3. USE CASE AND ACTORS

ELEMENTAL FUNCTIONAL & COGNITIVE SAFETY IN DISASTER PREPAREDNESS & MANAGEMENT

Abstract

This paper discusses the concept of Safety Grid in the evolving Public Safety LTE Network and relates to system of systems as in internet of everything. The aspects of an integrated system are compared against Safety-Grid. Chemical accidents are reviewed and chemical storage tank is taken as a case to identify disaster preparedness aspects against *Theory of Constraints, Cognitive Requirements, and Functional Safety*. The disaster management guidelines from OSHA's 1910.210 is constructed in the backdrop of Functional, Operational and Cognitive safety aspects with Situation Handling attributed to Boyd's OODA Loop. The NIEM 3.0 model on emergency management is reviewed and aspects related to disaster management scenarios and inter organizational communication needs are found missing. These findings are corroborated with the APCO's unified CAD functional requirements. The paper concludes with summarizing the different requirements for compliance management in Construction, Operation and Management of Chemical Storage Tanks and highlights importance of cognitive aspects and Information Model.

Keywords

Theory of Constraints, Functional Safety, OODA, NIEM, Safety grid.

1. INTRODUCTION

Safety Management can be defined as a businesslike approach to safety. It is a systematic, explicit and comprehensive process for managing safety risks. As with all management systems, a safety management system provides for goal setting, planning, and measuring performance. A safety management system is woven into the fabric of an organization. It becomes part of the culture, the way people do their jobs. Globally governments have begun to adopt a national broadband plan and also provide a dedicated spectrum for Public Safety utilizing the Evolved Packet Core Long term Evolution.

Safety Management deals with both the prevention of accidents and as well as managing emergencies. The suitability of the LTE networks and the architectures for emergency response has been detailed out by the Dept. of Homeland security [1]. Safety Life Cycle encompasses design corrections, periodic maintenance, layers of protection to emergency management.

The California department of Public safety had detailed out in its CAPSCOM program the need for System of Systems approach for an effective public safety system coinciding with the National Broadband Plan. The systems thinking paradigm creates a human centered approach in the systems design and the overall system safety is then a function of interactions, interfaces and risk reduction by proactive monitoring and probabilistic failure models.

In this paper we discuss the relational aspects of the System of Systems and deduce the elemental and cognitive aspects of functional safety for such a communication system for Emergency Preparedness and Management.

This paper excludes the elemental redundant reliable communications channel from the study as this has been covered extensively in various papers on Sensor Networks and Public Safety LTE[2]

An elaborate review of Functional Safety design and management techniques is outside the scope of this paper. The material available [3] can be used for further reading.

2. THE SOS VIEW & THE SAFETY GRID

The California department of public safety had given in its view the next generation public safety system shall be a system of systems and this helps the scalability and reliability of the overall system[4]. In our earlier paper on review of public safety management system[5] and the vision of Ex. CTO of the United States[6], the representation of the ***S***afety ***G***rid looked as in Figure 1.

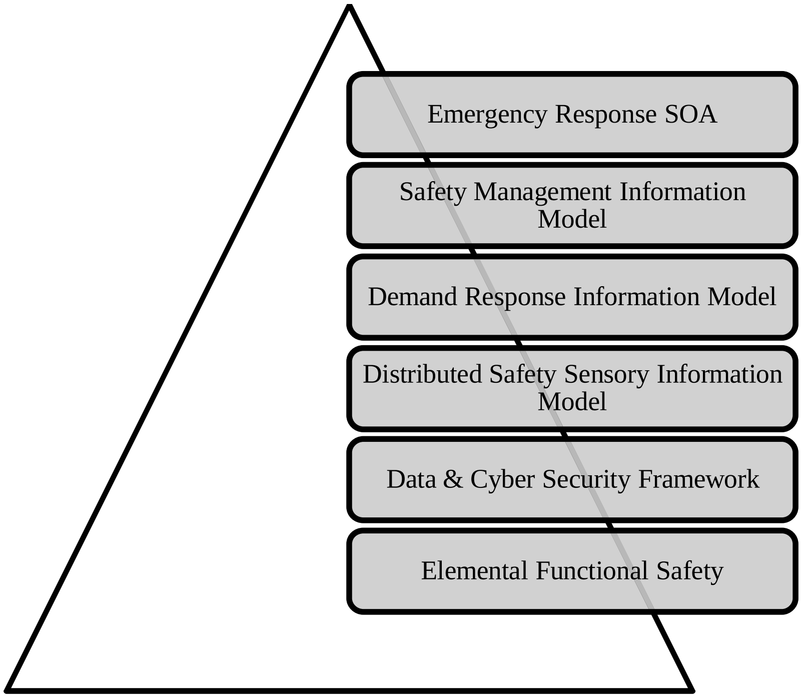

FIGURE 1 SAFETY GRID

This research is concentrated around chemical plants and hazards due to fire and gas sources. We begin by examining a fire and gas detection and control system in the Safety Grid. The integrated safety system in a plant looks as in Figure 2 [7].Mapping this to the Safety grid, a relational matrix is obtained as in Table 1.

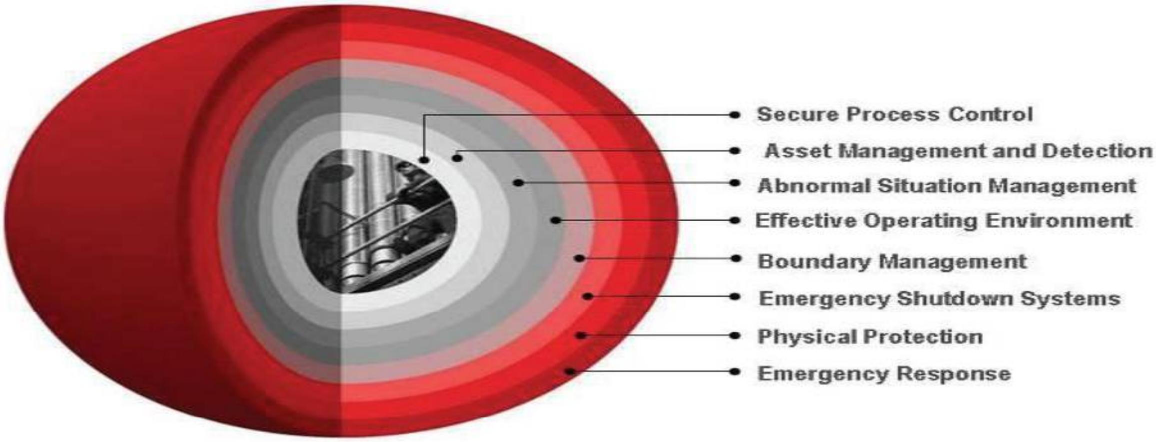

FIGURE 2 INTEGRATED SAFETY SYSTEM

From the relevance information in the Table 1, it is evident that the relational correlation between the Safety Grid and the integrated safety system exists.

It is seen that the Emergent needs of Integrated safety systems is strongly grounded on Functional Safety , effective operating environments and emergency response as a layer of protection. When looking at the Emergency Management, cognitive aspects of Alarm Visualization and Perception take higher root. The emergent needs of cyber security has become another layer of protection and alerting independently. The scope of this paper is limited to the functional safety aspects in the system. The security integrity of the framework shall abide the standard security guidelines driven by NIST and other security organizations.In this paper we develop the vital requirements for functional safety in Communicating Safety Systems for the Safety Grid by taking a case of safety in storage tank construction & operation.

TABLE 4 RELATION B/W SAFETY GRID & INTEGRATED SAFETY SYSTEMS

Safety Grid	Integrated Safety System	Relevance
Elemental Functional Safety	Asset Management & Detection	Design of systems Functionally safe and with Periodic Maintenance and regular proof tests
	Emergency Shutdown Systems	Emergency shutdown acts as the last layer of Automates Safety. This also has to be Functionally Safe and proof tested regularly.
Data & Cyber Security Framework	Physical Protection	Focus on Man in the Middle and Right Authorization of user's access physically and logically.
	Secure Process Control	Focus on Cyber Threats with right security functions.
Distributed Safety Sensory Model	Effective Operating Environment	Information passage for Safety Devices that feed into Emergency Shutdown Systems
Demand Response Information Model		Information Model for the effective process operations and analyzing peak performances.
Safety Management Information Model		Information Model for Effective Safety Management i.e. Visualizing Compliance and Regular Audits
Emergency Service SoA	Emergency Response	Service Models for passing emergency information for Alerting and during Incidence
	Boundary Management	Layers of Separation to physically and logically Alert concerned stake holders
	Abnormal Situation Management	Cognitive Aspects for Alerting and Incident Control.

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3. FUNCTIONAL , COGNITIVE & SITUATIONAL SAFETY : A STUDY

Elemental Functional Safety is about characterizing the various systems and sub systems in the overall interaction plane as individual elements and the relationship of ***SUM OF ITS PARTS***. The process industry has already gone forward in this notion by characterizing the level of Safety Integrity of each element participating in a particular Safety Function. The Automotive Industry has also taken the same view of Sum of Parts approach for the overall functional safety of a vehicle with ISO 26262 or ASIL requirements.

In Emergency Preparedness and Management case the elemental functional safety plays a critical role in the design, construction, operation and maintenance phase of the Safety Life Cycle. Applying the principles of SIL/ ASIL the Safety integrity of the design and construction is achieved. In order to maintain a particular level of safety integrity of the system, the users (or) asset managers have a great deal of responsibility in staying compliant to the needs.

The functional safety framework as detailed by the IEC 61508 ranges from concept development to decommissioning as shown in Figure 3.

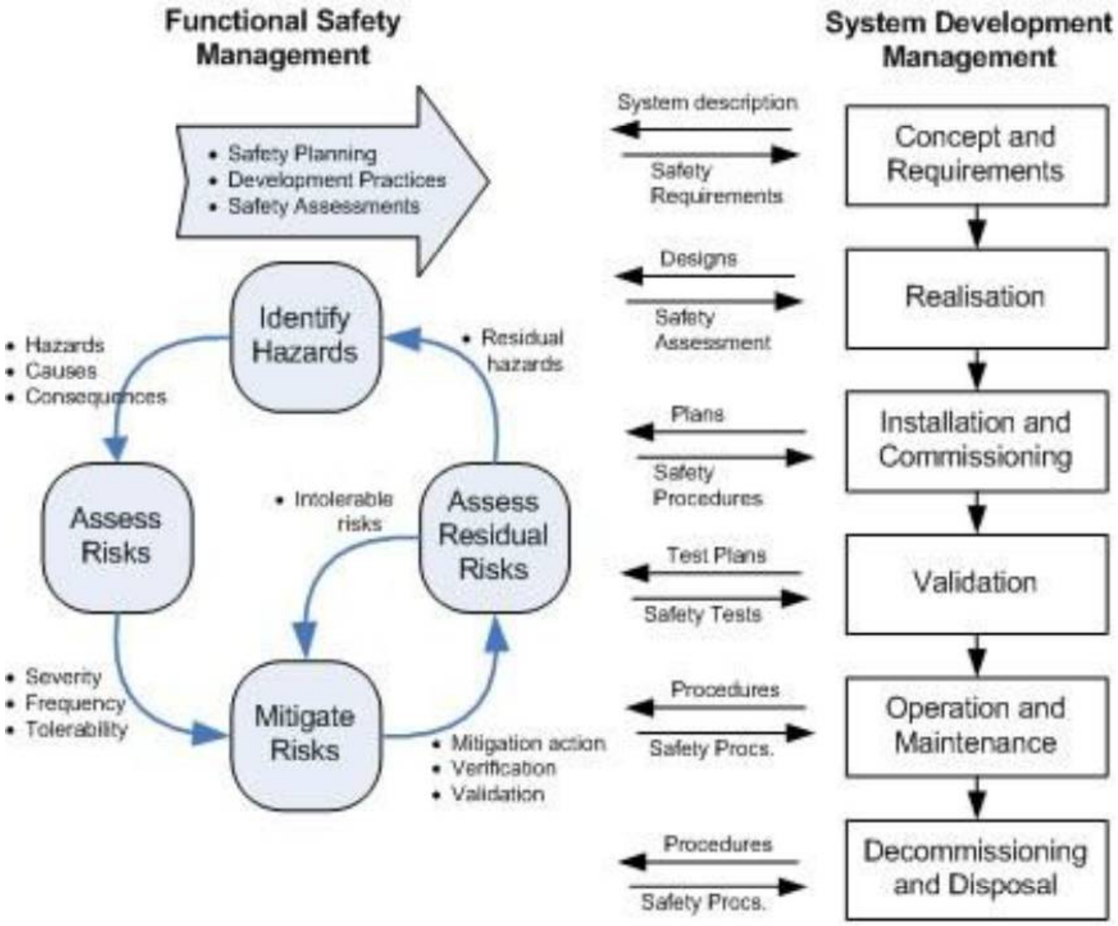
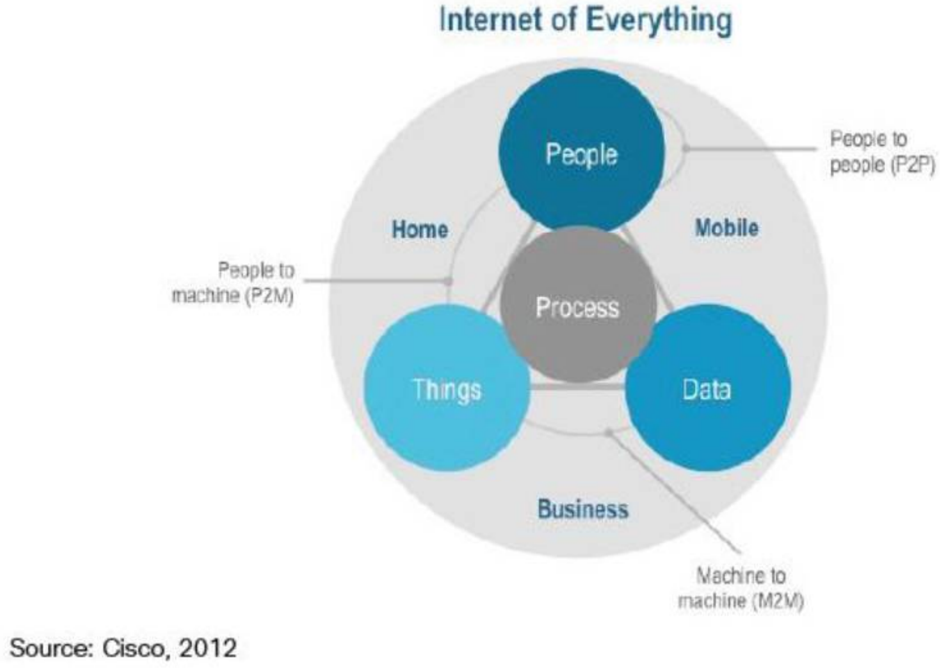


FIGURE 3 FUNCTIONAL SAFETY MODEL

The Functional safety is best assured by Design and continuous monitoring. Safety Integrity categorizes systems into 4 grades of reliable operations SIL 1, 2, 3, & 4 based on Failure levels as defined by the *Safe Failure Fractions which is a ratio of undetected failures to total failures*. Safety management is primarily dependent on FMEA techniques and probabilistic risk reduction techniques like ALARP (As Low as Reasonably Possible). This is done by continuous assessment and periodic monitoring or proof testing[3].

In the integrated system perspective the safety integrity is best assured by convolving the needs of different consumers which could be a human, an automated process agent (thing) or the process itself. The following info graphic represents Figure 4 the complex web of integration[8].



Source: Cisco, 2012

FIGURE 4 INTERNET OF EVERYTHING[8]

The safety integrity of such an integrated safety system would then be a function of the process, people, and the interacting component itself. In a public safety system, a process could be represented as in Figure 5.

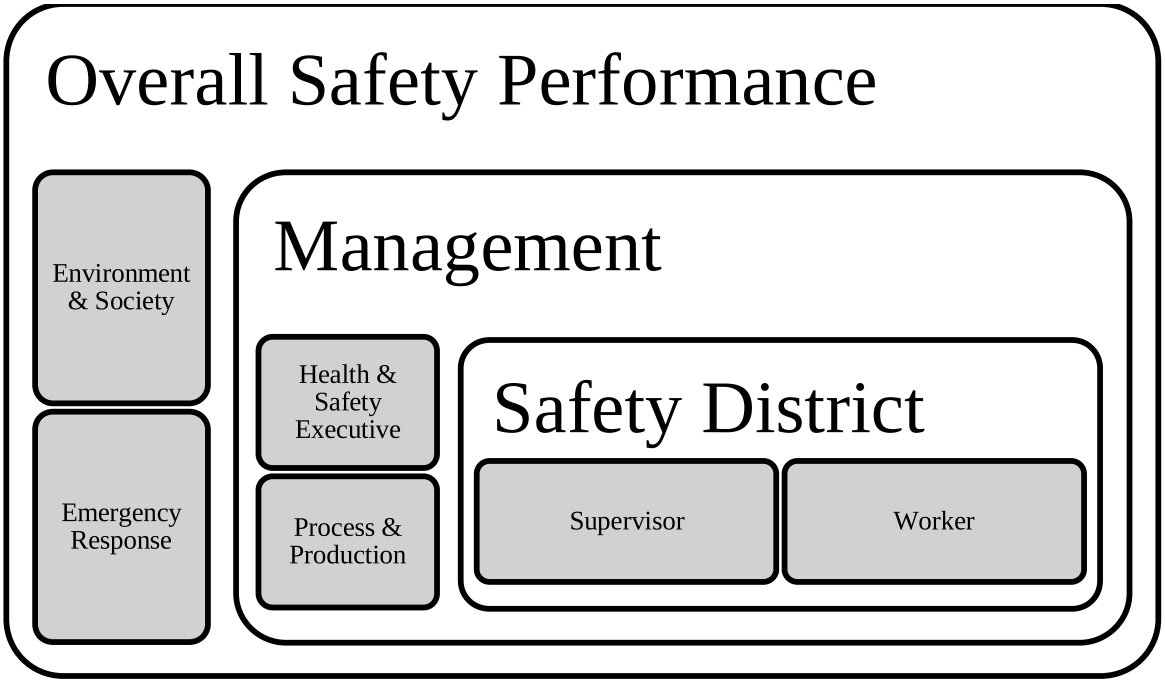


FIGURE 5 SAFETY SYSTEM INTERACTION VIEW

This view signifies us the elemental functional safety required in each of the work sections and the Asset design and Management requirements. We see that in the entire process there is human always in the chain and his interaction with the process is critical for effective functioning of the integrated system.

In the integrated systems human play a crucial role and as stipulated by different System Safety practitioners, the safety and accident are characterized as "Accidents are treated as the result of flawed processes involving interactions among people, social and organizational structures, engineering activities, and physical and software system components [9]". The overall emphasis is thus on the systemic nature of the system and its dynamic behavior of interactions.

As per STAMP theory Leveson suggests accidents as manifestation of Constraints or Lack there-of. In the safety management of integrated systems as depicted in Figure 5, we see the safety function is function of Cognitive ability and the safety integrity of the System or Component participating in the process.

On the other hand Abnormal Situation Management is all about communicating the right alert with effective information to the user or the process to act further[10]. The different users and the process involved here then require right information to act upon. The cognitive ability of the human is considered as a major source of producing and operating safer systems. The Human/Socio Technical Ability and accidents are modeled by Hollnagel as Functional Resonance Analysis methods. The breadth-first principle applies to

1) Understanding the system as a whole and developing the constraints
2) Understanding the various functions involved (Human, Systems, Social) and characterizing the resonance to categorize risks.
3) Applying the model to understand risks as well as accident behaviors.[11]

The situational awareness thus becomes the output of this risk model and potential accident behaviors and scenarios. The overall safety is then a function of the Functional Safety behaviors, conformance to constraints and human cognition. The Human Cognitive error types as described by HSE at Govt. of UK, is both willful and inadvertent as in Figure 6.

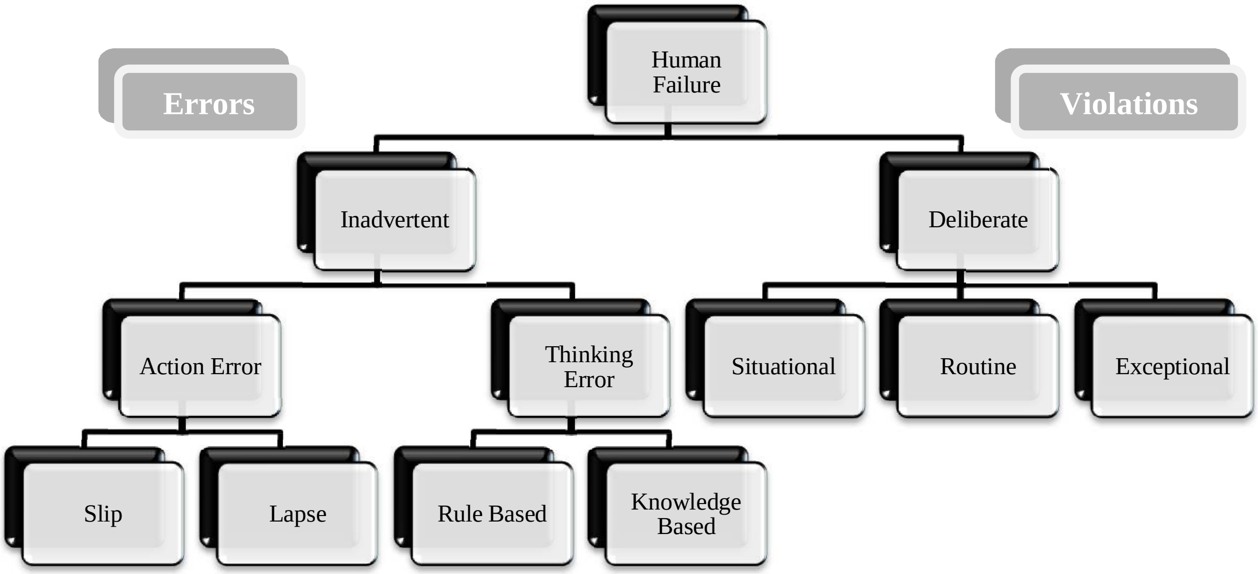


FIGURE 6 COGNITIVE INFLUENCE IN ACCIDENTS

Based on this, the systems design has to handle reductions in Action and Thinking Errors and the further subject has to handle violations by regular forced and random audits to mitigate errors occurring. Situational Awareness during Emergency Management is governed by a different set of cognitive process, where the efficiency of the current awareness is more critical. The OSHA standards like 1910.120 [12], categorize the emergency response into the following as in

Table 5.

TABLE 5 OSHA EMERGENCY RESPONSE CRITERIA

Emergency Response Plan &	Pre-emergency planning and coordination with outside parties.
Elements of an emergency response plan	Personnel roles, lines of authority, training, and communication.
	Emergency recognition and prevention.
	Safe distances and places of refuge.
	Site security and control.
	Evacuation routes and procedures.
	Decontamination.
	Emergency medical treatment and first aid.
	Emergency alerting and response procedures.
	Critique of response and follow-up
	PPE and emergency equipment.
	Emergency response organizations
Procedures for handling emergency response	Observe – Orient – Decide – Act
Skilled Support Personnel.	Roles of People to Handle Emergency Response
Specialist Employees.	Sharing of Responsibilities
Training	Utilization and focus of Specialists
Trainers	Specialization focused on Day-to-Day Operations
Refresher Training	Periodic Refreshment for preparedness
Medical Surveillance and Consultation	Availability of Emergency Personnel
Chemical Protective Clothing	Protection of Emergency Personnel
Post-emergency Response Operations.	Decontamination

4. SAFETY IN CHEMICAL STORAGE TANK: A CASE

In controlled systems there is a fair expectation that effective documentation control is available and used to control the changes in the system and correspondingly the associated behaviors. The auditing functionality acts as the sensing boundary. There has been an insufficiency in effective and regular auditing by authorized third parties as cited by Mannan[13] . Compliance to Guidelines and Constraints are surrounded by Cognitive Capabilities of the users and are situational as well as bound by the organizational commitments. Table 6 lists the major accidents related to Tanks and spills.

TABLE 6 MAJOR ACCIDENTS IN TANK SPILLS

Accident, industry and date	**Consequences**	**Human contribution and other causes**
Union Carbide Bhopal, India *Chemical processing* *1984*	The plant released a cloud of toxic methyl isocynate. Death toll was 2500 and over one quarter of the city's population was affected by the gas.	The leak was caused by a discharge of water into a storage tank. This was the result of a combination of operator error, poor maintenance, failed safety systems and poor safety management.
Texaco Refinery, Milford Haven *Chemical processing* *1994*	An explosion on the site was followed by a major hydrocarbon fire and a number of secondary fires. There was severe damage to process plant, buildings and storage tanks. 26 people sustained injuries, none serious.	The incident was caused by flammable hydrocarbon liquid being continuously pumped into a process vessel that had its outlet closed. This was the result of a combination of: an erroneous control system reading of a valve state, modifications which had not been fully assessed, failure to provide operators with the necessary process overviews and attempts to keep the unit running when it should have been shut down.
Fertilizer plant explosion in West, Texas *April 2013*	An explosion occurred at the West Fertilizer Company storage and distribution facility in West, Texas, 18 miles (29 km) north of Waco while emergency services personnel were responding to a fire at the facility	At least 14 people were killed, more than 160 were injured and more than 150 buildings were damaged or destroyed. Storage of Ammonium Nitrate had not been intimated to DHS and excessive lapses in safety procedures.

These accidents signify the lapses in compliance adherence and inadequacy of audits to prevent failures and accidents. The public safety disaster preparedness requires building such adequacies in continuous measurements and audits against the documented constraints and cognitive requirements.

The requirements for tank construction and management were categorized in three different buckets i.e.1) Theory of constraints 2) Cognitive Requirements and 3) Elemental functional safety. Table 7 summarizes these requirements.

Category	**No. of Requirements**	**Coverage %**	**Design Requirements**	**Operational Requirements**
Theory of Constraints	37	30	34	3
Cognitive Requirements	50	44	39	11
Functional Safety	31	26	23	8
Total	**118**	**100**	**96**	**22**

TABLE 7 REQUIREMENTS FOR TANK CONSTRUCTION

Table 7 indicates that there is a higher level of requirements arbitrated towards Construction time, i.e. to Design things Right the First Time. There is a good emphasis placed on Cognitive Requirements both during Design and Operations. Theory of constraints plays a significant role during design stage. Identifying the constraints for design, enables design first time right. It is presumed that the Constraints are controlled during the operational stage, though there is a practical limit on how the constraints are contained.

Utilizing the emergency management guidelines from

Table 5, a relationship diagram is drawn between the elements as either 1) ***Implements*** or 2) **Utilizes** as shown in Figure 7**.** In an emergency management scenario theory of constraints is ruled by Tactical Support and operational effectiveness. Hence the map is loaded with categories of a) Functional, b) Operational and c) Cognitive safety. Boyd explains the emergency operations and military operations as tactical operations management principle and governs the framework as OODA (Observe, Orient, Decide & Act). The emergency response handling is characterized by the OODA [14] framework. Safety grid hypotheses earlier would act as an effective instrument in the emergency management. The National Information Exchange Model

(NIEM) the nodal agency for standardization of information has been developing the Emergency management information model. We discuss the OODA needs w.r.t public safety applications and compare the NIEM model later in this paper.

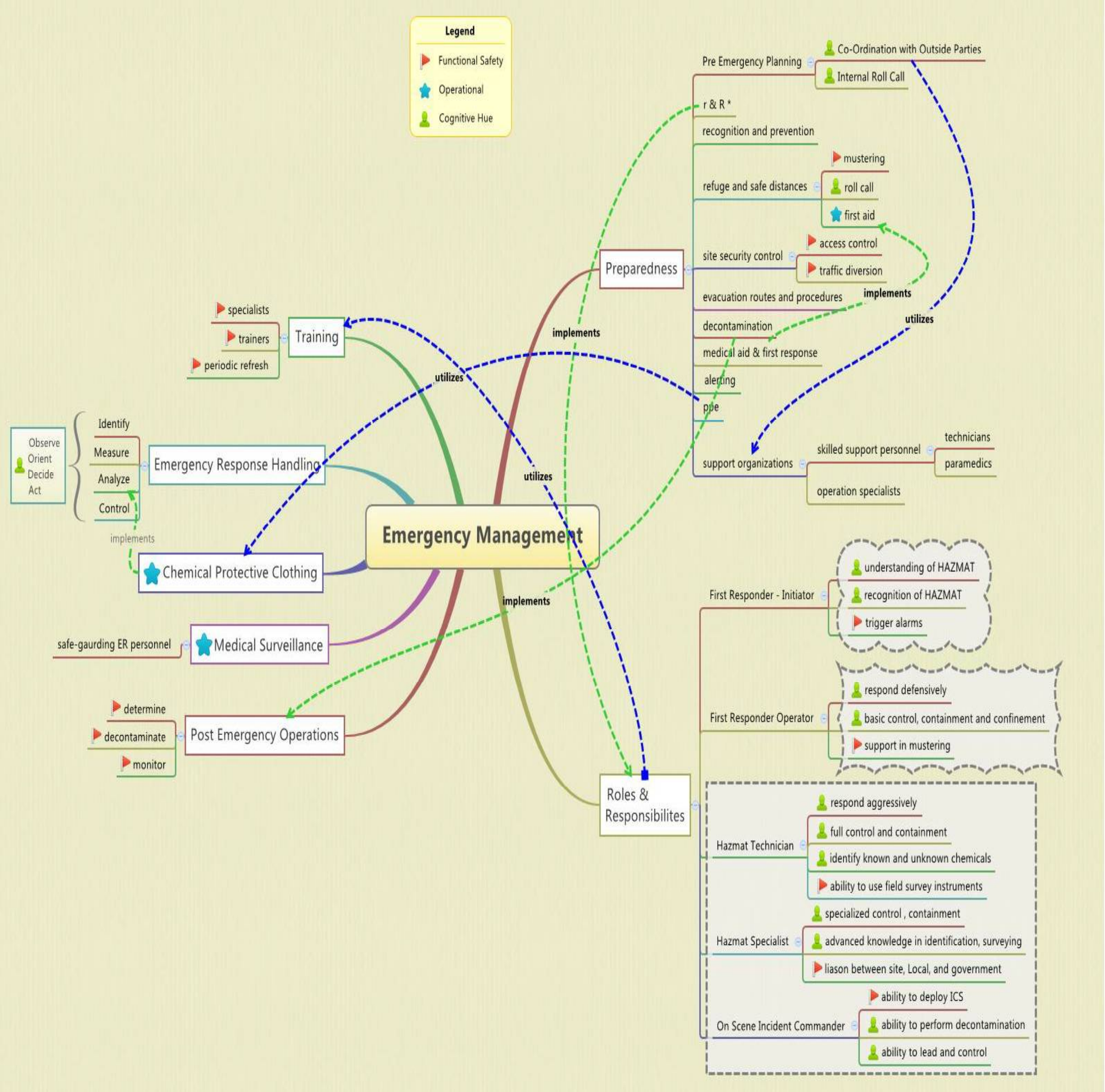


FIGURE 7 SEGREGATION OF COGNITIVE AND FUNCTIONAL SAFETY OF OSHA ER

5. DISCUSSION

In the cases described in Table 6 , the amount of lack of compliance is evident and both STAMP theory and the FRAM theory have proved right. The audit functions are also in lapses and as Mannan puts it, it is impossible to have government bodies alone to sufficiently monitor compliance[13]. Auditing Bodies and Supplementary Auditing Systems (Manned and Unmanned Sensors) have to be placed to enforce compliance and reduce such accidents. The requirements in tank construction and operations are further categorized with respect to 1) Diagnostic Sensing, 2) Automated Sensing, 3) Manual Verification & 4) Periodic Inspection.

The summary of this categorization is shown in Table 8.

TABLE 8 SENSING & VERIFICATION CATEGORY

Safety Requirement Category	Measurement Method					Total
	Diagnostic Sensing	Automated Sensing	Manual Verification	Periodic Inspection	Not Applicable	
Cognitive Requirements	6	7	22	7	8	50
Theory of Constraints	10	7	14	5	1	37
Functional Safety	12	2	14	2	1	31
Total	28	16	50	14	10	118

The number of requirements that the Manual Verification can solve in the safety of the Tank Construction and Maintenance is 50. Of this 22 are Cognitive Requirements, and 28 are based on Constraints and Functional Safety. The 28(56%) requirements from Functional Safety and Constraints can be rule based and can trigger alarms. The other 44% that require Manual Verification require the Cognitive Efficiency of the user to verify the compliance. There are 20 requirements under cognitive requirements which can be diagnosed or be Rule based. There are 7 cognitive requirements which have to be dealt with Periodic inspection. Functional Safety inherently mandates that systems that are designed for safety integrity are maintained through life time. Thus the 44 odd requirements under diagnostic sensing and automated sensing have to behave fail safe, i.e. there is adequate time to replace these safety or safety enablement devices. In the purview of the Public Safety, the accidents are caused by improper management and human errors either inadvertent or willful, the public safety system of Systems network should consider the ways in which it can improve the Compliance Adherence and periodic audits. The audit system thus should be composed of Cognitive efficiency and Functional efficiency.

Table 9, depicts the OODA needs and a shared Situational Awareness View during a disaster of a storage tank fire or explosion. The Enumeration codes or the Standard Objects defined by the Emergency Management domain do not provide a situational awareness or a Common Operating Picture view to the different subscriber community (Law Enforcement, EMS, Fire Department). This observation is also corroborated with the findings and recommendations from APCO international on the High Priority Information Sharing Needs for Emergency Communications and First Responders [15], which observes twelve critical needs, out of which the following three are critical as shown in Table 10.

TABLE 9 OODA INFORMATION SHARING NEEDS

Information Sharing Needs

Tag	Title	Description	Cross Reference	First Responders			**ECC**
				Fire	EMS	LE	
R_001	Records Management	Availability of Onsite Plans, Jurisdiction, Compliance Adherence Information **–** *OBSERVE* 1) *Tank Size* 2) *Stored Chemical Identifier* 3) *Tank NDT – Proof Testing Information* 4) *Mandatory regulatory Health Check Records*		X	N	A	**N**
R_002	Rapid Assessment	Situational Assessment, typically available from the first crew to investigate damages, typically the First Responder **–** Initiator - *ORIENT* 1) Identification of Gas Leak or Chemical Spill 2) Estimated number of People / Life under threat 3) Best Muster Zone		X	N	X	**A**
R_003	Hazard Assessment	Typical Assessment of Hazard and potential cause. **–** *ORIENT – OBSERVE* 1) Identifying Safe resorts and Musters 2) PPE Identification and call for specialists 3) Identifying known and unknown chemicals.	R_001	X	X	X	**A**
R_004	Resource Management	Deployment Planning of Trained Resources, PPE, Hospital Management **–** *DECIDE*	R_002	X	A	X	**X**
R_005	Tasking	Execution Strategy and real-time availability of information - *ACT*	R_004	X	X	X	**A**

Common Operating Picture

Legend
X – Need is there
A – Information Source
N – Information Not Needed

EMS – Emergency Medical Services
LE – Law Enforcement
ECC – Emergency Communications Center

TABLE 10 APCO NIEM EM MODEL NEEDS

Need	Rationale
NIEM Emergency Communications Domain.	Since the NIEM EM domain is focused on the classic emergency management mission, it excludes many aspects of the emergency communications/first responder information sharing needs, such as typical law enforcement, fire and EMS incidents.
Situational Awareness via CAD	Need for Common Operating Picture and ability to utilize the ECC infrastructure.
Public Safety LTE API	Open APIs provide a stable interface between the applications and the underlying LTE network, shielding applications from low-level changes and enhancements of the LTE network as public safety LTE networks continue to evolve. Standardized APIs are an essential component for the future LTE interoperability capability—therefore, we recommend the creation of a collaborative program for the development of open, public safety, broadband APIs.

6. CONCLUSION

In this paper, we developed a view of the functional and cognitive safety required in the overall Safety/Emergency Management function. We demonstrate the need for cognitive safety from the requirements in constructing and operating the Storage Tanks. This accounts to more than 42 percent of the overall functional safety while “Theory of Constraints” accounts for 32 percent. The principle of functional safety is important though it only accounts for 26 percent of the safety requirements. On the other hand, our hypothesis that the NIEM model was sufficient to satisfactorily accommodate the Disaster Management Scenario proved insufficient and further substantiated the high priority needs identified by the APCO. Further, the APCO needs corroborate the initial model of Service Oriented Architecture and availability of API for the broadband public safety LTE networks.

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APPENDIX – 1 :

TANK SAFETY CONSTRUCTION & OPERATIONS : CATEGORIZATION W.R.T SAFETY SEGMENTATION & VERIFICATION METHOD

		Elemental Requirements		
		Use Case : Asset Design and Construction of Tank Farm		
Design	System Selection	Have the storage system selection and design criteria accommodated the following aspects: ⍰ Economic concerns? ⍰ Technical and practical aspects? ⍰ Manufacture requirements? ⍰ Installation requirements? ⍰ Future operation, maintenance and inspection activities?	Theory Of Constraints	Manual Verification
		Have risk assessments been carried out?	Functional Safety	Manual Verification
		Has the impact on surrounding activities and the environment been assessed?	Cognitive Requrements	Manual Verification
		Has the system been designed to be as simple as possible?	Cognitive Requrements	Manual Verification
		Have the needs of the manufacturer, installer and end user been considered?	Cognitive Requrements	Manual Verification
		Has the system been designed in accordance with relevant codes of practice and guidance?	Cognitive Requrements	Manual Verification
		Have specialist designers been used for system components outside the scope of your experience?	Theory Of Constraints	Manual Verification

		Have manufacturers / designers been consulted where there is any doubt?	Theory Of Constraints	Manual Verification
		Have reused and recycled components and materials been incorporated where possible (if so, has caution been taken to ensure their condition and suitability)?	Theory Of Constraints	Diagnostic Sensing
		Are you confident that the design is right first time?	Cognitive Requrements	Not Applicable
		Are the materials from which the storage system is to be constructed compatible with the chemicals which can be expected to be stored?	Theory of Constraints	Automated Sensing
		Multiple material system components and their compatibility?	Theory of Constraints	Automated Sensing
		Coatings and linings?	Theory of Constraints	Diagnostic Sensing
		Cathodic protection systems?	Functional Safety	Diagnostic Sensing
		Have the specifications for the storage system been checked for correctness?	Cognitive Requrements	Manual Verification
		Has advice been obtained from a reputable designer/contractor?	Functional Safety	Manual Verification
		If an ‘off the shelf’ system is to be used, is this appropriate for your needs?	Theory Of Constraints	Manual Verification
		Have the following aspects been considered: • Nature of the chemical stored, the process requirements and the intended use? • The volume of chemical to be stored? • Layout of the system, number of tanks, their dimensions, shape and orientation? • Available space (plan area, height and minimum separation distances)? • Adequacy of ground conditions for supporting the system and the level of groundwater if excavation is required?	Theory Of Constraints	Manual Verification
		Planning issues, such as environmental and visual impact and light restriction?	Cognitive Requrements	Periodic Inspection

		Have the following locations for chemical storage systems within a site been avoided ? Roofs (prone to environmental attack, difficult to access, etc.)? Adjacent to watercourses and other environmentally sensitive areas (including where potential connections exist via surface water drainage systems)? Adjacent to drainage systems, particularly if these lead to watercourses? Within potential floodplains? In areas where wind loading may be high? Adjacent to external roads, main site thoroughfares? High risk delivery routes that may be tortuous or pass through sensitive areas? Close to non process or public access stairs and walkways? Flammable liquids in proximity to ignition sources? Proximity to other chemicals? Proximity to the site boundary? Adjacent to residential areas or to other areas, such as leisure facilities, where the public may gather in significant numbers and thereby be put at risk? In places where the available area is limited such that bunding or secondary containment may not feasible?	Theory Of Constraints	Manual Verification
		Where any of the above locations are unavoidable, have additional precautionsbeen taken?	Theory Of Constraints	Manual Verification
	System Design	Has the baseplate been designed to conform to good practice for preventing corrosion?	Functional Safety	Manual Verification
		Has corrosion protection been specified for use on the underside of tank baseplates?	Cognitive Requrements	Periodic Inspection
		Has the design ensured that no voids are created (as these may cause a corrosion problem)?	Functional Safety	Diagnostic Sensing
		Are the ground conditions suitable for good foundation design?	Functional Safety	Diagnostic Sensing
		Has the foundation material included concrete or bitumen sand ('bit sand')?	Functional Safety	Manual Verification

		Have tanks been founded on reinforced concrete bases?	Functional Safety	Manual Verification
		Has the system had a chemically resistant membrane barrier placed below the tank?	Theory Of Constraints	Manual Verification
		Has secondary containment been built around the tank?	Cognitive Requrements	Periodic Inspection
		Have the correct design codes been followed?	Cognitive Requrements	Manual Verification
		Have the number of fixings and brackets been minimised (whilst ensuring adequate strength)?	Theory Of Constraints	Manual Verification
		Have long strip connections been avoided (for items such as tank access stairs)?	Functional Safety	Manual Verification
		Have connections been reinforced (particularly where components may exert force on the tank or fitting such as on plastic tanks)?	Functional Safety	Diagnostic Sensing
		Have fixings and brackets been oriented to avoid formation of conditions which may promote corrosion?	Theory Of Constraints	Diagnostic Sensing
		Has corrosion protection been provided whenever aluminium surfaces are joined to steel?	Functional Safety	Diagnostic Sensing
		Is insulation absolutely necessary?	Cognitive Requrements	Manual Verification
		Has tank wall insulation been stopped before it meets the baseplate, roof curb or pipe and associated connections?	Cognitive Requrements	Manual Verification
	Bunding and containment	Does size and layout take account of all reasonably foreseeable modes of failure of primary containment, and compatibility of chemicals stored?	Theory Of Constraints	Manual Verification
		Do systems containing flammable liquids incorporate firebreaks into containment design?	Cognitive Requrements	Periodic Inspection

		Is the capacity volume the sum of all of the following: ▯ At least 100% of primary storage capacity? ▯ Allowance for rainfall (pre- and post-incident)? ▯ Allowance for cooling water? ▯ Freeboard for fire fighting water and foam and dynamic effects? ▯ Volume of pipes, equipment, supports, etc. within bund?	Cognitive Requrements	Periodic Inspection
		Is the containment capable of retaining maximum design volume of prescribed chemical for not less than 8 days?	Theory Of Constraints	Manual Verification
		Is containment impermeable and resistant to degradation by the chemical stored?	Functional Safety	Diagnostic Sensing
		Is the containment capable of withstanding the static and dynamic loadsassociated with:▯ Release of liquid from primary storage tanks?▯ Release of water from hoses during fire fighting operations?▯ Wind (50-year design life)?▯ Potential impact by site vehicles (if not protected by barriers)?	Theory Of Constraints	Periodic Inspection
		Is the containment capable of resisting the effects of weather, aggressive ground conditions and abrasion, fire and corrosive chemicals?	Cognitive Requrements	Manual Verification
		Are bund walls structurally independent from the primary containment?	Functional Safety	Manual Verification
		Are walls and, where practicable, floors sufficiently accessible to permit inspection and for maintenance to be carried out?	Functional Safety	Manual Verification
		Are bund wall heights less than 1.5 m, unless circumstances are exceptional?	Functional Safety	Manual Verification
		Where access to parts of the bund floor is not practicable is provision made to detect any leakage through the base of the primary containment?	Cognitive Requrements	Diagnostic Sensing
		Has bund volume and wall height and tank accessibility been checked for adequacy?	Theory Of Constraints	Automated Sensing
		Have emergency shut off valves been located between the tank and the bund wall?	Functional Safety	Automated Sensing

		Are bunds capable of being emptied, preferably by a pump located in a sump?	Cognitive Requrements	Automated Sensing
		Are pumps capable of removing the volume of liquid required within the time required to avoid overspilling of bund, and able to withstand attack from the chemicals stored?	Theory Of Constraints	Automated Sensing
	Pipes, fittings and connections	Is the chemical being transferred and its source and destination clearly defined?	Theory Of Constraints	Periodic Inspection
		Where gravity feed is proposed, is the fall between source and destination sufficient?	Theory Of Constraints	Diagnostic Sensing
		Have connections with other systems, supplies and processes been specified?	Theory Of Constraints	Manual Verification
		Have any other special requirements such as pressure or temperature control been specified?	Theory Of Constraints	Periodic Inspection
		Has a competent pipework designer been used?	Cognitive Requrements	Manual Verification
		Is the design in line with appropriate pipe design codes and guidance such as BS8010: Code of practice for pipelines?	Cognitive Requrements	Manual Verification
		If flexible hoses have been specified are they absolutely necessary?	Cognitive Requrements	Not Applicable
		Have frost protection requirements been considered?	Cognitive Requrements	Not Applicable
		Have secondary containment requirements been considered?	Cognitive Requrements	Not Applicable
		Have the maintenance and inspection requirements been accommodated?	Cognitive Requrements	Not Applicable
		Has the pipework been designed to minimise its length?	Cognitive Requrements	Not Applicable
		Does the design avoid (or include protection against) potential physical or environmental impacts?	Functional Safety	Manual Verification
		If the pipeline is below ground, is it in an impermeable duct with provision for access?	Cognitive Requrements	Manual Verification

		Has provision for isolation in emergency situations been included?	Functional Safety	Diagnostic Sensing
	Control and monitoring systems	Has a risk assessment been carried out?	Functional Safety	Not Applicable
		Has the system been designed to fail to safe and trigger alarm on failure?	Functional Safety	Periodic Inspection
		Have the alarms been backed up by another system that operates on a different basis?	Functional Safety	Diagnostic Sensing
		Have electric, electronic or programmable electronic systems (E/E/PES) been designed in accordance with BS IEC 61508: 2000?	Functional Safety	Periodic Inspection
		Will flow into the tank impinge on the device?	Theory Of Constraints	Automated Sensing
		Have sampling points been located at ground level wherever possible?	Cognitive Requrements	Diagnostic Sensing
		Have self-closing valves been specified?	Theory Of Constraints	Diagnostic Sensing
		Have high level alarms and cut-offs been specified to allow generous safety factors between alarm and cut-off?	Cognitive Requrements	Periodic Inspection
		Have alarms and cut-offs been set independent to primary control and monitoring equipment?	Cognitive Requrements	Automated Sensing
		Have high and low level alarms been fitted on bunds?	Cognitive Requrements	Diagnostic Sensing
		Have high and low level alarms for temperature and pressure been specified, that are suitable to operate within the system specifications?	Cognitive Requrements	Diagnostic Sensing
		Has the need for intrinsically safe alarms been considered?	Functional Safety	Manual Verification
		Has specialist advice on fire alarms been sought from a suitably qualified and experienced fire engineer or specialist, and local fire authority?	Cognitive Requrements	Manual Verification
		Is the level of sensitivity appropriate to individual storage systems?	Theory Of Constraints	Manual Verification

		Has the need for strain gauges been considered?	Cognitive Requrements	Manual Verification
		Are emergency stop buttons easily accessible?	Cognitive Requrements	Manual Verification
	Tank venting, pressure and explosion relief systems	Has the potential for the stored chemical to crystallise in vent systems, potentially blocking them, been considered?	Theory Of Constraints	Not Applicable
		Has the potential release of odours been considered?	Cognitive Requrements	Not Applicable
		Are systems in line with latest regulatory requirements?	Cognitive Requrements	Not Applicable
		Have pressure drops in long vent lines been considered and addressed ifappropriate?	Theory Of Constraints	Not Applicable
		Have vermin proof and weatherproof cowls been fitted?	Theory Of Constraints	Not Applicable
		Have provision for pressure relief and vacuum breaking both been taken into account in system design?	Theory Of Constraints	Diagnostic Sensing
		Have vents been adequately sized to take account of the maximum filling and emptying rates?	Theory Of Constraints	Diagnostic Sensing
		Has the scrubber back pressure and gas flow rate been set to an adequate level for the pressure rating of the tank?	Theory Of Constraints	Not Applicable
		If a floating roof is to be installed are the seal materials and arrangement fit for purpose?	Cognitive Requrements	Not Applicable
	Security	Have the systems been designed to fail to safe?	Functional Safety	Diagnostic Sensing
		Have road barriers been designed to withstand impact from the heaviest vehicle expected on site?	Cognitive Requrements	Not Applicable
		Have road barriers been located a suitable distance away from system components?	Cognitive Requrements	Not Applicable
		Have road barriers been located at strategic points for most likely vehicle movement damage?	Cognitive Requrements	Not Applicable

Operations & Maintenance	Permit to Work Systems	Does Work Permit System exist with necessary information for Qualifying People, and with appropriate Guidelines available to the People ?	Cognitive Requrements	Not Applicable
		Details of the Emergency Procedures made available ?	Cognitive Requrements	Automated Sensing
		Validity of the Work Permit ?	Theory Of Constraints	Automated Sensing
		Lock Out and Tag Out Procedures Implemented ?	Theory Of Constraints	Automated Sensing
	Change Control	Necessity of the Change is Documented?	Cognitive Requrements	Manual Verification
		Does the change include change of chemicals stored or passing through any part of the system, if so has material compatibility been considered and checked?	Theory Of Constraints	Diagnostic Sensing
		Does the change involve replacement of component parts, and if so are these parts appropriate to the system in terms of performance and compatibility?	Functional Safety	Manual Verification
		Has a risk assessment of all relevant hazards been undertaken and appropriate actions included within the change plan and are the risks ALARP?	Functional Safety	Manual Verification
		When considering storing specialist chemicals (such as ones that might generate a hazardous reaction with other chemicals stored on the site) has proper assessment been made of the ability to store the chemical elsewhere in the event of a failure or an emergency arising?	Theory Of Constraints	Diagnostic Sensing
		Has the change been recorded in the Health and Safety File ?	Cognitive Requrements	Automated Sensing
	Operational Safety	Have all chemical storage tanks been clearly labelled with their contents and all relevant hazard warning labels?	Cognitive Requrements	Automated Sensing
		Material & Chemical Safety Data Sheets and Permissble Levels Labeled and Available. ?	Cognitive Requrements	Automated Sensing
		Requisite PPE's listed and made available ?	Cognitive Requrements	Automated Sensing

	Inspection & Integrity Testing	Has the frequency of testing been determined as a result of risk assessment?	Functional Safety	Manual Verification
		Are high risk tanks inspected on a more frequent basis than those with lower risk?	Functional Safety	Automated Sensing
		Are the following areas adequately considered:Containment (ie the tank)?The tank base?	Cognitive Requrements	Not Applicable
		If a dip stick has been used the possible damage to the area below the dipping point?	Cognitive Requrements	Diagnostic Sensing
		Has all testing been carried out in accordance with manufacturers' recommendations and by a suitably qualified and experienced engineer?	Functional Safety	Diagnostic Sensing
		Has careful attention been paid to acid/air and oil/water interfaces?	Theory Of Constraints	Periodic Inspection
		Has pipework been subject to a planned inspection regime including visual inspection and non-destructive testing as appropriate?	Functional Safety	Diagnostic Sensing
		Has special attention been paid to insulation, particularly at the base of tanks, around pipe connections and the roofs of tanks?	Cognitive Requrements	Diagnostic Sensing
		Have vents, valves and gauges been subject to regular testing?	Functional Safety	Diagnostic Sensing
		Have large tanks been fitted with low level accessways?	Cognitive Requrements	Manual Verification

APPENDIX – 2:

NIEM EMERGENCY MANAGEMENT MODEL DOMAIN

NIEM Model Class	Values / Parameters	Category
Alarm Audible Description Code	Audible, Silent,	Enumeration
Alert Category Code	Ack, Cancel, Dispatch, Error, Report, Request, Response, SensorConfiguration, SensorControl, SensorDetection, SensorStatus, Update,	Enumeration
Alert Event Details Category Code	CBRNE, Env, Fire, Geo, Health, Infra, Met, Other, Rescue, Safety, Security, Transport,	Enumeration
Alert Event Details Certainty Code	Likely, Observed, Possible, Unknown, Unlikely,	Enumeration
Alert Event Details Response Recommendation Code	Assess, Evacuate, Execute, Monitor, None, Prepare, Shelter,	Enumeration
Alert Event Details Severity Code	Extreme, Minor, Moderate, Severe, Unknown,	Enumeration
Alert Event Details Urgency Code	Expected, Future, Immediate, Past, Unknown,	Enumeration

Contact Role Code	Approver, Requester, Responding Org, Sender, SME,	Enumeration
Notification Distribution Scope Category Code	Private, Public, Restricted,	Enumeration
Notification Function Category Code	Ack, Alert, Cancel, Error,	Enumeration
Notification Status Code	Actual, Exercise, System, Test,	Enumeration
Resource Component Capability Category Code	Other, Type I, Type II, Type III, Type IV,	Enumeration
Hospital Information	Capability Capacity Occupancy	Super Object
Triage Details	Green Quantity Black Quantity Yellow Quantity Red Quantity	Super Object
Resource Type	Resource Details Tracking Information Schedules Availability Resource Constraints	Super Object
Alarm Details	Alarm Information Location Permit Certainty Level	Super Object
Alarm Confirmation	Confirmation Status Confirmation Mode Local Confirmation	Super Object