Specification

LaseCPV Container Profiling Vessel

- **Collision Prevention between load and stack**
- **Spreader tracking**
- **Soft landing**

Version 1.2

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1 Scope

This document describes the product LaseCPV Container Profiling Vessel as a collision prevention system between the load (Spreader with or without container) and the container stack on the vessel.

1.1 Used symbols

The book symbol shows, that in the text is referred to additional documents or documentations of the respective manufacturer of the component

ATTENTION! - This symbol with the yellow triangle indicates dangers. Text passages marked with this symbol should be read very carefully and to be followed to avoid accidents!

The “i” symbol indicates text passages with special notes/information. This text passages should be read carefully.

1.2 Abbreviations

API	Application programming interface
ARMG	Automatic Rail Mounted Gantry Crane
ACRMG	Automatic Cantilever Rail Mounted Gantry Crane
CAN	Controller Area Network (standardized Field bus system with communications orientated data exchange protocol)
CCS	Crane Control System
CS	Control System
Dll	Dynamic link library
IPC	Industrial Personal Computer
LCU	LASE Control Unit
LMS	2D Laser Measurement System
LSP	LASE Servo platform
PLC	Programmable Logic Controller
RTG	Rubber Tyred Gantry Crane
STS	STS Crane
TCP/IP	Transmission Control Protocol / Internet Protocol – network protocol
2D	2 dimensional
3D	3 dimensional
3D laser scanner	LASE Servo platform (LSP + 2D laser scanner as complete unit)
2D laser scanner	Individual laser scanner without swivel platform

2 Requirement

Ports having identified that there is a need to improve the safety around STS Crane operation. There is a risk of a spreader/load colliding with containers in the stack / bay, resulting in containers being knocked over and falling down in the vessel or in worst case onto the quay. This is resulting in hazardous situations that could possibly lead to severe incidents involving people working in and around the crane area.

2.1 General conditions

For a reliable and accurate working measurement, system following general conditions is expected:

- **Temperature range**: -20°C to +50°C
- **Distance between 2D Scanner ➔ LCU** max. 30m
- **Siemens PLC with decentralize periphery in the driver cabin**

3 Solution

The LASE solution is a measurement system working with two 2D-Laser scanners mounted under the trolley and a software application which collects the scan data, doing all needed calculation and sending the results to the machine PLC.

The laser scanners are looking downwards with their scan planes across a bay. When the trolley drives over the vessel, the measurement system generates a 2D-profile of the stacks in the bay. Additional the spreader is in the view of the scanners. By comparing the actual position of the load (Spreader with or without container) with the profile of the stacks collision prevention can be done.

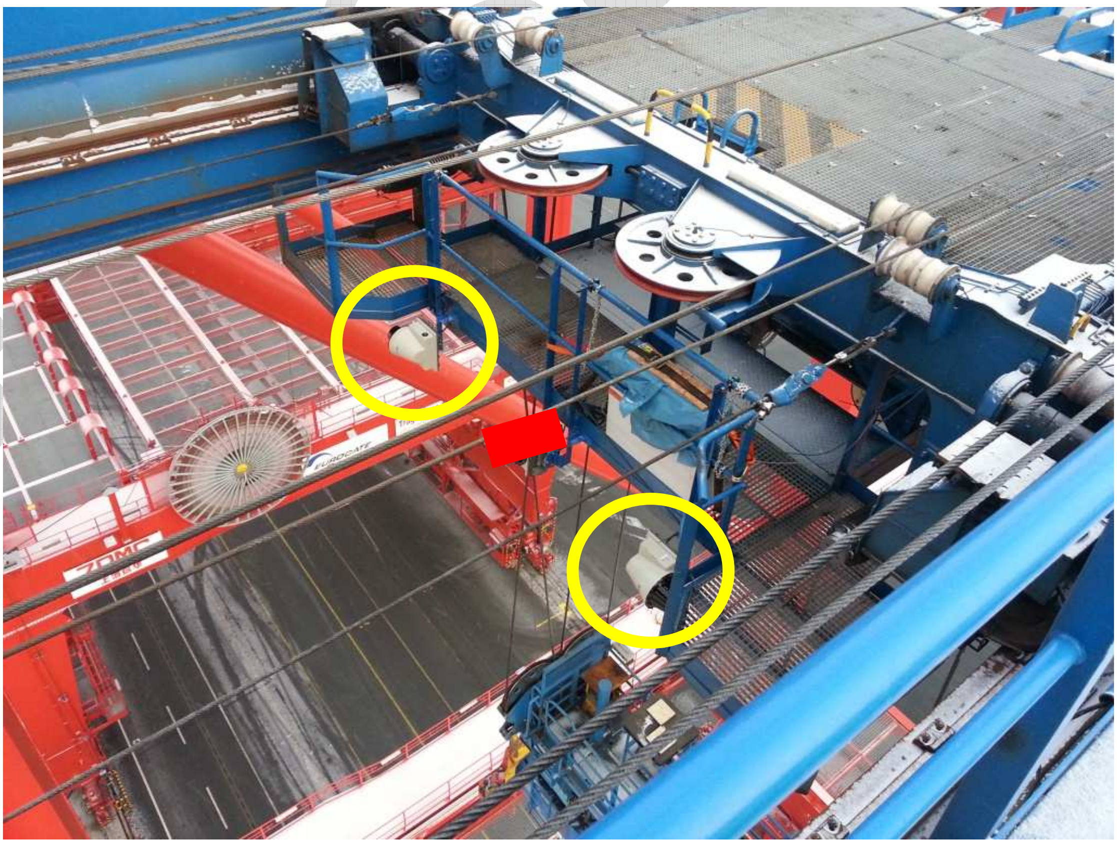

Figure 1: Position Laser scanners on the trolley

Figure 2: View into the vessel with indicated laser lines in yellow

Figure 3: Mounting position of the two laser scanners

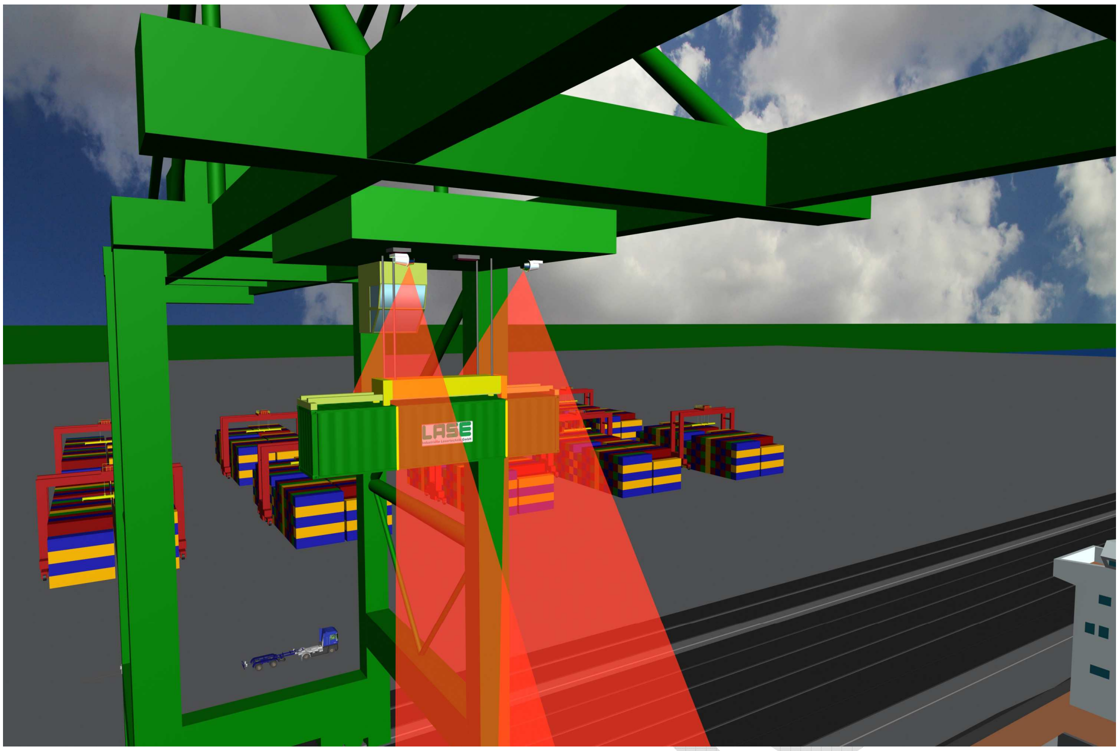

Figure 4: Position Laser scanners on the trolley

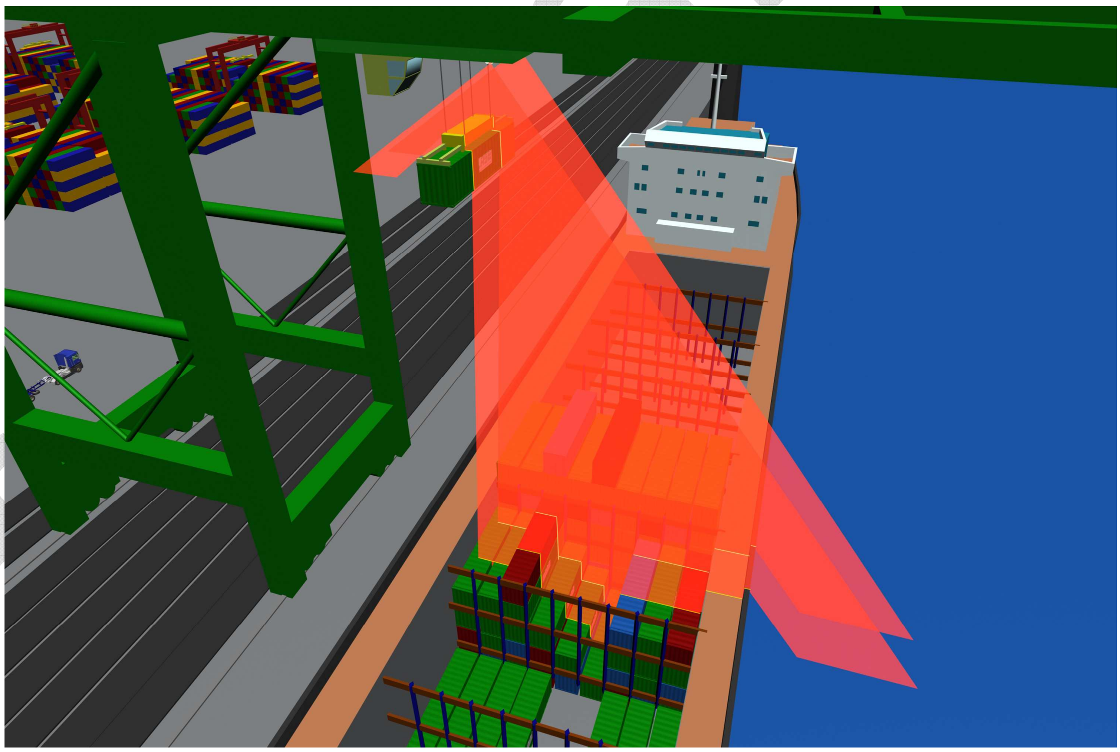

Figure 5: Overview with 2 x scan plane in red cutting the bays in two lines and the load (yellow lines)

3.1 Coordinate system

The coordinate system is defined as follows and based on a so called right handed system.

- X = Crane moving direction (not important in this system)
- Y = Trolley moving direction
- Z = Hoist movement

The point of origin is near the edge of the crane. All values do have a positive sign. Arrows are pointing in positive direction. The rotation angles (like trolley skew) are defined as follows:

Clockwise (view from the origin)	= positive angle
Counter clockwise	= negative angle

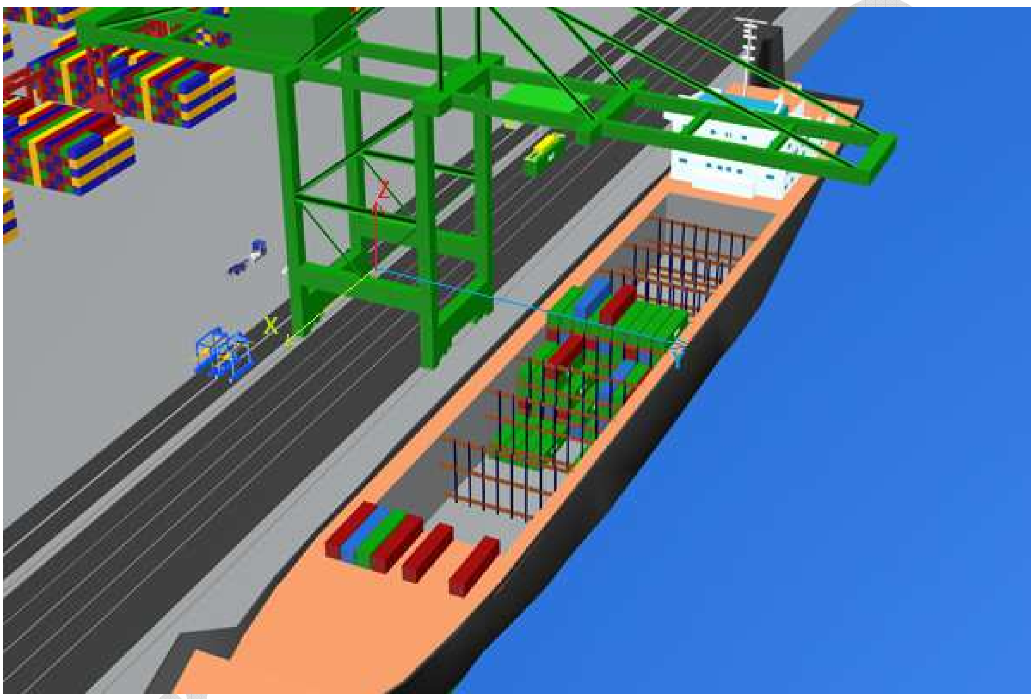

Figure 6: Coordinate system

4 Hardware

The measurement system consists of the following main components:

- 1 x LASE LCU + Switch cabinet
- 2 x Laser scanner LASE 2000D-138

4.1 Hardware Overview

The drawing below gives an overview above the used hardware and the internal connections.

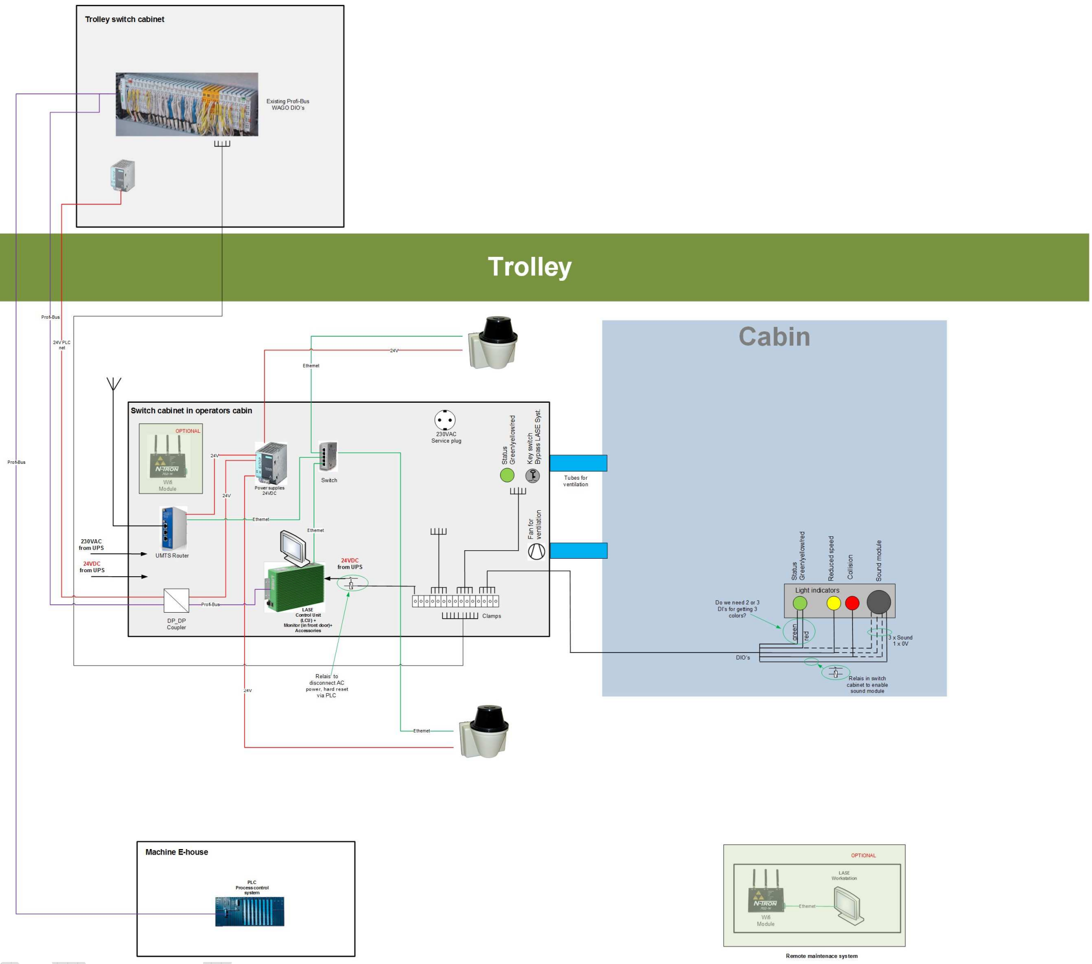

Figure 7: Hardware configuration

4.2 LASE Switch Cabinet

The switch cabinet will be placed in the driver's cabin. The switch cabinet contains the following main components:

- LASE Control Unit LCU (which is an Industrial PC)
- Light indicators
- Switch
- Relay
- Power supply 230VAC/24VDC
- Clamps and Fuses
- WLAN device

4.3 Wiring

To avoid influences to the data and power cables for the Scanner due to electrical fields from high voltage cables for the drives or similar we recommend using shielded cables for the power cables.

LASE expect that a decentralize connection to the PLC is in the driver cabin available, like an ET 200 (when we have Siemens PLC System on the machine).

When the PLC is on another place (resp. the decentralized periphery) then additional cabinets and wiring has to be done.

4.4 2D-Laser scanner (LASE2000D-138)

The LASE 2000D-138 Long-Range outdoor scanner is a two-dimensional contactless distance measuring system built for the industrial environment and outdoor purposes.

The scanner interface outputs the contour data of the recorded surroundings in form of constant raw data which incorporates distance and angle values. The 2D profile of the surrounding is scanned by multiple pulsed IR laser beams transmitted via rotating lens head. The LASE 2000D-138 sends extremely short light pulses, measures the running time of these pulses to the object and back, thereby calculating the distance as well as determining the angle of the pulses which are sent back. This is produced at a maximum rate of 10 times per second providing a captured profile of the complete environment, including all objects.

The LASE 2000D-138 has a capture range of 80 m radius on dark targets, and 250 m on bright targets over it is 300° field of view.

Figure 8: 2D-Laser scanner (LASE2000D-138)

4.5 Lase Control Unit LCU

The Lase Control Unit is an Industrial-PC. On the LCU the application software LaseCPV is installed.

Figure 9: LASE-LCU

Component	Description
Operating system	Windows 7 32/64 Bit Ultimate
Processor	Intel® Core™ i5-3340 / 4x 3.10 GHz or similar
RAM	Min. DDR3-RAM 4 GB PC1333
Drives	SSD 120 GB
Graphic controller	1GB RAM VGA / DVI etc.
Interfaces	2 x LAN RJ45 (Ethernet 100/1000 Mbps) 6 x USB 2.0

Table 1: Technical data LASE LCU

4.6 Mounting position of Scanner

The two Laser Scanners are mounted under the trolley. Depending on the machine structure it might be necessary to install additional mounting plates or frames.

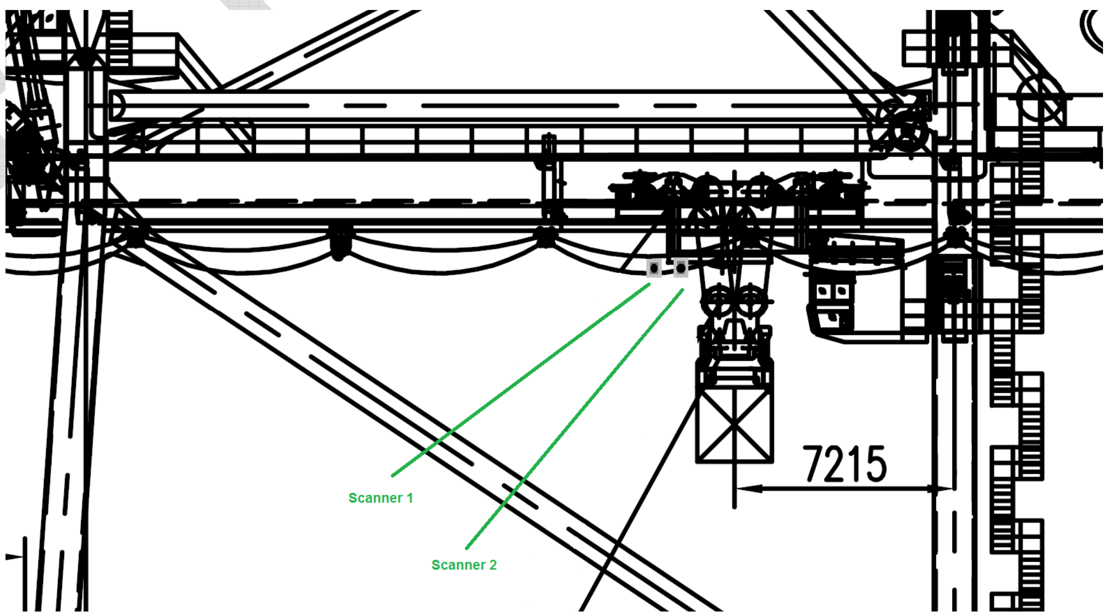

Figure 10: Side View Scanner Position on Crane

There should be a distance of approx. 1.5 m between both scanners in Trolley driving direction. It is not important which of the laser scanner is closer mounted to the trolley. With the offset of the two laser scanners, it is easier to detect whether it is a normal or a high cube container (measuring with Scanner 1). The mounting place of Scanner 2 enables it also to measuring between two high container stacks.

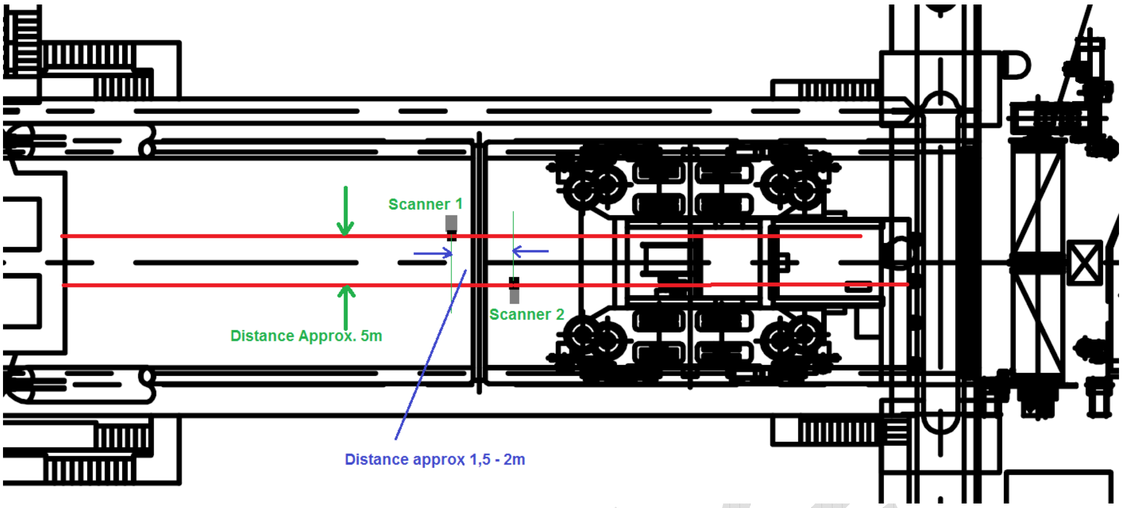

Figure 11: Top View Scanner Position on Crane

To be sure to detect all transports of single 20ft container, a lateral offset of 5 meters is required. This allows enough clearance when the container is sideward swinging.

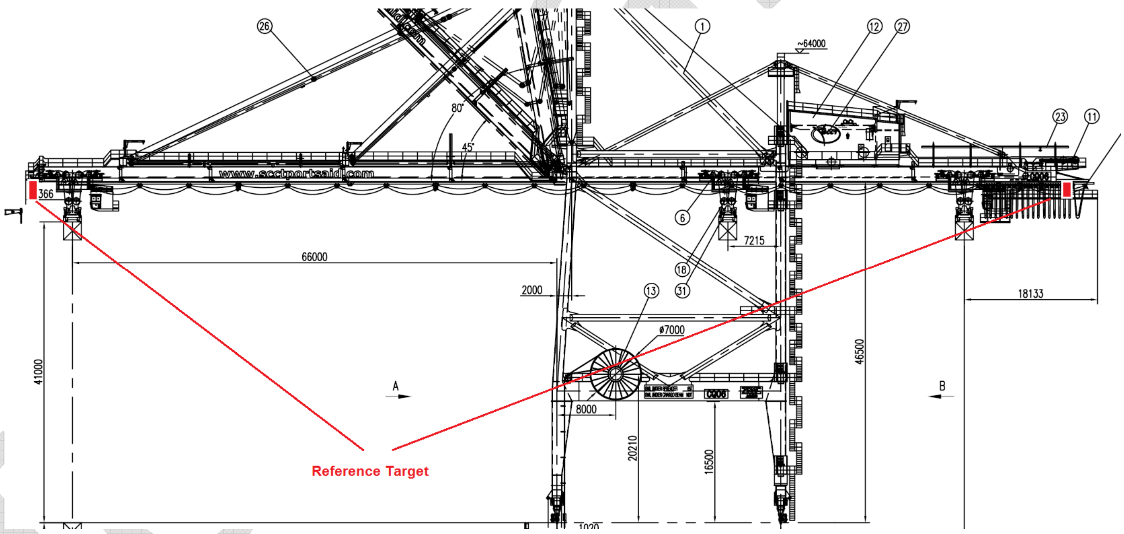

Figure 12: Crane Side View with Reference marks at front and end

For Trolley tracking a reference targets must be available at the beginning and the end of the crane boom, like in the drawing above.

5 Software

The software consists of the Application Framework Lase CEWS Basic and the application specific software LaseCPV.

Only trolley and hoist movements are allowed, no crane movements.

5.1 LASE CEWS Basic

The LASE CEWS Basic Module is the framework software of the LASE CEWS application core and consists of following modules:

- Communication module laser (parameterization and data handling for following laser types (LASE 2000D, 2000T, 3000D-Series) following interfaces are usable according to the laser types – Ethernet TCP/IP, RS 422
- Communication module Input/Output, parameterization and data handling for following Input / Output modules: SPS, Level 2 und Level 3 (further on request); following interfaces are supported: – Ethernet TCP/IP, Profibus (optional), analogue
- Communication LASE CEWS application core measurement data processing and handover to the application core
- Data recorder function: all measurement- and process data are permanently and completely logged. For analysis- and simulation purposes the data can be written back into the program.
- Graphical operating surface: for a simple and intuitive usage of the measurement system, incl. status messages, result displays, controlling
- 2D- and 3D-Visualisation: For the visualization and evaluation of the measurement data. Scan image in 2D- and 3D-images, zoom function, free selectable perspective
- Application parameter: dialogue guided input of the process parameters for hardware and software
- Error- and event lists: Logging and display of error and events for a quick diagnostics

5.2 LASE CEWS Application Core LaseCPV

The individual software consists of following functions:

- Collision prevention
- Surveillance field
- Soft landing
- Image 2D (profile of the stack)
- Trolley tracking (if reference targets are available)
- Status machine
- Calibration
- Communication interface

In the following Figure an example of 2D Profile is shown.

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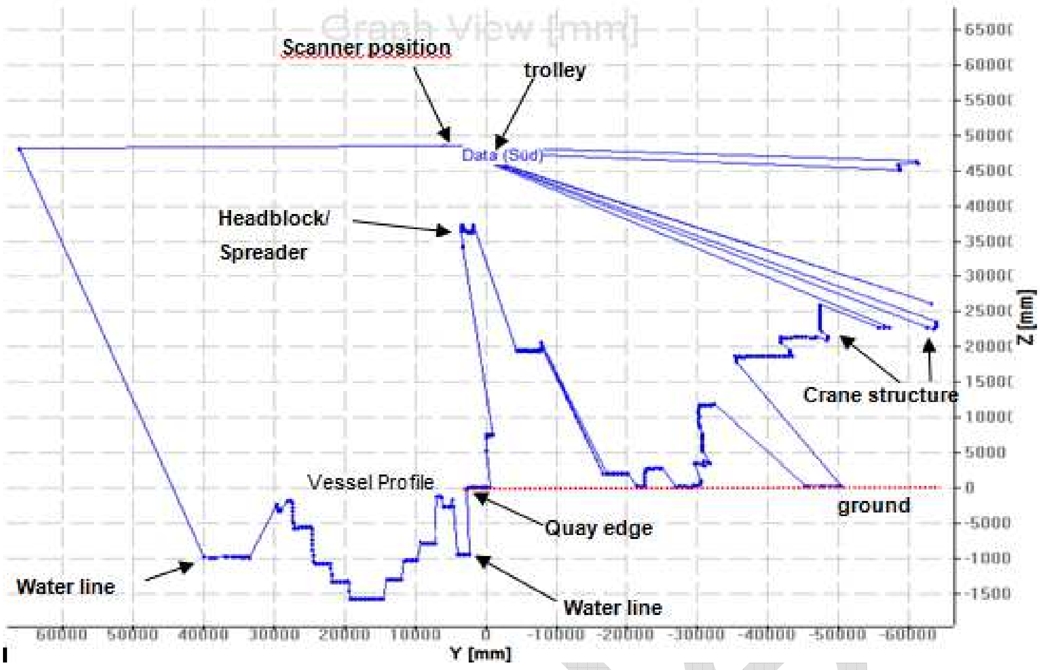

Figure 13: Vessel profile

5.3 Software masks

The following mask showing the application in action.

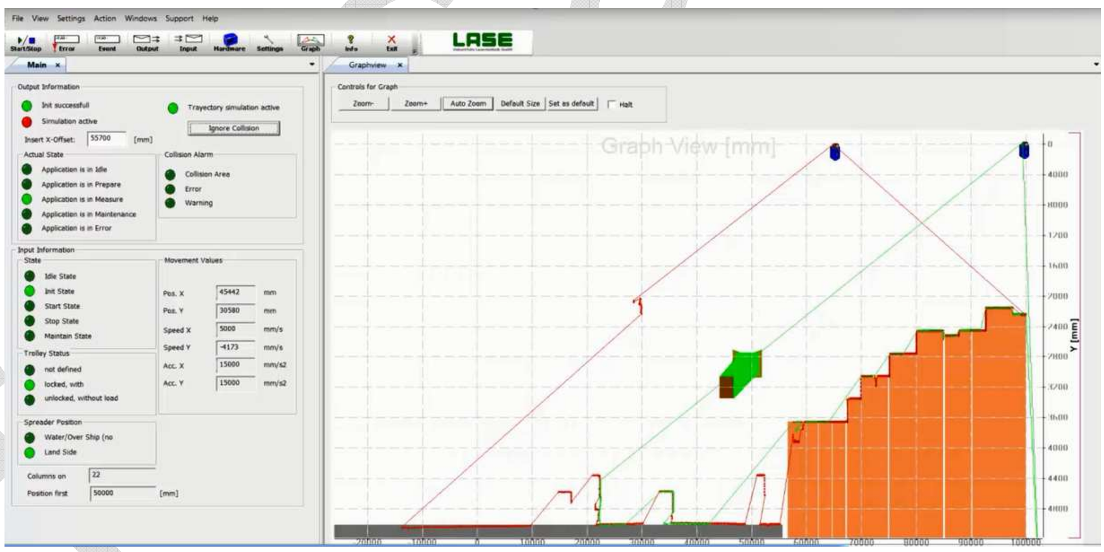

Figure 14: Software mask LaseCPV – green field is surveillance field. The container is been moved with hoist and trolley drive, in load moving direction is no overlapping with the stack profile.

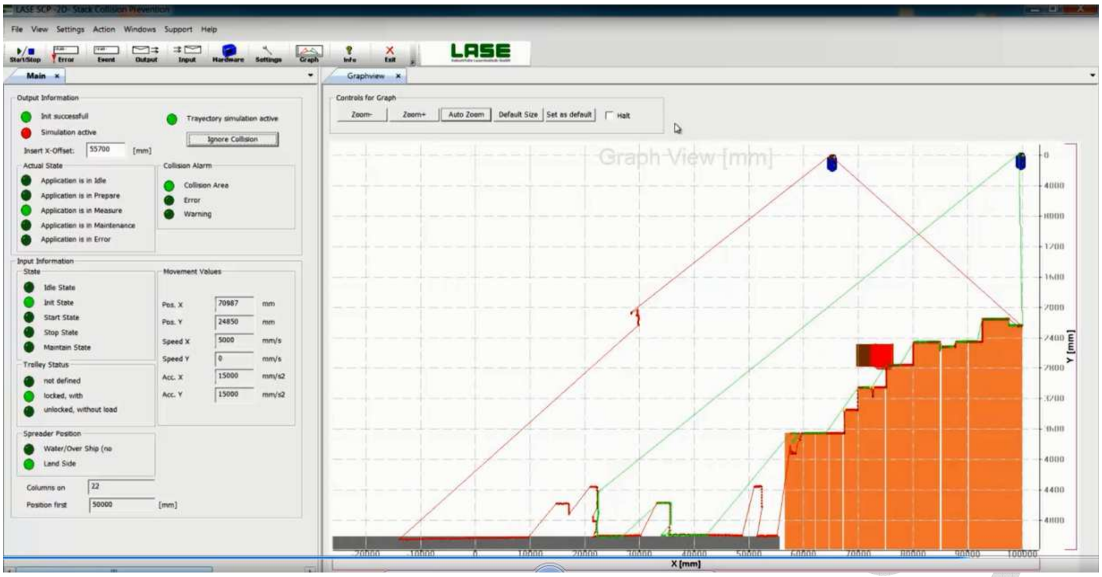

Figure 15: Software mask LaseCPV - detected collision occurance, red cube overlap with the stack profile

As shown in the picture above the advantage of the 2D-Scanner is that in each scan it can see the position of the spreader and the height of the container hanging at the spreader. By scanning reference points (like a cross pipe or similar) this scanner provide the position of the trolley as well.

5.4 Software check

The LASE system is working on Windows operating systems (Win7™). To ensure that the software is running an additional small application is installed beside the measurement application. This small auxiliary application is checking whether the main application is still proper running. If the main application is not running an automatic restart of application will be initialized.

6 Functions

6.1 Collision prevention

For Collision prevention a surveillance field is necessary. The surveillance field is an area which is used by the LASE application to prevent collisions between the empty spreader or a container hanging at the spreader and containers in the vessel.

The position is located at the center point of the spreader. The size of the surveillance area mainly depends on:

- Height of container hanging at the spreader
- The moving direction
- The velocity and position of trolley and hoist
- Delay times (PLC, mechanics)
- Swing behavior of the load according the rope system

The calculation of the dimensions is done in the software under consideration of the needed space to warn and finally stop the trolley safely in case of a collision occurrence was detected.

Figure 16: Surveillance field (green) – trolley do not move

The picture above shows an example of a surveillance field. The dimensions of the field in this example are adjusted in that way that the field covers the spreader and the hanging container. In the example the trolley is not moving. Thus the field lays around spreader and container quite close.

If now for instance the spreader shall be moved to the right side (see pictures below – Collision case) the area will be extended to the right side as well.

The area is adapted to the direction of the movement, so diagonal, vertical and horizontal field will be used during the calculations.

If the area overlaps with any object a collision warning is given and the trolley will be slowed down and finally stopped.

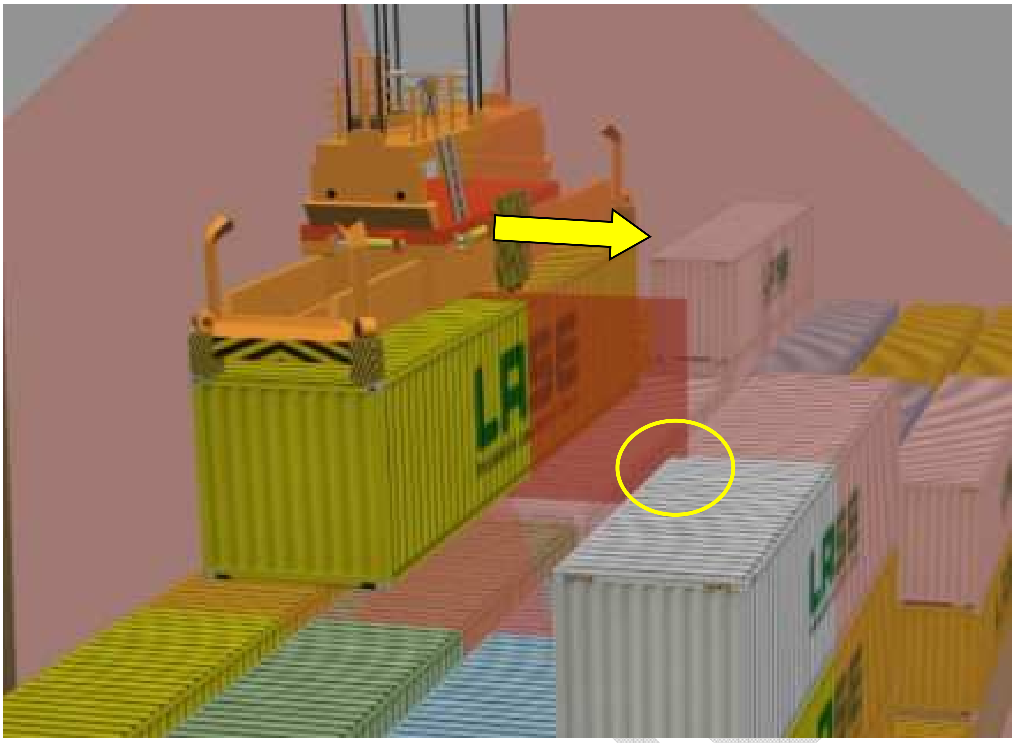

Figure 17: Surveillance Filed – trolley moves to the right (Collision case)

To permit a soft braking and avoid oscillations in the crane the surveillance field will be divided in different sections. Every section will limit the set point speed of the driver in an adapted way.

The number of sections and the speed limitation per section can be parametrized according to the crane I/O available and other requirements. The dimension of the section will be adapted to its speed limitation.

In the next example the surveillance area are divided in 4 sections (might be more in real application) every area could limit the speed in a configured way:

1. 90% of demanding speed
2. 75% of demanding speed
3. 40% of demanding speed
4. 10% of demanding speed

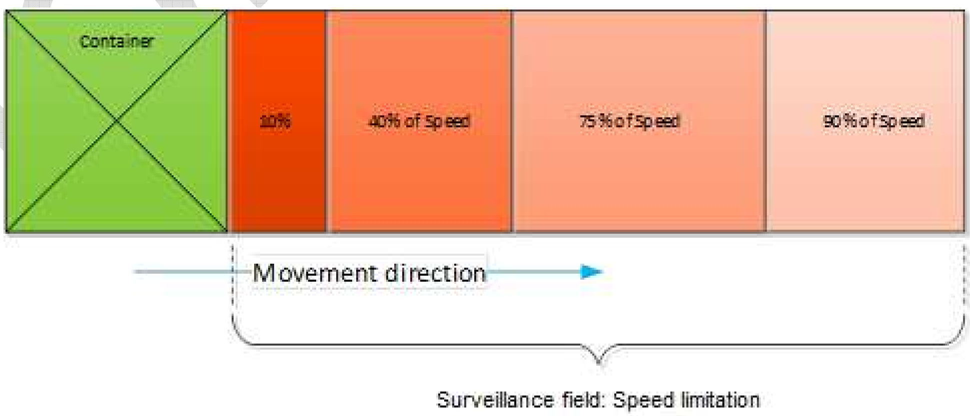

Figure 18: Surveillance field example

When the operator tries to move the crane, the requested hoist or trolley speed is read. According to the speed and the other parameters the dimension of the surveillance field is calculated. During the movement it is checked if some object is inside the field, and when this happen the nearest point of the object relative to the beginning of the field is processed. Then the speed requested for the operator will be limited according to the section where the point was detected. For example in the Figure 19 the speed will be limited to the 40% of the requested value. In this case the system knows from the beginning of the trolley movement which maximum velocity is allowed if the field overlaps with an obstacle already. If the distance to a potential obstacle is far enough of course full velocity is allowed.

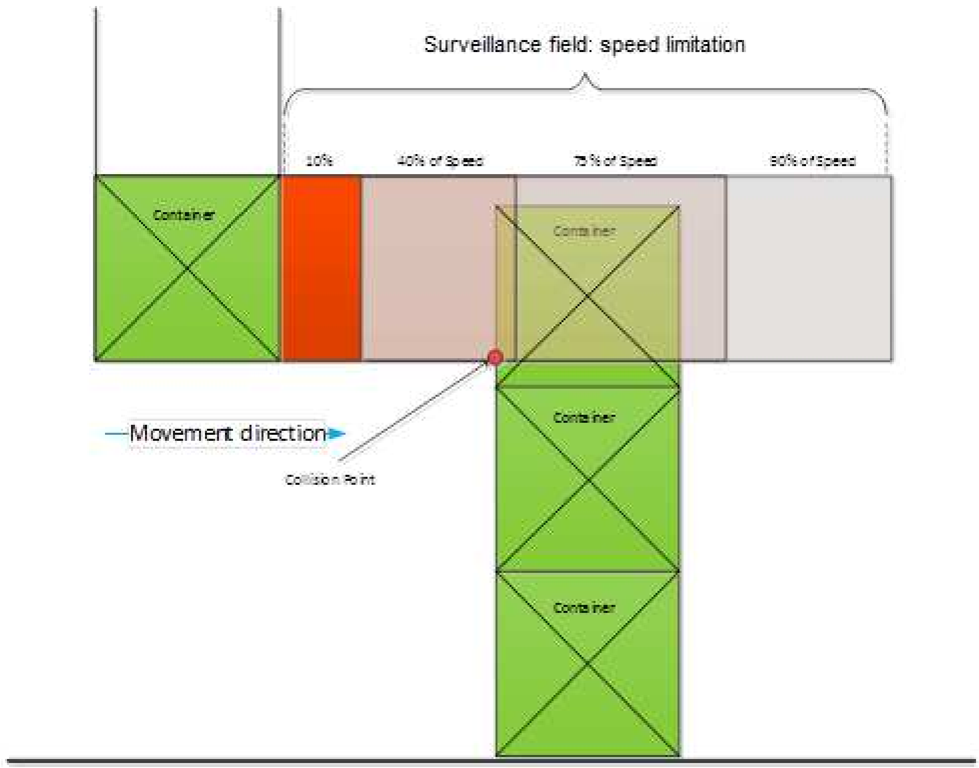

Figure 19: Surveillance field - Speed reduction example

In addition to the speed reduction field some collision field could be activated. These fields are located around the spreader and the hanging container and could be used to avoid or limit the movement in a specific direction. There are two collision fields and they could be seen in the Figure 20.

They are fully configurable and work like the surveillance field to reduce the speed. When an object is detected inside them the speed reduction is triggered. This was designed to assist the operator during recovery process after a collision situation, considering that the movement will be allowed only in the opposite direction of the collision area or upwards/downwards (configurable).

Some options of these areas and their configuration are:

- Dimension, the size of this areas if defined in a parameter and do not change during the movement
- Speed reduction behavior, when an object is detected inside this areas the axis linked to it could be stopped or its speed could be limited to a configured percentage

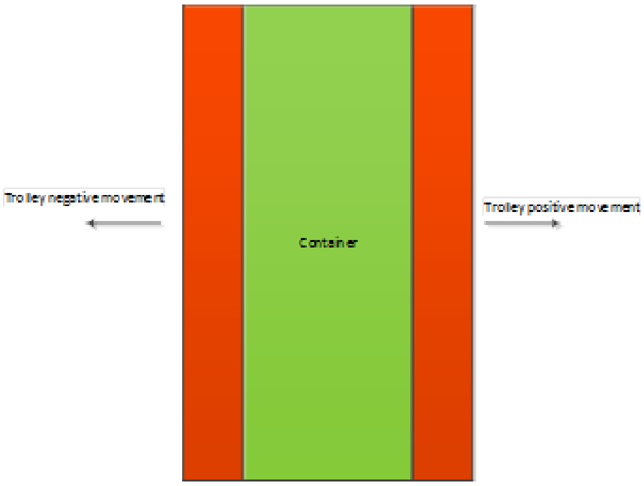

Figure 20: Surveillance field – Collision field (Upper view)

6.2 Spreader Tracking

To be able to track the position of the Spreader the scan of the two Laser Scanners have to able to see the headblock/Spreader or the container hanging at the spreader. On the headblock special reference markers have to be placed.

In the following figure only the profile of one Laser scanner is visible. The yellow line is showing the measurement spots on spreader (with container in transport).

Figure 21: Spreader Tracking – Profile of one Laser Scanner

The following 2D Measurement Figures show the moving of the spreader in some different positions. All together show a sequence of moving.

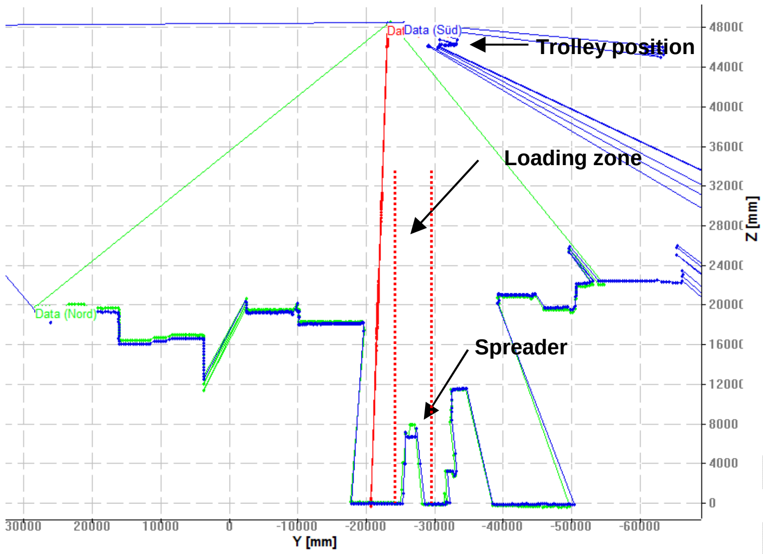

Figure 22: Spreader Tracking – 2D view Sequence 1

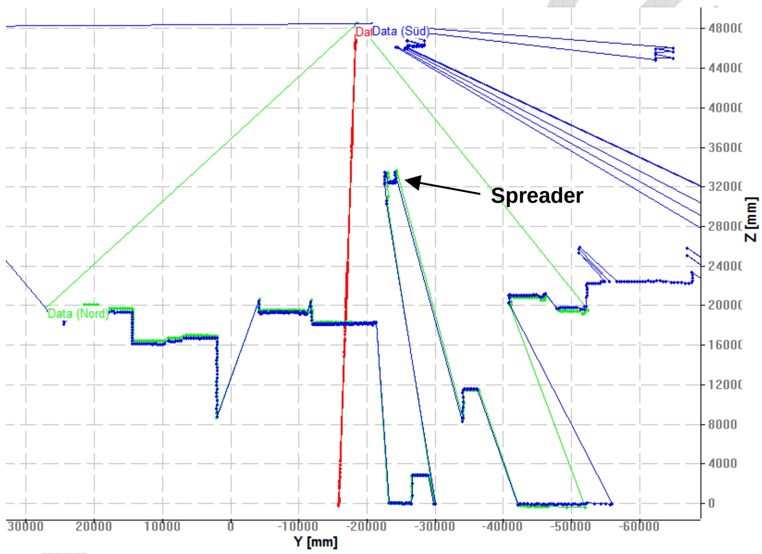

Figure 23: Spreader Tracking – 2D view Sequence 2

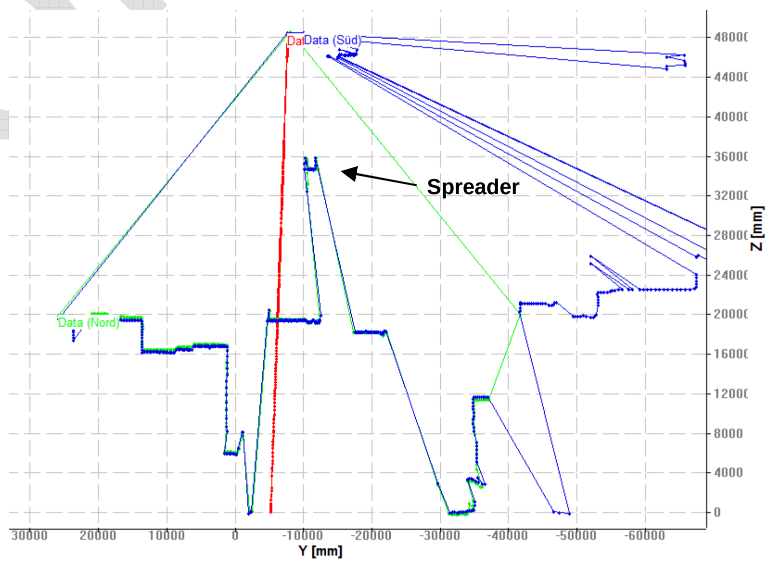

Figure 24: Spreader Tracking – 2D view Sequence 3

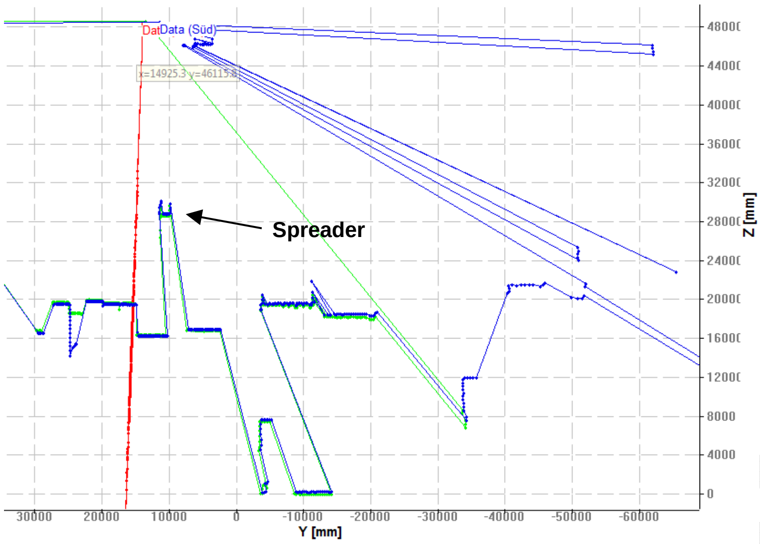

Figure 25: Spreader Tracking – 2D view Sequence 4

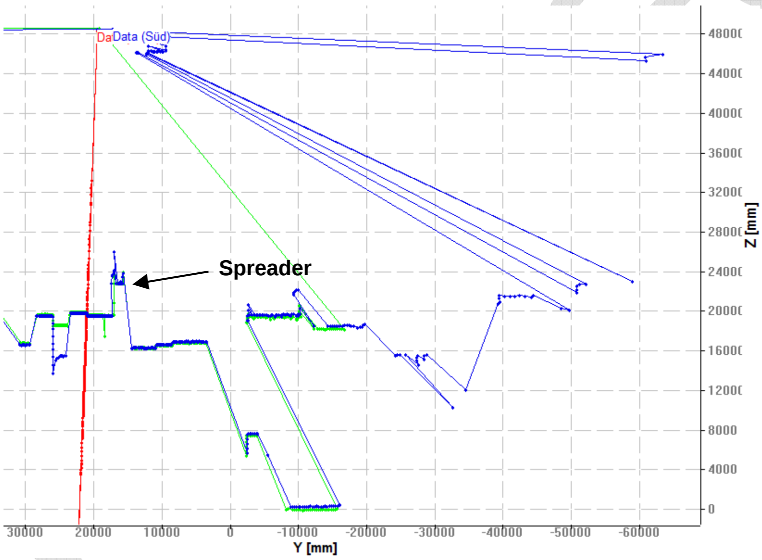

Figure 26: Spreader Tracking – 2D view Sequence 5

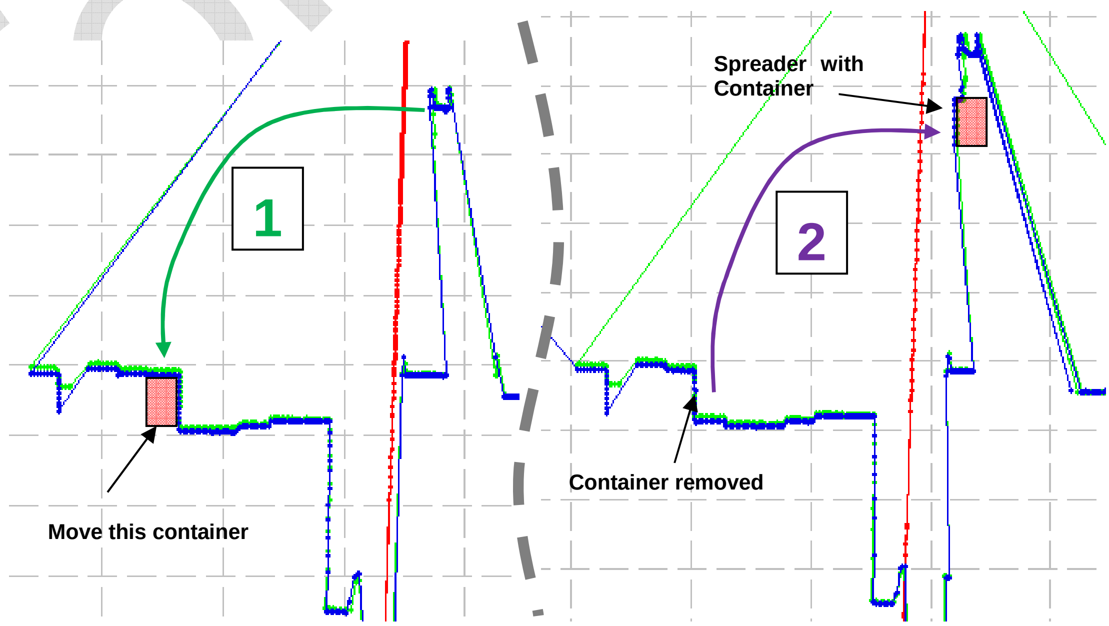

Figure 27: Container profile on ship

6.3 Soft Landing

For the Soft Landing function a permanently measuring of the Container structure in the area of Vessel and under the crane is necessary. The Container dimension will be saved in internal memory of application for each scanner (see following Picture). The orange and grey lines are for the structure in memory of application. At the beginning it's possible to have undefined areas. After the first movement to water side (nearest Container Colum to waterside), the total area is known.

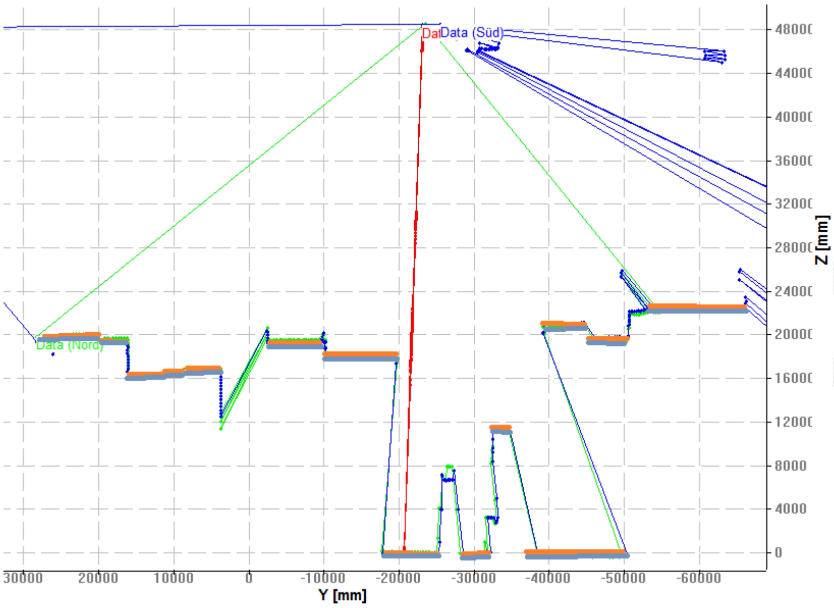

Figure 28: Container profile on ship (orange and grey show saved Container structure)

The distance in driving direction of trolley, will be separated in sections. Every section is for the width of nearly a container.

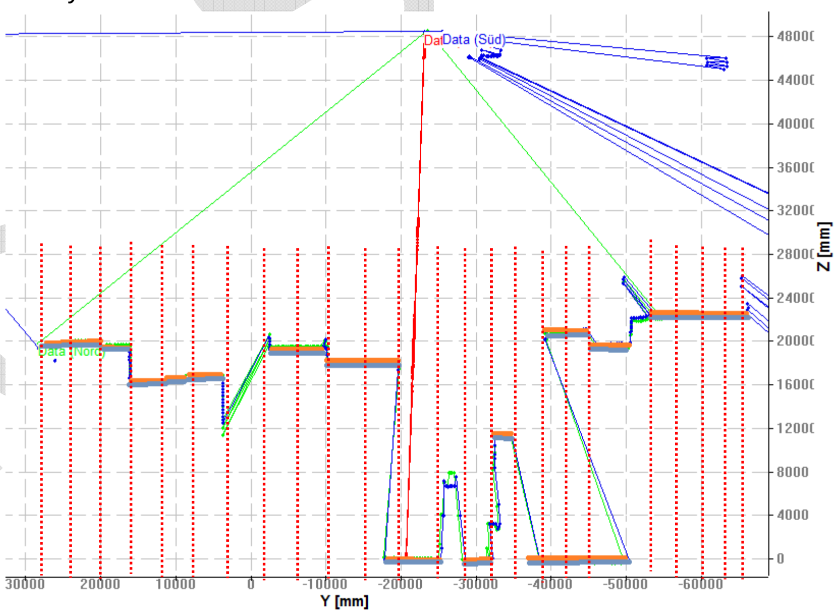

Figure 29: Container structure separated in sections

While doing the transport of Container, the LaseCPV is able to calculate the distance between saved structure and the bottom position of transported container. For a pickup of a container, the distance between bottom position of the spreader and saved Container top, will be used to generate the Soft Landing. There will be a parameter to slow down at the best position.

6.4 Calibration

The alignment of the laser scanner will be carried out at the commissioning and should not be changed under normal circumstances. If there is a defect in one of the devices, so a replacement is needed. After replacing the new device the actual orientation should be checked and may be corrected.

The calibration is an essential part of the LASE measurement system. To ensure as accurate as possible measurement results a precise calibration has to be performed.

Main issue of the calibration is to determine the mounting position of the 2D-system in relation to the trolley center. For each of the scanners several offset parameters have to be determined. These offset values are used by the LASE application to transform the incoming scans in order to create 2D-image which exactly represents the reality under the crane.

For the internal transformations following parameters have to be determined per scanner:

Degrees of freedom:

- Rotation X, Y, Z
- Translation X, Y, Z
- Internal scanner errors (like distance error etc.)

6.4.1 Mechanically adjustment of Laser scanner

The laser scanner produces no visible light, so a measuring device must be used. This special laser detector is called beam finder. With the help of the beam finder, it is possible to detect the impact of the measurement points.

Figure 30: Beam-finder in first figure to low, in second to high, in third the beam is in center (see arrow in display window)

Most important is to have the laser scanner oriented parallel to the Trolley driving direction. This correction must be done mechanically by turning the scanner itself. Here the beam-finder is a very helpful tool.

6.4.2 Software adjustment of Laser scanner

If the mechanically adjustment is finished, the software adjustment can be done. For this a transport of a container is necessary.

The calibration will be performed with a standard container, size is not important. The calibration is performed in different height levels. Following a list of the calibration sequence respectively the single steps of the calibration:

- As a first step a container should be picked from the vessel or from terminal truck

- Trolley then moves to the center of the lanes
- Container will be lifted to highest possible position
- A permanent 2D-Scan will be performed
- Container will be placed at ground and Spreader is lifted up to highest position (Trolley must not move!)
- Finally all internal calculations (offset determination) will be done by the software

7 Limit of supply (Scope of the customer)

- Mobile crane with work-platform to do the installation of the laser scanner underneath the trolley
- Mechanical and electrical support during installation
- Remote access from Germany to the LCU during commissioning and after initial test period
- Support by engineer during commissioning