Systems Nature of Large Complex Programs[1]

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This paper explores the system characteristics and behaviors of large engineering and construction programs with a particular focus on those that would be characterized as complex. It recognizes the interrelated and interacting elements of both programs and projects as they strive to form a complex whole. Large complex programs and projects are not well bounded as classical project management theory as espoused by Taylor, Gantt and Fayol[2] would have us believe but rather behave in both independent and interconnected ways in a dynamic systems environment.

Large complex programs demonstrate the evolutionary nature of all complex systems; uncertainty; and emergence that comes with human actions and interactions. They struggle from insufficient situational awareness, treating the program to be more well-bounded than reality would suggest and using simplified models to understand the complexity inherent in execution. Best practices from project management literature were typically not derived from such environments and, worse, have fallen short on other large complex programs and projects.

Large complex programs are characterized by boundaries that change in response to changing environments (traditional PM theory limits communication across boundaries); emphasize coping with challenges and change (traditional PM theory restrains/limits managerial response to changes); go beyond uncertainty and require change in perspective (Agile PM helps deal with uncertainty); face a high level of unknown unknowns and unclear/incompatible stakeholder needs. They encourage and likely require innovativeness in execution which is beyond the mechanistic approach of traditional PM theory.

General Systems Theory and Key Characteristics

Systems theory represents a different way of seeing, thinking and acting.[3]

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[2] See R. Prieto, Theory of Management of Large Complex Projects
[3] De Rosnay, Macroscope: A New World Scientific System, 1975

Systems are viewed as greater than the sum of their parts. A system's holistic properties can never be completely known. Different perspectives will provide different views that may overlap and not be completely compatible. Complexity of systems may exist at multiple levels – component, sub-system, system and system of systems. Flexibility, adaptability and responsiveness provide resilience in complex systems and redundancy of information flows and critical resources are essential characteristics in well performing systems. Time must be managed to accommodate disruptions and disturbances and provide adequate time for the system to recover. Positive feedback loops may drive multi-finality while negative feedbacks aid equilibrium and stability. Systems methodologies are characterized as either hard or soft systems methodologies.

Hard systems methodologies sometimes referred to as operations research does not deal as effectively with complex human conflictual problems as does soft systems methodologies. The later consider the broader environment including human and sociological elements. Soft systems methodologies are often iterative, learning at each stage.

While systems may be considered to be closed or open, the focus in this paper is on open systems which are more analogous to large complex programs.

Large Complex Program Characteristics Align with General Systems Theory (GST)

Large complex programs and projects inhabit the open system world described by general systems theory. The adoption of a systems approach to the management of large complex programs carries with it a requirement to think strategically.

Shared concepts and best practices of large complex programs and projects and general systems theory include:

- Life cycle approach
- People-centric issues
    - Leadership
    - Stakeholder engagement and benefit clarification
    - Communication
    - Motivation and team building
    - Negotiation
- Importance of processes
- Focus on taming complexity
- Clarity of purpose (SBO)

Systems tools that can aid in management of large complex programs and projects include:

- Rich pictures[4]
- Root definitions[5] (SBO)
- Soft systems methodology using a 7-step approach:
    - Entering the problem situation.
    - *Expressing the problem situation.*
    - *Formulating root definitions of relevant systems.*
    - *Building Conceptual Models of Human Activity Systems*[6].
    - Comparing the models with the real world.
    - Defining changes that are desirable and feasible.
    - Taking action to improve the real world situation.
- Integrative thinking using holistic models
- System of systems understanding in programs (multi-project domains) and trans-domains (program to supply chains as an example). Interactions deliver important emergent properties.

[4] Rich pictures are informal drawings that express how an individual feels about a situation. The goal is richness of personal
expression, unrestrained by social conventions and predetermined frameworks. The rich picture identifies the issues and related processes in a problem situation. Rich pictures are useful in surfacing the mental models and metaphors associated with the situation. The metaphors are indicative of mental models, values, and attitudes that are unstated but extremely influential in the governance and management of the project. They provide an excellent method of surfacing the true diversity of stakeholders' goals.
[5] A root definition of a project is a high-level definition of overall purpose, its SBOs if you will.
[6] Steps in *italics* are iterative

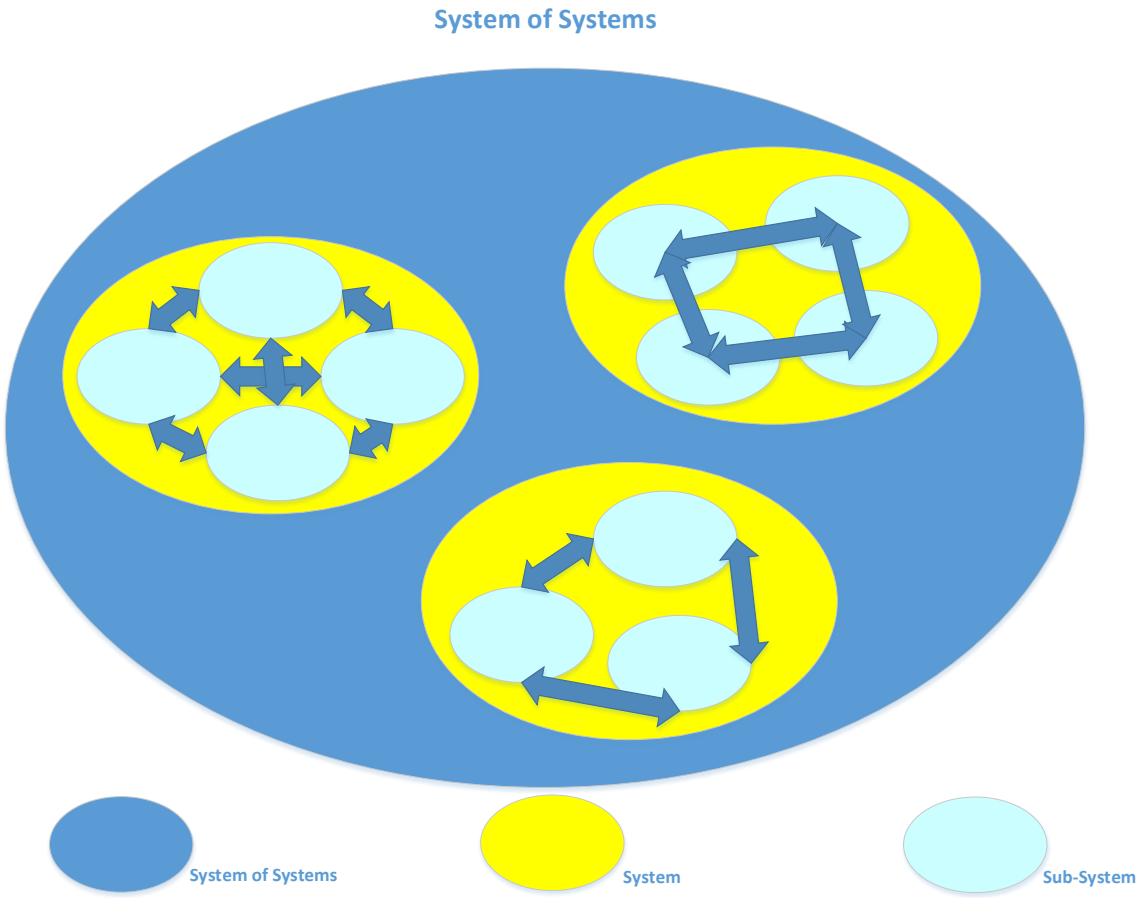

Figure 1
System of Systems

Table 1 compares traditional PM theory and neo-classical theory of PM from a systems perspective.

Table 1
Comparison of Traditional and Neo-Classical PM Theory from a Systems Perspective

	Traditional PM Theory	**Neo-classical PM Theory (Systems Theory)**
Predominant Project Type	Traditional	Large complex programs and projects
Foundational Thoughts	Taylor; Fayol; Gantt	von Bentalanffy
Nature of Projects	"Newtonian"[7]; mechanistic; deterministic (Descartes)	Relativistic (Einstein, quantum physics); organismic (Darwin, evolutionary theory); they represent change, not just are changed
Nature of PM	Control	Synthesis
Thinking	Reductionist	Anti-reductionist, holistic
Project Boundary	Well bounded; closed systems do not interact with their environment	Open exchange with environment; open systems have an ongoing relationship with their environment; part of a larger System of Systems (SoS)
View of project	Well-bounded	Embedded in and interacting with other systems (SoS)
Feedback loops	Defined to support positive control (negative feedback loop)	Emergent; positive and negative feedback; reactions to changes in environment (also change environment)
Properties	Defined; fixed; derived from sum of the parts (components)	Emergent; systemic[8]

[7] Newtonian view held that the Universe was made up of closed systems.
[8] Metaphysics (Aristotle) recognized that…many things have a plurality of parts and are not merely a complete aggregate but instead some kind of whole beyond its parts…"

Table 1 **Comparison of Traditional and Neo-Classical PM Theory from a Systems Perspective**		
	Traditional PM Theory	**Neo-classical PM Theory (Systems Theory)**
Organizations (individuals, groups, departments)	Machine like closed systems; mechanistic structures (highly specialized, compartmentalized, strict rules, well defined and rigid hierarchy; well defined formal tasks)	Flexible organismic structures (decentralized, self-organizing (ongoing process of order-disorder interaction), distributed leadership, extensive interdependence, high individual discretion, informal tasks, 360°communication)
Planning basis	Environment is "knowable"; predictable; limited impact on strategy and execution	Continuous stakeholder engagement
Stability	More stable closed system; in equilibrium with no exchange with their environment	Less stable open system; potential disequilibrium (bad = disruption; good = change, creativity, innovation); stabilized by flows Structural stability relative as it is transferred by exchanges with environment
Emergence	Non-emergent	Emergence of novelty
Strategic Business Objectives; goals	Fixed	Exist in continuous interaction with environment
Complexity	Reductionist approaches do not handle well; complexities considered in isolation from their environment	Complexities considered in context of broader ecosystem; arises from inclusion of relationships as a dynamic property at various levels starting with components and activities[9]

[9] See Appendix 1, Program Action Matrix

Table 1 **Comparison of Traditional and Neo-Classical PM Theory from a Systems Perspective**		
	Traditional PM Theory	**Neo-classical PM Theory (Systems Theory)**
Most valuable contributor	Specialist	Generalist
Project execution	Master schedule; recovery to the plan	Equifinality[10] recognized; provision for contingent execution
Predictability	Predictable (order); outcome determined by initial conditions	Unpredictable (shifting balance of order and disorder); outcomes influenced through interaction with environment; continual evolution
Logic	Binary; evaluation separates behavior (inside) from environment/context (outside)	Spectrum of possibilities; relational context matters
Nature of Flows	Steady, laminar; clear information	Turbulent; information admidst the noise

Implications for Management of Large Complex Programs

Large complex programs can benefit from greater attention to systems theory and availing themselves of many of the hard and soft tools available. These include:

- Soft systems methodology
- Strategic assumption identification, characterization and monitoring
- Scenario planning and contingent strategy development
- Critical system heuristics[11]
- Gap analysis

[10] Equifinality is way systems can reach the same goal through different paths
[11] Critical System Heuristics provides a framework for questioning a program's purpose, source of legitimacy and intended beneficiaries. It is used to surface, elaborate, and critically consider boundary judgments. It views understandings of any situation as inherently incomplete, based on the selective application of knowledge. Through systematic questioning it makes boundary judgments explicit and defensible.

Additionally, large complex programs benefit from understanding the impacts of various program elements at all levels interacting on other program elements. Appendix 1 includes a Program Action Matrix developed from a System of Systems perspective that one would encounter in a large complex program. The reader should consider the description of the various elements in the accompanying legend.

To be successful, large complex programs must:

- Ensure alignment, continuous alignment, on the program's strategic business outcomes and individual project objectives. This begins with strong and continuous communication, especially important given the dynamic nature of implementing organizations over the extended time-frames often associated with such programs. Feedback is essential.

- Continuously engage stakeholders in reaching consensus on the newly emergent stakeholder issues that are inevitable given the fluid boundaries associated with large complex programs.

- Seek broader input into what is often dynamic problem solving. This expertise may be crowd sourced in manners similar to those employed in open innovation. The crowd may include stakeholders recognizing that owner led 'engagement' often shifts to a perceived 'management' of stakeholders as the execution team is established and begins operations. During execution, engagement grows in importance and the notion of stakeholder management should be discarded to the dustbin of failed best practices.

- Recognize that project plans, no matter how well developed, will likely not survive real world contact. Work sequencing and established organizational and communication hierarchies will break down to different degrees. The resultant requirements of contingent execution and broad 360°communication represent organizational properties which must be inoculated into project planning.

- Incentives work and careful pre-thought about the best type of incentives to be deployed (given the project setting), the level of such incentives, the clarity of outcomes to be achieved to earn such incentives and importantly, the timing of their use. This last point is important. All too often incentives are deployed when the program has already come off the rails whereas they may be more effective in keeping the program on the rails. One excellent example is in mature safety programs where safety bonuses are earned as the projects advance and lost until sustained safe performance returns for a defined period.

- Focus on flows[12], better managing their timing and coordination; understanding their impact on other flows; and, importantly, anticipating their changes and rates of change[13].

- Prepare the organization and execution strategies and plans for four types of operations:
  - Regular
  - Irregular (often the norm)
  - Emergency
  - Catastrophic/contingent – this mode of operations focuses on true resilience of the program execution operation and plan. It most certainly aids in handling Black Swans but also the Black Elephants[14] we often ignore. This concept of operations is characterized by flexibility, adaptability, responsiveness, capabilities and capacities.

- Define team to include not only the resources immediately available and under the program's day to day control but also the broader set of skills, knowledge and authorities that will act to enable execution. Importantly, stakeholders need to be viewed as team members and not adversaries and appropriately engaged in successful program delivery. This last concept is often the very antithesis of traditional project management's closed system thinking.

- Empower the execution team by defining outcomes, expectations, behaviors, values, responsibilities and engagement with the broader team. Emphasize 360°communication and prudent risk taking. Emphasize use of self-directed teams focused on contributing to achievement of overall outcomes (SBOs). This is the antithesis of Taylor's assembly line where each team member is only focused on a narrow accomplishment.

- Ensure team composition matches the range of potential changes and challenges in the external environment. Adequate team diversity of skills, experiences and thoughts is essential. When problems are complex, diversity (cognitive differences) trumps ability. Access to required diversity can be accomplished by access to others outside the project team.[15]

[12] See R. Prieto, Theory of Management of Large Complex Projects
[13] R. Prieto, Generalized Analysis of Value Behavior over Time as a Project Performance Predictor, PM World Journal, Vol. I, Issue III – October 2012
[14] R. Prieto, On the Subject of Black Elephants, PM World Journal Vol. IX, Issue VII – July 2020
[15] Law of requisite variety from cybernetics

- Recognize that sole-decision making may be required under chaos but even then decisions benefit from a diversity of views and challenge.

- Strong process, procedures and performance are supported by strong social capital. Connections between people (team members; stakeholders) must be built early and continuously sustained and nurtured. Alignment, collaboration and true leadership act to increase social capital. Effective use of social networks to gather knowledge and support are leading indicators of project success.

- Risk and opportunity must be equally managed. Recognize that entropy (disorder and randomness) are present and create or contribute to threats and opportunities depending on how we address them.

- Ensure comprehensive understanding of changes, including disruptions, on the entirety of the program. They are not discrete or localized events; they change the program in ways we must seek to understand. Emergent properties are visible only when considering the program as a whole.

- Related to this is ensuring root causes are understood and not acting elsewhere in the program or subject to recurrence at a later stage.

- Recognize that stakeholders do not exist in isolation and that they are part of a broader interacting ecosystem. Even when the number (N) of potential stakeholders may be limited there are still $(N^2 – N)/2$ potential communication channels between them that may act as sources/precursors to influencing flows.

- Understand that traditional project control systems actually control nothing but rather act to inform[16] and influence the real control points, the individuals on the team and to a lesser degree various stakeholders. This does not alleviate the need to strengthen project foundations[17]. Also recognize the broader environment often acts to constrain or otherwise dictate the actions which individuals can or choose to take. Leadership is important.

- Recognize the key points of leverage in large complex programs shown in Table 2 in order of significance.

[16] Estimating uncertainty and measuring variance
[17] National Academy of Construction Executive Insight, Foundations for Success

- Meaningfully deploy strategies for leverage shown in Table 3 to guide the program to its desired outcomes.

Table 2 **Key Leverage Points in Large Complex Programs**
1. Business and environmental context in which the industry, enterprise or program exists
2. Strategic Business Outcomes (SBO) the program is to deliver
3. Who makes the rules (shareholders, stakeholders, regulators)
4. Rules that impact program execution (resources, constraints, incentives, penalties, latent risks and opportunities)
5. Information flows (leading (insight), contemporaneous, lagging; information vs noise)
6. Logistical flows (supply chain; management/sequencing/coordination of engineering and construction)
7. Advantaging negative feedback loops (stabilizing)
8. Limiting/controlling positive feedback loops (drive multi-finality)
9. Monitoring/controlling assumption migration
10. Fixed parameters, standards, regulations

Table 3 **Strategies for Leverage**[18]
Preserve flexibility of response (contingent execution)
Provide for decentralization of decision making and action (Workface Planning)
Encourage 360°communication
Resist opening of regulatory and control loops without dealing with full effects on the program (Law of unintended consequences)
Identify critical points of weakness or control and act upon to reinforce or retard change
Decentralize program and project control to retain overall control on large complex programs
Resist changes unless full program impacts understood
Do not remove or impose constraints without understanding why they existed initially or the systemic impact of imposing them
Encourage diversity of thought (Avoid cognitive lock)
Encourage prudent risk taking and require people to “tell, tell, tell”[19]
Set outcomes. They allow for feedback.

[18] Adopted from De Rosnay “The Ten Commandments” of the Systemic Approach”
[19] Admonishment to young staff earlier in my career: “If you don’t screw up at least once a day you are not doing your job!” Corollary was “tell, tell, tell”. Then we can help you fix it and learn from it.

Table 3 **Strategies for Leverage**[18]
Transparent broad distribution of information leads to good outcomes[20]
Value time and timing

Conclusion

Large complex programs are not well served by traditional PM theory and require a significantly changed perspective. Their nature more closely resembles open systems first defined as part of General Systems Theory. This paper seeks to succinctly highlight the open systems nature of large complex programs, contrast it with traditional PM theory and, importantly, provide meaningful guidance on mindsets, behaviors and practices required to improve achievement of successful outcomes.

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Appendix 1
Program Action Matrix

Program Action Matrix Legend

System of Systems – The interaction between a capital asset program (system), consisting of one or more projects, with other systems, independently managed and subject to similar and different system drivers. The behaviors of one system may act as a system driver on other systems in the system of systems. They represent trans-domain networks of heterogeneous systems that exhibit operational and managerial independence, geographical distribution (distributed) and emergent behaviors not apparent if looked at separately.

System Drivers – This represents the broader ecosystem in which the program and other systems it interacts with exist. The program (and other interacting systems) also act on this ecosystem which acts organically as a living and open system. System drivers include economic, social, political, cultural and technical and technology influences. System drivers act to enable, accelerate, constrain or modify system behaviors at the system or lower levels (functional element, component, activities). Stakeholders as specific system drivers are treated separately.

External Stakeholders – Together with internal stakeholders, external stakeholders are a key component of the social domain. They may represent individuals and organized or ad hoc groups with defined interests which may change over time. External stakeholders influence a program's SBOs, define program (system) boundaries and may exert a degree of control over functional elements, components and activities. External stakeholders may include regulatory authorities, the general public and users or customers of the capital asset being developed.

Internal Stakeholders – These represent a 360 degree scan within the enterprise undertaking the program. These may include an organization's board of directors, C-suite, other organizational elements outside the program's span of control and employees, most notably those engaged with the program. In some instances shareholders and key outside investors may be considered as if they were internal stakeholders.

Strategic Business Outcomes/Objectives – Strategic Business Outcomes are typically associated with enterprise level objectives or significant mega or giga programs. Strategic Business Objectives have a less broad implication and are often associated with discrete projects. While the focus here is on capital asset projects (first delivery) the same thinking process is extendable across a full lifecycle perspective. Let me reinforce one point, which is the cascading of Strategic Business Objectives (SBOs) throughout the project lifecycle. While it is appropriate, and even necessary, to translate SBOs into more specific key performance indicators (KPIs) or key results areas (KRAs), it is essential that the SBOs themselves not be lost. In effect they provide the guideposts for the alignment activities

that must cascade down and outside the organization, touching all key stakeholders. In conducting lifecycle analysis it is important that achievement of ALL SBOs represent a pass/fail criterion for any strategy, set of tactics, and project or projects that are undertaken. SBO migration (to be polite) is a symptom of programs that are not well founded and are usually accompanied by delay and cost overruns. This in effect calls for the development of outcome type metrics linked to the SBOs.

Finally, achievement of multiple objectives is often the result of an efficient frontier optimization process.

Program – This represents the coordinated and often simultaneous delivery of a family of projects in a coordinated way to deliver a desired Strategic Business Outcome.

Project – Delivery of a capital asset meeting well defined Strategic Business Objectives which may or may not be able to achieve an enterprise's Strategic Business Outcomes alone.

Functional Element – These would represent integrated portions of an overall project and typically would comprise one or more related systems or structures. Functional elements achieve their intended purpose and contribute to overall project achievement of defined SBOs. An example would be onsite power generation for a remote process unit. The functional power element could be complete and operational but the project not yet delivering its product. A tunnel could be complete but the tunnel "system" not yet ready for traffic.

Components – These comprise the physical elements of the project that comprise the functional elements and are necessary for the project to achieve its SBOs. This would include related infrastructure and the various tools to execute the project.

Activities – The processes, procedures and tasks to execute the various elements of the project and program.

Instructions for Reading the Program Action Matrix

In the Program Action Matrix that follows, the columns represent the various systems elements of a large complex engineering and construction program and how they interact on other elements of the program.

Reading the columns provides a perspective of how a given systems element impacts different aspects of the program. Reading across the rows provides a perspective of the various influencing elements that will act on a given aspect or system feature.

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**System Drivers**	Interaction of multiple system drivers on a program (system) may dramatically shape the SBOs that may be achievable or the ways in which they may be achieved. An example might be constraining political drivers that limit economic achievement of SBOs to a range other than what might have been optimally desired.	Stakeholder activism acts to modify legislation, regulation or local ordinances.	Internal stakeholder decision can act to constrain or amplify the impacts of various system drivers. These can include political and economic drivers for example.	Failure to meet SBOs related to operating performance may effect one or more system drivers (demand; availability of financing; level of regulatory oversight)

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Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**External Stakeholders**	System Driver affects external stakeholder composition, attitudes and issues (changing demographics)	This represents the social network with a plurality of stakeholders and stakeholder issues and objectives.	Effectiveness of engagement with external stakeholders is often a primary determinant of outcomes in large complex programs.	SBOs may act to create stakeholder opposition, often broader than the concerns associated with the specific program (expansion of coal fired project at one location leads to broader stakeholder opposition to enterprise's climate policy
Acted On	**Internal Stakeholders**	System Driver affects focus areas of internal stakeholders (social justice; pandemic)	Shareholder activism changes Board of Directors or causes them to modify original program objectives.	This is the land of organizational politics and less than full readiness by the owner organization	SBOs act to disenfranchise an existing organizational segment resulting in passive resistance

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Program Action Matrix					
Part 1					
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	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Strategic Business Outcomes/ Objectives (SBO)**	System Driver affect demand or requisite timing modifying an SBO. (Sharp rise in global iron ore demand/ price drives SBO for greater than originally contemplated volumes, sooner.	Stakeholder engagement acts to modify the original SBO's conceived. Often stakeholder satisfaction demands the addition of one or more ESG objectives	Internal stakeholders are the primary influencers of SBOs. They must reflect the art of the possible not the improbable. SBO migration may come from internal stakeholders where initial SBO development was inadequate or incomplete.	The achievement/ reconciliation of multiple SBOs amy result in multiple potential solutions along an efficient frontier.

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Program**	System Drivers shape program execution plans and represent a primary source of emergence.	External stakeholder engagement which should have proceeded program initiation must be continued in the execution phase. Stakeholders must become part of the solution and not an adversary to be vanquished. They have the capacity to significantly impact program performance.	Internal stakeholders can impact the efficiency of program execution. Stagegate processes provide necessary structure and governance to the program but unbridled changes or introduction of "wants" versus "needs" can significantly negatively impact the program.	SBOs guide and shape the program. The program team must have well-articulated SBOs that are agreed to and continuously communicated. SBO migration significantly impacts program outcomes irrespective of the forces driving the migration.

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Project**	Similar impact to what programs may experience but here the drivers may be more discrete (one element of a project specific supply chain) or localized (one trade unique to one project in program)	External stakeholder impacts on projects can be significant as they would be at a program level or could reflect a death by a thousand cuts (persistent delays in RoW permits or utility relocations)	Internal stakeholders with interest in per projects have the potential to delay and disrupt elements of oone project to the detriment of the entire program)	SBO clarity with an objectives focus is required at the project level and SBO migration, driven by “wants” vs “needs” is a major source of project disruption.

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Functional Element (systems and structures)**	System Driver acts to modify nature of functional elements (green power)	Relationships between functional elements is modified by external stakeholder actions. This could be added reporting; stakeholder oversight boards; requirement for batch vs continuous operations of specific functional elements.	Internal stakeholder engagement in functional reviews must be clearly established and basis of design agreed to and established at the onset of design.	SBOs act to define the functional decomposition of the system (program/ project). Own or buy choices are affected by description of the SBOs.

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Components**	System Driver acts to prohibit use of China sourced electronics in critical industries and infrastructure.	Employee or user stakeholders drive modifications to various components out of health, safety or comfort concerns.	Internal stakeholder engagement in component reviews must be clearly established and limited based on a basis of design agreed to and established at the onset of design.	SBOs that have extensive impacts on component design and selection should be limited to the dominant technology (reactor type; turbine vendor; transit car provider)

Appendix 1					
Program Action Matrix					
Part 1					
Acted On		**Acting On**			
	System of Systems	**System Drivers**	**External Stakeholders**	**Internal Stakeholders**	**Strategic Business Outcomes/Objectives (SBO)**
Acted On	**Activities**	System Driver limits work after dusk or requires excessive number of "hold points" for regulatory inspection.	Organized labor or trade organization representing staff drive changes in work processes.	Internal stakeholder reviews of specific execution activities should occur at defined points or reflect ongoing safety, quality or other check and audit processes. Injection of internal stakeholders deeper into the execution process is often indicative of weak governance regimes or a program already in significant trouble.	SBO impacts of various program execution activities should be focused on conformance with law, regulations, standards and stakeholder agreements. Changes in SBOs can affect the planned execution of the program.

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**System Drivers**	Programs may act on various system drivers including supply chains and general labor markets. Their success or failure may influence other similar programs in the world.	Project impacts on system drivers are more localized than programs. Projects potentially modify local labor markets and logistics chains.	Functional elements may impact various systems drivers through temporary or permanent resource/ supply chain consumption.	Component design and specification influence susceptibility to various system drivers. Performance based specifications can act to inoculate components to volatility in various system drivers.	Activities often act to inform system drivers, reinforcing implemented activities or driving their modification.

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**External Stakeholders**[21]	Programs may act to modify stakeholder concerns and desires both in the local setting but also in similar global markets. Elevated concerns may include requirements for increased mitigation measures or broadened efforts to resist this and similar programs.	Negative project experiences may elevate general stakeholder concerns, impacting other project in the program. This impacts overall program performance and outcomes.	Scale and visual appearance of structures may invoke stakeholder opposition to "eyesores" or out of local character appearances. System properties such as noise or condensate plumes may similarly impact external stakeholders.	Component selection may evoke stakeholder reactions with respect to sourcing (Buy America; child labor; modern day slavery; conflict minerals)	Activity performance informs external stakeholders and may modify stakeholder beliefs and perceptions

[21] Supporting System Documentation - Stakeholder Matrix (reflect changes in stakeholder characteristics over time)

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Internal Stakeholders**[22]	Program performance influences other internal stakeholder's programs; overall enterprise performance and benefit realization associate with program outcomes. Internal power balances and support for the program are also modified.	Discrete project performance acts as a precursor of broader program performance, often modifying internal stakeholder governance regimes.	Internal discipline stakeholders may modify standard approach and best practices as functional elements are deployed	Program component selection may influence internal stakeholder repair and replace decisions elsewhere in the enterprise.	Activity success in delivering desired safety, productivity, cost and schedule outcomes and a key element of management oversight.

[22] Supporting System Documentation - Stakeholder Matrix

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Strategic Business Objectives (SBO)**[23]	Programs are emergent and may act to modify the outcome based SBOs originally established.	Project objective achievement may act to influence enterprise level benefit realization especially with respect to timing.	Functional element performance directly (or indirectly) relates to achievement of SBOs	Significant variance in component performance, especially that associated with new technologies can measurably impact SBOs and in the extreme can lead to abandonment of the program.	Activities that are associated with extreme HSES risks and for which a substitute approach is not readily available may drive modification of SBOs.

[23] Supporting System Documentation - SBOs linked to Execution Strategy, KPIs and KRAs. Cascaded through Program and Projects; SBO x Stakeholder Matrix

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Program**	Program to program impacts may arise in resource (capital) constraints within a given enterprise; denial of resource to other similar programs; and from a systems perspective impact other global supply chain programs focused on input supply.	Project performance may impact the program it is part of through any of a number of negative performances.	Challenges in overall functional system and structures delivery can cause program approach to be modified.	Component and related material shortages or recurrent unresolved quality problems (defective welds) can impact overall program execution plans.	Programs may be affected by negative interactions of activities from one or more projects (interference) or common activity challenges across projects linked by common (now changed) assumptions.

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Project**	Program impacts on projects within the program may be (positively) associate with program optimization or (negatively) associate with constraint coupling.	Project to project impacts can be both direct as well as the result of constraint coupling.	Challenges in overall functional system and structures delivery can cause project approach to be modified.	Component and related material shortages or recurrent unresolved quality problems (defective welds) can impact overall project execution plans.	Modified sequence of project activities resulting from delayed precedences; unavailability of labor, equipment or materials; or delayed receipt of required information.

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Functional Element (systems and structures)**[24]	Changes in program requirements, often as a result of emergence, may act to modify functional elements	Project design development and late stage O&M requirements may necessitate changes to functional elements.	Flows and relationships between functional elements (information, materials, energy, spatial relationships). May be hierarchal.	Cost of components are influenced by functional element specifications. Value engineering can allow component selection and functional design to be optimized.	Construction work process development or changed O&M requirements may introduce safety or operational changes to functional elements.
Acted On	**Components**[25]	Similar impacts to functional elements but may also be driven by desire to reduce the number sku's.	Similar to functional elements	Functional elements act to define component properties and characteristics.	Component to component technical interaction	Activity interactions with specific components represent a major focus area in workface planning.

[24] WBS representing functional decomposition of project strategic business objectives into a set of Functional Elements including their interactions and interfaces to achieve the SBOs.
[25] Technical design delivering the Functional Elements and addressing component to component interaction and interface.

Appendix 1						
Program Action Matrix						
Part 2						
Acted On		**Acting On**				
	System of Systems	**Program**	**Project**	**Functional Element (systems and structures)**	**Components**	**Activities**
Acted On	**Activities**[26]	Changing program requirements and timing may change the nature and sequencing of engineering and construction activities. Program limitation and constraints may also influence planned lifecycle activities.	Overall project performance may impact sequence of planned activities necessitating use of contingent execution plans.	Functional elements act to require adaptation of established processes, procedures and tasks due to changes and delayed precedences.	Components required to accomplish discrete activities benefit from innovation and deployment of new project and construction technologies.	Task-task dependencies. May be coupled by constraints.

[26] . Master schedule relating project processes and tasks to each other

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Bob Prieto is a senior executive effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering and construction industries. Currently Bob heads his own management consulting practice, Strategic Program Management LLC. He previously served as a senior vice president of Fluor, one of the largest engineering and construction companies in the world. He focuses on the development and delivery of large, complex projects worldwide and consults with owners across all market sectors in the development of programmatic delivery strategies. He is author of nine books including "Strategic Program Management", "The Giga Factor: Program Management in the Engineering and Construction Industry", "Application of Life Cycle Analysis in the Capital Assets Industry", "Capital Efficiency: Pull All the Levers" and, most recently, "Theory of Management of Large Complex Projects" published by the Construction Management Association of America (CMAA) as well as over 700 other papers and presentations.

Bob is an Independent Member of the Shareholder Committee of Mott MacDonald. He is a member of the ASCE Industry Leaders Council, National Academy of Construction, a Fellow of the Construction Management Association of America and member of several university departmental and campus advisory boards. Bob served until 2006 as a U.S. presidential appointee to the Asia Pacific Economic Cooperation (APEC) Business Advisory Council (ABAC), working with U.S. and Asia-Pacific business leaders to shape the framework for trade and economic growth. He had previously served as both as Chairman of the Engineering and Construction Governors of the World Economic Forum and co-chair of the infrastructure task force formed after September 11th by the New York City Chamber of Commerce. Previously, he served as Chairman at Parsons Brinckerhoff (PB) and a non-executive director of Cardno (ASX)

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