"Global CSP Laboratory"
Cranfield University, UK

Concentrating Solar Power

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Precision Engineering Institute
Cranfield University, UK

March 2014

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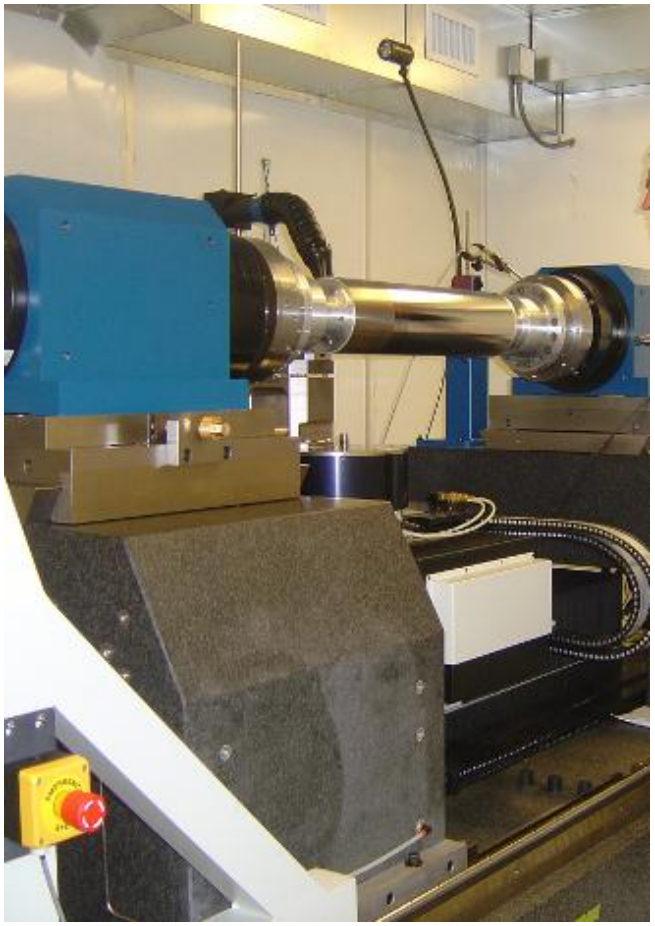
"Precision Engineering Institute"
Accuracy capability to 1 part in 10^8



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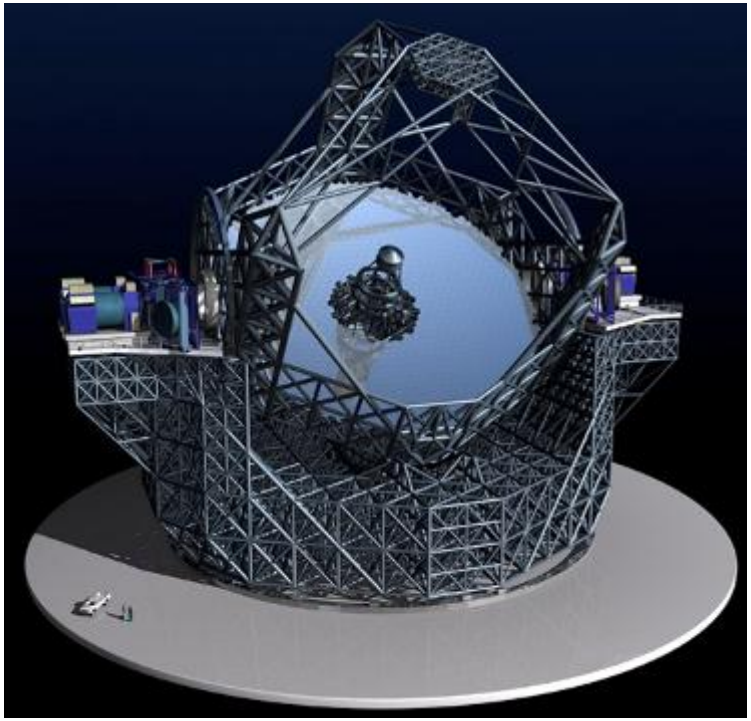
ESO European Extremely Large Telescope ('E-ELT')

This will be the largest telescope in the world

- **39m f/1 primary mirror:**

- **Consortium formed:**
  - **Cranfield University**
  - **Optropreneurs Ltd**
  - **Zeeko Ltd**
  - **QioptiQ Ltd**
  - **TNO (Delft)**

  Cranfield PEI role :
  - **Primary mirror segment grinding,**
  - **Subsequent smoothing,**
  - **Optical and mechanical assessment**



Concentrating Solar Power (CSP)

Solar Thermal Concentrating systems for:

- Electricity (energy) generation,
- Heating and cooling,
- Desalination, water purification, cooking, and
- Industrial process heat

Line Focusing		Point Focusing	
			
Trough	**Fresnel**	**Tower**	**Dish**

Large-scale technologies that also have the potential to incorporate thermal energy storage.	Small-scale technology – no storage

Only UK research team working exclusively on CSP

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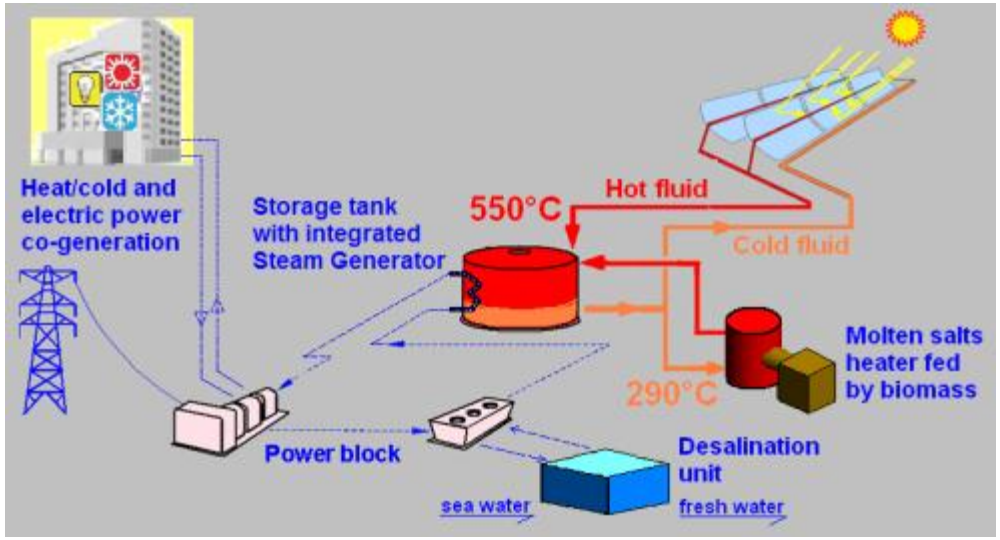
Example of large current solar Collaborative project



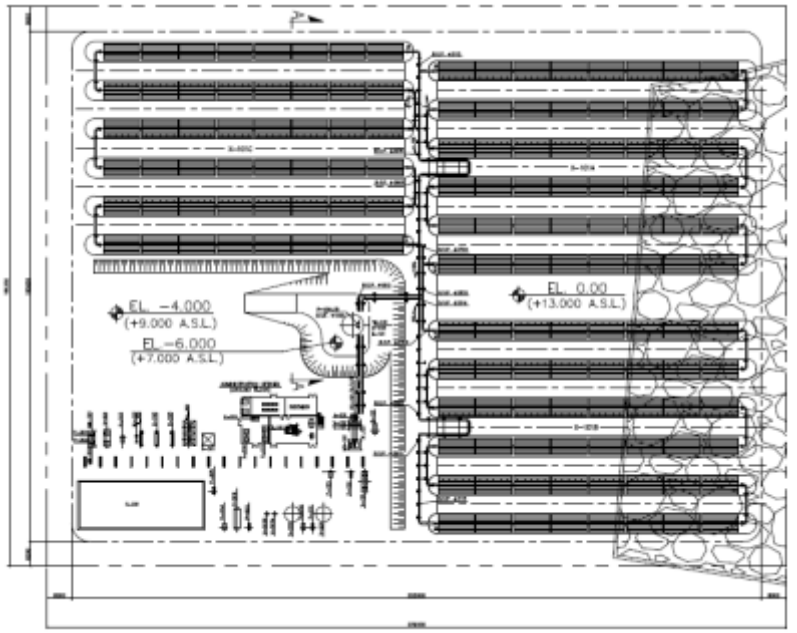
Solar thermal power plant

- 5 MW_{th} , 1 MW_{el} output
- 9 GWhr annual power output
- Cooling (LiBr chiller)
- Desalination (250m^3/day)

Egypt-Italy-Cranfield
"MATS" FP7 Project 2011-15

Multipurpose Applications of Thermodynamic Solar

€20 million project



Characterization of CSP collector surfaces

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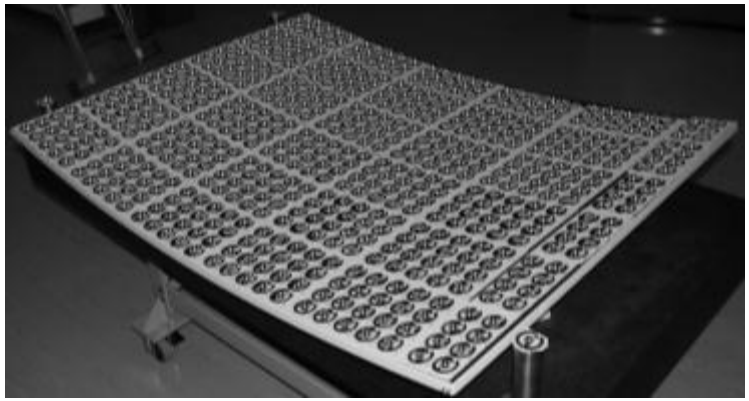
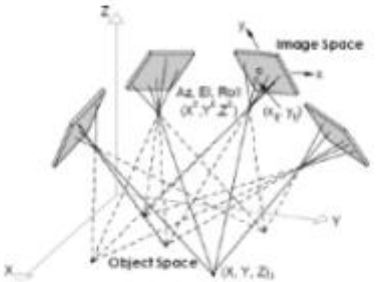
Collaboration with Ronda, ASE (Italy) – FP7
Collaboration with CEDT, KAU (Saudi Arabia – PhD students)
Collaboration with KSU (Saudi Arabia – KACARE programme
Collaboration with COMSATS (Pakistan – PhD student, projects)



2. Coordinate Measuring Machine (CMM)



3. Photogrammetry principles

4. Photogrammetry targets

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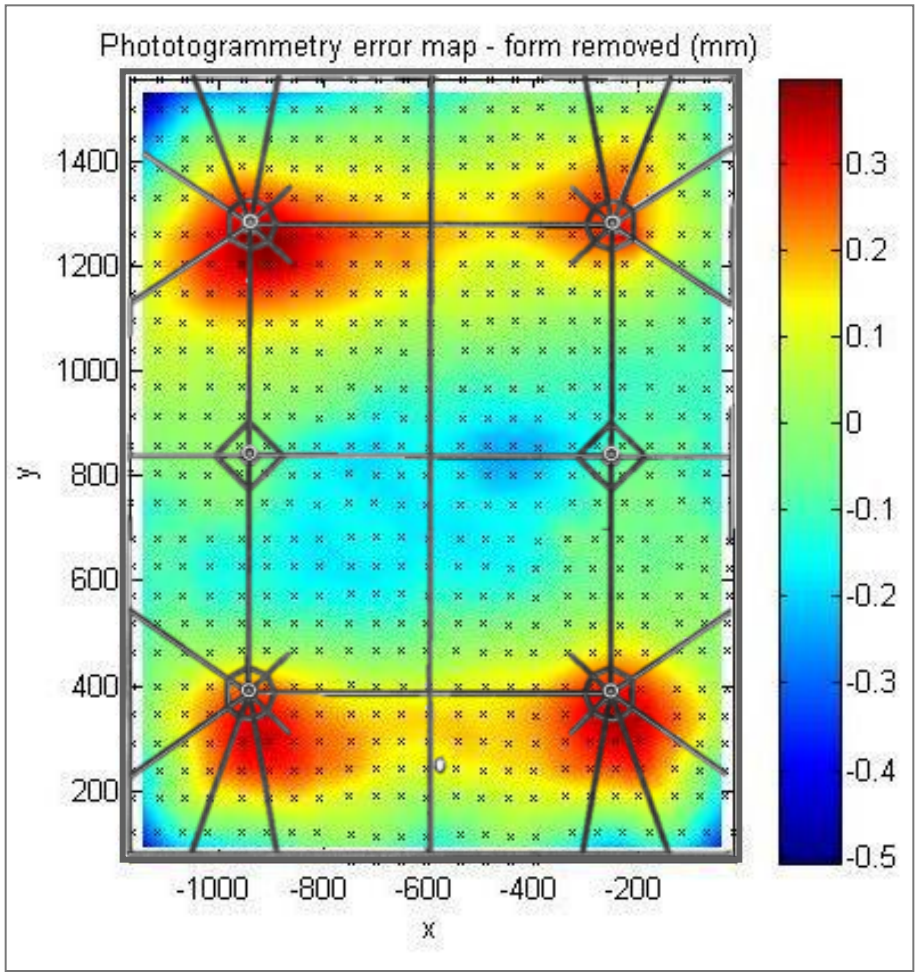
Characterization of CSP collector surfaces - Ronda mirror segment

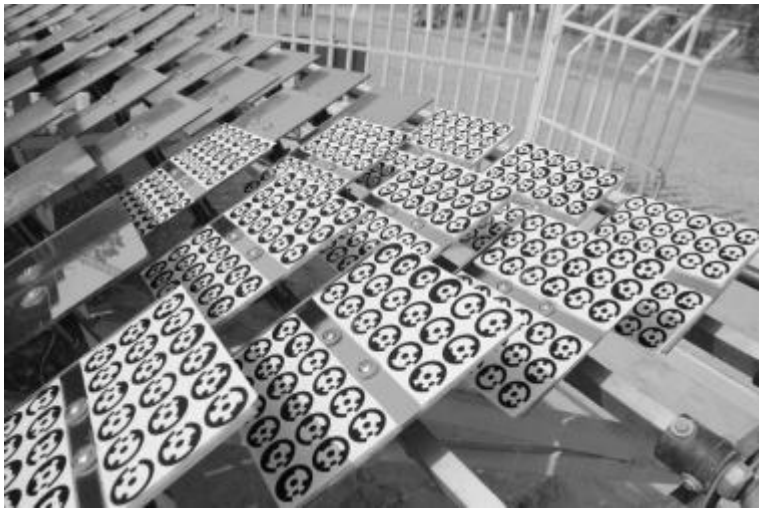


Removing focal error reveals the smaller variations.

These error positions correspond to structural points where the mirror is supported.

Concentrating Solar Power (CSP) – photogrammetry on-site

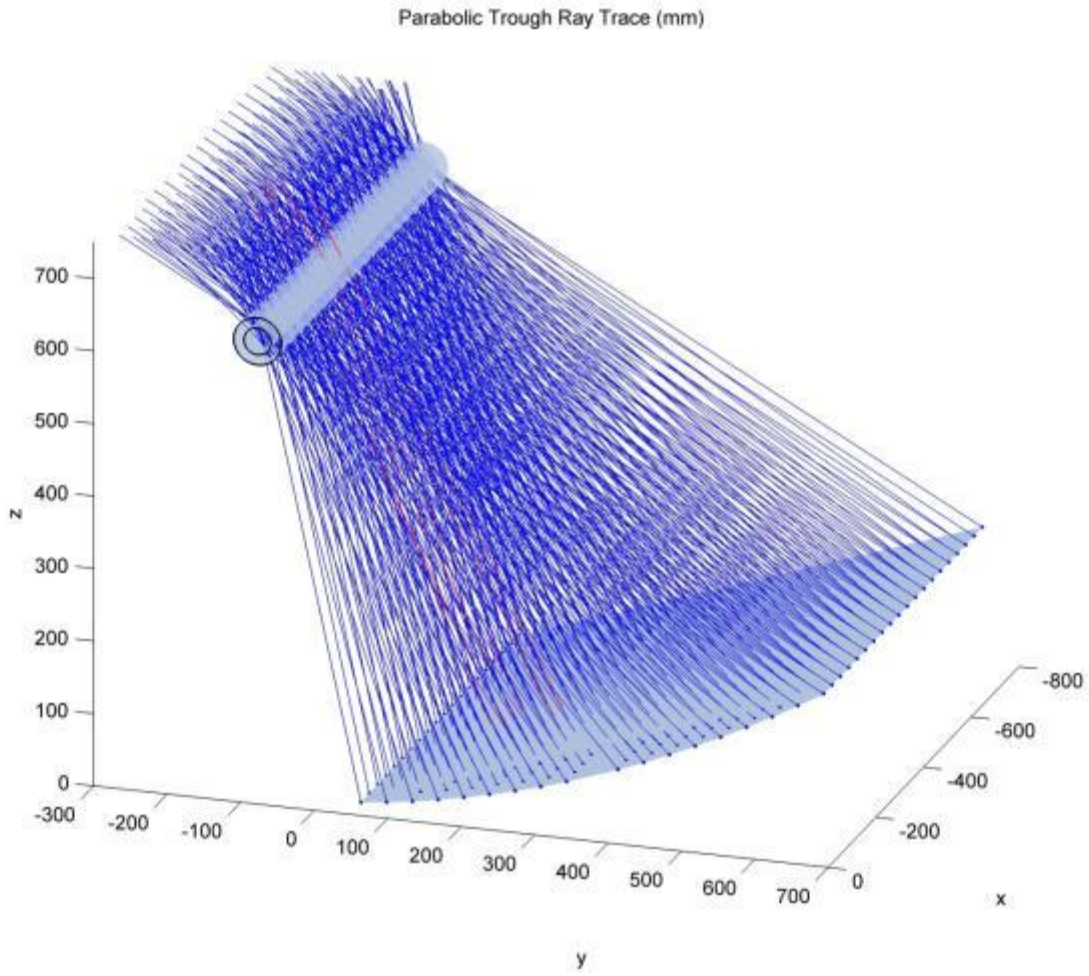
CEDT, King Abdulaziz University, Jeddah



Mechanical Engineering Department, King Saud University, Riyadh

Concentrating Solar Power (CSP) – photogrammetry on-site

CEDT, King Abdulaziz University, Jeddah (Parabolic Trough)



Concentrating Solar Power (CSP) – photogrammetry on-site

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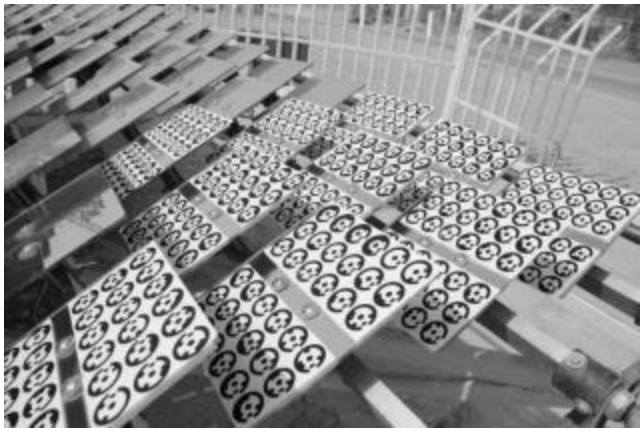
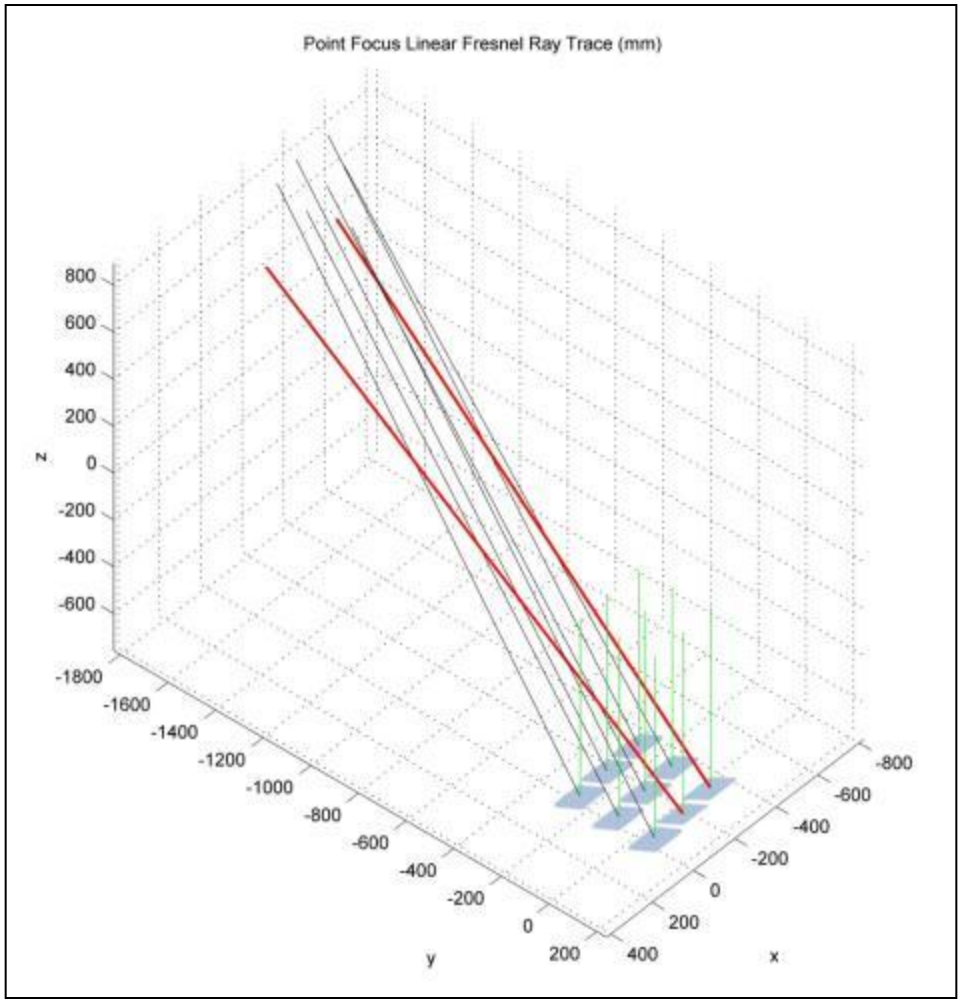
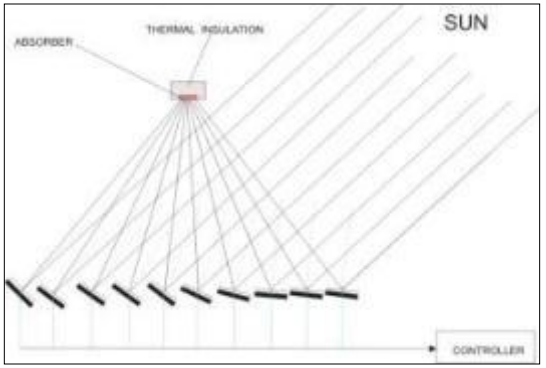
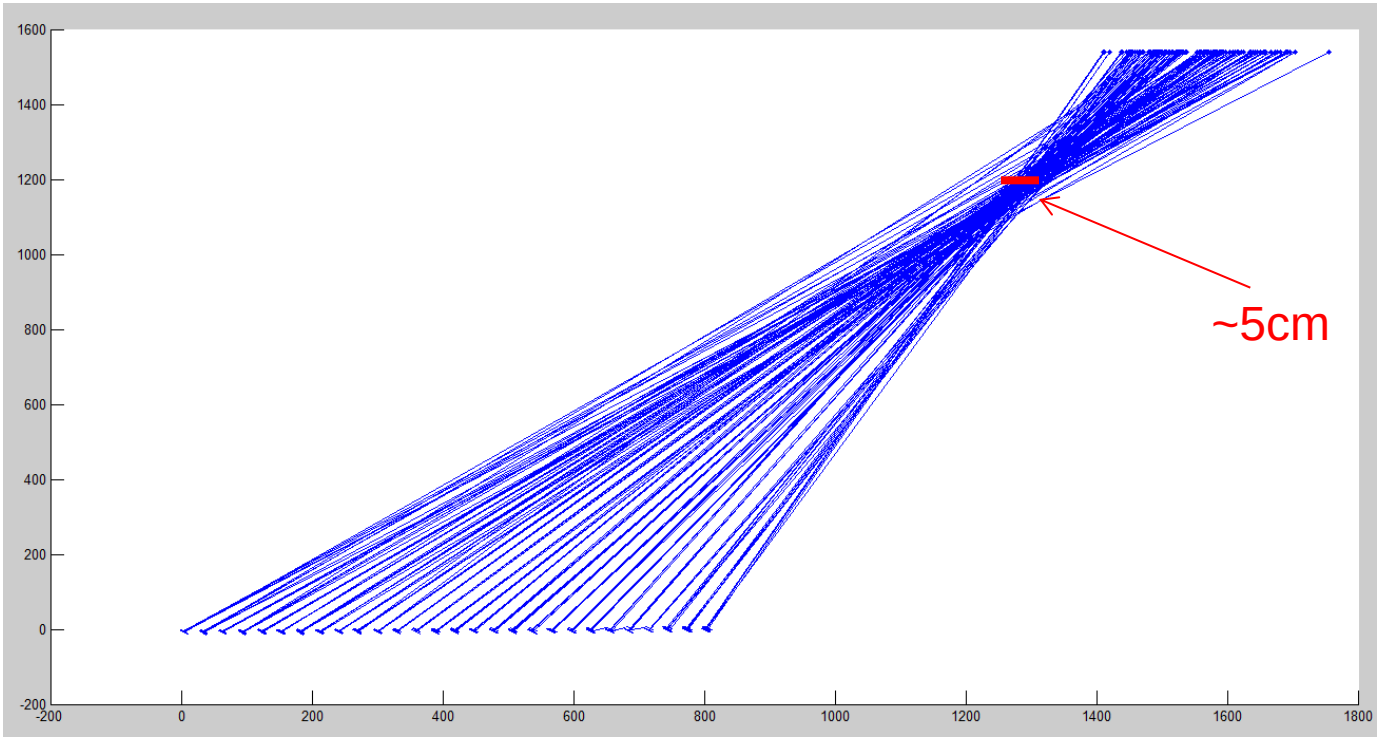
Point-focus linear Fresnel configuration
Mechanical Engineering Department, King Saud University, Riyadh





Linear Fresnel configuration solar cooker (collaboration with COMSATS, Pakistan)





Cooking and water purification
For remote off-grid communities

LF focus on receiver tube, showing misalignment of some collectors strips

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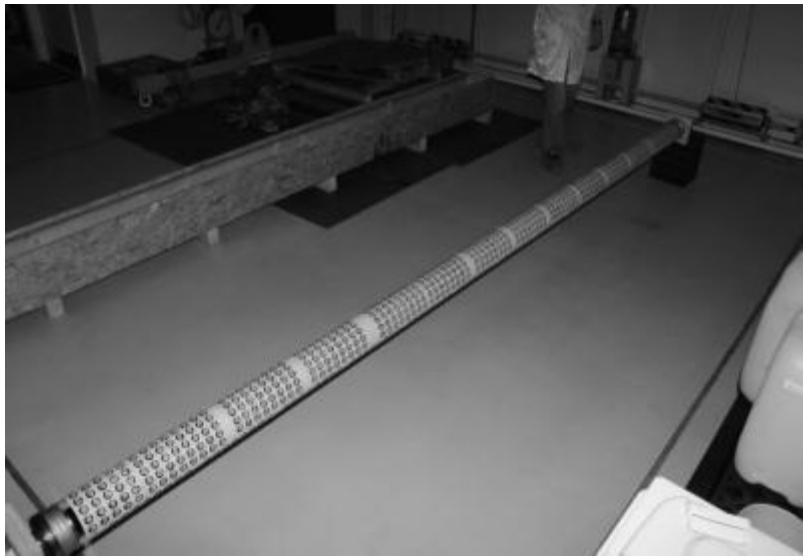
Characterization of CSP absorber tubes - ASE evacuated tube for molten salts

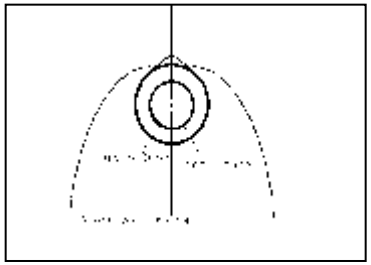
- In addition to the parabolic trough, a 4m absorber tube has been measured using photogrammetry.
- The tube has initially been measured for its sag, which has been found to be around 2mm.

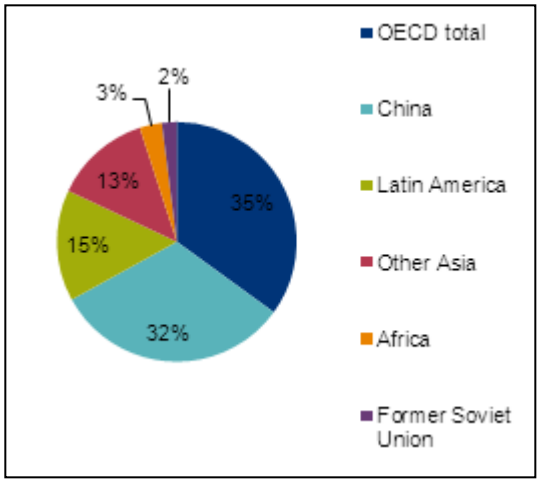


CSP FP7 Project – design and build of a receiver tube and absorber tube coating system (with 4m capability)

Design properties of the innovative receiver: (transmittance >96%, absorptance >95%, emittance$_{250°C}$ <7%).

Low-cost, high throughput Manufacturing of receivers





Regional breakdown of solar thermal potential for process heat in industry (UNIDO)

This corresponds to 1000 500kW plants across Africa and 5000 500kWplants across Latin America in 2050

CSP FP7 Project – design and build of a receiver tube and absorber tube coating system (with 4m capability)

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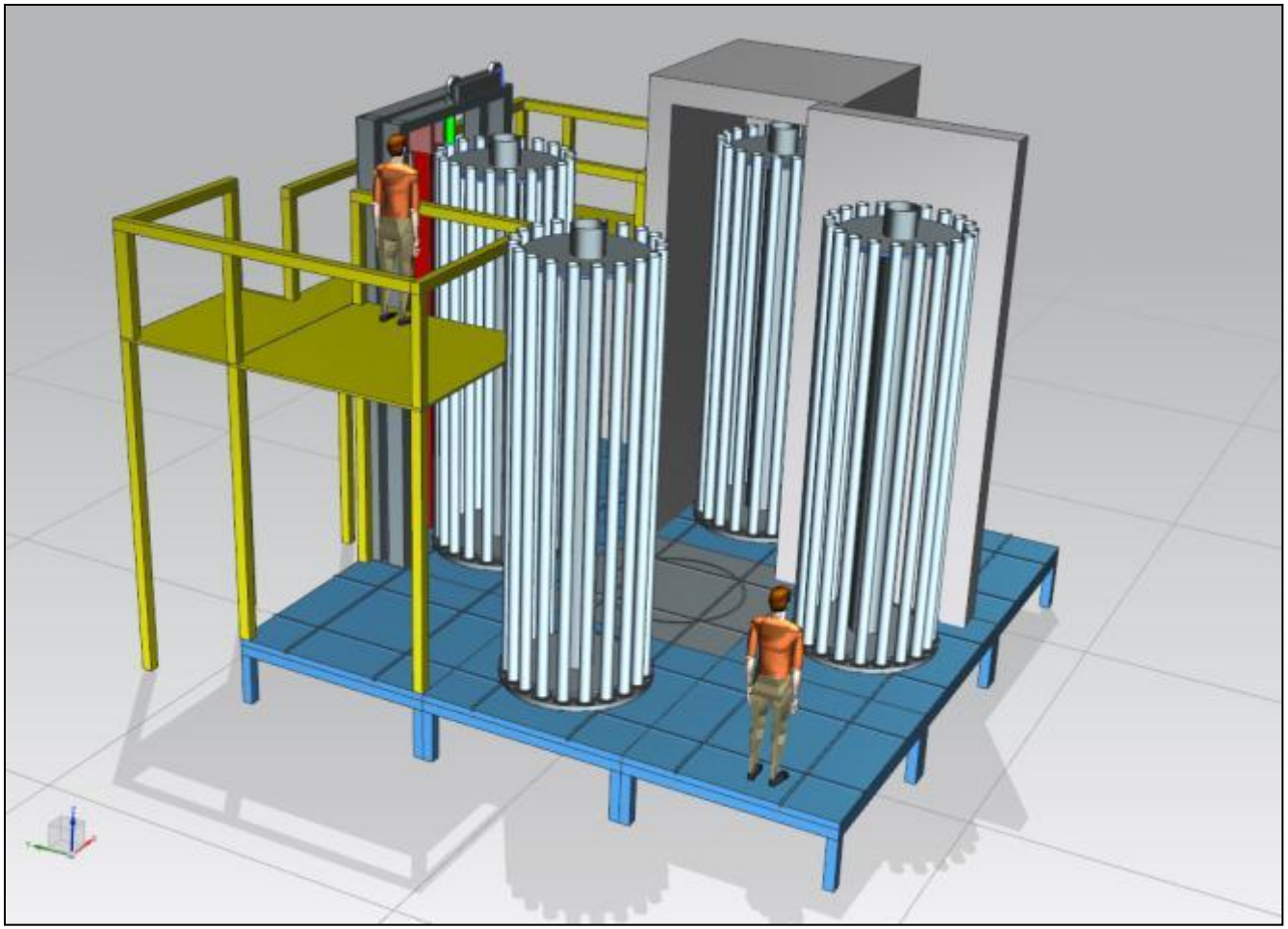
Concept Design

Using a capability for design and fabrication of large machines for large optics applications



Receiver tube coating concept

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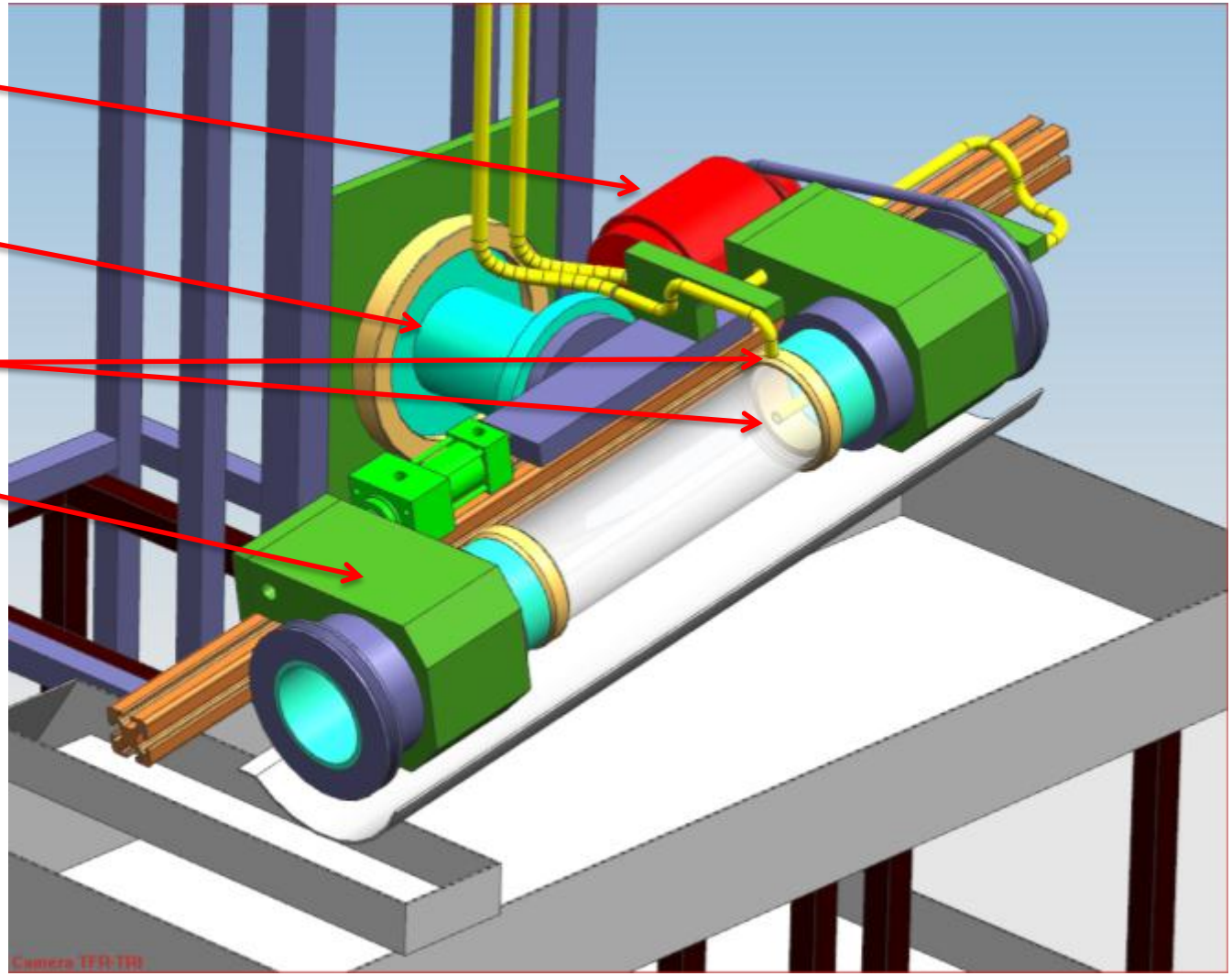
Rotation

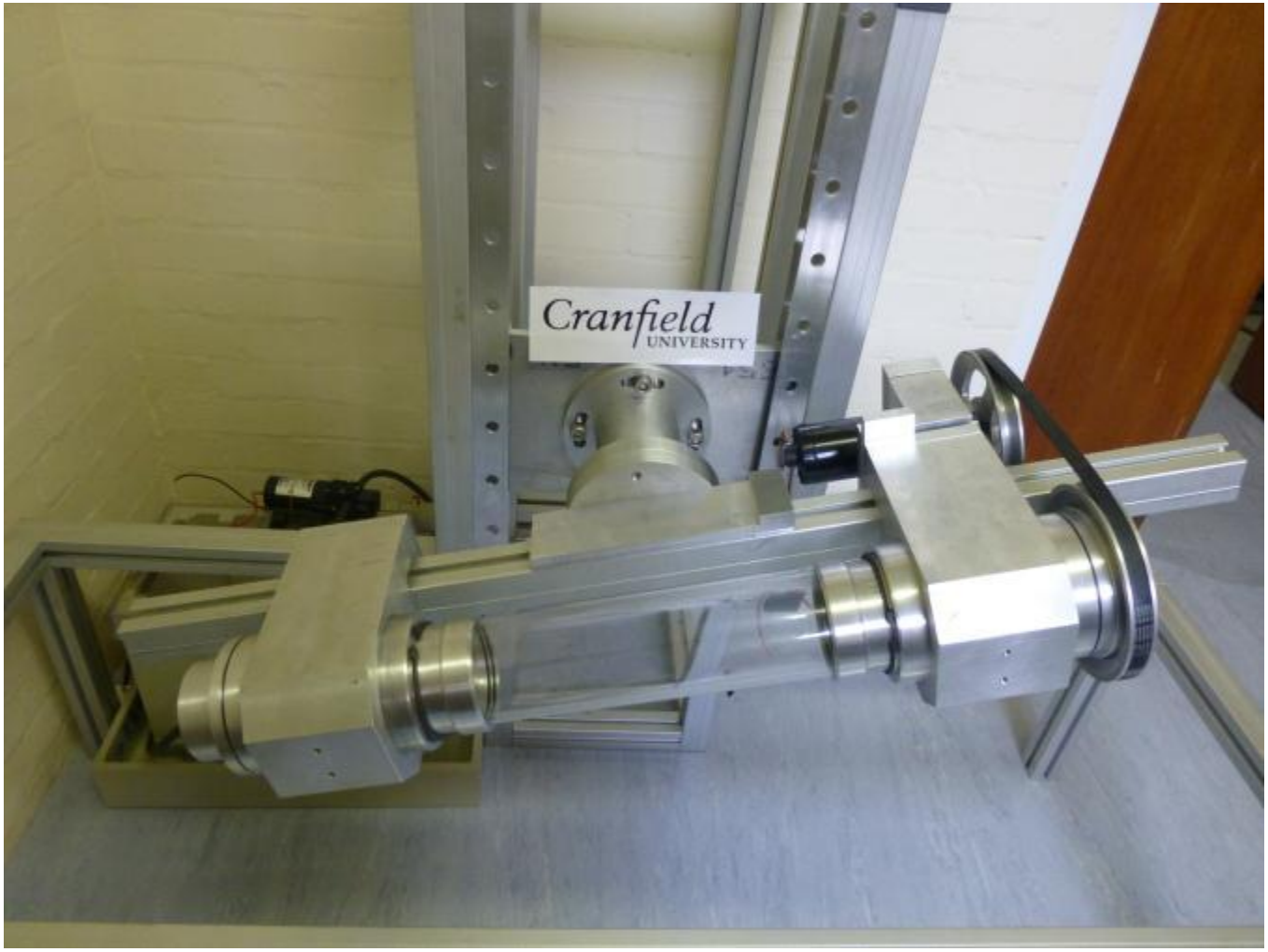
Modified angle

Drip feed

Sliding system



Receiver tube coating prototype



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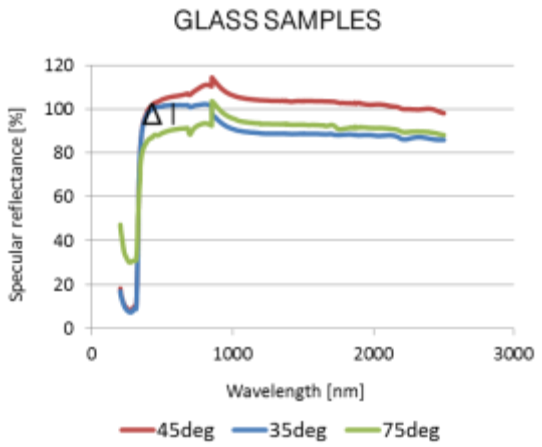
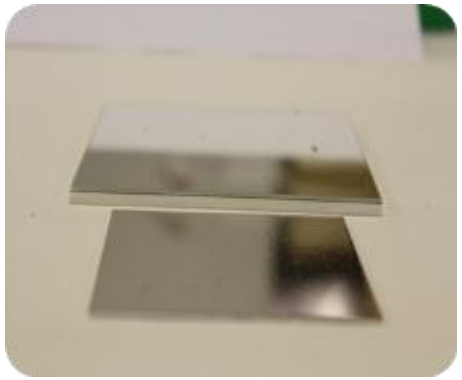
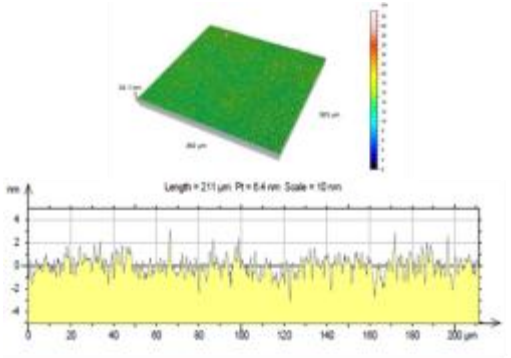
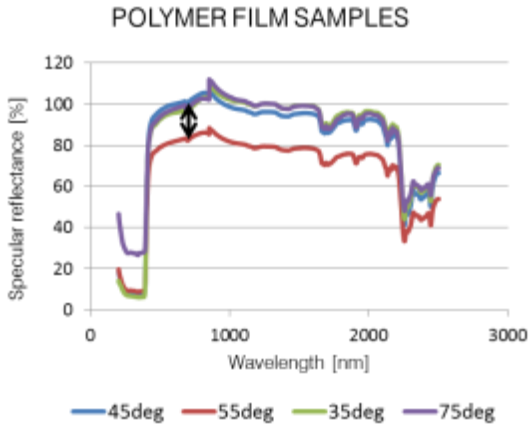
Polymer film Collectors for CSP – properties

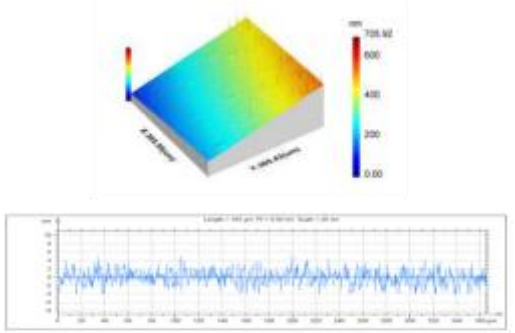






Top figure presents surface of glass mirror;
Bottom figure presents roughness of glass (profile);

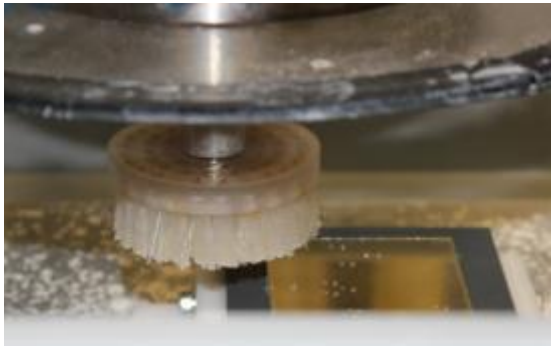




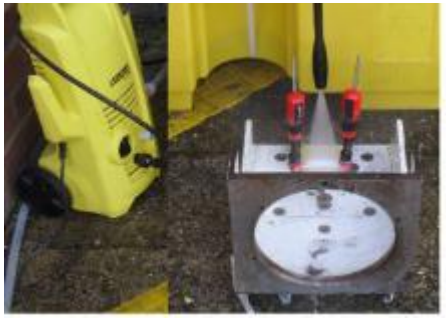
Top figure presents surface of polymer film laminated on aluminium;
Bottom figure presents roughness of polymer film (profile);

Contact Cleaning - simulation

- FANUC Robot M-710i
- Rotary head (300 rpm)
- Brush unit (ASTM 2486 standard)
- Wash cycles 400, linear speed 285mm/min



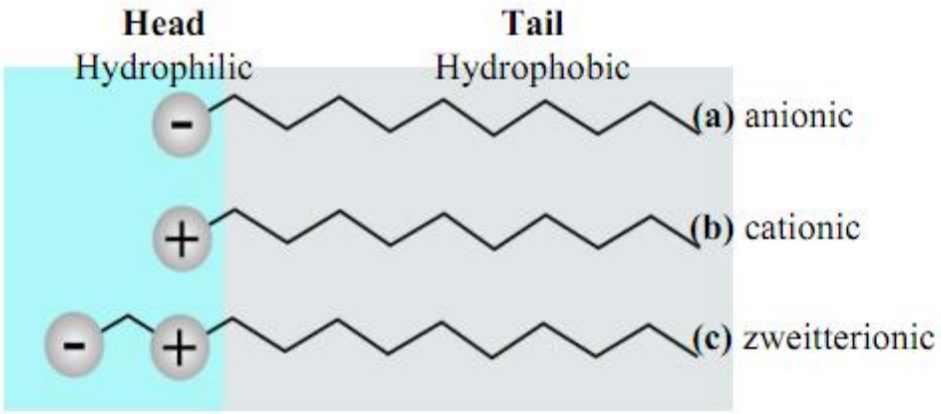
Non-contact Cleaning simulation



- Kärcher K2.36 water jet washer
- Input power 1400W
- Water flow 360L/hr
- Washer nozzle 200mm from sample
- Cleaning in raster pattern

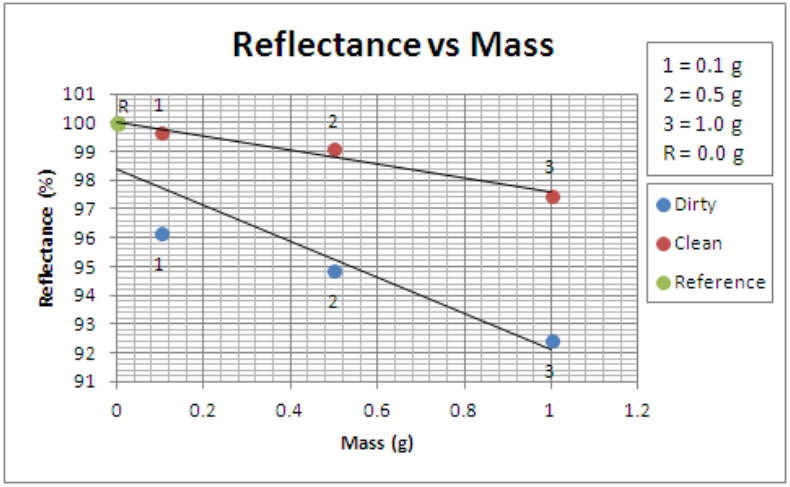
Anti-soiling coatings

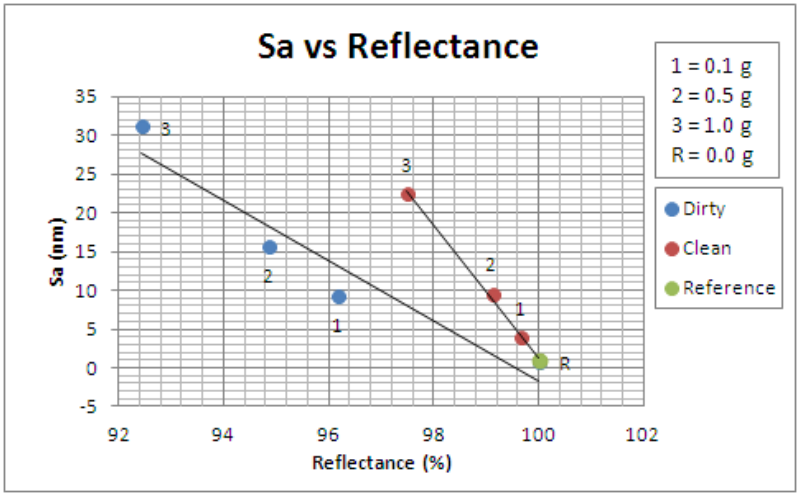
- Based on novel copolymers that can adhere strongly to surfaces
- One block adheres strongly to the surface
- The second block projects away from the same surface making that surface unattractive for dust and dirt to stick to.
- The copolymers should form aggregates
- The aggregates resulting in a very high coverage of the copolymer
- The aggregates provide an efficient barrier to dust and dirt.
- The polymers are able to adsorb from a water based formulation and the layer that adheres is only nanometres thick meaning it is essentially invisible



RepelSmart solar product

Sand Erosion of collectors



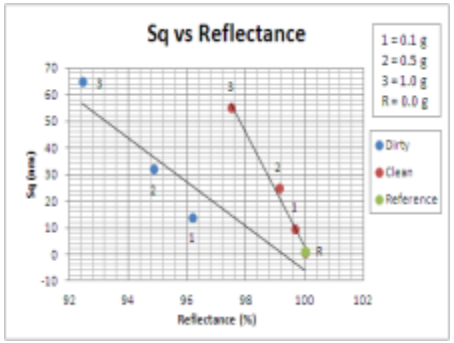


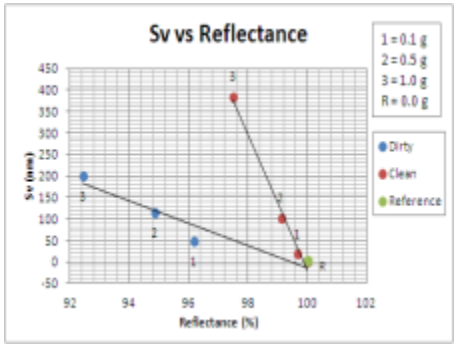
Pressure 0.4 Bar

(28.5, 28.7, 27.4 m/s)

Sample	Mass (g)
R	0
1	0.1
2	0.5
3	1

Increasing mass of abrasive medium produced higher density damage on samples





Heliostat Design and Manufacture - 1

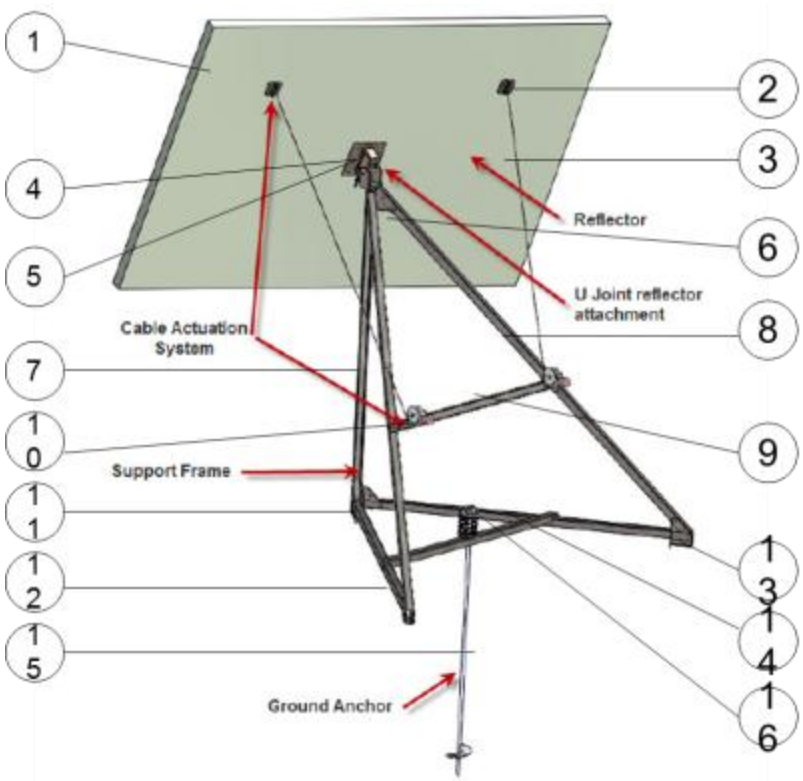
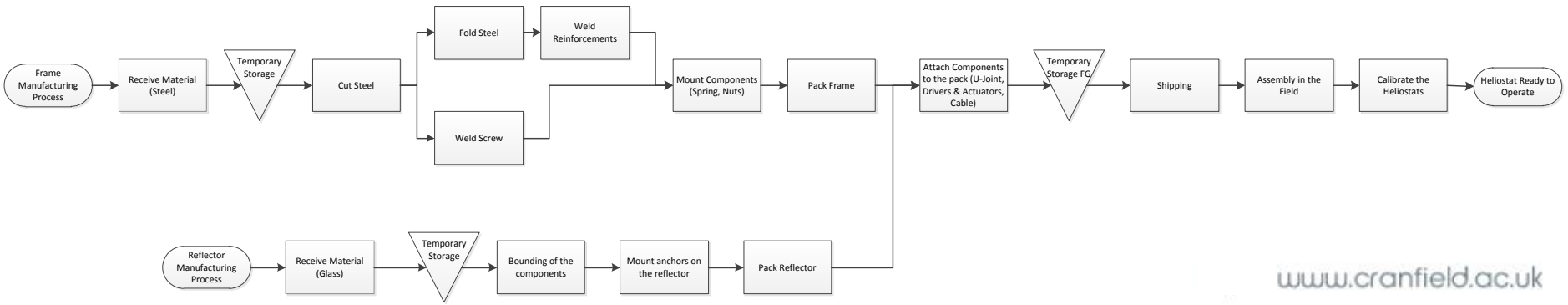
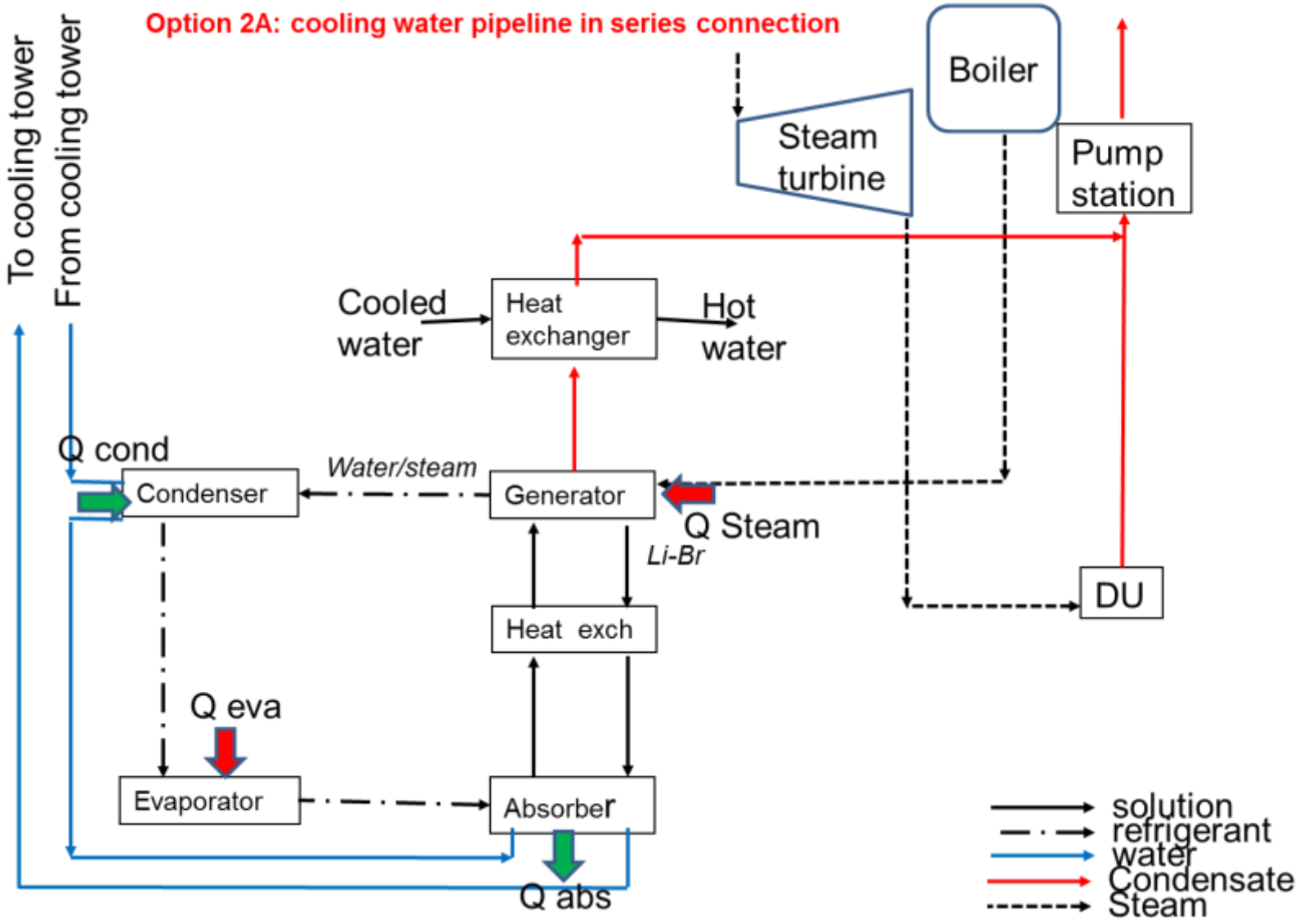


Diagram of prototype heliostat frame

Number	Description	Quantity	Material
1	Reflector	1	Glass honeycomb-style matrix Optical quality mirror A sheet of structural support Glass
2	Cable anchors	2	Galvanized steel sheet (2mm)
3	Steel Cable	2	(1.5 meters each one)
4	U-joint reflector mount	1	Galvanized steel sheet (2mm)
5	U-joint	1	
6	Reinforcement	1	Galvanized steel sheet (2mm)
7	C-shaped cross section	1	Galvanized steel sheet (2mm)
8	C-shaped cross section	2	Galvanized steel sheet (2mm)
9	C-shaped cross section bar	1	Galvanized steel sheet (2mm)
10	Actuators	2	
11	Reinforcement	1	Galvanized steel sheet (2mm)
12	C-shaped cross section bar	2	Galvanized steel sheet (2mm)
13	Reinforcement	2	Galvanized steel sheet (2mm)
14	C-shaped cross section bar	1	Galvanized steel sheet (2mm)
15	Ground anchor	1	Galvanized steel bar
16	Inoxydable Nut	1	Inoxydable steel



Heat & Cold Cogeneration/Distribution Subsystem – Example of analytical simulation activities



Concentrating Solar Power (CSP) – FEA for structural and thermal analysis

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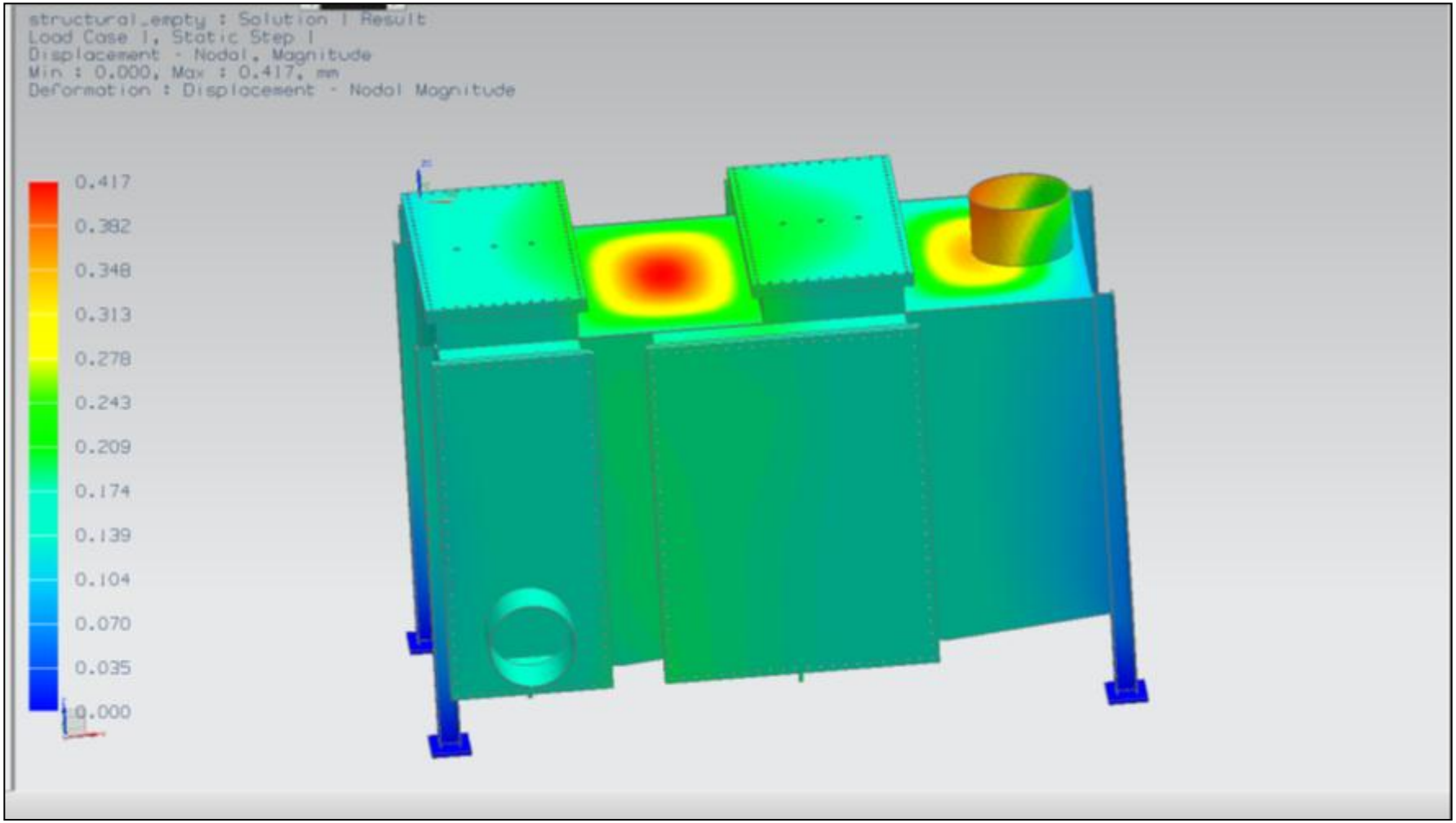
Multiple Effect Desalination (MED) modeling and design
(collaborations with CEDT, Saudi Arabia and ASRT, Egypt)



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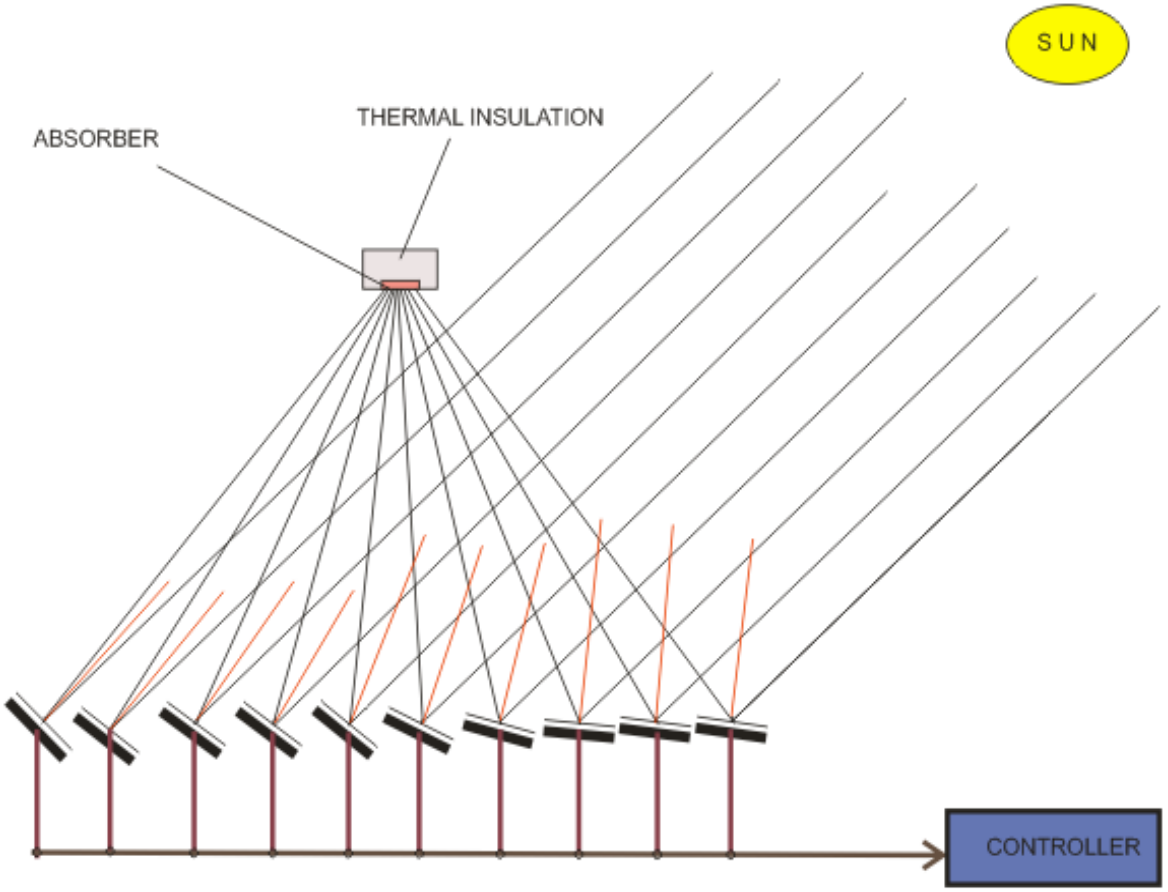
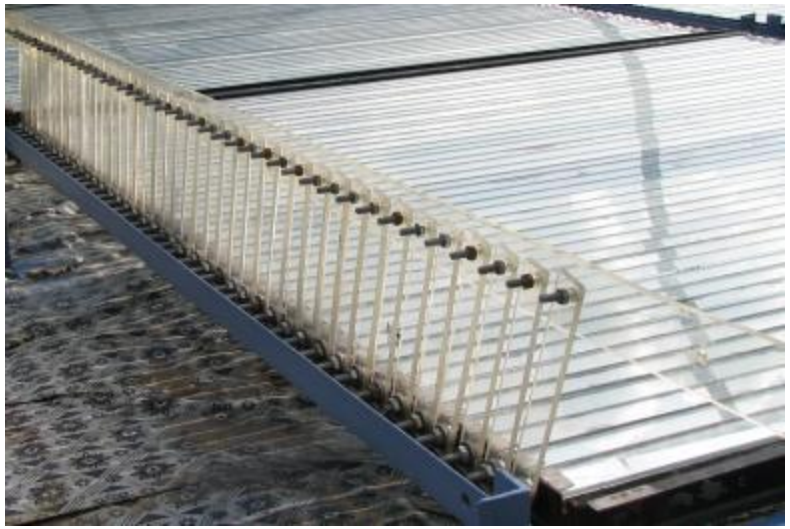
Low-cost solar cooker design – optical components only



With acknowledgements to COMSATS (Pakistan)

Low-cost solar cooker design – optical reflectors demonstrated



Number of Panels = 4

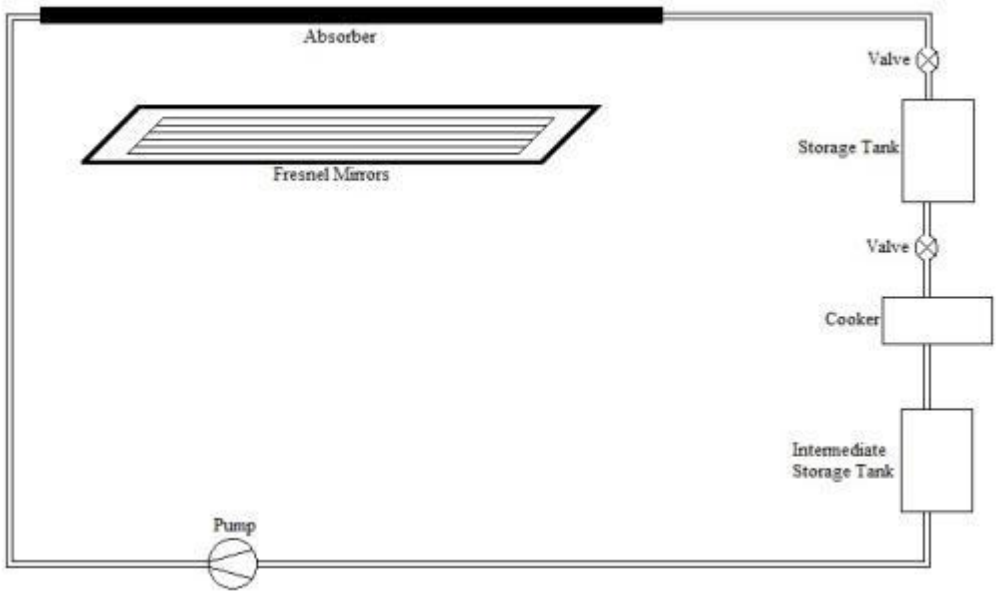
Size of each panel = 1.5 m^2

Number of Mirrors per panel = 42

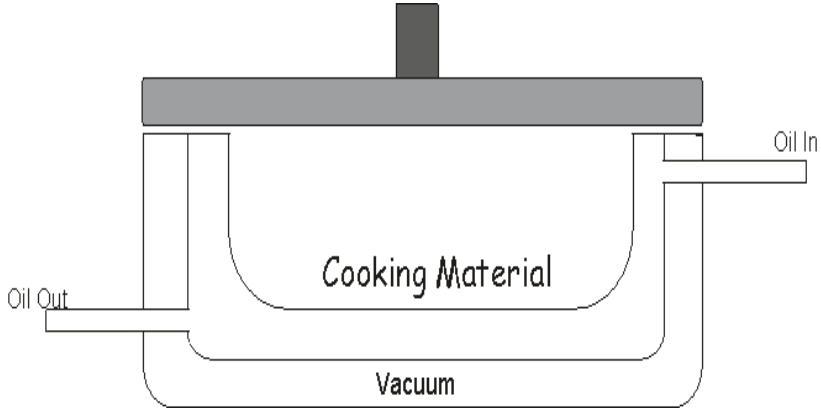
Size of each mirror = 125 x 2.5 cm^2

With acknowledgements to COMSATS (Pakistan)

Low-cost solar cooker design – schematics and prototype

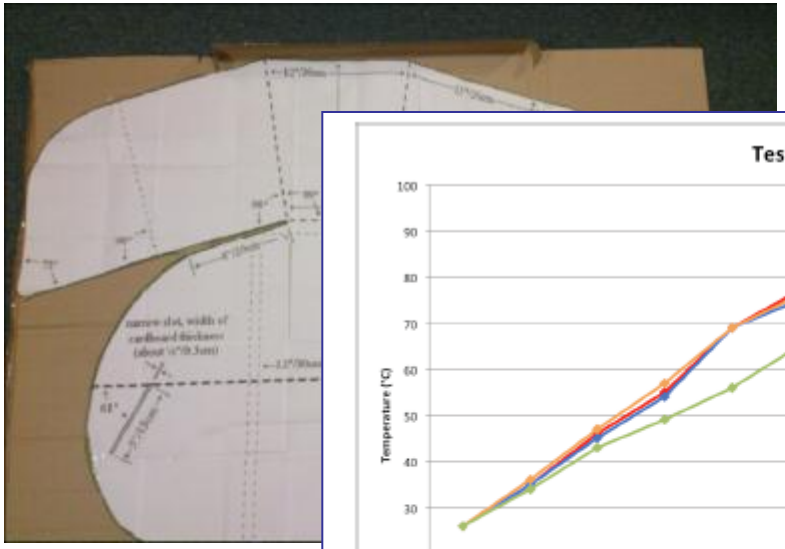


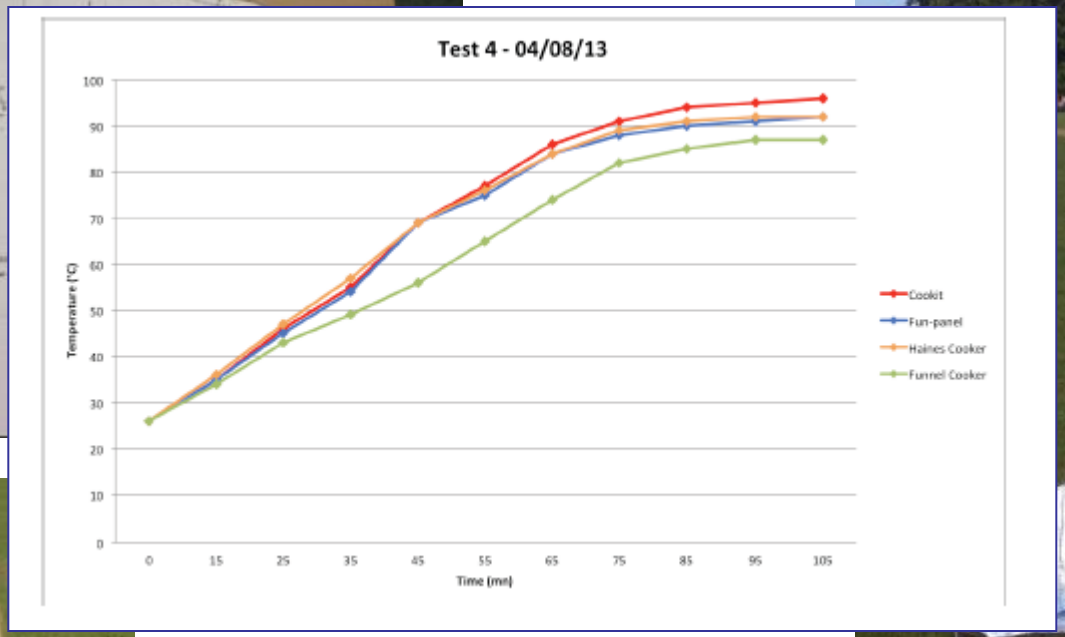
Current collaboration between COMSATS, University of Islamabad, Pakistan and Cranfield University. Precision Engineering Centre

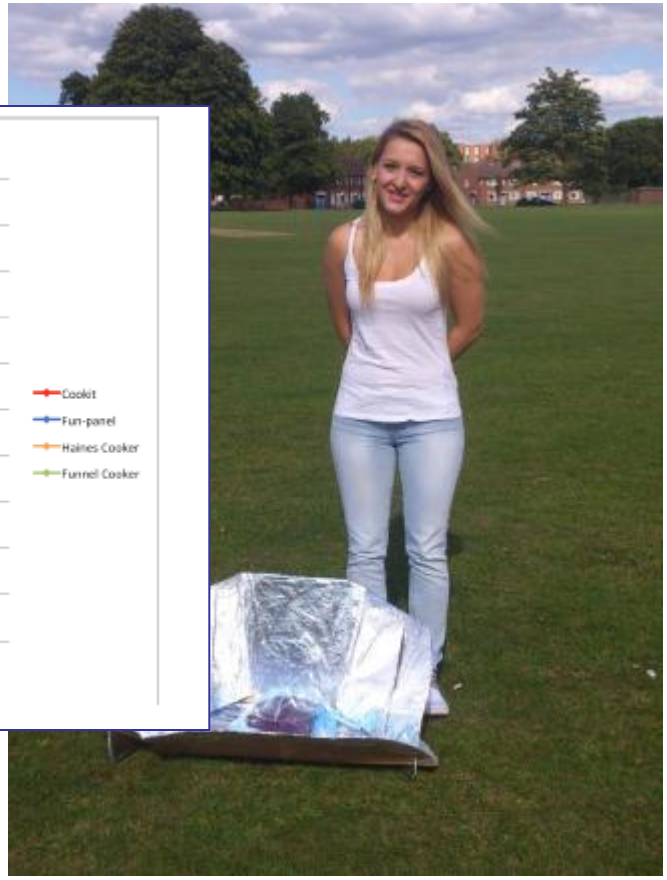


With acknowledgements to COMSATS (Pakistan)

Low-cost solar cooker design – Cranfield prototype







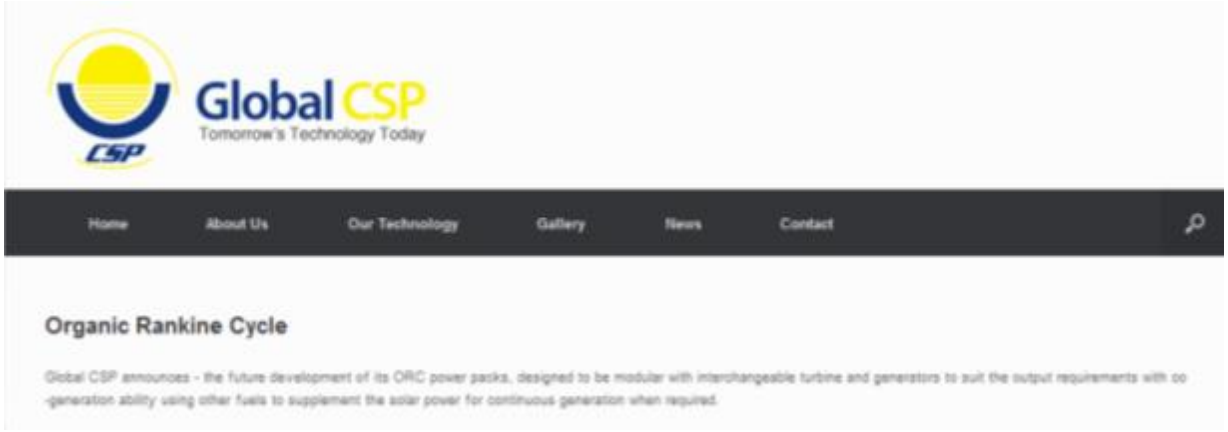
1. Rice : (Solar Cookers International Network , 2013)
- 4 cups rice
- 6 cups water

Cover and cook 10-15 minutes.

2. Chicken in the Pot : (Solar Cookers International Network, 2013)
- 4 chicken breasts
- 4 potatoes quartered
- 2 carrots cut
- 2 tomatoes
- pepper
- salt
- herbes de provence

Cover and cook approximately 1 1/2 to 2 hours.

Electrical Power Generation - ORC



Group Project 2014 (£20k)

Conversion from $300kW_T$ to $100kW_e$

Contract 2014-2016 (£1m+)

Design and build ORC at Cranfield

Cranfield University – International presence in CSP

Collaborative research:
- Italy, France, Germany, Egypt, Libya
- Saudi Arabia, Jordan, Pakistan

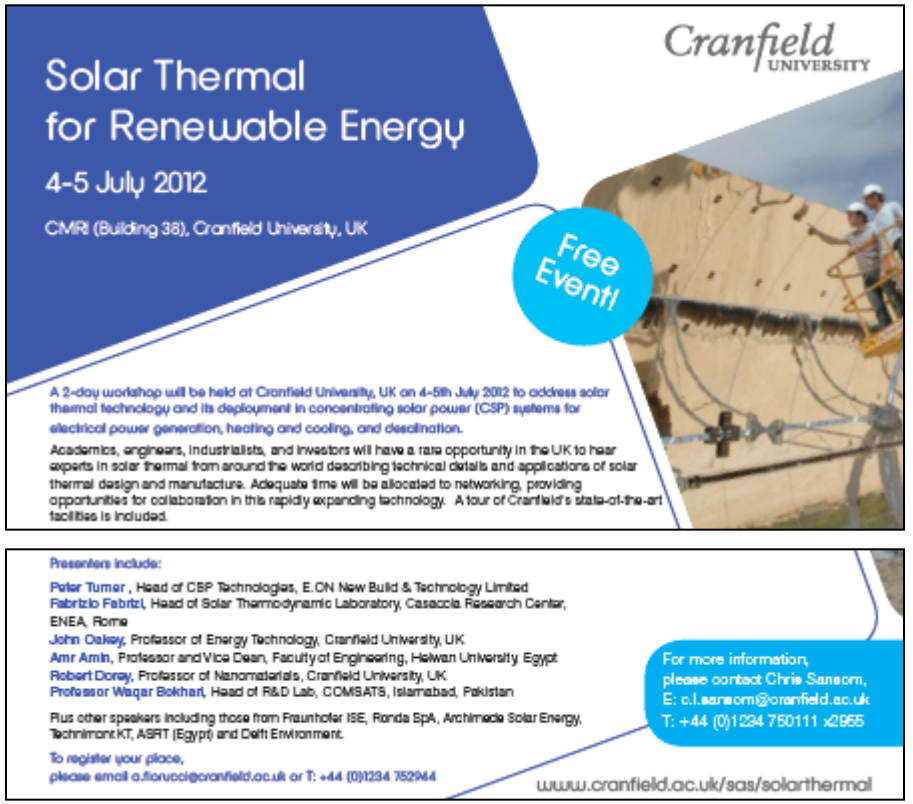
International events
- Solar Thermal workshop 2012
- CSP short-course 2013

EERA-CSP
- Only UK representative

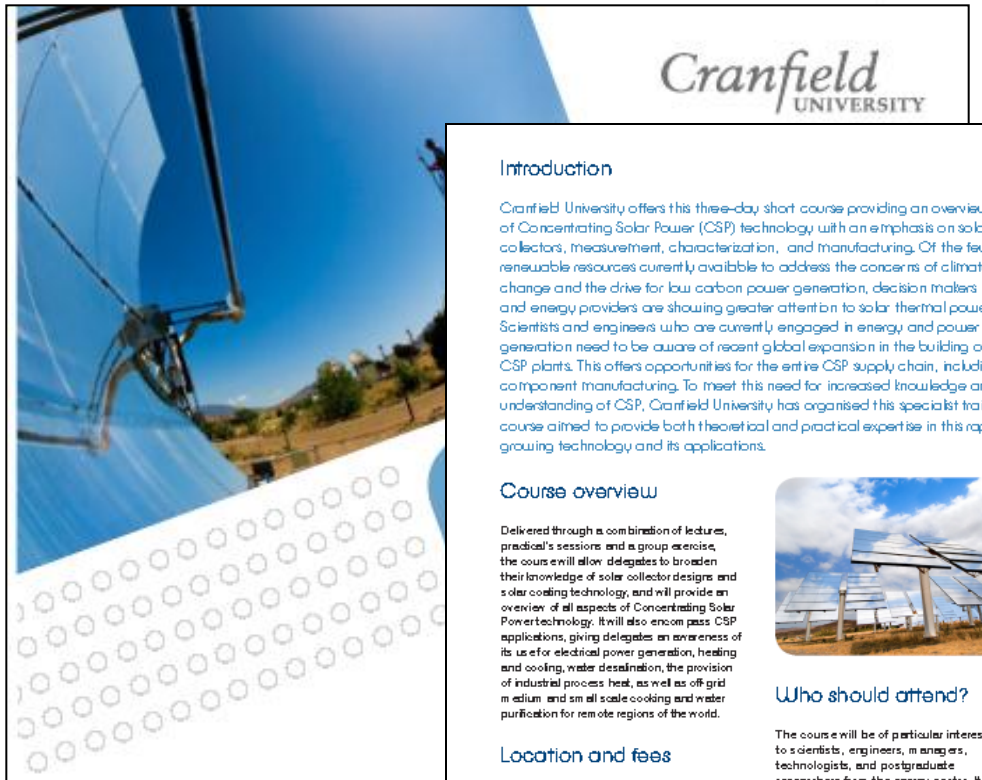
Consultant to Carbon Trust on CSP

DECC/DFID advisor on CSP for Sub-Saharan Africa and South America

Future work planned with Tunisia, Morocco, Algeria, Spain



Cranfield University Short course on CSP



Cranfield UNIVERSITY

Short course

Concentrating Solar Power (CSP)

20 - 22 March 2013

Introduction

Cranfield University offers this three-day short course providing an overview of Concentrating Solar Power (CSP) technology with an emphasis on solar collectors, measurement, characterization, and manufacturing. Of the few renewable resources currently available to address the concerns of climate change and the drive for low carbon power generation, decision makers and energy providers are showing greater attention to solar thermal power. Scientists and engineers who are currently engaged in energy and power generation need to be aware of recent global expansion in the building of CSP plants. This offers opportunities for the entire CSP supply chain, including component manufacturing. To meet this need for increased knowledge and understanding of CSP, Cranfield University has organised this specialist training course aimed to provide both theoretical and practical expertise in this rapidly growing technology and its applications.

Course overview

Delivered through a combination of lectures, practical's sessions and a group exercise, the course will allow delegates to broaden their knowledge of solar collector designs and solar coating technology, and will provide an overview of all aspects of Concentrating Solar Power technology. It will also encompass CSP applications, giving delegates an awareness of its use for electrical power generation, heating and cooling, water desalination, the provision of industrial process heat, as well as off-grid medium and small scale cooking and water purification for remote regions of the world.

Who should attend?

The course will be of particular interest to scientists, engineers, managers, technologists, and postgraduate researchers from the energy sector. It will also be valuable to manufacturing and engineering companies, policy makers, investors, research academics, technical professionals, technical staff and non-specialists who wish to gain a better understanding of CSP technology, its opportunities, and its applications.

Location and fees

The course takes place in the Cranfield Management Development Centre (CMDC) on the Cranfield campus. The non-residential fee for the course that includes tuition charges, lecture notes, use of laboratory tools and materials, refreshments, lunches and a course dinner, is £850. Discounts are available.

Course timetable

Day 1 Wednesday	Day 2 Thursday	Day 3 Friday
9.30 - 9.55 Registration	9.00 - 9.45 Lecture 4: Solar Collector technologies	9.00 - 9.45 Lecture 9: Performance Measurements and evaluation of CSP power plants
10.00 - 10.30 Introduction	9.45 - 10.30 Lecture 5: Receiver and absorber tube technologies	9.45 - 10.30 Lecture 10: CSP applications, including power generation, heating, cooling, desalination, and industrial process heat
10.30 - 11.15 Lecture 1: Linear Fresnel systems	10.30 - 11.00 Break	10.30 - 11.00 Break
11.15 - 11.30 Break	11.00 - 11.45 Lecture 6: Thermal storage and power generation	11.00 - 13.00 Group project assignments (selected to reflect the interests of the course delegates)
11.30 - 12.15 Lecture 2: Parabolic Trough systems	11.45 - 12.30 Lecture 7: CSP: Materials design	13.00 - 14.00 Lunch
12.15 - 13.00 Lecture 3: Heliostats and Central Receiver systems	12.30 - 13.15 Lecture 8: CSP: Optical and thermal design	14.00 - 16.00 Group project presentations
13.00 - 14.00 Lunch	13.15 - 14.15 Lunch	16.00 Close
14.00 - 17.00 Practical workshop on CSP collector form measurement	14.15 - 17.00 Practical workshop on CSP coatings for CSP receiver and absorber tubes:	
	19.00 Course Dinner	

Cranfield University Short Courses Concentrating Solar Power (CSP)

Contact C.L.Sansom@cranfield.ac.uk

Thank you for your attention

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