Summary Report

I C E P S

Contract No.: AI-97-AM.0235 - ICEPS

Project Coordinator: **TÜV Kraftfahrt GmbH (TÜV), Germany**

Partners: **Hapag-Lloyd Flug GmbH (HL), Germany**

Leopold Franzens University of Innsbruck Institute of Forensic Medicine (GMI), Austria

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Injury Criteria for Enhanced Passive Safety in Aircraft (ICEPS)

Table of Contents

Page

1 Partnership

Project Co-ordinator:	Project Partners:	
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Participants per work package:

Participants	WP1	WP2	WP3	WP4	WP5	WP6	WP7
TÜV	C	C	C	P		C	C
GMI		P		C	C	P	
HL		P				P	
C= Work package co-ordinator, P = participant in work package							

2 Objectives of the Project

The ICEPS Project work about the following work packages:

Work package 1 - Project Management - is designed to provide management of the internal project work as well as liaison with DGVII.

The objective of **work package 2** - Accident Analysis - is the development of an analysis of the Kegworth and Warsaw accidents with Part 25, aircraft. This work package will focus on all relevant information about passive safety in an aircraft cabin during an emergency landing or a crash.

Work package 3 - Evaluation of Injury Criteria - will give an overview of the existing evaluation criteria in aircraft and automotive technology. All known criteria will be listed and explained. It will be demonstrated that it is possible to transfer the results from the automotive sector to the aircraft sector and it will be discussed how useful such results are.

Work package 4 - Correlation between Injury and Evaluation Criteria - is aimed at demonstrating the interaction of injuries, or the failure behaviour of the cabin interior and evaluation criteria.

In **work package 5** - Biomechanics -, a compilation of biomechanical tolerance data of the human body will be established. On the one hand, human tolerance as regards the entire body will be dealt with, and on the other hand, injury criteria such as head, cervical spine, thoracic/lumbar spine, thorax, pelvis and upper as well as lower extremities will be examined.

The objective of **work package 6** - Injury Criteria for enhanced Passive Safety in Aircraft Cabins - is the development of new, improved evaluation criteria in order to increase aircraft passenger survivability in an emergency landing or in a crash.

Work package 7 - Proposals for European Airworthiness Requirements - will provide proposals for the further development of European Airworthiness Requirements and prepare an exploitation of these main project deliverables. It will submit the final contribution of work package 6. The proposed criteria will be discussed and agreed with the representatives of European aviation authorities (Luftfahrt-Bundesamt, Germany, and Austro Control GmbH, Austria).

3 Technical description / Results

Two accidents with Part 25 aircraft were analysed, and passenger injuries represented. The two accident analyses focused on the assessment of the decelerations effective in the aircraft cabins and on the determination of passenger injuries. The passenger injuries were related to the individual body regions. The correlations between the loads acting on the passengers and the injury patterns were analysed, based on the available accident examination reports and interviews with witnesses as well as with persons conducting the accident examination.

During the **Warsaw** crash in September 1993, one passenger out of 64 passengers died; 30 passengers were injured, and 33 passengers remained uninjured. The aircraft touched down the runway in bad weather, however, it was not possible to reduce the speed to a standstill. At the end of the runway, the aircraft slipped over an unpaved meadow and then, with a slight angle of yaw, it slid against a hill of approx. 6 m height. The fuselage slipped over the hill and came to a stop behind the hill. The tail then lay on the hill, with the nose being on the ground. The fuselage structure remained undamaged during the crash, only after the survivors had left the aircraft, the fuselage burnt out completely.

It results from the analysis of the whereabouts, that the aircraft nose, upon slipping over the hill, hit the ground from a height of approx. 6 m. The relevant decelerations during this crash were mainly effective in the vertical aircraft axis. The decelerations in the longitudinal axis were within the range of strong slow-down decelerations, especially when the aircraft slipped over the hill.

The injuries determined in the passengers of the Warsaw flight showed a high number of injuries of the lumbar (42 percent) and thoracic spine (16 percent). These passenger injuries mainly occur in loads acting in the direction of the vertical axis. This correlates well with the determined decelerations.

The second examined crash took place in England, near the town of **Kegworth**, in January 1989. 39 passengers out of 119 passengers died. The aircraft had a damaged power unit and was approaching the airport of Midland, which, however, it did not reach. The aircraft underwent two impacts, with the second main impact against the embankment of a motorway. In this process, the fuselage brake into three parts.

After the crash, various English institutes conducted comprehensive examinations. The decelerations during the second impact effective in the central fuselage segment were reconstructed, among other things. The results show that high decelerations both in the longitudinal axis and the vertical axis were effective during the crash.

The passenger injuries in the Kegworth accident show a high percentage of arm and leg injuries, among others (together 38 percent). The examination conducted by the Queen's Medical Centre draw a connection between the leg injuries and the high decelerations in the longitudinal aircraft direction. Also the arm injuries can be referred to the decelerations in the longitudinal aircraft direction.

JAR 25.562 "Emergency Landing Conditions" require dynamic examinations for aircraft passenger seats. The analysed accidents show that the loads effective in aircraft crashes are closely comparable with the dynamic tolerance tests outlined in JAR 25.562. However, the JAR does not take more than one subsequent impacts into consideration, as have occurred e. g. in the Kegworth crash (first impact, second impact).

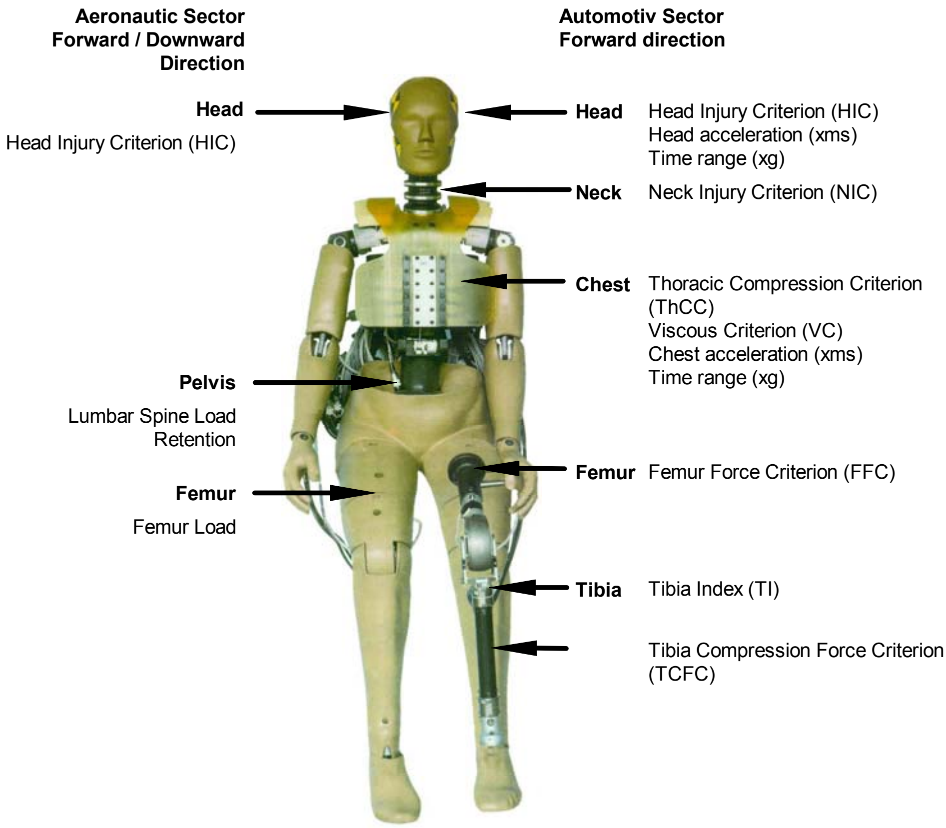

Figure 1: Known dummy protection criteria

With the formerly performed dynamic tests in accordance with the "Emergency Landing Conditions", the structural rigidity of aircraft passenger seats is verified, among other things. Moreover, the measured loads acting on the dummy must not exceed the limit values for the head, the lumbar spine and the longitudinal forces in the femurs.

In the automotive industry, dummy criteria are evaluated for the head, neck, thorax, pelvis, femurs, knees and tibiae. The criteria currently applied in the aeronautical and automotive industry to evaluate loads in dynamic tests with dummies are represented in a compilation, see figure 1. The comparison of these criteria with the injury patterns determined in the two aircraft crashes shows that the criteria applied in aviation are not sufficient alone. The criteria used in the automotive industry are much more comprehensive.

The regulations for passenger cars furthermore outline methods to evaluate the risk of injury in the interior, see figure 2. Methods and criteria are represented to determine and evaluate e. g. sharp edges, projecting parts, padding or covering of structural parts. Some methods and criteria were applied, evaluated and represented at the example of two different aircraft cabin types.

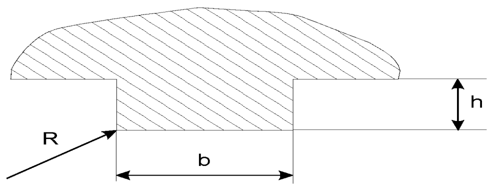

Figure 2: projecting parts, criteria example

A further focus of ICEPS was the outline of biomechanical tolerance limits for the human body regions. The main and generally accepted tolerance values for head/face/brain, neck/cervical spine, chest, abdomen, pelvis/vertebral spine, upper extremities, lower extremities and others/overviews are listed. It is an interesting fact that there are only relatively few data on biomechanical tolerance for the upper extremities.

In enhancing passive safety in aircraft, research should be based on the objective that passengers are able, upon a crash, to evacuate the aircraft on their own, without external aid. Passengers' autonomous action is necessary particularly because there is always a high risk of fire after a crash and it is not possible to wait for external aid. Based on this requirement, the following central ideas were deducted:

1. Passengers must be in a state of consciousness after a crash in order to be able to act on their own.
2. Passengers must be able to free themselves, i. e., they must be able to use their hands.
3. Passengers must be able to leave the aircraft on their own and to go away from the aircraft.

4 Conclusions

It is not possible with the criteria currently applied in the aeronautical sector to enhance passive safety in aircraft cabins comprehensively and concertedly. The former criteria only consider partial aspects from the field of passive safety. For a comprehensive consideration, passengers' survival space must be examined as well, see figure 3. In the survival space, passengers can be protected during a crash, and for this reason, it must be ensured that passengers are able to act and walk after an accident. Only thus it is possible for passengers to withdraw from the hazardous area.

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Figure 3: typical survival space

The proposed enhanced criteria consider the risk of injury for all human body regions, i. e. injury criteria are outlined for the head/face/brain, neck/cervical spine, chest, pelvis/vertebral spine, upper extremities and lower extremities. Moreover, it is proposed to examine passengers' survival space in view of sharp edges, and covered structures must provide of a minimum of energy consumptive capacity.

This project, however, found that further research is necessary beyond this project.

The accident analyses performed in this research project demonstrate that are very few data or even no information at all on what happened to the passengers during the crash, what decelerations were effective in the aircraft cabin and how the interior behaved.

For a continuous enhancement of passive safety in aircraft cabins, further analysis of aircraft accidents is useful. Thus, each aircraft crash should be examined with regard to the correlations of the accident mechanisms and injury mechanisms. However, this requires new means of information gathering to perform the respective analysis.