APPROVED
Head of department
S.V. Pavlova
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# GRADUATION WORK

## (EXPLANATORY NOTES)

## FOR THE DEGREE OF MASTER

## SPECIALITY 173 “AVIONICS”

**Theme: Runway Length Residue Aircraft Control System**

Done by: student of the AV-209Ma group, Korovkin Vitalii Andriiovych
(student, group, surname, name, patronymic)

Supervisor: D.Sc., Hryshchenko Y. V.
(scientific degree, academic rank, surname, name, patronymic)

Consultant on ‘Labor protection’: ____________ Kovalenko V.V.
(signature) (surname, name, patronymic)

Consultant on ‘Environmental protection’: ____________ Dmytrukha T.I
(signature) (surname, name, patronymic)

Standard controller: ____________ Levkivskyi V.V.
(signature) (surname, name, patronymic)

Kyiv 2021

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІОНІКИ

**ДОПУСТИТИ ДО ЗАХИСТУ**
Завідувач кафедри
___________С.В.Павлова
«__»_________2021 р.

# ДИПЛОМНА РОБОТА (ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«АВІОНІКА»

**Тема:**

Виконав: студент групи АВ-209Ма, Коровкін Віталій Андрійович
(студент, група, прізвище, ім’я, по-батьвові)
Керівник: д.т.н., Грищенко Ю. В.
(наукова ступінь, вчене звання, прізвище, ім’я, по-батькові)

Консультант розділу ‘Охорона праці’: ________ Коваленко В.В.
(підпис) (прізвище, ім’я, по-батькові)

Консультант розділу ‘Охорона навколишнього середовища’: ___________ Дмитруха Т.І
(підпис) (прізвище, ім’я, по-батькові)

Нормоконтролер: ___________ В.В. Левківський
(підпис) (прізвище, ім’я, по-батькові)

Київ 2021

**NATIONAL AVIATION UNIVERSITY**
Faculty of Air Navigation, Electronics and Telecommunications
Department of avionics
Specialty 173 ‘Avionics’

APPROVED
Head of department
S.V. Pavlova
“___”___________2021

# TASK
## for execution graduation work

V. A. Korovkin

1. Theme of graduation work is the ’Runway Length Residue Aircraft Control System’, approved by order 1945/ст of the Rector of the National Aviation University of 22 September 2021.
*2*. Duration of which: 18 October 2021 to 31 December 2021.
3. Background to the work:
4. Content of explanatory notes: List of conditional terms and abbreviations; Introduction; Chapter1: Factors that can influence the landing performance; Chapter 2: Data analysis and calculations; Chapter 3; Chapter 4; Chapter 5; Conclusions; References;
5. The list of mandatory graphic material: landing overrun distribution by aircraft and by region, runway conditions distribution, device internal parts interaction scheme,
6. Planned schedule

| № | Task | Duration | Signature of supervisor |
|---|---|---|---|
| 1. | Validate the rationale of graduate work theme | 18.10.2021 | |
| 2. | Carry out a literature review | 19.10.2021 – 25.10.2021 | |
| 3. | Develop the first chapter of diploma | 26.10.2021 – 01.11.2021 | |
| 4. | Develop the second chapter of diploma | 02.11.2021 – 10.11.2021 | |
| 5. | Develop the third chapter of diploma | 11.11.2021 – 20.11.2021 | |
| 6. | Develop the fourth and fifth chapters of diploma | 20.11.2021 – 11.12.2021 | |
| 7. | Tested for anti-plagiarism and obtaining a review of the diploma | 12.12.2021 | |

7. Consultants individual chapters:

| Chapter | Consultant (Position, surname, name, patronymic) | Date, signature | |
|---|---|---|---|
| | | Task issued | Task accepted |
| Labour protection | Ph.D., Associate Professor Kovalenko V.V. | | |
| Environmental protection | Ph.D., Associate Professor Dmytrukha T.I. | | |

# ABSTRACT

Explanatory notes to master`s work ‘Runway Length Residue Aircraft Control System’ contained pages, figures, tables, graphs, references.

**Object of research** – overrun accidents in different regions.

**Aim of research** is to identify most problematic regions in accordance to the runway overrun accidents, develop the concept of a new device which can help to decrease the number of overrun accidents.

**Research method –** data analysis, archival study, case studies, surveys, participant observation, document screening

**The scientific novelty of the research:**

- ***For the first time***: runway length residue aircraft control system
- ***Improved***: accuracy of determining the aircraft position on the runway, especially in extreme weather conditions; recommendations for pilots to decrease the number of overrun accidents.

**Keywords:** OVERRUN, ROLL OUT, LANDING, ILS, INDICATORS, PRECISE LANDING, SAFE LANDING

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# LIST OF CONDITIONAL TERMS AND ABBREVIATIONS

CAST – commercial aviation safety team
PF – pilot flying
PNF – pilot non-flying
PM – pilot monitoring
DC – direct current
EMAS – Engineered Material Arresting Systems
FSF – Flight Safety Foundation
ILS – instrument landing system
CAT – category of operation
CSB – carrier and side bands
SBO – side bands only
NF – near field

# Introduction

Landing overruns are among the most often reported accident types across the world. Fortunately, passengers and crew members are rarely injured as a result of landing overruns. Despite this, landing overruns can still pose a significant risk to aviation safety. As a result, it's useful to get a full picture of the elements that raise the risk of a landing overrun, as well as trends in data and the impact of safety efforts. These concerns were addressed in a safety study on landing overruns of commercial transport aircraft.

When one of the following variables is present during a landing, there appears to be a substantial increase in landing overrun risk on a global scale: Excessive approach speed, visual approach, considerable tailwind present, high on approach, wet/flooded runway, and/or snow/ice/slush coated runway are all examples of non-precision approaches. Excess approach speed was followed by a danger increase when the aircraft touched down well beyond the threshold (long landing).

Furthermore, it was shown that the rate of landing overrun accidents has decreased by a factor of three globally during the last 35 years.

Improvements in braking equipment (antiskid, autobrakes, etc.), a greater knowledge of runway friction concerns, and safety awareness campaigns are all potential contributors to this decrease.

The failure to apply available stopping measures on time or at all was frequently shown to be a factor in landing overrun accidents. All of these overrun incidents might have been avoided if the crew had the information about distance of the runway on which it is possible to stop the aircraft.

# CHAPTER 1

# FACTORS THAT CAN INFLUENCE LANDING PERFORMANCE

## 1. Good landing definition

It all starts with a steady approach in terms of speed, trim, and glide path. The airplane is positioned to land in the touchdown zone during the approach. The airplane is at the proper height and speed when it crosses the threshold.

A flare without any fast control column movements concludes the approach, which is followed by a positive touchdown without floating. The spoilers (if available) are raised (manually or automatically) once the main gear lands, the brakes are applied (manually or automatically), the reverse thrust or propeller reverse is selected (if available), and the nose is dropped. All of these activities are carried out quickly and in accordance with normal operating procedures. This is how flight crew training manuals describe the landing.

However, hardly many landings are carried out in this manner every day. Departures from this good practice happen all the time with no severe effects. When there are significant variations from the "best" technique, however, stopping the plane on the runway becomes more difficult.

## 2. Approach speed

The approach speed is governed by a variety of parameters, including flap setting, aircraft weight, headwind, turbulence, and pilot management. The pilot generates a target approach speed (bug speed) based on a number of these parameters, which the pilot tries to fly throughout the approach.

Some planes are more prone to floating than others.

This is mostly influenced by the aerodynamic ground effect, which varies depending on the kind of aircraft. When a pilot is floating, he or she will frequently try to bleed off the surplus speed. This action uses up a large portion of the remaining runway to bring the plane to a halt. The effect of the extra speed on the ground roll distance is generally smaller than the increase of the flare distance due to floating. This is due to the fact that the aircraft's declaration during the flare is a fraction of what can be accomplished while braking on the ground, especially on slick runways. As a result, rather of bleeding off the additional speed in the air, it is critical to land the aircraft with an excess of speed. Non-precision and visual approaches are more frequently connected with excessive approach speed landings than precision approaches. Precision approaches are inextricably linked to a technique that establishes a consistent fall gradient from the final approach altitude through touchdown. During the flight, the fall gradient may be checked. Non-precision methods can be made to be a more stable approach procedure. However, this isn't always the case, leaving such techniques prone to excessive speed.

## 3. Approach path

Departures from the nominal glide route can be caused by atmospheric turbulence, guidance problems, and incorrect pilot control. It's critical that the plane crosses the threshold at the proper height and with the desired glideslope. The landing distance can be increased if the threshold is too high. When the glideslope is shallower, the same applies. For an aircraft on a 3-degree glideslope approach with extra height of 30 ft. at the threshold, the increase in landing distance is about 700 ft. This increases to about 1,000 feet when combined with a one-degree shorter glideslope. When reaching the runway threshold, some pilots use a so-called duck under maneuver. The pilot is flying the airplane below the nominal route with a steeper glideslope in this circumstance. The likelihood of doing so varies by pilot, aircraft type, and visual circumstances. Longer landings may be the outcome of such a flying method.

Non-precision and visual approaches are more frequently connected with excessive height landings than precision approaches. Precision approaches are inextricably linked to a technique that establishes a consistent fall gradient from the final approach altitude through touchdown. During the flight, this fall gradient may be checked. Non-precision methods can be made to work as a stabilized approach procedure. However, this isn't always the case, making these techniques more susceptible to excessive height.

## 4. Flare and touchdown

During the flare maneuver, the pilot slows down the fall rate to avoid a harsh landing. The pilot uses his or her judgment and experience to execute the flare. The pilot chooses when to start the flare and how much elevator input to give during the flare. The touchdown should happen right after the flare is completed. However, before landing, the plane frequently floats for a while. This may need a significant amount of runway. The DC10 landed 4,700 feet beyond the barrier in the scenario provided in the beginning to this study. After the first landing flare, the aircraft drifted for a little distance. Three times the 20-foot callout was made. The captain (PNF) then instructed the First Officer (PF) to land the plane. The propensity to float is influenced by a variety of variables that are difficult to generalize. The ground effect, for example, appears to be essential. The ground effect is the ground's aerodynamic impact on the flow surrounding an aircraft. As the ground is approached, it increases lift, decreases aerodynamic drag, and creates a nose down pitching moment. The aircraft configuration has a significant impact on the kind and amount of ground effect. The ground effect offers a very pleasant landing cushion for the pilot. This might account for the ground effect's influence on the inclination to float to some extent. As previously stated, excessive approach speed can cause the aircraft to float after the flare as the pilot attempts to bleed off the excess speed. The touchdown should be done in a good manner without being overly forceful. When the runway is slick, the tires' spin up may be delayed if the touchdown is too smooth. As will be discussed later, this can have an impact on the deployment of ground spoilers and the antiskid system's correct operation. After the main wheels have touched down, the nose should be dropped as soon as possible to maximize the stress on the tires. In order to maximize drag and decrease the required runway length, some fighter jet pilots hold the nose up as long as possible. This method is known as 'aerodynamic braking,' and it is used on some fighter planes. However, it is not a recommended approach for commercial transport aircraft. The braking forces required for this technique are a fraction of those required when the airplane is braking with the nose down. In the past, the method of 'aerodynamic braking' has resulted in landing overruns with commercial transport planes. As a result, it should never be utilized during commercial cargo aircraft landings.

## 5. Rollout

The employment of all available stopping mechanisms as soon as possible helps to reduce the rollout distance. These gadgets should be used immediately after the plane has landed. Ground spoilers, reverse thrust, and tire brakes are among the braking systems employed. A considerable number of commercial transport aircraft have ground spoilers. Ground spoilers are particularly common on jet transport aircraft. On a variety of jet and propeller aircraft, reverse thrust is offered. This mechanism provides a reliable way of bringing the plane to a halt. Every airplane is equipped with tire brakes as a means of stopping. The airframe aerodynamic drag is another free stopping force that occurs with every aircraft during the ground roll. Problems with the stopping systems, as well as any delays in deploying them, might make it difficult for the pilot to bring the plane to a complete stop on the runway. Following that, we'll go over some of the difficulties with the specified stopping devices.

Tire braking is one of the most common ways for an airplane to generate stopping forces. To create braking power, the tire must slide. At a tire slip of 10-15%, maximum braking force is attained. The braking force applied to a tire is proportional to its vertical load.

The amount of braking force a tire may generate is also affected by the circumstances on the runway. On dry surfaces, the maximum braking forces are achieved. Lower braking forces are obtained when the runway is wet, flooded, or coated with snow, ice, or slush than when the runway is dry. The texture of the runway surface is also significant when it is wet. Higher braking forces can be achieved on a wet, rough surface than on a wet, smooth surface.

Antiskid systems are installed on the majority of commercial transport aircraft. By regulating the braking pressure, this technology eliminates tire lockups and automatically optimizes tire slip for maximum braking forces. As a result, the pilot may apply maximum brake pedal input without worrying about tire lockups or optimal braking. To work, the antiskid requires a reference wheel speed. Immediately upon touchdown, the wheel generates this speed. When landing on flooded runways, however, wheel spin-up may be delayed. The airplane tires can hydroplane on such runways. A layer of water then separates the tire's imprint from the surface. Because water cannot produce substantial friction forces, frictional forces between the tire and the ground are relatively low. To begin the tire spinning, friction forces are required. The rate at which a tire begins to hydroplane is determined by a variety of factors, including tire inflation pressure, forward speed, tire type (radial or cross-ply), and so on [3]. If the pilot applies braking before the tires have spun, the tires may become stuck. As a result, braking forces are reduced substantially.

Automatic braking systems are available for jet transportation. In the early and mid-1970s, the autobrake system was introduced. After touchdown, the autobrake system automatically regulates the aircraft's braking. The pilot can choose from different landing deceleration settings using an autobrake selector switch. After touchdown, the brakes are automatically deployed throughout the landing roll. To maintain the desired deceleration level, the system adjusts brake pressure to compensate for the effects of aircraft drag, thrust reversers, and spoilers. When the pilot performs manual braking, the autobrakes system disarms instantly. The autobrake system is a very efficient technology that pilots may not usually recognize. When compared to hand braking, the autobrake system's deceleration is typically more constant. Pilots also have a tendency to keep their braking input to a minimum. This behaviour might be crucial if the aircraft needs to be stopped and just a little amount of runway is available. Flying simulators are excellent at mimicking an aircraft's flight characteristics. They are, however, poor at imitating ground troops. It is impossible to accurately recreate the sense of a true maximal braking effort. Noises, vibrations, and deceleration associated with a maximal braking effort are not representative of real-world conditions. As a result, simulator training to familiarize pilots with maximum manual braking situations is ineffective in most cases. As a result, if the pilot performs maximal manual braking, he or she will frequently lower the brake pedal input. Accident investigation organizations have previously suggested using autobrakes instead of manual braking when landing on slick runways.

On the apex of the wing are ground spoilers (also known as lift dumpers). They enhance aerodynamic drag when deployed. They also considerably reduce aerodynamic lift, resulting in a larger stress on the tires. At high speeds, ground spoilers are most effective. Ground spoilers placed on the wings of aircraft can automatically rise once the main gear touches down. Prior to touchdown, the ground spoilers must be activated. Ground contact sensors are mounted on the aircraft to avoid automatic deployment of ground spoilers in the air. Contact sensors come in a variety of shapes and sizes.

The main gear tires' wheel spin-up can be utilized to detect ground contact. The oleo compression in the main landing gear can also be employed (often in combination with wheel spin-up). The tilt angle of the main landing gear on aircraft with bogie main landing gears can be utilized to indicate ground contact. When landing on flooded runways, as mentioned previously in this section, wheel spin-up might be delayed. Because the friction force on a tire is related to the load on the tire, getting as much weight on the tires as soon as possible after touchdown is critical. Ground spoilers are specifically intended to accomplish this.

If the ground spoilers, on the other hand, are waiting for the tires to spin up, a significant issue has arisen. The ground spoilers must then be manually deployed. Ground spoilers can also deploy when thrust reversers are used on various aircraft. The spoilers do not need to be armed before touchdown to do this. In the event of inoperative reversers or no usage of the reversers, it is always advisable to arm the ground spoilers before touchdown. Selecting the reversers might also take some time, delaying the deployment of the spoilers.

Thrust reversers are stoppers that are independent of runway conditions. They are particularly useful in generating stopping pressures on slick runways. At high speeds, thrust reversers on jet transporters produce the strongest stopping forces. Maximum reverse thrust is frequently prohibited below a particular speed. On a jet transport, the reverse thrust is set to idle between 80 and 60 knots IAS to avoid foreign object damage to the engine and the ingestion of turbulent air from the reverse thrust into the main engine inlet, which might cause an engine surge or stall. The propellers on turboprop aircraft are often pulled out of reverse at slower speeds than on jet carriers. Due to the likelihood of asymmetrical reserve thrust on some turboprop aircraft, full reverse cannot be selected at high speeds. Another concern is that jet transport reversers may make a lot of noise. As a result, their usage on airports is often limited to idle thrust only. If thrust reversers are available and the conditions are marginal (e.g., wet/contaminated runway, high winds, short runway, etc.), they should be employed regardless of environmental constraints. In rare situations, thrust reversers might cause directional controllability issues. For example, a tail-mounted engine can reduce rudder effectiveness by altering the flow around the vertical tail. In addition, using thrust reversers in strong crosswinds might cause controllability issues. Reducing the reverse thrust can help with controllability issues. The pilot, on the other hand, loses a critical stopping force.

## 6. Automatic and manual types of landing

Aircraft equipped with a technology that allows them to land in limited visibility and/or cloud ceilings (CAT III) have a completely automated landing capability. The majority of airplanes equipped with these technologies can only perform a completely automated landing up to touchdown (autoland with no roll-out guidance). The crew must disconnect the autopilot and assume control of the aircraft after touchdown. Although the autoland system is quite precise, it is unable to consistently land the aircraft on the same place on the runway. The touchdown dispersion of an automated landing is significantly less than that of a manual instrument landing. During a manual instrument landing, the average distance from the threshold to the touchdown location is roughly 30% longer, according to unpublished flight data. During a manual landing, the scatter in this distance (in terms of standard deviation) is around 130 percent larger. These data are not surprising, given pilot flight handling has a significant impact on manual instrument landings. During automated landings, factors like touching down far down the runway, flying quickly, and/or flying high above the flight route are less likely to happen.

When visibility or the cloud ceiling are too low for a safe manual landing, autolands are usually used. This does not, however, preclude out the deployment of autoland systems in better weather. Indeed, autolands are done when the weather is clear and visibility is good (although not many). In such situation, full ILS protection is not necessary. The crew will also be required to have enough visual references to detect and fix any deviations from the planned flying route. However, executing autoland operations on runways that do not meet CAT II/III requirements carries considerable risk. The ILS sensitive region is not guaranteed to be protected, as other aircraft and vehicles may interfere with the localiser signal. When the autopilot tries to follow the disrupted beam bends at a very low altitude, unexpected flight control movements may occur. As a result, pilots should be aware of the risk of aberrant autopilot behaviour and keep a close eye on the flight controls during the automated landing. The crew should also be prepared to turn off the autopilot and land or go around manually. Disconnecting the autopilot at low altitudes during heavy crosswind landings, on the other hand, might be dangerous. For autoland landings in favourable visibility circumstances, the operator should always provide the necessary instructions in the flight operations handbook. In the above-mentioned scenario, the crew should additionally notify ATC of their plan to perform an autoland. In that situation, ATC can alert the flight crew to any known or predicted ILS beam disturbances caused by other planes and vehicles.

# CHAPTER 2

## DATA ANALYSIS AND CALCULATIONS

Estimate the risk associated with the various landing criteria as a goal (excess speed, tailwind, runway condition etc.). It was therefore critical to know how common these particular conditions were during landings that did not result in a landing overrun. To evaluate the danger of lengthy landings, for example, it is necessary to know how many long landings have occurred without resulting in an overrun.

These numbers were gathered in a variety of methods. To begin with, the NLR Air Safety Database has information that enables for quite reliable estimates of the prevalence of a variety of risk variables in non-accident landings. The number of landings made on various runway surface conditions is an example. For additional risk concerns, data from a small number of operators' Flight Data Monitoring systems was utilized. These figures were used to calculate the prevalence of certain risk variables in non-accident landings. Excessive approach speed, protracted landings, and high approaches are all examples. It should be noted that this merely provides an approximate estimate of the prevalence of those risk variables for operations throughout the world. When analysing the findings, keep this in mind. Calculating a risk ratio provided an assessment of the risk of a landing overrun event when a certain risk factor was present. This risk ratio reveals the relationship between a component and the risk of a landing overrun mishap. The risk ratio is the ratio of the chance of an accident with the factor present to the probability of an accident without the factor present.

The risk ratio may be calculated using the following formula:

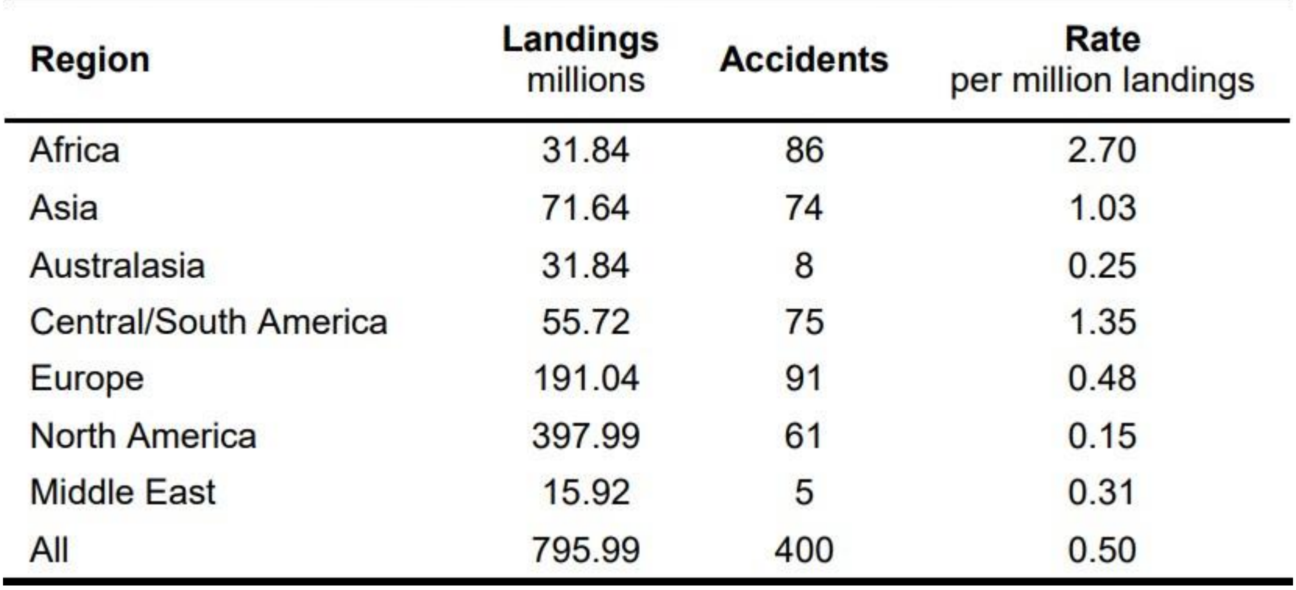
$$Risk\ Ratio = \frac{\left(\dfrac{\text{accidents with presence of a risk factor}}{\text{normal landings with presence of a risk factor}}\right)}{\left(\dfrac{\text{accidents without presence of a risk factor}}{\text{normal landings without presence of a risk factor}}\right)}$$

A risk ratio larger than one indicates that the existence of a certain element increases the amount of danger. A risk ratio of four suggests that the chance of an accident is four times higher with the risk factor present than without it. Positive correlations between a risk factor and landing overruns accidents indicate that a link has been established.

## Calculations

There were 400 landing overrun accidents discovered that matched the criterion for data inclusion. Approximately 796 million landings were estimated to have taken place globally between 1970 and 2004 with passenger and freight aircraft with a take-off mass of 5,500kg or more. For the research period [1], the projected landing overrun accident rate was 0.5 per million landings globally. The accident distribution by region is shown in Table 2. Also included is the rate of landing accident overruns per million landings. The disparities in landing overrun rates between global areas are clearly shown in Table 2.

Table 2: Aircraft accident distribution by region



| Region | Landings millions | Accidents | Rate per million landings |
|---|---|---|---|
| Africa | 31.84 | 86 | 2.70 |
| Asia | 71.64 | 74 | 1.03 |
| Australasia | 31.84 | 8 | 0.25 |
| Central/South America | 55.72 | 75 | 1.35 |
| Europe | 191.04 | 91 | 0.48 |
| North America | 397.99 | 61 | 0.15 |
| Middle East | 15.92 | 5 | 0.31 |
| All | 795.99 | 400 | 0.50 |

Table 3 shows the distribution of accidents by aircraft category. At the 5% level, the difference in landing accident overrun rate between jets and turboprops was not statistically significant. This indicates that the chances of a jet plane landing overrunning are similar to those of a turboprop plane.

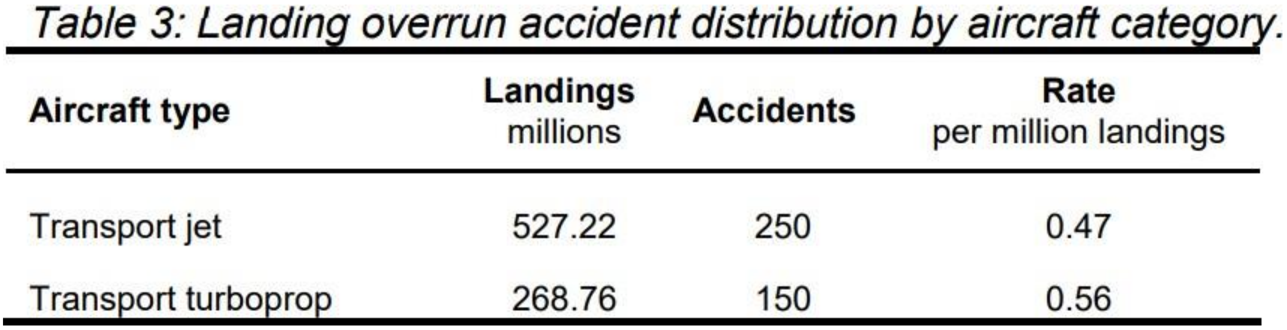


*Table 3: Landing overrun accident distribution by aircraft category.*

| **Aircraft type** | **Landings** millions | **Accidents** | **Rate** per million landings |
|---|---|---|---|
| Transport jet | 527.22 | 250 | 0.47 |
| Transport turboprop | 268.76 | 150 | 0.56 |

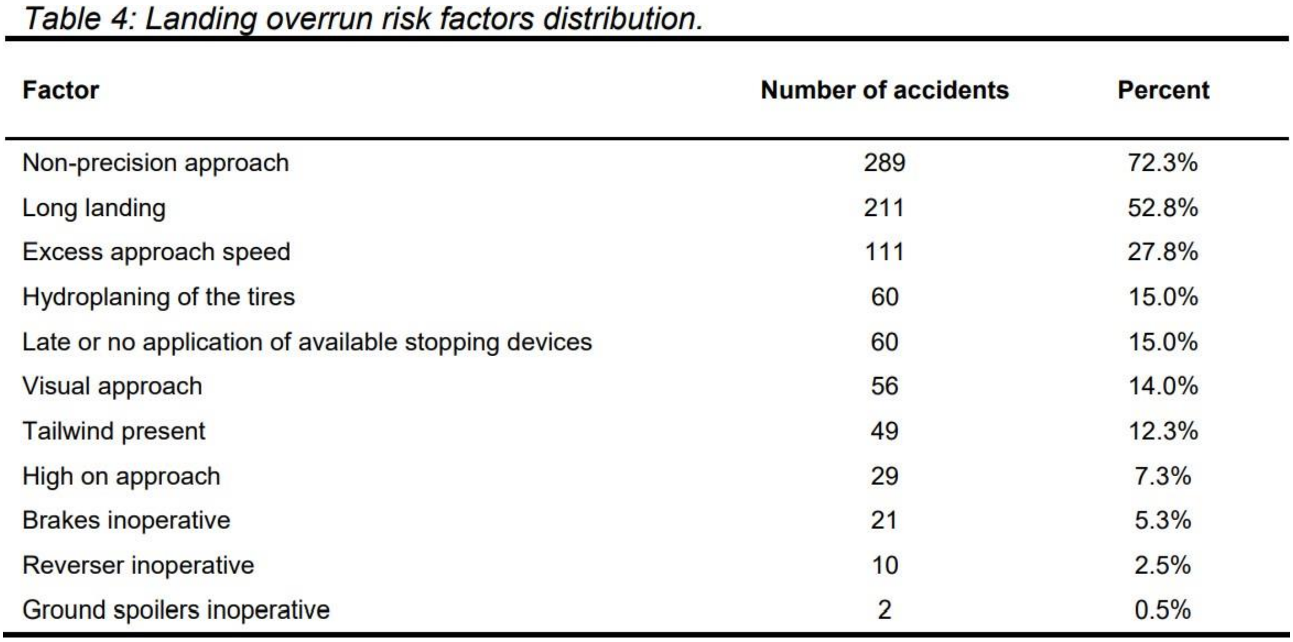


*Table 4: Landing overrun risk factors distribution.*

| **Factor** | **Number of accidents** | **Percent** |
|---|---|---|
| Non-precision approach | 289 | 72.3% |
| Long landing | 211 | 52.8% |
| Excess approach speed | 111 | 27.8% |
| Hydroplaning of the tires | 60 | 15.0% |
| Late or no application of available stopping devices | 60 | 15.0% |
| Visual approach | 56 | 14.0% |
| Tailwind present | 49 | 12.3% |
| High on approach | 29 | 7.3% |
| Brakes inoperative | 21 | 5.3% |
| Reverser inoperative | 10 | 2.5% |
| Ground spoilers inoperative | 2 | 0.5% |

The distributions of the landing overrun risk variables for the entire data sample are shown in Table 4. The numbers in Table 4 represent unprocessed data. They haven't been adjusted for the number of landings.

Figure 1 shows the many types of runway surface characteristics seen in landing overrun incidents. The surface quality of the runway varies a lot. For example, a portion of the runway may be slippery while another is covered with snow. In the event of flooded runways, it was also common for only a portion of the runway to have pools of standing water, leaving the rest of the runway wet. As a result, Figure 1 groups the many surface conditions that can exist. The values in Figure 1 are merely raw values. They are not adjusted for the number of landings made on such runways, which is done in the next portion of the article.

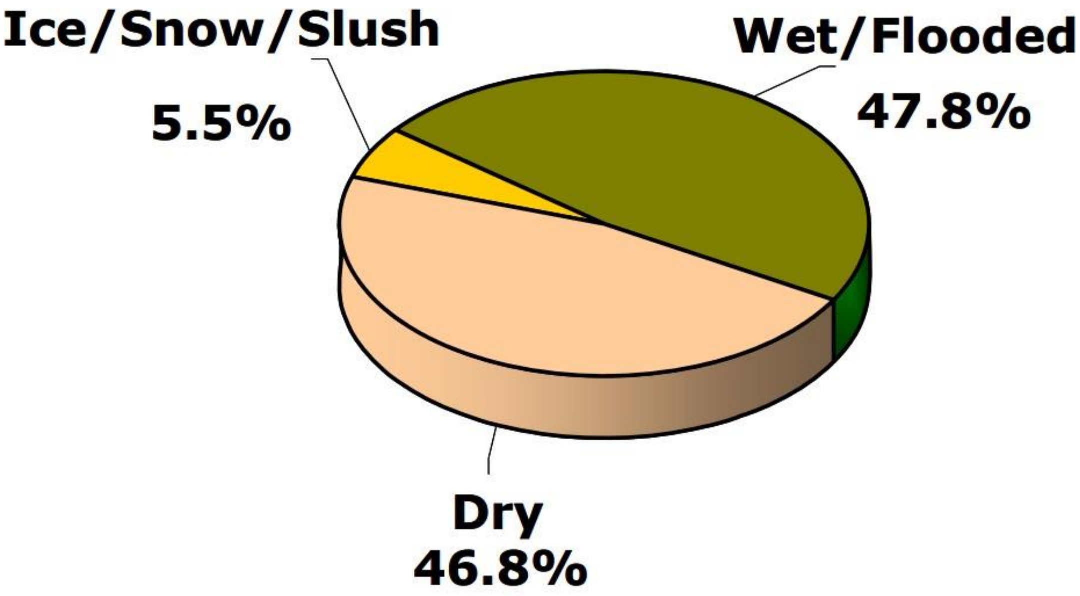
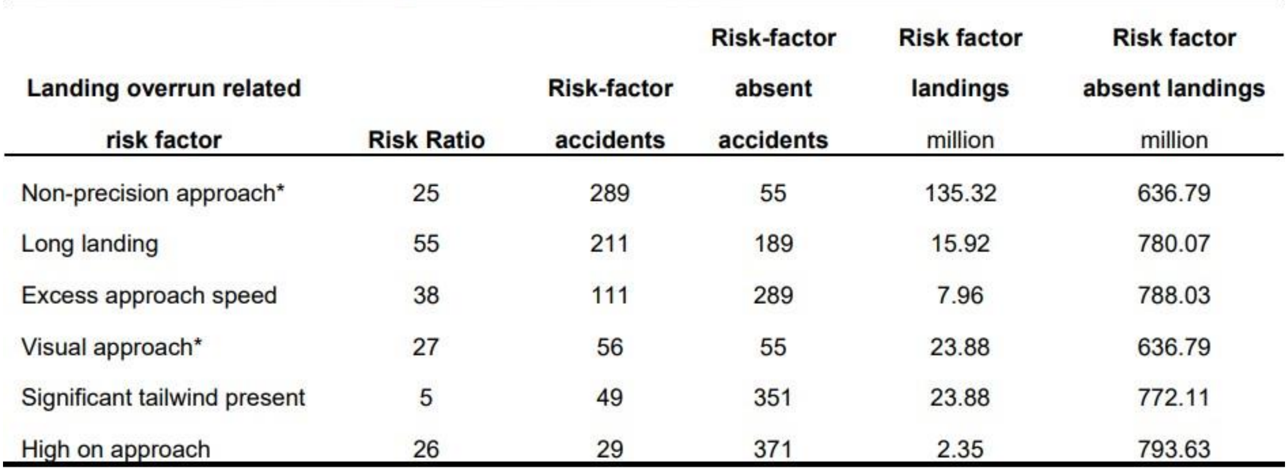


*Figure 1: Runway condition distribution.*

Table 5 shows the relationship between landing overrun risk factors and the number of landings included in each component, adjusted for the number of landings involved in each factor. A risk of larger than one is indicated by a value greater than one. The greater the link between the factor and the likelihood of a landing overrun mishap, the higher the risk ratio value. At the 5% level, all of the risk ratios in Table 5 are statistically significant. When flying a non-precision approach, the probability of a landing overrun was twenty-five times higher than when making a precision approach. When flying a visual approach versus a precise approach, the danger ratio was twenty-seven. The chance of a landing overrun mishap was fifty-five times higher when the landing was extended than when it was not. When there is too much approach speed, the danger of a landing overrun is 38 times higher. A five-fold increase in the chance of landing overrun occurs when there is a tailwind of 5 knots or greater. Finally, being high on approach multiplies the danger by twenty-six. The extended landing (touching down much beyond the threshold), excess approach speed, high approach, and approach type factors are treated as independent variables in Table 5. In certain situations, however, these factors were linked. High and quick landings, for example, frequently resulted in protracted landings.

*Table 5: Risk ratio for landing overrun related risk factors*



| Landing overrun related risk factor | Risk Ratio | Risk-factor accidents | Risk-factor absent accidents | Risk factor landings million | Risk factor absent landings million |
|---|---|---|---|---|---|
| Non-precision approach* | 25 | 289 | 55 | 135.32 | 636.79 |
| Long landing | 55 | 211 | 189 | 15.92 | 780.07 |
| Excess approach speed | 38 | 111 | 289 | 7.96 | 788.03 |
| Visual approach* | 27 | 56 | 55 | 23.88 | 636.79 |
| Significant tailwind present | 5 | 49 | 351 | 23.88 | 772.11 |
| High on approach | 26 | 29 | 371 | 2.35 | 793.63 |

*Compared to a precision approach.

The risk ratios associated with runway condition are shown in Table 6. At the 5% level, all of the risk ratios in Table 6 are statistically significant. When landing on a wet or flooded runway, the danger of a landing overrun accident rises by a factor of ten. The probability of a landing overrun mishap is fourteen times higher when the runway is coated in snow, ice, or slush than when landing on a dry surface.

## Landing overrun accidents

Figure 2 depicts the fluctuation in the rate of landing overrun accidents from 1970 to 2004 [1]. To improve the statistical robustness of the data, it was divided into 5-year blocks. The percentage of landing overrun incidents in the total number of approach and landing accidents worldwide is shown in Figure 3. The data was organized into 5-year chunks.

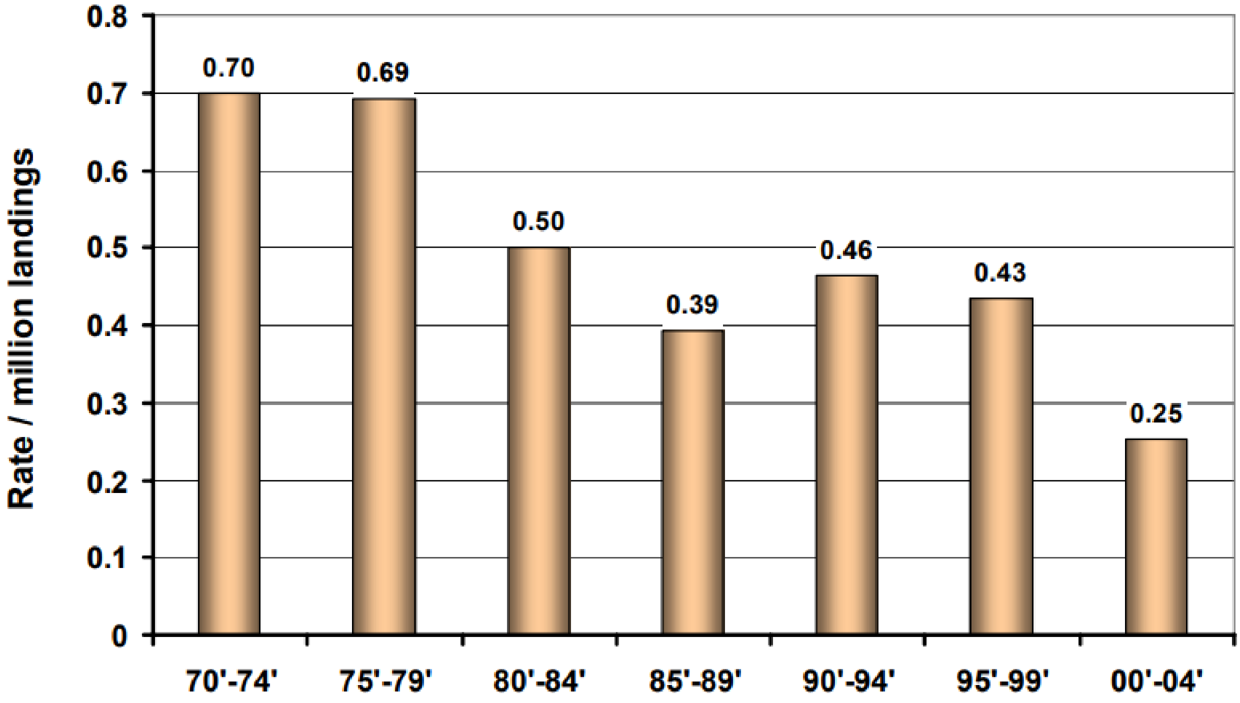


*Figure 2: Landing overrun accident rate trend.*

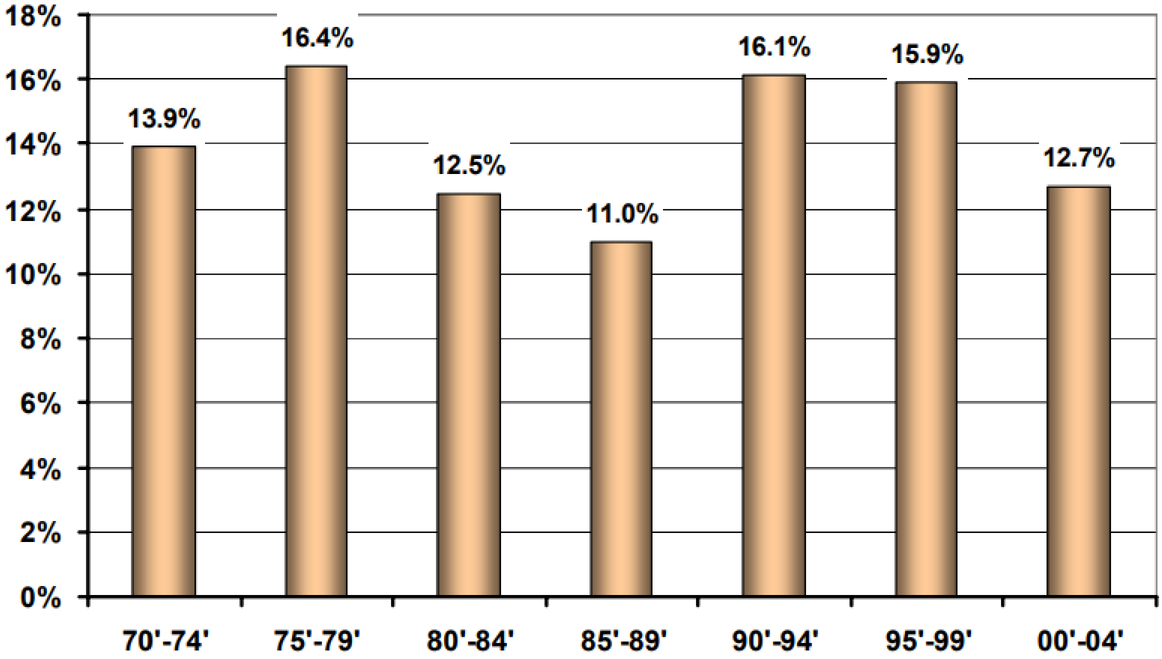


*Figure 3: Trend in share of landing overrun accidents in approach & landing accidents.*

This discovery can be explained in a number of ways. In general, there is a diversity in the quality of aviation safety across various areas. This might have an impact on the probability of a landing overrun.

More than half of all accidents had a prolonged landing, which means the plane touched down on the runway well beyond the threshold. The risk of touchdown overrun increased the most when landing well beyond the threshold. A protracted landing isn't necessarily dangerous in all cases. When a small turboprop plane lands on a long runway, landing long does not inevitably mean the plane will have trouble stopping on the remaining runway. Long landings, on the other hand, can become more dangerous when the available runway to stop the plane shrinks or the runway gets wet or contaminated with water. The risk ratio was calculated using an estimate of the number of lengthy landings, which included landings on a variety of runways of various lengths. The determined risk ratio for lengthy landings provides an average risk value in this regard. Landing quickly and/or high considerably enhanced the danger of landing overrun. Fast, high landings and/or tailwind landings are frequently connected with long landings. High approach speed is a common cause for a pilot to float the plane after the landing flare, in which the pilot attempts to eliminate the excess speed.

Excess approach speed was observed in 37.4 percent of all lengthy landings (79 out of 211). Landings might take longer if you're flying high during approach. High on approach was indicated in 12.8 percent of all lengthy landings (27 out of 211). There was no lengthy landing reported in only two high approach incidents. During the last stages of the approach, pilots must precisely follow their protocols for monitoring and managing airspeed and height. The inclination to float might also be assisted by a tailwind [2]. In 15.2 percent of all lengthy landings (32 out of 211), there was a tailwind. Excessive speed, high approaches, and other factors alone cannot contribute for a long landing. Clearly, the pilot's flying skill influences the probability of a lengthy landing.

When performing a non-precision or visual approach, the chance of landing overrun is significantly higher. These approach types are more probable than precision approaches to become unstabilized. During a non-precision or visual approach, the great majority of overruns with an excess approach speed occurred (81 percent). The approach type was non-precision or visual in 80% of all high-over-the-threshold landing overrun accidents. The approach type was a non-precision or visual approach in 82 percent of all overruns when a lengthy landing was observed. A greater probability of a landing overrun accident was linked to slick runway conditions (see Table 6). This discovery comes as no surprise to those in the aviation industry. However, the level of the risk increase remained unknown. The braking forces that airplane tires may generate are affected by runway conditions. Furthermore, on slick runways, wheel spin-up might be delayed, affecting the antiskid system's performance and the deployment of ground spoilers [4]. The tire may hydroplane on wet/flooded or slush-covered runways, reducing the braking forces between the tire and the runway greatly. The brake friction levels on snow and ice-covered runways are extremely low, making it difficult to stop the plane. Many efforts have been made over the last 35 years to gain a better understanding of runway traction.

## Overrun prevention systems

One or more stopping mechanisms failed in 8.3 percent of landing overrun events (see Table 4). The reason for this was mostly due to issues with the hydraulic systems. This also prevented the flaps usage, resulting in excessive approach speeds and landings. More concerning is the fact that in 15% of the incidents, the available stopping measures were applied late or not at all (see Table 4). Many of these incidents may have been avoided if the available stopping equipment had been used appropriately. The ground spoilers were not armed in the majority of the cases (52 percent of all cases with a late or no use of the applicable stopping device). The pilots in these instances frequently fail to detect that the spoilers did not deploy. Thrust reversers were frequently used late or not at all in the incidents (67 percent of all cases with a late or no application of the available stopping device). In several circumstances, reverse thrust was chosen first. However, it was quickly removed from consideration. Insufficient manual braking was frequently an issue; however, this could not be deduced from the data. However, precise flight data recorders must be examined in order to determine this truth.

There was no information that any of the investigated landing overrun accidents were caused by a malfunction or incorrect use of the autoland system. One mishap from the data sample had a crew who attempted to autoland but then took manual control of the plane shortly after exceeding the threshold. In a small number of other incidents, it was assumed that an autoland was carried out due to the poor visibility at the moment of landing. However, there were insufficient information supplied to be certain about these facts. This made calculating an accurate risk ratio for manual landings problematic. Autolands, on the other hand, can be claimed to lower the possibility of landing overruns by reducing the likelihood of flying too high, too fast, and making protracted landings.

Figure 2 illustrates the global trend in landing overrun accidents. It can be shown that the rate was greatest in the 1970s within the time period studied (1970-2004). The rate considerably improved during the 1980s. However, this upward trend did not continue in the 1990s. The rate of landing overrun accidents ultimately decreased in the first five years of the twenty-first century. It's difficult to pinpoint what caused the decrease in accident rates between 1970 and 2004. However, there were a number of activities that may have helped to increase safety. We'll go through a few of the more significant ones right now.

The effectiveness of antiskid technologies has considerably increased over time. The first antiskid systems, which were introduced in the 1950s, were basic on-off systems with a braking efficiency of 60%. Later (in the 1960s), modulated antiskid systems with braking efficiency of 70-85% were introduced. For the first time in the 1970s, modern antiskid systems were able to reach braking efficiency of routinely above 90%. Older airplanes with less complex antiskid systems were gradually replaced by newer ones with more effective antiskid systems.

During the 1970s, autobrake systems were introduced. They may now be found on a large number of jet transport aircraft. During the research period, autobrakes were projected to be employed in 30% of all landings. This proportion was expected to be approximately 50% of all landings in 2004.

Tire braking friction research has been going on since the 1960s. These researches shed light on runway friction and how it may be reduced. As a result, runways with grooved and porous friction courses have been developed. Although these surfaces improved runway friction on wet runways, they do not rule out the chance of a runway being overrun. On grooved runways, there were a number of landing overrun accidents. Many investigations employing ground vehicles to evaluate runway friction were also performed. It was frequently the goal to compare the braking friction of these ground vehicles to that of an airplane. Unfortunately, despite the tremendous effort, more work has to be done in this area in order to arrive at a suitable method of correlating ground vehicles with full-scale aircraft.

Various safety studies were started in the late 1990s with the goal of improving the level of flight safety. Accidents that happened during the approach and landing, such as landing overruns, were given special attention. Studies on approach and landing accidents have been done by the commercial aviation safety team (CAST), the Flight Safety Foundation task force on approach and landing accidents (FSF, 2001), and the joint research into landing assistance (Khatwa, 1996). These studies gave a set of mitigation strategies to the aviation sector. The FSF Approach-and-Landing Accident Reduction Briefing Notes, in particular, are crucial. A number of briefing papers are devoted to topics that might lead to landing overruns. However, it is too soon to say if these activities had a significant impact on the reduction of landing overrun accidents.

Another innovative technique worth mentioning is the use of a ground arrestor system that is cantered on the extended runway centreline and positioned beyond the end of the runway. A ground arrestor system uses deceleration forces on the landing gear to bring an overrunning aircraft to a stop. Although this technology cannot avoid overruns, its use can make the difference between a major issue and a minor one. In the 1970s, many types of ground arrestor devices were investigated in the United Kingdom and later in the United States. Engineered Material Arresting Systems is an example of a soft ground arrestor system. A soft ground arrestor system, such as EMAS, deforms as an aircraft tire passes over it. The drag forces slow the airplane while the tires crush the material, bringing it to a safe halt. In recent years, EMAS has gained popularity in the United States at airports that have struggled to comply with the FAA's restrictions on runway safety areas. At least three documented overruns resulted in the aircraft being stopped by EMAS. Overruns are unavoidable, and no soft ground arrestor technology can prevent them. However, it appears that such a mechanism can help to mitigate the repercussions. Other arrestor methods have been investigated in the past.

Loose gravel, water ponds, and arrestor wires are all examples. These technologies have only been used in a few commercial airports.

Each of the variables studied played a significant influence in the sequence of events that led to an overrun. In most cases, the existence of more than one variable did not indicate a landing overrun.

The airplane often overran the runway as a result of a combination of issues. The study's quantitative risk ratios show that there are links between a variety of landing-related characteristics and the chance of a landing overrun event. Such relationships do not indicate causality; rather, they imply that when the component is present, the likelihood of a landing overrun accident increases.

## Intermediate conclusions

The continent of Africa has the greatest rate of landing overrun accidents, followed by Central/South America and Asia. There was more than one mishap per million landings in all of these areas. The remainder of the globe had rates of fewer than one mishap per two million landings, which was less than half of the prior listed areas' rate. Of all the regions, North America had the lowest rate.

There was no statistically significant difference between commercial transport jet and turboprop aircraft in the predicted landing overrun accident rate.

When one of the following conditions is present during a landing, there appears to be a considerable increase in landing overrun risk on a global scale: excessive approach speed, visual approach, strong tailwind present, high on approach, wet/flooded runway, and/or snow/ice/slush coated runway, non-precision approach. Excess approach speed was followed by a danger increase when the aircraft touched down well beyond the threshold.

Over the last 35 years, the rate of landing overrun accidents has decreased by a factor of three overall. Improvements in braking equipment (antiskid, autobrakes, etc.), a greater knowledge of runway friction difficulties, and safety awareness campaigns are all possible contributors to this decrease.

The failure to apply available stopping measures on time or at all was frequently shown to be a factor in landing overrun accidents. All of these overrun incidents might have been avoided if the crew had employed the appropriate stopping measures immediately. The aim of on-board runway measuring device is to inform pilots if it is better to stop or to perform go around procedure.

# CHAPTER 3

## THE CONCEPT OF AN AIRCRAFT RUNWAY LENGTH RESIDUE CONTROL SYSTEM

Previously, blind landing radio assistance were usually in the form of various sorts of beam systems. These were usually made of of a radio transmitter and a motorized switch that produced a Morse code pattern of dots and dashes. The signal was also transferred to one of two directional antennas through the switch. Dots are transmitted to one side of the runway and dashes are sent to the other in the resultant signal launched into the air. The beams were large enough to overlap in the middle.[5]

An airplane simply needed a standard radio receiver to use the system. They would tune in to the signal and listen to it through their headphones as they neared the airport. If they were to the side of the runway or properly oriented, they would hear dots or dashes, which would be combined together to generate a constant tone, the equisignal. The accuracy of this measurement was greatly reliant on the operator's ability to listen to the signal through headphones in a loud plane while also speaking with the tower.

The system's accuracy was usually on the order of 3 degrees. While this was effective for aligning the aircraft with the runway, it was not precise enough to safely bring the aircraft into visual range in adverse weather; an aircraft generally descends at a rate of 3 to 5 degrees, and if they were 3 degrees below that, they would crash. Beams were only employed for lateral direction, and the system proved insufficient to land in heavy rain or fog on its own. Despite this, the decision to land was taken at a distance of 300 meters from the runway.

To attain improved precision, the ILS system employed a more complicated communication system and an antenna array. The base station and transmitters must be substantially more complicated, yet the signals may be reliably decoded in the aircraft using basic electronics and shown immediately on analog instruments. The instruments can be positioned directly in front of the pilot, removing the requirement for a radio operator to constantly check the signals and report the findings to the pilot over the intercom.

The amplitude modulation index, a measure of how strongly the amplitude modulation is applied to the underlying carrier frequency, is critical to its performance. The signal was completely switched on and off in older beam systems, equating to a modulation index of 100 percent. The angle within the beam is determined by comparing the audible strengths of the two signals.

In ILS, a more complicated set of signals and antennas modulates two signals throughout the beam pattern's whole span. Sidebands, or secondary frequencies formed when two separate signals are merged, are used in the system. For example, if a 10 MHz radio frequency signal is mixed with a 2500 Hz audible tone, four signals are produced: the original 2500 and 10000000 transmissions, as well as sidebands 9997500 and 10002500. The modulating signal at 2500 Hz is too low in frequency to travel far from an antenna, but the other three signals are all radio frequency and may be transmitted efficiently.

ILS combining two modulating signals, one at 90 Hz and the other at 150 Hz, onto the carrier. This results in a transmission with a total of five radio frequencies: the carrier and four sidebands. The CSB, which stands for "carrier and sidebands," is a combined signal that is transmitted out equally from an antenna array. The CSB is also sent via a circuit that eliminates the original carrier, leaving only the four sideband signals. SBO stands for "sidebands only," and it is also supplied to the antenna array.

The antenna for lateral guiding, also known as the localizer, is usually positioned off the far end of the runway and comprises of many antennas in an array that is roughly the same width as the runway. Each antenna contains a phase shifter that is exclusively applied to the SBO, causing the signal to be 90 degrees delayed on the left side of the runway and advanced 90 degrees on the right. The 150 Hz signal is also reversed on one side of the pattern, resulting in another 180-degree shift. The SBO signals destructively interact and remove each other along the centreline due to the way the signals mix in space, leaving just the CSB. The SBO will not totally cancel out at any other place, on either side of the centreline.

Both of these signals will be mixed together and received by a receiver in front of the array (fig. 4). The original carrier and two sidebands may be isolated and demodulated using basic electrical filters to obtain the original amplitude modulated 90 and 150 Hz signals. After then, the two direct current (DC) signals are averaged. Each of these signals indicates the modulation intensity relative to the carrier, which fluctuates over the broadcast pattern, rather than the original signal strength. This has the significant benefit of allowing angle measurement to be independent of range.[6]

The two DC signals are then fed into a standard voltmeter, with the 90 Hz output pulling the needle to the right and the other to the left. The two sidebands will be cancelled out along the centreline, and both voltages will be zero, leaving the needle centred in the display. The 90 Hz signal will create a significant DC voltage and the 150 Hz signal will produce none, dragging the needle all the way to the right if the airplane is far to the left. As a result, the voltmeter shows both the direction and amount of the turn required to return the plane to the runway centreline. [6] The measurement gives angular resolution of less than a degree and permits the building of a precision method since it compares multiple elements of a single signal fully in electronics.

Amplitude modulation is the modulation type used by all ILS transmitters (AM). The carrier oscillation is modulated with a 90Hz and 150Hz tone signal in the localizer frequency range of 108.00 MHz to 111.975 MHz.

This signal is known as CSB (Carrier and Side Bands).

It may be expressed mathematically as:

$$s(t) = [1 + M90 * \sin(3\omega_{car} t) + M150 * \sin(5t) ]\cos(\omega_{fund} t)$$

Where
$\omega_{car}$ – the angular frequency of the carrier;
$\omega_{fund}$ – the angular frequency of the fundamental frequency 30 Hz;
M90, M150 – modulation factors.

Also, a signal with suppressed carrier is generated. In this SBO signal, the 150Hz NF signal becomes out of phase and the 90Hz AF signal in-phase modulated.

$$d(t) = k[\sin(5\omega t) - \sin(3\omega t) ]\cos(\omega t + f_{i)}$$

where k is the SBO signal's relative level to the CSB signal, and f is the SBO signal's relative phase to the CSB signal, and

$$\omega = 2\pi f$$

Although the encoding process is sophisticated and needs a significant amount of ground equipment, the final signal is significantly more precise and immune to common sources of interference than prior beam-based systems. Static in the signal, for example, affects both sub-signals equally, hence it has no influence on the outcome. Similarly, fluctuations in total signal intensity as the plane approaches the runway, or fading, will have no influence on the measurement because they would ordinarily affect both channels equally. Because the system uses many frequencies, it is prone to multipath distortion effects; however, because these effects are dependent on the topography, they are normally fixed in place and may be compensated for using antenna or phase shifter changes.

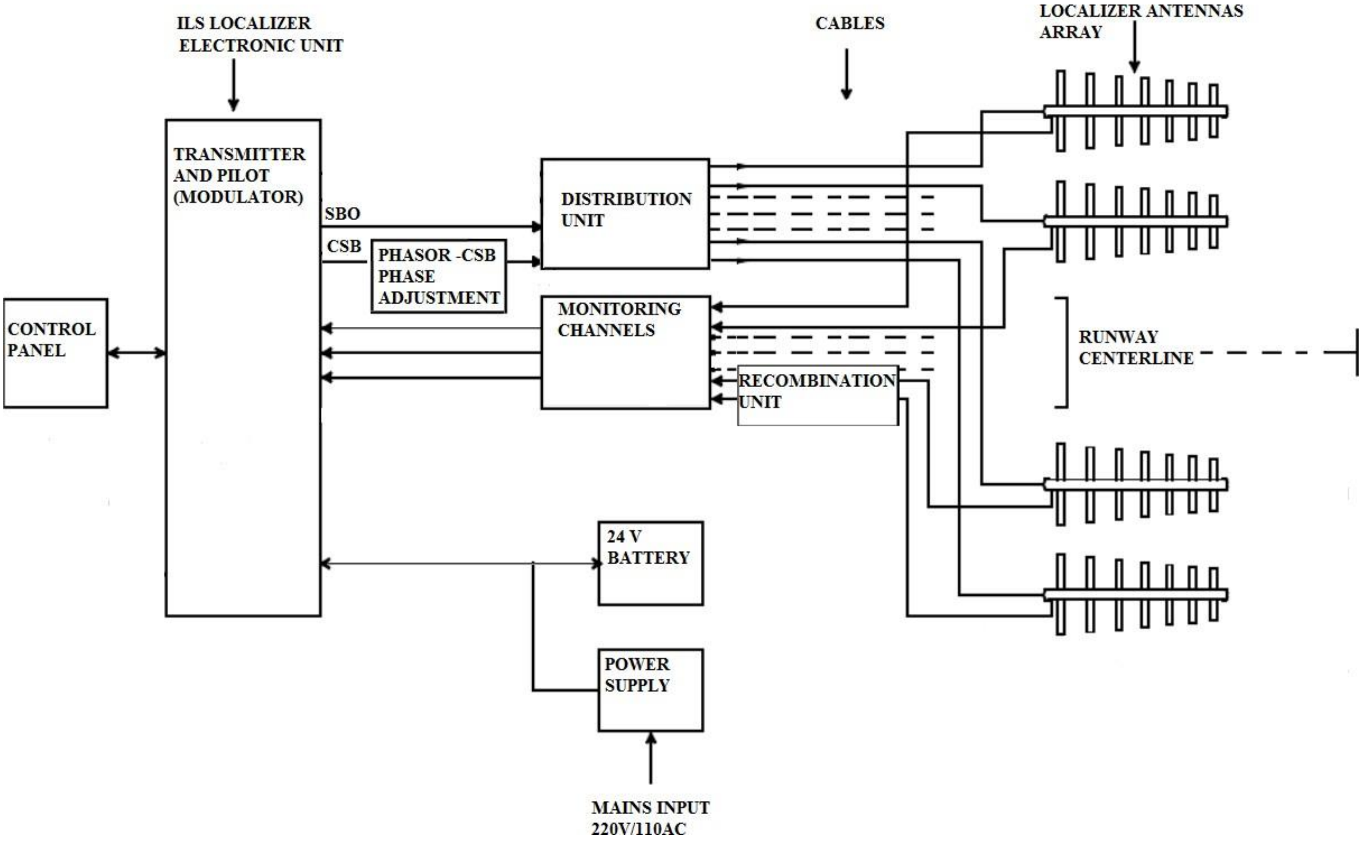


*Figure 4: ILS block scheme*

## The concept

The main idea – is to create something simple yet handy to help pilots orient on the runway during extreme conditions. Such indicator may help aircraft during landing on short runways preventing them from roll out. The device also may prevent from roll out overloaded aircraft which try to take off in conditions of very high temperature of environment.

Such device should be located at the height comfortable for pilots. For example, in Boeing 737-800 (fig. 4) it is advised to place the indicator under the mode control panel (MCP).

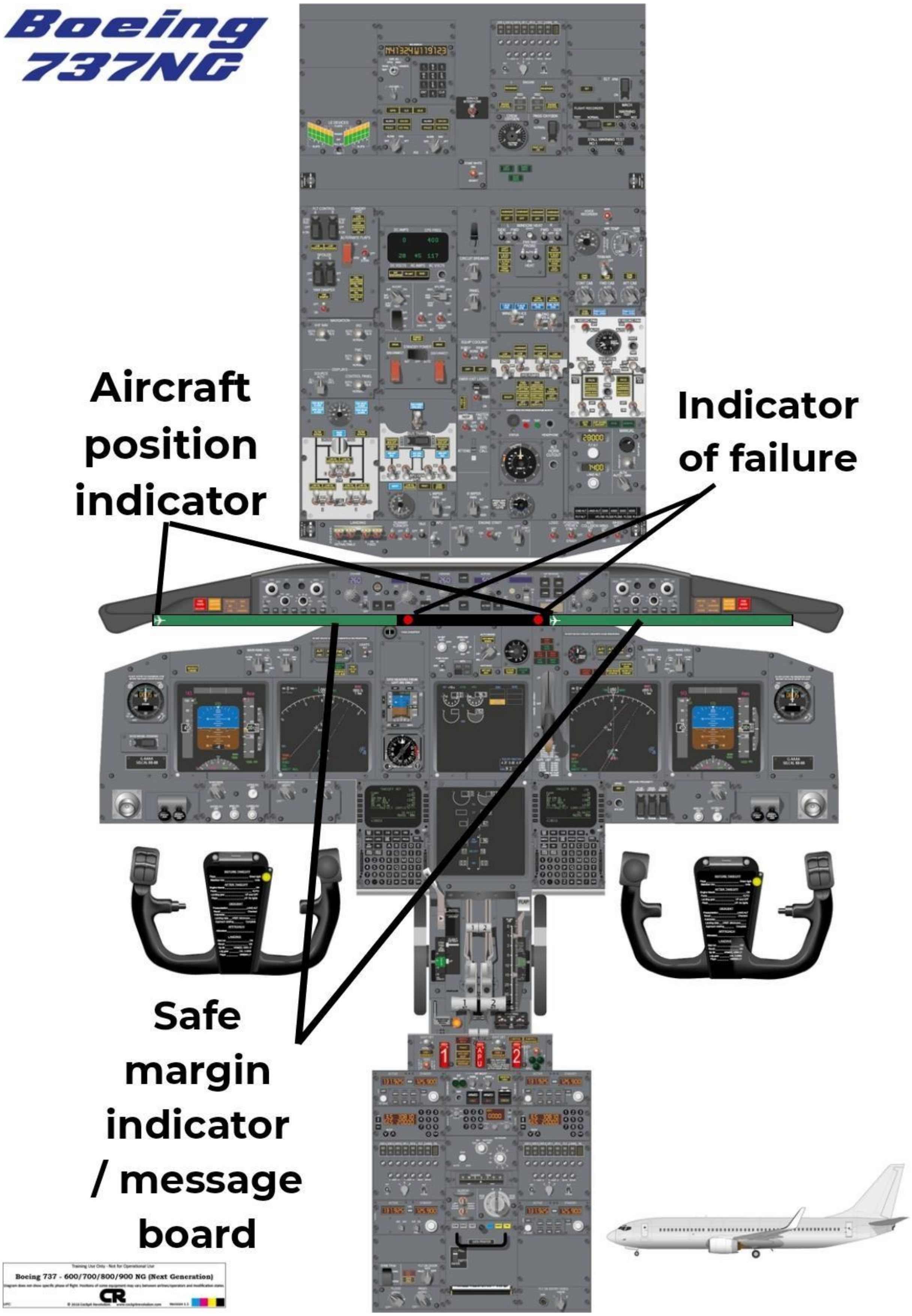


*Figure 5: Boeing 737 NG indicator location*

The main indications can be divided into two groups: positive and negative. Positive recommendations can show the aircraft operators that the current stage of flight can be performed by the normal check list. Negative indications show the pilots if it is safe to proceed the landing or take off. Such recommendations are based on the calculations of the analysing computer, which is receiving data from the frequency generator and transmitter, in extended version also from speed indicator, RPM indicator, thermometer.

## Functions and indications

The device is meant to be simple and have user friendly environment. Such device should produce no extra load on pilots. The location chosen (fig. 5) makes the instrument almost invisible part of the flight deck interior while in steady flight. [7]

The indicator activates while the aircraft reaches the altitude of 60 m (200 ft). Display becomes active as it receives the radio waves from located on the ground transmitter. In case of transmitter-receiver onboard principle the device may also be activated with flaps extension or manually. Deactivation of the device should be performed with pushing the button which is closer to the device. Automatic stand-by mode may be activated as the aircraft reaches 90 m (300 ft).

The indication must show different recommendations for different scenarios:

1. If the situation is controlled and the aircraft will manage to safely take-off or stop without roll out, the indication should show the runway represented with green quadrangle and the white aircraft symbol moving across it. As shown at the *Figure 6.*
2. In case of critically big speed that cannot be reduced in any way while aircraft is almost touched the ground or landed and moving across the runway, the runway indication should be in red colour with the “GO AROUND” blinking message (fig. 7).
3. In case of lack of engine thrust and if the calculations made by analyser computer shows that performing take-off is impossible without rolling out of the runway border the indications should show the represented runway in red and the alert “STOP STOP” for pilots to abort the take-off procedure and check the presence of cargo overload or engine malfunction (fig. 8).

*Figure 6: Normal procedure indication*

*Figure 7: Unsafe landing warning*

*Figure 8: Unsafe take-off warning*

4. In case of high speed and short runway residue and flaps being not fully extended the flashing indication “FLAPS FLAPS” engaged (fig. 9).
5. In case of short runway residue and spoilers being retracted the indication “SPOILERS” is displayed (fig. 10)
6. The indication regarding failure of the device should be indicated as the nearest to the device button glow with static red colour near, while the main display remains blank (fig. 11)

*Figure 9: Flaps retracted. Full deployment needed.*

*Figure 10: Spoilers retracted. Deployment needed.*

*Figure 11: Device malfunction*

## Measurement Methods

Using the same principle that is used for the radar altimeter the remaining length of the runway can be established. The method is based on the measuring the time it takes for radio waves to reflect from the ground and turn back to the receiver. In the case of remaining runway measurement two different technologies may be used. Still, the methods are related as they both use the radio waves to calculate the distance.

First method (fig. 12) requires the installation of both receiver and transmitter antenna on the airplane, the reflective panels or paints should be installed on the runway as well. The reflective panels should change the wave frequency, so the received frequency will be different from the frequency transmitted to the panels on the runway. As the different panels have unique reflection index different frequencies will be received by the aircraft. The digital frequency counter should be installed on the aircraft.

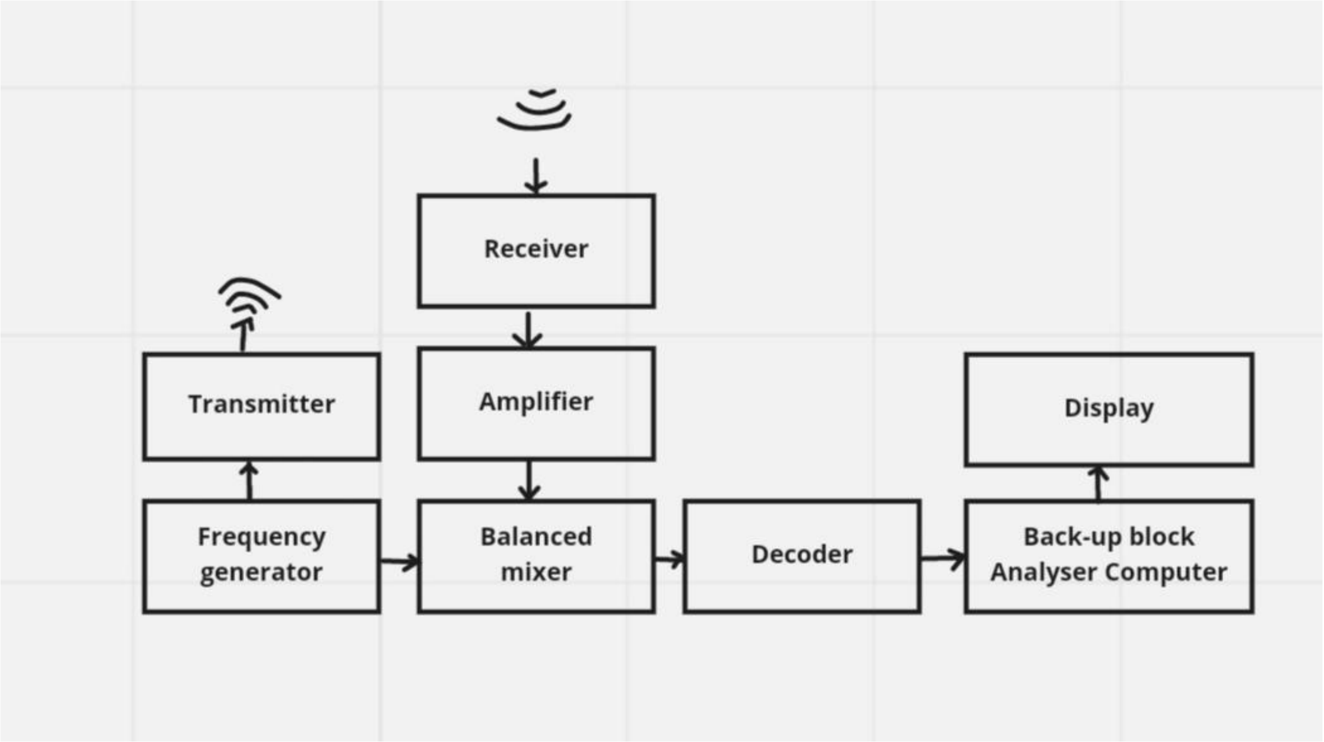


*Figure 12: Control system connections*

Frequency generator creates radio waves. Continuous frequency modulated fluctuations should be used for transmitting to the reflection panels. Reflected and distorted signals will be obtained by the receiver transmitted then to the balanced mixer where the random distortions are cut down. Balanced mixer obtains unreflected fluctuations from the frequency generator as well. As a result of combination initial and reflected signals, a new signal occurs. Such signal represented by modulated by the frequency and amplitude high frequency fluctuations.

Another runway measurement device is based on the radio range finder principle (fig. 13). The measurement is performed by comparing the time delay between the received signals.

Such method requires airfields to install the transmitter at the rare edges of the runway directed along the centre line. The transmitters send encoded signals to the aircraft.

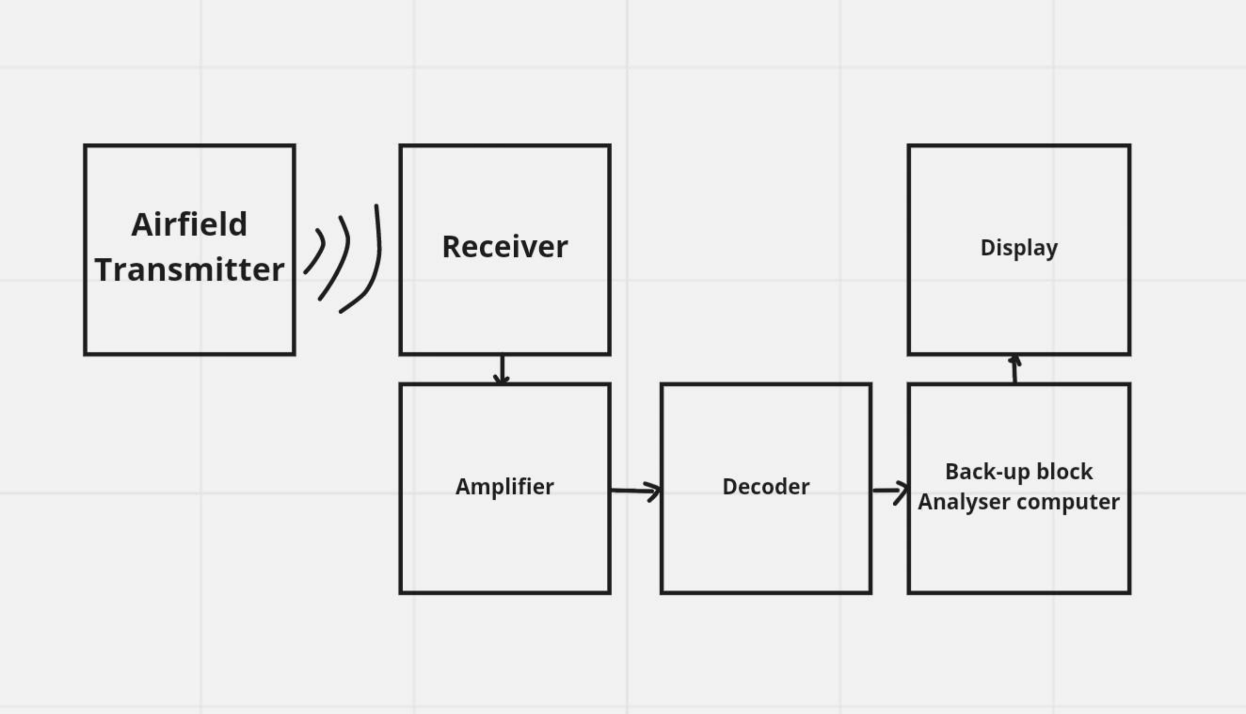


*Figure 13: Connections of the receiver-based onboard system*

Overall calculations will include obtaining the tendency of the aircraft to accelerate or decelerate. Calculations are based on the comparing the increase of the indicator speed and the changes in range.

Using the simple formulas, it can be determined:

The acceleration $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$,

Where $V_1$, $V_2$ – indicator speed in time interval of 1 second.

Displacement $S = Vt + \frac{at^2}{2}$.

Obtaining the information of flaps and spoilers extension the calculations may be changed as the additional coefficients will substitute.

### Location and connection

The transmitter-receiver system should be located at the nose part of an aircraft. The computer that calculates the position of the aircraft on the runway should be located at the 7-8 aircraft frame.

*Figure 14: Computer location*

## CHAPTER 4-5

### labour protection

labour protection is a set of legal, normative, socioeconomic, organizational-technical, sanitary-hygienic, and medical-preventive policies and methods aimed at maintaining human health and working capacity.

A series of state legislative statutes governs labour protection. The Constitution of Ukraine, the Labour Code, the Law of Ukraine "On labour Protection," the Law of Ukraine "On Ensuring Sanitary and Epidemic Welfare," the Law of Ukraine "On Fire Safety," the Law of Ukraine "On Compulsory State Social Insurance Against Workplace Accidents and Occupational Diseases That Have Caused Disability," and bylaws on labour protection are the general laws of Ukraine that define the main provisions on labour protection.

### Environmental protection

Environmental protection is a system of legislative acts and measures aimed at reducing the impact of harmful and productive factors on soil, water, atmosphere, vegetation, fauna.

Environmental protection is becoming increasingly important. The number of new devices is growing every year. Therefore, it is very important to ensure that they meet the state standards of the country. Each device is a source of negative factors that affect both environment and operators. The main ones are excessive noise, vibration and electromagnetic radiation.

In Ukraine such factors are controlled by the government standards:

GOST 20444-85 (1994) Noise. Traffic flows. Methods of measuring noise characteristics;

GOST 12.1.050-86 SSBT. Methods of measuring noise in the workplace;

GOST 20296-81 Aircraft and helicopters of civil aviation. Permissible noise levels in crew cabins and cabins and noise measurement methods;

DSTU 2300-93 Vibration. Terms and definitions;

DSTU ISO 2631-2: 2004 Vibration and shock mechanical. Assessment of the impact of general vibration on humans;

GOST 12.1.012-78 "Vibration. General safety requirements"

DSTU ISO / TS 15694: 2005 Mechanical vibration and shock. Measurement and evaluation of single impacts transmitted from hand-held and hand-operated machines to the brush-hand system;

DSTU EN 14253: 2005 Mechanical vibration. Measurement and calculation of the impact on health of total industrial vibration;

DSTU EN 50364: 2006 Electronic equipment operating in the frequency range from 0 Hz. up to 10 GHz. Limit the effects of electromagnetic fields on humans from electronic surveillance equipment, radio frequency object recognition and similar applications;

DSTU EN 50371: 2006 Electronic and low-power equipment. Confirmation of compliance with the basic limit levels associated with the action of electromagnetic fields from 10MHz. up to 300GHz. in general.

GOST 12.1.006-84 "Electromagnetic fields of radio frequencies. Acceptable levels in the workplace and control requirements. "

## Atmospheric air pollution near airports

Aviation is an ecologically dangerous branch of the country's economy, as in the process of activity of this branch environmental pollution and harmful effects on humans are always present.

Air pollution in the area of the airport is the result of the operation of mobile and stationary sources.

The investigation of air pollution sources at the airports of Ukraine and other countries showed that the main sources of pollutants are:

- aircraft;
- special vehicles;
- passenger vehicles;
- fuel and lubricant warehouses;
- boiler plants;
- technological sections of the aviation technical base of the airport.

In most cases, airplanes are the main sources of pollution,

mostly pollutants such as carbon monoxide CO, hydrocarbons CH, nitrogen oxides NOx and smoke (suspended particles), i.e. substances characteristic of the combustion products of any vehicle.

Airplanes pollute the atmosphere as a result of exposure to harmful substances from the exhaust gases of aircraft engines. Gases are emitted into the atmosphere by nozzles and exhaust pipes of engines.

As the sulphur content in aviation fuel is strictly limited, the sulphur content is normalized to no more than 0.3% of the total mass of fuel, so the emission of sulphur oxides by aircraft engines is not controlled (and not regulated).

The analysis of calculations of air pollution in the area of one of the airports of Ukraine showed that emissions of incomplete combustion products - CO and NS are maximum for the stages of starting and warming up engines, for taxiing aircraft before take-off and after landing, i.e. at those stages of the take-off and landing cycle, in which the operating modes of the engines are close to low gas.

Emissions of nitrogen oxides are maximum at the stages of take-off and initial ascent.

The study of air pollution consists of two calculation units:

1) assessment of air pollution from mobile sources according to the EDMS model;

2) assessment of air pollution from stationary sources according to the EOL program (OND-86 method).

The EDMS model calculates emissions (emissions from aircraft engines during the take-off cycle stages) and dispersions of pollutants (oxides of carbon, nitrogen and sulfur, hydrocarbons and suspended solids) at the airport.

Thus, the model and software allow you to assess the quality of ambient air within the airport.

The OND-86 methodology, which is a normative document for use during the development of the maximum allowable emission project, does not correspond to the features of aircraft as a mobile source of pollutant emissions.

Airplanes are a special class of sources of pollutants. These are mobile sources, the temperature of the exhaust gases of aircraft engines which differs significantly from the temperature of the outside air.

## Methods of reducing the harm effect of the noise

Noise is one of the important factors of harmful impact on the environment, it is no less dangerous than air or water pollution.

Acoustic oscillations in the frequency range 16 ... 20000 Hz, which are perceived by a person with normal hearing, are called sound, and the space where they propagate - the sound field.

The main characteristics of sound waves are:

- frequency (Hz);

- wavelength X (m);

- intensity (W / m2) - the density of the flow of sound power per unit area perpendicular to the direction of wave propagation;

- sound pressure P (Pa) - a variable of excessive pressure, which occurs as a result of oscillations of the sound source.

The relationship between intensity and pressure is defined by:

$$I = P^2/\rho\alpha,$$

Where $\rho$ – density, kg/m$^3$;

$a$ – speed of sound, m/s.

The speed of sound depends on the environment conditions:

$$\alpha = \sqrt{kRT} \ ,$$

where k is the adiabatic index (for air k = 1,4);

R – universal gas constant (for air R = 287.3 J/kg*K);

T – the temperature of the environment (K).

Sources of noise and infrasound can be oscillations that occur during collisions, friction, sliding of solids, leakage of liquids and gases.

In production conditions, the sources of oscillations are operating production equipment (electric motors and generators, turbines, compressors, hoisting and transport equipment, fans, air conditioners, etc.).

Sources of noise are vehicles, aircraft power plants with gas turbine and reciprocating engines, auxiliary power plants of aircraft with launch units; The sources of sound shock are aircraft or bodies that move at supersonic speeds and create seals.

Sound intensity and sound pressure can vary widely. Thus, a person can perceive sound pressure in the range from 200 to $2 * 10^{-5}$Pa, the sound intensity can vary from 100 to $10^{-12}$ W/m$^2$.

The characteristics of constant noise, as well as to determine the effectiveness of measures aimed at reducing its negative impact, are the levels of sound pressure in decibels in octave bands with geometric mean frequencies (Hz): 31.5; 63; 125; 250; 1000; 2000; 4000; 8000.

In general, medical research on the noise problem is aimed at determining the relationship between the physical characteristics of noise and its biological effects. A person exposed to noise may experience adverse physiological reactions, and prolonged exposure (increased exposure) causes disorders that increase the risk of chronic clinical diseases and environmental dissatisfaction. Everyone perceives noise differently. Much depends on age, temperament, health, environment. Children and the elderly are most sensitive to noise.

Studies of the effects of noise on living organisms have shown the development of a general nonspecific reaction, characterized by decreased oxygen consumption by all brain tissues, dystrophic changes in the brain and internal organs, vascular disorders, biochemical changes in internal organs, indicating tension of protective forces. organism.

Noise excites the centers of the brain, regulates the endocrine glands and biorhythms, which can lead to changes in heart rate per minute, respiration rate, blood pressure, cause changes in blood and dilation of the pupils. Noise contributes to the development of hypertension, gastric and duodenal ulcers. High noise levels can stimulate the vestibular apparatus, dizziness occurs.

Analyzing various types of harmful effects of noise on humans, we can state that:

- aviation noise (AS) does not cause permanent hearing loss or even temporary significant;

- the most characteristic reaction to the influence of AS is irritation, and the degree of irritation depends on the individual character of the person, his attitude to the situation, to a greater extent even on what the person expects from this situation.

Adverse effects of AS on humans are determined by a combination of the following factors:

1) the intensity and frequency composition of the AS, which depend on the type, power and number of engines installed on the aircraft, their mode of operation, the direction of noise radiation, distance and speed of the aircraft, the values of meteorological values;

2) the duration and frequency of recurrence of the impact of the AS, which are affected by the speed and altitude of the aircraft, the intensity of the fleet;

3) individual characteristics of people, time of day, etc.

The criteria used to assess the adverse effects of AS differ from these factors and take into account the mathematical structure. The simplest criteria are the volume and volume level of noise, which take into account the spectral composition and intensity of noise to determine the degree of its perception.

The analysis of researches gives the chance to draw conclusions, concerning noise:

1) Noise affects the results of human life both indoors and outdoors. Comparing the levels of external and internal noise, it is necessary to take into account the sound insulation of buildings and structures: for the warm season

("windows open") sound insulation of the normal structure of a residential building is 15 dBA; for cold ("windows closed") - 25 dBA.

2) Noise level $L_{Аекв}$ = 75 dBA is a threshold that provides protection against hearing damage.

3) The maximum noise level, which provides calm communication with normal vocal effort and 100% legibility of words - 45 dBA.

4) According to the reception of TV and radio programs, listening to music is ensured without interference at a noise level of 45 dBA.

5) Transport noise up to $L_{Аекв}$ = 60 dBA close to the human ear does not affect the accuracy and efficiency of mental activity, such as reading or calculating.

## Methods to reduce the harmful effects of vibrations

According to the method of transmission of vibrations to humans are divided into:

- general - those that are transmitted through the supporting surfaces;
- local (local) - those that are transmitted through human hands.

The direction of vibration is determined by the orthogonal coordinate system

X, Y, Z.

The main parameters that characterize vibration are oscillation frequency, oscillation speed and amplitude.

The oscillation speed is directly dependent on the oscillation frequency and amplitude:

$$v = 2пfA = wA$$

where v is the oscillation speed, cm/s;

f is the oscillation frequency, Hz;

A - amplitude at harmonic oscillating motion, i.e. the magnitude of the largest deviation from the equilibrium position, cm;

w is the circular frequency, i.e. the number of complete oscillations made in time is equal to 2pf s.

By analogy with noise, an important characteristic of vibration is its level, measured in logarithmic units - decibels.

Logarithmic vibration velocity equation

$$L = 2 \lg v/(5*10\ )$$

where v is the root mean square velocity, m/s;

5 * 10 - reference vibration speed, m/s;

The sources of vibration in the aircraft are the same as the noise. Accelerations caused by vibration increase with increasing aircraft speed, worsening weather and reduced payload. The effect of vibrations on humans is determined by their amplitude and frequency. Vibration impairs visual perception, reduces the quality of attention, causes fatigue, headaches.

In order to reduce vibration, it is recommended to use a rigid seat without springs, as it is a good shock absorber. Vibration acts on a person through the back, pelvis, arms. To reduce the vibration of the machine, special seats should be installed on specially designed shock absorbers made of steel springs or elastic materials.

To reduce the transmission of vibration and noise through the air conditioning system and piping, connect them to fans and pumps with a flexible insert made of rubberized fabric or rubber pipe.

It is necessary to cover vibrating surfaces and equipment with vibration-absorbing and damping materials (rubber, special mastics, asbestos, bitumen, plastics such as "Agate" and so on). Shock-absorbing materials (rubber, cork, cardboard, asbestos, spring-loaded shock absorbers) should be used at the joints of the mating parts to ensure a snug fit.

Reduce vibration in the source of vibration, i.e. in the source of its formation can be in the following ways: exclusion from the design of the shock interaction of parts, replacing the reciprocating motion of rotating parts, eliminating the imbalance of rotating parts and machine components.

When working with pneumatic and electric hand-held machines, vibration is transmitted through the handlebars and dashboards to the pilot's arms and sometimes to the legs, usually when exposed to air holes and turbulent flows. To reduce vibration in this case, use handles with devices that dampen vibration or with an automating effect.

Personal protective equipment against vibration is used when other means are ineffective. Shoes with shock-absorbing soles, gloves with vibration-absorbing elastic pads, earphones and so on are used as means of individual protection against vibration.

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