MARIN

BETTER SHIPS, BLUE OCEANS

TopTier Joint Industry Project

Securing Container Safety at Sea

Proposal

16 March 2021

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1 BACKGROUND

In the last two years we have witnessed several major losses of containers from modern container ships with capacities in the 13,000 to 19,000 TEU range. In comparison with the past, the scale of these incidents is excessive. In several cases hundreds of containers and in one case more than 1,800 containers were lost overboard. The public awareness was raised not only by the scale of the incidents but also by the fact that many of these containers, some with dangerous cargoes, were lost in the ocean whereas others washed ashore and spilled their contents in nature reserves.

The number and scale of these accidents and their impact on the marine and coastal environments have fuelled wide concerns under public and governments on the safety of these Ultra Large Container Ships (ULCS). Authorities and industry are urged to evaluate and to improve current practices and regulations for design regarding container securing to avoid such accidents in future. The size of deep-sea container ships has increased exponentially over the past decades. The question is if the rules developed in the past are still fit for purpose, and if these large vessels can be operated within the assumed design limits. The TopTier Joint Industry Project (JIP) is initiated to address the relevant technical topics with an active participation of all stakeholders to obtain a common understanding, arrive at a safe and level playing field and to be ready for future innovations.


Intercontinental container transport has enabled the growth of worldwide trades and the global economy. Since the introduction of container vessels in the early sixties, the economy of scale has resulted in an exponential growth of the fleet both in vessel number and size. Shipping aims for a maximum efficiency of transport within the rules and boundaries defined by flag states and classification societies. Unsafe situations may occur if such rules and limits are not up to date, unclear or not respected.

Although the loss of containers overboard is not a new phenomenon, the recent incidents have drawn special attention of all involved parties. The incidents concerned ULCS's recently built by major shipyards according to class rules and operated by leading shipping companies. In the past, the damage on board was local and restricted to the loss of individual containers, one stack or a single bay. In the recent cases multiple bays of containers distributed over the length of the vessel have collapsed.

The questions that these accidents have raised in the industry are:

1. What were the conditions of vessel and weather? Were these conditions properly covered by the current design limits or defined as "off-design" conditions?

2. Was the vessel crew aware of the dangerous situation? Could the vessel be reasonably operated within safety boundaries?

3. What were the failure mechanisms? What are the commonalities? Have these been properly accounted for in the rules for container securing? Should they be accounted for explicitly? Are existing safety margins adequate?

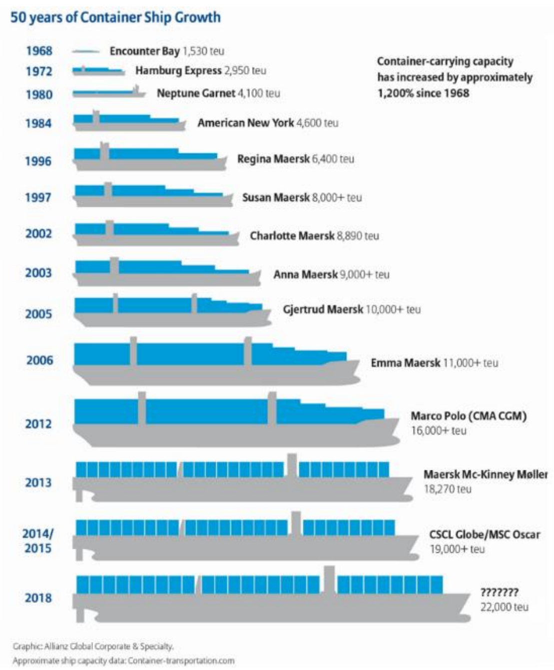
4. Were port/terminal procedures correctly followed with regard to container arrival, verified gross mass, adherence to stowage plans and cargo securing manuals?

5. Were the containers, stowage pattern and the lashing gear fit for purpose? Are new standards and/or limits needed?

The character and extent of recent damages indicate that the current design practice does not cover all relevant aspects of container securing for the newest classes of ultra large container ships. The design limits e.g. with respect to motions, hull girder dynamics, stack interaction and securing forces exhibited by these large vessels need to be reviewed. At the same time, it is recognised that the ship officers are lacking information to make them aware of potentially dangerous situations and to navigate the vessel in the safest possible way. For all these issues a better understanding of the underlying vessel behaviour, the container securing loading mechanisms, the hazards, and the operations is required.

The Lashing@Sea Joint Industry Project (MARIN, 2006-2009) investigated cargo security on container carriers, Ro-Ro vessels and heavy lift cargo vessels. The project was conducted in close co-operation with shipping operators, suppliers and supported by flag state administrations. For container vessels with a capacity of 6 to 9 kTEU, the project showed the importance of vessel motions, wave slamming, hull deformations, stack dynamics, correct container weight declaration and the integrity of cargo securing systems. Over the following decade several recommendations from the project were implemented in international regulations and industry practices. In the meantime the exponential growth of container vessels continued and today vessels with a capacity of 24 kTEU are in operation. Recent newbuilding orders confirm that this trend will continue in the coming years.

The increased carrying capacity has been achieved by additional length of the vessel but in particular by an increased width of the hull and even more by the increased number of containers carried on deck. A typical 24 kTEU vessel measures 400 m in length and 61 m in width, corresponding to almost twice the original Panamax width. Due to water depth restrictions the design draught has not increased proportionally. The dominant growth factor in carrying capacity has been the use of the space on deck. The 24 kTEU class of carriers, are stowing some 60 percent (14 kTEU) of the container capacity on deck subdivided in 24 bays, 24 rows and up to 12 tiers in height.



Each container is secured in a stack and coupled to the container below by twist locks. The lower tiers are further secured by the lashing bridges on deck. Lashing rods are applied on top of the lashing bridges until the bottom of the second or third tier above the lashing bridge. The upper tiers are thus only secured by twist locks.

The maximally optimised designs of modern-day stowing arrangements have stretched operational working loads of lashing rods, container racking, corner post compression and twist locks loads to their respective maximum allowable loads. Safety relies on accuracy of calculation models and validity of the safety factors on safe working loads. The design conditions only account for linear loads due to accelerations originating from first-order wave-induced vessel motions. Motions statistics used in the current design rules have been developed in a period that the vessels were modest in size, more conventionally shaped and were carrying fewer tiers on deck. For larger vessels these rules assume that all motions and thus acceleration levels decrease with vessel size. This assumption has allowed higher numbers of tiers on deck.

The present-day wide body ULCS's operated with a wide range of transverse stability (GM) and vast windage, feature specific motion characteristics in severe weather. Their structural flexibility can result in hull vibrations due to wave impacts. Moreover, rows of high container stacks can suffer from resonant dynamic behaviour including row interactions. All these effects contribute to the accelerations experienced by containers and thus to higher loads on containers and in lashing gear.

The largest vessels are operated on the Far East - Europe trades in relative mild weather conditions. Due to the new Panama locks, increased trades, and cascading effects in the fleet, many NPX-class vessels (14 kTEU) are now operated on Trans-Atlantic and Trans-Pacific routes. The wave conditions on these trades are known to be more severe than those on the Far East - Europe route.
The operation of these vessels and their cargo securing in severe weather require further attention. In the design approach it is assumed that the vessel will always be operated within "in-design" safe boundaries. Explicit "off-design" conditions are known to exist and are to be avoided by operational decisions. The sheer size of the vessels however has proven to pose a challenge for ship officers to develop a reliable 'look and feel' for conditions that are potentially dangerous. To operate these vessels in a safe manner, ship officers need to be aware of critical situations they may encounter. Additional on-board data and operational tools may assist them in their tasks. Otherwise the validity of "in-design" and "off-design" conditions, and the used safety factors need to be reviewed.

The passage over sea is only a single link in the chain of global container transport. Each container vessel is thus strongly dependent on activities on shore. The containers, owned by shipping lines and large fleet leasing companies, are loaded by clients to a Verified Gross Mass (VGM) and transported by trucks, trains and inland vessels to sea port terminals. Stowage plans are provided by planning agencies. Terminal operators take care of the pre-storage and the loading sequence on board. Stevedores fit the twist locks, provided by the vessel, to the containers and, once loaded, lash the container stacks by the lashing rods and turnbuckles. Due to tight schedules, changes in planning and late arrival of trucks, all involved parties are continuously challenged to maintain the quality of their work and to arrive at the stowage of the vessel as planned. For the safety of the vessel it is paramount that the data provided corresponds with the actual stowage on deck.

In the stowage of containers on deck, there is no redundancy; the collapse of a single container can lead to a major loss. Several investigations have indicated that the failure of containers and lashing gear could have been the root cause of the container loss. On board the vessel containers are subjected to extreme and cyclic- and thus fatiguing-loads. Additionally, during their operational life containers experience a variety of loadings and damages due to cargo, crane actions, handling but also corrosion. Corner posts can be dented, corner castings deteriorated. Lashing configurations have changed in time and are now more heavily loaded. Design standards for containers and lashing gear need to be reviewed and technology and infrastructure to ensure the integrity of containers and gear have to be introduced.

The present TopTier initiative is a follow-up of the Lashing@Sea JIP to address the safety concerns with respect to present-day and future deep sea container carriers. TopTier JIP will review the current practice and recent incidents, identify knowledge gaps, investigate the technical items, and arrive at reliable modelling of loads on containers lashing gear on board present-day and future ULCS's. It will address the improvements in design and operation that can be taken to mitigate the risks of container loss. In view of the urgency, measures that can be implemented on short-term as well as medium and long-term actions will be recommended. The project will be conducted in close co-operation between major stakeholders from both industry and authorities, aiming at a common understanding and contributing to a safe and level playing field.

2 OBJECTIVES

The primary objective of the TopTier Joint Industry Project is to restore fidelity in the safety of container transport with the present-day and future fleet of ULCS's and to provide the technical and common understanding that is needed to arrive at a level safe playing field. Safe container transport can only be achieved by the combination of reliable design of the cargo stowage, adequate stowage planning, utilizing containers and lashing gear that is fit for purpose and operating the vessel within certain safety boundaries. Therefore TopTier will address each of these areas and is aiming at improvements on the following subjects:

- Adequate Design cases
- Container securing load modelling and stowage calculation,
- Awareness of crews in limiting conditions
- Integrity of stowage planning, containers and lashing gear

The project will provide data on the actual motions and acceleration levels experienced on board ULCS's. The work will focus on finding the limiting conditions of what can be reasonably avoided by the crew and what can not be avoided. This will form the basis for an improvement of the design cases and rates used for lashing and stowage calculations.

Better insight in the governing mechanisms in loads on containers and their securing systems will be obtained from dedicated tests and computational analysis. Existing approaches and computational models for container securing loads and stowage calculations will be compared and analysed. A new non-linear model for container securing loads will be developed and used for optimum stowage calculations.

To improve safe navigation of these vessels, TopTier is aiming at increasing the awareness of ship officers and how they can be supported by on board data and practical tools to avoid 'off design' conditions. The JIP is also address ship-shore interfacing including the integrity of stowage planning, containers and lashing gear.

TopTier JIP will provide recommendations to avoid container loss. Both short term improvements on the operation of the existing fleet and medium term improvements in ship and equipment design and operation are foreseen. Implementation of these recommendations in the practice of all stake holders will be encouraged and for relevant subjects improvements of rules and regulations will be submitted to the relevant authorities and organisations.

TopTier addresses these objectives in close co-operation with a wide consortium of stakeholders and R&D institutes to ensure the required expertise, to arrive at a common understanding and to achieve leverage of acceptance and implementation of the recommendations by industry. Implementation in international rules and regulations is envisaged through co-operation with high level bodies such as IMO, WSC, ILO, ITF, IACS and ISO by submitting results and recommendations and monitoring follow-up actions.

3 APPROACH

The safe transportation of containers at sea starts with adequate design limits and rules which are observed during design, plan approval and construction. The container stowage relies on the lashing load calculation approach as well as on the integrity of the stowage planning. At the same time we should acknowledge the role of the operation and navigation of the vessel. Only by controlling the condition of the vessel (e.g. the level of transverse stability GM) and navigating the vessel within the safety boundaries and avoiding so-called “off-design” conditions, failures in cargo securing can be avoided. Finally, all equipment on deck; containers and lashing gear should be fit for purpose.

The TopTier JIP addresses the above areas by the following brief:

1. Review of current practice and the major container losses over the last three years to identify the root causes and rank the aspects that need to be addressed in this project.

2. Share existing data and knowledge to recommend measures that can be taken to mitigate the risks on short term,

3. Provide vessel motion and acceleration data to develop adequate design cases and –rates and to decide what should be ‘in design’,

4. Obtain a better technical understanding of vessel behaviour and the mechanisms in the dynamic loads on containers and their securing systems at sea. Compare existing methods for lashing and stowage calculations. Develop a computational model for container securing loads ,

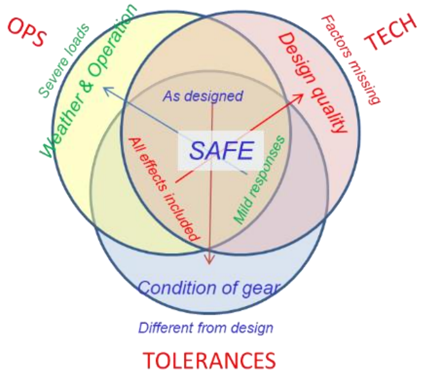
5. Improve the computer data and shore-ship processes to better represent the reality on deck,

6. Maximise awareness and ability of the crew to perform their operational role to navigate the vessel within safe boundaries,

7. Indicate measures for maintaining integrity of stowage plan, containers and lashing gear,

8. Summarise the results of the JIP and submit the recommendations to all stakeholders and to the relevant international organization for implementation in rules and regulations for design and operation of ULCS’s.

Based on the findings from these investigations and developments conclusions will be drawn and recommendations for design and operation will be stipulated. Recommendations on short term measures to mitigate risks will be reported at the end of step 2. A best practice for design as well as improvements in operations will be formulated during the project and proposed to the relevant organisations. Implementation of the results in rules and regulations will be actively supported.



4 SCOPE OF WORK

4.1 Task 1: Current practice, incidents, and recommendations

Task 1.1: Current practice

The starting point of this project will be a review of the current practice in design and operation of ULCS's with respect to container stowing and securing. Typical ULCS stowing arrangements and criteria will be considered including design load cases and backgrounds.
Interviews and questionnaires will be held with relevant parties such as designers, operators, ship officers, ship and terminal planners, terminal operators and stevedores to derive a better understanding of the current practice and the observations ashore and at sea.

The 'state of art' in terms of knowledge from previous studies will be described. Available experience, data and knowledge on the subject will be shared with and between participants. Data from previous R&D projects such as Lashing@Sea and investigations related to specific incidents will be reviewed. Permission from owners will be sought to use multiple year acceleration data recorded on medium sized container vessels. Such data sets will be compared against current design rates.

Task 1.2: Review of recent incidents

The major incidents with large container vessels over the past three years will be reviewed with a focus on the recent large-scale damages in the Pacific where hundreds of containers were lost overboard per incident. Potential failure mechanisms and root causes will be identified and documented. Further analysis of data may be required to compare those stacks that failed and those that did not. Commonalities in the incidents will be identified and related to the current practice.

One of the questions that need to be answered is about the conditions during these accidents. Were these conditions considered "off-design" in the current practice? Or are these conditions so difficult to anticipate that they cannot be avoided, and should they therefore be accounted for as "in-design" load cases? Some of these large-scale incidents have already been investigated in depth and available results and reports will be shared in the project.

Task 1.3: Short-term recommendations & Gap analysis

Based on the review of the current practice, the interviews and the analysis of recent incidents, and taking into consideration the available existing knowledge, short-term actions to mitigate the risk of container loss will be recommended. The focus of these short-term recommendations will be on the existing fleet and equipment.

For the medium-term and long-term improvements, a gap analysis will be conducted to identify the aspects that require further technical investigation and development work.
With these answers, the JIP objectives and tasks will be confirmed or adapted and ranked in priority.

4.2 Task 2: Technical investigation

This task is aimed at a better understanding and quantification of the relevant aspects of container securing which are presently not included in the procedures and practices.
A sound technical understanding of the governing mechanisms in the dynamic behaviour of containers on board and the resulting loads experienced by containers, twist locks and lashing systems will be obtained by dedicated investigations comprising studies, model testing and on-board measurements.

The aim is to understand, demonstrate and recommend how to deal with effects of extreme vessel motions, high levels of transverse ship stability (GM), hull girder flexibility, flexibility of containers and lashing gear components, high stack dynamics, row interactions, multi row resonance and non-linear cargo securing loads.

The final specification of this task is subject to the results of Task 1 but based on the subjects already identified above, the following subtasks have been outlined:

Task 2.1: On-board measurements

Containers are stacked higher on ULCS's because the design rules are based on the assumption that wave induced ship motions and corresponding accelerations of containers in general are lower compared to those of smaller vessels. The safety margin for extreme motions and accelerations have thus decreased with high stacked cargo configurations. Incidents become more likely when design conditions have lesser margin to operationally accepted conditions.

Common experience with operational motions and accelerations on ULCS vessels however is limited. Partly because ULCS with their large size, specific hull shapes and large windage, are a recent development in shipping, so experience is only just building up. Secondly, the variation in loading conditions and operational GM is huge compared to more classic designs so much larger variation in design limit states may be expected. And last but not least, accelerations by hull girder flexibility have become important and can trigger incidents even without excessive motions.

A measurement campaign is proposed to capture operational accelerations and motions on board ULCS's and correlate these to wave conditions, vessel dimensions and loading condition. The points learned from the most recent incidents will be taken into account while defining the measurement scope.

At this moment an extensive monitoring campaign on four ULCS's is anticipated with the dedicated instrumentation to capture the following items:

- Rigid body ship motions and accelerations along the hull,
- Accelerations due to hull girder flexibility resulting in whipping, springing and twisting deformations along the hull,

- Multi-stack container response (selected transits),
- Loading condition of the vessel (container stacking, draught, trim & GM),
- Speed and heading of the vessel,
- Wind and wave conditions encountered by the vessel.

To capture the differences in wave climate conditions, the monitoring campaign will comprise ULCS's on the Far East - Europe service and on the Trans-Pacific service. The campaign will run for two years. Statistics from measured and derived data will be derived on a regular basis and shared with all participants.

Task 2.2: Extreme ship motions

In the current practice, the level of accelerations used for lashing load is based on statistical and empirical ship motion data derived for conventional ships of moderate sizes. When applied on larger ships it is assumed that the motions and thus the acceleration levels decrease with the ship size. For heave and pitch motions this is a plausible assumption. Roll motions however have a resonant character and large roll amplitudes may occur when the wave periods coincide with the natural roll period of the vessel (synchronous roll). Accurate prediction of roll motion is complex due to the importance of the non-linear character and the viscous effects in damping.

The present day ULCS's feature relatively wide and shallow hulls. Due to large variations in container loads on deck and due to the limited volume of the ballast water tanks, these vessels are operated in a large range of transverse stability (GM). Roll resonance under high GM values result in high transverse acceleration levels and low GM values in large roll amplitudes. In the low GM condition, these vessels may experience non-linear behaviour such as parametric roll in head waves or following waves. In severe following and stern quartering waves temporary loss of stability can be experienced. Both cases can yield very large roll angles in a sudden and unexpected manner.

Due to the high container stacks and taking into account the wind profile, the wind gusts and their spatial distribution, it is clear that the wind loads experienced by ULCS's are extreme compared to other ships. Large following and stern quartering waves (broaching conditions) may lead to rocking motions with extreme roll angles and large wind loads can contribute to the loss of steering control in these conditions.

In the present task the seakeeping of ULCS's will be investigated to establish the extreme behaviour and the motion envelopes. Voyage simulations with GULLIVER will be used as a core tool to determine the motion envelopes. At this stage such simulations are foreseen for an NPX container vessel at a range of operational profiles (loading/stabilities) on two shipping routes (Far East - Europe and Trans-Pacific). The voyage simulation tool will be fine-tuned using model test results.

Model tests will be conducted focussing on dynamic stability, parametric roll (low speed) and pure loss of stability (higher speeds) in relevant wave headings. Forced roll tests will be conducted to provide accurate roll damping for the numerical simulations.

Time-domain simulations with FREDYN/PANSHIP will be conducted to investigate non-linear ship motions due to loss of stability for large numbers of wave realisations covering relevant sea states derived in Task 1. The probability of exceeding certain roll angles will be derived from these simulations.

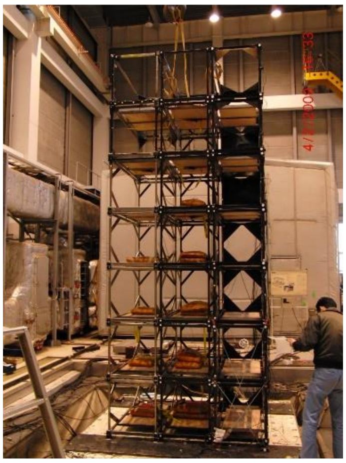
The probability of occurrence of both operational motions and extreme vessel behaviour will be derived. Based on the results, design motion envelope statistics for these vessels will be derived.

<u>Task 2.3: Container stack dynamics</u>

High container stacks on board ships feature their own dynamic behaviour. This behaviour can lead to interactions between rows. Stack dynamics can be excited by the wave induced ship motions, by hull vibrations and by direct loading on the stacks e.g. by wind gusts and green water. The weight distribution within the stack, flexibility of the containers, their supporting structures, and the lashing gear are important parameters in this stack behaviour.

Row interaction and multi-row resonance were demonstrated at model scale on an earth quake simulator in Japan during the Lashing@Sea project in 2009. At that time, multi stack dynamics was identified as the most likely explanation for full bay container incidents. It has later also been observed on board actual ULCS vessels causing large damages. This mechanism has remained an "off-design" condition in present practice. However, no means are available to anticipate, and thus avoid, its occurrence. The fact that it appears only seldom suggests that it may be related to a probability combination of unfavourable factors that, if known, could be avoided.

Following the earlier tests on the earth quake simulator, in the present scope a comprehensive test program on the same simulator will be conducted. The purpose of these tests is to develop and verify a calculation model for multi-row response and to quantify the contribution of stack dynamics and row resonance to lashing and container loads. This model can also be used to recognise and thus avoid stowage configurations that would be sensitive to resonant response.



Task 2.4: Benchmark container stowage calculation

Traditionally the flag state approves the Cargo Securing Manual (CSM) which stipulates the stowage and lashing of cargo for each individual vessel. Over the last decade class societies have developed rules for the lashing and stowage of containers and are offering class notations on the subject. These rules include weather conditions, navigation, ship motions and accelerations, lashing arrangements and stack response. Different approaches and computational processes can be followed and for practical reasons use is made of empirical data, design rates, assumptions and safety factors. Several classes allow for weather dependent lashing; reduced lashing may be applied when the weather forecasted on the route is within certain limits. Computational tools are offered and some of these are included in operational stowage planning tools and loading computers on board. These computational tools are not always transparent and may contain elements beyond the actual rules. Variations in outcome have been observed.

Therefore, in the TopTier JIP a benchmark study on container stowage calculation will be conducted with the participation of class societies. For this purpose several cases (ships, routes, conditions) will be specified. It is acknowledged that each calculation procedure is a process chain with individual links containing specific data, assumptions and computational models. Under-prediction in one link may be balanced by over-prediction in a following link. For a thorough analysis it is important to look into both the results of the complete chain as well as those of individual links. This requires a careful preparation of the benchmark task. For example, the calculations can be conducted for a generic situation, for a specific route, sea condition, or even for specified accelerations. Results from Task 1, 2.1, 2.2 and 2.3 will assist to set the proper benchmark cases.

The benchmark will be conducted by the participating class societies and possible other providers of such stowage calculations. The results of the calculations will be mutually compared and differences will be analysed. In this task use will be made of the results from the previous tasks i.e. the acceleration levels found, the contributions from stack dynamics and the new design rates proposed.
Results and recommendation on improvements of lashing and stowage calculations will be reported.

4.3 Task 3: Development

With the understanding and quantification of the relevant aspects for container securing from Task 2, we will be able to develop mitigation measures and tools. In the present scope the following is subtasks are foreseen:

1. Improvement of design rates
2. Improvement of the securing loads calculation model
3. Development of guidelines for stack optimisation
4. Development of prototype tools to raise the situational awareness of the crew
5. Identification of the technology and infrastructure required to assess the condition of container corner posts, castings and lashing equipment

The scope of each of the subtasks is described in more detail in the following sections.

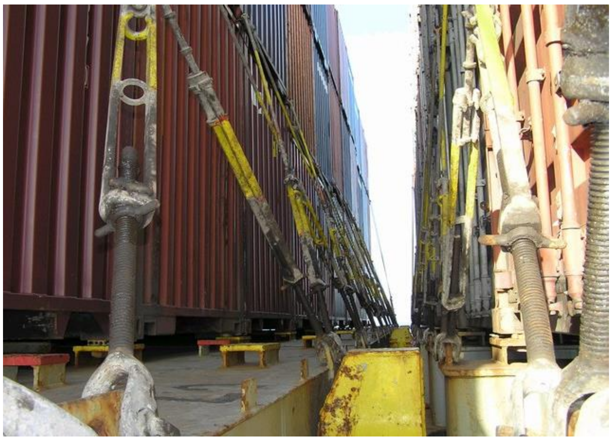
<u>Task 3.1: Design rates</u>

Taking into account the reviewed incidents and based on the results from the seakeeping analysis of the ULCS's in Task 2.2, probability envelopes and realistic design rates for container securing calculations will be developed and compared to those in the current practice.

- Representative extreme value distributions for motion and flexible hull girder related accelerations.
- Load distributions and realistic extreme value distributions for lashing loads and container loads.
- Discuss realistic design probability levels of exceedance from transport point of view, versus public safety point of view.
- Determine probabilities for "in-design" and "off-design" load cases. Review required safety factors to account for "off-design" conditions.

<u>Task 3.2: Securing loads model</u>

The results of Task 2 will be evaluated and used to develop a model of the non-linear container racking and compression loads and the tensions in the lashing gear taking into account the governing parameters. Results of the new approach will be compared to those of the current practice for a range of vessel sizes and conditions.



Task 3.3: Stack and lashing optimisation

Taking into account the insights and results of the present study and utilising the new model for securing loads, the container stack heights and lashing configuration can be tailored to avoid extreme compression and overloading of lashing gear and to minimise the probability of resonant row behaviour. In this task, guidelines for stack and lashing optimisations will be developed based on the results from the previous tasks. A best practice will be formulated.

Task 3.4: On-board tools and data

The maximum allowable motions change per loading condition. Clear indications on limits are usually not available for ship officers, neither are objective indicators for the actual occurring loads easily accessible.

A high level of situational awareness is critical to understand potential risks and make the best decision to mitigate these. An information or advisory system can be a valuable tool to create and maintain situational awareness for an operator. This task concerns the development of demonstrator tools for use on board.

The following levels of situational awareness may be distinguished (Endsley, 1995):

- Perception: inform about the present state of the vessel motions and loading
- Comprehension: compare the state to the limits
- Projection of Future Status: give insight developments and effect of actions

In this project we will focus on providing more complete information and provide an interpretation of that information to improve both the perception and comprehension. The following developments are foreseen:

- *Securing load indicator based on measured response and the cargo securing load calculation*: Provide feedback to ship crews on the design limit value that was considered in the loading computer calculations, and the ratio to that limit of the present loads as calculated from measurements and best practice securing calculations.
- *Threat indicator for extreme motions based on real-time ship motions and actual ship condition*: Provide a threat indicator signalling increased risk of occurrence of an extreme event that needs attention to be avoided in order not to exceed the design boundary.

Additional developments may be undertaken to reduce threat levels by adjusting the vessel condition (e.g. ballasting) or optimising the navigation (i.e. weather routing, course and speed) to avoid extreme ship motions and cargo securing loads.

The tools will utilise data available on board from the navigation, loading and lashing computers. Furthermore dedicated monitoring equipment such as for vessel motions and accelerations may be used.

The provided demonstrators will aid ship officers in their decision-making while respecting the expertise, overall situational awareness and responsibility of the crew. Critical to adding valuable and meaningful additions to their operations, the future users are foreseen to be involved in te development of the tools.

<u>Task 3.5: Shore-ship interface</u>

As each container is provided to the vessel from the quayside, activities onshore play an important role in the safety of the vessel as well as the safe working conditions for terminal operators and stevedores. Three subjects will be addressed in this task: the quality of the stowage planning, the integrity of the container, and the integrity of the lashing gear.

It is paramount that the data provided by the stowage planner and used in the vessel’s loading computer corresponds to the actual situation on deck. This implicates that the position of each individual container is according to the plan, and that its VGM is reliable. Deviations have to be accounted for in the data processing. From Task 1 information will be derived on the actual practice and together with terminal operators and stevedores recommendations will be drawn up on how to improve from the current situation.

Essential for the safety of high stack container transport is not only an accurate understanding of the loads and a safe operation of the vessel, but also the strength of each individual container and each lashing gear component on board.

The lashing gear (i.e. the twist locks, lashing rods and turnbuckles) is equipment that belongs to the vessel but is normally handled by stevedores who are working within severe time constraints. In the present task the hazards for lashing equipment will be identified and a best practice for assuring the condition of the lashing equipment by means of inspection, maintenance and replacement will be stipulated.

Containers have their own logistics and follow their individual routing over the globe. Container corner postings have to resist the extreme compression loads of the stack. The corner castings have to accommodate the peak loads of the twist locks and the lashing rods. Wear and tear due to operations, rough handling as well as the aggressive marine climate, gradually will deteriorate the condition of the postings and the corner castings. It is crucial for the safety at sea, that the structural integrity of each and every container is ensured prior to loading it on board.

In this task the technology and infrastructure required to assess and track the structural condition of containers will be identified. It is acknowledged that this task involves port and terminal operators as well as container fleet owners.

4.4 Task 4: Evaluation and implementation

In this task the results of the JIP will be summarised and evaluated against the current practice. Final conclusions and recommendations will be drawn up.

Improvement of the relevant design and operation rules and regulations will be initiated by sharing the results to authorities and relevant international organisations such as IACS, ILO and IMO and ISO for a top-down implementation, ensuring a safe and level playing field both at sea and onshore.

It is acknowledged that this task will surpass the duration of the JIP. Experience from the Lashing@Sea JIP learns that it may take several years after completion of the JIP to get results implemented in international regulations.

4.5 Task 5: Management

This task concerns the overall organisation of the TopTier Joint Industry Project which will be conducted by MARIN. This task includes the contacts with all participating organisations, JIP administration, finance, subcontracting of tasks, organisation of the work, Steering Group meetings, JIP website and sharing of results.

5 DELIVERABLES

Task 1: Report describing current practice
Report Review of the recent incidents
Report Recommendations for short-term improvements & gap analysis

Task 2: Reports with statistical data of on board measurement campaigns
Report ships motions
Report container stack dynamics
Calculation model container stack dynamics and row resonance
Report Benchmark container stow calculation

Task 3: Report with design rates
Report developed container load model
Report on development of operational demonstrator tools
Demonstrator tool for use on board
Report on stack and lashing optimization
Report on ship-shore interface

Task 4: Report with overall evaluation, conclusions and recommendations
Progress reports on implementation

Task 5: JIP Progress reports

6 ORGANISATION

This project will be conducted as a Joint Industry Project managed by a MARIN. The funding of the project will be from both public and private sources. Relevant stakeholders from industry, authorities and flag state administrations are invited to participate in this project.

Active participation from the following organisations is envisaged:

- Ship Operators
- National Authorities (Flag states and Coastal states)
- Classification Societies
- Port Authorities
- Terminal Operators
- P&I Clubs & Insurance
- Lashing gear manufacturers
- Workers representatives, ILO
- On board system developers
- Independent R&D institutes

The actual work will be conducted by a consortium led by MARIN and consisting of participating companies with the relevant expertise. An active role for all major Class societies is foreseen.
Once the tasks are specified in detail, MARIN will issue a fixed price Work Order to the partner selected to conduct the task.

Organisations confirm their participation by signing the TopTier JIP Participation Agreement with MARIN and will be represented in the JIP Steering Group. Meetings of the Steering Group with all participating organisations will be held every 6 months preferably in conjunction with the Vessel Operator Forum (www.vesseloperatorforum.com).

Data and results will be treated confidentially in the project and will only be shared outside the project after approval of the JIP Steering Group.

7 TIME SCHEDULE

The TopTier JIP will run over a period of three years.

An outline proposal and draft Participation Agreement will be circulated in February 2021. The same month online meetings with interested parties will be held to discuss the objectives and scope of work. The full proposal and Participation Agreement will be circulated in March 2021. Participating organisations are invited to sign the Participation Agreement in April 2021. The formal start of the TopTier JIP is foreseen on May 1, 2021. A tentative schedule of all tasks is provided in the table below.

	Year	2021								2022												2023												2024				
	Month	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	**Review**																																					
1.1	Current Practice																																					
1.2	Incidents																																					
1.3	Recommendations																																					
2	**Technical Investigation**																																					
2.1	On board measurements																																					
2.2	Motions																																					
2.3	Stack dynamics																																					
2.4	Benchmark stowage																																					
3	**Development**																																					
3.1	Design rates																																					
3.2	Container load model																																					
3.3	Stack optimization																																					
3.4	Operational support																																					
3.5	Ship-Shore interface																																					
4	**Evaluation & Implementation**																																					
	Milestone Meetings																																					

8 FINANCE

Based on the outline proposal, the budget estimates are presented in the table below. At the end of Work package 1, a more detailed specification of the required tasks 2 and 3 can be made. Re-allocation of budgets may be decided by the Project Steering Group at that time.

Budget Estimate TopTier JIP			Cost [kEuro]	
WP	**Task**	**Description**	**Task**	**WP**
1		**Current Practice, Incidents & Recommendations**		
	1.1	Current Practice	20	
	1.2	Recent incidents	80	
	1.3	Recommendations	25	
				125
2		**Technical Investigation**		
	2.1	On board measurement campaign		
		Instrumentation & monitoring	530	
		Analysis and reporting	190	
	2.2	Ship motions	440	
	2.3	High tier stack dynamics	340	
	2.4	Benchmark container stowage	240	
				1740
3		**Development**		
	3.1	Design rates	80	
	3.2	Container securing load model	240	
	3.3	Stack and lashing optimization	40	
	3.4	Operational support tools	190	
	3.5	Ship-Shore Interface	110	
				660
4		**Evaluation & Implementation**	120	**120**
5		**Contingency**	180	**180**
6		**JIP Management**	175	**175**
		Total JIP		**3,000**

Based on the interest of the involved parties, the expected financial contributions of the participating organisations are listed in the table below.

TopTier JIP Contributions			
Participant	**#**	**Fee [kEuro]**	**Total [kEuro]**
National Authorities			**1,500**
Ship operators	**6**	**90**	**540**
Class Societies, Insurance Companies	**5**	**60**	**300**
Others	**6**	**30**	**180**
Marin			**480**
Total			**3,000**

The TopTier JIP participation fees are thus as follows:

Ship Operators	30,000.- Euro / year (90 kEuro total)
Class Societies, Insurance	20,000.- Euro / year (60 kEuro total)
Others	10,000.- Euro / year (30 kEuro total)

The annual fee will be invoiced in November 2021, November 2022 and upon completion of the JIP in May 2024. Terms of payment: within 90 days after receipt of invoice.

The participation fees are fixed lump sum contributions. If necessary the scope of work can be adjusted by the Participant Steering Group to meet the available budget.

9 CONTACT

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