measurement

BUILD, COMMUNICATE AND USE A PROJECT/WORK BREAKDOWN STRUCTURE (PBS/WBS)

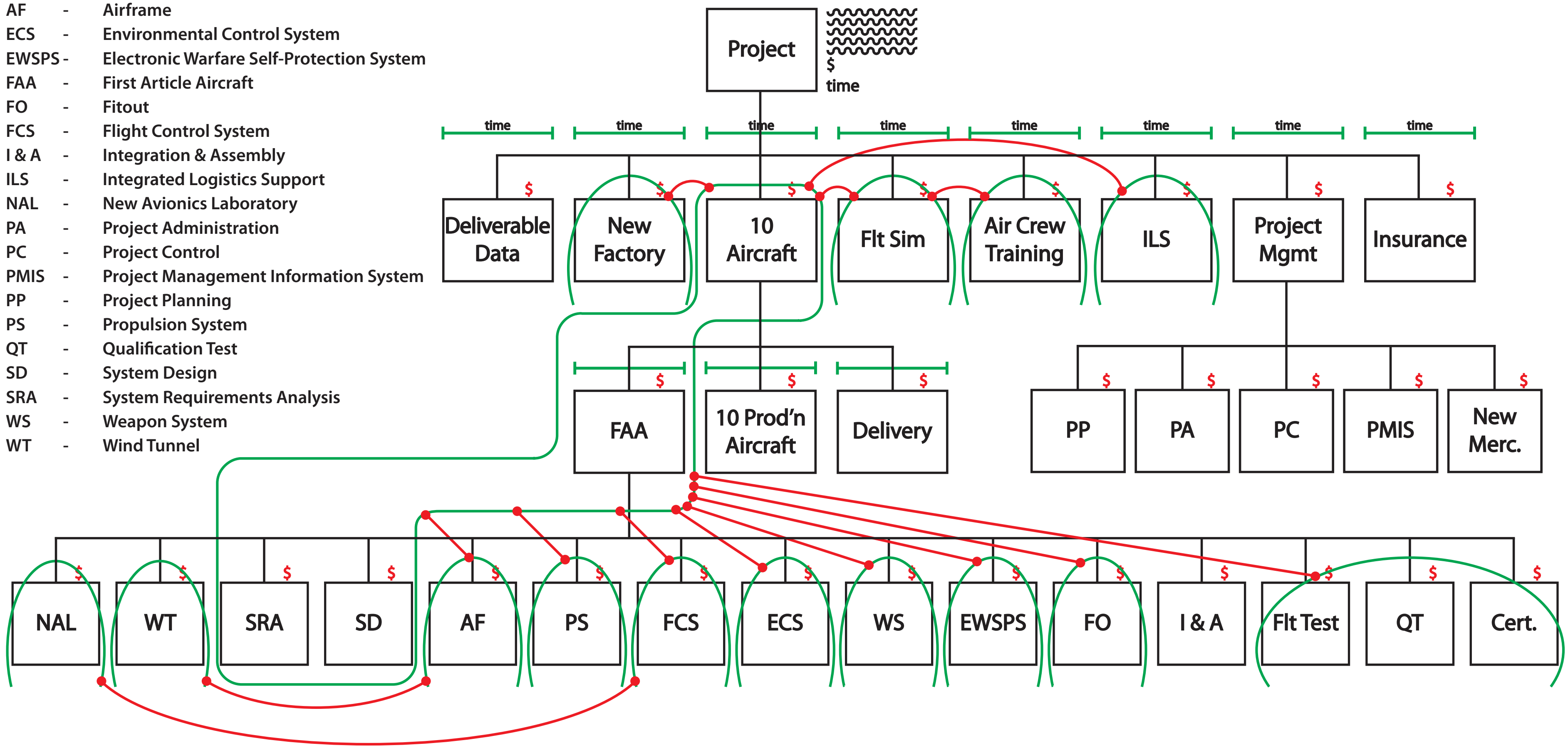
Project (Work) Breakdown Structure (PBS/WBS)

as a Framework for Project Definition, Costing, Scheduling, Risk Analysis, Measurement, Reporting and Organizational Design

Legend:

- (green line) Boundary of scope of an Integrated Product Team
- (red arc) Cross-team membership
- (green bar) Schedule: start and finish

AF	-	Airframe
ECS	-	Environmental Control System
EWSPS	-	Electronic Warfare Self-Protection System
FAA	-	First Article Aircraft
FO	-	Fitout
FCS	-	Flight Control System
I & A	-	Integration & Assembly
ILS	-	Integrated Logistics Support
NAL	-	New Avionics Laboratory
PA	-	Project Administration
PC	-	Project Control
PMIS	-	Project Management Information System
PP	-	Project Planning
PS	-	Propulsion System
QT	-	Qualification Test
SD	-	System Design
SRA	-	System Requirements Analysis
WS	-	Weapon System
WT	-	Wind Tunnel



Systems engineering activities populate the WBS below level 2, or if there is only one deliverable of the project, at level 2 and below.

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HOW A PBS/WBS FOSTERS PM/SE INTEGRATION:

A well-constructed PBS/WBS provides a framework for:

- focus towards project outcomes in all work conducted, all money spent, from bottom to top
- project management/engineering management/engineering integration through a PBS/WBS-influenced team of teams structure, with the project manager a member of the team responsible for each major project deliverable
- specifying, measuring and controlling the quality, cost and schedule attributes of the intermediate products and work tasks from which the project deliverables are to be realized
- estimating, accumulating to the level of project outcomes, tracking over time and reporting project risk and its origins.

DEVELOPMENT LOGIC FOR A PROJECT WITH TWO OR MORE DELIVERABLES

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The level 1 element is the project.

To define level 2 elements:

1. What products (physical/software/data) are required to be delivered by the project?
2. What services are required to be delivered by the project?
3. What services are necessary, internal to the project, to deliver the project outputs and outcomes, that are not needed uniquely to create (for physical/software/data product) or deliver (for a service) just a single element from questions 1 and 2?

One answer to this last question is always "Project Management"

4. What products, if any, internal to the project, that involve project cost or other resources in their realization, are necessary to deliver the project outputs and outcomes, that are not needed uniquely to create (for a physical/software/data product) or deliver (for a service) just a single element from questions 1, 2 and 3?

To define sub-elements below level 2, the questions for a product element are:

5-1. What products are to be integrated to create this product element?

5-2. In addition to the products from question 5-1, what services are to be performed to create this product element, that are not needed uniquely to create just a single sub-element from question 5-1?

5-3. In addition to the products and services from questions 5-1 and 5-2 respectively, what products are necessary, that involve project cost or other resources in their realization, to create this product element, that are not needed uniquely to create (for physical/software/data product) or perform (for a service) just a single sub-element from questions 5-1 and 5-2 respectively?

To define sub-elements below level 2, the questions for a service element are:

6-1. What services are to be integrated to perform this service element?

6-2. In addition to the services from question 6-1, what products are necessary to perform this service element, that involve project cost or other resources in their realization, and that are not needed uniquely to perform just a single service sub-element from question 6-1?

USE INTEGRATED PRODUCT TEAMS AS MAJOR PROJECT BUILDING BLOCKS, WITH PROJECT MANAGEMENT PARTICIPATION IN THE LEAD IPTs FOR MAJOR PROJECT DELIVERABLES.

MATCH KNOWLEDGE, SKILLS AND ATTITUDES TO ROLES.

PBS/WBS AND INTEGRATED PRODUCT TEAMS (IPTS) RELATED

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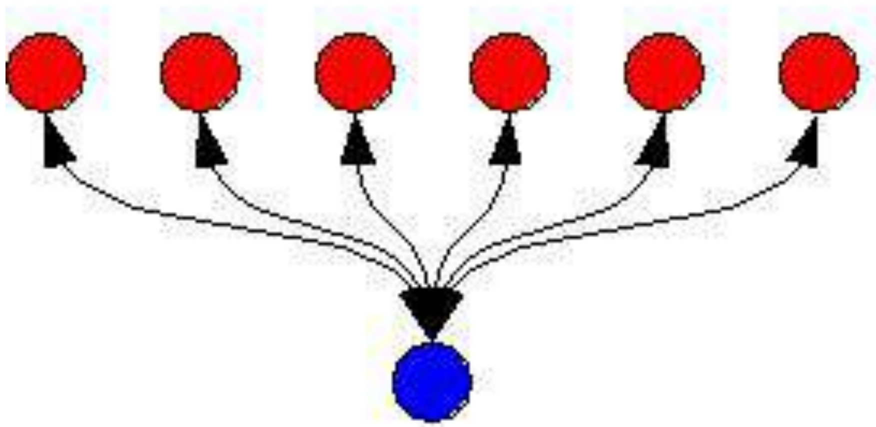
- An Integrated Product Team (IPT) is a multi-disciplinary team tasked and empowered to take a product from requirements to delivery. It has stakeholder participation, and works on a consensus basis of decision-making.

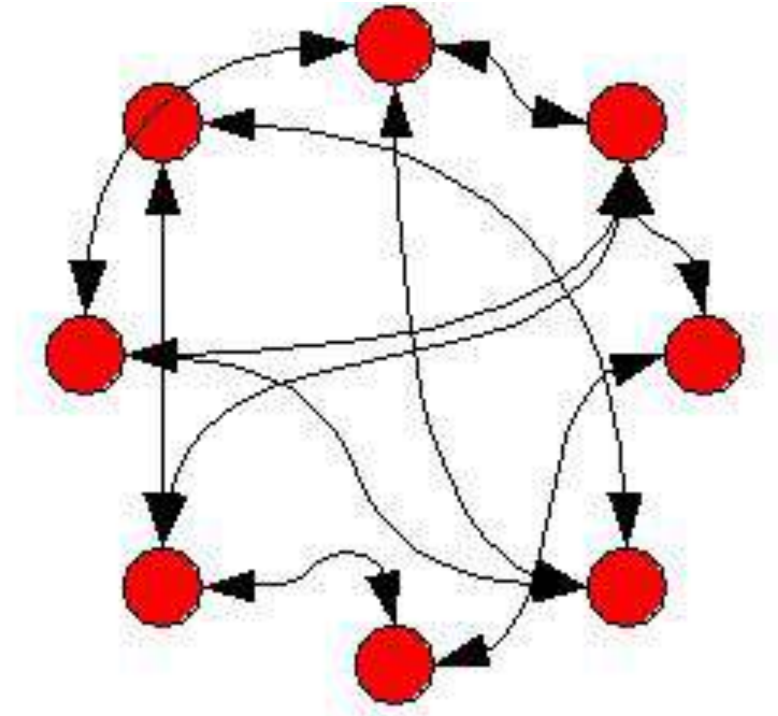
- Integrated Product Team (IPT) structure and PBS/WBS should be closely related, down to the level(s) below which IPTs are not beneficial.

A GROUP VERSUS A TEAM



GROUP

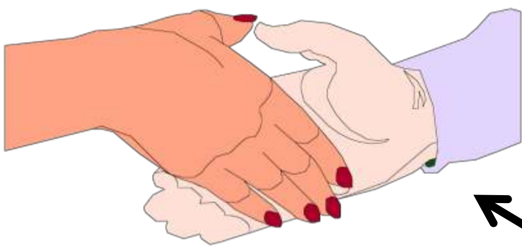
people working towards a goal whose work is coordinated by someone else (e.g. a manager) for them



TEAM

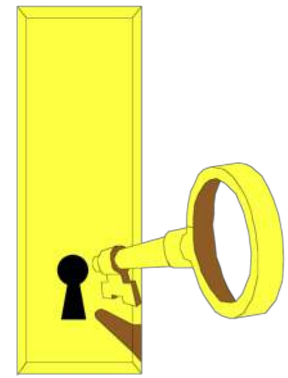
people working towards a common goal who coordinate their work amongst themselves

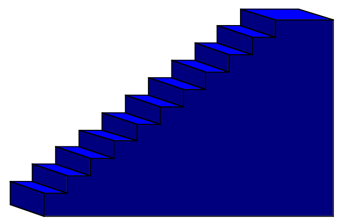
KSF - CREATE AN ENVIRONMENT THAT DEVELOPS:



Trust

Empowerment

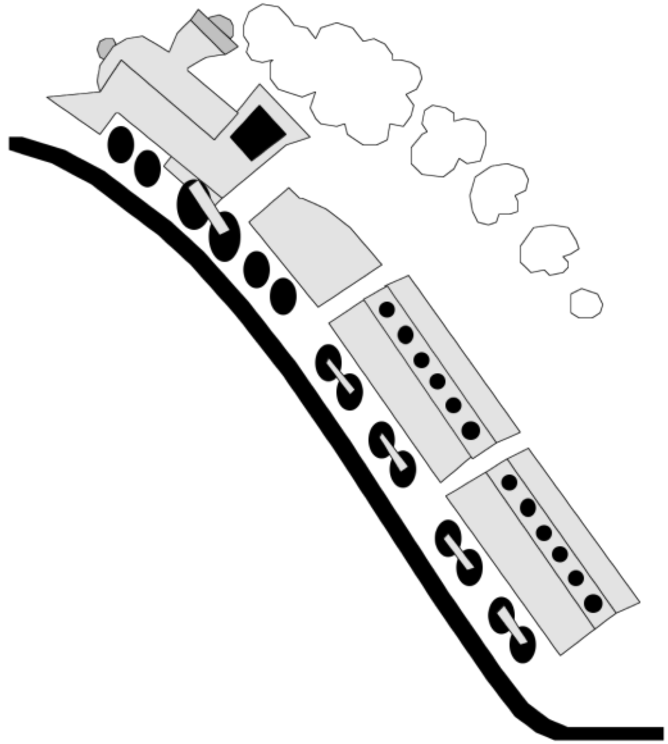




Open Communication

Dedication

KSF - GROW LEADERS FROM TOP TO BOTTOM OF THE ORGANIZATION



Team leadership: the ability of the team leader to inspire, motivate and develop the team and its members. The team leader is the lead coach and the team members' greatest supporter.

KSF – SHARED VISION

Shared Vision: the commitment in words and action of the stakeholders, team leader and other team members to an explicitly stated common goal.

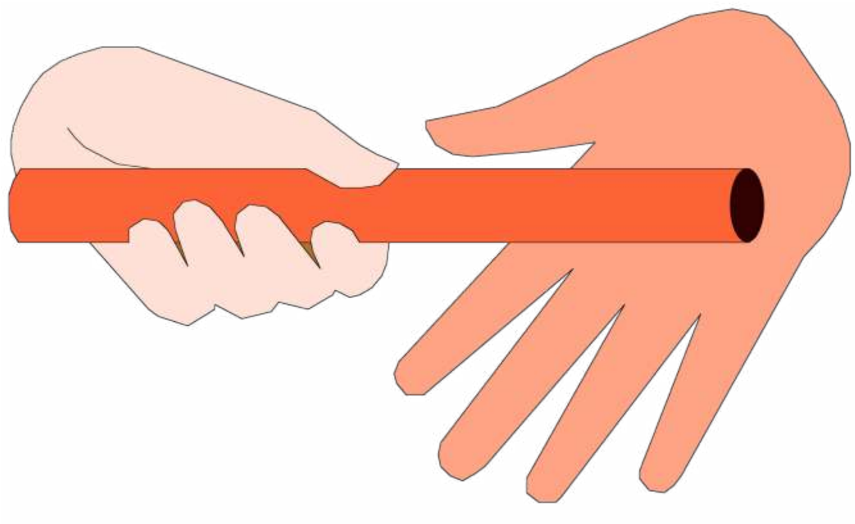
KSF – COMMITMENT TO THE APPROACH

Commitment to Approach: the existence of a common understanding of, and agreement to, by all, the method of approach of the team to do the job.

KSF – TEAM MEMBER COLLABORATION

Team Member Collaboration: an approach of working involving mutual support in pursuit of team goals without hidden agenda or power games.

KSF – EMPOWERMENT



Empowerment: the authority of team members and of the team to make decisions within the scope of performance of the designated IPT task, and within defined constraints.

KSF – TEAM LEARNING

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Team Learning: When a team is first formed, managers, team leaders and other team members rarely have the complete set of skills, knowledge and attitudes necessary for the team to perform well. Mental models of the world differ between individuals. Successful teams incorporate mechanisms for development of a shared mental model, and other aspects of team learning, and exist in an environment in which shared learning is fostered.

KSF - STAKEHOLDER FEEDBACK

Stakeholder Feedback: teams are most effective when team performance is continuously being verified and improved by feedback from project management, customers of the team's products, and from all other external stakeholders to which the team owes allegiance.

KSF – GOOD UNDERSTANDING OF RISK & OPPORTUNITY

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Understanding of risk and opportunity: Both planning and product development are about making decisions in the presence of uncertainty. Consistently good decision-making requires a good understanding of risk and opportunity, and the basis of decision making in their presence.

KSF – EXCELLENCE IN NEEDED KNOWLEDGE, SKILLS AND ATTITUDES

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Knowledge, Skills and Attitudes well matched to roles: No amount of soft skills will make up for incompetence in management or engineering.

TO RECAP - MAJOR FACTORS IN ENGINEERING TEAM PERFORMANCE:

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- A **coaching style** of **team leadership**
- **Personal qualities** of the team leader and team members
- Well-defined, outcomes-oriented **success criteria** associated with a **shared vision**
- **Empowerment** – delegated authority to make decisions within defined constraints
- A **consensus-basis** of **team decision-making**
- A good **understanding** by team members of **risk and opportunity**
- Excellence in the necessary, role-related **Knowledge, Skills and Attitudes (KSAs)** of team members

SYSTEMS ENGINEERING MANAGEMENT KSAs - KNOWLEDGE

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- Broad, but not necessarily detailed, **knowledge of the technologies** involved in the engineering activities being managed, and related methods
- Deep knowledge of the **principles and methods of systems engineering**
- Deep knowledge of the **principles and methods of project management and systems engineering management**
- Deep knowledge and **understanding of risk and opportunity**
- Substantial knowledge of **human psychology and related behavior**

SYSTEMS ENGINEERING MANAGEMENT KSAs - SKILLS

PROJECT PERFORMANCE INTERNATIONAL

- Skills to apply knowledge to **planning, organizing resources, motivating people, measuring performance and applying corrections** where necessary
- Very good **decision-making skills in the presence of incomplete information and uncertainties as to outcomes**
- Skills to **manage outwards, engendering confidence** in the engineering from the stakeholders
- Very good **communication skills**

SYSTEMS ENGINEERING MANAGEMENT KSAs - ATTITUDES

- **Respect for technical expertise**
- **Results orientation**
- Where subordinates are performing the engineering, **willingness to delegate**
- **Issues focus, not personalities focus**
- **Patience**
- A personality type that **gains satisfaction from enabling others** to succeed
- **No blame**

EXAMPLE ENGINEERING ROLE: REQUIREMENTS ANALYSIS KSAs - KNOWLEDGE

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- Knowledge of the **history of projects** and the **role of requirements in project outcomes**
- Knowledge of the **information parameters that define the problem domain**
- General **understanding of risk**
- Deep knowledge of the **principles and methods of requirements analysis**
- At least basic familiarity with the **application domain** for the item which is to be the subject of the requirements analysis
- At least base level knowledge of **systems engineering principles and methods**

REQUIREMENTS ANALYSIS KSAs - SKILLS

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- Deep skills in **applying the knowledge of the principles and methods of requirements analysis**
- Skills in **identifying defects in requirements**
- Skills to **distinguish between**, and **switch thinking between, problem domain and solution domain**
- Skills in **measuring requirements quality**
- Deep skills in **human communication**
- Skills in **writing individual requirements**, in applicable language(s)
- Skills in the **development of verification requirements**

REQUIREMENTS ANALYSIS KSAs - ATTITUDES

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- **Respect** for the **right of the owners of requirements to decide what they require**
- **Desire to address requirements issues** in terms of **outcomes for the stakeholders**, not in terms of competencies of the requirements owner/writer - "*being on their side*"
- **Willingness to accept approximation and incompleteness** in requirements, and related requirements analysis tasks - **"adequacy" not "perfection"**
- Subject to the "adequacy" criterion, **attention to detail**

EXAMPLE ROLE: PHYSICAL DESIGN KSAs – KNOWLEDGE

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- General knowledge of the **problem domain, i.e. the area of application**
- Deep knowledge of the **relevant solution technologies**
- Knowledge of **basic problem solving**, involving problem definition, candidate solution identification, and solution selection
- **General understanding of risk**
- **Understanding that design creates requirements on solution elements**

PHYSICAL DESIGN KSAs – SKILLS

PROJECT PERFORMANCE INTERNATIONAL

- Skill to **distinguish between**, and **switch thinking between, problem domain and solution domain**
- Deep creative and innovative skills in **relating understanding of the problem and knowledge of relevant solution technologies** to develop candidate solutions to the problem
- Skills in **explaining design**, verbally and in writing
- Skills in **creating through sound design decisions sound requirements** on elements of the solution

PHYSICAL DESIGN KSAs – ATTITUDES

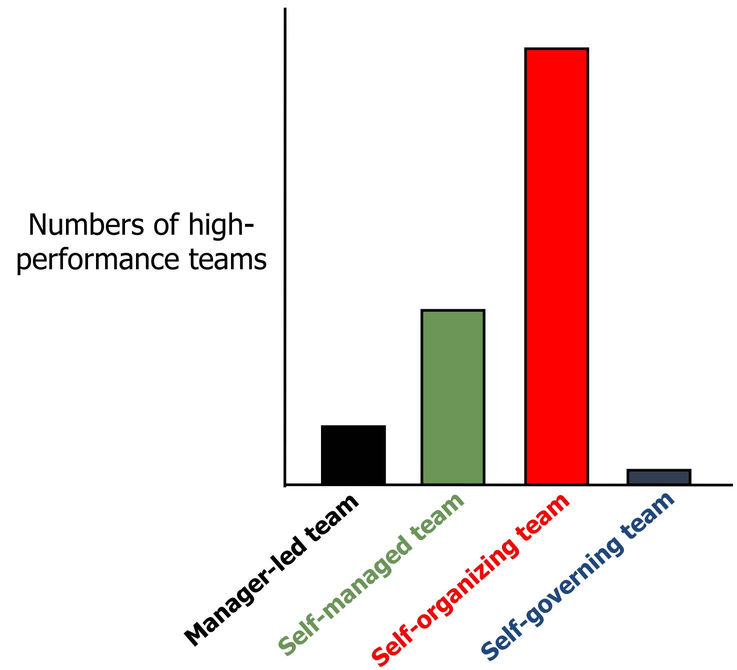
- Respect for the **right of owners of the requirements to define the problem** that is to be solved
- **Attention to detail**
- Willingness to **accept and respond constructively to questioning**, and to **criticism**, of the design
- Focus on **maximization of value to the stakeholder(s)** whom the design is to serve, normally the employer
- Willingness to **raise requirements issues with stakeholders** when defects in requirements are discovered, rather than unilaterally deciding, or assuming, or guessing

Most high-performance teams are self-organizing teams

FOUR TYPES OF TEAM

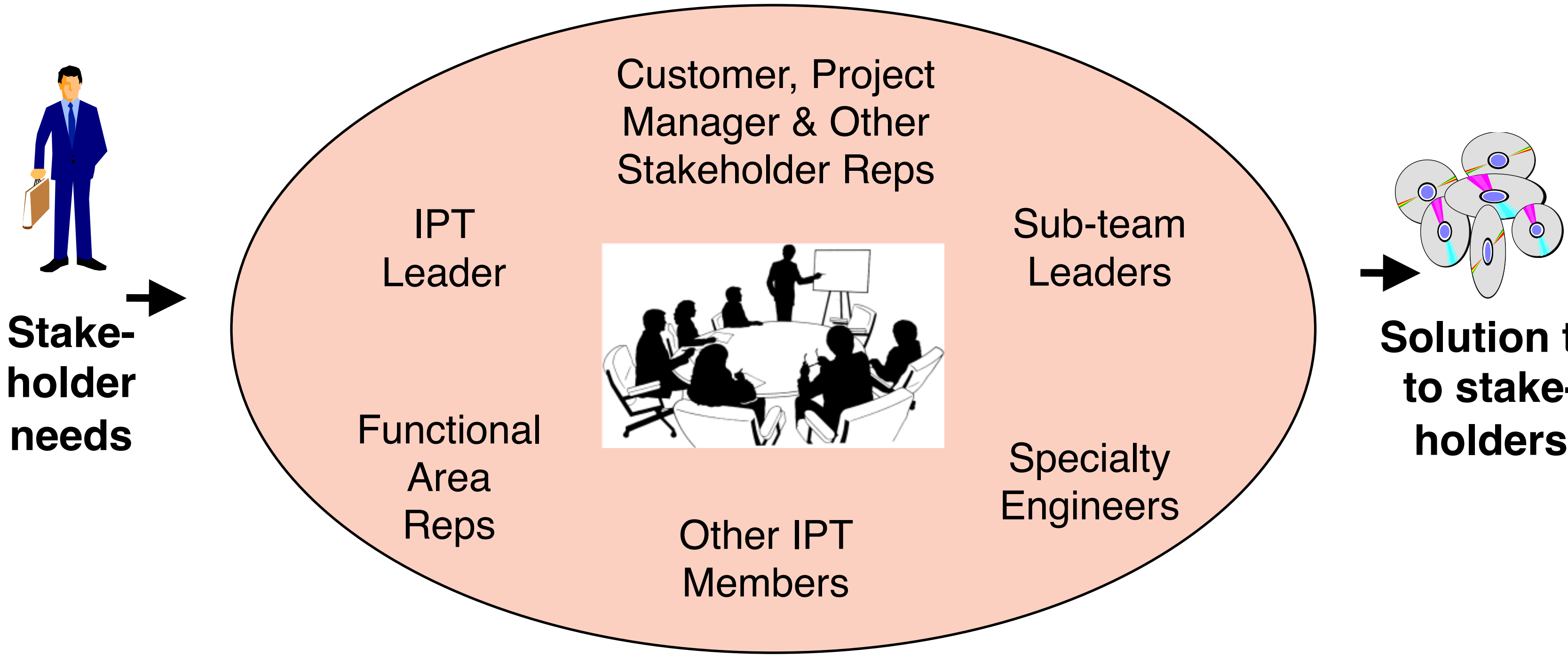
	Manager-led teams	Self-managing teams	Self-organizing teams	Self-governing teams
Setting overall direction for the team				
Designing the team and its context				
Managing work process and monitoring progress				
Executing the team tasks:				

Where are high-performance teams found?



Source: SteveDenning.com

INTEGRATED PRODUCT TEAMS



- A multi-disciplinary, cross-functional, stakeholder-focussed team solely responsible for taking a product from need to delivery.
- Knowledge, skills and attitudes of the team members are complementary

IPT MEMBERSHIP:

Membership of a Lead IPT could include:

- Project Manager
- Team leaders of subordinate IPTs
- Specialists including specialty engineers
- Functional representative - engineering
- Functional representative - HR
- Functional representative - production
- Functional representative - purchasing
- Functional representative - marketing
- Functional representative - finance
- Functional representative - quality
- Functional representative - IT
- Representatives - interfacing WBS elements
- IPT Leader

The number of people on the IPT will depend on the nature of the IPT and its environment

BUILD, COMMUNICATE AND USE A PROJECT EFFECTIVENESS MODEL

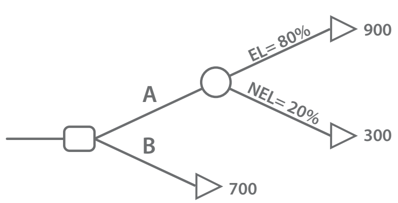
MEASURES OF EFFECTIVENESS (MOES)

- Beyond requirements (must be met) ....
- Measures that represent degrees of goodness of a product or of a project, e.g.
  - speed
  - accuracy
  - unit cost of production
  - reliability
  - aesthetic appeal
  - time to market
  - consequential votes in a marginal electorate!

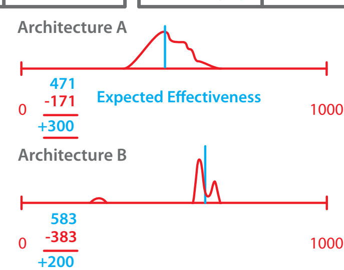
Value (System Effectiveness) Model

Architecture A Evaluation

MOEs	Worst	Best	Pri	Pts	Weight %	UF	Value of MOE	RVC	AVC (RVC x wt)	
Cost, $k's per unit	200	50	1	100	25		~~55k~~ 57	10	250	
Reliability, %	95	100	1	100	25		~~95.5%~~ 97	~~100~~ 5	~~25~~ 125	+100
Interoperability	0	17	7	14	4		0	0	0	0
Size(A/B/C)	C	A	8	3	1		~~C~~ B	~~0~~ 5	~~0~~ 5	+5
Schedule (MonthS)	12	6	3	40	10		~~7~~ 8	~~10~~ 9	~~100~~ 90	-10
Visible Optical Range	1000	5000	5	30	7		~~1200~~ 2500	~~2~~ 5	~~14~~ 35	+21
Duration of Transmission, hr	48	96	6	27	6		50	0.5	3	
Readiness, %	90	100	4	39	10		~~91~~ 95	~~1~~ 5	~~10~~ 50	+40
OS & D Cost, $k pu/10 years	300	10	2	50	12		~~200k~~ 106	~~1.5~~ 8	~~18~~ 96	+74
				403	100				Σ 560	



80% x 900 = 720
20% x 300 = 60
TOTAL 780



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IMPLEMENT TECHNICAL PERFORMANCE MEASUREMENT (TPM)

OR

INTEGRATED PERFORMANCE MEASUREMENT

ALTERNATIVE STRATEGIES FOR IMPLEMENTING PERFORMANCE TRACKING

- Technical Performance Measurement (TPM)
- Earned Value Methodology (EVM)
- Integrated Performance Measurement (IPT)

EXAMPLE PERFORMANCE INDICATOR PROFILE WITH ALARM THRESHOLDS

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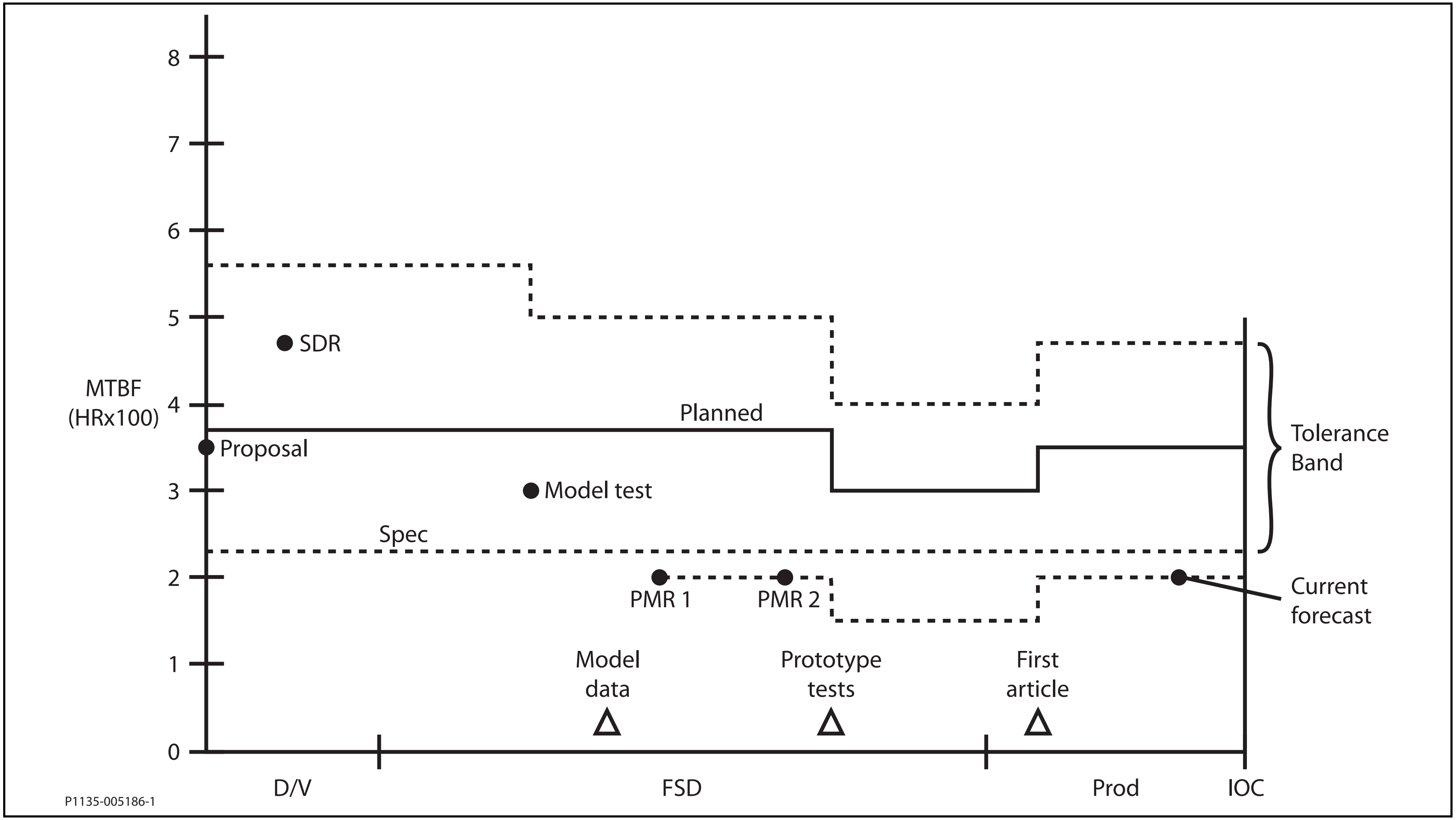

EXAMPLE PERFORMANCE INDICATOR PROFILE

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CATEGORY QUALITY ASSURANCE

FACTOR: SCRAP, REWORK & REPAIR

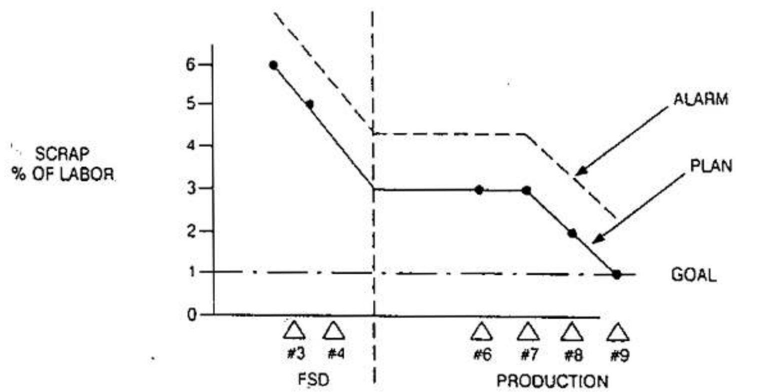
GOAL: 1% OPR: ABCD

METHOD OF CALCULATION:

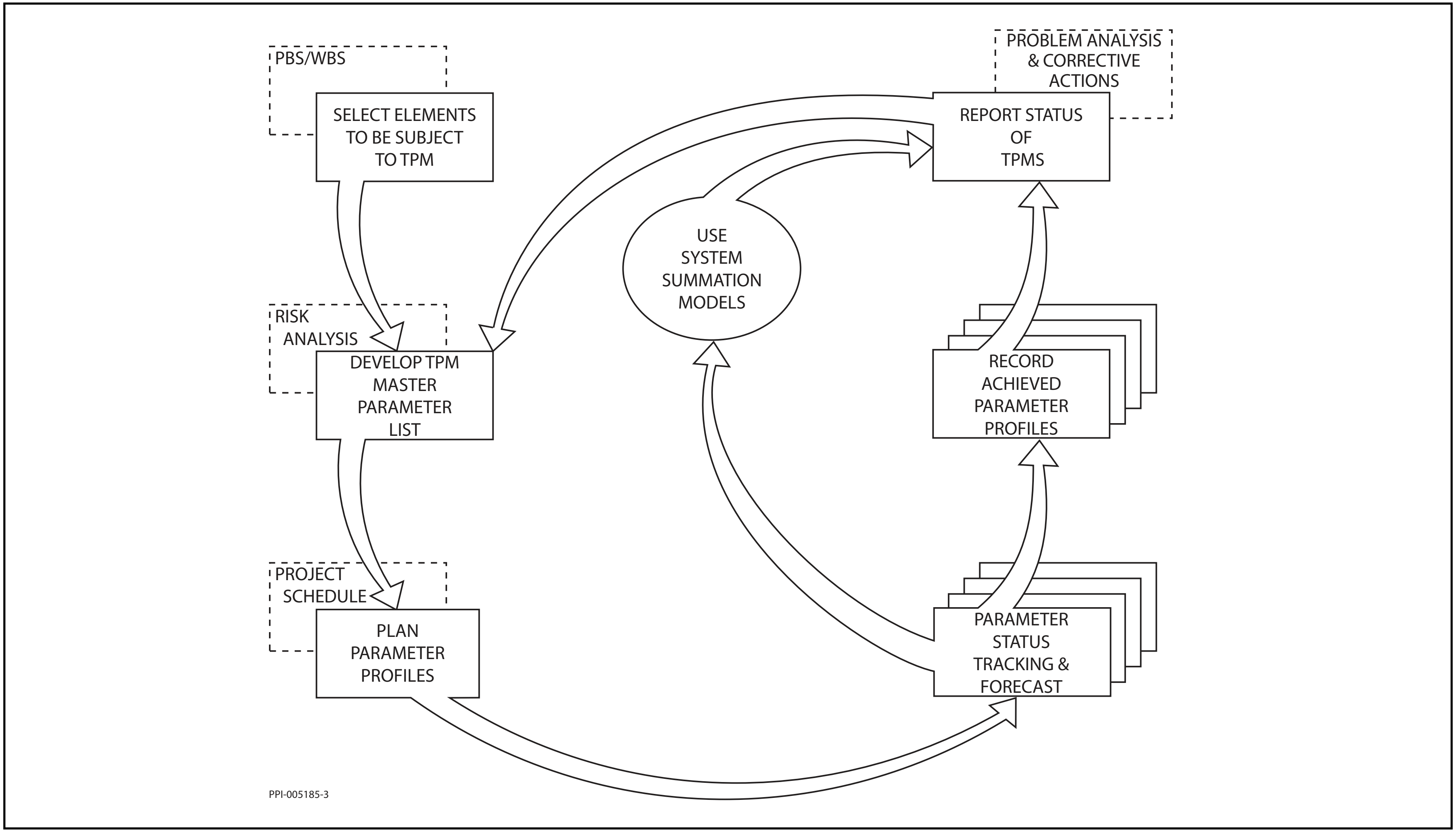
METHOD OF OBSERVATION

MEASUREMENT MILESTONES

MILESTONE	DESIRED VALUE	METHOD	RATIONALE
(#3)	6%	CALC	
(#4)	5%	CALC	
(#6)	3%	CALC	
(#7)	3%	OBS	
(#8)	2%	OBS	
(#9)	1%	OBS	



TPM INFORMATION PLANNING AND EXECUTION



EXAMPLE TPM PARAMETERS - AIRCRAFT ENGINE

TPM PARAMETERS - AIRCRAFT ENGINE SUB-SYSTEM

MAXIMUM THRUST SEA-LEVEL STANDARD (LBS)

INTERMEDIATE THRUST SEA-LEVEL STANDARD (LBS)

INTERMEDIATE THRUST AT B-1 REFUEL (LBS)

SPECIFIC FUEL CONSUMPTION AT B-1 SUPERSONIC CRUISE (LB/HR/LB)

SM REQ'D/SM AVAIL (STATIC MARGIN)

TOTAL ENGINE WEIGHT (LBS)

RELIABILITY - MYBPL (HR) (MEAN-TIME-BETWEEN-POWER-LOSS)

MAINTENANCE MAN-HOUR RATE (MAN-HOURS/EFFECTIVE FLYING HOURS)

EARNED VALUE METHODOLOGY INDICATORS

- An Earned Value Method provides **cost and schedule variance data**, including trend data, based on the value of actual work accomplishment (earned value).
- A **Cost Performance Index (CPI)** below 1 indicates cost risk. A CPI downward trend indicates increasing cost risk.
- A **Schedule Performance Index (SPI)** below 1 indicates schedule risk. A SPI downward trend indicates increasing schedule risk.

INTEGRATED PERFORMANCE MEASUREMENT (IPM)

- Based on the project effectiveness model or a derivative thereof
- Each parameter in the model is assigned a Performance Improvement (PI) profile
- Weights from the project effectiveness model are applied to the profiles to derive a weighted utility profile for each parameter
- The component weighted utilities are summed on a periodic basis and/or at milestones to give a baseline project effectiveness profile
- Current actuals are entered into the same model to give actual against planned effectiveness variance
- Adverse variances flag increasing project risk

May your project managers, engineering managers and engineers align in driving towards the same vision.

Thank you for your interest ☺

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