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# Team Resource Management for Development Organizations

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**Working in the social context of a company, a division or a team means to communicate, to make decisions and to work in hierarchies but it means also to make mistakes and to make wrong decisions. Looking in the world of embedded systems engineering we find a wide spread from tayloristic hierarchical approaches to zero-hierarchical structures and team empowerment in the agile development concepts.**

**How do people work and collaborate when developing technical solutions? What is the influence of hierarchies, of communication, of psychological and physiological conditions? What distinguishes an average team from a high performance team?**

**When we try to find answers to these questions it is worth to have a look at the industry which spends considerable amounts of money and time for research and training for leadership and teamwork: the aviation industry. The concepts used in the daily work of airline crews, designated as "Crew Resource Management", found already their way into two other team based industries: healthcare and fire-fighting.**

## I. History of Team Resource Management (TRM)

### A. *Hero education*

Aircraft where traditionally flown by a single pilot. The whole system of aviation training was focused on single persons. The first solo flight is an important step in every pilot's career; every skill check has to be performed without assistance of other crewmembers. Then, in the 1950s and 1965s the first real airliners came along. Aircrafts, which were too complex to be handled by a single pilot. Operators had to develop concepts for the teamwork within the default cockpit team of three (captain, first officer, flight engineer). The military history of aviation, which is also reflected in the ranks mentioned above, hat a simple solution: a steep hierarchy within in the team, orders instead of discussions.

"Hero education" is not limited to the former aviation training and "command and control" is not limited to military structures. Both concepts may be as well encountered in the world we know as "industry". So it is worth having a look how the aviation industry encounters this teamwork challenge.

### B. *From Cockpit Resource Management to Team Resource Management*

In the 1970s several aircraft disasters shook the world. Amongst this, the crash with the highest death toll up to today, the crash of Tenerife in 1977, which left 582 people dead. The newly invented technology of flight data recorders made it possible to determine the causes of these disasters and showed that a significant amount of victims in airline crashes died because of errors made by the cockpit crew. Triggered by the investigation report of a United Airlines crash in 1978 [1] the airlines introduced team trainings to increase the performance of the aircraft crews. Accompanied by a NASA research center the aviation industry spent a lot of time and money to understand teamwork, team performance, human error and human performance. The core concept was to recognize the first officer and the flight engineer as useful resources for decision making instead of a machine operator without an own experience or own opinion. The role of the captain changed from commanding the crew to managing the crew resources. The discipline of "Cockpit Resource Management" (CRM) was born. Later on the concepts included the cabin crew and the ground crew and the term changed to "Crew Resource Management". In the 1990s the CRM concepts where adopted by medical teams and fire fighters and were named "Team Resource Management" (TRM).

### C. *Disciplines*

In contrast to management and teamwork trainings in the industry, which are mostly focused on communication and leadership, TRM cares about more disciplines:

- Decision making
- Human error
- Situational awareness
- Information acquisition
- Automation
- Fatigue
- Communication
- Stress
- Teamwork
- Workload Management
- Attitudes
- Process adherence
- Environment

Regarding a specific situation, a critical situation or an accident the causes never can be derived from a single discipline in the list above. The disciplines interact with each other, which will be shown later on within some case studies.

## II. Teams and Management

### A. Selected studies

Hundreds of studies have been made in the last four decades to examine the secrets of team performance in cockpits. In general, the results can be easily transferred to the teamwork in development organizations:

#### 1) The power of the team

A study was set up to show the impact of fatigue on the performance of human beings. Cockpit crews hat to fly several missions for three days in a flight simulator. Flight scenarios with bad weather and many technical problems challenged the crews for the whole three days in order to fatigue the team. While the scientists expected a gradually decrease in the team performance (measured by judging how the crew handled abnormal flight situations), the performance increased over the three days although the crew got obviously tired. What has happened? The effect of teambuilding overcompensated the impact of fatigue [2]. A stable team can be much more than the sum of its members. This is an insight, which is a core concept of agile approaches in the product development.

#### 2) The role of the leader

Another simulator study was set up to examine the collapse of men's performance when getting overstressed. The setup provided a couple of flying missions with technical problems and was designed to provide a lot of workload to the flight engineer. The members of the cockpit team where mixed for every session to isolate the performance of the flight engineer from the rest of the team. Counter-intuitively the flight engineers taking part in the tests did not show a stable performance or a repeatable performance drop in the overload situation. However, the scientists discovered a correlation between the performance of the flight engineer and the name of the captain in the team under test. Further investigations showed that not the mental strength of the engineer was relevant for his performance but the management capabilities of the corresponding captain [2]. In this case "management capability" means the capability to balance workload between the team members and to detect when a member becomes overstressed. The "good" captains made a good team resource management.

### B. Authority Gradient

If a leader wants to take benefit of all human resources within his organization, he has to keep a certain authority gradient. Autocratic leadership suppresses the opinions of other colleagues and loses their experience. The other extreme is the so-called laissez-faire leadership, which has a too flat authority gradient. Laissez-faire leadership may disenable a team or an organization; it has the risk that in critical situations no decisions are made by the leader. May aviation accidents in the 1970s where caused by solo actions of the captains. While captains nowadays are trained to regulate the authority gradient all the time while working with a team, this issue is sometimes neglected in development organizations which have a strong tayloristic character. Leaders should be aware of the social climate in every situation when working with their staff. This is the basis for using all valuable resources provided by the unique colleagues. In contrast to agile development approaches, TRM concepts call for a dedicated leader instead of a mere peer team to balance discussion culture versus the speed of decision-making.

### C. Communication

Communication is often reduced to the exchange of information. According to Barbara Kanki, communication has five important purposes [2]:

1. Information transfer
2. Interpersonal/team relationships
3. Predictable behavior
4. Task monitoring / situation awareness
5. Crew and workload management

This combination makes communication the most important management tool. Agile approaches honor this importance by demanding co-located teams, which facilitates communication. However, not only the physical environment is important for effective communication, the culture of the organization has to encourage an open communication. With steep authority gradients, it is often hard to communicate concerns or different opinions. Two approaches help to establish communication about critical issues:

1. Professional language: In the aviation, there are many standardized terms and verbalizations. This helps to keep communication of the facts instead of the persons.
2. Nonviolent communication: The concepts introduced by Marshal B. Rosenberg in the 1970s help to offer criticism while preventing that criticism is felt as an assault.

### D. Team Risks

In the chapters above, the benefits of teamwork have been depicted. While agile approaches emphasize the power of the team, Team Resource Management shows also the other side of the coin: team risks.

#### 1) Risky shift

Studies show, that teams tend to take more risks in their decisions as the single team members would do. By applying decision-making processes like FORDEC (see later on) these risks can be mitigated.

#### 2) Follow the leader

Depending on the character of a person and the current authority gradient between the leader and that person there is a tendency of team members to align with the mental model of the leader instead of establishing an own model. It is the job of the leader to recognize this effect and to encourage the participation of team members at decision-making.

#### 3) Plan Continuation Error

The power, which emerges in a performant team, can also have a negative impact on decision-making. Teams are more susceptible to continue on plans even if the plan should be revised. This is why the decision checklists/processes demand a check after the execution of a decision.

### E. Hazardous Attitudes

During the researches for Crew Resource Management, the scientists made a classification of attitudes of human beings. The occurrence of these attitudes is not limited to aviation. They may be encountered in every job as well in private life as in work life. Knowing these patterns, everyone has a chance to detect own attitudes in a specific situation. The recommended antidotes are also depicted in the table below. If one detects a hazardous attitude, he can lessen it by saying loud the antidote formula. This sounds a bit funny but this is the recommended action on a hazardous attitude.

| Attitude | Symptom | Antidote |
|---|---|---|
| Antiauthority | "Don't tell me..." | “Follow the rules; they're usually right.” |
| Impulsivity | “Do something quickly!” | “Not so fast - Think first!” |
| Invulnerability | “It won't happen to me....” | “It could happen to me!” |
| Macho | “I can do it.” | “Taking chances is foolish.” |
| Resignation | “What's the use?” | “I'm not helpless.” |

The knowledge of attitudes patterns is not only useful for self-management. The patterns may also be used in the job to address a specific behavior within colleagues while staying factually.

### F. NOTECHS

In the aviation, a perfect teamwork of the crew is inevitable for the safety of hundreds of people. To improve teamwork and leadership or to correct problems it is necessary to measure the quality of the teamwork. Airlines assess regularly the teamwork within the cockpit crews using a standardized scheme, the NOTECHS (non-technical skills). NOTECHS score forms are grouped in four disciplines:

1. Co-operation
2. Leadership
3. Situational awareness
4. Decision making

The complete NOTECHS score form looks like this:

| | |
|---|---|
| **Co-operation** | |
| 1 | Teambuilding & maintaining |
| 2 | Consideration of others |
| 3 | Support of others |
| 4 | Conflict solving |
| **Leadership** | |
| 1 | Use of authority & assertiveness |
| 2 | Providing & maintaining standards |
| 3 | Planning & coordination |
| 4 | Workload management |
| **Situational awareness** | |
| 1 | Awareness of aircraft systems |
| 2 | Awareness of external environment |
| 3 | Awareness of time |
| **Decision making** | |
| 1 | Problem definition & diagnosis |
| 2 | Option generation |
| 3 | Risk assessment & option selection |
| 4 | Outcome review |

The assessor and the team member discuss the results of such assessments in confidence. Periodical feedback helps to improve the teamwork. Most of the NOTECHS topics can be used to build a useful checklist for managers in development organizations or scrum masters to evaluate the quality of teamwork. Such feedback requires a culture of transparency and professionalism, which has evolved in the aviation industry over the last four decades. Thinking about development organizations, such a culture can’t be taken as granted. The cultural change has also been a huge effort in the aviation industry and was not for free. Close and frequent feedback is also a core concept in agile approaches.

## III. Decision making and Human Error

### A. Types of errors

Human errors can be categorized in different ways. James Reason offers the following approach by distinguishing between intended and unintended actions on the top level **Fehler! Verweisquelle konnte nicht gefunden werden.**.

| | | |
|---|---|---|
| Unintended actions | Slips | Attention Failures, Intrusions, Omissions, Misordering, etc. |
| | Lapses | Memory Failures, Losing Place, Omitting Items, etc. |
| Intended actions | Mistakes | Rule based or knowledge based |
| | Violations | Routine, Optimizing, Exceptional, |

This provides the three basic types of human error: slips, lapses and mistakes (a violation is an intentional mistake and does not count as an error). Slips and lapses can be detected easily in a teamwork if corresponding processes or procedures are established. This can be achieved for example by peer reviews in classical development organizations or by pair doing as promoted by some agile approaches. However, it is not that easy to detect mistakes as the rules, knowledge and mental models which lead to this intentional unsafe act may be spread over the whole team. Mental models will be discussed later on in this paper.

Another important categorization of failures is the difference between active failures and latent failures. While active failures have an immediate impact, latent failures have been made a long time ago and get active under certain circumstances. Active failures are for example human errors like depicted above or technical breakdowns. Latent failures can be found in processes or technologies; they need a special environment to get visible or to do harm.

### B. The SHELL Model

The SHELL model was designed years before the CRM researches came up in the aviation industry [2]. SHELL stands for the person and its environment:

| | | |
|---|---|---|
| S | Software | The software around a person: processes, procedures, etc. |
| H | Hardware | The mechanical environment: machines, tools, etc. |
| E | Environment | The physical environment: temperature, noise, vibrations, etc. |
| L | Liveware | The person itself |
| L | Liveware 2 | Other persons to interact with |

Up to the SHELL model, the interaction of person with its environment was not seen in a systemic view. Traditionally every aspect in the table above is optimized without taking care of the interfaces. The results are well known:

- Bad user interfaces of machines (L-H interface)
- Bad communication in an organization (L-L interface)
- Impractical Processes with no acceptance (L-S interface)
- Bad working conditions (L-E interface)

The SHELL model shifts focus from the single “components” in a working environment to their interfaces. Optimizing the SHELL interfaces is a core issue to reduce the probability of human error and to enhance performance and quality.

### C. The Swiss Cheese Model

Most accidents, catastrophes or dramas are not caused by a single failure. A sum of failures, each one not critical by itself, is seen as the cause of the depicted events. The combination of small failures that lead to undesired situation is called an error chain. The countermeasure is to introduce several layers of error detection or quality assurance. These layers are often visualized as slices of a Swiss cheese, the flaws in error detection are represented by with the typical holes in the Swiss cheese. In this model, the undesired situation occurs when the holes of all slices become aligned and let the failure pass through. Countermeasures would be more cheese slices or smaller holes, each would reduce the probability that all holes become aligned. In the real world, this means to add additional checkpoints and to increase the quality of tests and reviews. Some of the holes are not known, they are latent failures.

### D. Violations

One of the most famous researchers concerning human error, James Reason, collected factors which increase the probability that people violate rules and processes. It is a very interesting collection, useful for every manager to reflect the culture and the circumstances within his own organization [3]:

- Manifest lack of organizational culture
- Conflict between management and staff
- Poor morale
- Poor supervision and checking
- Group norms condoning violations
- Misperception of hazards
- Perceived lack of management care and concern
- Little élan or pride in work
- A macho culture that encourages risk-taking
- Beliefs that bad outcomes won’t happen
- Low self-esteem
- Learned helplessness
- Perceived license to bend rules
- Ambiguous or apparently meaningless rules
- Age and Sex: young men violate

## IV. DECISION MAKING

### A. Information Acquisition

Everyone knows optical illusions that easily trick the perception of the image from our eyes. Objects disappear or the observer recognizes things, which don't exist. The effects, which lead to such misperceptions, do not disappear in the job; they are part of everyone's life. To trap illusions and wrong mental models it is important to understand how these problems arise.

The "good side" of information acquisition is the so called fact based information acquisition: Facts are perceived, filtered and then computed by the brain. Decisions made on this basis are normally good decisions. Hover information takes two additional paths: unfiltered information is computed by the subconsciousness and the information computed by the brain is stored in the memory. These two paths are important for the "bad side" of information acquisition. The subconsciousness influences how the brain computes information and data stored in the memory are computed by the brain to mental models. This called the hypothesis based information acquisition.

### B. Mental Models and Biases

The human brain loves consistent information. The brain does not feel uncomfortable with incomplete information but it does with inconsistent information. Therefore, the human brain tends to manipulate received information to fit them in existing mental models **Fehler! Verweisquelle konnte nicht gefunden werden.**. Several cases in the aviation history (as well as in the industry) show how teams were trapped in mental model and were not able to evaluate other models for the given situation. The most successful way is to exchange opinions with others while knowing the danger in information acquisition by mental models. The data manipulation by the brain is called "cognitive bias". The most famous biases are:

#### 1) Confirmation bias

When receiving information the brain tries to fit them into an existing mental model. Mental models can be extended with additional information but it is not possible to remove elements from a mental model. Therefore information is transformed to match the model.

#### 2) Framing bias

Facts, expressed in numbers, are evaluated by the human brain in their context. If the context causes positive, optimistic emotions facts are taken as more positive than the same facts in a negative, pessimistic context. For example if a medicine is said to rescue 20% of the patients more people would chose this therapy as if the medicine is said to leave 80% of the patients dead.

#### 3) Halo effect

The human brain tends to build a model of a person or a thing by treating unrelated information as related information. If, for example, a pupil always has achieved good grades in school, a written test with a poor quality will be rated with better grades than the same test results of an unfriendly pupil with bad grades.

#### 4) Frequency gambling

If a risky situation turns out all right several times, it get's difficult for people to still recognize the risk. People bet, that the situation would always turn out like in the past. This effect is called frequency gambling.

The only countermeasure against biases is a continuous alignment of own mental models with the models of others, which requires the ability and the possibility for an appropriate communication. It also is important that all people involved in this kind of quality assurance have a common knowledge about the psychological effects depicted above.

### C. Three ways to decisions

How decisions are made depends mainly on two factors:

1. is the problem understood?
2. how much time is available?

If the problem is understood and there is enough time available, a decision will be made by electing different options and choosing the best option. If no option is available because the situation has never occurred before, a new solution has to be created. If there is no time available, decisions are made bay applying ready-made rules (pattern matching). However, this approach will also be conducted if the problem is not understood by transforming the situation in an available mental model. The following table shows examples for the cockpit team as well as for management decisions in the industry.

| **Decision process (Circumstances)** | **Aviation Example** |
|---|---|
| | **Industry Example** |
| Applying a rule (rule available, no time available, problem understood) | Engine Fire: Warning lights trigger the memorized actions of the crew |
| | Execution of actions described in a risk management plan |
| Applying a rule (rule available, no time available, problem NOT understood) | Fuel starvation Air Transat Flight 236 |
| | Intuitive management decisions based on former success with the same pattern |
| Choose option (time available, multiple options available) | Bad weather at destination: Diverting to an alternate Airport |
| | Purchasing a new toolchain |
| Create novel solution (Time available, no option abailable) | Hudson river landing |
| | Customer-oriented problem resolution beyond existing processes |

### D. FORDEC

An antidote for the risks in decision making by cognitive biases is to establish a process for decision-making. Developers are familiar with process but it is necessary to have a very lightweight process which can be used quickly. FORDEC is such a micro process or a checklist for decision-making. FORDEC helps to separate the collection from the evaluation of facts and options and encourages a risk evaluation. FORDEC stands for:

| | | |
|---|---|---|
| F | Facts | Collect facts together with team members. Do not evalutate facts yet |
| O | Options | Discuss options in the current situation derived from the facts |
| R | Risks and Benefits | Discuss risks and benefits |
| D | Decision | Make the decision |
| E | Execute | Execute the decision |
| C | Check | Verify if things develop in the desired direction. If not, consider a re-application of FORDEC |

## V. STRESS AND FATIGUE

### A. Stress

Stress itself is not negative at all. Without stress or arousal, the human being cannot perform, neither physically nor psychologically. So in a "normal operating range" human performance increases as the stress increases. This is valid up to a tipping point, where a further increase of stress will cause a significant reduction of performance. The performance of an overstressed person will collapse suddenly. It is very hard to predict the tipping point; this point varies from person to person, from day to day and from hour to hour. It is important for every person to learn to recognize if he approaches the tipping point. As well, it is important that leaders and team members learn to recognize such a trend at other team members. Each person has his own patterns when getting overstressed. To learn one's own patterns the following attributes should be monitored: voice, breath, and somatic effects. A culture of an open communication helps affected team members to talk about their stress level. This helps the team or leaders to adjust the current workload management and to keep the team performance up.

Stress can be divided in positive stress, called eustress and negative stress, called distress. Distress is more likely to move a person to the point of sudden performance drop, but eustress can also do so. It is important to know, that the current stress level of a person is composed of dynamic stress (short time stress, caused by the current situation) and chronical stress (long time stress, caused by the environment of the person). So independent of the stress resistance of a person at a certain time, the stress level cannot be predicted neither, because of the unknown chronical distress (e.g. financial problems, relationship problems, etc.).

### B. Fatigue

While fatigue sometimes has a "hero image" in some development organizations, it is recognized as a huge problem in the aviation industry. A sustainable sleep management is necessary to keep the performance on the required level. Every night, a human being goes through several sleep phases, starting with a deep sleep, which is used to regenerate the physical aspects of a person. Waking up from a deep sleep is very hard. The opposite of the deep sleep is the REM sleep where REM stands for rapid eye movement. The REM sleep is used to regenerate he psychological aspects of a person. Dreaming does only take place in the REM phase. Waking up from the REM phase is easy. In an undisturbed sleep, the human body alters four times between deep sleep and REM sleep, which is necessary for a full recreation. If the time to sleep is too short for four deep sleep phases or the alternation between the phases is disturbed by consumed alcohol, the body builds up sleep debts, which are accumulated from day to day.

A recognized antidote for sleep depts. Is the so-called micro nap, which helps to catch up with the sleep deficit. Micro naps are well known in the Japanese culture but are not welcome in the western hemisphere. NASA scientists developed a guideline for micro naps (also called NASA naps): The nap should not exceed the time a person needs to reach deep sleep. Otherwise it could be difficult to get awake quickly again. The sleep time should be limited to 15 minutes. For a complete NASA nap session, an employee and the organization should calculate one hour: 15 minutes to calm down, 15 minutes to sleep, an 30 minutes to get awake completely again.

### C. Impact on Decision Making

Sleep debts as well as too much stress, have a huge impact on decision-making. Several aviation accidents had fatigue among the main causes, e.g. Ethihad Flight 409 or Colgan Air 3407. Fatigue and stress decreases the quality of information acquisition and deteriorates the ability of recognizing traps in the information acquisition and the effects of mental models. Stress as a negative impact on communication, workload management and teamwork, which increases stress furthermore, a vicious loop. However, an active management of stress and fatigue rarely can be found in development organizations. It is the job of managers and team leaders to care about this issue, to keep the team performance an adequate level.

## VI. CONCLUSIONS

### A. Correlations

All disciplines depicted in the first chapter interact in different ways. In the following lines, some possible connections are discussed.

- The core is "decision-making" all other disciplines only have an indirect impact on a situation. Quality and performance of a cockpit crew and a development team only can be measured by the quality of their small and large decisions.
- Decision-making depends on the automation level (e.g. code generation), human error, information acquisition, and communication.
- Information acquisition and human error depend on fatigue.
- Communication depends on teamwork, stress and fatigue

- Teamwork depends on attitudes, communication, stress and fatigue
- Workload management depends on teamwork and communication
- Stress and fatigue depend on workload management, teamwork and environmental conditions.
- Attitudes depends are related to process adherence

### B. *Leadership*

The main task for leaders is Team Resource Management. This puts teambuilding and the adjustment of authority gradients in focus. Successful leaders care more about teams than about tasks. Leaders are responsible for the social climate, the communication infrastructure and workload management. Teams need leaders. Even in agile teams that are peer teams by definition unofficial leaders will arise and help the team to get a performant team.

### C. *Organiazation and Culture*

Efficient Team Resource Management requires a good error culture and culture of transparency and open communication. While agile teams represent such a culture, there are still development organizations that work in a tayloristic way with steep authority gradients. Communication is the key for team performance. Therefore, co-located teams can provide more performance and will produce better quality. The organization has to admit that human beings are imperfect by their "system design", which has an impact on trainings and error culture.

### D. *Teams*

Teams perform better than a group of individuals. Teams provide an inline quality assurance and the possibility of workload management. Teams need leaders, either unofficial leaders in agile teams (agile teams will develop leaders by themselves) or a leader defined by the hierarchy. For efficient quality assurance teams need to know about team risks and human error.

### E. *Training*

It is hard to train teamwork or decision-making. The way of CRM trainings provided by airlines to their crews is to raise awareness of human error, and team risks. This helps teams to recognize some of the effects described in this paper. Contrary to the industry, there trainings are seen as "single shot" events, CRM trainings are conducted every year in the airline industry. Periodically trainings help to keep the awareness on shortcomings in human information acquisition.

## VII. CASE STUDIES

All case studies below are well documented in the "Mayday" TV-series and can be found on video sites on the internet. Watching the events in the cockpit and knowing the key concepts of TRM, most of the behavior and the mistakes of the crew can easily be transferred to development teams.

### A. *Crossair Flight 3597*

In 2001, on November 14, a regional jet crashed on the approach to Zürich Airport, leaving 24 of 33 persons on board dead. The captain violated procedures and limits and the first officer did not intervene due to the steep authority gradient [5]. CRX 3597 can be related to the following TRM topics:

- Authority gradient
- Attitudes
- Stress
- Fatigue
- Plan continuation error

### B. *American Airlines Flight 965*

In 1995, on December 20, a Boeing 757 crashed into a hill in Colombia, killing 159 of 163 persons onboard. Due to stress and a chain of minor errors the crew got lost and hit the hill in the darkness [6]. AA965 can be related to the following TRM topics:

- Stress
- Fatigue
- Autority gradient
- Attitudes
- Plan continuation error

### C. *American Airlines Flight 1420*

On June 1st 1999, a MD-85 Airliner overshot the runway in Little Rock, USA. Eleven of 145 people on board were killed in this crash. The flight seemed to be a routine flight in bad weather. When the weather got worse in Little Rock, the crew did not evaluate other plans and continued the approach. A pilot error due to stress prevented a normal breaking action. Contrary to the case studies above, in this case the crew decided as team. The crash was not an issue of the authority gradient [7]. AA1420 can be related to the following TRM topics:

- Stress
- Attitudes
- Plan continuation error
- Risky shift
- Frequency gambling

### D. *Lufthansa Flight 44*

On March 1st 2008, a Lufthansa Airbus encountered a wing strike during landing on Hamburg Airport. No one was injured. This case shows the build-up of an error chain, including latent failures made at the system design of the aircraft [8]. LH44 can be related to the following TRM topics:

- Latent failures
- Error chain

- Plan continuation error

### *E. Air Transat Flight 236*

On Auguts 24th 2001, an Airbus suffered fuel starvation over the Atlantic. The aircraft lost fuel due to a technical problem and lost both engines during the flight. The crew managed to land the airbus as a glider on the Azores. The problem could have been isolated and the remaining fuel would have been enough for a safe landing with one engine. However the crew was caught in a mental model and did not recognize the leakage until the landing [9]. TS236 can be related to the following TRM topics:

- Mental Model
- Attitudes
- Process adherence
- Stress


[1] NTSB accident report AAR-79-7

[2] B. Kanki, R. Helmreich, J. Anca, “Crew Resource Management”, 2010

[3] J. Scheiderer, H.-J. Ebermann, “Human Factors im Cockpit”, 2011

[4] Daniel Kahneman, “Thinking fast and slow”, 2012

[5] Büro für Flugunfalluntersuchungen, Schlussbericht Nr. 1793

[6] AERONAUTICA CIVIL of THE REPUBLIC OF COLOMBIA, Final AIRCRAFT ACCIDENT REPORT CONTROLLED FLIGHT INTO TERRAIN AMERICAN AIRLINES FLIGHT 965, 1996

[7] NTSB accident report AAR-01-02

[8] Bundesstelle für Flugunfalluntersuchung, Abschlussbericht 5X003-0/08, 2010

[9] MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES, Accident Investigation Final Report 22 / ACCID /GPIAA / 2001, 2004