Unconscious Competence and Safety Assurance

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Abstract

Providing safety assurance for anything but the simplest of systems is difficult and these difficulties increase significantly when individual and organizational human factors must be considered. The aim of this paper is to raise awareness of the importance of competence management for organizations and individuals involved in developing safety-related systems. The paper will examine how individual and team competence plays a vital role in the overall safety assurance process. A basic understanding of competence is required before it can be examined in any detail and this paper will review some common definitions of competence before identifying its basic components. Much of the competence literature originates from the teaching profession and is encapsulated in various theories of learning. The paper will examine the Conscious Competence Model to facilitate a discussion of the basic process of developing and maintaining competence. The paper will then present an overview of general competence management principles including the essential process of specifying safety competence criteria. Safety assurance is ultimately based upon the competence of the people involved in safety engineering and competence is a vital requirement for the validity of any safety claims made. The paper will examine common deficiencies related to competence for safety assurance and some suggestions will be made regarding how to improve the validity of safety claims based upon competence.

Introduction

In the article entitled The Alchemy of Competence, Durand stated:

> *"In medieval times, alchemists were seeking to turn base metals into gold. Today, managers and firms seek to turn resources and assets into profits. A new form of alchemy is needed in the organization. Let's call it competence."* (ref. 1).

Durand suggests that competence is an important organizational concept and, accepting the validity of this assertion, by extension it can be stated here that competence is critical for organizations and individuals operating in safety-related domains and applying professional judgement to safety-related claims. The achievement of sufficiently low levels of system risk is now critically dependent on both individual and team competence.

Safety-related systems often include a complex mixture of hardware, software and people and they frequently use new technologies. While new technologies have enabled systems to function more effectively this has brought its own challenges; particularly increased design complexity leading to greater demands when providing safety assurance. The prevalence of complex systems using novel technologies has accentuated the vital role of people engaged in the design, development, maintenance and operation of safety-related systems. In addition to increasing systems complexity the modern, rapid pace of technological and environmental change often results in regular restructuring of organizations and roles often leading to the erosion of organizational competence as staff and team changes are frequent.

Many current systems safety standards have recognised the importance of competence and some have even made competence management a specific requirement for the development and operation safety-related systems. For example, IEC 61508 Part 1 specifies normative requirements for the competence of staff performing safety-related functions (ref. 2). Annex B of Part 1 is informative and provides guidance on what should be considered when assessing a person as competent to perform a particular safety-related role. Unfortunately, the requirements and information provided in IEC 61508 lacks detail on how the requirements can be achieved in practice.

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A potent combination of increasing systems complexity, new technologies and organizational changes are now typically affecting safety-related industries and these factors can have an detrimental effect upon staff safety competencies. Any degradation of competence in safety-related industries can pose significant risks unless the effects of both systems and organizational change are managed through the implementation of competence management processes that are proportional to the risk involved.

It can be concluded that a crucial component in the management of functional safety is the competence of all those with a role to play throughout the safety system lifecycle. Safety standards such as IEC 61508 (ref. 2) specify explicit requirements for the management of functional safety including reference to the need for those involved in any part of the safety system lifecycle to have the necessary competence. However, before competence can be managed it must be understood. Taking a reductionist approach, the concept of competence will be examined here and reduced to its component parts before considering how it may be managed.

Understanding Competence

Competence is a term that is frequently used by safety practitioners but it can mean different things to different people therefore it is valuable to examine common definitions of the term.

General Definitions: The term 'competence' generally means *the ability to do something successfully or efficiently* and many synonyms are used for competence including: capability; ability; proficiency; expertise and skill. A differentiation is sometimes made between the closely related terms 'capability' and 'competence' whereby capability can mean the ability of an organization while competence can mean the ability of an individual to do something (ref. 3). However, it is more common to use the term competence to relate to both organizations and individuals and that convention will be used throughout this paper.

The UK Engineering Council (EC) defines competence as:

> *"The ability to carry out a task to an effective standard. Its achievement requires the right level of knowledge, understanding and skill, as well as a professional attitude."* (ref. 4).

The definition of competence given by UK Office of Rail Regulation (ORR) is similar:

> *"The ability to undertake responsibilities and to perform activities to a recognised standard on a regular basis. Competence is a combination of practical and thinking skills, experience and knowledge, and may include a willingness to undertake work activities in accordance with agreed standards, rules and procedures."* (ref. 5).

The UK Health & Safety Executive (HSE) defines competence as:

> "*The ability to undertake responsibilities and perform activities to a recognised standard on a regular basis"* (ref. 6).

The HSE also assert that to be competent an organization or individual must have:

- Sufficient knowledge of the tasks to be undertaken and the risks involved.
- The experience and ability to carry out their duties in relation to the project, to recognise their limitations and take appropriate action to prevent harm to those carrying out work, or those affected by the work.

Competence develops over time and individuals develop competence through a progressive mix of initial training, on-the-job learning, instruction, assessment and formal qualification. In the early stages of training and experience, individuals should be closely supervised. As competence develops, the need for direct supervision should be reduced (ref. 7).

Competence Components: While general definitions of competence are helpful, a more detailed understanding of the constituent elements of competence can help to understand how it may be managed. There are many existing explanations of the elements of competence; however, many are consistent with EC, ORR and HSE in identifying the three main components of competence which are shown in Figure 1.

Figure 1 – Basic Competence Components

- **Skills** are the things that experienced people often do subconsciously. For example, a guitarist requires motor skills and must *know how* to coordinate the hands to finger chords and execute strum patterns. Skills can be thought of as the automatic execution of a plan of action.
- **Knowledge** is acquired through training and it is required to enable people to formulate a plan of action. For example, a guitarist must *know what* fingers go where to play a certain chord (but may not have the skill to do so).
- **Attitude** is associated with personal attributes such as morality, determination, fastidiousness etc. For example, a dedicated guitarist with a high degree of determination will *know why* a good attitude will make them more competent than an aimless guitarist with exactly the same knowledge and skills.

IET publications on competence (refs. 8-9) suggests that competence consists of: technical skills; behavioural skills; underpinning knowledge and underpinning understanding. A distinction is made by IET between technical skills and behavioural skills. Technical skills can be thought of as those vocational skills learned for a specific role (e.g. an aircraft pilot's motor skills or their ability to interpret meteorology reports) while individual behavioural skills are more general (e.g. the ability to communicate or problem solving ability).

Whatever definition of competence is used, one thing is consistently clear. Competence involves much more than technical training, it includes attitudes and behaviour as well as experience and knowledge of the application domain (ref. 6). Competence might be transferable from one work situation to another, but the extent to which this is possible depends very much on the *context* in which apparently similar competence is required. For example, an individual considered competent to develop software for an aircraft In-Flight Entertainment system will almost certainly not be considered competent to undertake the development of the Flight Management System (FMS) for that aircraft without having the experience and detailed knowledge of FMS functionality and, importantly, how the FMS is used operationally.

Understanding and defining competence is necessary, but it is not sufficient to facilitate an understanding of how competence may be acquired and maintained which is also required to enable competence to be properly managed.

Developing and Maintaining Competence

Much of the literature on competence comes from the teaching profession and is encapsulated in various theories of learning. One prevalent model of learning, and change management in general, is the Conscious Competence Model (CCM) which will be examined here as it is useful to frame the discussion presented later on organizational and individual safety competence.

The earliest origins and various definitions of the 'conscious competence' learning theory are uncertain; ancient sources such as Confucius and Socrates are cited as possible early originators of seminal thinking and writings relating to the 'conscious competence' model, together with more recent authors and academics. Several claims of original authorship exist for the four stage 'conscious competence' model,

terminology, definitions, structure, etc., one of the strongest being from Robinson (ref. 10). Notwithstanding the various claims to original authorship, many of the proponents of the CCM consistently advocate the separate stages of learning (or change) depicted in Figure 2.

- **Unconscious Incompetence** state is when a person or organization is blissfully unaware of their lack of a specific skill, knowledge or attitude required for a given task.
- **Conscious Incompetence** state is when a person or organization becomes aware of their lack of a specific skill, knowledge or attitude required for a given task.
- **Conscious Competence** is when a person or organization has consciously attained a degree of skill, knowledge or attitude required for a given task but it requires conscious effort to complete.
- **Unconscious Competence** is when a person or organization has attained a high degree of automatic skill, knowledge and attitude required for a given task and it requires minimal or no conscious effort to complete.

Figure 2 – Conscious Competence Model

Some practitioners and academics have suggested that there should be a fifth state of the CCM to address a missing step whereby an unconsciously competent person can regress to unconscious incompetence due to changing environmental factors or the erosion of competence through the development of bad habits. Consider a car driver who is unaware that there has been a change to urban speed limits (environmental factor) or who becomes complacent and ignores safe braking distances (bad habits). It has also been argued that unconscious actions may be undesirable in a safety-related context as they may increase the probability of a hazardous human error even in a competent person (ref. 11).

Once a state of unconscious competence is attained, proactive measures must be taken to maintain that state; for example professional engineers (or chartered engineers) are required to undertake Continuing Professional Development (CPD) to maintain their knowledge, experience, skills and personal qualities. CPD encompasses both the acquisition of new skills to broaden competence and the enhancement of existing skills to keep abreast of evolving knowledge. It should be considered that the name of the CCM model may not be appropriate as the name implies that conscious competence is the aim when in fact the ultimate aim is the acquisition and maintenance of *unconscious competence*.

Notwithstanding these issues, the CCM is a useful model to frame any discussion of safety competence and how it may be acquired and maintained both at the organizational and individual level. Typically, an organization can be characterized as operating at the unconscious incompetence level until some point in time when they are either awarded a contract with some safety requirements to fulfil or they simply recognize that developing safety-assured systems is a good business strategy and from necessity they will transition to the conscious incompetence level. The organization could then take action to initiate training to take individuals and teams to the conscious competence state and after time (and perhaps some on-the-job training) individuals and teams could transition to the unconscious competence state. The organization could even transition directly from the conscious incompetence to unconscious competence through judicious recruitment of competent staff.

The aim for any organization should be to facilitate the transition of the organization and individuals from conscious incompetence to unconscious competence and to maintain that level through the formal development and implementation of a Competence Management System (CMS) and competence criteria.

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Competence Management and Criteria

To attain a state of unconscious competence within an organization there are two main issues to address. Firstly, the organization needs to implement a formal CMS to provide the framework (processes and procedures) that will ensure that competence can be successfully acquired and maintained. CMS processes and procedures are not unique to safety-related organizations; they are usually similar regardless of the role of an organization: they will be the same for a clothes manufacturer or a space agency.

Secondly, as part of the establishment of a CMS, an organization must specify competence criteria specific to the roles, functions, attributes and tasks for which competence is required. Competence criteria will be very different between organizations and even within organizations. For example, even within a safety-related organization the roles, functions, attributes and tasks undertaken by the software engineering staff will differ from the systems engineering staff. A brief examination of CMS and competence criteria follows to provide the foundation for an examination of potential problems related to competence and the provision of safety assurance.

Competence Management Systems: There are numerous generic CMS models available (see refs. 5 and ref. 7 for two good examples). Like many other management systems, most CMS involve a number of related management activities and processes to integrate a iterative cycle of: planning, design, operation and maintenance. It is not the intention of this paper to present a detailed examination of a specific CMS. However, an overview of the HSE CMS model is provided here to identify safety-related aspects of what is essentially a generic competence management model. The HSE CMS model is shown in Figure 3 (ref. 7) and some further explanation of the main CMS phases, and it's focus on competence criteria, is also provided.

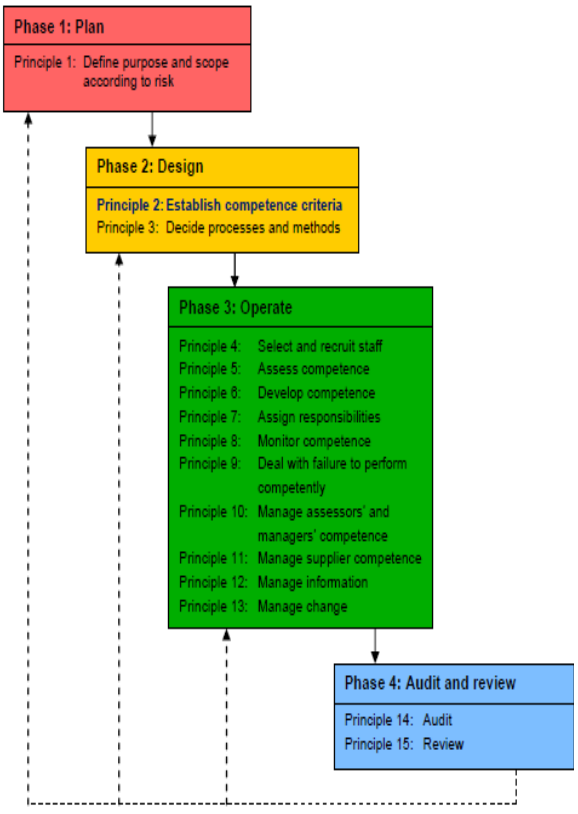

Figure 3 – HSE Competence Management Model

Phase 1: Plan. The planning phase aims to specify all work activities to be included in the CMS based on the risk associated with those activities. This activity is equally applicable to all phases of the CMS development including the specification of competence criteria as the plan will include a defined list of roles, functions, task and activities for which safety-related competence is required within a given organization.

Phase 2: Design. Principle 2 of the CMS Design phase requires developers to establish competence criteria that covers all activities within the scope of the CMS and gives sufficient confidence that all staff that meet particular criteria are competent to perform the related work activity.

Phase 3: Operate. This phase aims to address all the issues related to the operation of the CMS from staff recruitment to the management of change. All of the underlying principles of the operation phase rely upon the adequate specification and application of competence criteria to the roles, functions, task and activities for which safety-related competence is required within a given organization.

Phase 4: Maintain. This phase aims to verify that the CMS, including the specified competence criteria, is fulfilling the aims and objectives identified and specified in the planning phase. Audits and subsequent

review activities may initiate changes to the specified competence criteria which in turn may necessitate some additional management action e.g. recruitment or training.

It can be concluded from Figure 3, and the discussion above, that the identification of functions, decomposition of functions into tasks and attributes and the specification of appropriate competence criteria is a critical part of the process for establishing an satisfactory CMS and therefore it is helpful to examine in some detail exactly what is required.

Safety Competence Criteria: Competence criteria must be specified for the roles, functions, attributes and tasks for which competence is required in an organization or individual. The relationship between roles and functions can be confusing and needs to be clarified. A function may be fulfilled by an individual or by a team. When working in a team, each individual contributes to the performance of the function by performing a role within the team and typically carrying out part of the function. If the entire function is fulfilled by an individual then they do still perform a role equivalent to carrying out the whole function. A role can therefore be equivalent to a function or it may be a part of a function.

A function can be thought of as the high-level things that an organization needs to do to achieve a specified goal; for example, functions arise from the activities associated with achieving the goal of providing functional safety assurance. Each function is decomposed into a set of tasks (e.g. functional failure analysis) each of which require the necessary technical skills and knowledge to be defined. In addition, each function is decomposed into a set of attributes (e.g. technical awareness) each of which require the necessary behavioural skills and knowledge to be defined.

For an organization developing safety-related systems an example function may be to provide *Functional Safety Management*; associated tasks may include: *Define Safety Management Policy*; *Allocate Safety Responsibilities* and *Promote Safety Culture*. Typical attributes for the individual or team undertaking the function may include: *Effective Communication*; *Professional Standing* and *Personal Integrity*.

The tasks and attributes defined for a specific function are typically specified at three different levels of competence which can be summarised as follows (refs. 8-9):

- **Supervised:** has sufficient knowledge and understanding of good practice, within the organization or within the relevant industry sector, to be able to work on the tasks associated with the overall function without placing an excessive burden on the practitioner or expert who is responsible for checking their work.

- **Practitioner:** has sufficient knowledge and understanding of good practice, and sufficient demonstrated experience, to be able to work on tasks without the need for detailed supervision.

- **Expert:** has sufficient understanding of why things are done in certain ways, and sufficient demonstrated managerial skills, to be able to undertake overall responsibility for the performance of a task or function.

For each of the competence levels that are appropriate to a given task or attribute, competence criteria will be specified. For example, for the function *Functional Safety Management*, the Expert level competence criteria for the task *Define Safety Management Policy* could be expressed as (refs. 8-9):

> *"Has developed at least one Corporate safety management policy and has been involved in the development/ review of others. Can identify organization methods and procedures, which have had to be updated to meet new standards in functional safety assurance, and show how the updated methods and procedures fit within the organization's safety management system."*

Similarly, the Expert level competence criteria for the attribute *Effective Communication* may be expressed as (ref. 8-9):

"Is acknowledged as proficient in communicating information orally in all situations. Has established effective liaison with the organization's management such that safety issues are raised at the highest level. Has effective relationships with relevant external organisations, such as regulatory bodies."

For any CMS established and operated within a safety-related domain, the validity of the competence criteria will have a critical influence on the efficiency and effectiveness of the CMS and in turn on the ability of an organization or individual to provide safety assurance for safety-related systems.

Competent Safety Assurance

The discussion so far has focused on the theoretical aspects of competence: what competence is; how it may be acquired and maintained and how it may be managed. The remainder of the paper will examine some prevalent issues related to organizations and individuals for whom competence is a crucial element for the provision of safety assurance.

Organizational Competence: If an organization does not have competent safety engineering staff working on the development (or operation) of safety-related systems then the organization is unlikely to produce tolerably safe systems. Organizations that are new to developing safety-related systems don't usually have safety competent staff and often the approach to competence will be reactive and programme dependent rather than the implementation and operation of a defined corporate-level CMS. In the absence of a CMS, commonly organizational competence deficiencies can be categorised as: Distributed Competence; Limited Competence or False Competence.

- **Distributed Competence**. Safety engineering relies significantly upon both general safety process expertise and specific system or domain knowledge and they are both equally important for safety assurance. Distributed competence can be characterised by an organization that predominantly (or exclusively) outsources the responsibility for the safety engineering process to specialist safety consultants while their own staff provide the system and domain knowledge. In this situation safety competence is distributed between internal and external staff. While this may appear a cost effective solution, there are real risks such as the likelihood that external staff will not share the values and culture of the organization which can lead to bad outcomes for the safety assurance process. When distributed competence is the norm an organization can at best be categorised at the *unconscious competence* stage and will remain so unless staff with competence in general safety process are trained or recruited.

- **Limited Competence**. Another common scenario occurs when an organization which does not have core safety competence is awarded a contract to develop, operate or maintain a safety-related system and they select existing employee(s) to undertake the safety roles (typically this will be someone in Quality Assurance or Logistics Management). The person(s) selected will usually have little or no safety competence and they will often be expected by management to teach themselves safety engineering skills and to apply them on the job. These organizations have limited competence and the responsible person undertaking the safety role will quickly reach the conscious incompetence stage while the organization itself can blissfully remain at the *unconscious competence* stage.

- **False Competence**. Some organisations have a false view of their own safety competence; this can occur when safety staff are out of date with changes in safety knowledge or have inadequate skills. For example, staff may not have appropriate systems or domain knowledge or their technical safety skills and knowledge may be for mechanical safety but not for software safety. Existing safety staff may not undertake continuing professional development in order to maintain proficiency with changing safety standards for example. An organization such as this may be consider to be at the unconscious competence level when it may in fact be these organisations exhibit false competence and may be regressing to *unconscious incompetence* (see discussion on CCM fifth stage above).

To be clear, a single organization could exhibit one or more of the above competence limitations but these are typical generalizations of many existing organizations, even including some that possess mature safety

management systems. Organizations that exhibit characteristics of Distributed Competence; Limited Competence or False Competence can often have serious problems providing adequate safety assurance as they will be operating at the *unconscious competence* state and will be unaware of the safety-related skills, knowledge and attitudes necessary to competently undertake safety-related activities.

In addition to addressing any safety competence deficiencies at the organizational level, a CMS must also consider potential deficiencies related to the competence of individuals (or team) involved in the provision of safety assurance.

Individual Competence Issues: Safety assurance is ultimately based upon the competence of the people involved in the safety assurance process and individual competence is a vital requirement for assessing the validity of any safety claims made. Individual competence can have a significant influence on the safety engineering process; particularly where professional judgement is applied and there is an critical relationship between safety competence and the application of sound professional judgement for safety-related systems developers. Professional judgement (or expert opinion or engineering judgement) can be defined as the ability of a person or group to draw conclusions, give opinions and make interpretations based on a combination of evidence from diverse sources such as experiments, measurements, observations, knowledge and experience (ref. 12). Professional judgement is frequently used by systems developers of all disciplines and it relies upon a combination of impartial and biased facts and opinions and, for anything but simple scenarios, subjectivity can be hard to discriminate from objectivity. For example, the problems of objectivity and perception when applying professional judgement to decisions on risk have been well documented (ref. 13).

Professional judgement is often used when an expert doesn't have any accurate or statistically significant data and the order of magnitude required for the solution to be acceptable is estimated by applying judgement gained through a combination of: academic training; experience and professional development - in other words competence. Professional judgement can be considered poor if highly subjective evidence is accepted as fact without consideration of where or how the evidence is derived and without an appreciation of when it is overstated or simply invalid. Safety assurance claims are always founded to some extent upon professional judgement and unless the individual (or group) making those judgements are competent to do so conclusions, opinions or interpretations may be derived from incomplete or inadequate evidence (see ref. 14 for a more detailed discussion on this topic).

Safety assurance is ultimately a matter of professional judgement and professional judgment is based inexorably upon competence. Safety-related system developers, operators and maintainers have a responsibility to show where professional judgement has been applied and, for safety assurance claims, how that judgement is defensible. The application of professional judgement is a necessity for any systems development; however, it remains problematic; particularly for safety-related systems development. Safety assurance evidence can be deficient due to safety competence limitations and also safety claims may be over-reliant on professional judgement.

Competence Evidence: At both organizational and individual levels it has been argued here that competence is a critical element for all safety assurance claims. Regardless of the specific method used for demonstrating safety assurance, it is also asserted that an essential goal for safety assurance must be to demonstrate competence validity at both organizational and individual levels. A claim of competence validity must be supported by comprehensive and compelling competence evidence which should be routinely sought to support an overall safety assurance claim.

All safety evidence must be both comprehensive and compelling and to demonstrate that both direct evidence and meta-evidence (i.e. evidence about evidence) should routinely be sought (ref. 14) to underpin safety assurance arguments. If it is accepted that the validity of a safety claim is critically dependent upon both organizational and individual competence then compelling evidence and associated meta-evidence related to competence must also be provided. Competence evidence must be presented to support both organizational level claims of competence and meta-evidence must be presented to support individual level competence-based claims.

- **Claims of Competence.** These claims will be founded upon the presentation by the organization of compelling evidence of the existence of a proportional CMS with adequately defined safety competence criteria that together enable an organization to effectively manage and assess the competence of the individuals involved in the safety assurance process. If safety competence cannot be managed and assessed then no claim can be made about the validity of either claims to fulfil explicit safety competence requirements (like those of IEC 61508 in Ref. 1) or the implicit requirement for competence where professional judgement is applied to other safety assurance activities.

- **Competence-Based Claims**. These claims are made to provide assurance that other safety claims, arguments and evidence are based upon sound professional judgements made by competent people. For example, a claim could be made that a safety-related system can achieve a certain failure rate and evidence would be presented to support the failure rate claim; perhaps from a Fault Tree Analysis (FTA) of the system. At some level the claimed system failure rate will be underpinned by the application of professional judgement (e.g. human failure rates in the FTA); therefore, some meta-evidence is required relating to the identification of where the judgement was applied and for each instance the competence of the individuals providing that judgement. The original claim is related to a failure rate and failure rate assessment is based upon professional judgement therefore the original claim is a competence-based claim and meta-evidence is required.

Conclusions

Competence has been defined as the ability to carry out a task to an effective standard; its achievement requires appropriate knowledge, skills and personal attributes. The CCM has been presented as a useful model to frame the discussion on how safety competence can be acquired and maintained both at the organizational and individual level. The aim of organizations and individuals should be to transition from unconscious incompetence to unconscious competence and to maintain that state through effective competence management processes and through the definition of suitable competence criteria.

All organizations that develop, maintain or operate safety-related systems need to implement competence management systems which are proportional to the risks involved and they must also address common competence deficiencies related to organizations and individuals as competence is critical for the provision of safety assurance. Organizations with significant competence deficiencies cannot provide adequate safety assurance as they operate at the unconscious competence state and are simply unaware that a problem even exists let alone have any awareness of the detailed competence requirements necessary to undertake safety assurance activities.

Professional judgment is always applied by safety engineers at some point in the safety assurance process and the validity of that judgement is critically dependent upon individual competence. Safety assurance therefore relies fundamentally upon the competence of all those contributing to the development, operation and maintenance of safe systems. As safety assurance is ultimately based upon the competence of the people involved in the process; it is essential that the validity and level of individual competence underlying safety assurance claims is identified and assessed.

The validity of any safety claim is critically dependent upon organizational and individual competence therefore compelling evidence and associated meta-evidence must be provided to support both *claims of competence* (safety competence can be assessed and managed) and *competence-based claims* (competent judgements are made).

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Biography

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