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SPOKe

STANDARDIZED PRODUCTION OF KELP

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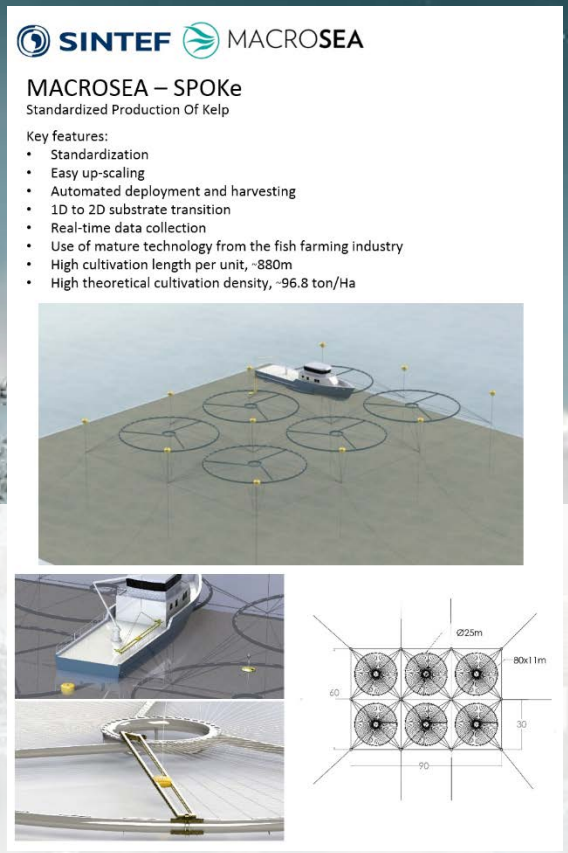


Summer internship, MACROSEA, 2017

Task:

Development of an area-effective concept for seaweed farming, fit for automation

student: Emil Scott Bale (industrial design, NTNU)

timespan: 7 weeks

Automation

- In order to automate, the problems must be simplified
- Simplifications are best fulfilled using standardizing
- Standard solutions gives **standard equipment**
- Modules, redundancy, focus of development costs:
  - Initially, one costly robot might be developed, maybe not ten

Industrialization and large scale

Large scale seaweed industry demands new methods

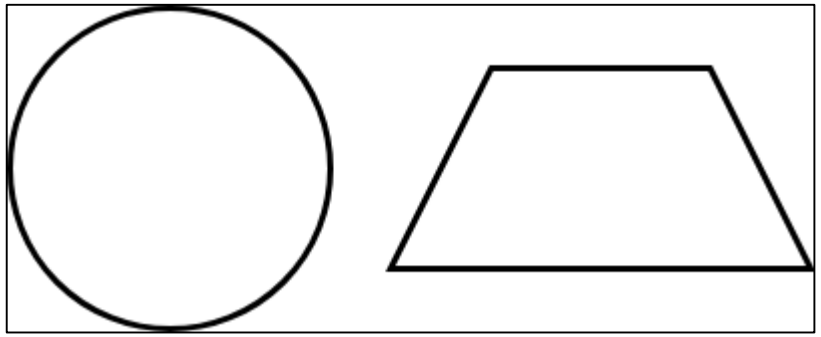
Areas of focus:

- Area
- Scalability
- Automation

This was the tasks background. Focus was held on technical aspects. Limiting parameters were reduced to area utilisation and light.

Choice of deployment module

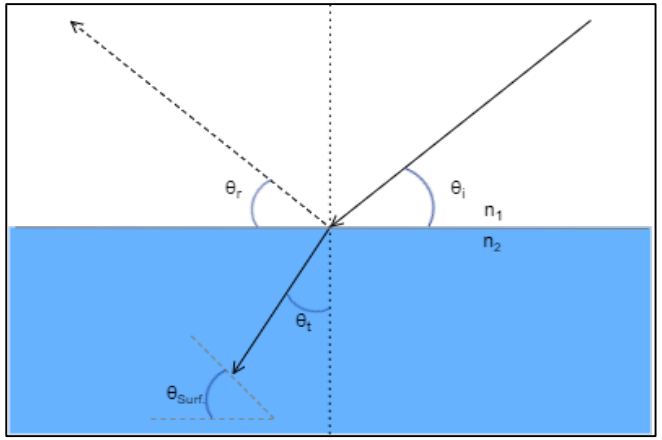
- Two geometrical shapes were evaluated:
  - Disk (2D)
  - Frustum (conical trapezoid - 3D)



- Both shapes are circular variants; frustum is built of two circles with different diameters
- High mechanical strength (no corners)
- Gives the opportunity to utilise 1D substrate in a 2D or 3D form for light coverage, and back to 1D for simplified harvest

Utilisation of light

- Hypothesis: Frustum gives better light utilisation compared to disc
- Calculations included average angles of the sun, refraction index, seawater refraction, and reduced PAR in water column



Utilisation of light

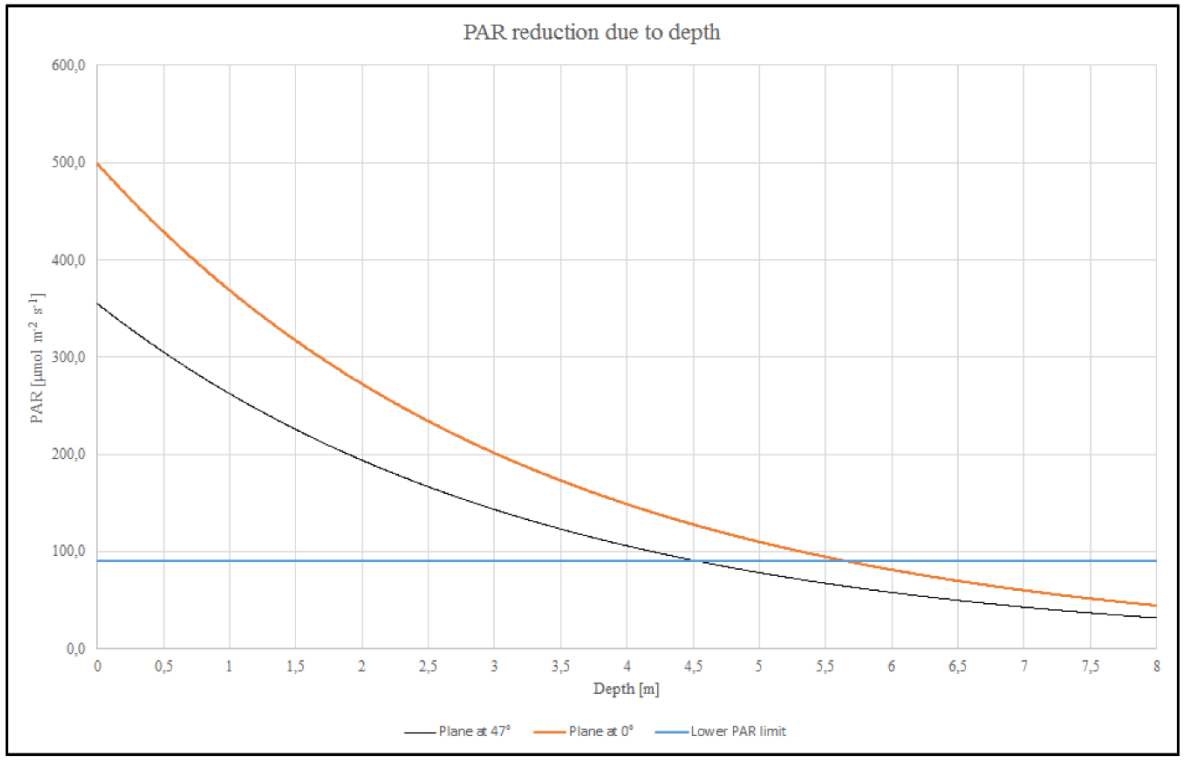
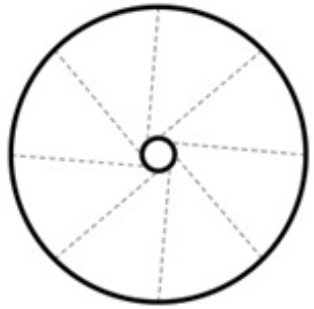
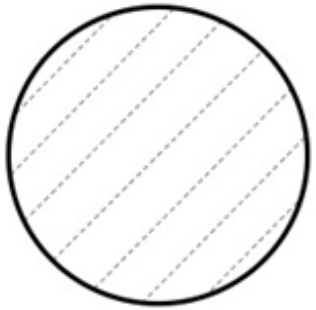
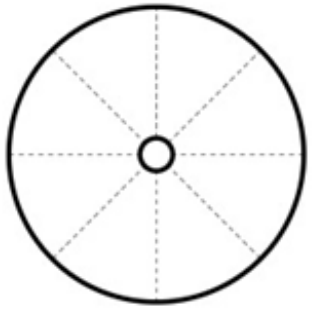
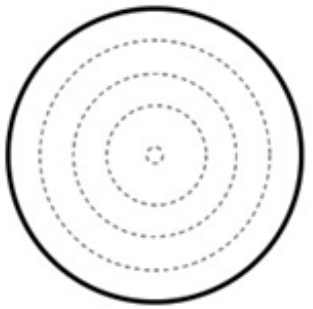


Figure 12 - Reduction of PAR as a function of depth

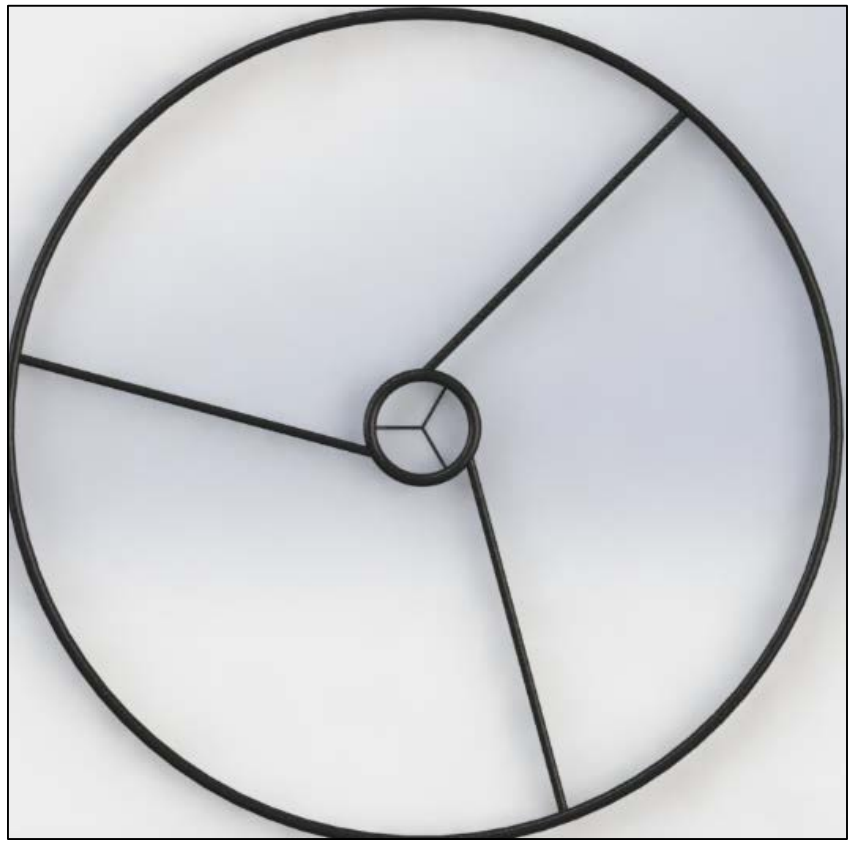
- Conclusion:
  - Frustum does not give an increase in average light influx, despite optimal angle on module
  - The 3D structure of a frustum is more complicated to work with
  - The 2D disk is selected as the concepts module

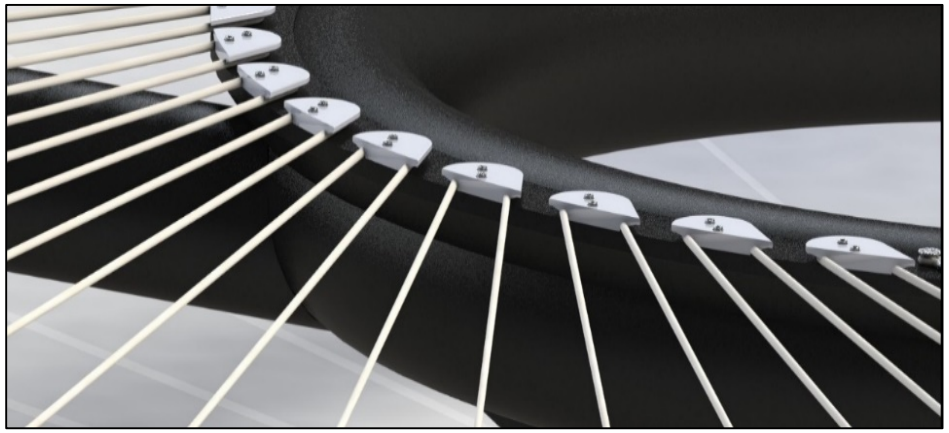
Area utilisation and rope configuration

				
Type	Slanted outward	Slanted	Outward	Helix spiral
Outer Ø.	25 m	25 m	25 m	25 m
Inner Ø.	3.5 m	-	3.5 m	-
Min. carrier rope spacing	0.15 m	0.60 m	0.14 m	0.60 m
Max. carrier rope spacing	0.98 m	-	0.98 m	-
Total cultivation length	896 m	815 m	860 m	791 m
Projected area	491 m^2	491 m^2	491 m^2	491 m^2

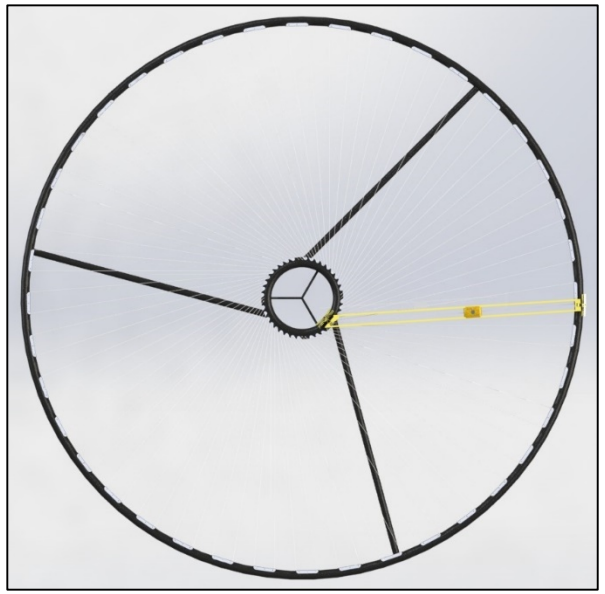
Frame structure

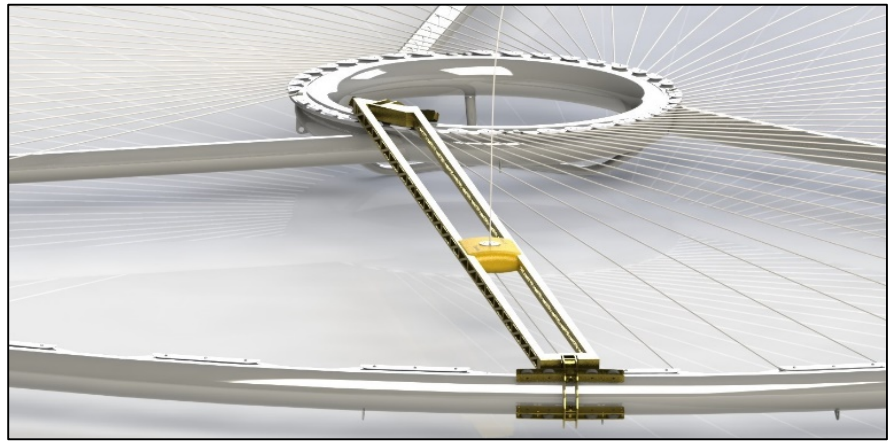
- Ø 25 meter
- 400 mm HDPE rør
- 300mm spokes
- Autolocking brackets

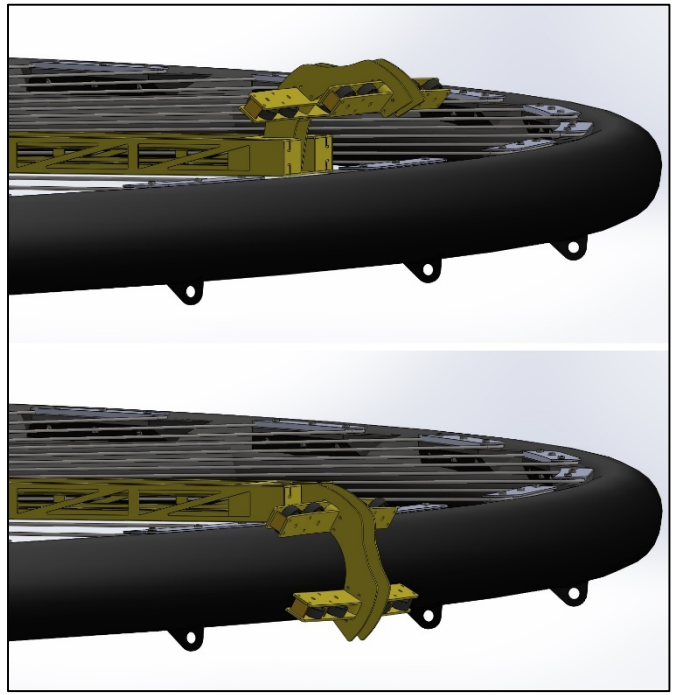




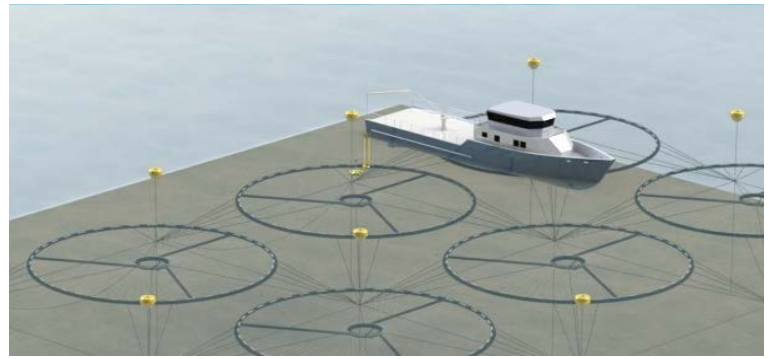
Specialised tool: Radial rails with robot



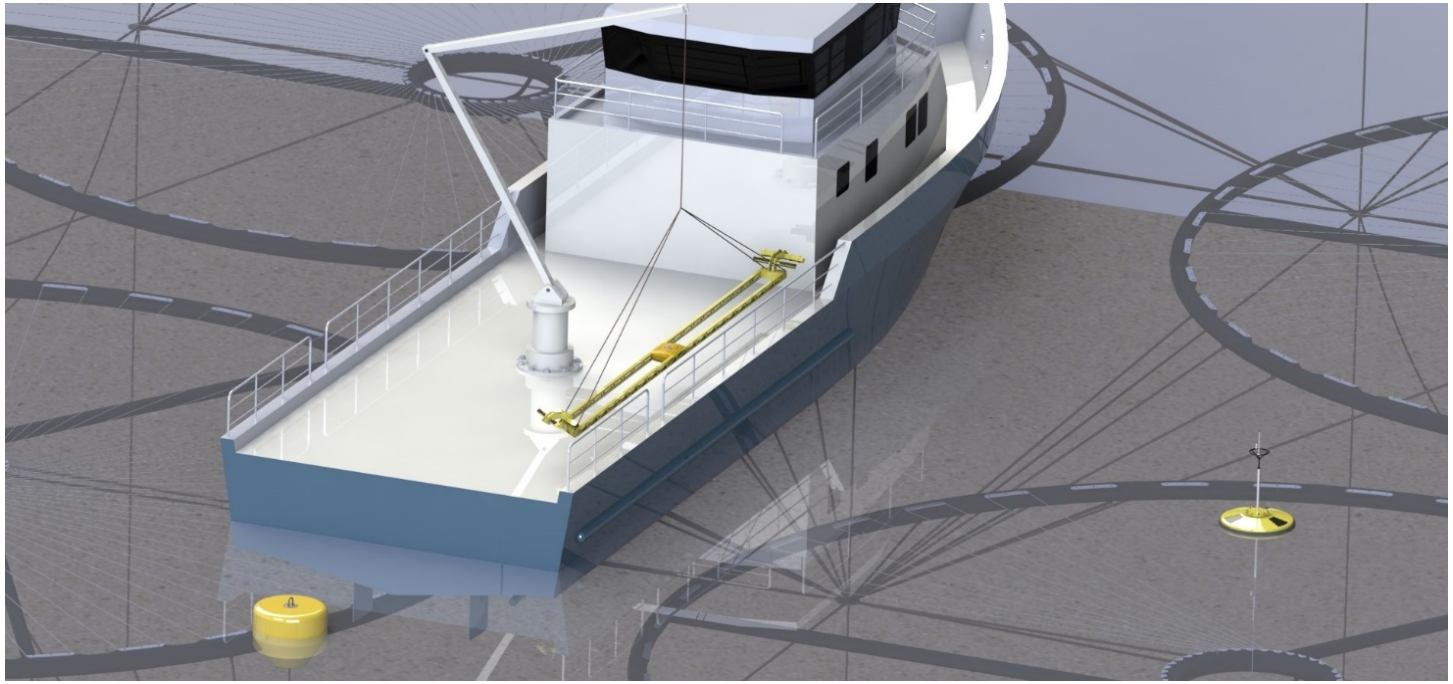




Automation of a seaweed farm



- Module based
- Standardized
- Specialized solutions

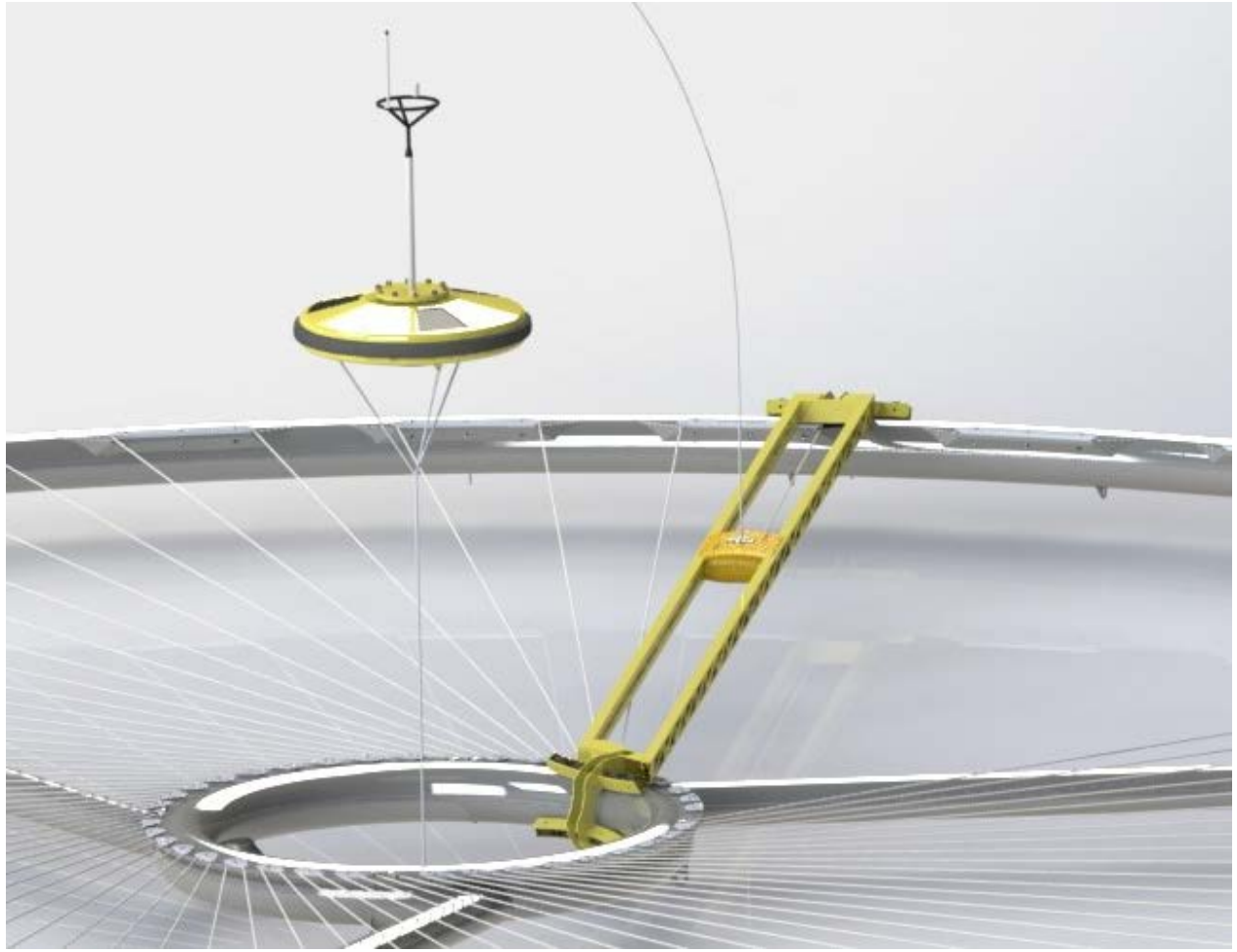


One service craft with the standard radial robot-rail can serve the whole farm (or facilities) as in the salmon industry

Automation of a seaweed farm

Data collection buoy

- Air temperature
- Water temperature at different depths
- Wind direction and velocity
- Water current direction and velocity
- PAR measurement at surface and at different depths (can be utilized to calculate biomass)
- Spectral measurements
- Wave height and period
- Macroalgae grow data
- Mooring tension forces
- Conductivity

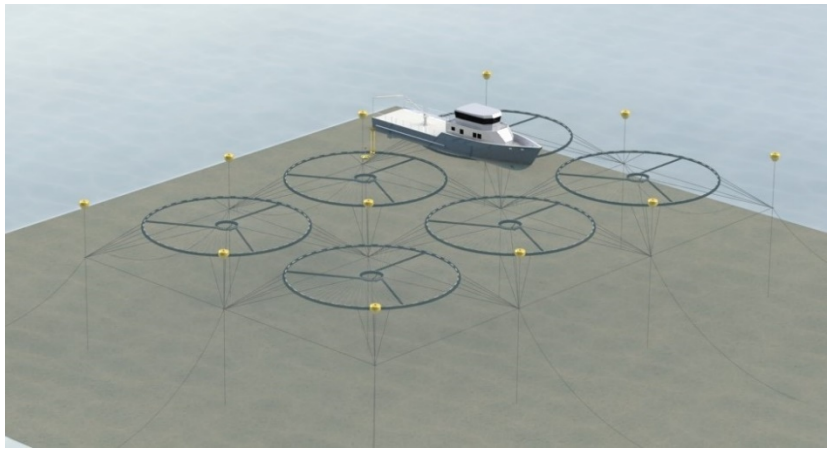


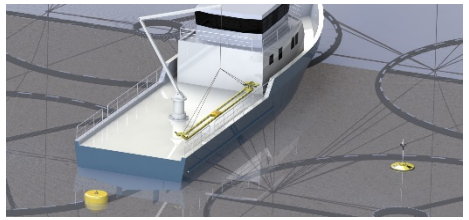
MACROSEA – SPOKe

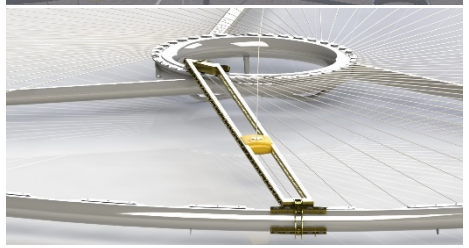
Standardized Production Of Kelp

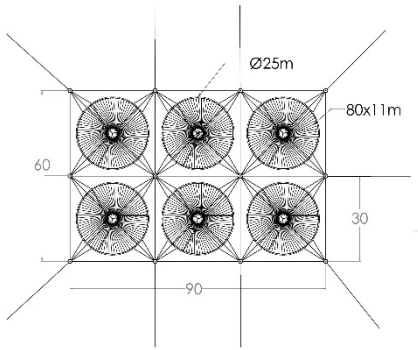
Key features:

- Standardization
- Easy up-scaling
- Automated deployment and harvesting
- 1D to 2D substrate transition
- Real-time data collection
- Use of mature technology from the fish farming industry
- High cultivation length per unit, ~880m
- High theoretical cultivation density, ~96.8 ton/Ha









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Technology for a better society