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Getting It Right: Human Factors helping the maintainer or ticking the box?

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A perspective on the application of the EASA Part 145 regulations for Maintenance Human Factors

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Introduction

A century of powered flight has seen incredible advances in aviation safety, mainly due to improvements in design and materials. However, Federal Aviation Administration (FAA), Civil Aviation Authority (CAA), Transport Canada (TC) and the Joint Aviation Authorities (JAA) research back in the late-nineties revealed that between 70 and 80% of all aircraft accidents were due to Human Factors. In a significant part of these, maintenance error was one of the main causes or at the very least a contributing factor. Recently at another Royal Aeronautical Society conference concerning Risk Management, Professor James Reason summed it up as only he can: *"Aviation unwanted events typically continue to be affected by the degree of human touching".*

Recent history has proven this contention; the Cypriot Helios Airways Boeing 737 that crashed in August 2005 underwent maintenance the night before. The chain of events apparently beginning when the maintainers left the pressurization controller in the manual mode. And in the same year the ATR 72 crashed after indicating more fuel on board than actual due to an incorrect (ATR 42) fuel gauge which had been fitted, despite a legend on the gauge, and the Illustrated Parts Catalogue stating otherwise. However, the more interesting contention is that when we apply the Heinrich Ratio to describe the relationship between fatal accidents, reported incidents, and unreported events the accident statistics pale in significance.

There have been some truly 'classic' near miss events in recent years. These in fact continue to mirror the events that led the CAA to recognise the need for some form of intervention in the first instance. They were as we all know the BAC 1-11 windscreen blow-out, the A320 spoilers left in the maintenance mode, and the B737 double engine oil loss. All following maintenance.

Up to 30th of June 2006 we have had 14 Fatal Airliner accidents (compared with 16 same period last year). We have achieved less than one accident per million departures (.76 actually) worldwide. The worst year was 1983 (@ 2.41 hull loss per million). The best year was 1984 (@ 0.67). It is therefore argued that Hull Loss accidents as a motivator to employ Human Factors programmes in Maintenance, is not the answer…the motivators are those on-going *near-miss* events that continue to reveal hitherto latent risk and cost.

Two recent large aircraft examples in the UK are the Boeing 757 (G-CPER) in September 2003. On the first scheduled passenger flight immediately following a 26-day major maintenance check, a hot oil smell resulted in the flight crew donning oxygen masks and initiating a diversion. During the approach, the aircraft drifted to the right after selection of Flap 30. When the autopilot was disconnected, a large amount of manual left roll control was needed to prevent the aircraft from turning to the right. It was necessary to maintain this control input until touch down. The aircraft landed safely despite these difficulties, but the investigation determined that the incident had been caused by maintenance errors that had culminated in the failure to reinstall two access panels on the right-hand outboard flap and incorrect procedures being used to service the engine oils. The second example was a Boeing 777 (G-YMME) in June of 2004, leaving a two-mile (fuel) vapour trail from the rear of the aircraft on departure because a small

fuel panel was hanging on a lanyard inside the fuel tank following maintenance.

Furthermore, recent statistics continue to show a relative increase in accidents where maintenance is a primary causative factor. Many of these accidents could have been avoided if human factors concepts had been applied to the maintenance process. The European authorities, led by the UKCAA, recognised the need to drive down the current accident rate by addressing the Human Factor (HF) in maintenance.

As of midnight tonight a major regulatory compliance milestone will have been reached. The question is: will it make a positive difference to our maintainers and therefore the risks that our industry faces?

Background

Our system of maintenance is under financial, time and production pressures. Therefore the chief motivator for a maintenance HF programme right now might typically be regulatory compliance, to get the box ticked and get back to the business of getting them out the door. However, an organisation with an informed management team, motivated by greater profit margins, should want an effective Maintenance HF programme because it recognises that:

An organisation that has a learning culture where visibility of 'near miss' events (rework) is afforded will enable the system of maintenance to mature at a rapid rate and therefore human variability (and risk/cost) will naturally diminish. Near-miss incidents are more frequent than more "serious" accidents. Incident reports are, therefore amenable to statistical analysis in a way that accident reports are not. Additionally incident/near miss (bottom of the Error Iceberg) reporting systems help to keep everyone in the maintenance system focused on safety issues. By submitting incident reports and by receiving feedback about the improvements based on those reports, it is possible to raise awareness about the potential for failure in the workplace. It can also be argued that these schemes are significantly cheaper to maintain than the costs that can be incurred in the aftermath of even a minor accident.

The motivation for a maintenance HF programme should be to help the maintainer and to improve his human reliability on the job.

An effective HF programme is good for the maintainer and good for business. Two identically approved maintenance organisations (whether they maintain A340s or cargo Power Drive Units) - one with a maintainer responsive Human Factors programme and one without will have very different cultures and therefore differing expenditure on their human error budgets.

The objective of the CAA Safety Goal back in 1998: 'to reduce the maintenance human factors contribution to aircraft accidents' has yet to be achieved. This culture change programme requires ongoing careful nurturing by the stake holders (the regulator and industry). Care that the regulated Human Factors programmes are just that, programmes and not simply a training course. Without this care we will doubtless be revisiting this subject in the future, and it will be a far more difficult problem to resolve the second time around. Meanwhile we will have achieved little by way of helping our maintainers. In fact we are likely to have further increased cynicism that human factors can affect positive change.

The objective of the JAA's not-inconsiderable efforts when drafting the Human Factors regulations back in December 1998, was to ensure that maintenance system staff (not simply the person with the spanner) were equipped with the ability to apply human factors. However, many companies I visit have neither equipped their maintainers (competence to apply Human Factors appropriate to their job function) nor do they possess workable Occurrence Management Systems. Therefore, the JAA's work eight years ago will be a wasted effort, resulting in no change to our industries risk profile.

Can we view the EASA Maintenance Human Factors regulations in the context of helping the maintainer? I believe we can, but to do so we must first define what we mean by the term Human Factors. In my experience the term Human Factors has become synonymous with a training course. When companies declare that they have 'done' Human Factors, they usually mean they have carried out some form of training for their staff. From what I am seeing this has been the sole focus leading up to this very date of compliance for both industry and the regulator (civil and UK Military).

Some Approved Maintenance Organisations (AMO's) believe that they have a system for the management of unsafe acts (errors/violations) by simply publishing procedures and giving their maintainer's some training (as little as possible in some cases) to tick the regulators compliance box.

Back in May of 2001 the JAA Human Factors Working Group Report (a good document and worth taking the time to read if you have not) identified two categories of issues: those that can be addressed through a regulatory rule change and those that can be addressed through dedicated Human Factors training. As discussed already, in many quarters we more often than not imprecisely use the term Human Factors, when we really are referring to a company-wide *Occurrence Management System*. In fact the UK CAA in Civil Aviation Publication 716 states:

The aims of Human Factors training should be to:

(i) impart knowledge on human factors,

(ii) to develop skills, where appropriate,

(iii) to influence people's attitudes and

(iv) to influence behaviour (all in support of improved safety).

"Training will not be successful in the long term unless what it teaches is supported within the organisation on a day-to-day basis. The human factors training requirement within Part 145 should not be considered in isolation but, rather, as a part of the total package of measures".

This package of measures which have been referred to as an Occurrence Management System (OMS) is I believe the answer to helping our maintainers to work safer and deliver safer products. This OMS includes (but is not limited to) Human Factors training, and the consistent management of:

- Design/Maintenance Interface – reporting bad data/design
- Safety culture
- Internal Occurrence Reporting
- Procedural Non-compliance
- Shift and task handover
- Fatigue of personnel
- Error management (Reduction, capturing and/or tolerating)
- Preparation of work (tasks, equipment and spares)
- Responsibility for "Signing off" tasks
- Initial and continuation training in Human Factors
- Non-compliance with procedures
- Time pressure
- Tools and equipment, design, accessibility and availability
- Workplace: lighting, temperature, climate and noise
- Behaviour: error provoking, non-compliance with procedures and violations
- Interruptions whilst performing tasks
- Personal performance: eyesight, hearing, physical condition and repetitive tasks
- Design: manufacturer's documentation, maintainability and Maintenance Manual validation

Two questions that remain unanswered are:

1. Will the European Aviation Safety Agency and the Military Airworthiness Authority for that matter, achieve any Return on Investment (ROI) from the time effort and cost being diverted to Human Factors (training) in our maintenance organisations?

2. More importantly to this conference (and the purpose of this paper) is the Maintainer being helped by these efforts or is their cynicism (formed by learned helplessness) being further fuelled?

What to do then to achieve the regulatory Return on Investment and to help the maintainer?

In order to ensure the two questions posed are answered in the positive, we should make certain that we have the following five enablers in place in our maintenance systems.

1. That we have equipped everyone in the maintenance system (not simply the maintainer) with the wisdom to recognise their error traps and how to deal/recover from them.

2. Ensure that we have not simply restricted our training efforts to the maintainer (*spanner turner*). What we know is that accident causation is not simply restricted to active human failure at the *sharp end*. One study contended that the spread of accident contributing factors is not concentrated at the active failure end, but looks more typically like this:

- Organisational processes 27.8%
- Local working conditions 20.9%
- Latent Failures 19.6%
- Failed defences 19.6%
- Active failures 12.2%

3. By taking the approach that all efforts taken to develop a system of maintenance that more closely meets the needs of the maintainer must add value to the business.

4. Develop a reporting system that is simple to use, but above all responsive to everything

5. Then, and only then, through initial HF training (or if the opportunity was missed, during recurrent training) develop knowledge, skills and attitudes in our maintainers to know why, how and what to report.

It's about behaviour modelling - telling them clearly what we are after – our maintainers are not used to thinking about reporting. Our friends in Flight Operations are used to reporting...for a start it is tougher for them not to. However, if a hole is miss-drilled in a component because the drawing or maintenance instruction was confusing, it will typically get fixed. It is not the Norm to report either the error or the drawing inaccuracy that facilitated it.

Interestingly it appears not to be that different in other high risk industries according to the National Patients Safety Agency spokesperson at a recent RAeS Risk conference in the UK “Pharmacists were happier correcting GP's errors for children’s dosages when the GP had incorrectly written the prescriptions. They wouldn't report, they just fixed it and moved on”. We might need to accept that our maintainers get a lot of satisfaction from fixing / working around problems. But they need to be educated to understand that these 'concealments' lead to burn-out and the 'known' failed defences will contribute to an expensive event, and therefore is an area with potential high ROI.

The key to achieving a sustained reporting culture is a rather simple one; change the Norm to one of reporting where the system fails to meet the persons needs. This is always successful in my experience – BUT, when our maintainers do as we request, they want almost instantaneous feedback. The most common cause of reporting culture failure is the ability of our maintenance systems to deliver effective and timely resolution to the reporter. This is why we have such an abundance of bad maintenance data still in circulation for very mature products.

It is worth discussing here some best practices for building a reporting culture that helps the maintainer.

Pushing reports through the existing continuous Improvement processes (Quality Assurance) and adding the human investigation element when it's appropriate.

Have a means of escalation to raise unaddressed items to a higher level. Many of our maintainers have real experience that the organisation is unlikely to react appropriately to their reports, especially if it’s a near miss…but it is my experience that this can quite quickly be turned around by responsive appropriate action that gets well publicised. As an example, I am working with one very large aviation maintenance organisation with a number of sites across the UK. At one of their sites they have a very healthy reporting culture. This was entirely as a result of the system set up before the HF training commenced. The reporting system is simple to use and responsive, with trusted and professionally trained maintenance error investigators, who (when the appropriate trigger level is reached) use the Maintenance Error Decision Aid (MEDA) (customised to their work scope) to investigate. This is of course embedded in a *Just Culture*.

Once all this preparatory work was completed, it was simply a case of switching-on the desired behaviour from the staff during initial HF training. As a result this particular site had 26 reports in one week (maintainers testing the system?) and in excess of 70 reports in a six month period. This site continues to generate a steady flow of reports.

What is of interest is that at other sites in the same company over the same period, and with similar numbers of staff had only 20, 30 and 50 respectively. You might say that 20 reports is a healthy number and I couldn't disagree, but the point is that 70 shows that the local culture engenders greater reporting and is responsive to the needs of the maintainer. In effect, what exists at the site in question, and not necessarily at other (same company) sites, is that reporting has been proven to be a worthwhile activity.

We are warned by the FAA Operator's Manual 'Human Factors in Aviation Maintenance': "to be prepared; as it will typically take 2 - 3 years before maintainers report to the level you should wish for". This is not my experience if the training course on initial Human Factors is competence driven, and one of those competencies is reporting (what, where, who, when, how and why), the maintainer is typically willing to report immediately following the training course as proven in the above example of 26 reports in one week. What will happen very quickly of course, is that if the system fails to respond they will cry *"I told you so"* and we are in a worse situation than when we began. The diagram below (Figure 1 - A4 version attached) demonstrates the above scenario.

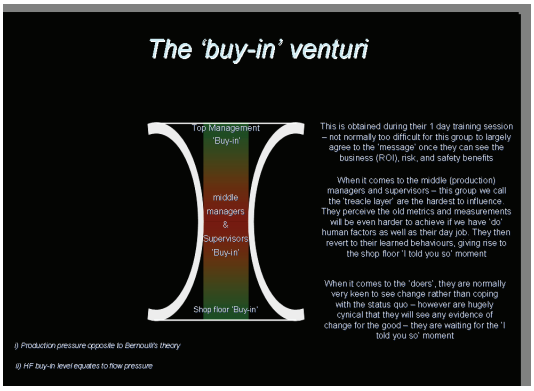

Figure 1

Another reporting opportunity, and one which will help the maintainer, is through the HF training programme. The EASA Part 145.A.30 (e) regulation clearly requires a feedback system that must exist between those under HF training and the Quality System. I advocate using an easy-to-use, but hugely popular system of capturing attendee-driven concerns.

This (*car park*) system is powerful at beginning to change the maintainers' normative behaviour; one of working around problems, to one of discussing them openly and reporting. A real example of just such a feedback (*car park*) system is shown below in figure 2.

We seem to have an increase in 'cleanliness' during announced audits- re-active rather than pro-active – no system to manage this.
I'm a supervisor, and I don't even know where to find the fatigue policy, so how can we be adhering to it?
Nightshift handovers there are none, on/off-going at same time - no overlap
No 'formal procedure on what to do if stamps are missing from stage-sheets- who is responsible for finding missing stamps - Do we stop maintenance
Not enough/correct tooling (i.e. test box which is used regularly has to be borrowed from XXXX)
Unsure how to raise a query note – too experienced to ask, as 'I should have known'
We used to have time for face-to-face handovers- but this has stopped (apart from Sundays)
Security - open panels after we certify them closed.
Guidance needed in the application of the company policy when faced with situations where whilst having consumed alcohol or being fatigued, we can be called in to make airworthiness decisions
Several situations discussed led delegates to conclude that the culture of XXXX is one of Pressure (coercion) to get the job done irrespective of safety issues
XXXX are pressurising certifiers to provide Form 1 releases despite these individuals not receiving training on Part 145 or understanding the release statement implications XXXX…

Figure 2

One large aircraft maintenance organisation in the UK is continuing to prove this point about value-adding two-way HF training. On many occasions the maintainers had been requesting additional PC's for a specific work area, but to no avail for all the usual reasons. This issue was raised as a training *car park* item based on the safety (helping the maintainer to comply with approved standards) and efficiency case. Immediately following the HF training the company purchased 30 additional computers and not surprisingly production output in that area went up dramatically. Of equal value the HF training facilitator was able to show a real

example of where the *car park* system helped the maintainer and reporting steadily began to climb.

Another example of ROI in the form of helping the Maintainer is from a smaller company. On the first HF training course the trainees reported through the feedback system that the engineers' Line Maintenance vehicle required maintenance, in fact that it was almost unusable, and dangerous. The language chosen was that it did not contribute to good aircraft maintenance standards. The HF training facilitator and Quality Assurance manager needed to convince the staff that this course was different, it was the beginning of change of culture and not simply a knowledge based (tick in the box) training course. The next course (only six days later) the issue of the maintenance engineers van was raised again and the facilitator was able to report that there was a replacement vehicle outside awaiting company logos. This is a simplistic example, but the ROI demonstrated here is that the challenge has been turned around to the maintenance system staff, and it has been proven that reporting is worthwhile. The Quality Assurance manager for the organisation quoted here has reported that he continues to receive some *interesting* reports and that his job of detecting system support failures has been made easier. What is of greater surprise to him is that he is receiving the majority of these reports from the more cynical maintenance staff.

How will we tell if we have been successful at helping the maintainer through our OMS?

- Heightened employee attitude towards safety: months after the initial HF training, they use the language of Human Factors.
- Consistent management follow-up to support system-wide improvements.
- Employees are not disciplined as a result of reporting their errors/near misses/hazards.
- Increased trust between workforce and leadership.
- Increased reporting from the maintenance system workforce, coupled with a willingness to share their ideas for improvement. Increased reporting may appear to be increased "errors." Be sure these two are not equated.
- A decline in the number of repetitive errors/rework.
- High interest (across the maintenance system) in event investigation results and OMS initiatives.
- Increased positive feedback on the OMS initiatives from all levels of the organisation.
- OMS interventions compete for resources. Senior managers ask for measures to show how Human Factors interventions can affect the 'bottom line'. They want to know the return on investment for Maintenance Human Factors.

After midnight tonight our EASA Part 145 Quality Assurance audits can assess the degree of effectiveness (at helping the maintainer) by simply looking at reporting and resolution quality and rates. John Anfield, Head of Learning and Development at Rolls-Royce Aero-Repair and Overhaul Business, contended in his paper to the Royal Aeronautical Society that after a few years with an OMS in place, organisations will most probably fall into one of the following three categories:

1. Organisations' with very effective OMS that generate lots of hazard reports which are actioned so as to prevent accidents, Quality failures and reduce costs.

2. Organisations with partially-effective OMS that may generate some hazard reports which may haphazardly be dealt with by leaders.

3. Organisations with sterile OMS systems that generate little or no hazard reports and a disinterested management culture that fails to address any matters that do arise.

Keeping the OMS alive through ROI modelling

The organisations management team will be asking "*what is this doing for us, how much is it costing, and what's the return on investment?"* The management will continue to like what they see from their OMS only if they can see positive change in terms of rate and cost. Demonstrating how much even the simplest unsafe act costs the business is the answer to keeping the management team bought-in. A version of the in-company customised Maintenance Error Investigation database (figure 3) should form part of any OMS if it is to retain its long-term effectiveness.

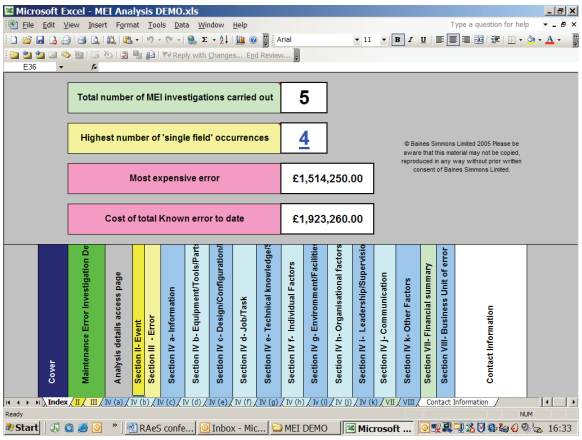

Figure 3

Even though in Europe our Human Factors programs are a regulatory requirement, they are more likely to retain their justification either on the grounds of safety or cost. Therefore, it could be summarised thus (figure 4).

Driver	**Results in**	**Demonstration**
Regulation	Procedures in MOE	HF Training carried out
Informed management system of learning organisation	Organisationally driven activity	Above plus catalogued reporting and corrective actions

Figure 4

The final element – The manufacturer's role in helping the maintainer

Of course, many of the reports now being made, and which must have been potentially bad Norms and workarounds are concerning bad data. The question which naturally remains is can the manufacturer deliver?

If our industry's maintenance systems are successful in engendering reporting and learning cultures, the next threat to sustained reporting is lack of response from the Author/Original Equipment Manufacturer (OEM)/Type Certificate Holder. With little exception all the EASA Human Factors regulations reside within EASA Part 145, and there is very little in the Manufacturers' regulations particularly those responsible for Initial Airworthiness (Part 21). Presently PART 21 GM 21A.3B(b) refers to the determination of an unsafe condition. Specifically it is titled: "Human factors aspects in establishing and correcting unsafe conditions. It provides guidance on the way to treat an unsafe condition resulting from a maintenance or crew error observed in service". It recognises that human factors techniques are under development. However, GM 21A.3B(b) is preliminary guidance on the subject and contains absolutely no reference to the need for the manufacturer to action any reports of bad data. This has to be a potential threat to any maintenance organisation attempting to build a reporting culture.

The Aircraft Maintenance and Dispatch Safety (ADAMS) project was completed in 1999. It was sponsored by the European Union and led by the Psychology Department, Trinity College in Dublin, Ireland. One of its more contentious conclusions was that 34% of Aviation Maintenance staff admitted to not following procedures from time to time and that our maintainers use *little black books.* This is testament to their ongoing unmet need. It is also briefly worth qualifying that the ADAMS report concluded that the maintainers' need was not being met in a number of key areas and that this was the underlying motivator to the non-use of data. Common examples reported were issues such as limited access, format, presentation, availability. As an industry we rely on compliance with data to assure airworthiness, the ADAMS report classified the belief versus non-use as a 'double standard', one that still remains some seven years later. A reporting culture (supported by a reactive manufacturer [OEM]) is the vital key to helping the maintainer to apply well drafted maintenance procedures.

The ADAMS report concluded that it was important to determine and document the best procedures, and to establish a situation whereby the best, quickest and safest way of doing the job is to follow the established procedures, abolishing the 'need' to work around procedures in order to get the job done. Currently there is a vast amount of maintenance data in our workshops, hangars and support departments that do not meet the needs of the maintainers.

Summary

It is worth remembering that time pressure, fatigue, poor data, bad lighting, lack of tooling etc. are not in themselves risks; they are the things that affect the probability of an unwanted outcome. In isolation these performance shaping factors may not present a significant issue, the extent of our maintainers' *error zones (a more threatening combination of the*

above) will affect the probability of unsafe acts. Without a reporting and learning culture these *error zones* will remain at best unidentified, and thus a latent (costly) threat to even the best performing business.

Compliant wording in an EASA Part 145 exposition will not affect these *error zones*, so if, after midnight tonight, Human Factors training was the sole focus of our occurrence management compliance efforts, we will have done almost nothing to help our maintainers.

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