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THEME

Digitizing Weight and Balance charts for the Agusta-Westland 139 Helicopter

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ABSTRACT

This manuscript proposes a computational approach for digitizing weight and balance charts for the AW139 helicopter, a vital asset within the Algerian Air Group of Civil Protection. this technique allows the Air Group to gain an enormous time advantage as a result of the deliberate adoption of this unique strategy, understanding the critical need of quick response in life-saving initiatives. By seamlessly transitioning to digital charts, the procedures for weight and balance are smoothly simplified an automated, ushering in a new era of operational efficiency and enabling speedy decision-making.

Key words: helicopter weighing, weight and balance, digitization, aeronautical procedures digitization, operational efficiency, data processing.

Résumé

Ce mémoire propose une approche informatique pour la numérisation des tableaux de poids et de centrage destinés à l'hélicoptère AW139, une ressource essentielle au sein du Groupement aérien de la Protection Civile algérienne. Cette technique permet au Groupe aérien de bénéficier d'un avantage de temps considérable grâce à l'adoption délibérée de cette stratégie unique, en comprenant l'importance cruciale d'une réponse rapide dans les initiatives de sauvetage. En passant sans heurts aux tableaux numériques, les procédures de poids et de centrage sont simplifiées et automatisées, ouvrant ainsi une nouvelle ère d'efficacité opérationnelle et permettant une prise de décision rapide.

Mots clés : pesée d'hélicoptère, masse et centrage, numérisation, numérisation des procédures aéronautiques, efficacité opérationnelle, traitement des données.

ملخص

تقدم هذه المذكرة المقترحة نهجًا حسابيًا لتحويل جداول الوزن والرسوم البيانية لمروحية أو139، والتي تُعد ركيزة حيوية ضمن مروحيات المجموعة الجوية الجزائرية للحماية المدنية. تهدف هذه التقنية المبتكرة إلى منح المجموعة الجوية ميزة زمنية هائلة نتيجة تبنيها لاستراتيجية فريدة، مدركةً تمامًا الحاجة الحاسمة للاستجابة السريعة في جهود إنقاذ الأرواح وإتمام مختلف المهمات. من خلال التحول السلس إلى الرسوم البيانية الرقمية، يتم تبسيط وتوحيد إجراءات الوزن والتوازن بشكلٍ آلي، مما يفتح الباب أمام عصر جديد من الكفاءة التشغيلية ويمكّن اتخاذ القرارات السريعة والفعالة. هذه الطريقة المبتكرة تحقق تقدمًا هامًا في مجال الطيران، حيث تعزز معايير التميز وتضمن السلامة القصوى وحماية المجتمعات خلال المهام الحرجة.

الكلمات المفتاحية: وزن الهليكوبتر، الوزن والتوازن، الرقمنة، رقمنة إجراءات الطيران، الكفاءة التشغيلية، معالجة البيانات.

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Thank you all for your invaluable contributions and for being a part of my academic journey,

« Last but not least, I wanna thank me

I wanna thank me for believing in me

I wanna thank me for doing all this hard work

I wanna thank me for, for never quitting

I wanna thank me for just being me at all times »

Alem Anissa Fairouz.

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Kabouche Abdallah Mohamed Karim.

DEDICATIONS

To Myself Fairouz,

Throughout the tapestry of my life, I have been both the artist and the masterpiece. With every step taken, every obstacle overcome, and every triumph celebrated, I have become the embodiment of resilience and determination; the path I have chosen has not always been easy. I have faced moments of doubt, when the weight of the world threatened to crush my spirit, I refused to yield, I embraced the challenges, knowing that they were the crucibles that forged my character, sharpened my skills, and propelled me towards greatness. I pause to acknowledge the extraordinary journey I have embarked upon the path of self-discovery, growth, and relentless pursuit of my dreams. I dedicate these words to honor the unwavering spirit that resides within me and to celebrate the profound impact of my studies and hard work.

To My Parents,

Words cannot adequately express the depths of my gratitude towards both of you. Your unwavering support and unconditional love have been my guiding light. Your constant encouragement and belief in me have fueled my determination to succeed. I am forever grateful for the sacrifices you have made and the endless love you have showered upon me. Thank you for being my rock !

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Alem Anissa Fairouz

DEDICATIONS

To Myself, karim

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1

INTRODUCTION

In today's fast-paced world, where every passing second can be a matter of preserving lives in the balance, the utilization of time becomes paramount, especially in airborne emergency services. The Algerian Civil Protection Air Group, a vital entity safeguarding communities during natural disasters and emergencies, plays a central role in ensuring the safety and protection of countless lives. However, the current methodology used in determining weight and balance for the AGUSTA-WESTLAND AW139 helicopter, through the utilization of traditional paper-based Charts, poses challenges that can result in significant delays during urgent missions, such as firefighting or medical evacuations.

One particular area where these delays are especially pronounced is during helicopter missions that involve equipment configuration changes based on the type of the mission. The Algerian Civil Protection Air Group must adapt the AW139 helicopter's equipment to suit the specific requirements of different emergency scenarios, such as firefighting, medical evacuations, or search and rescue missions. However, the reliance on paper-based weight and balance charts exacerbates the complexities of these equipment changes. Therefore, a more methodical and accurate approach to weight and balance analysis is necessary to expedite strategic decision processes and optimize emergency response efforts.

Driven by a relentless pursuit of innovation, we embarked on a profound mission to explore the existing landscape of weight and balance analysis for the AGUSTA-WESTLAND AW139 helicopter within the esteemed Algerian Civil Protection Air Group. However, our exhaustive search revealed an intriguing void: no prior work had been undertaken in this specific area. The magnitude of this realization filled us with a profound sense of exhilaration and pride, as we realized that we were the first students given the honor of starting this revolutionary initiative.

To tackle this pressing challenge head-on, our aim is to develop a comprehensive programmatic approach for digitizing weight and balance charts, referred as Chart B, Chart C, and Chart C for the AW139 helicopter. By leveraging advanced computational methods, specifically through the use of Python, we aim to transform the manual analysis process into a streamlined and efficient digital solution. This approach will enable operators within the Civil Protection Air Group to swiftly determine the center of gravity, facilitating timely decision-making and improving the overall mission effectiveness of the AW139 helicopter.

We will thoroughly analyze and evaluate the existing weight and balance charts to gain a deep understanding of their strengths and limitations. This analysis will serve as a foundation for identifying areas that require optimization. Based on the insights gathered, we will proceed to design a cutting-edge computational approach. This approach will employ innovative methods to enhance the digitization process specifically utilizing the capabilities and adaptability of the Python programming language, to augment the existing charts.

Furthermore, our computational approach will enable us to generate graphical representations of the center of gravity, providing visual insights into the aircraft's balance. This graphical representation will serve as a valuable resource for operators, enabling them to make timely and well-informed decisions, especially in urgent and critical scenarios.

This manuscript encompasses four chapters, each introduced with clarity and purpose as follows:

In Chapter 1, we examine two distinct parts that form the foundation of our exploration. The first part centers around the introduction and comprehensive overview of the esteemed Civil Protection Air Group. In the second part, our focus shifts to the AW139 helicopter, where we unravel its intricate features, capabilities, and attributes.

In Chapter 2, our primary objective is to provide readers with a solid foundation of knowledge by defining key concepts related to weight and balance analysis. Through concise explanations and illustrative examples, we aim to foster a comprehensive understanding of the terminology used in this field. By clarifying these fundamental concepts, we enable readers to navigate the subject matter effectively, facilitating enhanced comprehension and communication throughout their exploration of weight and balance procedures.

Building upon the foundational knowledge established in chapter 2, chapter 3 looks into the weighing procedure technique, weighing instruments, and real chart computations. It gives practical insights into precisely measuring the weight and balance of the AW139 helicopter. This chapter examines the fundamental instruments used in the weighing process and displays the actual application of real charts for exact calculations.

Chapter 4 unveils the integration of Python programming as a transformative tool in digitizing weight and balance processes for the AW139 helicopter. Our focus centers around the development of a computational approach that incorporates three key charts: the Helicopter Weighing Record (Chart B), Basic Weight and Balance Record (Chart C), and Weight and Balance Computation Form (Chart E) to ultimately display the center of gravity in a graphical representation.

At the end of this manuscript, a compelling conclusion awaits, summarizing the crux of our research: the key findings, insightful perspectives, and profound implications. As we look beyond the confines of this manuscript, we are eager to witness the doors of progress swing open, revealing pathways to future advancements and innovative possibilities in this field.

2

CIVIL PROTECTION AIR GROUP PRESENTATION AND AGUSTA-WESTLAND AW139 HELICOPTER OVERVIEW

This chapter contains two parts. In the first part, we will present the unit of Civil Protection Air Group. The second part focuses on the presentation of the AGUSTA-WESTLAND AW139 helicopter.

Contents

2.1 Introduction

The Algerian Civil Protection is an emergency service resulted from the executive decree n° 64-129. This service deals with saving the lives of humans and animals. The Civil Protection headquarter has seen significant growth due to the implementation of new technologies and personnel training.

In order to effectively execute its duties and reduce intervention delays, the Algerian Civil Protection has been bolstered by an aerial fleet. Hence the creation of the Civil Protection Air Group which is specialized in reconnaissance, rescue, emergency evacuation and the fight against forest fires.

In this chapter, we will present the missions, the structure and the different responsibilities of the departments of the Civil Protection Air Group. Also, we will talk about fleets of the Air Group, specifically the AGUSA-WESTLAND AW139 Helicopter which will be detailed later.

2.2 Civil Protection Air Group Presentation

2.2.1 Creation and headquarter of the Civil Protection Air Group

The Civil Protection Air Group CPAG is resulted from the executive decree No. 12-70 of 19 Rabie El Aouel 1433 corresponding to the 12th of February 2012. Its infrastructure is set at the airport of Algiers « Houari Boumediene » in Dar El-Beida. But CPAG, and it also has several advanced bases such as those in Tikjda and Medea. [7]

Figure 2.1: The Civil Protection Air Group hangar

2.2.2 The missions of the Civil Protection Air Group

The Air Group carries out a mission of prevention and aerial intervention for the protection of the population, property, and the environment, under the rules and procedures in effect. Thus, it is in charge of:

- Providing an emergency medical service for primary air evacuations from the scene of a disaster to appropriate medical facilities;

Figure 2.2: Emergency medical service for primary air evacuations

- Firefighting;
- Rescuing in dangerous and difficult access areas;
- Conducting recces of disaster areas for damage assessment purposes, to engage the appropriate intervention means;
- Ensuring the provision of supplies to the populations in the disaster areas;
- Transporting rescue teams and specific civil protection equipment to disaster areas;
- To participate in the surveillance of forest areas and firefighting actions

Figure 2.3: Firefighting Operations

2.2.3 The structure of the Civil Protection Air Group

2.2.3.1 General organization chart of the Civil Protection Air Group

The general structure of the Civil Protection Air Group is given by Figure 2.4 **[6]**. Several departments are defined whose responsibilities are mentioned in paragraph 2.2.4.

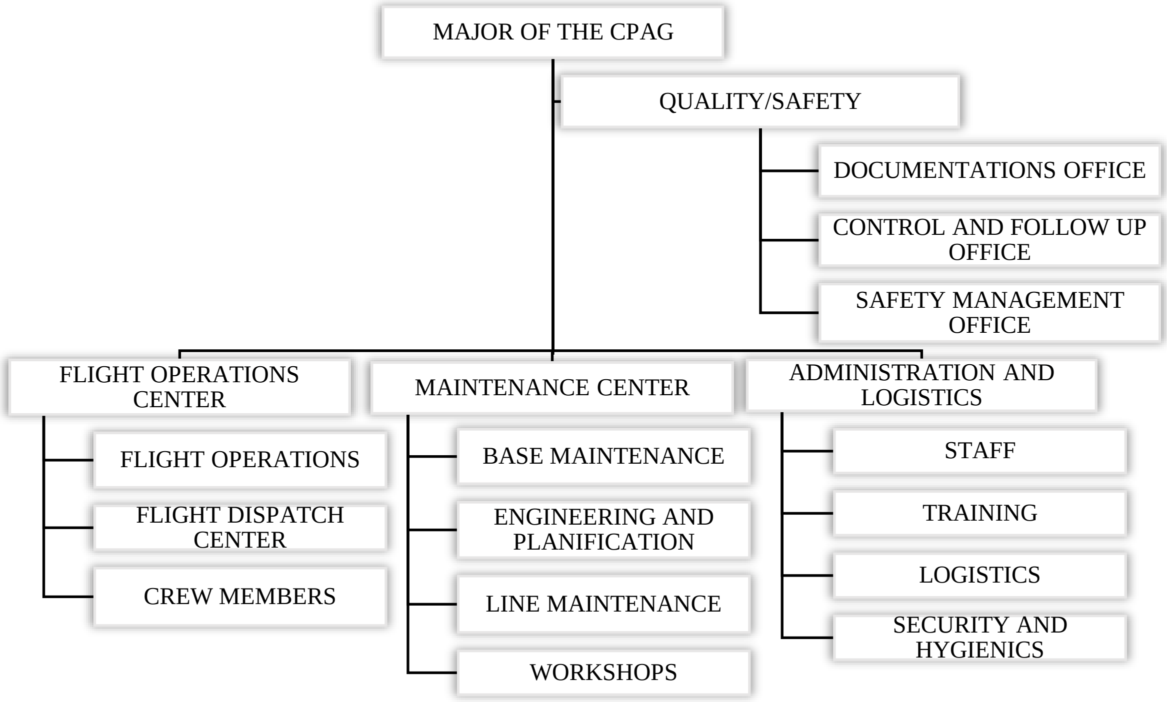


Figure 2.4: Organization chart of CPAG

2.2.3.2 General organization chart of regional units

The CPAG has regional air rescue units in Saïda, Oum El Bouaghi, Boughezoul and Ouargla of the structure given by Figure 2.5 **[6]**, below.

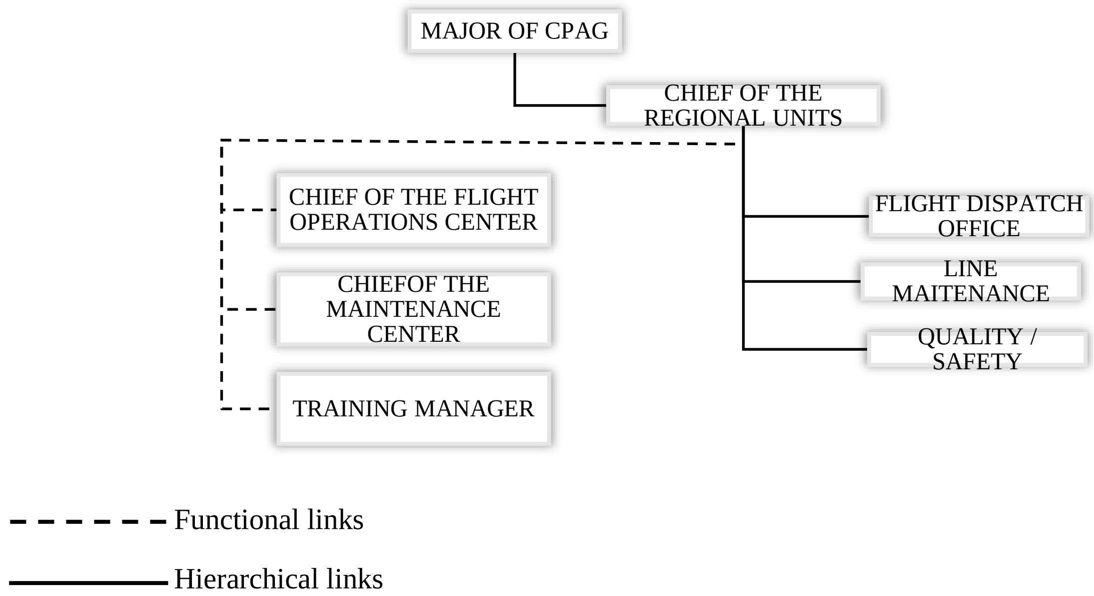


Figure 2.5: Organization chart of CPAG regional units

2.2.3.3 General organization chart of the flight operations center

The flight operations center's primary mission is to coordinate and manage flight operations. It is structured as shown in Figure 2.6 **[6]**.

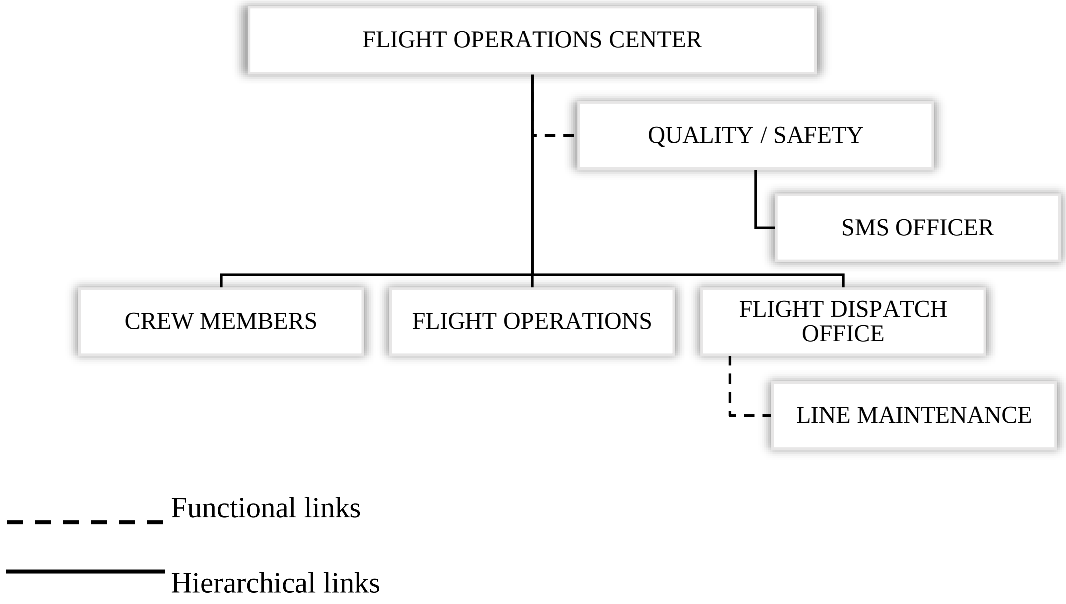


Figure 2.6: Organization chart of the flight operations center

2.2.4 The departments of the Civil Protection Air Group responsibilities

The Civil Protection Air Group is composed of a team of highly skilled professionals, including 22 helicopter pilots, with 5 currently undergoing training, and 4 airplane pilots, one of whom is currently in training. In addition, there are 6 rear crew members, 57 engineers and technicians, of which 32 are qualified on the type, and 4 flight operation engineers, along with support staff. These personnel are strategically distributed across various centers and departments, each with specific responsibilities aimed at ensuring the successful execution of the group's missions.

2.2.4.1 Responsibilities of the quality and flight safety services

The services of the quality and flight safety have the following responsibilities:

- Ensuring the application of civil aviation standards and rules;
- Assessing risks and analyzing procedures specific to major events and enhancing the aviation safety of the air group;
- Develop and update the quality manual and safety management manual of the air group;
- Implement and include an audit and control program that allows a regular review of all structures and services of the air group;
- To ensure the issuance and renewal of specific licenses to aviation personnel by the competent authorities;

The department comprises three (3) offices:

- Documentations office;

- Control and follow up office;
- Safety management office ;

2.2.4.2 Responsibilities of the flight operations center

The flight operations center ensures the following responsibilities:

- Prepare the technical files and all needed documents for the execution of the air missions for each flight;
- Manage and coordinate flight operations with the relevant authorities and services.
- Coordinate with the national coordination center CENAC;
- Ensure compliance with operating standards and practices and ensure their conformity with the regulations governing civil aviation;
- Coordinate with the maintenance department regarding the airworthiness of aircraft;
- Develop and update the MANEX and the Flight Manual and validate them by the Civil Aviation Authority by the legislative and regulatory provisions;
- Validate the flight crew designation program;

This department comprises 3 offices:

- Flight Operations;
- Flight dispatch office;
- Flight crews.

2.2.4.3 Responsibilities of the maintenance center

The responsibilities of the maintenance center are mentioned as below:

- Monitor and ensure that the maintenance system is carried out following the procedures approved by the Civil Aviation Authority;
- Plan and schedule aircraft maintenance and inspection following approved standards;
- Ensure the airworthiness of aircraft;
- Ensure the repair and overhaul of failed aircraft, equipments or parts.
- Develop and update the maintenance guide and manuals according to the manufacturer's and civil aviation authority's standards;
- Ensure the management of airworthiness directives and other requirements imposed by the Civil Aviation Authority or the manufacturer.

The center comprises 4 offices :

- Base Maintenance ;
- Engineering and Planning ;
- Line Maintenance ;

- Workshops.

2.2.4.4 Responsibilities of the Administration and Logistics Department

The Administration and Logistics Department ensure the following responsibilities:

- Monitor the management and distribution of human and material resources of the services and structures belonging to the Air Group;
- Prepare and execute the specialized training program for the personnel of the air group;
- Ensure the supply and acquisition of the means, equipment, and materials necessary for the operation of the air group;
- Ensure the maintenance and protection of the air group's facilities;
- Participate in the preparation of the contracts of the air group and ensure the follow-up of their execution.

The department contains 4 offices :

- Staff ;
- Training ;
- Logistics ;
- Security and hygiene.

2.2.5 The fleet of the Civil Protection Air Group

The current CPAG fleet is composed of:

- 4 Zlin Saphir Z43 airplane, which are used for patrols, and reconnaissance in anticipation of forest fires, but also for taking images and photos during serious disasters (earthquakes, floods, etc.);
- 6 AGUSTA-WESTLAND AW139 helicopters, which are used for rescue, search and emergency evacuations, as well as for extinguishing forest fires.

2.2.5.1 Zlin Saphir Z43 airplane

The Zlín Saphir Z43 is a light, single-engine, four-seat aircraft designed at the ECA in its Algerian version of the Czechoslovakian Zlin Moravan. It has a wingspan of 9.76 m, a length of 7.75 m, a height of 2.69 m, and a wing area of 13.15 m^2. It is powered by a LOM M337 piston engine with a power of 210 hp.

Figure 2.7: Zlin Saphir Z43 (7T-VQR)

The performance of Zlin Saphir Z43 is as follows:

- Cruise speed of 210 km/h;
- A maximum speed of 250 km/h;
- A climb speed of 5 m/s with a ceiling of 5.500 m for a range of 1,200 km;
- Autonomy of 5 hours.

Table 2.1 shows the Maximum Take-Off Weight MTOW value and engine type of the four Zlin Saphir Z43 available to CPAG.

Table 2.1: Zlin Saphir Z43 aircraft immatriculations

Immatriculations	MTOW (Kg)	ENGINE
7T-VQR	1350	LOM M337AK
7T-VFZ	1350	LOM M337AK
7T-VQQ	1350	LOM M337AK
7T-VWQ	1350	LOM M337AK

2.2.5.2 AGUSTA-WESTLAND AW139 helicopter

The Civil Protection Air Group has six AGUSTA-WESTLAND AW139 Long Nose (enhanced) helicopters, with a Low Density cabin configuration.

The AW139 was put into service in 2003. It is equipped with a Pratt and Whitney PT6C-67C engine, for a total usable fuel capacity of 1588 liters, a proposed endurance more than 03 hours. Its performances are:

- Cruising speed equals to 120Kts;

Figure 2.8: AGUSTA-WESTLAND AW139

- VNE speed equals to 167Kts;
- A maximum gross weight MTOW equals to 6.400 kg.

The MTOW and engines of the six AW139 available to CPAG are given by Table 2.2.

Table 2.2: AGUSTA-WESTLAND AW139 aircraft registration marks

Immatriculations	MTOW (Kg)	ENGINE
7T-VWD	6400	PT6C-67C
7T-VWE	6400	PT6C-67C
7T-VWF	6400	PT6C-67C
7T-VWG	6400	PT6C-67C
7T-VWH	6400	PT6C-67C
7T-VWI	6400	PT6C-67C

The Civil Protection Air Group is expecting 6 other helicopters from the same type, which will be delivered soon.

2.3 AGUSTA-WESTLAND AW139 Helicopter Overview

In this part of chapter, we will detail the main components of AW139 as well as its performance and mass limitations.

2.3.1 Principal dimensions and structure of AW139

The AW139 helicopter is a popular medium-sized twin-engine aircraft commonly used for a variety of operations. One of the major components of the AW139 is its fuselage, which houses the cockpit, cabin, and cargo compartments. Figure 2.10 **[2],** shows the principal dimensions of AW139.

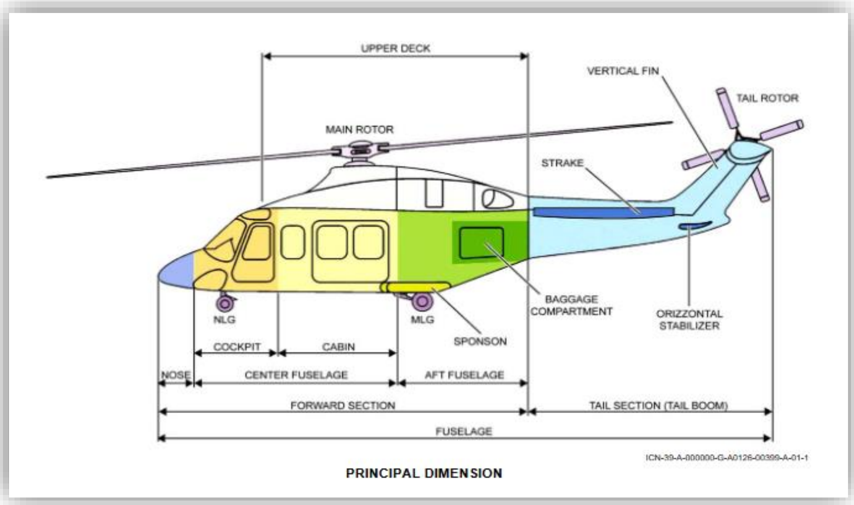


Figure 2.9: Main components of AW139

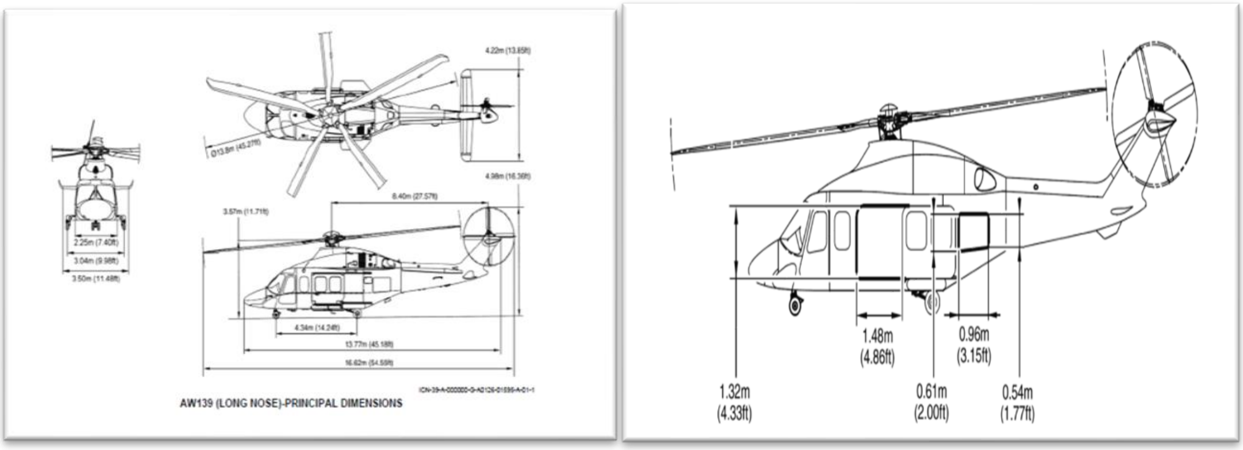


Figure 2.10: AW139 enhanced dimensions

The fuselage of the AW139 is made primarily of aluminum, which provide a high strength-to-weight ratio and excellent resistance to corrosion. It is designed to provide the required safety conditions defined by:

- Crash loads producing controlled deformations without jeopardizing occupants escape;
- Sustaining lightning effects;
- The center fuselage is also designed to be fireproof in fire critical areas.

In discussing the AW139 helicopter, it's essential to understand the fuselage's four primary sections. These sections include the forward fuselage, center section, rear fuselage, and tail section, each providing specific functions and properties critical to the helicopter's overall performance:

- **Forward Fuselage:** The front part of the helicopter, including the cockpit, is called the forward fuselage. It is constructed with longerons, frames, and sandwich panels and houses the pilots' cabin floor, the nose landing gear, and the canopy assembly.
- **Center Section:** The middle part of the helicopter is called the center section, which is composed of sheet, beams, frames, and sandwich panels. It holds the passengers' cabin, fuel and hydraulic systems, dynamic components such as the landing gear and flight controls, and supports the engine installation.
- **Rear Fuselage:** The back part of the helicopter is called the rear fuselage, which is also made of sheet beams, frames, and sandwich panels. It has a baggage compartment, avionics installation, and engine installation.
- **Tail Section:** The tail section is the end part of the helicopter and is attached to the rear section with six bolts. It is also a metallic semi-monocoque construction and includes sheet, beams, frames, and sandwich panels. It helps balance the helicopter and houses tail rotor control systems.

In addition, composite materials such as Kevlar, Fiber carbon and fiberglass used in certain areas of the fuselage, the tail cone and rotor blades, to further enhance the aircraft's durability and performance Figure 2.11 **[2]**. The use of these materials not only makes the AW139 a reliable and versatile helicopter, but also allows it to operate in a wide range of environments and weather conditions.

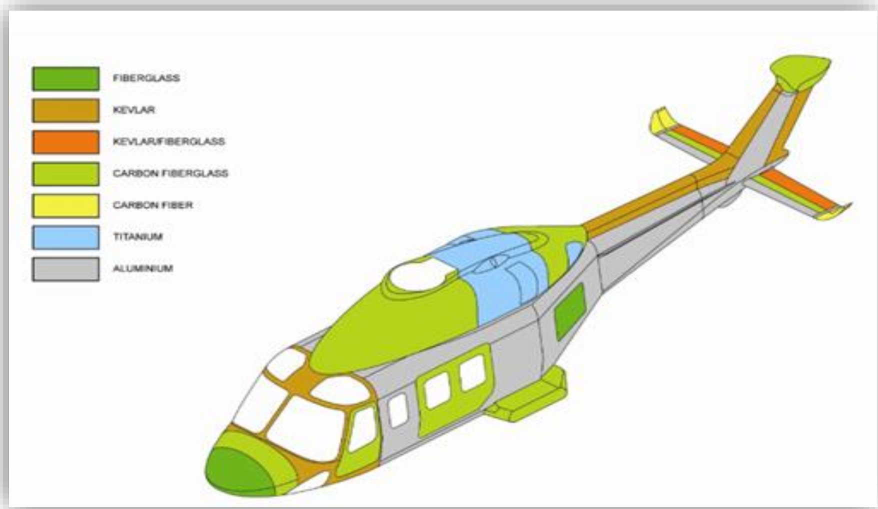


Figure 2.11: Structures of AW139

2.3.2 Systems Overview

2.3.2.1 Power plant

The power plant shall comprise engines and related installation, fire detection and extinguishing system, as shown in Figure 2.12 **[2]**.

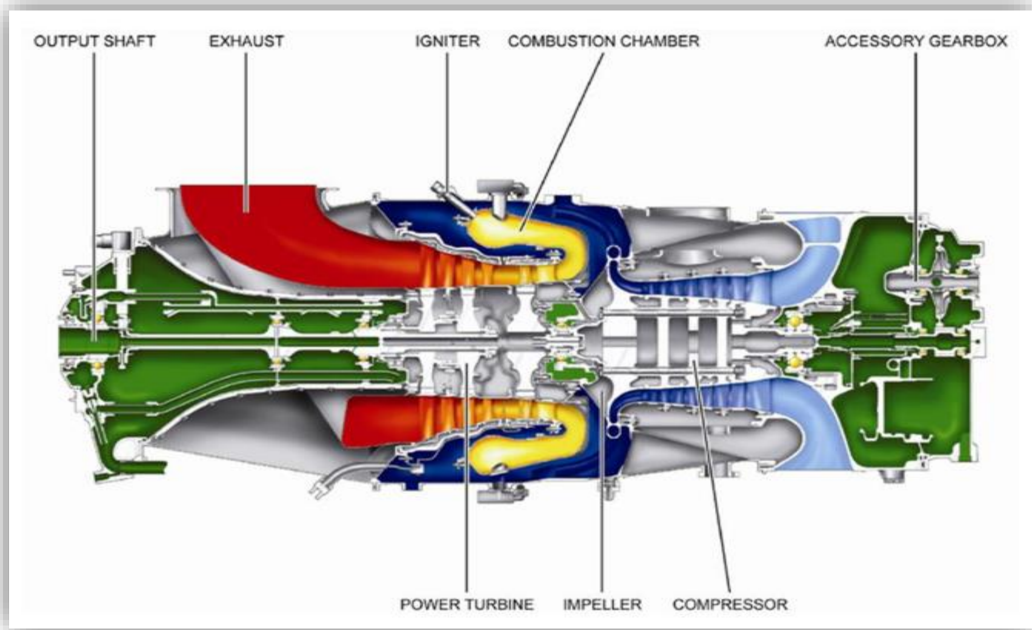


Figure 2.12: Power plant schematic

2.3.2.2 Engines

The helicopter is powered by two PT6C-67C turboshaft engines as shown in Figure 2.13 **[2]**. Each engine is installed in a separate fireproof area above the cabin roof and supplies power to the drive system by means of a rotating shaft. The engines are connected to the airframe by means of two attachment points on the engine body and to the main gearbox by means of a tube and a gimbal joint.

Air is supplied to the engine via individual, side-facing air inlets. The engines are started by a DC starter-generator.

Engine control is achieved via a control panel located in the cockpit and manual back-up of the engine control via push-pull cables.

The engines are provided with torque sensing and matching.

Figure 2.13: Pratt and Whitney PT6C-67C engine

2.3.2.3 Rotors

The rotor system consists a main rotor (MR) and tail rotor (TR) as shown in Figure 2.14 **[2]**.

The main rotor is a five blades, fully articulated rotor. The tail rotor is a four blades, fully articulated rotor.

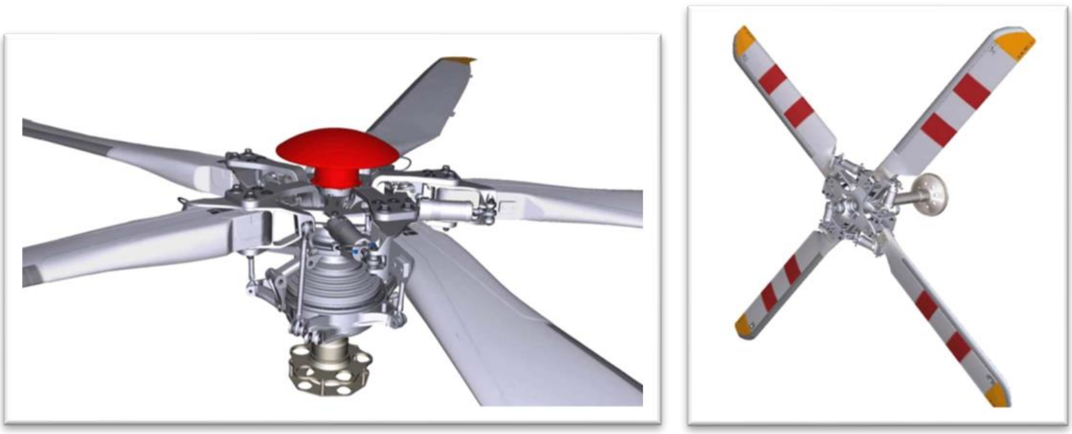


Figure 2.14: Main and tail rotors

2.3.2.4 Drive Systems

The Main Rotor Drive System as shown in Figure 2.15 **[2]**, mainly consists of the Main Gearbox (MGB) that is mounted on the roof of the cabin by means of four struts and an anti-torque device.

The MGB has three stages of reduction and includes a duplicated oil lubrication system. It provides the attachment points for the rotor brake coaxial with the tail rotor drive output. The MGB drives three hydraulic pumps and other accessories.

Figure 2.15: Main rotor drive system

The tail rotor drive system as shown in Figure 2.16 **[2]**, consists of three drive shafts driven by the MGB, the Intermediate Gearbox IGB and the Tail Gearbox TGB oil splash lubricated.

Figure 2.16: Tail rotor drive system

2.3.2.5 Hydraulic power system

The hydraulic power system as shown in Figure 2.17 **[2]**, consists of two independent circuits that supply hydraulic fluid at a nominal working pressure of 3000 psi (207 bar). Both hydraulic power system circuits supply the hydraulic power necessary to operate the flight control servo-actuators and the landing gear.

For ground test and malfunction condition, a shut-off valve allows to shut-off the flight controls circuits.

For safety reason, another shut-off valve allows to shut the landing gear circuits off, increasing the survivability of the flight control functions. Hydraulic power to the landing gear actuators is used to extend and retract the main and the nose landing gears.

The main and nose landing gear are maintained in UP position by the hydraulic pressure (no mechanical uplocks are provided).

The extended DOWN position is maintained with mechanical locks in the main and nose gear actuators.

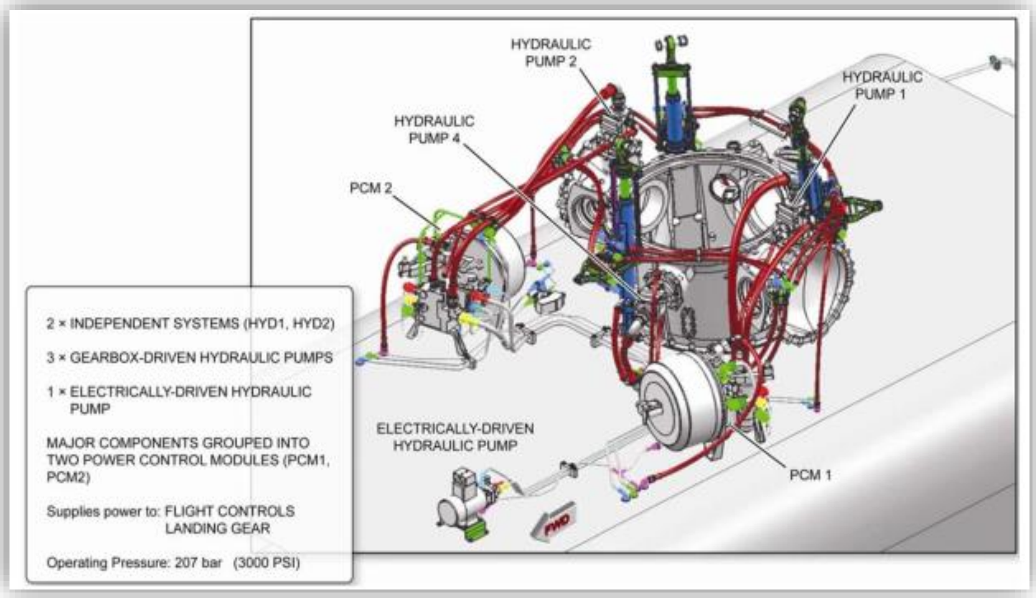


Figure 2.17: Hydraulic power system

2.3.2.6 Fuel system

The fuel system includes crashworthy fuel tanks located in the rear area of the cabin. Each tank contains a booster pump, an engine feed line, a fuel and water drain valve. Filling with fuel is achieved by gravity.

The fuel selector manifold allows fuel to supply each engine separately or fuel both engines in a cross-feed condition. It provides the pilot with flexibility in managing the fuel supply to the engines, allowing them to adjust the fuel flow according to the flight conditions and the situation at hand.

In addition to the fuel tanks and selector manifold, the fuel system includes other important components. The fuel quantity gauging system, for example, is responsible for monitoring the amount of fuel in each tank. It consists of four capacity probes, which are sensors that detect the fuel level, a Fuel Computer Unit (FCU), which calculates the amount of fuel remaining in each tank, and a fuel low-level sensor for each tank. This system helps ensure that the pilot is aware of how much fuel is left and can plan accordingly.

Another critical component of the fuel system is the fuel venting, it is designed to allow air to enter and exit the fuel tanks while preventing fuel from escaping, especially in the event of a roll-over after a crash landing. This system helps ensure the safety of the helicopter and its passengers by preventing fuel leakage that could cause a fire or explosion. The fuel venting system is an essential safety feature and is carefully designed to meet safety standards and regulations, as shown in Figure 2.18 **[2]**.

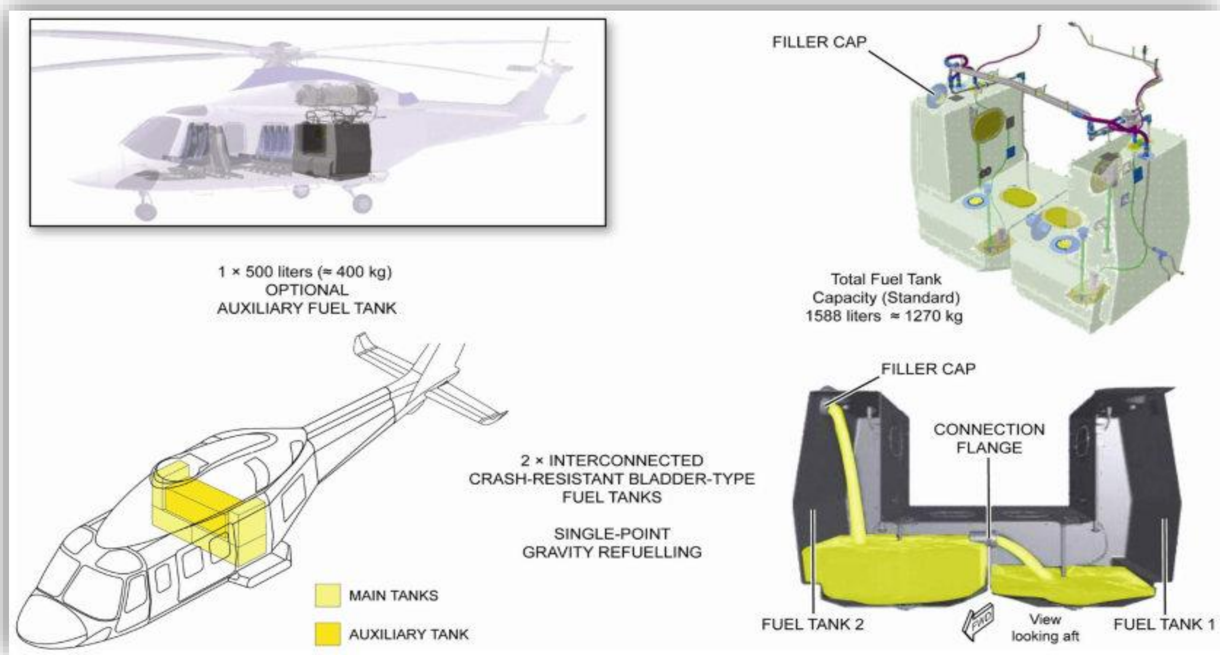


Figure 2.18: Fuel system

2.3.2.7 Electrical power system

DC power is generated by two 30V, 300A DC air cooled generators. Two batteries provide a back-up source of emergency power in the event that both generators fail and power for autonomous ground operations and engine starting.

The electrical power is delivered to aircraft systems by a dual system of distribution bus bars consisting of the Main (MAIN), Essential (ESS) and Non-Essential (NON-ESS) busses. Power from a DC external power source can also be connected to the aircraft busses.

Its electrical synoptic page is shown in Figure 2.19 **[2]**.

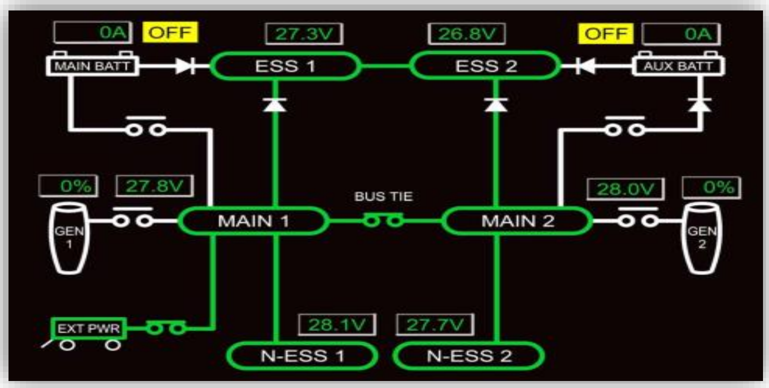


Figure 2.19: Electrical system synoptic page

2.3.2.8 Avionic system

In the AW139 helicopter, the PRIMUS EPIC system is an integrated avionic system that provides pilots with advanced flight instrumentation, navigation, and communication capabilities. It uses advanced computer technology to process and display information from various aircraft sensors and systems, providing the pilot with a comprehensive view of the helicopter's operation. The system also includes features such as weather radar, traffic collision avoidance, and terrain avoidance to enhance safety and situational awareness during flight, as shown in Figure 2.20 **[3]**.

The PRIMUS EPIC system includes the following sub-systems necessary to operate:

- Auto-Pilot
- Flight Management System
- Communications
- Indicating and Recording Systems
- Aural Warning Generator
- Navigation System
- Crew Alerting System
- Central Maintenance Systems (CMS)

The PRIMUS EPIC system is integrated into:

- Two Modular Avionics Units (MAU)
- Four flat panel color LCD Display Units (DU) to show data in the cockpit
- Two Modular Radio Cabinets (MRC) that include the following radios:
    - VHF-COMM
    - VOR/ILS
    - ADF
    - DME
    - Transponder (XPDR)

The MAUs, the DUs and the MRCs are directly connected to each other via a bi-directional digital data bus named Avionic Standard Communication Bus-D (ASCB-D).

A LAN digital bus also interconnects the same units for maintenance purposes. In addition to the PRIMUS EPIC integrated avionics system, the following systems are also part of the aircraft standard avionics configuration:

- Standby Instrument
- Emergency Locator Transmitter (ELT)
- Flight Data Recorder / Cockpit Voice Recorder FDR/CVR)

A great variety of optional systems is available to fulfil Customer’s operational requirements.

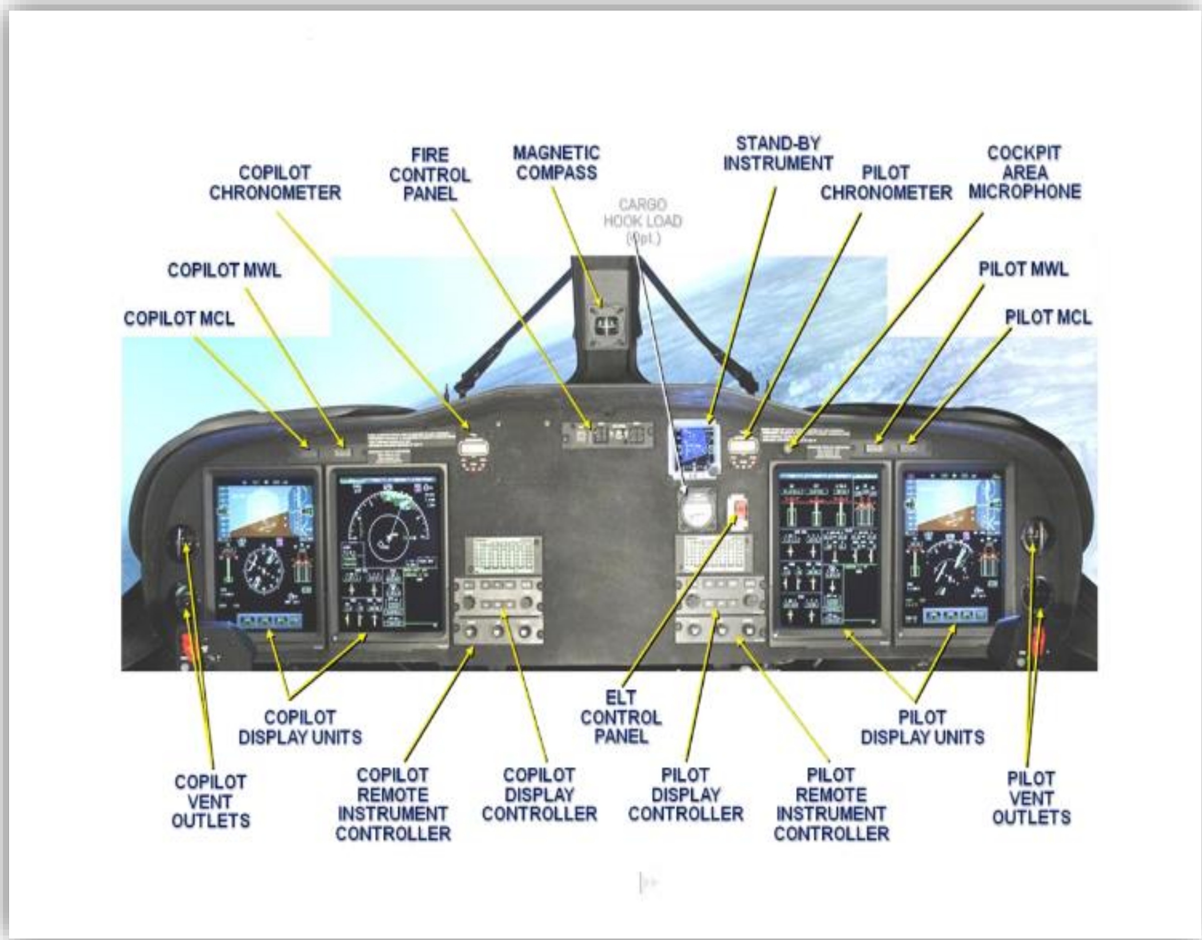


Figure 2.20: AW139 Instrument panel

2.3.3 Limitations and Performances of AW139

The performance and mass limitations of AW139 are given as follows:

Operational performances

- VNE (AEO) = 167 KIAS.
- Rate of climb (AEO) = 2150 fpm.
- Service ceiling (Hp or Hd) = 20000 ft.
- Hover Ceiling (IGE and OGE) = 18000 ft.
- Takeoff and landing ceiling =14000 ft.
- Operating temperature = from -40°C to 50°C.

Mass limits

- Maximum take-off weight = 6400 Kg.
- Maximum take-off weight increased = 6800/7000 Kg.
- Minimum weight for rotor rotation = 4400 Kg.

2.4 Conclusion

As demonstrated throughout this chapter, the Civil Protection Air Group plays a crucial role in protecting communities, property, and the environment through its prevention and aerial intervention missions. The Air Group's headquarters, established with the aim of coordinating and executing emergency management activities, is responsible for ensuring that the Air Group's mission is carried out with effectiveness and precision. The Group's structure is designed meticulously to guarantee the successful execution of its missions. Each department within the Air Group has specific responsibilities aimed at achieving the overall goal of securing the safety and well-being of the population. Additionally, the fleet of the Civil Protection Air Group, which includes the AGUSTA-WESTLAND AW139 helicopter, is equipped with cutting-edge technology and systems that enable safe and efficient operations under various conditions.

Moreover, we have gained valuable insight into the AGUSTA-WESTLAND AW139 helicopter, which is critical component of the fleet, providing a versatile and robust platform for the Air Group's aerial interventions. The helicopter's principal dimensions and structure, coupled with its advanced systems and capabilities, allow it to perform a broad range of missions, including transportation of personnel and equipment, search and rescue, firefighting, and more.

However, despite its high-performance capabilities, the AW139 helicopter has certain limitations and performance characteristics that must be considered to make certain safe and effective operations.

As we scrutinize deeper into the design and operation of aircraft, it becomes increasingly clear that the factors of weight and balance are fundamental in ensuring the structural soundness and optimal performance of an aircraft. In the upcoming chapter, we will explore the various elements that influence helicopter weight and balance calculations, and their impact on the stability and control of flight.

3

TERMS AND DEFINITIONS OF WEIGHT AND BALANCE

In this chapter, we will focus on defining key concepts related to weight and balance. Understanding these terms is essential for grasping the nuances of the subject matter and for effective communication. Each definition will be presented in a clear and concise manner, with examples where appropriate. By the end of this chapter, we will have a solid foundation of the terminology used in weight and balance procedure.

Contents

3.1 Introduction

In the world of helicopter operations, weight and balance determination is a crucial aspect that cannot be overlooked. In this chapter, we will delve into the importance of accurate weight and balance determination and explore various concepts that play a critical role in the process. We will start by defining weight, balance, center of gravity (CG), and forward and aft limits, all of which are vital in determining the loaded CG of a helicopter.

Moving on, we will explore different methods of weighing a helicopter, such as the jackpoints and balance methods. These methods involve using specialized equipment to measure the helicopter's weight and balance accurately, which is crucial for determining the loaded CG. Additionally, we will discuss the examination of the effects of payload distribution on helicopter weight and balance, including the impact of passenger and cargo distribution and equipment installation. This examination will help pilots and technicians to understand how to load a helicopter correctly to avoid balance issues and ensure safe and efficient operation.

Finally, we will cover the weight and balance determination process, which involves using charts and forms such as Charts A, B, C, D, and E. These charts and forms provide a comprehensive and systematic approach to accurately calculate weight and balance and determine the loaded CG of a helicopter. They also ensure continuous control of weight and balance, enabling operators to maintain safe and efficient helicopter operations. After reading this chapter, we will possess a thorough comprehension of the significance of weight and balance determination in helicopter operations, along with the tools and techniques implemented to accomplish it. We will also acquire a comprehensive understanding of the terminologies and definitions pertinent to weight and balance, as well as the methods utilized for weighing a helicopter and the utilization of charts.

3.2 Terms and definitions

The following list of terms and their definitions are standardized, and knowledge of these terms aids better understanding weight and balance calculations of any aircraft.

- **Arm (moment arm):** the horizontal distance in meters from the reference datum line to the CG of an item. The algebraic sign is plus (+) if measured aft of the datum and minus (–) if measured forward of the datum, as shown in Figure 3.1 **[8]**:

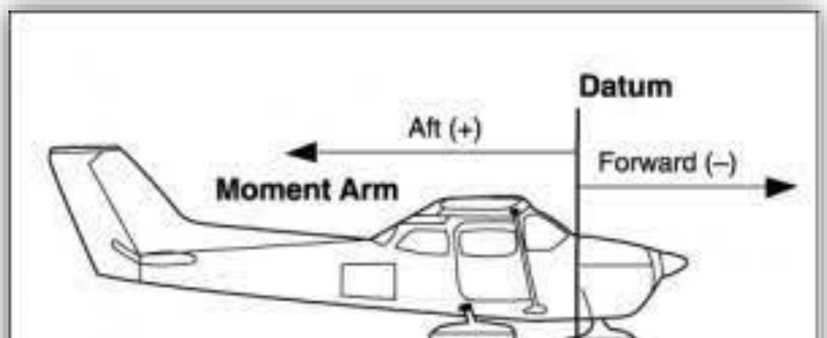


Figure 3.1: Moment arm

- **Center of Gravity (CG):** the point about which an aircraft would balance if it were possible to suspend it at that point. It is the mass center of the aircraft or the theoretical point at which the entire weight of the aircraft is assumed to be concentrated. It may be expressed in meters from the reference datum or in percent of MAC. The CG is a three-dimensional point with longitudinal, lateral, and vertical positioning in the aircraft, as shown in Figure 3.2 **[8]**:

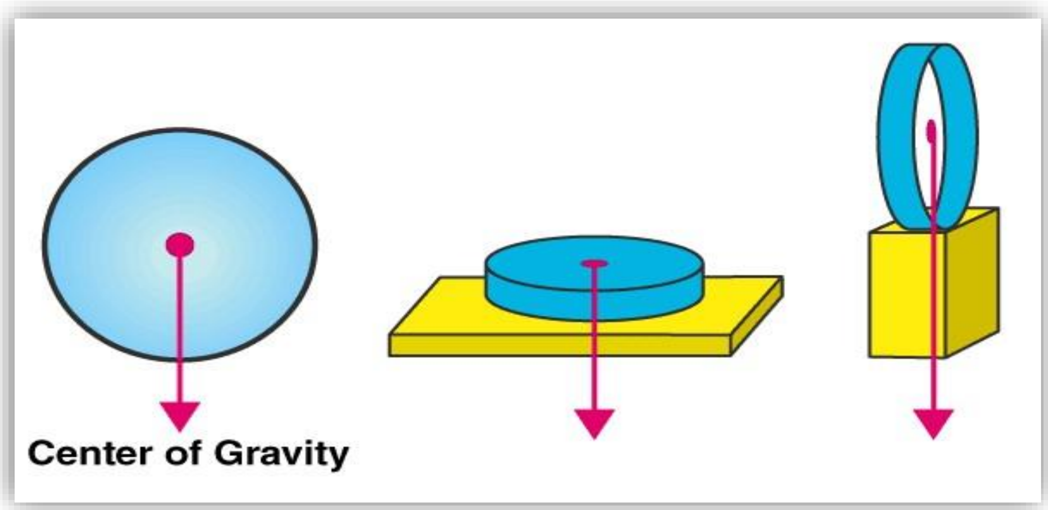


Figure 3.2: Center of gravity

  → **CG limits:** the specified forward and aft points within which the CG must be located during flight. These limits are indicated on pertinent aircraft specifications.

  → **CG range:** the distance between the forward and aft CG limits indicated on pertinent aircraft specifications.

- **Datum (reference datum):** an imaginary vertical plane or line from which all measurements of the arm are taken. The datum is established by the manufacturer. Once the datum has been selected, all moment arms and the location of the CG range are measured from this point.

- **Delta:** a Greek letter expressed by the symbol Δ to indicate a change of values. As an example, ΔCG indicates a change (or movement) of the CG.

- **Moment:** the product of the weight of an item multiplied by its arm. Moments are expressed in kg-m. Total moment is the weight of the airplane multiplied by the distance between the datum and the CG, **[8]**:

$$M = W \times D \tag{3.1}$$

Such as:

M: moment (Kg.m)

W: weight (Kg)

D: distance (m)

- **Moment index (or index):** a moment divided by a constant such as 100, 1.000, or 10.000. The purpose of using a moment index is to simplify weight and balance computations of aircraft where heavy items and long arms result in large, unmanageable numbers, **[8]**:

$$M_{index} = \frac{M}{W \times arm} \quad (3.2)$$

Such as:

M_{index}: Moment index

M: Moment (Kg.m)

W: Weight Kg)

arm: Arm (m)

- **Standard weights:** established weights for numerous items involved in weight and balance computations. These weights should not be used if actual weights are available.
- **Station:** a location in the aircraft that is identified by a number designating its distance in meters from the datum. The datum is, therefore, identified as station zero.
- **Stability:** the ability of an aircraft in the conditions of external disturbances to keep the specified flight regime without pilot management.
- **Maneuverability:** the ability for the aircraft to commence and sustain maneuvers, its responsiveness and its performance rate of roll or turn and pitch rate.
- **Control:** There are three major controls in a helicopter that the pilot must use during flight. They are the collective pitch control, the cyclic pitch control, and the antitorque pedals or tail rotor control.
- **Total Weight:** the weight of the airplane and everyone and everything carried on it or in it. The total weight comprises the three elements bellow:
  - **Basic Weight:** This is the airplane weight plus basic equipment, unusable fuel and undrainable oil. Basic equipment is that which is common to all roles plus unconsumable fluids such as hydraulic fluid.
  - **Variable Load:** This includes the role equipment, the crew and the crew baggage. Role equipment is that which is required to complete a specific tasks such as seats, toilets and galley for the passenger role or roller convey or, lashing points and tie down equipment for the freight role.
  - **Disposable Load:** is the traffic load plus usable fuel and consumable fluids. The traffic load is the total weight of passengers, baggage and cargo, including any non-revenue load. The disposable load is sometimes referred to as the useful load.

Although the weights above are the weight definitions used in the load sheet, there are other terms which are commonly used such as:

- **Absolute Traffic Load:** The maximum traffic load that may be carried in any circumstances. It is a limitation caused by the stress limitation of the airframe and is equal to the maximum zero fuel weight minus the aircraft prepared for service weight.
- **All Up Weight (AUW):** The total weight of an aircraft and all of its contents at a specific time.
- **Design Minimum Weight:** The lowest weight at which an airplane complies with the structural requirements for its own safety.

- **Dry Operating Weight:** The total weight of the airplane for a specific type of operation excluding all usable fuel and traffic loads. It includes such items as crew, crew baggage, catering equipment, removable passenger service equipment, and potable water and lavatory chemicals. The items to be included are decided by the Operator. The dry operating weight is sometimes referred to as the Aircraft Prepared for Service (APS) weight. The traffic load is the total weight of passengers, baggage and cargo including non-revenue load.
- **Empty Weight** (Standard Empty Weight)**:** The weight of the aircraft excluding usable fuel, crew and traffic load but including fixed ballast, engine oil, engine coolants (if applicable) and all hydraulic fluid and all other fluids required for normal operation and aircraft systems, except potable water, lavatory pre-charge water and fluids intended for injection into the engine (demineralized water or water-methanol used for thrust augmentation).
- **Landing Weight:** The gross weight of the airplane, including all of its contents, at the time of landing.
- **Maximum Ramp Weight:** The maximum weight at which an aircraft may start taxiing and it is equal to the maximum take-off weight plus taxi fuel and run-up fuel. It must not exceed the surface load bearing strength.
- **Maximum Structural Landing Weight:** The maximum permissible total airplane weight on landing in normal circumstances.
- **Maximum Structural Take-Off Weight**: The maximum permissible total airplane weight at the start of the take-off run.
- **Maximum Total Weight Authorized (MTWA):** The maximum total weight of aircraft prepared for service, the crew (unless already included in the APS weight), passengers, baggage and cargo at which the aircraft may take-off anywhere in the world, in the most favorable circumstances in accordance with the Certificate of Airworthiness in force in respect of aircraft.
- **Maximum Zero Fuel Weight:** The maximum permissible weight of an airplane with no usable fuel. The weight of fuel contained in particular tanks must be included in the zero-fuel mass when it is explicitly mentioned in the Airplane Flight Manual limitations. This is a structural limitation imposed to ensure that the airframe is not overstressed.
- **Zero Fuel Weight:** This is the dry operating weight plus the traffic load. In other word, it is the weight of the airplane without the weight of usable fuel, **[8]**:

$$\mathrm{ZFW} = \mathrm{DOW} + \mathrm{P} \tag{3.3}$$

Such as:

ZFW: zero fuel weight (Kg)

DOW: dry operating weight (Kg)

P: payload (Kg)

- **Payload:** Anyone or anything on board the airplane the carriage of which is paid for any someone other than the operation. In other word, it is anything or anyone carried that earns money for the airline.
- **Total Loaded Weight:** The sum of the aircraft basic weight, the variable load and disposable load.
- **Useful load:** the weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil. It is the basic empty weight subtracted from the maximum allowable gross weight. This term applies to general aviation (GA) aircraft only.

3.3 Effects of Weight

The majority of contemporary airplanes are built in such a way that they are significantly overloaded when all seats are occupied, all baggage compartments are full, and all fuel tanks are full. The pilot must carefully examine the needs of each individual flight when using this type of design. If the maximum range is needed, passengers or luggage must be left behind. Alternatively, if the maximum load must be carried, the range, which is determined by the amount of fuel on board, must be decreased. Several issues might arise from an aircraft being overloaded:

- A longer takeoff run is necessary due to the aircraft's demand for a faster takeoff speed.
- The climb's rate and incline are both lowered.
- A decrease in the service ceiling.
- A lower cruising speed is maintained.
- The cruising distance is reduced.
- The capacity to maneuver is reduced.
- Because the landing speed is faster, a longer landing roll is necessary.
- The structure is subjected to excessive loads, particularly the landing gear.

3.4 Determination of the loaded CG of a helicopter

A helicopter's Empty Weight and Empty Weight Center of Gravity (EWCG) are calculated similarly to an airplane. The moments at each weighing point are calculated using the sum of the weights recorded on the scales supporting the helicopter and their distances from the datum. To get the CG's distance from the datum in meters, we divide the total moment by the total weight, **[8]**:

$$CG = \frac{\sum M}{\sum W} \tag{3.4}$$

Such as:

CG: center of gravity (m)

$\sum M$: Total moment (Kg.m)

$\sum W$: Total weight (Kg)

Certain helicopters have their datum at the middle of the rotor mast, but since this causes some arms to be positive (behind the datum) and others to be negative (ahead of the datum), the datum is typically located forward of the aircraft on most modern helicopters and airplanes.

All longitudinal arms are positive when the aircraft's datum is in front of it. The lateral CG is calculated in the same manner as the longitudinal CG, with the exception that the arms are the distances between the scales and Butt Line zero (BL 0). Arms on the right and the left of BL 0 are positive and negative, respectively. The Butt Line zero, often known as the buttock, runs from the nose to the tail through the symmetrical center of an airplane. It acts as the reference point for measuring the arms needed to determine the lateral CG. The airplane rolls counterclockwise when lateral moments are negative, and clockwise when they are positive.

3.4.1 Weight Limitations

Weight limitations are necessary to guarantee the structural integrity of the helicopter, as well as enabling us to predict helicopter performance accurately.

Based on the amount of lift that the rotors can produce under the operational circumstances for which the aircraft is designed, an aircraft's designers have set the maximum weight. The maximum weight that an airplane may safely carry is also restricted by its structural strength. Despite the fact that a helicopter has an approved maximum gross weight. The structural integrity of the helicopter is compromised when operating above the maximum weight restriction, and performance is negatively impacted. Weight limitations are required to ensure the structural integrity of the helicopter and to accurately forecast its performance.

3.4.2 Balance or Center of Gravity (CG)

Helicopter performance is not only affected by gross weight, but also by the position of that weight. The theoretical location where all of the weight of the aircraft is thought to be concentrated is known as the Center of Gravity (CG).

Changing the center of gravity alters the angle at which the aircraft hangs from the rotor because the fuselage behaves as a pendulum dangling from the rotor. The designers painstakingly selected the perfect point for the Center of Gravity (CG), and they also computed the maximum deviation permitted from this precise location. It's crucial to adhere to the helicopter-specific balance restrictions. It is dangerous to launch a helicopter outside of the permitted limits for balance. A helicopter's load should be balanced properly to avoid major control issues. The "CG range" refers to the permitted range in which the CG may fall. Each helicopter's rotorcraft flying manual specifies the precise CG position and range.

A helicopter should ideally be perfectly balanced to eliminate the need for cyclic pitch control when hovering and keep the fuselage horizontal.

3.4.2.1 Center of Gravity envelop

The Center of Gravity (CG) envelope refers to the range of locations where the center of gravity of an aircraft must lie for safe and stable flight. The CG is the point where the total weight of the aircraft is considered to be concentrated, and it plays a crucial role in determining the aircraft's stability and handling characteristics.

The CG envelope is determined by the design of the aircraft, taking into account factors such as the weight and distribution of various components, fuel tank location, and payload. The envelope is typically represented graphically as a series of limits, including forward and aft limits, lateral limits, and maximum and minimum CG limits, as shown for the A350 case in Figure 3.3 **[8]**:

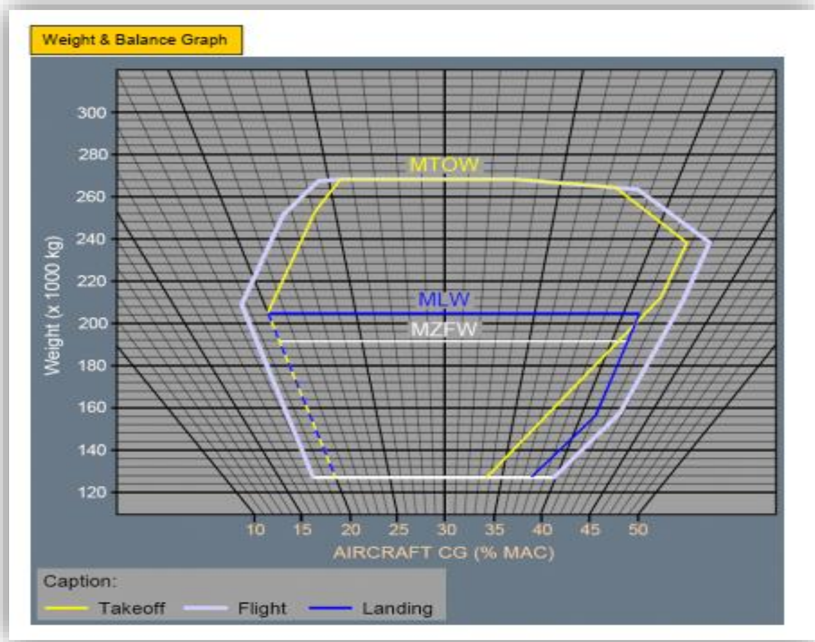


Figure 3.3: Weight and Balance envelope chart of an A350

The helicopter hangs horizontally when the Center of Gravity (CG) is directly beneath the rotor mast. When the CG is too far forward of the mast, the helicopter hangs with its nose slanted down and when the CG is too far aft of the mast, the helicopter hangs with its nose tilted up.

3.4.2.2 Longitudinal CG Forward of Forward Limit

When the majority of the crew, passengers, and cargo are positioned forward of the rotor mast, a forward CG may happen. This situation is apparent when landing vertically and coming to a hover. To maintain a hover in a no-wind situation, the helicopter will have a nose-low attitude and we will need to move the cyclic control excessively rearward. In this situation, we shouldn't continue flying since we risk quickly losing rearward cyclic control. Additionally, we might not be able to slow down the chopper down enough to stop it. We might not have adequate cyclic control in the event of engine failure and the ensuing autorotation to correctly flare for the landing.

3.4.2.3 Longitudinal CG Aft of Aft Limit

When the majority of the passengers, luggage, and cargo are situated behind the rotor mast, exceeding the aft CG may happen if there is insufficient ballast in the cockpit.

When landing vertically and coming to a hover, the aft CG state is apparent.

To maintain a hover in a no-wind situation, we will need significant forward displacement of cyclic control since the helicopter will have a tail-low attitude. The forward cycle needs to be considerably higher if there is wind.

If flying is continued under these circumstances, we might not be able to maintain a nose low attitude or fly in the upper permitted airspeed range due to insufficient forward cyclic authority.

3.4.2.4 Lateral CG Out of Left or Right Limits

For routine flight instruction and passenger flights in the majority of helicopters, it is typically not essential to calculate the lateral CG. This is due to the fact that helicopter cabins tend to be compact and that the majority of optional equipment is placed close to the centerline.

Some helicopter manuals, however, outline which seat is required for solo flight. Additionally, the position of the circumstance should be compared to the Lateral CG envelope if it has the potential to alter the lateral CG, such as WINCH OPERATION.

3.5 Weighing Methods

3.5.1 Jackpoints Method

The jackpoints method is a common technique used to perform weight and balance measurements on helicopters. It involves suspending the aircraft from a set of specially designed jackpoints located at specific points on the airframe. By elevating the helicopter off the ground, the weight of the aircraft can be accurately measured using scales placed underneath the jackpoints. The weight and balance data obtained from this method is then used to determine the correct distribution of weight within the aircraft to ensure safe and stable flight. The jackpoints method is preferred for helicopter weight and balance measurements as it allows for precise measurements to be taken in a controlled environment, ensuring accurate and consistent results. Additionally, the method is relatively simple and can be performed quickly.

Here are the general steps for performing the jackpoints method for weighing a helicopter:

1. Positioning the helicopter on a level surface and ensuring that it is securely parked and that the rotors are stopped.
2. Locating the jackpoints on the helicopter, which are usually marked with placards or stickers.
3. Positioning hydraulic jacks under each jackpoint and ensuring that they are secure and level.
4. Carefully raising the helicopter using the jacks until it is off the ground and the weight is fully supported by the jacks.
5. Placing calibrated scales under each jackpoint to measure the weight of the helicopter at each point.
6. Recording the weight measurements from each scale and calculating the total weight of the helicopter.
7. Determining the Center of Gravity (CG) of the helicopter by using the weight and moment calculations based on the weight measurements from each jackpoint.
8. Checking that the CG falls within the allowable limits specified in the helicopter's Weight and Balance manual.

9. If necessary, adjusting the weight distribution of the helicopter by repositioning equipment or cargo to ensure that the CG falls within the allowable limits.
10. Finally, lowering the helicopter back onto the ground and remove the jacks.

It's important to note that the exact steps for performing the jackpoints method may vary slightly depending on the specific helicopter and equipment being used. It's essential to follow the procedures outlined in the helicopter's Weight and Balance manual and to seek the assistance of a qualified technician if we are not familiar with the process.

It’s also noted that Hangar space is an important option in keeping our aircraft safe from the elements and other damaging situations, it should closed during the weighing procedure.

3.5.2 Balance Method

The Balance Method is another commonly used technique for determining the weight and balance of helicopters. This method involves lifting the aircraft from a level beam or bar, with support points located at specific points along the fuselage. The weight of the aircraft is then measured using scales placed under each support point. Once the weight is determined, the distance between the support points is measured, and the center of gravity is calculated based on the weight and distance measurements. This method requires accurate measurements of the support points and can be more time-consuming than the jackpoints method. However, it allows for precise determination of the center of gravity and can be used on helicopters with more complex shapes or configurations. The Balance Method is commonly used for initial weight and balance measurements, as well as for major modifications or changes to the helicopter's configuration.

Another often employed approach for figuring out an aircraft's weight and balance is the balancing method. The airplane is elevated using this technique from a straight beam or bar with support points placed at strategic locations along the fuselage. The airplane is then weighed using scales positioned beneath each support point. The center of gravity is then computed using the weight and distance data, after the support points' distances have been assessed and the weight has been established. This method can take longer than the jackpoints method and calls for precise measurements of the support points. Yet, it may be used to helicopters with more complex shapes or configurations and enables accurate measurement of the center of gravity.

The Balance Method can also be employed for initial weight and balance assessments as well as for significant alterations or configuration changes to the helicopter.

The general steps for performing the Balance Method are:

1. Ensuring that the helicopter is parked on a level surface and that the rotors are stopped.
2. Locating a level and sturdy beam or bar that is capable of supporting the weight of the helicopter.
3. Positioning the helicopter so that its suspension points are located at specific points along the beam or bar as specified in the helicopter's Weight and Balance manual.
4. Using a lifting device such as a crane or hoist to carefully raise the helicopter onto the beam or bar.
5. Adjusting the position of the helicopter until it is level and stable on the beam or bar.

6. Placing calibrated scales under each suspension point to measure the weight of the helicopter at each point.
7. Recording the weight measurements and calculate the total weight of the helicopter.
8. Using the weight measurements and moment calculations to determine the center of gravity of the helicopter.
9. Checking that the center of gravity falls within the allowable limits specified in the helicopter's Weight and Balance manual.
10. Adjusting the weight distribution of the helicopter if necessary to ensure that the center of gravity falls within the allowable limits.
11. Carefully lowering the helicopter off the beam or bar and remove any lifting devices.

3.6 Examination of the Effects of Payload Distribution on Helicopter Weight and Balance

3.6.1 The impact of passenger distribution on helicopter Weight and Balance

It requires exploring how different passenger configurations impact the weight and balance of a helicopter. This area of study may involve examining several factors such as passenger weight, location, and movement, as well as the total number of passengers on board.

For instance, we may investigate the effect of uneven (not fairly balanced**)** distribution of passenger weight on the helicopter's balance or the consequences of passenger movement during flight on the aircraft's stability. Additionally, we could consider how different passenger seating arrangements, like side-facing versus forward-facing seats, can affect the weight and balance of the helicopter. For example, a passenger seated on the side of a helicopter could cause the aircraft to tilt to one side, creating an imbalance that the pilot would need to adjust for.

3.6.2 The effects of cargo distribution

The effects of cargo distribution on helicopter weight and balance are a critical consideration in helicopter operations. The location of cargo and the effect of its movement during flight must be carefully managed to prevent a shift in the helicopter's center of gravity, which could result in a loss of control or even a catastrophic failure.

Moreover, cargo distribution has a significant impact on helicopter performance. An unbalanced load can cause the helicopter to be less responsive to pilot input, reduce its maximum speed, and increase fuel consumption. In addition, the location of the center of gravity affects the helicopter's longitudinal stability and may impact its vertical climb rate and rate of descent.

Therefore, helicopter operators must develop a comprehensive understanding of cargo distribution principles and adhere to weight and balance limitations set by regulatory authorities. They must also consider various factors such as the size, shape, and weight of the cargo and how its placement affects the helicopter's center of gravity, especially during external load operations. By doing so, they can optimize cargo placement and minimize the risks associated with improper weight and balance distribution.

3.6.3 The role of equipment installation

The installation of various types of equipment can affect the weight and balance of a helicopter. This might involve analyzing the weight and location of equipment such as cameras, hoists, firefighting equipment, or other specialized gear.

To illustrate, when mounting a camera on the helicopter's nose or belly, the additional weight may shift the center of gravity forward or downward, which could cause the helicopter to pitch forward or reduce its ability to maintain level flight. This could also result in a reduction in the helicopter's maneuverability, as well as a decrease in its cruising speed and range.

3.6.4 The impact of different payload distribution scenarios on helicopter performance metrics

In this area of investigation, we can focus on how different payload distribution scenarios can impact various aspects of helicopter performance, such as fuel consumption, range, or maneuverability.

For example, we could examine how different payload configurations affect the helicopter's fuel burn rate, or how different types of cargo affect the aircraft's range. We might also consider the influence of payload distribution on the helicopter's ability to perform certain maneuvers (such as hovering, autorotation, or steep turns).

3.6.4.1 Payload configurations effect on the helicopter's fuel burn rate

Changes in payload weight distribution can affect the helicopter's aerodynamic efficiency, which can further impact fuel consumption. For example, if the payload is distributed unevenly, it can create asymmetrical lift and drag, causing the helicopter to burn more fuel to maintain level flight.

To optimize fuel efficiency and minimize the impact of payload configuration on fuel burn rate, helicopter operators can perform weight and balance calculations to determine the optimal payload configuration for a given flight. These calculations consider factors such as payload weight, location, and fuel consumption to find the most fuel-efficient configuration for a particular flight.

3.6.4.2 The influence of payload distribution on the helicopter's ability to perform certain maneuvers

Payload distribution can significantly affect the helicopter's ability to perform certain maneuvers such as hovering and autorotation.

In the case of hovering, the helicopter's center of gravity plays a crucial role. When the payload is not well distributed, the helicopter's center of gravity can shift, causing instability and affecting the helicopter's ability to maintain a steady hover. This instability can result in an increased workload for the pilot, who will have to make constant adjustments to maintain the helicopter's balance.

Autorotation is another maneuver that can be affected by payload distribution. During autorotation, the helicopter's rotor blades are not being powered by the engine, but instead, they rely on the energy stored in the rotor's rotational inertia to keep the helicopter airborne. A heavy payload, especially if it is not evenly distributed, can cause the rotor blades to slow down faster than usual, which can result in a loss of altitude and, in extreme cases, a hard landing.

Additionally, payload distribution can also impact the helicopter's response to control inputs. If the payload is located far from the helicopter's center of gravity, it can cause the helicopter to become sluggish in response to control inputs. This can affect the pilot's ability to maneuver the helicopter precisely, especially during rapid or aggressive maneuvers.

Helicopter weight and balance play a crucial role in determining the fuel consumption and operating costs of the aircraft. The weight of the helicopter directly affects the amount of fuel required for flight, as well as the aircraft's ability to fly at certain altitudes and speeds. An improper weight and balance can result in an inefficient use of fuel, which can significantly increase operating costs.

An aircraft that is overweight may require more power to achieve the same performance as an aircraft with a proper weight and balance. This increased power requirement results in higher fuel consumption and, ultimately, increased operating costs. Furthermore, an aircraft with an improper weight and balance may also require more maintenance, which can further increase operating costs.

3.7 Reference Lines

Several lines are taken as a reference, including the following:

- **Station Line:** The station line is a reference line that runs along the length of the helicopter from nose to tail. It is used to measure the distance between components and to determine the center of gravity, as shown in Figure 3.4 **[1]**:

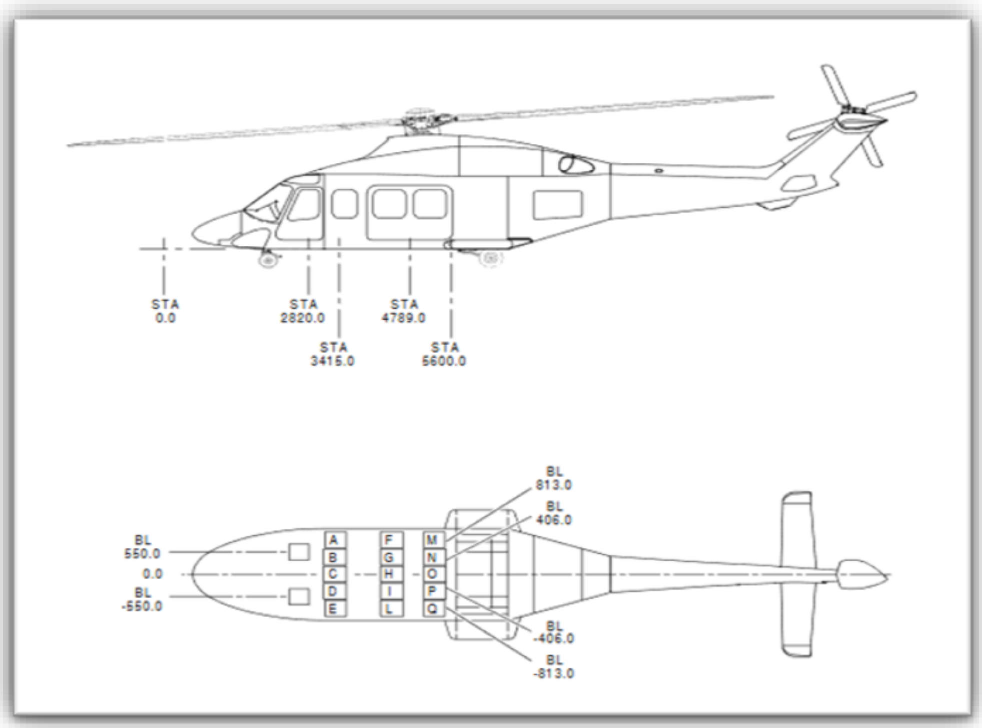


Figure 3.4: Station Line

- **Buttock Line:** The Buttock line is a reference line that runs along the width of the helicopter from one side to the other. It is used to measure the distance between components and to determine the lateral balance of the aircraft, as shown in Figure 3.5 **[1]**:

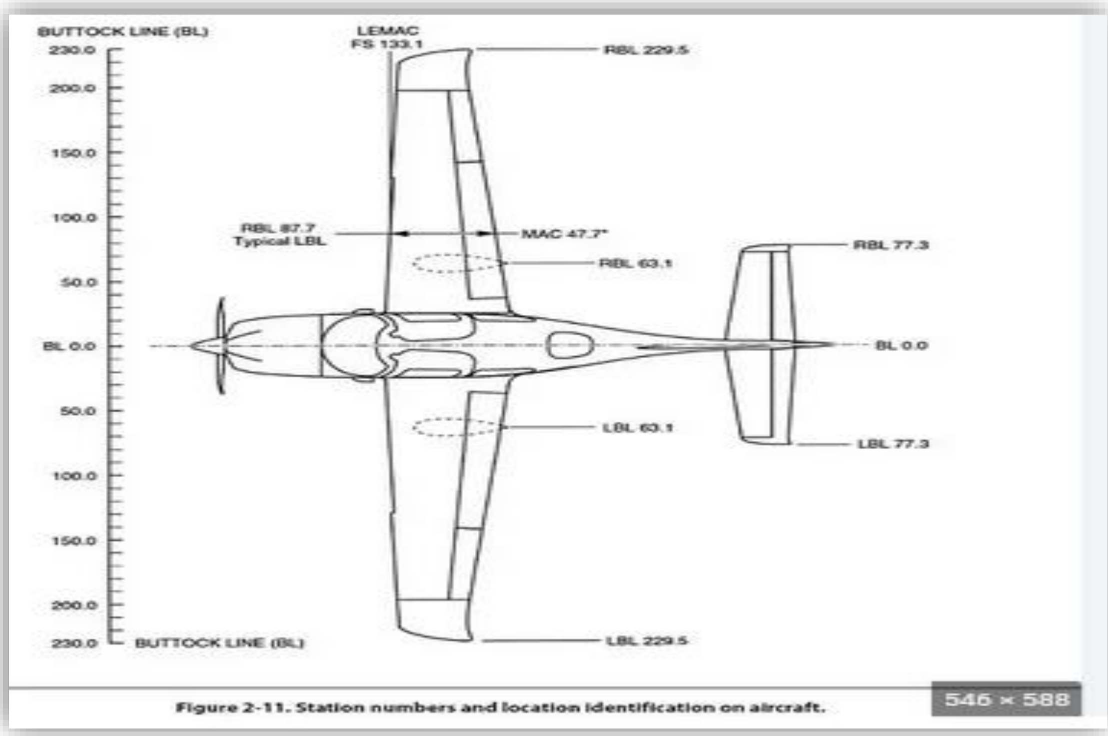


Figure 3.5: Buttock Line

- **Water Line:** The Water line is a reference line that runs along the height of the helicopter from top to bottom. It is used to measure the distance between components and to determine the vertical balance of the aircraft, as shown in Figure 3.6 **[1]**:

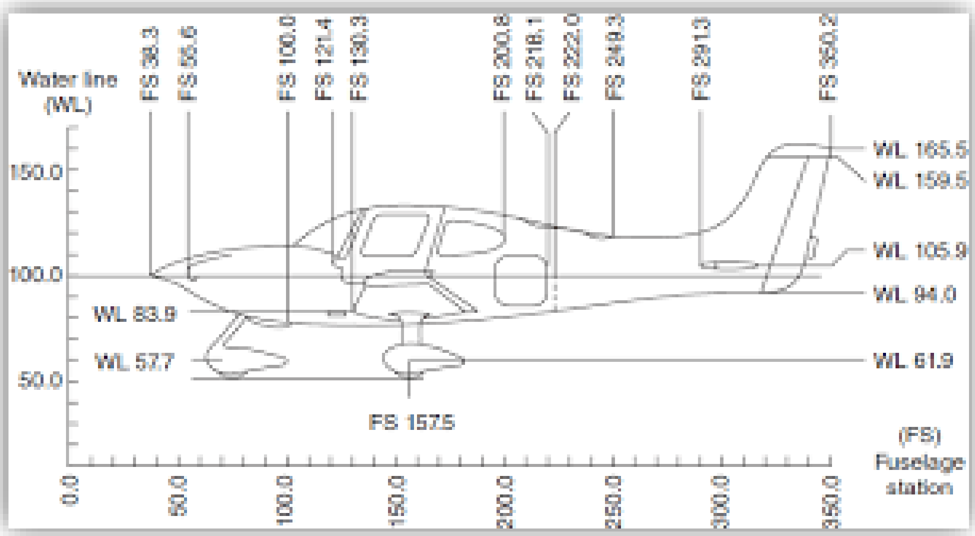


Figure 3.6: Water Line

3.8 Weight and Balance determination

Instructions for weight and balance determination are herewith enclosed with instructions for use of charts to enable the operator to obtain all necessary data as to basic helicopter configuration, empty weight and center of gravity. These charts will also provide for continuous control of weight and balance of the helicopter.

The system of weight and balance computation requires the use of charts and forms. They are identified as follows:

- Chart A - Equipment List.
- Chart B - Helicopter Weighing Record.
- Chart C - Basic Weight and Balance Record.
- Chart D - Data for Helicopter Weight and Balance Computation
- Chart E - Weight and Balance Computation

3.9 Use of Charts and Forms

3.9.1 Use of Chart A

The Chart A gives the weight, arm and moment of all the standard and optional equipment, as shown in Figure 3.7 **[1]**. The manufacturer of the helicopter places check marks in the "Basic Configuration" column to identify the items of equipment in the helicopter for the weighing condition. A check (V) in the columns headed "In Helicopter" (Fig 3.7), indicates the presence of the item in the helicopter, and a zero (0) indicates its absence. The next columns of chart A will permit inspection of the helicopter for equipment actually installed. When making an inventory, note whether any items of equipment have been installed or removed and if so enter corresponding weight and moment change on Chart C.

Subsequent check list inventories shall be carried out in the following cases:

1. When the helicopter undergoes modification, major repair or overhaul.
2. When changes in equipment are made for a different type of operation.
3. When the helicopter is reweighed.

For all pages of Chart A:
— √ Means installed on the helicopter
— O Means not installed on the helicopter

CHART A - EQUIPMENT LIST
Report

Page of

RECORD OF CHECKING (Date and Signature)

MODEL: AW139 | REGISTRATION MARKS | S/N

ITEM NUMBER	POWER PLANT SYSTEM P/N	POWER PLANT SYSTEM DENOMINATION	Qty	WEIGHT (Kg)	ARM (mm)	MOMENT (Kgmm)	Basic configuration	In helicopter	Chart C entry	In helicopter	Chart C entry	In helicopter	Chart C entry

Figure 3.7: Chart A- Equipment list

3.9.2 Use of Chart B

The use of Chart B is as follow:

1. Enter the actual scale readings in the first column of sheet 1. Subtract tare, if any, from the scale readings to obtain the net weight.
2. Multiply the net weights by their respective arms.
3. Add the net weight and moments.
4. Divide the total moment by the net weight to obtain “as weighed” CG position. Transfer the “TOTAL” (as weighed) weight arm and moment to the sheet 2 of Chart B.
5. Subtract the total weight and moment of equipment weighed but not part of the basic helicopter (list these items in column one).
6. Add the weight and moment of unusable fuel.
7. Add the total weight and moment of the basic items not in helicopter when weighed (list these in column two). Added items shall be marked on Chart A.
8. Enter the new basic weight and moment on Chart C.

We find the Chart B, sheet 1 and 2, shown in Figure 3.8 and Figure 3.9 **[1]**.

CHART B - HELICOPTER WEIGHING RECORD			Sheet 1 of 2
MODEL:	S/N:	REGISTRATION MARKS:	
DATE:	PLACE:	SIGNATURE:	
Reason for weighing:			
Scale type:			

JACKPOINTS	SCALE READING	TARE	NET WEIGHT	STA (1)	LONGITUDINAL MOMENT	BL (2)	LATERAL MOMENT
	(Kg)	(Kg)	(Kg)	(mm)	(Kgmm)	(mm)	(Kgmm)
FORWARD				3160		0	
LH AFTERWARD				6700		-905	
RH AFTERWARD				6700		905	
TOTAL (as weighed) (to Sht. 2 of 2)							

Note 1
The forward lower Central Cabin is provided by two FWD jack points, only one FWD jack point is assured by using a proper tool which collect both jacking points.
The Station Reference Datum (STA 0) is located 3160 mm forward the FWD jack points. Therefore the STA are positive.
E = Distance from the reference datum (STA 0) to the FWD jackpoint Station of 3160 mm.
F = Distance from the reference datum (STA 0) to the LH and RH aft jackpoints Station of 6700 mm.

Note 2
The Buttock Line Reference Datum (BL 0) is located on the fuselage Center Line.
Therefore the BL are negative on the Left Hand side and positive on the Right Hand side.

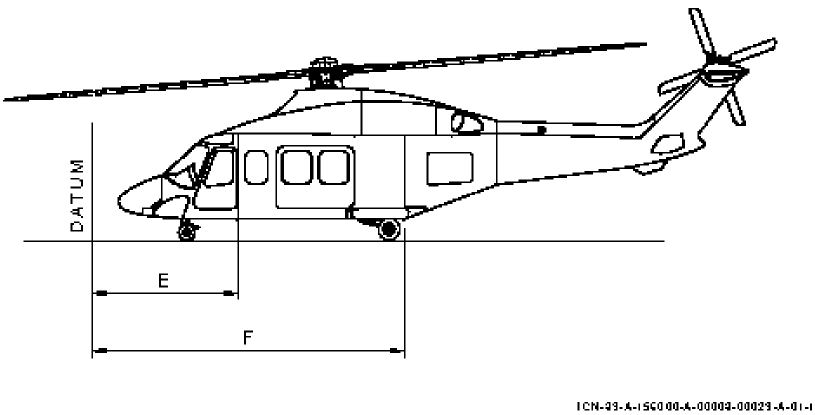


Figure 3.8: Chart B- Helicopter weighing record Page 1

CHART B - HELICOPTER WEIGHING RECORD					Sheet 2 of 2
DESCRIPTION	NET WEIGHT	STA	LONG. MOMENT	BL	LAT. MOMENT
	(Kg)	(mm)	(Kgmm)	(mm)	(Kgmm)
TOTAL (as weighed) (from Sht. 1 of 2)					
SUBTRACT (from Tab. 1)					
ADD (from Tab. 2)					
BASIC AIRCRAFT (to Chart C)					

TABLE 1 ITEMS WEIGHED BUT NOT PART OF BASIC WEIGHT					
DENOMINATION	WEIGHT	STA	LONG. MOMENT	BL	LAT. MOMENT
	(Kg)	(mm)	(Kgmm)	(mm)	(Kgmm)
TOTAL					

TABLE 2 BASIC ITEMS NOT INSTALLED WHEN WEIGHED					
DENOMINATION	WEIGHT	STA	LONG. MOMENT	BL	LAT. MOMENT
	(Kg)	(mm)	(Kgmm)	(mm)	(Kgmm)
TOTAL					

Reasons of the weighing:	Type Scales:

NOTE :
Remove the weight of the mission equipment items, which are pointed out in Chart A in [ ]

Figure 3.9: Chart B- Helicopter weighing record Page 2

3.9.3 Use of Chart C

Chart C is a continuous history of the basic weight and moment resulting from modifications and equipment is considered the current weight and balance status of the basic helicopter, as shown in Figure 3.10 **[1]**. We make additions or subtractions to the basic weight and moment in Chart C as follows:

1. When the helicopter undergoes modification, major repair or overhaul.
2. When changes in equipment are made for a different type of operation.
3. When the helicopter is reweighed.

If any equipment is not listed on Chart A, we determine its weight and arm, and we list corresponding data on Charts A and C.

CHART C BASIC WEIGHT AND BALANCE RECORD														Page N°
MODEL				S/N			REGISTRATION MARKS							
DATE	Item n° see Chart A		DENOMINATION	LOADING CHANGE					BASIC WEIGHT, MOMENT & COG					SIGNAT.
	IN (1)	OUT (2)		WGT (3) (Kg)	STA CG (mm)	LONG MOMENT (Kgmm)	BL CG (mm)	LATERAL MOMENT (Kgmm)	WGT (Kg)	LONG MOMENT (Kgmm)	STA CG (mm)	LATERAL MOMENT (Kgmm)	BL CG (mm)	

Note 1 IN = installed component **Note 2** OUT = removed component
Note 3 Weight of an installed component is positive (+) Weight of a removed component is negative (-)

Figure 3.10: Chart C- Basic weight and balance record

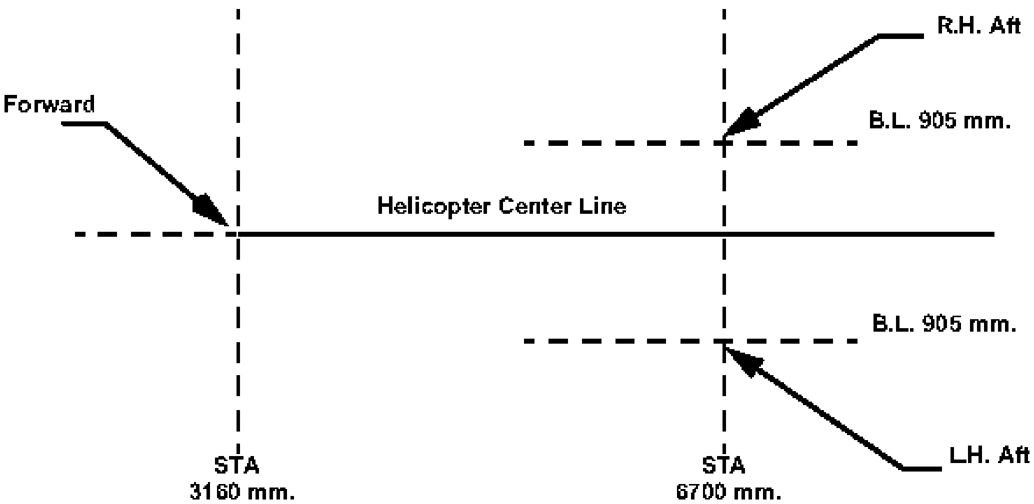
3.9.4 Use of Chart D

The Chart D provides information necessary for weight and balance computation. It is described, as shown in Figure 3.11 **[1]**.

CHART D - DATA FOR HELICOPTER WEIGHT & BALANCE COMPUTATION

MODEL AW139

JACKPOINTS LOCATION



Longitudinal STA. 0 (Datum) is 3160 mm. Forward of the front jackpoint.

TYPICAL DATA

		ARM		WEIGHT (Kg.)
		STA (mm.)	BL (mm.)	
FUEL	Capacity		0	
FUEL	Unusable	6206	0	16
ENGINE OIL	Capacity	6676	0	16
ENGINE OIL	Undrainable	—	—	0
ENGINE OIL	Baggage	7700		

NOTE 1 - For pilot and crew station and for further information see Section 6 of this Flight Manual.

NOTE 2 - For further information see specific section of this Flight Manual.

NOTE 3 - Empty weight includes undrainable oil and unusable fuel.

Figure 3.11: Chart D - Data for helicopter weight and balance computation

3.9.5 Use of Chart E

The Chart E serves as a work sheet and records the calculations and any corrections that must be made to ensure that helicopter will be within weight and CG limits, as shown in Figure 3.12 **[1]**.

A Chart E shall be filled prior to any flight. It is used as follow:

1. Enter the helicopter basic weight and moment. Obtain these figures from the last entry on Chart E,
2. Enter the weight of all applicable items in the marked “Weight”. Obtain the corresponding arms from Chart D and calculate the moments,
3. Add weight and moments. Divide total moment by total weight to obtain CG arm,
4. Ascertain that CG is within allowable limits,
5. Should corrections be required, readjust ballast to return CG within allowable limits.

CHART E - WEIGHT & BALANCE COMPUTATION FORM - (12 passengers)

MODEL	S/N	REGISTRATION MARKS		DATE	PLACE	COMPUTED BY
Ref.	ITEM	WEIGHT (Kg)	STA (mm)	LONG. MOMENT (Kgmm)	BL (mm)	LAT. MOMENT (Kgmm)
1	HELICOPTER EMPTY (Ref. To Chart C)					
2	PILOT		2820		550	
3	COPILOT		2820		-550	
4	PASSENGER A		3415		737	
5	PASSENGER B		3415		254	
6	PASSENGER C		3415		-254	
7	PASSENGER D		3415		-737	
8	PASSENGER E		4789		737	
9	PASSENGER F		4789		254	
10	PASSENGER G		4789		-254	
11	PASSENGER H		4789		-737	
12	PASSENGER I		5600		737	
13	PASSENGER L		5600		254	
14	PASSENGER M		5600		-254	
15	PASSENGER N		5600		-737	
16	LOOSE EQUIPMENT					
17	CABIN LOAD					
18	BAGGAGE COMPARTMENT LOAD		7700			
19						
20						
21	FUEL					
22	OIL		6878		0	
23						
24	**TOTAL WEIGHT**					
25	**BALLAST (If required)**					
26	**TAKE-OFF CONDITION**					

LIMITATIONS	REMARKS
Refer to Section 1	

Figure 3.12: Chart E – Weight and balance computation form

3.10 Conclusion

In conclusion, the importance of weight and balance determination in helicopter operations cannot be overstated. A solid understanding of weight and balance concepts, their impact on helicopter performance, and the various weighing methods and examination of payload distribution are crucial for safe and efficient helicopter operation. Accurate weight and balance determination is not only essential for safe flight, but it also helps to maintain the longevity of the aircraft, avoid premature wear and tear on the structure, rotor blades, and engines, and optimize fuel consumption and overall performance.

Moving forward, Chapter 4 will build on the knowledge gained in this chapter and delve deeper into the practical aspects of weight and balance determination. We will explore the weighing procedures required to determine accurate weight and balance, including preparing necessary tools, lifting the helicopter on jacks, and maintaining weight and balance records. Sample data will be used to illustrate the process, giving readers a comprehensive understanding of the weighing procedures involved.

4

Weighing Procedure

In this chapter, we will focus on defining key concepts related to the weighing procedure and weight and balance calculations. For efficient understanding of the subtleties of our topic, both the technical and operational weighing procedures must be understood. Each step of it will be presented in a clear and concise manner, with pictures and sketches where appropriate. By the end of this chapter, we will have a solid foundation of the terminology used in weight and balance calculations.

Contents

4.1 Introduction

Ensuring the safety and efficiency of an aircraft is a top priority for pilots and maintenance crews. Achieving these goals requires adherence to the parameters specified by the aircraft's designers, particularly with regards to weight and balance. In fact, proper weight and balance are critical to maintain an aircraft's structural integrity and performance, as well as its stability and control. The process of achieving proper weight and balance involves three key elements: weighing the aircraft, maintaining accurate records, and loading the aircraft correctly. Any inaccuracies in these elements can render the weight and balance calculations meaningless, compromising the aircraft's safety and efficiency.

The weight and balance of a helicopter are critical factors for organizations that use them for rescue and emergency operations. Improper balance can lead to a loss of control, resulting in accidents. Therefore, the center of gravity (CG) must be considered for each mission. As changes in payload or configuration can shift the CG.

Calculating the weight and balance for each mission can be time-consuming and challenging. However, it is essential to ensure that the helicopter is safe to fly and can operate at peak performance. The weight and balance calculations take into account the weight of the helicopter, fuel, crew, and any payloads.

4.2 Weighing

4.2.1 Definition of Weighing

Weighing an aircraft is the process of determining the weight and balance of an aircraft. It involves measuring the weight of various components of the aircraft, including the engines, fuel, cargo, passengers, and any other items on board, as well as the location of these components with respect to the aircraft's center of gravity. This information is used to ensure that the aircraft is within its maximum weight and balance limits and to calculate the correct takeoff and landing speeds, as well as the amount of fuel required for a given flight. Weighing an aircraft is a critical safety procedure that is required by aviation authorities to be carried out periodically, typically at regular intervals or when any significant modifications or repairs are made to the aircraft.

4.2.2 Periodicity of Weighing

The helicopter must be weighed, in these cases:

- when major modifications or repairs are made, or kits are installed /removed.
- when the basic weight data is suspected to be an error.
- at time of major overhaul.
- in accordance with E.A.S.A. instructions.

4.2.3 Necessity of Weighing

Weighing an aircraft is an essential safety procedure that helps ensure that it is loaded and operated within its safe weight and balance limits, which is critical for safe and efficient flight operations. There are several reasons why an aircraft must be weighed, including:

- **Safety:** The weight and balance of an aircraft are critical factors that affect its performance, stability, and safety. If an aircraft is loaded improperly, it may become unstable, difficult to control, or even crash. Weighing an aircraft helps ensure that it is loaded correctly and within its safe weight and balance limits.
- **Compliance with regulations:** Aviation authorities require that aircraft be weighed periodically to ensure compliance with safety regulations. These regulations specify maximum weight and balance limits for different aircraft types and configurations.
- **Maintenance:** The weight and balance of an aircraft can change over time due to factors such as modifications, repairs, or the accumulation of dirt and debris. Weighing an aircraft periodically helps operators to detect any changes in weight and balance and take corrective actions if necessary.

4.3 Weighing procedure

The helicopter weighing procedure is a critical task that needs to be done with most care and accuracy. The following steps should be taken to prepare and weigh the helicopter.

4.3.1 Safety instructions

In order to ensure safety, the following instructions must be followed:

- The helicopter must be weighed in a closed hangar.
- Dirt, grease, moisture, etc. must be removed from the helicopter.

4.3.2 Preparing the necessary tools for the weighing

The following tools are used to calculate the aircraft's total weight and center of gravity, which are critical factors for ensuring safe and efficient flight.

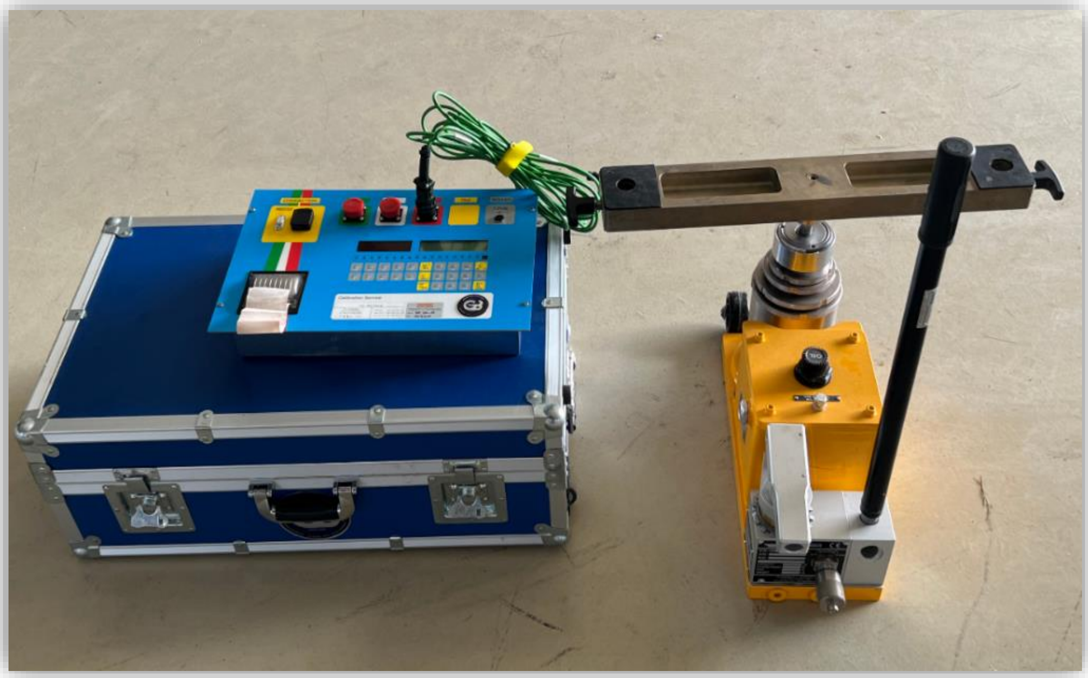


Figure 4.1: The necessary tools for weighing procedure

4.3.2.1 Jack

A jack is a specialized tool used to lift or support an aircraft during maintenance, repair, or servicing. Its Height is equal to 254 mm **[5]**. Aircraft jacks are designed to safely and securely lift and hold the weight of an aircraft, while distributing the load evenly to prevent damage to the airframe.

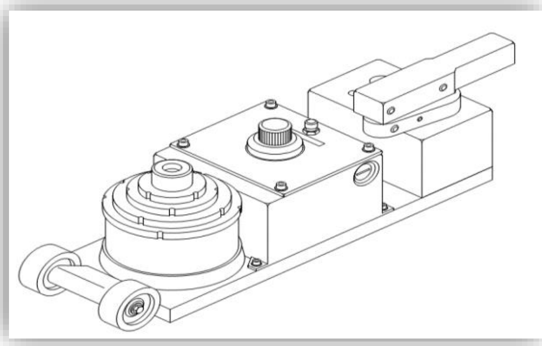


Figure 4.2: Jack's sketch

There are various types of jacks used in aeronautics, including hydraulic jacks, screw jacks, and bottle jacks. Hydraulic jacks are the most commonly used type and work by using hydraulic pressure to lift and hold the aircraft.

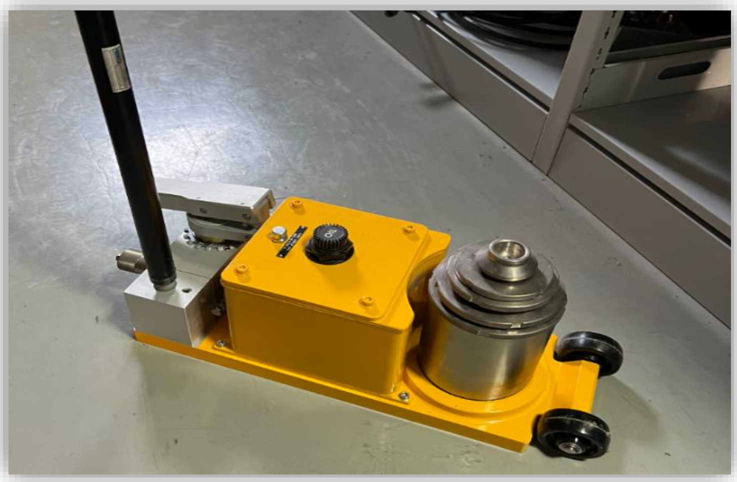


Figure 4.3: Hydraulic jack

Proper use of jacks is crucial in ensuring the safety of both the aircraft and the maintenance personnel working on it. The location and method of attachment of the jack must be carefully selected to avoid causing damage to the airframe or interfering with any critical systems or components.

Additionally, jacks should always be operated by trained and experienced personnel, and should be regularly inspected and maintained to ensure their safe and effective use.

In the weighing procedure of an AW139, we usually use three jacks on three jack points.

Figure 4.4: AW139 leveled by jacks

4.3.2.2 Weighing bucket bar

The weighing bucket bar is a device used to determine the weight and center of gravity of an helicopter. It typically consists of a long bar or beam that is suspended from a support point put on the jack and equipped with attachment points for the aircraft. The aircraft is positioned on the weighing bar, and the weight and balance of the aircraft are measured by recording the weight on each attachment point and the distance between the attachment point and the support point.

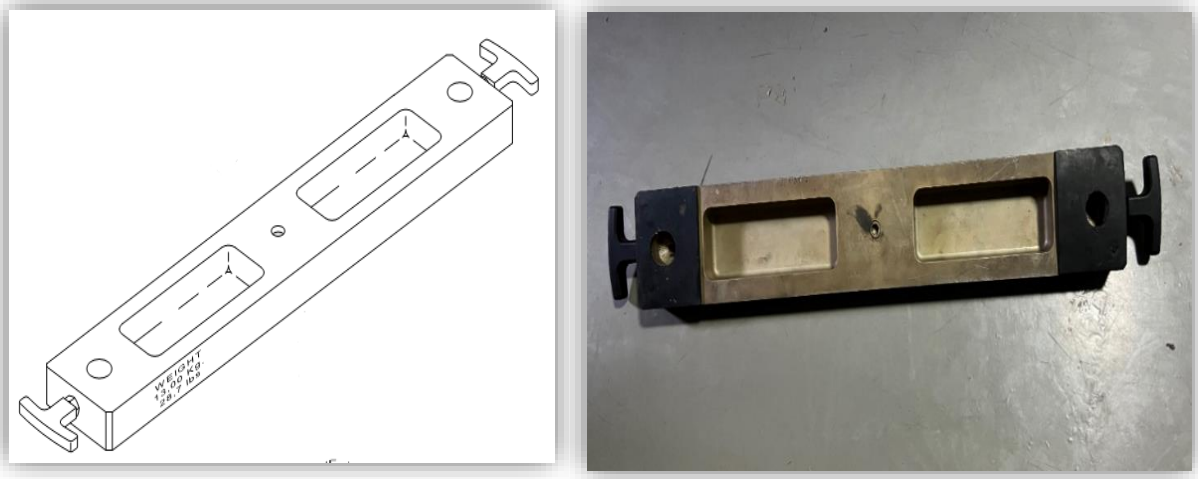


Figure 4.5: Weighing bucket bar sketch and real

4.3.2.3 Weighing tool kit equipment

The weighing tool kit consists of a set of equipment used to measure the weight and balance of an aircraft. This tool kit may include items such as weighing scales, digital or mechanical balances, load cells, tension meters, plumb bobs, spirit levels, and calculators that are used in conjunction with the jacks and the weighing bar to measure the weight and balance of various parts of the aircraft. The tool kit is an essential component of aircraft maintenance and it is used to ensure that is properly balanced and meets regulatory requirements for safe and efficient flight.

Figure 4.6: JetWeigh Weighing tool kit equipment

Figure 4.7: JetWeigh Weighing tool kit equipment with calculators

4.3.3 Preparing the helicopter for weighing

To prepare the helicopter for weighing, we must do the steps bellow.

- **Defueling the fuel tanks:** This step involves removing all fuel from the fuel tank to get the helicopter's basic empty weight during the weighing process.

Figure 4.8: Defueling evacuation hole

- **Checking the oil level in the engines:** It is essential to ensure that the oil level in the engines is at the appropriate level before the helicopter is weighed. If the oil level is low, it should be topped up with the appropriate oil.

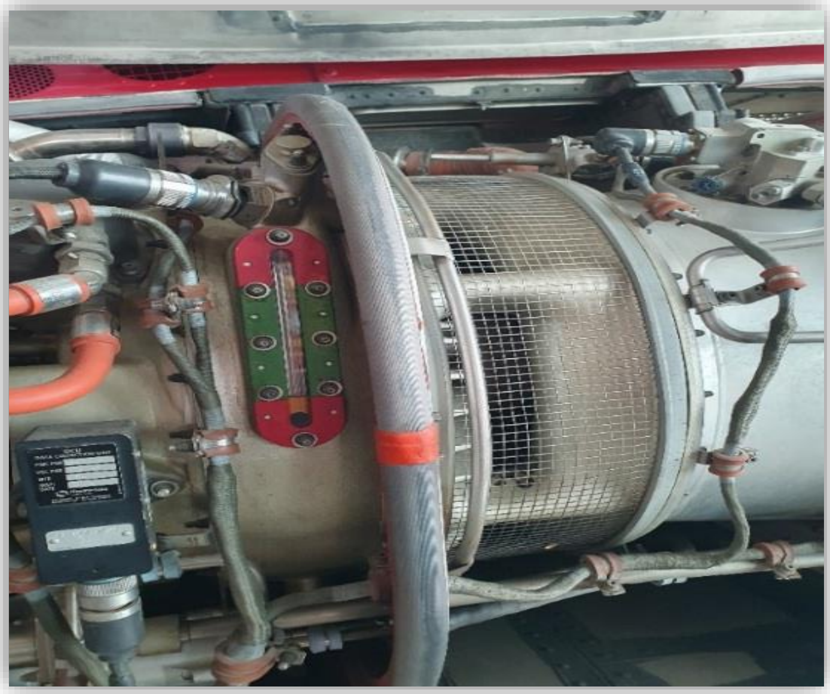


Figure 4.9: The engine's oil gauge

- **Checking the oil level in the main gearbox:** The main gearbox is a critical component of the helicopter, and it is essential to ensure that it has the appropriate amount of oil. If the oil level is low, it should be topped up with the appropriate oil.

Figure 4.10: The main gearbox's oil gauge

- **Checking the oil level in the intermediate gearbox:** Similar to the main gearbox, the intermediate gearbox is also essential, and its oil level should be checked and topped up if necessary.

Figure 4.11: The intermediate gearbox's oil gauge

- **Checking the oil level in the tail gearbox:** The tail gearbox is also an important component that needs to have the appropriate oil level. If the oil level is low, it should be topped up with the appropriate oil.

Figure 4.12: The tail gearbox's oil gauge

- **Checking the fluid level in the power control modules:** The power control module is responsible for regulating the power delivered to the helicopter's rotor. It is essential to ensure that it has the appropriate amount of fluid.

Figure 4.13: The power control modules

- **Checking the fluid level in the brake reservoir:** The brake reservoir is responsible for storing hydraulic fluid for the helicopter's brakes. It is essential to ensure that it has the appropriate amount of fluid.

Figure 4.14: The brake reservoir

- **Aligning the main-rotor blade with the tail cone:** It is important to position the main rotor blade correctly to ensure that the helicopter's blade weight is distributed equally during the weighing process.

Figure 4.15: The AW139's aligned main and tail rotors

- **Setting the rotor brake to ON:** After aligning the main rotor blade, the rotor brake should be turned ON to ensure that the rotor is stationary during the weighing process.

-a- OFF position **-b- Pumping action until having a nominal pressure** **-c- ON position**

Figure 4.16: Rotor brake in different positions

Ultimately, before lifting the helicopter on jacks for weighing, it should be noted that certain individuals must be present during the weighing of the helicopter, such as:

- VERITAL authorities.
- Maintenance engineers.
- Flight operations engineers.
- Quality and safety flight engineers.

Figure 4.17: The weighing procedure attendees on the 5th April 2023

4.3.4 Lifting the helicopter on jacks for weighing

We install leveling equipment on helicopter as outlined in the Maintenance Manual, and it’s a must that the helicopter is in an area where the wind cannot affect it. The helicopter should be lifted on jacks in a hangar where there is no wind, because it can cause the helicopter to move and affect the safety of the weighing process.

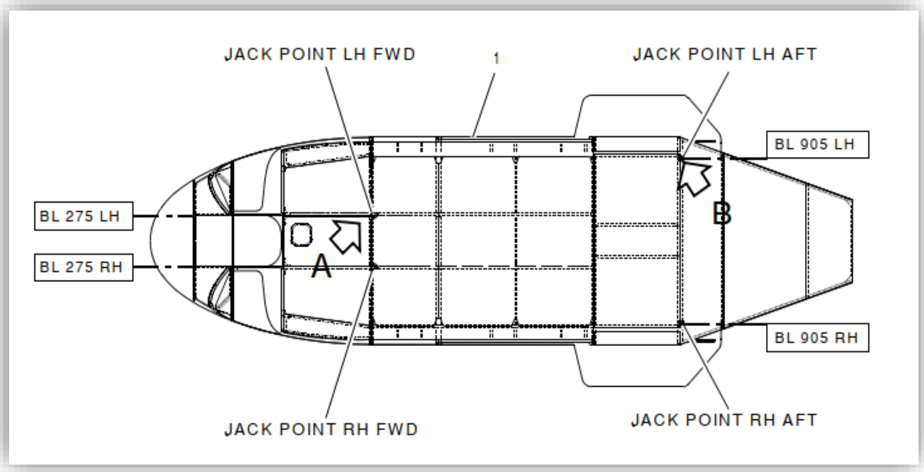


Figure 4.18: Forward and afterward jack points of the AW139 (bottom view)

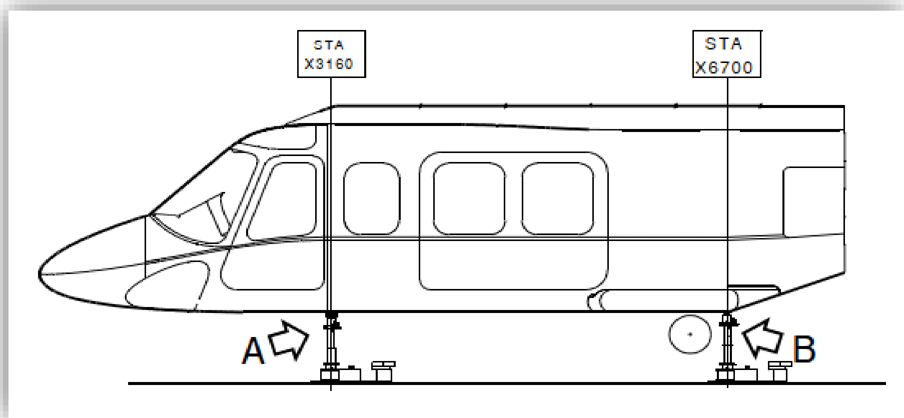


Figure 4.19: Forward and afterward jack points of the AW139 (profile view)

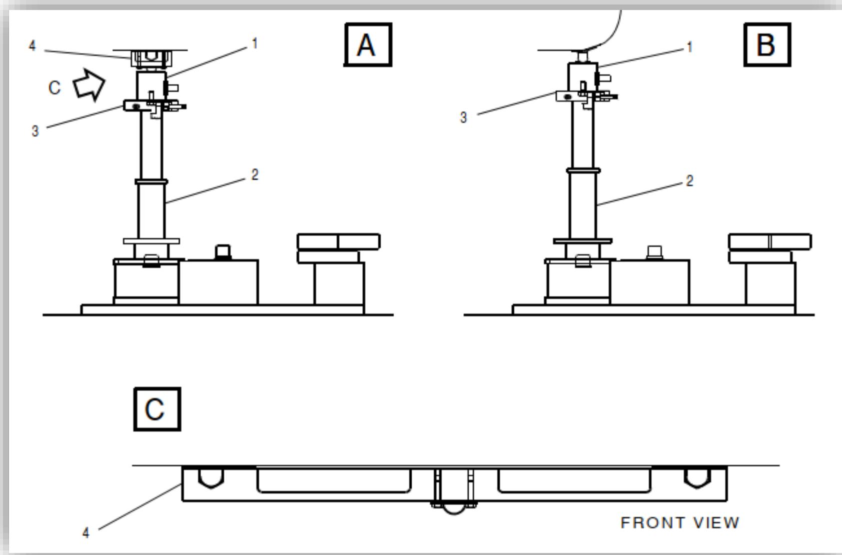


Figure 4.20: Forward and afterward jack points of the AW139 (front view)

As seen in the sketches of the positions of the jack points of the AW139, four engineers will make sure to lift the helicopter correctly on the jacks, each one of them will take the responsibility of each jack and the fourth one will guide them during this procedure.

Figure 4.21: Forward and afterward jack points respectively of the AW139

4.3.5 Weighing procedure progress

The first necessary step of weighing procedure progress is making sure that weighing equipment is zeroed during the weighing procedure to ensure that the values that will be extracted correctly.

Figure 4.22: Weighing equipment zeroed

And then, connecting each cell to the scales equipment. This step is essential to relate each jack with its accordinate scale. Color coded spherical adapters must be used, in conjunction with color load cells, as shown in Table 4.1.

Table 4.1: Jack point configuration

Three load cells for helicopters		
Channel 1	Red	Left
Channel 2	Yellow	Right
Channel 3	Blue	Nose

Figure 4.23: Helicopter lifted by three jacks related to scales

After that, letting each cell and the scale indications become stable while they're just being connected. This permits to stabilize the reading, to ensure that the values that will be extracted correctly.

Figure 4.24: Weighing equipment stabilizing

Then, recording the weights shown on the scales for each cell, making sure that the records are related to jack position for each weight.

Table 4.2: Scale reading weights

Forward jack point scale reading weight	1536 Kg
Left afterward jack point scale reading weight	1458 Kg
Right afterward jack point scale reading weight	1558 Kg

Therefore, we can calculate the total weight and longitudinal and lateral Center of Gravity (CG) positions by the equations bellow.

The Total weight is calculate using the following equation, **[1]**:

$$\text{Total weight} = \sum \text{jack point scale reading weights} \quad (4.1)$$

$$= \text{Forward jack point scale reading weight}$$
$$+\text{Left afterward jack point scale reading}$$
$$+\text{Right afterward jack point scale reading weight} \quad (4.2)$$

Taken the previous jack point scales reading of Table 4.2 as an example, we obtain:

$$\text{Total weight} = 1536 + 1458 + 1558$$
$$= 4552 \text{ Kg} \quad (4.3)$$

The formula for the total longitudinal moment (M_{long}) is given by, **[1]**:

$$M_{long} = \sum \text{forward and afterwards } M_{long}$$
$$= \text{Forward } M_{long} + \text{Left afterward } M_{long} + \text{Right afterward } M_{long} \quad (4.4)$$

such as, the longitudinal moments are defined as follows, **[1]**:

$$\text{Forward } M_{long} = \text{forward jack point scale reading} \times STA_{(FD)}, \quad (4.5)$$

$$\text{Left afterward } M_{long} = \text{Left afterward jack point scale reading} \times STA_{(LAD)}, \quad (4.6)$$

$$\text{Right afterward } M_{long} = \text{Right afterward jack point scale reading} \times STA_{(RAD)}. \quad (4.7)$$

Using weight values from Table 4.2, we can calculate forward and afterward M_{long}. For example:

$$\text{Forward } M_{long} = 1536 \times 3160$$
$$= 4853760 \text{ Kgmm} \quad (4.8)$$

$$\text{Right afterward } M_{long} = 1558 \times 6700$$
$$= 10438600 \text{ Kgmm} \quad (4.9)$$

with, $STA_{(FD)}$ = 3160 and $STA_{(RAD)}$ = 6700, from Chart B.

From Equations (4.4), (4.5), (4.6), (4.7), and Table 4.2, the total longitudinal moment (M_{long}) is obtained as follows:

$$M_{long} = 4853760 + 9768600 + 10438600$$

$$= 25060906 \text{ Kgmm} \tag{4.10}$$

The Total Station (STA) is given by, **[1]**:

$$\text{Total STA} = \frac{M_{long}}{\text{Total weight}} \tag{4.11}$$

We can deduce the value of the total Station (STA), using Equations (4.3) and (4.10), as follows:

$$\text{Total STA} = \frac{25060906}{4552}$$

$$= 5505.48 \text{ mm} \tag{4.12}$$

The formula for the total lateral moment is given by, **[1]**:

$$M_{lat} = \sum \text{forward and afterwards } Ms_{lat}$$

$$= \text{Forward } M_{lat} + \text{Left afterward } M_{lat} + \text{Right afterward } M_{lat} \tag{4.13}$$

where, the lateral moments (M_{lat}) are given by, **[1]**:

$$\text{Forward } M_{lat} = \text{forward jack point scale reading} \times BL_{(FD)} \tag{4.14}$$

$$\text{Left afterward } M_{lat} = \text{Left afterward jack point scale reading} \times BL_{(LAD)} \tag{4.15}$$

$$\text{Right afterward } M_{lat} = \text{Right afterward jack point scale reading} \times BL_{(RAD)} \tag{4.16}$$

with BL the Buttock Line.

From Equation (4.15) for example, we have:

$$\text{Left afterward } M_{lat} = 1458 \times (-905)$$

$$= -1319490 \text{ Kgmm} \tag{4.17}$$

Thus, the total lateral moment is deduced as follows:

$$M_{lat} = 0 + (-1319490) + 1409990$$

$$M_{lat} = 90500 \text{ Kgmm} \tag{4.18}$$

The total Buttock Line (BL) is also calculated by, **[1]**:

$$\text{Total BL} = \frac{M_{lat}}{\text{Total weight}} \tag{4.19}$$

Using Equations (4.18) and (4.3), we obtain:

$$\text{Total BL} = \frac{90500}{4552}$$

$$= 19.88 \text{ mm} \tag{4.20}$$

After calculating the total weight and the total longitudinal and lateral moments, we continue the procedure by disconnecting each cell from the scales equipment then lowering the helicopter and repeating this procedure two times to confirm that the previous calculations are correct, to avoid every instrumental error.

Once the right records choosen, we calculate the new real empty weight by subtracting the weight of the items weighed, even that they are not a part of the basic weight (engine oil and bracket), and adding the weight of basic items, that are not installed during the weighing procedure, as shown in the next calculations related to our previous weighing.

Let the Items weighed, but not part of basic weight, be considered as engine oil and bracket, and let Basic items not installed when weighed be considered as the seats and the unsusable fuel. Therefore, the real empty weight, or basic weight, is given as follows, **[1]**:

$$\text{Basic weight} = \text{Net weight} - W_{\text{sub}} + W_{\text{add}} \tag{4.21}$$

where Net weight is the weight recorded, W_{sub} and W_{add} are the weight of the Items weighed, but not part of basic weight, and the weight of basic items not installed when weighed respectively, given by, **[1]**:

$$W_{\text{sub}} = W_{\text{engine oil}} + W_{\text{bracket}} \tag{4.22}$$

$$W_{\text{add}} = W_{\text{seats}} + W_{\text{unusable fuel}} \tag{4.23}$$

with,

$W_{\text{engine oil}}$: weight of the engine oil, equal to 16 Kg

W_{bracket} : weight of the bracket, equal to 13.1 Kg

W_{seats} : weight of the seats, equal to 56.4 Kg

$W_{\text{unusable fuel}}$: weight of the unusable fuel, equal to 16 Kg

From the values above, W_{sub} and W_{add} obtained are:

$$W_{\text{sub}} = 16 + 13.1$$

$$= 29.1 \text{ Kg} \tag{4.24}$$

$$W_{add} = 56.4 + 16$$

$$= 72.4 \text{ Kg} \tag{4.25}$$

Using Equations (4.3), (4.21), (4.24), and (4.25), the basic weight, is:

$$\text{Basic weight} = 4452 - 29.1 + 72.4$$

$$\text{Basic weight} = 4595.3 \text{ Kg} \tag{4.26}$$

And this basic empty weight is directly recorded in the Chart C, with its necessary information as the longitudinal and lateral moments, station and buttock line.

4.3.6 Weight and balance records

As a result of the previous procedure, the weight and balance records include all the information about any modifications or repairs made to the aircraft that affect its weight or balance to determine the new correct weight and balance for the aircraft. All these information are mentioned in both Chart B and Chart C. Then the center of gravity will be represented on its graphic envelope, as shown in Figure 4.28 and Figure 4.29 below.

CHART B - HELICOPTER WEIGHING RECORD		Sheet 1 of 2
MODEL: AW139	S/N: 31402	REGISTRATION MARKS: 7T-VWF
DATE: 05/04/2023	PLACE: DEB	SIGNATURE:

Reason for weighing: To find empty weight & CG to comply with the authority requirements

Scale type: JetWeigh PN: 64001-06J5 SN: 1156G4

JACKPOINTS	SCALE READING	TARE	NET WEIGHT	STA (1)	LONGITUDINAL MOMENT	BL (2)	LATERAL MOMENT
	(Kg)	(Kg)	(Kg)	(mm)	(Kgmm)	(mm)	(Kgmm)
FORWARD	1536		1536	3160	4853760	0	0
LH AFTERWARD	1458		1458	6700	9768600	-905	-1319490
RH AFTERWARD	1558		1558	6700	10438600	905	1409990
TOTAL (as weighed) (to Sht. 2 of 2)			4552	5505.48	25060960	19.88	90500

Note 1
The forward lower Central Cabin is provided by two FWD jack points, only one FWD jack point is assured by using a proper tool which collect both jacking points.
The Station Reference Datum (STA 0) is located 3160 mm forward the FWD jack points. Therefore the STA are positive.
E = Distance from the reference datum (STA 0) to the FWD jackpoint Station of 3160 mm.
F = Distance from the reference datum (STA 0) to the LH and RH aft jackpoints Station of 6700 mm.

Note 2
The Buttock Line Reference Datum (BL 0) is located on the fuselage Center Line.
Therefore the BL are negative on the Left Hand side and positive on the Right Hand side.

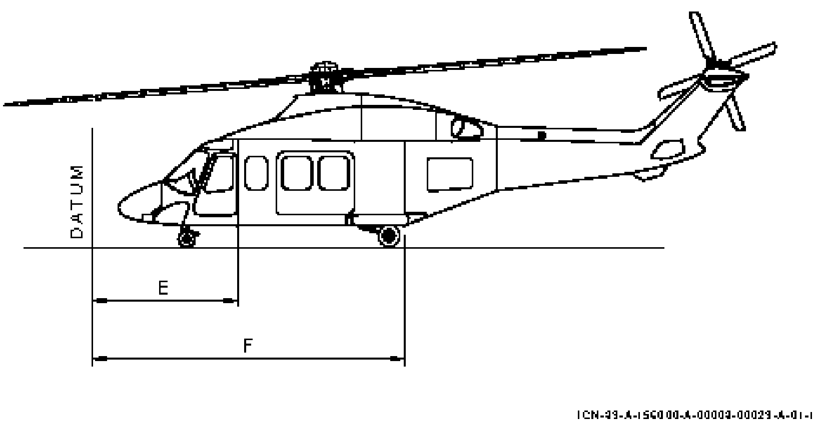


Figure 4.25: Chart B's page 01 of the weighing procedure made on 05th April 2023

CHART B - HELICOPTER WEIGHING RECORD					Sheet 2 of 2
DESCRIPTION	NET WEIGHT (Kg)	STA (mm)	LONG. MOMENT (Kgmm)	BL (mm)	LAT. MOMENT (Kgmm)
TOTAL (as weighed) (from Sht. 1 of 2)	4452	5505.48	25060960	19.88	90500
SUBTRACT (from Tab. 1)	-29.1	5202.61	-151396	0	
ADD (from Tab. 2)	72.4	5102.14	369395.6	0	
BASIC AIRCRAFT (to Chart C)	4595.3	5405.01	25278959.6	19.69	90500

TABLE 1 ITEMS WEIGHED BUT NOT PART OF BASIC WEIGHT

DENOMINATION	WEIGHT (Kg)	STA (mm)	LONG. MOMENT (Kgmm)	BL (mm)	LAT. MOMENT (Kgmm)
engine oil	16	6875	110000		
bracket, forward jacking	13.1	3160	41396		
TOTAL	29.1	5202.61	151396		

TABLE 2 BASIC ITEMS NOT INSTALLED WHEN WEIGHED

DENOMINATION	WEIGHT (Kg)	STA (mm)	LONG. MOMENT (Kgmm)	BL (mm)	LAT. MOMENT (Kgmm)
unusable fuel	16	6206	99296		
seat × 4	56.4	4789	270099.6		
TOTAL	72.4	5102.14	369395.6		

Reasons of the weighing:	Type Scales:
To find empty weight & GC to comply with the authority requirements	JetWeigh PN: 64001-06J5 SN:1156G4

NOTE :
Remove the weight of the mission equipment items, which are pointed out in Chart A in [ ]

Figure 4.26: Chart B's page 02 of the weighing procedure made on 05th April 2023

CHART C BASIC WEIGHT AND BALANCE RECORD													Page N°	
MODEL AW139			S/N 31402		REGISTRATION MARKS 7T-VWF									
DATE	Item n° see Chart A		DENOMINATION	LOADING CHANGE					BASIC WEIGHT, MOMENT & COG					SIGNAT.
	IN (1)	OUT (2)		WGT (3) (Kg)	STA CG (mm)	LONG MOMENT (Kgmm)	BL CG (mm)	LATERAL MOMENT (Kgmm)	WGT (Kg)	LONG MOMENT (Kgmm)	STA CG (mm)	LATERAL MOMENT (Kgmm)	BL CG (mm)	
05/04/2023	V		EMPTY WEIGHT Weighed with these parts removed : - Kit Cargo Hook - Hoist System - Search Light SX16						4595.3	25278959.6	5405.01	90500	19.69	

Note 1 IN = installed component **Note 2** OUT = removed component
Note 3 Weight of an installed component is positive (+) Weight of a removed component is negative (-)

Figure 4.27: Chart C of the weighing procedure made on 05th April 2023

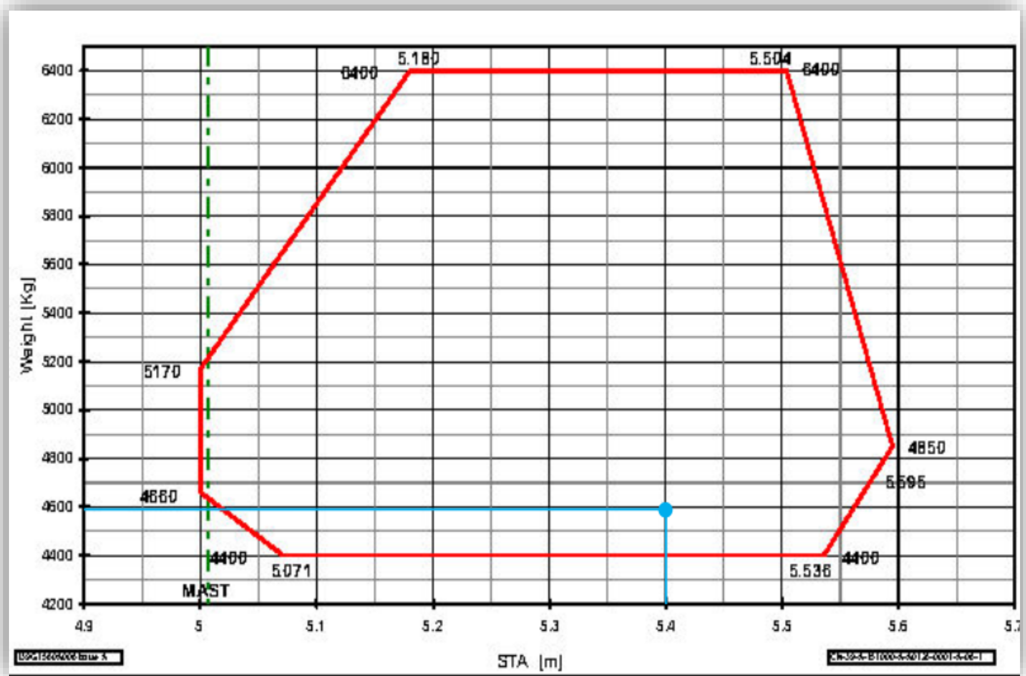


Figure 4.28: Longitudinal CG envelope

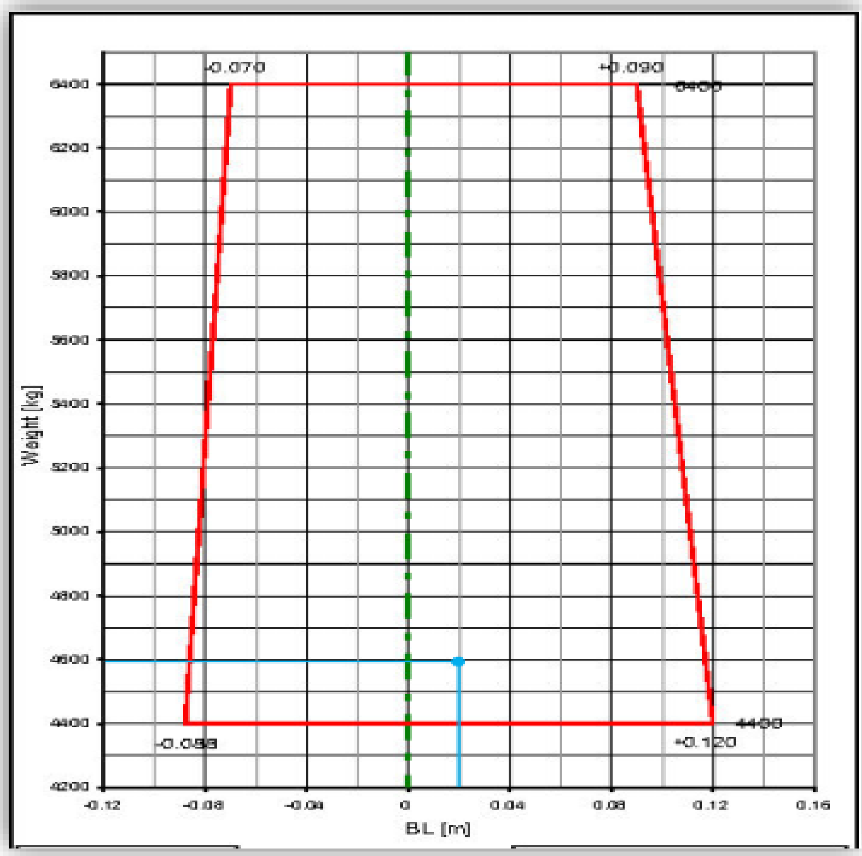


Figure 4.29: Lateral CG envelope

4.3.7 Preparing a new flight

After that the weighing procedure is done and both Chart B and Chart C are filled with the necessary information about the weight and balance of the helicopter, the CG is determined in its envelope. In case a new flight mission is scheduled, we have to prepare the Chart E that contains the previously recorded data and the real new payload (crew, fuel, ..), and a new CG is depicted for the desired flight on the D-day, as shown below :

- First, we enter the helicopter basic weight and moment, obtained from the last entry on Chart C.
- Second, we enter the weight, longitudinal and lateral moments, stations and buttock lines of the new equipments added to the configuration depending on the mission.

Then, we enter the weight of all applicable items in the marked “Weight”, than we calculate the longitudinal moment of the pilot as fellows, **[1]**:

$$M_{\text{long (pilot)}} = W_P \times STA_P \tag{4.27}$$

where,

$M_{\text{long (pilot)}}$: Longitudinal Moment of the pilot (Kg.mm)

W_P : Weight of the pilot (Kg)

STA_P : Station of the Pilot (mm)

In the case where $W_P = 80$ Kg and $STA_P = 2820$ mm, we have :

$$\begin{aligned} M_{\text{long (pilot)}} &= 80 \times 2820 \\ &= 225600 \text{ Kgmm} \end{aligned} \tag{4.28}$$

- Then, we add weight and moments, and devide total moment by total weight to obtain CG arm value using Equation (4.10):

$$\begin{aligned} STA_{\text{Total}} &= \frac{34604333{,}16}{6259{,}44} \\ &= 5528{,}34 \text{ mm} \end{aligned} \tag{4.29}$$

- Ascertain that CG is within allowable limits, using the CG longitudinal and lateral envelope,

CHART C BASIC WEIGHT AND BALANCE RECORD														Page N°
MODEL AW139				S/N 31402			REGISTRATION MARKS 7T-VWF							
DATE	Item n° see Chart A		DENOMINATION	LOADING CHANGE					BASIC WEIGHT, MOMENT & COG					SIGNAT.
	IN (1)	OUT (2)		WGT (3) (Kg)	STA CG (mm)	LONG MOMENT (Kgmm)	BL CG (mm)	LATERAL MOMENT (Kgmm)	WGT (Kg)	LONG MOMENT (Kgmm)	STA CG (mm)	LATERAL MOMENT (Kgmm)	BL CG (mm)	
05/04/2023	V		EMPTY WEIGHT Weighed with these parts removed : - Kit Cargo Hook - Hoist System - Search Light SX16						4595.3	25278959.6	5405.01	90500	19.69	
06/04/23	V		Stretcher Kit Aerolite (Installed)	95.6	4508	430964.8	0	0	4690.9	25709924.4	5480.81	90500	19.29	
06/04/23	V		Hoist Breeze (Installed)	89.94	4149	373161.06	950	85443	4780.84	26083085.46	5455.75	175943.0	36.8	
06/04/23		V	Middle Row Seat (Removed)	-56.4	7489	-270099.6	0	0	4724.44	25812985.86	5463.71	175943.0	37.24	

Note 1 IN = installed component Note 2 OUT = removed component
Note 3 Weight of an installed component is positive (+) Weight of a removed component is negative (-)

Figure 4.30: Chart C of the emergency medical service for primary air evacuations mission

CHART E - WEIGHT & BALANCE COMPUTATION FORM - (12 passengers)						
MODEL	S/N	REGISTRATION MARKS		DATE	PLACE	COMPUTED BY
Ref.	ITEM	WEIGHT (Kg)	STA (mm)	LONG. MOMENT (Kgmm)	BL (mm)	LAT. MOMENT (Kgmm)
1	HELICOPTER EMPTY (Ref. To Chart C)	4724.44	5463.71	25812985.86	37.24	175943.0
2	PILOT	80	2820	225600.00	550	44000.0
3	COPILOT	80	2820	225600.00	-550	- 44000.0
4	PASSENGER A		3415		737	
5	PASSENGER B		3415		254	
6	PASSENGER C		3415		-254	
7	PASSENGER D	80	3415	273200.00	-737	- 58960.0
8	PASSENGER E		4789		737	
9	PASSENGER F		4789		254	
10	PASSENGER G		4789		-254	
11	PASSENGER H		4789		-737	
12	PASSENGER I	70	5600	392000.00	737	51590
13	PASSENGER L		5600		254	
14	PASSENGER M		5600		-254	
15	PASSENGER N		5600		-737	
16	LOOSE EQUIPMENT					
17	CABIN LOAD					
18	BAGGAGE COMPARTMENT LOAD	25	7700	192500.00		0
19						
20						
21	FUEL	800		4985600.00		0
22	OIL		6878		0	
23						
24	**TOTAL WEIGHT**	5859.44	5479.62	32107485.86	28.77	168573.00
		REMARKS				

Figure 4.31: Chart E of the emergency medical service for primary air evacuations mission

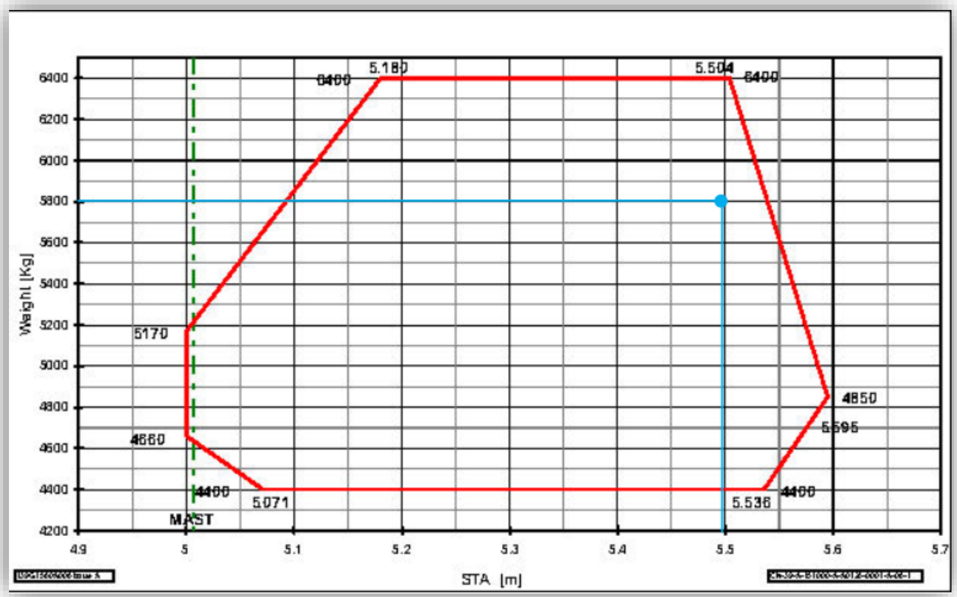


Figure 4.32: Longitudinal CG envelope of the emergency medical service for primary air evacuations mission

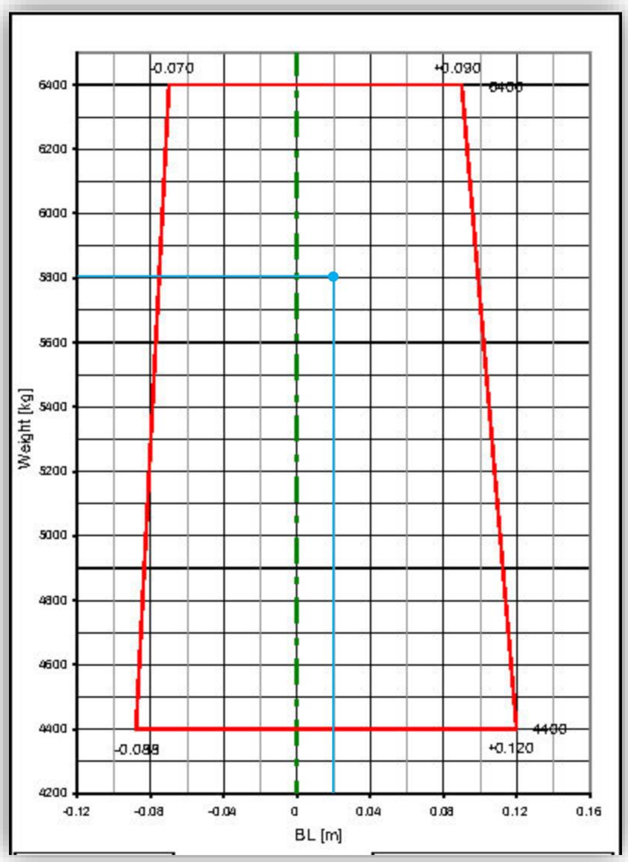


Figure 4.33: Lateral CG envelope of the emergency medical service for primary air evacuations mission

4.3.8 Particular case

In certain missions, the CG may be outside the envelope, and in such cases, it is determined based on the 6800 Kg envelope, as mentioned in Chapter 01, the AW139 is capable of conducting flights with a maximum takeoff weight ranging from 6400 Kg to 6800 Kg, like some operations are approved for weights between 6400 and 6800 kg with the following limitations:

- Hoist operations (Load Lowering or Raising): is permitted with helicopter in stationary hover and up to 80 KIAS in forward flight.
- Hoist operations (Load Deployed): cargo hook operations with maximum airspeed equal to 90 KTS

And the new CG envelopes used are shown below in Figure 4.34 and Figure 4.35 **[1]**.

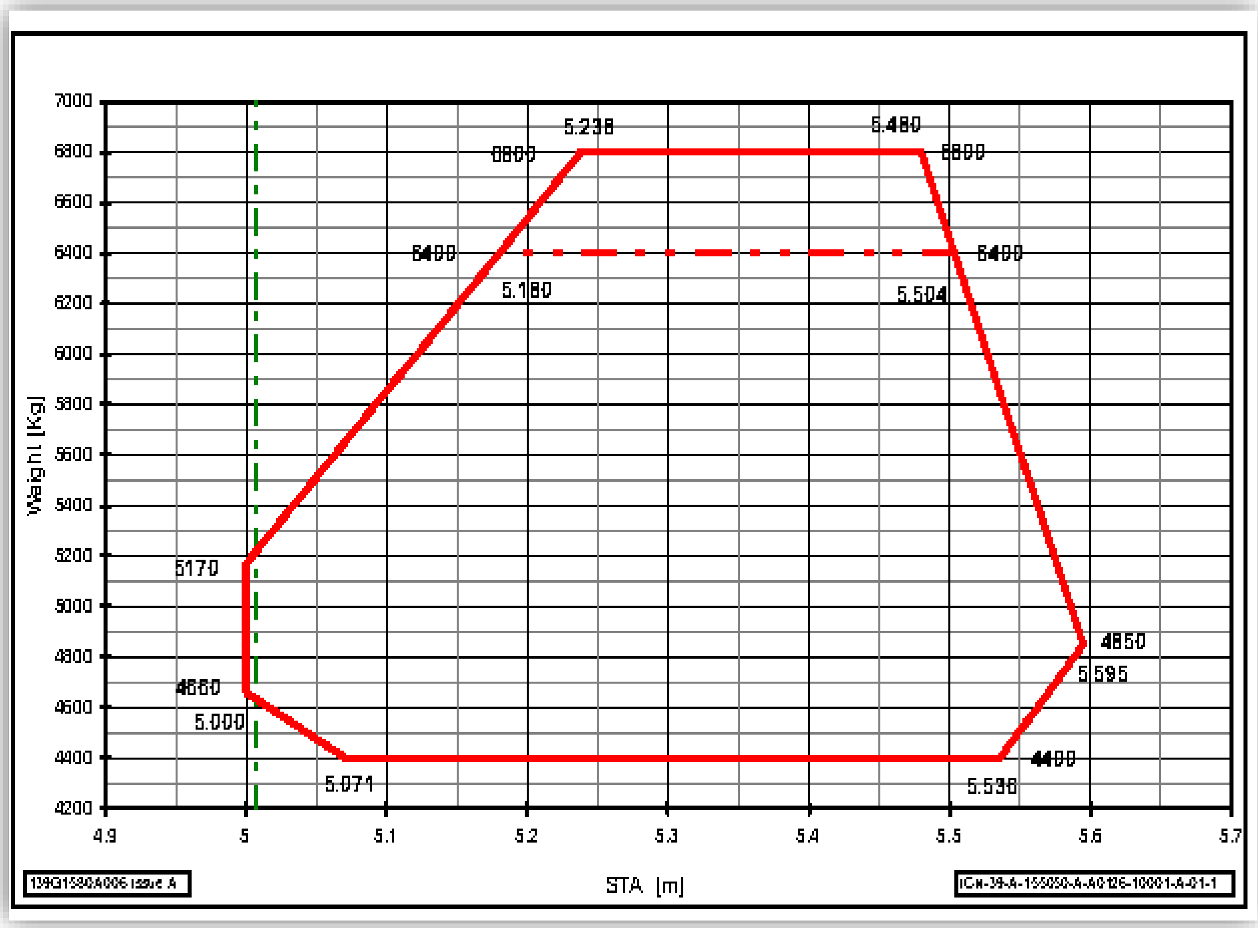


Figure 4.34: Longitudinal CG envelope for 6800 Kg

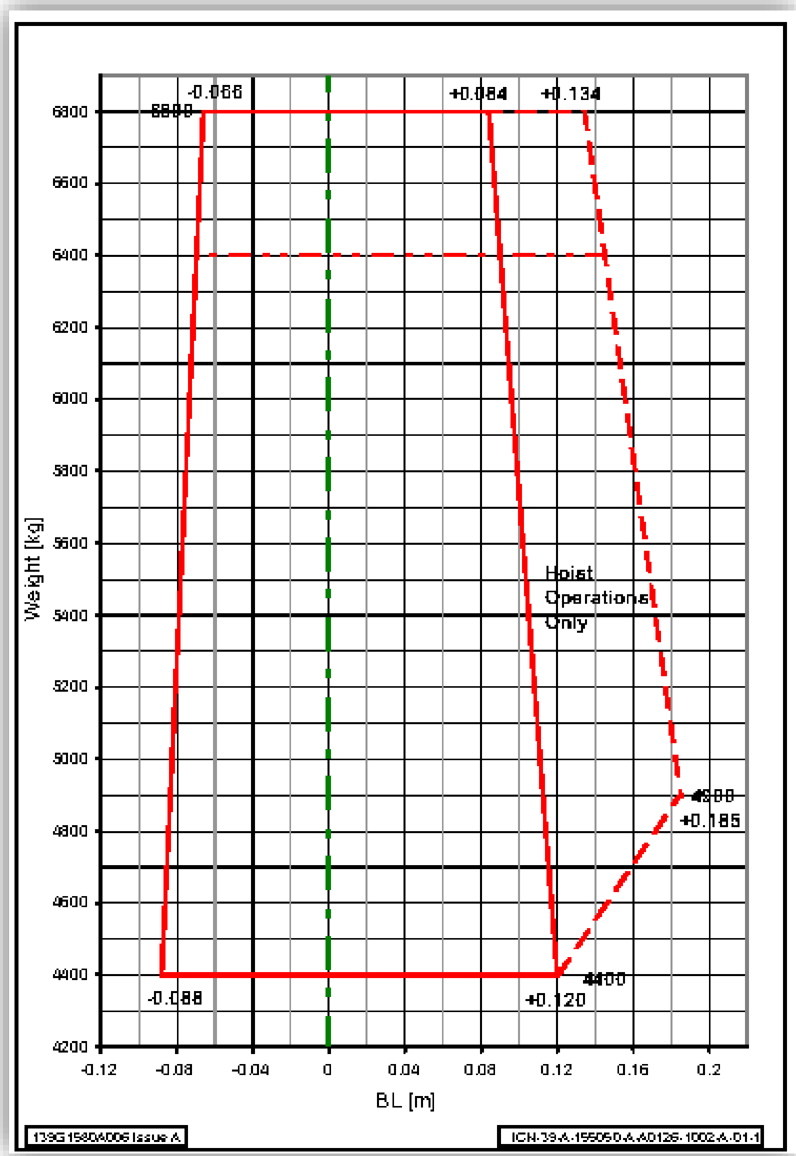


Figure 4.35: Lateral CG envelope for 6800 Kg

4.4 Conclusion

In conclusion, this chapter has provided a comprehensive analysis of the weighing procedure, and has shed light on both technical and operational steps during this process. Additionally, we've mentioned also all the necessary calculations to determine the total weight and both the longitudinal and lateral Center of Gravity (CG) positions.

Also, this chapter has identified several limitations encountered during the weighing procedure. These limitations highlight the need for further works to overcome them, as we will see in the next chapter.

Overall, this chapter has successfully addressed the research objectives and has presented the weighing process from many sights.

5

DIGITIZING WEIGHT AND BALANCE CHARTS OF THE HELICOPTER AW139: A COMPUTATIONAL APPROACH

This chapter explores the integration of Python programming to digitalize Weight and Balance processes for the AW139 helicopter within the Air Group of Civil Protection. Our focus lies in the development of a computational approach incorporating three key charts: the Helicopter Weighing Record (Chart B), Basic Weight and Balance Record (Chart C), and Weight and Balance Computation Form (Chart E). By leveraging the power of Python, we aim to enhance the efficiency and accuracy of Weight and Balance calculations.

Contents

5.1 Introduction

In the fast-paced world of aviation, the demand for efficient and accurate information is essential. Crews rely heavily on navigational charts to ensure safe and precise flight operations. However, the traditional method of using paper charts can be cumbersome and prone to errors. To address these challenges, the digitization of charts has emerged as a game-changing solution, revolutionizing the way crews access and interpret critical information.

This chapter delves into the process of digitizing three key charts of the AW139, the helicopter weighing record (Chart B), basic weight and balance record (Chart C), and weight and balance computation form (Chart E). The focal point of our discussion lies in utilizing Python, a versatile and powerful programming language, to automate this process. We will explore the fundamental concepts of Python, its relevance in the aeronautics field, and its exceptional capabilities for handling complex tasks.

Python has gained immense popularity in recent years due to its simplicity, readability, and extensive range of libraries and frameworks. It is widely recognized as a language that excels in data processing, automation, and visualization, making it a natural choice for digitizing charts. By leveraging Python's flexibility, we can streamline the labor-intensive process of manually converting paper-based charts into digital formats.

Throughout this chapter, we will display a guide through the step-by-step process of using a Python application specifically developed for the digitization of AW139's charts. By following the detailed instructions, we will provide visual aids to enhance the reader's understanding, ultimately leading them to acquire a comprehensive understanding of how to effectively implement this solution.

5.2 Overview of Python

Python has grown significantly in popularity across a number of industries, including aviation and aeronautics. Python is a flexible and adaptable computer language. It is the perfect option for creating computational algorithms for Weight and Balance operations because of its readability, simplicity, and robust library environment. We will give an overview of Python and emphasize its benefits in our effort to digitize society in this part.

Python's syntax is designed to be readable and simple, making it easy for developers to write and understand code. Because of its simplicity, quick development and efficient prototyping are made feasible, which are both crucial for creating software for intricate domains like flight operations. The wide ecosystem of libraries for Python also provides pre-built modules for a number of tasks, including data administration, visualization, and mathematical computations **[14]**.

5.2.1 Brief overview of Python programming language

Python is a high-level, interpreted programming language known for its simplicity and readability. Python, which Guido van Rossum developed and originally made available in 1991, has grown significantly in popularity as a result of its adaptability and variety of uses. Python's design philosophy places a strong emphasis on code readability, encouraging simple, unambiguous syntax that resembles natural language and enabling programmers to convey complicated concepts simply.

Python's interpreted nature provides instant feedback, allowing developers to write, test, and debug code iteratively. This rapid development cycle is useful when developing computational techniques for Weight and Balance operations since it allows for rapid prototyping and refinement. Its cross-platform interoperability ensures that code can be run on a variety of operating systems without requiring major changes. This portability enables for the easy deployment of our Weight and Balance computational technique across multiple environments, increasing its accessibility and utility **[9]**.

5.2.2 Importance of Python in aviation and aeronautical applications

Python is essential in the aviation and aeronautical domains, providing particular advantages that aid in the development of effective and dependable software solutions. Python has become a popular programming language for a variety of applications in this industry due to its ease of use, readability, and broad library support. Its ease of use and clear syntax enable rapid prototyping and development of software solutions adapted to aviation and aeronautics unique needs. This enables developers to efficiently translate complex notions into succinct and understandable code.

As an example, in the development of flight simulation software, Python's quick prototyping capabilities enable the creation of realistic and interactive virtual environments. By leveraging libraries like Pygame or Pyglet, developers can simulate aircraft behavior, weather conditions, and control systems, facilitating effective training and research.

Another advantage of Python is its cross-platform adaptability. It enables Python software to be executed easily across several operating systems, providing constant performance and simplifying widespread deployment. This adaptability is especially significant in the aviation and aerospace industries, where systems must be interoperable with a wide range of hardware and software environments.

5.3 Program Overview

The AW139 helicopter Weight and Balance computational approach is a comprehensive software solution made to make figuring out the Weight and Balance of the helicopter quick and easy. Charts B, Chart C, and Chart E are the three main charts included in this application. Login authentication is also used to verify permitted access.

In order to ensure the safety and stability of the helicopter during flight operations, it intends to give flight operators and pilots with a trustworthy and effective instrument for carrying out precise Weight and Balance calculations.

5.3.1 Login Authentication

A secure login and authentication procedure is the first step in the AW139 helicopter Weight and Balance calculation algorithm. Only authorized personnel can access and use the program according to this login system’s username and password that are defined in our program code. Users can access the program's core features once authentication is completed.

Figure 5.1: Login Interface

5.3.2 Helicopter and Chart Selection

After a successful login, a window is shown to the users with a window that displays a selection of six helicopter types that are owned by the Air Group of Civil Protection. This interface allows users to choose the specific helicopter they want to work on.

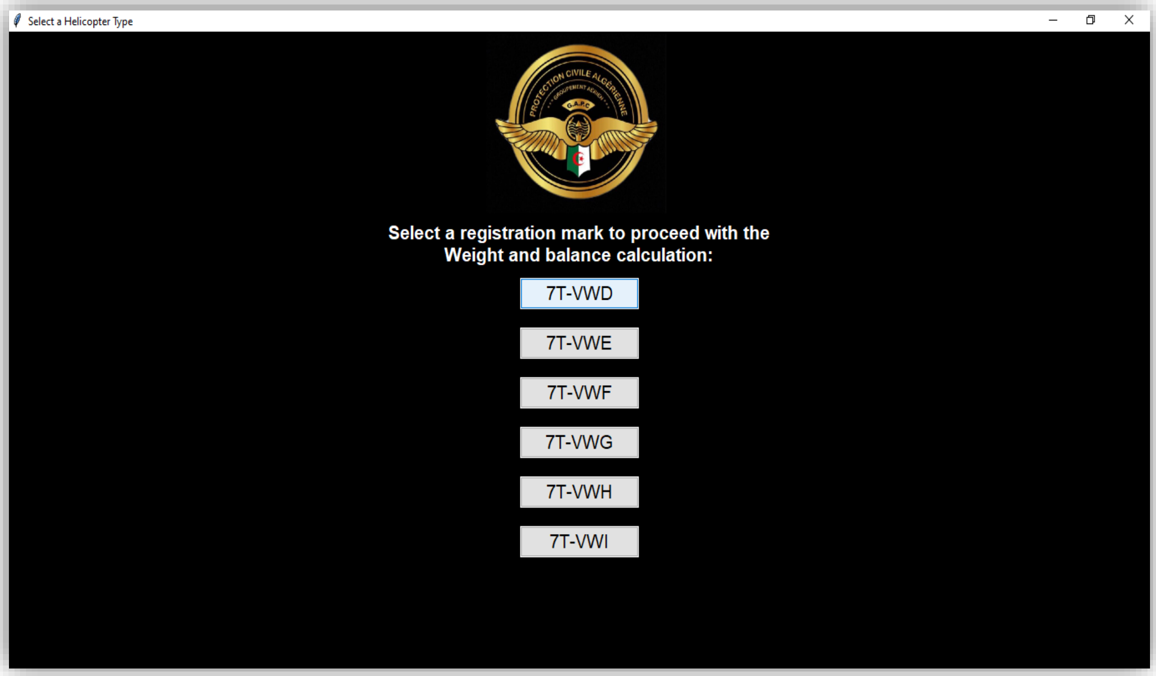


Figure 5.2: Helicopter selection interface

After clicking on a particular registration mark for the chosen helicopter, users can move on to the following step, where a menu with options for Chart B, Chart C, and Chart E for each helicopter will be provided.

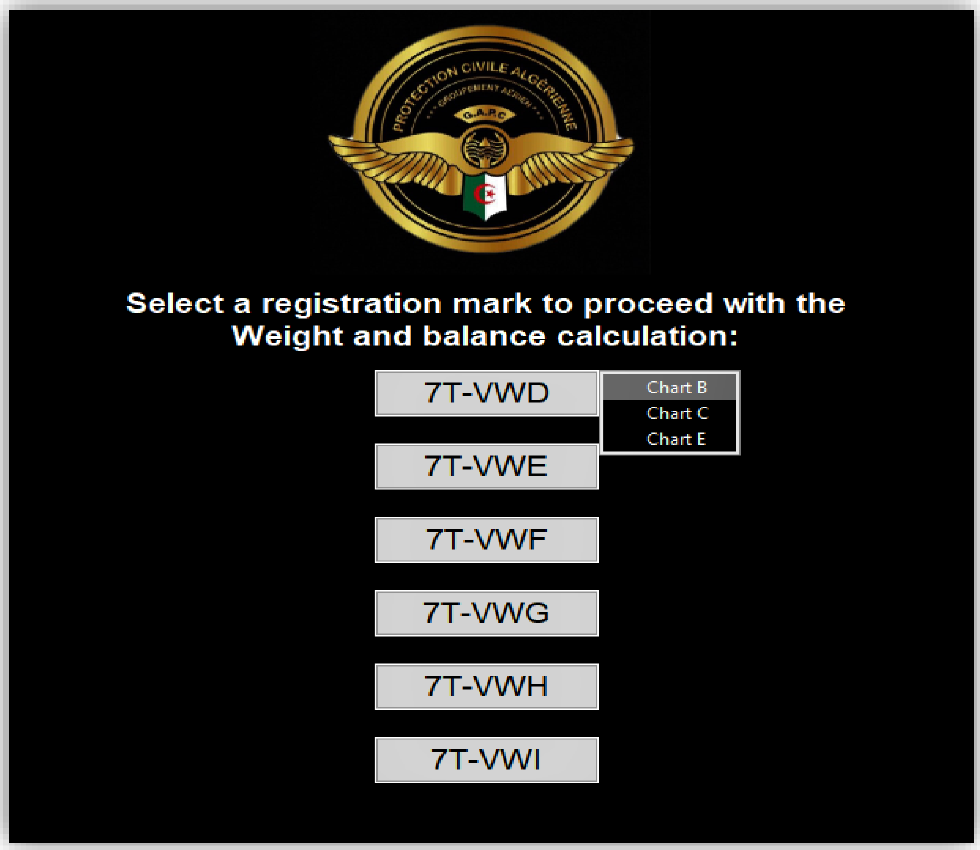


Figure 5.3: Weight and balance charts menu

5.3.3 Helicopter Weighing Record Program: Chart B

5.3.3.1 Data entry of Chart B

After clicking on the desired helicopter and selecting Chart B from the menu, the program opens the Chart B window. It allows the users to perform Weight and Balance calculations specific to the chosen helicopter registration mark. In the first displayed Chart B window, users are presented with labeled entry widgets where they can input the accurate weight values for the forward, left-hand (LH), and right-hand (RH) weights of the helicopter which are obtained through the weighing procedure of the aircraft.

Each helicopter's registration mark is prominently shown in the windows of the Chart B computation application. This inclusion guarantees that the data transfer and storing procedures are particular to each helicopter, enabling customized and precise data control. The registration mark is linked to each window so that users may quickly recognize and retrieve the information about the specific helicopter. By using this method, any potential muddle or mix-up between several helicopters is avoided, and it is ensured that the data has been tailored to the requirements of each individual aircraft.

Figure 5.4: Chart B weight input interface

Once we have entered the weight values accurately, the program will automatically perform the necessary calculations. It will calculate the total weight, longitudinal moment, lateral moment, Station Line (STA) in millimeters (mm), and Buttock Line (BL) in millimeters (mm).

5.3.3.2 Results display of Chart B

The program then presents the results of the calculations, including the total weight, longitudinal moment, lateral moment, STA, and BL. These results are presented in a new GUI window using clear labels and a Treeview widget for an orderly and understandable display.

The program provides an alternative to save the calculated findings for Chart B in an Excel file in order to simplify record-keeping and data storage. When working on Chart B for a particular aircraft for the first time, the program automatically creates a file in the "Chart B Data" directory with the registration mark of the helicopter. The results are subsequently appended to this file.

For subsequent calculations of Chart B for the same helicopter, the program checks if the Excel file already exists in the "Chart B Data" directory. If it does, the program appends the newly calculated results to the existing file. This Excel file can be quickly accessed and used as a reliable source for past Weight and Balance data analysis.

Moreover, a convenient button can be found below the "Save to Excel" button in the Chart B results window. After saving the results to Excel, simply click on this button to proceed directly to the Chart C calculations. This feature eliminates the need to navigate back to the main menu or search for the next step manually.

5.3.4 Weight and Balance Record Program: Chart C

5.3.4.1 Data entry of Chart C

In the Chart C window, we will find a treeview that displays valuable information regarding the selected helicopter's registration mark and its corresponding Chart B data. This treeview offers a thorough description of the equipment that has been added to or removed from the helicopter. The parameters that are displayed in each column are broken down as follows:

- **Date:** This column indicates the date when the equipment operation was performed. It helps track the chronological order of equipment additions or removals.
- **Registration Mark:** The second column displays the registration mark of the selected helicopter. It serves as a unique identifier for the aircraft.
- **Equipment Name:** In the third column, we will find the name of the equipment that has been added or removed from the helicopter.
- **Weight:** The fourth column, labeled "Weight," represents the weight of the equipment in kilograms (Kg). It indicates the individual weight contribution of each equipment item.
- **Longitudinal M:** The fifth column, named "Longitudinal M," displays the longitudinal moment of the equipment in kilogram-millimeters (kgmm). It signifies the contribution of each equipment item to the longitudinal balance of the helicopter.
- **Lateral M:** The sixth column, titled "Lateral M," represents the lateral moment of the equipment in kilogram-millimeters (kgmm). It indicates the contribution of each equipment item to the lateral balance of the helicopter.
- **St (mm):** The seventh column, labeled "St (mm)," denotes the Station Line of the equipment.
- **Bl (mm):** The eighth column, named "Bl (mm)," signifies the Buttock Line of the equipment.

The columns from 3 to 8 exclusively focus on the equipment values, providing detailed information about each equipment item's weight, moments, Station Line, and Buttock Line.

The Weight and Balance values obtained from the Chart B treeview and the ensuing addition or removal of equipment are presented in the columns 9 through 13 moving forward. In each column, the following parameters are represented:

- **Weight (Kg):** The ninth column, labeled "Weight Kg," displays the total weight of the helicopter, taking into consideration the combined weight of the original Chart B values and the weight of the added or removed equipment.
- **Longitudinal Moment (kgmm):** The tenth column, titled "Longitudinal Moment (kgmm)," represents the total longitudinal moment of the helicopter. This moment accounts for the weight distribution and contributions from both the original Chart B values and the equipment modifications.
- **Lateral Moment (kgmm):** The eleventh column, named "Lateral Moment (kgmm)," signifies the total lateral moment of the helicopter. Similar to the longitudinal moment, this moment

considers the weight distribution and contributions from both the original Chart B values and the equipment modifications.

- **STA (mm):** The twelfth column, labeled "STA (mm)," represents the Station Line of the helicopter. This parameter reflects the precise location or position of the helicopter's center of gravity along its longitudinal axis. It is calculated by considering the weight and placement of the equipment in relation to the original Chart B values.
- **BL (mm):** The thirteenth column, titled "BL (mm)," is the Buttock Line of the helicopter. This parameter represents the specific location or position of the helicopter's center of gravity along its lateral axis. It is determined by considering the weight and placement of the equipment in relation to the original Chart B values as well.

The impacts of both the initial Chart B values and the additional or removed equipment are taken into account in these columns, which give a thorough picture of the helicopter's Weight and Balance characteristics. They provide vital data for determining the stability of the helicopter and its adherence to center of gravity restrictions.

- The fourteenth and last column is titled "Equipment Status." If an item of equipment has been added to the helicopter or taken away, it is shown in this column. It offers a clear overview of modifications made over time and aids in tracking the status of equipment operations.

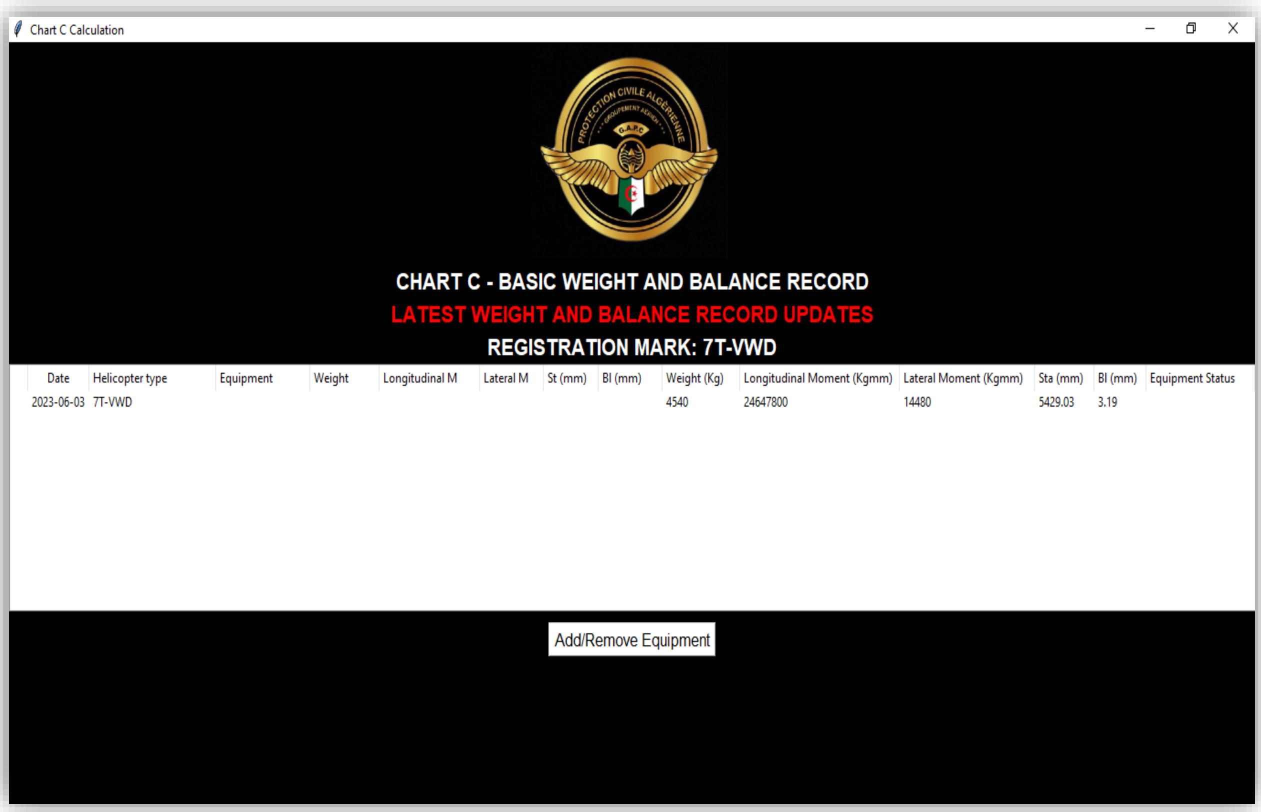


Figure 5.5: Chart C Data history

The current window displays the values retrieved from the Chart B treeview of the selected helicopter's registration mark.

5.3.4.2 Adding and Removing equipment

To modify the equipment configuration, we need to click on the "Add/Remove Equipment" button. By performing this operation, a new window will be displayed, allowing us to choose and specify what equipment we wish to add or to remove from the helicopter.

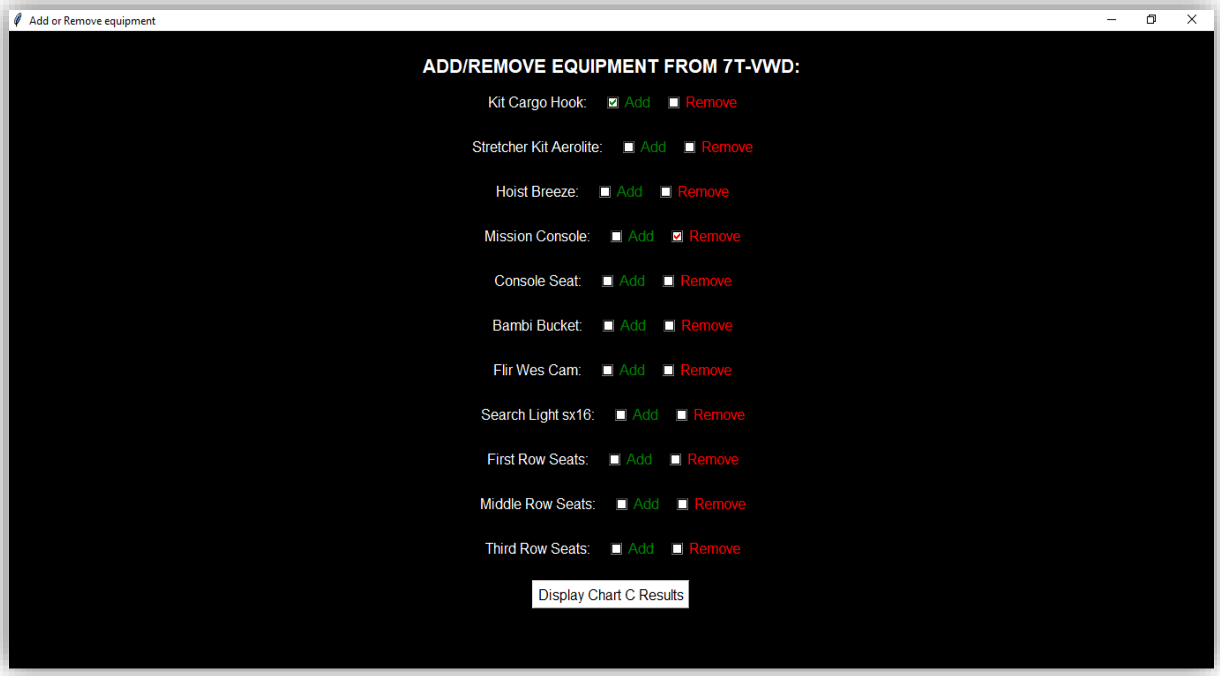


Figure 5.6: Equipment list

In this following example, Kit Cargo Hook is “Added” and Mission Console is “Removed” from the AW139 7T-VWD helicopter as shown in Figure 5.7 bellow.

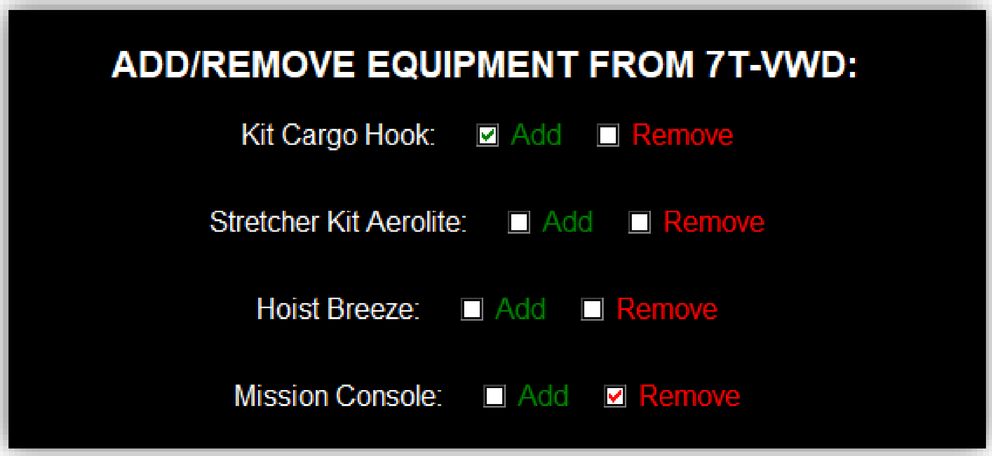


Figure 5.7: Adding/Removing equipment process

5.3.4.3 Results display of Chart C

By clicking on “Display Chart C Results” button after making the appropriate equipment selection, it will show a new GUI window representing the results from this operation.

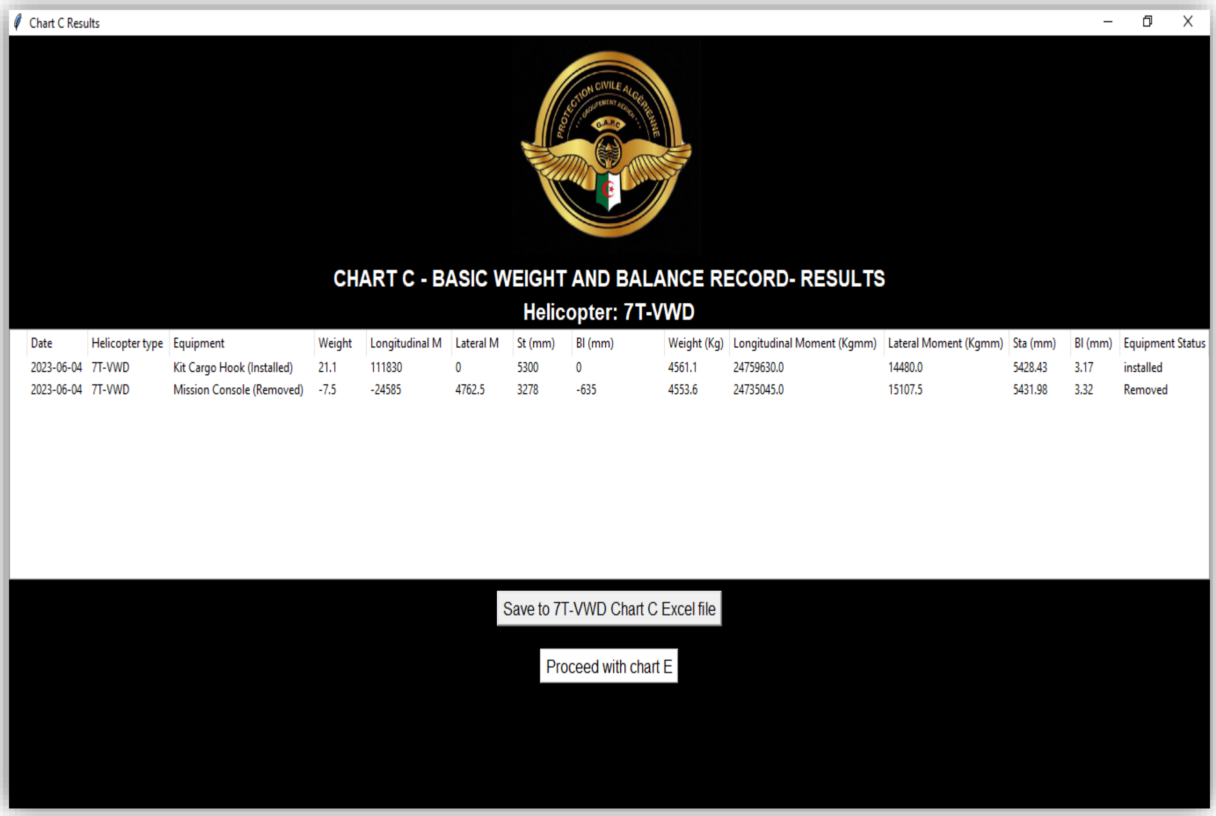


Figure 5.8: Chart C Results interface

Each save button within the Chart C results window contains the registration mark of the aircraft. When clicked, the program will automatically create a specific Excel file in the "Chart C Data" directory after running the initial Chart C calculations for each particular helicopter. The file will be given a name based on the registration mark of the helicopter to facilitate quick identification.

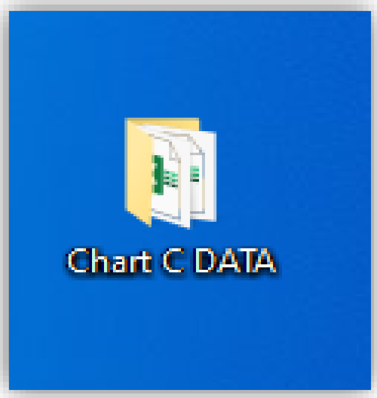


Figure 5.9: Chart C data directory

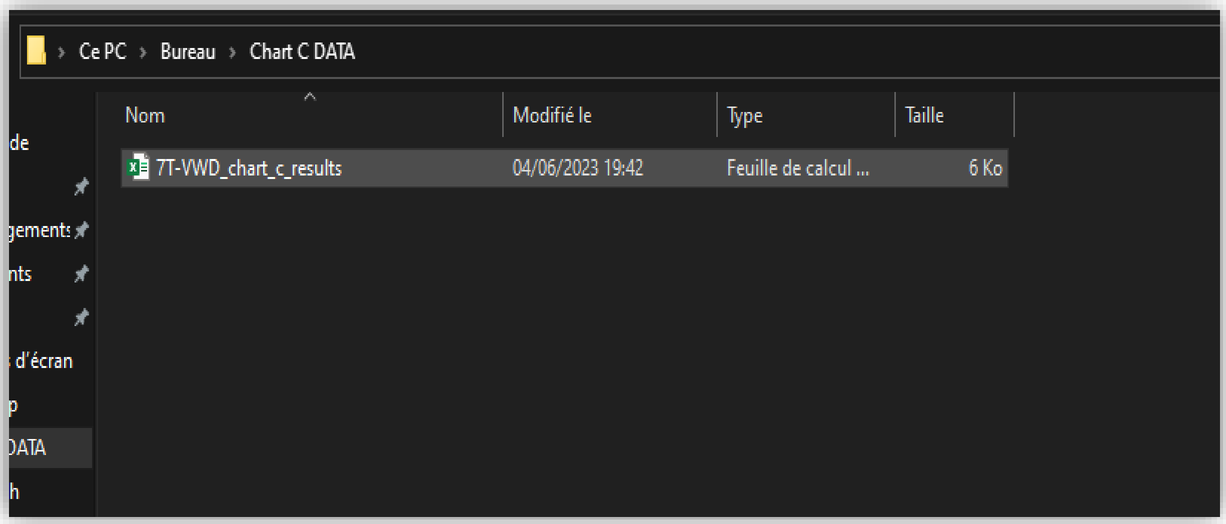


Figure 5.10: 7T-VWD helicopter Chart C data file

When opening the specific excel file of the helicopter, all the treeview values of the Chart C results will be displayed in the excel sheet as shown in Figure 5.11.

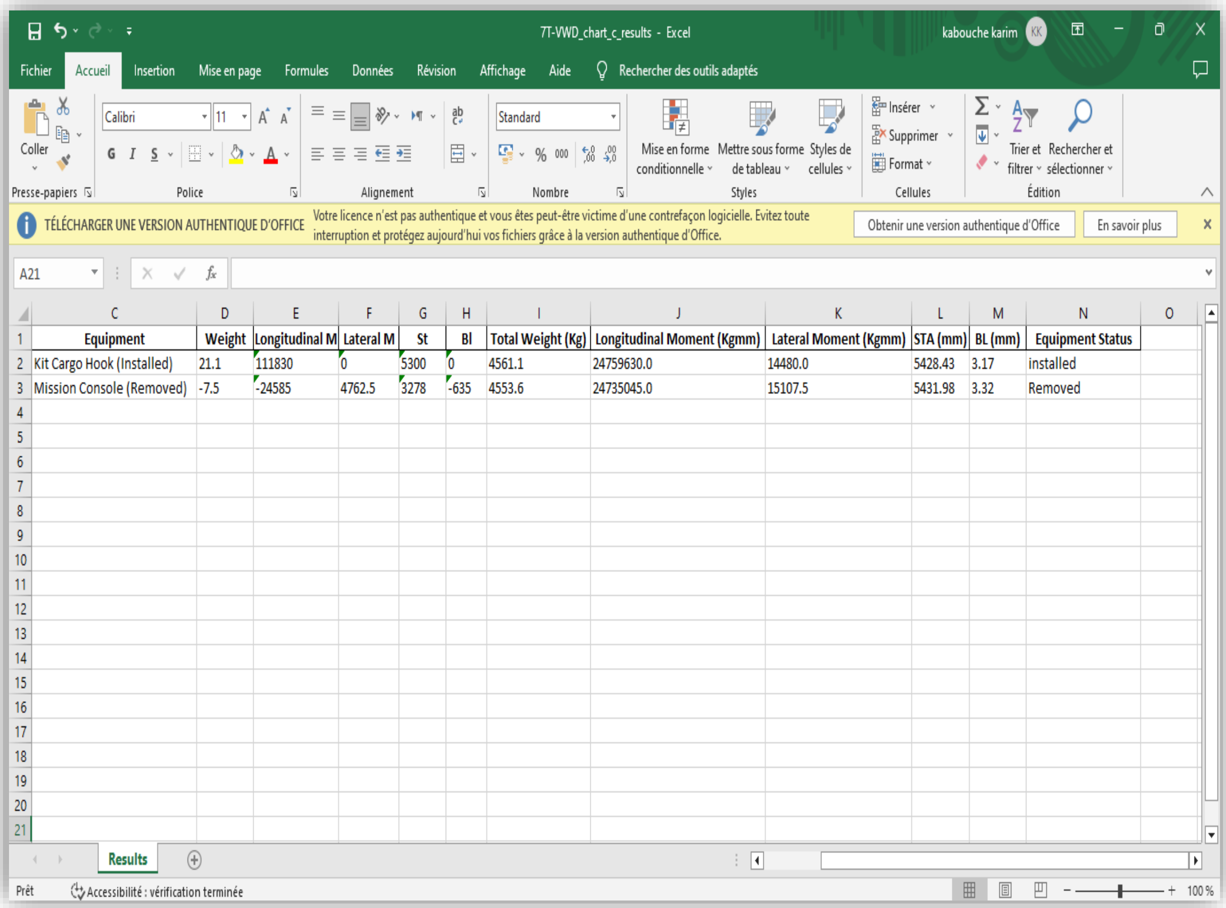


Figure 5.11: 7T-VWD Chart C appended results

We'll see an additional button just below the "Save to Excel" button in the Chart C results box. This button acts as a useful shortcut to speed up our process. Simply click on this option to proceed directly to the Chart E calculations after successfully saving the Chart C data to the Excel file.

5.3.5 Weight and Balance Computation Form: Chart E

Chart E is an essential part for precisely determining the weight distribution and balance of the AW139 helicopter. It enables a thorough study of the center of gravity in both longitudinal and lateral limitations by using the values obtained from Chart C computations and the user-provided item weights. The application presents the findings in a systematic manner using a treeview interface, giving flight operators helpful insights into the AW139 helicopter's Weight and Balance configuration for their particular operational needs.

5.3.5.1 Data entry of Chart E

Upon entering the Chart E section, we will encounter an input window. This window allows the user, to input the weights of various items specific to the intended flight. At the top of the window, we will find the registration mark indicating the helicopter under consideration. It is imperative, as shown in the red text of Figure 5.12, to provide weights in kilograms for precise calculations.

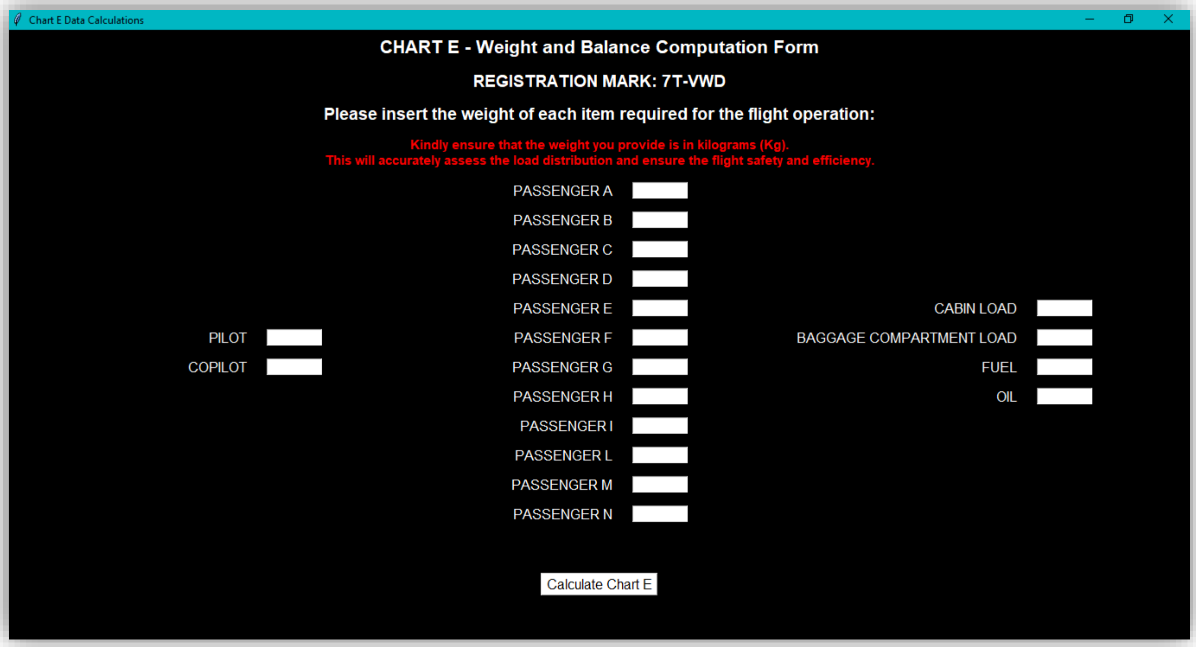


Figure 5.12: Chart E Input window

In the input window, we enter the weights of the various items required for the flight, such as the pilot, copilot, passengers, and fuel, among others. By accurately inputting the weights of these items, we enable the program to perform precise calculations for the weight and balance of the helicopter.

Once we have entered the weights of the items, we click on the "Calculate Chart E" button. This action triggers the program to process the values from the previous Chart C operation, along with the newly inputted item weights, to calculate the weight and balance for Chart E.

As an input example, we are going to add to the 7T-VWD helicopter those following weights:

$Pilot = 100Kg$

$Copilot = 80Kg$

$Passenger\ A = 85Kg$

$Passenger\ D = 120Kg$

$Baggage\ Compartment\ load = 12Kg$

$Fuel = 60Kg$

$Oil = 45Kg$

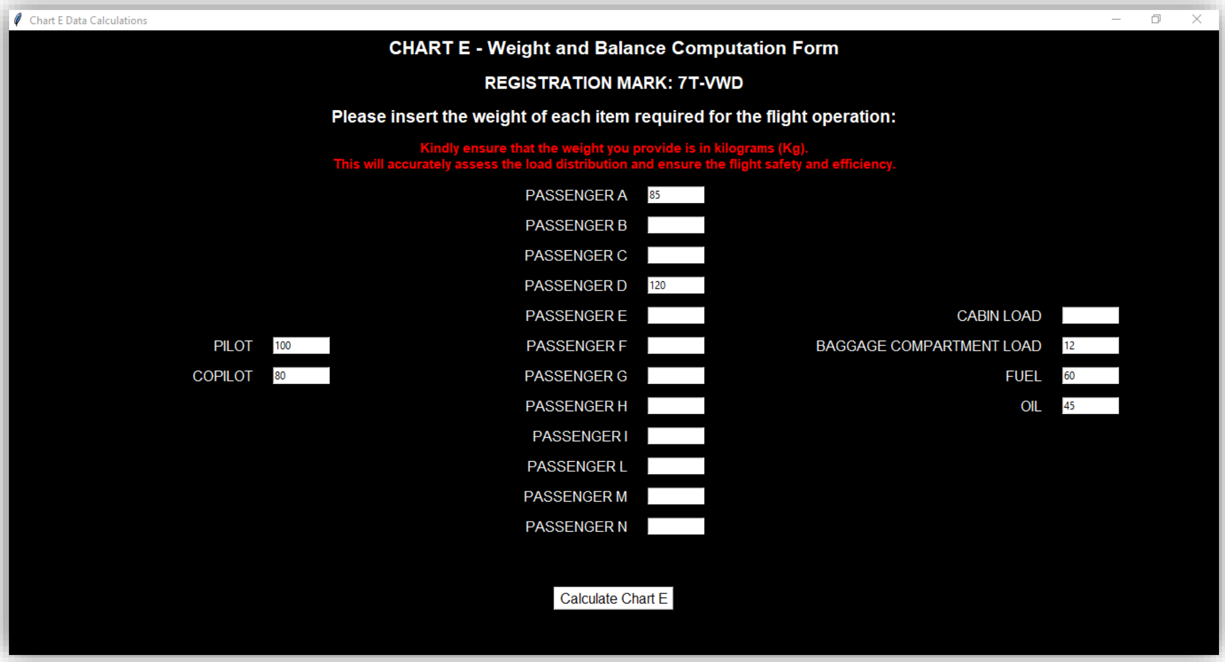


Figure 5.13: Chart E weight input

5.3.5.2 Results display of Chart E

After the calculations are completed, a results window is displayed. The results are presented in a structured format using a treeview component, which consists of several columns. Here is an explanation of each column:

- **Registration Mark:** This column represents the registration mark of the helicopter we worked on.
- **Item:** The second column displays the items we added in the input window
- **Weight (Kg):** The third column shows the weight of each item in kilograms.
- **Longitudinal (mm):** The fourth column represents the longitudinal moment of each item in millimeters.

- **Lateral Moment (mm):** The fifth column indicates the lateral moment of each item in millimeters.
- **STA (mm):** The sixth column displays the Station line (STA) of each item in millimeters.
- **BL (mm):** The seventh column represents the buttock line (BL) of each item in millimeters.

Within the treeview, we will observe an automatically appended last item named "TOTAL WEIGHT". This item consistently appears in every Chart E calculation and reflects the comprehensive values obtained by incorporating the results from Chart C and the additional provided item weights. The center of gravity determination in both longitudinal and lateral moments rely on the values of the "TOTAL WEIGHT" item.

In Figure 5.14, we are an example of the results from the previous weight input.

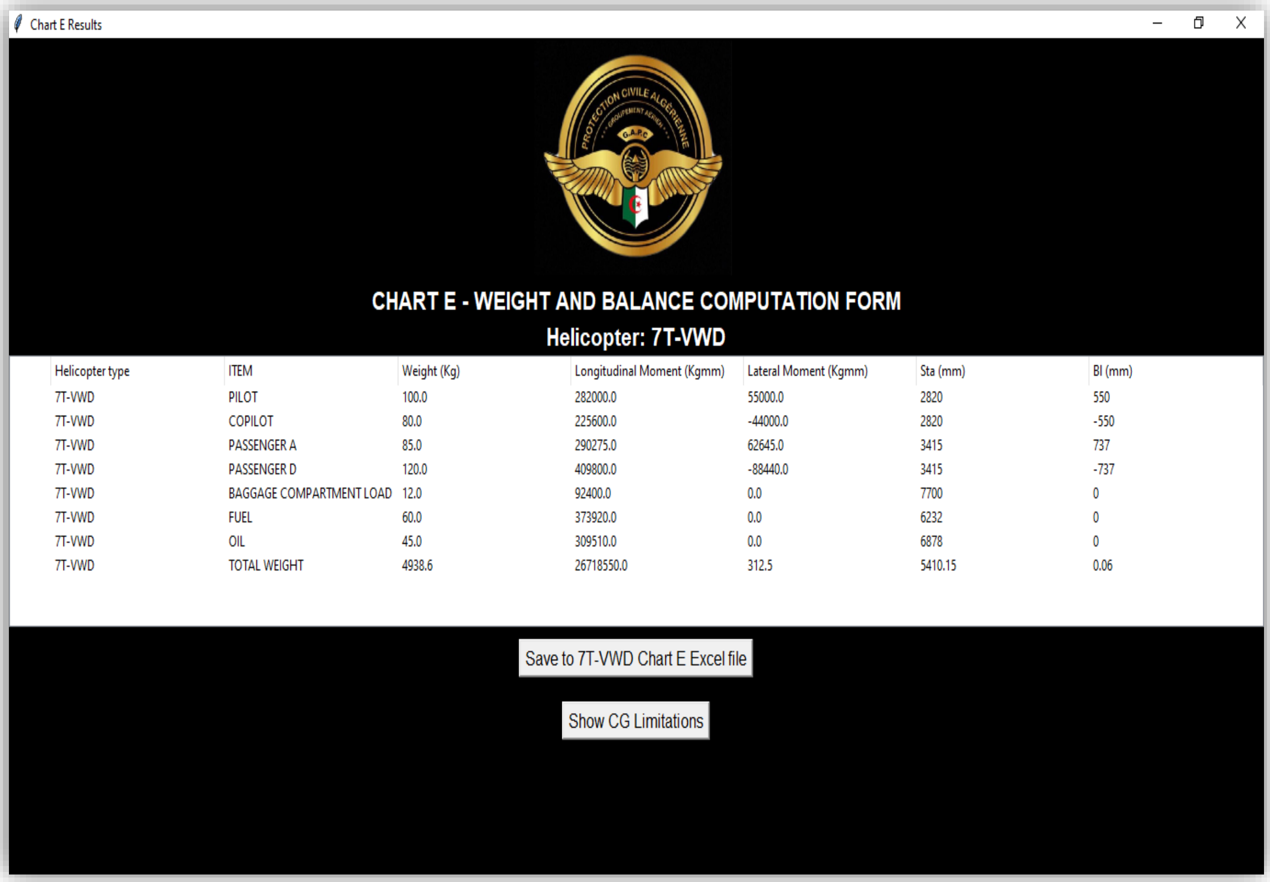


Figure 5.14: Chart E results window

By specifying the directory and clicking the "Save to 7T-VWD Chart E Excel file" button, the program generates an Excel file that contains all the relevant information and calculations from Chart E. The saved data includes the actual date of the saving, the registration mark of the helicopter, the weights, longitudinal and lateral moments, Station line (STA), and Buttock line (BL) for each item entered by the flight operator.

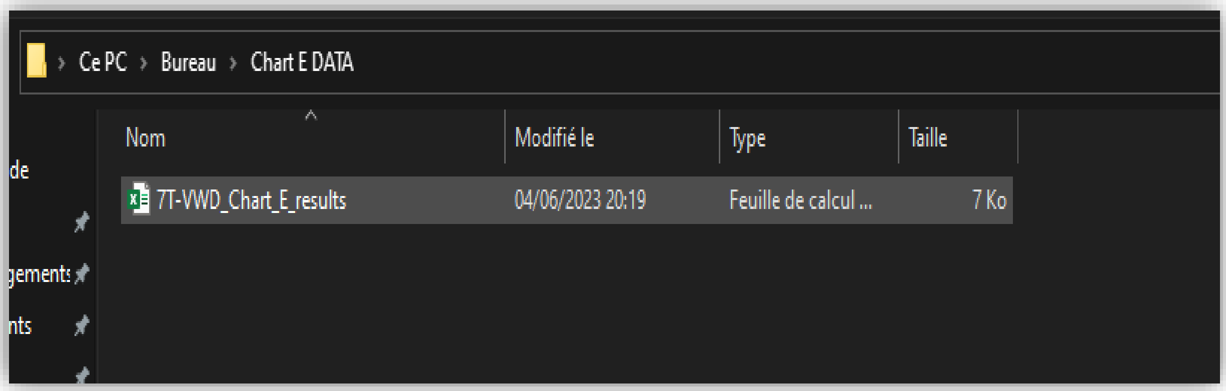
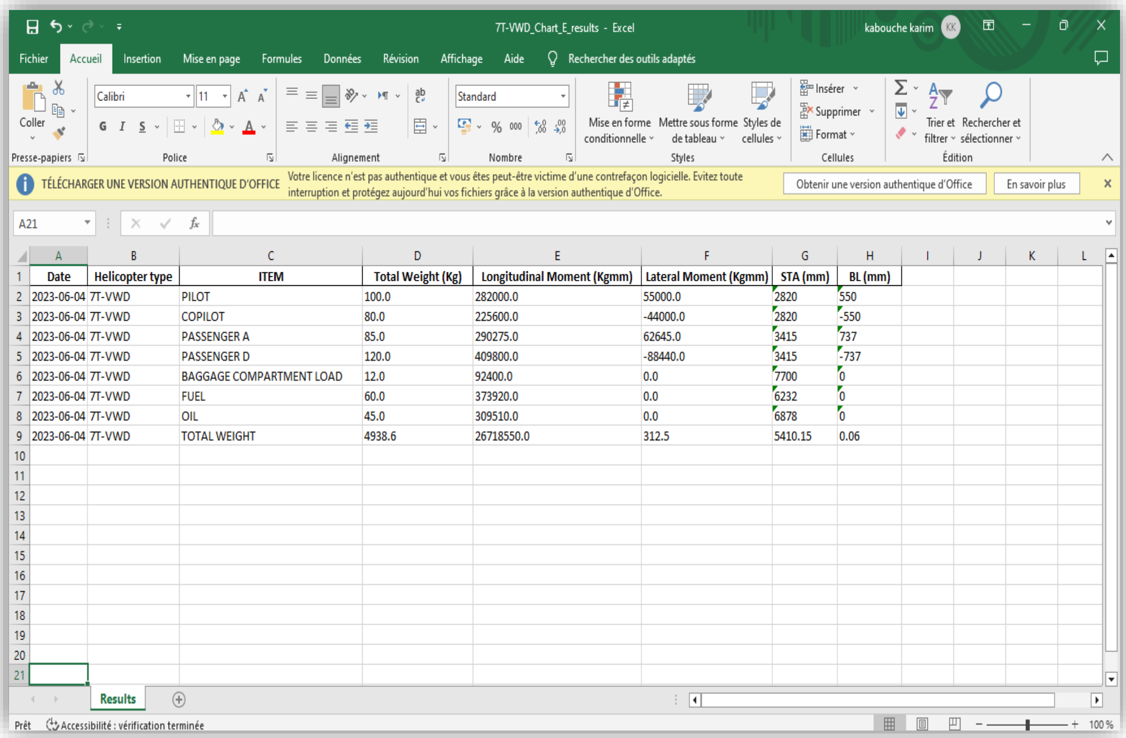


Figure 5.15: Chart E Excel file



Date	Helicopter type	ITEM	Total Weight (Kg)	Longitudinal Moment (Kgmm)	Lateral Moment (Kgmm)	STA (mm)	BL (mm)
2023-06-04	7T-VWD	PILOT	100.0	282000.0	55000.0	2820	550
2023-06-04	7T-VWD	COPILOT	80.0	225600.0	-44000.0	2820	-550
2023-06-04	7T-VWD	PASSENGER A	85.0	290275.0	62645.0	3415	737
2023-06-04	7T-VWD	PASSENGER D	120.0	409800.0	-88440.0	3415	-737
2023-06-04	7T-VWD	BAGGAGE COMPARTMENT LOAD	12.0	92400.0	0.0	7700	0
2023-06-04	7T-VWD	FUEL	60.0	373920.0	0.0	6232	0
2023-06-04	7T-VWD	OIL	45.0	309510.0	0.0	6878	0
2023-06-04	7T-VWD	TOTAL WEIGHT	4938.6	26718550.0	312.5	5410.15	0.06

Figure 5.16: Chart E 7T-VWD appended results

5.3.5.3 Displaying CG Limitations Graphs

It is critical to confirm that the AW139 helicopter's Weight and Balance are within the operating limits after all relevant calculations and data entries have been done in Charts B, C, and E to evaluate compliance with these limitations.

Simply clicking the "Show CG Limitations" button will allow the flight operator to view the weight and balance CG in both longitudinal and lateral limitations. When a button is clicked on, the program uses values from Chart E, which shows the initial weight and balance data, to calculate the center of gravity (CG).

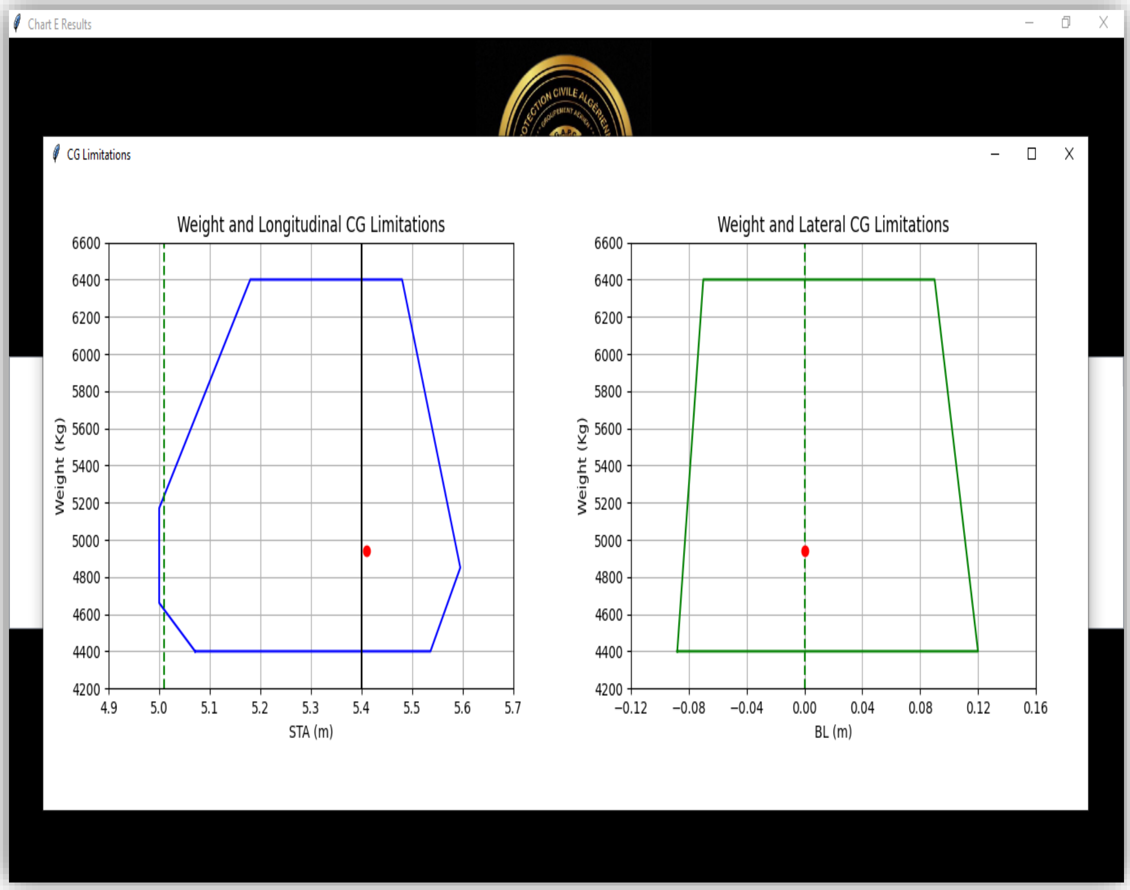


Figure 5.17: Longitudinal and lateral center of gravity limitations

Following that, the program plots a point on the graphs for the longitudinal and lateral CG limitations. These graphs provide as visual representations of the AW139 helicopter's permitted CG ranges. The lateral graph shows the CG limitations along the left and right axis, whereas the longitudinal graph shows them along the forward and aft axes.

The flight operator and pilots can easily determine whether the CG is within the safe operational envelope by looking at the plotted point on these graphs. The weight and balance of the helicopter are within acceptable bounds, ensuring safe flight circumstances, if the point falls within the permitted limitations. However, if the point is outside of the operational envelope, it means that the weight and balance limits are not being met, signaling a potential safety concern.

5.3.5.4 Warning for Exceeding Max Gross Weight

After inputting the weights of various goods in the Chart E portion of the program, it is crucial to remember that the AW139 helicopter has a maximum gross weight limit of 6400kg. This restriction guarantees safe operation and compliance with Weight and Balance laws.

The program includes a warning mechanism to help flight operators stay in compliance with this weight restriction. A caution box will automatically show if the total weight is greater than 6400kg. The flight operator and the pilot are alerted by this warning box that will be displayed in the window that the weight restriction has been exceeded.

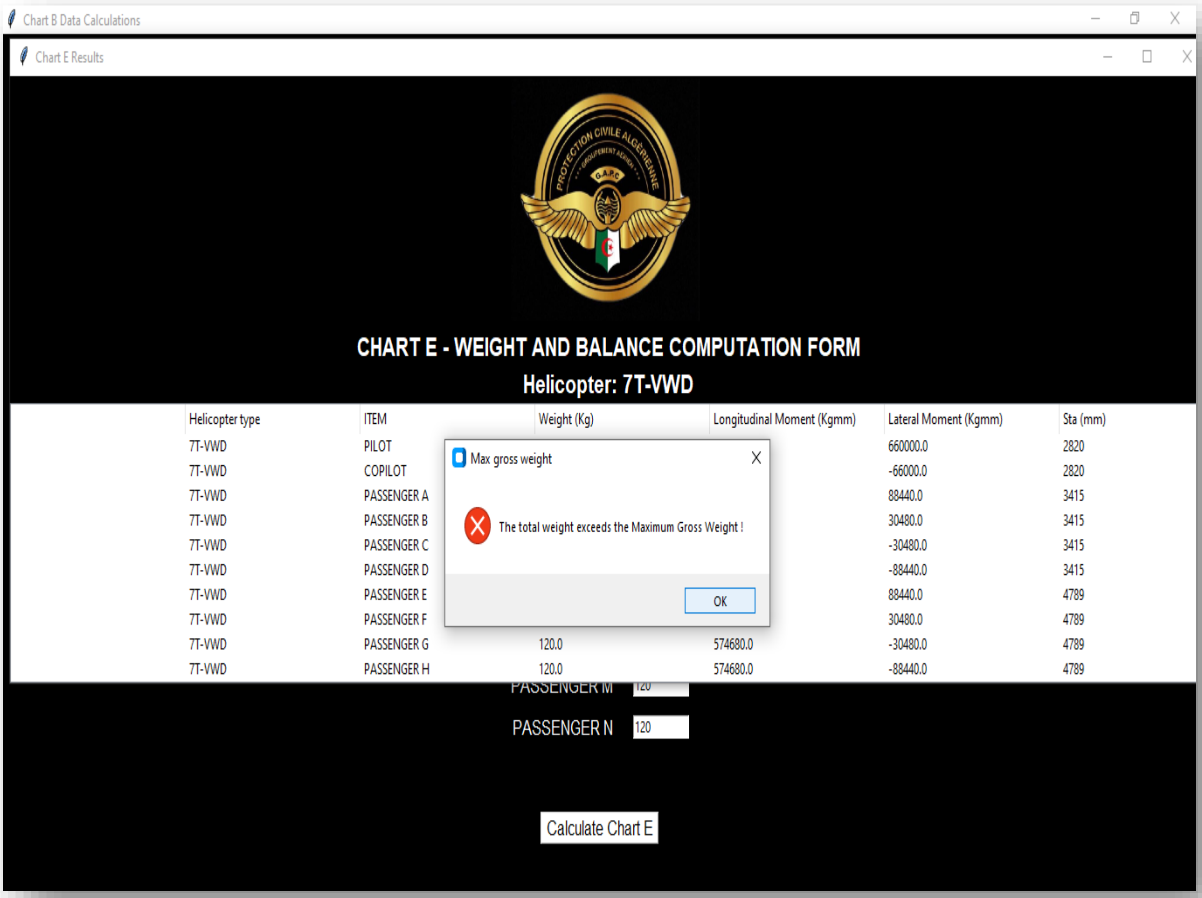


Figure 5.18: Weight Exceedance Warning Box

This warning's objective is to alert the flight operator right away to the weight situation and prompt them to take the appropriate action. To ensure compliance with the maximum gross weight limit, it is imperative to act quickly to remedy the issue by reassessing the weight distribution and making modifications.

5.4 Error Handling in the Weight and Balance Program

Error handling is a vital part of the Weight and Balance Program, assuring the correctness and dependability of the computations and minimizing any problems that may develop during operation. A strong error handling features are built into the AW139 helicopter program to guarantee efficient and error-free operation.

5.4.1 Invalid Credentials: Wrong Username or Password

In the event of an incorrect username or password input during login, the Weight and Balance Program promptly detects the error and displays a dedicated message box. This notification informs the user about the invalid credentials, enabling them to rectify the situation and gain authorized access to the program. By safeguarding against unauthorized access attempts, the program ensures the security and integrity of user accounts.

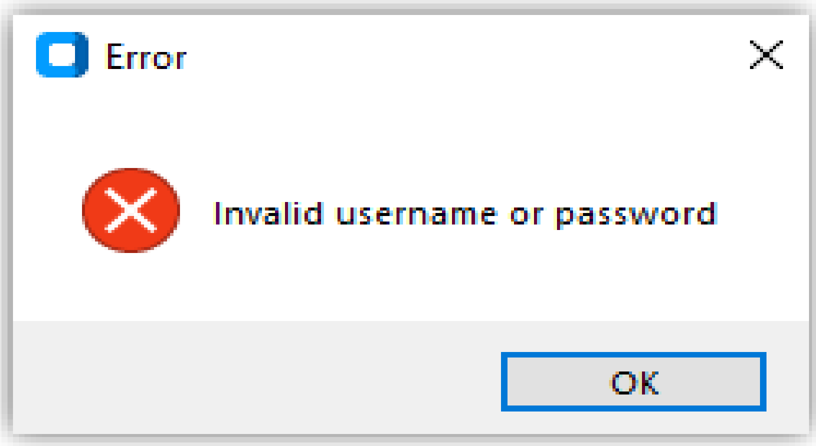


Figure 5.19: Wrong Credentials Notification

5.4.2 Missing Chart B Data: Dependency Alert

When a user attempts to access Chart C for a specific helicopter that lacks a corresponding Chart B record, the program recognizes the dependency between the two charts. In such cases, an intelligent notification is presented to the user, highlighting the requirement of Chart B data. This proactive approach ensures that accurate and comprehensive information is available for weight and balance calculations, minimizing potential errors and enhancing the overall reliability of the program.

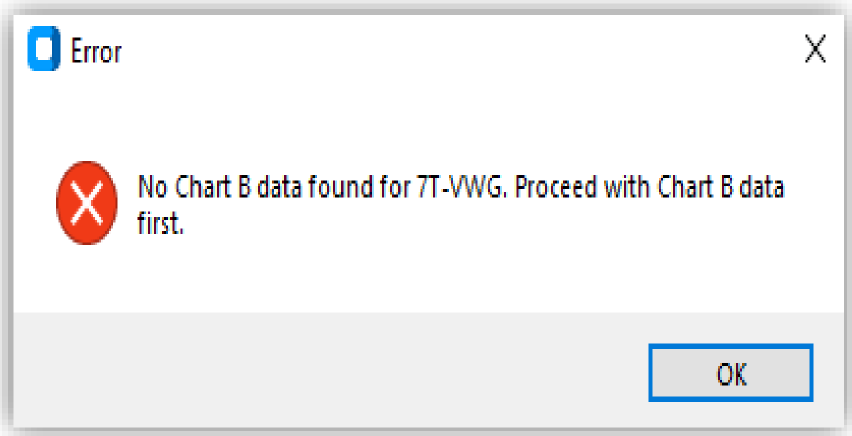


Figure 5.20: Missing Chart B Data Notification

5.4.3 Exceeding Maximum Gross Weight: Safety Alert

To maintain safe flight operations, the Weight and Balance Program actively monitors the total weight entered in Chart E. If the cumulative weight exceeds the maximum gross weight of the AW139 helicopter (6400kg), an error message is displayed, alerting the user to the weight limit violation. This crucial error handling feature prevents the operation from proceeding with potentially unsafe weight configurations.

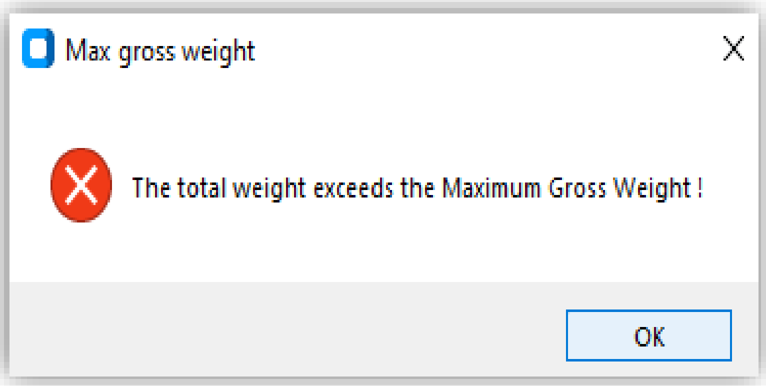


Figure 5.21: Exceeded Maximum Gross Weight Alert

By incorporating robust error handling mechanisms, the Weight and Balance Program upholds its commitment to accuracy, and reliability. These features give users the ability to spot mistakes and fix them right away, ensuring ideal weight distribution, reducing risks, and facilitating smooth and effective flight operations.

5.5 Validation of Program Accuracy: Real Operational Data Analysis

In this part, we will use the program to do three different Weight and Balance missions for the **7T-VWF** helicopter. We intend to assess the weight distribution and center of gravity for each flight using Charts B, Chart C, and Chart E, assuring compliance with safety laws and operating restrictions.

5.5.1 Operation 1: Emergency Evacuation

In the first mission, we want to quickly transport a patient from Setif state to Algiers in the event of an emergency medical evacuation. To guarantee the patient's safety and wellbeing, this critical mission demands careful preparation and execution. A committed physician will be on board with the experienced pilots to provide critical medical care during the flight.

To conduct a thorough weight and balance analysis for this mission, we will utilize the program and refer to Chart B, Chart C, and Chart E. The following individuals and items will be accounted for:

- **Operator:** The presence of an operator is crucial for coordinating and overseeing the firefighting activities. They will be strategically positioned in Seat A for optimal communication and control.
- **Doctor:** Seat we will be occupied by the doctor with competence in emergency medical care during the evacuation. It is essential that this doctor attend to the patient in need right away and treat them.
- **Middle Row Seats (Removing):** To create space for the stretcher kit installation, the middle row seats will be removed, ensuring proper accommodation and securing the patient during transport.

- **Stretcher Kit Aerolite (Installed):** The stretcher kit Aerolite is a specialized medical equipment designed to provide a secure and comfortable platform for transporting the patient. It ensures the patient's stability and safety throughout the flight.
- **Hoist Breeze (Installed):** The hoist breeze is an essential device used during emergency evacuations. It facilitates the safe and efficient transfer of the patient from the ground to the helicopter and vice versa, ensuring swift medical evacuation operations.

First of all, we open the program and enter our credentials at the login page to access the system. Then, we choose the 7T-VWF helicopter from the list of available aircraft and click on Chart B.

Figure 5.22: Login page with username and password written

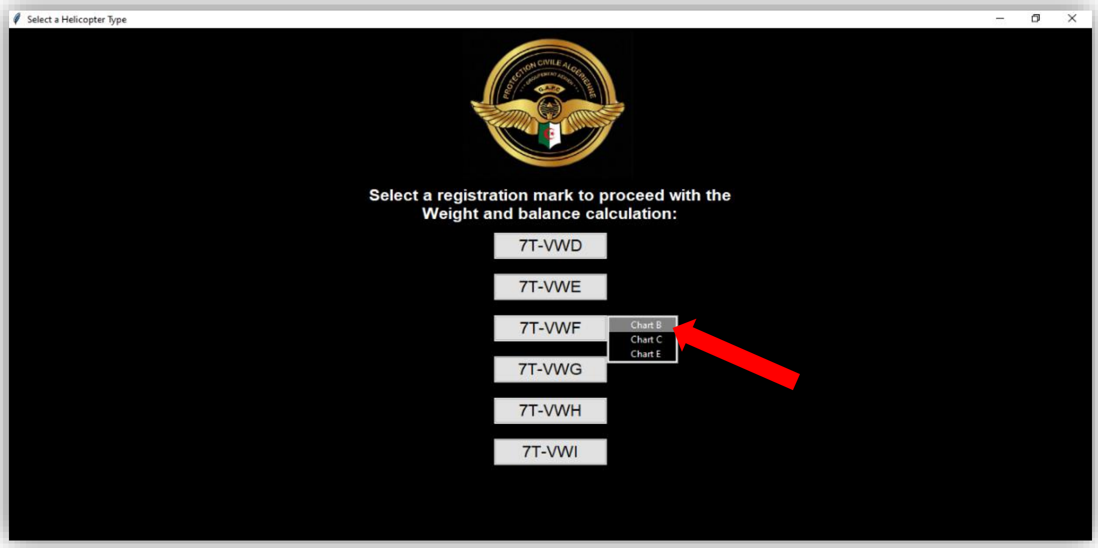


Figure 5.23: 7T-VWF helicopter and Chart B choice

We enter the weights and values obtained from the weighing procedure of the 7T-VWF AW139 helicopter. And then, we press "Show Results" button to get the results shown in (Figure 5.24).

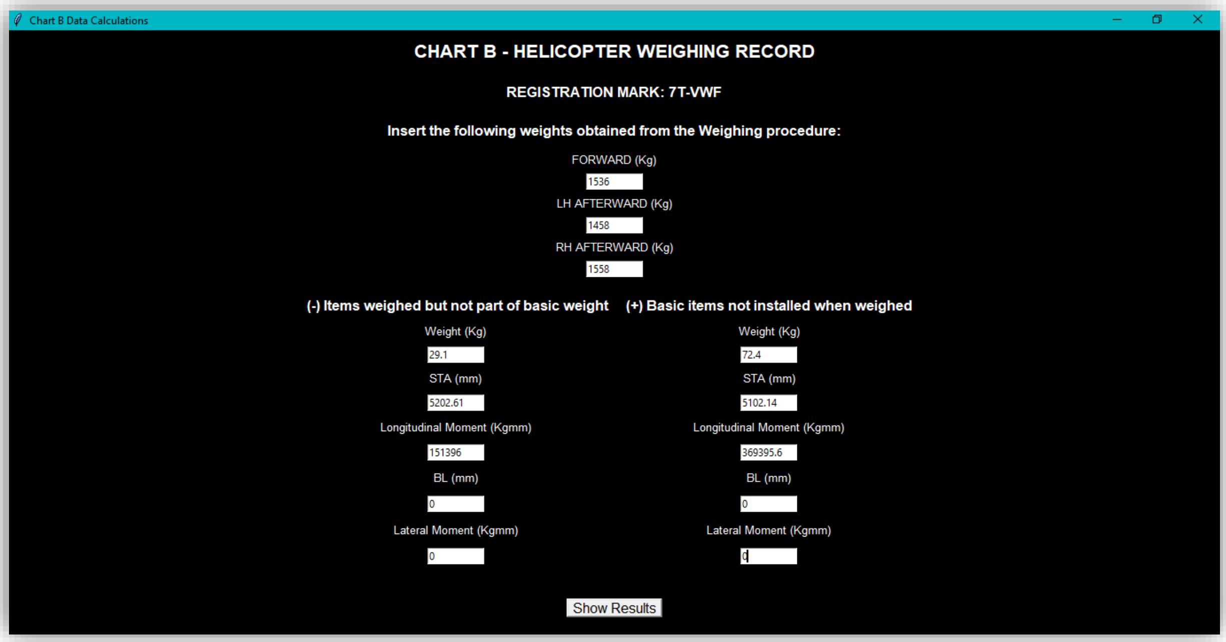


Figure 5.24: The weights and values obtained from the weighing procedure of the 7T-VWF AW139 helicopter

After that, we save the results by clicking on "Save to 7T-VWF Chart B Excel file" then proceed with calculating Chart C.

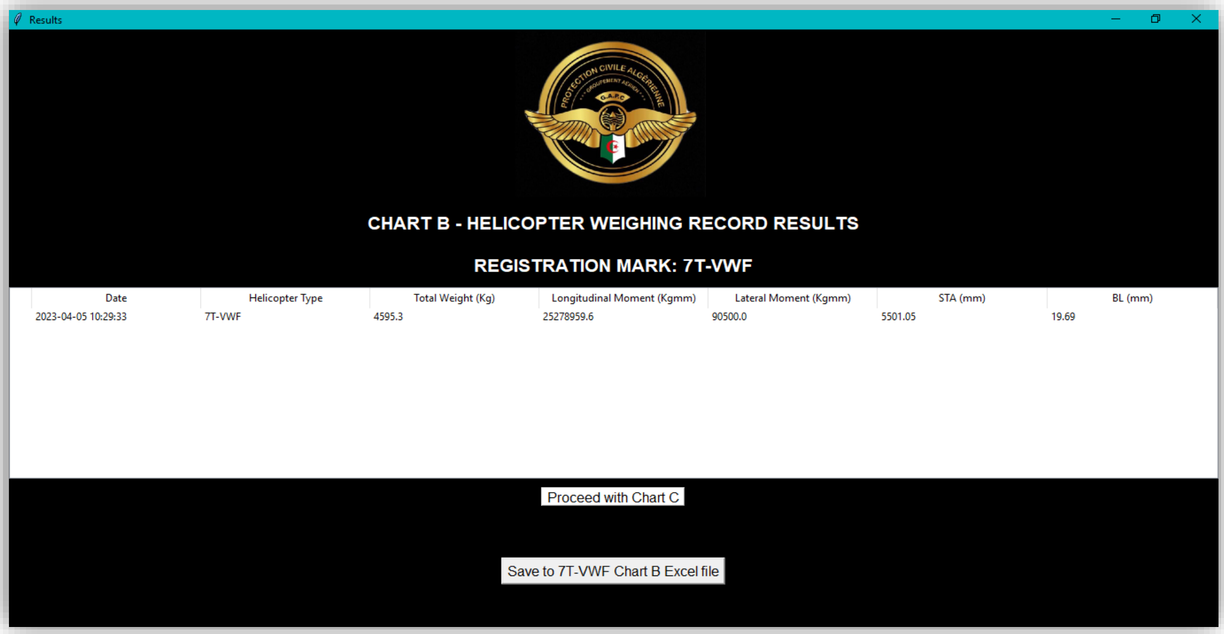


Figure 5.25: Emergency evacuation mission Chart B results

To add and remove the necessary equipment for this mission, we click on Add/Remove equipment button of Figure 5.26.

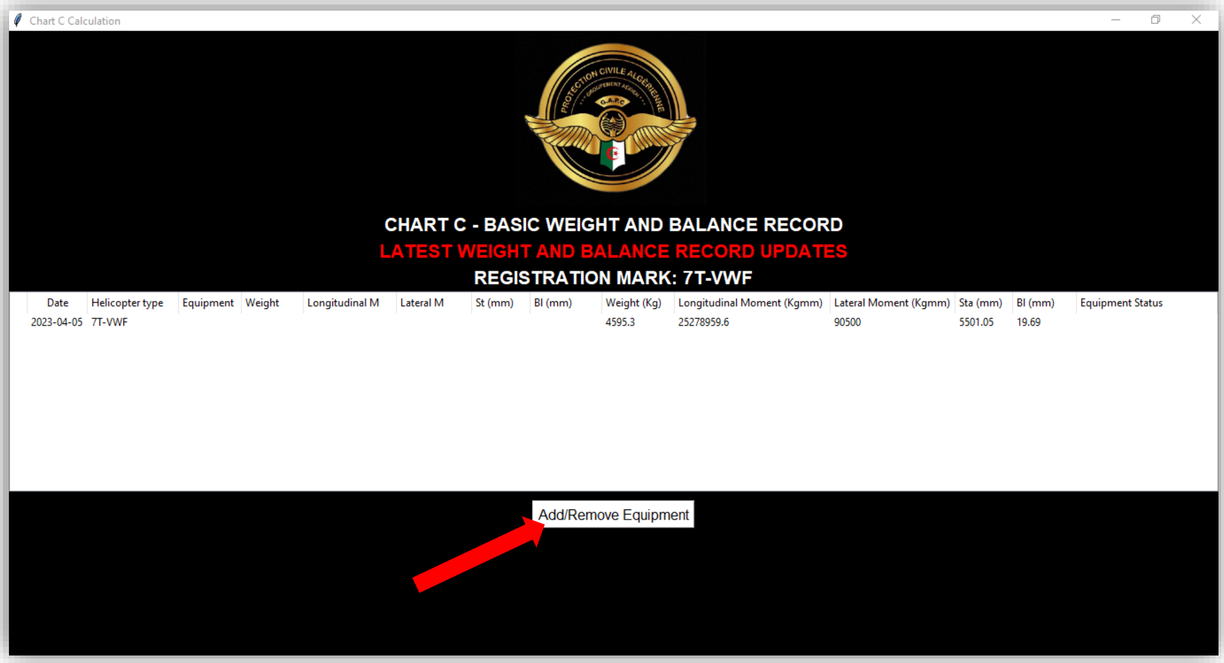


Figure 5.26: Add/Remove equipment button

We select the equipment to add or remove by crossing the convenient checkbox, then we click on "Display Chart C Results" button of Figure 5.27.

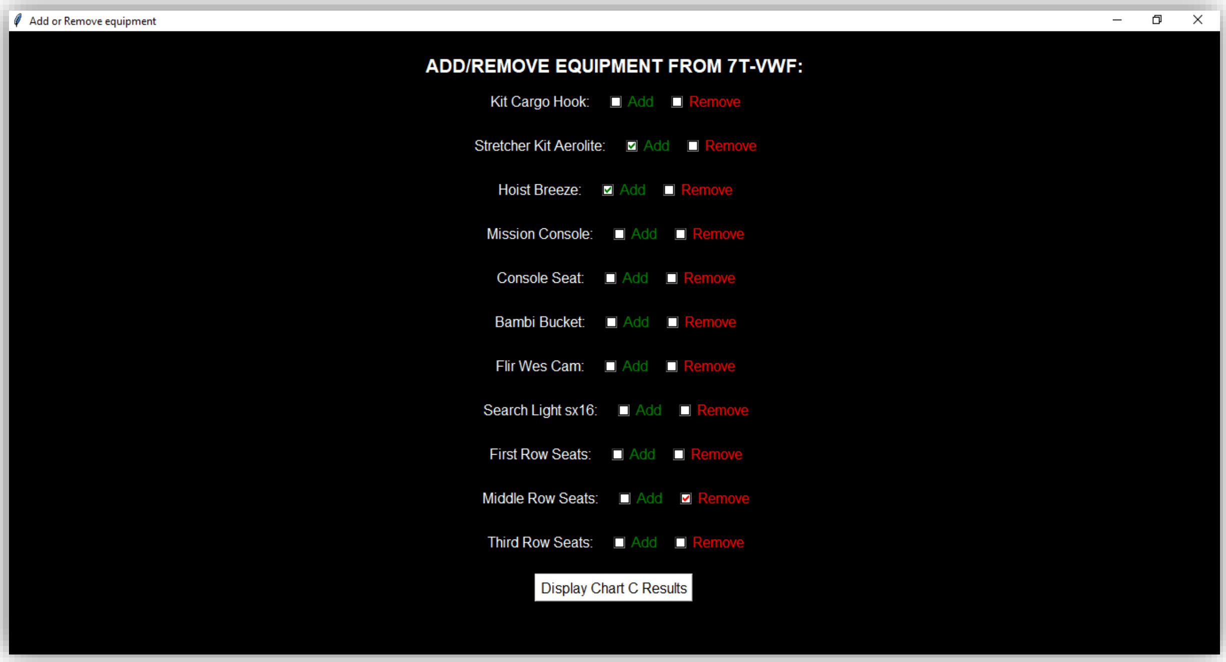


Figure 5.27: Add/Remove necessary equipment for Emergency evacuation mission

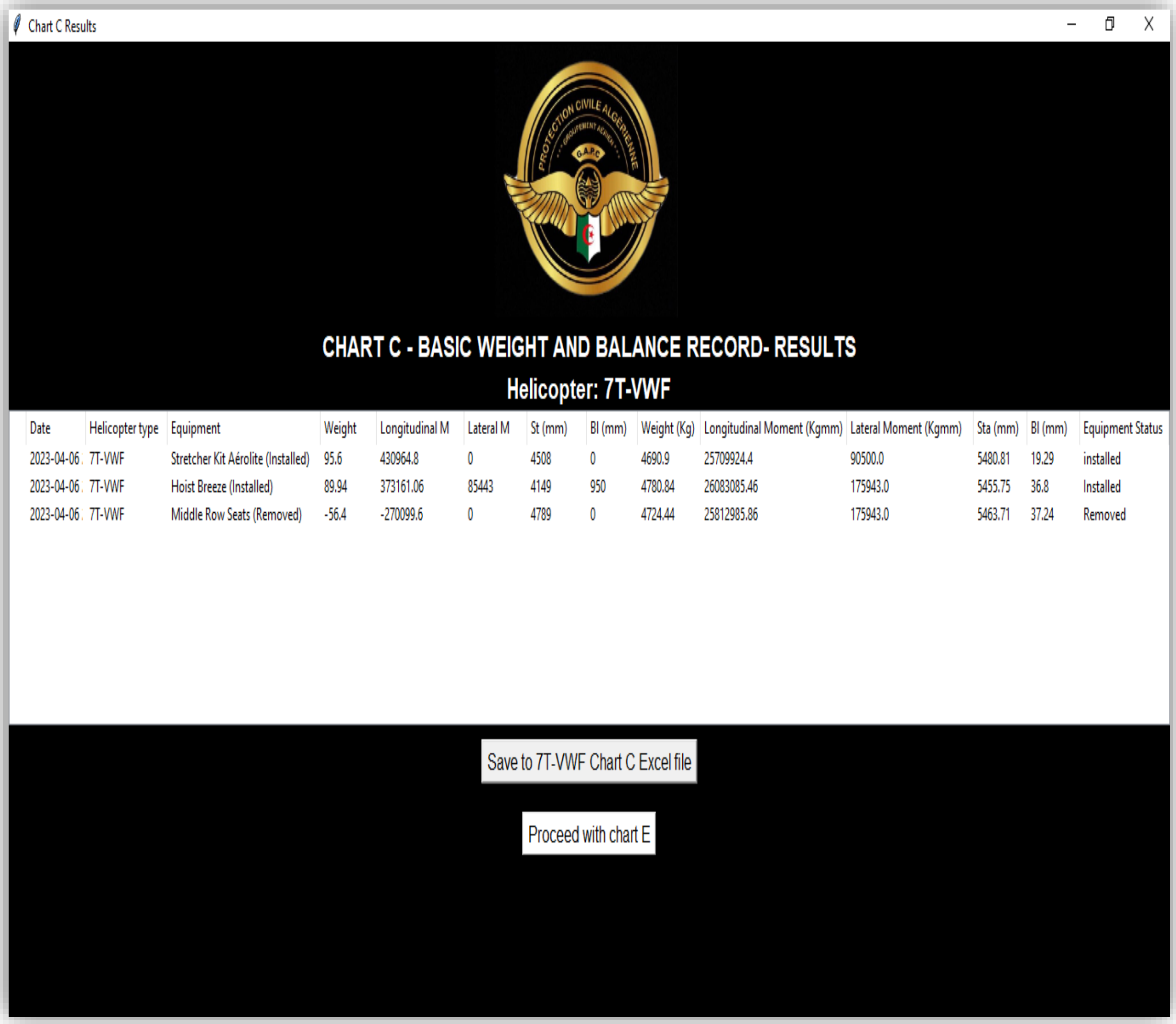


Figure 5.28: Emergency Evacuation Chart C display

The results are saved to the 7T-VWF excel file by clicking on “Save to 7T-VWF Chart C excel file” button of Figure 5.28.

To proceed to Chart E, we can either select from the menu of the helicopter selection page or with clicking on “Proceed with Chart E” from the results of Chart C page.

Insert the weight of the Items in the Chart E input window. For our case, we have:

$$Pilot = 80Kg$$

$$Copilot = 80Kg$$

$$Passenger\ D\ (Operator) = 80Kg$$

$$Passenger\ I\ (Doctor) = 70Kg$$

$$Baggage\ Compartment\ load = 25Kg$$

$$Fuel = 800Kg$$

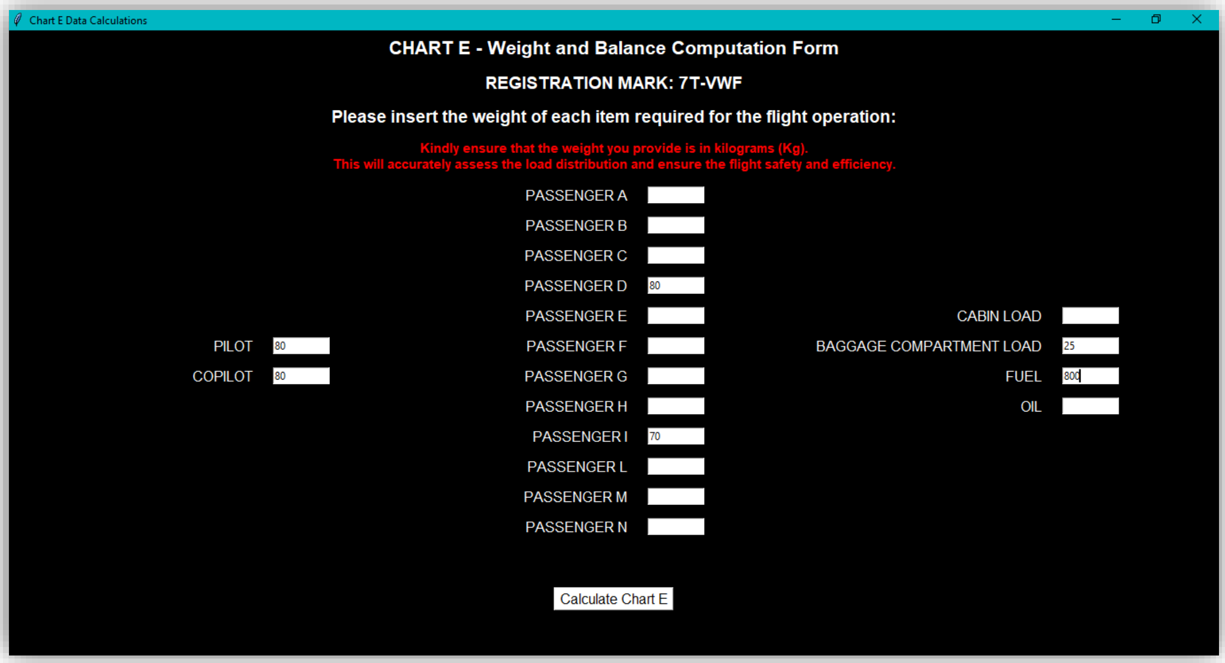


Figure 5.29: Chart E input window

We click on "Calculate Chart E" button to display the results bellow.

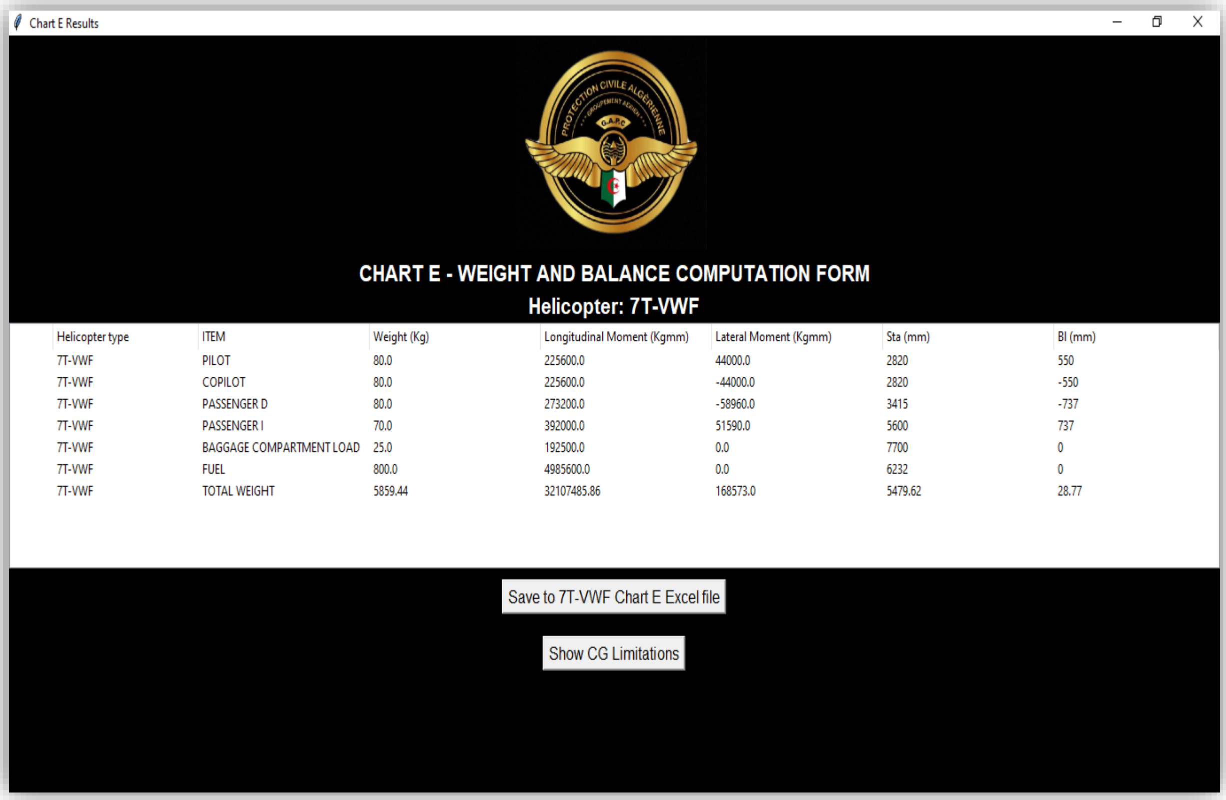


Figure 5.30: Chart E results

And, we save the results to the Chart E excel file by clicking on “Save to 7T-VWF Chart E Excel file” button. Then to check the center of gravity in both longitudinal and lateral limitations, we click on “Show CG Limitations”

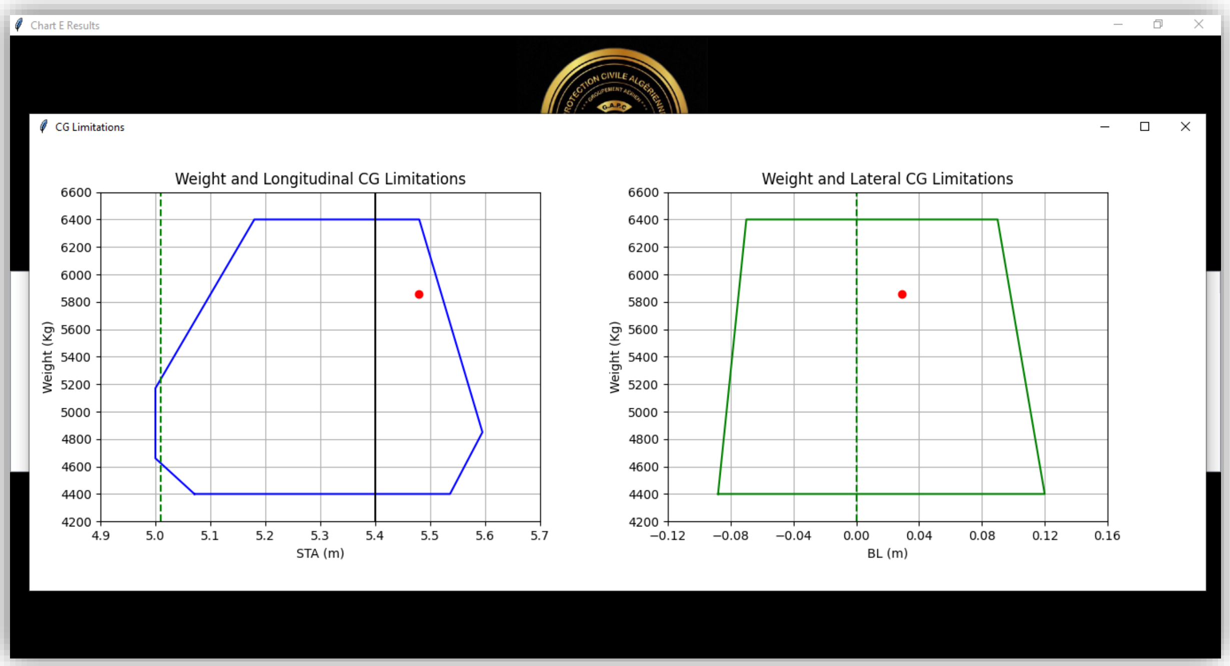


Figure 5.31: CG display

5.5.2 Operation 2: Firefighting Mission

In this second mission, the goal is to combat a fire outbreak in Tizi Ouzzou state. This demanding mission requires the swift mobilization of resources and specialized equipment to effectively suppress the fire. Alongside the skilled pilots and copilots, additional personnel will be on board to support the firefighting operations.

We will once again rely on the program to perform a full Weight and Balance study for this mission, using those main components:

- **Operator in Seat A:** The presence of an operator is crucial for coordinating and overseeing the firefighting activities. They will be strategically positioned in Seat A for optimal communication and control.
- **Stretcher Kit Aerolite (Removed):** As this mission does not involve medical evacuation, the stretcher kit Aerolite will be removed from the previous operation. This adjustment allows for additional space and ensures the optimal allocation of resources.
- **Hoist Breeze (Removed):** Similar to the stretcher kit Aerolite, the hoist breeze will not be utilized in this firefighting mission.
- **Bambi Bucket (Installed):** The Bambi Bucket is a specialized firefighting apparatus installed on the helicopter. It is designed to efficiently scoop and transport large volumes of water or fire retardant to combat the fire outbreak effectively.

- **Cargo Hook (Installed):** The cargo hook serves as an important component during firefighting operations. It enables the transportation of additional equipment or supplies, enhancing the helicopter's versatility in responding to the firefighting needs.

Since we are using the same helicopter selection for this mission, we can directly click on Chart C, from the menu of 7T-VWF, to add and removing the necessary equipment:

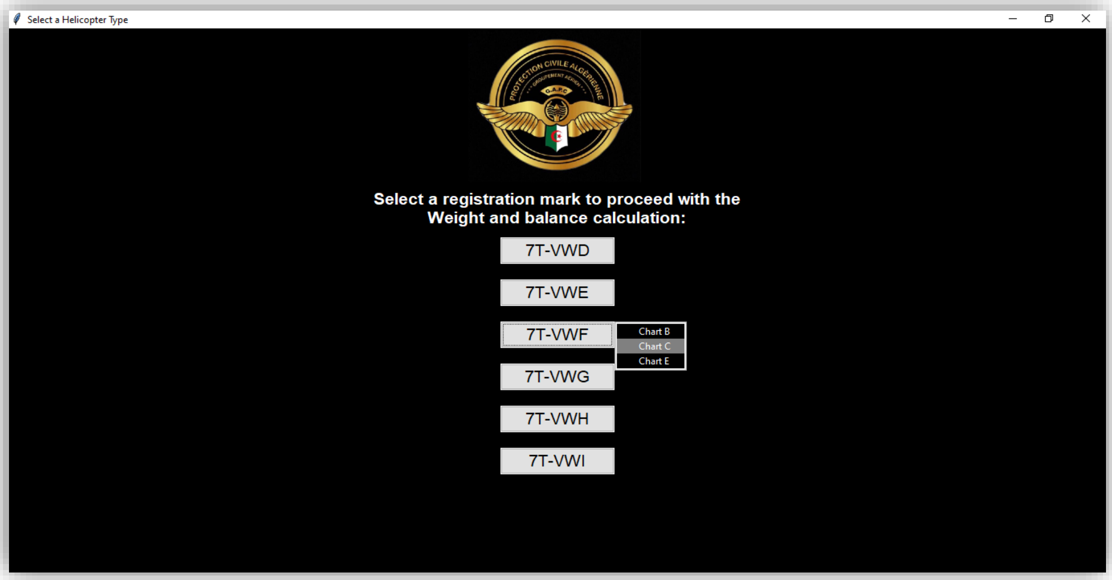


Figure 5.32: Helicopter selection for firefighting mission

So, we click on “Add/Remove Equipment” button to add and remove the necessary equipment for this mission.

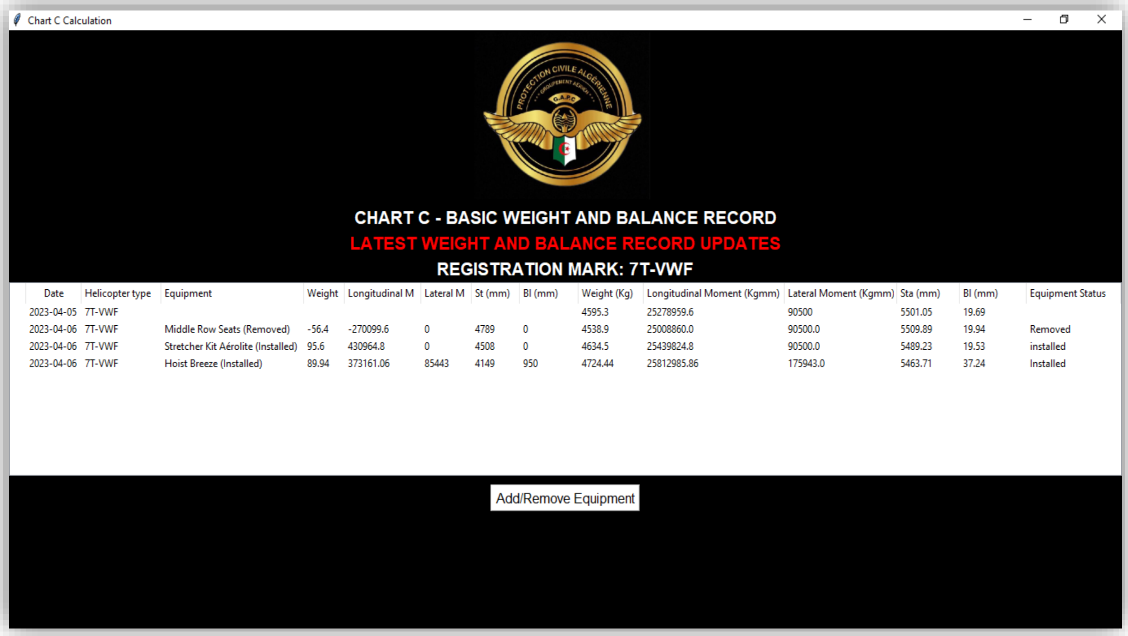


Figure 5.33: Firefighting Mission Chart B and Chart C History

Then, we Add and remove the equipment that are needed in this mission, then we click on "Display Chart C Results":

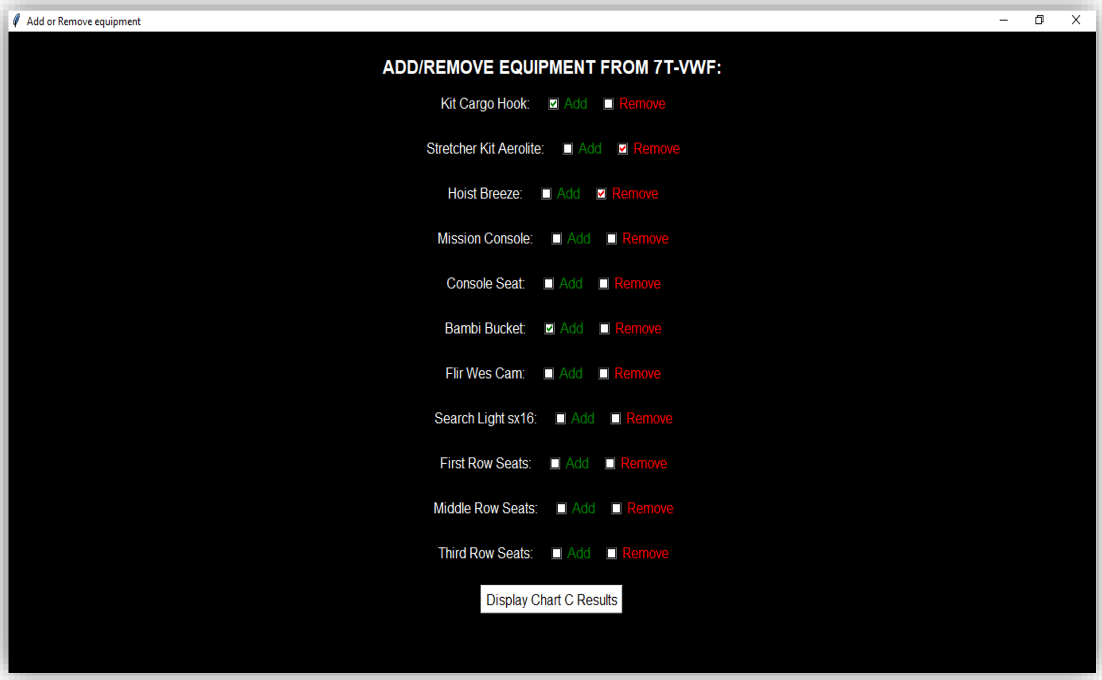


Figure 5.34: Firefighting Mission Adding Equipment

We click on "Save to 7T-VWF Chart C Excel file" and proceed with Chart E by clicking on "Proceed with Chart E", as shown by Figure 5.35.

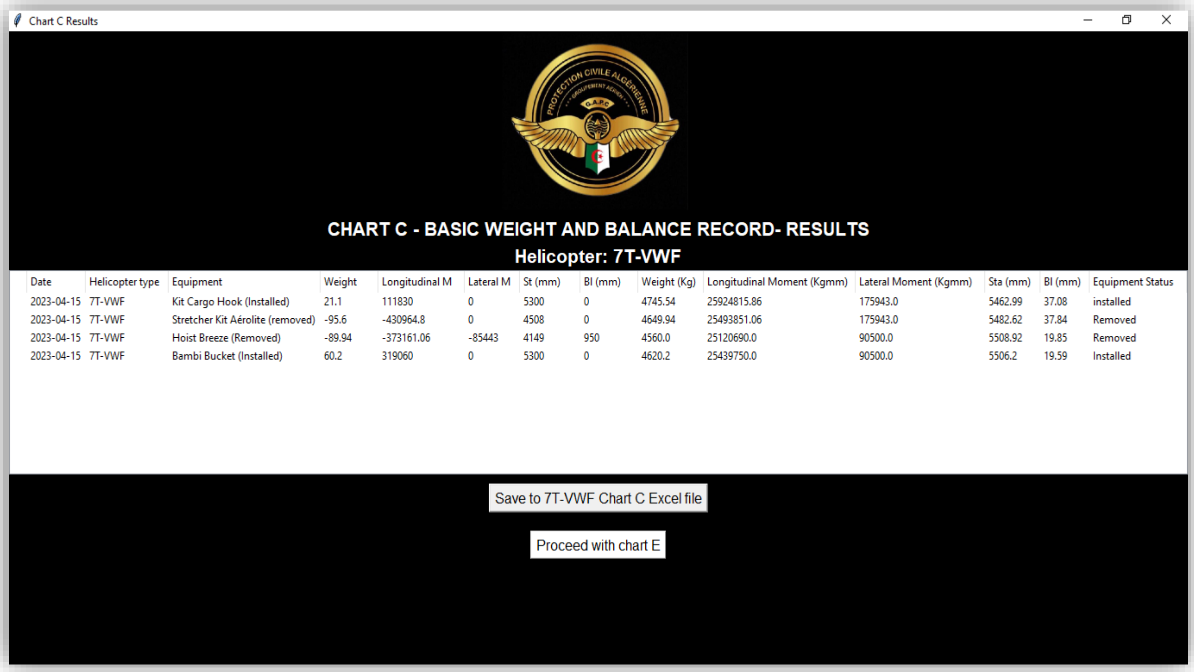


Figure 5.35: Firefighting Mission Chart C

The following weights inserted are as follows:

$Pilot = 80Kg$

$Copilot = 80Kg$

$Passenger\ A\ (Operator) = 70Kg$

$Baggage\ Compartment\ load = 20Kg$

$Fuel = 800Kg$

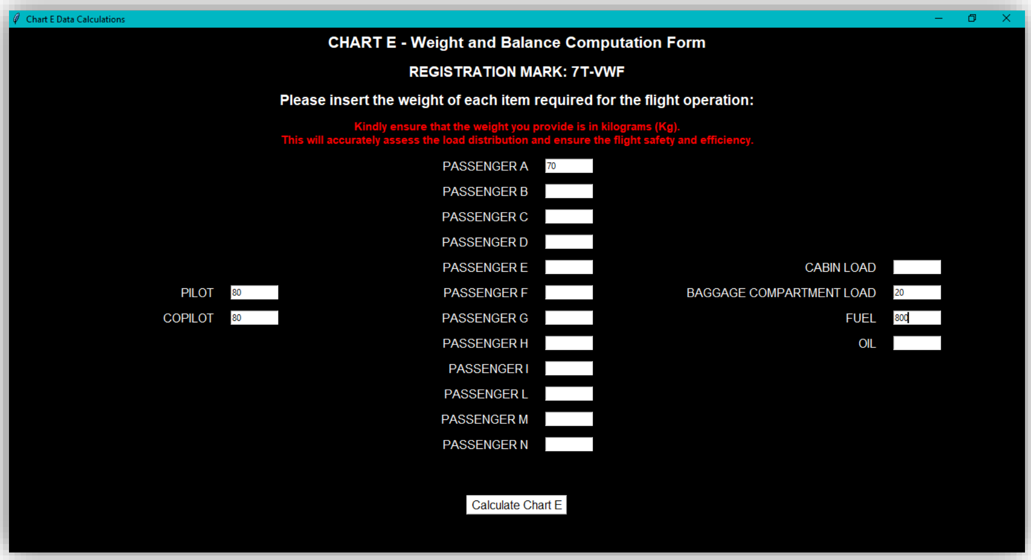
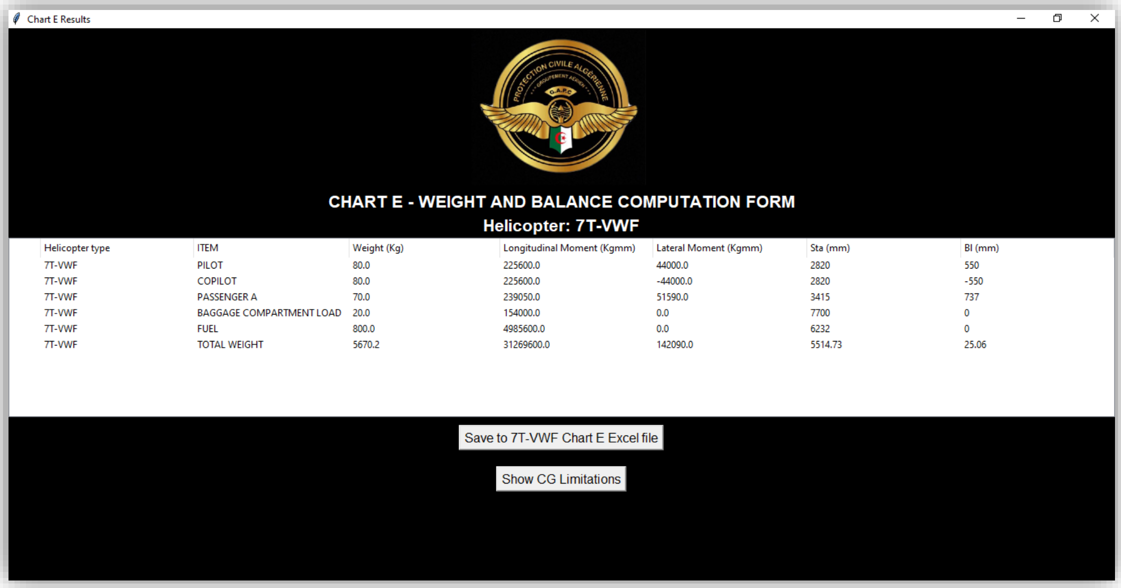


Figure 5.36: Firefighting Mission Chart E

We click on "Calculate Chart E" to see the results of Chart E.



Helicopter type	ITEM	Weight (Kg)	Longitudinal Moment (Kgmm)	Lateral Moment (Kgmm)	Sta (mm)	Bl (mm)
7T-VWF	PILOT	80.0	225600.0	44000.0	2820	550
7T-VWF	COPILOT	80.0	225600.0	-44000.0	2820	-550
7T-VWF	PASSENGER A	70.0	239050.0	51590.0	3415	737
7T-VWF	BAGGAGE COMPARTMENT LOAD	20.0	154000.0	0.0	7700	0
7T-VWF	FUEL	800.0	4985600.0	0.0	6232	0
7T-VWF	TOTAL WEIGHT	5670.2	31269600.0	142090.0	5514.73	25.06

Figure 5.37: Firefighting Mission Chart E results

And we save the results by clicking to “Save to 7T-VWF Chart E Excel file”, then we check the CG limitations:

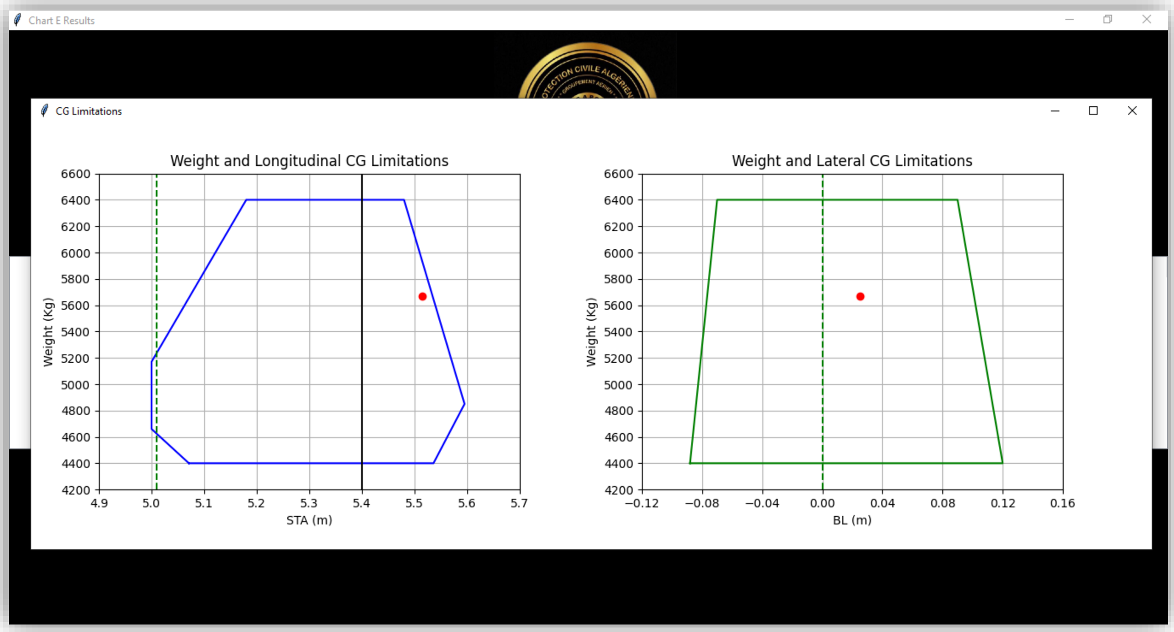


Figure 5.38: Firefighting Mission CG

5.5.3 Operation 2: Search And Rescue (SAR) Operation

The third mission takes us on a crucial Search and Rescue (SAR) operation in Bouira state, where each second counts in finding and saving people who are in need of assistance.

For this mission we need:

- **Operator in Seat A:** An experienced operator will be positioned in Seat A, overseeing the SAR activities, coordinating communications, and managing the rescue operations.
- **Bambi Bucket (Removed):** As this mission does not involve firefighting operations, the Bambi Bucket, used for water or fire-retardant transport, will be removed to optimize the helicopter's payload capacity.
- **Cargo Hook (Removed):** Given the focus on search and rescue operations, the cargo hook will be detached to maximize the interior space and accommodate additional personnel or survivors during the rescue mission.
- **Installed Middle Row and Third Row Seats:** To provide seating capacity for the rescue team or additional personnel, the middle row and third row seats will be installed.
- **Flir Wes Camera (Installed):** The installation of the Flir Wes camera enhances visual capabilities during SAR missions, enabling improved situational awareness and facilitating the identification and location of individuals in challenging environments.
- **Kit SX16 (Installed):** The installation of the Kit SX16 further enhances our aerial reconnaissance and search capabilities. With advanced features such as zooming and thermal

imaging, it assists in swiftly identifying and locating individuals in diverse and demanding scenarios.

Simply, we proceed with Chart C by clicking on it from the menu of the selected helicopter, which is 7T-VWF in our case. We can see the history of all the equipments by clicking on “Add/Remove Equipment” button.

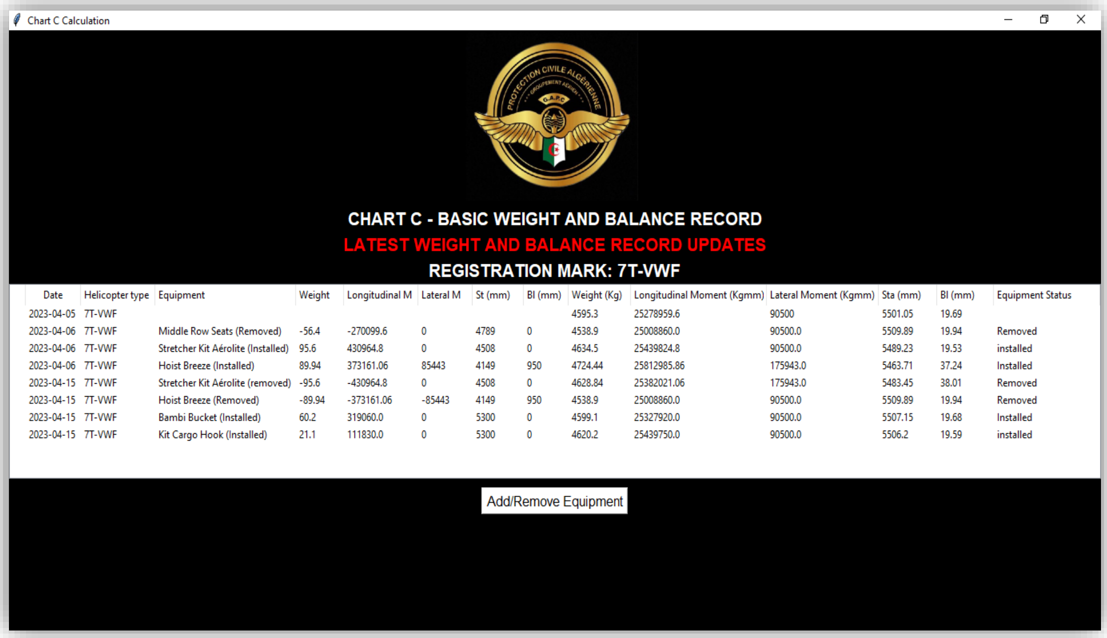


Figure 5.39: Search and Rescue (SAR) Operation Chart C history

Then we select add the middle and thirst row seats, Flir Wes Cam and the SX16 while removing the Bambi Bucket and the Hoist breeze.

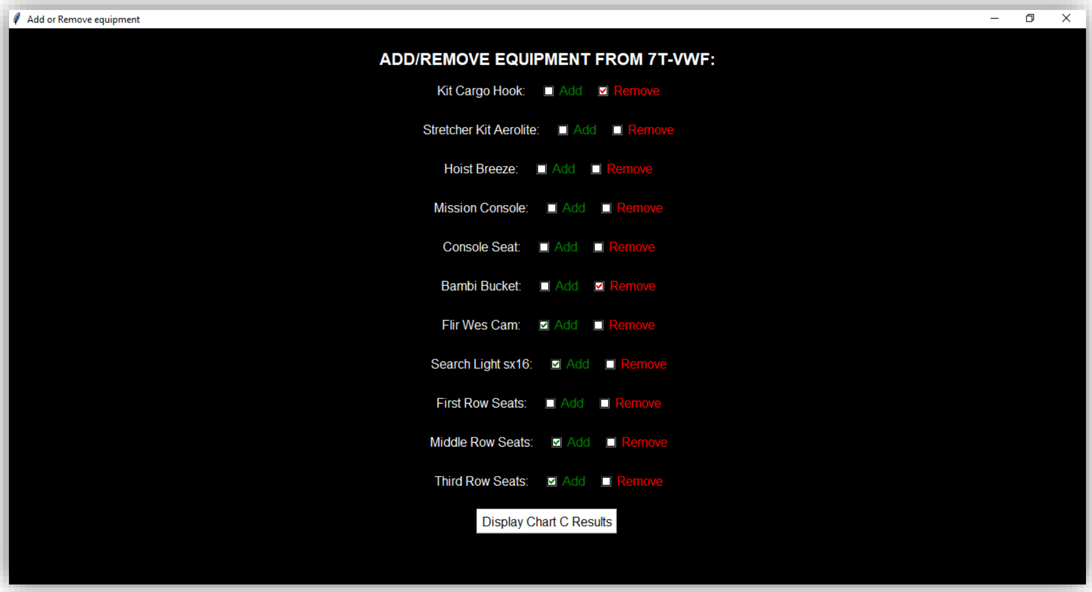
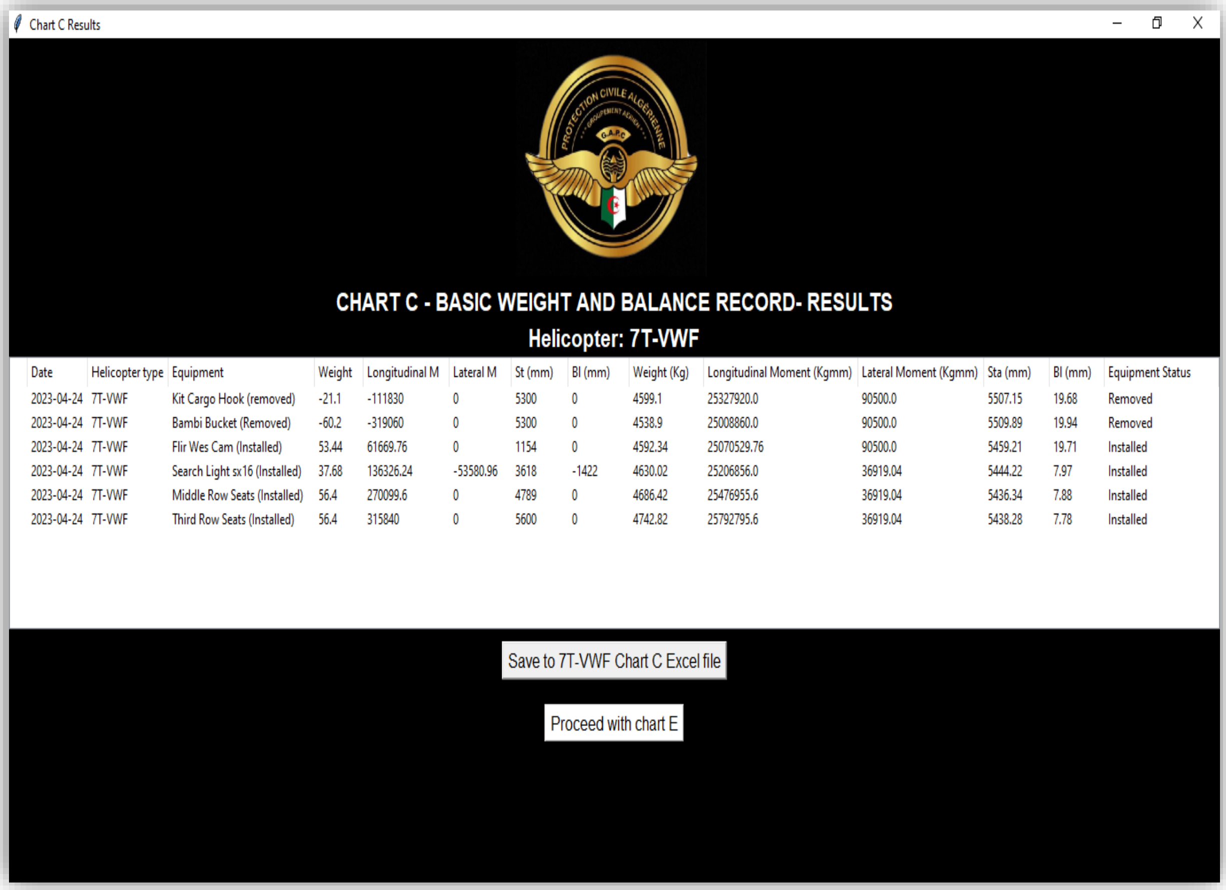


Figure 5.40: Search and Rescue (SAR) Operation Equipment

We click on “Display Chart C Results” to display the Chart C results from this operation.



Date	Helicopter type	Equipment	Weight	Longitudinal M	Lateral M	St (mm)	Bl (mm)	Weight (Kg)	Longitudinal Moment (Kgmm)	Lateral Moment (Kgmm)	Sta (mm)	Bl (mm)	Equipment Status
2023-04-24	7T-VWF	Kit Cargo Hook (removed)	-21.1	-111830	0	5300	0	4599.1	25327920.0	90500.0	5507.15	19.68	Removed
2023-04-24	7T-VWF	Bambi Bucket (Removed)	-60.2	-319060	0	5300	0	4538.9	25008860.0	90500.0	5509.89	19.94	Removed
2023-04-24	7T-VWF	Flir Wes Cam (Installed)	53.44	61669.76	0	1154	0	4592.34	25070529.76	90500.0	5459.21	19.71	Installed
2023-04-24	7T-VWF	Search Light sx16 (Installed)	37.68	136326.24	-53580.96	3618	-1422	4630.02	25206856.0	36919.04	5444.22	7.97	Installed
2023-04-24	7T-VWF	Middle Row Seats (Installed)	56.4	270099.6	0	4789	0	4686.42	25476955.6	36919.04	5436.34	7.88	Installed
2023-04-24	7T-VWF	Third Row Seats (Installed)	56.4	315840	0	5600	0	4742.82	25792795.6	36919.04	5438.28	7.78	Installed

Figure 5.41: Search and Rescue (SAR) Operation Chart C display

We click on “Save to 7T-VWF Chart C Excel file” then we proceed with Chart E by clicking on the button below.

We insert the following weight for this Search and Rescue operation:

$$Pilot = 80Kg$$

$$Copilot = 80Kg$$

$$Passenger\ A\ (Operator) = 70Kg$$

$$Baggage\ Compartment\ load = 20Kg$$

$$Fuel = 1000Kg$$

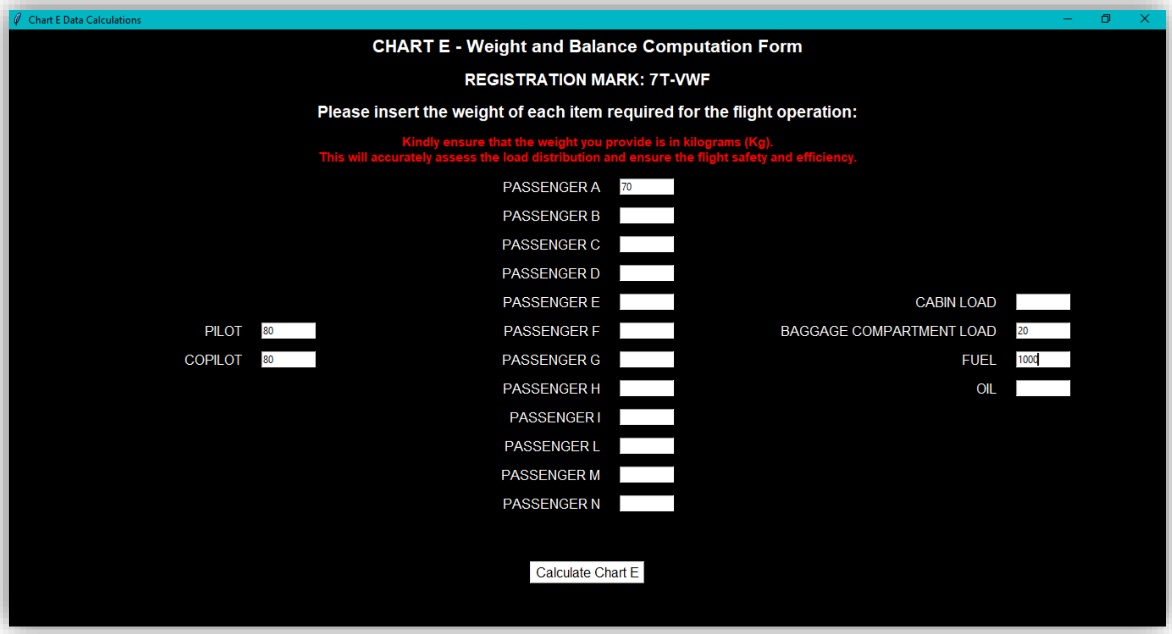
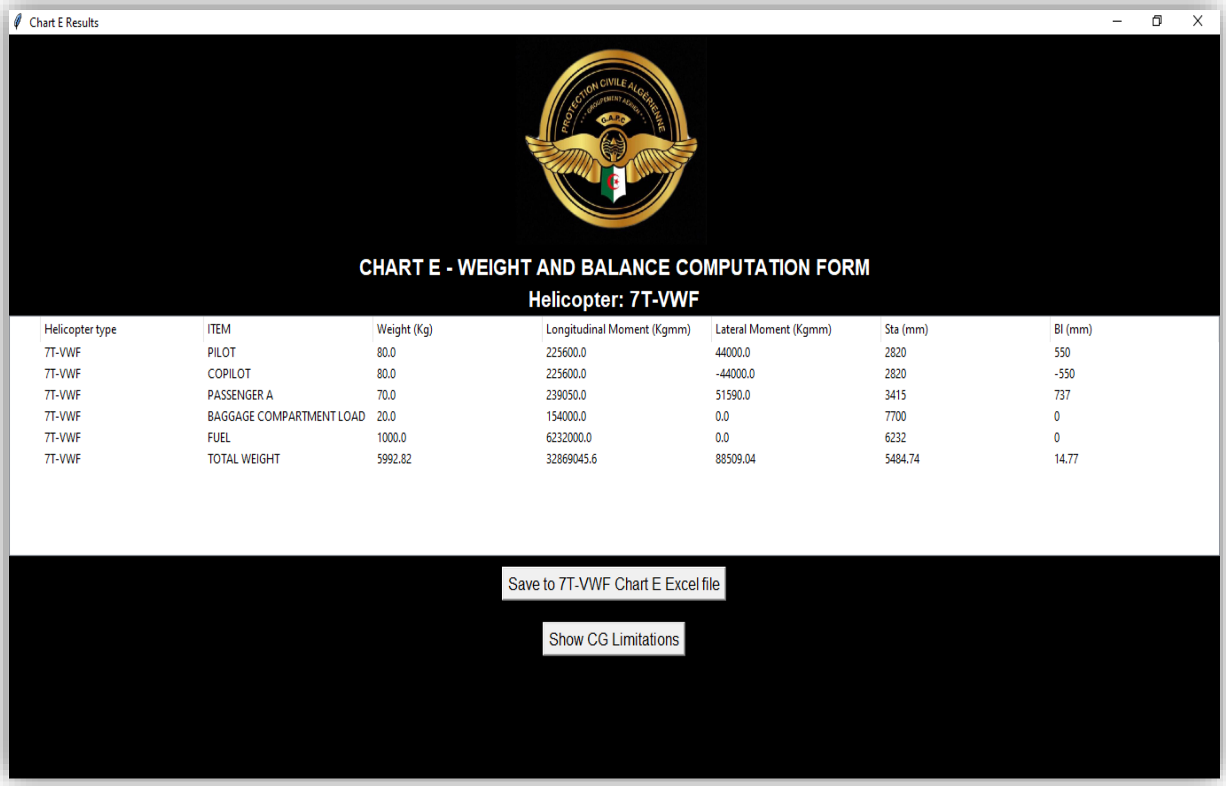


Figure 5.42: Search and Rescue (SAR) Operation Chart E

The results bellow will be displayed when clicking on "Calculate Chart E" of Figure 5.42 above.



Helicopter type	ITEM	Weight (Kg)	Longitudinal Moment (Kgmm)	Lateral Moment (Kgmm)	Sta (mm)	Bl (mm)
7T-VWF	PILOT	80.0	225600.0	44000.0	2820	550
7T-VWF	COPILOT	80.0	225600.0	-44000.0	2820	-550
7T-VWF	PASSENGER A	70.0	239050.0	51590.0	3415	737
7T-VWF	BAGGAGE COMPARTMENT LOAD	20.0	154000.0	0.0	7700	0
7T-VWF	FUEL	1000.0	6232000.0	0.0	6232	0
7T-VWF	TOTAL WEIGHT	5992.82	32869045.6	88509.04	5484.74	14.77

Figure 5.43: Search and Rescue (SAR) Operation Chart E display

After saving the results from that operation, we check the CG limitations shown by Figure 5.44.

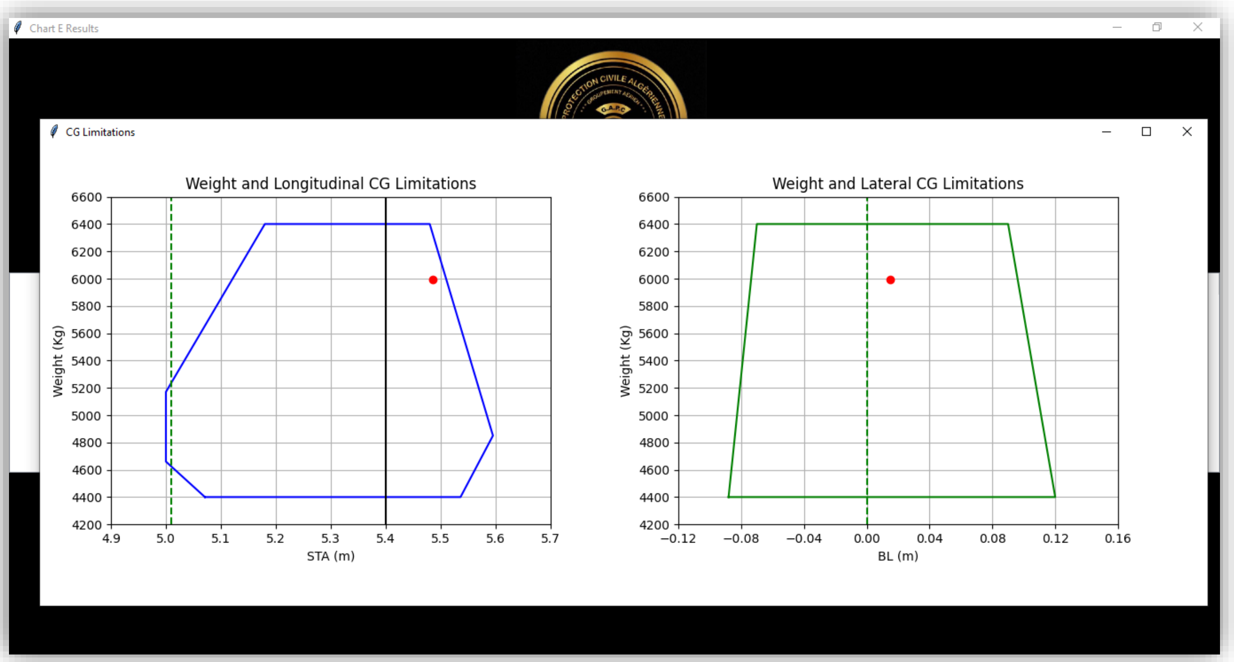


Figure 5.44: Search and Rescue (SAR) Operation CG

Following the completion of the three missions (Emergency Occupation, Firefighting, and Search and Rescue), the program's computations regularly produced trustworthy findings that were in line with what was anticipated. We were able to better comprehend the helicopter's Weight and Balance characteristics because to Chart E's in-depth research and graphical representations.

5.6 Conclusion

The creation and implementation of the AW139 helicopter's Weight and Balance program has proven to be a crucial step in improving flight operations and assuring safety. Focusing on the program's usability and the reliability of its findings, we have examined the actual use and utilization of the software throughout this chapter.

The program's intuitive architecture and ease of use have made it simple for flight operators to enter data, carry out Weight and Balance calculations, and get precise results. The use of digital charts, such Charts B, C, and E, has removed the need for manual computations and offered a more effective and dependable method for determining Weight and Balance.

In result, the AW139 helicopter's Weight and Balance computations have become much more efficient owing to the Weight and Balance program's time-saving features. This application helps flight crews to work with increased efficiency by reducing processes and delivering prompt and accurate results, ultimately resulting in safer and more productive flights. Further time-saving improvements are planned as the program develops, assuring its continuous relevance and usefulness in the constantly changing aviation landscape.

Through the fusion of Python and our digital approach, we aim to facilitate improved decision-making and ensure flight safety within Weight and Balance operations for the AW139 helicopter.

6

Conclusion And Perspectives

6.1 General conclusion

As our work nears its conclusion, it is essential to revisit the fundamental issue that sparked our investigation and evaluate the profound transformation brought about by our computational approach. The heart of the matter lay in the reliance on outdated paper-based methods for weight and balance analysis, resulting in cumbersome processes and consequential delays. Our objective was to devise a digital solution that not only remedied these challenges but also elevated the overall effectiveness and timeliness of the entire procedure.

The results of our application have been nothing short of remarkable. Through our computational approach, we have revolutionized the way weight and balance charts are utilized, providing a faster and more seamless experience for operators. Gone are the days of laborious manual calculations and error-prone pen and paper charts. Our program has streamlined the process by visually represent the center of gravity in both longitudinal and lateral graphs, saving valuable time and eliminating potential errors.

One key advantage of our digital solution is its simplicity and ease of use. Operators have embraced the intuitive interface, enabling them to quickly grasp the information presented and make well-informed decisions. This approach has not only improved efficiency but also instilled confidence in the accuracy of the results.

our application has facilitated a direct link between the weight and balance charts, enabling fast and automatic data transfer. This seamless integration has eliminated the need for tedious manual data entry, reducing the risk of human error and enhancing overall data integrity. This direct linkage has created a cohesive system that saves time and optimizes the strategic decision process.

Based on the extensive data analysis and careful examination of our computational python-based program, we confidently affirm that our fundamental objective, diligently pursued with steadfast determination, has been unequivocally achieved. The potent integration of advanced algorithms and data processing techniques has catalyzed an unprecedented breakthrough, pushing the boundaries of conventional methodologies. The diligent scrutiny of the resulting metrics and profound insights gleaned from the utilization of our advanced solution indisputably substantiates the remarkable accomplishment of our pursuit. Thus, fueled by the spirit of innovation and commitment to excellence, we proudly declare the resounding success of our transformative undertaking.

6.2 Perspectives

Through the successful implementation of our computational approach, we have established a solid groundwork for an auspicious future characterized by boundless possibilities for progress. As we delve into the profound influence our program has exerted on weight and balance analysis for the AGUSTA-WESTLAND AW139 helicopter, we envisage a myriad of augmentations poised to fine-tune and amplify its functionalities, propelling it to unprecedented levels of sophistication such as:

- **Advanced Visualization:** Building upon the foundation of graphical representation, future iterations of the program can aim to provide even more precise and visually immersive displays. This would allow operators to intuitively perceive the results in a format closely resembling traditional charts, facilitating seamless interpretation.
- **User Customization and Preferences:** A notable enhancement for the computational approach can be the inclusion of user customization and preferences within the application. This feature allows operators to tailor the software to their specific needs and preferences, providing a personalized user experience. Operators can customize the interface layout, color schemes, and data visualization options according to their preferences. Additionally, the application can offer the flexibility to save user-defined templates or presets for weight and balance calculations, making it quicker and easier to perform repetitive tasks. By incorporating user customization and preferences, the software becomes more intuitive, and adaptable to individual operator requirements.
- **Mobile Application Integration:** Recognizing the need for accessibility and convenience, the development of a dedicated mobile application holds immense promise. Such an application would enable operators to access weight and balance data on-the-go, eliminating the need to rely solely on office-based systems. This mobility would greatly enhance operational flexibility, allowing critical decisions to be made promptly, regardless of geographical location.
- **Real-time Data Synchronization:** Expanding the program's capabilities to incorporate real-time data synchronization would further streamline operations. By establishing a direct link between the computational approach and existing weight and balance systems, the program can automatically update and transfer data, reducing the potential for human error and ensuring accurate and up-to-date information.
- **AI-Driven Weight Distribution Analysis:** By using the capabilities of artificial intelligence, the program goes beyond mere data analysis, exploring an in-depth examination of the data from charts B, chart C, and chart E. Through advanced algorithms and machine learning, it thoroughly examines the weight and balance parameters, evaluating each component's impact on the helicopter's center of gravity. By studying various variables such as operator seats, weights, and other factors, the program intelligently suggests modifications for an optimized weight distribution. This approach not only ensures a safer flight but also provides operators with a deeper understanding of how each adjustment influences the center of gravity, enabling them to make informed decisions that enhance overall flight performance.

Documents

[1] Agusta Westland 139 - Leonardo Helicopter, Rotorcraft Flight Manual, Document / Rev. 28: 08-09-2022

[2] Agusta Westland 139 (AMTTC)- Leonardo Helicopters.Airframe Maintenance Type Training Course Manual, Document / Rev. 28: 08-09-2022

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[6] « Généralités Et Fondements » Partie A Manuel D'exploitation Du Groupement Aérien De La Protection Civile, Document / 17-01-2022.

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Web Sites

[10] https://arc.aiaa.org/

[11] https://patents.google.com/patent/US4574360A/en

[12] https://www.python.org/

[13] https://www.jetbrains.com/idea/

[14] https://www.stat.berkeley.edu/~spector/python.pdf

Appendix A

List of abbreviations and parameters

Abbreviations	Definitions
	A
ADF	Automatic Direction Finder
AEO	All Engine Operative
AFT	Afterward
APS	Aircraft Prepared For Service
ASCB-D	Avionics Standard Communication Bus version D
AUP	All Up Weight
AW	Agusta Westland
	B
BL	Buttock Line
	C
CENAC	(The National Coordination Center) Centre National De Coordination De La Direction Générale De La Protection Civile
CG	Center Of Gravity
CMS	Central Main Systems
CPAG	Civil Protection Air Group
CVR	Cockpit Voice Recorder
	D
DC	Direct Current
DME	Distance Measuring Equipment
DOW	Dry Operating Weight
DU	Display Unit
	E
EASA	European Aviation Safety Agency
ECA	Entreprise De Construction Aéronautique
ELT	Emergency Locator Transmitetr
EWCG	Empty Weight Center Of Gravity

F

FCU	Fuel Computer Unit
FDR	Flight Data Recorder
FWD	Forward

G

GA	General Aviation

I

IGB	Intermediate Gearbox
IGE	In Ground Effect
ILS	Instrument Landing System

L

LCD	Liquid Crystal Flight Display

M

M	Moment
M_{lat}	Lateral Moment
M_{long}	Longitudinal Moment
MANEX	Manuel d'Exploitation
MAU	Modular Avionics Unit
MGB	Main Gearbox
MR	Main Rotor
MRC	Modular Radio Cabinets
MTOW	Maximum Take Off Weight
MTWA	Maximum Total Weight Authorized

O

OGE	Out Ground Effect

S

STA	Station

T

TGB	Tail Gearbox
TR	Tail Rotor

V

VHF-COMM	Very High Frequency Communication
VNE	Vitesses Never Exceed
VOR	Very High Frequency Omni-Directional Range

X

XPDR	Transponder

Z

ZFW	Zero Fuel Weight

Appendix B

List of definitions

A

ADF Electronic navigation equipment that operates in the low- and medium-frequency bands. Used in conjunction with the ground-based nondirectional beacon (NDB), the instrument displays the number of degrees clockwise from the nose of the aircraft to the station being received.

Arm. (The horizontal distance from the reference datum to the CG of an item. The algebraic sign is plus (+) if measured aft of the datum or to the right side of the center line when considering a lateral calculation. The algebraic sign is minus (–) if measured forward of the datum or the left side of the center line when considering a lateral calculation.

Airplane Flight manual (AFM) An FAA-approved document, prepared by the holder of a type certificate for an aircraft, that specifies the operating limitations and contains the required markings and placards and other information applicable to the regulations under which the aircraft was certificated.

B

Basic Empty Weight The starting point for weight computations is the basic empty weight. This is the weight of the standard helicopter, optional equipment, unusable fuel, and all operating fluids including engine and transmission oil, and hydraulic fluid for those aircraft so equipped. Some helicopters might use the term “licensed empty weight,” which is nearly the same as basic empty weight, except that it does not include full engine and transmission oil, just undrainable oil. If flying a helicopter that lists a licensed empty weight, be sure to add the weight of the oil to the computations.

Balance Helicopter performance is not only affected by gross weight, but also by the position of that weight. It is essential to load the aircraft within the allowable CG range specified in the rotorcraft flight manual’s (RFM) weight and balance limitations. Loading outside approved limits can result in insufficient control travel for safe operation.

C

CVR the Cockpit Voice Recorder records the flight crew's voices, as well as other sounds inside the cockpit. The recorder's "cockpit area microphone" is usually located on the overhead instrument panel between the two pilots.

Center of Gravity The theoretical point where the entire weight of the helicopter is considered to be concentrated. The pilot should ensure that the helicopter is properly balanced and within its center of gravity limitations, so that minimal cyclic input is required during hovering flight, except for any wind corrections.

Since the fuselage acts as a pendulum suspended from the rotor, changing the CG changes the angle at which the aircraft hangs from the rotor. When the CG is directly under the rotor mast, the helicopter hangs horizontally; if the CG is too far forward of the mast, the helicopter hangs with its nose tilted down; if the CG is too far aft of the mast, the nose tilts up.

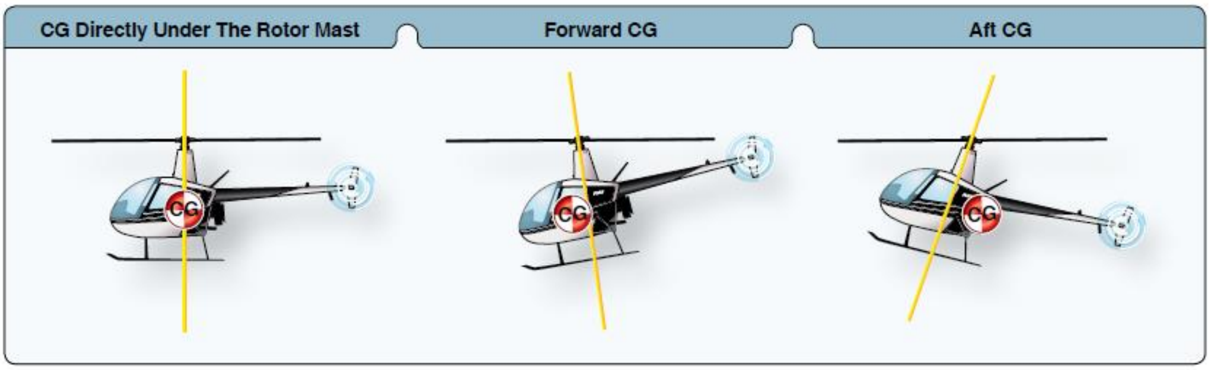


Figure B.1: The location of the CG strongly influences how the helicopter handles

D

DME A pulse-type electronic navigation system that shows the pilot, by an instrument-panel indication, the number of nautical miles between the aircraft and a ground station or waypoint.

E

EASA the European Aviation Safety Agency (EASA) is responsible for ensuring safety and environmental protection in air transport in Europe.

ELT An emergency locator transmitter that helps rescuers find aircraft and people in distress following an aircraft impact with terrain.

F

FDR the Flight Data Recorder (FDR), monitors parameters such as altitude, airspeed and heading.

G

Gross weight the sum of the basic empty weight and useful load.

I

ILS An electronic system that provides both horizontal and vertical guidance to a specific runway, used to execute a precision instrument approach procedure.

ILS categories Categories of instrument approach procedures allowed at airports equipped with the following types of instrument landing systems:

ILS Category I: Provides for approach to a height above touchdown of not less than 200 feet, and with runway visual range of not less than 1,800 feet.

ILS Category II: Provides for approach to a height above touchdown of not less than 100 feet and with runway visual range of not less than 1,200 feet.

ILS Category IIIA: Provides for approach without a decision height minimum and with runway visual range of not less than 700 feet.

ILS Category IIIB: Provides for approach without a decision height minimum and with runway visual range of not less than 150 feet.

ILS Category IIIC: Provides for approach without a decision height minimum and without runway visual range minimum.

L

Load factor the ratio of a specified load weight to the total weight of the aircraft.

LCD Is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid.

M

Maximum Gross Weight The maximum weight of the helicopter is referred to its maximum gross weight. Most helicopters have an internal maximum gross weight, which refers to the weight within the helicopter structure and an external maximum gross weight, which refers to the weight of the helicopter with an external load. The external maximum weight may vary depending on where it is attached to the helicopter. Some large cargo helicopters may have several attachment points for sling load or winch operations. These helicopters can carry a tremendous amount of weight when the attachment point is directly under the CG of the aircraft.

MAU It provides a custom solution to suit aircraft configurations with minimal engineering. The MAU is designed to fit general, business and military aircraft which require a standalone or integrated flight data acquisition system.

P

Payload the term used for the combined weight of passengers, baggage, and cargo.

R

Reference Datum Balance is determined by the location of the CG, which is usually described as a given number of inches from the reference datum. The horizontal reference datum is an imaginary vertical plane or point, arbitrarily fixed somewhere along the longitudinal axis of the helicopter, from which all horizontal distances are measured for weight and balance purposes. There is no fixed rule for its location. It may be located at the rotor mast, the nose of the helicopter, or even at a point in space ahead of the helicopter.

The lateral reference datum is usually located at the center of the helicopter. The location of the reference datum is established by the manufacturer and is defined in the RFM.

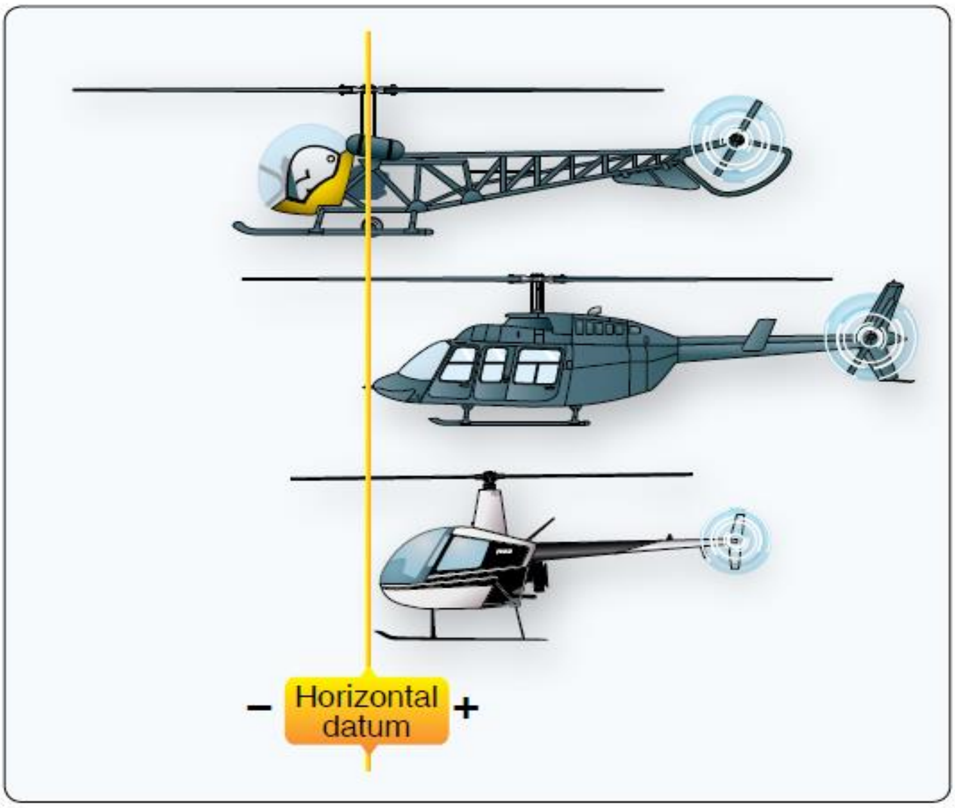


Figure B.2: *While the horizontal reference datum can be anywhere the manufacturer chooses, some manufacturers choose the datum line at or ahead of the most forward structural point on the helicopter, in which case all moments are positive. This aids in simplifying calculations. Other manufacturers choose the datum line at some point in the middle of the helicopter, in which case moments produced by weight in front of the datum are negative and moments produced by weight aft of the datum are positive.*

U

Useful load the difference between the gross weight and the basic empty weight. It includes the flight crew, usable fuel, drainable oil, if applicable, and payload.

V

VOR Electronic navigation equipment in which the flight deck instrument identifies the radial or line from the VOR station, measured in degrees clockwise from magnetic north, along which the aircraft is located.

W

Weight When determining if a helicopter is within the weight limits, consider the weight of the basic helicopter, crew, passengers, cargo, and fuel. Although the effective weight (load factor) varies during maneuvering flight, this chapter primarily addresses the weight of the loaded helicopter while at rest.

It is critical to understand that the maximum allowable weight may change during the flight. When operations include out of ground effect (OGE) hovers and confined areas, planning must be done to ensure that the helicopter is capable of lifting the weight during all phases of flight. The weight may be acceptable during the early morning hours, but as the density altitude increases during the day, the maximum allowable weight may have to be reduced to keep the helicopter within its capability.

The following terms are used when computing a helicopter's weight:

- Basic Empty Weight.
- Maximum Gross Weight.

X

XPDR A transponder XPDR is a receiver/transmitter, which will generate a reply signal upon proper interrogation; the interrogation and reply being on different frequencies.

The paper version of the weighing procedure

In the next figures, the paper version of the weighing procedure used by the engineers of the CPAG is shown, noting that this job card is extracted from the IETP of the AW139, and it contains all the steps that must be done as a checklist.

	MAINTENANCE JOB CARD 39-A-08-31-00-00A-028A-A	AGUSA 139AW IETP Rev. date:26/02/2023

Helicopter - Weigh procedures - General	Mech.	Insp.

References

Table 1 References

Data Module	Title
39-A-00-20-00-00A-120A-A	Helicopter safety - Pre-operation (make helicopter safe for maintenance)
39-A-07-11-00-00A-028A-A	Helicopter - Lift on jacks - General
39-A-08-21-00-00A-028A-A	Helicopter - Level procedure - General
39-A-12-11-02-00A-218A-A	Wheel brake system - Fill with other liquid
39-A-12-11-03-00A-212A-A	Main gearbox - Fill with oil
39-A-12-11-04-00A-212A-A	Intermediate gearbox - Fill with oil
39-A-12-11-05-00A-212A-A	Tail gearbox - Fill with oil
39-A-12-11-06-00A-212A-A	Number 1 engine - Fill with oil
39-A-12-11-07-00A-212A-A	Number 2 engine - Fill with oil
39-A-12-11-08-00A-218A-A	Number 1 power control module - Fill with other liquid
39-A-12-11-09-00A-218A-A	Number 2 power control module - Fill with other liquid
39-A-12-12-01-00A-221A-A	Number 1 fuel tank - Defuel and drain fuel
39-A-12-12-02-00A-221A-A	Number 2 fuel tank - Defuel and drain fuel

Preliminary Requirements

Required Conditions

Table 4 Required Conditions

Conditions	Data Module/Technical Publication
The helicopter must be safe for maintenance	39-A-00-20-00-00A-120A-A

Support Equipment

Table 5 Support Equipment

Nomenclature	Identification No.	Qty
Helicopter weighing kit	HA-27-00	1
Case with digital indicator and printer	HA-27-01	1
Load cell, (3500 kg) with cable	HA-27-02	3
Jack point adapter	HA-27-03	3
Load cell adapter	HA-27-04	3
Jack, hydraulic	HA-01-00	3
Bracket, forward jacking	HA-17-00	1

Safety Conditions

WARNING

Be careful when you lift or lower the helicopter. Make sure all the persons who are not necessary for the procedures are clear of the helicopter. Do not stay near or on the helicopter during lift operation.

CAUTION

Put ropes around the work area and put the jack warning signs at the four end sides of the helicopter.

Effectivity: AW139 – DGPC - SN, LN, ENH, PLUS PAGE 1 OF 5

Figure C.1: page 1 of 5 weigh procedures, maintenance job card

	MAINTENANCE JOB CARD **39-A-08-31-00-00A-028A-A**	AGUSA 139AW **IETP** Rev. date:26/02/2023

	Mech.	Insp.

Procedure

Note

To lift on jacks/lower the helicopter during this procedure refer to 39-A-07-11-00-00A-028A-A

1 Prepare the helicopter for weighing as follows:

1.1 Defuel the Number 1 fuel tank. Refer to 39-A-12-12-01-00A-221A-A.

1.2 Defuel the Number 2 fuel tank. Refer to 39-A-12-12-02-00A-221A-A.

1.3 Do a check of the oil level in the Number 1 engine. If necessary, fill with oil. Refer to 39-A-12-11-06-00A-212A-A.

1.4 Do a check of the oil level in the Number 2 engine. If necessary, fill with oil. Refer to 39-A-12-11-07-00A-212A-A.

1.5 Do a check of the oil level in the main gearbox. If necessary, fill with oil. Refer to 39-A-12-11-03-00A-212A-A.

1.6 Do a check of the oil level in the intermediate gearbox. If necessary, fill with oil. Refer to 39-A-12-11-04-00A-212A-A.

1.7 Do a check of the oil level in the tail gearbox. If necessary, fill with oil. Refer to 39-A-12-11-05-00A-212A-A.

1.8 Do a check of the fluid level in the Number 1 power control module. If necessary, fill with fluid. Refer to 39-A-12-11-08-00A-218A-A.

1.9 Do a check of the fluid level in the Number 2 power control module. If necessary, fill with fluid. Refer to 39-A-12-11-09-00A-218A-A.

1.10 Do a check of the fluid level in the brake reservoir. If necessary, fill with fluid. Refer to 39-A-12-11-02-00A-218A-A.

1.11 Get access to the cockpit and set the rotor brake to OFF.

1.12 Turn the main rotor head to align the Number 1 main-rotor blade with the tail cone.

1.13 Set the rotor brake to ON. make sure that the rotor brake is engaged.

2 Lift the helicopter on jacks for weighing as follows:

2.1 Make sure that the helicopter is in an area (such as a hangar) where the wind can have no effect

Effectivity: AW139 – DGPC - SN, LN, ENH, PLUS PAGE 2 OF 5

Figure C.2: page 2 of 5 weigh procedures, maintenance job card

MAINTENANCE JOB CARD	AGUSA 139AW
39-A-08-31-00-00A-028A-A	IETP Rev. date:26/02/2023

Mech. Insp.

on it.

2.2 Put the helicopter on a level ground.

2.3 Install the Helicopter weighing kit (HA-27-00) as follows:

2.3.1 Install one Load cell adapter (HA-27-04) (2, Figure 1) on each of the three Jack

Jack, hydraulic (HA-01-00) (1).

2.3.2 Put one Load cell, (3500 kg) with cable (HA-27-02) (3) in its position on each of the load cell adapter (2).

2.3.3 Install one Jack point adapter (HA-27-03) (4) on each of the load cell (3).

2.3.4 Put one hydraulic jack (1) in position between the forward jack points at STA 3160.

2.3.5 Put the Bracket, forward jacking (HA-17-00) (5) on the jack point adapter (4).

2.3.6 Align the adapters of the weighing bracket (5) to the forward jack pads at STA 3160.

2.3.7 Put the other two hydraulic jacks (1) below the aft jack points at STA 6700.

2.3.8 Align the adapters of the weighing bracket (5) to the forward jack pads at STA 3160.

2.3.9 Put the Case with digital indicator and printer (HA-27-01) on side of the helicopter

2.3.10 Connect the cable of each load cell (3) to the digital indicator.

2.3.11 Set the digital indicator on.

2.3.12 Make sure that the digital indicator is correctly set. Refer to the manual of the digital indicator

2.4 Lift the helicopter on jacks (1)

2.5 Level the helicopter. Refer to 39-A-08-21-00-00A-028A-A.

3 Weigh the helicopter as follows:

3.1 Let each load cell and the scales indications become stable.

3.2 Record the weights shown on the scales for each load cell.

3.3 Make sure that you record the related jack position for each weight.

3.4 Calculate the longitudinal and lateral Center of Gravity (CG) positions. Refer to "CHART B-HELICOPTER WEIGHING RECORD" in the Rotorcraft Flight Manual.

3.5 Record the Center of Gravity (CG) positions. Refer to "CHART C - BASIC WEIGHT AND BALANCE RECORD" in the Rotorcraft Flight Manual.

Effectivity: AW139 – DGPC - SN, LN, ENH, PLUS PAGE 3 OF 5

Figure C.3: page 3 of 5 weigh procedures, maintenance job card

MAINTENANCE JOB CARD 39-A-08-31-00-00A-028A-A	AGUSA 139AW IETP Rev. date:26/02/2023	
	Mech.	Insp.

4 Lower the helicopter on ground.

5 Remove the helicopter weighing kit as follows:

5.1 Set the digital indicator off.

5.2 Disconnect the cable of each load cell (3) from the digital indicator.

5.3 Remove the weighing bracket (5) from the jack point adapter (4) of the hydraulic jack (1) at STA 2830.

5.4 Remove the three jacks (1) from the helicopter.

5.5 Remove the jack point adapter (4) from each of the load cell (3).

5.6 Remove the load cell (3) from each of the load cell adapter (2).

5.7 Remove the load cell adapter (2) from each of the three hydraulic jack (1).

Requirements After Job Completion

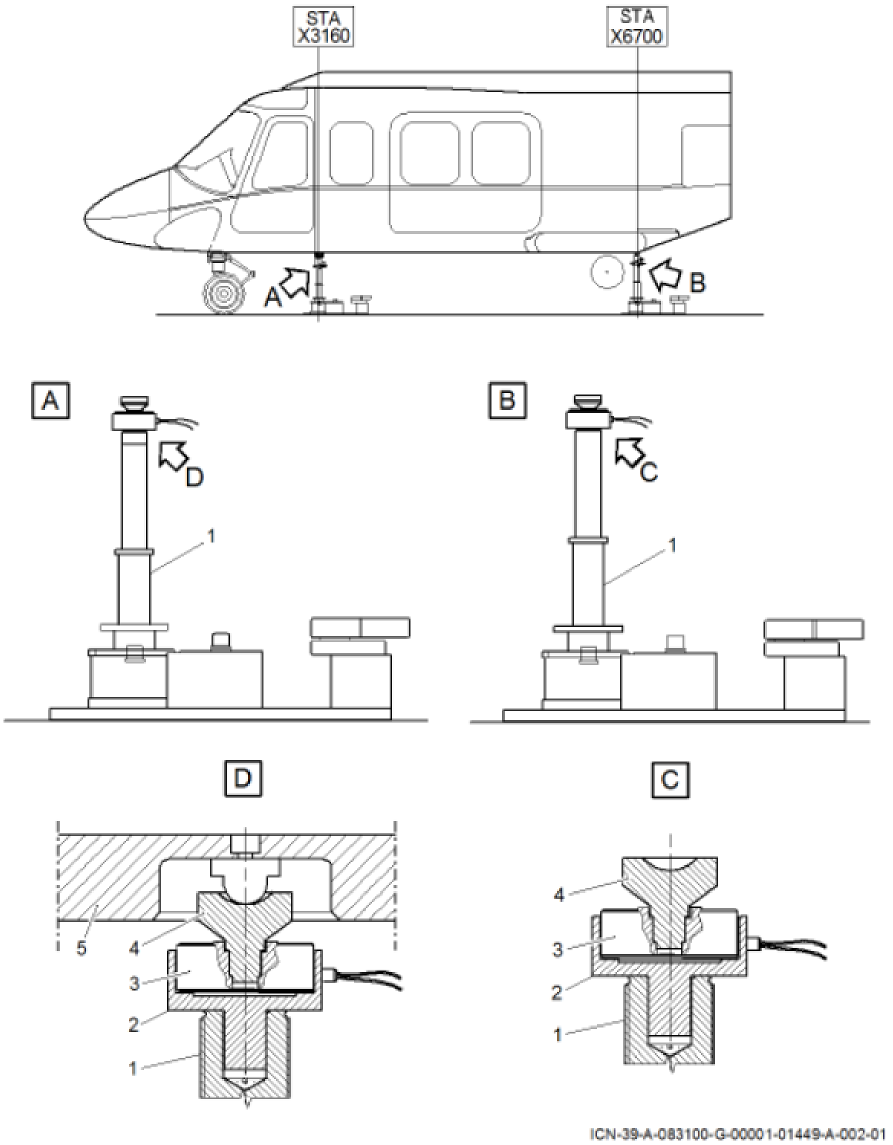
1 Remove all the tools and the other items from the work area. Make sure that the work area is clean.

Effectivity: AW139 – DGPC - SN, LN, ENH, PLUS PAGE 4 OF 5

Figure C.4: page 4 of 5 weigh procedures, maintenance job card

	MAINTENANCE JOB CARD **39-A-08-31-00-00A-028A-A**	AGUSA 139AW **IETP** Rev. date:26/02/2023

	Mech.	Insp.



Effectivity: AW139 – DGPC - SN, LN, ENH, PLUS

PAGE 5 OF 5

Figure C.5: page 5 of 5 weigh procedures, maintenance job card

Appendix D

Comprehensive Information on Weight, Longitudinal, and Lateral Moments of Mission Equipment

In the upcoming figures presented in this annex, we will find all the necessary information regarding the weight, longitudinal moment, and lateral moment of the equipment used for various missions. These figures are intended to provide comprehensive details and insights into the characteristics of the equipment, allowing for a better understanding of their performance and capabilities.

The weight of the equipment refers to its mass or the force exerted by it due to gravity. Knowing the weight is crucial for determining the load capacity of vehicles or structures involved in the missions. It helps in ensuring proper balance and stability during transportation or operation.

The longitudinal moment indicates the tendency of the equipment to rotate around its longitudinal axis. This moment is significant for assessing the balance of the equipment during acceleration, deceleration, or changes in direction. It plays a vital role in maintaining control and stability, especially in dynamic situations.

Similarly, the lateral moment represents the equipment's inclination to rotate around its lateral axis. It is crucial for understanding the equipment's behavior when subjected to side forces or when navigating uneven terrain. Evaluating the lateral moment allows for effective planning and decision-making, ensuring safe and efficient operation.

By including these specific details in the upcoming figures, we aim to provide a comprehensive overview of the equipment's characteristics. This information will prove invaluable for engineers, operators, and decision-makers involved in the missions. It enables them to make informed choices regarding equipment selection, load distribution, and overall mission planning.

It is important to note that the figures will be accompanied by detailed labels, units of measurement, and clear legends to facilitate easy interpretation. Additionally, any relevant assumptions or limitations associated with the data will be explicitly mentioned, ensuring transparency and accuracy in the analysis.

We anticipate that the inclusion of these figures will enhance the understanding of the equipment's performance and enable effective decision-making in diverse mission scenarios.

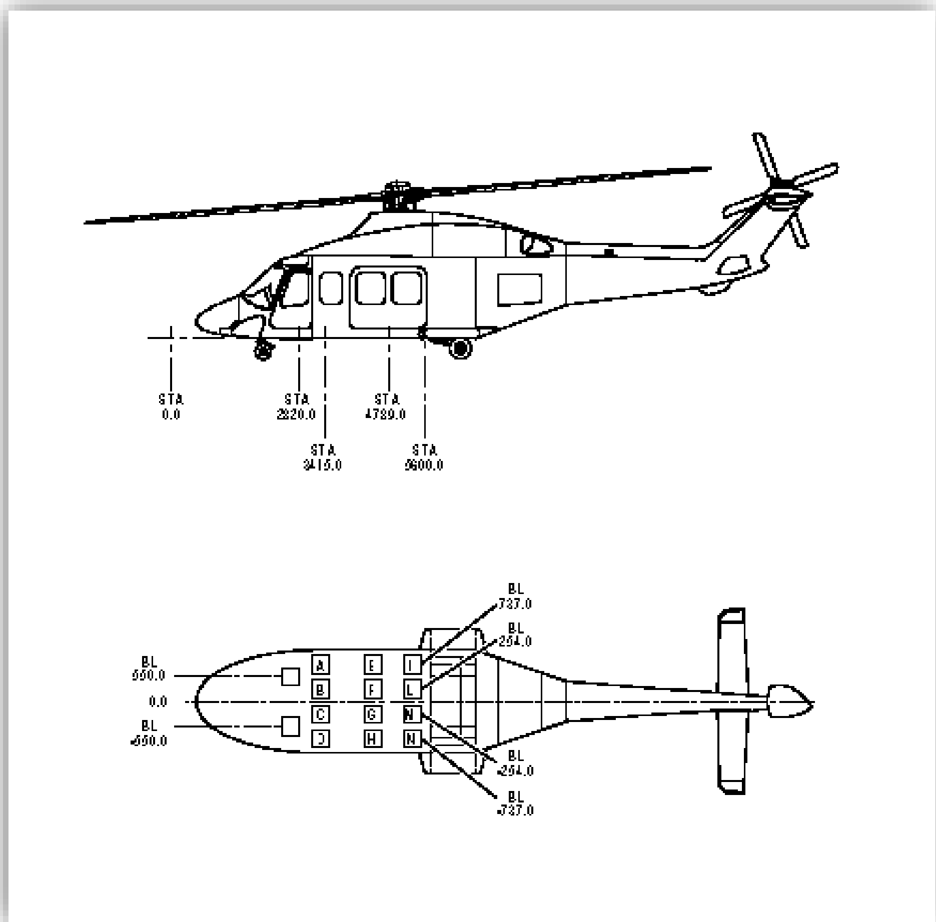


Figure D.1: Helicopter stations diagram

PASSENGERS (12 SEATS)	ROW	STATION (mm)
A	1	3415
B	1	3415
C	1	3415
D	1	3415
E	2	4789
F	2	4789
G	2	4789
H	2	4789
I	3	5600
L	3	5600
M	3	5600
N	3	5600

Figure D.2: Passengers Loading

Pilots and Passengers						
Weight (kg)	Pilot (Arm 550 mm) Moment (kg m)	Copilot or passenger (Arm -550 mm) Moment (kg m)	Passengers max left (Arm -737 mm) Moment (kg m)	Passengers left (Arm -254 mm) Moment (kg m)	Passengers right (Arm 254 mm) Moment (kg m)	Passengers max right (Arm 737 mm) Moment (kg m)
70	39	-39	-52	-18	18	52
80	44	-44	-59	-20	20	59
90	50	-50	-66	-23	23	66
100	55	-55	-74	-25	25	74
110	61	-61	-81	-28	28	81
120	66	-66	-88	-30	30	88
130	72	-72	-96	-33	33	96
140	77	-77	-103	-36	36	103
150	83	-83	-111	-38	38	111
160			-118	-41	41	118
170			-125	-43	43	125
180			-133	-46	46	133
190			-140	-48	48	140
200			-147	-51	51	147
210			-155	-53	53	155
220			-162	-56	56	162
230			-170	-58	58	170
240			-177	-61	61	177
250			-184	-64	64	184
260			-192	-66	66	192
270			-199	-69	69	199
280			-206	-71	71	206
290			-214	-74	74	214
300			-221	-76	76	221
310			-228	-79	79	228
320			-236	-81	81	236
330			-243	-84	84	243
340			-251	-86	86	251
350			-258	-89	89	258

Figure D.3: Weight, arms and moments of persons on board– Lateral moments

Pilots and Passengers						
Weight	Pilot Copilot or passenger	Passengers first row (4 seats & 3 mid of 5 seat)	Passengers first row Seats A & E for 5 seat	Passengers second row (4-5 seats)	Passengers third row (4 seats & 3 mid of 5 seat)	Passengers third row Seats M & Q for 5 seat
(kg)	(Arm 2820 mm) Moment (kgm)	(Arm 3415 mm) Moment (kgm)	(Arm 3449 mm) Moment (kgm)	(Arm 4789 mm) Moment (kgm)	(Arm 5600 mm) Moment (kgm)	(Arm 5556 mm) Moment (kgm)
70	197	239	241	335	392	388
80	226	273	276	383	448	444
90	254	307	310	431	504	500
100	282	342	345	479	560	555
110	310	376	379	527	616	611
120	338	410	414	575	672	667
130	367	444	448	623	728	722
140	395	478	483	670	784	778
150	423	512	517	718	840	833
160	451	546	552	766	896	889
170	479	581	586	814	952	944
180	508	615	621	862	1008	1000
190	536	649	655	910	1064	1055
200	564	683	690	958	1120	1111
210	592	717	724	1006	1176	1167
220	620	751	759	1054	1232	1222
230	649	785	793	1101	1288	1278
240	677	820	828	1149	1344	1333
250		854		1197	1400	
260		888		1245	1456	
270		922		1293	1512	
280		956		1341	1568	
290		990		1389	1624	
300		1025		1437	1680	
310		1059		1485	1736	
320		1093		1532	1792	
330		1127		1580	1848	
340		1161		1628	1904	
350		1195		1676	1960	
360		1229		1724	2016	
370		1264		1772	2072	
380		1298		1820	2128	
390		1332		1868	2184	
400		1366		1916	2240	
410		1400		1963	2296	
420		1434		2011	2352	
430		1468		2059	2408	
440		1503		2107	2464	
450		1537		2155	2520	
460		1571		2203	2576	
470		1605		2251	2632	
480		1639		2299	2688	

Figure D.4: Weight, arms and moments of persons on board – Longitudinal moments

ENGINE OIL (Arm 6878)		
Welght (kg)	(L)	Moment (kgm)
16	16	110,0

MAIN TRANSMISSION OIL (Arm 5094)		
Welght (kg)	(L)	Moment (kgm)
20	21,1	101,9

NTERMEDIATE GEAR BOX OIL (Arm 12315)		
Welght (kg)	(L)	Moment (kgm)
1,0	1,0	12,1

TAIL GEAR BOXOIL (Arm 13410)		
Welght (kg)	(L)	Moment (kgm)
1,5	1,6	20

Figure D.5: Weight, arms and moments of oil – Longitudinal moments

BAGGAGE			
Welght (kg)	Moment (kgm)		
	Arm 7200	Arm 7700	Arm 8200
25	180	193	205
50	360	385	410
75	540	578	615
100	720	770	820
125	900	963	1025
150	1080	1155	1230
175	1260	1348	1435
200	1440	1540	1640
225	1620	1733	1845
250	1800	1925	2050
275	1980	2118	2255
300	2160	2310	2460

Figure D.6: Weight, arms and moments of baggage – Longitudinal moments

TOTAL FUEL			
Weight (kg)	L (0,8 kg/L)	Arm (mm)	Moment (kg m)
25	31	6208	155.2
50	63	6209	310.5
75	94	6210	465.8
100	125	6210	621.0
125	156	6210	776.3
150	188	6210	931.5
175	219	6210	1086.8
200	250	6210	1242.0
225	281	6210	1397.3
250	313	6210	1552.5
275	344	6210	1707.8
300	375	6210	1863.0
325	406	6210	2018.3
350	438	6211	2173.9
375	469	6211	2329.1
400	500	6211	2484.4
425	531	6211	2639.7
450	563	6211	2795.0
475	594	6211	2950.2
500	625	6212	3106.0
525	656	6212	3261.3
550	688	6212	3416.6
575	719	6212	3571.9
600	750	6213	3727.8
625	781	6213	3883.1
650	813	6214	4039.1
675	844	6214	4194.5
700	875	6214	4349.8
725	906	6215	4505.9
750	938	6215	4661.3
775	969	6216	4817.4
800	1000	6217	4973.6
825	1031	6219	5130.7
850	1063	6221	5287.9
875	1094	6223	5445.1
900	1125	6225	5602.5
925	1156	6225	5758.1
950	1188	6226	5914.7
975	1219	6227	6071.3
1000	1250	6228	6228.0
1025	1281	6228	6383.7
1050	1313	6229	6540.5
1075	1344	6229	6696.2
1100	1375	6230	6853.0
1125	1406	6230	7008.8
1150	1438	6231	7165.7
1175	1469	6231	7321.4
1200	1500	6232	7478.4
1225	1531	6232	7634.2
1250	1563	6233	7791.3
1270	1588	6233	7915.9

Figure D.7: Weight, arms and moments of total fuel– Longitudinal moments

UNUSABLE FUEL			
Weight (kg)	L (0,8 kg/L)	Arm (mm)	Moment (kg m)
16	20	6206	99,3

Figure D.8: Weight, arms and moments of unusable fuel – Longitudinal moments

Table D.1: Equipment informations

Equipement	**Weight (Kg)**	**Station (mm)**	**BL (mm)**	**Longitudinal moment**	**Lateral moment**
Cargo hook	21.1	5300	0	111830	0
Stretcher aerolite	95.6	4508	0	430964.8	0
Hoist breeze	89.94	4149	950	373161.06	85443
Mission console	7.5	3278	-635	24585	-4762.5
Console seat	14.1	3973	-635	56019.3	-8953.5
Flir wes cam	53.44	1154	0	61669.76	0
Kit sx16	37.68	3618	-1422	136326.24	-53580.96
Seats 12 pax	14.1	Various	Various	Various	Various
Bambi bucket	60.2	5300	0	319060	0

Appendix E

Equipment for AW139 Helicopter

In this appendix, we provide a detailed explanation of the various equipment used in the AW139 helicopter. The equipment listed below plays a major role in the helicopter's functionality and mission capabilities.

E.1 Kit Cargo Hook

The cargo hook is a strong lifting equipment situated on the AW139 helicopter's belly. It enables the carriage of external freight by securely connecting loads to the aircraft. Cargo hooks are commonly employed in humanitarian missions, building projects, and cargo transit. It allows the helicopter to transport supplies, equipment, or vehicles underslung.

Figure E.1: Cargo hook

E.2 Stretcher Kit Aerolite

The Stretcher Kit Aerolite is a medical equipment set built specifically for air ambulance and medevac missions. It provides a safe and comfortable surface for transporting injured or sick people. A lightweight and solid stretcher, patient restraints, and storage compartments for medical equipment and supplies are included in the kit. During essential medical evacuations, the Stretcher Kit Aerolite guarantees that patients receive the necessary treatment and assistance.

Figure E.2: Stretcher kit aerolite

E.3 Hoist Breeze

The Hoist Breeze is a rescue hoist system installed on the AW139 helicopter. It enables precise vertical lifting or lowering of personnel or equipment during search and rescue operations. The hoist features a powerful electric winch and a cable with a hook or rescue harness for personnel. The Hoist Breeze is an essential tool for retrieving individuals in remote or inaccessible areas.

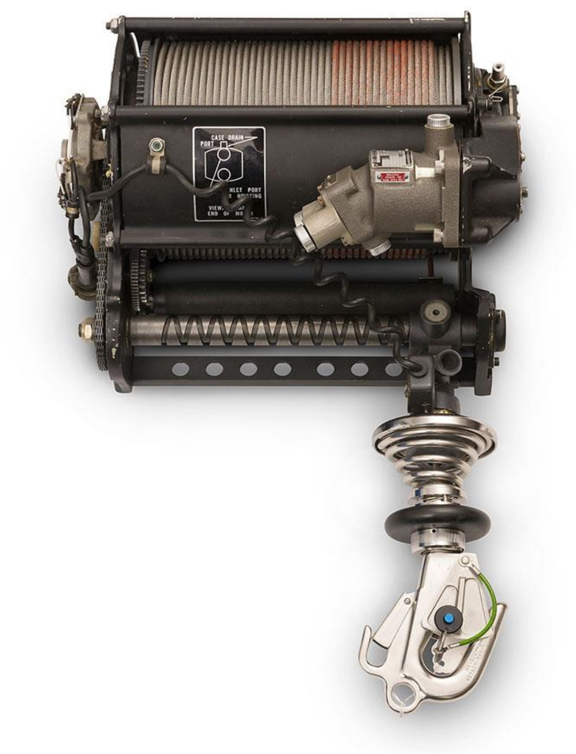


Figure E.3: Hoist Breeze

Figure E.4: Hoist Breeze implemented on AW139

E.4 Mission Console

The mission console serves as a central control unit within the AW139 helicopter's cabin. It provides operators with interfaces and controls necessary to manage mission-specific systems and equipment. The console integrates multiple displays, communication equipment, and mission planning tools. It allows the crew to monitor and control the helicopter's systems, navigate, and execute mission tasks efficiently.

Figure E.5: Mission console

E.5 Console Seat

The console seat is a specialized seating arrangement designed for crew members who operate the mission console. It offers ergonomic design, adjustable features, and enhanced comfort for individuals who spend extended periods operating mission-specific systems. The console seat is strategically positioned to provide easy access to controls and displays.

Figure E.6: Console seat

E.6 Flir Wes Camera

An innovative electro-optical device called the Flir Wes Camera is used for both daytime and nighttime surveillance operations. Operators can find and follow items of interest in a variety of environmental circumstances with to its high-resolution images and infrared imaging capabilities. To maintain steady and crisp imaging, the camera is often installed on a stabilized platform. The Flir Wes Camera assists tasks including search and rescue, surveillance, and law enforcement activities.

Figure E.7: Flir wes camera

Figure E.8: Flir wes camera implemented on AW139

E.7 Search Light SX16

The AW139 helicopter is equipped with a high-performance searchlight called the Search Light SX16. For nighttime operations, such as search and rescue missions, it offers a strong beam of light. The searchlight's high-intensity bulb and sophisticated optics allow it to precisely illuminate wide areas. The crew can precisely steer the beam thanks to remote control of the Kit SX16 from the cockpit. The searchlight considerably improves visibility during nighttime operations, ensuring the mission is carried out safely and effectively.

Figure E.9: Search light x16

E.8 Bambi Bucket

The Bambi Bucket is an external firefighting tank used to combat wildfires. It is suspended from the helicopter's cargo hook and can rapidly deliver large volumes of water or fire retardant to the affected areas.

Figure E.10: Bambi bucket

Appendix F

In the following appendix, we will explore the tools used with Python for the development of the AW139 Chart Digitization application.

F.1 IntelliJ IDEA: A Cutting-Edge Professional Development Tool

IntelliJ IDEA is a sophisticated integrated development environment (IDE) designed specifically for professional software development. Developed by JetBrains, IntelliJ IDEA offers an extensive array of features and tools that cater to the needs of developers across various programming languages and technologies.

Figure F.1: IntelliJ IDEA logo

One of the standout features of IntelliJ IDEA is its powerful code editor, which provides intelligent code completion, code analysis, and refactoring capabilities. This enables developers to write code more efficiently and accurately, minimizing errors and enhancing overall productivity. The IDE also offers comprehensive code navigation features, allowing developers to easily explore their codebase and quickly locate specific functions, classes, or variables.

IntelliJ IDEA places a strong emphasis on automated testing and debugging. It integrates seamlessly with popular testing frameworks and provides a wide range of testing tools, enabling developers to write and execute tests with ease. The built-in debugger offers advanced features such as breakpoints, watches, and variable inspection, facilitating efficient bug detection and resolution.

Another notable aspect of IntelliJ IDEA is its extensive plugin ecosystem. The IDE supports a vast array of plugins, both official and community-driven, that extend its functionality and enable integration with external tools and technologies. Whether it's version control systems like Git or tools for cloud deployment, there is a plugin available to streamline the development workflow and enhance productivity.

IntelliJ IDEA also excels in providing excellent support for various popular programming languages and frameworks, including Java, Kotlin, Scala, Python, JavaScript, and more. It offers specialized features tailored to each language, ensuring a seamless development experience and empowering developers to leverage the full potential of their chosen technologies.

Collaboration is made easy with IntelliJ IDEA through its integration with popular collaboration platforms, such as GitHub and Bitbucket. Developers can effortlessly manage their version control, review code changes, and collaborate with teammates directly within the IDE.

The user interface of IntelliJ IDEA is clean, intuitive, and highly customizable. Developers can adapt the IDE to their preferences, configuring keyboard shortcuts, color schemes, and layouts to create a personalized development environment that fosters efficiency and comfort.

F.2 Programming work environment

A programming work environment, also known as an Integrated Development Environment (IDE), is a software application that provides developers with a comprehensive set of tools and features to write, edit, compile, debug, and deploy their software projects. It is designed to enhance productivity and streamline the development process by providing a centralized workspace for coding and project management. Here are some key components and features commonly found in a programming work environment:

- Code Editor: The core component of an IDE is a code editor, which offers syntax highlighting, code completion, and formatting to help developers write and edit code efficiently. It typically supports multiple programming languages and may provide code templates or snippets to facilitate common programming tasks.
- Build System: IDEs often include a build system that automates the process of compiling, linking, and building the code into an executable or deployable artifact. This allows developers to easily build and test their applications without needing to rely on external tools or command-line interfaces.
- Debugging Tools: IDEs provide debugging capabilities, allowing developers to set breakpoints, step through code, inspect variables, and analyze the flow of execution. Debuggers help identify and fix issues or bugs in the code during the development process.
- Version Control Integration: Many IDEs integrate with version control systems (e.g., Git, SVN) to provide seamless code collaboration and version management. Developers can commit changes, switch between branches, merge code, and resolve conflicts directly within the IDE.
- Project Management: IDEs often include features for managing projects, such as organizing files and directories, managing dependencies, and configuring project settings. They may also offer project templates or wizards to quickly set up new projects based on predefined structures or frameworks.
- Integrated Terminal: IDEs often include a terminal or command-line interface within the workspace, allowing developers to execute commands, run scripts, and interact with the operating system without leaving the IDE.
- Code Analysis and Refactoring: IDEs typically offer code analysis tools that identify potential errors, performance issues, or code smells. They may also provide automated code refactoring options to improve code readability, maintainability, and performance.
- Plugins and Extensions: IDEs often support plugins or extensions that extend their functionality or integrate with additional tools. These plugins can enhance the IDE with language support, project templates, custom themes, or other developer-specific features.
- Collaboration Tools: Some IDEs offer collaboration features, allowing developers to work on the same codebase simultaneously. These tools enable real-time code sharing, pair programming, and collaborative debugging.

- Documentation and Help: IDEs often provide context-sensitive help, documentation, and API references to assist developers in understanding libraries, frameworks, and programming languages. This helps developers find information and learn new concepts without leaving the IDE.

F.3 Python's Libraries used in the AW139 Chart Digitization application

- NumPy: NumPy is a fundamental library for scientific computing in Python. It provides support for large, multi-dimensional arrays and matrices, along with a collection of mathematical functions to operate on these arrays efficiently.
- pandas: pandas is a powerful library for data manipulation and analysis. It offers data structures such as DataFrames and Series, which allow for easy handling and manipulation of structured data, including cleaning, merging, filtering, and aggregation.
- Matplotlib: Matplotlib is a widely-used plotting library in Python. It provides a variety of functions for creating static, animated, and interactive visualizations, including line plots, bar charts, scatter plots, histograms, and more.
- tkinter: tkinter is the standard Python interface to the Tk GUI toolkit. It provides a set of modules and classes for creating graphical user interfaces (GUIs). With tkinter, you can create windows, buttons, labels, and other GUI components to build interactive applications.
- datetime: datetime is a module in Python's standard library that provides classes and functions for working with dates, times, and time intervals. It allows you to create, manipulate, format, and perform calculations on date and time values.
- openpyxl: openpyxl is a library for reading and writing Excel files in the .xlsx format. It provides functions and classes to interact with Excel workbooks, worksheets, cells, and formulas. With openpyxl, you can automate Excel-related tasks and extract data from or populate data into Excel files.
- PIL Image: PIL (Python Imaging Library) is a library for opening, manipulating, and saving many different image file formats. The Image module within PIL provides functions and classes for working with images, such as opening images, resizing, cropping, applying filters, and saving images in different formats.
- customtkinter: customtkinter seems to be a custom module or package specific to your project. Without further information, it's difficult to provide a specific definition. Typically, a custom library is developed to extend the functionality of tkinter or provide additional custom widgets and features for building GUI applications.
- os: os is a module in Python's standard library that provides functions for interacting with the operating system. It allows you to perform various operating system-related tasks, such as working with files and directories, executing shell commands, accessing environment variables, and managing processes.