SYSTEMS ENGINEERING

VISION 2035

ENGINEERING SOLUTIONS FOR A BETTER WORLD

EXECUTIVE SUMMARY

INCOSE | Vision35 Systems Engineering

The purpose of the Systems Engineering Vision 2035 is to ***inspire and guide*** the strategic direction of systems engineering across diverse stakeholder communities, which include:

- ENGINEERING AND EXECUTIVE LEADERSHIP
- ENGINEERING PRACTITIONERS
- PROFESSIONAL ORGANIZATIONS
- RESEARCHERS, EDUCATORS, AND STUDENTS
- STANDARDS BODIES
- TOOL VENDORS
- POLICY MAKERS

ADDRESS

FUTURE SYSTEMS ENGINEERING CHALLENGES

BROADEN

THE BASE OF SYSTEMS ENGINEERING PRACTITIONERS

ALIGN

SYSTEMS ENGINEERING INITIATIVES

PROMOTE

SYSTEMS ENGINEERING RESEARCH, EDUCATION, AND PRACTICE

EXPLORATION SYSTEMS

POWER AND ENERGY SYSTEMS

TRANSPORTATION SYSTEMS

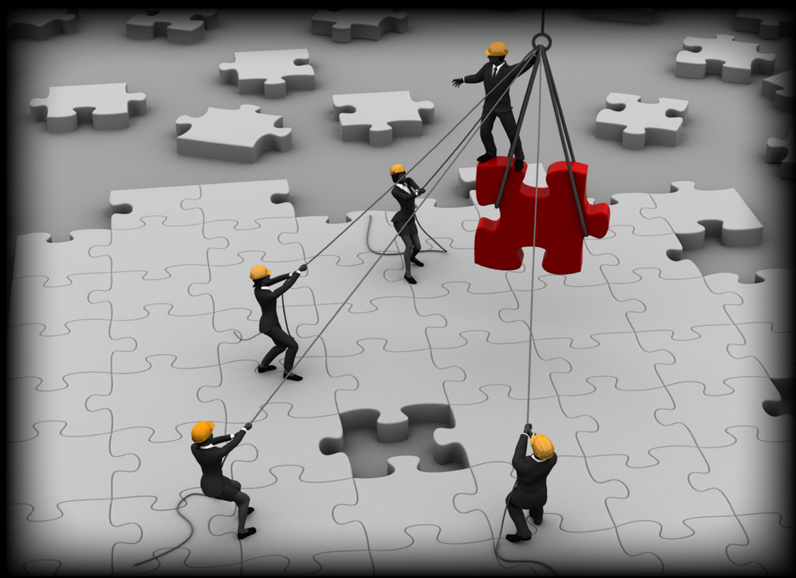
INFORMATION SYSTEMS

HEALTHCARE SYSTEMS

TELECOMMUNICATION SYSTEMS

The complete vision is available from the INCOSE website at www.incose.org/sevision

VALUE STATEMENT



SYSTEMS ENGINEERING AIMS TO ENSURE THE PIECES WORK TOGETHER TO ACHIEVE THE OBJECTIVES OF THE WHOLE.

- ARCHITECT BALANCED SOLUTIONS THAT SATISFY DIVERSE STAKEHOLDER NEEDS FOR CAPABILITY, DEPENDABILITY, SUSTAINABILITY, SOCIAL ACCEPTABILITY, AND EASE OF USE

- ADAPT TO EVOLVING TECHNOLOGY AND REQUIREMENTS

- MANAGE COMPLEXITY AND RISK

EXECUTIVE SUMMARY

This Vision is intended to inspire and guide the strategic direction of systems engineering for the global systems community. This community includes leaders of organizations, practitioners, students, and others serving this community that includes educators, researchers, professional organizations, standards bodies, and tool vendors.

This vision can be used to develop strategies to evolve the systems engineering capability of an enterprise or project. This, in turn, will help deal with the continuously changing environment, be more responsive to stakeholders, and become more competitive. The vision can also be used to help direct investments and support collaborative efforts to advance the discipline and grow the skill base to meet current and future challenges. Finally, the reader will gain insights on trends that impact enterprise competitiveness and how systems engineering will respond to these trends, which include the digital transformation, sustainability, smart systems and complexity growth, and advancements in modeling, simulation, and visualization.

THE COMPLETE VISION DOCUMENT IS ORGANIZED INTO THE FOLLOWING FOUR CHAPTERS:

CHAPTER 1

Provides the global context for systems engineering. It summarizes some of the key trends and influencing factors that are expected to drive changes in the practice of systems engineering. These factors include:

- **the societal and environmental condition,**
- **technology,**
- **nature of systems,**
- **stakeholder expectations,**
- **enterprises and the workforce.**

CHAPTER 2

Highlights the current state of systems engineering including systems engineering competencies, practices, foundations, and current challenges. It points to the fact that basic elements of systems engineering apply to all kinds of systems, small and large, but that there is significant variation in maturity across industries and organizations.

CHAPTER 3

Describes the future state of systems engineering needed to address the changing global context and the current challenges. It addresses the digital transformation and the direction towards a fully model-based systems engineering environment. It touches upon theoretical foundations, and the education and training needed to develop the competent systems engineering work force of the future. It also provides an example of how the daily life of a systems engineer could look in 2035.

CHAPTER 4

Describes what is needed to realize the vision. It identifies a set of systems engineering challenges, and the high-level roadmaps needed to transition systems engineering from the current state to the future state. It also highlights the need for collaboration among the global systems community to evolve and implement the roadmaps.

The Changing Global Environment

We live in a world whose global social, economic, political, and physical environment continually changes, alongside advances in technology and new scientific discoveries. The world is highly interconnected, and increasingly interdependent, where information is shared instantly, and enterprises compete in one global marketplace.

The pace of technology advancements continues to accelerate, and impacts the nature of systems solutions along with their positive and adverse effects on society.

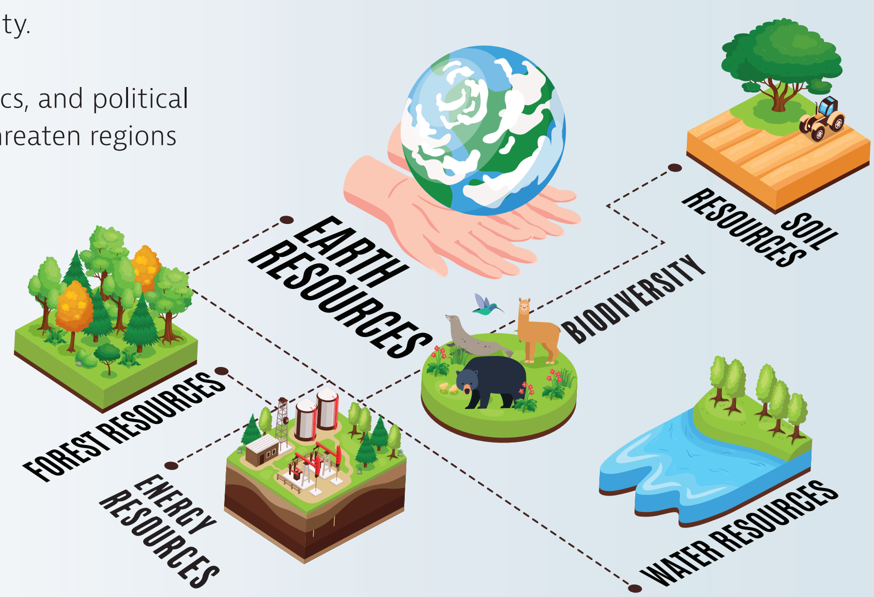
Global interdependence

Socio-economic trends include significant increases in urbanization and lifespan, and reductions in poverty in many places around the globe. These trends will most likely continue through the 21st century.

Impact of changing technology

At the same time, increasing population and improved global economic conditions have resulted in increased consumption and waste that stress natural resources, including air, water, soil, and biodiversity.

In addition, natural disasters, pandemics, and political and economic upheaval continue to threaten regions and nations around the globe.



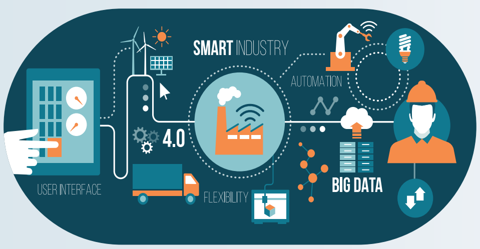
Increasing demands on the global environment and natural resources.

Changing Nature of Systems and Technology

In response to this changing environment, system solutions will leverage new technologies, including digital, material, power conversion and energy storage, biotechnology, and others. These solutions can provide enterprise and consumer value, while at the same time, they can benefit society and limit the stress on the finite natural resources. These system solutions apply to all aspects of society, including transportation, agriculture, energy production, healthcare, and many other services.

Most system solutions include increasing amounts of embedded and application software to provide their functionality, and increasing amounts of data to process. Many systems also provide services, such as those used to purchase items in the global marketplace. Other system solutions are increasingly characterized as cyber-physical systems (CPS) that include sensors, processing, networks, and data storage to control physical processes.

Changing nature of systems that are more inter-connected and smarter.



These systems are often interconnected with other systems to share resources and data as part of a broader systems of systems. For example, smart buildings, smart transportation, smart utilities, and smart waste management systems are part of smart cities.

These systems increasingly leverage artificial intelligence (AI), that may include machine learning, to enable the system to adapt to its environment and other changing conditions. The interconnected nature of these systems also introduces system design challenges, such as their vulnerability to cyber-threats.

As society benefits from advancements in system capabilities, consumers and users continue to expect more from these systems. This includes expectations that systems are more capable, dependable, sustainable, and affordable. They expect systems to be more socially acceptable by considering their impact on society and the environment. Users also expect systems to be more autonomous, enabling them to seamlessly interact, and understand and respond to their requests.

Demands on Enterprises

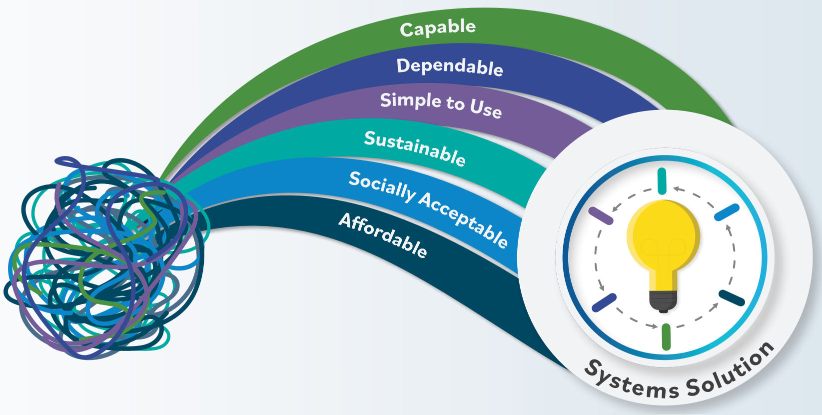
The enterprises that develop, produce, operate, and support these systems face increasing competition in the global marketplace to meet stakeholder expectations. This requires that they provide innovative products and services, while reducing costs and cycle time, increasing sustainability, and responding to regulatory changes, cyber threats, and supply chain disruption. The workforce skills must continuously evolve for the enterprise to remain competitive.

Knowledge is a critical enterprise asset. It must be properly managed for an enterprise to continue to learn and advance. Digital technology enables the transformation of how enterprises capture, reuse, exploit, and protect knowledge through digital representation and semantic integration of all information. Evolving digital technology, including the broader application of AI, will enable automation and autonomy to be used to perform increasingly complex tasks, providing further opportunities for humans to add value through innovation.

Knowledge sharing through the digital trans-formation.

Evolving the Practice of Systems Engineering

Aspects of systems engineering have been applied to technical endeavors throughout history. However, it has only been formalized as an engineering discipline beginning in the early to middle of the 20th century. Systems engineering was applied to address the growing challenges of the aerospace, defense, and telecommunications industries. Over the last few decades, systems engineering practices have been codified in international standards and a shared body of knowledge. There is a recognized professional certification program and a large number of degree programs in systems engineering. Many other industries have begun to recognize and adopt systems engineering practices to deal with the growing systems complexity. This complexity results from the increasing software and data content, increasing systems interconnectedness, competing stakeholder expectations, and the many other social, economic, regulatory, and political considerations that must be addressed when designing systems in a systems of systems context.



Systems engineering brings stakeholder value while managing growing complexity and risk.

Systems engineering aims to ensure the elements of the system work together to achieve the objectives of the whole. This requires systems engineering to deal with the complexity and risk by integrating across system elements, disciplines, the life cycle, and the enterprise. Systems engineering balances system solutions that satisfy diverse and often competing stakeholder needs and expectations such as performance, reliability, security, privacy, and cost. To accomplish this, systems engineering is inherently trans-disciplinary, and must include representation and considerations from each discipline and each affected stakeholder. Systems engineering must guide and orchestrate the overall technical effort including hardware, software, test, and specialty engineering to ensure the solution satisfies its stakeholder needs and expectations.

The practice of systems engineering will further evolve to support the demands of ever-increasing system complexity and enterprise competitiveness. By 2035, systems engineering will leverage the digital transformation in its tools and methods, and will be largely model-based using integrated

descriptive and analytical digital representations of the systems. Systems design, analysis, and simulation models, immersive technologies, and an analytic framework will enable broad trade-space exploration, rapid design evolution, and provide a shared understanding of the system throughout its life cycle.

Automated and efficient workflows, configuration and quality management of the digital thread, integrated tool chains, and AI will enable systems engineering to seamlessly collaborate and quickly adapt to change. By 2035, model-based reuse practices will effectively leverage enterprise investments. These practices include reference architectures and composable design, product line engineering, and patterns. Human-centered design, using models of the systems and users, will enable more seamless user-system interactions.

By 2035, the systems engineering practices will be based on a set of theoretical foundations and other general principles that are taught consistently as part of systems engineering curriculum. These foundations provide a common basis for applying systems engineering to the broad range of industry domains. Systems engineering education and training will address both the technical, business, socio-economic, leadership, and soft skills needed to enable collaboration among globally distributed development teams. Systems engineering education and training will continue throughout a career to stay abreast of changing practices, tools, technologies, and application domains. The systems engineering workforce will support the growing needs from small, medium, and large enterprises across the range of industry and socio-technical systems applications.

In this changing world, systems engineering must continue to evolve to deliver stakeholder value and be responsive to change, while managing complexity and risk. This vision identifies the following systems engineering challenges in five categories that are needed to achieve the future state of systems engineering that is described in Chapter 3.

Applications

1. Systems engineering contributes innovative solutions to major societal challenges.

2. Systems engineering demonstrates value for projects and enterprises of all scales, and applies across an increasing number of domains.

Practices

3. Systems engineering anticipates and effectively responds to an increasingly dynamic and uncertain environment.

4. Model-based systems engineering, integrated with simulation, multi-disciplinary analysis, and immersive visualization environments is standard practice.

5. Systems engineering provides the analytic framework to define, realize, and sustain increasingly complex systems.

6. Systems engineering has widely adopted reuse practices such as product-line engineering, patterns, and composable design practices.

Tools and Environment

7. Systems engineering tools and environments enable seamless, trusted collaboration and interactions as part of the digital ecosystem.

Research

8. Systems engineering practices are based on accepted theoretical foundations and taught as part of the systems engineering curriculum.

Competencies

9. Systems engineering education is part of the standard engineering curriculum, and is supported by a continuous learning environment.

Realizing this vision will require collaboration and leadership across industries, academia, and governments to meet these challenges and implement the high-level roadmaps outlined in Chapter 4.

STATEMENTS FROM REVIEWERS OF THE VISION

"As a summary, I find the document valuable and inspiring for the engineering community."
— Costas Stavrinidis, NAFEMS

"The document presents an exciting vision for a world transformed by the widespread application of modern systems engineering to be a better connected and more prosperous world."
— Daniel Hastings, MIT

"SE Vision 2035 offers a cogent cosmopolitan set of competencies and capabilities to engage with the complex systems we live by."
— Guru Madhavan, US National Academy of Engineering

"INCOSE's initiative to plan for the future of the SE community is commendable as an example of what a professional technical organization needs to do to anticipate engagement of challenges and opportunities."
— Christopher Nemeth, IEEE Systems, Man, and Cybernetics Society Liaison to INCOSE

"An important reference to evolve systems engineering as a digitally enabled, value driven practice."
— Grant Veroba, Petronas

"Vision 2035 summarizes the major challenges of our society - and derives what it means for the technical systems of the future and their development."
— Frank Thielemann, Unity AG

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The vision authors considered expert inputs including those from the vision reviews, many publications, and the collective experience of the vision team to determine the content of this vision. Time will tell the accuracy of the projected changes to systems engineering and the global context that it responds to. If this Vision 2035 can inspire engineers, policy makers, and other professionals anywhere to deeply reflect upon their own future paths and strategies, then we will have succeeded in our objectives for this Vision.

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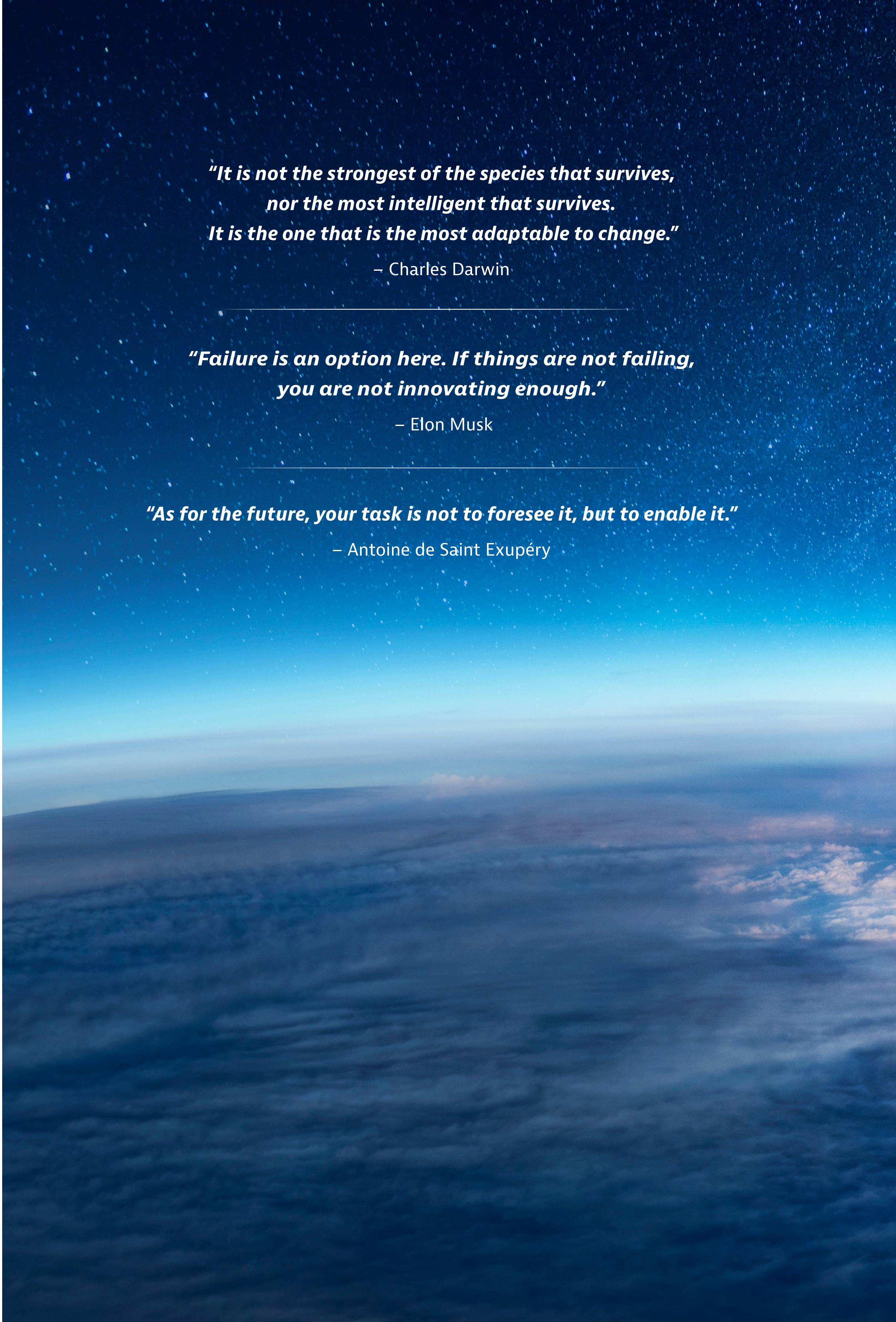

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change."

– Charles Darwin

"Failure is an option here. If things are not failing, you are not innovating enough."

– Elon Musk

"As for the future, your task is not to foresee it, but to enable it."

– Antoine de Saint Exupéry