Independent Research

Civil Aviation Authority

Pilot training review – task 3 interim report: gap analysis and risk assessment report

CAP 1581a

Published by the Civil Aviation Authority, 2017

Civil Aviation Authority
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR

The latest version of this document is available in electronic format at: www.caa.co.uk

Preface

This independent research, initiated and funded by the CAA, and part of the CAA's strategic approach to improving safety, reviews UK pilot training in the wider international context. Against a background of increasingly highly automated aircraft, with air travel as a major UK industry with a consumer expectation of the highest safety standards, it is essential that pilots receive effective, evidence-based training that keeps pace with technological, operational and organisational change. This report, together with associated reports below, detail current research directions, current training issues and opportunities. We will explore with the aviation industry how potential safety improvements may be achieved to maximise the benefits of this study.

Related publications

- CAP 1581 – Recommendations and Conclusions
- CAP 1581b – Literature Review
- CAP 1581c – Interview Study

FRAZER-NASH CONSULTANCY

Pilot Training Review

Task 3 Interim Report: Gap Analysis and Risk Assessment Report

FNC 46243/46559R Issue 1

Prepared for Civil Aviation Authority (CAA)

SYSTEMS AND ENGINEERING TECHNOLOGY

DOCUMENT INFORMATION

Project :	Pilot Training Review		
Report Title :	Task 3 Interim Report: Gap Analysis and Risk Assessment Report		
Client :	Civil Aviation Authority (CAA)		
Client Ref. :	2217		
Report No. :	FNC 46243/46559R		
Issue No. :	1	**Compiled By :**	Georgina Fletcher
Date :	18-Sep-2017	**Verified By :**	Gordon Bisset
		Approved By :	Gordon Bissett
		Signed :	*On original*

DISTRIBUTION

Copy	Recipient	Organisation
1	Graham Greene	CAA
2	File	Frazer-Nash Consultancy

Copy No.: ______

Originating Office: FRAZER-NASH CONSULTANCY LIMITED
The Cube, 1 Lower Lamb Street, Bristol, BS1 5UD
T: +44 (0)117 9226242 F: +44 (0)117 9468924 W: www.fnc.co.uk

EXECUTIVE SUMMARY

This interim report describes work conducted in Task 3: Gap analysis and risk prioritisation as part of the CAA's Pilot Training Review project (research contract 2217).

This objective of the gap analysis was to compare the findings from interviews with stakeholders from the aviation training community and a review of the human factors and training research literature to identify gaps and other issues in pilot training. The gap analysis identified gaps and any other issues, including good practices, such that they could all be included in the risk assessment and subsequent prioritisation. This risk analysis was undertaken using an adapted Bow-tie approach to highlight the threats for UK pilot training and the necessary barriers for addressing these.

The bow-ties were set up for each of the five themes describing the pilot training system:

- Content and Delivery;
- Training Tools / Devices;
- Pilots;
- Instructors;
- Governance and Regulation.

A total of 47 threats were identified from the gap analysis, with 27 of these being viewed as most critical and important based on previous analyses of current practice and literature in the project. The analyses also involved mapping controls to these threats, which are barriers that prevent the threats turning into hazards. Across the five bowties 79 barriers were identified, with 70 of these applying to the most critical threats. Most of these barriers are activities that are already in place to some degree but 28 were additional controls being proposed to address current gaps. Frequency counts were then conducted on the controls to identify the most common barriers and hence the ones that would address the most threats across the training system.

The barriers which control the most critical threats are:

- Comprehensive training needs analysis (TNA);
- Provision of support resources and accessible guidance;
- Consistent application of standards and checks;
- Regulatory oversight for compliance;
- Defined ownership of development responsibility;
- Formal training and continuous evaluation for all types of Instructor/Examiner (I/E);
- Rigorous evaluation processes informing iterative development and need;
- Appropriate balance of technical and non-technical competencies;
- Defined exploitation pathways and implementation processes for research outputs;
- Understanding and managing skill fade for all competencies;
- Formal tracking of pilot / instructor training provenance;
- Information sharing, lessons learnt and benchmarking;
- Job design and career management for I/Es;

- Understanding the 'how' of training;
- Ability to justify training need and change;
- Available appropriate supporting tools and training media;
- Avoidance of minimum compliance;
- CAA organisational structure based on industry need;
- Maintaining instructor currency in training developments, aircraft systems etc.;
- Pilot selection;
- Regular competence checks for I/Es that consider ability to train (rather than just ability to fly);
- Regulation supporting competence-based approach across training;
- Training knowledge, skills and attitudes (KSAs) to support flexibility and resilience in performance;
- Advanced accreditation standards;
- Clear regulatory definitions of training terms and consistent usage, e.g. Competence, proficiency;
- Easy access to training facilities for self-guided and instructor-led practice;
- Industry influence on research and development agenda;
- Instructor selection;
- Regulation appropriate to the differing resource availabilities of Approved Training Organisations (ATOs) / Organisations;
- Resilience and flexibility of training programmes.

It is proposed that these cross-system areas of training should be the main focus of future work to strengthen and sustain pilot training in the UK going forward. Recommendations to this effect will be made to the CAA in the final project report.

CONTENTS

THIS PAGE IS INTENTIONALLY BLANK

1. INTRODUCTION

1.1 BACKGROUND

This document is an interim technical report produced as part of the Pilot Training Review being conducted for the CAA. It reports on work conducted in the Gap Analysis and Risk Prioritisation task (Task 3) of the project.

1.2 OBJECTIVE

This objective of the gap analysis was to compare the findings of interviews with stakeholders from the aviation training community and a review of the human factors and training research literature to identify gaps and other issues in pilot training. These gaps and issues were then sorted to highlight the emerging, potential risks in pilot training. From this, in the final phase of the project (Task 4), recommendations will be made in for improvements to the pilot training system to support safety outcomes.

1.3 APPROACH

The first step was a gap analysis, comparing current practice in UK aviation training established from the Interview Study (Task 2) with the state-of-the art on pilot training determined in Literature Review (Task 1). This was a desktop exercise. Due to the different foci and levels of detail of the two inputs, there was only partial mapping between the literature review and interviews. Furthermore, there were gaps and limitations in the results from both the literature and information obtained on current practice. As such, the gap analysis identified gaps and any other issues, including good practices, such that they could all be included in the risk assessment and subsequent prioritisation.

Having identified the issues and possible mitigations we developed Bow Tie diagrams to structure our findings, support the analysis and help with visualisation of the full range of issues identified. The bow tie diagrams were structured with the residual risks identified through the research project as threats, and possible mitigating activities recorded as prevention controls. Building on all previous project findings and the bow-tie visualisations, overall conclusions and recommendations can then be formulated for the final report.

1.4 DOCUMENT STRUCTURE

The report is divided into two main sections describing the approach and results of the work undertaken:

Section 2 – Gap analysis observations;

Section 3 – Bow-tie analyses.

A Conclusion section has been included to draw the key points together. Further details and results are included in the annexes where appropriate.

2. GAP ANALYSIS OBSERVATIONS

2.1 OVERVIEW

This section presents discussion of the comparison between the output of the literature review, and the reported current practice in aviation training from 16 interviews with representatives from airlines, offshore helicopter operators, military aviation, professional associations and regulators. The literature describes the state-of-the-art in aviation training research and so offers, or should offer, source material for training organisations to consider in training design and development, whilst current practice describes how training is conducted at present.

One of the first questions asked in the gap analysis was simply: how well does the research match with and support practice? While it is important for research to drive innovation and development, it would be helpful for this to link to the requirement of the industry. As part of the literature review, a number of gaps were already identified in the spread of activities (that could be identified – see the literature review report for a description of the search criteria). Another question asked was: do these gaps mean there are also gaps in knowledge that is then made available to industry? A final consideration was how well is the conversion of research into practice supported? For example, are research findings provided in a manner that best supports practical exploitation?

The discussion in the following sections considers various elements of the mapping between the literature and the interview findings. Not all questions were relevant for all areas, indeed, section 2.2 highlights why the overall gap analysis activity proved more challenging than originally anticipated.

2.2 GENERAL DIFFERENCES BETWEEN THE LITERATURE AND PRACTICE

The literature review focussed on research and not existing regulation, although it did consider available guidance material, e.g. for Evidence Based Training (EBT). This review found the main focus to be around the content of training, including a range of training topics or investigations on how to train different Knowledge, Skills and Attitude (KSA) elements. For example, research continues to be conducted into how to train monitoring skills, decision making and upset prevention and recovery, but the studies are mainly just research studies rather than practical documents with guidance that can be easily exploited into industry to support and improve training. Some discussion papers consider wider topics about improving the overall training pathway, but overall relatively little consideration of broader training system issues and other influencing factors was found, e.g. pilot selection or the role of instructors. The defence training guidance and research is the one area where a broader view was taken, but this is not aviation specific. It is also worth noting that most of the literature centres on fixed wing aircraft and not helicopters.

While the focus on the research appears mainly to be on content, the main issues arising from the interview study related more to the wider training implementation and delivery system. A clear message was about needing support from the regulation to be able to deliver training appropriate to current operations, e.g. via EBT, which is discussed in more detail below. Challenges reported related more to the reducing supply of pilots, the overall lowering of experience in the community, needing to maintain suitably qualified and experienced instructor numbers, and overall maintenance of standards. The notion of standards was not something discussed in the literature at all. The ability to provide smarter training for the increasing complexity of operations is an on-going requirement and can be related to the research, but there would need to be more holistic thinking about how the whole training pipeline can be managed together, and on-going research of this type was not evident.

All these topics will be discussed further in the following sections to show where the gaps in either knowledge or practice could result in residual risks in the training system.

2.3 APPROACH TO TRAINING

Both the literature and the interviewees were committed to the need for future training to follow a competence based approach that uses performance focussed training and assessment. Both sources were also unified in the lack of a framework for implementation, in terms of definition of competence, regulatory barriers and instructor limitations.

The first step of implementation is defining the approach. In both the literature review and through the response to the interview, the Ministry of Defence's (MOD) approach to performance-based training was highlighted. Military aviation training is migrating to competence-based training, as part of a wider strategy, the Defence Systems Approach to Training (DSAT; MOD 2016), which provides a framework to support implementation across military training. The findings of the literature review and interviews suggest that civil aviation is limited by not having a defined framework for implementation, leading to variation and inconsistency in approach.

The clear definition of competencies and the associated KSAs are the foundation for a competence-based approach for training approaches, such as EBT or the Alternative Training and Qualification Programme (ATQP). The literature review emphasised gaps relating to the definition of the current competency framework suggested by International Air Transport Association (IATA, 2013) and lack of detail available regarding the associated KSAs across all aspects of flight. These limitations result in difficulties when trying to focus training and addressing the interrelations between technical and non-technical skills. Within the interviews, the definition of competencies by training operators was found to increasingly be based on a training needs analysis. These are used to meet specific competency requirements and local risks as well as incorporating the competencies covered in EBT guidance and the content defined by regulations. It was, however, noted that without defined KSAs, competencies were open to interpretation. For example, it was felt that some organisations interpreted 'competencies' as being equivalent to only non-technical skills. The high level nature of competency definitions may introduce this ambiguity. Having well-defined KSA and experience requirements considering both technical and non-technical areas would encourage a more integrated approach to training.

Indeed, without a clear definition of competence and the associated KSAs, that are reflective of operational requirements and offer the ability to incorporate airline specific attributes, the risk is that competency approaches will not be adopted as it is too vague, or it will be too easy for training organisations to imitate compliance as they can claim most approaches fit the requirements, with opportunities for integration missed.

Regulatory barriers were identified in the interviews, where regulation that is designed for previous approaches to training inhibits the implementation of new techniques. This seems to be due to the competence-based approach being integrated as an add-on, rather than a standalone approach. The interview findings found that the current requirement to comply with traditional proficiency checks alongside EBT training reduces the amount of time that can be given to competence-based training approaches, e.g. simulators are booked out for assessment rather than training and addressing proficiency requirements reduces the time for training in operational risk areas. This limits the opportunity to deliver fully flexible risk-based competence training and results in implementation that does not reflect a competence-based approach. For successful delivery of a competence based approach, the regulatory requirements need to join up with the aims of competence training.

The role of instructors in training will be addressed in more detail at a later stage in this report. In regards to instructor limitations in implementing a competence based approach, neither the literature review nor the interviews addressed this in detail. The International Civil Aviation Organisation (ICAO)/IATA report outlines that instructors should undergo suitable training in order to adapt to the needs of competence based training and this should provide the framework for existing instructors to develop their own competency to undertake competence-based training and assessment. This training was not discussed more widely in the literature or within the interviews, and therefore it is not clear the extent to which instructors are supported in the transition. It is likely that instructors bear the brunt of the barriers discussed, as they have to implement the training, possibly without clear KSA definitions, contrasting approaches and contrasting regulatory requirements.

Competence-based training also has a role in its application throughout the training pathway. One interviewed organisation described its use in ground-school training to enable flexibility in adapting the training to different learning styles and different student backgrounds. The literature review raised criticisms that school and early flying training is seen as less developed and does not use modern training approaches. The use of competence-based approaches could help with the need to draw skills through into Ab Initio that are relevant for operational flight, through knowledge-based training and the ability to be flexible to trainee needs. However, it is of note that this may be limited by the experience of the instructors and the presence of a culture that encourages training to pass the test.

The challenges discussed above are not unique. Within the literature review, Todd and Thomas (2013) concluded that competence based training is difficult to implement due to problems in the definition of competencies, implementation and assessment. Their research does conclude that the approach has value, but successful implementation requires the consideration of the flight training system as a whole. Todd and Thomas also raised that there is limited information available about the evaluation of competence based training techniques. This is highly relevant for the civil aviation industry going forward. This gap needs to be addressed to provide a systems approach to training, enabling validation and further development.

2.4 CONTENT OF TRAINING

2.4.1 Overview

An important observation arising from the interview findings is that whilst the demand on pilots has increased over the years, for example the need for skills in automation management, manual flying and an increasing need for commercial awareness, the footprint (overall amount) of pilot training has not changed to the same degree. If anything, it has reduced. While realistically the amount of training is unlikely to grow to match the increasing list of KSAs to be addressed, the point highlights the importance of finding smarter ways of training pilots, and the need to extend this knowledge across the whole industry.

The literature focussed in detail on training content and the state of the art approaches within each competency, the interviews addressed training content at a much higher level. It is clear that operational training addresses the key areas identified within the literature review, however, a level of detail regarding the approach to each was not provided. This means that it is not possible to directly compare the state of the art approach with that reported in the interviews, but key areas raised will be discussed, and this has not inhibited the identification of gaps for further consideration.

2.4.2 Automation

The operational issues and challenges relating to automation that were identified in the interviews as requiring addressing through training correspond with those identified in the literature review:

- Knowledge of the system;
- Mode management;
- Levels of automation and transitions;
- Transitions to manual flight;
- Automotive surprises.

The interviews focused on knowledge of the system and automation surprises, however it could be that knowledge of the system was felt to mitigate issues with mode management, levels and transitions if this was 'got right' the first time.

The foundation for training in automation is knowledge of the automation system, also known as system logic and mental models. Both the literature review findings and the interviews emphasise the importance of training pilots to understand the underlying logic of the automation, enabling them to 'think around' the system to support optimal responses.

Within the interviews, barriers to this have been identified as issues associated with variations between manufacturers and different variants of the same aircraft (for helicopters), as well as differences between the manufacturers design and operating philosophies (across aircraft). These issues are associated with equipment design and the flexibility of training platforms. This presents challenges for the instructors, who have to 'distil' the automation into a useful model to deliver training and in the transfer of training from training systems to operations. The risk associated with not understanding the system was discussed by Lyall and colleagues (2008), who describes how, when trainees cannot match the automation's behaviour with their expectations, it can lead to unexpected responses from the automation that the pilot will struggle to interpret. Barriers to achieving training transfer include the ability to relate the automation into a useful model, the types of systems trained and possibly the lack of simulation and training resource. These were not explored in the interviews but may impact on the value of early training in automation.

The interviews also reported that there is increasing complexity: in flight requirements; procedures; the appropriate responses from pilots; and the automation. This increasing complexity throughout the system may provide an explanation as to why there are still training issues associated with training automation, even though it has been highlighted as an area of focus since the FAA report in 1996. The literature review identified a need to 'simplify' automation systems for training to aid understanding, but not oversimplify obscuring the logic of the system. If the system is difficult to interpret in the first place (i.e. lacks transparency) it is likely that developing training models will be challenging or impossible, presenting a challenge in training design, delivery and content.

The literature review identified a recognised gap that training for automation was not being introduced to trainees early enough in their training journey. The interviews found that this was indeed being addressed operationally, with automation management being covered within the earlier stages of training. This is an example of state-of-the-art in operational training, although how this was achieved and the extent to which it was integrated was not discussed in detail. There were concerns raised in the interviews that some early training provides trainees with knowledge, but not an understanding of how it should be applied in the operational context and so further research is required.

Within airlines and helicopter operators both reported using training to address startle or automation surprise as part of resilience training. This was described as incorporating an understanding of precursors, preplanning activities and conditioning the right responses. The literature review reported the incorporation of training to address automation surprise as a specific area for improvement for flight management system training (Holder, 2013). This provides an instance where state-of-the-art is being used in current training approaches. The literature review identified types of training techniques that could be used to train for startle, i.e. incorporating cognitive flexibility training, adaptive expertise training and metacognitive training. The extent to which these specific approaches are incorporated in training to support with management of startle is not known.

Monitoring, whilst addressed as an area of focus in the literature review (and for which guidance has recently been developed by the CAA[1]), was not specifically raised by participants in the interviews. Typically the discussions addressed high-level how automation was trained rather than the exact skills that were trained. Participants were asked about specific training they might do for a range of automation management related competencies but most organisations felt all were addressed in current training.

Within the literature, a gap was identified in regards to issues around the perceived exclusivity of manual flight and use of automation and the integration of non-technical and technical skills. This was not addressed within the interviews. It may be that because of the challenges faced in training automation there is not the capacity to finesse the associated non-technical skills.

2.4.3 Manual Flying Skills

The literature review raised concerns surrounding pilot's manual flying skills: when skills are taught; on what system; and how skills are retained. The literature review emphasised that success in manual flying skills is the ability to continue to maintain situational awareness and manage workload when flying the aircraft manually, however, due to pilots having less practise in manual flight, these skills often drop off due to the increased workload experienced. In the literature review, issues were raised around training transfer in terms of how initial training in manual flying does not reflect the requirements of manual flying in line operations and skill fade. The interviewees expressed the importance of manual flying skills, as well as the intention to increase the time available for trainees to develop these skills, however how these skills are trained and maintained was not addressed. Evidence from the literature identifies that purely increasing time commitment to manual training may not necessarily provide the training outcomes needed. This, alongside the finding that pilots are poor at identifying and addressing their own learning needs, indicates that a structured approach is required. It was not clear from the findings if this is currently implemented.

2.4.4 UPRT

Loss of control is relevant to both training in automation and training in manual handling skills. Upset Prevention and Recovery Training (UPRT) has been developed with the aim of reducing loss of control incidents. The literature highlights the need for this training to be knowledge and skill based, with realistic training content as far as is practicable. The feedback provided in the interviews was that the UPRT rules have not been helpful. The training was described as limited due to simulator capabilities, which is in keeping with other criticisms of simulator

[1] CAA (2013). Monitoring Matters. Guidance on the Development of Pilot Monitoring Skills. CAA Paper 2013/02.

training. There were also questions by operators about the requirement to train Captains who fly from both seats for training purposes to themselves be required to receive full UPRT for each seat. This was seen as unnecessary. There was also concern that the focus of the training was too much on managing upsets and not avoiding them in the first instance. These issues may have been addressed in recent reviews of the regulations, however, the introduction of UPRT may prove an interesting case study for considering how training needs and KSAs are identified and then applied in training, and the relationship between training delivery and regulation. The interviews identified that the military engage in more training for unusual attitudes and upsets as a matter of course. Their training not only includes physical handling but also inputting data, situation awareness, recognition of spatial cues for unusual attitudes. It could be interesting to compare the approaches of civilian and military training.

2.4.5 Cognitive Skills

Within the literature review, multiple approaches for training in metacognitive skills, workload management and decision making were identified, but they often lacked detail about techniques and implementation examples. Interview responses did not provide a comprehensive overview of how cognitive skills (such as problem solving and decision making) are trained. Professional and Industry bodies raised questions about workload and capacity limitations of pilots and how decision making can be better trained. Of the other respondents, the military emphasised the importance of cognitive skills and decision making, with training addressing these areas to support pilots dealing with the demands of flight. This includes the use of a comprehensive assessment matrix that incorporates criterion, subjective and objective measures.

Metacognitive skills were reported within the state-of-the-art literature. These refer to an individual's awareness of his or her own cognitive processes and how these are influenced by the information available to them from the outside world. These skills enable individuals to be critical of their thinking processes and adapt to novel situations, and are therefore relevant to training in adaptability and resilience. Their use in decision making, through the awareness of decision heuristics (or shortcuts) is a valuable component of training for safety critical environments. Specific training for metacognitive skills was not identified in there but should be considered as an area of further investigation. Similarly, decision making mnemonics were highlighted as a 'best practice' tool in the literature, but the extent to which these are incorporated in training and found useful in operations is not known.

Workload management has a role in manual flight, unexpected events, mode selection and errors / deviations and therefore should be a focus for training techniques. Interestingly this was only addressed by the Professional and Industry bodies, with the interviewees reiterating questions about how these should be trained. It is of note that these areas are all operationally focussed, i.e. they are influenced by stress and reflect issues faced in line flight. Therefore, they may not currently be addressed specifically during assessment, resulting in reduced training focus. Training may fail to synthesise realistic operational environments (pressure, number of decision options) and therefore the skills associated with these areas are not relied upon and shortfalls are not identified. Furthermore, the abstract nature of these areas may present a challenge for assessment.

The interviews identified that the key skills that should be considered from the start of training include: resilience, stress and threat and error management. Stress management training was highlighted in the literature review, but was not directly addressed in the interviews. This could be an area for development of state-of-the-art training.

In summary, the gaps identified within the literature are also reflected in the current training environment. The military approach to training cognitive skills appears to be superior, probably due to their operational and manual flight requirements. It is not sufficient to rely on these skills being developed through experience or as traits that pilots either have or do not.

2.4.6 CRM

All organisations interviewed reported integrating non-technical skills/Crew Resource Management (CRM) training with technical training across all parts of training. This was identified as an area of need in the literature review and therefore demonstrates a state-of-the-art approach, however the interviews did not provide the detail required to understand how this is achieved. The literature review raised a number of gaps regarding CRM. At the highest level this can be defined as the question: what is taught in CRM and how? There are various different definitions and this was taken to indicate that there is not a systematic approach to CRM training. In terms of competence, this translated into a lack of detail regarding how non-technical skills are defined and assessed. At a lower level of detail, many of the gaps identified related to communication, for example: CRM in multicultural crews; the ability to challenge; and team dynamics. The interviews did not go into a level of detail that would shed light on the delivery of CRM in general or these specific areas.

2.4.7 Stress, Resilience and Adaption

The flexibility of training organisations to incorporate change has implications for the resilience and adaptation of the training programmes as well as their ability to train resilience and adaptation in personnel.

In terms of training programmes, there is a requirement to be flexible in developing operational and training needs, for example incorporating new areas of training and responding to wider issues. A finding from the interviews was that ground school training is out of date, and has not changed in multiple years, especially considering how automation and manual flying skills are trained. If training programmes have low resilience and adaptability they are placed under greater pressure when incorporating new training requirements due to limited flexibility. This issue was also raised with interviewees expressing that although the number of ‘must train’ areas has increased over the past years, there had not been a corresponding change in the training footprint to accommodate this – in fact it was felt to have shrunk.

Training pilots in resilience skills was described as part of training in cognitive skills and so incorporated decision making, workload management and supporting pilots in coping with unexpected events. The interviews showed an awareness that there is a requirement to move away from declarative (knowledge) based learning and testing (i.e. question banks) and focus on procedural skill based learning. Demonstrating awareness of the best practice identified in the literature which emphasised training the application of knowledge and experience rather than rule based thinking, to allow flexibility. For the military, the focus on cognitive skills was described as a mitigation in response to concerns about pilots managing in flight demands. Resilience, stress, and threat and error management were highlighted as key operational skills that should be considered from the start of ground school training. The transition to this was described as gradual shift. This demonstrates an interest in integrating resilience skills into training. UPRT should be considered a more direct form of resilience training, and the iterations the interviewees had experienced was criticised for not focusing enough on prevention and planning – key components of resilience and adaptability.

Gaps identified in the literature review were the limitations in training techniques in representing and enabling training in resilience and these barriers were also highlighted in the interviews: simulator capabilities fail to create the physiological reaction experienced in real settings and it is challenging to introduce realistic psychological stress in training environments.

2.4.8 Skill Fade

Skill Fade and the role of recurrent training is an area of great interest in the literature and was raised in interview discussions. The ability to understand skill fade, and model recurrent training appropriately would guarantee the skills of the pilots across time. This would support pilots' competence retention, and their ability to manage upsets whilst providing training organisations, airlines and regulators with assurance of pilot competence over time. The literature reviewed in this area gave an operational insight into skill fade, focusing on manual flight. The research reviewed tended to focus on the fact that there were issues with skill retention rather than presenting a solution or mitigation. This was also the case within the interviews, with no approaches to support training/reduce skill fade and maintain confidence reported, apart from the use of routine exercises. Our findings replicate those of PARC and CAST (2013), who found that although instructors and operators were concerned about manual handling skills deterioration, they were uncertain as to how to encourage retention of skill through operational policies and line practice.

Furthermore, whilst both the literature reviewed and the interviews emphasise the significance of skill fade with result to manual flying, a gap was also identified regarding skill fade in other competence areas. Problems with maintenance of skills for automated flying activities may be harder to identify but could still exist. Different working patterns may afford less opportunity for pilots to practise skills on the line, which could be a further contributor in this.

Skill fade is an area of high risk, as it is the infrequent and demanding events that pull it into focus. The research highlights that training to address these risks needs to be structured because pilots cannot be expected to be aware of their limitations (Gillen, 2008). There was an interest expressed from our communications with the CAA that a timeframe for recurrent training would be of benefit. Detailed research on training intervals to maximise retention was not identified in the aviation research but work had been conducted in the defence environment that could be exploited here[2].

Although recurrent training is a mitigation for skill fade, it also has wider applications, including enhancing aviation knowledge and skills, supporting career progression and training new equipment as well as ensuring a level of proficiency has been maintained. Within the literature it was found that time to command varies across operator, with some offering formal command courses, command preparation courses and command mentorship programmes. This could be seen as an example of recurrent training and demonstrates the variation across the industry. Whilst the role of recurrent training was discussed in the literature, it was not reported within the interviews. This reflects the lack of detail in how training is achieved.

2.4.9 Training Effectiveness and Transfer

A theme throughout the literature review was the concern that current training may prepare pilots for specific tests rather than providing skills that can be generalised to unique situations (training to pass the test, as mentioned previously). This is relevant across the areas of competence, as it refers to the application of training to line flight operations. Notably, this concern was not raised within the interviews. This could indicate that the organisations interviewed did not prioritise this area, did not recognise it as an area of need, or merely did not bring it up in interview.

[2] In the first instance see the Ministry of Defence's (2016), JSP 822, Annex B to Ch 1, Sec 1.2, pp68-72. This provides guidance on DSAT but also and a summary of recent defence training research.

2.5 PILOTS

Pilot supply and demand was highlighted within the literature review as a current issue which will impact pilot training. In summary, growth in the market creates a greater demand for pilots, placing a pressure on training to increase pilot throughput, availability and reduce time to command. Within the interviews, the main issue raised was the reducing number of pilots available. The concerns were based around: where the compromise will fall to meet demand; the role of available funding influencing who can achieve a licence, with less reliance on skill; and the impact of increasing complexity alongside the reducing pilot supply.

Major stakeholders raised concerns in the interviews that pilot quality will be reduced, something already being seen in initial ground school. Different standards across ATOs mean licences can be obtained in other countries at a lower standard and transferred to the UK with no further checks. This concern was raised in the literature review, but focused more on the impact in terms of pilot diversity and team working, rather than the overall quality of the recruits.

An area of focus within the literature review was the demand for pilots resulting in reduced time to promotion and command. Currently the progression from First Officer to pilot required extensive flight experience; however, as the demand for pilots increases, the number of First Officers with such a high level of flight hours will reduce. This development was not discussed within the interviews.

The demand for pilots also has an organisational impact, placing an added pressure on Approved Training Organisations (ATOs). For example, an ATO described working to bring its training more in line with competence-based approaches, sometimes including training scenarios with unexpected failures. However, this introduces organisational barriers because as the level of difficulty in the training goes up so does the level of trainee failure, which the operators (their customers) do not like.

Selection was described in detail in the literature review. The interviews praised the military and Multi-crew Pilot Licence (MPL) training approach to selection, with the military using clear performance standards and selection approaches whilst the MPL approach focuses on needs and values. Details of other selection approached were not provided, and selection was not discussed in terms of KSAs. The role of organisational fit was mentioned, and was felt to be missing from training approaches where the trainee attends multiple training schools. The literature review identified two gaps – how capabilities inform selection and a lack of information about aptitude testing for later career phases. These were not addressed in the interviews.

An interesting area raised within the interviews was the availability of flexible working patterns for pilots. This is in-keeping with employment trends in wider society, which shows an increased interest and uptake in flexible working patterns, but was not identified in the literature review as a broader issue impacting pilot training. The use of flexible working in aviation raises concerns regarding skill fade and issues as to whether lower skilled pilots are disproportionally represented as choosing flexible working arrangements.

Comments were made within the interviews regarding the changing definition of a pilot’s role. The role was described as increasing in breadth by an ATO, describing that as well as technical handler that they have to be a safety manager, a commercial manager, and consider issues of other stakeholders and the broader team. This was also raised regarding the changing interactions of the role with air traffic control (ATC). Interestingly the literature review identified multidisciplinary training as a ‘state-of-the-art’ training solution, whilst the interviews reported that collective training was previously used to engage ATC in training with pilots but has become infrequent. This type of training was described as being useful for air traffic controllers so they can see first-hand the impact of their request, e.g. the high workload generated by late runway changes.

2.6 INSTRUCTORS

Gaps were identified in the literature review regarding how instructors train future pilots, specifically regarding automation and the mitigation of skill fade. These specific areas were not raised in the interviews as the focus was at a higher level. Instead there was discussion around how instructors implement the training approach and how quality is ensured.

There is a recognised need, mirrored across the literature and interviews, for instructors to keep up to date with developments in technology and automation. Developments in the industry have impacted upon the KSAs and training needs for instructors, with a requirement to be competent in teaching a breadth of skills at an advanced and technical level, e.g. metacognitive skills and models of automation. Within the interviews, the barrier of instructors training at the edge of their own experience envelope was raised as a concern. The changing approach to training also requires instructors to possess the ability to teach and assess in terms of competence, requiring subjective and objective assessment resulting in decision making based on multiple weighted variables rather than hours. Just as pilots need metacognitive skills, instructors need delivery skills including how to create a learning environment, manage performance and evaluate competence. Furthermore, just as the demand for pilots increases, so does the demand for instructors, so the capabilities needed from instructors is growing.

Indeed, instructor quality and consistency was also raised as a concern in both elements of the project. The literature review identified that some training programmes have regular evaluations, assessing manoeuvres and instructor technique, but this approach is not consistent. The literature review identified that instructors would benefit from structured programmes to support their own skill development, use of the training tools available, and direct career development. The interviews identified barriers to this: a lack of methods to update training skills; no formal qualifications and lack of regulation. This was felt to result in issues about the currency of instructor skills and the breadth of their experience envelope, risking instructors having to teach outside of their KSAs.

There are also organisational influences such as dependence on company norms and the clarity of competency definitions, routes into becoming an instructor and career progression opportunities which result in variation between airlines and training schools. The literature called for regulatory influence to review the current requirements.

2.7 TRAINING TOOLS

Simulators play a key role in the delivery of pilot training. The literature emphasises their use in training manual and automated flying skills, procedures, as well as non-technical skills including decision making. Low fidelity training options were also reported in the literature as being used for situational awareness, workload management, communication, leadership and teamwork. It is to be expected that training utilises a combination of approaches for each competency.

Focusing on simulation, the literature review and interviews identified the availability of simulation as a barrier to training. Ideally, interviews participants outlined the benefit of being able to use simulators flexibly, with trainees being able to access simulator platforms for non-jeopardy (i.e. not including assessment) training, to practise skills they have learnt. This is currently limited by the time each simulator is available. The typical focus for simulator use is currently on checking, but there was an interest from interviewees in their increased use in training.

Another barrier relevant to the use of simulators in training is simulator fidelity and scenario complexity, for example non-technical skills are reported as requiring more complex scenarios. The literature review addressed this in great detail as it was often raised as a limitation of current training approaches. This was not addressed in detail in the interviews. The literature review also commented on the demands placed on instructors to use the training tools available, with their training and workload not necessarily supporting the development of effective simulator scenarios. This feeds into concerns about resilience and adaptability, where training and tests may prepare pilots for specific tests rather than providing skills that can be generalised to unique situations

Simulators are not available for every aircraft and at all airlines and training organisations. The interviews identified that there is a current trend advocating lower-cost training devices. These are devices without full motion and visuals and can be used to train parts of tasks and procedures. The use of tablets for this purpose does appear to be growing, primarily for ground school type training but also for learning the layout panels and systems menus etc., and some procedures. One step that has not yet been taken, but was emphasised in the literature review as having value, is use of low-cost simulation and games-based training. These are used in various areas of the military but it was observed in the interviews that civil operators and training schools do not have the resources to spend on expensive training development, or would certainly struggle to make a business case for it.

Looking forwards, it is of interest as to whether regulation will support a greater proportion of training assessment and competence to come from simulator use. Within the military there has been work undertaken to assess the balance between live and simulator training, this could also have value in aviation.

2.8 GOVERNANCE

2.8.1 Support

Developments in training are supported by regulatory bodies, who determine areas of need, and research that identifies new and novel approaches.

Regulatory support was not identified as an area of focus within the literature review, but was consistently raised in the interviews. Responses to this question focussed mainly around support associated with the CAA. There were two main messages in the responses from the operators. The first: that at an individual level the CAA is very supportive and people have good relationships. The second: that organisationally there are limitations in the support provided by the CAA, resulting in provision gaps. These gaps were described as: a loss of resources (reduced availability of expertise and materials due to turnover and workload within the CAA), limitations to access for small ATOs, and differences in focus of regulatory support and the perceived need. This is experienced by the industry community as seeing high levels of turnover amongst staff, high workload for inspectors, fewer number of staff, reduction in some activities previously undertaken by the regulator and a sense that some expertise has been lost. Most participants acknowledged that the CAA has a difficult role now but there was still a need for more guidance material, funding to support training development and a greater ability to influence at EASA.

At present, the operators see the current standard, i.e. non-ATQP, training as preventing them properly addressing the real risks faced, and as such they are trying to drive change by exploiting the benefits of ATQP/EBT as far as possible.

Organisational considerations were also highlighted. Some of the perceived changes could be due to a shift towards performance-based oversight but as one interviewer commented, this will need to be enabled (supported) in industry. The new approach to regulation itself will mean further changes at the CAA and the way it operates: different ways of working, different inspector training, different tools and guidance. One suggestion was offered to provide additional support to the community as things change was to initiate the role of a development ATO to encourage more sharing of expertise in training.

The literature review raised questions about how research is taken up within pilot training activities as well as how successfully the research answers the questions that are relevant to the organisations. Section 2.4 considered how state-of-the-art research informs developments in training. Three of the airlines interviewed described projects where they were working with academia to develop research in training relevant to safety data analysis, resilience, mentally flying the aircraft and safety culture. These could be examples of where relationships between academia and operations support the feed through of research into training activities. The ability to collaborate to receive research benefit was also raised in the interest in low cost alternatives to simulator training (e.g. serious games, tablet and mobile training); however, a barrier to this was identified as the inability to develop this technology themselves. Better co-ordination with academic and private research could bridge this gap, and regulatory support could assist in training development.

Making a case for training change and development was identified as a challenge by the interviewees. Although responses were only gained from a small proportion of respondents, the idea that training needs to be discussed in terms of performance and outputs to overcome the barriers in making business cases for training developments. The move to EASA is seen by interviewees as slowing down the pace of change in regulation through increased bureaucracy and less opportunity for industry engagement, and increasing variability in training standards, which can be passed on to the UK.

2.8.2 Standards

Due to different standards in licensing and operational requirements, a proportion of pilots who are able to obtain a license are not of the standard required for operational flight. This has two implications: one route for pilots who do not find airline jobs is to go into instructing, but this means the standards of training could be lowered; another is to undertake further training at a different ATO or to find an operator with less strict operator standards. This is where variation in standards across Europe and organisations becomes an issue, which is compounded by the availability of trainees and the demand faced. The reduced regulatory resources available to support organisations was also identified as a concern. Several interviewees observed that one-size fits all regulation is not appropriate and where standards are of concern different approaches might be needed.

2.8.3 Evaluation

Evaluation was identified as a gap across both the literature review and the interview study. Within the literature review, evaluation of the effectiveness of training courses and programmes along the pilot career pathway was defined as a key gap in knowledge and the available information. The majority of interviewees did not provide information on their evaluation process. Organisations running ATQP are required to include evaluation of their training because it forms part of the continuous development of the evidence-base for the training. The ATQP process used includes reviewing training reports and feedback and using data from the organisation’s safety management system including flight data. There was less information about the evaluation processes used by ATOs. One participant described collecting feedback from their airlines they train for, but beyond this no further information was obtained. A couple of responses indirectly suggested that because the checks are fixed externally, if pilots pass these checks then the training has met its purpose.

As discussed regarding the approach to pilot training and discussions surrounding the implementation of change, the evaluation of a training programme is central to determining training efficacy and presenting a business need for change.

3. BOW TIE ANALYSIS OF PILOT TRAINING

3.1 RATIONALE

Following on from the gap analysis the next step of the original project plan was to assess the output to establish the main risk areas in pilot training, i.e. topics or activities where industry has difficulties and where the research is not able to provide a solution, and prioritise these using a hazard workshop facilitated by safety engineers. However, because there was only limited mapping between the two data sources, the list of issues and considerations, some of which were positive and some of which indicate potential concerns, or threats, did not lend itself to this type of quantitative analysis. Nor was it possible to scale the threats through comparison with safety occurrence data because these data are highly specific and the majority of issues associated with current practice are higher level, more system related issues. Therefore, a Bow Tie analysis approach was adopted as the most suitable way to present the projects varied findings and to facilitate prioritisation of issues to inform the final recommendations.

3.2 DEVELOPEMTN OF BOW TIES

The bowtie approach to risk assessment builds on a barrier thinking approach to informing prospective safety management activities. It was used in this project because it allows for visualisation of qualitative information around hazards and mitigations to develop a 'risk picture' associated with pilot training. The basic format of a bowtie is shown in Figure 1.

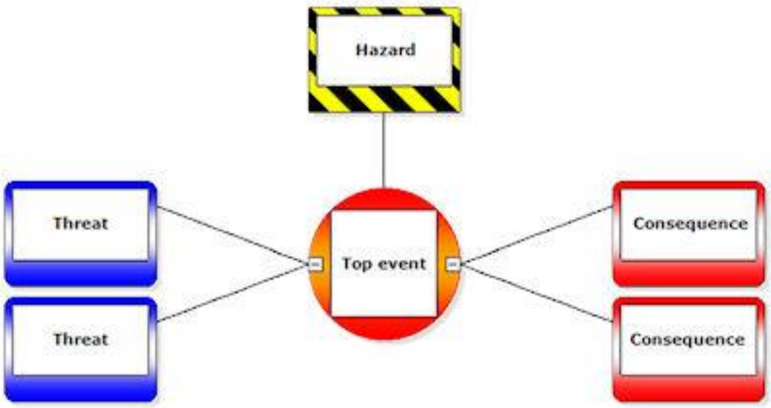

Figure 1. High level diagram of the contents bow tie structure (from the CAA website)[3]

For the purposes of this study the different elements of bow-tie were defined as

- **Threats = Elements of the training system that do or could result in problems occurring;**
- **Top Event = Sub-optimal pilots within the system;**
- **Hazard = Reduced Pilot Effectiveness;**
- **Consequence – Pilot training as a casual factor in adverse events.**

[3] The CAA website provides a summary and examples on use of the Bowtie approach for risk assessment. This information is available from: https://www.caa.co.uk/Safety-Initiatives-and-Resources/Working-with-industry/Bowtie/

In this study, the ‘threats’ form a summary of the ‘residual risks’ derived from the gap analysis (described in Section 2). The initial concern is that these threats could result in sub-optimally trained pilots within the system, although there are other reasons why pilot could perform sub-optimally beyond the scope of training. If sub-optimal pilots get ‘on to the line’ then the effectiveness of their performance would be reduced, which can then result in increased risk of adverse events. Reduced pilot effectiveness could also have an impact on other measures of organisational performance and effectiveness, however, the focus of this study was on training. To prevent the threats turning into hazards, there are ‘controls’ in place. The first line of controls should reduce the likelihood of even having sub-optimal pilots in the system. In the event they are unsuccessful there are further controls that should prevent the negative ‘consequences’ of reduced pilot effectiveness, which in this case is pilot training as a causal factors in adverse events.

3.3 PILOT TRAINING BOWTIES

Five bow tie diagrams were developed to reflect the categories identified in the gap analysis:

- Content;
- Pilots;
- Instructors;
- Tools and devices;
- Governance and regulation.

The overall approach to training issues are provided throughout the other themes.

The bow tie diagrams were structured with the residual risks identified through the research project as threats, and possible mitigating activities recorded as prevention controls. The top event, hazard, recovery controls and consequence are consistent across the diagrams and therefore each diagram can be seen as an element of a summative bow tie. A snapshot of one full bowtie is shown in Figure 2 (outline schematic only, component-legible bowties are depicted in Figures 3-8).

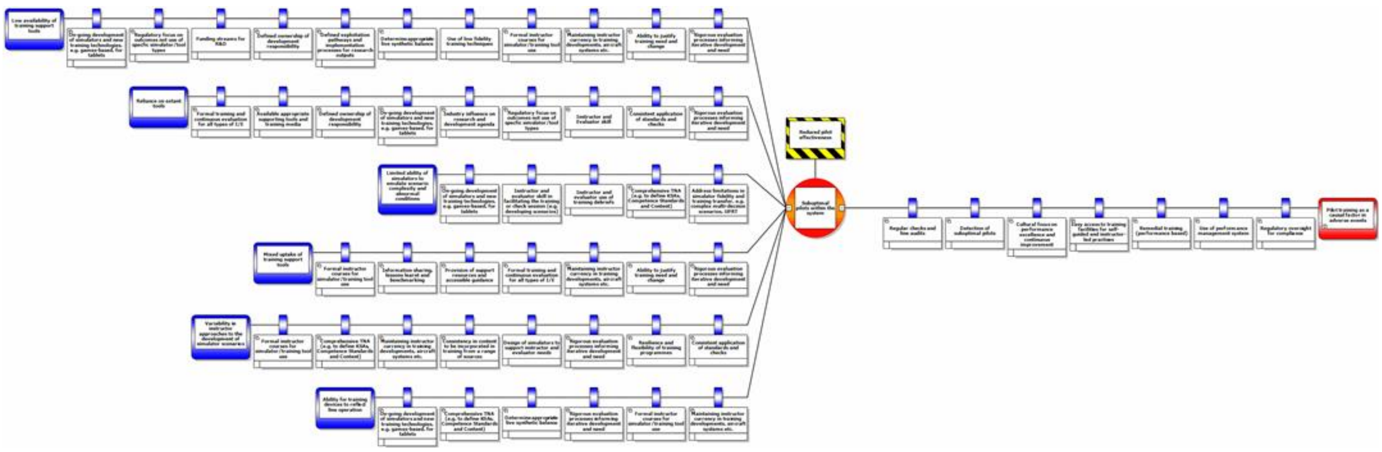

Figure 2. Example of complete Pilot Training Bowtie – Tools and Devices

Diagrams of the bowties are presented in fold-out pages in Figure 3 to Figure 8. The actual bow-ties in BowTieXP software (version 7.0.8) are provided separately.

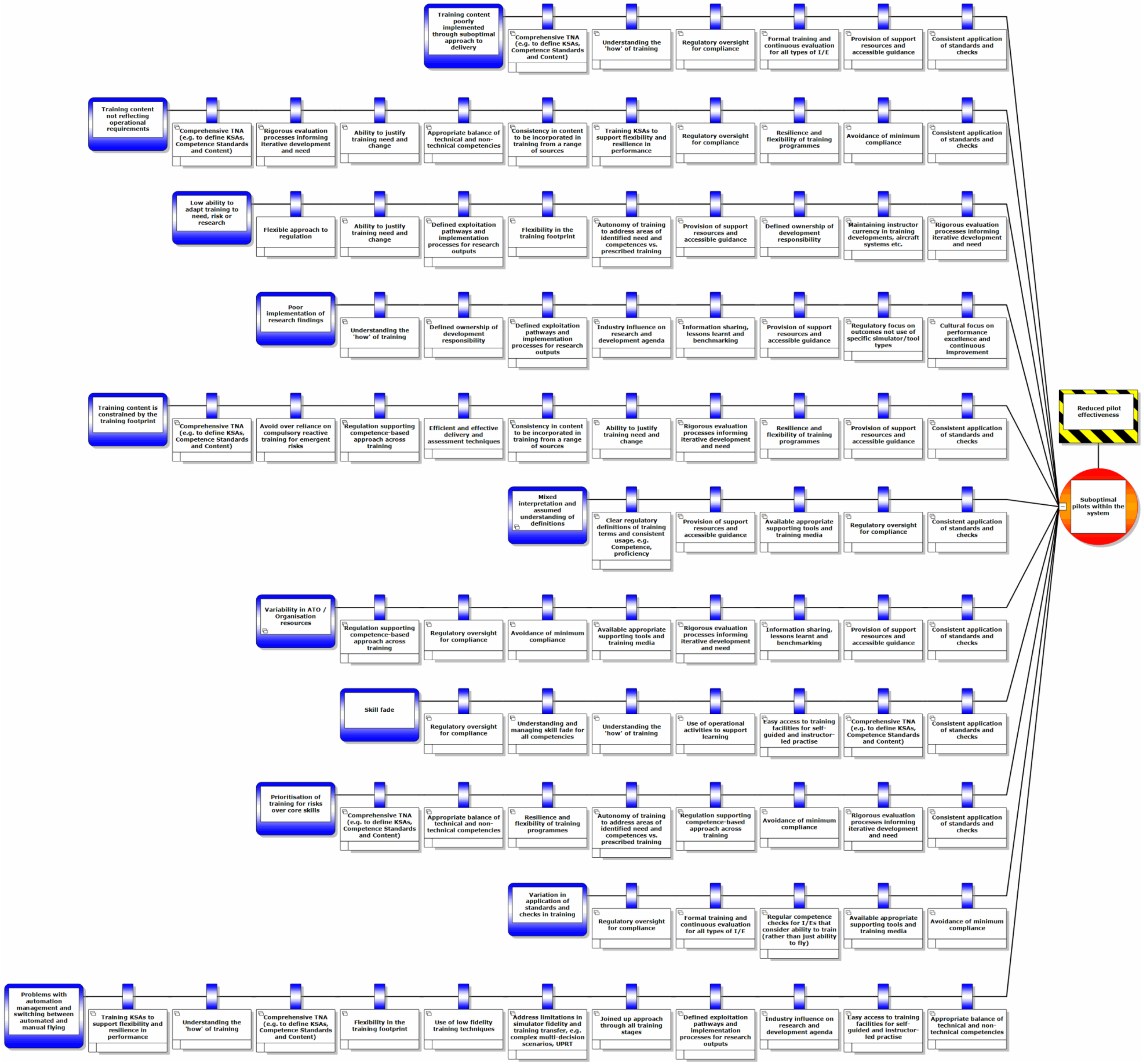

Figure 3. Pilot Training Bowtie – Content and Delivery Threats

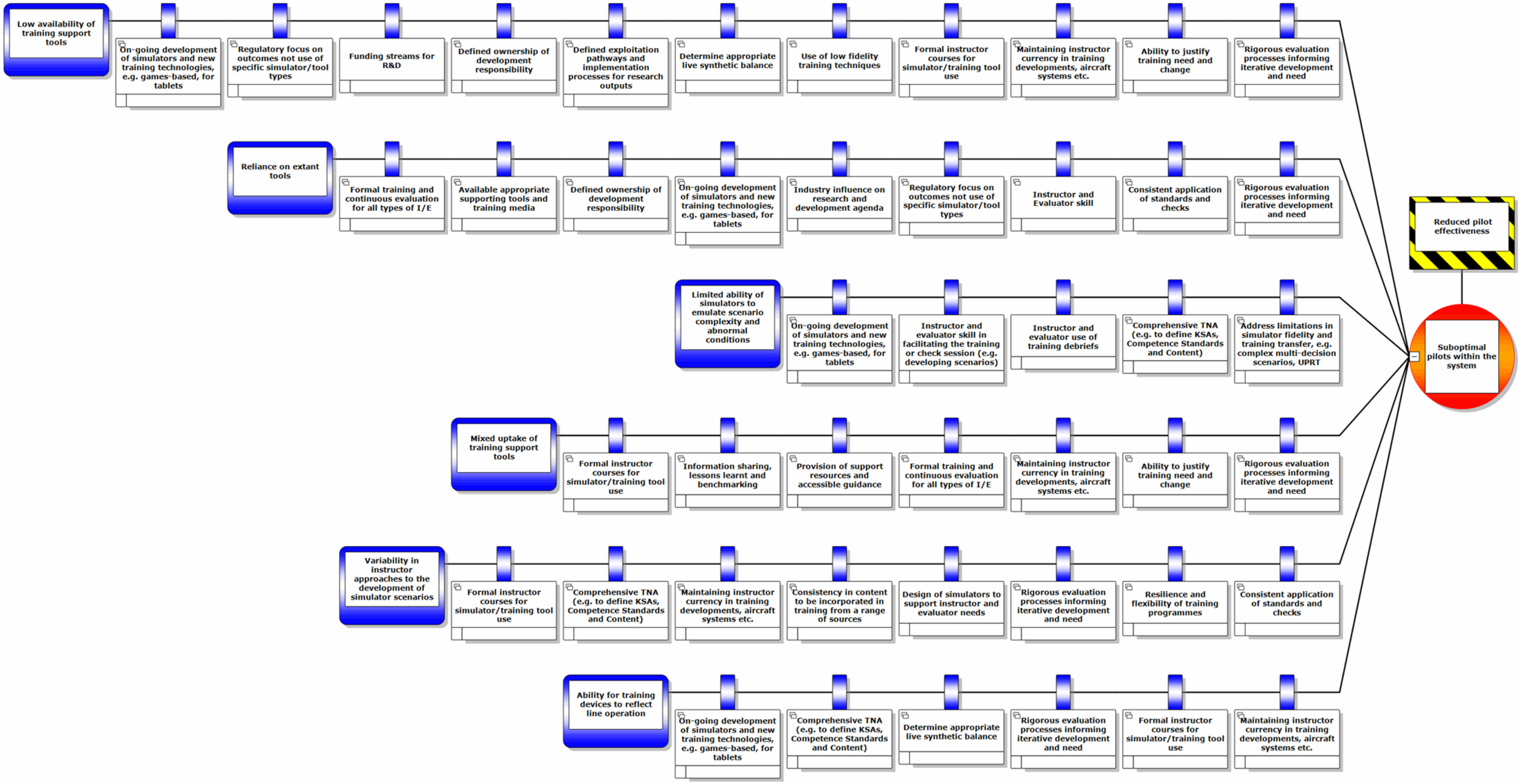

Figure 4. Pilot Training Bowtie – Tools and Devices Threats

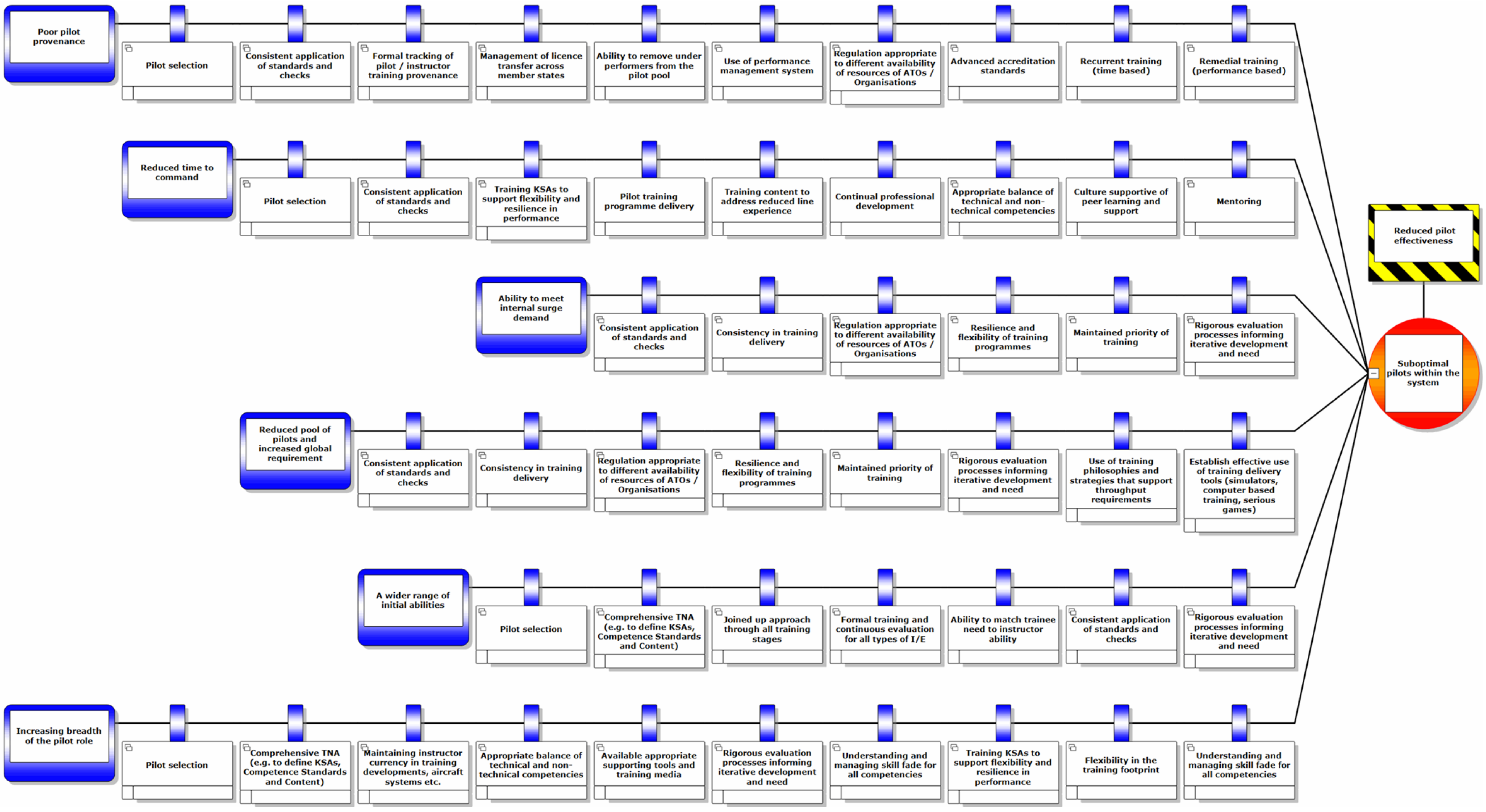

Figure 5. Pilot Training Bowtie – Pilot Threats

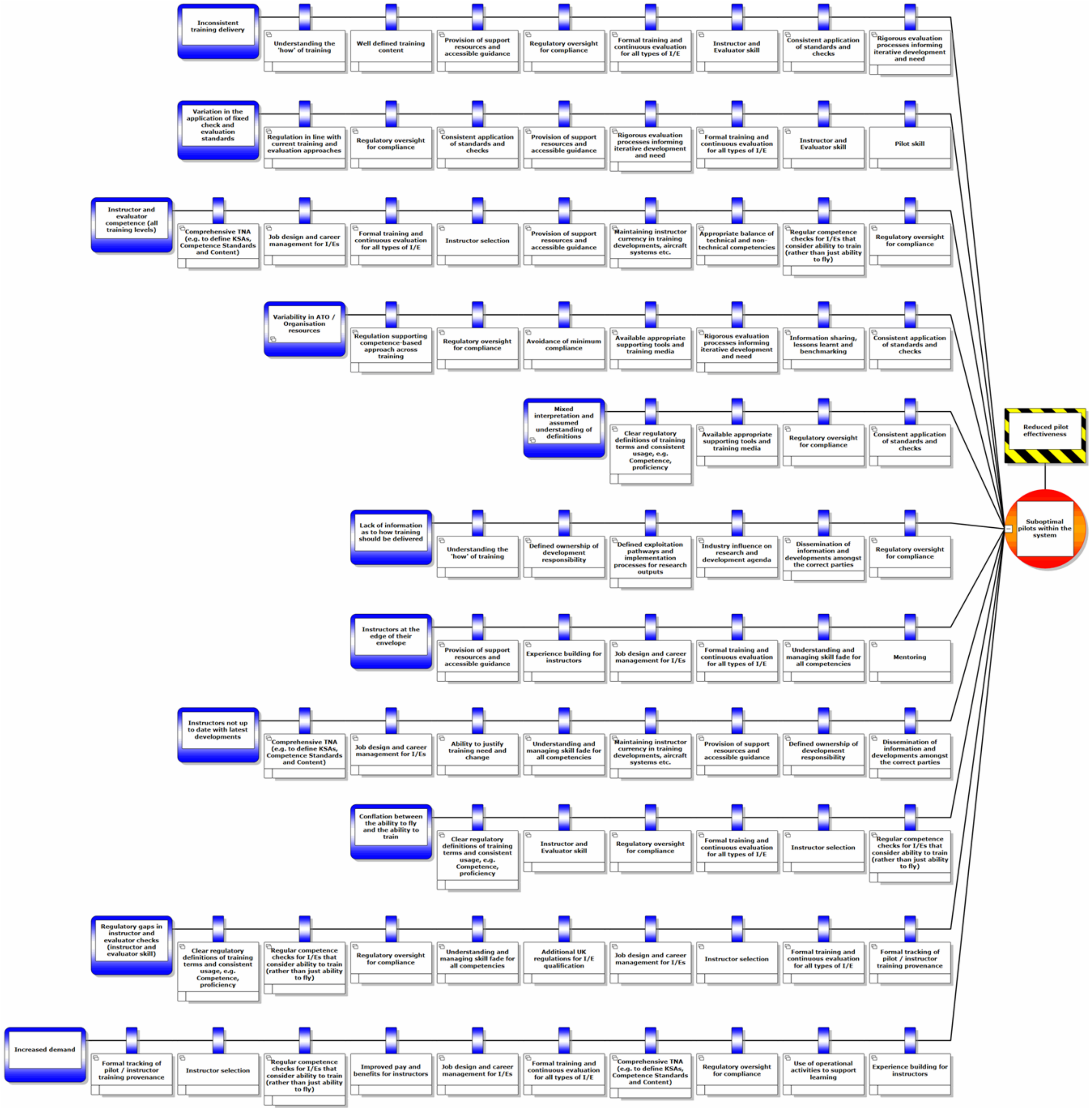

Figure 6. Pilot Training Bowtie – Instructor Threats

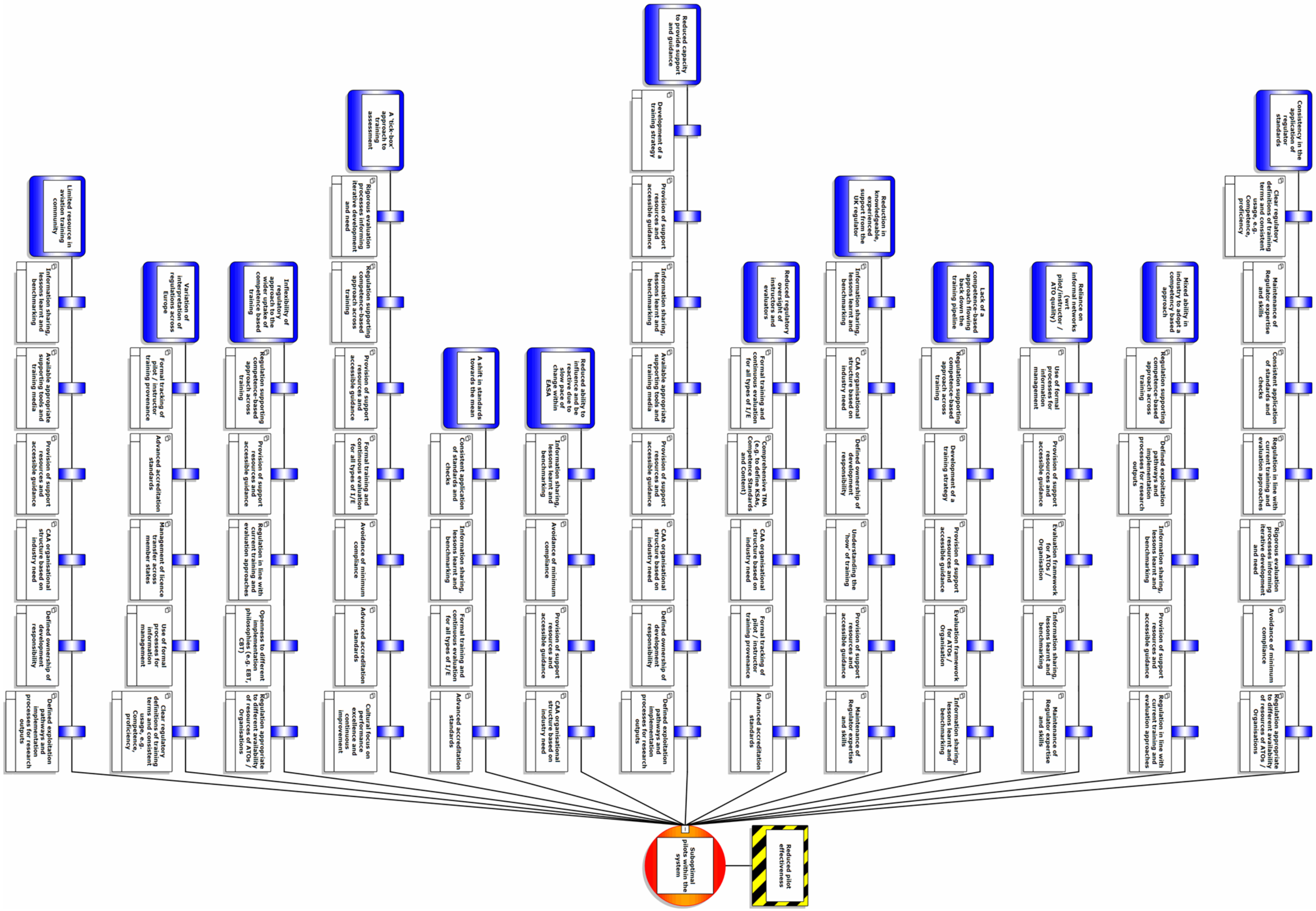

Figure 7. Pilot Training Bowtie – Governance and Regulation Threats

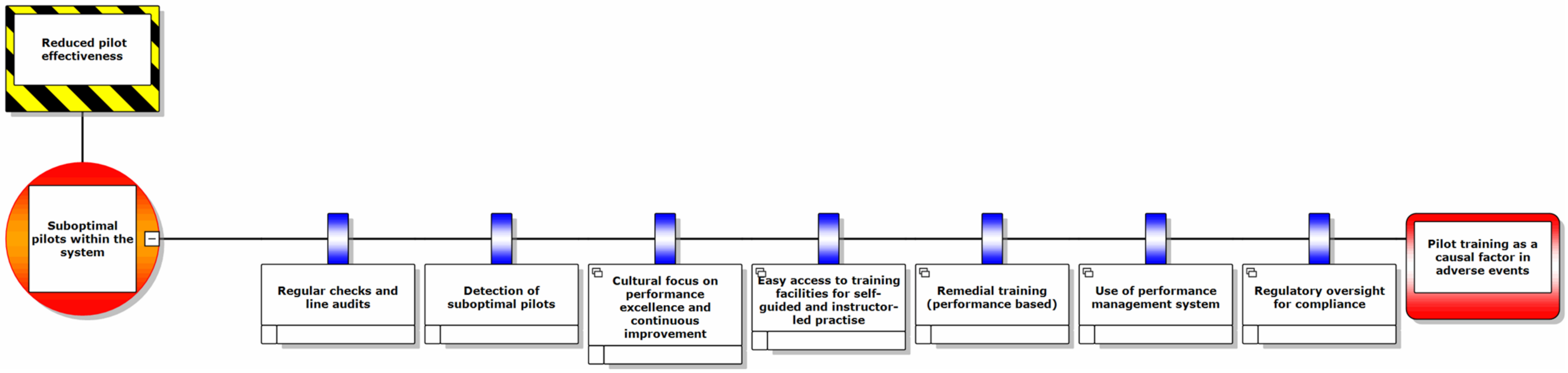

Figure 8. Pilot Training Bowtie – Consequences (All)

3.4 ANALYSIS FROM BOWTIES

3.4.1 Threats

A total of 47 threats were identified across the five themes comprising the overall pilot training system. The full set of these threats is shown in Table 1. These threats are at different levels of granularity, with some describing quite specific issues and other reflecting more general concerns. Based on the authors' judgement of the findings from previous stages of the project, the most salient and critical of these threats have been identified in this table in **red bold text**. The other threats are also important and need to be managed, but the 27 in bold are considered to represent the biggest challenge or greatest risk for pilot training and safety.

Table 1. Identified 'threats' for pilot training

Theme	Threats
Content & Delivery (n=11)	▸ Training content poorly implemented through suboptimal approach to delivery ▸ **Training content not reflecting operational requirements** ▸ Low ability to adapt training to need, risk or research ▸ **Poor implementation of research findings** ▸ **Training content is constrained by the training footprint** ▸ Mixed interpretation and assumed understanding of definitions ▸ Variability in ATO / Organisation resources ▸ **Skill fade** ▸ **Prioritisation of training for risks over core skills** ▸ **Variation in application of standards and checks in training** ▸ **Problems with automation management and switching between automated and manual flying**
Training Tools / Devices (n=6)	▸ **Low availability of training support tools** ▸ Reliance on extant tools ▸ **Limited ability of simulators to emulate scenario complexity and abnormal conditions** ▸ Mixed uptake of training support tools ▸ Variability in instructor approaches to the development of simulator scenarios ▸ Ability for training devices to reflect line operation
Pilots (n=6)	▸ **Poor pilot provenance** ▸ **Reduced time to command** ▸ Ability to meet internal surge demand ▸ Reduced pool of pilots and increased global requirement ▸ **A wider range of initial abilities** ▸ **Increasing breadth of the pilot role**
Instructors (n=11)	▸ Inconsistent training delivery ▸ Variation in the application of fixed check and evaluation standards ▸ **Instructor and evaluator competence (all training levels)**

Theme	Threats
	Variability in ATO / Organisation resources Mixed interpretation and assumed understanding of definitions **Lack of information as to how training should be delivered** **Instructors at the edge of their envelope** **Instructors not up to date with latest developments** Conflation between the ability to fly and the ability to train **Regulatory gaps in instructor and evaluator checks (instructor and evaluator skill)** **Increased demand**
Governance & Regulation (n=13)	**Consistency in the application of regulator standards** Mixed ability in industry to adopt a competence-based approach Reliance on informal networks (wrt pilot/instructor/ATO quality) **Lack of a competence-based approach flowing back down the training pipeline** **Reduction in knowledgeable, experienced support from the UK regulator** **Reduced regulatory oversight of instructors and evaluators** **Reduced capacity to provide support and guidance** Reduced ability to influence and be reactive due to slow pace of change within EASA A shift in standards towards the mean A ‘tick-box’ approach to training assessment **Inflexibility of regulatory approach to the wider uptake of competence based training** **Variation of interpretation of regulations across Europe** **Limited resource in aviation training community**

3.4.2 Barriers

An analysis has been conducted to show the frequency of occurrence of the different controls. The full list of controls for all threats across the five bow-ties are provided in Annex A.1, and the list of controls for the most critical threats, i.e. those in red in Table 1, are shown in Annex A.2.

The top 30 most frequently occurring barriers for the most critical threats are listed in Table 2. These are controls that appear three or more times across the bow-ties. The barriers that are highlighted in blue *italics* are new barriers that have been added to address explicit gaps in current controls. These are discussed further in section 3.4.3.

Table 2. Most frequently occurring controls for critical threats

Barrier	*Occurence*
1. Comprehensive TNA (e.g. to define KSAs, Competence Standards and Content)	**12**
2. Provision of support resources and accessible guidance	***11***
3. Consistent application of standards and checks	**8**
4. Regulatory oversight for compliance	**8**
5. Defined ownership of development responsibility	***7***
6. Formal training and continuous evaluation for all types of I/E	***7***
7. Rigorous evaluation processes informing iterative development and need	**7**
8. Appropriate balance of technical and non-technical competencies	**6**
9. Defined exploitation pathways and implementation processes for research outputs	***6***
10. Understanding and managing skill fade for all competencies	***6***
11. Formal tracking of pilot / instructor training provenance	***5***
12. Information sharing, lessons learnt and benchmarking	***5***
13. Job design and career management for I/Es	**5**
14. Understanding the 'how' of training	***5***
15. Ability to justify training need and change	***4***
16. Available appropriate supporting tools and training media	***4***
17. Avoidance of minimum compliance	***4***
18. CAA organisational structure based on industry need	***4***
19. Maintaining instructor currency in training developments, aircraft systems etc.	**4**
20. Pilot selection	**4**
21. Regular competence checks for I/Es that consider ability to train (rather than just ability to fly)	**4**
22. Regulation supporting competence-based approach across training	***4***
23. Training KSAs to support flexibility and resilience in performance	**4**
24. Advanced accreditation standards	***3***
25. Clear regulatory definitions of training terms and consistent usage, e.g. Competence, proficiency	***3***
26. Easy access to training facilities for self-guided and instructor-led practise	***3***
27. Industry influence on research and development agenda	***3***
28. Instructor selection	**3**
29. Regulation appropriate to different availability of resources of ATOs / Organisations	**3**
30. Resilience and flexibility of training programmes	**3**

The most frequently occurring controls are those that would address the most threats across the training system. Hence highlighting these is one approach for prioritising areas of future work. However, this does not mean that unique controls could not provide an important (or even critical) benefit for addressing specific threats. For example:

- "Management of licence transfer across (EASA) member states" is a control that helps to address two threats: "Poor pilot provenance" and "Variation of interpretation of regulations across Europe", which are perceived as being real risks for UK aviation community. The current regulation processes make this a paper exercise rather than a proactive management activity that would ensure more thorough verification and standards checking for pilots looking to transfer into or return to the UK following training elsewhere in the EASA area;

- "Improved pay and benefits for instructors" is a control for the threat of "Increased demand" for instructors". It only appears once but improving the employment offer for instructors, particularly for non-operator, early career training ATOs, would support recruitment and retention, providing more capacity in the market and driving improved quality and standards.

With a full bow tie analysis it would normally be possible to rate the effectiveness of the controls. The data collected from this study are not broad enough to do this because of the broad nature of the interviews and limitations of the sample of smaller organisations. However, such an activity could be undertaken in future industry workshops, perhaps grouping organisations according to the scale of organisation and operations. The majority of the barriers relate to existing control mechanism. Their levels of effectiveness will likely depend on the organisation being considered. This would have led to most being rated as 'variable' – or Amber in a simple traffic light coding, hence this coding has not been applied because it provides no discriminating value. Indeed, even large organisations reported struggling with a number of challenges for training suggesting that all areas of the community could benefit from improvements across a wide variety of barriers.

As examples:

- "Rigorous evaluation processes informing iterative development and need" is done very thoroughly in some organisations, not least because it is required for ATQP but for other organisations training evaluation is difficult or not a priority; it may be particularly challenging for independent training schools to evaluate the long term effectiveness of their programmes when the pilots they train move on and are flying for operators. Also, if the final point of training is to pass a basic licencing or type rating proficiency check, the pass rate may be used to indicate training quality but this does not consider transfer to an operational environment;

- "Comprehensive TNA (e.g. to define KSAs, Competence Standards, Content)" is likewise also completed by some organisations, although the extent of the processes underpinning this were not identified. So how far this is undertaken in non-ATQP organisations and smaller ATOs is not clear. Nor was it possible to locate any aviation industry guidance for conducting rigorous TNAs, with the exception of military organisations;

- "Job design and career management for I/Es" is something that would be done by individual organisations (perhaps beyond a certain size) but it does not appear to be considered across the industry in terms of how to have a career as a ground school or flying instructor. Improved consideration of the overall career path for being an instructors might be one step to making it a more popular and rewarding option.

3.4.3 Proposed additional barriers

As stated previously, there were some clear gaps in the training system where there some types of control that would be beneficial are apparently missing or not defined explicitly. To address these gaps additional controls have been proposed. The full list of additional barriers is shown in Table 3.

Table 3. Additional barriers suggested to address gaps (in frequency order for all threats)

Barrier
Provision of support resources and accessible guidance
Formal training and continuous evaluation for all types of I/E
Information sharing, lessons learnt and benchmarking
Defined ownership of development responsibility
Avoidance of minimum compliance
Defined exploitation pathways and implementation processes for research outputs
Regulation supporting competence-based approach across training
Understanding the 'how' of training
Ability to justify training need and change
Clear regulatory definitions of training terms and consistent usage, e.g. Competence, proficiency
Understanding and managing skill fade for all competencies
Advanced accreditation standards
CAA organisational structure based on industry need
Formal tracking of pilot / instructor training provenance
Industry influence on research and development agenda
On-going development of simulators and new training technologies, e.g. games-based, for tablets
Maintenance of Regulator expertise and skills
Development of a training strategy
Joined up approach through all training stages
Management of licence transfer across member states
Use of formal processes for information management
Use of low fidelity training techniques
Additional UK regulations for I/E qualification
Avoid over reliance on compulsory reactive training for emergent risks
Evaluation framework for ATOs / organisations
Funding streams for R&D
Improved pay and benefits for instructors
Training content to address reduced line experience

Examples of some of these include:

- "Defined ownership of development responsibility" is included because it became clear that following a change in role of the CAA there is a lack of ownership of responsibility for driving pilot training developments. Without this, there is no coherent strategy and plan for on-going development in the training system. Individual organisations may do what they can to support their own requirements (providing they can justify it) but there is no mechanism to encourage proactive, broader reaching, longer term improvements;

- "Advanced accreditation standards" would provide an additional layer of governance to allow operators and ATOs to work to higher standards that set by the standard regulations. They could propose appropriate training industry best practice for development, delivery and evaluation, along with a quality assurance function to check the practices are being properly implemented;
- "Understanding and managing skill fade for all competencies" while it is recognised that manual flying skills degrade there is still a gap in understanding about the exact training requirements to address this for different types of operations, including maintaining the confidence to make the switch to manual flight. Furthermore, skill fade can apply to other types of (knowledge and) skills if they are not maintained to the requisite level of frequency, and this would apply to both pilots and instructors.

3.4.4 Consequences

As stated previously, for the purpose of this project just one negative consequence of training risks was identified for this project: "Pilot training as a causal factors in adverse events." A list of barriers to mitigate against this should sub-optimal pilots get into the system, i.e. previous controls for mitigating the basic threats have not been effective, are shown in Table 4.

Table 1. Barriers to sub-optimal pilots in the system resulting in adverse events

Barrier	*Occurrence*
Regulatory oversight for compliance	16
Cultural focus on performance excellence and continuous improvement	3
Easy access to training facilities for self-guided and instructor-led practise	3
Remedial training (performance based)	2
Use of performance management system	2
Detection of suboptimal pilots	1
Regular checks and line audits	1

It is worth noting that all of these barriers also act as a control elsewhere in the bowties. For example, "Easy access to training facilities for self-guided and instructor-led practise" is also a mitigation for threats from "Problems with automation management and switching between automated and manual flying" and "Skill fade" in the Content and Delivery area.

Clearly, there are also other consequences to having sub-optimal pilots in the system, which are important for organisations overall performance and effectiveness. Indeed, considering some of these could make it easier to demonstrate the case for further or continuous training improvement when safety standards are already high but due to growing demands and complexity in the aviation industry the threats still remain. For example, it might be easier to justify changes to training that would provide improved automation management if it were possible to show a commercial benefit from more effective use.

3.5 ESCALATION FACTORS

Escalation factors are not identified within the bow tie diagrams as the aim is for these diagrams is to show a high level summary. The research programme focussed on identifying the risks, and, therefore, there is a limit into the detail that can be provided about risks associated with the prevention controls. Instead we have included a section of generic escalating factors that apply across all of the diagrams.

Table 5 illustrates the escalating factors that will influence pilot training going forward. These factors, identified from the interview study by direct questioning about the challenges for pilot training in the future, demonstrate that the training system is going to face increasing pressures and strains. The factors have identified may reduce the effectiveness or erode proposed suggested mitigations against the identified risks, increasing the likelihood of risks resulting in hazards and consequences.

Table 5. Escalating Factors

Theme	Escalating Factor
People-related	Increased levels of competency required for modern aircraft Instructor quality Reducing supply of pilots Reducing supply of instructors and evaluators Level of experience in reduced pool Pressure on training throughput The time it takes to generate a trained pilot Increased training with international students Increased flexible working
Economic	Increased selection by bank account Time available for training because of demands on the line Pressure on training throughput Commercial demands and pressures
Governance	Regulatory authority funding Different interpretation in regulation across EASA Movement around EASA states More cultural differences; different accountabilities Training standards
Operations and environment	Increasingly busy airspace Complexity in helicopter operations, e.g. from ATC, O&G companies Air space design and new ways of ATM Drag management
Technology	Increasing levels of technology: e.g. use of auto flight systems, use of electronic flight bags Aircraft design for the X-box generation Single pilot operations Unmanned systems

This list of escalating factors indicates that the demands on the training system, which produces the pilots and I/E needed by the aviation industry, is only going to grow in complexity going forward. As such, the threats identified will become more of a risk, and having effective controls in place across the system will be increasingly important.

4. CONCLUSION

The purpose of this task in the review of pilot training was to compare the state-of-the-art in pilot training from latest published research activities with current practice in industry to identify where there are gaps or other challenges that could increase the risk to aviation safety in the UK resulting from training.

The first stage of the task highlighted that most of the challenges in current practice are in different areas to those addressed in the research literature. The research literature tends to focus on the content of training, e.g. addressing safety concerns about how to improve training around automation, whereas the problems perceived by the training community relate more to practical issues and broader training system considerations. Clearly both of these elements of training are critical. However, the consequence of this is that the research may be poorly exploited by operators, partly because it does not address immediate practical concerns and partly because it tends to look at what to train and not how to train it. Whilst training organisations, operators and even the regulators are still having to address a range of system challenges without any practical guidance.

With this, and in the context of an increasingly demanding aviation environment, a wide range of threats were identified to the effectiveness of the pilot training. The most critical of these for maintaining safety have been highlighted. The threats have been presented in a Bow-tie analysis, with the focus being on avoidance of having poorly trained, sub-optimally performing pilots flying or instructing others at any point in the training pipeline because this could lead to increases in accidents and safety incidents. In line with the bow-tie analysis technique barriers have been identified that provide controls for managing the threats. Overall, the underpinning data and the analyses conducted did not identify any specific urgent safety risks associated with UK pilot training at present but they did indicate that the training system itself is being placed under increasing strain due to the demands being placed upon it. The combination of on-going growth, reducing pilot supply, increasingly advanced technology and ATM and changes in regulatory approach, mean that if the barriers are not fully effective, which not all are at present, then the scale and impact of these threats could be amplified in the future leading to more tangible problems and increasing safety risks. It could also be damaging to industry confidence if the necessary mechanisms are not in place to mitigate against real and potential issues arising from different standards in pilot training in other parts of the world, including the EASA zone.

Based on the outputs of this task and the two proceeding ones, what emerges is the need to consider pilot training in the UK in a more holistic, system-based manner. There needs to be improved integration across the training provided along a pilot’s career. In recognition of the broader role of pilots and the need to widen the initial pilot entry pool so training needs to be optimised. This must come through consideration of how the content is developed and adapted to development and retention of both core competence and emerging operational requirements. Instructors across the training pipeline need to be properly selected, trained and accredited to meet the needs of training new generations of pilots. Research is needed to continue exploring the best approaches and tools for learning and developing both technical and non-technical skills and knowledge associated with advanced automation, and teaching and evaluating pilot competences in a consistent fashion. All of this must then be assured considering both development processes and output standards within a governance framework that considers not just individual organisations but the relationship between them including how the regulator and other professional or industry organisations can provide support.

The key message from this analysis is that there is not just one line of activity needed to manage safety risks for pilot training, instead a range of issues need to be considered, which must be managed through a coherent set of strategies and plans. These will also allow the training community to continue developing and adapting to meet the changing needs of the industry, whilst delivering the traditional UK ‘gold standard’ for pilot training. Recommendations for achieving this are provided in the project’s Final Report.

5. REFERENCES

Federal Aviation Administration. (1996). Human factors team report on: The interfaces between flight crews and modern flight deck systems. Washington, DC: Federal Aviation Administration.

Gillen, M. W. (2008). Degradation of Piloting Skills. Accessed at: http://understandingaf447.com/extras/Gillenstudy.pdf Accessed on: 15/01/15

Holder, B. (2013). Airline Pilot Perceptions of Training Effectiveness. Boeing.

International Air Transport Association (IATA). (2013). Evidence-Based Training Implementation Guide. Accessed at: https://www.iata.org/whatwedo/ops-infra/itqi/Documents/ebt-implementation-guide.pdf Accessed on: 09/04/2015

Lyall, E. A., Boehm-Davis, D. A. & Jentsch, F. (2008). Automation Training Practitioners' Guide. http://www.researchintegrations.com/publications/lyall_etal_2008_automation_training_practioners_guide.pdf Accessed on: 06/02/15

Ministry of Defence (2016). Joint Service Publication (JSP) 822: Defence Systems Approach to Training – Direction and Guidance for Individual and Collective Training. Part 2: Guidance. Version 2.0, March 2016.

Performance-based operations Aviation Rulemaking Committee (PARC) and Commercial Aviation Safety Team (CAST). (2013). Operational Use of Flight Path Management Systems.

Todd, M. A. and Thomas, M. J. W. (2013). Experience, Competence Or Syllabus? Influences on Flight Hours at Licensing of Commercial Pilots. The International Journal of Aviation Psychology. 22, 2. pp 169-180.

ANNEX A - ADDITIONAL BOWTIE RESULTS

A.1 BARRIERS FROM BOW-TIES

The barriers currently identified to address all 47 threats across the five bow-tie diagrams. Controls may be more or less effective irrespective of the frequency of their occurrence across the bowties. Lines shown in blue *italics* represent new (additional) barriers to address current gaps.

Barrier	***# Times occurring***
1. Provision of support resources and accessible guidance	*22*
2. Consistent application of standards and checks	20
3. Rigorous evaluation processes informing iterative development and need	19
4. Regulatory oversight for compliance	16
5. Comprehensive TNA (e.g. to define KSAs, Competence Standards and Content)	15
6. Formal training and continuous evaluation for all types of I/E	*15*
7. Information sharing, lessons learnt and benchmarking	*12*
8. Available appropriate supporting tools and training media	9
9. Defined ownership of development responsibility	*9*
10. Avoidance of minimum compliance	8
11. Defined exploitation pathways and implementation processes for research outputs	*8*
12. Maintaining instructor currency in training developments, aircraft systems etc.	8
13. Regulation supporting competence-based approach across training	*8*
14. Understanding the 'how' of training	*7*
15. Ability to justify training need and change	*6*
16. Appropriate balance of technical and non-technical competencies	6
17. Clear regulatory definitions of training terms and consistent usage, e.g. Competence, proficiency	*6*
18. Resilience and flexibility of training programmes	6
19. Understanding and managing skill fade for all competencies	*6*
20. Advanced accreditation standards	*5*
21. CAA organisational structure based on industry need	*5*
22. Formal tracking of pilot / instructor training provenance	*5*
23. Job design and career management for I/Es	5
24. Regular competence checks for I/Es that consider ability to train (rather than just ability to fly)	5
25. Regulation appropriate to different availability of resources of ATOs / Organisations	5
26. Formal instructor courses for simulator/training tool use	4
27. Industry influence on research and development agenda	*4*
28. Instructor and Evaluator skill	4
29. Instructor selection	4
30. On-going development of simulators and new training technologies, e.g. games-based, for tablets	*4*

Barrier	***# Times occurring***
31. Pilot selection	4
32. Regulation in line with current training and evaluation approaches	4
33. Training KSAs to support flexibility and resilience in performance	4
34. Consistency in content to be incorporated in training from a range of sources	3
35. Cultural focus on performance excellence and continuous improvement	3
36. Easy access to training facilities for self-guided and instructor-led practise	3
37. Flexibility in the training footprint	3
38. Maintenance of Regulator expertise and skills	*3*
39. Regulatory focus on outcomes not use of specific simulator/tool types	3
40. Address limitations in simulator fidelity and training transfer, e.g. complex multi-decision scenarios, UPRT	2
41. Autonomy of training to address areas of identified need and competences vs. prescribed training	2
42. Consistency in training delivery	2
43. Determine appropriate live synthetic balance	2
44. Development of a training strategy	*2*
45. Dissemination of information and developments amongst the correct parties	2
46. Evaluation framework for ATOs / Organisation	*2*
47. Experience building for instructors	2
48. Joined up approach through all training stages	*2*
49. Maintained priority of training	2
50. Management of licence transfer across member states	*2*
51. Mentoring	2
52. Remedial training (performance based)	2
53. Use of formal processes for information management	*2*
54. Use of low fidelity training techniques	*2*
55. Use of operational activities to support learning	2
56. Use of performance management system	2
57. Ability to match trainee need to instructor ability	1
58. Ability to remove under performers from the pilot pool	1
59. Additional UK regulations for I/E qualification	*1*
60. Avoid over reliance on compulsory reactive training for emergent risks	*1*
61. Continual professional development	1
62. Culture supportive of peer learning and support	1
63. Design of simulators to support instructor and evaluator needs	1
64. Detection of suboptimal pilots	1
65. Efficient and effective delivery and assessment techniques	1
66. Establish effective use of training delivery tools (simulators, computer based training, serious games)	1
67. Flexible approach to regulation	1

Barrier	***# Times occurring***
68. Funding streams for R&D	*1*
69. Improved pay and benefits for instructors	*1*
70. Instructor and evaluator skill in facilitating the training or check session (e.g. developing scenarios)	1
71. Instructor and evaluator use of training debriefs	1
72. Openness to different implementation philosophies (e.g. EBT, CBT)	1
73. Pilot skill	1
74. Pilot training programme delivery	1
75. Recurrent training (time based)	1
76. Regular checks and line audits	1
77. Training content to address reduced line experience	*1*
78. Use of training philosophies and strategies that support throughput requirements	1
79. Well defined training content	1

A.2 BARRIERS FOR MOST CRITCAL THREATS

The currently identified barriers for the 27 most critical threats from all bow-ties. As in A.1, the controls may be more or less effective irrespective of the frequency of their occurrence across the bowties, and lines shown in italics represent new (additional) barriers to address current gaps.

Barrier	***# Times occurring***
1. Comprehensive TNA (e.g. to define KSAs, Competence Standards and Content)	**12**
2. Provision of support resources and accessible guidance	***11***
3. Consistent application of standards and checks	**8**
4. Regulatory oversight for compliance	**8**
5. Defined ownership of development responsibility	***7***
6. Formal training and continuous evaluation for all types of I/E	***7***
7. Rigorous evaluation processes informing iterative development and need	**7**
8. Appropriate balance of technical and non-technical competencies	**6**
9. Defined exploitation pathways and implementation processes for research outputs	***6***
10. Understanding and managing skill fade for all competencies	***6***
11. Formal tracking of pilot / instructor training provenance	***5***
12. Information sharing, lessons learnt and benchmarking	***5***
13. Job design and career management for I/Es	**5**
14. Understanding the 'how' of training	***5***
15. Ability to justify training need and change	***4***
16. Available appropriate supporting tools and training media	**4**
17. Avoidance of minimum compliance	***4***
18. CAA organisational structure based on industry need	***4***
19. Maintaining instructor currency in training developments, aircraft systems etc.	**4**
20. Pilot selection	**4**
21. Regular competence checks for I/Es that consider ability to train (rather than just ability to fly)	**4**
22. Regulation supporting competence-based approach across training	***4***
23. Training KSAs to support flexibility and resilience in performance	**4**
24. Advanced accreditation standards	***3***
25. Clear regulatory definitions of training terms and consistent usage, e.g. Competence, proficiency	***3***
26. Easy access to training facilities for self-guided and instructor-led practise	***3***
27. Industry influence on research and development agenda	***3***
28. Instructor selection	**3**
29. Regulation appropriate to different availability of resources of ATOs / Organisations	**3**

Barrier	***# Times occurring***
30. Resilience and flexibility of training programmes	**3**
31. Address limitations in simulator fidelity and training transfer, e.g. complex multi-decision scenarios, UPRT	**2**
32. Consistency in content to be incorporated in training from a range of sources	**2**
33. Cultural focus on performance excellence and continuous improvement	**2**
34. Development of a training strategy	***2***
35. Dissemination of information and developments amongst the correct parties	**2**
36. Experience building for instructors	**2**
37. Flexibility in the training footprint	**2**
38. Joined up approach through all training stages	***2***
39. Maintenance of Regulator expertise and skills	***2***
40. Management of licence transfer across member states	***2***
41. Mentoring	**2**
42. On-going development of simulators and new training technologies, e.g. games-based, for tablets	***2***
43. Regulation in line with current training and evaluation approaches	**2**
44. Regulatory focus on outcomes not use of specific simulator/tool types	**2**
45. Remedial training (performance based)	**2**
46. Use of low fidelity training techniques	***2***
47. Use of operational activities to support learning	**2**
48. Use of performance management system	**2**
49. Ability to match trainee need to instructor ability	**1**
50. Ability to remove under performers from the pilot pool	**1**
51. Additional UK regulations for I/E qualification	***1***
52. Autonomy of training to address areas of identified need and competences vs. prescribed training	**1**
53. Avoid over reliance on compulsory reactive training for emergent risks	***1***
54. Continual professional development	**1**
55. Culture supportive of peer learning and support	**1**
56. Detection of suboptimal pilots	**1**
57. Determine appropriate live synthetic balance	**1**
58. Efficient and effective delivery and assessment techniques	**1**
59. Evaluation framework for ATOs / Organisation	***1***
60. Formal instructor courses for simulator/training tool use	**1**
61. Funding streams for R&D	***1***
62. Improved pay and benefits for instructors	***1***
63. Instructor and evaluator skill in facilitating the training or check session (e.g. developing scenarios)	**1**
64. Instructor and evaluator use of training debriefs	**1**
65. Openness to different implementation philosophies (e.g. EBT, CBT)	**1**
66. Pilot training programme delivery	**1**

Barrier	*# Times occurring*
67. Recurrent training (time based)	**1**
68. Regular checks and line audits	**1**
69. Training content to address reduced line experience	**1**
70. Use of formal processes for information management	***1***

Frazer-Nash Consultancy Ltd
The Cube
1 Lower Lamb Street
Bristol
BS1 5UD

T +44 (0)117 9226242
F +44 (0)117 9468924

www.fnc.co.uk

Offices at:
Bristol, Burton-on-Trent, Dorchester,
Dorking, Glasgow, Plymouth, Warrington
and Adelaide