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

ДОПУСТИТИ ДО ЗАХИСТУ
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«___» ____________ 2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Конвертація середньомагістрального пасажирського літака у медичний»

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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 medical"

Fulfilled by:	____________	**Maksym KOSTYANETSKIY**
Supervisor: **PhD, associate professor**	____________	**Vadim ZAKIEV**
Standards inspector: **PhD, associate professor**	____________	**Volodymyr KRASNOPOLSKIY**

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, проф.
________ Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

КОСТЯНЕЦЬКОГО МАКСИМА ОЛЕКСІЙОВИЧА

1. Тема роботи: «Конвертація середньомагістрального пасажирського літака у медичний», затверджена наказом ректора від 15 травня 2024 року № 794/ст.

2. Термін виконання роботи: з 20 травня 2024 р. по 16 червня 2024 р.

3. Вихідні дані до роботи: маса комерційного навантаження 132000 кг, дальність польоту з максимальним комерційним навантаженням 5500 км, крейсерська швидкість польоту 850 км/год, висота польоту 10 км.

4. Зміст: вступ, основна частина: аналіз дослідних зразків і короткий опис конструкції літака, вибір вихідних даних, розрахунок геометрії крила і компонування літака, конструкція шасі, вибір двигуна, розрахунок центру ваги, спеціальна частина: переробка пасажирської кабіни літака в медичну.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (А1×1), компонувальне креслення пасажирської кабіни фюзеляжу (А1×1), компонувальне креслення медичної кабіни фюзеляжу (А1×1), модель SolidWorks та розрахунок на міцність Ansys.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик	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	Озайомлення з літературою і необхідними нормами стосовно конвертації пасажирського літака	28.05.2024 – 29.05.2024	
6	Обробка даних. Інтергування необхідного медичного обладання.	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 ____________ Максим КОСТЯНЕЦЬКИЙ

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

Maksym KOSTYANETSKIY

1. Topic:"Passenger medium range airplane conversion to medical", approved by the Rector's order № 794/ст from 15th May 2024.
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: payload 132000 kg, flight range with maximum capacity 5500 km, cruise speed 850 km/h, flight altitude 10 km.
4. Content: 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 passenger cabin into medical.
5. The list of mandatory graphic (illustrative) material: general view of the aircraft (A1×1), layout drawing of passenger cabin (A1×1), layout drawing of medical cabin (A1×1), SolidWorks model and Ansys strength calculation.

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight characteristics of prototype aircraft.	20.05.2024 – 21.05.2024	
2	Selection and calculation of parameters of the projected aircraft.	22.05.2024 – 23.05.2024	
3	Performing the layout of the aircraft and calculating its alignment.	24.05.2024 – 25.05.2024	
4	Development of drawings for the main part of the thesis.	26.05.2024 – 27.05.2024	
5	Familiarization with the literature and necessary standards for converting a passenger aircraft	28.05.2024 – 29.05.2024	
6	Data processing. Integration of necessary medical equipment.	30.05.2024 – 31.05.2024	
7	Design of the explanatory note and graphic part of the work.	01.06.2024 – 02.06.2024	
8	Submit your work for plagiarism testing.	03.06.2024 – 06.06.2024	
9	Preliminary defense of the qualification work.	07.06.2024	
10	Correction of comments. Preparation of accompanying documents and presentation of the report.	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: ____________ Vadim ZAKIEV

Student: ____________ Maksym KOSTYANETSKIY

РЕФЕРАТ

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

64 с., 12 рис., 9 табл., 10 джерел

Ця кваліфікаційна робота зосереджена на розробці середньомагістрального медичного літака, який відповідає міжнародним стандартам льотної придатності, безпеки, економічності та надійності. Модифікація медичної кабіни та інтеграція інших необхідних компонентів.

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

Практичне значення результатів кваліфікаційної роботи полягає у створенні попереднього дизайну медичної кабіни, та полегшенню роботи персоналу.

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

Дипломна робота, аванпроєкт літака, компонування, медична евакуація, розрахунок на міцність, кріплення.

ABSTRACT

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

64 pages, 12 figures, 9 tables, 10 references

This qualification work focuses on the development medium-haul passenger aircraft design that meets international standards of airworthiness, safety, economy and reliability. The modification of the medical cabin and the integration of other necessary components.

The research used methods of analytical calculation, computer-aided design using CAD/CAM/CAE systems, equipment integration and strength calculation.

The practical significance of the results of the qualification work is to create a preliminary design of the medical cabin, facilitate 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.

Bachelor thesis, aircraft advance project, layout, alignment, medevac, strength calculation, fittings.

Format	#	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 24 11K 00 00 00 67 TW	Task for work	1	
	2	NAU 24 11K 00 00 00 67	Mid-range medical aircraft	2	
A1		Sheet 1	General view	1	
A1		Sheet 2	Fuselage layout	1	
A4	3	NAU 24 11K 00 00 00 67 EN	Mid-range medical aircraft	65	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 24 11K 00 00 00 67	Design of medevac plane	1	

	Sh.	# doc.	Sign	Date	NAU 24 11K 00 00 00 67 EN		
Done by		Kostyanetskiy M.O.			Passenger cabin to medical evacuation conversion	list	sheet / sheets
Supervisor		Zakiev V.I.				Q	9 / 64
						404 ASF 134	
St.control.		Krasnopolskyi V.S.					
Head of dep.		Yutskevych S.S.					

CONTENT

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Sh.	№ doc.	Sign	Date
Done by	Stovbun P.V.		
Supervisor	Krasnopolskyi V.S.		
St.control.	Krasnopolskyi V.S.		
Head of dep.	Ignatovich S.R.		

Content

list	sheet	sheets
Q	10	63

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INTRODUCTION

The requirement of the aircraft in aviation today is changing, and there is a need to develop aircraft that can adapt to the ever changing needs of the commercial travel and disaster reliefs. This thesis aims at effectively addressing this challenge through a process of conducting a preliminary design of a medium haul aircraft based on the models used in the current market like the Boeing 757, Airbus A321 and Tupolev Tu-204. This work aims to design aircraft that can easily carrying passengers and transporting medical patients, meeting the versatile needs of the client in various situations.

This project includes documentation of the airplane specifications, the arrangement of the passenger compartment, and medevac modification. The first stage will therefore entail a very thorough assessment of the said prototypes with a view of ascertaining their greatest strengths, possible weaknesses and opportunities for enhancement. Thus, using the experience of these well-proven aircraft as a starting point, our goal is to take the best of it for the new design, and also to avoid the shortcomings of the initial concept.

The medevac conversion does not pose any complicated engineering issues on its own. Another challenge is the integration of different sorts of medical equipment to create life support systems, monitoring equipment, and other essential equipment to support critical care. Moreover, the position of the various facilities has to be convenient for the employees in the medical field and safe for the patients when moving around.

1. PRELIMINARY DESIGN OF MID RANGE AIRCRAFT

1.1. Analysis of prototypes and short description of designed aircraft

Let's analyze why the selected aircraft became the prototype for our advance project. The Boeing 757 and Airbus A321, narrow-body twin-engine airliners, have long been leaders in the short- and medium-haul transportation market. Despite the fact that their purpose is the same, they have excellent performance characteristics in different operational needs.

The Boeing 757, known for its impressive flight range of up to 4,100 nautical miles, can comfortably fly transcontinental and even some intercontinental routes. Its spacious cabin can accommodate up to 289 passengers in one class, making it a favorite for airlines with high route density. The powerful Rolls-Royce RB211 or Pratt & Whitney PW2000 engines installed on the 757 provide exceptional takeoff performance, which is an advantage for airports with shorter runways. The cruising speed of the aircraft is Mach 0.80, which provides a relatively short travel time, which further increases its attractiveness for both airlines and passengers.

On the other hand, the Airbus A321 with a range of up to 3,700 nautical miles (4,000 in the A321LR variant) is well suited for most medium-haul routes too. Despite its slightly smaller capacity than the 757 and accommodating up to 244 passengers, it remains a popular choice due to its fuel efficiency and lower operating costs, thanks to CFM International CFM56 or Pratt & Whitney PW1000G engines. Although its cruising speed of Mach 0.78 is slightly lower than that of the 757, the difference is negligible for most medium-haul flights.

The Boeing 757 and Airbus A321 have unique advantages. The strengths of the Boeing 757 are its range and capacity, which makes it ideal for long-haul or high-density passenger routes. Conversely, the A321's fuel efficiency and lower operating costs make it a more economical choice That is why two aircraft models were taken as a prototype for my advance project, combining their best characteristics [1, 2, 3].

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Done by		Kostyanetskiy M.O.		
Checked by		Zakiev V.I.		
St.control.		Krasnopolskyi V.S.		
Head of dep.		Yutskevych S.S.		

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Analytical Part

list	sheet	sheets
Q	13	63

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Table 1.1

Performances of prototypes

Parameter	B757 200	A 321	Tu-204-100	Designed aircraft
Max. payload, kg	30700	25000	21000	26000
Crew, number of pilots	6/2	3/2	5/2	5/2
Passengers	220	230	210	238
Wing loading, kg/m^2	625.64	727.12	607.18	6.163
Flight range with max. payload, km	5435	4150	4600	5500
Cruise speed, km/h	850	833	850	850
Cruise altitudes, km	12.500	12.100	12.000	10000
Thrust/weight ratio, N/kg	0.3365	0.329	0.289	3.1
Approach speed, km/h	253	248	259	268
Landing speed, km/h	268	268	296	231
Take-off speed, km/h	268	268	296	282
Take-off run distance, m	2360	2210	2400	1330
Landing run distance, m	1550	1577	2100	252.26
Take-off distance, m	2800	2400	2652	1908
Landing distance, m	1700	1243	1636	1376
Maximum take-off mass, kg	99800	93500	107.5	132368
Landing mass, kg	88600	73400	88000	86041
Empty weight kg	58967	48000	57000	65000
Wing span, m	30	34.5	35	44.7
Sweepback angle at ¼ chord, °	25	28	25.02	36
Wing aspect ratio	7.22	9.37	9.2	7.89
Wing taper ratio	0.285.	0.283	0.340	4.11
Fuselage length, m	47.32	44.51	46.2	53.5
Fuselage diameter, m	3.76	3.95	3.8	3.95
Fuselage fineness ratio	12.58	11.27	12.16	11.26
Passenger cabin width, m	3.54	3.70	3.57	3.78
Cabin height, m	2.34	2.24	2.26	2.12
Aisle width, m	0.51	0.53	0.52	0.46
Horizontal tail span, m	14.35	13.4	14.35	14.35
Horizontal tail sweepback angle, °	29	33	30	29
Horizontal tail taper ratio	0.330	0.303	0.228	0.4
Vertical tail height, m	7.16	6.26	9.069	7.16
Vertical tail sweepback angle, °	39	34	35	38
Vertical tail aspect ratio	1.56	1.82	1.73	1.94
Vertical tail taper ratio	0.350	0.340	0.340	3.69

1.2. Brief description of the aircraft

1.2.1. Wing

One of the most distinctive features of the prototype's wing is its moderately swept configuration. This design choice is ordinary decision, which aimed at optimizing the aircraft's performance for its intended mission profile. The sweep angle strikes a balance between minimizing drag at high speeds, which is most suitable for efficient long-haul operations, and maintaining good low-speed handling characteristics, which are essential for safe takeoffs and landings.

The swept wing design also contributes to the prototype's impressive lateral stability. By increasing the effective dihedral, or upward angle of the wings, the swept configuration provides a natural stabilizing effect that helps to keep the aircraft level during flight. This inherent stability translates to a smoother and more comfortable ride for passengers, especially during turbulence or crosswinds.

In addition to its aerodynamic benefits, the wing incorporates several advanced features to further enhance its performance. Double-slotted flaps, which are large hinged sections on the trailing edge of the wing, can be extended to significantly increase lift and drag during takeoff and landing. This allows the prototype to operate from shorter runways and achieve steeper approach angles, increasing its versatility and operational flexibility.

Leading-edge slats, located on the front edge of the wing, are another critical component of the wing's design. These slats automatically deploy at high angles of attack, such as during takeoff and landing, to smooth out the airflow over the wing and delay the onset of stall. This provides the pilot with increased control and maneuverability at low speeds, enhancing safety during critical phases of flight.

The wing's internal structure is equally impressive. It is constructed from lightweight yet durable materials, such as aluminum alloys and composites, to minimize weight while maintaining structural integrity. The wing also incorporates an efficient fuel transfer system, which helps to optimize the aircraft's weight distribution and fuel consumption throughout the flight.

1.2.2. Fuselage

The fuselage of the prototype, a twin-engine, narrow-body jet, is a testament to modern aerospace engineering, designed to maximize efficiency, safety, and passenger comfort. Its semi-monocoque construction, a hallmark of modern aircraft design, combines a lightweight aluminum alloy skin with internal structural elements to create a robust yet lightweight airframe. This design not only reduces the overall weight of the aircraft, leading to improved fuel efficiency, but also provides exceptional strength and rigidity, ensuring the safety of passengers and crew in all flight conditions.

The fuselage is meticulously sculpted to minimize aerodynamic drag, a critical factor in achieving optimal fuel efficiency and range. Its sleek, streamlined profile, with carefully contoured curves and smooth transitions, allows the aircraft to slip through the air with minimal resistance. This not only reduces fuel consumption but also contributes to a quieter and more comfortable cabin environment. The fuselage also incorporates advanced materials, such as carbon fiber composites, in certain areas to further reduce weight and enhance structural integrity.

Internally, the fuselage is designed to maximize passenger comfort. The seats are ergonomically designed with adjustable headrests and lumbar support to provide optimal support and comfort during long flights, while the large windows, measuring approximately 10 x 15 inches, offer panoramic views of the surrounding landscape. The cabin is also equipped with advanced lighting and climate control systems to create a pleasant and relaxing atmosphere for passengers.

The fuselage also incorporates numerous safety features, such as reinforced structural members in critical areas, multiple emergency exits strategically located throughout the cabin, and advanced fire suppression systems utilizing halon or other

fire extinguishing agents. These measures are designed to protect passengers and crew in the unlikely event of an emergency, ensuring the highest level of safety throughout the flight.

Thus, in the fuselage of the prototype, priority is given to efficiency, safety and comfort, which ultimately contributes to a good flight

1.2.3. Tail unit

The tail unit of the prototype, a conventional T-tail configuration, is designed to provide stability and control during flight. It consists of a horizontal stabilizer with elevators and a vertical stabilizer with a rudder.

The horizontal stabilizer, a fixed wing-like structure mounted on the rear fuselage, generates a downward force that helps to maintain the aircraft's pitch stability. The elevators, hinged surfaces attached to the trailing edge of the stabilizer, control the aircraft's pitch attitude by deflecting upwards or downwards to increase or decrease lift on the tail.

The vertical stabilizer, a tall fin-like structure also mounted on the rear fuselage, provides directional stability by resisting yawing motion. The rudder, a hinged surface attached to the trailing edge of the stabilizer, controls the aircraft's yaw attitude by deflecting left or right to generate a side force.

Both the horizontal and vertical stabilizers are constructed from lightweight yet durable materials, such as aluminum alloys and composites, to minimize weight while maintaining structural integrity. The control surfaces (elevators and rudder) are actuated by hydraulic actuators, which provide precise and reliable control inputs from the pilot.

The T-tail configuration offers several advantages over other tail designs. Its high placement above the fuselage reduces the potential for interference from the engine exhaust or wing wake, resulting in improved stability and control. Additionally, the T-tail design allows for a shorter vertical stabilizer, which can reduce weight and drag.

The tail unit of the prototype is a critical component of the aircraft's overall design, playing a vital role in ensuring stability, control, and safety during all phases of flight.

1.2.4. Landing gear

The tricycle type of landing gear was chosen because it more efficient and safer than alternative designs. The most significant benefit is that it gives pilots better visibility. during such as taxiing, takeoff and landing, they have a clear view ahead as a result of nose wheel position. This contributes to more accurate control and increased safety margins when maneuvering on the ground. Another important benefit is stability during braking. The nose gear grants that the aircraft does not pitch forward when applying a strong brake force, which is most suitable during an emergency landing. They are easier to turn especially at low speeds thus making it easier to taxi within the confined environment of an airport. The nose gear design also has the advantage of protecting the tail of the aircraft from being damaged. This is done by minimizing the chances that the tail section will drag on the runway during takeoff or landing, a characteristic commonly associated with aircraft that use the tailwheel type of landing gear.

However, the tricycle landing gear arrangement also has its own disadvantages. The nose gear steering system can be more complicated than in the case of aircraft with the tailwheel landing gear, so more technical solutions may be needed. There is also a higher tendency of “shimmy” which is vibration of the nose gear especially at high taxiing speeds. This is a process that should be constantly supervised and maintained in order to prevent or minimize its negative effects. In addition, aircraft with nose gear may also be more affected by cross winds during taxiing and during takeoff, and this may call for more effort and careful maneuvering by the pilots. Despite these drawbacks, the advantages of the tricycle landing gear arrangement significantly outweigh them. This is why it has chosen for this aircraft.

1.2.5 .Cockpit

The cockpit of the prototype, designed with a focus on ergonomics and functionality, is a testament to modern aviation technology. It features a glass cockpit layout, where traditional analog instruments are replaced by digital displays, providing pilots with a wealth of information in a clear and concise format. This enhances situational awareness and reduces pilot workload, contributing to safer and more efficient operations.

The cockpit is equipped with a fly-by-wire control system, which replaces conventional mechanical flight controls with electronic interfaces. This system provides several advantages, including lighter weight, reduced maintenance requirements, and improved handling characteristics. It also enables the implementation of advanced flight control features, such as envelope protection and automatic trim, which further enhance safety and reduce pilot workload.

The cockpit layout is designed to be intuitive and user-friendly, with controls and displays logically arranged to minimize pilot distraction and fatigue. The seats are ergonomically designed to provide optimal support and comfort during long flights, while the large windows offer excellent visibility, enhancing situational awareness and reducing the risk of collisions.

The cockpit also incorporates numerous safety features, such as dual control yokes, redundant flight control computers, and comprehensive warning and caution systems. These measures are designed to provide pilots with the information and tools they need to safely manage any situation that may arise during flight.

1.2.6. Control system

The prototype aircraft features a fly-by-wire (FBW) control system, a significant departure from traditional mechanical flight controls. In a FBW system, pilot inputs from the control yoke, rudder pedals, and thrust levers are converted into electronic signals, which are then processed by dual-channel flight control computers and transmitted to electro-hydraulic actuators that move the aircraft's ailerons, elevators, rudder, and thrust reversers.

This system offers several advantages over mechanical controls. Firstly, it reduces the aircraft's weight due to the elimination of heavy hydraulic lines and mechanical linkages. Secondly, it simplifies the aircraft's design and reduces maintenance requirements. The absence of physical connections also translates to a more streamlined and aerodynamically efficient aircraft.

Moreover, the FBW system enables more precise and responsive control of the aircraft. The flight control computers can process pilot inputs and adjust the control surfaces with greater accuracy and speed than a human pilot could achieve with mechanical controls. This results in improved handling characteristics, making the aircraft easier and safer to fly, particularly during critical phases like takeoff and landing.

The FBW system also allows for the implementation of advanced safety features. For example, envelope protection prevents the pilot from exceeding the aircraft's structural or aerodynamic limits, ensuring the aircraft remains within safe operational parameters. Automatic trim adjustments, another feature of the FBW system, reduce pilot workload and enhance safety by maintaining the desired aircraft attitude without constant pilot input. Additionally, the FBW system can be programmed to compensate for adverse conditions, such as turbulence or crosswinds, further improving the aircraft's stability and control.

However, it's important to note that FBW systems also introduce new challenges.

The reliance on complex software and electronics raises concerns about potential failures and cybersecurity vulnerabilities. To mitigate these risks, the prototype's FBW system incorporates redundancy with dual-channel flight control computers and fault-tolerant design features, ensuring that the aircraft remains controllable even in the event of a system malfunction.

1.2.7. Choice and description of power plant

The decision to integrate the Pratt & Whitney PW4000-49 engine into the prototype aircraft represents a significant upgrade over the original powerplant. This modern turbofan engine, a dual-spool, axial-flow, high-bypass design, was selected to achieve the required thrust of 220 kN, as determined by aerodynamic calculations for takeoff.

The PW4000-49 offers several key advantages that enhance the aircraft's overall performance, efficiency, and environmental footprint. One of the most notable advantages is its superior fuel efficiency compared to the original engine. The PW4000-49 boasts a higher bypass ratio, which means a greater proportion of air bypasses the engine core and contributes directly to thrust. This results in lower fuel consumption and reduced operating costs, making the aircraft more economical to operate.

Furthermore, the PW4000-49 delivers increased thrust compared to the original engine. This translates to improved takeoff performance, allowing the aircraft to carry heavier payloads or operate from shorter runways. The increased thrust also enhances the aircraft's climb rate and cruising speed, leading to faster and more efficient flights.

In addition to its performance benefits, the PW4000-49 is also significantly quieter than the original engine. This is due to its advanced fan design and noise-reducing technologies, such as acoustic liners and chevrons on the engine nacelle. The reduced noise levels not only enhance comfort but also contribute to a more environmentally friendly operation by minimizing noise pollution.

The PW4000-49 also boasts improved reliability and maintainability compared to the original engine. Its modular design allows for easier access to components, simplifying maintenance tasks and reducing downtime. This, in turn, leads to increased aircraft availability and lower maintenance costs. The engine boasts a dispatch reliability rate of 99.96% and is certified for ETOPS 180, meeting rigorous safety standards for extended-range twin-engine aircraft. With a typical operating life of 13,500 flight hours before maintenance and a low shop visit rate of 0.073 per thousand hours, the PW4000-49 offers superior reliability and maintainability.

Below is a table with the main characteristics of the power plant:

Table 1.2

Engine performances

Model	Dry weight (kg)	Take-off thrust (N)	Bypass ratio	Pressure ratio	Temperature in combustion chamber (C)	Thrust-specific fuel consumption
PW 4000	3900	2280	4273	279	70	3.48

Conclusions to the analytical part

This part describes medium-haul aircraft which is a result of the analysis of the Boeing 757, Airbus A321, and Tupolev Tu-204 with the introduction of development in aerospace engineering.

The application of the semi-monocoque fuselage, a conventional empennage, and the tricycle type of landing gear provides a strong and stable structure along with reliable functionality. This a framework protects the passengers and offers easy ground operations, which are very important for any middle distance airplane.

The Pratt & Whitney PW4000-49 engine that is used. It is modern turbofan engines because, in addition to providing more thrust, it focuses on the most important factors, such fuel consumption. This ensures that the aircraft aligns with increasing environmental conservation concerns while at the same time trying to standardize its operating costs amid existing stiff competition in the current aviation market.

In addition to these overtures, the aircraft has other key features such as the swept wing, and fitted with the high-lift devices on. This configuration enhances the flow of the air over the wing and reduces turbulence hence increases lift to drag ratio and therefore increasing the range of the aircrafts.

The idea about interior of the aircraft takes into account different needs of the passengers. The cabin layout is designed fairly flexibly and allows for different modifications of seating and class options which is well-suited for a variety of the market segments. Newer age technologies in the avionics and entertainment domains serve to make the flights more comfortable for the passengers and thus add more value to the aircraft in the market.

In addition, the whole design process has been carried out with certain principles of sustainability. The efficient utilization of lightweight material, aerodynamic designing and efficient engine lead for a reduced environmental impact. This is an indication of a shift in the aviation business to find environment-friendly solutions.

2. AIRCRAFT MAIN PARTS CALCULATIONS

2.1. Geometry calculations for the main parts of the aircraft

The design and construction of a new medium range passenger aircraft implicates a number of mathematical calculations and the enhancement of the main components of the aircraft. These subsystems consist of the fuselage, wings, empennage or tail assembly and the landing gear; these are fundamental aspects of aircraft design that influence the aircrafts aerodynamics and structural and operational capacity.

Part of the airplane, known as the fuselage, is within the main body of the aircraft and contains the passengers, the cargo, and main components. It greatly affects the aerodynamics and overall size of the aircraft, controlling drag, lift, and internal volume that affects fuel consumption, the number of passengers, and storage space for cargo.

The wings, the primary lift-generating surfaces, it is imperative to get it right for the optimum flight performance. Geometry of the wings such as span, chord and airfoil shape of the wing comes into play in determining lift to drag ratio, stall behavior and maneuverability. The structure of wings that contains spars, ribs and stringers must be designed carefully to carry the loads which is applied on them during the flight and also to minimize the weight of the structure.

The empennage consists of the vertical and the horizontal stabilizers that help in maintaining the pitch, yaw and roll of the aircraft. These surfaces affect the aircrafts size, shape and how it is designed to fly in different modes of the flight, as well as the overall behavior of the aircraft.

The undercarriage, which serves as the support structure of the aircraft when it is on the ground, must be strong enough to absorb the shocks from landings and facilitate easy maneuvering when taxiing or during takeoff. The position of the landing gears and their structure in terms of their width and length influence the height of the aircraft above the ground, turning radius and the overall stability when taxiing.

The Boeing 757, Airbus A320, and Tupolev Tu-204 are chosen as typical examples for the study of the structure of the aircraft in this thesis. Here, calculations is made to design a medium-range aircraft that would outperform any other aircraft by adopting geometries that have been proven to be successful in their designs and incorporating new ideas that have not been previously implemented [10].

2.1.1. Wing geometry calculation

Full wing area is:

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{132368 \cdot 9.8}{6.163} = 210 \text{ m},$$

where m_0 – take-off weight, kg; g – gravity acceleration, m/s^2; P_0 – specific wing load, N/m^2.

Wing span is:

$$\mathrm{l_w} = \sqrt{\mathrm{S_w} \cdot \lambda_{\mathrm{w}}} = \sqrt{253 \cdot 7.89} = 44.7 \text{ m},$$

where λ_w – wing aspect ratio.

Root chord is:

$$C_{root} = \frac{2S_w \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 253 \cdot 5}{(1+5) \cdot 44.7} = 9.4 \text{ m},$$

where ηw – wing taper ratio.

Tip chord is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{9.4}{5} = 1.88 \text{ m},$$

Maximum wing thickness is:

$$c_{\max} = c_w \cdot b_t = 0.12 \cdot 2.97 = 0.36 \text{ m},$$

where c_w – medium wing relative thickness.

On board chord is:

$$C_{board} = C_{root} \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_{\mathrm{f}}}{\eta_w \cdot l_w}\right) = 8.39 \cdot \left(1 - \frac{(5-1) \cdot 5}{5 \cdot 44.7}\right) = 7.64\ \mathrm{m},$$

where D_f – fuselage diameter.

For mean aerodynamic chord determination the geometrical method was used (fig. 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.

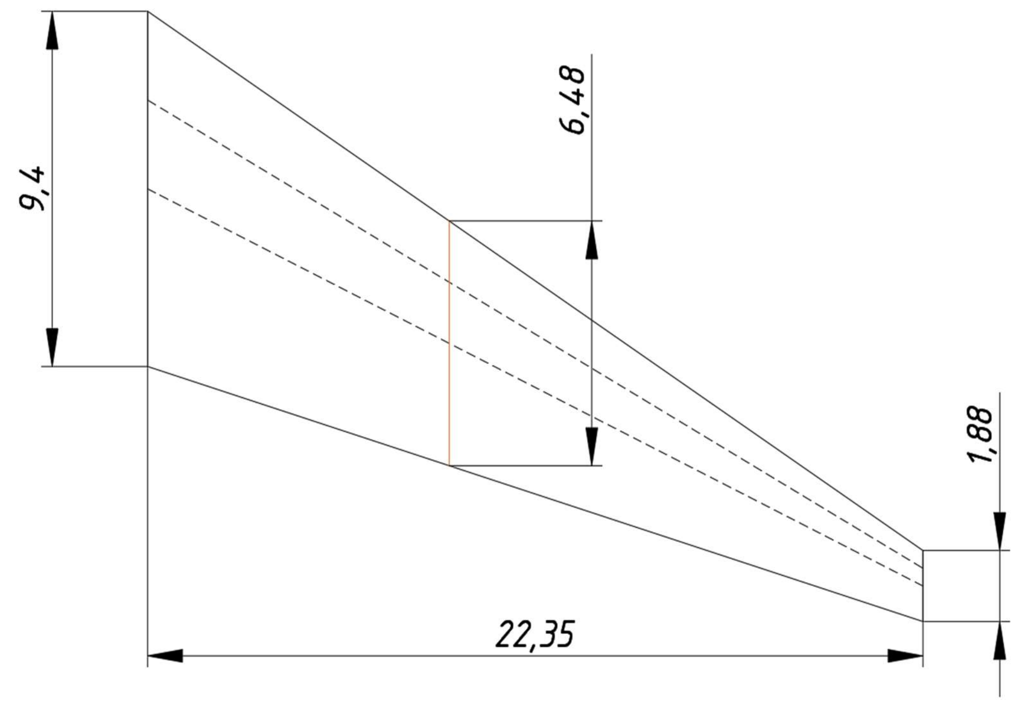

Fig. 1.1. Geometrical method of determination of mean aerodynamic chord

So the mean aerodynamic chord is equal to 6.49 m.

To meet the requirement of strength and keep structure light. Let's choose scheme with two spar like in the prototype.

Then is it necessary to calculate the main parameters for control surfaces and wing structure elements:

For the ailerons span parameters will be next:

$$l_{ail} = (0.3...0.4) \cdot \frac{l_w}{2} = 0.4 \cdot \frac{44.7}{2} = 8.4\,\text{m},$$

Ailerons chord:

$$b_{ail} = (0.2...0.26) \cdot b_t = 0.25 \cdot 2.8 = 0.55\,\text{m},$$

Aileron area:

$$S_{ail} = (0.05...0.08) \cdot \frac{S_w}{2} = 0.06 \cdot \frac{253}{2} = 12.65\,\text{m}^2,$$

Area of ailerons trim tab. For two engine airplane:

$$S_{tt} = (0.04...0.06) \cdot S_{ail} = 0.05 \cdot 12.65 = 0.63\,\text{m}^2,$$

Range of aileron deflection for upward is 25 degrees, downward is 15 degrees.

2.1.2. Fuselage layout

Fuselage layout designing consist of designation by calculation main parameters and passenger cabin sketch drawing.

When figuring out the shape of the airplane, we need to consider how it will perform aerodynamically under different conditions, including normal and extreme flights based on its intended use. The design of the fuselage, the main body of the plane, is most important part where we want to minimize drag caused by various factors like friction and airwaves, and make sure the fuselage can handle aerodynamic forces with a high safety factor. At first, aim is to create economy class passenger cabin suitable for medium haul flights according to EASA and FAR requirements.

Second part as interior drawing based on passenger capacity of the plane [9]. Since decided that plane will have two pilots and medium range calculating of main geometrical characteristics of the fuselage will look following:

Length of nose part:

$$l_{np} = (2...3) \cdot D_f = 2 \cdot 3.76 = 7.52 \text{ m}.$$

But in this case length of nose part will me 7.2 m like in prototype.

Fuselage length is:

$$l_f = \lambda_f \cdot D_f = 14.2 \cdot 3.76 = 53.5 \text{ m},$$

where λ_f – fuselage fineness ratio.

Fuselage nose part fineness ratio is:

$$\lambda_{\text{np}} = \frac{l_{np}}{D_f} = \frac{7.2}{3.76} = 1.9 \text{ m},$$

Length of the fuselage rear part is:

$$l_{rp} = \lambda_{rp} \cdot D_f = 2.19 \cdot 3.76 = 8.25 \text{ m},$$

where λ_{rp} – fuselage rear part fineness ratio.

Cabin height is:

$$H_{cab} = 1.48 + 0.17 B_{cab} = 1.48 + 0.17 \cdot 3.76 = 2.1 \text{ m},$$

where B_{cab} – width of the cabin.

The length of passenger cabin is:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{seatpitch} + L_2,$$

$$L_{cab} = 1395 + (39 - 1) \cdot 750 + 2 \cdot 920 + 400 = 32.135 \text{ m},$$

where L_1 – distance between the wall and the back of first seat; n_{rows} – number of rows; $L_{seatpitch}$ – seat pitch; L_2 – distance between the back of last seat and the wall.

2.1.3. Luggage compartment

The area of cargo compartment is:

$$S_{c\arg o} = \frac{M_{bag}}{0.4 \cdot K} + \frac{M_{c\&m}}{0.6 \cdot K} = \frac{250 \cdot 20}{0.4 \cdot 600} + \frac{250 \cdot 15}{0.6 \cdot 600} = 30.4 \text{ m}^2,$$

where M_{bag} – mass of the baggage, kg; $M_{c\&m}$ – mass of the cargo and mail, kg.

Cargo compartment volume is:

$$V_{cargo} = \nu \cdot n_{pass} = 0.2 \cdot 250 = 49.2 \text{ m}^3,$$

where ν – relative mass of baggage (0.2…0.4 for $D_f \le 4 \text{ m}$ and 0.36…0.38 for $D_f > 4 \text{ m}$); n_{pass} – number of passengers.

2.1.4. Galleys and buffets

Volume of buffets (galleys) is:

$$V_{galley} = \left(0.1...0.12\right) \cdot n_{pass} = 0.1 \cdot 246 = 24.6 \text{ m}^3,$$

where V – volume of buffets; n_{pass} – number of passengers.

Area of buffets (galleys) is:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{24.6}{1.91} = 12.8 \text{ m}^2.$$

2.1.5. Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t > 4 hours should be one toilet for 40 passengers. The number of lavatories is equal to:

$$N_{lav} = \frac{n_{pass}}{40} = \frac{246}{40} = 6.15,$$

So the chosen number of lavatories is 7. Area of each lavatory is 1.6 m^2.

Toilets design is similar to the prototype.

2.1.6. Calculation of basic parameters of tail units

Tail unit scheme is conventional. This part should meet the requirements of aircraft stability and controllability. So. For estimating parameter let’s calculate:

Area of vertical tail unit is:

$$S_{VTU} = \frac{l_{wx} \cdot S_w}{L_{VTU}} \cdot A_{VTU} = \frac{6.49 \cdot 44.7}{20.5} \cdot 0.1 = 56.55 \text{ m}^2 \cdot$$

where L_{VTU} – length of vertical tail unit; A_{VTU} – coefficient of static momentum of vertical tail unit (see the table in methodical guide).

Area of horizontal tail unit is:

$$S_{HTU} = \frac{b_{MAC} \cdot S}{L_{HTU}} \cdot A_{HTU} = \frac{6.49 \cdot 253}{21} \cdot 0.7 = 54.7 \text{ m}^2,$$

where L_{HTU} – length of horizontal tail unit; A_{HTU} – coefficient of static momentum of horizontal tail unit.

Determination of the elevator area and direction:

Altitude elevator area is:

$$S_{el} = k_{el} \cdot S_{HTU} = 0.35 \cdot 56.55 = 16.965 \text{ m}^2,$$

Rudder area is:

$$S_{rud} = k_r \cdot S_{VTU} = 0.21 \cdot 51.9 = 10.89 \text{ m}^2,$$

where k_r – relative rudder area coefficient (k_r = 0.35…0.45).

Choice of the aerodynamic balance area:

$$0.3 \le M \le 0.6,$$

$$S_{eb} = (0.22...0.25) \cdot S_{el} = 0.22 \cdot 16.965 = 3.729 \text{ m}^2,$$

Area of rudder trim tab is:

$$S_{rb} = (0.2...0.22) \cdot S_{rud} = 0.2 \cdot 10.89 = 2{,}178 \text{ m}^2,$$

where k_{eb} – relative elevator balance area coefficient; k_{rb} – relative rudder balance area coefficient.

The area of altitude elevator trim tab is:

$$S_{te} = k_{te} \cdot S_{el} = 0.08 \cdot 16.965 = 1{,}357 \text{ m}^2,$$

Area of rudder trim tab is:

$$S_{tr} = k_{tr} \cdot S_{rud} = 0.04 \cdot 10.89 = 0.436 \text{ m}^2,$$

where k_{tr} – relative trim tab area coefficient

Tip chord of horizontal stabilizer is:

$$b_{tip} = \frac{2 \cdot S_{HTU}}{(\eta_{HTU} + 1) l_{HTU}} = \frac{2 \cdot 54.7}{(2.5 + 1) 14.3} = 2.18 \text{ m},$$

where η_{HTU} – horizontal tail unit taper ratio; l_{HTU} – horizontal tail unit span, m.

Root chord of horizontal stabilizer is:

$$b_{root} = b_{tip} \cdot \eta_{HTU} = 2.18 \cdot 2.5 = 5.45 \text{ m},$$

Tip chord of vertical stabilizer is:

$$b_{tip} = \frac{2 S_{VTU}}{(\eta_{VTU} + 1) l_{VTU}} = \frac{2 \cdot 56.55}{(1.25 + 1) \cdot 8.94} = 5.62 \text{ m},$$

where η_{VTU} – vertical tail unit taper ratio; l_{VTU} – vertical tail unit span, m.

Root chord of vertical stabilizer is:

$$b_{root} = b_{tip} \cdot \eta_{vtu} = 5.62 \cdot 1.25 = 7 \text{ m},$$

where η_{VTU} – vertical tail unit taper ratio; L_{VTU} – vertical tail unit span.

2.1.7. Landing gear design

On this stage of design when airplane center of gravity isn’t determined and no general drawing, landing gear can be calculated

$$B_m = 0.2 \cdot 6.49 = 1.298 \text{ m}.$$

Balance for nose landing gear should be find because with large distance of landing gear can cause to strike of the airplane tail. With the low load airplane will be not stable on a runway

$$B = 0.368 \cdot 53.5 = 19898,$$

$$B_n = B - B_m = 19898 - 1298 = 18600.$$

Wheel track is:

$$T = 0.7 \cdot 53.5 = 11.04.$$

The load on the wheels is determine d:

$$F_{main} = \frac{\left(18.6 - 1.298\right) \cdot 132368 \cdot 9.81}{18.6 \cdot 2 \cdot 4} = 150989,$$

$$F_{nose} = \frac{1.298 \cdot 132368 \cdot 9.81 \cdot 1.5}{18.6 \cdot 2} = 67963.4.$$

Nose gear

Size	Construction			Service Rating				Tread Design/ Trademark	Weight (Lbs)
	Ply Rating	TT or TL	Rated Speed (mph)	Rated load (Lbs)	Rated Inflation (Psi)	Max. Breaking Load (Lbs)	Max. Bottoming Load (Lbs)		
34×9.25-16	16	TL	222	16200	210	34500	69000	Rib	24.5

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
22.2	21.6	6.8	6.4	9.45	7.4	5.75	14	1	2.1

Main gear

Size	Construction			Service Rating				Tread Design/ Trademark	Weight(Lbs)
	Ply Rating	TT or TL	Rated Speed (mph)	Rated load (Lbs)	Rated Inflation (Psi)	Max. Breaking Load (Lbs)	Max. Bottoming Load (Lbs)		
40.5×15.5-16	28	TL	235	34200	190	51300	105600	Flight Leader	137

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
40.5	39.5	15.5	14.7	16.7	0.795	11.5	16	1.75	3.6

2.1.8. Power plant

Pratt & Whitney PW4000-49 is used for achieve required thrust which is designated by aerodynamic calculation for the design of the aircraft at take-off mode and is 220 kN.

The engine is a dual-spool, axial-flow, high-bypass turbofan developed by Pratt & Whitney. It's the successor to the JT9D. The PW4000 boasts a dispatch reliability rate of 99.96% and is certified for ETOPS 180, meaning it meets safety standards for extended-range twin-engine aircraft.

These engines typically operate for about 13,500 flight hours before needing maintenance, with a Shop Visit Rate of 0.073 per thousand hours.

2.2. Determination of the aircraft center of gravity position

2.2.1. Determination of centering of the equipped wing

Centering one of the main characteristic because it affect on the overall plane stability and maneuverability.

Regardless of the place of mounting (to the wing or to the fuselage), the main landing gear and the front gear are included in the mass register of the equipped wing.

The mass register includes names of the objects, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers

is chosen by the projection of the nose point of the mean aerodynamic chord (MAC) for the surface XOY. The positive meanings of the coordinates of the mass centers are accepted for the end part of the aircraft.

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

Table 2.1

List of equipped wing masses

#	Object name	Mass		Center of gravity coordinates, m	Moment of mass, kg·m
		Units	Total mass, kg		
1	2	3	4	5	6
1	Wing (structure)	0.089	11849.58	2.7907	33068.6
2	Fuel system	0.0094	1244.2	2.75825	3431.97
3	Flight control system, 30%	0.00156	206.49	3.894	804.08
4	Electrical equipment, 20%	0.003	397.1	0.649	257.7
5	Anti-icing system, 70%	0.0026	346.27	0.649	224.7
6	Hydraulic system, 30%	0.010	1408.32	3.894	5484.29
7	Power plant	0.098	12973.38	-2.45	-31784.79
	Equipped wing without landing gear and fuel	**0.2719**	**39344**	**0.900**	**35428.08**
8	Nose landing gear	0.011	1472.06	-16.437	-24196.32
9	Main landing gear	0.025	3434.81	2.334	8016.86
10	Fuel for flight	0.31	41365	1.947	80537.655
	Totally equipped wing	**0.56**	**74697.38**	**1.015**	**75844.83**

2.2.2. Determination of the centering of the equipped fuselage

The starting point settled for the coordinates at the projection on the nose of the fuselage on the horizontal axis. The X-axis corresponds to the structural part of the fuselage. For aircraft with engines mounted beneath the wings, a list of components is provided in the table as an example. After we determined the C.G. of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

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

After determination of the wing MAC leading edge position relative to fuselage, means $\boldsymbol{X_{MAC}}$ value by formula:

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

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.

Table 2.2

List of equipped fuselage masses

#	Object name	Mass		Center of gravity coordinates, m	Moment of mass, kgm
		Units	Total mass, kg		
1	2	3	4	5	6
1	Fuselage	0.09352	12379.05	27	334234.49
2	Horizontal tail unit	0.0087	1151.60	48.28	55599.32
3	Vertical tail unit	0.00846	1119.83	49.983	55972.63
5	Dashboard and instrument equipment	0.0049	648.62	1.5	972.9048
6	Aero navigation equipment	0.0042	555.9456	1.5	833.9184
7	Radio equipment	0.0025	362	6.000	2170.47
8	Flight control system, 70%	0.00364	481.81952	29.535	14230.53
9	Electrical equipment, 90%	0.027	3573.936	26.85	95960.18
10	Hydraulic system, 30%	0.00456	603.59	28.365	17121.04
11	Anti icing system, 20%	0.003052	403.98	48.28	19504.49
12	Air-conditioning system, 40%	0.002616	346.27	24.165	8367.72
13	Emergency equipment	0.0038	500	24.53	12265
14	Tools	0.01	2468.66	26.85	66283.60
16	Lavatory 1, galley 1	0.0075	1000	6.3	6300
17	Lavatory 2, galley 2	0.007	1000	42.6	42600
24	Baggage equipment	0.037	4920	24.036	118257.12
26	Passengers' seats 1 (business class)	0	0	0	0
27	Passengers' seats 2 (economic class)	0.143	18942	24.036	455289.912
30	Non-typical equipment	0.011	1534.14	3.43	5262.11
	Equipped fuselage without commercial load	**0.229**	**30331.06**	**25.42**	**771162.1**
31	Passengers 1 (economic class)	0.14	18942	24.036	455289.912
32	Passengers' baggage	0.03	4920	24.036	118257.12
33	Cargo, mail	0.01	2459	24.036	59104.54
34	On board meal	0.0023	369	24.45	9022.05
35	Flight attendants	0.00371	490	24.53	12019.7
36	Crew	0.0011	154	2.4	369.6
	Totally equipped fuselage	**0.431**	**57665.06**	**24.71**	**1425225.046**

2.2.3. Calculation of center of gravity positioning variants

The list of mass objects for Centre of gravity variant calculation given in Table 2.3 and Center of gravity calculation options given in table 2.4, completes on the base of both previous tables.

Table 2.3

Calculation of the C.G. positioning variants

#	name of object	mass, m_i kg	mass moment miXi	center of mass X
1	take-off mass (L.G. extended)	132362.44	3143558.23	23.74
2	take-off mass (L.G. retracted)	132362.44	3164605.8	23.90
3	landing weight (LG extended)	96190.24	2266335.27	23.56
4	ferry version (without payload, max fuel, LG retracted)	105182.44	2510912.5	23.87
5	parking version (without payload, without fuel foe flight, LG extended)	68856.24	1612272.36	23.41

Table 2.4

Calculation of center of gravity position variants

#	Object name	Mass, kg	Center of gravity coordinates, m	Moment of mass, kg·m
1	2	3	4	5
1	Equipped wing without landing gear and fuel	28425.50	22.71	645497.49
2	Nose landing gear (extended)	1472.06	24228,00	8334.83
3	Main landing gear (extended)	3434.82	17.86	61345.84
4	Fuel for flight	36172.20	24.25	877222.96
5	Reserve fuel	5192.80	24.25	125932.07
6	Equipped fuselage without commercial load	30331.06	25.42	771162.14
7	Passengers 1 (business class)	0.00	0.00	0.00
8	Passengers 2 (economic class)	18942.00	45406.00	455289.91
9	Baggage of passengers	4920.00	45406.00	118257.12
10	Cargo, mail	2459.00	45406.00	59104.52
11	On board meal	0.00	0,00	0.00
12	Flight attendants	490.00	24.53	12019.70
14	Crew	154.00	14642.00	369.60
15	Nose landing gear (retracted)	1472.064528	4.7	6918.70
16	Main landing gear (retracted)	3434.817232	24.4	83809.54

Conclusions to the project part

The preliminary design of this project has focused on creating a conceptual framework for a medium-range aircraft capable of serving for passenger roles. This stage has involved a detailed analysis of various aspects, including cabin layout, center of gravity calculations, landing gear design, and wheel selection. The findings of this phase paint a promising picture for the feasibility and potential success of the proposed aircraft.

Here was calculated geometrical parameters of the wing. Design of such a wing combining high structural reliability and maximum functionality with minimized drag for this type of wing.

Passenger cabin layout is designed with aerial requirements for safety. It aims to provide much more comfort with compromise in number of passengers on board too. Size of galley and number of toilets selected in such way – to provide maximum comfort with optimized volume and mass parameters.

A key from this preliminary design phase is the high thrust-to-weight ratio that has been achieved. This is a direct result of the chosen engine configuration, which not only ensures exceptional take-off performance and the ability to operate in adverse weather conditions but also opens up possibilities for future adaptations.

Analysis of the landing gear and wheel selection means that the aircraft will have excellent stability, braking performance, and maneuverability during ground operations. These attributes are important for safe and efficient operations in a variety of airport environments.

In conclusion, the preliminary design phase has laid a strong foundation for the development of high-performance medium-range aircraft. By combining the best attributes of existing prototypes, this project aims to create an aircraft that sets a new standard for efficiency, and safety in the medium-haul market.

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3. SPECIAL PART

3.1. Introduction

The Russian invasion Ukraine, and the recent COVID-19 pandemic have demonstrated that it is important to have flexible air medevac system. These disasters have exposed the flaws of modern society and brought attention to the fact that there is a demand for quick, effective, and adaptable means of moving individuals and equipment.

In an effort to assist with this problem, this thesis will center on the design of an improved medevac aircraft that will be built for use in high risk environments such as war zones and disease affected regions. This new plane will not only be fast and efficient but will also incorporate medical technologies, flexibility, and structures into it to make the transport of patients and medical equipment in complex terrains.

To achieve this, we will first have to assess the current medevac planes in the field and identify the strengths and weaknesses of each plane. This research will analyse real-life scenarios, and with information from medical practitioners as well as aviation engineers, it will develop a new generation of medevac aircrafts that will be more effective in their operations, thus saving more lives and alleviating suffering.

But let’s take a look at what is going on in medevac design today before we begin the process. This means that there is a need to assess the current market trends, major players and new innovations. This will assist us in identifying what is lacking or required by the people and what can be offered to them. In this way, we can ensure that the new medevac aircraft we plan to acquire is not only equipped with the latest technology but also suitable for the intended purpose and serves the needs of the target audience.

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St.control.	Krasnopolskyi V.S.						
Head of dep.	Yutskevych S.S.						

3.2. Medical airplanes market analysis

The air ambulance services market is a vital component of the healthcare and emergency medical services industry. Air ambulance services are equipped with aircraft and helicopters that are fully equipped with medical facilities. It involves the transportation of critically ill or injured patients via aircraft to medical facilities for prompt medical attention. The primary function of an air ambulance service is to deliver a level of care that surpasses ground-based medical transportation. Additionally, air ambulances ensure patient comfort during short or long distance journeys.

The air ambulance services market is also growing at a rather constant rate, but mostly due to day to day increase in need of quick transport of patients. There are several factors behind this growth that include enhanced rate of accidents, technological changes in the air ambulance services, and company in the increasing global population of elderly people, mainly in the developed countries. The growth of diseases has also resulted from the aging population leading to the increase in the number of people in need of specialized medical care to result in the increase of air ambulance services. This has led to increased demand for fast and efficient emergency medical help in various areas of the world and especially in the remote and disaster affected area to meet such need there has been increased utilization of air ambulances. Many regions have witnessed increased availability of air ambulance services in order to address concerns of timely responses within remote or such uncharted territories. This expansion helps ensure that the people of these places are able to obtain proper medical help as soon as possible. Technological advancements in the aviation industry have offered better ways of safety and navigation thus, making air ambulance operations to turn out to be helpful for the patients.

Air ambulances are thus becoming an entrenched part of the emergency health care systems in regions and functional as an organized network which ensures proper coordination between emergency responders, healthcare organizations, and air ambulance actors for efficient patient transport. Presently, air ambulance services may contain enhanced medical care teams such as critical care nurses and paramedics capable of providing high caliber treatment during the transport. This means that the integration of telemedicine within air ambulances has received greater consideration. This enables the doctors on board to Radio in touch with their fellow doctors on the ground offering medical advice from the aircraft. The industry pays a significant amount of attention to its safety and, therefore, conducts safety trainings as frequently as possible and uses the safety equipment that provides fairly low risk levels of accidents during air ambulance flights

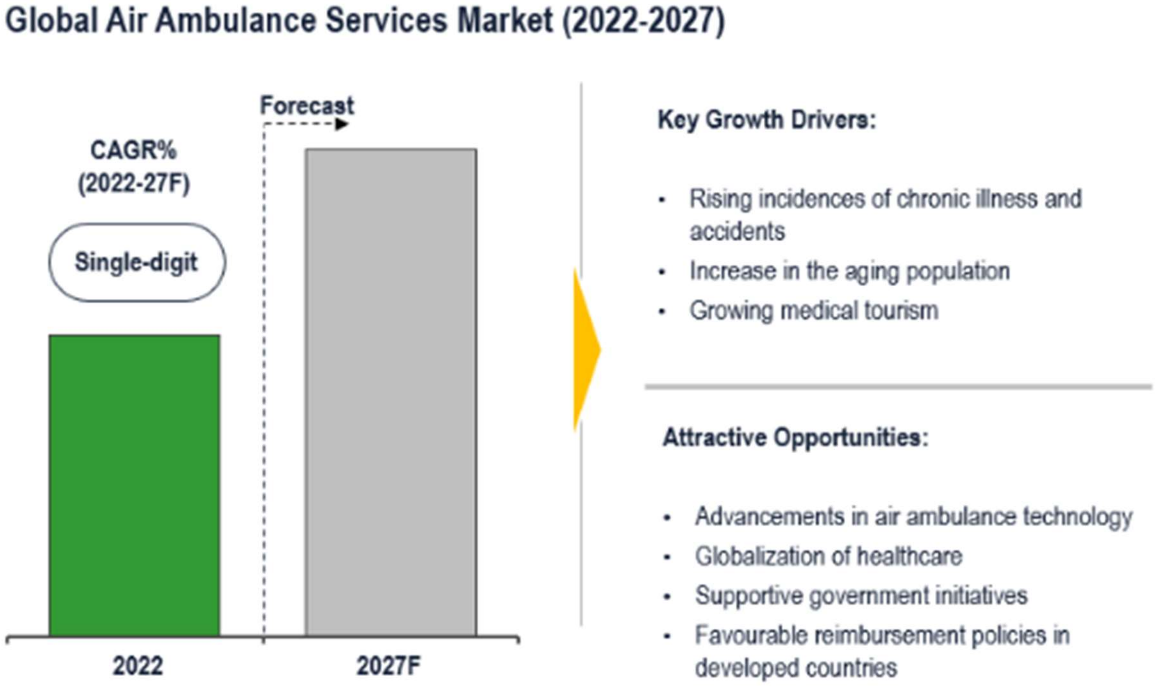


Fig. 3.1 Forecast of market

Due to these changes as influenced by several factors the air ambulance services market experienced extraordinary transformations especially by the onset of COVID-19. The initial levels of the pandemic saw a significant increase in the flow of employment for air ambulance companies, mostly to transfer COVID affected patients to appropriate care centers. This resulted in increased business for air ambulance providers as their activities have just been described. However, the air ambulance service industry faced numerous challenges in terms of finance amid the growing need for such critical services. The delivery of such services became considerably expensive to justify due, amongst others, to the need to provide personal protective equipment to the crew and undertake highly rigorous measures, such as aircraft sanitation.

The pandemic also introduced travel limitations such as lockouts, and closed borders raising challenges on the transportation of patients across borders or to other States hence affecting the cross-border expectations of air ambulance services. Bearing in mind that most emergencies are unforeseeable, air ambulance providers had to ensure that they responded accordingly to the changing circumstances. The leadership in healthcare facilities tightened the measures they had put in place regarding safety and disinfection practices to protect the health of the patients receiving care and the healthcare workers attending to them. It is important to mention that the changes in this market due to COVID-19 effects might be unpredictable and may last for a long time. As vaccination programs are being stabilized and the impact of the pandemic is decreasing, the industry is expected to stabilize and move to a more normal state eventually.

While harnessing tremendous growth potential, the air ambulance services industry is marred with challenges such as high operating costs, strict regulatory policies, lack of a strong healthcare framework and limited number of aircrafts in emerging markets. It is important for strict rules and regulations be set for air ambulance services to abide by in a bid to protect the patient and improve health's care quality. However, present in these regulations, along with difficulties regarding the possibility of reimbursement and the overall high costs associated with air medical services, factors act as constraints to the global rate of penetration of the market in emerging nations.

The size of the air ambulance carrier market varies from vicinity to vicinity, with advanced countries generally having more mounted infrastructure. It is one of the largest air ambulance markets in North America and Europe. North America dominates the worldwide market, basically because of the presence of set up flight clinical facilities, superior scientific facilities, and helicopter fleets within the United States. In contrast, Asia Pacific is expected to witness the quickest increase throughout the forecast length. This is due to the rapid enlargement of the clinical tourism enterprise in rising economies along with India and China, which creates a massive demand for air ambulance services in the area in addition to, the developing healthcare quarter in Asia Pacific, airlines a is developing and general contributes to the expansion of the market in this geographic location [7].

Conclusively, this research findings provide a clear understanding of the aeromedical transport market and emphasizes that the air ambulance industry has vast market opportunity as well as the expansion of demand for aeromedical transport services. The growing prevalence of chronic diseases, aging of population today across the globe, increased infrastructural developments of health care in the uncharted territories, and awareness of air ambulance services. It is the key factors that are fuelling rapidly growing market for air ambulance services.

In addition, the events of the current year such as the situation in Ukraine and the unprecedented pandemic of COVID-19 have highlighted the necessity and the importance of having quick and highly effective medical evacuation means. Apparently, the need of time access of specialized care through air ambulances especially in the difficult operational terrains has been more prominent now than ever.

3.3. Analysis of required aviation medical equipment

A medevac aircraft is not some moving machine; it is an airborne emergency hospital. To be precise, to save lives of the sufferers, it needs equipment which are essential during flight towards providing treatment. This equipment needs to be carry-on portable and modular for the applications of airborne contexts.

The essential medical equipment on board a medevac aircraft typically includes: Patient Monitoring Systems: These systems always check easy to measure body functions like heart rate, blood pressure, oxygen level and respiration rate while giving feed back to the medical team present.

Ventilators and Respiratory Support: A ventilator is a medical device which helps patients perform the breathing process on their own when they are unable to do so. Other related pieces of equipment that include oxygen tanks and masks are also essential.

Defibrillators and Cardiac Monitors: These are used for controlling heart beats and to perform echocardiograms, important tools for handling heart complications during flights.

Infusion Pumps and Medication Administration Systems: Intravenous administration of fluid and medications requires controlled and accurate delivery of preset amounts during transport, which is enabled by infusion pumps.

Suction Devices and Airway Management Equipment: Suction apparatus removes fluids and secretions from individuals' airways and help in intubation by practices such as using laryngoscopes and endotracheal tubes.

Stretchers and Patient Transport Systems: Conforming stretchers and loading techniques enable the transport of patients without subjecting them to other ailments that may arise from the loading and offloading processes.

In addition, equipment used both on a fixed and routine basis could include patient transport equipment such as life support incubators and infectious disease isolation units where required based upon the specific mission assigned to the medevac aircraft.

Fig. 3.2 Spectrum Aeromed 2800 series

One of the key factors influencing the choice of this system is its compliance with the aviation requirements set out in ISO 10079-1:2022. The lightweight and compact design of the 2800 series Fig.3.2(weight from 15.9 to 66.9 kg, depending on configuration) allows maximum efficient use of limited space on board the aircraft, while providing sufficient freedom of movement for medical personnel (corresponds to section 6.2.2 ISO 10079-1:2022, concerning weight and size requirements, and section 6.2.3, concerning ergonomics).

The use of high-strength materials such as aluminum and stainless steel and careful design guarantee reliable operation of the system in the conditions of vibrations, pressure drops and temperatures typical for flights (complies with section 6.3.2 of the standard concerning mechanical strength and stability), which is confirmed by numerous tests and FAA certification. Ease of installation and maintenance (the system can be installed and dismantled in 15 minutes without the use of special tools, unlike some other systems such as FAA-PMA Modular Medical Interior, which require longer time and special skills) is also an important advantage, allowing you to reduce downtime and increase the efficiency of the medical team (corresponds to the section 6.2.4 of the standard concerning ease of use and maintenance).

In addition to compliance with aviation regulations, the 2800 series has a number of advantages over other models of medical equipment. Its modular design provides a high degree of versatility and flexibility, allowing the system to be adapted to the specific needs of each medical mission, which meets the requirements for functionality and adaptability of medical equipment in the ISO 10079-1:2022 standard (Section 6.1). The ability to quickly transform from a stretcher into a transport platform for infants or other specialized equipment, which is not available in some other systems, such as the Stat MedEvac Modular Air Ambulance Interior, makes it an indispensable tool for solving a variety of medical tasks.

Functionality and convenience are two more important aspects that set the 2800 series apart from the competition. The system is equipped with everything necessary to provide high-quality medical care in flight, including a life support system, patient monitoring, infusion pumps and other equipment, which meets the requirements for the configuration and functionality of medical equipment in the ISO 10079-1:2022 standard (Section 6.4). The ergonomic design, which includes a fully adjustable backrest, thick foam and expandable armrests, ensures the convenience of medical personnel and maximum comfort for the patient, which is especially important for long flights, and surpasses some other systems in convenience, such as the Air Ambulance Worldwide Modular System [8].

Finally, it should be noted that the 2800 series offers the best value for money. Although accurate price data on medical equipment for aviation is usually not publicly published, experts estimate that the cost of the Spectrum Aeromed 2800 system is in the middle price segment, which makes it more affordable than some similar systems such as Lifeport AeroSled, while not inferior to them in quality and functionality. This makes it an attractive choice for organizations involved in medical evacuations and other types of air medical care, where cost-effectiveness plays an important role.

Thus, the choice of the Spectrum Aeromed 2800 series modular system for converting a passenger aircraft into a medical one is a reasonable and balanced decision that fully meets the requirements of ISO 10079-1:2022 standard. Its unique characteristics FAA-PMA Modular Medical Interior, Stat MedEvac Modular Air Ambulance Interior and Air Ambulance Worldwide Modular System, and optimal price-performance ratio make it an ideal tool for providing reliable and effective medical care in the air. It’s performances are given in table 3.1.

Table 3.1

Performances of module 2800 series

Bench Length	75 inches (190.5 cm)
Width	17 inches (43.25 cm)
Height	10.6 inches (25.40 cm) (To top of Bench)
Base Unit Weight	35 lbs -147 lbs (15.9 Kgs – 66.9 Kgs)
Overhead Console Weight	14 lbs. (6.4 Kgs)
Dual Air .Pumps	Air Pump Capacity (each) 11 lpm @ 50 psi (in ALS systems only)
Vacuum Pump	14 lpm @ 14 in hg (in ALS systems only)

Ending of table 3.1

Electrical Supply	(1) 28 volt DC outlet and (2) 115 volt AC outlets or (4) 230 Volt AC outlets (in ALS systems only)
Inverter	115 volt AC and 230 volt AC options (in ALS systems only)
Oxygen Supply	3500 Liter

Advantages of picked equipment:

-Versatile Power: Multiple outlets for oxygen, medical air, and vacuum.

-IV Access: Four integrated IV mounts for convenient fluid administration.

-Quick Conversion: Unique seat rail adapter enables swift conversion from executive to EMS configuration in just 15 minutes, without special tools.

-Patient Comfort: Fully adjustable backrest, thick foam pad, lightweight yet durable frame, and expandable armrests for maximum patient comfort, including bariatric patients.

-Secure Equipment Mounting: Modular systems accommodate patient monitors, medical equipment, and IV poles.

-Adaptable Medwall: Overhead/Medwall supply panel is movable or removable, featuring an exam light and pneumatic outlets, keeping the workspace organized.

-Flexible Configuration: Accommodates both adult stretchers and infant transport decks [4].

3.4. Fitting for medical equipment

The Ancra Rear Leg Ultra-Lightweight Titanium Seat Fitting (70150-10) is an essential component for setting up a medevac aircraft, particularly when advanced medical equipment like the Spectrum Aeromed 2800 Series is involved. This seat fitting is durable, lightweight, and strong, making it ideal for ensuring the safety of medical gear on board.

Constructed from highly resilient titanium, the Ancra seat fitting is capable of withstanding the demanding task of transporting medical equipment in the air. It provides a stable and secure base for the gear, ensuring the safety of both patients and crew during the flight. Additionally, its lightweight nature contributes to fuel efficiency and allows for longer flights.

One of the notable features of the seat fitting is its special release system, which enables quick and easy attachment or removal of medical gear. This feature is particularly best in time-sensitive situations, such as emergency medevac missions.

The Ancra Rear Leg Ultra-Lightweight Titanium Seat. The versatility allows for secure attachment of various medical devices, facilitating the work of medical staff.

By choosing the Ancra Rear Leg Ultra-Lightweight Titanium Seat Fitting, medevac crews can ensure the safety and readiness of their medical gear. At figure below shown general dimention of chosen fitting. (All dimentions is in inches) [6].

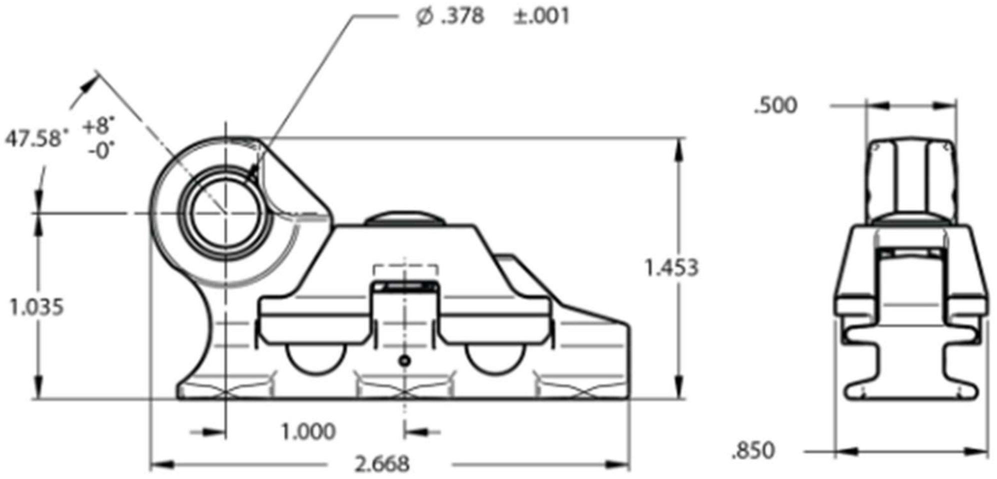


Fig. 3.3 Ancra Rear Leg Ultra-Lightweight Titanium Seat Fitting

3.4.1. Strength analysis

In order to ensure the secure and stable installation of the Spectrum Aeromed 2800 Series Modular Unit within the medevac aircraft, four fitting will be used.

For properly selecting the seat fittings and to prove the structures requirement tests would be performed using finite element analysis. To do this analysis, different software available in this industry like SolidWorks and ANSYS would be applied on the fittings to calculate forces and stress that the fittings undergo in the different flight conditions.

The FEA model will involve geometric characteristics of the rear leg fitting Ancra UTC.Verification simulations:

Studying the stress concentration, deformation and safety factors involved in FEA model of seat fitting will enable prediction of the threats and vulnerable region on the existing seat fitting design.

This will further strengthen the trust in Ancra seat fittings and its ability to perform while consistently locking the Spectrum Aeromed 2800 Series in the safest manner possible throughout the various phases of a flight.

In accordance with the example the CAD model of fitting with help of SolidWORKS software modeled. It mean to be noticed that this model is created for strength analysis so it can differ from reference.

From SolidWORKS Database adding Socket button hex bolt M5. Modelling the seat track which will have following look. (Fig 3.4) Creating assembly with help of assembly mode of SolidWORKS.

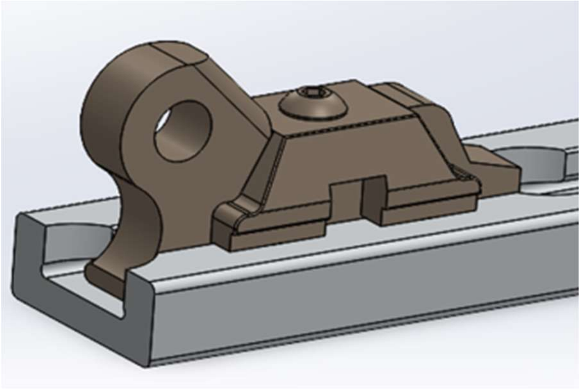
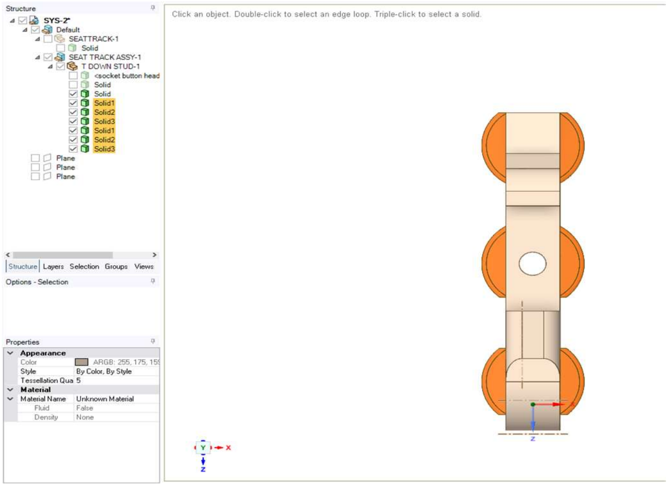


Fig. 3.4 SolidWORKD assemly model of fitting

After ensuring that all components fit well proceeding to the Ansys Workbench, where picking module static structural, importing geometry.

Checking model convertion through spaceclaim. For preventing problems with mesh elements deformation separating some elements in independent solids (Fig3.5).

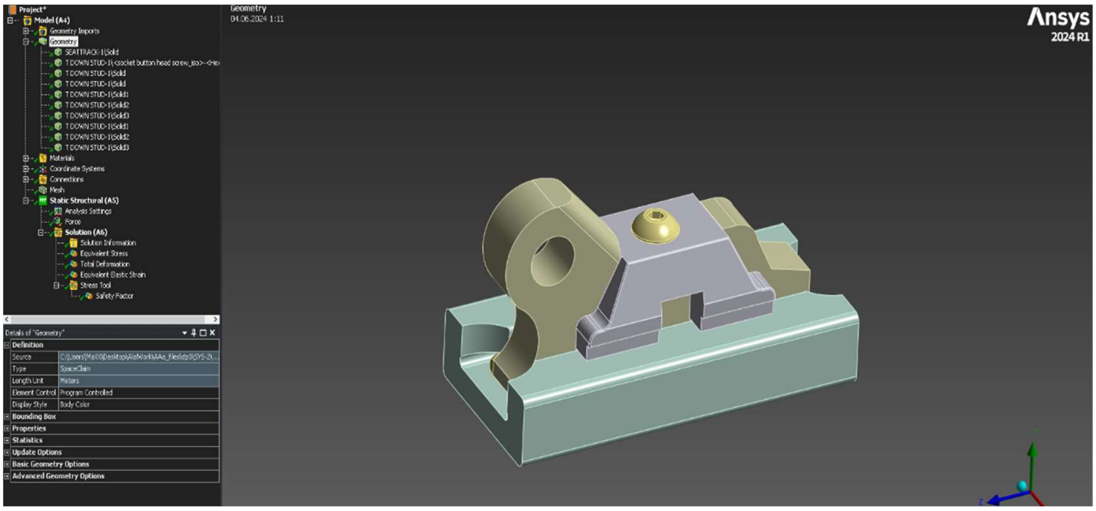


Properties

Appearance	
Color	ARGB: 255, 175, 15
Style	By Color, By Style
Tessellation Qua	5
Material	
Material Name	Unknown Material
Fluid	False
Density	None

Fig. 3.5 View at detail in SpaceClaim

After model checking and separation some difficult elements proceeding to static structural module. Assining titanium for fitting elements and setting mesh parameters which is 1 mm element size.(Fig. 3.6) Such size caused compromise of performance and accuracy of calculations (Better quality of mesh means most accuracy and greater distribution of loading in the model).



Details of "Geometry"

Definition	
Type	SpaceClaim
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Properties	
Statistics	
Update Options	
Basic Geometry Options	
Advanced Geometry Options	

Fig. 3.6 Matherial assigment

Then applying force in quantity which is equal to mass of bench and mass of patient divided by 4:

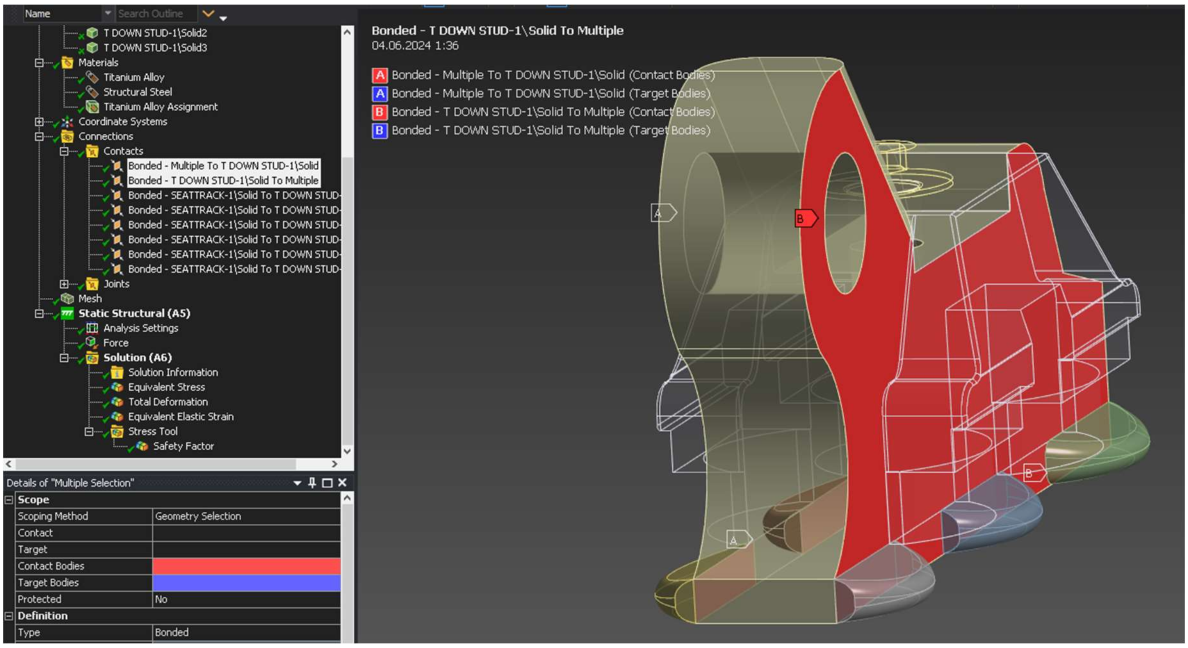
$$\frac{m_p + m_d}{4} = \frac{120 + 70}{4} = 137.5\,\text{kg},$$

Where is m_p – mass of patient; m_d – mass of spectrum 2800

To convert this value to Newtons it need to be multiplied on 10:

$$137.5 \cdot 10 = 1375\ \text{N},$$

After applying force settings let's set connections



Details of "Multiple Selection"

Scope	
Scoping Method	Geometry Selection
Contact	
Target	
Contact Bodies	🟥
Target Bodies	🟦
Protected	No
Definition	
Type	Bonded

Bonded - T DOWN STUD-1\Solid To Multiple
04.06.2024 1:36

A Bonded - Multiple To T DOWN STUD-1\Solid (Contact Bodies)
A Bonded - Multiple To T DOWN STUD-1\Solid (Target Bodies)
B Bonded - T DOWN STUD-1\Solid To Multiple (Contact Bodies)
B Bonded - T DOWN STUD-1\Solid To Multiple (Target Bodies)

Fig. 3.7 Connections to the body shown

In the figure 3.7, where is shown connection of divided elements to the main body through bonded connection which simulating a rigid body. At next figure 3.8 configuration of seat track fixation which will be fixed to the sowftware ground. This created for simplified connection to plane floor.

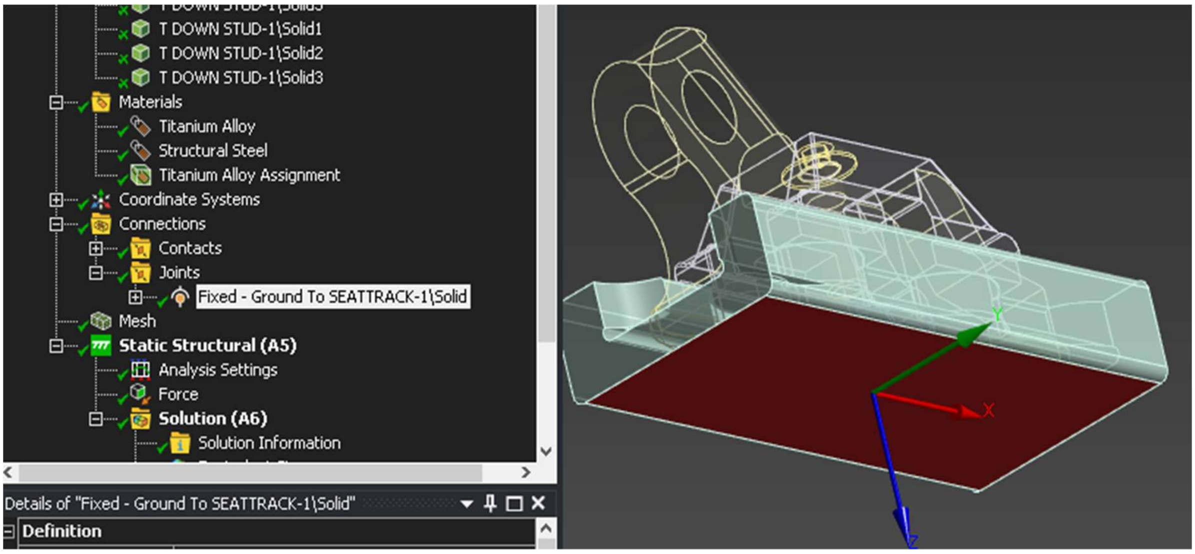

T DOWN STUD-1\Solid1
T DOWN STUD-1\Solid2
T DOWN STUD-1\Solid3
Materials
Titanium Alloy
Structural Steel
Titanium Alloy Assignment
Coordinate Systems
Connections
Contacts
Joints
Fixed - Ground To SEATTRACK-1\Solid
Mesh
Static Structural (A5)
Analysis Settings
Force
Solution (A6)
Solution Information
Details of "Fixed - Ground To SEATTRACK-1\Solid"
Definition

Fig. 3.8 Ground connection

Since model ready to start calculation and obtaining following results. Results below will show in scale which is greater than a real displacement in almost 2 times. Equivalent stress is show at figure 3.9

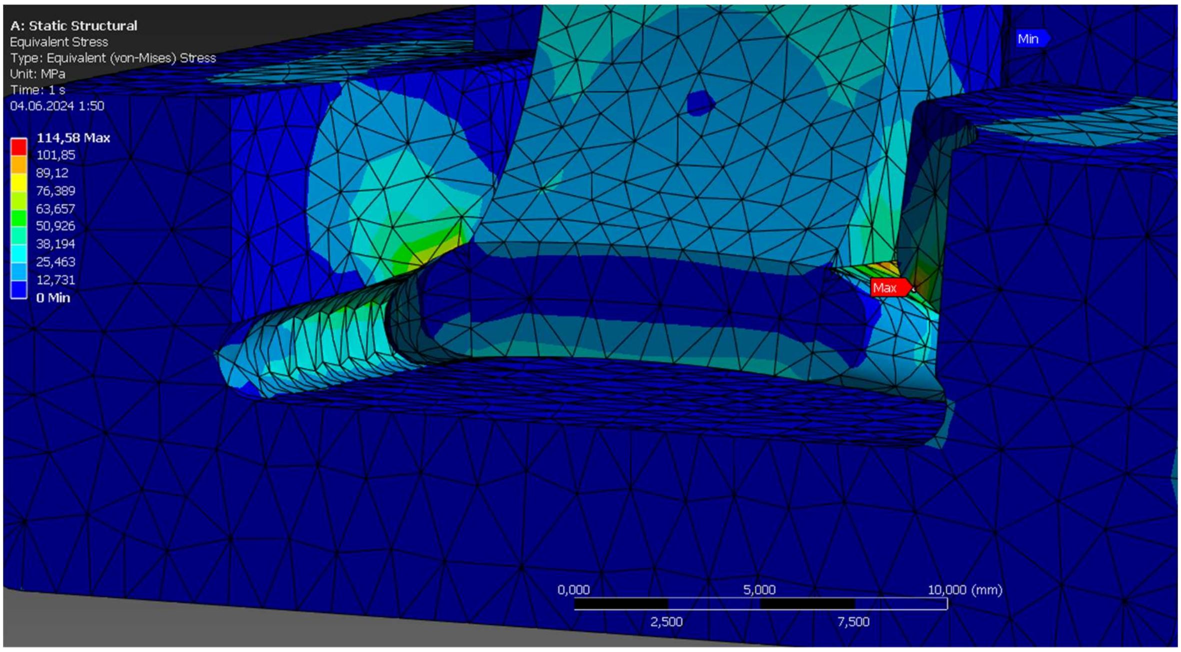

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
04.06.2024 1:50

Fig. 3.9 Equivalent stress monitor

The next picture shows safety factor which is greater than 8, so it means that fitting will be strong enough to withstand load more in 8 times than required. (Figure 3.10)

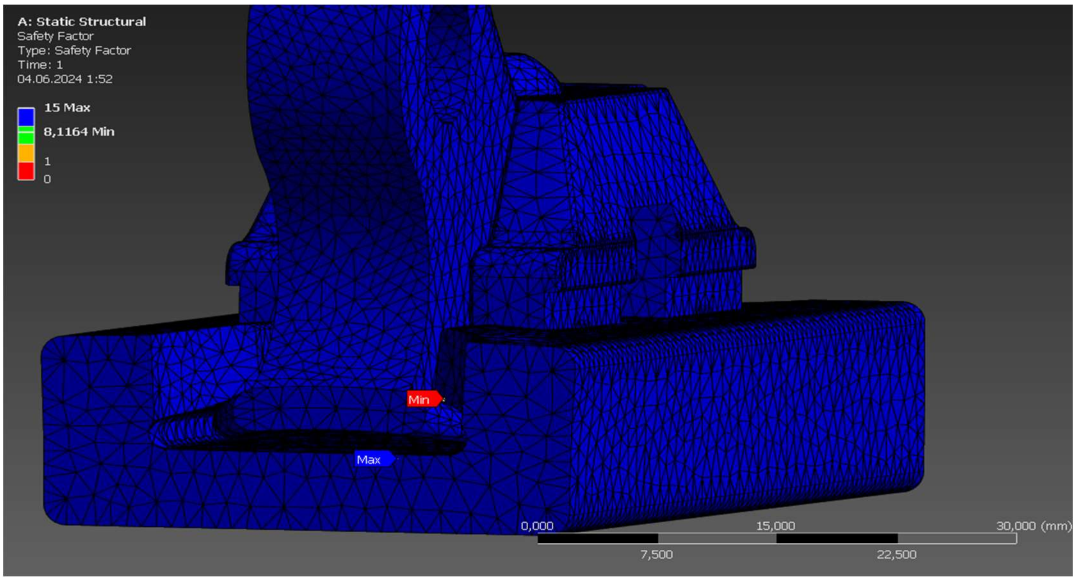


Fig. 3.10 Safety factor monitor

3.5 Layout

After picking medical equipment, making some calculation of strength next step is placing equipment in the cabin with the requirements.

It has to be mentioned that medical aviation didn’t have direct requirements and from plane to plane it should be discus with authorized people. This plane woudn’t have something specific in means of aviation or medical equipment so let’s follow overall rules for medical aviation. At first should provide enough place for injured and medical stuff in the plane so it will have following look:

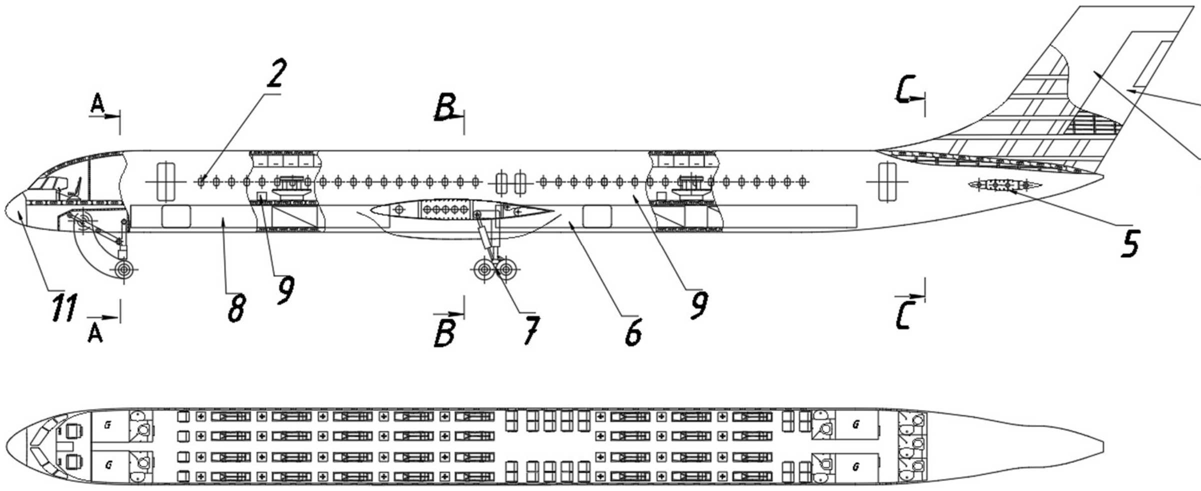


Fig. 3.11 Medical cabin layout

At figure 3.11 provided view of the medical airplane cabin layout. Spectrum benches is placed in means of providing much more space for medical stuff and maximised quantity of injured. Passage created in that way that here can simply pass peoples with stretcher and in flight 2 peoples can be in 1 passage simultaneously. Passenger seats placed for carrying such quantity of medical stuff that can make attention to each patient simultaneously or for some patients which health status is worsen and need help of more than 1 medic intended.

Then let's find out which equipment is required for medical care providing. It's need to be mentioned that all stuff which is carrying patients is for stable patients. But in case of worsen health status mid flight can be reanimation provided or some medical intervention. For this in overhead bins placed such a stuff: masks of various size, endotracheal tubes, nasopharyngeal duct, oropharyngeal duct, Ambu bag. For quick access near each bench installed locker where is bandages, bandage tape, tubes (nasogastric, Foley tubes, test tubes), gloves (sterile, disposable), droppers (solution, catheters, tubes). In this locker situated too the toolbox with procedure tray, laryngoscope, suture material, local anesthetics, syringes and needles [5].

3.6 Determination of the centering of the modified equipped fuselage

From calculation made in this part can be designated that center of gravity in the plane will change not significantly in comparison with previous one.

After analyzing the need for the medical equipment on the aircraft and all the conditions that surround the placement of these equipment, one of the most important factors that would need to be considered is the need to maintain the center of gravity of the aircraft. If there are variations in the weight distribution, then modification of the position of the landing gear or change of other equipment in the plane may be done to provide better balance for stable flight.

In the previous work, we assumed the mass of a patient to be 120 kg, while the medical bench to be 70 kg. Furthermore, we also have to consider the weight of full equipped lockers which are a bit over 20kg each. Adding to the total weight gain are the supply of ration and drinking water along with medical requirements kept in the lavatory and galleys.

Table 3.2

#	objects names	mass		C.G coordinates Xi, m	mass moment (kgm)
		units	total mass (kg)		
1	2	3	4	5	6
1	fuselage	0,093	12379,05	27	334234,4
2	horizontal tail	0,0087	1151,6	48,28	55599,3
3	vertical tail	0,00846	1119,8	49,9	55972,6
4	radar	0,0028	370,6	1	370,6
5	radio equipment	0,0021	277,9	1	277,9
6	instrument panel	0,0049	648,6	1,5	972,9
7	aero navigation equipment	0,0042	555,9	1,5	833,9
10	flight control system 70%	0,00364	481,8	29,5	14230,5
11	hydraulic system 30%	0,00456	603,5	28,3	17121,05
12	electrical equipment 90%	0,027	3573,9	26,85	95960,6
13	not typical equipment	0,004	529,4	4,15	2197,3
14	lining and insulation	0,0074	979,5	24,1	23670,1
15	anti ice system, 20%	0,003052	403,9	48,28	19504,4
16	airconditioning system, 40%	0,002616	346,2	24,165	8367,7
17	injured passengers mass 1st row	0,0166	2200	16,6	36520
18	spectrum benches 1st row	0,013	1800	16,6	29880
19	seats of flight attendance 1st row	0,0045	600	26,6	15960

1	2	3	4	5	6
20	attendants 1st row	0,021	2850	26,6	75810
21	injured passengers mass 2nd row	0,0099	1320	33,3	43956
22	spectrum benches 2nd row	0,0129	1680	33,3	55944
23	seats of flight attendance 2nd row	0,0012	160	38,9	6224
24	attendants 2nd row	0,0057	760	38,9	29564
25	seats of pilot	0,00022	30	2,56	76,8
26	emergency equipment	0,0075	1000	26,6	26600
27	lavatory1, galley 1	0,015	2000	6,3	12600
28	lavatory2, galley 2	0,027	3700	42,6	157620
29	operational items	0,018	2468,6632	26,85	66283,6
30	additional eguipment	0,011	1534,14512	3,43	5262,117762
31	equipped fuselage without payload	0,34	45525,061	26,175	1191613,892
32	on board medicine	0,0046	614	24,45	15012,3
33	cargo	0,037	4920	16,6	81672
34	cargo, mail	0,018	2459	16,6	40819,4
35	crew	0,0011	154	2,4	369,6
36	TOTAL	0,405	53672,061	24,771	1329487,192

Table 3.3

Calculation of center of gravity position variants

object	m_i	X_i, м	Mass moment(kgm)
equipped wing (without fuel and landing gear)	28425,50	21,05	598308,88
nose landing gear (extended)	1472,06	5,66	8334,83
main landing gear (extended)	3434,82	17,86	61345,84
fuel reserve	5192,80	22,59	117311,61
fuel for flight	36172,20	22,59	817174,20
equipped fuselage (without payload)	45525,06	26,17	1191613,89
passengers(economy)	3520	24,95	87824,00
on board meal	1200	24,45	29340,00
cargo	4920	24,04	118257,12
cargo, mail	2459	24,04	59104,52
flight attend	3610	32,75	118227,50
crew	154	2,40	369,60
nose landing gear (retracted)	1472,064528	4,7	6918,70
main landing gear (retracted)	3434,817232	24,4	83809,54

Estimations made in this section show that the displacement expected for the center of gravity does not differ much from the original design and stays within reasonable limits. This implies that any changes that would have to be made would need to cater for the stability of the aircraft as well as it’s its ability to flow through the air. However, the current computations seem to show signs of hope of the fact that the proposed medevac modifications do not have to be incorporated into the design of the aircraft so as to affect its design stability and performance in the process.

Conclusions to the special part

Lastly, this project successfully meets the goal of designing and developing a medium range aircraft which can be easily converted from passenger to medevac use and back. It is a new conception of transport aircraft based on the careful study of the current prototypes: Boeing 757, Airbus A321, Tupolev Tu-204 and combining the best traditions of these aircraft with some innovations in design solutions.

The developed aircraft has a capability of carrying up to 32 patients and has a well equipped, comfortable and efficient medical bay that has Spectrum Aeromed 2800 Series Modular Advanced Unit. This modern concept of a medical solution is boosted by the use of Ancra Rear Leg Ultra-Lightweight Titanium Seat Fittings to provide comfort and safety for a patient during transportation.

More important, complex calculations as to the aircraft's center of gravity that would take into account the additional weight of equipment and patients provide only a slight deviation from passenger configuration. This finding proves beyond reasonable doubt that the medevac conversion is feasible and ensures the aircraft is able to retain the basic flight rate and other critical operating margins as required in any of the identified applications.

This project takes the initiative of incorporating technology in the medical field in the efficiency of the aircrafts required for aeromedical evacuation as the global demand rises. As such, this aircraft is a convenient solution which can easily be modified to meet specific operational requirements; therefore, it is most useful to healthcare facilities, rescue teams, and governments from all over the world, which are mainly aimed at enhancing patient care and saving lives.

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GENERAL CONCLUSIONS

The first part of this thesis focused on a critical review of various aircraft prototypes where the details of design features and performance specifications as well as trends in technology were examined with utmost care. This kind of detailed study proved very helpful in determining what kind of engineering approach is best for the projected medium-haul plane. But as the design of the rocket evolved and the specifics of its payload became more concrete, it was realized that the rocket would need increased thrust in order to meet the goals set for it. This realization led to the strategic selection of the Pratt & Whitney PW4000 engine, which offers more power, efficiency, and reliability than many other engines. This decision on choosing the engine is not only significant to provide the necessary thrust for the airplane, but is also critical in terms of efficiency and functionality of the aircraft. As the second part of the thesis, the process continued with the development of a first external concept of a medium-range passenger aircraft based on findings from the analysis of the prototypes. As the new aircraft can carry up to 246 passengers, it can also rival such models as Airbus A321 and Boeing 757. However, the proposed design stands out as more appropriate since it incorporates an extended operational range, especially when fully laden with passengers. This is a nice step as it opens the possibility of new routs and customer base for the plane. Moreover, due to the design nature, the improvements in the future and loading capacity changes are possible, which can provide an even greater reach, comparable with or higher than that of contemporary airplanes in its category. Medevac Aircraft Design and Configuration: The thesis also applies the solutions to the broader context of medevac while emphasizing the lack of effective solutions to the transport issue. In this particular specialized section, as well as a well thought out format, are provided for a medevac aircraft that will carry a total of 32 injured people. The choice of the Spectre 2800 medbench is the advanced medical module, which will help to provide the necessary care to patients during the transportation process.

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9. Авіаційна та ракетокосмічна техніка: методичні рекомендації до виконання кваліфікаційної роботи / уклад: С. В. Хижняк, М. М. Свирид, Т. П. Маслак, В. С. Краснопольський// - К.: НАУ, 2022. – 48 с.

Основи авіації (вступ до спеціальності): підручник / С. Р. Ігнатович, О. В. Попов, В. О. Максимов та ін.// - К.: НАУ, 2023. – 296 с.

Appendix

Appendix A

INITIAL DATA AND SELECTED PARAMETERS

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Performed by: Kostianetskiy Maksym
Supervisor: Zakiev Vadim

                       PRELIMINARY DESIGN OF THE AIRCRAFT
                      INITIAL DATA AND SELECTED PARAMETERS

Passenger Number                                                    250.
Flight Crew Number                                                   2.
Flight Attendant or Load Master Number                               7.
Mass of Operational Items                                          2469.12 kg
Payload Mass                                                      26125 kg

Cruising Speed                                                      850.   km/h
Cruising Mach Number                                                  0.787
Design Altitude                                                      10.00 km
Flight Range with Maximum Payload                                  5500.   km
Runway Length for the Base Aerodrome                                  2.95 km

Engine Number                                                         2.
Thrust-to-weight Ratio in N/kg                                        2.3000
Pressure Ratio                                                       32.50
Assumed Bypass Ratio                                                  5.00
Optimal Bypass Ratio                                                  5.00
Fuel-to-weight Ratio                                                  0.320

Aspect Ratio                                                          7.89
Taper Ratio                                                           5.00
Mean Thickness Ratio                                                  0.120
Wing Sweepback at Quarter Chord                                      29.0  deg
High-lift Device Coefficient                                          1.05
Relative Area of Wing Extensions                                      0.050
                       Wing Airfoil Type - Supercritical
                       Winglets          - Yes
                       Spoilers          - Yes

Fuselage Diameter                                                     3.76 m
Fineness Ratio                                                       12.60
Horizontal Tail Sweep Angle                                          36.0  deg
Vertical Tail Sweep Angle                                            38.0  deg


                CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point          0.44807

Induce Drag Coefficient                                               7.60000

            ESTIMATION OF THE COEFFICIENT    Dm = Mcritical - Mcruise
Cruising Mach Number                                                  0.78701
Wave Drag Mach Number                                                 0.79836
Calculated Parameter Dm                                               0.01135

Wing Loading in kPa (for Full Wing Area):
                           At Takeoff                                 6.163
                           At Middle of Cruising Flight               5.162
                           At the Beginning of Cruising Flight        5.352
```

```
Drag Coefficient of the Fuselage and Nacelles                         0.44807
Drag Coefficient of the Wing and Tail Unit                            0.00914

Drag Coefficient of the Airplane:
                           At the Beginning of Cruising Flight        0.78701
                           At Middle of Cruising Flight               0.03051
Mean Lift Coefficient for the Ceiling Flight                          0.44807

Mean Lift-to-drag Ratio                                              14.68455

Landing Lift Coefficient                                              1.574
Landing Lift Coefficient (at Stall Speed)                             2.361
Takeoff Lift Coefficient (at Stall Speed)                             1.984
Lift-off Lift Coefficient                                             1.422
Thrust-to-weight Ratio at the Beginning of Cruising Flight            0.619
Start Thrust-to-weight Ratio for Cruising Flight                      2.330
Start Thrust-to-weight Ratio for Safe Takeoff                         3.127

Design Thrust-to-weight Ratio                                         3.283

Ratio  Dr = Rcruise / Rtake-off                                       0.745


                    SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):
                 Takeoff                                             36.3619
                 Cruising Flight                                     58.7076
                 Mean cruising for Given Range                       64.0085

                             FUEL WEIGHT FRACTIONS:
                                        Fuel Reserve                  0.03923
                                        Block Fuel                    0.27327

                      WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:
                        Wing                               0.08952
                        Horizontal Tail                    0.00870
                        Vertical Tail                      0.00846
                        Landing Gear                       0.03707
                        Power Plant                        0.09801
                        Fuselage                           0.09352
                        Equipment and Flight Control       0.12466
                        Additional Equipment               0.01159
                        Operational Items                  0.01865
                        Fuel                               0.31250
                        Payload                            0.19737

                Airplane Takeoff Weight               132368.   kgf
        Takeoff Thrust Required of the Engine            217.30 kN

Air Conditioning and Anti-icing Equipment Weight Fraction             0.0218
Passenger Equipment Weight Fraction
(or Cargo Cabin Equipment)                                            0.0152
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction       0.0074
Furnishing Equipment Weight Fraction                                  0.0142
Flight Control Weight Fraction                                        0.0052
Hydraulic System Weight Fraction                                      0.0152
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Electrical Equipment Weight Fraction                                  0.0300
Radar Weight Fraction                                                 0.0028
Navigation Equipment Weight Fraction                                  0.0042
Radio Communication Equipment Weight Fraction                         0.0021
Instrument Equipment Weight Fraction                                  0.0049
Fuel System Weight Fraction                                           0.0094

           Additional Equipment:
Equipment for Container Loading                                       0.0076
No typical Equipment Weight Fraction                                  0.0040
(Build-in Test Equipment for Fault Diagnosis,
Additional Equipment of Passenger Cabin)

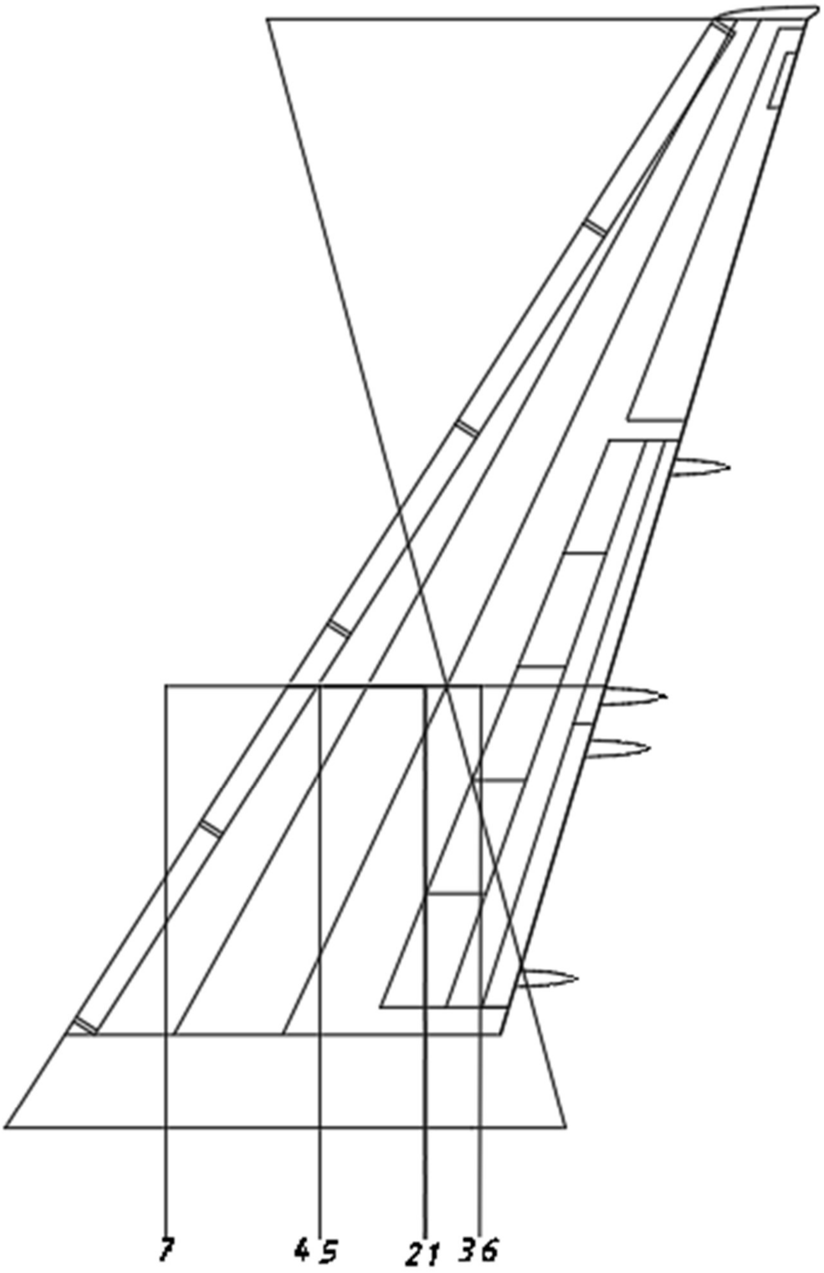
           TAKE-OFF DISTANCE PARAMETERS
Airplane Lift-off Speed                                             299.68 km/h
Acceleration during Takeoff Run                                       2.60 m/s*s
Airplane Take-off Run Distance                                     1330.   m
Airborne Take-off Distance                                          578.   m
Take-off Distance                                                  1908.   m

           CONTINUED TAKE-OFF DISTANCE PARAMETERS
Decision Speed                                                      284.70 km/h
Mean Acceleration for Continued Take-off on Wet Runway                0.37 m/s*s
Take-off Run Distance for Continued Take-off on Wet Runway         2088.28 m
Continued Take-off Distance                                        2666.66 m
Runway Length Required for Rejected Take-off                       2760.77 m

           LANDING DISTANCE PARAMETERS
Airplane Maximum Landing Weight                                   101626.   kg
Time for Descent from Flight Level
till Aerodrome Traffic Circuit Flight                                20.8  min
Descent Distance                                                     49.19 km
Approach Speed                                                      268.37 km/h
Mean Vertical Speed                                                   2.13 m/s
Airborne Landing Distance                                           524.   m
Landing Speed                                                       253.37 km/h
Landing run distance                                                852.   m
Landing Distance                                                   1376.   m
Runway Length Required for Regular Aerodrome                       2298.   m
Runway Length Required for Alternate Aerodrome                     1954.   m

           ECONOMICAL EFFICIENCY
The equipped aircraft mass to payload mass ratio                  2.4249
The mass of empty equipped aircraft per 1 passenger             253.40   kg/p
Relative performance with full load                             433.39   km/h
Aircraft performance with maximum payload                     21222.3    kg*km/h
Average time fuel consumption                                  5342.543  kg/h
Average distance fuel consumption                                 6.58   kg/km
Average fuel consumption for ton-kilometer                      251.742  g/t*km
Average fuel consumption for passenger-kilometer                 23.2121 g/p*km
Approximate evaluation of relative expenses for ton-km            0.3375 $/t*km
```

Appendix B



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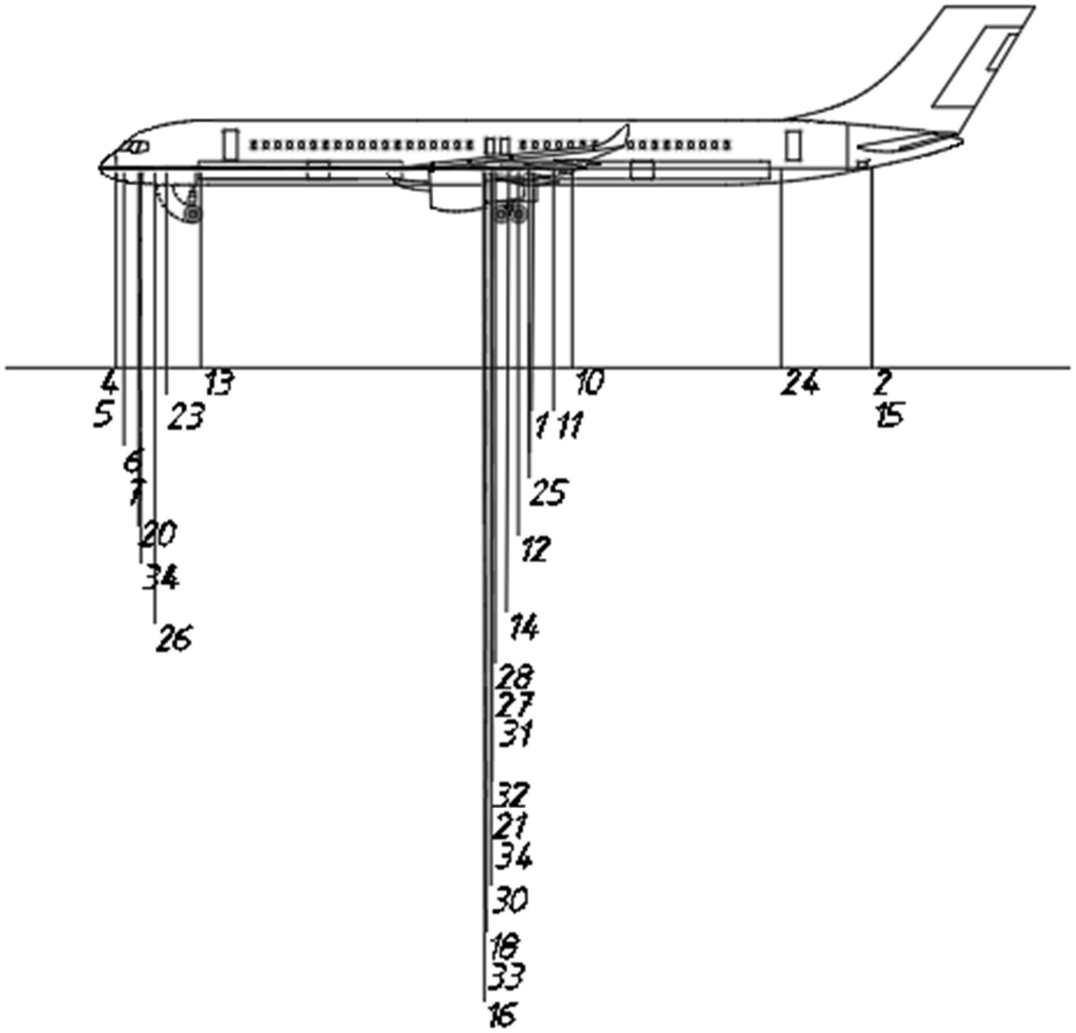
Ch.	Sheet	Document #	Sign.	Date	Center of gravity of the wing	Letter S	Weight	Scale 1:125
Performed		Kostyanetskiy R.O.					
Checked		Zakiev V.I.				Sheet 1	Sheets 1
Reviewed		Krasnopolskyi V.S.			Appendix B	404 ASF 134	
Approved		Yutskevych S.S.					

Appendix C



NAU 23 07K 00 00 00 36

Ch.	Sheet	Document #	Sign.	Date
Performed		Kostyanetskiy R.O.		
Checked		Zakiev V.I.		
Reviewed		Krasnopolskyi V.S.		
Approved		Yutskevych S.S.		

Center of gravity of the fuselage

Letter	Weight	Scale

Sheet 1 | Sheets 1

Appendix C

404 ASF 134