

Application of Systems Lifecycle Processes to Large, Complex Engineering and Construction Programs ¹

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The complexity of megaprojects and programs continues to grow and with it the challenges of delivering ever larger and more complex programs. These large complex programs open the door to many new opportunities but also to increased challenges in delivery and sustainment throughout their lifecycle. Prior articles have described the open nature of this large complex program system² and compared its attributes to many we find in the world of relativistic physics³. These challenges must be addressed recognizing that they arise from a combination of physical, fiscal and human attributes in a realm of complexity which challenges the very foundations of project management theory.

This paper looks at hard systems aspects as contrasted with the soft system aspects more characteristic of an open system. Its purpose is to adapt a systems engineering framework associated with the hard closed elements of these large complex project systems without losing site of the overall open systems nature of large complex programs.

The systems life cycle process codified in ISO 15288 lends itself to application in large complex engineering and construction programs. It provides a framework to aid in the integration of physical, fiscal and human factors from a lifecycle perspective. This life cycle spans the assets initial conception through ultimate disposal of the consumed asset.

The table that follows identifies where specific outcomes and the associated activities to accomplish them may reside. These have been defined as at a program level (PMC, Program Management Consultant), project level (PM, Project Manager) or at a lower project execution level (PExec). Several limitations should be noted. First, the standard itself and the application as presented in this table do not do sufficient justice to the social and environmental aspects of a triple bottom line perspective. Here the reader would benefit from a closer view as can be seen in Prieto 2012⁴. Second, the open systems

¹ How to cite this paper: Prieto, R. (2020). Application of Systems Lifecycle Processes to Large, Complex Engineering and Construction Programs; *PM World Journal*, Vol. IX, Issue X, October.

² Prieto, R. (2020) Systems Nature of Large Complex Programs; *PM World Journal*, Vol. IX, Issue VIII, August

³ Prieto, R. (2020). A Deeper Look at the Physics of Large Complex Projects; A Neo-classical Project Management Theory is Required; *PM World Journal*, Vol. IX, Issue VIII, August

⁴ Application of Life Cycle Analysis in the Capital Assets Industry; *PM World Today*; March 2012;

https://www.researchgate.net/publication/272504721_Application_of_Life_Cycle_Analysis_in_the_Capital_Assets_Industry

aspects of large complex programs are not truly covered and as such this may best be regarded as a subset of a larger open system perspective related to large complex programs.

The table follows the general format of ISO 15288, grouping system processes into four groups:

- Agreement processes
- Enterprise processes
- Project processes
- Technical processes

The table is intended to provide a framework where each activity can be further broken down into a series of tasks. In an earlier use IP under development related to the management of large complex projects was mapped to this system life cycle process.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
1.0 Agreement Processes	1.1 Acquisition	PMC,PM,PExec	Acquisition strategy	Acquisition plan
			Supplier selection	RFP
			Supplier communication	Supplier dialogue including partnering
			Supplier justification	Supply evaluation; selection; justification
			Agreement for product or service	Negotiate/execute contract; confirm contract compliance
			Acceptance of product or service	Resolution of exceptions to contract; final acceptance
			Payment	Periodic and final payments
	1.2 Supply to Client	Pre-Engagement	Client identification	Authorizing, financing and

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				accepting client elements
			Respond to client request (RFQ;RFP)	Bid no-bid; Identification of contract exceptions requiring resolution
			Agreement for work to be performed	Negotiate and execute agreement
			Communication with client	Assess execution of the agreement
			Project execution per contract and agreed procedures	Deliver project in accordance with agreement
			Final acceptance by client	Transfer facility
			Payment	Accept and acknowledge payment
2.0 Enterprise Processes	2.1 Enterprise Environment Management	PMC	Policies and procedures for the strategic management of lifecycles	Establish top level strategies and plans that will be undertaken to achieve strategic business objectives ⁵
				Define, integrate, communicate the roles and responsibilities,

⁵ National Academy of Construction Executive Insights; The Importance of Strategic Business Objectives <https://www.naocon.org/wp-content/uploads/The-Importance-of-Strategic-Business-Objectives.pdf>

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				authorities to implement system life cycle processes and management
				Define business criteria that control progression through the system life cycle (stage gate ⁶)
			Accountability and authority for system life cycle management	System life cycle processes and procedures
			Policy to improve system lifecycle processes	Conduct periodic reviews of life cycle model
				Communicate to projects policies and procedures
	2.2 Investment management Process	PMC	Qualification and selection of investment opportunities	Identify project portfolio and required thresholds
				Prioritize projects
				Define projects, accountabilities and authorities (program view)
				Identify expected projects outcomes (link to SBO)

⁶ PMO & the Tollgate Process; PM World Journal; May 2013;
https://www.researchgate.net/publication/272505052_PMO_the_Tollgate_Process

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			Resource and budget identification and allocation	Allocate resources to achievement of project outcomes
			Project Management accountability and authorities defined	Clear identification of multi-project interfaces
				Project reporting and review requirements
				Authorize project execution
			Projects meeting agreement, stakeholder and organization requirements (SBO etc.) are sustained	Evaluate ongoing project progress
				Evaluate compliance with project directives
				Evaluate conformance with system life cycle plans and procedures
				Confirm continuing project necessity and validity (SBO test)
			Projects not meeting agreement, stakeholder and organization requirements	Evaluate alternatives to cancel, suspend and redirect

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			are redirected or terminated	
	2.3 System life cycle process management	PMC	System life cycle processes are defined	Establish standard sets of system life cycle processes for applicable system life cycle stages
			Policy to apply processes are defined	Establish acceptable tailoring and application policies and procedures with approval requirements
			Policy on adapting defined policies to specific project needs is defined	Establish acceptable tailoring and application policies and procedures with approval requirements
				Methods and tools to support life cycle process execution are identified
			Measures are defined to evaluate application of the system life cycle process	Establish performance measures
				Monitor process execution and identify

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				enterprise level trends
			Improvements to the definition and application of system life cycle performances are undertaken	Identify opportunities for improvement
				Improve processes, methods and tools
	2.4 Resource Management Process	PMC	Necessary resources, materials and services are provided to projects	Map necessary resources, materials and services to project plans and future business/program needs
				Define applicable physical and human factors and how they may change in the future
				Determine and provide the resource infrastructure support needed and provide project support
				Obtain non personnel resources to implement and support projects
				Maintain and manage the pool

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				of personnel necessary to staff ongoing projects
			Skills of personnel are maintained and enhanced	Manage competency throughout the life cycle
				Provision of training and education to improve skill sets and support career path
				Motivate staff through career development and rewards
			Conflicts in multi-project resource demands are resolved	Control multi-project resources to resolve schedule conflicts
	2.5 Quality Management	PMC	Quality management policies and procedures are defined	Establish quality management policies, standards and procedures (ISO 9001; 9004)
			Quality goals and objectives are defined	Establish quality management goals and objectives to achieve SBO, support top level strategies and achieve client satisfaction
			Quality management accountability	Define responsibilities

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			and authority defined	for quality management
			Status of client and stakeholder satisfaction is monitored	Assess client and stakeholder satisfaction and report
			Corrective action taken when quality goals not achieved	Conduct periodic reviews of project quality plans assuring quality objectives based on stakeholder requirements have been established
				Monitor the status of quality improvement
3.0 Project Processes	3.1 Project Planning Process	PM	Project plans exist	Objectives and constraints identified including performance, quality, cost, time, stakeholder
				Objectives sufficiently defined to permit selection and implementation of appropriate processes and activities
				Define project scope ⁷ as

⁷ Prieto, R. (2019). The Primacy of the Scope Baseline in Engineering & Construction Projects; PM World Journal, Vol. VIII, Issue IX, October;

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				established in agreement
				Define all activities to complete the project successfully
				Establish a work breakdown structure
				Define and maintain a project schedule based on project objectives and work estimates. Includes duration, relationship, dependencies, sequence, achievement milestones, resources and reviews.
				Define project achievement criteria for life cycle stage decision gates, delivery dates, major dependencies on external inputs or outputs
				Define project costs and plan a budget

<https://www.researchgate.net/publication/336496336> The Primacy of the Scope Baseline in Engineering Construction Projects

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			Roles, responsibilities and authorities are defined	Define the project organization, staff acquisitions, staff skills development and work methods
				Establish the structure of authorities and responsibilities of project work
			Resources and services necessary to achieve project objectives are formally requested	Define the infrastructure and services required by the project
				Plan the acquisition of materials, goods and enabling system services supplied from outside the project ⁸
				Technical management plan developed and communicated (includes reviews)
			Project performance	Define project measures to be used, data to be

⁸ National Academy of Construction Executive Insights; Procurement Management in Large Complex Programs <https://www.naocon.org/wp-content/uploads/Procurement-Management-in-Large-Complex-Programs.pdf>

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			measures are defined	collected (including sources), validated and analyzed ⁹
				Prepare project quality plan
			Project staff directed in accordance with project plans	Conduct project audits
	3.2 Project assessment process	PMC,PM	Project performance measures or assessment results are available	Assess project status against plans to determine actual and projected performance, identifying variations ¹⁰
				Perform quality assurance in accordance with project plans
			Adequacy of roles responsibilities and authorities assessed	Assess effectiveness of project team structure, roles and responsibilities
			Adequacy of resources and services necessary assessed	Assess adequacy of team member competencies

⁹ Prieto, B. (2019). Impacts of Artificial Intelligence on Management of Large Complex Projects. PM World Journal, Vol. VIII, Issue V, June;
https://www.researchgate.net/publication/334162272_Impacts_of_Artificial_Intelligence_on_Management_of_Large_Complex_Projects

¹⁰ National Academy of Construction Executive Insights; Effective Project Review Meetings
<https://www.naocon.org/wp-content/uploads/Effective-Project-Review-Meetings.pdf>

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Assess adequacy and availability of the project's supporting infrastructure
				Confirm intra-organizational commitments are met
			Deviations in project performance are analyzed	Assess project performance using measured achievement and milestone completion
				Determine effectiveness and adequacy of evolving capabilities to meet a range of future needs
				Conduct required management and technical reviews, audits and inspection to determine readiness to proceed to next life cycle stage or milestone ¹¹
				Monitor critical processes and new work methods and technologies

¹¹ National Academy of Construction Executive Insights, Owner Readiness <https://www.naocon.org/wp-content/uploads/Owner-Readiness.pdf>

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Analyze data for variations and make recommendation for appropriate action
			Concerned parties are informed of project status	Provide periodic status and required deviation reports
	3.3 Project Control Process	PM	Corrective action is defined and directed when achievement not meeting targets	Manage project requirements and changes to requirements in accordance with the project plans.
				Initiate the corrective actions needed to achieve the goals and outputs of project tasks that have deviated outside acceptable or defined limits.
				Re-deployment and re-assignment of personnel, tools and project infrastructure assets when inadequacy or unavailability has been detected.
				Initiate preventive

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				actions, as appropriate, to ensure achievement of the goals and outputs of the project.
				Initiate problem resolution actions to correct non-conformances.
				Performing corrective actions to the implementation and execution of the life cycle processes when non-conformances are traced to them.
			Project re-planning is initiated when project objectives or constraints change or assumptions invalidated or migrated	Evolve with time the scope, definition and the related breakdown of the work to be carried out by the project in response to the corrective action decisions taken and the estimated changes they introduce.
				Initiate change actions when there is a contractual

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				change to cost, time or quality due to the impact of client or supplier request.
				Act to correct defective provision of acquired goods and services through constructive interaction with the supplier.
			Project action to advance to next milestone is authorized	Authorize the project to proceed toward the next milestone or event if justified
			Project objectives are achieved	Conduct project audit ¹²
	3.4 Decision Making Processes	All	Decision-making strategy is defined.	Define a decision-making strategy including the identification and allocation of responsibility for, and authority to make decisions.
			Alternative courses of action are defined.	Involve relevant parties in the decision-making in order to draw on experience and knowledge.

¹² Program Management Audit Checklist

https://www.researchgate.net/publication/273118616_Program_Management_Audit_Checklist

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Identify the circumstances and need for a decision.
				Record, categorize and promptly and objectively report problems or opportunities and the alternative courses of action that will resolve their outcome.
			Preferred course of action is selected.	Select and declare the decision-making strategy for each decision situation. Identify desired outcomes and measurable success criteria.
				Evaluate the balance of consequences of alternative actions, using the defined decision-making strategy, to arrive at an optimization of, or an improvement in, an identified

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				decision situation.
			Resolution, decision rationale and assumptions are captured and reported.	Record, track, evaluate and report decision outcomes to confirm that problems have been effectively resolved, adverse trends have been reversed and advantage has been taken of opportunities.
				Maintain records of problems and opportunities and their disposition, as stipulated in agreements or organizational procedures and in a manner that permits auditing and learning from experience.
	3.5 Risk Management Process	PMC,PM	Risks are identified and categorized.	Establish a systematic approach to risk identification, assessment and treatment.
				Identify and define the risks.
				Identifying the initiating events associated with each risk in each

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				risk category, and defining the interrelationships between sources of risk.
			The probabilities and consequence of risks are quantified.	Determine the probability associated with risk occurrence using established risk criteria. Criteria can include associated cost, legal and statutory requirements, socio-economic and environmental aspects, the concerns of stakeholders, priorities and other inputs to the assessment.
				Evaluate the risks in terms of their possible consequences using the established criteria.
				Prioritize the risks in terms of their probability and consequences.
			Strategy to treat each risk is specified.	Determine the risk treatment strategies.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Define a threshold of acceptability for each identified risk.
				Identify the risk treatment actions to follow if the threshold of acceptability is exceeded.
				For risks that have high consequences ¹³ , establish contingency plans that will be initiated if mitigation actions are unsuccessful.
			Risk status is available and communicated.	Communicate the risk treatment actions and their status in accordance with the agreement, policies and procedures.
				Maintain a register of risk throughout the life cycle. Register includes a definition of the current

¹³ National Academy of Construction Executive Insights, Fat Tails
https://www.researchgate.net/publication/340949652_Risk_and_Opportunities_Fat_Tails_Key_Points

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				perception of risks, and the relationship to risk treatment actions and budgets.
			Risks that have become unacceptable are acted upon	
	3.6 Configuration Management	PMC, PM	Configuration management strategy is defined.	Define a configuration management strategy compatible with the guidance provided in ISO 10007.
			Items requiring configuration management are defined.	Identify items that are subject to configuration control.
			Configuration baselines are established.	Maintain information on configurations with an appropriate level of integrity and security.
			Changes to items under configuration management are controlled.	Ensure that configuration information permits forward and backward traceability to other baselined configuration states.
			The configuration of released items is controlled.	Ensure that changes to configuration baselines are

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				properly identified, recorded, evaluated, approved, incorporated, and verified.
			Status of items under configuration management is made available throughout the life cycle.	Ensure that changes to configuration baselines are properly identified, recorded, evaluated, approved, incorporated, and verified.
				Perform audits to verify conformance of a baseline to drawings, interface control documents and other agreement requirements.
	3.7 Information Management Process	All	Information to be managed is identified.	Define the items of information that will be managed during the system life cycle and, according to organizational policy or legislation, maintained for a defined period beyond.
				Designate authorities and

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				responsibilities regarding the origination, generation, capture, archiving and disposal of items of information.
				Define the rights, obligations and commitments regarding the retention of, transmission of and access to information items.
			Forms of the information representations are defined.	Define the content, semantics, formats and medium for the representation, retention, transmission and retrieval of information.
			Information is transformed and disposed of as required.	Obtain the identified items of information.
			Status of information is recorded.	Maintain information items and their storage records according to integrity, security and privacy requirements.
			Information is current,	Define information

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			complete and valid.	maintenance actions.
			Information is made available to designated parties.	Retrieve and distribute information to designated parties as required by agreed schedules or defined circumstances.
				Provide official documentation as required.
				Archive designated information, in accordance with the audit and knowledge retention purposes.
				Dispose of unwanted, invalid or unverifiable information according to organization policy, and security and privacy requirements.
4.0 Technical Processes	4.1 Stakeholder Requirements Definition Process	PMC, PM	Required characteristics and context of use of services specified.	Identify the individual stakeholders or stakeholder classes who have interest in the system

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				throughout its life cycle ¹⁴ .
				Elicit stakeholder requirements.
			Constraints on a system solution are defined.	Define the constraints on a system solution that are unavoidable consequences of existing agreements, management decisions and technical decisions.
			Traceability of stakeholder requirements to stakeholders and their needs is achieved.	Define a representative set of activity sequences to identify all required services that correspond to anticipated operational and support scenarios and environments. Scenarios are used to analyze the operation of the system in its intended environment in order and to identify

¹⁴ Stakeholder Management in Large Engineering & Construction Programs; PM World Today; October 2011
https://www.researchgate.net/publication/273119019_Stakeholder_Management_in_Large_Engineering_Construction_Programs

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				requirements that may not have been formally specified by any of the stakeholders, e.g. legal, regulatory and social obligations.
				Context of use of the system is identified and analyzed. Include in the context analysis the activities that users perform to achieve system objectives, the relevant characteristics of the end-users of the system, the physical environment and any equipment to be used.
				The social and organizational influences on users that could affect system use or constrain its design are analyzed when applicable.
			Basis for defining the system	Identify the interaction between users and the system.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			requirements is described.	
				Usability requirements are determined, establishing, as a minimum, the most effective, efficient, and reliable human performance and human-system interaction.
				Define required physical, mental, and learned capabilities
				Define work place, environment and facilities, including other equipment in the context of use
				Define normal, unusual, and emergency conditions;
				Define operator and user recruitment, training and culture
			Basis for validating the conformance of the services is defined.	Specify health, safety ¹⁵ , security, environment and other

¹⁵ National Academy of Construction Executive Insight, Safety Through Design
https://www.researchgate.net/publication/340949703_Safety_Through_Design_Key_Points

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				stakeholder requirements and functions that relate to critical qualities.
				Identify safety risk and specify requirements and functions to provide safety.
				Identify risks associated with methods of operations and support, health and safety, threats to property and environmental influences.
				Identify security risk specify all applicable areas of system security, including physical, procedural, communications, computers, programs, data
				Identify functions that could impact the security of the system, including access and damage to protected personnel, properties and information,

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				compromise of sensitive information, and denial of approved access to property and information.
				Specify the required security functions, including mitigation and containment, referencing applicable standards and practices
				Analyze the complete set of elicited requirements.
				Resolve requirements problems.
				Feed back the analyzed requirements to applicable stakeholders to ensure that the needs and expectations have been adequately captured and expressed.
			Basis for negotiating and agreeing to supply a service	Explain and obtain agreement to the proposals to resolve

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			or product is provided	conflicting, impractical and unrealisable stakeholder requirements.
				Establish with stakeholders that their requirements are expressed correctly. Confirm that stakeholder requirements are comprehensible to originators and that the resolution of conflict in the requirements has not corrupted or compromised stakeholder intentions.
				Record the stakeholder requirements in a form suitable for requirements management through the life cycle
				Maintain stakeholder requirements traceability to the sources of stakeholder need.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Review stakeholder requirements at key decision times in the life cycle
	4.2 Requirements Analysis Process	PMC,PM,PExec	The required characteristics, attributes, and functional and performance requirements for a solution are specified.	Define the functional boundary of the system in terms of the behavior and properties to be provided.
				Define each function that the system is required to perform, how well the system, including its operators, is required to perform that function, the conditions under which the system is to be capable of performing the function, the conditions under which the system is to commence performing that function and the conditions under which the system is to cease

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				performing that function.
				Reference states and required modes of operation of the system.
			Constraints that will affect the design of a system and the means to realize it are specified.	Define necessary implementation constraints that are introduced by stakeholder requirements or are unavoidable solution limitations.
				Define technical and quality in use measures that enable the assessment of technical achievement.
				Define critical performance parameters associated with each effectiveness measure identified in the stakeholder requirements.
				Analyze critical performance measures to ensure stakeholder requirements are met and to ensure

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				identification of project cost
				Specify system requirements and functions
				Analysis and definition of safety considerations
				Analyze security considerations including those related to compromise and protection of sensitive information
			Integrity and traceability of system requirements to stakeholder requirements is achieved	Analyze the integrity of the system requirements to ensure that each requirement, pairs of requirements or sets of requirements possess overall integrity.
				Check each system requirement statement to establish that it is unique, complete, unambiguous, consistent with all other requirements, implementable and verifiable.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Identify deficiencies, conflicts and weaknesses and resolve within the complete set of system requirements.
				Analyze resulting system requirements to confirm that they are complete, consistent, achievable (given current technologies or knowledge of technological advances) and expressed at an appropriate level of detail.
				Confirm that they are a necessary and sufficient response to stakeholder requirements and a necessary and sufficient input to other processes, in particular design.
			Basis for verifying that the system requirements are satisfied is defined.	Demonstrate traceability between the system requirements and the

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				stakeholder requirements.
				Maintain the set of system requirements together with the associated rationale, decisions and assumptions throughout the system life cycle.
	4.3 Design Process	PExec	Design baseline is established.	Define appropriate logical designs.
				Define appropriate expanded basis of design (BOD ^X) ¹⁶¹⁷
				Identify and define derived requirements for describing functional and performance requirements, services and attributes, timeline requirements, data flow requirements, etc.

¹⁶ National Academy of Construction Executive Insights, Business Basis of Design
https://www.researchgate.net/publication/340949572_Business_Basis_of_Design_Key_Points

¹⁷ Prieto, R. (2014) Addressing Project Capital Efficiency through a Business Basis of Design; PM World Journal
https://www.researchgate.net/publication/264942989_Addresssing_Project_Capital_Efficiency_through_a_Business_Basis_of_Design

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Conflicts among and between various logical descriptions are resolved and each element is shown to be complete and consistent by making mutual traceability checks with the defined system requirements.
			Implementable set of system element descriptions that satisfy the requirements for the system are specified.	Partition the system functions identified in requirements analysis and allocate them to elements of system architecture. Generate derived requirements as needed for the allocations.
				Analyze the resulting design to establish design criteria for each element.
				Determine which system requirements are allocated to operators.
				Identify limitations of

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				human capabilities;
				Identify human actions critical to safety and how the consequences of error are addressed;
				Identify integration of human performance into systems and their operation..
			Interface requirements are incorporated into design solution.	Determine whether elements that satisfy the design and interface criteria are available off-the-shelf.
			Basis for verifying the system elements is defined.	Evaluate design elements that are not readily available in order to determine if an element is to be developed, or if existing system elements will be re-used or adapted.
				Establish the costs, schedule, and technical risks associated with these make/modify/buy decisions.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Evaluate alternative design solutions, modeling them to a level of detail that permits comparison against the specifications expressed in the system requirements and the performance, costs, time scales and risks expressed in the stakeholder requirements.
				Assess and communicate the emergence of adverse system properties resulting from the interaction of candidate system elements or from changes in a system element
				Ensuring that the constraints of enabling system are taken account of in the design
				Perform effectiveness assessments,

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				trade-off analyses and risk analyses that lead toward realizing a feasible, effective, stable and optimized design.
			Basis for the integration of system elements is established.	Define and document the interfaces between system elements and at the system boundary with external systems.
				Human-system and human-human interfaces are defined and controlled
				Specify the selected physical design solution as a design baseline in terms of its functions, performance, behavior, interfaces and unavoidable implementation constraints.
			Traceability of design to system requirements is established.	Record the design information (structural and functional

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				partitioning, interface and control definitions and the design decisions and conclusions, with traceability to the requirements baseline)
				Maintain mutual traceability between design and system requirements.
	4.4 Implementation Process	PExec	An implementation strategy is defined.	Generate an implementation strategy.
				Develop implementation procedures, fabrication processes, tools and equipment, implementation tolerances and verification uncertainties.
				Achieve consistent and repeatable producibility in reference design elements and modular construction
			Implementation technology constraints on	Identify the constraints that the implementation

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			the design are identified.	strategy and implementation technology impose on the design solution.
			A system element is realized.	Realize or adapt system elements using enabling systems
				Deliver appropriate training to prepare operators for performing tasks in accordance with required performance standards and operational procedures
				Confirm that the specified range and level of competence has been attained.
				Record evidence that the system element meets supplier agreements, legislation and organizational policy.
			A system element is packaged and stored in accordance with an agreement for its supply.	Package the system element and store as appropriate. Conveyance and storage media, and their durations,

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				influence the specified containment.
	4.5 Integration Process	PMC,PM,PExec	A system integration strategy is defined.	Define an assembly sequence and strategy that minimizes system integration risks.
			Unavoidable constraints of integration that influence requirements are defined.	Identify the constraints on the design arising from the integration strategy such as accessibility, integration enabling systems and required interfacing/interconnections for intermediate assembly configurations.
				Obtain integration enabling systems and specified materials according to the defined integration procedures.
			A system capable of being verified against the specified requirements from design is	Obtain system elements in accordance with agreed schedules.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			assembled and integrated.	
				Assure that the system elements have been verified against acceptance criteria specified in an agreement.
				Integrate system elements in accordance with applicable interface control descriptions and defined assembly procedures
			Non-conformances due to integration actions are recorded.	Record integration information in an appropriate database.
	4.6 Verification Process	PMC,PM,PExec	A verification strategy is defined.	Define the strategy for verifying the systems throughout the life cycle. Include the context and purpose for each instance of verification action, e.g. verifying the design, ability to build the design correctly, ability to reproduce the system, ability to

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				correct a fault arising, ability to predict failures.
				Define a verification plan based on system requirements.
			Verification constraints are provided as inputs to requirements.	Identify and communicate potential constraints on design decisions.
				Ensure that the enabling system for verification is available and associated facilities, equipment and operators are prepared to conduct the verification.
				Conduct verification to demonstrate compliance to the specified design requirements.
			Data providing information for corrective action is reported.	Make available verification data on the system.
				Analyze, record and report verification, discrepancy and corrective action information.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Conduct fault diagnosis to a level of resolution consistent with cost effective remedial action, including re-verification following defect correction, and/or organizational quality improvement actions.
			Objective evidence	Verification data is collected
				Analyze verification data to detect essential features such as trends and patterns of failure
	4.7 Transition Process (Construction)	PMC, PM, PExec	A system transition strategy is defined.	Prepare a transition strategy.
			A system is installed in its operational location.	Prepare the site of operation in accordance with installation requirements.
				Site preparation is conducted in accordance with applicable health, safety, security and

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				environmental regulations.
				Deliver the system for installation at the correct location and time.
				Install the system in its operational location and interfaced to its environment according to its system specification.
				Demonstrate proper installation of the system.
			A system, when operated, is capable of delivering services.	Activate the system.
				Demonstrate the installed system is capable of delivering its required services.
			The configuration as installed is recorded.	Record the installation data, including the operational configuration, anomalies detected, actions taken and lessons learned.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			Corrective action reports are recorded.	
			A service is sustainable by enabling systems.	
	4.8 Validation Process	PMC, PM, PExec	A validation strategy is defined.	Define the strategy for validating the services in the operational environment and achieving stakeholder satisfaction.
				Prepare a validation plan.
				Define validation steps, e.g. various operational states, scenarios and missions that progressively build confidence in conformance of the installed system and assist diagnosis of any discrepancies.
				Specify methods and techniques needed to implement the validation strategy and the purpose, conditions and conformance

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				criteria for each validation.
				Ensure that any operators, enabling system for validation and associated facilities are ready in order to conduct validation
			The availability of services required by stakeholders is confirmed.	Conduct validation to demonstrate conformance of services to stakeholder requirements.
				Objectively record and approve validation actions and results.
				Confirm that the system not only satisfies all operational, functional and usability requirements, but also satisfies the often less formally expressed, but sometimes overriding, attitudes, experience and subjective tests that comprise

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				customer satisfaction.
			Validation data is provided.	Make available validation data on the system according to legal, regulatory or product sector requirements.
				As appropriate to agreement terms or organizational objectives, conduct validation to isolate that part of the system giving rise to a non-conformance.
				Conduct fault diagnosis to a level of resolution consistent with cost effective remedial action, including revalidation
			Data capable of providing information for corrective action is reported.	Analyze, record and report validation data according to criteria defined in the validation strategy.
				Categorize non-conformances according to their source and

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				corrective action owner.
				Analyze validation data to detect essential features such as trends and patterns of failure, evidence of design errors and emerging threats to services.
	4.9 Operation Process	PExec	An operation strategy is defined.	Prepare a strategy for operation.
				Define availability of services as they are introduced, routinely operated and withdrawn from service.
				Define co-ordination with pre-existing, concurrent or continuing services delivered by other systems that provide identical or similar services
				Define staffing strategy and schedules for operators.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Define the release and re-acceptance criteria and schedules of the system to permit modifications that sustain existing or enhanced services.
			Services that meet stakeholder requirements are delivered.	Obtain other services related to operation of the system.
				Assign trained, qualified personnel to be operators.
				Activate the system in its intended operational situation to deliver instances of service or continuous service according to its intended purpose.
				Maintain continuous service capacity and quality when the system replaces an existing system that is being retired.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				During a specified period of changeover or concurrent operation, manage the transfer of services so that continuing conformance to stakeholder needs is achieved.
				Consume materials, as required, to sustain the services.
				Monitor operation to ensure that the system is operated in accordance with the operations plans, in a safe manner and compliant with legislated guidelines concerning occupational safety and environmental protection.
				Monitor the system operation to confirm that service performance is within

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				acceptable parameters.
			Approved corrective action requests are satisfactorily completed.	Perform failure identification actions when a non-compliance has occurred in the delivered services.
				Determine the appropriate course of action when corrective action is required to remedy failings due to changed need.
				Introduce remedial changes to operating procedures, the operator environment, human-machine interfaces and operator training as appropriate when human error contributed to failure.
			Stakeholder satisfaction is maintained.	Continuously or routinely communicate with users to determine the degree to which delivered services satisfy their needs.

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				Analyze results and take required action to restore or amend services in order to provide continued stakeholder
	4.10 Maintenance Process	PExec	Maintenance strategy is developed.	Prepare a maintenance strategy.
				Define schedules and resources required to perform corrective and preventive maintenance in conformance with operational availability requirements.
				Develop corrective and preventive maintenance strategy to sustain service in the operational environment in order to achieve customer satisfaction
				Define scheduled preventive maintenance actions that reduce the

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				likelihood of system failure without undue loss of services
				Define number and type of replacement system elements to be stored, their storage locations and conditions, their anticipated replacement rate, their storage life and renewal frequency
				Define skill and personnel levels required to effect repairs and replacements, accounting for maintenance staff requirements and any relevant legislation regarding health and safety, security and the environment.
			Maintenance constraints are provided as inputs to requirements.	Define the constraints on system requirements that are unavoidable consequences of the maintenance

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				strategy.
			Replacement system elements are made available.	Obtain the enabling systems, system elements and services to be used during maintenance of the system.
				Confirm that logistics actions satisfy the required replenishment levels so that stored system elements meet repair rates and planned schedules.
				Monitor the quality and availability of spares, their transportation and their continued integrity during storage.
			Services meeting stakeholder requirements are sustained.	Implement problem reporting and incident recording to guide diagnosis of individual events and histories to support future corrective, adaptive, perfective and

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				preventive maintenance.
				Implement the procedures for correction of random faults and/or scheduled replacement of system elements.
				Perform preventive maintenance by replacing or servicing system elements prior to failure, according to planned schedules and maintenance procedures.
			Need for corrective design changes is reported.	Initiate corrective action to remedy previously undetected design errors.
			Failure and lifetime data is recorded.	Perform failure identification actions when a non-compliance has occurred in the system.
				Maintain a history of problem reports, corrective actions and trends to inform

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				operations and maintenance personnel, and other projects, that are creating or utilizing similar system elements
	4.11 Disposal Process	PMC,PM,PExec	System disposal strategy is defined.	Define a disposal strategy for the system, to include each system element and any resulting waste products.
			Disposal constraints are provided as inputs to requirements.	Communicate unavoidable constraints on the system design arising from the disposal strategy.
				Define issues related to disassembly, including their associated enabling systems, access to and availability of storage locations and available skill levels.
			System elements are destroyed, stored,	Acquire the enabling systems or services to be used during

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
			reclaimed or recycled.	disposal of a system.
				Deactivate the system to prepare it for removal from operation.
				Address interfaces to other systems (power, fuel, are disconnected in accordance with disassembly instructions and relevant health, safety, security and privacy legislation)
				Withdraw operating staff from the system and record relevant operating knowledge.
				Disassemble the system into manageable elements to facilitate its removal for reuse, recycling, reconditioning, overhaul, archiving or destruction.
			Environment is returned to its original or an agreed state.	Remove the system from the operational environment for

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				reuse, recycling, reconditioning, overhaul or destruction.
				Specify containment facilities, storage locations, inspection criteria and storage periods if the system is to be stored.
				Conduct destruction of the system, as necessary, to reduce the amount of waste treatment or to make the waste easier to handle.
				Obtain destruction services required in order to melt, crush, incinerate or demolish the system or its elements as necessary.
				Safeguard and secure knowledge and skills possessed by operators.
				Confirm that no detrimental health, safety, security and environmental

Process Group	Process	Level (PMC,PM,PExec)	Outcomes	Activities
				factors exist following disposal.
			Records allowing knowledge retention of disposal actions and the analysis of long-term hazards are available.	Archive information gathered through the lifetime of the system to permit audits and reviews in the event of long-term hazards to health, safety, security and the environment, and to permit future system creators and users to build a knowledge base from past experiences.

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