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FORM B

Control Change Cause Analysis

Investigator's Manual

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3CA
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Preface

The Noordwijk Risk Initiative was founded to promote sharing of knowledge in the field of risk management. Based on the belief that a virtuous circle exists between making tools and developing theoretical understanding, the Foundation develops tools for risk management and maintains them in the public domain.

Purpose of this document

The Noordwijk Risk Initiative Foundation publishes this document to encourage the efficient and effective investigation of incidents. It is intended for line managers and supervisors, as well as specialists in various disciplines such as occupational safety, environmental protection and quality management.

The NRI Foundation intends to maintain this manual in the public domain. Our motivations are:

1. to help decision-makers identify from unwanted events the lessons they need to learn;
2. to provide a reference point for investigators, tool developers, researchers and students.

Structure of this document

Within this manual, the Control Change Cause Analysis method (3CA, B-form) is explained in three complementary ways. First, the ideas and conventions are introduced. Second, with the novice user in mind, 3CA is described as a set of procedural steps. Third, to support the more experienced 3CA user, summary instructions for 3CA are provided in a single-page aide memoire.

Status of this manual

3CA was produced to provide supervisors and line managers in industry with an easy-to learn, easy-to-apply method for identifying the underlying causes of accidents and incidents.

3CA now comes in two versions, Forms A and B. The manual for the A-form of 3CA was produced in 2002 following a co-operative project run in 2000 by Humber Chemical Focus and the UK Health & Safety Executive (HSE). The manual for the A-form is available at www.nri.eu.com/NRI3.pdf.

In 2007-8, the NRI Foundation and HSE worked in partnership to produce the B-form of 3CA. Initially, this project aimed at revising the original 2002 manual. However, the revision process produced sufficient changes in the method itself for the result to be considered as something new. This is the origin of the B-form of 3CA.

Acknowledgements

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Control Change Cause Analysis

1 Introduction

Control Change Cause Analysis – 3CA – is designed to help investigators structure their inquiries into the underlying cause of incidents and to make it easy for others to review their reasoning. This manual provides an explanation of the 3CA method and a description of the process.

An incident or accident happens as part of a continuous flow of changes. From this complex whole, the 3CA analyst selects facts by using various tests of relevance to the incident or accident. The analyst sets out these facts in a worksheet to form explanations and sets of questions. The result of the analysis is a concise description of the incident – seen in terms of changes and limitations in the control of changes – and a set of questions that the investigator needs to fill gaps in the description.

2 Description of Control Change Cause Analysis

The analyst can begin the 3CA process as soon as they have the basic facts about what happened. It is best to start early because the analysis is likely to raise questions. In most investigations, the 3CA analysis will be revisited one or more times; as new facts emerge, the analyst can answer the questions posed earlier. These answers sometimes trigger new questions.

In 3CA, the analyst treats accidents and incidents as a sequence of events in which unwanted changes occur. This sequence begins with the moment that reduces control and ends with the moment that restores control. Some of the events in the sequence are “significant” in the sense that they increase risks or reduce control in the situation, so allow further unwanted changes to occur. The first job for the 3CA analyst is to identify these significant events.

With the set of significant events established, the analyst identifies what measures could have prevented them or limited their effects. To ensure the thoroughness of this identification, the analyst describes each significant event in terms that make explicit who/what is acting, the action and who/what is acted upon. In this way, the analyst scrutinises all the elements of unwanted change from the point of view of prevention.

The analyst has to identify in what ways prevention was ineffective. In the first part of the analysis the focus is on tangible barriers and controls, those at the operational level. Next, the analyst restates the facts as differences between what was expected (based on norms such as standards and procedures) and what was true in the actual situation. The differences between the actual and expected situations provide the agenda for the rest of the analysis. The investigator seeks to account for these differences in terms of the reasoning used by people responsible for the barriers and controls, the organisational and cultural factors that influenced the situation and, the systems and management arrangements that caused or allowed the difference to exist.

2.1 Sequence of the analysis

The analysis runs in parallel with other investigative efforts; after the initial 3CA analysis, you will likely make one or more revisions as further enquiries yield new insights and, in some cases, new questions. The initial 3CA analysis is performed in two parts in the sequence described below and indicated in Table 1.

In the first part, you complete column 1 (the significant events) before completing column 2 (the barriers and controls). You finish the first part of the analysis by setting priorities in column 3; these priorities decide the sequence for the second part of the analysis. In the second part of the analysis, you complete columns 4 and 5 for one significant event at a time

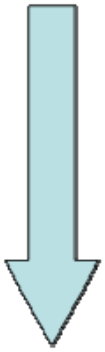
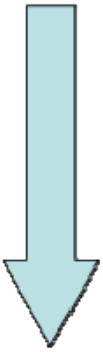
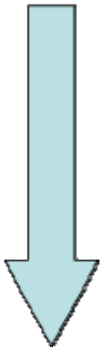
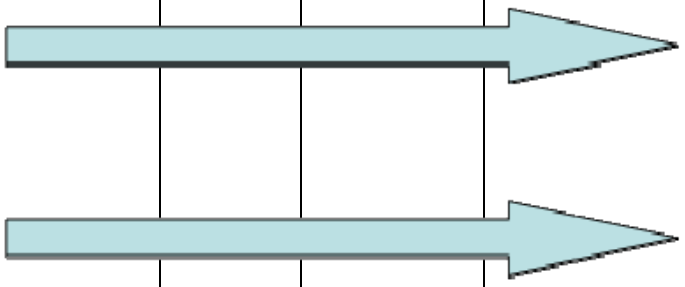
(1) Significant EVENTS	(2) Safety Barriers & Work Controls	(3) Priority for analysis	(4) Difference between situation in incident and expectations in (2)	The difference between the observed and expected behaviour is because…		
				(5a) "Original logic"	(5b) Systems	(5c) Organisational & Cultural Factors
						

Table 1. Schematic showing sequence of analysis

2.2 Begin the analysis: identify significant events

In 3CA, an event is defined as a moment of change. To be significant in 3CA terms, an event must significantly decrease the control over subsequent events and/or increase significantly the risk of subsequent unwanted events.

You begin the analysis by identifying a set of significant events from the wider collection of events that comprise the incident. The outcome of this part of the 3CA process is a list of the events marking important moments of unwanted change. It is important that you select items for analysis from a full, rather than a partial set of events. If the picture of what happened and how is incomplete, you may miss events that warrant inclusion in the analysis. To ensure completeness, you might consider using an "event sequencing" method (such as Events and Conditional Factors Analysis (ECFA+, Kingston et al[1], 2007 or STEP, Hendrick and Benner[2], 1987).

[1] Available via internet: ww.nri.eu.com/NRI4.pdf
[2] Hendrick, K. and Benner, L. (1987), "Investigating accidents with STEP". Marcel Dekker

You should keep the 3CA analysis open for review until the investigators have finished gathering evidence; this will allow you to include additional significant events as they appear in the emerging picture of facts.

2.3 In column 1, state significant events

When stating significant events, you must always phrase events in a way that makes it clear:

who or what is acting,

the action itself, and;

what is affected by the action.

When phrasing "events", you need to:

- use the form actor + action + object, in which the actor can be a person or a thing;
- use the present tense. This helps to clarify logical relationships and to exclude passive conditions from column 1;
- use the active voice. This form requires the subject of the sentence to perform the action. Hence, the passive voice sentence "*the injured person is given first aid by the paramedic*", in the active voice becomes "*the paramedic gives first aid to the injured person*". As Frei et al. (2007) note, "the active voice makes obvious the identity of the actor. It also obliges the investigator to acknowledge when they do not know who or what the actor is";
- use a transitive verb to describe the action. A transitive verb is one which requires an object, so you need to specify what is acted-upon. There can be exceptions to this rule, but transitive verbs should be the norm;
- use a verb which is concrete rather than abstract. For example, in the event "Firefighter rescues Mr Brown" it is unclear what actions the firefighter performed. An informal test of 'concreteness' is whether you can form a mental image of the event described. On this test, the phrase "Firefighter carries Mr Brown from the room" is preferable to the previous example.

2.4 In Column 2, identify barriers and controls of the 3CA table

In column 2, you need to identify barriers and controls that could have prevented the unwanted change or limited its degree. The difference between barriers and controls is that barriers exist to protect, whereas work controls exist to facilitate goals of the system. Work controls offer protection from unwanted change as a by-product. The purpose of this distinction in 3CA is to prompt you to consider both means of avoiding unwanted change. In some cases, it will not be clear whether a particular measure is a control or a barrier: this does not affect the analysis.

In column 2, you need to identify barriers and controls that are required by explicit standards; standards include written procedures, codes and technical

standards. You must also explore the possibility that best practice[3] requires a higher level of protection than achieved by these standards. These "could" barriers and controls need to be identified by a combination of knowledge of best practices and a 'first principles' approach. Concerning first principles, you can apply the ten phrases (adapted from Haddon, 1973[4]) below to the nouns and verbs used to phrase the significant event.

1. *Do not use…*
2. *Use less of…*
3. *Use safer form of…*
4. *Prevent build-up of (or divert)…*
5. *Barrier on…*
6. *Barrier between…*
7. *Separate in time or space.*
8. *Use stronger…*
9. *Evasion by…*
10. *Less people exposed or use less valuable thing…*

Table 2. Hierarchy of barriers and controls

Later on in the analysis, you will need to decide which barriers and controls it is reasonable to expect in the situation. Table 3 gives examples of barriers and controls.

Ex. 1: Mr Brown falls into the inspection pit	A barrier would be a load-bearing cover on the pit; this protects pedestrians like Mr Brown from falling. Another barrier would be to exclude pedestrians from the area. A control would be Mr Brown's awareness of where he is walking; this would direct him to his destination, avoiding traps and obstacles.
Ex. 2: Mr Brown closes valve no. 129	A barrier would be a mechanical limitation of the valve to protect it from forceful closure. A control would be for operators (like Mr Brown) to put the valve in the right state; this would require them to count the turns of the valve
Ex.3: Mr Brown starts portable pump	A barrier would be a lock-out device fitted to the pump to prevent an operator using it before an independent check by a supervisor. A control would be a "pre-use" checking routine to ensure that the assumptions of safe operation (e.g. ventilation) are met before starting the pump.
Ex. 4: Mr Brown signs off permit for hot work in area 1	A control would be the means used by Mr Brown to verify the readiness of the area before signing the permit.

Table 3. Examples of Barriers and Controls

[3] E.g. as defined by the industry or sector in general, or as defined by an application of ALARP (to reduce risks to a level as low as reasonably practical) principles.
[4] Haddon, J. (1973) *Energy Damage and the Ten Countermeasure Strategies.* Human Factors, 355-366, August 1973

2.5 In column 3, prioritise significant events

If the accident or incident is very serious, you might choose to analyse all significant events. For other incidents, the objectives of the investigation might be met by focussing attention and investigative resources on only the most important events; informing this selection is your task in column 3.

What defines importance varies from investigation to investigation. Some analysts may wish to emphasise the "risk gap" between the actual situation and one in which the risks were better controlled. Some analysts may which to highlight 'learning potential', choosing events which seem most promising with respect to identifying lessons to be learned. Whatever basis is used, setting priorities in column 3 is a subjective process and it is prudent for you to reach these decisions through consultation with others.

Criteria for assessing importance include:

- the size of the change in risk or control created by the significant event;
- the degree of risk reduction achievable if the barrier or control had been in place;
- the extent to which the barrier or control is relied upon in other situations;
- the potential for identifying valuable lessons to be learned;
- the extent to which the investigators are surprised by the facts of the event.

How to grade priority is for you to decide. Options include assigning a rank to all events, assigning labels such as high, medium and low, etc. Whatever basis you use, to allow review, you should note down your reasoning.

2.6 In Column 4, state actual and expected performance

The goal of this step is to create *contrasting pairs* of statements that make clear the difference between was expected and what actually happened. At this point you will need to review the barriers and controls identified in column 2 and decide which they can adopt legitimately as expectations. This decision is made transparent in the analysis by stating explicitly the basis for the expectation. What constitutes a legitimate basis depends on the context; examples include a procedure, expert opinion of best practice, a published standard, etc. Table 4 contains examples of pairs of "actual vs. expected" statements.

The "contrasting pairs" approach to describing is designed encourage inquiry into the immediate and underlying causes. This approach removes the need to use phrases such as *"did not…"* or *"lack of"*. Although common parlance, *"did not…"* or *"lack of"* phrases serve poorly as technical language. In particular, these phrases are judgmental, over-emphasise individual responsibility and obscure the role of perceptions, systems and culture in shaping behaviour and creating situations. Using judgemental phrases can close an analyst's mind, instead of facilitating inquiry; in 3CA analysis the aim is to explain, not to explain-away.

Example 1	ACTUAL: Inspection pit is open and Mr Brown is walking backwards operating a floor cleaning machine. EXPECTED: Inspection pit covered when not in use. [BASIS: *Company*

	Procedure xyz]
Example 2	ACTUAL: Mr Brown rotates the valve handle until limit of travel. EXPECTED: Number of turns for valve handle specified and operator counts turns. [BASIS: Industry standard, *see Training Notes xyz*].
Example 3	ACTUAL: Mr Brown starts portable pump in unventilated basement EXPECTED: Portable pump controls locked until ventilation established [BASIS: ALARP argument based on reported fatal accident frequency and cost-benefit analysis, *see dossier xyz*]
Example 4	ACTUAL: Mr Jones tells Mr Brown that the site is ready and Mr Brown signs off the permit for hot work in the area. EXPECTED: Mr Brown personally verifies condition of the site before signing permit. [BASIS: company Permit-to-Work procedure]

Table 4. Examples of 'actual—expected' pairs

2.7 In columns 5(a)-(c), explain why the expected behaviour is different from the actual

3CA analysis assumes that accidents happen, not because people want them to, but because of limitations in preventative efforts. The objective of the analysis is to understand these limitations with a view to informing improvements. To this end, the focus of the analysis in column 5 is on the difference between the actual situation (as revealed by the significant events) and a situation in which all appropriate barriers and controls are present; you should seek to explain why the difference existed. When the reasons are unknown or unproven, you will need to phrase questions to follow-up by further enquiries.

The 3CA process will lead you to think about the difference between actual and the expected in a tightly focussed way. An unwanted effect of this is a tendency for analysts to record the analysis using incomplete sentences or even just single words. To permit review by others and to facilitate writing reports, you must write questions or assertions in column 5 using complete sentences.

2.7.1 In column 5a, explain the original logic in the mind of the actor at the time in question

In column 5(a), you need to explain the difference between the actual and expected situations from the standpoint of the individuals involved. Often, the individuals will be the actors in the accident situation. Sometimes, the relevant individuals will be managers or designers of procedures or equipment.

The notion of "original logic" relates to the thoughts, motivations and assumptions accompanying an action. Even if the individual's action seems ill-considered, in retrospect, it probably made sense to them *at the time*. The questions for you to consider include "why did this action make sense to the individual before the accident?" and "what led the individual to believe this was the right way to do the job in this particular instance"? The individual may forget this "logic", or may not want to admit the errors in their reasoning. In either case, the willing participation of the individual and skilful investigative interviewing will be needed to elicit "original logic" and to discriminate this from post-accident alibis and rationalisations.

2.7.2 In column 5(b), explain the difference between actual and expected performance in terms of cultural factors and organisational issues

In column 5(b), you need to explain the influence of culture and the impact of organisational issues on behaviour. These factors can sometimes have a potent effect on behaviour, and accounting for them can contribute greatly to explaining the accident. Although of explanatory value, the focus of this part of the analysis is on conditions that are sometimes difficult to evidence and so present more of a challenge to the investigator.

The phrase 'Organisational issues' refers here to any relevant property of the organisation other than 'systems' (as defined earlier). By way of illustration, organisational issues include leadership, industrial relations, business difficulties, ownership, market-value, etc. Because change is often implicated as a cause of accidents, you need to be especially sensitive to relevant changes in these conditions.

Culture can be regarded as "patterns of behaviour that act as patterns for behaviour[5]". Culture can also be defined as "the way we do things around here" and as shared attitudes and history. Cultural factors are likely to be more stable over time than organisational issues.

2.7.3 In column 5(c), explain why systems allowed or caused the difference between actual and expected performance

In column 5(c), you need to explain the gap between actual and expected behaviour in terms of systems. In this context, the word *'systems'* refers to any organised set of activities directed to the measurement and control of behaviour, whether of people, things or conditions.

Identifying relevant systems is partly subjective; systems are constructs and people will differ, however slightly, about what a particular system will consist of. Although systems are abstract in this respect, the activities that achieve the goals of the systems are more concrete. Accident investigations tend to reveal that systems' activities controlled or measured behaviour and conditions less reliably than their designers envisaged.

You can adopt a normative approach to this part of analysis, meaning you could create a frame of reference in which to compare the situation in the accident to a model or standard system. In the literature of management, there exist many such models, some of these are encoded in published standards (e.g. such as those of ISO, ANZI etc.). If using a normative approach in 3CA, it is not enough to identify deviations from the ideal system; deviation is not explanation in itself. Instead, you need to develop a more detailed description of how the system allowed (or widened, in some cases) the gap between the behaviour expected and the actual behaviour in the significant event.

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[5] This is paraphrasing Kroeber and Kluckhohn: "*Patterns, explicit and implicit, of and for behaviour acquired and transmitted by symbols, constituting the distinctive achievement of human groups, including their embodiments in artifacts"*. Kroeber, A.L., Kluckhohn, C. (1952). A Critical Review of Concepts and Definitions. Peabody Museum Papers 47, 1. Cambridge, Mass.: Harvard University Press

Whether employing a normative system in the analysis, or if working from first principles, you need to be able to justify your assertions. Every analytical statement in column 5(b) needs to withstand a test: is it reasonable to expect the organisation in question to have the capability you are presuming.

A list of generic systems includes (in no particular order):

1. Verification of readiness
2. Housekeeping
3. Briefings and allocation of tasks
4. Selection of workers or contractors
5. Training and assurance of competence
6. Inspection
7. Maintenance
8. Worker motivation and welfare
9. Co-ordination between groups supervisors (including shift change-over)
10. Supervision of task, workers and area
11. Design/selection of equipment & buildings
12. Procurement and supply
13. Risk assessment of tasks, equipment or area
14. Procedures & technical Information
15. Planning
16. Budgeting
17. Monitoring
18. Change control systems (especially control of change to equipment and plant configuration)
19. Emergency systems
20. Audit and review

2.8 Review until investigation completed

The analysis should be regarded as provisional until a final revision is made when evidence collection is completed. This does not necessarily mean that all questions will have been answered, simply that the investigating organisation calls an end to data collection. Answered questions should be left visible in the analysis; as well as giving an accurate representation of the analyst's state of knowledge this also helps to inform any subsequent re-investigation should the case be reopened.

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3 Procedure

This procedure is written with the new user in mind: detailed steps are provided together with guidance. Once familiar with this procedure, the worksheet (appendix 1) alone should be enough to remind you of the key steps.

Task Steps	Description & Criteria	Guidance
Preparation	Study all available information about the incident	Start the analysis as soon as the facts of what happened are available. Be sure to review all steps of the analysis as new facts emerge, especially if the analysis is started early.
Column (1) Identify significant events	Review all events. Select those that significantly increase the risks of accidents or which decrease control of subsequent events. Write down the significant events in column (1) of the 3CA worksheet. Significant events MUST be phrased to make it clear who or what is acting, and how. In general, the phrase should take the form [Actor] + [action] + [object]. Complete column (1) before moving on.	*(This step is discussed in section 2.1 on page 1)* Review the events comprising the incident or accident. This step needs care: if you leave out significant events, the analysis will be incomplete and possibly misleading. You can support this task using an appropriate sequencing method (e.g. STEP or ECFA+); a carefully constructed sequence makes the identification of significant events more reliable. NB: For safety and environmental accidents, its is helpful to identify unwanted energy transfers as these often prove to be an informative sub-category of significant event.

Task Steps	Description & Criteria	Guidance
Column (2) Identify barriers and controls	In column (2) state what protective barriers and work controls apply to each significant event. Consider the barriers and controls that SHOULD have been in place according to norms applicable in the context (e.g. a work procedure). Consider barriers and controls that COULD have stopped or limited the change if they had been used. The hierarchy (shown, right) provides a list of guide phrases for this purpose. Annotate the list of barriers and controls, assigning a letter (e.g. (a), (b), (c)…) to every unique barrier or control that you identify. Repeat the letter if the same barrier or control appears more than once. This part of the analysis may need technical knowledge of the accident context. In any event, once the analysis is complete, consider requesting review by someone with expert knowledge of the technology or activity in question.	*(This step is discussed in section 2.4 on page)* The barriers and controls need to be those that operate directly on the actor, action or object comprising in the significant event. If operational, these barriers or controls would prevent the event limit its degree. A first principles approach to identifying "could" barriers and controls is to apply the list of ten phrases to each word used to phrase the significant event in column (1): 1. Do not use… 2. Use less of… 3. Use safer form of… 4. Prevent build-up of (or divert)… 5. Barrier on… 6. Barrier between… 7. Separate in time or space. 8. Use stronger… 9. Evasion by… 10. Less people or less valuable thing exposed

Task Steps	Description & Criteria	Guidance
Column (3) Prioritise significant events	In column (3) indicate the importance of each significant event to your investigation. If you are setting priorities to *deselect* events from further analysis (e.g. you might drop from further consideration all events coded "1" or "low"), you should ask others to review your decision. Record your decisions in column (3) using whatever grading scheme fits the context of your investigation. For example, assign words (e.g. high, medium, low) or rank by assigning numbers (e.g. where '1' is the highest priority).	*(This step is discussed in section 2.5 on page 5)* The aim here is to decide in which order you will consider the significant events. Criteria for assessing importance include: • the size of the change in risk or control created by the significant event; • the degree of risk reduction achievable if the barrier or control had been in place; • the extent to which the barrier or control is relied-on in other situations; • the potential for identifying valuable lessons to be learned; • the extent to which the investigators are surprised by the facts of the event.
Column (4) State actual and expected behaviour	In column (4) write <u>pairs</u> of sentences that make clear the difference between was expected and what actually happened. Use the form: [Actual:] + [Expected:] + [Standard:] You may need to write more than one pair of sentences to express all the differences between what was expected and what actually happened in the accident.	Avoid using judgemental words, such as: • 'lack of' • 'should have' • 'did not' • 'poor', 'inadequate' etc. You need to state clearly a demonstrable standard for each expectation stated. For example, the basis might be a published standard, a risk or cost-benefit analysis or expert opinion of best practice.

Task Steps	Description & Criteria	Guidance
Column (5a) Explain the difference between (expected versus actual) in terms of original logic	In column (5a) state why the actors' behaviour made sense to them at the time. Identify (or pose questions about) what led the individual to believe this was the right way to do the job in this particular instance. Be sure to state whose reasoning is the subject of discussion.	The willing participation of the individual, and skilful investigative interviewing, is needed to elicit "original logic" and to discriminate this from post-accident alibis and rationalisations. NB. Record your analysis, whether statements or questions, using complete sentences; you need to be able to reconstruct your reasoning.
Column (5b) Explain the difference between (expected versus actual) in terms of culture and organisational issues	In column (5b) explain the difference between actual and expected behaviour in terms of: (i) Cultural factors (e.g. dominant habits, attitudes, norms and local expectations); (ii) Organisational issues (e.g. structure, leadership, politics, change, business difficulties, etc.).	Culture can be regarded as "patterns of behaviour that act as patterns for behaviour". Culture can also be defined as "the way we do things around here" and as shared attitudes and history. The title 'Organisational issues' refers here to any relevant property of the organisation. Of particular relevance are changes (e.g. change of senior personnel, ownership, market-value, etc). The aim of this part of the analysis is to understand how these conditions act as factors of the behaviour observed in the accident.

Task Steps	Description & Criteria	Guidance
Column (5c) Explain the difference between (expected versus actual) in terms of 'systems'	In column (5c) state why existing systems (or those which it is reasonable to expect in the context) allowed the difference between expected and actual behaviour. If any data is missing, you should indicate this with a "?" and make an entry on your list of further enquiries. N.B. All entries in column (5) should be <u>complete sentences</u>; you need to be able to reconstruct your reasoning.	In this context, the word *systems* refers to any organised set of activities directed to the measurement and control of behaviour, whether of people, things or conditions. In 3CA terms, systems exist to minimise the gap between actual and expected behaviour. Approach this ad hoc or adopt an external frame of reference (e.g. a "management" model from published standard). Generic systems include: *(1) Verifying Readiness; (2) Housekeeping; (3) Briefings and task allocation; (4) Personnel selection; (5) Competence Assurance; (6) Inspection; (7) Maintenance; (8) Motivation; (9) Co-ordination between groups; (10) Supervision; (11) Design of Hardware and premises; (12) Procurement and Supply; (13) Risk Assessment; (14) Procedures and Technical Information; (15) Planning; (16) Budgeting; (17) Monitoring; (18) Change control systems; (19) Emergency systems; (20) Audit and review.*

Task Steps	Description & Criteria	Guidance
Review the analysis	Keep the 3CA analysis open (live) until the end of the investigation. Ensure that you: • remove as many "?" from the worksheet, as the facts emerging from the investigation allow; • Identify any additional significant events from the new facts emerging from the investigation.	Keep in mind that the "?" that you have entered into the worksheet are a valuable "deliverable" of the analysis. The investigation will leave some questions unanswered. In some cases investigators may need to: • change the objectives or terms of reference of their investigation to allow the questions to be pursued; • recommend that separate research is conducted into the questions; • accept the uncertainty remaining at the end of an accident investigation.

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Appendix 1: Aide Memoire

First, fill in these columns | *Next, fill in these columns. Start with the highest priority event. Use a new sheet for each event*

(1) Significant EVENTS	(2) Safety Barriers & Work Controls	(3) Priority for analysis	(4) Difference between situation in incident and expectations in (2)	The difference between the observed and expected behaviour is because…		
				(5a) "Original logic"	(5b) Organisational & Cultural Factors	(5c) Systems
List the events that increase risks significantly and/or significantly decrease control IMPORTANT: state each significant event in the form ACTOR + ACTION and OBJECT Ideally, select from an ECFA+ analysis; if not, carefully review the sequence of events revealed by witnesses and other sources	Identify the safety barriers and work controls that would have limited or prevented each significant event. State only barriers and controls that operate directly (i.e. overt behaviours and/or tangible things or states of things)	*How significant is this event?* *Significance should reflect how useful it will be to analyse issues using columns 4 & 5)*	State the actual behaviour/situ-ation observed and the expected behaviour or situation [mention the standard on which the expectation is based]. e.g. ACTUAL: Mr Brown closes valve no. 129. EXPECTED: Mr Brown rotates the valve 8 clockwise turns, counting the turns as he does so. [STANDARD: *Operational Note No. 123*]	Why did the 'action' people think that their Behaviour, or the situation, was okay?	How did ORGANISATIONAL issues (e.g. structure, leadership, politics, change, etc.) contribute to the issues in (4)? What CULTURAL factors (e.g. dominant habits, attitudes, norms and expectations) are relevant, and how?	How did systems cause or allow the difference? Generic systems could include: (1) Verifying Readiness (2) Housekeeping (3) Briefings and task allocation (4) Personnel selection (5) Competence Assurance (6) Inspection (7) Maintenance (8) Motivation (9) Co-ordination between groups (10) Supervision (11) Design of Hardware and premises (12) Procurement and Supply (13) Risk Assessment (14) Procedures & Technical Information (15) Planning (16) Budgeting (17) Monitoring (18) Change control systems (19) Emergency systems (20) Audit and review

Appendix 2: Example

(1) Significant EVENTS	(2) Safety Barriers & Work Controls	(3) Priority for analysis	(4) Difference between situation in incident and expectations in (2)	The difference between the observed and expected behaviour is because…		
				(5a) "Original logic"	(5b) Organisational & Cultural Factors	(5c) Systems
Warehouse supervisor orders FLT	(A) Specification of FLT	2nd	**Actual:** Request replacement **Expected:** Request 'suitable' replacement **Standard:** PUWER Reg 4 "Suitability of Work Equipment"	**Warehouse manager:** FLT broke down during busy period urgent replacement required **Hire company:** Weather protection provided only if asked for ? Why were hire company not accountable?	**Duty holder:** Reliance on generic risk assessments so bypassing active hazard seeking by their supervisors **Hire company:** Not identifying accurately client's needs for hire equipment	**Procurement & supply:** Specification of equipment to fit actual conditions of use No proactive seeking out of particular requirements by supplier
Mr Handsworth climbs between mast and cab of FLT	(B) Separate in space (don't climb) (C) Use covered FLT (D) Physical guard of side access to FLT mast-cab danger zone	3rd	**Actual:** Climbs onto cab to wrap clingfilm **Expected:** No modifications **Expected:** Alight by proper steps **Standard:** Company safety rules	**Mr Handsworth:** Need to work in moderately comfortable environment Other vehicles similarly adapted so validates it as an acceptable practice Task not seen as dangerous **Manufacturer / designer:** ? Why were additional barriers (side access) and signs (danger zone) not fitted?	**Duty holder:** Culture of allowing warehouse staff to set their own operating norms	**Duty holder:** Higher supervision (audit/inspection) ineffective **Supervision of task, workers & area:** Lack of supervision Routine violations not corrected
Mr Handsworth pushes lever	(E) Separate in space (foot/lever) (F) Ledge to prevent slip (toe-board) (G) Windscreen	4th	**Actual:** Foot contacts 'tilt' and 'raise' levers **Expected:** Physical barrier **Standard:** Supply of Machinery Safety Regulations: "Controls – control devices" **Standard:** EN 14121 Machinery Risk Assessment: "Ergonomic hazard – design, location and identification of controls"	**Manufacturer / designer:** ? Why were additional barriers (ledge or lever position) not fitted? **Hire company:** **?** Why was deficiency not identified when first procured?	**Hire company:** Absence of a culture of 'active hazard seeking' in that equipment procured for further hire to end-users	**Design of equipment:** **?** Design risk assessment did not foresee need for barrier?
FLT mast tilts inwards	(H) Seat interlock isolate energies	1st	**Actual:** System partially live when driver outside FLT **Expected:** System wholly dead when driver outside FLT **Standard:** Supply of Machinery Safety Regulations: "Protection of risks related to moving parts" **Standard:** EN 14121 Machinery Risk Assessment: "Maintenance– isolation of energy sources"	**Manufacturer / designer:** ? Why is partial isolation of energies by seat interlock acceptable? **Hire company:** ? Why was poor design feature not identified previously? **Regulator:** Identify issue and communicate appropriately ? Why was design fault not identified when third party tested?	**Manufacturer / designer:** ? Mech. engineers blind spot on human factors? **Hire company:** ? Unquestioning reliance on CE marking? **Regulator:** Compliance and enforcement issues across regulatory boundaries (BERR/HSE/LA)	**Risk assessment of equipment:** Foreseeable misuse. Revised risk assessment required. Additional risk controls (decals/training/instruction) **Procedures and technical information** Safety alerts by manufacturer, hire company and regulator. Feed-forward to BS Technical Committees

Appendix 3: Summary of differences between A and B Form of the 3CA analytical format

3CA Version			Comments
A-Form	**B-Form**		
(0) Significant Events	(1) Significant Events		Forms A and B share the same definition of significance. In the B-form, event is defined using the ECFA+ criteria which require an event to have an actor, an action and an object.
(1) Change to person or thing			The B-form requires the 3CA analyst to specify an object when stating the event
(2) Agent of change			The B-form requires the 3CA analyst to specify an Actor when stating the event
(3) Adverse effect of change			The B-form omits stating the adverse effect. The loss of information is believed to be restored by column (4).
(4) Work controls or protective barriers implicated in (1)/(2)	(2) Safety Barriers & Work Controls		Very similar. The term "protective barriers" was changed in the B-form to the more familiar term "safety barriers".
(5) Significance Rating	(3) Priority for analysis		Very similar.
(6) In what way was each measure at column (4) ineffective	(4) Difference between situation in incident and expectations in (2)		The B-form requires analyst to create pairs of statements –actual vs. expected – and to state the basis for the expectation. The A-form required statement of a failure mode (e.g. "did not use"); although "did not" type statements can be factual, they tend to be treated as explanations in themselves. Setting-up contrasting statements creates an impetus for further reasoning.
	The difference between the observed and expected behaviour is because…	(5a) "Original logic"	This column has been included in the B-form to promote insight into the reasoning and assumptions made by people who invariably did not want to cause an accident. The A-form did not prompt analysis of this form; if original logic was discussed it was as an adjunct of "upstream processes".
(7) What upstream* processes failed to identify or prevent the problems noted in (6)		(5b) Systems	The label "upstream processes" has been found to be <u>obscure</u> to many users of the A-form. The term 'Systems' is a more familiar term and trials suggest the term prompts reasoning in the way intended by the author.
		(5c) Organisational & Cultural Factors	This column has been included in the B-form to encourage analysts to consider the influence of culture and organisational context. These factors were sometimes addressed in the catch-all column (8).
(8) Why?			The three columns (5a to 5c) in the B-form provide enough room to explore the reasons underlying the accident; the catch-all column 8 of the A-form is no longer needed.

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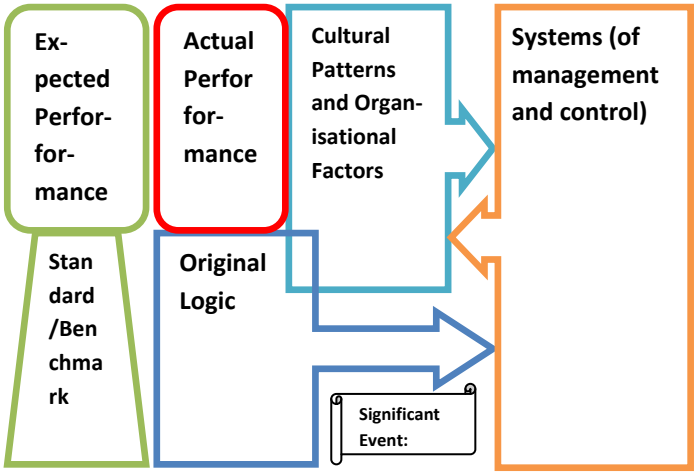
Appendix 4: Graphical Approach to 3CA

Ideally, a tool should be easy to use and to learn. The authors have observed that although some new users intuitively understand the 3CA method and table, others need to apply it to several examples before the ideas fall into place. Beginning as a training prop, a graphical approach to 3CA analysis has emerged as a simpler alternative to the 'traditional' 3CA table.



This appendix is in three parts:

Section 1 describes how to perform 3CA using a graphical approach;

Section 2 sets out the differences between the tabular and the graphical formats;

Section 3 is an aide memoire for the graphical approach.

1 How to perform 3CA using the graphical format

The aim of 3CA analysis is to help an investigator or team, to:

- ❖ thoroughly examine a significant event from a number of perspectives and to;
- ❖ capture their thinking, insights and questions. Write using complete sentences; to write reports and briefings, you'll need to be able to reconstruct your reasoning after the analysis.

The analysis begins by identifying all the significant events in the accident sequence. These need to be put in order of priority. Use <u>one</u> graphical sheet for <u>each</u> significant event to be analysed. Starting with the highest priority, analyse one significant by following the steps described below. Repeat the process for any other significant events that require analysis.

1.1 Set-up the statements of actual and expected performance

3CA analysis uses a method of "contrasting statements": a statement of what actually happened is contrasted with a statement of what is expected to happen. The resulting analysis flows from trying to explain why the actual situation was different from what was expected.

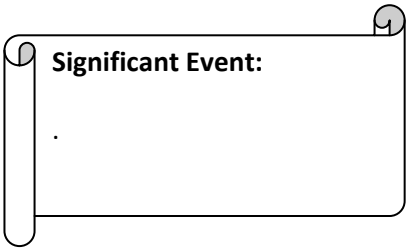
There may be one or several statements of expected performance. Each statement needs to be unambiguous and specific.

This analysis relies on expert knowledge of the activity and/or technology within which the significant event occurred. This knowledge is needed to competently identify expected performance.

1.1.1 State the Significant Event

Describe the event; say what is acting (e.g. the person or machine) and what action is being performed.

If you have performed an Events and Conditional Factors Analysis[1], phrase the significant event word-for-word as it appears in the ECFA+ analysis.



1.1.2 Describe the Actual performance

Describe what the actor actually did. Phrase your description to include the actor and the action; make this a simple, positive statement. Avoid negative phrases (e.g. failed to, did not etc.).

Sometimes this description is exactly the same as the “significant event”, but sometimes it is different. As the analysis goes on, other details of the event might turn out to be important. These extra details can be added to the description of the actual performance.

1.1.3 Describe the Expected performance

The significant event will contain an actor and an action; focus on the action and describe what performance was expected.

There may be one expectation or several; write-down every option that can be justified.

As well as prescribed options—those explicitly required by unambiguous codes and procedures—try also to identify from 'first principles' any other options that could be justified in the circumstances. Any 'first principles' option must be justified; plausibility is not enough.

[1] (ECFA+, www.nri.eu.com/ECFA_Page.htm)

1.1.4 State the Standard/Benchmark that justifies the expectation

Refer to a specific standard, code, procedure or documented good practice that justifies each statement of expected performance. This is to ensure that only legitimate comparisons are made between actual and expected performance.

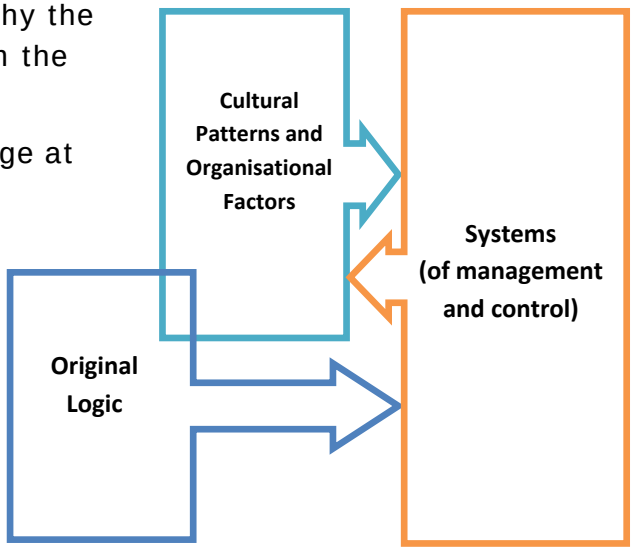
If relying on a general code or standard, you should also explain what this requires in the context of the significant event. As well as providing a defendable basis for your analysis, this may also deepen your insight into the context of the accident.

If at any point you are uncertain— if, for example, you don't know the standard, how a general code relates to the specific context of the accident, or whether a particular expectation is legitimate—phrase a question and follow-it-up later.

1.2 Explain the difference between the actual and expected performance

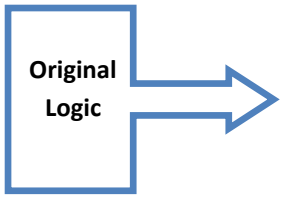
3CA provides three ways to explain why the actual performance was different from the expected performance:

- ❖ the individual's goals and knowledge at the time of their action;
- ❖ relevant cultural patterns (e.g. set by individual's peer group) and the influence of organisational factors;
- ❖ relevant systems of control and management that could have pre- empted, detected and corrected the significant event or its circumstances.



As well as gaining insights under each of these three headings, the analysis should aim to get insight into the interaction between the headings. For example, if a cultural pattern had established behaviour that is different from the expected performance, the examination under the heading of 'systems' should try to explain why the pattern had become established. Teamwork may be helpful to the analysis, group discussion naturally makes conversational connections between topics.

1.2.1 Original Logic



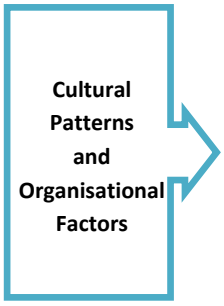
Identify (or pose questions about) what led the individual to believe this was the right way to do the job in this particular instance.

State whose reasoning is the subject of discussion. Often the responsible person is the 'actor' in the significant event but, if the actor is a machine or a component, discuss the logic of the machine's designer or controller.

Try to discriminate between “original logic” from post-accident alibis and rationalisations.

Record your analysis, whether statements or questions, using complete sentences; you need to be able to reconstruct your reasoning.

1.2.2 Cultural patterns and organisational factors

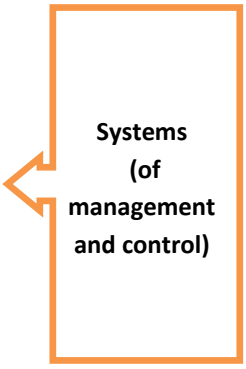


Describe attitudes or behaviours in the actor's peer group that may have established a pattern for the actual performance. Think about proof; if you don't know the answers, or lack evidence, phrase questions.

Describe organisational factors that may explain original logic or behaviour. Organisational factors include properties such as management structure, leadership, politics, change.

1.2.3 Systems

Identify each system relevant to the significant event. For each system, explain why it did not ensure that the actual performance would be the same as the expected performance. If you don't know the answers, or lack evidence, phrase questions.



There are two aims here:

- to explain the significant event, and
- to identify system problems that could affect other work.

Try to go "a spade deeper" in your explanations. If, for example, you concluded that the difference between actual and expected performance was due to over-prescriptive procedures which lacked guidance, try also to account for the origins of these problems. In other words, refocus your attention on the system(s) that, in this case, researched, developed, tested and maintained the procedure. In this way, you can identify general lessons for the organisation.

Rather than impose a rigid question set, the 3CA method leaves room for the analyst's views and ideas. However, some users value having prompts to help them cover the relevant issues and 'systems' seems to be one of those headings where a promptlist is particularly helpful. The promplist below is broad

Systems Promptlist

- Verifying Readiness before use/start of work
- Housekeeping
- Briefings and task allocation
- Personnel selection
- Competence Assurance
- Inspection
- Maintenance
- Motivation
- Co-ordination be-tween groups
- Supervision
- Design of Hardware and premises
- Procurement and Supply
- Risk Assessment
- Procedures & Technical Information
- Planning
- Budgeting
- Monitoring
- Change control systems
- Emergency systems
- Audit and review

2 Notes on the tabular and graphical 3CA formats

The graphical and tabular formats support the 3CA method in different ways.

2.1 Differences between the Tabular and Graphic approach to 3CA

Some users find the graphical form of 3CA to be more usable than the tabular form; there are three likely reasons. First, for some, form-filling stems the flow of creative, analytical thought. Second, the tabular format suggests an inflexible, linear approach more suited to convergent thinking. A graphical format, in contrast, invites users to move back and forth between the various headings and

encourages divergent thinking. Third, by focusing on just one significant event, the graphical form is simpler to use than the tabular form.

The tabular form and the graphical form are different with respect to two headings. The table allows the user to list barriers and controls for each significant event and allows the set of significant events to be prioritised.

2.1.1 The 3CA Table allows multiple significant events to be analysed on the same page

The tabular format allows several significant events to be seen together, compared and connected to common themes. The graphical format allows only one significant event to be considered at a time, and to conduct a full 3CA analysis, which may need to consider several significant events, the user will need several graphical sheets, one for each significant event.

- ***Themes common to two of more significant events***

  The tabular format allows the user to analyse several significant events on the same page. This means that themes common to more than one significant event need only be written once. This is particularly true for issues noted by the analyst in columns 5(a) to (c).

  The graphical format limits the analyst to considering one significant event on each page. It is possible for the analyst to cross-refer between sheets, if more than one page is used, the user will need to develop a system for doing this.

- ***Overview of the full set of significant events***

  Analysis using 3CA table results in a list of significant events, this constitutes a concise summary of the accident. Users of the graphical format should consider making first a comprehensive "master list" of the significant events.

- ***Prioritisation occurs 'off-the-page'***

  Using graphical format means that any prioritisation of significant events occurs 'off-the-page'. Whether the analyst is going to consider all the significant events, or just a selection of them, prioritisation still needs to occur.

2.1.2 Could vs. Should Barriers and Controls

In the tabular form of 3CA, the analyst is prompted to consider barriers and controls that could have prevented or mitigated a significant event. This list will include two sorts of options:

- ***'prescribed' options that are normal requirements, those that 'should' have been in place according to some regulation or procedure.***
- ***'non-prescribed' options that are not obligatory but which might nonetheless be justified in the context in which the accident occurred.***

In the graphical form of the method, identifying 'non-prescribed' options for preventing or mitigating significant events needs to be done 'off-the-page'. In practice, this is done when analysing "expected performance" by taking a 'first-principles' approach.

2.2 Resources

Two versions of the graphical format are shown on the next pages. These can also be downloaded from the NRI Foundation web site; one is for handwritten notes and the other can be filled-in on-screen using Microsoft Word. The word-processing version can also be used as an aide memoire.

- Blank Graphic Format
- Graphic format for word processing

Should these hyperlinks not work for some reason, visit the NRI Foundation webpages at www.nri.eu.com/3CA.htm.

3CA Control Change Cause Analysis

Expected Performance

Insert text here (and delete below)

The significant event will contain an actor and an action; focus on the action and describe what performance was expected. Note the basis for this expectation in the "Standard" box.

If there is more than option, describe each of the alternatives.

Write questions if you need to.

Actual Performance

Insert text here (and delete below)

Describe what the actor actually did. Phrase your description to include the actor and the action. Make this a simple, positive statement.

NOTE: Often this description is exactly same as the "significant event", but sometimes it is different.

Cultural Patterns and Organisational Factors

Insert Text here (and delete below)

Describe attitudes or behaviours in the actor's peer group that may explain his/her individual logic or behaviour.

Sometimes an actor's "original logic" is truly unique and without precedent, but normally he or she is influenced by existing attitudes or patterns of behaviour in their peer group.

Describe ORGANISATIONAL factors that may explain his/her individual logic or behaviour. (e.g. management structure, leadership, politics, change).

To help you make a note of your thinking, use COMPLETE SENTENCES.

Write questions if you need to.

Systems (of management and control)

Insert text here (and delete below)

Identify each system relevant to the problems noted. For each system, explain why the system did not pre-empt, detect or correct the problems. To help you make a note of your thinking, use COMPLETE SENTENCES. Write questions if you need to.

Systems include:-

- *Verifying Readiness before use/start of work*
- *Housekeeping*
- *Briefings and task allocation*
- *Personnel selection*
- *Competence Assurance*
- *Inspection*
- *Maintenance*
- *Motivation*
- *Co-ordination between groups*
- *Supervision*
- *Design of Hardware and premises*
- *Procurement and Supply*
- *Risk Assessment*
- *Procedures & Technical Information*
- *Planning*
- *Budgeting*
- *Monitoring*
- *Change control systems*
- *Emergency systems*
- *Audit and review*

Standard/Benchmark

Insert text here (and delete below)

Describe your justification for believing that the performance stated in the "expected performance" is reasonable and relevant to the actor's situation. Justification might include reference to a procedure, expert opinion of good-practice, a regulation, or other types of norm. It must be something for which you can provide evidence.

Write questions if you need to.

Original Logic

Insert text here (and delete below)

Describe the perceptions and reasoning of the actor (or the controller or designer, if the actor is a thing). This should explain why the 'actual performance' seemed (to the actor) to be a good course of action.

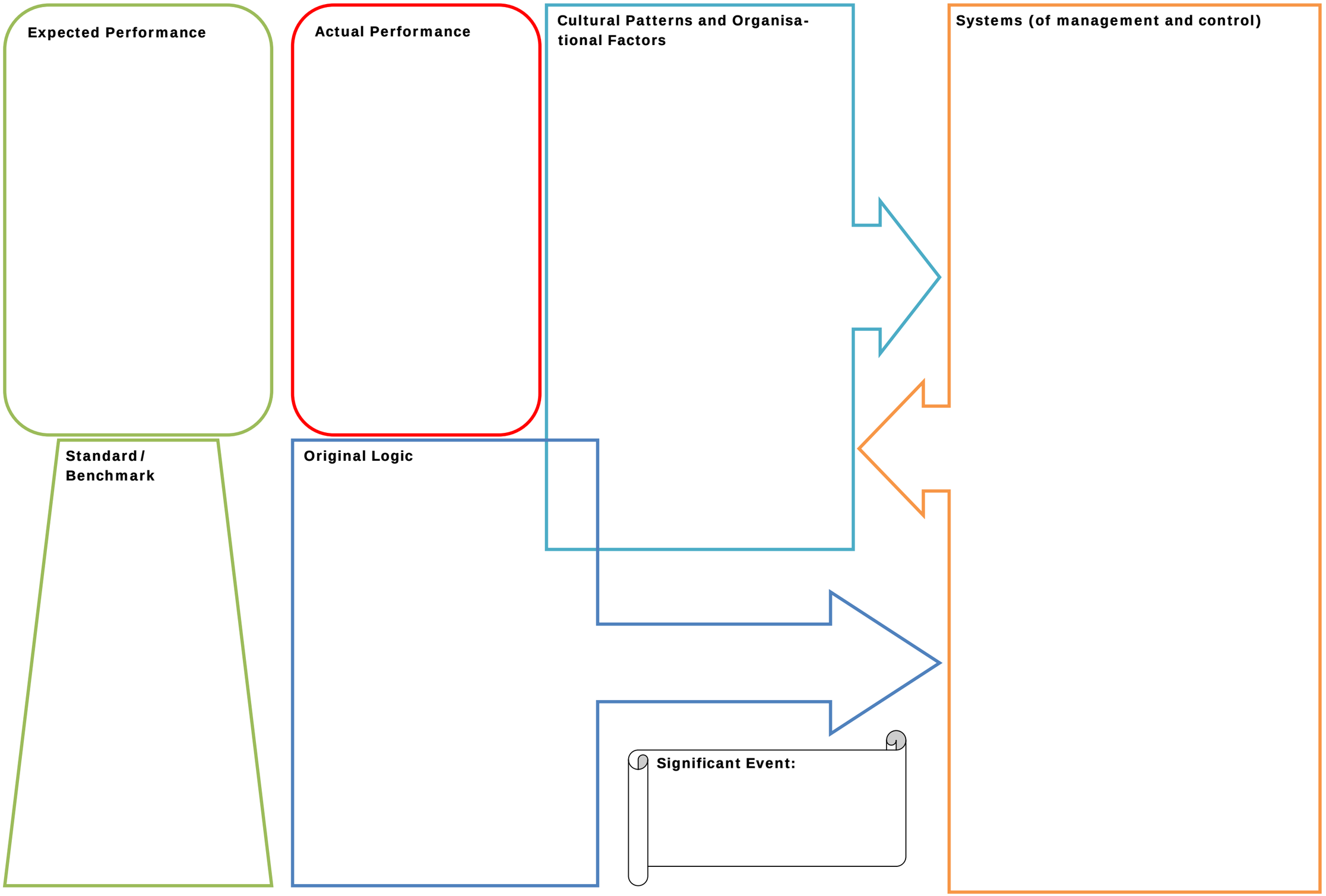
To help you make a note of your thinking, use COMPLETE SENTENCES.

Write questions if you need to.

Significant Event:

Insert text here (and delete below)
Describe the event; say what is acting (e.g. the person or machine) and what action is being performed.

3CA Control Change Cause Analysis



Graphical Format for use with 3CA (Form B) Manual, available www.nri.eu.com/NRI5.pdf

NRI Document Improvement Proposal		
1. Document reference NRI-5 (Rev 1.1)	**2. Document date** 5 December 2008	**3. Document title** 3CA Manual, B-Form
4. Recommended improvement *(identify page, paragraph and include modified text or graphic, attach pages as necessary)*		
5. Reason for recommendation		
6. Originator of recommendation		
Name:	Organisation:	
Address:	Phone: Fax: E-mail:	**7. Date of submission**
8. Send to NRI Secretariat		
Name: J.Kingston	***Address:*** Noordwijk Risk Initiative Foundation P.O. Box 286 2600 AG Delft The Netherlands	Phone: +44 (0)121 288 3206 Phone: +31 (0)31 15 278 1080 Fax: +44 (0)797 009 1890 email: info@nri.eu.com