Robotic systems to gain integrity insights in confined spaces

9th November 2021

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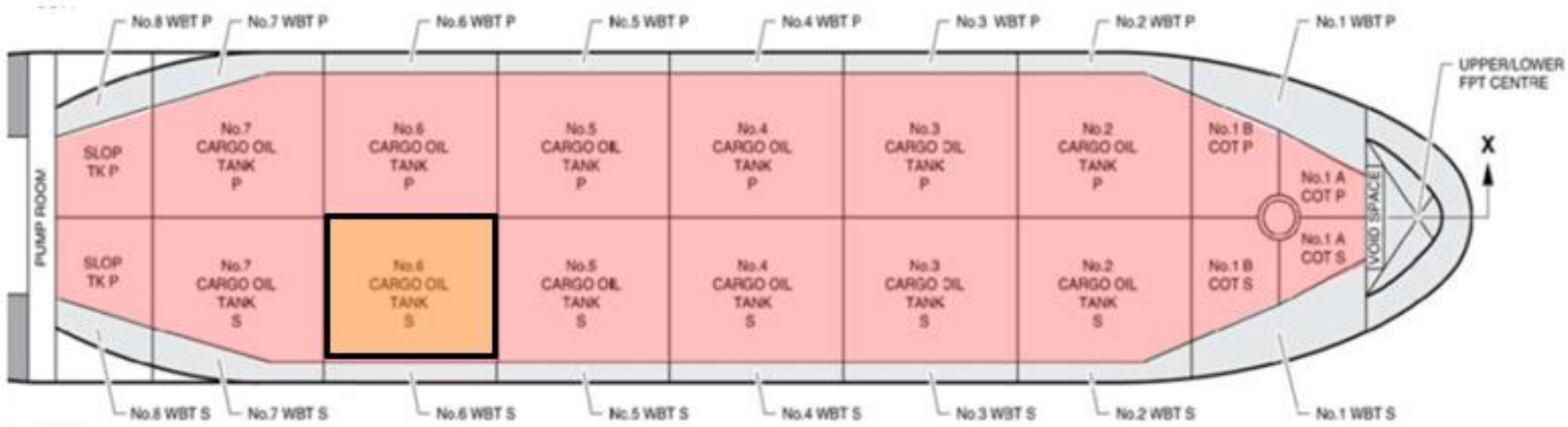
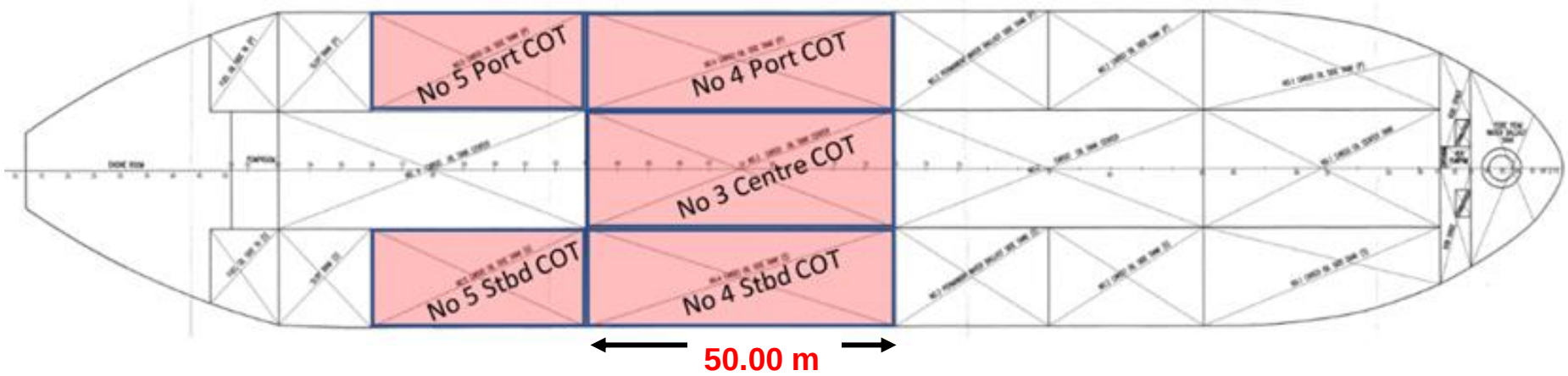
The Challenge

HITS
HULL INSPECTION TECHNIQUES & STRATEGY

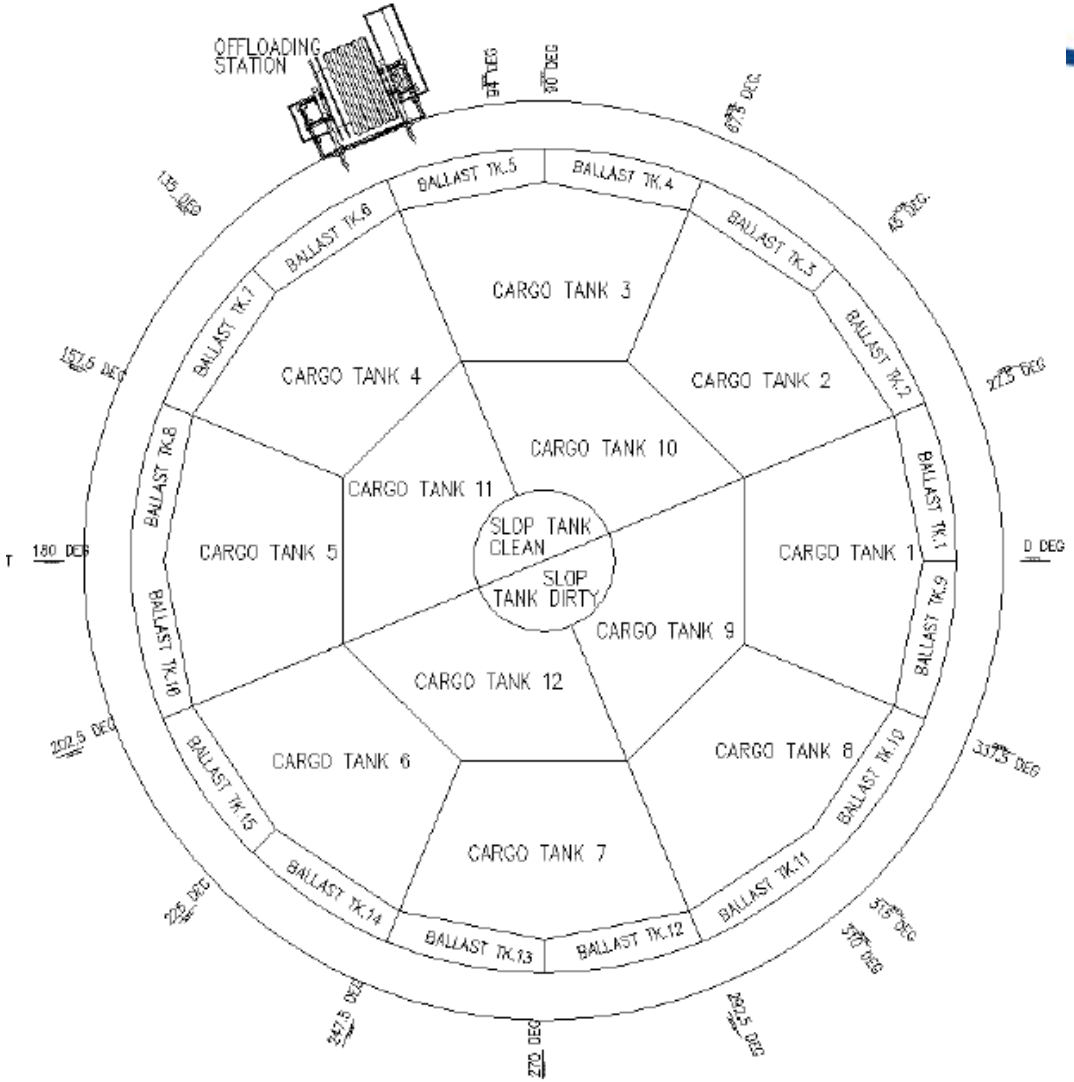
Different FPSO sizes, layouts and arrangement



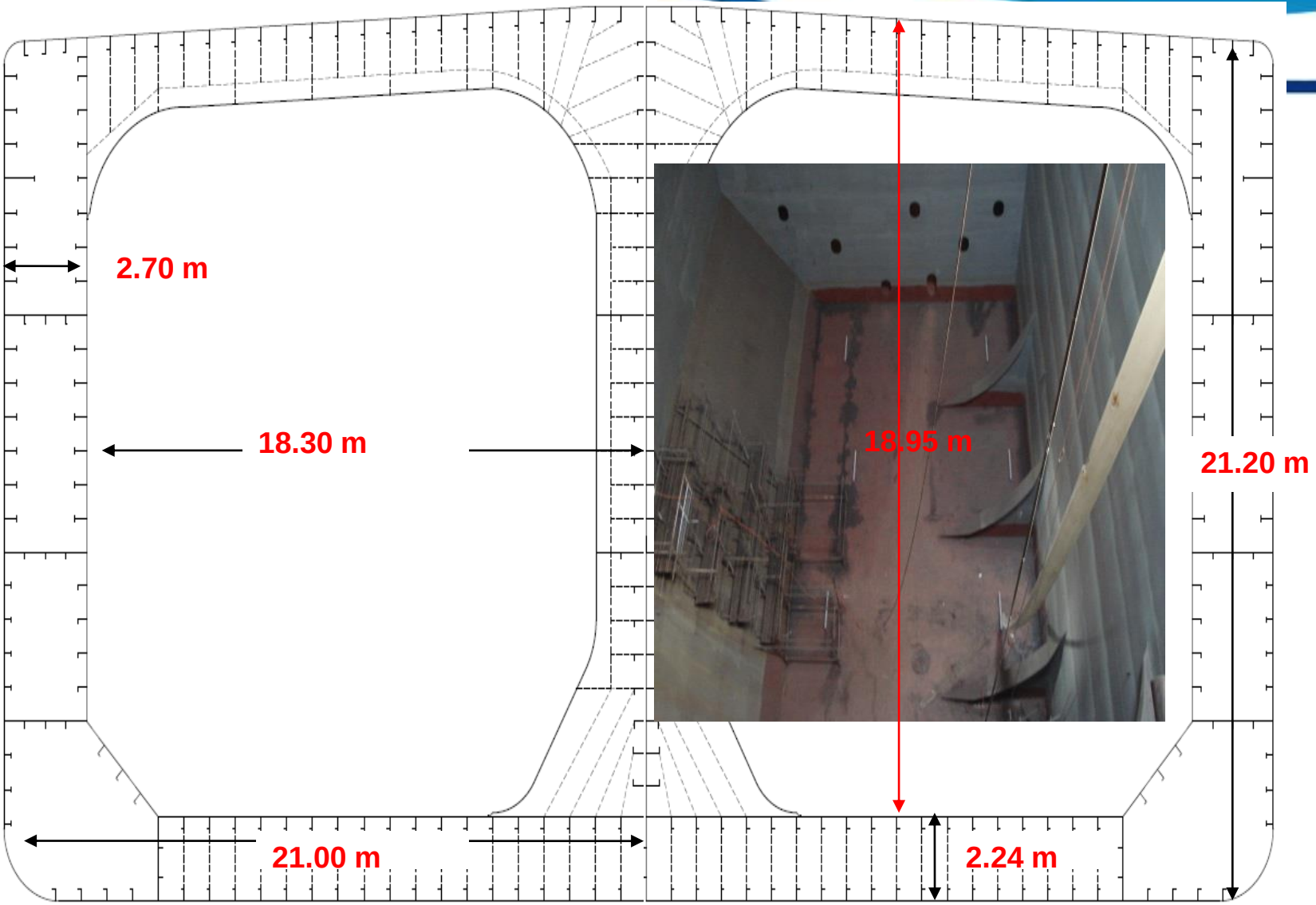


The Challenge

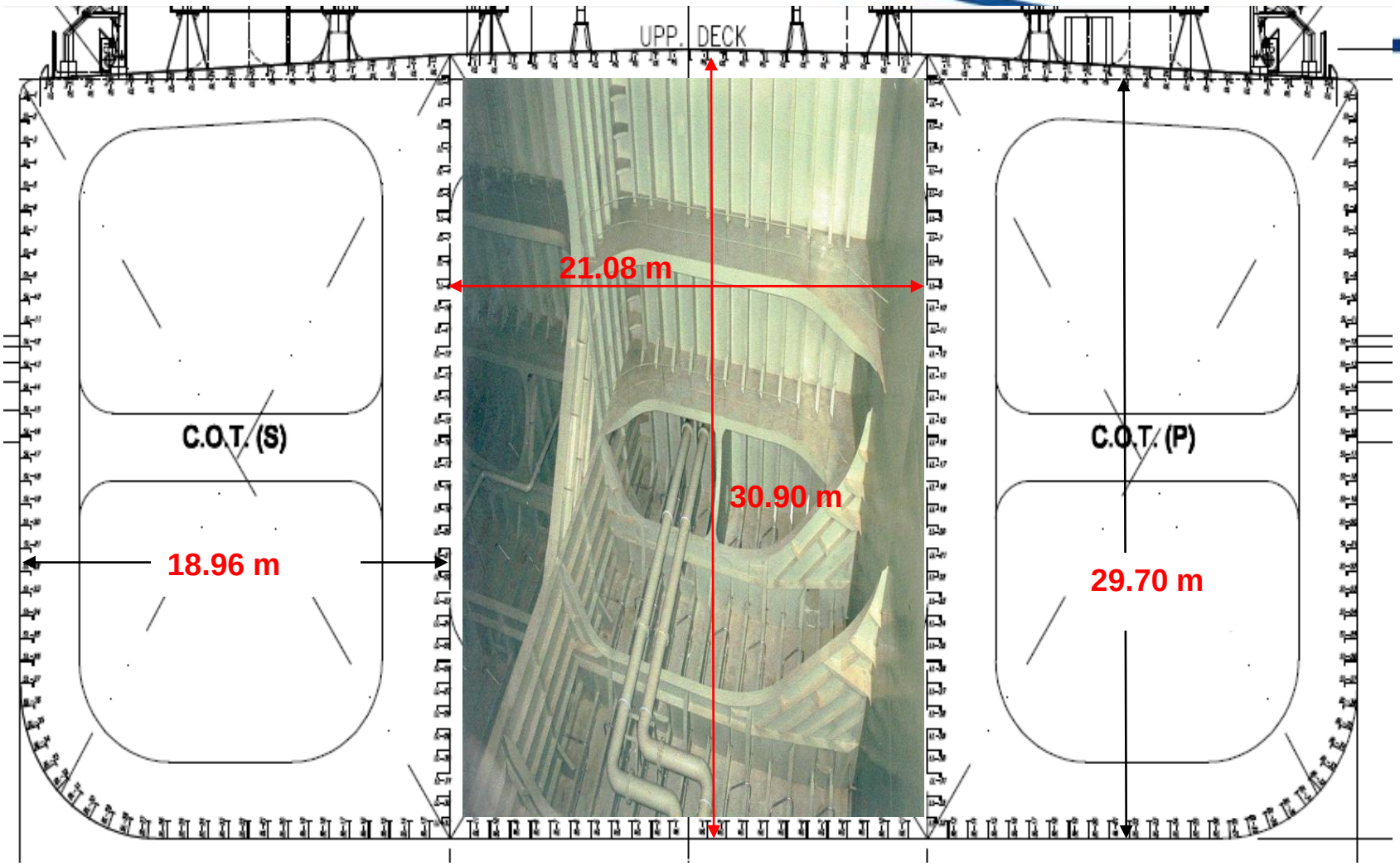
Even round ones



The Challenge



The Challenge



The Challenge

Access Difficulties

- Ventilation
- Lighting
- Cleanliness

The Challenge

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Dangers

- Asphyxiation
- Working at height

From 2011 to 2018, 1,030 workers died from occupational injuries involving a confined space. The annual figures range from a low of 88 in 2012 to a high of 166 in 2017. These data are from the Bureau of Labor Statistics, Census of Fatal Occupational Injuries (CFOI).

Table 1. Fatal occupational injuries involving confined spaces, 2011-2018

Year	2011	2012	2013	2014	2015	2016	2017	2018
Fatal work injuries	120	88	112	116	136	144	166	148

Potential Robotic Solutions

The HITS JIP has carried out trials on:

- Robotic crawlers
- Unmanned Aerial Vehicles (UAV) / Drones
- Robotic arms

Robotic Crawlers

Pros

- Able to carry NDT tools

Cons

- Manoeuvrability is the critical constraint
- Their remote deployment into and their removal from a tank remain a challenge
- Navigation within a tank is a challenge
- Umbilical required

Conclusion – Not yet ☹

UAVs

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Pros

- No working at height requirement
- Good CVI capability

Cons

- Confined space entry requirement(*)
- Inspection quality dependent on cleanliness
- Poor GVI capability
- Presently unable to carry out UT gauging
- Line of sight required(*)
- Time consuming
- Significant battery life limitations

(*) – One known drone capable of avoiding this

Conclusion – Limited capability 😐

Robotic Arms

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Pros

- No confined space entry requirement
- No working at height requirement
- Good overall GVI capability
- Good CVI capability
- Very efficient
- No additional lighting required

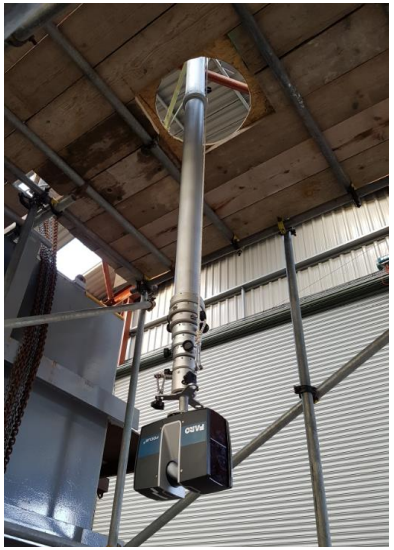
Cons

- Inspection quality dependent on cleanliness
- Access can limit effectiveness

Conclusion – Proven effective for COTs ☺

EM&I's NoMan® Suit of Robotic Arms

- Standard NoMan camera with offset lighting
- NoMan laser scanner deployed using an inverted tripod
- NoMan laser scanner deployed using a quadpod
- NoMan laser scanner deployed using the 'bridge' ™



Field Deployment Feedback

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Standard NoMan camera

Field Deployment Feedback

Standard NoMan camera with offset lighting

- Offset lighting was located 1 - 1.5m above the camera
- Proven to be very effective

Field Deployment Feedback

Standard NoMan camera with offset lighting

Without additional lighting

With additional lighting

Field Deployment Feedback

NoMan laser scanner deployed using an inverted tripod

- Easy to deploy
- Telescopic arm extension to 10m
- Satisfactory scan results

Field Deployment

NoMan laser scanner deployed using an inverted tripod

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Field Deployment Feedback

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Field Deployment Feedback

NoMan laser scanner deployed using a quadpod

- Scaffold frame required

- Lowered between longitudinals

Field Deployment Feedback

NoMan laser scanner deployed using a quadpod

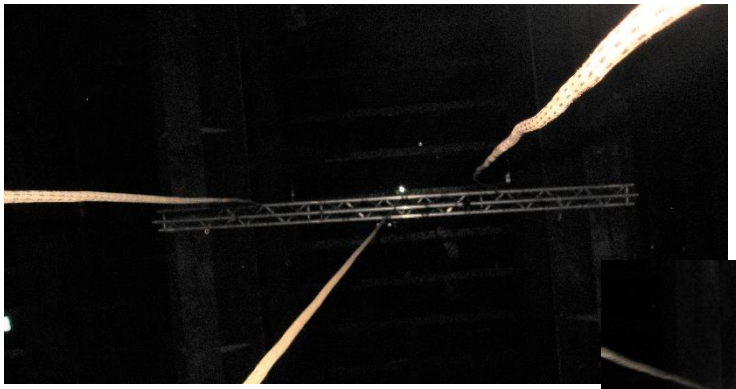
Telescopic arm unextended

Telescopic arm remotely extended

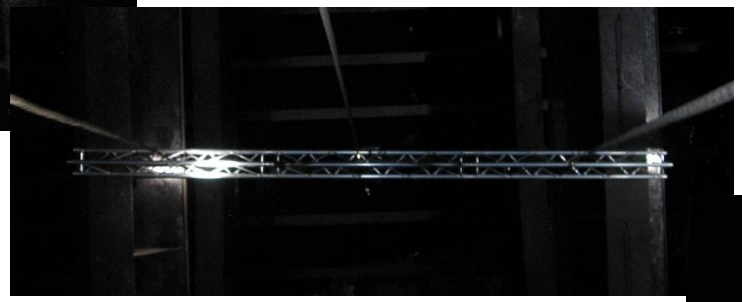
- Satisfactory scan results

Field Deployment Feedback

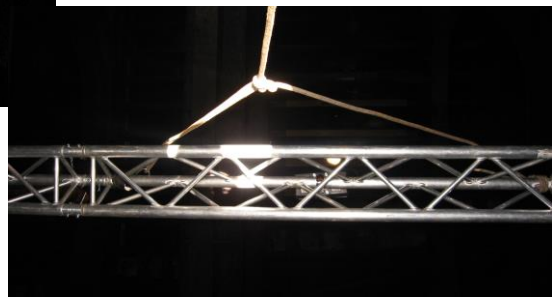
NoMan laser scanner deployed using the ‘bridge’ TM



Bottom deployment



Cross-tie deployment



Underdeck deployment

- Satisfactory scan results

Field Deployment Feedback

NoMan laser scanner deployed using the NoMan Bridge™

- Potential use for over-the-side scanning

- Second generation Bridge being developed with scanner on rails

Field Deployment Feedback

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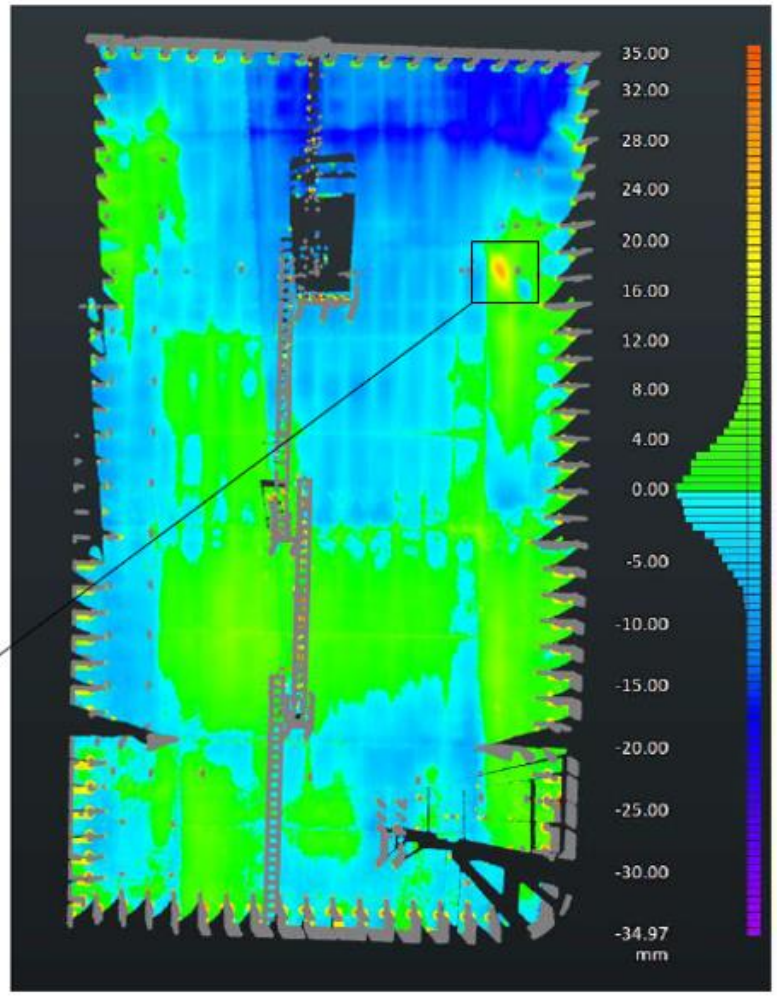
Results

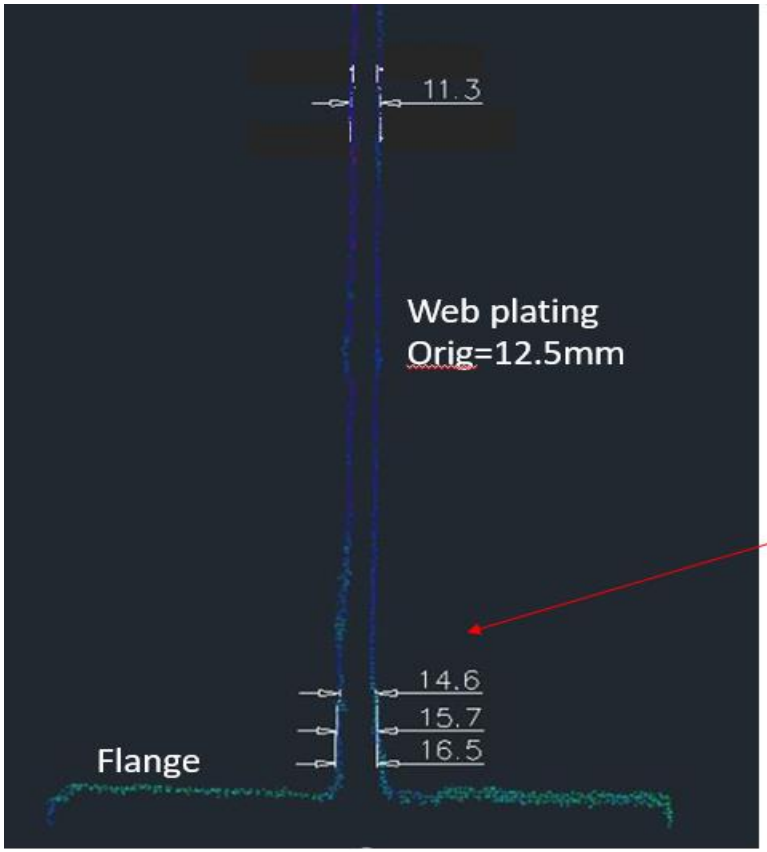


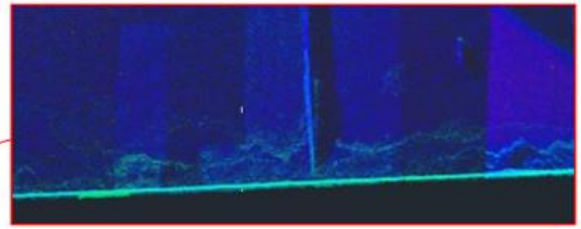
Surface deviation analysis of forward bulkhead shows a 30mm indication from nominal plane which will be further investigated prior to final report.

Field Deployment Feedback

Results

- Require expertise





Field Deployment Feedback

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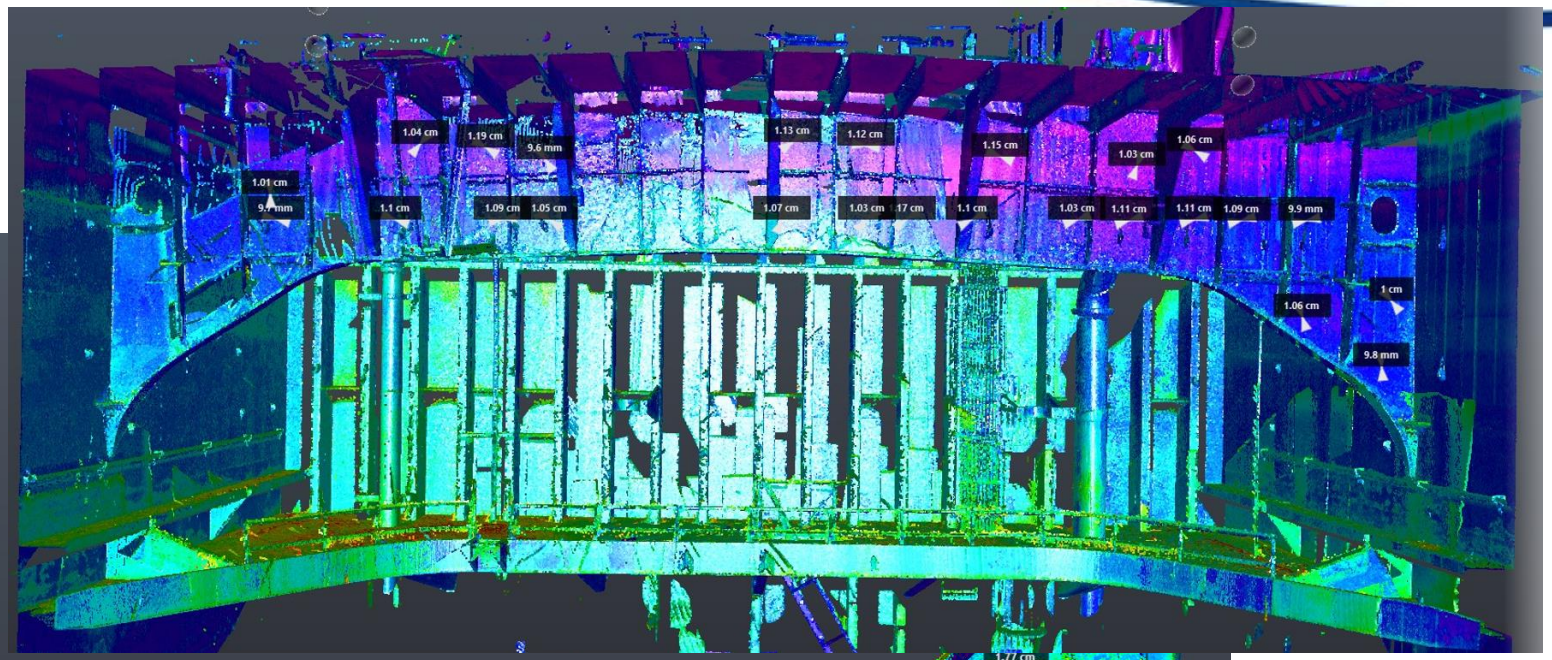
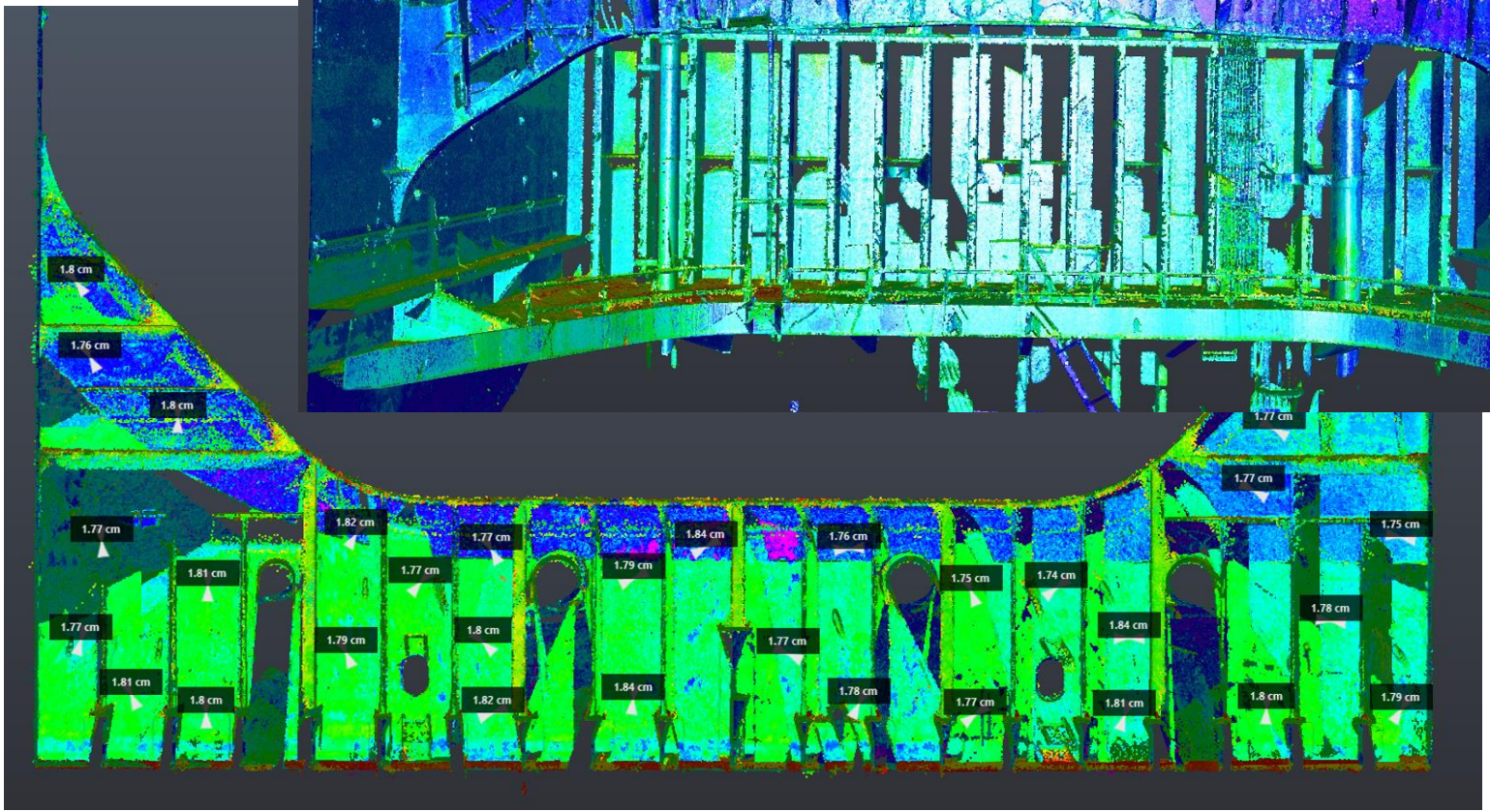
Results





Field Deployment Feedback

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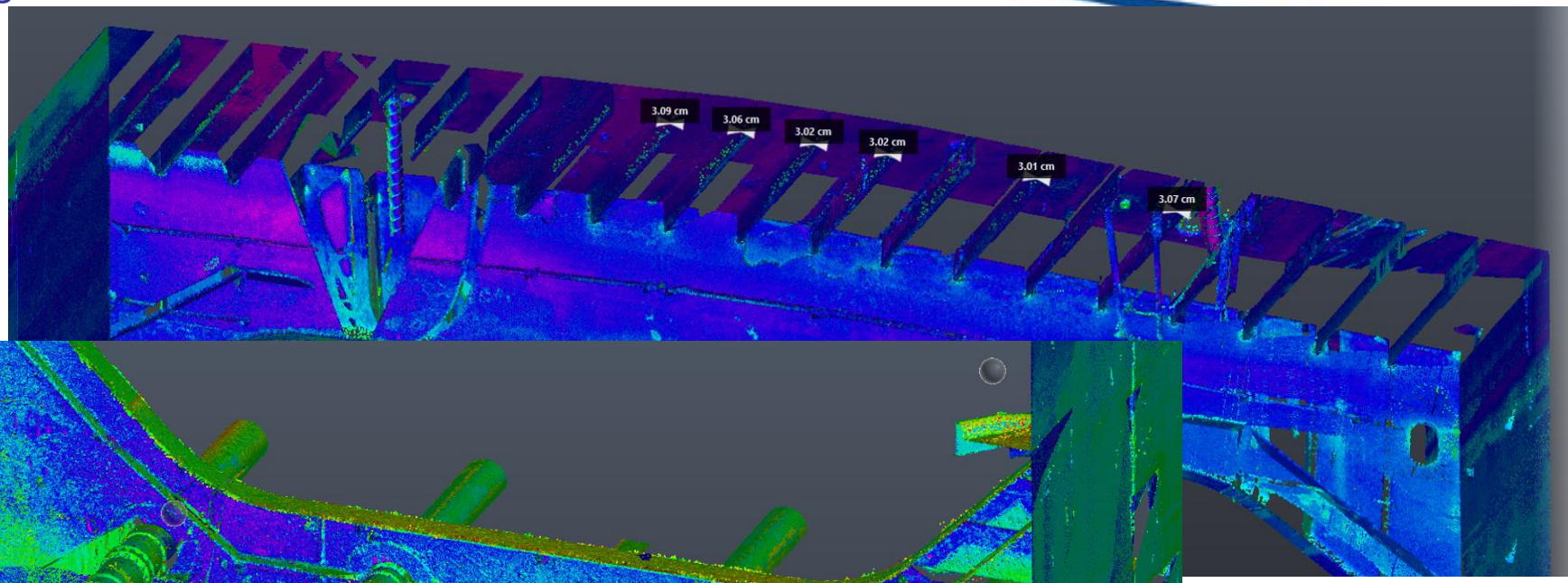

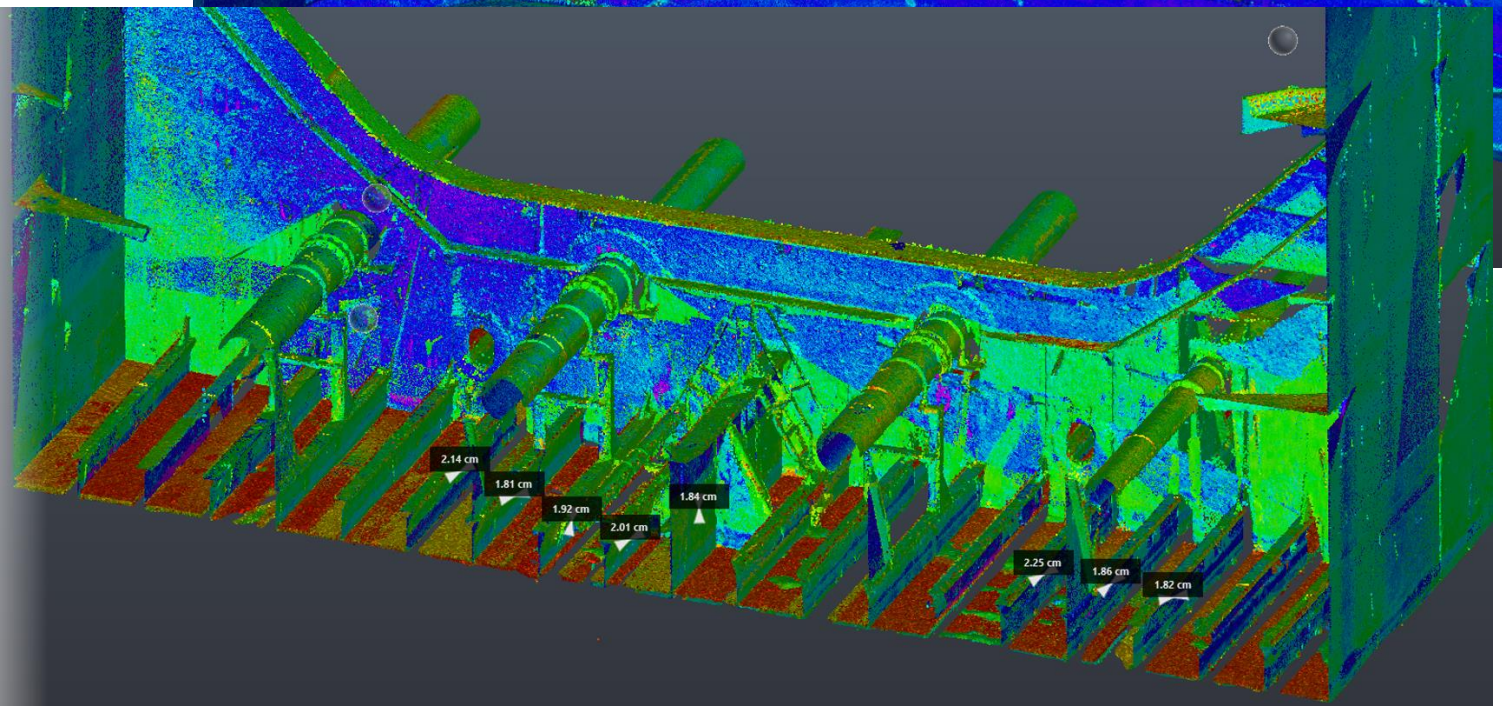

Field Deployment Feedback

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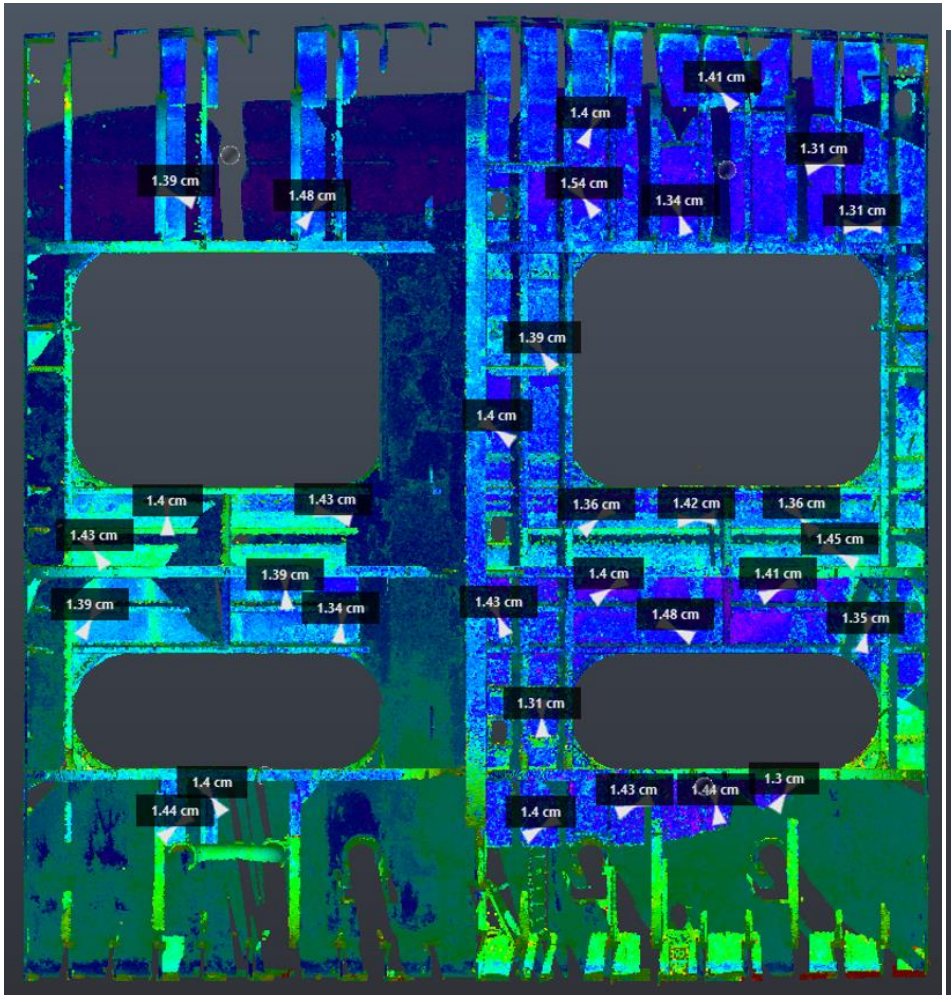

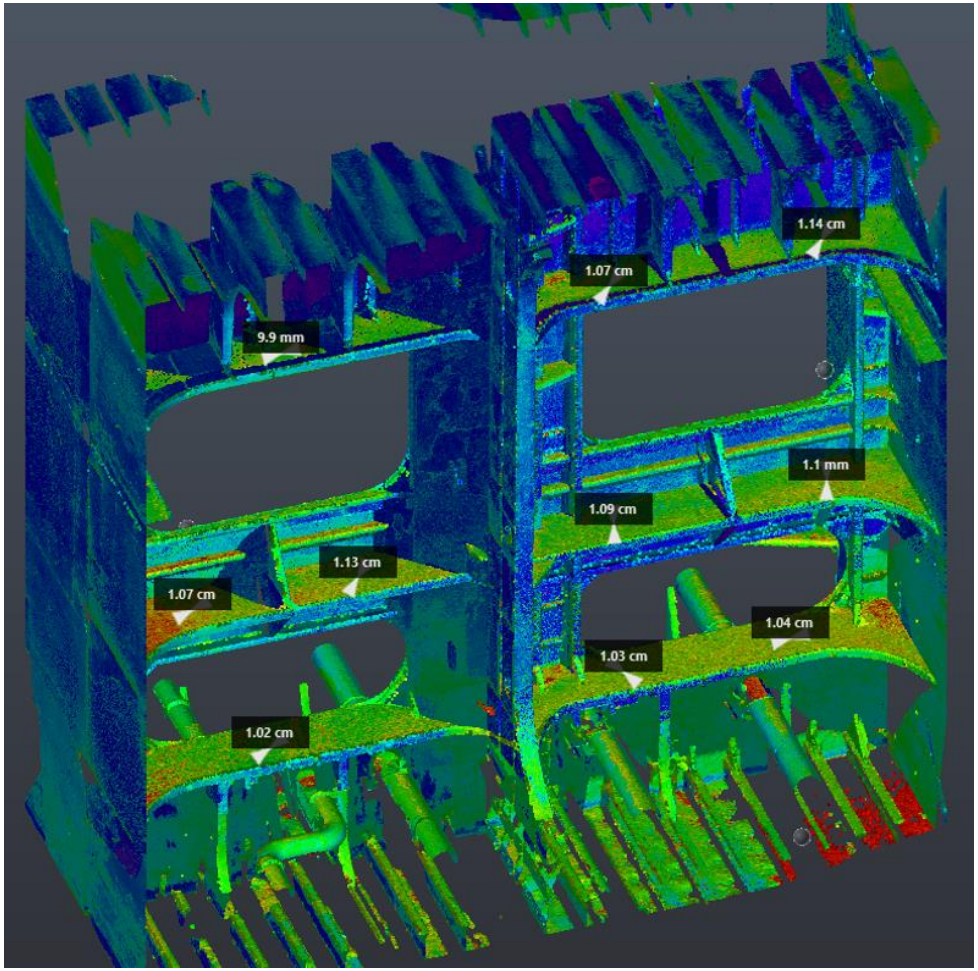

Ongoing Research – HITS 8

The Cleaning Challenge

We can't 'bury our heads in the sand' on this topic.

- No remote inspection techniques (or even manned techniques) can look through sludge
- Labour intensive
- Requires manned entry
- Dangerous

Ongoing Research – HITS 8

The solution will be robotic