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**SPECIAL EDITION:
Best Global Practices in Internal OD**



Published by
the Organization Development Institute



**WINTER 2007
VOLUME 25: NUMBER 4**

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Submissions to the journal are encouraged on an ongoing basis. Manuscript submission information can be found in this issue. Authors who are not already receiving the OD Journal, will receive one complimentary copy of the journal in which their article appears. Articles should be submitted to Wei Huang, PhD, Managing Editor (Regular Edition), at wei Huang@nyu.edu.

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People and Error: “Human Factors” Principles in Safety Critical Industries

John Anfield, Rolls-Royce

Abstract

This paper explores the subject of Human Factors (HF) and argues that proven, error reduction methods used in “safety critical” industries including Aerospace, Nuclear and Medicine can migrate into mainstream business and offer considerable business performance gains. The methods used fit well with the values and ethics of the O.D. profession, and suggests how business leaders, O.D. practitioners and academics, can gain more knowledge about this important subject.

About the Author:

John Anfield is Head of Organisation Development and Learning for a large Rolls-Royce business unit who joined the company after an early career in the Royal Air Force, an organization which gave high priority to flight safety. At Rolls-Royce, John spearheaded a three-year Human Factors campaign that commensurately enhanced the safety culture in aero-engine maintenance facilities and met new regulations set by the European Aviation Safety Agency. John has an MBA, and is a Fellow of the Chartered Institute of Personnel and Development (UK), as well as a Senior Professional in Human Resources (USA).

Introduction to Human Factors:

In safety critical industries, where simple human mistakes can cost hundreds of lives and billions of dollars, considerable organisational effort is put into multi-layered, preventive measures aimed at reducing or eliminating all known risks. Despite all these safeguards, tragic errors still occur. For example, the July 1988 Piper Alpha Oil Rig disaster in the UK’s North Sea cost

165 lives and had direct costs of over £2billion. The cause was traced to a single, missing pressure safety valve.

Often the hardest lessons learned are those that are gained from painful hindsight. In industries that carry an inherent risk, such as aerospace, rail, nuclear and medicine; post accident investigation typically reveals a large human error component. When the human element, typically 75%-100% of the contributing cause is investigated in greater detail, often the final failure is discovered to be the result of a chain of smaller errors which have combined in an unexpected or untimely way. In nearly every case, there are clear, early warning signs in the system that leaders ignore.

Another tragic example of Human Factors at play was the Helios Airline accident in Greece. A design feature of a cabin air pressurisation valve allowed that part to remain incorrectly positioned during flight. When the positioning error combined with a maintenance error (someone left the valve in its ground position), the result was cabin oxygen starvation. As the aircraft climbed past 10,000 feet on autopilot, the aircrew became confused and argued about the meaning of various cockpit-warning bells. The incapacitated crew lost control of the still fully flyable aircraft, which ran out of fuel, crashed, and killed all 121 passengers and crew.

Given these high stakes, it is imperative that preventive measures focus on understanding why well-intentioned and correctly trained professionals make serious mistakes, which can sometimes circumvent the considerable defences of a safety system. This question transitions into a broad field labelled Human Factors (or HF for short). Today, HF research includes aspects of design (latent errors); ergonomics (human-

machine interfaces); cognitive research (stimulus, memory, information retrieval and processing); bio-medical research (drugs, alcohol and the circadian effects of shift working) and systems engineering (processes and process compliance in socio-technical systems in particular).

Much of this HF territory will be familiar to an experienced Organization Development consultant. There are also many overlaps between HF and Total Quality Management (TQM) systems; although, in the opinion of this author, TQM has become much more remote from people in the past decade (i.e. more IT based and highly procedural). Furthermore, an HF approach offers a better and much more effective method than conventional, compliance-based, audits, which I believe have become an ineffective error prevention tool.

The HF Approach:

What is special and unique to the HF approach is the considerable investment and effort made to seek out information about errors and hazards from the people who work inside the system, and to design a process for them to share their learning with others before any unwanted events happen.

The HF approach can be described as a method of accelerating the acquisition and application of operational lessons learned across an organisation to avoid their reoccurrence. The following five key conceptual features of any HF-based approach to error reduction are generated from this author's own research and experience:

1. HF accepts that error is normal and will occur in all human systems.
2. HF uses a high level of employee engagement to discover all unreported events and potential hazards, i.e. reading the weak, warning signals early.
3. HF methods demand a fast and effective feed back and communication loop.
4. HF acknowledges that an individual's awareness of error potential is the single best defence against their occurrence.
5. HF requires that leaders behave ethically, build trust, and accept their personal and often legal duty to address all reported hazards.

Formal Definitions of Human Factors:

While each high-risk industry may have its own definition of Human Factors, within the field of aviation there has been a convergence on one specific definition, which was originally issued by the International Civil Aviation Organisation in 1986. It reads as follows:

Human Factors is about people in their living and working situations; about their relationship with machines, with procedures and with the environment about them; and also their relationships with other people.

Given this definition of HF, there is little doubt of the overlap with the O.D. practitioner domain; yet, to this author, it seems that these two related worlds rarely converge. Beyond the human error that is known to exist in safety critical industries, imagine the number of human errors that must occur in banks, insurance companies, manufacturing, catering, retail, social, and in not-for-profit organisations. If a conservative estimate of 10-15% of an organisations' output may be lost through unrecognised human errors, it stands that any CEO, CFO, or OD professional could project the effect of 'error reduction' on the bottom line of their own organisation.

Supporting HF Cognitive Research:

Having defined HF, and before considering whether HF principles can be transferred to the wider business community, two important questions are in order: First, 'why does human error occur?' and second, 'what can we do to prevent errors in organisations?' Former Manchester University Professor James Reason spent many years researching the causes of error and methods for their possible prevention. In his book, Human Error Reason provides a good first step in understanding HF principles and setting them into a useful psychological framework.

Typical HF Error Reduction Methods:

From Professor Reason's work, my own and others' experiences implementing HF error reduction methods across safety-critical organisation, the following factors are usually found in effective systems:

- Customer and product safety are declared as strategic goals.

- Probabilistic risk assessments are used to focus efforts on key hazards
- Risk management and risk mitigation risks techniques are applied
- Elimination of the opportunity for error, often by foolproof design.
- Application of decision support systems and/or clear safety policies.
- Use of checklists, models and other visible memory aids.
- Leaders model a culture of trust, reporting, and openness.
- Multi-format, communication channels are used for error reporting and feedback.
- Prompt action is taken by leaders to address all reported hazards and errors.
- O.D. and Learning interventions are used at different organisational levels:
 - Education for all on the underpinning HF theory, principles and concepts.
 - Training for competence in the actual tasks being performed.
 - Training in hazard awareness and risks of specific errors.
 - Simulation of scenarios that could be faced in high-risk industries.
 - Behavioural training including surveys of group cultural norms.
 - Leadership training to reinforce personal responsibility for safety.
 - Executive education on safety ethics and decision making models

Reason and Hobbs (2003) well-written and readable book for managers in safety critical industries expands on all the above techniques and methods.

Assessing HF-Based Interventions:

United States civil aviation statistics reveal that the number of hours flown on scheduled carriers between 2004 and 2005 was close to 19 million hours during which there were 32 total loss accidents resulting in 22 deaths. While not a direct correlation for road fatalities in the United States, the 2002 road death statistic was 42,815. These data reveal an enormous discrepancy between the error rates of two mass transportation systems. Indeed, pilot training standards are much higher than driver training standards, and the aviation industry is highly regulated. That notwithstanding, these two numbers are so disparate that they beg to suggest some very different and fundamental system behaviours.

Rolls-Royce and HF:

Within Rolls-Royce, our Aftermarket business overhauls civil and military aircraft gas turbine units. Our 7,000 employees work in 17 facilities on four of the five continents and operate under the jurisdiction of the European Aviation Safety Agency (EASA) with an EASA Part 145 licence. Rolls-Royce has an excellent safety record and a world-class reputation for delivering excellent products and service. Why, one might ask, did we need a Human Factors campaign?

The Human Factors campaign was driven by several factors. First, in 2003, the newly formed EASA organisation gave notice that all Part 145 certified maintenance facilities must train all their employees in Human Factors and as well as to implement a Maintenance Error Management System (MEMS) to allow employees to report potential hazards or to highlight errors or omissions. The primary business driver, then, was a change in industry legal and regulatory requirements.

Behind these new requirements was a secondary driver, focused on the remaining cause of civil aviation accidents: maintenance error. While statistics had shown that over the past two decades the number of civil aviation accidents declined as a result of improvements in aircrew training, navigation systems, better Air Traffic Control and better weather forecasting, the most persistent cause of civil aviation accidents was maintenance error. This was the reasoning behind the EASA two-pronged approach.

However, as Rolls-Royce addressed EASA's mandatory HF and MEMS requirements we discovered through focus groups and management workshops that there were many costly unreported errors in our businesses affecting both quality and productivity. While we did not have any product safety concerns, we had accidentally discovered a large 'Error Iceberg' in our own organisation.

The 'Iceberg' analogy for HF refers to the fact that 10% of an iceberg is visible above the waterline, while more than 90% is underwater. The concept is that mistakes are latent, hidden, re-worked or sometimes passed on unreported through to the customer. A similarly high ratio (10%-90%) between known errors and unreported errors and hazards were seen in both the NASA Challenger and Columbia Accident Reports. In the Columbia report in particular, the Accident Board referred to 'unknown unknowns'.

It is reasonable to assume, then, that most non-safety critical industries will have their 'Error Icebergs' too, and that these 'ugly lumps of inefficiency and business risk' in organisations may be surprisingly large. Similarly, it is likely that someone inside will always know about them!

Finally, to underscore this point, it is worthwhile to explore who in an organisation knows what about the real the error rates. One assessment by the Australian Defence Force's Aviation Maintenance Improvement Project reveals the existence of an Ignorance Iceberg - The farther one moves from the hangar floor, the less knowledge of the organisation's errors are known at approximately these percentages:

- o 4% of senior managers are aware of errors (above the waterline)
- o 6% of managers are aware of errors (above the waterline)
- o 75% of first line supervisors are aware of errors (below the waterline)
- o 100% of employees are aware of errors (below the waterline)

This is a sobering finding, considering that it is senior managers who make all the key decisions about customer issues, quality, people, resources and processes. The percentages above suggest that significant decisions are made based on little knowledge of the realities of the errors in the complex systems that leaders run!

The Rolls-Royce Journey into the Error Iceberg:

Rolls-Royce was challenged to meet the two critical EASA requirements within two-years. First we needed to implement comprehensive HF training for all 2,500 people in the UK. Second, we needed to implement a Maintenance Error Management System, which Rolls-Royce calls MEMS that would rely on trust and openness. This is how we achieved these objectives:

The Burke-Litwin (1992)⁸ models gave us insight into how an organisation works and can change culture. The model proved very useful in planning our approach. Burke-Litwin makes a distinction between three transformational areas of strategy, leadership and culture, and of the other parts of an organisation that are more transactional in nature.

To effect a large-scale organisational and cultural change such as the introduction of HF and MEMS into our own businesses, we knew that we had to first ad-

dress these transformational areas, in particular the areas of leadership and culture. Addressing Strategy was less critical because our aftermarket strategy was reasonably stable and successful.

Tackling leadership first, we executed several interventions at various levels of our structure. At an Executive Seminar held in 2004, we gained full commitment from our senior leaders to support the HF programme and introduce the MEMS system. After this event we distributed a personalised letter of commitment from our managing director to all employees to announce the launch of the main HF programme. We also issued several general communication articles.

Over the following six months we implemented an introductory programme for all 190 managers and gave them an overview of HF, beginning with the EASA mandate, the potential operational impact of running a large-scale training programme for their 2,500 employees, and the potential value to Rolls-Royce. This programme was effective in meeting its goals by enabling us to review the past to better prepare for the future. Within the confidential format of this event, we were able to see how past errors had resulted in considerable cost, and in many cases, became aware that repeated human errors could have easily been avoided through feedback.

Errors identified in this leadership programme formed the basis of a clear ROI (return on investment) business case for the external delivery of an employee HF programme which we showed would be repaid two-fold within three years, by teaching employees how to reduce error. This business case was fully accepted by Finance.

Another important group of people we involved were our trade union leaders, first in face-to-face briefings, and later with their participation in Managers' HF programmes. Trade union support for our HF campaign has been 100% from the start and several trade union officials are now full members of the HF Steering and Policy Group that was formed early in 2004.

The HF Steering Group includes Heads of Operations, the Heads of Quality, our HF Training Vendor and several of our O.D. team who have been involved in the design and delivery of the interventions. The Chair of the HF Steering Group has revolved among our Director of Quality, our Director of Engineering, and me. Our Managing Director attends for part of the Steering Group meetings, and he has also included HF and MEMS status reports as two standing agenda items on his regular Quality Board meetings.

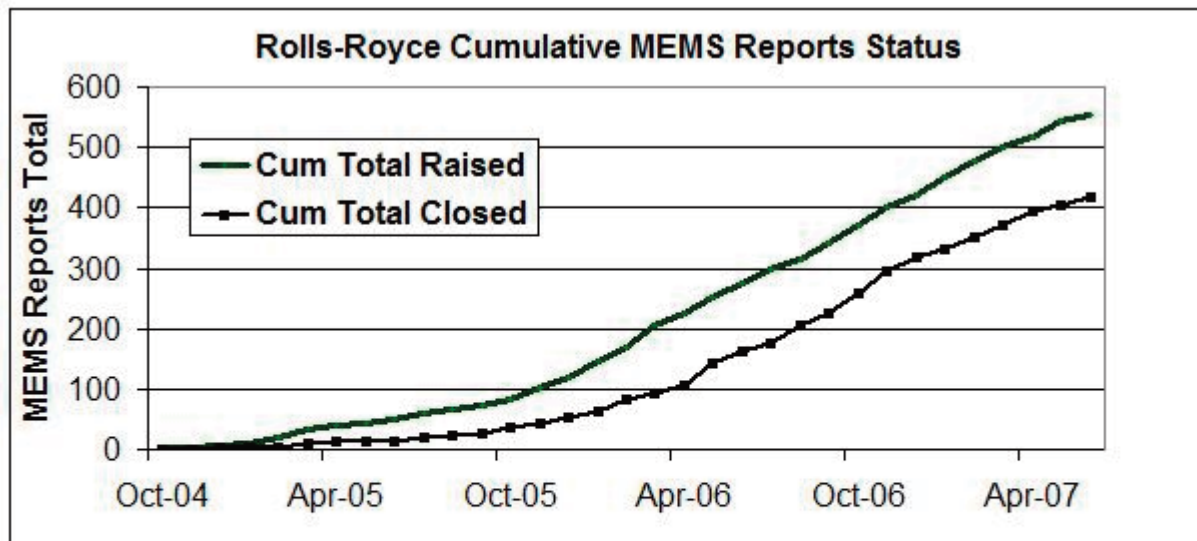


Figure 1. Number of Employee Raised MEMS (Maintenance Error Management System) Reports between 2004-2007

Full credit must be given to our vendors, Baines-Simmons Ltd, a specialised aviation safety and training consultancy based in Woking in the UK. Directors Bob Simmons and Kevin Baines have extensive knowledge of HF, and have been critical to our campaign from the start by providing invaluable advice and guidance on our long and ongoing journey. The Baines-Simmons team have now run over 150 events at four UK sites.

To this point we had formed a coalition of key stakeholders, all passionate about enhancing safety, and who were certain that we could use the HF campaign to improve quality and reduce the costs of errors. The creation of such an internal-external coalition with a common goal is often the key milestone for moving on to the next phase of a culture change, which in our case meant training all employees to help build enough trust for them to start using the MEMS system, which by this time had “gone live” on our Company’s Intranet site.

The “acid test” for any adult learner’s training programme is its relevance to the work and/or life roles of each participant. Anticipating this need, we worked with Baines-Simmons to create a series of customised programmes designed to have very high-relevance to the particular facilities and product lines that we manage. In fact, our four programmes were identical in their core content but used specific, relevant product examples and images from the local site to engage those learners.

Building Trust at Rolls-Royce to Make HF Work:

There can be many inhibiting factors in business organisations to obstruct the development of trust, or reduce the open sharing of errors and the lessons to be learned. They can include fear of punishment, strong peer pressure, financial consequences, concern about adverse impact on the performance management processes, career limitations, and group social norms, all of which regulate the boundaries of what information is normally shared between employees and managers. This was an area where we spent a great deal of effort to get things right.

In asking our employees to report incidents and hazards that would normally be secretly reworked or kept under cover, we focused on the benefits of reporting and avoiding of errors. The programme had three main goals, the first two related to HF knowledge and personal error avoidance, the third and most important goal was to build trust and encourage open reporting.

For us it was a slow start. After six months of training we had only a handful of employees who had generated MEMS inputs. However, when a critical mass of 40% of employees had been trained, and people saw that raising MEMS reports did result in some positive actions, the rate of submission rapidly increased, and today all businesses are now participating at similar rates. To date we have now had 580 employee generated MEMS reports and about another 400 issues arise from the training programme summaries. See figure 1.



From discussions with other organisations, this slow start and rapid ramp-up of employee input is typical of all HF programmes, and HF should not be viewed as a quick fix. At minimum, expect two years of consistent HF communication, training, and MEMS activity to embed this approach into the culture of any business or organisation.

At the end of the employee HF training programme we used a poster campaign to advertise the successful completion and to keep the message out there in the work-areas, see examples:

The True Leadership Challenge:

We have addressed the HF leadership component on many levels, and now that the original employee HF programme has ended, we have reached a critical phase. The impact of leadership and training efforts are at their peak, and employee expectations are high that leaders will address issues that have been identified. From here, there are two potential scenarios: Any failure of the leadership to respond to hazard reports will rapidly erode trust and risk a decline to a position lower than where we began. Clearly we must avoid this risk.

Our intended model is one where leaders will take the initiative and positively address all reported hazards and problems, and it is this management passion and drive that will take our HF campaign to the next level. After three years of effort, we are in the middle of this

critical consolidation phase and have already closed out about 70% of our MEMS reports. Some are very complex and will be more difficult to resolve.

Our future plans include three important components:

- a new, biannual HF Continuity Training Programme employee refresher
- a major communication campaign focused on error-feedback
- a new Leader HF workshop that will include an HF update, a MEMS clinic and a structured decision making model based upon a recently developed safety ethics model by Patankar, Brown and Treadwell (2005).

Evaluation of Benefits:

Evaluating and measuring the Return on Investment (RoI) of HF programmes will always involve some judgements made by business leaders even where a wide range of quality and operating metrics are available:

At Rolls-Royce, we measured the investment in our HF programme. To date, 2,500 UK employees have spent 6,000 days in off-job training time and about £0.5m in external costs directly attributable to the HF programme. What have received for this investment?

Our recent evaluation shows heightened employee positive attitude towards safety up to 24 months after training (88%) and a reasonable degree of belief that we are serious about HF.

- Over 580 MEMS reports have been submitted by employees in the first two years, giving us rich data from the base of the 'error iceberg', this proves that our efforts to build up trust are now paying off (77% of employees state that they openly report errors).
- Over 70% of these MEMS have been closed out with remedial actions, about 20% of the MEMS reports are complex and we now use a formal process to investigate them.
- Increased positive feedback on HF matters and a common 'HF and error' language are evident in the workplace at all levels, for example in planning meetings.
- We cannot measure the costs of accidents and incidents that have not occurred, however, in the evaluations we have done we have identified many incidents which if they had not been reported would have caused us major operational problems.
- The experience of other organisations, such as air lines, is that it usually takes about two-three years to get an effective HF campaign and MEMS fully working and that the reductions in the costs of non-quality will really begin to flow through in years three-five, we are at that stage now and we are seeing definite downwards trends.

Nevertheless, at this time we do not claim any major Return on Investment victories; however, we do maintain our belief that we are safer now with HF embedded, than without it; and the next two years will determine how this translates to the bottom line.

The Transferability Question:

Many large organisations cycle through huge investments in 'Customer Care, Total Quality, Business Process Improvement and Six-Sigma Programmes, and inevitably, senior leaders are often disappointed with the results of these campaigns when each is considered in the context of promised benefits. Somehow, that last 10-15% of improvement is rarely realised; regardless of what is adjusted in the formal systems.

This author contends that some of these well-intentioned improvement programmes are missing the essential point: "Unless you build a culture in which employees will tell the leaders what is, or might be going wrong and hold leaders accountable for addressing these issues", then your organisation is prob-

ably destined to relive many costly improvement interventions in the vain attempt to remove human error.

Encouraging new work on the integration of operational excellence and safety improvements and the seemingly natural convergence of these two approaches has been revealed by Ward (2006) who, during her assignment with the UK's Lean Aerospace Initiative, made a very good case for significantly increasing the dialogue between the HF, Quality and Process Improvement communities. This is the true road ahead where OD can best help.

Motivational factors:

In a safety critical industry there are many intrinsic motivators to avoid life-threatening accidents and much of initial training is focused on multi-layered safeguards and rules. Therefore, an interesting question to ask is 'What might be equivalent motivating factors in a non-safety critical' organisation? Possible answers might include:

- Providing better levels of customer service
- Reducing the cost of non-quality and rework
- Reducing stress and pressure caused by errors
- Making the organisation more profitable
- Increasing job satisfaction
- Increasing employee employment security

Some of the answers are similar to, but not as powerful as the factors present in aviation, nuclear or medical organisations. In my opinion there are two options to enhance such motivation. The first would be to incentivise error reporting financially; the second would be to reward error reporting by non-monetary means, such as employee recognition events and publicity about individuals who demonstrate a high standard of professionalism.

Two activities that have been used in organisations which may provide an avenue for the type of error dialogue that we are seeking are; Quality Circles and Suggestion Schemes, which are often categorised under the banners of 'Participative Management' or Japanese style management. I will not describe these, as I am sure most readers will have a general appreciation of their use. What is interesting though is the way most western organisation have tried these methods, often as a fad, then dismissed them and moved on to something else like Processes Improvement or Six Sigma. There must be a way to re-energise these two methodologies to achieve a similar response to an HF

campaign and release the unknown error data from the base of the iceberg to the leaders in an organisation.

In Summary:

In safety critical industries the Human Factors based approach, which combines human error awareness with a reporting and learning culture has been shown as a most effective way to engage employees and elicit detailed information on secret errors that the organisation can then use in preventive campaigns based on education and feedback communication systems to improve safety and quality. An 'ethical and just culture' is a key prerequisite for trust.

There is considerable evidence that formal systems, e.g. TQM methods of controlling quality and processes in organisations are not fully effective and that they are too reactive to events; senior leaders are often bemused as to why this is, and exactly what to do about the situation.

A Human Factors based approach may offer a better alternative, but is neither a panacea nor a (palliative) short-term measure. Considerable effort over a long period of time will have to be invested to bring around cultural changes, educate the leaders and allow the building up of trust. The key is to demonstrate that leaders do care about, and will take action to resolve those items at the base of the Error Iceberg that are perennial and invisible.

Next Steps:

Actions that can be recommended to others as a result of my experiences with an HF based, error-reduction campaign within Rolls-Royce include:

- Educate academics in business schools and universities to HF principles and error reduction methods, and encourage their inclusion within existing curricula, especially in Business schools, e.g. in MBA or MSc programmes.
- Educate consultants and OD professionals in HF and during OD assignments they should aim to build mutual trust and dialogue around error management, supported by an appropriate internal reporting and feedback system.
- Educate employees in basic HF training during their induction into any organisation and teach them how to report errors and participate in feedback activities.
- Educate Quality and business improvement

professionals about how to review their approach and consider if they can adapt HF principles to the benefit of their line-customers, remembering that audits only reveal what is above the waterline of the error ice-berg.

- Conduct further research to fully explore the potential of HF based, error-reduction methods in non-safety critical businesses and run a pilot programme within a very large commercial organisation.

Epilogue: As I write this final paragraph, I hear a broadcast news report of a train derailment which seems to be due to a maintenance error on a set of points, with missing bolts alongside the track and a safety inspection that was overlooked.....

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Author's Reflection

Rolls-Royce plc is a provider of power systems for use on land, at sea and in the air. The company operates in four global markets – civil aerospace, defence aerospace, marine and energy. Gas turbine products are at the core of the Company's activities and the provision of repair and aftermarket services provides a long-term revenue stream, managed under 'Total Care' contracts. Aftermarket Services now generate over 54% of the company's total profits.

John Anfield is Head of Organisation Development and Learning for the Aero Repair and Overhaul Business, which provides aftermarket services through a network of seventeen facilities, based on four continents. The business employs over 6,000 people, including many in Joint Ventures established with major Airlines. From within the unit's central HR function, John leads an OD team, which focuses on strategic issues related to organisations, people and teams. The large-scale, Human Factors intervention described here was a very challenging OD project that took place over a four-year period from 2003-2007 and which is still in progress today. The critical challenges included: convincing an executive team of the opportunity to take a regulatory driven requirement and turn it into an opportunity for building employee trust and creating an open reporting culture, so that preventative steps could be taken to avoid costly maintenance errors.

The challenge was overcome through a number of direct interventions involving a strong HF communication programme and training of the entire workforce, coupled with the building of an HF infrastructure to support the reporting of errors and their investigation. To undertake this project the author personally led the campaign and has used his role as an internal consultant to gain significant momentum, which eventually resulted in the engagement of an external vendor to deliver the majority of the face-to-face training for managers and employees.

Rolls-Royce's HF campaign has been highly effective and a recent evaluation shows that 88% of the employees report an enhanced safety awareness regarding potential human errors and over 77% stated that they will open report hazards and errors to their leaders; as

evidenced by the 580 reports received in the past two years. Over 60 % of the reports have now been closed by management, and the nature of the reports has recently changed, with tougher issues being highlighted by employees. For the more complex problems, we use formal investigative methods.

The HF Campaign continues today with five new programmes being delivered in 2007-2008, the most significant one is the HF Seminar for Leaders. These events will use real data from the operational engine fleets and the local business error reports from their own employees to drive a local dialogue around the business pressures, ethical issues and decision making models that managers must employ to operate safely while meeting some very tough commercial targets.

Finally, at the two-year point our executives are now reporting a clear downward trend in errors and re-work costs; and, in addition, we now fully meet the European Aviation Safety Agency's (EASA) regulatory requirements for Human Factors Training and Maintenance Error Reporting.

Author's Bio

John is the Head of Organisation Development and Learning for Rolls-Royce's Aftermarket Services business, which has 4,700 employees, who overhaul civil and military jet engines. Overhaul facilities are located at 17 sites in the UK, USA, Canada, Brasil, Hong-Kong and Singapore, several are Joint Ventures with major Airlines. From 1998-2003 John was the Director of Career Development for Rolls-Royce North America Inc; and before that he was based in Derby as the Aerospace Group's Management Development and Resourcing Manager. John joined Rolls-Royce in 1992 and was the Engineering Group's Training Manager during a period of major organisational change and growth of the product range.

Before joining Rolls-Royce John enjoyed a successful career as an officer in the Royal Air Force Education Branch, where he worked in operational squadrons, management colleges, maintenance bases and helicopter flying training units.

John is a Fellow of the Chartered Institute of Personnel & Development, and a member of the American Society for Human Resource Management, and he is also certified in the USA as a Senior Professional in Human Resources (SPHR).

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