FLAGSOL

Solar Millennium LLC

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Advanced High Temperature Trough Collector Development

CSP Program Review

February 10, 2010

Statement of Project Objectives

- **The Solar Millennium group, with its subsidiary Flagsol, has developed a design of an advanced geometry parabolic trough collector, the HelioTrough. The HelioTrough design has three primary goals: higher performance, lower cost, and the potential to operate with a molten salt heat transfer fluid (HTF). The overall project objectives are to:**

- **Complete the final design of selected components of the HelioTrough Collector**
- **Construct and test a prototype HelioTrough-VP1 (oil HTF) collector loop at the SEGS V plant at Kramer Junction, working with host NextEra**
- **Develop design modifications to the HelioTrough collector to enable operation with molten salt, modify the prototype HelioTrough Collector Loop to accommodate salt HTF, and implement a prototype loop test of the HelioTrough-MS (molten salt HTF) collector.**

Timeline and Subtasks – Phase 1

Phase 1: Molten Salt Feasibility Study

Task 1.1: Evaluation of previous work

Task 1.2: Operation strategy for molten salt systems

Task 1.3: Investigation of thermodynamics of the new cycle

Task 1.4: Identification of new components

Task 1.5: Conceptual design of molten salt system

Task 1.6: Cost evaluation

Task 1.7: Cost comparison and economical analysis

Task 1.8: Risk Analysis

CRITICAL MILESTONE 1

A positive outcome of the Phase 1 study represents an additional critical milestone preceding Budget Period 2: Technical feasibility must be pointed out, and the concept has to show lower LCOE compared to the competitive technologies (synthetic oil / direct steam generation systems as the HTF).

Critical Milestone 1 was completed October 2008

Timeline and Subtasks – Phase 2

Phase 2: Engineering necessary for integration into SEGS V, and procurement and erection of the HelioTrough-VP1 demonstration loop

Task 2.1: Detailed engineering of HelioTrough reference loop

Task 2.2: Detailed engineering of new assembly tools

Milestone 2.1: **Detailed engineering for the procurement and erection of the HelioTrough-VP1 reference loop is finished. - completed July 2009**

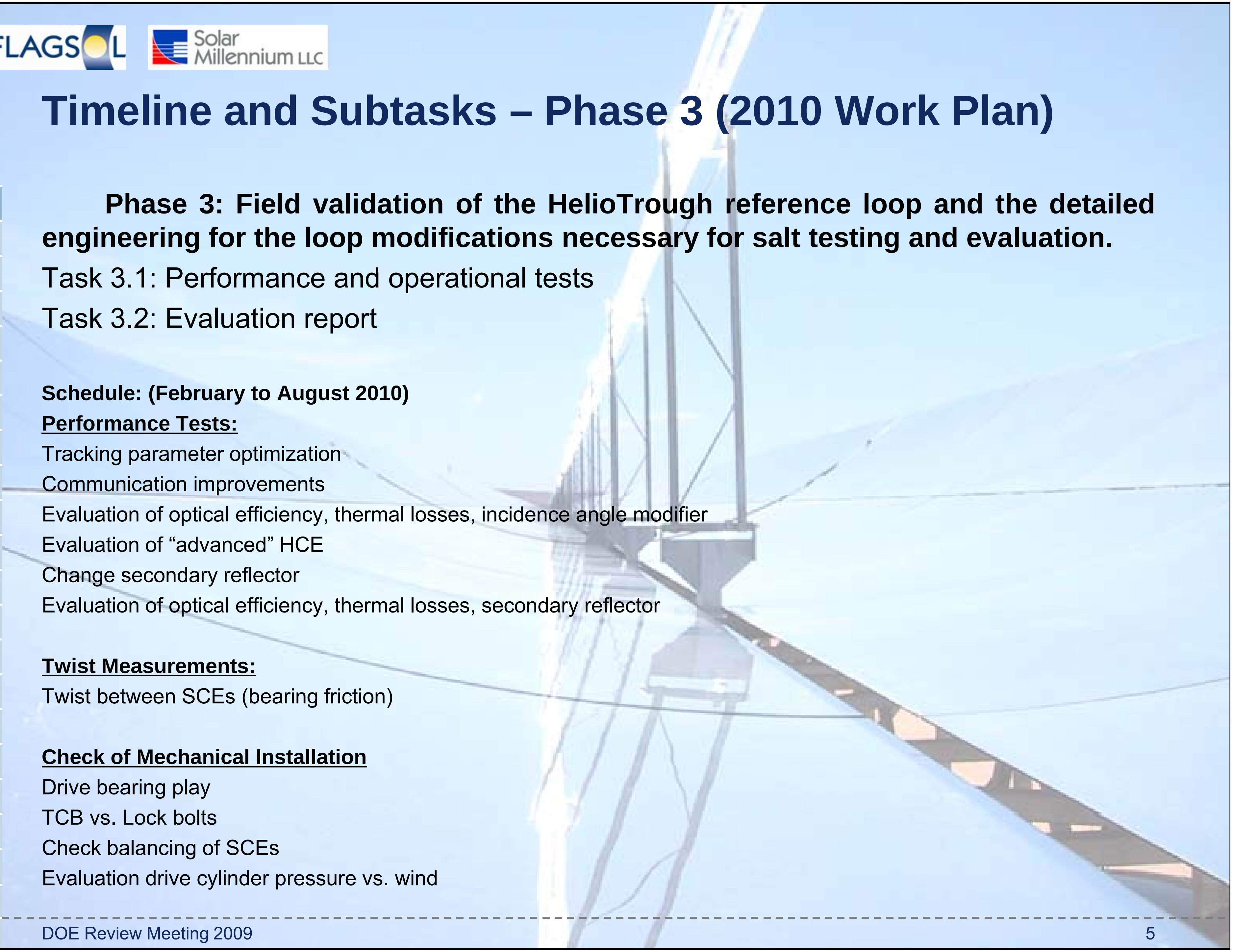
Task 2.3: Procurement, Erection, Commissioning

<u>CRITICAL MILESTONE 2</u>

Completion of the HelioTrough loop erection, including mechanical and electrical checkout.

Critical Milestone 2 was completed December 2009

Timeline and Subtasks – Phase 3 (2010 Work Plan)



Phase 3: Field validation of the HelioTrough reference loop and the detailed engineering for the loop modifications necessary for salt testing and evaluation.

Task 3.1: Performance and operational tests

Task 3.2: Evaluation report

Schedule: (February to August 2010)

Performance Tests:

Tracking parameter optimization

Communication improvements

Evaluation of optical efficiency, thermal losses, incidence angle modifier

Evaluation of “advanced” HCE

Change secondary reflector

Evaluation of optical efficiency, thermal losses, secondary reflector

Twist Measurements:

Twist between SCEs (bearing friction)

Check of Mechanical Installation

Drive bearing play

TCB vs. Lock bolts

Check balancing of SCEs

Evaluation drive cylinder pressure vs. wind

CRITICAL MILESTONE 3.1

The critical Milestone 3.1 is successful conclusion of the HelioTrough reference loop test period. Detailed performance modelling, including evaluation of data covering all sun angles of incidence is required.

Timeline and Subtasks – Phase 3 cont.

Task 3.3: *Development of new salt components*

Task 3.4: *Detailed engineering of advanced HTF balance of plant (BOP)*

Task 3.5: *Detailed engineering of HelioTrough-MS reference loop modification*

Task 3.6: *Cost evaluation of modifications*

Task 3.7: *Re-evaluation of cost comparisons*

Critical Milestone 3.2: Completing the detailed engineering of the component modifications necessary for salt operation is an important milestone.

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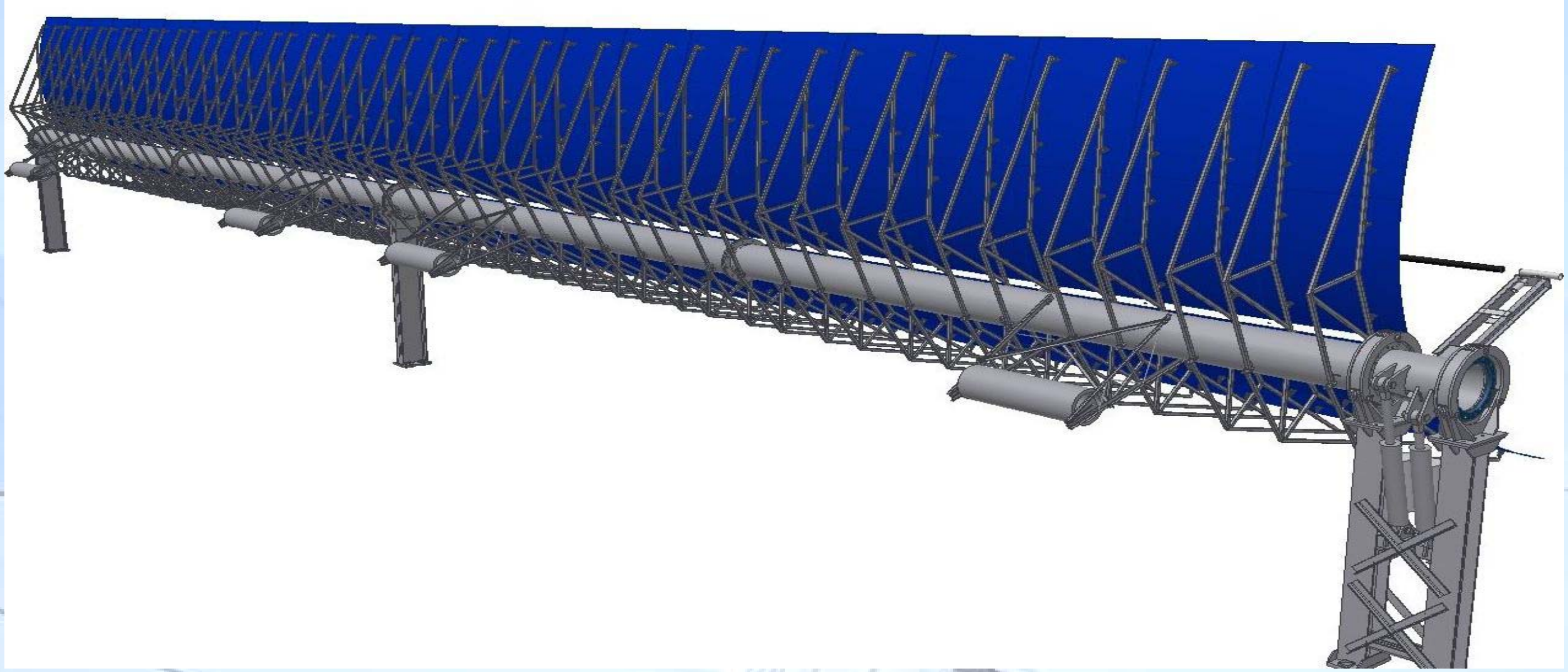
Timeline and Subtasks – Phase 4

Phase 4: Field validation of the HelioTrough-MS advanced HTF loop

Task 4.1: Procurement, Modification of reference loop, Commissioning
Task 4.2: Performance and operational tests
Task 4.3: Evaluation report

Schedule:
Start Date: January 1, 2011
Completion Date: December 31, 2012

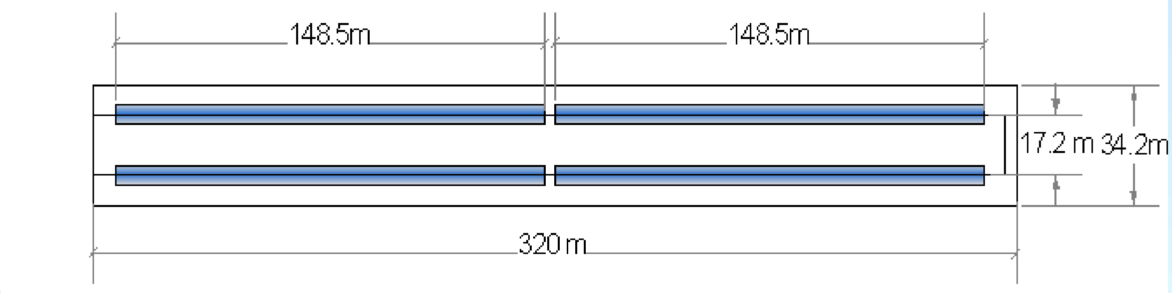
HelioTrough Development – Background Information



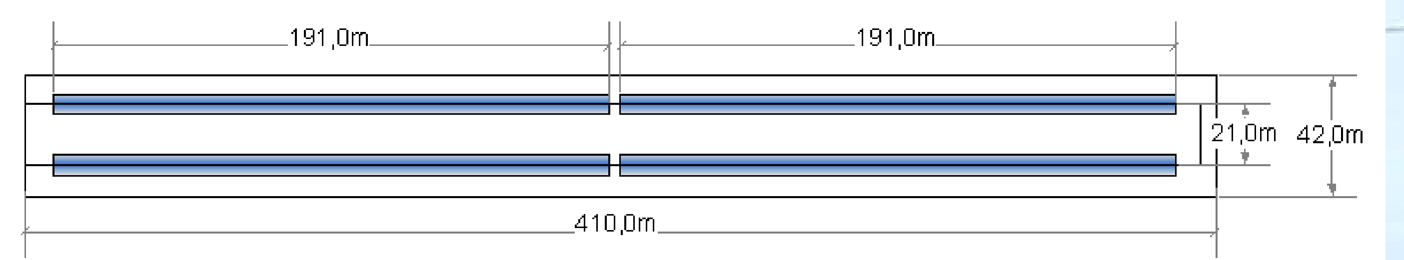
- Torque tube design
- Center of gravity below mirror surface (Counter weights)
- Gapless SCA (no mirror gap across the pylons)
- Hydraulic drive
- Aperture width: 6.77 m (+ 20 %)
- HCE: 89.9 mm diameter (+ 27 %)
- 4.7 m length per HCE (+ 18 %)
- Length of one SCE: 19.1 m (+ 60 %)
- 10 SCEs per collector (Total length: 191 m)
- Aperture area: 1293 m² gross / 1263 m² net

Comparison with SKALET Technology

SKALET Loop layout



HelioTrough Loop layout



- → Same thermal output with 10% smaller solar field:1250 m^2 SKALET / 740 m^2 HelioTrough
- → Shorter header pipe lines
- → Less investment costs (piping, HTF)
- → Significant decrease of auxiliary consumption
- → Fewer drives, foundations, wiring

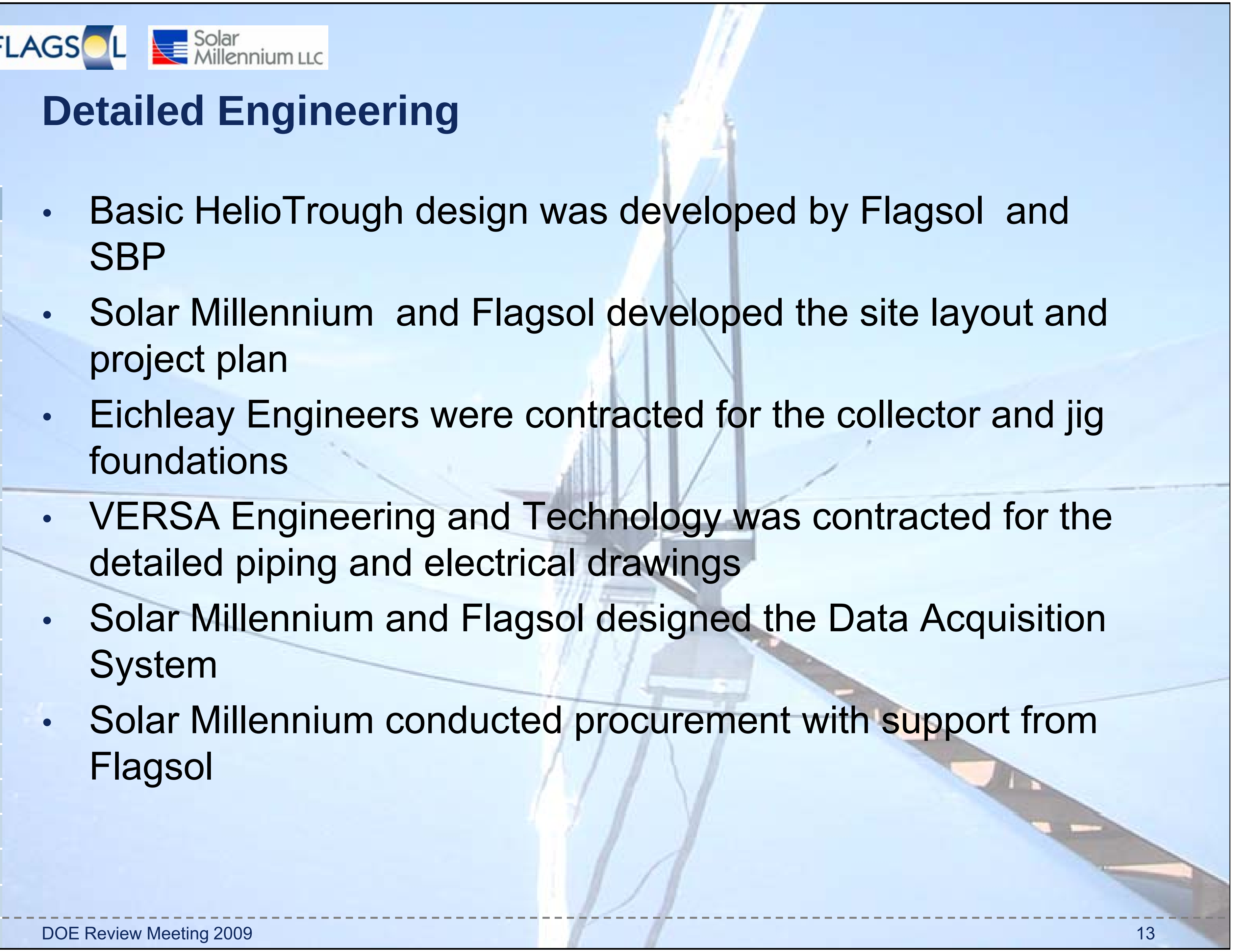
Prototype Erection

- → Two prototype SCEs assembled in warehouse in Dortmund, Germany
- → Assembly concept validated
- → Geometrical accuracy proven

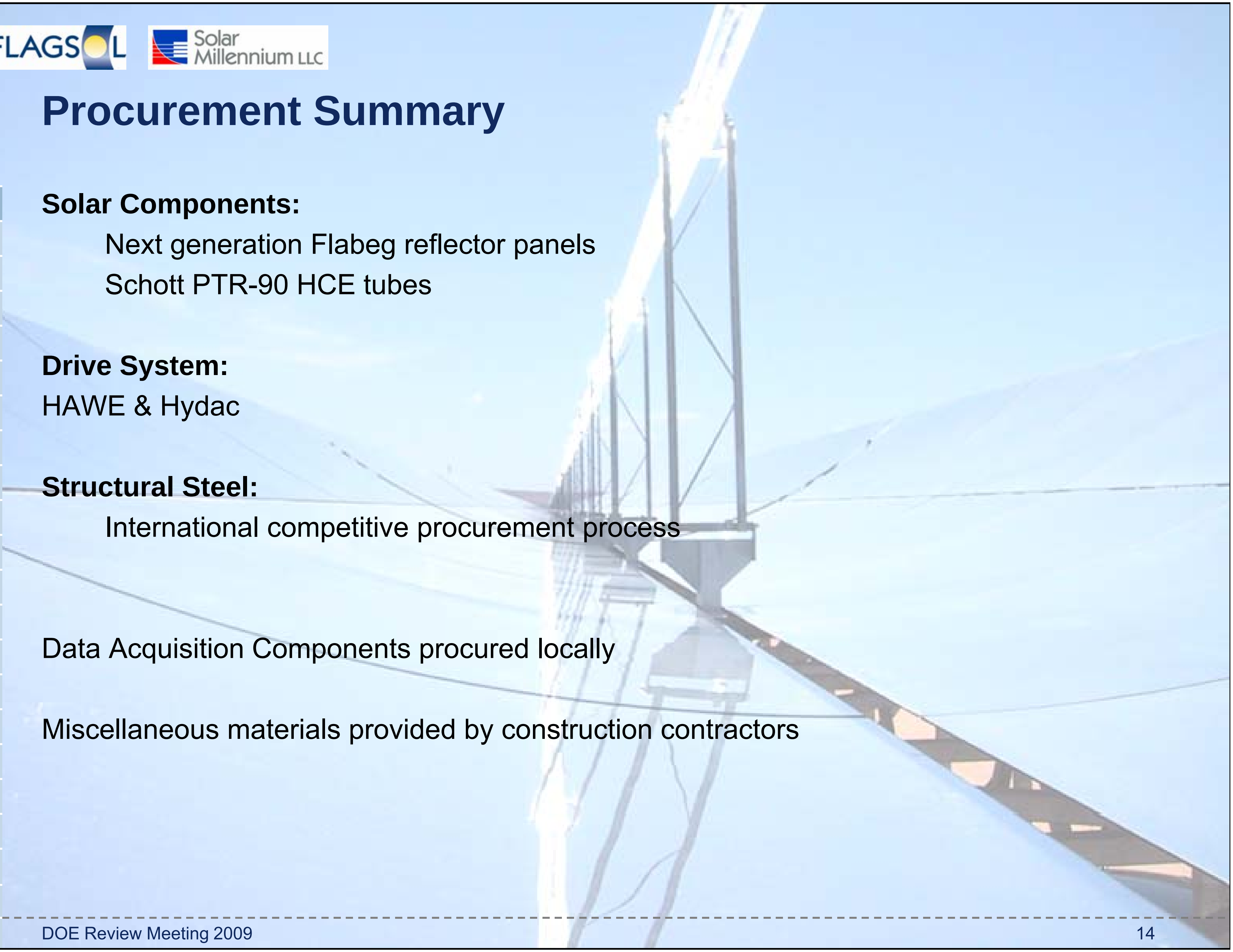
Prototype Erection

First HelioTrough Collector Element

Detailed Engineering



- Basic HelioTrough design was developed by Flagsol and SBP
- Solar Millennium and Flagsol developed the site layout and project plan
- Eichleay Engineers were contracted for the collector and jig foundations
- VERSA Engineering and Technology was contracted for the detailed piping and electrical drawings
- Solar Millennium and Flagsol designed the Data Acquisition System
- Solar Millennium conducted procurement with support from Flagsol



Procurement Summary

Solar Components:

- Next generation Flabeg reflector panels
- Schott PTR-90 HCE tubes

Drive System:

HAWE & Hydac

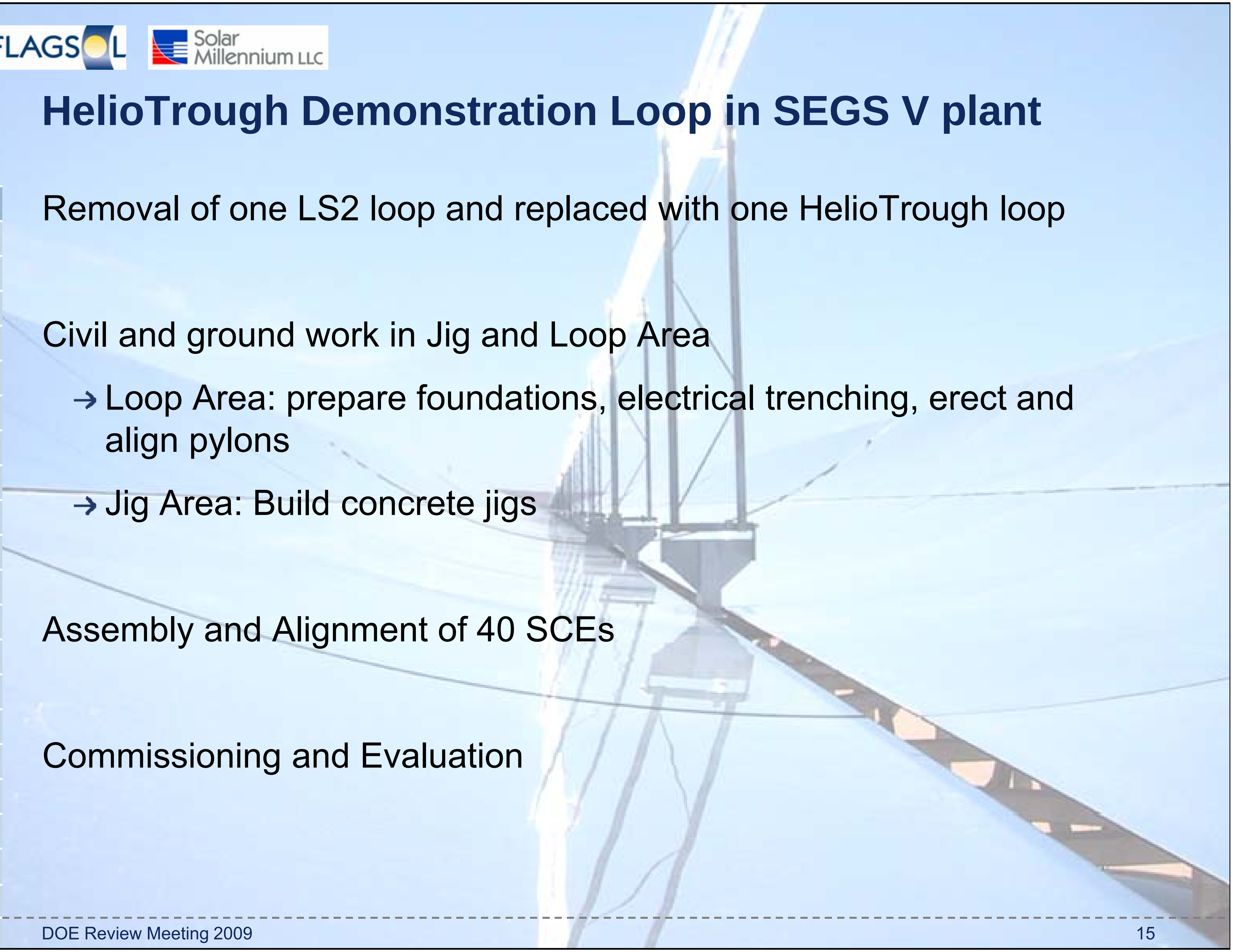
Structural Steel:

- International competitive procurement process

Data Acquisition Components procured locally

Miscellaneous materials provided by construction contractors

HelioTrough Demonstration Loop in SEGS V plant



Removal of one LS2 loop and replaced with one HelioTrough loop

Civil and ground work in Jig and Loop Area

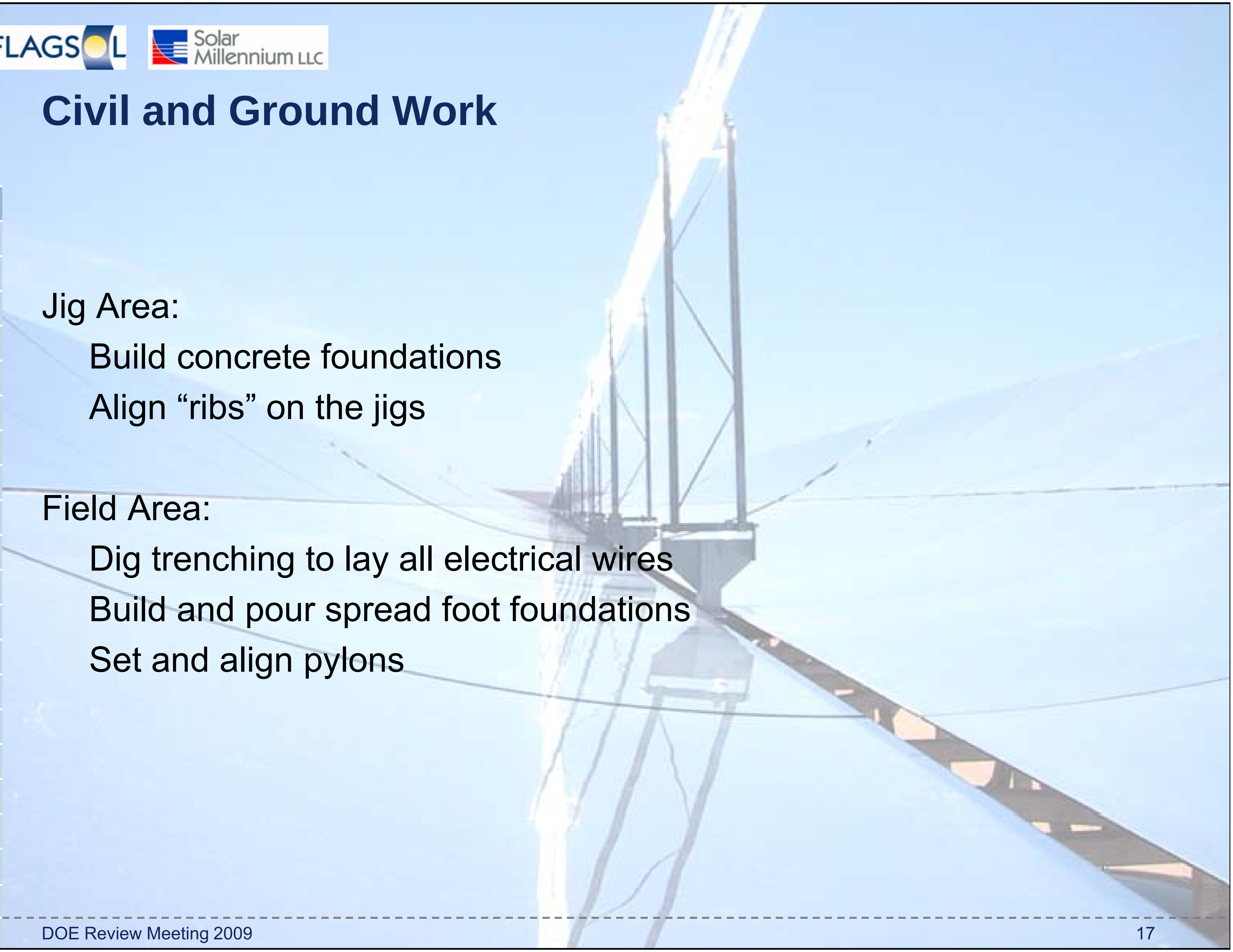
- → Loop Area: prepare foundations, electrical trenching, erect and align pylons
- → Jig Area: Build concrete jigs

Assembly and Alignment of 40 SCEs

Commissioning and Evaluation

Removal of old LS-2 collector

Civil and Ground Work



Jig Area:

- Build concrete foundations
- Align “ribs” on the jigs

Field Area:

- Dig trenching to lay all electrical wires
- Build and pour spread foot foundations
- Set and align pylons

Civil and Ground Work – Jig Area

Pouring concrete for the base of the jig

Concrete Jig

Civil and Ground Work - Loop

Setting the anchor bolts for the drive pylon

Pylon Field Erection

Drive Pylon Commissioning

Pylon Erection

SCE Assembly

TIC was contracted for the construction and alignment of 40 HelioTrough SCEs

SCEs were built on a series of alignment jigs:

- Torque Tube Station
- Structural Jig
- Mirror Jig
- Balancing Station

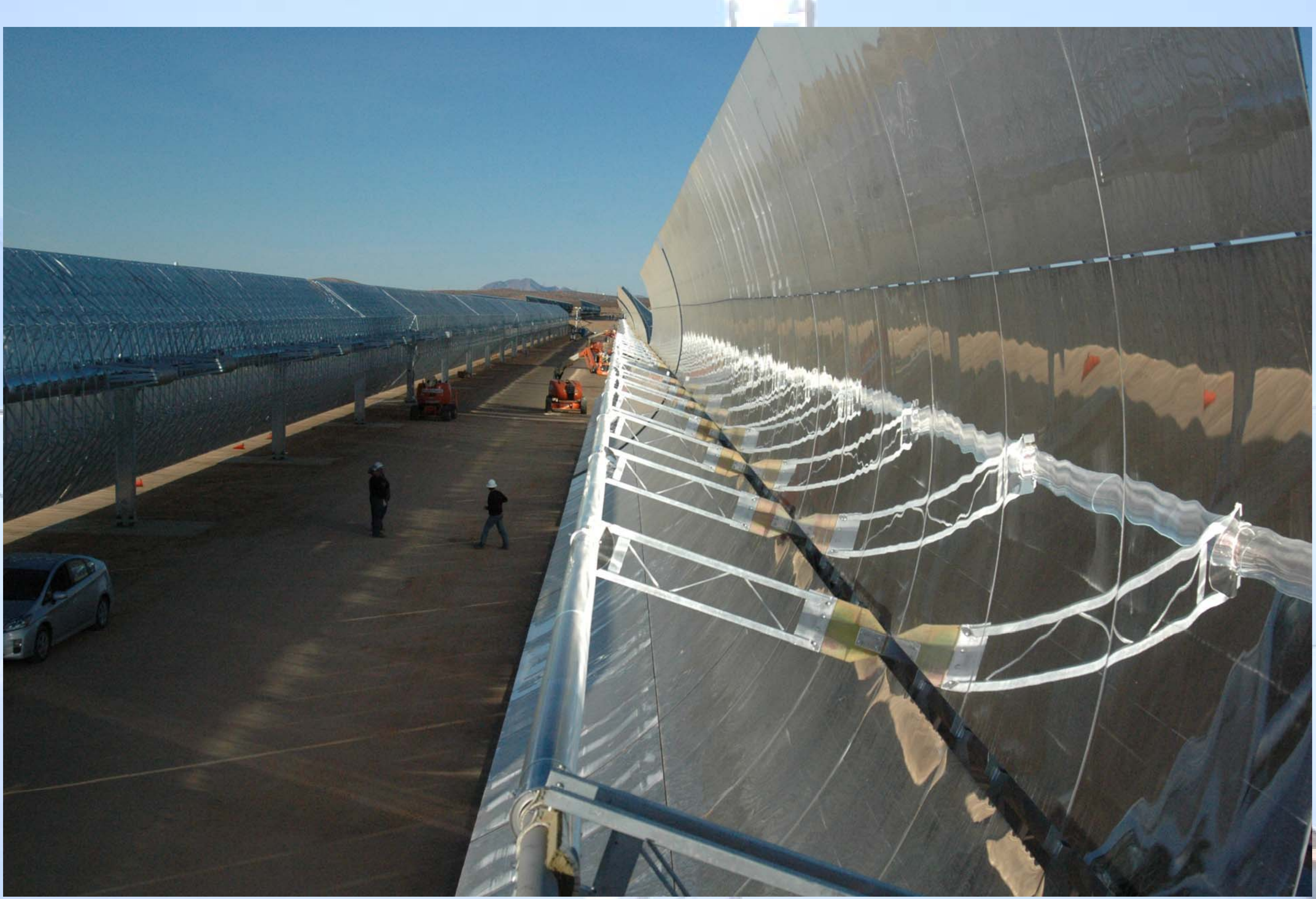
SCE Assembly

Balancing Station

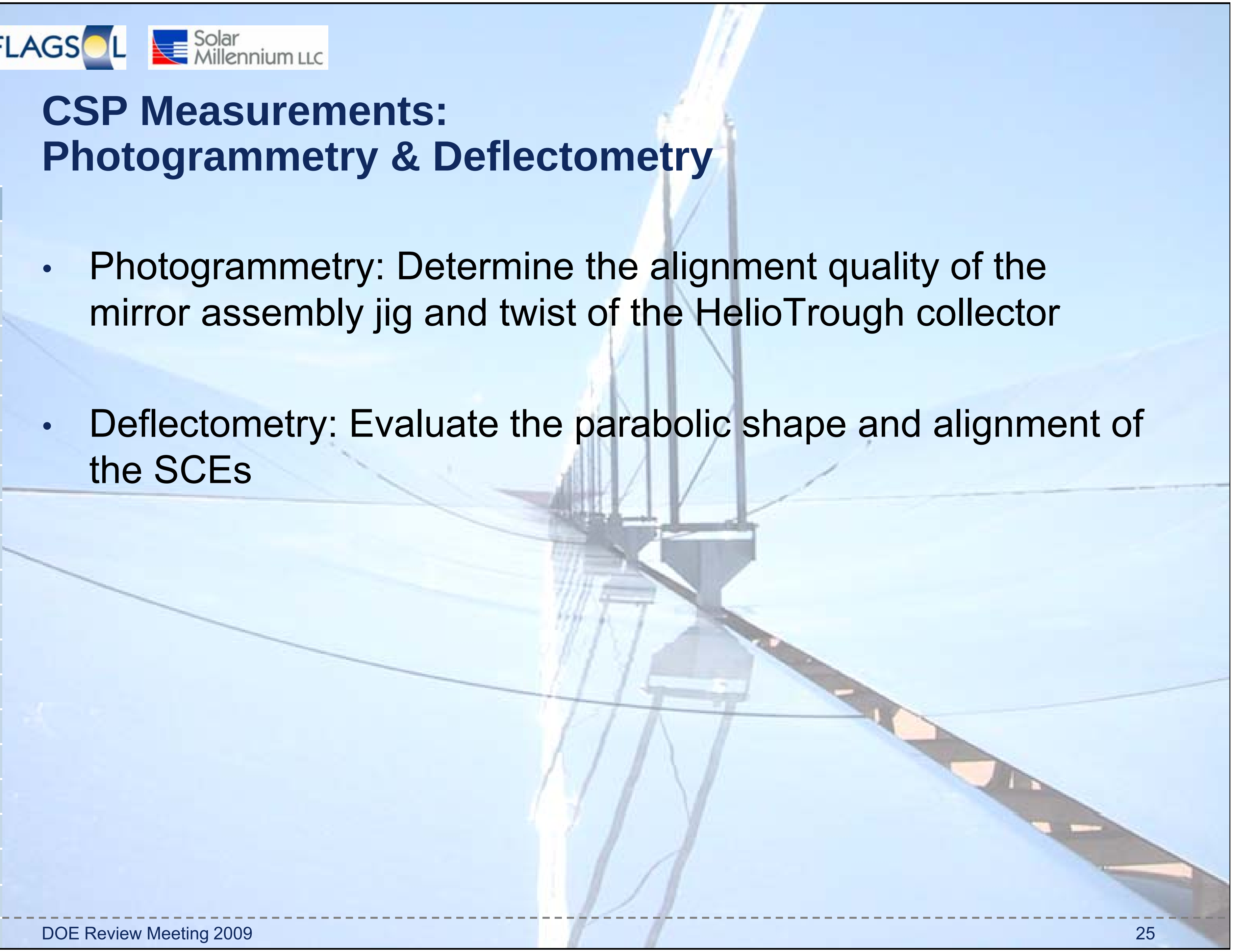
- Adjust counter weights for center of gravity
- Attach cantilever arm weights to even out the distribution of weight

SCE Field Installation and Alignment

Completed Loop - Tracking HelioTrough Collector



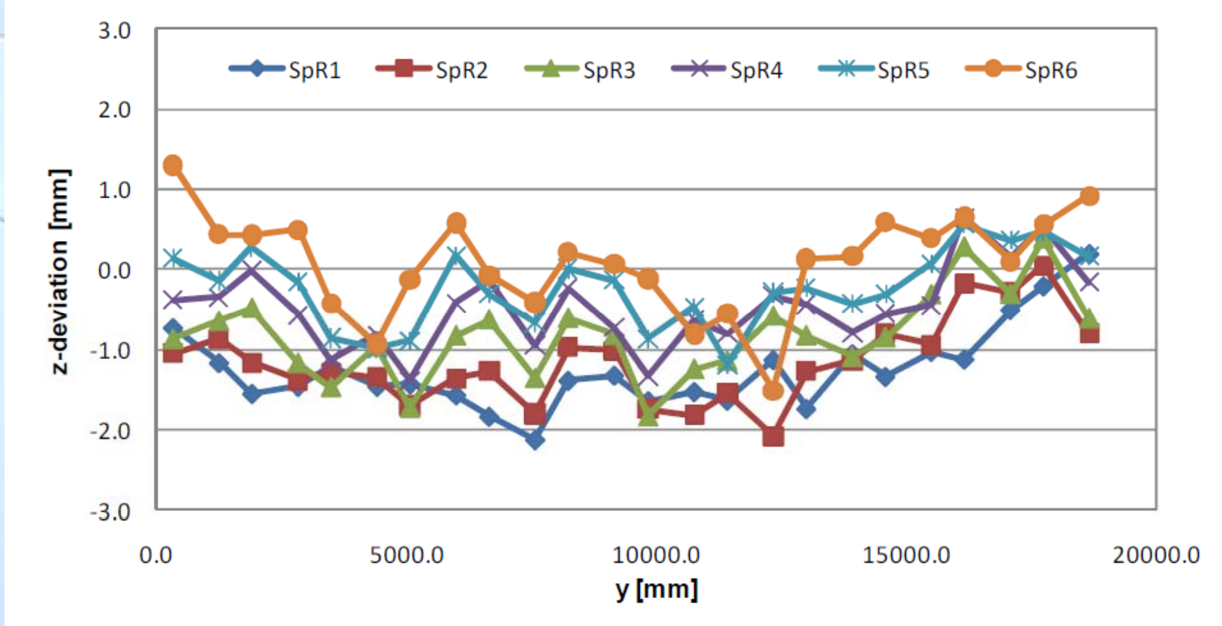
CSP Measurements: Photogrammetry & Deflectometry



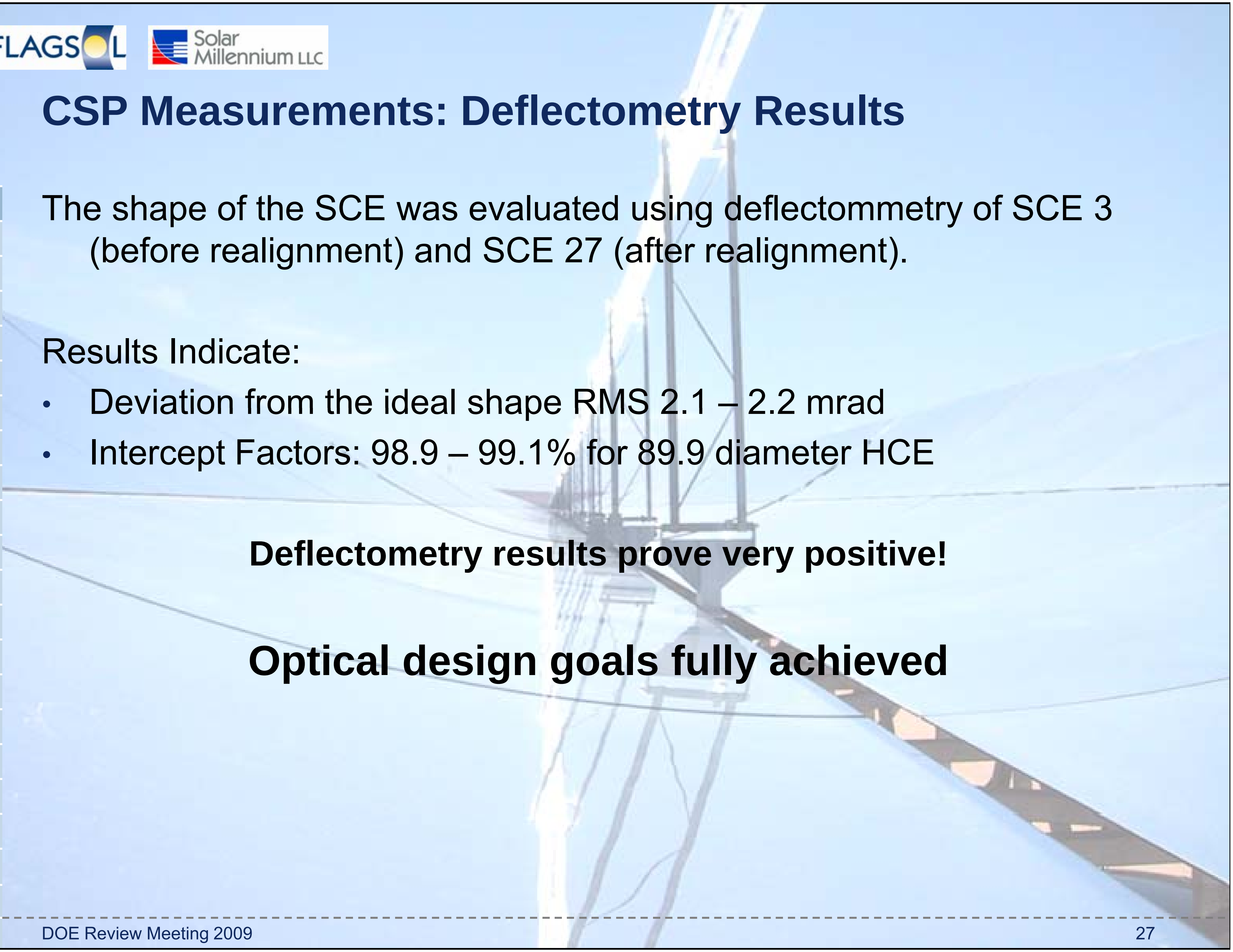
- Photogrammetry: Determine the alignment quality of the mirror assembly jig and twist of the HelioTrough collector
- Deflectometry: Evaluate the parabolic shape and alignment of the SCEs

CSP Measurements: Photogrammetry Results

- The mirror jig was measured twice with photogrammetry. Initial measurements indicated that realignment was necessary.
- Because the jigs were built outside, wind and heat can affect the precision required for the jig.
- For a commercial plant, collectors will be built inside a warehouse to mitigate these problems.



CSP Measurements: Deflectometry Results



The shape of the SCE was evaluated using deflectommetry of SCE 3 (before realignment) and SCE 27 (after realignment).

Results Indicate:

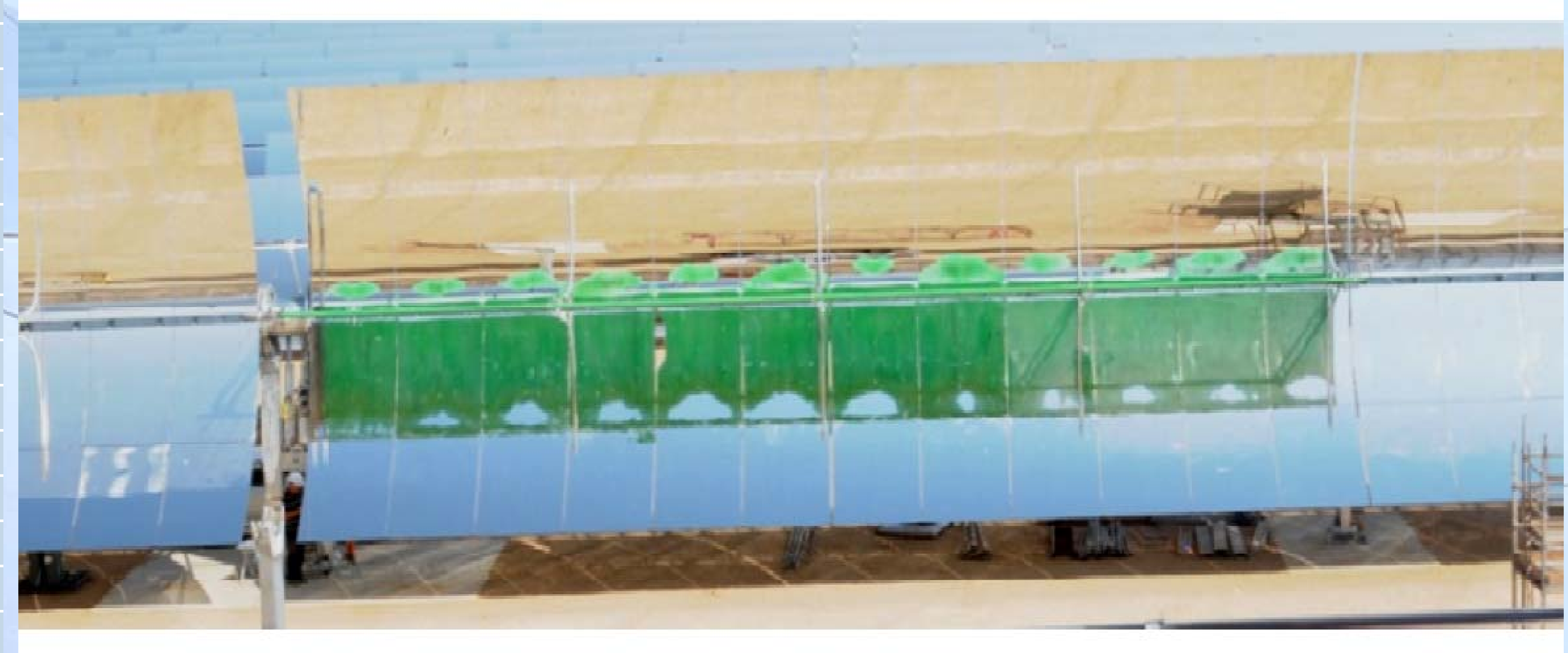
- Deviation from the ideal shape RMS 2.1 – 2.2 mrad
- Intercept Factors: 98.9 – 99.1% for 89.9 diameter HCE

Deflectometry results prove very positive!

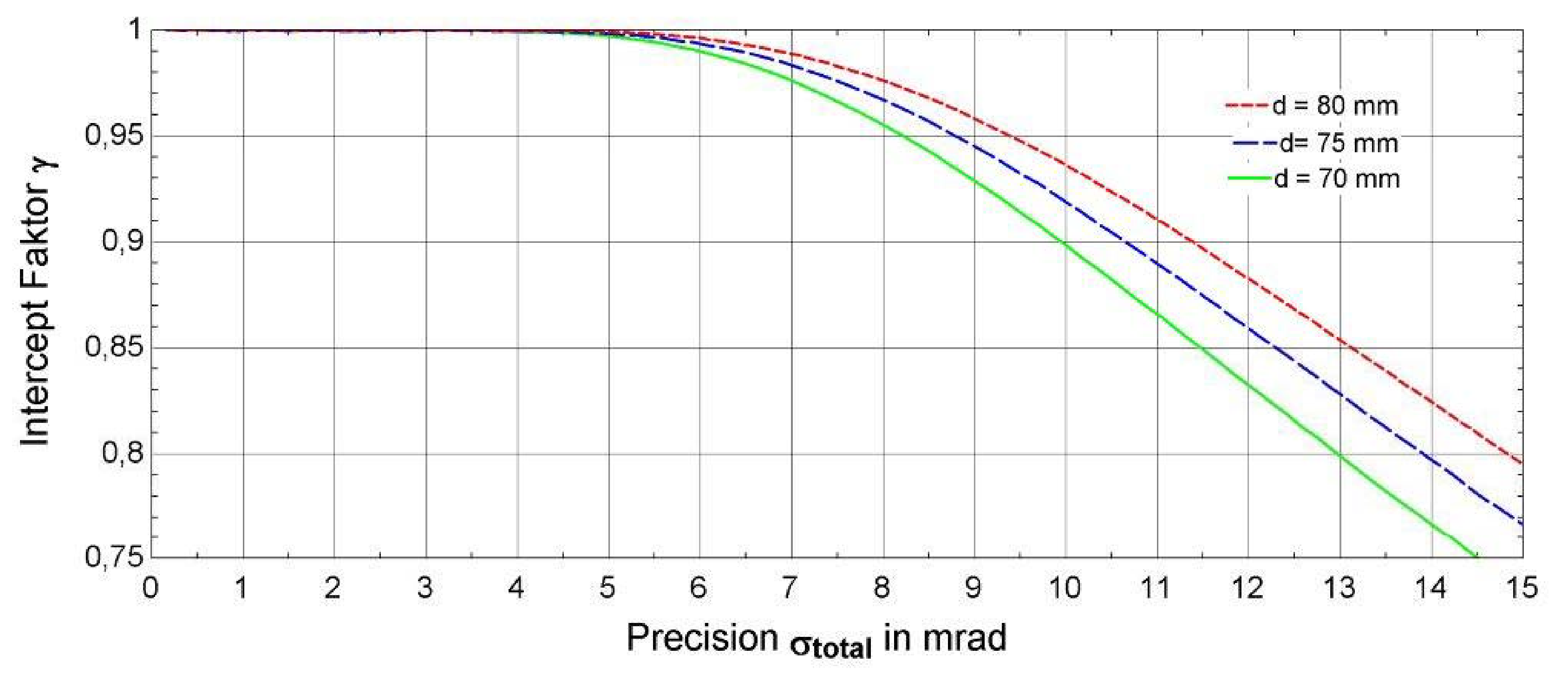
Optical design goals fully achieved

Deflectometry

- The green area in the concentrator is the reflection of the dummy absorber tubes



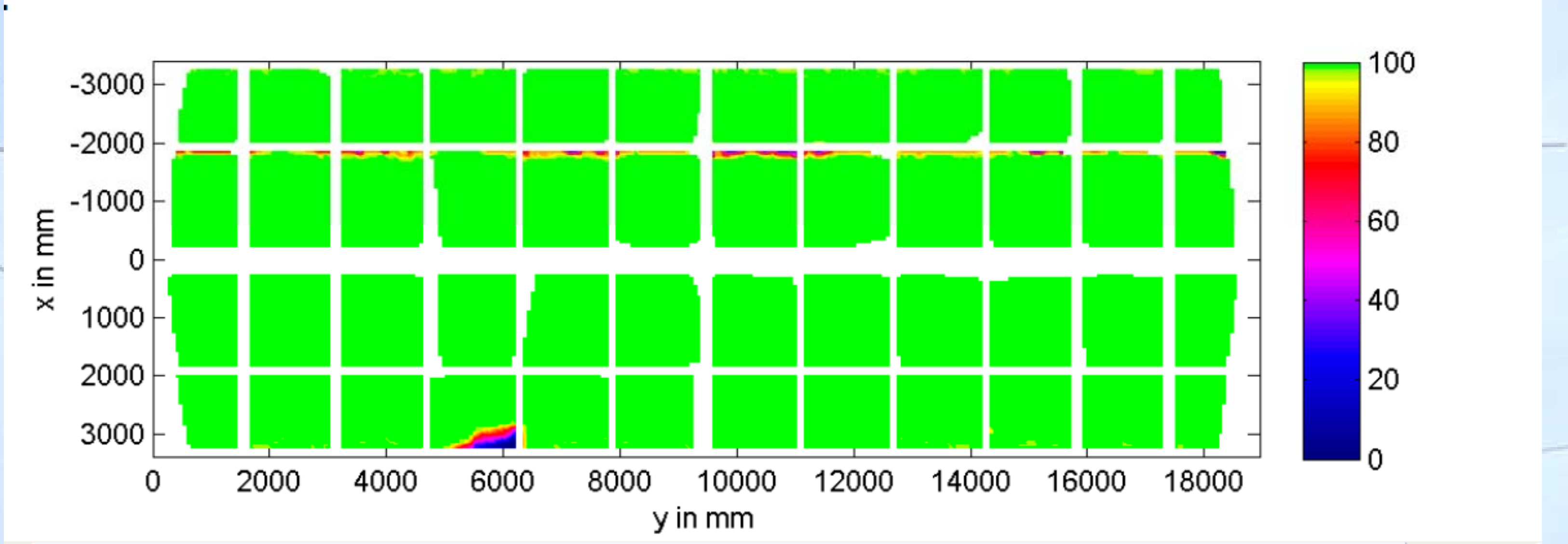
Deflectometry Results Continued



Deflectometry – SCE 3

Local Intercept Factor:

- Green: All reflected rays hit the absorber tube
- Red: Part of the reflected rays miss the absorber tube
- Blue: Reflected rays will most likely miss the absorber tube

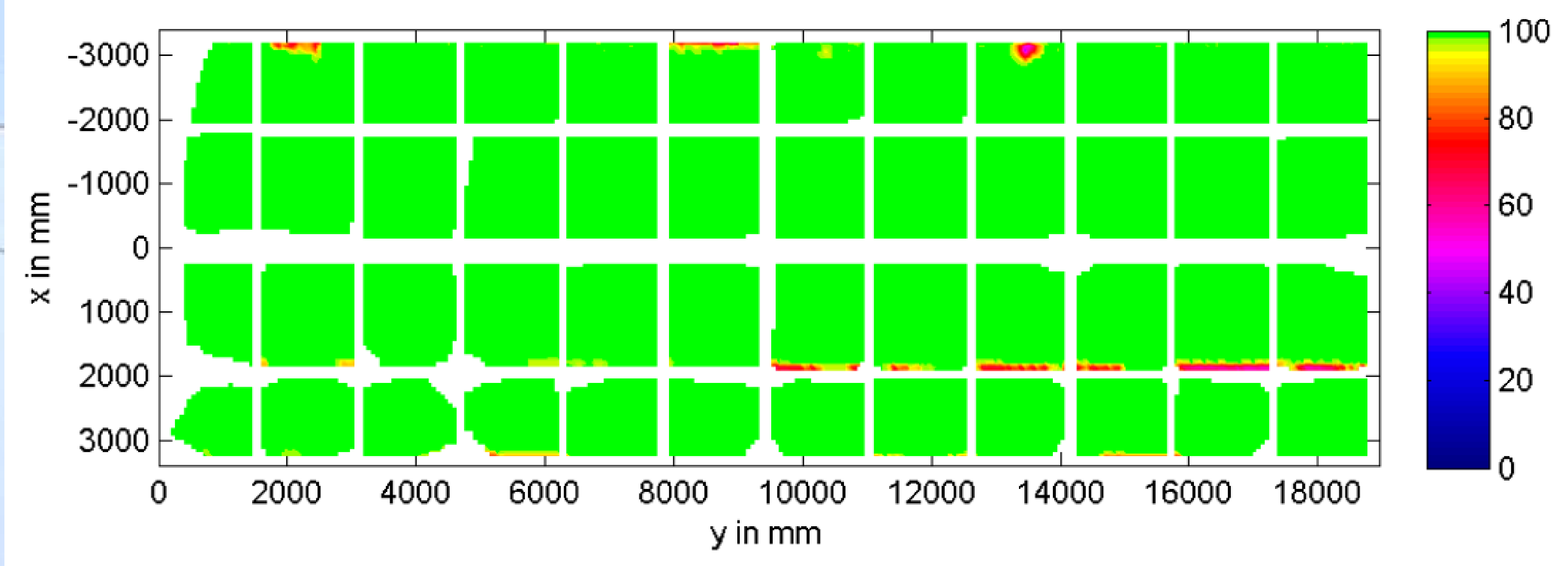


Total intercept factor with the sun-shape is calculated to be 98.9%

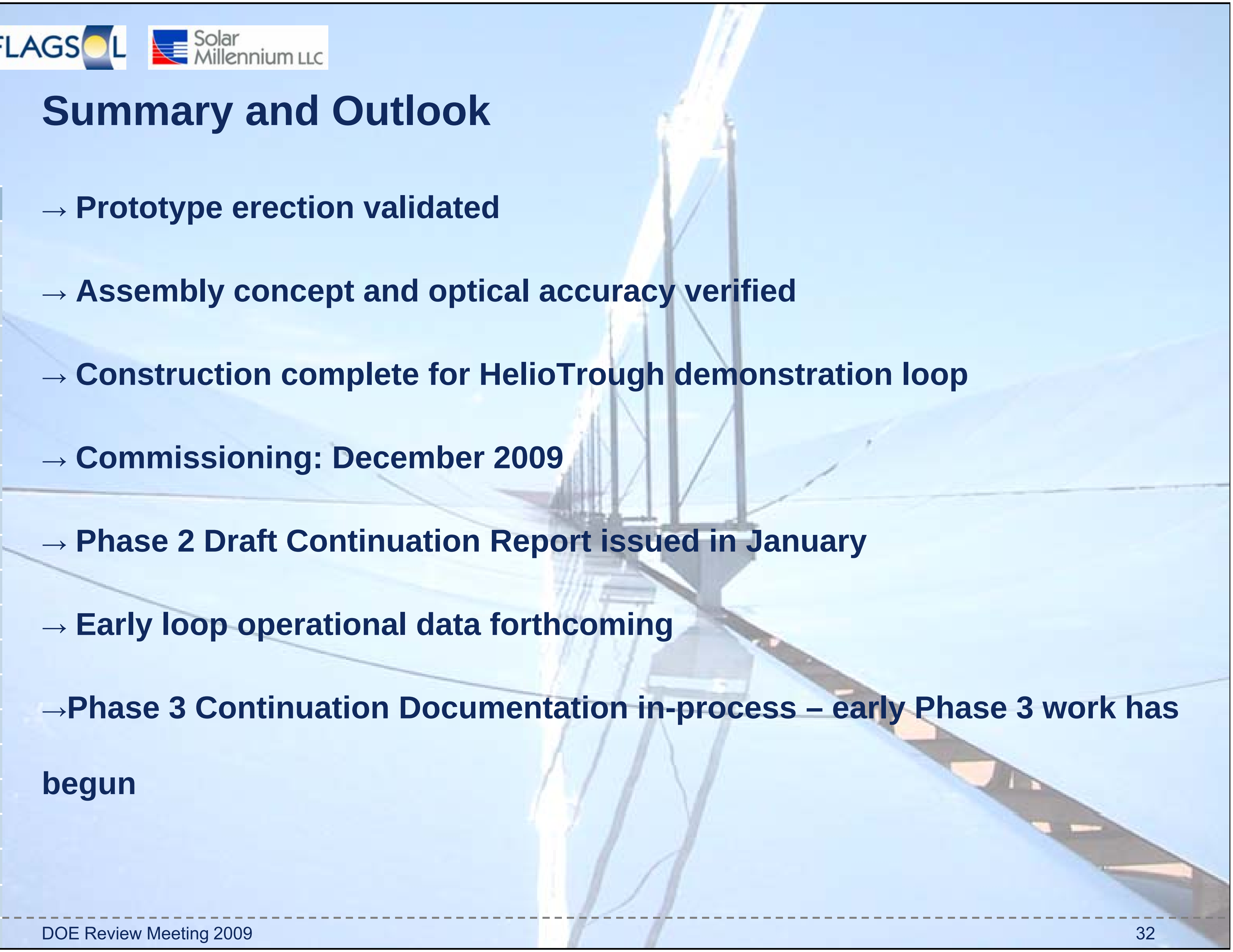
Deflectometry – SCE 27

Local Intercept Factor:

- Green: All reflected rays hit the absorber tube
- Red: Part of the reflected rays miss the absorber tube
- Blue: Reflected rays will most likely miss the absorber tube



Total intercept factor with the sun-shape is calculated to be 99.1%



Summary and Outlook

→ Prototype erection validated

→ Assembly concept and optical accuracy verified

→ Construction complete for HelioTrough demonstration loop

→ Commissioning: December 2009

→ Phase 2 Draft Continuation Report issued in January

→ Early loop operational data forthcoming

→Phase 3 Continuation Documentation in-process – early Phase 3 work has begun

Thank you
Questions & Comments