Quantitative Risk Management

Cpt. Manfred Mueller
Head of Flight Safety Research Lufthansa AG
Lecturer on Risk Management, Univ. Bremen
SAMSYS - Safety Performance Index (SPI)
Quantitative risk assessment and their protective measures in aviation

More than 25 University Experts

Institute for Production an Logistics GmbH
affiliated institute at the University of Bremen

BIBA

Lufthansa
Section Operation / Safety
Project Leader

Cognidata
Software Development

> 5.000.000 -$

Institute of Strategic Management

Institute of Flight System Dynamics
Institute of Ergonomics
Institute of Mathematics

Institute of Aeronautics and Astronautics
Chair of Flight Guidance & Air Transportation

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Is flying an „ultra-safe“ system?
40 years ago driving to the airport was the most dangerous part of an Airline-flight
Hull Loss per Million Sectors (1958-2011)

...last 40 years in Germany:
Increase in car-safety ~40 times
Increase in flight safety ~4 times
Risk of driving to the airport in Germany versus an average IATA-Flight (2014)

\[ P_{\text{fatal car ride}} : 7.2 \times 10^{-8} \text{ (1 in ~15 Million)} \]

\[ P_{\text{fatal flight}} : 0.3 \times 10^{-6} \text{ (1 in ~3 Million)} \]

driving to the airport is now 5 times safer than an Ø Airline-Flight
>400 cars
Why don‘t we see the problems?

The number of all Airline-flights worldwide per year equals the number of car-trips in Germany within 4 hours

6 years of worldwide Airline flights => 1 day car traffic in Germany:

~5 fatalities in cars per day, (without country roads ~2 fatalities daily)
after deregulation...
Economical pressure
every 90 hours

one per month
### How dangerous are various jobs?

**Number of fatal accidents per 100,000 workers per year**

<table>
<thead>
<tr>
<th>Job</th>
<th>Accidents Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>fisherman</td>
<td>123</td>
</tr>
<tr>
<td>seaman</td>
<td>68</td>
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<tr>
<td>railroad worker</td>
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<td>docker</td>
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<td>miner</td>
<td>15</td>
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<td>farm hand</td>
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<td>construction worker</td>
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<td>crane driver</td>
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<tr>
<td>chemical worker</td>
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<td>Fireman</td>
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<td>policeman</td>
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<tr>
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<td>painter</td>
<td>6</td>
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<tr>
<td>soldier</td>
<td>6</td>
</tr>
<tr>
<td>electrician</td>
<td>5</td>
</tr>
</tbody>
</table>

*Source: University of Oxford*
Continental CEO Jeff Smisek
(cost saving: worked one year without getting salary)

2010 „Manager of the year“

2004 bis 2009 „Most Admired Global Airline“
„Highest Ranked Network Airline“

increasing economical pressure
Continental Airlines

Safety is our top priority: Flights can stop for extra fuel en route if necessary!

Continental Airlines fuel emergencies

(less than 30 minutes of fuel!) at Newark Airport

2005: 19
2006: 42
2007: 96
Defining an acceptable level of safety ALoSP (Limit)

measuring the actual risk level

Identifying Deviations (Δ)

Corrective action(s)
ALoSP (Acceptable Level of Safety Performance)

How safe should it be?

What should be the safety target for an Airline flight?

Lufthansa
ALoSP (Acceptable Level of Safety Performance) versus Lufthansa accident rate

**LH:** ALoSP $10^{-8}$ in average one total loss every ~100 years

**EU:** ALoSP $10^{-7}$ in average one total loss every ~10 years

**IATA-Rate:** $0.5 \times 10^{-6}$ in average one total loss every ~2 years
Defining an acceptable level of Safety ALoSP (Limit)

measuring the actual risk level

Corrective action(s)

Identifying Deviations ($\Delta$)
### How dangerous are various jobs?

**Number of fatal accidents per 100,000 workers per year**

<table>
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<tr>
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<th>Rate</th>
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<td>docker</td>
<td>19</td>
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<tr>
<td><strong>airline pilot</strong></td>
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<tr>
<td>miner</td>
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<td>truck driver</td>
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*University of Oxford*
How dangerous are various jobs?
Number of fatal accidents per 100,000 workers per year

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<th>Number of Fatal Accidents per 100,000 Workers per Year</th>
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<tbody>
<tr>
<td>Fisherman</td>
<td>123</td>
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<tr>
<td>Cargo pilot</td>
<td>90</td>
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University of Oxford
### TOP 10 MOST DANGEROUS US-JOBS IN 2010
*(with fatal work injury rate)*

| 1.  | Fishermen          | 116.0 |
| 2.  | Logging workers    | 91.9  |
| 3.  | Airplane pilots    | 70.6  |
| 4.  | Farmers and ranchers | 41.4 |
| 5.  | Mining machine operators | 38.7 |
| 6.  | Roofers            | 32.4  |
| 7.  | Sanitation workers | 29.8  |
| 8.  | Truck drivers and delivery workers | 21.8 |
| 9.  | Industrial machine workers | 20.3 |
| 10. | Police officers    | 18.0  |
Why is this accepted by the authorities?
Safety Management System (SMS)

ICAO DOC 9859 / 01.01.2009:
…an Airline has to define an acceptable level of safety (ALoSP)

Definition: An acceptable level of safety is a safety level which is acceptable for the respective Airline. (e.g. 10E-5)

Do not rely on oversight authorities!

LH-Group: 1 per month
Aviation Accident Statistic

Kind of Operation

Risk

LH-Safety Target
Best Practice
IATA Ø
Aviation Accident Statistic

- Kind of Operation
- Risk

- LH-Safety Target
- Best Practice
- IATA Ø
- Business
- Glider flying competition

10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8}

log-scale
Theoretical background

STRUCTURE defines RISK

Prof. Dr. Franz Porzsolt, Univ. Ulm
angle deviation $< 0,000001°$
Transition Probability ($P_T$)

$H^+ + H^+$ hydrogen nucleus

$P_T = 10^{-8}$ Transition Probability

$\Rightarrow$ He$^{++}$

Sunlight for 5 x $10^7$ years
Quantitative Study

**Downhill Skiing**
- approx. 8 Mio. skiers in Germany
- approx. 80 Mio. skiing days per winter

**Skiing Accidents**
- 80,000 severe injuries per winter
- personal risk $10^{-3}$ per skiing day
- approx. 4 victims daily per skiing area
Transition Probability $P_T$

Did your car’s safety belt ever save your life?

$\sim 10\%$ of the audience

$P_T \quad 10e^{-5}$: required in 1 out of 100,000 car rides per person: $\sim 500$ rides per year: $\emptyset$ every 200 years

Error interval: minimum ONE, maximum less than ALL
Calculation Model

- Number of flights worldwide
- Incidents correlating to a Top Event

Incident Probability

- Number of flights Lufthansa
- Incidents DLH corr. to a Top Event

Incident Probability

Transition Probability

Accident Probability

- Accident
- Top Event

SPI

Accident Probability DLH

Enis Aksu FRA CF
SPI calculation for a specific aircraft series and event

Calculation of worldwide Incidents in specific Aircraft Series and Event

\[ I_W = I_A \times \left( \frac{F_W}{F_A} \right) \times ASF \times UCF \]

Aircraft Manufacturer (Airbus)

Aviation Data Provider (OAG, Innovata, Ascend)

Probability Incident worldwide

\[ P_{IW} = I_W / F_W \]

Probability Accident worldwide

\[ P_{AW} = A_W / F_W \]

Accidents worldwide

Transition Probability

\[ P_T = ? \]

Accidents in Airline (theoretical)

\[ A_A = I_A / F_A \]

Unreported Cases Factor

UCF

Airline Safety Factor

ASF

Airline (Lufthansa)

Accident

Airline (Lufthansa)
Incidents correlating to a Top Event
Mid Air Collision with TCAS

IATA, ANSP's, etc.

AIRPROX ACAS ALERT LOSS OF SEPARATION NEAR MIDAIR-COLLISIONS

Top Event
MAC

Standard Events
ASR Datenbank
TCAS-OWN PILOT
TCAS-ATC, OTHER PILOT
AIRPROX (NO TCAS)
TCAS FALSE WARNINGS
TCAS NUISANCE OWN
TCAS NUISANCE OTHER
Number of TCAS / AIRPROX Events
all Lufthansa Fleets

- TCAS-OWN PILOT
- TCAS-ATC, OTHER PILOT
- AIRPROX (NO TCAS)
Mid Air Collision Risk

1 Accident

23.260.877
Honeywell Study

8,0 \times 10^{-4}

729.590

Airline Safety Factor \times 2,4

18.609

\approx 80 \%

240

3,3 \times 10^{-4}

18.609

\approx 80 \%

240

TP 5,4 \times 10^{-5}

\approx 80 \%

Accident Probability DLH

SPI = 1,9 \times 10^{-8}

Accident DLH?

Enis Aksu FRA CF
Evidence Based Risk Management

Every Flight is confronted with a number of various threats. The summ of all different threats has to be $<10^{-8}$.

The probability of a single threat has to be significantly lower than $10^{-8}$.

How can we calculate the Total Risk?
Overall Accident Risk of an Airline Flight

- Failure Scenarios: $F_1, F_2, \ldots, F_n$
- Overall Failure Probability:
  \[
  \Pr(F) = \Pr(F_1 \cup F_2 \cup \cdots \cup F_n) = 1 - \Pr(F_1^\complement \cap F_2^\complement \cap \cdots \cap F_n^\complement)
  \]

Independent Risks:

\[
= 1 - (1 - \Pr(F_1))(1 - \Pr(F_2)) \cdots (1 - \Pr(F_n))
\]

\[
\approx \Pr(F_1) + \Pr(F_2) + \cdots \Pr(F_n)
\]

Approximation for Aviation Risks:

\[
\Pr(F) = \Pr(F_1) + \Pr(F_2) + \cdots \Pr(F_n)
\]
Overall risk = \textbf{Sum} of all single risk factors (~100)

Prof. Dr. Daniel Straub
Institute for Risk Analysis Technical University Munich

SaMSys
This failure rate (Human) can be influenced by Procedures / Selection / Training / Time (Fuel)
Risk Calculation

P Engine Failure on final: $10^{-7}$

Acceptable Failure rate (SIM): $10^{-3}$ (1 out of 1,000 exercises)

Safety Target (2nd Sub-Level): $10^{-10}$
Limit:

$10E - (Safety \ Target + 2)$
**Accident-Category: Suicide by Airline-Pilot**

<table>
<thead>
<tr>
<th>Date</th>
<th>Airline</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.08.1994</td>
<td>Royal Air Maroc Flight 630</td>
<td>44</td>
</tr>
<tr>
<td>19.12.1997</td>
<td>Silk Air Flight 185</td>
<td>104</td>
</tr>
<tr>
<td>31.10.1999</td>
<td>Egypt Air Flight 990</td>
<td>217</td>
</tr>
<tr>
<td>29.11.2013</td>
<td>LAM Mocambique Flight 470</td>
<td>33</td>
</tr>
<tr>
<td>24.03.2015</td>
<td>German Wings Flight 9525</td>
<td>150</td>
</tr>
</tbody>
</table>

$P_T \text{ Flight / Pilot Suicide: } \sim 0.8 \times 10E-8$
Approach during a thunderstorm

$T_p : \sim 10E-5$

Traffic flow is not interrupted: ALoSP: $10E-5$ (ICAO)

If 20% (+/-10%) of the flights continue to land:
IATA-average (80% do not land)

EASA-ALoSP: ~2 (+/-1) % land (99% do NOT land)

LH-ALoSP: ~0.2 (+/- 0.1)% land (99.9% do NOT land)
Challenge for Flight Operations in the 21st Century

- Defining an acceptable level of Safety ALoSP (Limit)
- Measuring the actual risk level
- Identifying Deviations (Δ)
- Corrective action(s)
Technische Universität München
Lehrstuhl für Ergonomie
Simulatorstudie zu manuellen Flugfertigkeiten
Flight data recording traffic scenario

Eye-tracking and communication recording

simulator control performance analysis
The Team (Samsys I + II)

- 11 Simulator Technicians and Engineers
- 8 Scheduling
- 7 Fleet & Trainings Management
- 192 Pilots (Captains and First Officers for A346 and A320)
- 12 Specialists for Simulator Operations and Data Recording
- 4 Union
- 5 DI-Bus Scheduling
- Lufthansa Flight Training
- 14 Meeting-Preparations / Catering

Sum: 262 Persons
Simulatorstudie zu manuellen Flugfertigkeiten

Randomised Study

NO volunteers
Traffic Scenario

realistic ATC environment
## Task Related Probability Of Errors MTBFs

**Prof. Bubb TU-Munich**

<table>
<thead>
<tr>
<th>Category</th>
<th>Error probability</th>
<th>MTBF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simple</strong> and regularly performed tasks at a low stress level.</td>
<td>$1 \cdot 10^{-3}$</td>
<td>~30 min</td>
</tr>
<tr>
<td><strong>Complex</strong>, regularly performed tasks in a well known working environment at a low stress level.</td>
<td>$1 \cdot 10^{-2}$</td>
<td>~5 min</td>
</tr>
<tr>
<td><strong>Complex</strong> tasks in unusual situations at a high stress level and/or time pressure.</td>
<td>$1 \cdot 10^{-1}$</td>
<td>~30 sec</td>
</tr>
</tbody>
</table>
Flight Safety Research looked at the following aspects:

- Pilot Selection concept Validation
- Basic Piloting Skills
- Raw data approaches
- Landing technique
- Go-around handling
- Side stick handling
- Handling of non-standard / complex Abnormals in a realistic environment
- CRM / Team Interaction
- Fuel Status
Flight Safety Research

Basic Piloting Skills
2. manual Flying

Capt Jacques Drappier, Airbus vice-president training, 17. September 2009:

“We need to refocus on basic handling…”

“...long-haul pilots typically actually < 2h / year, although this could include less than 3h of stick time, the year, although this could include less than 3h of stick time, the majority of which is accumulated on final approach and flare.”

“We put people into our training today who have forgotten how to fly, basically,”

But (same presentation):

Airbus expects pilot type conversion training to take five days between the A380 and the A350, compared with 10 days from the A330/A340 family to the A350 and 11 days from the A320.
manual Flying

Many accidents occur during flight phases requiring manual flying skills (2010):

Percentages may not sum to 100% due to numerical rounding.
Datarecording
(A340 & A320 FFS)

Raw data approaches
Maximum Localizer (LOC) Deviation between 3.000ft and 1.000ft AGL
Maximum Glideslope (GS) Deviation between 3,000ft and 1,000ft AGL

CPTs

F/Os
## Manual Flying Skills

### Root Mean Square Error on LOC and GS Between 3,000ft and 50ft/200ft Above Ground Level

<table>
<thead>
<tr>
<th></th>
<th>SaMSys 1</th>
<th>SaMSys 2</th>
<th>SaMSys 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE on Localizer [dol]</td>
<td></td>
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<tr>
<td>0.5</td>
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</table>

**recurrent training and basic flying skills**
Manual Flying Skills

FO A320 > CPT A320 > FO A340 > CPT A340

reccurrent training and basic flying skills
Simulator Study: manual flying skills

Typical correlation SIM-Study DLR-Test (CP A346)

- Risk: $>10^{-6}$
- Simulator Study: manual flying skills
- Risk: $<10^{-7}$
Correlation SIM-Study DLR-Test (CP A346)

Correlation $r = -0.87$

Risk: $>10^{-6}$ $<10^{-7}$

Simulator Study: manual flying skills

Stanine
Psychomotoric

54% (8)
47% (5)
39% (4)
53%
55%
42%
47%
41%
37%
(6)
(6)
33% (ne)
31% (ne)
33% (ne)
Correlation SIM-Study DLR-Test (CP A346)

Stanine
Psychomotoric

5
Training ! (5)
39% (4)
55%

4
Training ! (6)
35%
54% (8)

3
33% (ne)

2
1
31% (ne)

Simulator Study: manual flying skills

Risk: $>10^{-6}$ $<10^{-7}$
Pilots’ Type of Grasp at a First Glance

Preliminary data from 19 out of 57 participants show many different ways to grab the sidestick.
3. Results: Types of sidestick inputs

Stick inputs can be done on one axis (sequential inputs) or two axes (simultaneous).
Inputs on one or two axes

Time slice for manual approach between 3,000 ft. and 200 ft. AGL

- Inputs on 1 axis
- Inputs on 2 axes
- no Inputs

The way pilots handle their control stick
Speed-Checks

Speed / Vertical Speed Checks below 100ft RA

- Speed checked below 100ft and TD
- V/S checked below 100ft and TD

Anteil der Piloten

CPT
FO
F/O A320
CPT A346
F/O A320

64.0% 60.0%
19.0% 9.5%

Speed checked below 100ft and TD
V/S checked below 100ft and TD
SaMSys Simulator Experiments

Measuring…

Economical Flight Performance

FMS Mode Awareness / Automation

**Handling unclear situations (Warsawa)**

Redundancy and team-interaction

Go-Around-decision and -performance

Basic Flying Skills (AI and Boeing)

Predictability of pilot performance (DLR-test)
## Runway Overrun Probabilities

<table>
<thead>
<tr>
<th>Combinations / Path</th>
<th>Probability</th>
<th>Rank</th>
<th>Conditional Overrun Probability</th>
<th>Overrun Probability</th>
<th>Total Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed not in limits AND Go-Around failed</td>
<td>2.61 E-2</td>
<td>1</td>
<td>4.0 E-5</td>
<td>Lognormal</td>
<td>1.04 E-6</td>
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<td>Tailwind not in limits AND Go-Around failed</td>
<td>2.07 E-5</td>
<td>5</td>
<td>6.0 E-4</td>
<td>GEV</td>
<td>1.2 E-8</td>
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<tr>
<td>Tailwind not in limits AND Speed not in limits AND Go-Around failed</td>
<td>6.00 E-7</td>
<td>8</td>
<td>6.0 E-3</td>
<td>GEV</td>
<td>3.6 E-9</td>
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<tr>
<td>A/SKID Fault AND Recognition failed</td>
<td>2.8 E-4</td>
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<td>&lt;1.0 E-16</td>
<td>GEV</td>
<td>2.8 E-20</td>
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<tr>
<td>Dual BSCU Fault AND Recognition failed</td>
<td>3.4 E-4</td>
<td>3</td>
<td>&lt;1.0 E-16</td>
<td>GEV</td>
<td>3.4 E-20</td>
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<tr>
<td>(Dual BSCU Fault OR A/SKID Fault) AND Recognition failed</td>
<td>6.2 E-4</td>
<td>4</td>
<td>&lt;1.0 E-16</td>
<td>GEV</td>
<td>6.2 E-20</td>
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<td>All Brakes Inoperative</td>
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<td>&lt;1.0 E-16</td>
<td>GEV</td>
<td>6.4 E-25</td>
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<td>Spoiler not deployed</td>
<td>1.0 E-7</td>
<td>6</td>
<td>2.4 E-4</td>
<td>Gamma</td>
<td>2.4 E-11</td>
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<tr>
<td>Spoiler not deployed AND Reverser Fault AND A/BRK Fault (Normal Wheel Brake Fault)</td>
<td>1.0 E-7 * 5.0E-3* 2.27 E-4 = 1.14E-13</td>
<td>9</td>
<td>1.5 E-4</td>
<td>GEV</td>
<td>1.71 E-17</td>
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</table>
Test Scenario 2

• The tower reported wind is within limits. However the actual surface wind is beyond the limit (18Kts instead of max. 10Kts)

• A Go-Around should be performed!

• In 70ft a Go-Around is triggered by the PM

• Runway change after the Go-Around.
Decision Making Analysis

(% of Pilots observing the TW during approach above 1000ft AGL)

-91
Decision Making Analysis

(% of Pilots observing the TW during approach below 1000ft AGL)
Decision Making Analysis

(% of Pilots who would have landed without the PM callout)
39% of all pilots discussed the tailwind situation during the approach briefing.

89% of all pilots talked about the strong tailwind during approach above 1000ft AGL.

50% of all pilots checked the wind indication during final approach below 1000ft AGL.

64% of all pilots would have landed without the wind information given by the PM (TW of 18 Kts).

14% of all pilots decided to land, knowing the tail wind was 18Kts.

44% of all A340 pilots performed the Go-Around only after the PM gave the command in ~70ft AGL.
Calculations:

R $\sim 10E^{-8}$

Is this result acceptable?

...according:

ICAO
IATA
EASA
LH
Calculations:
R \sim 10E-8
Is this result acceptable?

...according:
ICAO **OK**
IATA **OK**
EASA **CRITICAL**
LH **NOT ACCEPTABLE**
SaMSys Simulator Experiments

Measuring…
Economical Flight Performance
FMS Mode Awareness / Automation
Handling unclear situations (Warsawa)
Redundancy and team-interaction

Handling the Go-Around
Basic Flying Skills (AI and Boeing)
Predictability of pilot performance (DLR-test)
Go-Around Analysis  
(MSc of Alexander Schmidt)

a) **1 A340-600 captain (3,7%)** performs the Go-Around correctly.  
**10 A320-F/O (33%)** perform the Go-Around correctly.

b) In general more than one SOP-violation per Go-Around  
Average: A340-600 Cpt.: 2, A320 F/O: 1,3.

c) Common SOP violations:  
• Flaps not operated according SOP.  
• Thrust Reduction to late and/or MCT is selected instead of CLB thrust.  
• Vertical speed is not reduced during the last 1000ft before reaching Go-Around Altitude.
Flight Recorder Data Analysis

- Only **5%** of all Go-Arounds are flown correctly.

- In average **2,7 SOP-violations** can be observed per Go-Around.

- Analysis of 150 Go-Arounds showed **415 SOP-violations**.

- Maximum number of violations per Go-Around: **10**.
**Go-Around**

Calculation of worldwide Incidents in specific Aircraft Series and Event

\[ I_W = I_A \times \left( \frac{F_W}{F_A} \right) \times \text{ASF} \times \text{UCF} \]

Probability Incident worldwide

\[ P_{IW} = \frac{I_W}{F_W} \]

Flights worldwide

\[ F_W \]

Probability Accident worldwide

\[ P_{AW} = \frac{A_W}{F_W} \]

Accidents worldwide

\[ A_W \]

Accidents in Airline (theoretical)

\[ A_A = I_A \times \text{PT} \]

Probability Accident in Airline

\[ P_{AA} = \frac{A_A}{F_A} \]

Incidents worldwide

\[ I_W \]

Incidents in Airline

\[ I_A \]

Unreported Cases Factor

\[ \text{UCF} \]

Aircraft Manufacturer

(Airbus)

Aviation Data Provider

(OAG, Innovata, Ascend)

Accident Database

(ECCAIRS, ASN etc.)

Airline

(Lufthansa)

Lufthansa

~10^{-2}

~10^{-8}

~10^{-2}

~10^{-8}
Calculations:

$R \sim 10^{-8}$

Is this result acceptable?

...according:

ICAO
IATA
EASA
LH
Calculations:
\[ R \sim 10^{-8} \]
Is this result acceptable?

...according:

ICAO **OK**
IATA **OK**
EASA **CRITICAL**
LH **NOT ACCEPTABLE**
...2014: B767 Go Around:
Pitch / speed second go-around (A340)
Exceeding max. flap speed causing flaps locked

Flight to the Alternate

Landing with less than < 5 min. remaining flight time
Flight Safety Research

Handling of non-standard / complex Abnormals in a realistic environment
Multiple Failures
EICAS Caution and Advisory Messages:

- DET FIRE/OVHT 1
- HYD OVHT SYS 1
- BLEED 1 OVHT
- BLEED HP ENG 1
- BLD 1 OVHT/PRV
- ENG 1 OVHT LP A
- ENG 1 OVHT LP B
- ENG 1 FIRE LP A
- ENG 1 FIRE LP B
- OVHT ENG 1 NAC
- FUEL SPAR VLV 1
- ENG 1 VIB

.....
4 Pilots in the Cockpit
Time versus Decision-Making

Start of the scenario:
Airports: New York or Nice
1h remaining fuel

Event:
Hydraulic fluid loss (>10^-5)
=> landing gear problem
NOSEGEAR UNLOCKED
Go Around

Consequence:
remaining flight time ~40min.
(~80% fuel flow increase)

Malfunction Probability: ~1 in 10 Million (10E-7)

During the second Approach
SLATS LOCKED
Simulator Study – Set up No. 2 (A340-600)

**Nose Landing**
Gear unlocked

**GREEN HYD lost**
go around,
ground gear extension

**Slats locked**
abort the approach,
determine landing conf.
calculate LDR

JFK Carnarsie-VOR Appr.: Arrival Fuel >7,500 kg ~1h+
Traffic Scenario

realistic ATC environment

„Lufthansa seven two seven“

„Continental one ooh six“

„Eurotrans zero seven“

„Quality nine three kilo“

„Whitestar one eight“

„Lufthansa one seven eight niner“

„Singapore three two eight“

„Lufthansa seven three one“
Daterecording
(A340 & A320 FFS)

Raw data approaches

Topansicht

X [ft]

Y [ft]
30x A320 Crews – Flight Tracks LFMN

Simulator Study II A320
Workload versus Performance

- mean rating: **medium workload** condition of $M = 3.04$, $SD = .82$
  **high workload** condition (time pressure) $M = 2.71$, $SD = .85$
- Time pressure leads to significant reduced performance, $t(58) = 5.6$, $p \sim .001$. 

Error indicator: standard error
Performance under Stress

\[ \Sigma \]

workload

- performance

- PM

- PF
During G/A:

Inefficient and disturbing callout: “SPEED”

Supporting callout: “INCREASE PITCH + SET CLB THR”
Findings regarding „10E-8“

10% (6) of these experiments ended in an accident. (NO accident in this scenario during normal recurrent training with >1.000 pilots!)

3% (2) of these experiments ended in a fatal accident.

All accidents were triggered by wrong PM-inputs.

\[ P_{\text{Scenario}} > 10E-8 \times \text{Error Rate} \sim 10E-1 \Rightarrow \]

accident probability \[ R_{\text{Scenario}} > 10E-9 \] (Limit exceeded!)
Calculations:

\[ R > 10\times 10^{-9} \]

Is this result acceptable?

…according:

ICAO  
IATA  
EASA  
LH
Calculations:

$R > 10E-9$

Is this result acceptable?

…according:

ICAO OK
IATA OK
EASA CRITICAL
LH NOT ACCEPTABLE
Challenge for Flight Operations in the 21st Century

Defining an acceptable level of Safety ALoSP (Limit)

measuring the actual risk level

Corrective action(s)

Identifying Deviations (Δ)
Bitte diesen Text mit dem Präsentationstitel überschreiben

Deutsche Lufthansa AG

Ground Ops

Technic

Flight Ops

Training Selection

Crew

Errors

Risk

Threats

Threats

Threats

Threats
Findings regarding „10E-8“

Standard Airbus (or Boeing) Type-Rating Courses are not sufficient for an ALoSP of „10E-8“.

**Manual / Basic Flying Skills have to be improved:**

- Sidestick Handling
- Raw Data Flying
- A346-Landing Technique
- X-Wind Handling
- Go Around Handling

Complex abnormals are not handled sufficiently well under time pressure.

PMs showed deficiencies in supporting / controlling the PF.
Recommendations to achieve „10E-8“

Additional training is required (Type Rating):
Sidestick-handling & manual flying skills / raw data / landing technique / x-wind / go around.

More than 4 x 4 hours Simulator Training per year is required (basic piloting skills including APP & LDG / GA / failure analysis).

Pilot Monitoring Performance has to be improved (support & controlling).
Recommendations to achieve „10E-8“

Ambiguous / complex malfuctions have to be trained in the simulator under realistic conditions (ATC).

Fallback Strategies for complex malfuctions are required.

A procedure TIME CRITICAL LANDING is required.

Minimum fuel at landing 45 minutes.
30x A340 Crews – Flapsetting und Malfunctions

A340-600 Slat/Flap Lever vs. Time (Malfunction G HYD RSVR LOW LEVEL active as dotted line)

A340-600 Slats vs. Time (Malfunction SLATS LOCKED active as dotted line)

A340-600 Flaps vs. Time (Malfunction FLAPS LOCKED active as dotted line)

A340-600 Gear vs. Time (Malfunction NOSE GEAR active as dashed line / G HYD RSVR LOW LEVEL active as dotted line)

A340-600 Altitude vs. Time (A/C TouchDown as dotted line)
SAMSYS II Remaining Fuel A346
(600kg for Final APP, additional fuel calculation with 180kg/min)

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<th>VPlid</th>
<th>Min[kg]</th>
<th>Time[min]</th>
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Est. Fuel at T/D KJFK: 45min.

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Additional Pattern possible

Est. Fuel at T/D KJFK: 30min.
Recommendations to achieve „10E-8“

Prerequisite for the additional training is a positive, relaxed and friendly learning atmosphere.

Mistakes and errors have to be expected, they are „normal“ and an important fundament for performance improvement.

A simulator session with complex and demanding content cannot be failed!

…required for an ALoSP beyond „10E-7“
...there are still „low hanging fruits“:
Evidence Based Risk Management

Diagnostically conclusive Pilot selection should be mandatory

Improved initial training and type rating
Increased and realistic recurrent training

Min. 45 minutes fuel at Landing