Risk Perception and Risk Management
- Experiences of the aviation industry -

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In times of increasing cost pressure, the field of tension between economic efficiency and safety gains more and more importance. In numerous economic sectors, product quality is deliberately reduced in order to save costs. The expenses resulting from complaints are set off against the saving potential offered by cheaper production methods. This approach can be optimized by defining specific error or reject rates (e.g. in the production of budged-priced textiles). As long as this approach is used for products with no or little safety requirements, there is no reason to object the concept, since the customer himself defines the desired quality level by means of the price. In some areas, however, this type of cost optimization cannot be accepted: As soon as life and limb of people are at stake, a management following the above principles can – as soon as the public takes notice – trigger the ruin of the respective company.

The common goal: risk minimization

For this reason, industries sensitive to safety must follow a different principle when defining their quality requirements: Maximum safety and minimum risk must be the topmost corporate objectives - and if it is only for ethic reasons. But there are also economic reasons for this target: The total loss of a large airplane causes an average cost of approx. 0.5 billion Euros. One single accident alone (a "complete loss of production") can mean the end of an airline (e.g. Birgen Air). If - on top of this - an airline is charged with negligence, which is mainly attempted by lawyers of the American legal system, there is virtually no upper limit to the possible claims of the damaged parties. (If, for example, it is proven that the crash of an Egypt-Air plane after departure from the U.S. was caused by the suicide of one of the pilots, Egypt-Air is fully liable. In this case, the insurance company is released from any indemnification, and the claims of the victims' relatives to be expected would certainly add up to several billion Euros, a sum that would mean the ruin of the airline).

The phenomenon having started in America, for example doctors and medical institutions are also increasingly exposed to extremely high financial claims from damaged parties. In the medical field, too, one single human error can trigger a human and a financial catastrophe. So there are also substantial economic interests in avoiding complications and accidents.

Why do catastrophes happen ? – A philosophic question

Why do disasters and catastrophes happen? Are we inevitably left unprotected to an unfavorable fate? In the past, efforts to find an answer to these questions inevitably led into the world of metaphysics. Evil spirits, magic and witchcraft were considered the causes of "negative events". And rather unspecific means were used to get rid of possible "catastrophe triggers": exorcism and the burning of witches ranked high. According to the understanding of those days, man and his action were hardly responsible for and had little influence on avoiding catastrophes. The power of destiny was the dominating factor. When the ideas of the Enlightenment pushed man's own responsibility into the foreground, safety could be enormously increased in many fields of human life. (The plague e.g. is not transmitted by the evil eye, but by fleas).

Acceptance of self-determined risks and of risks determined by others

The personal acceptance of risk, however, is no objective variable, but highly dependent on the – *subjectively perceived* – question in how far the actual risk potential is determined by oneself. A motorcyclist, for example, readily and voluntarily accepts an extremely high risk when exceeding the speed limit on a winding road on his Sunday joyride (self-determined). After an accident caused by the described driving behavior, the motorcyclist's readiness to accept a risk involved in the treatment of a poly-trauma tends towards zero (determined by others). For the medical and the aviation industry this means that the "customer" has extremely high expectations with regard to safety. In addition, it is normally very difficult to assess the personal risks since this assessment is influenced by emotions (fear of a meteorite impact, but no fear of driving a car when under the influence of alcohol).

A definition of safety

In the past, any flight included a very high risk. Detailed investigations of accidents - mainly executed in the U.S. after World War II - made it possible to selectively identify the most important causes of accidents. Especially when the financial resources for risk minimization are limited, optimal use of the limited resources is paramount. The return on investment is highest, when investments are made in exactly those fields where the highest risk is encountered. Reacting in this sense to the main risk areas resulted in an increase in flight safety to approx. 1.2 million flight hours per total loss. Here, the following "equation" applies:

Safety = Prevention Strategy / Threat

A high threat requires a powerful defense strategy in order to increase the “value” of safety. To identify the respective risk areas, a detailed error analysis is required. Since aviation catastrophes are of very high public interest, the pressure to identify root causes of accidents is much higher in aviation than it is in many other fields of society. The detailed investigation of more than 500 total losses of large jetliners (takeoff weight > 20 tons) since 1960, made it possible to create an extensive database that reveals weak points and system deficits with the largest possible objectivity.

Man : risk and rescuer

A detailed investigation of the work environment combined with the analysis of the flight recorder data and the voice recorder of the cockpit communication provides a clear picture of the work conditions and errors that lead to a catastrophe.

Accident statistics prove that it is the human being in the cockpit who causes about three quarters of all accidents. The large share of human errors suggested the – at first sight brilliant – solution to replace the fallible human being by an “infallible” digitally operating computer. This measure was meant to eliminate all human insufficiencies from the man/machine control loop. A computer never gets tired, it is not emotional, does not need a holiday and has a constant level of motivation, etc. (A considerable share of human work has been taken over by robots. In many cases this measure has increased productivity and guarantees an unchanging product quality).

Automation and safety

In aviation, an increased degree of automation has not changed the share of human errors in the cause of accidents. Even after the introduction of the so-called HITEC-airplanes, the factor "human error" still accounts for 75 % of all accidents. Up to now, the assumption that an increased degree of automation will necessarily lead to an increase in safety has not come true. In some cases the "human error" was simply replaced by a "computer error". Experience has shown that the digital computer increases or guarantees safety only in “trivial” cases. Since even the best programmer is not able to anticipate all possibly occurring situations, the computer frequently “fails” when unconventional decisions are required or when influencing variables must be weighed and assessed that have not been planned to occur in the respective context by the programmer. Plainly speaking: The machine is an aid as long as support is not really necessary, but it leaves you alone when a demanding decision is required.

Artificial intelligence, the ultimate solution?

Extensive and comprehensive research projects have made us recognize that the so-called "artificial intelligence" (AI) has narrow limits. Even such trivial phenomena as, for example, the healthy common sense can be "imitated" by the computer only within very narrow limits. The artificial generation of intuition or of ingenious new ideas by digital technology is miles away.

Risk factor software

I would like to demonstrate the problems resulting from the use of a complex calculating program by means of a little intellectual experiment: Imagine a high-capacity computer whose task it is to control an operation or a flight fully automatically. Before using the computer for the first time, a software test must be carried out for reasons of safety. Assuming that 100 different parameters have an impact on a flight (which is a very conservative approach, if you take into consideration that more than 30.000 parameters are constantly monitored in a modern airplane), then 2^{100} or 1.27×10^{30} system conditions result from those 100 parameters.

Even if a still-to-be-designed mega-computer would be able to check 100 million (10^8) system conditions per second, the test run would take 1.27×10^{30} divided by 10^8 years, i.e. 4×10^{15} years. The dimension of this figure becomes clear when comparing it to the age of our earth, which is "only" approximately 5×10^9 years. This arithmetic example shows that complex software is most likely to be faulty and that there is no possibility to prove freedom of fault. A software test must, therefore, always be limited to more or less comprehensive random sampling.

How easily minor errors can have serious consequences was demonstrated by the NASA Mars mission of 1999: An unmanned spacecraft crashed on the red planet because the entry into the Mars orbit had been calculated incorrectly: One department had used nautical miles to measure the distance, the other department had used kilometers. When exchanging the data, the units of measurement were, by mistake, not matched (programming error). Since complete control of a complex calculating program is impossible, operations that decide over life or death of a person committed to our care must always be subjected to a plausibility check carried out by a specialist as the last control instance.

Optimized team interaction

But if the computer is ruled out as the ultimate safety system, how else can complex operations involving quick and difficult decisions be controlled?

We must seek new answers in fields of activity that depend on smooth and safest possible interaction of man and machine. In this context, findings of biology, psychology and social sciences are gaining importance.

To be able to optimally utilize the capacities of the human brain and to correct potential errors, we have to create operating structures that can identify and correct possible errors. The interdisciplinary exchange of ideas and experience has shown that an optimal interaction of humans (team) and machine(s) in solving complex tasks under time pressure require the use and observance of rules and standards that are applicable to all systems. In this context, it is of minor importance whether operating procedures in the operating theatre, in the cockpit of an airplane or in the control stand of a power station are considered.

Parallel connection of thought machines

Since a single person is always “highly error-prone”, the principle solution of the problem is to have him/her supported and controlled by a second person with the best possible and most suitable qualification.

The probability that two persons working independently of each other make exactly the same mistake at one and the same point within an operating process is relatively low, as long as the two thought machines collect and evaluate the available facts independently from each other before discussing and clarifying the further steps (parallel connection of several independent thought machines). In case they have different opinions, the reasons for a decision as well as its advantages and disadvantages must be discussed. The independent work of mind of those individuals influencing or controlling the process results in a safety network that is able to cushion human errors. The “mesh size” is determined by the qualifications of the respective individuals and the quality of cooperation.

Error omission in the legal sense

To develop effective defensive strategies, information on the actually occurring problems must be available. Unfortunately, the “legal treatment” of human errors according to the principle “errors must be punished and errors with severe consequences must be punished severely" has caused much harm: the legislator assumes that threatening with or inflicting a severe penalty can keep people from acting against the rules. This approach might be true with regard to the planning of crimes (bank robbery, shoplifting), but an accidental human error cannot be avoided by the threat of punishment. Possible sanctions prevent an objective investigation and follow-up of an incident and impede the development of effective defensive strategies to avoid similar problems in the future. The fear of punishment leads to hushing up and incorrect assignment of guilt.

Zero defect strategy ?

Quality management, too, is only partially suited for error omission. The complete and continual documentation of production steps and operating procedures is to guarantee constant quality on a high level. However valuable these measures may be, there remains one serious weakness: Dynamic processes in which flexible reactions to unexpected problems are required cannot be recorded without gap, and despite all efforts the fact remains that man does not work without ever failing. “Errare humanum est." As a consequence, the aim cannot be the human being working without fault, but to create structures that ease unavoidable human errors or that eliminate the unintended impacts of errors before they can develop their undesired effects.

Non-punitive error management

To be able to tackle the actual problems, we have to create an environment that is characterized by an atmosphere of mutual trust. The open discussion of errors made must not be endangered by the threat of punishment or the fear of a possible interruption of the career. It should be made clear that the "real professional" distinguishes him/herself by the fact that he/she addresses errors openly and discusses them. This concept is based on the conviction that even the best expert can make nearly any serious mistake under unfavorable conditions. It is not the mistake itself that is "reprehensible", but the hiding of valuable information from the colleagues. It has been shown in the past that progress is primarily achieved by investigating and following up mistakes, failures and catastrophes (that nearly happened).

Every pilot has already experienced elements of accident scenarios of others. If we succeed in identifying and eliminating single links of a possibly mortal chain of errors before a catastrophe happens, the system has worked. If the relevant knowledge is only acquired after a catastrophe, the system has failed.

Limits of confidentiality

To gain the confidence of the colleagues for a so-called non-punitive reporting system, certain prerequisites need to be given:

The reporting system must be operated independent of the disciplinarian. The relevant incidents must be collected and analyzed by an independent organization unit. Protection of the "reporting person" must have top priority. Analogous to the seal of confession in church, the confessing person must be protected under all circumstances. Only if the staff fully trusts the reporting system, will serious incidents be reported. If we do not succeed in building up a basis of confidence, only minor incidents will be reported, which will frequently result in the assignment of guilt to others. Experience with non-punitive reporting systems has shown that it is usually single persons and not abstract organizations that enjoy the trust of the staff members. An accepted confidential person is the prerequisite for the system's success. Of course the required basis of confidence cannot be built up over night; in fact, it is a rather time-consuming process. A suitable confidential person is an experienced colleague who is appreciated by everybody and who has already reached his/her own professional goals. This person should also be supported by younger colleagues as contact persons for staff members their own age.

Human factor research project

The analysis of accident statistics involves the dilemma that due to the – fortunately –

low number of catastrophes it is very difficult to make valid statistical statements. Reference to the number of incidents that have actually occurred is often missing. A comprehensive survey is, therefore, unrenouncable in order to obtain an objective picture of the safety situation: A well-structured analysis of as many “almost occurred” catastrophes as possible makes visible the part of the “incident iceberg” that is “below the waterline” – i.e. outside the immediate access of the “event analysts”. In addition, the question arises, how large is this normally invisible part.

In order to get a better idea of situations that are potentially safety-critical, the aviation industry has conducted a so-called Human Factor Research Program. It has been the most comprehensive study of its kind: 2,070 pilots filled in a 120-page questionnaire. The survey asked for explanations and descriptions of the safety-critical incident that was *experienced last*. The answers added up to three million two hundred thousand data records. Evaluation of the data took more than two years.

Table 1: Six risk classes were established:

Risk class 1:	There was an irregular incident. But there was **no need to act**. It was clear that there would be no safety-relevant impacts (“No problem”).
Risk class 2	There was a safety-relevant incident. Appropriate actions of the crew made it possible to **avoid the building up** of any effects that would have impaired safety (“Routine”).
Risk class 3:	There was a safety-relevant incident. The crew was able to **control all** the **effects** of the incident **completely** (“Well done”).
Risk class 4.	There was a safety-relevant incident. The **effects** of the incident could be **controlled only partially** by the crew (cockpit, cabin). (“Things turned out all right in the end.”)
Risk class 5:	There was a safety-relevant incident. The **effects** of the incident **could not be controlled** by the crew (cockpit, cabin). In the end, it was only possible to manage the situation because no further aggravating factors occurred. The last link in the error chain was missing. (“By a hair’s breadth…”)
Risk class 6:	There was a safety-relevant incident. The situation **got completely out of control** and we survived only by chance or by luck. (“Oh, Shit!”)

The mean risk value in the above survey is 3.4, i.e. an incident in which the safety-critical impacts could nearly entirely be controlled by the pilots. It is striking that the higher risk classes 4, 5, and 6 together make up for more than 40% of all safety-critical incidents. So the reported events were not just “peanuts”, but a large share of them represent a significant danger potential. Different from a collection of reports on safety-critical incidents, the questionnaires do not, however, reveal how the event developed in detail (no scandalous stories), but they only deal with possible influence and disturbance variables – also for reasons of anonymity.

Based on the survey data, four main categories have been established, which cover the major aspects of the problems:

- **TEC**: Technical problems, failure of systems
- **HUM**: Human errors
- **OPS**: Operational problems, complications
- **SOC**: Aggravating social factors

The category Operational Problems *OPS* (complications) refers to influences complicating the operating procedure beyond the standard rate. Aggravating social factors *SOC* refer to the team situation in the cockpit: deficits in communication, bad CRM (Crew Resource Management: a strategy for optimal utilization of all resources and information that are available to a team), conflicts (which are quite often not openly expressed), a too steep or too flat hierarchy, psychic or psychological problems, etc.

For evaluation, the different risk categories were first considered separately. If the above factors occur alone, the following percentages result (percentage of the total number of incidents):

TEC: 7.7%
HUM: 4.9%
OPS: 1.2%
SOC: 0.7%

It shows that, when considering individual incidences, technical problems TEC are at the top of the scale with 7.7% of all events, followed by human factor HUM with 4.9%. At first sight, this is surprising: How does this figure relate to the fact that 75% of all accidents worldwide are human factor accidents? The analysis shows that cockpit crews are normally well able to manage one **single** error. The safety network of structured cockpit work eases solitary human errors.

The effect of simultaneously occurring risk factors

In a second step the analysis comes closer to the actual risk potential: Now two categories are combined respectively (e.g. TEC+HUM or OPS+SOC, etc.). Here we see that the dangerous impact of the human factor increases, when it is combined with other factors. If operational problems (complications) and a human error occur simultaneously, the share of safety-critical incidents increases to 8.3%. The statistics show that a well organized work environment has a considerable risk-reducing influence. The largest risk group with two combined factors is the combination of human factor (HUM) and problematic social climate (SOC). 13.7% of all incidents show this combination. This shows that the work atmosphere has a much larger influence on risk than complications.

All three categories (HUM, HUM+OPS and HUM+SOC) together, however, account only for 26.9% of all safety-critical incidents. So what is the most important share of the often potentially mortal human factor ?

Social factors – a "turbofactor" with regard to human error

The next evaluation step gives an answer to this question: When considering combinations of three risk factors (e.g. TEC+OPS+SOC), the following picture develops: Far and away the most frequent safety-critical situation (37.8% of all events) consists of the following "mixture":

1. A complication develops (OPS).
2. In this situation of increased stress a human error occurs (HUM).
3. ***The negative effects of the error cannot be corrected or eased because the working climate (SOC) is not optimal.***

This means that a negative social climate has the effect of a "turbocharger" when a human error occurs: In many cases it takes tense human relations to turn a "harmless" error into a potentially life-threatening situation. It needs to be pointed out that a tense atmosphere is usually not identical with a dispute. In many cases the working climate is burdened without the person responsible for the bad climate noticing it. The others involved in the situation frequently only sense an "undefined feeling of unease". A first negative impression, too much or too little respect, contempt, misunderstandings, a bad mood brought from home, lack of motivation, etc. can reduce the efficiency of a team considerably.

A first and important step to ease the problem is to clearly express one's own feeling of unease or the personal feelings.

Normally a considerable inner reluctance needs to be overcome first to be able to do this. But already statements such as: "…I do not feel comfortable in our teamwork" or "…I have the feeling that there are problems nobody addresses" can be a first step to improve the cooperation.

Especially in professions characterized by the picture of brilliant experts who solve any problem without difficulties it is a real challenge to address soft "psycho-social factors". Nonetheless, this area must not be neglected or repressed; for this risk potential was not "discovered", articulated and put into the foreground by "worldly innocent" psychologists, but by those people responsible for the problems.

Working climate and safety

Everybody knows that the working climate has an influence on the quality of work and on safety; it is, however, definitely surprising that the impact of “atmospheric disturbances” is that high. According to the above findings, the fact that colleagues do not get along well with each other ranges highest on the scale of safety problems. Social tensions in the team increase the risk of a safety-critical incident by the factor 5, or with other words:

An optimal working atmosphere could mitigate or ease 80% of all safety-critical human errors.

The study has thus proven a *quantitative* connection between the “soft factor” Social Climate and the risk of dangerous incidents. However, not only the number of incidents increases, but also the risk class! (The mean risk of incidents caused by the human factor (HF) amounts to 3.57).

Training for optimized teamwork

What does this statement imply for our work organization and for training?

The efforts to achieve an optimal CRM (Crew Resource Management) and optimal team structures must be intensified. In the past, bad team behavior or a miserable atmosphere in the work environment were frequently tolerated with the argument: “…but he/she is technically quite competent!” This statement should no longer be accepted. Survey evaluations show that bad team behavior triggers a major share of safety-critical incidents; and they are frequently not eased by excellent abilities, but simply by good luck.

This implies that deficits in team behavior must be addressed consequently by individual colleagues as well as by trainers and superiors. As already mentioned, this is more easily said than done, since the subject often requires more far-reaching discussions. A first reaction to this result of the survey could be to ask not to assign any “unpleasant” colleagues to the job who do not immediately create a “great atmosphere” in the team. But in general, this measure would not ease the problem since everybody once in a while - and often unconsciously - burdens the work climate for the colleagues by his/her behavior. Therefore, it will probably be more successful to provide *all* colleagues with tools that ensure an optimal handling of social problems (in a wider sense).

Social competence obviously is also important for managing safety problems in technically oriented fields of work, a fact that has been seriously underestimated in the past.

The various risk categories

The following graph shows the percentages for the individual risk groups. The figures reveal that the survey made it possible to break down the fine structure of the safty-relevant human factors: When adding up all categories in which the factor HUMAN appears, the total is 79.1 %, and this is the figure that corresponds more or less with the 75% of the IATA accident statistics.

Frequency of event configurations

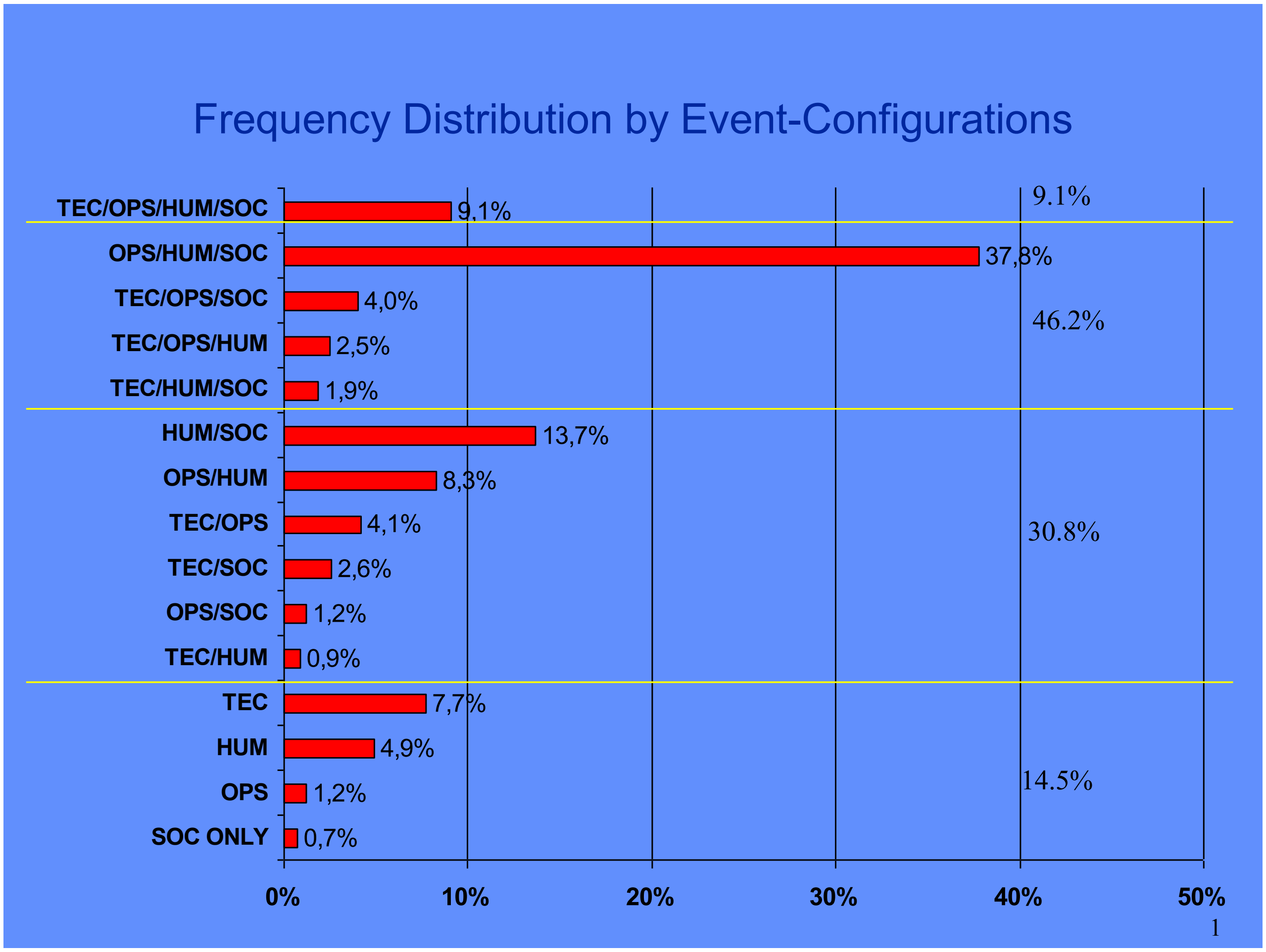

Fig. 1: Possible combinations of the various risk categories. The uppermost line shows the combination of all four groups: Technology (TEC), Operational Problems (OPS), Human Error (HUM), and Social Problems (SOC) account for 9.1% of all incidents. The second data block shows the combinations of three factors. By far the largest block (37.8%) consists of OPS, HUM, SOC. As to the combinations of two factors, the mixture of HUM and SOC is at the top of the table. The smallest group – in the lowest data block – are social problems only with 0.7%.

Social problems in the team

But what does the term SOC mean if you look at it more closely? The structure of the questionnaire deliberately addressed possible impairments:

Approximately 32% of these “unfavorable CRM events” are triggered by “single-handed action” of one pilot. This figure shows that a behavior that is not jointly coordinated and agreed upon poses a safety problem. There is normally no “ill” will behind such an approach. Time pressure, target fixation or unexpected complications shortly before the expected completion of a task can turn a good team player into a “Rambo” in no time.

It is in the nature of things that the problem of a “single-handed attempt of one team member” is usually triggered by the captain. Due to the hierarchical structure and the overall responsibility, it is normally a simple matter for the boss to stop a single-handed action of a team member. For a hierarchically subordinate employee it is much more difficult to convince the boss of the problematic nature of a decision that was made alone, because he/she has to overcome a huge emotional hurdle before expressing criticism from the position of the “subordinate”. The larger the difference in age or in hierarchy between the team members, the more difficult it can be for the employee to utter criticism.

The fact that approximately one third of all CRM problems is due to lone-wolfing, shows that there is an urgent need for action in this field and that you have to make efforts again and again to create a common work basis. To avoid any rush is a very important preventive measure in this context.

The above graph shows that the factor SOC ONLY represents the tail-light of the table with only 0.7%. This clearly tells that social problems – as an isolated factor – are practically irrelevant as the cause of a safety-critical event. Great efforts are being made to create a positive working atmosphere. Existing difficulties only become obvious when additional burdening factors occur.

Who is going to teach optimized teamwork?

Who should carry out the relevant training? Basic knowledge of CRM-subjects should certainly be taught by psychological experts. However, this method of teaching can only be applied to a relatively limited extent, since the actual knowledge transfer takes place with reference to the personal working situation, and must therefore be explained and accompanied by colleagues of the same professional field. In order to be efficient and accepted, the training must be implemented in the specific environment and can, therefore, only be rendered by specialists (pilots, engineers, medical doctors) as trainers and multipliers. The results of the survey give additional support to these efforts. More training in this field must, however, never make cutbacks in basic technical training tolerable. CRM-training does not substitute technical knowledge, but is “only” a necessary supplement.

Communication deficits

The following figures should illustrate the problems assigned to the field of SOC:

It has already been mentioned that in *68.4%* of all events described “additional aggravating factors in the field of social interaction" were found. That this very rarely means a dispute in the common sense or an openly fought conflict has already been explained. In *77.4%* of the cases with aggravating factors in the area of social interaction, communication problems were reported.

In 48% of all incidents:

- necessary statements were not made, corresponding hints were not given,
- unclear concerns were not expressed,
- important statements were incomplete, insufficient or were not heard.

In the above cases the *"sender"* of the message is the one who was negligent, since the quality of communication is entirely determined by whatever arrives at the other end. For this reason, the sender of a message has the obligation to check what information has actually been perceived by the receiver.

So the problem is not the captain's lack of readiness to put a hint received into according action, but the missing courage of the first officer to address deviations consequently and clearly.

In only 23% of all communication problems no corresponding reaction followed a clearly understood hint. But there is a strategy to deal with this type of situation, too: If there is no reaction to a correcting hint, the concern must be repeated.

If the first officers does not speak up and the captain is exclusively fixed on the target, this can result in the non-correction of an error. (The worst accident in civil aviation with 583 casualties happened because a young co-pilot did not have the courage to correct the experienced trainer captain a second time).

Violation of rules

The so-called violation of rules makes up for a large share of human errors of the cockpit crew. A few years ago, a task-force of Boeing dealt with this phenomenon: The study analyzed accidents. When investigating cases of total loss, the team investigating did not ask what caused the accident, but searched for means that could have prevented it. The survey shows that about 80% of all accidents could have been prevented by strictly observing the rules and regulations. For this reason, the area "working in accordance with rules" is of special interest to us in the evaluation of the cockpit study, because the statement of the Boeing study means that the number of accidents (at present approx. 18 per year on average) could be reduced by 80% (or approx. 14 total losses per year) at once, if the pilots observed the rules strictly.

77% (N=940) of all human errors that trigger a safety-critical incident are "non-observances of rules" (omission/violation). The total number of reported violations of rules is 1513, and thus much higher, which is due to the fact that multiple violations (non-observance of at least two rules) were reported in 573 cases. The usefulness and protective effect of the rules is not questioned in principle. Nonetheless, violations of fundamental rules obviously occur again and again: time pressure, immense routine, complacency, and the feeling of being invulnerable reduce the threshold to violating rules.

Standard procedure (SOP)

As a principle rule, there are several procedures to solve a task – all offering the same level of safety. For this reason it does not necessarily become clear at first glance, why they should be limited to a few strictly defined standard procedures. But there are several reasons for making and observing binding agreements:

To be able to control each other and to address deviations from the rules, all cockpit members must be able to refer to commonly accepted procedures. When applying “personal procedures”, the controlling person can no longer determine whether the working step is desired in the way it is implemented or whether an unintentional human error has crept in. If a crew works in this “gray zone”, it has to rely on its feelings, which are bad or even mortal advisors – as is documented by many flight accidents.

Failure and readiness to take a risk

Behaviorism presents another important argument for disciplined work: After a tolerated rule violation the threshold for further, often even more serious violations is reduced. For this reason, deviations from rules must be addressed as soon as they occur, in order to prevent a cascade of violations.

The captain is responsible for the observance of binding rules. He is assisted by a responsible first officer as a means of support and additional “control and redundancy organ”. Thus, a violation of defined rules always means that the redundancy structure in the cockpit has failed. The tolerance threshold accepted by the first officer determines the mesh size of the safety network.

Experience and adherence to rules

A high level of self-discipline is required in order to consequently observe rules that are partly considered as inflexible after years of successful work. Training and management personnel is particularly endangered in this respect: A person who has participated in working out the rules and constantly remembers the partially controversial discussion resulting in their implementation, will sometimes have great difficulties in adhering to these rules. However, due to the trainer’s model function a violation of rules by the trainer has an especially strong negative effect, because human errors occurring in this context will most probably not be corrected by the inexperienced colleague, since he/she does not expect this type of rule violation.

Risk and motivation

In this context, motivation plays a major role, too. An investigation of the United States Navy has shown that 90% of the pilots who get involved in a human error accident have serious motivation problems. With fading motivation the readiness to violate a rule and to accept a higher risk increases. Only those who are highly motivated work carefully and foresightedly, and are highly concentrated. To “anticipate” possible consequences is the more difficult the more reluctantly one does his/her job.

Apart from discipline and motivation, the readiness to accept one’s own imperfection is an imperative prerequisite for good teamwork. Only who accepts his/her own weaknesses will be convincing when asking for and expressing criticism (passive and active ability to criticize).

Moral and values

The personal system of values also plays a decisive role: If we do not show empathy and a certain principal bestowal to our fellow men, our fellow combatants will not point out “incongruities” and possible mistakes with the necessary clarity in a complex critical situation.

Complex technology as “teacher” of human interaction

The expectation that a high level of technology will render the technical knowledge of the machine operator and the common sense of man superfluous to a large extent, has not been fulfilled. It is almost a paradox of human history that man’s efforts to develop machines that compensate human weaknesses have lead to the situation where now the "inherently human" abilities of social competence and optimal teamwork rank especially high when dealing with HITEC devices.