NRI-4 (2007)

ECFA+

Events and Conditional Factors Analysis Manual

Produced by

The Noordwijk Risk Initiative Foundation

Published and distributed by:

The Noordwijk Risk Initiative Foundation
P.O. Box 286,
2600 AG Delft,
The Netherlands.

Email: Info@nri.eu.com
Website: www.nri.eu.com

ISBN 978-90-77284-05-6

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Events and Conditional Factors Analysis Manual

April 2007

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In memory of Dr Robert J. Nertney,
our friend and colleague.

6 September 1923 – 13 July 2004

Preface

The Noordwijk Risk Initiative Foundation exists to further the understanding and 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

This document has been prepared by the Noordwijk Risk Initiative Foundation 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.

This manual describes a method that is based on "Events and Causal Factors Analysis", ECFA (Buys and Clark, 1995) and attempts to distil refinements of approach that have been collected over the last decade. These refinements were arrived at through the experiences of the authors and by applying criteria and methods published by others (see the bibliography). In order to distinguish this method from its predecessor, it is called ECFA+, Events and Conditional Factors Analysis.

It is the intention of the NRI Foundation to maintain this manual in the public domain. Our motivations are:

1. to help investigators produce accounts of incidents that are robust with regard to evidence and completeness;
2. to encourage stakeholders to share information about incidents;
3. to provide a reference point for practitioners (of investigation), tool developers, researchers and students.

Structure of this document

ECFA+ is explained in three complementary ways. First, the ideas and conventions are introduced (pages 9-13). Second, with the novice user in mind, ECFA+ is described as a set of procedural steps (pages 16-19). Third, to support the more experienced ECFA+ user, summary instructions for ECFA+ are provided in a single-page aide memoire (Appendix 1).

Status of this document

This document does not replace the 1995 edition of the ECFA manual (Buys and Clark) but is intended as an alternative method added to the sequencing tools "drawer" of the metaphorical "investigator's toolbox" (Frei et al, 2003).

Acknowledgements

Many people have contributed and reviewed this manual. The authors would like to extend particular thanks to: ENI Netherlands for their help with the initial drafting of this manual; Prof. Germund Hesslow (Lund University) for his help with Appendix 5; Robin S. Birchs, Cedric Gilson (University of Westminster), Jane Paul and the late Robert J. Nertney (NRI Foundation) for their contributions to Appendix 6; Dr. oec. publ. Mauro Iacobacci for his help comparing ECFA+ with Events and Causal Factors Analysis; 3M United Kingdom plc for permission to use the term "Post-it Note" (a registered trademark of the 3M Company) and Cara Dawson (CAS Ltd, United Kingdom), Prof. Peter Waterhouse and Ludwig Benner for reviewing and commenting on the text.

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1 Introduction

1.1 Overview

ECFA+ is a method of producing a sequential description of an incident[1] which accounts for the logical relationships between the facts presented. Using witness narratives, logs and other sources of evidence, ECFA+ helps an investigator to build an account of the events that comprise an incident. Each event is stated using the present tense. These events are put into chronological order and linked together by identifying logical relationships. These links are tested to ensure that each event is explained satisfactorily. When needed, conditions are identified to ensure the completeness of these explanations. Every event, condition and logical relationship must be established to the standard of evidence required by the investigator.

ECFA+ analysis is generally an iterative process, running in parallel with other investigative activities. New information is added to the evolving ECF chart and this often raises new topics for further inquiries. If one were to add together the various iterations of work on an ECFA+ analysis, it will seldom take less than one hour, often two hours and sometimes more than this if the incident is complex. The fact that ECFA+ benefits from a team approach will add to opportunity cost associated using the method.

The ergonomics of ECFA+ means that it is best approached as a paper and pencil method, but this assumes that there is a sufficient physical space in which to do the work: a blind wall, four metres wide is adequate for most analyses. Experience suggests that a computer-based approach is not effective for performing ECFA+ in real time, especially when a team approach is used. If report quality materials are needed, it is normal practice to transcribe the ECFA+ chart using a flow-charting package or other vector graphics software application.

1.2 Team Approach

ECFA+ is generally approached as a team activity; the photograph below would be familiar to most ECFA+ users.

A team approach can help to:

- ensure that the analysis is supported by knowledge of the activity and technology involved in the incident;

[1] Throughout this text we will use ‘incident’ to include all unwanted events.

- reflect the perspectives of the different stakeholders involved in the incident and the remedial activities which flow from it;
- promote learning; investigators learn from taking part in investigations and a team approach is more likely to be able to maintain learning over time within the organisation.

To gain these benefits, the team needs be selected to include the right mix of disciplines and experience relative to the incident to be investigated.

When involving a team in ECFA+, it can be effective to have one team member act as a facilitator. This helps to keep the work moving forward whilst maintaining a disciplined approach to the analysis. It is also helpful to have the analysis challenged by someone familiar with the method but not the content of the investigation.

1.3 Benefits of ECFA+ to investigation

ECFA+ will work with virtually any type of occurrence, whether positive or negative. However, the authors are firmly of the view that ECFA+, like any tool, should be the servant of the investigator and not the master. Only apply ECFA+ in situations where you believe that the benefits outweigh the costs in time and effort. Generally speaking, the benefits are:

- identification of a clear set of events to support subsequent root cause analysis. Methods like 3CA (Kingston, 2008) rely on robust descriptions of events;
- development of a structured and verified account of the sequence of events for the written report;
- a working model of the incident that allows investigators to divide their effort between the investigation and other, unrelated, tasks;
- a useful tool for helping to familiarise people with the current picture of what is known within the investigation and its key areas of uncertainty.

2 Fundamentals of ECFA+

This section describes the things that need to be understood before applying ECFA+ and provides some insight into the underlying ideas.

ECFA+ is a method for structuring data acquired from sources such as witnesses, logs from electronic systems, photographs and physical evidence. From such sources, the investigator identifies activities and circumstances that account for how an incident occurred. This account is referred to as an ECF chart.

2.1 Events

The main task in ECFA+ is to identify changes of activity and to transcribe them as simple phrases, referred to as “events”. The aim of this is to make visible three particular attributes of every event:

- the “*actor*” effecting the change; *(e.g. Mr. Bloggs)*
- the “*action*” of the *actor* on the *object; and,* *(e.g. moves)*
- what is being changed – the *object;* *(e.g. a valve handle)*

Once visible, these attributes provide a focus for analysis: in each case they must be identified, evidenced and explained.

2.2 Conditions

In searching for explanations of events, investigators also need to identify *conditions* which, had they been different, would have altered the course of events. Conditions are the second type of data that need to be identified and transcribed as part of ECFA+ analysis.

In the first instance, conditions are included into the analysis *only* when they are needed to explain events that are already visible in the ECF chart. This helps to ensure that the analysis of the incident is as economical[2] as possible. It also helps to avoid force-fitting conditions, the relevance of which has not yet been established in the analysis. Once these "primary" conditions are included in the ECF chart, they themselves will need to be accounted for in terms of the "secondary" events and conditions that explain[3] their occurrence.

For ECFA+ purposes, the key distinction between events and conditions is that events are active whereas conditions are passive; conditions persist until acted upon. This is sometimes – but not always – reflected in duration. In a similar vein, subjective states are better stated as conditions rather than events (e.g. Mr Bloggs considers calling for assistance).

2.3 Non-Events

A special type of condition is the *non-event*: an event that would be expected to occur given the circumstances, but which did not happen on the occasion in question. For example, if an actor does not perform an action that is assumed as necessary by a procedure, the non-event is likely to be identified as a significant part of the explanation of any consequences[4]. There are two reasons why non-events are treated as conditions. Firstly, non-events are passive, whereas events are active. Second, ECFA+ requires investigators to state their basis for judging a non-event to be relevant (by identifying the standard of judgement that they are using – such as a procedure, custom or practice, or theory). This approach enables other stakeholders to challenge the judgement of the analyst and reminds the analyst of the need to justify their reasoning in such instances.

2.4 Evidence

By the end of the analysis, every event and condition in the ECF chart should be:

(a) supported by appropriate evidence or identified clearly as lacking evidence; and
(b) explained by other events and conditions in the chart, or identified clearly as needing further information.

What constitutes "appropriate evidence" of fact may be different for each item in the analysis and will depend of the context of the investigation. ECFA+ requires that analysts state the evidence that they are relying on for every event and condition they transcribe. This helps investigators to recognise where they need to make further enquiries, but leaves it to individuals to assess what level of confidence needs to be achieved.

[2] This is an application of *Occam's razor*: the principle that entities must not be multiplied beyond what is necessary. In other words, select the simplest explanation that fits the facts of the occurrence in question.

[3] Appendix 5 discusses different approaches to selecting causes.

[4] Appendix 5 contains a discussion of this issue; item (e) is of particular relevance.

2.5 Explanation

What constitutes an explanation of an event or condition is a matter of *necessity* and *sufficiency*.

- *Sufficiency*: for a particular item in the ECF chart, if the stated events occur at the time when the stated conditions exist, the to-be-explained item will always result; and,
- *Necessity*: if any of the stated conditions or events were absent, the to-be-explained item would not result.

For those items in the ECF chart that are not explained to this standard, the analyst is expected to make it clear that further information is required (even when there is no intention to make further enquiries).

2.6 ECFA+ Start and Stop-rules

Incidents can be seen as unplanned sequences of events with outcomes different from those expected. ECFA+ uses the notion of control to characterise incidents: the incident begins when control of outcomes is compromised and ends when the control of outcomes is restored.

The beginning and ending points are seldom clear-cut because control is generally a matter of degree rather than absolute. For example, the end point of an ECFA+ analysis could be defined as time at which actions aimed at regaining control of the situation succeed in stopping things getting worse. Alternatively, the end point could be defined as the time at which all consequences have been remedied (e.g. injured people restored to full health, customers compensated, lost production recouped etc.).

The answer to “how far back in time an investigator may need to reach” depends on whether we are discussing the primary or secondary events. Primary events are generally close in time to the unplanned outcomes which are the focus of the investigation; in the order of minutes, hours, or days. Secondary events are included to explain the coming into existence of conditions; these may reach back days, weeks, or years.

2.7 Conventions used in ECFA+

ECFA+ can be seen as a set of conventions that are designed to help investigators to be systematic in their approach to transcribing events and conditions, stating uncertainties and for representing these graphically.

2.7.1 Active Voice

Events are stated in the *active voice*, the subject of the sentence is the person or thing that carries out the action (e.g. the scaffold pole hits the fence). This is in contrast to the *passive voice* in which the subject is acted-on (e.g. the fence is hit by the scaffold pole). 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. The preferred form for phrasing events is *actor + action + object*.

2.7.2 Transitive Verbs

In a similar vein, ECFA+ encourages the use of *transitive verbs* to describe actions. Transitive verbs must have an object (e.g. John opens the door). In this way, the transitive verb does for the object what the active voice does for the actor: it makes it obvious what or who is on the 'receiving-end' of the action and prompts the investigator to recognise when they do not know. There will be many instances when a transitive verb is not appropriate (reflexive verbs are the most common exception); the rule is to be sure that the event is stated in a way that makes it clear what is acting, how it is acting and the object affected.

2.7.3 Simple Present Tense

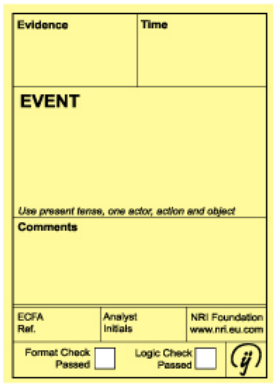
Events are stated in the *simple present tense*. The simple present has a number of advantages:

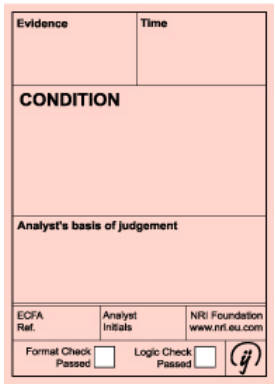
- it is an efficient tense in which to phrase statements of fact;
- it encourages the analyst to state what is happening in an event, not what results from it (sometimes called '*staying in present time*');
- it reduces the scope for ambiguity.

2.7.4 Visualisation

Visualisation provides an informal test of whether an event is well-described. If an individual cannot form a mental picture on the basis of the phrase used to describe the event, this may indicate the need for rephrasing or re-transcription (e.g. transcribed as multiple events or as a condition). Ideally, the 'mental image' would match the objective reality of what is being described, but this is not what the test is assessing; that the phrase is "visualisable" is all that is needed.

2.7.5 Coloured Post-it Notes





Events are transcribed onto yellow Post-it Notes. Post-it Notes are used because they are quick to use and easily repositioned as the ECF chart evolves. Plain Post-it Notes are all that is required to work with ECFA+, but pre-printed Post-it Notes help to prompt investigators for information in the format (phrasing etc.) described here. Appendix 3 contains artwork that can be used to produce Post-it Notes specially designed for use in ECFA+.

Conditions, which are transcribed onto pink Post-it Notes, describe passive states that endure for some period of time. Many conditions are the result of preceding events shown in the ECF chart, especially those that are controllable by stakeholders in the incident investigation.

2.7.6 Dashed Lines

Events and conditions need to be evidenced to the standard required of the investigation. If they cannot be proven adequately, but represent a plausible hypothesis, they can be included in the ECF chart if bordered with a dashed line. This indicates to anyone viewing the analysis that evidence is lacking for the items in question and serves to reinforce the overall message that the investigators have kept the matter of evidence clearly in view.

2.7.7 Arrows denote logical relationships

As described in the procedure (starting on page 16), the analyst must verify the format of events and conditions before moving-on to identify the logical relationships between items in the ECF chart. The artwork for the Post-it Notes (Appendix 3) includes a check-box that should be ticked only if the event or condition satisfies the format rules.

In ECFA+, connecting arrows are used to denote logical relationships: an arrow starting at one item (meaning an event or condition) and ending at another, means *causes*. If there is more than one arrow arriving at an event or condition, the logical relationship is equivalent to AND logic, as used in Fault Tree Analysis (FTA). Unlike FTA, alternative hypotheses cannot be shown in the one ECF chart.

The ‘dashed lines’ convention also applies to the connecting arrows:

- If the evidence for the logical relationship allows it to be validated, the lines should be solid;
- If the evidence is not strong enough, a dashed line indicates a presumed relationship for which evidence is lacking, and;
- a ‘?’ is placed next to the arrow, to show that there is a line of further enquiry aimed at strengthening the evidence for a dashed-line arrow;
- if sufficient evidence is forthcoming, the dashed line can be redrawn as solid.

2.7.8 Further Enquiries and Uncertainties

There are two ways of indicating that a line of further enquiry is pending: one is to place a question mark near to a line or in place of a missing datum (e.g. “? opens valve” shows that a further enquiry has been noted to identify the actor). The other way of showing that further information is needed is the blue ‘Query’ Post-it Note. Most often, query notes appear during logic checking, as this process identifies incomplete explanations. Query notes provide a way of “parking” an uncertainty while keeping it visible in the analysis. This avoids the need to resolve the issue immediately as this can interrupt the flow of the analysis. Whether denoted by a “?” or blue Query Note, a corresponding entry is made on the list of further enquiries.

2.7.9 Recording ECF Charts

Lastly, preserving an ECF+ chart, whether at the end or during the analysis, is done by adding a unique reference to each item and making a drawing of the pattern of references and lines. The referencing system is a matter of individual taste, but one that works well is to:

- number events sequentially;
- itemise conditions with lowercase letters;
- identify queries with a 'Q' prefix followed by the number given in the list of further enquiries.

2.8 ECFA+ is a dynamic process

It is useful to start the analysis as early as possible and run it in parallel with other investigative activities. This is because the ECFA+ analyst has a dual role – to structure what is known and to identify gaps. As more data become available, they can be transcribed into the evolving ECF chart. This provides a means for structuring what is known at a given point in the investigation and, just as importantly, identifying gaps in knowledge and evidence. These gaps provide the stimulus for further enquiries.

Ordinarily, the level of detail in an ECF chart (as indicated by the number of Post-it Notes used) at first increases and later decreases. When filtering data on the basis of relevance, initial transcription from evidence sources should err on the side of caution: at this stage of the analysis, more detail is better than less. Later, when logic checks are applied to the contents of the ECF chart, the number of items will decrease as redundant detail is weeded-out.

In the early stages of the analysis, it is often helpful to have a row for each actor. This helps the analyst to spot missing action (e.g. time not accounted for) and makes the early part of the analysis easier. However, once each actor's actions are accounted for in the first sweep of the analysis, maintaining separate rows becomes less important. Furthermore, the logic checking process, in which items are connected with arrows, often involves repositioning Post-it Notes.

The following rules of thumb help analysts produce clear ECF charts.

- minimise the number of crossing lines by rearranging the Post-it Notes;
- place primary events and conditions towards the horizontal axis of the chart;
- put query notes near to the item to which they relate;
- preserve the time-ordering of events and conditions.

3 Procedure for ECFA+

This procedure is written with the new user in mind: detailed steps are provided together with guidance. Once familiar with this procedure, the one-page aide-memoire (Appendix 1) should be enough to remind users of the key steps.

Task Steps	Description & Criteria	Guidance
1. Study all available information about the incident		Start the analysis early. Applying ECFA+ stimulates new lines of enquiry and the chart is easy to update in the light of new information. Work in pencil (easier to amend).
2. Transcribe information about actions onto 'Event' Post-it Notes (yellow).	Each event should: (a) describe a single, discrete occurrence of very short duration;	It is <u>not</u> essential to use pre-printed Post-it Notes (artwork provided in Appendix 3) but the designs do help to encourage a systematic approach to analysis (especially among new users). If you wish to transcribe an action that continues for some time, consider breaking it down into its constituent actions (separate Post-it Notes for each) or transcribe as a condition.
	(b) have just one actor and one action;	An actor can be a person or a thing. If there is more than one actor (e.g. "crew leave site") they must be acting as a single unit. If not, consider transcribing events for each distinct actor.

Task Steps	Description & Criteria	Guidance
2. (Continued) *Transcribe information about actions onto 'Event' Post-it Notes (yellow).*	(c) be phrased in the present tense as actor + action + object;	Use the active voice: make the actor the subject of the sentence stating the event (e.g. Bloggs undoes clip). Try to describe actions using only transitive verbs (a transitive verb will always have an object). If you find yourself needing to use the progressive form of a verb (e.g. with an –ing ending) either identify the constituent events or consider transcribing the activity as a condition.
	(d) be an event, not a non-event. An example of a non-event is "Bloggs did not close exit valve";	Non-events are things that did not happen but which should have happened according to some ideal way of carrying-out a task (such as a procedure or standard). Transcribe non-events as conditions using (pink) Post-it Notes. State both the evidence you have for believing the condition to be factual and the standard you are relying on to make the judgment (e.g. a specific written procedure, code, standard). If you do not know the specific standard that applies – make an entry on your list of further enquiries to find out.
	(e) state the evidence for the event occurring (if you lack proof, put a "?" in the evidence box and make a note on your list of further enquiries;	It is essential that all events and conditions either cite evidence or are connected explicitly to a further enquiry. Cross-references to specific items of evidence can be speeded up by using a systematic referencing system.
2. (Continued) *Transcribe information about actions onto 'Event' Post-it Notes (yellow).*	(f) state the time, if known;	Knowing the time helps to correlate different sources of evidence for a given event or condition. If you do not know the precise time the event occurred, use a question mark. For example, if after 12:50 but before 13:00 use "12:5?". If wholly unknown just put "?". Consider adding a corresponding entry to the list of further enquiries.

Task Steps	Description & Criteria	Guidance
3. Put event Post-it Notes onto a wall and position them using these rules-of-thumb:	*(a) vertically* – it is often helpful for each actor to have his/its own row;	It is not essential to have a separate row for each actor but it can be helpful if there is a lot going-on in the incident you are analysing. Later in the ECFA+ process, you will probably re-arrange events to emphasise certain sequences.
	(b) horizontally – put events in time order, so that later events are always to the right of earlier events.	ECFA+ does not use a fixed base for time (meaning equal intervals of time marked on the horizontal axis of the ECF chart).
4. Check the format of every event and condition	Is the event stated in the simple present tense? Is the event stated in the form "actor, action & object"? Is the event of very short duration? Is evidence cited? Is the time stated? Can the event be visualised? If the condition is a "non-event" is the standard stated?	Format checks are essential to ECFA+. Poorly stated events can complicate or undermine analysis of cause and effect. In addition, if a format check identifies the need for further enquiries, time may be of the essence (witnesses forget, logs get overwritten etc.). Check early and check with care. If time is not stated, make a judgement about the importance to the analysis of knowing the time. If it is critical, do <u>not</u> pass the format check. Visualisation: you should be able to form a mental image of every event described on an event Post-it Notes. If you cannot, there is either a problem with how the event is stated or with your understanding of the action described. Conditions that are non-events (e.g. X did not do Y) should state the standard that requires the 'missing' action to be performed. Note however that non-events normally appear only during logic checking (step 5), their presence earlier in the analysis may indicate that you are force-fitting judgments into the analysis.

Task Steps	Description & Criteria	Guidance
4(a) Tick the "format check passed" box if all details are correct.	If there is any missing data, add an entry to the list of further enquiries and do not tick the box.	The two tick boxes on the EVENT and CONDITION Post-it Note artwork (Appendix 3) are provided as a 'book-keeping' function. A tick in the "format check passed" box means that the analyst is satisfied that the event is a truthful representation of the action described. An example format for a further enquiries list is provided in Appendix 4.
5. Check the logic of cause and effect for every event and condition.	Start with the last event. Focus on the event to be checked for logic: a) identify the earlier events (or conditions) that directly cause the event in question; b) if these earlier events occur will the event in question always happen?	The 'logic checking' process is about identifying the flows of cause and effect that link together the various events and conditions. It is often helpful to reposition the Post-it Notes, moving the note being 'logic-checked' to the right and, if appropriate, drawing connecting arrows from the Post-it Notes identified as causes.
	c) If the event can be explained by earlier events and conditions: i) draw linking arrows from the relevant events and conditions to the event in question;	A linking arrow between two Post-it Notes means that the earlier "causes" the later to occur. You need to consider the strength of evidence for this causal relationship. If the evidence is not strong enough, join the two Post-it Notes with a dashed line, write a '?' above the line, and make a corresponding entry on your list of further enquiries. Leave the logic box (of the 'caused' event or condition) empty until you have found the extra supporting evidence needed.
	ii) reposition the Post-it Notes to achieve the simplest arrangement (but preserve time order);	When repositioning, try to apply two rules of thumb: first, have as few crossing lines as possible; second, position the main actions towards the horizontal axis of the chart.
	iii) tick the "logic check passed" box.	A tick in the logic check box means that the event is explained

Task Steps	Description & Criteria	Guidance
5. (Continued) *Check the logic of cause and effect for every event and condition.*	d) If the event <u>cannot</u> be explained by the events and conditions present in the ECF analysis: i) identify the other events or conditions that are needed to explain the event in question; ii) if you do not have data about the missing events or conditions, add a question(s) using a query Post-it Note; iii) position the query Post-it Note near to the event in question; iv) make an entry on your list of further enquiries and note the reference number on the query note; v) leave the "logic check passed" box <u>empty</u>.	The logic check will often trigger you to recognise the relevance of events or conditions that need to be added to the ECFA+ chart. This stage of the process is where most of the Condition Post-it Notes are transcribed. Query notes are blue and provide a way of "parking" an uncertainty that needs to be kept visible in your analysis but without trying to resolve the issue there and then (which might bog-down this stage of the analysis). Further enquiries should be numbered sequentially. A proforma for recording these is provided in Appendix 4.
6. As new events and conditions are added to the analysis, apply the format and logic checking rules.		
7. Perform final revision	Challenge any events left in the analysis that do not satisfy format or logic criteria:	When all evidence collection is finished, the ECF chart needs to be finalised to show the final state of information, including remaining uncertainties. Most investigations leave some uncertainty. It adds to the value and credibility of your analysis to be explicit about what was not explained by your investigation.

Task Steps	Description & Criteria	Guidance
7. (Continued) *Perform final revision*	a) Remove, or outline with dashed lines, events or conditions that do not pass the format check: i) If you judge that the event or condition is not critical to the analysis, leave it out. ii) If the item is essential, but lacking detail or evidence, enclose it in dashes.	Dashed events and conditions should be used sparingly in ECFA+. Try to ensure that all dashed items are based on some evidence or reasoned hypothesis (and not purely opinion).
	b) Remove or apply dashed lines to events or conditions that do not pass the logic check: i) If you judge that the event or condition is not critical to the analysis, leave it out. ii) If the item is essential: connect to causally relevant events and conditions using dashed lines only, and ensure that a Query note is posted near to it that specifies the data missing from the explanation.	

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Appendix 1: Aide Memoire

1. Familiarise yourself with available information (including site if accessible)

2. Transcribe actions into Event (yellow) Post-it Notes

3. Each event should conform to the following criteria:

   - Describes a discrete occurrence
   - Shows source of evidence (e.g. statement, photograph)
   - Gives time and other numerical data (if known)
   - Identifies the actor – the who or what that is acting
   - Describes the action simply and in the present tense
   - Identifies the object affected by the action

4. Conditions may appear as a by-product of identifying events. Unlike events, conditions endure and are passive. Conditions, which are transcribed onto pink Post-it Notes, should conform to the following criteria:

   - Be precisely described
   - State the evidence relied on
   - If a deviation, explicitly state the basis of judgement
   - State the duration of the condition, if applicable
   - Give any relevant quantitative data

5. "Park" queries on your list of further enquiries. Keep the analysis moving.

6. Put events into chronological order

7. Verify that events conform to ECFA criteria. Be careful to ensure that events are not summations or results of implied events. Ideally, present the analysis to a colleague: ask them to try to visualise the event line. If they have trouble, there may be gaps.

8. Note items requiring further enquiries

9. Question causation event-by-event (more conditions are produced by this stage)

   - Can you prove that there is a direct causal connection between precursors and the event in question? If yes, draw arrows from the precursor blocks to the event block in question. If no, make a note of the further enquiries required on a blue Query Post-it Note and cross refer with the list of further enquiries.
   - Are the precursor events and conditions stated sufficient to explain the event? Will these precursors always produce this event – if not, note further enquiries, add-in and connect the necessary conditions.

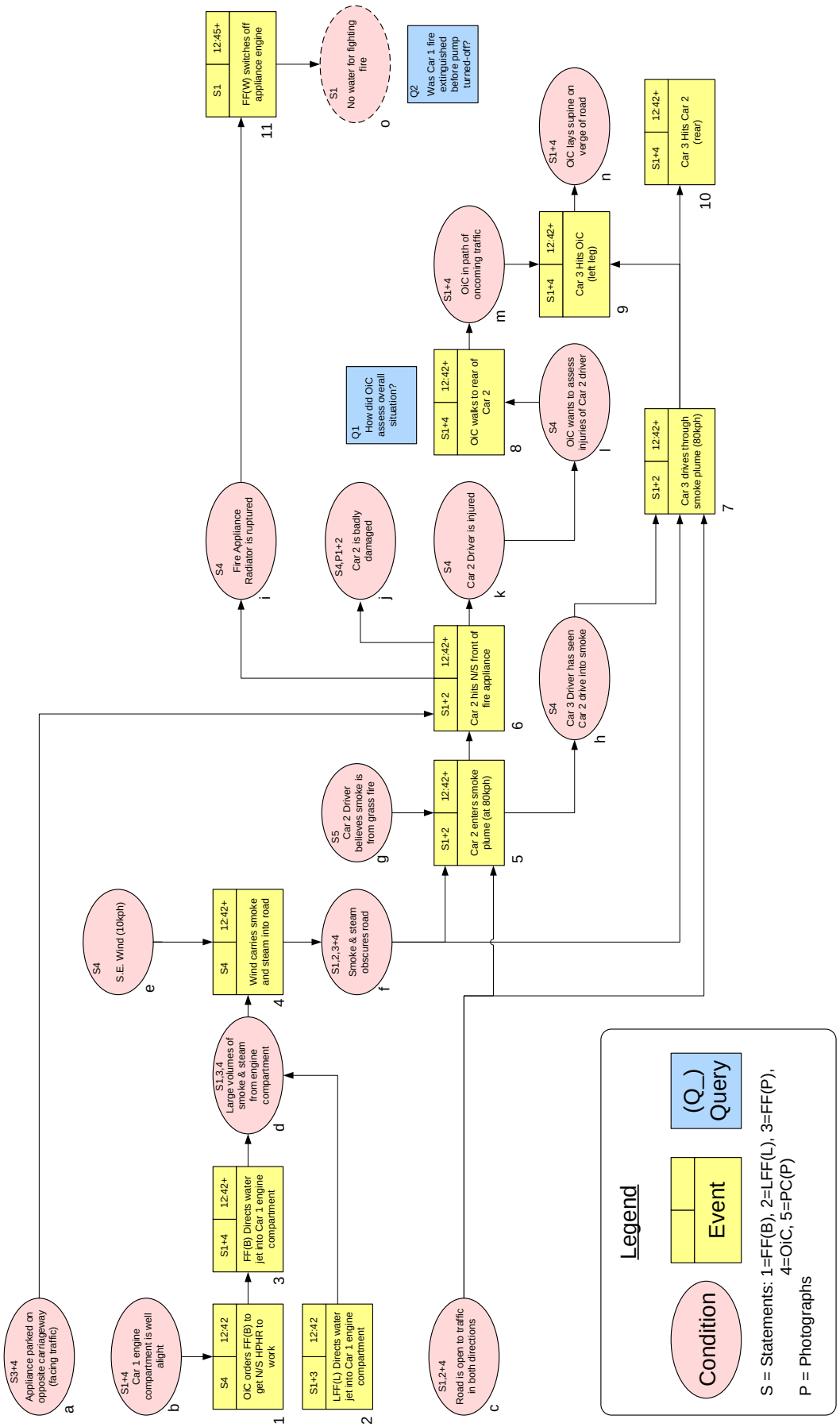
10. Correlate with other techniques. Root cause methods often produce conditions (especially, deviations in risk management). When integrating these into the ECFA chart, ensure that the conditions meet ECFA criteria (for evidence and precision in particular).

11. Record the Chart: number all Post-it Notes

    Events: Numbers (1, 2, 3…)
    Conditions: Letters (a,b,c…)
    Queries: Prefix “Q” plus the relevant entry in the further enquiries sheet (e.g. Q1)

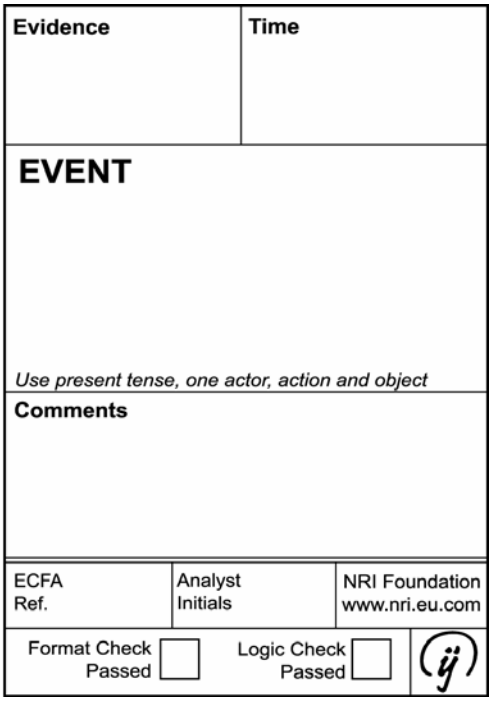
    Draw the pattern of numbers and arrows on a piece of paper. Remove and store the Post-it Notes.

Appendix 2: Excerpt from an ECFA+ analysis.

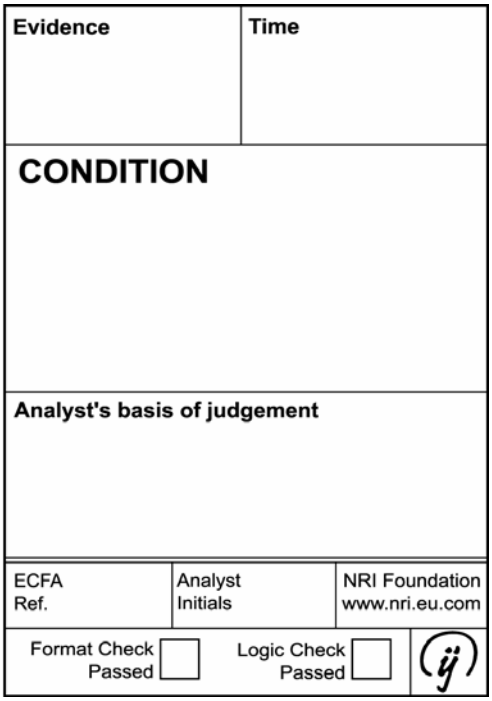


Appendix 3: ECFA+ Artwork for printed Post-it® Notes†.

EVENT: Print onto yellow



CONDITION: Print onto pink



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† *Post-it is a registered trademark of 3M Company.*

QUERY: Print onto blue

Appendix 4: Pro-forma for Further Enquiries List

Ref.	Information required	Source of Info	Priority

Appendix 5 : Note on Causal Selection

This note is a condensed version of the chapter written by Germund Hesslow and published in "Contemporary Science and Natural Explanation: Commonsense Conceptions of Causality". D. Hilton (ed.), 1988, Brighton, Harvester Press.

The full text, which contains many examples, extensive discussion of the issues and a full attribution of sources, can obtained from: http://www.mphy.lu.se/avd/nf/hesslow/index.html

THE PROBLEM OF CAUSAL SELECTION

Introduction: the plurality of causes

Events, facts, states or properties have infinitely many causes. There are three reasons for this:

1. an event will normally depend on the immediately preceding occurrence of several different events;
2. it will usually be possible to trace a causal chain backwards in time;
3. it is generally possible to conceptualise the causes in infinitely many different ways.

Selecting one or more causes from a set of conditions is a special case of the weighting of causes according to their relative importance. For instance, although we might explain someone's alcohol problems by their biochemical susceptibility to alcohol dependence, we might also concede that other factors, such as personal problems, were contributory. When the selection criterion unequivocally picks out one condition we call this the cause, but when other conditions come close to satisfying the criterion these are termed contributory, and the condition which best fits the criterion is considered more important than the others.

Two basic distinctions: "selection versus connection", "individual versus generic"

The selection problem has two interrelated aspects:

- the "connection problem" – the existence of a causal relation between two events. The connection problem is the problem of understanding the process by which we determine that, say, the presence of oxygen, combustible material and a source of ignition are all *necessary* conditions for houses catching fire.

- the "selection problem" – the relative importance of causes. The selection problem is the problem of deciding which of the necessary conditions was the most important, in a concrete individual case. We do not say that a fire was caused by oxygen, in spite of the fact that we know that there is a causal connection between oxygen and fire. Instead, we mention only the combustible material and the source of ignition.

There are two kinds of causal relationship, individual and generic:

- Individual causal relationships are those which obtain between concrete individual occurrences of events, such as the house's catching fire at 9.05 p.m. yesterday because of the explosion in the television set a moment earlier or the fact that Smith's recent death was caused by a heart attack.

- Generic causal relationships are those which obtain between kinds of events (generic events) or between properties, such as the general propensity of explosions to cause fires, or the fact that heart attacks cause death.

One view of the relationship between these two kinds of causal relation is that we arrive at generic causal relations by generalising from individual cases of co-occurrence and then apply this general knowledge to other individual occurrences. Thus, since a large proportion of

those who have heart attacks die, we conclude that the disease is deadly. If Smith has an infarction and dies, we use our knowledge of the general causal relation to justify the belief that his death was caused by the infarction. *Note, however, that a general causal statement can be true while a corresponding individual statement is not.* Smith's heart attack may not have killed him and he may have been killed by something else.

Criteria which govern causal selections and weightings

There are many different criteria that can be applied to the task of selecting a relevant subset of causes from the infinitely large set of causes that can be argued to precede any event or state. It is not self-evident that any of the criteria described below, are "true" or "correct". Most people, when confronted with this list of selection criteria, would probably find some truth in each of them. To those of us who like compromises, it is tempting to conclude that all, or at least most, of the criteria are true but that different criteria are used in different contexts.

(a) Unexpected conditions. According to Mill, *"If we do not... enumerate all the conditions, it is only because some of them will in most cases be understood without being expressed, or because for the purpose in view they may without detriment be overlooked. For example, when we say, the cause of man's death was that his foot slipped in climbing a ladder, we omit as a thing unnecessary to be stated the circumstance of his weight, though quite as indispensable a condition of the effect which took place"*.

On this basis, some conditions are not mentioned because they are presumed to be already known to the listener, and stating them explicitly would be superfluous. Consequently, we select as causes only such conditions that are unknown or unexpected.

We do not generally require explanations when things behave normally; we ask "why" mainly when something unexpected happens. A relevant explanation will state events which were both unexpected and would have enabled us to predict the surprising event if we had known about them.

(b) Precipitating causes. It is often possible to divide the complete cause into more-or-less permanent states and instantaneous changes or events. We usually select the events immediately preceding the effect which we are trying to explain. In such cases, we explicitly use the distinction between permanent conditions and the instantaneous event which came last into existence.

(c) Abnormal conditions. This selects factors on the basis of making the difference between an accident and normal functioning. In a railway accident there are conditions such as the normal speed, weight of the train and routine stopping and acceleration. These conditions are true both in the case where such accidents occur and in the normal cases where they do not, and so we reject them as the cause of the accident, *even though it is true that accident would not have occurred without them*. It is this consideration that leads us to conclude that to cite factors which are present both in the case of disaster and normal functioning, would explain nothing: such factors do not 'make the difference' as would a bent rail.

There is substantial difference between unexpected and abnormal conditions: abnormality refers to objective facts; things are normal or abnormal independently of our knowledge of them, while unexpectedness refers to a subjective state.

(d) Variability refers to the selection of those conditions which are variable in contrast to more permanent conditions. This is a blend of the first three criteria discussed.

(e) Deviation from theoretical ideal. Theoretical concepts often guide causal selections. For instance, in explaining a deviation we select causes which are also deviations from an ideal model of the system in question.

(f) Responsibility. Causal statements may have an evaluative component. Indeed, the Greek word for cause, *aitia*, also means guilt. The ancient Greeks modelled their idea of causation in nature by analogy using ideas about social organisation. A *cause* was thought of as some-

thing that brings about a disturbance in state of harmonious equilibrium in nature, and the *effect* as something that restores this equilibrium, much as a punishment restores the social harmony after a crime. In general, we identify the cause of a tragedy before assigning blame. However, it may be claimed that in selecting among the causal conditions we pick out those events or actions which deviate, not from what is normal, but from what is good, reasonable or appropriate. A cause will often be an omission which coincides with what is reprehensible by established norms of conduct. Thus, when we say that a fire was caused by negligence of the authorities (who failed to notice the special dangers in the building), we are not denying that oxygen, a heat source etc. had something to do with it. Neither are we saying that negligence is abnormal. We are, rather, specifying what went wrong.

(g) Predictive value. This holds that an explanation for a certain event consists of information that, had we had access to it before the event to be explained occurred, would have enabled us to predict it. In view of this, a natural and intuitively compelling selection criterion would be that we select as the most important causes those that most effectively predict the effect.

(h) Replaceability and necessity. Most of us think about certain historical figures like Napoleon, Gandhi or Lenin as being important causal factors in history. Historians sometimes take a different view and argue against the role of the individual in history – that even if the person X had not done this or that, someone else would have done it instead, and therefore history would not have been much different. This argument does not deny that X did bring about certain things, only that X was not necessary. However, if there were other people with similar characters, motives etc., they could have achieved the same effects, hypothetically speaking. X was, we might say, replaceable, and therefore not as important a cause for historical developments as causes which were irreplaceable.

There are similarities between the replaceability criterion and the criterion of predictive value: a condition which could be replaced is also a bad predictor of the effect. However, predictive value focuses on the probability that the effect occurs, whereas replaceability focuses on the probability that the effect does not occur in the absence of the causal candidates.

(i) Instrumental efficacy. It is possible to consider causes as levers by means of which we can produce or prevent certain effects. If causality is viewed in this way, it is very natural to think that we select those conditions which enable us to manipulate effects. If we want to bring about something, we will select conditions which come as close as possible to being sufficient for a desired end, and if we want to prevent something, we select conditions which come as close as possible to being necessary for whatever it is we wish to avoid.

(j) Interest. This holds that causal selections are governed by the particular interests of the person giving an explanation. For example, explaining a road accident, a road engineer might point out that the road had a poor surface and that the cause of the accident was the slippery highway. A policeman might instead pick out some other factor, like the excessive speed of the car, and a psychologist yet another factor such as the driver's disturbed state of mind. Each person looks at the situation from a special point of view and singles out that factor that interests him or her most.

Appendix 6 : Standards of Evidence

ECFA+ has three levels of confidence, these are denoted by: solid lines (established as fact); dotted lines (presumptions); and queries (queries need to be justified by some reasoning). It is essential that the analyst ensures that all items and connections shown in an ECF chart are supported by adequate evidence. What constitutes *adequate* is a complex matter that needs to be decided in context. This paper highlights principles for the reader to keep in mind during ECFA+; it does not advocate a particular standard of proof or any particular methodology for acquiring and handling evidence[5].

Reliability and validity

Reliability and validity are two qualities often associated with matters of measurement and which provide insight into the more general topic of evidence. *Validity* is the extent to which a quantity measures what it purports to. *Reliability* is the extent to which measurements of a given phenomenon give consistent results and are uninfluenced by other factors. Applied to evidence, *reliability* is about the way that the evidence was created, collected and relayed; whereas validity is about the extent to which evidence is a true indicator of the fact asserted. The two qualities are connected: evidence cannot be valid without being reliable; but reliable evidence can be invalid. In practice, validity often implies interpretation on the part of the person receiving the evidence.

Promoting reliability

Evidence can be seen as the link between a person such as an investigator and the specific condition or event from the past that they are considering. In this perspective, evidence can be seen as a process of communication between a particular historical state or action and the investigator. Error and distortion can affect any stage of this communication, which can be considered as a five stage process:

- Create – the change created in the witness plate[6] by the action or state in question;
- Collect – the collection of data from the witness plate;
- Conserve – the preservation of the data in or acquired from the witness plate;
- Convey – the transfer of the data to the investigator or other interested party;
- Consider – the examination of the data as evidence for the action or state in question.

Reliability is a necessary but not sufficient condition to consider when evaluating evidence. However, highly reliable tests and assessments can give the impression of scientific credibility which may seduce investigators into assuming that the data so produced are valid evidence about the matter question.

Assuring Validity

Assessing the validity of evidence is a matter of gauging the extent to which the evidence supports the assertion as fact of the event, condition or causal connection in question. The following questions may be useful in stimulating critical assessment if the validity of evidence:

- Could the same evidence support another interpretation?
- What other evidence would we expect to find given the fact in question?
- What is the justification for asserting a relationship between the evidence and the fact in question?

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[5] For readers interested in the consideration of evidence within systems of law, texts such as Tapper (2003) and Giannelli (2003) are helpful guides. However, the detailed conventions developed in legal systems do not constitute a complete solution for the complex issues of evidence.

[6] Witness plates, which can be people or things, “provide data about the events that changed them” … “One investigative task is to identify the people and things who or which were the witness plates to an accident. Obtain the accident data, the signals, that the witness plates have captured, and then read the data to reconstruct the events that produced the data. The witness plate idea helps locate and evaluate sources of data recorded during an accident.” (Hendrick and Benner, page 73-74, 1987).

Appendix 7: **ECFA+ criteria developed to assist the investigation of the emergency service response to the fire and explosion at Enschede, the Netherlands, 13 May 2000**

On 13 May 2000, there was a large explosion in the town of Enschede in the Netherlands. To advance the subsequent investigation, the emergency services needed to process substantial quantities of data collected by several teams of investigators from a variety of sources. To assist with this task, NRI worked with the investigators to develop criteria for identifying relevant events and conditions. The criteria are listed below:

A. Communication

1. inter-agency (e.g. between Fire Brigade and Police)
2. intra-agency
3. external

B. Decision making

1. assessing the situation (to inform decision making)
2. to deploy resources
3. to disseminate information
4. to enact a plan or procedure

C. Operation

1. actual deployment of resources (following decision making)
2. a planned change
3. unplanned change (positive)
4. unplanned change (negative)

The criteria have different bases: category “A” is needed to integrate data provided by the various agencies and to bring into focus command and control; category “B” makes decision-making visible to analysis, and; category “C” is an important catch-all that helps to identify differences between theory and practice of disaster management.

The criteria were used to filter the data obtained by the various investigation teams. When applied to reports, the investigators noted which criterion was relevant to each datum. This ensured that the transformation of source reports and other material into ECF charts was transparent. It also provided traceability between each item in the ECF chart and the evidence that corresponded to it.

Lastly, when applying criteria to select-in relevant data, it is prudent for the analyst to watch for instances where seemingly pertinent data are filtered-out. This “sense” check was applied by investigators in the Enschede analysis to develop and refine the criteria as well as to ensure that relevant data were included.

Appendix 8: Glossary of Terms

Action: The means by which an actor changes the state of an object. In ECFA+ actions are described using transitive verbs.

Active Voice: Chambers (1996) states that "A verb is said to be in the active voice when the subject of the verb is performing the action or is in the state described by the verb. 'Voice' is simply the technical word for that aspect of the grammar of verbs that is covered by the terms 'active' and 'passive'. For example, in *The boy stroked the cat,* the *boy* is the subject of the verb *stroked* and it is the boy who is performing the action of stroking; *stroked* is therefore in the active voice." … "The opposite of an active verb is a passive verb, as in *The cat was stroked by the boy*…".

Actor: A person or thing that acts on an object.

Condition: A passive state that endures for some period of time. E.g. "40kph SE wind", "Valve shut", "Road open to traffic". Written onto pink Post-it Notes, if available.

Dashes *and* ***dashed-lines*** are used to denote uncertainty in ECF charts and can be applied to both connecting arrows and to the outlines of events and conditions.

ECFA+ is the acronym of the title "Events and Conditional Factors Analysis". The "+" character is used to distinguish this method from its predecessor "Events and Causal Factors Analysis" (Buys and Clark, 1995).

ECF chart: Any diagram produced by applying the ECFA+ procedure.

Event: A moment, generally of short duration, characterised by a change of state. In ECFA+, an event is described by the action of an actor on an object (e.g. "Car enters smoke plume", "Smith moves PTO lever to 'on' position"). Written on yellow Post-it Notes, if available.

List of Further Enquiries: an open-ended table in which questions and uncertainties can be noted as they arise during the investigation. An example is provided in Appendix 4.

Non-event: an event that would be expected to occur given the circumstances, but which in fact did not happen. In ECFA+, non-events are treated as conditions and the analyst is required to identify the standard of judgement that they are using – such as a procedure, custom or practice, or theory). This approach enables other stakeholders to challenge the judgement of the analyst and reminds the analyst of the need to justify their reasoning in such instances.

Object: The person or thing receiving the action of an actor.

Occam's razor refers to the principle of minimising the number of items in an explanation to only those needed. It is also sometimes called *the principle of economy*.

Primary Events/Conditions are generally close in time (i.e. minutes, hours, or days) to the unplanned outcomes in question. Primary is defined in relation to Secondary (see *Secondary Events/Conditions,* below*).*

Query: The third type of item that can be used in ECFA+ (the others are events and conditions). Queries are used to denote areas of uncertainty, especially where this has causal relevance. Written on blue Post-it Notes, if available.

Secondary Events/Conditions: Secondary events are included to explain the coming into existence of primary conditions; these may reach days, weeks, or years back in time from the unplanned outcomes which are the focus of investigation.

Simple Present tense: Chambers (1996) states that "The present tense of a verb is the tense which refers, among other things, to actions going on or states existing at the present time or in general". This is in contrast to the progressive or continuous form of the present tense which "…consists of the *-ing* form of the verb in combination with the auxiliary Verb *to be*".

Start-rules and stop-rules are used to determine the first and last event or condition in the primary sequence. These should be informed by the terms of reference drawn up for the investigation. The default is that the ECF chart should include both the first event that compromises control of what follows and the event that restores the control of outcomes.

Transitive Verbs are verbs that express an action directed toward or performed on an object. In most circumstances, a transitive verb has a corresponding object in the sentence (e.g. "Bloggs foots the ladder", "The falling scaffold pole strikes the valve handle"). In ECFA+, the analyst should endeavour to phrase events using transitive verbs.

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NRI Document Improvement Proposal

1. Document reference	2. Version date	3. Document title
NRI-4	20 June 2008	ECFA+ Manual

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

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