

SolarPACES, Santiago, 28/09/2017

# Lay-Down Heliostat with Monolithic Mirror-Panel and Closed Loop Control for Minimum Cost

DLR, Institute of Solar Research

Fabian Gross

Andreas Pfahl

Phillip Liedke

Johannes Hertel

Jens Rheinländer

Stefano Giuliano



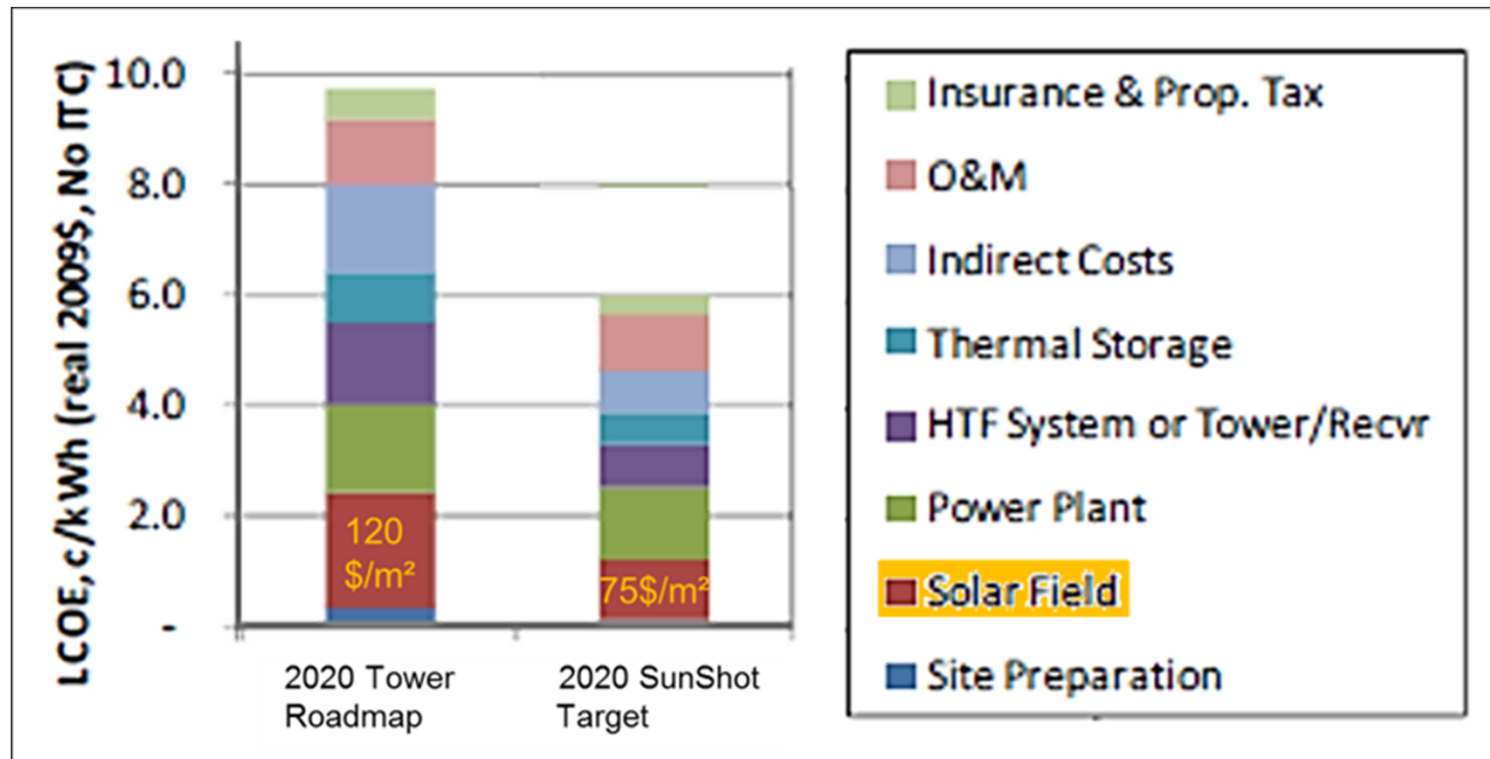
Knowledge for Tomorrow

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# Introduction: Motivation to Reduce Heliostat Cost



Jesse Gary et al., CSP and the DOE SunShot Initiative, SolarPACES 2011, Granada.

Heliostat field cost: 30-40% of investment (high impact on local content)  
20% of LCOE



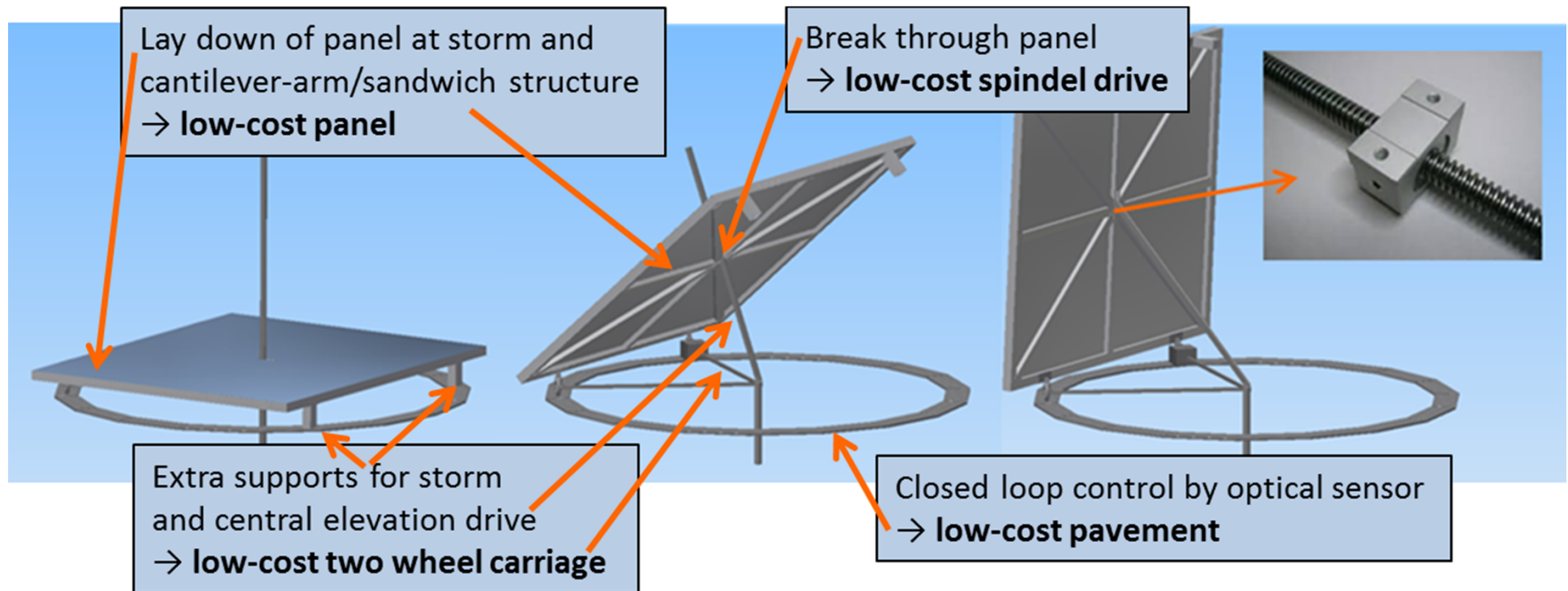
# Innovations: Overview

Requirements	Heliostat Properties	Innovation
1. Wind Loading	Dimensioning	Lay-Down Option
2. Accuracy	Precision	Closed Loop Control
3. Efficiency	Quantity	Sandwich Panel



# Innovations: Overview

Innovations to achieve challenging cost targets:



Pfahl, A. et al., Solar Device, patent WO 2016202941 A2, 2016.



# Innovations: Monolithic Sandwich Concentrator (sbp)

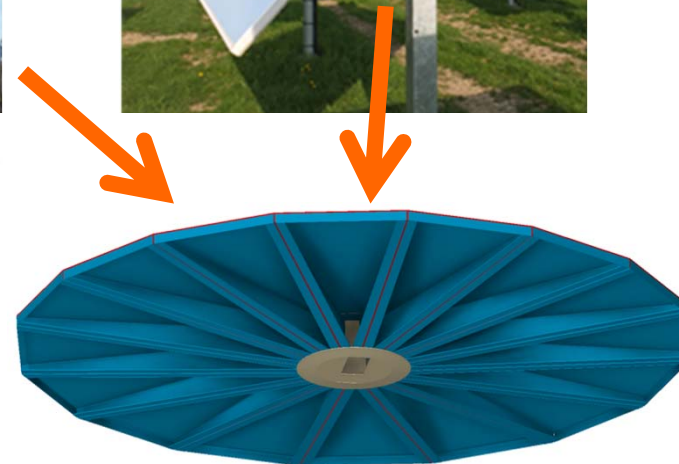
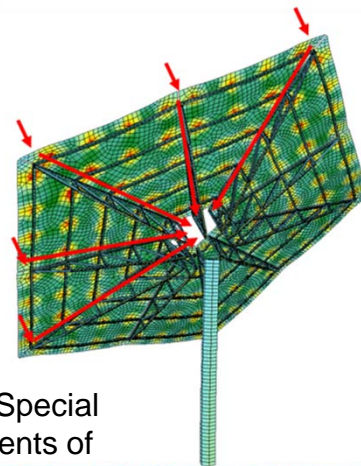
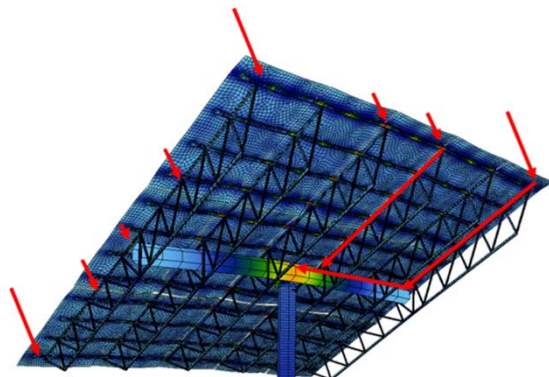
Light weight  
frame work  
cantilever arms



Centralized beams  
for better flux of force  
avoid torque tube



Sandwich panels of 5% higher  
efficiency by higher reflectivity  
and shape accuracy



Combination:  
**Cantilever-Sandwich Concentrator**



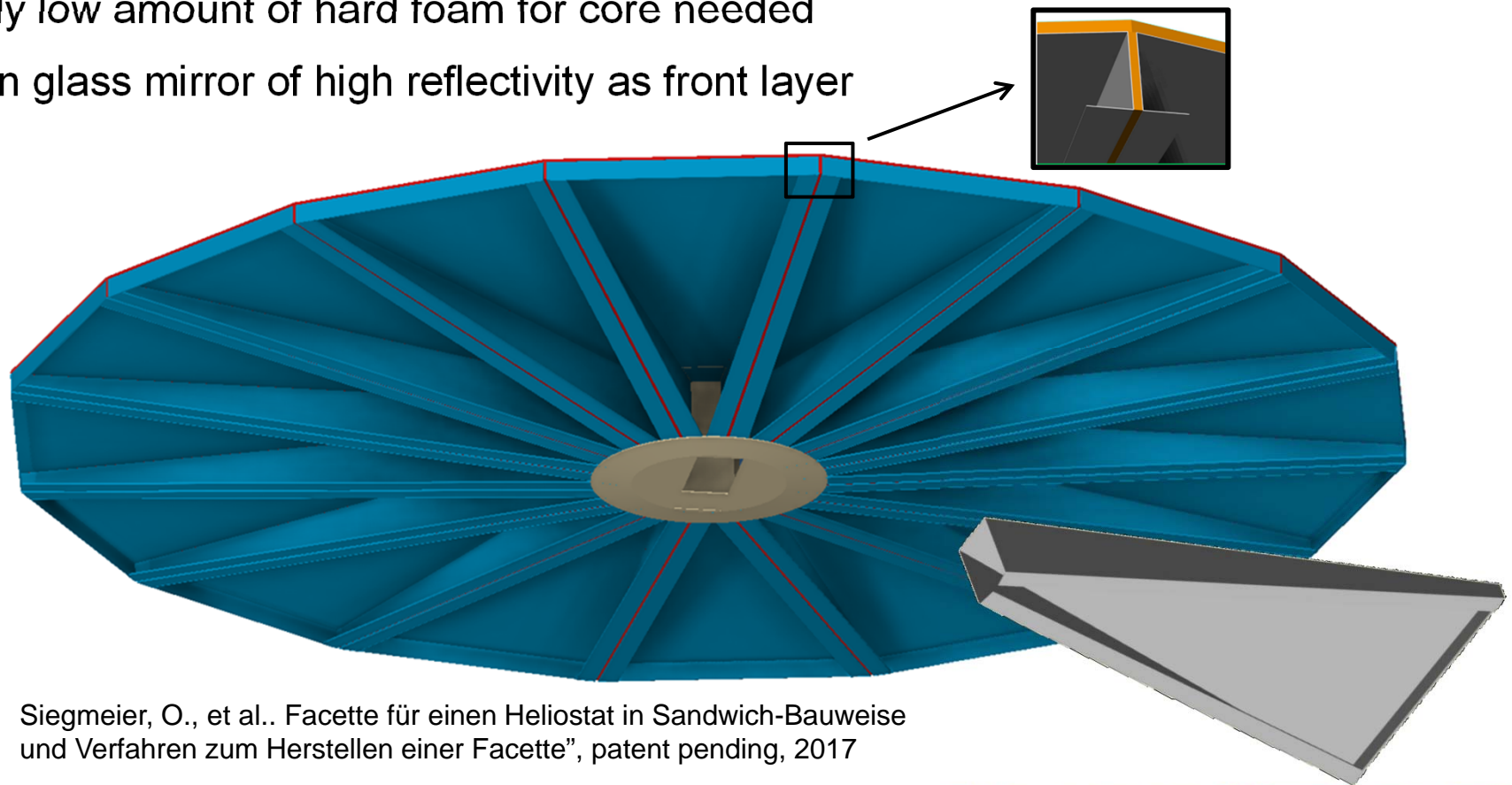
von Reeken et al., Special  
Stiffness Requirements of  
Heliostats for Regions With High  
Operational Wind Speeds,  
SolarPACES 2016.



## Innovations: Monolithic Sandwich Concentrator (sbp)

### Features:

- Back layers made from identical folded metal sheets
- Only low amount of hard foam for core needed
- Thin glass mirror of high reflectivity as front layer

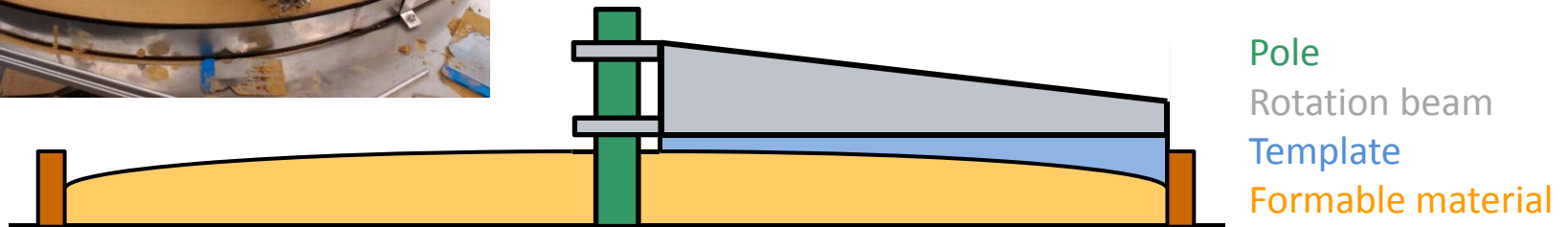


Siegmeier, O., et al.. Facette für einen Heliostat in Sandwich-Bauweise und Verfahren zum Herstellen einer Facette”, patent pending, 2017



# Innovations: Monolithic Sandwich Concentrator

- Big mold needed for fabrication of monolithic sandwich concentrator
- Low cost mold by rotating template to shape a formable material



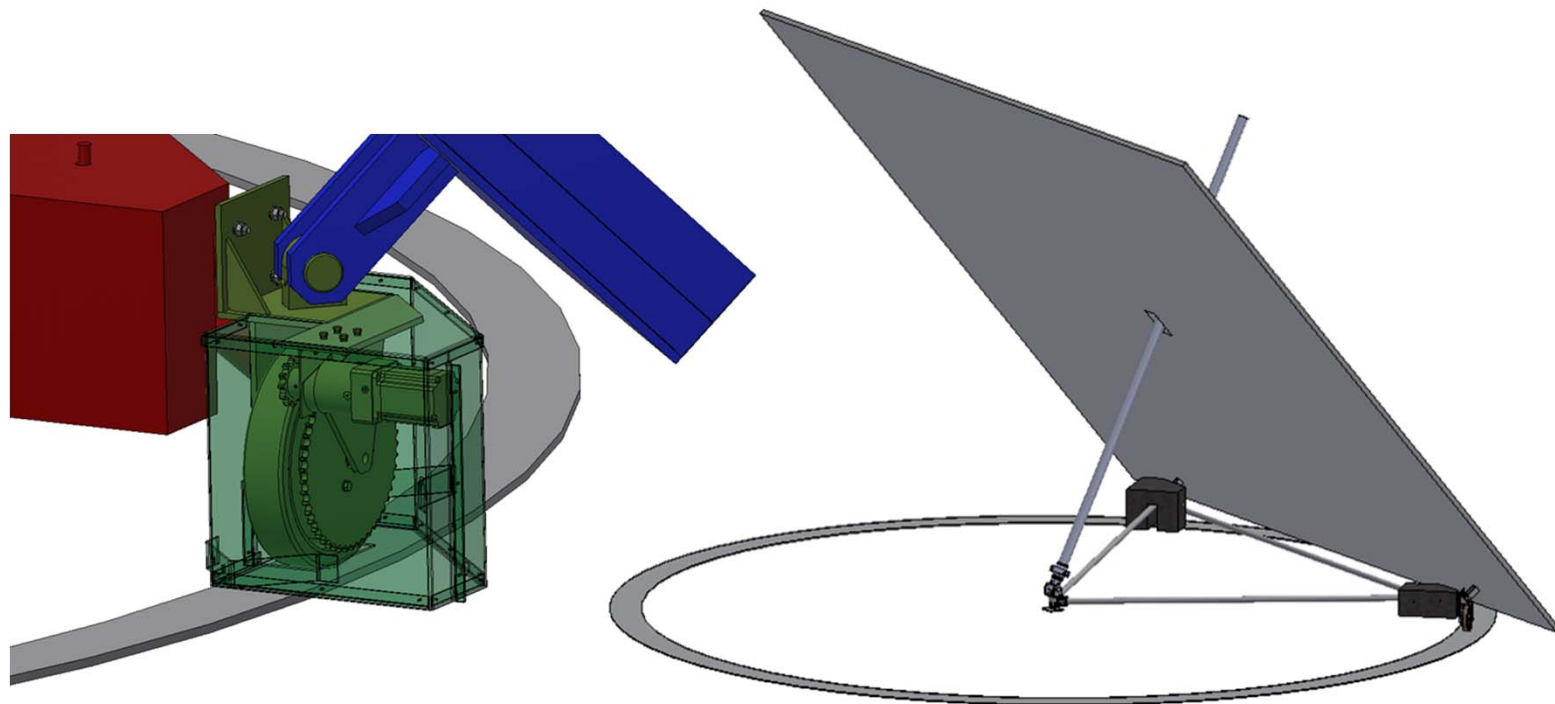
Pfahl, A. et al., Solarvorrichtung, Verfahren zur Herstellung eines Formteils und Verfahren zur Herstellung eines Formgebungselements, German patent application 2016.





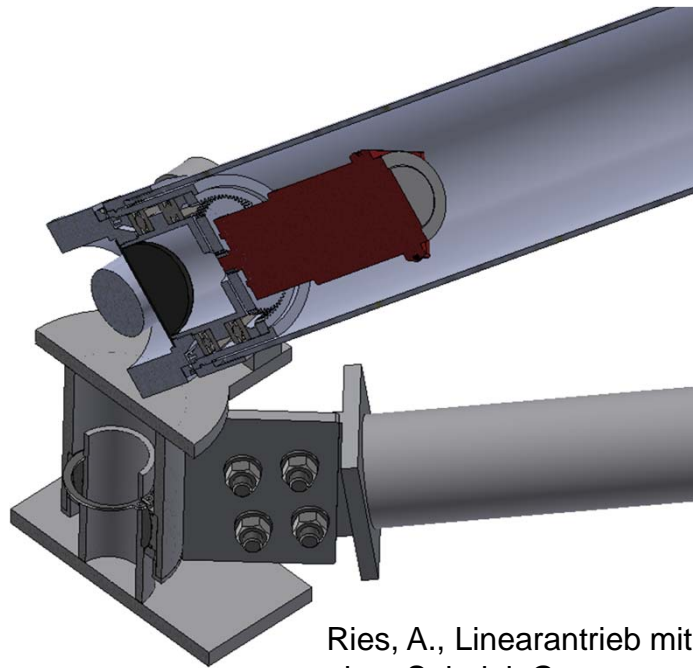
## Innovations: Azimuth Drive

- Weighted wheel drive with long lever arm and chain gear for low cost gear motor
- Pretensioned chain gear for low back lash
- With central elevation drive only two wheels needed
- For runway stabilized soil instead of concrete ring (for suitable soil)



## Innovations: Elevation Drive

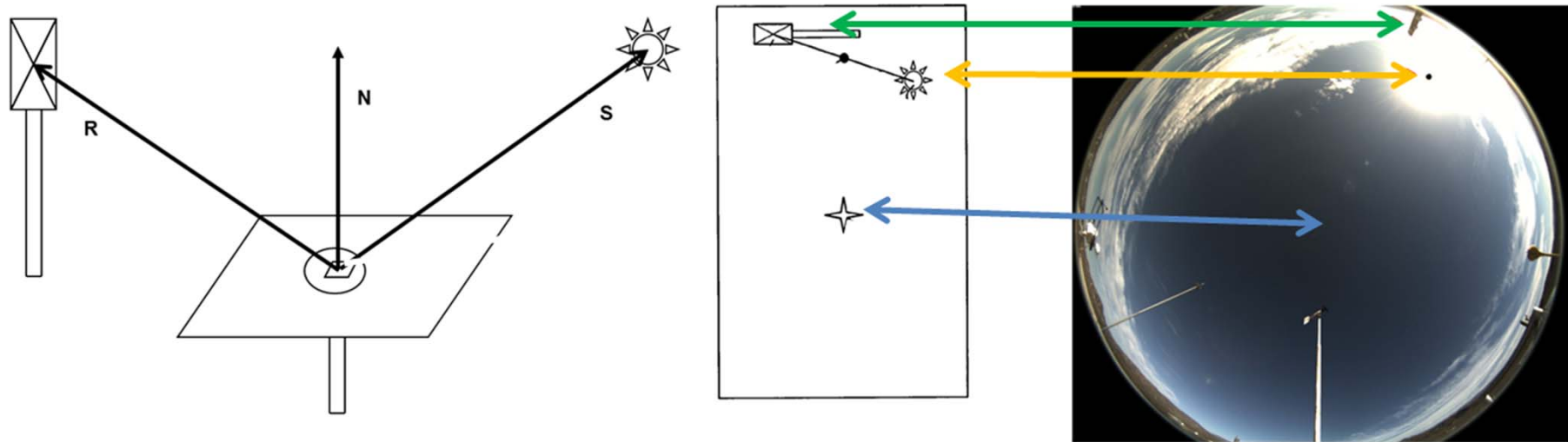
- Long lever arm for low loading of drive unit
- Break through panel avoids costly scissor mechanism
- Drive unit in spindle avoids extra housing



Ries, A., Linearantrieb mit einer Spindel, German patent application 2017.



# Innovations: Closed-Loop Control by Optical Sensor



- Low cost smart phone camera with fish eye lens mounted in sandwich panel
- Correct orientation when center between sun and tower is in center of image
- No need for high accuracy of heliostat mechanics

Pfahl, A., et al., Method for Controlling the Orientation of a Heliostat on a Receiver, Heliostat Apparatus and Solar Power Plant, patent WO2008/058866A1, 2008.



## Innovations: Closed-Loop Control by Optical Sensor

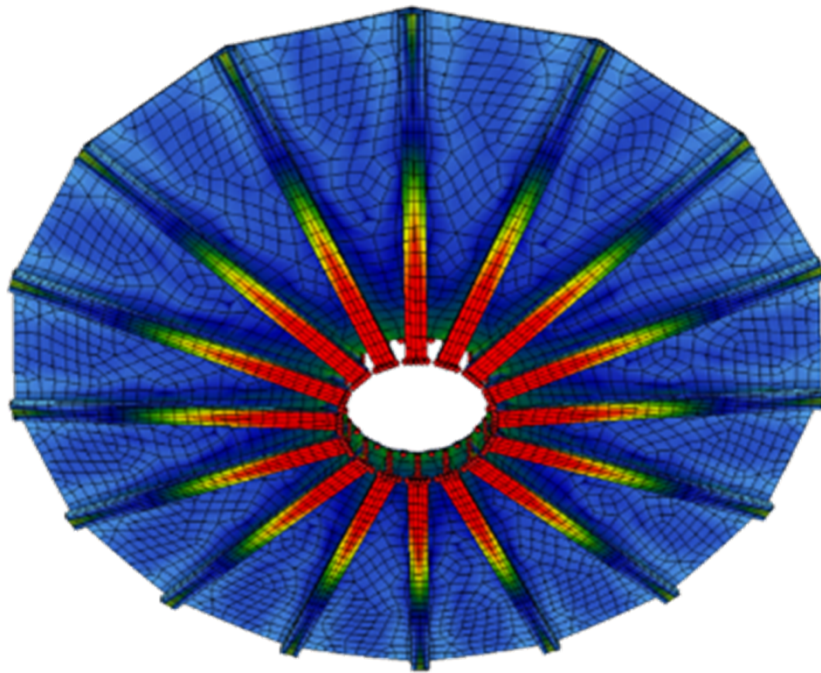


- Sun filter and different exposure times allow recognition of Sun and tower position
- Characteristic points of tower were successfully identified
- First tests: Accuracy < 1 mrad expected

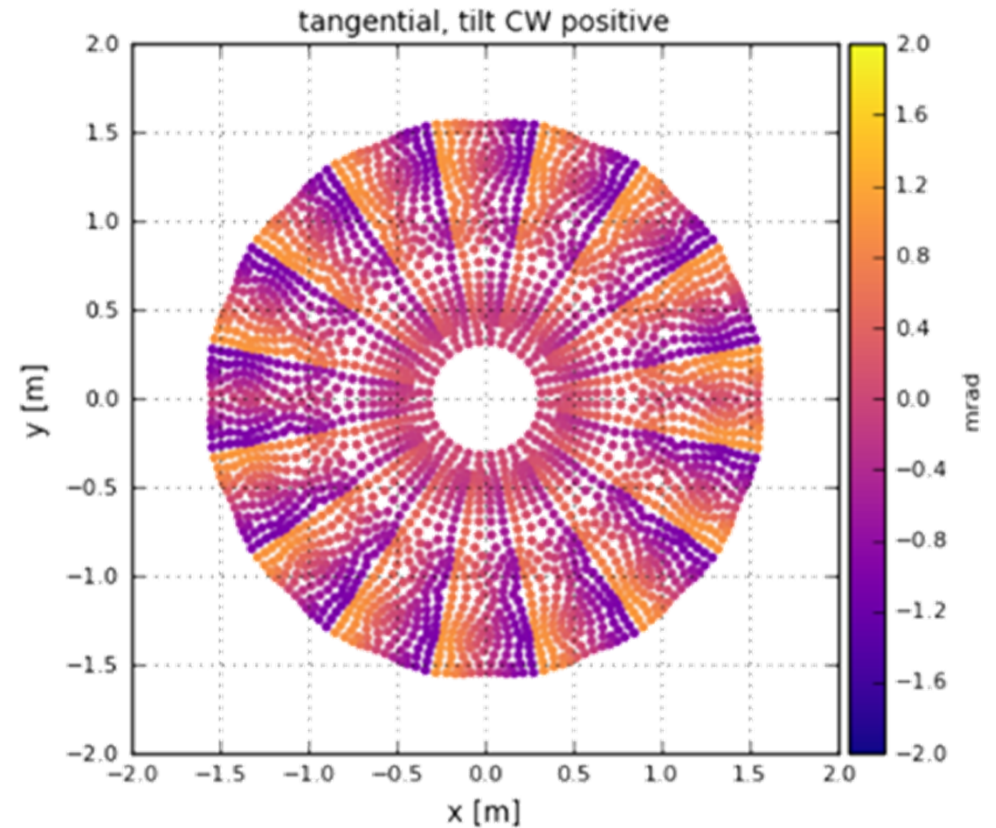


# Design/Layout: Dimensioning Regarding Wind Loads

Maximum stress under gravity and storm wind loads



shape accuracy under gravity and operational wind loads

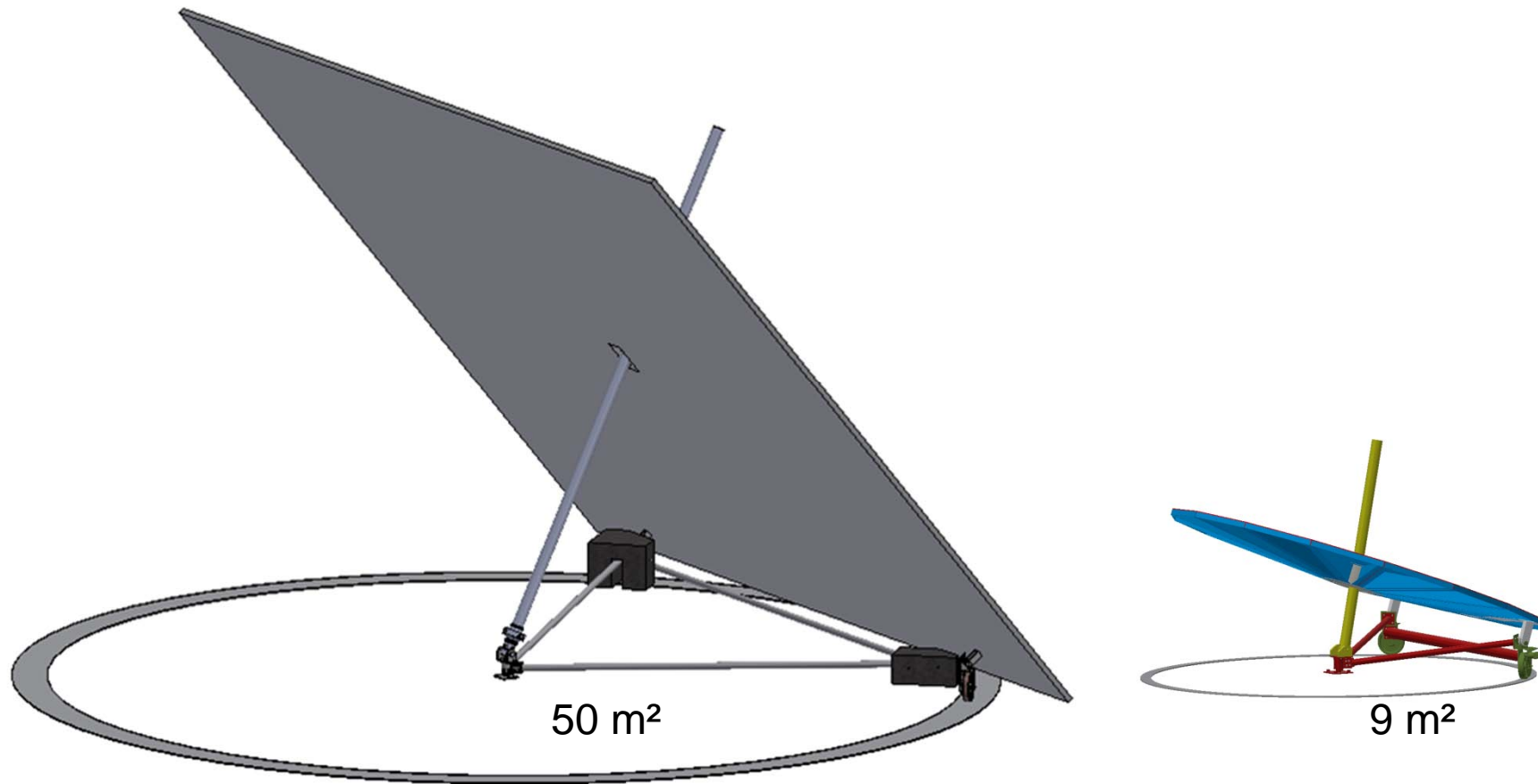


Siegmeier, O., Entwurf und Strukturoptimierung einer neuartigen Sandwichfacette für Heliostate, master thesis, sbp-sonne, Technical University Berlin, 2017.

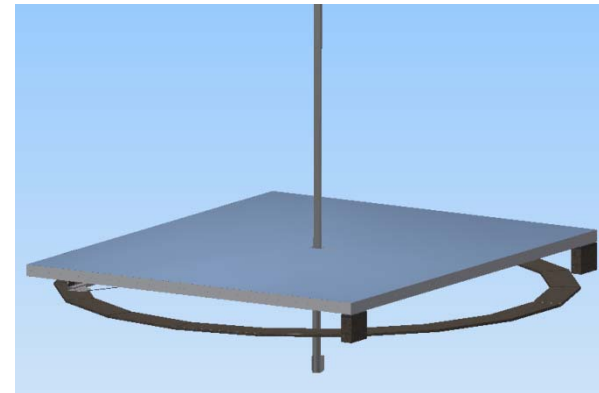
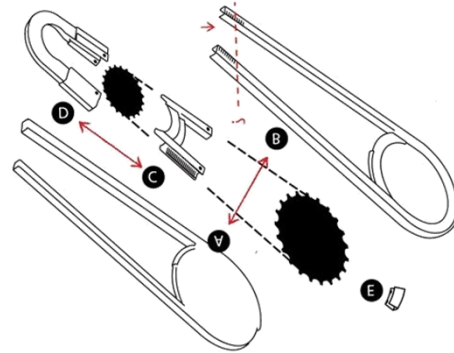
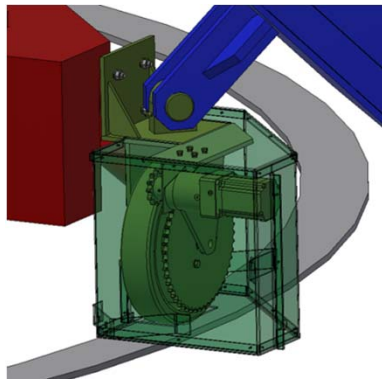


# Design/Layout: Dimensioning Regarding Wind Loads

Drives and beams dimensioned for 50 m<sup>2</sup> but first tested with 9 m<sup>2</sup> prototype



# Design: Protection from Desert Conditions



- Protection of azimuth drive unit can be simplified by enclosing only chain, sprockets and geared motor
- Low cost concepts for substitution of below for spindle protection at stow under development

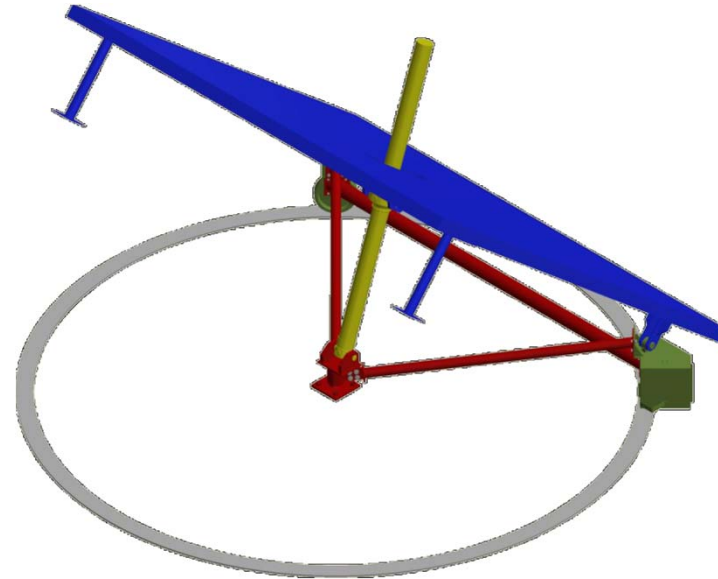


## Cost: Local Content

Cold rolled spindle



HelioMaroc 9 m<sup>2</sup> heliostat prototype



- Reduction of load and accuracy requirements > no high-end products needed
- All mechanical parts can be produced locally (incl. spindle, besides low cost geared motors)
- Project “HelioMaroc”: Design of 9 m<sup>2</sup> prototype to be adapted for high local content





## Cost: Comparison with Traditional Heliostats

for 10'000 heliostats of 50 m<sup>2</sup>

Part	Innovations	\$/m <sup>2</sup> tradit.	\$/m <sup>2</sup> new
Mirror panel	Lay-down, sandwich-cantilever panel, low-cost mold	50	30
Carousel carriage	Simple pavement, 2 wheels, weighted wheel drive	23	17
Elevation drive	Direct spindle drive, gear motor housed in spindle	11	8
Control/cabling	Closed loop control	12	14
Fabrication/installation/profit 10%		24	21
Total cost		120	90
Efficiency	5% higher optical efficiency -1% shading by spindle	-	-4
Effective cost		120	86
Further reduction	Simplified runway, spindle protection, wheel housings		
Cost outlook			<b>&lt;80</b>



## Summary

1. Lay-Down option: Avoiding high storm wind loads
2. Closed-Loop control: No need for high mechanical accuracy
3. Sandwich panel: Increased optical efficiency
4. Long drive lever arms: Low cost drives
5. Low amount of parts: Low fabrication and installation cost

➤ Requirements significantly reduced whereas efficiency increased:

**Heliostat field cost < 80 \$/m<sup>2</sup> and high local content feasible**



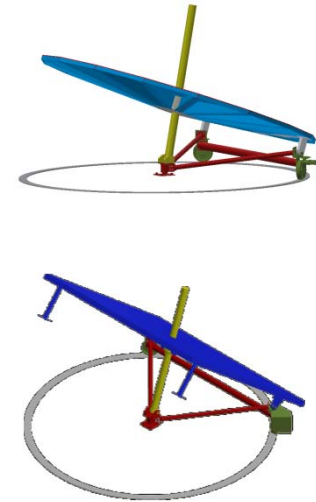
# Outlook

9 m<sup>2</sup> heliostat prototypes soon under construction

- within DLR-TM project “KOSMOS”
- by 2-3 Moroccan industrial consortia within “HeliMaroc” project with MASEN and supported by the German Federal Foreign Office

Next steps for future project

1. Lessons learned from 9 m<sup>2</sup> heliostat prototypes
2. Further cost reduction of heliostat components
3. Upscaling to 50 m<sup>2</sup> and demonstration



## Outlook

*Partners welcome!*

Please contact us:

Andreas Pfahl

DLR, Institute of Solar Research

Pfaffenwaldring 38-40, 70569 Stuttgart, Germany

**[andreas.pfahl@dlr.de](mailto:andreas.pfahl@dlr.de)**

**+49 711 6862 479**



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Andreas Pfahl et al., CSP Focus MENA, Dubai, Sept. 14, 2017

**THANK YOU**  
for your attention.

