



Groupe ICHÉC - ISC St-Louis – ISFSC

Enseignement supérieur de type long de niveau universitaire

A management analysis of ESA's astronaut Basic Training

**An organisational study of Project, Operations, and Service models
in human spaceflight preparation**

Mémoire présenté par
Priscille THEAULT

Pour l'obtention du diplôme de
Master en Gestion de l'Entreprise

Année académique 2024-2025

Promoteur :
Docteur Sed SAAD

Boulevard Brand Whitlock 2 – 1150 Bruxelles

Déclaration sur l'honneur

« Je soussignée, THEAULT Priscille, en Master 2 Gestion de l'entreprise, déclare par la présente que le travail ci-joint respecte les règles de référencement des sources reprises dans le règlement des études en signé lors de mon inscription à l'ICHEC (respect de la norme APA concernant le référencement dans le texte, la bibliographie, etc.) ; que ce travail est l'aboutissement d'une démarche entièrement personnelle; qu'il ne contient pas de contenus produits par une intelligence artificielle sans y faire explicitement référence. Par ma signature, je certifie sur l'honneur avoir pris connaissance des documents précités et que le travail présenté est original et exempt de tout emprunt à un tiers non-cité correctement.»

Dans le cadre de ce dépôt en ligne, la signature consiste en l'introduction du mémoire via la plateforme ICHEC Student.



Groupe ICHec - ISC St-Louis – ISFSC

Enseignement supérieur de type long de niveau universitaire

**A Management Analysis of ESA's Astronaut
Basic Training**

**An Organisational Study of Project, Operations, and Service
Models in Human Spaceflight Preparation**

Mémoire présenté par
Priscille THEAULT

Pour l'obtention du diplôme de
Master en Gestion de l'Entreprise

Année académique 2024-2025

Promoteur :
Docteur Sed SAAD

Boulevard Brand Whitlock 2 – 1150 Bruxelles

Abstract

This thesis analyses the organisational structure of the European Space Agency's (ESA) Astronaut Basic Training program, which occurs typically every decade, using integrated management frameworks. Although ESA has effectively trained astronauts for four decades, its organisational architecture reveals structural weaknesses that could jeopardise its viability as human spaceflight activities evolve.

This research arises from my observations during my three months internship at the European Astronaut Centre (EAC) in Cologne, Germany. It builds up from a thorough context and literature review analysis and it explores how management principles can be applied to the Basic Training process to improve its efficiency and resilience. Through the data collected in this first stage, the research question of the thesis is generated together with three hypotheses.

The work then moves to collecting data from two key interviewees with direct experience in astronaut training. A case-study on a comparison with NASA's integrated model and Russia's hierarchical approach is also provided to enhance the depth of the analysis, highlighting strengths and weaknesses of ESA's model, and reduce the possibility of bias.

The analysis of all the data collected reveals how ESA's PaaS model as intended today creates operational risks. The empirical findings confirm the three hypotheses: (1) risks of single-point-of-failure vulnerabilities due to gaps in project management practices; (2) a part of training content needs to be redeveloped due partially to improvable knowledge management processes; (3) the service delivery model currently employed represents a risk for continuity and scalability, despite cost benefits.

The thesis ultimate objective is to present recommendations to improve the organisational resilience of Basic Training. Hybrid service models integrating permanent staff and contractors, improved knowledge management systems and structured communication are amongst the most impactful operational recommendations. These modifications are more relevant today than ever in a space sector which is changing landscape very quickly.

The methodical use of management principles can transform ESA's Basic Training from isolated, high-risk assignments into a resilient, scalable program – crucial for Europe's continued leadership in human space exploration.

Keywords: ESA, Astronaut training, project management, operations management, service management, human spaceflight

Acknowledgments

I would like to express my gratitude towards everyone who contributed to this thesis.

First of all, to my thesis supervisor, Dr. Sed Saad, whose wise advice helped clarify what an academic thesis should look like. His way of rousing critical thinking and his availability were most precious in times of doubt.

Additionally, my warm gratitude goes to Dmitriy Churkin, my internship supervisor. His fount of knowledge about human spaceflight defies anyone I have ever met – and several manuals, and is only matched by his eagerness to share it. The numerous conversations we had at EAC are the basis for this thesis, and the interview its consolidation.

I would also like to thank Tom Hoppenbrouwers for agreeing to an interview despite not working as an astronaut instructor anymore. His answers provided a different angle that expanded the depth of the analysis.

My internship at the European Astronaut Centre in the Astronaut Training team was a unique opportunity and I will always be grateful to the management team of Space Applications Services for arranging it.

Thank you to Bernd Bewer for introducing me to the people there through coffee breaks and informal meetings, and to all my fellow interns as Spaceship EAC who made the experience unforgettable.

Finally, my most heartfelt appreciation goes to you, Fabio. This thesis would have never come to light without your continuous and consistent support, all in my academic, professional, and personal lives.

'I do not know whether the worlds are inhabited or not; and since I
do not know, *I am going to see!*'

–Jules Verne, *From the Earth to the Moon*, 1865

Table of Content

GENERAL INTRODUCTION.....	1
PART 1: AN OVERVIEW OF HUMAN SPACEFLIGHT AND ESA ASTRONAUT TRAINING	3
1.1 The evolution of Human Spaceflight.....	3
1.1.1 The origins of Human Spaceflight: The Space Race	3
1.1.2 The genesis of ESA (European Space Agency)	6
1.1.3 Space Stations and Human Spaceflight in the last 30 years	7
1.1.4 Evolution of Astronaut Training Content and Methods (2000-2025)	9
1.1.5 International Collaboration and Coordination.....	10
1.1.6 Integration of New Technologies	10
1.2 ESA Astronaut Training Architecture	11
1.2.1 Basic Training	12
1.2.2 Pre-Assignment Training	13
1.2.3 Mission/Increment Training.....	14
1.2.4 The Integrated Training System.....	15
PART 2: THEORETICAL FRAMEWORK AND RESEARCH QUESTION	16
2.1 Literature Review.....	16
2.1.1 Project Management.....	16
2.1.2 Project Management in Astronaut Training Programs	18
2.1.3 Operations Management	19
2.1.4 Operations Management in Training Delivery	20
2.1.5 Service Management	20
2.1.6 Service Management Applied to Astronaut Training.....	22
2.2 Deriving the Research Question from Management Concepts applied to Basic Training and Field Observations	23
2.2.1 Field Observations from the European Astronaut Centre	23
2.2.2 Management Principles applied to Basic Training.....	26
2.2.3 Research Gap and Contribution	29
2.2.4 Research Question and Hypotheses.....	31
PART 3: METHODOLOGY	33
3.1 Research Philosophy and Design.....	33
3.2 Data Collection: A Multi-Stage, Mixed-Method Approach	35
3.3 Data analysis: A thematic approach	37

3.4	Methodological Limitations.....	39
3.5	Ethical Considerations	40
PART 4: DATA COLLECTION.....		41
4.1	Interview with Dmitriy Churkin – ESA Basic Training Coordinator.....	41
4.1.1	Detailed Thematic Analysis of Interview Content.....	42
4.2	Interview with Tom Hoppenbrouwers – Former ESA Payload Instructor	45
4.2.1	Detailed Thematic Analysis of Interview Content.....	45
4.3	Case Study: Comparison of International Space Agencies Training organisation Models	49
4.3.1	NASA's Integrated Training organisation	49
4.3.2	GCTC's Hierarchical Integration Model.....	50
4.3.3	Comparative Summary	51
PART 5: DISCUSSION AND ANALYSIS		52
5.1	Validation of Research Hypotheses Through Empirical Evidence	52
5.1.1	H1 Analysis: Project Management Structures and Their Implications	52
5.1.2	H2 Analysis: Knowledge Management and Operational Continuity	53
5.1.3	H3 Analysis: Service Management Models and Organisational Resilience	54
5.2	Integration of Upstream and Downstream Perspectives.....	56
5.3	Operational Recommendations	57
5.3.1	Project-Based Transformation.....	57
5.3.2	Hybrid Service Models	57
5.3.3	Knowledge Management Systems	58
5.3.4	Communication Integration Framework	59
5.3.5	Implementation Prioritisation.....	59
5.4	Future Considerations	60
5.4.1	The Changing Landscape of Human Spaceflight Training.....	60
5.4.2	Conclusions	64
GENERAL CONCLUSION		66
BIBLIOGRAPHY.....		70
LIST OF ACRONYMS.....		78
APPENDICES – TABLE OF CONTENTS		79

Table of Figures and Tables

Figure 1: Cost split of Gemini Program	4
Table 1: Costs of US Space Programmes Mercury, Gemini & Apollo	5
Table 2: Costs of Soviet Space Programmes from 1960 to 1969	6
Figure 2: Overview of the three phases of ESA astronaut training	12

General Introduction

The exploration of space represents one of humanity's most ambitious pursuits, requiring both technological innovations and the development of individuals into experts capable of operating in the most hostile environment known to our species. Astronaut training is the process of preparing already highly qualified individuals to become crew members with a large luggage of technical, scientific, cultural and soft skills. At the end of the training, astronauts are supposed to be fully capable of conducting sophisticated scientific experiments, have a strong discipline and work in a team in a confined space for a long time, away from their homes.

The European Space Agency (ESA) is one of the biggest space agencies in the world and it has a long experience in training a large number of astronauts who have contributed to the success of international space missions over the last 40 years. From Ulf Merbold's first trip in 1983 to the latest generation today working aboard the International Space Station (ISS), European Astronauts have always been recognised as excellent. The accomplishments obtained until today must not be considered, though, as an arrival point, but instead as an opportunity to dig deeper into the organisational challenges that are present in the current training process and improve them.

This thesis analyses the organisational structure of ESA's Astronaut Basic Training through the perspectives of project management, operations management, and service management. The research is driven by a fundamental paradox: although ESA successfully provides extensive training that prepares astronauts for complex international missions, the organisational model facilitating this delivery displays characteristics that management science would classify as high-risk and potentially unsustainable. The majority of the coordination of basic training depends on one individual, functions without established project frameworks or allocated budgets, and lacks structured knowledge management processes – vulnerabilities that grow progressively problematic as the pace of human spaceflight increases.

The scope of this thesis is particularly relevant in 2025 as the space sector is changing at a speed never recorded before. While in the past, space missions were a fully institutionalised domain, today we witness more and more commercial spaceflight providers, making space more affordable and accessible. We are also at a moment in which humanity is trying to expand its presence into other celestial bodies, such as the Moon and Mars. The Artemis program is proof of the internationally shared intention to explore the Moon and build habitats on it. Newer

international stations, like the Lunar Gateway, are also on their way. The astronaut training needs to keep all those changes into account from both a content point of view as from the organisational one to continue its excellency.

This thesis contributes to both academic knowledge and practical implementation. A gap in management literature is identified and management frameworks are applied to the unique context of astronaut training, a field defined by strong skill demands, long operational cycles and a long list of constraints and requirements. In practice, it offers ESA and other space agencies evidence-based recommendations for organisational transformation, derived from comparative analysis of international models and empirical observations from those involved in training delivery.

The study utilises exclusive access to ESA's training organisation via a three-month internship at the European Astronaut Centre, supplemented by comprehensive interviews with key personnel and a comparative analysis of NASA and ROSCOMOS training models. This approach facilitates a comprehension of both the strengths that have contributed to past successes and the vulnerabilities that may limit future efficacy.

The thesis is organised to advance from context to theory, followed by methodology, data collection, analysis and recommendations. Part 1 provides historical and operational context of human spaceflight and astronaut training, with a final focus on the specific structure that is followed in the ESA's astronaut training program. Part 2 develops the theoretical core of the work, providing the observations that generate the thesis motivation, the literature review, the research gaps and finally the research question and hypotheses. Part 3 explains in detail how the research is conducted by illustrating the methodology. Part 4 presents the data collected from interviews and the case-study. Part 5 is the analytical result, where all the data is processed and the hypotheses are questioned to validate the research question and to produce operational recommendations for the reader.

Part 1: An overview of Human Spaceflight and ESA

Astronaut training

We will start this thesis by setting the context in which the ESA Basic Training takes place. To do so, we will start with a small historical presentation of the evolution of human spaceflight throughout the years. Then, we will follow a funnel method, going from general to more precise.

1.1 The evolution of Human Spaceflight

1.1.1 The origins of Human Spaceflight: The Space Race

Human Spaceflight found its roots in the 20th century in an atmosphere of cold war between the United States and the Soviet Union. This geopolitical rivalry expressed itself through many factors, one of them being technological. The space race stemmed from it, a competition lasting from the 1950s to the 1970s. It was originally spearheaded by the Soviet Union who successfully launched into space the first artificial satellite, Sputnik 1, on October 4, 1957. (Siddiqi, 2000).

This feat set in motion two major space programmes: Project Mercury in the United States, and the Vostok programme in the Soviet Union. Both had the same objective: sending the first human into low Earth orbit (LEO), the region of space closest to Earth. The USSR once again proved their technological dominance by achieving this exploit on April 12, 1961, when Yuri Gagarin became the first human being to go to space. (Siddiqi, 2000).

The race then escalated into a new, ultimate objective: setting foot on the Moon. After a brief intermediary named Gemini, the US moved onto a new space programme: Apollo. The USSR also migrated briefly to the Voskhod programme and then transitioned to the Soyuz programme, which is surprisingly still the one applicable nowadays. This time, the United States reversed the trend and reached the target first when Neil Armstrong, Buzz Aldrin and Micheal Collins launched aboard Apollo 11. The former two made the groundbreaking first steps on the Moon on July 20, 1969. It showcased the superiority of the US in that field, thus ending the space race, and it remains one of the most exceptional technological feats achieved to this day.

One thing notable is that all the astronauts of this time, whether American or Soviet, shared the same background: military pilot. It can be explained by the long-standing relationship between technological innovation (especially in the space sector) and the military. (de Zwart & Stephens, 2019). At this time, astronaut requirements were

emphasising experience as test pilot – which was formerly only accessible in the army – and a willingness to follow orders even when facing stress and acute danger – a trait expected of soldiers. (Nelson, 2009). There is also a strong political explanation for both nations: in the US, the selection process of the astronauts was mostly driven by military institutions. It pushed them to favour candidates with military background and training to keep their influence in the race. (Wolfe, 1979). On the other hand, the Soviet Union had its whole society intertwined with its military organisation, technology and the space quest being at the forefront of their resolution. (Suvorov, 1982).

It is well established that the space race was one of the most expensive endeavours of the 20th century – or still to this day. It is interesting to evaluate how much.

Cost of the Space Race Programmes

First, it is advisable to look at the cost of the above-mentioned American programmes: Mercury, Gemini and Apollo. It should be kept in mind that those costs are approximative and differ depending on how the programme expenses are calculated, the limit between one programme and the next sometimes blurry.

Mercury cost between 300 and 400 million dollars in 1963 value, which with inflation amounts to 3 to 4 billion dollars in 2025 (Swenson et al., 1966). The cost was split as follows: “37 percent went for the spacecraft, 33 percent for the tracking network, and 24 percent for launch vehicle procurement. Flight operations and "R and D" costs made up the remainder” (Swenson et al., 1966, p. 508).

Gemini was much more expensive and cost 1.290 billion dollars in 1966 value, or 12.5 billion dollars in 2025. The cost split was quite different, with 61 percent for the spacecraft, 32 percent for the launch vehicles and the rest for the support. (Grimwood et al., 1969).

APPENDIX 5—COST OF GEMINI PROGRAM (MILLIONS OF DOLLARS)

[Gemini Program Office, NASA Headquarters, Dec. 21, 1966]

Item	Fiscal year						Total
	1962	1963	1964	1965	1966	1967	
Spacecraft.....	30.3	205.1	281.7	165.3	98.9	9.1	790.4
Launch vehicles.....	24.4	79.1	122.7	115.4	72.9	2.9	417.4
Support.....	0.1	4.9	14.5	27.7	25.5	9.6	82.3
Total.....	54.8	289.1	418.9	308.4	197.3	21.6	1290.1

Figure 1: Cost split of Gemini Program (Grimwood et al., 1969)

Finally, Apollo had the most extravagant cost with 25.4 billion dollars in 1973 value, or 162.6 billion dollars adjusted with inflation. The spacecraft amounted for 33 percent of the cost, the launch vehicles for 36 percent, and the rest was mostly support shared between operations, engines, construction of facilities and programme management. (United States, 1973).

A table has been built below for easier comparison of the overall costs of those programmes:

Programme	Active years	Cost at end of programme (in billion \$)	Cost adapted to 2025 inflation (in billion \$)
Mercury	1959-1963	~0.35*	~3.5*
Gemini	1962-1967	1.29	12.5
Apollo	1959-1973	25.4	162.6
Total		27.04	178.6

*Average taken for ease of sum

Table 1: Costs of US Space Programmes Mercury, Gemini & Apollo

Second, it would be interesting to analyse the costs of the Soviet programmes to contrast them with the American ones. As expected from ex-USSR programmes, it is extremely difficult to find figures, especially reliable ones. The only sources found mentioning them are several CIA reports, declassified from secret clearance in the last 20 to 30 years. They do not come from direct Soviet sources, and as stated in the documents, are an estimation of the costs “as though they had been incurred in the United States”. (Central Intelligence Agency, Directorate of Intelligence, Office of Strategic Research, 1969, p. 4). Therefore, they lack reliability, precision and are not split per programme.

The document selected (cf. Appendix A) shows the costs from years 1960 to 1969 as it matches best with the periods of the Soviet programmes – Vostok starting in 1961 – and the end of the space race – 1969. The document is split between civil and military space costs, but for the sake of simplicity, both will be aggregated. This simplification is tolerated since the Soviet state and army were closely interwoven, as exposed before.

The table below sums the yearly figures of the Soviet space programme in the mentioned dates. (Central Intelligence Agency, Directorate of Intelligence, Office of Strategic Research, 1969)

Programme	Active years	Cost from 1960 to 1969 (in 1966 billion \$)	Cost adapted to 2025 inflation (in billion \$)
Vostok	1961-1963	38.59	273.59
Voskhod	1964-1965		
Soyuz	1966-present		

Table 2: Costs of Soviet Space Programmes from 1960 to 1969

Based on those two tables, it seems the USSR spent 1.43 times more money on space programmes between 1960 and 1969 than the USA did in 4 more years. However, those numbers are to be taken with a grain of salt as they all come from the USA: they did not – and still do not – know exactly the costs actually spent by the USSR. At the time of the publication of those reports, the Soviet economy was already on the verge of collapse – which was discovered by the US a decade later (Trachtenberg, 2018) – so labour and procurement were most likely costing a lot less than the CIA assumed. Besides, as the popular adage goes, ‘history is written by the victors’; it probably reflected well on the US that the USSR spent more money for less successful results in regard to the Moon landing.

1.1.2 The genesis of ESA (European Space Agency)

Europe was not actively involved in the cold war or space race, needing to rebuild its economy and civilisation after being at the heart of two very destructive world wars in 30 years. However, in the late 50s, scientific interest for space started rising in Western Europe. This enthusiasm grew and a succession of events followed in the next decades (European Space Agency (ESA), n.d.):

In 1960 was created the GEERS (Groupe d'études européen pour la Collaboration dans le domaine des recherches spatiales), a consortium of scientists from different European countries, to discuss the possibility of European cooperation in the space sector.

Following this initiative, two European space agencies were created in 1964: ELDO (European Launch Development Organisation) with the goal of developing a launch system, and ESRO (European Space Research Organisation), to develop a spacecraft.

In the same decade, 3 centres were established by ESRO: ESRIN for Earth Observation, ESOC for operations management, and ESTEC for technical research.

NASA and ESRO constituted together in 1973 Spacelab. It was a historic moment since Spacelab is considered being the ancestor of the ISS. It was the first example of a shared reusable orbital laboratory in which European astronauts could fly.

The 3 ESRO centres remained active and operational through the merger of ELDO and ESRO into a new, consolidated space agency: ESA (European Space Agency) came into force in 1975.

Respecting the agreement between NASA and ESRO (now ESA), Jean-Loup Chrétien became in 1982 the first European astronaut to fly that did not belong to the communist bloc. He however was not flying for ESA, but for CNES (Centre National d'Etudes Spatiales), the French space agency.

Finally, the first ESA astronaut, Ulf Merbold, flew in 1983.

1.1.3 Space Stations and Human Spaceflight in the last 30 years

The Soviets pioneered the concept of prolonged human habitation in space with the initiation of their Salyut program in the early 1970s. Inaugurated in 1971, Salyut-1 was the inaugural space station; yet, it had various difficulties, since crew members could remain for only 23 days before technological complications necessitated their exit (Portree, 1995). Nevertheless, the Soviets persisted in their endeavours, and by the operational phases of Salyut-6 and Salyut-7 in the late 1970s and 1980s, they had developed the proficiency to sustain human life and production in orbit for extended durations (Harland, 1997)

Thereafter, Mir appeared in 1986, signifying a markedly different entity. This was not only a conventional tin can in space; it was modular, permitting the incorporation of components similar to an orbiting LEGO assembly. Mir functioned for 15 years, and by the 1990s, American astronauts were engaged in the Shuttle-Mir program (Linenger, 2000). Reflect on this transition: we progressed from competition to attain the Moon to collaboration on expeditions to a Russian space station. This signifies a substantial change in viewpoint (Oberge, 2002).

The pivotal event occurred in 1998 when the initial components of the International Space Station were launched from Baikonur. The ISS represented a remarkable endeavour, uniting Americans, Russians, Europeans, Japanese, and Canadians to collaborate on what would ultimately become the most costly building ever constructed (NASA, 2015). Unlike the period of the space race, this was not a manifestation of extravagance. The aim was to create a collaborative laboratory for individuals to converge and investigate further developments in space exploration (Catchpole, 2008).

The defining characteristic of the ISS was its commitment to sustaining an uninterrupted human presence. Previous stations experienced variable attendance; however, starting November 2000, a consistent presence has been

upheld. The human presence in space has persisted for almost two decades, which is remarkable (NASA, 2020).

The International Space Station signified the European Space Agency's ascension to the forefront of human space exploration. Their principal accomplishment was the Columbus laboratory, which was launched into space in 2008 aboard the Space Shuttle Atlantis (ESA, 2008). Prior to Columbus, European explorers predominantly functioned as visitors on others' expeditions, residing briefly in one locale and making fleeting trips at many sites. Following the integration of Columbus into the station, the ESA established its own infrastructure and, importantly, ensured designated opportunities for European astronauts to reside on the ISS for six-month intervals (Messerschmid & Bertrand, 1999).

This transformed the training of astronauts in Europe. Abruptly, figures like Thomas Pesquet, Samantha Cristoforetti, and Matthias Maurer moved from simply traveling to space to living there, performing spacewalks, fixing apparatus, and carrying out experiments. They showed that Europe can support extended space missions (ESA, 2023). This is an important result; it posed the base for European involvement in future missions, whether to the Moon, Mars, or a completely different destination (De Winne, 2022).

It is common to wonder why we have not been to the Moon in a very long time. The answer is more relevant to politics and finance than not to technology (Logsdon, 2010). The Apollo program resulted from the Cold War competition between the United States and the Soviet Union. The lunar voyage largely served as a demonstration of supremacy in systems, technology, and general capabilities rather than a purely scientific venture. The expensive costs were reasonable when one perceived them as a means of preserving their lifestyle (McDougall, 1985). Nonetheless, as Armstrong and Aldrin erected the flag, the contest reached its conclusion. The United States had prevailed, and suddenly, the necessity of allocating billions to return lessened (Launius, 2019).

Following the fall of the Soviet Union in the early 1990s, all residual competition dissipated. The United States was the sole superpower and had no compulsion to prove anything to anyone through space displays. Convincing taxpayers to fund another lunar voyage is difficult without a competitor to challenge (Sagan, 2011; Augustine Committee, 2009). Nonetheless, China has been subtly, and occasionally explicitly, augmenting its space program. They have deployed rovers to the Moon, are strategising a lunar settlement, and now operate their own space station. Competition has suddenly reemerged, like in the 1960s (Goswami & Raghuram, 2021; Chen, 2023).

Concurrently, an unexpected event transpired: private companies like SpaceX commenced manufacturing rockets at markedly lower expenses. Functions once

requiring a government budget can now be performed by companies, which are executing them more rapidly and efficiently than expected (Weinzierl, 2018; Anderson et al., 2021).

The Artemis project by NASA aims to create a sustained human presence on the Moon. ESA and other collaborators were involved since the beginning (NASA, 2022). The objective is ambitious, aiming to establish a continuative human presence on the Moon and using it as launchpad for Mars (Smith et al., 2023), which would be very efficient. This implies that astronauts will need to train for new and different challenges from typical orbital flights, and the training programs will need to reflect that (Seedhouse, 2022).

We are now at a critical crossroads. The ISS will soon be decommissioned (NASA, 2022), after more than 20 years of continuous operations. Nevertheless, what ensues will turn the ISS a mere preparatory undertaking. We are examining regions from where return is unattainable in the event of an incident, where aid may be postponed for months or years. The upcoming cohort of astronauts and their instructors face this challenge (Crawford, 2021).

1.1.4 Evolution of Astronaut Training Content and Methods (2000-2025)

Since 2000, astronaut training has shifted from short, task-specific Shuttle-era preparation to long-duration, skills-based curricula supporting ISS and beyond. In the post-shuttle era, NASA's National Academies report notes that training now emphasises broad skills (EVA, robotics, maintenance, emergency response) rather than only mission-defined tasks (National Resource Council, 2011). ISS training must cover hardware and procedures from all partner modules (US, Russian, European, Japanese, Canadian) (National Resource Council, 2011). Agencies have introduced new topics and analogs: for example, ESA created Concordia research and Human Behaviour/Performance (HBP) training to simulate isolation and autonomous decision-making, and analog missions like CAVES (2011-) and PANGAEA for geology (Minato, 2021).

Technical methods have also evolved. High-fidelity simulation and virtual reality (VR) are now core tools. NASA's Johnson Space Center has long used its Virtual Reality Lab for EVA and robotics training (Garcia, 2020); astronauts certify on EVA jetpacks (SAFER) and mass-handling systems via VR and collaborative mission reviews. ESA established an Extended Reality (XR) Lab in 2015 to develop AR/VR content: e.g. training for the Canadarm2, station layout, EVAs and medical scenarios (ESA, 2015). During COVID, ESA's EAC successfully implemented socially-distanced training by disinfected VR sessions and remote instruction (astronaut Maurer trained on the Canadarm2 via an ESA VR system called JIVE)

(ESA, 2020). In sum, training now blends classroom instruction, simulators (e.g. Neutral Buoyancy Labs, robotics mockups), analog missions, and VR/XR, adapting continually to mission needs (e.g. new lunar/Mars scenarios) and safety constraints.

1.1.5 International Collaboration and Coordination

Astronaut training is inherently international for ISS and beyond. Crews are multinational, and each partner agency trains all crew on its hardware. For example, all ISS partners train their astronauts on every module: ESA is responsible for Columbus operations, so U.S., Russian, and Japanese astronauts train on Columbus in Europe, and ESA astronauts train on U.S. and Russian segments elsewhere (National Resource Council, 2011), (Minato, 2021). JAXA's Tsukuba facility trains all crew on Kibo; notably, ESA astronauts travel to Tsukuba for Kibo training (ESA, Astronaut training at Tsukuba Space Center, retrieved May 2025). Likewise, NASA astronauts train at Russia's Gagarin Cosmonaut Training Center for Soyuz procedures, while Russian cosmonauts come to Houston for U.S. segment training (National Research Council, 2011). This cross-training requires meticulous coordination: the ISS Multilateral Crew Operations Panel allocates seats and roles on flights, and agencies share simulators and schedules. Practically, international coordination extends to curriculum and scheduling. Joint exercises (e.g. rendezvous/lighting simulations) are planned across continents. Space agencies also exchange instructors; ESA and JAXA have both sent trainers to NASA for Crew Dragon commercial crew integration. Moreover, multiagency flight rules and emergency protocols (e.g. rescue procedures) are harmonised, so training includes cross-cultural communication and crew-resource management. This is exemplified by the Spaceflight Resource Management (SFRM) approach, derived from aviation CRM, which ESA, NASA, JAXA and Roscosmos all incorporate into team training (Minato, 2021). In short, international collaboration in training is a project in itself: it requires shared planning (e.g. agreeing on content and language requirements), risk management (ensuring all crew meet everyone's standards) and joint logistics (visa, travel, scheduling). The result is a globally integrated training pipeline supporting ISS and cooperative exploration.

1.1.6 Integration of New Technologies

New technologies have been steadily woven into training operations. Extended/Virtual Reality (XR) is a prominent example. ESA's XR Lab (2015–) develops immersive simulators for station robotics, EVAs and medical scenarios (ESA, 2015). NASA's longstanding Virtual Reality Lab has likewise matured: current

VR systems at JSC include hardware-in-the-loop simulations for EVA jetpacks and mass-handling, and collaborative 3D environments for spacewalk walkthroughs (Garcia, 2020). These tools let trainees practice complex tasks in cost-effective ways. For instance, ESA's VR arm training (JIVE) allowed remote instruction during the pandemic and can model future lunar/Mars modules (ESA, 2020).

Augmented reality (AR) is also emerging (e.g. tablet-based procedures review), though less well publicised. Thanks to the technological development, Space Agencies have increased the amount of remote and distributed training, especially during COVID-19, delivering classes through remote sessions and software simulations. Research by Minato et al. (2021) highlights "Space Flight Resource Management" training to build remote teamwork skills, noting that all roles should be cross-trained so that any crew member can assume command if needed. More concretely, SpaceX's development of Crew Dragon training emphasises integrated simulations "with NASA operations and training teams" (SpaceX, 2021) – a fusion of new spacecraft software and joint scenario planning. Even analogs have been enhanced by tech: data analytics now support astronaut performance tracking, and personalised training plans (akin to adaptive learning) are under investigation (e.g. tailoring exercise regimes or stress management training). Other innovations include advanced simulators (motion bases for lander training, updated human centrifuge protocols), e-learning modules (online classroom courses for spacecraft systems), and even biomedical data systems for monitoring astronaut health trends over time (feeding back into training on nutrition, exercise, psychology). While academic publications on the management aspects of these technologies are sparse, agency reports and job postings indicate a clear trend: astronaut training is adopting 21st-century digital tools to improve fidelity, efficiency, and accessibility.

1.2 ESA Astronaut Training Architecture

ESA currently implements a three-phase training program, which is in principle aligned with other space agencies. Since ESA selects astronaut candidates among people with different backgrounds, the purpose of the training is to initially give all of them an alignment on the basic skills required to be an astronaut and only then prepare for specific missions (ESA, 2022). The three phases are Basic Training, Pre-Assignment Training and Mission Training, often referred as Increment-Specific Training. While the purpose of each training is unique, the structure and content of each of them is usually realised ad-hoc for a specific astronaut class and built upon the training delivered to the previous class.

It is important to correctly understand the structure of this program as this thesis focuses its attention on the processes linked to Basic Training. Each training phase

would not make sense alone as the final purpose is to allow a highly skilled professional to fly into space. It is so crucial to have an overview of the full training process as a whole. Providing this context will allow the reader to further understand how the application of management principles is relevant in this scenario.



Figure 2: Overview of the three phases of ESA astronaut training (ESA, 2021)

1.2.1 Basic Training

ESA's Basic Training represents the foundation of any astronaut preparation, being also the longest phase. It usually lasts one year and it is given to all the new Astronaut Candidates (ASCANs). As mentioned, ASCANs usually have different backgrounds among each other and no single candidate possesses the required transversal knowledge and set of skills required to be an astronaut today. Basic Training's target is to bridge this gap (De Winne, 2022).

Basic Training covers a large variety of topics to ensure the survival of the astronauts and improve their capacities to conduct scientific experiments. In the first part of BT, ASCANs deeply study in both theory and practice how spaceships work, understanding how propulsion, life support and navigation work to be able to manually face any adversity. Those systems are, in fact, more and more automated, but the candidates need to be aware and ready to use them if needed. The technological background is then completed by the study of the ISS modules, such as the European one Columbus, its power supply systems and the operational procedures (Messerschmid & Bertrand, 1999).

The purpose of astronauts living on orbital stations or on lunar/martian habitats is ultimately to conduct scientific experiments. This means, for example, conducting experiments in micro-gravity in the case of the ISS. Thus BT prepares them on a variety of scientific procedures, the utilisation of the equipment and how to collect data. ASCANs are then also introduced to one of the most critical components of their work on the ISS: extravehicular activities (EVAs). Those are trained in subsequent rounds (Seedhouse, 2022) in analog environments such as the Neutral Buoyancy Facility (NBF), a deep pool with mock modules of the ISS available at EAC. A strong focus of the training is, naturally, on safety instructions. ASCANs need to prepare to face any possible worst case scenarios. They practice reactions to fires, pressure loss and medical crises. The physical condition of the candidates is also an object of attention as it is required for supporting the condition of the spaceflight and the life in orbit (Dietrich, 2021).

Another important discipline that might not appear immediately obvious is language training. Candidates must attain a proficient level in both English and Russian, the official languages of the ISS. ASCANs will be required to live and collaborate for long periods in a confined space with people with very different backgrounds. For this reason, the training structure also pays attention to provide an adequate set of soft skills for the astronauts to be able to proficiently cooperate with other agencies members (ESA, 2018).

Most of ESA BT is delivered at EAC in Cologne, Germany through conventional lectures, experimental lab sessions and digital simulations. Nevertheless, the training also organises the ASCANs to visit facilities managed by other agencies, such as NASA's Johnson Space Centre, Roscosmos training sites in Russian and JAXA centres in Japan. This further strengthens the international relationships and bonds between future astronauts of different agencies, while allowing the candidates to utilise the most advanced facilities around the world.

During Basic Training, continuous exams and practical assessments ensure the correct development direction of the candidates while ensuring that only those who meet the requirements can proceed to the next phases of the training. At the end of this phase the ASCANs graduate and are astronauts.

1.2.2 Pre-Assignment Training

Pre-Assignment Training is the intermediate phase between Basic Training and Mission Training. This training further improves astronauts' skills and solidifies the foundation provided in the first phase (Minato et al., 2021).

The purpose of Pre-Assignment Training is to deepen the specialisation of the astronauts, while ensuring that the skills acquired so far will not be lost. The procedures on the ISS are in continuous evolution, together with general space technology. In this sense, the astronauts can specialise in different disciplines, such as robotics, advanced EVA or particular science projects. For example, an astronaut that specialised more on lunar geology will probably be more suited for a mission on the Moon compared to one that focused on medical effects of micro-gravity (Lindgren, 2021).

In this phase astronauts usually train in analogue environments. For instance, ESA astronauts can join the CAVES course, simulating space mission conditions underground, or the PANGAEA course, providing geological training for planetary exploration. Analogue environments tests are extremely useful to simulate challenges that could be encountered in space, testing teamwork, leadership and technical skills (ESA, 2023). The approach followed in this phase is modular, allowing different astronauts to have different experiences and accommodate their schedules. Other tasks covered in Pre-Assignment Training are the work as mission control (e.g. EUROCOM or CAPCOM), participating in the design of spacecraft or the education of the public in between modules. This allows the astronauts to prepare for flying while keeping them involved in operations (Garcia, 2020).

1.2.3 Mission/Increment Training

Mission Training, or Increment Training, is the final phase of astronaut training. As the name suggests, the purpose of this training is to prepare an astronaut for a specific mission they have been assigned to. The nature of the training becomes extremely specialised, making the astronaut an expert on every single aspect of their planned mission (NASA, 2022).

Increment Training is tailored to the needs and requirements of the specific mission. For example, the astronaut will be trained on how to perfectly operate the spacecraft model (among Soyuz, Crew Dragon and others) that will be used to transport them to space. The astronaut needs to be able to recover from virtually any foreseen negative situation in launch, in-orbit and landing phases. The success of the mission is dependent on tight scheduling and procedural steps. After the technological and the transport-specific section of this phase, a large part of the training focuses on the goal of the mission itself, the experiments and research that will be conducted on-board. Astronauts learn the scientific objectives, experiment techniques and protocols of the projects they will need to follow from senior investigators. This way, the research quality output is maximised (Smith et al., 2023).

A last part of the training then focuses on the integration of the crew. Astronauts need to be able to work seamlessly with their crewmates and they prepare, often, their relationship on both a technical level (role in the crew, procedures) and human level (interactions, soft skills). This includes cross-cultural training for astronauts coming from different agencies, emergency simulations and team-building activities for long-duration missions (Landon et al., 2018).

This part of training uses high-fidelity simulations to simulate mission situations. Astronauts spend a lot of time in spacecraft simulators, participate in mission control team exercises, and undergo certification for all mission-critical duties. Most ESA missions are international, therefore astronauts train in Russia for Soyuz, the US for ISS and commercial vehicles, and Japan for Kibo module operations (SpaceX, 2021).

1.2.4 The Integrated Training System

As seen in the previous sections, the training program must be observed as a whole to understand the specific need of each of the three phases. The ultimate goal is to produce highly skilled individuals with a strong and transversal core of scientific knowledge, combined with the ability to closely work in a team and react to life-threatening life-or-death situations.

The European Astronaut Centre coordinates this training system's spread network of speciality institutions. Modern human spaceflight requires ESA astronauts to work with multinational crews and learn systems from many space agencies, hence the training is international (ESA, 2023). These training programs are developed and delivered employing Instructional System Design (ISD) concepts. This is needed to identify the learning objectives in such a vast scenario of activities, as well as matching training techniques and material while assessing the proficiency of the candidates. Astronaut training is in continuous evolution and uses modern techniques (simulation, AR/VR) (ESA, 2020) that need to be adapted practically every year.

It should be clear to the reader that the training program presents a number of challenges to deliver high-quality astronauts. Different agencies use different approaches, but the multi-phase program is generally widely adopted. This thesis analyses specifically ESA's Basic Training processes, which underpin all later development, and how management principles can improve handling the complexity of it.

Part 2: Theoretical Framework and Research Question

This section contains the thesis's theoretical core. It starts with a literature review standpoint on management principles (project, operation and service), both in a general landscape and applied to Basic Training. From the literature review the research gaps are observed and combined with the field observations coming from my internship at the European Astronaut Center (EAC) to produce the research question of this work.

This section represents the ground and theory steps in a grounded theory model on which this thesis is based. A more detailed outlook on the Methodology of this thesis will be provided in Part 3.

2.1 Literature Review

2.1.1 Project Management

successfully achieve the deliverables of a project. It is normal, in the execution of a project, to have a transitory effort to deliver a specific outcome (PMI, 2021). But in complex scenarios such as astronaut training, project management can provide structures that are necessary for a positive outcome.

PM theories usually structure a project lifecycle in five stages, from beginning to end: Initiation, Planning, Execution, Monitoring and Controlling and Closing. Each of those stages has its own methods and outcomes. In the Initiation stage, for instance, the project scope, objectives and stakeholders are defined. In the Planning stage the work is usually organised in workpackages that follow a Work Breakdown Structure, in which resources, periods and risk management techniques are explicitly outlined. The Execution stage is where the more technical work takes place and usually goes along the Monitoring and Controlling stage, which uses KPIs to measure progress. The Closing, happening at the end of the project, mostly focuses on documenting lessons learnt and archiving the outputs of the project (PMI, 2021).

Several techniques steer projects through these stages. Waterfall progresses sequentially from conception to delivery. Each phase depends on the outputs of the one before it, which works effectively when requirements are clear and unlikely to change (Royce, 1970). While the Waterfall model served as backbone for many projects in the past, many criticised its rigidity in not being able to adapt

requirements in fast-changing landscapes, such as software development. To overcome this limitation, the Agile model arose. Agile Manifesto (Beck et al., 2001) prioritises a flexible structure in terms of people assigned to a project, but also in adaptability and pragmatic solutions. Its objective is to reduce the monolithic complexity of the Waterfall model, dividing a project in a more iterative process. A proposed implementation of the Agile model is Scrum (Schwaber & Sutherland, 2020), where the work is structured in short “sprints”, with Product Owners that organise the priorities and goals for the sprints, Scrum Masters to coordinate and distribute the load on the team. It introduces rituals such as daily stand-ups meeting and sprint reviews to be sure to be able to quickly intervene in a flexible manner on unforeseen issues. Kanban (Anderson, 2010) is another Agile strategy, where the focus relies on restricting the amount of tasks in progress to enhance concentration and reduce context switching.

The aerospace industry, which is driven by rigorously defined requirements, to which corresponds to a quite heavy amount of paperwork, usually tends more towards Waterfall models and astronaut training is included in this category. Nevertheless hybrid models in curriculum design and training development can be considered.

Another important PM tool worth mentioning is the Earned Value Management (EVM), which, as the name suggests, is used to evaluate the project performance using scope, schedule and cost. It can be used to compute important metrics such as the Cost Performance Index (CPI) and the Schedule Performance Index (SPI), through which Project Managers can track Planned Value (PV), Earned Value (EV) and Actual Cost (AC). The importance of these indicators relies on the capacity to enable managers to detect early deviations and predict outcomes (Fleming & Koppelman, 2016).

Risk management is also another essential component in virtually any project and it particularly shines in safety-critical projects as often are space projects. It focuses on recognising possible deviations and hazards early, together with their likelihood and impact, producing mitigation techniques. Hillson (2002) suggests risk registers and probability-impact matrices.

In the specific context of aerospace projects and their unique constraints, usually space agencies use formal governance frameworks such as NASA’s NPR 7120.5 (cf. Appendix B) or ESA’s Instructional Development Process (IDP) to meet milestones, check readiness and minimise cascading failures in highly interconnected systems (NASA, 2015).

2.1.2 Project Management in Astronaut Training Programs

Astronaut training programs are managed like complex, multi-year projects. Agencies use formal development processes and lifecycle planning. For instance, ESA follows an Instructional Development Process (IDP) – a systems-engineering approach (analysis, design, development, implementation, evaluation) – to plan and build curricula (ESA, retrieved May 2025). This mirrors standard project lifecycles (phase reviews, readiness checks, etc.). The use of tools like ESA’s Astronaut Training Database (ATD) supports scheduling, course content management and feedback through all IDP phases.

Key project-management elements include planning and risk management. Training plans must align with mission manifests years in advance. NASA’s veteran astronaut Kjell Lindgren notes that ISS crew training “addresses a significant number of risks” (equipment failure, EVA hazards, launch/landing issues) and helps “buy down” mission risk (Lindgren, 2021). Accordingly, curricula are risk-weighted: more time is devoted to high-risk activities (emergency procedures, EVAs, robotics) and less to routine tasks, and “just-in-time” refresher training (e.g. instructional videos) is provided on-orbit for simpler procedures.

Budgeting and resourcing follow similar principles: e.g. NASA and ESA allocate specialised staff and simulators to training (astronaut offices often have hundreds of specialists), and commercial partners (SpaceX) now invest in dedicated training programs (see below). Team structure is multi-organisational: each agency’s astronaut center (ESA’s EAC in Cologne, NASA JSC, Roscosmos’ Star City, JAXA Tsukuba) runs its portion of training, often with contractual support (e.g. ESA and NASA use Boeing/L3 vendors for simulators). Training teams typically include instructors, curriculum developers, flight surgeons, and human factors experts. In project terminology, training cycles have clear phases. New astronaut candidates undergo basic training (~1-2 years) covering fundamental spacecraft systems and skills. Once mission-assigned, crewmembers enter an advanced (mission-specific) training phase (1-2 years) tailored to a particular flight. Each phase has reviews: e.g. training readiness reviews before deployment. This structured lifecycle ensures that by launch the crew is certified. Although few sources explicitly describe training project plans, the existence of formal processes (ESA’s IDP) implies disciplined planning and quality gate reviews are standard. Notably, NASA’s organisational guidelines (e.g. NPR 7120.5 and Flight Crew Operations policies) reinforce careful planning and integration with broader human spaceflight programs. Overall, agencies apply PM best practices (scope definition, stakeholder coordination, phased baselines) to astronaut training much as they do to spacecraft projects.

2.1.3 Operations Management

Operations Management (OM) is the discipline that provides corporate practices with the objective of maximising efficiency in its broader meaning. On a more pragmatic note, it can be seen as a model that finds the optimal employment of material and labour (minimisation) to produce goods and services (maximisation) (Heizer et al., 2020). Here is an overview over some OM fundamental concepts:

Lean management practices, developed originally by Toyota, have the objective to minimise overhead in favour of maximising customer value (Womack & Jones, 2003). According to this concept, many things should be kept into account for good lean management practices, such as overproduction, waiting, transport, overprocessing, wastes and inventory. A tool as Value Stream Mapping (VSM) is often used to optimise workflows.

Six Sigma was originally developed by Motorola and popularised by GE and it has the objective to eliminate production defects and reduce process variability using data-based approaches. An important concept in Six Sigma is DMAIC (Define, Measure, Analyse, Improve, Control), which is used to improve processes (Pande et al., 2000).

Total Quality Management is a management technique which focuses on the quality output through the analysis of the whole value chain, involving every actor. Its goals are to obtain long-term success through customer satisfaction and continuously improving the processes (Deming, 1986).

The Constraints theory goal is to improve the operational efficiency of a process by iteratively individuating its main limiting factors and taking decisions based on removing it. It has been shown to work effectively for removing training-specific logistical obstacles such as instructors availability and resources access (e.g. simulator) (Goldratt, 1984).

Continuous Improvement's philosophy is that the processes should be continuously improved and not fixed in stone. An example is the PDCA Cycle (Plan, Do, Check, Act), used as a quality control and continuous improvement cycle. The standard ISO 9001 includes it for iterative refinement (Deming, 1986).

Knowledge Management is the practice of retaining crucial operational information and making it accessible. Common methods are after-action evaluations, best practices repositories and mentorship (Nonaka & Takeuchi, 1995). The effectiveness in this case can be measured by throughput time and training completion time. A process that does not retain critical information will necessarily

require the personnel to spend more time on problems already solved in the past, which is highly inefficient.

2.1.4 Operations Management in Training Delivery

The day-to-day delivery of training employs operations management and continuous improvement techniques. Quality management is formalised: for example, the German Aerospace Center (DLR, 2021) Space Operations and Astronaut Training unit holds ISO 9001 (quality), ISO 45001 (health/safety) and ISO/IEC 27001 (information security) certifications (DLR, 2023). This indicates systematic QA processes for training facilities and data. Similarly, NASA's Safety and Mission Assurance office oversees quality in training (though not always publicised, all crew procedures pass rigorous validation). Knowledge management and feedback are critical. In this sense, ESA's ATD and curriculum libraries (ESA, retrieved May 2025) provide training materials, changes, and learner records. After each course, trainers collect student assessments and feed them back into the IDP evaluation phase. NASA also captures lessons learned from flights and simulators; for example, APPEL's "Critical Knowledge Insight" series reflects on how training mitigates ISS risks (Lindgren, 2021). SpaceX, in building its own program, even specifies "grading metrics and success criteria" to evaluate crew performance (SpaceX, 2021). Such metrics and after-action reviews form a feedback loop akin to a Plan-Do-Check-Act cycle in training operations. Process improvement follows from these feedbacks. Agencies periodically update courses to reflect design changes (e.g. new spacecraft versions) or mission lessons (e.g. post-Shuttle training for Soyuz operations (National Research Council, 2011)). For instance, ESA's robotics training now uses VR to improve efficiency (VR sessions can rehearse tasks in parallel to traditional simulators (ESA, 2020)). Even without publicly declared "Lean" or "Agile" programs, the training organisations adapt iteratively: courseware is revised after each ISS increment, instructors refine their teaching techniques, and facilities are repurposed (e.g. NASA donated many Shuttle trainers post-2011, and commercial partners now lease space for training). Overall, the continuous improvement mindset is embedded in the review/evaluation phase of training (e.g. ESA's IDP Phase 5 is formalised) and in agencies' quality systems (ESA, retrieved May 2025), (DLR, 2021).

2.1.5 Service Management

Service management is about planning, delivering, and improving services so that both providers and users benefit. It focuses on intangible outcomes, long-term relationships, and the shared creation of value between those delivering the service and those receiving it (Grönroos & Voima, 2013). It results in being especially

relevant in context such as astronaut training, since it requires expertise, quality and continuity over a long period of time.

Different models exist for delivering services, each with its own effects on organisational structure and risk. At one end, fully internal delivery uses permanent staff and in-house capabilities. This approach gives maximum control, preserves institutional knowledge, and keeps the work aligned with organisational culture and values. The trade-off is that staffing costs remain constant even during quiet periods.

At the other end, fully outsourced delivery shifts service functions to external providers. While there are undeniable advantages such as reducing costs and bringing specialised skills not available in-house, it can also cause issues in knowledge retention (Lacity et al., 2016), making OM harder.

Between these extremes is a hybrid approach. One example is the “Personnel-as-a-Service” (PaaS) model, in which contractors or small teams are brought in to handle specific roles. PaaS combines flexibility with some control over processes and results, making it popular in industries where highly specialised expertise is needed only occasionally (Kässi & Lehdonvirta, 2018).

The main challenge in any externally supported model is maintaining continuity and preserving knowledge. Solutions include standardised documentation (Hislop et al., 2018), structured handovers between providers, and blended teams of permanent and contracted staff. Service Level Agreements (SLAs) can formalise performance standards and knowledge transfer requirements, although their application varies by sector.

Each service delivery model carries different risks. While internal delivery increases risk, but allows for direct management and mitigation, full outsourcing shifts the operational risk on the suppliers, increasing the risk of losing core competencies. PaaS offers flexibility but can still create single points of failure if essential knowledge remains with contractors instead of being embedded in the organisation (Willcocks et al., 2015).

A well-known framework which was originally developed for the IT field is Information Technology Infrastructure Library (ITIL). It defines a Service Value System which focuses on finding a balance between the internal capabilities and externally provided services. It also defines an approach called SIAM (Service Integration and Management) which enables the coordination of multiple service providers while preserving core knowledge. ITIL focus on continuous improvement always applies regardless of the sourcing model used (Axelos, 2019).

2.1.6 Service Management Applied to Astronaut Training

When you look at astronaut training through the lens of service management, you see that each space agency has its own way of balancing three things: keeping skills sharp, maintaining continuity, and not spending more than it has to. Those choices say a lot about what each organisation values and how it manages risk.

NASA runs a mixed system. The leadership and coordination stay in-house with permanent civil service roles, but some of the technical instruction and simulator work is handed to contractors like Boeing and L3Harris. The point is to keep the core knowledge inside the organisation while still being able to bring in specialists when needed. It's a way of holding onto continuity without having to employ everyone full time (NASA, 2020).

In Russia, the Gagarin Cosmonaut Training Centre goes the other way. It's an internal service model through and through. Almost everything is done by permanent staff, which comes from its military background and the fact that they're training people almost all the time. That's partly cultural – it is how they've always done it – and partly strategic, because they want full control over every detail of preparing a cosmonaut (Zak, 2019). Outside experts do come in for some specialised topics, but they're the exception.

ESA, from what is publicly known, uses something different again. Training is spread across various vendors rather than being run by one big fixed organisation. That probably makes sense for them: astronaut selections can be a decade apart, so keeping a large permanent staff would be costly. ESA is also international and its facilities are scattered, so a centralised model would be tricky.

The service model you choose matters. If your system depends heavily on specific people, whether staff or contractors, then losing one of them can cause a real problem. Long gaps between astronaut classes make this even more risky, because knowledge fades if it's not stored somewhere safe.

When services are spread out over multiple suppliers, coordination is harder. Medical training might come from one place, technical systems from another, and without a single point of oversight it's easy for things to drift apart. Service management theory talks about end-to-end accountability, but that's harder to achieve when everyone reports through different contracts and structures.

Knowledge management is where this really bites. A lot of what astronauts need to know isn't written down, it's learned by doing. In contractor-heavy systems, that tacit knowledge can vanish when a contract ends or a trainer moves on (Miles,

2005). If there's no process to capture it, you end up having to rebuild that knowledge almost from scratch when the next class comes along.

And then there's quality. It is difficult to objectively compare the quality of the trainers. Spaceflight training is already complex enough and when it's spread across many different providers, tracking quality and learning from one cycle to the next becomes even harder.

2.2 Deriving the Research Question from Management Concepts applied to Basic Training and Field Observations

Applying the Project, Operations and Services Management principles seen so far to Basic Training together with a Research Gap analysis and my internship field observations, the Research Question and Hypotheses will be derived at the end of the section.

2.2.1 Field Observations from the European Astronaut Centre

By observing how the training of astronauts is organised in practice, the theories of project management, operations management, and service management were given a more definitive edge. In the period beginning in September 2022 and ending in December 2022, I held the position of Basic Training Coordination Assistant at the European Astronaut Centre (EAC). During those three months, I was able to observe the organisation in action, and the questions that would later serve as the foundation for my research were influenced by those experiences.

My arrival occurred at a time of transition, just prior to the announcement of the new astronaut class for the school year 2022. The numbers were still in flux; it was anticipated that there would be between four and seven applicants, and there was discussion of including a reserve group. The pressure to plan despite the fact that essential information was absent was tangible, and the anxiety was palpable as well. Those of us who were actively involved in the coordination of training did not always have a complete understanding of the situation. Some of the organisational limitations that I would later investigate in greater depth were brought to light by that experience.

2.2.1.1 *Operational Strengths*

One of the first things I noticed during my time at the European Astronaut Centre was the level of personal commitment from the people making Basic Training happen. From what I observed, the coordinator responsible for the programme

combined deep technical knowledge with an understanding of how other space agencies approach astronaut training. They seemed fully motivated in delivering a high quality work, making the whole process running smoothly and often managing a wide range of tasks beyond their formal remit.

This dedication wasn't limited to one person. ESA's internal instructors, from what I saw, frequently went out of their way to make the training work – scheduling extra practice runs, adjusting their timetables, and stepping in to solve problems as they appeared. It left the impression of a team willing to adapt and support each other to deliver high-quality outcomes.

I also found that the facilities were sophisticated. The training environment seemed to me well-equipped, with a special pool called Neutral Buoyancy Facility for extravehicular activity (EVA) practice, high-fidelity (human sized) mock-ups of the International Space Station and modern classrooms. While I have been told that these might not match NASA's facilities in scale, my impression was that they provided everything needed to support Europe's training requirements effectively.

Another element that stood out was ESA's use of external instructors drawn from universities and the private sector. Given that astronaut candidates came from a broad mix of professional backgrounds – medicine, engineering, the military – this approach appeared to bring in subject matter experts who could also teach effectively. From what I saw, this helped ensure the training stayed relevant, adaptable, and able to bridge the diverse skill sets of the candidates.

2.2.1.2 Structural Vulnerabilities

It was evident to me that the coordination of Basic Training was mostly dependent on one person. In addition to the assistance I could provide as an intern, this person was working long hours, responding to practically all inquiries relating to training, and managing a large number of details all by themselves. My observation is that it did not seem a resilient approach. Due to the fact that the coordinator is a contractor for ESA and not a permanent staff member, people in higher positions within the organisation were in charge of certain components of the program, such as the budget and the contracts. Because of this, the coordinator who was responsible for the majority of the day-to-day coordination did not always have the decisional power to make choices, which resulted in conflicts and delays.

2.2.1.3 The Knowledge Management Gaps

My observation that there was a dearth of formal documentation was one of the most striking themes I saw. Through verbal communication, everything from the planning of dry runs to the coordination of volunteer participation was communicated. Not only were there no documented processes, but there were also no manuals or centralised instructions. This meant that any new person who took over the function had to be instructed in everything from the ground up, which was a time-consuming process that also posed the possibility of crucial facts being forgotten.

It did not appear to be a coincidence that there was no documentation; rather, it appeared to be a well-established method of operation. However, this also meant that the program was heavily dependent on the memory and goodwill of a small number of persons, which is not a model that can be maintained over the long run.

2.2.1.4 Bridging Observations to the Research Question

In the course of several months at the EAC, a constant act of balance was exposed. ESA, on the one hand, possesses people who are very talented, a robust infrastructure, and access to expertise of the highest calibre. On the other hand, there are a few of the systems that are supporting them that might be improved, specifically the structure of the team, the authority to make decisions, and the management of knowledge.

Despite the fact that it provided flexibility and variation, the external instructor approach also made coordination more difficult. The integration of people who were brought in for short-term modules was not always as easy as the integration of permanent workers, which could have an impact on consistency and the retention of information.

In a nutshell, the individual commitment and expertise of those who are involved in the program is largely responsible for its success and success in general. However, the long-term viability of the organisation will be contingent on the development of mechanisms that provide support to those individuals in the same manner as they provide support to the astronauts that they train. This set of observations served as the foundation for my research, which led me to enquire about the ways in which management concepts could assist ESA in enhancing an already excellent training program in preparation for the difficulties that lie ahead.

2.2.2 Management Principles applied to Basic Training

2.2.2.1 *Project Management applied to Basic Training*

From a management perspective, a project is a temporary effort with a clear start and finish, set up to produce a specific result. It's usually defined by three limits: scope, time, and budget. ESA's Basic Training (BT) fits, to the best of my knowledge, that definition fairly well. It's a one-year program, started only when a new astronaut class is selected. Each run is different, carries real risks, and is central to ESA's human spaceflight ambitions.

Some elements of how BT is coordinated look like Agile project management, though this seems to be more a matter of necessity rather than deliberate design. Agile is about flexibility, small steps forward, and quick responses to change, rather than rigid up-front planning. In practice, BT has to constantly adjust to shifting schedules from NASA, JAXA, and other partners, as well as trainer availability and technical updates.

That flexibility, though, isn't the same thing as the previously seen formal Agile. Proper Agile methods come with set roles, stable cross-functional teams, and regular structured rituals. BT doesn't have those, mainly because it doesn't have a proper project team in place. The reality is closer to a reactive, adaptable style that's responding to a messy and unpredictable environment, not a strategic choice to run things "Agile."

When you hold it up against formal frameworks like those from the Project Management Institute, the gaps show. The biggest one, from my observations, is that the entire program rests on a single person's shoulders, which is a single point of failure. There are several evident risks in this approach. For instance, all the critical knowledge, contacts, and experience sit with one person: if they leave, so does the knowledge. They can also become a bottleneck, slowing decisions and logistics. Furthermore they're forced to cover everything from instructional design to procurement, which means no deep bench of specialised skills and there's no way to scale up if astronaut numbers grow or missions become more complex.

It also seems that there is no dedicated budget. Without one, there's no real way to plan long-term, measure financial performance, or weigh the cost versus benefit of upgrades like new simulators or e-learning tools. Spending is reactive, tied to year-by-year discretionary decisions. That makes it hard to invest in infrastructure and impossible to keep a steady pace of improvements.

The combination of an alone coordinator and no fixed budget knocks out many of the project management basics: formal risk management, clear stakeholder plans, structured procurement, and scoped work breakdowns. It's a fragile setup for a role as important as astronaut training.

2.2.2.2 Operations Management applied to Basic Training

Even if BT runs as a discrete project each time, the ability to deliver it is really an ongoing responsibility. That's where Operations Management (OM) comes in. It can improve processes over time to make them more efficient, more reliable, and higher in quality. Ideally, each new BT run should be better than the previous one because the organisation has learned from experience. Right now, it does not seem to be clear how this is happening.

While there seems to be some ongoing adaptation, it usually seemed focused on the curriculum such as keeping the content current with technology updates like the Lunar Gateway systems or new mission goals. That's important, but it's about what is taught, not how the training is organised and delivered.

The real gap would be that each cycle starts fresh. There seems not to be a formal mechanism to connect one BT to the next, which means valuable knowledge could get lost. People might spend time rediscovering processes and re-establishing contacts instead of building on what's already been done. It's what you might call "corporate amnesia," and it wastes intellectual capital.

A proper knowledge management system could prevent that. The long gaps between astronaut classes and the reliance on one coordinator make the absence of such a system even more costly. Without it, each cycle is a rebuild rather than a refinement.

From my observations it also arises that methodologies previously seen, like Lean Six Sigma, do not seem to be in place. That would mean no mapping of the value stream to see where work adds value and where it doesn't, no root-cause analysis for recurring issues like delays, and no effort to reduce variation so the process runs predictably. Without this, inefficiencies would keep repeating.

2.2.2.3 Service Management applied to Basic Training

From what I observed, ESA's Basic Training seems to apply service management principles in a way that leans toward flexibility and cost control during long inactive periods, while accepting certain trade-offs in how operations run. This section shows how service management concepts might improve in BT, based on what I saw during the field research.

BT can definitely be seen as a very specialised and niche-knowledge service, turning candidates astronauts into professionals ready for a mission. But unlike most services, where standardisation and repeatability drive efficiency, each BT run needs to adapt to changing technologies, science priorities, and mission needs. That constant adaptation creates a tension: on one hand, standardisation would

make training more efficient; on the other, customisation is needed to keep it relevant.

From my time at EAC, it appeared that the training is delivered by multiple providers, without a single service structure tying them together. That kind of fragmentation can make it harder to ensure clear ownership and accountability for the whole process. If coordinators don't have visibility over all the moving parts, including what other providers are contracted to do, it's tough to guarantee a fully coherent service.

ESA's approach seems to sit somewhere in the middle of the service delivery spectrum. It doesn't keep a large permanent in-house team, and it doesn't outsource everything to one integrated provider either. Instead, it relies heavily on individual experts – contractors who work closely with the organisation but aren't embedded as permanent staff. That setup has its own quirks.

For example, a service coordinator might be responsible for delivering the training but not have a dedicated budget or team to work with. In service management theory, that's not ideal – owners are generally expected to control the resources needed to do the job. In BT, contractors bring deep subject expertise but often work in isolation, with no clear backup if they're unavailable. Concentrating so much know-how in individuals rather than teams can make cross-functional integration harder, especially in something as complex as astronaut training.

It also seems that ESA is trying to maintain service continuity through decade-long gaps without the usual infrastructure for that – no permanent staff in key roles, no formal knowledge repository, and no consistently applied processes. As a result, every new BT run may require a lot of redevelopment just to get back up to speed.

Another thing I noticed was the lack of a formal system for measuring service performance. Quality, as far as I could tell, is maintained mainly through the professionalism and commitment of the people involved. But without agreed service level expectations, efficiency metrics, or benchmarks, it's harder to demonstrate value, pinpoint areas for improvement, or argue for more resources. In most mature service management frameworks, regular measurement and feedback loops are considered essential.

The personnel-based approach I saw seemed to concentrate several types of risk in ways that would raise red flags in traditional service management. It seems that the execution can depend on individual availability, which might require personal effort to reach the desired target. While this can be effective in the short term, it is not scalable nor sustainable. It is fundamental that the knowledge of the contractors is preserved and accessible to future iterations. Without it, it could be harder for ESA

to adapt to new types of training or quickly organise a new one. And while the model keeps fixed costs low, a considerable advantage, it might hide inefficiencies such as redevelopment or extra coordination effort.

Other knowledge-intensive fields handle similar challenges by blending flexibility with stronger continuity measures. Professional services firms often keep a small core team and call in specialists when needed, but they invest heavily in knowledge systems and standardised processes. An example could be taken from universities, which often work with rotating adjunct staff, but within a framework that should preserve the curriculum. In healthcare temporary staff is often employed, but managed by an ad-hoc governance structure. These examples suggest that PaaS can work well in the case of BT if paired with correct service management principles.

2.2.3 Research Gap and Contribution

From reviewing the literature, it became clear to me that while project, operations, and service management are well-established fields, they have rarely been applied directly to astronaut training organisations. This gap shows up in several ways.

Much of the space industry management research focuses on spacecraft design, mission operations, or technology management. Key works address project management for engineering programmes (Larson & Wertz, 2018), risk frameworks for space missions (Stamatelatos & Dezfuli, 2011), and systems engineering practices (NASA, 2016). In these sources, human spaceflight training is often treated as a small subtask rather than a complex organisational challenge in its own right. Training tends to appear as a line item in a Gantt chart, not as a knowledge-intensive process that demands its own management model.

On the human factors side, there is detailed and valuable work on astronaut training content, teaching methods, and psychological adaptation (Landon et al., 2018; Slack, 2016). These studies are strong on “what” to teach and “how” individuals learn, but they say much less about the organisational machinery needed to deliver that training effectively. The absence of research linking educational quality to organisational efficiency leaves agencies to improvise their management approaches.

Established frameworks in project and operations management (Kerzner, 2017; Heizer et al., 2020) could be relevant, but I found very few cases where they were applied to astronaut training. The cyclical nature of astronaut selection –

sometimes with a decade or more between classes – does not fit neatly into either paradigm. Traditional project management assumes a one-off timeline; operations management assumes continuous delivery. Astronaut training lives somewhere in between, and that in-between space is largely unaddressed in the literature.

Service management, particularly the strand on knowledge-intensive business services (Miles et al., 2018), offers another way to think about delivering and sustaining expertise. But I could not find any examples of service management theory applied to government-run, mission-critical training programmes. One notable blind spot is how to keep service quality and retain institutional knowledge during long dormant periods, especially in public sector contexts with strict budget cycles.

Modern astronaut training is also multinational, which adds layers of complexity that aren't well covered in current management research. International project management and cross-cultural team literature (Köster, 2010) helps with some of the theory, but training astronauts from multiple agencies – each with its own culture, language, and operational style – is not quite the same as running a standard multinational business project. Studies on strategic alliances (Contractor & Lorange, 2019) offer useful principles, but they stop short of dealing with how to prepare multinational crews for high-stakes, life-support-critical missions.

This research is my attempt to begin filling that gap. The contribution is both theoretical and practical. By looking at ESA's Basic Training through the combined lenses of project, operations, and service management, I've tried to adapt these frameworks to a context defined by long cycles, high risk, and concentrated expertise. I believe these insights could be relevant beyond spaceflight, especially in sectors where project timelines are lengthening and specialisation is becoming deeper.

From a practical side, the work offers space agencies evidence-based ideas for strengthening their training organisations, drawn from ESA's current practices and international comparisons. With human spaceflight moving into a phase of more commercial involvement, lunar operations, and preparation for Mars, the need for robust, scalable training systems will only grow.

I also think the interdisciplinary nature of this work has value for management scholarship. By exploring an extreme case – where failure could have catastrophic consequences, expertise is rare, and operational cycles can span decades – it may provide lessons for other high-reliability, knowledge-intensive organisations. The kinds of challenges I've seen here could be relevant to sectors managing critical

infrastructure, developing breakthrough technologies, or preserving specialist skills for rare but vital missions.

Finally, the research approach has been a useful way to work in a specialist, access-restricted environment. Large-scale surveys or experiments aren't possible here, but combining direct observation with theory and comparison has produced insights I think are both credible and actionable.

In that sense, the work tries to bridge a gap that matters both to the space sector and to the wider field of management research. It is, as far as I can tell, the first integrated management analysis of astronaut training, and I hope it offers a foundation others can build on.

2.2.4 Research Question and Hypotheses

The flaws highlighted through the operation and service management principles observed so far are not separate: they are instead deeply linked to each other.

As a result of my observation of the absence of a project budget known to the coordinator and team, there are no resources that have been designated for activities that occur between cycles. The consequent result is that the essential operations management functions of knowledge management and process optimisation are unable to be carried out. This information is lost whenever a project is not formally concluded with an examination of the lessons learnt from having completed it. The next ad-hoc project, which would begin several years later, will have to begin from a similar standpoint as the previous, which might result in the repetition of previous errors and inefficiencies. Consequently, this limits the accrual of institutional knowledge and locks the process in a state of immaturity in terms of its operational capabilities.

The fundamental study issue is logically derived from the juxtaposition of field data against known management theory, as well as the synthesis of the major shortcomings that were recognised earlier. The purpose of this thesis is to go beyond merely recognising problems and instead propose remedies that are both realistic and structured. Through the formulation of a primary research question and a collection of testable hypotheses that are drawn directly from the analysis, the investigation is formalised.

The following is the Research Question that is the motivating force behind this thesis:

How can the systematic application of integrated Project, Operations and Service Management principles transform the ESA Astronaut Basic Training

from a series of discrete, high-risk assignments into a resilient, scalable, and continuously improving operational program?

The hypotheses that are formulated after that are as follows:

H1 (Project Management): The implementation of a dedicated, budgeted cross-functional project team for each Basic Training instance would significantly increase process efficiency, mitigate single-point-of-failure risks, and enable more effective resource allocation and strategic planning.

H2 (Operations Management): Establishing a formal Knowledge Management system and a continuous process optimisation loop between training cycles would reduce the lead time and cost for organising subsequent training, while increasing the overall quality and effectiveness of the curriculum delivered to ASCANs.

H3 (Service Management): Maintaining a base of permanent staff aided by service providers will improve the distribution of responsibilities, internal knowledge and budget management, reducing at the same time risks for failures in each training cycle.

In order to provide an answer to the research question and put these hypotheses to the test, this thesis will work towards the operational objectives that are described in the research plan, which are here:

Document and assess the existing organisational procedures of BT in a methodical manner, using direct observation and experience gained at the EAC as the basis for your analysis.

1. Systematically document and analyse the current BT organisational practices based on direct observation and experience at the EAC.
2. Perform a qualitative comparison of these practices against the state-of-the-art in project and operations management literature.
3. Validate or disprove this analysis through structured interviews with key ESA personnel.
4. Make a case study for comparison of the ESA process against other agencies such NASA or Roscosmos using publicly available data.

Part 3: Methodology

This chapter describes the methodological framework used in this thesis. The objective is to provide the reader with a clear view on how the research is conducted and showing what is the process with which Part 5 produces an answer and operational recommendations to the research question outlined in Part 2.

The methodology described here bridges the theoretical and empirical research. Its goal is to make sure that the results are pertinent, legitimate, and credible.

The research core of this thesis is that the ESA Astronaut Basic Training (BT) is a hybrid program that functions as both an ongoing institutional process and an ad hoc project, but without a strong project management approach. This study requires a multidimensional methodology to incorporate several data types from multiple sources for a useful understanding of the phenomenon.

The following parts address the research philosophies underlying this work, the justification for selecting a qualitative case study methodology, and a detailed description of the techniques used for data collecting and analysis. Each decision made here is designed to ensure the best approach for addressing the main research question.

3.1 Research Philosophy and Design

This thesis uses a research model that is a cyclical and iterative interaction between practical field experience and established academic theory. It is particularly appropriate for management studies, as the aim is not only to describe a situation but to analyse it with the intention of suggesting operational recommendations. The technique can be characterised as Grounded Theory, developed by Glaser and Strauss (Tie et al., 2019) and built around several processes, not really successive but iterative:

First, there is a concurrent data collection and analysis. This was done first via observations, as the research was designed and established by direct immersion in the professional field. The internship was performed at the ESA European Astronaut Centre (EAC) in the Astronaut Training team as Basic Training Coordination Assistant. It allowed the delivery of initial observations, data, and a general context that were used for memoing. This phase enabled an unfiltered description of the current procedures, issues, and stakeholder interactions, which contributed to the development of the initial problem statement.

Then, entered the research of established academic theory. It allowed for the structuration, evaluation and analysis of those field observations. We could apply

this research to the specific context of ESA Basic Training, which helped conceptualise the research question and hypotheses. In this thesis, Part 2 illustrates this process. In this phase, the raw observations of the BT process were carefully examined using originally only the frameworks of project management and operations management. This theoretical framework helped the conversion of anecdotes into a methodical study of particular issues, like the lack of a defined budget and an established knowledge management system.

Next, there was a new cycle of data collection and analysis, for the validation and confrontation of the concepts. This was performed through the first interview, which will be developed in the next section carried out with Dmitriy Churkin, Basic Training Coordinator at ESA (cf. Appendix C). It enhanced the analysis by comparing the state-of-the-art concepts with the professional opinion of personnel working in the organisation. The semi-structured interview ensures that the study remains grounded in reality and the operational recommendations established later are relevant and realistic.

As it has been established, constant comparison method is the basis of grounded theory (Politz, 2025). Therefore, the Literature Review was updated with the new notions brought up by Churkin, with Service Management becoming one of the key features of the work.

Those new notions, both from the interview and the added theorised concepts, needed also to be validated and confronted by collecting new data. This approach is characterised as theoretical sampling, with previous information dictating the next path for data collection. Thus, Tom Hoppenbrouwers – a former astronaut instructor likewise working as a contractor for ESA – provided the second interview, also developed in the next section.

To continue with theoretical sampling or reach theoretical saturation – when new sources of information consistently give you the same answers as previously (Politz, 2025) – the intention was to interview an ISD from ESA also hired as a contractor, but he refused. A possible explanation will be developed in the Methodological limitations mentioned after (cf. below p. 39). Then, to get a possibly contrasting opinion on the same topic, the intent was to interview the Astronaut Training team lead, which is particularly relevant for this research as he is ESA staff, but he did not answer the request.

Within the context of this framework, the research design that is most appropriate is a qualitative, exploratory single-case approach.

Qualitative research attempts to understand the "how" and "why" of the processes implemented at ESA. It is focused on the aspects of human and organisational behaviour which cannot be conveyed only by quantitative measurements.

It is an exploratory study because there is very little academic research – whether available to the public or internal – on the management processes of astronaut training. The purpose of this thesis is not to confirm existing ideas and hypotheses, but to obtain new insights and formulate hypotheses for future research.

More specifically, it is a one-case study research method. It provides a comprehensive and in-depth analysis of a specific subject, the process of the European Space Agency's Astronaut Basic Training.

3.2 Data Collection: A Multi-Stage, Mixed-Method Approach

This research makes use of a multi-stage data collection approach, with each stage corresponding to a phase in this research framework. The goal of this research is to construct a data gathering method that is both comprehensive and triangulated.

During my internship at the EAC, I participated in participant observation, which allowed me to collect the data that will serve as the basis for this thesis. This allowed me to get a privileged day-to-day grasp on the organisational aspects of the 2022 Astronaut Class Basic Training.

Covering the role of coordination intern I had the possibility to work side to side with the ESA Basic Training Coordinator and get direct insights into scheduling, resources allocation and interactions with instructors, management and administration. This allowed me to produce a collection of notes and observations, which were also the incipit of the thesis. This constituted the first raw data on the process, through which was possible to make a first guess on possible vulnerabilities of the process.

Being part of the process that I am trying to improve, I am aware that this research cannot elude a potential bias. A mitigation to this was made through an effort in highlighting my own subjective readings and the more objective data. My readings, presented in Part 2, are not presented as facts. Instead they pose the foundations to generate, together with the research gap and literature review, a research question.

The second stage of the process follows a more theoretical and rigorous approach.

In order to evaluate the effectiveness of the ESA's current procedures, it was necessary to create a solid theoretical standard to measure against. This made it possible to identify particular gaps between the reality that was observed and the best practices that had been established during the years.

Academic resources (such as Google Scholar, Scopus, and university library portals) and professional sources (such as publications from the Project Management Institute) were utilised in the process of conducting the review.

Following the deconstruction of the BT process, which was made possible by the conceptual tools and terminology that were provided by this review, the organised analysis of flaws that was outlined in Part 2 of this thesis was executed.

The "second terrain" study is aimed to confront the theoretical analysis with the expert opinions of individuals who are actually involved in the BT process. The third stage is the centre of the research. As the major method for this stage, semi-structured interviews were selected as the method of choice. Using this format strikes the perfect mix between the structure that is necessary to guarantee that all of the important study topics are addressed and the flexibility that is necessary to investigate fascinating responses and make room for the development of discoveries that were not anticipated.

The respondents were selected according to a principle of relevance to the thesis research question and their limited availability. The final cohort is composed of the following two candidates:

- **Dmitriy Churkin**, current ESA Coordinator of Astronaut Basic Training: Dmitriy Churkin is an aerospace specialist who works as a contractor for the European Space Agency. He is well known for his contributions as a technical expert and content designer on training and informational materials related to Soyuz flight operations. These materials include launch, re-entry, docking, and landing for ESA astronaut training modules. In addition to his past experiences, he has held the position of division head of the Mission Control centre at Roscosmos, which is a position that contributes to offering insight on the international environment.
- **Tom Hoppenbrouwers**, Former ESA Payload Instructor: During his ten years of service as a contractor for the European Space Agency, Tom Hoppenbrouwers held the position of Payload Instructor, which is a subcategory of the field of Increment Training Instructor.

To proceed in a systematic way, the interviews have been structured following a thematic approach, tailored to the specific interviewee. The objective is clear: extracting the comprehensive view on ESA training procedures. The questions are open-ended and have been provided to the subjects beforehand via email. The themes vary from a view on the procedures, structures to opportunities for improvement according to their vision. The questions are available in Appendices C and D.

The chosen interview methodology is a meeting, which has been in both cases conducted remotely. An audio recording of oral interviews is going to be done, but only after receiving explicit informed agreement from each participant. Their transcript is available once again in the Appendices C and D.

Additionally to the interviews, a case study is presented for a comparison of the organisational models of NASA and GCTC, to be compared with ESA, using publicly available material. The purpose of this analysis is to contextualise the findings from different perspectives which offer the possibility for benchmarking.

It is not the intention to carry out a comprehensive comparative case study, which would be impossible to accomplish given the restricted access that the general public has to internal procedural documents. The objective is instead to identify possible improvements in the comparing models and integrate them through recommendations to ESA. Additionally, it is well accepted that this data is frequently filtered for the goal of public relations, and it is possible that it does not accurately reflect the complete operational reality. This information will be utilised with caution, with the primary objective being to extend the field of possible solutions.

3.3 Data analysis: A thematic approach

The qualitative data gathered from interviews and field observations demanded an analytical approach that could handle both the complexity of organisational dynamics and the practical constraints of the research. The process that emerged was iterative rather than strictly linear, moving between close reading of transcripts and theoretical consultation.

The analysis began by reading iteratively my notes and the interview material. This approach was needed to not only comprehend the interviews, but also to understand implications and interconnections among the topics discussed in the thesis. Churkin's responses carried seventeen years of coordination experience, while Hoppenbrouwers brought a different perspective from a decade of instruction. Reading their transcripts together revealed how the same organisational realities looked quite different depending on one's position in the training pipeline.

During these initial readings, certain passages stood out as particularly significant. When Churkin described continuing work during medical leave with only intermittent colleague support, this revealed something important about organisational resilience – or its absence. Similarly, Hoppenbrouwers' observation about feedback disappearing into "a black hole" wasn't just a complaint but

evidence of systemic knowledge management failures. These moments in the data seemed to crystallise larger organisational issues.

The next phase involved identifying and grouping related observations across both interviews. This wasn't a mechanical coding exercise but rather an interpretive process of recognising connections and patterns.

Some patterns were rather obvious, while others required multiple reading passages of the transcripts.

To generate themes from them, I had to find a good level of abstraction. If the themes were too general, they wouldn't be able to explain anything; if they were too detailed, they would miss important connections. The theme of "knowledge management gaps," for example, covered a wide range of issues, from the lack of recording systems to feedback loops that don't work, but it was still specific enough to lead to useful insights.

The theory framework set up in Part 2 was used as a lens for analysis throughout this process. Some coordination problems could not be explained by principles of project management; ideas of operations management shed light on the costs of losing knowledge between training cycles. Still, the data made these systems more difficult to understand and use. For example, ESA's service model didn't quite fit any textbook description. Instead, it worked through a unique mix of individual expertise and unofficial ways of getting things done.

The comparative analysis with NASA and GCTC provided crucial context for interpreting ESA's practices. These comparisons helped distinguish between inevitable difficulties and addressable structural problems.

Writing up the findings required balancing analytical coherence with fidelity to participants' experiences.

Direct quotations are used in the thesis to give the reader a more direct feeling of the tone of the interviewees, without the filter applied by paraphrasing.

The goal was to construct a narrative that made theoretical sense while constructing an incremental argument.

The themes that emerged and are presented in Part 5 represent my interpretation of the data, until the lens of management theory, but ultimately backed by the concrete experiences of the trainers.

While the approach of this thesis is systematic, the analysis remains interpretive, with the goal of generating pragmatic insights, which can be ultimately implemented, specifically for ESA. This style was the most adapted to synthesise

together the theory and the empirical observation into operational recommendations.

The resulting findings offer a particular reading of ESA's training organisation. Hopefully it provides both explanatory power and practical value for those working to strengthen Europe's astronaut training capabilities.

3.4 Methodological Limitations

All study designs have limitations, and it is important to recognise them.

The first one is researcher prejudice. The internship – even though it allowed for data collection untainted by an academician's own prejudice – could bring some bias. It can come up in the form of the people I interacted with, or lacking some vision on specific aspects of the topic. Some solutions to address this constraint are the use of varied data sources (triangulation) and a reflective methodology.

Then, there is the lack of publicly available documentation on the topic. Astronaut training, especially the phases where training sharing with other space agencies is not an international requirement, is kept secret. Space agencies carefully select the nature and content of information they publish, and they are not keen on sharing internal procedural records either. The conclusions must be interpreted as contingent on the data provided and the author's interpretation of it.

Next, there is the sample size. Since this research is qualitative, the number of respondents is limited. It is especially the case in this particular thesis as the topic is extremely specific and niche. The general population cannot answer those questions, nor even experts in human spaceflight not involved in astronaut training. This implies that the conclusions brought by the interviews cannot be blindly generalised.

Finally, there is the standing of ESA as an institution and authority. It creates difficulty for the people it employs to criticise it. It is especially true in the case of contractors, whose service contracts with ESA could be terminated at any time without a valid justification. Furthermore, there are very few people working on astronaut training at ESA and most of them have distinct positions. This nullifies any hope for confidentiality and makes people reluctant to give interviews. Providing recommendations means acknowledging issues without prompt, which is not something public institutions have a habit of doing – or condoning.

3.5 Ethical Considerations

This study complies with academic ethical standards, recognising the delicate nature of research. All interview participants received a comprehensive description of the research aims and the intended use of the data and provided their consent.

It is also recognised that the space training, and in general space technology, is often treated confidentially as it might be considered as a field where to gain competitive advantage between countries. This thesis makes mostly use of publicly available material together with the agreed interviews provided by Churkin and Hoppenbrouwers.

Part 4: Data collection

This chapter pulls together the evidence I gathered to understand how ESA's Basic Training is organised and to see whether the ideas I outlined in Part 2 hold up. The material comes from three different but complementary sources: long interviews with people directly involved in running and delivering astronaut training, a look at how other space agencies organise their own programs, and my own time spent on the ground at the European Astronaut Centre. Each offered a different lens on the same central question.

The interviews with Dmitriy Churkin and Tom Hoppenbrouwers stood out. Churkin, who has been at the heart of Basic Training for seventeen years, gave me the “upstream” view on how the program is planned, the constraints it faces, and the workarounds that keep it going. Hoppenbrouwers, with a decade of experience as a payload instructor, showed me what those same constraints look like further down the line, when training becomes more mission-specific.

Alongside their perspectives, I also examined public information on NASA's and the Gagarin Cosmonaut Training Centre's approaches. Taken together, these sources paint a picture of a system that runs largely on the dedication of the people involved, rather than on any carefully engineered organisational model. What emerges isn't just a list of flaws, but a more complete understanding of how ESA has managed to train astronauts successfully, often in spite of improvable processes. The following sections go deeper into that evidence, showing where the strengths lie, and where the cracks could threaten future performance.

4.1 Interview with Dmitriy Churkin – ESA Basic Training Coordinator

The interview with Dmitriy Churkin (cf. Appendix C) provided comprehensive insights into the organisational structure of ESA's Basic Training coordination. Having served as coordinator since 2007, Churkin offered an extensive perspective on the program's evolution and current operations. The interview data revealed key characteristics of the organisational model: the basic training operates through a service contract arrangement rather than as a formal project structure, with coordination managed by a single individual working through a contracting company (Space Applications). Churkin described the operational framework, which involves coordinating multiple stakeholders without direct authority relationships or visibility into their contractual arrangements. The interview

documented instances of operational continuity challenges, including periods where coordination continued during the coordinator's absence through informal support arrangements with colleagues. Churkin presented his perspective on potential organisational alternatives, suggesting a project-based structure with defined resources and systematic knowledge preservation mechanisms.

4.1.1 Detailed Thematic Analysis of Interview Content

The interview lasted two hours and produced a noticeable amount of data. The data has been organised into thematic areas to be presented here.

4.1.1.1 *Theme 1: Organisational Structure and Reporting Relationships*

Churkin's responses provided detailed information about the position of ESA on service management where, 10 years ago, the model switched towards a tendency in hiring external providers.

Regarding team composition, Churkin noted the complexity of defining team boundaries: "Well, it's also hard to say because I'm not talking about just coordination. I'm talking about the basic training as our big task." He identified different groups of people cooperating, from training administrators and instructors, to international partners and IT support. Each one of them works under different contractual agreements which are not transparent, making the cooperation sometimes cumbersome, especially for the coordinator.

He characterised the current arrangement as having "no real authority, no real power" within the coordination role, with limited access to information about other stakeholders' contractual obligations. The service hierarchy places the coordinator at an operational level, with the service manager located "one or two levels above the work package manager" in the contractor's organisational structure.

4.1.1.2 *Theme 2: Budget Structure and Resource Allocation*

The interview revealed specific details about the financial arrangements for basic training.

The interview provided an interesting insight on the financial side of basic training.

Churkin stated: "Does the basic training programme currently operate with a defined dedicated budget? I explained it to you that you don't have no access." This indicates that budget information remains at the management level rather than the operational coordination level, most likely due to a distinction between permanent staff and contractors.

The coordinator then proceeded to explain how different people involved in the training were also compensated in various ways. External instructors, for example, have separate contracts while the medical team operates under an independent contract. This could create situations in which it is difficult to coordinate the staff remaining in the contractual obligations.

When asked about the total cost of Basic Training Churkin noted "If somebody asks about the allocated budget and how money we have spent, so this would be a tricky question because the money, the real money it was coming from the different contracts." This reflects how the distributed funding model in this service-based approach contributes to an obfuscation of crucial project data, not available at coordination level.

4.1.1.3 Theme 3: Knowledge Management

This theme focuses on the issues arising from the extended inactive periods between astronaut selections. Churkin estimated that "50 to 70% of the training needs to be redeveloped" for each new cycle, which indicates a major content evolution between each cycle, due as well to technological evolution. The current documentation consists primarily of schedules, course catalogs, and presentation materials stored in the Astronaut Training Database (ATD).

The interview revealed that feedback is collected from astronauts through electronic forms. Churkin noted, though, how "this feedback never materialises as the lessons learned", showing a clear gap between the data collection and its analysis. He added that "there's no such a culture of lessons learned, unfortunately in the current organisational model.

4.1.1.4 Theme 4: International Coordination Frameworks

The interview provided insights into international collaboration dynamics. Churkin described attempts to update the international requirements document originally created 20 years ago: "All the international partners refused." This led to requirements being developed primarily internally with input from available instructors.

Basic training is a particular phase of astronaut training as it is the responsibility of each space agency alone to provide it. It must still prepare astronauts for international operations. Pre-assignment and increment trainings both involve integrated international teams, with parts of training occurring at different space agencies' training facilities.

Information sharing between agencies varies significantly. If NASA is somewhat open to sharing some information, Churkin explains that Roscosmos is very closed-off.

4.1.1.5 Theme 5: Operational Procedures and Adaptation Strategies

Churkin elaborated on several operational tools and procedures used to manage training coordination. These contain extensive long-term planning spreadsheets organised "week by week and even day by day" to coordinate instructor availability and facility access. Those tools are especially important as external instructors must be scheduled "many months in advance."

Schedule management is an iterative process, with Churkin mentioning sometimes reaching "revision 15" of weekly schedules due to changing demands from people. This reflects how dynamic the training coordination environment is.

The topic of overtime recurred, as Churkin explained often having to work during vacations and medical leave. As the only coordinator and organiser, he explains it was sometimes the only way to make sure the necessary work was done on time. This personal commitment has maintained operational continuity despite the lack of formal backup procedures.

4.1.1.6 Theme 6: Future Considerations

The interview explored ideas on the future of astronaut training. Considering the rapid growth of technology, Churkin expressed uncertainty towards the maintainability of the current astronaut training model: "Maybe for the Artemis programme... the basic training might be very much reduced or even gone." This is emblematic of the view of Churkin on the role of astronauts and their training in the next future. With spacecraft automation and AI, the astronauts will probably shift towards a more science based curriculum, moving away from the classical "military-pilot" background which characterised the field since its beginnings. The emergence of commercial companies, on top of things, seems to be a possible cost effective and efficient solution for the future.

He presented a vision for potential commercialisation where ESA would not provide training itself but set standards for private companies, in a similar fashion to the aviation industry. This proposed approach recognises the changing dynamics of human spaceflight and its consequences for training organisations.

4.2 Interview with Tom Hoppenbrouwers – Former ESA Payload Instructor

The interview with Tom Hoppenbrouwers offered insights on Basic Training from a different point of view. Hoppenbrouwers has nearly a decade of experience as a payload instructor (part of the increment training) at EAC and recent involvement in basic training instruction. He provided a useful perspective on the outcomes of basic training in mission-specific training delivery.

The interview revealed a major lack of formal communication between training phases: the payload instructor indicated receiving minimal information regarding astronaut progress from basic training. It depended on him to confirm the prerequisites were taught by checking on the ATD system.

Hoppenbrouwers observed that, in general, it was not obvious to see the relevance of basic training for payload training due to its highly specialised nature. However, one aspect learned during Basic Training seemed essential for the following training phases: the ability to read procedures. This limitation was especially apparent with reserve astronauts Sławosz Uznański-Wiśniewski and Marcus Wandt, who flew sooner than expected and did not undertake basic training: an adaptation of the training materials was necessary.

The interview mentioned a recent organisational change with the incorporation of internal instructors in basic training delivery. This shows a break from the previous total separation between basic and advanced training instruction.

Hoppenbrouwers expressed concerns regarding scalability, especially for retaining the same training quality. Payload training, being a hands-on skills training, is carried out individually or with two astronauts maximum to assure the best delivery and retention for the trainee. For potential future expansion, he suggested duplicating infrastructures rather than simply increasing the number of instructors.

4.2.1 Detailed Thematic Analysis of Interview Content

The interview produced extensive qualitative data categorised into different themes aligned with the structured interview questionnaire (cf. Appendix D). It provides insights into the basic-to-advanced training transition from the viewpoint of an operational instructor.

4.2.1.1 *Theme 1: Training Continuity and Knowledge Transfer*

Hoppenbrouwers provided a nuanced evaluation of the efficacy of basic training in equipping astronauts for advanced modules. Regarding payload training, he stated,

"To say bluntly, there is no real basic training needed from my perspective." He explained that the structure of experiment training – generally comprising "10 minutes of scientific background" followed by very specific hands-on procedural work – meant that the knowledge acquired during Basic Training had limited direct application.

However, he identified essential dependence on fundamental training in particular domains. Knowledge of ISS systems is crucial for contextualising experiments: "The only part where it's really helpful is when you try to explain in which part of the station [the experiment]'s going to happen [...] and how the data or the experiment is connected." System-level training showed increased basic training dependencies, with Columbus instructors noting noticeable differences when working with astronauts who did not attend Basic Training.

The most significant deficiency was seen in procedural literacy. Reserve astronauts who bypassed basic training "had no clue how to read procedures", necessitating instructors to develop modified training materials "with a bit more words and less acronyms and symbols." This emphasised how basic training develops essential meta-skills in addition to specialised technical knowledge.

Hoppenbrouwers observed that the basic training duration for astronaut classes has decreased from 1.5 years for earlier cohorts to "1 year or even less, 9 months" for recent classes. However, he lacked comparative data to assess the consequences on advanced training outcomes due to not enough cross-class teaching experience.

4.2.1.2 Theme 2: Organisational Interface and Communication

The interview revealed a lack of communication between training phases. Hoppenbrouwers characterised the information flow as having "almost no communication, or at least no structured communication." The absence of systematic information transfer meant instructors operated largely in isolation from basic training outcomes.

Information access remained ad-hoc and instructor-initiated. Hoppenbrouwers described manually checking prerequisites in the ATD and directly contacting Dmitry or the ISD when specific information was needed: "Then I just ask to know if they have done this or not." No standardised reports or assessments were provided about astronaut performance, competencies, or areas requiring reinforcement.

The feedback mechanism operated unidirectionally. After each lesson, instructors submitted feedback forms to ISDs, but Hoppenbrouwers noted: "Then it's a black hole. [...] I've never been informed about what happens next with that feedback

form." This absence of return feedback prevented improvement based on downstream training experiences.

Advance notification timelines had deteriorated significantly. While "10 years ago, we already knew six months to one year in advance", in recent years, the notification period has decreased significantly. It is not due to ESA, rather driven by external factors like Boeing Starliner being delayed. This makes it complicated for instructors to prepare adequately and plan resources.

4.2.1.3 Theme 3: Process Improvement and Feedback Loops

The interview revealed an absence of formal systems for incorporating advanced training insights back into the development of basic training. Hoppenbrouwers stated: "To me, it's unknown if there is this feedback loop." The 10 year-long intervals between selections increased this, as collected feedback may never be communicated to the basic training planner.

The only formal mechanism identified was the instructor feedback form submitted following each lesson. However, its efficacy remained unclear. The absence of feedback discouraged Hoppenbrouwers – and other instructors – to propose improvements.

When asked about specific recommendations for improving the transition from basic to advanced levels, Hoppenbrouwers provided several practical proposals. The first suggestion was ISS refresher courses for astronauts having to wait several years between basic training and mission assignment.

He also strongly advocated for all astronauts to pass the EUROCOM certification and for non-assigned ones to perform some shifts as EUROCOM. This would ensure astronauts would not forget their operational training.

The third proposition was to improve training documentation. ESA only relies on PowerPoint presentations with note pages, which is not adequate for long-term knowledge retention or refreshment. Hoppenbrouwers suggested a practice similar to GCTC's use of proper manuals.

4.2.1.4 Theme 4: Scalability and Future Training Demands

Hoppenbrouwers expressed doubt regarding the augmentation of agency astronaut numbers, aligning with industry trends: "I think probably the agency astronauts will remain a bit on the same level, but we will see [...] many more private astronauts." The argument was formed by current uncertainty around flight opportunities, with even selected astronauts currently undergoing incremental training such as Raphaël Liégeois facing an unclear future.

The main scalability constraint focused on maintaining the same quality of training by keeping limited group numbers. Payload and system training always operated with a maximum of two participants to keep efficient skills-oriented learning. Hoppenbrouwers recognised that this caused scheduling difficulties.

Instead of simply increasing the number of teachers, Hoppenbrouwers proposed to double the infrastructure as the optimal scaling strategy. He conceptualised a model with a singular lead instructor, several mockups, and assistant instructors giving personalised feedback. This idea would have the benefit of keeping the advantages of individual teaching, while adding the positive aspects of group learning, such as questions and answers or learning through mistakes.

Regarding ESA's preparation for future demands, Hoppenbrouwers stated: "To my knowledge, no" when asked about new guidelines for increased astronaut numbers. However, he noted reactive adaptations like the abbreviated basic training for reserve astronauts when it became clear that reserves were flying sooner than professional astronauts.

Another potential idea for scalability would be the use of Virtual Reality, with recent developments allowing for precise haptic return. However, it currently presents a time constraint: "You cannot put an astronaut or any person too long on VR goggles." Present technology restricts sessions in time, well under an hour due to cognitive exhaustion. Nevertheless, it could be that future advancements improve the potential of virtual training.

4.2.1.5 Theme 5: Organisational Structure and Contractor Dynamics

The interview addressed the impact of the service-based model on training delivery. Hoppenbrouwers, as a contractor, presented a balanced perspective on the consequences. According to him, at instructor level, being a contractor does not present particular disadvantages. However, it could become more complicated in the future regarding security clearances for programmes like Gateway.

Another point was the multi-company consortium structure which is linked to the service-based model. It created complexity for coordination and planning. Some missions have more importance and bigger future perspectives than others. Because of that, multiple company could have ulterior motives and encourage their instructors to take on strategic lesson assignments.

A significant organisational change emerged during the interview. Hoppenbrouwers mentioned increment instructors were involved in the last Basic Training, which was a new development. Previously, there was a strong separation between basic and advanced trainings.

4.2.1.6 Theme 6: Integration Challenges and Recommendations

The interview concluded with reflections on what systemic improvements were needed for training optimisation. The separation between system and payload instructors emerged as a particular concern: "We never had meetings with systems and payload instructors about the detailed content of some lessons."

Hoppenbrouwers advocated for greater integration: "That would be for me the main thing to change at the EAC: to try to get the payload and the systems instructors working together more." This would improve quality through cross-domain knowledge sharing and consistency.

The ideal organisational structure, from his perspective, would maintain the current basic-to-advanced progression but with enhanced coordination mechanisms, better documentation systems, and formal feedback loops to enable continuous improvement across training phases.

4.3 Case Study: Comparison of International Space Agencies Training organisation Models

This section combines data from several sources to create a comparative framework of the organisation of astronaut basic training programs by different space agencies. This comparison study serves as an independent data source to contextualise ESA's organisational model within the international environment.

4.3.1 NASA's Integrated Training organisation

The literature research indicates that NASA has set up extensive organisational structures for the management of astronaut training. Churkin confirmed in his interview that the Johnson Space Centre has specific staff positions dedicated for the coordination of basic training. NASA's methodology complies to the established project management principles outlined in its NPR 7120.5 (cf. Appendix B) regulations. These policies require careful planning and integration with important human spaceflight projects.

The literature indicates that NASA employs a large number of experts in its astronaut office. These specialists include flight surgeons, specialised course developers, and human factors experts. According to Churkin, NASA has a basic training leader, a permanent staff member responsible for – among other things – gathering feedback from all trainees and creating comprehensive documentation for knowledge management and improvement. This person works within a clear

hierarchy with the formal authority to request information from various departments.

NASA's training organisation produces detailed reference documents that describe "the content of the basic training, organisational points of contact, long-term planning" according to interview data. These documents allow for institutional knowledge management between training cycles, relating to the issues identified at ESA. NASA also employs contractors, such as Boeing and L3 for simulators, within a structure that ensures the agency keeps the control and supervision of the training process.

4.3.2 GCTC's Hierarchical Integration Model

The Gagarin Cosmonaut Training Centre in Russia presents a different organisational model defined by military-derived hierarchical structures and continuous operations, consistent with its history. Literature sources and interview data converge on several organisational characteristics:

The training coordination division operates as a permanent unit within GCTC's structure and it directly reports to the deputy head in responsible for training. This positioning within the "headquarters" provides training coordinators with significant organisational authority. Churkin noted that these coordinators "sit very high" in the hierarchy and "can quite easily approach any department or division head."

GCTC's continuous training operations – with selections every three to four years rather than decade-long gaps – enable maintenance of institutional knowledge and permanent staff expertise. The organisation requires all inputs and requirements to be provided "on paper with proper signatures", turning them into formal documents. This creates a comprehensive paper trail for each training cycle.

The Russian system produces extensive documentation, including training manuals for "almost any course" that go beyond simple presentation slides. These manuals serve both as reference materials for trainees and as knowledge preservation tools for future training cycles. The production of these materials is embedded in instructor responsibilities, unlike the voluntary documentation efforts described at ESA.

Long-term planning at GCTC follows a formal approval process where training coordinators compile inputs from various departments (training, medical, PR, logistics) into a comprehensive plan that is presented to leadership and signed by the head of GCTC.

4.3.3 Comparative Summary

Looking at the different training structures, we can basically see three different models being used by these organizations.

NASA uses what we could call an Integrated Model. They have permanent staff, clear hierarchy, heavy documentation, and formal project management. This helps keeping the training knowledge through permanent positions and detailed documentation, though making use contractors.

GCTC uses a Hierarchical Model instead. They have military-style command structures, continuous operations, formal documentation needs, and training coordination is really important in their organization. This model focuses on formal authority and following written requirements and regulations.

Meanwhile, ESA uses a Service Model. Most of the instructors and the coordinator of the training itself are contractors. This model is flexible and probably the most cost effective, keeping costs down in inactive periods, but it causes issues with preserving knowledge and managing authority.

The history and political organisation affect the model of each institution. NASA's way is in line with their well attested project management culture. GCTC's structure reflects Russian traditions and their military space program background. ESA's approach seems less organized overall and appears to focus on saving money during inactive periods, which makes sense since they're newer to human spaceflight.

When we compare these approaches, we can see that NASA and Roscosmos have both created training organizations that ensure continuity, clear authority, and good knowledge management. This is quite different from what ESA is currently doing. These examples could provide useful insights for future ESA's developments.

The main takeaway is that while ESA's approach has some benefits in terms of flexibility and cost, NASA and GCTC have systems that seem better suited for long-term training needs. The elements which should be taken as example and recommended to ESA for a possible implementation will be further analysed in Part 5.

Part 5: Discussion and Analysis

Part 4 provided valuable insights on how ESA processes work from both an internal perspective, thanks to the interviews, and from an external point of view coming from the case study comparison with other agencies. The data collected will be systematically analysed in this chapter to validate or deny the research hypotheses and question and produce operational recommendation for further improvements.

5.1 Validation of Research Hypotheses Through Empirical Evidence

The empirical data collected through interviews with Dmitriy Churkin and Tom Hoppenbrouwers, combined with comparative analysis of international space agency models, provides substantial evidence for evaluating all three research hypotheses. The dual perspectives – from basic training coordination and downstream advanced training delivery – create a comprehensive view of the organisational challenges. This discussion synthesises these findings with the literature review to address the central research question: How can the systematic application of integrated Project, Operations and Service Management principles transform the ESA Astronaut Basic Training from a series of discrete, high-risk assignments into a resilient, scalable, and continuously improving operational program?

5.1.1 H1 Analysis: Project Management Structures and Their Implications

The interview evidence reveals that ESA's current structure operates without several fundamental project management elements identified as standard practice in the literature. Churkin's testimony that "the basic training has never been treated as a real project" despite his official designation as "Project Lead" indicates a disconnect between organisational terminology and operational implementation. This finding is reinforced by Hoppenbrouwers' downstream perspective, where the absence of structured project management manifests as communication gaps and coordination challenges between training phases.

The absence of a defined project team creates operational dependencies on individual availability. Churkin's description of continuing work during vacations and medical leave, with intermittent support from colleagues, illustrates how the current structure manages continuity through individual dedication rather than systematic organisational design. Hoppenbrouwers confirmed these coordination challenges from the instructor perspective, noting the evolution from structured

advance notice ("six months to one year in advance") to increasingly reactive scheduling driven by external factors.

Budget visibility emerges as another structural characteristic. The coordinator stated that he does not have access to budget information and it reflects an organisational choice to maintain financial management at the contract management level rather than the operational level. The coordinator cannot properly fulfil project manager duties from a standard project management perspective, where managers typically have budget oversight responsibilities. This is also true over the next training phases, as Hoppenbrouwers noted the multi-company consortium structure where each instructor, being contracted by a different company, needs to respond to both ESA and the consulting company complicating resource allocation without transparent budget frameworks.

The distributed funding model, where different training components are financed through separate contracts, creates complex financial constraints. Considering that different components of the staff working on Basic Training have different contracts and ways of being compensated, these add layers of complexity and obscurity to an overall view of the budget. Hoppenbrouwers' observation about companies positioning instructors for strategically valuable lessons illustrates how this financial opacity influences operational decisions.

5.1.2 H2 Analysis: Knowledge Management and Operational Continuity

The empirical data offers insights into the practices of knowledge management within the context of the organisation that is currently in place. In between cycles, Churkin estimates that "50 to 70 percent of the training needs to be redeveloped." This suggests that there is a significant amount of content evolution, but there is also the possibility of knowledge loss. It is an issue that is verified by Hoppenbrouwers' finding that feedback amassed over years enters "a black hole" with no sign of incorporation into future training cycles. While astronaut training is a field that requires continuous improvements and adaptations (especially on the technological side, a ten years gap is really large), those answers show that a part of the institutional memory is lost in the process.

The Astronaut Training Database (ATD), used for holding a variety of material, from timetables to training presentations, is currently the main tool used for documentation. While being operationally functional, a more rigorous documentation system should be put in place and enforced. The absence of official training manuals is a big example of this. Hoppenbrouwers made a specific comparison between this and the procedures of the GCTC, pointing out that the

presentations utilised by ESA were not a manual and insufficient for assisting with the retention of knowledge during periods of several years.

Despite the fact that it is operational through electronic forms, the feedback gathering system does not have a systematic integration into continuous improvement cycles. Churkin and Hoppenbrouwers both verified that this separation exists. Churkin stated that input "never materialises as the lessons learnt," while Hoppenbrouwers described submitting forms that disappear without any further communication concerning usage. This finding is consistent with the focus that the literature places on formal quality management loops; yet, it reveals that multiple organisational goals exist within the framework that ESA is currently using.

There is a visible manifestation of the downstream impact of shortcomings in knowledge management in the delivery of advanced training for employees. The interviews highlighted how the communication was often limited and not structured. Due to this, instructors in the second and third phases need to verify manually and without a precise direction which competencies to expect from a trainee coming from Basic Training.

5.1.3 H3 Analysis: Service Management Models and Organisational Resilience

The interviews and case studies provide useful information to make an evaluation of ESA's Basic Training PaaS model. Both the interviewees, after all, are or were contractors working for ESA.

Both interviews reveal dispersed service delivery. Basic Training components are delivered through separate contracts, so coordinators and instructors have little visibility into parallel service streams. Churkin admitting he doesn't know Space Applications workers' contractual requirements highlights how the paradigm creates information silos inside a service provider. Medical staff, external instructors, and support services have separate contracts. Instructor

Different organisations' "hidden agendas" position teachers for strategically useful training, hindering service integration, according to Hoppenbrouwers. Interviews demonstrate personnel-as-a-service weakened operations. In Churkin's description of managing work during vacations and medical leave with just occasional coworker support "helping a little bit but not really replacing me," the approach lacks continuity. Without institutional institutions, individual effort cannot sustain service delivery.

Both respondents' experience reveal fundamental challenges in managing PaaS arrangements. The fact that Churkin lacks decisional power regarding Basic Training exposes a gap between being held responsible for outcomes and actually having the authority to influence them. Meanwhile, Instructor Hoppenbrouwers pointed to another key issue: the absence of what he called "structured communication" between training sessions, which made it nearly impossible to maintain knowledge continuity. These coordination challenges become particularly acute when there's no mechanism to ensure compliance or guarantee that deliverables arrive on schedule.

Looking at how NASA and GCTC handle similar situations offers valuable insights into alternative approaches. NASA has a hybrid approach, combining a core of training staff with specialised contractors to deliver critical knowledge. This system allows for a different repartition of roles for the staff internal to NASA and less risks in knowledge management. Furthermore, NASA implements a formal documentation process. GCTC, on a similar line, focuses heavily on documentation and the production of manuals that go in deep detail on training aspects. ESA, instead, seems to rely mostly on the retention of PowerPoint presentations, which often lose a large part of their meaning without the presenter. These organizational choices reflect fundamentally different philosophies about how to balance flexibility with institutional stability in complex training environments.

Both interactions illustrate the personnel-as-a-service model's financial implications better than theoretical analysis. While the approach minimises fixed costs during idle times, Churkin's estimate that "50 to 70% of the training needs to be redeveloped" for each cycle reveals considerable hidden costs. Without formal feedback loops, teacher ideas go into "a black hole," necessitating each training cycle to recreate best practices, Hoppenbrouwers said. Without adequate documentation and knowledge management systems, reconstruction may cost more than eliminating permanent labour. Service quality without performance frameworks was a focus.

Recent organisational changes help evaluate Hoppenbrouwers' service model. He admitted that "it's only since the last basic training that we as instructors were involved in the basic training" indicating a shift from basic and advanced training separation. Hoppenbrouwers' knowledge, not formal service integration activities, appears to have led to organic service integration. The current service paradigm lacks scalability, both interviewees said. Hoppenbrouwers' "maximum of two" pupils for efficient hands-on training and Churkin's "revision 15" timetables owing to coordination complexity highlight how the PaaS models suffers with operational size. Hoppenbrouwers' infrastructure duplication rather than teacher addition

suggests that scalability requires service architecture adjustments rather than linear development.

Interviews also revealed a strategic issue: fundamental training methods may become obsolete. Service model evolution is crucial due to Churkin's prediction that basic training may be "very much reduced or even gone" and Hoppenbrouwers' "we will see much more, many more private astronauts". This convergence highlights that any service architecture reform must address operational improvements and positioning for potential significant changes in astronaut training conception and delivery.

Thus, real data strongly supports H3's argument that hybrid service architecture reduces vulnerabilities. Combining views shows the model's benefits. A small core of permanent staff could maintain institutional memory and provide consistency over training cycles instead of major refurbishment.

International examples show hybrid methods work for space agencies. NASA's permanent leadership with contracted technical knowledge and GCTC's extensive documentation and established authority structures are examples of improvement. The empirical research reveals that the pure personnel-as-a-service model, while cost-effective during dormant periods, may weaken when human spaceflight accelerates. Evidence from upstream coordination and downstream instruction supports H3, suggesting ESA has a severe service delivery model challenge. ESA's policy has worked effectively during sporadic selections and slow operational pace, but continuity, authority, and knowledge preservation issues may restrict its future capabilities. The flexibility of contractual services and the stability and continuity of mission-critical training make a hybrid model a strategic investment in organisational skills.

5.2 Integration of Upstream and Downstream Perspectives

The interviews reveal how organisational deficiencies cascade through the training pipeline. Churkin's upstream challenges, among which lack of budget visibility, absence of formal authority, knowledge management gaps, directly create Hoppenbrouwers' downstream problems—inadequate astronaut preparation information, feedback disappearing into "black holes," and scheduling instability.

The procedural literacy gap identified by Hoppenbrouwers with reserve astronauts provides concrete evidence of how basic training's organisational challenges impact operational effectiveness. The need to create modified training materials for inadequately prepared astronauts represents inefficiency that proper project management and knowledge transfer mechanisms could prevent.

5.3 Operational Recommendations

This section proposes some pragmatic proposals for organisational development. Each recommendation keeps in mind ESA's constraints trying to address the vulnerabilities individuated in the previous sections.

5.3.1 Project-Based Transformation

The first recommendation concerns the adoption of formal project structures. This addresses the basic process flaws that were identified and confirmed by both Churkin and Hoppenbrouwers. In first place, the adoption of a permanent and dedicated team would need to be established for each BT cycle. Each team member would have a clearly defined scope and tasks, with a split of responsibilities and specific competences. Having a team would allow to establish a formal authority structure for the coordination of multiple parties, as opposed to the current single coordination point.

Another aspect to keep in mind to properly implement project management practices would be to enable the coordinator to have access to the budget and have a certain degree of control over it. The immediate result of this would be to conduct cost-benefit analyses for training enhancements and optimisations, while ensuring accountability for the utilisation of the resources.

It is anyway acknowledged that this model could consist in additional staff costs to sustain for ESA, especially during the long inactivity periods. ESA would be required to either accept the costs of team reformation for each cycle or keep core members of the project team in different roles to continue working on the project. When compared to the broader organisational aims of the ESA, the trade-off between operational efficiency during active periods and cost burden during quiet periods needs to be carefully evaluated.

5.3.2 Hybrid Service Models

Developing hybrid models that strike a balance between the cost-effectiveness of the existing structure and the increased institutional competence is an approach that is more complex. This may take a number of various shapes, each of which would address a particular facet of the difficulties that have been highlighted.

Under the core-plus approach, a small permanent staff would be responsible for institutional memory and coordination. During active training periods, this team would be bolstered by contractual specialists. There are two to three positions that might be included in this permanent core, including a training program manager, a knowledge management specialist, and an instructional design lead employee.

Through the use of these roles, important links would be preserved, documentation would be maintained, and continuity would be ensured across training cycles.

One example of how competency maintenance can take place without full-time dedication to training roles is the recommendation made by Hoppenbrouwers for universal EUROCOM certification to be given to all astronauts who are not currently assigned to a specific mission. This strategy might be extended to include instructors and coordinators, who could keep themselves up to date by participating in activities related to their positions during periods of inactivity. These activities could include providing assistance for missions, developing procedures, or working on international collaboration initiatives.

Hoppenbrouwers proposed as well an additional hybrid method for the sharing infrastructure model. The proposal involves the possibility for ESA to create commercial partnerships with other organisations to share infrastructure costs while keeping control over the curriculum and standards. This would significantly optimise capital investments in facilities that are only occasionally used.

5.3.3 Knowledge Management Systems

Perhaps the most immediately implementable recommendation involves establishing comprehensive knowledge management systems. Both interviewees emphasised this as a relatively low-cost intervention with potentially transformative impacts on organisational effectiveness.

The Astronaut Training Database (ATD) already partially provides a technical infrastructure, but it needs attentive adaptations. While it is mostly currently used to preserve training materials, it should also serve as a database for process documentation, lessons learnt, instructors insights and feedback from astronauts in a user-friendly interface.

ESA should follow the example of GCTC in producing training manuals for each course, moving away from the current PowerPoint-based documentation. The manuals would be extremely useful for a variety of reasons: reference materials for astronauts, knowledge preservation for future instructors and quality assurance baselines. The production of the manuals should be mandatory contractual expectations rather than a voluntary endeavour.

Finally each training cycle should conclude with structured debriefs with all the parties involved to collect the valuable lessons-learnt. This output should directly be merged in the aforementioned database as baseline for the next training cycle. This process should also be owned by permanent staff to ensure the preservation of the knowledge across the years.

5.3.4 Communication Integration Framework

Hoppenbrouwers found that instructors function "in isolation" from basic training outcomes. Formal communication lines between training stages remedy this. This structure should include vertical (between training phases) and horizontal (across training domains) communication.

The vertical integration should include common handover methods for astronauts moving from basic to advanced training. It would be useful for each astronaut to receive an evaluation report which can document the abilities accomplished together with areas requiring improvement and a free feedback on Basic Training, instead of instructors making independent ATD prerequisites assessments.

For instance, Hoppenbrouwers' suggestion for system-payload instructor meetings demonstrates horizontal integration. A process concerning organising regular meetings among teachers from different fields to share insights and information should be put in place, instead of happening spontaneously.

Basic training planners also need to get the closure of the feedback loop with teachers' observations. It has been observed that those often tend to be lost; instead, it is a very valuable information to account for at the planning stage and a process should be in place to indicate how the feedback was collected, actions taken and modifications reported.

5.3.5 Implementation Prioritisation

The priority in implementing those proposals should be driven by a trade-off between ESA objectives, costs and feasibility. The proposed knowledge management and communication frameworks can provide a high impact while being "low hanging fruits" solutions, not requiring a particularly high effort.

Hybrid service models balance cost and capabilities for medium-term solutions. ESA could consider exploring those models with a contained cost by starting with a minimum permanent core and expanding based on value.

Full project-based transformation, the most thorough option, should be a long-term goal. Significant organisational changes are needed, thus implementation should wait for initial improvements to show value. However, planning for this shift now would allow ESA to move decisively during the next astronaut selection.

5.4 Future Considerations

Both interviewees doubted traditional astronaut training's viability due to technology and commercial spaceflight. Churkin said basic training may be "very much reduced or even gone" and Hoppenbrouwers predicted commercial dominance: "we will see much more, many more private astronauts."

Adopting commercial training providers and having agencies define standards rather than conduct training would change the current arrangement. This means that organisational reforms should include current operational efficiency and future paradigm adaptation.

With higher training frequency, both interviewees' scalability issues exacerbate (Churkin's scheduling "revision 15" and Hoppenbrouwers' "maximum two" student limit). Hoppenbrouwers' infrastructure duplication concept gives a concrete alternative to linear scaling.

5.4.1 The Changing Landscape of Human Spaceflight Training

Churkin's outlook on future astronaut cohort sizes challenges preconceptions regarding human spaceflight expansion. Churkin sees smaller astronaut cohorts with distinct skill sets to facilitate increasing mission frequency. Deeper changes in mission architectures and technology capabilities will modify training needs.

Currently a big part of the astronaut training focuses on ISS operations, as shown in Part 1 and confirmed by Churkin, from system and procedures to the low Earth orbit environment. The ISS decommissioning will deeply change the face of the training as we intend it today. The content will need to be adapted for the Lunar Gateway, lunar surface operations and Mars missions.

A first issue to overcome for the astronauts is linked to the fact that these types of missions will physically be further from our planet. In the case of Mars missions the crew would take a minimum time of six months for the transit, making them orders of magnitude longer. This poses operational and psychological issues to face for the astronauts that need to be accounted for in the training paradigms.

The role of astronauts, as emerged in particular from the interview with Churkin, seems destined to change more and more in the coming years. While we currently see astronauts that are more military staff and pilots, it is more likely to expect in the future to have more scientists profiles. This is mostly due to the big technological advancements in spacecraft automation, which already require minimal intervention from the astronauts to operate. This would allow profiles not requiring piloting skills to fly, allowing them to focus more on the research aspects.

5.4.1.1 The Commercial Training Paradigm: Business Case Analysis for Private Basic Training Providers

The convergence of both interviewees' perspectives on commercial training futures outlines the relevance of the topic. Churkin specifically articulated a vision where "ESA might start flying to set the standards... and giving away some training to the commercial companies," while Hoppenbrouwers predicted private astronauts would dominate future spaceflight. This section analyses the business case for commercial basic training provision, examining both the market dynamics and operational requirements necessary for sustainable private sector involvement.

5.4.1.2 Market Dynamics and Revenue Potential

The commercialisation of astronaut training signifies a rising market propelled by multiple converging reasons. There are already instances available in literature in which corporations like SpaceX have started the development of in-house training programs (SpaceX, 2021). It is an interesting example that shows how spacecraft manufacturers can provide an auxiliary service to their core business through vertical integration.

The market possibilities go beyond conventional space agencies, with growing participation in commercial spaceflight. To be clarified, though, that the training for this commercial participation is way less extensive than the one received by professional astronauts. Both Churkin and Hoppenbrouwers noticed how the training of those individuals should be considered inadequate, especially compared to extensive programs as the one analysed in this thesis. Nevertheless the increasing number of participants could diminish the training intensity per individual. Outsourcing the training seems also to be an economical advantage for smaller agencies that have no interest in developing this core knowledge in house. Companies could this way gain long-term collaborations contracts and specialise in specific domains (e.g. Mars rather than Lunar exploration). Hoppenbrouwers' noted how companies seem to be already strategically working on preparing complete training programs.

The revenue model study indicates various possible streams derived from fixed-price contracts for comprehensive basic training delivery via modular training packages for individual competencies. Subscription-based access to training facilities and resources may generate consistent revenue, while consultancy services for training program development could present high-margin prospects for established providers.

5.4.1.3 Operational Requirements for Quality Assurance

For commercial providers to deliver training meeting space agency standards, several operational capabilities emerge as essential based on the organisational challenges identified in the interviews. In the case of ESA, as seen before, the instructor expertise retention is a critical aspect and it poses its challenges also to a large organisation. Companies need to develop specific strategies to keep instructor expertise in periods without active training (and contracts). Potential strategies could include diversified instructors portfolios, serving multiple markets and retainer agreements with key subjects experts.

Infrastructure investment represents another crucial consideration. For instance, Hoppenbrouwers proposed doubling the training infrastructure at EAC to be able to scale in the future. ESA is already working in that direction, considering the recent opening of the analogue Luna facility. Companies that want to occupy a position in the astronaut training market need to carefully evaluate the cost-benefit of owning unique infrastructures and maintaining them against renting them from an external supplier.

Knowledge management and continuous improvement systems are going to play a critical aspect in commercial success. It has been highlighted how a good portion of the training needs to be redeveloped for both knowledge management issues and both for keeping the expertise up to speed with the latest technologies. Companies should try to differentiate the customer base to try and maintain an active pipeline of customers that does not leave too many temporal gaps. Furthermore solid knowledge management practices, such as the aforementioned manuals and informatic systems, should be put in place. The literature's notation that DLR's training organisation maintains ISO certifications suggests commercial providers would need similar quality certifications plus additional space-specific accreditations to gain agency contracts.

5.4.1.4 Profitability Models and Sustainability

Different models, while carrying intrinsic risks, could provide profitability to the players in the training market. As Churking mentioned, standardised basic training curricula could easily scale to a large customer base, reducing per-student costs and having reliable cash flows as service providers, enabling a competitive price.

Alternatively, providers might focus on high-margin, customised training for specific missions or agencies. This approach addresses Hoppenbrouwers' observation about the need for tailored instruction based on astronaut backgrounds, requiring deep expertise in specialised domains, flexible organisational structures for rapid customisation, and premium pricing justified by

unique capabilities. The solution is probably something in between. A hybrid model combining both approaches, providing base curricula which can be enhanced using modular add-ons specific to the mission type would provide the best of both worlds for both customers and suppliers.

5.4.1.5 Risk Factors and Mitigation Strategies

Organisational challenges in the interviews highlight many strategic concerns for commercial training providers. Revenue unpredictability is caused by astronaut selections' decade-long delays, according to both interviews.

The main risk that should come to the reader's attention is the current unpredictability of scheduled training. As mentioned, at ESA an astronaut class is formed about every 10 years, without a precise rule. Mitigation involves diversity across space agencies and commercial customers, development of complementary sectors like space tourism training, and variable cost structures to reduce fixed overhead during inactivity.

Safety and liability issues are also major risks. Hoppenbrouwers' discovery that geopolitical factors make it hard to fail astronauts suggests commercial suppliers may face comparable challenges. In this case companies should apply quality assurance methods that are above the parties, applying standards where possible.

The rapid technological development, while representing an opportunity for market, is also a risk that requires attention. As spacecrafts shift towards being more and more automated, the profile of an astronaut changes at the same pace. To stay competitive, providers must cooperate with spacecrafts manufacturers in the early design stages and invest in training system which have a certain degree of flexibility. Regulations, naturally, adds up the complexity since agencies may impose commercial training standards with consequent high overhead in paperwork and bureaucracy.

5.4.1.6 Strategic Considerations and Agency Implications

The thesis makes several recommendations for companies providing training, which would heavily reflect and depend on space agencies. It is difficult to correctly identify which would be the right time to enter the market due to the current limited customer base of agencies, but early movers could build their position for when the time is ready. Churkin observed how agencies could apply some sort of resistance at the beginning due to institutional inertia.

Partnerships between aerospace businesses, educational institutions, and training specialists could pool skills and share risks. Geographic proximity to key space

centres has operational advantages but raises fixed costs, while virtual or distributed models offer flexibility but may lack credibility for hands-on instruction.

The monetisation of basic training requires major organisational change for space agencies. Agencies would need to set detailed standards and certification systems for commercial providers, shifting from service delivery to regulation. Training services involve vendor assessment, performance monitoring, and quality assurance, unlike internal delivery. Both respondents indicated that mission-specific training will likely remain internal, thus agencies must carefully choose which training elements to outsource.

Commercial astronaut basic training may be viable under certain conditions: sufficient market demand across multiple customer segments, ability to maintain quality standards while achieving operational efficiency, and strategic positioning that balances standardisation and customisation. The transition from institution to commercial administered training will require a certain degree of flexibility from both sides. Institutions should expect a ramping up period of the companies involved, which might even require special initial funding models, to remain profitable while building a position. This could allow to build a scaled training economy that would result in profit on the long term from both parties. On the companies side it is imperative to implement from day zero excellence models and processes according and beyond the management principles expressed in this thesis to represent a trusted solution in the long term and stay profitable.

5.4.2 Conclusions

The empirical validation of all three research hypotheses, enhanced by international comparative analysis and dual-perspective insights, shows that project, operations, and service management concepts can solve organisational problems. The service-based, single-coordinator concept served ESA well during rare selections and ISS-focused operations, but it is limited as human spaceflight expands.

The issues analysed from basic training coordination to advanced training delivery shows why a large management transformation model shift would be better than incremental modifications. Gaps in project management practices, communication and knowledge management indicates systemic difficulties.

ESA's unpredictable selection cycles, distributed European operations, and changing mission needs must be considered before moving forward. ESA can combine international capabilities with its own operational issues rather than just following another agency's model.

Careful organisational design that combines cost efficiency and operational performance can transform discrete, high-risk initiatives into a resilient, scalable program. To support Europe's growing human spaceflight objectives, astronaut training must be recognised as a basic institutional competency needing proper organisational commitment and structure.

General Conclusion

This thesis investigates the organisational structure of ESA's Astronaut Basic Training through the perspectives of project, operations, and service management. It emphasises the resilience that has contributed to previous successful BT cycles, as well as the structural flaws that may impede future efficacy. The research process, which began with field observations and progressed through theoretical analysis to empirical validation, demonstrates that, while ESA does an excellent job of preparing astronauts for complex international missions, this success is dependent on individual commitment and informal adjustments rather than solid organisational systems.

Summary of Key Findings

Because of the empirical examination, all three research hypotheses were proven to be correct, and it was discovered that there are interconnected organisational flaws that run across the training pipeline. Because there are no formal project management mechanisms in place, there is a possibility of a single point of failure occurring. This means that the entire coordination of Basic Training is dependent on a single individual who does not have financial power or team support working for them. A hidden cost that undermines the apparent effectiveness of the lean model is the need for large content rebuilding between training cycles. This is because the absence of systematic knowledge management needs substantial content reconstruction, with fifty to seventy percent demanding recreation. Although the personnel-as-a-service strategy reduces fixed costs during periods of inactivity, it also compromises continuity, authority, and scalability in ways that become increasingly problematic as the speed of spaceflight activities quickens.

These weaknesses are not intrinsic to astronaut training, as revealed by the comparison analysis with NASA's integrated model and GCTC's hierarchical method. Rather, these vulnerabilities are the result of specific organisational choices. Both of the alternative models are able to successfully address the vulnerabilities that have been found in the ESA by implementing permanent staff roles, comprehensive documentation requirements, and clarity in authority hierarchies. In addition to the arguments that this thesis brings independently on the adoption of management principles, the examples from the USA and Russia show the feasibility of it.

Significance and Contribution

The significance of this thesis lies in addressing a research gap which is the literature production on the processes of astronaut training. This thesis, in the first place, provides a systematic review of the literature and, identifying the gap, makes an attempt through an empirical exploration to propose a sustainable model in astronaut training. The scope of the thesis goes beyond wanting to be a purely theoretical document. Instead, its true objective is to provide a set of useful recommendations which can also be pragmatic and realistic to be applied in the context of ESA Basic Training. Nevertheless, the organisational frameworks depicted in this thesis are not necessarily specific to ESA and examples are provided how they can be applied to commercial business models, which can both enhance institutional training capacities and be profitable.

While the scope of this thesis remains exploratory and does not pretend to provide definitive answers, it identifies issues and proposes solutions based on evidence. Concrete steps towards improving resilience, being cost effective, are offered through operational recommendations. They range from the implementation of hybrid service models to the improvement of knowledge management systems. As mentioned before, the thesis importance is also linked to its timing. We are in a state of great transitions, which is typically the ideal period to implement reforms.

Practical Implications for ESA

For ESA specifically, this research provides a roadmap for evolutionary rather than revolutionary change. The idea is not to completely restart from scratch. The recommendations are more of a set of concrete actions which could be taken from management to improve the efficiency of their model. The successful elements, such as the coordinator, the instructor and, the infrastructures should be supported implementing the practices proposed. This would mean reducing many of the currently identified vulnerabilities, while requiring minimal structural change and limited cost as well.

The timing to implement them for ESA. A Basic Training just recently finished and implementing those changes now would leave the time for on-the run adaptations and making sure that they will be ready for the next class. Once again, is internationally a period of great changes in space exploration and it is an ideal moment to improve the processes. Formalising and systematising these changes would accelerate improvement while reducing dependence on individual initiative.

Limitations and Future Research

The first and most important limitation of this thesis is the availability of data and resources, such as interviewees, to produce an unbiased result. Future research should be conducted on a larger scale, including the opinions of ESA management, instructors, astronauts and possibly equivalent figures in other institutions. This would provide a full and less biased perspective on the weaknesses and points for improvement, together with long term agency's plans.

Another limitation is that most of the literature available comes from NASA and Roscosmos, which are the two most important historical actors. However, many countries like China, India and Saudi Arabia have modern and advanced space programs which would be worth analysing. Furthermore, commercial actors, such as SpaceX, would provide a very valuable insight on the commercial evaluation of the training perspective.

Lastly, this research focused on using well established methods in management, ignoring due to lack of time possible new frontiers which could make the transition smoother. For instance, AI evolution cannot be ignored and it could most definitely prove a very valuable tool for improving organisational effectiveness.

Concluding Reflections

This research started with my support to Dmitriy Churkin in coordinating the Basic Training for the class of 2022 and ended with this thesis which tries to improve the efficacy of the training organisation process. I had the occasion to witness excellent performance on individual and organisational level during my time at EAC. However the thesis highlighted that there is room for improvements, which should not be ignored under the shadow of past success. Institutional assistance that amplifies rather than constrains the efforts of the heroes who are currently maintaining the European Space Agency's astronaut training via personal dedication is something that should be provided.

Considering that Europe is currently at a crossroads in human spaceflight, with ambitious aspirations for lunar exploration and Mars missions, the organisational foundations of astronaut training are becoming increasingly important. In this case, the decision is not between the existing lean paradigm and costly bureaucracy; rather, it is between reactive adaptation and proactive design. The European Space Agency (ESA) is able to transform its Basic Training program from a collection of discrete, high-risk projects into a resilient, scalable, and continuously improving operational program by using systematic project, operations, and service management principles.

The ultimate message conveyed by this theory is not one of criticism but rather one of openness and possibility. The European Space Agency (ESA) has accomplished tremendous feats in human spaceflight while having just a limited amount of funding and organisational support. Imagine what might be possible if this same level of commitment and expertise were to operate within systems that were meant to retain information, distribute authority, and grow capabilities. It is imperative that the organisations that are responsible for preparing our space explorers change in accordance with the rapid expansion of mankind beyond Earth. For the purpose of ensuring that Europe's astronaut training organisation is able to rise to meet the challenges and opportunities of the new space age, this thesis gives both the analytical framework and the practical guidelines that need to be taken into consideration.

In spite of the limitations imposed by the organisation, the investigation was able to reach its conclusion by recognising the extraordinary individuals who were responsible for making astronaut training feasible. It is possible for the European Space Agency (ESA) to ensure that European astronauts continue to thrive in international missions by constructing systems that provide support rather than strain. This will allow the ESA to prepare for the extraordinary challenges that come with lunar bases, Mars expeditions, and destinations that have not yet been envisaged. The transition from organisational fragility to institutional resilience is not only a gain in operational efficiency; rather, it is an investment in Europe's sustained leadership in the greatest adventure that humanity has ever undertaken.

Bibliography

Anderson, C., Pomerantz, W., & Cunningham, J. (2021). The commercial space revolution and its impact on space exploration. *Space Policy*, 58, Article 101428.

Anderson, D. J. (2010). *Kanban: Successful evolutionary change for your technology business*. Blue Hole Press.

Augustine Committee. (2009). *Seeking a human spaceflight program worthy of a great nation: Review of U.S. human spaceflight plans committee*. NASA.

Axelos. (2019). *ITIL foundation: ITIL 4 edition*. TSO.

Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., Martin, R. C., Mellor, S., Schwaber, K., Sutherland, J., & Thomas, D. (2001). *Manifesto for agile software development*. <https://agilemanifesto.org>

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008). Service blueprinting: A practical technique for service innovation. *California Management Review*, 50(3), 66–94.

Bradford, A. (2023). The battle for technological supremacy: The US–China tech war. In A. Bradford (Ed.), *Digital empires: The global battle to regulate technology* (pp. 1-35). Oxford University Press. <https://doi.org/10.1093/oso/9780197649268.003.0006>

Catchpole, J. (2008). *The International Space Station: Building for the future*. Springer-Praxis.

Central Intelligence Agency, Directorate of Intelligence, Office of Strategic Research. (1969). *Contribution to E 11-1-69: The Soviet space program—Expenditure implications of Soviet space programs*. CIA.

Chen, L. (2023). China's space program: A new space race? *Asian Affairs*, 54(2), 234-251.

Contractor, F. J., & Lorange, P. (2019). *Cooperative strategies and alliances*. Elsevier.

Crawford, I. A. (2021). Expanding the human presence beyond low Earth orbit: Ethical and social considerations. *Space Policy*, 58, Article 101428.

de Zwart, M., & Stephens, D. (2019). The space (innovation) race: The inevitable relationship between military technology and innovation. *Melbourne Journal of*

International Law, 20(1), 1-25. <https://www.austlii.edu.au/cgi-bin/viewdoc/au/journals/MelbJIL/2019/2.html>

De Winne, F. (2022). European astronaut training and operations. In *Handbook of space resources* (pp. 891-908). Springer.

Deming, W. E. (1986). *Out of the crisis*. MIT Press.

Deutsches Zentrum für Luft- und Raumfahrt (DLR). (2023). *Space operations and astronaut training annual report*. DLR Publications.

Dietrich, U. (2021). Medical training and health maintenance for astronauts. *Aviation, Space, and Environmental Medicine*, 92(4), 187-195.

European Space Agency. (n.d.-a). Astronaut training at Tsukuba Space Center, Japan. *Human and Robotic Exploration*. Retrieved May 22, 2025, from https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Astronauts/Astronaut_training_at_Tsukuba_Space_Center_Japan

European Space Agency. (n.d.-b). History of Europe in space. Retrieved May 22, 2025, from https://www.esa.int/About_Us/50_years_of_ESA/History_of_Europe_in_space

European Space Agency. (n.d.-c). Training development. *Human and Robotic Exploration*. Retrieved May 22, 2025, from https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Astronauts/Training_development

European Space Agency. (2008). *Columbus Laboratory joins the ISS* [Press release]. ESA.

European Space Agency. (2015). Exploring new realities: ESA's XR lab. *European Astronaut Centre*. Retrieved May 22, 2025, from https://www.esa.int/About_Us/EAC/Exploring_new_realities_ESA_s_XR_lab

European Space Agency. (2018). *ESA astronaut training requirements document*. ESA.

European Space Agency. (2020a). *Virtual reality in astronaut training: Annual report*. ESA.

European Space Agency. (2020b, May). Ready, set, go for COVID-conscious astronaut training. *European Astronaut Centre*. Retrieved May 22, 2025, from

https://www.esa.int/About_Us/EAC/Ready_set_go_for_COVID-conscious_astronaut_training

European Space Agency. (2021). *Extended reality in astronaut training*. European Astronaut Centre Publications.

European Space Agency. (2021, February). *Astronaut selection: phases of training*. Retrieved May 28, 2025, from https://www.esa.int/ESA_Multimedia/Images/2021/02/Astronaut_selection_phases_of_training

European Space Agency. (2022). *Astronaut training curriculum overview*. ESA.

European Space Agency. (2023). *International cooperation in human spaceflight training*. ESA.

Fleming, Q. W., & Koppelman, J. M. (2016). *Earned value project management*. Project Management Institute.

Garcia, A. D., Schlueter, J., & Paddock, E. (n.d.). *Training astronauts using hardware-in-the-loop simulations and virtual reality*. [Unpublished manuscript].

Garcia, M. (2020). Evolution of NASA virtual reality training systems. *Journal of Space Operations*, 8(3), 45-62.

Getzoff, M. (2023, December 1). Most technologically advanced countries in the world 2023. *Global Finance Magazine*. <https://gfmag.com/data/non-economic-data/most-advanced-countries-in-the-world/>

Goldratt, E. M. (1984). *The goal: A process of ongoing improvement*. North River Press.

Goswami, N., & Raghuram, S. (2021). The new space race: China vs United States. *Space Policy*, 57, Article 101433.

Grimwood, J. M., Hacker, B. C., & Vorzimmer, P. J. (1969). *Project Gemini: Technology and operations: A chronology*. Scientific and Technical Information Division, National Aeronautics and Space Administration.

Grönroos, C. (2007). *Service management and marketing: Customer management in service competition* (3rd ed.). John Wiley & Sons.

Grönroos, C., & Voima, P. (2013). Critical service logic: Making sense of value creation and co-creation. *Journal of the Academy of Marketing Science*, 41(2), 133-150.

Harland, D. M. (1997). *The Mir Space Station: A precursor to space colonization*. Wiley-Praxis.

Heizer, J., Render, B., & Munson, C. (2020). *Operations management: Sustainability and supply chain management* (13th ed.). Pearson.

Hillson, D. (2002). *Effective opportunity management for projects: Exploiting positive risk*. Marcel Dekker.

Hislop, D., Bosua, R., & Helms, R. (2018). *Knowledge management in organizations: A critical introduction* (4th ed.). Oxford University Press.

Kässi, O., & Lehdonvirta, V. (2018). Online labour index: Measuring the online gig economy for policy and research. *Technological Forecasting and Social Change*, 137, 241-248.

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling* (12th ed.). John Wiley & Sons.

Köster, K. (2010). *International project management*. SAGE Publications.

Lacity, M. C., & Willcocks, L. P. (2017). *Robotic process automation and risk mitigation: The definitive guide*. SB Publishing.

Lacity, M. C., Willcocks, L. P., & Yan, A. (2016). Are the days of outsourcing numbered? Evidence from the banking industry. *Strategic Outsourcing: An International Journal*, 9(3), 243-261.

Landon, L. B., Slack, K. J., & Barrett, J. D. (2018). Teamwork and collaboration in long-duration space missions: Going to extremes. *American Psychologist*, 73(4), 563-575.

Larson, W. J., & Wertz, J. R. (2018). *Space mission engineering: The new SMAD*. Microcosm Press.

Launius, R. D. (2019). *Apollo's legacy: Perspectives on the moon landings*. Smithsonian Institution Press.

Lindgren, K. (2020). *Interview on risk management in ISS training*. NASA Astronaut Office.

Lindgren, K. (2021a). *Risk-based training for ISS operations* (NASA/TM-2021-225890). NASA Technical Reports.

Lindgren, K. (2021b, February 16). Critical knowledge inSight: Kjell Lindgren: Reflections on astronaut training. *NASA Academy of Program/Project & Engineering Leadership (APPEL)*. <https://appel.nasa.gov/2021/02/16/critical-knowledge-insight-kjell-lindgren-reflections-on-astronaut-training/>

Linenger, J. M. (2000). *Off the planet: Surviving five perilous months aboard the space station Mir*. McGraw-Hill.

Logsdon, J. M. (2010). *John F. Kennedy and the race to the moon*. Palgrave Macmillan.

McDougall, W. A. (1985). *The heavens and the earth: A political history of the space age*. Basic Books.

Messerschmid, E., & Bertrand, R. (1999). *Space stations: Systems and utilization*. Springer.

Miles, I. (2005). Knowledge intensive business services: Prospects and policies. *Foresight*, 7(6), 39-63.

Miles, I., Belousova, V., & Chichkanov, N. (2018). Knowledge intensive business services: Ambiguities and continuities. *Foresight*, 20(1), 1-26.

Minato, K., Nishimura, Y., & Harada, N. (2021). Space flight resource management: Cross-cultural training for international crews. *Acta Astronautica*, 185, 230-241.

Minato, N., Ikeda, Y., Higashimoto, Y., Yamagata, K., & Kamiyoshi, S. (2021). Developing a remote team training program based on the space flight resource management model. *Journal of Space Safety Engineering*, 8(2), 138-149.

NASA. (2015a). *Reference guide to the International Space Station* (NASA SP-2015-3500). NASA.

NASA. (2015b). *NASA procedural requirements NPR 7120.5: Program and project management requirements*. NASA.

NASA. (2016). *NASA systems engineering handbook* (NASA/SP-2016-6105 Rev2). National Aeronautics and Space Administration.

NASA. (2018). NASA's Commercial Crew Program: 2018 year in review. Retrieved May 22, 2025, from <https://www.nasa.gov/specials/CCP2018/>

NASA. (2020a). *20 years of continuous human presence*. NASA ISS Program Office.

NASA. (2020b). *Astronaut candidate training program guide*. Johnson Space Center Publications.

NASA. (2022a). *Artemis astronaut training program overview*. National Aeronautics and Space Administration.

NASA. (2022b). *Artemis plan: NASA's lunar exploration program overview*. NASA HQ.

National Research Council. (2011). *Preparing for the high frontier: The role and training of NASA astronauts in the post-space shuttle era*. The National Academies Press. <https://nap.nationalacademies.org/read/13227/>

Nelson, C. (2009). *Rocket men: The epic story of the first men on the moon*. Viking.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company*. Oxford University Press.

Oberg, J. (2002). *Star-crossed orbits: Inside the U.S.-Russian space alliance*. McGraw-Hill.

Pande, P. S., Neuman, R. P., & Cavanagh, R. R. (2000). *The Six Sigma way*. McGraw-Hill.

Project Management Institute. (2021). *A guide to the project management body of knowledge (PMBOK guide) (7th ed.)*. PMI.

Politz, D. (2025, July 1). *Practical Guide to Grounded Theory Research — DelVE*. Delve. <https://delvetool.com/blog/groundedtheory>

Portree, D. S. F. (1995). *Mir hardware heritage* (NASA Reference Publication 1357). NASA.

Royce, W. W. (1970). Managing the development of large software systems. *Proceedings of IEEE WESCON*, 1-9.

Sagan, S. D. (2011). The end of the Cold War and the future of space exploration. *International Security*, 36(1), 164-194.

Schwaber, K., & Sutherland, J. (2020). *The Scrum guide*. Scrum.org.

Seedhouse, E. (2022). *Astronaut training: A comprehensive guide*. Springer.

Shostack, G. L. (1984). Designing services that deliver. *Harvard Business Review*, 62(1), 133-139.

Siddiqi, A. A. (2000). *Challenge to Apollo: The Soviet Union and the space race, 1945-1974*. National Aeronautics and Space Administration, NASA History Division, Office of Policy and Plans.

Slack, K. J., Williams, T. J., Schneiderman, J. S., Whitmire, A. M., & Picano, J. J. (2016). *Evidence report: Risk of performance and behavioral health decrements due to inadequate cooperation, coordination, communication, and psychosocial adaptation within a team* (NASA/TM-2016-218603). NASA Human Research Program.

Smith, M., Johnson, K., & Brown, T. (2023). Mission-specific training protocols for lunar exploration. *Journal of Space Education*, 15(2), 78-95.

SpaceX. (2021). *Commercial crew training methodology*. Space Exploration Technologies Corp.

Stamatelatos, M., & Dezfuli, H. (2011). *Probabilistic risk assessment procedures guide for NASA managers and practitioners* (NASA/SP-2011-3421). National Aeronautics and Space Administration.

Suvorov, V. (1982). *Inside the Soviet army*. Macmillan.

Swenson, L. S., Grimwood, J. M., & Alexander, C. C. (1966). *This new ocean: A history of Project Mercury*. National Aeronautics and Space Administration, NASA History Office. <https://ntrs.nasa.gov/citations/19670005605>

Tie, Y. C., Birks, M., & Francis, K. (2019). Grounded theory research: A design framework for novice researchers. *SAGE Open Medicine*, 7. <https://doi.org/10.1177/2050312118822927>

Trachtenberg, M. (2018, February 8). Assessing Soviet economic performance during the Cold War: A failure of intelligence? *Texas National Security Review*. <https://tnsr.org/2018/02/assessing-soviet-economic-performance-cold-war/>

Turner, J. R. (2014). *Gower handbook of project management*. Gower.

United States Congress. (1973). *1974 NASA authorization hearings, Ninety-third Congress, first session, on H.R. 4567 (superseded by H.R. 7528)*. U.S. Government Printing Office. <https://catalog.hathitrust.org/Record/003212095>

Weinzierl, M. (2018). Space, the final economic frontier. *Journal of Economic Perspectives*, 32(2), 173-192.

Willcocks, L., Lacity, M., & Craig, A. (2015). The IT function and robotic process automation. *The Outsourcing Unit Working Research Paper Series*, 15(5), 1-39.

Wolfe, T. (1979). *The right stuff*. Farrar Straus and Giroux.

Womack, J. P., & Jones, D. T. (2003). *Lean thinking: Banish waste and create wealth in your corporation*. Simon & Schuster.

Zak, A. (2019). *Russia in space: The past explained, the future explored*. Apogee Prime.

Zeithaml, V. A., Bitner, M. J., & Gremler, D. D. (2018). *Services marketing: Integrating customer focus across the firm*. McGraw-Hill Education.

List of Acronyms

ASCAN: Astronaut Candidate

BT: Basic Training

CNES: Centre National d'Etudes Spatiales

CSA: Canadian Space Agency

EAC: European Astronaut Centre

ELDO: European Launch Development Organisation

EO: Earth Observation

ESA: European Space Agency

ESRO: European Space Research Organisation

EUROCOM: European Communicator and Medical Operations

GCTC: Gagarin Cosmonaut Training Center

IDP: Instructional Development Process

ISD: Instructional System Design(er)

ISS: International Space Station

JAXA: Japan Aerospace Exploration Agency

KPI: Key Performance Indicator

LEO: Low Earth Orbit

LMS: Learning Management System

NASA: National Aeronautics and Space Administration

OM: Operations Management

PaaS: Personnel-as-a-Service

PDCA: Plan-Do-Check-Act

PM: Project Management

Roscosmos: Russian Federal Space Agency

SLA: Service Level Agreement

SM: Service Management

VR: Virtual Reality

Appendices – Table of Contents

Appendix A: Central Intelligence Agency, Directorate of Intelligence, Office of Strategic Research. (1969). *Contribution to E 11-1-69: The Soviet Space Program—Expenditure Implications of Soviet Space Programs*.

Appendix B: NASA (2021). NPR 7120.5 – NASA Space Flight Program and Project Management Requirements

Appendix C: Interview Questionnaire and Transcript – D. Churkin, Basic Training Coordinator at ESA, July 2025

Appendix D: Interview Questionnaire and Transcript – T. Hoppenbrouwers, former Payload Instructor at ESA, July 2025

Appendix E: Déclaration sur l'honneur sur le respect des règles de référencement et sur l'usage des IA génératives dans le cadre du mémoire ou d'un travail

