Master Class
Integrating
***Systems Engineering* (SE)**
and
***Project Performance Management* (PPM)**
The Match Made in Heaven Which Increases the Probability of Project Success

Why do so Many Large Projects Overspend and Overrun?

The projects are managed as if they were merely complicated – when in fact, they were complex.
They are planned as if everything is known or knowable at the start – when in fact, they involve high levels of reducible (Epistemic) and irreducible (Aleatory) uncertainty and resulting risk.
Combining Systems Engineering and Project Management is a critical success factor in reducing these uncertainties, resulting in increased probability of program success. [93]

Glen B. Alleman
Thursday 22 August 2019, 9:00 AM – 5:00 PM

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Sobering Thoughts About Managing Complex Systems [143]

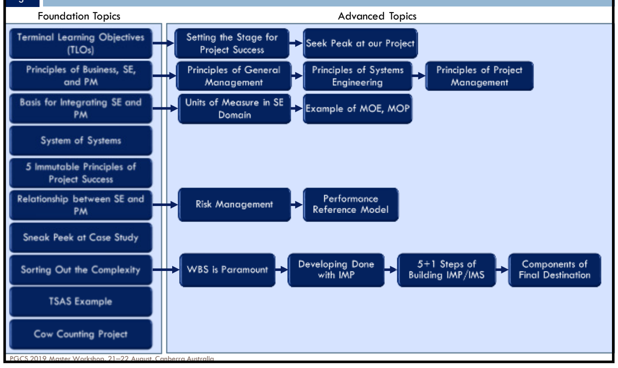
NEW SYSTEMS MEAN NEW PROBLEMS

Unconstrained System – a collection of component systems, simple or complex, managed, operated, developed, funded, maintained, and sustained independently of its overarching principal system that creates a new capability.

Complex System – a collection of large, multifaceted, and interrelated component systems that are dependent on the entirety of the principal system for management, operations, development, funding, maintenance, and sustainment. Complex systems are non-deterministic, adaptive, holistic, and with nonlinear interfaces between attributes.

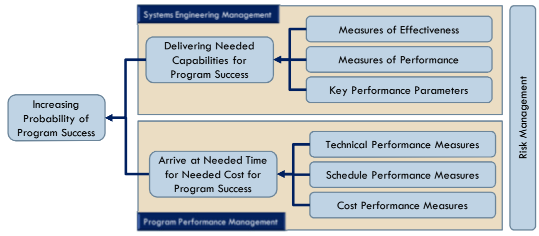
IN COMPLEX SYSTEMS, MALFUNCTION AND EVEN TOTAL NON-FUNCTION MAY NOT BE DETECTABLE FOR LONG PERIODS, IF EVER [9].

Workshop Contents



From Key–Note Talks Here's The Framework for the Workshop

Connecting the dots between Systems Engineering and Project Performance Management starts with Shared Data and Processes



Seeing the Three Phases of *Project as a Whole* is the Foundation of Systems Thinking [148]

Systems Thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns rather than static 'snapshots.' Systems Thinking is a discipline for seeing the 'structures' that underlie complex situations. [182]

During all 3 Phases There is Shared Data Supported with the Risk Management Process

Systems Engineering	Program Performance Management
□ Concept of Operations (ConOps) □ System Architecture □ Measures of Effectiveness (MOE) □ Measures of Performance (MOP) □ Key System Attributes (KSA) □ Key Performance Parameters (KPP)	□ Programmatic Architecture (IMP/IMS) □ Technical Performance Measures (TPM) □ Quantifiable Backup Data (QBD) □ Cost Performance (CPI) □ Schedule Performance (SPI) □ Physical Percent Complete (P%C) □ Estimate To Complete (ETC) □ Estimate at Completion (EAC)

- □ Risk Burndown Performance
- □ Cost Margin Burndown Performance
- □ Schedule Margin Burndown Performance

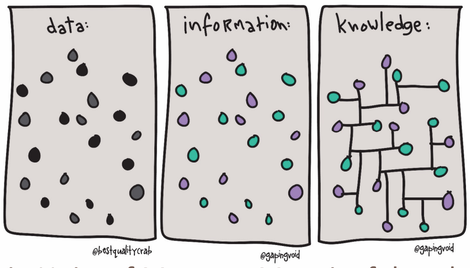
Knowing where to aim is the foundation of all project success.

Aiming starts with the Systems Engineer's Description of Done of the needed Capabilities for Mission or Business Success.

Managing the performance of work needed to *Get to Done*, is the role of Project Performance Management.

Workshop Framework

The Integration of SE and PPM provides …



… in Units of Measure Meaningful to the Decision Makers.

If it can't be expressed in figures, it is not science; it is opinion (Robert Heinlein).

Concluding a project within the initial estimated budget and time frame does not necessarily guarantee it has been a success.

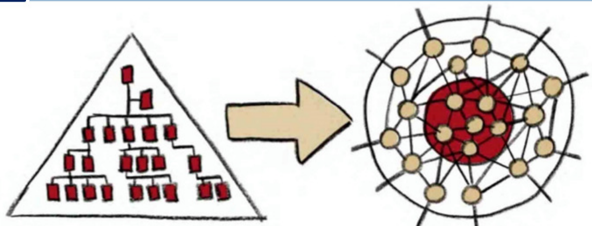
The success of a project is defined by more than the triple constraint; success encompasses other elements such as client acceptance, reputation of the company, alignment to the business strategy, ethical behavior, and team cohesiveness.

The business factor, correlated with the value that a project adds to the company, has become a key element for defining a project's success.

This success, with all its multiple facets, should be proved to sponsor, client, management, or other influential stakeholders.

This workshop discusses how and when we measure project performance, the indicators of this performance, and some of the tools used to perform these measurements, integrated with the Systems Engineering processes that define the needed Capabilities to be produced by the project.

Transformation Context of SE + PPM [163]



- Mechanistic
- Differentiated
- Work the people
- Top-Down, Managed
- In Parallel
- Efficiency Oriented

- Systemic
- Integrated team based
- Work the work
- Outside-In, Lead
- Each Other, for Each Other
- Complexity, Robust

The Starting Point for Our Workshop

Complex systems usually come to grief, when they do, not because they fail to accomplish their nominal purpose. Complex systems typically fail because of the unintended consequences of their design (and their management) …

I like to think of system engineering as being fundamentally concerned with minimizing, in a complex artifact, unintended interactions between elements desired to be separate.

Essentially, this addresses Perrow's [181] concerns about tightly coupled systems. System engineering seeks to assure that elements of a complex artifact are coupled only as intended.

– Michael Griffin, NASA Administrator, Boeing Lecture, Purdue University, March 28, 2007.

Why ***Project Performance Management*** rather than ***Project Management***?

- Project Management methods are everywhere, from PMI, to guides for each country and industry, to internal governance documents and all the tools that implement those *Guides*.
  - The Egyptians had project management methods to build the pyramids [158]
- What's missing is a single, concise set of ***Principles*** and ***Processes*** for *Increasing the Probability of Project Success*. This starts with Five Immutable Principles:
  1. *What Does Done Look Like?*
  2. *What's our Plan to Reach Done?*
  3. *What resources are needed to reach Done?*
  4. *What implements impacting our ability to reach Done?*
  5. *How do we measure progress to Done?*

What Does It Mean When We Say Project Success?

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Project Management Paradigm	Systems Engineering Paradigm
On Budget	Capabilities to accomplish the mission or meet Business Goals
On Schedule	Tangible benefits to organization
Delivered Requirements arrive for the planned cost at planned time	Tangle benefits to stakeholder
	Enable future benefits to organization & stakeholder
Project Efficiency	**Project Efficacy**

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Critical Success Factor for All Projects

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Risk Management is Project Management for Adults – Tim Lister

Both Systems Engineering and Project Management have foundations in Risk Management

For Success we must seamlessly integrate Risk Management into Both SE and PPM

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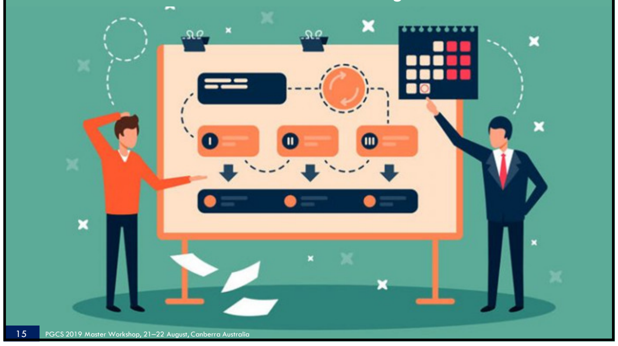
The Core Question to be Answered by Integrating SE & PPM

What Data and Processes need to be Integrated?

Why, When, and What are the Tangible Benefits to the Project the Business from this Integration?



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Roles of PPM and SE [98]

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Systems Engineer

- Focused on the Business Solutions that deliver Capabilities
  - What are they?
  - How are they assembled?
- Responsible for defining, designing, and delivering this solution that meets:
  - Measures of Effectiveness and Performance [105]
  - Measures of Performance Key Performance Parameters
  - Key System Attributes

Project Manager

- Focused on the Business Requirements
  - When are these needed?
  - How much will they cost?
- Responsible for designing and operating the control system that manages the work associated with the solution that meets:
  - Technical Performance Measures
  - Quantifiable Backup Data

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Responsibility of PPM and SE [136]

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Systems Engineer

A systems engineer is the project's supreme technical arm.

System engineer must understand the accepted product development processes, "tailor" them to each specific project, implement them in the development process, and pass them on to production.

Project Manager

The project managers are responsible for meeting all project targets, especially providing the product on time and within the determined budget, while systems engineers lead the technical efforts necessary to developing the system.

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We Need to End the Tug of War Between Competing Paradigms …

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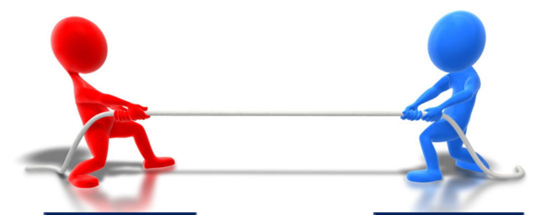
… and

Start Integrating the Processes and Data Needed to Increase the Probability of Project Success (PoPS)



Systems Engineer — Project Manager

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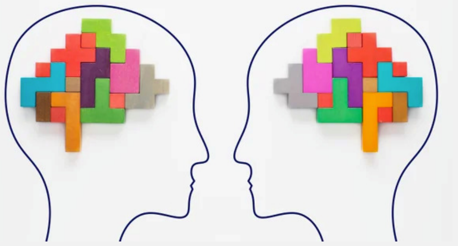
Introduction

Integrating Systems Engineering and Project Performance Management [98]

Project Performance Manager
- Focused on Business Requirements
  - How Much and When
- Responsible for designing and operating the project control system to manage work that produces the system

Systems Engineer
- Focused on Business Requirements
  - How Much and When
- Focused on Business Solution
  - What and How
- Responsible for Defining, Designing, and Delivering the Solution



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Integrating these Two Perspectives [98]

Introduction

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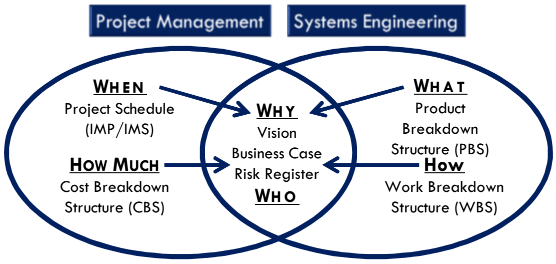

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TLO's

Start with the end in mind – Stephen Covey …

What knowledge, skills, and experiences will we leave this workshop with?

Even though these may be *restating the obvious*, we need to be on the same page to successfully integrate Systems Engineering and Project Management.

Terminal Learning Objectives (TLO's)

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TLO's for the Workshop

TLO's

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We will Learn …

1. The *Immutable Principles* of Program Performance Management (PPM) and Systems Engineering (SE).
2. How integrating the principles of SE and PPM creates an **Integrated Project Performance Management System** (IPPMS)
3. The Practices and Processes of the IPPMS
4. How the IPPMS can measurably contribute to increasing the Probability of Program Success (PoPS)

A Successful IPPMS is a *Closed Loop Control* System

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TLO's

The purpose of all processes, their application and continuous improvement is to *Increase the Probability of Project Success*

Setting the Stage for WHY we Need an Integrated Project Performance Management System

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Projects are "One-Off" Events.

You've got one chance to get it right.

What's your ***Probability Of Success?***

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The 4 + 1 Elements Needed To Increase Project's Probability of Success

Capabilities | Requirements | Plans | Execution | + Continuous Risk Management

1. What Capabilities are needed to fulfill the Concept of Operations†, the Mission and Vision, or the Business System Requirements?
2. What technical and operational requirements are needed to deliver these capabilities?
3. What is the cost and schedule that delivers product or services that meet the requirements?
4. What are the periodic measures of physical percent complete?
5. What will be impediments are there to success and what are the mitigations?

† A Concept of Operations (ConOps) describes the characteristics of a proposed system from the viewpoint of an individual who will use that system. It is used to communicate the quantitative and qualitative system characteristics to all stakeholders.

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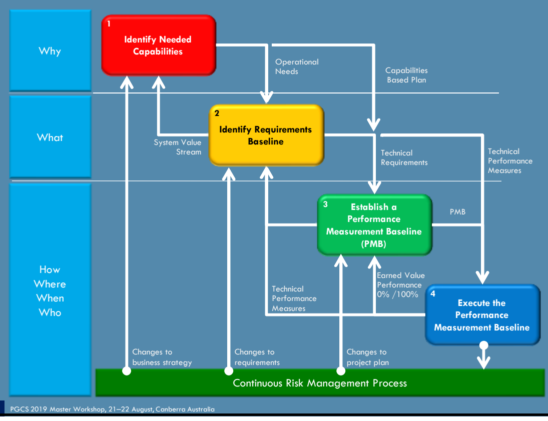
The Relationships Between the Five Success Processes



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But First, Some History of the SE / PPM Integration Problem

- Systems Engineering, Project Management, and Program Management evolved from similar roots during World War II. [89], [90]
- Program and Project Management and Systems Engineering are Different
  - *Program Management* and *Project Management* not universally defined
  - *Systems Engineering*, is also not universally defined
- Lack of an Integrated Planning system is a primary source of disconnect between SE and PPM
- Integration of PPM an SE is difficult, but not Impossible [1]
  - Integrating roles and cultures creates other issues …

This workshop starts with integrating the ***Processes*** and ***Data*** as the foundation of removing the organizational conflicts

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A Hypothesis of the Workshop

- When PPM and SE organizations are separate but equal, using separate processes, stove pipes are created [88]
- It is difficult to close the gaps between these stove pipes by changing the Cultural, another approach is needed.

The Hypothesis

- The stove pipe gaps between Systems Engineering and Project Management can be closed with a shared ***Integrated Project Performance Management Process*** (IPPMS).

Conway's Law – Organizations which design products … are constrained to produce designs which are copies of the communication structures and processes of those organizations. [87]

Change Process – Remove Stove Pipes – Integrate SE and PM

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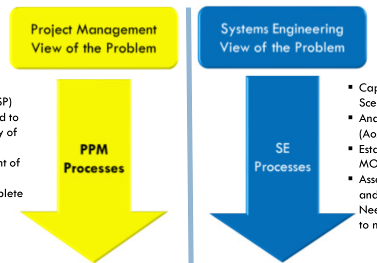
The Core Failures Resulting from the *Separate but Equal* Paradigm [22], [23], [26], [27], [28]



- Cost, Schedule, Performance (CSP) measures needed to manage delivery of Requirements
- Risk Management of C,S, and P
- Physical % Complete
- EAC, ETC, TCPI
- CSP Margin management

- Capabilities as Scenarios in ConOps
- Analysis of Alternatives (AoA)
- Established MOE's MOP's, KPP's and KSA's
- Assessment Technical and Operational Needs, Cost, and Risks to needed Capabilities

Separate Solutions create cultural barriers to Increasing Probability of Success. These barriers isolate data and processes needed for success. Only by removing the barriers through in Integrated Project Performance Management System can the Probability of success be Increased

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Components Integrated into a ***Integrated Project Performance Management System***

- Technical and Programmatic management of work processes
- Defining Technical and Programmatic components of the Integrated system
- Defining interfaces and interactions between the Technical and Programmatic components
- Implementing deliverables built from the components
- Integrating the deliverables into a *System* to deliver needed Capabilities
- Confirming the Capabilities meet the MOE's, MOP's, TPM's, KPP's and KSA's

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A Process–Centric Solution to the Organizational Problem [22], [23], [26], [27], [28]

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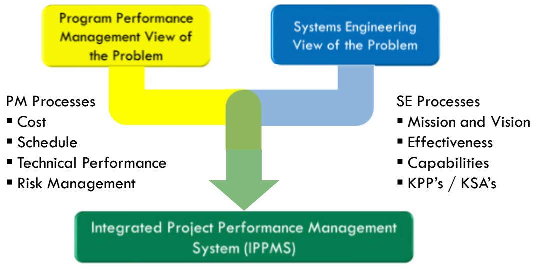

Integrating two separate process models into a Single Integrated Project Performance Management System (IPPMS) provides the solution to the problem is isolated paradigms. But the Challenge is, *How to Perform this Integration*

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Overview of the Integration [28]

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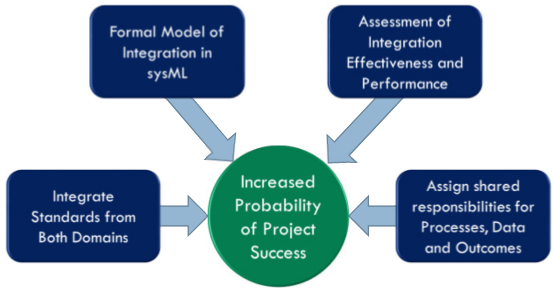

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Integrating Project Performance Management & Systems Engineering [26]

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- The Integrated PPM and SE delivers an …
  - Increased likelihood of efficiency and effectiveness of the project's resources and funding
  - Improved transparency between SE and PPM efforts, common understanding, and adaptability to change
- Without this integration, PPM and SE disciplines are not well aligned in their objectives and incentives leading to …
  - Lack of efficiency
  - Duplication of effort
  - Working at cross purposes

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Practices of an *Integrated Project Performance Management System*

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Practice	Systems Engineering	Project Management	IPPMS
Define needed Capabilities of the System to accomplish the mission or deliver Business Value	Increasing maturity of Deliverables defined in the Concept of Operations	Develop the Integrated Master Plan, showing the Program Events, Significant Accomplishment, and Accomplish Criteria for each Capability	Connect the IMP with the Concept of Operations where the Capabilities are defined
Identify the Measures of Effectiveness (MOE) and Measures of Performance (MOP)	The operationally relevant and measurable MOE's and the MOP's required to satisfy the MOEs from WBS for each deliverable	Integrated Master Plan, with Significant Accomplishment and Accomplishment Criteria define the MOPs and MOEs	Connect the MOEs and MOPs with the TPMs, KPPs and KSA's in a vertical and horizontal trace from top to bottom
Identify reducible and irreducible uncertainties that create risk	Identify risks to accomplishing MOEs and MOPs	Identify risks to accomplishing Technical Performance Measures	Fully integrated risk management and margin management activities vertically and horizontally

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Processes of an *Integrated Project Performance Management System*

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Process	Systems Engineering	Project Management	IPPMS
Managing work processes	INCOSE Vee	Integrated Master Plan Integrated Master Schedule	Program Events, Significant Accomplishment, and Accomplishment Criteria connected to steps in Vee
Defining components of the system	ConOps [89], Capabilities Based Planning	Work Breakdown Structure for Deliverables	WBS elements connected to delivered Capabilities
Defining interfaces between the components	Design Structure Matrix (DSM) showing dependencies between deliverables		
Implementing deliverables from the components	Capabilities Breakdown Structure in sysML	Work Packages and Tasks in the Integrated Master Schedule	Integrated Master Plan Physical Percent Complete at SA and PE level showing compliance with MOE and MOP maturity assessments
Integrating deliverables into a *System* to produce needed Capabilities	Delivered Capabilities to implement Concept of Operations	Vertical traceability to increasing maturity of the delivered Capabilities	Deliverables connected to Concept of Operations Capabilities to meet Mission Requirements

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The Integration of Systems Engineering and Project Performance Management Share Technical Measures [71]

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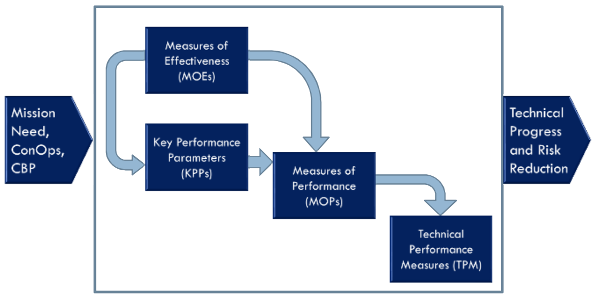

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With the outcomes of the SE + PPM Workshop, we will Understand the Combined Solution based on …

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Principles	Practices
Define Framing Assumptions for connecting SE and PPM [95] Define units of measure found in SE and PPM supporting each framework Identify methods for integrating each framework to enhance Probability of Program Success	Apply Principles and Practices to a System of Systems Unmanned Aerial Vehicle Identify artifacts of individual Processes Define the practical measures needed to increase the Probability of Program Success (PoPS) Define the Essential Views of Integrated Project Performance Management System (IPPMS)

TLO's

Motivation for Integrating SE and PPM starts with 4 Known Root Causes of Project Failure

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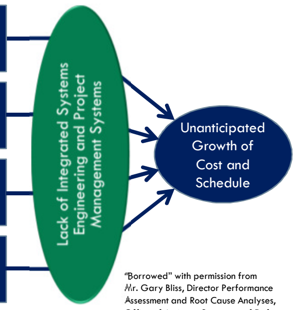
- *Unrealistic* Performance Expectations, with missing Measures of Effectiveness (MOE) and Measures of Performance (MOP).
- *Unrealistic* Cost and Schedule estimates, based on inadequate risk adjusted growth models.
- *Inadequate* assessment of risk and unmitigated exposure to these risks without proper handling plans.
- *Unanticipated* technical issues without alternative plans and solutions to maintain effectiveness of the product or service.



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TLO's

Core Project Failure Root Causes in the Systems Engineering Paradigm

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- Inadequate understanding of the requirements
- Lack of systems engineering, discipline, and authority
- Lack of technical planning and oversight
- Stovepipe developments with late integration
- Lack of subject matter expertise at the integration level
- Lack of availability of systems integration facilities

TLO's

Core Project Failure Root Causes in the Project Management Paradigm (Continued)

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- Incomplete, obsolete, or inflexible architectures
- Low visibility to risk
- Over Estimates of Technology maturity
- Failure to measure *Physical Percent Complete*
- Failure to identify reducible and irreducible uncertainty and missing risk management processes to handle resulting risk

TLO's

Common Goals – Different Perspectives

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Both SE and PPM seek successful outcomes – *completing the project to produce a new or enhanced system, for the needed cost, on the needed date.*

System Engineering	Project Management
Capabilities Based Planning Concept of Operations (ConOps) From the ConOps, produce an Integrated Master Plan (IMP) with: - Measures of Effectiveness (MOE) - Measures of Performance (MOP) - Key Performance Parameters (KPP)	Integrated Master Schedule (IMS) with: - Technical Performance Measures (TPM) - Quantifiable Backup Data (QBD) - Work (WBS), Cost (CER), Risk (RBS), and Organizational Breakdown Structure (OBS) Risk Management Cost, Schedule, Risk Management integrated in a single Performance Measurement Baseline (PMB)

TLO's

Proper System Requirements Attributes

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Attribute	Definition
Correct	Every requirement represents something that is required for the system to be built.
Unambiguous	Every requirement has only one interpretation and includes only one requirement (unique).
Complete	Requirements possesses these qualities: 1. Everything it is supposed to do is included. 2. Definitions of the responses of software to all situations are included. 3. All pages are numbered. 4. No sections are marked "To be determined." 5. Is necessary
Verifiable	Every requirement is verifiable.
Consistent	1. No requirement that conflicts with other preceding documents, 2. No subset of requirements are in conflict.

TLO's

Proper System Requirements Attributes (Continued)

TLO's

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Attribute	Definition
Understandable by Customer	There exists a complete unambiguous mapping between the formal and informal representations of the requirements.
Achievable	The designer should have the expertise to assess the achievability of the requirements, including subcontractors, manufacturing, and customers/users within the constraints of the cost and schedule life cycle.
Design Independent	The requirements does not imply a specific architecture or algorithm.
Concise	Given two requirements for the same system, each exhibiting identical level of all previously mentioned attributes—shorter is better.
Modifiable	The structure and style are such that any necessary changes to the requirement can be made easily, completely, and consistently.

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Proper System Requirements Attributes (Continued)

TLO's

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Attribute	Definition
Traced	Origin of each requirement is clear and traceable to a document, design, or regulation.
Traceable	Requirements are written in a manner that facilitates the referencing of each individual requirement stated therein.
Annotated	There is guidance to the development organization such as relative necessity (ranked) and relative stability.
Organized	Requirements contained are easy to locate.

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The World of *Engineered* Systems

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The World of Project Management [151]

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These Individual Processes must be Assembled into an ***Integrated Project Performance Management System***

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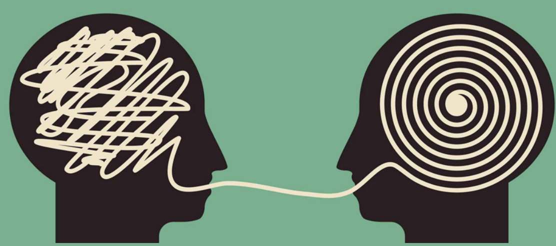
TLO's

Let's Sort Out the Complexity of the Integration of Systems Engineering and Project Management Starting with General Management [119]



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TLO's

Success Requires Everything Is Integrated

"Understanding alone isn't enough get people moving." — Shigeo Shingo

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Keeping track of Live Stock is a traditional role for horse–back staff and their dogs.

This is expensive, risky, error prone, and requires supporting facilities for the horses and dogs as well as the Cow Boys.

A Sneak Peek at our Case Study

A Livestock Counting System using an Unmanned Aerial Vehicle

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The Notional Project

Notional Project

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- We work for an Unmanned Aerial Vehicle (UAV) firm entering the ranching and farming market place.
- We know how to build complex equipment, including flying machines, electronics, and training systems for government agencies.
- We now want to do the same for farmers and ranchers.

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Our Case Study Project Will Be …

Notional Project

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- A System of Systems, to provide live stock counting capabilities on Colorado ranch
- Four components are:
  - Command and Control – what we want the UAV to do an when we want it to do it
  - Airborne Sensors – what sensors needed in needed spectrum, for different times of the year
  - Ground sensors – for collection of data at entry and exit points of the pastures
  - Animal Sensors – to augment the airborne and ground sensors
- We'll focus on the airborne system for this workshop

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Principles

As to methods there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble.

— Harrington Emerson, August 2, 1853 to September 2, 1931[91]

Immutable Principles

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Max Wideman Suggests a Principle of Project Success …

Immutable Principles

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- Express a general or fundamental truth [or] a basic concept
- Makes for a high probability of project success. The corollary is that the absence of the condition will render project success on a majority of the key criteria as being highly improbable.
- Provides the basis for establishing logical processes and supporting practices that can be proven through research, analysis, and practical testing.
- Be universal to all areas of project management application.
- Be capable of straightforward expression in one or two sentences.
- Be self-evident to experienced project management personnel.
- Carries a concise label reflecting its content.

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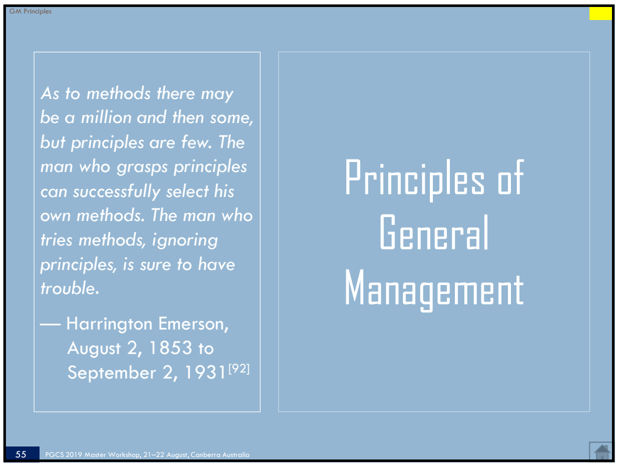
GM Principles
As to methods there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble.
— Harrington Emerson, August 2, 1853 to September 2, 1931 [92]
Principles of General Management
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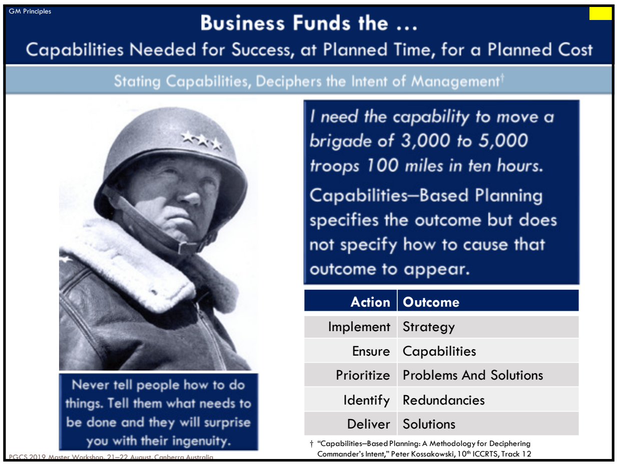
GM Principles
Business Funds the …
Capabilities Needed for Success, at Planned Time, for a Planned Cost
Stating Capabilities, Deciphers the Intent of Management†
I need the capability to move a brigade of 3,000 to 5,000 troops 100 miles in ten hours.
Capabilities–Based Planning specifies the outcome but does not specify how to cause that outcome to appear.
Never tell people how to do things. Tell them what needs to be done and they will surprise you with their ingenuity.
Action | Outcome
Implement | Strategy
Ensure | Capabilities
Prioritize | Problems And Solutions
Identify | Redundancies
Deliver | Solutions
† "Capabilities–Based Planning: A Methodology for Deciphering Commander's Intent," Peter Kossakowski, 10th ICCRTS, Track 12
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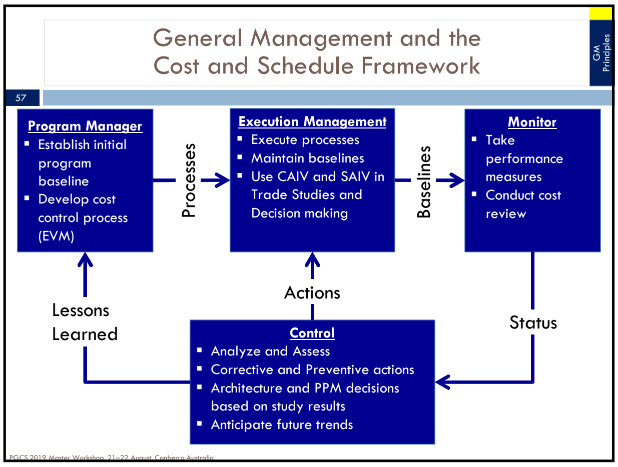
General Management and the Cost and Schedule Framework
GM Principles
57
Program Manager
Establish initial program baseline
Develop cost control process (EVM)
Processes
Execution Management
Execute processes
Maintain baselines
Use CAIV and SAIV in Trade Studies and Decision making
Baselines
Monitor
Take performance measures
Conduct cost review
Lessons Learned
Actions
Status
Control
Analyze and Assess
Corrective and Preventive actions
Architecture and PPM decisions based on study results
Anticipate future trends
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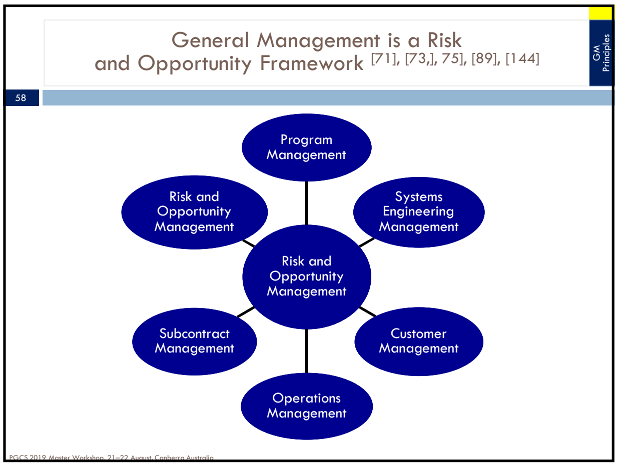
General Management is a Risk and Opportunity Framework [71], [73,], 75], [89], [144]
GM Principles
58
Program Management
Risk and Opportunity Management
Systems Engineering Management
Risk and Opportunity Management
Subcontract Management
Customer Management
Operations Management
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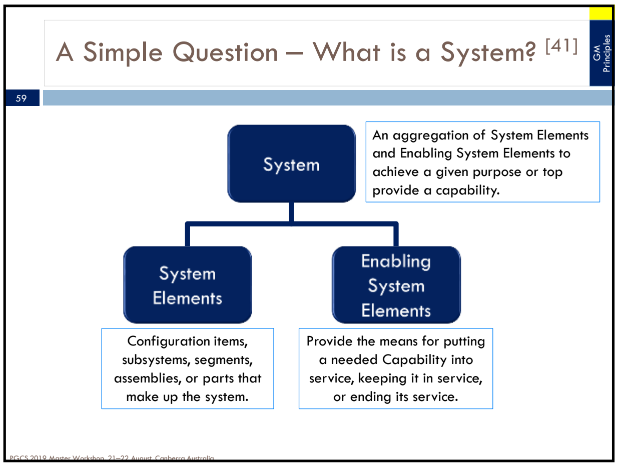
A Simple Question – What is a System? [41]
GM Principles
59
System
An aggregation of System Elements and Enabling System Elements to achieve a given purpose or top provide a capability.
System Elements
Configuration items, subsystems, segments, assemblies, or parts that make up the system.
Enabling System Elements
Provide the means for putting a needed Capability into service, keeping it in service, or ending its service.
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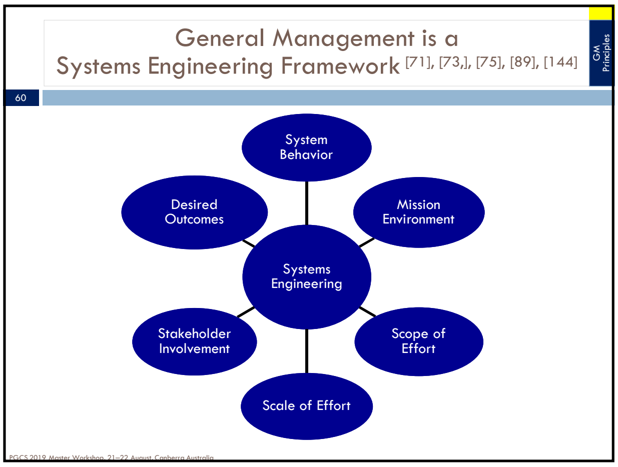
General Management is a Systems Engineering Framework [71], [73,], [75], [89], [144]
GM Principles
60
System Behavior
Desired Outcomes
Mission Environment
Systems Engineering
Stakeholder Involvement
Scope of Effort
Scale of Effort
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General Management Principles A Summary

- General Management is a participant in Systems Engineering
  - Technical – Capabilities Elicitation from Customer
  - Programmatic – Contracting for delivering Capabilities
  - Financial – Budgeting and funding work
  - Customer – product and customer facing management

As to methods there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble.

— Harrington Emerson, August 2, 1853 to September 2, 1931 [92]

Principles of Systems Engineering

Systems Engineering is [156] …

… A Process, NOT an Organization

Led by Systems Engineers, where:

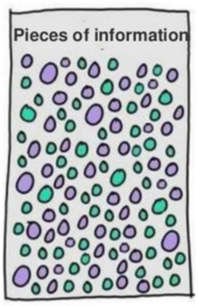
- All functions play a role through an Integrated Process and Product Development (IPPD);
- With the Functions rigorously applied across the program;
- To provide the technical *glue* allowing separate design disciplines and subsystems function together to provide an integrated system performing a specific job.

Systems Engineering is a systematic, interdisciplinary approach to transform customer needs into a total system solution.

The *Systems* Viewpoint

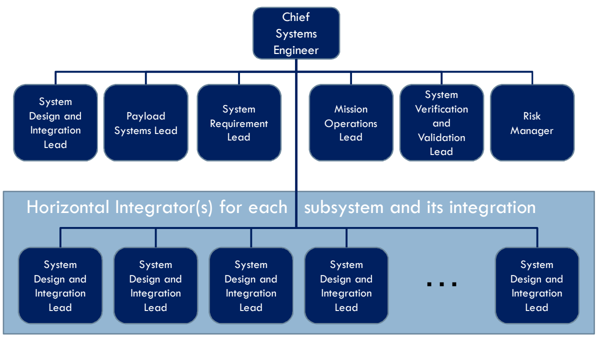
- Design Engineers – view the system from the inside
  - Concerned with other system elements only as they affect their own design task; but not necessarily how theirs may affect others
- Systems Engineers – view the system from the outside
  - Concerned with the effect of all system elements as they affect overall system design / performance / cost / schedule
- Project Performance Management – views the system as
  - Project planning of the objectives, roles and responsibilities for delivering those objectives
  - Monitoring progress towards of the objectives
  - Controlling and implementing corrective and preventive actions to keep the project moving toward the objectives as planned

System Engineering *Connects the Dots* Between all the Project Information [178]



- Stakeholder Needs
- Use Cases
- Operational Scenarios
- Stakeholder Requirements
- System Requirement
- Interfaces
- System Architectures
- Verification Objectives
- Test Cases

A Systems Engineering Organization for our Cow Counting Project



Systems Engineering Leads the Technical Execution of the Project [140]

SE Principles

67

	Project Management	Systems Engineering Management
Planning	▪ Project Management Plan (PMP), Integrated Master Plan (IMP), and Integrated Master Schedule (IMS)	▪ Systems Engineering Management Plan, technical elements of the IMP/IMS, technical processes
Organizing	▪ Organizational Breakdown Structure (OBS) ▪ Work Breakdown Structure (WBS)	▪ Systems Engineering Organization Chart ▪ Working Groups ▪ Review ▪ Risk Management
Staffing	▪ Project Manpower Plan, Roll-on/Roll-off, Project Office Staff	▪ SE recruiting, training, team building
Controlling	▪ Earned Value Management, project reviews, Monthly Management Reviews	▪ EVMS, Engineering Change Board, Technical Metrics, Baseline Control, System Design Meetings
Directing	▪ Policies, Procedures, Training, Supervising, Performance Appraisals	▪ Requirements development, verification and validation, performance appraisals

The Hypothesis of Systems Engineering [108]

SE Principles

68

- If a solution exists for a specific context, then there exists at least one ideal Systems Engineering solution for that specific context
- System complexity greater than or equal to the ideal system complexity is necessary for fulfill all system outputs
- Key Stakeholder preferences can be represented mathematically
- The real physical system is the perfect model of the system

Systems Engineering Principles [108]

SE Principles

69

Systems Engineering …

1. Integrates the systems and the disciples considering the budget and schedule constraints
2. Confirms Complex Systems build Complex Systems
3. During the development phase, is focused on progressively deeper understanding of the interaction, sensitivities, and behaviors of the system
4. Has a critical role through the entire system life–cycle
5. Based on a middle range set of theories
6. Maps and manages the disciple interactions present in the decision-making process

Systems Engineering Principles [108]

SE Principles

70

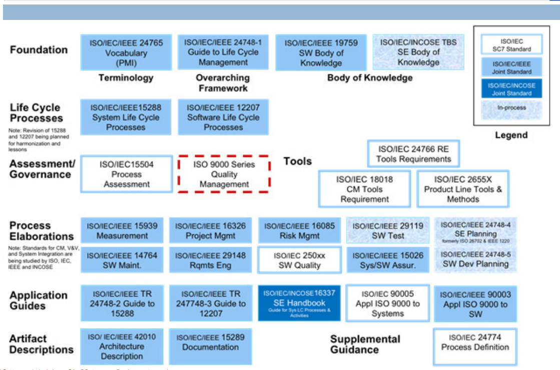
Systems Engineering …

7. Assures decision quality depends on coverage of system knowledge present in the decision-making process
8. Requires Policy and Law are properly understood for all system functions and interactions in the operational environment
9. Assures decision made under uncertainty account for risk
10. Verifies the system's value is demonstrated for the stakeholders
11. Validates the system's value is demonstrated for the stakeholder
12. Constrains the engineered solution is based on the decision timeframe for the system need

A Taxonomy of ISO System Engineering Standards

SE Principles

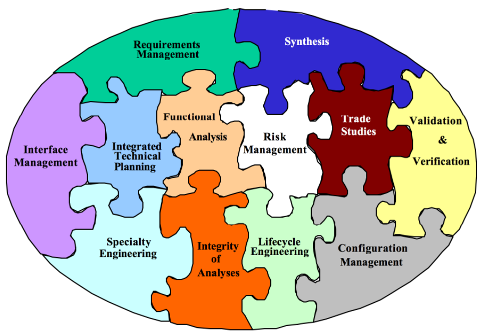
71

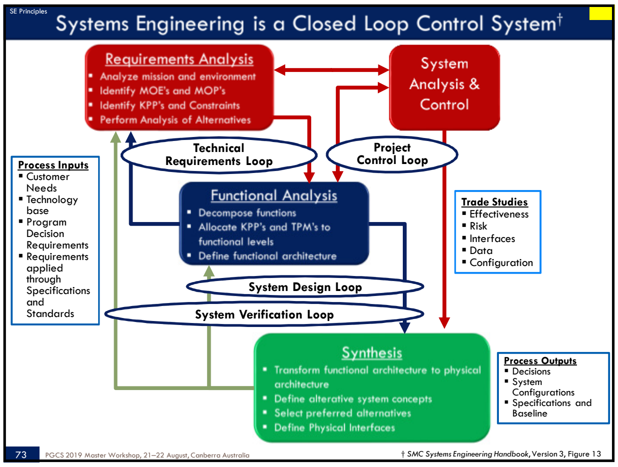


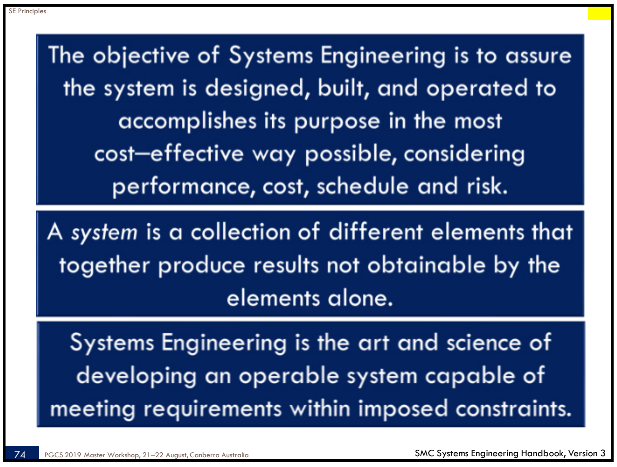
The Composite Elements of Systems Engineering

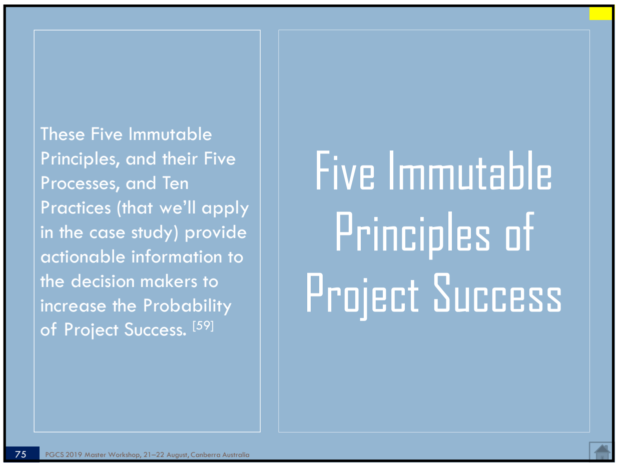
SE Principles

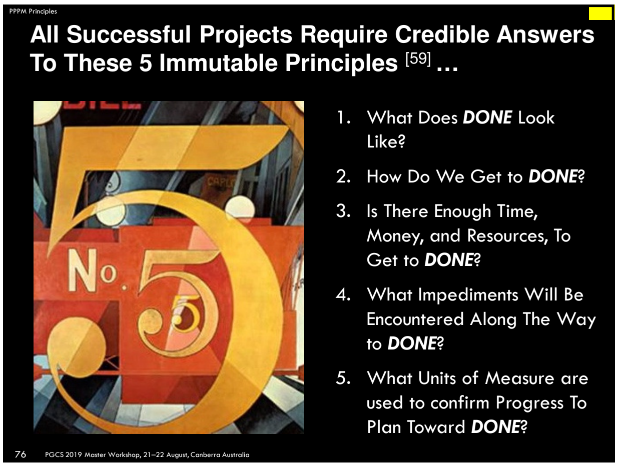
72

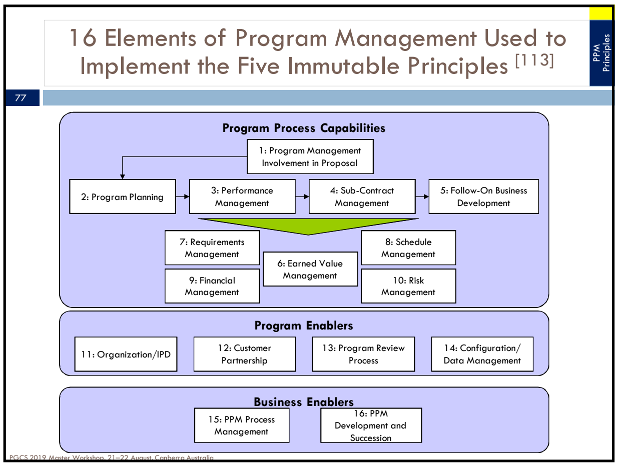


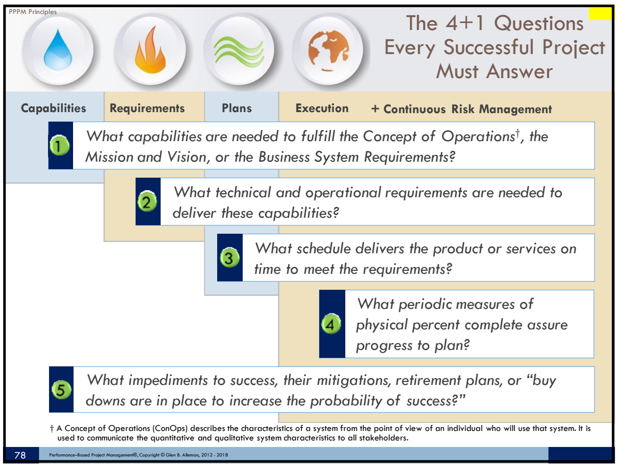

SE Principles
Systems Engineering is a Closed Loop Control System†
Requirements Analysis
Analyze mission and environment
Identify MOE's and MOP's
Identify KPP's and Constraints
Perform Analysis of Alternatives
System Analysis & Control
Technical Requirements Loop
Project Control Loop
Process Inputs
Customer Needs
Technology base
Program Decision Requirements
Requirements applied through Specifications and Standards
Functional Analysis
Decompose functions
Allocate KPP's and TPM's to functional levels
Define functional architecture
Trade Studies
Effectiveness
Risk
Interfaces
Data
Configuration
System Design Loop
System Verification Loop
Synthesis
Transform functional architecture to physical architecture
Define alterative system concepts
Select preferred alternatives
Define Physical Interfaces
Process Outputs
Decisions
System Configurations
Specifications and Baseline
73
† SMC Systems Engineering Handbook, Version 3, Figure 13

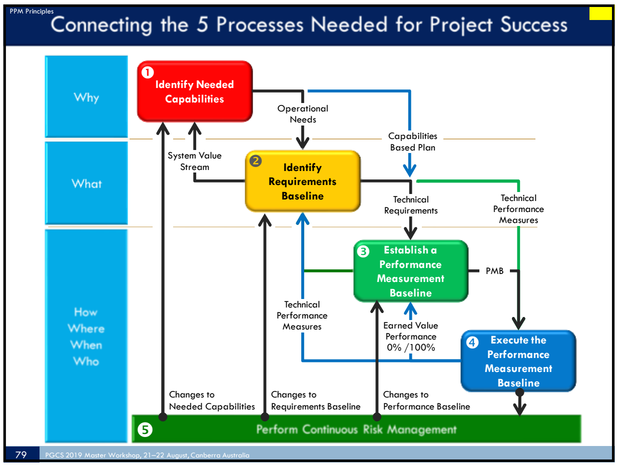

SE Principles
The objective of Systems Engineering is to assure the system is designed, built, and operated to accomplishes its purpose in the most cost–effective way possible, considering performance, cost, schedule and risk.
A system is a collection of different elements that together produce results not obtainable by the elements alone.
Systems Engineering is the art and science of developing an operable system capable of meeting requirements within imposed constraints.
74
SMC Systems Engineering Handbook, Version 3


These Five Immutable Principles, and their Five Processes, and Ten Practices (that we'll apply in the case study) provide actionable information to the decision makers to increase the Probability of Project Success. [59]
Five Immutable Principles of Project Success
75


PPPM Principles
All Successful Projects Require Credible Answers To These 5 Immutable Principles [59] …
1. What Does DONE Look Like?
2. How Do We Get to DONE?
3. Is There Enough Time, Money, and Resources, To Get to DONE?
4. What Impediments Will Be Encountered Along The Way to DONE?
5. What Units of Measure are used to confirm Progress To Plan Toward DONE?
76


16 Elements of Program Management Used to Implement the Five Immutable Principles [113]
PPM Principles
77
Program Process Capabilities
1: Program Management Involvement in Proposal
2: Program Planning
3: Performance Management
4: Sub-Contract Management
5: Follow-On Business Development
7: Requirements Management
6: Earned Value Management
8: Schedule Management
9: Financial Management
10: Risk Management
Program Enablers
11: Organization/IPD
12: Customer Partnership
13: Program Review Process
14: Configuration/ Data Management
Business Enablers
15: PPM Process Management
16: PPM Development and Succession


PPPM Principles
The 4+1 Questions Every Successful Project Must Answer
Capabilities
Requirements
Plans
Execution
+ Continuous Risk Management
1 What capabilities are needed to fulfill the Concept of Operations†, the Mission and Vision, or the Business System Requirements?
2 What technical and operational requirements are needed to deliver these capabilities?
3 What schedule delivers the product or services on time to meet the requirements?
4 What periodic measures of physical percent complete assure progress to plan?
5 What impediments to success, their mitigations, retirement plans, or "buy downs are in place to increase the probability of success?"
† A Concept of Operations (ConOps) describes the characteristics of a system from the point of view of an individual who will use that system. It is used to communicate the quantitative and qualitative system characteristics to all stakeholders.
78


PPM Principles
Connecting the 5 Processes Needed for Project Success
Why
What
How
Where
When
Who
1 Identify Needed Capabilities
Operational Needs
Capabilities Based Plan
System Value Stream
2 Identify Requirements Baseline
Technical Requirements
Technical Performance Measures
3 Establish a Performance Measurement Baseline
PMB
Technical Performance Measures
Earned Value Performance 0% /100%
4 Execute the Performance Measurement Baseline
Changes to Needed Capabilities
Changes to Requirements Baseline
Changes to Performance Baseline
5 Perform Continuous Risk Management
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PPM Principles
Five Process Areas Of Project Performance Management Success
1 Identify Needed System Capabilities
What capabilities are needed to fulfill the project's mission or business goals?
Define the set of capabilities needed to achieve the project objectives or the particular end state for a specific scenario. Using the Concept of Operations (ConOps), define the details of who, where, and how this capability is to be accomplished, employed, and executed.
2 Establish System Requirements
What technical and operational requirements are needed to produce these capabilities?
Define the technical and operational requirements for the system capabilities to be fulfilled. First, define these requirements in terms isolated from any implementation details. Only then bind the requirements with technology.
3 Establish the Performance Measurement Baseline
What is the schedule and cost to deliver products or services that meet the requirements?
Build a time–phased network of work activities describing the work to be performed, the budgeted cost for this work, the organizational elements that produce the deliverables, and the performance measures showing this work is proceeding according to plan.
4 Execute the Performance Measurement Baseline
What are the periodic measures of physical percent complete?
Execute work activities, while assuring all performance assessment represent 100% completion before proceeding. This means – No rework, no forward transfer of activities to the future. Assure all requirements are traceable to work & all work is traceable to requirements.
5 Perform Continuous Risk Management
What are the impediments to success and how are they being handled?
Apply the processes of Continuous Risk Management for each Performance–Based Project Management® process area to: Identify, Analyze, Plan, Track, Control, and Communicate programmatic and technical risk.
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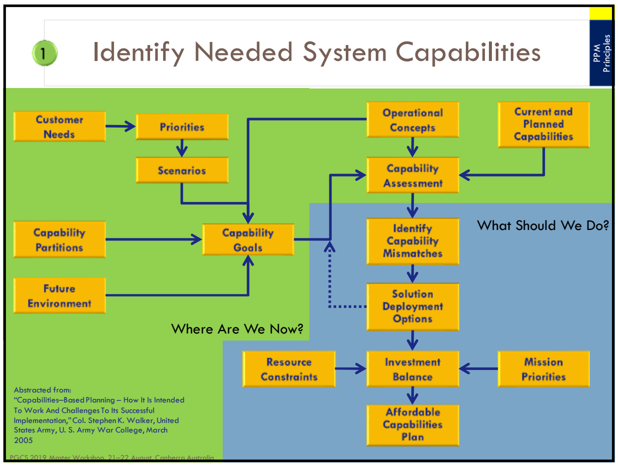
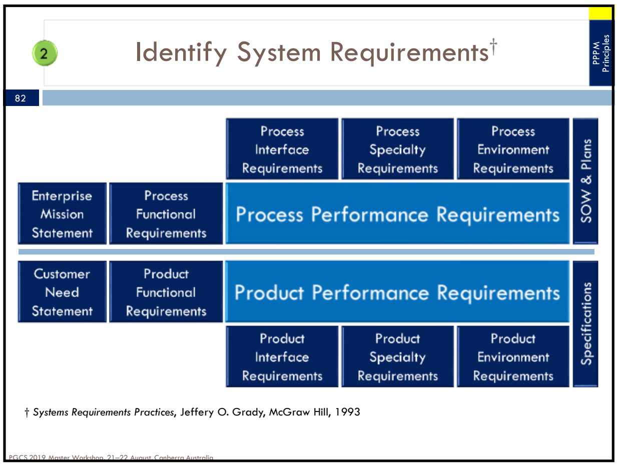
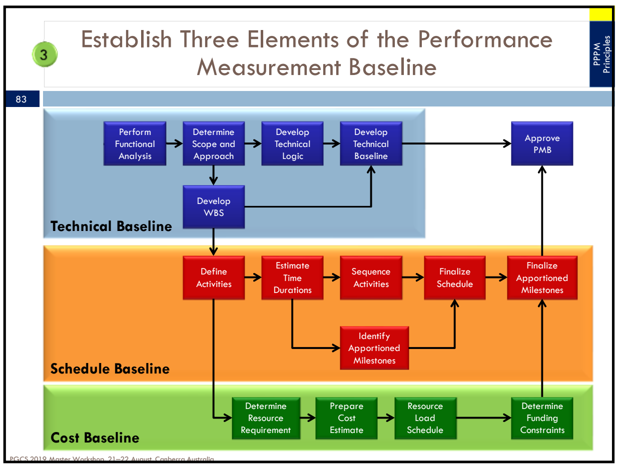
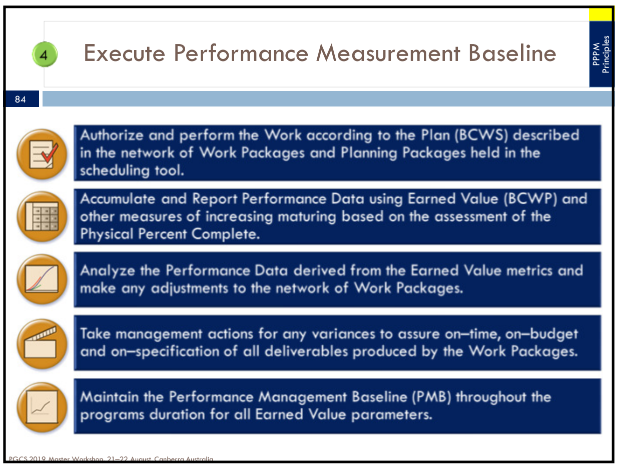
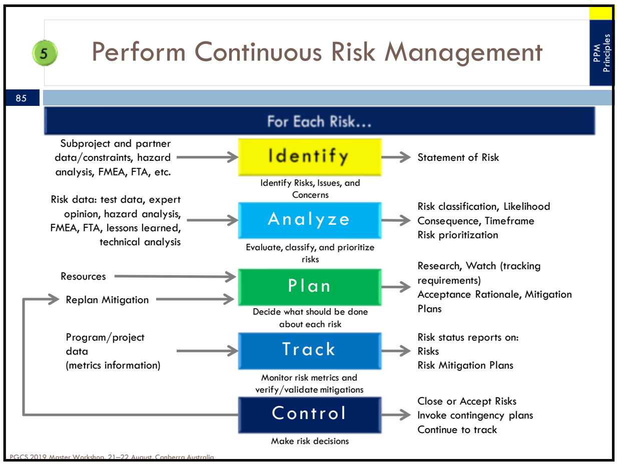
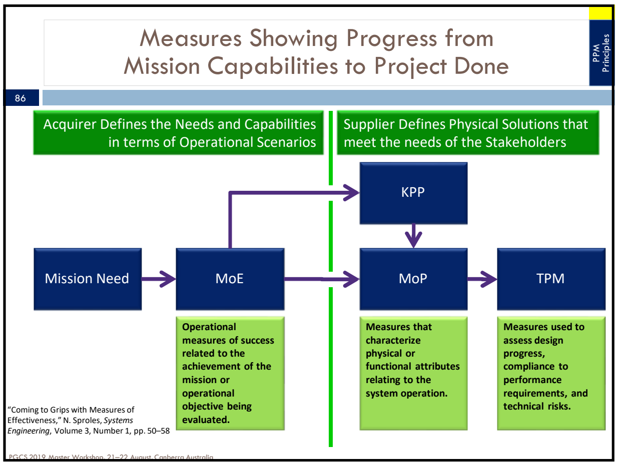

1 Identify Needed System Capabilities
PPPM Principles
Customer Needs
Priorities
Scenarios
Operational Concepts
Current and Planned Capabilities
Capability Assessment
Capability Partitions
Capability Goals
Future Environment
Identify Capability Mismatches
What Should We Do?
Solution Deployment Options
Where Are We Now?
Resource Constraints
Investment Balance
Mission Priorities
Affordable Capabilities Plan
Abstracted from: "Capabilities–Based Planning – How It Is Intended To Work And Challenges To Its Successful Implementation," Col. Stephen K. Walker, United States Army, U. S. Army War College, March 2005


2 Identify System Requirements†
PPPM Principles
82
Process Interface Requirements
Process Specialty Requirements
Process Environment Requirements
Enterprise Mission Statement
Process Functional Requirements
Process Performance Requirements
SOW & Plans
Customer Need Statement
Product Functional Requirements
Product Performance Requirements
Product Interface Requirements
Product Specialty Requirements
Product Environment Requirements
Specifications
† Systems Requirements Practices, Jeffery O. Grady, McGraw Hill, 1993


3 Establish Three Elements of the Performance Measurement Baseline
PPPM Principles
83
Perform Functional Analysis
Determine Scope and Approach
Develop Technical Logic
Develop Technical Baseline
Approve PMB
Develop WBS
Technical Baseline
Define Activities
Estimate Time Durations
Sequence Activities
Finalize Schedule
Finalize Apportioned Milestones
Identify Apportioned Milestones
Schedule Baseline
Determine Resource Requirement
Prepare Cost Estimate
Resource Load Schedule
Determine Funding Constraints
Cost Baseline


4 Execute Performance Measurement Baseline
PPPM Principles
84
Authorize and perform the Work according to the Plan (BCWS) described in the network of Work Packages and Planning Packages held in the scheduling tool.
Accumulate and Report Performance Data using Earned Value (BCWP) and other measures of increasing maturing based on the assessment of the Physical Percent Complete.
Analyze the Performance Data derived from the Earned Value metrics and make any adjustments to the network of Work Packages.
Take management actions for any variances to assure on–time, on–budget and on–specification of all deliverables produced by the Work Packages.
Maintain the Performance Management Baseline (PMB) throughout the programs duration for all Earned Value parameters.





Tangible Benefits of This Approach

PPM Principles

87

Project Performance Management	Benefits to the Customer
Program, Planning, and Controls	Rapid creation of the risk adjusted Performance Measurement Baseline.
Earned Value Management	ANSI–748D compliant processes, tools, and training.
Programmatic and Technical Risk Management	Credible integrated risk management process guided by DoD, DOE, AACE, and PMI standards.
Management Process Improvement	Value focused organizational change management.
Program Performance Assessment	Unbiased External Independent Reviews (EIR).
Proposal support – Management Volume	IMP/IMS, Basis of Estimate (BoE), and Risk sections.

Experience ensures performance and risk management needs are met through Project Performance Management principles, processes, and practices, to increase the Probability of Program Success.

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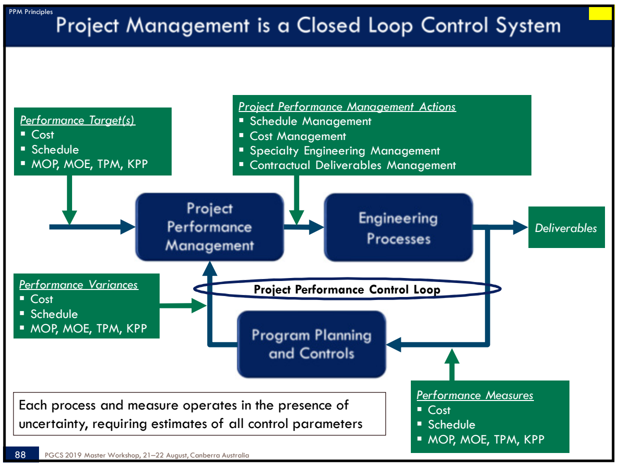

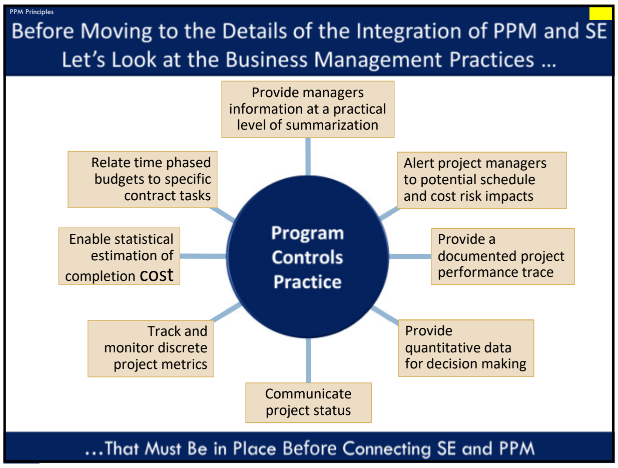

Two distinct paradigms can be integrated if the processes they are based on can be connected in a logically consistent manner.

— Plato's Dualism in *Phaedo*

Basis for Integrating *Systems Engineering* with *Project Management*

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Seven Key Principles of Program and Project Success [125]

91

1. Establish a clear and compelling vision.
2. Secure sustained support "from the top".
3. Exercise strong leadership and management.
4. Facilitate wide open communication.
5. Develop a strong organization.
6. Manage risk.
7. Implement effective systems engineering and integration.

Some Simple Definitions of PPM and SE

92

Project Performance Management

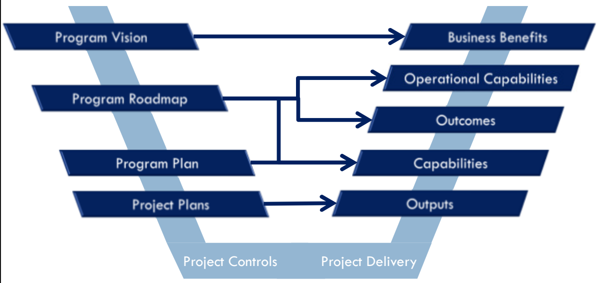
- Plan and coordinate work activities needed to deliver a satisfying product.
- Monitoring accomplishments of project objectives.
- Control and implement corrective and preventative action that are impediments to project progress to plan.

Systems Engineering

- The art and science of developing operable systems capable of meeting requirements within opposed constraints.
- Seek a safe and balanced design in the face of opposing interested and multiple, sometimes conflicting constraints.

Using the Vee to Integrate SE and PPM [98]

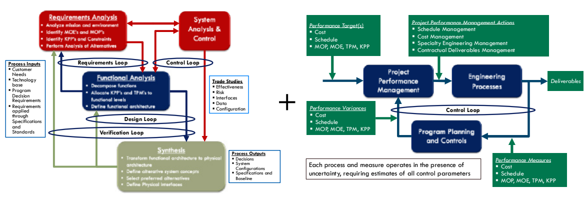
93



Separate but Equal Components of an Integrated Project Performance Management System (IPPMS)

94

System Engineering + Project Performance Management



Separating *What* from *How* is a Critical Success Factor for the IPPMS [88]

95

- Understanding the Problem (***What***) is independent of the managing the development of the solution (***How***)
- For any given problem (***What***) there are many possible solutions (***How***)
- The *separation of concerns* is the basis of good Systems Engineering
- Seldom are systems built from scratch
  - Most systems are implemented using new technology or integrating previous systems into the new system

What is an Integrated Project Performance Management System (IPPMS)?

96

- Project Performance Management – is preplanned to achieve the desire results, or actions taken as a corrective or preventative measures prompted by the monitoring process.
- Project performance management is concerned with the metric of the Project – quantities, time, cost, and other resources.
- Forecasts of project revenues, delivered customer value, and cash flow.
- Performance metrics of the IPPMS starts by focusing on delivery of business or mission *Value* in exchange for the *Cost* of that *Value* at the need delivery date.

Success Starts with Capabilities–Based Planning

97

- What capabilities do we need to posses to accomplish our mission?
- What are the *Measures of Effectiveness* and *Measures of Performance* for these Capabilities?
- What *Technical Performance Measures* are needed for each deliverable that fulfills the Measures of Effectiveness and Measures of Performance?

Units of Measure in the Systems Engineering Domain [96]

98

- Measures of Effectiveness (MOE)
- Measures of Performance (MOP)
- Key Performance Parameters (KPP)
- Key Systems Attributes (KSA)
- Technical Performance Parameters (TPM)

Measures of Effectiveness (MOE)

99

Operational measures of success that are closely related to the achievements of the mission or operational objectives evaluated in the operational environment, under a specific set of conditions.

Measures of Effectiveness …

- Are stated in units meaningful to the buyer,
- Focused on capabilities independent of any technical implementation, and
- Are connected to the mission success.

MoE's Belong to the End User

"Technical Measurement," INCOSE–TP–2003–020–01

Measures of Performance (MOP)

100

Measures that characterize physical or functional attributes relating to the system operation, measured or estimated under specific conditions.

Measures of Performance are …

- Attributes that assure the system has the capability and capacity to perform the need Capabilities,
- An assessment of the system that assures it meets design requirements to satisfy the MoE.

MoP's belong to the Program – Developed by the Systems Engineer, Measured By CAMs, and Analyzed by PP&C

"Technical Measurement," INCOSE–TP–2003–020–01

Key Performance Parameters (KPP)

101

Measures that Represent the capabilities and characteristics so significant that failure to meet them can be cause for reevaluation, reassessing, or termination of the program

Key Performance Parameters …

- Have a threshold or objective value,
- Characterize the major drivers of performance,
- Are considered Critical to Customer (CTC).

The acquirer defines the KPPs during the operational concept development – KPPs say what DONE looks like

"Technical Measurement," INCOSE–TP–2003–020–01

Key System Attributes (KSA)

102

Are attributes considered most critical or essential for an effective capability but not selected as KPPs.

- Key System Attributes …
- Provide decision makers with an additional level of capability prioritization below the KPP.
- A KSA does not have to be related to a KPP and there is no implication that multiple KSA's equal a KPP.

Technical Performance Measures (TPM)

103

Attributes that determine how well a system or system element is satisfying or expected to satisfy a technical requirement or goal

Technical Performance Measures …

- Assess design progress,
- Define compliance to performance requirements,
- Identify technical risk,
- Are limited to critical thresholds,
- Include projected performance.

"Technical Measurement," INCOSE–TP–2003–020–01

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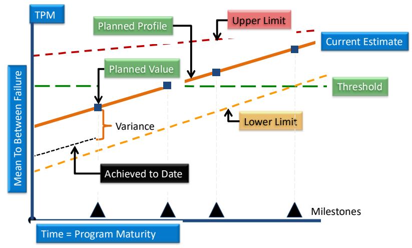
Technical Performance Measurement

104

Technical Performance Measurement (TPM) involves a technique of predicting the future value of a key technical performance parameter of the higher-level end product under development based on current assessments of products lower in the system structure. [154]



TPMs are the measurement to inform Physical Percent Complete at the Task level

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As an Example, Let's Start with Measures of Effectiveness (MOE) and Measures of Performance (MOP) For a New Stylish Coffee Cup

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MOE and MOP Starting Points of Success of a Stylish Coffee Cup [167]

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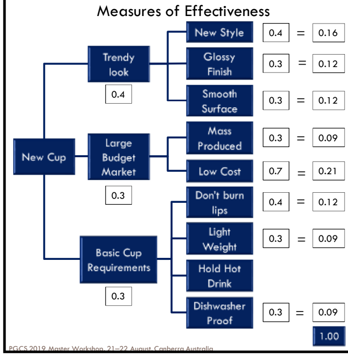
Measures of Effectiveness



Measures of Performance

Need Want	Specification
N	Weight < 120g
W	Weight < 100g
N	Non-Porous
N	Thermal Conductivity < 2.5W/m.K
W	< 1.4 W/m.K
W	Surface Finish <±0.04mm
N	Produce > 5000 items/day
W	> 8000 items/day
N	Rigid solid @ ~110°C
W	Reflective coating
W	Volume ~ 280–350ml

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These Two ½'s Make a Whole

107

SE is an interdisciplinary field of engineering and management focused on to designing and managing complex systems over their life cycles.
At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge.

\+

PM is the Principles, Processes, and Practices for identifying and managing work needed deliver the outcomes meeting the Measures of Effectiveness (MOE) and Performance (MOP) and their Key Parameters (KPP)

=

With the Measures of ***Physical Percent Complete*** from the Principles, Processes, and Practices we can answer…

- What is our progress to plan?
- Are we ahead or behind schedule?
- Are the deliverables complaint with the requirements?

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The Challenge of Integrating SE and PPM is to *Increase the Probability of Project Success*

108

Systems Engineering and Project Management are tightly intertwined domains.

– *Handbook of Systems Engineering and Management*, Sage and Rouse, 2009

While Project Management has accountability for cost and schedule performance and Systems Engineering has accountability for technical and systems elements of the program – these activities are not separate.

Both Project Performance Management and Systems Engineering are part of in integrated framework for increasing the Probability of Project Success.

– *Toward a New Mindset: Bridging the Gap Between Program Management and Systems Engineering*, PMI® Global Congress 2011

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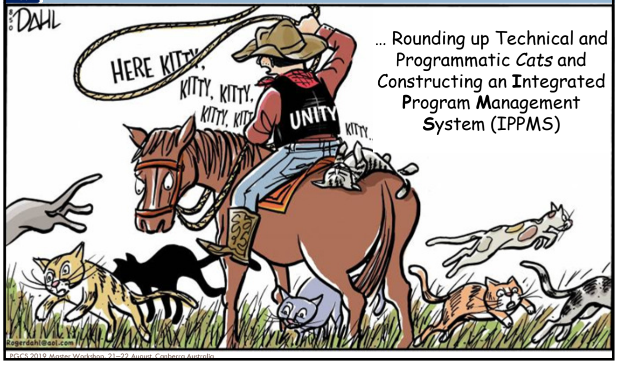
Increasing the Probability of Project Success Start By …

Integrating SE & PPM

109



… Rounding up Technical and Programmatic *Cats* and Constructing an **I**ntegrated **P**rogram **M**anagement **S**ystem (IPPMS)

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SoS

"Complex systems usually come to grief, when they do, not because they fail to accomplish their nominal purpose.

Complex systems typically fail because of the unintended consequences of their design …

"I like to think of System Engineering as being fundamentally concerned with minimizing, in a complex artifact, unintended interactions between elements desired to be separate.

Essentially, this addresses Perrow's [181] concerns about tightly coupled systems. System engineering seeks to assure that elements of a complex artifact are coupled only as intended."

– Michael Griffin, NASA Administrator, Boeing Lecture, Purdue University, March 28, 2007

A System of Systems (SoS) Framework

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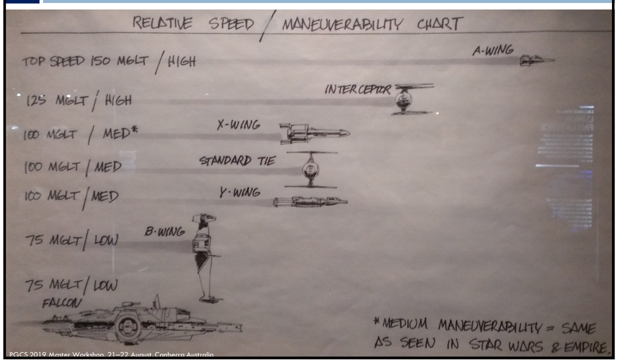
At The Top of the SoS is Where We Define *Needed Capabilities*

System of Systems

111



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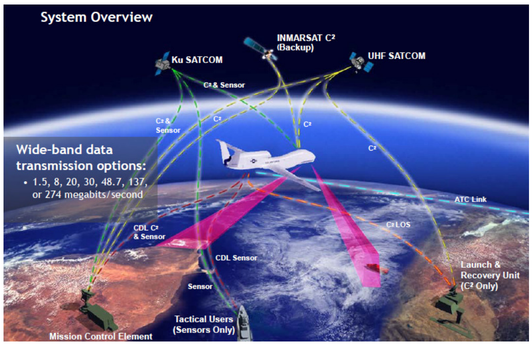
An Actual System of Systems (SoS)

System of Systems

112



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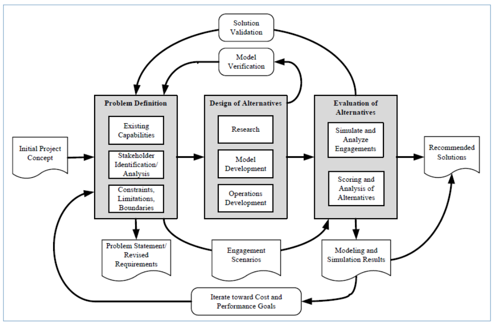
A System of Systems Process Model †

System of Systems

113



† Roving UAV IED Interdiction System, MSSE Cohort 311–093A, Naval Post Graduate School, March 2001

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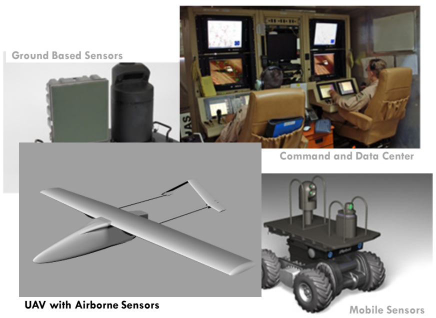
A Look Ahead to a System of Systems

System of Systems

114



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Learning's from Prior SoS UAV Projects

System of Systems

115

Requirements Complexity	▪ Challenging requirements downstream raise unavoidable complexity throughout program lifecycle ▪ Lack of requirements rationale permit unnecessary requirements ▪ Requirements volatility creates moving target for designers
System Level Design and Analysis	▪ Engineering trade studies not done: a missed opportunity ▪ Architectural thinking/review needed at level of systems, hardware, software, and operational processes
System Complexity	▪ Inadequate system architecture and poor implementation ▪ General lack of design patterns (and architectural patterns) ▪ Coding guidelines help reduce defects and improve static analysis ▪ De–scopes often shift complexity to operations
V&V Complexity	▪ Growth in testing complexity due to Cross–Cutting functions ▪ More components and interactions to test ▪ COTS products a mixed blessing
Operational Complexity	▪ Shortsighted decisions make operations unnecessarily complex ▪ Numerous "operational workarounds" raise risk of command errors

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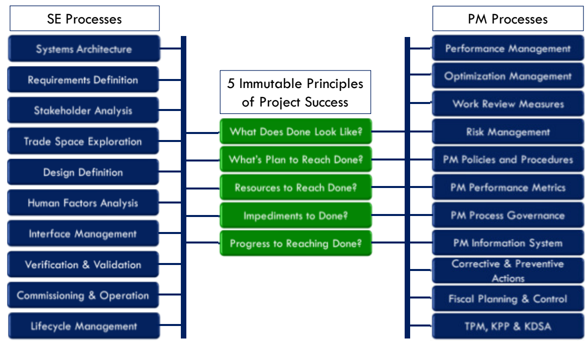
Connecting the Dots Between Systems Engineering and Project Management

System of Systems

116



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SE + PM

It has been shown that we can increase the Probability of Project Success (PoPS), by integrating Systems Engineering and Project Performance Management

Relationship between Systems Engineering and Project Management

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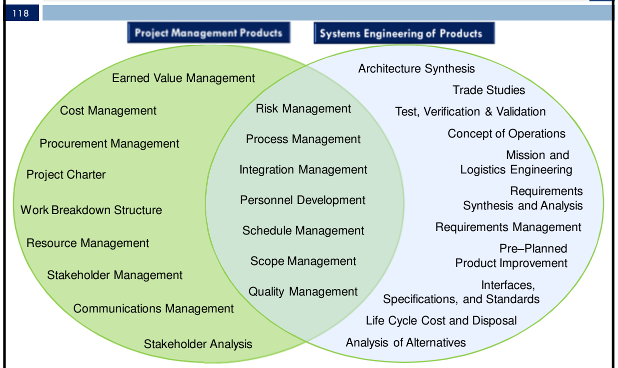
Relationships Between PPM and SE

SE + PM

118

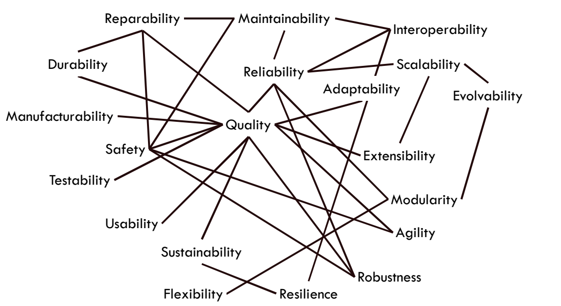


PGCS 2019 Master Workshop, 21–22 August, Canberra Australia Dennis Van Gemert, 2013

…ilities are Critical Attributes of all Systems

SE + PM

119



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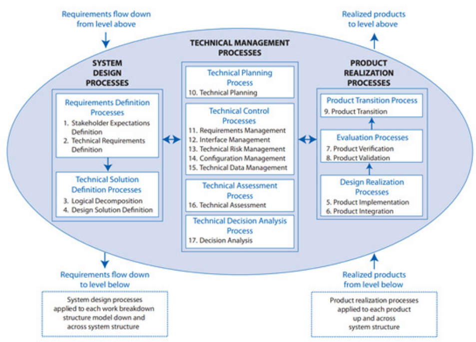
Fundamentals of Systems Engineering [26]

SE + PM

120



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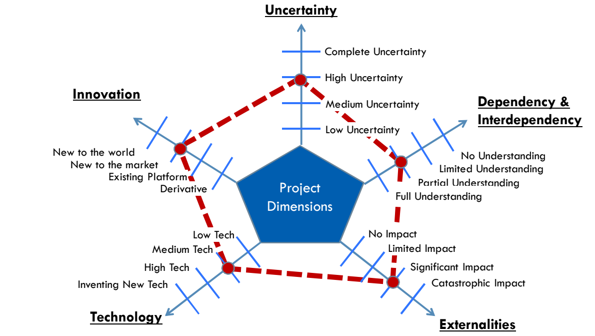
Dimensions of Project Complexity and the Problems it Creates

SE + PM

121



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Risk

Risk Management is Project Management for Adults

— Tim Lister

Risk Management of Cost, Schedule, and Technical Performance Starts with Systems Engineering

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Risk

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Managing in the Presence of Reducible and Irreducible Uncertainty that Created Risk

Risk

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It is moronic to predict without first establishing an error rate for the prediction and keeping track of one's past record of accuracy.
— Nassim Nicholas Taleb, *Fooled By Randomness*

Naturally occurring uncertainties (Aleatory) in cost, schedule, and technical performance are modeled with a Monte Carlo Simulation tool.

The Event Based uncertainties (Epistemic) require capturing, modeling of impacts, defining handling strategies, modeling effectiveness of these handling efforts, and residual risks, and their impacts of both the original risk and the residual risk on the program.

The management of Uncertainties in cost, schedule, and technical performance critical success factors for all programs.

Risk Management starts with ***estimating*** the probability of Epistemic Event Based Risks and the statistical Aleatory uncertainty of the normal work.

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Risk

Core Elements of Project Risk Management

Risk

125

- The effectiveness of risk management depends on the people who set up and coordinate the risk management process.
- On many program's risk management consists only of having a policy and oversight.
- If we treat *red flags* as false alarms rather than early warnings of danger this incubates the threats to program success.
- Group think of dominate leaders often inhibits good thinking about risks.

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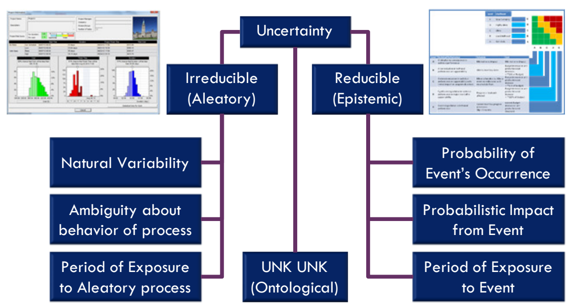
All Risk comes from Uncertainty, which comes in two forms — reducible and irreducible

Risk

126



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Aleatory & Epistemic Uncertainty

Risk

127

- ***Aleatory*** Pertaining to stochastic (non–deterministic) events, the outcome of which is described using probability.
  - From the Latin *alea*
  - For example in a game of chance stochastic variability's are the natural randomness of the process and are characterized by a probability density function (PDF) for their range and frequency
  - Since these variability's are natural they are therefore irreducible.
- ***Epistemic*** (subjective or probabilistic) uncertainties are event based probabilities, are knowledge–based, and are reducible by further gathering of knowledge.
  - Pertaining to the degree of knowledge about models and their parameters.
  - From the Greek episteme (knowledge).

Separating these classes helps in design of assessment calculations and in presentation of results for the integrated program risk assessment.

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Technical and Programmatic Risk

Risk

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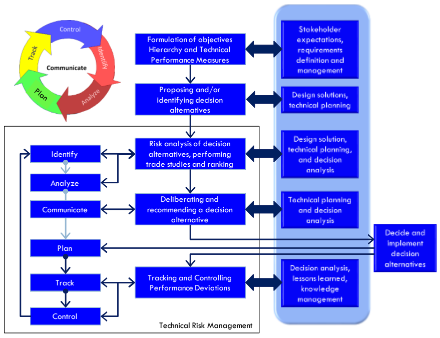

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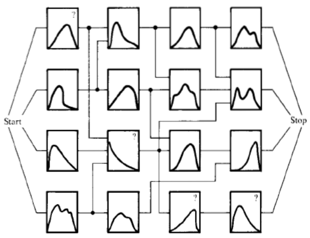
Naturally Occurring Uncertainty in the IMS Creates Risk

Risk

129

- Cost
- Schedule
- Capacity for work
- Productivity
- Quality of results
- Activity correlation



With the naturally occurring uncertainty between –5% to 20% in our work effort durations, we have an 80% confidence of completing on or before our target date – PP&C speaking to PPM

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Complex

All non-trivial systems have complexity, are complex, and may be complicated.

We need a means to sort these out and produce a clear and concise description of what the system does, how we're going to develop the system, and how to measure our progress toward DONE

Sorting Out the Programmatic Complexity Needed to Address the Technical Complexity

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Sorting Out Complexity Starts with a Credible Performance Measurement Baseline (PMB)

Complex

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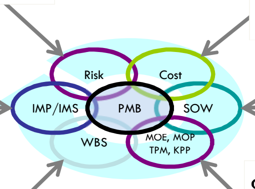
❸ Technical and Programmatic ***Risks*** Connected through the WBS, Risk Register, IMP and IMS

❷ ***IMS*** contains all the Work Packages, BCWS, Risk mitigation plans, with traces to the ***IMP*** measuring increasing maturity through Measures of Effectiveness (MoE) and KPPs (JROC and Program)

❶ ***WBS*** contains Products and Processes in a "well structured" decomposition, traceable to the deliverables



The PMB is the Document of Record for the Project ***Performance is Measured through the PMB***

❹ BCWS at the Work Package level, rolled to the Control Accounts showing cost spreads for all work in the IMS

❺ Deliverables defined in the SOW, traced to the WBS, with narratives and Measures of Performance (MoP)

❻ Starting with MoP for each critical deliverable in the WBS and identified in each Work Package in the IMS, used to assess maturity in the IMP

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1 The WBS is Paramount

Complex

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- The WBS defines the deliverables and the supporting processes that produce them
- The WBS Dictionary describes the technical and operation behaviors that will be assessed during the development of the deliverables
- The terminal nodes of the WBS define the deliverables produced by the Work Packages in the IMS and assessed through the IMP Accomplishment Criteria (AC)

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2 Integrated Master Plan (IMP) Integrated Master Schedule (IMS)

133

- The IMP defines increasing maturity for the deliverables as the program "moves from left to right"
- Significant Accomplishments (SA) assessed with Measures of Effectiveness (MoE)
- Accomplishment Criteria (AC) assessed with Measures of Performance (MoP)
- Work Packages rolled up the AC's
- Risks are assigned at all levels of the IMP and IMS

3 All Risk Comes from Uncertainty

134

- Natural occurring (Aleatory) uncertainties create risk in cost and schedule processes create risks to completing on time and on budget
- Event based uncertainties (Epistemic) create risk that impacts to cost, schedule, and technical performance
- Epistemic risks are *handled* through risk mitigations
- Aleatory risks are *handled* through in cost, schedule, and technical performance margin
- To be credible, the PMB must include both type of risks with their handling strategies

4 Costs are assigned to *Package of Work*

135

- Labor and material cost are represented in the Integrated Master Schedule (IMS) and provide visibility to the probability of program success
- Variances in labor and material costs are modeled in the same way as work durations
- Event based risks impact both cost and schedule and are modeled in the PMB
- Risk retirement cost is allocated for the work effort in response to Event Based risks

5 Statement of Work

136

- Work in the PMB starts with the Statement of Work and flows through the Work Breakdown Structure to the Deliverables
- Measures of Effective (MoE) and Measures of Performance (MoP) defined in the SOW or WBS Dictionary with Technical Performance Measures
- Traceability from the IMP to the IMS to all performance measures in the SOW is the basis of program performance measurement
- Measures of Physical Percent Complete for each Deliverable is the Basis of Project Success

6 Technical Performance Measures

137

- Key Performance Parameters (KPP) and Technical Performance Measures (TPM) define how deliverables comply with the Statement of Work (WBS) and Concept of Operations (CONOPs).
- TPMs inform Physical Percent Complete for cost and schedule measures of delivered project outcomes.
- TPM, MoE, MoP, and KPPs provide assessment of the cost and schedule performance.

WBS

The Work Breakdown Structure is the starting point for developing all other elements needed for the Performance Measurement Baseline.

The TSAS WBS is defined using the MIL–STD–881D Appendix H for the UAV.

From this, the details of the avionics subsystems will be used for the development of the Integrated Master Plan and Integrated Master Schedule.

Project Success Starts with the Work Breakdown Structure is Paramount

138

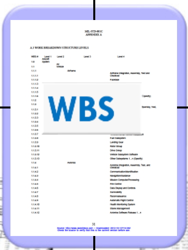
The WBS is Paramount†

WBS

139

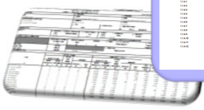
Technical
- TPMs
- Specifications
- Design docs
- Performance char.

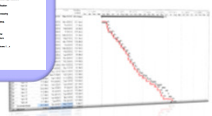
Risk & Risk Assessment
- Level of Detail
- Program Oversight level of detail



Earned Value
Cost and Schedule Status

Plan and Schedule
IMP / IMS



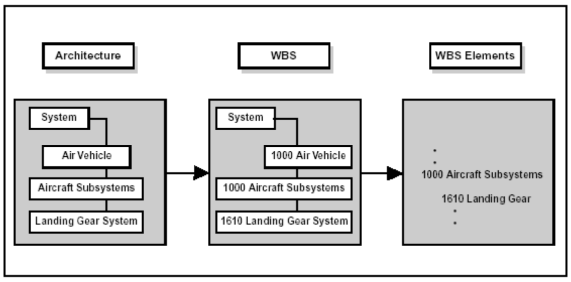


† Glen B. Alleman, Institute for Defense Analyses
Gordon Kranz, DOD (OSD) PARCA

Physical Architecture and the WBS

WBS

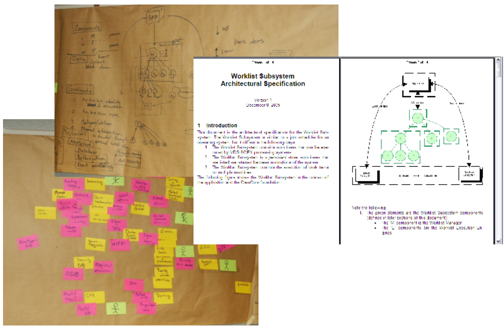
140



Systems Architecture Drives the Work Breakdown Structure

WBS

141



IMP

A primary failure mode of complex programs is not having a clear, concise, measurable definition of Done, in units of measure meaningful to the decision makers

This starts with the Integrated Master Plan [112]

The Description of DONE Starts with the Integrated Master Plan (IMP)

The IMP tells us What Done Looks Like in Units of Measure Meaningful to the Decision Makers

The Integrated Master Plan (IMP) Is A Strategy For The Successful Completion Of The Project

The Plan describes where we are going, the various paths we can take to reach our destination, and the progress or performance assessment points along the way to assure we are on the right path.

These assessment points measures the "maturity" of the product or service against the planned maturity. This is the only real measure of progress – not the passage of time or consumption of money.

Quick View of Step–By–Step IMP

IMP

144

1. Identify Program Events (PE) – Maturity Assessment
2. Identify Significant Accomplishments (SA) – entry criteria to the PE's
3. Identify Accomplishment Criteria (AC) – exit criteria from Work Packages
4. Identify Work Packages needed to complete the Accomplishment Criteria (AC)
5. Sequence the Work Packages (WP), Planning Packages (PP), Summary Level Planning Packages (SLPP) in a logical network in the IMS.
6. Adjust the sequence of WPs, PPs, & SLPPs to mitigate major risks.

Attributes of the IMS

IMP 145

- Integrated, networked, multi–layered schedule of efforts required to achieve each IMP AC
  - Detailed tasks and work to be completed
  - Calendar schedule shows work completion dates
  - Network schedule shows interrelationships and critical path
  - Expanded granularity, frequency, and depth of risk areas
- Resource loading
- The IMS is vertically traceable to IMP events, through AC's and SA's

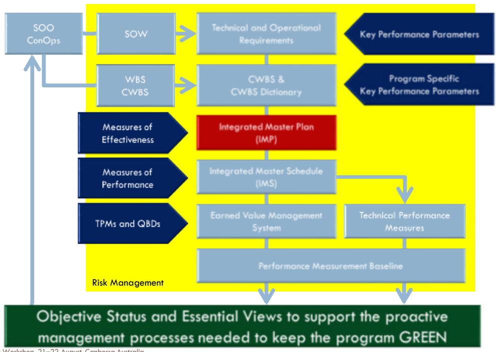
The Importance of the IMP

IMP 146

- The IMP is the single most important document to a program's success
  - It clearly demonstrates the providers understanding of the program requirements and the soundness of the approach a represented by the plan
- The IMP/IMS provides:
  - Up Front Planning and Commitment for needed Capabilities from all participants
  - A balanced design discipline with risk mitigation activities
  - Integrated requirements including production and support
  - Management with an incremental verification for informed program decisions

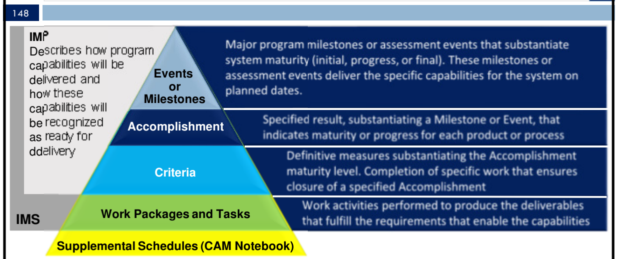
Building the IMP Starts at the RFP with Systems Engineering Measures

IMP 147



The IMP / IMS Structure

IMP 148

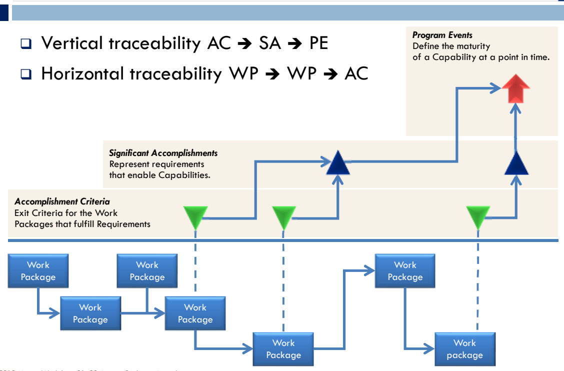


This decomposition is not unique to the IMP/IMS paradigm. Without some form of decomposition of what ***DONE*** looks like, it is difficult to connect the work of the project to the outcomes of the project. This decomposition – which is hierarchical – provides the mechanism to increase cohesion and decrease coupling of the work effort. This coupling and cohesion comes from the systems architecture world is has been shown to increase the robustness of systems. The project cost, schedule, and resulting deliverables are a system, subject to these coupling and cohesion.

Vertical and Horizontal traceability of project work shows increasing maturity as units of ***Physical Percent Complete***

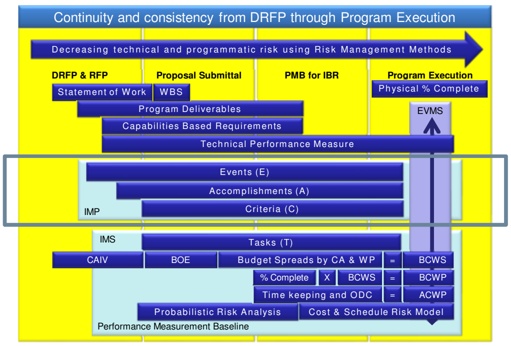
IMP 149

- Vertical traceability AC → SA → PE
- Horizontal traceability WP → WP → AC



The Integrated Master Plan's role during Project Execution

IMP 150



F–22 IMP Example

- Program Event (PE)
  - A PE assess the readiness or completion as a measure of progress
  - *First Flight Complete*
- Significant Accomplishment (SA)
  - The desired result(s) prior to or at completion of an event demonstrate the level of the program's progress
  - *Flight Test Readiness Review Complete*
- Accomplishment Criteria (AC)
  - Definitive evidence (measures or indicators) that verify a specific accomplishment has been completed
  - *SEEK EAGLE Flight Clearance Obtained*

IMP

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5 Steps

The Integrated Master Plan (IMP) says what Done looks like in measures of increasing maturity of the Deliverables, through assessment of the Significant Accomplishments and Accomplishment Criteria [111]

5 + 1 Steps to Building the IMP/IMS

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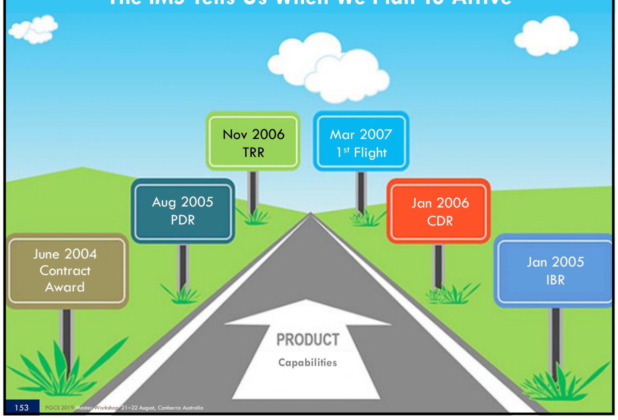
5 Steps

The IMP Tells Us Where We Are Going The IMS Tells Us When We Plan To Arrive



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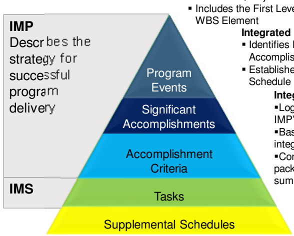
IMP and IMS evolves from RFP to Performance Measurement Baseline, providing traceability from RFP to delivered products and services

5 Steps

154



Program Master Schedule
- Presents the Contract Period of Performance (POP), Program Events (PE), Key Milestones, Major Program Deliverables, and Reports Progress at a Summary Level
- Includes the First Level WBS and Significant, Measurable Events for Each Level-Two WBS Element

Integrated Master Plan (IMP)
- Identifies Program Events (PE), Significant Accomplishments (SA), and Accomplishment Criteria (AC).
- Establishes the Structure, Parameters & Basis For the Integrated Master Schedule (IMS) Development

Integrated master schedule (IMS)
- Logic network schedule of program planned activities keyed to the IMP's accomplishment criteria
- Basis of performance measurement system; common element integrating cost, schedule, & performance
- Constructed to provide integrated planning down to the work package task level, provides horizontal & vertical traceability, summarization of info and critical path identification and analysis

Supplemental schedules
- Created - as needed - to provide lower levels of detail data within these schedules are summarized in the IMS and are part of the program's Performance Measurement Baseline (PMB)
- Supports control account schedules and the management of day-to-day operations

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5 + 1 Steps to a Credible IMP/IMS

5 Steps

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The problem of … process change is often complicated by the fact that no one is responsible to make it happen. If it is important enough to do, however, someone must be assigned the responsibility and given the necessary resources. Until this is done, process development will remain a nice thing to do someday, but never today.
– Watts Humphrey

1. Identify Program Events (PE)
2. Identify Significant Accomplishments (SA)
3. Identify Accomplishment Criteria (AC)
4. Identify work for each Accomplishment Criteria
5. Sequence Work Packages
6. Assemble IMP/IMS

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1 Identify Program Events

5 Steps

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Actors	Processes	Outcomes
Systems Engineer	Define the process flow for product production from contract award to end of contract	Confirmation that the Program Events represent the logical process flow for program maturity
Program Manager	Confirm customer is willing to accept the process flows developed by the IMP	Engagement with contracts and customer for PE definition
Project Engineer	Identify interdependencies between program event work streams	Value Stream components identified at the PE level before flowing them down to the SA level
IMP/IMS Architect	Capture Program Event contents for each IPT or work stream	Lay the foundation for a structure to support the description of the increasing mature as well as the flow to needed work.

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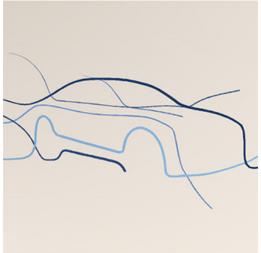
1 Program Events are the Assessment of the Evolving Maturity of the Program's Capabilities

5 Steps

157



- Program Events are maturity assessment points in the program
- They define what levels of maturity for the products and services are needed before proceeding to the next maturity assessment point
- The entry criteria for each Event defines the units of measure for the successful completion of the Event
- The example below is typical of the purpose of a Program Event

The Critical Design Review (CDR) is a multi-disciplined product and process assessment to ensure that the system under review can proceed into system fabrication, demonstration, and test, and can meet the stated performance requirements within cost (program budget), schedule (program schedule), risk, and other system constraints.

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2 Identify Significant Accomplishments (SA) for Each Program Event (PE)

5 Steps

158

Actors	Processes	Outcomes
System Engineer	Identify Integrated Product Teams (IPT) responsible for the SA's	Define the boundaries of these programmatic interfaces
Technical Lead	Confirm the sequence of SA's has the proper dependency relationships	Define the product development flow process improves maturity
Project Engineer	Confirm logic of SA's for project sequence integrity	Define the program flows improves maturity
CAM	Validate SA outcomes in support of PE entry conditions	Confirm budget and resources adequate for defined work effort
IMP/IMS Architect	Assure the assessment points provide a logical flow of maturity at the proper intervals for the program	Maintain the integrity of the IMP, WBS, and IMS

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2 The SA's Define The Entry Criteria for Each Program Event

5 Steps

159

Preliminary Design Review Complete

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3 Identify Accomplishment Criteria (AC) for SA

5 Steps

160

Actors	Processes	Outcomes
CAM	Define and sequence the contents of each Work Package and select the EV criteria for each Task needed to roll up the BCWP measurement	Establish ownership for the content of each Work Package and the Exit Criteria – the Accomplishment Criteria (AC)
Project Engineer	Identify the logical process flow of the Work Package to assure the least effort, maximum value and lowest risk path to the Program Event	Establish ownership for the process flow of the product or service
Technical Lead	Assure all technical processes are covered in each Work Package	Establish ownership for the technical outcome of each Work Package
IMP/IMS Architect	Confirm the process flow of the ACs can follow the DID 81650 structuring and Risk Assessment processes	Guide the development of outcomes for each Work Package to assure increasing maturity of the program

3 AC's Are Higher Fidelity Models of the Program's Increasing Maturity Flow

5 Steps

161

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4 Work Packages Identify Work for Each Accomplishment Criteria

5 Steps

162

Actors	Processes	Outcomes
Control Account Manager	Identify or confirm the work activities in the Work Package represent the allocated work	Bounded work effort defined "inside" each Work Package
Technical Lead	Confirm this work covers the SOW and CDRLs	All work effort for 100% completion of deliverable visible in a single location – the Work Package
IMP/IMS Architect	Assist in the sequencing the work efforts in a logical manner	Foundation of the maturity flow starting to emerge from the contents of the Work Packages
Earned Value Analyst	Assign initial BCWS from BOE to Work Package	Confirmation of work effort against BOEs

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4 Work is Done in "Packages" that Produce Outcomes Measured with TPM's

5 Steps

163

5 Sequence Work Packages (ACs) for each Significant Accomplishment (SA)

5 Steps

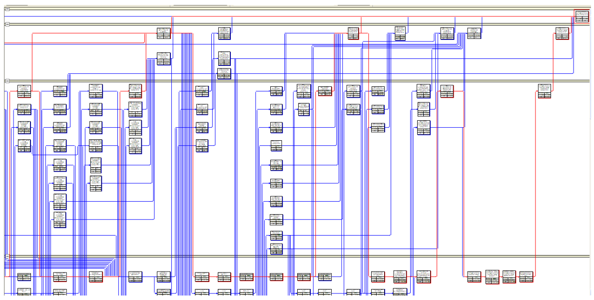
164

Actors	Processes	Outcomes
CAM	Define the order of the Work Packages needed to meet the Significant Accomplishments for each Program Event	Define the process flow of work and the resulting accomplishments to assure value is being produced at each SA and the AC's that drive them
IMP/IMS Architect	Assure that the sequence of Work Packages adheres to the guidance provided by DCMA and the EVMS System description	Begin the structuring of the IMS for compliance and loading into the cost system
Program Controls	Baseline the sequence of Work Packages using Earned Value Techniques (EVT) with measures of Physical Percent Complete	Direct insight to progress to plan in measures of physical progress

5 Sequence Work Packages (AC's) into an IMS for each Program Event

5 Steps

165



6 Assemble Final IMP/IMS

5 Steps

166

Actors	Processes	Outcomes
IMP/IMS Architect	Starting with the AC's under each SA's connect Work Packages in the proper order for each Program Event to increase the maturity of each deliverable	Establish the Performance Measurement Baseline framework with EAC and their measure
Program Manager	Confirm the work efforts represent the committed activities for the contract	Review and approval of the IMS – ready for baseline
Project Engineer	Assess the product development flow for optimizations	Review and approval of the IMS – ready for baseline
Systems Engineer	Confirm the work process flows result in the proper products being built in the right order	Review and approval of the IMS – ready for baseline

The 6 Steps Result In An IMP/IMS Showing What Done Looks Like

5 Steps

167

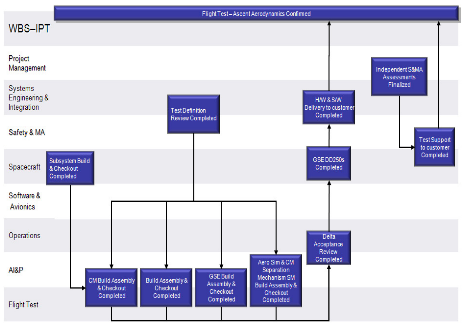
The ***Plan*** Tells Us "How" We are Going to Proceed Toward Done
The ***Schedule*** Tells Us "What" Work is Needed to Make Progress Toward Done

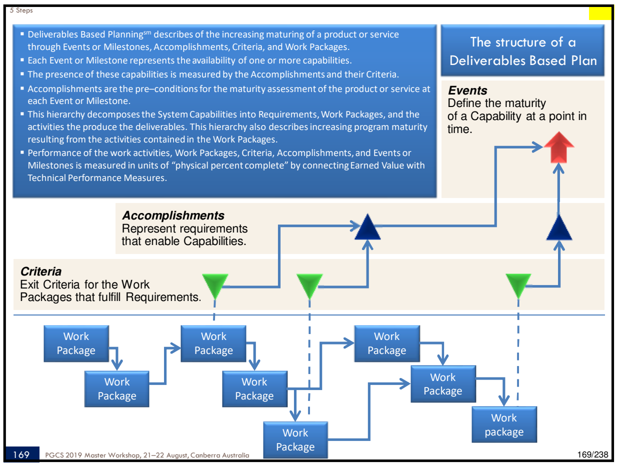
- The IMP is the "Outer Mold Line", the Framework, the "Going Forward" Strategy for the Program.
- The IMP describes the path to increasing maturity and the Events measuring that maturity.
- The IMP tells us "How" the program will flow with the least risk, the maximum value, and the clearest visibility to progress.
- The IMS tells us what work is needed to produce the product or service at the Work Package level.

Sequencing of Significant Accomplishments for a Program Event

5 Steps

168




5 Steps
Deliverables Based Planningsm describes of the increasing maturing of a product or service through Events or Milestones, Accomplishments, Criteria, and Work Packages.
Each Event or Milestone represents the availability of one or more capabilities.
The presence of these capabilities is measured by the Accomplishments and their Criteria.
Accomplishments are the pre–conditions for the maturity assessment of the product or service at each Event or Milestone.
This hierarchy decomposes the System Capabilities into Requirements, Work Packages, and the activities the produce the deliverables. This hierarchy also describes increasing program maturity resulting from the activities contained in the Work Packages.
Performance of the work activities, Work Packages, Criteria, Accomplishments, and Events or Milestones is measured in units of "physical percent complete" by connecting Earned Value with Technical Performance Measures.
The structure of a Deliverables Based Plan
Events
Define the maturity of a Capability at a point in time.
Accomplishments
Represent requirements that enable Capabilities.
Criteria
Exit Criteria for the Work Packages that fulfill Requirements.
Work Package
Work package
169
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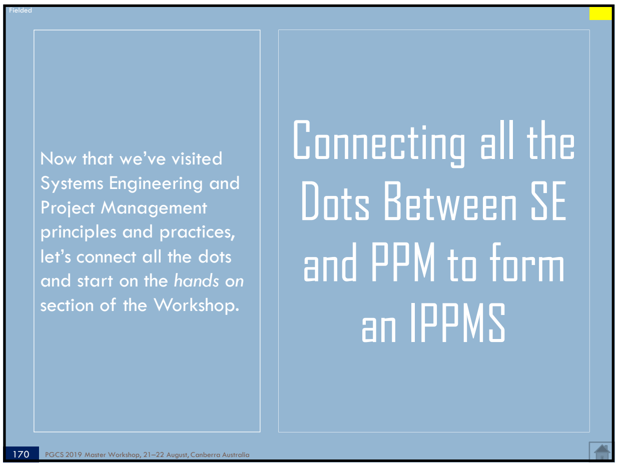
Now that we've visited Systems Engineering and Project Management principles and practices, let's connect all the dots and start on the hands on section of the Workshop.
Connecting all the Dots Between SE and PPM to form an IPPMS
170
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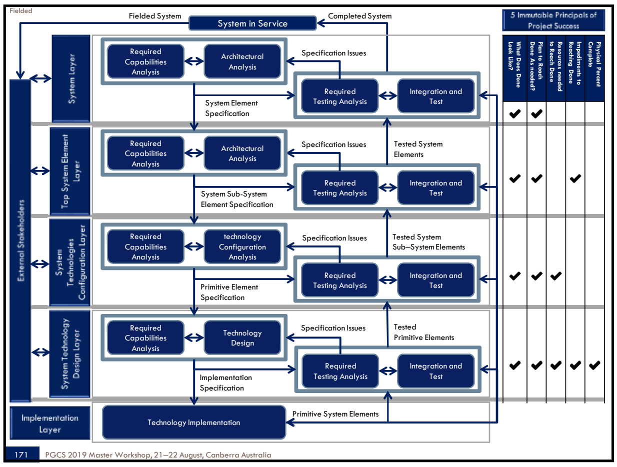
Fielded System
System in Service
Completed System
5 Immutable Principals of Project Success
External Stakeholders
System Layer
Top System Element Layer
System Technologies Configuration Layer
System Technology Design Layer
Implementation Layer
Required Capabilities Analysis
Architectural Analysis
technology Configuration Analysis
Technology Design
Specification Issues
Required Testing Analysis
Integration and Test
System Element Specification
System Sub-System Element Specification
Primitive Element Specification
Implementation Specification
Tested System Elements
Tested System Sub–System Elements
Tested Primitive Elements
Technology Implementation
Primitive System Elements
171
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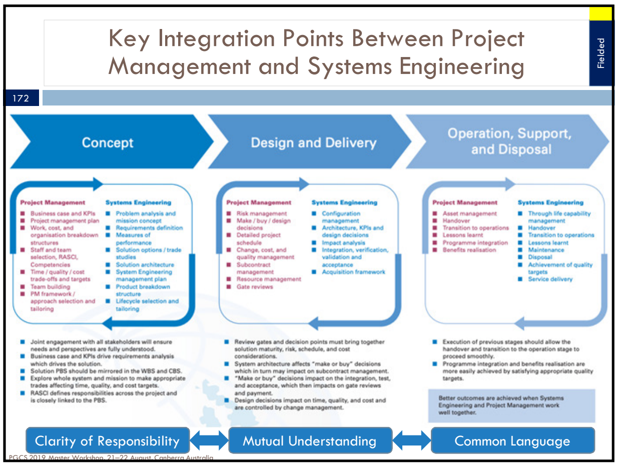
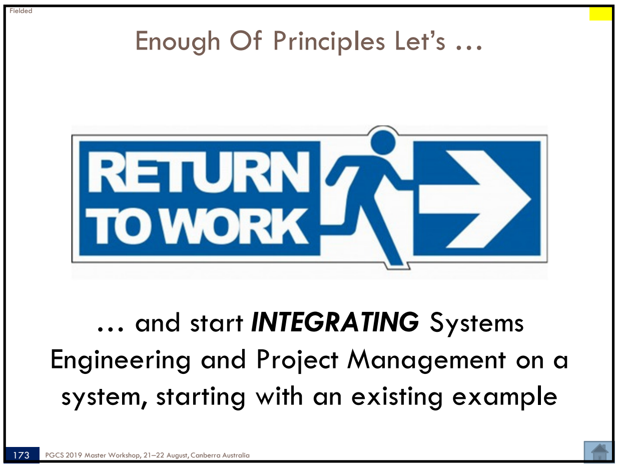

Key Integration Points Between Project Management and Systems Engineering
Fielded
172
Concept
Design and Delivery
Operation, Support, and Disposal
Project Management
Systems Engineering
Clarity of Responsibility
Mutual Understanding
Common Language


Enough Of Principles Let's …
RETURN TO WORK
… and start INTEGRATING Systems Engineering and Project Management on a system, starting with an existing example
173
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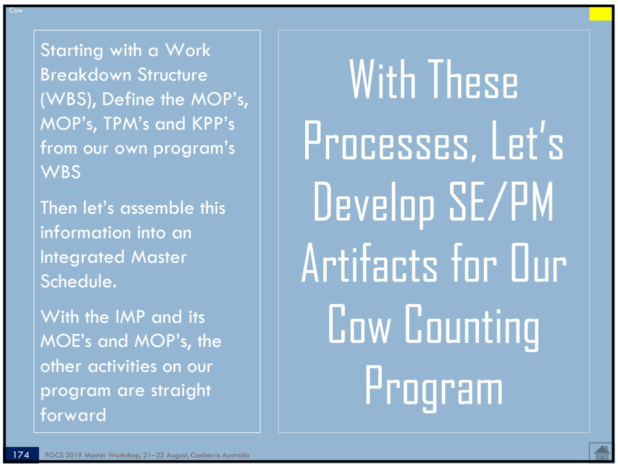
Starting with a Work Breakdown Structure (WBS), Define the MOP's, MOP's, TPM's and KPP's from our own program's WBS
Then let's assemble this information into an Integrated Master Schedule.
With the IMP and its MOE's and MOP's, the other activities on our program are straight forward
With These Processes, Let's Develop SE/PM Artifacts for Our Cow Counting Program
174
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A Hands On Example

175

Count Cows without having to go count cows

How Many Cows, of What Breed, Do We Have in the Pastures?

176

Belted Galloway's
In the Front Pasture

Herford's
In the Back Pasture

This is an actual picture from our back yard
Not our cows, but we see them every day

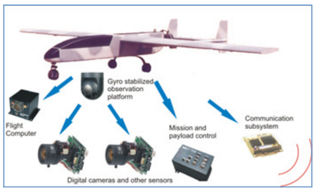
Benefits of UAVs in Cattle Management

178

- Collect more data with less labor
  - Labor shortage addressed with UAV
- Aerial maps improve land management practices
  - Rangeland monitoring
- Monitor livestock, fences, and water resources
  - Drought stress monitoring
- Collect data on individual animals
  - Smart ear tags
  - Biometrics and animal behavior

Our Project Starts with Documents

179



- ConOps
- SOW
- MOE
- MOP
- TPM
- WBS
- Risk / Opportunities
- Deliverable Outcomes

Our UAV has many parts all interacting with each other and external systems. We'll start with the Concept of Operations (ConOps). The Statement of Work is built for the over all system. Then we'll develop the *Effectiveness* and *Performance* capabilities for the mission.

From there the *Technical Performance Measures* and the WBS elements that implement them.

Business Needs Analysis

180

- Out of the many applications for UAV technology, cattle tracking is one where technology can be applied *off the shelf*.
- Ranchers in the Western United States have a difficult time tracking down their cattle and rely heavily on personal recognizance of their farm ground to do cattle counts.
- With the availability of low cost unmanned aerial vehicle systems, the rancher can now know where their livestock located may be, using a UAV system to replace the role of the manual livestock surveyor.

Concept of Operations

181

- Our UAV is a suite of sensor based aerial and stationary ground, platforms that provide real-time Reconnaissance, Surveillance, and Asset information to a managers and staff of a commercial cattle ranch.
- It supports this staff as they plan, coordinate, and execute operations through increased situational awareness (SA) by integrating intelligence, surveillance, and reconnaissance (ISR) into a single platform about their assets – *cows on the open range*.

Concept of Operations (Continued)

182

- The user sends a UAV to an area of interest (within a 5-mile radius) from a pickup truck mounted launch system.
- The user pre-programs the gas-powered autonomous UAV for the designated 77 square mile area.
- The UAV must be able to launch and be recovered on a rough surface less than 200 meters in length, be able to reach the designated area within 10 minutes hour, loiter as high as 1,000 feet above ground level.
- The UAV and payload sensors are to provide 4-hour persistent coverage of 77 square mile area four times in a 24 hour loiter time and provide imagery between three and ten seconds of data capture.
- UAV will contain EO/IR to provide the user with initial asset situation.
- Based on this preliminary information, the user may direct the UAVs to fly at lower levels to capture Full Motion Videos (FMVs) of the herd.

CONOPS (Concluded)

183

- Because the system must be packaged and transported with limited cargo capacity of ranch vehicles, the UAV suite must conform to limits on power, weight and size.
- We will be using weight as the TPM, as derived from the Business Case and an Energy Key Performance Parameters (KPP), to demonstrate better cost and schedule performance.

Measures of Effectiveness (MOE)

184

- Range of flight
- Resolution of images
- Ability to return home safely when commanded to do so, or with loss of communication or any other disruptive event
- Reliability and maintainability in a ranching environment

Measures of Performance (MOP)

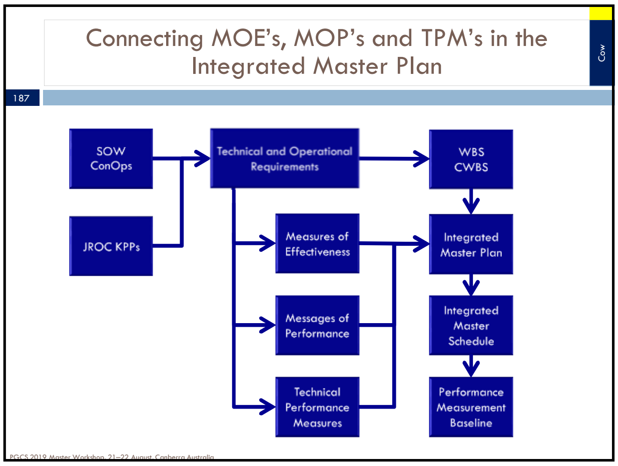
185

- Speed during transit and during loiter
- Loiter time, once on station
- All the …ilities
- Weight of aircraft and payload
- Fuel consumption, to and from station and while on station
- Accuracy of location once on station
- Sensor performance across the spectrum – Visual and Infrared

Technical Performance Measures (TPM)

186

- Weight limits for each major subsystem
  - These needed to define and maintain center of gravity of other flight dynamics parameters
- Full Motion Video resolution and frame rate
- Electroptical / Infrared sensitivity
- Fuel consumption


Connecting MOE's, MOP's and TPM's in the Integrated Master Plan
Cow
187
SOW ConOps
JROC KPPs
Technical and Operational Requirements
Measures of Effectiveness
Messages of Performance
Technical Performance Measures
WBS CWBS
Integrated Master Plan
Integrated Master Schedule
Performance Measurement Baseline
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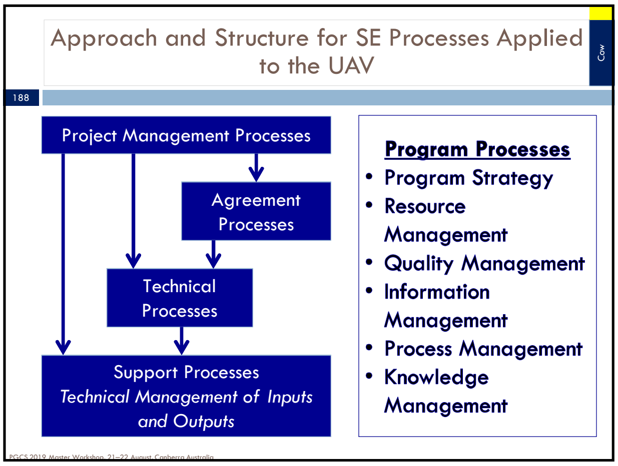
Approach and Structure for SE Processes Applied to the UAV
Cow
188
Project Management Processes
Agreement Processes
Technical Processes
Support Processes
Technical Management of Inputs and Outputs
Program Processes
Program Strategy
Resource Management
Quality Management
Information Management
Process Management
Knowledge Management
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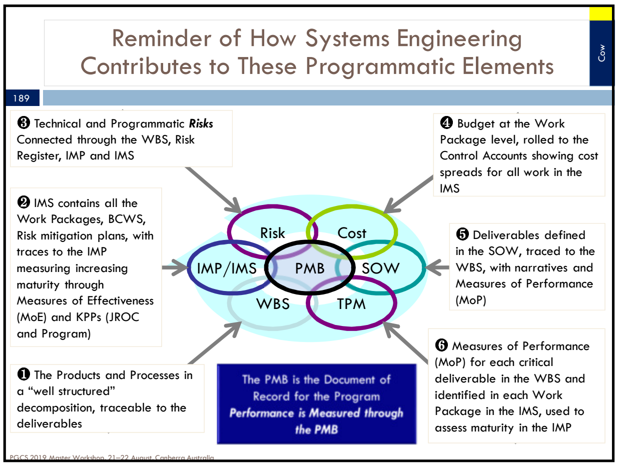
Reminder of How Systems Engineering Contributes to These Programmatic Elements
Cow
189
❸ Technical and Programmatic Risks Connected through the WBS, Risk Register, IMP and IMS
❹ Budget at the Work Package level, rolled to the Control Accounts showing cost spreads for all work in the IMS
❷ IMS contains all the Work Packages, BCWS, Risk mitigation plans, with traces to the IMP measuring increasing maturity through Measures of Effectiveness (MoE) and KPPs (JROC and Program)
Risk
Cost
IMP/IMS
PMB
SOW
WBS
TPM
❺ Deliverables defined in the SOW, traced to the WBS, with narratives and Measures of Performance (MoP)
❶ The Products and Processes in a "well structured" decomposition, traceable to the deliverables
The PMB is the Document of Record for the Program
Performance is Measured through the PMB
❻ Measures of Performance (MoP) for each critical deliverable in the WBS and identified in each Work Package in the IMS, used to assess maturity in the IMP
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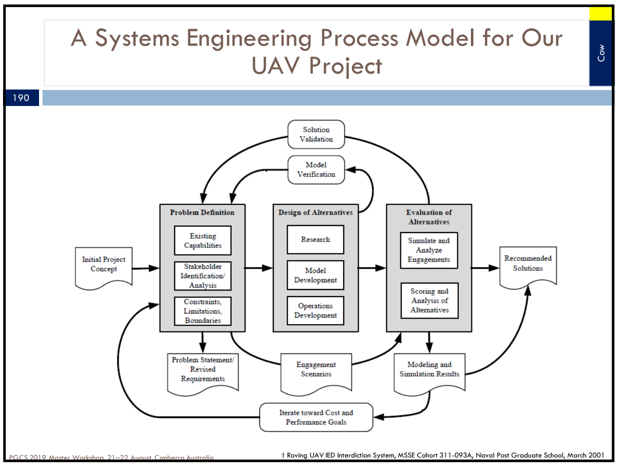
A Systems Engineering Process Model for Our UAV Project
Cow
190
Solution Validation
Model Verification
Initial Project Concept
Problem Definition
Existing Capabilities
Stakeholder Identification/ Analysis
Constraints, Limitations, Boundaries
Design of Alternatives
Research
Model Development
Operations Development
Evaluation of Alternatives
Simulate and Analyze Engagements
Scoring and Analysis of Alternatives
Recommended Solutions
Problem Statement/ Revised Requirements
Engagement Scenarios
Modeling and Simulation Results
Iterate toward Cost and Performance Goals
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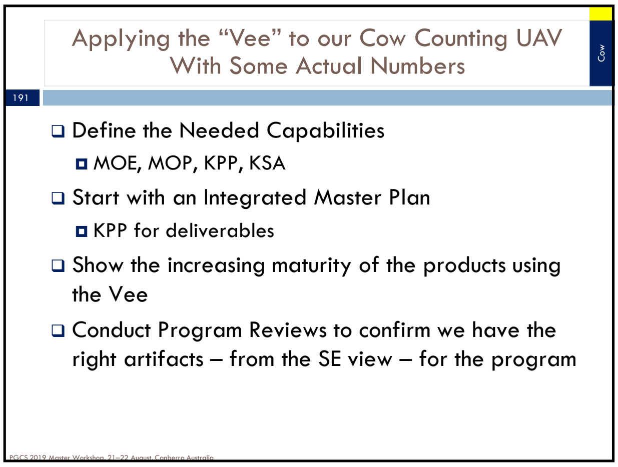
† Roving UAV IED Interdiction System, MSSE Cohort 311-093A, Naval Post Graduate School, March 2001


Applying the "Vee" to our Cow Counting UAV With Some Actual Numbers
Cow
191
Define the Needed Capabilities
MOE, MOP, KPP, KSA
Start with an Integrated Master Plan
KPP for deliverables
Show the increasing maturity of the products using the Vee
Conduct Program Reviews to confirm we have the right artifacts – from the SE view – for the program
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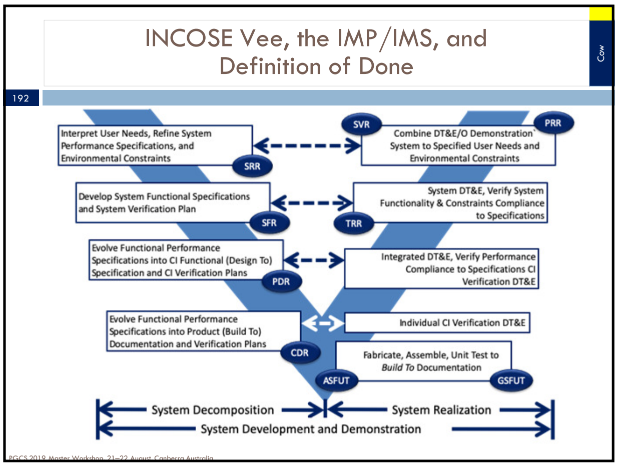
INCOSE Vee, the IMP/IMS, and Definition of Done
Cow
192
Interpret User Needs, Refine System Performance Specifications, and Environmental Constraints
SRR
SVR
Combine DT&E/O Demonstration System to Specified User Needs and Environmental Constraints
PRR
Develop System Functional Specifications and System Verification Plan
SFR
TRR
System DT&E, Verify System Functionality & Constraints Compliance to Specifications
Evolve Functional Performance Specifications into CI Functional (Design To) Specification and CI Verification Plans
PDR
Integrated DT&E, Verify Performance Compliance to Specifications CI Verification DT&E
Evolve Functional Performance Specifications into Product (Build To) Documentation and Verification Plans
CDR
Individual CI Verification DT&E
Fabricate, Assemble, Unit Test to Build To Documentation
ASFUT
GSFUT
System Decomposition
System Realization
System Development and Demonstration
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Event Based Planning Defined in the Integrated Master Plan

193

- SRR (Systems Requirements Review)
- SFR (System Functional Review)
- PDR (Preliminary Design Review)
- CDR (Critical Design Review)
- ASFUT/GSFUT (Air System/Ground System Functional Unit Test)
- TRR (Test Readiness Review)
- SVR (System Validation Review)
- PRR (Production Readiness Review)

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Cow Counting UAV Systems Engineering Processes

194

- User Needs
- Functional Specifications
- Performance Specifications
- Product Specifications
- Build a System
- Verify Individual Components Work
- Verify Performance to Specifications
- Verify System Functionality
- Demonstrate System

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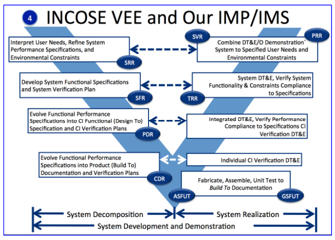
Cow Counting UAV Project Management Processes

195

- Integrated Master Plan and Integrated Master Schedule vertically and horizontally traceable.
- The left side of the Vee and the right side are connected by the IMP program events.



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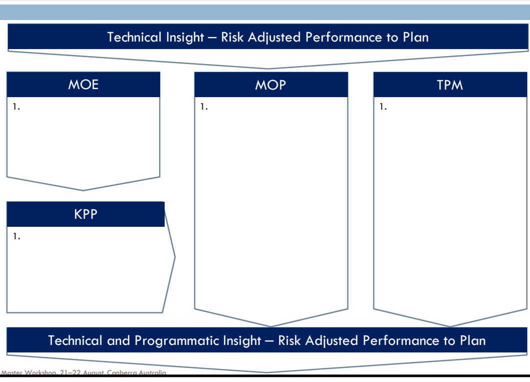
Cow Counting UAV MOE's, MOP's and TPM's

196



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Topology of a SE Based Organization

ConOps, SOO, SRD, Goals and Specifications		Defines product function, performance and verification requirements, program and product objectives
WBS		Defines the product structure and support processes
	SOW	Defines the work activities needed to meet the project objectives
ORG	Specs	Defines product-based organization that parallel the WBS
Trades Analysis Models	IMP	Defines the single authorities program plan for technical and programmatic activities needed to provide mission capabilities
		Defines the design that meets specification requirements
KPP/TPM, Risks, Cost, MOE		Key development, integration, and operational methods to assure product's performance measures and parameters are measurable and all work to produce the deliverables defined in the Integrated Master Schedule. For each deliverable, risks are defined and mitigated. Measures of Effectiveness used to assure mission needs are fulfilled within the cost parameters to allow tradeoffs to be made.
MOP	IMS	Defines single schedule to design, build, and verify the product
EV	EVMS	Provides basis for cost and schedule performance management

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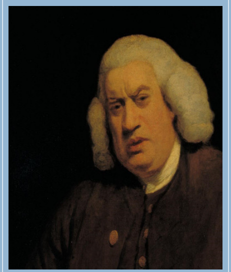

Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it. When we enquire into any subject, the first thing we have to do is to know what books have treated of it. This leads us to look at catalogues, and at the backs of books in libraries.
– Samuel Johnson
18 April 1775

Notes on this Bibliography

- The documents below are a collection of materials I've applied over my career working complex software intensive system of systems
- If you were to read only one text it should be:
  - *Systems Engineering Guide: Collected Works from MITRE's Systems Engineering Experts*, https://www.mitre.org/publications/systems-engineering-guide/about-the-seg
- The second book I depend on is
  - *Systems Engineering Principles and Practice*, Second Edition, Alexander Kossiakoff, et al, John Wiley & Sons 2011.

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References Bibliography

201

1. *Integrating Program Management and Systems Engineering: Methods, Tools, and Organizational Systems for Improving Performance*, Eric Rebentisch, Editor–in–Chief, John Wiley and Sons, 2017.
2. *Systems Thinking: Building Maps for World Systems*, John Boardman and Brian Sauser, John Wiley & Sons, 2013.
3. *Systems Thinking: Coping with 21st Century Problems*, John Boardman and Brian Sauser, CRC Press, 2008.
4. *The Art of Systems Architecting*, Second Edition, Mark W. Maier and Eberhardt Rechtin, CRC Press, 2000.
5. *Engineering Complex Systems with Models and Objects*, David W. Oliver, McGraw Hill, 1997.
6. *Decision Making in Systems Engineering and Management*, 2nd Edition, Gregory Parnell, Patrick Driscoll, and Dale Henderson, editors, John Wiley & Sons, 2010.
7. *Systems Requirements Analysis*, Jeffrey O. Grady, Academic Press, 2006.
8. *Systems Engineering: Coping with Complexity*, Richard Stevens, Peter Brook, Ken Jackson, and Stuart Arnold, Prentice Hall, 1998.
9. *Systematics: How Systems Work and Especially How They Fail*, John Gall, Quadrangle, 1975.
10. *The Systems Bible: The Beginners Guide to Systems Large and Small*, Third Edition, John Gall, General Systemantics Press, 1975.
11. *Thinking in Systems: A Primer*, Donella H. Meadows, Chelsea Green Publishing, 2008.
12. *The Requirements Engineering Handbook*, Ralph R. Young, Artech House, 2004.
13. *Requirements Engineering: A Good Practice Guide*, Ian Sommerville and Pete Sawyer, John Wiley & Sons, 1997.

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References Bibliography

202

14. *Enterprise Risk and Opportunity Management: Concepts and Step–by–Step Examples for Pioneering Scientific and Technical Organizations*, Allan S. Benjamin, John Wiley & Sons, 2017.
15. *Effective Risk Management: Some Keys to Success*, Second Edition, Edmund H. Conrow, AIAA Press, 2003.
16. *Design Structure Matrix Methods and Applications*, Steven D. Eppinger and Tyson R. Browning, The MIT Press, 2012.
17. "Engineering Complex Systems: Implications for Research in Systems Engineering," *IEEE Transactions on Systems, Man, and Cybernetics – Part C: Applications and Reviews*, Vol. 33, No. 2m May 2003.
18. "A Framework for Understanding Uncertainty and its Mitigation and Exploitation in Complex Systems," Daniel Hastings and Hugh McManus, 2004 Engineering Systems Symposium.
19. "System Engineering Plan and Systems Engineering Management Plan Alignment," Chet Bracuto and Bob Scheurer, *NDIA 11th Annual Systems Engineering Conference*, October 21, 2008.
20. "The Extension of Systems Architecting to the Architecting of Organizations," Eberhardt Rechtin, *ICSE '99*
21. "A Project–Product Lifecycle Management Approach for Improved Systems Engineering Practices," Amira Sharon and Dov Dori, *INCOSE International Symposium*, Session 8, Track 2, June 2008.
22. "Toward a New Mindset: Bridging the Gap Between Program Management and Systems Engineering," Mark Langley, Samantha Robitaille, and John Thomas, *PMI Global Congress*, 22 October 2011.
23. "Improving Cooperation between Systems Engineers and Project Managers in Engineering Projects – Towards the Alignment of Systems Engineering and Project Management Standards and Guides, Rui Xue, PhD Thesis, Institut National des Sciences Appliquées de Toulouse (INSA de Toulouse).

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References Bibliography

203

24. *Systems Engineering Handbook: A Guide for System Lifecycle Processes and Activities*, Fourth Edition, 2015.
25. *NASA Systems Engineering Handbook*, NASA–SP–2016–6105 Rev 2, December 2016
26. "Integrating Project Management and Systems Engineering," Ann Hodges, Sandia National Laboratories, National Nuclear Security Agency
27. "Integrating Systems Engineering with Project Management: a Current Challenge!," Rui Xue, Claude Baron, and Daniel Prun, 24th Annual INCOSE International Symposium, June 2014.
28. "Survey Report: Improving Integration of Program Management and System Engineering: Results of a Joint Survey of PMI and INCOSE," Edivandro Conforto, Monica Rossi, Eric Rebentisch, Josef Oehmen and Maria Pacenza, 23rd INCOSE Annual International Symposium, June 2013.
29. "Systems Engineering the Project," Van Gemert, PMI Global Congress, 2013.
30. *Engineering Complex Systems with Models and Objects*, David W. Oliver, Timothy P. Kelliher, and James G. Keegan, McGaw Hill, 1997.
31. *Modelling Complex Projects*, Terry Williams, John Wiley & Sons, 2002.
32. "Project Management vs. Systems Engineering Management: A Practitioners' View on Integrating the Project and Product Domains," Amira Sharon, Olivier L. de Weck, and Dov Dori, Systems Engineering, 2011.
33. "The Relationship of System Engineering to the Project Cycle," Kevin Forsberg and Harold Mooz, National Council On Systems Engineering (INCOSE) and American Society for Engineering Management (ASEM), 1991.

System Engineering and Project Performance Management Resources

References Bibliography

204

34. "The Case for Systems Management," Hal Mooz and Kevin Forsberg, Center for Systems Management, 2002.
35. *The Essentials of Project and Systems Management* 2nd Edition, Howard Eisner, John Wiley & Sons, 2001.
36. Systems Engineering Body of Knowledge 1.9.1, "Systems Engineering and Project Management," pp. 823–846.
37. *Seven Key Principles of Program and Project Success: A Best Practices Survey*. NASA/TM–2008–214692.
38. NASA Space Flight Program and Project Management Handbook, NASA/SP–2014–3705
39. *The Handbook of Program Management*, Second Edition, James T. Brown, McGraw Hill, 2014.
40. *Performance–Based Project Management*, Glen B. Alleman, American Management Association, 2014.
41. "Chapter 3: Systems Engineering," of the Defense Acquisition Guidebook, Defense Acquisition University, 9820 Belvoir Road, Fort Belvoir, VA 22060.
42. A Project Manager Lessons Learned, https://www.nasa.gov/pdf/2383253main_62682main_jerry_madden_forum7.pdf
43. *Integrating Program Management and Systems Engineering: Methods, Tools, and Organizational Systems for Improving Performance*, Eric Rebentisch, Editor–in–Chief, John Wiley, 2017.
44. *The Handbook of Program Management: How to Facilitate Project Success with Optimal Program Management*, Second Edition, James T. Brown, McGraw–Hill, 2014.
45. *Integrated Project Performance Management and Control: First Comes the Theory then the Practice*, Mario Vanhoucke, Springer, 2014.
46. *Systems Engineering Principles and Practice*, Second Edition, Alexander Kossiakoff, William Sweet, Samuel Seymour, and Steven Biemer, John Wiley & Sons, 2011.

System Engineering and Project Performance Management Resources

References Bibliography

205

47. *Essential of Project and Systems Engineering Management*, Second Edition, Howard Eisner, John Wiley & Sons, 2002.
48. *Defence Systems Engineering Handbook*, Defence Engineering Group, University College, London, 2002.
49. *Systems Engineering – Application and Management of the Systems Engineering Process*, IEEE Std 1220–2005.
50. "Systems Engineering – Systems Life Cycle Processes," ISO/IEC 15288.
51. "Evaluation and Synthesis of Methods for Measuring Systems Engineering Efficacy within a Project and Organization," Timothy Daniel Flynn, Massachusetts Institute of Technology, February 2007.
52. "SMC Systems Engineering Primer & Handbook: Concepts, Processes, and Techniques," Space & Missile Systems Center, U. S. Air Force, 29 April 2005.
53. "SMC Systems Engineering Specialty Engineering Disciplines: Frameworks and Descriptions," Space & Missile Systems Center, U. S. Air Force, 3 October 2011.
54. "Investigating Relationships and Semantic Sets Amongst System Lifecycle Properties (ilities)," 3rd International Engineering Systems Symposium, TU Delft, the Netherlands.
55. "Framework for Managing Systems–of–Systems Ilities," Kang Shian Chin and Sim Kok Wah, DSTA Horizons, 2013/14.
56. "Engineering Enterprise Using Complex–System Engineering (CSE)," Brian E. White, 1st Annual Systems of Systems (SoS) Engineering Conference, 13–14 June 2005.
57. *Design Software–Intensive Systems: Methods and Principles, Pierre F. Tiako, Information Science Reference, 2009.*
58. "Systems Engineering and Program Management," David E. Stem, Michael Boito, and Obaid Younossi, RAND MG413.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

206

59. *Performance–Based Project Management*, Glen B. Alleman, American Management Association, 2014.
60. *Integrated Project Performance Management sand Control: First Comes the Theory, then the Practice*, Mario Vanhoucke, Springer, 2014.
61. *Integrating Program Management and Systems Engineering: Methods, Tools, and Organizational Systems for Improving Performance*, Eric Rebentisch, Editor–in–Chief, John Wiley, 2017.
62. "Clarifying the Relationships between Systems Engineering, Project Management, Engineering and Problem Solving," Joseph Kasser and Deek Hitchins, *Asia–Pacific Council on Systems Engineering Conference*, Yokohama, 2013.
63. "Systems Engineering for Project Managers," Mike Wilkinson, *INCOSE/APM Joint Workshop*, 15 January 2013.
64. "The Art and Science of Systems Engineering," Michael Ryschkewitsch, Dawn Schaible, and Wiley Larson, *Systems Research Forum*, Vol. 3, No. 2 pp. 81–1000, 2009.
65. "Twelve Roles and Three Types of Systems Engineering." Sara A. Sheard, Software Productively Consortium, February 11, 2003.
66. "Systems Engineering, Program Management conjoined Disciplines over the Project Life Cycle," William Lyders, *NDIA 8th Annual Systems Engineering Conference*, October 2005.
67. *Handbook of Systems Engineering and Management*, Andrew P. Sage and William B. Rouse, John Wiley and Sons, 1999.
68. *Systems Engineering Management*, Fifth Edition, Benjamin S. Blanchard and John E. Blyler, John Wiley & Sons, 2016.
69. Federal Acquisition Institute Project Manager's Guidebook, November 25, 2015.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

207

70. "A Project-Product Lifecycle Management Approach for Improved Systems Engineering Practices," Amira Sharon, Valeria Perelman, and Dov Dori, June 2011.
71. "Systems Engineering Measurement Primer A Basic Introduction to Measurement Concepts and Use for Systems Engineering SEBOK Measurement," https://www.sebokwiki.org/wiki/Measurement
72. "Visualizing Project Management and System Engineering as an Integrated Process," Harold Mooz and Kevin Forsberg, *Center for Systems Management*, 1997.
73. Space and Missile Systems Center Risk Management Process Guide, Version 2.0 – 5 September 2014.
74. "Guide to the Systems Engineering Body of Knowledge (SEBoK), *IEEE Computer Society*, https://www.sebokwiki.org/wiki/Guide_to_the_Systems_Engineering_Body_of_Knowledge_(SEBoK)
75. "Relationships between Systems Engineering and Project Management," Guide to the Systems Engineering Body of Knowledge, https://www.sebokwiki.org/wiki/Relationships_between_Systems_Engineering_and_Project_Management
76. "Systems Engineering Guide for System of Systems," Systems and Software Engineering Deputy Under Secretary of Defense (Acquisition and Technology), Version 1.0, August 2008.
77. *Primer for Model–Based Systems Engineering*, Vitech, 2011.
78. "The Art and Science of Systems Architecting" Mark Maier, Aerospace Corporation.
79. "Best Practices for Using Systems Engineering Standards (ISO/IEC/IEEE 15288, IEEE 15288.1, and IEEE 15288.2)," April 2017.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

208

80. *System of Systems Engineering: Innovations for the 21st Century*, Mo Jamshidi, Editor, John Wiley & Sons, 2009.
81. *Systems Engineering: A 21st Century Systems Methodology*, Derek Hitchins, John Wiley & Sons, 2007.
82. *Systems of Systems Engineering Principles and Applications*, Mo Jamshidi, CRC Press, 2009.
83. "Reducing Unwelcome Surprises in Project Management," Tyson Browning and Ranga Ramasesh, MIT Sloan Management Review, Spring 2015.
84. "Understanding and Managing Project Complexity," Syed Waqar Azim, The University of Manchester, 2010.
85. "Complexity Management for Project, Programmes, and Portfolios: An Engineering Systems Perspective," Josef Oehmen, Christian Thuesen, Pedro Parraguez Ruiz, and Joana Geraldi, PMI White Paper, 2015.
86. *System of Systems Engineering: Innovations for the 21st Century*, Edited by Mo Jamshidi, John Wiley & Sons, 2009.
87. *System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices* (Wiley Series in Systems Engineering and Management) 2nd Edition, Charles S. Wasson, John Wiley & Sons, 2015.
88. *Process for Systems Architecture and Requirements Engineering*, 1st Edition, Derek Hatley, Peter Hruschka, and Imtiaz A. Pirbhai, Dorset House, 2000.
89. "Toward Project Management 2.0, Raymond E. Levitt, Engineering Project Organization Journal, 1(3), pp. 197–210, September 2011.
90. "Systems Engineering and Project Management: Complementary Disciples, or Competing Paradigms," T. Cooke-Davies, INCOSE Symposium, July 2012.
91. An Empirical Analysis of the Relationship Between Project Planning and Project Success," Dov Dvir, Tzvi Raz, and Aaron J. Shenhar, International Journal of Project Management 21, pp. 89–95, 2003.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

209

86. "Systems Engineering and Project Management for Product Development: Optimizing Their Working Interfaces," Mariela I. Santiago, Naval Postgraduate School, September 2013.
87. "How Do Committees Invent?" Melvin E. Conway, *Datamation*, 14(5), pp. 28–31, April 1968.
88. "The Value of Systems Engineering in Product Management," Oliver Hoehne and Steven Turner, *INCOSE International Symposium*, July 2016, Edinburgh, Scotland, UK
89. IEEE Guide for Information Technology – System Definition – Concept of Operation (ConOps) Document, (IEEE STD 1362-1998), in "Systems Engineering Guide, MITRE Corporation, https://www.mitre.org/publications/systems-engineering-guide/se-lifecycle-building-blocks/concept-development/concept-of-operations
90. Chapter 28, "Capabilities-Based Planning," TOGAF® Standard, Version 9.2
91. "The Twelve Principles of Efficiency," Harrington Emerson, *The Engineering Magazine*, New Work, https://babel.hathitrust.org/cgi/pt?id=bc.ark:/13960/t2g746111;view=1up;seq=13
92. *Processes for System Architecture and Requirements Engineering*, Derek Hatley, Peter Hruschka, and Imtiaz Pirbhai, Dorset House, 2000.
93. *Architecting Systems. Concepts, Principles and Practice Concepts, Principles and Practice*, Hillary Sillitto, College Publications, 2014.
94. "Managing development projects: The partnership between project managers and systems engineers," Sigal Kordova, Eyal Katz, and Moti Frank, *Systems Engineering*, Volume 22, Issue 3.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

210

95. "Identifying Acquisition Framing Assumptions Through Structured Deliberations," Mark V. Arena and Lauren A. Mayer, Rand Corporation, RAND TL 135
96. "INCOSE Systems Engineering Measurement Primer v2.0," INCOSE-TP-2010-005-02, 5 November 2010.
97. Megaprojects and Risk: An Anatomy of Ambition, Bent Flyvbjerg, N. Bruzelius, and W. Rothengatter, Cambridge, Cambridge University Press, 2003.
98. "Integrating Systems Engineering and Project Management: Cutting the Cost and Boosting the Success of Complex Projects," Andrew Wright and Arty Tailor, *APM/INCOSE UK, Joint Working Group of SE/PM Integration*, APM Systems Thinking SIG.
99. "System Testing in the Avionics Domain," von Aliki Ott, zur Erlangung des Grades einer Doktorin der Ingenieurwissenschaften, Vorgelegt im Fachbereich 3 (Mathematik & Informatik) der Universit¨at Bremen im Oktober 2007.
100. "A Systems Engineering Approach to Unmanned Aerial Vehicle Design," M. Sadracy, *10th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, 13—15 September 2010.
101. "Autonomous Vehicles in Support of Naval Operations," Committee on Autonomous Vehicle in Support of Naval Operations, Naval Studies Board, National Research Council, 2005.
102. "Unmanned Aerial Vehicles Landscape Analysis: Application in the Development Context," USAID Global Health Supply Chain Program: Procurement and Supply Management, 2017.
103. "Unmanned Aerial Vehicles: A Survey on Civil Applications and Key Research Challenges," Hazim Shakhatreh, Ahmad Sawalmeh, Ala Al-Fuqaha, Zuochao Dou, Eyad Almaita, Issa Khalil, Noor Shamsiah Othman, Abdallah Khreishah, Mohsen Guizani, *IEEE Access*, Volume 7, 2019.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

211

References Bibliography

104. "Challenges of Developing UAV Applications: A Project Management View," Ahmed Idries, Nader Mohamed, Imad Jawhar, Farhan Mohamed, Jameela Al-Jaroodi, *Proceedings of the 2015 International Conference on Industrial Engineering and Operations Management* Dubai, United Arab Emirates (UAE), March 3 – 5, 2015.
105. "Theory of Effectiveness Measurement," Richard K. Bullock, Major, USAF, Air Force Institute of Technology, September 2006.
106. "Systems Engineering Guide for System of Systems," Version 1.0, August 2008.
107. "Recommended Practices: System of Systems Considerations in the Engineering of Systems," TTCP technical Report, TR-JSA/TP4-1-2104, August 2014.
108. "System Engineering Principles, Reference Section 3.2," in *Engineering Elegant Systems: Theory of Systems Engineering*, 4th Draft, Michael D. Watson, NASA Marshall Space Flight Center, 9 February 2018.
109. "Uses of Drone Applications to Monitor Productivity," Piero Anticona Tello, PPM *World Journal*, Vol. V111, Issue IV – May 2019.
110. "NASA's Systems Engineering Competencies," Academy of Program/Project & Engineering Leadership
111. "Better Schedule Performance Assessments Derived from Integrated Master Plan-References Schedule Metrics," David C. Bachman.
112. "Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide," Version 0.9, October 21, 2005
113. "Program Management Framework," from Booz Allen training for national Nuclear Security Agency (NNSA), US Department Energy.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

212

References Bibliography

114. "Leading Complex Projects," Steven R. Meier, PMI Loudon County Chapter, 13 May 2013.
115. *A Handbook of Software and Systems Engineering: Empirical Observations*, Laws and Theories, Albert Endres and Dieter Rombach, Pearson – Addison Wesley, 2003.
116. "Aligning Systems Engineering and Project Management Standards to Improve the Management of Processes," Rui Xue, Claude Baron, Phillippe Esteban, and Abd-El-Kader Sahraoui, Springer-Verlag, Berlin 2011.
117. "Systems Engineering Management and the Relationship of Systems Engineering to Project Management and Software Engineering," Ray Madachy, Naval Postgraduate School, July 19, 2011.
118. "Exploring the Relationship between Systems Engineering and Software Engineering," Art Pyster, Rick Adcock, Mark Ardis, Rob Cloutier, Devanandham Henry, Linda Laird, Harold 'Bud' Lawson, Michael Pennotti, Kevin Sullivan and Jon Wade, 2015 Conference on Systems Engineering Research, Procedia Computer Science 44, pp. 7-8-717, 2015."
119. "A Complexity Primer for Systems Engineers," INCOSE, July 2015, https://www.incose.org/docs/default-source/ProductsPublications/a-complexity-primer-for-systems-engineers.pdf?sfvrsn=0&sfvrsn=0
120. "Systems Engineering to Improve the Governance in Complex Project Environments," Giorgio Locatelli, Mauro Mancini, and Erika Romano, *International Journal of Project Management*, pp. 1395-1410, November 2014.
121. "Toward a Typological Theory of Project Management," Aaron Shenhar and Dov Dvir, Research Policy, 25(4), pp. 607-632, 1996.
122. "Clarifying the Relationships between Systems Engineering, Project Management, Engineering and Problem Solving," Joseph Kasser and Derek Hitchins, *Asia-Pacific Council on Systems Engineering* Conference, 2013.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

213

References Bibliography

123. "Identifying Relationships between Systems Engineering Processes and Project Success in NASA Complex Projects and Other Organizations," Kathryne Angela Schomburg, Iowa State University, 2015.
124. "Project Management: Systems Engineering & Project Control Processes and Requirements," Johnson Space Center, JPR 7120.3, March 2004.
125. "Seven Key Principles of Program and Project Success – A Best Practices Survey," Vincent J. Bilardo, et. al, NASA/TM-2008-214692, April 2008.
126. "A Conceptual Framework for Defense Acquisition Decision Makers: Giving the Schedule Its Due," Chad Dacus and Col Stephen Hagel USAF (Ret.), *Defense ARJ*, Vol. 21, No. 1, pp. 486-504, 2014.
127. "Engineering Elegant Systems: Theory of System Engineering,"
128. "A Model-Based Approach To System-Of-Systems Engineering Via The Systems Modeling Language," Kevin Hughes Bonanne, Purdue University August 2014.
129. *A Primer for Model-Based Systems Engineering*, 2nd Edition, David Long and Zane Scott, Vitech, 2011.
130. *Modeling and Analysis of Dynamic Systems*, Second Edition, Ramin S. Esfandiari and Bie Lu, CRC Press, 2014.
131. *Systems Analysis and Design, 5th Edition*, Alan Dennis, Barbara Haley Wixom, and Roberta M. Roth, John Wiley & Sons, 2012.
132. "Agile Systems, Agile Systems Engineering, and Self-Organizing Agile Systems Security," Rick Dove, ILTAM/INCOSE IL, Tel Aviv, 8 Jan 2014.
133. "Project Management vs. Systems Engineering Management: A Practitioners' View on Integrating the Project and Product Domains," Amira Sharon, Olivier L. de Weck, and Dov Dori, *Systems Engineering*, 2011.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

214

References Bibliography

134. "Improving Project-Product Lifecycle Management with Model-Based Design Structure Matrix: A Joint Project Management and Systems Engineering Approach," Amira Sharon, Olivier L. de Weck, and Dov Dori, *Systems Engineer*, Vol. 16, No. 4, 2013.
135. "Integrating Systems Engineering with Program and Project Management," Randy Ade, *INCOSE INSIGHT*, 23 June 2015.
136. "Managing development projects—The partnership between project managers and systems engineers," Sigal Kordova, Eyal Katz, and Moto Frank, *Systems Engineering*, Volume 22, Issue 3, May 2019.
137. "Best project management and systems engineering practices in the preacquisition phase for federal intelligence and defense agencies," Steven R. Meier, *Systems Engineering*, Volume 39, Issue 1, March 2008.
138. "Key Concepts in Integration," Eric S. Rebentisch, in *Integrating Program Management and Systems Engineering*, John Wiley & Sons, 2017.
139. "Behavioral Competencies of Highly Regarded Systems Engineers at NASA," Mary Ellen Derro and Christine R. Williams, *IEEEAC Paper #1198*, Version 1, December 18, 2008.
140. Systems Engineering: Roles and Responsibilities," Dr. Steve Jolly, NASA PI-Forum, July 27, 2011
141. *Guide to the Project Management Body of Knowledge*, Fifth Edition, Project Management Institute.
142. "A Framework for Systems Engineering Development of Complex Systems," Dr. Karl L. Brunson, Dr. Jeffrey Beach, Dr. Thomas A. Mazzuchi, and Dr. Shahram Sarkani, *CrossTalk*, July/August 2009.
143. "Complex Acquisition Requirements Analysis: Using a Systems Engineering Approach," Col. Richard M. Stuckey, Shahram Sarkani, and Thomas A. Mazzuchi, *Acquisition Research Journal*, April 2017, Vol. 24, No. 2, pp. 266-301.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

215

References Bibliography

144. *Systems Engineering Guide: Collected Wisdom from MITRE's Systems Engineering Experts*, https://www.mitre.org/publications/systems-engineering-guide/about-the-seg
145. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, 8th Edition, Harold Kerzner, John Wiley & Sons, 2003.
146. *Systems Thinking, Third Edition: Managing Chaos and Complexity: A Platform for Designing Business Architecture*, Jamshid Gharajedaghi, Morgan Kaufmann, 2011.
147. *Enterprise Systems Engineering: Advances in the Theory and Practice (Complex and Enterprise Systems Engineering)*, edited by George Rebovich and Brian White, CRC Press Taylor & Francis Group, 2011.
148. "Project Management and Systems Engineering – Z11," Issue 1.1, Jan 2018, INCOSEUK and Association for Project Management.
149. "Perspectives on the Use of Unmanned Aerial Systems (UAS) to Monitor Cattle," Jayme Garcia Arnal Barbedo and Luciano Vieira Koenigkan, *Outlook in Agriculture*, *47*(3), pp. 214-222, 2018.
150. "Comparison of Three Techniques to Identify and Count Individual Animals in Aerial Imagery," Pat A. Terletzky and Robert Douglas Ramsey, *Journal of Signal and Information Processing*, *7*, pp. 213-135, 2016.
151. "How do you find the green sheep? A critical review of the use of remotely sensed imagery to detect and count animals," Tracey Hollings, Mark Burgman, Mary van Andel, Marius Gilbert, Timothy Robinson, and Andrew Robinson, *Methods in Ecology and Evolution*. 19 January 2008.
152. "Best Practices for Using Systems Engineering Standards, (ISO/IEC/IEEE 15288, IEEE 15288.1, and IEEE 15288.2) on Contracts for Department of Defense Acquisition Programs," April 2017.

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

216

References Bibliography

153. "The Measurement Handbook: A Practical Guide for Developing and Analyzing the Capabilities-based Assessment, pre-Materiel Development Decision Analysis, and Analysis of Alternatives," Office of Aerospace Studies, Air Force Materiel Command, Kirkland AFB, 6 August 2014.
154. "Technical Measurement Guide," Garry Roedler and Cheryl Jones, INCOSE-TP-2003-020-01, December 2005.
155. "EIA-632, Processes for Engineering a System"
156. "Systems Engineering Revitalization: An Industry Perspective," DSP Conference, Dr. John B. Noblin, LM IS&S.
157. "If it can't be expressed in figures – project performance management," Simona Bonghez and Adina Grigoroiu, *PMI Global Congress 2013—EMEA*, https://www.pmi.org/learning/library/project-performance-management-project-life-cycle-5818
158. "Project Management as Perceived from Ancient Egyptian Projects, Abdel-Fattah El-Marshly, pp. 275-290, in *Dimensions of Project Management: Fundamental, Techniques, Organizations, Applications*, Springer-Verlag, 1990.
159. "Will Cattle Producers Be Willing To Adopt Electronic Cattle Monitoring Systems?," Lori D. Allmon, Masters Thesis, Oklahoma State University, Stillwater Oklahoma, 2013.
160. "Drones Count Wildlife More Accurately and Precisely Than Humans," Jarrod C. Hodgson, et. al. *Methods in Ecology and Evolution*, 4 January2018.
161. "Strategic Cattle Roundup using Multiple Quadrotor UAVs," Sunghun Jung and Kartik B. Ariyur, *International Journal of Aeronautical & Space Science*. 18(2), pp. 315-326, 2017

PGCS 2019 Master Workshop, 21–22 August, Canberra Australia

System Engineering and Project Performance Management Resources

References Bibliography

217

162. "Systems Engineering: The Art of Gluing Pieces," Bernardo A. Delicado, *INCOSE Institute for Technical Leadership*, Madrid, Spain, 22 May 2017.
163. Organize for Complexity: How to Get Life Back Into Work to Build the High Performance Organization", Niels Pflaeging, BetaCodex Publishing, 2014.
164. *The Engineering Design of Systems: Models and Methods*, 2nd Edition, Dennis M. Buede, John Wiley & Sons, 2009.
165. "On Evidence-Based RE Risk Management," Daniel Mendez Fernandez, Michaela TieBler, Marcos Kalinowski, Michael, Felderer, and Marco Kuhrmann, arXiv:1707.00144v2, 31 July 2017.
166. Unmanned Aerial Vehicle, Wikipedia page, https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
167. "Design Methods Fact Sheet: Measures of Effectiveness (MOE) and Measures of Performance (MOP)," The University of Queensland, MECH4551 – System Design Projects, Semester 2 2001.
168. "Distinguishing Two Dimensions of Uncertainty," Craig R. Fox and Gulden Ülkümen, Chapter 1m *Perspectives on Thinking, Judging, and Decision Making*, Oslo Norway.
169. "Planning, Tracking, and Reducing a Complex Project's Value at Risk," Tyson R. Browning, *Project Management Journal*, Vol. 50(1), pp. 71-85, 2019.
170. "Can Project Management Learn Anything From Studies of Failure in Complex Systems?," Chris Ivory and Neil Alderman, *Project Management Journal*, Vol 36, Issues 3, 2005.
171. *Normal Accidents: Living with High Risk Technologies*, Basic Books, 1984.
172. "Review of Research into the Nature of Engineering and Development Rework: Need for a Systems Engineering Framework for Enabling Rapid Prototyping and Rapid Fielding," Shawn Dullena, Dr. Dinesh Verma, Dr. Mark Blackburn, *17th Annual Conference on Systems Engineering Research (CSER)*.

System Engineering and Project Performance Management Resources

References Bibliography

218

173. ISO/PAS 19450:2015 – Automated Systems and Integration – Object–Process Methodology.
174. *Model-Based Systems Engineering with OPM and SysML*, Dov Dori, Springer, 2016.
175. *Systems Thinking: Coping with 21st Century Problems*, John Boardman and Brian Sauser, CRC Press, 2008.
176. *Systems Engineering: Coping with Complexity*, Richard Stevens, Peter Brook, Ken Jackson, and Stuart Arnold, Prentice Hall, 1998.
177. "Summary Research Report on Critical Success Factors in Government Program Management," James H. Dobbins and Richard G. Donnelly, *Acquisition Quarterly* – Winter 1998.
178. "Model-Based Systems Engineering (MBSE), Connecting the Dots Process." Loyd Baker, EnergyTech 2015.
179. "A framework to improve performance measurement in engineering projects," Li Zheng, Claude Baron, Philippe Esteban, Rui Xue, Qiang Zhang, INSIGHT - International Council on Systems Engineering(INCOSE), Wiley, 2017, 20 (4), pp.40-43.
180. "Situation-Oriented Requirements Engineering," Nimanthi Atukorala, Iowa State University, 2019.
181. *Normal Accidents: Living with High-Risk Technologies*, Charles Perrow, Princeton University Press, 1999.
182. *The Fifth Discipline: The Art and Practice of the Learning Organization*, Peter Senge, March 2010.
183. "Model-Based Design of Project Systems, Modes, and States," Ali Shafaat and C. Robert Kenley, *Systems Engineering*, Vol 22, Issue 4, July 2019.

Systems Engineering and Project Performance Management Websites

219

1. https://segoldmine.ppi-int.com/
2. https://www.incose.org
3. https://www.nasa.gov/offices/oce/functions/systems/index.html

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