

# TETRA

N a n j i n g   T E T R A   E l e c t r o n i c s

Integrating Bifacial PV trackers and  
automated cleaning at extreme desert  
locations



# Content



## 1. Tetra Robotic Cleaning System

## 2. Technical

- Power generation improvement (project references +case study)
- Cleaning Efficiency Test
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- Major needs in desert environment
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# Robotic Cleaning System



T6 is an autonomous, water-free robotic cleaning system that optimizes solar panel performance while reducing operation and maintenance costs .



**Water Free**



**Fully Autonomous**



**Self-Powered**



**Reliable Bridging**



**Secured  
Locking**



**Weather  
Intelligence**



**Remote  
Management**



**Cloud based  
Communication**



# Projects in China

## Jiangxi

Yugan

⚡ 50MW    🤖 289 Units

- Withstand wind up to **70km/hour**

## Ningxia

Yinchuan

⚡ 10.8MW    🤖 14 Units

- Increase power generation by **40%**
- Overcome large temperature difference between day and night

## Liaoning

Jinzhou

⚡ 20MW    🤖 220 Units

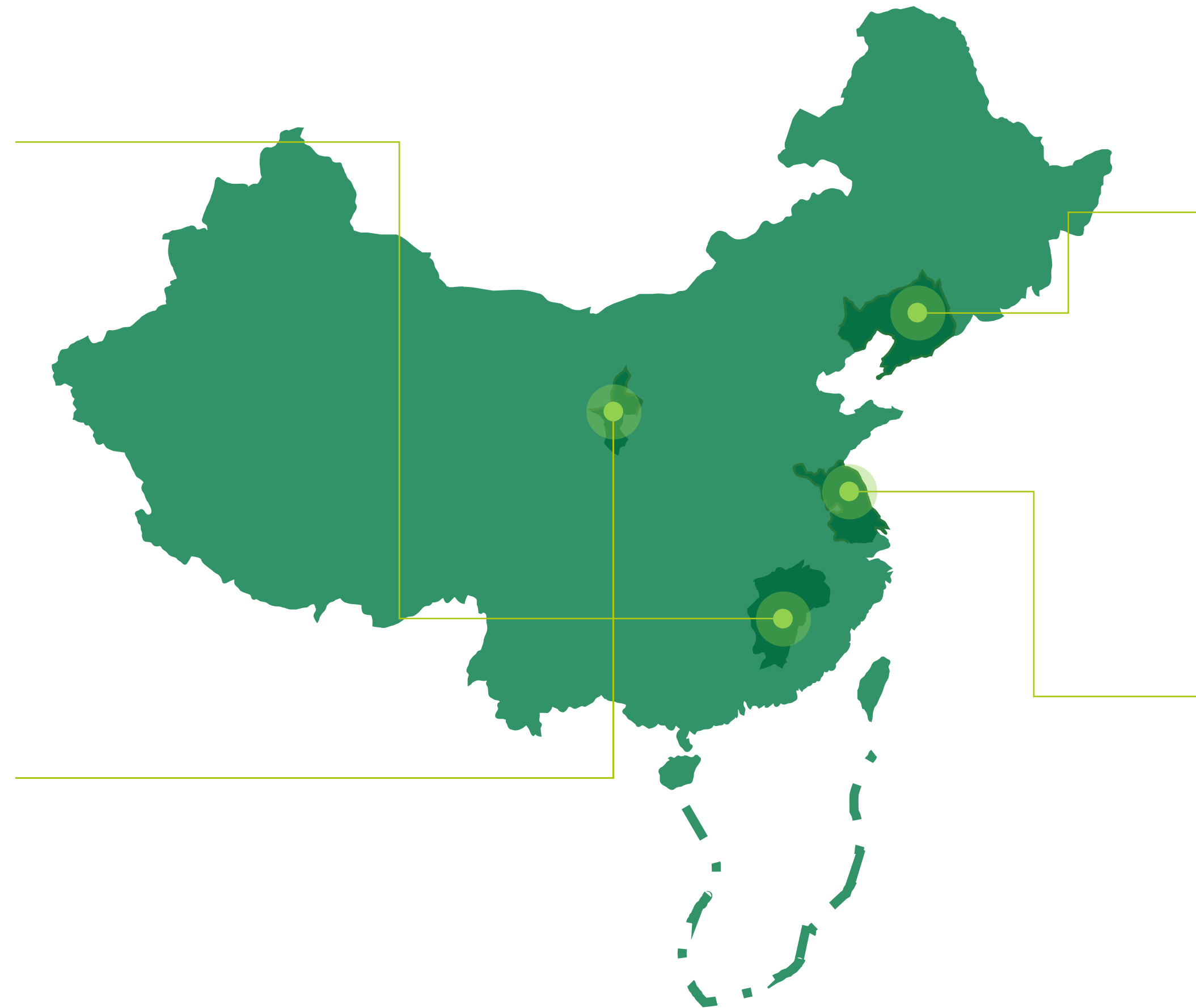
- **First** application of 8-meter length robots
- **First** project at **-30°** temperature environment

## Jiangsu

Lianyungang

⚡ 118.8MW    🤖 1443 Units

- **Largest** deployment at one power plant
- Successful anti-corrosion application under costal climate



# Case Study

Basic climatic characteristics:  
drought, little rain, windy, heavy  
sand, sufficient sunshine,  
intense evaporation

temperature:  $-18\sim 37^{\circ}\text{C}$

precipitation:  $166.9\sim 647.3\text{ mm}$

evaporation:  $1312.0\sim 2204.0\text{ mm}$

wind speed:  $5\sim 30\text{ km/h}$

solar radiation:  $> 4950\text{-}6100\text{ MJ/m}^2$



- 📍 Ningxia, Yinchuan
- ⚙️ Roof top (Fixed)
- ⚡ 1.8MW
- 👤 14 Units
- ⊕ 30%



# Cleaning Efficiency Test

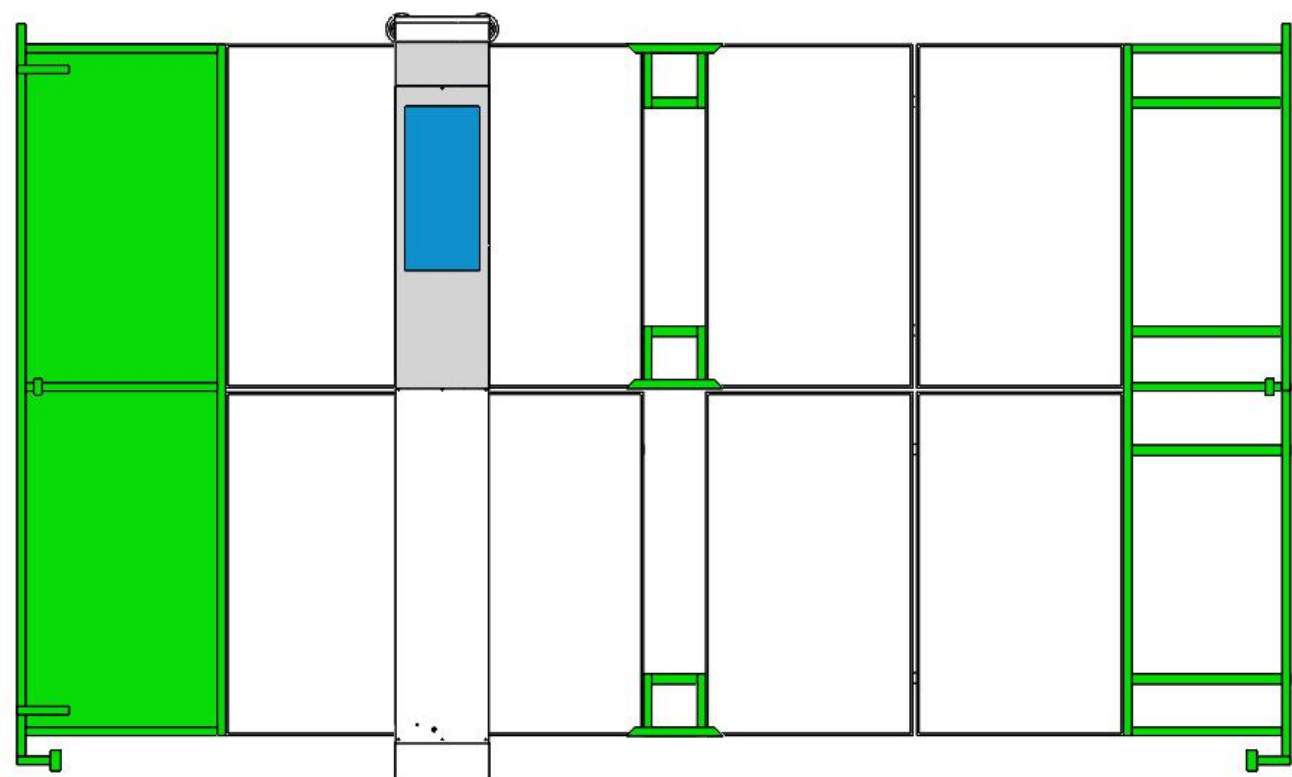
## Test Result

	Test1: Apply talc powder one time	Test 2: Apply talc powder two times	Test 3: Apply Arizona A4 test dust two times	Test 4: Apply Arizona A4 test dust three times
Glass light transmittance decrease (%)	0.633%	1.517%	0.8%	2.316%
Cleaning rate (Forth way cleaning)	99.7%	98.9%	99.6%	99.3%
Cleaning rate (Back way cleaning)	100%	99.7%	99.8%	99.8%

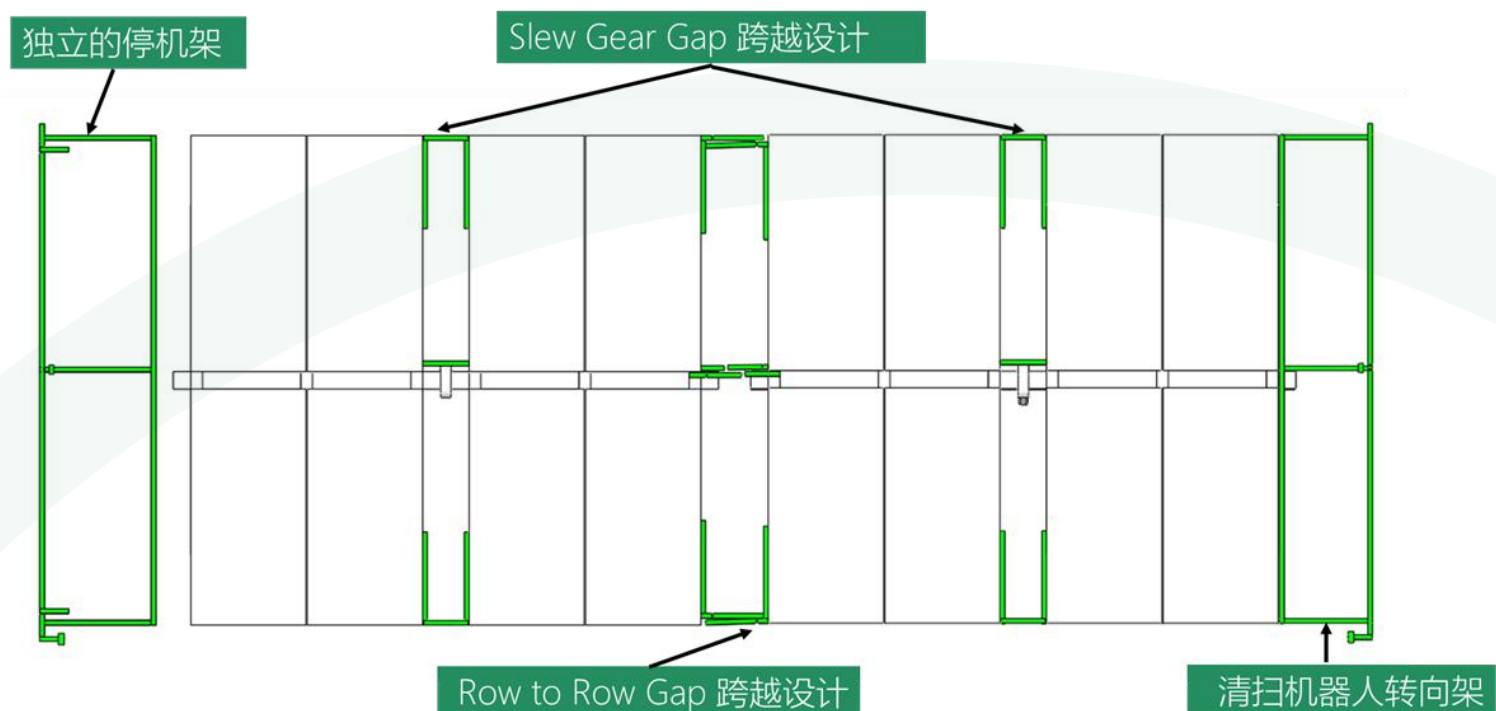


# Structure Compatibility Test

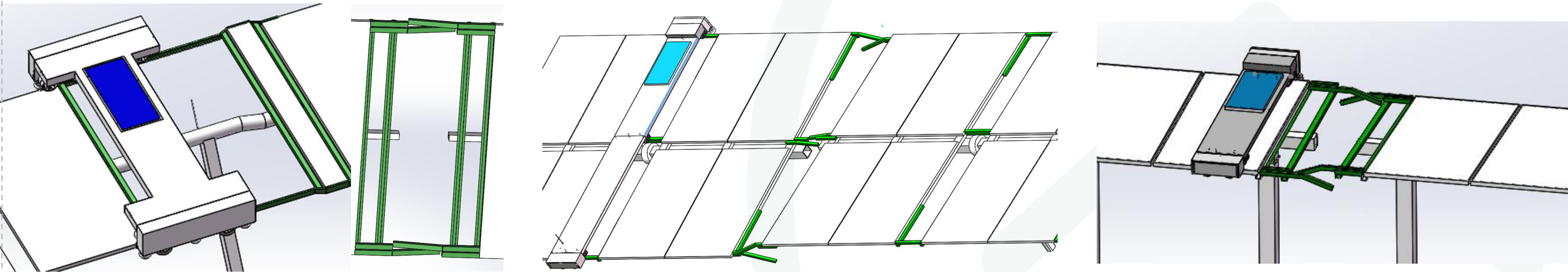
Fixed Structure



Flat Single Axis Structure



Customized Flat Single Axis Structure








# Structure Compatibility Test

Reference: Technical Requirements for integration with SF7

Test Location: Tetra Jinghu Robot Test Center

Test Environment: Test environment is set according to Reference offered by Soltec (SF7)

1. Module Adaptation Test  
Test robot if it is able to across height difference between modules



T6 PV Cleaning Robot & SF7

### Integrated Cleaning Solution

**No Damage**  
Tetra runs on minimal panel surface using soft rollers.

**Max Cleaning Length**  
Up to 2,000 m, equivalent to 1.5MW per each robot.

**Fully Automated**  
Remotely controlled and Monitored.

**Reliable and Simple**  
No power transmissions, cables, gears or pulleys.

**Landing Dock**  
Designed to avoid shading when stationary on both ends for reverse travel.

**Solar powered**  
No electricity source or grid power needed. Fast charging long life batteries.

**Adjustable bridges**  
High tolerance between Slewing-drive, Tracker rows and heights up to 8°.

**Water free cleaning**  
No need for water infrastructure and water supply.

**Real time analytics**  
Connectivity to weather real time and forecasted data ensuring cleaning performed in optimal time.

**Max tracker tolerances**  
The SF7 integrates with the T6 solution to overcome misalignments during installation, and optimize PV performance.

Angular Misalignment between Trackers	±2° (4° total)
Slope within a Tracker table	10°
Distance between tubes in adjacent Trackers	±100 mm
Misalignment in the horizontal plane	±48 mm





# Structure Compatibility Test

## 2. Tracker Crossing Test

Reference: Technical Requirements for integration with SF7

Test Location: Tetra Jinghu Robot Test Center

Test Environment: Test environment is set according to Reference offered by Soltec (SF7)

Test robot if it is able to pass adjacent trackers when they are in differences of horizontal , slope & angular



Soltec

### Integrated Cleaning Solution

- No Damage**  
Tetra runs on minimal panel surface using soft rollers.
- Max Cleaning Length**  
Up to 2,000 m, equivalent to 1.5MW per each robot.
- Fully Automated**  
Remotely controlled and Monitored.
- Reliable and Simple**  
No power transmissions, cables, gears or pulleys.
- Landing Dock**  
Designed to avoid shading when stationary on both ends for reverse travel.
- Solar powered**  
No electricity source or grid power needed. Fast charging long life batteries.
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- Max tracker tolerances**  
The SF7 integrates with the T6 solution to overcome misalignments during installation, and optimize PV performance.



SF7 | TETRA ELC  
天创电子

T6 PV Cleaning Robot & SF7





# Module Performance Test

**Test Purpose:** cleaning robot wipes test samples to **simulate 25 years** life time of PV module, laboratory performs performance measurement for PV modules and special samples **before and after wiping**

**Sample Quantity:** 6 pcs

**Test Item:** 1.PV modules: IV、EL and curvature 2. Special samples: light transmittance rate of glass and glass curvature)

**Test Location:** 288# Chenfeng Road, Yangshe Town, Zhangjiagang City, Jiangsu, PRC

**Test Methods & Reference Standards:**

- 1. IEC61215-2:2016 <Crystalline silicon terrestrial photovoltaic (PV) modules design qualification and type approval-part 2: Test Procedure>
- 2. JC/T2001-2009< Glass industry standard for solar>) Note: the test method of the PV modules curvature refers to the test method of the glass curvature

## 1. Max. power measurement of PV modules

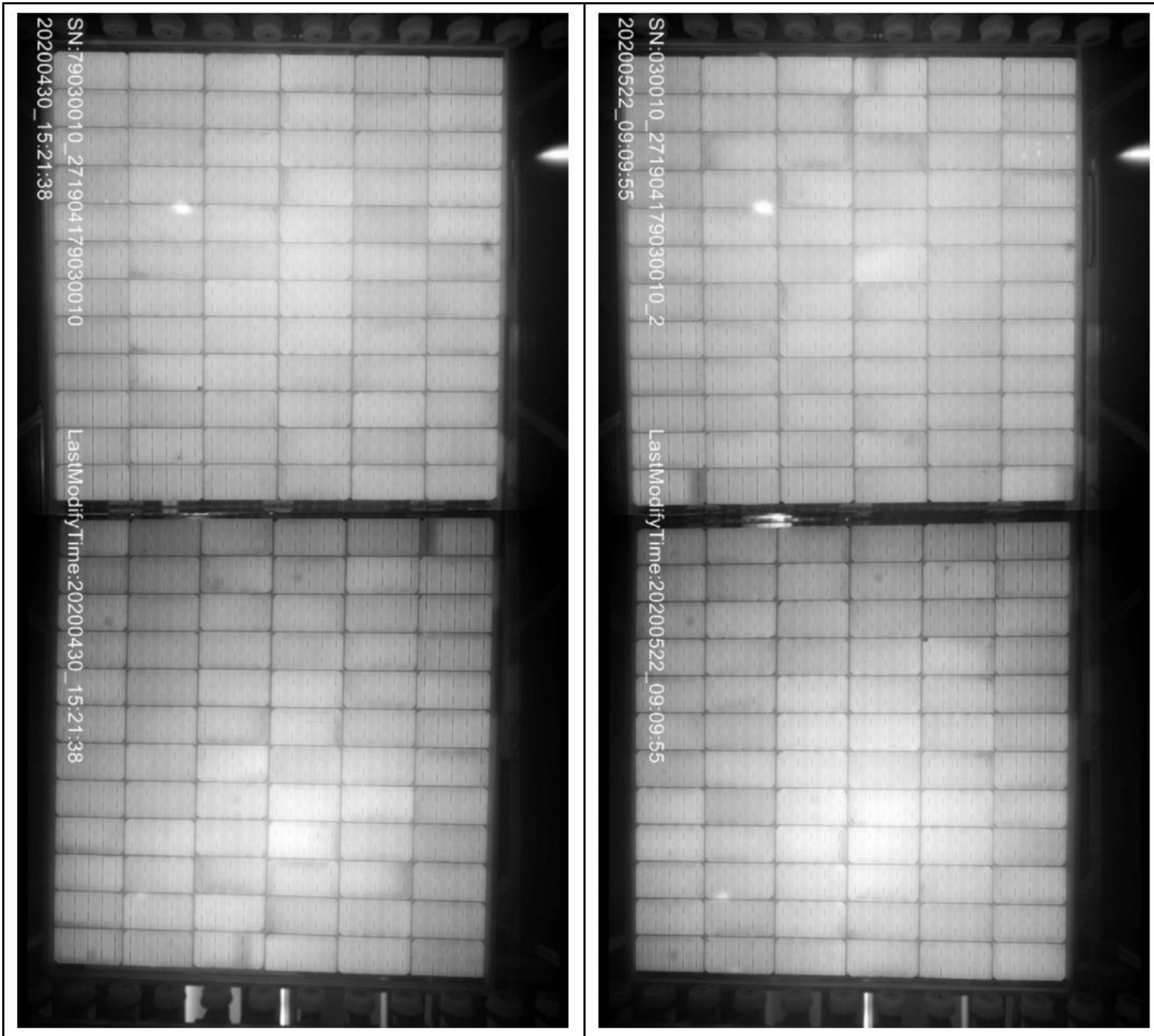
Serial No.	Max. power before wiping(W)	Max. power after wiping(W)	Max. power difference(W)	Max. power difference (%)
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****



# Module Performance Test

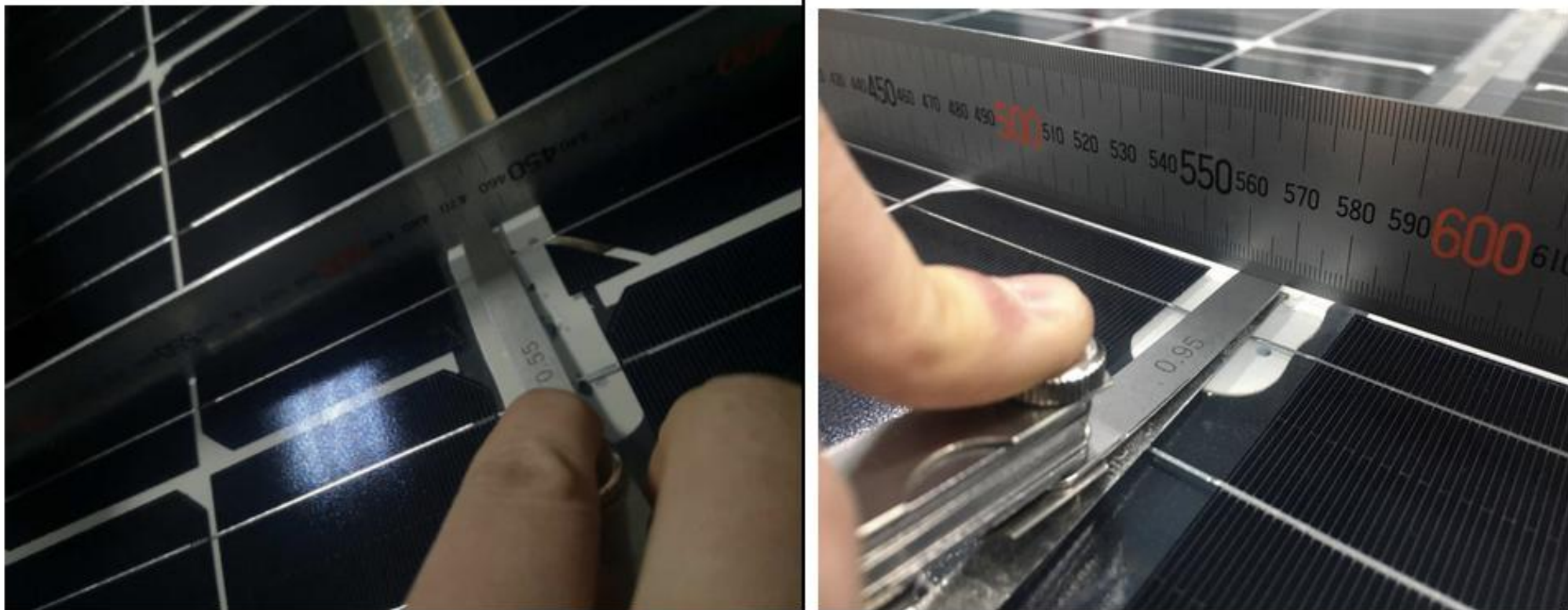
## 2. EL images of PV modules

EL images of PV modules before and after wiping (Ex.)



## 3. PV modules curvature

Serial No.	Curves degree (mm) (before)	Curves degree (mm) (after)	Curvature (%) (before)	Curvature (%) (after)
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****
*****	*****	*****	*****	*****

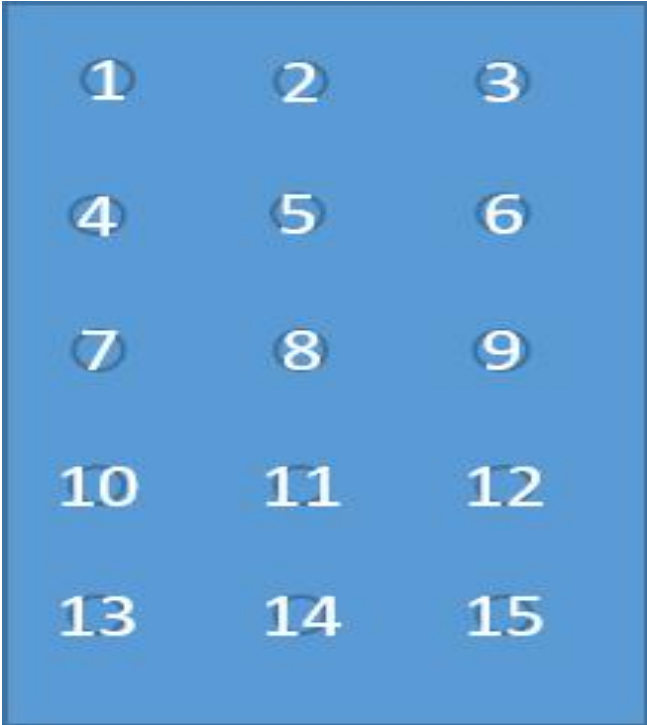




# Module Performance Test

## 4. Light transmittance rate of glass

- 1.Test equipment: Aoptek 2100
- 2.Waves: 380-1100nm
- 3. The measuring points refer to the following picture



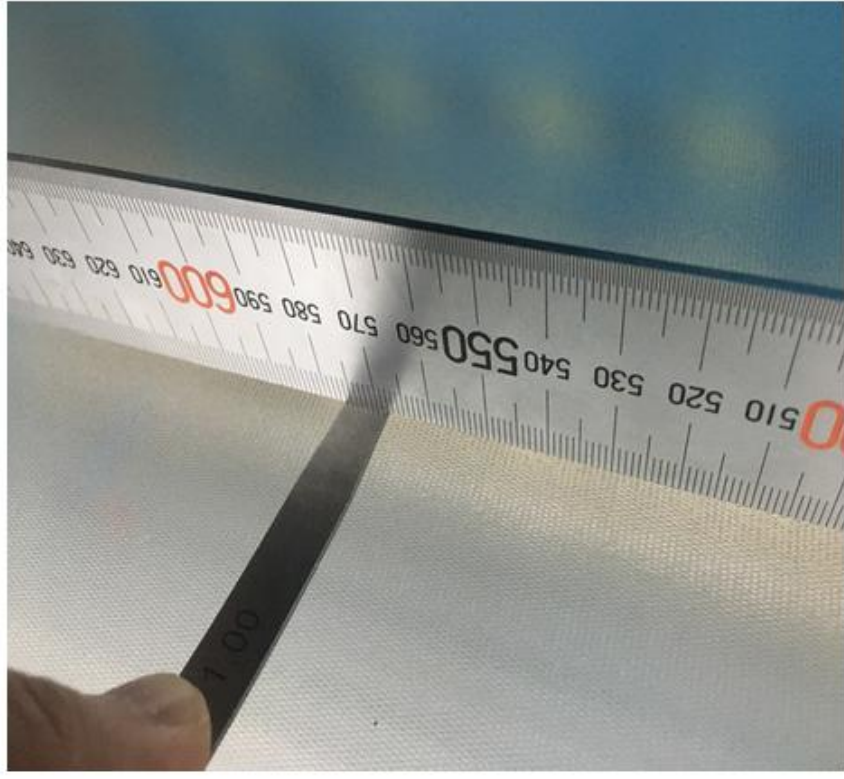
Serial No.	Average transmittance rate of glass before wiping (%)	Average transmittance rate of glass after wiping (%)	Difference (%)
Glass #1	*****	*****	*****
Glass #2	*****	*****	*****

## 5. Glass curvature

The curvature is expressed as a percentage of the height of the arc and the length of the arc. For local measurement, use a straight edge or metal wire to measure the length of 300 mm, and the curvature is indicated by the height of the trough or crest measured by a feeler gauge.



Before Wiping



After Wiping

Serial No.	Curves degree(mm) (before)	Curves degree(mm) (after)	Curvature(%) (before)	Curvature(%) (after)
Glass 1	*****	*****	*****	*****
Glass 2	*****	*****	*****	*****



# Project Pathway

## 1. Planning

- Collaborative work with developers, EPCs, module providers and structure providers
- Goal: optimize design and minimize initial investment

## 2. Commissioning

- Detailed configuration and installation instruction for deployment
- Professional technique support throughout the installation process
- Systematic training to constructors before the installation
- Testing cycle before acceptance check

## 3. Operation

- Train on-site O&M team on the basic operation of robots (Cleaning task set up, weather intelligence system connection, components status check-up, SCADA training, etc.)
- Monitor real time data from the central remote system of Tetra

## 4. Maintenance

- Monthly, quarterly and annual reports on all data related to cleaning performance, maintenance work and any other significant issues
- Maintenance manual for trouble shooting
- Assistance from Tetra customer service team



# Major Needs in Desert Environment

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## Fully Autonomous

Safe cleaning without human intervention

## Frequent

\*Middle East market mostly requires daily cleaning frequency

## Reliable

Robot is able to run smoothly cross modules and between trackers; Robot is able to withstand certain wind speed

## Effective

Comparison tests on cleaning efficiency, soiling rate (No cleaning vs. manual cleaning vs. robot cleaning)

## Cost

Overall project investment vs. increased energy generation





# Cost Breakdown

## CAPEX

1. Robot
2. Supporting structure  
(Docking station, Reversing station, Bridges)
3. Manpower for installation

## OPEX

1. Robot spare parts (for 20 or 25 years)
2. Manpower for O&M of the robot

**LCOE** ↓ =

LEVELIZED COST  
OF ELECTRICITY

**CAPEX** ↑

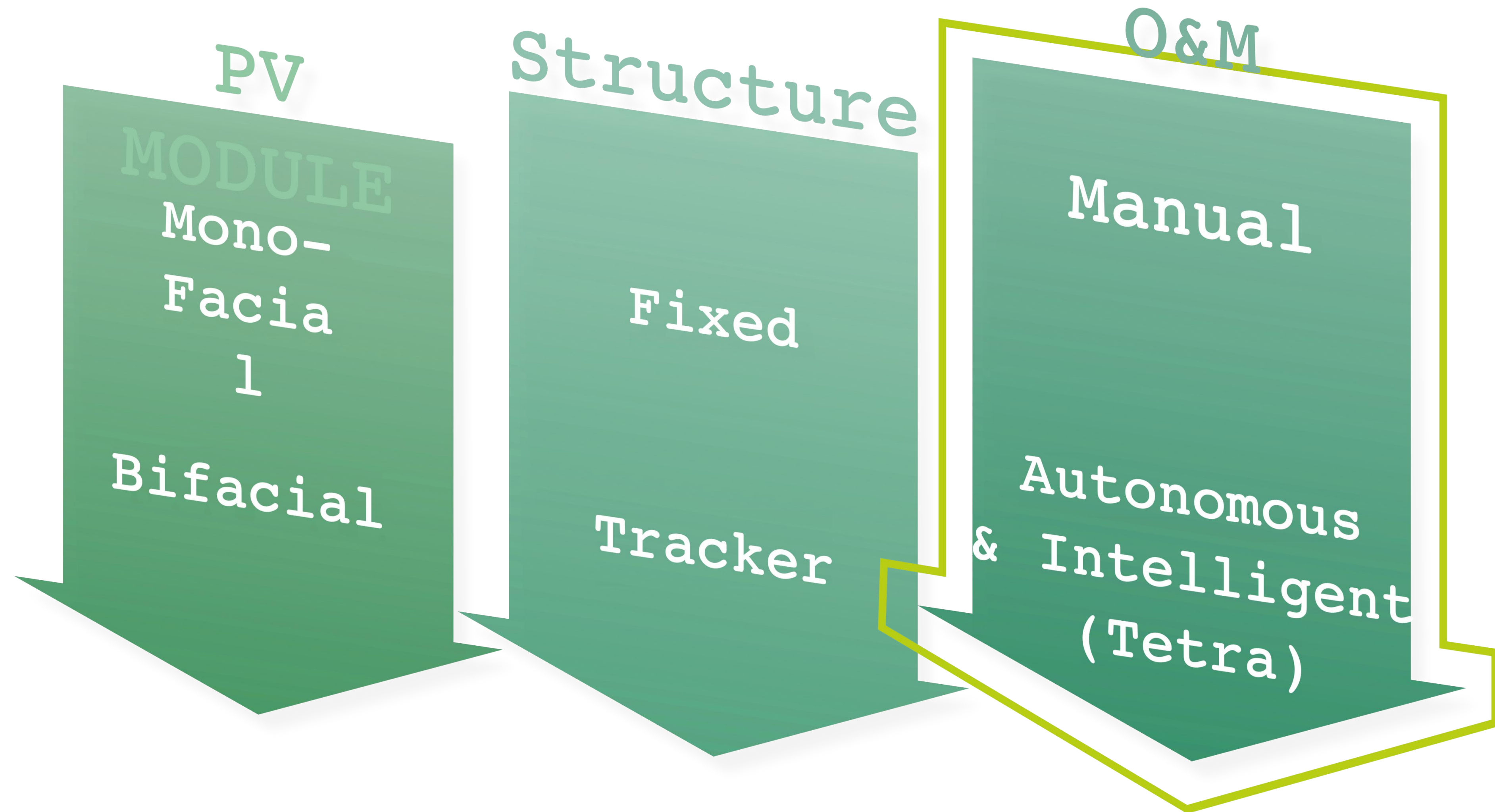
+ **OPEX** ↓

**Sum of Yields** ↑



# More Power Generation, More Effective O&M

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# TETRA

# THANK YOU

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