# FLYING IS NOT SAFE

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## Abstract

Many distinguished scientists have provided papers for this congress. As an airline pilot I am about the only one active at the operational end of transportation, which you could also call the receiving end when we are discussing accidents. In other words: for many of you safety or subjects related to safety are interesting and challenging topics in scientific terms. For us, airline pilots, safety is literally a matter of life or death. And not only for our passengers. We promise them a safe flight and by sharing that flight with our passengers we provide the ultimate guarantee: our own life. That goes a few steps beyond putting your money where your mouth is.

We fully subscribe the aim of this congress which I take to be to advocate the creation of a European Transportation Safety Board. Aviation is pretty new. Once people like the Wright brothers overcame the initial technical problems of manned flight and flying became a mode of transportation it needed an organizational structure. A lot was then copied from shipping. We still use nautical miles and we still carry red lights on port and green lights on the starboard side of our aircraft. However, the air-ocean is even more unforgiving of mistakes and ignorance than the cruel sea. So we had to develop additional procedures and deeper insights into the causes behind accidents to survive. What we learned and what I will address in this paper might very well be useful for other modes of transportation too. While we started out with receiving information only, we are now ready to repay our debt and give some information back. At the same time, in the spirit of this congress, we are eager to receive any information that could help us further on the way to our common goal: safe transportation.

**Aviation is not safe.**

This title needs a bit of clarification. Because if it were true as is, I would not be standing here. One more line should be added, a line that reads: at least not automatically. Flying is easy however, but only for birds. A 1897 drawing shows the skeletons of a man and a bird drawn to the same height to indicate that these two look basically the same, implying that flight should be possible for men too. However. although they look the same, the bird bones were especially adapted for flight over an evolutionary period of about 120 million years. And so was the bird brain. We don't have bird bones and we don't have bird brains. So to be able to fly we need a lot of technical contraptions. That is the first problem making flying inherently dangerous.

The second is, that once mankind learned how to fly we were not content with a nice circuit around the local church on a lazy sunday afternoon. We wanted to fly always, day and night, and never mind the weather: we wanted to fly in rain, snow and fog, in weather when the average bird would wisely decide to sit tight on his twig. And we wanted to fly on time, to keep a dependable schedule. This called for even more technical contraptions, posing even more potential problems in more adverse circumstances.

Third problem, once a bird starts flying and the situation deteriorates, he can call it a day and sit down on the nearest telephone wire or in the nearest tree to await improvements and get rested. Once man starts flying he is committed to continue, whatever happens weatherwise or technically. He can only stop when he finds a piece of concrete long enough to land his aircraft on.

Yet it is possible to provide a safe flight as we prove day in and day out. But safe flight is only possible under very specific conditions. Where the borders are that outline the area within which safe flight is possible we learned the hard way. We learned it literally with blood, sweat and tears. Those borders are marked with the wrecks of aircraft and the remains of passengers and crew.

**Safety does not exist**

You might wonder what the Dutch Airline Pilot Association or, for that matter, IFALPA, the International Federation of Airline Pilot Organizations has to do with safety. The answer is: a lot, and for a long time too to boot. If we mark the beginning of aviation at 1903, the first flight of the Wright brothers, or Orville to be more specific, on December 17th, aviation is 89 years old. VNV, Dutch

ALPA, is the oldest pilot organization of the world and was founded in 1929. Aviation is a very global activity and to have an effective voice you have to be organized globally as well. That is why IFALPA came into existence, founded in 1948 with VNV being one of the founder members. So we, as VNV, are 63 years old and right from the very beginning safety was one of our major concerns. And with good reason. The first board of VNV counted five members. One of these failed a medical check, which ended his career. The other four all ended their career flying. Literally: every one of them died in an aircraft accident. So much for the safety level of that pioneer period.

We have come a long way since those days. The indicator we use to show how we are doing safety wise is "hull loss per million departures". A more common statistic used is "passenger seat miles per life lost". The latter one is indeed a good parameter for a potential passenger deciding on the best way of transportation for a given trip. However, most aircraft accidents happen in the take off or landing phase and do not depend very much on the size of the aircraft. So if you let bigger aircraft fly over longer distances, your safety record based on the latter indicator improves automatically without having done anything else. For knowing how you are really doing hull loss per million departures is more informative.
If we pick up the statistics in the late fifties we find them coming from 45 losses per million departures, decreasing rapidly to about 1.5 per million in the early seventies and remaining stable at that low rate till now. So despite great increases in the complexity of modern aircraft, much heavier traffic density and more adverse environments (we now land and take-off in dense fog where you would not even want to ride your bike) we see a dramatic and stable improvement in flight safety. This would be great, were it not for the fact that safety does not exist. What exists is a level of safety. When we say driving a car is safe we mean that we feel it is safe enough to drive a car to actually do it. Safety is relative, and unfortunately not even that.
Most people consider negotiating Niagara falls in a barrel pretty unsafe. The safety level has proven to be not quite zero, as some people actually survived such a ride. Chess on the other is considered by most people to be a quite safe activity. Driving a car ranks somewhere in between, but is also considered by most people to be safe enough to do. So far so good. But then we get to the funny part. Airline flying has been proven to be considerably safer than driving a car. And indeed a great many people find it safe enough to do. But there are also many who will either never ever enter an aircraft or do so when they really

can not avoid it but are then scared out of their wits for the whole duration of the flight. So safety is not only relative, it is also subjective: it is a perception. And as they say in modern management perception is reality.
A neat demonstration of this reality has been provided in the US in the year 1985. In that year 45,000 people died in automobile accidents. With a population of 240 million at that time the probability of dying in a car accident was 1 in 5,300. That year was also marked by many terrorist attacks against US targets abroad. 17 US citizens died in those attacks that received widespread newscoverage. 28 million US citizens made one or more foreign trips that year. So the probability of dying in a terrorist attack was only 1 in 1,600,000. These are the objective figures. Yet the next year I think not one US citizen decided to leave the car alone for a year, while millions of them cancelled their foreign trips. Here in Amsterdam the international hotels were half empty and the total economic loss in the Netherlands alone was in the order of 200 million guilders.
Going back to our stable rate of 1.5 losses per million departures that meant about 18 accidents with the 12 million departures a year we had at the end of the eighties. If we however combine that stable rate with the doubling of traffic that is still expected by the end of this century, we will then have 24 million departures with statistically 36 hull losses per year. Which translates into a smoking wreck on the tv screens almost once every week. Imagine what that will do for the perception of the safety level of aviation.

## Human Factors and System Failure

So this problem needs to be addressed. If no solution were possible you could define it as a public relations problem and go to work on that. However, we feel real improvement is still possible. Although of course it will be very difficult, which is indicated by the fact that despite all efforts the loss rate has stabilized at 1.5 losses for quite some time now. When addressing a difficult problem it sometimes helps to look at its parts. Which is the case here. Although aircraft accidents are almost always the result of a complicated train of events, investigating authorities have the habit of attributing the accident to one major final cause. When you brake down the accidents of the last thirty years according to various major causes the result is very interesting. Although the actual number has diminished quite a bit, the division among the several causes has remained basically unchanged. About 75% of the accidents have been attributed to flight crew failure. What used to be called pilot error in the past and what we prefer to call human factors. Not because we do not want to be blamed, but because we do not want the investigation and learning proces to halt once it is found that the flight crew did not function as expected. We want the investigation to continue and to investigate why the flight crew did not function properly. Obviously not by choice, because the pilots are normally amongst those killed. Before we go a bit further into this human factor area and even expand it into system failure I would like to illustrate my point with a classic example of what used to be called pilot error.

In the beginning an aircraft carried an altimeter with only one needle, indicating hundreds of feet. When aircraft started to fly higher a shorter second needle was added, indicating thousands of feet. Finally, when cabins became pressurized and even higher flight altitudes became possible and economical, an even shorter third needle was added indicating tens of thousand of feet. Thus was the three-pointer altimeter created. Then a lot of fatal accidents started to happen because of misreading of this altimeter. The cause: pilot error. These stupid pilots should learn to read their altimeters correctly. Even when they are tired after a long flight and have to land in adverse weather conditions, they should not make mistakes. But mistakes and accidents continued to happen: you can not order a human being not to make mistakes, as you can not order a human being not to become ill. People are not omniscient and infallible. Even pilots aren't. Eventually it was decided to change the altitude presentation and after several failures in this area we now have a very satisfactory altimeter that gives the altitude as a digital readout and on top of that uses a needle to indicate the hundreds of feet, thus providing rate of change and direction of change information.

This is what pilot error is. Of course this is a very simple example and all the simple items have by now been eliminated. However there are still many complicated ones lurking within the system and it is the task of all of us active in aviation to track these down and to eliminate them. As pilots of a specific flight we are standing on top of a pyramid of activities leading to that specific flight. The base of that pyramid is the design of the aircraft and some of the subsequent layers are the manufacturing of the aircraft, its maintenance, the tanking of fuel for the specific flight, the providing of meteorological information, the providing of air traffic control services for that flight, and so on. And at any level in that pyramid things can go wrong and things do go wrong. As a matter of fact, standing on top of a pyramid of activities is a glorious image, and I therefore wish it were true, but it is not. Reality is that we are not the top of a pyramid but more the stop in a funnel. With the design of the aircraft as the topmost level. And in every level, as stated before, things can and do go wrong. All these things drift down to ever lower levels. Sometimes they are detected in the process. A failure in the manufacturing stage might well be detected in the maintenance levels. But some failures drift all the way down till they reach the pilots. The pilots add to those latent failures their own failures and mistakes, because they are not infallible and omniscient, and they have to cope with the resulting explosive mixture. Normally we do cope, normally we are able to handle whatever we find on our plate. But occasionally a potential failure falls through and a major accident is then the result.

This of course is what we set out to prevent: we want a lower accident rate, even lower than the already low 1.5 we have. When we picture the pilot as a goalkeeper we have two ways to improve our record: we can improve the goalie and we can try to reduce the number of scoring opportunities. For both we have to analyze what went wrong. We have to analyze the full accident train and cannot stop at the verdict pilot error or even human factors. A problem, all be it a luxury problem, is that we have not enough accidents to make enough progress. We must therefore also learn from incidents. And we are at the moment studying ways to make available the information about our day to day operation that is stored in the computer memories of modern aircraft for maintenance reasons. Of course the use of these types of information depends on the willingness of individual pilots to come forward with reports of things that, although handled nicely afterwards, were things that were done wrong or went wrong in the first place. It stands to reason that the individual will only be willing to provide all necessary details if the objective of the procedure is clear and endorsed by everyone involved: the objective must be to learn. Not to apportion blame. Progress through learning, those are the keywords.

**The changing role of the captain**

As a matter of fact we have learned quite a few things already. The two most important ones are a different perception of the role of the captain and the realization that the complete system that should be studied goes far beyond the aircraft/crew combination; it also involves management and authorities.

As far as the role of the captain is concerned we see quite a change over the years. In the beginning pilots were considered to be just plain hero's. And they were. If we look at the fifties, we see the captain, like so many things in aviation at that time, modelled after what had been succesfull in the nautical world. The

Captain as Skipper next to God. It was probably the best model at that time in the prevailing circumstances. However, a captain is not infallible nor omniscient, so over the years a new model was developed. We nowadays view the captain as the manager of all the people and resources he (or she) has available both inside and outside his crew. But not as the type of manager common in hierarchic bureaucratic organizations, but as a different type. A type that can be defined by just two words: communication and information.

We learned that to be able to use all available resources to the fullest communication is essential. Not only must the captain communicate what he intends to do and why, he must also be open to receive any signals others may send. A first officer must always feel free to make any comment he sees fit, he must be convinced that he will never be ridiculed nor frowned upon whatever his remark.

We learned that we have to realize that the mental picture we have of any given situation is a perception and not necessarily an actual representation of the real world. So we must always be open and ready to adjust that perception.

We learned that the human mind can handle only a limited amount of information at the same time, that once the mind is focused on an important item other items and even new items tend to be ignored, even if these new items may rapidly lead to far greater problems than the one at hand. We call this the "deadly set" as we have seen at least two cases of aircraft crashing while the attention of the crew was focused on in the final analysis minor problems.

We have learned that decision making is for most people a traumatic experience and that once a decision has been made the natural tendency is to not take it into consideration again. New facts indicating that a decision was a bad one tend to be ignored, with sometimes disastrous results.

We have learned that most people like to belong to a group and that it is for many people difficult to go against the views of the group, and especially against the views of the leader of the group.

With all these subjects communication and information can be the items that save the day.

To summarize the comparison of the manager role of the captain with the traditional manager model: the aim is not to give directions and then check if these directions have been followed closely. The aim is to use all people and means available. The captain does not pretend to be omniscient and infallible. He does have trust, in his own capacities as well as in those of other people. Although he knows he will make errors, he is also aware of his own skills and he is confident he can handle almost any situation. He has to trust himself for two reasons. First it enables him to trust other people. When I take a 747 for a flight to New York I am responsible for and I sign for its technical status. I have no way on earth to really check what I sign for. I trust the ground engineer and the organization behind him blindly. And I trust my own skills, I am convinced that if they made a mistake and if we lose an engine just after take-off, that I will be able to handle that. Second trust in his own skills makes the captain open for criticism. If he knows he does a good job he will accept a critical remark for what it is: addressing a factual situation. He will act upon that remark and he will not take it to be an attack on his person or his functioning and get distracted into addressing one of those issues while the aircraft continues its perhaps fatal flight.

Of course this implies that the aviation environment must be basically fault tolerant, so that one fault is not by definition fatal but that error recovery is always possible. And it also implies that we must be willing to learn from every event.

Furthermore we cannot manage safe flight through fixed rules and fixed rules alone. Things always go wrong in unexpected ways, so knowledge and tools are needed to handle every possible situation. That is also the reason why the human being cannot be designed out of the loop. As artificial intelligence experts have come to realize expert systems can only assist humans, not replace them. And the computer systems we have should be adapted to the human mind. Asking the human to adapt to the computer, which has been customary in aviation, is asking for trouble.

**System failure**

All this only addresses the functioning of the pilot in his crew on a specific flight. However, we should also regard the pilot in the total system, we should look at the complete funnel of activities trickling down to a specific flight. Major work in this area has been done by the Professors Reason, Hudson and Wagenaar. They developed a powerful model to address many safety issues in a broader perspective.

Traditionally there was an accident and there was the cause of the accident, in our case a mistake or, more generally speaking, an unsafe act by the crew. The traditional reaction has been to tell the pilots not to commit unsafe acts, which is pretty useless, to devise more rules and procedures and/or to install defence lines: warning systems. Like ground proximity warning systems, altitude alert

systems and, the most recent addition to our multitude of horns, lights and artificial voices, TCAS, a Traffic alert and Collision Avoidance System. When a simple error will lead to a major accident a defense line is certainly needed. Relying to heavily on defense lines however carries additional risk: breaking through a heavy defense line, which will happen sooner or later, will very likely lead to a very serious accident. A side effect can also be that the real problem is not addressed: why should one bother when there is a defense line to counter unwanted situations at no additional cost. This is one of the problems that might crop up with TCAS. TCAS is meant to prevent midair collisions, in other words to catch failures in the Air Traffic Control system. It might be very tempting for authorities to rely more and more on TCAS instead of correcting weaknesses in the ATC-system.
So, although defense lines and additional training and procedures certainly are useful they also have their limitations. In the end they lose their effect: it does not help much to impose ever more regulations and warning systems if you do not address the underlying causes.

The first level of underlying causes lies still within the crew: these are the psychological precursors and are common to mankind. You cannot change them, but you have to take them into account when designing procedures, instruments and warning systems. These are things like the fact that we are likely to be the victims of visual illusions. Or that we respond better when receiving information about changing situations through more of our senses at the same time. The reason why a fire in an engine not only lights a warning light but also sounds a horn. Also the reason why it is very useful when an automatic throttle system not only changes engine rpm but also moves the throttle handles in an appropriate way.
Other precursors are the fact that the human brain can handle only a limited amount of information at the same time and feeding it more information will lead to overload and to not noticing sometimes vital information, and the fact that our memory has its own limitations and peculiarities. A lot of this is well known and specific training to counter these problems is available. Generally speaking this training is aimed at teaching more effective cockpit communications.

With the next two levels we proceed beyond the crew: they fall within the scope of management. The first of these are what we call latent failures, mainly caused by the second one: management decisions.

Latent failures are for instance not having efficient standard operating procedures and not using standard calls to inform other crewmembers of changes in the aircraft configuration. Or having a confusing layout of checklists and/or manuals or unclear or even faulty information in manuals. Other categories are technical shortcomings or software bugs that are known but not corrected.

Management decisions finally are things like allowing very tight schedules, thus putting even more pressure on on time operations than normal. Or buying aircraft without a defense line proven to be useful like a ground proximity warning system only because the national authority allows operation without that system. Management can make a great many decisions that in itself might look harmless or even justified but that in effect reduce the safety margins a pilot has and a pilot needs when several things go wrong at the same time. Instead of error tolerant the total system then becomes vulnerable causing latent failures to lead through psychological precursors to the commitment of unsafe acts that may break through defense lines and cause a major accident. This scenario and this model can be applied to all modes of transportation and in all cases a major accident will be the likely end result
The only way to prevent this is for management to become safety conscious and to be open to feedback that has to be provided by the users of the system. In these areas too a European Transport Safety Board could play an important role.

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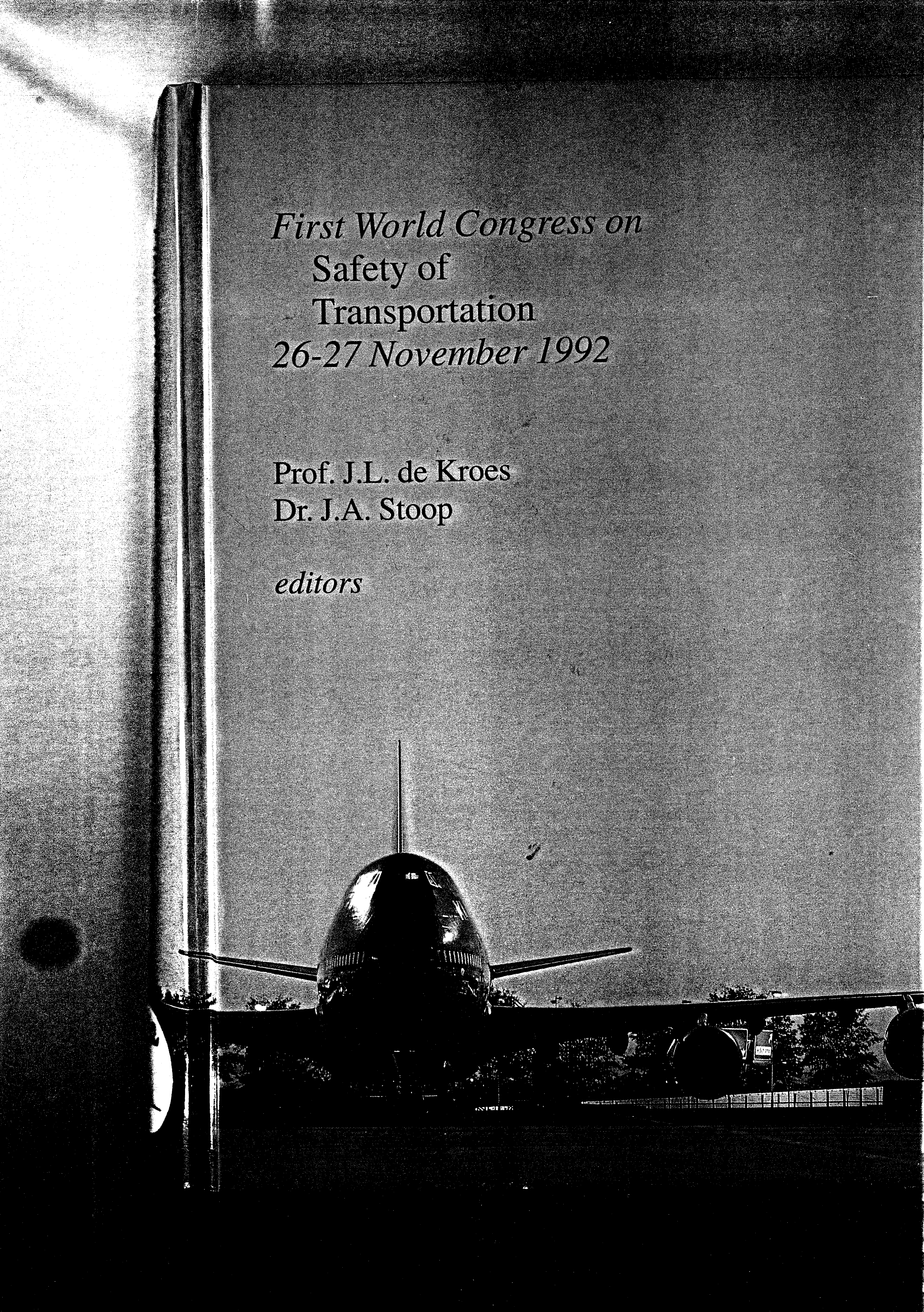
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