МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д.т.н., проф.
_____________ Сергій ІГНАТОВИЧ
«_____» ___________ 2022 рік

ДИПЛОМНА РОБОТА

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ "БАКАЛАВР"
ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Аванпроект середньо-магістрального вантажного літака вантажепід’ємністю до 47 тонн»

Виконала: ___________ **Валерій СТЕПАНЕНКО**

Керівник: канд.техн.наук, доцент ___________ **Вадим ЗАКІЄВ**

Нормоконтролер: канд.техн.наук, доцент ___________ **Сергій ХИЖНЯК**

Київ 2022

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Department of Aircraft Design

PERMISSION TO DEFEND
Head of the department
Dr.Sc., Professor
_________ Sergiy IGNATOVYCH
«___» _______ 2022

BACHELOR DEGREE THESIS
ON SPECIALTY
"AVIATION AND AEROSPACE TECHNOLOGIES "

Topic: «Preliminary design of the medium range cargo aircraft with payload up to 47 tones»

Prepared by: __________**Valeriy STEPANENKO**

Supervisor: PhD, associate professor __________**Vadim ZAKIEV**

Standard controller: PhD, associate professor __________**Sergiy KHIZNYAK**

Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Specialty: 134 "Aviation and Aerospace Technologies"

APPROVED BY

Head of the Department

Dr.Sc., Professor

_________ Sergiy IGNATOVYCH

«___» _______ 2022

TASK

for the bachelor degree thesis

VALERIY STEPANENKO

1. Topic: « Preliminary design of the medium range cargo aircraft with payload up to 47 tones» confirmed by Rector's order № 489/ст from 10.05.2022.
2. Thesis term: from 23.05.2022 to 19.06.2022.
3. Initial data: cruise speed V_{cr}=750 kmph, flight range L=3000 km, operating altitude H_{op}= km, capacity 47 tonnes.
4. Content (list of topics to be developed): choice and substantiations of the airplane scheme, choice of initial data; engine selection, aircraft layout, center of gravity position calculation, conversion of cargo aircraft to medical evacuation
5. Required material: general view of the airplane (A1×1); layout of the airplane (A2×1); layout of the medical module (A2×1).

6. Thesis schedule:

Task	Time limits	Done
Task receiving, processing of statistical data	23.05.2022–28.05.2022	
Aircraft geometry calculation	28.05.2022–31.05.2022	
Aircraft layout	31.05.2022–03.06.2022	
Aircraft centering	03.06.2022–05.06.2022	
Graphical design of the parts	05.06.2022–12.06.2022	
Completion of the explanation note	12.06.2022–14.06.2022	
Defense of diploma work	14.06.2022–19.06.2022	

7. Date: 23.05.2022

Supervisor ____________ Vadim ZAKIEV

Student ____________ Valeriy STEPANENKO

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, д.т.н, проф.

__________ Сергій ІГНАТОВИЧ

«_____» _____________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

ВАЛЕРІЙ СТЕПАНЕНКО

1. Тема роботи: «Аванпроект середньо-магістрального вантажного літака вантажепід'ємністю до 47 тонн», затверджена наказом ректора № 489/ст від 10 травня 2022 року.

2. Термін виконання роботи: з 23 травня 2022 р. по 19 червня 2022 р.

3. Вихідні дані до роботи: дальність польоту з максимальним комерційним навантаженням 3000 км, крейсерська швидкість польоту 750 км/год, висота польоту 7 км. максимальна нагрузка 47 тонн.

4. Зміст пояснювальної записки: вибір параметрів та обґрунтування схеми проектованого літака, вибір двигунів, розрахунок геометрії та центрування літака, конвертація вантажного літака в літак медичної евакуації.

5. Перелік обов'язкового графічного матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А2×1), загальний вигляд медичного модуля (А2×1).

6. Календарний план-графік:

Завдання	Термін виконання	Відмітка про виконання
Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів	23.05.2022–28.05.2022	
Вибір та розрахунок параметрів проєктованого літака	28.05.2022–31.05.2022	
Виконання компонування літака	31.05.2022–03.06.2022	
Розрахунок центрування літака	03.06.2022–05.06.2022	
Виконання креслень літака	05.06.2022–12.06.2022	
Оформлення пояснювальної записки та графічної частини роботи	12.06.2022–14.06.2022	
Захист дипломної роботи	14.06.2022–19.06.2022	

7. Дата видачі завдання: 31.05.2022 рік

Керівник дипломної роботи __________ Вадим ЗАКІЄВ

Завдання прийняв до виконання __________ Валерій СТЕПАНЕНКО

РЕФЕРАТ

Дипломна робота **«Аванпроект середньо-магістрального вантажного літака вантажепід'ємністю до 47 тон»**

48 сторінок, 4 рисунків, 9 таблиць, 9 літературних посилань, 3 креслення

Об'єкт проектування: середньо-магістральний вантажний літак вантажепід'ємністю до 47 тонн

Предмет проектування: медичні модулі .

Мета роботи: аванпроект середньо-магістрального пасажирського літака відповідно до прототипів, та розташування медичного модуля

Методи дослідження: аналіз прототипів і вибір найбільш досконалих технічних рішень, оцінка геометричних характеристик, розрахунок центру мас літака, конвертація розробного літака для медичної евакуації, розрахунок центру мас літака з урахуванням встановлених медичних модулів..

Наукова новизна результатів. Конвертація вантажного літака в літак медичної евакуації.

Практична цінність роботи:. Результати роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

ЛІТАК, АВАНПРОЕКТ ЛІТАКА, КОМПОНУВАННЯ КАБІНИ, ЦЕНТРУВАННЯ ЛІТАКА, ЦЕНТРУВАННЯ ЛІТАКА, КОНВЕРТАЦІЯ ВАНТАЖНОГО ЛІТАКА В МЕДИЧНИЙ, РОЗРАХУНОК ЦЕНТРУ МАС .

ABSTRACT

Bachelor thesis « **Preliminary design of the medium range cargo aircraft with payload up to 47 tones**»

48 pages, 4 figures, 9 tables, 9 references, 3 drawings

Object of study: design of the medium range cargo aircraft with payload up to 47 tones.

Subject of study: the cargo aircraft converted into its medical version.

Aim of bachelor thesis: medical modules.

Research and development methods: analysis of prototypes and selection of the most advanced technical solutions, evaluation of geometric characteristics, calculation of the center of mass of the aircraft, design of converted aircraft, calculation of the center of mass taking into account the medical module.

Novelty of the results: Conversion of freighter to medical evacuation.

Practical value: The results of the work can be used in the aviation industry and in the educational process of aviation specialties.

AIRCRAFT, PRELIMINARY DESIGN, AIRCRAFT CENTERING, CONVERSION OF FREIGHTRT AIRCRAFT TO MEDICAL EVACUATION, CALCULATIONS CENTER OF GRAVITY

Format	№	Designation	Name	Quantity	Notes
			General documents		
A4	1	NAU 22 M 00 00 00 65	Task for work	1	
	2		Documentation for assembly units	3	
A1		NAU 22 M 00 00 00 22	General view		
A1		NAU 22 M 00 00 00 22	Fuselage layout		
A1		NAU 22 M 00 00 00 22	Medical module	1	
A4	3	NAU 21 M 00 00 00 22 EN	Medium range cargo aircraft	55	

Ch	Sheet	Document №	Sign	Date
Performed by		Stepanenko		
Supervisor		Zakiev V.		
Adviser				
Stand.contr.		Khyzhnyak.		
Head of dep.		Ignatovych.		

NAU 22 M 00 00 00 65 EN

List of diploma work

Letter	Sheet	Sheets

AF 402 134

CONTENT

Ch	Sheet	Document №	Sign	Date	NAU 22 M 00 00 00 65 EN		
Performed	Stepanenko V				Content	Letter	Sheet	Sheets
Supervisor	Zakiev V.							
Stand.contr.	Khyzhnyak.S					AF 402 134		
Head of dep.	Ignatovych							

INTRODUCTION

With the development of aviation science and technology due to such advantages as speed and comfort, air transport has become a necessity.

The main stages of analysis and calculation include the calculation of the total takeoff mass, the load on the wing, determining the geometric parameters of the components, design and calculation of the fuselage and cabin.

Main task of the diploma project was Preliminary design of the medium range cargo aircraft with payload up to 47 tones . To design comfortable cargo airplane that will quickly and safely transport goods. It is also important to reduce the time and cost of transporting goods.

Aircraft design in industry is primarily based on accumulated experience. Optimization of complications. New designs are often found frequently with aircraft already installed by the manufacturer. This also follows from the need to shun the risks of improvement. The configuration is described mainly in the former, the applicable definition and parameters apply. The 1st flight that ever reminded us of what we now know as cargo transportation was another millennium in the eleventh year when aircraft were called to account. However, the 1st genuine cargo aircraft was developed in a single setting. It was then that the UK decided to make an airplane in order to cope with the cargo, with the delivery of soldiers and their property. In 1021, Vickers Vernon was transferred to the Royal Air Force (RAF). Two years later, the aircraft involved five hundred Sikh soldiers at a time. The idea of using for military purposes has spread. This was the place of their repetition, and, gravitation of a natural new source, modifications were made to the original design. In one millennium of the end of the ninth year, aircraft with rear doors were created, which greatly simplified loading and unloading [1].

1. PROJECT PART

1.1. Analysis of prototypes and short description of designing aircraft

1.1.1. Choice of the projected data

A cargo aircraft is a fixed-wing aircraft designed to carry cargo, not passengers. Such aircraft do not have doors for passengers. They often have only one or more loading doors. Cargo planes can be used by both state and private airlines, carrying various cargoes. Most of these aircraft are used to transport special ULD containers in compartments.

Aircraft that were designed for cargo transportation have features that distinguish them from passenger ones, for example, an oval fuselage section for convenient location inside, a high-wing aircraft that would be able to reduce the loading height, more landing gear for landing on unprepared places

Freighter planes are made to carry only freight both on the lower and the main deck. The freighter floors have embedded rollers to help slide the freight into position. Hook locking facilities are provided along the floor to secure the freight. Some of the freighters have winches built-in to help lift or lower freight, which is a big help to move and position heavy loads in the cabin. Statistic data of prototypes are presented in table 1.1. Cargo aircraft are supposed to be based on a number of technical and operational characteristics, based on which the logistics company selects various options for vehicles, taking into account the weight, application, technical equipment of the board and terminals at points of departure and destination, and other objects.

Table 1.1 – Operational-technical data of prototypes

Name of the prototype	**B767**	**B747**	**B777**
Max payload ,kg	52 480	70 620	68 500
Flight crew, [persons]	2	3	2-3
Passengers	269	336	312-388
Wing loading, [kN/m^2]	504	652	578
Flight range with $G_{payload,max}$, [km]	6 482	9 200	9 038
Range of cruising altitudes, [km]	12 195	13 700	10 668
$V_{cr\ max}$ / H, [km/h / km]	851	820	875
$V_{cr,econ}$ / H, [km/h / km]	570	610	700
Thrust/weight ratio kN/kg	170	210	200
Power/weight ratio kWt/kg	1120	970	1240
Specific fuel consumption [gt/km]	18	24.6	76
Power plant data			
Number of engines and their type	2	4	2
Take off thrust, [kN]	210	190	436
Take off power, [kN]	184	275	260
Cruising thrust, [kN]	100	120	110
Pressure ratio	25:1	27.5:1	40:1
Bypass ratio	6.5 :1	10:1	9:1
Take off and landing characteristics			
Aerodrome code letter	C/D	D	D
Approach speed, [km/h]	246-278	263-283	256-278
Landing speed, [km/h]	255	276	263
Speed of lift, [km/h]			
Take off run distance, [m]	1539	2916	3 048
Landing run distance, [m]	934	2000	2 500
Take off distance, [m]	2713	3854	4390
Landing distance, [m]	1178	2129	1720

Table 1.2 – Geometry characteristics

Name of the prototype	**B767**	**B747**	**B777**
Wing span, [m]	48	64	64.8
Sweepback angle at ¼ of the chord, [°]		29	31.6
Mean geometric chord, [m]	9.4	10	9.8
Wing aspect ratio	7.99	6.96	9.96
Wing taper ratio	0.207	0.284	0.149
Fuselage length, [m]	48.5	76.25	63.7
Fuselage diameter, [m]	4.72	6.1	6.2
Fuselage fineness ratio	7.9	9.3	9.1
Passenger cabin width, [m]		5.9	
Passenger cabin length, [m]		56.4	
Cabin height, [m]	4.93	5.89	5.96
Cabin volume, [m^3]	624	692	732
Seat pitch, [m]			
Aisle width, [m]	0.38	0.45	0.46
Horizontal tail span, [m]	18.62	22	21.35
Horizontal tail sweepback angle, °	39	42	41
Horizontal tail relative area, %	22	28	26.6
Horizontal tail aspect ratio	4.46	3.57	4.5
Horizontal tail taper ratio	0.2	0.284	0.3
Relative area of elevator, %			
Vertical tail height, [m]	9.01	10.16	18.5
Vertical tail span, [m]	18.42	22	23.41
Vertical tail sweepback angle, [°]	42	42	42
Vertical tail relative area, %	26	24	27
Vertical tail aspect ratio	1.76	1.34	1.6
Vertical tail taper ratio	0.306	0.33	0.290
Relative area of rudder, %			
Landing gear base, [m]	19.69	25.6	25.8
Landing gear track, [m]			

1.1.2. Brief description of the main parts of the aircraft

Four-engine, narrow-body, medium-haul cargo aircraft The aircraft is a free-wing aircraft with a high mono-wing and conventional tail unit with one empennage and rudder. The aircraft has good technical achievements in power plant, aerodynamics, avionics and materials.

The aircraft has some new features, including a redesigned wing, underwing section. Engines and lighter materials, as well as the forward fuselage, cockpit layout and low tail configuration. The aircraft can provide cheap transportation of goods
It can operate continental flights with a claimed range of up to 3,000 km.

Fuselage is is one of the basic structural elements. The fuselage is a long tube, cylindrical in shape, hollow inside, which is designed to carry passengers or cargo. This place includes the cockpit (located in the front). When choosing the fuselage, several considerations were taken into account, the implementation of the design, the strength and manufacture of the fuselage. These include the presence of panels, a wire frame (truss structure) or an injection molded fuselage. All use cases were ideal for this project, and at the same time, the choice of a specific fuselage design was found. Wire frame construction has its advantages, such as being very strong (if built correctly), lightweight, affordable, and allowing access to the entrance. These characteristics are ideal for this type of project where we have to use lightweight and other components. However, a wire frame is difficult to build, and although its construction is relatively strong, it may not reveal visibility due to improper fit. If the aircraft does not make a perfect landing, increased stress will occur in the joint area, and the wire frame may collapse due to breakage. Another design contemplated fuselage choice was a single-panel design. Panels are generally lightweight, easy to make and assemble, and are considered affordable, but they are not as strong as wireframe construction.

Due to its cost, ease of assembly and seems to be a good choice, regardless of strength. The panels also provide easy access to the cargo area, engine, fuel tank and other components. The command to clarify the possibility of using the fuselage mold.

Injection molded, it gets a very precise shape, which in turn gives it aerodynamic advantages, the fuselage is very strong and does not require assembly. These factors are very important in choosing the ideal design, however, it is very expensive to manufacture, it is heavier than other designs, and its aerodynamic shape is not required for low speed flight. The design of the panel was chosen after building the design matrix.

Wings are aerodynamic surfaces that, when they move quick on the outer surface, collect force. They come in almost all shapes and sizes. The wing design can be used for the expected lethal properties. Control of various operating parameters, the value of the lifting speed of the balance, the variation of the speed of change of the shape of the wing. Both the leading and trailing edges of a wing can be straight or curved, or one edge can be straight and the other curved. One or both edges can be tapered so that the wing is narrower at the tip than the base where it extends with the fuselage. The wings are clearly prepared to lift it into the air. Their specific design for those specific options depends on choices such as size, weight, application, desired speed in flight and landing, but desired rate of climb. The internal structure of most of the wings consists of spars and cross members running along the span, plus ribs and frames or bulkheads. Spars are structural developments of the wing. They introduced all distributed loads, as well as targeted weights such as the fuselage, landing gear and engines. The skin, attached to the wing structure, takes care of some of the movements, moving them during the flight. It also transmits stress to the wing nerves. The ribs, in turn, transfer the loads to the wing spars.

The tail unit is one of the principal structural units of the aircraft and the element of airplane frame. Tail assembly or empennage is located at the rear of the airplane. The tail unit consists of two surfaces. One is vertical and the other is horizontal. They are of symmetrical airfoil section. Each section is divided into two parts[3]. the front part is fixed. The front part is fixed. The rear part is in the form of a flap. The vertical surface is called the fin. It provides directional control of the aircraft in flight. The horizontal surface is known as the "stabilizer". Both the fin and the stabilizer are very similar to the wings in construction They are usually of all-metal construction. The will vertical stabilizer or fin provides directional stability of the airplane in flight. It also serves as the base to which the rudder is attached The rudder is a movable surface hinged to the trailing edge of the fin. It provides directional control of the airplane in flight, being deflected to the right or left. The horizontal stabilizer provides longitudinal stability of the airplane in flight. It serves as a support for the elevators.

The landing gear is the main support encountered during parking, taxiing, takeoff. takeoff or landing. A feature of the small hull type consists of wheels. The wheel origin on small assembled ones consists of 3 wheels: 2 main wheels (one each from the entire side of the fuselage) and three wheels located either in front or behind the assembled ones. A chassis with rear wheels is referred to as an ordinary chassis. Aircraft with conventional undercarriage are occasionally referred to as tailwheel aircraft. The two main wheels are attached to the plan in front of its highlighted density (DH) and a huge huge portion of the body's mass. The tail wheel is located at the very rear of the fuselage and occupies a third of the fulcrum. With this arrangement, road progress was made for a larger nose propeller and more desirable for operation in unfertilized fields. A tailwheel landing can, depending on speed, generate enough lift (due to the increased angle of attack (AOA)) and force the aircraft back into the air. Reduced visibility when the tail wheel is on the ground or on the ground Special training is required to fly aircraft with a tail wheel.

1.2. Geometry calculations for the main parts of the aircraft

Layout of the aircraft consists from composing the relative disposition of its parts and constructions, and all types of the loads (passengers, luggage, cargo, fuel, and so on). The geometrical calculating principle of the wing, fuselage, tail fin, landing gear, and other structural parts is included in the layout. The choice of composition and aircraft parameters is based on a solution that aims to best meet operational requirements.

1.2.1. Determination of the geometric parameters of the wing

An aircraft wing is designed to generate the lift needed to support the aircraft in the air. The aerodynamic quality of the wing is greater, the greater the lift and the less drag. The lift and drag of the wing depend on the geometric characteristics of the wing. The geometric characteristics of the wing are mainly reduced to the characteristics of the wing in plan and the characteristics of the wing profile. Main characteristics is sweep angle, cross wing angle, wing profile.

Table 1.3. – Geometrical characteristics of the wing.

Aircraft wing parameters	Take-off weight of the aircraft			
	Up to 15t	20 – 40 t	50 – 100t	150t+
λo	8...12	7...9	6,5…8	6,5.. .9,0
χ°	6°...8°	20°...25°	30°...32°	32°...35°
C_A	0,12...0,14	0,11...0,12	0,10...0,12	0,12...0,14
Po(CPa)	2,0...3,0	3,5...4,0	4,5...5,5	8,5...6,0

The aerodynamic characteristics of the wing are largely determined by the shape of the wing in plan. The profile parameters ($\bar{x}C$, f) and the relative thickness of the wing ($\bar{C}_A$), as the practice of aircraft construction shows, depend on the number of Mach (M) of the cruising flight Mk shown in the table below.

Table 1.4. - Dependence of profile parameters on the Mach number

Mk	χ°	λ	η	$\bar{C}_A$,%	$\bar{x}C$	*f*,%
0,85-0,9	35º…40º	6,5…8,5	3,5…4,5	9…12	35…45	0…2,5
0,6- 0,8	0º…25º	7…12	2,5…3,5	12…18	30…40	1…3,5

The determination of wing geometrical characteristics is based on the take-off mass m_o and the specific load on the wing P_o:

Firstly, find the area of the wing:

$$S_{wfull}=\frac{m_0 \cdot g}{P_0} = 481,23 * (1-0,1) = 457,17 \text{ m2}.$$

The wingspan is calculated by the formula:

$$l = \sqrt{s_w \cdot \lambda_m} = 62.96 \text{ m}$$

Root chord

$$b_0 = \frac{2S_w\eta_w}{(1+\eta_w)\cdot l} = 11.37m$$

Tip chord

$$b_t = \frac{b_0}{\eta_w} = 3.16m$$

In order to select a wing strength scheme, the constituent parts must be calculated. Modern aircraft use a cassional wing and two or three spars; one spar is used on small range, medical and other aircraft.

The relative position of the spars in the wing on the chord is equal to:

The magnitude b_{cax} = 8,47 m

The geometric parameters of the aileron are determined in the sequence:

aileron range: l_{el} = (0,3…0, 4)*l/2=4,28 m;

chord aileron: b_{el} = (0,22…0,26)*bi;

aileron area: S_{el} = (0,05…0,08)*S_w/2= 3,05m2.

The ailerons are attached to the outboard trailing edge of each wing and, when a manual or autopilot control input is made, move in opposite directions from one another. In this configuration, both ailerons on each wing are active during slow speed flight.

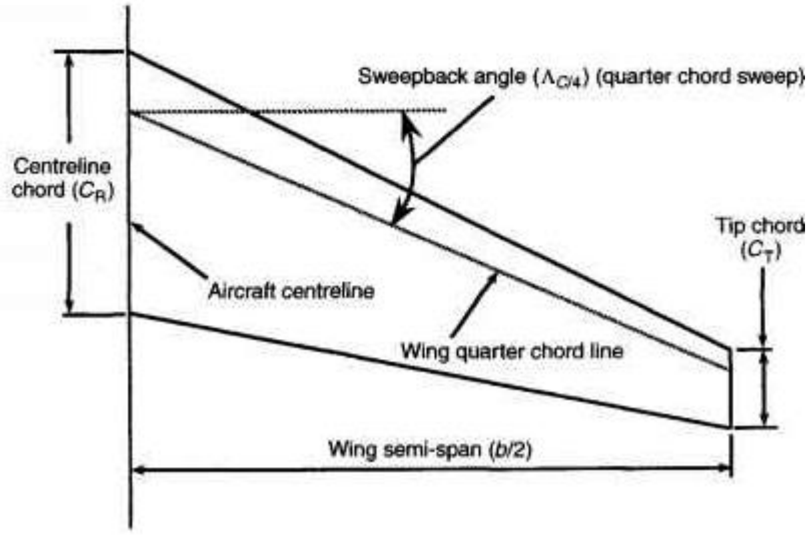

Figure1.1 – Wing geometry

$$S_{tail}=0.06 \cdot S_{ail}=0.06 \cdot 3.05=0.183\ m^2$$

The main goal of calculating the parameters of the wing lift is to acquire high performance of the wing during landing and takeoff, which are predicted in observations calculated based on the parameters of the choice of lift and the type of airfoil.

1.2.2. Fuselage layout

When choosing the dimensions and shape of the fuselage cross section, one should proceed from the requirements of aerodynamics (streamlining and cross-sectional area). Due to passenger and transport aircraft, the speed of which is less than the speed of sound (V < eight hundred km/h), the wave drag has practically no effect. Consequently, the shape should be chosen under the conditions of ensuring the lowest values of the corresponding friction resistance[4].

C_{xf} and profile drag C_{xd}. In supersonic flights, the shape of the nose of the fuselage affects the value of the wave drag C_{xf}. The use of the chewing shape of the nose of the fuselage greatly reduces its wave resistance. For transonic aircraft, the forward fuselage should $l_{nf}=(2...3)\times D_f$, where D_f is the fuselage diameter. In addition to taking into account the requirements of aerodynamics, when choosing the shape of the intersection, it is necessary to take into account layout conditions and strength requirements. In order to ensure a minimum weight, a particularly preferred fuselage cross-sectional shape should be recognized as a circular cross-section. In this case, the thickness of the fuselage skin is less. As a variation of this section, combinations of two or more occiles can be used both vertically and horizontally. For transport aircraft when choosing the shape of the cross-section of the fuselage

fuselage diameter D_f; = 4.9m

fuselage length L_f =43.61 m

fuselage extension $\lambda_f = L_f/D_{te}$ = 8.9 m

extension of the nose of the fuselage: $\lambda_{nf} = L_{nf} / D_{nf}$

fuselage tail extension: $\lambda_{te} = L_{te} / D_{te}$

where L_{nf} i L_{te} - the length of the nose and tail parts of the fuselage.

1.2.3. Layout and calculation of basic parameters of tail unit

One of the most important tasks of aerodynamic layout is the choice of the location of the horizontal tail unit. To ensure the longitudinal static stability of the aircraft overload, its CM must be in front of the focus of the aircraft and the distance between these points, attributed to the value of the average aerodynamic chord (CAC) of the wing, determines the degree of longitudinal stability, $m_x^{Cy} = \underline{x_T} - \underline{x_F} < 0$, where m_x^{Cy} – is the moment coefficient; x_T, x_F- center of gravity and focus coordinates. If m_x^{Cy} = 0, then the plane has the neutral longitudinal static stability, if m_x^{Cy} > 0, then the plane is statically unstable. In the normal aircraft scheme (tail unit is behind the wing), focus of the combination wing – fuselage during the install of the tail unit is moved back.

The area of the vertical tail unit is:

$$S_{VTU} = \frac{l_w S_w}{L_{VTU}} \cdot A_{ATU} = 60.38 \cdot 383.85 / 14 \cdot 0.01189 = 19.683 m^2$$

Area of horizontal tail unit is equal:

$$S_{HTU}=\frac{b_{MAC}\cdot S_W}{L_{HTU}}\cdot A_{HTU}=5.4847\cdot 383.85/_{14}\cdot 0.01186=17.834m^2$$

Area of the altitude elevator:

$$S_{el}=0.35\cdot S_{HTU}=6.214\ m^2$$

Rudder area:

$$S_{rud}=0.4\cdot S_{vtu}=7.873\ m^2$$

Choose the area of aerodynamic balance.

$$0.3\leq M\leq 0.6,\ S_{eb}=(0.22..0.25)S_{ea},\ S_{rb}=(0.2..0.22)S_{rd}$$

Elevator balance area is equal:

$$S_{eb}=0.235\cdot S_{HTU}=4.190\ m^2$$

Rudder balance area is equal:

$$S_{rb}=0.22\cdot S_{vtu}=4.330\ m^2$$

The area of altitude elevator trim tab:

$$S_{te}=0.10\cdot S_{el}=0.612\ m^2$$

Area of rudder trim tab is equal:

$$S_{tr}=0.05\cdot S_{rud}=0.394\ m^2$$

Root chord of horizontal stabilizer is:

$$b_{0HTU}=\frac{2S_{HTU}\cdot\eta_{HTU}}{(1+\eta_{HTU})\cdot l_{HTU}}=7.29\ m$$

Tip chord of horizontal stabilizer is:

$$b_{0HTU}=\frac{b_{0HTU}}{\eta_{HTU}}=2.43\ m$$

Root chord of vertical stabilizer is:

$$b_{0VTU}=\frac{2S_{VTU}\cdot\eta_{VTU}}{(1+\eta_{VTU})\cdot l_{VTU}}=7.59\ m$$

Tip chord of vertical stabilizer is:

$$b_{0VTU}=\frac{b_{0VTU}}{\eta_{VTU}}=\frac{6.802}{2.778}=2.45\ m$$

1.2.4. Landing gear design

Only a subset of the properties of the L.G can be related to the initial detection when the high concentration state is known and there is no value of a generally recognized species.

Main wheel axel offset is:

$$e=0.275\cdot bMAC= 1.466\ m$$

When the back of the airplane is loaded first, the lift-off of the front gear during takeoff is complicated, and when it is minor, the airplane may drop on the tail. The term "landing gear wheelbase" is derived from the phrase:

$$B=0.395\cdot Lf=0.395\cdot 43.61\ m$$

The last equation means that the nose support carries 6...10% of aircraft weight.

Front wheel axial offset will be equal:

$$d_{ng}=B\text{-}e =18.271\ m$$

Wheel track is:

$$T=0.502\cdot B=0.502\cdot 19.737=11.984\ m$$

In order to prevent a side nose-over, the value K should be more than 2H, where H is the distance from the runway to the center of gravity.

The take off weight determines the size and run stress on the landing gear wheels; for the front support, we also consider dynamic loading.

The type of pneumatics (half balloon,balloon, arched) and pressure in it are determined by the runway surface. We use breaks on both the main wheel and, on sometimes, the front wheel.

The load on the wheel is determined:

Kg = 1.75 was used as the dynamics coefficient.

The nose wheel load is:

$$P_{NLG}=\frac{9.81\cdot e\cdot k\cdot m_0}{B\cdot z}=\frac{9.81\cdot 1.466*2*162667}{19.737*2}=118528.09\ N$$

Main wheel load is equal:

$$P_{NLG}=\frac{9.81\cdot (B-e)\cdot m_0}{(B\cdot n\cdot z)}=\frac{9.81\cdot (19.737-1.466)*162667}{19.737*2*6}=123102.93N$$

1.3. Center of gravity calculation

During perform volume-mass layout, calculations center of gravity are performed, finding such a position of the center of mass (CM) of the aircraft relative to the geometric mean wing chord (MAC), at which:

- in the case of the variation with an extremaly rear location of the CM the minimal allowable margin of static stability of the aircraft is ensure;
- in the case of the variant with the most forward position of the CM, the conditions of sufficiency of the deviation of the rudder or stabilizer for longitudinal balancing of the aircraft in all flight modes are provided.

The more effective longitudinal control and balancing are evident, the more acceptable the frontal center frequency can be and, consequently, the wider the operating range of center of gravity[5].

During operation, the state of its CM is observed, which changes both as fuel enters flights, and in a variety of loading options and flight masses.

Therefore in diploma it is necessary to calculate ranges of centers of the plane for the most characteristic cases of its operation:

- take-off mass when the chassis is released;
- takeoff weight with the chassis removed;
- landing weight with the chassis released;
- distillation option (without commercial load at maximum fuel) with the chassis removed;
- parking option (without commercial load, fuel, crew) with the chassis released.

1.3.1 Trim-sheet of the equipped wing

When performing a volumetric-mass layout, the calculations of the center of mass are performed, finding such a state of the center of mass (CM) of the aircraft relative to the geometric mean wing chord (MAC), in which: in the case of execution with a very rear distance of the CM, the minimum possible reserve of the static stability of the aircraft is provided; in the case of a variant with a very forward state of the CM, circumstances are provided for the sufficiency of deflection of the rudder or stabilizer for the longitudinal balancing of the aircraft in all flight modes. The more effective the longitudinal control and balancing of the aircraft, besides, the frontal balance can be acceptable and, consequently, the operating range of balances is wider. During the operation of the aircraft, the position of its CM changes both as fuel is produced in flight and as a result of different loading options and flight masses. parking option (without trade load, fuel, crew) with the chassis released. The calculation of the balance of the aircraft is usually an iterative process, which is performed by successively approaching the required result, either by changing the layout, or by regrouping the mass groups, or by applying both options at the same time. The wing found itself producing lift, which had, one might say, the negative by-product of a dive moment tending to force the aircraft into a dive[6]. The plane did not dive, on its observed sharply pronounced small winglet - stabilizer, which dives in this way manifestations, a tendency to decrease, that is, a negative lift force. Such an aerodynamic scheme is presented under the name "normal". The stabilizer lift is found to be negative, it accumulates with increasing gravity, and the wing must have lift, increased gravity. Such an aerodynamic scheme of the aircraft is called a "duck". And in order to prevent the aircraft from diving, the destabilizer must create an upward, that is, positive, lifting force. It adds up to the lift force of the wing, and this sum is equal to the aircraft's gravity.

$$X_w^{/} = \frac{\Sigma m_i^{/} x_i^{/}}{\Sigma m_i^{/}}$$

Table 1.5 - Trim sheet of equipped wing

N	object name	Mass		Coordinate ,X_m	MTM
		units	total mass m(i)		Mass moment
1	wing (structure)	0,10459	17 013,34	3,81	64820,83
2	fuel system	0,0047	764,53	3,81	2912,88
3	airplane control, 30%	0,00129	209,84	5,08	1065,99
4	electrical equipment, 30%	0,00759	1234,64	0,85	1049,45
5	anti-ice system , 70%	0,00896	1457,5	0,85	1238,87
6	hydraulic systems , 70%	0,00875	1423,34	5,93	8440,38
7	power plant	0,1471	23928,31	1,5	35892,47
8	equipped wing without landing gear and fuel	0,28298	46031,5	2,50	115420,87
9	Nose landing gear	0,00679	1104,51	-17	18773,34
10	Main landing gear	0,0385	6262,68	2,74	17159,74
11	fuel	0,15987	26005,57	3,81	99081,23
	Total	0,48814	79404,27	3,15	250435,18

1.3.2 Trim-sheet of the equipped fuselage

The beginning of coordinates is indicated in the projection of the horizontal axis of the forward fuselage. An excerpt of the fuselage structure is presented for the X axis. Table 1.5. demonstrates the available list of aircraft elements which engines are located under the wing.

The CG coordinates are obtained using the following formulas:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}};$$

We constructed the moment equilibrium equation relative to the fuselage nose after determining the C.G. of the fully equipped wing and fuselage:

$$m_f x_f + m_w (x_{MAC} + x_w^{/}) = m_0 (x_{MAC} + C)$$

From here, we calculated the wing MAC leading edge location relative to the fuselage, which yielded the following X_{MAC} value:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w}$$

where m_0 – aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; C – distance from MAC leading edge to the C.G. point, determined by the designer.

C = (0,22...0,25) B_{MAC} –low wing ;

C = (0,25...0,27) B_{MAC} – center wing;

C = (0,23...0,32) B_{MAC} – high wing;

For swept wings; at X = 30°...40° C = (0,28...0,32) B_{MAC}

at X= 45° C = (0,32...0,36) B_{MAC}

The following loads act on the fuselage in the design flight mode: distributed mass forces from the weight of the fuselage structure itself; weight force of units, equipment located in the fuselage; the force of the weight of the crew with service load, passengers with seats and baggage, baggage and cargo compartments, including related baggage and cargo; wing reaction forces on the fuselage applied in the wing attachment points (along the spars); reaction forces of the horizontal and vertical tails on the fuselage (for the corresponding attachment points);

Table 1.6. – Trim sheet of equipped fuselage

N	objects names	Mass		C.G coordinates Xi,	mass moment
		units	total mass		
1	fuselage	0,10135	6444,95	21,80	140532,08
2	horizontal tail	0,01186	754,19	45	33938,51
3	vertical tail	0,01189	1934,11	45	87034,97
4	radar	0,0033	209,85	1	209,85
5	radio equipment	0,0024	152,62	1	152,61
6	instrument panel	0,0057	362,47	2,5	906,17
7	navigation equipment	0,0049	311,59	2	623,19
8	aircraft control system 70%	0,00294	186,95	21,80	4076,6
9	hydro-pneumatic sys 30%	0,00375	238,46	30,52	7279,65
10	electrical equipment 70%	0,01771	1126,19	21,80	24556,71
11	not typical equipment	0,0006	38,15	15	572,31
12	furnishing equipment	0,039	2480,04	13	32240,63
13	Antiiceandaircondit.system	0,0064	406,98	21,80	8874,25
14	seats of pilot	0,00047	29,88	2,5	74,71
15	additional equipment	0,00196	124,95	18	2249,21
16	fuel without payload	0,214235	14801,43	23,19	343321,54
17	cargo, mail	0,28893	18373,34	18	330720,2
18	crew	0,00817	519,53	7,5	3896,53
	TOTAL	0,511335	34594,31	19,59	677938,3
	TOTAL fraction	0,999475			

Table 1.7. – Calculation center of gravity position variants

Name	mass in Kg	coordinate	mass moment
object	m_i	$X_{i,}$, m	Kg.m
equipped wing (without fuel and landing gear)	46031,50	21,27	979444,6
Nose landing gear (extended)	1104,50	3,24	3578,606
main landing gear (extended)	6262,67	20,24	126756,6
fuel/fuel reserve	764,53	7,05	5390
equipped fuselage (without payload)	14801,43	18,58	275010,6
cargo	18374,34	17	312363,9
crew	519,53	7,5	3896,535
nose landing gear (retracted)	479,47	4,077	1954,824
main landing gear (retracted)	1917,90	18,07	34594,59
reserve fuel	2570,98	20	51419,68

Table 1.8. – Airplanes center of gravity position variants

№	Name	Mass, m_i, kg	mass moment m_iX_i	center of mass X_{cm}	center X_C %
1	take off mass (L.G. extended)	63591	1706440,81	26,83	2,43
2	take off mass (L.G. retracted)	63591	1612654,99	25,35	2,02
3	landing weight (LG extended)	89664,99	1752470,49	19,54	0,41
4	ferry version	64514,39	1300291,09	20,15	0,58
5	parking version	68200,12	1384790,37	20,31	0,62

An airplane in flight can be maneuvered by the pilot using the aerodynamic control surfaces; the elevator, rudder, or ailerons. The center of gravity is the average location of the weight of the aircraft. The weight is actually distributed throughout the airplane, and for some problems it is important to know the distribution. But for total aircraft maneuvering, we need to be concerned with only the total weight and the location of the center of gravity.

Conclusion to the project part

When creating an aircraft, it is very important to take into account all the details. The aircraft must meet all operating criteria, as well as effectively perform its functions. Have all the needs and functions of the customer and meet all flight performance characteristics. Therefore, it is important to ensure safe and comfortable transportation of goods[7]. When transporting oversized cargo, it is necessary to take into account the convenience of loading and unloading.

Flight performance parameters must be observed in accordance with the regulations, this is necessary to save money while meeting all safety requirements. When doing my thesis, I compared and took into account the data of the prototype, made calculations of the geometry and centering of the aircraft to obtain the best option. A medium-haul aircraft was developed that is capable of carrying cargo up to 47 tons. Based on the obtained calculations of the geometry of the center of mass, the aircraft turned out to have good take-off and landing characteristics. The fuselage diameter of 5 meters allows to carry cargo of different sizes and dimensions, such as pallets or cargo containers. Wing parameters show not bad strength.

From the calculation of the center of mass, obtains that the wings provide sufficient lift. For the center of gravity of the aircraft, the most forward center of gravity position is the leading edge of the main aerodynamic chord and the most rearward center of gravity position is the leading edge of the main aerodynamic chord. The final center of gravity position for equipped aircraft is the leading edge of the main aerodynamic chord. The flight range is 3000 meters, which ensures a high speed of delivery. As well as saving on fuel, which will reduce the cost of transportation. Since the aircraft is not the largest in its dimensions, this makes it possible to load it faster than large aircraft.

2. SPECAIL PART

In connection with the current situation in Ukraine, at as important for the whole world to think about the future and be ready for anything. It is relevant to convert a cargo aircraft into a flying medical center for transporting patents of varying degrees of injury.

The danger of war around the world significantly endangers all countries, as well as aviation as a whole. Because of this, at as important to use every opportunity to protect yourself and the lives of people in general.

Human life as the most important and valuable resource. Many people do not receive the necessary medical care due to one reason or another. One of the important ones as the transportation of a patent in serious condition to a competent clinic. Since sometimes this requires traveling thousands of kilometers for ground transportation, at sounds long and not safe, unlike an airplane with a medical unit. At can contain various equipment and the necessary number of doctors to maintain the necessary care for a patent (or a wounded solder). The medical version of this aircraft will allow you to quickly and efficiently transport the seriously wounded, as well as seriously ill patients at a distance of up to 3 thousand meters, which in turn will provide a higher level of medical care. This aircraft will be equipped with medical containers that are suitable for any degree of injury or illness of the patient. Dimensions and equipment will make it easy to fix any problem in the container itself. The type of installation and fastening does not change from the usual one, which makes it possible not to change the geometry of the aircraft.

Based on the above data, we can conclude that such improvements are an urgent task.

2.1. An overview of Medical Evacuation aircraft

Typically, when a patent needs to be transferred to another location for medical reasons, there are two different methods of transportation available. The first is ground ambulance transportation, which often involves an ambulance or other vehicle driving the patent to their destination. While this method is usually preferred in certain situations, it can sometimes take hours before the patent arrives at their destination and receives the urgent care he or she needs.

Medevac flights are faster, more reliable, and overall more efficient, especially on larger distances. This can be crucial in certain cases, as fast transportation can be the difference between life and death.

Also, when an accident occurs in a very remote location, like in the mountains, land transport is simply not an option, and only a medevac flight can bring the necessary medical attention to the patent in time. In the case of a ski accident high up in the mountains, the only way to get the patent out would be helicopter. [9]

However, medical evacuation flights can also be used for less urgent situations, such as an elderly person who requires critical medical treatment that is only available in another city or country.

Figure2.1. – example of medical evacuation aircraft

The cost of a medevac flight can vary, depending on several different factors. For instance, larger aircraft are more expensive to operate than smaller ones, and the cost of running a medevac flight also goes up depending on the distance being traveling

Some other factors that may determine the cost of a medevac flight:

- Any additional ground ambulance transport needed;
- The number of patents that need to be transported, and people accompanying them;
- Departure and destination locations;
- The type of airplane
- The number of medical staff required on board;
- Possible airport landing fees and taxes.

A fixed-wing medevac flight usually takes more time to plan and coordinate, as these are often international flights or to/from a larger airport.

However, even these flights can usually be in the air within 30 minutes when they are organized in a true, time-sensitive emergency. In most locations round the world, there are specialized air ambulances with medical crews standing by 24/7 to respond to emergency calls as quickly as possible.

2.2. Medical module equipment

Of greatest importance is the use of medical equipment in the modules. Use of equipment to detect cases of disease, to assess the needs of the patent. As a result, it is important to know what types of medical equipment are reduced, the various functions of each person and all of them work, have the ability to call for help to the patent and treat him accordingly. There are a few types of necessary equipment:

- Durable medical equipment it is a type of medical equipment that is designed to last and provide safe and comfortable patent support.
- Diagnostic medical equipment or supplies that are used to diagnose, test, or determine a patients condition. Without diagnostic equipment, healthcare professionals would not be able to correctly diagnose a patient and provide proper treatment.
- Electronic medical equipment is designed to monitor and record bodily functions such as heartbeat and brain waves.

- Surgical medical equipment. The success of the operation depends on the accuracy of the surgical equipment and instruments. There are many different types of equipment used in surgery, each with a different purpose.
- Life support equipment performing, in one episode, a function that ensures the life of the patient or bringing him to consciousness, the violation of which can be of significant serious significant to the patient or life to death

Figure 2.2. – Example of equipment

Companies are increasingly introducing their own air ambulance conversion kits, which allow operators to convert cargo planes to transport patents. Designed for both civilian and government applications, the medical evacuation solution will be installed exclusively by the organization Over the past few months, many operators have transitioned from transporting cargo aboard their aircraft to transporting vital medical supplies and personal protective equipment. Now the aviation industry is picking up again with air ambulance configurations for aircraft.

2.3. Conversion of aircraft

Medical aviation for selected industries is becoming much more popular over time than before, as it guarantees the speed of transportation of patents or the wounded

Cargo aircraft transport 47% of all cargo in the world. However, when it is necessary to raise the level of medical care, cargo and passenger aircraft are converted into medivac. If you look at its original version, then this is a cargo aircraft capable of accommodating a large number of containers and pellets with cargo inside. Such in aircraft already has the potently to be re-equipped of necessary.

Due to the fact that the conversion of the aircraft does not involve a redesign of the main structure of the aircraft, this can bring some difficulties. Unlike aircraft specially prepared for this.

Therefore, it is possible to narrow down the range of tasks that a given aircraft can perform and determine what changes are needed to achieve medical goals. However, the ease of installation of containerized medical modules is a plus, since all attachments and loading mechanisms remnant the same. The main modifications that need to be made when converting in aircraft will be listed below. Often, in order to convert a cargo aircraft into a medical aircraft, it is first necessary to determine whether these will be medical containers or not. If the goal is to turn the cargo compartment into a medical one, you need to change the floor covering for convenient movement, make fasteners for all the necessary equipment, arrange lying places for patients. Since a cargo plane was developed, the installation of modular medical containers that I described will be optimal.

2.4. Medical module installation

The dimensions of the container are determined in accordance with the dimensions of the cargo compartment and medical units, which can be miniaturized to reduce their dimensions, as well as depending on the number of people, medical personnel and patents. [10]

Figure 2.3. – Installation of medical module

Medical modules dimensions should combine such features as compactness, proper location inside the module itself and ease of use. In my work, I used modules from components for automotive industry, etc.). But there are not enough cargo planes.

Aeromedical Bio-Containment Evacuation Systems (ABES), this will be a good choice for many aircraft, as they have all these qualities.

Maximum elasticity

- May vary depending on the number of patients
- Can be modified for the acuity of the patients, including safe infectious disease transport;
- Medical equipment can be wall-mounted or litter based;
- Full, independent environmental system for temperature and humidity control; Maximum air exchanges per hour;
- Vibration and noise dampening interior;
- Enhanced lighting;
- Ability to perform resuscitative and major trauma procedures;
- Separation of the medical crew from the aircrew;
- Easy decontamination processes;

- Locks into the Cargo Handling System (CHS);
- Self-enclosed modular unit controlled environment;
- Acoustically treated

The dimensions are height 1.9 meters, width 2.1 meters, length 7.5 meters. Based on these figures, I can calculate the number of containers to fit and change the center of gravity. According to size of my aircraft, I can understand that 4 such modules will fit in the cargo hold.

2.5. Calculation of center of gravity

The origin of the coordinates is packed in the horizontal axis projection of the fuselage's snout.

The CG coordinates are obtained using the following formulas:

$$X_f = \frac{\Sigma m_i^/ X_i^/}{\Sigma m_i^/};$$

Table 2.1. – Center of gravity calculation with equipped medical modules

N	objects names	Mass		C.G coordinates Xi, m	
		units	total mass		mass moment
1	fuselage	0,10135	6444,94	21,8	140532,08
2	horizontal tail	0,01186	754,18	45	33938,51
3	vertical tail	0,01189	1934,11	45	87034,97
4	radar	0,0033	209,85	1	209,85
5	radio equipment	0,0024	152,61	1	152,61
6	instrument panel	0,0057	362,46	2,5	906,17
7	aero navigation equipment	0,0049	311,59	2	623,19
10	aircraft control system 70%	0,00294	186,95	21,8	4076,6

11	hydro-pneumatic sys 30%	0,00375	238,46	30,52	7279,65
12	electrical equipment 70%	0,01771	1126,19	21,8	24556,71
13	not typical equipment	0,0006	38,15	15	572,31
14	furnishing and thermal equipment	0,039	2480,04	13	32240,63
15	anti ice and air-conditioning system	0,0064	406,98	21,8	8874,25
16	seats of pilot	0,00047	29,88	2,5	74,71
17	additional equipment	0,001965	124,95	18	2249,21
18	equipped fuel without payload	0,214235	14801,43	23,19	343321,54
19	medical module №1	-	2600	7,25	18850
20	medical module №2	-	2600	14,75	38350
21	medical module №3	-	2600	22,25	57850
22	medical module №4	-	2600	29,75	77350
23	crew	0,00817	519,53	7,5	3896,53
	TOTAL	0,23	26591,08	20,29	539543,36
	TOTAL friction	0,71			

Conclusion for special part

As we can see from the calculation of the center of gravity, modifying the cargo compartment into medical modules changes many parameters:

Firstly, the center of gravity of the entire aircraft slightly deviates by 0.7 meters, which does not play a cardinal role;

Secondly, the total moment of mass has become slightly less compared to the cargo inside, due to the weight of containers with equipment;

Thirdly, the total weight of the aircraft has become lower, which makes the use of the aircraft cheaper and more profitable.;

At the present time, it is very important to use all opportunities to improve the quality of life. Aviation has already taken a huge step forward, which makes its use a necessity.

Based on the results obtained, it can be concluded that such a modification fully meets all the requirements, since the center of gravity of the aircraft changes within acceptable limits. The installation of 4 modules corresponds to the geometry and will not affect the characteristics of the aircraft. This will allow the aircraft to be used for the necessary purposes.

GENERAL CONCLUSION

Based on the work done, it can be concluded that aviation today is a difficult process, but a very important thing these days. Using cargo planes, you can significantly speed up the process of transportation around the world. As an example, let's take the plane that was calculated above. This is a cargo medium-haul cargo aircraft with a maximum load of up to 47 tons. It is capable of transporting goods over a distance of up to 3,000 meters with good speed. The compact design of the aircraft will allow you to load it quickly and conveniently. Just as important is the versatility of the aircraft. An equally urgent issue is the conversion of the aircraft for different needs.

Conversion is already used all over the world, for example, when passenger flights stop, it is possible to convert an aircraft into a cargo one. Due to the situation all over the world, and especially in Ukraine, there is a drop in the level of demand for passenger aviation, however, as in all wars, the number of wounded is only getting larger. Providing assistance is often a difficult task due to insufficient qualifications, in which case medical aircraft will be relevant. My plane is designed in such a way that by installing medical modules, the plane turns into a medical one. Such modules do not require additional manipulations with the structure, since they are attached in the same way as ordinary containers. Based on the above, we can conclude that such actions will only have a positive effect.

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Appendix A

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                    П Р О Е К Т
            С А М О Л Е Т А   С   Т В Д
           НАУ, кафедра   К Л А
 ПРОЕКТ    дипломный              Расчет выполнен    23.09.2021
 Исполнитель Степаненко Валерий     Руководитель

        ИСХОДНЫЕ ДАННЫЕ И ВЫБРАННЫЕ ПАРАМЕТРЫ
Количество пассажиров                                      0.
Количество членов экипажа                                  3.
Количество бортпроводников или сопровождающих              2.
Масса снаряжения и служебного груза                     1369.78 кг.
Масса коммерческой нагрузки                            47000.00 кг.

Крейсерская скорость полета                              750. км/ч
Число "М" полета при крейсерской скорости                  0.6843
Расчетная высота начала реализации полетов с крейсерской
экономической скоростью                                    9.000 км
Дальность полета с максимальной коммерческой нагрузкой  3000. км.
Длина летной полосы аэродрома базирования                  1.90 км.

Количество двигателей                                      4.
Оценка по статистике энерговооруженности в квт/кг          0.3000
Степень повышения давления                                28.00
Относительная масса топлива по статистике                  0.2800

Удлинение крыла                                            8.70
Сужение крыла                                              2.90
Средняя относительная толщина крыла                        0.116
Стреловидность крыла по 0.25 хорд                         16.0  град.
Степень механизированности крыла                           0.970
Относительная площадь прикорневых наплывов                 0.000
Профиль крыла - Лапминизированный скоростной
Шайбы УИТКОМБА - установлены
Спойлеры - установлены

Диаметр фюзеляжа                                           4.90 м.
Удлинение фюзеляжа                                         8.90
Стреловидность горизонтального оперения                   20.0 град.
Стреловидность вертикального оперения                     30.0  град.


                 Р Е З У Л Ь Т А Т Ы   Р А С Ч Е Т А
                 НАУ,     КАФЕДРА   "К Л А"
 Значение  оптимального  коэффициента  под'емной силы в расчетной точке
 крейсерского режима полета     Су        0.41168

 Значение коэффициента          Сх.инд.   0.00926

     ОПРЕДЕЛЕНИЕ КОЭФФИЦИЕНТА  Dм = Мкрит - Мкрейс

 Число Маха крейсерское              Мкрейс  0.68426
 Число Маха волнового кризиса        Мкрит   0.73312
 Вычисленное значение                Dm      0.04887

   Значения удельных нагрузок на крыло в кПА(по полной площади):
             при взлете                        4.528
             в середине крейсерского участка     4.169
             в начале крейсерского участка       4.379
```

Значение коэффициента сопротивления фюзеляжа и гондол 0.00849
Значение коэфф. профиль. сопротивления крыла и оперения 0.00928
Значение коэффициента сопротивления самолета:
в начале крейсерского режима 0.02894
в середине крейсерского режима 0.02848

Среднее значение Су при условном полете по потолкам 0.41168
Среднее крейсерское качество самолета 14.45568

Значение коэффициента Су.пос. 1.757
Значение коэффициента (при скорости сваливания) Су.пос.макс. 2.635
Значение коэффициента (при скорости сваливания) Су.взл.макс. 2.195
Значение коэффициента Су.отр. 1.581
Энерговооруженность в начале крейсерского режима 0.155
Стартовая энерговооруженн. по условиям крейс. режима No.кр. 0.255
Стартовая энерговоруж. по условиям безопасного взлета No.взл. 0.177

Расчетная энерговоруженность самолета No 0.260

Отношение Dn = No.кр / No.взл Dn 1.444

УДЕЛЬНЫЕ РАСХОДЫ ТОПЛИВА (в кг/кВт*ч):
взлетный 0.1767
крейсерский (характеристика двигателя) 0.1435
средний крейсерский при заданной дальности полета 0.1446

ОТНОСИТЕЛЬНЫЕ МАССЫ ТОПЛИВА:
аэронавигационный запас 0.02587
расходуемая масса топлива 0.13400

ЗНАЧЕНИЯ ОТНОСИТЕЛЬНЫХ МАСС:

крыла	0.10459
горизонтального оперения	0.01186
вертикального оперения	0.01189
шасси	0.04525
силовой установки	0.15180
фюзеляжа	0.10135
оборудования и управления	0.11547
дополнительного оснащения	0.00061
служебной нагрузки	0.00842
топлива при Lрасч.	0.15987
коммерческой нагрузки	0.28893

Взлетная масса самолета "M.o" = 162667. кГ.
Потребная взлетная мощность двигателя 10588.4 kВт

Относительная масса высотного оборудования и
противообледенительной системы самолета 0.0128
Относительная масса пассажирского оборудования
(или оборудования кабин грузового самолета) 0.0002
Относительная масса декоративной обшивки и ТЗИ 0.0048
Относительная масса бытового (или грузового) оборудования 0.0390
Относительная масса управления 0.0042
Относительная масса гидросистем 0.0125

Относительная масса электрооборудования	0.0253
Относительная масса локационного оборудования	0.0033
Относительная масса навигационного оборудования	0.0049
Относительная масса радиосвязного оборудования	0.0024
Относительная масса приборного оборудования	0.0057
Относительная масса топливной системы (входит в массу "СУ")	0.0047
Дополнительное оснащение:	
Относительная масса контейнерного оборудования	0.0000
Относительная масса нетипичного оборудования	0.0006

[встроенные системы диагностики и контроля параметров, дополнительное оснащение салонов и пр.]

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ

Скорость отрыва самолета	241.94 км/ч
Ускорение при разбеге	3.34 м/с*с
Длина разбега самолета	674. м.
Дистанция набора безопасной высоты	472. м.
Взлетная дистанция	1146. м.

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ ПРОДОЛЖЕННОГО ВЗЛЕТА

Скорость принятия решения	217.74 км/ч
Среднее ускорение при продолженном взлете на мокрой ВПП	1.75 м/с*с
Длина разбега при продолженном взлете на мокрой ВПП	791.09 м.
Взлетная дистанция продолженного взлета	1263.34 м.
Потребная длина летной полосы по условиям прерванного взлета	1302.24 м.

ХАРАКТЕРИСТИКИ ПОСАДОЧНОЙ ДИСТАНЦИИ

Максимальная посадочная масса самолета	148050.	кг.
Время снижения с высоты эшелона до высоты полета по кругу	19.4	мин.
Дистанция снижения	40.51	км.
Скорость захода на посадку	237.07	км/ч.
Средняя вертикальная скорость снижения	1.93	м/с
Дистанция воздушного участка	522.	м.
Посадочная скорость	221.77	км/ч.
Длина пробега	621.	м.
Посадочная дистанция	1143.	м.
Потребная длина летной полосы (ВПП + КПБ) для основного аэродрома	1909.	м.
Потребная длина летной полосы для запасного аэродрома	1623.	м.

ПОКАЗАТЕЛИ ЭФФЕКТИВНОСТИ САМОЛЕТА

Отношение массы снаряженного самолета к массе коммерческой нагрузки	1.9057
Масса пустого снаряженного с-та приход. на 1 пассажира	0.00 кг/пас.
Относительная производительность по полной нагрузке	336.60 км/ч
Производительность с-та при макс. коммерч. нагрузке	32790.7 т*км/ч
Средний часовой расход топлива	5069.226 кг/ч
Средний километровый расход топлива	7.27 кг/км
Средний расход топлива на тоннокилометр	154.593 г/(т*км)
Средний расход топлива на пассажирокилометр	0.0000 г/(пас.*км)
Ориентировочная оценка приведен. затрат на тоннокилометр	0.3242 $/(т*км)

REQUEST FOR CALCULATION WORK

Aircraft Prototypes: B777

Student: Valeriy Stepanenko **Supervisor:**

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	0
Flight Crew Number	3
Flight Attendant or Load Master Number	2
Mass of Operational Items	1369.78kg
Payload Mass	47000kg
Cruising Speed	750 km/h
Cruising Mach Number	0.6843
Design Altitude	9 km
Flight Range with Maximum Payload	3000 km
Runway Length for the Base Aerodrome	1.9 km
Engine Number	4
Thrust-to-weight Ratio in N/kg	0.3000
Pressure Ratio	28
Accepted Bypass Ratio	5.00
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.2800
Aspect Ratio	8.70
Taper Ratio	2.90
Mean Thickness Ratio	0.116
Wing Sweepback at Quarter of Chord	16°
High-lift Device Coefficient	0.970
Relative Area of Wing Extensions	0.000
Wing Airfoil Type	laminar high speed type
Winglets	yes
Spoilers	yes
Fuselage Diameter	4.90m
Fineness Ratio of the fuselage	8.90
Horizontal Tail Sweep Angle	20°
Vertical Tail Sweep Angle	30°

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point Cy=0.41168

Induce Drag Coefficient Cx = 0.00926

ESTIMATION OF THE COEFFICIENT $D_m = M_{critical} - M_{cruise}$

cc

Wave Drag Mach Number 0.73312

Calculated Parameter D_m 0.04887

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	4.528
At Middle of Cruising Flight	4.169
At the Beginning of Cruising Flight	4.379

Drag Coefficient of the Fuselage and Nacelles	0.00849
Drag Coefficient of the Wing and Tail Unit	0.00928

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.02894
At Middle of Cruising Flight	0.02848

Mean Lift Coefficient for the Ceiling Flight	0.41168
Mean Lift-to-drag Ratio	14.45568

Landing Lift Coefficient	1.757
Landing Lift Coefficient (at Stall Speed)	2.635
Takeoff Lift Coefficient (at Stall Speed)	2.195
Lift-off Lift Coefficient	1.581
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.155
Start Thrust-to-weight Ratio for Cruising Flight	0.255
Start Thrust-to-weight Ratio for Safe Takeoff	0.177

Design Thrust-to-weight Ratio Ro	0.260

Ratio $D_r = R_{cruise} / R_{takeoff}$ Dr	1.444

SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):

Takeoff	0.1767
Cruising Flight	0.1435
Mean cruising for Given Range	0.1446

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.02587
Block Fuel	0.13400

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.10459
Horizontal Tail	0.01186
Vertical Tail	0.01189
Landing Gear	0.04525
Power Plant	0.15180
Fuselage	0.10135
Equipment and Flight Control	0.11547
Additional Equipment	0.00061
Operational Items	0.00842
Fuel	0.15987
Payload	0.28893

Airplane Takeoff Weight	M =162667kg
Takeoff Thrust Required of the Engine	10588.4kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0128
Passenger Equipment Weight Fraction	0.0002

(or Cargo Cabin Equipment)

Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0048
Furnishing Equipment Weight Fraction	0.0390
Flight Control Weight Fraction	0.0042
Hydraulic System Weight Fraction	0.0125
Electrical Equipment Weight Fraction	0.0253
Radar Weight Fraction	0.0033
Navigation Equipment Weight Fraction	0.0049
Radio Communication Equipment Weight Fraction	0.0024
Instrument Equipment Weight Fraction	0.0057
Fuel System Weight Fraction	0.0047

Additional Equipment:

Equipment for Container Loading	0.0000
No typical Equipment Weight Fraction	0.0006

(Build-in Test Equipment for Fault Diagnosis,
Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	241.94 km/h
Acceleration during Takeoff Run	3.34 m/s^2
Airplane Takeoff Run Distance	674m
Airborne Takeoff Distance	472m
Takeoff Distance	1146m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	217.74 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	1.75m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	791.09m
Continued Takeoff Distance	1263.34m
Runway Length Required for Rejected Takeoff	1302.24m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	148050kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	19.4min
Descent Distance	40.51km
Approach Speed	237.07km
Mean Vertical Speed	1.93m/s
Airborne Landing Distance	522m
Landing Speed	221.77km/h
Landing run distance	621m
Landing Distance	1143m
Runway Length Required for Regular Aerodrome	1909m
Runway Length Required for Alternate Aerodrome	1623m

AIRCRAFT PERFORMANCE

The ratio of the curb weight of the aircraft to payload weight 1.9057

The mass of the empty curb with-that parish. per 1 passenger 0.00 kg/pas.
Relative performance at full load 336.60 km / h
Productivity with - that at max. commercial load 32790.7 t*km/h
Average hourly fuel consumption 5069.226 kg/h
Average kilometer fuel consumption 7.27 kg/km
Average fuel consumption per ton-kilometer 154.593 g/(t*km)
Average fuel consumption per passenger kilometer 0.0000 g/(pas.*km)
An indicative estimate is given. cost per ton-kilometer 0.3242 $/(t*km)