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FLIGHT SAFETY ISSUES DURING AIRCRAFT LANDING APPROACH

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Abstract*—This paper examines the psychophysiological stress experienced by flight crews during a standard landing approach, a phase considered one of the most critical in aviation operations. Elevated levels of cognitive and emotional strain can significantly influence pilot performance, including situational awareness, decision-making accuracy, and reaction time. The study emphasizes the pivotal role of timely and precise avionics diagnostics in mitigating risks associated with equipment failure or misinterpretation of instrument data. In this context, a method for calculating the reliability of critical onboard instruments during landing is proposed. The approach integrates both technical reliability factors and operational stressors to provide a comprehensive evaluation framework. The findings aim to support enhanced safety protocols and inform the development of more resilient avionics systems.*

Keywords—Flight safety; instrument reliability; radio altimeter; in-flight failure; landing approach; psychophysiological stress; pilot response; avionics diagnostics; system redundancy.

I. INTRODUCTION

A wide range of technical systems exists, whose failures may pose threats to human A broad array of technical systems exists whose malfunctions can lead to catastrophic consequences, including threats to human life, substantial financial losses, and reputational damage. These systems include contemporary aircraft, spacecraft, and other high-technology platforms that operate in dynamic, high-risk environments. In such systems, reliability is a fundamental criterion for assessing overall performance and safety. Ensuring high reliability is synonymous with ensuring quality, as it enables the full utilization of the systems' technological, operational, and economic advantages.

Modern aircraft are complex, digitally integrated systems comprising numerous subsystems and components that must function harmoniously. In contrast to earlier generations of aircraft, which relied heavily on analog components or hybrid analog-digital architectures, the transition to fully digital systems has substantially reduced the frequency of technical malfunctions. This improvement stems from the enhanced dependability and consistency of digital electronic components.

However, as classical technical failures have decreased, new challenges have emerged–primarily associated with malfunctions in avionics systems. These systems, though more advanced and reliable, are susceptible to failure modes that are less predictable and potentially harder to diagnose in real-time.

At present, two dominant models are employed to assess the reliability of onboard electronic systems:

1) The exponential model, which assumes a constant failure rate over time.

2) The diffusion-nonmonotonic model, which accounts for more complex, time-dependent failure behavior, including aging and environmental stressors.

Experimental research focused on the integrative dynamic behavioral stereotype (IDBS) of pilots has demonstrated that in-flight failures (IFF) can significantly impair pilot performance. Specifically, these failures result in larger oscillations of flight parameters – sometimes exceeding operational safety margins – and may lead to stress-induced pilot errors.

Simulation-based studies using full-flight simulators (FFS) have provided further evidence. During landing approach simulations – covering final base and final turns through touchdown – pilots must maintain precise control using instrument guidance (e.g., ILS or ground-based radio aids). Under such conditions, aircraft control exhibits ergodic and stationary dynamics, reflecting consistent but complex behavior over time. In simulated scenarios involving two to five simultaneous system failures, over 70% of pilots demonstrated ineffective responses, with increased psychophysiological stress amplifying deviations in flight parameters. These deviations often go unnoticed by pilots, presenting a latent safety threat and increasing the risk of flight incidents.

II. Problem Statement

Ensuring flight safety during critical phases of flight – particularly during approach and landing – remains one of the most pressing challenges in aviation. Despite advances in avionics and automation, human operators continue to play a central role in interpreting sensor data and responding to dynamic situations in real-time. These phases are especially sensitive because of their limited temporal and spatial margins for error, increased pilot workload, and the complexity of coordinating multiple subsystems under pressure.

Landing approach represents a phase of flight characterized by rapid altitude loss, increased cockpit workload, and often limited visibility due to meteorological conditions such as fog, rain, or snow. During this phase, the aircraft transitions from automated systems (autopilot, autothrottle) to manual control, requiring the pilot to precisely maintain glide slope and heading, often using only a few critical instruments. In this environment, even minor failures can escalate into major incidents [1] – [6].

The main objective of this study is to identify and analyze the specific threats to flight safety during the landing phase caused by failures of individual avionics components, with a focus on altimeter malfunctions. Such failures not only disrupt the direct perception of flight parameters but also trigger a cascade of cognitive and psychophysiological effects on the pilot, including disorientation, misjudgment, delayed reaction, and increased error probability.

As illustrated in Fig. 1, a failure during landing initiates a multi-stage sequence of crew reactions, shaped by both the nature of the fault and the pilot's psychophysiological state. The response process includes:

- recognizing the failure (which can be hindered by stress and information overload);
- diagnosing its source;
- determining the urgency and consequences;
- deciding on corrective action under time constraints.

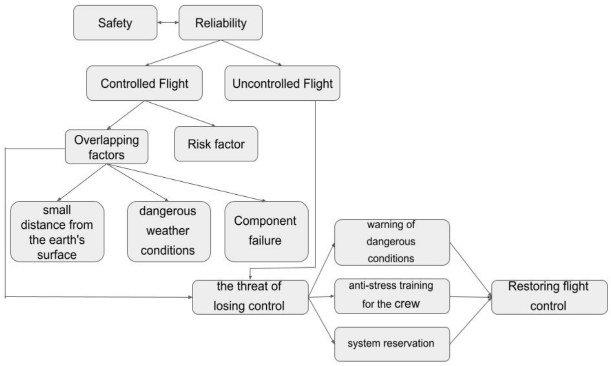

Fig. 1. Crew warning system about the operation of the FN during the aircraft approach to landing

If the pilot is not adequately informed about the failure – either due to poor warning system design or sensory overload – critical time is lost, increasing the likelihood of an incorrect response or total non-response. For example, a delayed or ambiguous warning about a barometric altimeter malfunction in poor visibility conditions can result in the pilot unintentionally descending below the decision height, violating minimums, and risking controlled flight into terrain (CFIT).

Furthermore, the reliability of the alerting systems themselves is seldom scrutinized with the same intensity as the primary flight instruments. This is a major oversight, as a highly reliable altimeter is of limited value if the associated warning system fails to communicate its malfunction in time.

III. Problem Solution

To address this, the paper emphasizes two key mitigation strategies:

1) System Redundancy – Ensuring critical systems like altimeters are supported by redundant counterparts (e.g., barometric + radio altimeter, GPS-based vertical positioning, terrain-following radar).

2) Enhanced Crew Training and Anti-Stress Protocols – Providing pilots with realistic, high-stress scenario training (via FFS) that includes simultaneous failures, degraded visibility, and conflicting instrument indications.

The research specifically proposes a quantitative method for assessing the reliability of a key altimetry component – the UV-5M altitude indicator, part of the RV-5M radio altimeter system widely used in civilian aviation. By focusing on a block-level reliability assessment, the study seeks to:

- isolate the weakest subsystems,
- recommend maintenance intervals;
- support avionics redesign where necessary.

The exponential failure model used in this work provides an efficient analytical framework, particularly for systems with a relatively constant failure rate over time. Each of the seven functional blocks in the UV-5M is analyzed for its individual contribution to system-wide reliability degradation.

This deeper understanding is vital for:

- predictive maintenance scheduling;
- redesign of system architectures;
- enhancing pilot confidence in their instruments during high-risk phases.

Ultimately, by quantifying the probability of failure for each component and mapping it to the pilot's response chain, we can better design both technical and human factors interventions to reduce the overall risk profile during approach and landing.

The results of Mathcad calculations for the blocks' reliability probabilities are shown in Figs 2–4.

To compare the reliability of each block, a diagram of $R(t)$ over time was constructed (Fig. 5).

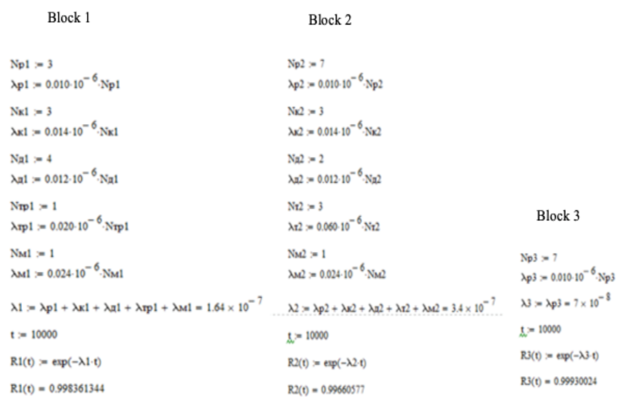

Fig. 2. Mathcad results of reliability for blocks 1–3

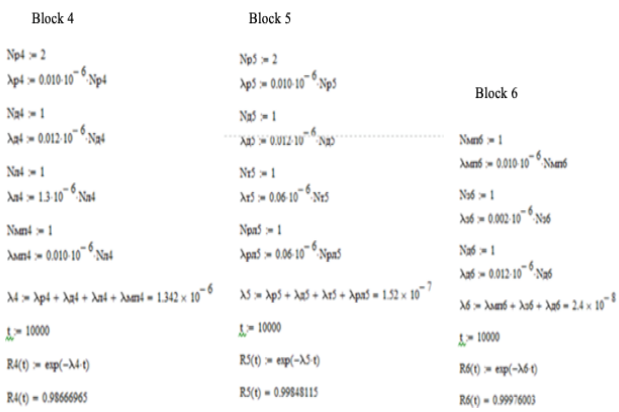

Fig. 3. Mathcad results of reliability for blocks 4–6

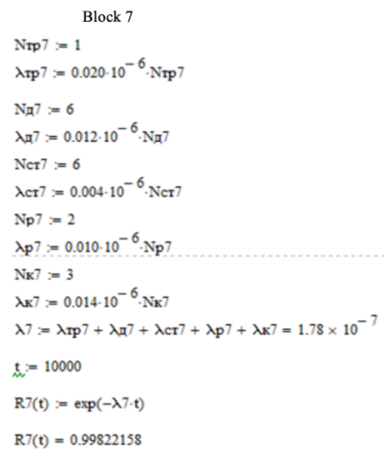

Fig. 4. Mathcad results of reliability for block 7

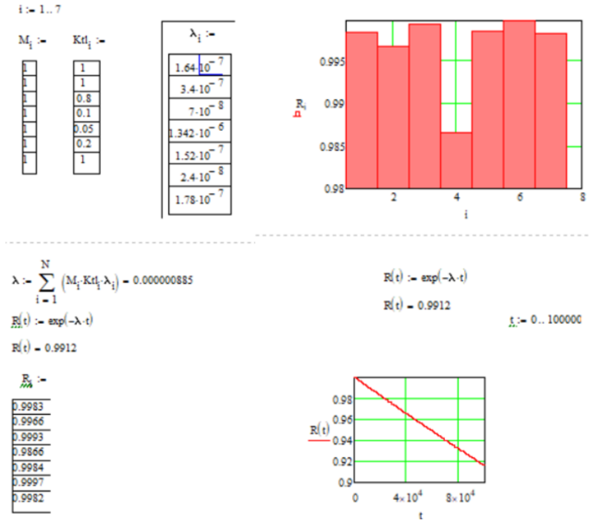

Fig. 5. Comparison of reliability for each block and $R(t)$ over time

We conclude that block 4 is the least reliable and requires quarterly inspections.

IV CONCLUSIONS

Effective maintenance and early detection of emerging faults can dramatically reduce the risk of failures during crucial flight phases. In particular, the landing phase and low-altitude operations are inherently vulnerable due to their reduced decision time, limited altitude margin for recovery, and increased dependency on precise instrumentation. These risks are further compounded by adverse weather conditions – such as fog, low visibility, wind shear, or precipitation – which place an even greater cognitive and physical load on the pilot.

Under such circumstances, the failure or even temporary malfunction of a single key instrument – such as an altimeter, glide slope indicator, or attitude reference system – can trigger a chain of negative effects**.** These include misjudgment of altitude, disorientation, and deviation from the intended flight path. For an unprepared or undertrained pilot, these stressors may escalate into a complete loss of situational awareness, delayed reaction times, and incorrect corrective actions.

Moreover, psychophysiological stress caused by unexpected failures often goes unnoticed or unacknowledged by pilots themselves. Yet, it plays a critical role in reducing decision-making accuracy and impairing motor coordination during critical tasks such as flare, touchdown, and rollout. Simulator-based experiments, as referenced in this study, clearly demonstrate that pilots under high stress levels tend to deviate more from nominal flight parameters and are slower to respond to alarm signals.

This underscores the necessity for:

- robust redundancy architectures in avionics systems;
- highly reliable warning and diagnostic subsystems that detect anomalies in real time;
- and targeted stress-management and failure-response training to prepare pilots for compound failure scenarios.

Ultimately, ensuring that flight crews are equipped – both technically and psychologically – to handle unexpected instrument malfunctions is essential for minimizing the risk of accidents and maintaining the highest safety standards in modern aviation.

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Ю. В. Грищенко, О. О. Чужа, М. Ю. Заліський, Т. С. Соломаха, Д. Ю. Іващенко. Питання авіаційної безпеки на етапі заходу на посадку

У статті досліджено психофізіологічний стрес, якого зазнає екіпаж під час стандартного заходу на посадку – одного з найвідповідальніших етапів авіаційного польоту. Підвищене когнітивне та емоційне навантаження може суттєво впливати на ефективність дій пілотів, включно зі зниженням ситуаційної обізнаності, точності прийняття рішень та швидкості реакції. Особливу увагу приділено важливості своєчасної та точної діагностики авіоніки для зниження ризиків, пов'язаних із відмовою обладнання або неправильною інтерпретацією даних приладів. У цьому контексті запропоновано метод розрахунку надійності критично важливих бортових приладів під час посадки. Підхід об'єднує технічні параметри надійності з урахуванням впливу експлуатаційних факторів стресу для створення комплексної системи оцінювання. Отримані результати спрямовані на вдосконалення протоколів безпеки та розробку більш стійких авіонікових систем.

Ключові слова: безпека польотів; надійність приладів; радіовисотомір; відмова в польоті; захід на посадку; психофізіологічний стрес; реакція пілота; діагностика авіоніки; резервування системи.

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