APPENDIX 1

Glossary

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This appendix gives a list of useful definitions found in the ARAMIS project, part WP1 (identification of scenarios). Most definitions are given in the full text, but are listed here in alphabetical order.

Atmospheric storage: Storage tanks working at ambient temperature and pressure and containing a substance in a liquid state..

Atmospheric transport equipment: Transport equipment working at ambient temperature and pressure and containing a substance in a liquid state.

BLEVE and possible fireball: The BLEVE (acronym for Boiling Liquid Expanding Vapour Explosion) happens when a vessel, containing a liquid highly superheated above its normal atmospheric boiling point, fails catastrophically. The BLEVE concerns pressure liquefied gas storage or pressurised liquids. The first consequence of a BLEVE is a blast effect due on the one hand to vapour expansion when the vessel fails, and on the other hand to the explosive vaporisation of the vessel liquid content. This effect is generally followed by missiles ejection. If the substance is flammable, the air-substance aerosol can ignite immediately. The flame front rapidly moves away from the ignition point and a ***fireball*** occurs. Its temperature is extremely high and it causes an important thermal radiation.

The way to take into account the BLEVE is explained in the Catastrophic rupture entry.

Boilover and resulting poolfire: Generally consequent upon a tank fire, the boilover phenomenon is the sudden and violent eruption of burning liquid out of an atmospheric storage on fire. This is the consequence of the transformation, into vapour, of liquid water contained in the bottom of the tank. An atmospheric storage can lead to a boilover if the following requirements are met:

- Presence of water in the bottom of the tank.
- The formation of a heat wave which meets the water layer under the hydrocarbons mass.
- A sufficiently viscous hydrocarbon so that the water vapour cannot easily go through it from the tank bottom.
- A average boiling temperature higher than the one of the water at the pressure of interface water/hydrocarbon. The condition is the following for the usual hydrocarbon storage :
  - $TBUL_{HC} > 393K$ (120°C)
- A range of boiling temperature enough large to generate a heat wave, that is to say 60° beyond the boiling temperature of the water at the pressure of interface.

Breach on the shell in liquid phase: This critical event is a hole with a given diameter on the shell in liquid phase (under the liquid level) of an equipment, leading to a continuous release. This hole can be due to a mechanical stress due to external or internal causes, to a deterioration of mechanical properties of the structure,…

Breach on the shell in vapour phase: This critical event is a hole with a given diameter on the shell in vapour phase (above the liquid level if a liquid phase exists) of an –equipment, leading to a continuous release. This hole can be due to a mechanical stress due to external or internal

causes, to a deterioration of mechanical properties of the structure,… This critical event includes also a breach on an equipment where a solid material is in suspension in air or in gas.

Catastrophic rupture: A catastrophic rupture is the complete failure of the equipment leading to the complete and instantaneous release of the substance. **A BLEVE is also a catastrophic rupture in particular operating conditions.** Depending on the circumstances, the catastrophic rupture can lead to overpressure generation and missiles ejection.

Collapse of the roof: The collapse of the roof may be due to a decrease of the internal pressure in the vessel leading to the collapse of the mobile roof under the effect of atmospheric pressure. The collapse of the roof is specially considered for atmospheric storage.

Critical Event (in the bow-tie): generally defined as a Loss of Containment (LOC). This definition is quite accurate for fluids, as they usually behave dangerously after release. For solids and more especially for mass solid storage, we would rather use Loss of Physical Integrity (LPI), considered as a change of chemical and/or physical state of the substances. The Critical Event is the centre of the bow-tie.

Cryogenic storage (with cooling system): Storage tanks working at atmospheric pressure or at a lower pressure and at a low temperature. The substance stored is a refrigerated liquefied gas.

Dangerous phenomenon (in the bow-tie, event tree side): event following the tertiary critical event (for example, the pool fire after the ignition of a pool). Examples of Dangerous Phenomena are a Vapour Cloud Explosion, a flash fire, a tank fire, the dispersion of a toxic cloud, etc.

Dangerous Phenomenon with a "limited source term": Dangerous Phenomenon for which the consequences of the critical event are limited by a successful safety barrier (for example by limiting the size of the pool or the release duration)

Dangerous Phenomenon with "limited effects": Dangerous Phenomenon for which a limiting barrier acts in the event tree, but not directly after the critical event (for example a water curtain which limits the quantity of gas constituting the cloud).

"fully developed" Dangerous Phenomenon: Dangerous Phenomenon for which no safety system limits the consequences of the critical event and no safety system mitigates the effects

Decomposition: This critical event concerns only solid substances. It corresponds to a change of chemical state of the substance (Loss of Physical Integrity, LPI) by action of a energy/heat source or by reaction with a chemical substance (incompatible reagent). The decomposition of the substance leads, as secondary and tertiary critical events, to an emission of toxic products or to a delayed explosion of flammable gas formed (reaction not spontaneous but can be violent). This critical event concerns only mass solid storage.

Detailed Direct Causes (in the bow-tie, fault tree side): either the events that can provoke the direct causes or, when the labelling of the direct cause is too generic, the detailed direct cause provides a precision on the exact nature of the direct cause.

Direct Causes (in the bow-tie, fault tree side): the immediate causes of the Necessary and Sufficient Causes (NSCs). For a given NSC, the list of direct causes tends to be the most complete possible.

Dust explosion: It can happen if a high enough dust concentration exists in an oxidising atmosphere. The reaction of combustion happens at the interface gas/solid and the intensity of the explosion depends directly on the area of reaction, that is to say the particle size. They can principally cause overpressure effects and missiles projection.

Effectiveness of a safety barrier: The effectiveness is the ability for a technical safety barrier to perform a safety function for a duration, in a non degraded mode and in specified conditions. The effectiveness is either a percentage or a probability of the performance of the defined safety function. If the effectiveness is expressed as a percentage, it may vary during the operating time of the safety barrier. For example, a valve which would be not completely closed on safety demand would not have an effectiveness of 100%.

Environmental damage: This dangerous phenomenon can be due to a dispersion in the environment of a substance with one of the following risk phrases: R50, R51, R54, R55, R56, R57 or R59. It can also be due to an emission of toxic vapours from the combustion of a substance with the risk phrase R100 or R101.

Event tree: Right part of the bow-tie, identifying the possible consequences of the critical event

Explosion: This critical event concerns only explosive solid substances with "explosive" risk phrases (e.g. R2, R3, R6 …). It corresponds to a change of physical state of the substance (LPI) by action of a energy/heat source or by action of a chemical source (incompatible reagent). This change of state implies a combustion of a solid with overpressure generation (or an explosion) due to a violent and spontaneous reaction. This critical event concerns only mass solid storage. In case of substance stored in a closed vessel, an explosion (or an explosive decomposition of solid) is considered as a internal cause of overpressure leading to a loss of containment (for example catastrophic rupture or breach on the shell). In this case, the loss of containment is the critical event considered in the bow-tie.

Fault tree: Left part of the bow-tie, identifying the possible causes of the critical event

Fire: The fire is a process of combustion characterised by heat or smoke or flame or any combination of these.

Hazardous substance: The SEVESO II Directive defines a hazardous substance as a substance, mixture or preparation listed in Annex 1, Part 1, of the SEVESO Directive or fulfilling the criteria laid down in Annex 1, Part 2, of the SEVESO II Directive and present as a raw material, product, by-product, residue or intermediate, including substances which may be generated in case of accident;

Finally, a hazardous substance is a substance whose toxicity, flammability, instability or explosivity may induce hazard for people, environment or equipment. The used hazardous properties are based on the hazardous categories of the SEVESO II Directive and the risk phrases of the 67/548/EEC Directive.

Initiating event: the first causes upstream of each branch leading to the critical event in the fault tree (on the left end of the bowtie).

Jetfire: The handling of pressurised flammable liquid or gas can lead to a jet fire in case of a leak on a pipe or on a vessel. The fluid ignition lead to form a jet flame characterised by a high radiant energy (largely higher than pool fire radiation) and by a noticeable kinetic energy.

Leak from gas pipe: This critical event is a hole with a diameter corresponding to a given percentage of the nominal diameter of the pipe. It can also be a leak from a functional opening on the pipe: flanged joints, pump seals, valves, plugs, seals,… This leak occurs on a pipe carrying a gaseous substance. This critical event includes also a leak on an equipment where a solid material is in suspension in air or in gas.

Leak from liquid pipe: This critical event is a hole with a diameter corresponding to a given percentage of the nominal diameter of the pipe. It can also be a leak from a functional opening on the pipe: flanged joints, pump seals, valves, plugs, seals,… This leak occurs on a pipe carrying a liquid substance.

Level of confidence of a safety barrier: the probability of failure on demand to perform properly a required safety function according to a given effectiveness and response time under all the stated conditions within a stated period of time. Actually, this notion is similar to the notion of SIL (Safety Integrity Level) defined in IEC 61511 for Safety Instrumented Systems but applies here to all types of safety barriers.

The **"design" level of confidence** is assessed with the help of instruction given in appendix 8. This means that the barrier is supposed to be as efficient as when its was installed, to have the same response time and the same level of confidence or probability of failure on demand.

The **"operational" level of confidence** includes the influence of the safety management system. The value could be lower than the "design" one if some problems are identified during the audit of the safety management system.

(Un)loading unit: unit used for inlet and outlet of substances in the establishment, involving transport equipment.

Major Events (in the bow-tie, fault tree side): significant effects from the identified dangerous phenomena on targets (human beings, structure, environment,…). The possible significant effects are the following ones: Thermal radiation, overpressure, missiles, toxic effects (on the humans or on the environment)

Mass solid storage: storage of solid substances in the form of powder or pellets. These substances may be stored in bulk or in silos (solid products storage in form of "small" bags are not taken into account here).

Material set in motion (entrainment by air): This critical event is reserved for a potentially mobile solid, to a fragmented solid (powder, dust,..) exposed to the ambience (e.g. fragmented solid in an open storage or in conveyor belts) and occurs due to the presence of an air vector (e.g. too high ventilation,…)

Material set in motion (entrainment by a liquid): This critical event is reserved for a potentially mobile solid exposed to the ambience (e.g. fragmented solid in an open storage or in conveyor belts) and occurs due to the presence of a liquid vector (e.g. flooding, liquid escaping from an other equipment,…)

MIMAH: Methodology for the Identification of Major Accident Hazards

MIRAS: Methodology for the Identification of Reference Accident Scenarios

Missiles ejection: Various equipment items can be concerned by an explosion or by a pressure increase causing their burst with missile(s) ejection.

- The BLEVE of a pressure vessel can generate missiles.
- Explosive phenomena can happen in process equipment and cause the projection of fragments, for instance a run-away in a reactor.
- Atmospheric or cryogenic storage tanks can also produce missiles (tank explosion). It can namely occur in the case of an accumulation of flammable vapours under the tank roof.
- Mechanical bursting of pressure storage due for example to a increase of the pressure in the tank.
- …

Necessary and Sufficient Causes (in the bow-tie, fault tree side): the immediate causes that can provoke a critical event. For a given critical event, the list of NSC is supposed to be exhaustive, which means that at least one of the NSC must be fulfilled so that the critical event can occur.

Overpressure generation: A rapidly propagating pressure or shock-wave in atmosphere with high pressure, high density and high velocity.

Padded storage: Storage tanks working at ambient temperature and at a pressure above 1 bar (the pressure is exerted by a pad of inert gas) and containing a substance in a liquid state.

Pipes networks (pipe): piping linking different units of the plant are considered as "pipes networks (pipes)" (for example a pipe linking an unloading unit and a storage unit, or linking a storage unit and a process unit), as well as pipes feeding the flare. Piping staying inside a unit (for example inside a storage farm, or between two process equipment of the same process unit) are not considered as "pipe". They are integral part of the equipment to which they are linked.

Poolfire: The combustion of material evaporating from a layer of liquid (a pool). The occurrence of the layer of liquid results from the failure of an equipment item containing a flammable liquid.

Pressure storage: Storage tanks working at ambient temperature and at a pressure above 1 bar (pressure exerted by the substance, eventually with an inert gas). The substance stored can be a liquefied gas under pressure (two phase equilibrium) or a gas under pressure (one phase).

Pressure transport equipment: Transport equipment working at ambient temperature and at a pressure above 1 bar (pressure exerted by the substance, eventually with an inert gas). The substance stored can be a liquefied gas under pressure (two phase equilibrium) or a gas under pressure (one phase).

Process unit: unit used for the processing of substances or for the production of energy used in the establishment. In the process unit, equipment is gathered in general categories, according to

their functions and their characteristics. For each category of equipment, examples are given but those last do not constitute an exhaustive list.

- Intermediate storage equipment integrated into the process: mass solid storage, pressure storage, padded storage, atmospheric storage, cryogenic storage
- Equipment involving chemical reactions: reactor
- Equipment devoted to the physical or chemical separation of substances: distillation column; absorption column; liquid – liquid extraction; centrifuge; separators; dryers; sieves, classifiers
- Equipment designed for energy production and supply: furnaces; boilers; direct-fired heated exchangers.
- Packaging equipment: Equipment dedicated to the packaging of material. Packages are not included here, but only the packaging system.
- Other facilities: pumps; heat exchangers; compressors; gas expansion facility; piping internal to the process unit; mixers; blenders, ….

Rain-out: Dropping of the small liquid drops from that fraction of the flashing liquid that remains initially suspended in the atmosphere.

Relevant hazardous equipment: equipment containing a quantity of hazardous substance higher or equal to a threshold–quantity.

Response time: duration between the straining of the safety barrier and the complete achievement (which is equal to the effectiveness) of the safety function performed by the safety barrier.

Safety barrier: The safety barriers can be physical and engineered systems or human actions based on specific procedures or administrative controls. The safety barrier directly serves the safety function. The safety barriers are the "how" to implement safety functions.

Safety function: A safety function is a technical or organisational action, and not an object or a physical system. It is an action to be achieved in order to avoid or prevent an event or to control or to limit the occurrence of the event. This action will be realised thanks to a safety barrier. The safety function is the "what" needed to assure, increase and/or promote safety.

Secondary Critical Event (in the bow-tie, event tree side): event following the critical event (for example, the formation of a pool after a breach on a vessel)

Start of fire (LPI): This critical event corresponds to the specific reaction between an oxidising substance and a flammable or combustible substance or to the autonomous decomposition of an organic peroxide leading to a fire. This critical event concerns only substances having a risk phrase describing a loss of physical integrity leading to a fire. These risk phrases are R7, "May cause fire (organic peroxides)"; R8, "Contact with combustible materials may cause fire" excluding any other risk phrase. This event can also be associated with pyrotechnic substances.

Storage unit: unit used for the storage of raw materials, intermediate goods, manufactured products or waste products.

Storage of solid in small packages: low capacity storage of solid in bags and in storage tanks with individual volume smaller than ≅ 1 m^3.

Storage of fluid in small packages: low capacity storage of fluid as carboys, drums and all storage tanks with individual volume smaller than ≅ 1 m³.

Tankfire: The tank fire is generally the consequence of the ignition of the gaseous phase in a vessel containing a flammable liquid.

Tertiary Critical Event (in the bow-tie, event tree side): event following the secondary critical event (for example, the ignition of a pool after the formation of a pool).

Toxic cloud: Mixing and spreading of toxic gases in air, which causes clouds to grow. The mixing is the result of turbulent energy exchange, which is a function of wind and atmospheric temperature profile.

Undesirable Events: last level of causes in the fault trees. The UE are, most of the time, generic events which concern the organisation or the human behaviour, which can always be ultimately considered as a cause of the critical event.

Unit: a part of an establishment forming a logical set, geographically separated from the other parts of the establishment (for example by a wall of an open space). Four kinds of units are defined: Storage Units, (Un)loading Units, Pipes networks, Process Units

(Un)loading unit: unit used for inlet and outlet of substances in the establishment, involving transport equipment.

Vapour Cloud explosion and flashfire: When a leakage occurs on an equipment item, a gaseous release can happen, either directly, or following the gradual vaporisation of a pool on the ground close to the leakage. This lead to the formation of a cloud which drifts and disperses with the wind. If the substance is flammable, there is an intermediate zone in which the vapour concentrations in the air are between the flammability limits of the substance. A sufficiently energetic ignition source, on the trajectory of the flammable zone of the cloud, may ignite this cloud. According to the front flame speed, the accident will lead to a *flash fire* or a *VCE* (Vapour Cloud Explosion). This last accident causes an overpressure – underpressure wave. The devastating effect is associated with the peak overpressure as well as with the wave shape.

Vessel collapse: A vessel collapse is the complete failure of the equipment leading to the complete and instantaneous release of the substance. It is due to a decrease of the internal pressure in the vessel leading to the collapse of the vessel under the effect of atmospheric pressure. The vessel collapse does not lead to overpressure generation nor missiles ejection.