Moving beyond compliance to performance-based regulatory oversight:
Measuring safety culture to enhance human factors and performance in aviation maintenance organisations.

Hok Goei – Transport and Water Management Inspectorate / CAA-NL [1],
The Netherlands
Prof. Patrick Hudson - Leiden University, The Netherlands

Summary

This paper presents the holistic approach that the Dutch CAA have initiated in their oversight program for the maintenance organisations since 2005. This initiative explores new methods for raising the effectiveness of the regulatory oversight and to apply a safety performance based approach using systematic safety management (SMS). This approach may be a first small step in how a regulator should conduct and supervise the SMS implementation. Many experiences in implementing SMS (both in and outside the aviation community) have demonstrated the importance of the maturity of an organisation's safety culture. Therefore, on the regulatory side we feel a need to improve the processes and to achieve effective SMS implementation by taking cultural issues into account, as well as technical and system-based approaches.

A specific assessment framework and model was developed by CAA-NL, focussing on human factors and safety culture aspects. The model makes use of the experiences within the Gas & Oil industry and other industries and is based on the main elements of the Part 145 Human Factors requirements. The assessments consist of several interviews with personnel within the organisations, including (top) managers, supervisors, engineers and other staff members, focussing on the identification of organisational cultural aspects such as safety philosophy and commitment, just culture, continuous learning, competence and other human factor issues. The analysis and evaluation of the assessment are structured using descriptions of the 5-step safety culture ladder from Pathological to Generative.

Twelve "Part-145 approved" maintenance organisations (MROs) were systematically assessed by the Dutch CAA between 2006 and 2008. Although the assessments were radically different from the traditional safety audits the responses of all organisations were positive. The results exposed the strengths and weaknesses of the organisation's behaviour, and they also created opportunities. With these perceptions and results the Dutch CAA will develop a new oversight strategy, including a strategy for SMS implementation.

Background

The aviation industry and the public sector have made huge investments in order to achieve the current level of safety. Technical innovations, reforming regulations, management systems improvement and improvement of human factors have been introduced successfully for the past three decades, resulting in improving aircraft safety. However the safety statistics have levelled off since 2000, and accident rates went up gradually[2]. For many years human factors have been the highest causal or contributing factors in air accidents, and aircraft maintenance errors also contribute to this. The reports by Boeing en ATA[3] in 1995 and by Rankin and Allen[4] in 1995 established the consequences of maintenance

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[1] The author leads the HF&SC program within CAA-NL's airworthiness department. He is very grateful to all colleagues within the department for their help and their contribution in establishing and finalizing this program. Without their considerable help this paper could not have been written.
[2] Based on safety data from various sources: CAA-NL's Civil aviation safety data 1993-2007, Flight International annual safety reviews 2005, 2006 & 2007, CAA - CAP763 Aviation Safety Review 2005.
3 A study conducted by Boeing and the US Air Transport Association (1995) found that maintenance error was a crucial factor in aircraft accidents from 1982 to 1991, contributing to 15% of the commercial hull loss accidents

errors on safety and the economic costs thereof in the USA. These studies made clear that considerable effort had to be put into the prevention of maintenance errors. The need for improvement in maintenance human factors was then recognized, also in Europe, and many initiatives were actively taken in various disciplines.

The developments of the last two decades include:

- Human Factors introduction in maintenance regulations, i.e. EASA Part –145[5]
- Safety Management Systems (SMS) endorsed by ICAO
- New maintenance techniques.
- Shift in organizational thinking and processes.
- New reporting and analysis tools, i.e. MEDA and other initiatives in this respect.

Experience has shown that auditing the implementation of the requirements on human factors was difficult. Although auditing organisations is familiar to us, it was clear that auditing how organisations comply with Human Factors rules and how they perform in that respect was new, and required further exploring. This also applies for safety management oversight approaches. Brian Fisher already mentioned in his publication[6] in ICAO journal (July 2005) the variety in safety management approaches, the underlying attitudes of organisations and how regulators should act. In his words: "Regulators interact with companies and persons across the safety spectrum. They need, therefore, to respond in a fashion appropriate to the behaviours exhibited by the organization or individual. They must develop appropriate strategies to ensure compliance with the minimum safety standards and provide the right inducements or bridging strategies to advance safety management thinking."
The essential first step for now is that we should put as much effort in ensuring that personnel and managers "*do the right things*" as to ensure that they are "*doing the things right*". Therefore, regulators should move beyond the traditional rule- or compliance-based approach to a performance-based approach using systematic safety management systems (SMS[7]). However, that is practically and principally one giant step further, as experienced by ICAO and other authorities that already implemented SMS. This shift is taking place in many industries, like the Oil & Gas and nuclear industries.

The challenge and objectives

The challenge facing us is:

> Oversight should not focus simply and solely on compliance monitoring but should play a proactive role in encouraging organisations to improve safety performance. This applies particularly for the application of Human Factors and the implementation of SMS. We feel that by focussing on and evaluating an organisation's safety culture and its treatment of Human Factors we can increase the safety awareness and the HF integration in their safety management. Influencing the industry in this manner could work more effectively at the end.

Therefore, the Dutch CAA initiated a specific HF and safety culture assessment program. We chose to undertake a pragmatic approach, and kept the process as simple as possible. The objectives of our specific program were:

(a) To evaluate and understand how the organisations perform with respect to Human Factors, and
(b) to get insight into their safety culture, their characteristics and maturity level. Our intention was to develop our perception of each organisation's behaviour and culture in safety aspects

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where five or more people were killed." [source: Boeing/ATA, 1995, "Industry maintenance Event Review Team"]

[4] Rankin and Allen (1995) estimated the economic costs of these maintenance errors, and found out that 20% to 30% of in-flight shutdowns are due to maintenance error, 50% of flight delays are due to engine problems caused by maintenance errors, and 50% of flight cancellations are due to engine problems caused by maintenance errors. [source: William Rankin, The maintenance error decision aid (MEDA) process, IEA2000/HFES 2000 congress.]

[5] The EASA Part-145 rules addressing Human Factors aspects were initially introduced in the JAR 145 amdt. 5. See ref. 2

[6] Ref. 22

[7] Ref. 3.

and successively to hold "the mirror up to their own face". Their response is of great importance in developing the perception.

Our basic idea was that this HF and Safety culture assessment (HFSC) program should be supplementary to the standard annual oversight program, and that this should be a total different approach from the normal and traditional audit. If this approach proves successfully we will consider integrating it into the annual program.
The scope of the program was the maintenance environment. Twelve large Part-145 organisations (e.g. organisations with more than 50 employees) in the Netherlands had been assessed in this program and the assessments took place in the period 2006 - 2008. The objective was to repeat the assessments in the very near future.

What is safety culture?

If you were asked what safety stands for in your organisation, what would you say? Are you describing the productivity or your safety record? Or perhaps your working behaviour or the safety culture in your organisation? Every organisation has some common, internal, characteristics that we call its culture. Everyone has his/her own interpretation of safety culture; that is why it is extremely difficult to describe it or even to measure it. However organisational psychologists have found ways to tackle this. The methodology used in Oil & Gas industry, also called The Hearts and Minds Programme, is a very practical way and reasonably easy to understood. The Hearts and Minds Programme makes use of the following general approach and observation of safety culture: *"Who and what we are, what we find important and how we go about doing things round here"*. This description covers both the static and dynamic part of organisational behaviour. Static referring to beliefs and values within the organisation, and dynamic referring to the continuous learning, problem solving and the working practices in the organisation.

This recognises a number of steps on the ladder of cultural maturity (Figure 1); here labelled as Hudson's culture ladder.

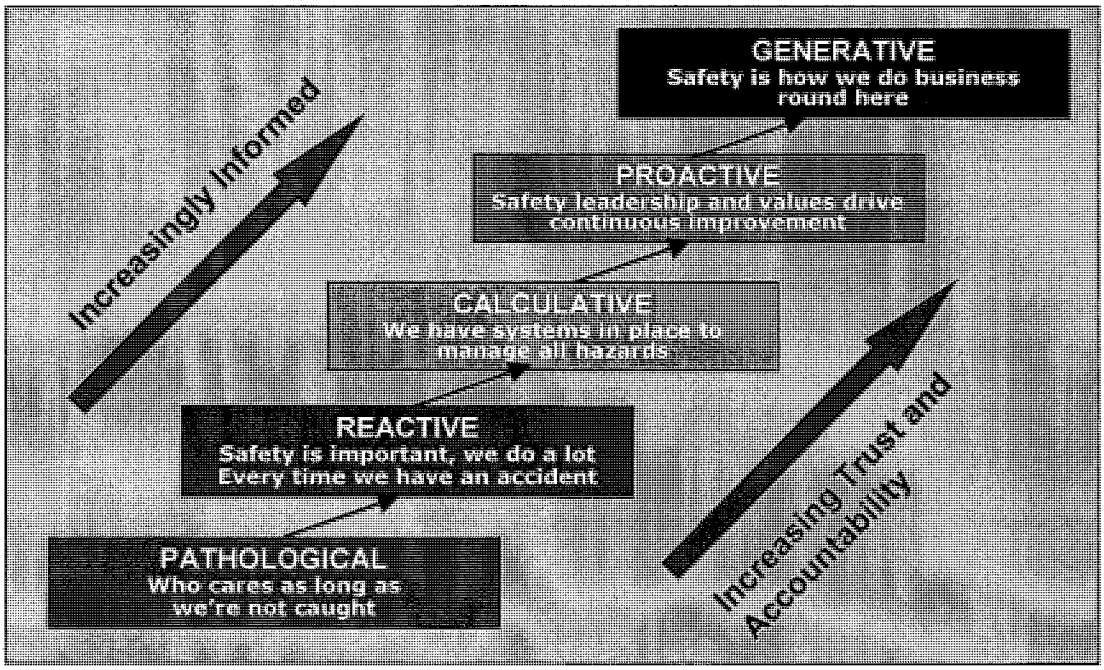

Figure 1. The evolution of Safety Cultures (ref. 13).

The best way to understand or to describe a safety culture is in terms of an evolutionary ladder model[8] (**Figure 1**). Each level has distinct characteristics and is a progression on the one before. Looking at it like this provides a route map, where every team, or company has a certain level of cultural maturity and can see which step of the ladder they are on, where they have been and what the next step looks like. The range of possible cultures runs from the Pathological, through the Reactive to the Calculative and then on to Proactive and the final stage, that we call the Generative.

- *Pathological*, is where people don't really care about Safety and are only driven by regulatory compliance and or not getting caught. We probably all recognise this from the past but is something we have hopefully move beyond. People say things like "it's a dangerous business". Sometimes it is a matter of "not knowing", but in some cases we may also observe an unwilling behaviour with respect to safety..
- *Reactive*, is where safety is taken seriously, but only gets sufficient attention after things have already gone wrong. People say things like "you have to understand it is different here" or "consider the conditions under which we work".. At the reactive level managers take safety seriously, but feel frustrated about how the workforce won't do what they are told: "We need to force compliance". The argument is made that safety systems are "in place', but there may be little use actually made of them in practice. When personnel is stressed or under pressure than they may drift away from good safety behaviour.
- *Calculative* is where an organization is comfortable with systems and numbers. The necessary systems have been implemented successfully and because quality and safety are taken *very* seriously, there is a major concentration upon the statistics. Numbers may even drive behaviours. Lots of data is collected and analysed, and we feel comfortable making process and system changes just to correct them. They may rely completely on quality assurance to deliver safety goals. The safety management system may be in place, and a lot happens, although there may be no clear impact on total performance.
- *Proactive* is where each organisation is aiming for. Here a safety management system starts to be effective. It is moving away from managing safety based on what has happened in the past to really looking forward. It is starting to consider what might go wrong in the future and take steps *before* being forced to. Proactive organisations are those where the workforce start to be involved in practice, as well as being mentioned in management statements of intent. Unlike the Calculative, where management still carries a lot of the responsibility, in Proactive organisations the Line begins to take over the safety function. "Are we doing the right things, rather than just being focused on incidents? "
- *Generative* organizations set very high standards and attempt to exceed them rather than being satisfied with minimum compliance. They are brutally honest about failure, but use it to improve, not to blame. They don't expect to get it right, they just expect to get better. They are doing the right things rather doing the things right. Management knows what is really going on, because the workforce is willing to tell them and trusts them not to over-react on hearing bad news. People live in a state of chronic unease, trying to be as informed as possible, because it prepares them for whatever will be thrown at them next. In this stage we are far beyond the compliance or regulatory based environment.

As an organisation climbs up the ladder the level of informedness and trust increases with people offering to accept accountabilities ("you can count on me") rather than just being told they will be held accountable for some outcome. Informedness is about managers knowing what is happening in their organisation and where all the problems are, and the workforce knowing exactly what managers expect – no mixed messages. Because managers and workers are aligned, this builds two-way trust. Because people know what is expected and are trusted to do it, there is less need for bureaucracy, audits and supervision, so workload decreases from after the *Calculative* stage.

Getting up the ladder in figure 1 can be reflected in the actual state of the systems as being *in place, in operation, effective* and *permanent.* It provides a valuable roadmap for the development of truly advanced safety cultures and development of effective safety management systems.

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[8] This model is based on one originally developed by Westrum. The original model distinguished Pathological, Bureaucratic and Generative cultures. The newer model expands the Bureaucratic level with a progression from Reactive, through Calculative to Proactive cultures.

Assessment framework

The Dutch CAA started in 2005 with a comprehensive development program. A dedicated project group (CAA's safety inspectors, HSE and safety experts) was commissioned to develop a methodology and an approach. This method must be tested before actual application.

It became clear that in order to fulfil our needs the project group prefer the use of an assessment method based on interviews rather than a survey based solely on questionnaire data.
The considerations were:

1. The method should be able to collect information with a sufficient level of detail.
2. Some flexibility, i.e. tailored to the size of the organisation, its product, and the individuals concerned.
3. The model should also be designed to create advanced awareness and lasting change.
4. Results or conclusions drawn during the assessment should be recognizable to the organisations.
5. Strive for maximum openness. It must be distinctive from the normal/traditional compliance audit; people should feel open to tell their own story.
6. Training the inspectors and auditors should be practicable and easy (3 days).

The assessment model
We selected to use a structure, originating from James Reason's ideas[9] (matrix of 3C and 4P) and the culture maturity model of Patrick Hudson[10]. Reason's 3C-4P model was modified by Stamina and University of Trinity (Dublin) into a model with 4P-4C[11] (Table 1), and integrated in Hudson's ladder and optimized for practical operation by CAA-NL. The C's represent the components or drivers for good and safe working behaviour including the Human Factors Integration. The four P's make a distinction in the organisational management structure. Since we strive for practical and flexible application of this model, combining elements is possible and even preferable depending how the interview moved on.

4 P (structure) → / *4 C (components)*	Principles or philosophies	Policies	Procedures	Practices
Culture				
Continuous Learning				
Competence				
Comprehensive HF Integration				
Target group for the interviews	*Accountable manager and Maintenance managers*		*Process owners Management*	*Maintenance engineers Practitioners Workplace personnel*

Table 1. Assessment structure (4P-4C).

The assessment framework is built upon the following aspects:

- The approach is more a "tell-me" approach rather than "show-me"
- Interviews arranged according a model named 4P-4C and a predetermined interview program. The attributes in Table 2 were used as guidance.
- No persons other than the interviewees are present during the interviews.
- One interview took 90 minutes, and in general a group of 2 or 3 persons were interviewed by two auditors/surveyors. They were assisted by one inspector taking notes.

[9] Refs. 5, 24.
[10] Refs. 12, 13 and 15
[11] This 4P-4C model was introduced at the first Human Factor auditing course held in Dublin in 2005.

- Conflicting information must be resolved; this could mean that the particular interviewees were asked again and confronted with extra information.
- The assessment should be completed in 2 working days. It could be expanded to a maximum of 4 days depending to the size of the organisation.
- Analysis and evaluation is done on the desk using the maturity safety culture model described above. All information gathered from the interviews and the evaluation were structured according to Table 1.
- Findings (i.a.w. Part 145) will not be reported[12] as we aimed for openness.
- Report and conclusions were discussed with the particular organisation.

	Attributes **Philosophies – Policies – Procedures – Practices.**
Culture	Vision & goals: firm, written principles & policies, outspoken, communicated. Visible Safety commitment & leadership: Walk the talk, words into action Shared perception about safety Participation in safety, Sharing of information Promotion and communication Hazard, Risk and safety awareness, vigilant. Culture of two-way trust such as approachable management
Continuous Learning	Reporting and just culture Learning culture Systems approach: learning from occurrences, audits, surveys. Systematic approach of analysis in risk assessment and management. Effective and comprehensive PDCA
Competence	Selection, training, appraisal, knowledge, commitment. Training needs analysis. Defining necessary knowledge and skills (hard and soft skills). Developing training Coaching, mentoring and leadership
Comprehensive HF Integration.	Planning and supervision Clear responsibilities and accountabilities HF awareness and knowledge. Provisions of adequate resources Human error management. Prevention 'Dirty dozen' occurrences. Tensions production and safety. Safety prioritised behaviour

Table 2. Attributes in 4P-4C structure (the P's are regrouped for simplicity).

It was our philosophy that we put the model into practice after testing various alternatives/approaches over 3 pilot assessments and as soon as the basic tools for the assessment were developed and the auditors were trained properly (theory and practice). After 2 assessments our safety inspectors were experienced with the assessment process. In total twelve well-trained surveyors participated in the whole program.

The best interviews were those in which the interviewees were at ease and were frank in their responses, openly providing their perceptions and information. This was the most important condition to get good and valuable results from the assessment.

Evaluation and scoring

The safety culture model (fig. 1) was used as basis for the evaluation of the information gathered during the interviews and also used for scoring purposes. This part of the assessment was the most delicate part, because we had to make a good translation from the information gathered to the well-known descriptions of the maturity levels (i.e. pathological through generative). For interpretation

[12] In the early beginning of the program a level-2 finding (based on Part-145) could be reported only if a distinct non-compliance was found. But later in this program the findings were reported as observations. This will improve openness during the interviews.

purposes we used several descriptions and formulations given by the Hearts and Minds programme[13] and other literature[14].
Roughly the scores[15] are characterised as follows:

- If the philosophies or policies for most of the attributes were absent to a large extent, then this indicates a *pathological* level. At this level a safety culture barely exists.
- If the appropriate systems were in place but not working properly or were only used or corrected after something happened, then the score is *reactive*.
- *Calculative* means systems working properly and systems were evaluated; data were confirming this. However, the follow-up actions were focussing on correcting the problems.
- If the systems were integrated effectively and everyone were working with them in practice and management were committed to doing the right things, then the score is *proactive*. There should be a serious focus and action on preventing problems and hazards.
- If we perceived that systems were continuously improved for effectiveness and that the personnel was always mindful, informed and respected for reporting concerns and hazards, then a *generative* score is given. All observed signs were beyond proactive behaviour.

The evaluation was carried out by the group that was conducting the interviews and in consultation with other knowledgeable inspectors. For each box in the 4P-4C matrix a score was given corresponding to the descriptions of one of the maturity levels.

Summary of the main results

The following considerations should be kept in mind:

1. The results represent a snapshot of the companies; they represent the position at the moment of the assessment.
2. The results should be considered as experimental.
3. Twelve organisations were assessed during a long period, 2006 – 2008. So, making comparison between the organisations should be done with some caution.

Of the twelve organisations were:
7 aircraft and rotorcraft maintenance organisations (line and base maintenance),
2 engine maintenance and overhaul organisations and
3 component maintenance and overhaul organisations.
These twelve organisations represent the whole spectrum of the largest Part-145 organisations in the Netherlands.

Comparison Culture and other C's
Based on the 12 evaluations we derived the following general conclusions (see **Figure 2**). The average scores for the four C's (square marks) are at least at the *calculative* level, which means that on average the systems are in place and being used to manage the 'hazards'. Some organisations obviously are less motivated in managing and realizing good performance in Continuous Learning and HF integration compared to Competence.

Competence received on average the highest score and we also found a smaller variation (vertical bars) in Competence than in the other C's. This could be explained by the fact that competence aspects have been worked on for many years and are very well covered by the Part-145 regulations. We may assume that the high competence level in organisations is one of the important drivers of the safety Culture. One remark however; technical training was traditionally a strong point in maintenance, but in the past years classroom training had often been replaced by electronic web-based training for various reasons. This was perceived by the workplace as a decline of the quality and effectiveness.

[13] Ref. 14
[14] Refs. 19, 20, 21, 23, 24, 25
[15] For mathematical purposes a 10-point scale is used to represent the culture levels. Each level is represented by a low or high. Example: a high *calculative* score is a 6. And a low *calculative* score is a 5. Etc.

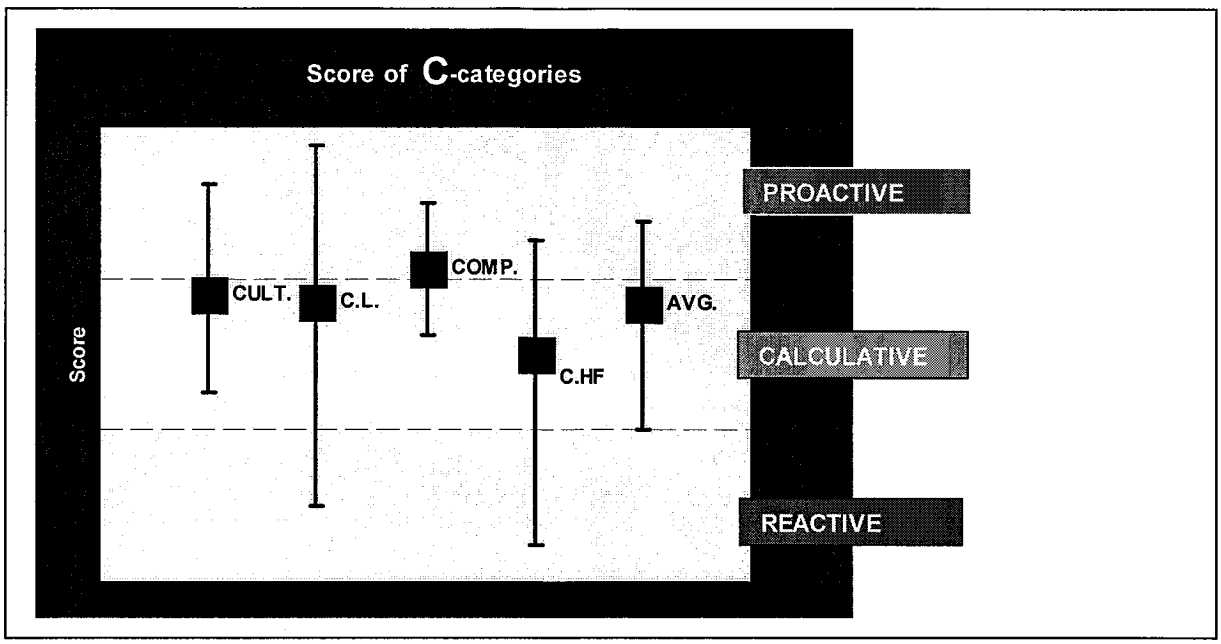

Figure 2. Comparison between the C-components: *Culture, Continuous Learning* (C.L.) , *Competence* and *Comprehensive HF integration* (C.HF). Total average (AVG) = average of all C's.
Based on assessments of twelve Part-145 organisations. The vertical bar represents the maximum variation within the 12 organisations.

One of the areas focussed on was the level of HF integration, because this subject has been specified in the Part-145 regulation. The results revealed, disappointingly, a low performance level with respect to HF integration, even in *reactive* levels. HF implementation in Part-145 organisations appeared to be difficult. In particular the development of policies and procedures with appropriate HF considerations was based on reactive behaviour, after the damage was done. There is a need for improvement in this respect.

Comparison between the four safety management components (P-components)

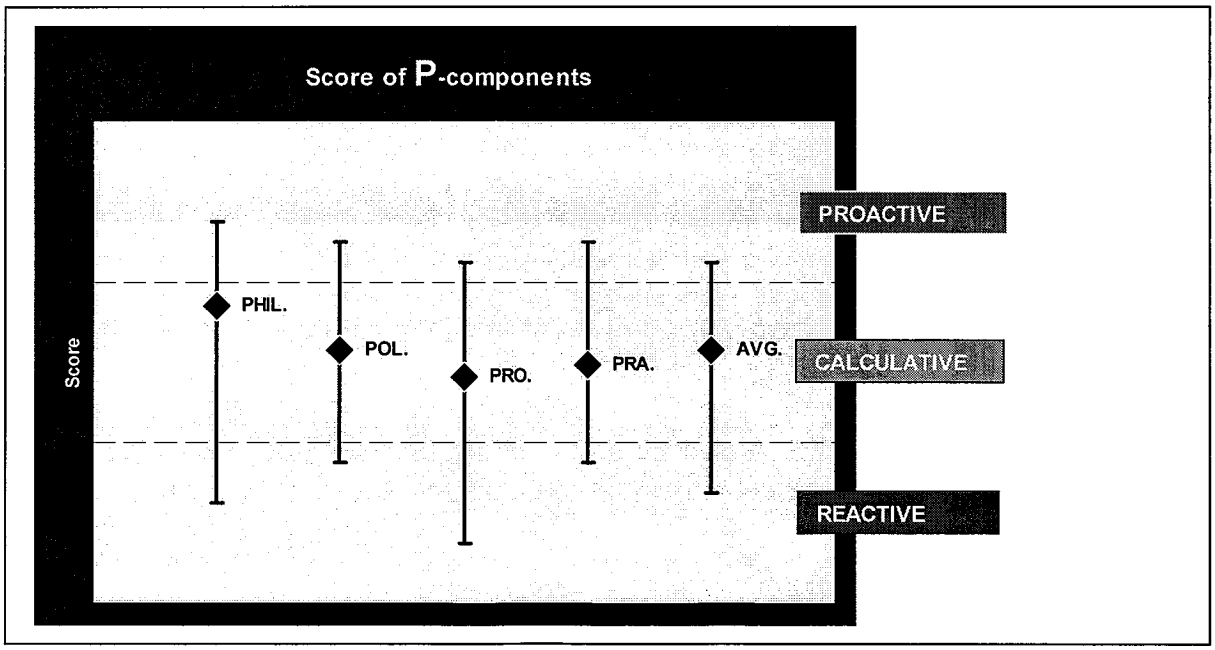

Figure 3. Comparison between the management levels (P's) – Philosophies, Policies, Procedures and Practices.

The first obvious result (Figure 3) is the high average score in p*hilosophy* (almost *proactive* on average level) compared to the other scores. The average scores decrease towards *policies* and *procedures*, but

the score in *practices* goes up. Few organisations showed some *reactive* characteristics, which were driven by the fact that economic or production pressure was perceived to be too dominant. In those cases "survival" was the leading argument. The average of all companies is at least *calculative*. A very remarkable consideration was that organisations in proactive levels also showed sound organisation health, both in terms of production and financial performance.

Generally, the alignment of organisations' philosophies to practices is rather weak, as indicated by the declining scores of *philosophy* to *practices*. Although the culture in general was characterized as open, this appeared not always the case in practice. Factors like lack of clear communication and problems with supervision are common. We observed a trend that time spent on administrative work is increasing, especially for group and team leaders and middle management, at the expense of time spent communicating, coaching or supervising. Employees claimed that workloads were increasing with respect to a few years ago. However they also claimed that it was not threatening their performance. Noteworthy was that *practice* scores higher than *procedures*, indicating that employees were relatively motivated and competent to do the right things, sometimes despite the lack of adequate procedures. The underlying factor may possibly be the high *competence* level as presented earlier.

Organisation scores

The 4P-4C scores of the each company tell us more with regard to the maturity of its safety culture, continuous learning, competence and HF integration. It makes clear their strengths and weaknesses, the underlying problems, but also opportunities for improvement.

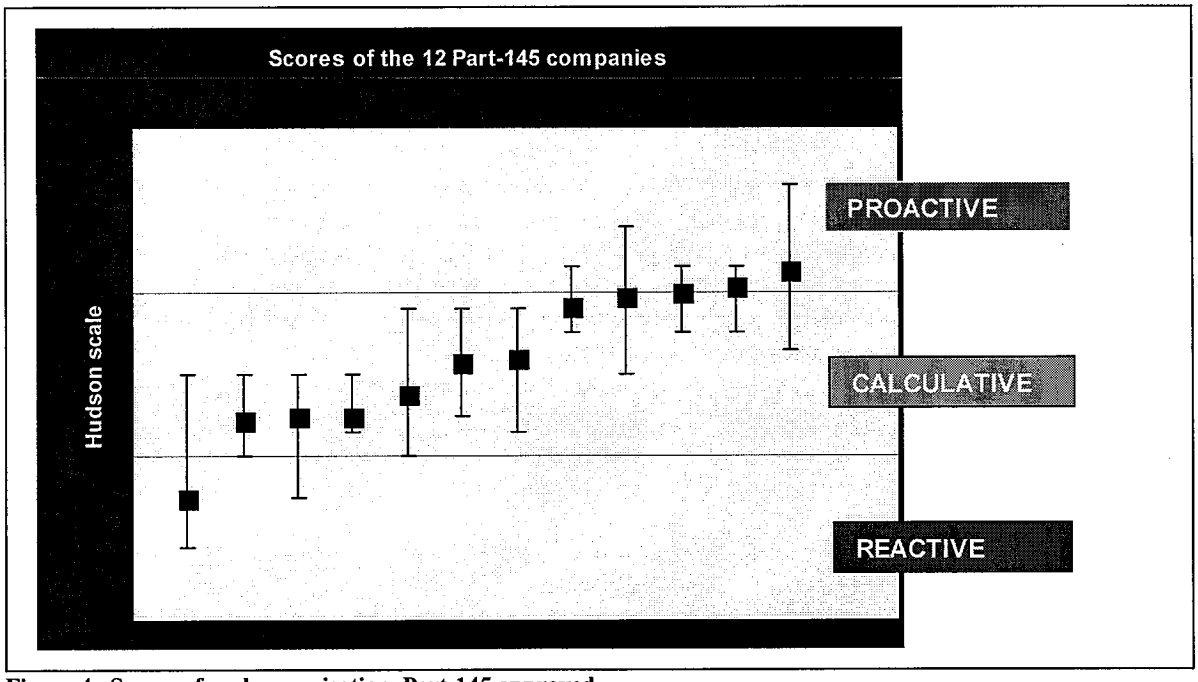

Figure 4. Scores of each organisation, Part-145 approved.

Summarized: looking at the average levels (= square marks) 50% (six) of the organisations investigated received the score *calculative*, 30% (four) are in or beyond the *calculative-proactive* transitional stage, while one organisation is in the transition from *reactive* to *calculative*.

Responses

One of the challenges was to raise an organisation's awareness and to encourage their responsiveness to the outcome of the assessment. It would be advantageous if they took the initiative, rather than because they were told to. The intention was that they had to arrange their own progression up the ladder. From the start we made clear to the organisations that we did not question the justification of their Part-145 approval. Making conclusions on the level of compliance based on the assessment results was not the objective of this assessment program.

In general the companies reacted positively to the assessments and they generally recognized and accepted the overall conclusions and the indicated level in Hudson's maturity ladder as well. Organisations arranged their actions or follow-up in various ways, depending on their actual state. One organisation even commissioned a consultancy company to conduct their own culture assessment. Its outcome appeared equal to ours, which raised our confidence in the approach reported here. Most importantly, they took serious considerations in advancing or even changing the culture. Although we did not require any specific action, we were aware of organisations taking appropriate actions. It was obvious that organisations had to select activities and had to prioritise. Some examples were:

- Initiating a safety (culture) program and committing themselves to the program.
- Restructuring and improving the reporting system. Even the number of reports sent to CAA-NL (compliance to mandatory regulation) went up!
- Making progress with implementation of SMS taking into account the results and conclusions of the assessment.
- Conducting specific studies focussing on workload and work motivation.
- Specific training in safety management skills and classroom training methods introduced.

However, we are still aware that any organisation could fall back to a lower level, despite the improvement or the opportunities they had.

Conclusions and lessons learned.

Twelve organisations were comprehensively assessed by CAA-NL with regard to their safety culture maturity and the integration of Human Factors. The Hudson model with the 4P-4C assessment structure proved to be effective and provided very valuable guidance for the organisations to advance their safety culture. The culture within the twelve organisations varied from *reactive* to *proactive* level, with the majority in the *calculative* and *proactive* level.

One of the important lessons learned was the fact that the regulator should recognize that he is a participant in the safety system, as the functioning of every management system interacts with the regulator's responsiveness. If we don't inflict a sense of consciousness on the players – because every management system sometimes needs that – we will accomplish little progress. We feel that it would be best if this is what they want, instead that they are told to. And we perceive that organisations tend to be more self-conscious after the assessments, realizing that safety management looks further to areas over which they have control but which they have not so far considered as being particularly important to manage.

The exploration in conducting safety culture assessments and experimenting in performance-based approach was seen as meaningful by both CAA-NL and the organisations studied. On the whole, it is questionable whether these results would be obtained using a traditional compliance-based audit. Two important limitations or serious comments should be mentioned here. First, the lengthy process, especially the evaluation of the interviews. We are currently working to solve this. The second concern was that any information could become public. We took precautionary measures to put into action when this situation may occur.

The assessment program outlined in this paper is a step that we can recommend to all aviation authorities. It could be still very beneficial for organisations if they were to conduct self evaluation in safety culture and HF integration. We are very much aware that this can lead to confusion of roles and responsibilities. Therefore, one should keep in mind that safety management of the organisation is the full and final responsibility of the organisation. However, this should not prevent the regulators from playing a more proactive role in promoting good safety behaviour and stimulating proactive safety management. We are convinced this proactive approach can create a positive spin-off in the long run. While we are in the process of implementing SMS in Europe, complying with ICAO Annexes, regulators should consider this approach as a starting point towards proactive and performance-based regulatory oversight.

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