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Feasibility study for an air ambulance in the Russian Federation

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Abstract

Objectives: This study aims to evolve a complete set of specifications and requirements for a viable air ambulance to benefit several nations across the globe. This article tries to explore the possibilities of constructing an aircraft that can meet identified requirements based on emerging technologies and existing technologies in the fields of aeronautical engineering. **Methodology:** The analysis is presented concerning the dynamic capabilities of the Russian aviation industry and the domestic needs of the Russian Federation to justify why the development of an air ambulance is feasible in Russian Federation. Design layouts of existing medical aircrafts are studied to identify constraints related to operations, manufacturing, finances, performance, safety, and other practical issues. This feasibility study studies the need for the development of air ambulance in the Russian Federation using PESTEL analysis. **Findings:** Based on the study, it is identified that the incidents in the existing air medical services have occurred not just because of the management and operational issues, dealing with several uncertain external factors but also due to the lack of some characteristics of the flight vehicles to operate in those conditions. These characteristics are identified and listed as requirements in this article. Two possible configuration layouts are identified and compared for their merits and demerits.

Keywords: Air medical services; Safety; Feasibility study; Flight characteristics; Design requirements

1 Introduction

1.1 Overview of the health care system in the Russian Federation

According to the report of Health Systems in Transition (HiT series) by WHO (World Health Organization), the Russian federation inherited its health-care system from the Semashko system. Since 1996, the Constitution of the Russian Federation has provided all citizens the right to free healthcare. Expenditure on healthcare was 5 to 6.5% of the Gross Domestic Product, which is considerably low compared to the EU countries and G8 countries. Russia has the highest doctors per capita among the members of the former Soviet Union. However, the number of primary health centers shut-down has increased in the past two decades. The increasing inequality among the urban and rural

populations in socio-economic conditions, migration, climatic conditions, and demographics have a significant influence on the public health-care system.⁽¹⁾

1.2 Statement of the problem

1.2.1 Demographics

Russian population density is diverse. [Figure 1](#) illustrates the distribution of the population, along with its territory. Therefore, densely populated regions have better hospitals and health care services compared to other areas.⁽¹⁾

[Figure 1](#) also shows the categorization of the Russian Federation based on population density and the need for medical services to the regions where the population density is scarce and geographically present challenges with logistics.



Fig 1. Population density of Russian Federation by Strategic Forecasting, Inc., 2017

1.2.2 Infrastructure

Lack of high-end medical equipment and resources—both financial and materials—is one of the reasons for customer dissatisfaction. There are a lot of primary health centers spanning all around the nation. However, due to the viability issues, a lot of these primary health centers are being shut off. Most of the prevailing health centers suffer from inadequate resources and funding to treat patients (especially outpatients) for chronic diseases, trauma care, sophisticated surgeries, and other cases that require facilities of a super specialty or multi-specialty hospitals. Thus, the accessibility of such facilities to the people living in moderately populated and sparsely populated regions is low.⁽¹⁾

1.2.3 Economic Viability

Government agencies at the municipality, state, and federal levels face viability issues due to financial constraints. Naturally, metropolitan cities and urban areas experienced such progress as they are densely populated. Thus, the drastic inequalities of

health care between various regions emerged and continue to increase.⁽¹⁾

1.2.4 Remarks

In an attempt to resolve the above-mentioned problems in the health care system of the Russian Federation, and to identify a viable solution, AMS (Air Medical services) is feasible. As the statistics are on average per capita, the health care system of the rural population is not evident in statistics. Though there are several aspects to the issues, the listed are those that can influence the design layout, mission profile, and operating framework of the AMS.

1.2.5 Air Medical Services

Air Medical Services (AMS) is the utilization of aviation technology in the health care system. AMS typically consists of the transportation of the medical team or patients to and fro health centers while delivering emergency medical services on transit.⁽²⁾ Use of the air transport that will provide emergency medical care on a battle traces back to World War I, and during the Korean and Vietnam wars, its importance became significantly increased.⁽³⁾ Aircraft subsequently began to be used in the domestic and commercial emergency medical services. Aircraft can move much faster as well as start operating in a broader area of coverage than land ambulances. Standard air ambulance equipment includes medications, ventilators, EKGs/ECGs and monitoring devices, CPR machines, and stretchers.⁽⁴⁾ Air ambulances have distinct advantages over land ambulances. They are:

1. They can operate in diverse climatic conditions and less densely populated regions.
2. They have significant importance in disaster management and humanitarian missions.

2 Aircrafts in AMS

Table 1 shows a few of the AMS around the world and their fleet and operations.

Table 1. List of air ambulance services those are studied in-order to acquire design requirements

S.No	Organization	Services	Operations	Fleet
1	Acadian Ambulance Air Medical Services	Providing Pre-hospital Emergency Care and patient transportation near Louisiana and Texas	Domestic & off-shore	EC-135 & EC-145 helicopters
2	Aerocare Air Ambulance Service, Inc	Air ambulance transportation, medical air flights, medevac flights, medical evacuation, medical repatriation, and commercial medical escorts	Domestic & International	Learjet air ambulances
3	Aero-Dienst GmbH & Co. KG	Transfer of Patients with state of medical facilities	Domestic & International	Dornier 328Jet-BADA , Learjet 60XR, King Air 350
4	Air Rescuers World Wide Pvt.Ltd	Medical Escort and patient transport services	Domestic & International	King Air B200, Bombardier Challenger 604, Agusta 109C, Hawker 700

Private companies own most of the air ambulance services across the globe. Some government agencies work on a contractual basis with these civilian air medical service providers. Multipurpose aircraft for military air medical services and evacuation programs are economically viable to the local governments. Air ambulances either helicopter or an aircraft operates more like a private jet with few exceptions as specified by the regional aviation authority.

The study of the existing design shows that most air ambulances are either helicopters or fixed-wing aircraft. An air ambulance is typically the passenger or military aircraft with modified interiors and added medical equipment. The usage of helicopters is limited to patient transportation. Fixed-wing aircraft, when compared to helicopters, present more operational capabilities. However, they need landing and take-off facilities like runways or pavements. Whereas helicopters have access to diverse terrain and have VTOL functions. However, helicopters cannot have an isolated interior environment or controlled environment system like a fixed-wing aircraft. It is increasingly difficult to diagnose and treat patients in the helicopter due to noise and vibrations. Patients do exclaim a degree of discomfort with helicopters.⁽⁵⁾ Few manufacturers developed air ambulances with STOL characteristics. Unmanned aerial vehicles role has been increasing in the transportation of medical products like blood from blood banks to the hospitals, first-aid kits to the localities faster than ambulances which increase the response

time⁽⁶⁾. However, to fully supplement emergency medical services, the inevitable need to have paramedics and skilled medical professionals rule out the option of drones for this case study.

2.1 Challenges

- **Cost:** A public health system obtains its financial resources from the government budget and spends most of its allocated budget for salaries, medicines, maintenance of buildings, vaccination, awareness programs, and other programs. Fixed-wing aircraft and helicopters are expensive to purchase or produce compared to automobile ambulances. The operating and maintenance costs of aircraft are comparatively high for several governments. Besides, charges incurred by airports and demographics make AMS liable for governments. While many governments suffer from inflation and budget allotments to public health care are notably low, it would be impractical to purchase aircraft and maintain them. Although, few air medical services receive funds from donors and several others charge fees from patients.⁽⁷⁾ In either way, cost-effectiveness is a major concern to establish and organize air ambulances.
- **Viability:** In some cases, the results of both air medical services and ground-based services remain the same. A notable example is London's Helicopter Emergency Medical Service. Therefore, it is important to identify the areas of operation and the viability of air medical services for that region as the cost of ground-based services are a lot cheaper than the air medical services. The improper choice regarding the region of operation can affect the ability of air ambulances to accomplish its mission financially, and this eventually threatens the survival of air ambulances in the health care system.
- **Incidents:** The number of flight crash incidents are increasing proportionally along with the air ambulances across the globe. To an extent, these crashes have become accepted as the aircraft and helicopters operate at the edge of their flight envelope.⁽⁸⁾ Operation of an aircraft or a helicopter in unfavorable weather conditions, demographic conditions like hill stations can lead to such tragic incidents.⁽⁹⁾ United States NTSB (National Transportation Safety Board) concluded that many air ambulance accidents could be avoided in 2006 as 50 % of deaths in air ambulances were due to crashes. This eventually led to an improvement in government standards and CAMTS (Commission on Accreditation of Medical Transport Systems) accreditation.
- **Regulatory guidelines & Laws:** The civil aviation laws among several nations around the world consider an air ambulance as a passenger or commercial aircraft. Although an air ambulance is a civilian aircraft, their operational purposes are quite different from typical passenger aircraft or business jet. Nevertheless, there is an ambiguity in civil aviation. As per RMT.0296 Review of airplane performance requirements for CAT operations conducted by the European Aviation Safety Agency, 6 out of 10 airline operators reported that there is inconsistency or missing elements in the current rules on the determination of flight performance for safety.⁽¹⁰⁾ The environmental laws, at times, restrict the development of infrastructures like runways and airports. In certain areas like dense forests, hill stations, river valleys, and other regions, where the population density is low and there is a definite need for air medical services are inoperable due to such laws.

3 Discussion

3.1 Necessity of AMS

Russian Federation has a divergent topology, lack of resources, environmental, and climatic obstacles to develop and maintain infrastructure due to irregular population distribution. From the survey of existing services and designs, it is evident that air ambulances help to reach out to the unreached section of the society. It is their right to receive medical help. It is equally a responsibility of governments and the engineering community to supplement them with the necessities. After all, aviation technology is for people, not for war. Thus, air ambulance services, when operated with the hub-spoke technique, can yield positive results and meet the contemporary needs of a particular region. Here, a hub is a typical area with landing and take-off facilities along with well-equipped hospitals. The spoke is a scarcely populated area where services have to be delivered.

However, concerning the resources of an organization, the air ambulance should be cost-effective to procure and maintain. The viability of air ambulances services depends on effective management and resource sharing. The main objective of an air ambulance should share human resources like doctors, paramedics, aviation experts, and others along with expensive medical equipment to benefit more sections of societies. So local governments and policymakers along with experts from the civil aviation industry, finance, and public health sectors must devise effective regulations and administrative policies. They vary from country to country.

3.2 Marketability of AMS

The development of a cost-effective air ambulance has significant market growth. Globally increasing air ambulance services indicate the requirement of specially designed air ambulance unlike modified passenger or civil aircraft with medical equipment. There are many economically struggling countries in Africa, Asia, and South America. These countries neither have enough skilled professionals nor resources and infrastructure to meet their societal needs. Moreover, to establish a fully functioning public health care network will take decades. Thus, the design of an air ambulance with due respect to the economic conditions of Russia will be appealing to many of these countries, which have a similar economic and public health care system. The need for more effective aircraft in the European countries, the United States of America, Canada, and Australia is evident from the alarming increasing incidents every year. Moreover, an acceptable design for the Russian Federation can be easily adaptable to many global conditions.

Thus, there is a need for air ambulances across the world, and designing an aircraft for the Russian Federation is feasible in terms of marketability globally. It will also contribute to financial benefits. The Russian aerospace industries are one of the best and cost-effective aircraft manufacturers across the world. Thus, Russian aerospace companies have a dynamic capability in terms of political, technological, and economic aspects for both designing a cost-effective and performance-oriented air ambulance.

4 Design requirements

Section 2.1 identifies the setbacks in the existing air ambulances. Due to the aforementioned reasons in section 2, helicopters are an omitted configuration layout.

4.1 Safety

- **Safety Envelope:** The safety envelope of an air ambulance is very different from a passenger jet or a military helicopter. The utilization of a passenger jet or military aircraft with the mere installation of medical systems comes with its limitations. Because of the design and mission profile of these air ambulances. They are designated to travel from one facility to another facility where all the suitable conditions for landing and take-off are available. When the air-crafts have to fly to a location without any landing or take-off facilities or into a hostile environment for flight operations, there is often a breach in its safety envelope. Thus, there is a need for aircraft to have additional systems like the anti-icing system and systems that ensure laminar flow around the aircraft even while operating at extreme climatic conditions. There is a need for a smooth thermal boundary layer and velocity layers over the aircraft to avoid turbulence and crashes.
- **Aerodynamic Shaping & Sizing:** The air ambulance must-have capabilities glide in case of any engine failures. Higher aerodynamic efficiency and gliding features for an aircraft affect its manufacturing cost. Military aircraft uses overpowered engine configuration to perform maneuvers, and passenger aircraft design contains an optimum range for payload carrying capability. Thus, they may not suffice the aerodynamic characteristics of an air ambulance.

4.2 Cost-effectiveness

- **Power plant:** The power-plant of air ambulance needs to supplement all the electric energy required for medical equipment for diagnosis and treatment. It will exert an additional load on the generator and subsequently increases the specific fuel consumption of the engines. Notably, this is one of the reasons for the helicopters to suffer crashes. Helicopters rely on the rotor blades to generate sufficient lift force to make the helicopter airborne. When the additional load exerts on the engine while operating at the edge of its safety envelope increases the probability of fatal incidents. As the maximum ceiling altitude of aircraft is nearly 10,000 ft, turboprop or turbofans will be more efficient.
- **DFMA:** The design of the air ambulance system should be incorporated with the design for manufacturing and assembly guidelines to make the manufacturing process more cost-effective. The design during the detail design phase should emphasize on the assembly process and must incorporate mostly with commercially off-the-shelf components. As commercially off the components are part of batch production and mass production, they can reduce the manufacturing costs. It will also increase the availability of spares for repair and maintenance.
- **Infrastructure:** The operations of air ambulances need landing and take-off facilities. They are not just expensive to construct and maintain, at certain localities, they present more challenges to develop.

4.3 Performance Requirements

The study suggests the performance requirements of an air ambulance. These requirements are contradicting as one can see an air ambulance must have high control & stability while capable of performing VTOL/STOL. VTOL/STOL are characteristics of a highly maneuverable flight. But high maneuvers can increase 'G-load' over a patient on-board. At the same time aircraft must be an amphibian aircraft to reach more destinations. But an amphibian aircraft contributes to additional weight and has less aerodynamic efficiency compared to conventional aircraft. As the aircraft must glide in case of an engine failure, this needs high aerodynamic efficiency. The aircraft must have high fuel efficiency and safety criteria. But fuel efficiency affects the VTOL/STOL characteristics. As the number of features and systems is directly proportional to the SFC of the engines, this contributes to low fuel efficiency. Moreover, from the requirements, it is evident the design of aircraft requires significant R&D work. It incurs both time and cost overs. Thus, this is a challengingly complex work.⁽¹¹⁾ It involves very rigid trade studies that require precision to great accuracy.⁽¹²⁾

Figure 2 illustrates the mission profile of the desired air ambulance and its mission segments are:

MAIN MISSION

- A: Start
- A-B: Warm-up
- B: Lift-off
- B-C: Climb
- C-D: Cruise
- D-S: Descent
- S: Loiter
- E: Approach
- E-F: Landing

GLIDING AT EMERGENCY SITUATION

- K-L : Transit
- L: Gliding

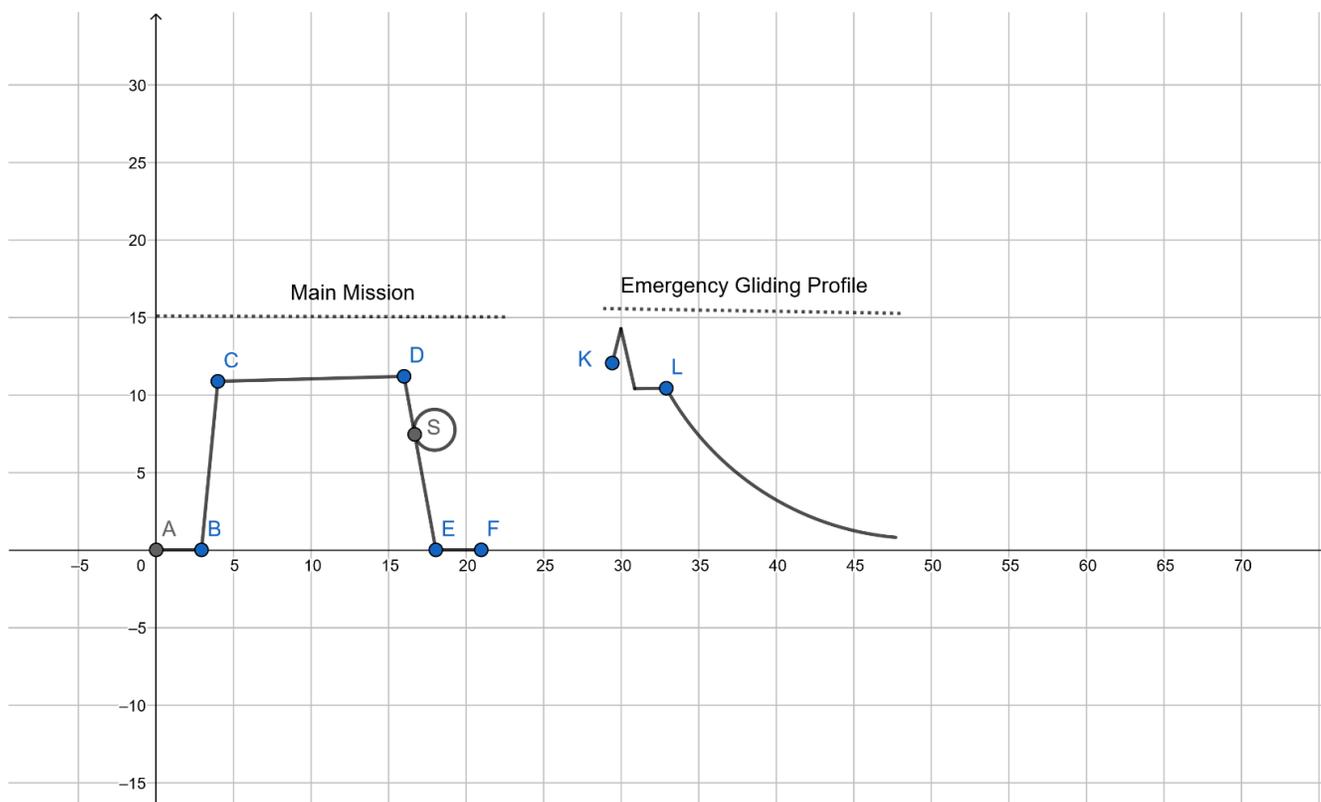


Fig 2. Mission profile of the air ambulance

Table 2. Required performance characteristics

S.No	Factors	Requirements
1	takeoff and landing	VTOL/STOL
2	rate of climb	Faster rate of climb
3	ceiling	Low altitude -10,000 to 13,000 ft
4	range	Long range
5	speed	Sub-sonic $M=0.6$
6	maneuverability	Moderate
7	stability & Control over the ambient conditions	Considerably good
8	fuel economy	High
9	Payload	Crew, Paramedics & Emergency medical dispatch kits = 1000-1200 Kg

5 Configuration Layout

So, there are two configurations that are practically designable for all the requirements. They are:

1. Fixed-wing amphibian aircraft with VTOL/STOL capabilities
2. Hybrid aerostats

The selection of the configuration is performed based on the technical feasibility of the conceptual design, development time, manufacturability, trade-offs, and the possibility of satisfying all requirements. Conceptually both configurations are capable of satisfying the requirements of an air ambulance.

However, to "what extent?" is the question. Which of them is more reliable? To answer these questions analysis is required by considering extant technologies, emerging technologies in the field along the rate at which they are developing. Table 3 presents a brief comparison of these configurations.

Table 3. Comparison of feasible configurations

Parameter	Fixed-wing amphibian aircraft VTOL/STOL	Hybrid aerostats
Extant literature	The history of amphibian aircraft is 100 years old. It helps to design, troubleshoot, certify, and regulate them.	Hybrid aerostats are relatively new concepts, and most of them are still in prototype stages.
Need for research	It is low, and this configuration mainly needs the integration of emerging technologies like automation, manufacturing technologies, aircraft systems, communications, control systems, and thrust vectoring with existing aerodynamic characteristics of amphibian aircraft.	It is high as hybrid aerostats data about its performance in various seasons and environments along with its control-ability, payload load capabilities, materials, maneuverability, system integration are widely unavailable.
Development time	7 to 10 years to produce a completely certifiable aircraft.	Given the current rate of progress in the research and civil aviation regulations, it is indeterminable.
Manufacturability & Assembly	Moderate to complex with existing manufacturing techniques.	Relatively simple compared to fixed-wing amphibian aircraft.
Durability	Longer & predictable based upon detail design.	Shorter as materials used for buoyant lift force have relatively less mass and durability than metals or composites.
Product Life Cycle Management	There are a lot of theories, methods, and strategies for effective management of the fixed-wing aircraft's life-cycle. The number of components and systems makes the whole process tedious.	Hybrid aerostats have fewer components, processes and systems. They are relatively less tedious and it is easy to manage their life cycle.

Thus, an amphibious aircraft or a hybrid aerostat as an air ambulance will reduce the necessity of landing and take-off facilities areas closer to rivers, lakes, and oceans. However, if they are unable to move or land vertically, they contend favorably with helicopters for some tasks and do so at a significantly lower cost. Amphibious aircraft can be much quicker and have a longer range than similar helicopters, and can cover almost a range as ground-based aircraft. Fixed-wing amphibious aircraft are fitted with retractable wings and acquire buoyancy by designing fuselages like a hull of a boat or ship. However, this comes at the cost of extra weight and size, with fuel economy relative to land or water-only aircraft.

6 Conclusion

Finally, this feasibility study concludes that existent air ambulances are not as effective as they need to be. It is due to the lack of certain characteristics that an aircraft must inherently possess to be an air ambulance and to carry out the mission successfully.

Thus, it can be concluded amphibian aircraft with VTOL/STOL capabilities, and Hybrid aerostats are more viable to be used as an air ambulance. It is economically more beneficial to the masses if such projects are undertaken and regulated by governments as the necessity to generate profits is considerably low. Considering Russian political policies regarding the health-care system, the dynamic capabilities in aerospace manufacturing sectors and societal needs, the development of air ambulance will benefit the Russian Federation as well as global communities.

The study presented in this article identifies two aircraft configurations from existing literature and emerging technologies. However, it is observed that requirements are quite contradicting and need rigid trade-off studies. Thus, an efficient design process and design strategies have to be identified to develop a viable air ambulance.

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