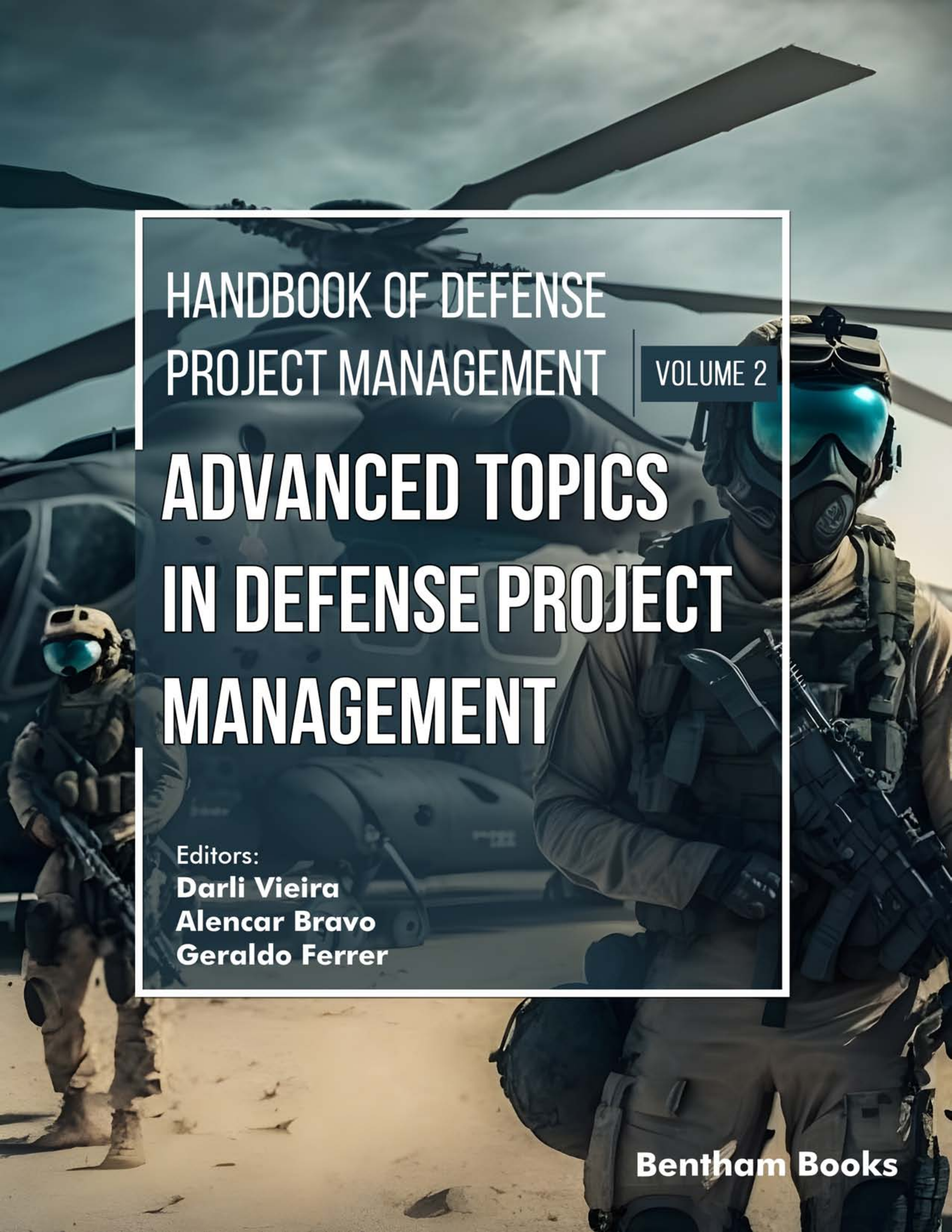

HANDBOOK OF DEFENSE PROJECT MANAGEMENT

VOLUME 2

ADVANCED TOPICS IN DEFENSE PROJECT MANAGEMENT

Editors:
Darli Vieira
Alencar Bravo
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Bentham Books

Handbook of Defense Project Management

(Volume 2)

Advanced Topics in Defense Project Management

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ISBN (Online): 979-8-89881-180-8

ISBN (Print): 979-8-89881-181-5

ISBN (Paperback): 979-8-89881-182-2

Published by Bentham Science Publishers Pte. Ltd. Singapore, in collaboration with
Eureka Conferences, USA.

First published in 2026.

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SCIENCE

CONTENTS

FOREWORD

In the unforgiving domain of defense, history has repeatedly underscored the cost of unpreparedness. General Douglas MacArthur captured the essence of failure in war with just two words: "*too late*." Nations enter conflict with the capabilities they possess on day one—not those they hope to develop later. This stark reality makes defense project management not just critical but existential.

In today's rapidly evolving world, where extraordinary technological advances continually redefine the boundaries of possibility, managing defense projects has never been more demanding or more vital. The relentless pace of innovation transforms operational doctrines and renders yesterday's breakthroughs obsolete, creating an environment of profound uncertainty. Success in this context requires unparalleled agility, precision, and the ability to adapt on an unprecedented scale. From my time in the Royal Canadian Air Force, I witnessed firsthand how innovative and strategic project management directly influences mission success and, ultimately, national security.

Building upon the foundational principles established in Volume 1, Volume 2 of the *Handbook of Defense Project Management* delves into specialized and complex areas that reflect the pressing demands of modern defense. The editors have expertly anticipated critical topics, including advanced systems integration, supply chain resilience under uncertainty, international collaboration, and the transformative potential of emerging technologies.

What sets this volume apart is its seamless blend of strategic vision and actionable insights. It addresses the intricacies of modern defense projects—from combat simulations that assess operational effectiveness to fostering technical and organizational innovation. It underscores the necessity for defense leaders to navigate uncertainty with precision, ensuring resilience in the face of asymmetric and evolving threats.

More than a guide, this volume is an indispensable resource. It challenges defense leaders and project managers to embrace collaboration, innovation, and adaptability as they confront the multifaceted challenges of their profession. It equips them with the tools and strategies necessary to ensure they are never "*too late*."

I commend the editors for this outstanding contribution to the defense community. Their foresight and dedication have produced a work of immense practical value—not only for defense industry specialists and military professionals but also for academia. Volume 2 of the *Handbook of Defense Project Management* stands as an essential resource for those committed to securing the capabilities we need today for tomorrow's battles.

Major-General (Retired) Sylvain Ménard, MSM, CD
Former Chief of Fighter and NORAD Capability (CFNC)
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PREFACE

The Handbook of Defense Project Management comprehensively explores the principles, strategies, and practices underpinning effective defense project management. Structured in two complementary volumes, it serves as an essential reference for academics and practitioners within the defense sector. While Volume 1 focuses on foundational principles, Volume 2 addresses advanced and specialized topics, offering an integrated perspective on the discipline. Together, these volumes form an indispensable resource for those seeking a holistic understanding of the discipline.

Volume 2—Advanced Topics in Defense Project Management—delves into the complexities and emerging trends that shape the contemporary defense landscape. It addresses the intricate challenges of managing defense projects in a dynamic and interconnected global environment. By exploring advanced topics such as managing large-scale, high-cost systems, adapting to evolving procurement practices, and creating resilient supply chains, this volume equips readers with the tools needed to address real-world complexities. It also introduces transformative methodologies and highlights the role of education, interdisciplinary collaboration, and innovation in fostering resilience and value creation.

Readers will gain new perspectives on how to navigate a range of advanced issues—from using simulation tools to enhance operational readiness to challenging traditional leadership paradigms in technology-intensive environments. Through these insights, this volume enables practitioners to anticipate and respond effectively to the defense sector's most pressing challenges. By engaging with these advanced concepts, both seasoned professionals and newcomers will find practical strategies for tackling challenges and contributing to the advancement of defense project management.

We extend our deepest gratitude to the authors, whose expertise and commitment have made this handbook an invaluable resource. We trust that Volume 2 will not only deepen understanding, but also inspire innovation and excellence as readers navigate the complexities of defense project management in today's fast-evolving world.

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Disclosure:

The similarities between the prefaces of Volume 1 "Foundations of Defense Project Management" and Volume 2 "Advanced Topics in Defense Project Management" of the Handbook of Defense Project Management are intentional. They ensure consistency and reinforce the complementary nature of both volumes, making them a comprehensive resource on defense project management.

The opening sections and acknowledgments are equal in both prefaces, providing a unified introduction and recognizing the collective contributions of the authors. While the structure remains uniform, each preface highlights the distinct focus of its respective volume—Volume 1 on foundational principles and Volume 2 on advanced topics. This parallel approach enhances clarity and underscores the handbook's integrated perspective.

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CHAPTER 1

Augustine Weapons and Challenges for Project Management and Procurement

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Abstract: Augustine weapons are costly, high-technology weapons. They are associated with Norman Augustine, who forecast that by 2054 the entire US defense budget would purchase just one aircraft. This reflected the observation that the unit cost of fighter aircraft had grown by a factor of four every ten years. According to Augustine, new technology opens vast new capability vistas, which are then crammed into each new generation of weapons. Computers and software represent vast new capabilities. An economic approach is taken, which begins with a principal-agent framework for procurement and project management. The military-industrial-political complex provides the background to procurement choices. A significant problem is the lack of any money valuation of defense output. The procurement problem is outlined in terms of what to buy, how to buy it, from which contractor, and when to make the purchase. A brief history of UK military aircraft and associated procurement policy is presented. The following section presents UK evidence on cost escalation and statistical evidence on the determinants of unit prices for UK fighter and bomber aircraft. Cost-quantity relationships for the Vampire aircraft are presented. The article concludes by assessing prospects and challenges.

Keywords: Augustine, Collaboration, Competition, Contracts, Cost escalation, Costs, High technology, Measures of defense output, Principal-agent problem, Substitution, UK military aircraft, Unit costs, Weapons systems.

INTRODUCTION: CHALLENGES FOR PROJECT MANAGEMENT

Covering the evolution of British air-power procurement from 1934 through the end of 2024, this chapter traces how "Augustine weapons" have driven costs and complexity across nine decades. Since Norman Augustine's seminal work (Augustine, 1987), defense planners have used that term to describe successive generations of high-technology systems whose unit costs rise faster than defense budgets. Because the United Kingdom is both a nuclear-armed power and home to a long-established defense-industrial base, its procurement choices occur under

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

political and industrial constraints not shared by many smaller buyers. Augustine showed that the price of a front-line fighter roughly quadrupled every ten years (Augustine, 1987), an observation still borne out today: platforms such as the F-35 cost more than ten times their 1970s predecessors (in real terms) because each generation absorbs exponentially greater computing power, sensors, and network connectivity.

Two intertwined pressures now dominate defense project management. First, run-away cost escalation continues, with inflation-adjusted unit prices for aircraft, submarines, and tanks growing at compound annual rates well above overall budget growth. Second, relentless technological complexity—driven by soaring software loads, stringent cybersecurity demands, and multi-domain integration—pushes schedules outward and makes reliability harder to achieve. Project managers therefore confront ever-tighter affordability envelopes and heightened risk of overruns, while procurement agencies act as principals who must manage information asymmetries with industrial contractors.

This chapter adopts a principal–agent economics lens to explore how these twin challenges play out. After presenting fresh cost-escalation data for recent UK combat-aircraft programs, it analyzes contract structures, incentive misalignments, and governance mechanisms that can mitigate—or magnify—Augustine's enduring cost and complexity problems.

A PRINCIPAL-AGENT PROBLEM

Economists can analyze project management and procurement using a principal-agent approach. This approach identifies two groups with distinct objectives. First, in the standard example, principals will be the owners of a business, represented by shareholders; and second, agents will be the managers of a business, appointed by principals to achieve the aims of the principals. Problems arise where these groups have different objectives. Shareholders will aim to maximize profits from the business, whereas managers may pursue other objectives, such as maximizing sales, growth, or their satisfaction (utility). This situation reflects asymmetry of information between the two groups: for example, managers are experts on the firm's production possibilities and its market opportunities. Nor is the approach confined to firms. Principals can be the citizens and voters in a nation where civil servants are agents supposed to reflect the tastes and preferences of voters. Applied to procurement and project management, principals might be voters, and agents might be project managers (*e.g.*, civil servants); however, it does not follow that agents will necessarily follow the wishes of their principals. For example, agents might prefer to spend public money on bright new office buildings rather than a costly new rail system, which voters prefer. Alternatively, in a military procurement context, voters might prefer to acquire a new, inexpensive combat aircraft, while agents might prefer to acquire a new, but costly, nuclear-powered submarine.

Acquiring Augustine weapons systems involves complex principal-agent problems. It is necessary to specify the demands for a highly complex weapons system that does not exist when a contract has to be awarded. The project requirements must be specified in detail in the form of a legally binding contract. For example, a contract for a new combat aircraft must specify the speed, weight, range, and tasks that the new aircraft will be capable of performing. In this case, principals rely on the advice of agents as in-house experts on the acquisition of costly complex systems. However, choices and decisions cannot ignore budget constraints: ultimately, the principals (voters or citizens) will have to pay the bill for such costly and complex systems, where costs are opportunity costs involving the sacrifice of alternatives (*e.g.*, spending on schools, hospitals, or tax cuts rather than complex weapons). Here, choices must be made regarding the type of contract to be awarded, ranging from cost-plus to fixed-price and target-incentive types, each with distinct budget constraints and incentives. Cost-plus contracts lack both budget constraints and efficiency incentives to minimize costs, compared to fixed-price contracts, which have budget constraints and profit incentives to minimize costs.

In project management, both principals and agents operate in political markets comprising political parties, voters, bureaucracies, and producer groups, each with different objective functions. Political parties seek votes, voters act as utility maximizers, bureaucracies aim to maximize budgets, and producer groups pursue profit or income maximization. These various groups form the Military-Industria--Political Complex (MIPC), which will combine to make decisions on Augustine weapons systems (also known as the military-industrial complex). Political parties will offer different tax and spending policies to maximize votes; voters will cast their votes to the party that offers them the most significant net benefits; bureaucracies in the form of agents will be represented by the armed forces (army, navy, air force) and by the procurement agency; and producer groups, as a further set of agents, will comprise private or publicly owned defense contractors. Each group faces different constraints and incentives, some of which reflect different attempts by principals to limit the ability of agents to pursue their personal preferences (*e.g.*, for leisure and a quiet life, reflected in X-inefficiency). Bureaucracies as budget-maximisers in the form of the army, navy, and air force will tend to underestimate the costs of their preferred projects and overestimate the demand for such projects, with producer groups supporting such procurement behavior (optimism bias). Moreover, costly projects mean larger budgets for bureaucracies. The usual arguments for supporting a new costly weapons system

CHAPTER 2

The Continuity of Challenges: Historic and Contemporary Defense Procurement in Perspective

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Abstract: This chapter utilizes the case study of the British aircraft industry between 1936 and 1939 to highlight the extent to which historical challenges of defense procurement persist in the twenty-first century. By examining the challenges of expanding the British aircraft industry from a relatively low productive base, which needed to be completed quickly to bolster British diplomatic efforts against Nazi Germany as part of the broader policy of appeasement, we observe that some of the inter-war challenges—most notably the shortage of skilled labor—might appear less acute in Britain's contemporary aerospace sector, yet similar constraints are unmistakable elsewhere. The U.S. naval shipbuilding base currently struggles to recruit welders and other trades, and Canada's surface combatant projects have been hampered for years by a limited pool of specialized workers. Recognizing that labor availability still shapes defense programs worldwide, this chapter treats the 1930s bottleneck as an instructive analogue and links it to today's reality of fewer firms capable of executing technologically complex projects for modern armed forces. This chapter, however, does not focus solely on the history of the British aircraft industry during the 1930s. The challenges of contemporary defense procurement are linked to the themes raised by exploring this particular aspect of historic defense procurement. These themes include the difficulties of producing technologically sophisticated defense equipment, applicable to both eras discussed in this chapter, as well as issues of capacity and the challenges of increasing productive capability in a short time with little to no warning. This is something that Western nations are beginning to experience after supplying Ukrainian forces with weapons and equipment that had been stockpiled and finding lead times prohibitive to replace stock. Finance and the ability to support domestic defense industries will also be explored to highlight the complex and strained relationship that exists between governments, militaries, and the firms that supply equipment.

Keywords: Air ministry, Aircraft Industry, Challenges, Contemporary procurement, Failings, Historical, Inter-war period, Reform.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

INTRODUCTION

Defense procurement in the UK has a poor track record of success, both in terms of timely deliveries and cost control (Retter, Muravska, and Black, 2021). While the case material that follows concentrates on Britain, the structural difficulties it exposes—long schedules, technological risk, political churn—recur widely. Italy's naval aviation programs, Canada's surface combatant initiative, and Pakistan's purchase of modified off-the-shelf aircraft all reveal comparable tensions between ambition, affordability, and industrial capacity. By treating the UK as a detailed exemplar, the chapter offers lessons that can be applied to other mid-size powers facing similar procurement pressures. This problem set is not confined to defense; it also appears in major public-sector infrastructure ventures (Park, 2021). Crossrail, for instance, initially had an estimated budget of £14.8 billion but ended up costing £17.6 billion, and it opened in 2021 rather than the planned date of December 2018 (Sweet, 2019). However, defense overruns attract even sharper public scrutiny, partly because they engage national security and partly because their price tags are so large that failure cannot be concealed (Giry and Smith, 2020; Louth and Boden, 2014; Vucetic, 2016).

The challenges involved in procuring major defense equipment in the twenty-first century bear no real difference from those of the past. When Treasury minutes from 1937 record cost-plus contracts spiraling beyond forecast, we hear an early echo of today's billion-pound "black holes" in the Equipment Plan. In both eras, the same pattern is visible: technological ambition outruns initial budgets, optimistic schedules slip, and emergency injections of funding follow. Wartime expedients, such as accelerated contracting and relaxed oversight, solved immediate needs but created a legacy of overruns—precisely the dynamic we now see when urgent operational requirements or mid-program specification changes inflate modern projects, like the F-35 or the Ajax armored vehicle. By setting these direct continuities alongside contemporary data, the chapter shows that the structural problems are not new and therefore must be managed and mitigated rather than eliminated. The analysis first traces the interwar British aircraft industry, then demonstrates how its recurring cost and schedule pressures persist—albeit in different technological forms—in twenty-first-century procurement, despite repeated reform efforts. There is, however, a significant consequence to cost overruns in the twenty-first century that did not exist in the inter-war period: the budgetary black hole that builds up through UK defense services' overspending on capital equipment.

This was not as big an issue in the inter-war years, despite additional estimates being granted by the Treasury to cover additional costs, as economic conditions saw reductions in defense spending in the 1920s and the 1930s saw money being found through borrowing to meet the demands of rearmament, with the capacity of the aircraft industry acting as a cap on how much of this money could be spent (Peden, 1979). A multi-billion-pound black hole existed in 2010, leading to drastic cuts in procurement projects, particularly in the numbers delivered, resulting in a reduction in capabilities (United Kingdom Ministry of Defense, 2012). As of the end of 2023, another multi-billion-pound black hole exists in the Ministry of Defense's capital equipment budget (UK National Audit Office, 2023). This suggests that the reforms of the 1980s and 1990s have had little to no effect on the outcomes of defense procurement, adding further weight to the argument that there are clear parallels between historic and contemporary defense procurement.

The aircraft industry in the UK is a prime historical case study for comparing historic and contemporary defense procurement, as many similarities exist. The supply of aircraft in the inter-war years, as well as major defense equipment in the contemporary era, comes from wholly private manufacturers. Both were or are at the cutting edge of the technological capabilities of their time. As a result, the delivery of equipment was delayed due to unforeseen technical difficulties, which in some instances led to project cancellations. Although not within the scope of this chapter, an excellent example of this enduring challenge is the Vickers-Supermarine Swift procurement project. Two Swift prototypes and 100 production aircraft were ordered from Vickers-Supermarine in November 1950. However, technical difficulties led to significant delays in the program, and the aircraft had not met the required specifications five years later. The RAF ultimately utilized some aircraft, but it was not the 100 that had been ordered, and with costs at £33 million, it was seen as an almost complete failure (Hayward, 1989). The requirements of rearmament in the 1930s meant that only one or two aircraft of a particular type were ordered, resulting in little cancellation of aircraft types. However, there were reductions in orders for aircraft from particular firms as the demands for aircraft increased drastically between 1936 and 1939 (TNA AIR 6/51, Secretary of State's Progress Meetings, A Note by AMRD on Design and Production, 3 December 1937; TNA AIR 6/31, Royal Air Force Expansion Measures, Secretary of State's Progress Meetings, Minutes of 93rd Meeting 21 September 1937; TNA AIR 6/58, 176th Progress Meeting – Castle Bromwich Factory, Memorandum by Permanent Under Secretary, 14 July 1939). This example highlights the enduring nature of the challenges posed by defense procurement. This chapter will utilize the available literature on the interwar British aircraft industry, as well as primary historical sources, to demonstrate the challenges faced by governments seeking to maintain and expand the Royal Air Force (RAF) between 1919 and 1939. It will also draw on the extensive literature examining reforms in the UK's defense procurement systems and the challenges that still exist in the contemporary defense procurement environment.

CHAPTER 3

Achieving Security of Supply in a Defense Context

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Abstract: The concept of “Security of Supply” has gained increasing attention in the wake of events, such as the Fukushima accident in 2011, the COVID-19 pandemic, the Suez Canal blockage in 2021, the invasion of Ukraine in 2022, and heightened rivalry between the US and China. These incidents have laid bare the vulnerabilities of global supply chains and the lack of access to critical resources, such as rare earth elements. Consequently, many nations, authorities, and companies have initiated efforts to secure access to resources essential for societal preparedness, national defense, and the production of vital goods and services. Achieving greater independence in critical sectors, reducing reliance on strategic materials and components, and enhancing the resilience of supply chains are crucial goals. The definition of critical resources and supplies varies depending on the perspective of the examining organization, whether it be a nation, authority, or company. This chapter aims to clarify the concept of “security of supply” and demonstrate various factors that influence the possibility of achieving a reasonable degree of security of supply. The approach posits that security of supply is attained through supply chains comprising various stakeholders, including authorities, suppliers, transporters, warehouses, receivers, and information and payment solutions. The endurance of security of supply is contingent on the robustness of the supply chain. The chapter includes a literature survey of the “security of supply” concept and empirical data from four companies and two authorities in Sweden involved in the defense sector. Beyond providing a deeper understanding of the concept, this chapter illustrates the interconnectedness of various factors influencing the development and sustainability of security of supply.

Keywords: Continuity management, Security of supply, Supply security, Supply endurance, Supply readiness.

INTRODUCTION

The concept of “Security of Supply” has gained increasing prominence following a series of significant global events, including the Fukushima nuclear disaster in 2011, the COVID-19 pandemic, the Suez Canal blockage in 2021, the invasion of Ukraine in 2022, and escalating tensions between the United States and China.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

These events have revealed the vulnerabilities inherent in global supply chains and highlighted the challenges associated with securing access to critical resources, such as rare earth elements and other vital assets located outside national borders (Teer and Bertolini, 2022b).

The COVID-19 pandemic, in particular, exposed the consequences of inadequate pre-storage (standby stock) and insufficient security of supply for medicines, protective equipment, and healthcare materials (Antai and Hellberg, 2023). The crisis led to disruptions in traditional business operations and compromised the integrity of the European Single Market (Chiaramonti and Maniatis, 2020). Additionally, defense industrial supply chains have faced increasingly adverse effects due to geopolitical conflicts and trade restrictions (Kleczka *et al*., 2023).

These incidents have underscored the importance of strategic autonomy and the significant costs associated with supply chain disruptions (EU Union, 2022). In response, numerous nations, governmental bodies, and corporations have undertaken assessments to secure access to resources critical for societal crisis preparedness, national defense, and the production of essential goods and services (Sharma *et al*., 2022; Rockström *et al*., 2023). In particular, the evolving security landscape has prompted armed forces to rapidly enhance their storage capabilities and reevaluate their supply chain strategies (Fiott, 2024). Yet this reassessment is hardly unprecedented; analysts have cautioned for decades that highly 'lean' just-in-time networks can collapse when shocks occur, a risk made clear by the global DRAM (Dynamic Random-Access Memory) shortage that followed Taiwan's 1999 Jiji earthquake. The current debate, therefore, builds on a recognized history of efficiency-driven logistics amplifying strategic vulnerability.

The concept of security of supply, also referred to as supply readiness, is not only a central topic in political discourse but is also embedded in various national legislations, including Sweden's Protection Act (2010:305), the Act (1976:295), and Finland's regulations (FBC, 2024) concerning companies' obligations to maintain storage for supply readiness. This concept encompasses a state of preparedness designed to ensure that essential goods and services are available to all relevant stakeholders.

For a nation's armed forces to operate effectively, the surrounding society must function properly (Shields, 2020). From this perspective, ensuring the security of supply for essential goods, such as food, water, electricity, fuel, and medicines, is critical not only for the armed forces but also for society as a whole. Additionally, the armed forces have specific requirements for certain types of goods, including weapon systems, ammunition, aviation fuel, spare parts, and reconnaissance and communication equipment. These items must be managed with careful consideration of confidentiality, geographic distribution, and security of supply. The nature of the goods and services involved plays a crucial role in determining the strategies and opportunities for strengthening security of supply. These strategies must be rigorously evaluated in terms of their costs and the potential consequences of supply shortages. As such, this chapter integrates both societal and defense-oriented perspectives on security of supply.

The fields of supply chain management and project management share overlapping concerns, particularly in the areas of risk management (Wei *et al*., 2021) and the need for a clear understanding of the requirements for security of supply.

In general, security of supply involves proactive measures designed to anticipate potential crises and disruptions, alongside continuity management strategies aimed at protecting critical functions. The overarching goal is to ensure the smooth functioning of society, the private sector, and the general population under secure conditions. However, the specific implications of these measures warrant further scrutiny. Key questions arise concerning the duration of supply contingencies, the intended beneficiaries, and the associated costs. These questions constitute the central focus of this chapter's investigation.

Empirical evidence for this study was collected through workshops conducted with four defense industry companies operating in Sweden, as well as with the Swedish armed forces and the Swedish Defence Materiel Administration (FMV). These data collection activities took place between February 2022 and December 2023.

THE CONCEPT OF SECURITY OF SUPPLY

The concept of security of supply lacks a clear and universally accepted definition, resulting in varied interpretations among different stakeholders (Autry and Bobbitt, 2008). In projects involving multiple stakeholders, such as suppliers, authorities, buyers, consumers, repairers, and others, it is crucial that all parties share a common understanding of what security of supply entails and encompasses. However, defining this concept in a universally applicable manner proves challenging, as its meaning and significance are often contingent upon the specific circumstances in which it is applied.

Security of supply is a multifaceted phenomenon, with its processes varying depending on whether value is created at the level of the individual, an organization, or society, as discussed in the value creation process by Lepak *et al*. (2007). Similarly, security of supply can be compared to service design, which necessitates interdisciplinary efforts to develop complex service systems, as

CHAPTER 4

Enhancing Defense Supply Chain Resilience through Segmentation of Supplies and Differentiation of Supply Chains

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Abstract: After the Cold War, many governments in the West downsized their armed forces, changed their objectives from territorial defense to participation in peace support operations, and made them increasingly dependent on global commercial supply chains. These governments considered this operational risk-taking acceptable because of the perceived lack of military threat to their nations. However, due to recent events in the world, the geopolitical situation has changed, and many of these governments are now transforming their armed forces back to territorial defense. Nevertheless, many military supply chains are still dependent on global commercial supply chains, which remain lean and thus vulnerable to disruptive events. This chapter addresses the question of how armed forces, together with defense procurement agencies and the defense industry, can enhance defense supply chain resilience to meet the reestablished operational requirements for readiness and sustainability. This chapter describes a model for the segmentation of supplies and a decision-making methodology for the differentiation of supply chain strategies. Defense acquisition projects can utilize the model and methodology to ensure that not only legal, commercial, and technical issues inform defense acquisition decision-making, but that military operational requirements are also given appropriate attention prior to any decisions. At the heart of the methodology is an in-depth discussion among relevant stakeholders, including the armed forces, to ensure that defense acquisition projects make informed decisions regarding defense supply chain resilience and, if necessary, lead to explicit operational risk-taking.

Keywords: Defense acquisition, Defense supply chain resilience, Differentiation strategies, Military logistics, Operational requirements, Segmentation model.

INTRODUCTION

Supply chains are vital to all sectors of society, including defense, and a frequently echoed warning is that “one size does not fit all.” Dependable defense

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supply chains are a prerequisite for power projection, credible deterrence, and, ultimately, combat effectiveness. Defense supply chains extend from raw material extraction to deliveries to warfighters and consist of commercial supply chains, operated by private companies, and military supply chains, operated by armed forces. Armed forces typically depend on several thousand commercial supply chains, which constitute a global defense supply network.

For contracting companies in these global networks to deliver supplies, defense acquisition and defense acquisition project management are essential. To deliver the supplies, the "last mile" to the military units, military logistics is a prerequisite. While different approaches to organizing military logistics exist, most armed forces commonly recognize four principal functions: supply, transportation, maintenance, and medical services (Foxton, 1994, p. 11). The present chapter focuses specifically on supply.

In many countries, responsibilities for defense acquisition and military logistics are separated and often carried out by different organizations, such as Defense Procurement Agencies (DPAs) and Defense Logistics Organizations (DLOs). The DPA is consequently responsible for selection and contracting many of the commercial supply chains on which the military supply chains will then depend. However, especially after the Cold War, the actions of DPAs have habitually been dictated by commercial and judicial considerations rather than the satisfaction of the operational requirements of armed forces. This occasionally creates friction because the DPA is frequently instructed to purchase at a low cost, and then the problems are "thrown over the wall" from the DPA to the DLO (Kincaid, 2002, pp. 14-15). The problems thus transferred to the DLO include the cost of ownership and the operational risk-taking associated with the contracts. In this chapter, the public defense sector, which is responsible for the acquisition of advanced military equipment, such as platforms, is referred to as a DPA, and the part of the armed forces that is responsible for military logistics is referred to as a DLO, which in many countries is also responsible for the acquisition of supplies other than major equipment. In addition, armed forces, DPAs, and DLOs are referred to as defense authorities.

After the Cold War, many countries in the West capitalized on the peace dividend, *i.e.*, reallocating funds from the military sector to other sectors of society, and transformed their downsized armed forces from forces for territorial defense to expeditionary forces for deployment on Peace Support Operations (PSOs). Reduced military budgets put increased pressure on DPAs and DLOs and compelled them to explore new public-private business models for defense acquisition, including outsourcing parts of military logistics to the private sector (Ekström, 2012), thus making armed forces progressively more dependent on commercial supply chains and contractors for maintenance and transportation. Since their armed forces were deployed on PSOs rather than standing in preparedness for territorial defense, this operational risk-taking was acceptable to most countries in the West.

Commercial supply chains are by default cost-minimizing entities (Basnet and Seuring, 2016), which has made them progressively cost-efficient, interconnected, electrified, digitized, automated, globalized, increasingly complex, and thus vulnerable to disruptive events, or Low-Frequency and High-Impact (LFHI) events. For military logistics, the changes after the Cold War implied a shift from a Just-in-Case logic to a Just-in-Time logic. Due to their increased dependence on commercial supply chains, military supply chains also became increasingly vulnerable to LFHI events. The new "era of turbulence" (Christopher and Holweg, 2011), or the VUCA (vulnerable, uncertain, complex, and ambiguous) world (Altay and Pal, 2023), with recurring LFHI events, instigated research into supply chain resilience (SCRES).

Actions, including re-shoring, friend-shoring, or ally-shoring of manufacturing, identification of substitute raw materials and components, pre-storage of supplies, and implementation of multi-sourcing strategies, are now being adopted across global supply chains, both in commercial and military supply chains, to enhance SCRES while sacrificing some of the cost-efficiency. However, there are different logics at play in the public and private sectors. Public authorities use money to produce public goods and services, such as the armed forces, whereas private companies produce goods and services, such as defense equipment, to make money. This means that the cost-benefit analyses by public authorities from a defense and security perspective, and private companies from a business economics perspective, regarding measures to improve SCRES will be quite different. Hence, the premise of this chapter is that if defense authorities want to ensure that private companies go beyond what is defensible from a business economics perspective to enhance SCRES, defense authorities will have to pay them to do so and consequently include such actions in contracts.

Recent events in Europe, Asia, and other countries have challenged the hegemony of the rules-based international order, and the geopolitical landscape is shifting. This has resulted in a paradigm shift for many governments in the West, from reductions in military spending to a significant increase, and from expeditionary forces back to forces for territorial defense. However, military supply chains still depend on global commercial supply chains, which fundamentally remain lean and thus vulnerable to LFHI events. For some raw materials and electronic components, this dependence is unlikely to change in the near future. So, how can armed forces, together with DPAs and the defense industry, enhance defense

CHAPTER 5

Model-based Systems Engineering for Defense Project Managers

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Abstract: Model-Based Systems Engineering (MBSE), the formal application of modeling to systems engineering activities, is widely used by the defense community for the development of new systems. It is used across the entire system life cycle, from the initial formulation of requirements through design and development to testing, production, and ultimately, operations. A major focus of MBSE is developing a system model that captures all relevant information about a system in a single model that can be viewed from multiple perspectives. This enables multidisciplinary and multi-organizational teams to communicate more effectively, manage change more efficiently, and trace the system architecture from initial stakeholder requirements to detailed engineering design decisions. In turn, the employment of MBSE results in a better-quality product that is delivered on schedule and within budget. MBSE is widely used in the defense industry for all of the aforementioned reasons and is now coupled with other modern engineering and product life-cycle management methods as part of a larger digital engineering ecosystem. This increasing demand makes it important for defense project managers to understand what MBSE is, what is required to implement it, and how to use it to inform decisions, reduce risk, and produce high-quality products. This chapter defines MBSE, reviews key MBSE elements including tools, modeling languages, and architecture frameworks, assesses project management decisions related to implementing MBSE on a project, and discusses how MBSE can inform key project management processes.

Keywords: Digital engineering (DE), Model-based systems engineering (MBSE), Project management (PM), Systems modeling language (SysML).

INTRODUCTION

Model-Based Systems Engineering (MBSE) is an important and growing aspect of the modern engineering landscape, particularly for the development of complex systems as seen in the defense industry. It is commonly defined as the "formalized application of modeling to [systems engineering]" (INCOSE, 2015). Although the

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

discussion that follows draws heavily on U.S. Department of Defense practices, MBSE's core principles now underpin acquisition in NATO, Australia, India, and several European states that have adopted SysML-based digital engineering policies (INCOSE, 2021; Department of Defense, 2018). The resulting lessons on tool selection, data integration, and life-cycle governance therefore possess wider relevance than a single-nation case might suggest. MBSE's benefits—improved communication, management of complexity, and higher product quality (INCOSE, 2015)—remain universal, though realizing them still demands deliberate resourcing. The chapter reviews those benefits and challenges, outlines implementation requirements, and explains how project managers in any national setting can tailor MBSE to local standards without losing its global interoperability.

MBSE OVERVIEW

Systems engineering is a young engineering discipline, first formalized in the 1940s. It was born with the advent of complex systems around World War II, primarily in the defense and aerospace industries (Buede & Miller, 2016). With modern information technologies, including computation and networks, integrating into an increasing percentage of the world's technology, systems engineering has expanded into multiple industries, such as infrastructure, automotive, healthcare, and others (INCOSE, 2021). MBSE is approximately 50 years younger than systems engineering, first coming into the lexicon around the early 1990s. In 1993, Wymore wrote a book, Model-Based Systems Engineering, that outlined foundational concepts for the field (Wymore, 1993). The field expanded significantly over the decade as computers and networking technologies became increasingly prevalent in all aspects of society. The systems engineering community adopted many practices from the software engineering community, particularly with regard to the concept of architecting and graphical modeling in the *Unified Modeling Language* (UML) (Maier & Rechtin, 2009; OMG, n.d.). In 2003, the Object Management Group (OMG) developed the standards for the Systems Modeling Language (SysML), which is popularly used for MBSE (OMG, n.d.). While SysML is not equivalent to MBSE, its evolution and rise in popularity correspond closely with the adoption of MBSE across a variety of industries.

While systems engineering is continuing to transition from a document-based approach to a model-based approach, a new goal has emerged for engineering future projects: Digital Engineering (DE). Digital engineering expands beyond the initial goals of MBSE to integrate all systems engineering activities into a more expansive perspective of seamlessly integrating all engineering activities—systems, hardware, software, people, processes, design, testing, scheduling, and costing, among others. The DoD issued a DE strategy in 2018 (Department of Defense, 2018), a DoD Instruction in 2023 (Department of Defense, 2023), and operationalized much of the digital engineering organization, resources, and processes under the Digital Engineering, Modeling, and Simulation Directorate within the Under Secretary of Defense for Research and Engineering (Department of Defense, n.d.). MBSE serves as the central methodology to integrate these disparate efforts in a digital engineering context. This philosophical and operational change is permeating all aspects of defense acquisition, and project managers in the defense industry benefit from understanding how this impacts and benefits their processes.

MBSE Contrasted with Document-based Systems Engineering

The International Council for Systems Engineering (INCOSE) defines MBSE as the "formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (INCOSE, 2015). In short, this is the formalized application of modeling to systems engineering activities throughout the system lifecycle. While systems engineers have always used modeling and simulation to develop systems, the formalized application of modeling to the entirety of the system development process is unique to MBSE. This distinction is subtle but key to understanding MBSE and the transition between a document-centric and a model-centric systems engineering approach.

Traditional engineering and project management processes are generally document-based, commonly referred to as Document-Based Systems Engineering (DBSE). This means that individual engineering and management activities are executed independently and captured in discrete documents that are not formally connected. In DBSE, a program might conduct an initial concept study, develop results, and document those results in a white paper. After that, another team might conduct requirements studies and capture those in a requirements document. Later, a design team may develop multiple system designs in disparate engineering tools such as documents, spreadsheets, or graphical models. As the team moves into prototyping, testing, and production, it may conduct analyses using databases, documents, and simulations. While some or even all of these analyses and events are completely digitized (*e.g.*, in a portable document format, or PDF file), and they may be stored in a common location, such as a shared drive

CHAPTER 6

Applying the Systems Decision Process (SDP) to Project Management

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Abstract: This chapter applies the Systems Decision Process (SDP) to the practice of Project Management (PM) through the lens of the defense industry, using applicable case studies and realistic examples. Systems thinking enables project managers to identify the root causes of problems they face, assess the risks associated with different alternatives, recognize the interconnected relationships and dependencies between system elements, and ultimately make informed decisions to meet their clients' needs. The SDP's *Problem Definition* phase ensures that the project manager considers the needs of all stakeholders within the broader environment, which is often vast in the defense sector, and establishes clear boundaries for the scope of work. *Solution Design* directs the project manager's focus to generating value-based alternatives that optimize outcomes within clear budget constraints, informing their choices as they transition into the *Decision Making* phase. Through the employment of value scoring methods, sensitivity and risk analysis, and tradeoff analysis, the project manager executes their plan during the *Solution Implementation* phase of the SDP. The SDP augments and enhances the most accepted approaches to PM by providing project managers with a clear and repeatable decision-making process that explicitly considers the systems' nature of the problem and focuses on stakeholder value when making decisions. This is invaluable as project managers make decisions in complex and dynamic environments, such as the defense industry. While Multi-Criteria Value Modeling (MCVM) is essential in the early phases of a project, it also serves as an invaluable tool for project managers as they encounter change order requests during execution, continuously conduct quality control and assurance, and ensure final deliverables are met while closing out a project.

Keywords: Decision making, Multi-Criteria Value Modeling (MCVM), Problem definition, Project environment, Solution design, Solution implementation, Stakeholder analysis, Systems decision process (SDP), Systems thinking, Value-focused thinking.

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INTRODUCTION

Project Management (PM) is a well-studied and defined field that enables organizations to achieve desired results in an effective and efficient manner that balances cost, schedule, and performance. While PM can be applied generically across multiple domains, it is most effective when tailored for the specific domain of interest. The defense domain presents a large variety of problems that are best addressed with a PM approach. In the defense industry, however, the project manager is challenged by the fact that these projects exist in a complex environment characterized by competing stakeholders, high levels of uncertainty and risk, and significant impacts on national security and citizens' well-being. This chapter demonstrates how the deliberate use of Systems thinking and multi-objective decision analysis (MODA) (Parnell, Driscoll, & Henderson, 2023) in a process called the Systems Decision Process (SDP) (Parnell, Driscoll, & Henderson, 2023) can enable project managers to succeed when leading complex defense projects. Furthermore, the SDP can be applied to PM practices, as discussed by the Project Management Institute (PMI) (Project Management Institute, Inc., 2021) in its Project Management Book of Knowledge (PMBOK), to enable a project manager's success.

The defense domain presents a wide variety of problems that may be addressed with PM practices. These include problems related to the acquisition of military equipment, as well as the construction and maintenance of defense infrastructure, among others. The problem sets are of particular interest because they are generally of high importance to the military and often very costly. While they have corollaries with non-defense domains, such as product development and construction, they have their own unique challenges due to the defense domain.

It is noteworthy that this chapter takes a U.S.-centric perspective on defense PM due to the size of the U.S. Department of Defense (DoD) and that it is the authors' area of expertise. That being said, all discussions generally apply to the defense domain in other countries, although the specifics will need to be updated for unique situations.

PROJECT MANAGEMENT

While PM is a process that has been practiced for centuries, it has been formally codified over the last few decades by large institutions as the practice has transformed into a profession. While there are many methodologies one could choose to follow, the Project Management Institute (PMI, 2021) has emerged in the U.S. as one of the main proponents of project management and provides a structured approach through which projects can be managed. PMI administers a certification exam that enables an individual to be recognized as a Project

Management Professional (PMP) or Certified Associate in Project Management (CAPM), and provides opportunities for certified professionals to maintain their status by completing Professional Development Units (PDUs) annually. PMI further defines its approach to PM through its PMBOK, which exists in its Seventh Edition as of the publication of this text. Other respected project management organizations in North America include the International Association of Project Managers (IAPM) and the Project Management Association of Canada (PMAC), which offer the Certified Project Management Professional and Certified Project Manager certifications, respectively.

PMI asserts that "projects exist within a larger system" and further identifies its process as being a "system for value delivery" (Project Management Institute, Inc., 2021). While PMI previously described PM through the lens of 49 individual processes divided into five process groups (Initiating, Planning, Executing, Monitoring and Controlling, and Closing) and ten knowledge areas, PMI transitioned away from this process-based approach in 2021 and moved to a principles-based framework (Project Management Institute, Inc., 2017; Project Management Institute, Inc., 2021). Although PMI no longer strictly uses the five process groups to define the lifecycle of a project, this framework can still prove beneficial to project managers for use as a general guideline rather than a prescriptive checklist. Beyond describing PM through 12 core principles (Table **1**: PM Principles as Defined by the PMBOK, Seventh Edition), the Seventh Edition was updated to incorporate Agile methodologies, emphasize tailoring approaches to meet individual projects' needs, and expand its focus on stakeholder engagement (Project Management Institute, Inc., 2021).

Projects operate within a broad environment that can be categorized into internal and external environments, both of which have direct and indirect impacts on a project manager's ability to create and deliver value to their customers (Project Management Institute, Inc., 2021). The internal environment consists of all systems, practices, and tools that an organization uses to operate, including its organizational structure and unique system for delivering value to customers. On the other hand, the external environments consist of everything else that can have a positive or negative impact on the project, including, but not limited to, the overall marketplace, physical environment, regulatory conditions, and cultural context. To effectively complete a project, the PM team must maintain a pulse on all internal and external environments in which the project exists and react to any changes occurring within them accordingly.

PMI's approach to PM focuses more on its 12 foundational principles within the PMBOK rather than detailed methodologies, as they assert that the "Principles for a profession serve as foundational guidelines for strategy, decision making, and

CHAPTER 7

Using Combat Simulation to Assess Measures of Effectiveness (MOEs)

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Abstract: Progress in a system development effort is tracked through a series of metrics, including Measures of Effectiveness (MOEs), which measure a system's operational performance. Quantifying MOEs in defense projects poses formidable challenges, particularly concerning metrics like lethality or survivability. Indeed, non-mature systems will not be deployed into an operational setting to determine the impact of the system on survivability or lethality. In practice, surrogate performance parameters are often employed as proxies for the MOEs. However, combat simulations are a more precise means of apprehending and assessing MOEs. Combat simulations can comprehensively operate in operational context while also anticipating second-order effects, for instance, the scenario of enhancing soldier survivability through body armor. Traditional performance metrics might link survivability to the armor's resilience against standard rounds. Yet, augmenting armor weight potentially compromises a soldier's agility and speed, inversely affecting survivability. This chapter discusses the use of combat simulations to evaluate MOEs throughout a system's developmental trajectory. It will include an overview of how to develop the appropriate simulation, model the system under development, execute the simulation, and analyze the outputs.

Keywords: Combat modeling, Combat simulations, Defense systems, Measures of Effectiveness, Surrogate performance parameters.

INTRODUCTION

The progress of a system development effort is typically measured through various metrics. A Measure of Effectiveness (MOE) is an outcome-oriented yardstick that expresses how well a system fulfills its military purpose once employed in context, whereas a Measure of Performance (MOP) or a Key Performance Indicator (KPI) describes the system's inherent technical or managerial attributes that are expected to drive that outcome. In defense projects,

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

MOEs usually target capabilities such as mission success, survivability, or lethality, while KPIs might track software defect rates and MOPs might track probability of hit or vehicle speed. Because MOEs depend on real-world interaction between the system and its environment, they are hard to quantify before fielding, and realistic tests are costly (Buede & Miller, 2016).

Defense project managers, however, need to gauge the progress of their development efforts and the impacts of program decisions on key metrics like survivability or lethality (Kossiakoff, Seymour, Flanigan, & Biemer, 2020). To overcome this hurdle, managers and engineers often use surrogate performance parameters as substitutes for MOEs; for example, weapon range or explosive power is often used as a substitute for lethality. Nevertheless, combat simulations have emerged as a more comprehensive approach to capture and evaluate MOEs (Dobias, Sprague, Woodill, Cleophas, & Noordkamp, 2008). Combat simulations offer the advantage of incorporating operational context and predicting second-order effects, allowing for a deeper understanding of system performance. Consider a scenario involving the enhancement of soldier survivability through body armor. Traditional performance metrics might solely focus on the armor's resistance against standard rounds, but augmenting the armor's weight could compromise the soldiers' agility and speed, ultimately impacting survivability in unexpected ways.

This chapter delves into the utilization of combat simulations for assessing MOEs across various stages of a system's development. It will provide an overview of MOEs and the roles that they play in system development and the process for using combat simulation to assess MOEs through the system lifecycle. The chapter then presents an example case study for an armored power exoskeleton. Through this exploration, the chapter highlights the utility and intricacies of employing combat simulations in the evaluation of measures of effectiveness throughout a system's developmental trajectory.

THE ROLE OF MEASURES OF EFFECTIVENESS

MOEs play a pivotal role in defense project management by serving as critical yardsticks to evaluate the attainment of specific objectives and the overall success of military operations, systems, or projects (Office of the Under Secretary of Defense for Acquisition and Sustainment, 2020). These metrics are designed to assess the extent to which a system or strategy accomplishes its intended goals, focusing on the outcome and impact rather than merely measuring activities or outputs. Assessments of operational performance are often required for acquisition decisions, such as in an analysis of alternatives, which is done early in the system development lifecycle (Department of Defense, 2022). Further, MOEs are used to derive the Measures of Performance (MOPs) and Key Performance Parameters (KPPs), which are technical measures that are tracked through the development of a system (INCOSE, 2015).

Given the operational nature of MOEs, it is often difficult to quantify them. This is because MOEs are not inherent to the system itself; rather, they are a function of the system and its interaction with its environment – the terrain, weather, friendly forces, and threat forces. For example, mission success rates can only truly be measured after the system has been built, tested, and deployed. As such, MOEs are often evaluated qualitatively. Meanwhile, an MOP will typically derive from the MOE, allowing for a quantitative tracking of the system's progress (INCOSE, 2015). For example, the MOE for a software development project could be the level of user satisfaction with the software. A derived MOP would be the average response time of the software. Throughout the development of the project, the design team will track the average response time of the software to ensure that the final deliverable will meet the intended goals.

Three common MOEs in the defense sector are mission success rates, survivability, and lethality (Department of Defense, 2022). While these can be quantified in a number of unique ways, these MOEs are not dependent solely on the nature of the system itself but on how it interacts with the environment. This is often hard to measure, and project managers and engineers often resort to substituting these with easier-to-measure MOPs.

Mission Success Rates

It is a system's ability to support a unit in completing a set of missions (Department of Defense, 2022). Each mission has a set objective, such as seizing a piece of terrain, denying enemy freedom of maneuver, or other similar tasks. The new technology should increase the probability of mission success for the user. To approximate the MOE, managers and engineers use proxy MOPs related to the presumed utility of the system on mission success. Consider the example of a new vehicle intended to deliver supplies to a unit. A relevant MOE might be the time to complete the supply mission. A naïve approach to assessing how a technology impacts this MOE would be to assess the vehicle's speed to measure the time to make a supply turn and then calculate how much cargo could be moved in a given time. This is a reasonable estimate, but it assumes that combat resupply speeds are purely a function of vehicle speed. This is generally not true, as combat resupply usually requires an external security escort. In this case, the true maximum speed of the unit conducting resupply is the minimum of both the resupply vehicle and the security escort vehicle. Even that improved estimation ignores other challenges to the timeline such as impacts of terrain or system

CHAPTER 8

Are Technical Competencies or Project Leadership the Key to Project Success?

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Abstract: Most of the major defense projects are carried out in civil-military partnerships. In the early days of these partnerships, responsibilities are shared, with the armed forces playing a key leadership role in ensuring efficient coordination, operationality, and political influence. However, today's major Defense projects are costly, risky, and complex. Emerging technologies and capabilities such as artificial intelligence, quantum technology, and sensor fusion technology present challenges. Primarily due to budget restrictions, limited personnel, and high turnover resulting in a shortage of knowledgeable staff, the armed forces have transferred many responsibilities to the civilian side, such as research and development, quality assurance, testing, and risk management. The duties of the armed forces are currently limited to defining the operational and technical requirements. At the same time, the Defense industry is tasked with delivering a product 'off-the-shelf,' *i.e.*, ready to be operated in a military environment. This raises the question of what role a military project manager should fill and what competencies are required? Remarkably, the value and importance of project leadership in the military are being called into question. This chapter aims to demonstrate that leadership is not necessarily as important as it used to be, but technical skills concerning the type of project are of the utmost importance for understanding the environment and situational awareness. The proposed model, where a project manager of a complex project should be selected based on their technical skills even to the detriment of leadership competencies, is based on both the real-life experience of one of the authors and a reconciliation of this experience with a literature review. Pragmatically speaking, prioritizing technical skills over leadership at the level of the project manager and their team, such as a PMO, could generate significant benefits and reduce, for example, the risk of cost and/or deadline overruns. Thus, the operationalization of the model tends to show the advantage of choosing a management team with high technical competency over a team with solid leadership abilities when a major project becomes highly complex in terms of technology.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

Keywords: Competencies, Defense, High technologies, Leadership, Organization, Project management.

INTRODUCTION

Leadership is a concept that has been studied for over 200 years, pioneered mainly by the work of Max Weber (Plane, 2015a). Since the emergence of the "Great Man" approach, this has led to the development of one of the most studied premises, determining the characteristic traits of a leader; especially with the insoluble question of whether leadership is innate or not. The main leadership theories have evolved, adapting to different organizational, socio-cultural, and technological practices. Leadership is difficult to define, and many studies have led to the development of new theories. One of the most recent leadership theories, which is emerging as an important area of research, is Authentic Leadership (T. Farid *et al*., 2020). However, this chapter aims not to develop a theory or determine the best approach to leadership in Defense project management but rather to position and determine the importance of leadership in the management of major Defense projects according to a specific leadership model. A major Defense project usually refers to capital equipment, information technology, and/or infrastructure projects over $10 million.

Before examining the chapter's subject in depth, it is essential to identify the leadership theories applicable to project management. Prabhakar's article (Prabhakar & Walker, 2004) shows us that, to achieve a level of success, a project manager must not necessarily adapt their leadership to the team but rather have a situational approach that involves several types of leadership. This adaptive approach enables optimum performance to be achieved by using several leadership methods in the different phases of a project. In this way, we can introduce a new adaptive method of using several leadership styles depending on the situation. This concept will be considered in the proposal for a leadership model in major Defense project management defined later in this chapter.

Other factors to consider in our proposal for a leadership model are the postmodern challenges of our time, including new technologies, globalization (opening up of markets), and the rapid growth of artificial intelligence. These factors have a major impact not only on project performance but also on the skills that project managers must now acquire. In complex projects, in general, one cannot be an effective project manager without a minimum mastery of the use and understanding of new technologies. Thus, the use of new technologies is introduced into project management and the application of high technologies involved in developing new military Defense capabilities; this results in a dual complexity.

"Today, a project manager spends 30% of his time on reporting and 10 to 20% of his time collecting information... According to Gartner, by 2030, 80% of the management tasks performed today will be taken over by AI to make life easier for project managers." (Prodecys, 2023).

Project managers can no longer only acquire skills in the specific field of project management but must also be able to manage extreme complexities in different technological fields. The project manager of the future must, therefore, be open-minded enough to learn about scientific and technological fields in an increasingly collaborative mode; especially in a world of astromodernity, which we will define and analyze at the end of this chapter. Unfortunately, contrary to a persistent belief, the author believes that a project manager with only limited project management skills, such as certification from a management institute, is no longer sufficient to succeed in Defense projects, regardless of their ability to use different leadership and management skills. Knowledge and expertise in technology and innovation are also beneficial for performance (W. Christopher & Sander van Triest, 2023).

According to traditional and modern schools of thought, a manager's leadership style is the key to success, with the latest trends emphasizing personality traits and ethics (Plane, 2015). Thus, we will see the emergence of Leadership 2.0. This approach highlights the changes of the postmodern world, including "flat hierarchical structures and autonomous teams... a democracy of ideas... favoring innovation and risk-taking" (Plane, 2015). However, based on the author's personal experience and interviews with project managers at Canada's Department of National Defense, it would appear that this concept of leadership is being called into question. The methods used to carry out major Defense projects and their predominantly technological complexity mean that leadership is no longer seen as a critical success factor but rather as relative skills and experience, depending on the level of technological complexity of the project (use and involvement, *etc*.).

DEVELOPMENTS IN MAJOR DEFENSE PROJECTS

Before elaborating on the leadership model proposed in this chapter, it is essential to understand the status of and approach to major Defense projects and their origins. This will give us a better understanding of their particularities and uniqueness compared to so-called traditional projects.

The Manhattan Project is an interesting starting point for analyzing its innovative organization. "The Manhattan Project was an unprecedented, top-secret World War II government program in which the United States rushed to develop and deploy the world's first atomic weapons before Nazi Germany" (National

CHAPTER 9

The Global Mosaic: A Cross-Country Analysis of Defense Acquisition Management Models

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Abstract: Due to increasing political tensions, the procurement of required weapon systems and supply products needed to satisfy a country's defense needs, in short, Defense Acquisition Management (DAM), is currently under the spotlight. Therefore, the question arises as to how DAM is structured and executed in project management across different countries, and what lessons can be derived from comparing these approaches. It also raises the question of whether DAM (strategic management of overall defense requirements, including the supplier base) is fully implemented, or if countries concentrate solely on modeling sub-concepts within Defense Procurement (DP) (with a focus on armaments). For this purpose, this chapter analyzes published models for DP. The database comprises 76 models from 34 countries. The findings reveal four key observations: First, there is a great variety of models, indicating that DP knowledge is not yet consolidated. There are national peculiarities and different views of DP in individual cases. Second, an imbalance in the relevance of individual model elements is recognizable. Demand management is addressed in a high proportion, indicating that DP models often cater to what future military users require. In contrast, the subordinate tasks of strategic procurement, and in particular, the operational ordering process, are rarely mentioned. They can be described as a "blind spot" in DP models. Strategic procurement tasks and processes are mentioned but are usually only focused on partial aspects (*e.g.*, definition of the planning framework), not elaborated and formulated in terms of content as a link between demand management and operational procurement. Lastly, the user forms the conceptual bracket and the orientation point for many DP models. The "utilization and implementation" section concludes many models, but without defining the interface between procurement and equipping the user. Furthermore, an outward orientation, *i.e.*, towards suppliers and the procurement market, remains underrepresented both strategically and on the user side, and procurement is too one-sided in terms of a comprehensive strategy. The analysis also examines whether the steps recorded in the DP models are sufficient to cover an all-encompassing DAM. It shows that although steps of utilization are already included, differentiation between objects and orientation along the supply chain are not yet sufficiently addressed. This chapter presents the observations and concludes with a proposition for a synthesized view of the global mosaic, incorporating an aggregated DP/DAM model.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

Keywords: Defense acquisition models, Defense acquisition process management, Defense procurement, International defense acquisition benchmark, Military.

INTRODUCTION

In the past, most countries planned for a reduction in military spending in their annual budgets to be cost-effective (Juntunen *et al*., 2012). However, today, the effects of current political tensions are evident in procurement figures: last year, military spending rose sharply. According to the latest updates released by the Stockholm International Peace Research Institute (SIPRI), global defense spending continued to rise after the 2022 record and is estimated to have increased by almost ten percent between 2023 and 2024, surpassing the US$2.4 trillion mark. This acceleration reflects both the Ukraine-related surge in European budgets and heightened investment in the Indo-Pacific, where the United States has begun to reorient resources (Tian *et al*., 2023). Several reasons can be considered triggers: Russia's invasion of Ukraine and increasing tensions in East Asia are just two aspects, in addition to crises, for example, in Africa (Sudan, Mali) or ongoing tensions between Israel and Palestine (Berlie *et al*., 2024; Kuzio, 2022; Ozili, 2022; Samuel, 2023). Many nations face similar defense challenges, and they must all execute the tasks of budgeting, planning, procuring, and supplying new weapons systems for their armed forces. As such, there is the assumption that Defense Procurement (DP) models around the world should have some similarities due to the same functional tasks these models address.

According to the SIPRI study, the highest military expenditures are occurring in the United States of America (USA) and China, while the figures for European armed forces have grown disproportionately. Compared to 2021, European countries have recorded a 13% increase in military spending (Diego Lopes da Silva *et al*., 2022; Tian *et al*., 2023). It appears that Europe is facing a tense situation, which German Chancellor Olaf Scholz declared a “Zeitenwende” (“turning point”) in 2022 (Scholz, 2022). This political turning point appears to herald a military shift; investments in DAM are highly needed. According to the European Commission, future efforts should place a stronger focus on cooperative procurement projects across (alliance) nations. Also introduced by the European Commission in March 2024, the European Defense Industrial Strategy (EDIS) outlines plans for a joint Defense Acquisition Management (DAM) (*European Commission*, 2024). To better execute cross-national (alliance) procurement, Defense Procurement (DP) models of each nation should be compatible with one another, which supports the assumption that DP models should exhibit some degree of similarity.

Not to mention that many defense acquisition projects face time and cost overruns. Referring to two very prominent defense projects, the Airbus A400M Atlas and the F-35 Lightning II, this can be exemplified. While the A400M is a military transport aircraft developed by a consortium of European countries, the F-35 series consists of advanced stealth fighter jets for the United States Air Force, Navy, and Marine Corps, as well as for the armed forces of various partner countries. Thus, one project emerged from the collaboration of several nations – the other with a national focus but across typical interorganizational limits. Both projects encountered significant difficulties during the development and procurement phases, resulting in delays and cost overruns. In the case of the A400M, it will take 16 years more to achieve full operational capability (Welt, 2023). In the case of the F-35, the project is over $183 billion over original cost estimates (GAO, 2023). The question arises as to whether existing procurement models are sufficient for such highly complex projects, or if defense acquisition management must consider new, joint models. The examples suggest that a more aligned or similar approach to DAM across branches or nations could help manage major defense projects and mitigate their risks with less coordination effort. As more projects are executed across branches or nations, this is another argument that similarities in DAM models develop and differences are reduced. To give readers an immediate sense of those differences but also some similarities, Table **1** contrasts seven defense acquisition systems with their main characteristics as well as indicative, perceived strengths following several sources (Bundeswehr.de, 2025; Defense Equipment and Support, 2025; Department of Defense, 2016; Kaufmann, 2022; Government of Canada, 2020; Ministry of Defense India, 2020; RAND Corporation, 2022).

Table 1. Illustrative defense acquisition system approaches across seven countries.

Country	Predominant Characteristics	Principal Strength (according to sources)
Germany	Centralized civilian oversight *via* the Ministry of Defense (MoD) and Purchasing organization (named BAAINBw).	Emphasis on parliamentary control, transparency, and lifecycle costing
United Kingdom	Centralized with procurement organization (named Defense Equipment and Support, DE&S) under MoD oversight; increasing privatization (*e.g.*, government-owned, contractor operated).	Strong project management culture and agile reforms (*e.g.*, DE&S Transformation)
USA	Decentralized; Department of Defense-led with services-specific acquisition offices and strong Congressional oversight.	Technologically ambitious programs and industrial innovation.
France	Centralized under procurement agency (named DGA) with strong state-industry coordination.	Strong integration between defense policy, R&D, and industry.

CHAPTER 10

International Defense Innovation as a Complex Sociotechnical System: A Case Study of the NATO Science and Technology Organization

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Abstract: Strategic defense project management does not operate in isolation; it depends on robust national and international innovation systems for technological foresight, insight, Research and Development (R&D), and risk mitigation. Given the complexities and risks associated with Emerging and Disruptive Technologies (EDT) and the demands of coalition and combined military operations, the international Science and Technology (S&T) community is a critical and essential component of the defense innovation system. S&T collaboration and coordination across the human, information, and physical sciences facilitate technological advancement, address legal, moral, and ethical concerns, and help to ensure interoperability at all levels. This, in turn, fosters technologically relevant and operationally effective defense capabilities. For more than 70 years, the Science and Technology (S&T) community of the North Atlantic Treaty Organization (NATO), particularly the Science and Technology Organization (STO) and its predecessor organizations, has played a crucial role for NATO and the Alliance. As the largest global network of defense and security researchers drawn from academia, industry, and government, the NATO STO has been instrumental in fostering these technologically relevant and operationally effective defense capabilities. Examining the NATO STO from the perspectives of sociotechnical systems and organizational theory provides valuable insights and highlights best practices, including those associated with collaborative project management. These insights underscore the importance of a global perspective in defence programme management, the structures that underlie its success, and the limitations and constraints inherent in collaborations across the global Science and Technology (S&T) network in defence and security.

Keywords: Capability-based planning, International collaboration, North atlantic treaty organization (NATO), Organisational theory, Programme management, Research and development (R&D), Science and technology (S&T), Sociotechnical systems, Strength-weakness-opportunity-threat (SWOT) analysis.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

INTRODUCTION

For defense and security project, program, and portfolio management (P3M) (Gray *et al*., 2016), deep knowledge of the operational context and supporting capabilities serves as an essential foundation (Possehl, 2022). However, Research and Development (R&D) is also necessary for this foundational knowledge, as it enables technological and scientific understanding, constrains the option space, supports technology demonstration, addresses human factors, facilitates capability integration, and reduces associated risks (Klein *et al*., 1958; Hansen, 1999; Possehl, 2022). Similarly, anticipating and leveraging knowledge management, as well as exploiting Emerging and Disruptive Technologies (EDT), within P3M promises to improve programmatic effectiveness, increase managerial efficiency, and reduce programmatic risk (Carayannis, 1998; Alhawari *et al*., 2012; Jiang *et al*., 2018; Khatib *et al*., 2022). Science and Technology (S&T) and operational knowledge are the "pierre angulaire" (cornerstone) of defense and security P3M and strategic management (Fig. **1**).

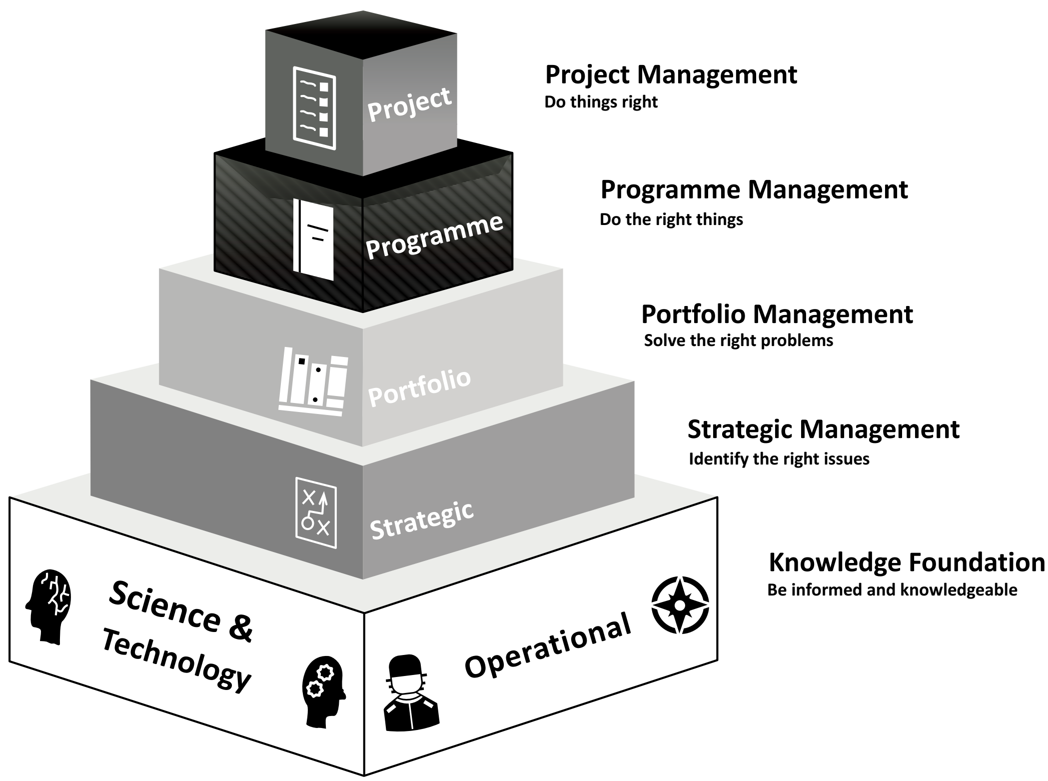

Fig. (1). Project, Program, Portfolio and Strategic Management (adapted from Gray *et al*., 2016; Masten, 2021).

P3M defense managers are responsible for staying informed about relevant Scientific and Technological (S&T) developments within national and international innovation ecosystems. Furthermore, they must be aware of the national and alliance defense challenges involved in operationalizing these technologies or using them to improve managerial efficiency. This situational awareness is indispensable for preventing capability obsolescence upon project delivery, ensuring interoperability with allies, and avoiding the pursuit of technology hype while maintaining agility and adaptability within an ever-evolving technological and geostrategic landscape. For North Atlantic Treaty Organization (NATO) nations, NATO S&T activities have historically supported international S&T cooperation necessary to develop technical standards, enhance S&T knowledge, gather scientific intelligence, and explore new operational concepts. Furthermore, this collaboration facilitates burden sharing, the exchange of innovative ideas and technologies, risk mitigation, and cost reduction in the development of military and security capabilities. Ultimately, this shared effort ensures that Alliance forces are effective and interoperable at all levels.

This case study examines the NATO Science and Technology Organization (STO), NATO's most successful science and technology institution, by addressing a central question: How has the NATO STO survived and remained effective for nearly three-quarters of a century amidst significant geopolitical and technological changes, and what lessons can be learned from this success? To answer this question, we will briefly review the historical context and character of NATO's defense and security Science and Technology (S&T). In doing so, we will also describe the desired characteristics of successful international collaborations. We then present an analytical framework to examine the NATO STO and its precursor organizations using a Sociotechnical Systems (STS) perspective. This includes a Strengths-Weaknesses-Opportunities-threats (SWOT) analysis, considering strategic system inputs and outputs, and bearing in mind typical success and failure behaviors found in STS. Using this analytical framework, we conduct a diagnostic assessment of the NATO STO, considering historical developments and foundational principles, but focusing on the current state of the NATO STO. Finally, we summarize the fundamental success characteristics of collaborative S&T organizations and contrast them with those identified in the literature (National Research Council, 2014b; Waruszynski, 2017; National Academies of Sciences, Engineering, and Medicine, 2021; UNESCO, 2021, 2022; Schmidt *et al*., 2022; Reding *et al*., 2023).

CHAPTER 11

Education as a Defense Project: Evidence from the Arabian Gulf

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Abstract: This chapter examines the emerging phenomenon of creating educational institutions *via* a defense contracting model. This approach has been particularly prevalent in professional military education projects in the Gulf, including institutions such as the UAE National Defense College, the Qatari Joint Command and Staff College, and several cases in Saudi Arabia. In the UAE and Qatar, both states used a contracting model to develop a degree-granting educational structure based on foreign models. Contracting agreements were utilized to bring foreign faculty to develop the curriculum, staff the courses, and largely run the educational components of the institution, in an approach conceptually similar to contracting foreign personnel and curriculum for a training course. The chapter will critically evaluate the strengths and weaknesses of creating an educational institution *via* contracting, drawing on secondary literature and the author's own experience as a contractor in the region. The chapter argues that while the contracting model has advantages in areas such as pace and flexibility in hiring, it also poses serious obstacles to the long-term academic goals of establishing a degree-granting educational institution, particularly in the areas of academic quality, faculty continuity, and international accreditation. Institutions considering adopting the contracting model should carefully weigh the implications of these disadvantages.

Keywords: Arabian gulf, Defense contracting, Education and defense, Foreign military sales, Professional military education, Qatar, Saudi Arabia, UAE.

INTRODUCTION

Defense contracting projects are often understood by the public as primarily entailing the procurement of expensive military equipment or perhaps contracts to service equipment. This chapter considers an emerging trend of establishing and running educational institutions *via* the same model. From curricular development to recruiting academic staff to providing classroom instruction and student

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

advising, some or all of the functions typically thought of as core academic tasks owned by a permanent, locally based academic faculty are instead managed by outside partners through defense contracts. In some instances, the faculty members themselves are employed by a third party rather than the educational institution. A contracting approach to building and delivering academic programs has been particularly prevalent in the creation and management of professional military education in the Arabian Peninsula. Prominent examples include the Saudi War College (SAIC, 2009), the Joaan Bin Jassim Joint Command and Staff College in Qatar (Serco, 2014), the UAE National Defense College (Toronto, 2018), King Fahd Security College (University of New Haven, 2016), and the Saudi National Defense University (NESA 2022). Indeed, in the example of the UAE National Defense College, a FMS (Foreign Military Sales) case was the vehicle chosen to finance and organize the development of the College, in cooperation with the Near East South Asia Center for Strategic Studies (NESA), a DoD regional center (DSCA 2015, 451). This approach is conceptually similar to contracting outside personnel and curriculum for a training course or for maintenance of equipment (Samaan 2023, 53; Samaan 2024). Indeed, the contracting model has long been adapted in many Gulf countries to develop essential expertise, particularly in the defense sector, which helps explain the attractiveness of this model in professional military education (Samaan 2024; Hividt 2016). However, developing and sustaining an academic institution that grants graduate degrees provides a distinct set of challenges compared to contracting short-term training courses.

This chapter accordingly considers the advantages and disadvantages of contracting in both the establishment and the operation of an educational institution offering a degree-granting course of study. It draws on an emerging academic and think tank literature on the topic and the author's own experience in the Gulf. First, it reviews the advantages promised by contracting and how well it has delivered on its promises. Then it examines the limitations of the contracting model, before providing analysis. Ultimately, it finds that developing a university through contracting results in significant trade-offs. Contracting provides speed, off-the-shelf curriculum and faculty, outside expertise, and representational benefits. However, this chapter argues that in the long term, a defense contracting model as commonly applied risks significant liabilities in accomplishing long-term academic goals related to program quality and durability and places obstacles in the way of achieving international accreditation. It concludes by offering alternatives that can mitigate some of the most significant problems identified.

CONTRACTING'S ADVANTAGES: PROMISE AND DELIVERY

What does contracting promise in the establishment of an educational institution, and how well does the process deliver on these promises? In press releases and news articles, the contracted foreign partner, using discourse strands of knowledge transfer, program development, and academic excellence, typically articulates its involvement as providing high-level expertise otherwise unavailable to the host. As the then president of New Haven University put it in a statement announcing an agreement to support the King Fahd Security College: "We are excited to put the University of New Haven's *world-renowned* programs…at the service of the Kingdom of Saudi Arabia's next generation of security professionals… we are honored to support the further development of security expertise upon which so many in the region and beyond depend" (University of New Haven, 2016, emphasis author). Similarly, US defense contractor SAIC described a partnership with Saudi Arabia utilizing SAIC's expertise as holding "the prerequisites for creating a prestigious military institution," and the ability to facilitate the development of a "world-class" program that "meets educational and administrative standards of US War Colleges" (SAIC, 2009). Serco, a prominent defense contractor, described its work as leading the development of a "flagship course [that] represents the first step towards a structured education and training pathway for Qatar's military leaders of tomorrow" (Serco, 2014).

When contracting is part of a relationship between governments, the language of a second discourse strand also speaks to the contract as enhancing international partnerships between countries, particularly in the area of security cooperation. Thus, a defense contracting agreement addressing military education can be used to signal close relationships between the two states (Alshateri, 2020). As former NESA Director James Larocco described the FMS case to support the UAE National Defense College (UAE NDC), "[t]he relationship between the US and the UAE has become closer and closer. What we're doing with the UAE National Defense College is an example of this" (quoted in Al Haddad, 2013). Indeed, NESA named the National Defense College's first Commandant, Major General Staff Pilot Rashad Al Sa'adi, one of only 10 (to date) distinguished alumni of its executive leadership courses, and the only UAE national so honored, reflecting the importance of the relationship between the DoD and the UAE NDC as a component of the larger strategic relationship (NESA 2024).

Finally, the language of contracting promises speed, providing a way to quickly develop a complete program with faculty and a high-quality, off-the-shelf curriculum. Indeed, this is an important advantage of the contracting process. The speed of contracting can be seen as an antidote to the red tape from local bureaucracy and perceptions of the glacial speed of establishing an academic

CHAPTER 12

Academia-Industry-Defense Successful Partnership Case Study in Mexico: FX05 Rifle

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Abstract: This chapter presents a case study on the successful partnership among academia, industry, and defense to develop weapons, starting from their conceptualization to their implementation. As for academia, public universities and research centers were called upon to support research and train defense personnel. In the industry, several small and medium-sized companies were selected to jointly manufacture certain weapon components as a strategy to produce high-quality parts, developing reliable suppliers as specialized techniques were required. A team of defense personnel, both engineers and technicians, had to be formed and trained in several areas, such as software for Computer-Aided Design (CAD), Computer-Aided Engineering (CAE), and Computer-Aided Manufacturing (CAM) applications; advanced and additive manufacturing; mold design and manufacturing; materials science; industrial property; and technological surveillance; and others. The successful results of this partnership suggest that interaction under clear rules and a willingness to collaborate among academia, industry, and defense leads to an accelerated pace of technological research and development, creating a virtuous circle in which all sectors benefit.

Keywords: Reliable suppliers, Specialized manufacturing processes, Technological surveillance, Weapon development strategy.

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Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

INTRODUCTION

As part of the third period of land armament (Herrera-Ramirez & Zuñiga-Aviles, 2022), the Mexican military industry underwent technological advances during the 20th century and the beginning of the 21st century, both in the construction of factories and in the improvement of production processes (SEDENA, 2006). The modern military industry began to crystallize in 1947 with the creation of the Department of Military Industry as an autonomous organization.

In the 1950s, although there was still much to be done in the Mexican military industry, there were few changes: new workshops were built and the Mauser system repeating rifle and carbine were produced (Reynolds, 2001). Mexico was in the process of industrialization, and there was great concern because there were more imports than exports, and industrial growth was insufficient to cover the country's needs. By that time, the military industry had centuries of experience and decades of effort in producing its own weapons; however, it was also part of the import dynamics and took advantage of the war experience of other countries. Thus, German technology was used for rifles and for projectile and grenade loading, while French technology was used for cartridges, and Belgian and Japanese technologies for rifles, just to give a few examples. It was indeed of utmost importance to benefit from foreign war technology but also to establish the necessary mechanisms to replace it with Mexican technology. With this purpose, in addition to many other advances, machinery was acquired in 1969 for manufacturing a large number of parts and assembling the Belgian Fusil Automatique Léger FAL (Sof, 2022) and Carabine Automatique Légère CAL (WaybackMachine, 2023) at the Weapons Factory.

In 1977, the Department of Military Industry was integrated into the National Defense sector with hierarchical dependence on the Secretariat of National Defense; the Mexican weapon industry began a new boom (SEDENA, 2006). In 1979, a manufacturing license was signed with the German company Heckler & Koch (HK, 2024). New machinery was acquired to complement the existing one and to start the production of the H&K family of weapons, consisting of the HK-G3 and HK-33 automatic rifles, the HK-MP5 submachine gun, the HK-21 machine gun, and the HK-P7 semiautomatic pistol.

In 1991, the Department of Military Industry was abolished, and the General Directorate of National Defense Factories was created (SEDENA, 2006). Its functions were the following: 1) To manufacture and repair machinery, armament, munitions, and war equipment necessary for the Armed Forces, 2) To carry out scientific-industrial research to improve the material required for the Armed Forces, and 3) To manufacture and repair equipment useful to the Armed Forces.

Finally, in 2002, the General Directorate of National Defense Factories became the General Directorate of Military Industry (SEDENA, 2015).

Another event that opened the doors of the 21st century for the Mexican military industry was the creation of the Center for Applied Research and Technological Development of the Military Industry in 2002. The objective of this center is to fulfill the historical aspiration of leaving behind foreign dependence and having a center for research, design, and development of new defense products (SEDENA, 2006).

From the study of models for knowledge creation, innovation models emerged, mainly the triple helix innovation model developed by Henry Etzkowitz and Loet Leydesdorff in 1995 (Zakaria *et al*., 2023). The triple helix innovation model focuses on the creation of networks that manage academia-industry-government relationships to develop technology under a clustering approach. This triple helix model was extended to a quadruple helix model, which integrates the triple helix by adding the 'media-based and culture-based public' and 'civil society' as a fourth helix (Carayannis *et al*., 2012). Then came the quintuple helix innovation model, which is even broader and more comprehensive as it contextualizes the quadruple helix and adds the helix (and perspective) of the 'natural environments of society' (Carayannis *et al*., 2012). Thus, the quintuple helix innovation model generates technology based on academia-government-industry-soci-ty-environment relationships. Going down this path, in 2019, the Secretariat of Science, Humanities, Technology and Innovation (SECIHTI) established the Mexican Innovation Model: The PENTAhelix and Open Innovation (SECIHTI, 2019).

With the arrival of the triple helix innovation model in the 21st century, the successful academy-industry-defense partnership that resulted in the development of the FX05 rifle in Mexico was embraced, incorporating social good and the environment as design considerations of the weapon, representing a preliminary implementation of the nascent quintuple helix innovation model.

In several regions and countries, it is well documented that the partnership between academia, industry, and defense brings benefits to the entities involved (Rahm *et al*., 2013). Collaborative research partnerships between universities and the defense sector are important to national and homeland security missions. From the defense sector's point of view, university collaborations help it to conduct world-class research while providing it with the opportunity to develop and grow a talent source. The benefits to universities range from the opportunity to work on cutting-edge problems of national importance to access to specialized research facilities and potential funding avenues (Gupta *et al*., 2014).

SUBJECT INDEX

A

B

C

Darli Vieira, Alencar Bravo & Geraldo Ferrer (Eds.)

D

E

F

G

H

I

J

K

L

M

N

O

P

R

S

T

U

V

W

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