

**МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ**  
**Національний авіаційний університет**  
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ  
Завідувач кафедри, к.т.н., доцент  
\_\_\_\_\_ Святослав ЮЦКЕВИЧ  
« \_\_\_\_ » \_\_\_\_\_ 2024 р.

**КВАЛІФІКАЦІЙНА РОБОТА**  
**ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ**  
**«БАКАЛАВР»**

**Тема: «Конвертація середньомагістрального пасажирського літака у  
вантажний.»**

**Виконав:** \_\_\_\_\_ **Микола ГРУШКО**

**Керівник: к.т.н., доц.** \_\_\_\_\_ **Вадим ЗАКІЄВ**

**Нормоконтролер: к.т.н., доц.** \_\_\_\_\_ **Володимир  
КРАСНОПОЛЬСЬКИЙ**

Київ 2024

**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE**  
**National Aviation University**  
Department of Aircraft Design

**PERMISSION TO DEFEND**

Head of the department,  
Associate Professor, PhD.

\_\_\_\_\_ Sviatoslav YUTSKEVYCH  
" \_\_\_\_ " \_\_\_\_\_ 2024

**BACHELOR DEGREE THESIS**

**Topic: " Passenger medium range airplane conversion to freighter "**

<b>Fulfilled by:</b>	_____	<b>Mykola HRUSHKO</b>
<b>Supervisor:</b> <b>PhD, associate professor</b>	_____	<b>Vadim ZAKIEV</b>
<b>Standards inspector:</b> <b>PhD, associate professor</b>	_____	<b>Volodymyr</b> <b>KRASNOPOLSKYI</b>

Kyiv 2024

# НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет  
Кафедра конструкції літальних апаратів  
Освітній ступінь «Бакалавр»  
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»  
Освітньо-професійна програма «Обладнання повітряних суден»

## ЗАТВЕРДЖУЮ

Завідувач кафедри, к.т.н, доцент  
\_\_\_\_\_ Святослав ЮЦКЕВИЧ  
«\_\_» \_\_\_\_\_ 2024 р.

## ЗАВДАННЯ

**на виконання кваліфікаційної роботи здобувача вищої освіти**

**ГРУШКА МИКОЛИ ВАДИМОВИЧА**

1. Тема роботи: «Конвертація середньомагістрального пасажирського літака у вантажний», затверджена наказом ректора від 15 травня 2024 року № 794/ст.
2. Термін виконання роботи: з 20 травня 2024 р. по 11 червня 2024 р.
3. Вихідні дані до роботи: 18.48 тон, дальність польоту з максимальним комерційним навантаженням 7050 км, крейсерська швидкість польоту 600 км/год, висота польоту 7.13 км.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проєктованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, переобладнання пасажирського літака у вантажну версію.
5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (A1×1), компонувальне креслення фюзеляжу (A1×1), креслення переобладнаної версії літака з необхідними модифікаціями (A1×1).
6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	20.05.2024–21.05.2024	
2	Вибір та розрахунок параметрів проектованого літака.	22.05.2024–23.05.2024	
3	Виконання компонування літака та розрахунок його центрування.	24.05.2024–25.05.2024	
4	Розробка креслень по основній частині дипломної роботи.	26.05.2024–27.05.2024	
5	Огляд літератури за проблематикою роботи.	28.05.2024–29.05.2024	
6	Розробка креслень по спеціальній частині дипломної роботи.	30.05.2024–31.05.2024	
7	Оформлення пояснювальної записки та графічної частини роботи.	01.06.2024–02.06.2024	
8	Подача роботи для перевірки на плагіат.	03.06.2024–06.06.2024	
9	Попередній захист кваліфікаційної роботи.	07.06.2024	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	08.06.2024–10.06.2024	
11	Захист дипломної роботи.	11.06.2024–16.06.2024	

7. Дата видачі завдання: 20 травня 2024 року

Керівник кваліфікаційної роботи \_\_\_\_\_

Вадим ЗАКІЄВ

Завдання прийняв до виконання \_\_\_\_\_

Микола ГРУШКО

# NATIONAL AVIATION UNIVERSITY

Aerospace Faculty  
Department of Aircraft Design  
Educational Degree "Bachelor"  
Specialty 134 "Aviation and Aerospace Technologies"  
Educational Professional Program "Aircraft Equipment"

## APPROVED BY

Head of the department,  
Associate Professor, PhD.

\_\_\_\_\_ Sviatoslav YUTSKEVYCH

" \_\_\_ " \_\_\_\_\_ 2024

## TASK

for the bachelor degree thesis

Mykola HRUSHKO

1. Topic: " Passenger medium range airplane conversion to freighter ", approved by the Rector's order № 794/CT from 15 May 2024.
2. Period of work: since 20 May 2024 till 11 June 2024.
3. Initial data: payload 18.48 tons, flight range with maximum capacity 7050 km, cruise speed 600 km/h, flight altitude 7.13 km.
4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: modification of the aircraft's transport cabin.
- 5 Required material: general view of the airplane (A1×1); layout of the airplane (A1×1); drawing of converted version of aircraft with necessary modifications (A1×1).

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	20.05.2024 – 21.05.2024	
2	Selection and calculation of the aircraft designed parameters.	22.05.2024 – 23.05.2024	
3	Performing of aircraft layout and centering calculation.	24.05.2024 – 25.05.2024	
4	Development of drawings on the thesis main part.	26.05.2024 – 27.05.2024	
5	Review of literature on the problems of the work.	28.05.2024 – 29.05.2024	
6	Development of drawings for a special part of the thesis.	30.05.2024 – 31.05.2024	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	01.06.2024 – 02.06.2024	
8	Submission of the work to plagiarism check.	03.06.2024 – 06.06.2024	
9	Preliminary defense of the thesis.	07.06.2024	
10	Making corrections, preparation of documentation and presentation.	08.06.2024 – 10.06.2024	
11	Defense of the diploma work.	11.06.2024 – 16.06.2024	

7. Date of the task issue: 20 May 2024

Supervisor:

Student:

\_\_\_\_\_

\_\_\_\_\_

Vadim ZAKIEV

Mykola HRUSHKO

## РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра « Конвертація середньомагістрального пасажирського літака у вантажний »

76 с., 3 рис., 7 табл., 19 джерел

Ця кваліфікаційна робота зосереджена на розробці попереднього проекту конвертації середньомагістрального пасажирського літака в вантажний, що відповідає міжнародним стандартам льотної придатності, безпеки, економічності та надійності.

У дослідженні застосовувалися методи аналітичного розрахунку, комп'ютерного проектування з використанням систем CAD/CAM/CAE.

Практичне значення результатів цієї кваліфікаційної роботи полягає у переобладнанні пасажирського середньомагістрального літака на вантажний, що сприятиме оптимізації процесу завантаження літака, підвищенню його ефективності та полегшенню роботи персоналу.

Матеріали кваліфікаційної роботи можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проектних установ.

**Літак, аванпроект літака, компонування пасажирської кабіни, центрування літака, конвертація пасажирського літака в грузовий.**

## **ABSTRACT**

Bachelor degree thesis " Passenger medium range airplane conversion to freighter "

76 pages, 3 figures, 7 tables, 19 references

This qualification work focuses on the development of a preliminary project for the conversion of a medium-haul passenger aircraft into a cargo aircraft that meets international standards of airworthiness, safety, economy and reliability.

The study used methods of analytical calculation, computer-aided design using CAD/CAM/CAE systems.

The practical significance of the results of this qualification work lies in the conversion of a medium-haul passenger plane into a cargo plane, which will contribute to the optimization of the process of loading the plane, increasing its efficiency and facilitating the work of the staff.

The materials of the qualification work can be used in the educational process and in the practical activities of designers of specialized design institutions.

**Aircraft, preliminary design, passenger cabin layout, aircraft centering, conversion of passenger aircraft to freighter.**





## CONTENT

INTRODUCTION.....	12
1. PRELIMINARY DESIGN OF MID RANGE AIRCRAFT .....	13
1.1 Analysis of prototypes and short description of designed aircraft .....	13
1.2 Brief description of the main parts of the aircraft.....	17
1.2.1 Purpose and scope.....	17
1.2.2 Selection of the scheme of aircraft .....	19
1.2.3 Selection of Basic Wing Parameters .....	21
1.2.4 Selection of the main parameters of the fuselage .....	23
Conclusions to the analytical part .....	26
2. AIRCRAFT MAIN PARTS CALCULATIONS .....	27
2.1 Geometry calculations for the main parts of the aircraft .....	27
2.1.1 Wing geometry calculation.....	28
2.1.2 Fuselage layout .....	32
2.1.3 Luggage compartment .....	37
2.1.4 Galleys and buffets .....	38
2.1.5 Lavatories.....	39
2.1.6 Emergency exits and emergency means.....	40
2.1.7 Layout and calculation of basic parameters of tail unit.....	42
2.1.8 Landing gear design.....	44
2.1.9 Choice and description of power plant.....	45
2.2 Determination of the aircraft center of gravity position .....	46
2.2.1 Determination of centering of the equipped wing.....	46
2.2.2 Determination of the centering of the equipped fuselage.....	47
2.2.3 Calculation of center of gravity positioning variant.....	49

					NAU 24 01H 00 00 00 61 EN		
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			
<i>Done by</i>	Hrushko M.V.				<i>list</i>	<i>sheet</i>	<i>sheets</i>
<i>Checked</i>	Zakiev V.I.				Q	10	75
<i>St.control</i>	Krasnopolskyi V.S.				Content		
<i>Head of dep.</i>	Yutskevych S.S.						
					404 ASF 134		

Conclusions to the project part.....	51
3. PASSENGER MEDIUM RANGE AIRPLANE CONVERSION TO FREIGHTER	
.....	53
3.1 Freighter Aircraft Types.....	55
3.2 Fire protection system changing in passenger to freighter conversion.....	58
3.3 Removing passenger compartment to convert aircraft into freighter .....	59
3.4 Types of doors in freighter aircrafts.....	61
Conclusions to the special part.....	66
GENERAL CONCLUSIONS .....	67
REFERENCES .....	68
Appendix A .....	70
Appendix B.....	75
Appendix C.....	76

## INTRODUCTION

Nowadays, air transportation is one of the fastest and most efficient ways to move goods and people around the world. What used to take days can now be done in just a few hours. This speed and efficiency are exactly what people need nowadays, providing both comfort and saving a lot of time. Air routes connect countries all over the world, following the same standards and regulations for both passenger and freight transport. These strong global networks are crucial for the aviation industry to function and grow, as they ensure that passenger travel (even during difficult times) and cargo shipments continue smoothly.

Creating airplanes, on the other hand, is no walk in the park. It's a complex, labor-intensive, and pretty expensive endeavor. But all that hard work pays off in the end when you get a sturdy, top-notch product that satisfies the needs of passengers or cargo clients for many years. The whole aircraft construction process can be broken down into different critical stages, and one of them is the initial design phase. In this article, we're going to dive deep into the nitty-gritty of this stage. So, let's get started!

The initial design phase is a crucial step in the aircraft development process. It involves a bunch of important tasks like collecting and analyzing statistical data from prototype aircraft and coming up with the technical specifications. We also calculate the takeoff weight of the aircraft, use computer simulations to optimize the weight of functional systems, evaluate flight characteristics, and determine the geometric parameters of different aircraft components. During this stage, we prepare preliminary drawings, balance the aircraft layout, and create detailed diagrams, including a three-view drawing and a cross-sectional layout of the fuselage. Finally, we wrap it all up by drafting and presenting the final project design.

					NAU 24 01H 00 00 00 61 EN			
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>				
<i>Done by</i>	Hrushko M.V.				Introduction	<i>list</i>	<i>sheet</i>	<i>sheets</i>
<i>Checked</i>	Zakiev V.I.					Q	12	75
<i>St.control</i>	Krasnopolskyi V.S.					404 ASF 134		
<i>Head of dep.</i>	Yutskevych S.S.							

# 1. PRELIMINARY DESIGN OF MID RANGE AIRCRAFT

## 1.1. Analysis of prototypes and short description of designing aircraft

Designing an aircraft, particularly in the selection of the design parameters, is a complex operation in the analysis of a multi-variable system in which the goal is to reduce the ‘vision’ of a next generation aircraft to reality. This configuration involves or rather entails other aspects of civil aircraft design, these include the flight performance, weight and balance, geometric design, aerodynamic design, and financial feasibility. Subsequently, it is during the first stage of the “Aircraft Design” that statistic methods are used for the purpose of data transfer and approximation by employing relatively crude aerodynamic models and statistical regression. These methods give initial design structure to the structure of the medical diagnostic system. The second involves a thorough aerodynamic assessment of all the car’s components. This is done by incorporating new and improved equations for computation of mass of each of the aircraft components and including experimental data to confirm the accuracy of the design. This progressive design concept ensures that the proposed aircraft not only possesses novel design features but is also viable with regard to the particular emphasis on vital aerodynamic performance and cost parameters.

Equipped with two engines [1], the Boeing 737 MAX 7 is 35.56 meters long and has a maximum range of 7,040 kilometers, typically accommodating 138 passengers for two classes or 172 in one class. The aircraft boasts a redesigned fuselage, enhanced aerodynamics, new engines, and modern fly-by-wire systems. With regards to the competition threat, the B737 MAX 7 will face competition from the E195-E2, as well as Airbus’s A319neo. The EMBRAER E195-E2 is a 1 996 regional jet powered by two of the most efficient engines ever developed, with modern design and advanced aerodynamics, avionics systems, offering option for 132 number of passengers, as well as having 4,815 km range of operations.

					<i>NAU 24 01H 00 00 00 61 EN</i>			
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>				
<i>Done by</i>	<i>Hrushko M.V.</i>				<i>Analytical part</i>	<i>list</i>	<i>sheet</i>	<i>sheets</i>
<i>Checked</i>	<i>Zakiev V.I.</i>					<i>Q</i>	<i>13</i>	<i>75</i>
<i>St.control</i>	<i>Krasnopolskyi V.S.</i>					<i>404 ASF 134</i>		
<i>Head of dep.</i>	<i>Yutskevych S.S.</i>							

Other models include the Airbus A319neo which is a member of the successful A320 family that incorporates new engines, aerodynamic improvements; it has a seating capacity of about 140 passengers and maximum operational range of about 6,950 km. There is stiff competition from EMBRAER through E195-E2 and Airbus with A319neo but this comes with the advantage of new generation aeroplanes, better technologies, and better engineering brains but this is balanced by Boeing through the 737 MAX 7 aircraft which has a range of 7,040 kilometers with fly-by-wire systems for the short and medium distances.

The operational-technical data of prototypes are presented in table 1.1.

Table 1.1. – Operational-technical data of prototypes

<b>Parameters</b>	Boeing 737 MAX7	Airbus A319neo	Embraer E195- E2	Designed aircraft
The purpose of airplane	Passenger	Passenger	Passenger	Freighter
Maximum take-off weight, $m_{tow}$ , kg	80.286	75.500	62.283	85.226
Crew and flight attendants (persons)	2 + 4	2 + 4	2 + 3	2 + 4
Passenger seats	138-172	140	120-146	160
Wing load, kN/m <sup>2</sup>	6.1	6.5	5.8	6.1
Range $m_{k,max}$ , km	7,040	6,950	4,815	7,040
The height of the flight $V_w$ $e_k$ , m	12,500	12,100	12,500	12,500
$V_{pitch\ max}/N$ , km/h/km	10.6	9.8	11.2	10.6
$V_{pitch\ e_{koh}}/N$ , km/h/km	9.0	8.5	9.4	9.0
<b>Power plant</b>				
Number and type of engines	2x CFM LEAP- 1B	2x CFM LEAP- 1A	2x PW1900G	2x CFM LEAP- 1B
Takeoff thrust, kN	21.4	120.0	120.0	21.4
Cruise thrust, kN	27.8	27.3	29.0	27.8



Ending of the table 1.2

Cabin volume, m <sup>3</sup>	113.32	119.00	120.00	113.32
Seats pitch, mm	737-864	737-813	737-813	737-864
Passage width, m	0.51	0.53	0.50	0.51
HT span, m	12.8	12.0	12.8	12.8
Quarter-chord sweep angle of HT, °	12.8	12.0	12.8	12.8
HT aspect ratio	5.5	5.5	5.5	5.5
HT taper ratio	0.3	0.3	0.3	0.3
VT height, m	8.3	8.2	8.4	0.3
Quarter-chord sweep angle of VT, °	35	35	35	8.3
VT aspect ratio	1.35	1.35	1.4	35
Gear nacelles, m	3.8	3.8	3.7	1.35
Wheel track, m	6.6	6.5	6.0	3.8





3. Horizontal and vertical tail (stabilizer and elevator);

4. An high powerful power plant that is based on the CFM International LEAP-1B engines.

5. A strong and stable structure of the proposed landing gear.

One of the significant aspects of the design of the aircraft is the engines and the body structure, which are optimised for fuel efficiency and lower emissions. Such enhancements have immensely contributed to reduced fuel consumptions and CO2 emissions. Fuselage has been designed in the aircraft to improve reliability, safety in case of a damaged structure, controlling rate of crack growth, prolonging service time, reducing weight and surface finish of the outer skin.

The cabin pressure is consistent with the normal altitude; therefore, providing sufficient ventilation to accommodate the passengers when cruising. Further, to manage the aerodynamic characteristics of the plane, the design also mitigate on aileron reversal, a phenomenon that affects planes with highly swept wings. This has also been achieved in landing distance through reducing the airport's runway length needed for a given aircraft.

Altogether, Boeing has made a new generation leap for the 737 family in the MAX 7 that provide operators with operational efficiencies, environmentally friendly performance, and passenger comfort.

					<b>NAU 24 01H 00 00 00 61 EN</b>	<i>Sh.</i>
						18
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>		





That has its other characteristics in the sense that the tricycle gear configuration offers the lever to have better stability for takeoff and landing, better ground handling, and better braking. The aircraft assumes the horizontal position on the longitudinal axis when parked and when on the ground, hence offers better visibility and passenger comfort. It is more convenient to take off and touch down on crosswind conditions when the gear is tricycle, whereas the self-orienting and damped landing gear struts offer better control and stability.

A fuel-efficient operation is a very high priority in the development of this aircraft. This is offered through a more fuel-efficient design in terms of its aerodynamics as well as through the use of the most fuel-efficient engines that are available on the market. The use of the CFM International LEAP-1B engines, which are known for an advanced design as well as for their fuel economy, is a featured aspect in the reduction of the cost of operations as well as lessening the impact on the environment. Other fuel efficiency innovations, in the form of split-tip winglets, further bring in fuel efficiency by the mitigation of the quantities of drag. Aircraft is a careful balance of the aerodynamic design, the sophistication of technology, as well as the efficiency of its operation. Each design parameter, from the configuration of the wings to the placement of the engines and the design of the landing gear, is scrutinized with care so as to provide the greatest amounts of safety, performance, as well as passenger comfort. Through the careful study and the demonstration of engineering mastery, the aircraft is a showpiece for the advances in modern aviation detailing.

### 1.2.3 Selection of Basic Wing Parameters

The basic parameters of a wing are its profile and relative thickness, quarter-chord line sweep angle ( $\chi = 0.25$ ), the aspect ratio ( $\lambda$ ), the taper ratio ( $\eta$ ), the dihedral angle, the specific wing loading (P), and the planform shape. The aerodynamic parameters of the wing are very much determined by its planform shape. The profile parameters and relative thickness are the functions of the cruising flight's Mach number (M).





Increased elongation ratio helps in providing a reduction in terms of the drag, but then it also demands due consideration to the distribution of weight in a way that this does not, in turn, compromise the integrity of the structure.

The fuselage has been designed of adequate length so that internal volume is proper to have adequate seating convenience and at the same time be proper to accommodate galleys, lavatories, and cargo compartments within the fuselage. This proper balance is required to provide convenience to the passengers along with operational efficiency of the aircraft. It helps in boosting the aerodynamic performance by tuning the elongation ratio besides ample space provision within the fuselage.

The fuselage diameter is very critical parameter in the design work. In the case of this aircraft, the fuselage diameter is provided as 3.76 meters. This parameter, again, is obtained through detailed statistical studies and benchmarking work against aircraft of similar class. A diameter of 3.76 meters allows a comfortable two-class arrangement of seats, with enough headroom and aisle space for the passengers. It also provides adequate space for the required volume of cargo, in order to satisfy the operational requirement of the airlines. The design of the fuselage is towards the comfort of passengers and the efficient utilization of available space. The internal arrangement of the same is designed to seat up to 172 passengers in a two-class arrangement, so that there is adequate own space for each passenger to move about and relax. The design also includes the use of advanced materials and construction techniques in order to provide low weight without any compromise in the structural integrity. By maximizing the internal volume, the aircraft tries to offer a comfortable experience for the passengers to travel in and, at the same time, is operationally efficient. The aerodynamic features of the fuselage take on critical importance to overall performance in the aircraft. The streamlined appearance of the fuselage is effective in reducing aerodynamic drag, and hence fuel consumption and overall operation cost. Flow transitions and appropriately arranged nose and tail geometries are arranged to ensure that air flows over the fuselage smoothly, and hence reduces resistance further and improves performance.



These aerodynamic features are critical in ensuring the high levels of efficiency required in contemporary aviation. The structural integrity is a critical area of concern in designing the fuselage of the aircraft. The construction of the aircraft is carefully designed using the latest materials and building techniques in order to ensure that the fuselage is able to withstand the force of a variety of loads, such as pressurization, bending, and torsional forces. The construction further incorporates the manner of distribution of these loads over the fuselage, in order to ensure that the structure remains sturdy and last-durable for the entire duration of the time that it is in operation.

					<i>NAU 24 01H 00 00 00 61 EN</i>	<i>Sh.</i>
						25
<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			

## Conclusions to analytical part

Based on the analysis of choused prototypes, the mid-range aircraft with a capacity of up to 160 passengers was designed. The Boeing 737 MAX 7 was chosen as the main prototype for the one, developed in this work, because of its novelty (As of May 2024, the MAX 7 have not been certified, with the FAA declining to put any timetable on approval.) and wide usage of high-tech technologies. The reason why this model is so attractive is because it offers better performance, a longer flight range, a bigger fuselage in its design. In this section, also was cover the selection of the aircraft's engine and give a technical description of its main structural components.

					<i>NAU 24 01H 00 00 00 61 EN</i>	<i>Sh.</i>
						26
<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			

## 2. AIRCRAFT MAIN PARTS CALCULATIONS

### 2.1 Geometry calculations for the main parts of the aircraft

The process of computing geometry in the design of airplanes is a multifaceted and complex exercise involving a number of procedures that are interdependent on each other: aerodynamic layout, volume-mass and structural-power configuration, and centering calculation. All these processes are integral to achieving high economic efficiency and performance in an airplane. To begin with, the aerodynamic layout is essential in ensuring the satisfaction of aerodynamic requirements. This procedure addresses a set of problems that optimize performance in different flight conditions. One of the fundamental objectives is to assure a wide range of speeds, from the takeoff and landing speeds to the maximum speed of the aircraft, with the least possible transition between these velocities during the start and end of the flight. This wide range of speed is critical in ensuring that the aircraft is versatile and efficient in operation. Achieving maximum aerodynamic efficiency during cruising flight at a specified speed is essential. In so doing, it is essential to ensure that the aircraft has the least amount of drag, as this is essential for fuel efficiency and overall performance. Also, it is essential to minimize balancing losses, as this contributes to the aircraft's stability and efficiency during flight.

A further essential aspect is to maximize the aircraft's dimensions during takeoff and landing. This objective ensures that the aircraft is able to operate effectively in a variety of airport environments and under a variety of operational conditions, making the aircraft more versatile and practical. In addition, the design has to assure the necessary stability and controllability reserves of all flight modes. Stability and controllability are essential to the safety and reliability of the aircraft, as this ensures that the aircraft is able to cope with different flight conditions and is also able to properly respond to the inputs of the pilot.

					NAU 24 01H 00 00 00 61 EN		
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			
<i>Done by</i>	Hrushko M.V.				<i>list</i>	<i>sheet</i>	<i>sheets</i>
<i>Checked</i>	Zakiev V.I.				Q	27	73
<i>St.control</i>	Krasnopolskyi V.S.				Project part  404 ASF 134		
<i>Head of dep.</i>	Yutskevych S.S.						



Root chord:

$$b_0 = \frac{2 \cdot S_w \cdot \eta_w}{(1 + \eta_w) \cdot l_w} = \frac{2 \cdot 150.81 \cdot 3.59}{(1 + 3.59) \cdot 37.73} = 6.25 \text{ m}$$

where  $\eta_w$  – wing taper ratio.

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = \frac{6.25}{3.59} = 1.74 \text{ m}$$

Maximum wing thickness is:

$$c_{\max} = c_w \cdot b_t = 0.11 \cdot 1.56 = 0.17 \text{ m},$$

where  $C_w$  – medium wing relative thickness.

On board chord is:

$$b_b = b_0 \cdot \left( 1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w} \right) = 6.25 \cdot \left( 1 - \frac{(3.59 - 1) \cdot 3.76}{3.59 \cdot 37.73} \right) = 5.8 \text{ m},$$

where  $D_f$  – fuselage diameter.

For mean aerodynamic chord determination the geometrical method was used (fig. 2.1.1). The geometrical method implies the measuring of parallel to the chords line which lies on the intersection of the section connecting the middles of tip and root chords with another section connecting the upper end of tip chord extension (which is equal to the length of root chord) with lower end of root chord extension (which is equal to the length of the tip chord). This method was chosen due to accuracy and simplicity in performance.

Thus, the mean aerodynamic chord is equal to 4.58 m.

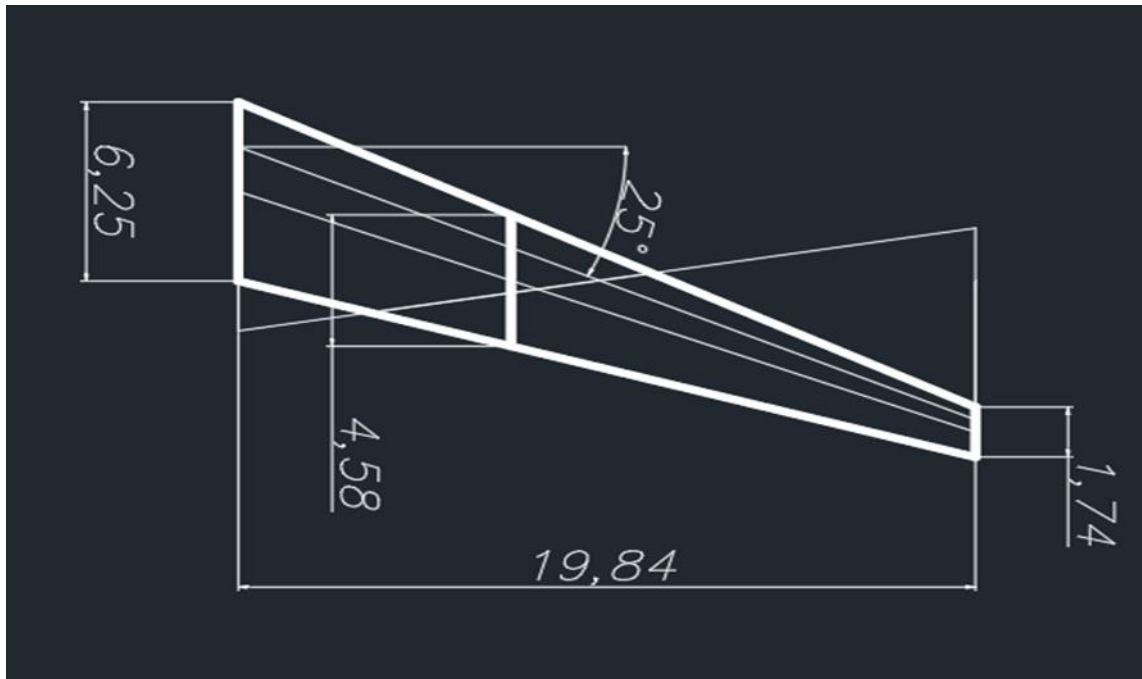


Fig. 2.1.1. Geometrical method of determination of mean aerodynamic chord.  
Also, we could calculate the MAC by the approximately formulas:

$$B_{MAC} = \frac{2}{3} \cdot \frac{b_0^2 + b_0 \cdot b_t + b_t^2}{b_0 + b_t} = \frac{2}{3} \cdot \frac{6.25^2 + 6.25 \cdot 1.74 + 1.74^2}{6.25 + 1.74} = 4.58 \text{ m.}$$

After determination of the geometrical characteristics of the wing we come to the estimation of the aileron's geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ail} = (0.3 \dots 0.4) \cdot \frac{l_w}{2} = 0.35 \cdot \frac{37.73}{2} = 6.6 \text{ m.}$$

Aileron chord:

$$b_{ail} = (0.2 \dots 0.26) \cdot b_t = 0.25 \cdot 1.74 = 0.435 \text{ m.}$$











Spacing for fuselage bulkheads typically, when doing a passenger cabin for any fuselage of passenger class, goes in the range of 360 to 500 mm. For diameters less than 2800 mm, more often, the cross-section of the intersecting circles is used, with the floor of the passenger cabin in one plane with the plane closing the area. Of the windows, either one row is installed with a diameter of 300 to 400 mm or one row with a rounded rectangular shape, the size related to the interval between the bulkheads from 500mm to 510 mm. The number of seat rows is a 3+4+3 economy class cabin row, and the width of the cabin must be determined to accommodate the exact comfort expectations of the passengers at the same time as providing the optimized arrangement for all seats. It should assure such design reliability that optimal structural integrity is taken into account with the requirements for passengers and cargo. When arranging the passenger cabin should take care to create proper comfort and safety of passengers.

The specifications developed with a safety focus and with an assurance that some level of comfort in flying is reached. These requirements have to include a number of issues: that the cabin must be airtight, with the need to maintain a minimum excess pressure because this is important for comfort of the passenger at great heights. Defined is the maximum with rate of change with time, because it is important for passengers that a level of time not be initiated due to discomfort or possible health problems.

One should not also be left out with the fresh, outside air, to be installed at the correct volume level for each occupant, where there are venting and air quality, the cabin temperature must be at a level that causes comfort : 18 to 22°C. Humidity should be kept at 30 to 60 percent at least so that the system for the passengers is a comfortable and healthy one.

Besides that, it should have a cabin with an aisle area height of 1900 to 2000 mm to ensure that passengers can move about freely. On the other hand, for more passenger friendliness, the floor of the cabin is flat without any design of protrusions or depressions; hence, it ensures easy movement, as well as safety.

Front door space does not lead to any threshold of the cabin for accessible entrance and exit. The width of the whole fuselage is designed to meet requirements, and the spaces between the two stringers should be such that they provide open space for a person to move around safely and effectively. These high-detail specifications have been set out so the cabin environment can be designed with passenger well-being to achieve the strict and regulatory safety requirements that ensure a safe and comfortable experience for the passengers.

$$B_{cab} = 2 \cdot (n_{3block} \cdot b_{3block}) + 2 \cdot b_{aisle} + 2\delta_{wall} = 2 \cdot 1320 + 2 \cdot 240 + 2 \cdot 50 + 2 \cdot 100 = 3.42m$$

The length of economy class is equal:

$$L_{cab} = L_1 + (n_{rows} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (23 - 1) \cdot 770 + 300 = 18.44m$$

The length of business class is equal:

$$L_{cab} = L_1 + (n_{rows} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (6 - 1) \cdot 930 + 300 = 6.15m$$

The cockpit must be designed to be as compact as possible while still providing adequate conditions for the flight crew's work and rest. The pilot positions, in particular, must meet the most stringent requirements to ensure convenience and a good field of view. The size of the crew cabin depends on the number of crew members. On mid-range and short-range flights, the crew typically consists of 3 to 4 members, while on local routes, it consists of 2 to 3 people. The crew includes the captain (ship's commander), co-pilot (first officer), flight engineer, navigator, and flight attendants. The composition of the crew may vary depending on the flight route. For instance, routes equipped with beacons and air traffic control systems may not require navigators and flight attendants. Pilots are seated next to each other, with the flight engineer usually positioned behind the co-pilot to maintain visual contact with the captain. No specific requirements exist for the positions of other flight crew members. The cockpit is separated from other areas by a rigid partition with a lockable door. Each passenger aircraft must have a specified number of flight attendants as follows:

For aircraft with a passenger capacity of more than 9 but less than 51 passengers, there must be 1 flight attendant. For aircraft with a passenger capacity of more than 50 but less than 101 passengers, there must be 2 flight attendants.

For aircraft with a capacity of more than 100 passengers, there must be 2 flight attendants plus an additional flight attendant for every 50 seats over the initial 100.

During take-off and landing, flight attendants should be positioned as close as possible to the required floor-level exits and distributed evenly throughout the aircraft to ensure efficient passenger evacuation in an emergency. This determines the location of flight attendant workstations.

Flight attendants' seats are located outside the cockpit and must be equipped with seat belts. These seats are sometimes folding to save space.

**2.1.3. Luggage compartment**

The luggage compartments are usually in the pressurized part of the fuselage below the cockpit floor or on the lower deck. Typically, the luggage is loaded behind or in front of the passenger cabin to give the proper balance to the airplane. This offers the right aircraft balance since the weight is on either side of the cabin, especially when the passenger load is not complete. This is mainly done in multi-seat and wide-body aircraft and further allows room for an increased mail-cargo load in such a way as to facilitate the aircraft to work under total commercial capacity but with a lesser number of passengers. The exterior openings leading into the cargo holds will be small, only creating enough space to allow the luggage and cargo to be correctly loaded and offloaded. The luggage compartments of the aircraft will, however, be accessible with the help of a hatch for loading and offloading. All additional baggage and other necessary items, such as aircraft equipment, should be placed in packages or installed in the most aft sections of the fuselage and tail cone to optimize space usage, achieving the most efficiency in transportation.

The designs and logistic elements related to this regard are incorporated into an airplane, ensuring the overall design supports the weight distribution, size of load, and operational efficiency.

Given the fact that the unit of load on floor  $K = 400 \dots 600 \text{ kg/m}^2$









The additional means must automatically deploy and be automatically erected with the opening of the exit. A non-slip surface will be provided on the critical oversize routes from each over-wing exit for safe passage. All routes will be at least the width of a Type A or B exit, the smallest of which accommodates 42 inches, with the other types requiring an accommodation of at least 24 inches. All routes will be marked and reflect less than 80% and a surface-to-marking contrast ratio of not less than 5:1. For understandable reasons, most requirements indicated for the aircraft's emergency exits are very stern in most aspects. Safety is necessary; once the evacuation has been ordered, the effect must be extensive. Such manuals range from slide deployments and clear escape routes to such detailed requirements of preparation that assurance for safety and quick evacuation in emergencies is specific for both passengers and crews. Such requirements stress that a proven complete plan in aircraft design is requisite so that every flight is safe up to the highest standards [4].

Main doors of the aircraft positioned at the front and rear on the left side, the dimensions of these doors are 890 mm in width and 1800 mm in height. These doors are designed to allow two people to pass through simultaneously, facilitating quicker boarding and disembarkation.

Service doors of the aircraft located on the starboard side at both the front and rear, these doors 690 mm in width and 1600 mm in height. They serve primarily for service crew operations but can also be used for emergency evacuations.

Emergency exits located near the wings on both sides of the aircraft. These exits are 510 mm in width and 1100 mm in height, providing additional evacuation routes during emergencies. According to airworthiness standards, these exits, along with the main doors, should facilitate evacuation within 90 seconds with 50% of the exits operational.

All doors can be used as emergency.

The passenger cabin windows on the aircraft are arranged in a single light line. The windows are rectangular with rounded corners and measure 260 mm by 350 mm. This design ensures both structural integrity and passenger visibility.

					<i>NAU 24 01H 00 00 00 61 EN</i>	<i>Sh.</i>
						41
<i>Sh.</i>	<i>Nº doc</i>	<i>Sign</i>	<i>Date</i>			





### 2.1.8 Landing gear design

To estimate the strut outline in this project, it was necessary to calculate the place of each strut relative to one another to determine the loads on the landing gear system and its place in consideration of the center of gravity of an airplane. The main scheme in this layout is based on the prototype data entirely. It needs to be provided with the desired stable and controllable means of support, either to land or to take off, on the ground when the aircraft is on the ground.

Main wheel axes offset is:

$$e = k_e \cdot b_{MAC} = 0.15 \cdot 4.58 = 0.687 \text{ m},$$

where  $k_e$  – coefficient of axes offset ( $k_e = 0.15 \dots 0.3$ );  $b_{MAC}$  – mean aerodynamic chord, m.

With the large wheel axial offset the lift-off of the front gear during take-off is complicated and with small the drop of the airplane on the tail is possible when the loading of the airplane back comes first.

Landing gear wheel base is:

$$B = k_b \cdot L_f = 0.4 \cdot 39.48 = 15.79 \text{ m},$$

where  $k_b$  – wheel base calculation coefficient ( $k_b = 0.3 \dots 0.4$ ).

That means that the nose strut holds 5...11% of airplane weight.

Front wheel axial offset is:

$$d_n = B - e = 15.79 - 0.687 = 15.1 \text{ m}.$$

Wheel track is:

$$T = k_T \cdot B = 0.7 \cdot 15.79 = 11.05 \text{ m}.$$

where  $k_T$  – wheel track calculation coefficient ( $k_T = 0.7 \dots 1.2$ ).

It is chosen for the landing gear to install wheels, opting for a particular size and running loading because the take-off weight is known. Dynamic loading should be thought over for the front support. The type of pneumatics (balloon, half balloon, arched) and its pressure are determined by the runway's surface over which it should be flown. The main wheels have brakes.

									Sh.
									44
	Sh	Nº dor	Sign	Date					







where  $X_f'$  – center of mass for equipped fuselage, m;  $m_i'$  – mass of a unit, kg;  $x_i$

– center of mass of the unit, m.

Table 2.2.2

**List of equipped fuselage masses**

#	Objects name	Mass		Center of gravity coordinates, m	Moment of mass, kg·m
		Units	total mass		
1	Fuselage	0.086	7314	19.38	141745.5
2	Horizontal tail	0.0095	810.49	34.3	27799.8
3	Vertical tail	0.0094	800.26	32.68	26152.59
4	Radar	0.0031	264.2	1	264.2
5	Radio equipment	0.0023	196	1	196.02
6	Instrument panel	0.0054	460.215	2	920.43
7	Aero navigation equipment	0.0046	392	2	784.07
8	Flight control system 70%	0.089	7571.13	16.925	128141.43
9	Hydraulic system 30%	0.00492	419.3	23.695	9935.48
10	Electrical equipment 90%	0.02898	2469.8	13.925	34392.25
11	Not typical equipment	0.0033	281.24	3	843.73
12	Lining and insulation	0.0065	554	16.925	9375.815
13	Anti ice system, 20%	0.0044	371.6	27.08	10062.41
14	Airconditioning system, 40%	0.022	1858	16.925	31445.04
15	Passenger seats (bussiness)	0.0023	197.47	8.54	1686.34
16	Passenger seats (economic class)	0.0115	979.08	22.6	22127.25
17	Seats of flight attendence	0.00029	24.68	1.82	44.92
18	Seats of pilot	0.00024	20.57	2.26	46.486
19	Emergency equipment	0.0014	123.275	8.1	998.53
20	Lavatory 1, Lavatory 2	0.006	511,35	7.41	3789.1
21	Galley 1, Galley 2	0.008	681.8	15.96	10881.53
22	Lavatory 3, Lavatory 4	0.006	511.35	32.6	909.2
23	Galley 3	0.004	340.9	33.5	11420.15
24	Operational items	0.00217	184.512125	26	4797.32
25	Additional equipment	0.00331	282.09475	5	1410.5
	<b>Equipped fuselage without payload</b>	<b>0.32</b>	<b>27619.26</b>	<b>17.39</b>	<b>480170.07</b>
26	Passengers(economy)	0.13	11088	22.6	250588.8
27	Passengers(bussiness)	0.011	924	8.54	7890.96
28	On board meal	0.0027	234	15.96	3734.64
29	Baggage	0.037	3120	15.96	49795.2
30	Cargo, mail	0.0076	650	15.96	10374









The power plant of the prototype, powered by CFM International LEAP-1B engines, is a significant advancement in aviation technology. These engines are renowned for their fuel efficiency, reduced emissions, and low noise levels, contributing to the aircraft's operational economy and environmental friendliness. The integration of advanced aerodynamics and efficient engines results in an aircraft that meets the demands of modern aviation with superior performance.

Stability and controllability are paramount in the aircraft's design, ensuring safety and reliability across all flight modes. The design incorporates measures to optimize the operation of the power plant, minimize losses at the air intake and exhaust, and enable safe performance in extreme flight conditions. The strategic placement of the horizontal and vertical tail units provides the necessary stability and control, reinforcing the aircraft's ability to handle various flight scenarios effectively.

Determining the aircraft's center of gravity is crucial for maintaining balance, stability, and controllability. The document details the calculations for the center of gravity, considering the distribution of mass in the wing, fuselage, landing gear, and payload. Accurate centering calculations ensure the aircraft remains stable and safe under different loading conditions, which is vital for overall flight safety.

In conclusion, prototype represents a pinnacle of modern aviation engineering, integrating advanced technology with meticulous design. The comprehensive approach to geometric calculations and design considerations detailed in the document underscores the aircraft's ability to achieve high efficiency, performance, and passenger comfort while adhering to stringent safety standards. This aircraft exemplifies the successful fusion of cutting-edge technology and precise engineering, setting a high standard for future advancements in the aviation industry.

### 3. PASSENGER MEDIUM RANGE AIRPLANE CONVERSION TO FREIGHTER

The shift to the digital economy brought about by e-commerce has resulted in more need for fast and reliable modes of delivery. This has led to aircrafts being the major players in air cargo when it comes to speed. Consequently, P2F (Passenger-to-Freighter) conversions are becoming a popular way for airlines and logistics firms to increase their cargo fleets quickly and cost-effectively.

Preferred models for P2F conversions include those with the right size, range, and availability. The Boeing 777, 767, and 737-800 are among these popular models known for their capacities as well as operational efficiency. Similarly, the A321-200 and A330 from Airbus have been highly sought-after in terms of conversion for they offer required range and payload capabilities appropriate to various cargo operations. There is a growing interest in widebody aircraft conversions because they provide larger cargo holds and longer ranges suitable on intercontinental freight routes. The major planes in this area are Boeing 777 and Airbus A330 that could handle the heavy ones across long distances without frequent stops between them. It is especially valuable for e-commerce which needs rapid and long-distance transport of goods.

The lack of appropriate feedstock - decommissioned or underused passenger planes that can be retrofitted - is one of the greatest challenges that this sector faces in the P2F conversion market. The pandemic as a result of COVID-19 has had an effect on how many old aircraft are retired with regard to the pandemic, with new airplane orders and deliveries temporarily declining. This has resulted in a shortage of available aircraft for conversion, forcing businesses to consider innovative alternatives or other models for their conversions. Furthermore, there is growing interest in converting small turboprop aircraft besides these large jets in order to cater for regional and niche markets needs.

					NAU 24 01H 00 00 00 61 EN			
	Sh.	№ doc.	Sign	Date				
Done by	Hrushko M.V.				Special part	list	sheet	sheets
Checked	Zakiev V.I.					Q	53	73
St.control	Krasnopolskyi V.S.					404 ASF 134		
Head of dep.	Yutskevych S.S.							

These turbo prop conversions prove particularly useful when it comes to goods delivery to remote or less accessible areas therefore enhancing overall logistics network. The market for Passenger-to-Freighter (P2F) conversions is expected to expand in the coming years, driven by the rise of e-commerce and evolving global supply chain demands. Various factors influence market dynamics, including regulatory frameworks, technological advancements in conversion processes, and the competitive landscape of conversion providers. Technological progress has improved the efficiency and safety of these procedures, making it more feasible for airlines to undertake such projects. Additionally, regulatory bodies are updating their frameworks to accommodate the increasing number of conversions while ensuring safety and operational standards are upheld. P2F conversions offer significant economic benefits, as it is often more cost-effective for airlines and logistics companies to convert existing planes rather than purchase new freighters. This approach allows for the expansion of cargo operations without the substantial expenses associated with acquiring new aircraft. Furthermore, P2F conversions extend the lifespan of existing planes, thereby enhancing the return on investment for these assets.

From an environmental perspective, P2F conversions have significant sustainability benefits. By extending the lifespan of aircraft, these conversions reduce the need for new airplane production, thereby minimizing environmental impact. The aviation industry is under increasing pressure to lower its greenhouse gas emissions, and converting passenger planes into freighters helps achieve this by reusing existing resources. The shift towards P2F conversions signals a change in aviation business dynamics, driven by the rapid growth of e-commerce and the demand for efficient air cargo solutions. This trend is set to continue shaping the future of air transport.



In its passenger mode, the aircraft operates as a typical airliner, complete with seating arrangements and amenities for transporting people during regular scheduled flights. When market demands shift or specific missions arise, the aircraft can be converted to a cargo configuration. This conversion process involves removing passenger seats and installing cargo loading systems, such as palletized floors, roller tracks, or specialized freight containers, to efficiently accommodate different types of cargo.

Convertible aircraft are highly valuable to operators because they provide the flexibility to adapt to varying operational requirements. For example, an airline might use the aircraft for passenger transport during peak travel seasons and then convert it to carry freight during off-peak times or for special cargo missions. This adaptability helps operators maximize the utilization of their fleet, reduce downtime, and respond effectively to changing market conditions or mission-specific needs.

Overall, the design and engineering of convertible aircraft prioritize ease of reconfiguration, ensuring that the transition between different roles is as seamless and efficient as possible. This capability not only enhances the operational flexibility but also contributes to the economic efficiency of airline operations by enabling them to meet diverse demands without the need for a separate fleet dedicated to each type of service [8].

Passenger aircraft are specially designed airplanes used primarily for transporting people from one location to another. These aircraft form the backbone of commercial aviation, enabling efficient and relatively quick travel across various distances, from short domestic flights to long-haul international journeys.

The design of passenger aircraft focuses heavily on safety, comfort, and efficiency. They feature a cabin layout with multiple rows of seats, often divided into different classes, such as economy, business, and first class. This division caters to varying levels of service and comfort, reflecting the diverse needs and preferences of travelers. The interior includes amenities such as overhead bins for carry-on



luggage, in-flight entertainment systems, and restrooms to enhance passenger comfort and convenience during flights.

From a safety perspective, passenger aircraft are equipped with advanced technology and systems. This includes oxygen masks, life vests, emergency exits, and sophisticated avionics for navigation and communication. The design and engineering of these planes prioritize the well-being of passengers, with stringent regulations and regular maintenance checks to ensure they meet high safety standards.

Operational efficiency is another critical aspect. Passenger aircraft are powered by advanced engines that offer improved fuel efficiency and reduced emissions, reflecting the industry's move towards more sustainable aviation practices. These aircraft also incorporate modern avionics and autopilot systems, enhancing their operational reliability and efficiency [9].

Cargo aircraft, or freighters, are airplanes designed or converted specifically to transport goods. These aircraft are essential to global trade, enabling fast and efficient movement of a wide range of products. Unlike passenger planes, cargo aircraft have interiors optimized for freight, featuring large, open spaces with reinforced floors and specialized loading equipment.

Safety and efficiency are key in cargo aviation. These aircraft maintain controlled environments to protect temperature-sensitive items and adhere to strict security protocols. Economically, cargo aircraft support various industries by facilitating just-in-time delivery and efficient inventory management, even reaching remote areas with limited infrastructure.

Environmental sustainability is becoming increasingly important, with advancements in aerodynamics, engine efficiency, and sustainable fuels reducing their carbon footprint. In summary, cargo aircraft are crucial to the global supply chain, combining specialized design and operational efficiency with evolving eco-friendly practices [9].



designed to address the challenges posed by potentially hazardous and diverse cargo.

**Cargo Hold Fires:** Fire detection in cargo holds relies on both smoke and heat sensors. When a potential fire is detected, the suppression system releases Halon 1301 or alternative agents in a two-stage process. The first stage involves an immediate release of a large quantity of the extinguishing agent to suppress the fire quickly. This is followed by a slower, prolonged discharge to prevent re-ignition, buying time for the aircraft to land safely.

**Specialized Extinguishing Agents:** Given the diverse nature of cargo, which can include flammable liquids, lithium batteries, and other hazardous materials, cargo aircraft may use a combination of extinguishing agents. These can include inert gases, dry powders, and water misting systems. The FAA has developed performance standards for these systems, ensuring their effectiveness in various fire scenarios.

**Fireproof Liners:** To contain any potential fire within the cargo hold, these areas are often lined with fire-resistant materials. This prevents the fire from spreading to other parts of the aircraft, thus protecting critical systems and ensuring the structural integrity of the aircraft during flight [11].

### **3.3 Removing passenger compartment to convert aircraft into freighter**

Converting a passenger aircraft into a freighter is a complex process that involves several significant modifications and removals to optimize the aircraft for cargo transport. This transformation is crucial to meet the growing demand for air freight and to extend the operational life of older passenger planes.

The first step in the conversion process is the complete removal of all passenger seats and associated fittings. This includes seat tracks, entertainment systems, and other related components. The removal of these elements creates an open space that can be reconfigured to hold cargo containers and pallets.

**Cabin Interiors:** Overhead bins, galleys, and lavatories are also removed. These components, essential for passenger comfort, are unnecessary in a freighter. Their

removal not only frees up additional space but also reduces the weight of the aircraft, allowing for more cargo capacity.

The cabin floor of a passenger aircraft is not designed to bear the weight of heavy cargo. Therefore, it is reinforced during the conversion process. This reinforcement involves the addition of stronger floor panels and support structures to ensure that the aircraft can handle the increased load without compromising safety. Passenger windows are typically plugged during the conversion. It enhances the structural integrity of the aircraft and provides a safer environment for cargo, which does not require external visibility. One of the most significant modifications is the addition of large cargo doors. These doors are either added a new or existing doors are reinforced and enlarged to facilitate the loading and unloading of large and heavy cargo. The positioning and design of these doors are critical to the efficiency of cargo operations. To streamline the cargo loading process, specialized cargo handling systems are installed. These systems include tracks, rollers, and locking mechanisms that help in the quick and secure placement of cargo containers and pallets. Beyond the floor, other parts of the aircraft's structure are strengthened to handle the different stress patterns experienced during cargo operations. This includes reinforcing the fuselage and wings to ensure the aircraft can safely carry heavy and dense cargo loads. The aircraft's avionics and other onboard systems are updated to support cargo operations. This may include changes to the environmental control systems to maintain optimal conditions for various types of cargo, from perishables to electronics [12].

Table 3.3.1

**List of equipped fuselage masses of cargo variant of aircraft**

#	Objects name	Mass		Center of gravity coordinates, m	Moment of mass, kg·m
		Units	total mass		
1	Fuselage	0.086	7314	19.38	141745.5
2	Horizontal tail	0.0095	810.49	34.3	27799.8
3	Vertical tail	0.0094	800.26	32.68	26152.59
4	Radar	0.0031	264.2	1	264.2
5	Radio equipment	0.0023	196	1	196.02
6	Instrument panel	0.0054	460.215	2	920.43
7	Aero navigation equipment	0.0046	392	2	784.07
8	Flight control system 70%	0.089	7571.13	16.925	128141.43
9	Hydraulic system 30%	0.00492	419.3	23.695	9935.48
10	Electrical equipment 90%	0.02898	2469.8	13.925	34392.25
11	Not typical equipment	0.0033	281.24	3	843.73
12	Lining and insulation	0.0065	554	16.925	9375.815
13	Anti ice system, 20%	0.0044	371.6	27.08	10062.41
14	Airconditioning system, 40%	0.022	1858	16.925	31445.04
15	Emergency equipment	0.0014	123.275	8.1	998.53
16	Operational items	0.00217	184.5	26	4797.32
17	Additional equipment	0.00331	282.09	5	1410.5
18	Seats of pilot	0.00024	20.57	2.26	46.486
19	Cargo	0.217	18480	15.34	283483
20	Crew	0.0019	160	8	1280
	<b>Totally equipped fuselage</b>	<b>0.461</b>	<b>39289.19</b>	<b>18.35</b>	<b>720956.56</b>

**3.4. Types of doors in freighter aircrafts**

Nose doors are a critical feature of certain freighter aircraft, significantly enhancing their capability to transport large and oversized cargo.

These doors, located at the front of the aircraft, open the entire nose section, allowing for straight-line access to the cargo hold.

One of the primary advantages of nose doors is their ability to facilitate the loading and unloading of oversized and long cargo items that would be difficult to maneuver through side doors. This capability is particularly beneficial for transporting large machinery, vehicles, and other outsized items. The nose door opens upwards, creating a wide opening that allows cargo to be loaded directly into the aircraft without the need for complex handling maneuvers or specialized equipment. The ease of loading provided by nose doors significantly enhances operational efficiency. The direct access to the cargo bay means that items can be moved in a straight line, reducing loading time and minimizing the risk of damage to both the cargo and the aircraft. This straightforward loading process is especially advantageous for time-sensitive shipments and tight turnaround schedules

Designing an aircraft with a nose door requires careful consideration of the structural integrity of the fuselage. The nose section must be reinforced to withstand the stresses associated with both the opening mechanism and the flight dynamics. This added complexity in design and maintenance is a trade-off for the increased loading capabilities provided by the nose door. The Boeing 747 is one of the most notable aircraft featuring a nose door. Known for its versatility and large cargo capacity, the 747's hinged nose swings upward, revealing a spacious cargo bay. This design is particularly useful for transporting large and heavy items that would be impractical to load through traditional side doors [13].

Side cargo doors are a fundamental feature in freighter aircraft, playing a crucial role in the efficient loading and unloading of goods. These doors are typically located on the sides of the aircraft, either on the main deck or the lower deck, and vary in size and design depending on the aircraft model and the type of cargo being transported. Side cargo doors are designed to accommodate standard cargo pallets and containers, known as unit load devices (ULDs).

The dimensions of these doors are optimized to fit various types of ULDs, which are used to streamline the loading process.

The doors are equipped with advanced mechanisms, such as hydraulic or electric systems, to ensure smooth operation and to handle the heavy loads associated with large cargo [14].

These doors typically feature integrated roller and locking systems. The rollers allow for easy movement of cargo into and out of the aircraft, while the locks secure the ULDs in place during flight, preventing any movement that could cause imbalance or damage [15]. The integration of these systems ensures that the cargo loading process is not only efficient but also safe.

One of the primary advantages of side cargo doors is their accessibility. Positioned on the side of the aircraft, they allow ground handling crews to load and unload cargo from multiple positions, making the process faster and more flexible. This is particularly beneficial in busy airport environments where quick turnaround times are essential [16]. Another advantage is their versatility. Side cargo doors can handle a wide range of cargo types, from small packages to large pallets, making them suitable for various shipping needs. This versatility is crucial for cargo airlines that need to transport different types of goods on a single flight [17].

Main deck cargo doors are a critical feature in freighter aircraft, providing access to the aircraft's primary cargo area. These doors are typically large, robust, and designed to facilitate the efficient loading and unloading of substantial and often heavy cargo directly onto the main deck.

Main deck cargo doors are engineered to handle the demands of loading and unloading large volumes of cargo. They are usually located on the side of the aircraft, although some designs, like those found on certain military transports, may have rear or front configurations. These doors are designed with strong, durable materials to withstand the rigors of repeated use and heavy loads.

The opening mechanisms for main deck cargo doors often include hydraulic systems that allow for smooth and controlled operation. These doors must be capable of opening wide enough to accommodate large cargo pallets and containers, ensuring that loading equipment can easily maneuver cargo into place. Additionally, the doors are integrated with advanced locking mechanisms to secure the cargo once it is loaded [14].

One of the primary advantages of main deck cargo doors is their ability to handle large and heavy cargo items. This feature is essential for transporting goods that are too big or heavy for lower deck compartments, such as heavy machinery, vehicles, and other oversized items. Main deck cargo doors also provide significant flexibility in cargo operations. They allow for the loading of a wide variety of cargo types, from palletized goods to bulk items. This versatility is crucial for cargo operators who need to maximize their load efficiency and adapt to different types of freight [18].

Lower deck cargo doors are an essential feature of freighter aircraft, designed to facilitate the loading and unloading of cargo in the lower fuselage compartments. These doors play a critical role in maximizing the cargo capacity and operational efficiency of freighter aircraft. This essay explores the features, advantages, examples, and modern innovations related to lower deck cargo doors.

Lower deck cargo doors are typically located on the sides of the aircraft, near the belly, providing access to the lower cargo compartments. These doors are generally smaller than main deck cargo doors but are still designed to handle substantial loads. They often feature hydraulic or electric actuation systems that ensure smooth and reliable operation [14]. The doors are equipped with sophisticated locking mechanisms and rollers to secure and move cargo within the aircraft. The locks ensure that the cargo remains stable and secure during flight, preventing any shifting that could disrupt the aircraft's balance. The rollers facilitate the easy movement of cargo containers and pallets into and out of the lower deck [18].







## GENERAL CONCLUSION

The conversion of passenger aircraft to cargo planes, known as Passenger-to-Freighter (P2F) conversion, offers economic benefits. Airlines can repurpose aging passenger planes instead of retiring them, extending their operational life and maximizing asset utilization. The cost of conversion is substantially lower than purchasing a new freighter, making it a financially prudent choice for many carriers. This economic aspect is crucial, especially in a market recovering from the financial strain imposed by global travel restrictions.

The rise of e-commerce has significantly boosted demand for air cargo services. Online shopping has surged, creating a need for rapid and reliable delivery networks. Freighter aircraft play a pivotal role in meeting this demand, particularly for time-sensitive shipments. Additionally, the global distribution of vaccines and medical supplies during the pandemic underscored the importance of a robust air cargo infrastructure. Converting passenger aircraft to freighters helps bridge the gap between demand and supply, ensuring efficient logistics.

Converting existing aircraft is also an environmentally sustainable practice. It reduces the need for new aircraft production, thereby lowering the associated carbon footprint. While the aviation industry is working towards greener technologies, utilizing existing assets aligns with sustainability goals. This approach contributes to a circular economy, where resources are reused and repurposed, minimizing waste.

					NAU 24 01H 00 00 00 61 EN		
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			
<i>Done by</i>	Hrushko M.V.				<i>list</i>	<i>sheet</i>	<i>sheets</i>
<i>Checked</i>	Zakiev V.I.				Q	67	76
<i>St.control</i>	Krasnopolskyi V.S.				General conclusion		
<i>Head of dep.</i>	Yutskevych S.S.						

## REFERENCES

- 1) **Boeing 737 MAX: Technical Specifications.** Access mode: <https://www.boeing.com/commercial/737max#technical-specs>.
- 2) **Boeing 737 MAX.** *Wikipedia.* Access mode: [https://en.wikipedia.org/wiki/Boeing\\_737\\_MAX](https://en.wikipedia.org/wiki/Boeing_737_MAX).
- 3) **Aileron.** *Wikipedia.* Access mode: <https://en.wikipedia.org/wiki/Aileron>.
- 4) **14 CFR § 25.810 - Emergency egress assist means and escape routes.** Access mode: <https://www.law.cornell.edu/cfr/text/14/25.810>.
- 5) **Passenger-to-Freighter Conversions Shift With Growing Cargo Activity.** *Aviation Week.* Access mode: <https://aviationweek.com/mro/aircraft-propulsion/passenger-freighter-conversions-shift-growing-cargo-activity>.
- 6) **Types of All-Cargo Aircraft: A Comprehensive Guide.** *Dfreight Blog.* Access mode: <https://dfreight.org/blog/types-of-all-cargo-aircraft-comprehensive-guide/>.
- 7) **Combi Aircraft.** *Wikipedia.* Access mode: [https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://en.wikipedia.org/wiki/Combi\\_aircraft&ved=2ahUKEwjD9cLJ9cOGAxVQJBAIHWEDOh0QFnoECDgQAQ&usg=AOvVaw02shv7xkgCkt5fIbPky\\_rz](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://en.wikipedia.org/wiki/Combi_aircraft&ved=2ahUKEwjD9cLJ9cOGAxVQJBAIHWEDOh0QFnoECDgQAQ&usg=AOvVaw02shv7xkgCkt5fIbPky_rz).
- 8) **What is the difference between a combi aircraft and a convertible aircraft?** *Quora.* Access mode: [https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.quora.com/What-is-the-difference-between-a-combi-aircraft-and-a-convertible-aircraft&ved=2ahUKEwjMr4\\_x9cOGAxVDFRAIHaiDK\\_QQFnoECCYQAQ&usg=AOvVaw1pgbbz6N-4jIDP7LtByZsI](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.quora.com/What-is-the-difference-between-a-combi-aircraft-and-a-convertible-aircraft&ved=2ahUKEwjMr4_x9cOGAxVDFRAIHaiDK_QQFnoECCYQAQ&usg=AOvVaw1pgbbz6N-4jIDP7LtByZsI).
- 9) **Airliner.** *Wikipedia (Chinese version).* Access mode: <https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://zh.wikipedia.org/zh-cn/en:airliner&ved=2ahUKEwiyjquG9cOGAxXdHBAIHVQGLK0QFnoECBYQAQ&usg=AOvVaw1aTHekG6s74GSVmrEh8xkB>.
- 10) **Passenger to Freighter Aircraft: Aircraft Design Considerations.** *Skybrary.* Access mode: <https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://skybrary.aero/sites/default/files/bookshelf/4419.pdf&ved=2ahUKEwjSpOzt38OGAxVgQPEDHYDaDR4QFnoECBsQAQ&usg=AOvVaw2VXjg7vymI0BXotFsbXVE6>

					NAU 24 01H 00 00 00 61 EN					
	Sh.	№ doc.	Sign	Date	References			list	sheet	sheets
Done by	Hrushko M.V.							Q	68	76
Checked	Zakiev V.I.									
St. control	Krasnopolskiy V.S.									
Head of dep.	Yutskevych S.S.							404 ASF 134		



**Appendix A**  
**INITIAL DATA AND SELECTED PARAMETERS**

Passenger Number **160**

Flight Crew Number **2**

Flight Attendant or Load Master Number **4**

Mass of Operational Items **1542.12 kg**

Payload Mass **18480 kg**

Cruising Speed **838 km/h**

Cruising Mach Number **0.7821**

Design Altitude **10.60 km**

Flight Range with Maximum Payload **5000 km**

Runway Length for the Base Aerodrome **2.55 km**

Engine Number **2**

Thrust-to-weight Ratio in N/kg **3.1000**

Pressure Ratio **31.30**

Assumed Bypass Ratio **5.50**

Optimal Bypass Ratio **5.50**

Fuel-to-weight Ratio **0.26000**

Aspect Ratio **9.44**

Taper Ratio **3.59**

Mean Thickness Ratio **0.110**

Wing Sweepback at Quarter Chord **26.0 °**

High-lift Device Coefficient **1.050**

Relative Area of Wing Extensions **0.010**

					<b>NAU 24 01H 00 00 00 61 EN</b>	<i>Sh.</i>
						70
<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>			









CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed 263.45 km/h

Mean Acceleration for Continued Takeoff on Wet Runway **0.33 m/s<sup>2</sup>**

Takeoff Run Distance for Continued Takeoff on Wet Runway **1938.49 m**

Continued Takeoff Distance **2516.87 m**

Runway Length Required for Rejected Takeoff **2606.43 m**

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight **69021 kg**

Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight **21.4 min**

Descent Distance **49.79 km**

Approach Speed **255.06 km/h**

Mean Vertical Speed **2.05 m/s**

Airborne Landing Distance **519 m**

Landing Speed **240.06 km/h**

Landing run distance **775 m**

Landing Distance **1294 m**

Runway Length Required for Regular Aerodrome **2161 m**

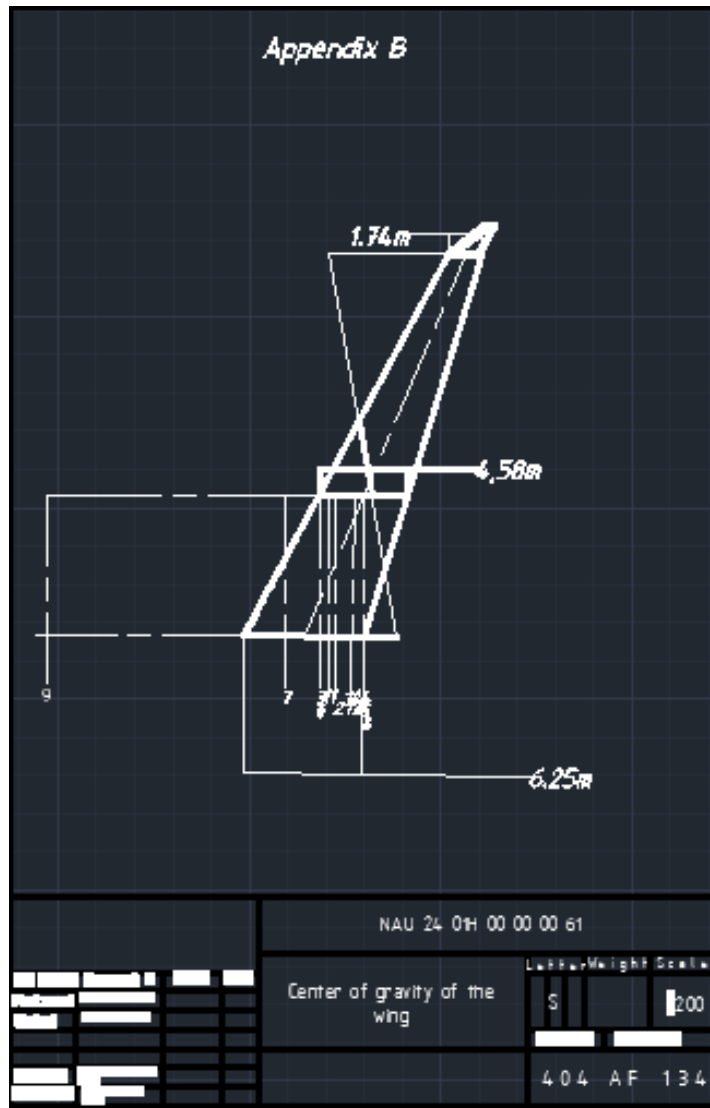
Runway Length Required for Alternate Aerodrome **1838 m**

ECONOMICAL EFFICIENCY

**THESE PARAMETERS ARE NOT USED IN THE PROJECT**

					<i>NAU 24 01H 00 00 00 61 EN</i>	<i>Sh.</i>
						74
	<i>Sh.</i>	<i>Nº doc.</i>	<i>Sign</i>	<i>Date</i>		

# Appendix B



Sh.	Nº doc.	Sign	Date	

NAU 24 01H 00 00 00 61 EN

Sh.

75

# Appendix C

