

## Annex A

### FMEA Sheets

#### Detection, Containment, Firefighting, and Prevention

##### Legend:

Columns F to K are to be read as follows:

The first row for each new method/function outlines standard responses for columns F - K that unless explicitly address count for all other rows in that method/function

Yellow highlights items added after the technical review group meetings and thus after the HAZID workshops

##### Code Ship types

1	Twin Island ULCS/VLCS
2	Standard Single Island Post-Panamax
3	Feeder with Aft Bay
4	Feeder with no aft bay and open cargo hold

##### Code Above or below deck?

A	Above
B	Below
A, B	Both

##### Code Dangerous goods

D	Declared
U	Undeclared
D, U	Both

##### Code Additional locations

1	Proximity to superstructure/ island/ accommodation
2	Reefer bay (electrical fire)
3	Proximity to machinery space/ fuels tanks
4	Other (see comments)

##### CINS risk location

RZ0  
RZ1  
RZ2  
RZ3  
RZ4  
RZ5

##### 2016 changes

<2016  
>2016  
both  
N/A

Method of detection	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared cargo	Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments		
Smoke detection system (sampling)	*Quick *Precise *Reliable *Robust *No added complexity *High detection rate & low false positives *Low maintenance required *Ability to monitor real time sampling levels *Identify fire location *Redundancy *Easily understandable information in fire panel	*Type of detector *Type of fire (e.g. liquid/solid, high smoke producing, high energy content etc.) *Ventilation *Weather conditions *Location of sampling points *Amount of cargo (number of containers) *Maintenance and state of system *Cargo hatch open *Hold size and location *Alarm panel design *Capacity of sampling fan *Location of fire *Cargo packing *Early detection *Detection of incipient phase	Faulty wiring to alarm system	*False alarms leading to deactivation *No detection alarm because it is not connected *Fault in alarm signal leading to wrong detection location	1,2,3,4* (*) if carrying dangerous goods)	Limited influence on detection, except maybe for explosion	B	No influence on 1 and 3. Reefer's (2) may imply more visit from crew, also more ventilation that can affect detection	Applies only to risk locations below deck	N/A	*Fault monitoring *Regular maintenance checks *Quality of cabling?			
			Sampling pipe leak	*Delay of detection and alarm signal *No detection due to high dilution of sample air *False detection location *False alarm							*Piping integrity checks *Regular maintenance checks			
			Clogging of sampling pipe	*Delay of detection and alarm signal *No detection due to lack of sample air from reduced or stopped air sampling *False detection location *False alarm								*Regular maintenance checks *filters on open ends		
			Failure to reactivate detection zones	*Delay of detection and alarm signal *No detection *False detection location								*Regular system performance checks		
			Sampling pipes too large dilute smoke	*Delay of detection and alarm signal *No detection due to high dilution of sample air								*Design performance checks		
			Smoke ventilated away from sampling points due to weather conditions (e.g. high wind, pressure)	*Delay of detection and alarm signal *No detection due to smoke not entering sampling points *False detection location *False alarm										
			Physical/mechanical damage to sample piping	*Delay of detection and alarm signal *No detection due to high dilution of sample air caused by leaks in sampling pipes *No detection due to pinched sampling pipes not able to suck in air *False detection location *False alarm								*Piping integrity checks *Regular maintenance checks *Fault monitoring		
			Fire without smoke	*No detection and alarm due to lack of smoke required to trigger alarms *Delayed detection due to lack of smoke production until fire spreads to other fuels										
			Insufficient knowledge to interpret the alarm message	*Delayed response time *Delay in decision making								*Crew training *User interface design considerations		
			Competing tasks / high workload	*Delay in interpretation time *Delayed response time *Delay in decision making										
			Atmospheric icing clogging detectors	*Delay of detection and alarm signal *No detection due to blocked sample pipes *False detection location *False alarm										
			Atypical fire event (e.g. decomposition of chemicals that release heat, smouldering)	*No detection due to atypical smoke/gaseous substances not triggering detection alarms *No detection and alarm due to lack of smoke required to trigger alarms *Delayed detection due to lack of smoke production until fire spreads to other fuels										
			Corrosion impeding sampling rate	*Delay of detection and alarm signal *No detection due to lack of sample air from reduced or stopped air sampling *False detection location *False alarm								*Choice of sampling pipe materials		
			Error in addressable alarm system	*Wrong assumption in fire location *Delay in response *Putting crew at risk due to false assumptions of fire location *CO2 released/fighting activities at wrong location										
			Fault of airflow detector in the system / amount of air drawn into the system too low	*Delay of detection and alarm signal *No detection due to low amount of sample air										*Sampling points inside the ventilation system *Needs verification and certification
			Numbers of sampling points and location.	*Delay of detection and alarm signal *Unable to locate fire origin due to insufficient sampling points										*Modelling - use of FSE techniques to optimise locations *Sampling points inside the ventilation system *Needs verification and certification
			Effect of mechanical ventilation in the holds / impact on smoke spread	*Delay of detection and alarm signal due to smoke redirected through ventilation *Delay of detection due to turbulence and mixing caused by ventilation *No detection due to lack of sample air from reduced or stopped air sampling *False detection location *False alarm									*Modelling to investigate its impact, and raise awareness *Sampling points inside the ventilation system *Needs verification and certification	
			Insufficient testing in the commissioning process and/or after maintenance (e.g. system not sufficiently designed)	*Delayed response in detection times *No detection *False alarms *Unable to use to locate fire origin										
			Smoke cooled and not buoyant enough to get to sampling pipes	*Delay of detection and alarm signal *No detection *False detection location										*Increase number of sampling locations *Additional detection methods
			Default / wrong position of the 3 way-valve (if connected to the CO2 piping system)	*No detection *False detection location *Delay in detection										
			Condition of the container of fire origin	*Highly sealed container not letting any/little smoke out leading to longer detection times, and potential higher preheating of surrounding containers										
			Air tightness of cargohold and/or hold hatches open	*Delay of detection and alarm signal due to smoke leaking out of cargo hold instead of going into sampling pipes *No detection *False detection location										*Regular maintenance checks

# Annex A

# CARGOSAFE

Method of detection	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared cargo	Above or below deck?	Additional locations	CINS risk location	Before or after 2016?	Potential Safety Measures	Comments
			The sampling pipes are too long (e.g. due to size of ship)	*No detection or delay in detection time due to dilution or loss of smoke particles through deposition within sampling pipes leading to weaker signal at detector								
			Failure of detector due to improper maintenance	*Unable to detect smoke leading to no detection alarm *Delayed response due to build-up of substances on detection system								
			Alarm not acknowledged by crew	*Delay in interpretation time *Delayed response time *Delay in decision making								
			Hatch covers open (port scenario)	*Delay in detection time *No detection	1, 2, 3							
			Sampling system is not specified for larger vessel types (Somewhat covered in more technical specificity in other lines, but added to ensure investigation)	*Delay of detection and alarm signal *Delayed response time	1, 2						*Make new specification for larger vessel types	
			Build up of explosive gases or explosion itself	*No detection before explosion *Detection leading to putting crew in danger by inspecting potential explosive atmosphere thinking its a fire							*Gas sensors for inspecting crew	
Manual detection by crew (sight, smell, heat)	*Precise communication to officers on bridge. *Immediate confirmation of fire *Safe *Seamless communication method especially on large container vessels *Number of crew *Location of crew *Weather conditions *Type of cargo *Time required for location of fire source *Fire indication signs *Time of day *Amount of cargo	*Training *Awareness *Fatigue *On-deck area packing *Number of crew *Weather conditions *Type of cargo *Time required for location of fire source *Fire indication signs *Time of day *Amount of cargo	Size of crew not able to have overview of the whole ship	*Delay in detection *Delay in confirmation *Delay in decision making *Escalation of fire, fire and smoke spread *Delay in detection *Delay in confirmation *Delay in decision making *Escalation of fire, fire and smoke spread *Safety risk to crew sending them into the cargo hold	1, 2, 3, 4		A, B					
			Difficult access to hold, especially for large container holds, where you maybe have to access 8,9,10 levels down in the hold	*Escalation of fire, fire and smoke spread *Safety risk to crew sending them into the cargo hold			B					
			Crew not able to raise alarm (e.g. lack of radio coverage, language barriers)	*Delay in confirmation and alarm *Delay in decision making *Safety risk to crew sending them into the cargo hold *Escalation of fire, fire and smoke spread *Sign of possibility of fire onboard overlooked or ignored								
			Crew lack of awareness of fire	*Delay in detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Difficulty to detect smoke at night/bad weather	*Escalation of fire, fire and smoke spread *Delay in detection *Escalation of fire, fire and smoke spread								
			Hard to detect heat/smoke until significant amounts start to come out of the container	*Escalation of fire, fire and smoke spread *Delayed detection *Delayed confirmation and alarm *Delay in decision making and action							*Portable IR camera	
			Cargo not easily visible due to e.g. view angle or location	*Escalation of fire, fire and smoke spread								
			Unfamiliar indications of fire	*Crew does not raise the alarm as they do not want to bother officers or they do not think it is a problem worth mentioning, leading to delay in detection and decision/action *Delayed detection *Fire escalation								
			Multiple/simultaneous alarms causing confusion, miscommunication and/or misidentification due to additional incidents occurring (e.g. collision, bad weather or bad vision)	*Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread *Delay in confirmation and alarm *Delay in decision making and action *Fire becomes uncontrollable								
			Crew intoxicated by smoke, cannot raise alarm	*Loss of life *Delayed detection *Delay in confirmation *Delay in decision making								
			Crew engaged in other activities, not monitoring cargo areas	*Fire and smoke spread *Wrong decision & wrong action not taken *Escalation of fire								
			Crew underestimation of fire scale	*Loss of life *Delayed-detection *Delay in confirmation *Delay in decision making							*Portable IR camera	
			Smouldering fire takes long time to leave the container	*Fire and smoke spread *Delayed confirmation and alarm *Delay in decision making and action *Fire becomes uncontrollable							*Portable IR camera	
			Lack of response training and lack of access to cargo areas	*Loss of life *Delayed detection *Delay in confirmation *Delay in decision making								
			Indecision/unsureness of crew to raise alarm	*Fire and smoke spread *Delay in detection *Delayed in confirmation and alarm *Delay in decision making and action *Fire becomes uncontrollable *Toxic environment *Explosion *Loss of life								
			Type of fire/smoke (e.g. low smoke production, highly reactive fuel)	*Wrong decisions *Delayed confirmation and alarm *Delay in decision making and action *Fire becomes uncontrollable *Fire occurs in different location *Toxic environment *Explosion *Loss of life							*Portable IR camera	
			Fire already started when loading									
			Cargo condition can not easy to understand by crew	*Unsure of required decision/action								

# Annex A

# CARGOSAFE

Method of detection	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undclared cargo	Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments
			Cargo inaccessible	*Delay in detection *Delayed in confirmation and alarm *Delay in decision making and action *Fire becomes uncontrollable *Toxic environment *Explosion								
			Crew fatigue	*Delay in detection *Delayed in confirmation and alarm *Fire becomes uncontrollable								
			Risk of confusion with naturally occurring smoke/steam/smells	*Delayed detection *Delayed in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Little to no crew presence in cargo holds	*Delay in detection *Delayed in confirmation and alarm *Escalation of fire, fire and smoke spread		B						Manual detection can happen in the hold, but this would be more coincidental rather than intentional
			Mistaken observations	*Wrong decision, for example activating ff system *Officer ignored the alarm & lost of time to control the fire in first beginning *Delay in decision making and action *Escalation of fire, fire and smoke spread							*Portable IR camera	
Manual detection by officers on the bridge (sight, smell, heat)	*Accurate in location of the fire seat/origin *Lead to immediate decision making *Backup when the fixed fire detection system doesn't warn the crew quickly enough *Officers need to be familiar with all of bridge resources which may be helpful for detection.	*Visibility *Time of day *Weather *Distance between fire seat and crew quarters (bridge) *Fire indication signs *On-deck area packing *Business with other tasks *Training *Awareness *Fatigue *Amount of cargo	The alarm on the bridge is muted	*Officer ignored the alarm & lost of time to control the fire in first beginning *Delay in decision making and action *Escalation of fire, fire and smoke spread	1,2,3,4		Mainly A, B if loss of containment					
			Cargo not easily visible due to e.g. view angle or location or ship size, from the bridge	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread							*IR cameras (installed at strategic locations). Coupled to a software solution to automate detection	Forward Bridge will lead to lack of detection from bridge, very long (size) vessel hard to overview from bridge
			Difficult to detect smoke at night/bad weather	*Delayed detection *Delay in confirmation and alarm *Escalation of fire, fire and smoke spread							*IR cameras (installed at strategic locations). Coupled to a software solution to automate detection	
			Type of fire/smoke (e.g. low smoke production, highly reactive fuel)	*Delay in detection *Delayed detection *Delay in confirmation and alarm *Fire becomes uncontrollable *Toxic environment *Explosion *Loss of life							*IR cameras (installed at strategic locations). Coupled to a software solution to automate detection	
			Smell is almost impossible to know from the bridge (totally enclosed)	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Smoke not visible from bridge (e.g. Dilution of smoke)	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Competing work tasks	*Not enough time to survey the cargo *Delay in detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Little time available for patrol	*Control of cargo is too brief or non-existent *Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread	1,2,3,4	A, B						
			Impossible to detect heat/smoke until smoke is starting to come out of the container without the appropriate detection equipment	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								*Additional equipment / for example IR camera
			Lack of competence around knowing the signs of fire	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
Fire patrol detection during inspection round	*Safe for crew carry out the patrol *Easy-to-use method *Precise *Possible to carry out also when wearing thick clothing, gloves etc. *Reliable communication / range / shielding *Reliable localization of ignition source *Patrol records, documented sightings *Procedures to follow on how the fire and what to do when fire is detected *Reliable communication tools (radio, etc) for alarming	*Intervals of patrol *Control of reporting *Location of seat of fire *Communication methods for further decisions *Training of patrols (i.e. what they should be looking for as indications) *Time of day *Weather *Available equipment *Fatigue *Size of ship *Amount of cargo	Risk of confusion with naturally occurring smoke/steam/smells	*No detection *Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Insufficient number of crew onboard	*No detection *Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Not following the standard practice/procedure of patrol	*No detection *Delayed detection *Delay in confirmation and alarm *Escalation of fire, fire and smoke spread								
			Size of vessel (time and area to cover makes it more difficult)	*No detection *Delayed detection *Delay in confirmation and alarm *Escalation of fire, fire and smoke spread								
			Low frequency of inspection by fire patrol.	*Delayed detection *Delay in confirmation and alarm *Escalation of fire, fire and smoke spread								
			Fire patrols do not take place in the cargo hold	*No detection		B						

Method of detection	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared cargo	Above or below deck?	Additional locations	CIN's risk location	Before or after 2016?	Potential Safety Measures	Comments
Detection from port facilities or staff	*Quick *Aware *Robust communication to decision makers *Well trained *Mindful of surroundings and safety *Notify port of incident *Notify ship crew/officers	*Training *Awareness *Fatigue *Size of vessel *On-deck area packing *Number of people in nearby area *Location of crew/officers *Weather conditions *Type of cargo *Time required for location of fire source *Fire indication signs *Time of day *Amount of cargo *Language skills *Ease of communication lines with relevant parties *Port location (country) *Port infrastructure/size		*No detection *Delayed detection *Delayed in confirmation and alarm *Escalation of fire, fire and smoke spread								*May be due to incompetence or organisational procedures
			No fire patrol carried out	*No detection *Delayed detection *Delayed in confirmation and alarm *Escalation of fire, fire and smoke spread								
			Difficult to perceive because of weather / time of day	*No detection *Delayed detection *Delayed in confirmation and alarm *Escalation of fire, fire and smoke spread								
				*Losing focus *No detection *Delayed detection *Escalation of fire, fire and smoke spread *Delay in confirmation and alarm								*Fire patrol becomes a rote activity carried out without real vigilance
			Crew doing patrols can become mentally fatigued from doing the same round again and again	*Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread *Safety risk for the crew								
			Crew not able to raise alarm (lack of radio coverage)	*No detection *Delayed detection *Delay in confirmation and alarm *Escalation of fire, fire and smoke spread								
			Difficult to perceive because of weather / time of day	*Delayed detection *Escalation of fire, fire and smoke spread *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread	1,2,3,4		A, B					
			Risk of confusion with naturally occurring smoke/steam/smells	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Port workers not able to raise alarm (e.g. lack of radio, language barriers)	*Delay in confirmation and alarm *Delay in decision making *Escalation of fire, fire and smoke spread								
			Port workers lack of awareness of fire	*Sign of possibility of fire onboard overlooked or ignored *Delay in detection and alarm *Delayed or improper decision making *Escalation of fire, fire and smoke spread								
Detection from port facilities or staff			Hard to detect heat/smoke until significant amounts start to come out of the container	*Delayed detection *Escalation of fire, fire and smoke spread *Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Cargo not easily visible due to e.g. view angle or location	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread								
			Low number of people around	*Delayed detection *Delay in confirmation and alarm *Delay in decision making and action *Escalation of fire, fire and smoke spread *Port workers do not give alarm as they do not want to bother others or they don't think it's a problem worth mentioning *Delay in detection and decision/action *Fire escalation								
			Unfamiliar indications of fire									

Method of firefighting	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared cargo	Above or below deck?	Additional locations	CINS risk location	Before or after 2016?	Potential Safety Measures	Comments
Internal container firefighting (in hold using lance or portable extinguisher)	*Ability to extinguish the fire in the container *Ease of use *Ability to penetrate container *Fast to penetrate container *Low training requirement *Robust *Flexible usage *Adequate extinguishing capabilities (water flow and disbursement) *Ability to use the equipment from a safe distance *Knowledge of the inside of the container *Well trained crew *Fast to setup *Firefighting equipment stored in a convenient location *PPE that corresponds to the risks *Low maintenance of the equipment *Safety of crew members	*Location of affected container *Access to container *Quality/properties of packing *Scale of fire *Type of fire *Training of crew *PPE of crew *Detection time *Equipment available *State of the hold, ability to enter safely *Fire management procedures *Organizational procedure, enter hold y/n *Time to penetrate container *Pump capacity *Environmental conditions *Type of fuel/cargo	Container of origin is out of reach	*Fire cannot be extinguished/suppressed with lance or extinguishers	1,2,3,4 Frequency and severity are abt. Proportional to the ship capacity, hence risk is increasing accordingly			Mainly 1, 3 *Firefighting willingness higher to protect accommodations and machinery spaces		At least 1 water mist lance if constructed on or after 2016 At least 2 or 4 mobile fire monitors if constructed on or after 2016 AND carrying 5 or more tiers of containers		Maybe half of the containers are accessible in the best-case scenario. In most cases it's less.
			Cargo may not be extinguishable with water and/or generally wrong extinguishing media used Supplied equipment cannot penetrate the container	*Fire cannot be extinguished/suppressed with lance or extinguishers *Escalation of fire, toxic gas release, explosion and/or *Additional risk to crew *Fire cannot be extinguished/suppressed with lance or extinguishers							Local firefighting with the lance will not be attempted unless it's a declared DG container with known content. The drilling equipment needs to be high enough quality. Otherwise, it will not be capable of drilling the hole. With the right drill you can drill the hole in 30-40 seconds.	
			Operator procedures do not permit it	*No firefighting				>2016			The hammer lance is not a feasible way forward. It's not efficient enough. Of the four operators who has taken part in the HAZIDs or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly.	
			Cargo hold is inaccessible by crew due to harsh/unsafe environment	*Fire cannot be extinguished/suppressed with lance or extinguishers							Of the four operators who has taken part in the HAZIDs or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly. In most cases the hold would not be accessed by crew for this type of firefighting.	
			Equipment failure (e.g. No activation of fire main fail due to design issues) Penetration/water disbursement is blocked internally by cargo in container unit	*Equipment not useable *Continued fire spread *Reduced effect of equipment *Fire cannot be extinguished/suppressed with lance or extinguishers								
			Insufficient equipment (e.g. hoses/hydrants) Time to deploy equipment too long	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread *Reduced effect of equipment *Fire cannot be extinguished/suppressed with lance or extinguishers *Unable to use equipment							Firefighting training is extremely limited. Some operators do drills on their own accord with the equipment. This is not part of the requirements.	
			Dangerous unknown container content	*Heightened risk to crew *Reduced effect of equipment *Fire cannot be extinguished/suppressed with lance or extinguishers *Unable to use equipment *Escalation of fire, toxic gas release, explosion	Undeclared							
			Using portable extinguishers requires manual opening of the container	*Heightened risk to crew *Reduced effect of equipment *Fire cannot be extinguished/suppressed *Unable to use equipment *Escalation of fire, toxic gas release, explosion				A priori, mainly <2016			Local firefighting with the lance will not be attempted unless it's a declared DG container with known content	
			Seat of fire container cannot be located (the fire has been detected, but the crew is unable to locate the origin to fight it locally) Explosion	*Fire cannot be extinguished/suppressed *Unable to use equipment *Escalation of fire, toxic gas release, explosion *Heightened risk to crew *Fire cannot be extinguished/suppressed with lance *Unable to use equipment *Escalation of fire, toxic gas release, explosion *Equipment damage				Portable IR cameras can aid with locating the container			Local firefighting with the lance will not be attempted unless it's a declared DG container with known content. If there has been an explosion, or there is perceived risk of explosion, local firefighting will not be attempted.	
						Risk increased with UD but true for others declared good too						
Local boundary cooling of container unit (in hold using water hoses/water monitors)	*Stop fire/heat spreading to neighbouring spaces/containers *Easy to use *Fast to initiate *Can be used from a safe distance *Able to provide sufficient water *Equipment is easy to move around (mobility) *Sufficient throw and spread *Sufficiently trained crew *Easy to setup *Safety of crew members while using the equipment *Keep crew safe until external help arrives *Ability to fix nozzles in place, and leave unattended *Sufficient hose, nozzles, and fire hydrants *Sufficient PPE for crew	*Location of affected container *Access to container *Cargo within container *Quality/properties of packing *Scale of fire *Type of fire *Training of crew *PPE of crew *Detection time *Equipment available *State of the hold, ability to enter safely *Number of crew onboard *Accessibility *Organizational procedure, enter hold y/n *Access, smoke, temperature, chemical etc. *Available manpower *Pump capacity *Type of fuel/cargo	All sides cannot be reached with water								Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			Boundary cooling initiated too late	*Inefficient boundary cooling *Continued fire spread *Fire has already propagated *Continued fire spread	1,2,3,4		B				Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			Equipment failure (e.g. No activation of fire main fail due to design issues) Mechanical damage to equipment	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			Inability to locate seat of fire	*Inefficient boundary cooling *Continued fire spread							Portable IR cameras can aid with locating the container	
			Equipment too cumbersome to use the hold (weight of water monitors, water hoses pathways in cargo hold)	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			PPE air quantity not sufficient for extended firefighting	*Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							PPE with gas detector	Of the four operators who has taken part in the HAZIDs or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly. In most cases the hold would not be accessed by crew for this type of firefighting.
				*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			Insufficient equipment (e.g. hoses/hydrants)									

Method of firefighting	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undclared cargo	Above or below deck?	Additional locations	CIN5 risk location	Before or after 2016?	Potential Safety Measures	Comments
			Hostile environment (e.g. steam, temperature, toxic smoke)	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread *Crew abandons firefighting							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	Of the four operators who has taken part in the HAZID0s or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly. In most cases the hold would not be accessed by crew for this type of firefighting.
			Operator procedures do not permit it	*No firefighting							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	Of the four operators who has taken part in the HAZID0s or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly. In most cases the hold would not be accessed by crew for this type of firefighting.
			Cargo hold is inaccessible by crew due to harsh/unsafe environment	*Continued fire spread *No boundary cooling							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	Of the four operators who has taken part in the HAZID0s or technical expert group meetings, 3 have procedures precipitin crew to go in the hold in case of a fire. One operator would consider it, but the decision is not taken lightly. In most cases the hold would not be accessed by crew for this type of firefighting.
			PPE insufficient for steam protection (steam is generated by boundary cooling)	*Injury to crew *Unable to fire fight							Adding an additional sprinkler/drencher system (or foam) would eliminate the need for crew to go in the hold. Would potentially reach more containers as well.	
			Explosion Unwanted build up of water in the hold	*Heightened risk to crew *Escalation of fire, toxic gas release, explosion *Equipment damage  *Potential stability /structural problems *Blockage of pumping system by debris								Local firefighting with the lance will not be attempted unless it's a declared DG container with known content. If there has been an explosion, or there is perceived risk of explosion, local firefighting will not be attempted.
Cargo hold cooling (bulkheads and hatch covers)	*Stop fire/heat spreading to neighbouring spaces *Easy to use *Fast to initiate *Can be used from a safe distance *Able to provide sufficient water *Functioning in all weather *Access to bulkheads *Ability to fix nozzles in place, and leave unattended *Safety of crew members while using the system *Knowledge about seat of fire *Keep fire manageable until external help arrives *Immediately available *Fire main designed to provide sufficient water *Sufficient PPE for crew *Sufficient throw and spread *Sufficiently trained crew *Easy to setup *Equipment s easy to move around (mobility)	*Location of affected cargohold *Cargo within cargohold *Scale of fire *Type of fire training of crew *PPE of crew *Decision making of officers *Sufficient water *Crew size *Acces to hatchcovers *Knowledge of seat of fire *Equipment condition and reliability *Access to bulkheads *Time of the event occurred *Accessibility (e.g. to hatch covers and bulkheads) *Pump capacity *Availability of hydrants and hoses *Type of fire *Detection time *Environmental conditions	Fire is already large, making cooling ineffective	*Inefficient boundary cooling *Continued fire spread								
			Cargo hold contains undeclared dangerous cargo	*Heightened risk to crew *Reduced effect of equipment *Escalation of fire, toxic gas release, explosion		Undeclared						
			Crew cannot cool the right areas due to lack of information	*Inefficient boundary cooling *Continued fire spread								
			Crew cannot cool the right areas due to inability to access	*Inefficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
			Mechanical damage to equipment	*Equipment not useable *Inefficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
			Equipment failure (e.g. No activation of fire main fail due to design issues)	*Equipment not useable *Continued fire spread								
			Equipment too cumbersome to use in the hold (weight of water monitors, water hoses pathways)	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
			Hatches not closed	*No boundary cooling on hatches, but fire cannot propagate upwards (no containers) *Increased burn rate in the affected hold (more O2 available)			1,2,3					
			Insufficient dimensioning of the fire main to support both fire fighting activities and boundary cooling	*Reduced effect of equipment *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread *Inefficient firefighting								
			Steam development while cooling bulheads	*Injury to crew *Potentially reduced firefighting *Lower visibility							Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
			Insufficient equipment (e.g. hoses/hydrants)	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
			Crew size insufficient to conduct boundary cooling	*Inefficient boundary cooling *No boundary cooling *Continued fire spread							DYI clamps are used by many operators to mitigate this problem. The clamps allows for fixation of the fire hoses and monitors and thereby frees up crew from manually holding the equipment at all times. This could be a relatively inexpensive RCO to implement.  Adding an additional sprinkler/drencher system (or foam). Would potentially reach more containers as well.	
CO2 System (Fixed fire extinguishing/suppression)	*Extinguish a fire in a cargohold *Allow fire fighting without endangerment of the crew *Capability to supply CO2 for more than "one shot" longer duration	*Time of usage (after ignition) *Type of cargo contributing to fire *Sealing of cargohold	Explosion  Seals on cargo hold hatches are not sufficiently air tight	*Heightened risk to crew *Escalation of fire, toxic gas release, explosion *Equipment damage *CO2 will leak out, making it less effective at suppressing a fire within the cargo hold as inert atmosphere will not be maintained			1,2,3			8		







Method of firefighting	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undclared cargo		Above or below deck?	Additional locations	CINS risk location	Before or after 2016?	Potential Safety Measures	Comments
	*Keep fire manageable until external help arrive *Sufficient PPE for crew *Sufficient throw and spread *Sufficiently trained crew	*Mobility of equipment available (weight) *State of sea *Equipment condition and reliability *Type of fire *Detection time *Time of day	Equipment too cumbersome to use (weight of water monitors, water hoses pathways)	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread								*Lightweight equipment *Riser pipes to not carry the equipment on the ladders *Fixed installations	
			Equipment failure (e.g. No activation of fire main fail due to design issues)	*Equipment not useable *Continued fire spread							*Permanent high pressure installation (potentially with remote activation)		
			Insufficient equipment (e.g. hoses/hydrants)	*Equipment not useable *Continued fire spread									
			PPE air quantity not sufficient for extended firefighting	*Equipment not useable *Inefficient boundary cooling *Insufficient boundary cooling *Crew exhaustion *Continued fire spread									
			Weather creates unfavourable conditions for cooling	*Inefficient boundary cooling *Insufficient boundary cooling *No cooling possible *Continued fire spread									
			The supplied equipment does not have capacity to reach the bay from a safe distance.	*Inefficient boundary cooling *Insufficient boundary cooling *No cooling possible *Continued fire spread							*Permanent high pressure installation (potentially with remote activation)		
			Number of available teams	*Increase risk of mistakes *Increase risks to crew *Crew exhaustion *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread							*Permanent installation (potentially with remote activation) *Clamps to enable use of hoses and monitors without presence of crew at all times		
			Event happens during night time	*Increase risk of mistakes *Increase risks to crew *Inefficient boundary cooling *Insufficient boundary cooling *Continued fire spread									
			Leakage of water into other areas	*Reduce the crews time for "safe" fire fighting *Added risks to crew and other cargo									Additional water damage has been discussed in the technical expert group meetings. Boundary cooling on deck and on hatch covers can lead to additional water damage of goods in otherwise unaffected holds
			Flooding of cargo hold	*Ability to decide to flood fast and without concerns *Maintain the structural integrity of the hull *A contingency plan for flooding of cargo hold beforehand should be available. *Ensure bulkheads between holds are not overloaded by hydrostatic pressure *To be effective at extinguishing/reaching fire *No warping of hull *No/limited hogging and/or sagging *Maintain stability *Ability to safely function unattended (emergency power and vessel abandoned) *Not endanger external environment *Ability to drain quickly	*Pump capacity and flow rate *Possible mixing of cargo due to flooding *Type of cargo *Nozzle types *Filling locations *Weather/sea conditions *Environmental concern (Potential contamination and treatment of accumulated water) *Ability to reach fire (allowed water level) *Speed of decision making process *Loading of the ship *Familiarization of such a contingency plan *Communication with shore based support	Non-return valves slows down the time to fill the cargo hold--	*Inefficient flooding *Fire continues to spread	1,2,3,4	B		Possible effect on flooding strategy, if any		*Quick flooding system / Hold to be designed for additional stresses implied
			Analysis required for go ahead is very long--	*Delayed flooding *Fire continues to spread							*Would smaller volume cargo holds be an option? That would make this solution more practical, allow faster filling and probably also make it a safer solution.	*Container invasive method. Many containers involved	
			Flooding takes too long	*Inefficient flooding *Fire continues to spread							*Rapid flooding of the hold		
			Fire is too high up in the cargo hold for flooding to have an effect	*Inefficient flooding *Fire continues to spread							*Possibility to add foam detergent		
			No go ahead info from class to start flooding	*No flooding *Fire continues to spread									
			Flooding not allowed due to stability or structural hazards	*No flooding *Fire continues to spread									
			Stability problem	*Flooding accepted only to a limited level/quantity *Inefficient flooding *Fire continues to spread									
			Decision making due to limited intel about cargo in the hold	*Inefficient flooding *No flooding *Delayed flooding *Fire continues to spread *Create other hazards e.g. explosion, toxic gas release									
			Delayed decision as its viewed as a last resort	*Inefficient flooding *Delayed flooding *Fire continues to spread									
			Pumps arent maintained properly	*Inefficient flooding *Delayed flooding *Fire continues to spread									
			Cargo weights not properly declared. So Class assessment of stresses with hold flooded may be more marginal than apparent	*Flooding accepted only to a limited level/quantity *Inefficient flooding *Fire continues to spread		U							
			Insufficient pump capacity to maintain boundary cooling while flooding is in progress	*Delayed flooding *Fire continues to spread *Inefficient flooding *Fire continues to spread *Create other hazards e.g. explosion, toxic gas release									
			Possibility of mixing cargo	*Inefficient flooding *Fire continues to spread *Create other hazards e.g. explosion, toxic gas release									
			Cargo reacts with sea water to create additional hazards	*Flooding accepted only to a limited level/quantity *Inefficient flooding *Delayed flooding *Fire continues to spread									
			Major difference between whether this is a planned RCO or an unplanned emergency measure	*Inefficient flooding *Delayed flooding *Fire continues to spread									

Method of containment	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared c	Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments
Flame/fire contained within a single container (Hold and weather deck)	<ul style="list-style-type: none"> <li>*No added requirements to container design</li> <li>*Container walls must be penetrable by fire fighting equipment to suppress fire inside</li> <li>*Logistical functions must remain</li> <li>*Easy accessible</li> <li>*Allows use of fire detection system</li> <li>*Unit price kept low</li> <li>*Remains a usable, seaworthy container</li> <li>*There is no desired fire safety function of a container, only logistical functions</li> <li>*Protect the cargo within from external environment</li> </ul>	<ul style="list-style-type: none"> <li>*Air gaps between containers (between tiers, rows and bays)</li> <li>*Quality of the floor in the given unit</li> <li>*Up, below, lateral spacing between bays, 20 or 40</li> <li>*State of container</li> <li>*Type of cargo</li> <li>*Type of fire</li> <li>*Cargo arrangement</li> <li>*Packing material inside the container</li> <li>*Porosity in the container AND porosity on the container boundaries (openings, seals, deformations)</li> <li>*Ventilation orientation</li> <li>*Orientation of the container (door)</li> <li>*Quality of the door seals</li> <li>*Cargo load/density</li> <li>*Ability to reach the container for active cooling</li> <li>*External environmental conditions</li> </ul>	Structural deformation enables flamespread	<ul style="list-style-type: none"> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Flame/fire not contained within a single container</li> </ul>	1,2,3,4	D, U	A, B	1,2,3	R20 to R25?	<2016, >2016, N/A	<ul style="list-style-type: none"> <li>*Container to be designed with a soft/weak spot(s) in order to ease penetration for cooling purpose - containment</li> </ul>	<ul style="list-style-type: none"> <li>*Designing a container to contain fire is not a realistic solution as we would be talking about introducing 340 mill containers new design. The onus must be on prevention not reaction at least not in design state. Existing solutions such as lance option remains relevant.</li> <li>*Container to be designed with a soft/weak spot(s) in order to ease penetration for cooling purpose - containment</li> <li>*Allows fire detection using smoke (Flames and smoke exit the container)</li> </ul>
			Flame propagation through door seal to other container due to orientation (doors facing each other)	<ul style="list-style-type: none"> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Flame/fire not contained within a single container</li> <li>*Seals produce flaming droplets</li> </ul>								
			Flame propagation through vents at side of the container ignites the wooden floor of container above	<ul style="list-style-type: none"> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Flame/fire not contained within a single container</li> </ul>								
			Liquid flammable substance leaks through container door	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Flame/fire not contained within a single container</li> </ul>								
			Flame propagation through seals	<ul style="list-style-type: none"> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Flame/fire not contained within a single container</li> <li>*Seals produce flaming droplets</li> <li>*Flame/fire not contained within a single container</li> </ul>								
			Flame propagation through damages or cracks in container	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Flame/fire not contained within a single container</li> </ul>								
			Dangerous goods in proximity to seat of fire	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Flame/fire not contained within a single container</li> </ul>								
			Wooden floor combusts and burns through creating heat propagation to container underneath	<ul style="list-style-type: none"> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Wood/char falling down acting as a spread mechanism</li> <li>*Flame/fire not contained within a single container</li> </ul>							<ul style="list-style-type: none"> <li>*Particularly problematic with undeclared cargo</li> </ul>	
			Explosion	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Mechanical damage to container and adjacent units/vessel</li> </ul>							<ul style="list-style-type: none"> <li>*Changing material of flooring</li> <li>*Adding foam insulation to the floor</li> </ul>	
Heat insulation (conduction and radiation) contained within a single container (Hold and weather deck)	<ul style="list-style-type: none"> <li>*No added requirements to container design</li> <li>*Container walls must be penetrable by fire fighting equipment to suppress fire inside</li> <li>*Logistical functions must remain</li> <li>*Easy accessible</li> <li>*Allows use of fire detection system</li> <li>*Unit price kept low</li> <li>*Remains a usable, seaworthy container</li> <li>*Durability</li> <li>*There is no desired fire safety function of a container, only logistical functions</li> <li>*Protect the cargo within from external environment</li> </ul>	<ul style="list-style-type: none"> <li>*Air gaps between containers (between tiers, rows and bays)</li> <li>*Quality of the floor in the given unit</li> <li>*Up, below, lateral spacing between bays, 20 or 40</li> <li>*State of container</li> <li>*Type of cargo</li> <li>*Type of fire</li> <li>*Cargo arrangement</li> <li>*Packing material inside the container</li> <li>*Porosity in the container AND porosity on the container boundaries (openings, seals, deformations)</li> <li>*Ventilation orientation</li> <li>*Orientation of the container (door)</li> <li>*Quality of the door seals</li> <li>*Cargo load/density</li> <li>*Ability to reach the container for active cooling</li> <li>*External environmental conditions</li> </ul>	Conduction in steel walls and doors transferring to heat transfer via convection and radiation to neighbouring containers/spaces	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> </ul>			A, B					*A great danger to the crew performing fire-fighting
			Container ceiling heats up and ignites floor of container above	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> </ul>							<ul style="list-style-type: none"> <li>*Changing material of flooring</li> <li>*Adding foam insulation to the floor</li> </ul>	<ul style="list-style-type: none"> <li>*Potentially make a test to determine whether changing the floor material or adding insulation would have a significant impact</li> <li>*Any measures which increase the weight of the container is considered less interesting due to lost carrying capacity.</li> <li>*Discuss with EMSA whether changes to container units are within scope of CARGOSAFE</li> </ul>
			Wooden floor combusts creating heat propagation to container underneath	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> </ul>							<ul style="list-style-type: none"> <li>*Changing material of flooring</li> <li>*Adding foam insulation to the floor</li> </ul>	
			Dangerous goods (especially with low ignition temperatures) in proximity to seat of fire (container of origin)	<ul style="list-style-type: none"> <li>*Heat propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> </ul>							<ul style="list-style-type: none"> <li>*Particularly problematic with undeclared cargo</li> </ul>	
Structural stability of single container maintained (Hold and weather deck)	<ul style="list-style-type: none"> <li>*Durability</li> <li>*Remain in stack supporting the load and ship motion with lashing, etc.</li> <li>*No desired function on fire stability so far</li> <li>*No added requirements to container design</li> <li>*Container walls must be penetrable by fire fighting equipment to suppress fire inside</li> <li>*Logistical functions must remain</li> <li>*Easy accessible</li> <li>*Allows use of fire detection system</li> <li>*Unit price kept low</li> <li>*Remains a usable, seaworthy container</li> </ul>	<ul style="list-style-type: none"> <li>*Load above &amp; accelerations of the ship</li> <li>*Temperature reached in the fire, i.e. steel losing structural integrity</li> <li>*Location of container in the stack</li> <li>*Air gaps between containers (between tiers, rows and bays)</li> <li>*Quality of the floor in the given unit</li> <li>*Up, below, lateral spacing between bays, 20 or 40</li> <li>*State of container</li> <li>*Type of cargo</li> <li>*Type of fire</li> <li>*Cargo arrangement</li> <li>*Packing material inside the container</li> <li>*Porosity in the container AND porosity on the container boundaries (openings, seals, deformations)</li> <li>*Orientation of the container (door)</li> </ul>	Container structure is compromised by pre-existing damage (e.g. mechanical or corrosion) and faults (e.g. insufficient welding)	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Structural collapse of the container, might lead to additional collapse of the stack and additional mechanical damage</li> </ul>			A, B				<ul style="list-style-type: none"> <li>*Strengthening of container structure, - pillars in each corner</li> </ul>	<ul style="list-style-type: none"> <li>*Revisit the survey regime for verification of structural integrity – is this efficient today?</li> </ul>
			Deformations/joint failure / Structural deformation enables flamespread	<ul style="list-style-type: none"> <li>*Fire propagation outside container</li> <li>*Other container boxes heating up, subsequently catching fire or collapsing</li> <li>*Loss of containment at the unit level</li> <li>*Difficult to tackle by the crew, potential harm to firefighting team</li> <li>*Structural collapse of the container, might lead to additional collapse of the stack and additional mechanical damage</li> </ul>								

Method of containment	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared c Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments
		*Cargo load/density *Ability to reach the container for active cooling *External environmental conditions	The temperature of container components exceeds the capacity of the steel structure	*Structural collapse of the container, might lead to additional collapse of the stack and additional mechanical damage. *Fire propagation outside container *Other container boxes heating up, subsequently catching fire or collapsing *Loss of containment at the unit level *Difficult to tackle by the crew							
			Structural collapse of a container in the bottom of the stack on the weather deck causing lashing module failure	*Fire propagation outside container *Other container boxes heating up, subsequently catching fire or collapsing *Loss of containment at the unit level *difficult to tackle by the crew, potential harm to firefighting team *Structural collapse of the container causing lashing module failure, might lead to additional collapse of the stack and additional mechanical damage							
			A structural collapse of container leads to combustible material leaking	*Fire propagation outside container *other container boxes heating up, subsequently catching fire or collapsing *Loss of containment at the unit level *Difficult to tackle by the crew, potential harm to firefighting team *Structural collapse of the container, might lead to additional collapse of the stack and additional mechanical damage							
			Structural stability of containers compromised due to sub-optimal loading configuration	*Increased risk of structural collapse of the container, which might lead to additional collapse of the stack and additional mechanical damage							
				*Fire propagation outside container *Other container boxes heating up, subsequently catching fire or collapsing *Loss of containment at the unit level *Difficult to tackle by the crew, potential harm to firefighting team *Mechanical damage to container and adjacent units/vessel							
Flame/fire contained within a single cargo hold	*The design of the hold doesn't add extra cost to the construction of the vessel *Desired function of SOLAS, contain the fire in the space of origin *Passive containment through physical barriers e.g. hatch covers and bulkheads	*Cargo load/density *Proximity of seat of fire to super structure, bridge, accommodation, etc. *The ability for flame to penetrate the hatch cover (seals) *Openings *Design of hatches and use of combustible materials *Type of fire *External environmental conditions	Explosion	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew		8				*There are possibilities in terms of watertightness below deck being investigated. There are also studies with regards to flooding. *Passive insulation (especially to deck)	
			The decision to boundary cool between the stacks is taken to late	*Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew						*Auto seawater cooling system with different designs for the weather deck and the cargo hold.	
			Openings/Ventilation not closed	*Stability of containers stowed on deck *Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew							
			Fire dampers on cargo hold ventilation not closed	*Stability of containers stowed on deck *Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew							
			Openings in hatches allowing flames to spread to containers above decks	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Explosion risk							
			Flame propagation through damages or cracks in cargo hold	*Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Manual extinguishing/boundary cooling not possible							
			Hold is not accessible due to hostile environment	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Stability of containers stowed on deck *Damage hull *Damage to bulkheads *Damage hatch covers and stacks on deck *Damage to ship systems *Other systems malfunction							
			Combustible gases leak out and are ignited elsewhere on the ship	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Stability of containers stowed on deck *Damage hull *Damage to bulkheads *Damage hatch covers and stacks on deck *Damage to ship systems *Other systems malfunction							
			Explosion	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Stability of containers stowed on deck *Damage hull *Damage to bulkheads *Damage hatch covers and stacks on deck *Damage to ship systems *Other systems malfunction							
			Flames damages other ship systems	*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Stability of containers stowed on deck *Damage hull *Damage to bulkheads *Damage hatch covers and stacks on deck *Damage to ship systems *Other systems malfunction							
				*Fire can spread from hold to weather deck *Loss of containment at hold level *Fire fighting/fire control becomes increasingly complex for crew *Stability of containers stowed on deck *Damage hull *Damage to bulkheads *Damage hatch covers and stacks on deck *Damage to ship systems *Other systems malfunction							
Heat insulation (conduction and radiation) contained within a single cargo hold	*Stowage of declared DG underdeck ideally between fire/explosion proof bulkheads such as in the R2 based DG stowage concept *Desired function of SOLAS, contain the fire in the space of origin *The design of the hold doesn't add extra cost to the construction of the vessel *Easy accessibility for crew to conduct boundary cooling of the given separation in question e.g. bulk head hatch covers *Passive containment through hatch covers and bulkheads	*Proximity of seat of fire to superstructure, bridge, accommodation etc. *Match between passive insulation and fire curve *Design of hatches and use of combustible materials *Access for boundary cooling *No insulation in general except local divisions *External environmental conditions	Radiating/conducting heat ignites cargo in adjacent space due to lack of insulation	*Lack of containment at the hold level *Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Fire spread to critical void space carrying fuel. Critical loss of containment. *Fire fighting/fire control becomes increasingly complex for crew		8				*Auto seawater cooling system with different designs for the weather deck and the cargo hold. *Stowable ballast tanks between holds to create insulation on demand	
			Radiant heat enables fire spread to fuel holding void space due to A60 being insufficient	*Fire spread to adjacent space *Fire propagation through gaps *Stability of containers stowed on deck *Lack of containment at the hold level *Fire fighting/fire control becomes increasingly complex for crew							
			Deformation of the hatch cover due to heat	*Fire spread to adjacent space *Stability of containers stowed on deck *Lack of containment at the hold level *Fire fighting/fire control becomes increasingly complex for crew							
			Radiant heat enables fire spread through hatch cover	*Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Lack of containment at the hold level *Fire fighting/fire control becomes increasingly complex for crew							
			Container not accessible i.e. manual extinguishing not possible nor boundary cooling	*Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Fire spread to critical void space carrying fuel. Critical loss of containment. *Fire fighting/fire control becomes increasingly complex for crew							
			Bulkhead insulation towards fuel tank (between cargo holds) is damaged (mechanical damage)	*Fire fighting/fire control becomes increasingly complex for crew *Fire spread to adjacent space *Manual extinguishing/boundary cooling not possible							
			Hold is not accessible due to hostile environment	*Manual extinguishing/boundary cooling not possible							
			Radiated heat may heat structural hull elements	*Reduced strength - compromised hull integrity							
				*Reduced strength - compromised hull integrity							
				*Reduced strength - compromised hull integrity							

Annex A  
CARSAFE



Method of containment	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared c	Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments
Heat insulation (conduction and radiation) contained within a container bay (Weather deck)	*Desired function of SOLAS, contain the fire in the space of origin *Easy accessibility for crew to conduct boundary cooling between the bays	*External environmental conditions (temperature, precipitation, wind, sea spray) *Lateral spacing between bays, 20 or 40 *Auto-seawater cooling system with different designs for the wr. deck and the cargo hold. *Crews ability to enter the affected area, experience in boundary cooling *Ability to use boundary cooling between bays- *Proximity of seat of fire to super structure, bridge, accommodation, etc. *Availability of equipment to conduct boundary cooling (not a requirement for vessels built before 2016)	The necessary boundary cooling equipment is not available due to vessel production date	*Loss of containment at bay level *Potential spread to other areas		A				B		
			The decision to boundary cool between the stacks is taken to late	*Loss of containment at bay level *Potential spread to other areas								
			Inadequate training in boundary cooling	*Loss of containment at bay level *Potential spread to other areas								
			Adequate access to the bay separation not possible due to smoke toxicity or too high temperatures	*Manual extinguishing not possible nor boundary cooling e.g. fire in container behind another container, and without other means of access *Loss of containment at bay level *Potential spread to other areas								
			No/insufficient water protection between bay on deck	*Loss of containment at bay level *Potential spread to other areas								
			Air gap insufficient between bays	*Loss of containment at bay level *Potential spread to other areas								
			Boundary cooling is not possible due to stacking method (Russian stowage)	*Manual boundary cooling not possible *Loss of containment at bay level *Potential spread to other areas								Boundary cooling, lancing etc., not possible due to i.e. russian stowage or twins. Both scenarios applicable OD and UD. On deck i.e. in brw 20' bays, overstowed or not and ud "in the gallery" i.e. behind the container that is reachable.
			Insufficient boundary cooling	*Loss of containment at bay level *Potential spread to other areas								
			Fire spread downwards through hatch cover via heat transfer	*Loss of containment at bay level *Potential spread to other areas								
Structural stability of container stack maintained within container bay (Weather deck) (lateral stability elements: lashings and twist locks)	*No need for new ways of ensuring *Unified rules for lashing gear - safety factors for load calculations *Remain in stack supporting the load and ship motion with lashing, etc. *No desired function on fire stability so far	*Load on the given stack *Temperatures reached - structural integrity of containers and lashings *Load above & accelerations & container/lassing elements (steel) *Weather conditions, state of sea-	Collapse of one container in the stack leads to excessive dynamic load on the stack underneath causing collapse of the bay	*Loss of structural containment potentially leading to mechanical damage to hull or other structures or personnel- *Containers lost at sea *Access for firefighting more complex/prevented *Willingness to firefight is impacted negatively		A						
			Container collapse due to loss structural stability of supporting structure (lashings + twist locks)	*Loss of structural containment potentially leading to mechanical damage to hull or other structures or personnel- *Containers lost at sea *Access for firefighting more complex/prevented *Willingness to firefight is impacted negatively *Loss of containment at bay level *Potential spread to other areas *Willingness to firefight is negatively impacted *Mechanical damage to lashing bridges and other structures/systems				Problematic in close proximity to super structure, engine island				
			Explosion	*Mechanical damage to personnel *Reduced structure stability *Loss of structural containment potentially leading to mechanical damage to hull or other structures or personnel- *Containers lost at sea *Access for firefighting more complex/prevented								
			Ageing and ill maintained ship									From regulatory perspective, many surveys are carried out by Class Societies or Port State Control. Conditions of container supports, cell guides, securing arrangements, etc. should be part of elements checked.

Method of prevention	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undclared cargo	Above or below deck?	Additional locations	CINIS risk location	Before or after 2016?	Potential Safety Measures	Comments				
Cargo preparation (including initial packaging of the goods, consolidation, packing and stuffing the container, and booking including declaration)	<p><b>General to all cargo preparation steps:</b></p> <ul style="list-style-type: none"><li>* Cargo preparation and handling is appropriate and in compliance with the IMDG Code</li><li>* Appropriately trained staff carry out all steps of the work</li><li>* Appropriate test methods for self-heating</li><li>* Applicable regulations are easily accessible and clear</li><li>* Instructions and methods are clear</li><li>* Tests available to ensure compliance</li></ul> <p><b>Initial (primary) packaging and preparation:</b></p> <ul style="list-style-type: none"><li>* Packaging is appropriate to contain the goods</li><li>* Cargo is of adequate quality to be shipped</li><li>* Packaging of the goods and packaging arrangement is according to their nature and IMDG class</li><li>* Cargo stabilisation is according to the IMDG Code</li><li>* Initial packaging and handling takes into consideration weathering of cargo that may occur in transit</li></ul> <p><b>Consolidation, packing and stuffing the container:</b></p> <ul style="list-style-type: none"><li>* Container is packed tightly to ensure no movement of goods</li><li>* Separation of incompatible goods</li><li>* The container is in good condition</li><li>* Weather protection provided for the goods as appropriate</li><li>* Stuffing of container is appropriate for sea passage</li><li>* Complies with regulations and guidelines (CTU and IMDG Code)</li></ul> <p><b>Booking and declaration:</b></p> <ul style="list-style-type: none"><li>* Declaration and booking information is correct and complete</li><li>* Complies with IMDG Code</li></ul>	<ul style="list-style-type: none"><li>* IMDG is very complex; new version released every two years</li><li>* Access to IMDG Code in an understandable format, including translation to all languages, may be limited</li><li>* Many exceptions and special provisions in the IMDG Code (e.g. smaller individual package sizes may permit large quantities to be loaded in a container without a dangerous goods declaration requirement)</li><li>* Standard for classification of self-heating of substances is associated with uncertainties</li><li>* Lack of a mandatory standard for dangerous goods declaration form</li><li>* Corporate culture and resources allocated for the work (working conditions)</li><li>* Economic situation of packer (leaves out dangerous declaration because they cannot afford extra charges)</li><li>* Quality of training of shore side personnel throughout the supply chain</li><li>* National standards and quality of training and inspection of land-based supply chain activities</li><li>* Land-based personnel could have lack of awareness of the conditions the container will encounter at sea</li><li>* Environmental conditions when the packing is done</li><li>* Quality of packing methods/materials</li></ul>	Defective packaging	<ul style="list-style-type: none"><li>* Potential leakage of dangerous goods</li><li>* Potential ingress into the package of unwanted substances such as water, air, etc.</li><li>* Damage to goods</li></ul>	D, U							Training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers				
			Packer is not sufficiently knowledgeable about packaging requirements	<ul style="list-style-type: none"><li>* Incorrect packaging used</li><li>* Potential release or self-heating due to incorrect packaging</li><li>* Potential cargo ignition</li></ul>								Improved training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers				
			Non-compliance with regulations due to lack of understanding/training	<ul style="list-style-type: none"><li>* Incorrect packaging, stuffing, or declaration</li><li>* Potential release or self-heating due to incorrect packaging</li><li>* Goods potentially not handled or stowed in manner compliant with the IMDG Code</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>								Improved training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers				
			Incorrect packaging used (non-compliance with IMDG Code packaging requirements)	<ul style="list-style-type: none"><li>* Potential release or self-heating due to incorrect packaging</li><li>* Potential cargo ignition</li></ul>								Improved training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers	* Photo documentation of cargo for AI analyses - risk rating of the unit			
			Incomplete/inaccurate passing of cargo information from previous, shore-based parties in the supply chain	<ul style="list-style-type: none"><li>* Vessel has insufficient information about the cargo and specific handling requirements</li><li>* Goods potentially not handled or stowed in manner compliant with the IMDG Code</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>								Declaration must be verified by reliable third party				
			Improper stuffing of container	<ul style="list-style-type: none"><li>* Shifting and potential damage to packages/containment of goods</li><li>* Possible leakage of dangerous goods in the event of damaged packaging</li><li>* Potential for self-heating</li></ul>								Improved training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers	* Photo documentation of cargo for AI analyses - risk rating of the unit			
			Incorrect segregation of cargo inside container	<ul style="list-style-type: none"><li>* Reaction between incompatible cargo types if there are leaks</li></ul>								Improved training of shore side personnel throughout the supply chain; consideration of identification/certification regimes for shippers/handlers	* Photo documentation of cargo for AI analyses - risk rating			
			Faulty DG Reefer unit is used	<ul style="list-style-type: none"><li>* Substances that should be transported under temperature control, may undergo a self-accelerating decomposition, possibility of explosive reaction when the temperature exceeds a certain value</li><li>* Self-ignition during transport</li></ul>												
			Goods not sufficiently processed/cooled before packing	<ul style="list-style-type: none"><li>* Self-ignition during transport</li></ul>												
			Cargo not declared or misdeclared	<ul style="list-style-type: none"><li>* Goods potentially not handled or stowed in manner compliant with the IMDG Code</li><li>* Self-ignition possible if conditions such as temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>								Declaration must be verified by reliable third party	Two possible reasons for non declaring were noted during the Technical Expert Group Meeting to be financial (extra cost for dangerous goods) and administrative (more paperwork, possible need to submit test reports on the cargo, etc.).			
			Packaging non-compliance regarding air gap: amount of air left inappropriate for inhibiting self-heating material transitioning to flaming	<ul style="list-style-type: none"><li>* Self-heating</li><li>* Self-ignition possible</li><li>* Goods are not handled as self-heating</li><li>* Self-heating occurs</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>								Photo documentation of cargo for AI analyses - risk rating of the unit				
			Booking processing	<ul style="list-style-type: none"><li>* Information is correctly evaluated and follow-up information collected when necessary</li><li>* Easy to understand</li><li>* Information is easy to access</li><li>* Easy for client to verify that they are compliant with requirements</li><li>* Information collected and shared with concerned parties adequately</li><li>* Screening of booking data to ensure detection of misdeclared or undeclared (keyword database and other methods)</li><li>* Continuous screening to detect when booking changes are made by shippers</li><li>* Identify containers for targeted inspections</li><li>* Potentially risk cargoes are highlighted</li><li>* Integration of information from different sources is not necessary or automatic</li><li>* Potential interaction between cargoes that might not mix well is taken into consideration</li></ul>	<ul style="list-style-type: none"><li>* Time limitations</li><li>* Resources available</li><li>* Software used</li><li>* Hardware used</li><li>* Access to IMDG rules/ data and validation not often available to shipper</li><li>* Language proficiency of booker</li><li>* Competence level, skills of consignor</li><li>* Integrity of bookers</li><li>* Different format of digital booking tools</li><li>* Complexity of the documents required</li><li>* Frequent updating of bookings</li><li>* Late arrivals</li><li>* Knowledge about and status of customers (known and key customers, unknown)</li></ul>	Undeclared or misdeclared dangerous goods rejected by one carrier are accepted by another	<ul style="list-style-type: none"><li>* Undeclared/misdeclared dangerous goods may be received through a partner booking</li><li>* Vessel has insufficient information about the cargo and specific handling requirements</li><li>* Goods may not be handled or stowed in manner compliant with the IMDG Code due to lack of correct information</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>							Communication between carriers about booking rejections so if a booking is rejected partner shipping lines can be aware if the booking is then presented to them.		
						Less of data during the processing	<ul style="list-style-type: none"><li>* Critical data not relayed</li><li>* Dangerous goods may not be handled or stowed in manner compliant with the IMDG Code due to lack of correct information</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>									
							<ul style="list-style-type: none"><li>* Self-heating occurs</li><li>* Self-ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>									

Method of prevention	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undeclared cargo	Above or below deck?	Additional locations	CIS risk location	Before or after 2016?	Potential Safety Measures	Comments
	* Secure system to prevent loss of information/data * Able to handle several clients using the same container		Screening alert is bypassed without verification	* Undeclared/misdeclared goods are loaded * Vessel has insufficient information about the cargo and specific handling requirements * Goods may not be handled or stowed in manner compliant with the IMDG Code due to lack of correct information * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting								
			Undeclared or misdeclared good accepted (due to various reasons included failure to understand the booking system)	* Undeclared/misdeclared goods are loaded * Vessel has insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting		D, U						
			Mistakes made due to lack of common software/portal for booking purposes across different companies	* Critical data not relayed * Vessel has insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting		U						
			Insufficient information on special requirements of cargo (requirements that are additional to IMDG requirements for specific cases)	* Cargo not handled correctly * Potential release and ignition		D, U						
			Bookings not consistently screened; failure of screening system	* Undeclared/misdeclared goods are accepted * Vessel has insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting		D					Develop common shared keyword database for screening to detect mis-declared or nondeclared DG	
			Faulty information introduced by late changes of booking	* Potential for acceptance of undeclared/misdeclared dangerous goods * Vessel has insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting		U						
			Technical failure in booking system	* Vessel may receive insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting		D, U						
			Water ingress	* Damaged goods * Unwanted reactions / self-heating		D, U						
			Containers stored under direct sunlight against recommendations for the particular cargo	* Increased heating * Temperature rises above critical point for decomposition reactions to take place (e.g. for thermal runaways)		D, U						
			Heating of container due to weather/sun exposure	* Initiation of self-heating processes and/or thermal runaways * Mechanical stress to goods and risk of leakage/damage leading to ignition * In the event of a fire, increased air flow into container allowing fire to burn better * Water ingress possible		D, U					HAZID attendees reported that this has happened with charcoal	
Terminal handling/storage	* Efficient movement of goods (no unnecessary delays and uncollected containers do not accumulate) * Appropriate environment conditions maintained: humidity and weather protection provided where applicable * Careful movement of goods to prevent mechanical damage * System in place for reporting damaged containers to the operator before they are loaded * Safe and separated zone for dangerous goods storage (compliance with IMO Revised Recommendations on the Safe Transport of Dangerous Cargoes and Related Activities in Port Areas)	* Climate (temperatures, weather changes, humidity) * Port personnel competencies and work practices * Observational skills of workers (for noting damage, leaks, smoke, etc.) * Information flow and process for personnel to report observations to decision makers * Knowledge of what is in the containers * Many and variable port and terminal prohibitions and restrictions * Equipment limitations with regards to avoiding damage from handling * Tard capacity * Available space / backlog within the supply chain * Time pressure / stress of workers	Containers/packaging damaged while lifting or moving	* Mechanical stress to goods and risk of leakage/damage leading to ignition * In the event of a fire, increased air flow into container allowing fire to burn better * Water ingress possible								
			Damaged containers are not reported to decision makers (failure in procedural information chain)	* Damaged container is loaded onto vessel * Potential release of goods from damaged container								
			Storage time is too long	* Potential ignition on board * Degradation/aging of cargo * Change in moisture content / temperature * Potential for self-heating due to degradation								
			Reefer containers: loss of power, electrical failure, or damage to refrigeration unit at the terminal	* Damaged goods * For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible * In the case of electrical faults, e.g. short-circuits, ignition may occur								
			Concealed goods missed during inspection	* Non-compliant goods shipped * Potential for release or self-ignition during transport		D, U						
			No or very limited inspection	* Some shippers more inclined to take a risk and ship undeclared or misdeclared * Wrong message to shippers regarding enforcement of the regulations * Non-compliant goods shipped * Potential for release or self-ignition during transport								
			Inspection not targeted	* Many inspections pass * If inspection resources are limited it is more likely that non-compliant CTUs will not be inspected * Non-compliant goods shipped * Potential for release or self-ignition during transport							Communication channel between parties carrying out screening and the regulatory body doing the screening	
			Inspections only target containers where there are declared DG	* Less responsible shippers may decide to not declare dangerous goods * Undeclared dangerous goods may not be detected and are loaded onboard * Vessel has insufficient information about the cargo and specific handling requirements * Goods potentially not handled or stowed in manner compliant with the IMDG Code * Self ignition possible if temperatures and ventilation are not appropriate for the goods * If ignition occurs, crew have insufficient information for containment and firefighting								

Annex A  
CAR-GDSAFE



Method of prevention	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undecared cargo	Above or below deck?	Additional locations	CNS risk location	Before or after 2016?	Potential Safety Measures	Comments
			Inspection ineffective (i.e. inspections take place but not all of the IMDG code violations are discovered)	<ul style="list-style-type: none"><li>* Non-compliant containers loaded to ship</li><li>* Potential release if packaging is non-compliant</li><li>* Potential self-ignition if undeclared or misdeclared self-igniting goods are stored in inappropriate locations</li><li>* Undeclared dangerous goods may not be detected and are loaded onboard</li><li>* Vessel has insufficient information about the cargo and specific handling requirements</li><li>* Goods potentially not handled or stowed in manner compliant with the IMDG Code</li><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods</li><li>* If ignition occurs, crew have insufficient information for containment and firefighting</li></ul>							Developed common protocol and reporting tools; experienced surveyors to provide instruction to improve quality of inspections	Inspectors should be aware of fire risks and allowed to act upon them - even if it is not a compliance issue (although in most cases it should be?)
			Mechanical damage not identified or ignored	<ul style="list-style-type: none"><li>* Mechanical stress to goods such as batteries may cause self ignition later on due to leakages or shorts</li></ul>								
			Container is difficult to access at the site	<ul style="list-style-type: none"><li>* In the event of ignition, increased air flow into container will allow fire to burn better</li><li>* Water ingress</li><li>* Inspection is not carried out</li><li>* Non compliant containers are loaded</li><li>* Potential release if packaging is non-compliant</li><li>* Potential self-ignition if undeclared or misdeclared self-igniting goods are stored in inappropriate locations</li></ul>								There is an IMO circular instructing all nations under the UN to perform DG container inspections and report same to IMO; however, less than 10 nations report. Some nations have dedicated inspection schemes, some nations are reactive and inspect only on the basis of screening, and some nations also inspect randomly (e.g. NCB in the US carried out a random inspection program).
			Non-standard inspections due to different practices by different authorities in different nations	<ul style="list-style-type: none"><li>* Less responsible shippers may take risks in certain areas of the world and ship non-compliant goods</li></ul>								
			Inspection activity may break or destroy packaging	<ul style="list-style-type: none"><li>* Leakage</li><li>* Potential ignition</li></ul>								
			Fumigated containers are not opened for inspection due to difficulties/risk	<ul style="list-style-type: none"><li>* Non-compliant goods may be present in fumigated containers</li><li>* Self ignition is possible if conditions (e.g. exposure to heat, ventilation) are not appropriate for the goods</li></ul>								
Stowage planning	<ul style="list-style-type: none"><li>* Stowage plan ensures optimum positions from a safety and logistics perspective and can be efficiently implemented</li><li>* Stowage is according to regulations: IMDG Code and ship's Document of Compliance (DoC)</li><li>* Dangerous goods stowage also in accordance with the Risk Based Stowage of Dangerous Goods on Containerships (CNS)</li><li>* Plan complies with carrier's in-house stowage rules</li><li>* Stowage plan is well communicated in sufficient time</li></ul>	<ul style="list-style-type: none"><li>* Tools, systems, and resources available to the operator, including AI and risk mapping</li><li>* Booking changes (although there is a cut-off for acceptance)</li><li>* Time pressure</li><li>* Availability of input data, including level of knowledge of goods</li><li>* Correctness of declaration (misdeclared or undeclared)</li><li>* Priorities of operator (economy, risk, etc.) may give different outputs from the planning process</li></ul>	Mistakes in planning due to lack of time	<ul style="list-style-type: none"><li>* Possible incorrect stowage that is not compliant with the IMDG Code</li><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods</li></ul>		1,2,3,4	D, U				Stowage software planning with comprehensive DG, special cargo functions	Risk Based Stowage of Dangerous Goods on Containerships (CNS) is not mandatory but is supported by the IMO and EU for risk reduction - aimed at consequence reduction rather than prevention. Risk-based Stowage assumes all DG is declared.
			Human error when developing the stowage plan	<ul style="list-style-type: none"><li>* Possible incorrect stowage that is not compliant with the IMDG Code</li><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods</li></ul>								
			Technical error with stowage planning	<ul style="list-style-type: none"><li>* Possible incorrect stowage that is not compliant with the IMDG Code</li><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods</li></ul>								
			Planning done according to logistics (business case) requirements and safety precautions are lacking	<ul style="list-style-type: none"><li>* Possible incorrect stowage that is not compliant with the IMDG Code</li><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods</li></ul>							Stowage planning according to the "Risk-based Stowage of Dangerous Good on Containerships" (developed by CNS)	During the Technical Expert Group meeting it was confirmed by operators that risk-based stowage is directed towards reducing consequences in the event of a fire. They aren't considered as a measure that could prevent ignition. In some cases the risk-based stowage may make it more difficult to monitor the cargo for detection. It is more difficult to apply risk based stowage on smaller vessels.
Physical stowage/ loading	<ul style="list-style-type: none"><li>* Stowage carried out according to the plan (including ensuring terminal complies with carrier's requirements in addition to IMDG such as risk-based stowage of dangerous goods)</li><li>* No physical damages occur during the operation</li><li>* Done in a timely manner</li><li>* Stowage of dangerous cargo between two hatches on first tiers on deck should be avoided, due to independent movement between hatches</li><li>* Acts as another check of goods and containers – observance by stevedores and crew while loading</li><li>* Done in a safe manner for crew and shore personnel</li><li>* Done according to lashing manual, using well-functioning lashes and corner locks</li></ul>	<ul style="list-style-type: none"><li>* Type and condition of equipment used</li><li>* Type of containers loaded</li><li>* Working conditions (weather, lighting, etc.)</li><li>* Time schedule of vessel (time pressure)</li><li>* Training and skill level of workers</li><li>* Stress of workers</li><li>* Information flow regarding observations (damage, smoke etc.) from personnel to decision makers</li><li>* Observational skills of workers</li></ul>	Water ingress to the container during loading operation	<ul style="list-style-type: none"><li>* Damage to goods, potential safety issue for goods that react with water</li></ul>		1,2,3,4	D, U				Increased control by ship operators and stevedores during loading and additional checks that positions agree with stowage plan	
			Containers stowed in the wrong location	<ul style="list-style-type: none"><li>* Self ignition possible if temperatures and ventilation are not appropriate for the goods (i.e. container with heat sensitive goods stored on outer row/top tier)</li><li>* Segregation according to IMDG may not be achieved which could result in reaction in the event of release</li><li>* Difficulty / delay in identification of contents in the event of an accident due to mismatch with stowage plan available to the crew</li><li>* Accessibility issues when it comes to firefighting</li></ul>								
			Container damaged during loading operations	<ul style="list-style-type: none"><li>* Mechanical stress to goods and packaging</li><li>* Risk of leakage / damage to cargo such as batteries</li><li>* Possible ignition</li><li>* In the event of ignition, increased air flow into container allowing fire to burn better</li><li>* Water ingress</li></ul>								
			Heavier containers are incorrectly loaded onto lighter ones due to incorrect weights or stowed in the wrong place	<ul style="list-style-type: none"><li>* Potential collapse or damage to lower container</li><li>* Mechanical stress to goods and packaging</li><li>* Water ingress</li><li>* Risk of leakage/release of goods from the packaging</li><li>* Possible ignition</li><li>* In the event of fire, increased air flow into damaged containers allowing fire to burn better</li></ul>								
			Spillage of chemical/liquid from an external source during lifting operations	<ul style="list-style-type: none"><li>* Chemical reaction with goods if the packaging is breached</li></ul>								
			Reefer containers: Damage to cooling equipment during loading operation	<ul style="list-style-type: none"><li>* Damaged goods</li><li>* For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible</li><li>* Possible risk of increased electrical fire in equipment, depending on type of damage</li></ul>								
			Damaged container is loaded (not noticed, reported, or acted upon)	<ul style="list-style-type: none"><li>* Water ingress</li><li>* Risk of leakage from the container if the damage includes breach of packaging</li><li>* Potential ignition</li><li>* In the event of a fire, increased air flow into container allowing fire to burn better</li></ul>								
			Dangerous cargo is stowed between two hatches on first tiers on deck	<ul style="list-style-type: none"><li>* Independent movement between hatches could lead to container damage and possible ignition</li></ul>								
			Lightning strike during loading operations	<ul style="list-style-type: none"><li>* High electrical discharge could cause ignition of goods</li></ul>								
Conditions on deck	<ul style="list-style-type: none"><li>* Appropriate to maintain the quality of the cargo (temperature, motions, ventilation, no ignition sources for sensitive goods etc.)</li><li>* Cargo can be monitored / overview is possible</li><li>* Lashing is maintained by crew</li><li>* Reefer conditions are monitored (also remotely)</li></ul>	<ul style="list-style-type: none"><li>* Weather (temperature, sun heat, air humidity, rain, etc.)</li><li>* Sea conditions, waves</li><li>* Fire patrol routines</li><li>* Size of vessel</li><li>* Number of Crew</li></ul>	Water ingress	<ul style="list-style-type: none"><li>* Damage to goods, potential safety issue for goods that react with water</li><li>* Degradation/aging of cargo</li><li>* Change in moisture content / temperature</li><li>* Potential for self-heating due to degradation</li></ul>		1,2,3,4	D, U		A			
			Longer voyage than expected - cargo stored too long									

Method of prevention	Desired function	Affecting conditions	Failure mode	Effect	Ship type	Declared/undecared cargo	Above or below deck?	Additional locations	CINIS risk location	Before or after 2016?	Potential Safety Measures	Comments
	<ul style="list-style-type: none"><li>* Hot works are done with consideration to nearby cargo and hazardous areas are respected</li><li>* Ignition sources (smoking, sparking tools) are excluded from areas with hazardous cargo</li><li>* Accessibility of containers is possible so that crew may intervene where necessary</li></ul>	<ul style="list-style-type: none"><li>* Crew's ability to be observant of safety/incident indicators while doing daily tasks (work load and training)</li><li>* Crew's ability to convey observations (retention, priorities) and the overall quality of the information flow</li><li>* Dichotomy between observations made by crew and actions taken by officers</li><li>* Accessibility during voyage for inspection</li><li>* Time/resources available to do things "right"/safe</li><li>* Electrical discharge/conduction</li><li>* Discharges from onboard equipment (e.g. exhaust pipes, etc.)</li><li>* Discrepancy between "work as done" and "work as imagined"</li><li>* Procedures for hot works (and crew's ability to follow them)</li></ul>	High external temperatures/humidity	<ul style="list-style-type: none"><li>* Initiation of self heating processes and/or thermal runaway.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This could potentially pick up containers that are heating to dangerous levels.	
			Lightning strike	<ul style="list-style-type: none"><li>* High electrical discharge causing ignition of goods.</li></ul>								
			Lashing failure	<ul style="list-style-type: none"><li>* Sparks from excessive friction</li><li>* Mechanical damage and possible release of cargo</li><li>* Possible ignition if there are vapours or cargo leakage and sparks from friction</li></ul>								
			Hot work not properly carried out	<ul style="list-style-type: none"><li>* Sparks entering containers and ignition of goods within</li></ul>								There is previous evidence that this can occur.
			Excessive cargo shifting due to extreme heavy weather	<ul style="list-style-type: none"><li>* Sparks from excessive friction</li><li>* Sparks entering containers and ignition of goods within</li><li>* Mechanical damage and possible release of cargo</li><li>* Possible ignition if there are vapours or cargo leakage and sparks from friction</li></ul>								
			Mechanical failure of reefer equipment	<ul style="list-style-type: none"><li>* Damaged goods</li><li>* For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This should pick up failure of reefer containers known to be carrying dangerous goods.	
			Loss of power supply to reefer containers	<ul style="list-style-type: none"><li>* Damaged goods</li><li>* For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This should pick up failure of reefer containers known to be carrying dangerous goods.	
			External heat source from equipment, exhaust pipes, etc. exceeds acceptable levels	<ul style="list-style-type: none"><li>* Excessive temperature</li><li>* Self heating initiated</li><li>* Possible ignition</li></ul>								
			Conditions onboard (time, temperature, etc.) exceed the tolerance of self-heating substances, where standard testing is inadequate to detect potential self-ignitors for sea voyages lasting more than 24 hours	<ul style="list-style-type: none"><li>* Self-ignition</li></ul>								
			Ignition sources such as smoking or non Ex classed equipment are present in close proximity to flammable goods	<ul style="list-style-type: none"><li>* Ignition of cargo</li></ul>								Electrical fires in reefer containers were stated to occur, but noted to not normally spread due to lack of nearby combustible material. This was also considered the case for any electrical equipment in the hold, which was stated to be low risk. IUMI concurred with this. "Hot work" was considered to be a potential ignition source but is carried out according to procedures and is assessed from a risk perspective before proceeding.
Conditions in cargo hold	<ul style="list-style-type: none"><li>* Appropriate to maintain the quality of the cargo (temperature, motions, ventilation, no ignition sources for sensitive goods etc.)</li><li>* Possibility to overview/monitor the cargo</li><li>* Lashing is maintained by crew</li><li>* Reefer condition is monitored</li><li>* Hot works are done with consideration to nearby cargo and hazardous areas are respected</li><li>* Ignition sources (smoking, sparking tools) are excluded from areas with hazardous cargo</li><li>* Accessibility of containers where relevant so that crew may intervene where possible</li></ul>	<ul style="list-style-type: none"><li>* Weather (temperature, air humidity, rain, etc.)</li><li>* Sea conditions, waves</li><li>* Temperature in the hold</li><li>* Fire patrol routines</li><li>* Size of vessel</li><li>* Number of crew</li><li>* Crew's ability to be observant of safety/incident indicators while doing daily tasks (work load and training)</li><li>* Crew's ability to convey observations (retention, priorities) and the overall quality of the information flow (deck crew and bridge)</li><li>* Dichotomy between observations made by crew and actions taken by officers</li><li>* Accessibility during voyage for inspection</li><li>* Time/resources available to do things "right"/safe</li><li>* Electrical discharge/conduction</li><li>* Discharges from onboard equipment (e.g. exhaust pipes, etc.)</li><li>* Container conditions - cases where product has escaped and is changing the cargo hold conditions (moisture, vapour)</li><li>* Discrepancy between "work as done" and "work as imagined"</li><li>* Procedures for hot works (and crew's ability to follow them)</li></ul>	Water ingress	<ul style="list-style-type: none"><li>* Damage to goods, potential safety issue for goods that react with water</li></ul>	1,2,3,4	D, U		B				
			Detection of hold conditions fails	<ul style="list-style-type: none"><li>* Conditions exceed expected range (e.g. temperature</li><li>* Self-ignition possible if self-heating goods are present</li></ul>								
			Hold temperatures/humidity above expected range	<ul style="list-style-type: none"><li>* Initiation of self heating processes and/or thermal runaway.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This could potentially pick up containers that are heating to dangerous levels.	
			Longer voyage than expected - cargo stored too long	<ul style="list-style-type: none"><li>* Degradation/ageing of cargo</li><li>* Change in moisture content / temperature</li><li>* Potential for self-heating due to degradation</li></ul>								
			Conditions onboard (time, temperature, etc.) exceed the tolerance of self-heating substances, where standard testing is inadequate to detect potential self-ignitors for sea voyages lasting more than 24 hours	<ul style="list-style-type: none"><li>* Self-ignition</li></ul>								
			Ventilation equipment failure	<ul style="list-style-type: none"><li>* Potential build-up of flammable vapours</li><li>* Possible ignition of vapours</li></ul>								
			External heat source from equipment, exhaust pipes, etc. exceeds acceptable levels	<ul style="list-style-type: none"><li>* Excessive temperature</li><li>* Possible ignition</li></ul>								
			Excessive heat from adjacent spaces such as engine room - acceptable temperature range exceeded	<ul style="list-style-type: none"><li>* Elevated temperatures, possible ignition</li></ul>								
			Mechanical failure of reefer equipment	<ul style="list-style-type: none"><li>* Damaged goods</li><li>* For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This should pick up failure of reefer containers known to be carrying dangerous goods.	
			Loss of power supply to reefer containers	<ul style="list-style-type: none"><li>* Damaged goods</li><li>* For dangerous goods needing refrigeration, temperature may rise to the point where self-ignition is possible.</li></ul>							Containers that are carrying known IMDG cargoes are inspected every 24 hours while onboard the ship as standard industry practice. The crew member is checking for leaks and also carrying a heat detection camera. This should pick up failure of reefer containers known to be carrying dangerous goods.	