Chapter

Introductory Chapter: Program Management Fundamentals and Current Trends

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1. Introduction

The five Program Management (PM) fundamentals consist of five key program phases that can be tailored to any type of program life cycles (LCs). These phases include program conceptual phase, planning phase, execution phase, monitoring phase, and program closing phase. These key phases are the basic framework that can help any program managers to lay their foundation for managing any types of programs and associated projects [1–5]. In general, the types of programs and associated LCs can be grouped into three groups, namely, defense program group (DePG), civilian program group (CiPG), and commercial program group (CoPG). This chapter provides an overview of the common practices of these five PM fundamentals, with an emphasis on the discussion of the DePG and CiPD that can easily be extended to CoPG. **Figure 1** describes these three program groups and associated program types in detail.

As depicted in **Figure 1**, DePG can have different program types, namely, traditional US Department of Defense (DoD), defense advanced concept technology (ACT), and DoD rapid acquisition program types. Like DePG, CiPG can have traditional National Aeronautics and Space Administration (NASA), ACT, National Oceanic and Atmospheric Administration (NOAA) weather satellites, and other civilian program types. Unlike DePG and CiPG, CoPG emphasizes on private for-profit programs, such as construction, satellite, and other commercial program types. Examples of construction program type include hotels, hospitals, parks, houses, etc. Examples of satellite commercial program type include Starlink,

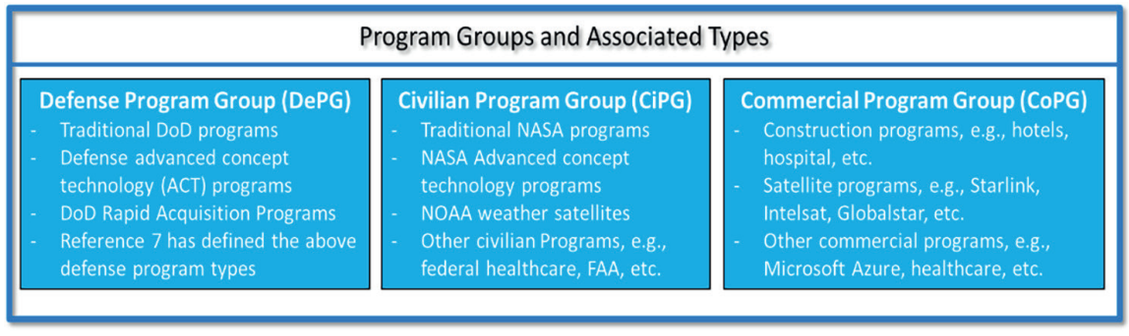

Figure 1.
Description of program groups and associated program types.

Intelsat, Globalstar, Capella Space, etc. Other commercial programs include Microsoft Azure, Amazon Web Services (AWS), commercial healthcare programs, commercial farming programs, etc. The five Program Management (PM) fundamentals mentioned above can be tailored to develop an effective program LC for any program groups and related program types, as described in **Figure 1**. Based on the five PM fundamentals, Ref. [6] and Tien M. Nguyen [7] have discussed and presented the program LC associated with traditional DoD and defense ACT program types with budgets greater than 100 M USD (US dollars) and less than 100 M USD, respectively. To manage each of the program phases specified in program LC, the program managers apply technical and management skills and knowledge, decision support tools, program management processes and techniques to define, plan, execute, and monitor desired program activities to achieve required project requirements.

As pointed out in Carayannis et al. [8], during 1900s–1950s, the program managers leveraged advanced telecommunication systems to gain better communications among the workers and managers allowing for effective resource allocation and mobility. As a result, the automobile manufacturing production schedule had been shortening with enhanced project monitoring and management. Thus, technology has played an important role in improving program planning, execution, monitoring, and management. This chapter also addresses existing state-of-the-art machine learning and artificial intelligent (ML-AI) technology enablers and related PM trends in the improvement of PM activities.

2. Program management fundamentals

As described in Section 1, programs and related projects can be classified into three groups, including DePG, CiPG, and CoPG. As shown in **Figure 1**, for each of these groups, there are different program types associated with it. In general, for DePG, there are several program types, including traditional DoD programs, advanced defense concept technology programs, and DoD Rapid Acquisition Programs. Tien M. Nguyen [7] has addressed the program planning and management (PPM) for the defense advanced concept technology (ACT) programs and further classified the ACT programs into four categories. These categories include ACT Demonstration (ACTD), Defense Advanced Research Projects Agency (DARPA), advanced Contract Research and Development (CRAD), and Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs [7]. Recently, due to the dynamic of the adversary threats to and rapid changes in technology, DoD has developed a new acquisition program type, which is referred to as rapid acquisition program. This program type focuses on the development of defense systems using rapid acquisition (rapid acquisition LC (RALC)). As discussed in Ref. [9], the proposed RALC requires a new and innovative acquisition framework and processes. Depending on the defense needs, an ACT program can use RALC to acquire a new and innovative technology for an existing defense system. It is important to point out that the characteristics of the program group and associated types will dictate the development of program LCs for acquiring and deploying a desired product or item. The program type's characteristics are the key driver for the tailoring of the five PM fundamentals and related frameworks to construct an efficient program LC. This section describes and discusses the PM fundamentals framework and how one can tailor this framework

to generate or select an efficient program LC for a specified program type. **Figure 2** depicts the tailoring process for the program management fundamentals framework to construct an efficient program LC. The section focuses on the DePG and CiPG and provides examples of existing program LCs for traditional DoD and NASA programs. As shown in **Figure 2**, a program LC consists of the five program fundamentals (conceptual, planning, execution, monitoring, and program closing phases) which are the key components of a program LC. From the Government or a buyer perspective, it is important to develop a program acquisition LC to acquire (buy) a new product or item to fill the needs. These program fundamentals should be tailored to align with the Government's needs and associated program's characteristics. The following sections describe the objectives and common practices of these program fundamentals and discuss how we can tailor them to generate an effective program LC.

2.1 Conceptual phase

This conceptual phase is the first phase of the program management fundamentals framework, and it is also referred to as the initial phase. This initial phase is deliberate and features methodological goal setting [10]. Regardless of the program groups and related program types, the objective of this phase is about finding out stakeholders' needs to justify and seeking the approval for the identified effort to acquire a system or an item of interest. To achieve this objective, the program manager requires to understand the required scope of work, budget, and schedule of the effort. For DePG and CiPD, the program manager will approach this phase differently depending on the contractor or Government perspective. From the Government perspective, the program manager must understand the agency objectives and national goals along with the warfighter needs (i.e., stakeholders) and related defense capability needs to

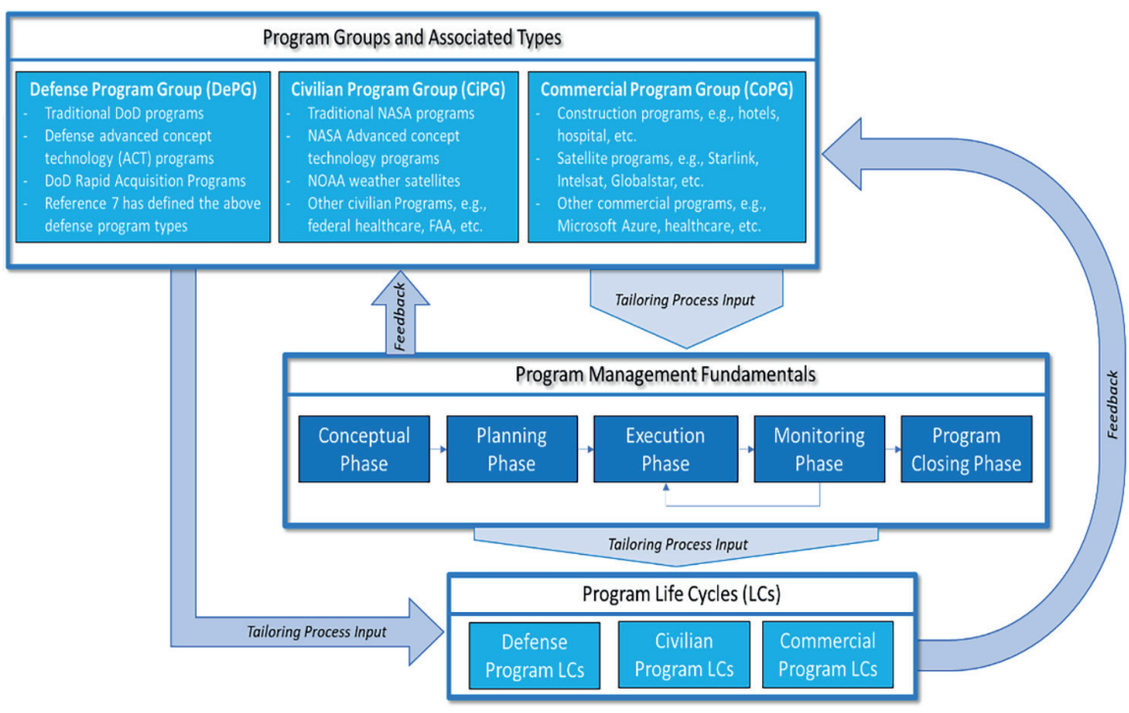

Figure 2.
Program management fundamentals and tailoring process for generating efficient program life cycle.

generate the program roadmap from the conceptual phase to program closing phase. From the contractor perspective, the program manager requires to understand the contractor's business area and the Government[1] program or capability roadmaps.

In practice, for DePG and CiPG, the contractor program manager usually "does not wait" for the request for proposal (RFP) or the broad announcement agency (BAA) to be published, he/she will work with the Government counterpart to shape the RFP/BAA. The focus of understanding of his/her (a.k.a. contractor) business is fundamental for tailoring the concept technology projects/programs for success. The simplest of tools for understanding the contractor's business is the Strength-Weaknesses-Opportunities-Threats (SWOT) analysis. This analysis frequently yields the strengths of the contractor organization, and they can be capitalized on when aligned with a customer's technology roadmap/capability roadmap. And to the extent that the contractor's business recognizes a technology or a capability "trajectory," these can frequently serve as the starting point for the business-customer alignment. In practice, shaping the RFPs/BAAs is a useful practice, especially in the case of DARPA interactions. DARPA's charter is currently expressed as "Creating Breakthrough Technologies and Capabilities for National Security." Originally chartered in response to the Sputnik incident and the Space Race during the Cold War, DARPA's top-level responsibility has not changed, i.e., "avoiding technological surprise in national defense," but DARPA's focus shifts periodically with the propagation of nascent technology waves.[2] A key tool for exploring potential programs with DARPA is the Heilmier Catechism (a.k.a. Heilmier Questions) [11]. It has been said that the Heilmier Catechism is a sort of "recipe" for managing innovation in technology-driven domains and related businesses. An example of a "do not wait for the RFP/BAA" approach is that of "Urgent Needs," frequently expressed as Urgent Operational Needs (UONs) or Joint Urgent Operational Needs (JUONs). The Defense Acquisition University (DAU) defines these as: "Urgent Operational Need (UON) – Capability requirements identified as impacting an ongoing or anticipated contingency operation. If left unfulfilled, UONs result in capability gaps potentially resulting in loss of life or critical mission failure" [12, 13]. When validated by a single DoD component, these are known as DoD component UONs. DoD components, in their own terminology, may use a different name for a UON. The Joint version of UONs recognizes that multiple services are in view for a UON, and hence the JUON designation and validation of the need by a joint force's authority, as opposed to a single service. For the commercial program group, the Government perspective is the buyer's perspective, and the contractor perspective is the seller's perspective. The extension from DePG and CiPD to CoPD is straightforward for the conceptual phase. The characteristics associated with the commercial program type will be the key for the program goal setting in this phase.

2.2 Planning phase

The conventional program planning approach is to identify the desired program planning and management (PPM) activities (a.k.a. tasks) and communicate the plan of these PPM tasks to team members and stakeholders. This PPM plan lays out the "how" of the project so that the program team members understand what they need

[1] From the contractor's point of view, this is also referred to as customer.

[2] This explains the recent interest in AI/ML applications for defense.

to do throughout the program LC. During this phase, the program manager develops work breakdown structure (WBS), budget and schedules, anticipating risks, and planning how to manage and mitigate the anticipated risks.

An innovative departure from the conventional program planning technique is described in Tien M. Nguyen [7]. Tien M. Nguyen [7] presents an application of Zachman framework to the program planning phase, especially applicable to DePG and CiPG. The genesis of this approach to planning stemmed from a realization pertaining to technical architecture frameworks, specifically DoD Architecture Framework (DoDAF) [14], which is commonly mandated for defense programs exhibiting complex operational environments. The realization, in a simplified form, is that DoDAF tends to be prescriptive; in contrast, small Research and Development (R&D) programs with budgets less than 50 M USD need to discover the answer to the question "what architectural views matter are impactful for this program?". The use of a Zachman architectural framework is superior in assisting with obtaining this answer quickly before one runs off and expends resources on a stack of conforming DoDAF views, which may not be helpful to the project/program. Although the proposed program planning framework is proposed for the DePG and CiPG with related ACT program types, it is also applicable to CiPG and related types. Regardless of the program group perspective, the program manager can use the proposed Zachman framework for ACT program planning shown in Table 1 of Tien M. Nguyen [7] to develop an effective PPM plan during the planning phase. As pointed out in Tien M. Nguyen [7], one of the key PPM activities is to identify the cost, technical, and program management risks and a plan to balance out these risks by identifying potential risk mitigation techniques. In practice, the program manager is also required to identify potential opportunities associated with these identified risks. The risks, opportunities, and mitigation approaches should be thoroughly analyzed and understood before the program enters the execution phase.

2.3 Execution phase

The execution phase usually occurs after the source selection, i.e., after the government or a buyer selects the best contractor or a seller to perform the contract. Again, regardless of the program group/type perspectives, for this phase, the program manager will put the PPM plan into action. The key approach for implementing this phase is to ensure "resources allocation" to execute the plan. The execution phase starts with a program kick-off where the program manager officially allocates the required program resources and ensures all team leads and their team members receive the resources that they need to have to do their jobs. In general, the resources include allocated budget, program documentations, configuration management, team development and arrangement, required member of technical staff (MTS), stakeholder engagement, quality assurance activities, and program schedule forecasting. The program manager actively works with the program leads to coordinate and assess how the program is running. During this phase, the government and contractor program managers will execute the approved government and contractor PPM plans, respectively. The status of executing these plans will be reported to the government and contractor stakeholders accordingly. In practice, for DePG and CiPG, the contractor stakeholders will also include the government counterparts. Similarly, the seller stakeholders will include the buyer for CoPG.

2.4 Monitoring phase

For DePG and CiPG, the contractor program manager manages the contractor team and monitors the health of the program by tracking the cost, schedule, MTS, technical performance, and program risks based on a set of "success criteria" defined for each program milestone and associated inch-stone. The program status and required program data will be reported to all stakeholders.

For the Government perspective, in addition to executing and managing the government team, the government program manager is also required to monitor the contractor progress. The objective is to ensure that the contractor team progresses according to the contractor program plan approved by all stakeholders. In practice, the execution and monitoring phases occur simultaneously and the contractor gets paid from the government as the program progresses. It's important to recognize up front that Execution and Monitoring (phases) need to be simultaneous; they need to go hand-in-hand. There is an element of "pay as you go" in this approach since the program management functions oftentimes "learn as they go" in the course of ACT projects. The simplest way to incorporate this into the execution phase is via an execution cadence with regular monitoring program metrics and program progress including monthly cadence with a weekly, focused check-in (program progress reviews).

In conjunction with simultaneous Execution and Monitoring, program management needs to periodically ask the question "has the success criteria changed or does it remain the same?" The process of "learn as you go" with ACT types of projects occasionally results in the realization that the target end point and/or the goals have shifted. Early recognition of this situation, and sharing the realization with the customer organization, may result in a shift of a Statement of Work (SOW) and an associated re-baseline of the program plan to align program segments (or phase) with the new objectives.

A key success factor for implementing this phase is to choose appropriate tools and techniques to monitor and disseminate the required program performance metrics. Concerning the DePG and CiPG programs, the Earn Value Management (EVM) system and associated tools are required to monitor the program cost, schedule, and associated program risks [7, 15, 16]. As indicated in Table 5 of Ref. [7], the DePG programs are required to fully implement the EVM system and tools when the programs' budgets exceed 50 M USD. As indicated in Refs. [15, 16], NASA (and NOAA) programs also followed the same EVM requirements as the DePG programs, i.e., full EVM system implementation and tools are required for NASA when the programs' budgets exceed 50 M USD. The extension to CoPG is straightforward, except that the use of EVM system and related tools is not the mandatory requirement. The monitoring approach and related tools will be selected depending on the program's characteristics and related success criteria.

2.5 Program closing phase

In general, the program closing phase is defined as a formal closing process marking the end of the program. In practice, depending on the program groups, the program closing phase can be different. For a traditional program in DePG or CiPG, closing a program can be (i) a delivery of an asset (e.g., a satellite system or a ground satellite tracking station), (ii) holding a final program review to discuss how it went, (iii) archiving program records, and (iv) celebrating the completion of a program. For ACT program in DePG or CiPG, closing a program can be a

transition of a developed technology into a program of record or an existing traditional program [7]. The program closing phase will be tailored for CoPG programs, and the program closing phase is expected to be similar to those for DePG and CiPG programs, and they will be tailored to meet the needs of the buyer.

3. Program life cycles and management approaches for defense, civilian, and commercial programs

Sections 3.1 and 3.2 describe the program LCs for typical DePG and CiPG programs with an emphasis on DoD and NASA traditional and ACT programs, respectively. Additionally, these sections also discuss the DoD and NASA program management approaches to manage and execute the existing program LCs.

3.1 Defense applications

For traditional program type, DoD has tailored the five program fundamentals and developed a very efficient and proven program acquisition LC for acquiring complex defense systems and related technical items to meet their mission critical needs [6, 17–19]. **Figure 3** describes a typical acquisition program LC for DoD traditional programs. Many space-based programs have successfully used this program acquisition LC to acquire complex defense satellite communication (SATCOM), satellite sensing, and global positioning satellite systems. At high level, the LC includes the pre-acquisition and post-acquisition phases. The pre-acquisition phase consists of the tailored version of the conceptual and planning phases to ensure (i) alignment with DoD mission needs and (ii) reduction in the overall acquisition risks. The post-acquisition phase includes the tailored version of the execution, monitoring, and program

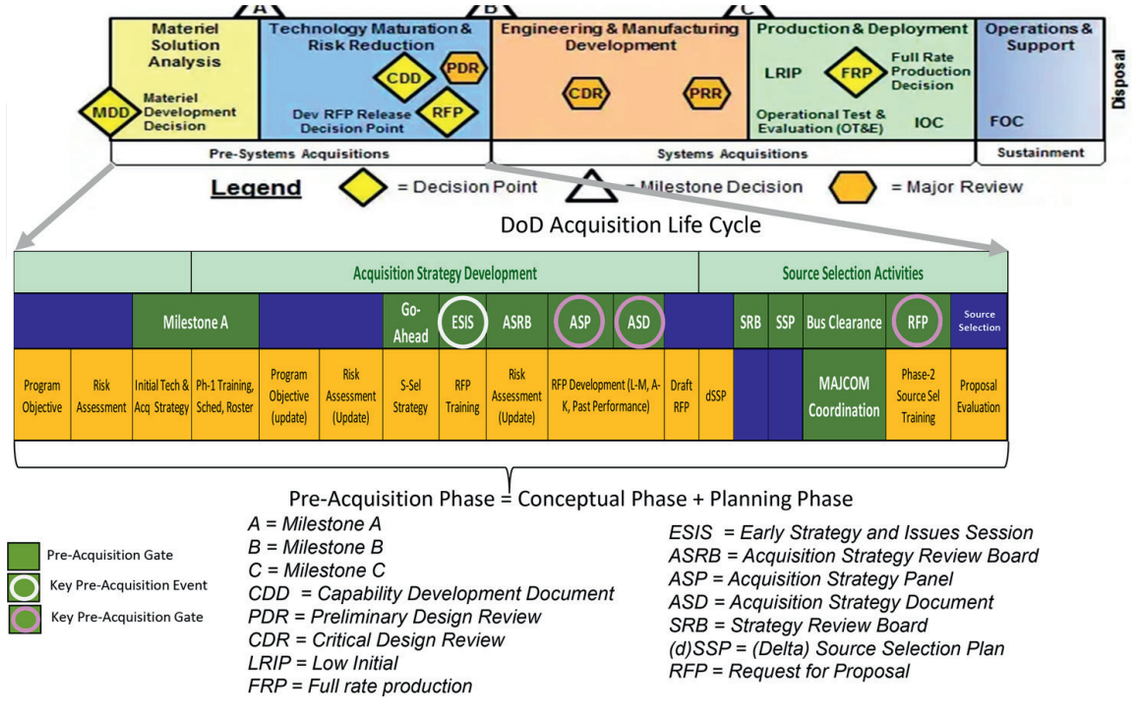

Figure 3.
Acquisition program life cycle for DoD traditional programs.

closing phases to ensure (i) the acquired system deliver the right defense capabilities meeting the warfighter needs and (ii) the manufacturing and deployment risks.

As shown in **Figure 3**, the pre-acquisition phase is also referred to as pre-systems acquisitions, which includes the Milestone A, the acquisition strategy, and the source selection activities. The post-acquisition consists of Milestone B, Milestone C, Initial Operating Capability (IOC) deployment, Full Operating Capability (FOC) deployment, and Disposal activities. The objective(s) and program requirements and related success criteria for each LC phase are discussed in Refs. [17, 20, 21]. To achieve the objectives of the pre- and post-acquisition phases, DoD has also developed a sophisticated and well-structured program management approach to allow the program manager to manage, execute, and monitor these activities with minimum program risk and maximum program opportunity [21, 22]. The program LC shown in **Figure 3** has been developed for acquiring defense products. For acquiring commercial products, DoD has tailored the program LC and program management approaches to align with the scope of work and mission requirements for commercial products [22].

For defense ACT programs, the program LC is very similar to the DoD tradition programs with the four distinct phases, including concept, pre-acquisition, post-acquisition, and transition phases [7]. The concept phase is not part of the pre-acquisition, post-acquisition, and pre-acquisition phases which have been tailored to align with the scope of work and related PPM activities for the defense programs. Ref. [7] discusses the program management approaches and desired PPM activities associated with program planning, program risk assessment, balance cost-technical-and-program risks, and EVM for defense ACT programs.

3.2 Civilian applications

Like DoD, NASA has also developed an efficient and proven program acquisition LC for acquiring complex systems and related technical items to meet their mission critical needs [23]. Similar to DoD, NASA has tailored the five program fundamentals to align with NASA needs for acquiring complex systems for civilian missions. The Concept Phase is mapped to pre-Phase A (concept studies), the Planning Phase mapped to Phase A and Phase B, the combined Execution-and-Monitoring Phase mapped to Phase C-Phase D-and-Phase E, and the Program Closing Phase mapped to Phase F. The objective(s) and requirements associated with each program LC phase are described in Ref. [23]. The desired program management approaches and related PPM activities that can be used to achieve objective(s) and requirements along with success criteria associated with each of the program LC phase are discussed in Refs. [15, 16, 23, 24]. The extension from the defense DoD ACT programs to NASA ACT programs is straightforward. The key factors for the extension are the agency goals/objectives and related mission requirements. The program management approaches and desired PPM activities should be tailored according to NASA goals/objectives and mission requirements.

3.3 Commercial applications

For commercial applications ranging from a simple housing construction project to a complex satellite program like Starlink, there is no existing program LC available that can fit this range of applications. From the buyer's perspective, the program LC can always be derived from the tailoring of the five program fundamentals, as described in **Figure 2**. As shown in **Figure 2**, the input to this tailoring process is the

required characteristics associated with a specific type of program that is required to develop an efficient program LC for acquiring a desired product or item. Usually some of the key program characteristics are the buyer's objectives, the program's/project's requirements, and the desired time for the product delivery. These program characteristics will dictate how one will tailor the five program fundamentals to ensure the (i) alignment with each of the program LC phases and (ii) program management approaches and related PPM activities are developed to execute and manage effectively at each phase, i.e., meeting the success criteria for each phase. It should be noted here that the program success criteria should be developed in response to the program objectives and related requirements. The tailoring process also requires the buyer acquisition team to have a deep understanding of the key program management (PM) areas and associated PM disciplines [14]. As pointed out in Ref. [14], there are nine key PM areas and twenty PM disciplines. The nine key PM areas include (i) PM Area 1—Enterprise, Organizational, and Program Goals Management, (ii) PM Area 2—Overall Financial and Program Cost Planning and Management, (iii) PM Area 3—Overall Program Risk Management, (iv) PM Area 4—Overall Program Schedule Planning and Management, (v) Technical Performance Management, (vi) Quality Assurance (QA) Management, (vii) Program Team Forming and Program Team Management, (viii) Internal and External Program Team Communications Management, and (ix) Program Integration Management. The twenty PM discipline areas across the four PM areas include (i) Program goals management, (ii) Systems engineering related to the systems/products/services being acquired, (iii) Specialized engineering related to the products and services being acquired, (iv) Contracts and legal dealing with contractors, suppliers, and stakeholders, (v) Program Financial management, (vi) Business and marketing practices for the newly acquired systems/products/services, (vii) System/product/service technical requirements and associated performance risk management, (viii) System/product/service cost planning and management, (ix) Program schedule planning and management, (x) Program cost planning and management, (xi) System/product/service risk planning and management, (xii) Program risk planning and management, (xiii) System test and evaluation, (xiv) Logistics and supply chain management, (xv) Production, Quality, and Manufacturing (PQM), (xvi) Program and system intelligence and security management, (xvii) Program and system software management, (xviii) Program and system configuration management, (xix) Program and system information technology, and (xx) Other Specialty Program Planning and Management. Note that from the seller's perspective, the program manager and his/her team are required to address the buyer's program LC and related requirements along with required success criteria at each program LC phase.

4. Current program management trends and conclusion

Gartner's research predicted that by 2030, 80% of project management tasks will be (i) run by machine learning and artificial intelligence (ML-AI), (ii) driven by big data, and (iii) processed using natural language processing language[3]. It also predicted certain aspects of the program management will be disrupted, including (i) selection and prioritization of alternative solutions, choices of products, etc., (ii) organizations streamlining and optimizing the role of the project management office

[3] Available from: https://hbr.org/2023/02/how-ai-will-transform-project-management.

(PMO), (iii) faster project definition, and improving project planning and reporting, (iv) virtual project assistant, (v) advanced testing and software, and (vi) creating a new role for program manager. Currently, industry has investigated approaches to integrate program management practices with emerging data and decision sciences (DDS) [14], which is referred to as PM-DDS integration. As discussed in Ref. [14], the key DDS technology enablers that can enhance the program planning, execution, and monitoring during a program LC include big data analytics, artificial intelligence, machine learning, deep learning, neural networks, and artificial intelligent. Tables 1 and 2 of Ref. [14] provide a summary of the proposed PM-DDS integration approaches for integrating DDS processes and ML-AI tools for program cost and schedule management, respectively.

For defense program management, the dynamic of the adversary threats will be the key factor driving the program LC and associated program management approach to ensure the system to be acquired is effective against the threats. Currently, DoD defense programs tend to be smaller in budget with a smaller system that is adaptable to the threats. Concurrently, the rapid acquisition LC is preferable for these smaller programs. For civilian and commercial program management, the rapid change in technology will be the key factor driving the program LC and program management approach. The program LC should be flexible and adaptable to the change in technology. In practice, a majority of defense ACT projects fall below the 50 M USD threshold, and frequently they fall below $20 M USD. EVM is not often mandated in these cases, and subsequently the question becomes, "what aspects of EVM are useful for managing small value ACT programs?" The current trend is to encourage the program manager to seek out and to select the EVM metrics that will be of value for managing and monitoring this type of program. "Tailor/tailor/tailor" is a mantra that can be used in order to prevent overburdening the small value program/project. Tailoring the nonmandatory EVM to match the program scope, limited key performance parameters (KPPs), key performance attributes (KPAs), etc., and then applying that tailored EVM regularly will often yield basic benefits to a program management team.

It is our hope that by reading this chapter, the reader can gain a deeper understanding of the other program management chapters presented in this book. It describes the five program management fundamentals along with the three program groups (DePG, CiPG, and CoPG) and associated program types. A high-level tailoring process presented in **Figure 2** explains how one can tailor the five program fundamentals to generate an effective program acquisition LC. To illustrate the tailoring process, the program acquisition LC for traditional program types is provided for DePG and CiPG. The extension to the development of an effective CoPG program LC is also discussed at high level allowing the readers to gain insight into the existing DoD and NASA program LCs for acquiring complex systems. Finally, the current trends in (i) the use of the state-of-the-art ML-AI technology enablers to enhance program planning, execution, and monitoring, and (ii) the program management practices are also presented.

Conflict of interest

The authors declare no conflict of interest. The opinions expressed in this chapter are those of the authors and they are not endorsed by California State University, Fullerton, California (CSUF) or Aerospace Corp. or Raytheon.

Additional information

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