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On the issue of creating a basic list of hazards associated with the activities of the developer of a promising supersonic civil aircraft

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Abstract: Currently, Russia has various documents, approved by government decrees, aimed at improving regional air transport connectivity and population mobility. One of the ways to address this issue could be the development of a new supersonic civil aircraft. Among the many challenges associated with the design, manufacture, and operation of such aircraft, an important place is occupied by the problem of ensuring flight safety, which is addressed through the development and implementation of flight safety management systems by developers, manufacturers, and operators of civil aircraft. This list should be based on an analysis of operational experience with supersonic civil aircraft, a study of the characteristics of supersonic flight, and familiarization with supersonic civil aircraft designs. Operational risks are inextricably linked to risks arising during the development and manufacture of the aircraft. Therefore, this paper attempts to create a basic list of hazards associated with the activities of a developer of a promising supersonic civil aircraft. An analysis of the design and operation of supersonic civil aircraft, based on open sources, revealed specific phenomena occurring during supersonic flight that must be considered when developing a list of hazards. Such phenomena include wave drag, rearward shift of the center of pressure and aerodynamic center (focus), reduced effectiveness of lifting surfaces, sonic boom, and others. When developing a list of hazards associated with the developer's activities, it should be taken into account that the developer must ensure the release of documentation for the manufacture of an aircraft with airworthiness no lower than that specified in the Airworthiness Standards. However, the currently applicable Airworthiness Standards for transport category aircraft do not take into account the specifics of aircraft operation at supersonic speeds, which is one of the sources of hazards. Therefore, this paper proposes a tentative basic list of hazards, sources, and threats during the development of supersonic civil aircraft that directly impact its operation. Risk assessment should be performed directly within the operator's organization using the procedures and tools approved in its Flight Safety Management System.

Keywords: supersonic civil aircraft, flight safety, flight safety management system, hazard, hazard source, flight safety risks, threat.

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К вопросу создания базового перечня факторов опасности, связанных с деятельностью разработчика перспективного сверхзвукового гражданского самолета

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Аннотация: В настоящее время в России существуют различные документы, утвержденные постановлениями Правительства Российской Федерации, направленные на повышение авиатранспортной связанности регионов и мобильности населения. Одним из способов решения данной задачи может стать создание нового сверхзвукового гражданского самолета. Среди многих вызовов, связанных с проектированием, изготовлением и эксплуатацией таких самолетов, важное место занимает проблема обеспечения безопасности полетов, что решается с помощью разработки и внедрения систем управления безопасностью полетов разработчиков, изготовителей и эксплуатантов гражданских воздушных судов. Важным условием эффективного управления рисками при эксплуатации сверхзвукового гражданского самолета является наличие полного перечня факторов опасности, их источников и угроз. Его разработка должна основываться на анализе опыта эксплуатации сверхзвукового гражданского самолета, изучении особенностей сверхзвукового полета, ознакомления с проектами сверхзвуковых гражданских самолетов. Риски при эксплуатации неразрывно связаны с рисками, возникающими при разработке и изготовлении самолета. В связи с этим в настоящей работе сделана попытка создания базового перечня факторов опасности, связанных с деятельностью разработчика перспективного сверхзвукового гражданского самолета. Анализ особенностей конструкции и эксплуатации сверхзвукового гражданского самолета, выполненный на основе открытых источников, показал, что существуют специфические явления, возникающие при сверхзвуковом полете, которые необходимо учитывать при разработке перечня факторов опасности. К таким явлениям относятся: волновое сопротивление, сдвиг центра давления и фокуса назад, уменьшение эффективности несущих поверхностей, звуковой удар и др. При создании перечня факторов опасности, связанных с деятельностью разработчика, следует учитывать, что разработчик должен обеспечить выпуск документации для изготовления воздушного судна, обладающего летной годностью на уровне, не ниже заданного в нормах летной годности. Однако действующие в настоящее время Нормы летной годности самолетов транспортной категории не учитывают особенности эксплуатации самолетов на сверхзвуковых скоростях полета, что является одним из источников факторов опасности. В связи с этим в настоящей работе предложен примерный базовый перечень факторов опасности, источников и угроз при разработке сверхзвукового гражданского самолета, непосредственно влияющих на его эксплуатацию. Оценка же риска должна выполняться непосредственно в организации эксплуатанта с использованием утвержденных в его Системе управления безопасностью полетов процедур и инструментария.

Ключевые слова: сверхзвуковой гражданский самолет, безопасность полетов, система управления безопасностью полетов, фактор опасности, источник фактора опасности, риски для безопасности полетов, угроза.

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Introduction

The State Program "Scientific and Technological Development of the Russian Federation" approved by Decree No. 377 of the Government of the Russian Federation dated March 29, 2019; the Transport Strategy of the Russian Federation until 2030 with a forecast for the period up to 2035, approved by Directive No. 3363-r of the Government of the Russian Federation dated November 27, 2021; and the Comprehensive Program for the Development of the Air Transport Industry of the Russian Federation until 2030, approved by Directive No. 1693-r of the Government of the Russian Federation dated June 25, 2022, set the task of increasing the air transport connectivity of regions and the mobility of the population. One way to solve this task could be the creation of a new supersonic civil aircraft [1].

Despite certain problems that led to the cessation of operation of the supersonic civil aircraft Tupolev 144 and Concorde, work aimed at creating supersonic aircraft continues both in Russia and abroad [2–16].

Among the many challenges associated with the design, manufacture, and operation of advanced supersonic civil aircraft, flight safety occupies a significant place. At the current stage, flight safety issues are resolved through the development and implementation of Safety Management Systems (SMS) by all major air service providers.

Having an SMS that complies with Russian aviation legislation, which is based on ICAO Standards and Recommended Practices (SARPs), is mandatory in the Russian Federation for developers, manufacturers, and operators of civil aircraft, including supersonic civil aircraft. Developing such an SMS will require addressing a number of important methodological issues.

A key requirement for effective safety risk management during the operation of supersonic civil aircraft is the availability of a complete list of hazards, their sources, and threats. Currently, such a list does not exist.

Its development should be based on additional analysis of supersonic civil aircraft operating experience, a study of the characteristics of supersonic flight, and familiarization with supersonic civil aircraft designs.

Operational risks are inextricably linked to the risks arising during the development and manufacture of the aircraft. Therefore, this paper attempts to create a basic list of hazards associated with the activities of a developer of a promising supersonic civil aircraft.

However, before presenting the essence of this paper, it is necessary to define some terminology. Specific terms have already been used above, the interpretation of which, unfortunately, still varies in both regulatory documentation and scientific works. Therefore, to ensure a proper understanding of the content of this paper, we will clarify some definitions.

Flight safety is a condition of the aviation transport system in which the risks associated with civil aviation activities related to the operation of civil aircraft or directly supporting such operation <…> are reduced to an acceptable level of flight safety[1].

Flight Safety Management System is an organized structure consisting of interrelated and interdependent elements that establish a hierarchy of responsibility, accountability, policies, and procedures to implement a systematic approach to managing the safety of civil aircraft operations.

A hazard is a condition or object that can cause or contribute to an aviation accident or incident[1].

Hazard sources are objective entities and phenomena that carry hazards.

Flight safety risk is the combination of the probability and severity of the consequences of one or more hazards.

Threat is an event in aviation activities that results from the occurrence (impact) of a hazard.

Analysis of Supersonic Civil Aircraft Design and Operational Features

To create a baseline list of hazards associated with the development of supersonic civil aircraft, information from various open sources was analyzed regarding the design and operational features of previously existing supersonic civil aircraft. This information also covered the specific phenomena that arise during supersonic flight and that can impact efficiency and safety. Balancing these phenomena is the primary objective of safety management. This is the management dilemma described in paragraph 2.7 of the ICAO Safety Management Manual[2], which is precisely the purpose for which an SMS should be developed. Subsequently, when developing measures to eliminate identified hazards, the impact of these measures on aircraft operational efficiency must be taken into account.

We will briefly present the results of this analysis.

Wave drag. At transonic and supersonic flight modes, additional wave drag occurs, the aerodynamic quality decreases (for example, the Concorde has a lift-to-drag ratio of 7.14, while the subsonic Boeing 747 has a ratio of 17[3]). As a result, fuel consumption will increase, and fuel efficiency, accordingly, will decrease, despite the increase in the efficiency of the power plant with increasing Mach number (fig. 1)[4].

To reduce drag, a highly swept wing (delta, ogive) is used, which has low lift at subsonic speeds. This necessitates an increase in wing area, which increases aerodynamic drag. Alternatively, a variable-geometry (sweep) wing can be used[5], which allows for high lift-to-drag ratio at low flight speeds compared to a low-aspect-ratio delta wing. This improves safety in the event of engine failure during takeoff, since a higher climb can be achieved with less thrust. However, this leads to a more complex design, increased weight, and increased maintenance.

[1] Federal Law No. 289-FZ dated 08.08.2024 "On Amending the Air Code of the Russian Federation and Certain Legislative Acts of the Russian Federation". *GARANT*. Available at: https://base.garant.ru/409494265/?ysclid=m1c5yfj38c934649864 (accessed: 21.10.2025). (in Russian)

[2] Doc. 9859: Safety Management Manual (SMM). (2013). 3rd ed. *ICAO*, 300 p.

[3] Supersonic passenger aircraft. *Wikipedia*. Available at: https://ru.wikipedia.org/wiki/Сверхзвуковой_пассажирский_самолёт (accessed: 21.10.2025). (in Russian)

[4] Supersonic passenger aircraft Sud Aviation – UAC Concorde. (1964). *Technical information (TsAGI Scientific Information Bureau)*, October, no. 20 (1018), pp. 1–17. (in Russian)

[5] Requirements for a Supersonic Transport Aircraft. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, January, no. 1 (999), pp. 1–14. (in Russian)

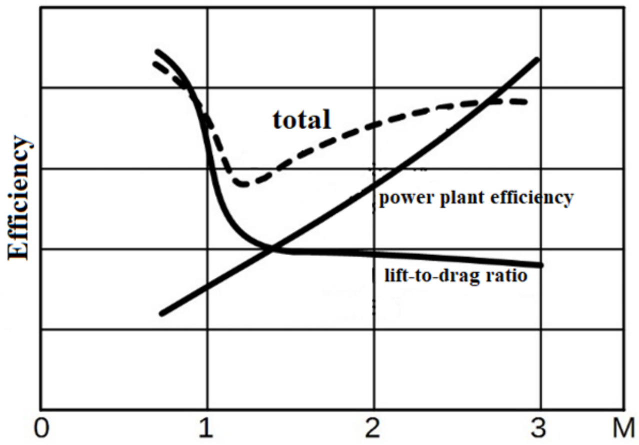

Fig. 1. Change in cruise flight efficiency depending on the Mach number

To minimize drag, one can also strive to reduce the thickness of the wing and empennage profiles, reduce the midsection area of the fuselage, and increase its aspect ratio. This generally leads to a decrease in structural rigidity and a reduction in the critical speeds of aeroelastic phenomena (divergence, reversal, flutter, buffeting). All this necessitates increasing rigidity by increasing the cross-sectional areas of the structural members, which, in turn, leads to an increase in the structural mass. Therefore, the relative mass of a supersonic aircraft is significantly higher than that of a subsonic aircraft, reducing the former's efficiency.

Rearward shift of the center of pressure and the aerodynamic center (focus). During the transition to supersonic flow, the center of pressure and the aerodynamic center (focus) of the wing shift rearward[4].

The rearward shift of the center of pressure creates a large nose-down pitching moment, since the aircraft's center of mass is initially located forward of the center of pressure and, accordingly, the aerodynamic center (focus) to ensure stability. Counteracting the nose-down pitching moment by deflecting the elevators or elevons (depending on the configuration) will lead to significant aerodynamic efficiency losses for trim. Therefore, the following measures are used to counteract this phenomenon:

– destabilizers (canard horizontal stabilizers, which become feathering at subsonic speeds and are fixed during the transition to supersonic flight). A highly reliable system is required to ensure the transition from the fixed to the feathering state; otherwise, the aircraft's longitudinal stability in subsonic flight may, at the very least, be insufficient;

– a wing with a leading-edge extension (at subsonic speeds, due to its high sweep, the leading-edge extension has very low lift capacity and creates almost no destabilizing effect, while at supersonic speeds it prevents the center of pressure and aerodynamic center (focus) from shifting significantly rearward);

– an ogival wing, as a development of the delta wing with a leading-edge extension, in which, additionally, during flight at high angles of attack during takeoff and landing, a system of vortices is generated along the entire wingspan along the leading edge, allowing for attached flow over the wing and eliminating the need for leading-edge high-lift devices;

– a variable-geometry wing (variable sweep), which allows adjusting the position of the center of pressure and the aerodynamic center (focus). In this case, the possibility of asymmetry between the left- and right-wing panels must be eliminated;

– fuel transfer to the rear trim tanks. This solution somewhat complicates the fuel system and necessitates additional fuel tanks. The fuel transfer system must be highly reliable, since returning to subsonic flight with the center of mass

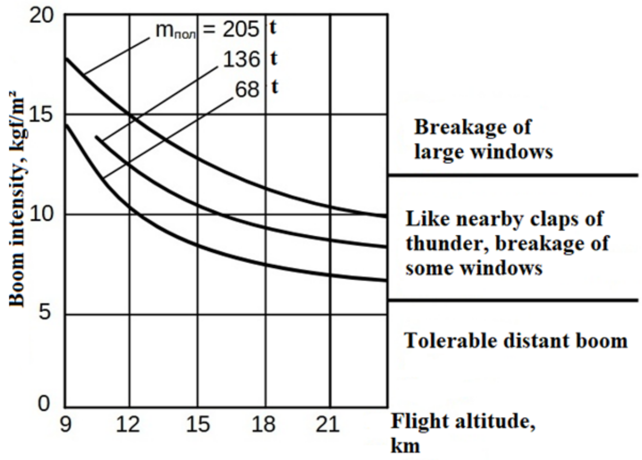

Fig. 2. Sonic boom intensity depending on flight altitude and aircraft flight mass ($m_{пол}$)[6]

positioned for supersonic flight will result in longitudinal instability. Reliable operation of the fuel transfer system can be ensured by redundant pumps and fuel transfer lines; as a last resort, provision can be made for emergency fuel drainage from the trim tank [13] or even emergency jettisoning of the trim tank.

Reduced lift surface efficiency. Due to the large sweepback of the lift surfaces, their efficiency is reduced, including in terms of aerodynamic damping of aircraft vibrations. Therefore, artificial damping using an automatic control system is required[5]. The main challenge is ensuring stable flight when the artificial damping system fails, especially at subsonic speeds. One solution could be the use of a variable-geometry wing, taking into account all the associated problems.

Sonic boom. During supersonic flight, a shock wave, a compression shock, is formed in front of the aircraft[5,6,7]. Reaching the ground, the shock wave creates a sonic boom on the terrain, which has a negative impact on both wildlife and ground structures. In this regard, supersonic cruising flight over populated areas is very problematic (fig. 2).

However, there are design measures that can reduce the sonic boom, for example:

– specially arranged interference of shock waves from different parts of the aircraft;

– a high degree of thrust boosting in the transonic range at high altitudes;

– low wing loading, a highly pointed nose section of the fuselage, and high sweep of the wing and tail surfaces.

Noise during takeoff and climb. One of the challenges associated with operating supersonic civil aircraft is the high engine noise level when flying over populated areas near airports[5]. Supersonic engines require a relatively high specific thrust (thrust per second of airflow through the engine) during supersonic flight to minimize engine cross-sectional area and, consequently, nacelle drag. Unfortunately, this implies high exhaust velocity, making the engines noisy and causing problems, especially at low speeds/altitudes and during takeoff.

To ensure acceptable noise levels, low exhaust velocities or improved noise suppressors are necessary.

The use of a variable-sweep wing can solve this problem. The noise level generated by an aircraft with a variable-sweep wing in the airport

6 Sonic Boom and Freedom of Airspace. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, October, no. 20 (1018), pp. 21–25. (in Russian)

7 Problems of Creating a Supersonic Civil Aircraft. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, January, no. 1 (999), pp. 21–35. (in Russian)

area and surrounding areas will be no higher than that generated by subsonic jet aircraft[8].

High flight altitude. Supersonic aircraft typically cruise at a higher altitude than subsonic aircraft. This is primarily due to the need to reduce the intensity of the sonic boom at the ground level caused by the shock wave generated during supersonic flight.

At higher altitudes, the air pressure is lower, so the pressure differential between the pressurized cabin and the surrounding space is greater in a supersonic aircraft, which also requires structural reinforcement and leads to increased mass. The reliability of the pressurized cabin design and the pressure regulation system within the pressurized cabin must prevent the possibility of rapid decompression.

Furthermore, high-altitude flight is associated with exposure to cosmic radiation, which may require special protection for the crew and passengers. Passenger protection should be the same as that provided to the crew, which includes flight attendants located in the passenger cabin[9].

Aerodynamic heating. During supersonic flight, the skin heats up significantly. Aluminum alloys, which are usually used in the construction of subsonic aircraft, lose their properties. Even the Tu-144 and Concorde, which flew at speeds corresponding to a Mach number of no more than 2.2, used heat-resistant aluminum alloys[10,11], but when flying at high Mach numbers, steel and titanium alloys have to be used (XB-70 “Valkyrie”)[12].

The Tupolev 144 aircraft required fuel with a special type of fuel[10] (T-6), used for supersonic aviation; synthetic motor oil was used in the engines; the tail section of the fuselage was covered with thin sheets of stainless steel; engine nacelle elements were made of titanium; special heat-resistant fluorine-containing plexiglass was used for the windows.

Large temperature differences between the skin and the internal wing structure under operating conditions will result in significant compressive stresses in the skin and tensile stresses in the internal structure. Particular attention should be paid to the selection and development of heat-resistant cabin glazing materials, as well as heat-resistant composite materials with increased erosion resistance for the radomes.

On the Concorde aircraft, fuel was used to reduce the temperature of structures subject to kinetic heating, as well as a heat absorber in the air conditioning system, hydraulic systems, and engine lubrication systems[13]. The amount of heat that fuel can absorb is limited by the fuel temperature at the engine inlet due to possible vaporization and subsequent cavitation in the engine fuel pumps and fuel supply lines.

When an aircraft flies at high Mach numbers, such as the XB-70 Valkyrie, designed for a cruise speed of Mach 3, water was used as a secondary cooling agent in cases where the fuel supply was too low and its temperature was too high, or when the engines were throttled and the fuel flow was insufficient for cooling.

Aircraft tires must withstand prolonged heat during high-Mach cruise flight. The landing gear wells on the XB-70 Valkyrie were cooled to 120°C using an ethylene glycol solution circulating through tubes welded to the walls. While the tires were not expected to require repairs during normal operation, they were cleaned and repainted with reflective paint before long-duration flights[12].

Insulating fuel tanks is difficult and adds weight. It was planned to use a system of pressurizing fuel tanks with inert gas on the aircraft.

[8] The Boeing 733 Supersonic Passenger Aircraft Project. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, July, no. 14 (1012), pp. 11–16. (in Russian)

[9] Pilots’ requirements for the safety of supersonic transport aircraft. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, October, no. 20 (1018), pp. 19–21. (in Russian)

[10] Tu-144. *Wikipedia*. Available at: https://ru.wikipedia.org/wiki/Ту-144 (accessed: 21.10.2025). (in Russian)

[11] Concord. *Wikipedia*. Available at: https://ru.wikipedia.org/wiki/Конкорд (accessed: 21.10.2025). (in Russian)

[12] North American XB-70 Aircraft. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, July, no. 14 (1012), pp. 1–6. (in Russian)

[13] Some Problems of Supersonic Aircraft Design. (1964). *Technical Information (TsAGI Scientific Information Bureau)*, October, no. 20 (1018), pp. 17–19. (in Russian)

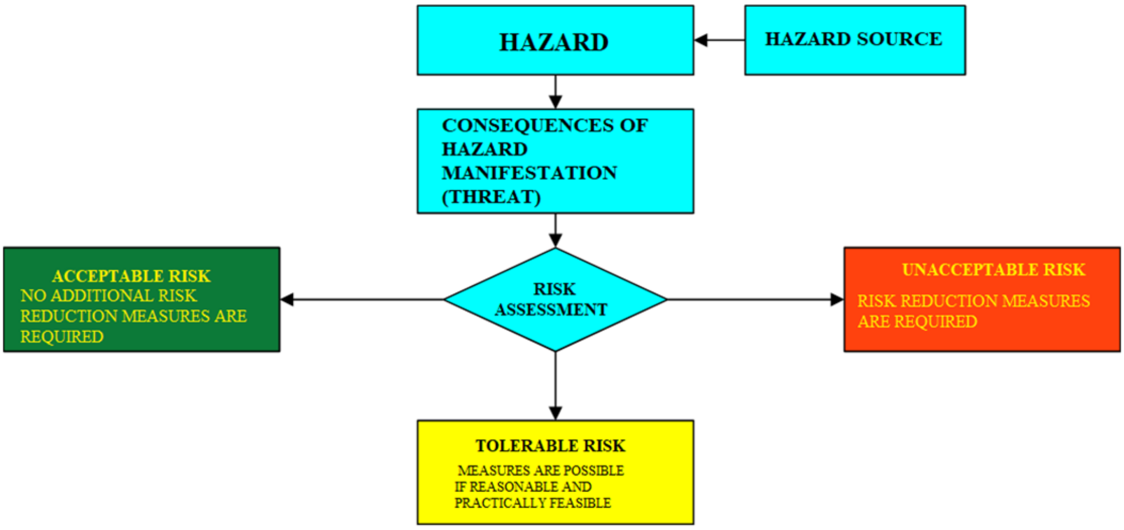

Fig. 3. General scheme of flight safety analysis and management

Air pollution. The International Council on Clean Transportation (ICCT) estimates that supersonic transport will burn 5–7 times more fuel per passenger[3]. The ICCT shows that “a supersonic flight from New York to London would consume more than twice as much fuel per passenger as a subsonic business class passenger, six times as much as an economy class passenger, and three times as much as a subsonic business class passenger for a flight from Los Angeles to Sydney”. Developers will have to either meet existing environmental standards with advanced technologies or lobby politicians to establish new standards for supersonic transport.

A basic list of hazards associated with the developer’s activities

In accordance with the above definition of flight safety, ensuring it requires rationally reducing risks to an acceptable level, which is, in fact, the purpose of an SMS. To determine risk acceptability, it is necessary to select a method for determining the risk magnitude or risk-related parameters and to establish a risk limit, the exceeding of which will be considered unacceptable. The limit established for an unacceptable risk may depend on potential benefits. Risk acceptability can also be determined by specifying an acceptable difference in specific performance indicators related to objectives. Using this approach, the following general framework for flight safety analysis and management can be proposed (fig. 3).

During analysis, the hazard and the source of the hazard are usually considered simultaneously. The possible consequences of exposure to the hazard (threat) are then determined. The risk is then assessed. If the risk is acceptable, the condition can be considered safe; if the risk is unacceptable, the condition becomes dangerous, and measures must be developed and implemented to mitigate the risk. If the risk is relatively small, it may be considered acceptable, but mitigation may be considered if it is reasonable and practicable.

The first step is to create a list of hazards. This is a separate, complex task. When creating a list of hazards associated with the activities of the developer, it should be taken into account that the developer must ensure the release of documentation for the manufacture of an aircraft with a level of airworthiness no lower than that specified in the Airworthiness Standards (AWS). However, the currently applicable Airworthiness Standards for Transport Category Aircraft (AWS-25)[14] do not take into account the opera-

[14] Airworthiness Standards for Transport Category Aircraft AWS-25. (2022). Approved by Order No. 961-P of the Federal Air Transport Agency dated December 27, 379 p.

tional characteristics of aircraft at supersonic flight speeds, not to mention the fact that there are no special standards for a supersonic civil aircraft, although the USSR had experience in creating such standards in the form of the Temporary Airworthiness Standards for Supersonic Civil Aircraft[15]. All of this indicates the need to improve the regulatory framework.

Below is an approximate basic list of hazards, based on an analysis of the problems associated with the development and operation of supersonic civil aircraft using materials from open sources, including an analysis of the USSR Temporary Airworthiness Standards for Supersonic Civil Aircraft and the current AWS-25.

This list primarily addresses hazards that will be inherent to any supersonic civil aircraft, regardless of its specific design. Specific design features, however, may present additional sources of hazards.

When identifying hazards and their potential consequences during the development of supersonic civil aircraft, it was assumed that, at this stage, the potential consequences of hazards include the creation of negative characteristics for the future supersonic civil aircraft. These negative characteristics themselves constitute hazards for supersonic civil aircraft, manifesting themselves during the operational phase, where potential consequences include exceptional situations arising in flight.

Table 1

An approximate basic list of hazard factors, sources and threats during the development of a supersonic civil aircraft that directly affect its operation

Description of the hazard	Source of the hazard	Threats
Inconsistency between the terminology of modern airworthiness standards and the generally accepted terminology in domestic aviation	Airworthiness Standards AWS-25	Misunderstandings of requirements could lead to the creation of a supersonic civil aircraft that does not have the required level of airworthiness
Lack of necessary methodological support, laboratory equipment, and testing facilities to determine the probabilities of possible failure modes of functional systems and assess the impact of these failure modes on flight safety, taking into account the operational characteristics of supersonic civil aircraft [AWS-25, paragraph 4.2]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient reliability of functional systems and supersonic civil aircraft as a whole
Lack of consideration of operating experience of similar systems when determining probabilities of possible failure modes of functional systems of a supersonic civil aircraft [AWS-25, paragraph 4.2(b)]	Designer competency level	Insufficient reliability of functional systems and the supersonic civil aircraft as a whole

[15] Temporary Airworthiness Standards for Supersonic Civil Aircraft of the USSR (TASS). (1976). Interdepartmental Commission on Airworthiness Standards for Civil Aircraft and Helicopters of the USSR. Effective date September 11, 1975. TsAGI Printing House, 327 p.

Continuation of Table 1

Description of the hazard	Source of the hazard	Threats
Lack of consideration of the dispersion of characteristics of similar systems when determining probabilities of possible failure modes of functional systems of a supersonic civil aircraft [AWS-25, paragraph 4.2(c)]	Designer competency level	Insufficient reliability of functional systems and the supersonic civil aircraft as a whole
Absence of recommendations in the Flight Manual enabling the crew to take measures to prevent the escalation of an emergency situation [AWS-25, paragraphs 4.8–4.10]	Competency level of the developer of operational documentation	Increased probability of an emergency situation escalating during flight operation of a supersonic civil aircraft
The absence of substantiated requirements in AWS-25 regarding the controllability and maneuverability characteristics of a supersonic civil aircraft at supersonic flight mode [AWS-25, paragraphs 25.143–25.149]	Airworthiness Standards AWS-25	Insufficient controllability and maneuverability of a supersonic civil aircraft in supersonic flight mode
Lack of consideration of significant changes in the characteristics of maneuverability, stability, controllability and balance of a supersonic civil aircraft when transitioning from one flight mode to another, for example, when transitioning from subsonic to supersonic flight mode and back [AWS-25, paragraph 25.143(b), paragraphs 25.143–25.181]	Designer competency level	1. Inability to maintain steady and controlled flight or the need for exceptional skill, reaction time, or physical strength on the part of the pilot when operating a supersonic civil aircraft. 2. Exceeding the operational overload limitations of a supersonic civil aircraft
Lack of consideration of the possibility of failure of the fuel transfer system if it is used as an additional means of trimming the aircraft when transitioning from subsonic to supersonic flight and vice versa	Designer competency level	1. Inability to balance the aircraft in supersonic flight. 2. Insufficient stability during the transition from supersonic to subsonic flight
Lack of consideration of the abrupt deterioration in stability and controllability characteristics in the event of failure of the automatic control system in subsonic flight modes of a supersonic civil aircraft due to the low efficiency of aerodynamic controls due to the large sweep of the wing and empennage	Designer competency level	Insufficient stability and controllability at subsonic flight modes
Lack of necessary methodological support, laboratory equipment, and a test base to prove the structural strength of a supersonic civil aircraft, taking into account the specific features of its operation [AWS-25, paragraph 25.307]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient strength and rigidity of the supersonic civil aircraft structure
The absence of substantiated requirements in AWS-25 regarding the load factor increment when approaching the buffet boundary or high angles of attack during cruise flight at supersonic speeds. [AWS-25, paragraph 25.251(a*)]	Airworthiness Standards AWS-25	Insufficient structural strength

Continuation of Table 1

Description of the hazard	Source of the hazard	Threats
Lack of consideration of the redistribution of loads on the structure of a supersonic civil aircraft during the transition from subsonic to supersonic flow [AWS-25, paragraph 25.301]	Designer competency level	Insufficient strength and/or rigidity of the structure at supersonic flight conditions
Lack of consideration of the specifics of supersonic flight in the methodology for calculating characteristic airspeeds, maneuver load factors, loads from atmospheric turbulence, and other loads, including loads on control surfaces (rudders, ailerons, spoilers, etc.) [AWS-25, paragraph 25.335–25.459]	Airworthiness Standards AWS-25	Insufficient strength and/or rigidity of the structure at supersonic flight conditions
The use of materials for the manufacture of structural elements of a supersonic civil aircraft without taking into account the environmental conditions expected in operation, such as temperature [AWS-25, paragraph 25.603]	Designer competency level	Insufficient strength and durability of structural elements
Lack of necessary methodological support, laboratory equipment, and testing facilities to prove the suitability of using materials in the design of a supersonic civil aircraft, taking into account the operating temperature conditions [AWS-25, paragraph 25.603, 25.613]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient strength, rigidity and durability of the supersonic civil aircraft design
Lack of necessary methodological support, laboratory equipment, and a test base to prove the suitability of new technological processes for the manufacture of structural elements of a supersonic civil aircraft, taking into account the operating temperature conditions [AWS-25, paragraph 25.605]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient strength, rigidity and durability of the supersonic civil aircraft design
Lack of design measures to ensure the temperature condition of interior surfaces that can be touched by passengers and crew members during the supersonic flight phase due to heating of the outer surface of a supersonic civil aircraft[AWS-25, paragraph 25.831(i*)]	Designer competency level	Exceeding the permissible temperature level of interior surfaces
Lack of consideration of the effect of heating of the skin, crew cabin and passenger cabin glazing, as well as other aircraft structural elements, on their strength and durability	Designer competency level	Insufficient strength and durability of structural elements
Lack of consideration of the effect of heating of wheel tires in the landing gear during prolonged cruise flight at high Mach numbers on their strength and wear resistance	Designer competency level	Insufficient strength and wear resistance of tires

Continuation of Table 1

Description of the hazard	Source of the hazard	Threats
Lack of consideration of the possibility of fuel tank ignition due to aerodynamic heating of the surface of a supersonic civil aircraft during supersonic flight mode	Designer competency level	Possibility of ignition of fuel tanks
The absence of substantiated requirements in AWS-25 regarding the assurance of aeroelastic stability [AWS-25, paragraph 25.629]	Airworthiness Standards AWS-25	Insufficient aeroelastic stability (possibility of flutter, divergence, flight control reversal)
Lack of necessary methodological support, laboratory equipment, and testing facilities to prove compliance with aeroelastic stability requirements [AWS-25, paragraph 25.629]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient aeroelastic stability (possibility of flutter, divergence, flight control reversal)
The absence of substantiated requirements in AWS-25 regarding the bird strike resistance of the crew cabin windshield [AWS-25, paragraph 25.775(b)]	Airworthiness Standards AWS-25	Insufficient or excessive strength of windshields
Lack of necessary methodological support, laboratory equipment, and testing facilities to prove the safety of an emergency landing of a supersonic civil aircraft on water, if a certificate for emergency ditching is requested [AWS-25, paragraph 25.801]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient safety of emergency landing of supersonic civil aircraft
Lack of understanding of the need for constructive measures to ensure acceptable ozone levels in the cabin [AWS-25, paragraph 25.832]	Designer competency level	1. Lack of on-board ozone monitoring equipment. 2. Ozone levels in the cabin exceeding the recommended limits
Lack of necessary methodological support, laboratory equipment, and testing facilities to prove the safety of pressurized cabins, taking into account the danger of explosive decompression at high flight altitudes typical for supersonic civil aircraft [AWS-25, paragraphs 25.841, 25.843]	Methodological and material support for the development process of supersonic civil aircraft	Insufficient safety of pressurized cabins
The absence of substantiated requirements in AWS-25 for flight and navigation instruments, including for the supersonic civil aircraft airspeed indicator [AWS-25, paragraph 25.1303(c)(1)]	Airworthiness Standards AWS-25	Unjustified sound signaling of exceeding the permissible speed or Mach number
The absence of substantiated requirements in AWS-25 for the airspeed indication system of a supersonic civil aircraft [AWS-25, paragraph 25.1323(c), (d), (e)]	Airworthiness Standards AWS-25	Unacceptable error in airspeed measurement
The absence of substantiated requirements in AWS-25 for the static pressure system [AWS-25, paragraph 25.1325(e)]	Airworthiness Standards AWS-25	Unacceptable error in measuring barometric altitude

Continuation of Table 1

Description of the hazard	Source of the hazard	Threats
The absence of substantiated requirements in AWS-25 for protective breathing equipment for supersonic civil aircraft [AWS-25, paragraph 25.1439(b)(5)]	Airworthiness Standards AWS-25	Insufficient level and duration of supply of protective oxygen
The absence of substantiated requirements in AWS-25 for the amount of oxygen on board of a supersonic civil aircraft [AWS-25, paragraphs 25.1441A, 25.1443, 25.1447]	Airworthiness Standards AWS-25	Insufficient oxygen supply on board a supersonic civil aircraft and/or improper distribution among consumers
The absence of substantiated requirements in AWS-25 for the leak-tightness of the air pressure sensing system [AWS-25, paragraph 8.2.5.9]	Airworthiness Standards AWS-25	Insufficient accuracy of airspeed measurement at high flight speeds
Misunderstanding of the need to assess the noise level in the area from engines and to assess the noise level in the area from sonic boom	Designer competency level	1. Lack of on-board means for assessing ground noise. 2. Violation of ground noise regulations during flight
Misunderstanding of the need to assess the radiation dose to crew and passengers	Designer competency level	1. Lack of on-board radiation dose assessment equipment. 2. Violation of on-board radiation dose standards

Conclusion

The analysis of the design and operational characteristics of supersonic civil aircraft, based on open sources, revealed that there are specific phenomena occurring during supersonic flight that must be considered when developing a list of hazards. These phenomena include: wave drag, rearward shift of the center of pressure and aerodynamic center (focus), reduced effecttiveness of lifting surfaces, sonic boom, ground noise during takeoff and climb, increased pressure differential between the pressurized cabin and the surrounding environment, cosmic radiation, aerodynamic heating, and air pollution.

As a result, an approximate basic list of hazards, sources, and threats during the development of supersonic civil aircraft that directly impact its operation was developed. Risk assessment, in accordance with the general principles of risk management, should be performed directly within the operator's organization using the procedures and tools approved in its SMS.

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