Mission first, safety always?

The balance of training in a simulated environment full of exceptions for a mission where safety has no compromise. A study of Aviation Maintenance Training on F-16 Aircraft.

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Acknowledgements

To my wife, my everything. Nothing would have been possible without your help. You have my deepest gratitude. I love you, Linda.

Abstract

This research project aimed to identify resource deficiencies in F-16 crew chief training. Initial feedback suggested the primary issue was the lack of an operational aircraft, though the data was insufficient to confirm this definitively. Employing Human-Centered Design (HCD) as the main methodology, the project focused on understanding the needs of students, teachers, and managers within the training program. HCD's iterative and user-focused approach, combined with expertise in human factors, F-16 operations, and learning theories, informed the research process.

Qualitative data was gathered through an electronic questionnaire and interviews with trainees who had completed the initial course and experienced its limitations firsthand. Analysis identified a significant gap in training resources, particularly the absence of a working engine necessary for launch and recovery procedures—high-risk tasks requiring meticulous safety protocols. Interview data was categorized into themes of training resources, attitude and culture, safety and human factors, and suggestions for innovation.

The findings highlighted critical shortcomings in the existing Training Needs Analysis and the psychomotor skills framework based on Bloom's taxonomy, exacerbated by the mismatch with the Romanian Air Force's procedures. The study revealed that inadequate resources led to procedural exceptions and alternative methods, impacting both trainee and instructor attitudes towards safety and adherence to protocols. Furthermore, cultural differences among instructors contributed to confusion among trainees.

To address these issues, stakeholders proposed various technological solutions, including haptic feedback devices, instructional videos, augmented reality for hazard visualization, and remote assistance technologies. These solutions, aligned with HCD principles, aim to enhance training effectiveness and foster a community of practice that supports continuous competence development. This preliminary research lays the groundwork for a comprehensive design effort to improve F-16 crew chief training through innovative technology integration.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Today's aviation industry is suffering from a severe lack of qualified technical personnel, both in the civilian and military sectors. According to Airbus [1] and Boeing [2], there is a need of approximately 700 000 maintenance technicians in the civilian market in the next 20 year period, 156 000 of them just for the Eurasian market alone. "Europe's aviation future hinges on its ability to train and retain a skilled workforce. As the industry grapples with this challenge, entrepreneurs have a unique opportunity to step up"[3]. Competing for the same personnel and expertise, is the military sector or, more specifically, the various air forces. The Royal Norwegian Air Force (RNoAF) reports a "marginal amount of maintenance technicians" [4], and that they are struggling to meet the necessary staffing to sustain activities with new airborne systems [5] such as the F-35 "Lightning II", P-8 "Poseidon" and AW-101 "SAR Queen".

The recent developments in geopolitics and deterioration of global stability with the 2022 Russian invasion of Ukraine, as well as the renewed conflict in the middle-east, have spiked a massive demand in military equipment and personnel. Aside from the soldiers who will operate military equipment on the battlefield, there is also a surge in demand for skilled workers within maintenance and manufacturing, which drives a need for increased training. In the case of the Ukraine war, several Western allies have pledged support in the form of both modern and outdated equipment ranging from fighter jets to artillery systems. In several cases, decommissioned equipment is pulled from storage warehouses and refurbished for operational use, but this solution is not without caveats. As a weapon, vehicle or system is phased out of active service, it is natural that all supporting activities and infrastructures for that system are discontinued as well. This includes staffing of qualified personnel, training, ordering of spare parts, maintenance, available facilities etc. Resurrecting abandoned supporting activities under the pressure of war, where no amount of support is ever enough, poses many challenges.

One of the most complex systems to operate, both in terms of personnel and infrastructure requirements, is combat aircraft. Several former Soviet nations pledged and delivered aircraft such as the MiG-29 "Fulcrum", L-39 "Albatros" and Su-25 "Frogfoot", presumably because Ukraine were already operating these types and had qualified personnel and infrastructure for them. While the aforementioned aircraft have the benefit of having a short way from storage to operational use, they suffer in terms of capabilities and are outmatched by their modern Russian counterparts. To improve Ukraine's ability to defend itself, several Western governments have pledged their decommissioned F-16 "Fighting Falcon" fighter jets. While these aircraft have better capabilities and are urgently needed, Ukraine had no infrastructure or personnel qualified to operate the aircraft. Therefore, an extensive international effort has been established to provide training, while Ukraine prepares the necessary infrastructure for their arrival. With no signs that the Russian offensives are slowing down , and frequent massive missile and drone barrages, the pressure to deliver these aircraft can not be understated.

Situated South-West of Ukraine is Romania which is also transitioning from a former Soviet fighter jet (MiG-21 "Lancer") to the F-16. In 2022, the Romanian government decided to purchase 32 Royal Norwegian Air Force (RNoAF) F-16 “Fighting Falcon” aircraft [6], as Norway transitions to the F-35 "Lightning II". Although the circumstances regarding war are different than Ukraine’s situation, there are arguably more similarities than there are differences. The paradigm-change from Soviet standard aircraft to NATO standard, the need to convert pilots, technicians and other staff from one aircraft type to a new one, introduction of new support equipment and infrastructure all dictate the need for extensive training. The responsibility of transfering the aircraft, and necessary support, such as training the Romanian maintenance technicians, sits at the Norwegian Defense Materiel Agency (NDMA). However, the NDMA is no training organization, and therefore Kongsberg Aerospace Maintenance Services (KAMS) was awarded the contract to deliver necessary F-16 refurbishment and upgrades, as well as technical training[7][8]. While KAMS has access to skilled workers, they do not have the resources to provide complete training on top of their other obligations, hence Agder Aviation Tech Team (AATT) was sub-contracted to provide theoretical and practical training. The training itself takes place at the Royal Norwegian Air Force training center Kjevik, however, the RNoAF are not contributing with instructors, but merely providing training facilities. This highlights an issue which should be questioned. How come it is not the RNoAF providing technical training instructors, considering the fact that until a couple of years ago, Norway was still operating the aircraft? Likely, while the F-16 was being phased out, most of the F-16 personnel began conversion to F-35 or other new aircraft types. Removing such personnel from their roles to provide F-16 training, even if only temporarily, would likely delay operations and implementation of the newly received aircraft types. As a result, most of the ***available*** F-16 expertise exists among ex-military personnel who have changed profession or entered retirement.

Besides competent instructors, another challenge presents itself. If aircraft, spare parts and support equipment is being prepared for transfer to its new owners, then what shall the training be carried out with? Typically, the focus of a sale are the items in question and the exchange of funds according to contract, but to perform training the same items, or resources, need to be available at the training facilities as well. If the equipment allocated to the training center is outdated, partial or in poor condition, it arguably becomes increasingly difficult to perform the necessary training to ensure that the minimum standards and experience requirements are met. There are several options to mitigate the lack of resources, such as incorporating simulation, creating physical mock-ups/replicas, or moving the training responsibility to the end-user. Ultimately, the aforementioned options have drawbacks and constraints such as time-demand, cost and conflicting prioritization, but there are incentives to study the problem and search for solutions. What are the potential costs of inadequate training? On the base assumption that lack of training increases risk of performing incorrect actions, then the outcome of performing incorrect actions on aircraft may cause damage or loss of equipment, injury or even death to personnel. The issue of ***safety*** is at the forefront of every serious actor in the aviation industry, but how elastic is the concept when put under pressure?

Whether there are passengers waiting to travel to their destination, or there are front line soldiers in need of air support, both civilian and military aviation face significant amounts of pressure to deliver on time. The consequences of delay could take form in financial and reputation loss, or military defeat and loss of lives, respectively. On the other hand, rushed decisions or actions could compromise safety. In the best case scenario, a safety violation may lead to a delay or canceled flight, but in the worst case the aircraft, crew and/or passengers are all lost. A common every-day phrase to remind ourselves to be careful is "safety first", usually referring to an action that minimizes risk. However, several military organizations [9] [10] [11] have adopted the phrase "Mission first, safety always", including the RNoAF Flight Safety Inspectorate. The phrase implies that no matter what the current objective is, safety is always present, yet it displays some ambiguity in that the "mission" takes priority (first) above all else, even safety. Regardless of semantics, it should be emphasized that occasionally accidents do happen, and therefore there is no such thing as a risk-free flight or environment. Fortunately, the risks may be reduced by applying safety measures and routines, including promoting a safety-aware culture. It is easy to understand that making rushed decisions or taking shortcuts will adversely affect flight safety, but how about during maintenance training? If an aircraft is found to have insufficient parts, or not enough time to complete a task it is usually grounded (prohibited from flight). What happens if a training course is set to start, but there are not enough instructors, a lack of materiel, or not enough time to prepare lessons? The consequences might not be as easily understood as it may take several months before they materialize into an observable symptom. If a technician decides to perform an incorrect action, is that decision influenced by malpractice or incorrect training several months ago? The question may not be simple to answer, but the importance and relevance of training is understandably there. Ultimately, the responsibility of airworthiness rests on the shoulders of maintenance personnel. In a situation where operational demands tend to take priority over training demands, can one confidently exclaim "safety always"? If not, what can be done about the situation?

The chief of staff of the Royal Norwegian Air Force holds the overarching responsibility of safety, and the importance of resources in relation to safety are underlined in the *Regulation on Safety Management in the Air Force*:

> "The division must have the necessary competence to ensure safety. Requirements for competence in various positions must be defined and described. Divisions should work to develop a good safety culture. The division must allocate and secure sufficient resources to maintain and improve safety. Reduced safety levels should not be justified by lack of resources, and activities must therefore be adapted to available resources. Resources include personnel, materials, protective equipment, finances, time, buildings, facilities, infrastructure, and other resources important for safety [12]."

The purpose of this thesis is to investigate the currently ongoing training of Romanian F-16 *crew chiefs* and identify a critical area of practical training which is affected by a lack of resources, prioritization, or other adverse factors. Thereafter, the problem will be analyzed and compared to existing aviation safety theory, as well as previous technological solutions with the goal of mapping out a course of action to improve the safety and quality of the training.

1.1 Hypothesis and Research question

Provided there are signs of personnel and materiel shortages, and an urgency to prioritize their limited quantities towards operational demands, it becomes interesting verify the problem. Moreover, to identify consequences, their impact on safety, and to search for possible solutions.

Therefore, the following hypothesis are put forward:

- There is a perceived lack of resources allocated for flight line training.
- The lack of resources lead to making exceptions to standard procedures.
- Training with a lack of resources affects the attitude towards training and the tasks involved.
- There are technological innovations that can minimize or nullify the effects of lack of

resources.

1.1.1

"How can the quality and safety of flight line personnel training be maintained in the event that there is a lack of resources" The main research question aims to maintain quality and safety of flight line personnel through training. Training is a prerequisite for all professional aviation maintenance personnel. Resources, such as qualified instructors, necessary training materials, equipment and specialized tools are central to learning to perform maintenance in a safe manner. Constant demand on aircraft and personnel lead to shortages that may force management into challenging decisions. In the event that training suffers from a lack of resources, what can be done to uphold the quality and safety?

1.1.1.1

"How does training without all the required resources affect the safety of both aircraft and personnel?" To help answer the main question, it is critical to establish which part of the technical training to focus on. Preferably a task where the risk of damage to equipment or injury to personnel is high. Furthermore, the task should be one where it is currently difficult or impossible to perform it in a complete and realistic fashion due to lack of materiel resources, priority or personnel. If one has no other option but to perform training, despite the aforementioned challenges, what are the potential consequences?

1.1.1.2

"What effects are there of exceptions during training, and how do they affect the attitude towards the task?" If a training course includes some tasks that are possible to fully complete, but also tasks that are impossible to complete, there could be confusion among students about when exceptions are acceptable. If a worn component does not meet the minimum requirements for service, it is natural to expect that the component must be overhauled or replaced with a new one. But what happens when there is no spare component, or equipment to overhaul the worn one? One could abort the task, and the student would not have the opportunity to practice their skills. Another approach is to perform the task, but make exceptions to the quality-requirements of the component to ensure the student can practice performing the task. Outside the training environment, the answer should always be to declare the aircraft unfit for service until a serviceable component is installed. However, more often than not, training is performed with unserviceable parts. This problem is not only limited to components, but even tools, manuals, facilities and the task environment itself. For instance, training on how to perform engine ground operations without a functional engine makes it impossible to recreate the sound, vibrations, airflow and temperature that a technician must contend with.

1.1.1.3

"Which solutions may be recommended to improve training of flight line personnel and minimize the risks?" Granted that there are negative and potentially dangerous effects of training with a lack of resources and widespread use of exceptions, what can be done about them? Are there some techniques or technologies that can minimize the challenges, or improve the training? Perhaps they can even offer improvements to areas of training that are not suffering from a lack of resources? There should be similar problems across both the aviation- and other high-risk industries. How have other teams or researchers managed to solve similar issues, and are their solutions applicable to this problem as well? There are certainly incentives to minimizing the risk and improving the safety, and thus it is interesting to verify existing solutions as well as develop new ones.

1.2 The researcher's role and credibility with respect to the subject matter

How does one arrive at the idea that there may be a problem worth investigating related to procedures training in an F-16 type course? My role as an instructor working at the RNoAF training facilities at Kjevik certainly plays a major part. To provide you, the reader, an opportunity to gauge my competence and credibility on the subject matter, I will provide some background information. I have worked in the Royal Norwegian Air Force as a maintenance technician and instructor between 2007 and 2021. From 2007 to 2009, I underwent boot camp and a leadership course, before qualifying the EASA Part66 B1.1 basic training and F-16 Systems type course in 2009. The next 3 years were spent as an F-16 Crew Chief on the flight line with 338 squadron at Ørland Main Air Base, before transferring to the air force training facilities at Kjevik in 2012. There, I worked as a fighter aircraft technical instructor, training F-16 system specialists, crew chiefs and crew chief assistants, as well as teaching EASA B1.1 and B2 basic training modules. In 2014 I qualified the Engine Ground Operation (EGO) course and later, in 2015, the F-100-PW-220E power plant (engine) type course, before being promoted to senior/main instructor on combat aircraft systems in 2016. My role as a main instructor was to manage, update, plan deliver courses related to combat aircraft systems and power plant. As an extra function I maintained, modified and operated several F-16 simulators that were used for technical training, some of which used Virtual Reality technology. Additionally I had a role as "super-user" in our Learning Management System and a desktop-based virtual maintenance training software known as the "F-16 Technical Training Package" (TTP). In 2018 I enrolled in a computer engineering Bachelor's programme at the University of Agder, where I combined a full-time job and study. After graduating with a Bachelor of science in computer engineering in 2021, I enrolled in the Master's programme of Multimedia and Educational Technology, also at the University of Agder. At the same time, I ended my military career by leaving the air force and joining the newly established Agder Aviation Tech Team (AATT). At the time, they were contracted to deliver EMAR 66 basic training for the RNoAF and in 2023 AATT was contracted to deliver F-16-related training for Romanian F-16 technicians and management staff, including F-16 type training courses.

In summary, my background indicates that I have over 16 years of experience in aviation maintenance and technical training, where I have learned about military aircraft operations, flight line operations, maintenance practices, maintenance organizations, human factors, technical training and much more. This allows me to draw on my own observations and interpretations of them throughout my career. However, I want to make it abundantly clear, that I will not admit my personal observations and interpretations as *evidence* or causation throughout this research, but rather use them as anecdotes and examples where they have relevance to the subject matter. It is difficult to find public information about *what* things are and *how* they work within the context of F-16 technical training and maintenance operations, as most if not all documentation is restricted from public access. This is an area where I will apply my domain knowledge to extract relevant information which is not considered sensitive, such as general concepts and methods within the industry. When it comes to *why* things are the way what they are, or work like they do, I will exert caution to prevent injecting personal sources of bias.

1.3 Previous research

The RNoAF have been implementing new aircraft types, ranging from the C-130J Super Hercules, to NH-90, F-35 Lighting II, AW101 SAR Queen and P-8 Poseidon, and the process of implementing new aircraft systems is not without challenge. Both maintenance personnel and aircrew require training and the new system introduces a restructuring of organizations, implementation of new logistics systems, establishment of new infrastructure and also a phase-out of existing systems.

I was personally on board a C-130J Super Hercules transport flight from Ørland to Bodø the same week as it crashed in Kebnekaise in 2012. The crash investigation has so far pointed out at lack of training and knowledge in use of new Terrain Awareness and Warning System as one of the key causes of the crash [13]. Few years later, in 2020, another C-130J found itself in a similar situation, and was merely 44 meters, or 1 second away from crashing into Mosken [14]. The report published a year later by chief of staff of the RNoAF pointed at *considerable competence challenges and an undeveloped safety culture* as one of the main challenges of the air force. In 2017, a brand new AW101 SAR Queen rolled over on the flight line during a ground maintenance procedures, destroying the helicopter in the process. The incident report pointed at multiple sources of error, including errors in the training, imprecise documentation and subsequent lack of system knowledge[15]. This lead to a lack of faith in the checklists and pilots skipping some steps in the procedure which caused the rotor to generate lift and roll the helicopter. A recent incident occured in Romania in 2022, where a MiG-21 LanceR crashed in the Black Sea, and the rescue helicopter which was sent to search for the pilot also crashed [16]. The accidents were attributed to several causes within human and environmental factors.

Drawing from losses of Norwegian aircraft, it is apparent that even with new systems, human error remains a common cause for accidents. These lead to substantial losses in capability, economy and, in the worst cases, human life. Such incidents are a strong motivator to stay vigilant and search for both problems and opportunities within safety, and particularly within training.

1.4 Scope and limitations

There is a clear concern regarding restricted access and exhibiting discretion where ever military activity is involved. From local military base regulations to international laws regulating arms traffic, there are several pitfalls to be aware of to avoid accidentally leaking sensitive information. Given that this research is performed in the context of two cooperating military forces (Norwegian and Romanian), being taught to maintain and operate military fighter aircraft produced in the USA, there is ample reason to proceed cautiously when collecting and disseminating information. This also limits which sources of information that can legally be cited in this thesis, and to which extent the procedures, activities, working environment and key personnel can be described. For instance, it is prohibited to take photographs on the premises of the training center, and the aircraft Technical Orders (TOs/manuals) are under International Traffic in Arms Regulations (ITAR) by the United States Department of Defense, and may not be disclosed. Therefore, generalizations and abstractions will be made for the sake of the reader understanding the context and underlying ideas behind a given item or procedure, while maintaining confidentiality. Use of direct quotations or paraphrasing of technical data, limits, values, procedures as well as figures and schematics from maintenance manuals shall be avoided.

1.4.1 International Traffic in Arms Regulations (ITAR)

"The ITAR (22 CFR parts 120-130) governs the manufacture, export, and temporary import of defense articles, the furnishing of defense services, and brokering activities involving items described on the United States Munitions List (USML)" [17]. The regulations are authorized under section 38 of the Arms Export Control Act [18]. There are fairly recent examples of violations to this regulation with undesired consequences for those involved such as a video game developer being sentenced to over 12 months in prison [19]. A popular video game *War Thunder*, has experienced multiple leaks of classified documents regulated by ITAR and equivalent arms export control laws [20]. These include classified documentation leaks about the F-16A, F-15E, LeClerc and Challenger 2 main battle tanks. The leaks are made by enthusiastic forum members who try to convince/argue their points about the vehicles' capabilities. To avoid breaching such rules, this thesis will be limited by data, specification and value omissions. Launch and recovery procedure information which is of relevance to this thesis will be highly generalized.

Chapter 2

Theory

This chapter includes background information and technical data about the F-16 and supporting elements, the F-16 Crew Chief, as well as key theories within the fields of learning and human factors in aviation maintenance.

2.1 F-16

The F-16 "Fighting Falcon" was originally conceived as the next-generation "light-weight fighter" of the United States Air Force (USAF). Originally designed by General Dynamics, the fighter aircraft started its career in 1978 as an air superiority fighter, but later evolved into an all-weather, multi-role aircraft capable of performing a slew of missions. Several European air forces were in need of replacing their aging fleets of older aircraft at the time and the F-16 presented itself as the natural choice to renew their capabilities. Norway found itself in this exact situation, and signed a contract for the purchase of 72 aircraft, 60 A-models (single-seat) and 12 B-models (two-seats), with a later order of 2 F-16B.

The RNoAF F-16 underwent several upgrades and improvements throughout its lifetime with the most comprehensive update being the "Mid-Life Update" (MLU). The MLU program was carried out throughout the 90s with the last airframe completing the upgrade in 2001. Among the improvements were a modernized avionics suite with color multi-function displays, a new radar, better pilot-aircraft interface, new weapons integration, a helmet-mounted sighting system and electronic warfare management system. Due to attrition, only 56 aircraft completed the modernization program, and continued to receive minor updates and improvements throughout its service life. Norwegian F-16s participated in five major international operations; Allied Force (1999), Enduring Freedom (2002), Baltic Republics Air Police (2004), Afghan Falcon (2006), and Unified Protector (2011).

In January 2022, after 42 years of service, the F-16 ended its operational life in the RNoAF. Most of the airframes were in such good condition, that 32 of them were sold to Romania with another 12 stapled for Draken International, a firm providing support services to other air forces [21].

2.1.1 F-16 technical data

The F-16 is a single-engine, fixed-wing fighter aircraft with several distinct features such as a frameless bubble-canopy, an underside-mounted air intake, a side-mounted control stick, and the first military aircraft to feature a relaxed stability design and "fly-by-wire" control system. It features a 20mm rotating (gatling) gun, 9 weapon stations and two hardpoints for mounting a variety of fuel tanks, targeting sensors, electronic warfare equipment, and air-to-air and air-to-ground weapons. Its Pratt & Whitney F-100-PW-220E afterburning turbofan engine allows the F-16 to reach speeds in excess of mach 2. An aerial refueling system allows the aircraft to receive fuel from a tanker aircraft during flight which extends the operational range and mission duration. The Norwegian and Dutch F-16s also have a drag-chute system to decrease the landing roll on short and/or icy runways. The aircraft's many sensors allow it to operate day or night, in all-weather conditions and perform multiple roles of air combat. The F-16 was originally delivered in two different models, "A" and "B", and as the first upgrades started emerging at the factories, these were incrementally designated as "Blocks". Norwegian F-16s were delivered as Block 1, 5, 10 and 15, and prior to MLU all the Block 1s and 5s were upgraded to Block 10, leaving the fleet at a mix of F-16As and F-16Bs at Block 10 and 15 configuration.

As the factories continued with the Block updates, several European air forces opted out of further improvements thus parting with the United States Air Force developments, until the introduction of the MLU program. After completing the MLU, all F-16 models were appended with the letter "M", leading to the designations F-16AM and F-16BM. Thereafter, software update packages were referred to as "M-tapes", such as "M1, M4.2 and M6.5", which were continuously deployed to fix software issues and improve the F-16s capabilities[22].

2.1.2 F-16 support systems and maintenance concept

The F-16 should be thought of as a complete system. Besides the aircraft itself, there is the training of pilots and maintenance personnel, support equipment, logistics system, infrastructure and other supporting elements which are all essential components to operate the aircraft.

The maintenance is split into three different categories known as "Organizational level" (O-level), "Intermediate level" (I-level) and "Depot level" (D-level), ranging from daily inspections and simple replacements at O-level, to complete disassembly and overhaul of aircraft and components at D-level.

Daily maintenance activities such as servicing, inspections and minor repairs are carried out at the O-level by squadron maintenance personnel who work on the flight line (aircraft operating area).

I-level maintenance includes scheduled inspections, testing and repair which require specialized equipment. I-level facilities are typically regionally located on an airbase, and is supported by workshops and specialist crew. The I-level facilities provide supporting services to the O-level maintenance activities.

Finally, the D-level maintenance includes major overhaul, disassembly, inspection and modification of aircraft and components. These facilities are often centralized and could be both military or civilian. A depot facility may serve multiple aircraft types, from multiple airbases and often provide manufacturing and engineering capabilities[23].

2.1.3 F-16 Crew Chief

On a general basis, the crew chief (CC) is a specialized category of technician who is responsible for the daily upkeep and maintenance of a jet. According to Kinman [24], origins of the crew chief can be traced back to 1944, when the air force launched the concept of "pride in ownership". They realized that to conduct effective maintenance, each aircraft needed a dedicated mechanic and crew, and hence the concept of crew chief was adopted. The crew chief would have basic training, as well as specialized training from the manufacturer. He would manage the aircraft maintenance, and a small team of mechanics who he trained through on-the-job training.

The responsibilities of the crew chief remain largely the same today. There are variations in roles and duties, depending on which aircraft you work on or which air force you belong to, but the general responsibilities are typically:

- Daily inspections;
- unscheduled maintenance;
- servicing;
- on-the-job training;
- coordination of specialists;
- aircraft marshalling;
- release to service.

Crew chiefs are usually the last people to interact with the jet and pilot before the aircraft departs on a mission, and in this sense they are the final "safety net" to detect any adverse conditions of the aircraft. They often work outdoors in all weather conditions, day or night, and must remain vigilant and focused at all times. Because the crew chief is tasked with preparing the aircraft for flight, they are also assisting the air crew (pilots) in starting the aircraft and checking all the critical system functions on the ground. As opposed to most other technicians, this places the crew chief in a particularly hazardous environment, where a lack of awareness may lead to serious injuries, death or damage and destruction of equipment. The crew chief often operates in a dynamic environment with multiple vehicles, personnel, obstacles or maneuvering aircraft, and must marshal (direct) the pilot on the ground. Apart from the aforementioned, the crew chief performs multiple daily inspections, before and after flights, to ensure the aircraft is safe for operation. The inspections and maintenance procedures are documented in manuals named Technical Orders, or "TOs". Any discrepancies are noted in the aircraft logbook, also referred to as "form", and dealt with accordingly. Tasks the crew chief is authorized to perform include servicing, operational checkouts, replacing certain parts and components, as well as releasing the aircraft to service. The latter underlines the importance of the crew chief, and is a nod towards aircraft "ownership". The aircraft does not fly until the crew chief deems that it is airworthy and signs the inspection. This places a lot of responsibility on the crew chief, who must balance the urgency and importance of the mission against the safety of aircraft and personnel.

The "snags" (technical problems) that require specialized skills or knowledge to repair prompt the crew chief to request and coordinte these specialists. In the RNoAF, an F-16 crew chief is usually accompanied by a Crew Chief Assistant (CCA), who assists with the duties of the crew chief. Usually they assigned to the right hand side of the jet, and perform the inspection tasks that are associated with their side. The CCAs are typically conscripts, and do not formally share responsibility with the crew chief. They merely report to the crew chief about problems or issues found during inspection, and assist with servicing and other maintenance tasks. The crew chief and crew chief assistant also provide on-the-job training for newcomers.

2.1.4 Launch inspection

The launch inspection is the name of a procedure that accompanies every aircraft startup procedure, when the aircraft is intended to fly. It describes all the required equipment and personnel, as well as all critical aircraft systems that must be verified for correct operation prior to flight. What makes the launch and recovery procedures different from many other maintenance manuals, is that they are normally carried out without the manual in-hand. To minimize the risk of Foreign Object Damage (items ingested into the engine), loose items are kept to a minimum. This requires the crew chief to train to the point that they know the procedure by heart, like a drill. The launch procedure for the F-16 can be broken down into the following main parts:

- Pre-start checks;
- engine start, fire and leak monitoring;
- post-start checks;
- system condition checks;
- flight control system checks;
- brake check;
- removal of protective covers, safety pins, intercommunication and wheel chocks;
- emergency power system checks;
- marshalling.

The crew (CC and CCA) must maneuver around the aircraft, inspect for leaks and malfunctions, check gauges for correct levels and pressures, as well as coordinate operation of various systems with the pilot to verify correct operation. The system gauges, indicators and sight glasses are accessible either in the open landing gear wheel wells, or through quick-access panels which open by push buttons.

Because the F-16 can have different operational requirements, missions, weapon loadouts and configurations; the associated risks and procedures may vary accordingly. During the procedure, the crew must walk, kneel and position themselves in various places to observe, inspect and verify the condition of the aforementioned items. In some areas, the crew can be less than a meter from a fatal hazard area. The importance of vigilance, focus and awareness can not be understated, as the engine inlet is large enough to ingest a person. Apart from the inlet, the flight control surfaces pose a threat. The hydraulic pressure and force is high enough to crush or dismember limbs with ease, and their speed of travel and weight can deliver blunt force blows to unsuspecting crew. The jet and weapons are full of sharp objects. The engine exhaust can send a person flying across the flight line, or propel objects and debris that can impact others. An engine malfunction can send severed turbine blades through the sides of the fuselage and cause massive fires in the blink of an eye. Hot gases and exhausts from the aircraft systems may cause burns, and there are a range of powerful electromagnetic devices such as the radar, jammers and radios which could emit hazardous levels of radiation if operated. In summary, the crew must not only fulfill their duties in a safe manner, but also be prepared to handle ground emergencies.

Throughout the launch procedure, crew and aircrew are normally able to communicate through an intercommunication system. This permits coordination and audio feedback with headsets and cables without requiring line of sight. In events where intercommunication is not available or used, crew and aircrew must communicate by hand signals. The noise levels surrounding the jet make it impossible to communicate without the aforementioned methods, and headphones also serve as hearing protection. If the crew chief or their assistant discovers an unsatisfactory, unsafe or emergency condition on the aircraft, the crew chief is responsible of making the decision to alert the pilot and abort the mission. The same applies to the pilot, when they detect a fault in the cockpit. At the end of the launch procedure, the crew chief transfers the responsibility of the aircraft to the pilot, which is usually signified by a salute gesture.

A generalized overview of the aircraft, surroundings and major hazard areas can be seen in figure 2.1.

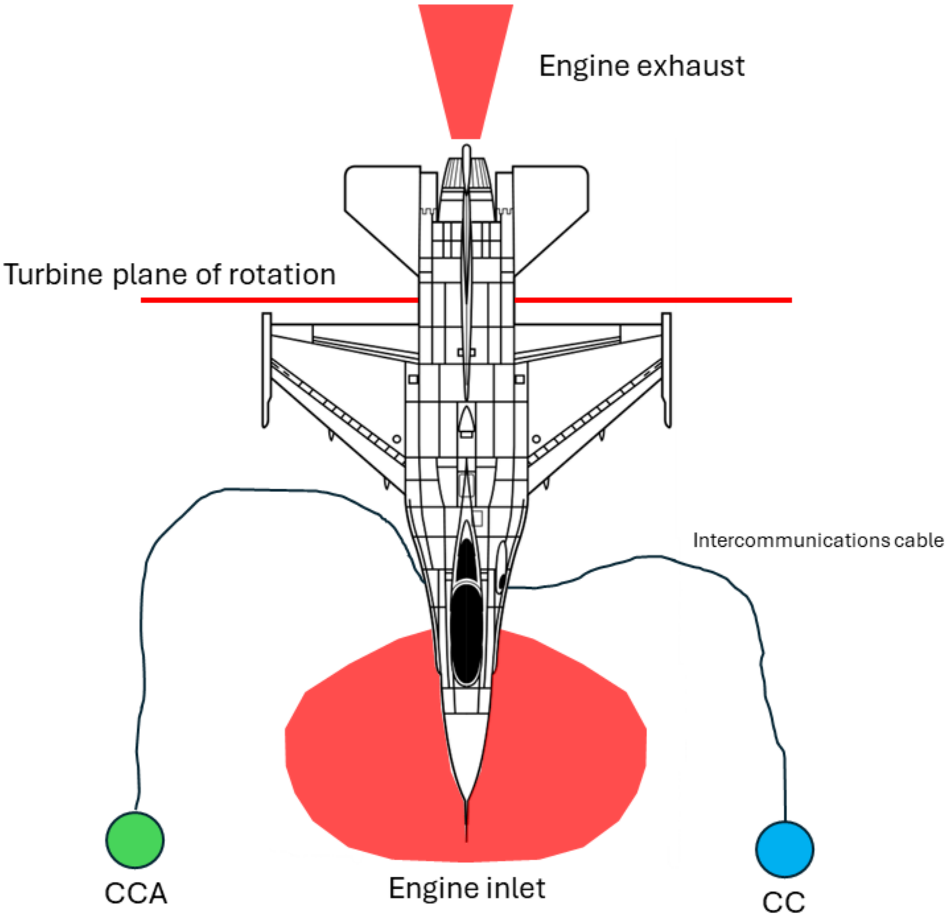

Figure 2.1: Aircraft overview with major hazard areas, generalized

2.1.5 Recovery inspection

The recovery inspection procedure describes how to receive an aircraft after a mission, ensure that it is in a safe condition, and shut down the aircraft. Because the aircraft is not about to fly again, the procedure is significantly less complex. It begins with signaling to the pilot by crew chief hand gesture that the responsibility of the aircraft is now returned to the crew chief. The crew chief directs (marshals) the aircraft to its parking position and proceeds to prepare it for shutdown. The recovery inspection can be broken down into the following main parts:

- Marshalling;
- installing protective covers, safety pins and wheel chocks;
- system condition checks;
- engine shutdown;

Similarly to the launch procedure, the recovery also requires crew to maneuver around the aircraft while the engine is operating. Depending on the mission activities, the weapon loadout may have changed, and other in-flight events may have affected the aircraft. Awareness should be maintained to observe these conditions, for example the aircraft could have overheated brakes which pose an explosive risk. In some cases, this requires the crew chief to redirect the aircraft to a designated safe area, where such events are less likely to harm others.

After shutdown, the crew chief assists the pilot in exiting the cockpit, is debriefed on the aircraft technical status and any issues thay may have occurred in flight, and proceeds to perform the next routine inspection, refuel the aircraft and service aircraft systems as required.

2.1.6 Historic F-16 Technical Training concept

The F-16 technical training has undergone multiple revisions throughout the aircraft's service life.

Initial training for the first batch of technical personnel was provided by instructors from the USAF through classroom lessons and practical training. Systems Training Manuals (STMs) were provided as learning material, and the courses were organized by O-, I- and D-level concepts depending on the duties of the technical personnel.

Eventually, Norwegian F-16 technical training was established at Rygge Air Force Base, before relocating to the Air Force Training Center at Kjevik. Locally developed training material started supplementing the STMs, before gradually replacing them completely with locally made books and slideshows.

The Norwegian F-16 organization underwent a major restructure of maintenance personnel categories in the 2000s, opting to convert from O-, I- and D-level concepts of the USAF to European Aviation Safety Agency (EASA) part 66 (Certifying staff) [25] B1 and B2 categories. As a result of this restructure, the F-16 technical training was divided into two courses known as B1 (Aircraft Systems and Power plant), and B2 (Avionics and Weapon systems) type courses. F-16 Crew Chief trainees were enrolled as B1 Type-Course students. The F-16 type training typically lasts between 3-4 months and consists of approximately equal parts of theoretical and practical training. Theoretical training is divided by aircraft system numbers, based on the Air Transport Association (ATA) 100 series [26]. The practical training consists of a minimum set of maintenance tasks that has been selected based on task frequency, complexity, variety, safety, criticality, novelty, etc. The duration of practical training should reflect the amount of time needed to perform the maintenance task set. Type training completion is determined by passing all theoretical exams with a minimum score of 75% and demonstrating satisfactory work methods and attitude through several practical assessments. Thereafter, the student will transfer to an organization (fighter wing/airbase) and perform On-The-Job (OJT) training. The OJT is provided as a program where the student must complete a minimum amount of tasks/hours under supervision of senior technicians before they are authorized to certify airworthiness of aircraft. This process usually takes approximately nine to twelve months to complete. Once the student is authorized, they are considered "certifying staff" and are allowed to declare the aircraft airworthy within the scope of their training/role. For a Crew Chief, this means that the technician is authorized to sign daily inspections, servicing and maintenance tasks related to aircraft systems and power plant.

The final F-16 B1 type course on behalf of the RNoAF was held in 2018. By this time the RNoAF was in process of transitioning from the EASA regime to European Military Aviation Requirements (EMAR), a military adaptation of EASA with the same goals of achieving the highest levels of airworthiness. EMAR is rapidly becoming the standard to which European military aircraft manufacturers, training facilities and continuing airworthiness organizations (air forces) adhere to. As a result of the establishment of the European Defence Agency (EDA) in 2004, [27] EMAR was conceived in an effort to harmonize airworthiness requirements and processes across member states. EMAR is also harmonized to EASA requirements, which further helps align civilian and military airworthiness processes. In relation to technical training, there are minor differences related to the list of aircraft systems, which has been expanded to include military/combat systems.

2.1.7 Current F-16 Technical Training concept

To deliver F-16 technical training for Romanian students, a Training Need Analysis (TNA) was carried out in a joint effort between Romanian and Norwegian representatives from the air force, governments, contractors and defense material administrations. The TNA results were used to form a Task Training List for the type courses. Initially, a theory and task-oriented approach was offered by Norwegian representatives, but per Romania's request, they wished to organize technical personnel according to specialists within aircraft systems, fuel systems, power plant, avionics, weapon systems, survival equipment and crew chiefs. Furthermore, they also decided to adopt the O-, I-, and D-level concepts which are inherent to the original F-16 maintenance concept. Based on the responsibilities of the respective specialists, knowledge, skill and attitude levels were adopted from Bloom's taxonomy [28] to facilitate establishing learning outcomes.

All aircraft systems were given a knowledge requirement ranging from 1-6, and specific maintenance tasks related to each system were given a skill requirement between 1-5. Because the F-16 crew chief works at the O-level, knowledge requirements in aircraft systems theory is generally low and placed at "K1". Given that crew chiefs interact with specific parts or functions of any given system, a special case knowledge level was established as "K1+" for them to understand select parts of the system in question. As an example, to service the fuel system (ATA 28), the crew chief does not need to understand the full extent of the system theory of operation, but should understand the mechanics related to ground refueling and defueling processes. A fuel system specialist, who is required to perform operational checkouts and troubleshooting on the system, would require more comprehensive knowledge and skill sets in their training, typically K3 and S3.

Before qualifying for the F-16 type course, all specialist categories must attend and complete a F-16 familiarization course, and a USAF TO (Technical Order) course. These courses establish a common ground for aircraft type knowledge, safety and handling procedures, and use of maintenance documentation and records.

Examinations must be passed with a score of at least 70%, and a minimum amount of practical assessments have to be passed to graduate the courses.

2.1.8 F-16 Crew Chief training

The Crew Chief type course is heavily focused on flight line inspections, servicing tasks and frequent O-level maintenance tasks. Therefore, aircraft systems theory is kept at a minimum, concentrated on areas that overlap the aforementioned tasks. Practical training is directed at providing experience and confidence in the typical workflow on the F-16 through repeated executions of relevant maintenance tasks. With the exception of the launch and recovery procedures, all activities are performed on a "cold" (shut down) aircraft. There is little difference between the training environment and the operational environment when the aircraft is cold. This is contrary to the launch and recovery procedures, which require a pilot, an engine start and movement of the aircraft. Historically, there has been material, qualified personnel and approved procedures to perform engine operation at Kjevik, but as the F-16 fleet was continuously being phased out of the RNoAF and prepared for foreign sales by KAMS on behalf of NDMA, access to aircraft and components have been restricted. It has been decided at a higher level to discontinue engine operations at Kjevik, and there is currently no plan to resume these activities.

Given the aforementioned conditions, the students have no way to experience training under operational conditions for tasks that will need extra consideration towards safety, complexity, criticality, etc. A previous attempt to solve this issue was to temporarily relocate the students to the depot-level maintenance center at Kjeller, where there are operational aircraft.

However, this solution was perceived as inadequate by the students as operational demands held higher priority than training. The result was that out of two weeks of practical training, only about 2 working days were spent performing the launch and recovery procedure, while the remaining 8 days were spent doing the same type of maintenance that they had already done at Kjevik for months. The students who voiced their opinions argued that this is insufficient to establish a level of experience where they are comfortable and confident to perform the tasks when they return to Romania.

Not much is known about the Romanian on-the-job training program or further qualification program, but the students who qualify the crew chief course are supposedly sent to Borcea (a Romanian base operating ex-Portuguese F-16s), where they will practice procedures according to the local style. This style is said to be based on a mix of United States, and Portuguese operations and do not necessarily match the Norwegian procedures.

2.2 Human factors

Human Factors (HF) may be defined as the technology concerned to optimize the relationship between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering[29]. *Ergonomics principles in the design of work systems* (ISO 6385:2016) describes human factors and ergonomics interchangeable terms, defining them as "scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being (2.1) and overall system performance"[30]. Spirochkin [31, p. 2] characterizes human factors as "the features of human nature and individual or group behavior of humans who are part of human–machine systems or are involved in the life cycle of a technical system by another way."

The European Human Factors Advisory Group states that "The entire aviation system relies on the behaviours and performance of individuals and teams for safety, efficiency and effectiveness. However, human error continues to be cited as a major factor in aviation accidents and incidents.[32]" Effective Human performance is fundamental to operational safety in aviation. They further argue that human factors "needs to be integrated into all aspects of aviation including equipment and system design, procedures, training and competency, etc and should not be considered in isolation."

The Federal Aviation Administration's (FAA) Aviation Maintenance Technician's Handbook describes Human factors science or technologies as multidisciplinary fields incorporating contributions from psychology, engineering, industrial design, statistics, operations research, and anthropometry [33]. HF are comprised of several disciplines such as Clinical Psychology, Experimental Psychology, Anthropometrics, Computer Science, Cognitive Science, Safety Engineering, Medical Science, Organizational Psychology, Educational Psychology, and Industrial Engineering.

Mueklich et al. [34, p. 1] state that "up to 80% of all aviation accidents and incidents identify human error as a casual or contributing factor." Upon their review of 87 ground operation incident reports, 32% of all incidents are related to Aircraft Pushback/Towing and 24% occur during aircraft arrival and departure operations.

There are several models and concepts within human factors which attempt to encompass all or parts of the typical problem areas within aviation. The PEAR model, Swiss Cheese Model, SHELL-model, Dirty Dozen and several more explain the relationship between human error and accidents.

2.2.1 SHELL model

The SHEL model, initially created in 1972 by Edwards [35], and later modified in 1984 to SHELL by Hawkins [36] is one of the earliest attempts at conceptualizing human factors. The SHELL model, as described by ICAO Doc 9859 [37] provides a framework for analyzing human (*liveware*) interactions between other humans (*liveware*, again), *software*, *hardware* and the *environment*, see figure 2.2.

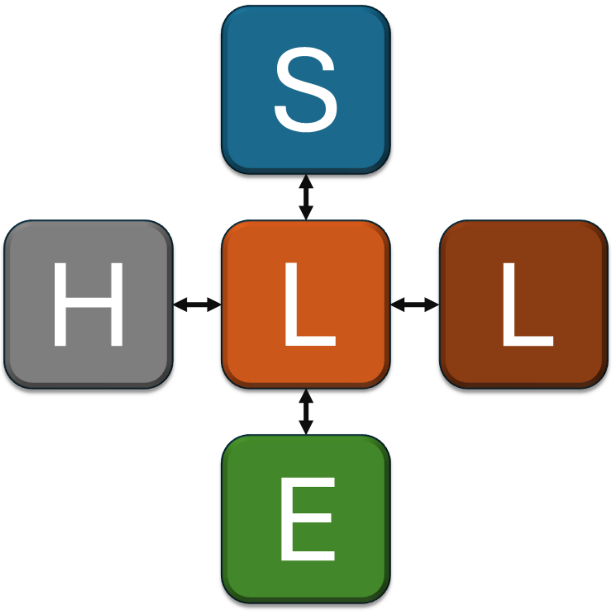

Figure 2.2: SHELL model, adapted from ICAO Doc 9859 (2012)[37]

Liveware refers to people in the work environment, ranging from pilots to air traffic controllers, management and maintenance crew. They are the centerpiece of the model and interact with all other elements. Hawkins made a contribution to the model so Liveware is mentioned twice to also account for inter-people relationships. An example could be communication and task assignment from a maintenance manager to a technician. It also relates to groups, teams, culture and other staff relationships.

Software is related to all legislation, aviation regulations, rules, operating procedures, standards, norms, habits, checklists and other non-physical conditions that are part of the work environment, and how people interact with these elements.

Hardware is all the physical items such as aircraft, structures, tools, equipment, vehicles, facilities, controls, displays and systems within the work environment. The relationship/interaction between people and hardware is used to highlight how humans interact with the hardware, possibly mitigating inherent problems or masking them through adaptation.

Environment is the working environment, where the liveware, software and hardware must operate. It is comprised of both internal and external factors. Internal factors are related to the workspace and may include noise levels, vibrations, temperature, air quality and ambient light. External factors include weather, terrain, aviation infrastructure etc. The environment also encompasses the human internal factors, such as thoughts and worries from events taking place outside the workplace, to physiological events such as illness, injuries and fatigue. The environment can also include effects from day/night sleep rhythm disturbances.

The relationships between liveware and the remaining elements should be carefully analyzed and understood for any aviation organization. The aforementioned components form the relationships [L-L], [L-S], [L-H] and [L-E]. It should be stressed that liveware (people) is the least predictable component and, according to the model, if the relationships are "mismatching" it will lay the foundation for errors to happen.

2.2.2 PEAR model

According to the authors of the model, Johnson and Maddox, the PEAR model is simple and may be applied to identify potential hazards and should be an integral part of an organizations Safety Management System (SMS) [38]. PEAR is an acronym for people, environment, actions and resources, see figure 2.3.

Figure 2.3: PEAR model, adapted from Johnson and Maddox [38]

The PEAR model can be thought of as such:

- People who do the job.
- Environment in which they work.
- Actions they perform.
- Resources necessary to complete the job.

People is focused on the physical, psychological, physiological, and psychosocial factors related to our behavior. Physical traits such as size, age, sex, strength and sensory limitations may affect us as we work. Physiological factors such as nutrition, health, lifestyle, fatigue and chemical dependencies have an effect on our performance. Psychological factors such as workload, experience, attitude, knowledge, training and mental states also influence us. Psychosocial elements also come into play, such as personal conflict with other colleagues. In summary, people are complex and require close attention across all four factors to avoid or accommodate conditions that may cause errors or problems.

Environment is divided into physical, and organizational parts. The physical part is self-explanatory and consists of variables such as temperature, humidity, lighting, noise, vibrations, cleanliness, workplace design etc. Organizations must take steps to mitigate adverse effects of changing conditions, which usually overlaps with the ***resources*** part of the PEAR model aswell. The organizational part concerns the more abstract environment of the workplace, including company policies, attitude, communication, cooperation, morale, culture, management, hierarchy etc. With a focus on problem reporting and corrective actions, company policies can promote safety awareness and help avoid incidents.

Actions are the activities and tasks performed in by the people. It is concerned with the requirements needed to perform a specific task. A Job task analysis (JTA) helps break down a task into individual steps, sequence, required tools and aims to determine the required attitude, knowledge and skill levels needed to safely perform the job. It also concerns the personnel, communication, information control, inspection and certification requirements. To ensure that tasks are performed as intended in a safe manner, it is important that documentation or instructions are as clear an concise as possible to make them usable and unambiguous.

Resources is often intertwined with the other elements, and typically the combination of people, environment and actions determine the resource requirements. Resources are commonly thought of as physical items such as consumable items, spare parts, tools, equipment and similar objects. However, resources also concern sufficient training, quality systems, software, manuals, qualified personnel etc. that are less tangible. Resources can be thought of as everything a member of the organization needs to perform a given task or responsibility.

In summary, the PEAR model provides a framework to study and analyse key areas for roots of problems in the context of human factors. Similar to the SHELL model in section 2.2.1, the people, environment, actions and resources interact with, and sometimes overlap one another. The relationship between these elements is continuously developing as a company progresses through new personnel, management, facilities, tools, equipment, procedures and tasks and should be continuously monitored and evaluated to catch any latent problems or rooms for error.

2.2.3 Dirty Dozen

The "Dirty Dozen", originally developed by Gordon DuPont in 1997, are 12 sources of error related to human factors in aviation maintenance and can help categorize causes of incidents related to an individual, a team or an organization's practices [39]. The Dirty Dozen is the twelve most common human errors conditions or preconditions that can act as precursors to accidents or incidents: Lack of communication, Complacency, Lack of Knowledge, Distraction, Lack of Teamwork, Fatigue, Lack of resources, Pressure, Lack of Assertiveness, Stress, Lack of Awareness and Norms [40]. Although there are further developments and additions to the initial Dirty Dozen and applications to other fields [41] [42], the original 12 sources of error provide a good introduction to the subject. DuPont's [39, ch. 7, pp. 49-52] Dirty Dozen is provided below, with the suggested "safety nets" to prevent incidents from occurring.

2.2.3.1 Lack of Communication

Can be in the form of both verbal and/or written communication, and is one of the most common sources of error.

Safety nets:

- Use logbooks, worksheets etc. to communicate and remove doubt.
- Discuss work to be done or what has been completed.
- Never assume anything.

2.2.3.2 Complacency

Often linked to experienced personnel or the performance of repetitive tasks. Because a task has been completed successfully several times before, or an item is inspected to be in a satisfactory condition, an incorrect judgment is made without properly performing a task or checking said item.

Safety nets:

- Train yourself to expect to find a fault.
- NEVER sign for anything you didn't do.

2.2.3.3 Lack of Knowledge

As the training provided becomes outdated in an evolving world of newer aircraft models, upgrades and modifications, lack of knowledge is likely to become a source of error. Technicians are often proactive problem-solvers, but combined with a lack of knowledge it poses a serious risk to safety.

Safety nets:

- Get training on (aircraft) type.
- Use up to date manuals.
- Ask a technical representative or someone who knows.

2.2.3.4 Distraction

Thought to be the cause of about 15% of all maintenance errors. It occurs when a technician physically or mentally abandons a task, only to return later and resume at the incorrect part, typically skipping steps of the procedure.

Safety nets:

- Always finish the job or unfasten the connection.
- Mark the uncompleted work.
- Lockwire where possible or Torqueseal.
- When you return to the job always go back three steps.
- Use a detailed check sheet.

2.2.3.5 Lack of Teamwork

Often related to lack of communication and could lead to critical errors. Maintenance often involves a wide variety of technicians, teams and supervisors and therefore teamwork becomes essential. It is important to communicate instructions, roles and responsibilities throughout the work.

Safety nets:

- Discuss what, who and how a job is to be done.
- Be sure that everyone understands and agrees.

2.2.3.6 Fatigue

Fatigue is a problematic cause of error because usually, the person who is becoming fatigued is not fully aware until it becomes severe. Prior to this awareness, the person may cause errors or accidents without realizing the effects of being fatigued.

Safety nets:

- Be aware of the symptoms and look for them in yourself and others.
- Plan to avoid complex tasks at the bottom of your circadian rhythm.
- Sleep and exercise regularly.
- Ask others to check your work.

2.2.3.7 Lack of Resources

Despite most aviation mechanics' desire to complete their assigned tasks and keep aircraft airworthy, there are situations where a lack of resources may force a decision between grounding or allowing an aircraft to fly.

Safety nets:

- Check suspect areas at the beginning of the inspection and ground the aircraft until the required parts are acquired.
- Order and stock anticipated parts before they are required.
- Know all available parts sources and arrange for pooling or loaning.
- Maintain a standard and if in doubt ground the aircraft.

2.2.3.8 Pressure

The aviation industry has high levels of inherent pressure to ensure that tasks are completed on time. The more time an aircraft spends on ground, the less time it can spend flying passengers or cargo around and generate revenue. This pressure can come from numerous levels in the organization, including from within oneself.

Safety nets:

- Be sure the pressure isn't self-induced.
- Communicate your concerns.
- Ask for extra help.
- Just say no.

2.2.3.9 Lack of Assertiveness

Generally speaking, an aircraft technician does not have to be assertive as part of their job. However, situations can occur where there is a disagreement or dispute about the condition of the aircraft. Such situations could be challenging, but it is crucial that potentially adverse conditions are not overlooked.

Safety nets:

- If it's not critical, record it in the journey log book and only sign for what is serviceable.
- Refuse to compromise your standards.

2.2.3.10 Stress

While stress is a common part of life and can even sharpen one's focus, excessive levels of stress can be dangerous and lead to mishaps. Therefore, it becomes vital to recognize when the levels of stress are becoming excessive, and begin taking measures against it.

Safety nets:

- Be aware of how stress can effect your work.
- Stop and look rationally at the problem.
- Determine a rational course of action and follow it.
- Take time off or at least have a short break.
- Discuss it with someone.
- Ask fellow workers to monitor your work.
- Exercise your body.

2.2.3.11 Lack of Awareness

Often happens to seasoned technicians who fail to predict possible outcomes of their decisions or work. In hindsight after mishaps, one can often point to "common sense" or that the situation could have been avoided if the technician made an effort to think about potential consequences.

Safety nets:

- Think of what may occur in the event of an accident.
- Check to see if your work will conflict with an existing modification or repair.
- Ask others if they can see any problem with the work done.

2.2.3.12 Norms

Norms can be both good or bad. A company may establish routines such as "double-checking" items, despite it not being referenced in any manual. However, norms may also manifest themselves as shortcuts, or other omissions of procedures to save time and or resources. People tend to follow large groups, and are therefore prone to align themselves with the norms which already exist in a group.

Safety nets:

- Always work as per the instructions or have the instructions changed.
- Be aware that "norms" don't make it right.

2.3 Learning theory

The context of technical training advocates the inclusion of learning theory. Discussing how we transform existing understanding into something new or different is essential when aiming to change teaching methods or introduce new technology. The current courses for Romanian technicians are based on an adapted version of Bloom's taxonomy[28], and rigidly anchored in the F-16's maintenance manual library, and it is arguably relevant to examine the current training and how it stands up to other educational schools of thought.

According to [43] Albatrosov, there are several experts in educational psychology who identify five main schools of thought:

- Behaviorism;
- cognitivism;
- constructivism;
- experientialism;
- social contextual.

Cherry [44] adds that while definitions may vary, learning is influenced by social, biological, cultural and emotional variables. The experiences with these variables may lead to permanent changes in our behavior. The following statement by Vipler and Sawatsky [45, p. 1184] relates to which elements of us change when learning: "Knowledge, skills and attitudes — Any educational context can break down its respective outcomes into one or more of these three domains." They further underscore that "Transformation means change. Learning, as a concept, also implies change. However, when we say *Transformative Learning*, we mean learning that results in attitudinal change [45, p. 1185]."

This section will focus on the cognitivist, social and constructivist approaches to learning.

2.3.1 Cognitivism

Emerging in the 50s and dominating the 60s, cognitive psychology departed from behaviorism and separate humans, as rational creatures, from animals [43]. Cognitive psychology focuses on understanding how people think, learn, remember and process information and accounts for factors such as memories, beliefs, emotions and motivations as contributors to the learning process [44]. Cognitivism attributes the learner's success or failure of acquiring knowledge to the learner's capacity, motivation beliefs and effort [43]. According to [46, p. 179]"The cognitivist approach to learning places emphasis on what goes on inside a learner's brain and focuses on mental processes rather than on observable behaviors." He further adds that cognitivism is a teacher-centered approach, and educators must be careful to organize instruction in a manner that the students can make connections between existing knowledge and new information.

2.3.1.1 Bloom's taxonomy

Initiated by Benjamin Bloom in 1949, a team of measurement specialists worked to develop and, in 1956, publish the work *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain* [47]. This was the foundation of what is known today as Bloom's taxonomy.

Although originally conceived as a measurement tool, Bloom believed it could serve as a:

- "common language about learning goals to facilitate communication across persons, subject matter, and grade levels;

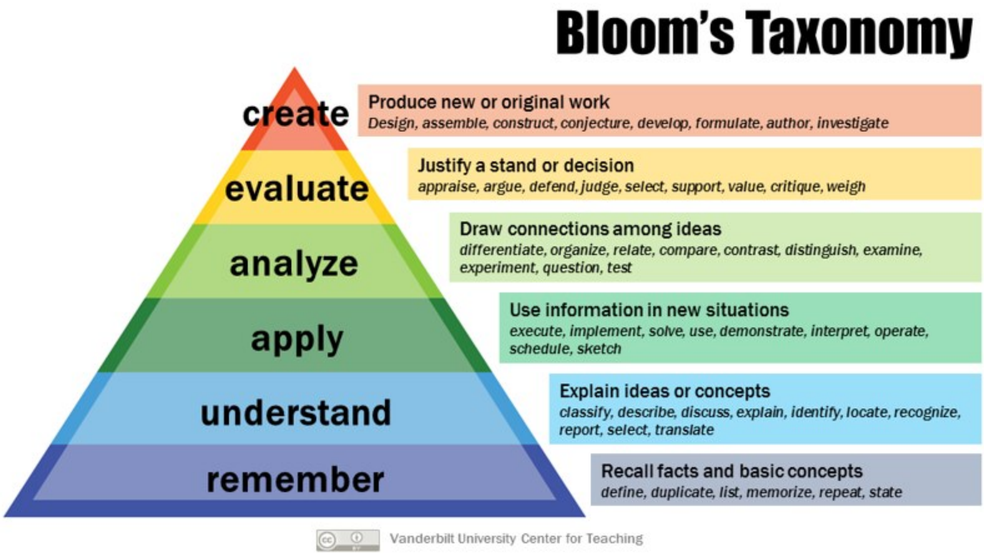

Figure 2.4: Bloom's taxonomy, by Vanderbilt University Center for Teaching [48].

Cognitive	Affective	Psychomotor
Creating	-	-
Evaluating	Characterisation	Naturalisation
Analyzing	Organisation	Articulation
Applying	Valuing	Precision
Understanding	Responding	Manipulation
Remembering	Receiving	Imitation

Table 2.1: The skill levels of each domain

- basis for determining for a particular course or curriculum the specific meaning of broad educational goals, such as those found in the currently prevalent national, state, and local standards;
- means for determining the congruence of educational objectives, activities, and assessments in a unit, course, or curriculum; and
- panorama of the range of educational possibilities against which the limited breadth and depth of any particular educational course or curriculum could be contrasted [47]."

According to [49], the latest *revised* framework (see figure2.4 was released in 2001 by Anderson and Krathwohl, two of his former students. It incorporates the three domains of *cognitive*, *a ective* and *psychomotor* domains. Each of the categories are then subdivided into levels of skill, ranging from lower-order to higher-order. For each incremental level, the person's ability to absorb, process, reflect on and apply a certain skill increases. The taxonomy serves as a guide for instructors who are designing learning objectives. Every skill level is denoted by a verb, as shown in table 2.1.

And each of those verb can be broken into sub-verbs as shown in figure 2.4. If we use the example of *remembering*, we can find the sub-verbs *list*, *define*, and *memorize*, whereas *applying* is subdivided into *execute*, *demonstrate*, and *sketch*. If a teacher were to design a course where the student learn some basics about aerodynamics, he may want the students to learn various things related to Bernoulli's principle and how the sum of static and dynamic pressure in a fluid is known as total pressure. For remembering an important concept, the main verb is *remember*, but a learning objective may sound like this : "The student shall be able to list the two main components of total pressure, according to Bernoulli's principle." If the student is supposed to apply that knowledge, the learning objective could be: "The student shall be able to sketch how total pressure is used to derive dynamic pressure in a pitot-tube." Depending on the learning objectives, learning and classroom activities may be developed accordingly.

According to Ekramul, Bloom's taxonomy has receives criticism for being too sequential and linear, suggesting that learners move up and down the skill levels, and jump back and forth between domains frequently [49]. It also largely fails to emphasize the social aspects of learning, such as group discussions and tours.

2.3.2 Social learning and constructivism

Social and interactive aspects of learning are central in Social learning theory [43]. These aspects challenge the individual-focused methods of cognitivism. An example is how colleagues observe each other in a group, and learn from different levels of experience.

As Wenger notes:

> In a social learning system, competence is historically and socially defined. How to be a physicist or how to understand the position of the earth in the universe is something that scientific communities have established over time. Knowing, therefore, is a matter of displaying competences defined in social communities [50, p. 226].

He underlines that people form ***competence*** in their social communities over time, a common understanding of how things should be done and therefore a measurement as to how well we perform while doing them. Then there is ***experience***, which is an ongoing process, unique to each and everyone. He claims that ***learning*** occurs in the interplay between these two components; the various relations between social competence and personal experience.

According to Cherry [44] and Albatrosov [43] an alternate social learning approach is suggested by Albert Bandura who suggested that learning occurs through observations that can occur at any time. He emphasizes the roles that social observation and modeling play in learning. Etienne Wenger stated that learning works best in a ***community of practice*** that produces social capital, improving the health of the community [43].

Constructivism places the learner in the center, where the teacher serves more as a facilitator or guide to help the student build their knowledge upon past understanding [43]. Cherry adds that constructivists believe that new knowledge can only be added and built onto existing knowledge [44]. In that way, it also includes social and cultural aspects through interaction and observation with our world. According to Clark [51], a constructivist teacher has to plan, design and implement a curriculum that encourages active engagement, while the student must also take responsibility to participate in learning activities. He adds that essentially, the learner has to create their own meaning from within instead of receiving it externally. The social aspects of constructivism are made apparent in Vygotsky's Zone of Proximal Development.

2.3.2.1 Vygotsky's Zone of Proximal Development

According to Pritchard [52, p. 25] ***zone of proximal development*** is a concept that can be defined as "a theoretical space of understanding which is just above the level of understanding of a given individual. It is the area of understanding into which a learner will move next. In the zone of proximal development, a learner is able to work effectively, but only with support." Vygotsky poses that learning can be achieved through guidance from a ***more knowledgeable other***, and stresses that this person does not have to be the instructor or someone older. They simply have more knowledge in the subject matter than the learner. He explains that through a process called ***sca olding***, the more knowledgeable other provides support to the learner, at the appropriate time and level to meet the learner's needs. An example could be that instead of demonstrating how to perform a car tire replacement, the more knowledgeable other (instructor) provides the necessary materials to do the job, such as a mechanic's handbook, and some tools. Perhaps the instructor assigns a second learner to work together in pairs, and encourage them to read through the procedure and discuss it together. The learners might get stuck in the process, upon which the instructor could provide a hint, or introduce a tool they might have overlooked and allow them to experience how the tools works on their own. In essence, scaffolding is about helping learners advance into the zone of proximal development by providing guidance from your own knowledge.

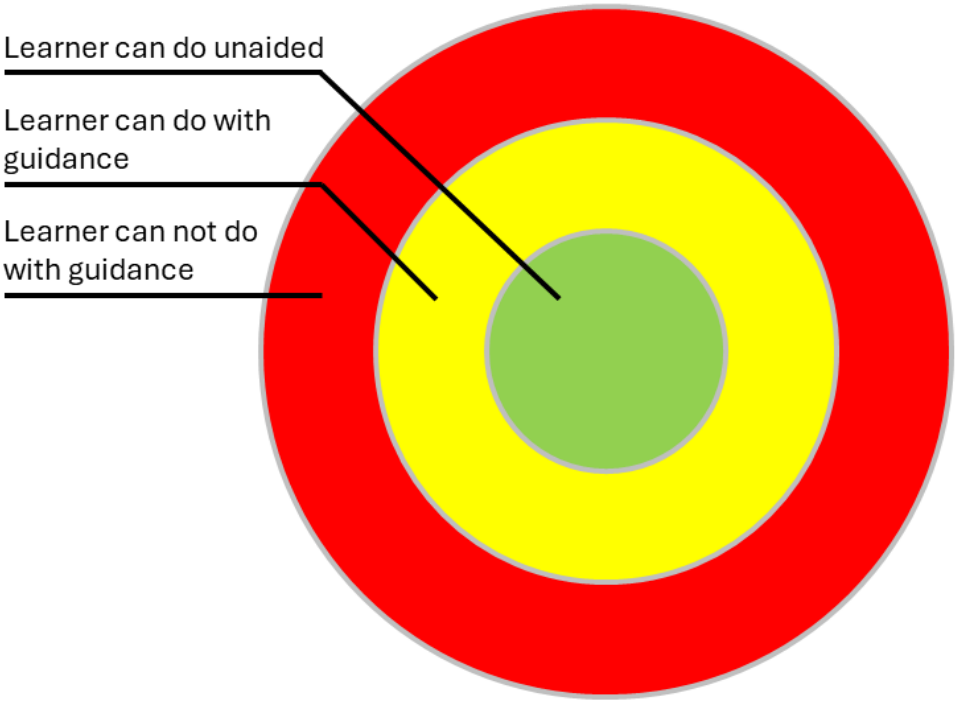

Figure 2.5: Vygotsky's Zone of Proximal Development [51].

2.3.2.2 Wenger's Communities of Practice

According to Wenger [50, p. 229], *Communities of practice* are "the basic building blocks of social learning systems", because each block represents a container of competences within that community. By participating in a community of practice, the people who are part of said community make their own definitions of what it means to be competent.

Wenger states that communities of practice define competence by combining three elements known as *joint enterprise*, *mutuality*, and *shared repertoire* [50]. The first element is about being collectively bound together by a shared understanding of what the community is about, and sustaining that notion. However, to be acknowledged in that community, there has to be strong relationships and connections within the community. Members must contribute and interact in a productive manner. This is known as mutuality. Finally, there must be an self-consciousness about the community, its practices, methods, perspectives, norms and this is known as shared repertoire. The ability to self-reflect on the community of practice helps develop it away from historical patterns to avoid becoming stuck in patterns or norms which may not be ideal.

In a more recent rephrasing, Wenger-Trayner & Wenger-Trayner have adopted the terms *domain*, *community*, and *practice*, to replace enterprise, mutuality and repertoire [53]. They state that in "the education sector, learning is not only a means to an end: it is the end product." In most other businesses, introducing the concept of community of practice adds and extra level of complexity, but it does not change what the businesses are about at the fundamental level. They argue that in schools, introducing the concept will challenge the learning theory, which is a much deeper transformation. They argue that the perspective of communities of practice will impact educational practices along these three dimensions:

- "*Internally*. How to organize educational experiences that ground school learning in practice through participation in communities around subject matters?
- *Externally*. How to connect the experience of students to actual practice through peripheral forms of participation in broader communities beyond the walls of the school?
- *Over the lifetime of students*. How to serve the lifelong learning needs of students by organizing communities of practice focused on topics of continuing interest to students beyond the initial schooling period? [53]"

They underline that the school is not a closed environment where learning occurs, only to be transferred to students before they take it out to the outside world. They argue it is not the class, but life itself that is the learning event, and the school merely functions as gathering point, which should serve the learning that happens in the world.

Chapter 3

Methods

Given the context of the research problem, it is reasonable to select methods which have previously proven themselves within the fields of technical training and design of technological problem solutions. This chapter describes the research methods chosen for this project, why they were chosen and what the resulting process looks like.

An end-goal of this thesis is to provide a research foundation on which to develop and deploy a technical or digital solution which can improve the flight line operations training. Therefore, Human-Centered Design (HCD) principles is chosen as the main method as it fits well within the scope of this thesis. Essentially, the users (students) of this solution, along with other stakeholders such as the instructors and training managers, and how they interact with it within the training *system* must be well understood to provide a meaningful improvement to the training quality and safety. Human-Centered Design principles are supported by several well-proven methods across multiple scientific fields, such as the use of questionnaires and interviews, which are used in this research and described in further detail below.

3.1 Human-Centered Design and principles

ISO 9241-210 (2019) [54] states that Human-Centered Design is an approach to interactive systems development that focuses on the users to make useful and usable systems. This is achieved by applying human factors/ergonomics and usability knowledge to enhance effectiveness, efficiency, human well-being, user satisfaction, accessibility and sustainability. It counteracts possible adverse effects of use that may impact human health, safety and performance.

According to the Interaction Design Foundation, Human-Centered Design follows the four main principles of being *people-centered*, *solving the right problem*, *treating everything as a system* and performing *small and simple interventions* [55]. The latter principle of small and simple interventions manifest in an *iterative* process with continuous testing and feedback with the users. The Design Council's Framework for Innovation [56] describes the principles of *put people first*,*communicate visually and inclusively*, *collaborate and co-create*, and, finally, *iterate, iterate, iterate*. ISO 9241-210 [54] lists the following six principles which a Human-Centered approach should follow:

- The design is based upon an explicit understanding of users, tasks and environments.
- Users are involved throughout design and development.
- The design is driven and refined by user-centered evaluation.
- The process is iterative.
- The design addresses the whole user experience.

- The design team includes multidisciplinary skills and perspectives.

Hass and Edmunds [57, p. 91] state that "...when it really counts, when lives are on the line, when decisions have significant effects on patient safety , health, well-being, livelihoods, or keeping other mission-critical and highly complex systems in motion, we strongly encourage you to engage experienced experts and human-centered design professionals from human-computer interaction (HCI), human factors (HF), user experience (UX) research, UX design, and related fields of computer science and information science."

3.1.1 Understanding the users, tasks and environments

The context of use can be described as a major source of information which is paramount to establish requirements and also serve as an input to the design process itself. The context of use is defined by understanding and describing the specified users, which have specified goals and are performing specified tasks in a specified environment. It is also stressed that in addition to the users, all relevant stakeholder groups should also be included in the research [54]. This process is also referred to as part of the "discovery phase" of Human-Centered Design, which includes understanding of a problem space, stakeholder perspectives, project goals, user interaction needs, and user information needs [57].

3.1.2 Involve users in the design and development process

A valuable source of knowledge is the users themselves, and involving them throughout the design process ensures that potential challenges may be detected even before development starts. The people involved in the process should exhibit the same capabilities, characteristics and experience that reflect the target group of users who will be using the product. Users should be involved in the design, data collection and evaluation of solutions [54]. Some activities that can be used as part of this research process are customer surveys, benchmark usability tests, focus groups, stakeholder interviews, visioning workshops, branding workshops, technical discovery, and any number of “pre-design” activities [57].

3.1.3 Design is driven and refined by user-centered evaluation

Another critical part of Human-Centered design is to evaluate the designs and refining them based on user feedback. The final acceptance test or validation of a design should also be conducted with the target users to confirm that the requirements have been met. User feedback is also essential in the operational phase, as certain issues may not present themselves until the product has been used over a longer period of time [54].

3.1.4 Iterative process

The end solution is seldom the same design as the first prototype. It has usually undergone several *iterations* before arriving at the final state. Iteration is used throughout the design and development process to verify the design or product at a certain stage. After testing, evaluation, and feedback, change could be made not only to the design but to the requirements, descriptions, and specifications as well. The expectations of the users and stakeholders may be different than their experience after interacting with the design, leading to new discoveries and understanding of it. This helps reduce the risk of misunderstanding the context of use and overall system [54].

3.1.5 Design for the whole user experience

User experience is a complex metric comprised of several parts which includes both the product, but also characteristics related to the users themselves. The product related items range from presentation, functionality, performance, to interaction and includes both software and hardware aspects. The user characteristics include personality, skills, attitudes, habits, and prior experiences. Designing for user experience includes, but is not limited to everything from packaging, branding and labeling to customer support, documentation, and maintenance. It is emphasized that for mission- or safety-critical systems, effectiveness or efficiency could be more important than user preferences [54].

3.1.6 Include multidisciplinary skills and perspectives in the design team

A design team does not have to be large, but it should be sufficiently diverse. They represent different fields of expertise and should hold different viewpoints throughout the design process. They also participate in discussion and collaborating on design choices, bringing together a wide set of skills and knowledge to the decision-making process. The following areas of expertise are suggested in [54]:

- human factors and ergonomics, usability, accessibility, human-computer interaction, user research;
- users and other stakeholder groups (or those that can represent their perspectives);
- application domain expertise, subject matter expertise;
- marketing, branding, sales, technical support and maintenance, health and safety;
- user interface, visual and product design;
- technical writing, training, user support;
- user management, service management and corporate governance;
- business analysis, systems analysis;
- systems engineering, hardware and software engineering, programming, production/-manufacturing and maintenance;
- human resources, sustainability and other stakeholders;

3.1.7 Human-Centered Design activities

When it is decided that human-centered design activities (see figure 3.1) will be used to solve a problem or develop a product, design or system, the following four design activities should take place:

- Understanding and specifying the context of use.
- Specifying the user requirements.
- Producing design solutions.
- Evaluating the design.

3.1.7.1 Understanding and specifying the context of use

It is essential to determine who will interact with the design, what their characteristics are, what their goals are, and in which environment it will be used. These aspects form what is known as the *context of use* and serve as a scope and guidance material when designing and developing a solution. To understand the context of use, the current system, a similar system or a predicted future system should be examined and contemplated to evaluate performance and satisfaction. This process may reveal weaknesses, problems or deficiencies with the system that should be addressed in the design. There could be a range of user- and stakeholder

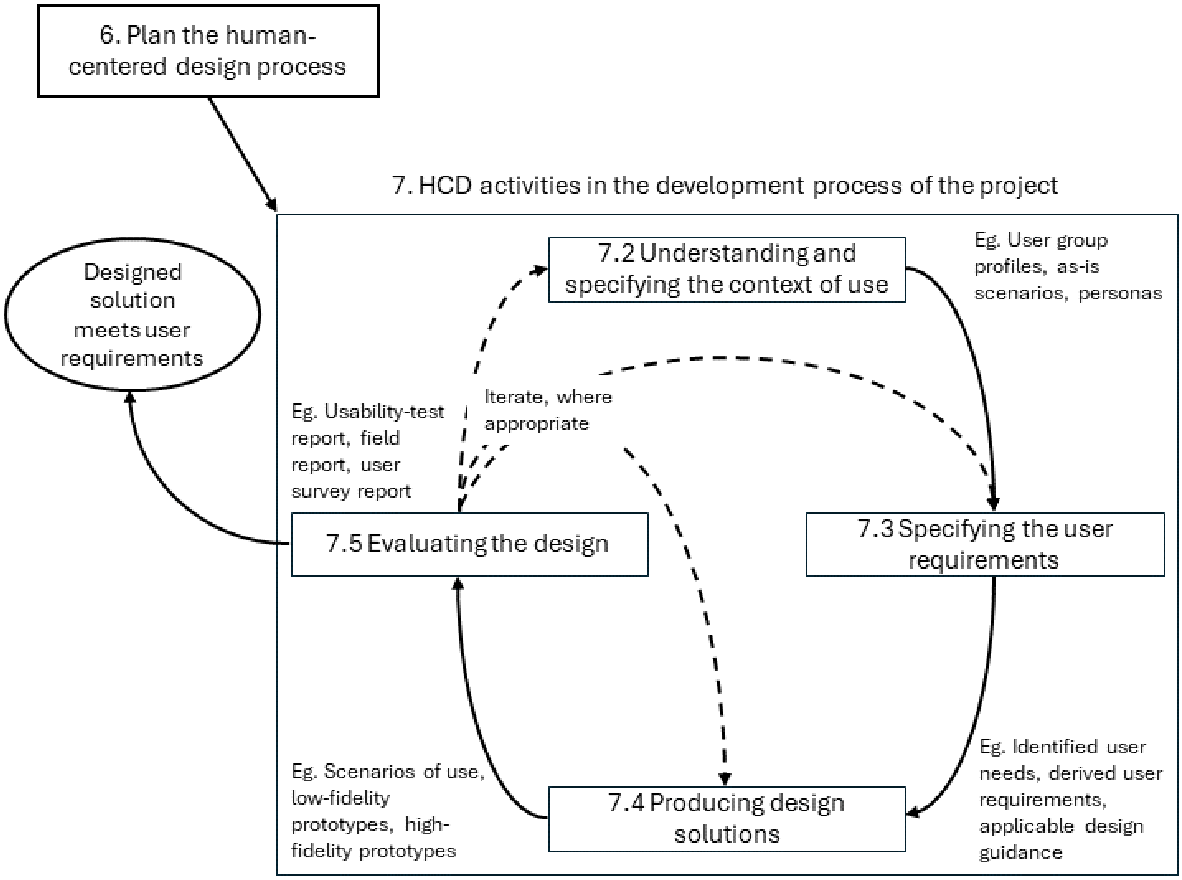

Figure 3.1: HCD activities, adapted from ISO 9241 part 210 [54]

groups who all have different relationships and needs related to the solution. These relationships may be used to form key goals and constraints that influence the design process. Once these groups have been established, their characteristics should be identified. These include a range of traits ranging from personality, skills and experience, to physical attributes such as size, weight and physical condition. Depending on the users' characteristics, the designed product should account for as many user characteristics as possible to maintain accessibility across a wide range of users with different capabilities. It is also necessary to establish the goals and tasks of the users. How the tasks are performed, how frequently and for which duration, if there is risk to health and safety, possibility of making mistakes or errors should also be identified. Finally, the environment of the system should be determined. The physical environment and materials, as well as the organizational, cultural and social aspects should be described. Physical attributes may include lighting, heating, ventilation, spatial layout, acoustics etc. Social and cultural aspects include attitudes, organization, hierarchy, work practices etc. [54].

3.1.7.2 Specifying the user requirements

Identifying the user's needs and specifying functional and other requirements for the product or system is a major activity. This process should be used to create a set of user requirements related to the context of use and business objectives of the system. Depending on system scope and complexity, the user requirements may include organizational changes, work styles and may influence not only the design and users themselves, but also the organizational processes and methods as well. The development process should therefore include the stakeholders who are involved in other areas of the system which will be affected. Once user and stakeholder needs are identified in relation to context of use, the user requirements should be derived from it, relevant ergonomics and user interface standards, usability requirements, usability performance and satisfaction and organizational requirements such as time or performance restrictions. The user requirements form the foundation for designing and evaluating interactive systems to meet the user needs, and are a part of the overall requirement specifications of a system. There could be conflicts between user requirements and other system requirements which result in trade-offs. Such trade-offs should be documented so they can be understood in the future. Finally, there should be quality assurance to verify that the user requirements are achieved according to requirement specification. The user requirement specification should be stated in terms that permit subsequent testing, verified by relevant stakeholders, internally consistent and updated as necessary during the life of the project [54].

3.1.7.3 Producing design solutions

Design solutions should be produced by combining data from the context of use description, any baseline research or evaluation, established state of the art within the application domain, design and usability guidelines and standards and the overall experience and knowledge of the multidisciplinary design team. The decisions made during the design process have a major impact on the user experience, which is why user-centered design considers the user experience throughout the design process. The user tasks, user-system interaction and user interface needs to meet the user requirements, but also cater to the whole user experience. Aspects such as meeting the users expectations, the requirement for user training or learning, customization, suitability to perform the task all come into play and influence the design decisions. When producing design solutions, it also becomes crucial to make the design solutions more concrete, meaning to develop simulations, mock-ups, prototypes or other types of models. These are used to communicate the design to user and stakeholder groups, which establishes experiences and interactions to draw feedback from. The more iterations of prototypes or models, the more opportunities to draw feedback early in the design phase, and implement improvements before the design moves toward the finalized product. Project plans should allow for sufficient time to make changes as a result of feedback, and the earlier in the design process the changes are made, the more likely they are to be cost-effective. Finally, the design solution must be communicated effectively and clearly to those responsible of implementation and manufacture. Documentation and explanations of all changes are important to convey their justification, especially where there are compromises or trade-offs [54].

3.1.7.4 Evaluating the design

Evaluation should be performed by the users' perspective and it is a required activity of human-centered design. User testing and evaluation can be used throughout all phases of the development, but there are cases where user testing may not be a cost-effective solution. In these cases, task modeling and simulations may be used as an evaluation tool, even if the users are not directly participating in the testing. User testing can be used to collect new information about the users' needs, identify strengths and weaknesses from the users' perspective, assess whether user requirements have been satisfied to local or international standards or law, and also act as benchmarks for different iterations or alternatives of a design. For effective user-centered evaluation, it is important to allocate sufficient resources to obtain feedback throughout several phases of the project. Furthermore, the evaluation should be planned to fit the constraints of the project timeline, and the tests have to be comprehensive enough to provide valuable results for the scope of the system. Once there are results, they must be analyzed and discussed to find and prioritize solutions that are forwarded to those responsible of implementing or manufacturing them. There are two commonly used methods to conduct user-centered evaluation, known as ***user-based testing*** and *inspection-based evaluation*. User-based testing involves the users themselves in the testing process and can provide deep insights into how the design performs in a real, or simulated situation. On the other hand, inspection-based evaluation is typically carried out by usability experts by applying known standards, practices, guidelines, heuristics as well as the user requirements to the design and evaluating it. This form of testing could be performed by a small team and identify several obvious problems in a cost-efficient manner. However, while it may uncover several of the most apparent issues, it may not sufficiently uncover deeper issues and mechanisms which apply when the user is interacting with the design. Lastly, there should also be an element of long-term monitoring to evaluate the design a long time after its first implementation. Typical intervals may be 6 to 12 months, when the design has been in use long enough to uncover emerging issues from within or outside of the environment defined in the context of use [54].

3.1.8 Sustainability and Humanity-Centered Design

Human-Centered Design is aligned with the first two pillars of sustainability, in accordance with the 1987 United Nation's *Our Common Future* report [58]. It supports *economic* sustainability, by aligning design with users' needs and characteristics it increases the likelihood that systems, products and services will be accepted and used as opposed to becoming a wasteful endeavor. Furthermore, HCD supports *social* sustainability by designing systems, products and services that are more accessible to a wider range of users, as well as better for health, well-being and user engagement. The environmental component includes a life-cycle approach to the design by encouraging those involved in the design to consider life-cycle effects of a product or service and how it may impact the environment [54].

Renown cognitive science and user-experience expert Don Norman introduces the concept of *Humanity*-Centered Design [59] as a *bigger picture* approach to human-centered design. He describes it as a practice where "designers focus on people's needs not as individuals but as societies with complex, deep-rooted problems." His first principle of humanity-centered design focuses on the entire ecosystem, all living things and the environment. "Everything is connected", he states and provides a point that actions on one side of the planet may have far-reaching effects that come into play on the other side of the planet. This has similarities to the *Butterfly e ect* which is a part of, but often used to describe *chaos theory* [60]. While the butterfly effect states that one seemingly tiny action in one place, can cause large effects in a different end of a system, Norman points out that a problem may have more than a single source, due to the interconnected nature of our world. Therefore, humanity-centered design seeks to solve *root issues*, and not just the *symptom* [59]. He stresses that because everything is a system, one must monitor the consequences of our changes over a long period of time, as they may take years to manifest. The final two principles are to continually test and refine the designs, as well as design *with* the community, and not *for* them. He emphasizes that often, the community experiencing a problem may already have the best understanding of it and ideas about what would solve it, they simply need help bringing those ideas to fruition.

3.1.9 Human-centered design criticism

There are some criticisms toward human-centered design, often pointing toward certain pitfalls which may be induced in the process. Dearden warns that using the efficiency and effectiveness metrics to measure usability often leads to an economic interpretation and results in a narrow consumerist focus during development [61]. He also underlines the tendency to assume that users are literate and have experience using devices, even when designing solutions for *developing* countries. There are also challenges with social and cultural differences, particularly relating to strict hierarchies often found in developing countries which may contrast the inclusive and egalitarian attitudes of developed nations.

Norman has also voiced concerns regarding challenges that may result from HCD activities, stating that several examples show that HCD can improve matters for a focus group, at the expense of worsening the situation for many [62]. He contrasts human-centered design with activity-centered design by stating that an activity focuses on the set of tasks the user will be doing, and how to best achieve the activity, rather than focusing on the user and how they best interact with the design while doing the activity. He argues there is a subtle difference in that an activity is a set of tasks to achieve a larger objective, while human-centered design often studies how people interact with tasks (subset of activity), omitting the bigger picture. An example of an activity would be cooking a meal, whereas boiling pasta is a task, and adding water or pasta to the pot are individual actions. HCD teams may focus on and improve the interaction with the pot of pasta, while forgetting that the tomato sauce and meatballs have to be prepared in parallel, perhaps while operating a kitchen timer and interacting with other elements that are part of the overall activity. Another point he makes is that sometimes the people simply do not know what's best for them. An example could be that a user lacks deep knowledge about how a hydraulic machine works, and that a user-requested feature would expose the user to life-threatening risks in the event that a system malfunction occurs. This could also hold true for less dramatic issues, such as human-machine interface design suggestions which break with proven guidelines and conventions, thus increasing the risk of misinterpretations. He states that there are several examples where excessive listening to the users' feedback leads to overly complex designs, making software less understandable with each iteration. Discussing the ***bigger picture*** and using a system approach to thinking about problems are some of his suggestions which are accommodated in humanity-centered design (see section 3.1.8).

3.2 Data collection

After completing the first crew chief type course, initial feedback was mainly collected by verbal communication and a Questback [63] questionnaire, distributed by AATT's management. The turnout of the questionnaire was low with only 2 out of 7 respondents. The students had few complaints about the overall training with one exception regarding the way "launch and recovery" training was carried out. Specifically, the complaints were directed towards insufficient training with operational equipment, during a two week visit to Kjeller. The problem was mainly described as limited access to aircraft and not enough task repetitions. The two week period was therefore perceived as "wasteful", given that only a few hours were dedicated to training for the launch and recovery procedure.

Provided the lack of respondents on the first questionnaire and the unreliable data of memorized verbal feedback, it was decided to develop a new questionnaire and attempt to achieve a greater turnout. Additionally, the questions should specifically target various aspects related to the quality and usefulness of the launch and recovery procedures training. The answers could provide direct feedback to experienced weaknesses or problems, as well as suggestions and ideas for improvement. The results from the second questionnaire were then used to narrow down the research problem to a more specific scope related to lack of resources. This scope was then used to revise the research questions and initiate a qualitative interview to investigate how and why training with a lack of resources may affect the quality, safety and attitude towards training. The participants were selected among students, instructors and training managers directly related to training of Romanian crew chiefs. Additionally, the interview aimed to establish if the participants have any suggestions or ideas about which type of technology can be applied to minimize adverse effects of a lack of resources. The data gathered from the interviews will serve is input into the HCD process.

3.2.1 Electronic questionnaire

As part of gathering data about potential problem areas with the current launch and recovery training, a questionnaire (Appendix A) was distributed to the 7 students of the first course. A total of 5 students chose to participate in the research, where they were asked to provide feedback on the course. The purpose of the survey was to gather long-term feedback once the initial class had accumulated some months of experience on the flight line after completing the course. My supervisors recommended that I use the University of Agder "Questionnaire - student evaluation of courses" form [64] as a template for the questionnaire. The template is structured as a series of topics related to different aspects of the course, using a combination of Likert-scale questions, radio-button (single choice) questions, and open-ended questions to gather student feedback. The questionnaire was split into five main parts:

- Age and maintenance experience
- Launch and Recovery practical training - General questions
- Launch and Recovery practical training questions - Kjevik
- Launch and Recovery On-the-job (OJT) questions - Kjeller
- Closing questions, feedback and suggestions

Students were asked not to include personal data, such as name, specific age, military rank etc. that could identify individual persons to maintain their privacy. Age and experience *ranges* were used to avoid specifying the exact age of participants to prevent identification of individual participants. Age and experience levels were included to investigate if there are any correlations between different data gathered from the survey. The second topic of the questionnaire seeks general feedback about the launch and recovery training at Kjevik. These questions are related to the subject content and learning outcomes, the working and teaching methods, and the learning environment. Answers may provide insights into problems or challenges in a broad context, as opposed to the following two chapters which seek to compare simulated procedures versus on-the-job training.

The main part of the questionnaire directly compares the training at Kjevik, using a simulated launch and recovery procedures, versus on-the-job training at Kjeller, where students had access to a fully operational F-16 with a working engine. It is interesting to evaluate how the students perceive and compare the two different methods of training, and therefore the questions are exactly the same for both methods. Does it provide a realistic method to practice the procedures? Does the method create emotional responses within them like the feelings of stress, urgency or danger? Does it improve their feeling of confidence to perform the tasks? Is their safety awareness improved? Lastly, do they feel like they are ready to perform the procedures in an operational environment? By providing direct comparison between the simulated training, and the OJT, the answers could provide subjective information about differences and areas of improvement. The open-ended questions provide a means of giving more specific and detailed feedback related to their experiences during the course.

In the last section of the questionnaire seeks answers to the usefulness of the launch and recovery training, as well as what factors they deem are the most important to improve the training at Kjevik and Kjeller, respectively. Finally, they are asked to provide further suggestions or ideas of their own on how to improve the training, such as by different teaching methods, use of other equipment, or use of new technologies.

The results from the questionnaire were also useful to narrow down potential challenges or problem areas and subsequently taken into consideration to later form the qualitative interview questions in the interview guide. The questionnaire platform chosen was "Nettskjema" [65] which is a service developed at the University of Oslo, capable of collecting, managing and storing data through the use of forms.

3.2.2 Qualitative research

According to Lazar et al. [66, p. 300] "The goal of qualitative analysis is to turn the unstructured data found in texts and other artifacts into a detailed description about the important aspects of the situation or problem under consideration." Ryen states that there is no "standard approach" to qualitative research, but rather a plethora of methods ranging from interviews to observations, text analysis and use of visual media [67, p. 18]. According to Ryen [67, p. 20], qualitative research prefers:

- qualitative data in the shape of images and words, not numbers.
- natural data such as observation and unstructured interviews.
- meaning before action, but from the actors own perspective.
- inductive hypothesis-generating research, rather than hypothesis-testing.

She stresses that when it comes to selecting an approach that "one must be able to argue why one decides to do as one does, and why one does not choose something else [67, p. 13]" Several analytical approaches to qualitative research [66][68] are founded on ***Grounded Theory*** by Glaser and Strauss [69] which is an approach that emphasizes the importance of anchoring theory development in specific, empirical research activities. According to Dalen [68, p. 41]"A "Grounded Theory"-approach is founded upon the empirical data material and is therefore "grounded" in data." This means that the perceptions and perspectives of the informants act as a base for for analysis. She further emphasizes that the core of ***Grounded Theory*** is to derive or induce theory through analysis the empirical data material, as opposed to being based on a theory backed by one or more predetermined hypotheses. This theory is developed through what is known as a coding scheme [66], or process [68], also described as categorization [67].

Corbin and Strauss [70] describe four stages of coding:

- open coding;
- development of concepts;
- grouping concepts into categories;
- formation of a theory.

The first stage involves studying the collected data for patterns, opinions or behaviors that appear interesting or repeat frequently. It is important to not be constrained by existing frameworks, concepts or theory in this part, and remain open-minded towards the emerging data. In the second stage, similar codes are grouped together to form concepts, which can later be grouped into categories. In the final stage, theories can be inferred or argued by linking observed phenomena with identified causal connections or correlations found in the data. Ryen [67] shares a similar description of the process, giving an example of a complete interview as raw data, which should be broken into "units" of information, which will finally be grouped into categories by relation to the same topic. Lazar et al. [66] describes this method of quantitative analysis coding as ***emergent coding***, where the topics of interest emerge as a natural process of data review.

Dalland states that there are two fundamental requirements that the collected data must meet. It has to be ***relevant*** to the research question, and it must be ***reliable*** [71]. Dalen also emphasizes the importance of ***validity*** and ***reliability*** in qualitative research. She highlights the differences between validity and reliability between quantitative and qualitative research, making a point that in qualitative research it is difficult to reproduce the exact conditions of data collection because it is greatly influenced by the particular researcher, respondents and situation at hand. This influences the ***reliability*** aspect, and it is thus common to describe the data collection process in great detail to increase reliability [68]. Dalland argues that to ensure data ***validity***, the selection of informants should target people who are capable of providing exhaustive information about the topic of interest. The questions also have to address the central issues related to the research question [71]. Ryen adds that when the researcher can demonstrate a deeper understanding of the topic, the confidence in the causation or reasoning provided by said researcher is strengthened [67]. Dalen [68, p. 94] lists some aspects that have importance with respect to the validity of qualitative research:

- the role of the researcher;
- the research scheme;
- selection;
- methodic approach;
- the data material;
- interpretation and analytic approach.

According to Lazar et al. [66] it is important to clearly document data and procedures to establish validity, but it is not sufficient on its own. To establish confidence in the interpretation of data, a method called data source ***triangulation*** can be used. There are several ways to achieve data source triangulation, such as using different data collection methods, or using multiple participants during an interview research. If multiple sources of data point in the same direction, it becomes easier to argue that the data is valid. Ryen states that the intention of data source triangulation, is to strengthen the conclusions drawn from the data, or make the study more complete. Simultaneously, one seeks to achieve certain, more nuanced advantages [67, p. 201]. Lazar et al. make an important point that despite taking steps towards strengthening validity it is important for researchers to acknowledge that qualitative studies are still interpretations of complex datasets, and as such it is not possible to claim one "true" answer. Different researchers or participants can interpret data differently which leads to alternative interpretations of data which are equally valid [66].

On the matter of ***reliability***, Dalen [68] states that it is difficult in qualitative studies to recreate the exact conditions to reproduce the same research results. To improve reliability, the researcher must thoroughly describe aspects related to the researcher, the informants and the interview situation as well as indicate which methods have been applied while processing the data. Dalland describes several aspects of data collection which influence reliability, such as interpretations of questions or answers (communication), audio quality of recordings, the accuracy of transcription and how it is important that the researcher takes measures toward eliminating causes for errors [71]. Lazar et al. discuss another method to strengthen reliability, which is related to coding. By using two different coders to code the same data, how consistent are their results? If both coders assign data to the same units or categories, one could argue that the reliability increases. Moreover, if the coders come from different disciplines or schools of thought and arrive at similar results, this is an even stronger indication of reliability [66]. Popper's principle of falsification is also mentioned by Ryen as a method of testing a hypothesis [67]. The idea is that a good theory is never built exclusively based on supporting examples. By including ***deviant cases*** in the data analysis, further investigation may reveal that the deviant cases also support the researcher's conclusions by failing to disprove them. An example could be that some participants answer unexpectedly with respect to a given hypothesis, but through further scrutiny it is revealed that the answers are rooted in unforeseen circumstances which directly confirm the hypothesis. Deviant cases, however, do not always confirm the researcher's hypothesis, and could prompt modification of their ideas, or even be regarded as exceptions.

3.2.2.1 Qualitative interviews

Lazar et al. highlight that one of the strongest arguments in favor of interviews is the ability to "go deep" [66]. Ryen [67, p. 16] emphasizes that "The interview is presented as a suitable method to procure authentic or real knowledge, and the role of the interviewer is to uncover the true identity which resides beneath the surface. According to Dalen, the qualitative interview is especially suited to gain insights into the experiences, thoughts and emotions of the informants [68, p. 13]." She further explains that for a researcher to gain insight in the informants' experiences and situation, the researcher should obtain knowledge about the subject at hand to be able to focus on the relevant aspects. She argues that ideally the researcher should have personal experience within the field of study. However, she warns that a deep personal connection to the subject could influence the research, possibly becoming a source of bias or influence that the researcher is unaware of. Dalland agrees by stating that while conducting research, everyone holds a pre-existing understanding of the research topic. We may have thoughts about the phenomenon and also what we will find during the research. This influences which data we decide to draw from our collection, and the selection may be filtered based on our personal history, knowledge and attitudes [71].

There are different types of interviews, and they are often separated as ***open*** or ***structured*** interviews [68]. Lazar et al. state that ***fully structured*** interviews follow a strict script and order and provides no opportunity to ask questions outside the script. This has the advantage of making the interview easier to compare and analyze. The disadvantage comes from not being able to elaborate on emerging comments or topics the informant may touch upon, potentially overlooking data that is highly relevant to your research. However, if you want some room for exploration and being able to move freely in the order of questions, then ***semi-structured*** interviews will give you the freedom to do so [66]. They further explain that ***unstructured*** (or ***open***) interviews may start off with an initial question, and the informant decides where to steer the answer depending on what they find the most relevant or important in relation to the question. Once the informant runs out of things to talk about, or introduces a new topic of interest, the interviewer may inquire or ask further questions. This interview form arguably requires more skill from the researcher to harvest relevant data from the informant.

3.2.2.2 Interview guide

Dalland [71, p. 26] underlines that "In every project that applies interview as method, there will be a need to develop an interview guide." Ryen supports this claim, stating that most researchers agree that at some point while meeting an informant, an interview guide should be used. Lazar et al. [66, p. 210] state that "a clear and concise interview guide can help you remember which steps to take and when." Dalen states that it can be helpful to have the working title of the research, as well as the research questions laid out when developing the interview guide [68]. This is to form questions that have relevance to the issues and overall theme of the research. She sets forth the following criteria to use when developing the interview guide [68, p. 27]:

- Is the question clear and unambiguous?
- Is it a leading question?
- Does the question require special knowledge and information which the informant may not possess?
- Does the question contain too sensitive topics which the informant will be hesitant to share about?
- Does the questioning provide room for the informant to have their own and nontradi-

tional opinions?

Ryen [67] underscores that the main idea is that the researcher has made thorough preparations for the interview. By knowing the interview guide well, it allows the informant to jump back and forth in the interview form without creating challenges for the researcher.

3.2.2.3 Informant selection

Dalland [71] suggests that a *strategic choice* when selection informants for research, is to search for people who there is reason to believe can contribute with useful data in relation to the research problem. Ryen [67] expresses that when selecting respondents who you have a close relationship to, such as students or coworkers, it can complicate the interview process. The respondents may feel like they do not have the opportunity to speak freely. Furthermore, the researcher may avoid asking certain questions or alter them slightly out of consideration of the relationship. A challenge when interviewing friends is making assumptions about what the respondent means, rather than investigating those assumptions further to achieve greater clarity. Dalen explains [68] that in several studies and certain subject areas it is appropriate to select informants from several groups. The informant groups may have different perspectives and insights into the subject, thus providing a more nuanced set of data which may be useful later during the analysis. It is relevant to point out that identifying different user- and stakeholder groups is part of understanding the context of use in HCD, as stated in chapter 3.1.7.1.

3.3 Research process

The following section will summarize the research process, the methodical decisions that were made, as well as the reasoning behind them. Before going into the choice of method, we should revisit the research problem, and sub-questions that were defined, and overall research goals. Specifically, the core issue is that as an instructor, my duty is to provide knowledge and help students develop the skills needed to perform a launch and recovery inspection of the F-16 aircraft. This task is associated with multiple challenges and risks to safety, which also means the student should develop a safety-oriented attitude. However, to perform this task according to the TO, the aircraft engine has to be operated, and there is currently no possibility of doing that at the training center. This raises several concerns as to how it is possible to ensure that the students meet their intended learning outcomes, and what effect this will have towards their safety after the course has been completed. Teaching becomes a matter of "I will demonstrate how to check these items during the procedure, but note that it will look, feel and sound completely different when you do it on your own on an operational jet". Arguably, if there is a mismatch between the intended learning outcomes, and what the training method is capable of providing, it could be defined as a training *quality* issue due to lack of physical resources. However, is the lack of an operating engine perceived as a problem, and by whom? Do instructors and students share the same opinion and reflections around training with a lack of resources? Perhaps the perception of lack of resources is a subjective phenomenon more likely to occur at the instructor, because they realize "how things should have been". Also, when or where will a consequence of inadequate training manifest in a serious problem, such as an accident? These questions are helpful when considering research methods.

3.3.1 Choice of methods

When selecting a main method to use for the research, I decided to use a process that puts the human at the center. Our needs play an important role in our actions and decisions, and as the old saying goes; necessity is the mother of invention. Coming from a career in the aviation industry, I have experienced that human factors is an integral concept embedded in the safety culture and that it has a goal of both understanding root causes of and preventing accidents. By examining previous research, I learned of different approaches to apply ICT solutions to the aviation maintenance and other safety-critical industries, and thus Human-Centered Design presents itself as an appropriate method. One of the main arguments to support this, is that the method encourages a system-wide analysis and not just the immediate surroundings of the problem in question. Perhaps the apparent lack of resources is merely a symptom of an obscure root cause? Also, will the solution I am designing have other positive or adverse effects outside of the training situation? Furthermore, Human-Centered Design advocates using multidisciplinary teams made up of experts within various fields, several of which I combine from vocational and higher education, as well as personal experience. An important acknowledgement to make at this point is that while I might represent several disciplines, I only serve as ***one*** single perspective. It is therefore imperative to include more perspectives through other stakeholders. Lastly, the method stresses the importance of user evaluation and feedback, as they ultimately have first-hand knowledge and experience about key issues in their domain. Adding to the aforementioned, it must be emphasized that identifying key stakeholders and user groups to understand different perspectives, needs and goals are central concepts of HCD.

Gathering data from the users is crucial, but who are they? One could argue that the users are the students who are there to learn a new procedure, but if you assume the position of teaching, then the user is clearly the instructor with the responsibility of providing learning material and instruction. Both parties arguably have their ***needs*** and ***objectives*** with the training solution, and they both become valuable information sources in a human-centered design process. Identifying stakeholders warrants an exhaustive thought about the ***system***. The F-16 crew chief type course could be thought of as a system on its own with instructors, students, course managers, school management and similar, but who is really the customer of the course? Who requested the training in the first place? That would be the Romanian air force because, after all, they need trained crew chiefs to keep their newly acquired fighter jets airworthy. The Romanian air force is responsible of structuring their maintenance organization, staffing and quality assurance. Local procedures in Romania may differ from Norwegian procedures that are taught during the type course, and therefore the needs of stakeholders in the Romanian maintenance organization are also highly relevant to how the training and training tools are designed. However, to keep data collection and analyzing manageable within the research time constraints, I decided to focus on the users and stakeholders who are directly involved in the training. These are students from the Romanian air force as well as instructors and managers from AATT who are responsible for delivering the course. The students were divided into two informant groups; ***Former students*** which consist of 7 course graduates who have 3-4 months of experience on the job, and ***Current students*** which are 9 students who had about 70% course completion at the time of interview. Among these students, three were asked to participate in the study. The instructors were selected from AATT's employees, and must have been involved in practical training with both courses. Two instructors were asked to participate. Finally, one manager and co-owner of AATT was invited to participate, who also has experience from instruction.

The selection of informants and research stage also influence the data collection methods. To keep personal bias and subjective influence to a minimum, I made the decision of using a questionnaire and qualitative semi-structured interview. This enables me to manage the main topics of the data collection while including open-ended questions to provide room for informant suggestions and contributions. This approach provides some questions that are structured for easier comparison and analysis, but establishes opportunities for emerging data which may not have been accounted for when designing the questions. By combining different informant groups, and collection techniques I set the stage to use data source triangulation, which strengthens the validity of the data. The informant group who received the questionnaire also satisfies the long-term evaluation principle from HCD, because these students graduated the type course in December 2022. At the time they participated in the questionnaire, they had accumulated approximately 4 months of experience and hold a unique perspective where they can assess which parts of the training has been the most useful, or if there have been obvious gaps in the learning objectives. The timeline difference between the graduated students, and the current students also serve as a form of data triangulation. If there are similar issues that are highlighted, despite the temporal separation, it is possible to argue that the issue is not a one-time occurrence. Data from the questionnaire were evaluated and aided in refining and narrowing down the topic to be discussed in the interviews (see figure 3.2).

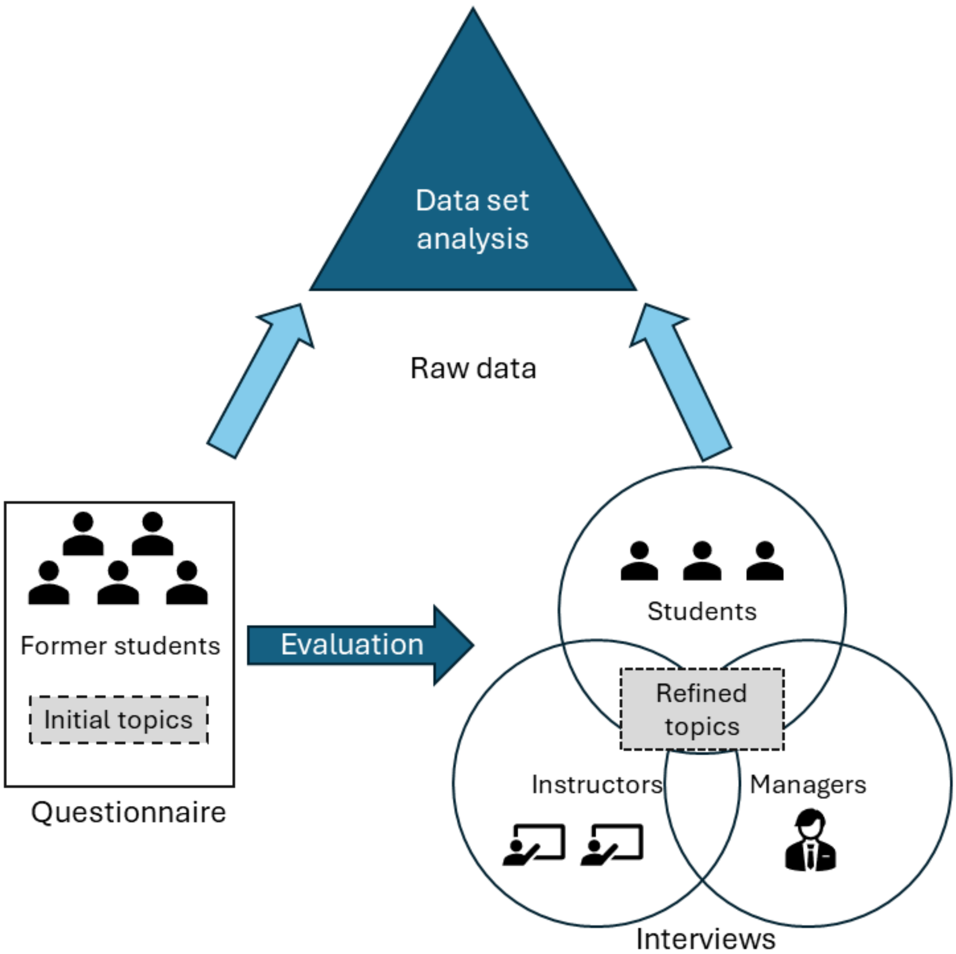

Figure 3.2: Data collection and source triangulation

Given that the initial course feedback questionnaire had a low turnout, I decided to develop a new questionnaire that would focus on the topic of the launch and recovery procedures. One of the goals of the questionnaire was to achieve a higher turnout. To do this, I sent a formal request to the supervisor of the Romanian crew chiefs that included information about the research, as well as a written consent form. They were provided a 10 day time period to respond, and by the end of that period 5 out of 7 former students had chosen to participate in the research. Another objective was to compare the launch and recovery training using simulated methods, with the launch and recovery training using an aircraft with an operating engine. These questions were identical for each theme to directly compare differences in the two training methods. The last goal was to gather suggestions to how the training could be improved.

3.3.2 Collecting and analyzing the data

All participants in the questionnaire and interviews were issued a letter with information about the purpose of the study, what they will be questioned about, a time estimation to complete the questionnaire, how their data will be used, their rights to withdraw from the research, and to access, change or delete their data. This letter also included a declaration of consent to participate in the research. Participants of the questionnaire were recruited through e-mail correspondence with the crew chief supervisor (line chief). The second informant groups were contacted directly; either in person, or through private messaging in social media. The first contact was presented as an invitation to participate in the research project, what the purpose of the project is, what type of data I will be collecting, what the main topics were and a time estimate. All 6 informants responded positively, and provided a schedule and location of where they preferred to conduct the interview. Upon meeting the informants, I welcomed and thanked them for their willingness to participate in the research, and asked them about their day and what expectations they had for the interview to warm up. I explained them about the formalities, walked through the information letter and declaration of consent and asked if they had any questions related to the personal data or privacy. Then I explained them the semi-structured format of the interview, underlining that it is important that I do not interrupt or direct the conversation, that there is no haste and ample time to reflect and recollect on their experiences, that there are no correct or incorrect answers, but focus should be upon providing personal experiences, ideas and reflections in an honest and transparent fashion. The informants were also encouraged not to reveal names or identifying information about individuals, but that it would not be a problem for me to de-identify them in the transcript later if they slip. I stated that if the informants struggled with language or interpretation of questions, do not hesitate to ask for rephrasing or providing some examples, and if they are stuck looking for words or terms, they are encouraged to use their smartphones to translate for them. Another important point is that I might ask them follow-up questions to extract more information, and even if there is an interview guide it is allowed to move outside the topic and estimated time frame of the interview.

The interviews were recorded using a smartphone app called "Voice Recorder" [72]. It records raw audio through the phone's microphone and permits pausing and "highlighting" timestamps of interest during recording and playback. It has built-in features for language detection and transcription, but upon suggestion from my supervisors, I opted to use "Autotekst" [73] by the University of Oslo for transcription. After the interviews were completed, the audio files were labeled by informant group and an incremental letter, such as "instructor A" or "student C" and kept on a secure storage device. The original audio recordings were deleted from my smartphone as soon as the transcripts were quality controlled, but backup audio files were kept on the secure storage device. The audio files were not edited at any point, and the audio quality was satisfactory with no background noise or errors that could influence the transcription process. As previously stated, I opted to use the Autotekst transcription service because it runs on a secure server and automatically detects language, and who is speaking. The output text file of the transcribed interview groups texts into blocks with a code such as "SPEAKER_00" and "SPEAKER_01", which makes it convenient to keep track of who is saying what. This service saves hours of time of manual transcription, but it does not guarantee that the transcription is perfect. To ensure data validity, I listened through every interview audio file while reading the raw text and made corrections. To provide an example of why this is important, and where subject matter knowledge plays an crucial role in transcription quality, Autotekst repeatedly makes mistakes related to F-16 components, parts and procedures, such as translating "SaltWire" and "Color Proverty Stay Generator", which should have been transcribed as "Safety Wire" and "Color Programmable Display Generator", respectively. In some instances, the transcription service failed to distinguish speakers, meaning that phrases spoken by the interviewer were mislabeled as being spoken by the informant, and vice versa. The feature of "highlights" in the voice recorder app was highly useful, as I could more easily locate the beginning of every question, and any interesting topics that emerged during the interview, thus saving time trying to search for specific topics or events. In summary, the combination of audio recording, automatic transcription and quality control was experienced as efficient and effective, despite the aforementioned caveats.

Finally, the raw data was coded to make analysis more reliable. The questionnaire was evaluated, where the likert-scale and radio-button data were used as direct comparison between respondents and topics, and the open-ended questions were evaluated to search for problems, challenges, solutions and ideas. Data from open-ended questions were coded to form units related to a specific phenomenon. In one case, respondents had described the same problem in an open-ended question, but assigned the problem root causes differently in the radio-button question. This demonstrates an example where the subjective nature of qualitative data creates challenges in interpretation. One clear weakness of questionnaires is that as a researcher, I have no opportunity to ask follow-up questions to dig deeper. However, the effort and time needed to collect the data were low and the data proved useful to identify topics and areas of deeper investigation, "such as lack of resources".

Regarding interviews, every question is related to one or two main topics, and therefore some keywords of interest such as safety, lack or resources, quality and attitude were predetermined. However, to prevent a filtering effect where data is forced to fit into a limited set of topics, emerging topics were actively sought after. These emerging topics, regardless of relevancy were kept and reused for subsequent analysis of further questions and interview transcripts, eventually forming ***categories***. The idea behind this choice is to on one hand make the analysis process more efficient, but at the same time accommodate for unpredictable or unexpected topics and categories. Ultimately, the data was divided into individual units of information, which were then assigned to categories which then served as results and discussion topics.

3.3.3 Ethical considerations

My role as an instructor and crew chief course manager places me in a position where I, as a researcher, am susceptible to bias from my own pre-existing knowledge, experience, attitudes and environment. Embarking on this academic journey, I must acknowledge and be aware of the implications of being directly involved with the ongoing F-16 type training. First of all, I have my own experiences and observations as an instructor which influences how I perceive several aspects of the current type training course. Prior knowledge could easily manifest in assumptions about root causes of existing problems, as well as how I suggest that future solutions to said problems should be. It is crucial that I put utmost effort into recognizing and avoiding tendencies to draw conclusions based on pre-existing experience. Moreover, I should rather direct the focus toward questioning those conclusions, should they arise. Most of the research data which does not come from my own experience and career or existing research data, comes from people who have a direct professional relationship with me either by being my student, colleague, or manager. It is my responsibility as a researcher to take every measure possible to not actively or passively influence the research through my role or relationships. Granted that I do have a professional relationship to the focus area of this study, I do not see how else I would have been able to access the people, activities and facilities if it had not been for my direct involvement in the first place.

To protect all who participated in data collection activities for this thesis, I have de-identified every participant's personal information and made efforts toward shielding participants from each other by contacting them directly and in private. Should the published thesis reflect individuals' opinions and experiences which negatively impacts a stakeholder in context of the F-16 type training, it should have no negative consequences for the individual. De-identification should not only protect the participants, but also help them feel more relaxed about being truthful and transparent about their opinions, experiences and beliefs which would greatly benefit the validity of the research data. All data collection was carried out according with Sikt's notification form service [74] that complies with data protection requirements. Permission to gather and store information about the participants is provided through written consent. Sikt provides guidelines and services which assist researchers in following legal requirements which depend on the nature of the study and the participants.

As stated in section 1.4, I also carry a responsibility of not leaking sensitive data with respect to the Romanian Air Force, The Royal Norwegian Air Force, Agder Aviation Tech Team, as well as restricted documentation data which is provided by various manufacturers of military equipment. To prevent leaking sensitive information, such data will also be anonymized and/or redacted from this thesis and generalized to the point where the context and general idea is understood, but the specific data is not disclosed.

There are also important ethical considerations which warrant these research methods and data collection. Because one of the purposes of having a capable air force is to ensure homeland security, anything that improves the ability of doing so will benefit the lives of those who are protected. The current geopolitical situation has demonstrated the importance of an air force's ability to protect civilian lives, infrastructure and sovereignty. At the organizational level, improved training and safety ensures that the personnel and equipment can operate with minimal risk to health and damage, death or destruction. Operating aircraft also have an environmental impact due to released emissions and chemicals, which are easy to overlook when contrasted against the utility of protecting a nation. Regardless, if new training methods and technology could replace or reduce the need of operating aircraft, it can help reduce the carbon footprint, as well as save maintenance needs and costs.

Chapter 4

Empirical data and Results

In this chapter, I present the results from my research. This includes empirical data gathered through questionnaire and interviews. The chapter is organized by topics, where I present the data retrieved from each group of informants. In chapter 5, I discuss the data, compare, and reflect on it in relation to theory. As previously stated, *emerging* topics were accounted for by incorporating them in the sections in this chapter.

For purpose of brevity, Former- and Current student respondents will be referred to as FS# and CS#, respectively with # indicating which respondent from 1-5.

The questionnaire with results, and the interview guide that was used can be found as appendix A and B, respectively.

4.1 Training and resources

The following section includes categories of data which are analysed to be connected to training and resources. This includes feedback, examples and experiences that have a relationship to lack of resources, and training quality. The overall goal is to identify challenges and problem areas that are perceived from different stakeholder groups and assess their implications toward training and resources, as well as identify needs or constraints related to the training. For the purpose of this research, course quality is determined by factors such as how satisfied the respondents are with the training, to which degree the learning outcomes are met, or if there are gaps identified in the learning outcomes.

4.1.1 Former students

Among the former students, general feedback regarding the course appears to be overwhelmingly positive. The likert-scale questions are all phrased to question whether or not the desired results have been achieved, and none of the 5 respondents have selected "I am neutral, I disagree or I strongly disagree" to any of the questions. In other words, the results range between "I strongly agree, and I agree".

The students were asked to rate how well they thought the *simulated* and *On-The-Job Training* launch and recovery training methods provide a *"realistic method to practice the procedures"*. Only one student responded "I strongly agree" to the simulated method, while all five students "strongly agreed" to the OJT method.

The following paragraph presents the results related to the *simulated* method. According to FS1 "it is a good simulation and very close to the real thing". FS2 agrees by stating that "It is a really close-to-reality experience." FS4 states that "the simulated experience helps a lot." However, 4 of the respondents commented that they need to practice more under real, as opposed to simulated, conditions. FS1 states that "It would be great to have a live jet to practice on. Kjevik needs live jets, because the instructors are great." FS2 adds that he needs "a moving plane for marshalling experience...I need more practice with a working plane." FS4 answers that despite the simulated method helping a lot, he still "needs practice in the real situation." This is similar to FS5's response which is that the training should "make a real simulated launch and recovery...with the engine running." FS3 directs some criticism towards the simulated method and states that "...the not good part is if we do this all day, it becomes boring."

For comparative purposes, this paragraph presents the results related to the OJT method. FS1 shares that "It was great to do all we learned, but it was too little... I'm confident, but I need way more practice." The same notions are shared by FS2: "More practice would have been good." FS4 also suggests "More sorties to practice."

4.1.2 Current students

On the importance of having the necessary resources available to perform training, CS1 explains that

> "Despite having previous experience with other fighter aircraft and the same job; when you have a new plane and new instruments, it's very important to have resources during training to get used to them. Having the resources during training is very important and will have a great consequence for us when we go back to Romania."

CS3 provides an example:

> "I think safety might be compromised, because if there is a lack of resources, you have to make shortcuts in order to do the job. We could learn to do the job in the wrong way, and then we might think we are allowed to do it like that at home, and that's not right."

CS2 compares to his experiences from home, and states:

> "When I started as a crew chief in the mid 2000s, I had to buy all my tools. Only the oldest guys had some equipment or tools. It was disappointing to me. After working on the MiGs, having the opportunity to come to Norway and see. It's really impressive, even here: it's only a training center, yet all the tools and equipment are in their positions. If we didn't have safety shoes we were not allowed to enter the hangar. It was a challenge for me to follow all the rules."

In relation to lack of personnel, none of the current students have experienced problems while training at Kjevik, but CS3 had experienced this while training in Romania:

> "There weren't any assigned instructors to do the training with me, so I had to ask the mechanics working on the aircraft about the steps and details of how to do the job. When I studied for myself and didn't understand something, I had to go ask somebody."

When questioned about lack of facilities, none of the current students experienced any issues with this.

Regarding lack of tools, CS1 and CS2 have not experienced a problem with lack of tools, while CS3 refers to an episode where:

> "We had to remove an external fuel tank and we did not have the right wrench to do remove a nut. We used a calibrated torque wrench to do the job anyways, but I think it would have been better to use a ratchet (not a calibrated tool)."

When asked to provide examples of lack of equipment being a problem, CS1, CS2 and CS3 state they don't experience problems due to a lack of equipment. CS1 adds that it's "not such a big issue to lack a working engine", but adds:

> "We are used to being near a plane that is started, with sounds and all those things. But having to inspect a new engine, a new type of aircraft; I think it's basic to have all the environment or simulate the entire environment before going to the real operational job and be prepared for

> that. But, when you go back to your own base, you will have to take a while to adjust. Adjust with what you've learned and apply it on the real job."

All students responded they had enough time, but CS3 shared his opinion that:

> "In aviation it's really bad to hurry. You have to patiently work and accomplish the job. You have to put quality in your work. So I don't think time should be a problem. It's better to leave the job unfinished and continue the next day, rather than do a bad quality job."

On lack of data, the students did not experience a lack of data (information), but shared some insights to how they perceive working with the manuals. CS2 compares it to his training in Romania:

> "When we were in Romania, it was a different concept to teaching. A different way. Somehow, you do the theoretical stuff first, and after that they demonstrate exactly how it works or looks. The students stand and watch one time, and then try to repeat. But here in Norway, it was challenging for us because from the beginning, there were a lot of jobs and we had to read the manuals how to do it. It was challenging, but great. Because your mind is working, and we worked it out in the end. And that was great. An inside pleasure because you managed the problem."

And CS3 concurs that:

> "It's not that the data is missing, it's that you need to gain experience to learn how to find it."

With regards to lack of skills, all respondents share some examples, and share a little about their own skill levels. CS1 states he has skills from similar aircraft and work, but not everyone is at the same level:

> "We worked as crew chiefs on the MiG-21, so it's not like we are doing this for the first time. I think the skills you need for this job, are almost the same as the skills we had on the MiG-21."

CS2 provides a different response with a problem and solution:

> "Some of us are handymen, some are good at theoretical stuff. That's why we are doing this like a team. If the situation requires a certain set of skills, we would decide to use the person with the most experience to do the job."

CS3 acknowledges and reflects on his own lack of skills, and how he mitigates that:

> "I have experienced a few times when my lack of skills showed up. I had to ask an instructor or colleague to help me. My other colleagues have more experience than me by working as crew chiefs on the MiGs, but I started as a different specialization and maybe my mechanical skills are a bit lower. Also, the way you check the aircraft or do a launch procedure. Maybe they could see some problems easier than me."

When asked about lack of experience, all three share some interesting perspectives: CS1 shares some insights into the differences among colleagues:

> "We have guys with 15, 20 years of experience, but also young guys who just finished the school last year without too much experience or skills. With your help in this course, and maybe our group they can manage to do the jobs and learn."

CS2 Emphasizes the importance of experienced instructors when transitioning to new aircraft:

> "You, and the other instructors teach us some theory, and after that we talk about a lot of experiences from the squadron. For us it's good because we are only at the beginning of our existence, and your experience is great for us. If you share that experience, we manage problems a lot more quickly."

CS3 reveals there are some tools that even experienced colleagues have not used, and how it resulted in an error:

> "Most of my colleagues told me they have never worked with a torque wrench before. One of them had to use it to tighten a screw, but he didn't adjust the wrench properly and broke the screws."

When questioned about lack of knowledge, they offer different perspectives and attitudes. CS1 refers to problems already originating from Romania:

> "The Romanian government and our HR-support had to choose who to send on the course. But, because of lack of personnel, they have to choose between people who maybe are not too skilled or experienced. Maybe that has an effect on the training process and the quality of training."

CS2 challenges the idea of lack of knowledge by sharing his attitude towards it:

> "You know, you're not supposed to learn everything on the F-16 by heart. If you have a problem, you should go research the manual or ask somebody."

CS3 shares a contrasting example with safety violations from Romania:

> "At my home base, mostly the youngsters had to refuel the aircraft. However, because many of them didn't have experience, they would overfill the tank and splash fuel over themselves. Sometimes they didn't use the grounding cable, which is a safety risk."

4.1.3 Instructors

The instructors explain on a general basis, what can happen with the training quality, when there is a lack of resources. Instructor A explains:

> "If you lack resources, you might not be able to conduct training according to standards, or provide the correct training. If you can't provide the correct training before the students use the tools and equipment in an operational situation, it can cause incorrect use and at worst damage the equipment or injure personnel."

Instructor B shares similar views:

> "The training quality deteriorates. You might not achieve your goals. Those who receive training may not achieve the level of competency that they should. The training will become more fragmented and you must resort to alternative solutions. The more things you change, the greater the chance that the training product won't be satisfactory. This gives the appearance of less professionalism, and can harm your motivation if it occurs frequently. It may also harm the students' motivation and respect toward the training."

In relation to lack of personnel, the instructors share some experiences and viewpoints: Instructor A:

> "If we have exactly enough instructors to perform training, and an instructor falls ill, then suddenly the students don't have anyone to teach them. It could happen, or what I have witnessed happen, is that they will fetch someone from outside (the training organization), which might not be competent. That results in poor training."

Instructor B describes some problems he is experiencing with lack of personnel:

> "We are suffering from lack of personnel right now. We lack both personnel and competence, which means that we are unable to perform the tasks we want to train. This affects the progression of the course. We are unable to connect practical training to theory to the degree we desire to achieve the full potential in the subject we are teaching."

Neither instructor provide any experiences of lack of facilities. Instructor B explains that:

> "We have a good hangar with all the installations we require."

Regarding tools, both instructors affirm that lack of tools is a problem. Instructor B states:

> "This is a problem. The aviation industry requires a lot of tools. A great variety of tools. Specialized tools. And you need competence to use the tools. And if you don't have either, you can't perform the task. It is a matter of safety."

Instructor A adds that:

> "It is very frustrating to not have test-equipment. As an example, we'll tell our students to perform a system test, and keep reminding them to follow the manual closely. Then suddenly everything stops because we lack test-equipment. We have experienced that we are stuck waiting for equipment or tools, and we can't really perform practical training without it. We can walk through it in theory, but the students won't experience the practical training. This happened with the test-equipment for the oxygen system. It was ordered 6 months ahead of the course, and it never arrived. My question then becomes: What next? Will they receive training in Romania later? Will they come back the Kjevik when we get test-equipment? Nobody knows yet, and it creates problems."

Instructor B states regarding lack of equipment:

> "We are forced to be creative with the tasks, because we don't have enough equipment to apply electrical power to all aircraft simultaneously. We're currently teaching a theoretical subject, where we should have access to test-equipment, but it doesn't work. We are unable to tie together theory and practical training."

When asked about examples of lack of time, the instructors share different angles to the problem. Instructor A:

> "To be fully ready to work independently within avionics, 6 months of type training is not sufficient. You need at least 12 months, maybe more of practical training. My students ask if they are "finished learning everything?". I remind them that they only have basic knowledge, and completed a decent amount of training, but there is so much more they have not experienced yet. Things we will be unable to teach them here. So they should really have one or two more years of practical training."

Whereas instructor B points at:

> "When there isn't enough time, it creates a bad mood. For the instructors who doesn't feel that he can finish the lessons, and for the student who feels like there should have been more time to do or learn things."

About lack of data, both instructors highlight challenges related to documentation. Instructor A:

> "I once held a course about the TETRA radio, the emergency radio for AW101 and Bell412. It was difficult to find information on the subject, but what saved me that time was an acquaintance in the Norwegian Defence Research Institute. He was able to provide a declassified document. All the figures were removed, but the text was still there."

Instructor B underlines that:

> "In the aviation industry, you are completely dependent on the data which the manufacturer requires you to have. It simply has to be available, or you shall not work on the aircraft without it."

Regarding lack of skills, experience and knowledge, they mention the importance of competence: Instructor B:

> "Every instructor that works here are teaching in a broad field with several different subjects and topics - theory and practical training. Lack of competence would mean that you are unable to teach about it in theory, or perform certain tasks on the aircraft. Competence is essential and it is difficult to acquire the correct, competent people at the correct time. The course we are teaching now is not basic training, it is type training. That means you have to visualize what's relevant for this specific aircraft type. It is not general, it is terribly specific. If you are not competent, then you won't be able to cover the specifics, or there will be gaps in your teaching that you don't even know that you should have taught. Suddenly we arrive at a situation where equipment or tools are used in the wrong way or there is an accident or incident with an aircraft."

Instructor A shares some recent experiences:

> "We have experienced examples of lack of knowledge. We asked our students, "do you know how to use safety wire?", to which they replied "yes". When we started working, we noticed

immediately that they did almost every mistake in the book. Such as locking the nut in the opposite direction, so it would loosen under vibrations or stress."

Instructor B elaborates on the importance of management, and the management's understanding of what we are doing:

> "It's also important that the management have the correct competence, because if they don't understand what we're talking about, they will not understand our needs. If you are managing a technical organization, like us in the aviation industry, they will never understand our questions, challenges or problems. This is essential."

When questioned about if the instructors have had to compromise during training, they provide some personal experiences as well: Instructor A explains that he has:

> "participated in some jobs where we replaced parts and o-rings, or cotter pins were not in stock. We had to reuse the old o-rings and cotter pins. Those are small violations, but again, those small violations may grow into bigger ones later."

He has also experienced a more severe compromise:

> "We lack equipment to load encryption keys in the tactical, and general communication systems of the jet. At this moment, I have no idea if we will receive such equipment, or how this problem will be solved. If we can't train on these tasks, then a lot of what is critical in a combat scenario, like having secure data communication in a combat aircraft. If the students can't perform the tasks, then that's a compromise."

Both instructors share the same opinions about compromise as a form of "contract breech" with the learning objectives. According to instructor B:

> "Because we are understaffed, there are times where I have to fill inn for someone else. I've stood in the classroom, and consciously decided not to teach about certain topics, subjects or challenges because I wasn't prepared for the class. Instead of heading into deep waters and get stuck because you can't explain myself, you decide to leave it be. But that means that the people who are sitting in that classroom and could have received a lot of information, won't be getting it. A lower quality of the training. Same with practical training. If you don't have necessary equipment, you avoid the tasks that depend on it, and the students don't receive that information. That's how we adapt."

When asked if they are aware of any safety regulations or rules that are broken due to such compromises, both instructors answer "no", but Instructor A adds some detail:

> "No, I have never done that. If we cannot do the task without compromising safety, then we abort the task. If I know in advance that we lack the equipment for a such a task, I will tell the students that we won't start because it will create problems for us along the way."

4.1.4 Manager

Regarding the effects on training quality due to lack of resources, the manager responds:

> "We are used to a theoretical training. The instructor plays a large role in the theoretical learning material. But when talking about a task-oriented approach, or practical training, then the resources play a major role. Without them, you can't perform the training. That would be a kind of "fake production" of tasks, which may have safety implications. It implies that you are teaching the students something that does not apply to the task in reality. To give an example, back in the day, we taught the new apprentice to replace igniter plugs on the engine. The problem was, we did not have the TO, so we taught him how to do it by heart, and he did. After takeoff, the igniter plug fell out of the engine, and the pilot received an "overheat" caution and had to abort his flight. It turns out, the apprentice had use the exact same method, but on the wrong igniter plug. We only taught him how to replace the aft plug, and he expected the same procedure applied to the forward plug, which it does not. We did a task, and didn't use the help that we should have had. The consequence was a failure on takeoff, which is very critical, and that ruined the mission. The mission became to turn around and land safely."

In terms of lack of personnel, he states that he experienced not being able to perform a task, because

> "one of my colleagues came from a party, and he was not fit for work so I had to send him home. The result was that we had to postpone the task to another day."

As for lack of facilities, he recalls how things have improved over the years:

> "We used to do more maintenance outside which gave us many challenges. Everything took more time. On one occasion, we had to swap an engine outside on a civilian airport. We lacked everything, so we spent 4 days instead of the usual 4 hours. Most of the time, waiting for a C-130 Hercules to ferry all the equipment needed back and forth."

With respect to lack of tools:

> "Sometimes we didn't have special tools, and that meant we had to manufacture them ourselves. We had to, or we would not be able to complete the job. But we couldn't just make anything, so we had to have our locally made tools approved by the [NDMA, Air Systems Division] professional office.

And for lack of equipment:

> "I'd like to include safety equipment. Helmets, ear plugs, safety googles. We had a lot of discussions. There were helmets specifically designed for noisy environments, but they were incredibly uncomfortable. In such cases, you either refrain from using it, or find something else to use that is unapproved. The solution was to obtain custom-molded helmets. It serves as an important point that if something is uncomfortable, even if just for an hour now and then, the chance increases that you will not use it at all."

When reflecting on lack of time, he responds:

> "Probably the biggest challenge is, does the customer who ordered the training have the necessary competence to define the time requirements? Preparation, production and delivery of courses? Years ago, we had a professional council. I was part of it, responsible for it. Their job was to verify that the training provided was aligned with the tasks the technicians are doing. If the level of ambition of those who perform the job was too high compared to the available time for training, there could be challenges, because you have to make a connection between the real situation, and how they are training for it."

Regarding lack of data, he states that:

> "At the surface level, there is usually ample sources of information. However, the minute you start diving into detail, components and depot-level maintenance, the documentation is usually requested from the manufacturer of the part. And they are not always willing to provide the documentation, which is awkward. It is possible to learn, and study how the things work but it would take an enormous amount of time to retrieve information and build up your own competence from it."

In terms of lack of skills, he makes a point that instructor skills should be maintained over time:

> "A major challenge among instructors, is to keep them updated in their profession. We used to have requirements for that, but that concept slowly faded away. If your course was task-oriented, you could maintain your skills. However, if you worked mostly with theory, then the practical skills slowly vanished. If you want relevant instructors, with relevant competence, there must be a connection between theory and practice. The instructors should perform the tasks."

Lack of experience is something he has personally went through:

> "I had to teach on the DA-20 Jet Falcon without any experience. The theory was easy enough to study and understand, but when I started with practical training, the lack of experience really showed. I couldn't connect the dots between theory and practice. Therefore, every school that conducts training in both theory and practical methods should have access to equipment. Maybe not everything, but at least what you need for the tasks you want to train."

About lack of knowledge:

"I think most instructors fear entering the classroom without enough knowledge. But the more important aspect is the pedagogical one. It's one thing to demonstrate to a colleague how to do something, it's entirely different to teach a theoretical theory of how things work. And the ability to draw from the experience in your class, because there are always people who know more than you. I have experienced a lot of talented, skilled people who are excellent at doing their jobs, but have decided to quit as instructors because they lack the pedagogical competence.

4.1.5 Discussion and summary

4.2 Attitude and culture

Attitude is an individual's deeper, or longer lasting way of thinking or feeling about a certain topic. The individual's attitude, despite knowledge and skill levels, could influence how diligent they are while working, or to which degree they respect safety regulations. Culture is defined as a given community's ways of doing things, their attitudes and norms. The categories are meant to catch experiences, views or concerns from the respondents from all stakeholder groups which relate to the training they have attended or are currently involved in.

4.2.1 Former students

The questionnaire was not directed at investigating these topics directly, however some responses mention social aspects such as attitude and culture, hence they emerged naturally and are included indirectly. In two questions, the former students are asked to select one option which they think is *the most important factor they think can improve the training* for *simulated* and *OJT* methods. Only one of the respondents, FS4, selected the option *Social* with respect to the *simulated* method, and he stated that "Human factors is very important."

Regarding the *simulated* method, FS1 describes that without an operating engine "...somewhere in my brain, I had a little thought that I don't have a real responsibility for launch or recovery."

On the other hand, FS4 experienced that he "was so scared about not being sucked into the inlet and divided by the "crew chief divider", even if it was simulated", but also adding that during the *OJT* method, he was "more stressed about colleagues watching" him "do mistakes and then to be judged by them."

One respondent highlighted that the procedures they learned in Norway were not the same as the Romanians were using when they arrived back at their base. FS3 explains that the "practical training was useful in Norway, but in Romania our pilots use different procedures...learned from Portugal and USA" and that they adapt what they learned in Norway to do "the Romanian way."

Regarding the social environment, FS5 states that "the social and physical environment are in top level" with FS4 adding that learning environment has "high standards compared to the Romanian learning environment." FS2 agrees and states that "the instructors created a very good environment in the class."

4.2.2 Current students

The students are questioned about the consequences of training without the resources, and if they have experienced having to compromise (violate a procedure or safety regulation), to complete a job. How does this affect their attitudes toward the task and safety, and what are possible consequences of this after completing the course. CS1 states:

"Making exceptions from the TO or not using the correct tools, I think this is the "spark from which the flame starts"... because if you start the training with the impression that you can

> make exceptions to the TO or correct tools, you might go home to your base, with this "spark" and at some point it will burn you and everything. Making exceptions at at the training center can lead you to catastrophic things later."

CS1 further highlights a challenge related to norms from different nationalities:

> "Basically we are here to train the Norwegian style of doing things. So having different ideas from one, two or maybe three instructors with different nationalities...I'm not saying they are not respecting the TOs, but having different procedures from different countries can lead us to confusion of which one is correct, or good to do. However, it may help us see different ways of doing the job, but regarding safety we will go with the Norwegian way in the end."

CS2 describes a challenge related to established practice in Romania:

> "When we finish the course and go back to Romania, we will surely have problems in the beginning. We will have an internal struggle between the guys who learned it in Norway, and those who learned it at Borcea (using Portuguese/US procedures). I will try to do my duties in the Norwegian style, because I see your experience and you follow all the rules."

CS3 describes an incident where a part was destroyed due to using the wrong part:

> "We had to replace a hydraulic gauge and found a spare one, but it wasn't rated for high pressure. When we installed it, the needle spun a few times and was destroyed, so we had to take one from a different aircraft to fix the problem."

When questioned about if he thought he had violated any standard procedures or safety regulations, he replied:

> "No, because these aircraft are used for training, so I think that taking a part from a different aircraft is okay."

Yet, he stresses that compromises during training can affect the flight line safety:

> "If you learn from the start to do things wrong, you will do them wrong later."

The respondents were asked about "safety nets", or mechanisms in place at their home base that can "catch" or accommodate for a lack of training. CS2 provides a concerned perspective related to Romanian quality assurance:

> "We have the quality assurance, but you know, they are supposed to control me, yet they have not attended the course here (in Norway). That's a problem. They remain in the same system as we used with the MiGs, but being in quality assurance is considered a reward. They earn a lot of money, and it's not the best or most experienced people with knowledge that get those jobs. They only attend a short course at Borcea and when they come back, they are a "quality assurance man". Maybe we have a problem here. Maybe it will change in the future. The MiG system, is not a good system for us."

The students were asked about how exceptions to normal procedures are handled, and the answers are that they work with their instructors, and colleagues to determine when to perform exceptions, such as stated by CS2:

> "We noted that the procedure didn't require us to inspect the speed brakes. We thought that was strange, and after discussing among us we approached the instructor. It was handled first individually, then as a group and finally with the instructor."

He adds that this kind of process is not always easy in Romania:

> "At home, it was really difficult if you had a problem and we have a lot to improve on. Often, our bosses are young. They could be engineers, but even if they have engineering qualifications, they lack experience."

CS3 did not recall any examples from the current training, but provided some insight into past experience from Romania:

> "Sometimes, if I found a problem with some system and the aircraft had to fly on another sortie, my boss would tell me to let them fly the sortie and we will fix the problem the next day. I wasn't entirely okay with that attitude, but I had to comply because I didn't have the authority

to change that decision, because of military rank...several times, I had to comply, but only when I thought the problem was not so big or dangerous."

One comment from CS2 addresses the relationship between simulating a launch instead of starting the engine like in a operational situation, and his attitude:

> "When I was at Rygge, I assisted with one launch, and it was so different. You have to focus and stay vigilant all the time. When I'm here, I try to focus, but somehow my brain says it's not real life and I see how all my colleagues do the same. To compare with Rygge, the dangers, such as engine inlet, hydrazine, anything could happen so you had to stay focused. In worst case, injury or death could occur. Here, there is no danger. In real life there is a lot of danger. That does something with your attitude."

CS3 shares some similar views:

> "I think the responsibility is bigger when you know that you're working on an aircraft that will take off the next day, rather than working on an aircraft that is only used for training."

Finally, when discussing the cultural impact on attitude related to training, the students made some comparisons between the Romanian and Norwegian cultures. CS1 explains that:

> "I like this mentality that is formed here. It's a very good one, because in the familiarization course, we learned about human factors. A very good course that manages to introduce ourselves to this kind of thinking and good approach of issues that may happen...In Romania, maybe we didn't have this mentality, to discuss a problem. At the end of the day, some of us who had problems just covered them up and went home. You have to discuss these things to prevent them from happening again."

CS2 shares similar experience with introduction to human factors:

> "For sure, we have different cultures. From the beginning, when you taught us human factors...We have little knowledge about this in Romania. If someone mentions human factors, it's supposed to be for civilian maintenance personnel. But when we arrived here and learned about the "dirty dozen" and human factors we see that they are applying to us in Romania, we just aren't aware of them. We have all the problems which you describe in the course, but now we realize the importance of following certain principles, or bad things will happen. However, it's difficult because culture is a hard thing to change, but I do hope that I change my mindset a little."

CS3 also underscores the importance of culture in the workspace:

> "You have to have an enjoyable workspace and do things with pleasure...I think culture influences these factors, how your colleagues treat you, or their mentality in general...the goal is to establish a culture where we are honest and help each other. I think the Norwegian culture is really good, and we can learn by example. For example, the military hierarchy is not that strong, and people treat each other as colleagues rather than subordinates. Another aspect is "Just Culture", where you always try to tell about your mistakes and not cover them. Another important factor is the modesty of the people here. I think in Romania, many people are lacking this quality, the modesty."

4.2.3 Instructors

With respect to how training while using exceptions to standard procedures, the instructors share the following: Instructor A:

> "If you start during the context of training to permit things such as using an outdated torque-wrench, but make the excuse that "it's okay this time, you can use it, it's only a week overdue, it doesn't matter", it creates a bad attitude with the student. Especially if the student takes your word for granted without criticism. If you start by compromising your attitude in a training context, it lays the foundation for future work being performed by your students. The notion that "it's okay to skip this thing because the chances things will go wrong are so low". That's when it usually goes wrong, eventually. I think you set the bar during training. You have to demand high quality. And they're not only going to learn to have high standards, they will bring

> those high standards and teach them to others. If you fail to introduce them at the training center, then there's a good chance the standard will not be carried forward."

Instructor B adds:

> "If you don't have the necessary resources to perform the task, then you shall not do the task. That is the consequence. Actually, you should say "no", because that "no" serves as training for the whole organization. If you want a learning organization, then they have to realize there are certain things that must be in order, otherwise things will end in accidents and incidents."

When instructor B was asked about the potential consequences of being pressured to do these tasks anyways he responded:

> "It destroys the motivation. It's not fun to send off a jet loaded with weapons if you can't vouch for the job that you've done. It doesn't matter if you wrote it up in the aircraft logbook, you will have a bad gut feeling. This directs attention towards management. If you address your management with these issues, and they don't acknowledge them, then it's time to find another line of work. It should never happen, but this is mainly a management responsibility."

An challenging situation and example is presented by instructor A:

> "There is actually a thing that I teach, which is not according to the manual. While replacing the wires on a micro-switch, the manual states to cut it in one area, but we always cut it closer to the switch. There's a good reason for it, because if you don't, the area you are supposed to cut it is going to be overcrowded with splices, making it impossible to install the harness sleeve later on. It also becomes easier to measure the cut length for the new wire. But you have to explicitly tell them that you can't repeat this on any job, just this one. Du need very much experience and, well. This is kind of difficult to explain. It's a gray zone."

In terms of how exceptions are handled during training, if they are at an individual level, or at the organizational level, instructor A responded:

> "That's a job for the experts. The people who take these decisions are usually in the management, often with many years of experience with the aircraft and work in the [NDMA, Air Systems Division] professional office. These guys are engineers with a lot of background knowledge and experience. They are highly qualified to perform such assessments. We are supposed to send a form with suggestions to improve the procedures, but that usually involved a long process. You had to go through local quality assurance, they had to agree to your suggestion, before forwarding it to NDMA, then I usually never heard of it again...Actually, regarding the micro-switch it would be better to submit a form, and have the procedure updated to reflect it. If an engineer approves it, then we can use the current method without violating the TO."

Instructor B adds to this by saying:

> "Sometimes the procedures or descriptions in the TO are not good. They are not exhaustive enough, or have poor depictions or schematics. Then you have to go beyond the TO. That's when experience, or competence comes in. Your own competence, as well as drawing from others. When we are going to teach our students how to go outside the book, we have to clarify how to do so. There is supporting documentation that can help you, as well as the competence within your community. Sometimes you have to."

When asked about if there was a system to manage such exceptions he replies:

> "No, here at Kjevik, managing such exceptions happens at the individual level. At the operational bases, there is a quality assurance department that you can consult with for support, guidance. Where there are competent people. But here, most of it is handled at the individual level.

The instructors also have different perspectives on how workspace culture affects the attitude towards training, with instructor A focusing on:

> "I teach in a way that is safe for the students and me. Life is more important than cultural differences, so if I happen to step on someones toes when telling them that they are making a mistake, then so be it. Cultural differences are nice to know about in a classroom environment, but it doesn't affect me at all."

And instructor B:

> "For us who deliver training, our desire is to deliver training in a good way. Then you have to attend courses, practical training, etc because ultimately you, yourself, are responsible for not doing something you are not qualified for. If you have a management, or function within the organization, that manages your training and urges you to attend courses and improve your competence. That would be great. On the contrary, if you are the one who has to seek out training and ask if you can attend courses, and also experience being turned down repeatedly. Then eventually you get the feeling that what we're doing is not that important. That nobody cares if something wrong happens. And that creates complacency. So we need to have a management which is proactive. It shapes the entire work environment."

4.2.4 Manager

Regarding having to compromise during training due to lack of resources, the manager shares and example and the possible consequences:

> "When changing a component, you sometimes need to replace "consumables" such as o-rings, locking devices etc. and we never had everything we needed at the school. The general idea, and what the TO states, is that you should never reuse these items, but that's what we had to do. We have to point out to our students that this is not okay in a "real situation", and that's unfortunate because you give them the impression that it's not important. In our culture, I am not worried about students straying away from the TO instructions, but maybe a different culture would think "hey, we can save some money here, we won't change these items even if the TO says so." which may have a big consequence if there is a leak.

Regarding safety nets, the manager share some thoughts on attitudes:

> "Barriers and fences may protect someone physically, but you can't address the trainee's attitude. With a supervisor, however, you can. Someone who sees how you think, how you do things when you work. He can provide feedback such as "you can't have that kind of mindset". The physical barriers exist, but the mental part, which is the most important, the attitudes need to be taught by someone who knows them."

Regarding the use of exceptions to standard procedures during training and how it affects the attitude towards training, he answers:

> "The students are dependent on building a good, satisfactory attitude over time. The moment we start to "fake" things, or make assumptions, but do something opposite, then this also impacts the student's attitude. It makes them indifferent. The more you are able to be "to the point", or match the real task, and convey the importance of doing it the correct way, the better you will build a good attitude."

When asked about how culture influences the attitude towards training, he replies:

> "I won't say I've met people who are incompetent, in terms of skills or knowledge. I have not experienced that, but when it comes to attitude I have several examples, such as "it's not that important", "it's just training", "we can do things incorrectly because it's just training". Of course, there's a point that you should be able to make mistakes during training, but intentional errors due a perceived lack of consequences needs a risk assessment. Which consequences does this have for the student? I think the aspect of attitude matters the most."

4.2.5 Discussion and summary

4.3 Safety and Human Factors

This section focuses on safety-related aspects and Human Factors. Safety-related aspects will be experiences, concerns or ideas that directly or indirectly affect personnel or aircraft and equipment by injury, damage, death or destruction. Human Factors, on the other hand, is a category reserved for responses that highlight or are otherwise directly concerned with key elements of human factors. The goal of this section is to highlight both problems and benefits related to safety, as well as experiences and issues directed at human factors during training.

4.3.1 Former students

When prompted with "the training methods improve my safety awareness", all respondents strongly agree that the *simulated* method satisfies this claim. while 4 respondents "strongly agree". 4 "strongly agree" that the *OJT* method improves safety awareness, while one "agrees". The respondent who answered "I agree" did not enter data in the accompanying text field in the questionnaire.

Following the pattern from the previous section, this paragraph is focused on responses related to the *simulated* training method. FS1 states that "the method was good to understand what we have to do and the penalties given by the instructors help us to prevent further mistakes...the rigor and attention of the instructors was very helpful." FS2 questions if "it is possible to have a working plane with a working engine for more real feel of the plane and the danger it possesses." FS4 says that he "still remembers all the snags. It was good practice...I thought I had to rush so the pilot could fly, but then I learned not to rush." FS5 says that the simulated procedures using hydraulic power "makes you feel motivated to do things better, and prepares you for the inspection while the engine is operating."

The following responses are related to the experiences from the *OJT* training method. FS1 remarks that "the noise, heat and vibrations around the jet didn't affect me, because I knew what I had to do." He adds that after the completion of the training "it was proven back in Romania that we were ready." To answer if the procedures improved his safety awareness, FS4 answered "Amazingly." FS1 responded "Everything was in a good, safe environment" to the same question.

FS1 adds that "safety and human factors are the most important things I have learned at Kjevik." FS4 agrees that "Human factors is very important."

4.3.2 Current students

CS1 makes a connection between access to equipment and the safety of personnel after training has finished:

> "Having a working plane and, seeing for yourself where it's dangerous and where it's not, this leads to safety for the future crew chiefs that will operate with the real airplane. It's very important to know the safety zones and know how to work safe on the on the plane. The engine inlet; I personally had some issues with this because on one of the assessments, we were simulating launch procedures. I assumed that the hazard zone for the inlet was somewhere beginning from the inlet and extending forward. But the TO says that it has to be another few inches aft of the inlet. So I moved in front of the external fuel tank which is not a safe zone. But for me, I thought that it was okay."

He also reflects on an incident, where he used an improper tool:

> "We had to use a torque wrench, but we couldn't because it was outdated (calibration date expired). We used another torque wrench with the same values, but it was hard to work with. But, we managed to do the job."

CS3 mentions the benefits of using simulators in relation to safety:

> "You don't suffer the consequences of doing the wrong thing, such as getting injured or killed."

He also draws a connection between making exceptions during training and safety implications:

> "We have to know that this shortcut only applies to training."

In response to safety nets in Romania, CS3 suggest that quality assurance staff check them frequently:

> "Maybe use quality assurance inspectors to check every time we do a job, because they could find possible problems. That's a solution I can think of."

4.3.3 Instructors

On the topic of how compromises during training can affect flight line safety after the course is finished, both instructors issue stark statements about consequences. According to Instructor A:

> "In the worst-case scenario, especially on the flight line, you could end up with fatal accidents and destruction of aircraft. One perfect example springs to mind from Belgium, from a few years ago[1]. During an exercise, a weapons specialist was performing an operational checkout of the gun-system. He made a series of mistakes, and suddenly fired a salvo of live ammunition into an aircraft parked on the flight line. It caught fire. In this example, I think the person was experienced, but if you don't have satisfactory training, this is a possible result."

Instructor B elaborates on the flight line implications:

> "The flight line is a dynamic area where incredible amounts of different things happen simultaneously. You have to be aware of everything around you, your assigned aircraft and its surroundings. If you do not have training in being vigilant on a flight line, then critical things can become unchecked. If a flight line consists of a large proportion of people who attended training courses where there have been made many compromises, then you are always close to an accident or an incident. Therefore, I think too many compromises in training is dangerous."

Both instructors provided some critical aspects or items at the flight line which have been listed below:

- Ingestion into the engine air inlet;
- liquid Oxygen;
- fuel and other flamamble liquids;
- high-explosive components;
- electro-static discharge sensitive items;
- ammunition.

When asked about if they are aware of any safety nets which can compensate for lack of training, they provide different answers: Instructor A:

> "Not that I can confirm, we have not heard of any. The only thing I have heard, is that when the students graduate here, they go back to Romania where they already have a valid license to certify release to service. They have all formalities required by their maintenance organization in order and are considered fully operational technicians. As far as I know, even if they fail our exams, we should let them finish the course anyways, and then Romania will assume responsibility after the course. That is frightening to me. If we experience that they do not meet the minimum standard we are teaching to, it doesn't matter because they will just "deal with it" later. So as far as I am concerned, until I hear that we have to provide extra training for those who fail, I do not see any "safety nets" in place."

Instructor B states that:

> "If there is a lack of quality or training, then I think you have to have enough personnel to reduce workload. Either that, or reduce the activity to remove pressure and stress from the personnel. To give everyone better time, and don't stress under a significant pressure. The operational requirements challenge the time available. If the pilots want to fly. They have special missions

[1] link to news article: A Belgian maintenance technician accidentally fired the F-16 gun during maitnenance, and destroyed a parked F-16 on the flight line.

> which are time-sensitive. Maybe they are cooperating with other units, squadrons, other nations. It is important to deliver. And the importance of delivering stems from the fact that they want the mission to come first. However, to do it safely, you need personnel, time, knowledge; you need the resources. That is a consequence."

4.3.4 Manager

When asked about what compromises during training could mean for the flight line safety after the course, he responds:

> "To understand, in a training context, that flight control surfaces move, you can run tests, operate various systems, especially when starting the engine...to understand and get a feeling of that critical part is extremely important when moving around the aircraft. It's something one should practice way more during training, a lot more than we are currently doing. We used to train on these things all the time, so by the time you were going to try this on the F-16, you already had a safety oriented attitude and awareness of danger. When you don't have the opportunity to spend time in an operational environment, then you miss out on the crucial safety bit. It's actually a frightening situation, and you should not really train somebody without the resources to perform this. What we know, is that there are not enough personnel on the base to follow up the new guys. The young ones are often inserted directly to operational service, and this can be dangerous. I've witnessed everything from people almost being sucked into the air intake, walk into the exhaust blast, or ride a bicycle into it. Those things have happened. So either the flight line tasks must be trained at the training center, as it should, or the students have to practice at the operational base. They need the resources to do it, which they don't have today."

Regarding safety nets, he explains how he acted as one when he used to be in active duty:

> "I was a form of safety net, because my responsibility was to greet the newcomers. My experience helped me in a type of supervisor function. The newcomers didn't do anything unless told to do so, what you'd call a good old on-the-job training, with a supervisor. That's a safety net, and a good one, but it requires a dedicated person. Other safety nets are often practical ones, such as fences, barriers, a grid you could fit on the engine intake. However, these barriers doesn't address the person's attitude.

4.3.5 Discussion and summary

4.4 Improvements and technology

Improvements are sought after, and some of those improvements may be as a result of using technology. This section includes respondents viewpoints about how to improve the current launch and recovery training through suggestions and ideas. When they are asked about which technological solutions that may be applied, they include which type of technology and reflect on their strengths and weaknesses. The objective is to collect information that helps improve the training, as well as map out different scenarios and cases for applying technology to do so.

4.4.1 Former students

While the questionnaire did not ask directly about technological solutions, the final block of questions were directed towards usefulness and improvement. When choosing which factor they think could improve the training, both *simulated* and *OJT* methods received most votes for *Method (The way the training is carried out, variation, task selection, number of repetitions, di culty, etc.*). Respectively, they received 2 and 3 votes. The remaining votes were spread among the alternatives and received at most 1 vote.

The final question of the questionnaire asks for *"suggestions or ideas on how to improve the launch and recovery training?*, and lists *New technologies* as one of 3 examples. Despite this, none of the respondents mention use of new technology.

The majority of suggestions for improvement are already stated in section 4.1, and is related to having a working engine at Kjevik, or spending more time performing OJT practice, which also includes a working engine. There is also a repeated suggestion to adopt local Romanian procedures in the training, as stated by FS3 in section 4.2.

4.4.2 Current students

The students were asked to provide general suggestions or list some opportunities they think could minimize the effects of lack of resources during training. CS1 suggests that using skills and adapting to the lack of resources can help:

> "Skills of the personnel, and your way to adapt. You can adapt quickly to uncertain situations where you have to finish the job without instruments, but always be sure to do it safely and not affect the quality and result of the job."

CS2 describes one specific problem related to the lack of equipment, and reflects on ways to improve that:

> "For me, it's only one problem; we are not able to do some steps in training, like they should in real life...for example, to start an engine on the aircraft. It's hard to do something about it, because we don't have an F-16 that is able to fly. And that's very hard to do, it doesn't rely on just one person - it's a whole system that must be in place. Maybe you could manage the problem with a simulator, but in my experience, all those solutions are good, but they can not compare to real life. It's different when you practice launch and recovery, and the control surfaces move, but the engine does not operate."

He proceeds to share his experience and opinion with use of technology and simulators:

> "You taught me how to operate the engine in the engine start simulator, which was great because it transformed me. All the buttons, and interfaces they were an exact copy of the real thing, but not virtual. Just physical. All the buttons and panels in the exact spot, and I could manage to do the same things as in the real cockpit. If it was only a digital simulator, I would not like it. But, maybe it could be a hybrid, a mix between virtual and physical, so you don't only hear the engine but can see things as well as touch and move physical things."

CS1 also reflects on use of technology to improve launch and recovery training:

> "I think that sensing and feeling are the most important things. Putting together hearing, seeing, feeling, all these senses should work together to simulate and create a more realistic training for future operations of launch and recovery. The problem with virtual reality is that you can see it, but not feel it. The feeling of vibrations, hot air being blown around, it's very hard to simulate. Maybe one of the best technologies to improve launch and recovery is haptic feedback. So that when you approach the plane, you recognize the sensation of being in a certain position around the plane."

CS3 introduces a new idea:

> "Maybe a simulator would be great, and make the first part of the training easier, but a much simpler solution would be watching videos of launch and recovery procedures, and analyzing the steps from the video in a list. Then you can compare and discuss. You don't need a lot of resources to accomplish this, and it's really helpful. Just like watching a video on YouTube of how to fix your car. You watch the video, then go repeat the steps."

Lastly, they are asked if technology can improve the training, even if there is no lack of resources at the training center. All of the respondents agree that there are some things you should not do during training, but can be done in a simulator: CS1 suggests using technology to mark hazard zones:

> "A technological solution to mark the hazard zones on the plane and the ground, to visualize it so you can have a mental model, or image in your head. It takes time to establish this, so maybe this image remains when we go back to Romania. However, as I have said before, having a plane and engine started will make it easy for us to implement these zones for launch and recovery inspection."

CS2 and CS3 both suggest that technology can be used, like in a simulator, without negative consequences like in real life:

CS2:

> "You can do a wrong procedure and if something happens, see the results without breaking something in real life. In real life, you make one mistake and it has really big consequences, such as breaking or injuring things and people."

CS3:

> "You can try the wrong steps without consequences, to see what would happen. You can learn from bad examples too, not only good ones."

4.4.3 Instructors

As general suggestions to what can be done to minimize the effect of training with a lack of resources, instructor A states:

> "Digital equipment, such as the Technical Training Package (TTP) is a very nice solution that allow students to perform checkouts, tests and inspections on the aircraft and equipment without physical access to it. Everything is accessible on a desktop computer, visalized. What you don't get with that, is the physical interactions, but you can still observe how systems work. The Emergency Power Unit springs to mind, where testing in real life is hazardous. You can get a little experience with the aircraft through simulations, but is it 100% effective? Not as good as the real thing, but maybe 80-90%? It's a good starting point to familiarize before going to the real aircraft...The students can familiarize themselves in a safe environment. They can build confidence and experience without risk to safety."

Instructor B, on the other hand, highlights a different approach to this problem:

> "If you are in the training business, then you have a customer which has an expectation or wish of what they will receive. And if you can't deliver to that customer, then at the very least you must define what is possible to deliver, and what is not. Or else, the customer may think he has more competent employees than he really does. The important thing to underline is communication. We have to clarify what is to be delivered. This has to be done with the customer, and the instructor. And if we don't have the necessary resources then, at least within the aviation industry, you can not deliver at a higher level than what you are equipped to do."

The next question prompts the instructors to provide suggestions as to what kind of technological solutions can be used to improve the flight line operations (launch and recovery) training. Which one they would prefer to use, and why.

Instructor A:

> "While sitting at a desktop computer, like the TTP, but you could develop something similar to a game, where you control a person around the aircraft using the mouse and keyboard, that's one method. Maybe Virtual Reality (VR) takes that to the next level. Just put on a head-mounted device and walk around. You will experience that you are walking around a jet, giving you a closer feeling to walking around a system and actually doing the job. But it's not a type of operational hands-on training. Even if it looks like it's hands-on. It's a good development if you don't have access to the physical equipment. Maybe haptic feedback can simulate the conditions around the jet, such as shock waves, engine audio, feel the air. I think that has a great potential, maybe 95% similar to the real thing."

Instructor B:

> "I think all types of technological tools and methods are relevant. As long as they are part of a "toolbox" of possibilities, I think you get the best result from applying different training media. It gives you opportunities to approach things from new and different angles. It makes the training exciting, and varied. But you can not replace all training with computer technology. You also have to get out there and experience smells, sounds, pressures, noise, the feeling of actually being near an aircraft that moves, different weather conditions, surface conditions. A combination of all these opportunities is what I think provides the best training."

When asked about which technological solutions they prefer, instructor A says he would choose Virtual Reality because:

> "You could walk around in Virtual Reality, but do it around the real aircraft. If you push buttons, or touch things, you could see the corresponding reaction in VR, even if nothing happens to the real aircraft. For example, move switches, see the lights turn on and off. In VR, you get all the feedback from your actions in the physical world. But, probably the easiest solution right now is to use a desktop solution. Ideally, I would want a VR solution.

Instructor B holds a slightly different preference:

> "The most important thing, is the real, hands-on experience, using real equipment. However, you can train certain procedures and aspects that you can not do with the real equipment. You can simulate emerging problems, standard procedures, emergency procedures...Check if the students detect them, and how they react to them. I think that provides the best training. But it can not replace the sensation of operating on the flight line. To walk around an operating jet is invaluable. But, if you have a background from different media before going on the flight line that has visualized what you are supposed to experience, and you experience exactly what you trained on in a simulation...then you see that "hey, this actually works like I thought." Then there are few surprises for the trainees. I have a strong faith in blended learning, by using different tools and approaches."

The final question regards technical solutions and if they can improve the attitude towards safety even if there is no lack of resources. Instructor A answers:

> "The main benefit is that you can input problems and errors to train how to handle unexpected situations. I don't think anyone wants to experience a catastrophic engine failure in real life, but to simulated it and prepare for it so that you can react appropriately is valuable."

Instructor B adds:

> "If you want good learning outcomes from a course, then you have to be motivated. A student's motivation is largely influenced by the competence of the instructor, but that on its own is not enough. You could have an excellent instructor, but if you are bored from sitting in the classroom all day, or just repeating things on the flight line, then other methods help. As an example, the Romanians were given tablets today, instead of the bulky laptops. Just the fact that they had a new device to use, which was more practical to use in the hangar than a laptop, helped a lot. It was something new and exciting."

4.4.4 Manager

When questioned about how to minimize the effects of lack of resources during training, the manager replies:

> "You produce many things to compensate for lack of resources. We made models, mock-ups and look-alike things, which had a great function. It wasn't exactly like the real thing, but it made the transition to the real thing smooth. Today you can use different technologies to display challenges. The moment you can look at things, in 3D, establish an overview of the job you are about to do, I would argue things are close to reality; that you will recognize things. You might not be able to recreate the physical forces and properties, but to give you an impression of the big picture I think technology can achieve a lot."

He suggests some technical solutions to flight line launch and recovery training:

> "There are several technologies that are suitable here. As long as you are working on an operational level, where there are hazard zones, then there is technology that can warn you about those dangers. I think that's very useful, but before that, there is perhaps a much simpler solution. Launch and recovery is a procedure that you perform. That procedure can also be taught by watching a video. A simple method, before going to do it yourself. It could be arranged in a format so the technician can have it on a mobile device, in their pocket. Of course, you could make advanced Augmented Reality solutions, but how great is the effect compared to a video? I have my doubts about that. The effect increases when you can involve a supervisor, simultaneously. During launch and recovery, you could always have the technology tell you what to do as you move around the aircraft. But the ability to communicate with someone who knows

> exactly what you are doing, and sees the same as you are seeing, I think has a huge potential. Because you are drawing on the experience from others, and bringing it into the current case. Not all tasks are defined in great detail either, therefore I think new and modern technology is essential as we go forward, but to combine it with existing experience would be invaluable. You establish a sense of safety, that there's someone to lean on with the correct attitude, who you can ask for assistance. Ongoing and online."

He further elaborates on the benefits of having an Augmented Reality system, with an experienced supervisor connected to it:

> "With Augmented Reality, the trainee could see text, warnings and hazard zones overlayed the real aircraft. But the ultimate dream is to have a service where an experienced supervisor can connect and support the trainee, interacting with what he sees and hears in the AR device. This makes support less dependent on time and location. Instead of having 20 supervisors spread across 20 trainees, you could have one supervisor connect remotely on request, correcting tasks, providing guidance. That would be optimal."

Finally, he reflects on some strengths and weaknesses of technology:

> "I believe you can use technology to train attitudes that normally wouldn't be trained in real life. Toward hazard zones, such as providing a warning, giving you an electric shock or vibration. The drawback of that could be that the student expects this warning in real life, too. You create a reality which isn't real. That's a concern, so you need to be weary of how you implement these solutions. A challenge is to not make the people dependent on the technology, but rather make them independent. Technology could help them become independent sooner, by practicing scenarios and situations that would take years to experience in real life.

Chapter 5

Discussion

In this chapter, I analyze and discuss the results from my research in relation to theory. The chapter follows the structure of chapter 4.

For purpose of brevity, Former- and Current student respondents will be referred to as FS# and CS#, respectively with # indicating which respondent from 1-5.

The questionnaire with results, and the interview guide that was used can be found as appendix A and B, respectively.

5.1 Introduction

Training is a central pillar in the aviation industry. The complexity of aircraft and their ever-evolving technology, modifications and upgrades dictate the need for competent personnel with the right skills and knowledge. An aircraft technician therefore requires not only a broad and general basic training, they must also undergo highly specific type training to learn all the aircraft peculiarities and specialized tools, documentation and practices for the type they are assigned to. And to be sure that the technician meets the expected level of competency, they must practice and demonstrate it through extensive on-the-job training programs and authorization in the maintenance organization. Despite boasting an exhaustive and robust competence as a foundation, it will slowly, but surely erode over time as new methods and technologies emerge in the industry. Recurrent training in core skills, type differences and human factors should preserve the level of competence needed to perform the maintenance tasks without compromise to safety. However, not even the most competent and qualified personnel are able to achieve the high standards of work and attention to safety, if they do not have the resources to do so. Training is merely one of many crucial resources needed to safely operate aircraft, and those crucial resources are coincidentally also in demand to conduct training. A dilemma may manifest itself, especially when the resources in question are in short supply, and so an airline or air force may have face difficult decisions when prioritizing those resources. An airline or air force is nothing but an aircraft storage service if the aircraft can not fly, but they are not competitive or potent either if the aircraft keep breaking down or falling out of the sky.

To underline the importance of training, it serves as core resources in the PEAR[34], SHELL[35] and Dirty Dozen[39] models of human factors. In the aviation industry, human factors serve as guidance and tools for individuals technicians, pilots, shift leaders, quality assurance inspectors and managers. A lack of training is defined as a source of error under "lack of knowledge" in the *dirty dozen*. According to ***PEAR***, the people who are performing actions require resources to do so, and without the correct or necessary training there is a latent source of error. There could be years between an established lack of knowledge and the time when this lack of knowledge becomes a measurable problem. "Nobody taught me that", "I didn't think this was going to be a problem", or "how was I supposed to know that" are all statements indicative of a lack of knowledge, and may serve as useful clues to isolate sources of error during post-incident investigations. It might trace back to the technician's basic training, and how the training center did not have the necessary parts, or how the instructor lacked experience with a procedure. The first safety net that could have prevented the incident may have begun with the conditions at the training center. But how does one identify and detect these conditions in a timely manner, and what are the consequences if they are left unchecked?

To more closely examine and discuss the current training, and the effect of lack of resources, the principles of human-centered design are applied especially related to *understanding the users, tasks and environments* and *involving the users in the design and development process*. As part of the *discovery* or *pre-design* phase, stakeholder interviews are conducted to collect and establish a deeper understanding of the underlying needs, goals, challenges or constraints related to key stakeholder groups in the context of training. HCD empasizes the importance of *designing for the whole user experience*, which includes accounting for the users and their characteristics such as personalities, skills, attitudes, habits and prior experience, several of which are key concepts of human factors. To ensure a broad representation of knowledge and experience in a design process, HCD underlines the significance of including *multidisciplinary skills and perspectives in the design team*, which is why this research is resting on the key disciplines and theories of human factors, subject matter expertise, training and associated learning theories as well as the users and stakeholders; the students, instructors and managers of the ongoing type training.

5.2 Training and resources

Working as an instructor at the training center provides a unique perspective to the training. As an instructor, one must prepare courses, assign learning objectives, select training activities and assessment methods. As a student, the perspective changes to what is observed and experienced through the training hours of the day, according to the results of the work of the instructor. As a manager, one holds a different perspective, where the daily activities and interactions may be obscured by the higher-level challenges and opportunities that emerge on the organizational level, ranging from staffing and finances to interaction with customers and partners. To establish a deeper understanding, qualitative data is used to identify potential gaps in the training, or a lack of resources.

Information collected from the former and current students indicate a specific, critical resource is missing, which is an F-16 with the possibility to operate the engine. To underscore the importance of this resource, all of the respondents who have already completed the type course and accumulated at least 4 months of experience still maintained the position that they "need more practice with a working plane", and "need practice in the real situation." This perspective is also described as a key concept of HCD, as *long-term evaluation* or monitoring, where, in this case, the results of the course are tested over time. The results maybe represented as the competence of the graduated F-16 crew chiefs and their ability to perform the job in comparison to the intended learning outcomes and expectations of the customer (the Romanian air force), respectively. Internally, the former students may experience a lack of competence if they constantly run into errors, or are unable to apply their knowledge to solve them. A lack of competence may also be experienced as external feedback from their peers in Romania, indicating that they are not at the expected levels of competence. It is difficult to quantify and assess the level of competence needed to independently work as a Crew Chief, which is likely why the RNoAF had a year-long qualification program to supervise and continuously assess the newly trained personnel. Regardless, the subjective feedback from the former students after gaining experience in Romania remains that there is a *need* to practice more on jets with operating engines.

To assess the training quality from a different perspective, comparisons can be made between the intended learning outcomes and the training methods used to achieve those outcomes. In the crew chief course syllabus, the launch and recovery inspection is highlighted as a required practical training task, set at the skill level of S3, or ability to *"execute skill independent of help"*. This implies that the student should be able to perform all steps of the task without assistance. What does that actually mean? Bloom's taxonomy refers to the domain of *psychomotor* abilities. The launch and recovery procedure is a series of incremental steps with instructions and corresponding images displaying what to check, when to check it, and the expected condition. The crew chief is required to perform these steps in an established sequence which is subject to local adaptations, but all steps should be performed irrespective of local conditions. If the crew chief is supposed to verify a correct oil level in a gearbox sight-glass, but it is impossible to replicate those conditions in training because it requires a running engine, does the method meet the expectations of S3? In fact, there are numerous such items in the launch and recover procedure, such as checking correct engine nozzle movement, verifying hydraulic system quantities, observing the startup for fires and fuel fogging (fuel spray out of the engine, but no ignition). Several of these aspects are currently not possible to check according to the procedure, and several of them have major implications to safety of the aircraft, pilot and ground crew. It is sensible to argue that based on these discrepancies alone, the launch and recovery procedure can not be practiced to the required skill level. Instructor B emphasized the importance of communicating these discrepancies to the customer of the training, and in doing so also points out a key stakeholder:

> "If you are in the training business, then you have a customer which has an expectation or wish of what they will receive. And if you can't deliver to that customer, then at the very least you must define what is possible to deliver, and what is not. Or else, the customer may think he has more competent employees than he really does."

A testimony to the gap in launch and recovery competence, is that the first crew chiefs who graduated from Kjevik were deployed to a different base in Romania for on-the-job training. For safety reasons, this was likely a good decision due to the level of experience among existing Romanian crew, compared to the freshly trained crew from Norway. However, the students experienced a new issue, which was brought to attention by FS3:

> "Practical training was useful in Norway, but in Romania our pilots use different procedures...learned from Portugal and USA."

This is also corroborated by current students who are in contact with their colleagues in Romania, and will be discussed more closely in section 5.3. Consider the two aforementioned perspectives in light of the manager's reflections:

> "Years ago, we had a professional council. I was part of it, responsible for it. Their job was to verify that the training provided was aligned with the tasks the technicians are doing...you have to make a connection between the real situation, and how they are training for it."

If the Romanians use different procedures than Norwegians, why train the Norwegian procedures at all? The launch and recovery should be trained until the point where it becomes a drill, or second nature. It takes multiple repetitions over long time to establish these routines and learn them "by heart", without having the TO in hand at all times. It seems counterproductive to spend considerable efforts to learn a drill just to re- or unlearn it later. The aforementioned problem could be attributed to failure to identify all relevant stakeholder groups during the development of the Training Needs Analysis (TNA). Did the authors of the TNA include the perspectives of Norwegian and Romanian crew chiefs and instructors? Was a professional council used or formed to evaluate the training needs? By the time corrective adjustments make it to the next iteration of the course, there is a chance that more than half of the total amount of crew chiefs scheduled to be trained will have received training using mismatching procedures.

Returning to the issue of discrepancies from the launch procedure and the lack of a working engine; In an attempt to mitigate such discrepancies, a *simulated* launch and recovery training method has been used. It involves the connection of ground-support equipment such as external electrical- and hydraulic power, which enable the movement of flight controls, operation of brakes, use of external lights, and the use of intercommunication systems (see figure 5.1. While the method closes some gaps in the procedure, it also introduces some non-standard elements that do not represent reality. The students must circumnavigate electrical cables, hydraulic lines and a cooling air hose which are normally not there, and some of the gauges and indicators will display the incorrect values. In essence, to achieve an improvement in some areas, one introduces errors in others. The improvements may allow students to form a better mental image of the overall workflow, but at the detailed level, which may make the difference between success and failure, the students have to contend with multiple observations that do not represent reality. The former students were all able to visit Kjeller air force base and attempt the procedure one or two times on a fully functional aircraft, and all students responded that the *simulated* method was good, but the real jet was more realistic to train on. Some of the current students, including CS2, were offered to travel to Rygge air force base to participate in the transfer of 3 F-16s to Romania. He shares similar experience in section 5.3.

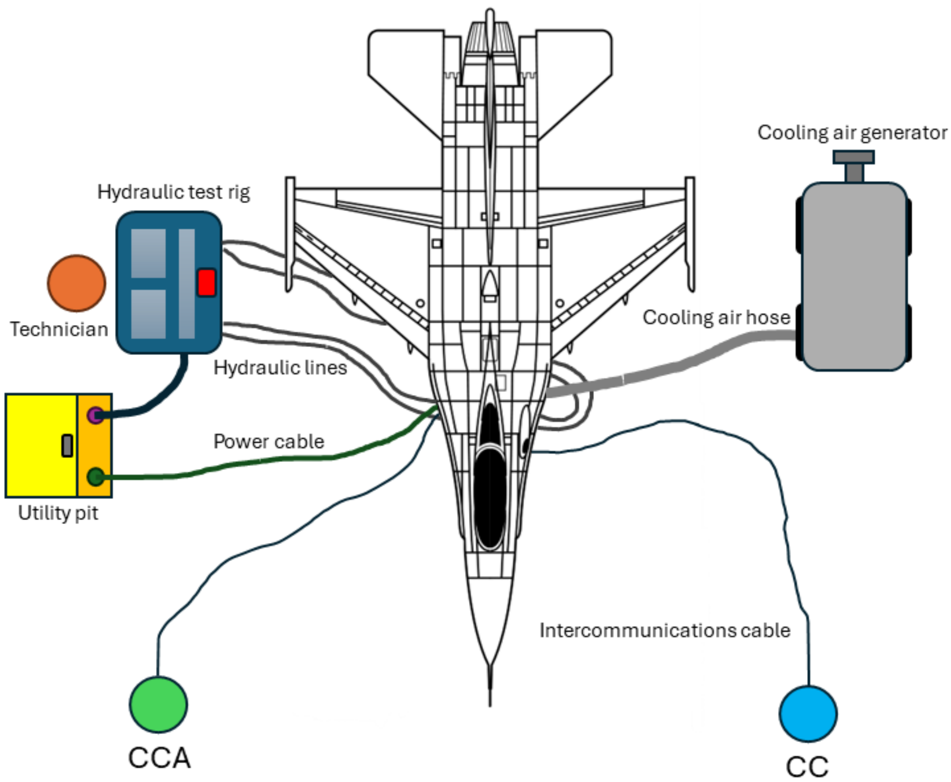

Figure 5.1: Aircraft overview during launch simulation, generalized.

A different aspect to learning outcomes, is if they use the correct measurement for this task? The launch and recovery is a procedure, but it does not inform the crew chief how to greet the pilot, clean the surrounding area, wipe off dirt and hydraulic fluid residue from the aircraft or how to react to time-induced pressure or stress. It does not explicitly tell the crew chief how to move around the aircraft, how their mental state and focus should be, or how to react to a specific sound, vibration or smell. Perhaps most importantly, it does not test or prepare the crew chief to interact or discuss with the pilot when and if there is a condition worth concern. To potentially abort the mission. These problems are absolutely central in the responsibility of the crew chief, yet completely absent in the learning objectives. The crew chief's skills and knowledge may allow them to demonstrate competence by performing all steps satisfactory "by the book", but people are not machines. To make the correct choice when under pressure or in doubt requires a safety-oriented attitude. This might explain why FS4 and FS1, despite not being questioned about the topic directly, described that "Human factors is very important." and "safety and human factors are the most important things I have learned at Kjevik.", respectively. The cognitivist approach to knowledge and psychomotoric learning objectives as presented by Bloom's taxonomy appears to be inadequate to measure all aspects of competence needed to perform the launch and recovery. Attitudes are deeper, long lasting ways of thinking about or valuing things, and the process of measuring them requires insight into why they act or decide as they do. A person might know what to do, and how to do it, but decide to do the wrong thing anyways because of their attitude.

To summarize the aforementioned about whether or not there are problems related to a lack of resources, the example of launch and recovery training exhibits several findings:

- the training procedure does not match the procedure which is used/taught in Romania;
- there are several discrepancies in the training procedure stemming from the aircraft condition not matching the expected results in the TO;
- the discrepancies make it impossible to succeed in reaching the intended learning outcome of "S3" with respect to the procedure;
- the intended learning outcomes fail to account for critical responsibilities of the crew chief related to attitude.

Another stakeholder, the Romanian air force maintenance organization is identified.

There are also some stakeholder needs identified.

- the students need more practice with working engines;
- the Romanian air force maintenance organization needs competent F-16 crew chiefs;

Based on these results, one can confidently claim that the intended learning outcome exhibits gaps in the required competence and the current training methods are unable to achieve those outcomes. This is largely due to lack of resources, but also failure to identify stakeholder groups with insights that are critical to designing the intended learning outcome. An important point emerges from these observations, which is that the lack of an engine lead to inventing the simulated training method, which is not in accordance with the procedure. The lack of resources lead to making exceptions to the procedures in an attempt to "make do" with what is available, rather than abort the training completely. This phenomenon will be further discussed in section 5.3.

Despite these findings, it is interesting to observe that the overall feedback from the former students was overwhelmingly positive. They considered the simulated and OJT training methods very useful, found that it helped them improve safety awareness, and it was realistic. Regarding the simulated method FS1 states

> "It is a really good simulation, and very close to the real thing."

, and FS 4 agrees that

> "the simulated experience helps a lot."

Meanwhile, FS3 criticises the method by stating that

> "..if we do this all day, it becomes boring."

suggesting there could be more variation. The impression is therefore that none of the former students experienced critical problems connected to lack of resources with the launch and recovery procedure training.

Among the current students, the overall experiences indicate that there are very few experienced problems at Kjevik connected to lack of resources. Even regarding lack of equipment, the category which the operational engine falls under, CS1, CS2 and CS3 stated that they did not experience lack of equipment, and CS1 even adds that it's not a big problem because "we are used to being near a plane that is started with sounds and all those things".

The instructors describe the consequences of lack of resources quite clearly, which correlate with the ndings above, as exempli ed by instructor B:

> "The training quality deteriorates. You might not achieve your goals. Those who receive training may not achieve the level of competency that they should. The training will become more fragmented and you must resort to alternative solutions. The more things you change, the greater the chance that the training product won't be satisfactory. This gives the appearance of less professionalism, and can harm your motivation if it occurs frequently. It may also harm the students' motivation and respect toward the training."

Instructor B

The manager also shares similar perspectives:

> "when talking about a task-oriented approach, or practical training, then the resources play a major role. Without them, you can't perform the training. That would be a kind of "fake production" of tasks, which may have safety implications. It implies that you are teaching the students something that does not apply to the task in reality"

Instructor A shares what he assesses is a critical problem:

> "We lack equipment to load encryption keys in the tactical, and general communication systems of the jet. At this moment, I have no idea if we will receive such equipment, or how this problem will be solved. If we can't train on these tasks, then a lot of what is critical in a combat scenario, like having secure data communication in a combat aircraft. If the students can't perform the tasks, then that's a compromise."

This example shows a profound understanding of the far-reaching consequences of training with a lack of resources. The consequence isn't dangerous in the immediate environment, but at the operational level.

An interesting issue is that while the students do not experience a problem with "lack of personnel", the instructors do. According to instructor B:

> "We are su ering from lack of personnel right now. We lack both personnel and competence, which means that we are unable to perform the tasks we want to train. This a ects the progression of the course. We are unable to connect practical training to theory to the degree we desire to achieve the full potential in the subject we are teaching."

And instructor A explains what has happened:

> "If we have exactly enough instructors to perform training, and an instructor falls ill, then suddenly the students don't have anyone to teach them. It could happen, or what I have witnessed happen, is that they will fetch someone from outside (the training organization), which might not be competent. That results in poor training."

The different focus of the students compared to the instructors and manager is quite contrasting, but could have numerous explanations:

- in the training context, the responsibilities of the student is to attend and learn through participation;
- while responsibilities of the instructors and managers is to deliver good courses;
- the training may exceed the students' expectations for numerous reasons;
- the instructors have experience from F-16 maintenance and expect to uphold the same standards;
- the instructors are able to compensate for problems to the point where it is not evident to the students,

and potentially other phenomenon as well, such as previous training experiences, as described by CS 2:

> "When we were in Romania, it was a different concept to teaching. A different way. Somehow, you do the theoretical stuff first, and after that they demonstrate exactly how it works or looks. The students stand and watch one time, and then try to repeat. But here in Norway, it was challenging for us because from the beginning, there were a lot of jobs and we had to read the manuals how to do it. It was challenging, but great. Because your mind is working, and we worked it out in the end. And that was great. An inside pleasure because you managed the problem."

The next chapter seeks to explore consequences of training with the use of *exceptions*, and to explore aspects related to attitude and culture.

5.3 Attitude and culture

Building on the issue from the previous section, there is an important question to answer in terms of training with *exceptions*: What effect does it have on the students, and teachers? Are the managers aware of this, and is it being addressed? The previous section makes the statement that there is a failure to meet the learning objectives, that the *simulated* method does not correspond to the real procedure, nor do the Norwegian and Romanian procedures match.

FS1, who was overly positive to the simulated launch training made an interesting remark about it:

> "...somewhere in my brain, I had a little thought that I don't have a real responsibility for launch or recovery."

This fragment of information may allude to the underlying attitude which is influenced by the teaching methods. If training doesn't match reality, or if it doesn't match the future method, then perhaps it isn't really important? At this stage, it is important to point out that FS4 from the same class responded completely opposite, claiming he:

> "was so scared about not being sucked into the inlet and divided by the "crew chief divider[1]", even if it was simulated.

However different these two statements are, the interesting observation is the students' attitudes toward the same task. One student is implying a lack of responsibility, while the other student is immersing himself in the scenario to the point it is invoking fear. Attitude is the main topic of this section and exploring the consequences of making exceptions during training.

[1] the "crew chief divider" is a nickname for the engine inlet strut, a vertical beam inside the air intake.

CS2 summarizes the difference of a real launch and simulated one quite clearly in his reflection:

> "When I was at Rygge, I assisted with one launch, and it was so different. You have to focus and stay vigilant all the time. When I'm here, I try to focus, but somehow my brain says it's not real life and I see how all my colleagues do the same. To compare with Rygge, the dangers, such as engine inlet, hydrazine, anything could happen so you had to stay focused. In worst case, injury or death could occur. Here, there is no danger. In real life there is a lot of danger. That does something with your attitude."

CS2 directly addresses the importance of having access to functioning equipment, and how that influences his attitude. The presence of immediate danger played a role in how focused and vigilant he was, and that it is difficult to achieve the same kind of focus during simulated procedure training. These changes in attitude and motivation that promote focus may indeed be instilled by fear of hazard areas and the way we are affected by them likely varies between individual people. Returning to the intended learning outcomes from section 5.2, the current system is task-oriented, focuses on the launch and recovery procedure and measures the skill level. In light of the aforementioned statements about attitude, it is clear that managing this task is about more than psychomotoric skills and the ability to perform sequential steps according to procedure. It also involves managing the reactions derived from the current context. This immediately draws parallels to HCD and understanding the context of use How are the students going to learn? How can the teachers leverage the possibilities within the context? Do the managers understand the significance of this aspect?

CS3 experienced an incident where they installed the incorrect hydraulic gauge, causing it to be destroyed. The destroyed gauge was discarded, and the part was cannibalized from another aircraft. When asked if he thought he had violated any procedures or safety regulations, his response was:

> "No, because these aircraft are used for training, so I think that taking a part from a different aircraft is okay."

The argument is arguably false, because parts are cannibalized from aircraft quite frequently provided that they are in serviceable condition. The interesting statement is his reasoning. He excuses himself with the fact that these aircraft are used for training, which implies he would not do this on a real jet. When questioned about the consequences of making compromises during training, he responds:

> "If you learn from the start to do things wrong, then you will do them wrong later".

CS1 shares a similar concern about exceptions during training:

> "Making exceptions from the TO or not using the correct tools, I think this is the "spark from which the flame starts"... because if you start the training with the impression that you can make exceptions to the TO or correct tools, you might go home to your base, with this "spark" and at some point it will burn you and everything. Making exceptions at the training center can lead you to catastrophic things later."

It would appear that making exceptions to procedures during training are understood to have bad consequences, and could adversely change the attitude for the worse. To make matters more complicated, the TOs and procedures are not always clear, or there are conditions where the equipment is locally manufactured and does not function the same way as the TO states and can even have a different appearance. A specific example is the hydraulic servicing cart, which does not have the same connection to the aircraft as the TO states. The TO requires the engine to be operating while servicing the hydraulic system, but the equipment used in Norway is designed to be used when the engine is shut down. This is what is referred to in human factors "dirty dozen" as a "norm". It's an unwritten rule, usually established in groups. They are often described as shortcuts, where one skips the steps in a TO, or uses a different tool because the proper one is unavailable. In a training context, how does one convey that all TOs must be followed to the point, except for some procedures that you can skip because the local tools or norms may allow it. In fact, based on the previous argument that due to lack of resources, the launch and recovery training does not satisfy the TO; the hydraulic servicing task training also fails to satisfy the learning outcome. How do the students know when to do what? Most likely, they do not know, not without guidance, and their maintenance organization in Romania does not necessarily know either. Who creates, de nes, and manages norms and local practices? It is reasonable to claim they emerged from the community where the norms apply.

Instructor A shares a relevant experience from the training:

> "We have experienced examples of lack of knowledge. We asked our students, "do you know how to use safety wire?", to which they replied "yes". When we started working, we noticed immediately that they did almost every mistake in the book. Such as locking the nut in the opposite direction, so it would loosen under vibrations or stress."

It would appear that by the student's standard, he was competent enough to answer yes, but the instructor did not agree with the results. The established idea of what is considered satisfactory di ers.

At the individual level, Vygotsky's Zone of Proximal development may be useful to explain how this matter of learning is solved in the training hangar. When a trainee is following the TO step by step, he encounters a mismatch between the TO and the available equipment. The more knowledgeable other, which could be a knowledgeable trainee or instructor, presents supporting documentation or a localized procedure, just enough to get the trainee back on track. The trainee has now created new knowledge about the procedure itself, but also learned about supporting documentation. The next time, this student may try a similar approach when stuck. While Vygotsky's model suit each individual learning experience well, there are other social learning models that can describe how communities maintain and exchange knowledge.

At this point, Wenger-Trayner's [53] communities of practice seems to o er a suitable explanation of what is going on. Through over 40 years of experience on the F-16, the technicians of the RNoAF have developed their own community of practice. Being an F-16 maintenance technician has developed a meaning, a common interest of maintaining the best F-16 eet there is. A sense of pride in The co eebar on the ight line is not merely a place to play cards and drink co ee. It is a place to share experiences on how to best maintain the F-16. How to x certain problems, how to handle speci c events. When someone is struggling with a malfunction, nearby technicians gather around, listen, suggest causes, investigate in the documentation, or recommend calling an expert at the other base who had similar problems. This is a community of practice; a common domain that invites membership, the members which make up the community and seek to engage, interact and build trust, and nally the practice. The practice is the collective selection of methods, tools, resources, experiences and ways of addressing recurring problems. Likely, a single maintenance squadron comprised of multiple elds of specialization is more of a constellation of several communities of practice. Avionics, weapons, survival equipment, crew chiefs, and other specialist groups have slightly di erent ideas of what it means to be competent within their respective elds. The communities may extend to other maintenance squadrons as well, on other bases. Two avionics specialists from di erent bases may occasionally call each other to solve problems, for example.

The social learning aspect is not merely useful to structure the norms into a box and call it "community of practice", but also to understand the mechanisms that happen when members from di erent communities of practice come together and exchange information. In short, people in communities of practice form competence, an existing knowledge and understanding of how things should be done, and what de nes a competent or incompetent person within that practice. The experienceis a subjective, unique, and ongoing experience.

CS1 shares some insights into how he experiences the mentality at Kjevik:

> "I like this mentality that is formed here. It's a very good one, because in the familiarization course, we learned about human factors. A very good course that manages to introduce ourselves to this kind of thinking and good approach of issues that may happen...In Romania, maybe we didn't have this mentality, to discuss a problem. At the end of the day, some of us who had problems just covered them up and went home. You have to discuss these things to prevent them from happening again."

The opinions of CS2 are strikingly similar and alludes to their existing competence does not include human factors, and re ects on the challenges of bringing this new experience home. He also expresses a desire to change his mindset:

> "For sure, we have di erent cultures. From the beginning, when you taught us human factors...We have little knowledge about this in Romania. If someone mentions human factors, it's supposed to be for civilian maintenance personnel. But when we arrived here and learned about the "dirty dozen" and human factors, we see that they are applying to us in Romania, we just aren't aware of them. We have all the problems which you describe in the course, but now we realize the importance of following certain principles, or bad things will happen. However, it's di cult because culture is a hard thing to change, but I do hope that I change my mindset a little."

CS3 also re ects on the culture and its e ect on training:

> "You have to have an enjoyable workspace and do things with pleasure...I think culture in uences these factors, how your colleagues treat you, or their mentality in general...the goal is to establish a culture where we are honest and help each other. I think the Norwegian culture is really good, and we can learn by example. For example, the military hierarchy is not that strong, and people treat each other as colleagues rather than subordinates. Another aspect is "Just Culture", where you always try to tell about your mistakes and not cover them. Another important factor is the modesty of the people here. I think in Romania, many people are lacking this quality, the modesty."

When a Romanian crew chief arrives at Kjevik, they bring with them their competence. This competence is likely not fully understood by their Norwegian instructors, because they do not know what it means to be a MiG-21 crew chief. The same applies to the Romanian who is experiencing the Norwegian crew chief community of practice. To want to become a competent F-16 crew chief, means to participate in the domain and seek to align with the practice, learn from it and participate in it. The more they engage in the community, the competence they acquire. The aforementioned statements clearly indicate that the students have found value and practices which they consider improvements over their own, and express a wish to adopt them. CS2 also re ects on the future challenges of trying to introduce these experiences in their own communities:

> "When we nish the course and go back to Romania, we will surely have problems in the beginning. We will have an internal struggle between the guys who learned it in Norway, and those who learned it at Borcea (using Portuguese/US procedures). I will try to do my duties in the Norwegian style, because I see your experience and you follow all the rules."

The instructors and manager provide some examples of the mindset and culture of Norwegian technicians: Instructor B talks about the importance of maintaining standards and a high degree of competence:

> "For us who deliver training, our desire is to deliver training in a good way. Then you have to attend courses, practical training, etc because ultimately you, yourself, are responsible for not doing something you are not quali ed for. If you have a management, or function within the organization, that manages your training and urges you to attend courses and improve your competence. That would be great."

A corresponding viewpoint is o ered from the manager:

Figure 5.2: A MiG-21 crew chief's journey through a new community of practice.

> "A major challenge among instructors, is to keep them updated in their profession. We used to have requirements for that, but that concept slowly faded away. If your course was task-oriented, you could maintain your skills. However, if you worked mostly with theory, then the practical skills slowly vanished. If you want relevant instructors, with relevant competence, there must be a connection between theory and practice. The instructors should perform the tasks."

This statement identi es two new stakeholder needs of delivering training in a good way, and to improve instructor competence.

The manager shares the connection between taking half-measures and the e ect on students attitudes.

> "The students are dependent on building a good, satisfactory attitude over time. The moment we start to "fake" things, or make assumptions, but do something opposite, then this also impacts the student's attitude. It makes them indi erent. The more you are able to be "to the point", or match the real task, and convey the importance of doing it the correct way, the better you will build a good attitude."

Instructor B also shared some insights into how he solves problems within his community of practice:

> "Sometimes the procedures or descriptions in the TO are not good. They are not exhaustive enough, or have poor depictions or schematics. Then you have to go beyond the TO. That's when experience, or competence comes in. Your own competence, as well as drawing from others. When we are going to teach our students how to go outside the book, we have to clarify how to do so. There is supporting documentation that can help you, as well as the competence within your community."

The aforementioned statement indicates how he seeks out competent people within his community, and in this way is learning through social interaction. This a part of aircraft maintenance training which is not clearly defined and explained in the existing course.

In this section, the concept of communities of practice and social learning are applied to the context of training. New stakeholder needs have emerged:

Students:

- Desire to align themselves with the culture and mindset.

Instructors:

- Deliver training in a good way;
- increase their competence.

Managers:

- Improve instructor competence.

The attitude and culture are important parts of aviation maintenance, and the students are introduced to this culture and seem to wish to embrace it. The instructors invite the students to be honest, modest and create a mindset with a focus on human factors and safety. In essence a part of the competence is to demonstrate good attitudes toward safety, to participate in a safety culture.

5.4 Safety and Human Factors

In the previous section, the importance of attitude and culture is discussed. Attitude, on the individual basis, greatly shape the decisions made while performing a job, but those decisions are also kept in check by the culture through peers. However, as some of the students already worried, is it simple to change a culture, even for the sake of improvement? This is arguably no simple task, especially if you are outnumbered, or outranked by peers. One of the crucial aspects of the Norwegian maintenance community of practice, is that safety holds top priority. It is encouraged by regulations, training, by management and culture to always prioritize safety. However, as a military organization, there is also a collective goal of completing the mission. After all, what point is there to maintaining fighter jets in the first place, if they are not going to be used to secure the sovereignty of our nation? The uniform binds everybody together, and there is a strong presence of "can-do" spirit.

In the RNoAF, rank plays a comparatively small role compared to other military branches, such as the army. The phrase "I say, you do", or "sir, yes sir" are commonly used to describe the mentality of strong military hierarchies. This mentality might work perfectly in combat when bullets are passing overhead, but it does not combine well with aircraft safety. If a pilot were to pull rank against a technician and order him to release the aircraft to service as soon as possible, it could place severe pressure on the technician and impact the quality of the work. In the RNoAF, among pilots and crew chiefs, there is a mutual understanding that the pilot merely "borrows" the aircraft from the crew chief. The aircraft is not exclusively the "pilot's business" until the crew chief has signalled it by salute. It is also common for pilots to thank the crew chief for borrowing the jet after the flight. It does not matter if the pilot is a lieutenant colonel and the crew chief a sergeant; there is a mutual understanding and respect for the colleague's job. And this definition of colleague in contrast to subordinate is described by CS3 in the previous section section.

In the aviation industry, safety and human factors are closely related. Human factors help model or conceptualize human behavior, relationships, and interactions to make people aware of symptoms before they materialize into incidents. As an example, in the previous paragraph the relationship between pilot and technician is described as mutually respectful. If it were opposite, that there is a strong sense of hierarchy, the relationship between pilot and crew chief might be based on the premise that "if the jet is not ready, the crew chief will be in big trouble". Things might look quite di erent. However, as long as there is an established safety culture which emphasizes human factors and just culture, it makes members of the organization, or community, cognizant of these issues and presents itself as a discussion topic.

There are some potentially dangerous experiences to draw from Romania, as noted by CS3:

> "Sometimes, if I found a problem with some system and the aircraft had to y on another sortie, my boss would tell me to let them y the sortie and we will x the problem the next day. I wasn't entirely okay with that attitude, but I had to comply because I didn't have the authority to change that decision, because of military rank...several times, I had to comply, but only when I thought the problem was not so big or dangerous."

The student describes not feeling comfortable with allowing a plane to y, and not being able to do anything about it due to being outranked. It is di cult to gauge the severity of the problem without the third party's comment, but CS3 still attributes the need to comply to being a subordinate. This is a good example where lack of assertiveness and pressure can play a role. The pressure is exerted by the relationship of military rank and to follow orders, and the lack of assertiveness means that the student is unable to express his concerns and compromises his own standards.

One student and instructor provide complementing experiences about a direct consequence of lack of resources. It is a suitable example for discussion. Instructor A and B explains the challenges of lack of personnel in section 5.2, stating that it's impossible to train without competent personnel, and sometimes personnel who lack competence can be brought in. Consider the following statement from CS1:

> "Basically we are here to train the Norwegian style of doing things. So having di erent ideas from one, two or maybe three instructors with di erent nationalities...I'm not saying they are not respecting the TOs, but having di erent procedures from di erent countries can lead us to confusion of which one is correct, or good to do. However, it may help us see di erent ways of doing the job, but regarding safety we will go with the Norwegian way in the end."

He is referring to one of the challenges of multiple communities of practice. It is possible to have the same aircraft and do tasks di erently. Tasks are even performed di erently within the same nation, depending on squadron or base such as between Bodø and Ørland main air station. In this example, he is saying that he is confused about which procedure to follow, depending on who is instructing. The situation develops to the following statement, with a new experience from CS1:

> "It's very important to know the safety zones and know how to work safe on the plane. The engine inlet; I personally had some issues with this because on one of the assessments, we were simulating launch procedures. I assumed that the hazard zone for the inlet was somewhere beginning from the inlet and extending forward. But the TO says that it has to be another few inches aft of the inlet. So I moved in front of the external fuel tank which is not a safe zone. But for me, I thought that it was okay."

The student knows about the safety hazard, but is unsure about its exact extent. He makes an assumption that it is okay and proceeds to walk between the tip of an external fuel tank, and the engine inlet. This is not a violation of any formal rules, and most other F-16 operators do this, but there is a Norwegian norm, due to local conditions, that we avoid this action due to ice conditions in the winter. The Norwegian norm also expects the same behavior in good conditions, with the intention of standardization and minimizing room for confusion and error. The nal piece of this chain of events is to examine the answer of CS1 in response to if he had faced issues with lack of skills:

> "We worked as crew chiefs on the MiG-21, so it's not like we are doing this for the rst time. I think the skills you need for this job, are almost the same as the skills we had on the MiG-21."

Here, he is saying he thinks that the skills needed on the F-16 are almost the same as on the MiG-21. That is likely correct. Mechanical skills, knowing how to use tools, working with fuel, weapons, inspections, much of which likely similar. However, the most dangerous area on an F-16 is arguably the air intake. On the MiG-21, the air intake is shaped so that people can not be ingested, while on the F-16 the intake poses a lethal risk. A person with a long career on the MiG-21, might have established a di erent attitude towards an air intake, than someone who are less experienced, or used to a di erent aircraft type.

This serves as an excellent point to chain together events that eventually lead to what could have been a fatal accident in a real situation. Starting from the beginning, there is a lack of personnel among the instructors. Not many Norwegian F-16 crew chiefs remain in service, as the aircraft o cially stopped operating years ago. Personnel have converted to new aircraft types, retired or found civilian work, and even among them it is not granted that they would want to teach. To meet the minimum required amount of instructors and avoid shutting down the training, experienced crew chiefs from other bases or nations are contracted to assist in practical training. Due to di erences in local procedures, students may receive slightly di erent answers depending on who they ask. When these answers relate to hazard zones, there should be no room for assumptions or doubt, yet the student remembers incorrectly according to Norwegian safety norms. What makes this situation interesting, is all the layers of issues that could have prevented this "incident". Starting at the top level, there is a lack of personnel, and a responsibility of the management to nd competent instructor. The instructor may be competent and exhibit excellent attitudes, but coming from a di erent community of practice may include di erent ways to do things. Mapping di erences and adjusting them to align procedures could minimize chances of multiple "truths" of how tasks and procedures are done. In turn, this minimizes the chance of students having to contend with multiple versions of how to do a task. Finally, once the student becomes aware that there is uncertainty, especially regarding safety, always ask.

To contrast CS1, CS3 has an opposite perspective on the issue of lack of skills:

> "I have experienced a few times when my lack of skills showed up. I had to ask an instructor or colleague to help me. My other colleagues have more experience than me by working as crew chiefs on the MiG-21s."

A lack of skills is not necessarily a problem, if one is aware of it and can implement counter-measures such as asking for help. It becomes an issue if one ignores it, or feels obliged to do the task due to other factors such as pressure or lack of assertiveness. CS2 shares the same outlook with respect to lack of knowledge:

> "You know, you're not supposed to learn everything on the F-16 by heart. If you have a problem, you should go research the manual or ask somebody."

And while that is a good attitude, the purpose of asking somebody is to get support, eliminate doubt and establish what is correct. There is a concerning re ection shared by CS2 regarding the quality assurance in Romania in response to if there are any known "safety nets" to compensate for a lack of training when they return to Romania:

> "We have the quality assurance, but you know, they are supposed to control me, yet they have not attended the course here (in Norway). That's a problem. They remain in the same system as we used with the MiGs, but being in quality assurance is considered a reward. They earn a lot of money, and it's not the best or most experienced people with knowledge that get those jobs. They only attend a short course at Borcea and when they come back, they are a "quality assurance man". Maybe we have a problem here. Maybe it will change in the future. The MiG system, is not a good system for us."

It is not currently possible to verify this speci c problem, but it is not unthinkable that when the Romanian maintenance organization transitions from MiG-21s to F-16s, the community of practice surrounding the MiG-21s faces considerable challenges to adapt. The F-16 is not

Student	Instructor	Manager
More practice with working engine	Deliver training in a good way	Improve instructor competence
Desire to align values	increase competence	-

Table 5.1: Identified stakeholders and needs.

merely a new aircraft that can be "dropped" in place of the MiG-21. The F-16 is of US, design, while the MiG-21 is originally Soviet. There is likely a substantial amount of norms, best practices and other elements of the community of practice that must be discarded to avoid violation of standard procedures and TOs. Implementing new aircraft is also a vulnerable period, where the whole organization must learn and adapt to its peculiarities. Despite having high thoughts about the Norwegian safety culture, the RNoAF has lost a C-130J Super Hercules, and an AW-101 Search And Rescue helicopter and the Helge Ingstad frigate shortly after introducing them.

The topic of Safety and Human factors bring emphasize that it is not only important to have the correct knowledge and skills, but also a safety-oriented attitude. When knowledge or skills fall short, technicians must be aware, but also demonstrate their attitudes through the corrective actions.

A complex system, ranging from the individual tasks and decisions made, to the greater picture of how different communities of practice interact is taking shape. It appears that flight line safety starts in course preparation and analysis, and reaches far into the future operations of the Romanian air force. There are several stakeholders involved with different needs and priorities. However, the fact remains that there is currently no indication that Kjevik will receive operational engines and the ability to perform extensive training in realistic conditions. Without changes with respect to prioritizing training, improvements must be found in different areas or innovation. This is the topic of the next section.

5.5 Improvements and technology

The final section seeks to gather input and preferences from the initial stakeholder groups as to what can be done to minimize the effects of lack of resources. Students, instructors and the manager were asked to come up with their own solutions to the resource problem, consider various technologies and reflect on the opportunities of these technologies. The suggestions serve as important pointers toward which type of technical solution solves the needs of the users and stakeholders. Its significance is already apparent in the possible fallout of leaving the lack of resources unchecked. To start off it is sensible to list the initial stakeholder groups and their needs, as can be seen in table 5.1.

These needs or goals help specify the context of use for a future design or solution, but first this section will summarize the suggestions from the respondents.

Starting with what is an obvious lack of resource, the operational engine to practice launch and recovery, CS2 summarizes:

> "For me, it's only one problem; we are not able to do some steps in training, like they should in real life...for example, to start an engine on the aircraft. It's hard to do something about it, because we don't have an F-16 that is able to fly. And that's very hard to do, it doesn't rely on just one person - it's a whole system that must be in place. Maybe you could manage the problem with a simulator, but in my experience, all those solutions are good, but they can not compare to real life. It's different when you practice launch and recovery, and the control surfaces move, but the engine does not operate."

The core of the problem is laid out clearly. The ideal situation for the student is to have access to the full capabilities of an F-16, including engine start, but there is an acknowledgement that this is no simple feat. It requires not only the engine and jet itself, it does also require fuel, lubricants, frequent maintenance, inspections, storage facilities, qualified personnel, risk assessment and many other factors to be accounted for. It is also stated that the simulation method is not satisfactory as a replacement, but with the support of other students who participated in the research, is acceptable as a preparation for the real situation.

He continues to describe what type of simulator he would prefer to use, and why:

> "You taught me how to operate the engine in the engine start simulator, which was great because it transformed me. All the buttons, and interfaces they were an exact copy of the real thing, but not virtual. Just physical. All the buttons and panels in the exact spot, and I could manage to do the same things as in the real cockpit. If it was only a digital simulator, I would not like it. But, maybe it could be a hybrid, a mix between virtual and physical, so you don't only hear the engine but can see things as well as touch and move physical things."

What he is referring to here is an Engine Start Simulator (EST) at Kjevik. It is a professionally built replica of the F-16 cockpit with all engine-related switches, indicators and controls available. The engine itself is virtual, simulated on a computer. Depending on the trainee's actions, the computer registers the operation of controls in the cockpit and displays the corresponding system logic on the relevant indicators. This simulator also features a fault-database with the most typical engine malfunctions, so trainees can practice emergency situations. It is possible to follow the aircraft manual step by step to perform engine related procedures. The next example he provides is a hybrid, being able to not only hear, but see and touch physical things as well, implying a mixed reality solution.

CS1 shares some similar thoughts about which factors are the most important in a technical solution:

> "I think that sensing and feeling are the most important things. Putting together hearing, seeing, feeling, all these senses should work together to simulate and create a more realistic training for future operations of launch and recovery. The problem with virtual reality is that you can see it, but not feel it. The feeling of vibrations, hot air being blown around, it's very hard to simulate. Maybe one of the best technologies to improve launch and recovery is haptic feedback. So that when you approach the plane, you recognize the sensation of being in a certain position around the plane."

To CS1, the multiple sensory inputs is important. The use of more senses could increase the immersion, or feeling of being in the virtual world, which is important if trying to convince someone that what they are experiencing is close to reality. The use of haptic feedback could replicate vibrations for sound, or sense of touch, but there are probably challenges to creating burn-inducing air temperatures in high-pressure blasts. Haptic feedback must not necessarily mimic the real sensations for it to have a useful effect, it could also serve as a warning device to alert the user of a dangerous condition, such as walking too close to the intake. He also suggests a device that can visualize hazard zones:

> "mark the hazard zones on the plane and the ground, to visualize it so you can have a mental model, or image in your head. It takes time to establish this, so maybe this image remains when we go back to Romania."

This feature could be implemented in numerous ways in different types of media. From advanced Augmented Reality glasses that overlay the hazard zones in real-time as the user moves around the jet, to simply marking the ground with tape or paint. Several air forces already use the latter method on the flight line.

CS3 suggests using video:

> "Maybe a simulator would be great, and make the first part of the training easier, but a much simpler solution would be watching videos of launch and recovery procedures, and analyzing the steps from the video in a list. Then you can compare and discuss. You don't need a lot of resources to accomplish this, and it's really helpful. Just like watching a video on YouTube of how to fix your car. You watch the video, then go repeat the steps."

This approach is likely to be one of the simplest, yet most useful suggestions to teaching the procedures. A video can show exactly what is needed to show to perform the job, and visualizes the process. Depending on the editing, videos can show multiple perspectives simultaneously, and use other aids such as 3D rendering or other visual e ects. The idea of using the video to analyze the steps and compare/discuss also promotes deeper learning and social interaction. As he indirectly points out, video is already highly accessible to most people who own a smartphone through til YouTube. The manager shares this perspective, and adds the following:

> "It could be arranged in a format so the technician can have it on a mobile device, in their pocket. Of course, you could make advanced Augmented Reality solutions, but how great is the e ect compared to a video? I have my doubts about that."

Augmented Reality is commonly mentioned, but obviously highly complex compared to video. Videos also playback on almost any device, making it suitable for mobile learning opportunities.

Instructor A suggest a di erent alternative using desktop computer:

> "While sitting at a desktop computer, like the TTP, but you could develop something similar to a game, where you control a person around the aircraft using the mouse and keyboard."

This is a quite familiar concept as rst-person view games using keyboard and mouse have been around for decades. Computers are also readily available in many formats.

Instructor B gives a more general answer, which carries importance:

> "If you want good learning outcomes from a course, then you have to be motivated. A student's motivation is largely in uenced by the competence of the instructor, but that on its own is not enough. You could have an excellent instructor, but if you are bored from sitting in the classroom all day, or just repeating things on the ight line, then other methods help. As an example, the Romanians were given tablets today, instead of the bulky laptops. Just the fact that they had a new device to use, which was more practical to use in the hangar than a laptop, helped a lot. It was something new and exciting."

The point being made is that the more tools and methods that are available to use, the less likely students are to become bored of the same learning activities. Several respondents add that simulators o er the opportunity to practice special events and emergencies, or test how a student may perform without any real-life safety hazards. These situations may prepare people for real life emergencies.

The manager closes this section with a nal Augmented-Reality based "ultimate dream" vision:

> "With Augmented Reality, the trainee could see text, warnings and hazard zones overlayed the real aircraft. But the ultimate dream is to have a service where an experienced supervisor can connect and support the trainee, interacting with what he sees and hears in the AR device. This makes support less dependent on time and location. Instead of having 20 supervisors spread across 20 trainees, you could have one supervisor connect remotely on request, correcting tasks, providing guidance. That would be optimal."

By wearing an Augmented Reality device, the trainee can visualize the hazard areas and zones as they move around the aircraft. But the idea of having a communication service, allowing a trainee and supervisor to connect and discuss is an interesting concept. This method is quite similar to how real life supervision is carried out during on-the-job training, except that the supervisor is not physically present. If combined with video feed, and an interface for the supervisor it could serve as a video-chat service where the supervisor might point or draw the trainee's attention to something that is visible to both users. With this solution, a supervisor could connect with trainees on-demand as they encounter problems, much like a tech-support function. Depending on the technology used, such a system could allow remote assistance from across the world.

Regardless of technology chosen, these suggestions form useful pointers toward which kind of initial prototypes and suggestions should be fronted in the next step of a HCD process.

The following technical solutions are fronted by the stakeholders:

Desktop

- First-person.
- Mouse and keyboard.
- Move around aircraft.

VR

- Hands-on, touch important.
- Combination with physical items.
- Visualization of hazard zones.
- Sound, vibration, wind.

AR

- Visualization of hazard zones.
- Connected to supervisor.
- Support with ability to display cues and text on trainee's device.
- Remote assistance.

Haptic

- All sensory feedback important.

Video

- Simple, yet e ective.
- Shows the procedures.
- Can be analyzed and discussed.
- Mobile format.

Chapter 6

Conclusions

In this chapter, I present the project summary, answer the research questions, present the main ndings and suggest further research.

6.1 Project summary

The research project set out to identify areas of F-16 crew chief training that are su ering from a lack of resources. Based on feedback from the rst course, a rough idea was formed suggesting that the most critical problem for F-16 crew chief trainees, was the lack of an operational aircraft. However, the feedback was quite thin and not exhaustive enough to be certain. In anticipation of developing a technical solution to ll the gaps created by lack of resources, the main method chosen was Human-Centered Design. The method places the users at center of research, design, development and evaluation with the overarching goal of e ciently establishing the design requirements through frequent iterations and user evaluations. To capture the wide array of users, scenarios, contexts and other variables, HCD encourages the use of a multidisciplinary team to acquire a deep understanding of the users, tasks and environments. Provided that the immediate users and stakeholders were the students, teachers and managers of the education organization, the research takes aim in understanding their needs. Given the context of technical training in the aviation industry, human factors, F-16 subject domain expertise and learning theories were applied. Human factors is renown in several industries, but it remains the rst concept people tend to think of when safety is mentioned within aviation. The training needs analysis and syllabus are anchored in Bloom's taxonomy, therefore learning theories from a di erent school of thought were included to challenge the existing ways of establishing knowledge levels.

From there, the method of collecting empirical data was chosen. The focus of the research is on the F-16 crew chief training, and considering the small group of students, qualitative data collection methods were chosen, which ts well into the principles of HCD. An initial electronic questionnaire was distributed to collect data from the rst class, who at the time had been working on the F-16s in Romania for approximately 3 months. These respondents had a unique advantage of having completed the rst course, and experienced the e ectiveness or lack thereof. The feedback from this questionnaire was analyzed and used to identify the lack of a working engine as a main call for improvement. This has to do with the launch and recoveryprocedure training, and hence this became the main target of the study. The launch and recovery procedures were tting to study in the detail because the procedures involve high-risk environments and requires utmost attention to safety. A qualitative interview process started where the students, teachers and manager were asked about their experiences from training related to lack of resources, use of compromises or exceptions, implications towards safety and attitude, and nally suggestions to improve the current training with a focus on technology.

The data from the interview was then processed, analyzed and ordered into the main themes and categories: training and resources, attitude and culture, safety and human factors, and suggestions and innovation. Experiences and thoughts from the students teachers and managers were compared and discussed against each other and the key theories. As the data was examined, effort was placed into identifying stakeholders, their needs and goals, as well as noting suggestions.

The research revealed that there were unsatisfactory conditions related to the existing Training Needs Analysis and psychomotoric abilities from Bloom's taxonomy. Considering the nature of the F-16s Technical Orders (TOs), it was deemed to be impossible to satisfy the intended learning outcomes under the existing circumstances with lack of resources. Furthermore, the intended learning outcomes did not account for the Romanian air force's local launch and recovery procedure adaption, suggesting the training towards memorizing the mismatching procedure will simply require to relearn it after the course. The intended learning outcomes were also found to fail at capturing the complete set of abilities needed to perform the procedures, particularly related to attitude. The learning quality was found to be deemed satisfactory by the students, despite the lack of resources, whereas the instructors held a more critical view.

The consequences of training with a lack of resources were found to have implications for the students' and teachers' attitude toward the training. Without the sufficient resources, there appears to be a tendency to make exceptions to procedures in the TO, or by use of alternative methods. With careful guidance and support in additional documentation, a safety-oriented attitude may be maintained. However, with a relaxed attitude toward doing things correctly or by the book, the motivation of instructors is impaired, and the students fear developing the wrong mindset which could lead to less emphasis on following the procedures. As different instructors with multiple backgrounds and nationalities participate in training, the various norms within each culture become an element of confusion for some students. The concept of communities of practice can help identify such communities and their characteristics, and illustrate how they can benefit from each other by challenging their existing competences with new experiences.

The effects of training with exceptions may lead to adverse impressions of how important certain tasks are or not. An established community of practice could accommodate individuals who face problems when technical documentation or uncommon events lead to uncertainty. Some indications reveal that there may be a considerable discrepancy between the Romanian maintenance organization and the Norwegian one, especially related to a stricter military hierarchy and absent competence within human factors and just culture. The research also indicates that the attitude, knowledge and skills of the future Romanian crew chief are shaped at the moment they enroll at Kjevik, with several students claiming that human factors remains the most important subject they have been taught during their stay. This prompts a closer look into which technologies may be desired by the stakeholder of the F-16 crew chief course.

As a preliminary research for what should later become a full-fledged design effort, the stakeholder were questioned about how to minimize the effects of lack of training using technology. Several proposals were made, and the initial user needs and goals were identified. Suggestions from the respondents have identified different digital media that can mitigate the lack of resources. These suggestions range from haptic feedback devices to instructional videos and augmented reality with visualization of hazard areas. Notably, there is a suggestion to establish a remote-assistance technology, which connects trainees and supervisors regardless of location. A connected technology may establish communication channels between communities of practice, and ensure mutually beneficial competence development. These suggestions, together with the study of Human-Centered Design principles, subject domain theory, human factors and learning theory combine to form a foundation upon which to develop future solutions for training. As an unexpected result of the research, Human-Centered Design principles were found be useful in the context of course development, speci cally noting the development of a Training Needs Analysis.

6.2 Research questions

The following subsections brie y answers the research questions.

6.2.1 How can the quality and safety of ight line personnel training be maintained in the event that there is a lack of resources?

Lack of resources have major implications to the quality and safety of ight line personnel training, depending on how critical the task is, and how di cult it is to perform without making exceptions. The results of this study indicate that it is possible to maintain quality and safety by adjusting the intended learning outcomes to match the level of training that the current resources permit. Furthermore, the training should not be strictly task-oriented, but actively seek to incorporate and foster development of safety-oriented attitudes which form an inherent safety net within every technician.

6.2.2 How does training without all the required resources a ect the safety of both aircraft and personnel?

Training without the required resources e ect the motivation of instructors and students. Lack of personnel among instructors may lead to reshu ing schedules or inabilities to carry out scheduled training tasks. Tasks a ected by a lack of resources may lead to use of exceptions for the sake of course progression at the expense of the instructors' and students' attitudes. The consequences of poor attitudes may not manifest immediately, but remain as latent issues until the students are working independently in an air force that is currently implementing a new ghter jet system.

6.2.3 What e ects are there of exceptions during training, and how do they a ect the attitude towards the task?

The exceptions were shown to create situations which may appear confusing to students, and in some occasions invoke the sense of indi erence. Students placed a strong focus on the importance of having access to operational aircraft and engines to accurately create the conditions that spark motivation and focus. When faced with tasks that do not follow TO or procedure, students struggle to distinguish which tasks are accommodated by local norms, and which are a result of neglect. The results of training with use of exceptions is that students are likely to develop incorrect attitudes to maintain safety.

6.2.4 Which solutions may be recommended to improve training of ight line personnel and minimize the risks?

The users and stakeholders who participated revealed several suggestions to technologies which may improve the training. Technologies which allow recreation of virtual and haptic elements such as noise, vibration, and heat, with elements of real world interaction were promoted as desirable. Cost-e ective alternatives such as instructional videos, which may be analysed and discussed may foster social learning and provide an arena for growth of human factors competence. An Augmented-Reality based remote-assistant solution could allow supervisors to support trainees regardless of location. Whatever the solution, it is important to o er a variety of tools which cater to di erent preferences and users. The important factor is that the solution keeps students and teachers engaged, building their community of practice in which to form the attitudes and safety culture that will ensure continued safe operations, regardless of mission demands.

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Chapter 7

Appendices

Appendix A

Launch and Recovery Survey

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7YFNIGX SJ XLI GSZIV] XIEQ SVMIRXEXMSR

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8LI WYFNIGX SJ XLI GSZIV] XIEQ
-J MX SR XLI WYFNIGX SJ XLI GSZIV] XIEQ

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-QKMZWRYJJMJGIMHIFEKGRKYMHEJRYGSXQLMRWXWYGXSV

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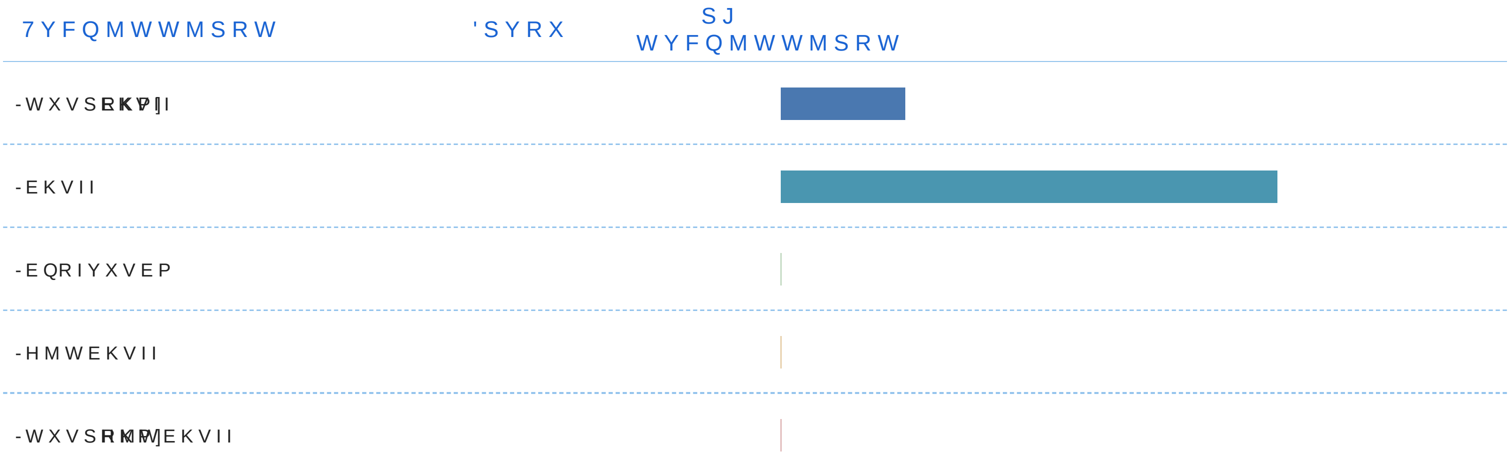

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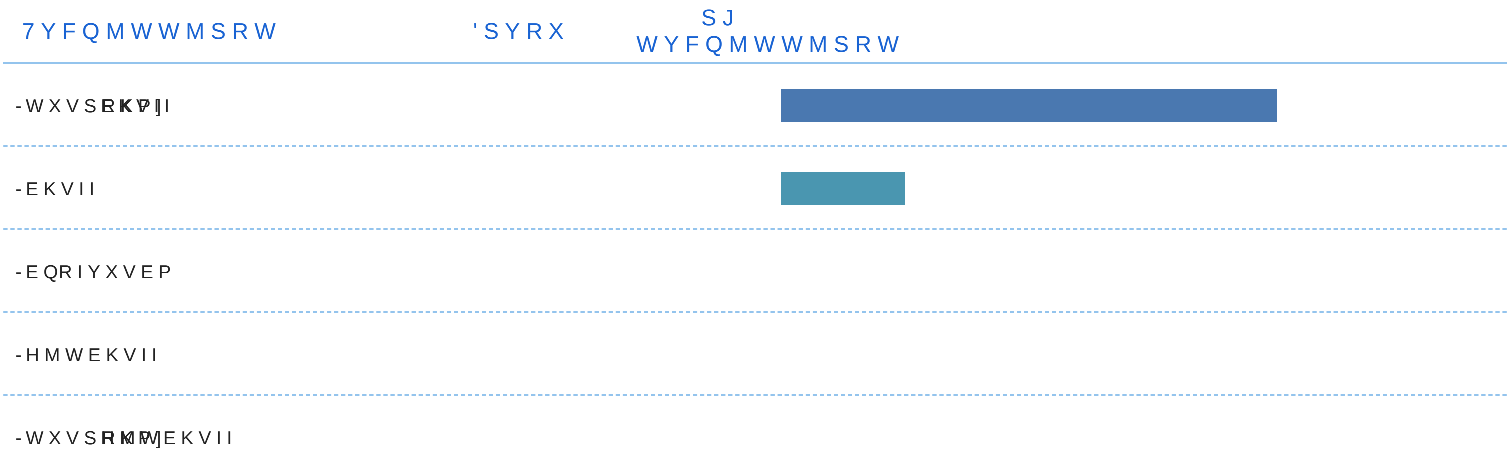

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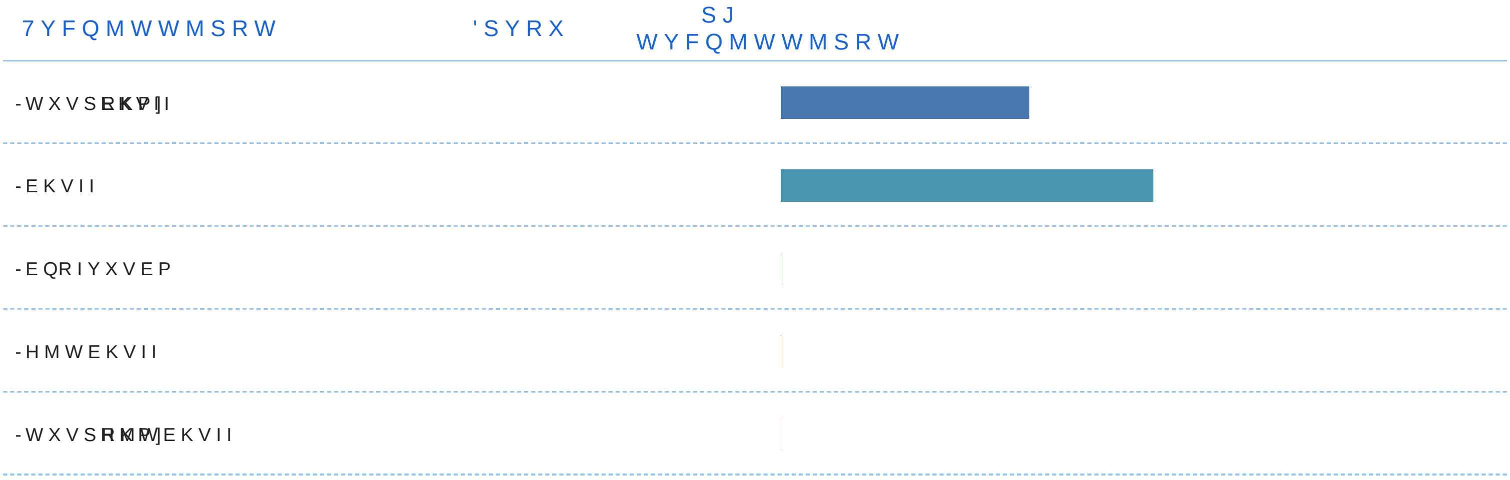

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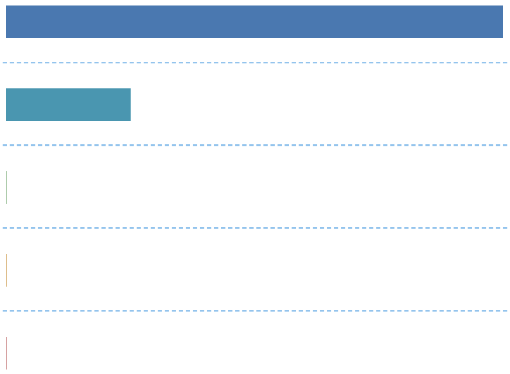

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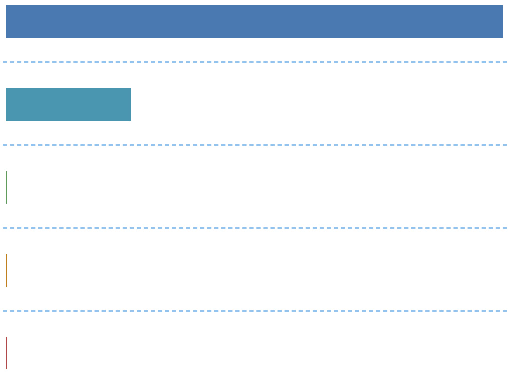

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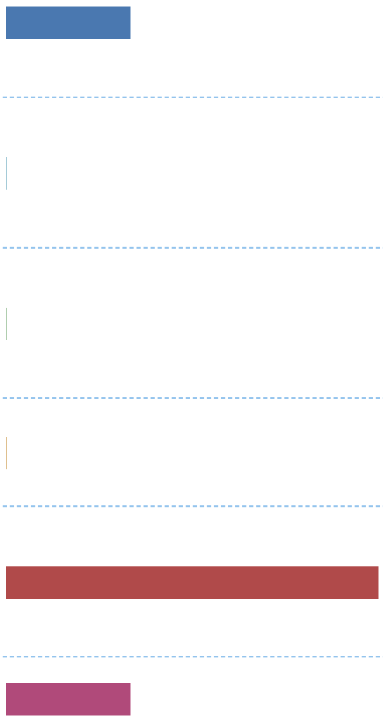

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Appendix B

Interview guide

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