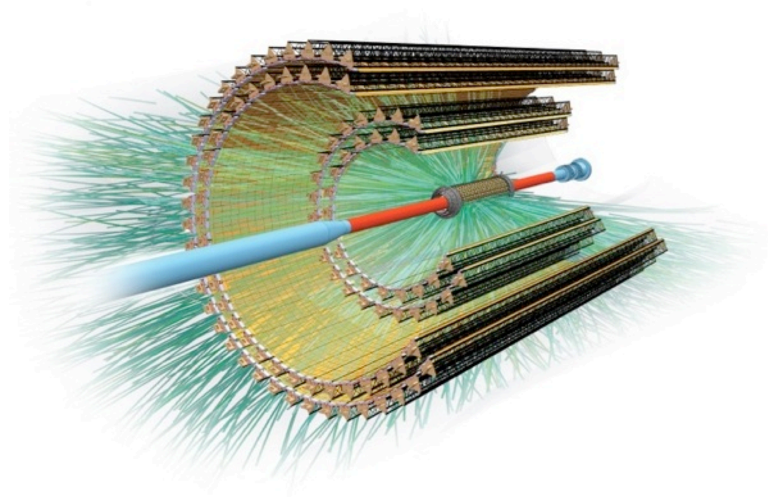
A Large Ion Collider Experiment

Module Construction

Pusan, 15 December 2014

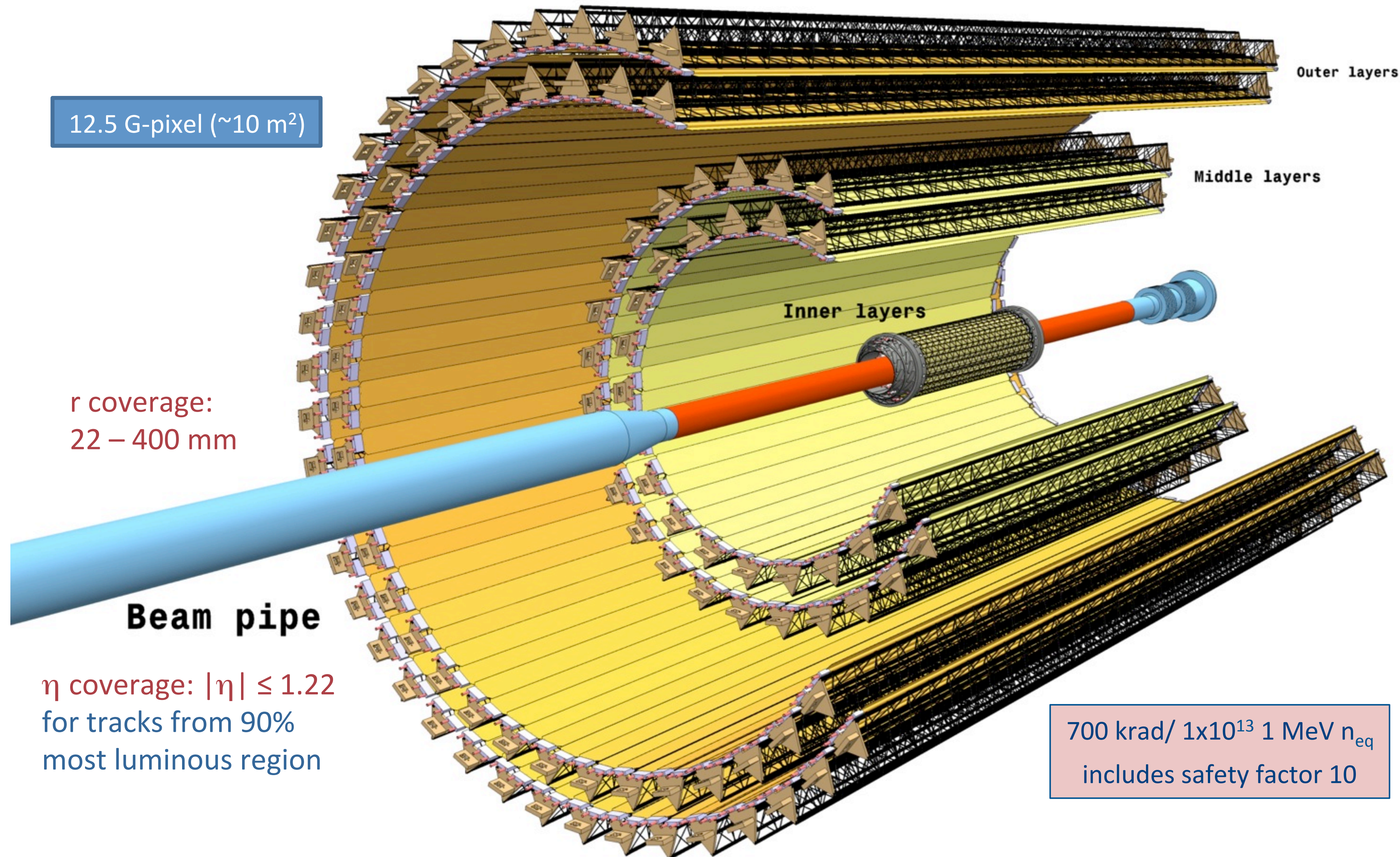
V. Manzari – INFN-Bari & CERN



4th ALICE ITS upgrade, MFT and O^2 Asian Workshop 2014 @ Pusan

Detector Layout Overview

7 layers of Monolithic Active Pixel Sensors



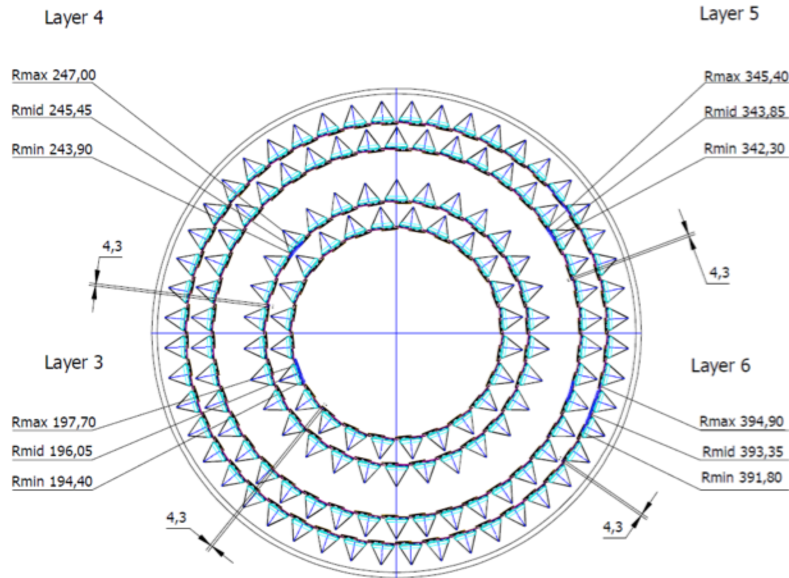
12.5 G-pixel (~10 m^2)

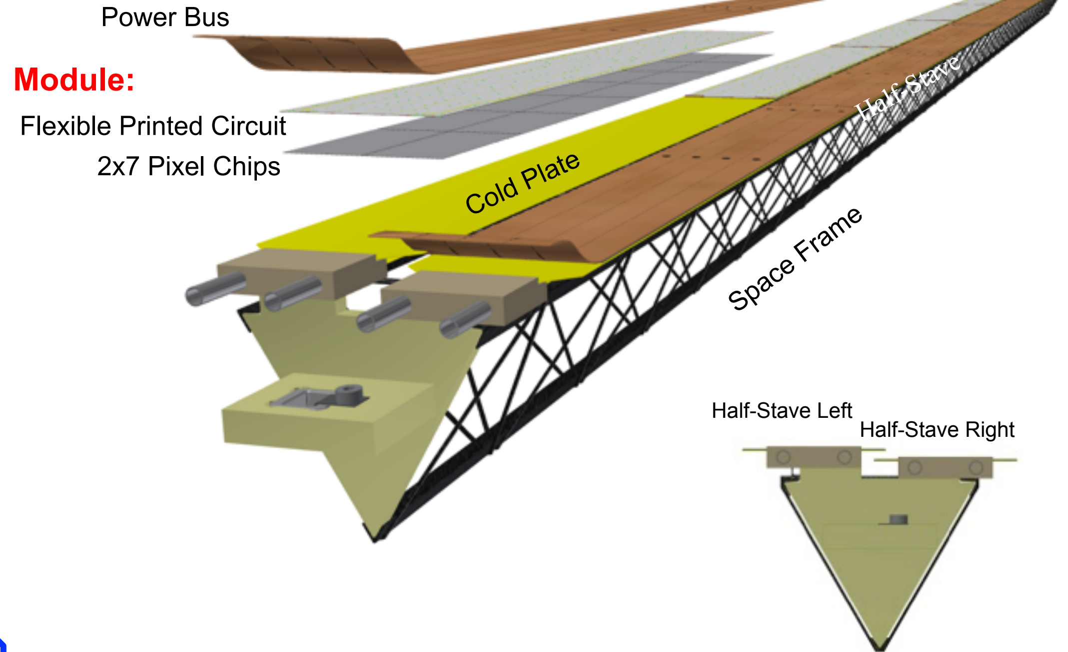
r coverage:
22 – 400 mm

η coverage: $|\eta| \leq 1.22$
for tracks from 90%
most luminous region

700 krad/ $1x10^{13}$ 1 MeV n_{eq}
includes safety factor 10

Outer Barrel

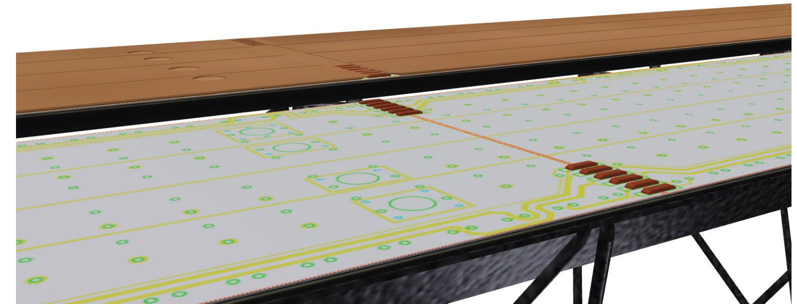




Outer Barrel (OB): 2 ML + 2 OL

Radial position (mm): 196, 245, 344, 393
Length in z (mm): 843, 1475
Nr. of staves: 24, 30, 42, 48
Nr. of half-staves/stave: 2
Nr. of modules/half-stave: 4 (ML), 7 (OL)
Nr. of chips/module: 14
Nr. of chips/layer: 2688, 3360, 8232, 9408
Material thickness: ~ 1% X_0 per layer

Module to Module and Power Bus connections



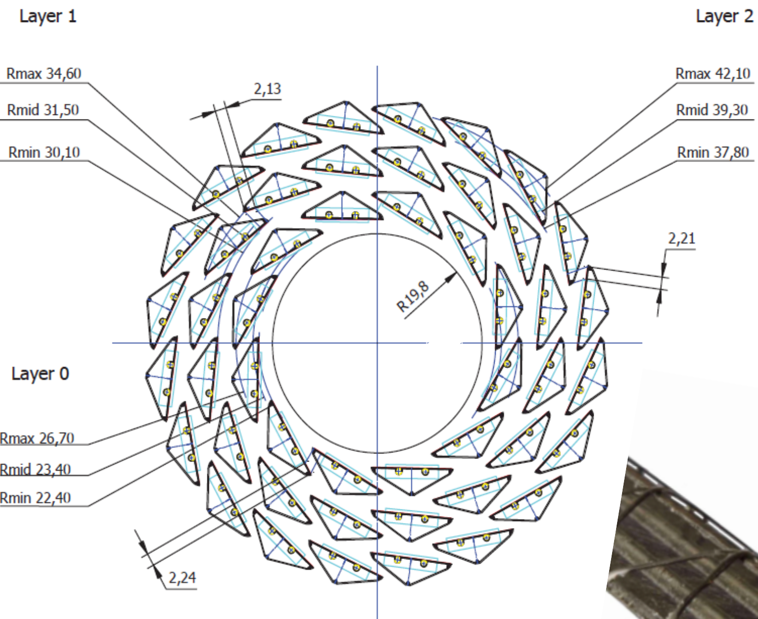
Outer Barrel: full-scale prototypes of the mechanical structures

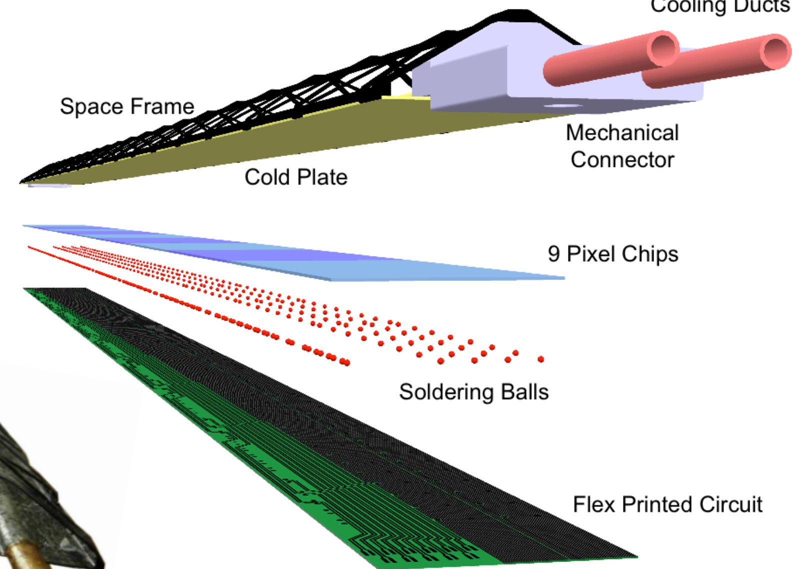
Space Frame

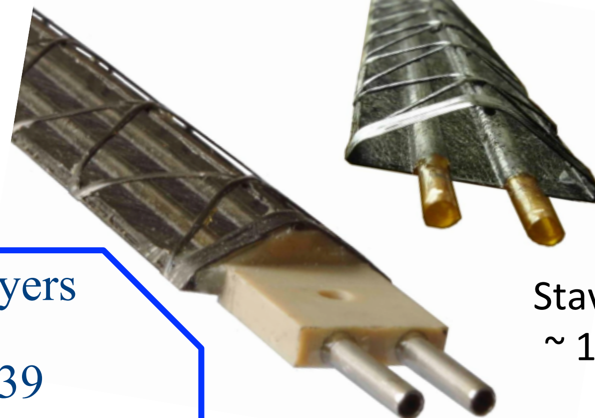
Cold Plates

Space Frame + Cold Plates

Inner Barrel







Stave weight
~ 1.4 grams

Inner Barrel (IB): 3 Inner Layers

Radial position (mm): 23, 31, 39

Length in z (mm): 271

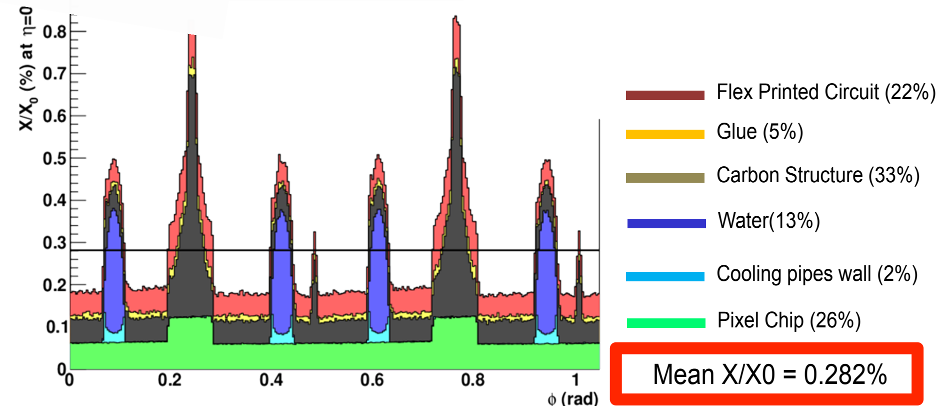
Nr. of staves: 12, 16, 20

Nr. of modules/stave: 1

Nr. of chips/module: 9

Nr. of chips/layer: 108, 144, 180

Material thickness: $\leq 0.3\%$ X_0 per layer



Inner Barrel: full-scale prototypes of the mechanical structures

Structural Sandwich

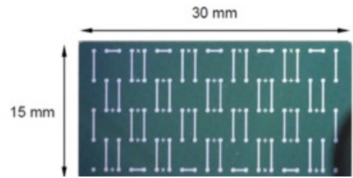
Layer 0

Layer 1

Layer 2

OB Module Components

Pixel chip with pads over logic



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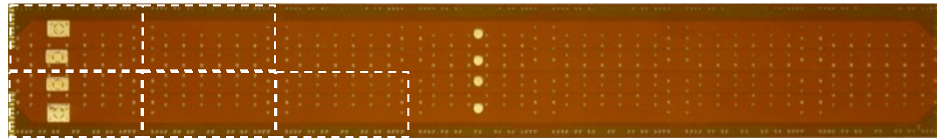
Flexible Printed Circuit (FPC) with plated holes Cu/Polyimide double layer (20/75/20 μm)



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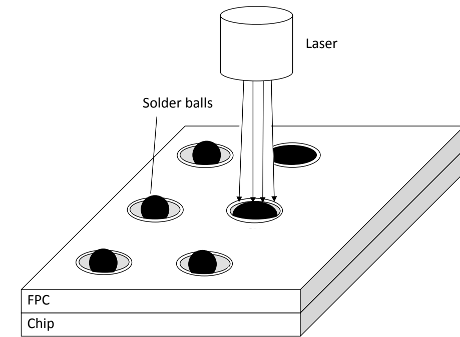
Laser soldering

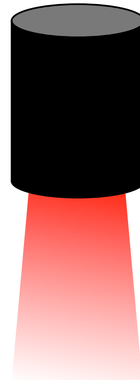


x 14

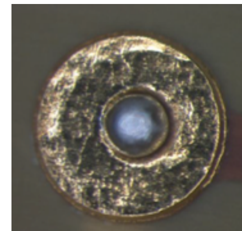
x 1

X 1400 (~100/chip)

Interconnection of Pixel chip to FPC by selective laser soldering



Before



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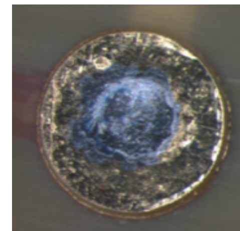

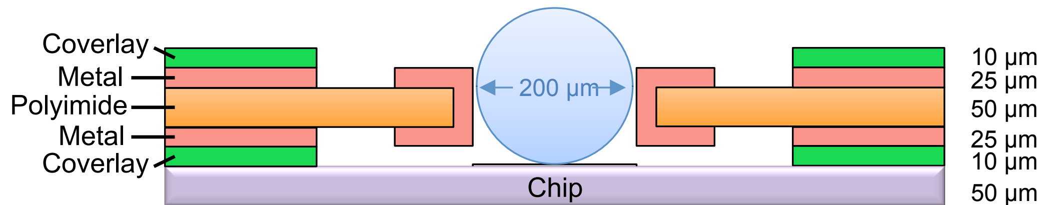

Standalone Laser Soldering Systems : CERN (operational) and Bari (delivery end of Jan '15)

OB Module development - planning and milestones

Activity	2015												2016			
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
ALPIDE-2 Module																
FPC Design and Production																
Module Production																
Module Characterization																
ALPIDE-3 Module																
FPC Design and Production																
Module Production																
Module Characterization																
Final Module																
FPC Design and Production																
Module Production																
Module Characterization																

Module Assembly Procedure

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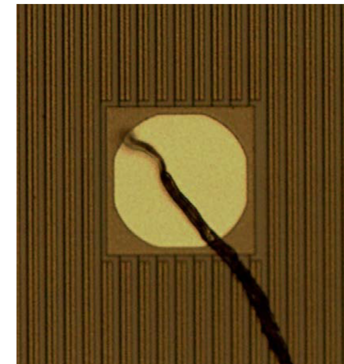
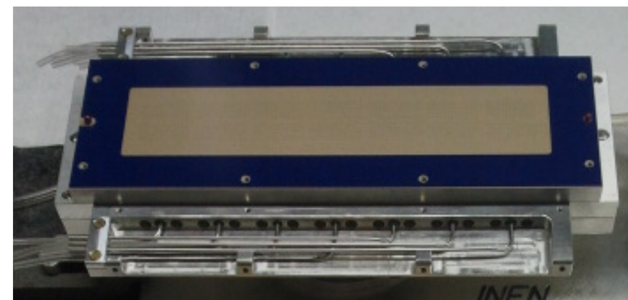
Main steps of the Module Assembly Procedure

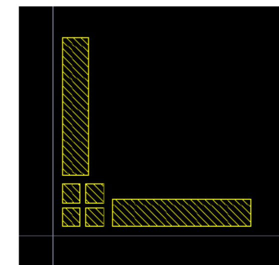
1. **Chip visual inspection** - dimensions, warp, integrity, cleanness



2. **Chip alignment** - pick up from the chip pallet and place above a vacuum chuck in nominal position with respect to reference markers

- 14 chips one after the other
- use reference markers on chip surface and vacuum chuck
- gap between adjacent chips:
  - 100 µm between nominal edge
  - 200 µm between center of cross reference markers





Module Assembly Procedure

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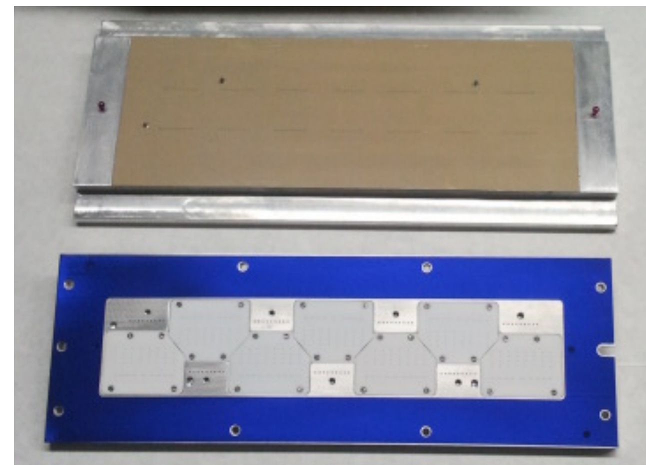
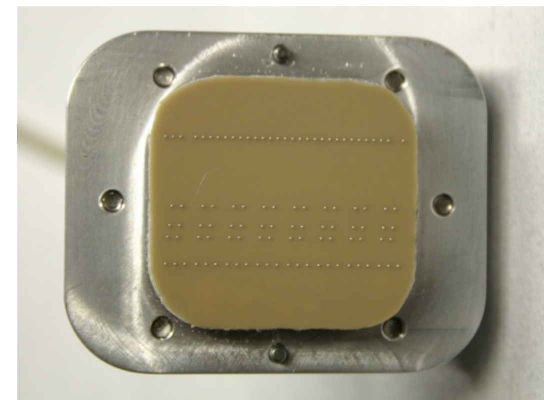
3. **FPC alignment** - placement above the chips arrays in nominal position by mean of a jig embedding a soldering grid



- use locating pinholes and ruby spheres
- the soldering grid is a ceramic plate with 0.5 mm holes corresponding to the FPC vias
- the jig gently press the FPC against the pixel chips to minimize the gap in between

4. **Soldering balls placement** - fill the soldering grid holes with the soldering balls by mean of the balls transfer tool

- the grid guides the soldering balls into the FPC vias
- one chip at a time, use pinholes for alignment
- visual inspection to ensure each hole is filled with one and only one soldering ball



Module Assembly Procedure

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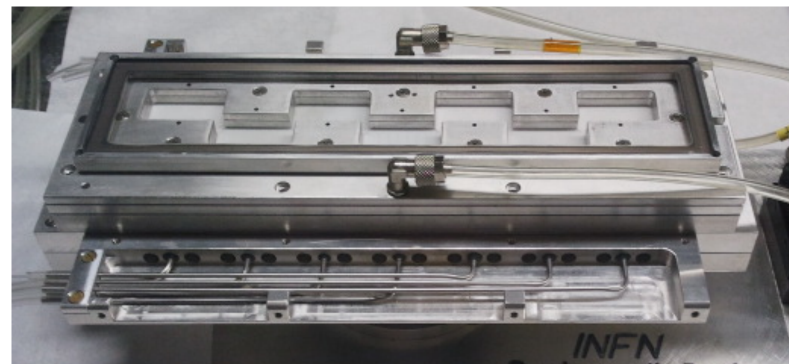
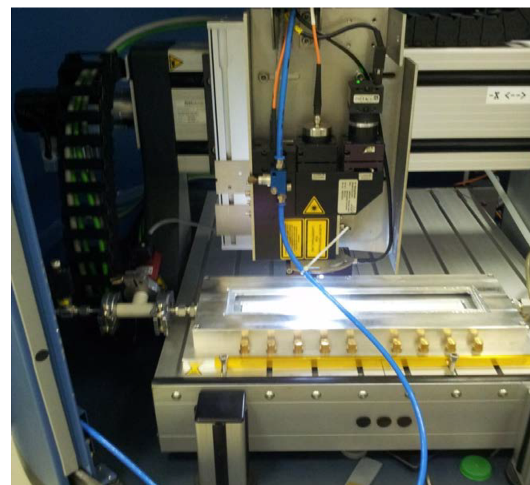
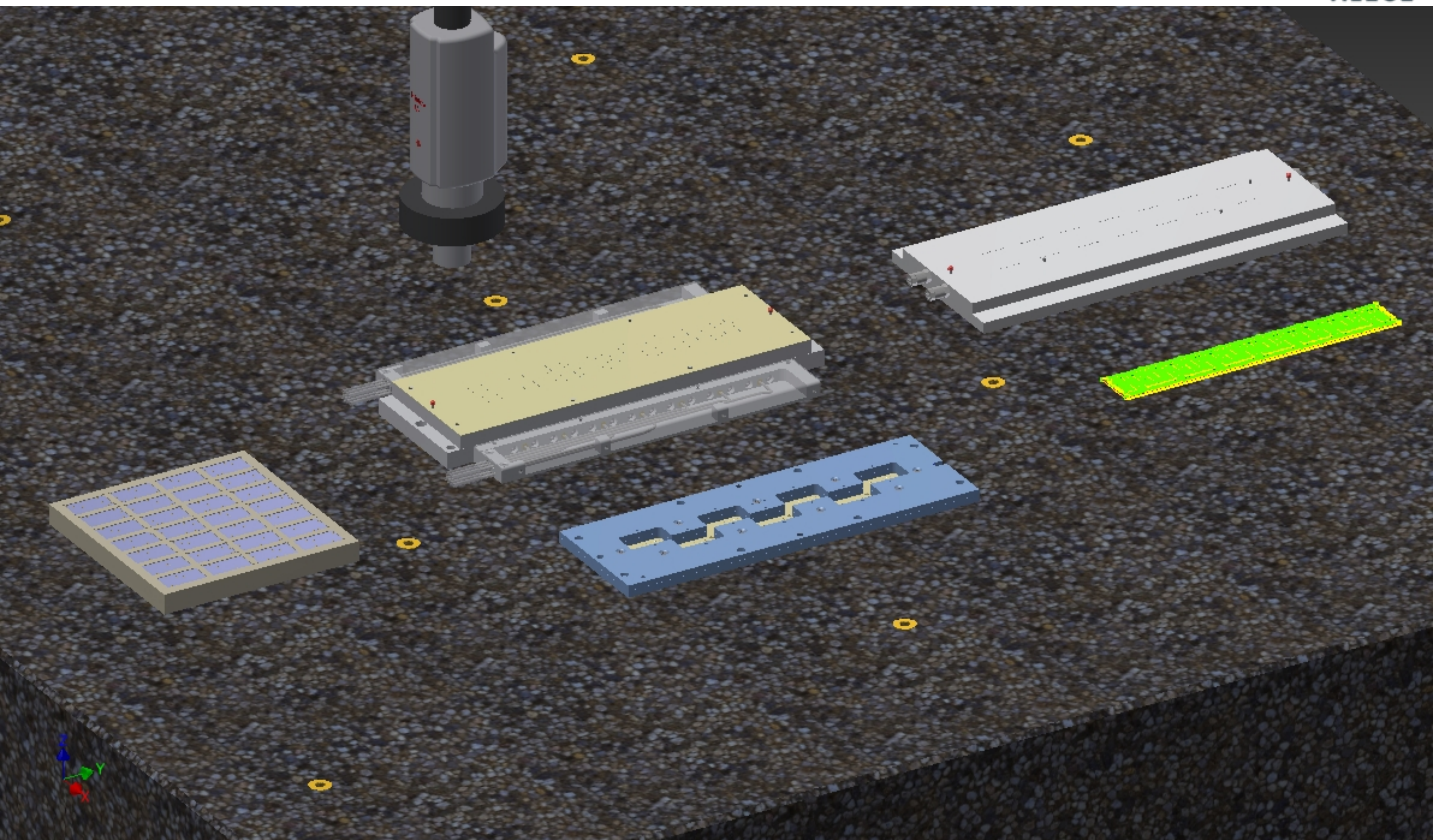
5. **Soldering readiness** - install the vacuum tight lid equipped with the quartz window above the pixel chips, FPC and soldering grid stack-up
   - start vacuum pump to empty the soldering volume till ready for laser soldering
   - pressure of the chip vacuum chuck always smaller than soldering volume



6. **Laser soldering** - shoot laser trough the quartz window onto each soldering balls in sequence to melt them and establish the connection between FPC and pixel chip
   - Visual checks of soldering joints

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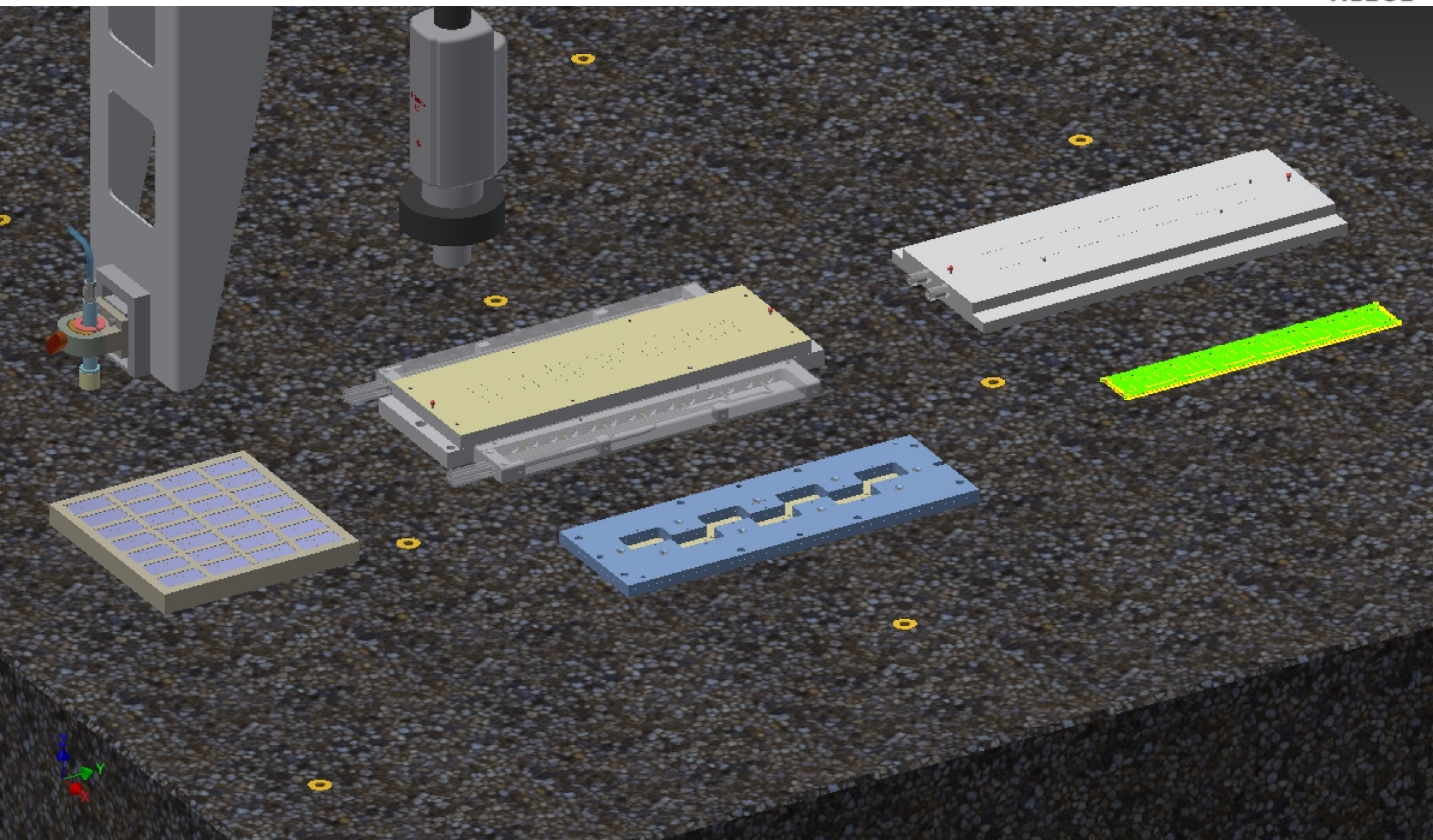

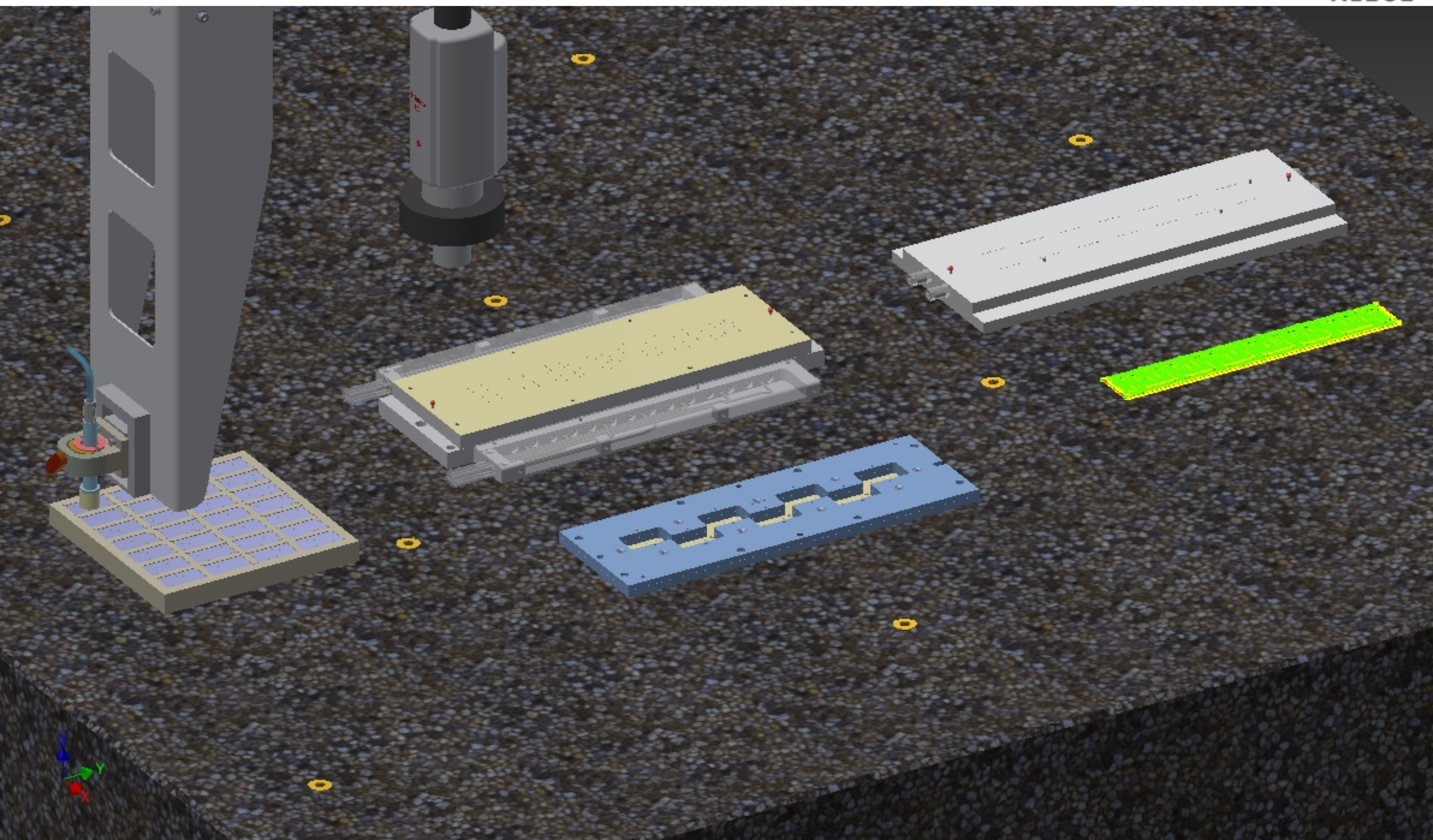
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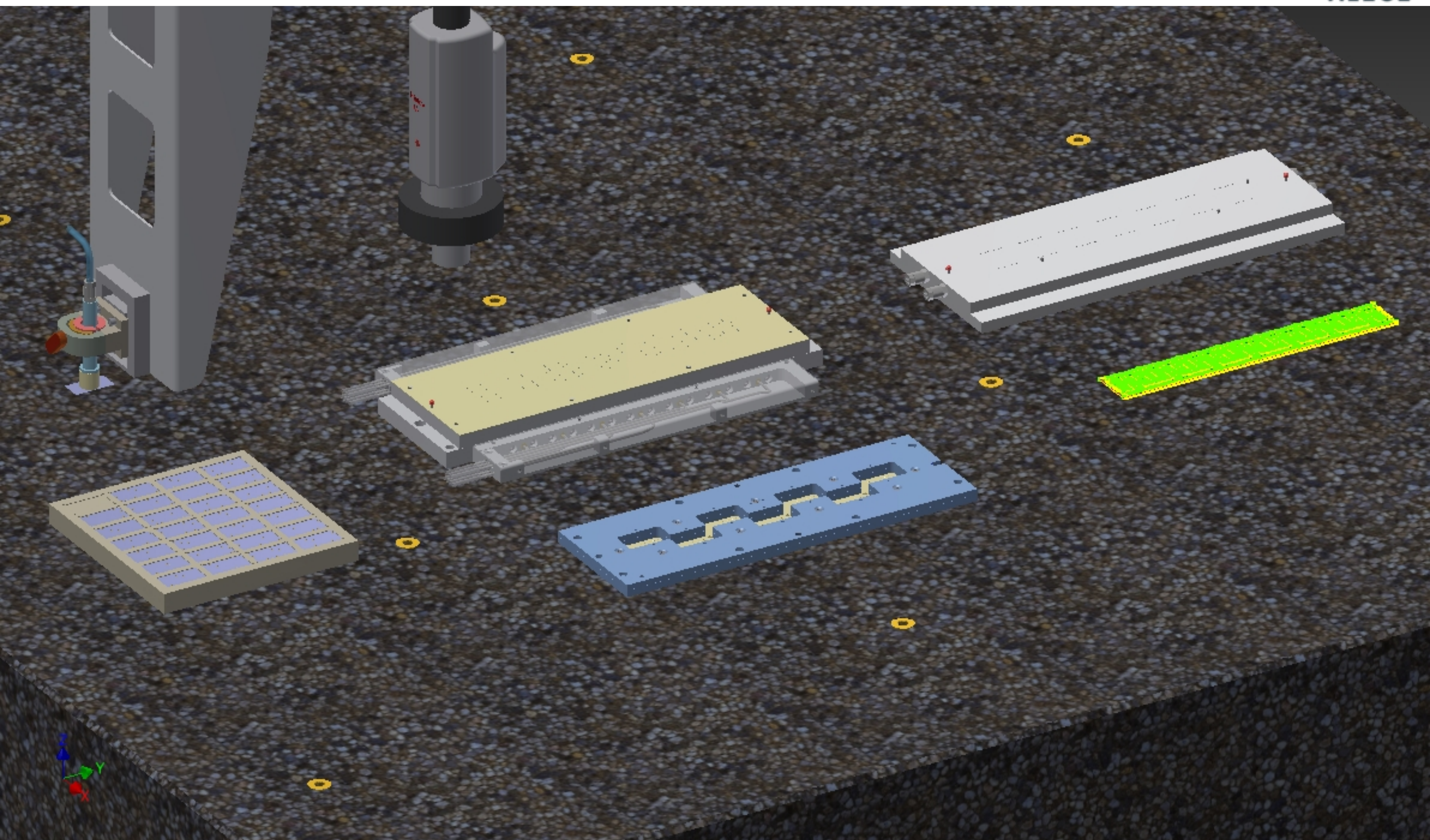
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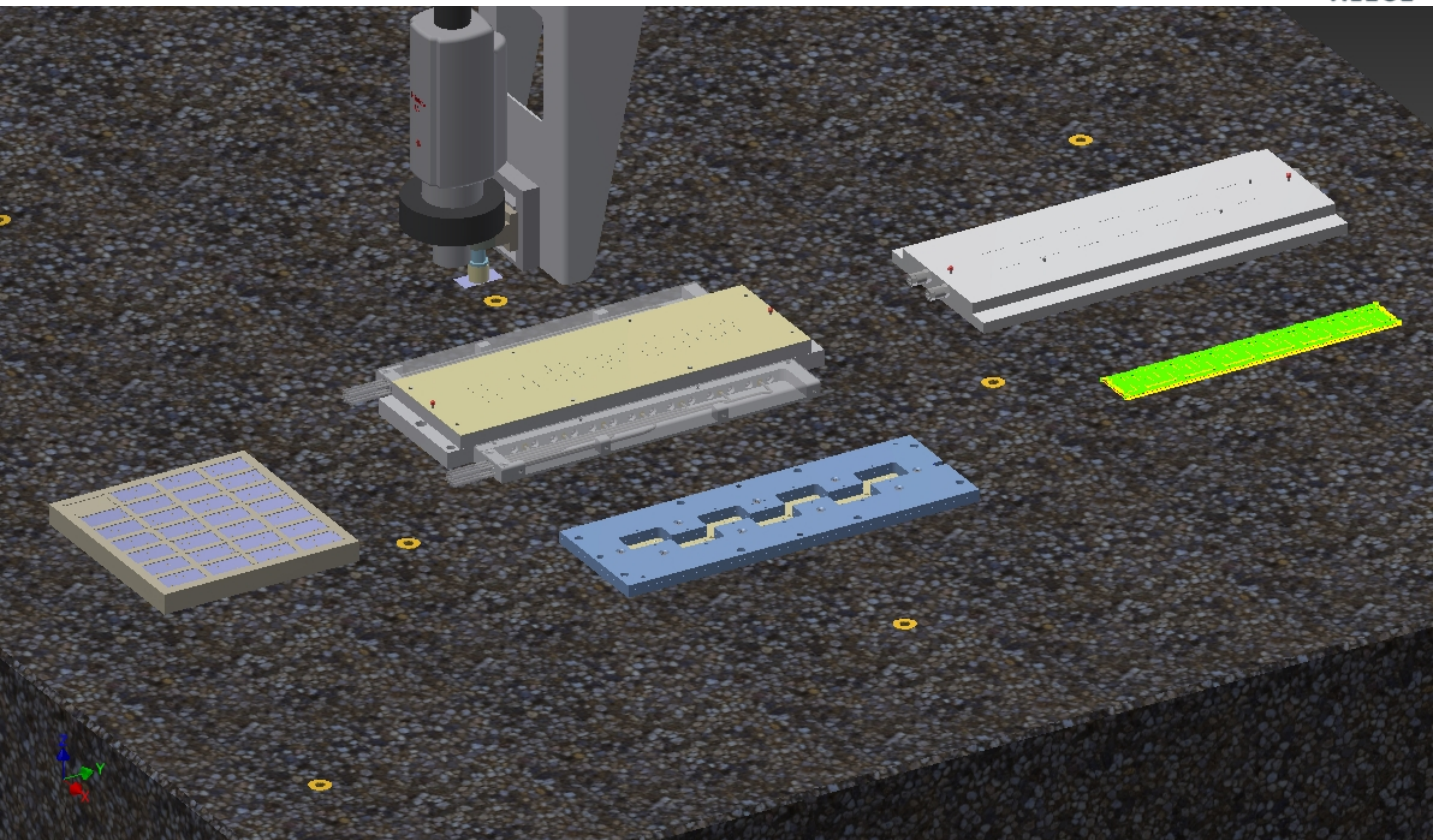

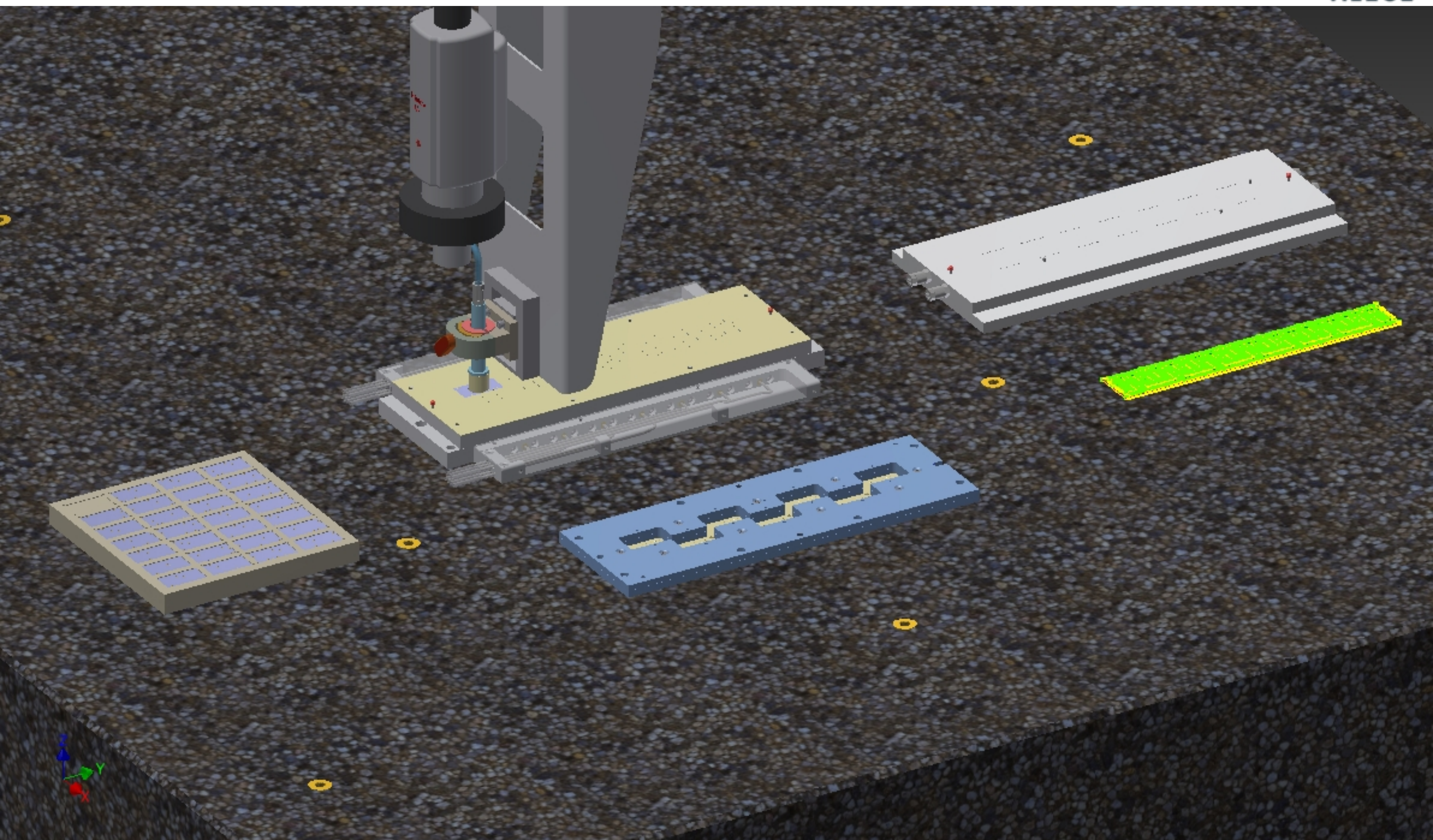

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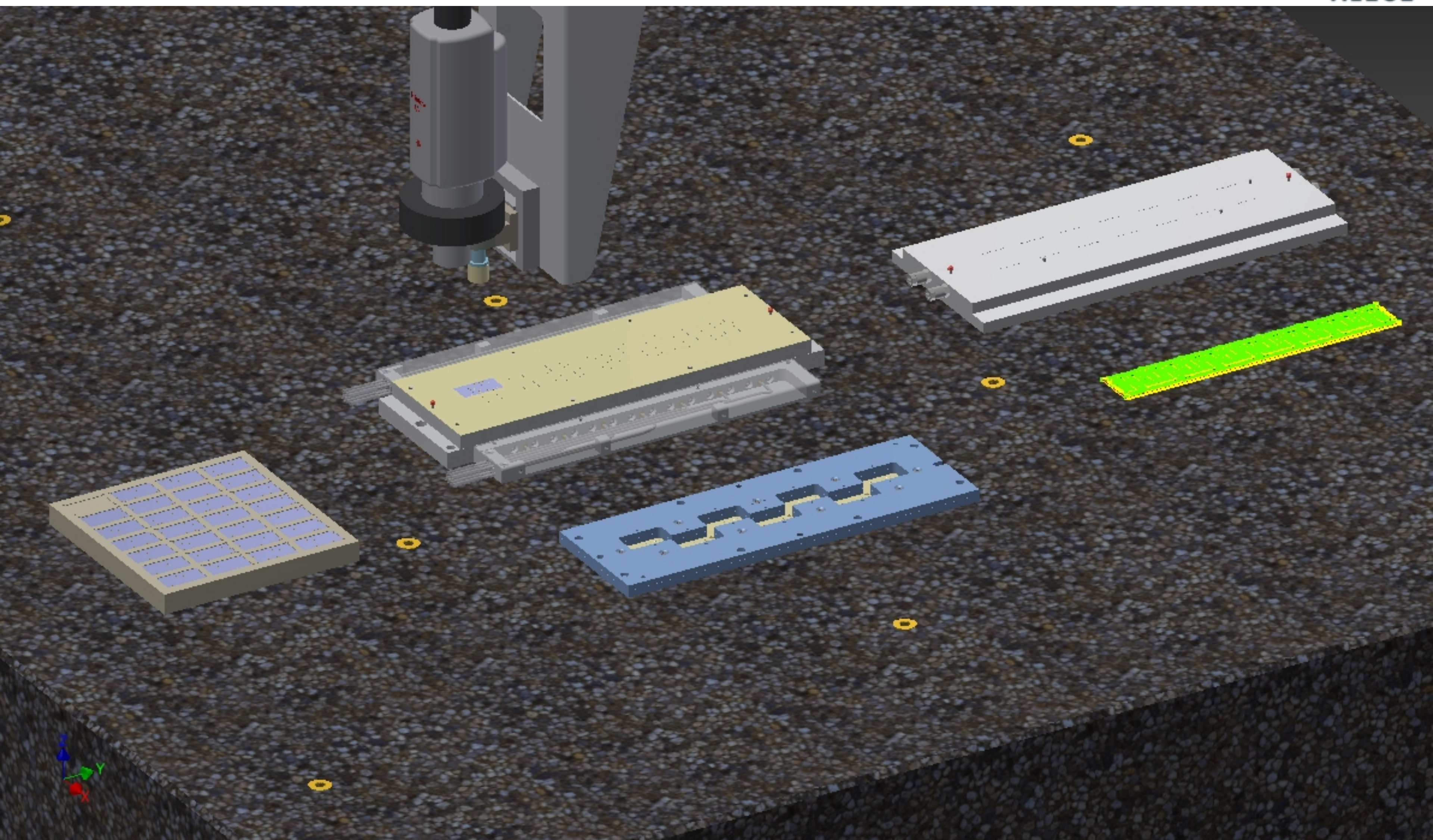
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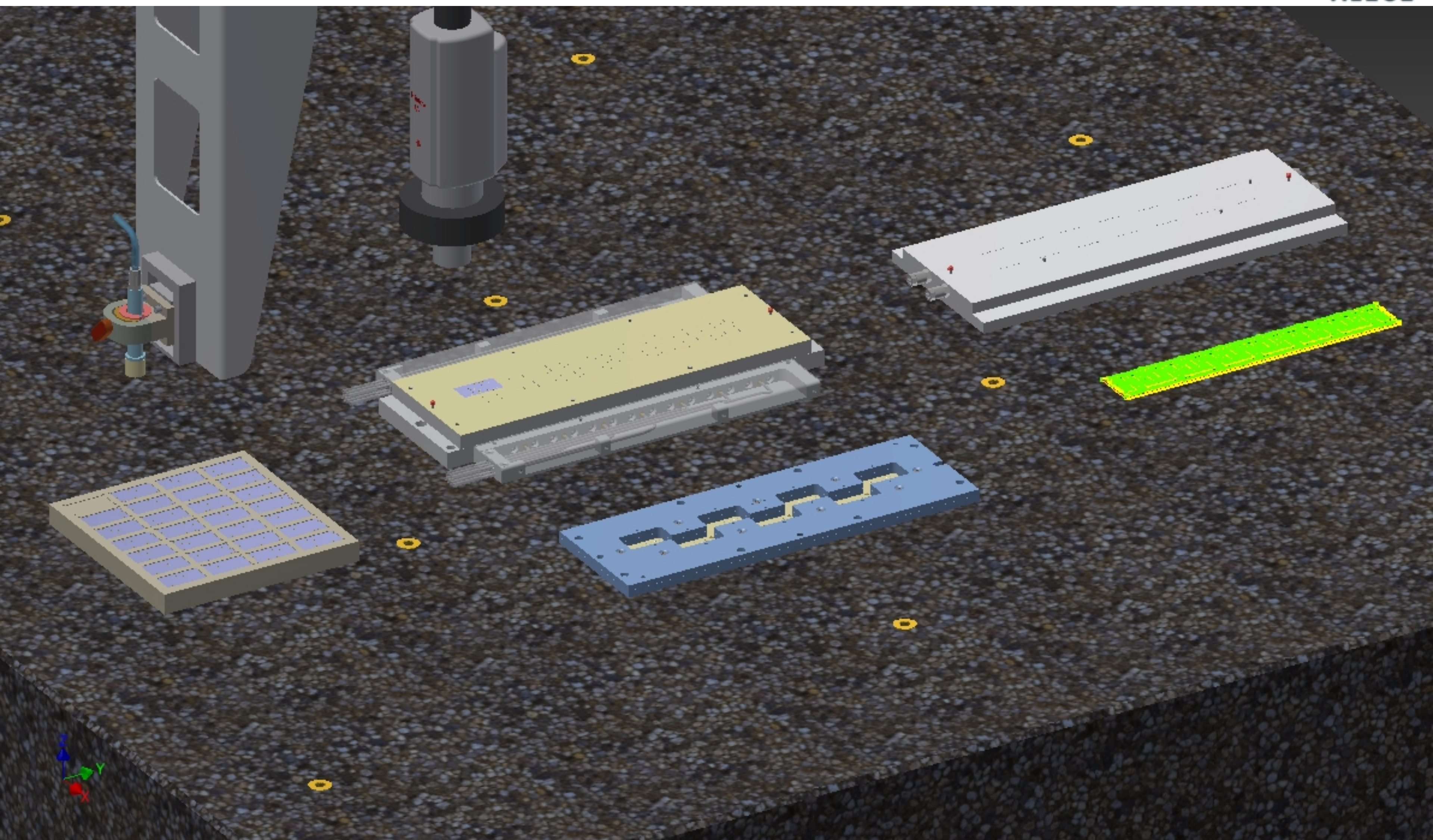

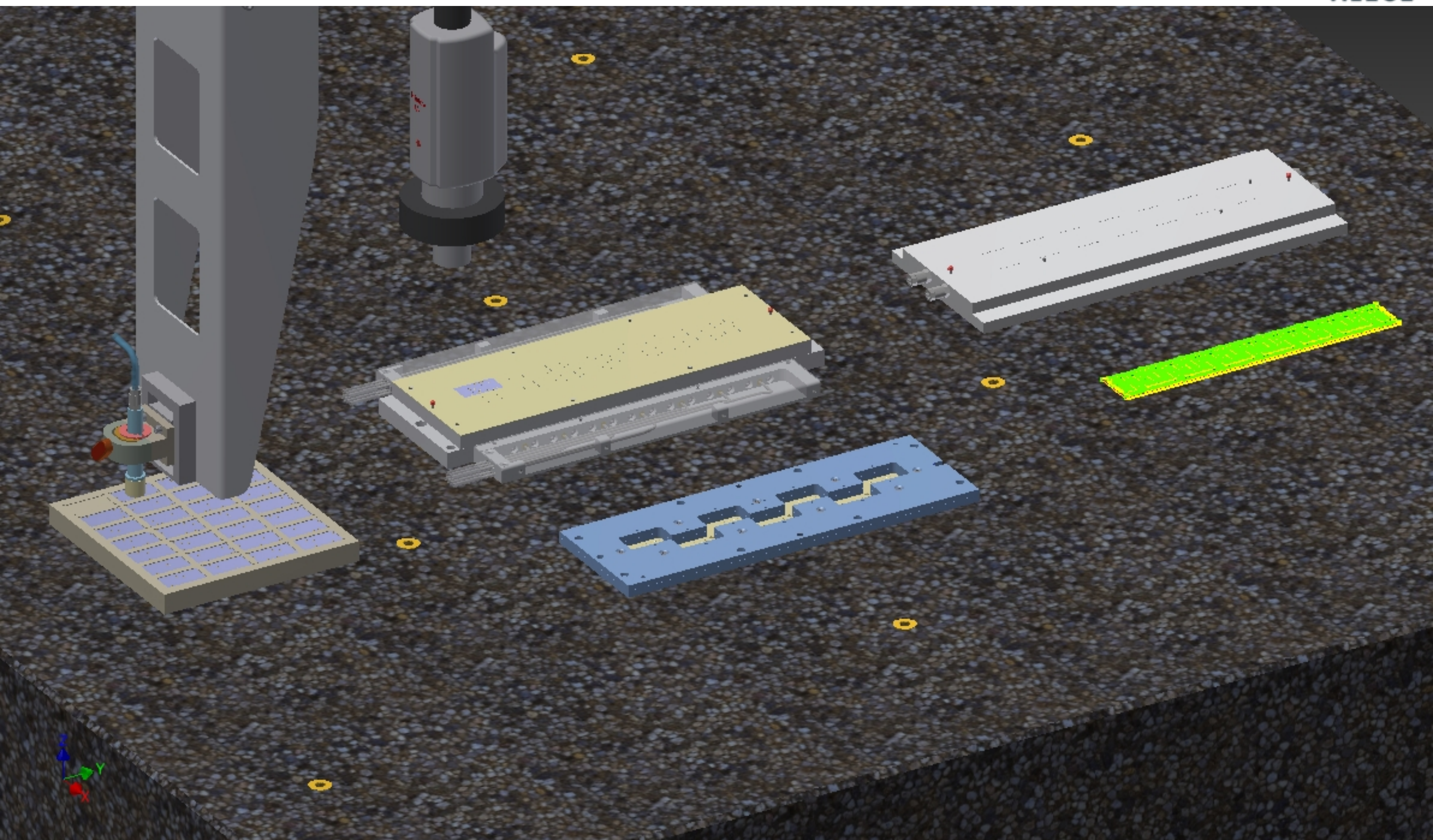
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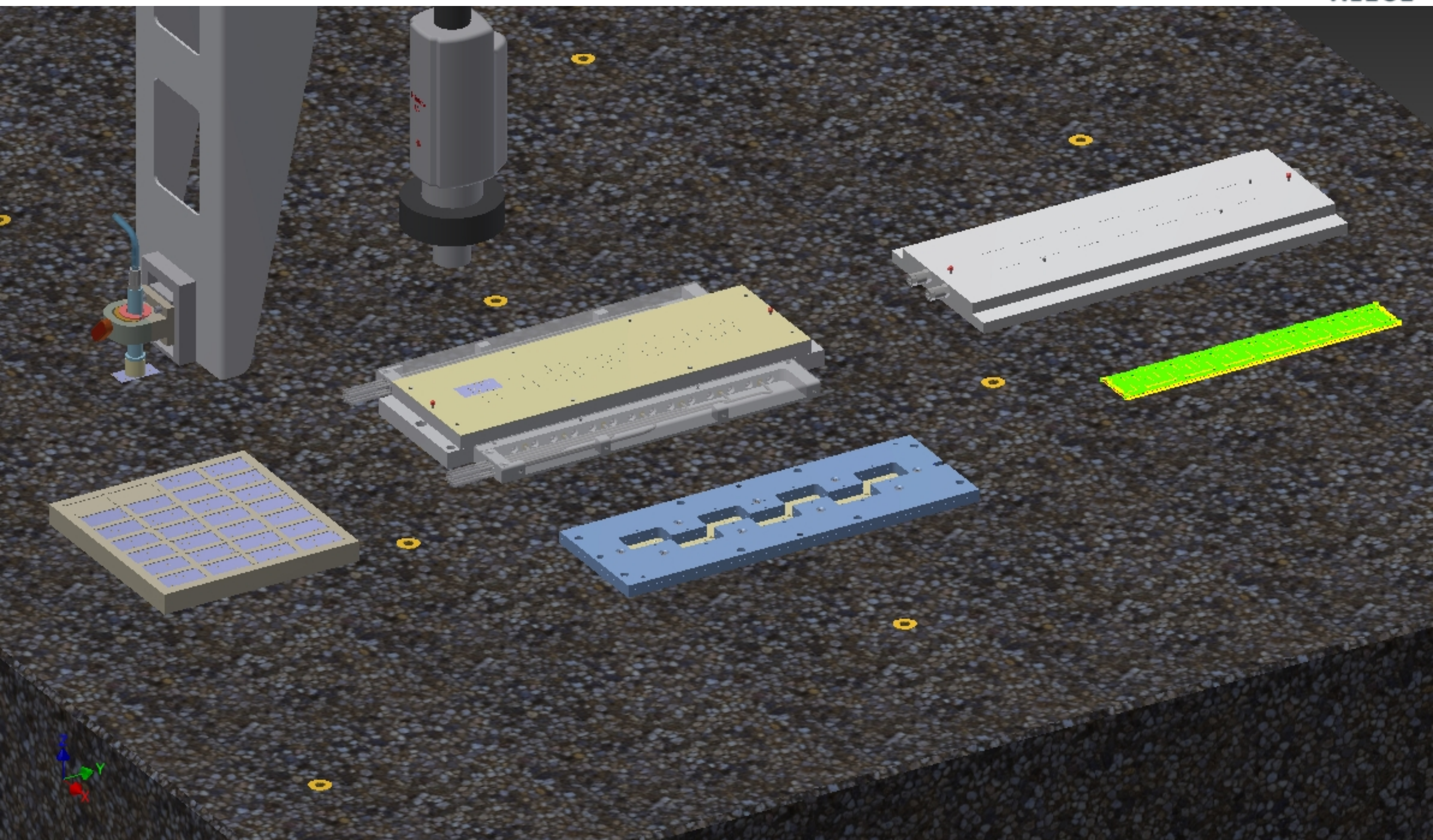

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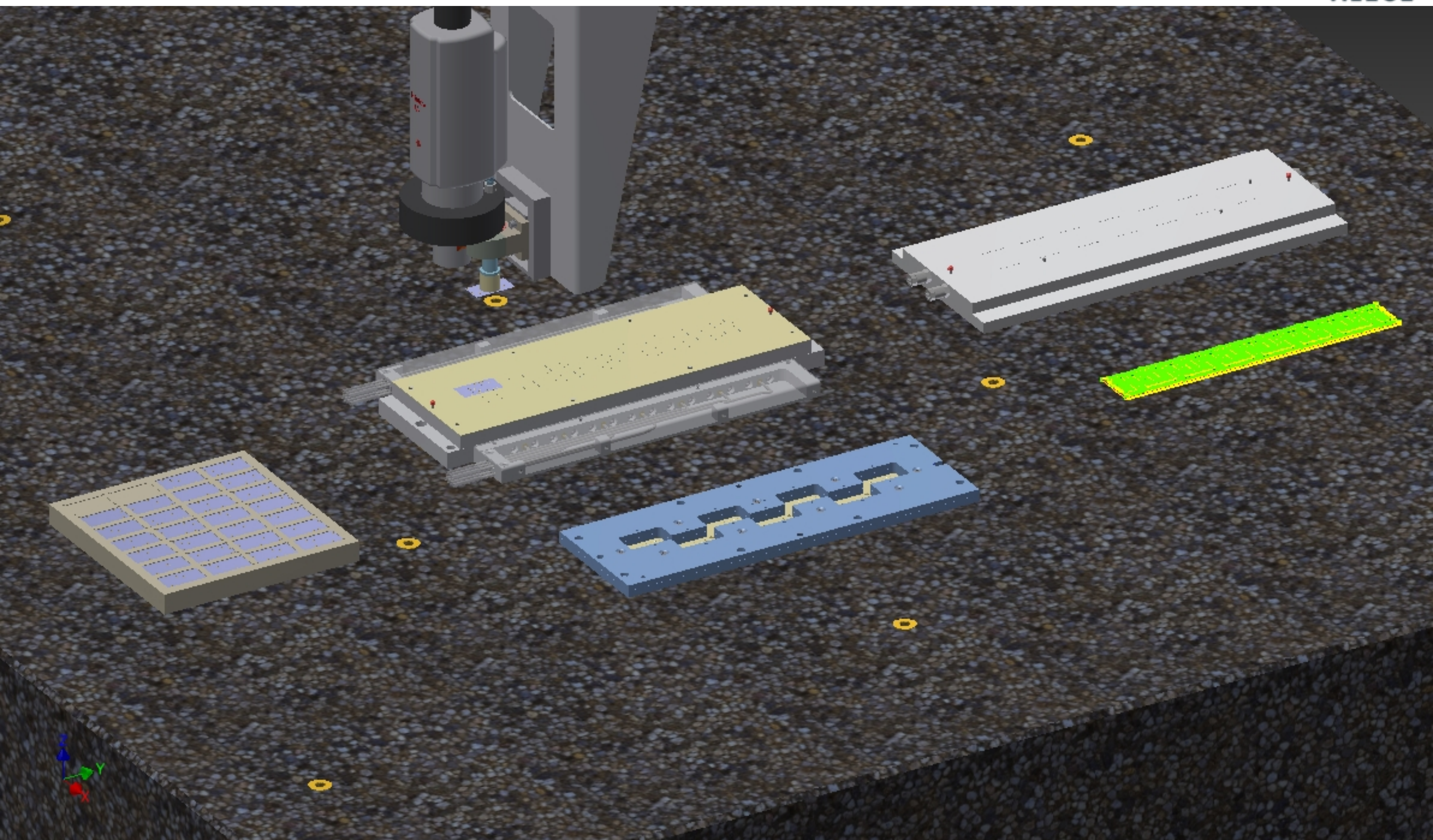

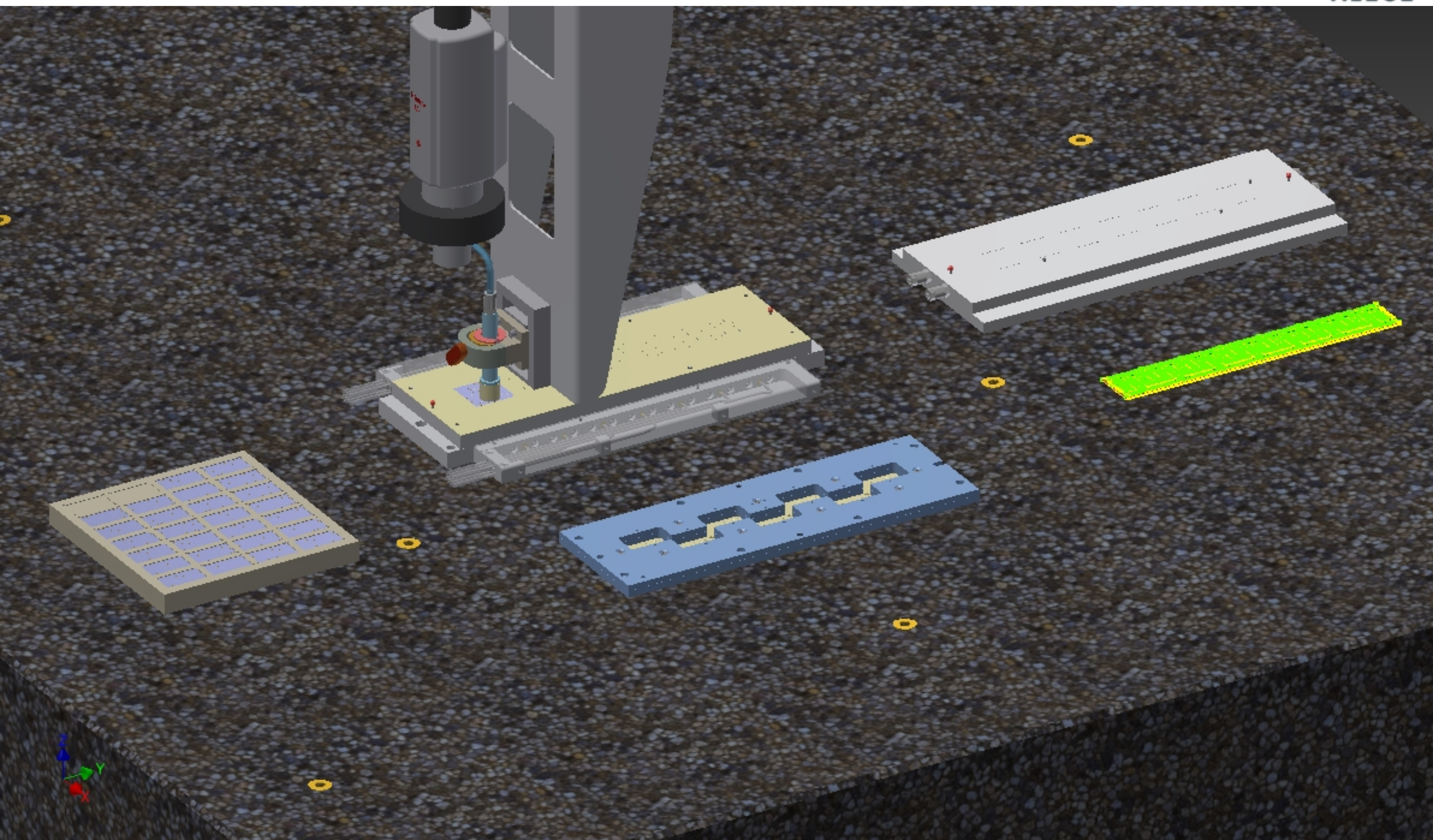

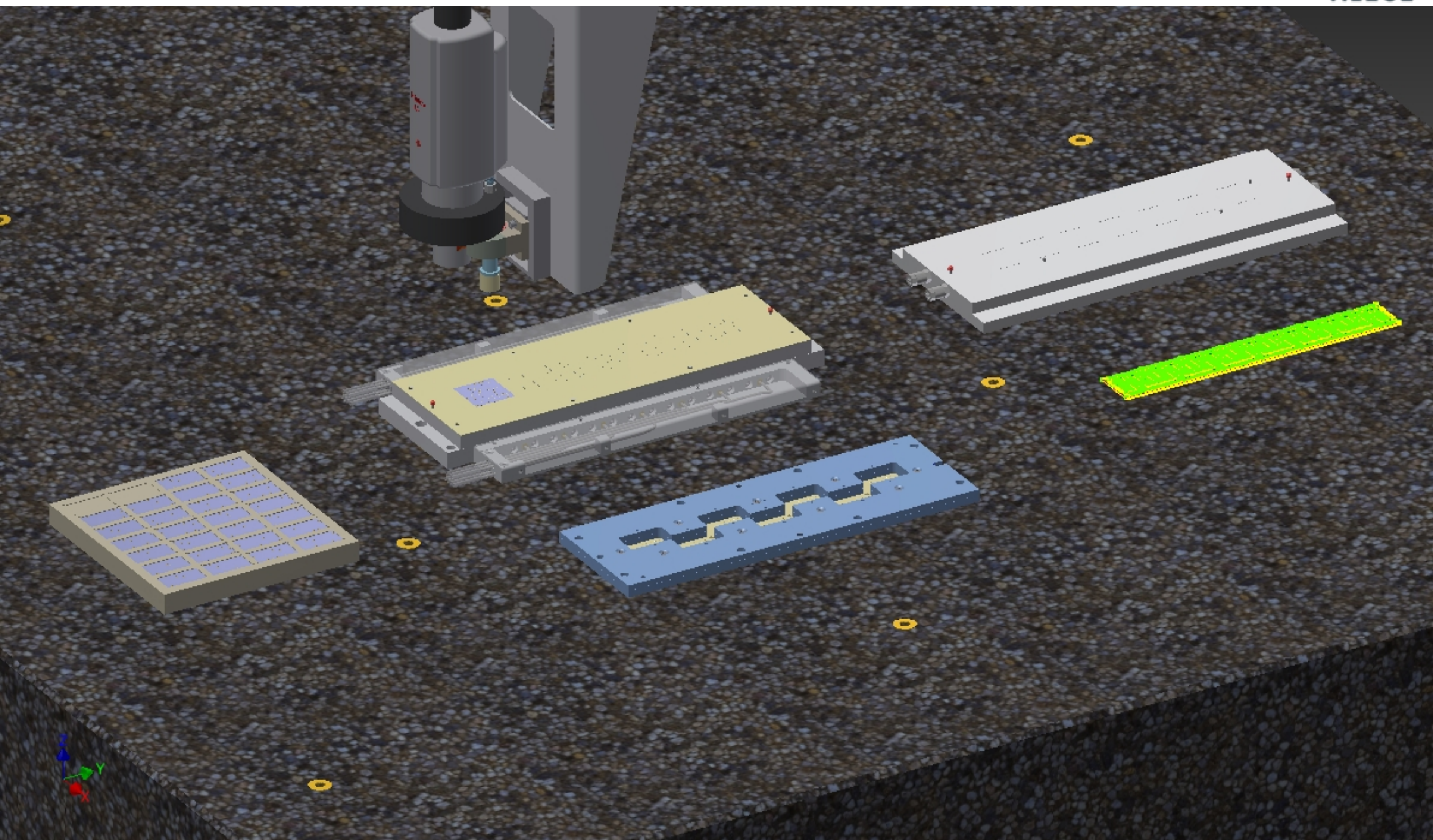

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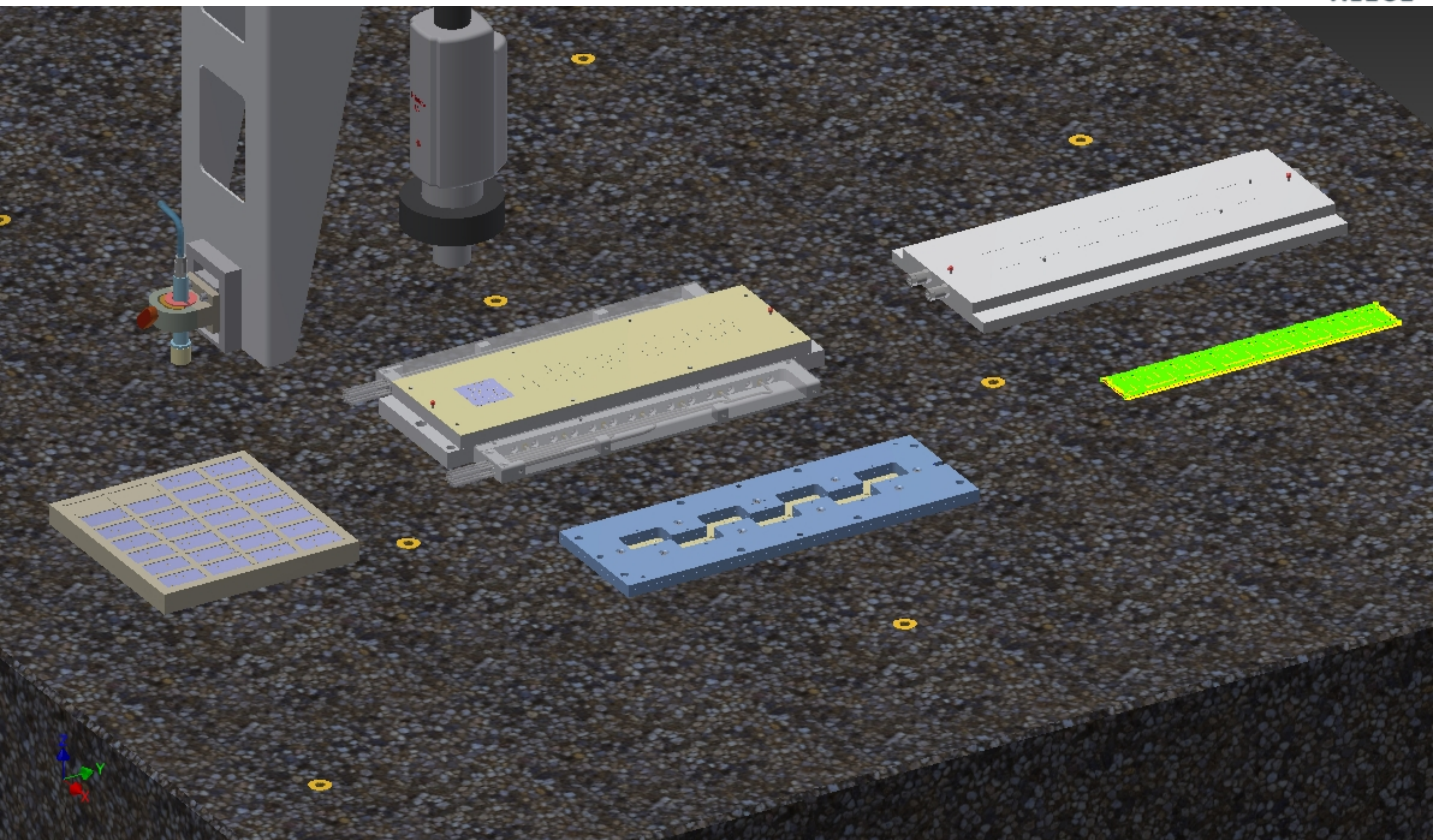

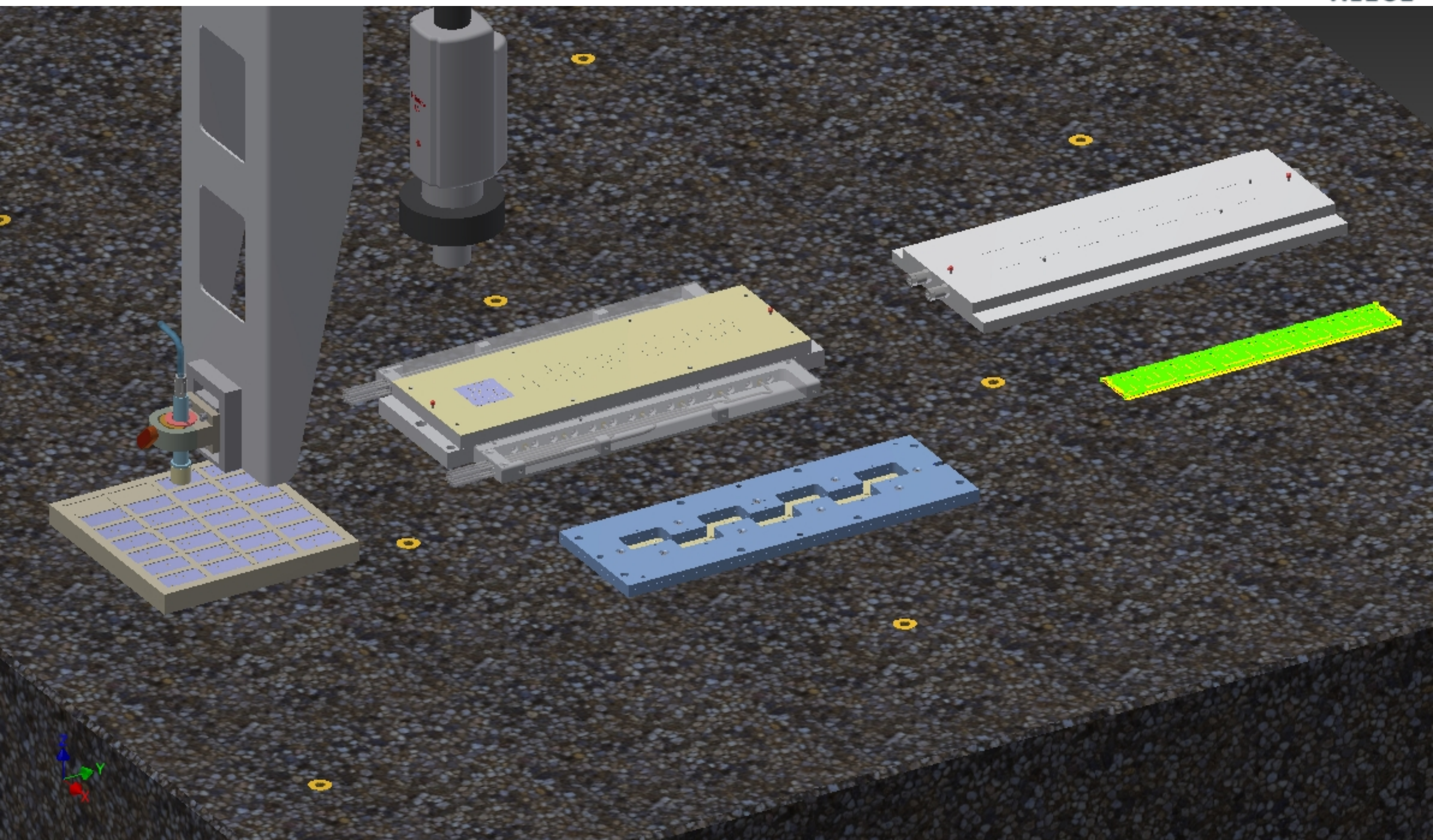
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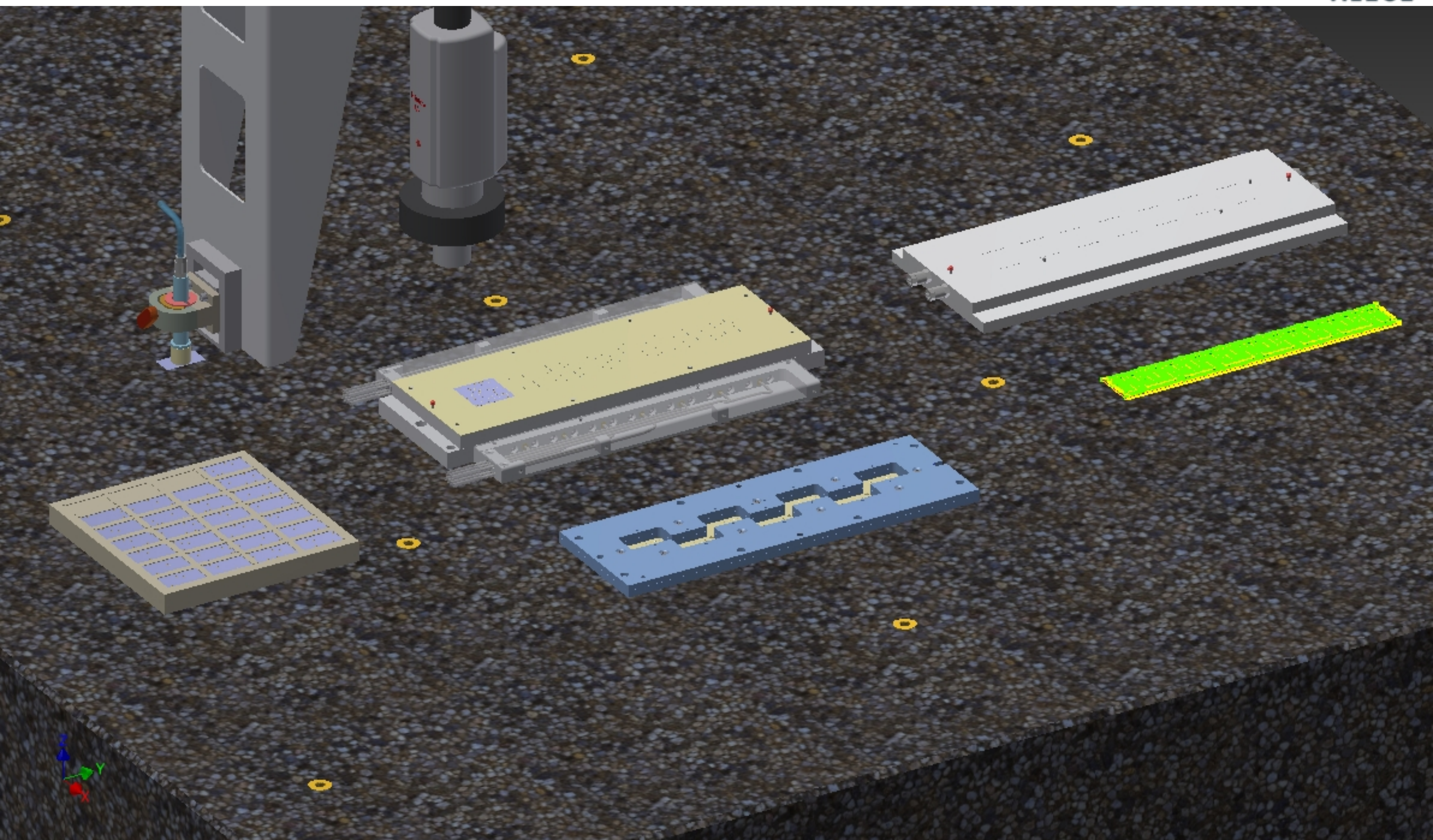

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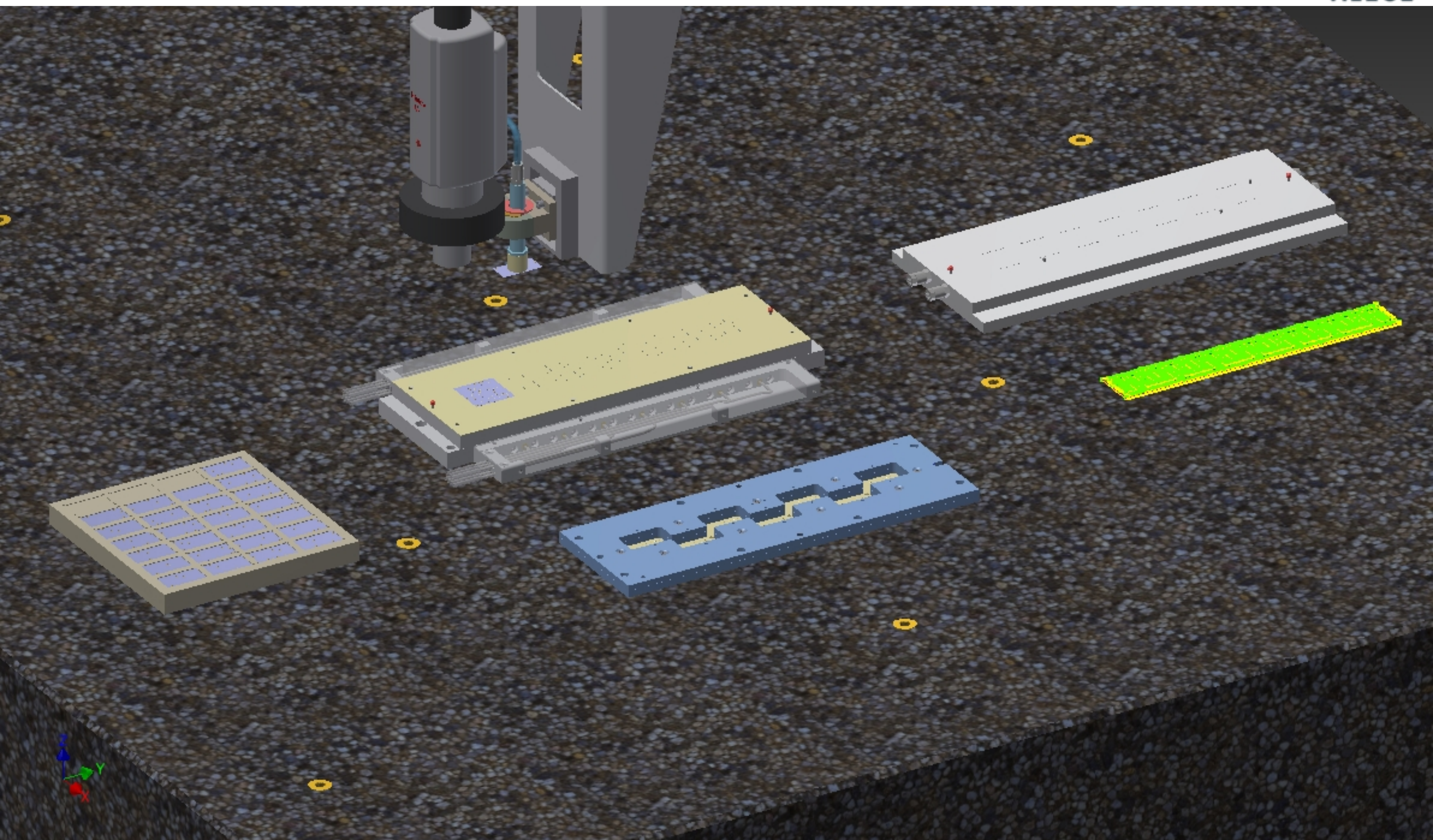
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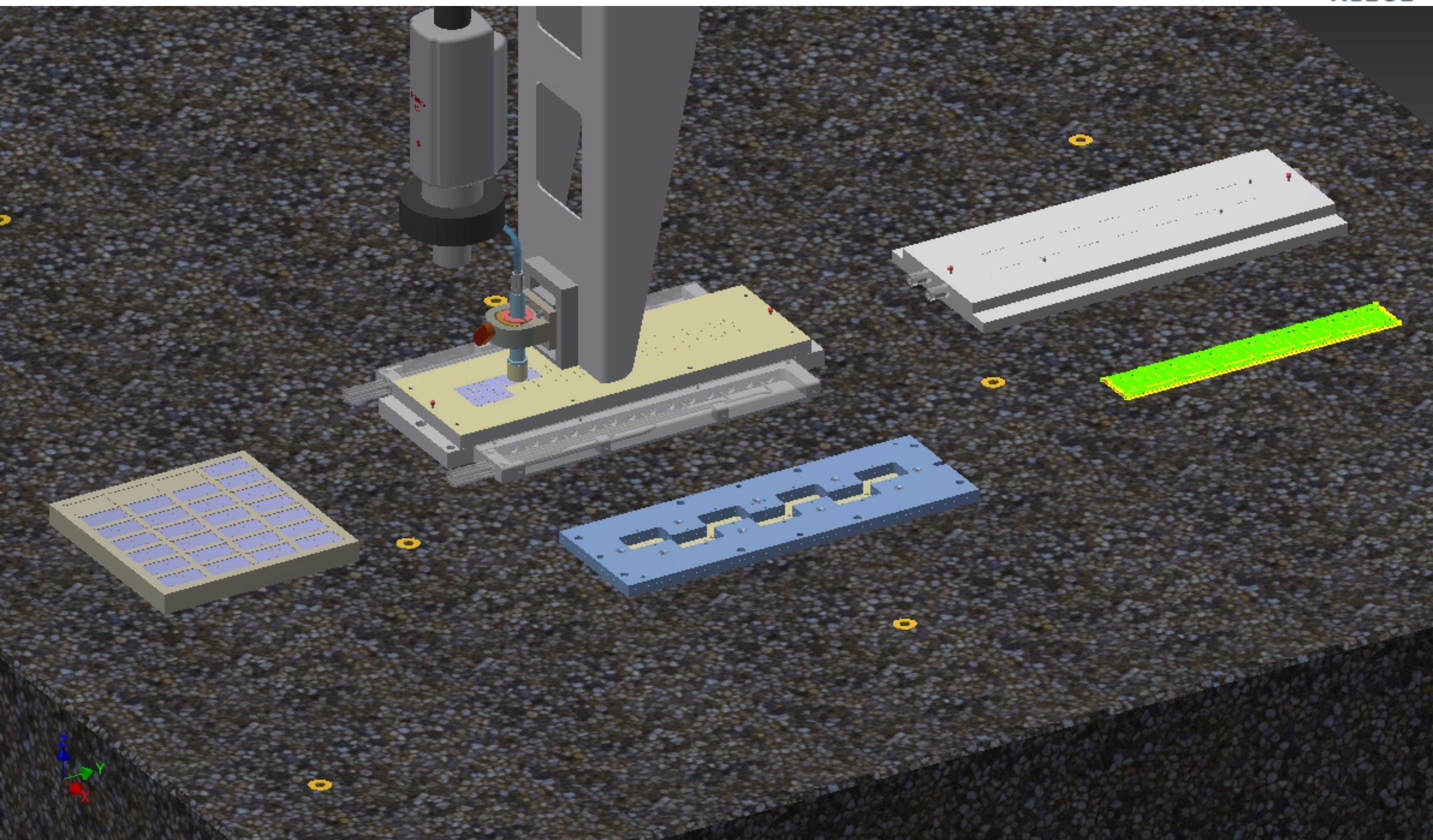

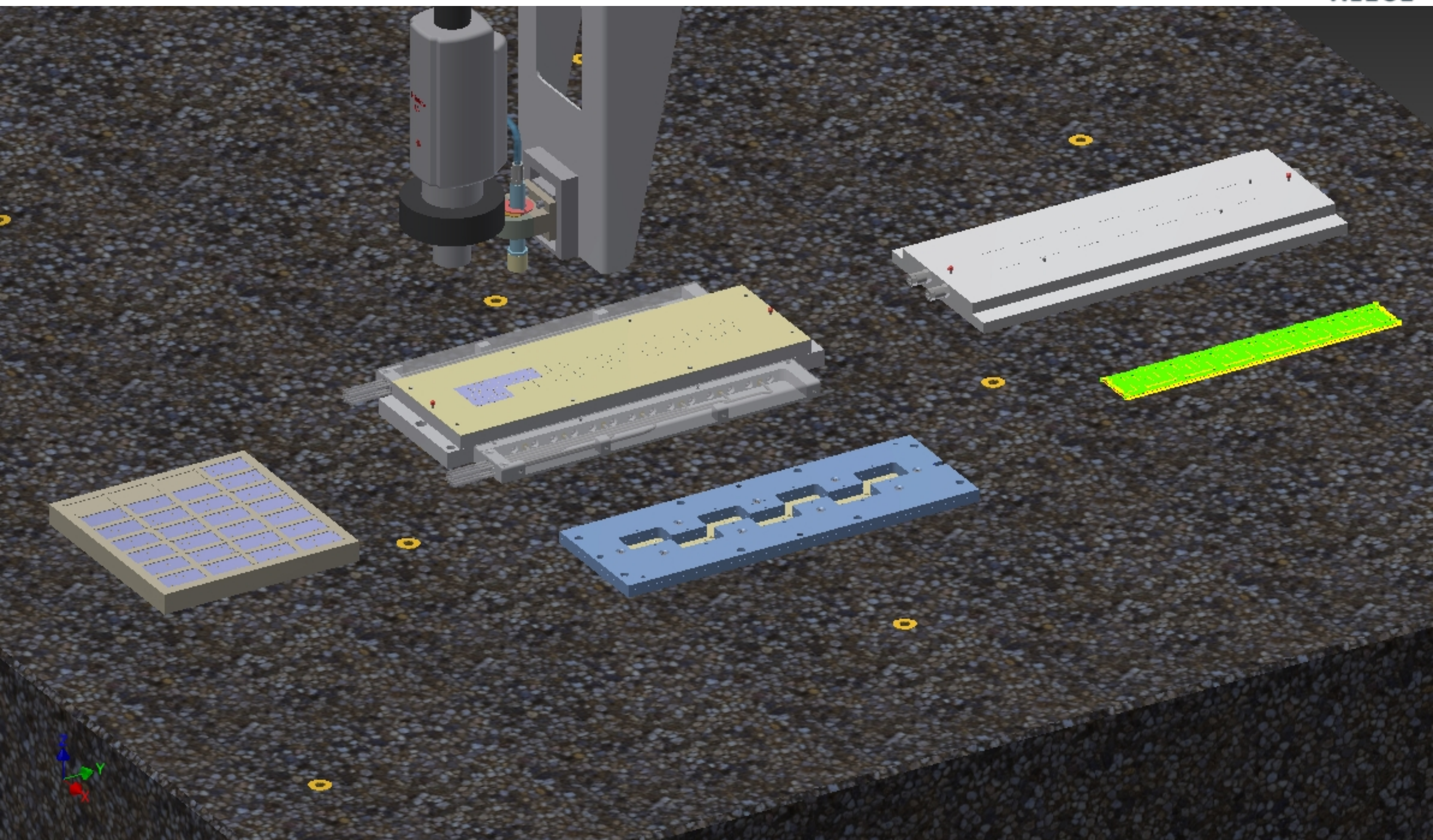

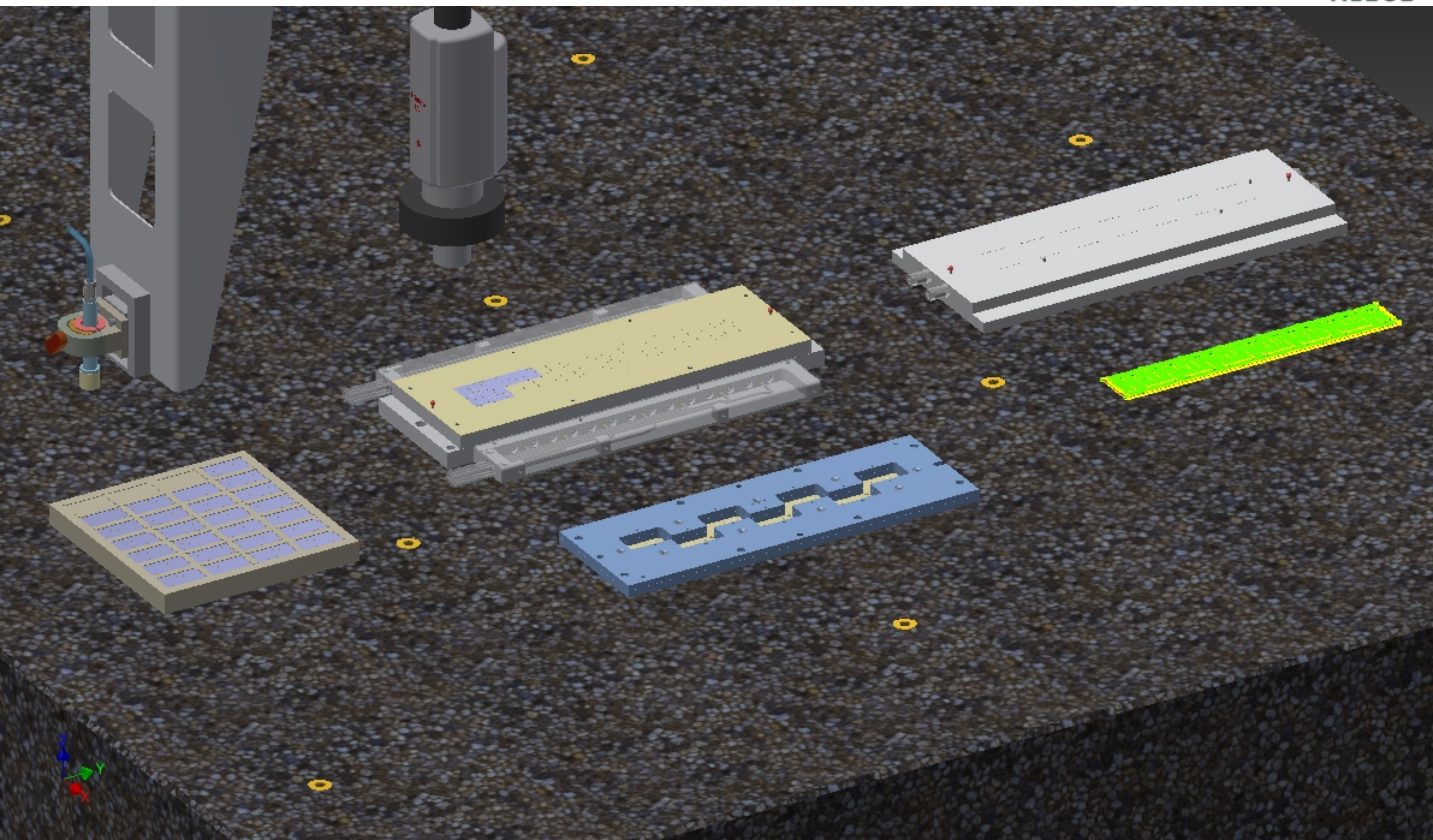

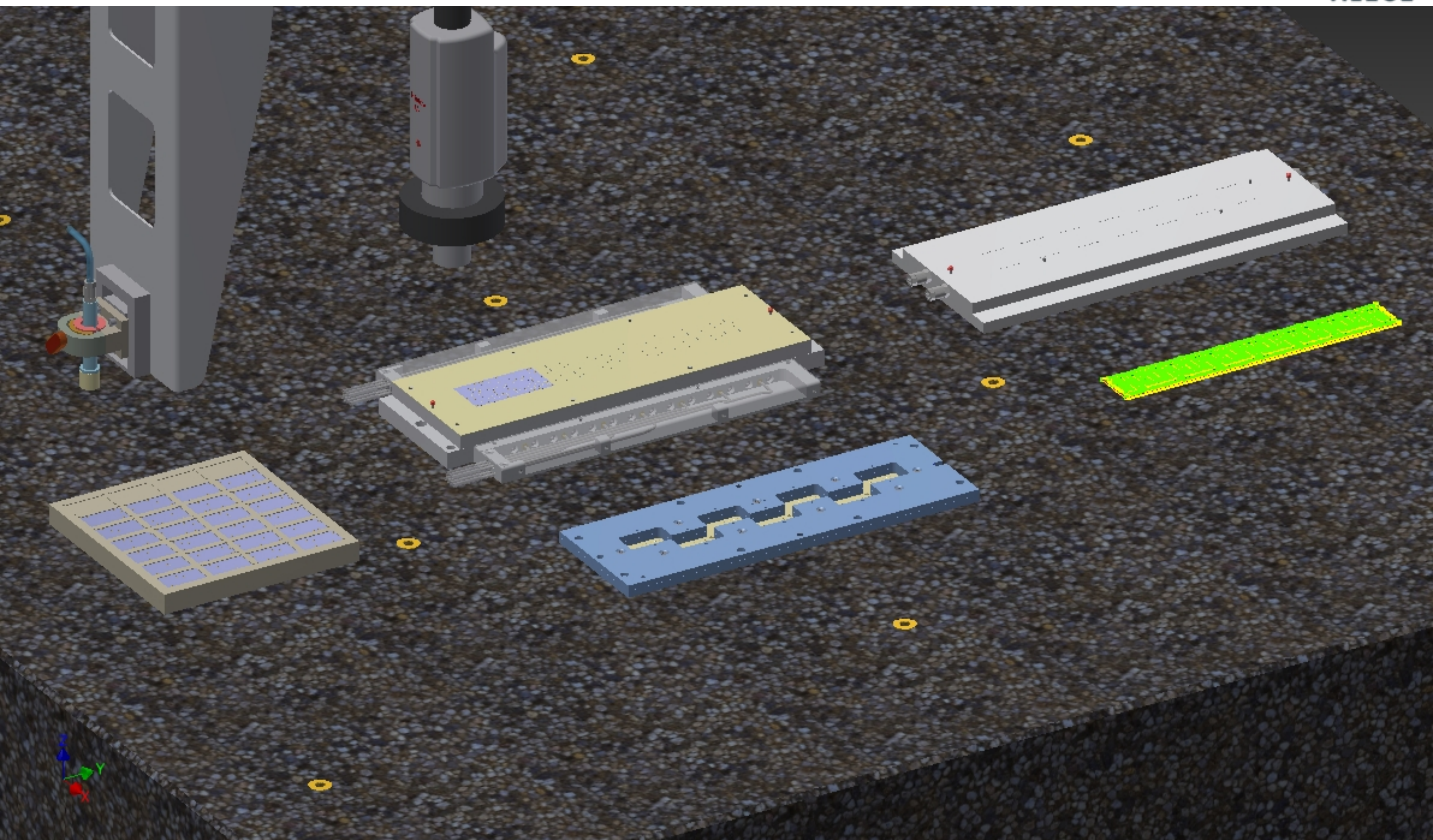

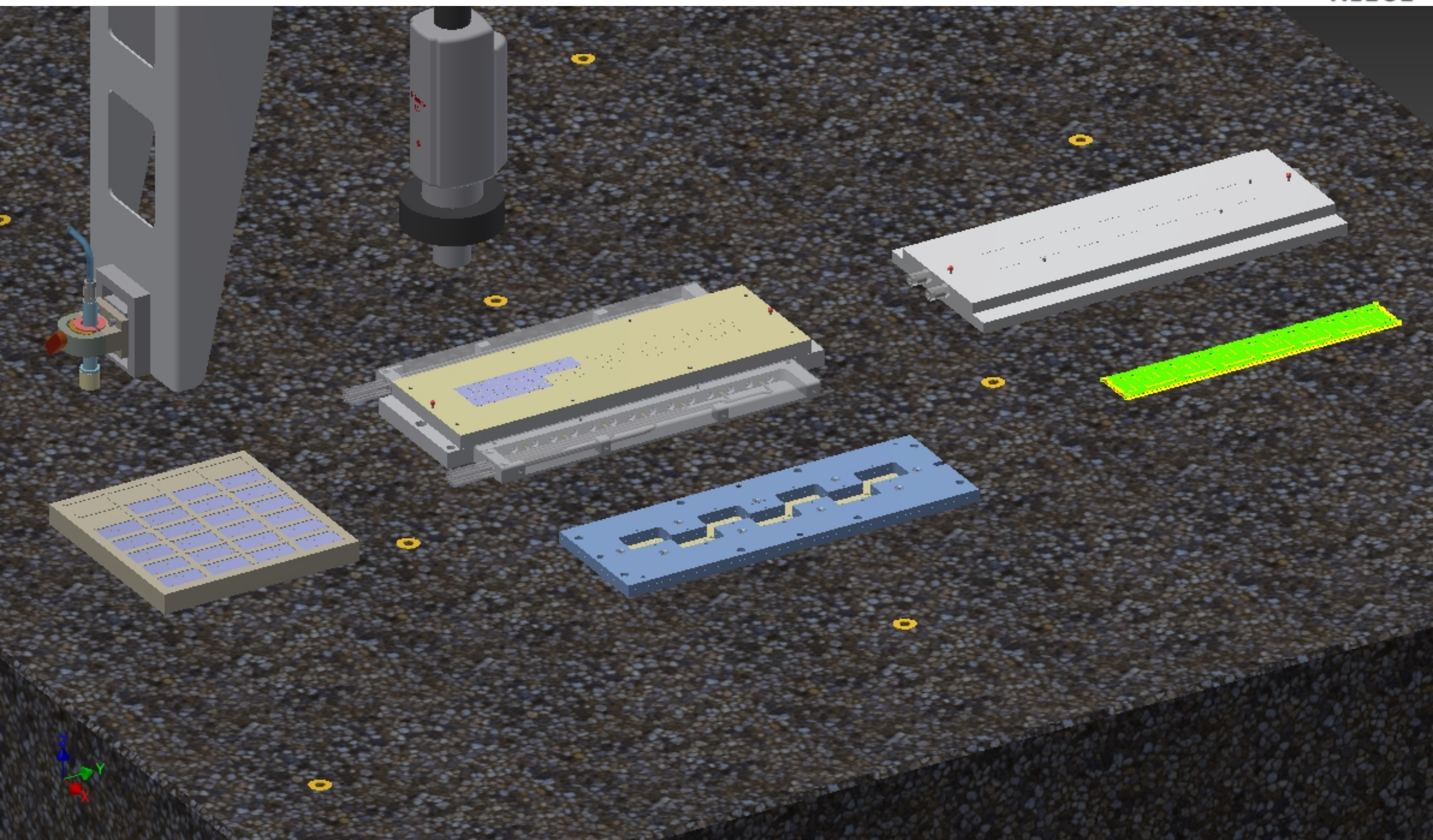
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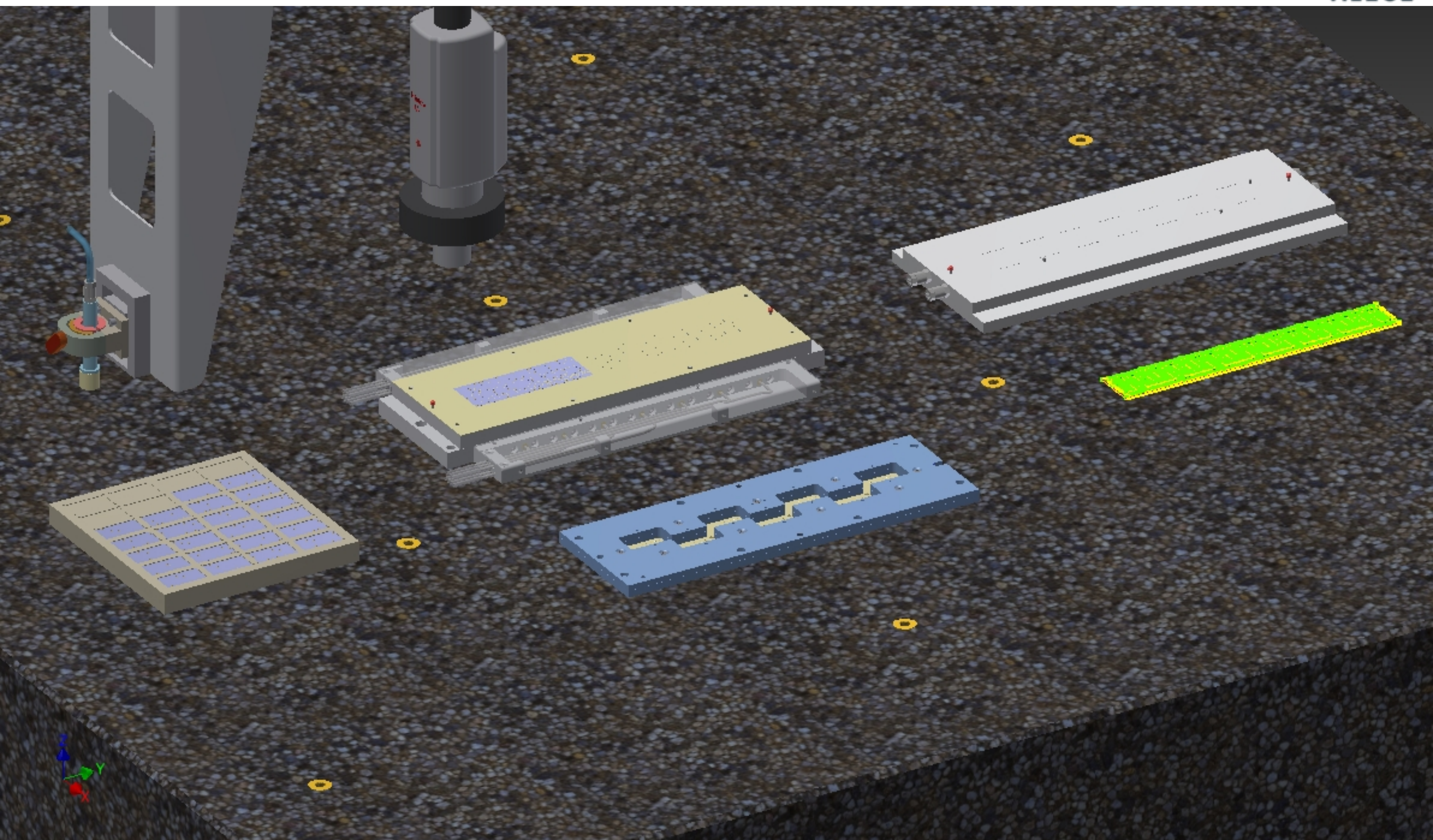

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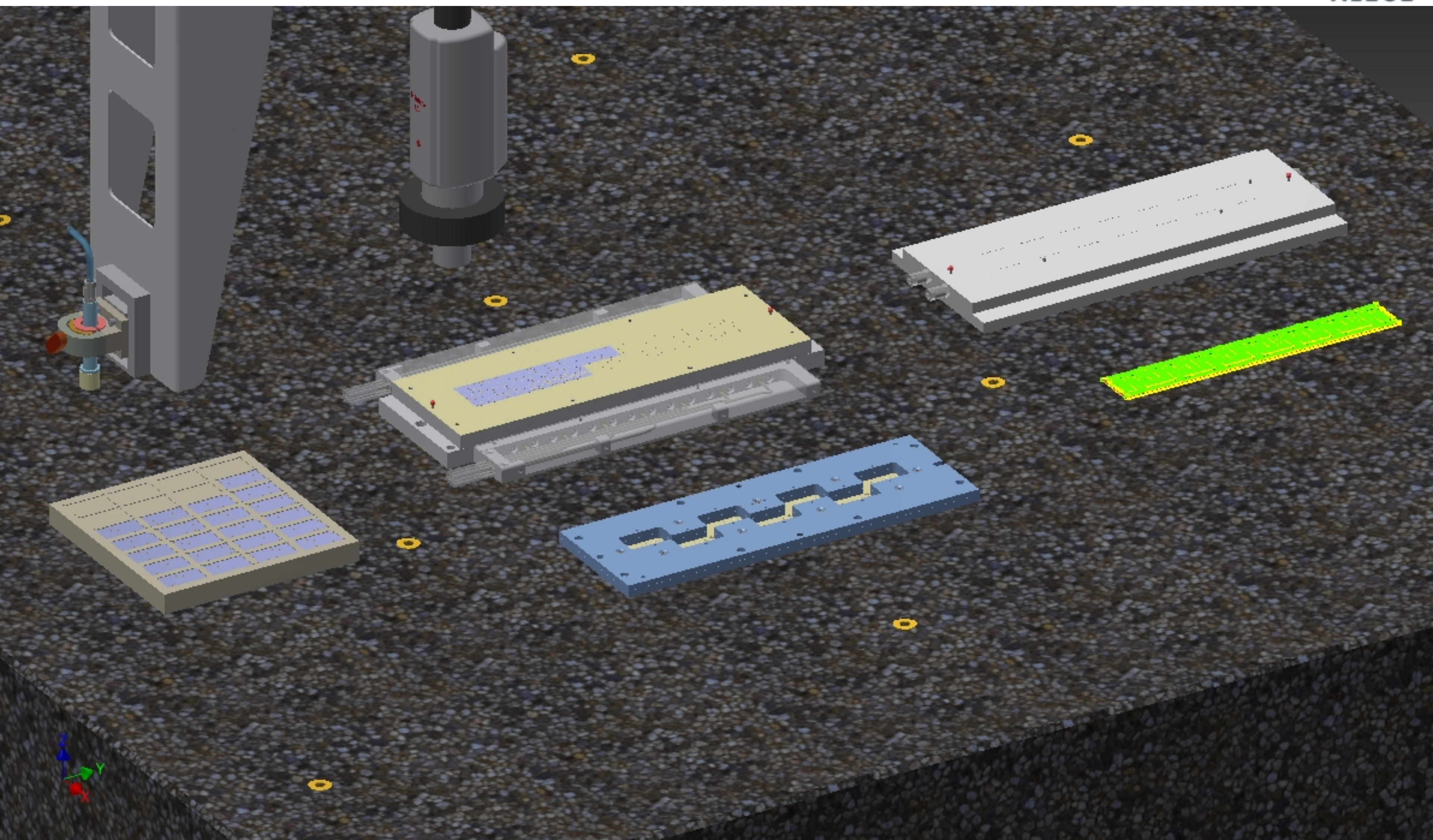

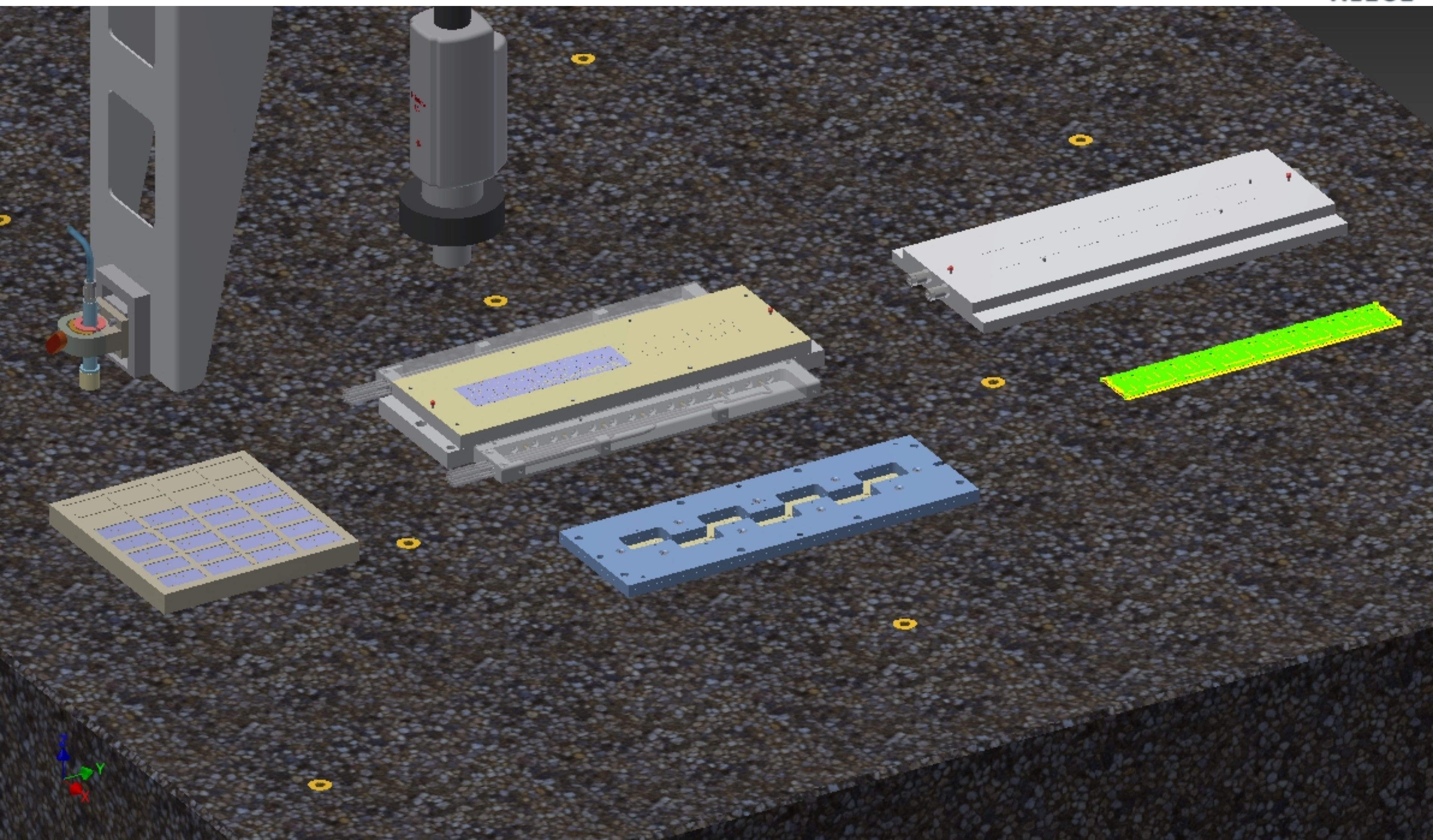

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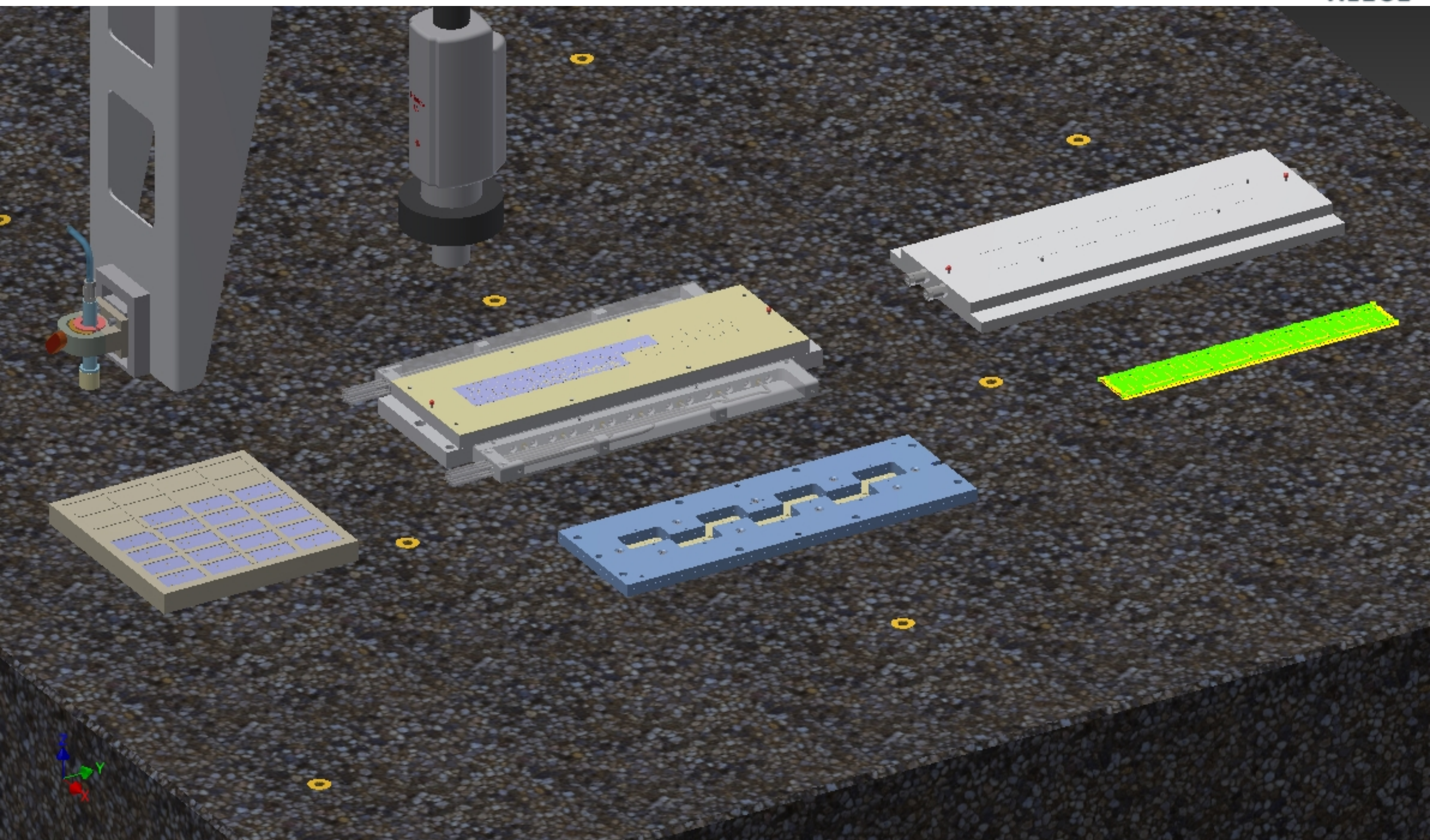

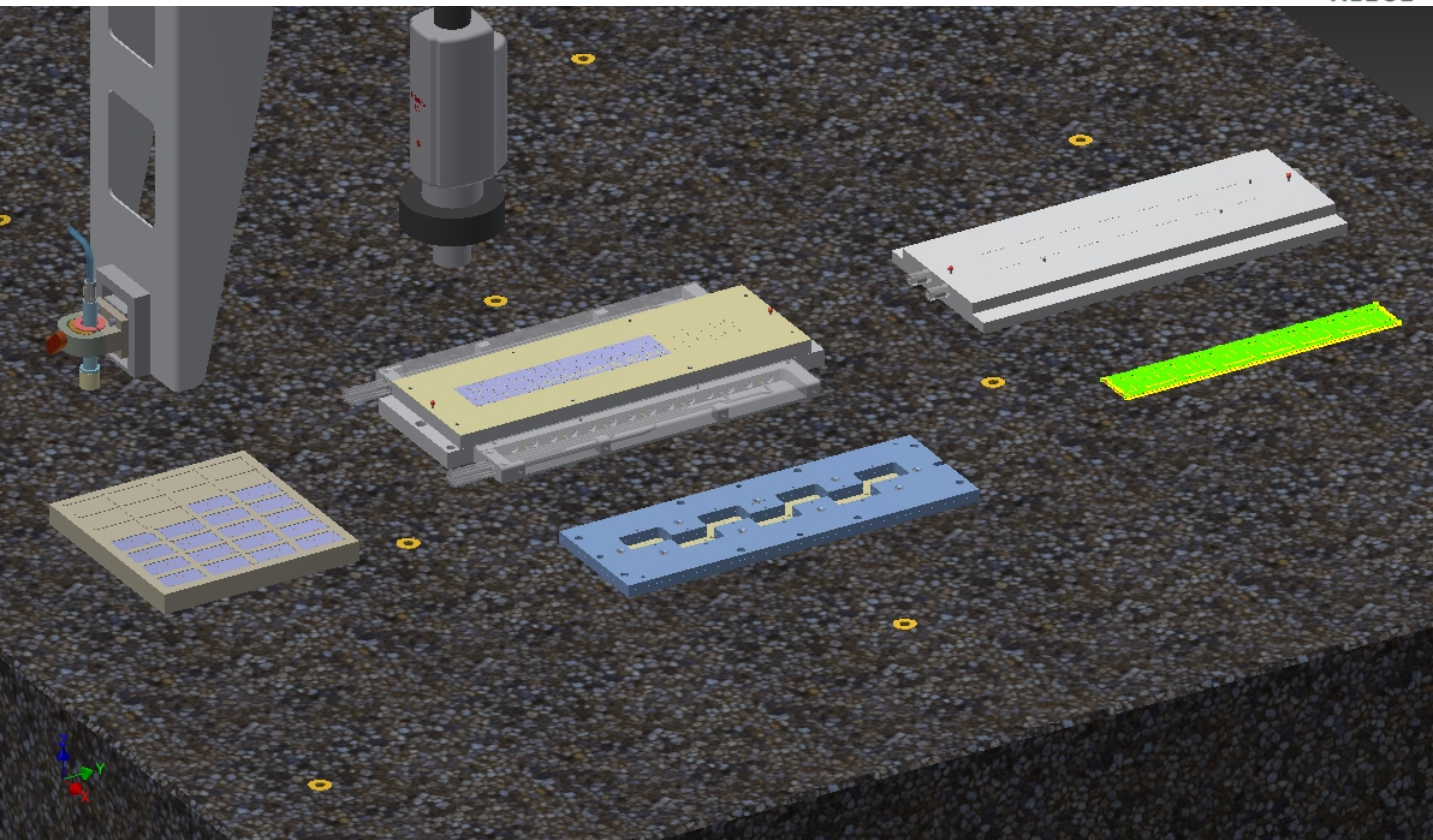

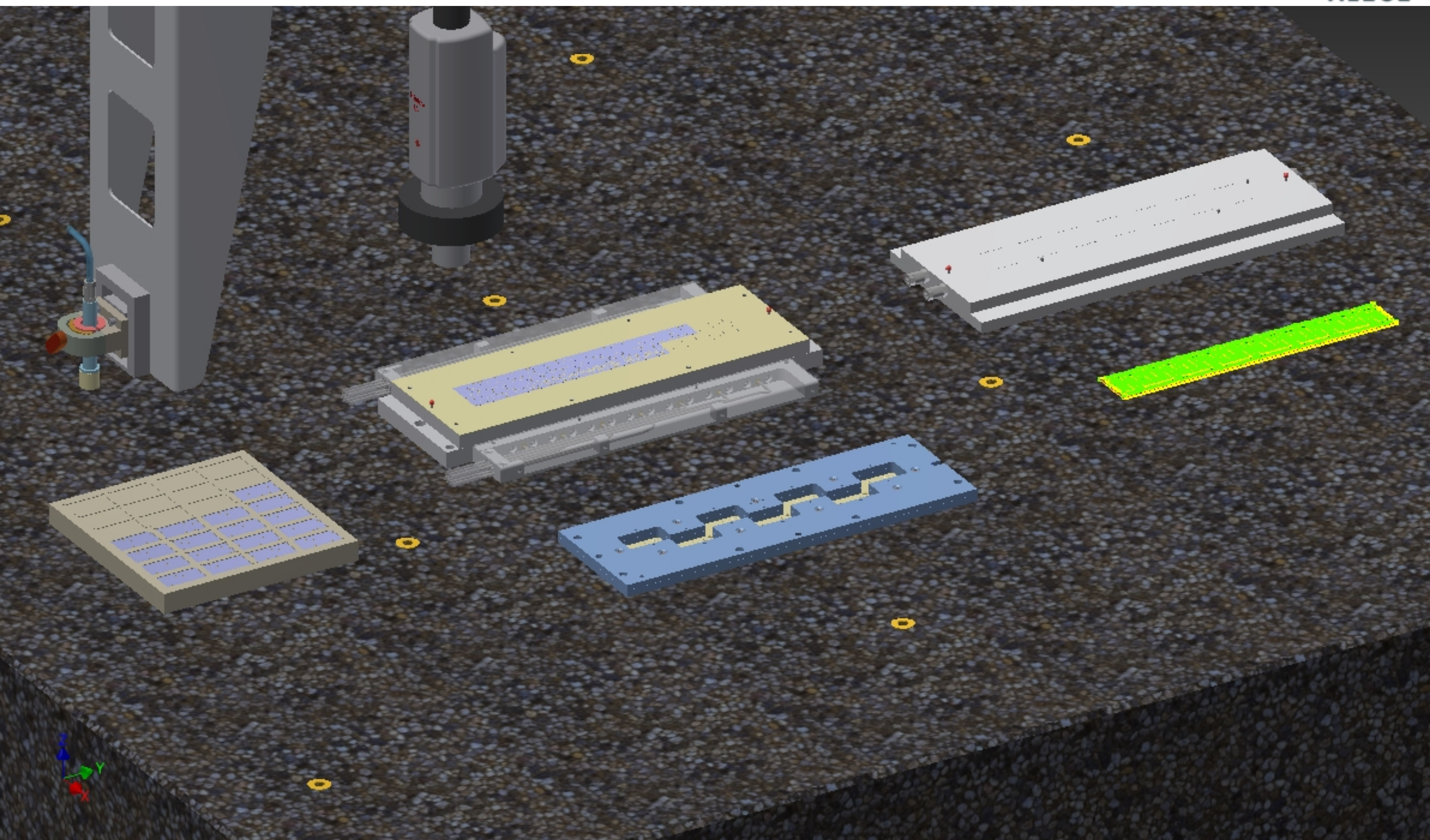
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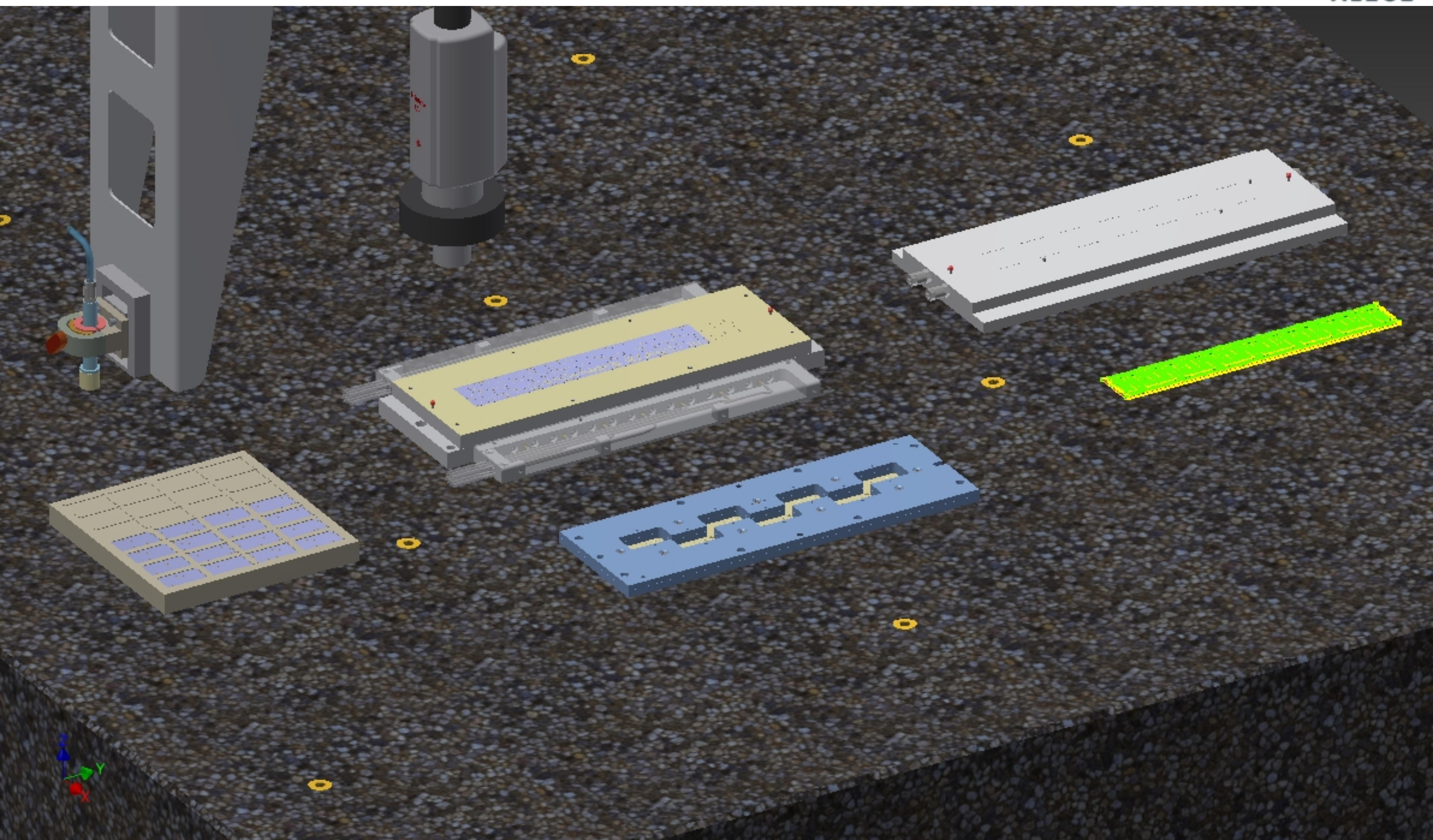

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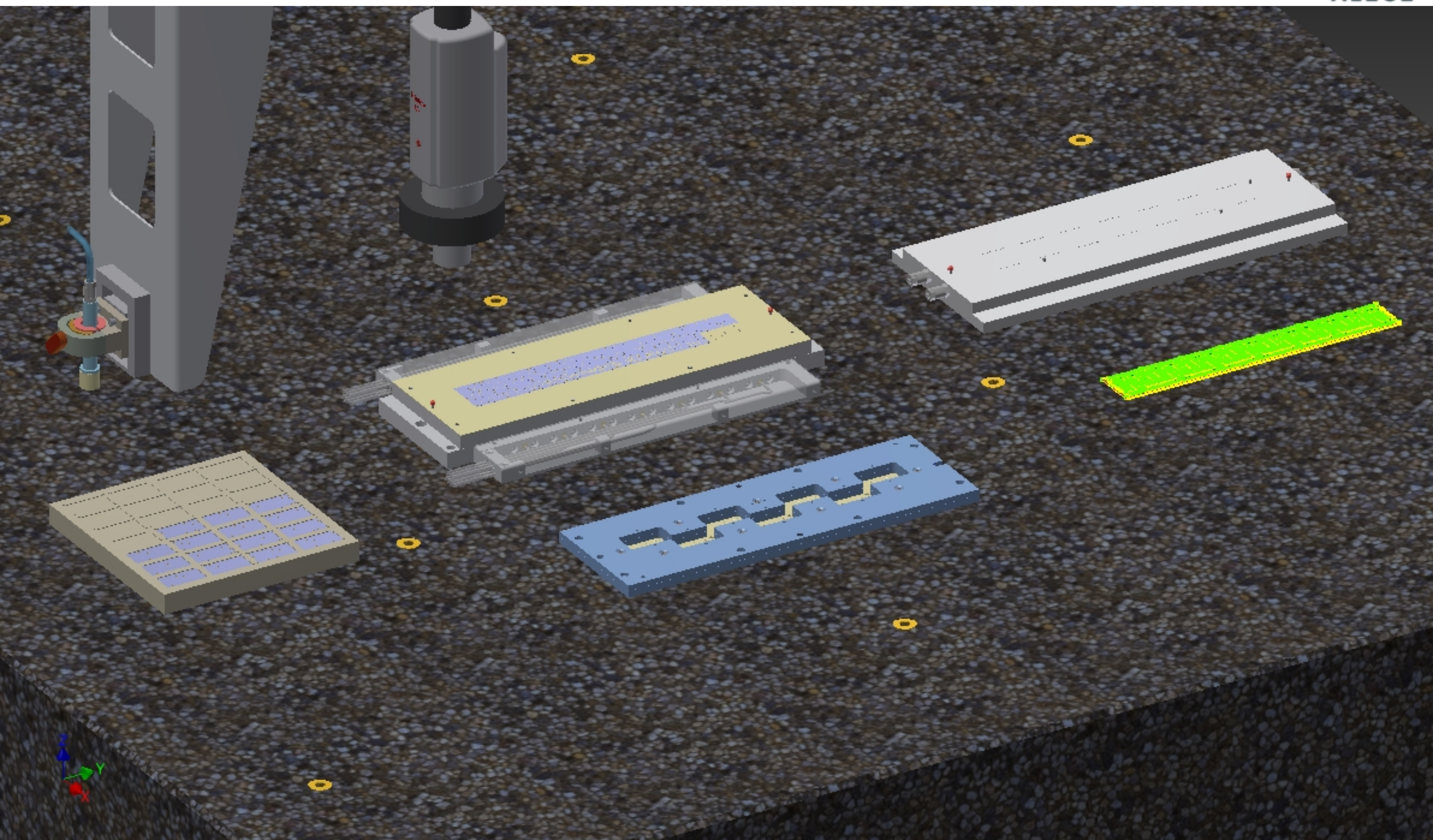

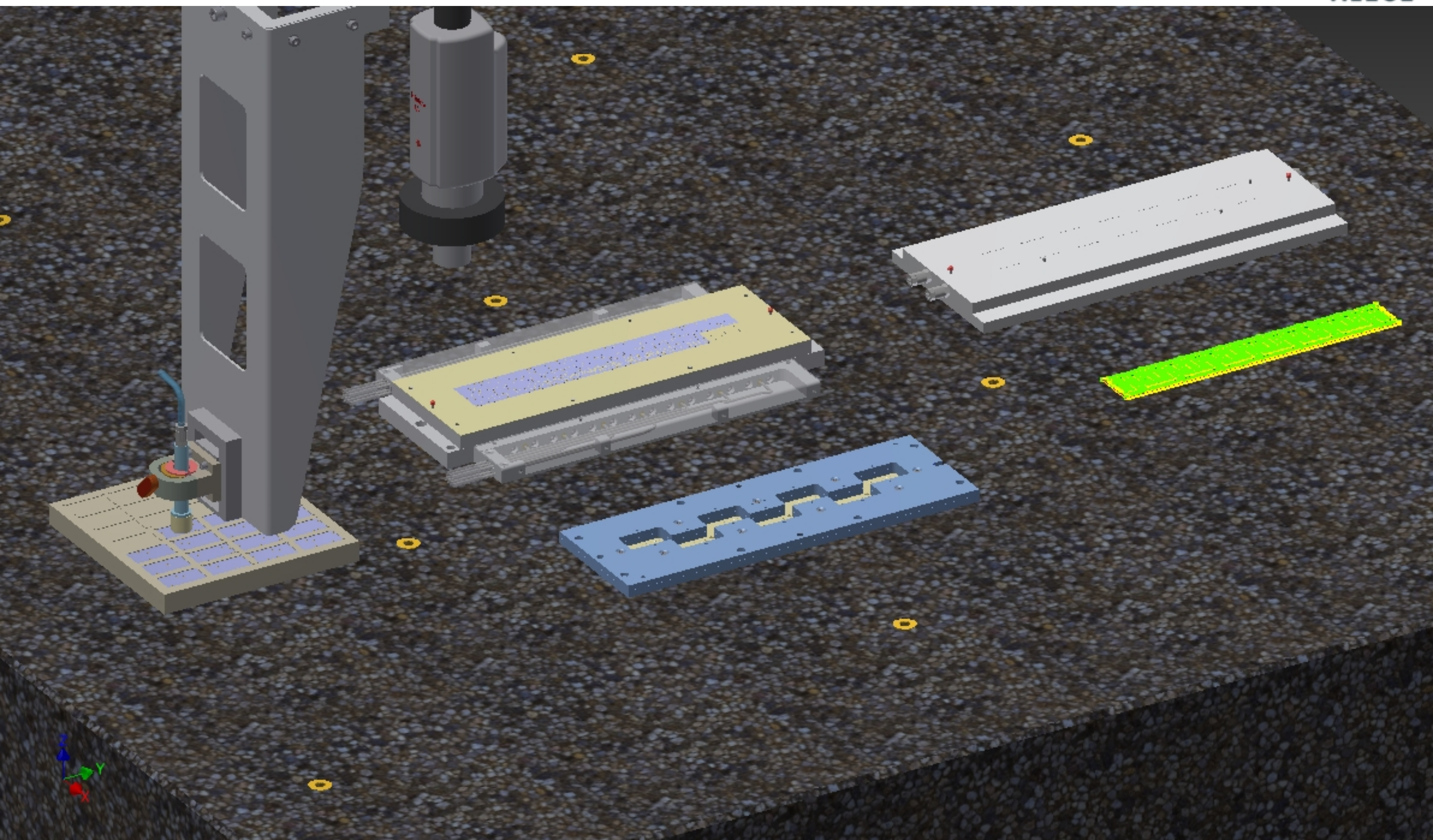

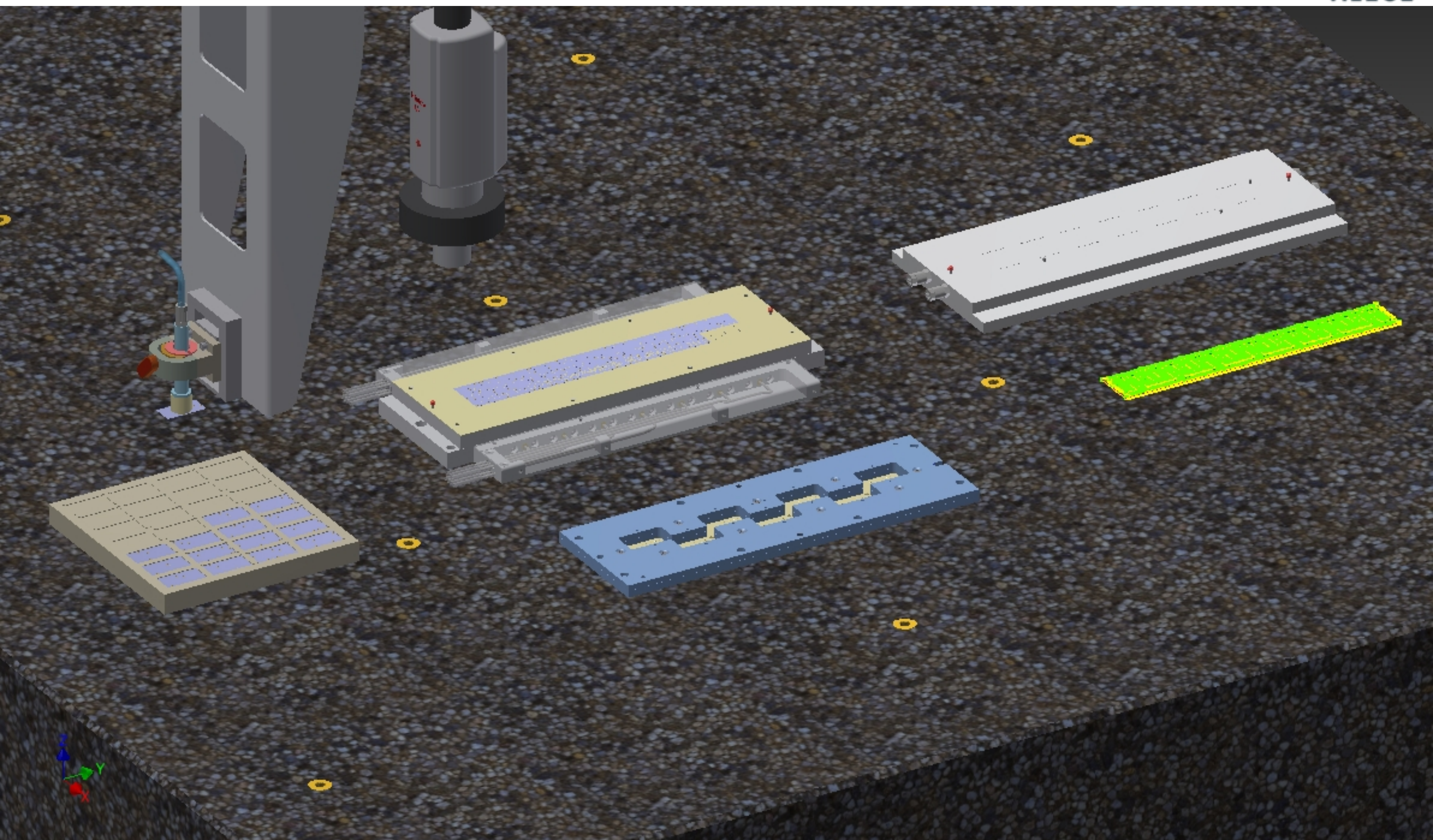

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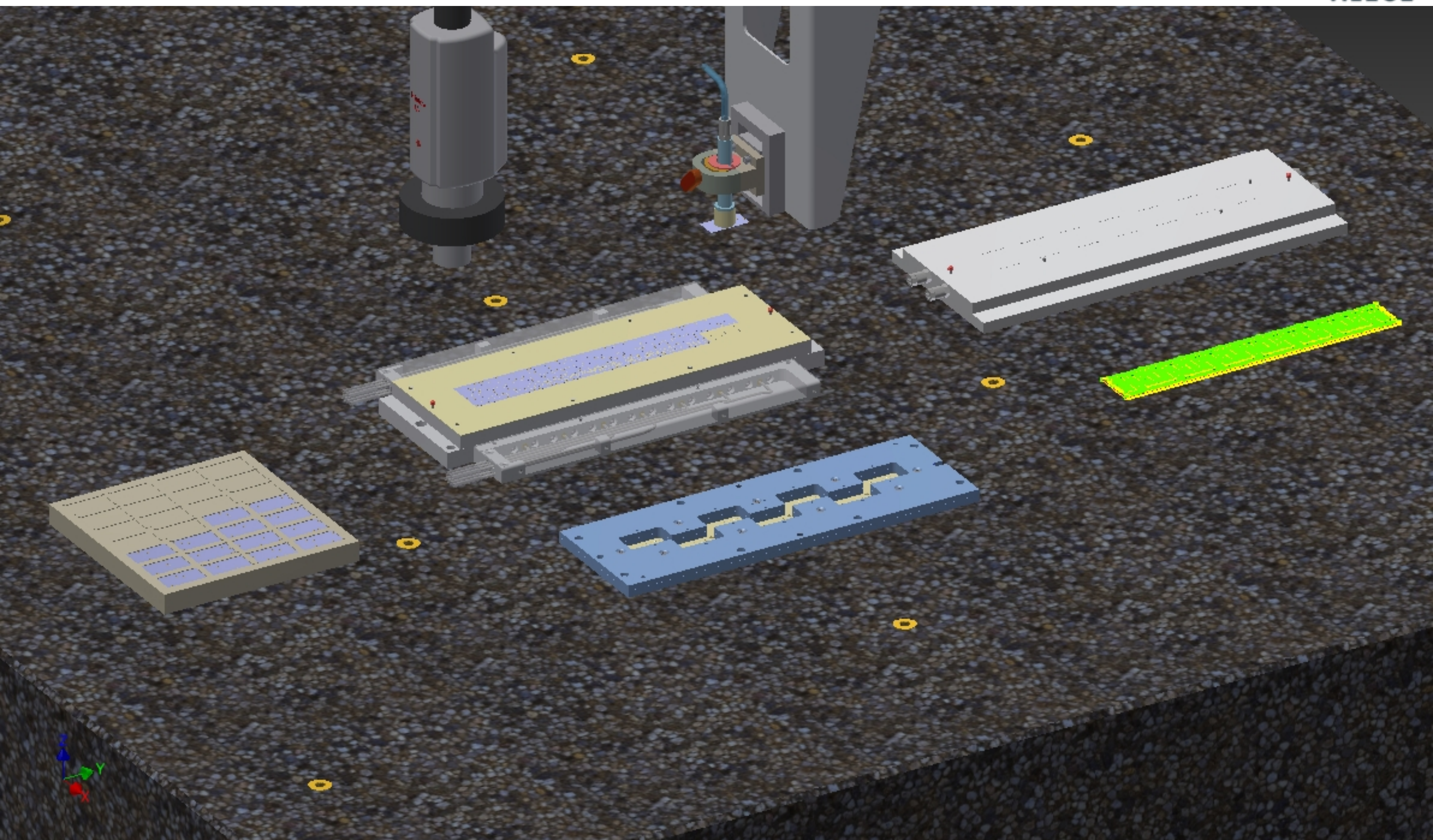

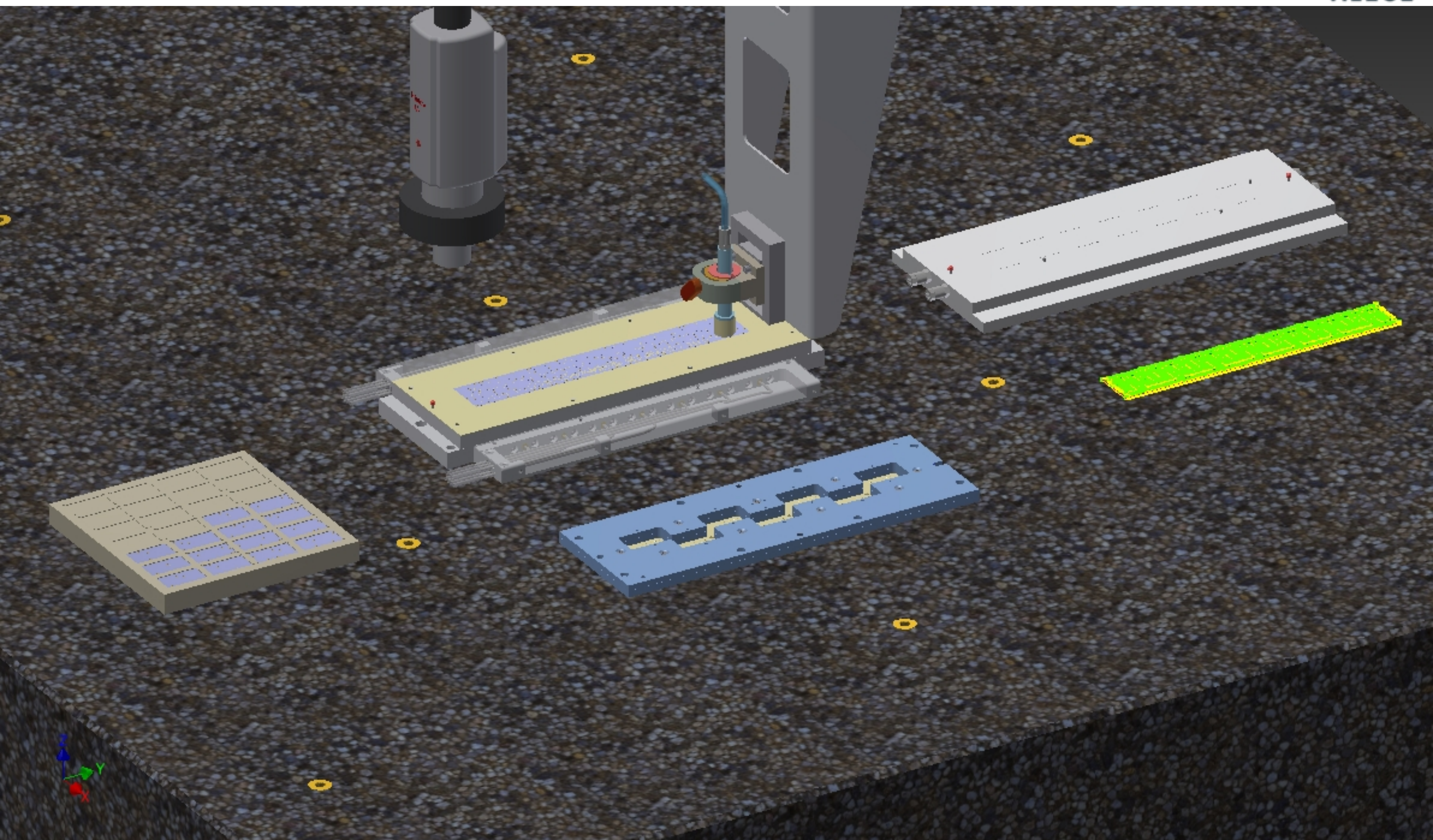
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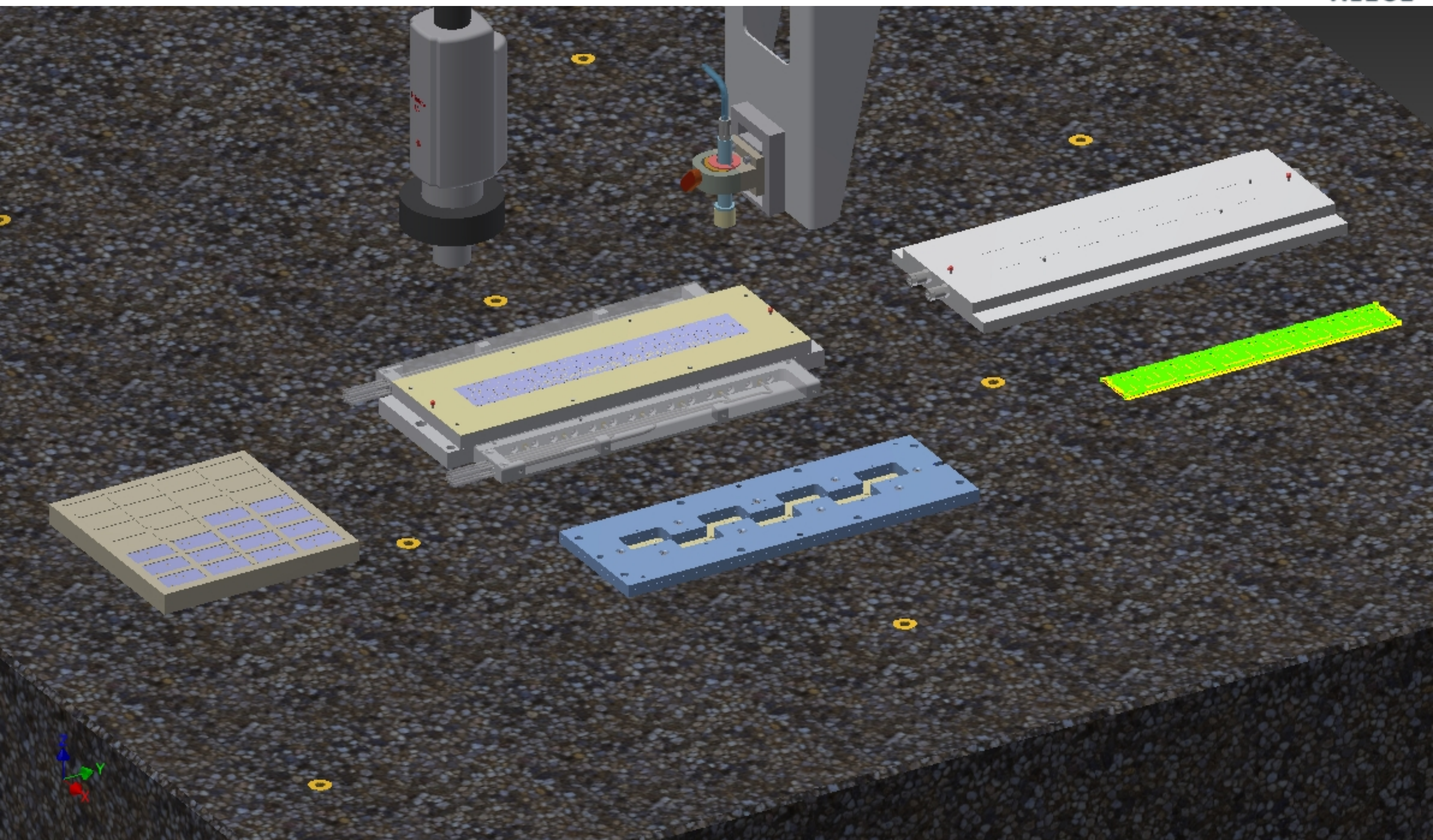

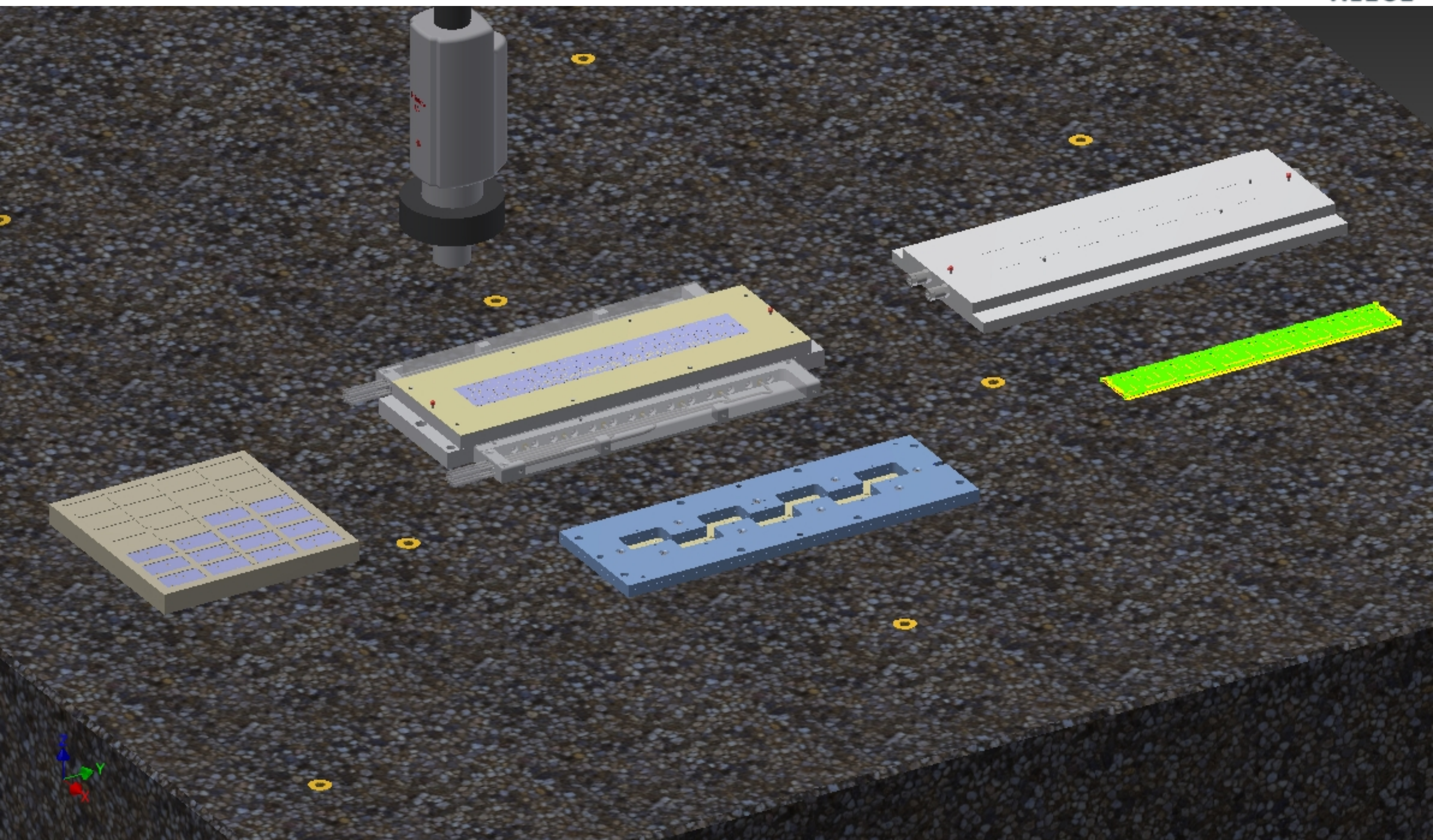

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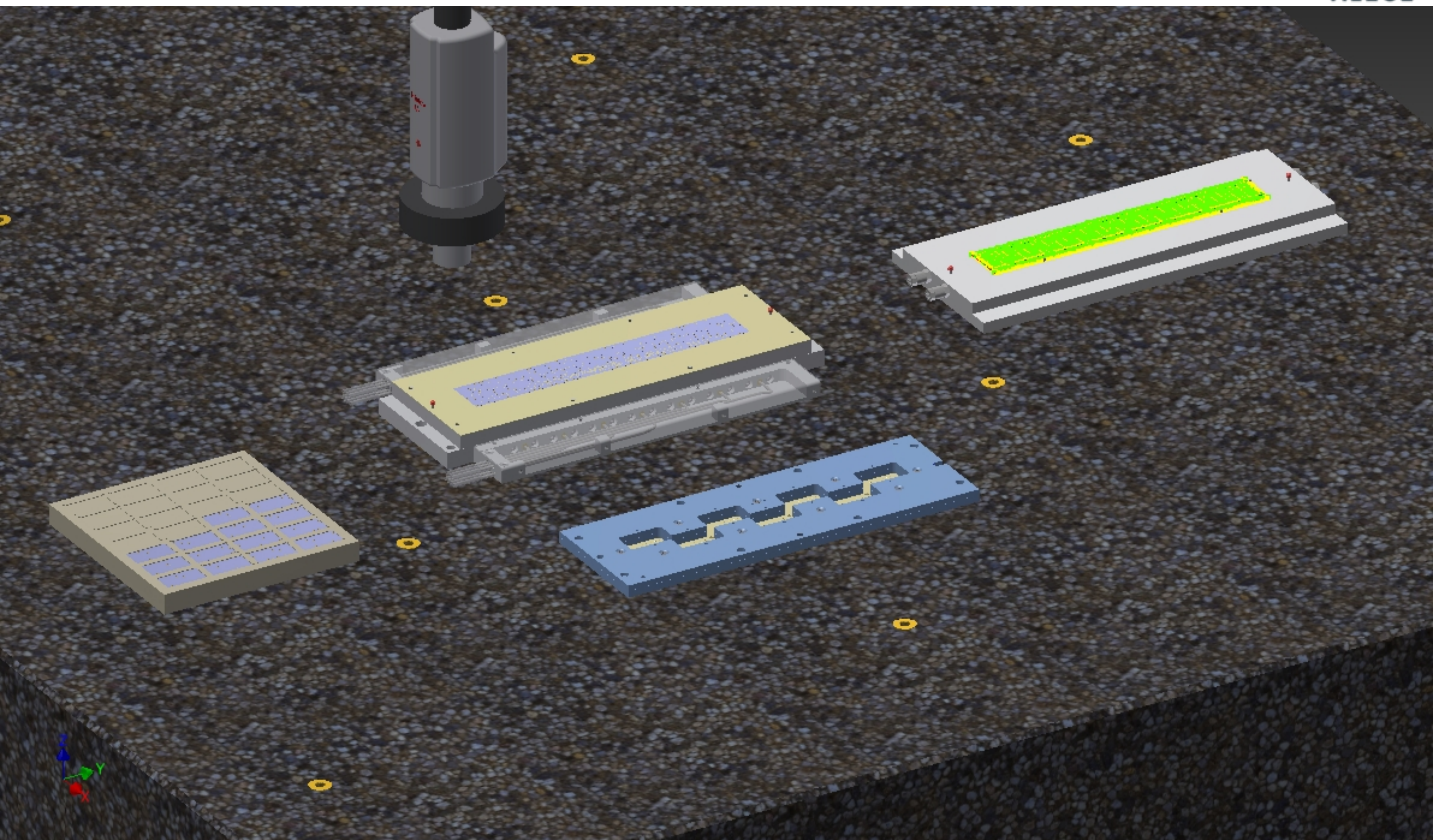

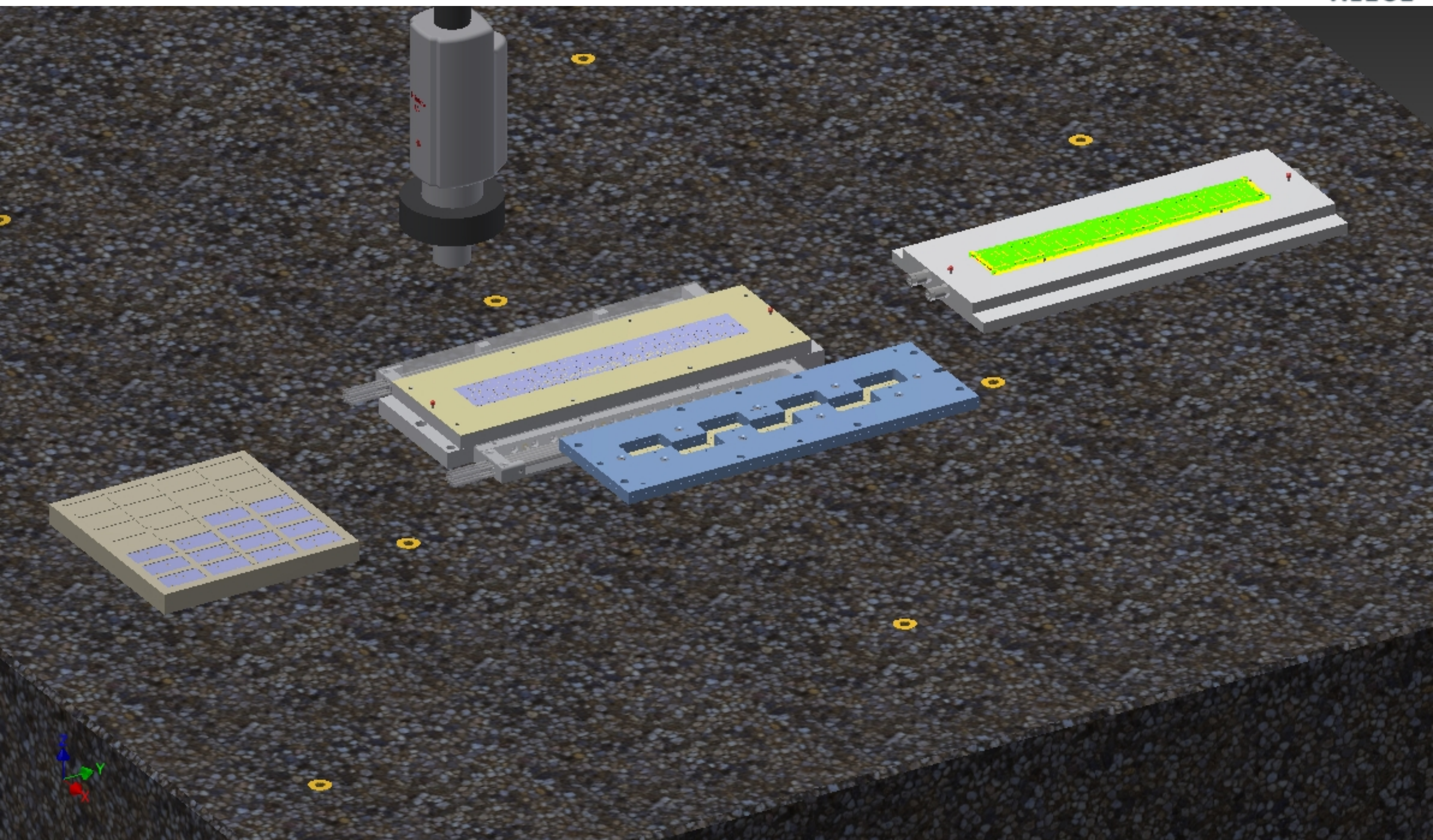
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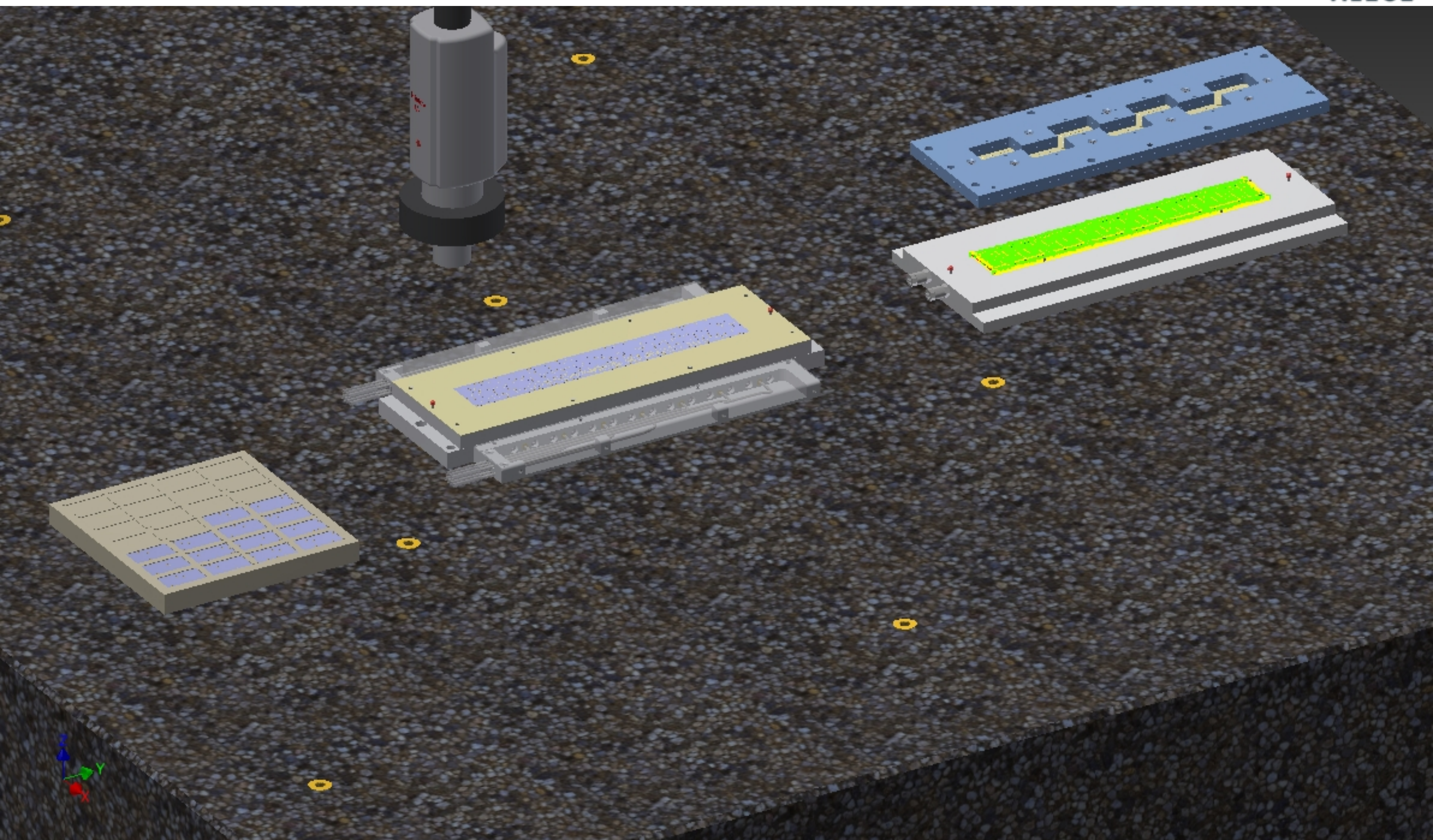
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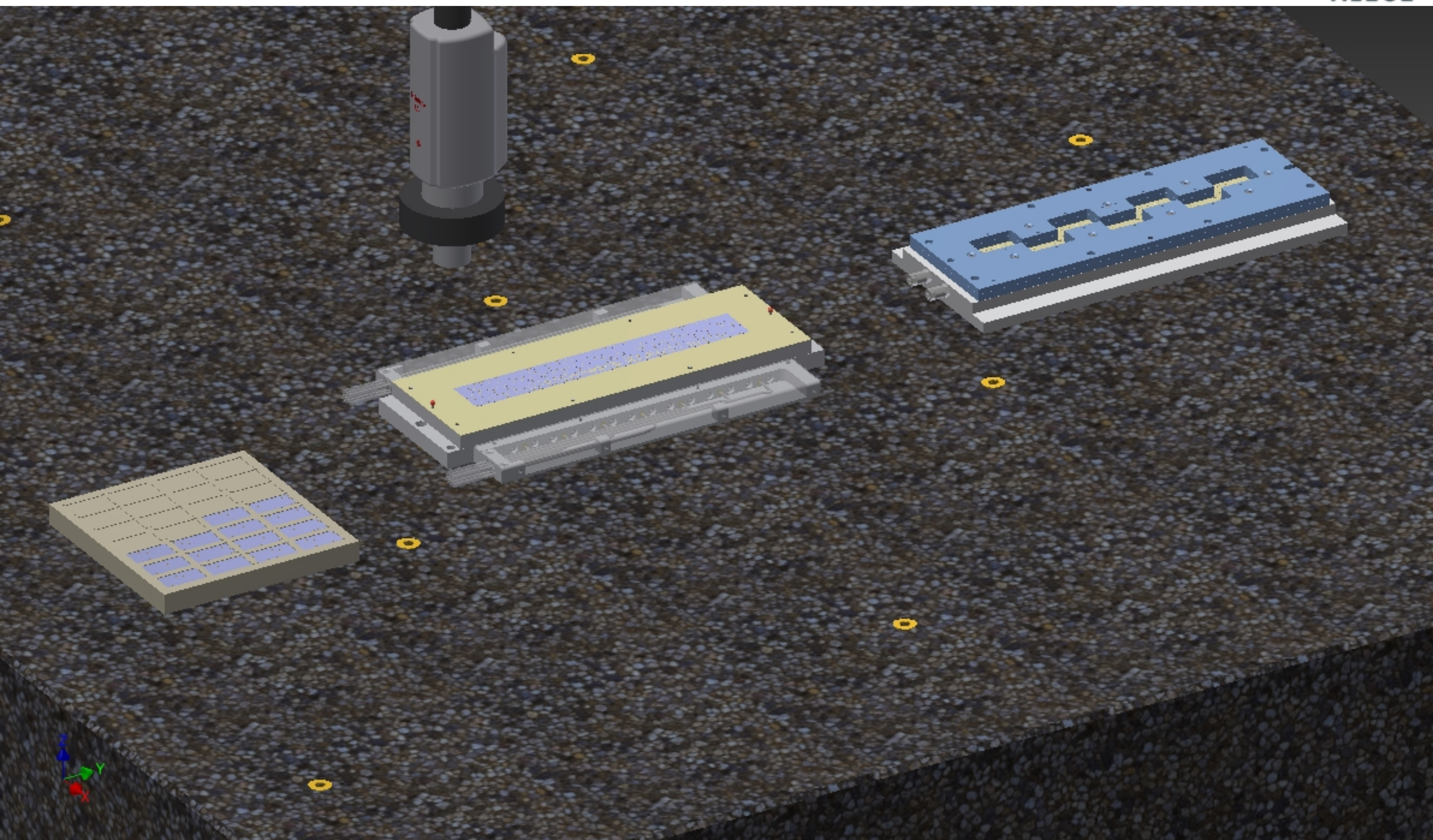

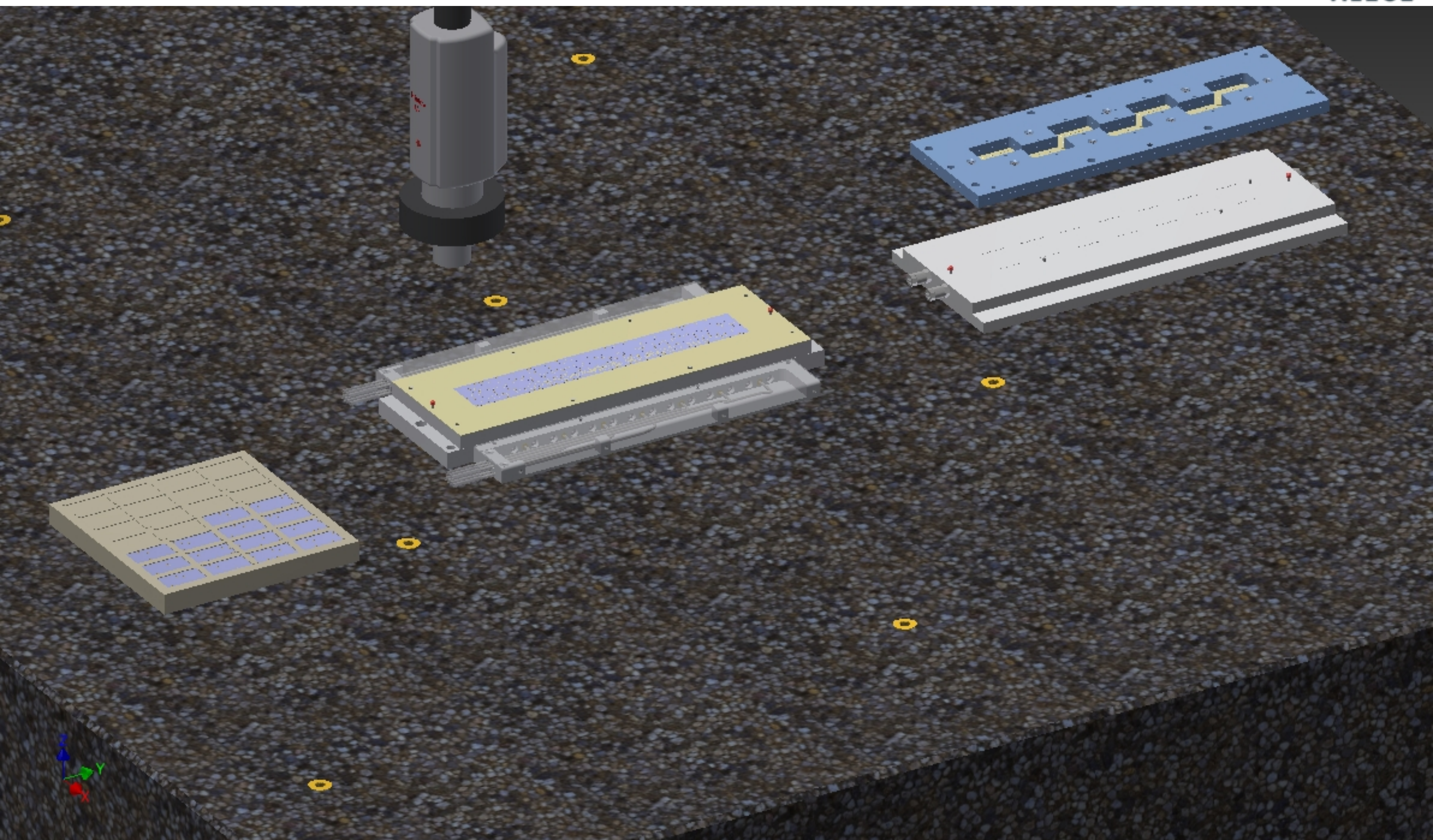

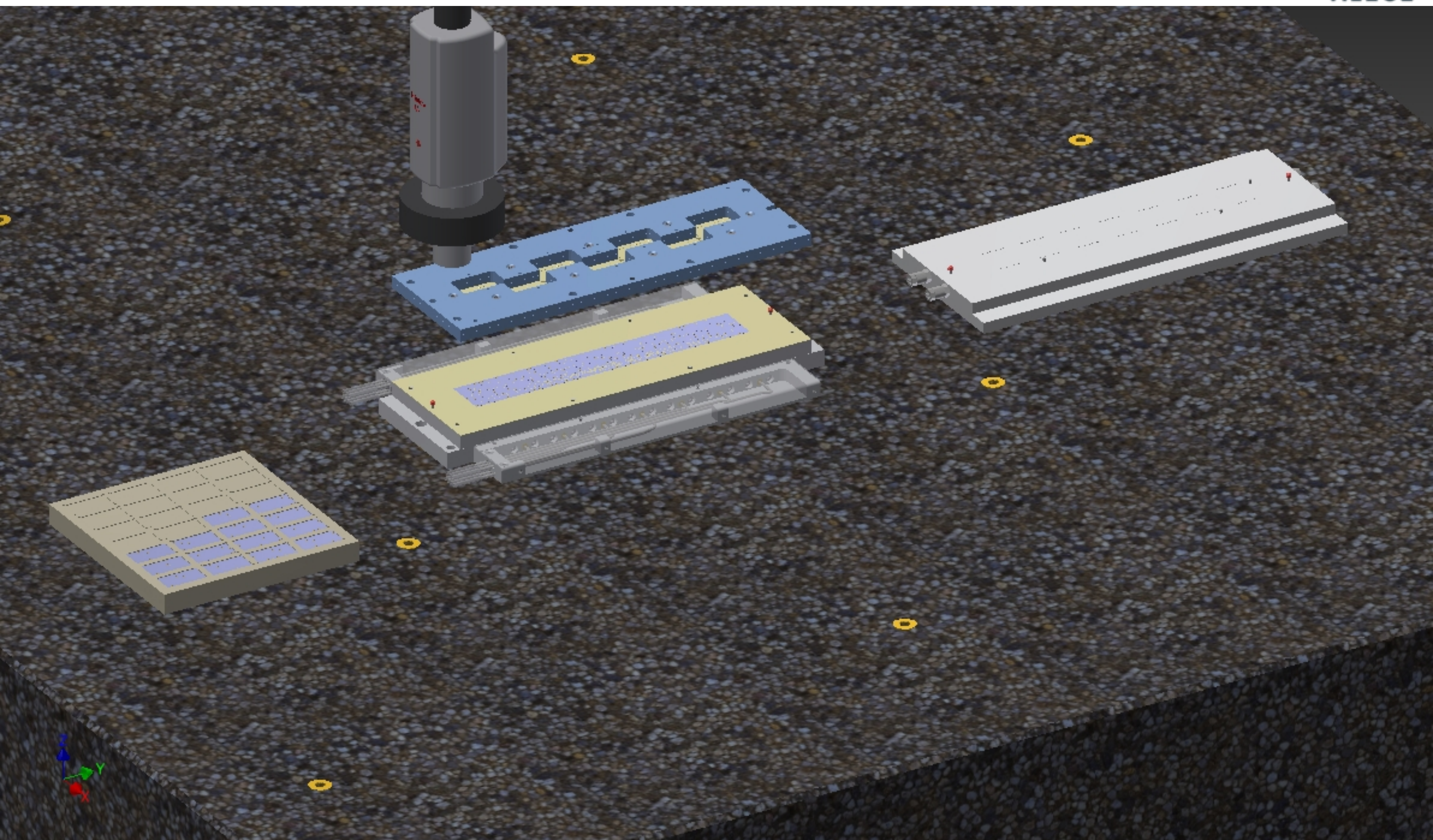

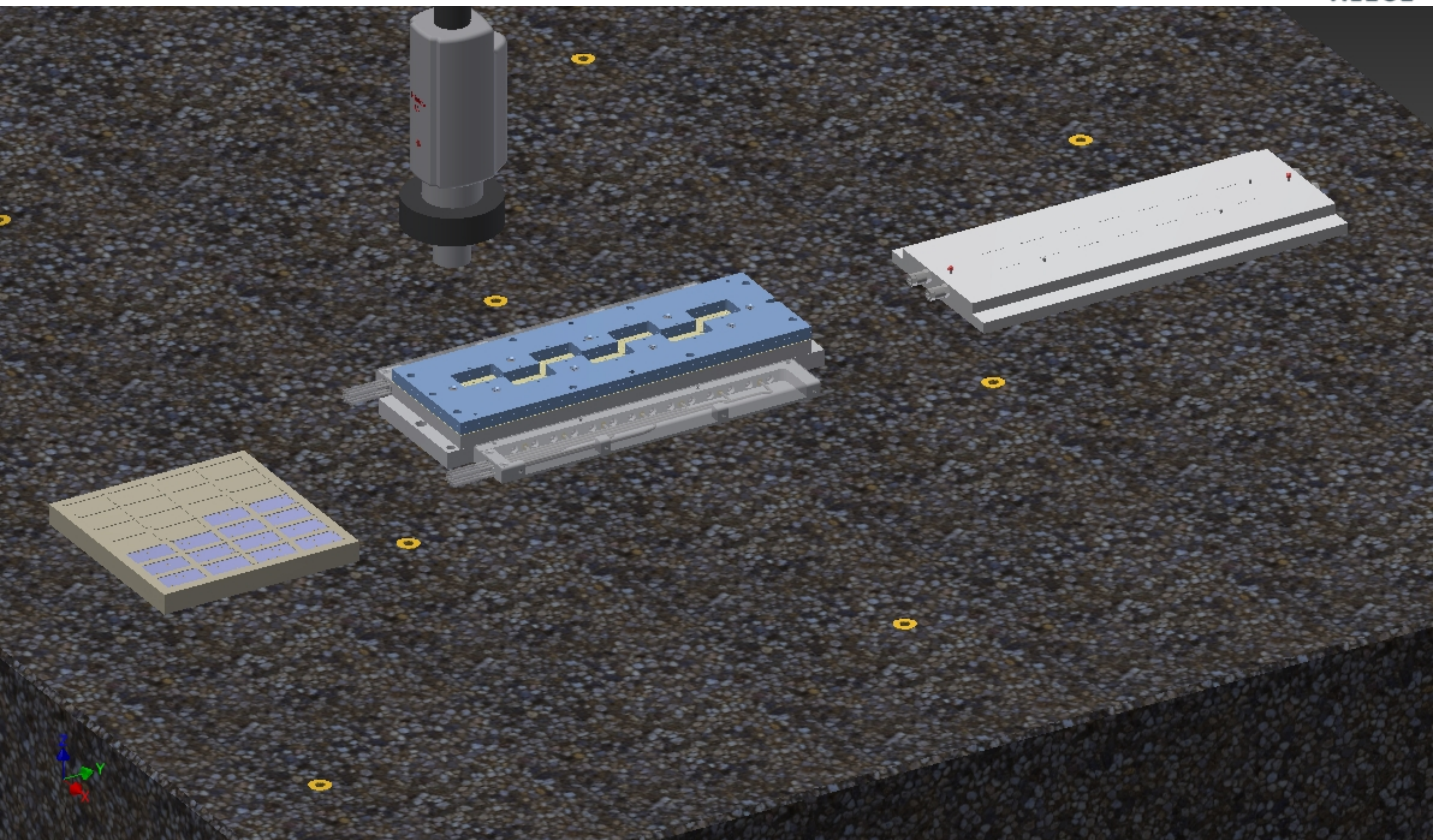

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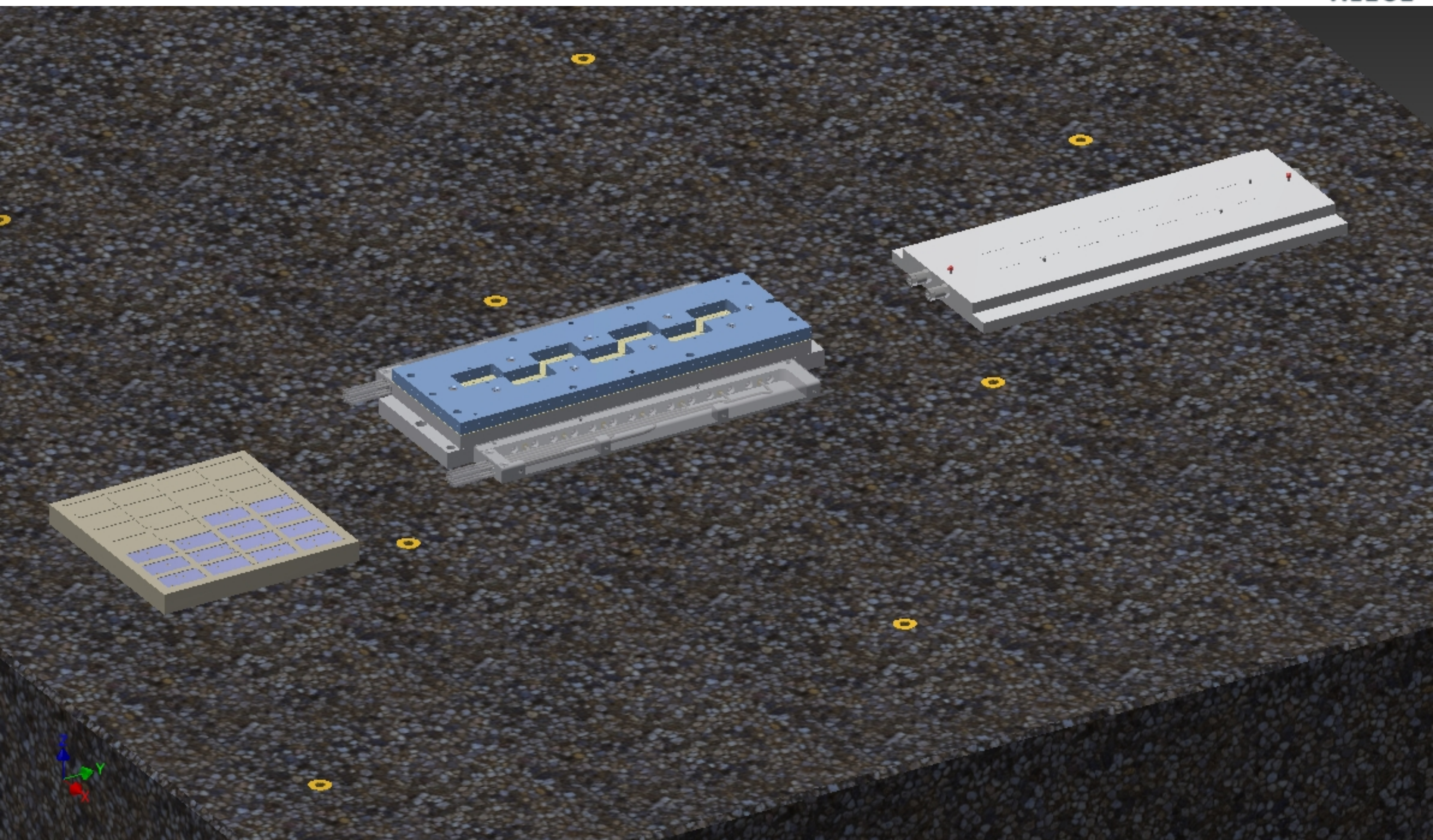

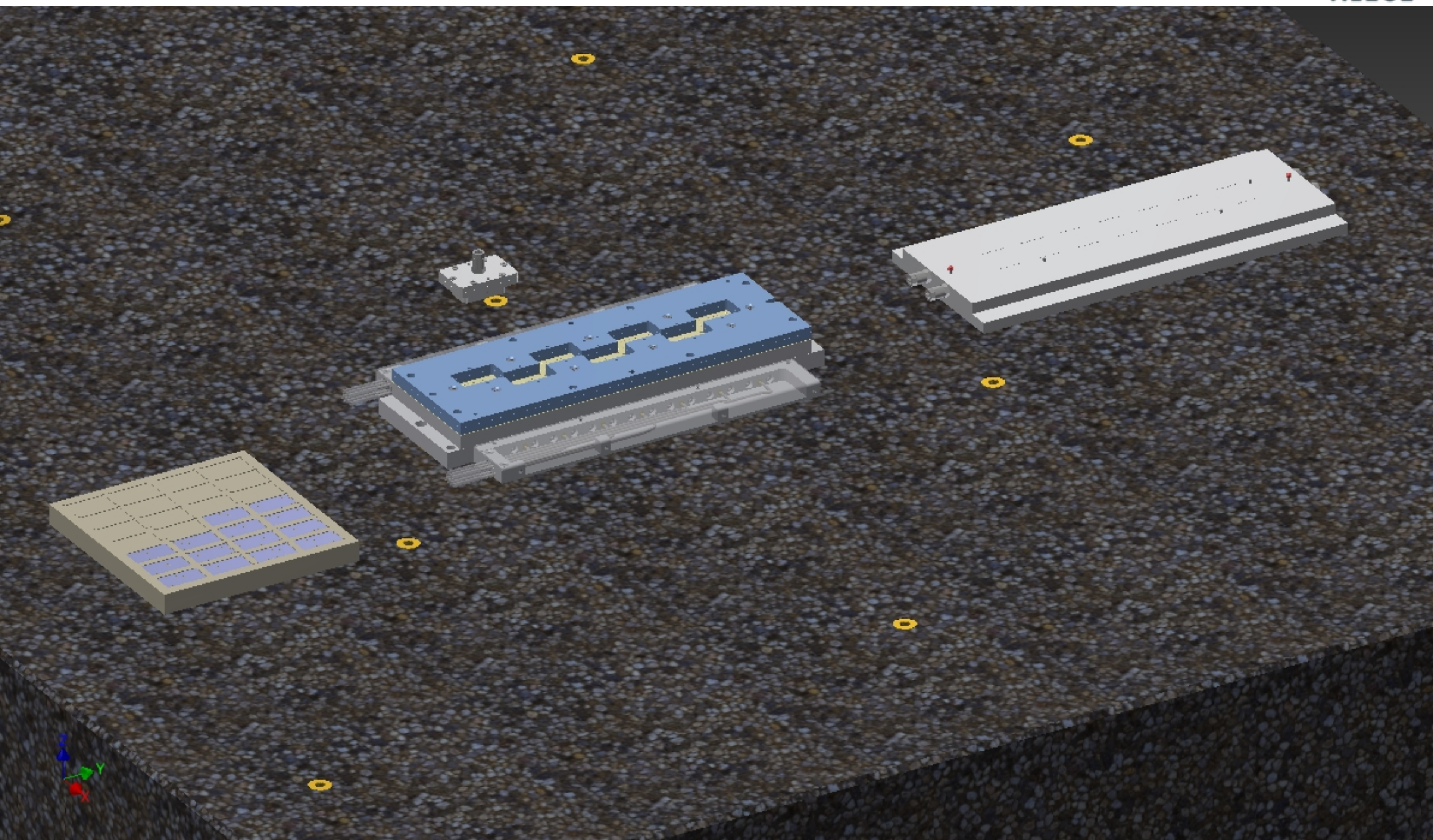

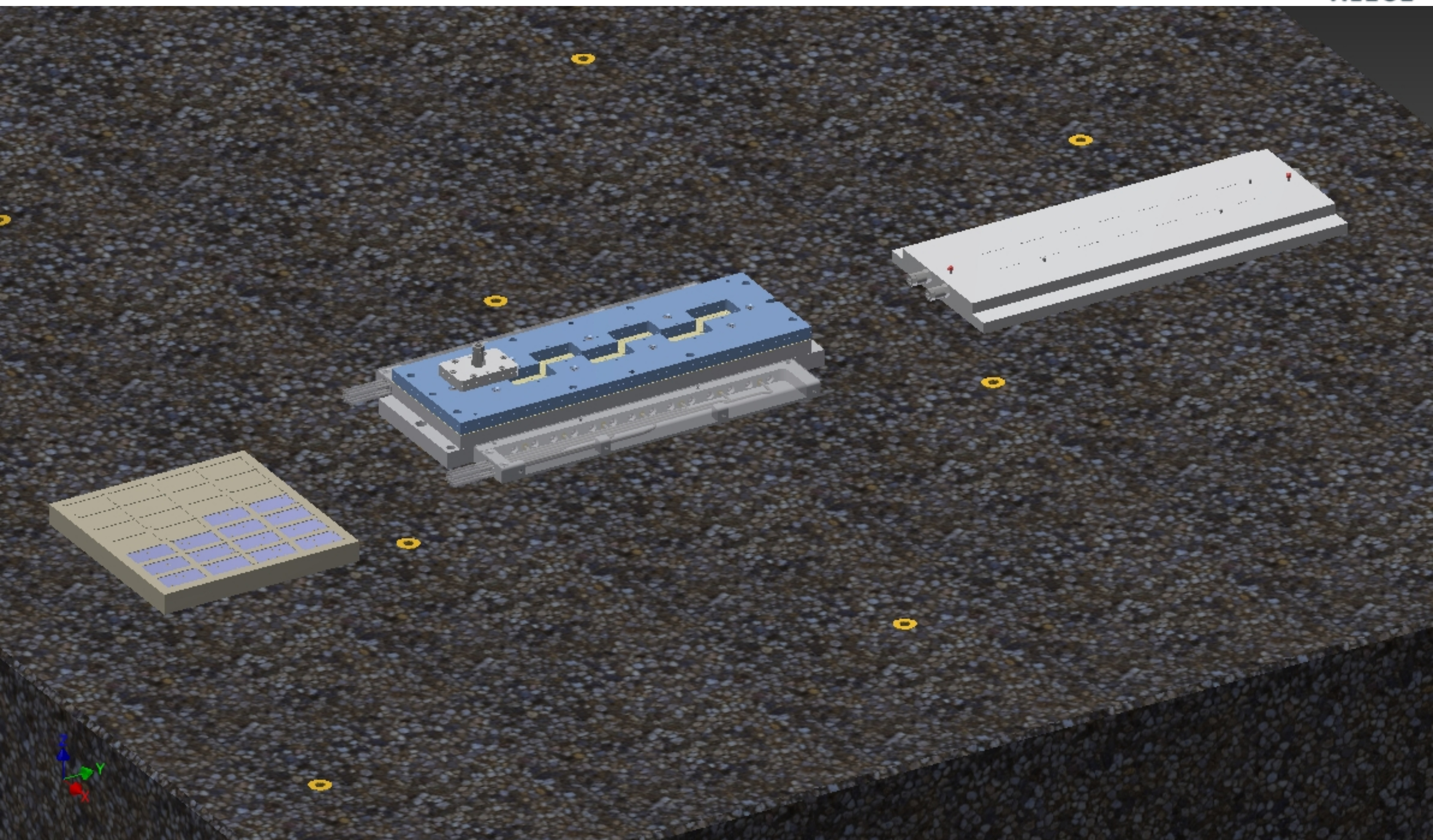

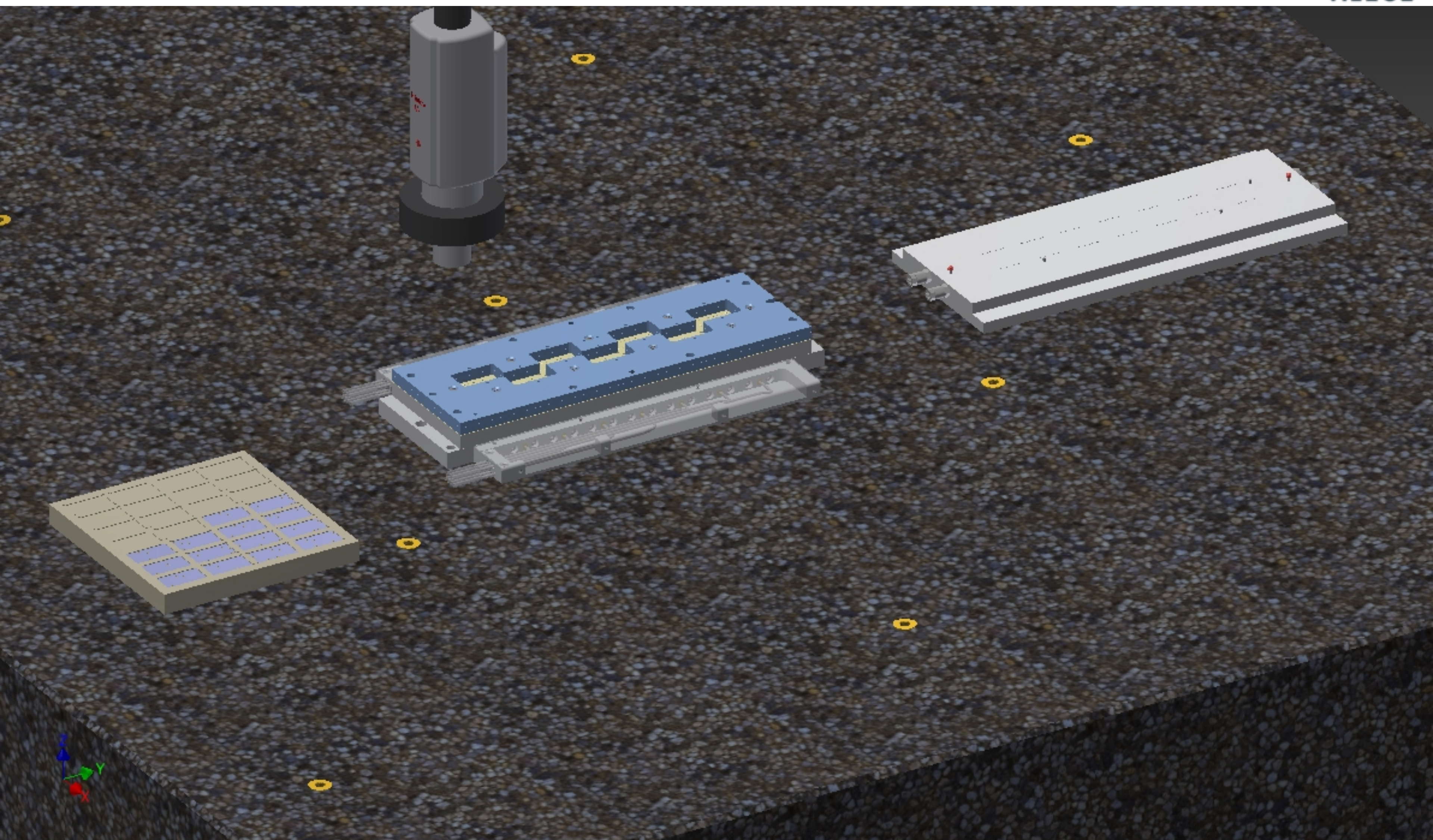

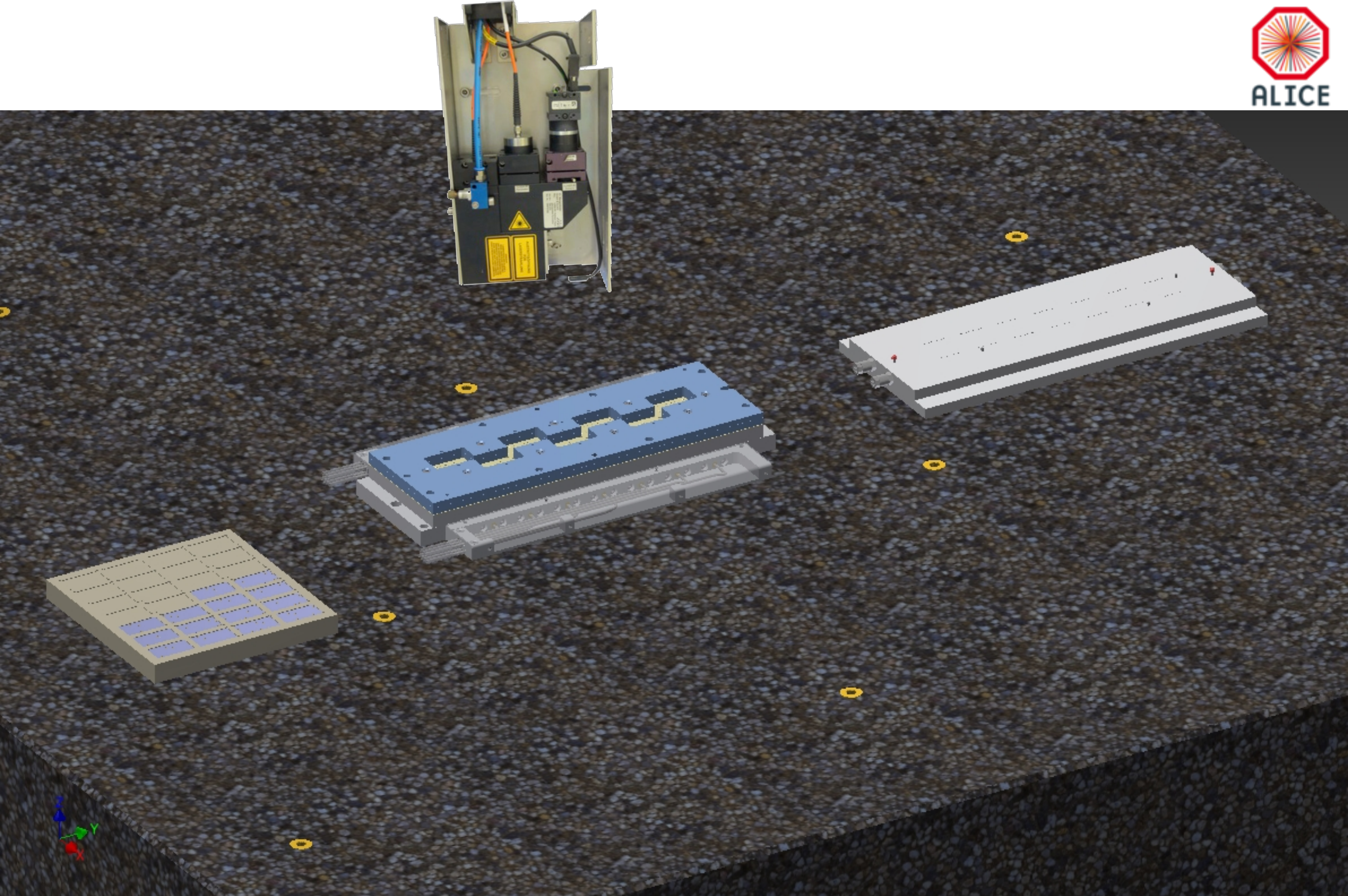
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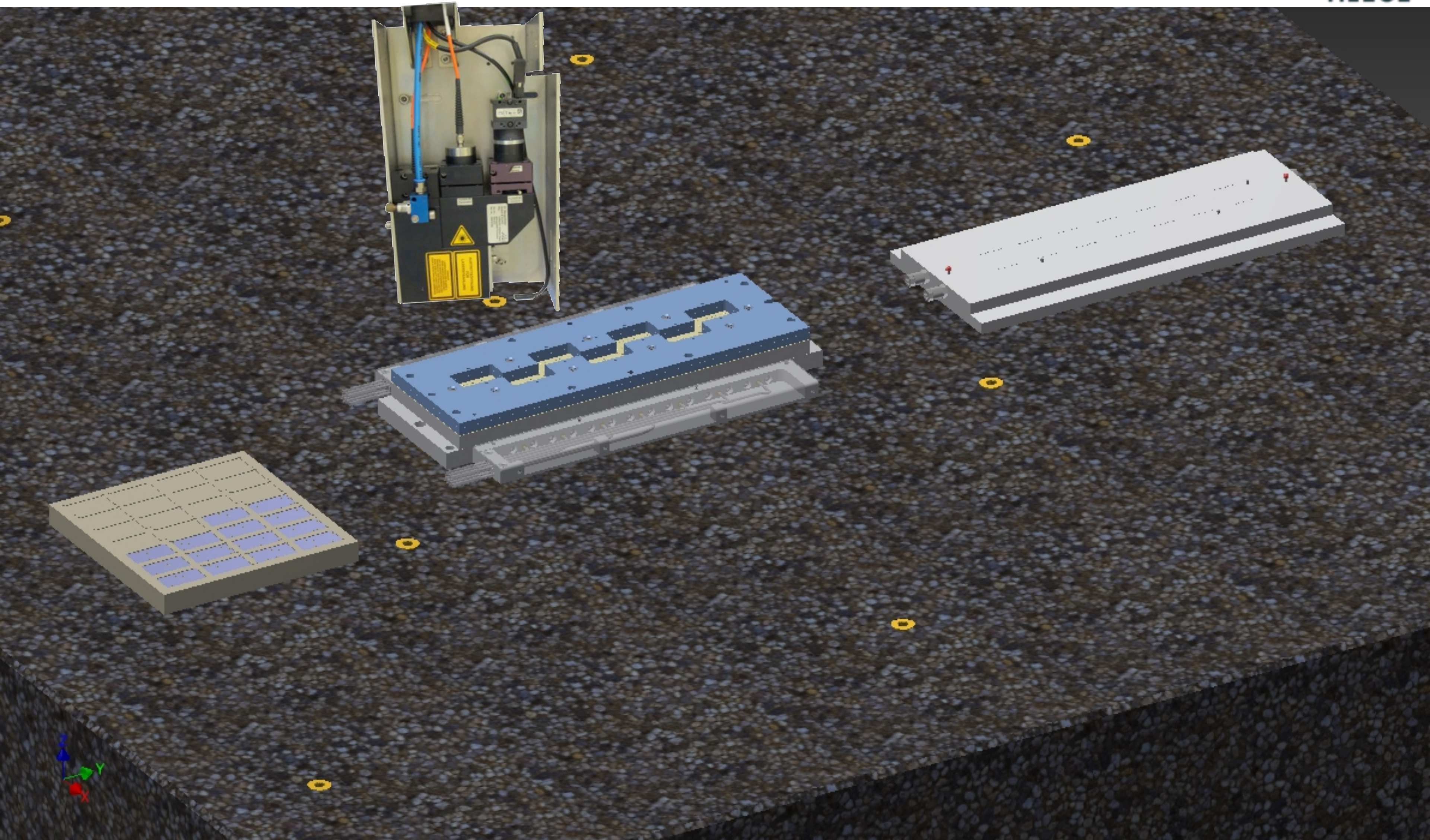
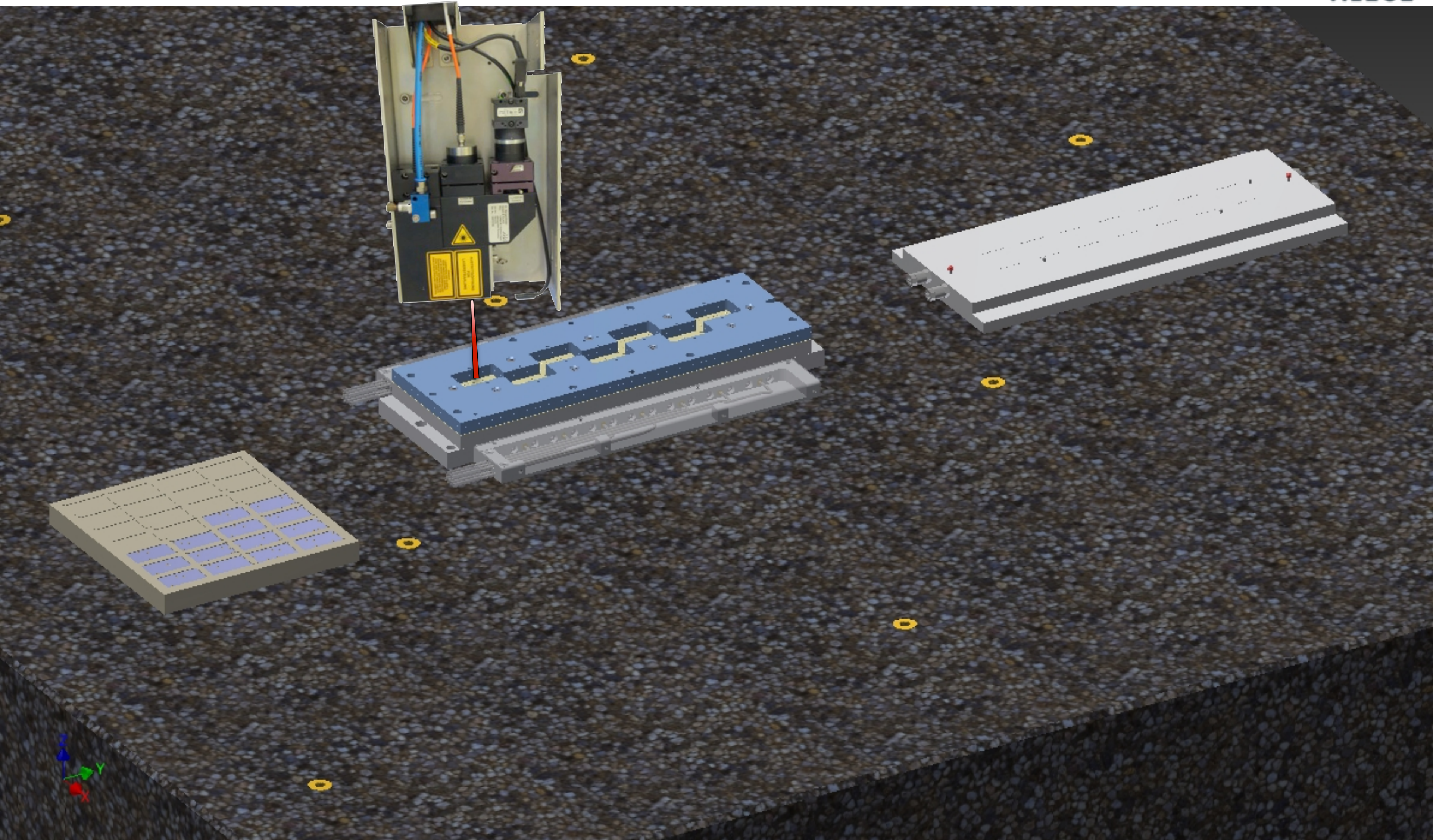
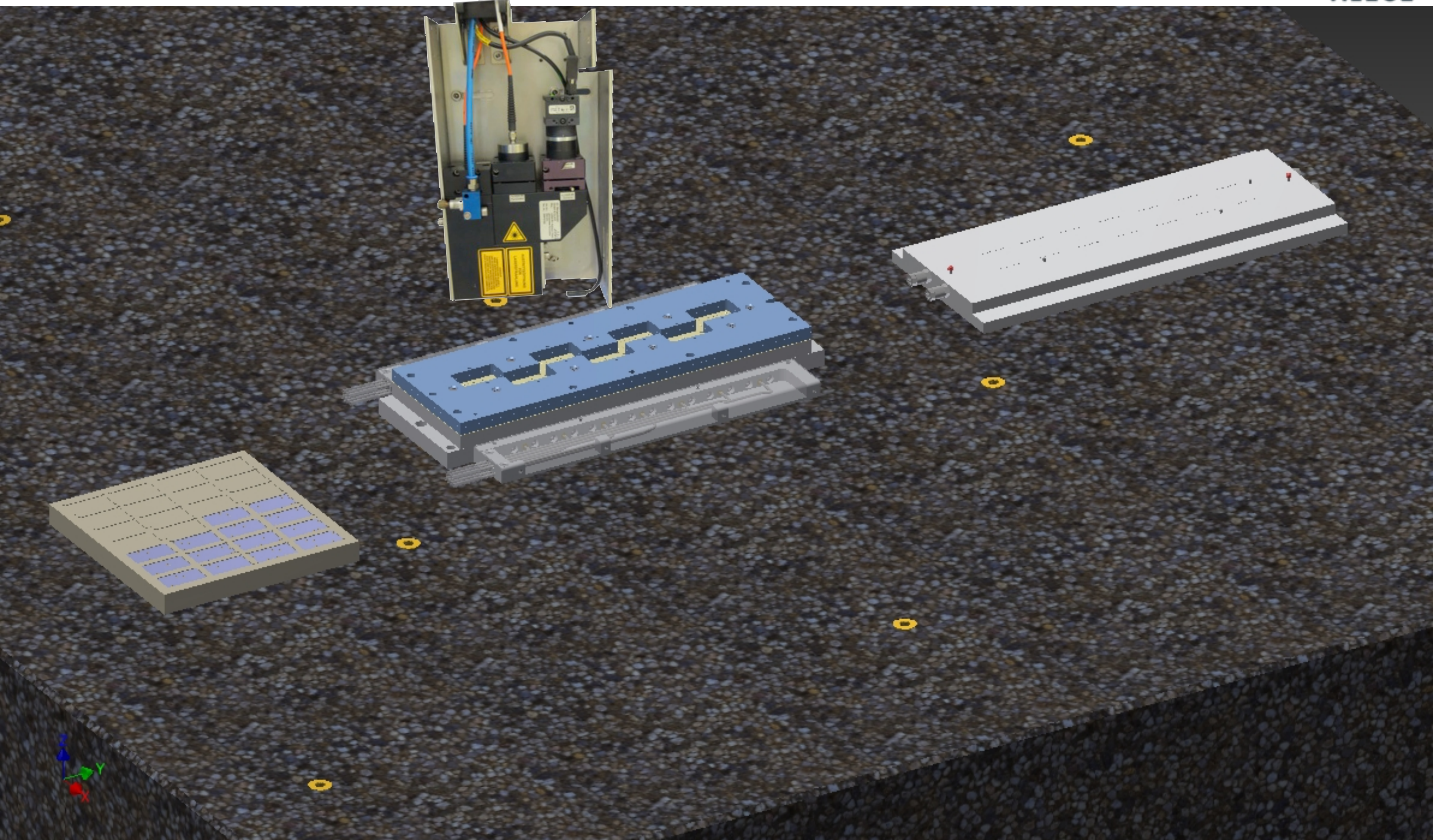
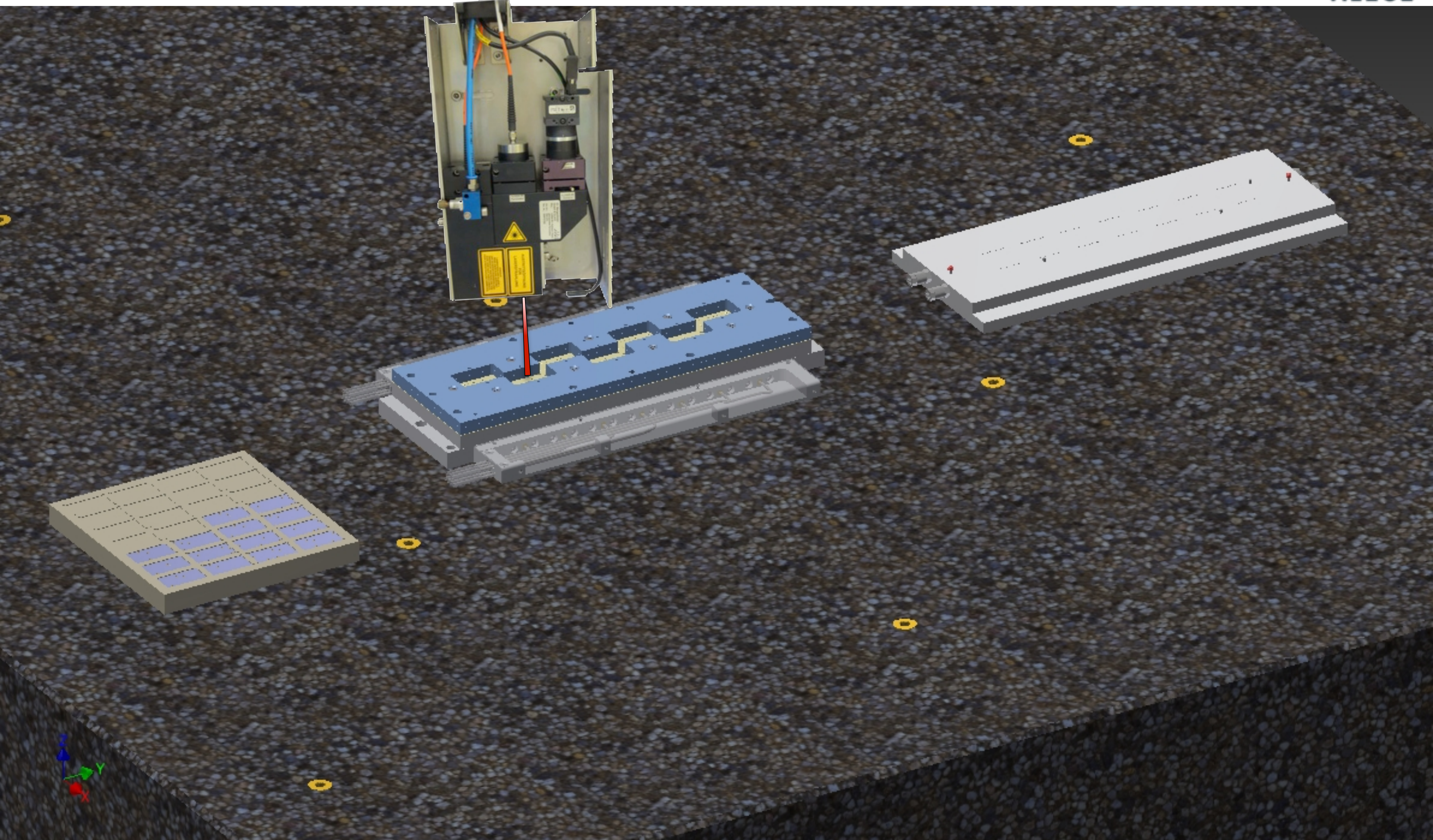
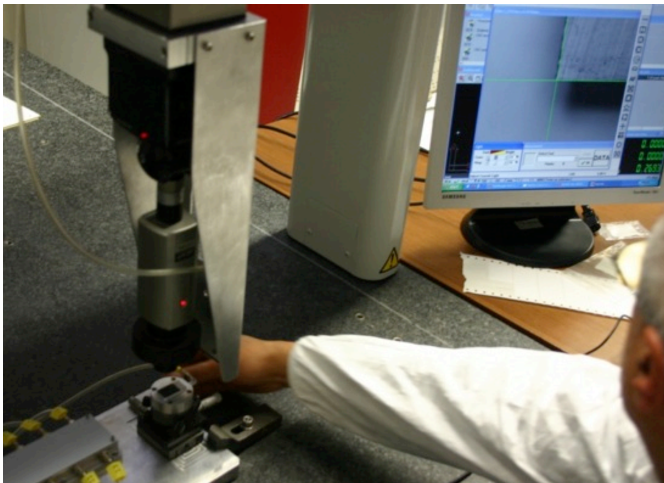


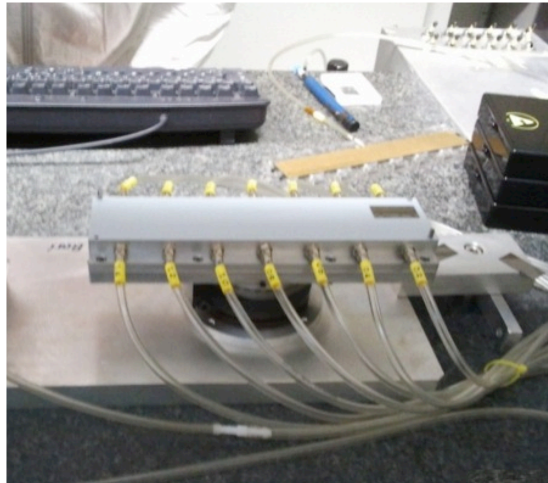


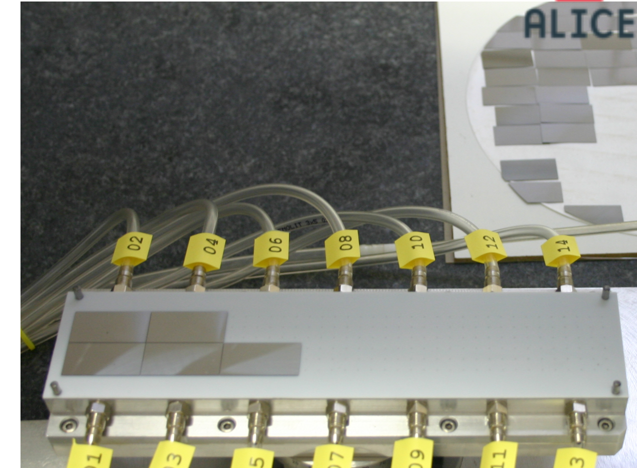


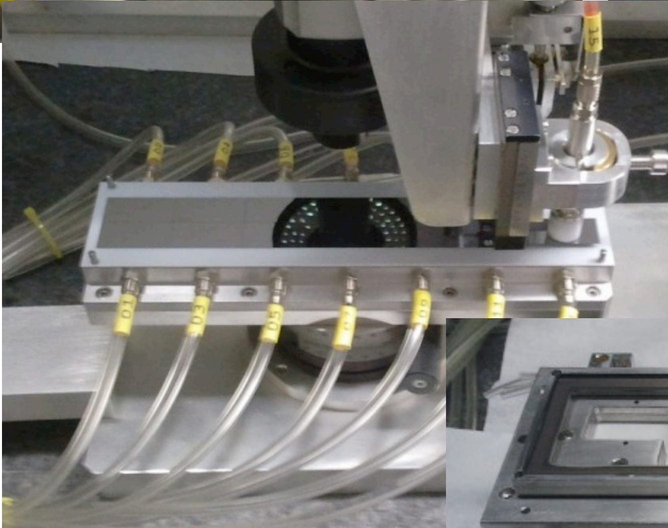


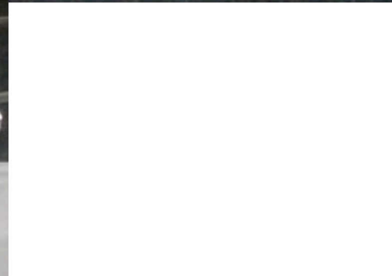
OB Module Assembly

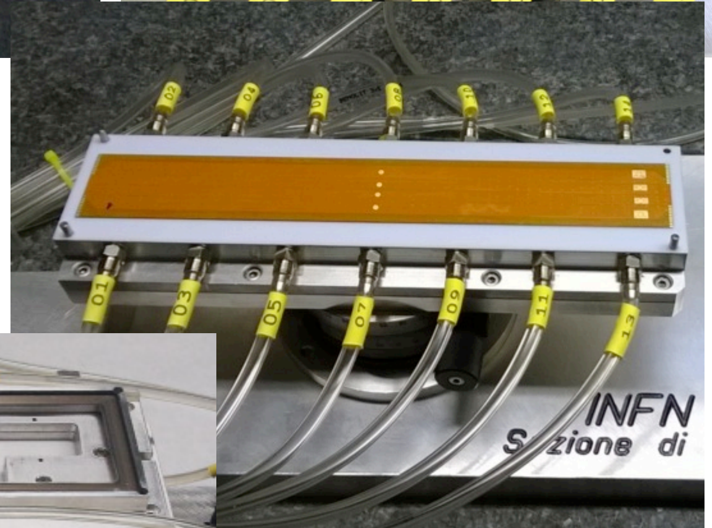


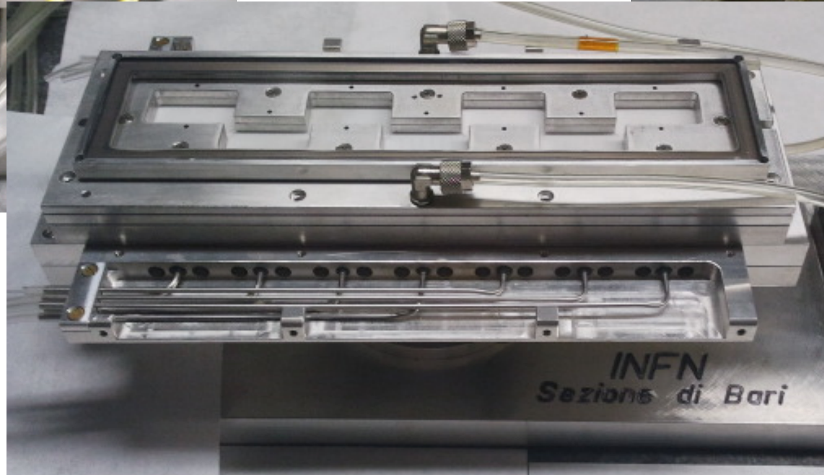






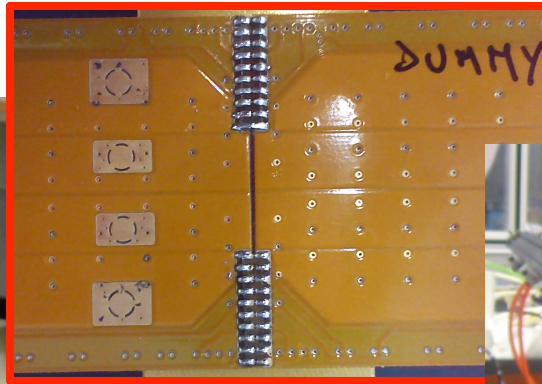


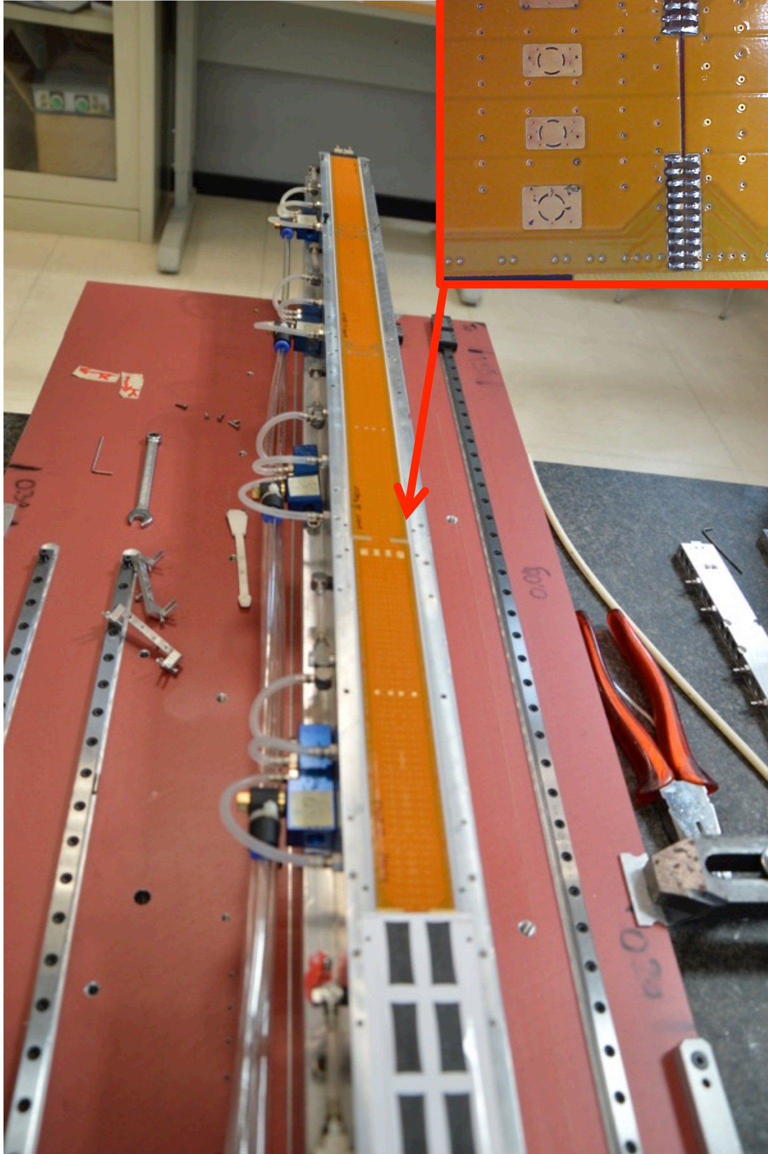


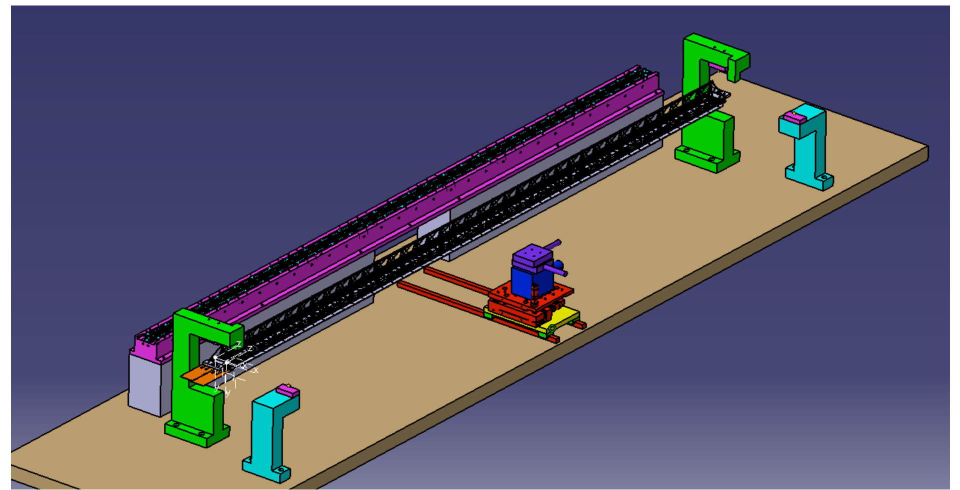


Half-Stave and Stave Assembly

ALICE

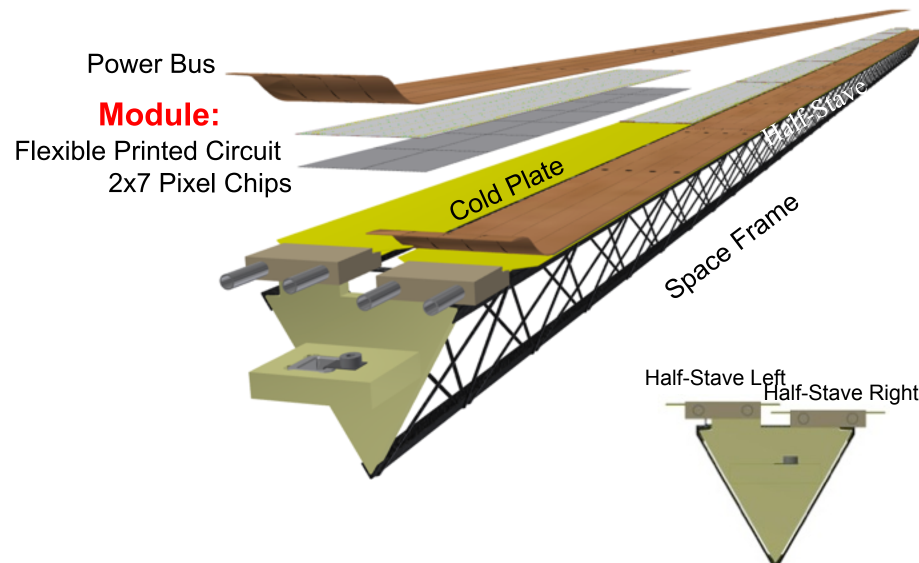






Summary Table of OB Modules and Staves

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 18	22 36	88 252	1232 3528
Total	65 108	130 216	**2032**	**28448**



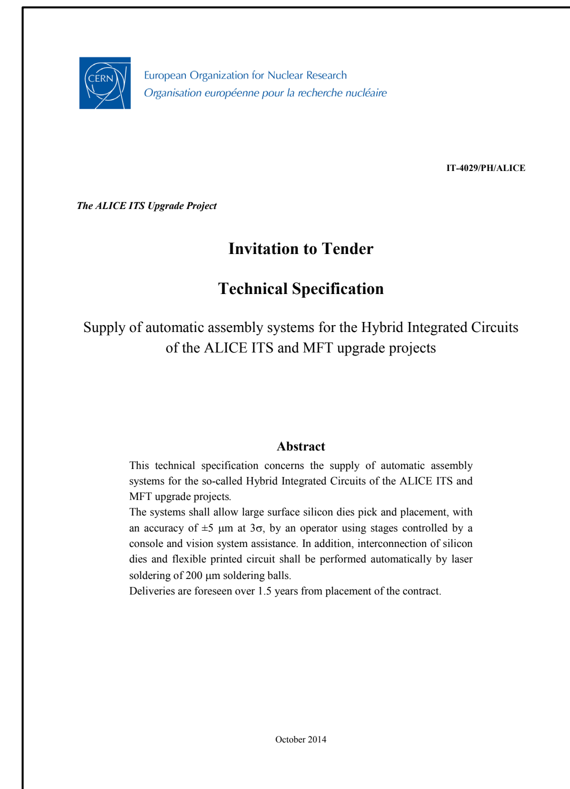
OB Module Construction - Organization

- Module production will be distributed among up to 6 production centers:
  Bari (Italy), CERN, Liverpool (UK), Pusan (South Korea), Strasbourg (France), Wuhan (China)

- Each production center will deploy an identical automatic assembly systems to ensures an homogeneous quality over the whole production

  Procurement of the automatic assembly systems is centrally managed by the project with a tendering launched from CERN

  Details in the next talk by Antonello



European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

IT-4029/PH/ALICE

The ALICE ITS Upgrade Project

Invitation to Tender

Technical Specification

Supply of automatic assembly systems for the Hybrid Integrated Circuits of the ALICE ITS and MFT upgrade projects

Abstract

This technical specification concerns the supply of automatic assembly systems for the so-called Hybrid Integrated Circuits of the ALICE ITS and MFT upgrade projects.
The systems shall allow large surface silicon dies pick and placement, with an accuracy of ±5 μm at 3σ, by an operator using stages controlled by a console and vision system assistance. In addition, interconnection of silicon dies and flexible printed circuit shall be performed automatically by laser soldering of 200 μm soldering balls.
Deliveries are foreseen over 1.5 years from placement of the contract.

October 2014

OB Module Test and Shipment

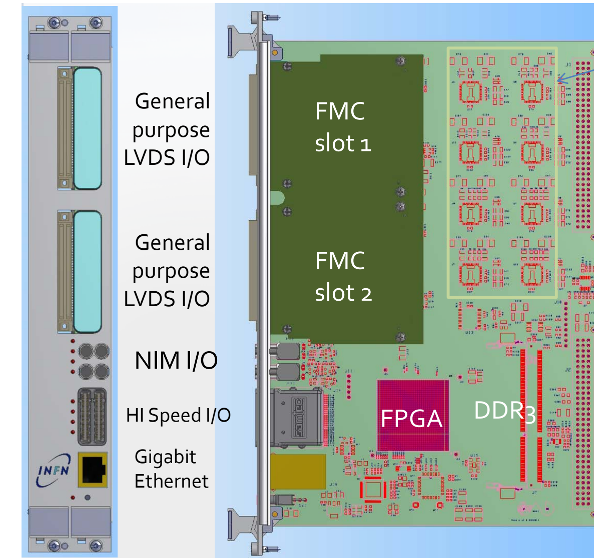
ALICE

Tasks at the Module Construction Center after the assembly

1. **Chips position -** measurements of chips position in the module with respect to reference markers, which will remain visible throughout the following construction and integration operations

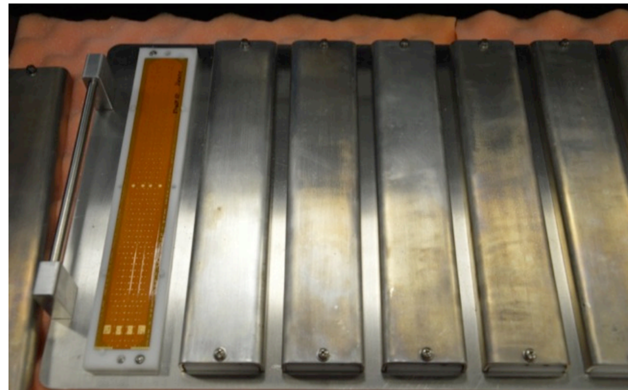
2. **Module characterization** - functional validation of modules according to a defined protocol

   - Test System developed by Bari group



3. **Module transport** - shipment of qualified modules to the Stave Construction Centers

   - Liverpool, LBNL, Turin and LNF, NIKHEF



Infrastructure and Equipment @ Construction Centers

ALICE

- ✓ ~40 m^2 of a clean room class 100000
- ✓ Compressed air and nitrogen supplies
- ✓ Automatic assembly system
- ✓ Optical microscope for visual inspections, equipped with image acquisition system
- ✓ Test bench equipped with readout and control test system, cooling system and power supply systems
- ✓ Radioactive source (typically ^{90}Sr, activity ~10MBq)
- ✓ Storage cabinets (antistatic, desiccator) for components and assembled modules
- ✓ ...

Timescale

ALICE

	2015				2016				2017			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Laboratory setting up												
Automatic Assembly System: Procurement, Installation and Commissioning												
Training (@ CERN and Bari/Italy)												
Manual assembly and Laser soldering												
Automatic assembly system												
Test System												
Module Production												

Expected delivery date and commissioning of the first prototype of the automatic assembly system

OB Construction flow-diagram

Pixel Chips
Test and Selection
(Tbd)

Flexible Printed Circuits
Production and Test
(Tbd)

Module Construction Center
Assembly and Test
(Bari, CERN, Liverpool, Pusan, Strasbourg, Wuhan)

Stave Production Center
Assembly and Test
(Liverpool, LBNL, Turin and LNF, NIKHEF)

Space frame & Cold Plate
Construction and Qualification
(CERN)

Power Bus
Production and Test
(Tbd)

End-wheels
Production and Qualification
(Padova, LBNL)

Detector & Service Barrels
Production and Qualification
(Tbd)

Half-layer & Half-barrel
Integration and Commissioning
(CERN)

Conclusions

- The manual assembly procedure for the OB (and IB) module is well advanced and the optimization is in progress

- This procedure will be implemented in the Automatic Assembly System, whose supply is object of a tendering, to ensure reproducible quality

  Some operations will be controlled or automatized

- The production of the OB modules will be shared between 6 laboratories

  Bari (Italy), CERN, Liverpool (UK), Pusan (South Korea),
  Strasbourg (France), Wuhan (China)

- Setting up of the infrastructures and training next year

- Start Module production mid 2016

Stave and Module construction are discussed in the WP6/7/8 meetings:
Thursday 16h:00 – 18h:00 (Geneva time) – dates for 2015 will be circulated soon