Table 1: Description of exercise

Description of exercise	Phase 1
Description of Method(s) used	***STEP (Tanja Heinimaa, results are mainly based on the previous study in Finland (Heinimaa 2015). Detailed analysis is not done in this accident)*** ***STEP (Sequentially Timed Events Plotting): Multi-linear event chain description in chronological order (several activities, by different actors take place at the same time). References: See in Table 4.*** ~~***other/ DISC (the Design for Integrated Safety Culture) (Tanja Heinimaa)***~~ ~~***The DISC framework includes criteria for good safety culture and a description of functions that the organization needs to implement in order to orient the organization toward the criteria.***~~ ***ACCIMAP (Frank Verschueren)*** ***Accimap (see Rasmussen and Hopkins) see reference in Table 4*** ***A generic approach for accident analysis in complex sociotechnical system. It focuses more than classic models on the causal flow of events and decisions upstream of the accident by considering a multi-level model (government policy and budgeting, regulatory bodies and associations, local area government, planning and budgeting, company management, technical and operational management ; physical processes and actor activities; equipment and surroundings.*** ***Purpose is to identify failures at all levels and to link them between and across levels based on cause-effect relations.*** ***CAST (Nancy Leveson)*** ***Based on the STAMP accident causality model, which is grounded in systems theory. Traditionally, accidents have been thought of as resulting from a chain of failure events, each event directly related to the event that precedes it in the chain. STAMP extends this model of accident causation to include the chain-of-events model as one subcase but includes the***

Comment [H1]: Not taken in use in Tukes. Is only "backround information" in investigation

	causes of accidents that do not fit within this model, particularly those that occur in the complex sociotechnical systems common today. These causes (in addition to component failure) include system design errors, unintended and unplanned interactions among system components (none of which may have failed), flawed safety culture and human decision making, inadequate controls and oversight, flawed organizational design, etc. In STAMP, accidents are treated as complex processes rather than simply chains of failure events. ***Storybuilder (*Bert Wolting)** **To help in accident investigation by entering accident paths into a graphically enhanced database. Aanalysis of the accident paths provides information about the direct and root causes of accidents. For this analysis a version dedicated to major accidents analysis was used.**
Accident(s) studied	Explosions at Moerdijk Shell
References used by the team, including tools, websites, publications.	***STEP*** See below in Table 4
	ACCIMAP (Frank Verschueren) See below in Table 4 ***Storybuilder*** See below in Table 4

Expectations of outcomes	***STEP is meant to be utilized during the investigation. If the accident is analyzed afterwards on the basis of the report, there may remain many questions about "when" something happened and about the causality of actions.***
	ACCIMAP is meant to be used so as much as possible different levels in an organization and around (the context) (up to Government) are taken into account
	CAST The result of the modeling and analysis is a comprehensive model of all the factors leading to the accident and how they interact. CAST does not find a "root cause" or someone to blame, but instead tries to understand why the accident occurred (what was wrong with the design and operatin of the system that led to the loss) so such events can be prevented in the future. A CAST analysis examines an accident in terms of lack of controls and unsafe behavior rather than failures or failure events. Instead of identifying what errors people made, the focus is on why it made sense for them to do what they did and how to redesign the system and operations to prevent the same things from happening again.
	Storybuilder A graphically enhanced database analysis of the accident paths provides information about the direct and root causes of accidents. Its additional value is shown when a number of accidents can be analysed.

Table 2: Findings relevant to the accident and report information

What was the result of this process? e.g., -findings -questions, gaps in information that you hope to resolve in the next steps -scope of the investigation -limitations imposed by information available -potential themes already emerging -gaps in information	**How did this phase meet your expectations?** ***FV : ACCIMAP : Not really a help for sequence of events*** *Accident report describes list of events*
	Scope of the investigation reports:
	Findings from report: I have found different information from different reference materials.
	Limitations of the report: ***FV Little information on involvement (decisions) of Higher Management and causes for several Management Systems shortcomings***
	Gaps in information in the reports: ***FV Involvement (decisions) of Higher Management and causes for several Management Systems shortcomings***
	Questions or gaps in information that you hope to resolve in the next steps : ***STEP*** ***Pre-accident events and underlying causes or further information on WHY?*** ***ACCIMAP*** ***Questions for Information on higher levels although the document contains already some (up to Regulators and Inspections)*** ***CAST*** ***There are many questions raised by the CAST analysis that are not answered in the accident report but would have guided the investigation in terms of what questions to ask. There were many factors that probably were related to the poor safety culture and safety management system at Shell, but these were not included in the accident report so the CAST analysis could only speculate about why they occurred.***

	Storybuilder no serious gaps
	TH ***It would be very important to discuss the difference between "how things seems on paper and how they are in practice". It would be very important to summarize both the good (positive) activities and those which should be improved (SMS, MOC, the maintenance, the roles of authorities, the safety culture (e.g. using DISC-model (structures-practices-understanding, see reference in Table 4) ,…).***
	FV : ***ACCIMAP Questions on SMS , more specific self-auditing, self-assessment , learning of incidents, transfer from knowledge through the WORLD GLOBAL organization*** ***NL*** **CAST-generated questions will be created during the analysis** ***Storybuilder*** The tab 'Barrier visualisation' contains for both sides of the bowtie the selected 'barrier status' and 'Underlying management system failures'.
If you were an investigator or inspector, what questions would you ask the site following this analysis?	
	FV - ***Why and how were the different deficiencies in several elements of the SMS generated?*** - ***Why did they stay undetected ? (is in itself an audit-deficiency)*** ***BW Why the failures of the barriers status as well as the underlying management system occurred.*** ***CAST: Too many to specify in this space. There are several dozen questions***

	that the CAST analysis identifies as unanswered about why the accident occurred.

Table 3: Findings relevant to the method

Summary of experience working with the method(s)	***TH*** ***It is very important to determine the scope and the aim(s) of the accident investigation and then decide the accident investigation method(s). In that case it is possible to achieve the greatest benefit of the method(s).*** ***FV (16/09)*** ***I agree with TH but think we have to wait the feedback on other methods*** ***ACCIMAP*** ***not 100 % negative but not 100 % positive*** ***Can be a method or maybe just a framework that is guiding the "depth" of the investigation into higher levels of the organization*** ***Inspectors can go higher than insiders so special added value for inspectors or safety boards*** ***NL(17/09)*** ***I do not agree with TH.*** ***CAST*** ***The technique provides a very complete analysis of any accident and in dozens of previous evaluations provides much more useful information than other methods. CAST is now being used in accident analysis in every type of industry. To find examples (although many of the causal analyses are proprietary, see http://psas.scripts.mit.edu/home/) and click on "sorted papers." In many cases, the results were compared with the official accident reports, which were found to be more limited than the CAST analysis.*** ***TO ELABORATE (comment FV 15/02/18) To be proven also in other cases (BP Texas City)*** ***TH (1909)***

Comment [BW2]: I would like to see prove of this as well.

The CAST analysis (mail 17-08-2017 16:31) lacks a table of content.

	I am not so familiar with CAST but what I meant e.g. Fault tree also can sometimes be very good accident investigation method ": IF there is some very technical thing need to be analysed more in detail. But do not ever analyse organisational factors with fault tree -> use the method for the purpose it is meant to. IF there are some complete methods -> it is allways usable. But if you want to analyse only some point, you don't need a complete method. ***Storybuilder no remarks TO ELABORATE (comment FV 15/02/18)*** ***BW (260318)*** ***The methods Accimap, STEP and Storybuilder provide a schematic/ graphical overview of the (causes) of the accident. For end-users this eases understanding.*** ***Cast can provide a broader and more systemic analysis if required/desired.*** ***Comment of FV as GROUPLeader: to ORGANISATION (Maureen and Zsuzsanna)*** *It is clear to me that we still have to discuss this as a group to see if we can reach a consensus or not. Consensus is not really needed and no real must as we are all have our individual opinions but still is important as group to try.* *If ISPRA/JRC could help us in providing a teleconference tool The 4 analysts (Nancy, Tanja, Bert and Frank) could exchange the ideas and may reach some conclusion* ***(comment FV 15/02/18)***
Advantages	***STEP:*** ***- A clear presentation*** ***- A good method for the systematic identification of actors, as well as for***

	the describing of the chain of events. *- Helps to detect weaknesses in the chain of events -> helps to determine what further information is required* *- Helps to standardize the terms used (-> the report is logical)* *- Helps to limit the review (when accident/ accident investigation begins and ends)* *- The method allows looking at both the technical, human and organizational factors.* *ACCIMAP :* *gives incentives to go and seek further than direct immediate causes (front-line operators , sharp edge) to more hidden contributory causes as managerial causes, organization factors (causes)* *Going from sharp end to blunt end* *CAST: Does not focus on blame but instead looks at all the contributing factors and how to prevent a reoccurrence. Too many accident analyses stop after they find a "cause" or perhaps several causea (usually blame is placed on a person or group) and not the dynamics of why the loss occurred. Provides the information necessary to prevent a large number of future accidents and not just the symptoms of the actual systemic causes that will lead to future losses unless the entire system is redesigned to eliminate them. Provides a structured method for performing the analysis on a model of the system.* ***Storybuilder no remarks*** *Its additional value is shown when a number of accidents can be analysed.* ***TO ELABORATE (comment FV 15/02/18)***

Disadvantages	*STEP:* *- This method may have too mechanical an approach. The method works at a general level well, but often a detailed review of other methods is needed.* *- Using the method for its original purpose, the method does not go very deep into the organizational factors behind (e.g. safety culture) the accident.*

Comment [H3]: - Analyses the accident at different levels of the socio-technical system
- Suitable to analyse authority's activities and the legislation -> is used method in Finland e.g. in Tukes and Safety Investigation Authority
- With AcciMap, actions can be linked between different levels.
- It is not a fault-based method, it describes the activity.
- Helps to consider which issues need to be further investigated.
- Drawing a graphical chart helps investigators to formulate a common understanding of the accident.
- Helps in writing a report

	- It's not easy to report the analysis in digital form (because of the amount of the information on Excel sheet or PowerPoint). ***ACCIMAP :*** ***visualization and oversight , the links are sometimes between levels not directly neighboring , limited oversight (technically in excel file)*** ***Maybe there is software for it (ask CSB !) to overcome !*** ***The article with some guidelines (Brashford, Hopkins) is not well known in the literature*** ***Storybuilder no remarks TO ELABORATE (comment FV 15/02/18)*** ***CAST: Does not find a simple "root cause" so the analysis and results are lengthy. So many factors are found to have contributed to the accident, that the number of recommendations can be lengthy (this was a criticism by some NTSB members when they saw the results of a CAST analysis of the Asiana SFO crash). Management also can be disturbed by the inclusion of their contributions and not just a finding of operator error. This comprehensiveness also contributes to the lack of a simple graphic to show what went wrong.***

Comment [H4]:
- Depending on the inspections group, different perspectives can be emphasised
- AcciMap can reduce the accident and events because AcciMap's goal is not a complete event chain.
- Reading a graphic chart can be difficult for the unexperienced

Advice for analysts/inspectors using this (these) method(s)	***STEP:*** ***- STEP is particularly suitable at the beginning for the documentation of the collected data and for the determining the need of additional data*** ***- At the beginning it is good to list all "actions", "actors" and "time" e.g. in Excel. Different color Post-it notes help when defining the timeline and what information is still needed.*** ***- It is possible to analyze also "positive events" in the accident.*** ***- It might be recommended to make a "lighter" STEP analysis (the collection and organization of data, the chain of events) and in addition AcciMap in order to determine more extensive underlying factors.*** ***FV (16/09) (comment as "Groupleader")) :*** ***it can be that another method should be used in addition*** ***but that is the reason why we do the bench mark*** ***CAST: Start with the physical system and then work upward in the control structure to identify why the physical events occurred. Avoid blame but instead ask at each step: "Why did it make sense at the time for the person to do what they did" (assuming that they were not intentionally trying to cause harm). If the answer to "why" is not immediately obvious, keep a list of questions that will need to be answered in the end to put the whole story together.*** ***ACCIMAP :*** ***If you want to check how deep your investigation is: use the different levels (you can create your own levels and add them depending on the broadness depth of the organizational structure. And link(s) to government and other organizations in the surrounding environment of the organization)*** ***There is a software (see UPLOADS project in Table 4) : this still has to be explored and elaborated(comment FV 14/03/18)***

Comment [BW5]:
The Accimap you provided (17-08-2017 12:50) is better to understand with:
-a legenda of colours (yellow, red, blue, black)
- adding missing connecting lines between or are they on purpose.
- indicate the (root)causes and conclusions

	TH:remark on ACCIMAP ***In Tukes in Finland the accident is described graphically by AcciMap in the accident investigation report. We think AcciMap is descriptive in the authority's investigation report (sociotechnical levels, incl. legislation).*** ***TO ELABORATE (comment FV 15/02/18)***

Table 4: Reference materials - List of Links

Date	Title	Link	Comment
2.9.2016	*Methods for accident investigation (Sklet, 2002)*	*http://frigg.ivt.ntnu.no/ross/reports/accident.pdf*	*e.g. descriptions of methods, incl. STEP, Accimap*
2.9.2016	*Guide to safety analysis for accident prevention (Harms-Ringdahl, 2013)*	*http://www.irisk.se/sabook/*	*e.g. descriptions of methods, incl. STEP, Accimap*
2.9.2016	*Root cause analysis: Literature review. Contract research report 325/2001. (HSE, 2001)*	*http://www.hse.gov.uk/research/crr_pdf/2001/crr01325.pdf*	*e.g. descriptions of methods, incl. STEP*
	STEP		
	Investigating Accidents with STEP (Hendrick, K. and Benner, L. 1987)		
	Guidance on investigating and analysing human and organisational factors aspects of incidents and accidents (Energy Institute, 2008).	*http://www.energypublishing.org/publication/ei-technical-publications/human-and-organisational-factors/guidance-on-investigating-and-analysing-human-and-organisational-factors-aspects-of-incidents-and-accidents.*	
	System modeling with the DISC framework: evidence from safety-critical domains (Reiman et al., 2012)	*Reiman, T., Pietikäinen, E., Oedewald, P., Gotcheva, N. Work 41(2012), pp. 3018-3025.*	*Article*
2.9.2016	*Improving the safety of Seveso-establishments in Finland by developing the accident investigation process*	*http://www.tukes.fi/Tiedostot/kemikaalit_kaasu/Onnettomuustutkinnan_vaikuttavuus_Seveso-laitoksilla.pdf*	*Licenciate Thesis (in Finnish)*
2.9.2016	*Explosions MSPO2 Shell Moerdijk (Dutch Safety Board)*	*https://www.onderzoeksraad.nl/en/onderzoek/2045/explosions-mspo2-shell-moerdijk*	*video and report*
	ACCIMAP		
FV	**An Accimap of the Australian Gas**		Book

Comment [BW6]:

Some general references are also on https://minerva.jrc.ec.europa.eu/en/shorturl/benchmarking_exercise/methodologies_and_other_reference_materials_benchmarking_project_private
Remove those?

Comment [H7]: Accimap, one reference:

Svedung, I. & Rasmussen, J. 2002 Graphic representation of accident scenarios: mapping system structure and the causation of accidents. Safety Science, 40, s. 397–417.

14. 3.2018	**Plant Explosion (Andrew Hopkins, 2000)**		
FV 14. 3.2018	**Proactive Risk Management in a Dynamic Society (Svedung I , J Rasmussen 2000)**	Analysis of Accident scenarion's p 18-24 ; Identification of decision makers p 51 ; Tool for Accident Analysis and Organisational Audit p 75-82 Appendices Illustrative Accidents A1, A3, A4, A5 and A6	Book Swedish Rescue Services Agency
FV 14. 3.2018	**Guidelines for Accimap Analysis (Branfor K., Naika N, Hopkins A 2009)**	In A. Hopkins (Ed.) Learning from high reliability organisations: 193–212.	Book Sydney CCH
FV 14. 3.2018	**Seeing the big Picture of Mishaps (Kate Branford 2011)**	Aviation Psychology and Applied Human Factors 2011, vol 1 (1) 31-37	
FV 14. 3.2018	**Lessons learnt from using Accimaps and the risk management framework to analyse lage-scale systemic failures (Waterson P.E. and Jenkins DP 2011)**	In Proceedings of the International Conference on Contemporary Ergonomics and Human Factors2011 London , Tylor and Francis	Article
FV 14. 3.2018	**Systems-based accident analysis methods: A comparison of ACCIMAP, HFACS and STAMP (Paul M.Salmon et al , 2012)**	Safety Science 50(2012) 1158-1170	Article
FV 14. 3.2018	**Assessing organisational factors in aircraft accidents using a hybrid Reason and Accimap model (Cees Bil et al, 2013)**	Engineering Failure Analysis 27 (2013) 52-60	Article
FV 14. 3.2018	**Appendix A Accimap Causal Analysis , CSB Investigation report on Tesoro Anacortes Refinery explosion and fire (2014)**	US Chemical Safety an hazard Investigation Board	Appendix of report

FV 14. 3.2018	**UPLOADS project**	https://uploadsproject.org/training-material/systems-analysis-of-causal-factors-accimap/ https://uploadsproject.org/training-material/install-the-uploads-software-tool/ UPLOADS: An incident reporting and learning system (by ACCIMAP) for the outdoor education, recreation and adventure sector in Australia Systems Analysis of Causal Factors (Accimap) The Accimap program allows you to conduct a systems analysis of the causal factors involved in your incidents. It is a special analysis tool, separate to the database, to summarise the causal factor and relationship data entered into the database.	
FV 14. 3.2018	**Wikipedia page Accimap**	https://en.wikipedia.org/wiki/AcciMap_approach	
	Storybuilder		
	RIVM analysis with Storybuilder of the Shell MSPO2 accident	The resulting bowtie is too extended for a good visualization but available on request. The spreadsheet contains in the tab 'Extended report' the various steps of the bowtie. The tab 'Barrier visualization' contains for both sides of the bowtie the selected 'barrier status' and 'Underlying management system failures'.	 Shell MSPO2 storybuilder data (Ex
	Journal of Loss Prevention in the Process Industries 26 (2013) 1039-1059	Analysis of underlying causes of investigated loss of containment incidents in Dutch Seveso plants using the Storybuilder method	Article
	Storybuilder	http://www.rivm.nl/en/Documents_and_publications/Scientific/Reports/2008/september/The_quantification_of_occupational_risk_The_development_of_a_risk_assessment_model_and_software	Website
	CAST (STAMP)	Nancy G. Leveson, *Engineering a Safer World*, MIT Press, 2012	

Field Code Changed

Field Code Changed

Comment [BW8]: or see :

BellamyAnalysisOfUnderlyingCausesSeves

		Nancy Leveson, A New Accident Model for Engineering Safer Systems, *Safety Science,* Vol. 42, No. 4, April 2004	
		Nancy Leveson, Applying Systems Thinking to Analyze and Learn from Events, Safety Science, Vol. 49, No. 1, January 2010, pp. 55-64.	
		For many public examples on major accidents, see http://sunnyday.mit.edu/STAMP-publications-sorted.pdf	