



## 3D Core Kits™

For Corecell™, PVC and  
PET structural foam core







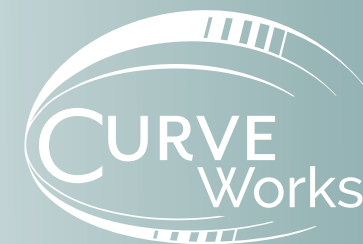


● countries served to-date

#### Curve Works

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The Netherlands  
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Curve Works BV is a privately held company founded in 2015. Located in Alphen aan den Rijn, The Netherlands, we supply products for architecture and high-end performance marine applications to an international customer base.



We offer the world's first 3D thermoformed structural foam core kits including chamfered edges and cut-outs. We do this using our fully automated adaptive mould and unique infrastructure to create all the shapes required for your build.

We have replaced traditional core laying methods with a new approach: curved structural core kits, with spring-back correction, enabling a much faster, and therefore lower cost of, installation.

Our 3D Core Kits™ take up less resin, thereby significantly reducing weight and improving mechanical performance of the structure. The 3D Core Kits™ are therefore key for high performance and eco-conscious boat builders.

The Curve Works team consists of very skilled and competent technicians that take a lot of pride in delivering the perfect Kit, on time. Our customers are returning customers and have abandoned traditional structural foam laying methods. We intend to continue living up to our reputation.



*The 3D Core Kit™ is certified according to Bureau Veritas Marine & Offshore Mode II Scheme*





## 3D CORE KIT™ FEATURES

- 3D Core Kits™ are offered for PET, PVC or SAN (Corecell™) structural foam core.
- Full sheets are thermoformed whenever possible to the required geometry, even in complex highly curved areas.
- In-plane tolerances are within +/- 1.5 mm, out-of-plane tolerances within +/- 3 mm.
- Radii of curvature as small as 250 mm are thermoformed on the adaptive moulds.
- Dedicated moulds are manufactured for areas with smaller radii, if required.
- Chamfers and cut-outs are implemented where required.
- Trimmed, labelled and supplied with easy-to-read core map, reducing build time and labour cost.
- Bureau Veritas Certification for 3D Core Kits™ from Curve Works



## *3D Core Kit™ Benefits*

Faster Installation

Lower weight

Maximum performance

Responsible manufacturing



# FASTER INSTALLATION

## Improve efficiency and claim back factory space

Our 3D Core Kits™ are supplied ready for installation with millimeter accuracy, corrected for spring-back, features-marked and identification-labelled. An installation core-map and procedure is included making installation clear for the builder to follow.

Compared to on-site thermoforming at the shipyard, core-installation is reduced by a factor 5. One week, for example, is reduced to one day.

Installation time is saved compared to that of 2D kits as well, because each panel in our 3D Core Kit™ fits in place in only one way. The amount of time saved also depends on the type of cuts (double-cut, contour-scrim, etc.), the different densities and thickness of core required in the hull, the curvature variation and the process (vacuum infusion or prepregging).

In practice, when comparing 2D kits to 3D Core Kits™, the time saving of the core-installation ranges from:

- 15% for >65 ft prepreg monohulls
- 50% for vacuum-infused multihulls
- > 60% when 2 layers of core are replaced by 1 curved sheet of equivalent thickness

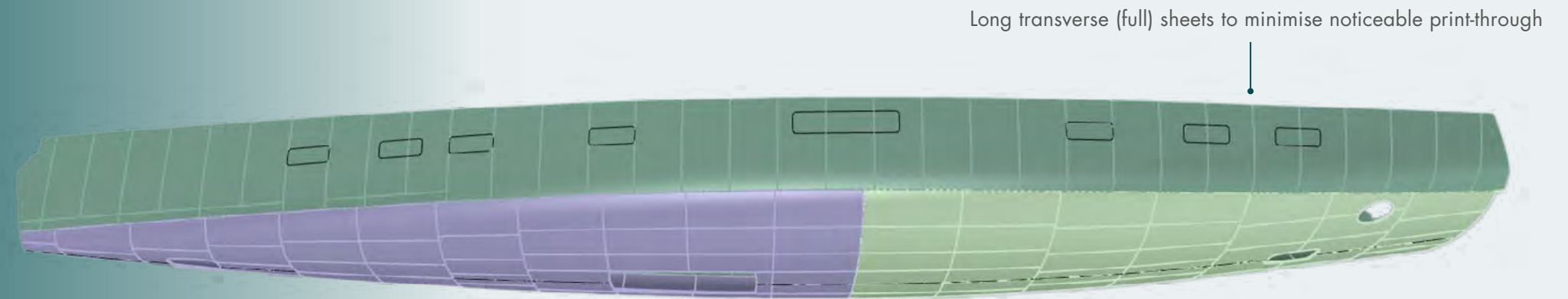
There are more opportunities that 3D Core Kits™ have to offer concerning the installation:

### Single-shot vacuum infusion process

the excellent shape conformity of the thermoformed panels provides the opportunity to skip the 3-stage infusion process (inner skin -> core bonding -> outer skin).

### Reduced risk on reaching prepreg out-life:

faster installation on the core leaves more time for working with the prepreg.





# LOWER WEIGHT

## Enabling Lighter & Faster Boats

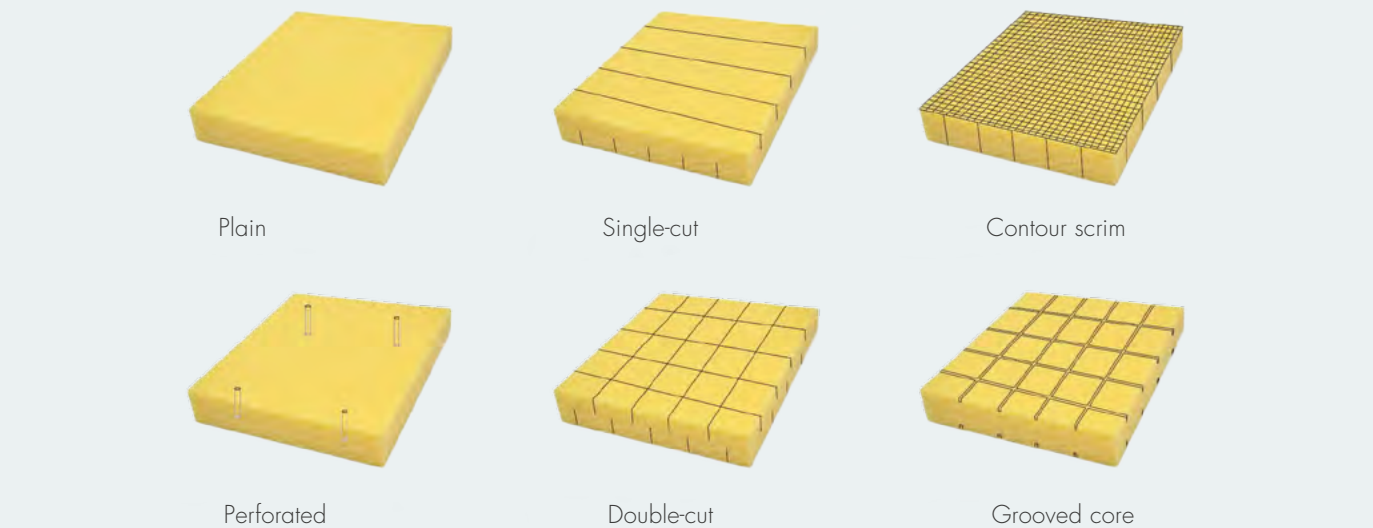
Thermoformed kits provide the lightest solution. To quantify this, Curve Works has developed and validated a resin-uptake calculator which is available on the Curve Works website. This tool compares resin uptake for cores with different types of finishing, thicknesses, radii of curvature and core material.

### Resin-uptake calculator: Thermoformed core versus double-cut Corecell™

The graph on the below right shows a comparison between perforated thermoformed core (TF), and flat double-cut core (DC). Real samples were vacuum-infused to verify the results of the calculator.

The test and calculator show that the resin-uptake for 20- and 30-mm double-cut core increases by 1.4 and 1.5 kg/m<sup>2</sup> respectively.

Saw-cut cores, used for high-density and/or 40+ mm thick cores, results in resin-uptake nearly 5 times higher than that of thermoformed perforated core.



Different types of finishing that have been incorporated in Curve Works’ resin-uptake calculator







Another major opportunity of weight saving is that customers no longer need to consider 2 layers of core for core thicknesses of 35+ mm. Curve Works thermoforms full core thicknesses, up to 50 mm.



Above: a thermoformed single layer of 40mm Corecell™ M130 for the bow area of a super yacht

Extrapolating the weight savings, using 3D Core Kits™ reduces the displacement of high-end composite yachts ranging from 1% ( for monohulls) to 5% (fast catamarans)



# MAXIMUM PERFORMANCE

## Shaped core that is as good as virgin material

The classification agencies recognise that high shear-elongation foams perform better under slamming loads than brittle cores.

In their design rules for high speed and light craft, DNV GL prescribe that the shear fracture elongation is at least 20%<sup>1</sup>. Similarly, the American Bureau of Shipping (ABS) has adopted even stricter rules and prescribe as shear fracture elongation of at least 40%<sup>2</sup>.

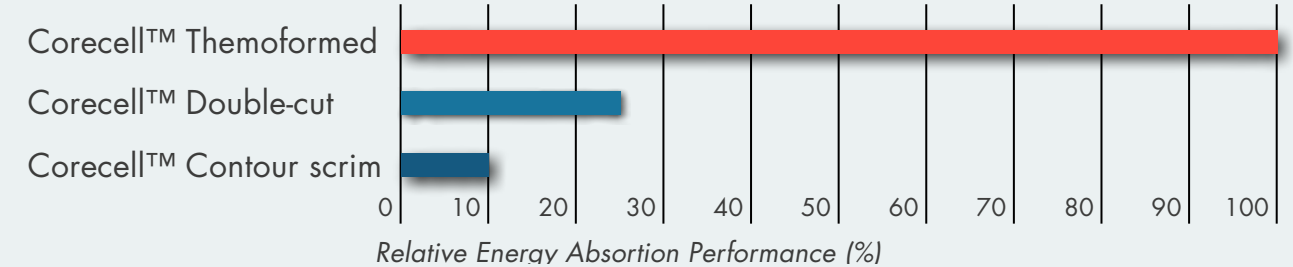
The slamming performance is heavily deteriorated by fully cut and scored core (i.e. contour-scrim, single-, double- and triple-cut) because the cuts significantly impact the energy the core can absorb.

Gurit and the University of Auckland<sup>3</sup> showed that:

- the slamming performance diminishes by approximately 75% when using scored core
- thermoforming SAN-foam has no effect on the static and dynamic mechanical properties of the foam

For contour-scrim, the shear elongation is entirely dominated by the filled resin cuts which means that ductile cores are reduced to performing as brittle cores.

Thermoforming is the process of choice to fit the core in the forward slamming areas that are typically curved.



Comparison of energy absorption performance between thermoformed, scored & cut core. Dynamic testing by University of Auckland Centre for Advanced Composite Materials<sup>3</sup> confirmed that thermoformed core can absorb the same level of dynamic energy as virgin material.

For core thicknesses of 30 mm or more, Curve Works advises to replace contour scrim Corecell™ or PVC-foam with a 35-50% higher density thermoformed cost-effective PET-foam. In this case the weight is equal or less, the mechanical performance & costs identical and the build-time & environmental impact of resin-uptake reduced.

<sup>1</sup> High speed and Light craft,, Part 3, Ch. 4, ed. 2015

<sup>2</sup> High Speed Naval Craft, Part 3, July 2019

<sup>3</sup> Quantitative dynamic energy absorption of sandwich core material, Basset et Al.



# RESPONSIBLE MANUFACTURING

## For eco-conscious boat builders and their clients

The environmental benefit of reducing the resin uptake by using 3D Core Kits™ is significant. When considering the building phase, every kilogram of epoxy or vinylester the boat builder saves results in a carbon footprint saving of 6 to 7 kg according to the EuCIA ECO Impact Calculator<sup>1</sup>. This is an equivalent of combusting 2 kg of gasoline.

When considering the operational phase, thermoformed core reduces the displacement of high-end builds ranging between 1-5%, corresponding to a fuel saving of 1-5%. Depending on the type and use of the boat, this results in hundreds to thousands of litres of fuel saving over a lifetime.

As an example, consider a 3D Core Kit™ for a monohull of 350 m<sup>2</sup> with a core-thickness of 40mm.

**Replacing this 3D Core Kit™ with a 2D kit would result in an additional resin uptake of 1000 kg; an equivalent of a 1% displacement saving and an equivalent of 2000 kg saving of combusted gasoline during the build phase.**

Using a 3D Core Kit™ is a very economical way in cutting greenhouse gas emissions, both during the build and operational phase and positively contributes to the climate goals.



<sup>1</sup> <http://ecocalculator.eucia.eu>



## *3D Core Kit™ Pricing*

Our pricing strategy

Lower installation costs

Lower resin costs



# 3D CORE KIT™ PRICING

## OUR PRICING STRATEGY

Our transparent pricing for 3D Core Kits™ is not assessed by the amount of square metres but by:

- the minimum amount of panels that need to be thermoformed, trimmed & marked
- The length-metres that need to be chamfered.
- The fabrication of manual moulds for thermoforming curvatures that are outside the range of our adaptive moulds, e.g. the first length-meter of the bow area of a sailing yacht.
- The number of CNC-machined nested panels that are used for sea-cocks, rudder bearings, windows and other features.

New clients seem to be surprised when receiving our quotation for their build. After serving multiple customers and thermoforming more than 3500 m<sup>2</sup> of core kits, we have not yet come across a shipyard that had full insight into the cost of their current core-laying method. Therefore we have run cost-analyses together with our customers.

When comparing our 3D Core Kits™ to traditional thermoforming methods at the shipyard, it is concluded that the traditional thermoformed core laying method cannot compete with the efficiency and quality of our process.

When comparing our 3D Core Kits™ with 2D kits, the purchase of a 3D Core Kit™ is typically 60-80 €/m<sup>2</sup> more expensive. The actual price difference is lower as a result of secondary benefits:

## LOWER INSTALLATION COSTS

- The savings in installation costs range from 7 €/m<sup>2</sup> to 30 €/m<sup>2</sup>. The savings are very dependent on the curvature of the boat, the type of core considered (thermoformed vs. double-cut vs. contour-scrim) and the process chosen (prepreg vs. vacuum infusion).

## LOWER RESIN COSTS

- For vacuum infusion: an epoxy-saving of approximately 8 €/kg. This gives a cost-saving ranging from 11 €/m<sup>2</sup> (20 mm core) to 30 €/m<sup>2</sup> (40 mm core).
- For prepreg: an adhesive-film saving of approximately 50 €/kg. The cost savings are so significant that 3D Core Kits™ already pay themselves back.

### In other words:

- For vacuum infusion: the 3D Core Kit™ is on average 35 €/m<sup>2</sup> more expensive than a 2D kit. For prepreps: a 3D Core Kit™ is more cost effective than a 2D kit.

Finally, 3D Core Kits™ should always be considered to replace 2 layers of core since 1 thick curved sheet (up to 50 mm) will always be more lightweight and more cost-effective.





## *3D Core Kit™ Service*

Engineering

Manufacturing

Packaging and shipment

Installation



# 3D CORE KIT™ SERVICE

## A ENGINEERING

Customer sends 3D drawing of hull/surface

Curve Works splits hull into panels:

- Optimised for minimum core waste
- Optimised for a minimum amount of panels

The core layout is generated & run through with customer

Panel shape, density & thickness is analysed and thermoforming temperature, time and spring-back correction is determined

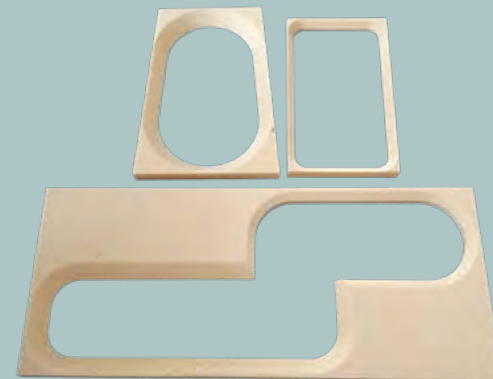
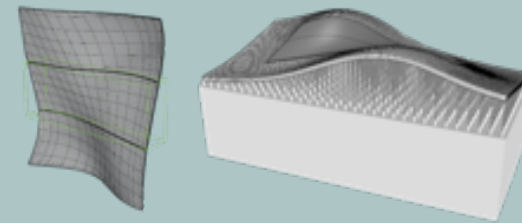
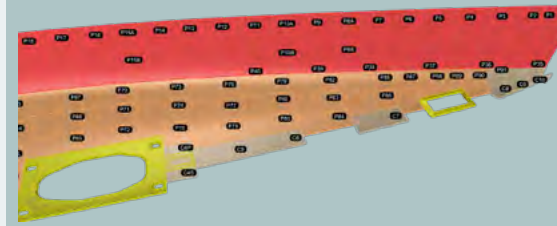
Output files for adaptive mould are generated, including:

- 3D geometry of the mould surface
- Laser projections of panel edges, cut-outs and reference lines

CAD-engineering for CNC-machined inserts and manual mould(s) is prepared & send to CNC-partner

Core-installation map and procedure is generated & communicated to customer

Structural foam core is ordered by Curve Works or by customer



## B MANUFACTURING

Full and partial sheets are thermoformed on adaptive and/or manual mould according to the processing window defined by the material supplier

Panel edges, cut-outs and reference lines are marked.

Dimensions are checked, and curved sheets are cut and/or chamfered to mm-accuracy using Curve Works' in-house developed tooling

Panels are labelled according to core-map

Inserts and other features are CNC machined and labelled according to core-map





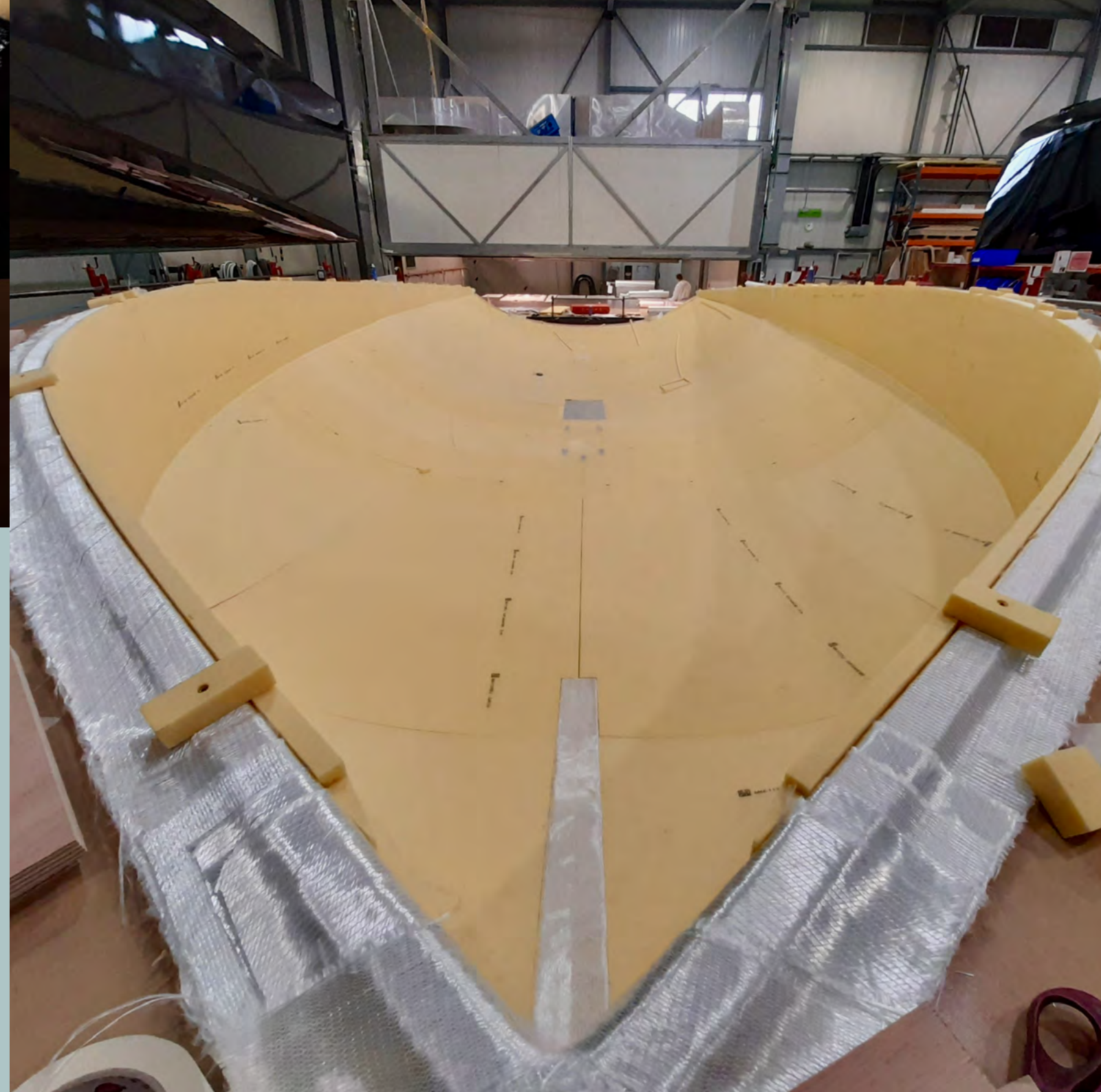
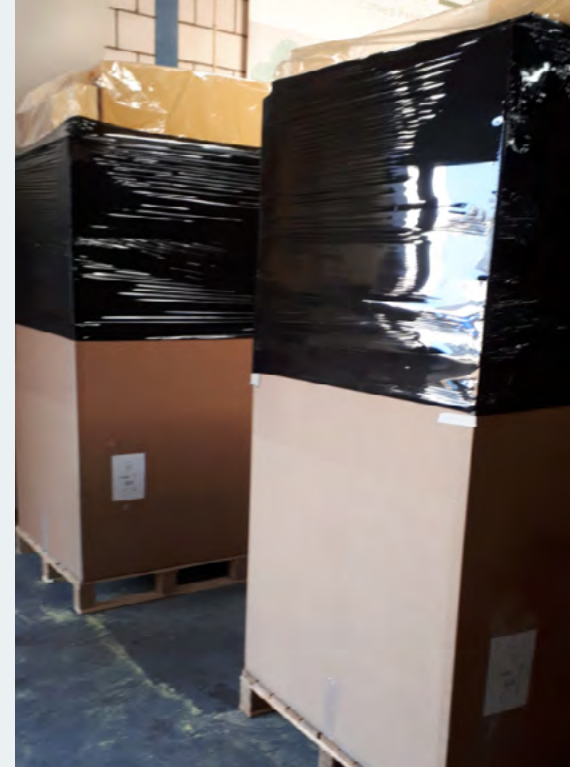
## C PACKAGING AND SHIPMENT

3D Core Kit™ is packaged in large cardboard boxes mounted on pallets as the lightest most sustainable solution

A packing list is provided with the names of each panel in the box.

3D Core Kit™ is sent on collated lorry transport unless dedicated courier is requested

Unused core sheets are returned with the 3D Core Kit™ at the customer's request

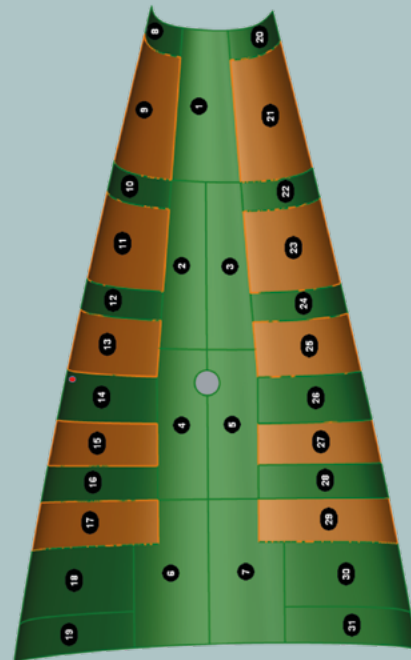


## D INSTALLATION

The 3D core map is provided to the customer

A work instruction is provided on the core fitting procedure.

Curve Works offers physical support on the installation as an optional extra





# 3D CORE KIT™ EVOLUTION

- 2015 Foundation Curve Works.
- 2017 Curve Works infrastructure up and running and operational.  
Curve Works supplies the first 3D Core Kit™ for a new-build; the prize-winning Rán Fast 40.  
Curve Works supplies a total of 180 m<sup>2</sup> of 3D Core Kits™.
- 2018 Curve Works revamps the core-kitting process & service. Large high-end yacht builders engage with our core-kitting services and Curve Works supplies 790 m<sup>2</sup> of 3D Core Kits™.
- 2019 Placed in the top 100 most innovative companies of 2019 by the Dutch Chamber of Commerce for the 3D Core Kit™ solution.  
Curve Works improves on the success of 2018 and supplies more than 2,000 m<sup>2</sup> of 3D Core Kits™.
- 2020 Curve Works puts a new adaptive mould & oven into operation dedicated for 3D Core Kitting.
- 2022 Curve Works gains *certification according to Bureau Veritas Marine & Offshore Mode II Scheme*
- 2023 Launch of 3D Core Kits™ for PVC structural foam



1. 2017: The prize-winning Rán Fast 40
2. 2018: Presenting 3D Core Kits™ for the first time at the JEC World 2018
3. 2019: A special highly curved core-kit for Syra-foilers



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