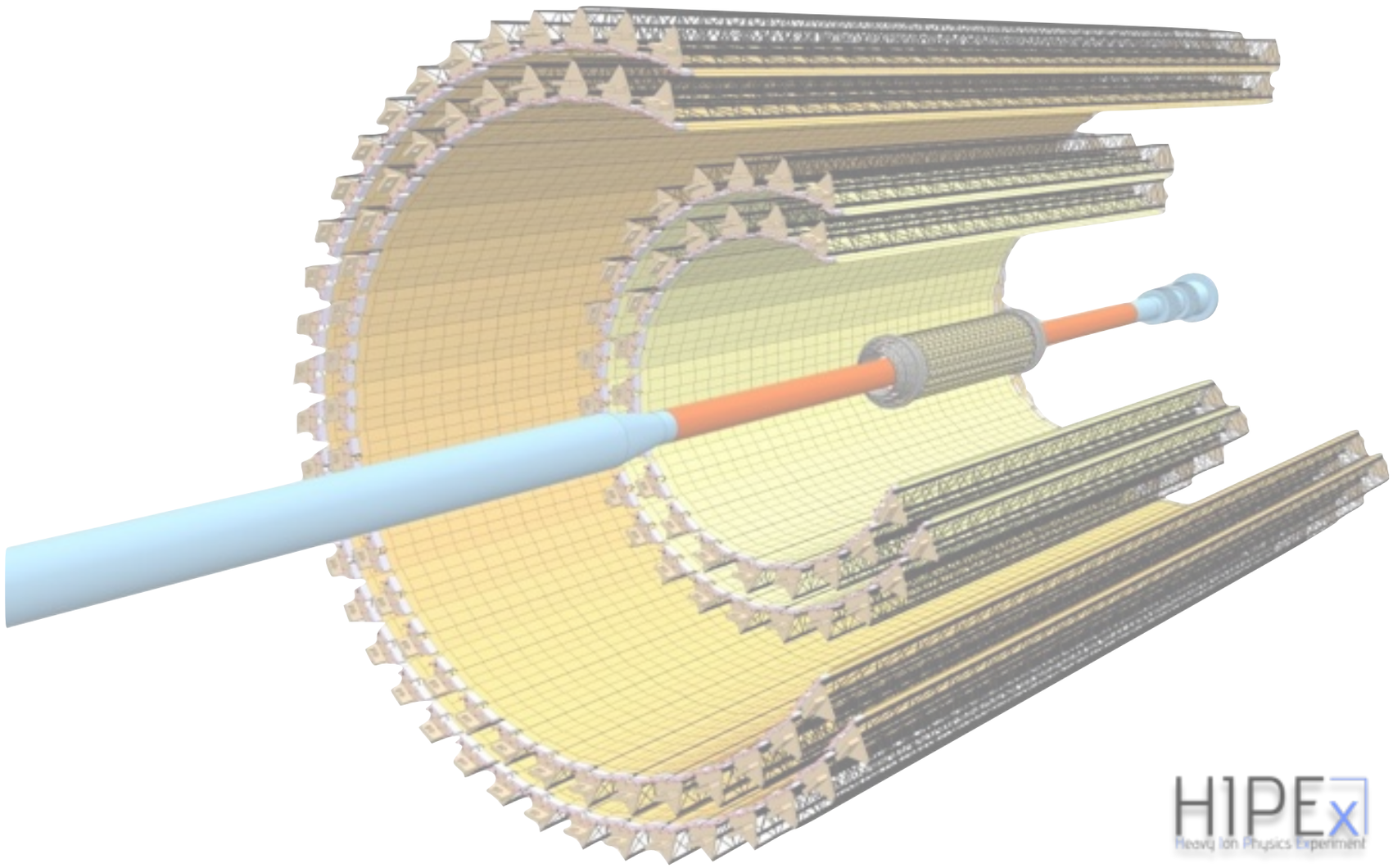
Hybrid Integrated Circuit Assembly system for the ITS upgrade in ALICE

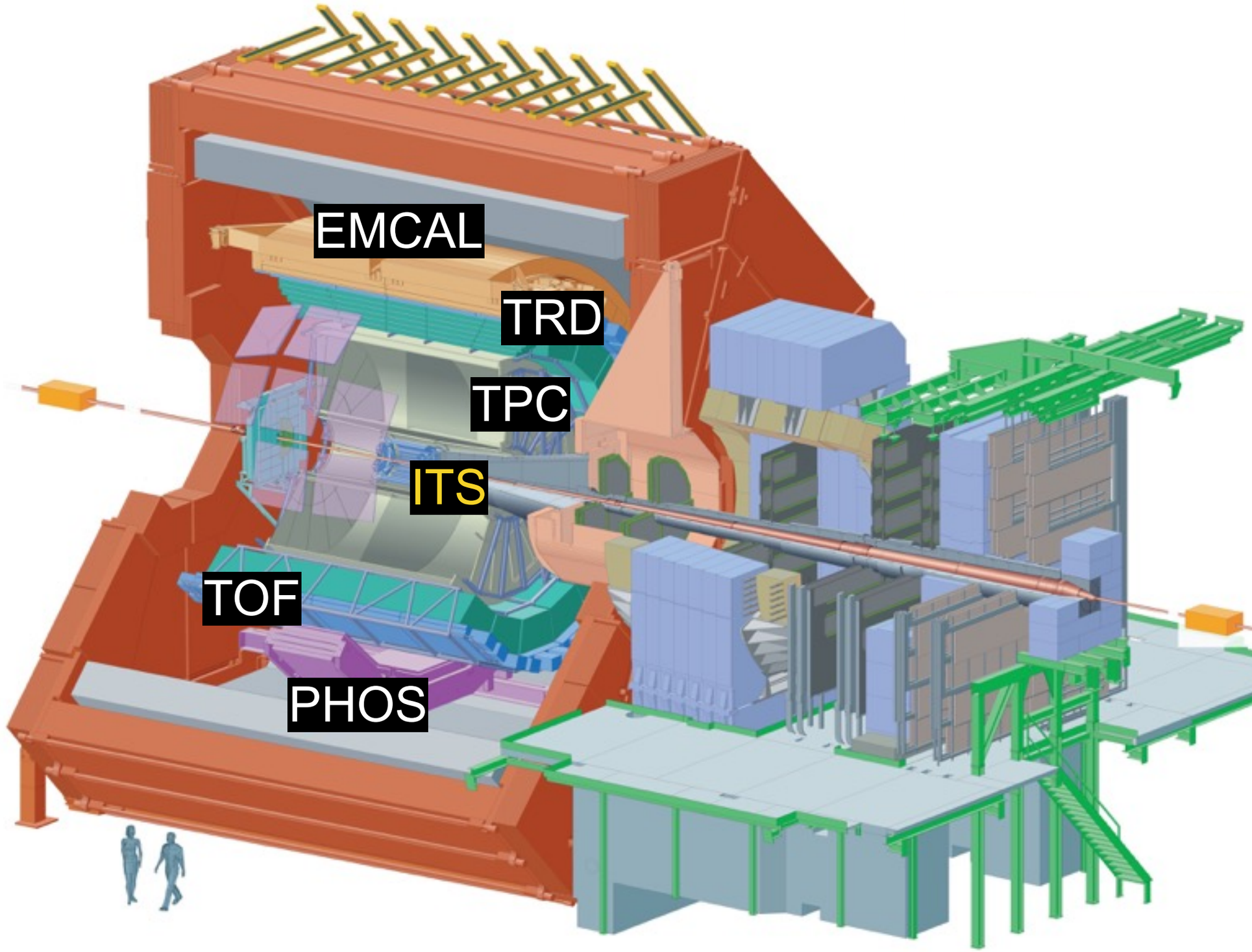
Bong-Hwi Lim
Pusan National University
Heavy Ion Meeting
2014.12.06.

Contents

- ITS upgrade project in ALICE
- HIC Assembly in ITS upgrade
- Laser Soldering in HIC Assembly

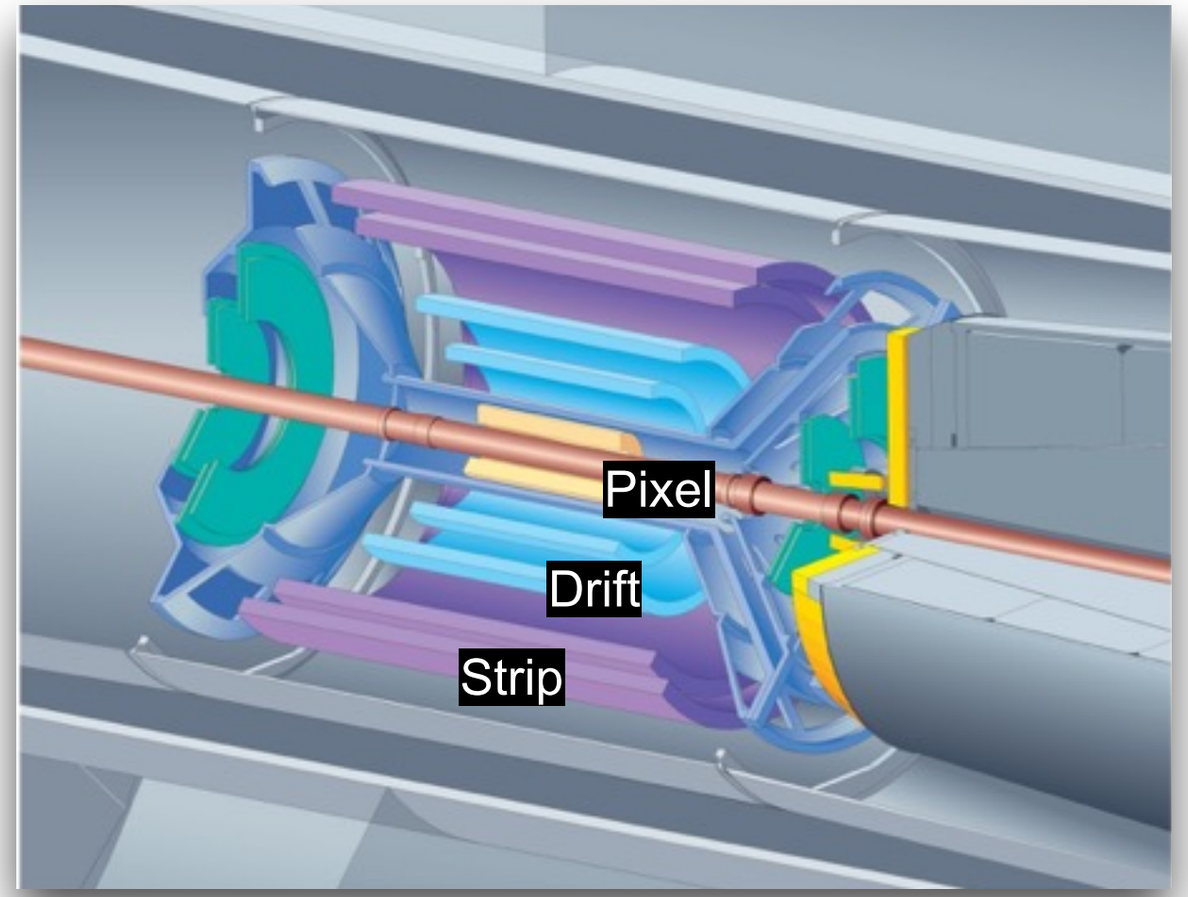


Inner Tracking System (ITS) in ALICE Detector

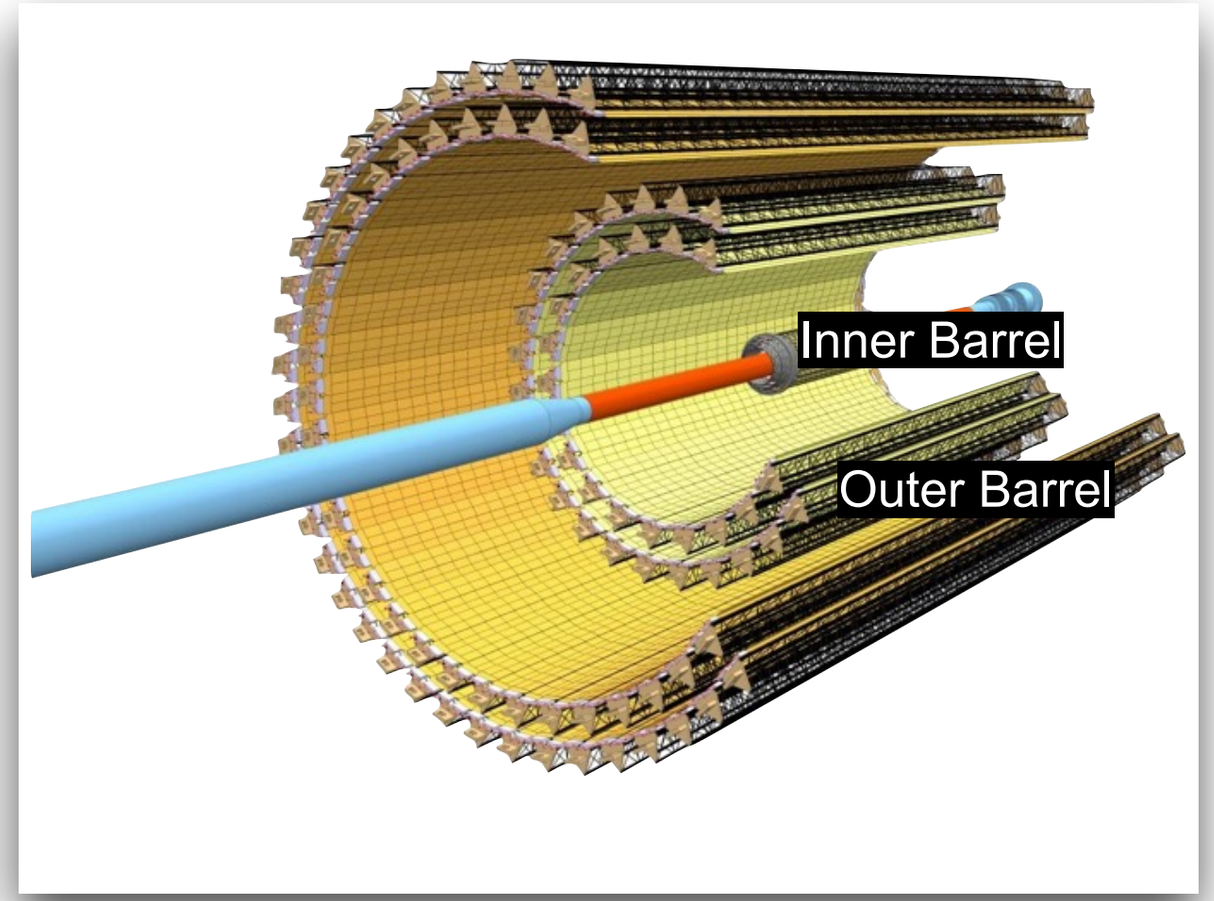


ALICE(A Large Heavy Ion Colider Experiment)

ITS upgrade project



Current ITS



New ITS

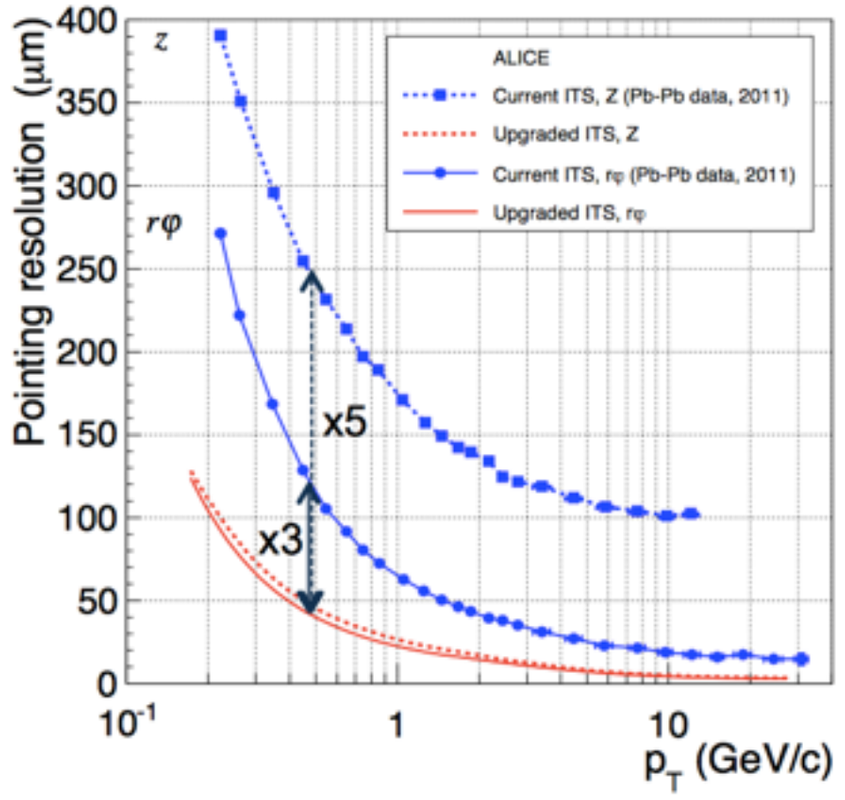
2 Silicon Pixel Layer
+ 2 Silicon Drift Layer
+ 2 Silicon Strip Layer

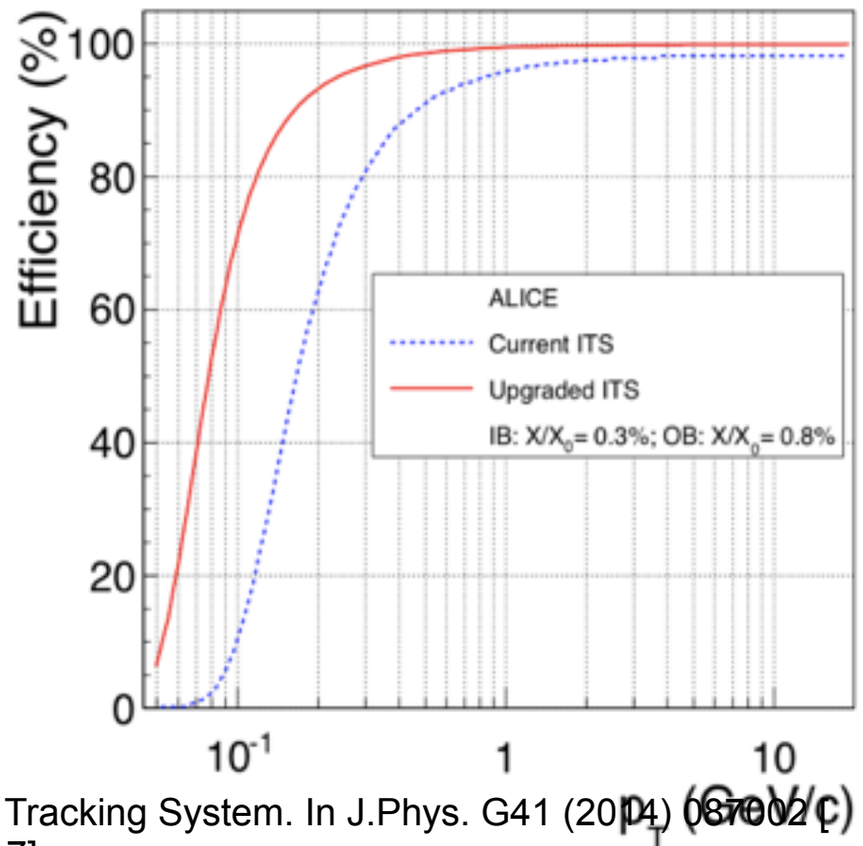
→

7 Silicon Pixel Layer

Main goal of new ITS

- **Increasing Impact parameter resolution by <u>factor 3</u>**
  - First Detection layer close to the beam line
    - Current: 39mm → **New: 22mm**
  - Reduction of material budget
    - X/X_0 / layer: Current: ~1.13%
      → **New: ~0.3% (for Inner layer)**
  - High-resolution to reduce pixel detector size
    - Current: 50um x 425um → **New: 30um x 30um**
- **Faster Read out rate**
  - Current: Maximum 1kHz
    → **New: <u>50kHz for Pb-Pb, 400kHz for pp collision</u>**



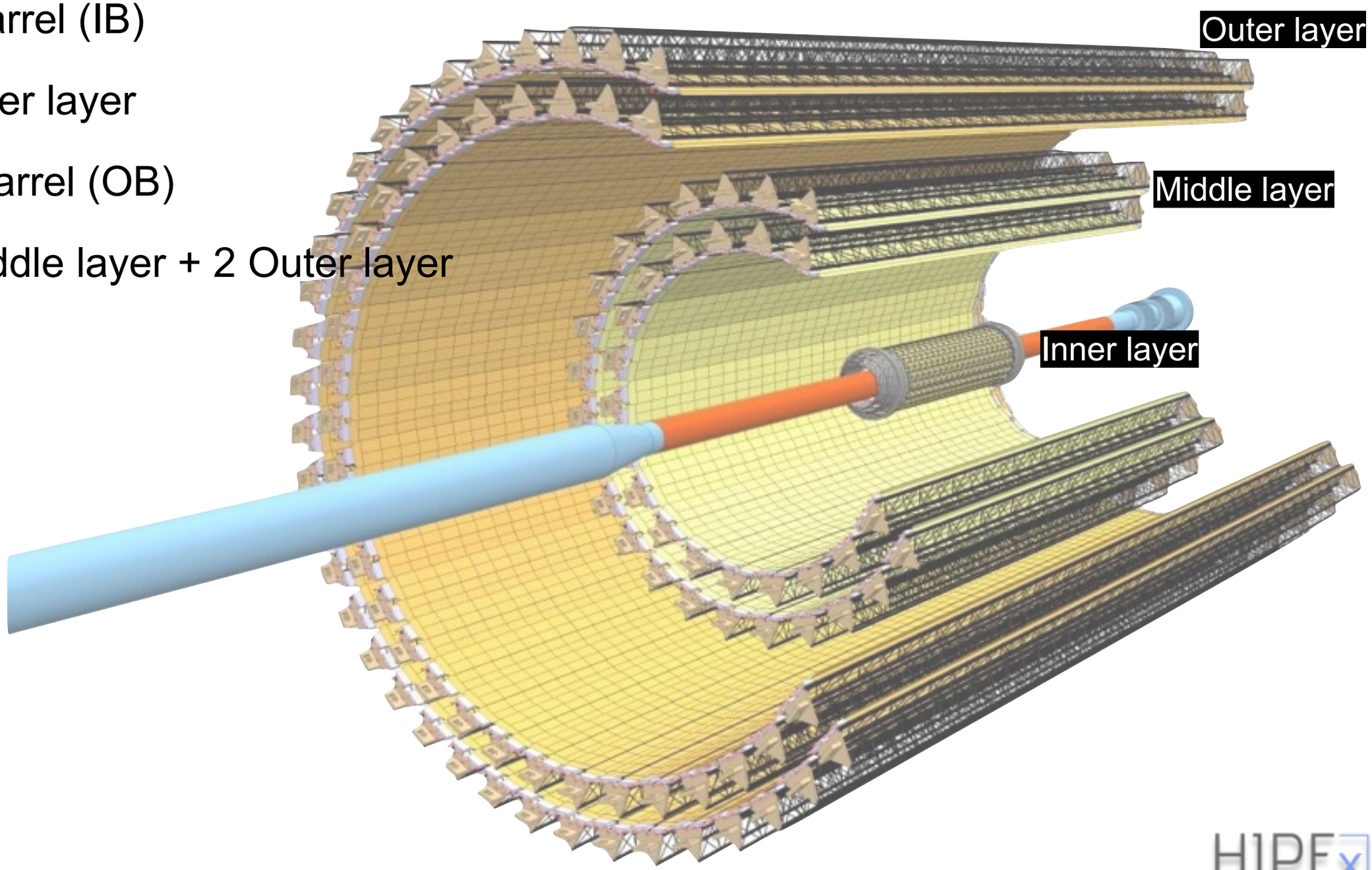


The ALICE Collaboration. Technical Design Report for the Upgrade of the ALICE Inner Tracking System. In J.Phys. G41 (2014) 087002 [CERN-LHCC-2013-024. ALICE-TDR-017].

Overall structure of new ITS

Overall structure of new ITS

- **Inner Barrel + Outer Barrel**
  - Inner Barrel (IB)
    - 3 inner layer
  - Outer Barrel (OB)
    - 2 Middle layer + 2 Outer layer



Stave - the unit of new ITS
(Outer barrel)

- Components

Power Bus

+

Flexible Printed Circuit

+

Pixel Chips

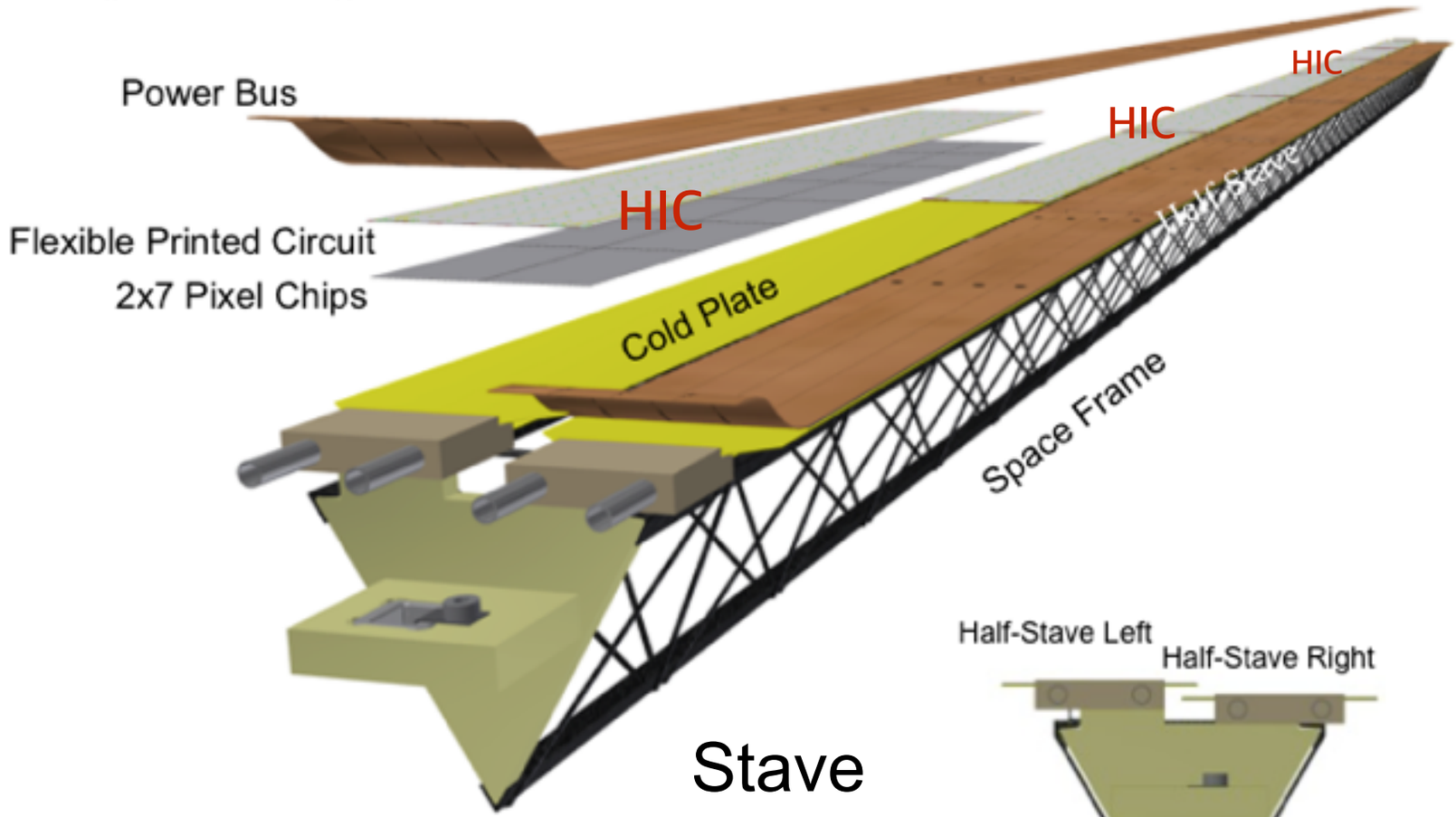
+ Hybrid Integrated Circuit(HIC)

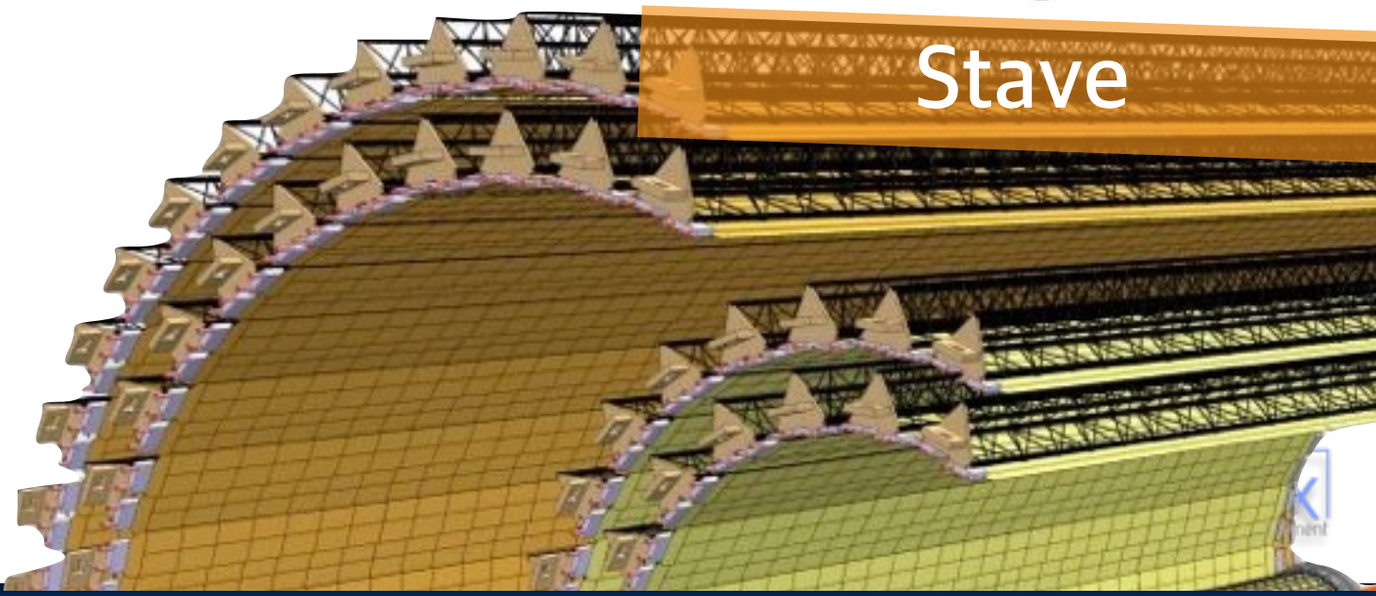
+

Cold Plate

+

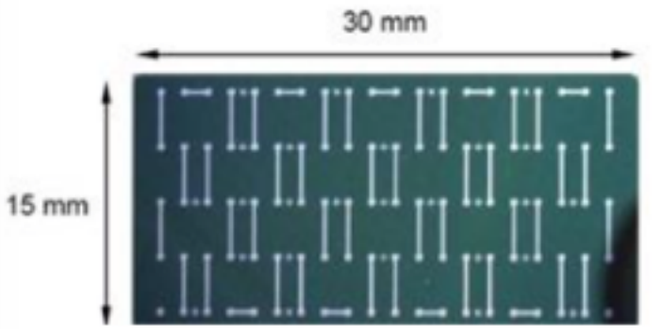
Space Frame





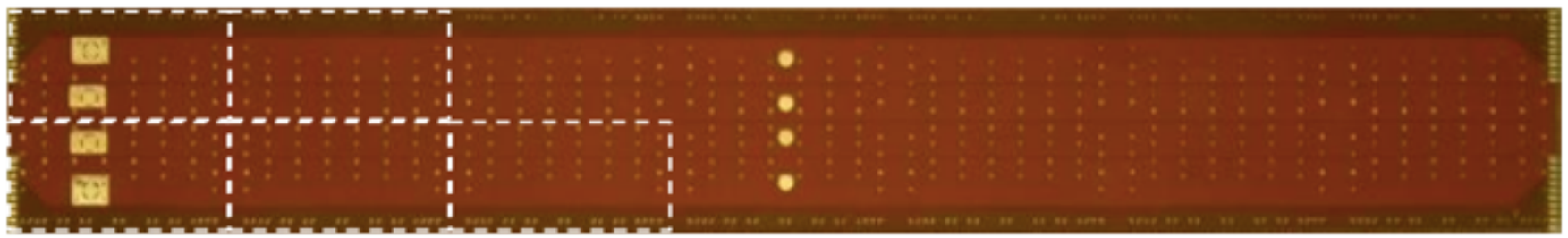
Hybrid Integrated Circuit

- Hybrid Integrated Circuit is **most important part** of the stave
- **Flexible Printed Circuit + Pixel Chips (500,000 pixels per chip)**



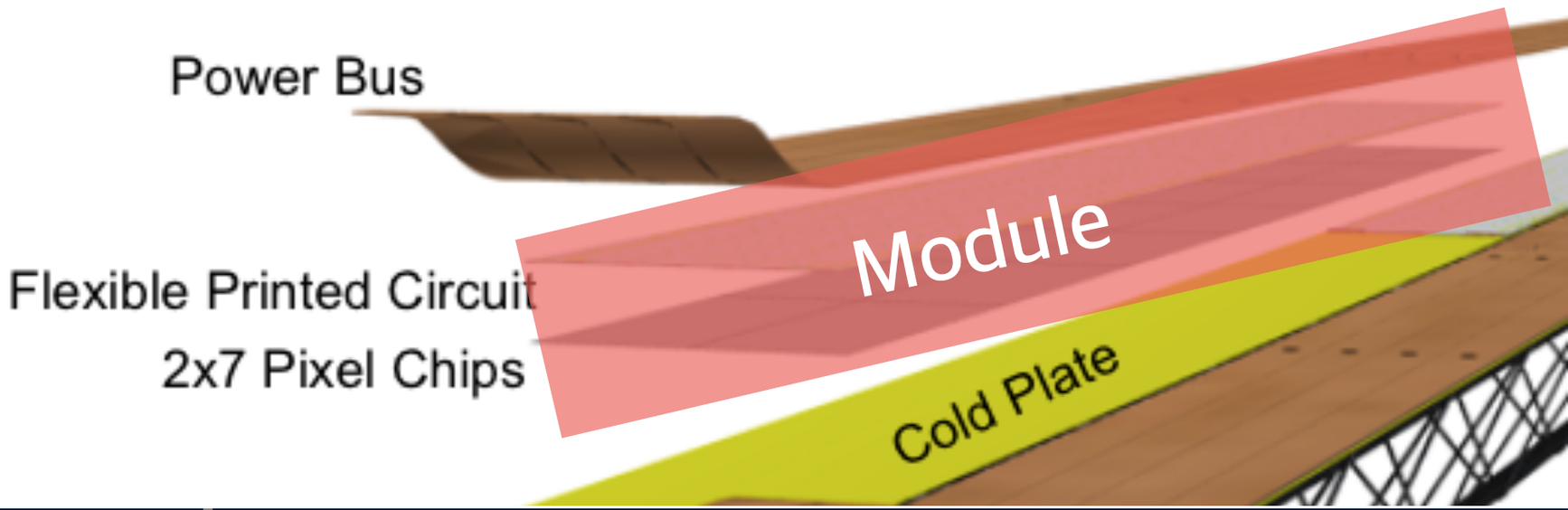
Pixel Chip (dummy) X 14

+



Flexible Printed Circuit (FPC)

- **Pixel chips are soldered to FPC by Laser soldering technique**

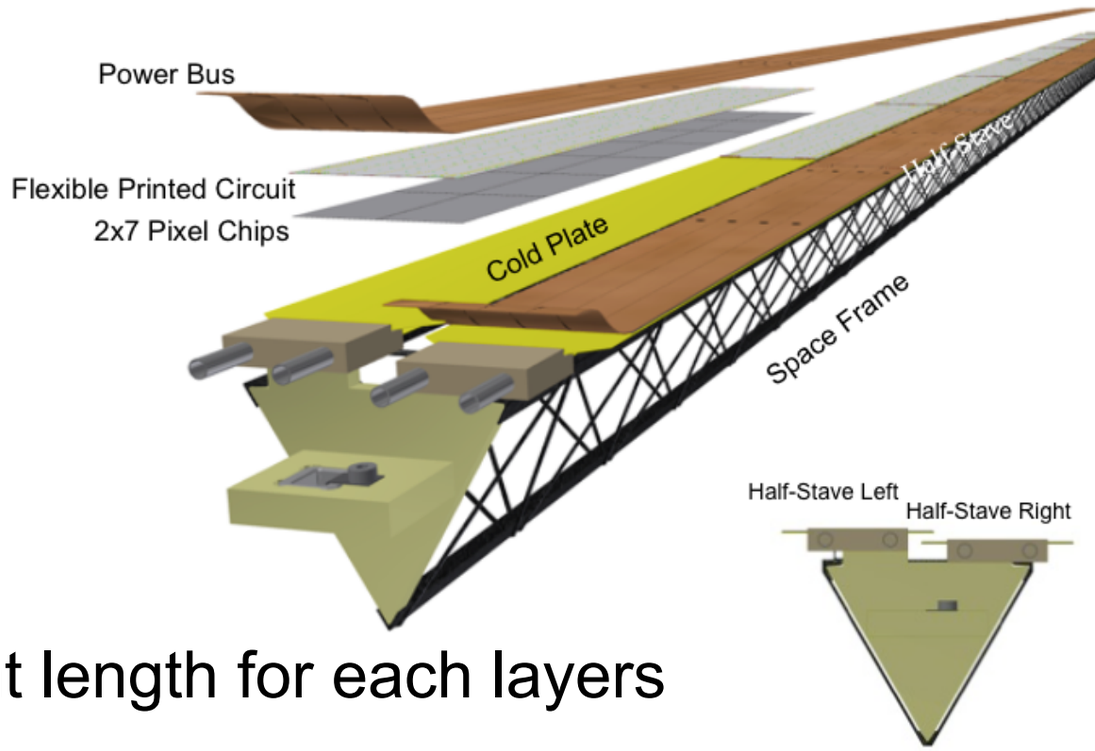


HIC Assembly in ITS upgrade

Construction of Outer Barrel

- **# of Stave for Outer Barrel**
  - **Middle layers: 24 + 30, length 843 mm**
  - **Outer layers: 42 + 48, length 1475 mm**
- **Main components of Stave**
  - Space frame & Cold plate
  - Power bus

→ different length for each layers



  - HIC → identical for Middle and Outer layers
- **Amount of needed HIC**
  - 2032 (including spare)
- **HIC construction Sites**
  - CERN, INFN (Italy), Strasbourg (France), **PNU+Inha (Korea)**
  - Up to 3 more sites, CCNU(China), LBNL(USA), Liverpool(England)

Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

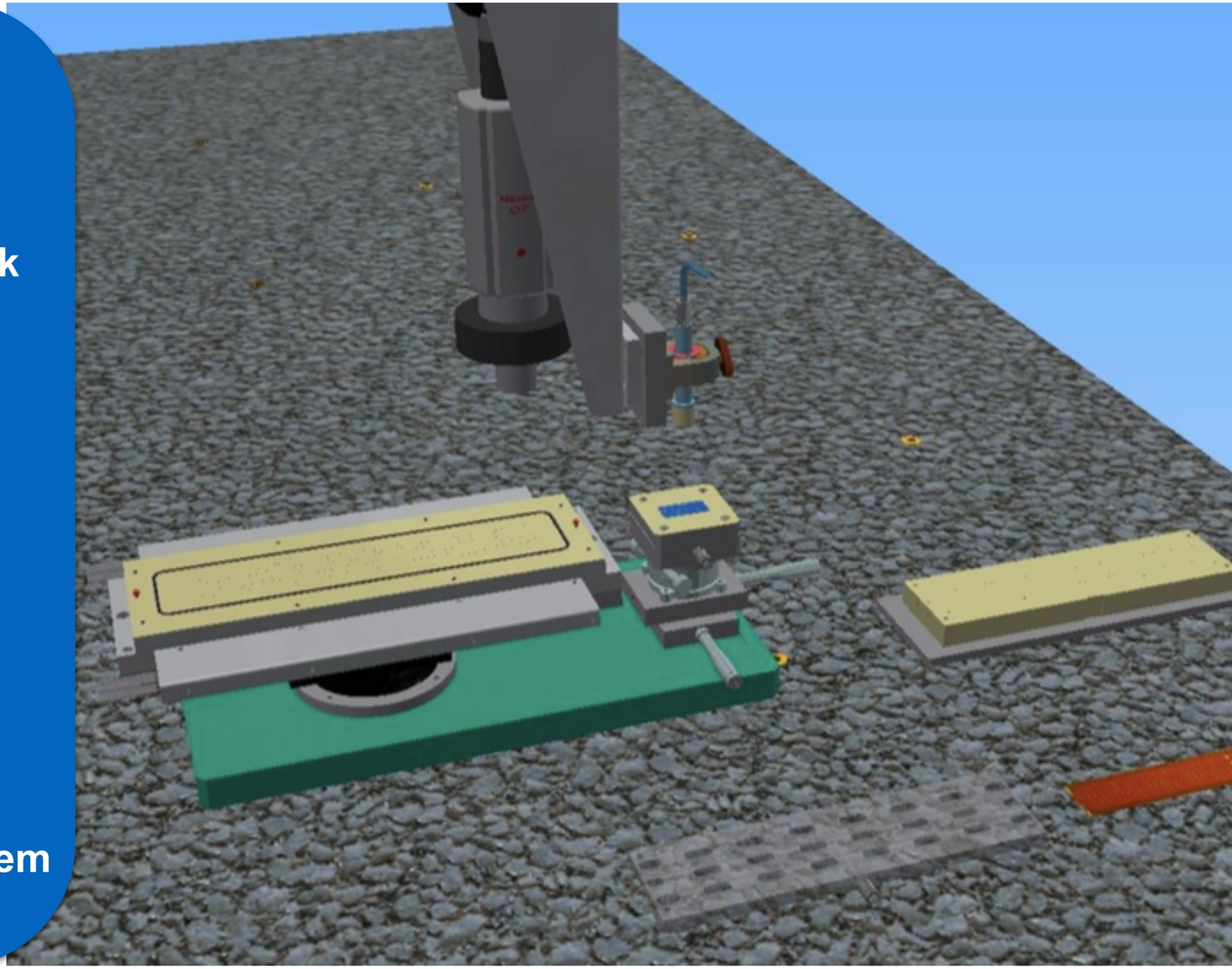
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

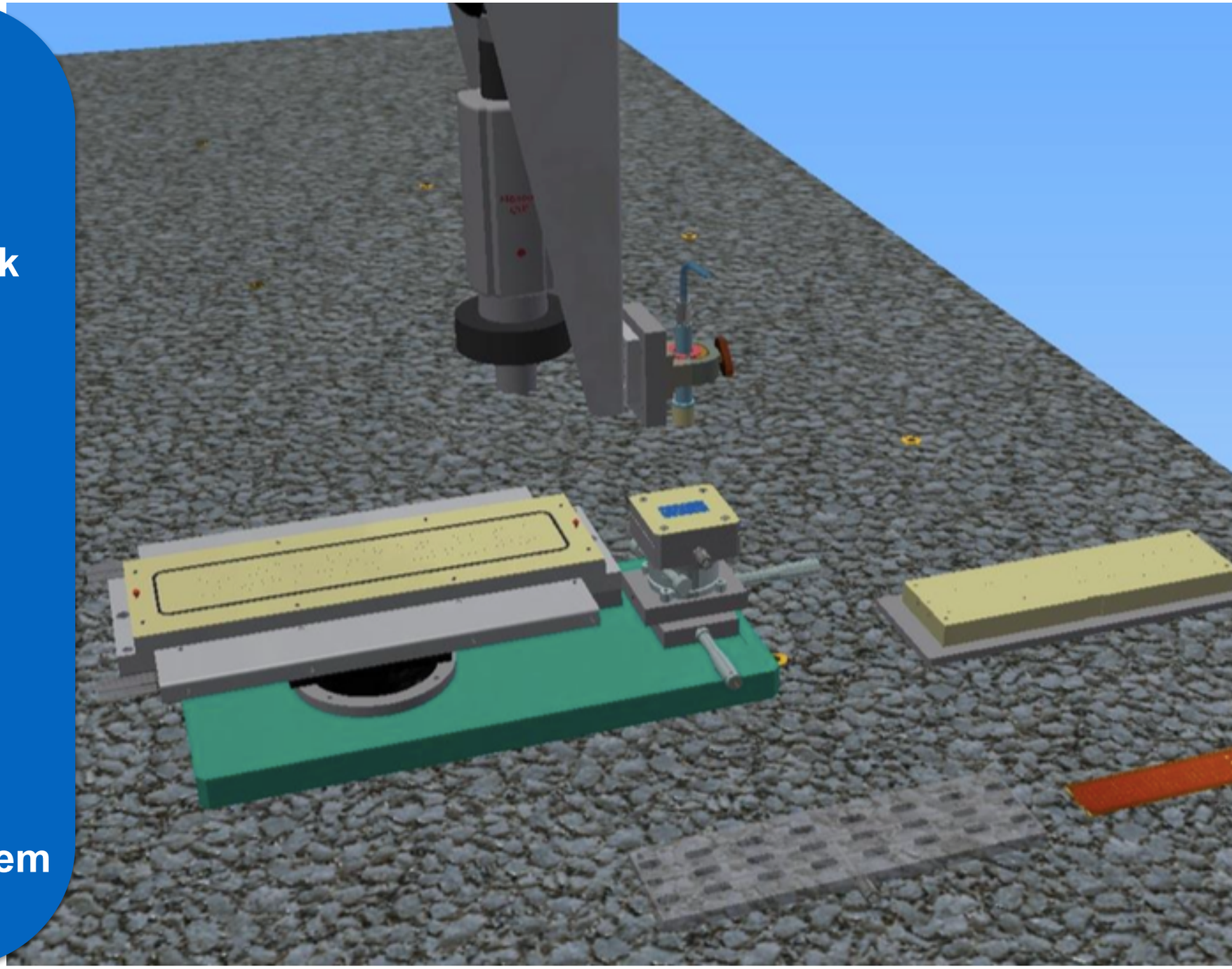
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

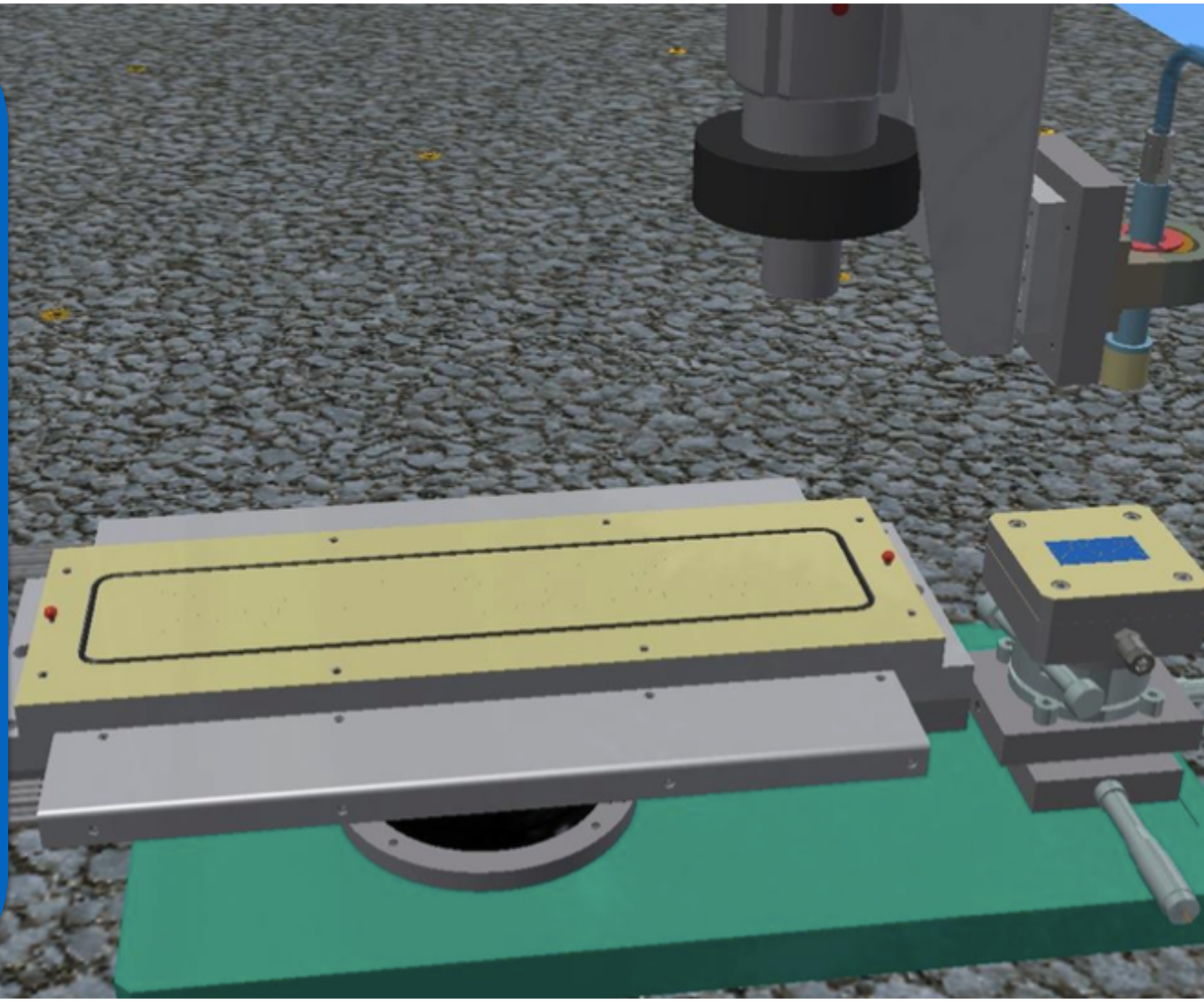
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

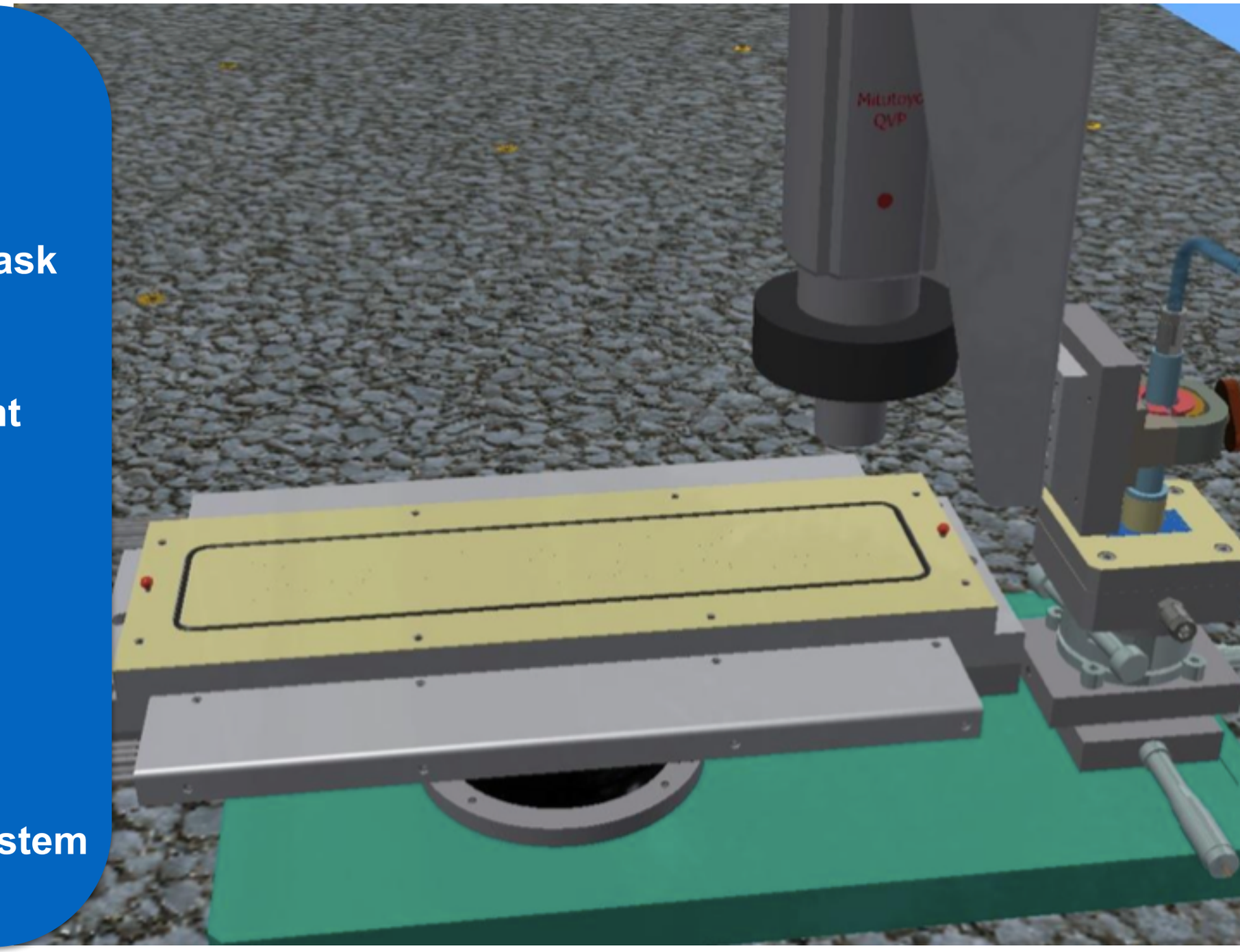
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

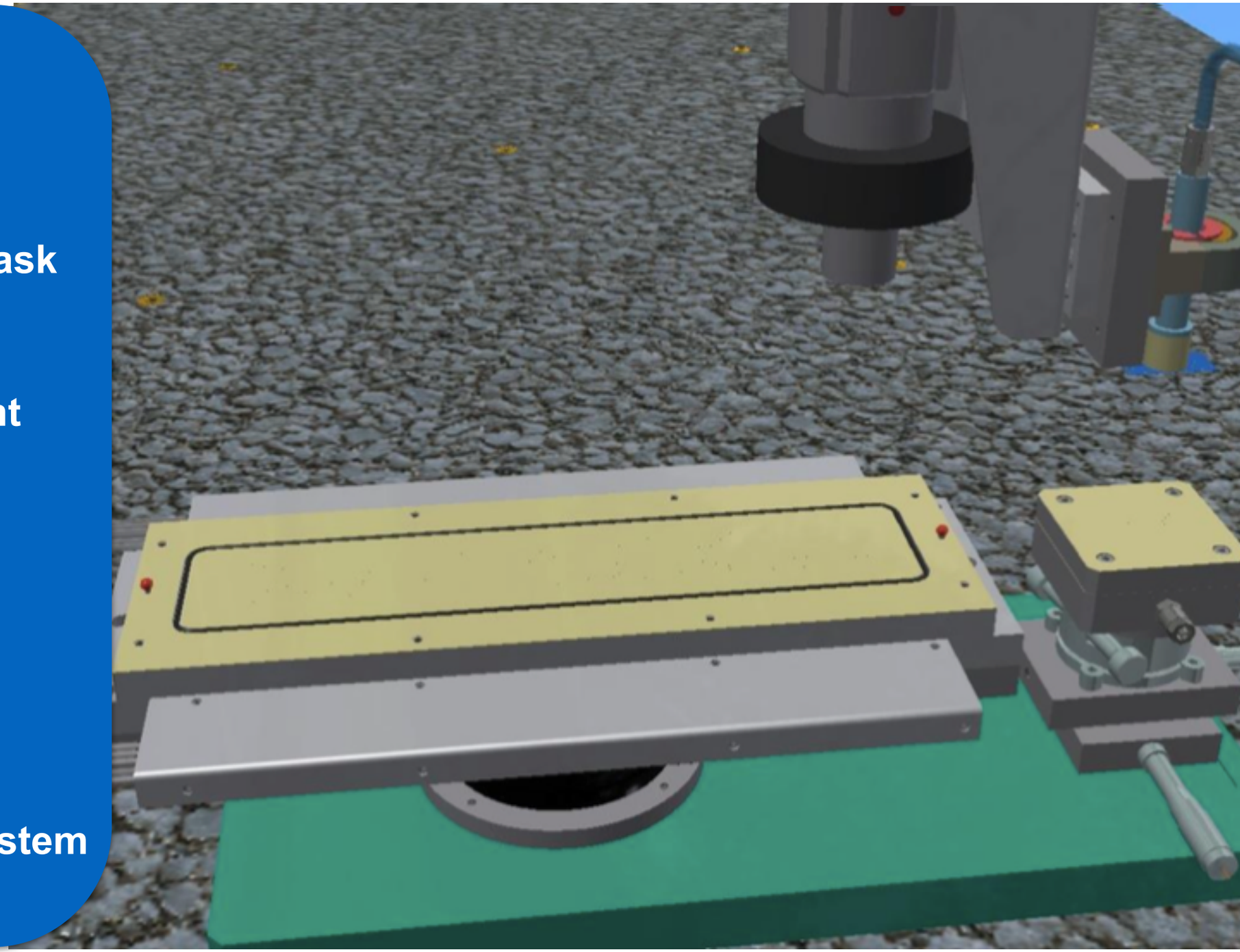
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

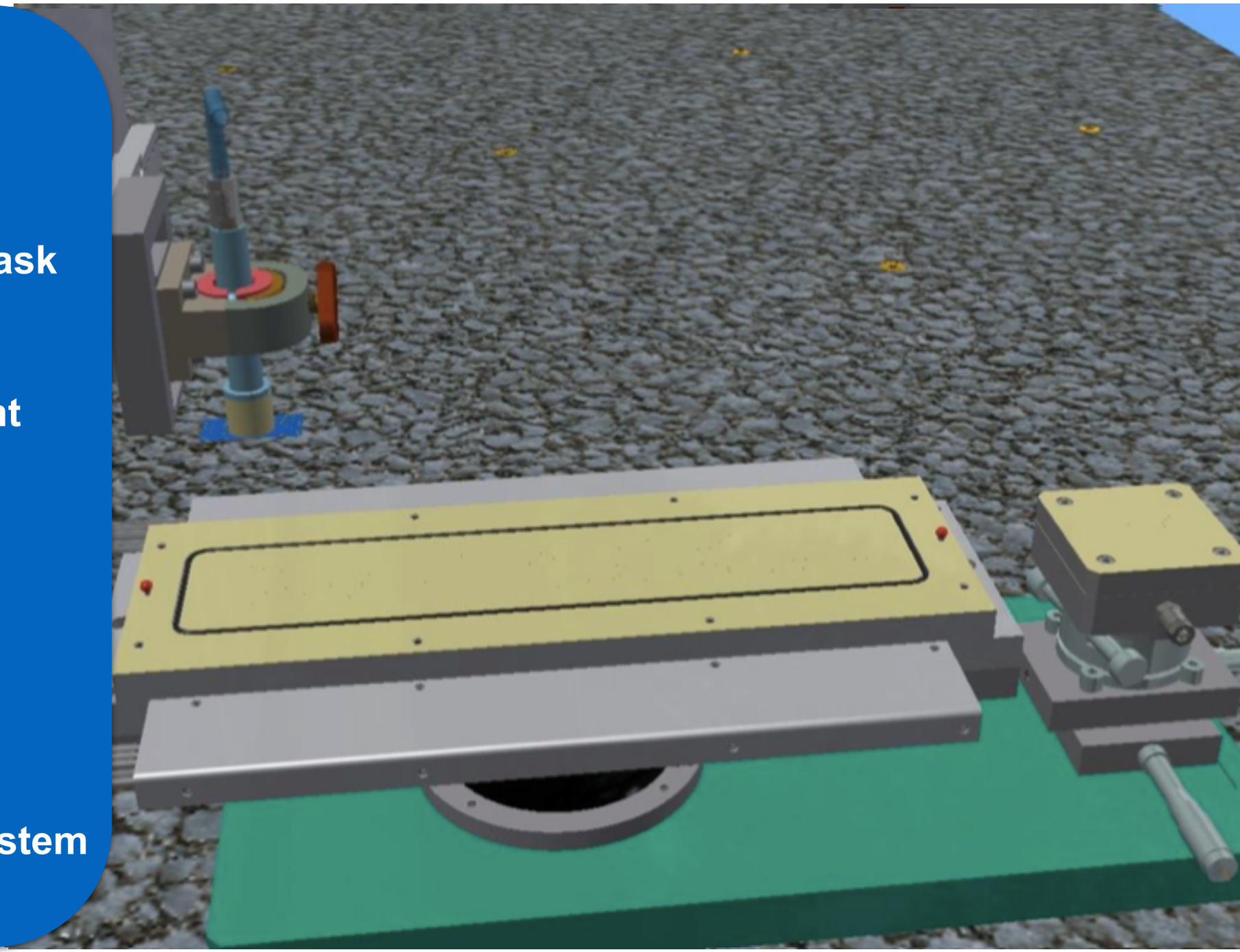
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

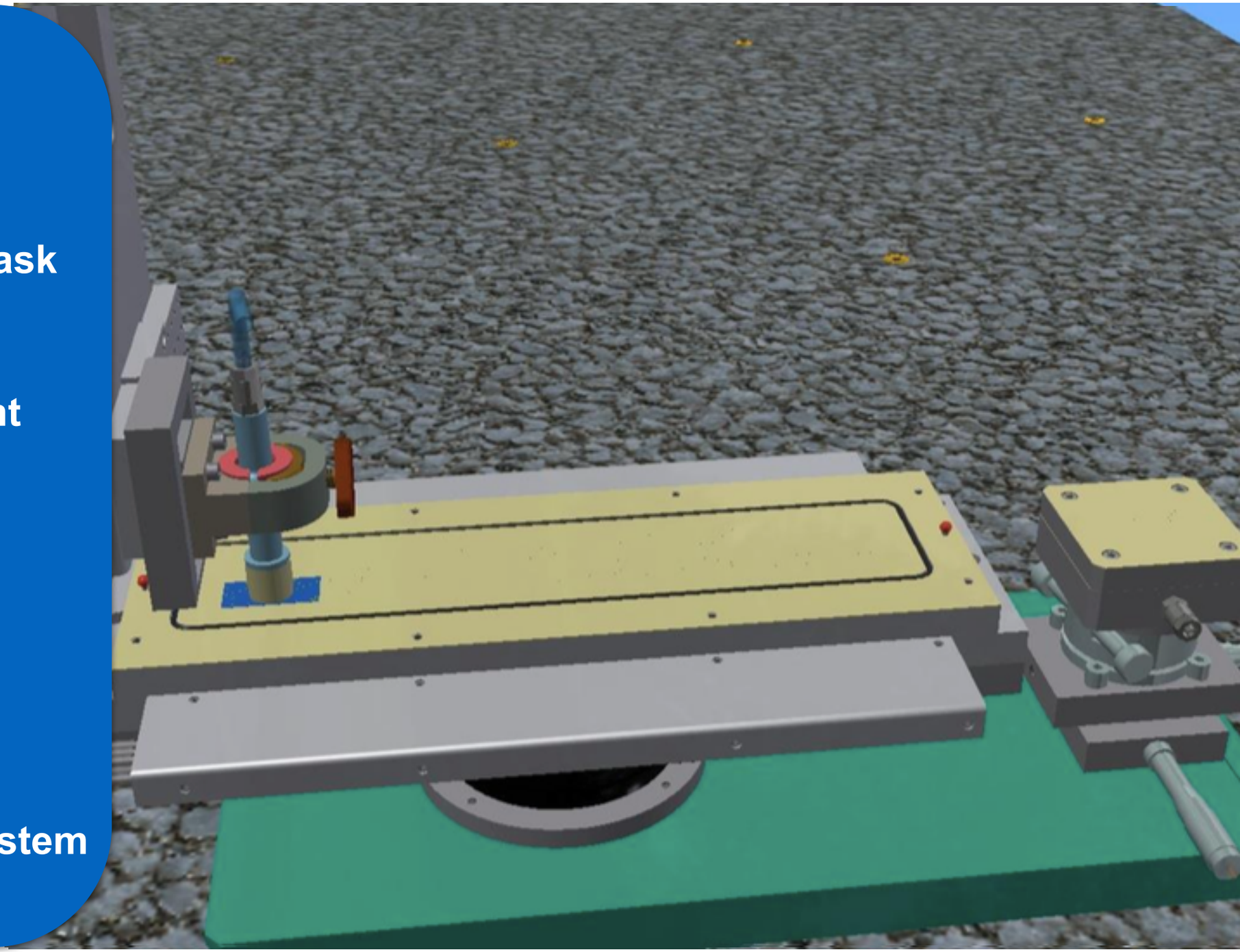
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

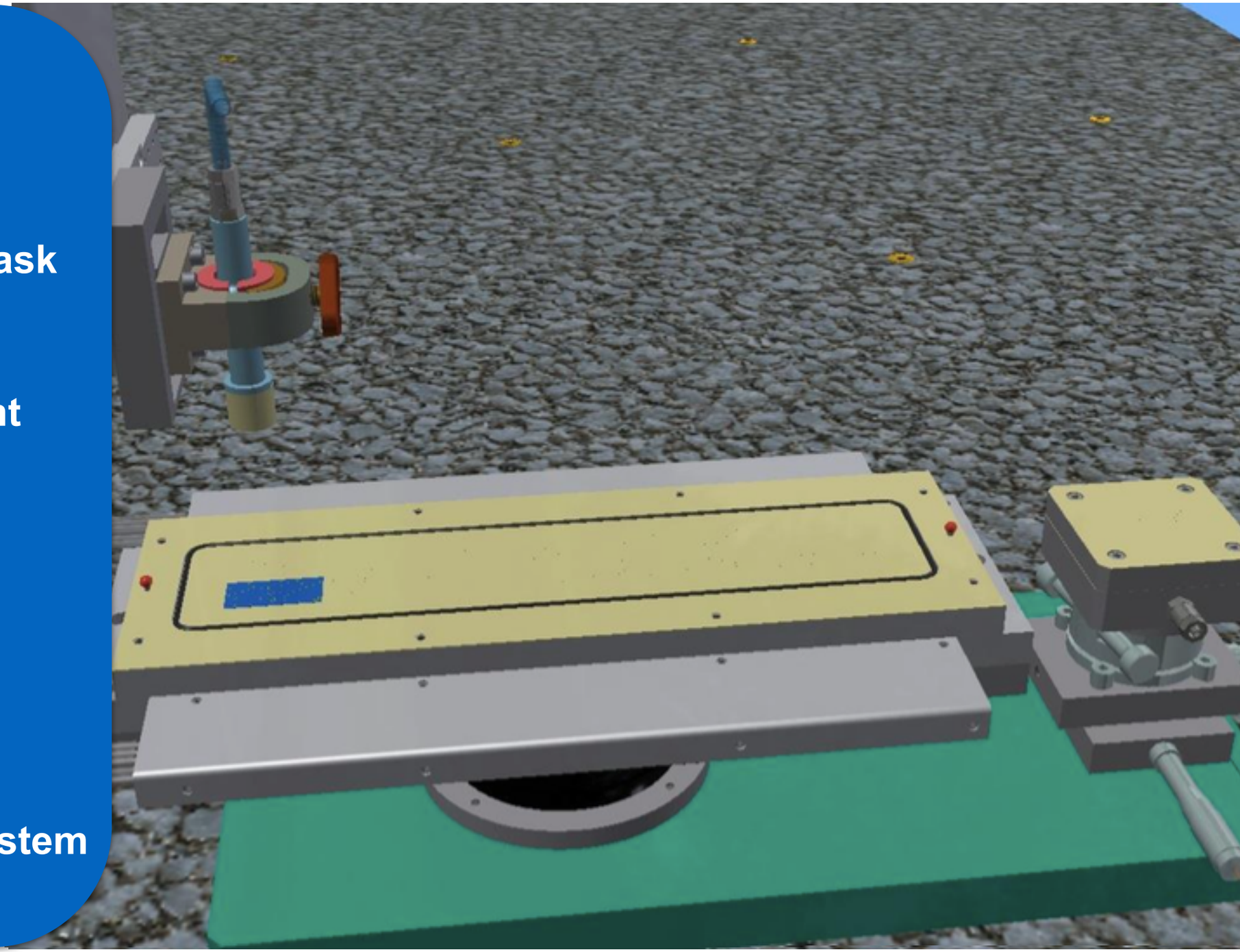
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

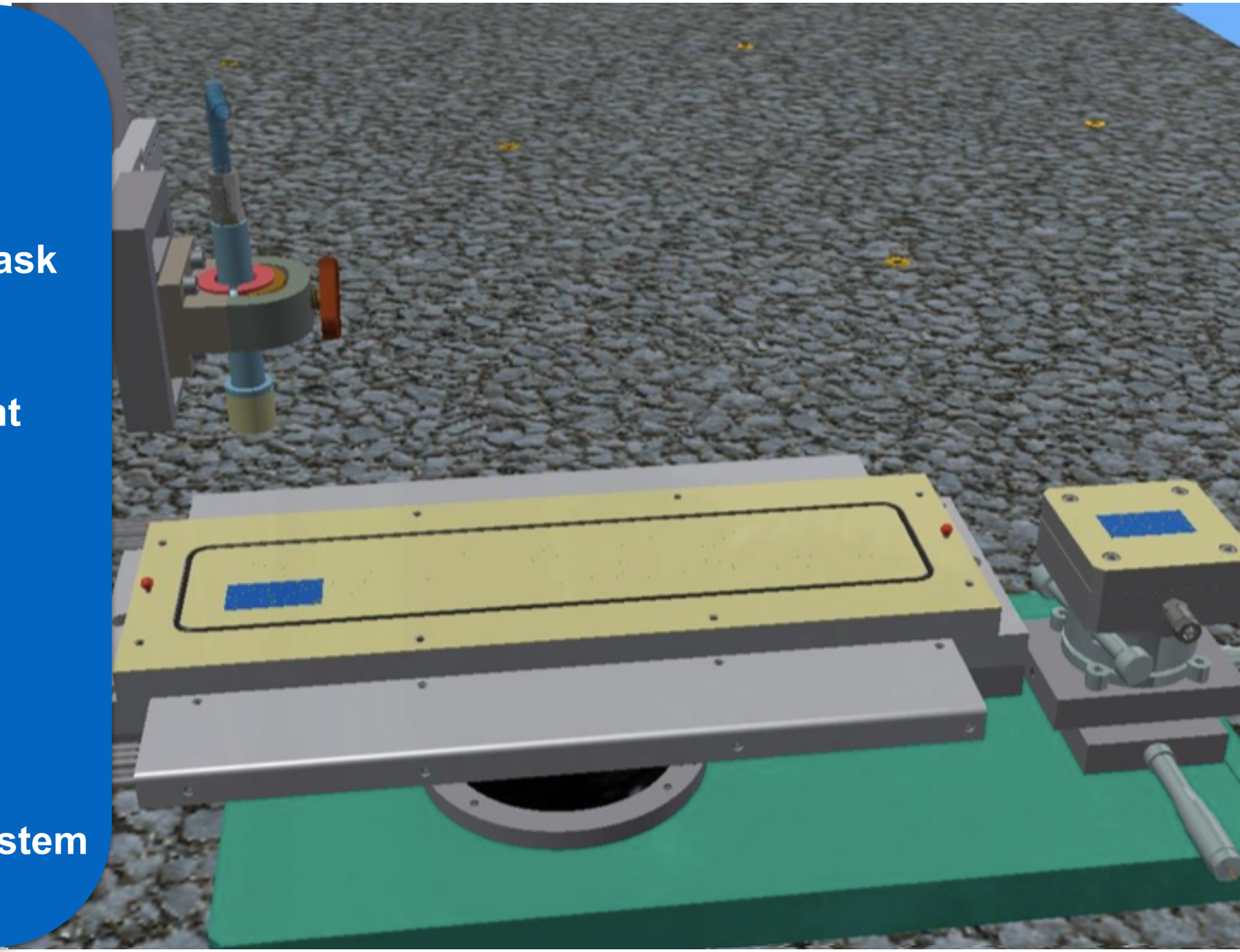
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

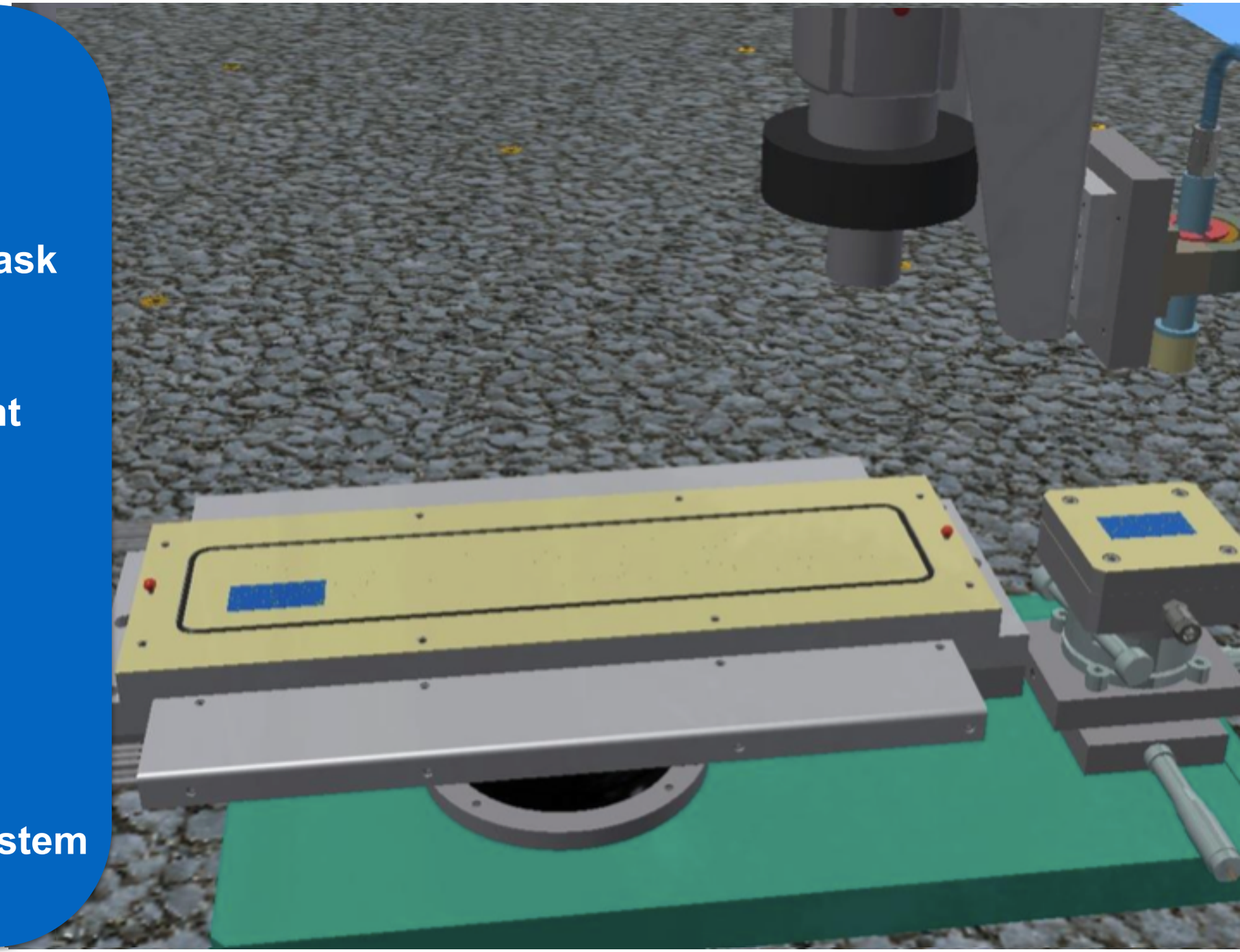
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

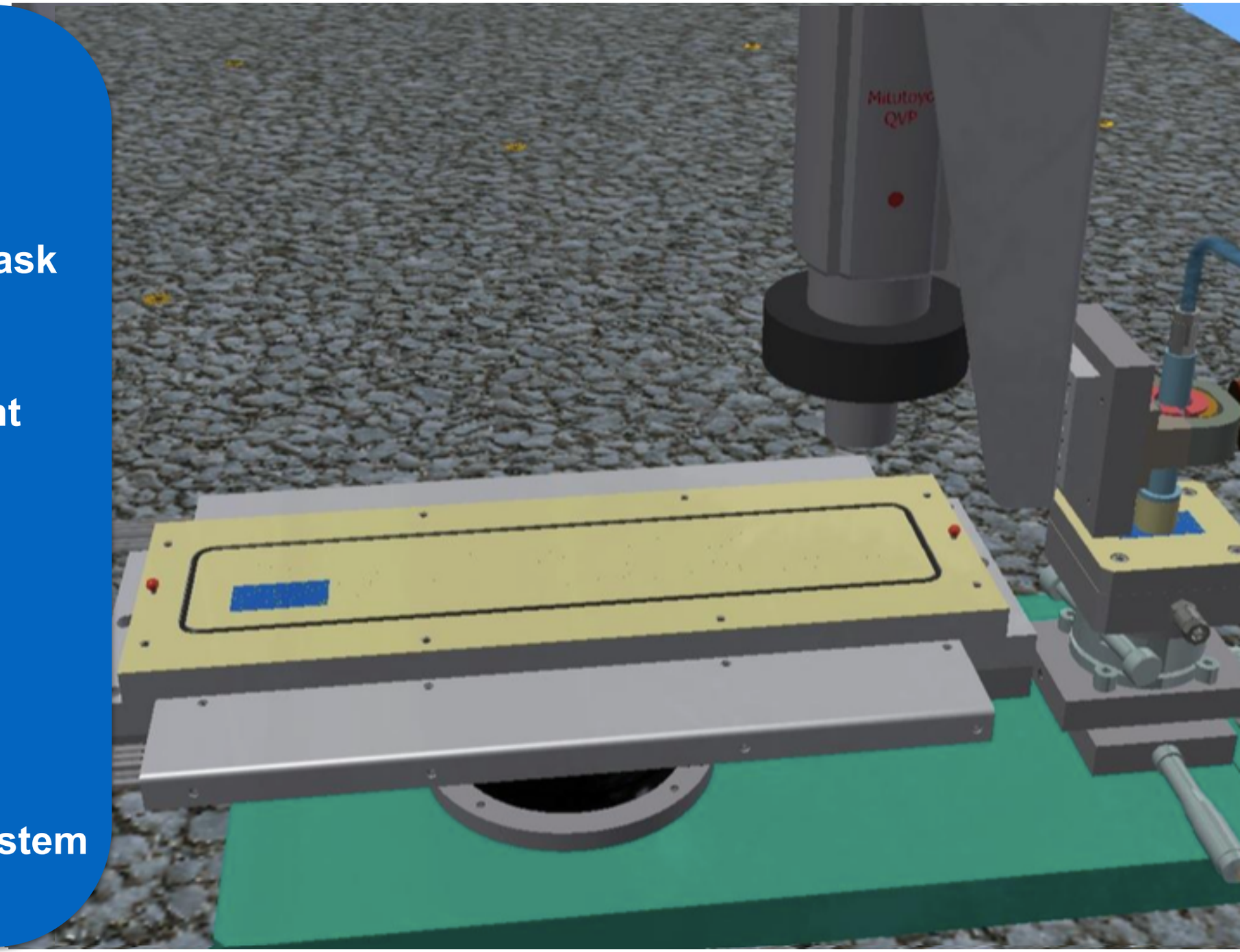
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

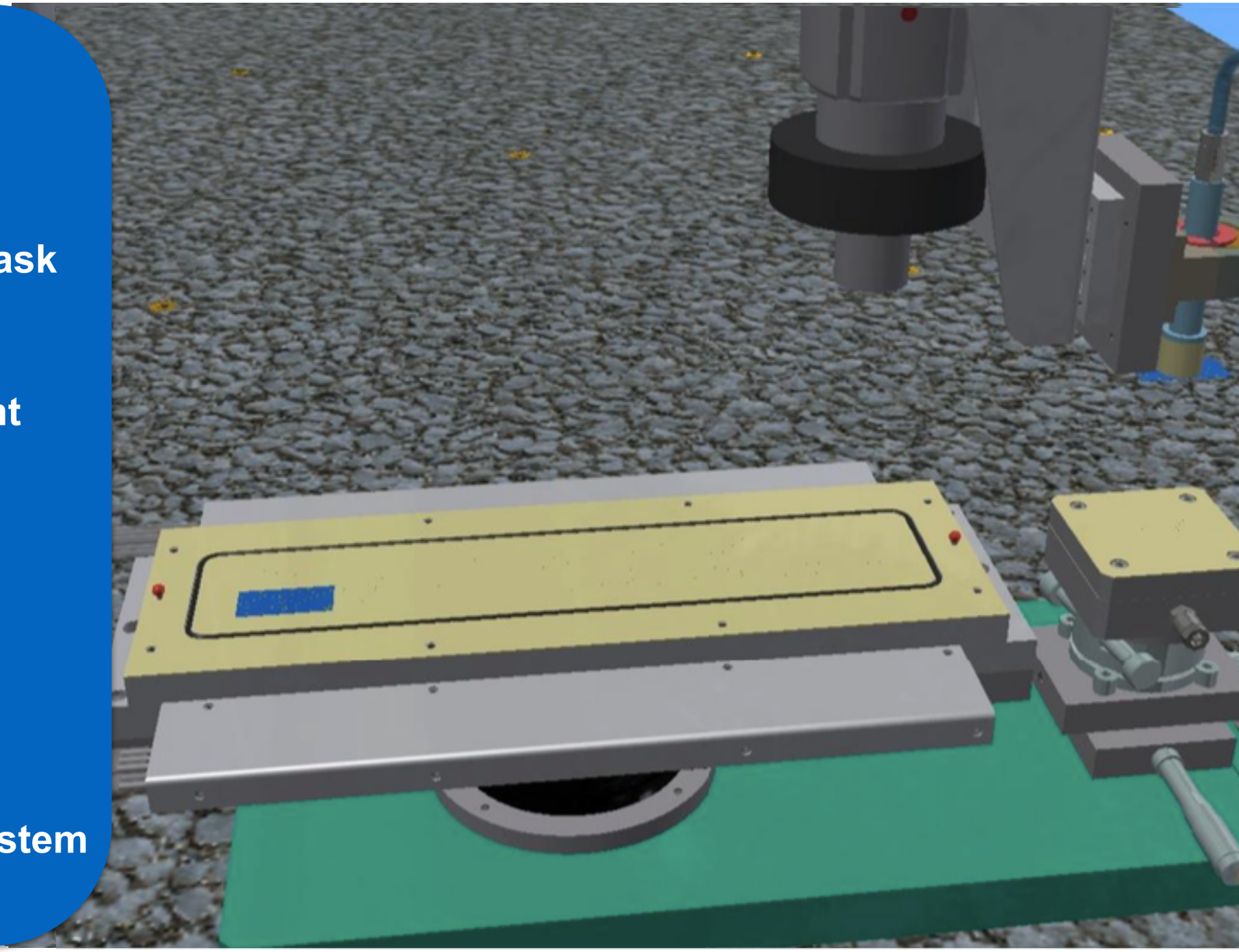
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

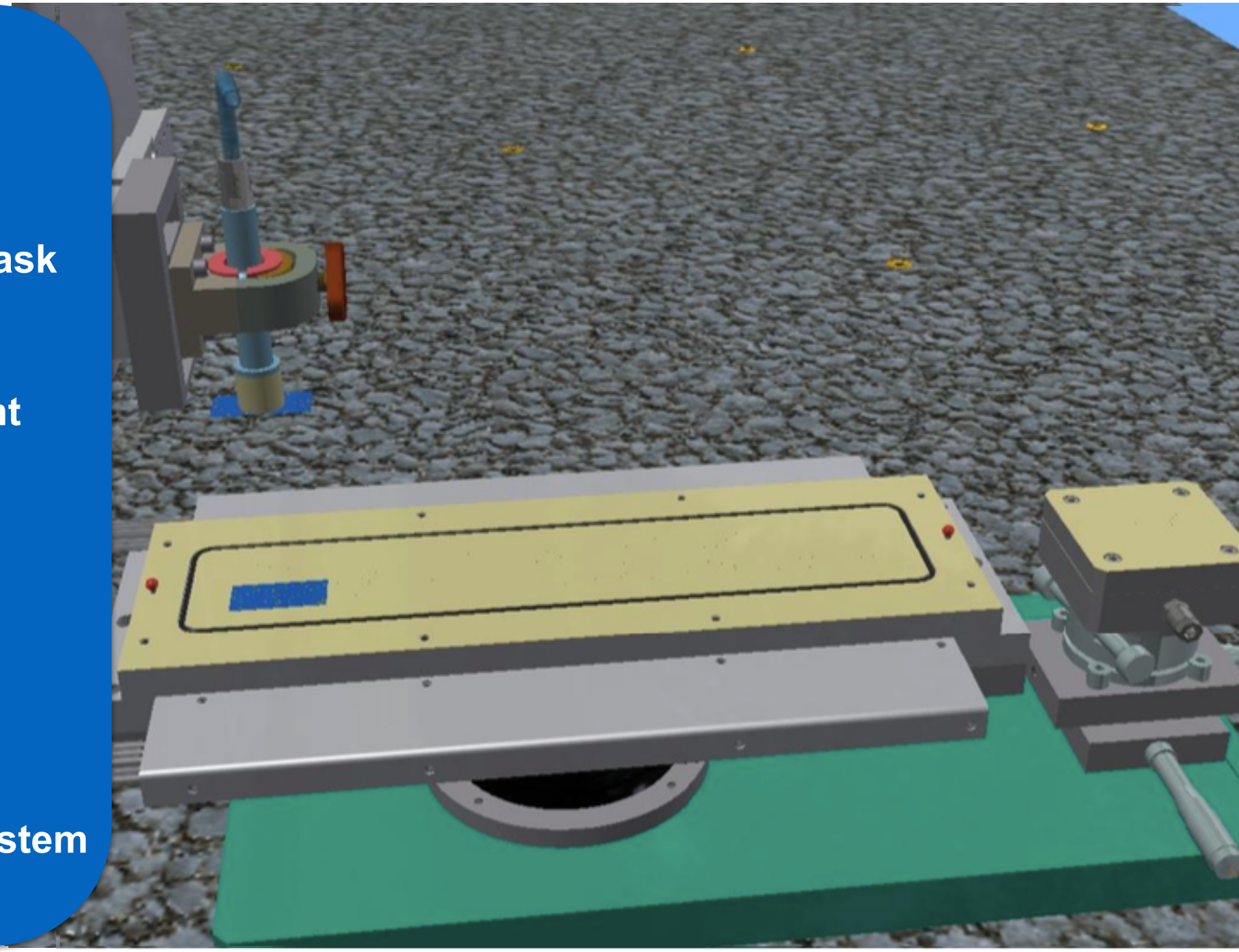
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

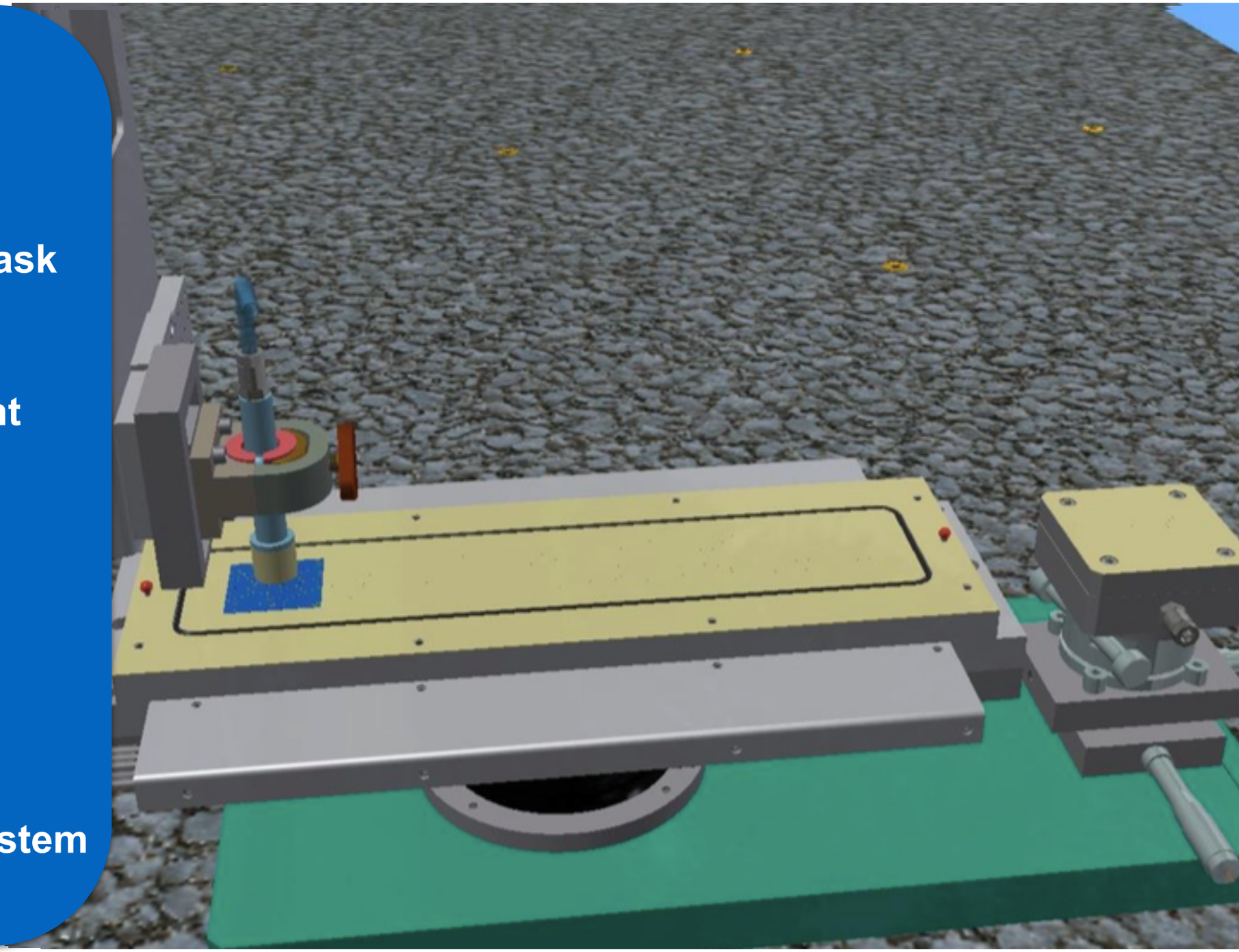
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

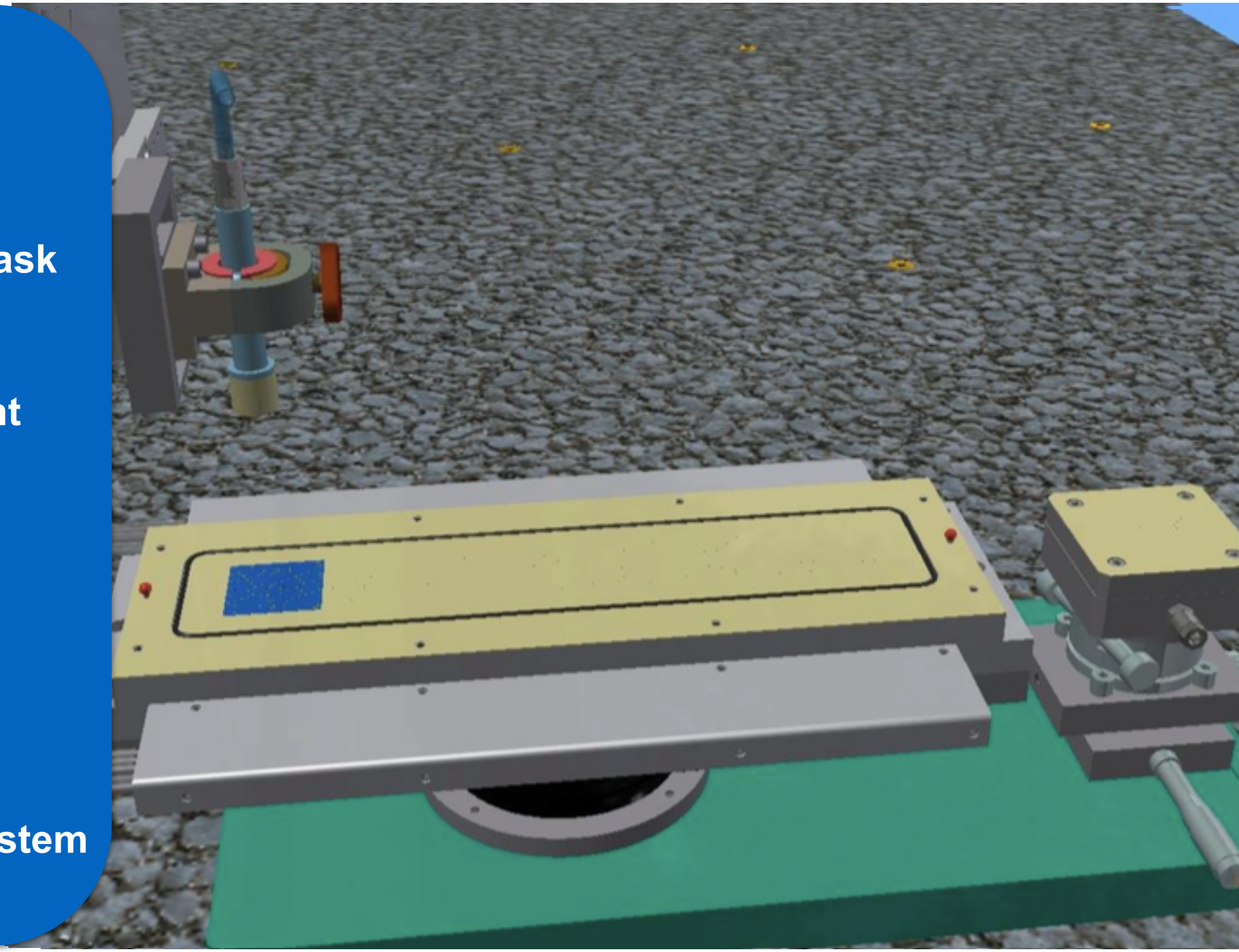
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

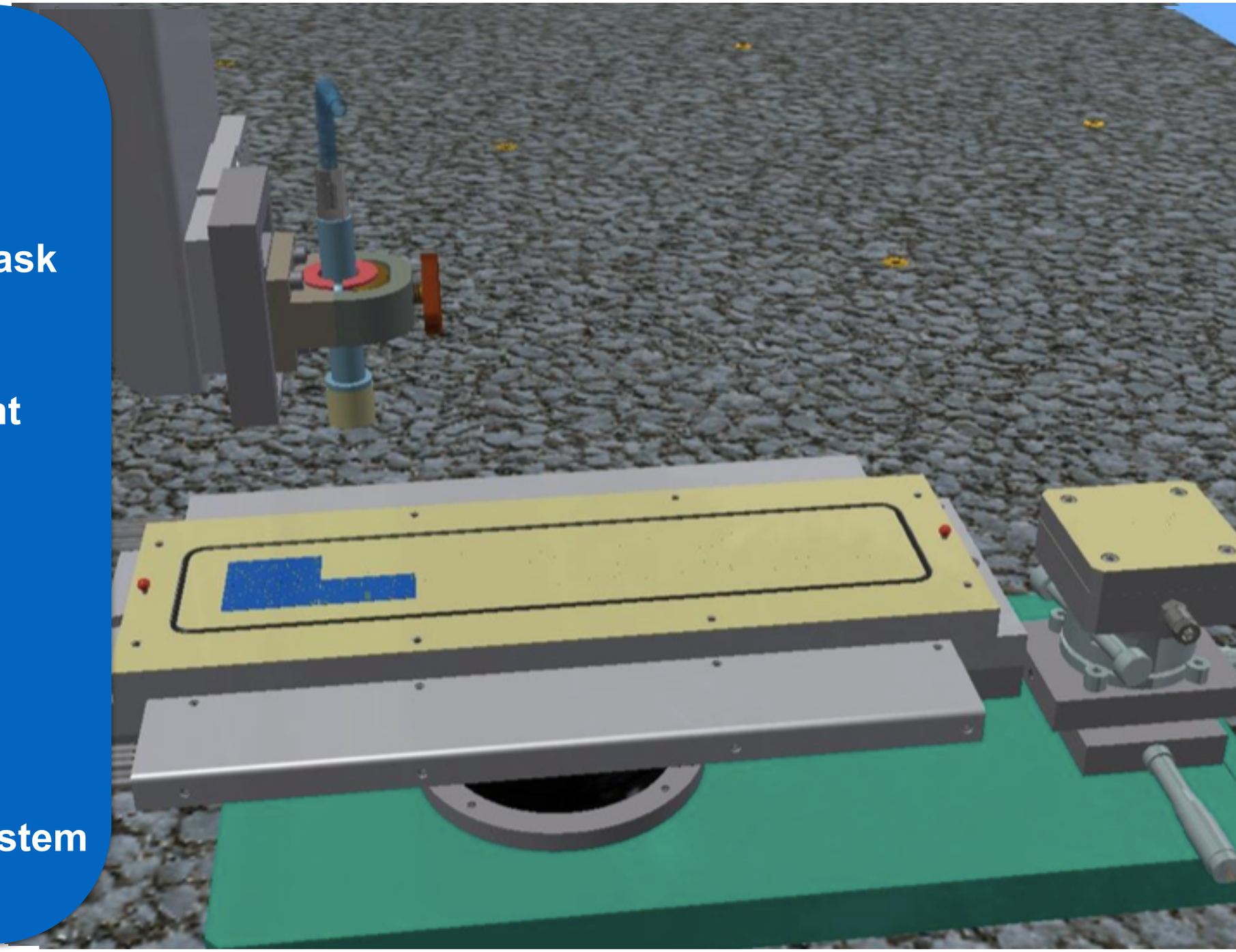
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

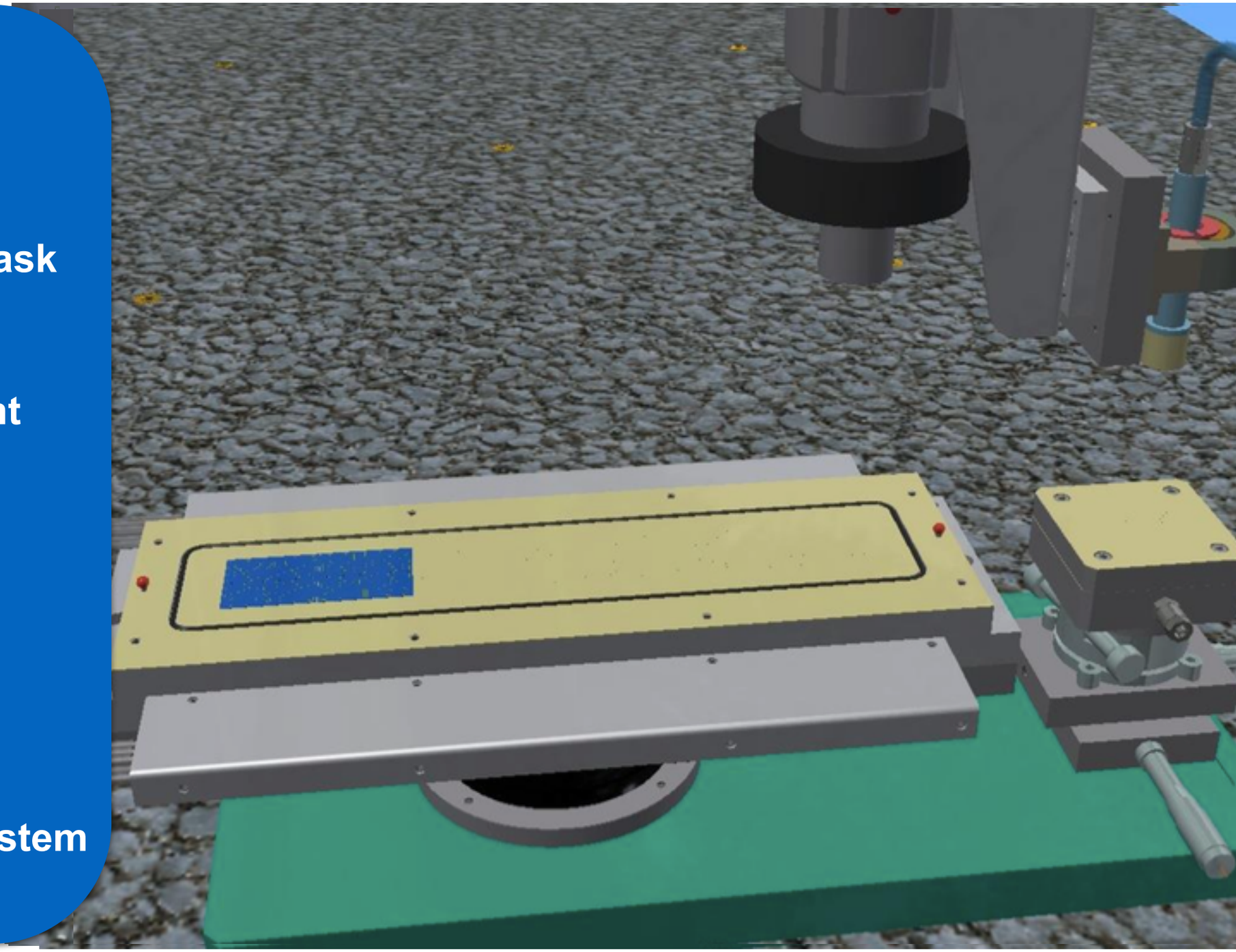
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

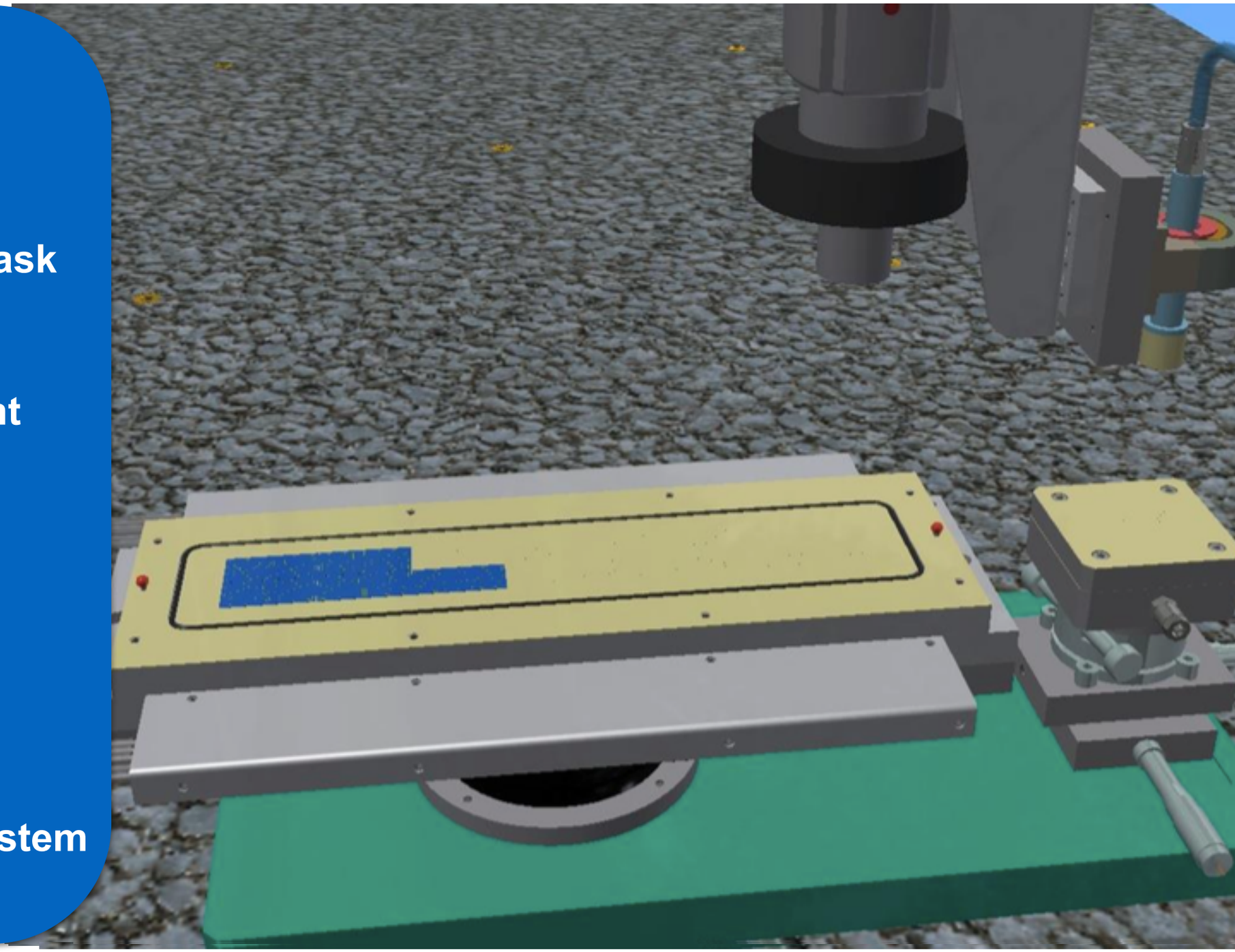
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

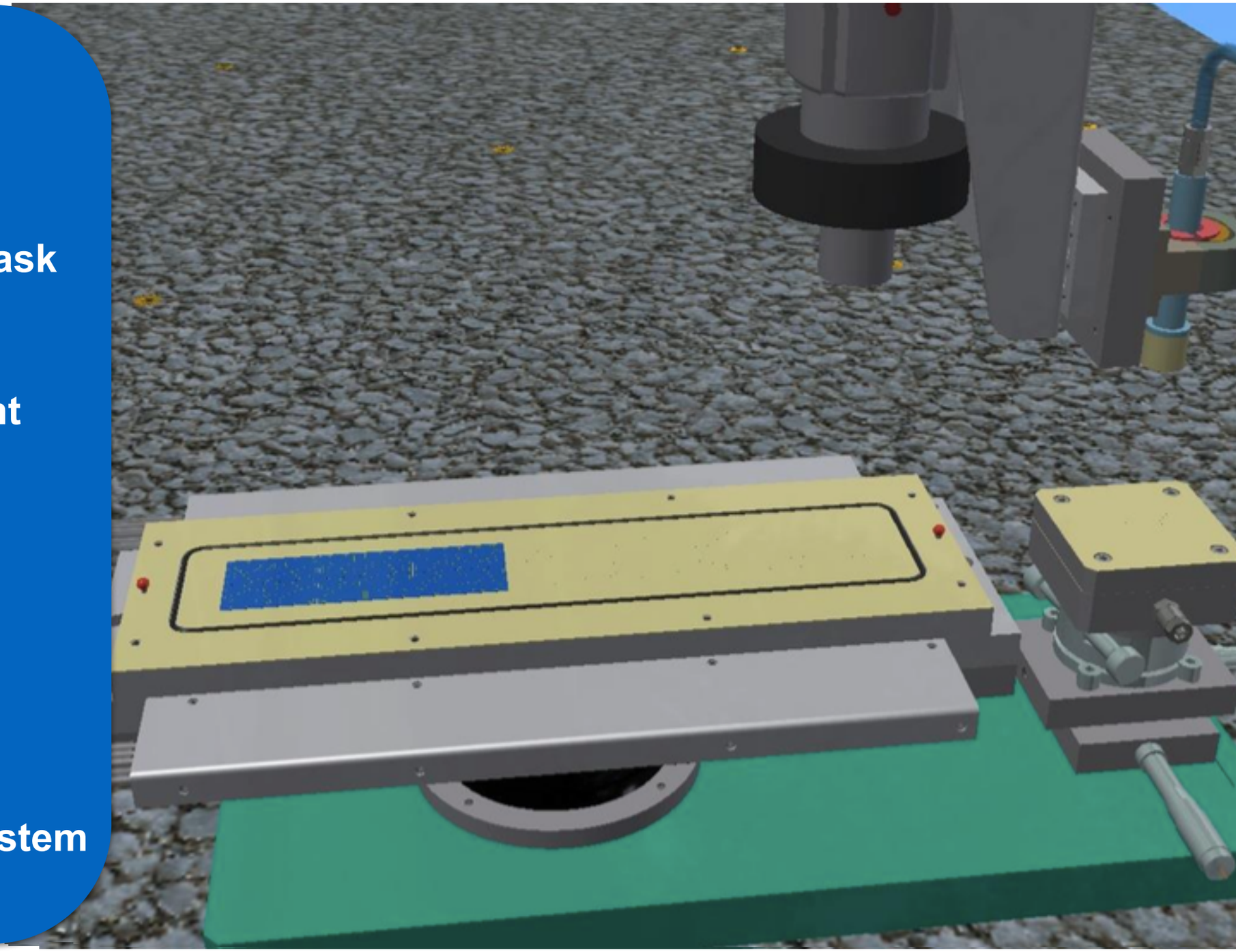
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

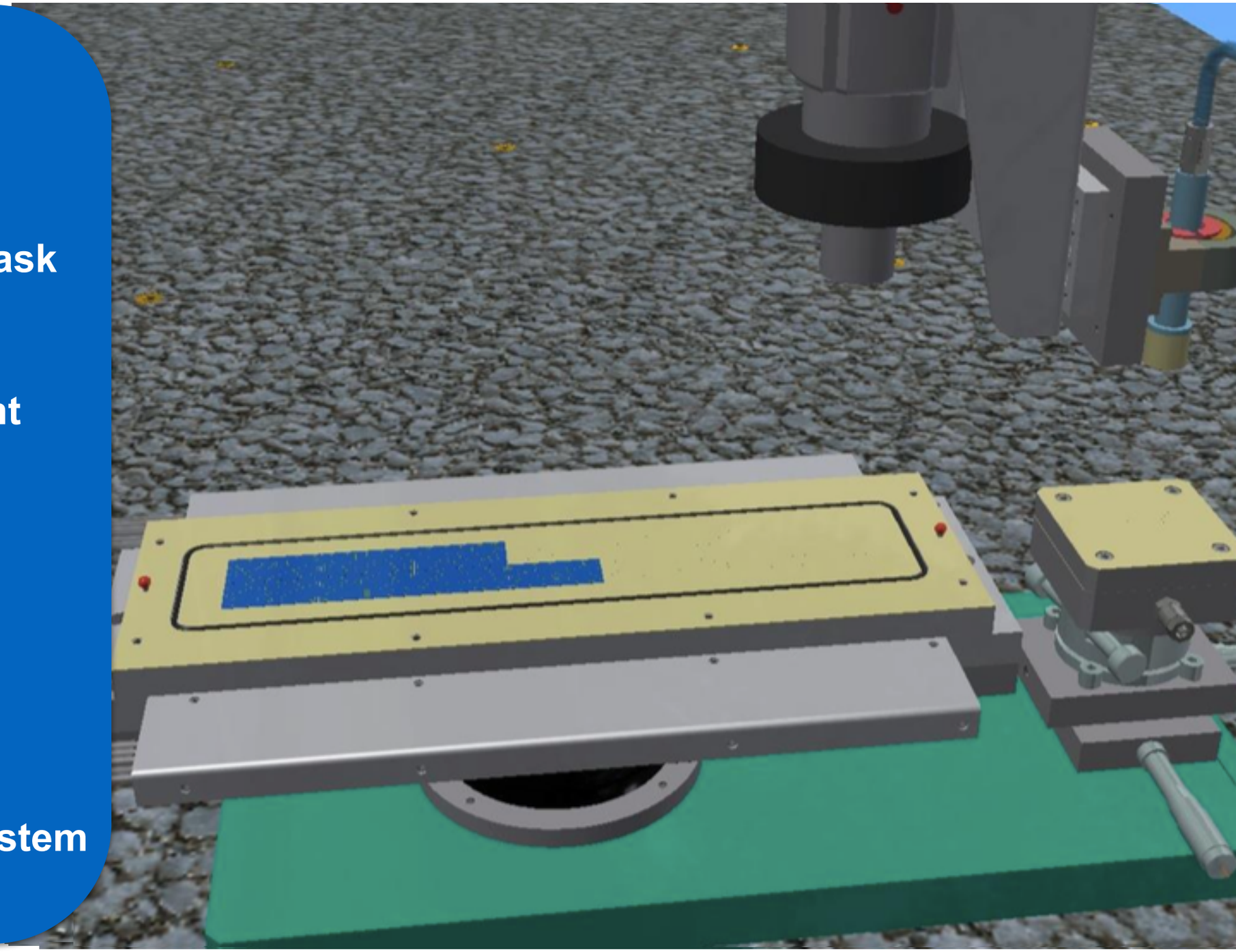
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

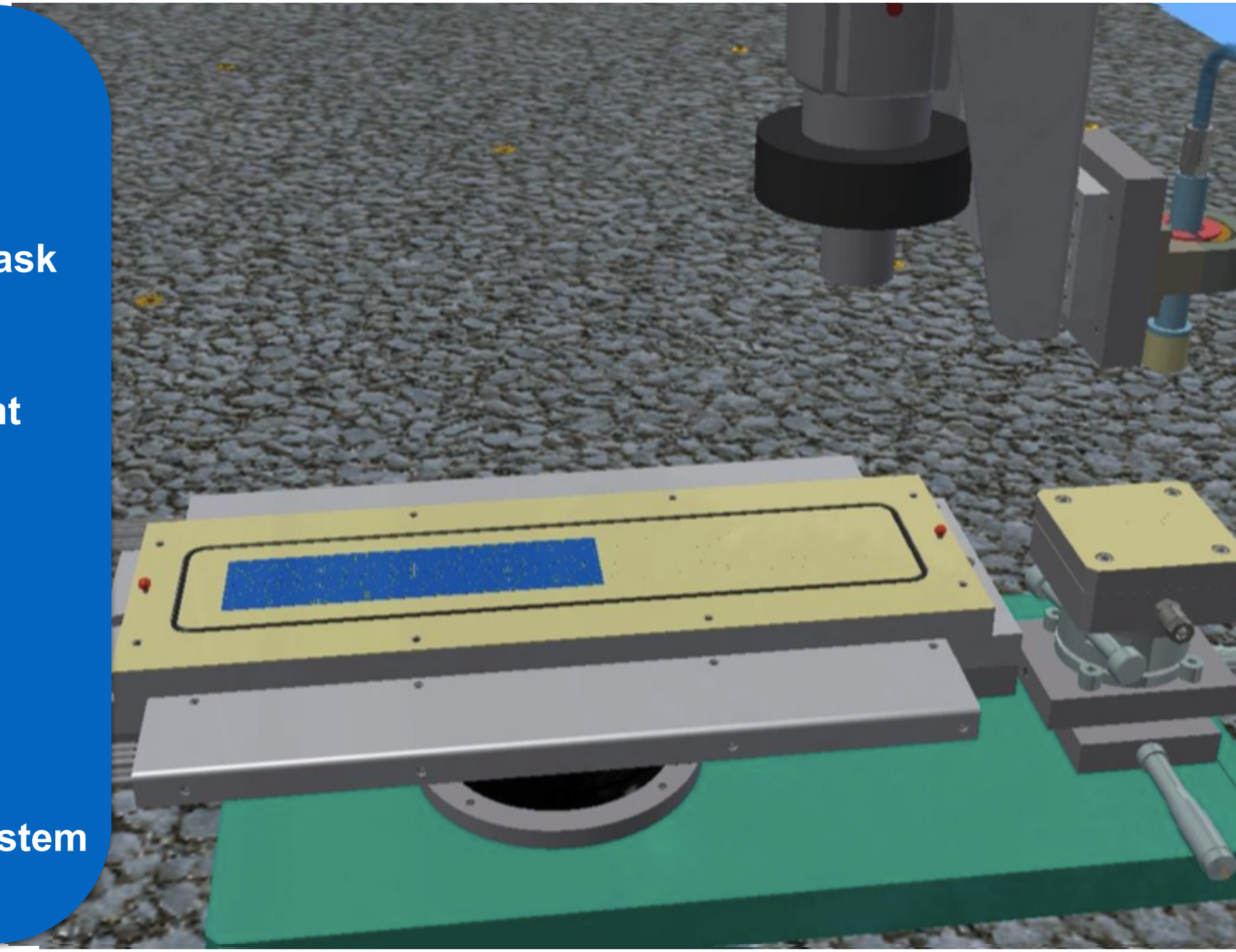
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

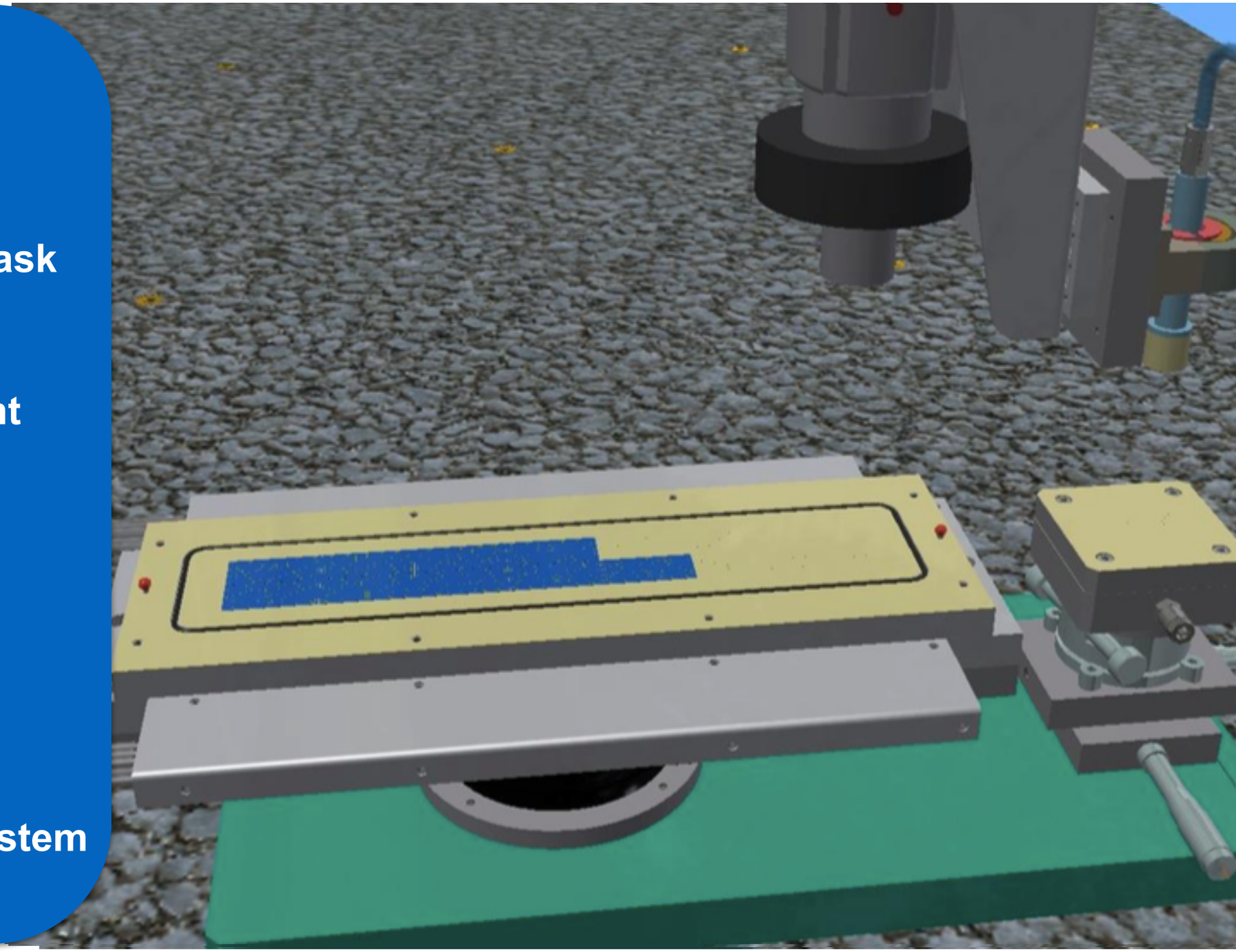
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

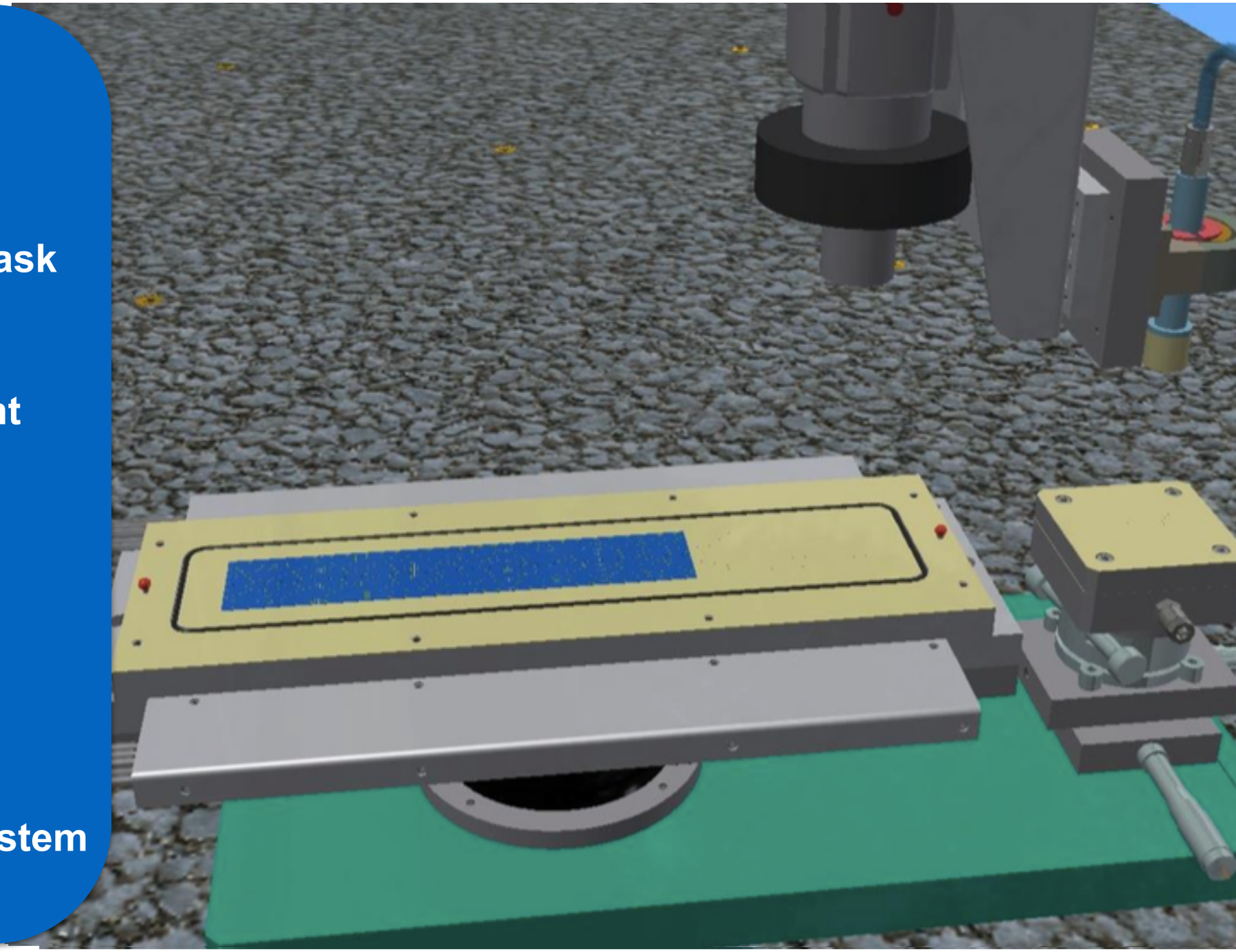
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

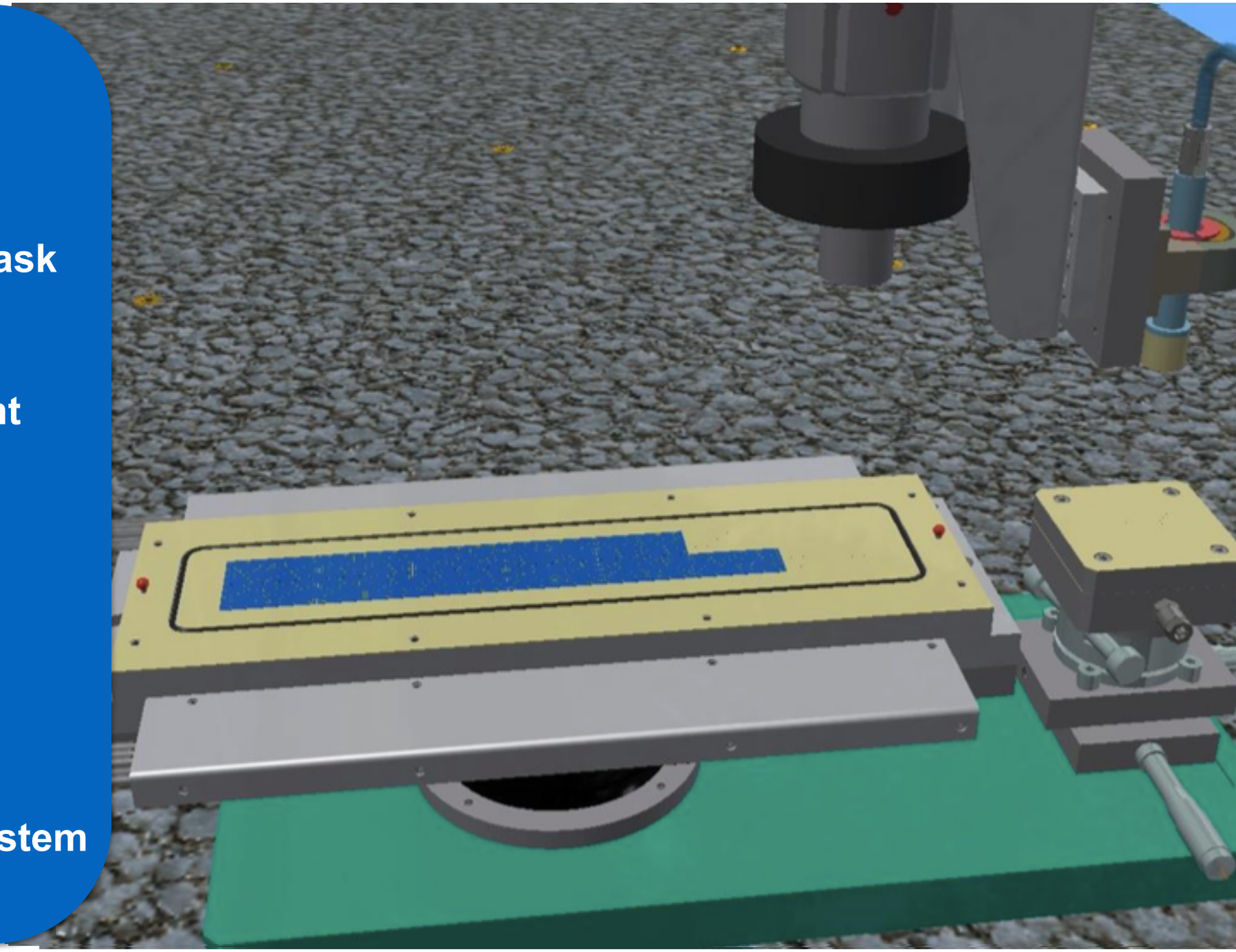
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

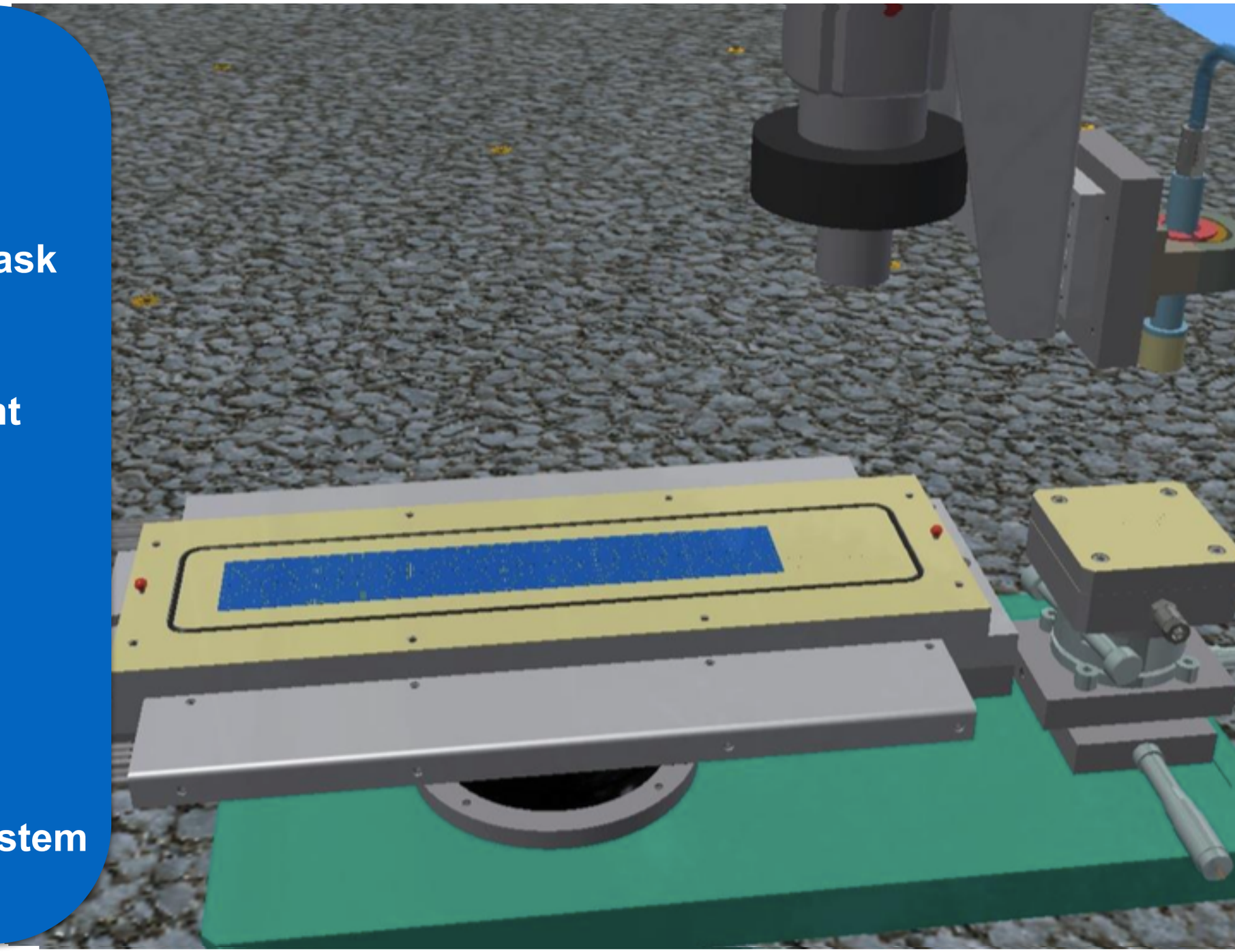
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

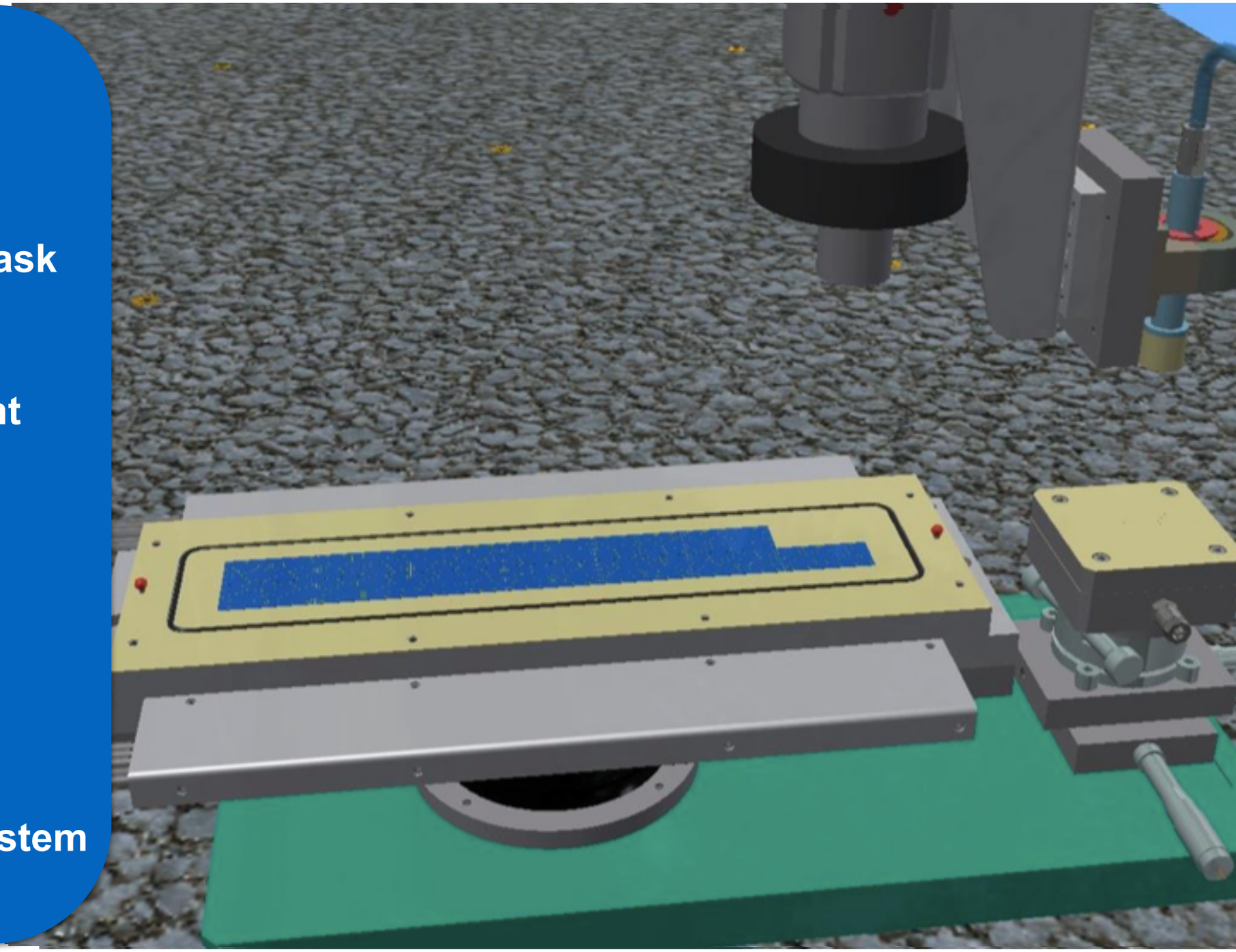
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

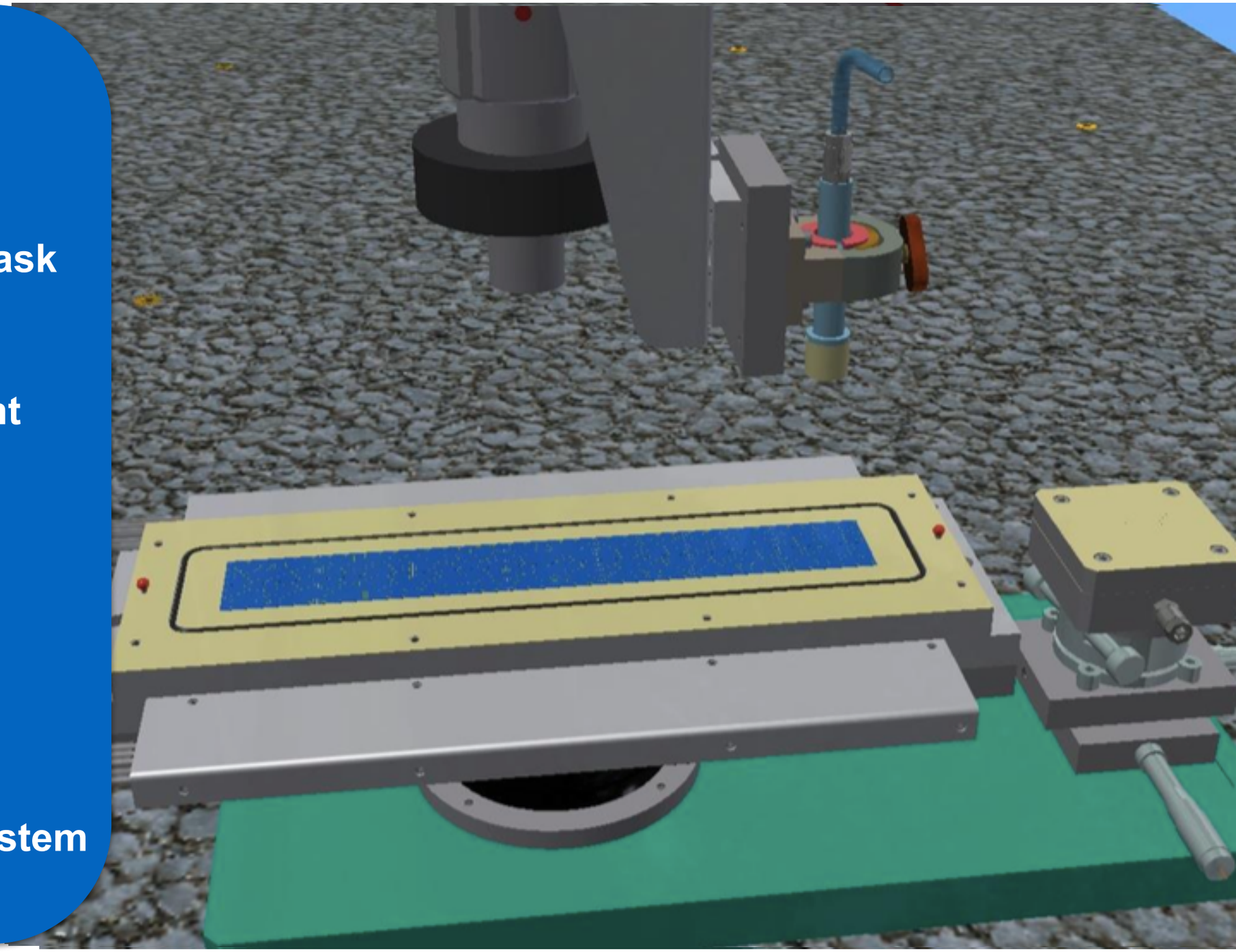
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

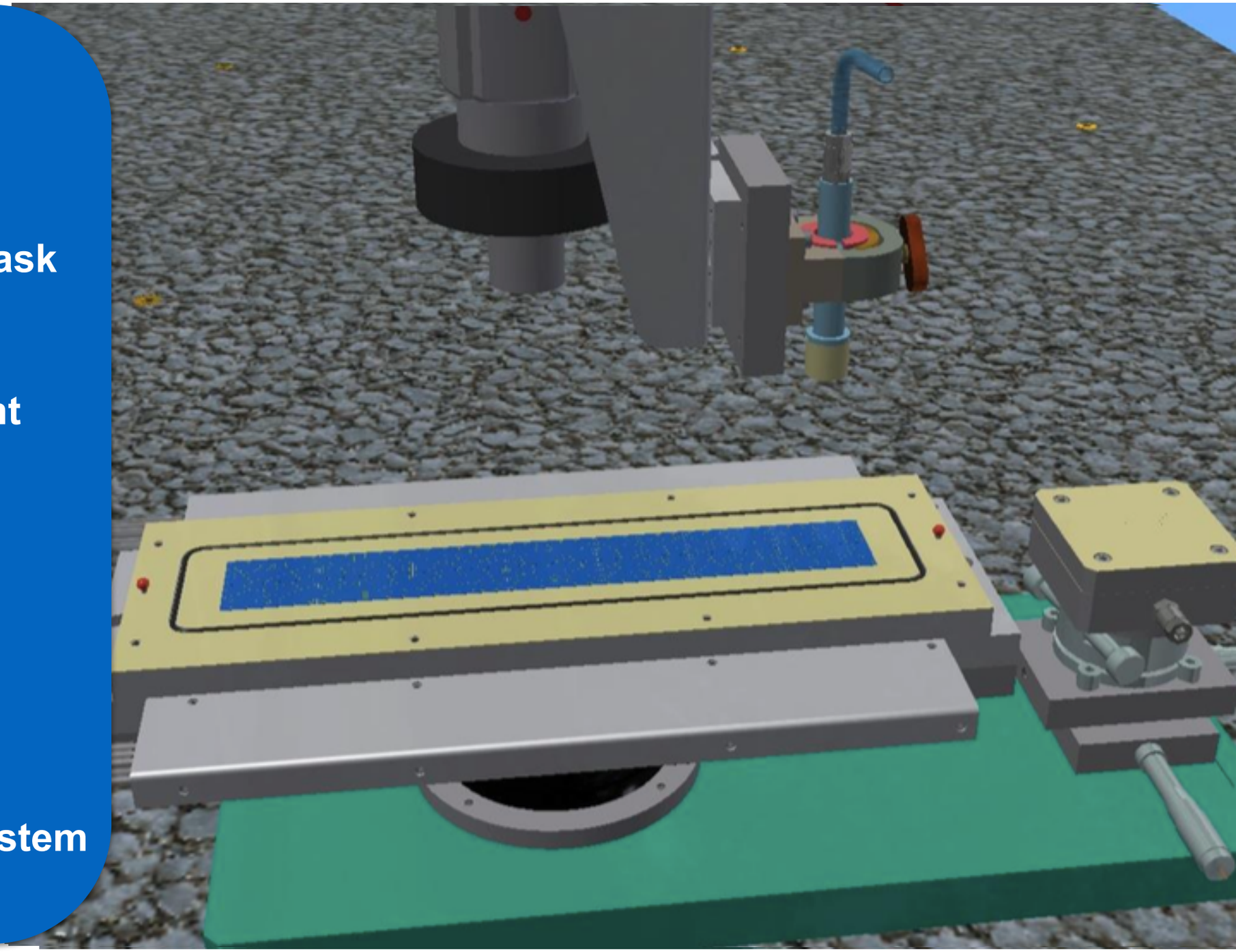
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

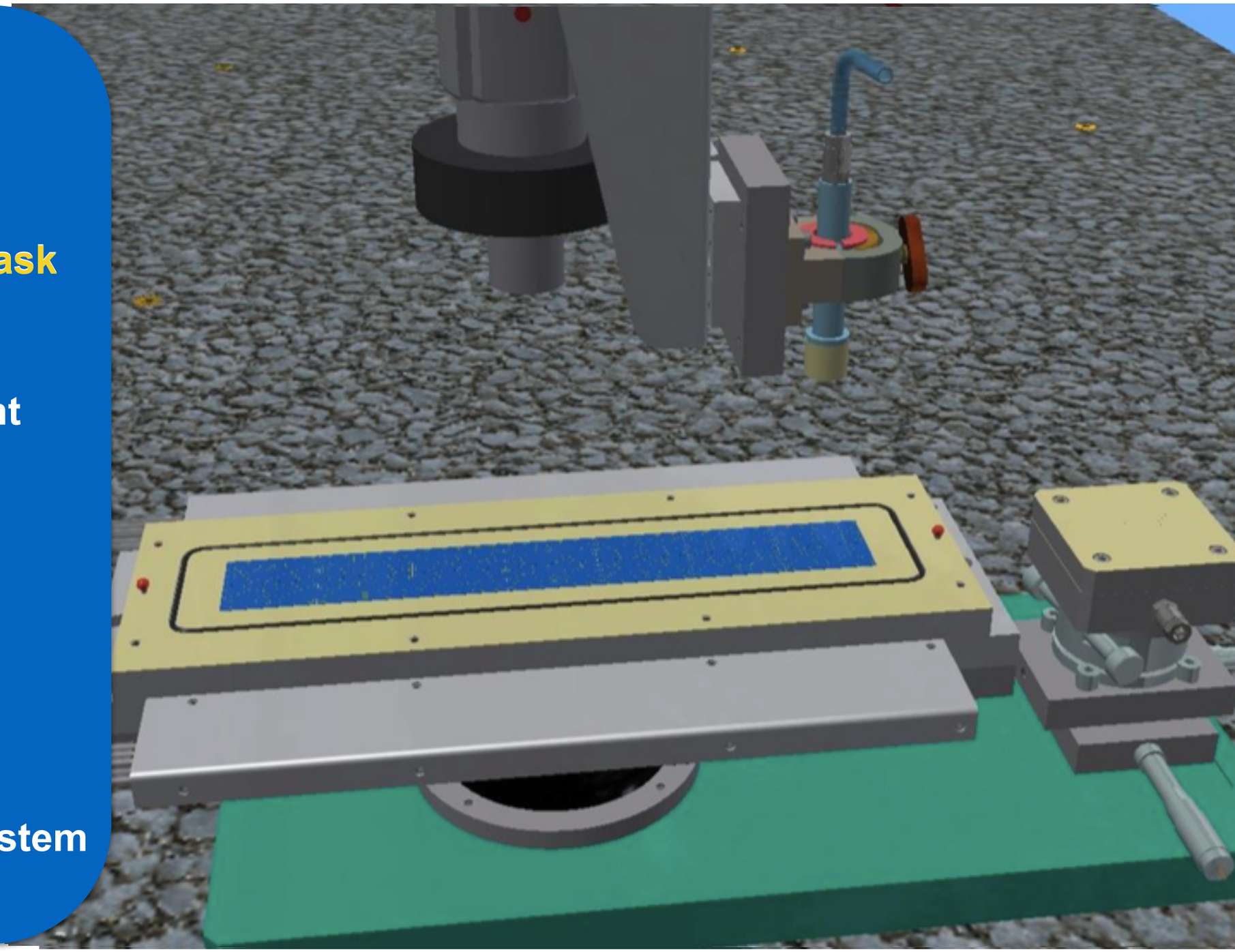
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

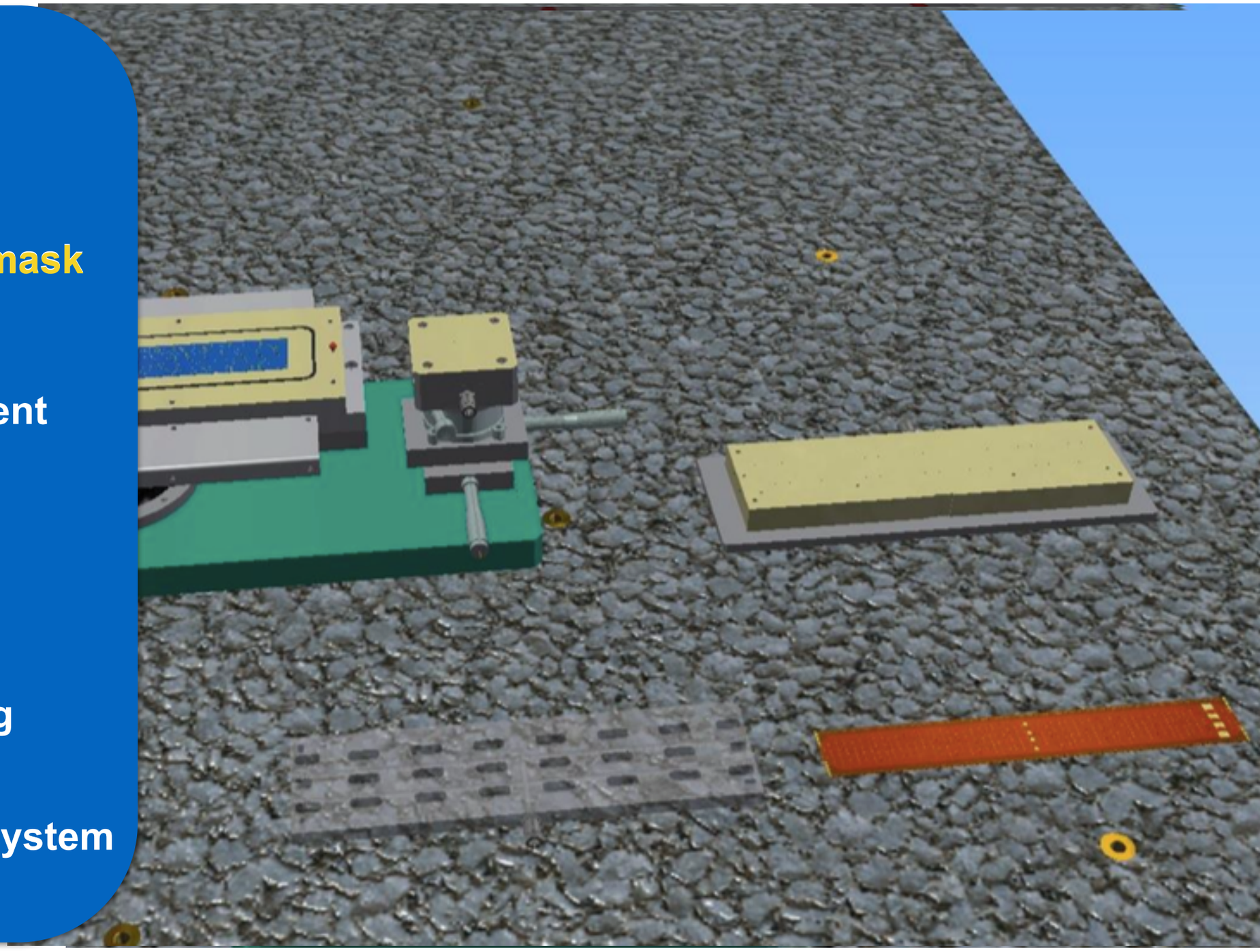
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

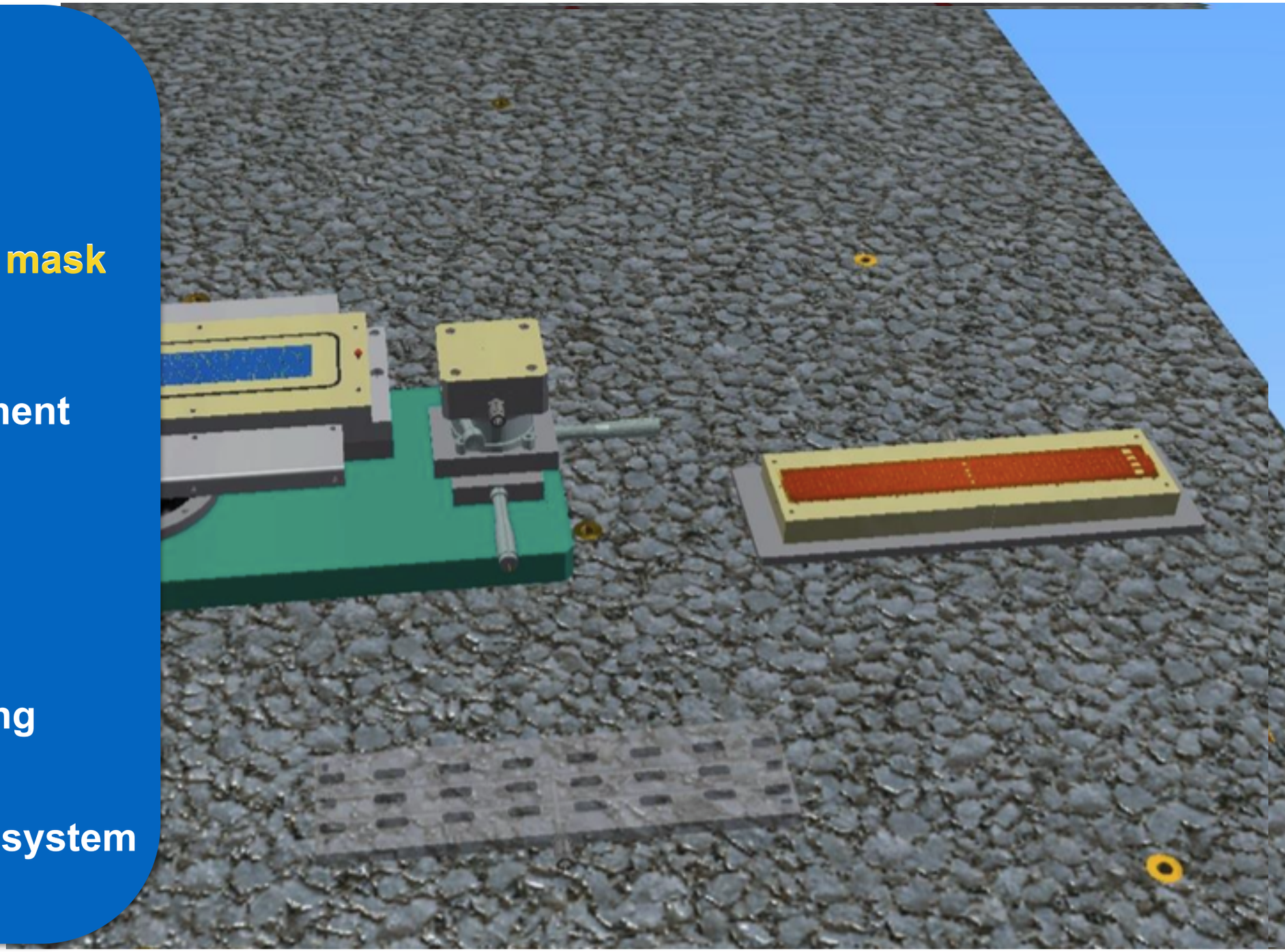
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

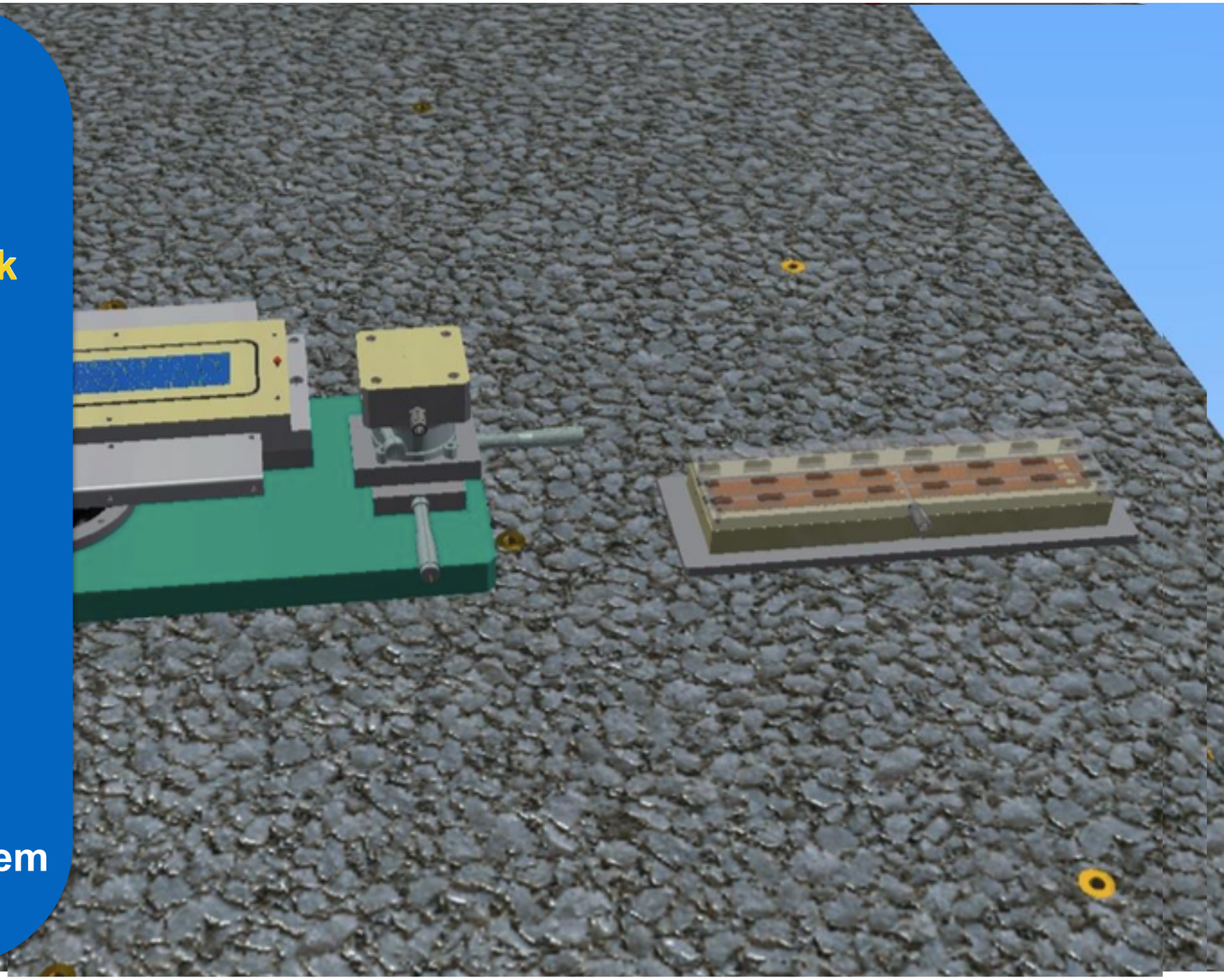
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

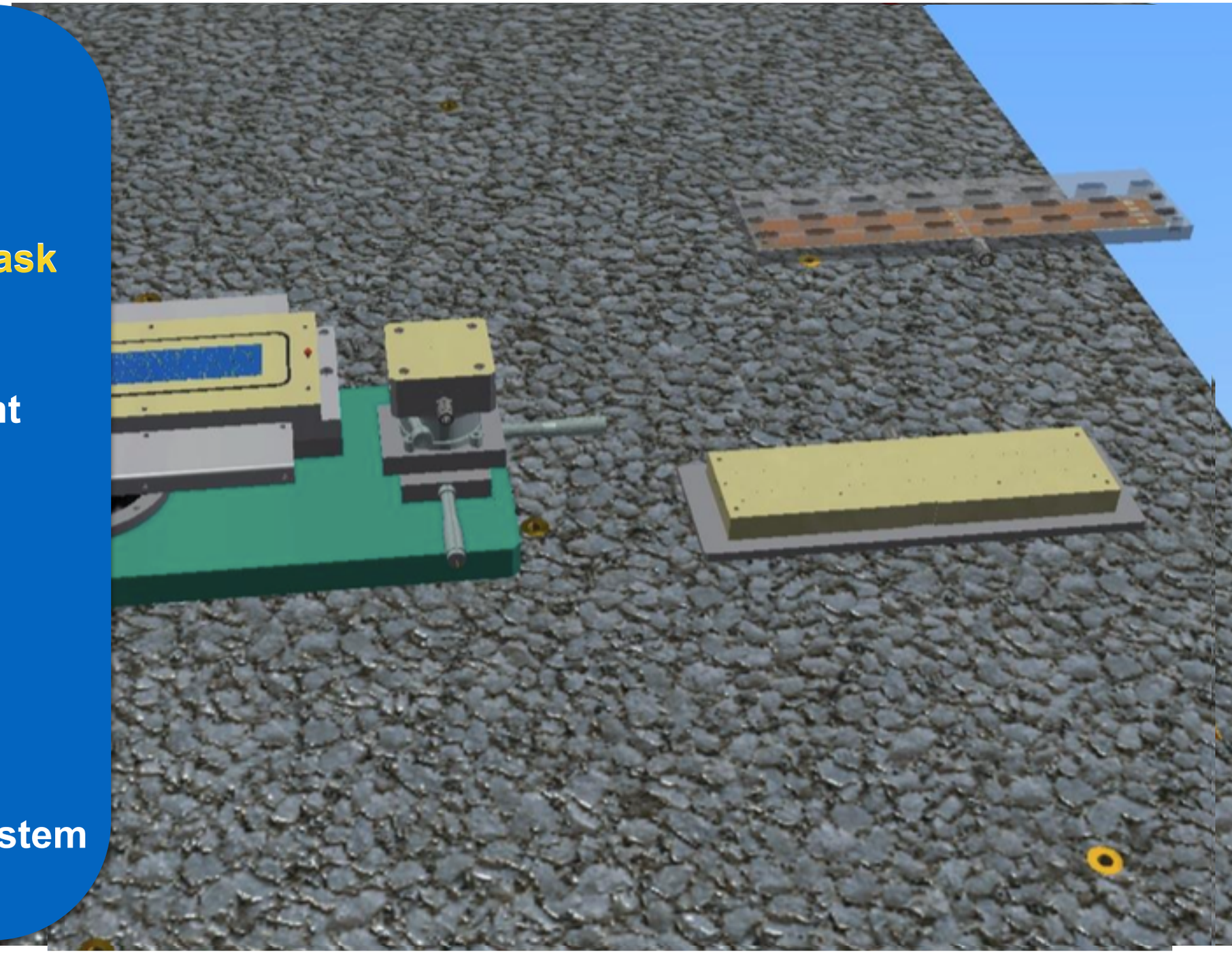
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

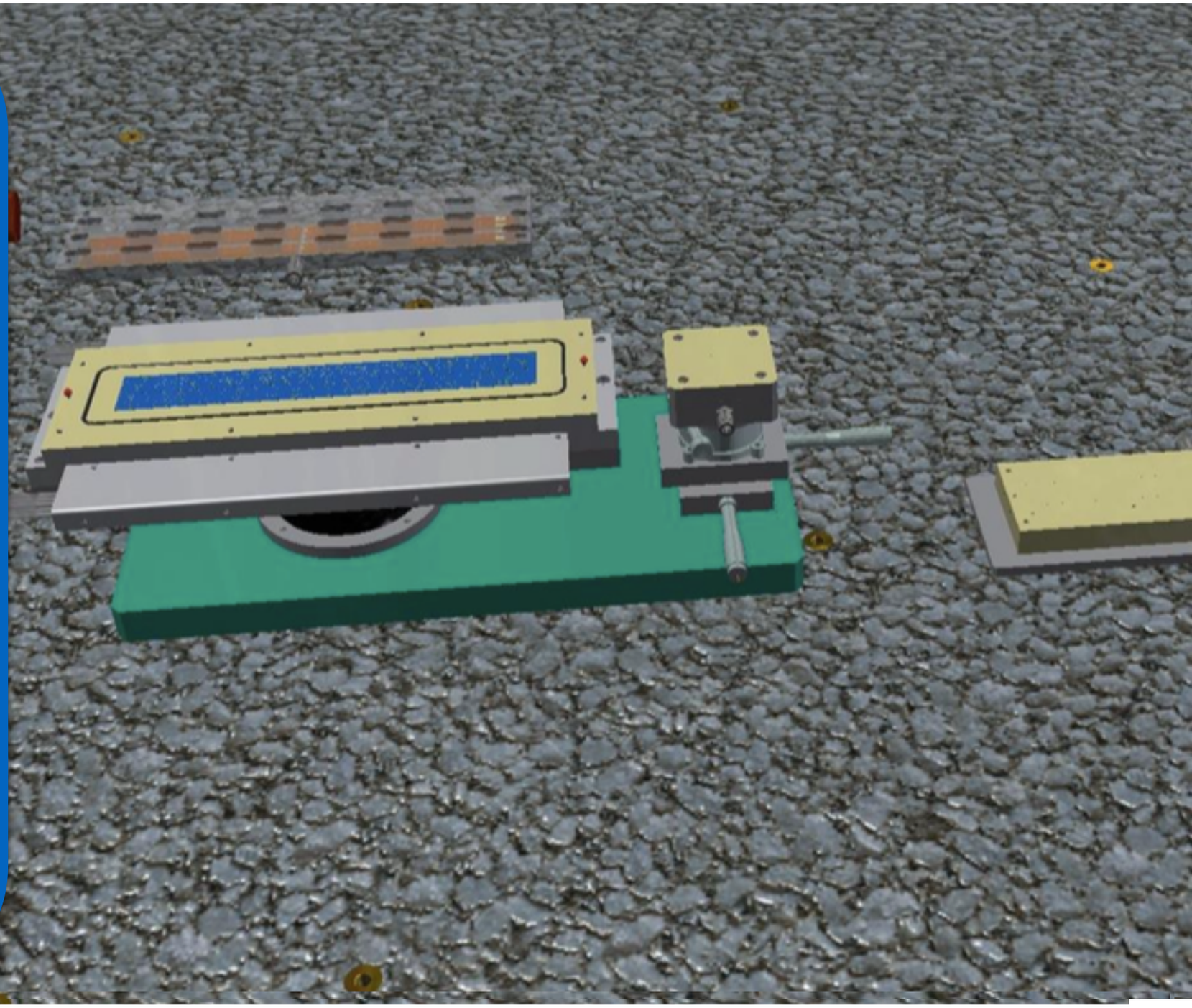
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

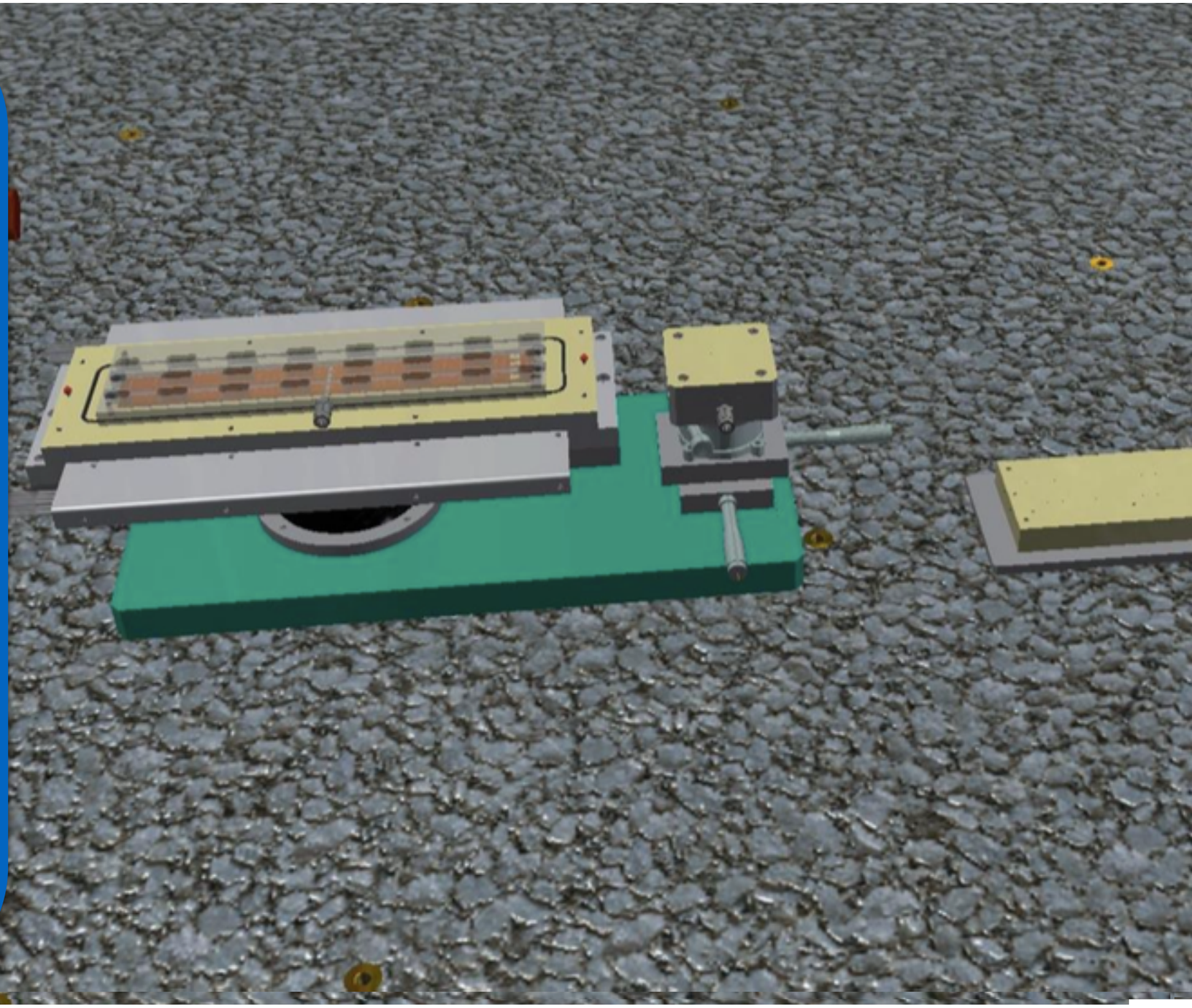
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

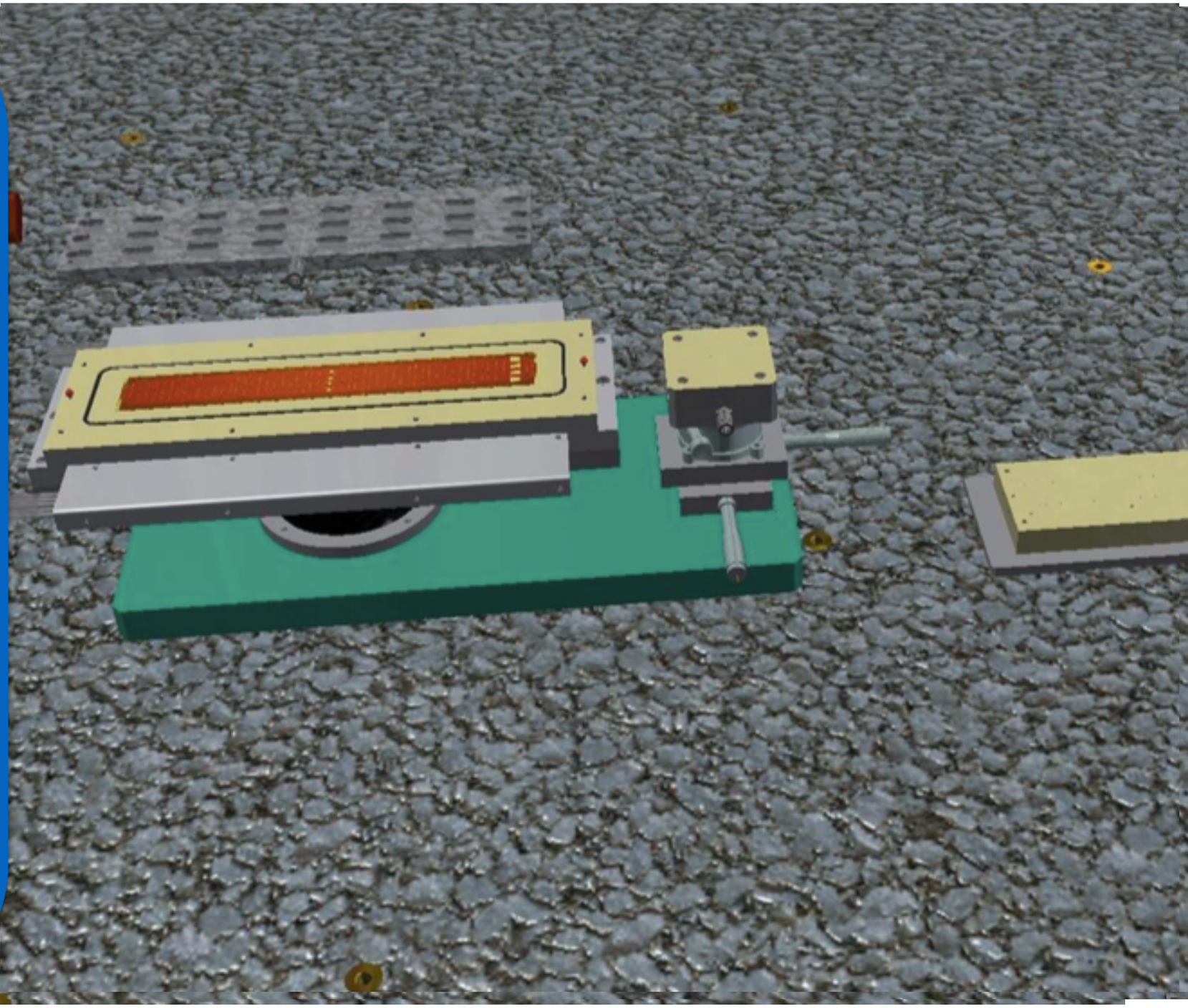
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

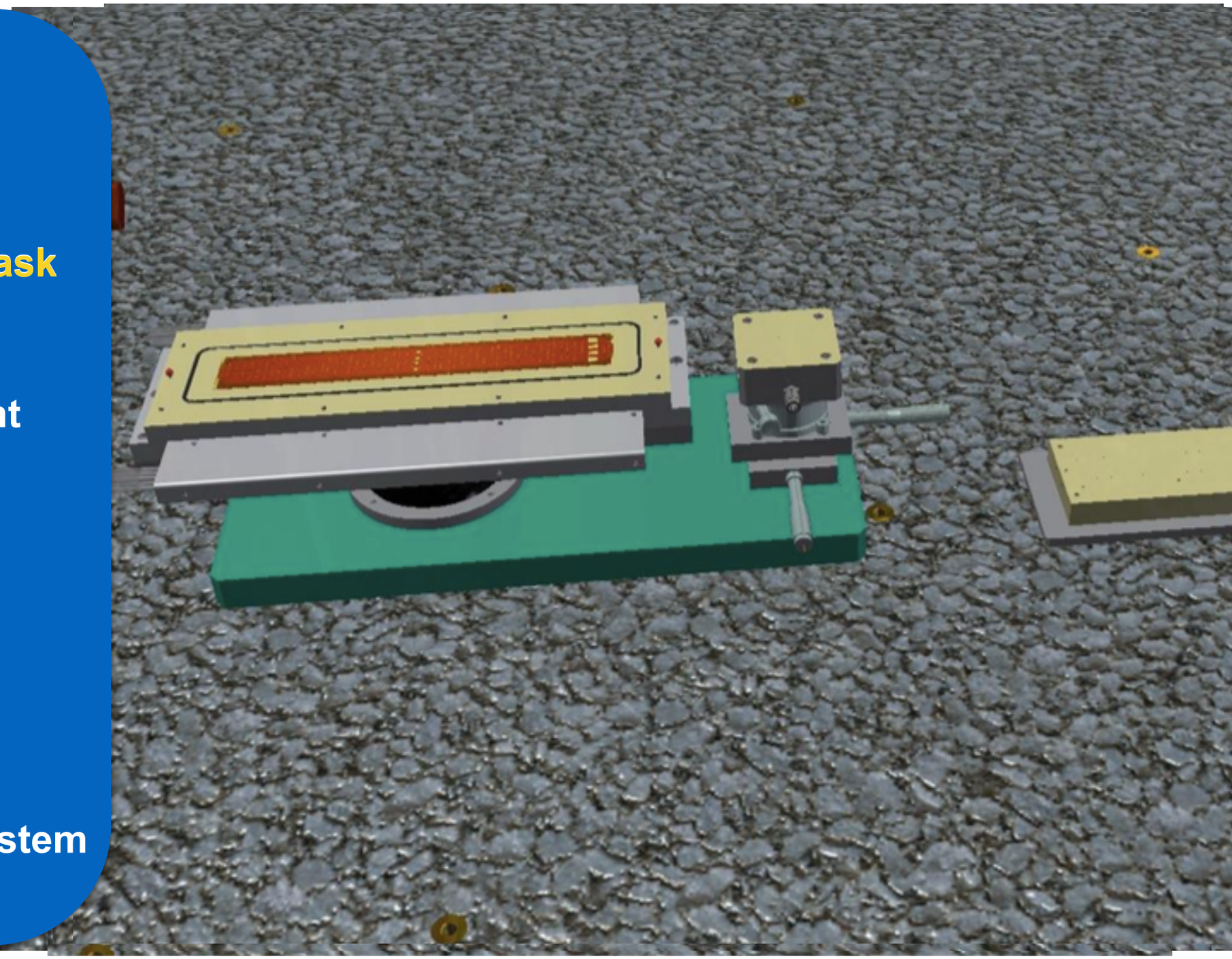
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

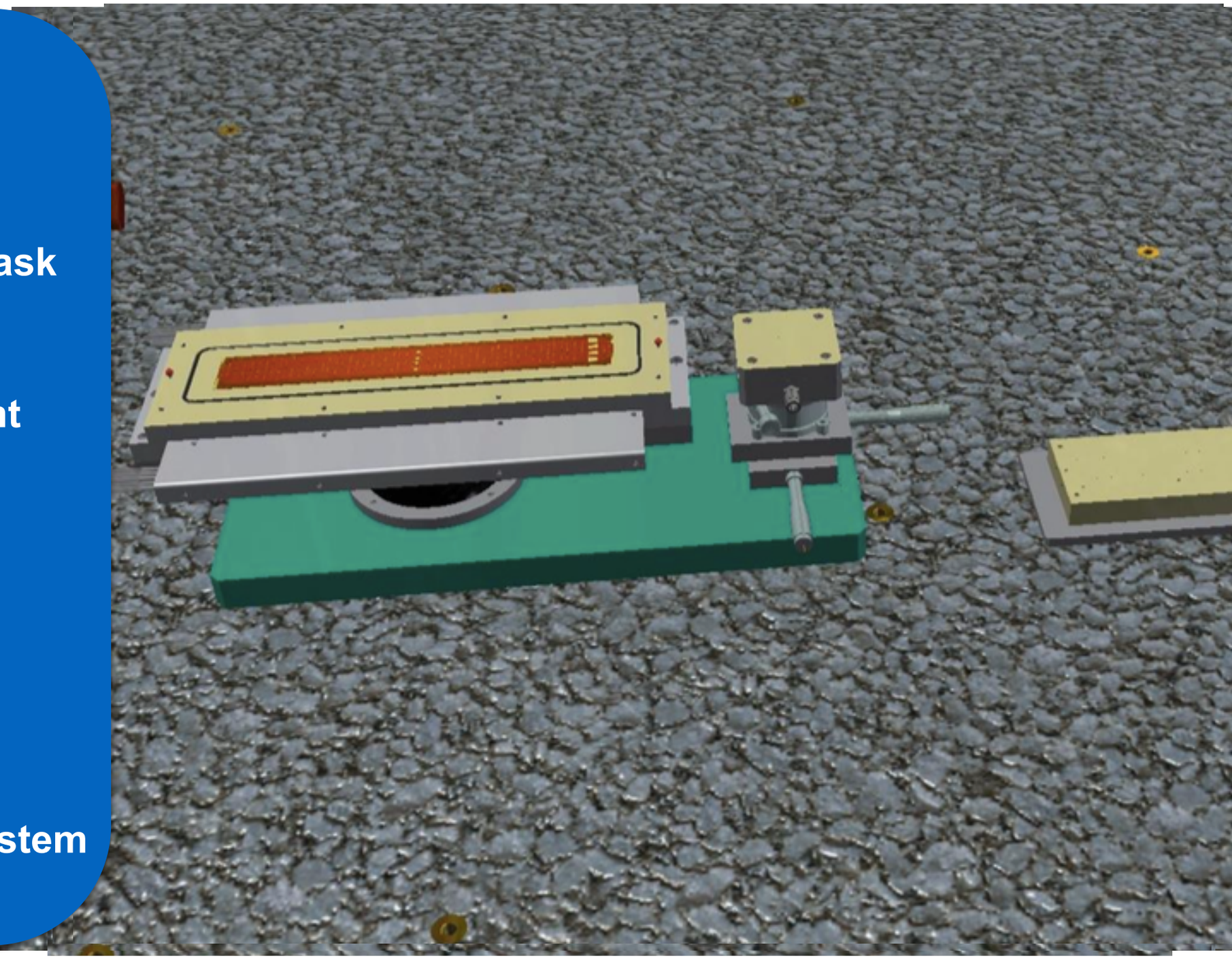
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

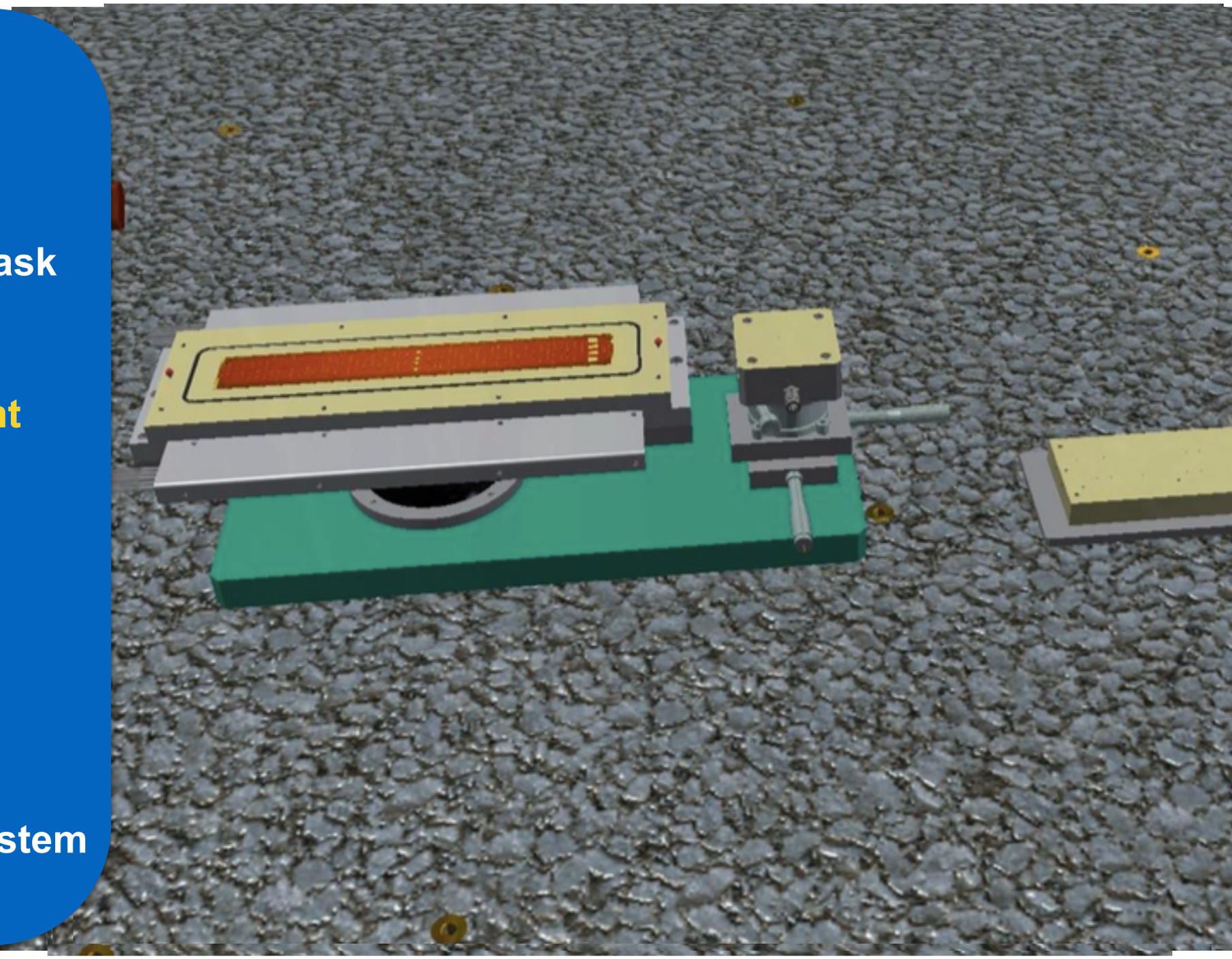
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

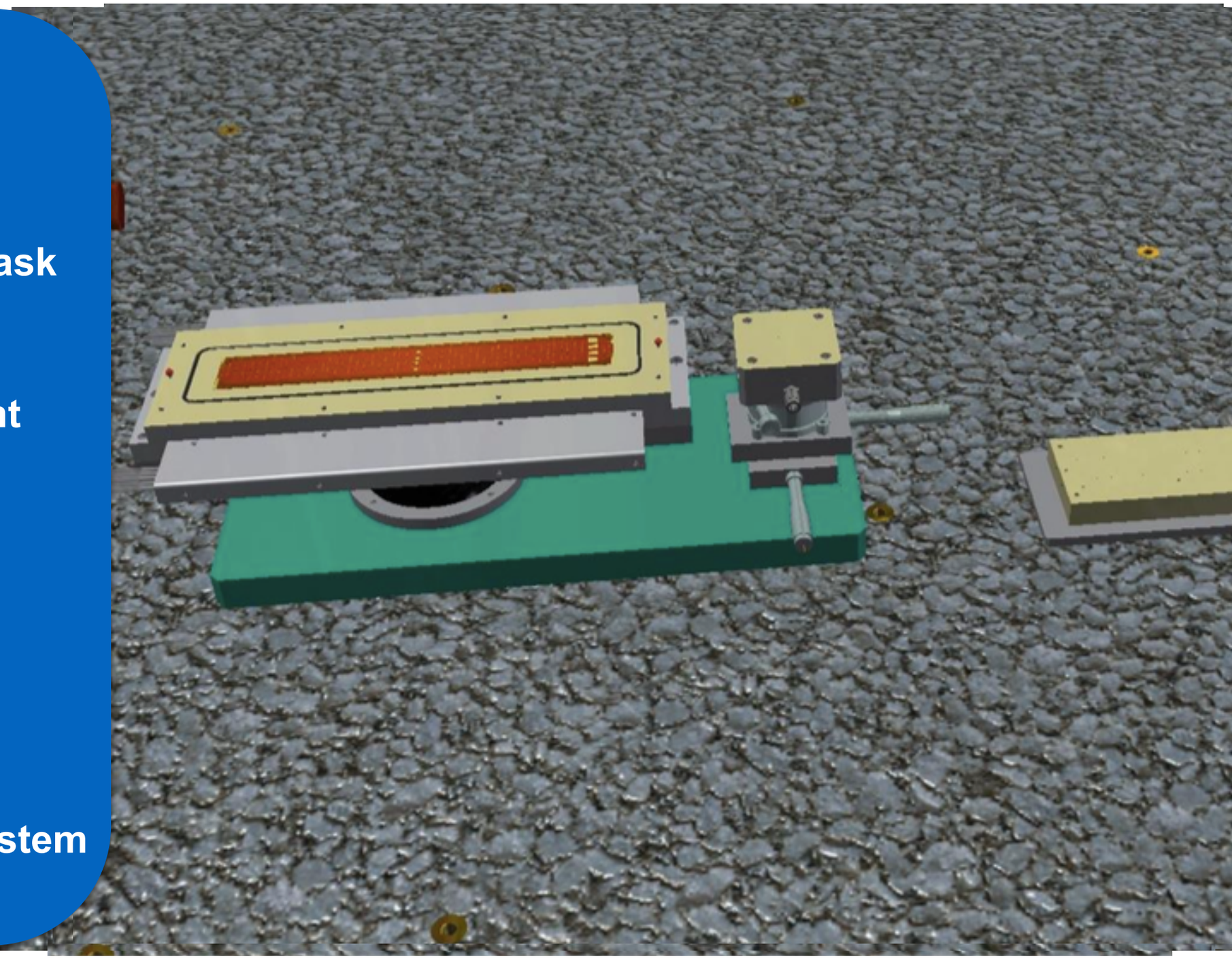
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

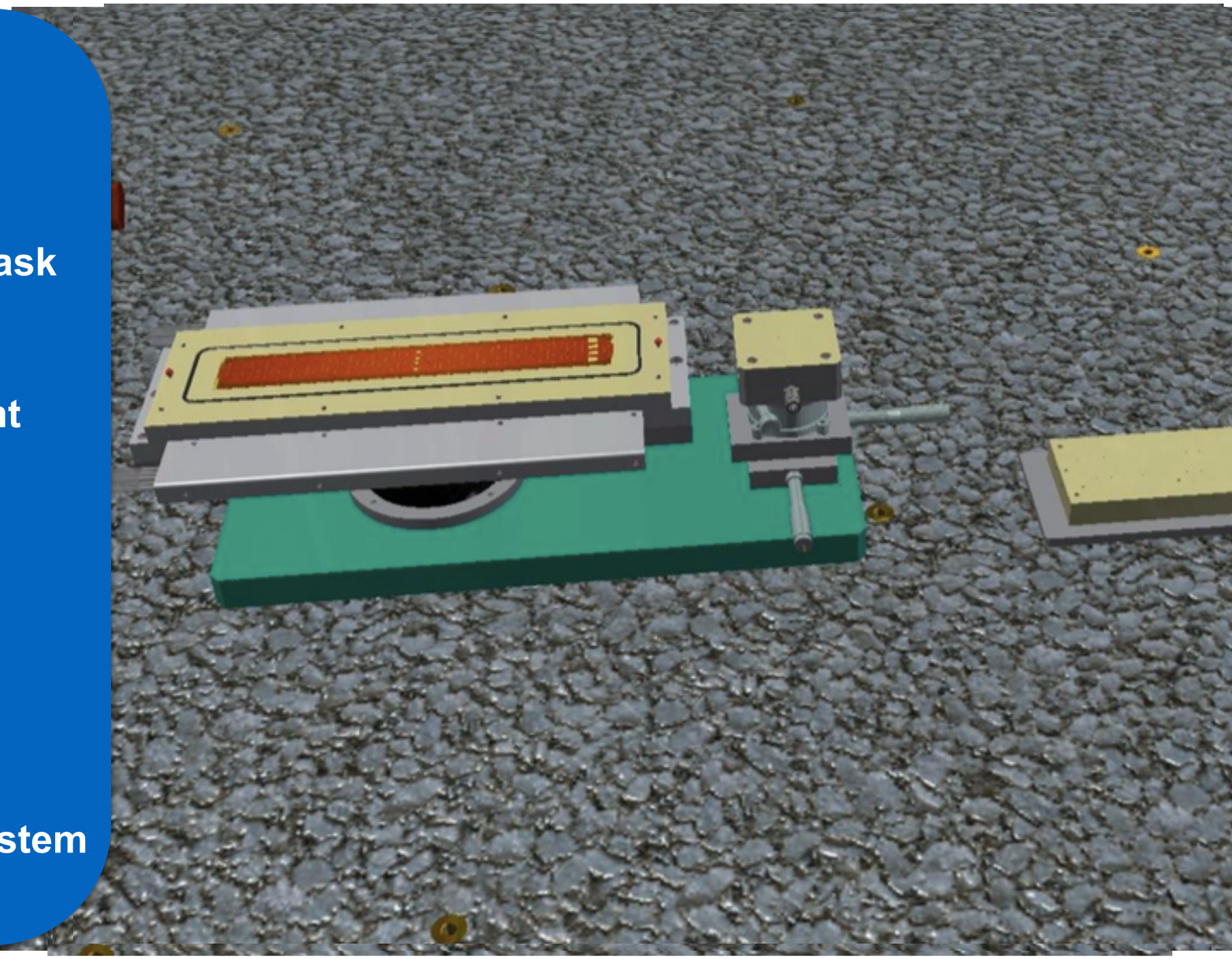
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

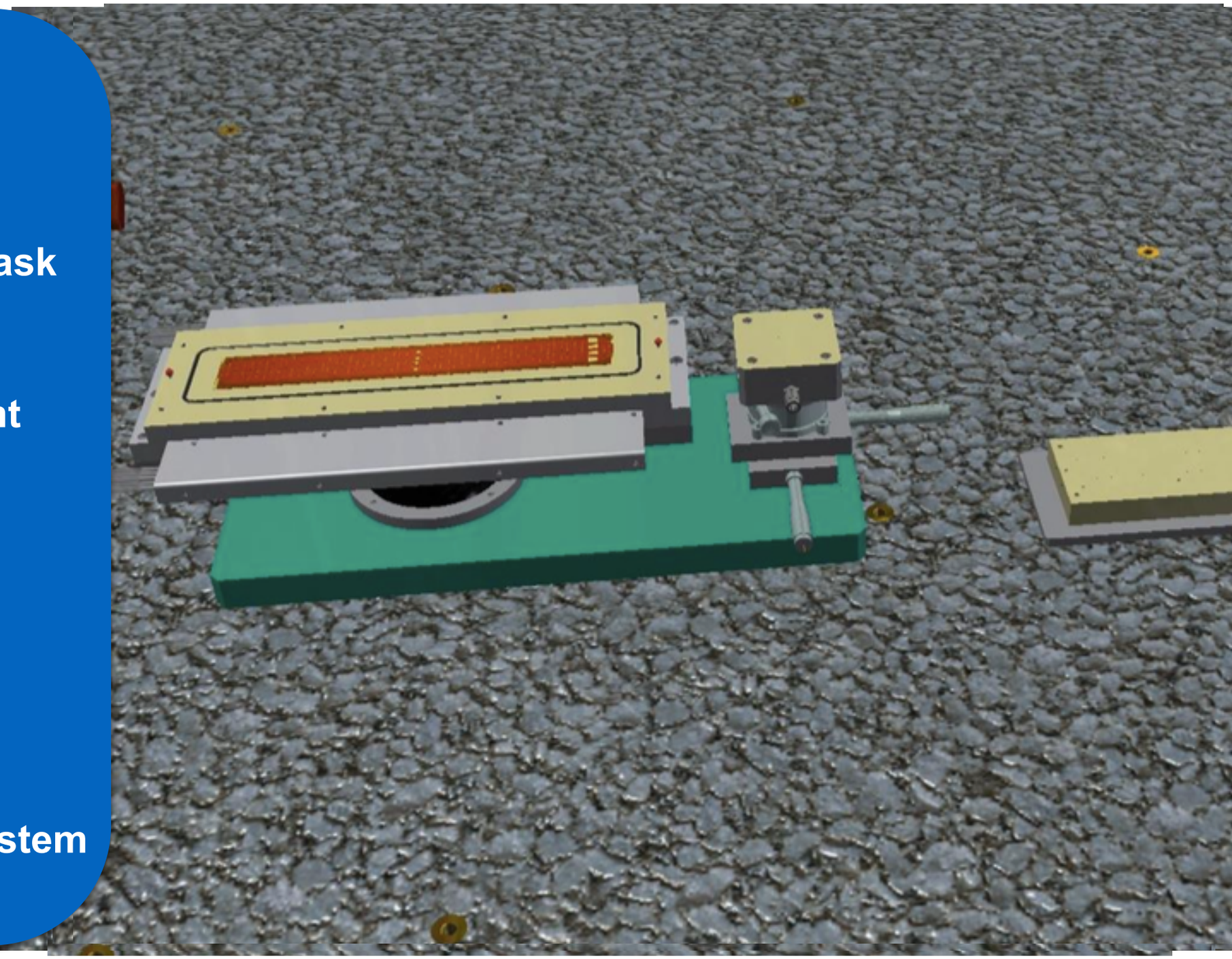
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

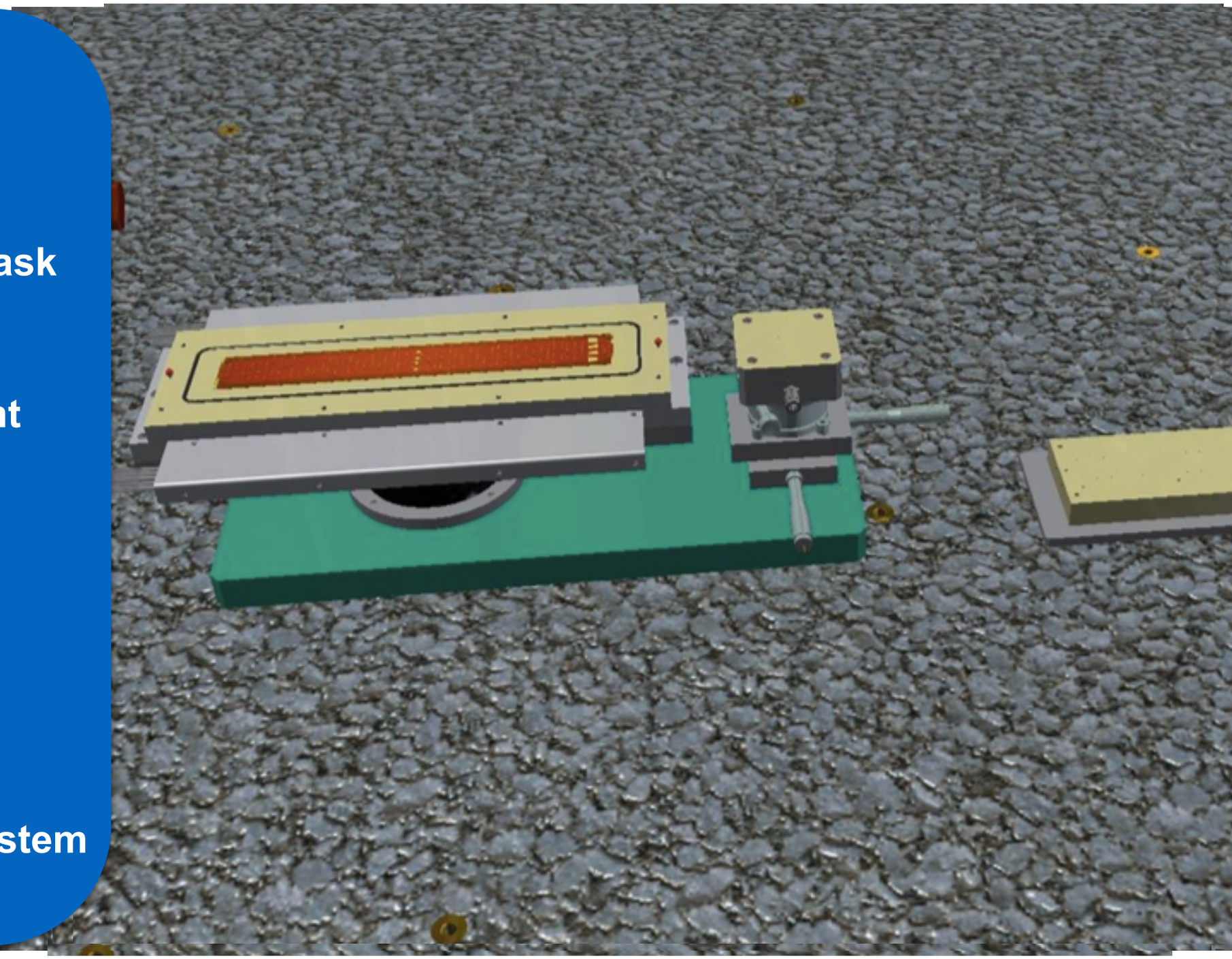
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

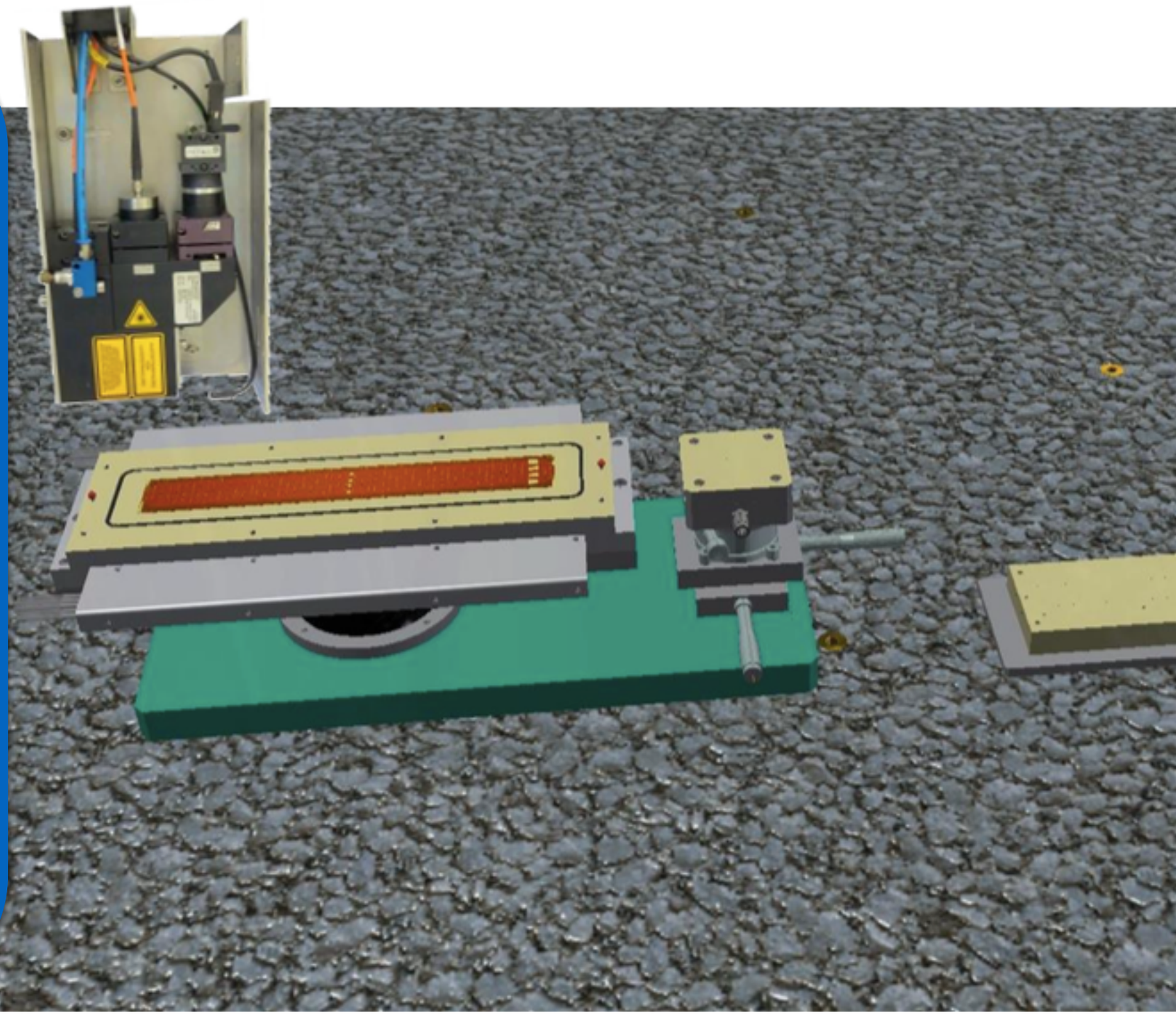
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

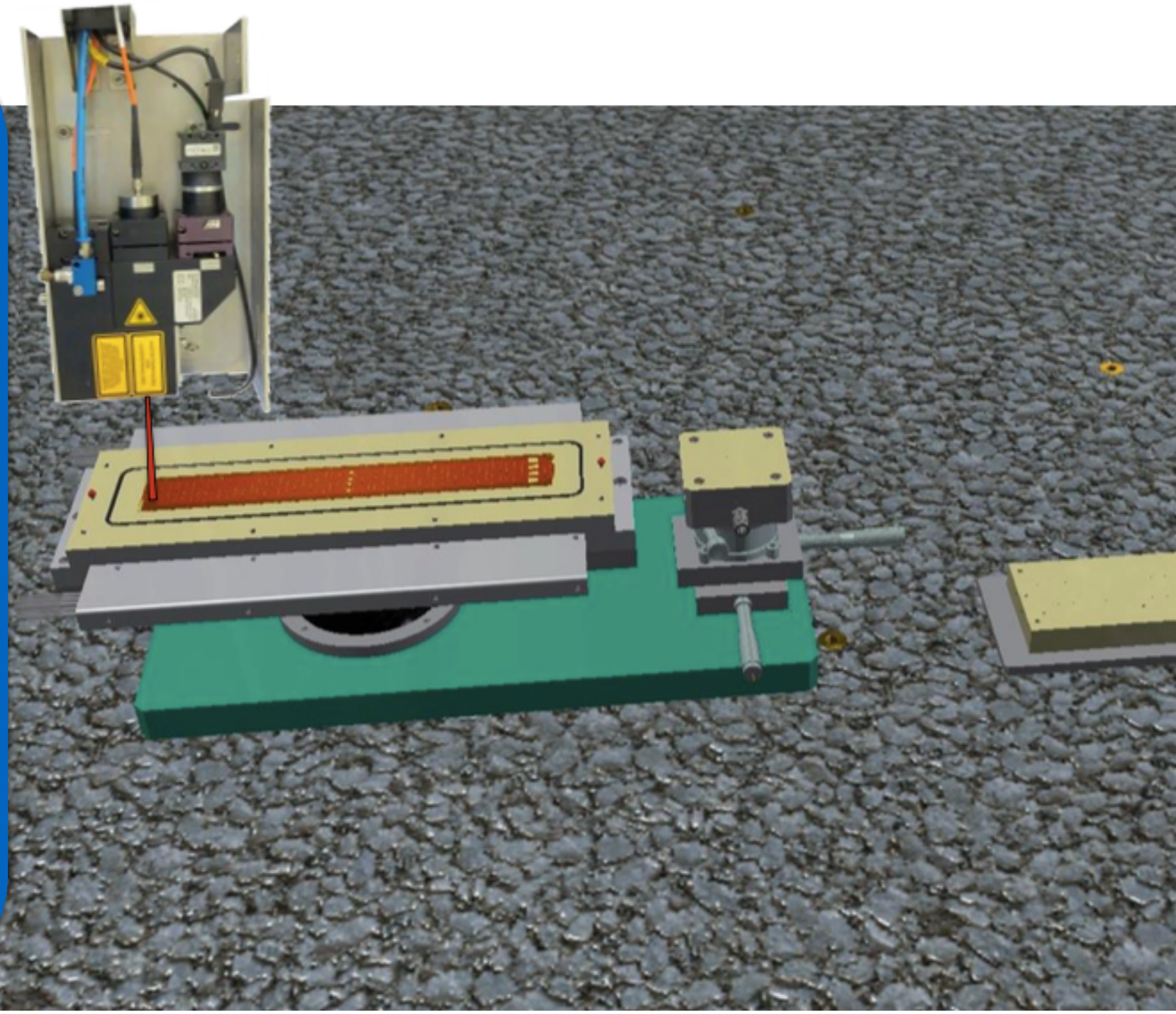
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

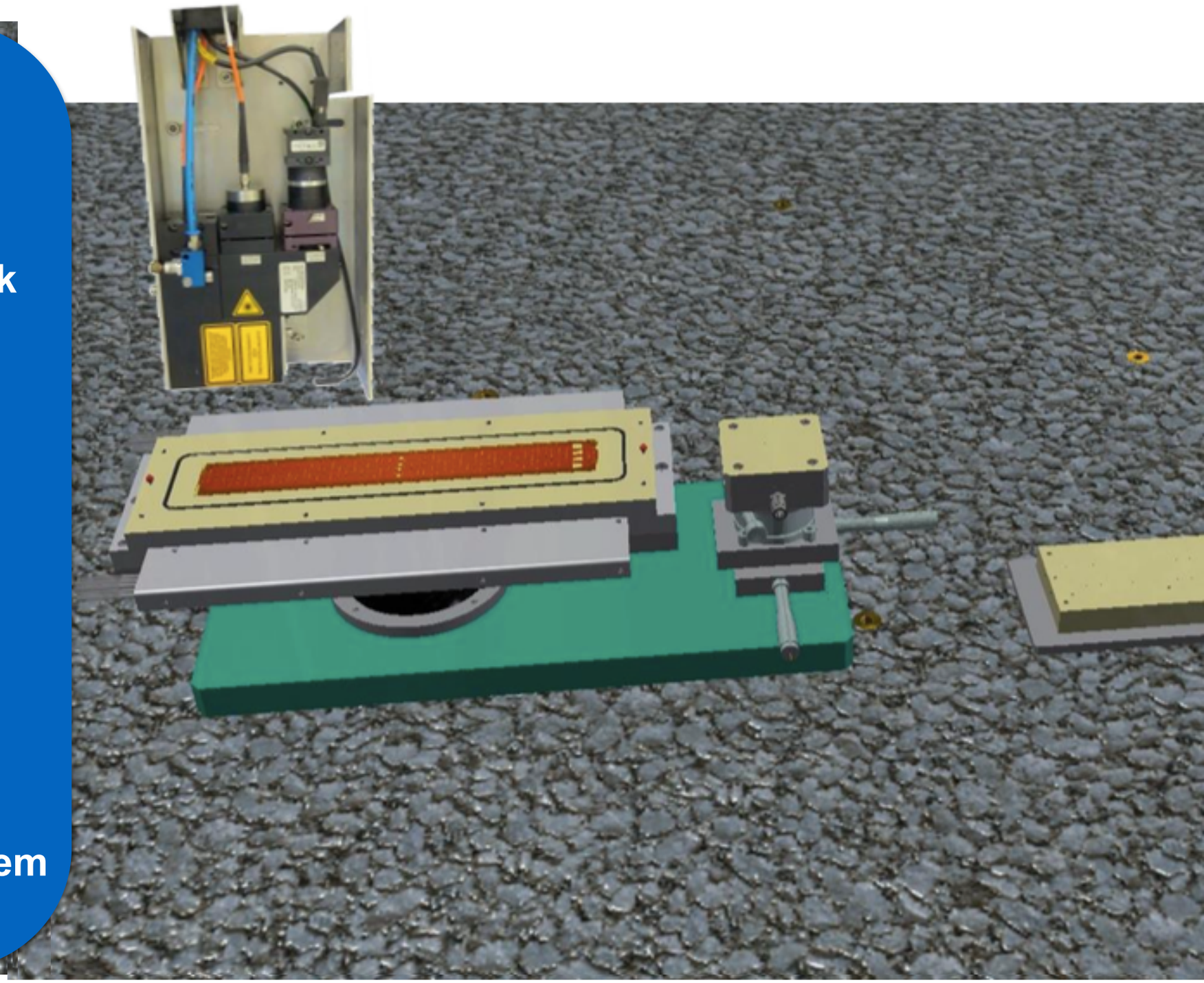
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

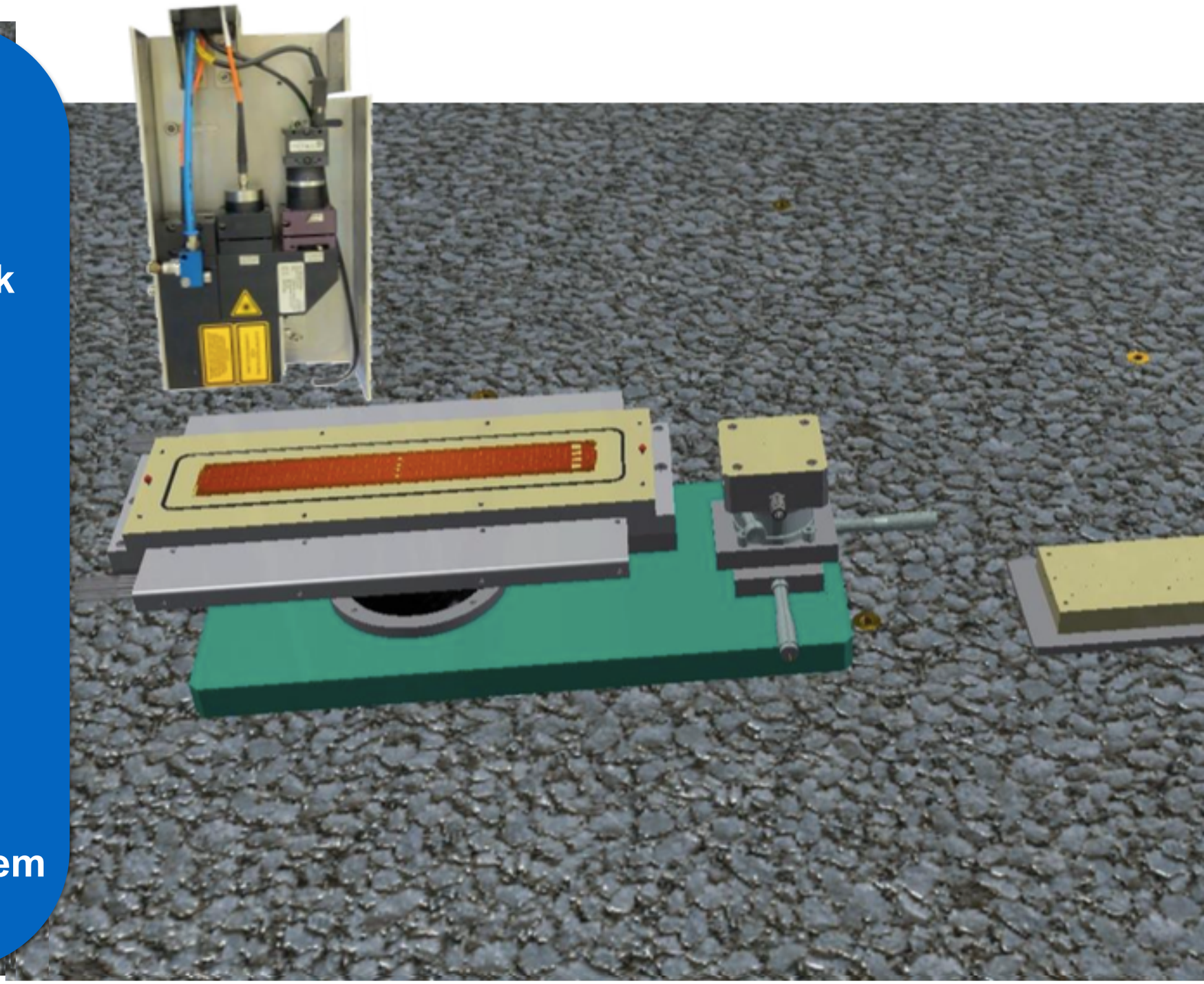
Cover the lid

↓

Start Laser Soldering

↓

Quality check by sensor system



Preliminary procedure of HIC Assembly

Chip placement

↓

Stack FPC & Soldering mask

↓

Soldering ball placement

↓

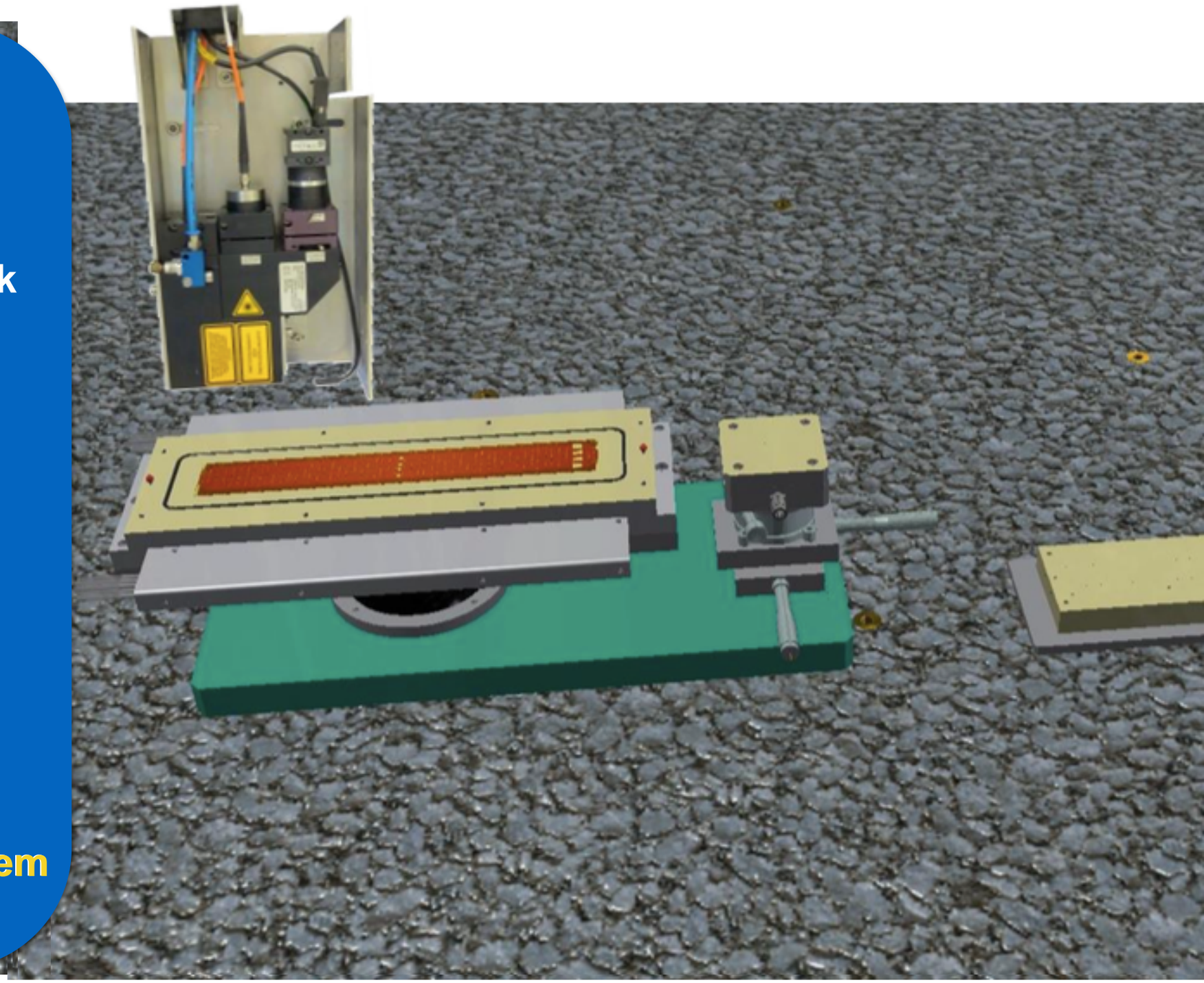
Cover the lid

↓

Start Laser Soldering

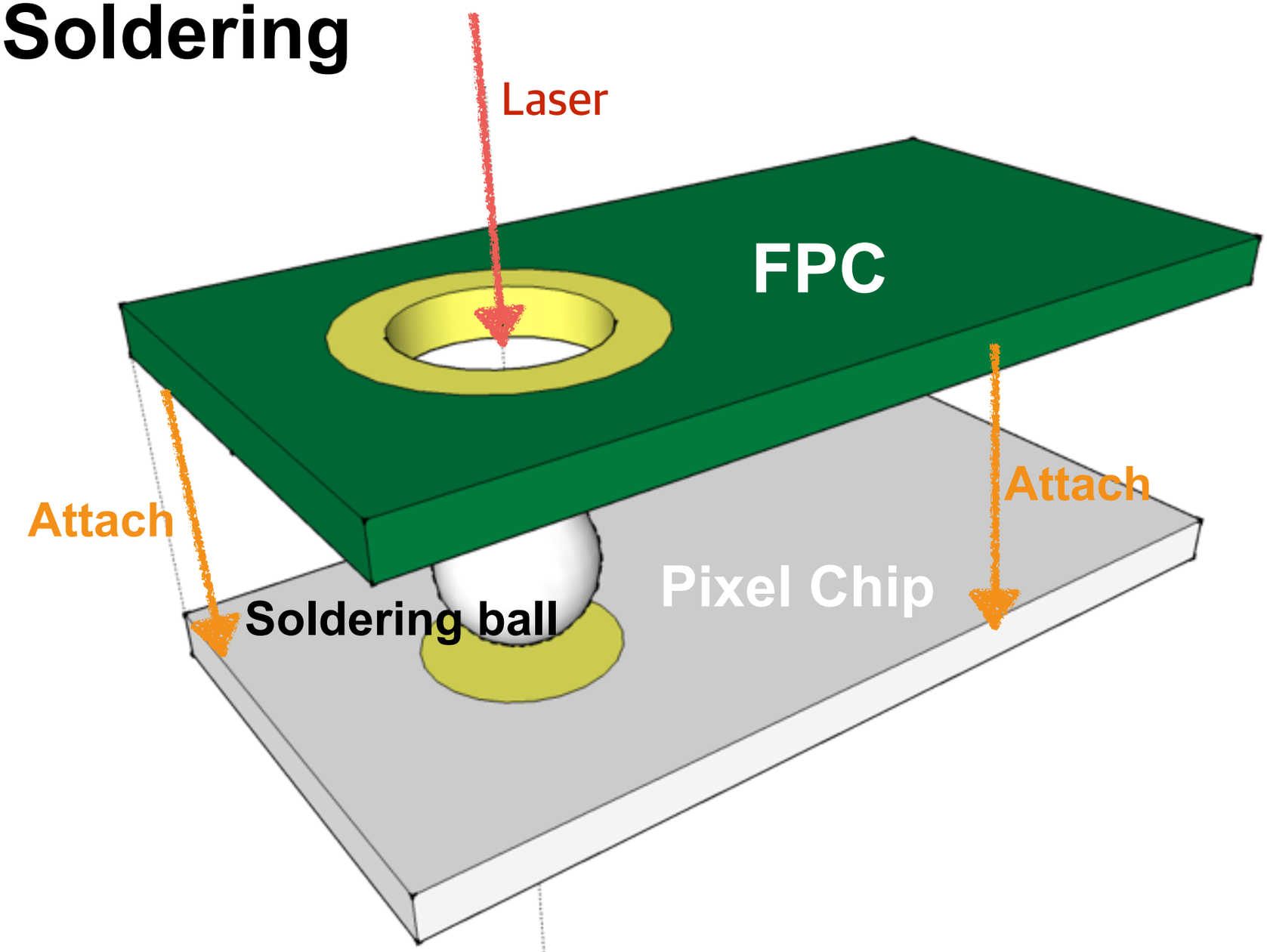
↓

Quality check by sensor system



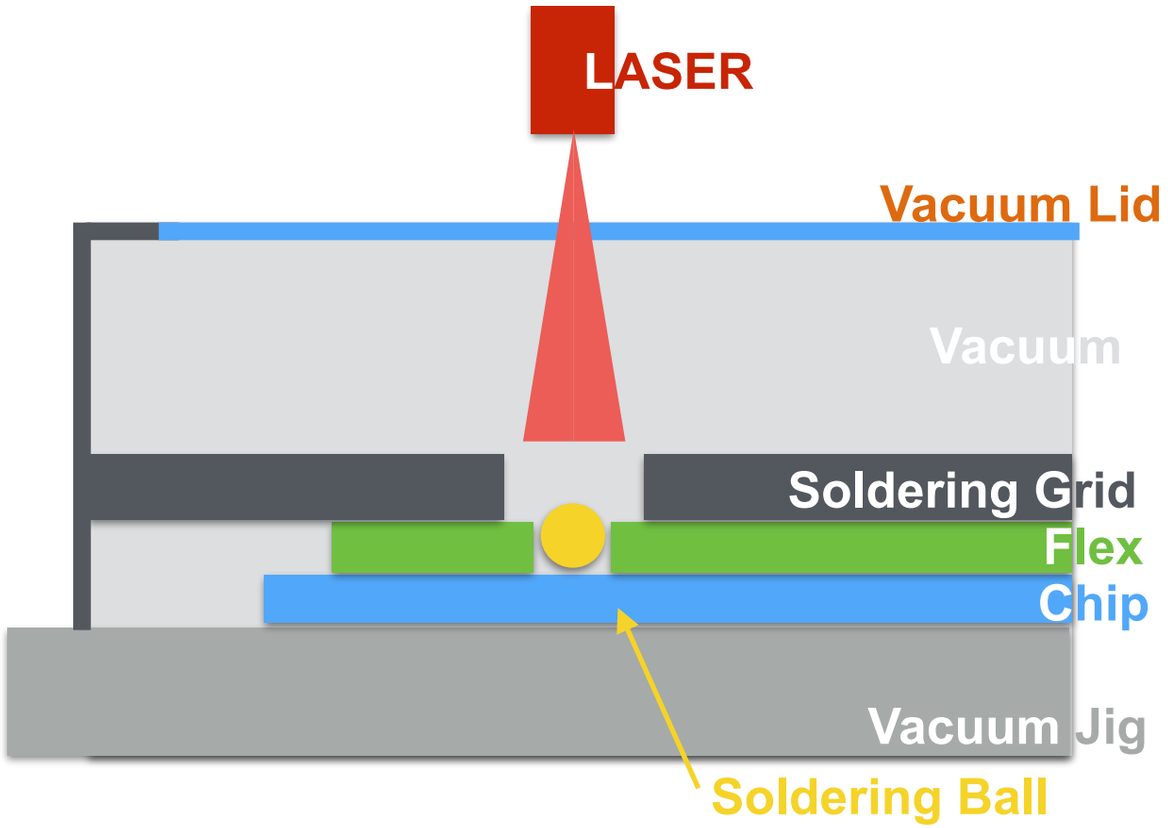
Laser Soldering for HIC Assembly

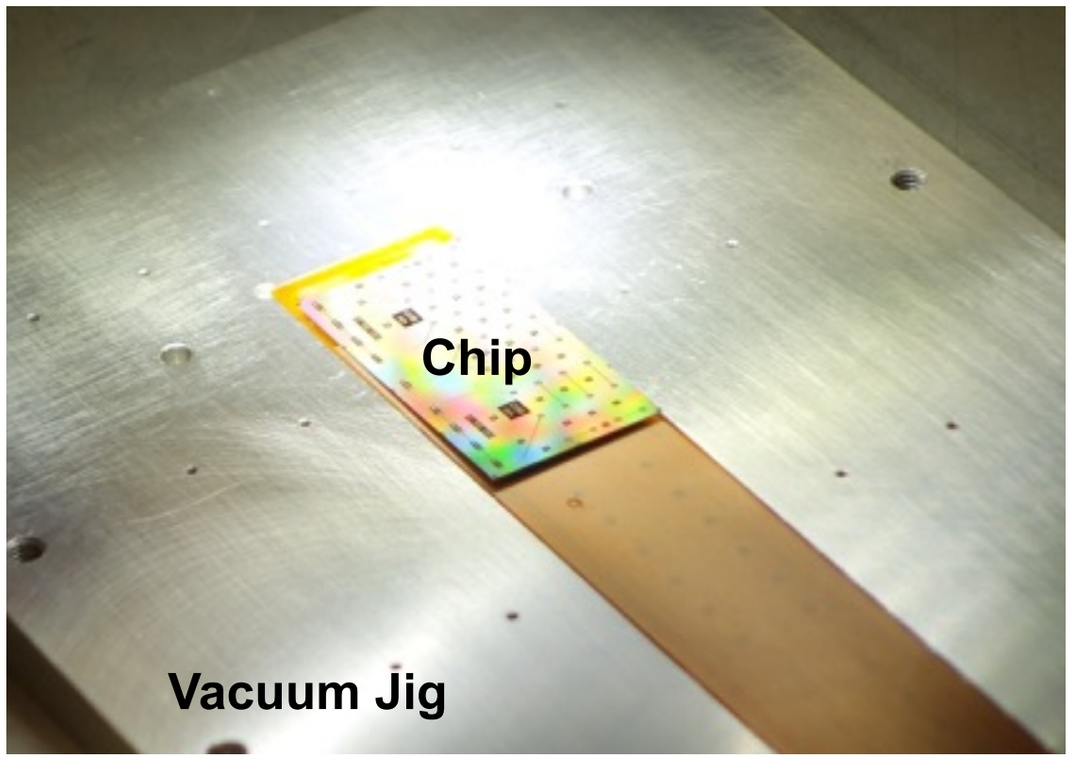
Laser Soldering



- **Pixel chips are soldered to FPC by <u>this technique</u>**
- It can avoid thermal stress on the full HIC Structure
  - The hit is only generated in the small local area of the size of connection pad

Procedure of Laser Soldering in R&D

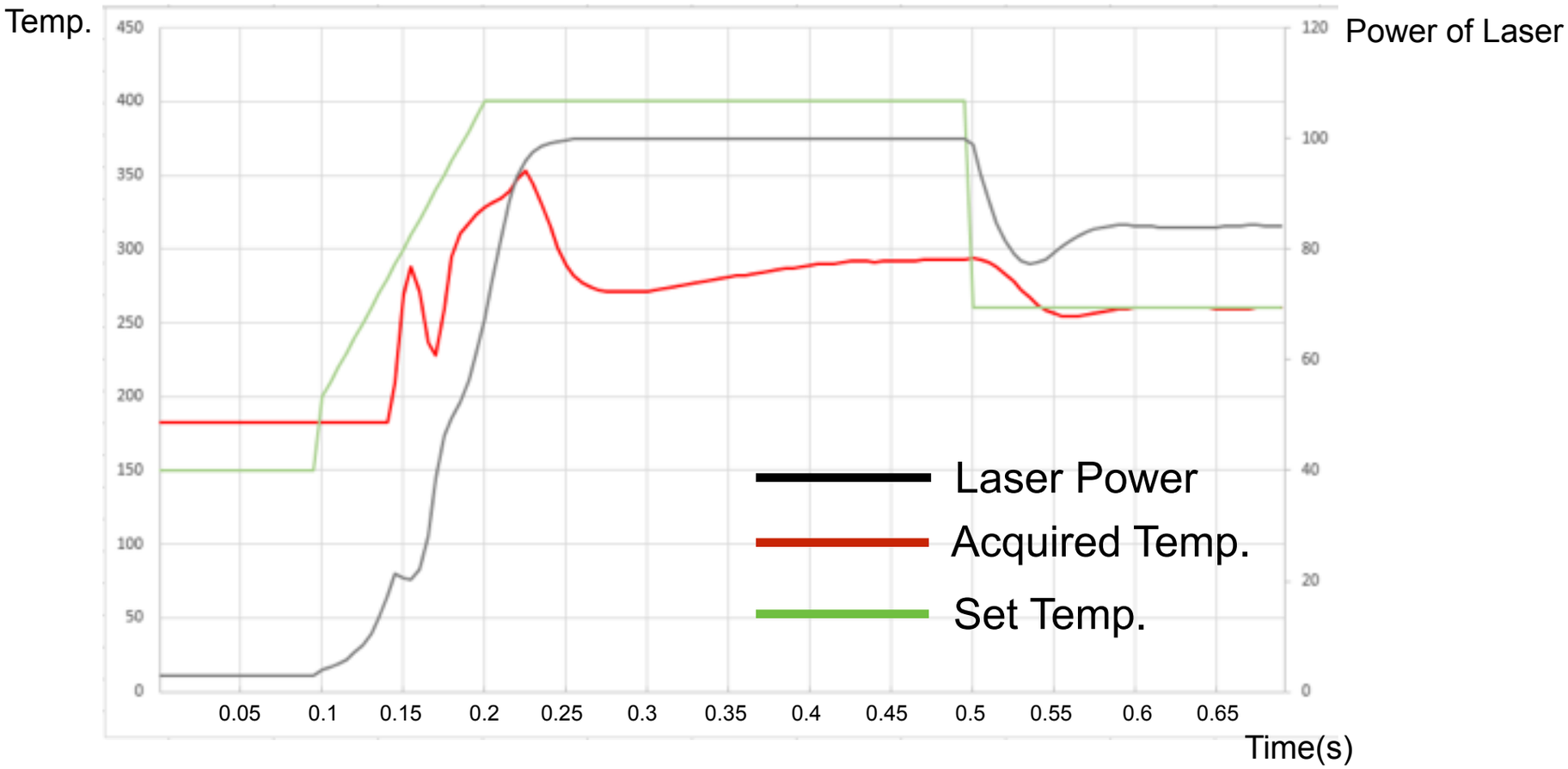




in real image

1. Stack & Align the **Chip**, **Flex** and **Soldering grid** on the **Vacuum Jig**.
2. Put the **Soldering ball** into the hole of **Soldering Grid**
3. Cover the **Vacuum Lid** and Make the vacuum inside.
4. Start **Laser Soldering** with using **Laser Profile**

Laser Profile



- **Laser Power is controlled by temperature set.**
  - If Acquired Temperature (Surface Temp.) under Set Temp., Laser Power increasing
- Acquired temperature contains information of soldering process
- Optimal setting of Laser Profile should be found

Laser Soldering Data

1. **Soldering Video:**

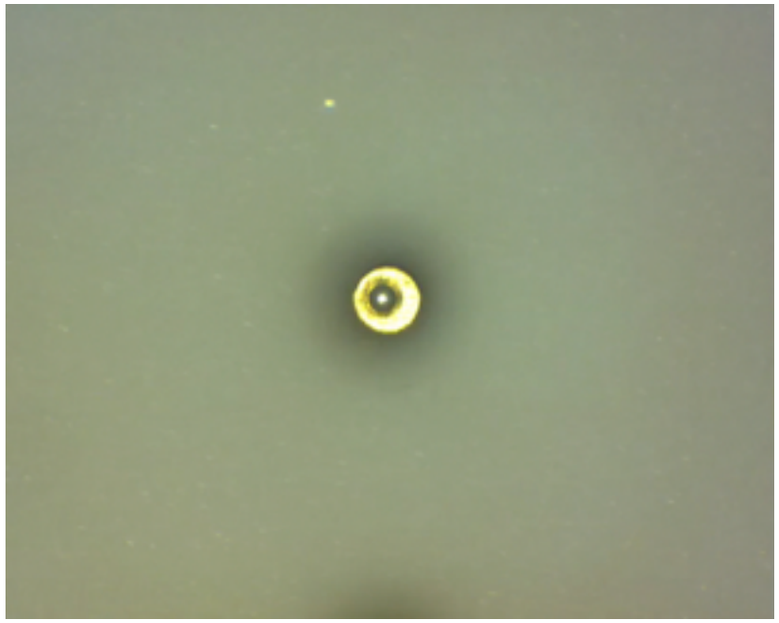
   ~ check the change of appearance at soldering point

2. **Measured Laser Power · Temperature:**

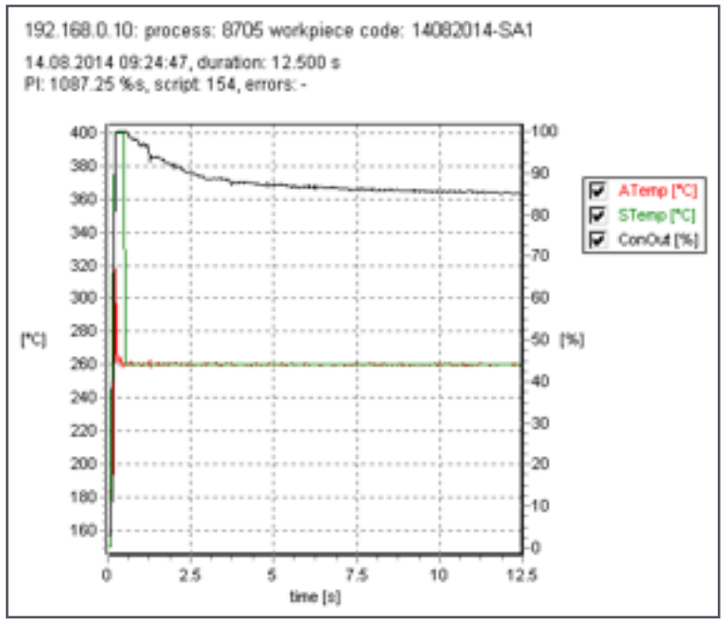
   ~ measure the laser power and surface temperature during the soldering process

3. **Cross-Section Picture:**

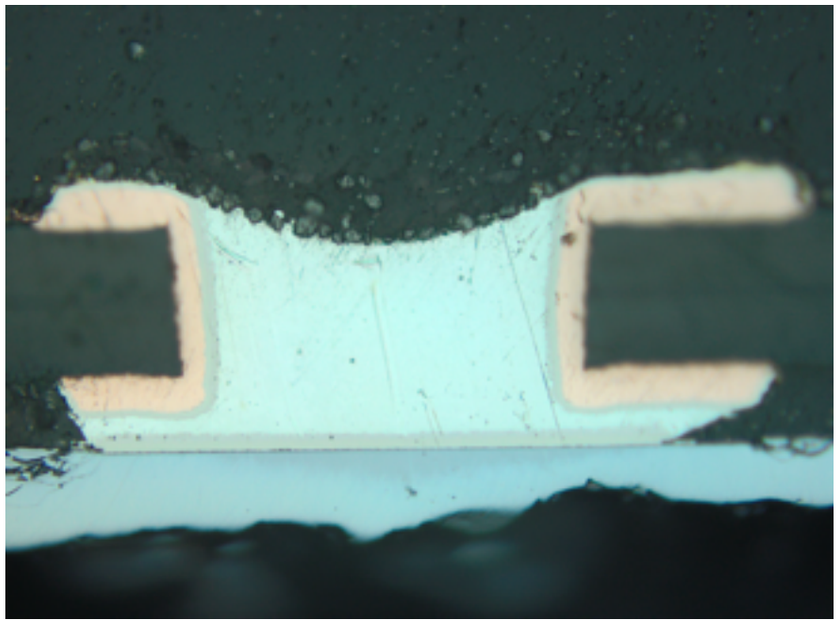
   ~ check the condition of soldering point by cutting the sample



Soldering Video



Measured Laser Power&Temprature



Cross-Section Picture

Laser Soldering Data

1. **Soldering Video:**

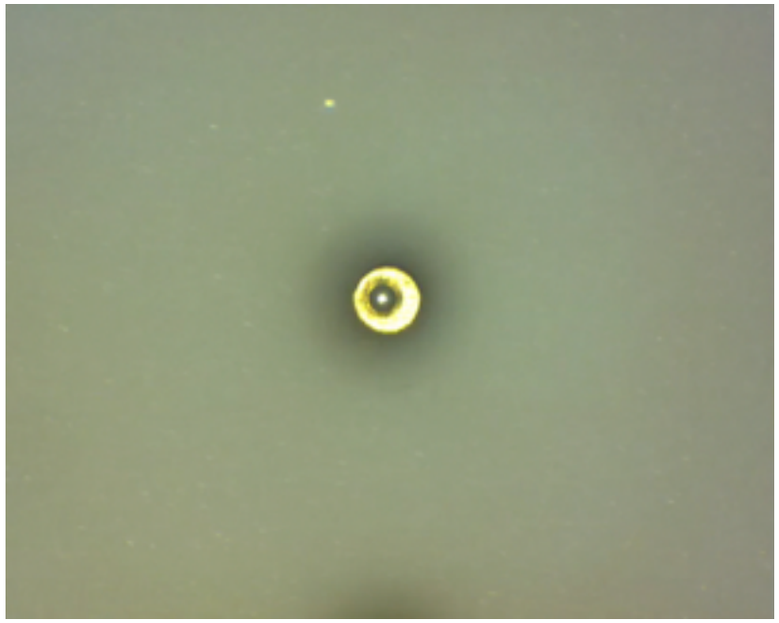
   ~ check the change of appearance at soldering point

2. **Measured Laser Power · Temperature:**

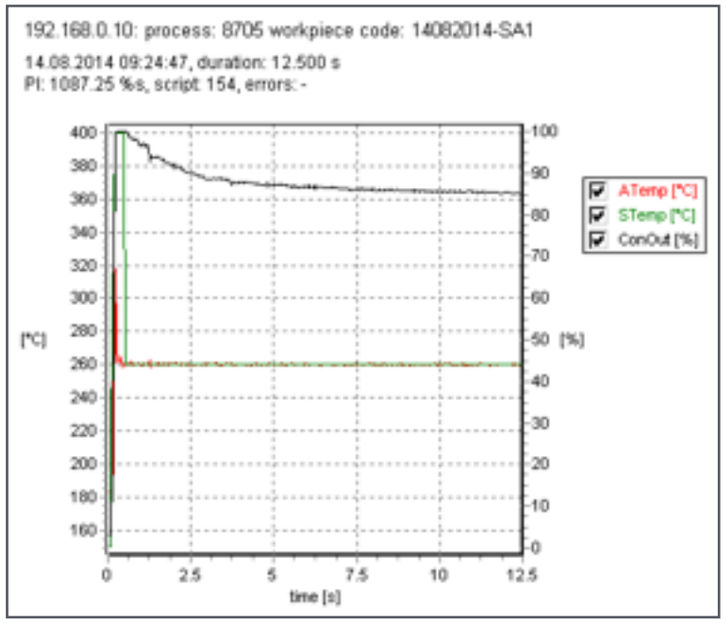
   ~ measure the laser power and surface temperature during the soldering process

3. **Cross-Section Picture:**

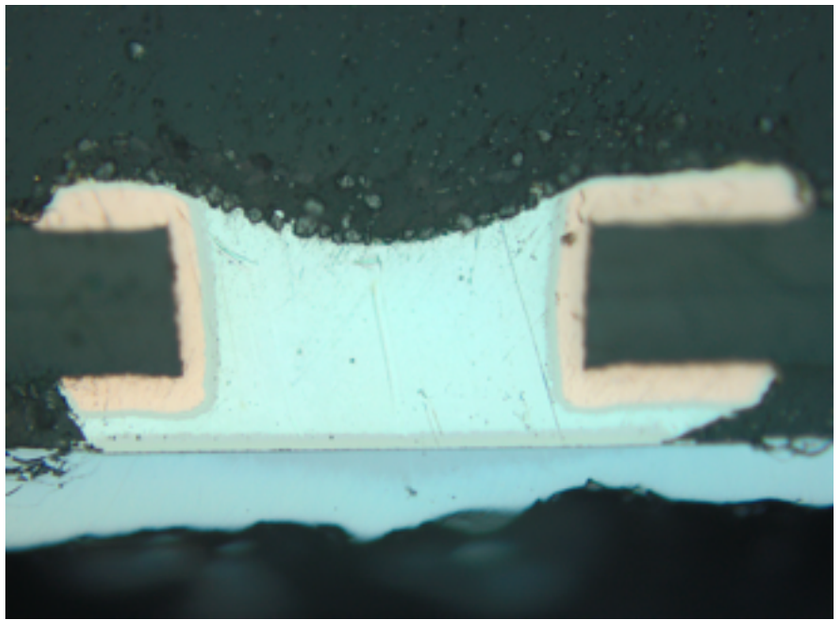
   ~ check the condition of soldering point by cutting the sample



Soldering Video



Measured Laser Power&Temprature



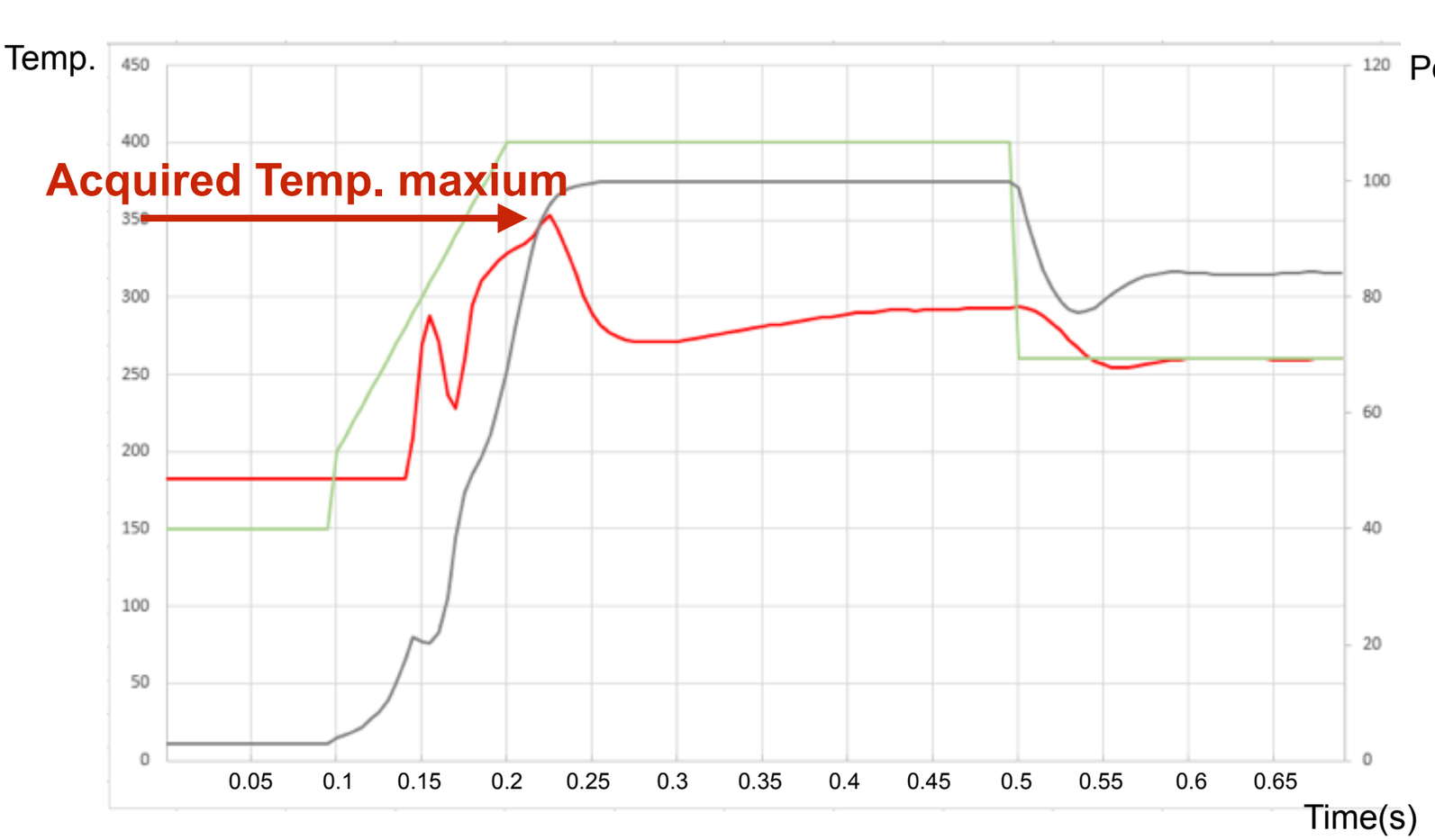
Cross-Section Picture

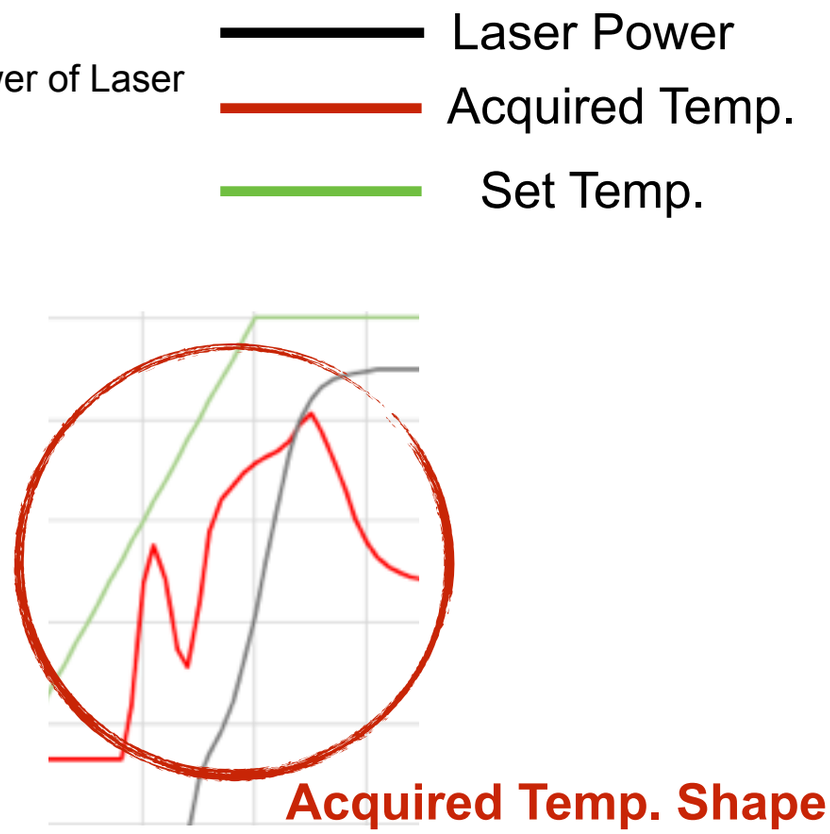
Data analysis of Laser Soldering

- **Goal**
  - Quality Assurance of Laser Soldering Quality with non-destructive method.
  - Find optimal Laser Soldering Profile
- **Available method**
  - Check Laser Profile
    ~ Laser Power, Acquired Temperature during soldering
  - Categorize connection shape from Soldering video
  - And more..

Available method #1: Laser Profile

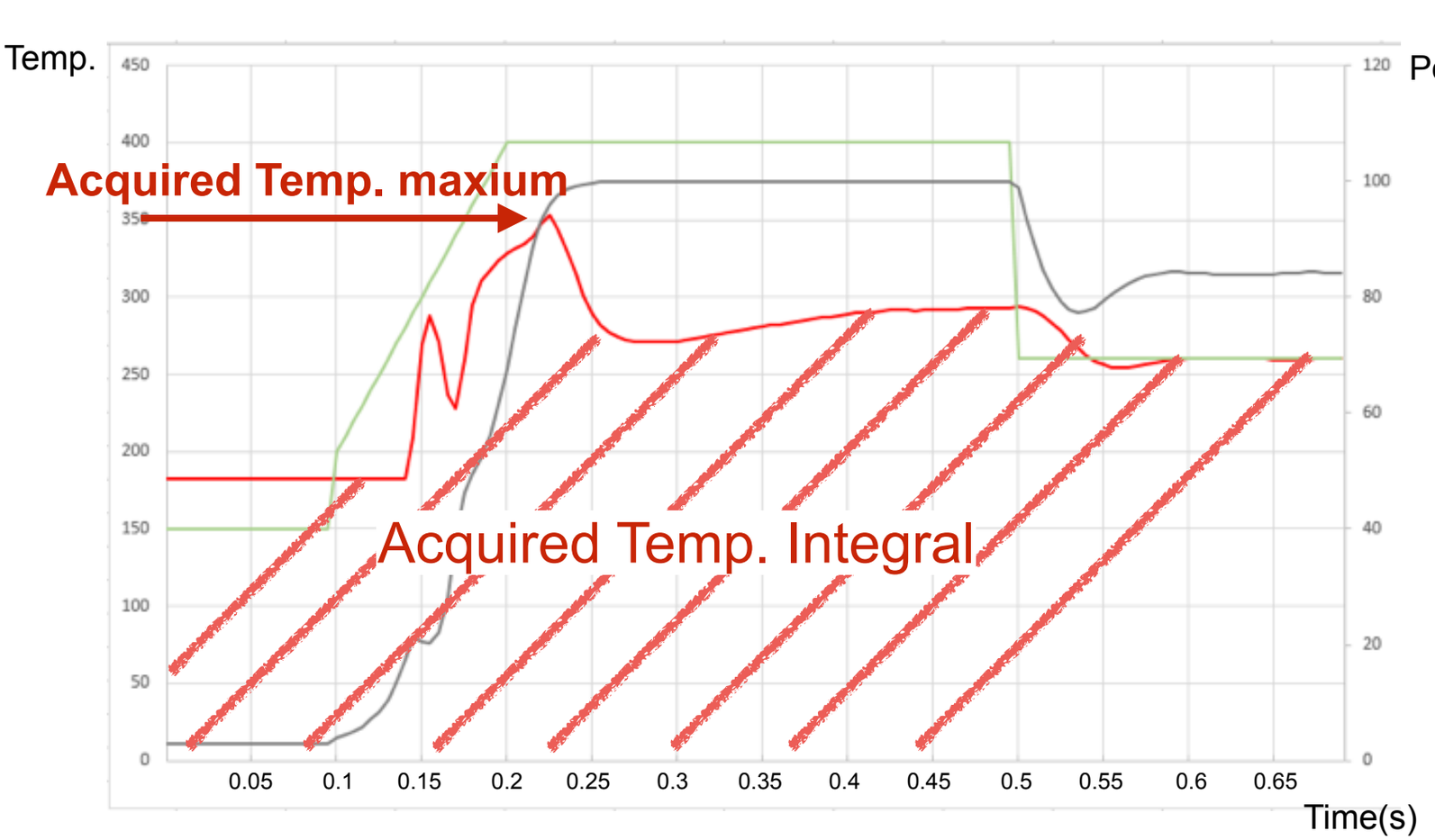
- **Check Acquired Temperature**
  - This value is directly related in real soldering condition
  - Laser Power is controlled by combination of Setted Temp. and Acquired Temp.
  - Acquired Temp. Maxium
  - Acquired Temp. Integration
  - Acquired Temp. Shape(on going)

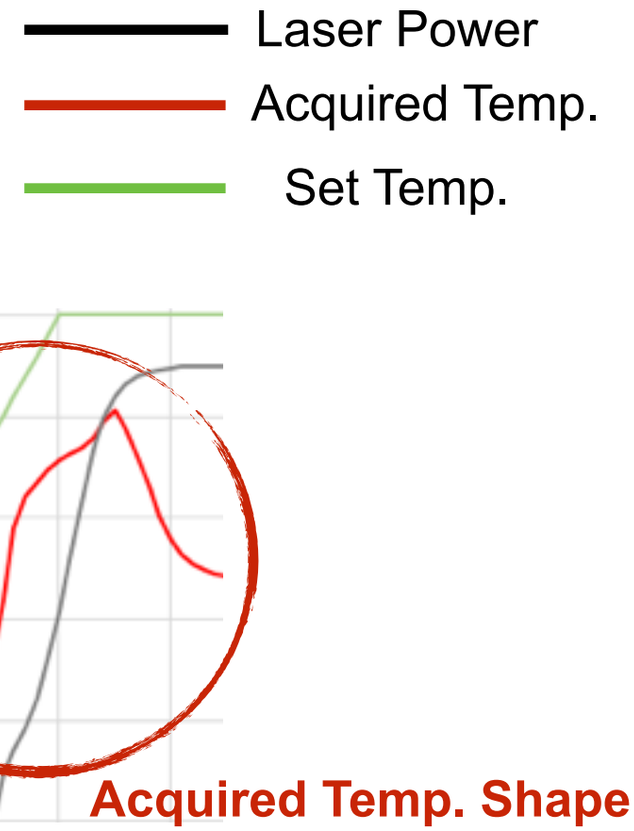




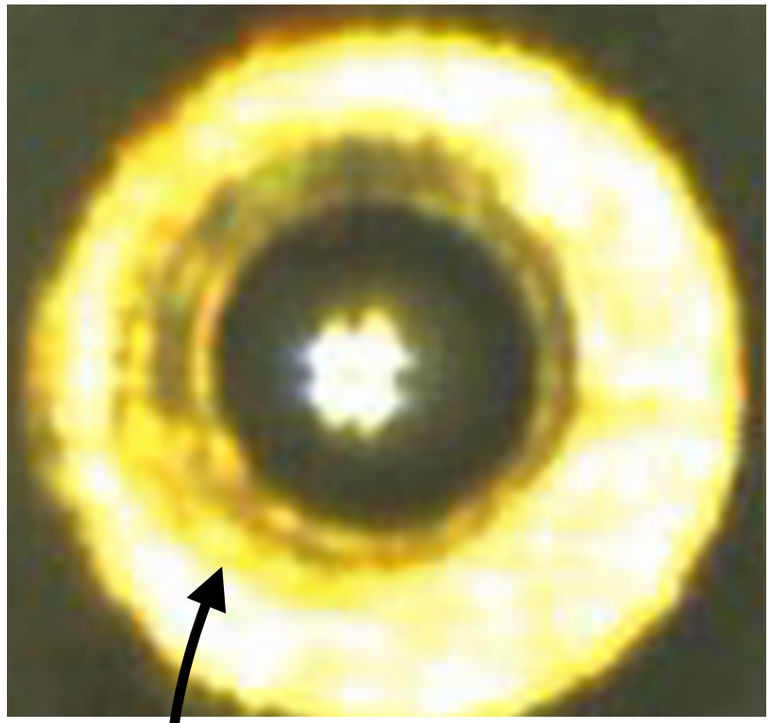
Available method #1: Laser Profile

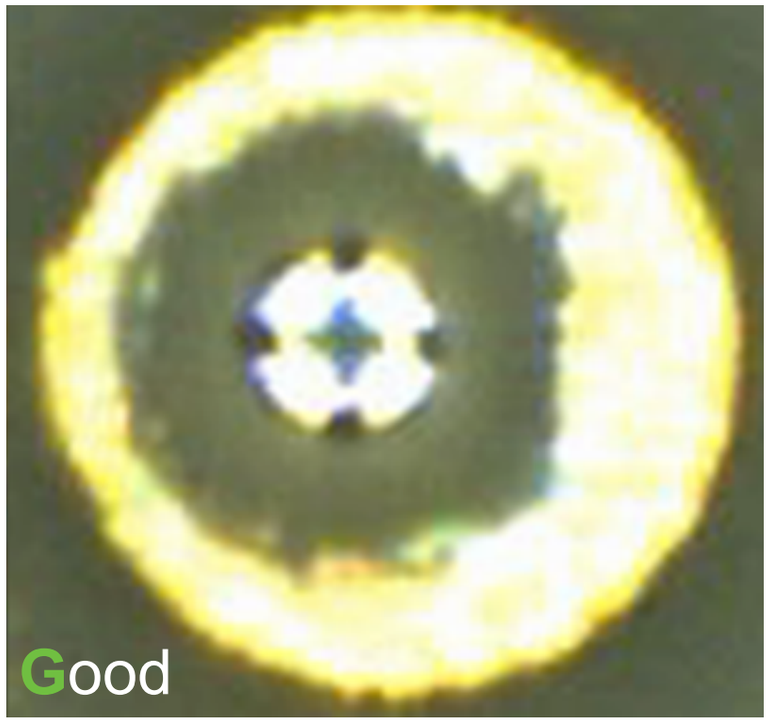
- **Check Acquired Temperature**
  - This value is directly related in real soldering condition
  - Laser Power is controlled by combination of Setted Temp. and Acquired Temp.
  - Acquired Temp. Maxium
  - Acquired Temp. Integration
  - Acquired Temp. Shape(on going)

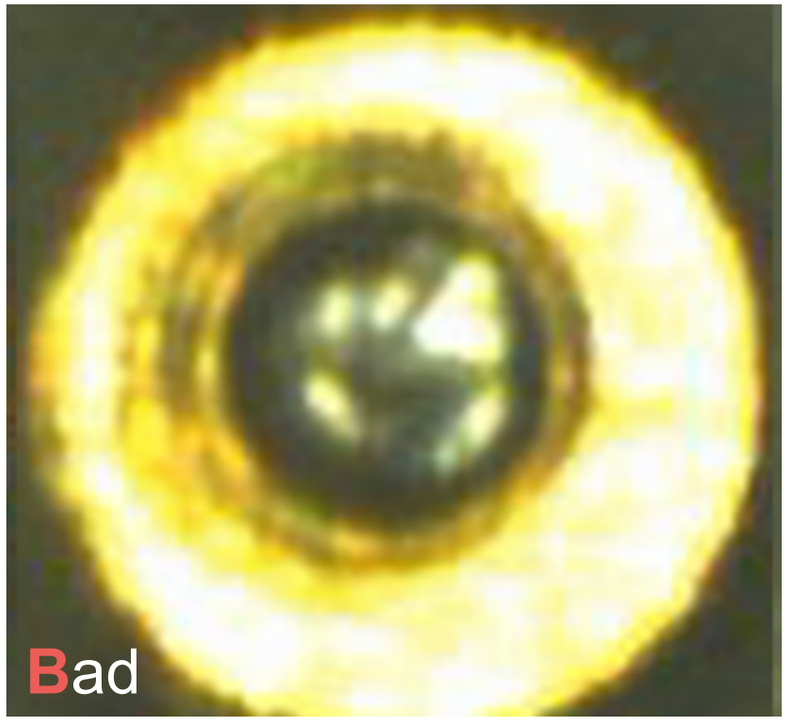




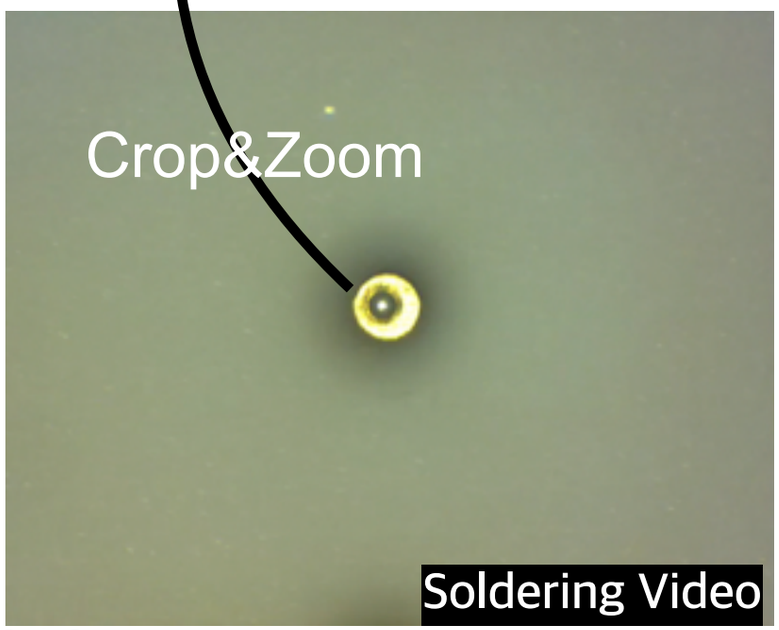
Available method #2:
Categorize Connection Shape from Video

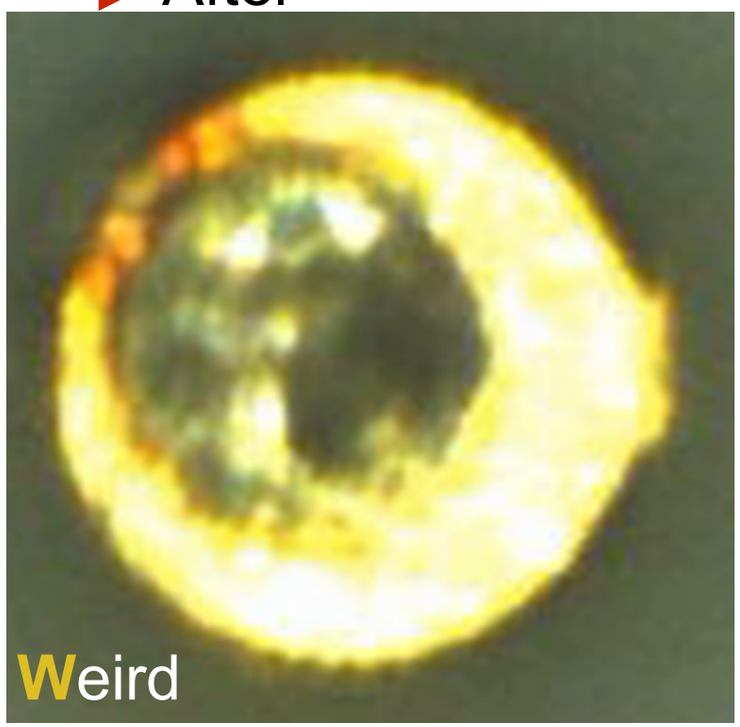


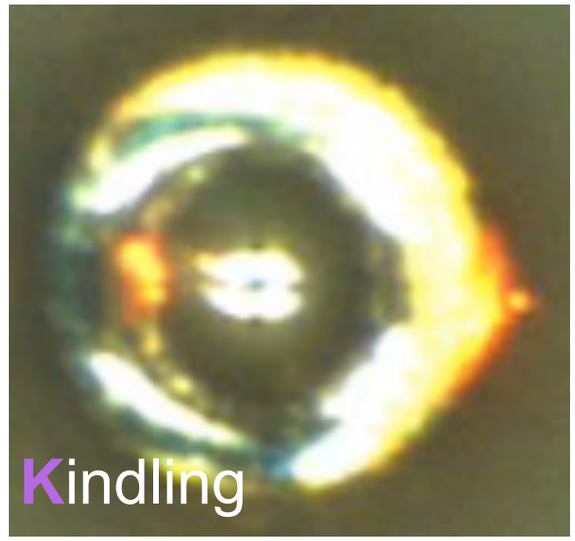




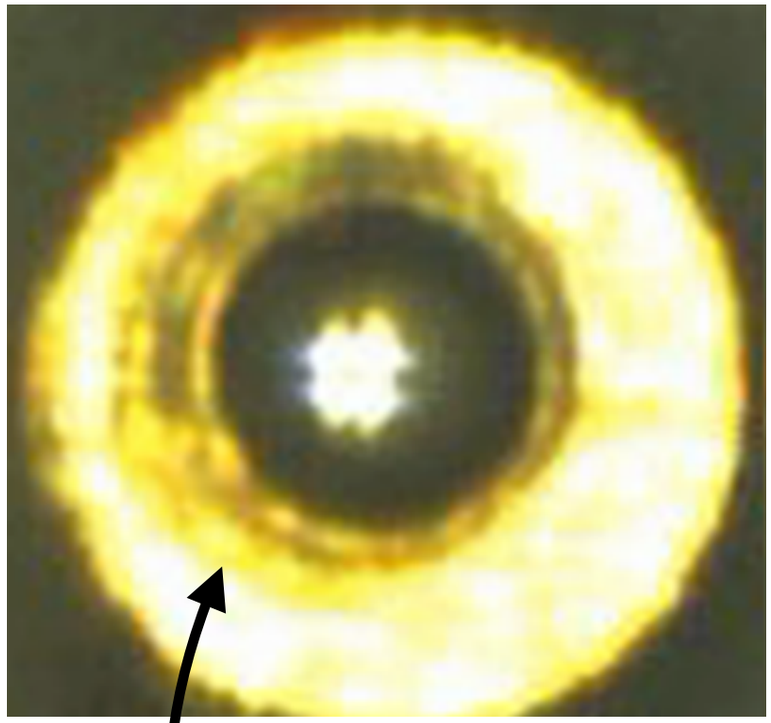
Before → After

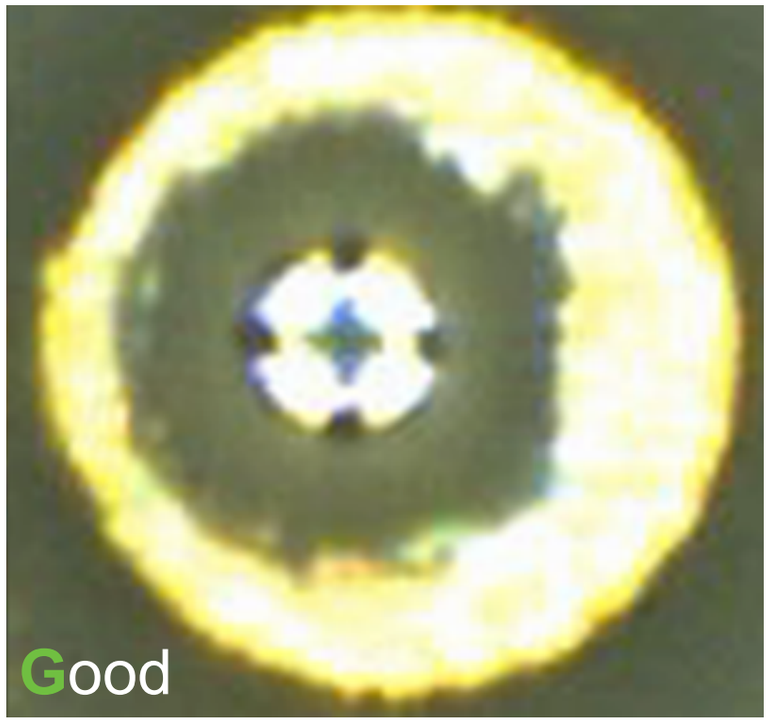


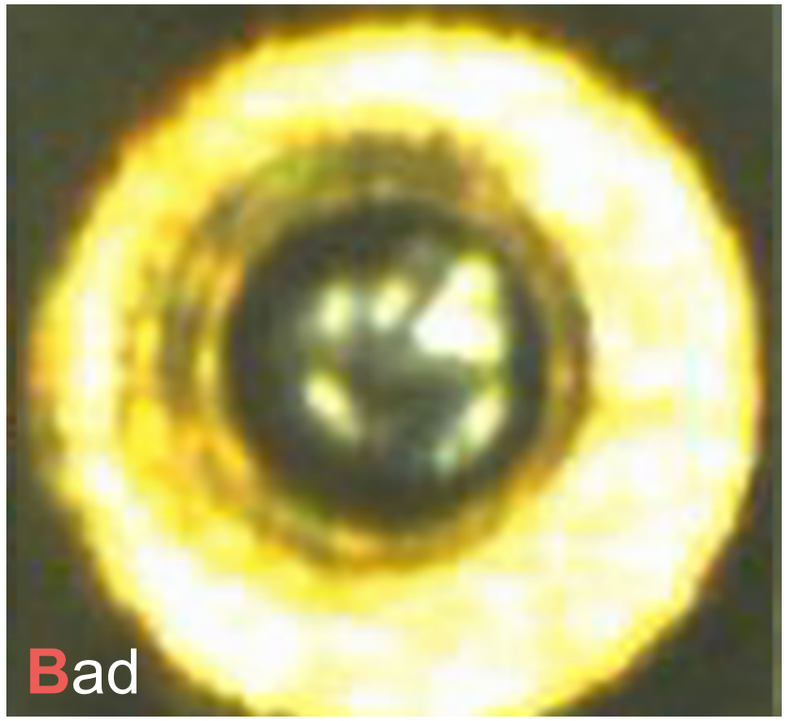




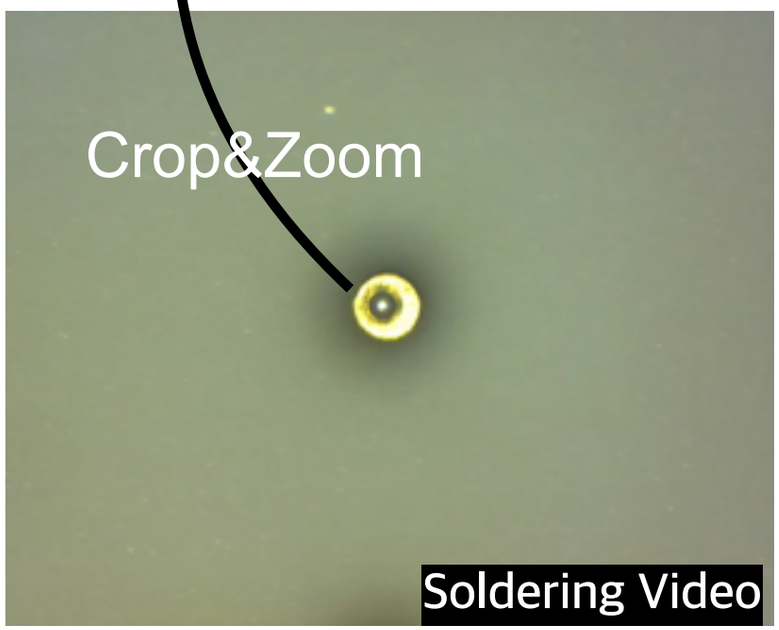
Available method #2:
Categorize Connection Shape from Video

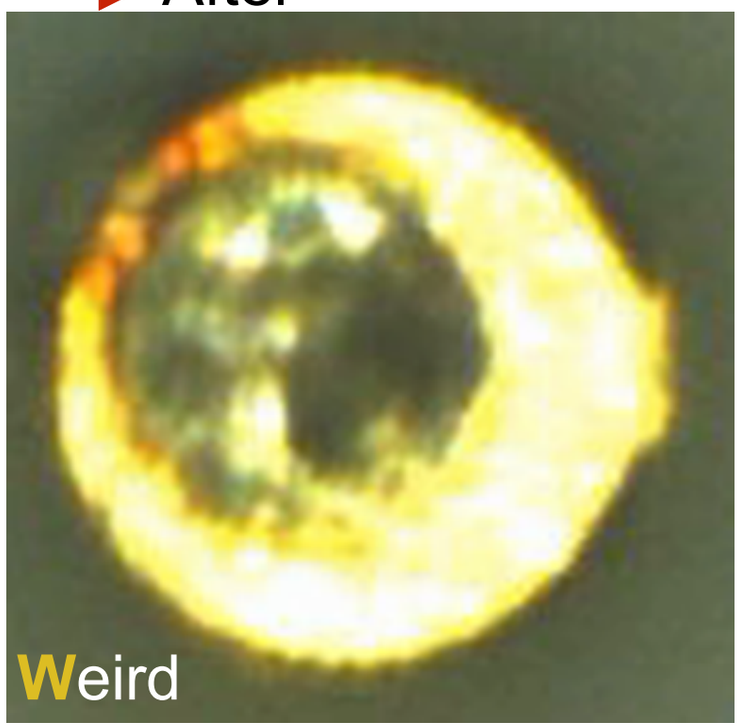


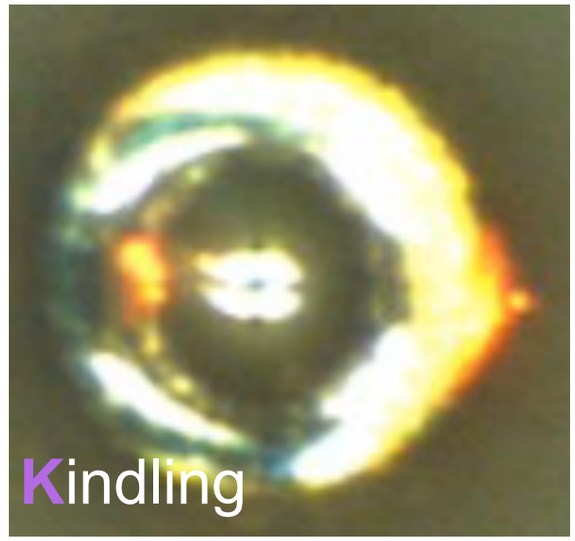




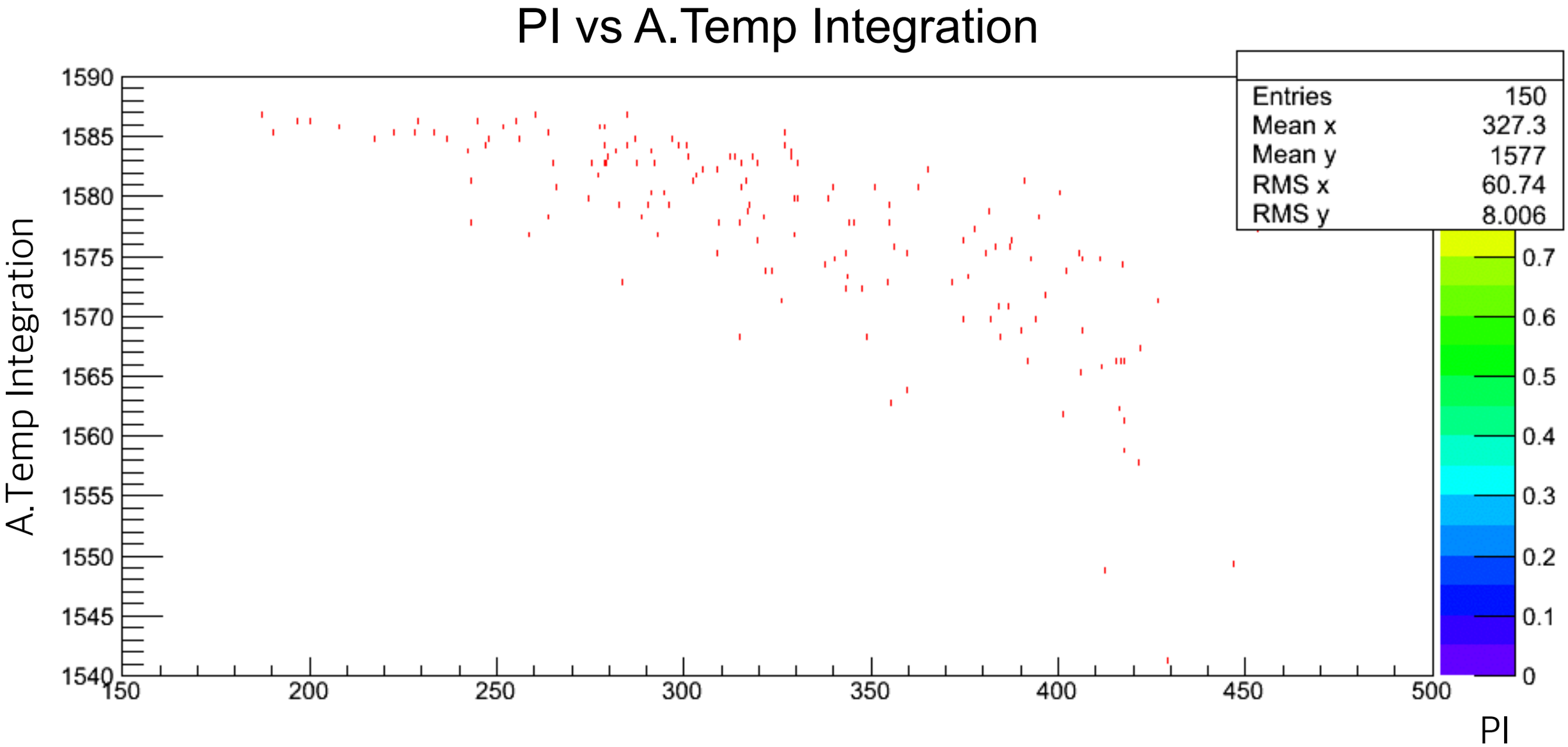
Before → After





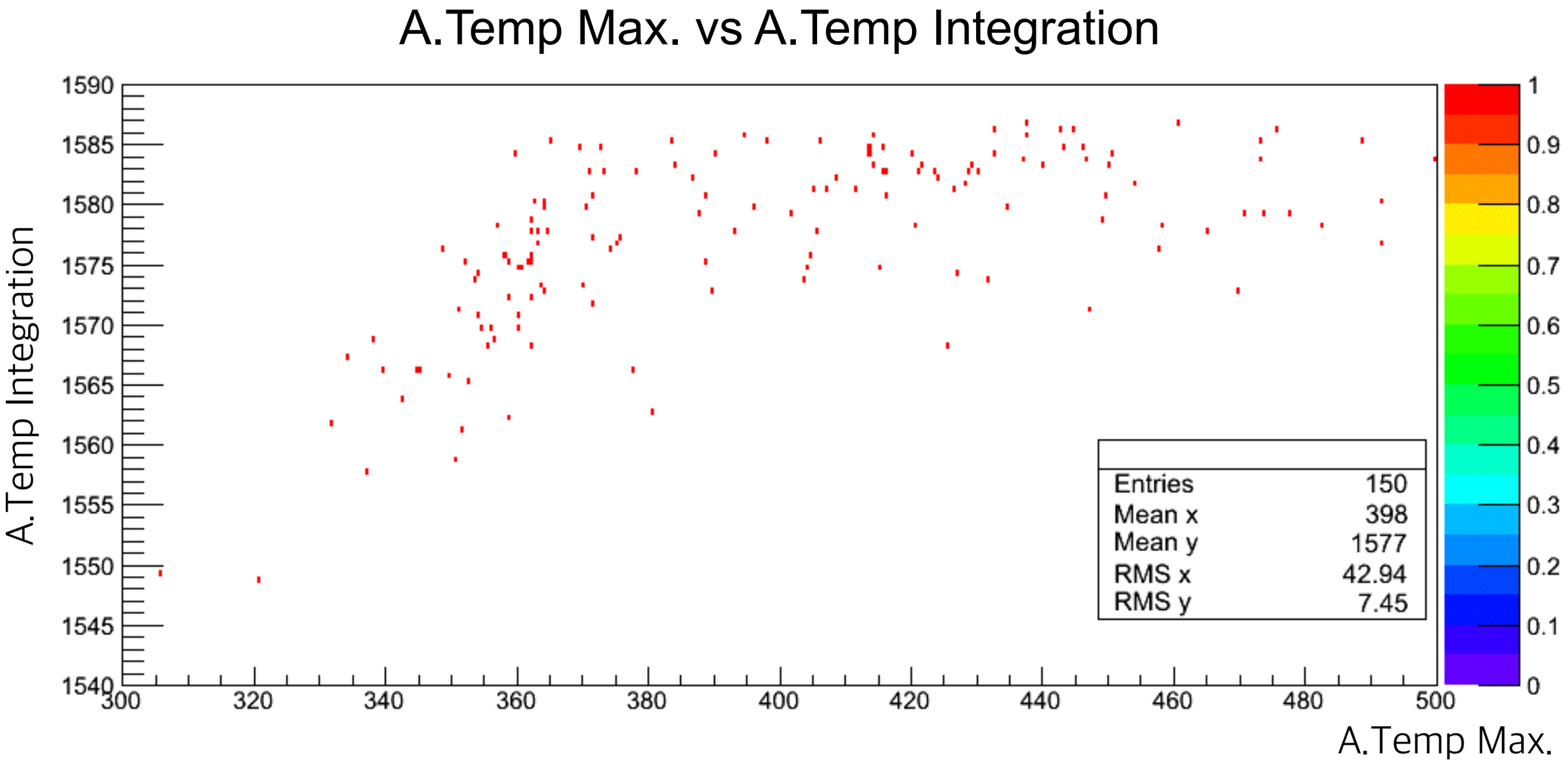


Preliminary Result #1: Laser Profile



A.Temp Integration tend to decrease by increasing PI

Preliminary Result #2: Laser Profile



A.Temp Integration tend to follow A.Temp Max where A.Temp Max. is in below 360

Prepare for Assembly System in PNU

Clean booth for Assembly(Planed)

Baseline system for HIC Assembly

- including automatic placement system and Laser soldering machine
- will be delivered May.2015

New room for assembly

- Available now

Clean booth for Assembly

- necessary for assembly silicon chips (clean room class ~ 100,000)
- will be installed just before the base -line system arrive

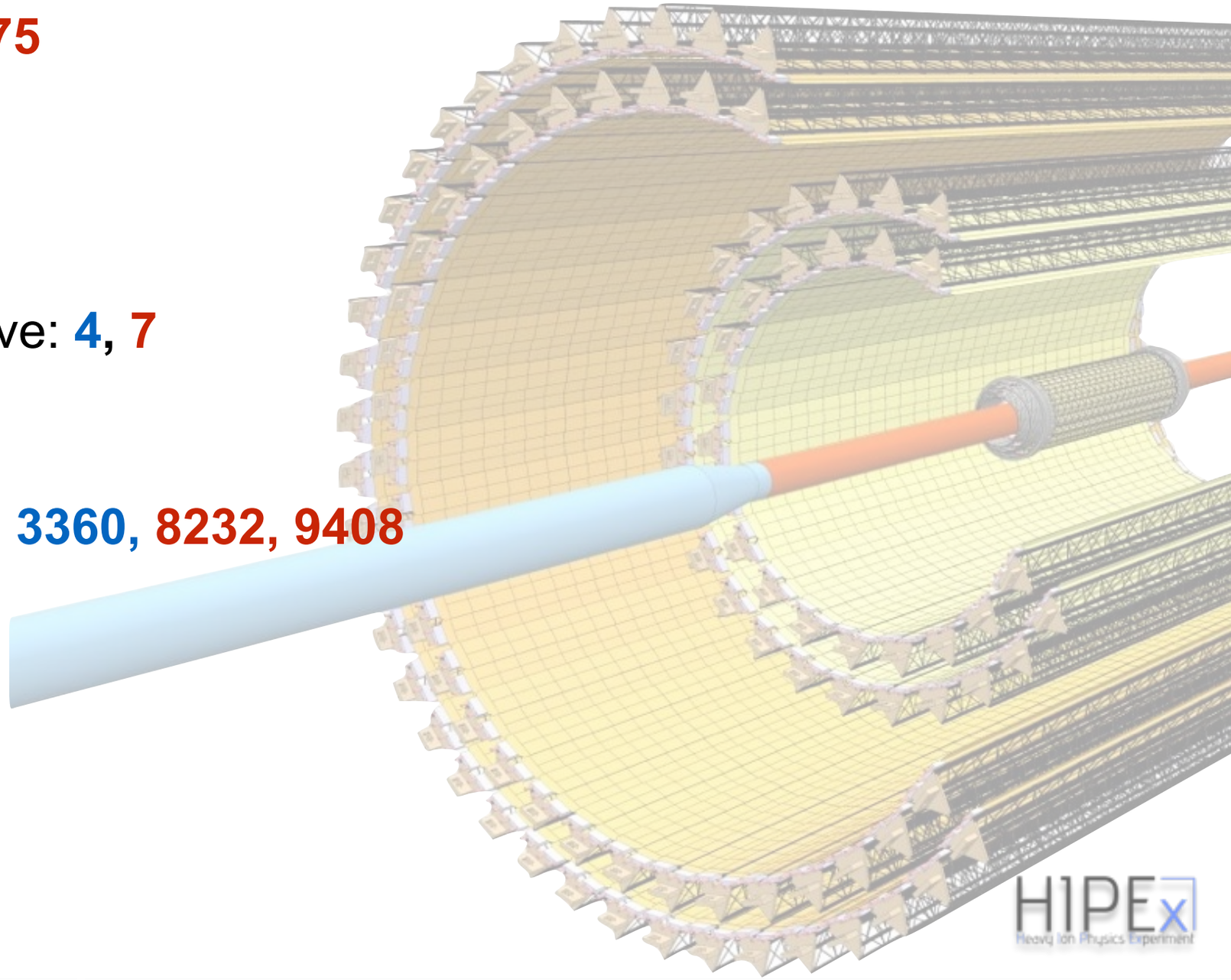
Summary

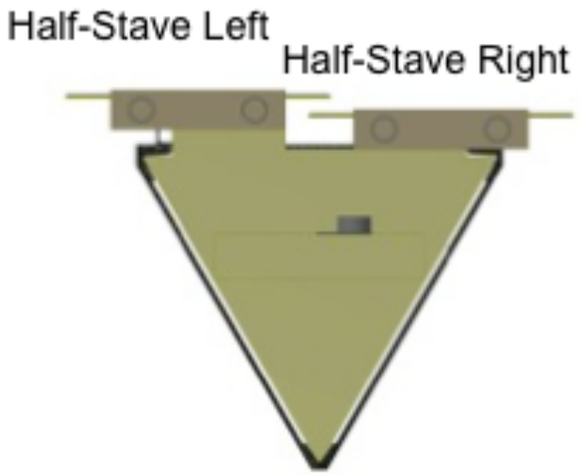
- **ITS upgrade project in ALICE**
  - ALICE prepare the next ITS detector.
- **HIC Assembly in ITS upgrade**
  - HIC Module can be manufactured by distributed site.
  - PNU is one of Module Assembly site, and preparing the Module Assembly.
- **Laser Soldering in HIC Assembly**
  - Laser Soldering is most important part in HIC Assembly
  - R&D of Laser soldering is on going now.
  - Data analysis of laser soldering is also on going now.

Back up

Outer Barrel Specification

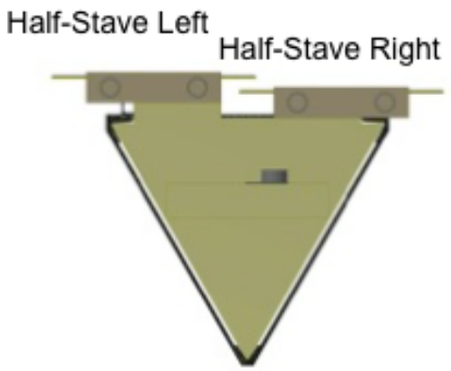
- Outer Barrel: 2 **Middle layer** + 2 **Outer layer**
- Radial Position(mm) : **196, 245, 344, 393**
- Length in z(mm) : **843, 1475**
- # of Staves: **24, 30, 42, 48**
  - # of half-Staves: 2
- # of moudules per half-stave: **4**, **7**
- # of Chips per module: 14
- # of Chips per layer: **2688, 3360, 8232, 9408**





Amount of needed HIC

Layer	Stave	Half-stave	Module	Chip
L3	24	48	192	2688
L4	30	60	240	3360
L5	42	84	588	8232
L6	48	96	672	9408
Spares(20%)	11(ML) 18(OL)	22(ML) 36(OL)	340	4760
Total	65(ML) 108(OL)	130(ML) 216(OL)	2032	28448



Each site would manufacture the 1 module per day for 1 ~ 2 years