1.1 Striving for Perfection in Complex Work

A once relatively common expression in the United States was “if we can put a man on the moon, why can’t we <insert complaint>?” It conveyed a sense that the country, its technical experts, its government, and its people were capable of amazing things if they put their minds to it. There was another term that went along with it—“rocket scientists.” Those were the clever people who made those miraculous things happen so that they seemed commonplace. Given enough rocket scientists, one imagined, just about any problem, no matter how complex, could be solved. Perhaps those expressions are locked in a certain time and place—the late 1960s and early 1970s—when the United States was routinely putting men on the moon, less than seven decades after people first took to the sky in the dawn of powered flight.

The same expression simultaneously conveyed a sense of frustration that things don’t always work as hoped or planned, no matter how clever or skilled we might appear or how much thought we put into the plans. Why is it that despite having advanced knowledge, tools, and capabilities, and even having demonstrated that it is possible to do something amazing, best efforts sometimes end in disappointment or failure? Many other human activities that don’t involve the complexities of spaceflight but are in their own way complex (think energy, infrastructure, transportation, public health) nevertheless invoke the same question. This book tries to answer that question in the context of complex programs.

The effort to send men to the moon and bring them back safely was a huge program that was itself embedded in the U.S. national space program, and was linked with other programs that served U.S. national strategies and priorities during the Cold War. The Apollo program comprised many individual, highly complicated engineering projects, but also other program activities that touched research, education, defense, and ultimately commercial products. The management challenges were significant, and so, of course, were the engineering challenges. To address these technical challenges, a new discipline called systems engineering rose to prominence. The marriage of systems engineering with program management approaches proved to be critical to the Apollo program’s success.

As successful as it was, though, it was not sustained or repeated in quite the same way. The last human to walk on the moon, Gene Cernan, stepped into his spacecraft and left the surface of the moon on December 14, 1972. Humans have not returned
since, nor left low earth orbit (LEO) for that matter. Of the 12 people who ever walked on the moon, only seven survive today. The passage of so much time has left those remaining elderly.

However often it might appear that the capability to accomplish important and inspiring things is diminishing, counterexamples seem to appear. It has been over four decades since people last set foot on the moon after the United States mobilized a national-level effort to accomplish that task. But a small U.S. company is defiantly working not only to recapture those capabilities, but to significantly exceed them. The Space Exploration Technologies Corporation, better known as SpaceX, during its relatively short existence has not only accomplished many important and inspiring things, but has done so in a way that significantly outperforms all competitors, both government and private, and seems poised to create a renaissance in the space sector.

1.2 Boldly Going Again Where People Have Gone Before

The founder of SpaceX, Elon Musk, is a successful entrepreneur with a tendency to disrupt business-as-usual in a surprising array of business sectors, including finance (PayPal), energy (Solar City), transportation (Tesla Motors), and of course space transportation (SpaceX). His long-term vision and the impetus for starting SpaceX was to make humans a multiplanet species by enabling them to settle on Mars, and more quickly than the perpetually slipping timetables of government space agency plans. Based on what SpaceX has accomplished so far, that vision seems achievable (Vance, 2015). Perhaps as compelling as the impressive launch hardware and support systems that SpaceX has created is the way that it has been able to assemble teams of, yes, rocket scientists, and to design a work system that enables them to be incredibly productive and produce complex systems quickly. The following case study describes how SpaceX has been able to accomplish this.¹

Since its inception in 2002, SpaceX has accomplished more in a short period of time than any of its competitors. SpaceX has logged over 30 successful flights and has achieved certification for NASA and United States Air Force launches. SpaceX has developed about 100 major flight-proven products in 14 years. These include the development of five engines (Merlin, Merlin Vacuum, Kestrel, Draco Thruster, Raptor), three launch vehicles (Falcon 1, Falcon 9, and the full-thrust Falcon 9) and Dragon and Dragon 2 spacecraft, an autonomous spaceport drone ship to enable landing reusable rockets, along with associated modern ground test, launch, and mission facilities. At the time of this writing SpaceX is completing development of the most powerful rocket since the Saturn V moon rockets, the Falcon 9 Heavy. It continues to fine-tune the propulsive landing reusable first stage of its Falcon 9 booster, and a reusable propulsive landing version its Dragon 2 spacecraft.

The development time and cost of these products are several times smaller than the competition. A NASA analysis of commercial space launch alternatives used a historical cost-based cost estimating tool to predict the development costs for space hardware
systems. It predicted that using a traditional NASA approach to develop a new launch vehicle would cost US$4 billion, but using a more commercial approach would cost about US$1.7 billion. It verified that SpaceX developed both the Falcon 1 and Falcon 9 vehicles for a total of US$390 million (NASA, 2011). United Launch Alliance (ULA), an incumbent launch services provider and SpaceX competitor, has acknowledged that developing a new engine has typically cost about US$1 billion and a new rocket development about US$2 billion (Ray, 2015).

The reduced costs directly impact the marketplace for launch services. SpaceX is the only launch provider that publicly lists the price of its launches. It quotes launch costs of US$62 million on its website; by comparison the cost of a ULA launch on an Atlas V is about US$164 million (Ray, 2015). For many years, the cost of launching a kilogram of mass to LEO hovered around US$14,000/kilogram, a benchmark in the industry. This cost had not changed much for the industry incumbents. Incremental improvements over time, particularly in the face of new competition, have lowered the cost per kilogram for LEO to between US$10,000 and $13,000. The Falcon 9 has reduced that cost to about US$4,000/kilogram. The Falcon Heavy is priced at a cost of US$2,200/kilogram to LEO (Stackexchange, n.d.), and is projected to achieve a cost of US$1,000/kilogram if all first stages are recovered and reused. SpaceX launch prices are so low that even heavily state-subsidized rockets like China’s Long March family cannot compete with them on price (Vance, 2015). Its low costs allow SpaceX to enjoy comfortable profit margins on each launch.

Its other activities illustrate the kinds of efficiencies that SpaceX is able to achieve in its operations. For example, the launch operations team for the Falcon 9 comprises eight people in the Launch Control Center. By comparison, the Space Shuttle launch control team comprised approximately 200 people (NASA, 1995). Similar differences in efficiency of operations are observed in a wide range of other activities.

SpaceX’s operational record is not perfect. It has experienced a few failures during testing, system development, and operations. The initial Falcon 1 experienced three anomalies, “rocket scientist” speak for vehicles that are lost during a launch, sometimes spectacularly. The Falcon flight 19 failed in June 2015 because an externally purchased structural strut that was supposed to be tested and certified by the vendor was not and failed in flight. A Falcon vehicle and its payload were lost during a fueling exercise on the launch pad in September 2016, with the cause of that accident under investigation at the time of this writing. Several tests of propulsive landing of the Falcon 9 reusable first stage failed during the initial testing. The Falcon flight 20 landing was successful, and a string of successes followed both on land and at sea on the autonomous spaceport drone ship. Landing a rocket booster intact after flying a typical orbital mission profile was unprecedented. Since the alternative to attempting to land and recover them was to let them fall into the ocean, these attempts are best thought of as low-cost add-on experiments to develop new technologies and operations models that would otherwise be too expensive to pursue independently.

This approach to using operational systems as test beds to learn, improve the product, and develop new technologies is intrinsic to the SpaceX development process. Most impressive is that with a complex and unforgiving technology, SpaceX has managed to build an organization that is capable of rapid learning. In addition to developing new
products rapidly, it has demonstrated that it can identify faults and corrective actions rapidly. The return to normal flight operations occurred only six months after the Falcon flight 19 loss, with Falcon flight 20 also marking the first successful intact landing of a Falcon 9 first stage. Return to flight after accidents involving other launch systems typically has taken longer—often two years or more.

How has SpaceX been able to accomplish this? A number of factors have played a role:

- **Focus on simplicity in the design.** SpaceX’s approach to rocket design revolves around the core belief that simplicity is the precursor to both reliability and low cost. From the very beginning SpaceX has designed its Falcon rockets with commonality in mind. Both of the Falcon 9 stages are powered by rocket-grade kerosene and liquid oxygen, which allows the use of a common engine. Both stages are the same diameter and are constructed from the same material, reducing the tooling and processes to significantly reduce costs in manufacturing. The Falcon 9 was designed from the beginning to be human rated, which increased the focus on producing a reliable system. Using nine smaller, common engines for the first stage rather than fewer (or one) large engines enabled the use of a few common engine models. This improves reliability since the rocket can tolerate an engine failure in flight without catastrophic failure or aborting the mission. It also helps drive up manufacturing volume to reduce costs through learning effects. It allows continuous product improvement efforts to focus on one engine instead of across a number of different engines. This has resulted in reducing the number of parts and increasing its power and efficiency. The Merlin 1D production model for the Falcon 9 has the highest thrust-to-weight ratio of any rocket engine ever made, and is designed with a service life measured in tens of missions (Chaikin, 2012).

- **Colocation.** SpaceX has avoided the practice of spreading its development activities geographically and outsourcing a significant portion of its product to suppliers. The original motivation for Musk to start the company was that by controlling much of the process from raw materials to flight hardware, he could dramatically reduce the cost of launch compared with existing providers. This is accomplished by tight colocation of most activities (engineering offices, test infrastructure, mission control, a complete factory for all products, logistics, management, and administration) in a single, one-million-square-foot building in Hawthorne, California (see Figure 1-1), where most of the approximately 4,000 people work. The floor layout in the facility is quite open. Everyone works in open cubicles, from the most junior intern to the CEO (the exception being job functions that require privacy, such as human resources). Only propulsion and large-scale structural testing is done at test facilities at McGregor, Texas. SpaceX uses or is planning to develop four launch sites in the southern United States. All of the sites are linked to Hawthorne by modern internet tools so that engineers at Hawthorne have a virtual presence at these remote sites. This colocation has vastly simplified communication and coordination, and enabled SpaceX to produce the results that it has.

- **Vertical integration.** SpaceX quickly learned in its early development efforts that suppliers in the launch sector were accustomed to the practices of their existing customers, particularly the long lead times and tolerance for high prices. It found
that it could often build what it needed in-house much more rapidly and for lower cost than by procuring it from outside vendors. It had the added benefit of keeping the expertise in-house, which enabled rapid responses to changes and continuous improvement. The company buys raw materials and develops, builds, assembles, and tests in-house all engines, rockets, and spacecraft, and a variety of support systems such as ground support equipment and remote tracking stations. Most of the components for these systems are manufactured in-house too, including parts normally procured from specialty subcontractors such as tank domes, stage tanks, flight computers, engine controllers, batteries, engines and thrusters, turbo-pumps, valves, star trackers, Lidars, radios, composite overwrap pressure vessels, and numerous other smaller items. Vertical integration enables efficient and frequent system development, testing, and integration activities.

**Mission assurance embedded in routine operations.** SpaceX relies on extensive system optimization and testing in all phases of development, production, and just-before-the-flight in the “what you fly” condition. Since testing is a pillar of SpaceX mission assurance, the company created a unique, highly modern, and advanced design-testing-manufacturing-integration-IT infrastructure for rapid, repeatable, advanced, and inexpensive testing over the entire life cycle: from prototype to design, qualification, integration, preflight, and flight testing. The focus is on assuring quality and performance with powerful and efficient system-level optimization and portfolio optimization. The optimization is performed by trading off major system-level parameters such as mass, orbit, and flight characteristics. In order to permit testing of all components, subsystems, and the system, all parts must be reusable, including a restartable engine and stage separation devices. The company designates individuals responsible for the
different aspects of development and integration during the system and mission life cycle. The highly coveted position of a “responsible engineer” comes with complete “horizontal” responsibility for the timely development, testing, acceptance, production, integration, and performance of an assigned component throughout its life cycle, including all coordination with any and all applicable individuals and departments. Vertical integrators assure the integration of elements into subsystem and the overall system. Vice presidents assure development and performance of major subsystems (propulsion, structures, avionics, etc.). Payload managers assure payload-vehicle integration. Mission managers assure the mission life cycle. These individuals coordinate with all relevant stakeholders efficiently, fully documenting their decisions and agreements using specialized software. All together, these individuals constitute a well-designed matrix of mission-assurance activities.

Culture. Arguably the most important pillar of SpaceX is the culture that promotes very high levels of teamwork, mutual support, coordination, and communication in the spirit of pushing the boundaries. Employees are encouraged to continuously seek better solutions. Senior employees are selected on the basis of experience and accomplishments. Junior employees are selected on the basis of competence, but also unusual interests, passion, and a “spark in the eye.” Information technology is regarded as a critically important activity supporting efficient execution of all other activities and extraordinarily efficient communication, coordination, and approval tools.

To be sure, SpaceX is not the only innovative company working in this area making the vision of expanded human presence in space a reality. There are a number of startups that are making inspiring progress in a number of different areas. SpaceX does, however, provide a good example of what can be accomplished using the right approach. In the end, a significant part of this success comes down to a new way of working together that SpaceX has pioneered, at least in this sector. It combines management practices, engineering practices, product strategy, organizational processes and tools, and a leadership climate that encourages responsibility, innovation, learning, and high performance. Perhaps this is a fitting return to the practices seen in the early days of the space industry. This example illustrates more than just the reinvigoration of a single sector. It demonstrates that organizations can bring together diverse skill sets to overcome challenging problems, and ultimately make miracles seem commonplace. This book argues that these behaviors are not just confined to SpaceX, but can be achieved in a wider array of settings where management and technical disciplines learn to work together seamlessly in order to create the benefits needed by their customers and other stakeholders.

1.3 Strategy Realization Requires Good Management

Program managers and chief systems engineers lead efforts like those within SpaceX to implement a strategy to realize its associated benefits, both tangible (e.g., financial,
market share) and intangible (e.g., new knowledge). They lead teams of individuals who take strategy—a vision or idea of what can be—and translate that strategy into products, services, or capabilities that are real and beneficial for customers, employers, and other stakeholders through collaboration, skill, and disciplined approaches. The Guide to Lean Enablers for Managing Engineering Programs (Oehmen, 2012) made a strong case for why engineering programs are vital to society and to organizational strategy:

Taking on large-scale engineering programs is one of the most difficult, risky, and—when done well—rewarding undertakings a government or company can attempt. It not only pushes the envelope of what is possible, but defines a new envelope. It generates capabilities, technologies, products, and systems that are innovative and unique, and generates tremendous societal benefits—from hybrid cars to a trip to the moon, from road networks to GPS navigation, and from carbon-neutral electricity sources to the “smart” city (p. 3).

One might argue that this is just about developing the right strategy. But the Economist Intelligence Unit (EIU, 2013) report, Why Good Strategies Fail: Lessons for the C-Suite, pointed to the need for linkages between strategy development and strategy implementation. Strategy implementation represented the collective organizational effort to execute strategy by investing in the right initiatives to deliver desired business benefits. The study found that organizational leaders recognize that there is a critical gap between what they want to accomplish and the ability of their organizations to successfully deliver.

Organizations depend on the professional capabilities of program managers and chief systems engineers to deliver strategy and amazing results. Recent examples include:

■ The Big Dig that unsnarled traffic between Boston, Cambridge, and other cities in Massachusetts and created opportunities for new economic development.
■ The 2012 London Olympics sponsored by the United Kingdom government that constructed new competitive venues with the deliberate intention of repurposing the infrastructure for ongoing commercial activities after the Olympics.
■ The Airbus A380 and the Boeing 787 Dreamliner, planes with longer range and higher fuel efficiencies.

There have been many other successes that have not captured headlines or garnered broad attention for the unsung individuals who led, facilitated, and contributed to results that delivered benefits to their customers and their employers.

The engineering programs that fail, and even many of the successes, experience performance challenges. The Big Dig cost over US$14 billion and will not be fully paid for until about 2038 at a full price tag of about US$24 billion, which is US$22.6 billion more than it was projected to cost (Hofherr, 2015). When the London Olympics Authority experienced cost overruns related to some of the Olympic venues, the Authority had to obtain money from the U.K. government, not all of which has been recovered (Kortekaas, 2012). Boeing and Airbus have had to do substantial rework on different components of their planes at significant cost to those organizations and to their customers (Botelho, 2015; Flottau, 2015; Hamlin, 2015). So although some programs ultimately deliver something vital, the delivery path is often painful.
PMI’s *2016 Pulse of the Profession®* study (PMI, 2016) found that for every US$1 billion invested in strategic initiatives, organizations waste US$122 million due to poor performance. Many of those strategic initiatives also fail to meet their original goals and business intent; fail to deliver within allocated budget parameters; or are delivered late. Other data points seem to bear this out. In 2009, the U.S. Department of Defense’s 96 largest engineering programs generated a cumulative cost overrun of nearly US$300 billion and an average schedule overrun of more than two years (GAO, 2009). The United Kingdom’s National Audit Office (2014) estimated that in 2014 at least £112 billion of major investments was at risk due to program performance issues.

In all fairness, many of today’s engineering programs represent leading-edge breakthroughs. The innovativeness, technical risk, and complexity of these endeavors cannot be overstated. Airbus and Boeing translated the dream of long-range and highly fuel-efficient aircraft into reality. Boston’s Big Dig ultimately reduced travel times and created new economic opportunities for areas of the city while sustaining the day-to-day commuter flow of thousands of people and vehicles. That is why INCOSE’s (2014) *A World in Motion: Systems Engineering Vision 2025* specifically calls out complexity as a growing factor that will continue to confront systems engineering professionals and require a new skill set to manage. But the perceived financial, social, and political pain among stakeholders in achieving those breakthroughs is most often what receives attention, inside and outside of organizations.

Despite the perceptions and realities related to program performance, one of the underlying challenges is building the will within organizations to invest in improving engineering program capabilities. Many executive leaders often do not view programs within their companies as being strategic, and activities that are not strategic often do not receive executive-level attention.

Enhancing engineering program capabilities must start with a better understanding of the linkages between engineering programs and strategy among executives. Highlighting the linkage between engineering programs and strategy also needs to make the case that investing in strengthening such capabilities could help to reduce the millions of dollars at risk from poor performance. Achieving these objectives necessitates an organizational culture that links talent management with strategy along with ongoing investments to improve workforce capabilities and enabling systems, structures, and process.

### 1.4 Workforce + Organizational Capabilities = Competitive Advantage

The increasing requirement for deeper knowledge by organizations emphasizes and rewards specialization. With increased specialization comes the potential to create barriers to sharing and collaboration as objectives, tools, and even syntax become more unique to each field. Rooted in the same historical and professional context of the Cold War, the arms race, and the race to the moon, the program management and systems
engineering disciplines have advanced along similar paths. Both show the hallmarks of traditional professions:

- Each has a unique body of knowledge that is codified, but continues to evolve to reflect good practice.
- There are professional certifications that demonstrate whether individuals can apply their knowledge and experience to effectively utilize tools, techniques, and practices to address challenges they are presented.
- Professionals from both disciplines have a broad range of professional development options to keep them abreast of evolving practice, build their skills, and help them to educate others.
- Academic, industry, and government research helps to inform and evolve practice, competence, and capabilities.
- Each has a community of like-minded professionals with whom to network and exchange information.

Despite having the same roots and following similar paths to professionalism, the two disciplines have experienced somewhat divergent evolutions. Program management has become much more defined within some organizations than systems engineering, particularly in the government sector. Program manager roles, responsibilities, and authority have become formalized and documented, and clear career paths for the role have sprouted. Program management processes and procedures have evolved, some by statutory requirement, some unique to the types of programs being managed, and others through the evolution of the practice. Most engineering programs have an assigned program manager from the very start, but a chief systems engineer may not be assigned before elements of the program requirements are defined. Today, elements of this divergent evolution appear to be impacting the ability of the two disciplines to effectively align their work practices and collaborate. This is a critical area where organizations need effective workplace cultures that guide the way people and groups work with each other.

In addition to potentially competitive issues between the two disciplines, organizational systems, or the lack thereof, also inhibit effective engineering program management and performance. Often, the lack of aligned practices is blamed when program disruptions occur. For example, the Professional Services Council (2013) report, *From Crisis to Opportunity: Creating a New Era of Government Efficiency, Innovation and Performance* noted:

...the services acquisition process is often driven by a loose amalgamation of regulations (Federal Acquisition Regulation and agency/component supplements) and a growing body of legislative and executive branch policy pronouncements that are at times ineffective and/or in conflict with one another. They often fail to align what is being acquired to a real strategy and are exceptionally difficult to implement consistently, even within a single government entity.

Effective practices are critical for integrating efforts to deliver results in program environments. Engineering program environments require good planning approaches,
proactive risk management, stakeholder engagement, and other, similar capabilities. The Professional Services Council (2013) report captured the challenge very effectively:

In an era when “collaboration” is increasingly recognized as a central operational component in the best of private sector organizations, and a critical element of their success, it is in worrisome decline within the government itself and such decline has frequently been cited in Government Accountability Office (GAO) studies as a contributing factor in underperforming government programs, duplication and fragmentation. Disconnects between the policy, human capital, mission, technology and acquisition communities have improved only marginally at the leadership levels and almost imperceptibly, if at all, at the operational levels. This stovepipe approach leads different components within an agency to pursue different immediate goals, often to the detriment of the desired overarching mission outcome.

Interestingly, while the report indicated that there is stronger collaboration in the private sector, the new research for this book on integration and collaboration found similar challenges in both sectors (Conforto, Rossi, Rebentisch, Oehmen, & Pacenza, 2013).

Every day, organizational leaders, systems engineers, and program managers are tackling these tough challenges. This book intends to capture some of the valuable lessons from their experiences in hopes of supporting their efforts to find approaches that yield better results.

1.5 Rays of Hope

All is not doom and gloom for two reasons. First, this book highlights successful engineering programs along with key integration elements that played a role in that success. For example, the Prairie Waters program discussed in Section 3.2 adopted a highly integrated teaming approach that aligned various program participants from various governmental bodies, contractors, and subcontractors. This book will share some of the innovative ways that Boston’s Big Dig program enabled stronger collaboration from which new best practices emerged. Second, learning from failure is absolutely critical to advancing engineering program performance. This book features examples from the National Aeronautics and Space Administration (NASA) and explores how NASA transitioned into a more collaborative and integrated organization.

1.6 Trekking toward a New Mindset

This book blazes a new path by focusing on approaches for better enabling collaborative work between program managers and systems engineers. While there is plenty of published material focused on enhancing the performance of each individual discipline, very little published matter spotlights how the two disciplines align their efforts and work collaboratively. This book intends to help close that gap by:

■ Uncovering how engaged people working within living systems called “engineering programs” align their efforts to deliver results. This book identifies potential
insights from the experiences of interdisciplinary teams that may be useful to program managers and systems engineers facing similar challenges. The case examples are not limited to program management and systems engineering, but all contain applicable insights that are discussed in the context of how those insights relate to engineering program management.

- Shining a light on enabling factors that support engineering programs. This book presents new research and a framework for integration to help program managers, systems engineers, and their executive leaders enhance joint effort, joined thinking, and common language. This examination yields insight into factors that either enable collaboration or create barriers to integrated approaches. While some of the case study examples in this book may be well known from an engineering or program management perspective, this book will objectively assess those case studies through the lens of interdisciplinarity to offer new insights. Prescribing specific practices for integrated systems engineering and program management is neither the intent nor focus of this book.

- Sparking further research to advance understanding of dynamics of interdisciplinary collaboration. Given the scant content—scientific studies, case studies, articles, etc.—exploring interdisciplinary challenges among teams collaborating on large-scale programs, this work attempts to fill that gap and to encourage further research and content in this important area.

This book is an amalgam of a diverse array of preliminary evidence about why the integration of program management and systems engineering is important to the practice of both disciplines, and ultimately to beneficiaries of their programs. The hope is that by bringing this content together now, practitioners may derive some near-term benefit, and others may be inspired to continue the investigation and documentation of this important area.

Because clearly defined terminology is critical to understanding, it is important to note here how the terms “program” and “project” are used in the context of this book. Readers will find that there are a range of definitions for these terms and, in some instances, the terms are used interchangeably. A program is “a group of related projects, subprograms, and program activities that are managed in a coordinated way to obtain benefits not available from managing them individually” (PMI, 2015). A project, on the other hand, is “a temporary endeavor undertaken to create a unique product, service or result” (PMI, 2015). In the specific context of this book, references to “programs” should be understood to mean the program and its subordinate projects that produce outputs required for the program and the realization of targeted benefits.

This book also uses terminology to identify key roles in the program environment, and those roles are defined as follows:

- **Program manager** refers to the job position that has the ultimate authority and accountability for the overall program.

- **Chief systems engineer** is used specifically in reference to research undertaken for this book and refers to the job position that has ultimate technical authority and accountability for the product or system being developed by the program.

- **Project manager** refers to the job position that has ultimate authority and accountability for project deliverables.
While program managers and chief systems engineers lead and integrate efforts at the program level, project managers and systems engineers drive delivery of project-level outputs for the program. Some case studies and examples in this book highlight project-level considerations that also have applicability or impact at the program level.

As part one of the book will show, integration and collaboration are critical in coordinating complex work, which ultimately advances organizational strategies or missions. It is important to understand the organizational dynamics and challenges that frame elements of interdisciplinary integration and collaboration that will be further elaborated upon in the remaining chapters of the book.

1.7 Summary

Engineering programs are challenging, but there are interventions that organizational leaders, program managers, and systems engineers can utilize to address those challenges. The key enablers include recognizing the linkages between programs and strategy, and supporting program leadership in enabling alignment and collaboration within the program team. Companies like SpaceX are pioneering methods for tackling tough engineering program challenges using these key enablers. This book provides additional insights and approaches that support realizing the benefits from such objectives.

1.8 Discussion Questions

1. On programs on which you have worked, were there any mechanisms that helped the team establish a sense of “collective consciousness?” Were those mechanisms formally structured in some way or informally developed by team members themselves? Did you observe any difference in the use of formal versus informal mechanisms to enable the team?

2. Identify a program that you felt had strong connections to strategy and one that did not. If applicable, identify any distinctions between those programs and the level of executive involvement. If applicable, how would you explain the differences?

3. How does your organization’s approach to talent management and development enable or hamper integration between program managers and systems engineers? What enhancements or changes do you think would better support integration?

1.9 References

REFERENCES


**Endnote**

1. Contributed by Bohdan Oppenheim, Professor of Systems Engineering, Loyola Marymount University.