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Model based correction of heliostat tracking errors

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Content

- Background & Motivation
- Objectives
- Control Problem Overview
- Systemic Error Sources
- System Overview
- Communication and processing aspects
- Results

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Background + Motivation

- Heliostat field is 40-50% of plant cost

  → Focus cost reduction efforts here.

- Smart tracking- and error correction strategies may allow the use of low cost, low tolerance mechanisms + installation → SAVINGS

- Understanding control requirements is a vital step towards developing local CSP content

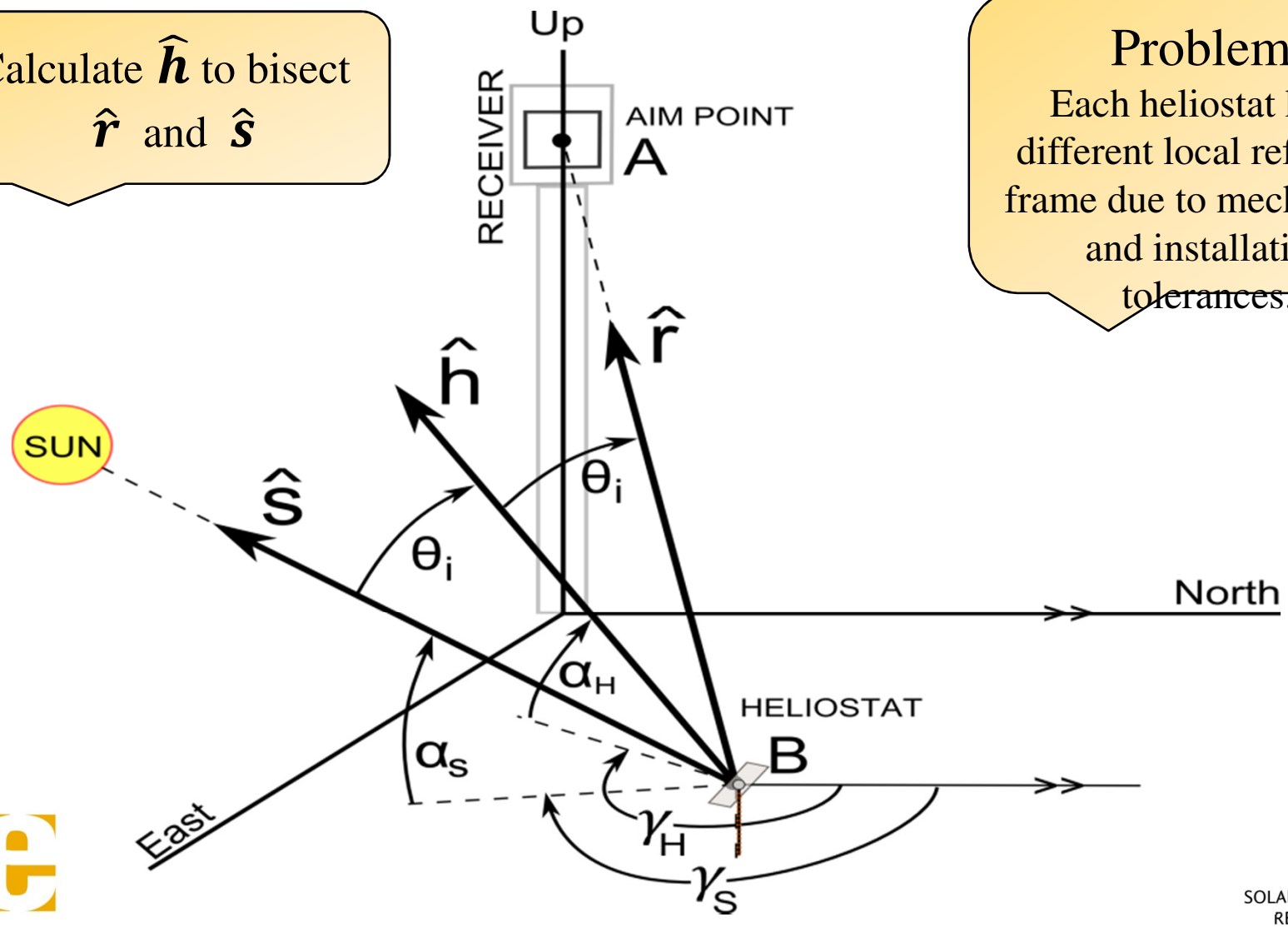
Objectives

- Develop high level control architecture for heliostat field ($5MW_E$ SUNSPOT context).
- Validate control architecture with prototype system which is scalable and modular.
- Demonstrate open loop tracking and error correction method with "learning" capability to minimize errors over time.

Open-loop Control: Heliostat Vector Calculation

Calculate $\hat{\boldsymbol{h}}$ to bisect $\hat{\boldsymbol{r}}$ and $\hat{\boldsymbol{s}}$

Problem:
Each heliostat has a different local reference frame due to mechanical- and installation tolerances.



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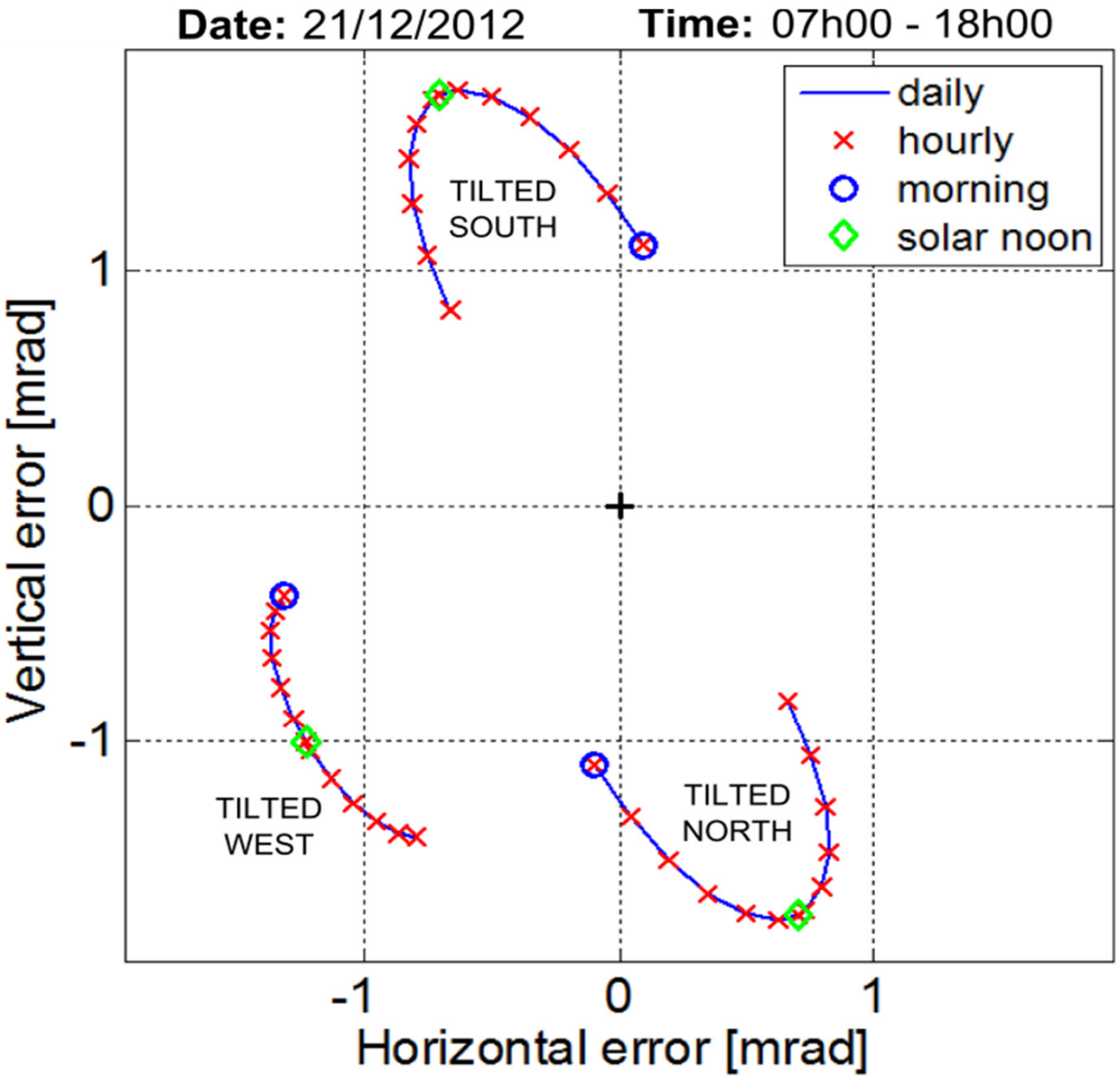
Typical Sources of OL Heliostat Tracking Error

- Pedestal Tilt (non-vertical azimuth axis)
- Bias Offsets
  - Reference North ≠ REAL NORTH , Reference Horizon ≠ REAL HORIZON
- Heliostat Location offset
- Non-orthogonal axes
- Gravity Sag
- NB: All except location offset cause tracking errors which **vary over days and seasons** and cannot be corrected by single offset adjustments

Tilted Pedestal Daily Tracking Error (SE heliostat)



Heliostat Location [m]

Z:	1
E:	30.8
N:	-19.2

Error Profile

Location Error [m]

Z:	0
E:	0
N:	0

Pedestal Tilt [mrad]

North-South: +1 / 0 / -1
East-West: 0 / -1 / 0

Axes Bias [mrad]

Azimuth	0
Elevation	0

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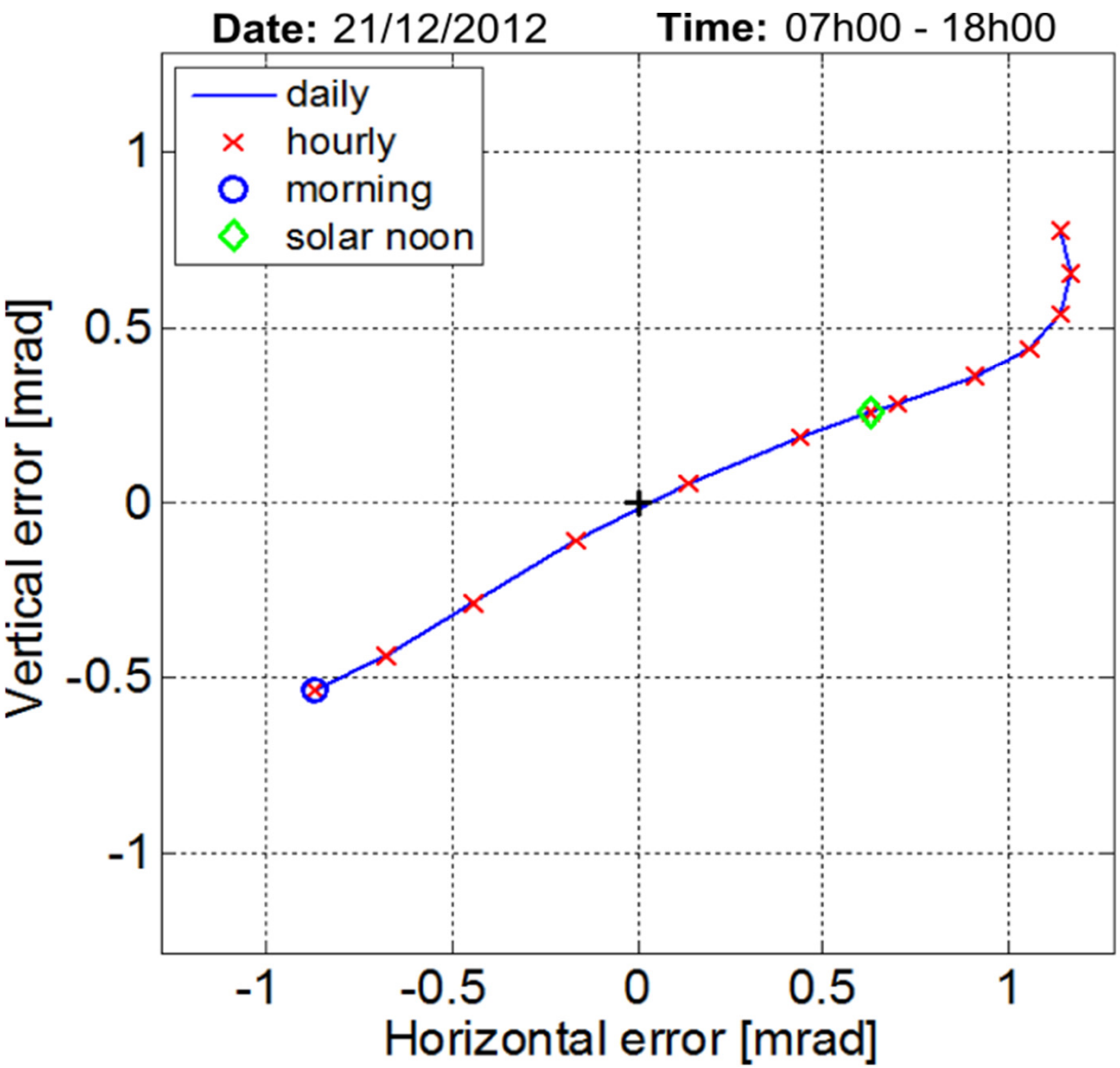
Pedestal Tilt "Corrected" with Angle Offset



Heliostat Location [m]

Z:	1
E:	30.8
N:	-19.2

Error Profile

Location Error [m]

Z:	0
E:	0
N:	0

Pedestal Tilt [mrad]

North-South:	1
East-West:	0

Axes Bias [mrad]

Azimuth	0
Elevation	1

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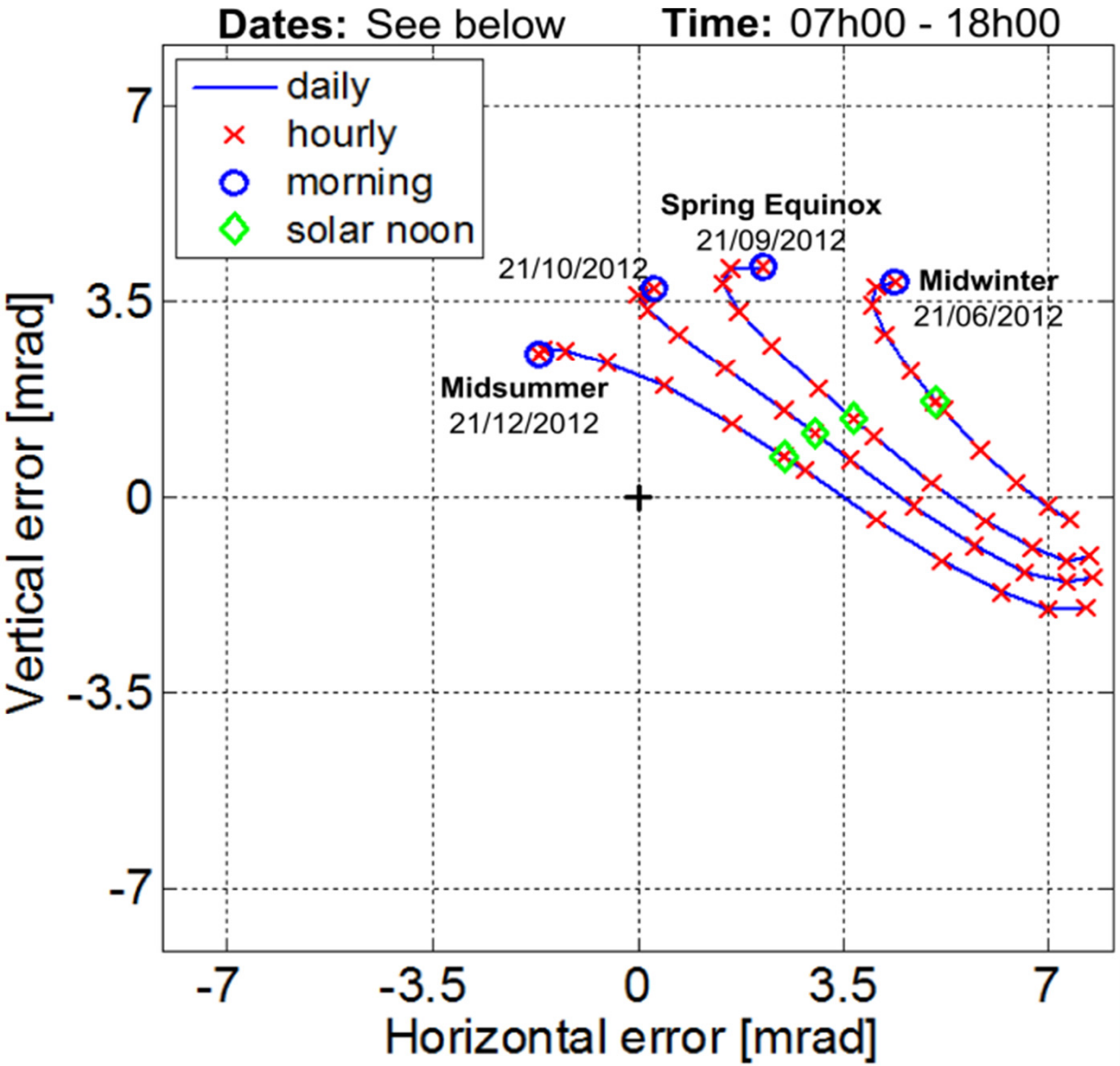
Inter-seasonal Variation of Tracking Error



Heliostat Location [m]

Z:	1
E:	30.8
N:	-19.2

Error Profile

Location Error [m]

Z:	0
E:	0
N:	0

Pedestal Tilt [mrad]

North-South:	1.87
East-West:	2.35

Axes Bias [mrad]

Azimuth	4
Elevation	3

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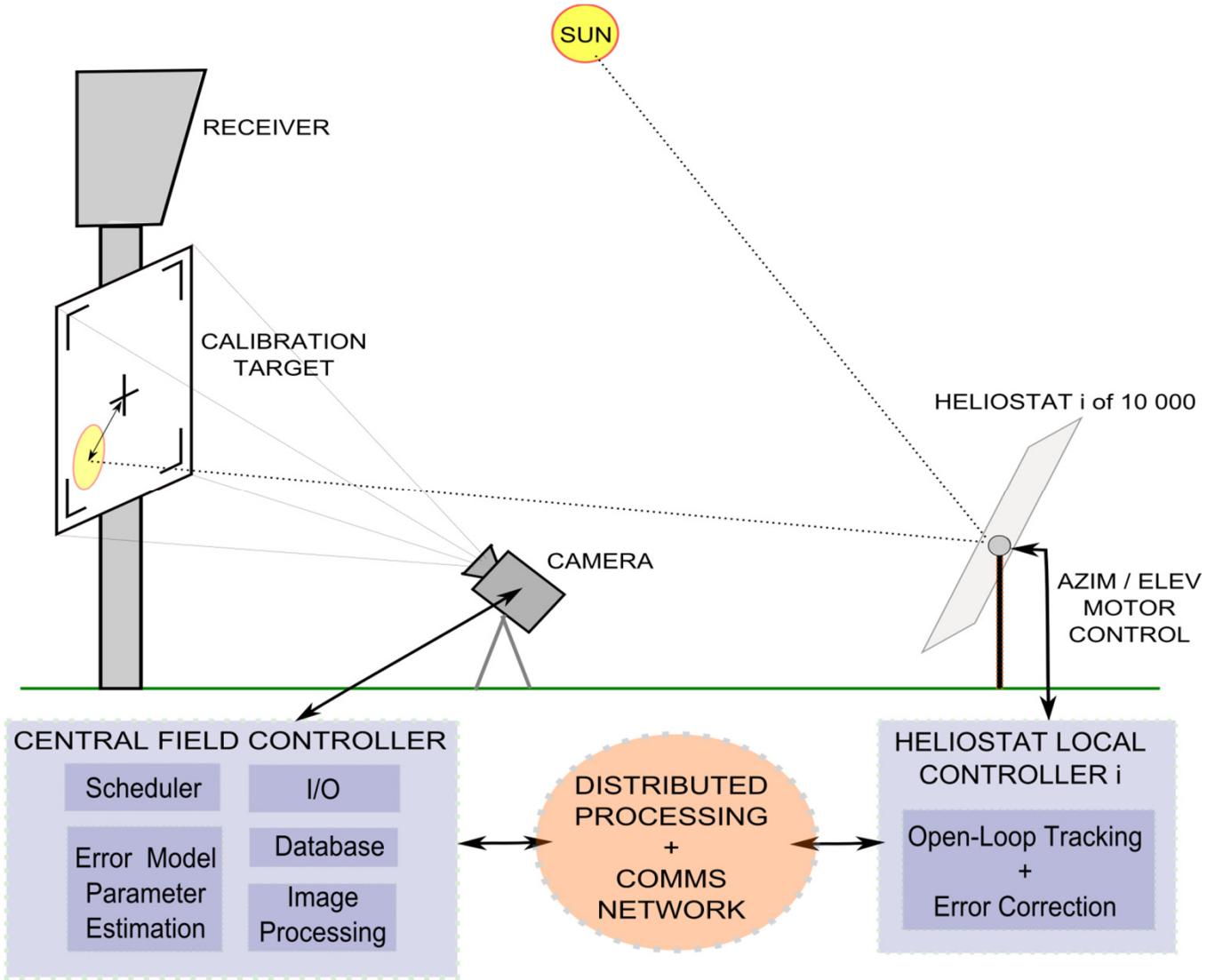
System Overview



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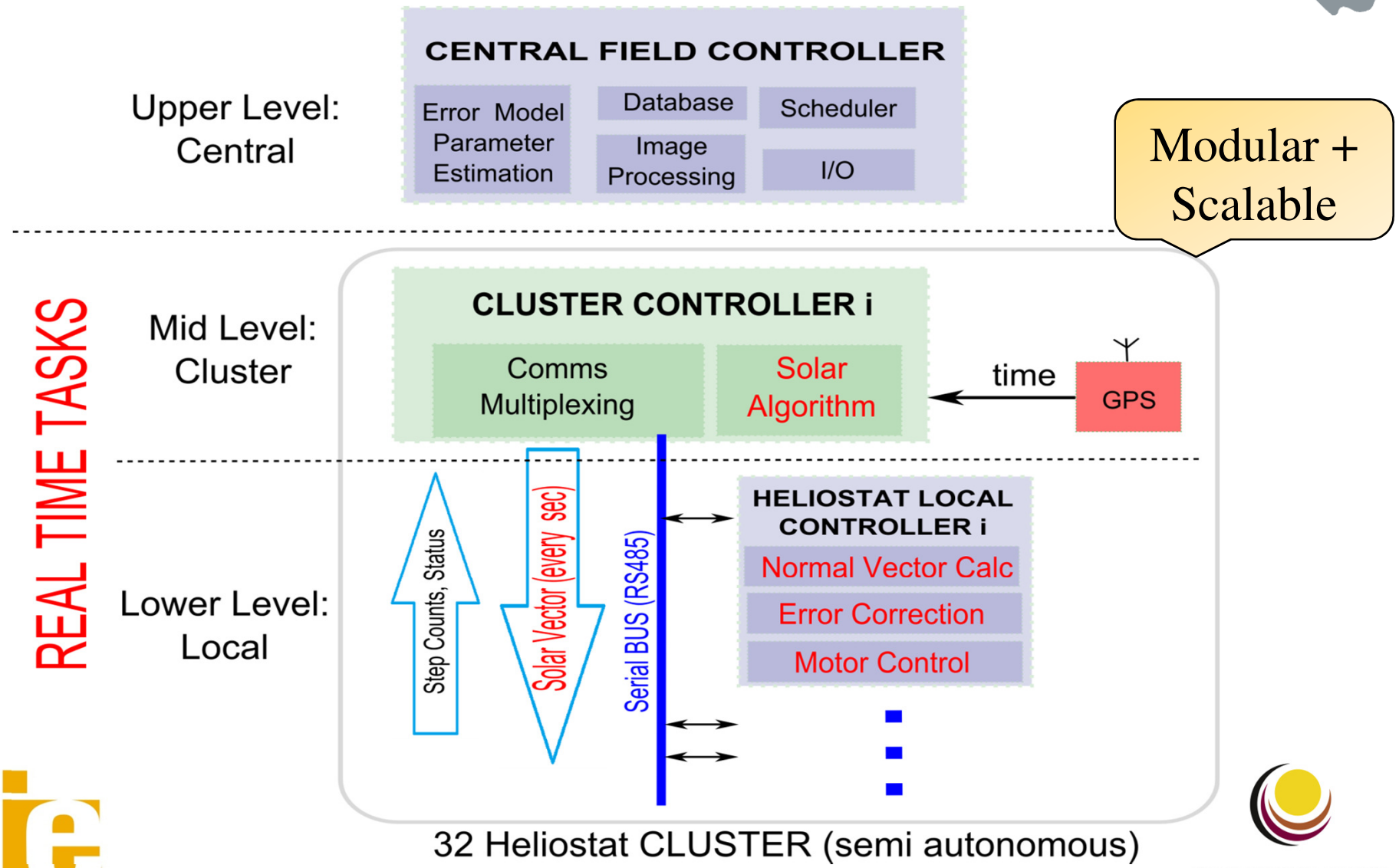
Distributed Control (3 Processing Levels)

→ All real-time tasks handled by Cluster- and Local Controllers



32 Heliostat CLUSTER (semi autonomous)

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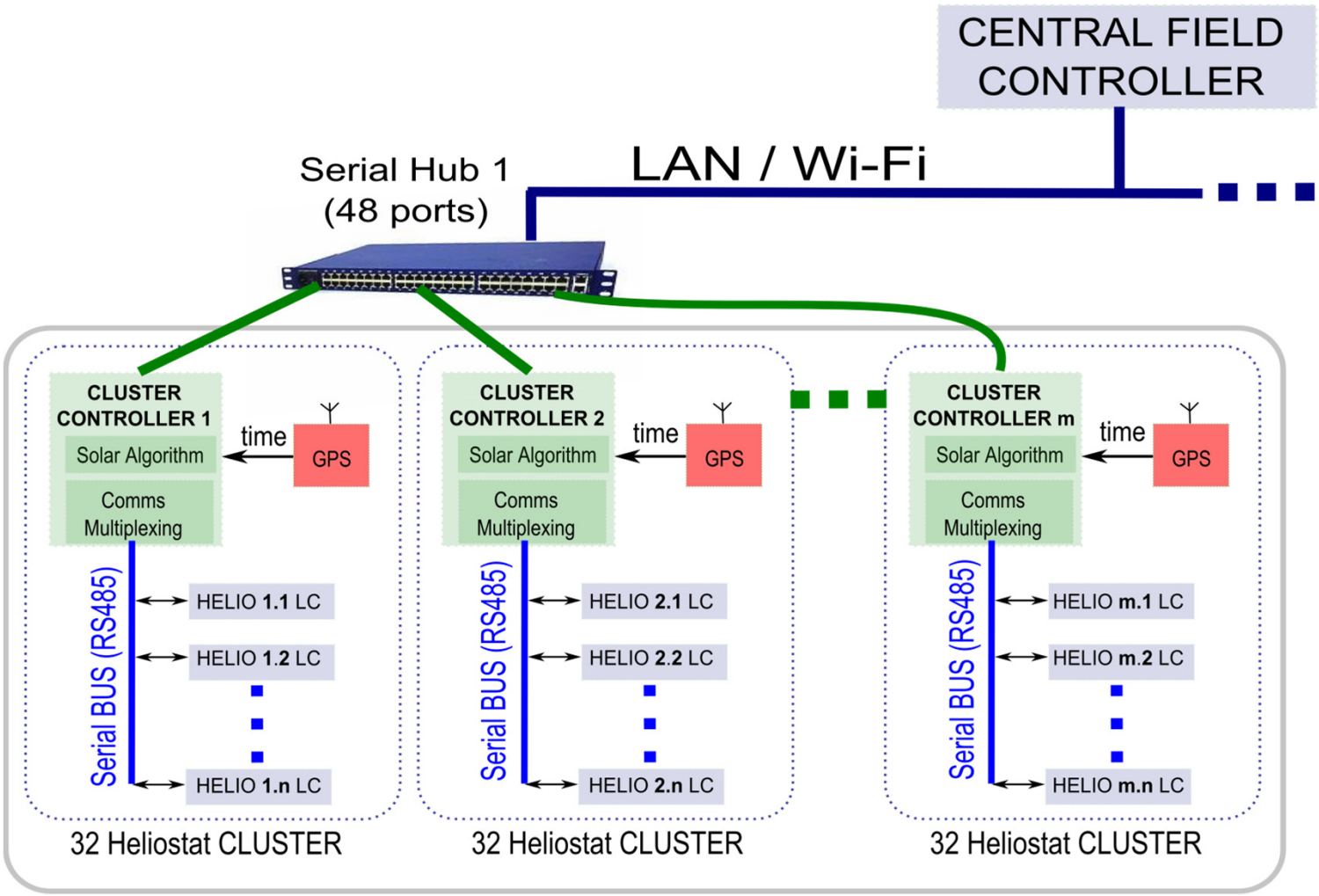
Scalability (one possible wired layout)



48 x 32 = 1536 Heliostat SECTOR

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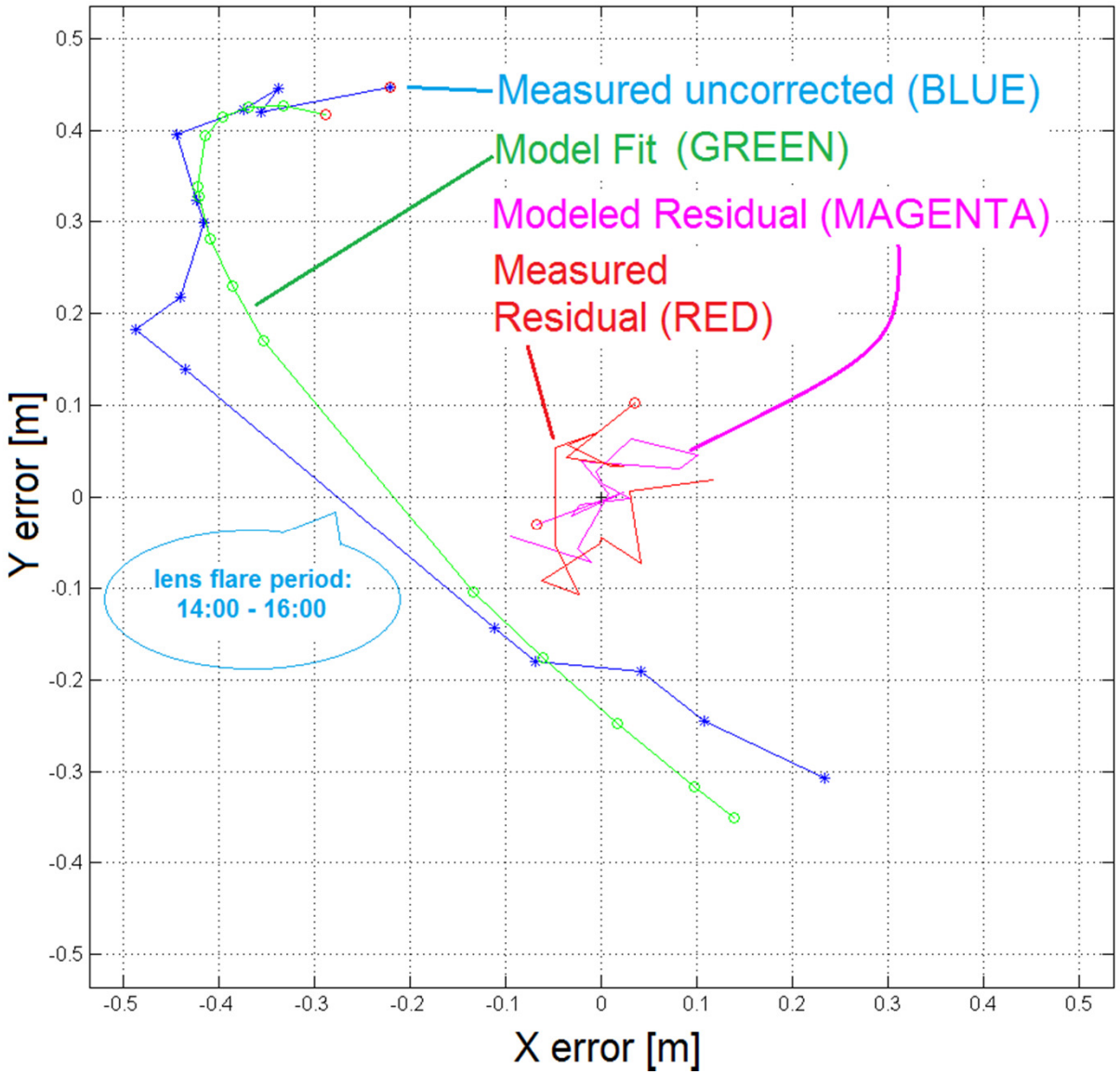
Results: Curve Fitting

Measured vs Modeled Error Curves 02/09/2012



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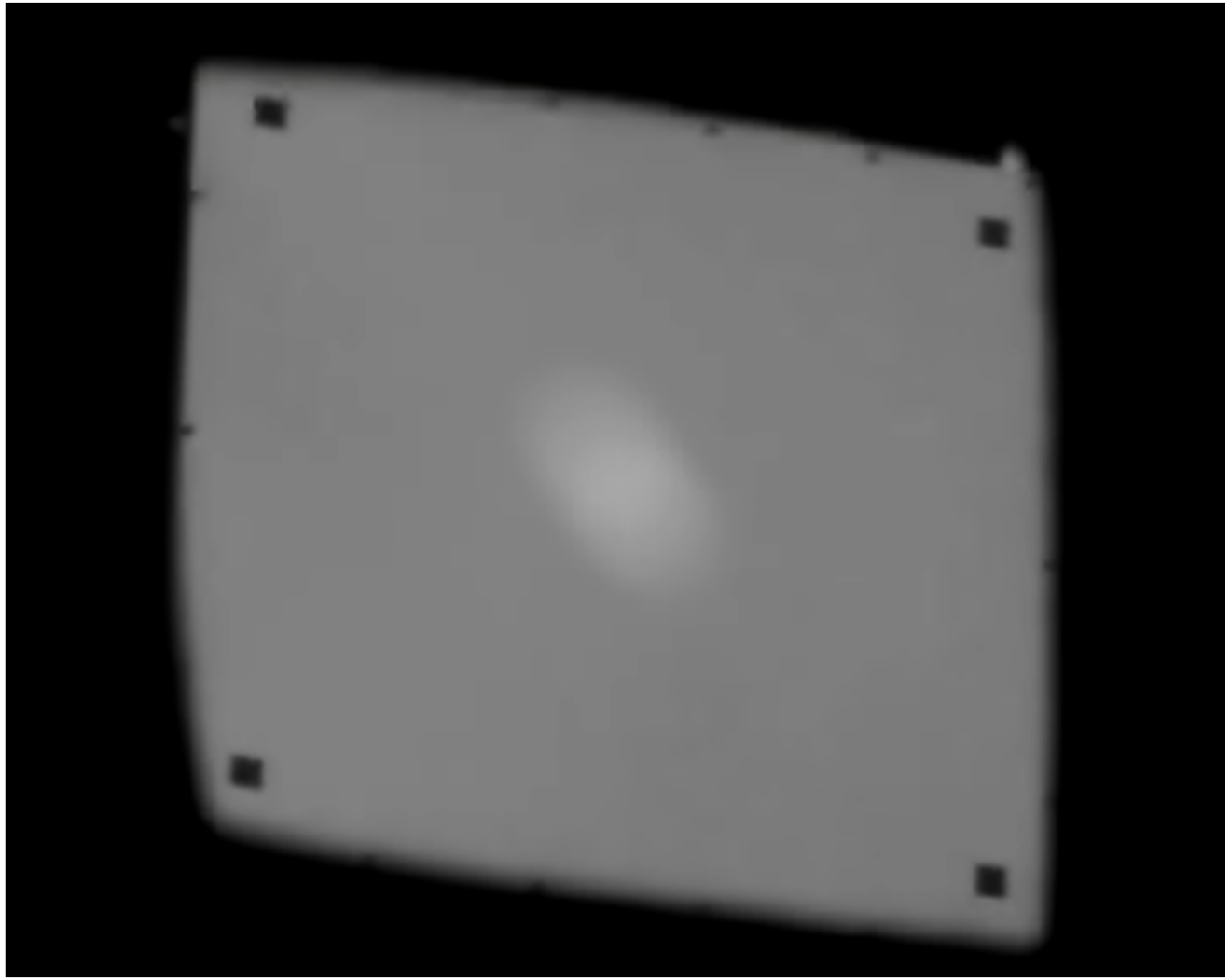
Software Calibrated Heliostat Open-Loop Tracking

Period: 13/09/2012 09h15 – 18h00 @ 24min/sec.

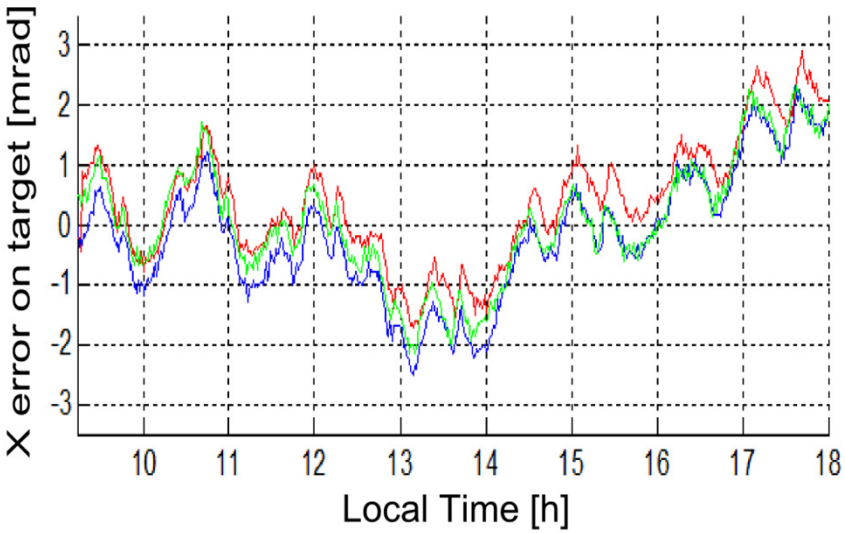
Slant Range ≈ 37m. $\hat{\boldsymbol{n}}_{\mathbf{H}}$ E_{RMS} ≈ 0.9 mrad

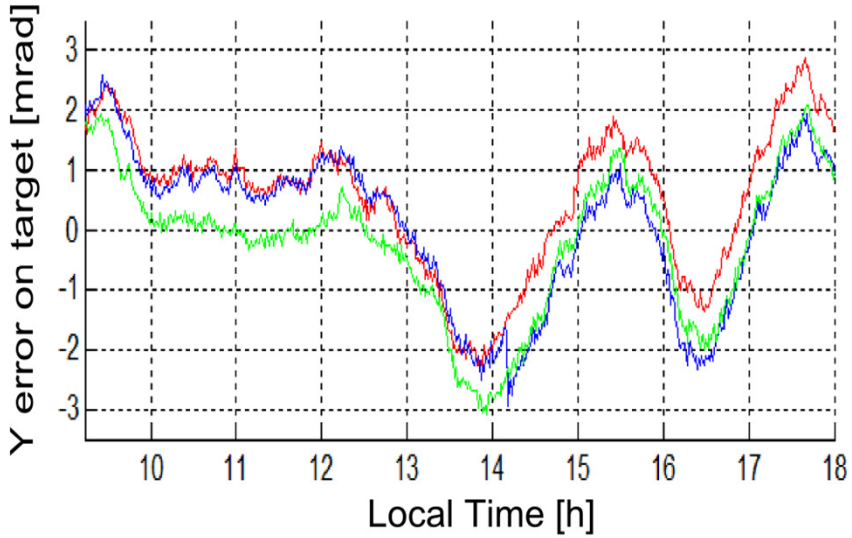


Note changing spot intensity and flaring (00:13→)

3 Days' OL Tracking

X and Y vs time. 06-08 Aug 2012: 09h15 - 18h00





Strong correspondence suggests residual determinism.

→ Further characterization may be possible which could allow improved OL tracking performance.

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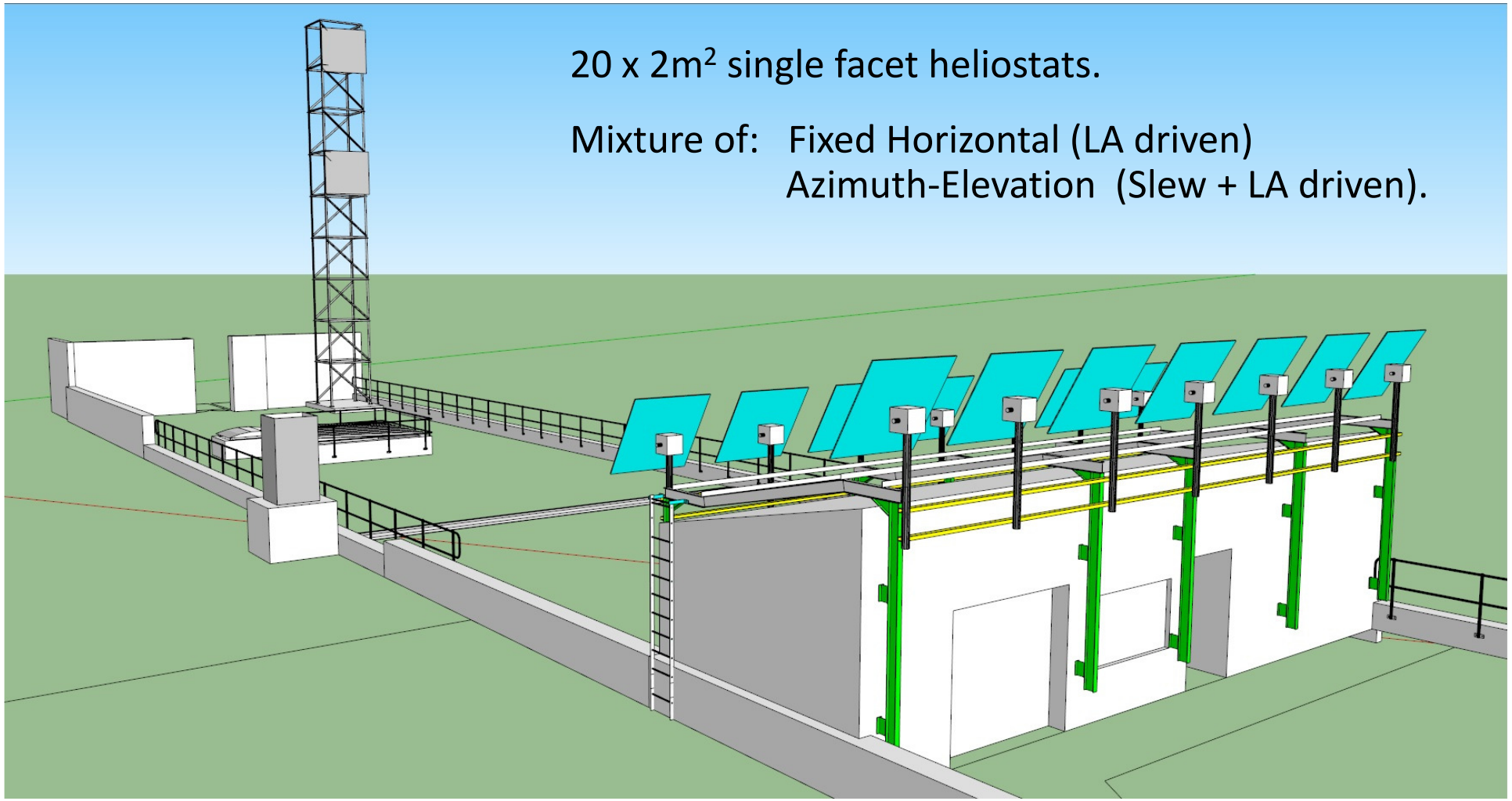
Sasol Helio40 under construction



‘Helio-18’ Start-up and Stow

‘Helio-40’ prototype heliostat (FH)

Thank you.

Questions?