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MAKING WAVES:
VISUALIZING FLUID FLOWS

WOUT ZWEERS & VALERIE ZWART & ONNO BOKHOVE

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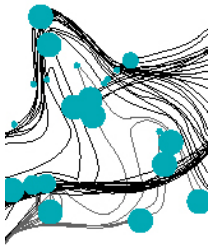
http://www1.maths.leeds.ac.uk/~obokhove



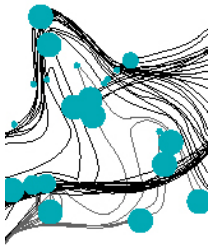
OUTLINE

To create, calculate and predict:

1. Fluid Dynamics & Mathematics (maths):
   - breaking waves on gravel beaches/a slice-of-beach
   - Bore-Soliton-Splash: a most extreme rogue wave

2. Wave Sculptures & Design (art):
   - Bore-Soliton-Steel Splash & `time-lapse' sculptures

3. Future Maths & Art:
   - Nano furniture?
   - Wave benches?



1. MATHS: BREAKING WAVES ON A SLICE-OF-BEACH

Built a science demonstration:

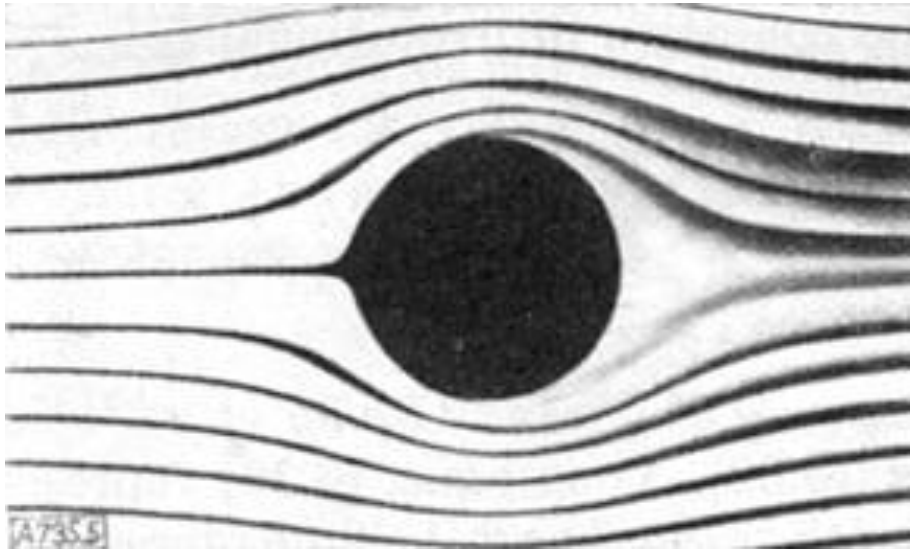
- For the general public in Qua Art Qua Science project Fluid Fascinations by Bokhove, Haveman, Zwart (2010)

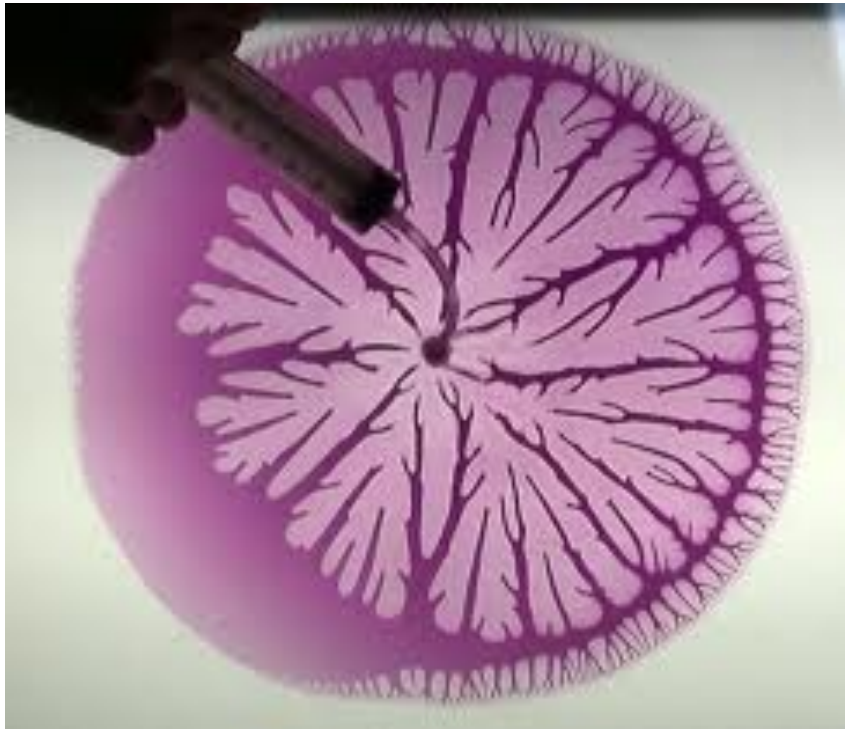
- Goals:
  - public dissemination
  - stimulate new science.

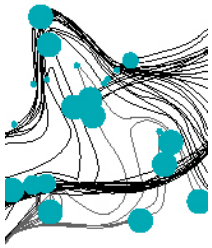
1. MATHS: HELE-SHAW SLICE-OF-BEACH

Classical fluid experiment by Hele-Shaw (1898):

- Visualize fluid flow between two closely-separated glass plates with one liquid/fluid & particle/dye for contrast.
  - Top views:



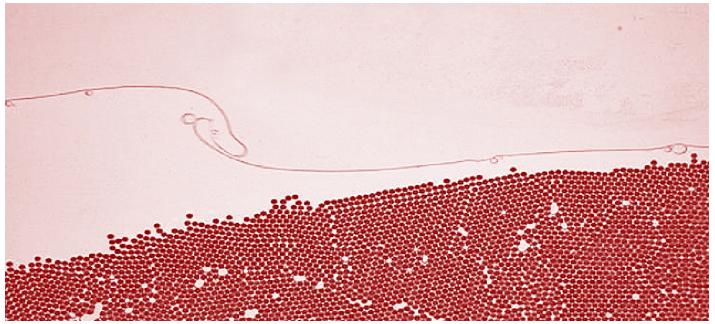


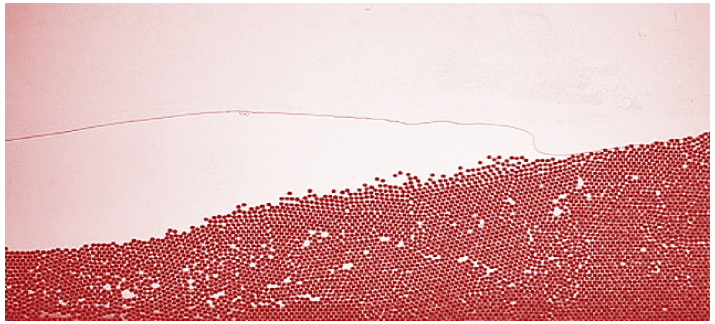


1. MATHS: HELE-SHAW SLICE-OF-BEACH

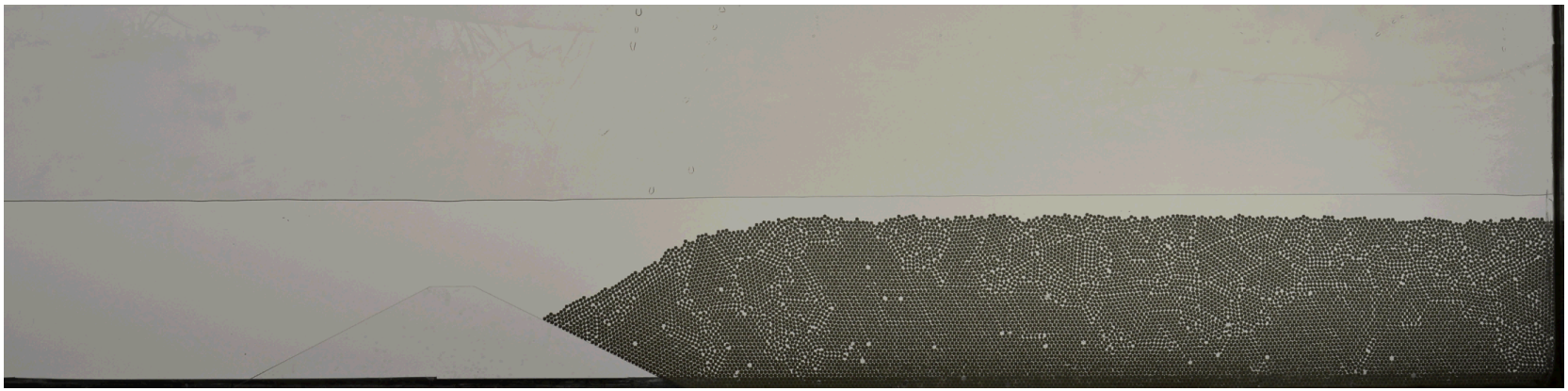
Calculated extension for vertical Hele-Shaw cell:

- with gravel/water/air
- applied mathematics required to estimate gap width
- 4 types of wave breaking (Movie1): *plunging*/collapsing/spilling/*surging*





- berm formation as on shingle/gravel beaches (hidden movie link):

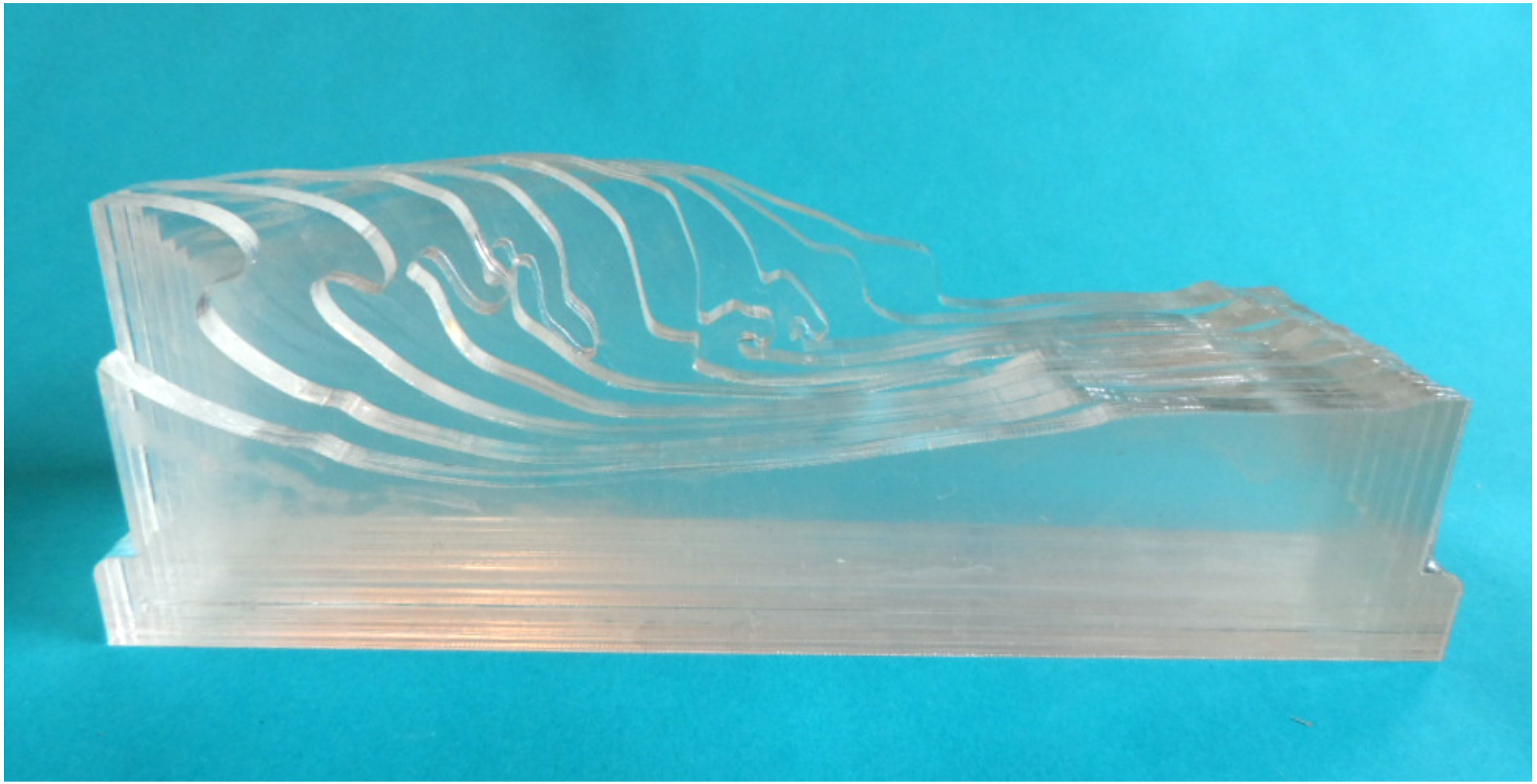


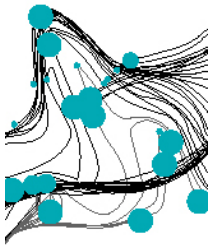
WOODEN & PERSPEX BREAKING WAVES

- Wooden plunging, collapsing, spilling and surging breakers:

WOODEN & PERSPEX BREAKING WAVES

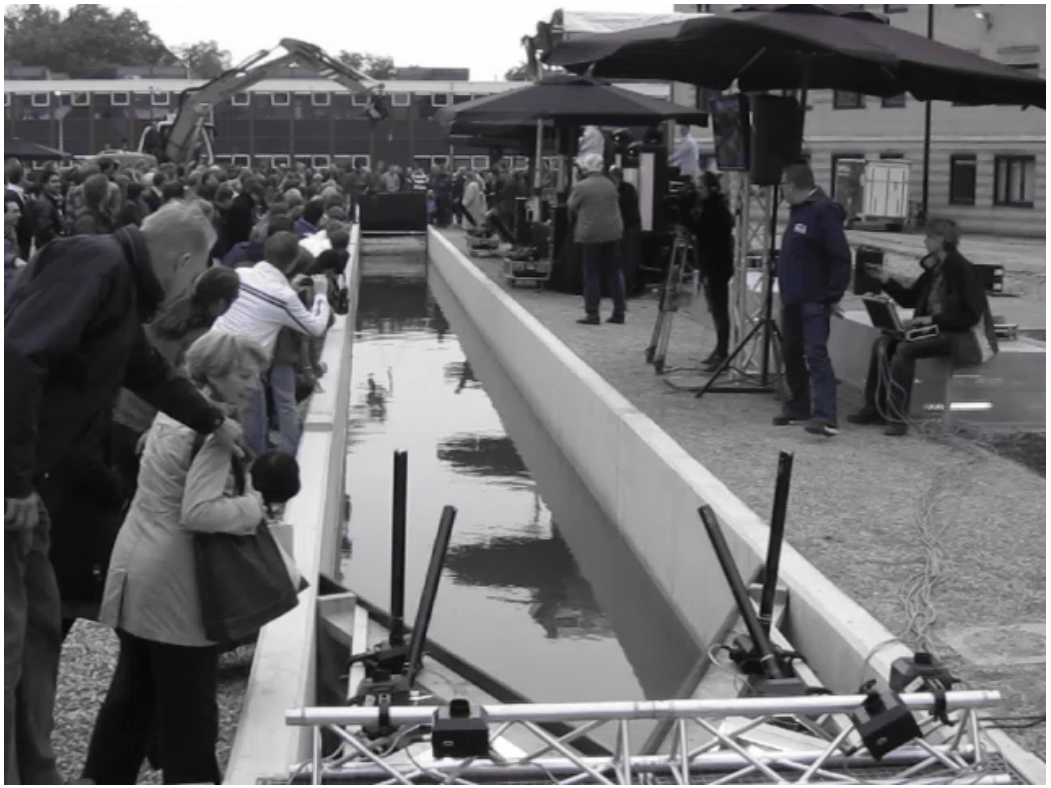
Perspex plunging breaker:



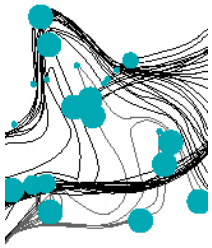


1. MATHS: A ROGISH BORE-SOLITON SPLASH

- Rogue Wave when [relevance to ships at sea]:
  - AI = ('height' rogue wave)/ (mean height ambient waves)>2.2
- Our Bore-Soliton-Splash (Movie2) AI =10 with a 3.5-4m high splash



- Challenge: CFD poorly predicts Splash!



2. ART: BORE-SOLITON-STEEL SPLASH

Aim:

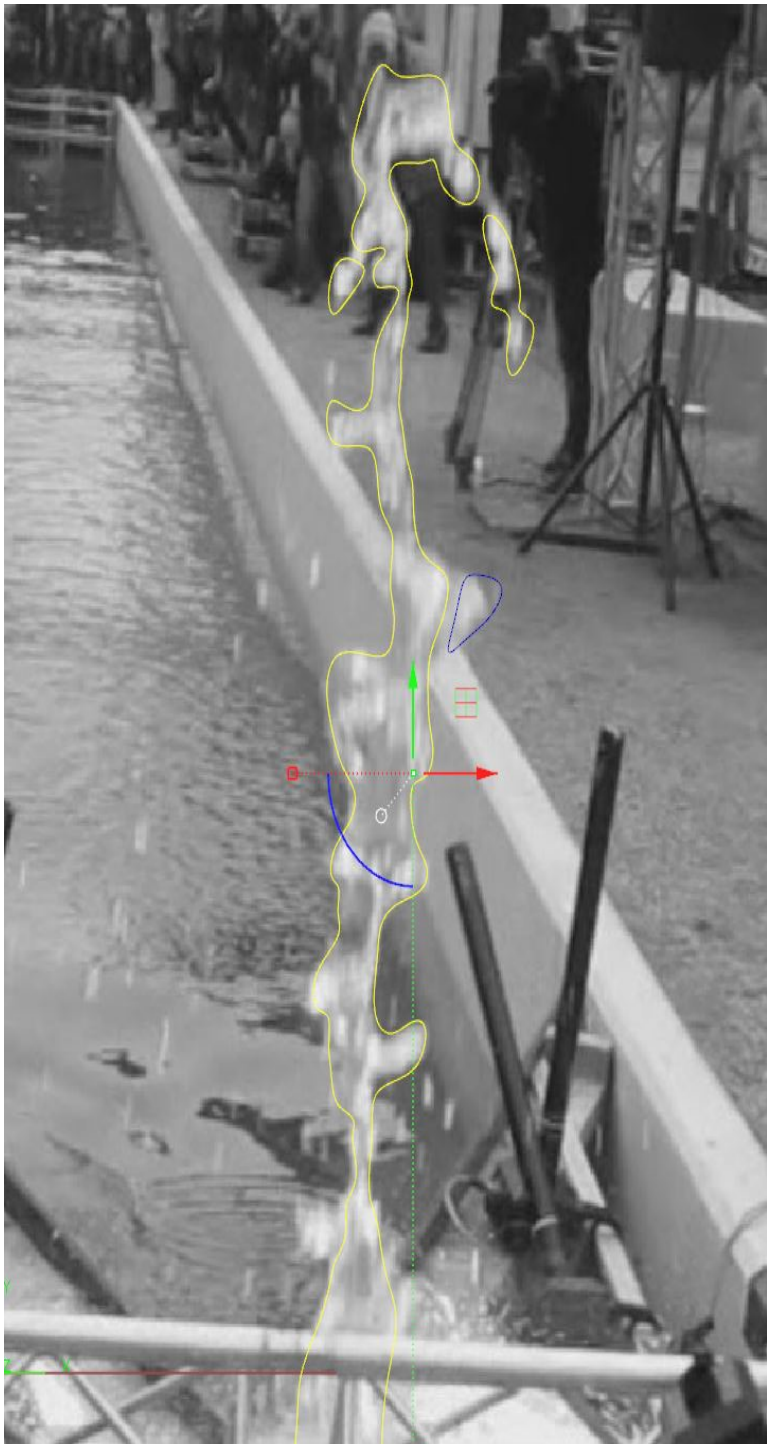
- to make a sculpture starting with the movie of the splash

- Find proper shape through doing various form experiments
- Outlines from chosen set of video stills were traced by hand
- Inspired by the wooden waves from the beach experiment.

2. ART: BORE-SOLITON-STEEL SPLASH

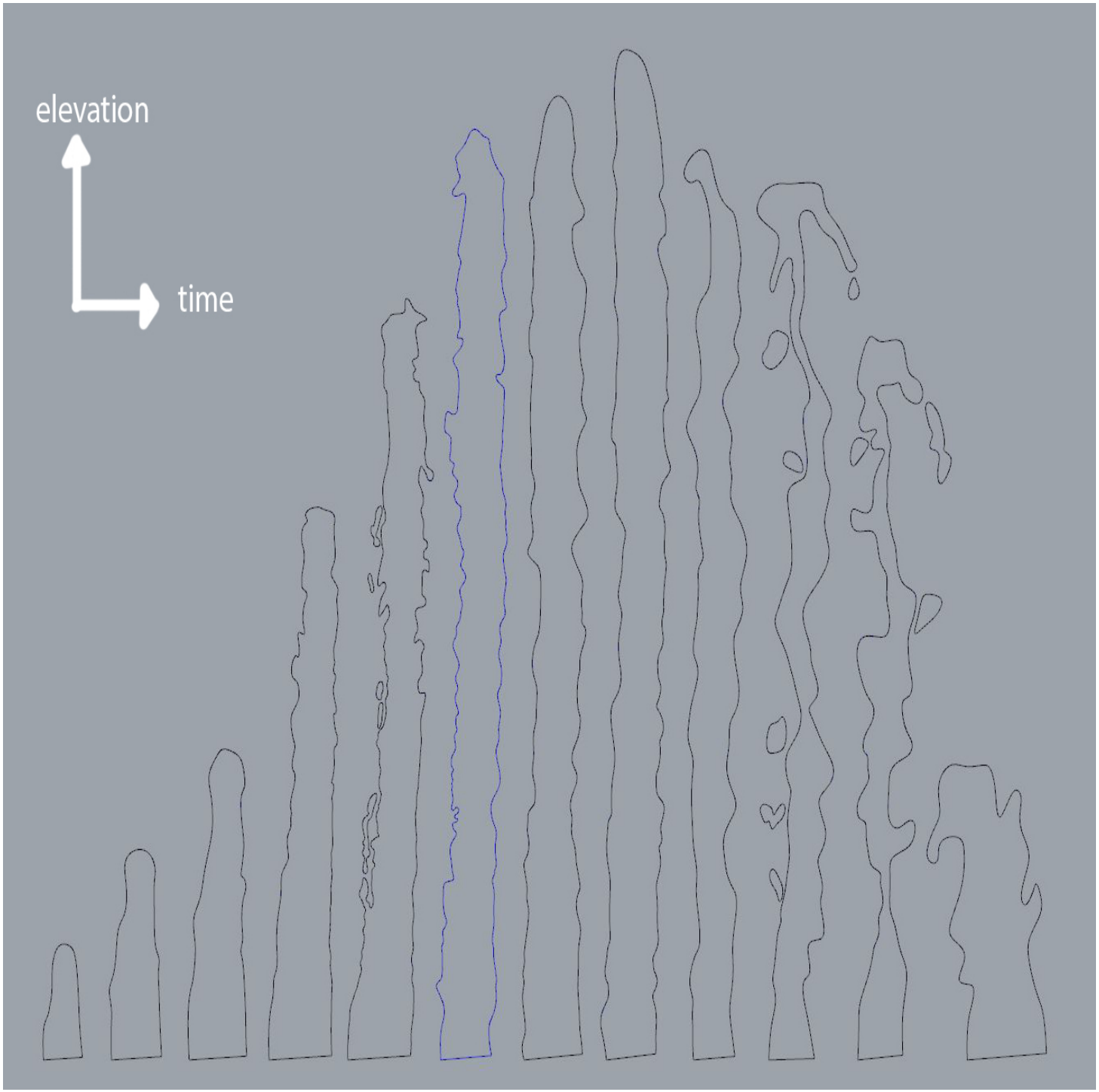
Hand-trace stilled video image in Rhino (CAD):

- Splash-shapes harder to trace than waves due to irregular form
- Shapes simplified
- Mental image how a splash interferes with actual shape
- Solutions, make separate forms of
  - stacked contours wood/acrylic
  - 3D prints of contours
- Change resulting shapes to make them attractive & informative.



2. ART: BORE-SOLITON-STEEL SPLASH

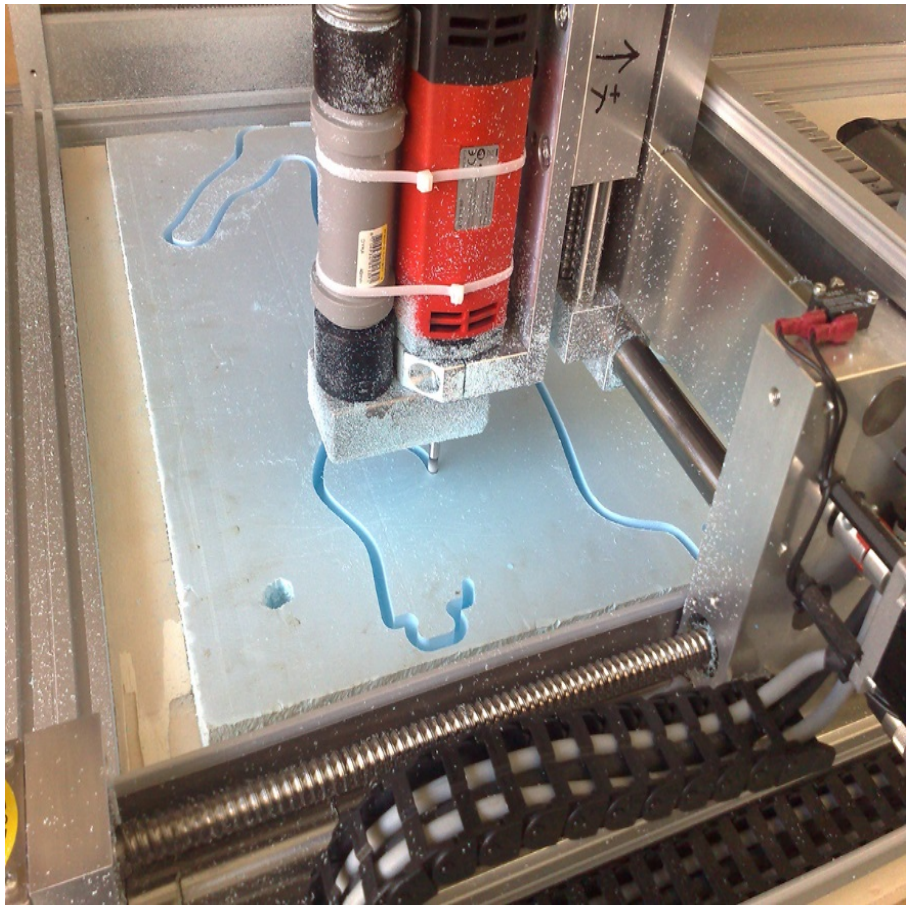
Sequence of tracings:



2. ART: BORE-SOLITON-FOAM SPLASH

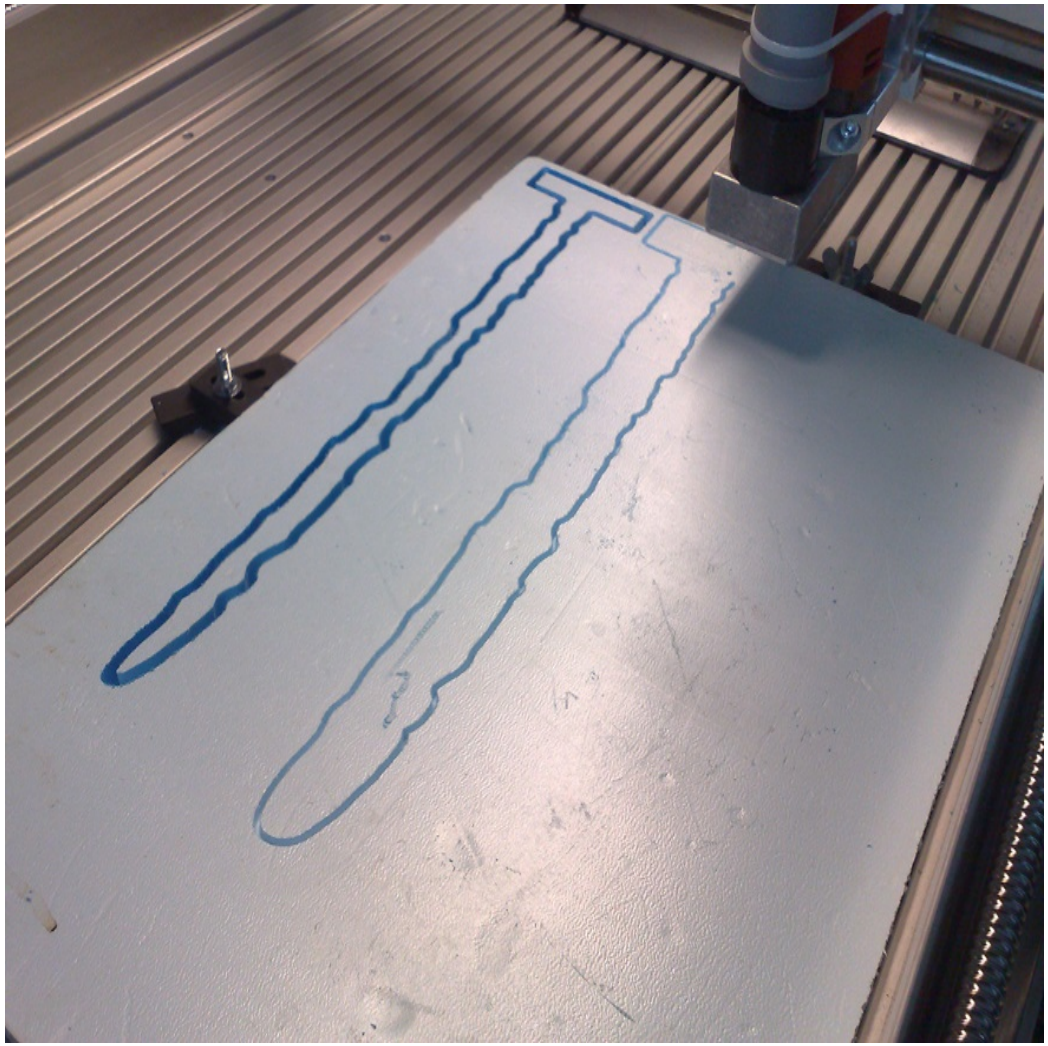
Foam form study:

- a model was made out foam.



2. ART: BORE-SOLITON-FOAM SPLASH

Error resulting in molten foam:



2. ART: BORE-SOLITON-WOOD SPLASH

Sculpture study:

- Model made in wood.

2. ART:
BORE-SOLITON-PERSPEX SPLASH

Sculpture study:

- Model made in plexiglass
- A plexi-glass sheet was cut with the outlines and lit from the side.

2. ART: BORE-SOLITON-PERSPEX SPLASH

2. BORE-SOLITON-SPLASH ART EXPERIMENT

- The whole process is an experiment and investigation into what can be done with a scientific result

- The most surprising results were:
  - the acrylic sheets and
  - the molten foam which reminds us of the fluidity of the original material

- Steel literally reflects the water, just as the necessary simplification of the rounded shapes evokes its fluidity.

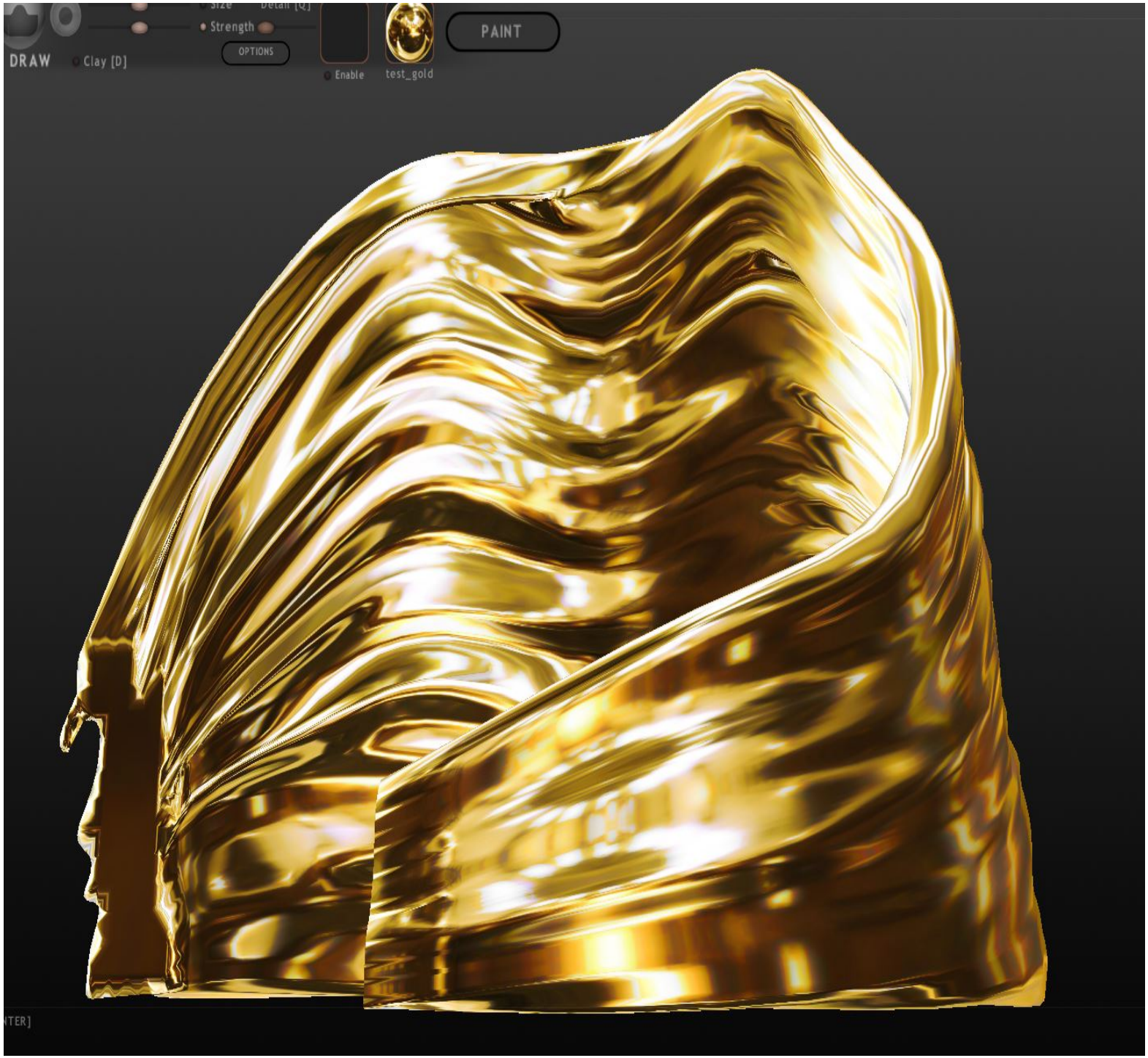
2. ART: BORE-SOLITON-STEEL SPLASH

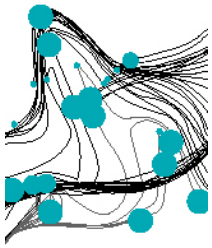
- Hence, smaller 1:3 steel sculpture was made
- A steel sculpture would be a great object to locate at the original spot of the Bore-Soliton-Splash (educational square UT)
- Too ambitious to realize in a couple of months.

2. ART: BORE-SOLITON-SPLASH PRINTS

- A form study using all time silhouettes was made using 3D-printing:
- The accuracy of curves and their use as scientific visualizations are limited
- With a better recording a more accurate visualization will be possible.

2. ART: BORE-SOLITON-SPLASH PRINTS





3. FUTURE MATHS & ART

Future work/requests/discussion?

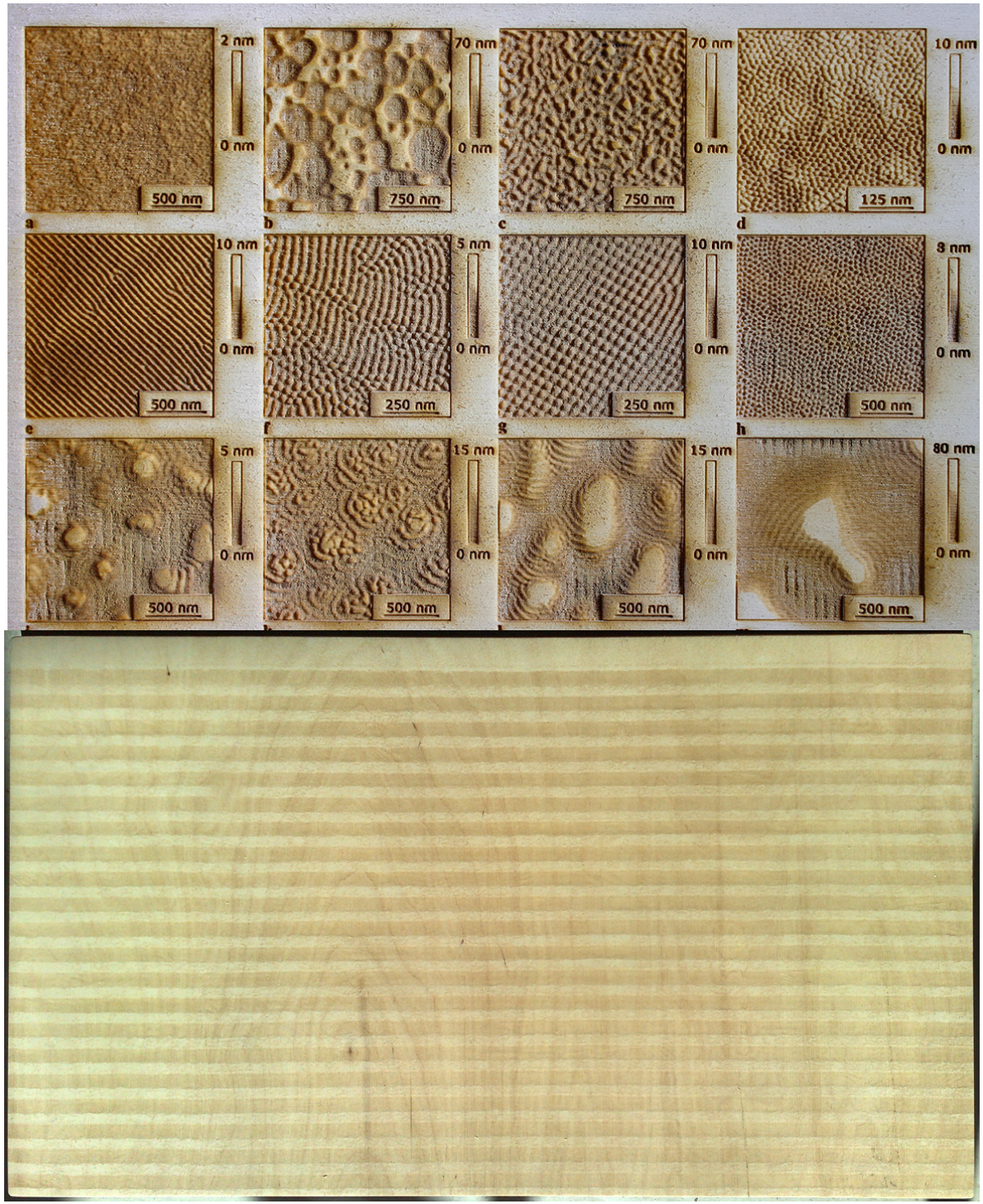
- Maths:
  - analytical & numerical modelling ion-beam sputtering &
  - surface patterns akin to beach patterns

- Fluid Dynamics (OB&WZ):
  - Design & testing of wave energy devices starting this week!

- Art & Design:
  - Nano furniture
  - Wave benches?

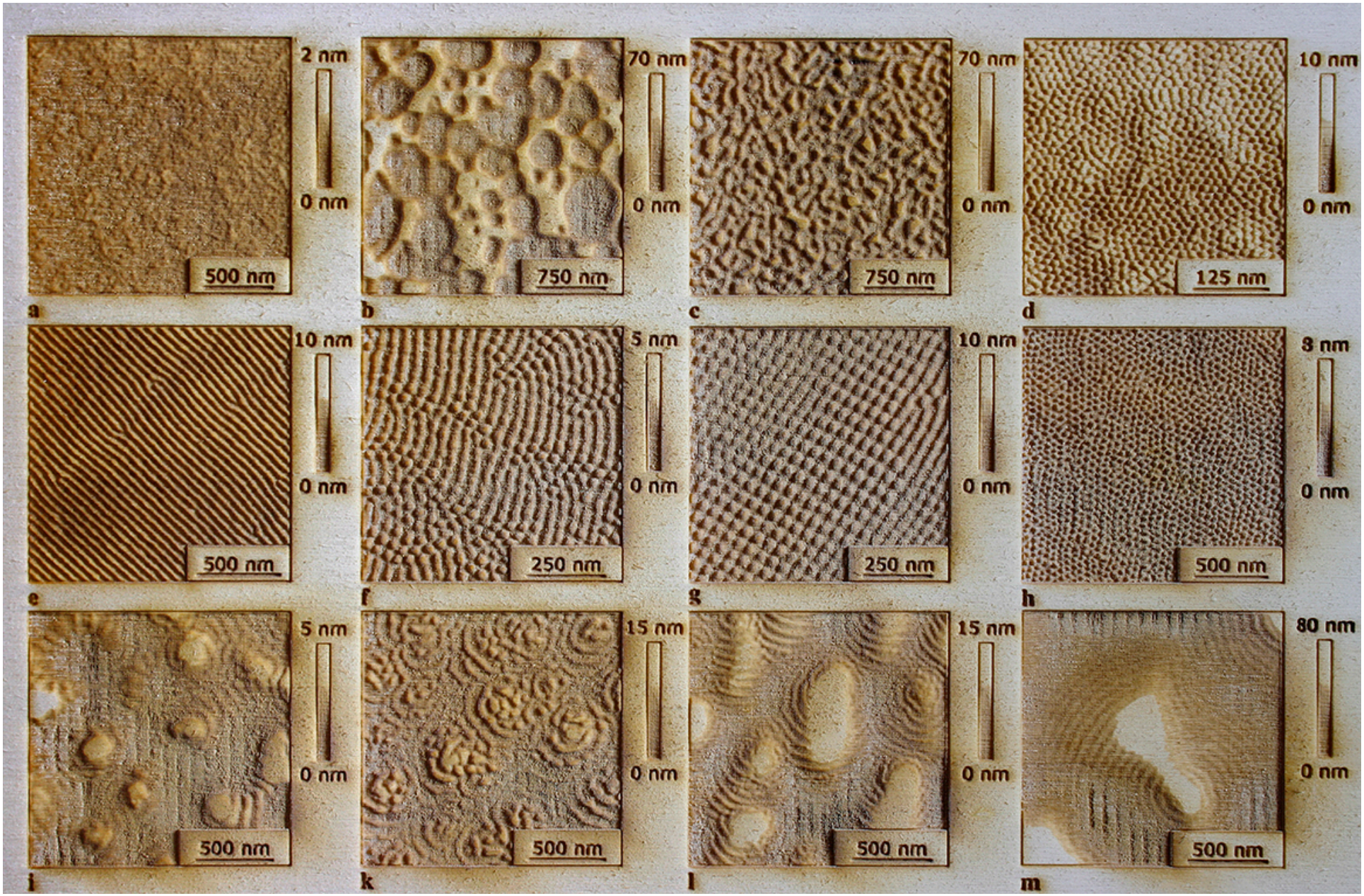
Art & Design?

- From Frost et al. (2000):
- Panels for Fred Bijkerk's new nano lab:
- What happens when we use nano patterns in design?



Art & Design

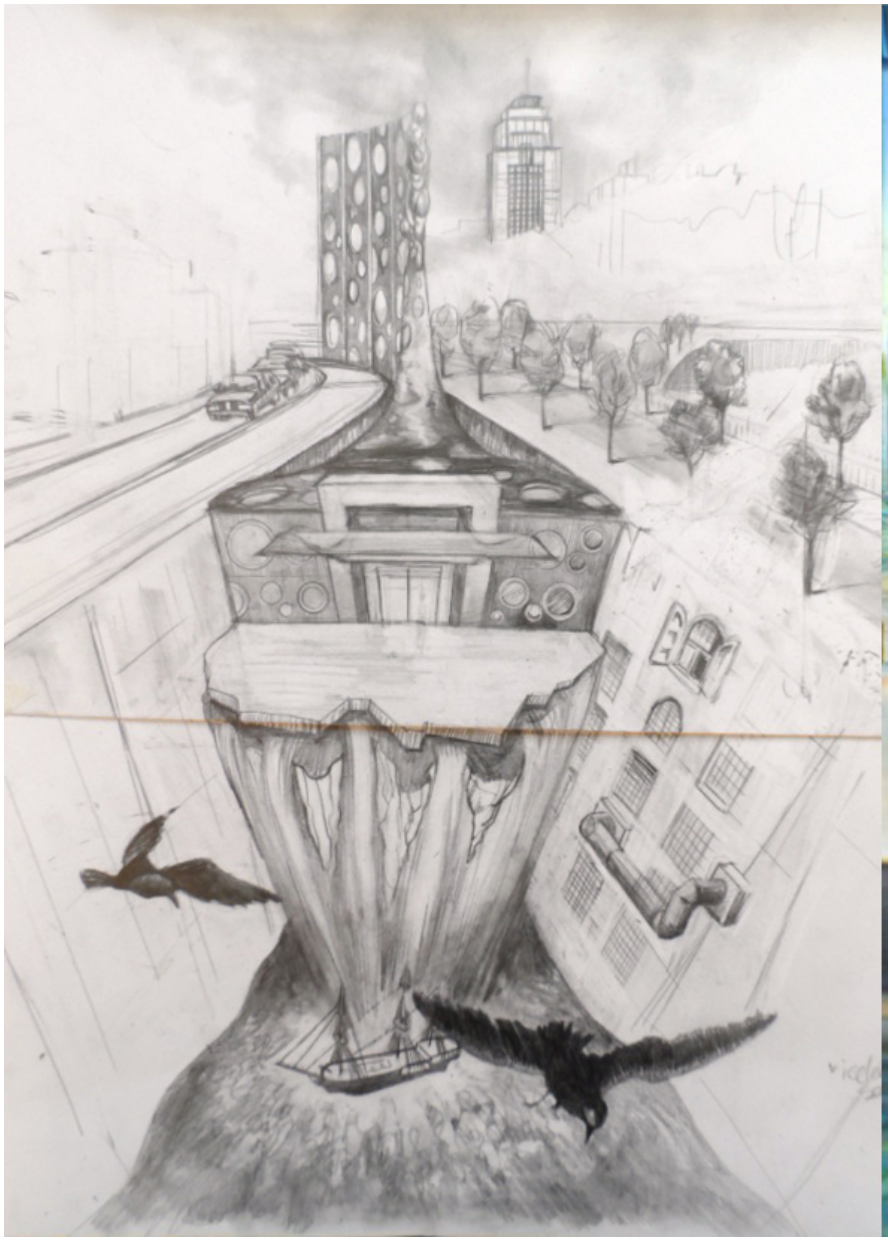
- From Frost et al. (2000):



Art & Design?

- Panels surrounding computer screens for Fred Bijkerk's new nano lab:

Questions?



3. ACKNOWLEDGMENTS

- Art for sale & on display at FabLab
- Aug: Wout Zweers' Rozendaal Studio
- Movie1 wave types:
  www.obardvantwenthe.eu/public/golfbakonno2.avi
- Movie2
  "Soliton splash opening O&O plein UTwente" at:
  http://www.youtube.com/user/woutzweers &
  www.woutzweers.nl/text_2013/SolitonSsplash.html

- Zweers, Zwart, Bokhove 2013: Making waves: visualizing fluid flows. http://eprints.eemcs.utwente.nl/23304/
- Bokhove, Haveman, Zwart 2010: Fluid Fascinations, Qua Art Qua Science http://eprints.eemcs.utwente.nl/17393/
- Kemp 2000: Visualisation. OUP

- Thanks to:
  - late Prof. Howell Peregrine
  - Martha Haveman & Dave Blank, & Pepijn Pinkse
  - Stichting Free Flow Foundation.