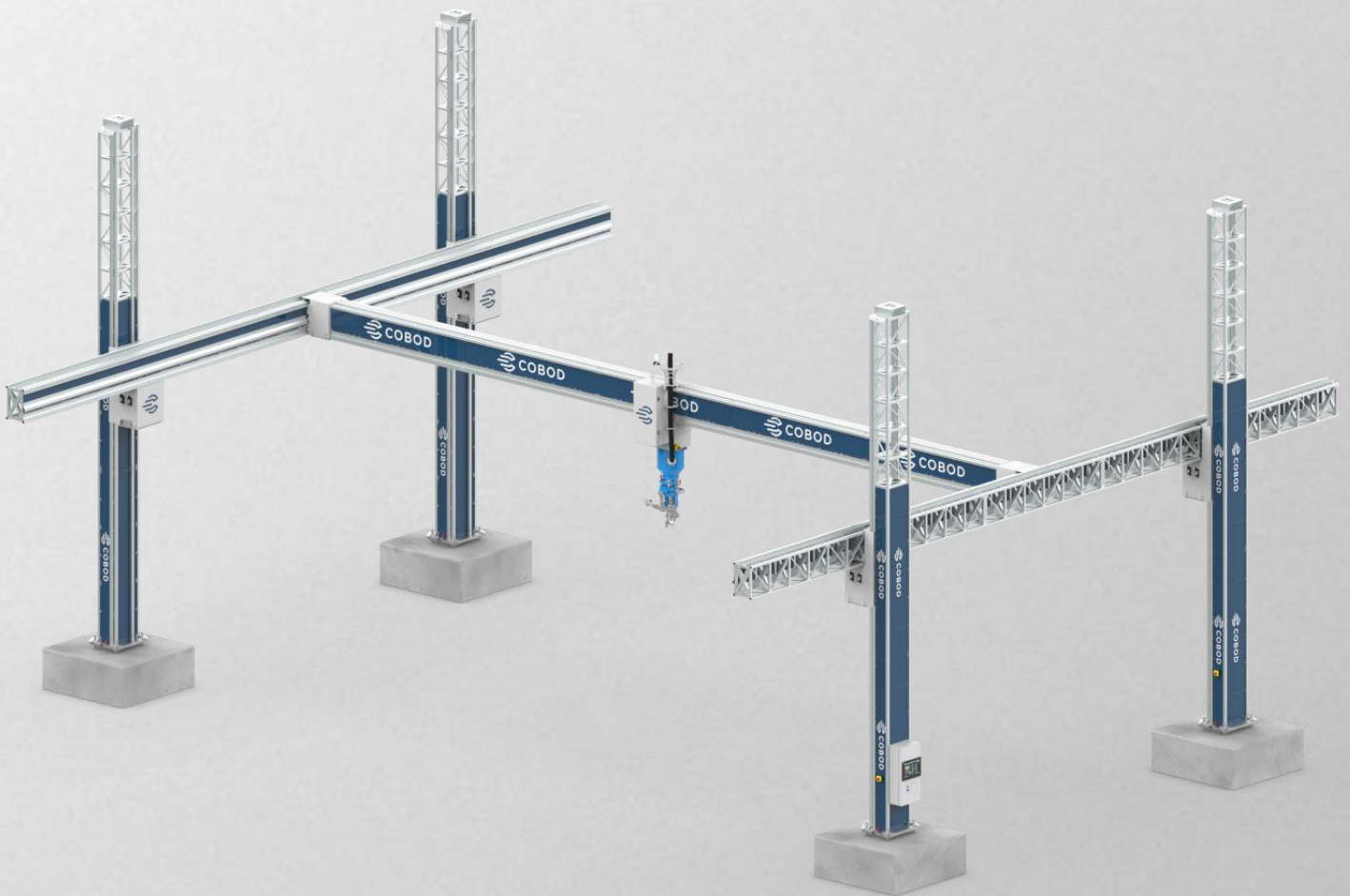


BOD2

STANDARD OPERATIONAL PROCEDURE



DOCUMENT VERSION

Date of issue: November 2022

This document is valid for the following versions of the product:

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- Improvements to wording
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- Changed visuals for wiring diagram, p. 24

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1.1 PURPOSE

The BOD2 Standard Operational Procedure (SOP) covers all standard procedures for installing and operating the BOD2 3D Construction printer. It does not cover:

- design, modelling, or slicing – please refer to the Modelling and Slicing SOP.
- any additional equipment, third party accessories or general site safety – please refer to the manufacturer and/or local code.
- waste treatment – please refer to local code.

Please see the Related Documents section for more information to support the application of the BOD2 3D printer.

1.2 APPLICABILITY

The BOD2 Standard Operational Procedure is intended as the main reference for BOD2 certified operators in the following scenarios:

- training (remote and on-site)
- packing and unpacking for shipping
- installation and disassembly
- operational procedure
- troubleshooting
- cleaning and general maintenance

All site personnel must be familiar with the EHS (Environmental Health and Safety) section (Chapter 1.6) of this document.

1.3 DEFINITIONS

3D Construction printing uses some common language and wording specific to the industry, listed below. The naming of the various machine components is covered under System Overview.

Word	Definition
3DCP	3D Construction Printing
BOD2	3D Construction Printer made by COBOD
3D Model	A digital representation of a structure, used as basis for any 3D printed building
Slicer: COBOD Slice	A piece of software, developed to translate the information in a 3D model to machine code, that can be read by BOD2.
PLC	Programmable Logic Controller
HMI	Human Machine Interface
Omron	Manufacturer of the PLC in BOD2

Soft-NA	The user interface to Omron
Duet	The operator's interface to the BOD2
X / Y / Z / E / U	Axes in the machine (physical and digital)
(A)HMS	(Advanced) Hose Management System
MDS	Material Delivery System
WCS	World Coordinate System
PO	Print Operator
POA	Print Operator Assistant
MO	Materials Operator
MOA	Materials Operator Assistant
GC	General Contractor

1.4 ROLES AND RESPONSIBILITIES

The 3D printing installation, operation and maintenance is the responsibility of a certified operator, who has successfully passed Level 2 training from COBOD or one of its certified affiliates.

The responsibility of the certified operator is:

- Printer operations
- Printer installation
- Verification of CAD models
- Preparation of printer files (Slicing)
- Cleaning and maintenance

A typical site crew will consist of a Printer Operator (PO), his assistant (POA), a Materials Operator (MO) and his assistant (MOA) and a site manager.

Site Manager		Planning, scheduling, and logistics Coordinate with external suppliers Coordinate with general contractors Day-to-day site management	
PO	Printer installation Printer operations Verification of CAD models Preparing print files (Slicing) Printer cleaning and maintenance	MO	Installation of MDS (Material Delivery System) Operation of MDS Cleaning and maintenance of MDS Quality assurance of materials Batching of concrete
POA	Secondary operation of printer Assist on start-up and shut-down procedures Assist on cleaning and maintenance Assist on installation	MOA	Refill cement and aggregate silos Assist on MDS installation Assist on cleaning and maintenance

1.5 TOOLS

When setting up and operating the BOD2 3D printer, it is important to have the right tools. COBOD offers complete tool kits with all tools needed on site. The vital tool kits are the Setup and Maintenance Kit (lasers, wrenches, levels etc.) and the Printing Kit (shovels, buckets, brooms, high-pressure washer etc.). If choosing to source the tools locally, the overview of the toolkits can be used as checklists (can be found in COBOD Connect).

Besides the physical tools offered in the toolkits, a Windows based laptop will be needed as well. A tablet can be used as well and can be useful for operating the printer wirelessly.

	INSTALLATION	OPERATIONS	MAINTENANCE
Physical tools			
Setup and Maintenance Kit (COBOD can supply)	×	×	×
Printing Kit (COBOD can supply)		×	×
Equipment			
Crane – requirements: Lifting capacity of 4 tons in 5 meters Lifting capacity of 2 tons in 14 meters	×		
Boom loader/telehandler – requirements: Lifting capacity of 2 tons in 5 meters Including shovel + forks		×	
Digital tools			
Windows based laptop and/or tablet	×	×	×
COBOD Slice Software		×	

1.6 ENVIRONMENTAL HEALTH AND SAFETY (EHS)

EHS is the backbone of operational efficiency when applied correctly and aims to protect people, assets and the environment when executing projects using the BOD2 3D printer.

EHS falls under the general contractor's project management responsibility. It should comply with all local and federal applicable regulations for each stage of the construction process to be successfully implemented and maintained over time. Not doing so, could result in accidents, negative media, and the consequential delay of technology adoption.

The objective of implementing EHS is to protect workers from job-related injuries and illnesses, identifying and mitigating physical, chemical, and biological hazards in the workplace as well as

constantly updating training and communication to promote a safe and healthy work environment.

By reducing the amount of labor, 3D printing could potentially contribute to a safer working environment. To do this, the few workers on site should follow a structured risk assessment and operational EHS program.

Some basic construction training subjects covered by employees in the construction industry **before** taking any additional heavy duty equipment trainings are:

- Fall Protection
- Electrocution
- Struck-By
- Caught-In/Between Hazards
- Health Hazards
- Material Handling
- Tools — Hand and Power
- Managing Safety and Health
- Stairways and Ladders
- Fire Protection and Prevention
- Welding and Cutting
- Scaffolds
- Cranes
- Excavations
- Concrete and Masonry
- Personal Protective Equipment
- Confined Space Entry
- Signs, Signals and Barricades

We highly encourage customers, GCs and developers to risk assess to specific site conditions to ensure a safe workplace and properly train and certify POs and MOs in accordance with local and federal guidelines for construction.

1.7 KEY PERFORMANCE INDICATORS

Key Performance Indicators (KPIs) are the critical (key) indicators of progress toward an intended result. KPIs provides a focus for strategic and operational improvement, create an analytical basis for decision making and help focus attention on what matters most.

On the following page you will find an overview of KPIs for:

- Shipping and installation
- Printer operations

1.7.1 KPIS FOR SHIPPING AND INSTALLATION

Inventory Management: Ensuring that all parts arrive on site in time. Keeping accurate shipping lists and verifying shipments before shipping.

Positioning: Correct positioning of the 3D printer on site in relation to surveyor. Better positioning will give more room for the operator. Critical if the full printing area will be utilized.

Alignment: Alignment of the Z axes during installation and Z+Y carriages during installation. Crucial to machine performance. Poor alignment can result in poor quality and damage to the equipment.

Performance: Ensuring that the printer is properly stable, can smoothly run at its intended speed and all safety functions engage properly.

TITLE	MEASUREMENT	GOOD	POOR	UNACCEPTABLE
Inventory management	Parts arriving on site in time (%)	100 %	95-98 %	< 95 %
Positioning	Deviation from optimal placement in mm	0-30 mm	30-50 mm	> 50 mm
Alignment	Deviation in mm Deviation in deg	≤ 3 mm < 0.1 deg	3-10 mm 0.1-0.5 deg	> 10 mm > 0.5 deg
Performance	Site Acceptance Test	Refer to SAT		

1.7.2 KPIS FOR PRINTER OPERATIONS

Layer quality: Visually inspect layer quality over the duration of the print. Adjust printer speed and extrusion speed to optimize quality of printed layer.

Productivity: Optimal build rate based on material, geometry, and environment. Modified by adjusting speed and extrusion.

Efficiency: Ensuring a stable continuous process. Relation between projected time and actual printing time. Impacted by thorough maintenance, cleaning, and quick resolution of errors.

Repeatability: Print with repeatable tolerance and surface quality. Impacted by calibration of printer and thorough planning of printing activities as well as layer quality.

TITLE	MEASUREMENT	MAX	DECENT	LOW
Layer quality	Visual inspection	Based on visual inspection		
Productivity	Concrete output in m ³ /h	3.6 m ³ /h	1.5-3 m ³ /h	0-1.5 m ³ /h
Efficiency	Printing time to downtime ratio in %	80-90 %	50-70 %	0-50 %
Repeatability	Layer-to-layer offset (mm)	0-2 mm	2-5 mm	> 5 mm

2. SYSTEM OVERVIEW

The BOD2 is a modular gantry-based 3D construction printer. The BOD2 printer is built from 2.5-meter modules and can be built to customer specifications.

The BOD2 printer works in three dimensions with the print head moving right/left on the X-axis, the X-axis moving forwards/backwards on the two Y-axes and the combined XY-group moving up/down on the Z columns, which are minimum 4, often more.

The gantry principle allows the printer to access any position within the print envelope and gives complete freedom of movement within the volume.



The BOD2 is connected to a Material Delivery System (MDS). The MDS ensures continuous delivery of 3D printable materials to the printhead. COBOD offers two Material Delivery Systems, one for printing mortars and one for printing concrete with larger aggregates.

The material is pumped from the MDS to the printhead through a hose. COBOD offers two systems for hose management – one for smaller and one for larger BOD2s.

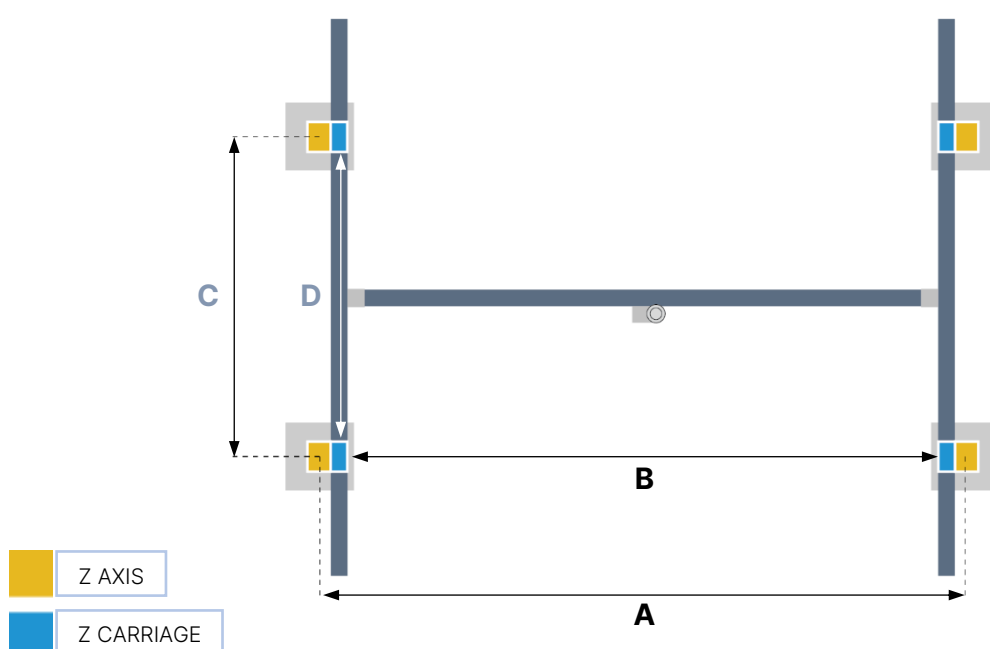
2.1 MACHINE SPECIFIC DIMENSIONS

The configuration of the BOD2 defines its machine specific dimensions including the printable area and installation area. All printer specific dimensions are listed on the table below.

Dimensions needed for setup:

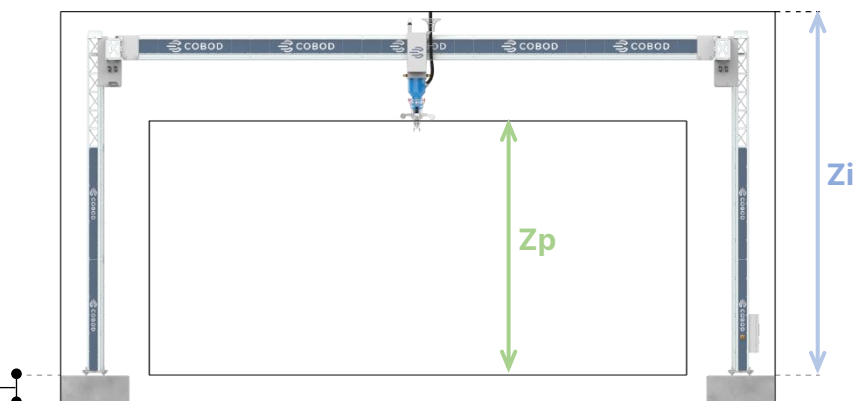
No. of trusses pr. axis	Center to center of Z-leg/concrete base:	Distance between surfaces of Z-carriages:
	X-direction	X-direction
	A	B
1	4510	3304
2	7036	5830
3	9562	8356
4	12088	10882
5	14614	13408
6*	17139	15933
	Center to center of Z-leg:	Distance between surfaces of Z-carriages:
	Y-direction	Y-direction
	C	D
2	4052	3498
≥3	7250	6696

*) Using 6 modules for the X-axis is possible, but not recommended and require special considerations.

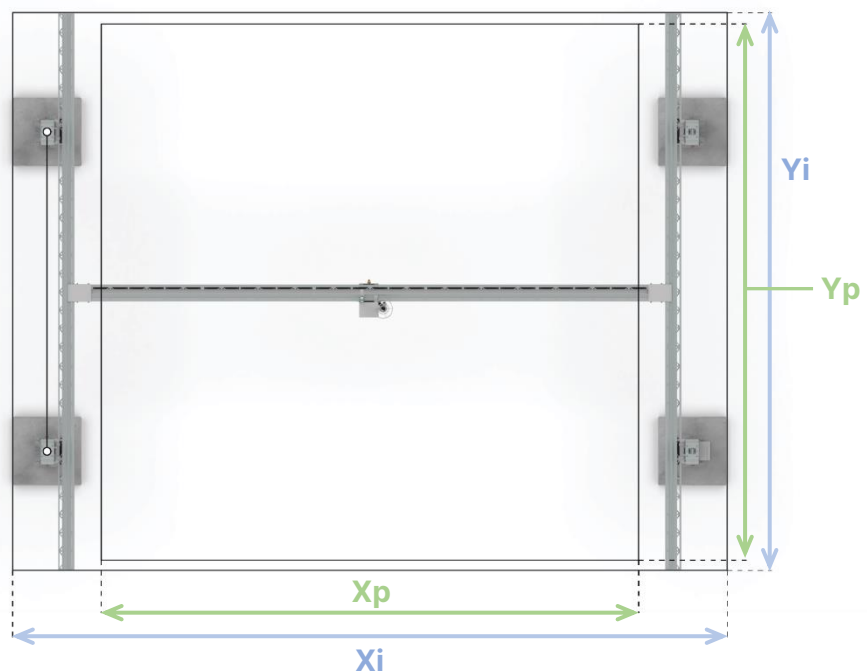


Printable Area (PA) and Installation Area (IA):

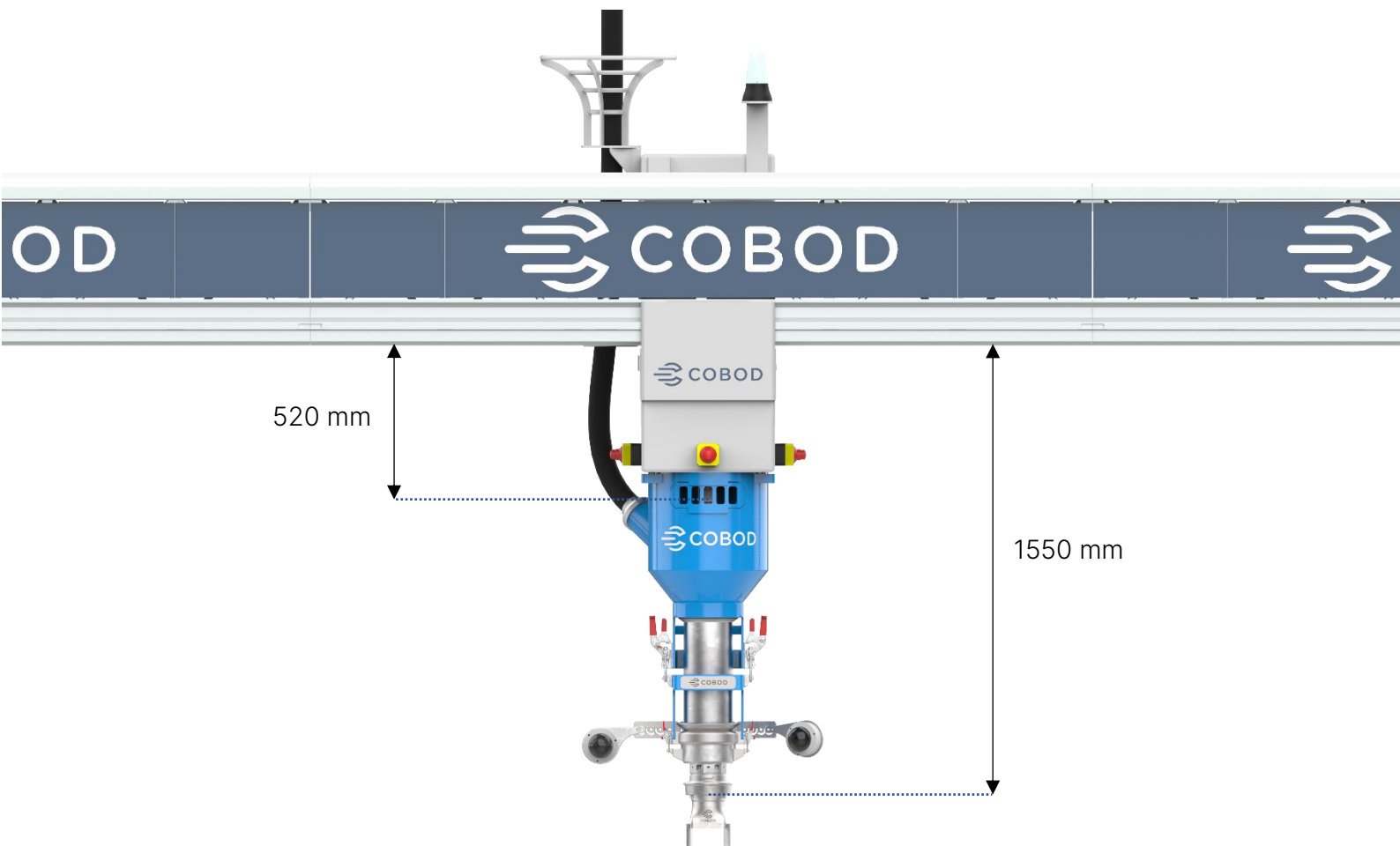
No. of trusses pr. axis	X-direction		Y-direction		Z-direction	
	PA	IA	PA	IA	PA	IA
TAG	Xp	Xi	Yp	Yi	Zp	Zi
1	2067	8510	-	-	501	4176
2	4593	11036	4596	9052	3027	6702
3	7119	13562	7122	11578	5553	9228
4	9644	16088	9648	14103	8079	11753
5	12170	18614	12174	16629	-	-
6	14696	21139	14700	19155	-	-
7	-	-	17226	21681	-	-
8	-	-	19751	24207	-	-
9	-	-	22277	26733	-	-
10	-	-	24803	29258	-	-
11	-	-	27329	31784	-	-
12	-	-	29855	34310	-	-



The height of the concrete feet should be added to both the printable area and the installation area in the Z direction. The concrete feet has already been included in the dimensions on X and Y.



2.2 CONSTANT DIMENSIONS



Constant dimensions, unlike the machine specific dimensions are universal to all BOD2 printers, no matter the overall configuration.

The dimensions can be used to plan more complex printing objects – e.g., printing a building in multiple parts, to match ideal layer time goals (material related).

The dimensions above show:

- the distance from the bottom of the X-axis to the bottom of the X-carriage (incl. space for the screw connection piece)
- the distance from the bottom of the X-axis to where the nozzle is attached – please note, that the dimensions will vary depending on the nozzle used

2.3 PERIPHERALS

When organizing the layout of the site, the following should be considered, among other things:

- Printer placement and orientation
- Placement of the MDS in relation to the printer
- Waste disposal for excess waste material
- Access to various elements such as electricity, water and tools must be considered prior to arrival and setup of the BOD2 3D printer

Furthermore, concrete bases (to install the printer on) and a print bed (or foundation) should be prepared. Please refer to Related Document for more information in this context.

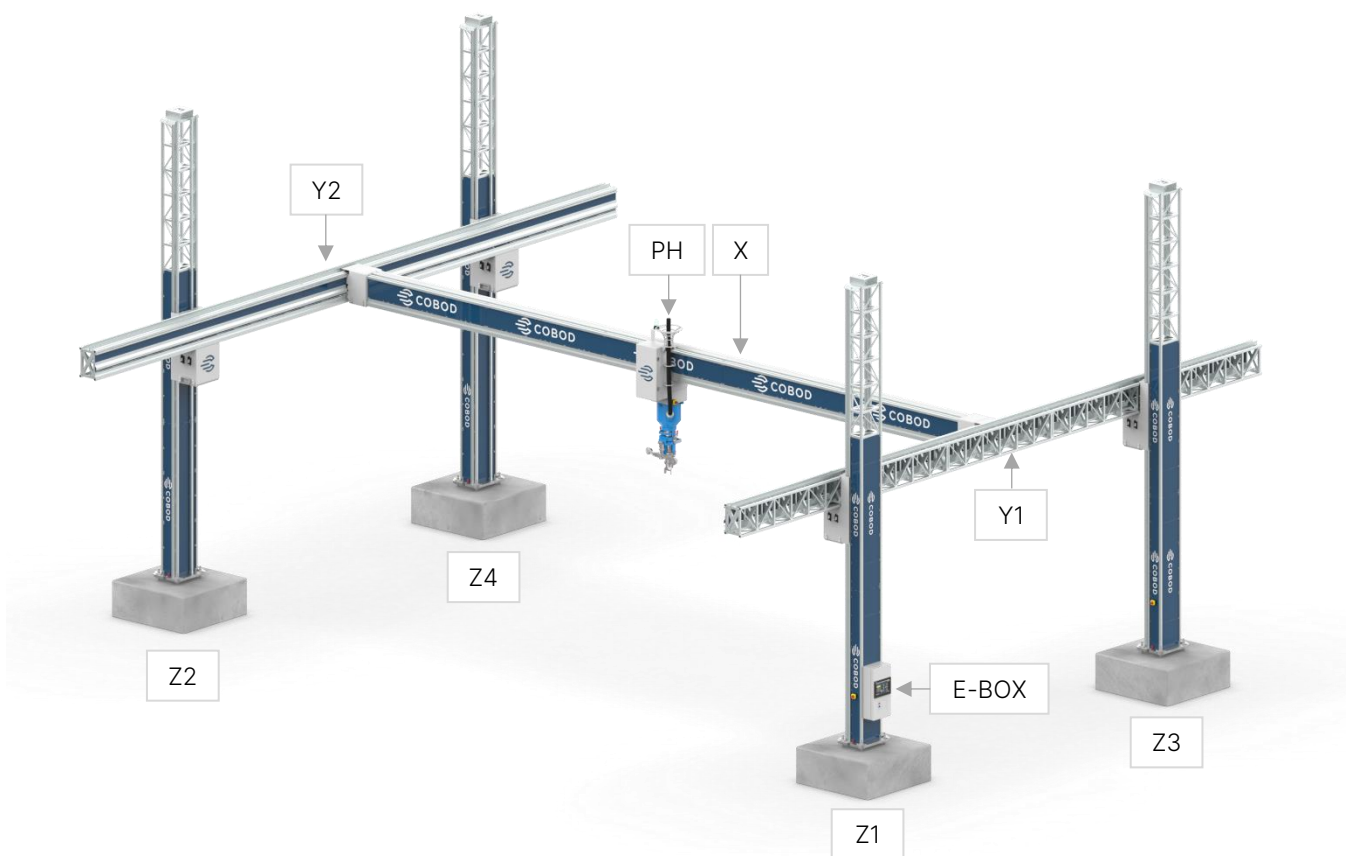
2.3.1 MACHINE INFORMATION

Description	Unit	Value	
Product	-	3D Construction Printer	
Model	-	BOD2	
Measurements (L x W x H)	[mm]	See table of all model-specific dimensions below.	
Short circuit current, IKmin	[A]	500	
Short circuit current, IKmax	[A]	1200	
Leakage current	[mA]	300	
Max. speed (X-axis)	[mm/s]	250	
Max. speed (Y-axis)	[mm/s]	250	
Max. speed (Z-axis)	[mm/s]	50	
Sound level	[dB(A)]	Max. 70	
Required bed plate flatness	[mm/m]	10	
Movement System	-	Servo	
Safety elements	-	Emergency stops (5 constant + 1 on each Z leg)	
Connection	-	Wi-Fi or LAN	
Software	-	Soft-NA and COBOD Web Control Interface (Duet)	
Interface	-	Web Client (through browser)	
Recommended operating temperature	[°C]	5-35	
Power requirements	Unit	EU value	US value
Current	[A]	32	30
Voltage	[V]	400 (3 phases, + N + PE (WYE))	480 (3 phases, + N + PE (WYE))
Frequency	[Hz]	50	60
Power consumption (normal operation)	[W]	1000	1000
Power consumption (peak)	[W]	8000	8000
Power consumption (idle)	[W]	50	50

3. SYSTEM COMPONENTS

Designed as a stand-alone unit consisting of several integrated components, the BOD2 3D construction printer consists of five main parts:

1. X-axis (one)
2. Y-axes (two – Y1 and Y2)
3. Z-columns (four or more – Z1, Z2, Z3, Z4, etc.)
4. Printhead (PH)
5. Control cabinet (E-box)



In this document a BOD2 model 5-5-3 is used for all illustrations.

3.1 KEYS

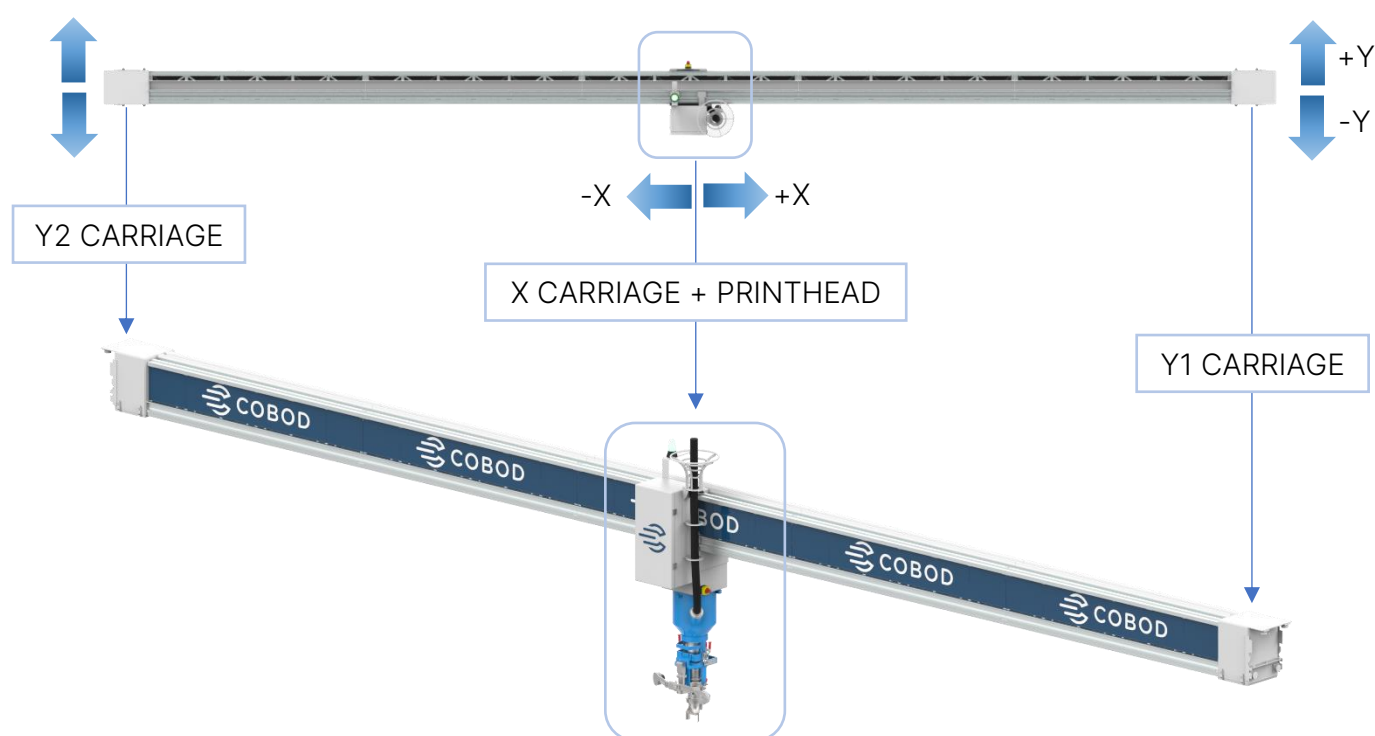
The BOD2 comes with the two sets of the following keys (incl. COBOD Keychain):

- One key for the yellow Operators Control Panel
- One key for the Safety Override Feature
- One cabinet key to open E-boxes

Each module is approx. 2.5 m long. The modules are aligned using fishplates and connected by four M16 bolts. Any printer can be setup in a smaller configuration than it was originally built by simply removing modules and rolling up the additional cable. Extending the printer would require new, longer E-chains (see 3.3 Electrical) and cables.

X – module and axis

- X-axes are assembled of 2-6 X-modules
- Company logos are typically displayed on the X-modules
- Each X-module has 1 tooth rack, 1 cable tray and 3 rails
- X-modules or axes must always be placed in stackers if placed on the ground, to protect the tooth racks underneath the modules
- On each end of an assembled X-axis, a Y carriage is attached – the Y carriages slide on to the Y axes



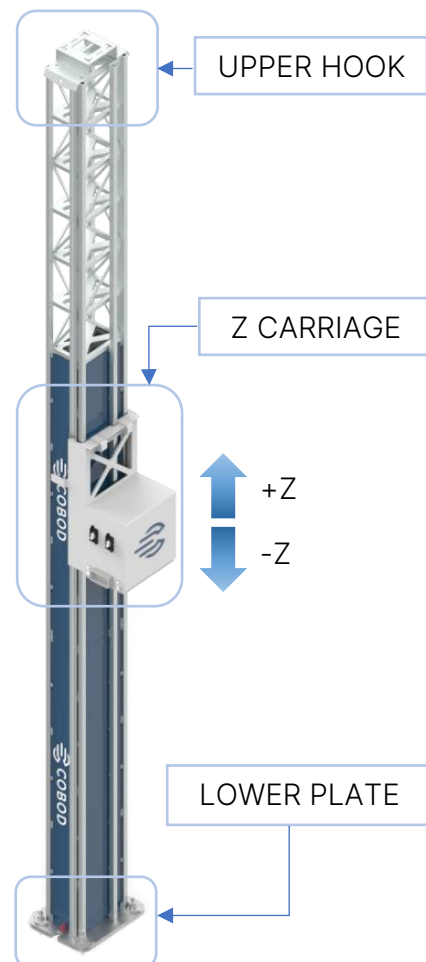
Y – module and axis

- Y axes are assembled of 2-12 Y modules
- Y axes have small tooth racks
- On each end of the fully assembled Y axis, EndStopMounts for homing and MechanicalEndstops (as a safety end stop) are placed
- The Y axes rest on the Z carriages:
 - > The Y1 axis, on which the Y1 carriage will slide on, rests on the Z-carriages with odd numbers (Z1, Z3, etc.)
 - > The Y2 axis, on which the Y2 carriage will slide on, rests on the Z-carriages with even numbers (Z2, Z4, etc.)



Z – module and axis

- Z-axes are assembled of 2-4 Z-modules
- Each Z-module has 2 rails, 1 tooth rack and one attached cable chain
- Z-axes can be extended without additional cables
- Z-axes can be identified by the lower plate and upper hook
- Z-modules have larger tooth racks than X- and Y-modules



3.2.2 LIGHT ON X CARRIAGE

The light above the printhead indicates the state of the printer.

- **Solid Red:** Drivers not engaged (can be missing key rotation, error or need for troubleshooting/error reset)
- **Solid Green:** Printer is ready to have drivers engaged. No errors. Material sensor indicates ABOVE MINIMUM to FULL (depending on value set in PLC)
- **Blinking Green/Yellow:** Printer has drivers engaged or is ready to. No errors. Material sensor indicates BELOW MINIMUM (depending on value set in PLC)
- **Blinking Green/Red:** Safety override key is engaged
- **Yellow LED blinks slow:** Piston pump pumping
- **Yellow LED blinks fast:** Piston pump reversing

3.2.3 PRINTHEAD COMPONENTS

The printhead is mounted on the X-carriage. The extruder screw is connected separately (inside the hopper, to the carriage) to be able to rotate freely inside the hopper. The rest of the parts are assembled and connected to the X carriage as one unit.

The printhead is mounted each day before printing and taken off after each day and/or for cleaning. A printhead stand comes with the printer, which can be utilized for mounting and unmounting the printhead. The stand can also be used for printhead storage and during cleaning of the printhead.

See detailed overview of all components on the following page.

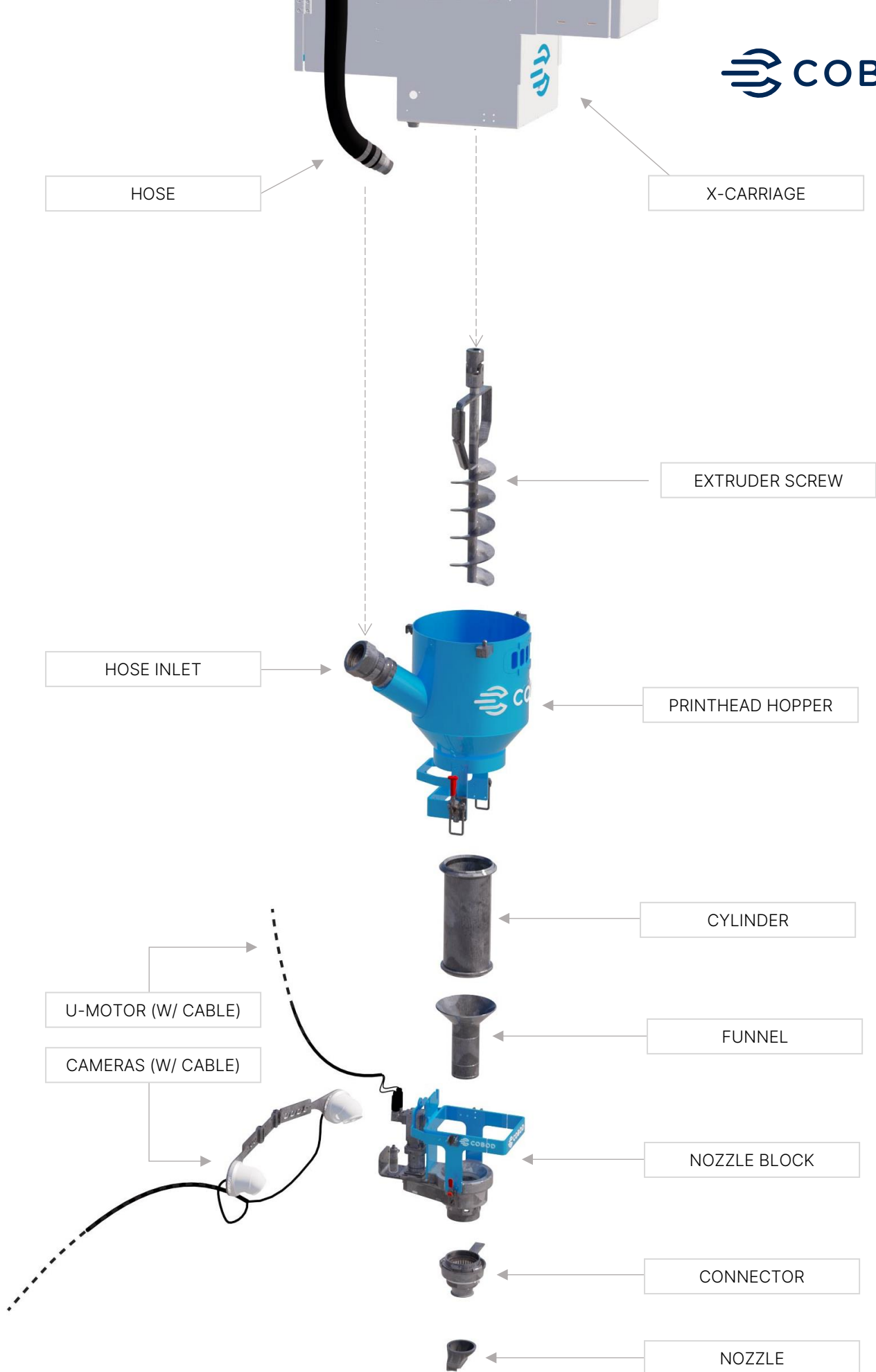


3.2.4 NOZZLES

The 3D printer comes with steel nozzles varying in size. For mortar printheads the default dimensions are 50x20 mm (width x length) and for HT (high throughput) printheads the dimensions are 50x40 mm and 80x30 mm (width x length).

Flaps can be attached to the nozzle on either one or both sides. The flaps help to ensure achieving the intended layer width and gives a better surface quality overall. See picture of nozzle without (left) and with flaps (right) to the right.





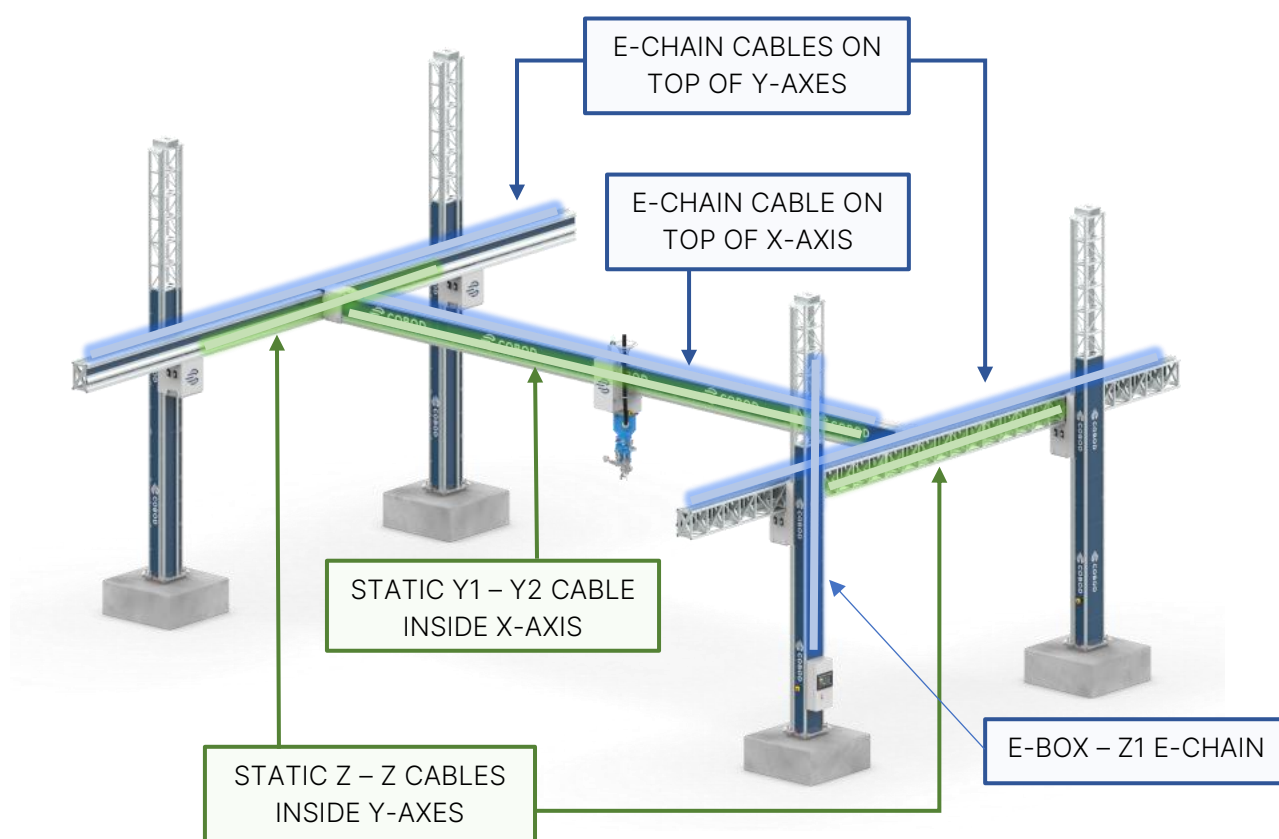
3.3 ELECTRICAL

Cables and connectors are vital for all internal and external communication in the printer. Their correct identification, installation, and general care is important for safety and maintenance.

All cables required to run the printer fall into one of the two categories: static cables without e-chain and moving cables inside an e-chain.

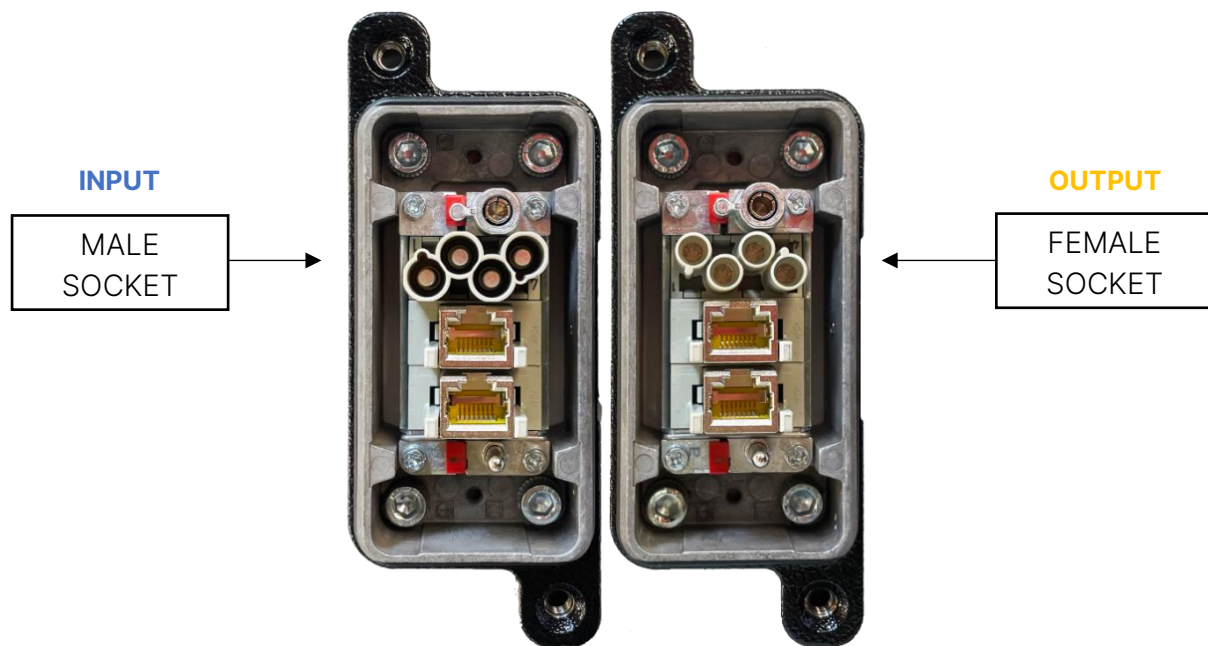
The static cables are used to daisy chain Z carriages within respective rows as well as connect Y1 and Y2 carriages. Static cables are run in the cable tray inside of the truss and the moving cables run in cable trays on top of the truss.

Below, the approximate locations of the cables that run throughout the printer and connect everything to the E-box is shown. The example below is found on machines with 4 Z-legs. Machines with 4 Z-legs has 7 cables (static and e-chain cables combined). For every additional pair of Z-legs added, a pair of static Z-Z cables are added as well.

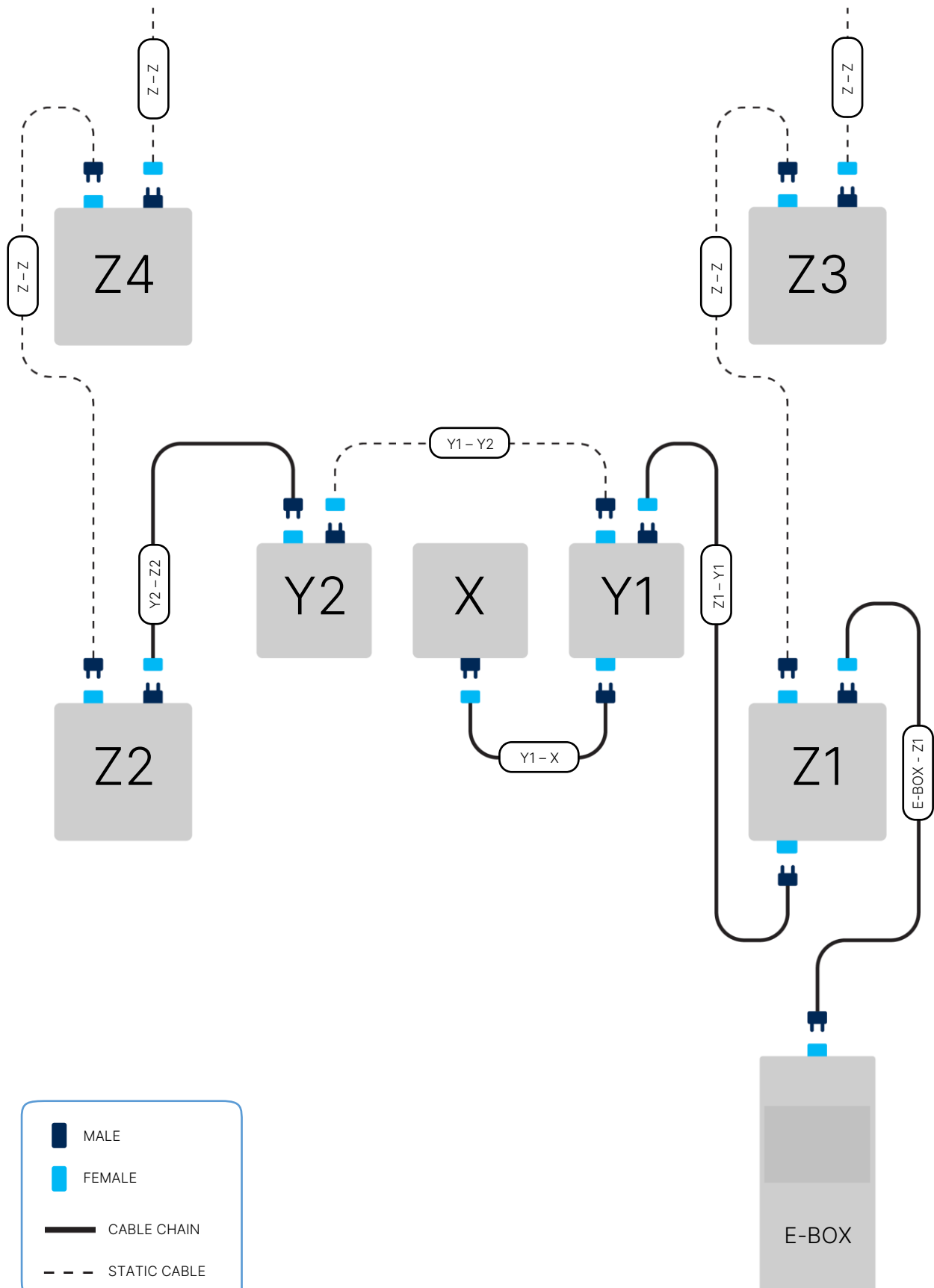


The E-box and carriages are connected to each other in a chain and connecting the chain in the correct order is vital for correct machine functionality. The E-box and carriages all have various heavy-duty sockets.

To identify if a socket is an input or output, inspect the socket – if it has four pins it is a male connector (input) and if it has four holes it is a female connector (output).



3.3.1 BOD2 WIRING DIAGRAM



3.3.2 E-BOX AND CARRIAGE CONNECTIONS

Main E-box

Being that the main E-box is the first link in the chain it only has one output socket for the printer wiring. And this output is where the male end of the “E-box – Z1” connects.

Z1

The Z1-carriage is slightly different from the rest of the Z-carriages as it has two output connectors, one more than the rest of the Z-carriages. Two of the plugs are placed on one side and the other single plug is placed opposite of those. The plug that is by itself is the output for Y1, so the male end of “Z1 – Y1” cable connects here. On the other side with the two plug there is an input where the female end of the “E-box – Z1” cable is connected. The third plug is an output where the male end of the “Z – Z” cable is connected.

Z2, Z3, Z4 etc

All Z-carriages other than Z1 are identical to one another. They have both an input and an output and can therefore be chained together to extend the printer in the Y-axis. These carriages have two plugs on one side and the use of these two plugs is dependent on where the Z-carriage is placed. If the carriage is positioned across from Z1 i.e., Z2 then the input plug will be where the female end of the “Y2 – Zn” cable connects. If the Z-carriages is placed anywhere else i.e., Z3, Z4, Z5, Z6 etc. then the input will be where the female end of the “Z – Z” cable connected. In either case the output on the Z-carriage will be where the male end of the “Z – Z” cable attaches.

Y1

The Y1 carriage has three plugs. Like the Z1-carriage, the Y1 carriage has two plugs on one side and a single plug opposite of those. The plug that is by itself is the output for the printhead, so this is where the male end of the “Y1 – PH” cable connects. The two plugs on the other side are an input and an output. The input is where the female end of the “Z1 – Y1” cable connects, and the output is where the male end of the “Y1 – Y2” cable attaches.

Y2

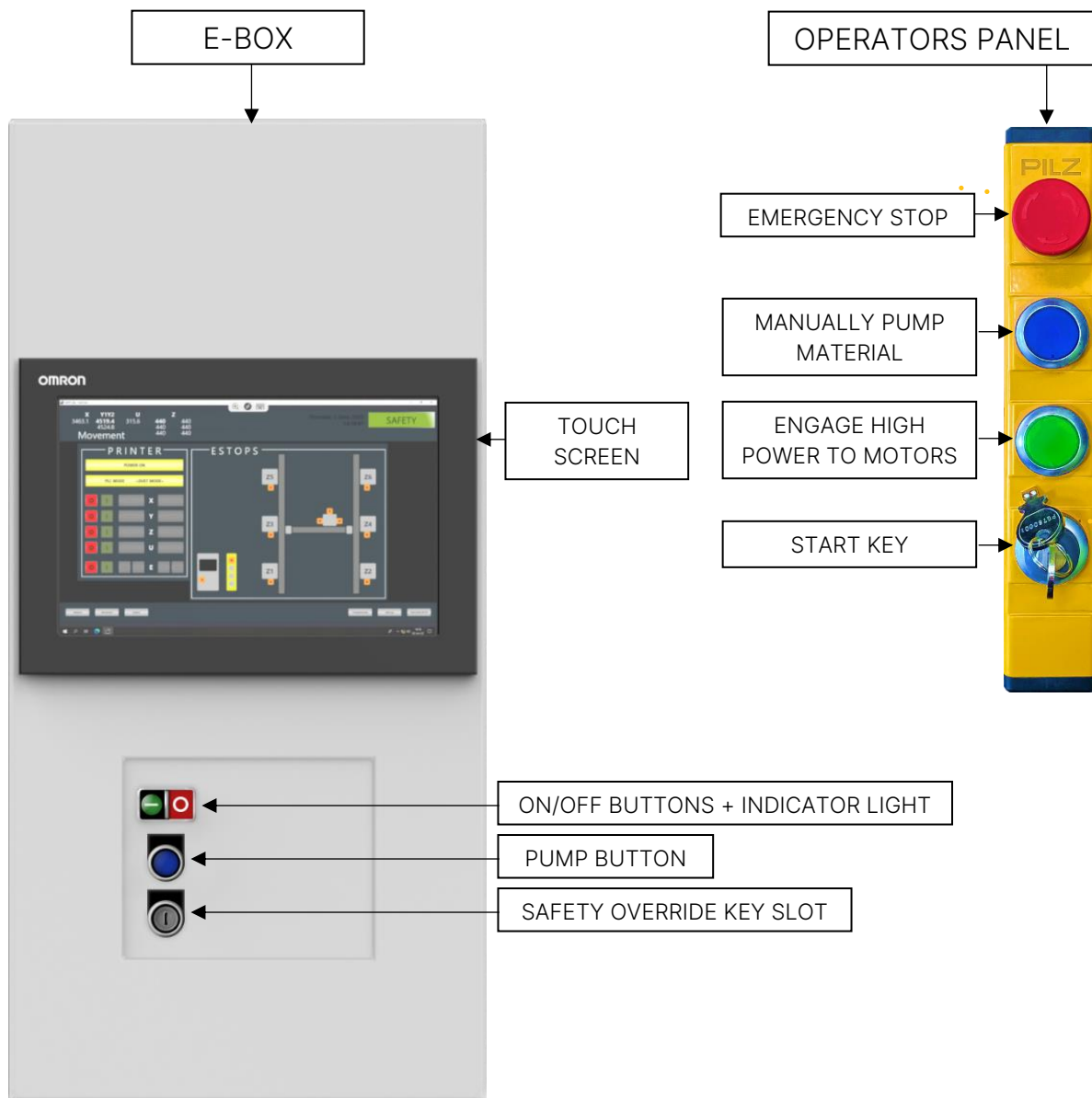
The Y2 carriage has two plugs on one side only. The input is where the female end of the “Y1 – Y2” cable attaches, and the output is where the male end of the “Y2 – Z2” cable attaches.

Printhead

The printhead has one input plug, which is for the female end of the “Y1 – PH” cable.

3.4 MAIN E-BOX

The E-box is located on the Z1 Column. The front of the E-box is equipped with the HMI touch screen interface, the on/off buttons for high power, pump signal indicator/button and safety override key slot. The main circuit breaker is located on the left side of the E-box and on the bottom is where the various plugs and connections are located.



Touch screen

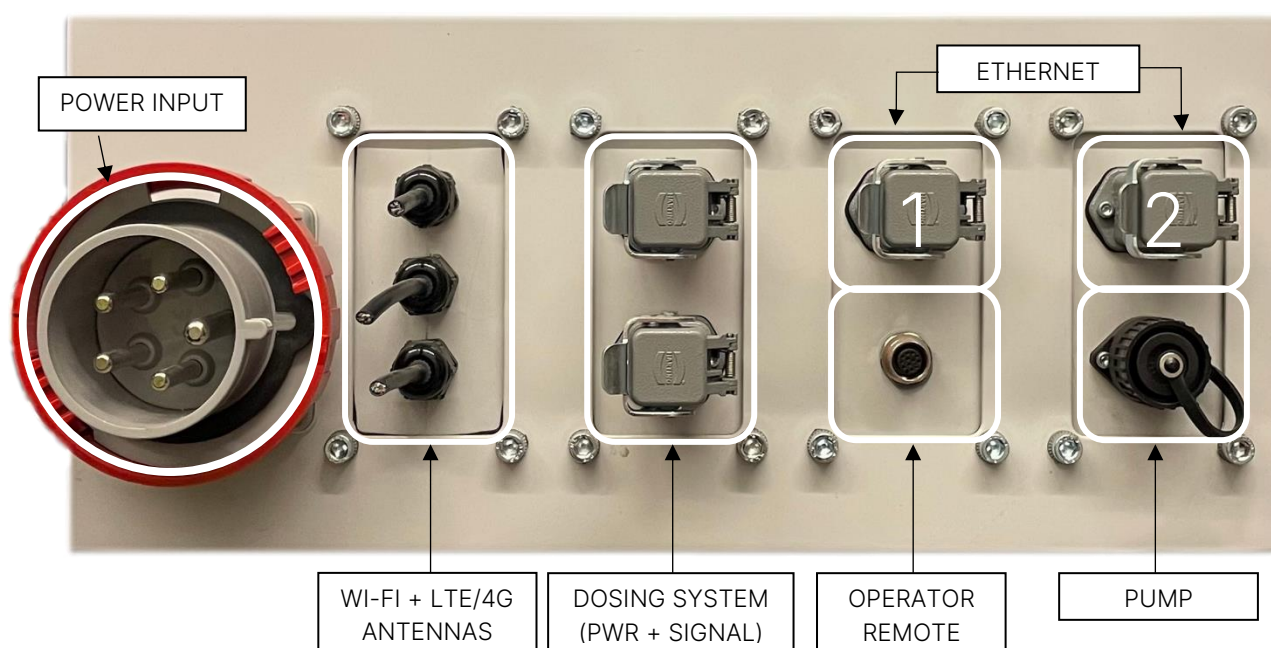
The printer is equipped with an IPC (Industrial Personal Computer) that runs the Soft-NA interface and can also run various other background operations. The IPC is operated using the built-in touchscreen. Being that this is a fully functioning Windows PC it has various standard connections on the backside.

Red/Green Buttons: The upper set of buttons are for arming and disarming the safety system. If any faults are present in the system this will not arm and therefore operation of the printer will not be allowed. When the safety system is armed the small light between the buttons will turn on.

Blue button: The blue button below has two functions. Firstly, it is an indicator of when the printer is requesting material from the material delivery system and will light up when material is needed in the hopper. Secondly, it functions as a button for manually requesting material (ie. Running the pump).

Safety override key: In the rare event of having to override the safety system this can be done by inserting the supplied key and turning the switch. The safety override key should only be engaged in certain situations or when instructed by a COBOD service technician.

3.4.1 E-BOX CONNECTIONS



All external connections on the E-box are placed at the bottom. Only the power connector and the operator safety remote are essential for powering on the printer.

The external connections include (from left to right):

- The power connector
- Antenna connections for Wi-Fi and LTE/4G
- Connections for the dosing system
- Ethernet (1) – internet connection for remote tech support (labelled “Internet”)
- Operator remote connection
- Ethernet (2) – LAN/PC access to the printer (labelled “Client”)
- Pump communication connection

3.4.2 EMERGENCY STOPS

The BOD2 3D printer has a series of Emergency Stops:

- One on the Operator Panel
- One on each Z leg
- Three on the X carriage

On the Movement page in Soft-NA there is an overview of all E-stops on the printer, which indicates if one has been triggered.

3.4.3 SAFETY OVERRIDE

IMPORTANT! Safety Override is a feature, which must be well understood by the machine operator. It should be performed with great caution and ONLY if necessary.



During normal printer operations, Safety Validation is responsible for making sure that everything in the system is functioning as it is supposed to, before allowing any movement of the machine.

However, using Safety Override disables the Safety Validation system. It will not fix any motor, hardware or cabling related issues. Functioning parts of the printer will still be allowed to move, while non-functioning ones will remain immobile! Allowing printer operations with the Safety Validation disabled can potentially damage the machine severely and cause serious injury to personnel on site.

Safety override can be used in various situation, some will be relatively safe for personnel and the printer, and some will endanger both – it is all down to the severity of the issue that demands using the override to move the printer. Either way safety override is only to be used in emergency situations as the safety of the machine and personnel is going to be compromised.

Before using the safety override to move the printer it is important to have diagnosed the issue or at the very least have an idea of where the issue might be affecting the printer's operation. If for example one of the Z-carriages has an issue that stops it from moving, you should not try to move that axis as that will drastically misalign the printer and very likely damage the equipment. When using safety override everybody on site should always pay extra attention to the movement of all the axes.

Potential situations where the safety override can be used:

- If you have crashed the printhead into the ground, the printhead clickers will in certain situations be activated until you move the printhead. To be able to do this, safety override will have to be used. Usually, the printhead moves up slightly (20 mm) when the clickers are activated.
- If you have top end stops installed on your machine, then you also must use safety override to lower the printer if they are triggered.
- If you are printing very high up and one of the e-stops on the Z-leg is triggered or even damaged by a worker not paying attention, then safety override can be used to lower the printer for cleaning.

Use:

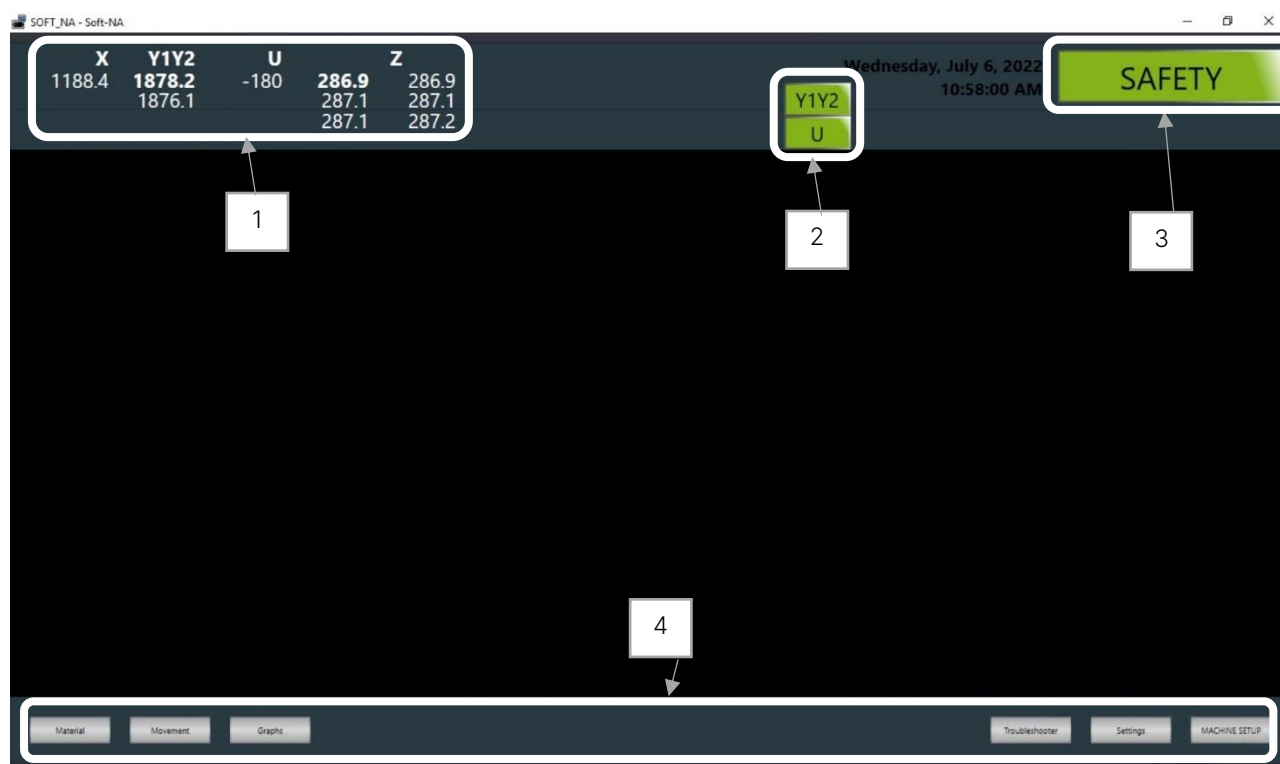
1. Insert the Safety Key in the keyhole right under the IPC of the main E-box.
2. Turn the key clockwise.
3. Soft-NA will indicate that the Safety Override is enabled by flashing the light above the X carriage green/red and beeping.

Access: Two sets of Safety override keys are included with the machine. It is recommended to have one copy bundled with the Control Panel Keys. Never leave the safety override key in the keyhole.

3.5 SOFTWARE/INTERFACES

3.5.1 SOFT-NA

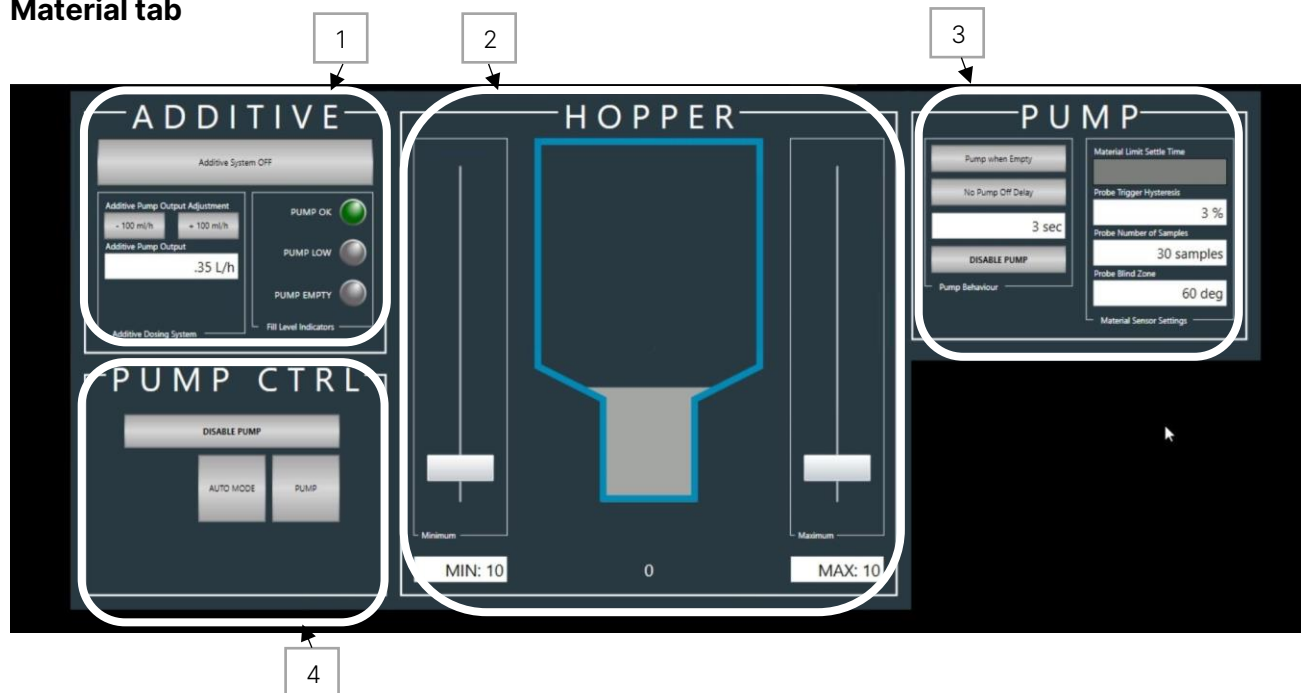
The BOD2 3D construction printer is controlled via the Soft-NA Software and Duet Web interface (DWC). The Soft-NA is the OMRON HMI software which is used for start-up and to control the motors directly, calibrate the machine and define the print area. The interface is available via the onboard industrial PC (IPC) which is mounted on the Main E-box, located on the Z1-column. The software starts automatically when the printer is turned on, otherwise it is accessible via shortcut on the desktop. The Soft-NA can also be accessed remotely through remote desktop.



1. **Machine positions** shows the current position of the U-motor and each carriage.
2. **Y1Y2 / U indicators** shows whether both Y and U are engaged (will turn red, if not)

3. **Safety indicator** shows if the safety features are engaged (will turn red, if they are not – e.g., if Safety Override is in use)
4. Tab/page navigation buttons:
 - > **Material tab:** material related settings, incl. setting hopper level
 - > **Movement tab:** includes switching between PLC/Duet mode, moving the printer manually and E-stop overview
 - > **Graphs:** data traces in graph format
 - > **Troubleshooter:** opens the troubleshooter screen
 - > **Settings:** set speeds, pump type and visual settings
 - > **Machine Setup:** homing and alignment

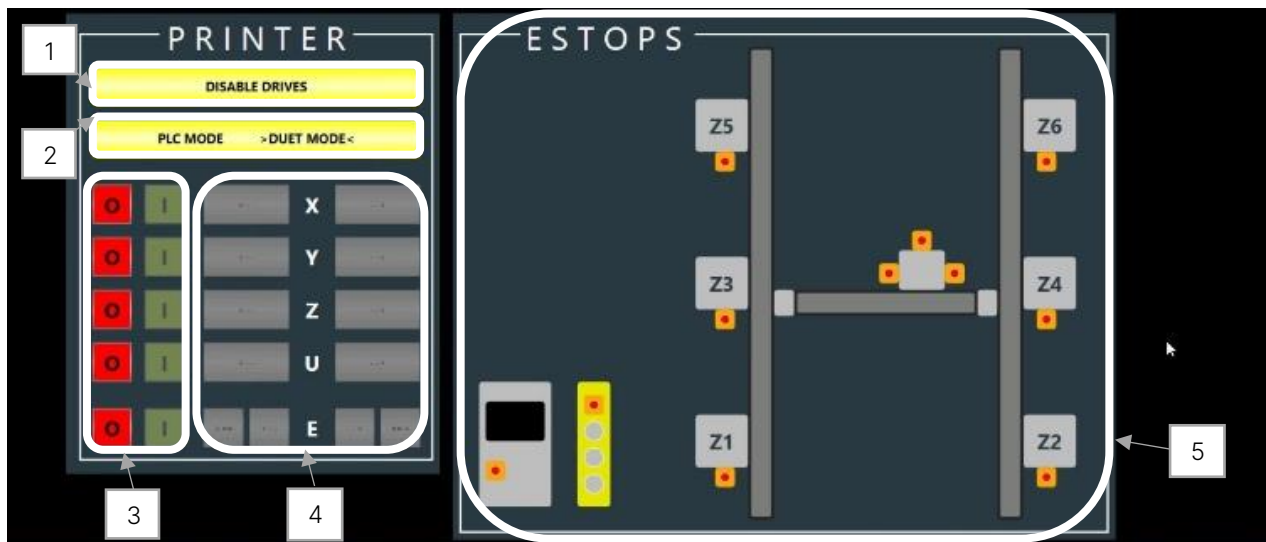
Material tab



1. These are the controls for the additive pump that adds the stiffening chemical in the printhead. Here you have the possibility of turning the system on and off. You can control the amount of chemical you want to add depending on the material. There are also three status light which will tell you about the operation of the pump and when the chemical canister is low or empty.
2. This image shows the material hopper and here you can adjust the material level with the two sliders. The one on the left adjusts the minimum level of material, i.e., when the concrete pump should start pumping material. The slider on the right controls the maximum level in the hopper, i.e., when the concrete pump should stop pumping material.

3. On the left side we have the pump signal delay settings for printers that are equipped with an air valve. On the left there are some settings regarding the hopper material sensor. These settings should not be changed unless specified by COBOD.
4. These are the concrete pump controls. Here, you can turn the pump signal on and off, you can turn on automatic mode (where the concrete pump will use the signal from the material hopper level sensor to know when to pump). There is also a “manual pump” button that will turn on the pump when pressed.

Movement tab



1. The function of this button is to enable/disable the drivers.
2. Use this function to switch between which system controls the machine's physical movement. In "Duet mode" the machine can only be moved via the Duet Web Interface and in "PLC mode" the printer can only be moved via the HMI.
3. This row of buttons gives you a visual indication of which axes are powered up and if any of them are not working correctly. You can also toggle the axes on and off independently.
4. These are the manual movement buttons. When the printer is in "PLC mode" these buttons are used for manual movements of the printer.
5. This shows an overview of the printer and locations of every E-stop button. When an E-stop is pushed this overview indicates where the activated E-stop is located.

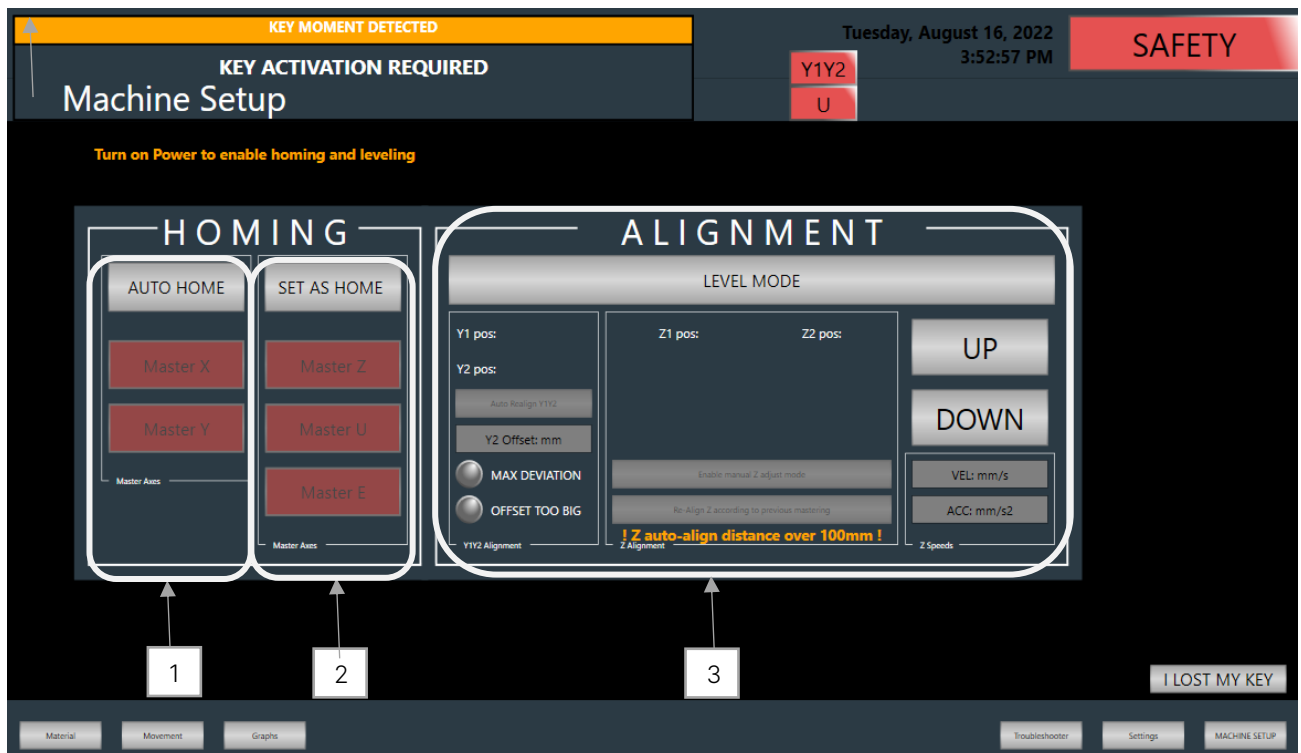
GRAPHS



This is the graphs page. Here, you can monitor data from all the servo drives and monitor your machine's performance.

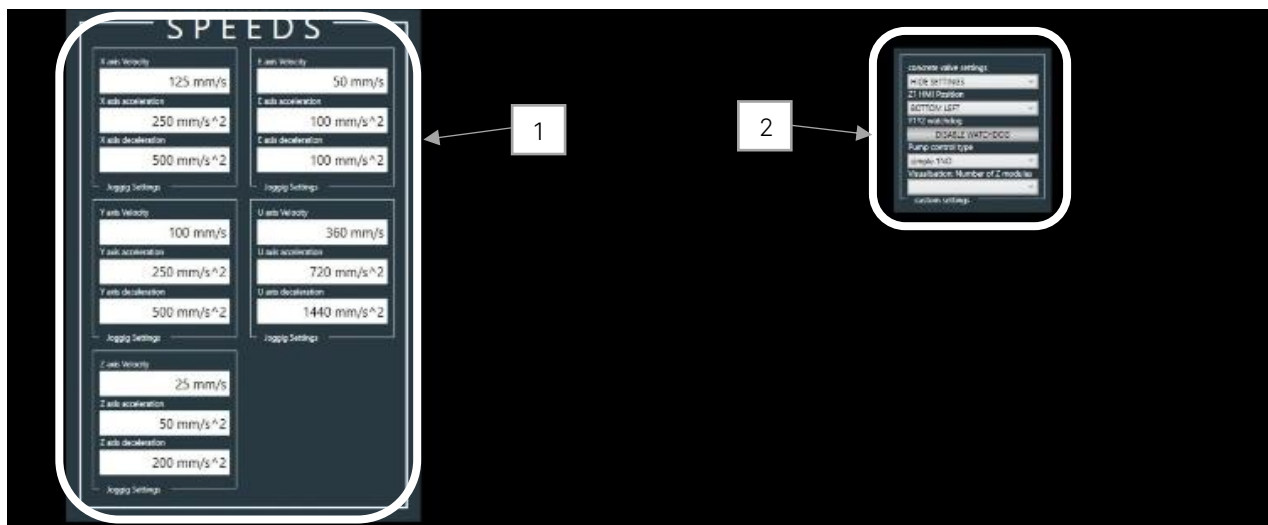
1. These buttons give you access to view different combinations of data.
2. These are the explanations of what the different colored graphs apply to.

MACHINE SETUP



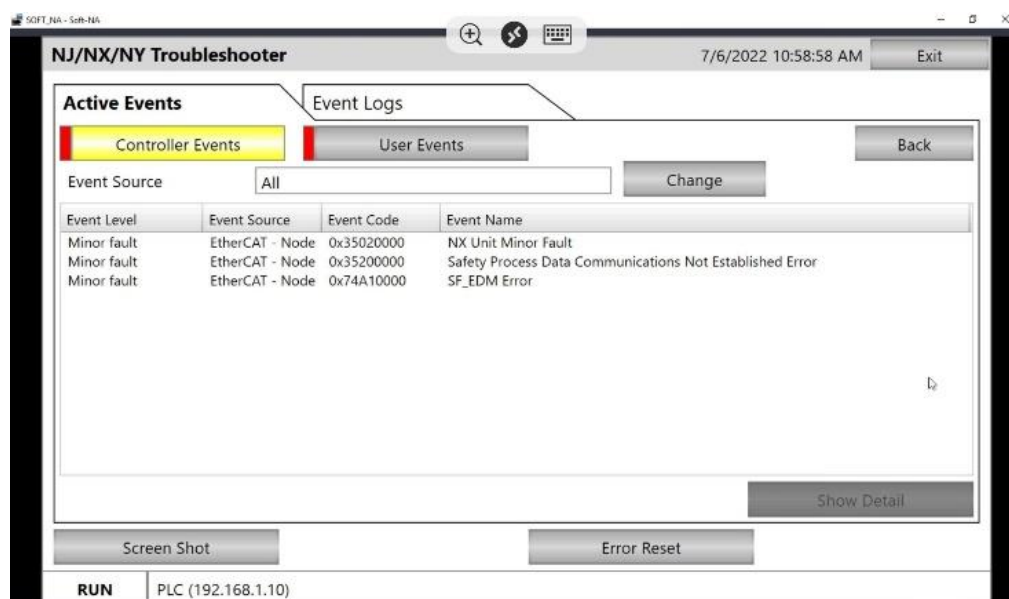
1. This is the homing interface. To the left you have the option of pressing “auto home”; this will activate the buttons for homing the X- and Y-axis individually. **Pushing any of these three buttons will move the printer, so make sure the print area is safe and that nothing is in the way of the printhead.**
2. Pushing the “set as home” button will activate the options below:
 - a. Master Z, which will set the zero height in the Z-direction i.e., right above you slab or print area.
 - b. Master U, which will zero the U-axis, this is done with the nozzle aligned along the X-axis.
 - c. Master E, which will zero the extruder axis. This needs to be done with the mixing arm of the extrusion screw right below the material hopper level sensor. This is to better process the signal coming from the sensor – if not done correctly, the automatic pump control will not work properly.
3. This is the alignment interface. Here, you can set up a Y2 offset to make sure that the X-axis is perfectly perpendicular to the Y-axis. You can also level all the connected Z-carriages; choose any of the carriages you have connected and move them separately or simultaneously.

SETTINGS



1. These are the settings for the speeds that the printer will move at when doing manual movement while in “PLC mode”. For every axis you can adjust top speed, acceleration, and deceleration.
2. Interface settings
This box contains interface settings. From the top, you have the possibility of toggling the air valve settings on and off, the possibility of choosing where the Z1 leg is placed in the visualization, disabling the Y1-Y2 alignment WatchDog system, choosing which type of concrete pump is connected to the printer and the amount of Z legs in the visualization.

TROUBLESHOOTER (POP UP)



The Troubleshooter in Soft-NA allows you to directly monitor and release the NJ/NX/NY Controller errors and events as well as the user-defined errors and events.

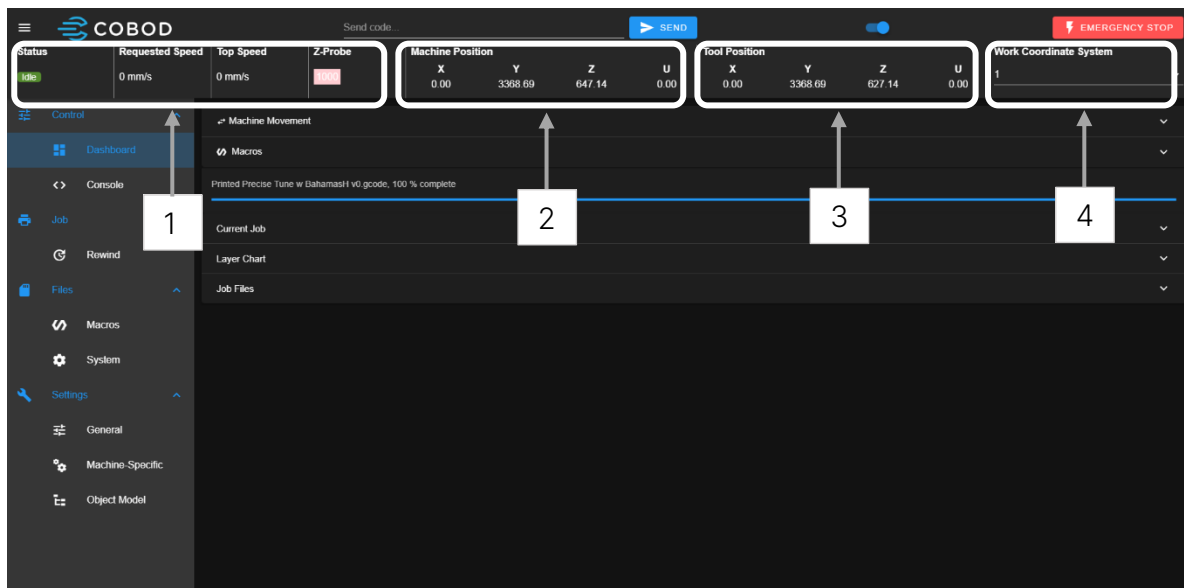
3.5.2 DUET

The DUET controller is a combination of hardware and software that reads G-code and sends the information to the OMRON PLC system of the printer. From the DUET interface you control the printer during most of your daily operation. To connect to the interface, you need to be connected to the printer either via wi-fi or ethernet and type the following IP address in your preferred web browser:

- 192.168.1.2

Before the user can control the machine via DWC, communication between motors and DWC needs to be established by “Gearing motors in” via Soft-NA. This is done via “Movement” section in Soft-NA, by clicking “Duet mode” button (Figure 6, A). With motors geared in, connect your device to the network the printer is on, either via Wi-Fi or via Ethernet cable directly to the main E-Box, “Client Socket”.

Front page



This is the front page of the Duet interface. In the top row you will find the following:

1. Status of the printer including at what speed it is currently moving and the Z-probe status.
2. This box shows the absolute position of the printhead as the PLC sees it.
3. This is the position of the printhead in your chosen WCS.
4. This is the drop-down menu where you choose which WCS you want to work in.

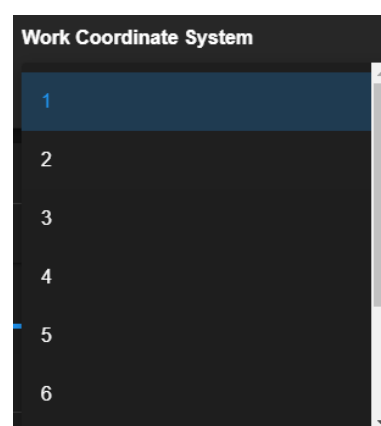
Next you can navigate the left column of tabs and you will find:

- **Dashboard**
- **Console:** Where you can see error codes and/or send commands.
- **Rewind:** Gives access to the rewind function.
- **Macro files:** Manage macro files.
- **System files:** View the printer's system files.
- **General settings**
- **Machine specific settings**

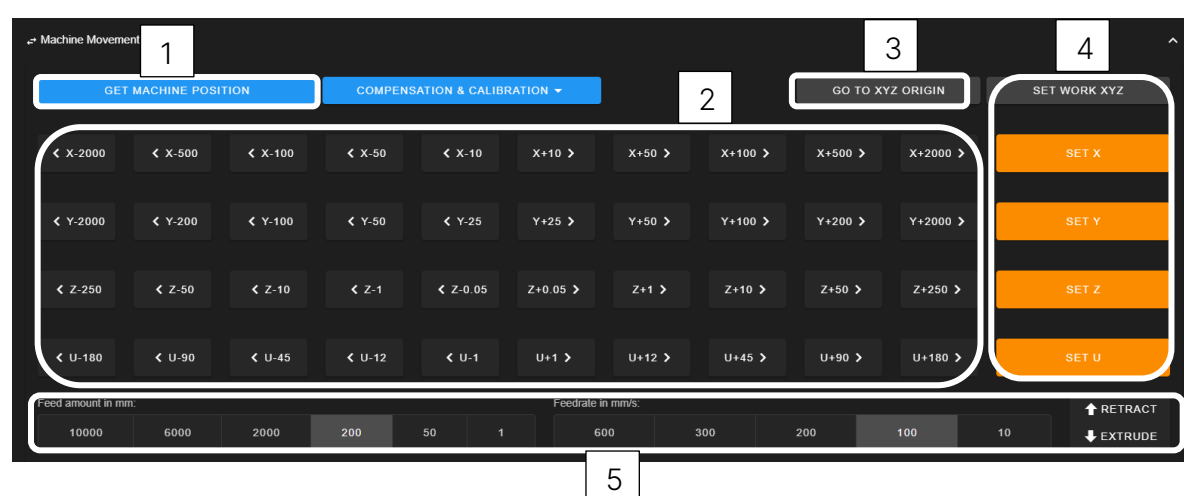
In the center you can access:

- **Machine movement:** Manual movement of the machine.
- **Macros:** Activate macros.
- **Current job:** Adjust settings while printing.
- **Layer chart:** View the layer time from the previous layers.
- **Job files:** View the job files stored on the DUET.

WCS (Work coordinate system): This is the menu that lets you choose which WCS you want to work in.



Movement tab



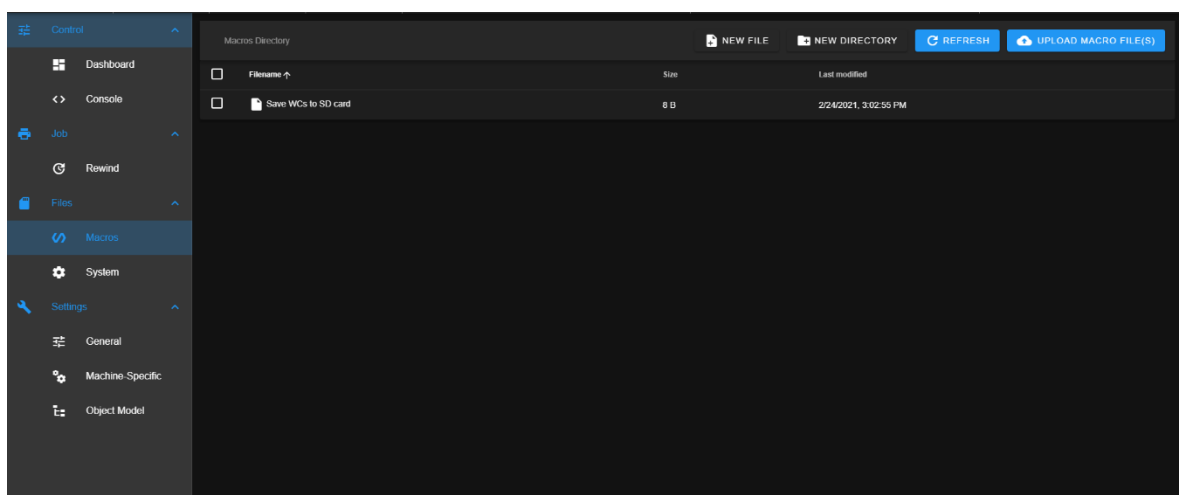
In this movement drop-down menu, you can control multiple things regarding movement and position.

1. This button will import the printhead position from OMRON and into the DUET. This button is usually used after moving the printer through the HMI.
2. Here you can control the printer by sending it movement commands. Controlling the printer from here will let you send a single movement command at a time to move the printhead to where you need it.
3. Pressing this button will move the printhead to the origin of the WCS that you are currently in.
4. Using these buttons, you can set the printheads current position as zero in the chosen WCS. The top button will allow you to set all axes at once and the orange buttons will allow you to set them individually. If using SET WORK XYZ, make sure that U is in a zero position or that it is manually zeroed afterwards.
5. This is the manual extrude/retract interface. When you just need to run the extruder to empty the material hopper you can use the feature. You input a "feed amount" and a "feed rate" and then you either press extrude or retract.

Macros

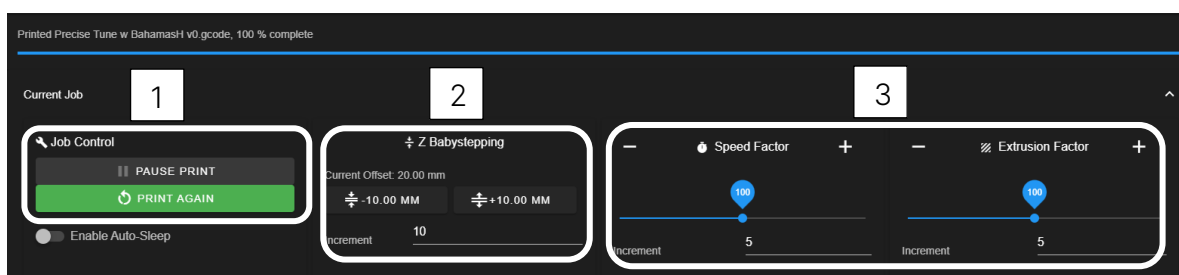


In the dropdown menu called “macros” you will find the available macros installed on your machine. A macro is a file that contains code that, when activated, makes firm-ware changes or performs a task in the printer.



In this tab you can access all the macro files that are installed. This is also where you add more macros.

Current job

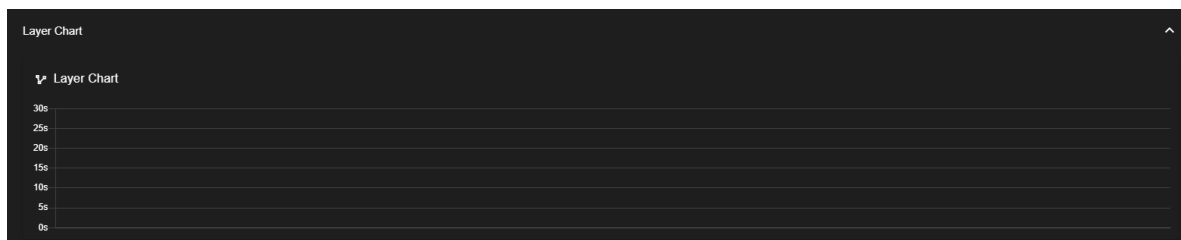


While running a G-code, relevant information about how the print is progressing and parameters allowing you to adjust the print will be shown under Current Job.

1. These buttons let you pause printing, continue printing, or cancel the current print.
2. This is the Z Babystepping interface. It allows you to adjust the Z-height while printing by offsetting your WCS either down or up. This is especially useful during the first couple of layers on uneven ground.
3. These are the sliders for controlling the speed of the printer and the extrusion factor. Both are usually adjusted continuously during a printing operation.

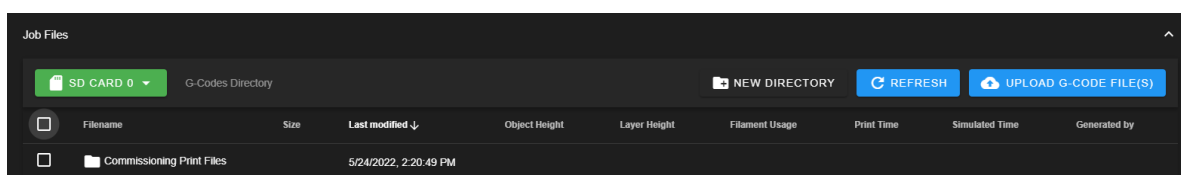
It is in here that you will also find the speed and extrusion rate sliders. These are the two most **crucial** settings to get right while printing. It is always the print operators' task to make sure the print speed is adapted to how the material is behaving.

Layer chart tab



Another important piece of data for the print operator is the layer time. In the “layer chart” drop-down menu this is displayed in a graph that shows the time of the last 50 layers.

Job files



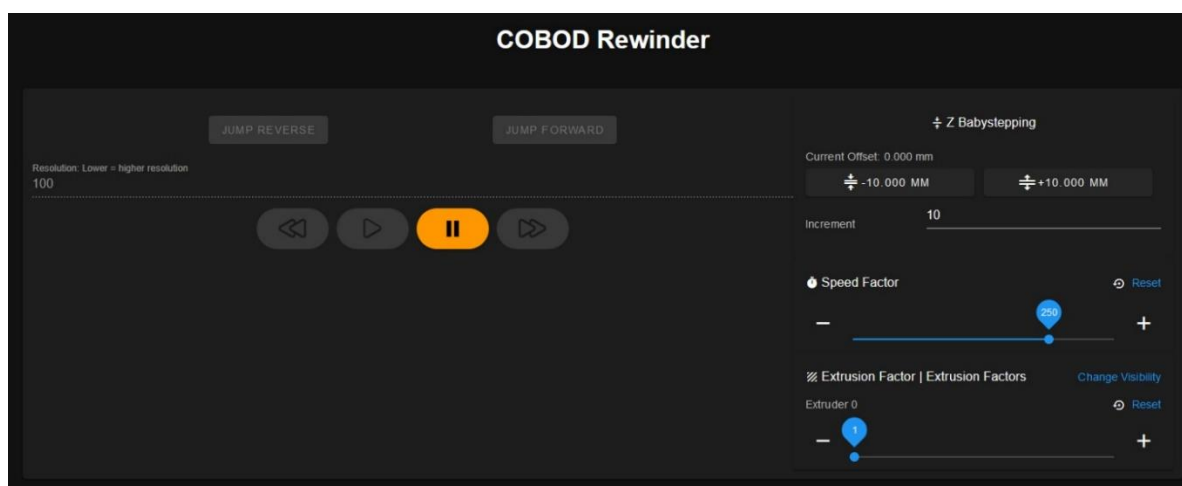
In the job files drop-down menu, all print files that have been uploaded are displayed. From here you can choose whichever file you need to print and upload new files by using the “upload G-code files” button.

3.5.3 REWIND

This plugin gives you control over rewinding and fast-forwarding a G-code file that is currently being printed. Main application is to quickly fix big prints without having to re-slice the geometry (in case of issues with material/extrusion).

Due to Duet plugin environment limitations, the **Rewind plugin needs to be manually activated** so it could be used right away when needed. To activate it, once the printer is turned on, the operator must click on the “Rewind” tab via the Duet Web Interface. If you see the Rewind interface, it is activated.

After activation, any G-code ran by the printer will have to be downloaded to the buffer of web browser used for the code manipulation via Rewind to work. If the plugin was activated, the download will start automatically after the print is started and that will be indicated by a progress bar found in bottom left corner. Keep in mind that if the browser window is closed or refreshed, G-code needs to be downloaded again.



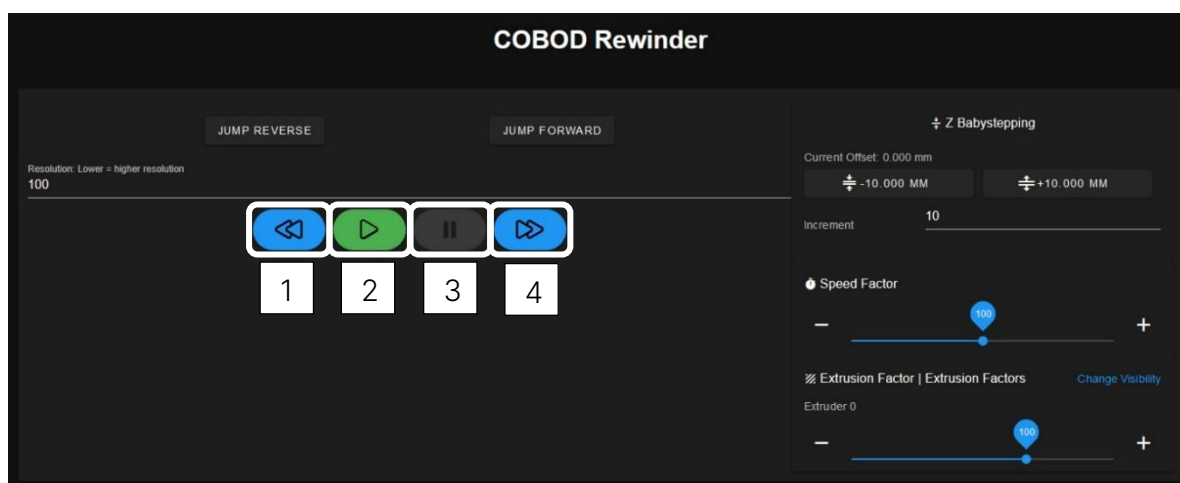
COBOD Rewind Plugin Interface while in idle mode

Pause the current print to Rewind

To start using Rewind, the print must be paused. That can be done either via Dashboard or Rewind tabs. It will have a different effect towards Speed and Extrusion values, depending on which Pause button the machine operator uses:

- If paused via Rewind tab, print speed will be reduced to 50 mm/s and extrusion to 1 %
- If paused via Dashboard, the values will be kept the same as before pausing

IMPORTANT! Always Resume the print from the Rewind tab! [Green “Play” button in the middle] Otherwise, if resumed via Dashboard it will resume at the place in which the operator originally paused.



Rewind controls

1. MicroStep reverse
2. Resume the print from here
3. Pause (either the print or the MicroStepping)
4. MicroStep forward

There are two sections here: Jumping and Continuous Micro Reversing/Forwarding. For Jumping, you can choose how many lines of G-code to jump at the time and click either "Jump Reverse" or "Jump Forward". Useful while looking for a place where print got interrupted by using bigger jumps to start with and small jumps to pinpoint the exact location.

Micro Reversing/Forwarding is a continuous movement either backwards or forwards along the G-code. Executed by clicking either << or >> icons. Micromovements reads only every second line of G-code, hence do not be surprised if the printer is performing some diagonal movement along X,Y and Z simultaneously.

Once going either direction, movement can be stopped with "Stop" button located in between "Rewind" and "Forward" buttons. Speed can be controlled via "Speed" slider present on the right-hand side. You can also extrude while doing this, just do not do it while going backwards and using flaps - you'll scrape the printed walls.

Quick guide

- Pause print via Dashboard or Rewind Tab.
- Z baby step up:
 - > If using flaps, Z baby step should be equal to the length of the Flaps + 5mm.
 - > In case no flaps are used, Z baby step should be set to a height equal to two times the layer height in which the print was sliced. I.e.: layer height of print was 20mm, then baby step Z up by 40mm.
- Use Jumping and/or continuous stepping to find a place where you want to print from.
- Z baby step back down to the height the print was paused at.
- INCREASE EXTRUSION! (If paused via Rewind tab, extrusion is automatically reduced to 1, to not extrude while rewinding).

- Depending on how long it took to find the location to resume from, you might consider extruding a little amount of material to make sure there is a good flow and material did not cure too much around the extrusion screw.
- Click "Resume from here".

3.5.4 WORLD COORDINATE SYSTEMS

Once setting the origin of the 3D printer (upon installation), the MCS (Machine Coordinate System) is determined. Within the MCS it is possible to set up multiple – up to 9 – WCS's (World Coordinate Systems).

Example:

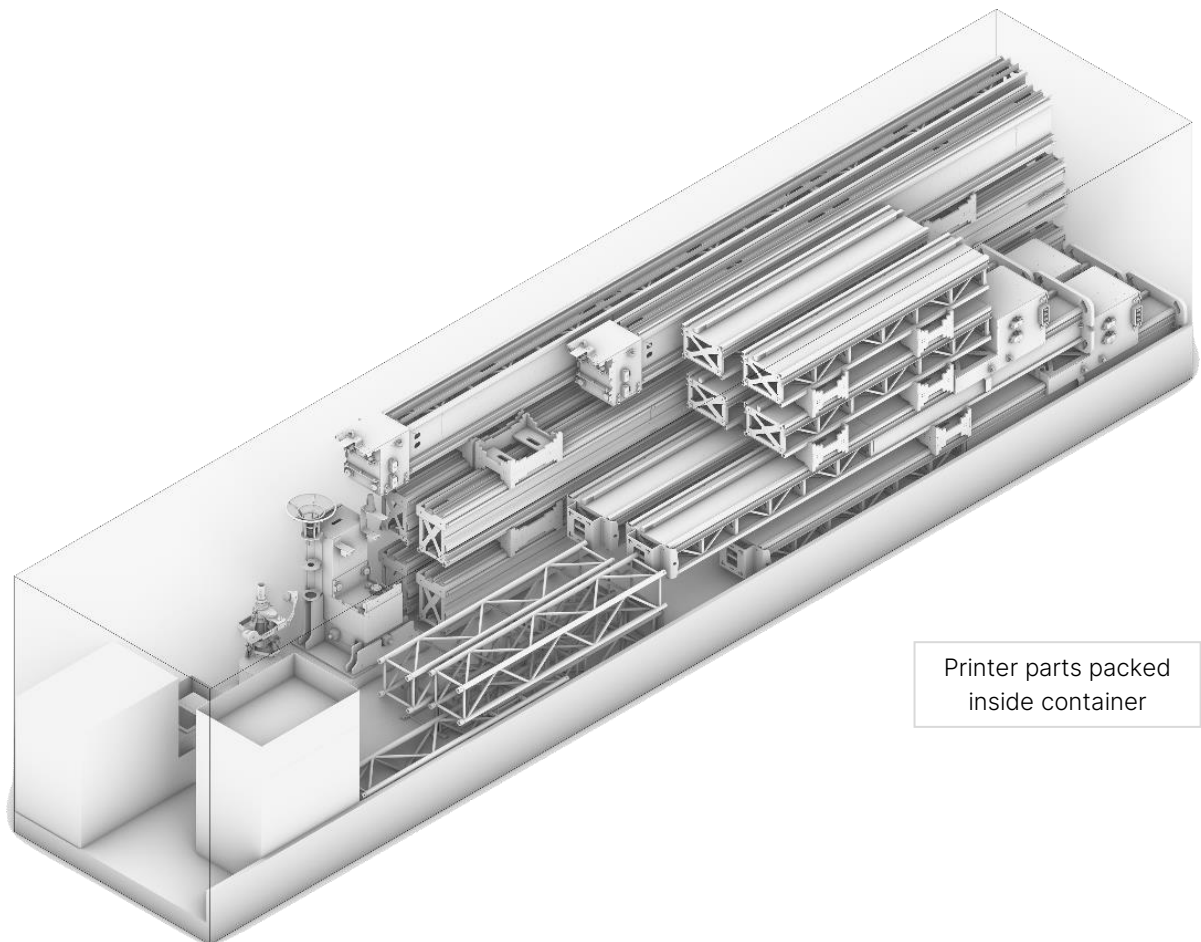
Prerequisite for the following is to have BOD2 set up including homing, printer powered on and having the machine operator PC connected to the Duet Web Interface.

Once Duet and motors are synchronized via Get Machine Position button, the Machine Position will be updated. This coordinate system refers to the minimum and the maximum physical positions and is defined by the configuration of your machine. For example, if your printer has 4X, 4Y and 2Z modules, the MCS Minimum values are X=0 Y=0 Z=0 and Maximum Values of X9644 Y9648 measured in millimeters. Z Maximum will vary depending on the set-up, i.e.: height of concrete blocks and anchors used, standard or HT print-head, nozzle length, etc.

It is perfectly fine to only use MCS while learning how to operate BOD2 machines to focus on other aspects of printing first: machine control, file preparation, dry runs, etc. However, WCS is a very useful tool while aligning smaller prints in the print area or offsetting bigger ones to match drawings with physical printer position. WCS is a coordinate system inside MCS. The printer remembers such systems as precise offsets from main MCS, and the printer operator can switch between the machine and multiple work coordinate systems on the fly.

IMPORTANT! Once WCS are created/updated, the macro named **Save WCS to SD Card** needs to be executed to be saved. If not done, the new WCS will be lost once the printer is powered off or the duet board is reset. Also, it is recommended having the "1" WCS identical to the MCS.

4. UNPACKING PROCEDURE



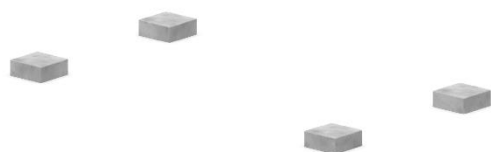
Before commissioning of the BOD2 a Factory Acceptance Test (FAT) is executed. Upon arrival and installation of the BOD2 on customer's location, a Site Acceptance Test (SAT) is completed additionally. The SAT is performed with the present COBOD personnel.

Unpacking procedure:

1. Perform an inspection of the equipment inside the container(s)
2. Take the opportunity to familiarize yourself with the names of the components
3. Check that all parts have been received – refer to belonging shipping list
4. Check for damaged parts in shipment
5. Unload container(s) in coherence with your site plan, to ease the installation

5. INSTALLATION PROCEDURE

Overview: order of mechanical assembly



1. Place concrete feet



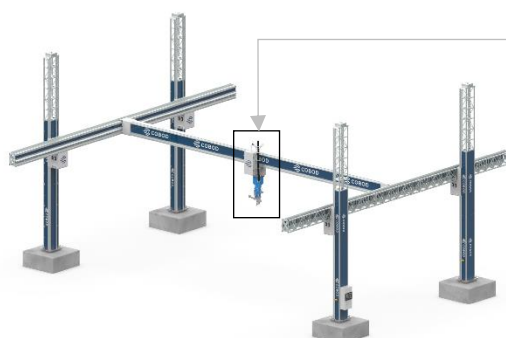
2. Install Z-columns



3. Install Y-axes



4. Install X-axis



5. Install printhead



Printhead zoom-in

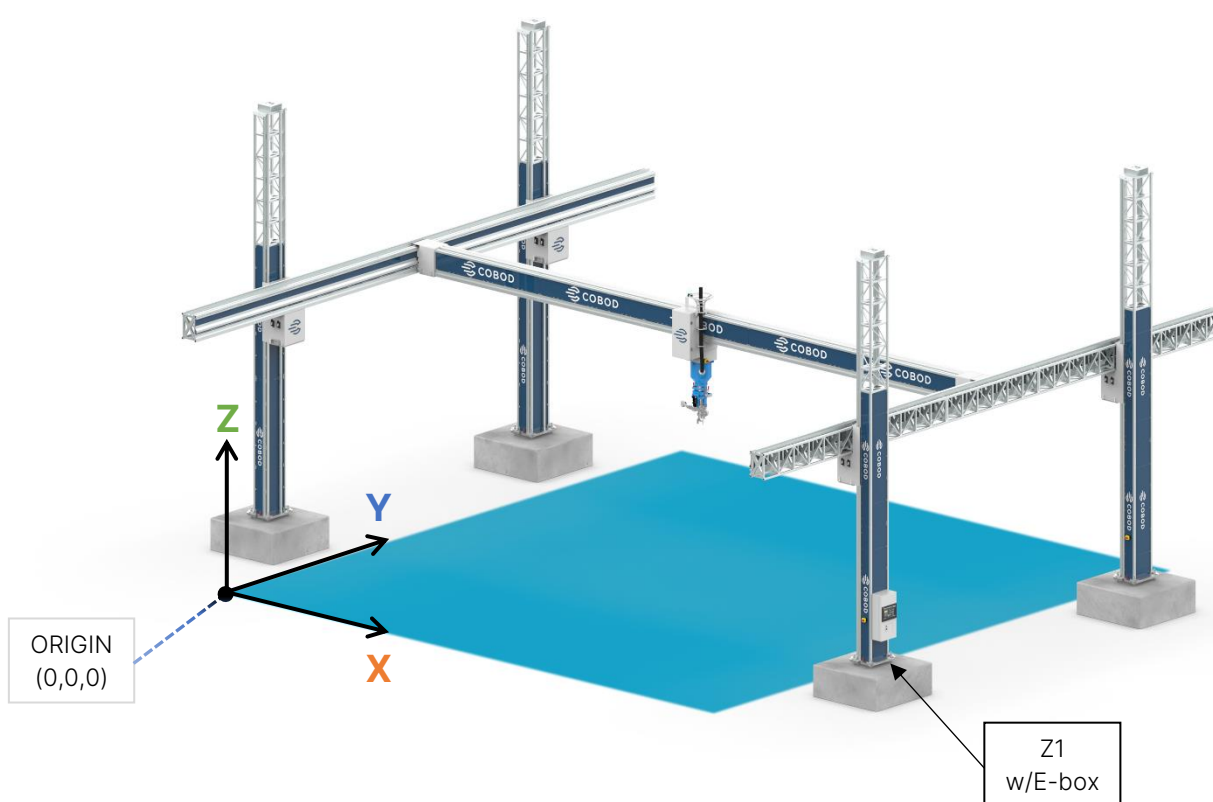
5.1 PREREQUISITES

5.1.1 CARTESIAN COORDINATE SYSTEM

The printer operator must be familiar with the three-dimensional Cartesian coordinate system. It is defined by 3 perpendicular axes: **X**, **Y** and **Z**.

If you are standing in front of the printer, facing the X carriage E-Box, the following applies:

- X axis: Right (X+) and Left (X-) movement
- Y axis: Forwards (Y+) and Backwards (Y-) movement
- Z Axis: up (Z+) and down (Z-) movement



5.1.2 BOD2 ORIENTATION FOR SETUP

See the figure above and take note of the position of the Z1 column (the one with the main E-box) in relation to the X carriage E-box. Always install your printer in the same manner to retain correct Right Hand Cartesian Coordinate System.

When the X Carriage is parked at the leftmost, backmost position and the printer nozzle is touching the ground – that is the Origin Point. Machine coordinates at the origin are X=0, Y=0 and Z=0. When in Duet mode, the printer only moves within positive coordinates as all negative values are considered outside the print area. When in PLC mode it is possible to move beyond the positive space.

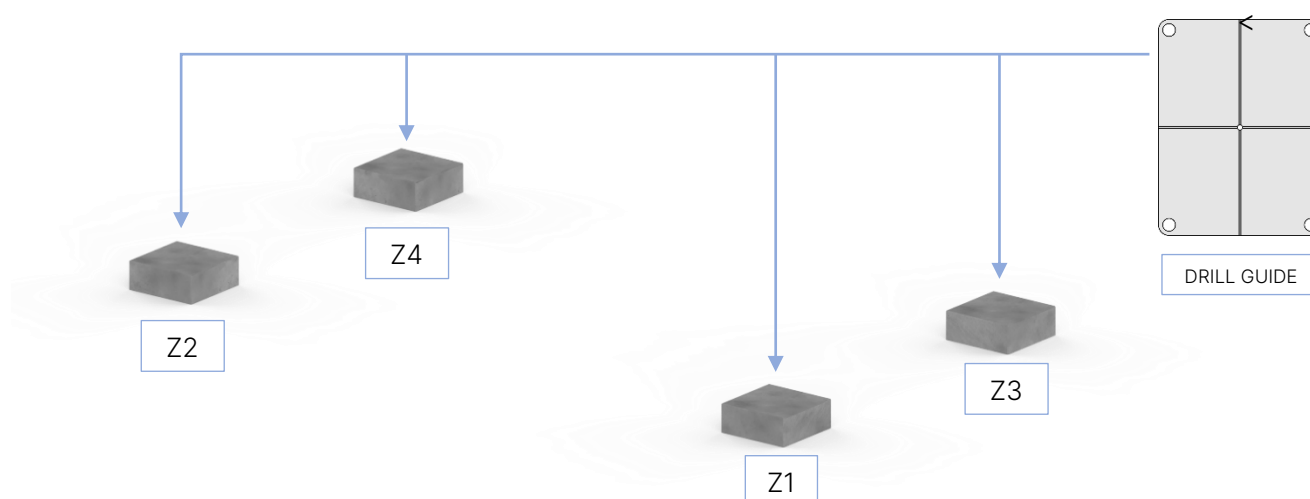
5.1.3 POSITIONING OF CONCRETE BASES

Determine the size of the BOD2 3D printer to be installed by checking the Machine Specific Dimensions chart. The tolerance for placing the concrete bases in relation to the intended print area is ± 20 mm in both X and Y direction.

If installing the printer in a warehouse or lab, roughly measure out the center points to ensure the printer is placed as intended. If installing on site, it is recommended to have the land surveyor mark the center positions for the concrete bases to assure correct placement.

Use a multi-line laser, a laser measurer and the drill guides provided with the machine to position the concrete bases:

1. Place the first concrete base on the marked position. As a rule of thumb, the Z1 concrete base is placed first.
2. Place the drill guide on top of the threaded anchor rods.
3. Place an angle laser on top of the drill guide centered, so the 90-degree angle lasers are in line with the grooves on the drill guide.
4. Place another concrete base on the point marked Z3 and place the drill guide on top. Ensure that the distance between the center of the drill guides is correct and that they are in line.
5. Now place the concrete base for Z2, place a drill guide on top and make sure that the distance between the centers of the drill guides is correct and that the Z1 and Z2 base are in line.
6. Move the multi-line laser to the Z2 concrete base and align the laser to the drill guide on Z1.
7. Place the Z4 concrete base and make sure that the distance to Z2 and Z3 are correct and that it is in line with the Z2 concrete base.



5.1.4 SPLITTING AND ASSEMBLING TRUSSES

To split trusses, remove fishplates prior to removing the four main bolts. Both X and Y trusses have 3 fishplates each – X has three small ones and Y has two small ones and one larger. If fishplates are not removed prior to disassembly, they will be snapped or

deformed. If fishplates are stuck, loosen the main bolts, and wiggle the truss gently from side to side, while trying to pry the fishplates out with a screwdriver. After removing the fishplates, remove the four large bolts connecting the trusses. Place fishplates and bolts in a bag or another safe place to keep track of them.

To assemble the trusses:

1. Align the ends of the trusses to be assembled. Y-modules can lay directly on, for example, a pallet or another stable surface, while the X-axis modules must always be placed on the provided stackers to protect the tooth racks placed underneath.
2. Once roughly aligned, place the main bolts (with nuts and washers). Do not tighten fully!
3. Place the fishplates to align the trusses. Once placed correctly, tighten them. Lastly, fully tighten the main bolts (should be torqued to 240 Nm/176 ft lbf).
4. Use the Tooth rack Alignment Tool to ensure that the tooth racks meet as expected. If not perfectly aligned, contact techsupport@cobod.com for further instructions.

5.1.5 MOUNT X-AXIS CARRIAGE

Mounting the X-carriage on the X-truss is a delicate task that requires precision and caution. To mount the X-carriage and assemble the X-axis truss you will need a lifting strap and the tools normally used to join two pieces of truss.

1. Place the one half of the X-axis truss on pallets lifting it high enough off the ground for the X-carriage to clear.
2. Place the lifting straps under the top bearing arms, lift the X-carriage and get it in position to slide its bearings onto the rails.
3. Carefully slide the X-carriage onto the rails and disconnect the lifting strap.
4. Assemble the other half of the X-axis truss on to the half you just slide the X-carriage onto.

5.2 BOD2 MECHANICAL ASSEMBLY

5.2.1 POSITIONING AND VERIFICATION OF Z COLUMNS

Positioning and verification of correct Z column installation is one of the most important steps in the printer setup. Getting this right means that first the Y-axes and then X-axis installation is going to be smooth. Get it wrong, and you won't be able to install the X-axis and you will have to go two steps back and redo the positioning. Be thorough and spend the time needed to get this perfect. Use a spirit level, laser distance measurer and a multi-line laser.

1. Lift the Z-axis truss assemblies into place one-by-one and try to center the studs in the holes of the baseplate. Use the washers and nuts to secure them to the concrete blocks.
2. Using the spirit level make sure that every axis is plumb in all directions.

3. Using the laser distance measurer and the multi-line laser make sure that each row of Z-axes is parallel and at equal distance to the opposite one. It is possible to adjust the Z-axis position only by twisting it around the slotted holes of the baseplate.
4. The distance between the front face of the Z-carriage to the front face of the opposite Z-carriage can be up to a maximum of three millimeters above the distance from the calculator, but never lower.

5.2.2 ADJUSTMENT OF Z CARRIAGE POSITIONING USING MANUAL CONTROL BOX

Layout

The manual control box can be used to power and move all Z-carriages. The intended use of the box is to manually move the carriages onto the Z-axes or to align the height of the carriages. This is done when installing the printer to create a levelled base for the Y axes or when the printer is dismantled for shipping, storage etc.



Connecting the box

The box should safely be connected to a 3 phase, 32A power outlet with enough cord needed for the appropriate movement of the Z carriages. The heavy-duty plug should be connected to the input socket on the Z carriage. Ensure that no other connections to the carriage box are present. Whenever power is switched on, the yellow “PLC ON” lamp should light up.

Button Descriptions

- The box contains a 3-stage switch and 4 buttons. The 3 stage “Mode” switch has the following modes:
 - > Left: No movement
 - > Middle: Slow movement
 - > Right: Fast movement
- The green start button is used to power on and start the carriage motor.
- The blue up and down buttons move the motor continuously when pressed.
- The red stop button is used to power off or reset the motor box. It will also flash if an error is encountered.

Start Up

Once the box is powered up, the yellow PLC ON lamp should be on and the green START button should be flashing. This indicates the box is ready to connect to a carriage.

- Press and hold the START button for 2 seconds, until a click from a relay is heard meaning the power is on.

After approximately 10 seconds, one the following 3 scenarios could happen:

1. All the buttons light up. The box is now ready to control the connected Z-carriage
2. Blinking red stop button. This means that the remote box has made configuration changes to the Z-carriage and now needs to power cycle. To do this press the red stop button once and wait around five seconds. Then hold the green button for two seconds and then the buttons should light up and the box is now ready to control the connected Z-carriage
3. Blinking red stop button but the steps in scenario 2 does not produce a functioning result. Please contact COBOD technical support.

Normal Operation

- When the blue buttons are lit, the drive should be ready to move the carriage. If the MODE switch is set to slow, the maximum speed is set to 10mm/s. In fast mode, the maximum speed is 40mm/s with higher acceleration.
- The carriage should only be moved when it is safe to do so. Ensure cables are not caught during movement of the carriage.
- To disengage the drives, press the red STOP button once. The drives can be engaged again with a single press of the START button after this.
- To turn the box off, press the red STOP button once to disengage the drives, then press it a second time to turn off the power to the carriage. Only after a click from a relay is heard is it safe to remove the heavy-duty connector from the box.
- To start up the carriage again, the green START button must be held for at least 2 seconds.

5.2.3 INSTALLATION OF Y AXES

After levelling the Z-carriages you are ready for the installation of the Y-axes. This operation involves lifting a long and heavy axis – precision and caution are required.

1. Using lifting straps and a crane or telehandler lift the Y-axis carefully onto the Z-carriages with the tooth racks facing the print area. Make sure that the 'overhang' of the axis in both ends is relatively equal.
2. Install the Y-axis hooks 'finger-tight' to secure it from slipping off the Z-carriages. At this stage leave roughly 10mm of room between the Y-axis and the hook to allow small adjustments.
3. Repeat steps 1 and 2 for the second Y-axis.
4. Make sure the ends of the Y-trusses are in line with each other. Readjust if needed.
5. When the X-axis has been installed, aligned, and moved down along the full length of the printer once, readjust the hooks to have no room between the Y-axis and the hook.
6. Secure the hook fully.

Pro tip! If your individual Y-axes consists of 9 more trusses, it can be an advantage to place the axis in two parts and assemble it while the two parts are resting on the Z-carriages.

5.2.4 INSTALLATION OF X AXIS

The last step of the mechanical assembly is to install the X-axis. Success of this operation is very dependent on the precision of the previous steps. Fitting the X-axis onto the rails of the Y-axes requires precision and caution. Damaging a bearing during this operation is very easy.

1. Make sure that the X-carriage is centered on the X-axis. This is important for keeping the X-axis level and stable while lifting.
2. Using straps lift the X-axis as straight and level as possible. Pay special attention if the axis is rotating either forwards or backwards. Readjust the lifting straps to get it level.
3. Slowly align the bearings on each end with the rails.
4. When both ends are good slowly push the axis onto the rails. Manually push the axis until all bearings are in the rails and you have clearance to mount the mechanical end-stop brackets.
5. Mount the end-stop brackets before undoing the lifting straps.

5.3 ELECTRICAL ASSEMBLY

The static cables and e-chains are connected to the printer after the mechanical assembly is done. The e-chains are quite heavy and are easiest to handle with a crane/telehandler. The e-chains that run on the two Y-axes are installed in the same way. Simply lift the rolled-up e-chain up into the cable tray and roll it out. Fix one end to the end of the truss and the other end is fixed to the Y1- or Y2-carriage. Connect the plugs.

Same goes for the X-axis, lift the rolled-up e-chain into the cable tray and roll it out. Fix one end at one end of the truss and the other end to the X-carriage. Connect the plugs.

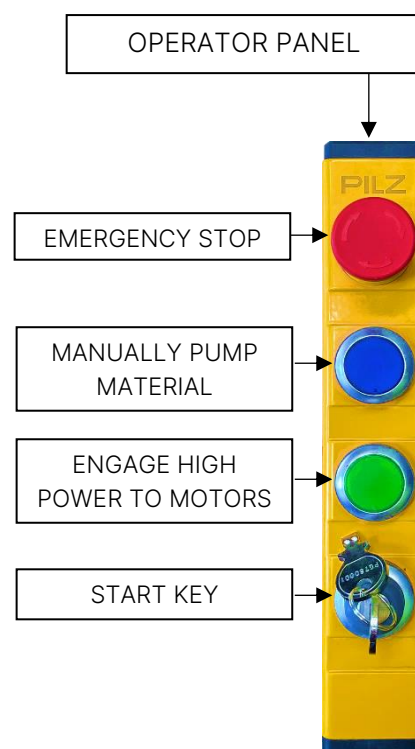
The e-chain that connects the main E-box and Z1 needs to be lifted in one end, rolled out while lifting and then fixed in position at the very top of the Z1 truss. The other end should be connected to the Z-carriage.

The static cables are to be placed inside of the X- and Y-axes in the designated cable tray and then connected to the correct sockets.

5.4 POWER UP

Turn the power switch on the E-box (located on the Z1-column) to “On”-position (I). Once the IPC starts, enter the password to Login. Wait for the Soft-NA software to start up.

Engage Motors by rotating the key on the Operator Panel (clockwise and hold until the light above the printhead turns on, blinking red and yellow). Then, firmly press the green button on the controller. The indicator light above the printhead should turn green. If the light does not turn green, make sure that none of the Emergency stop buttons are pressed by looking at the ‘Movement’ tab in Soft-NA (there are three on the printhead, one of each of the Z-columns and one on the Operator Panel).



If the light is still not turning green, check the Soft-NA for errors. It can be viewed by clicking the ‘Troubleshooter’ button, on the lower right corner. Here, the encountered errors are displayed. Try resetting the errors and then pushing the green button on the Operator Panel once more. If the light still doesn’t turn on, consult the Troubleshooting section for further instructions.

Next, via IPC on the E-box, open Soft-NA. Click the ‘Movement’ button to access the tab and press ‘Enable drives’ followed by pressing ‘Duet mode’. Open the Duet Web Interface in your browser to control the printer.

In Duet > Dashboard > Machine Movement, click on ‘Get Machine Position’. This synchronizes the actual position of all drivers in Soft-NA to the Duet Web Interface. This action must also be performed every time the printer has been moved via Soft-NA.

IMPORTANT! Never press Get Machine Position while printing.

If the printer is set to “Enable Drives” while the Duet mode is not engaged, the carriages and/or axes can be moved directly via Soft-NA. If moving printer via Soft-NA, the coordinates in Duet are not updated, hence always remember to ‘Get Machine Position’ before starting to use the Duet mode.

If both “Enable Drives” and “Duet Mode” are enabled, the machine can be moved via Duet only.

5.5 ALIGNMENT

5.5.1 Z CARRIAGE ALIGNMENT

Via Soft-NA, disable Duet Mode and click on “Machine Setup”. Enable “Level Mode” as well as “Manual Z adjust mode”. Click on the Z-carriage you want to adjust and use the move up/down buttons. Have a Spirit Level in the middle of X or Y axes and adjust individual Z-carriages until all axes are levelled.

Another method is to plug in the “Z Level Controller” remote to the carriage you want to adjust and move it up/down via the dedicated buttons on the remote. A self-levelling line laser can be used to make a level line – then the Z-carriages can be aligned using a line detector.



Pro tip! When adjusting directly through Machine Setup in Soft-NA, multiple Z-carriages can be chosen and moved simultaneously.

5.5.2 Y2 CARRIAGE ALIGNMENT

Upon installation of the X-axis truss you must go through the following steps to make sure the X-axis is perfectly square to the Y-axes. This alignment is very important for the accuracy of the prints that are produced. If the X-axis is skewed, then the printed walls will also be skewed. It is also very important to accurately do this alignment to manage the loads that are put on the Y-axis bearings. Misalignment will drastically compromise the bearing's lifetimes. To do this operation you will need a multi-line laser.

1. Locate the X-axis between the Z1- and Z2-carriages.
2. Place the multi-line laser on the Z1 concrete foot and align it so that it perfectly lines up with the Y1 truss.
3. Using the laser finder align the end of the X-axis closest to Y1 with the laser line.
4. Using the laser finder now align the other end of the X-axis with the laser line but this time use the “Y2 offset” value in the machine setup page on the HMI.
5. Move the Y-axis the full length of the printer and listen for uncommon noises or vibrations.

5.6 PRINthead INSTALLATION

If there is not enough space for the printhead to be installed, go to master homing and master X, Y and Z axes to move the printer up to a position in which you will be able to install the printhead. Then install the printhead and proceed with homing U and E.

1. Place the Extrusion screw inside the hopper.
2. Place the printhead stand with the fully assembled printhead below the X-carriage.

3. Lower the X-carriage through Duet until it is approx. 5 cm above the hopper and the clamps can reach.
4. Attach the cardan joint with the Archimedes screw to the X-carriage shaft.
5. Secure the hopper to the X-carriage by locking all three clamps.
6. Turn off the printer and connect the plugs for the U-motor and the camera connections – turn printer on again afterwards.
7. Connect the hose.

5.7 MASTER HOMING

Master homing is to be performed each time the machine has been moved and re-assembled on a different site. Before initiating homing, make sure the mechanical printer set-up is on par with provided installation instructions. Also, make sure there are no obstacles in the print area and that both the Limit Switches and EndStopBracket are installed correctly.

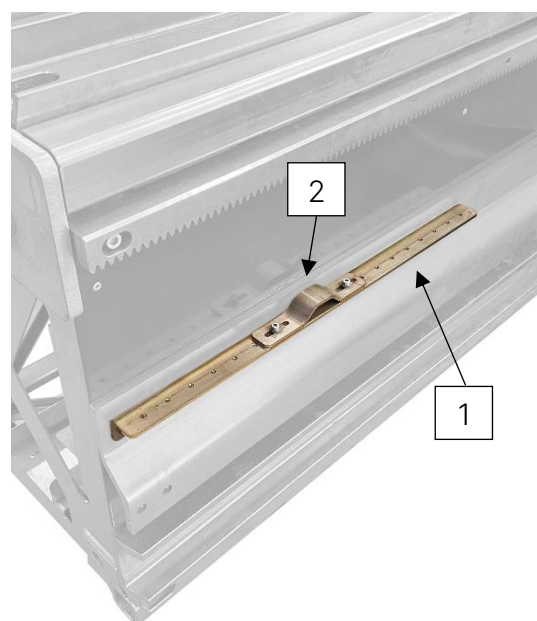
5.7.1 LIMIT SWITCHES AND ENDSTOPBRACKETS

Ensure that the EndStopBrackets are installed correctly for both X and Y axes. Before using the automatic homing functions in both X and Y directions, carefully move the X or Y carriage with the Limit Switch over the bracket until you hear it click. By default, only the Limit Switches on X and Y1 are active, but the remaining ones can be activated as well.

To adjust the bracket, simply loosen the screws and move the bracket to the wanted position along the mount. The position of the bracket will have an impact on your maximum printable area – the further from the end of the Y-truss, the larger the decrease in printable area.

The Limit Switches are only active when performing Homing and will not detect being pushed in any other case.

Axis EndStopMount (1) and -Bracket (2)



IMPORTANT! After performing either homing or any other movement via Soft-NA, remember to click Get Machine Position in Duet to update the machine position to the correct coordinates.

5.7.2 MASTER X AND Y

The procedure for both X and Y Master Homing is identical. During X/Y homing, the printer will move along the chosen axis towards the negative direction until it reaches the limit switch.

Once the BOD2 is powered on and all axes are aligned, go to Machine Setup, enable Homing Mode, and click on Master X or Master Y, depending on which axis you want to home. It is of no importance which axis is homed first. Upon completion, the system will retain the origin by keeping track of any motor movements, even when the printer is powered off.

5.7.3 MASTER Z

To set the Z origin (the lowest point the printer can reach), carefully move the machine (fully assembled including complete printhead) for the nozzle to barely touch the ground level. To master Z, disable Duet mode, go to Machine Setup, enable Homing Mode, and press Master Z.

5.7.4 MASTER U

While having the printer powered on and Duet mode enabled, rotate the U-axis so that the teeth of the nozzle are aimed at the Printhead E-box and the 'front' (flat side) is parallel to the X axis. Then, via Soft-NA, disable Duet mode, go to Machine Setup, Enable Homing Mode and press Master U. To validate, turn Duet mode back on and go to the Duet web interface. Via the Machine Movement selection press Get Machine Position. U-axis value should be equal to 0 or 360 at that position.

5.7.5 MASTER E

Home E is used to set positioning of the highest point of the mixing arm regarding the level sensor and the level of material in the hopper on the printhead. The Home E setting is to counter for the height of the mixing arms to determine the correct material level in the hopper and thereby give the pump the signal to deliver material to the printhead.

To **Master E** the highest point of the mixing arm needs to be positioned right underneath the material-level-sensor which is in the middle and front of the printhead and then homing the E in the machine settings.

Follow steps below:

1. Install the printer and the printhead.
2. **For safety reasons, keep the printer turned off for this step:** Turn the extruder screw into position – the highest part of the mixer arms should be right below the sensor on the bottom of the X-carriage.
3. Turn on the printer.
4. Enable drives.

5. On the HMI (Screen, SoftNA) go into the “Movement” tab and “engage the drives”.
6. Next in SoftNa, go to “Machine setup” tab and press the “Homing” button to activate homing, and then press “Home E”.

Now that the E is homed the printer will filter out the height of the mixing arms and will give a stable reading on the material level in the hopper.

Pro tip! Whenever touching any of the moving parts on the printhead, press one of the Emergency Stops and keep it pressed until you are done!

5.8 CONNECTING TO A PC OR TABLET

This section describes how connect a PC and/or tablet either via Ethernet or Wi-Fi to the printer. If using a tablet (or a PC without an ethernet port) it is only possible to use Wi-Fi unless having a dongle with a RJ45 (ethernet) port.

- We advise not to use a Macintosh or Linux PC. Use a Windows PC – only Windows is capable of running COBOD Slice.
- It is possible to use any tablet if it can run a browser, preferably Edge, Chrome, or Firefox.
- The best PC solution for this application is a tablet PC with a detachable keyboard for easy maneuvering while printing.

Attention: for all remote connection, please make sure that the antennas are mounted on the Z-axis next to the E-box, as high as possible and connected to the router in the E-box. Also, never rely on a wireless connection alone – have the possibility to connect via Ethernet in case of an unexpected event.

5.8.1 DIRECT CONNECTION TO PC VIA ETHERNET (LAN)

Direct connection to the printer (LAN connection) is established by inserting a LAN cable into the ethernet port (the ethernet connector furthest to the right on the E-box).

The IP settings on your PC needs to be set to “Automatic DHCP” (Default settings).

5.8.2 WI-FI CONNECTION TO EITHER PC OR TABLET

Wi-Fi connection to the printer is established by going to Wi-Fi and selecting the Wi-Fi sent out by the printer. The name of the printer will be shown as “BOD2 *company name*”P#”.

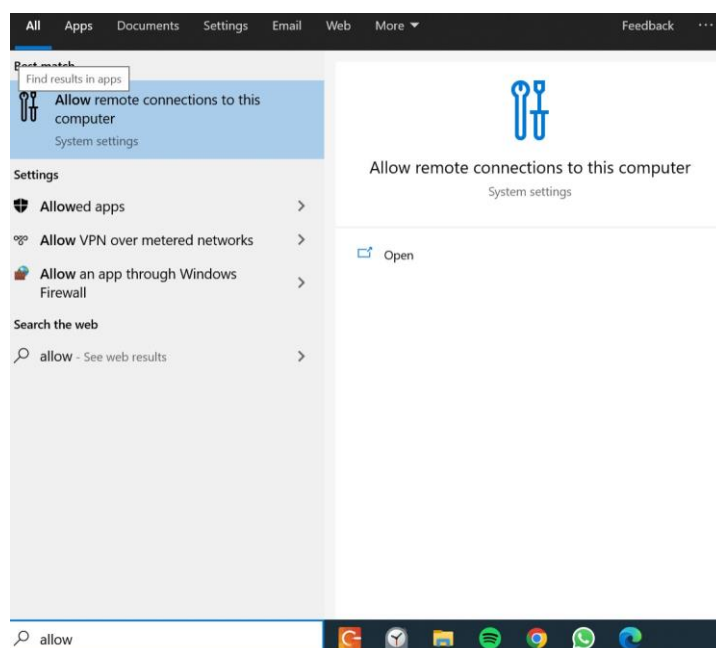
The IP settings on your PC needs to be set to “Automatic DHCP” (Default settings).

5.8.3 REMOTE DESKTOP

This is a guide on how to establish remote control of the desktop on the BOD2.

1. Allow remote connections.

Make sure the setting on the IPC is allowing the connection of a remote desktop. Search “allow remote connections to this computer” on the IPC.



When in the settings, go to “Remote Desktop” and check off allow remote connections.

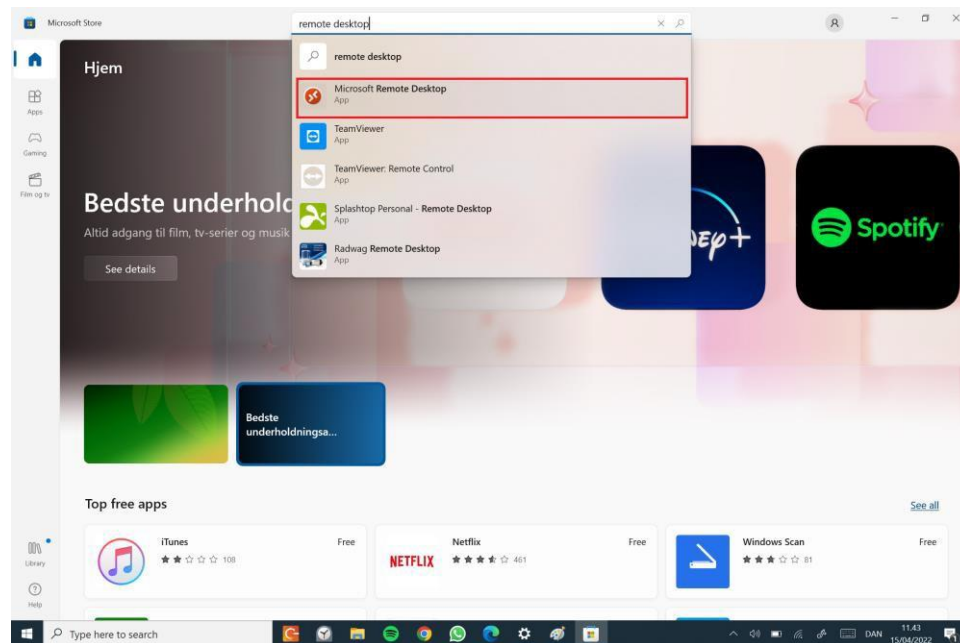
Remote Desktop

Apply the following settings to enable Remote Desktop and ensure machine availability.

- ☒ Change settings to allow remote connections to this computer [Show settings](#)
- ☒ Change settings to only allow connections from computers running Remote Desktop with Network Level Authentication [Show settings](#)
- ☒ Change settings so that the PC never goes to sleep when plugged in [Show settings](#)
- ☒ Change settings so that the PC never hibernates when plugged in [Show settings](#)

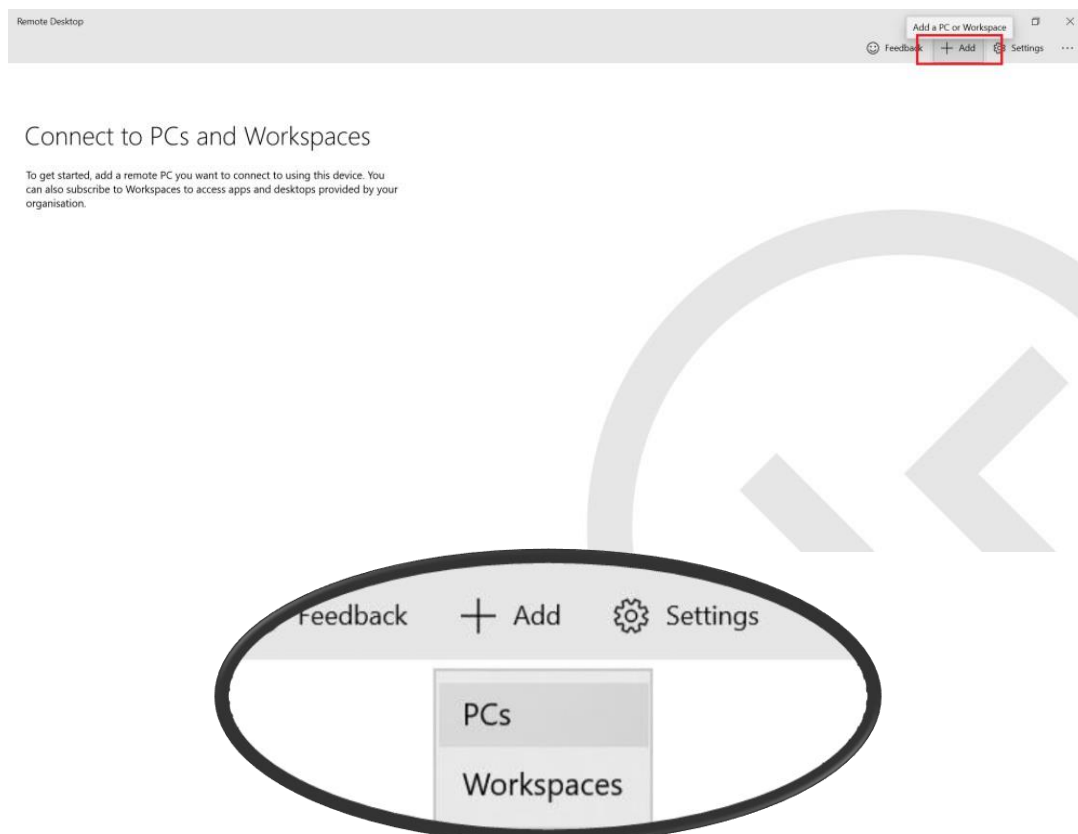
Apply

Go to MS Store and download Microsoft Remote Desktop. Select the App and install this on the Operator PC.



2. Download and install MS Remote Desktop.

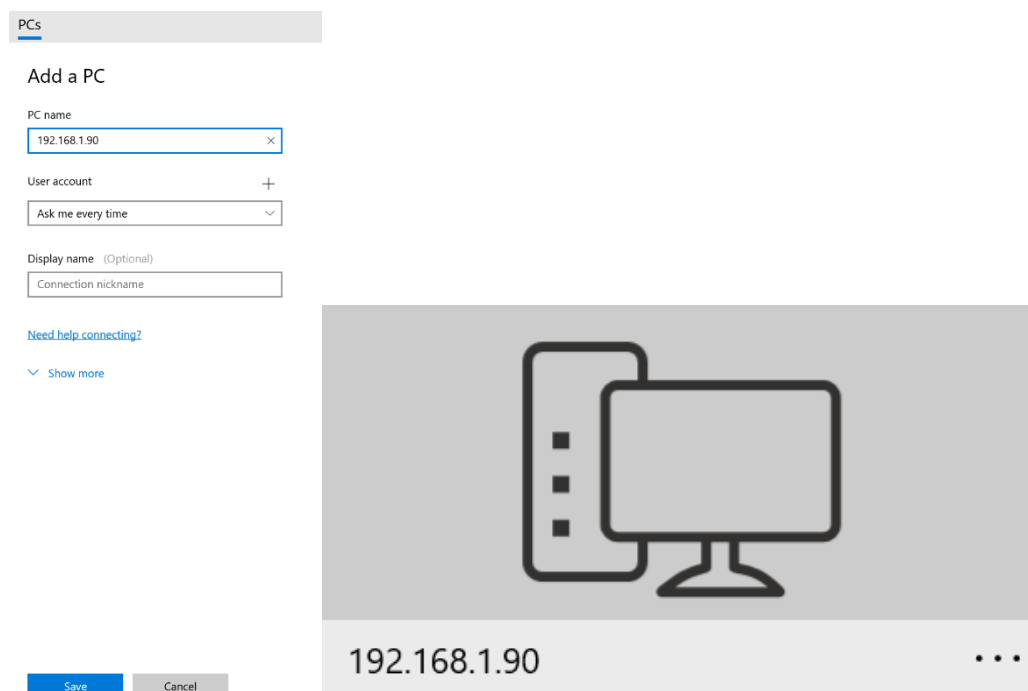
Open "Microsoft Remote Desktop" and add a PC.



3. Connect to the BOD 2.

Enter the IP of the IPC and save. Create a stable connection to the printer.

Go online to the Desktop of the IPC. (Click on this window)



PCs

Add a PC

PC name
192.168.1.90

User account
Ask me every time

Display name (Optional)
Connection nickname

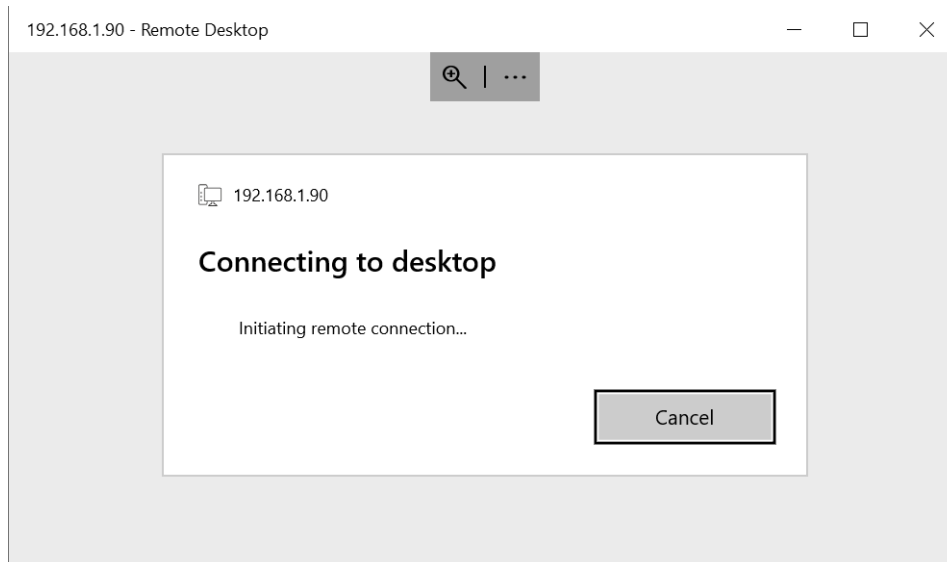
[Need help connecting?](#)

Show more

192.168.1.90

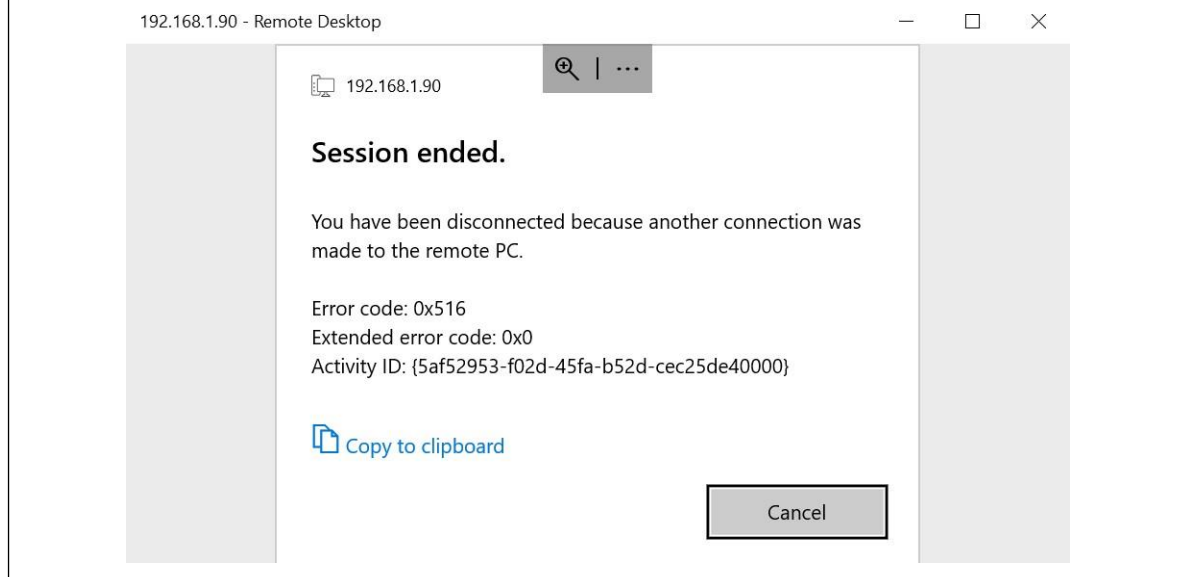
Save Cancel

A “pop-up” will emerge, and the Operator PC will try to connect to the IPC.



An additional pop-up will ask for the Credentials of the IPC, which is: Username: BOD2.5 “Customer name” (Displayed on the printer) Password: cobod”Manufacturing year” (ex. cobod2021).

If the connection fails, the “pop-up” will look like this:



Remote Desktop Troubleshooter:

If it does not work, check the following steps:

1. Check that the setting on the IPC is allowing Remote Desktop.
2. Check the connection by accessing 192.168.1.1 (Router) or 192.168.1.2 (Duet)
3. Check the IP in the Remote Desktop App is correct 192.168.1.90
4. Check that the Credentials are correct according to the specific printer.
5. If none of the above is solving the issue, please contact techsupport@cobod.com

5.8.4 REMOTE CONNECTION FOR TECH SUPPORT

Adding an internet connection for a remote link to the printer for tech support can be achieved by three different methods.

Method 1 – Cabled connection from a router or switch

This method is usually done when installing the printer in a warehouse or workshop where there is a cabled internet connection already installed. The way this works is by plugging into an existing internet outlet, either in the wall or from a router or switch and plugging the other end into the ethernet port on the main E-box (the one to the left, when looking at the front on the E-box).

Note! If there is a firewall or login credentials on this network, this will not work

How to establish this connection:

1. Insert the RJ45 ethernet port into a port with internet.
2. Insert the other end of the internet cable into the ethernet port on left on the main ebox.

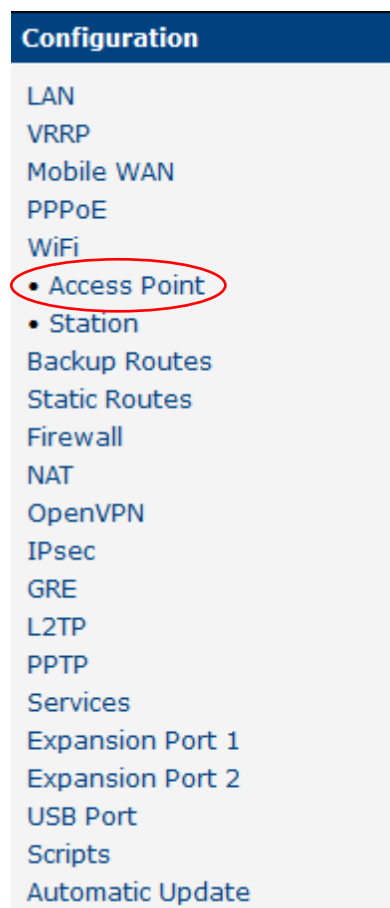
Note! This connection is the fastest and most stable.

Method 2 – WiFi Station connection

This method can be used on-site as one can use the WiFi hotspot on a phone or mobile WiFi router and connect to this. The way this works is by disabling the WiFi access point on the printer's router and enabling the WiFi station. When enabling the WiFi station and inserting the credentials of the hotspot, the router will stream the WiFi to the printer allowing remote access.

How to establish this connection:

1. Connect to the router via 192.168.1.1
 - Username: root
 - Password: cobod + production year
Example: cobod2021
2. Go into Wi-Fi under Configuration
3. Go into Access Point and disable Enable Wi-Fi AP. Click Apply – this will disable the Wi-Fi sent out by the printer's router.
 - a. (I.E *Customer Name* BOD 2)



4. Go into Station and enable 'Enable Wi-Fi STA'

☐ Enable Wi-Fi STA

	IPv4	IPv6
DHCP Client	enabled ▼	disabled ▼
IP Address		
Subnet Mask / Prefix		
Default Gateway		
DNS Server		

SSID

COBOD A/S

Probe Hidden SSID

disabled ▼

Authentication

WPA2-PSK ▼

Encryption

AES ▼

WEP Key Type

ASCII ▼

WEP Default Key

1 ▼

WEP Key 1

WEP Key 2

WEP Key 3

WEP Key 4

WPA PSK Type

ASCII passphrase ▼

WPA PSK

5. Under "SSID" type in the name of your local Wi-fi network (or phone hotspot) that the printer will be connected to (here it is connected to the "COBOD A/S" Wi-Fi network)
6. Change the Authentication to WPA2-PSK and encryption to AES
7. Change "WPA PSK Type" to "ASCII Passphrase" and type in the password for the chosen Wi-fi network (in this case there is no password)
8. Click apply

Note! This will disable the Wi-Fi of the machine, so you can only connect to the machine via ethernet.

Note! If the hotspot (phone) is moved away from the antennas, the remote connection might be lost.

Method 3 – SIM Card connection.

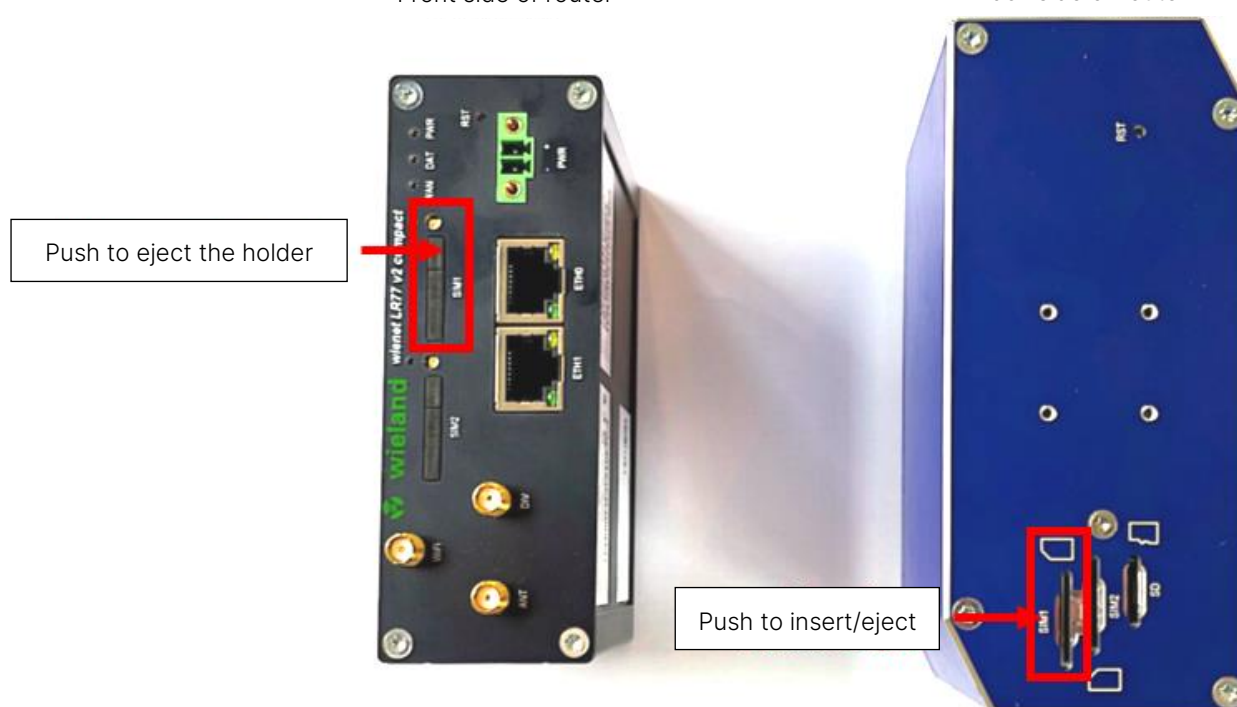
This method is primarily used for on-site connection as it is the most effective connection on site. A SIM card is inserted into the router and connection would automatically be established. The SIM card should be inserted in the “SIM 1” slot.

Important! Disconnect power for this operation.

1. On a European version, push the ejection button to release the SIM card holder and insert the SIM card in the holder and insert the holder back into the router.
2. On the US version (The North Americas), unplug the 24v power plug, then push down the whole router to release it from the DIN rail that it is mounted on, and then insert the SIM card in the back until there is a “click” sound, then release. Mount the router back on the DIN rail and connect the power before turning on the printer.

EU/APAC/MEA/South America
Front side of router

North America
Back side of router



Note! For any complications with SIM card configuration please contact Tech Support for assistance.

5.9 CONNECTING TO THE CAMERAS

The connection to the cameras is through a web browser and with the use of two IP-addresses.

Connecting to the cameras:

1. Open your web browser.
2. Connect to print head monitor cameras:
To access the cameras, open two new windows in your web browser. Enter the IP addresses below.
Camera 1: 192.168.1.200
Camera 2: 192.168.1.201
3. Accessing the IP addresses will direct you to the camera login page. Enter the username and password.
Username: admin
Password: cobod/COBOD+"year", e.g.: "cobod2022" or "COBOD2022"

Entering the credentials will direct you to the live video feed. The cameras cannot be adjusted through the web interface. For adjustments of the camera please open the dome and carefully adjust the camera direction by turning the inside.

5.10 SITE ACCEPTANCE TEST (SAT)

Upon the first installation on-site COBOD will perform an SAT. After each project, before disassembling and packing the printer, the SAT can be used as a guideline to make sure the printer is up to date. The SAT includes:

- Safety checks
- Check all Estops
- Check print head safety switches
- Performance test
- Check movement directions on all axes
- Check movement on full axes
- Check material hopper sensor functionality and setting
- Check pump signal
- Test cameras
- Ensure connection to cameras

6. PRINT PROCEDURE

All operational activities, including start up and shutdown, should happen in cooperation with the other team members in charge of the MDS. For all procedures described below you will find checklists to refer to on site as well.

6.1 STARTUP PROCEDURE

1. To turn on the printer, flip the power switch on the side of the E-box. Now, you will see the IPCs OMRON or COBOD logo light up and shortly after, the login screen will appear. Login using the code specific to your printer. Soft-NA should open.
2. Using the Operator Panel, turn the key clockwise and hold until the light above the X-carriage starts blinking yellow/red. Then, press the green button on the panel for a few seconds. The light will now switch to blinking yellow/green instead.

If the light is not blinking yellow/green, but still yellow/red, follow the steps below:

- Make sure that none of the emergency stops are pushed/triggered by checking the Emergency Stop overview in the Movement page in Soft-NA.
- If an emergency button was pushed, release it, and go into the Troubleshooter and reset all errors.
- Again, firmly hold the green button, release, and check that the light is now blinking yellow/green.

3. Once light is blinking yellow/green, go to the Movement Page in Soft-NA. Click Enable Drives and go into Duet mode by pressing the button below.
4. Check that all axes are green – this means that all axes are fully functional, and that the printer can be moved safely. If U has not yet been connected, ignore this axis.

If any axes show to be nonfunctional, try the following solutions one by one:

- Clear any errors in the troubleshooting page and see if this solved the issue.
 - Restart the printer.
 - Check all cables and ensure that there are no loose connections anywhere.
5. Go back to PLC mode and go to Machine Setup to check for any misalignment. Auto-realign if needed, to ensure your machine position will be aligned with the original origin. Exit Machine Setup, then go to Movement and enable Duet mode.
 6. Connect to the printer either via Wi-Fi or Ethernet and go to 192.168.1.2 in your web browser to control the printer using the Duet interface.

6.2 OPERATIONAL PROCEDURE

Before printing, make sure that your G-code has been prepared in accordance with the instructions found in the Modelling and Slicing SOP.

1. Before moving, make sure to get Machine Position. Move the printer to the desired position for your job and choose the correct WCS for your print.
2. In the HMI check that all axes are green – this means that all axes are fully functional, and that the printer can be moved safely.
3. Connect to the printer either via Wi-Fi or Ethernet and go to 192.168.1.2 in your browser to control the printer using the Duet interface.
4. Upload your G-code via 'Upload job' in the bottom of the Duet interface.

6.2.1 DRY RUN

Performing a dry-run means running a G-code file without any material in the system. This is done to ensure that the file is printable without any apparent issues, as you want to avoid having to pause mid print to fix any issues while having material in your printer system.

To perform a dry-run, move the printer to the approximate position you know the G-code will begin at, and press Print File. Throughout the first layer of the dry run, one should monitor the nozzle closely and ensure that the print path is aligned with its print base. Stay close to an Emergency Stop in case the printer is heading towards any obstacles. Remember, that there are collision detectors in the printhead, which will cause the printer to pause if it collides with the foundation/print base or any other objects appearing from it. However, avoid putting unnecessary force on the printer, if possible.

Dry run troubleshooting – what to do, if:

- printer is skewed compared to base: if the path of the nozzle is off by a certain degree, this can be fixed by rotating the 3D model as much as needed and slice again.
- nozzle is offset in X and/or Y direction: adjust your WCS in the config.override file (can be found in Duet > System). Remember to run the M501 command directly in the command bar after changing the WCS to load the changes.

During the dry run, you want to make sure, that the nozzle will not hit any objects potentially appearing from the base (pipes, reinforcement attachments, wires, etc.). Let the dry run continue for at least 2 layers.

When printing on top of an already 3D printed structure, you must perform a dry run as well. Use the Slicing Range feature in COBOD Slice to create a file that begins at the height at which you previously finished. You can open the G-code directly in a text editor and see the coordinate at which the printer will start. Move the printer up to the height

you will be printing at first, and then move to a X/Y coordinate approximate to the start point of the G-code. Using the command bar for this is very helpful.

When satisfied with the dry-run press Pause Print, followed by Cancel print.

6.2.2 PRINTING

Before initiating a print session, ensure that the entire team is ready and that everyone is aware of their area of responsibility. Communication is key when it comes to running a print operation – if needed, communication can be aided using walkie-talkies.

You are now ready to dump the already prepared slurry into the pump and start pumping material towards the printhead:

- On the materials page in the HMI check the hopper level settings. A good starting point would be 60 as lower level and 65 as the upper level. Adjust this during the first couple of layers. The goal is to have great mixing of the material in the hopper and have a level that is as stable as possible.
- Move the printer to an area where you can dump material and extrude until the material quality is satisfactory.
- When the material is good, press “Print again” and the machine will start printing.
- Carefully monitor the speed, extrusion rate and U-axis during the print.

6.3 SHUTDOWN AND CLEANING PROCEDURE

When working with concrete cleaning is always essential and as the printhead assembly is a very precisely engineered piece of equipment it is even more important. Failing to clean it properly will cause operational issues down the line.

This task is usually performed with a pressure washer but is recommended to show caution and spray the water from a reasonable distance on the more delicate parts.

Disassembly for cleaning:

1. In the HMI turn off the pump signal output.
2. Disconnect the concrete hose from the hopper.
3. Now manually extrude until the hopper is as empty as possible.
4. Move the printer so that the hopper is centered in the printhead stand but still a few centimeters too high.
5. Turn off the printer using the main power switch on the E-box and disconnect the U-axis plug. It is important to place a cover not only on the plug but also on the socket on the X-carriage for protection. **Failing to turn off the power before disconnecting this plug can cause damage to the machine's electrical system.**
6. With the printhead disconnected from the printer loosen the three red clamps and carefully lower the printhead into the printhead stand.

7. Turn on the printer and carefully raise the Z-carriages to get access to the extruder screw.
8. Carefully disconnect the extruder screw from the cardan joint and take away for cleaning.
9. Carefully loosen the two red clamps on the assembly to remove the pipe and the U-axis assembly.
10. Bring all the parts to the cleaning station.

Cleaning the U-axis assembly:

With the U-axis one needs to show a little extra bit of caution when cleaning. Especially the area where the wires connect to the servo motor is fragile and if broken will leave the printer in a non-operational state until spares arrive.

1. Remove the funnel from the assembly and clean thoroughly inside and out. Put away for drying.
2. Clean the nozzle block and have extra focus on getting the inside of this assembly clean. This is one of the places where concrete can leak into through extended print sessions. Put away for drying.

Cleaning the hopper, pipe and extruder screw

These parts are less sensitive than the U-axis assembly and can therefore be cleaned with a pressure washer without worrying about damage.

1. Leaving the hopper in the printhead stand aids cleaning and allows access to every angle of the component.
2. Clean the hopper thoroughly and especially focus on the concrete inlet area and chemical input nozzle.
3. Remove the top and bottom O-ring on the pipe and clean every surface thoroughly.
4. Reinstall the O-rings and put away for drying. Grease O-rings before reinstalling.
5. Clean the extruder screw on every surface. This part can be deceptively difficult to clean so make sure to spray with water from many angles.
6. Any stubborn buildup on this part can be removed with the steel brush or the pointy end of a hammer.

Cleaning the X carriage:

As the outside bottom of the X-carriage also acts as the lid on the material hopper this area also needs cleaning after a print session. This is done after the printhead has been removed and taken away for cleaning. As this area usually isn't too dirty, cleaning this part can be done with a low-pressure water sprayer.

1. Clean the cardan joint thoroughly and inspect the seal covering the moving parts of the joint.

2. If the seal is damaged, has been moved out of position or otherwise compromised remove the seal, clean the moving parts and grease with HHS lubricant. Reinstall or replace seal.
3. Clean the bottom of the X-carriage, showing special attention to the lamp and hopper level sensor as the function of these components directly relate to their cleanliness.

7. MAINTENANCE PROCEDURE

The cleaning and maintenance of the BOD2 3D printer is the responsibility of a certified operator. Maintenance can be handled by site assistants or helpers but must be approved by the certified operator. Failing to follow the maintenance schedule can damage the equipment and can cause downtime.

A yearly maintenance and service check is required to be performed by a COBOD technician or a certified technician with a Level 3 certification. In case of neglect of the yearly service check, any warranty given by COBOD International A/S will be void.

7.1 MAINTENANCE SCHEDULE

Descriptions of all tasks can be found below the table.

WHEN	#	TASK
After each installation:	1	Perform a full SAT
Before printing:	2	Inspect external cables and connectors
After printing:	3	Disassemble and clean all printhead components
Daily/weekly:	4	Inspect rails (frequency depends on location)
Monthly:	5	Inspect bearings
	6	Grease tooth racks and cogs
	7	Inspect electrical E-chain for wear or damage
	8	Disassemble and clean nozzle block

7.1.1 PERFORM A FULL SITE ACCEPTANCE TEST (SAT)

To be performed after each installation. Follow the procedures set in the BOD2 Site Acceptance Test and register your results. Ensure to note down damaged or missing components in the checklist.

7.1.2 INSPECT EXTERNAL CABLES AND CONNECTORS

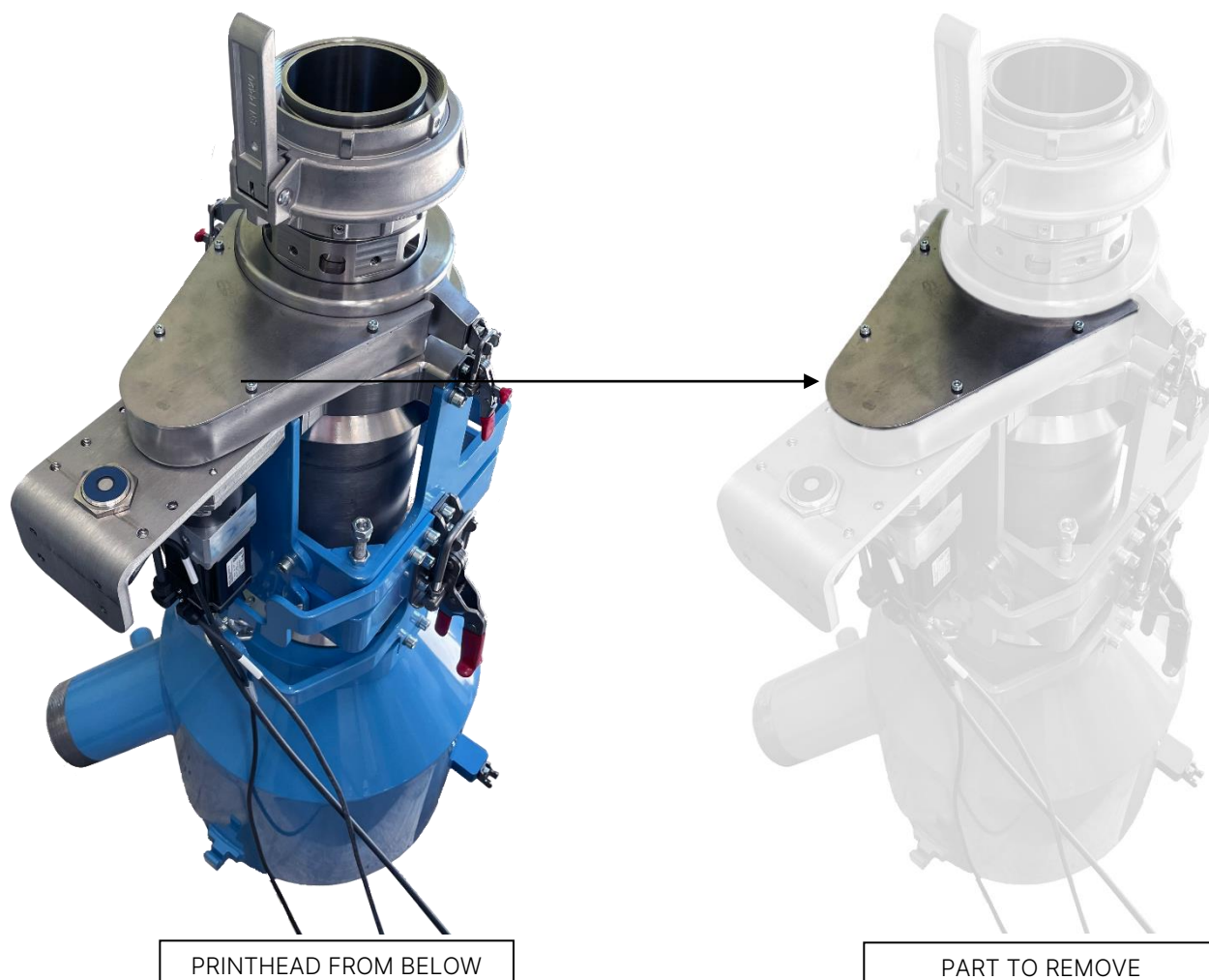
Visually inspect all external cables and connectors on the machine. Ensure no cables has been damaged and that no connectors are clogged or dirty. All cable connections to be checked enter the printer underneath the E-box. See System Components > Main E-box section for a visual overview.

Cable	Description
Power cable	Thick, black cable connecting power to the BOD2
Operator Module Cable	Yellow cable connecting the Operator Panel to the BOD2
Pump control cable	Black cable that goes from the BOD2 to the pump (for automatic pump signal)
Antenna cable	Thin black cable connecting the E-box to the LTE/4G and Wi-Fi antennas
Ethernet cables (if used)	Grey or white cables connecting the BOD2 to a PC
Dosing system cables (if used)	Two cables connecting the BOD2 to the dosing system

7.1.3 DISASSEMBLE AND CLEAN ALL PRINTHEAD COMPONENTS

The printhead should be disassembled and cleaned every week to avoid long term damage and to extend the service life of the components.

1. Disassemble the printhead – see overview of parts under System Components.
2. Using a scraper and a wire brush, remove all concrete and dirt inside and outside each steel component.
3. Use a wet cloth to clean the cameras.
4. Remove the shield below the motor to access the cog and timing belt inside the nozzle block and clean all parts.



7.1.4 INSPECT RAILS

Visually inspect all guide rails on all axes – X, Y and Z – for damage or wear. Ensure that rails are clean and free of concrete debris and dust.

If there are any signs of damage to any rail, please notify techsupport@cobod.com to order spare parts and receive instructions on how to replace items.

7.1.5 INSPECT BEARINGS

Inspect all bearings for wear and dirt. If necessary, clean using a high-pressure water hose. There are 6 bearings on the X-carriage, 4 on each Y-carriage and 4 on each Z-carriage.

If there is sign of damage of any bearing, please notify techsupport@cobod.com to order spare parts and receive instructions on how to replace items.

7.1.6 GREASE TOOTH RACKS AND COGS

Using a grease pump, apply grease to both tooth racks and cogs on all axes (X, Y and Z).

1. Using a high-pressure washer, ensure to fully clean the tooth racks for old grease, debris, and dust.
2. Apply a drop of grease for each 500 mm along the full length of the tooth rack.
3. Move the axis along the total length of the axis back and forth until the grease is evenly distributed, covering the whole length of the axis.

7.1.7 INSPECT ELECTRICAL E-CHAIN FOR WEAR OR DAMAGE

Visually inspect E-chains carrying electric cables inside the machine for any visible damage or wear.

- Look for missing brackets. If they fall off, they can sit in the E-chain tray and further damage the E-chains and the cables inside. Pay close attention to the attachment pieces of the E-chain.
- Inspect the wear and the “gliding feet”, the small grey pieces that sit on only one side of the chain. If they are worn to thinner than 2 mm of material, please contact COBOD (techsupport@cobod.com) to order replacements.

7.1.8 DISASSEMBLE AND CLEAN NOZZLE BLOCK

The nozzle block assembly is made of the assembled steel components that contains the moveable parts of the print head. As concrete can sieve into these parts, it is important to regularly disassemble, inspect, and clean the individual components.

8. DISASSEMBLY

Disassembly of the printer for shipping or storage is fundamentally the reverse of assembly. However, there are certain procedures, tips and tricks that simplify the operation.

1. Before turning off the power or unplugging any cables, bring the printer to a position from where it is easy to disassemble.
 - a. Move the Z-carriages down – leave enough room to undo the bolts holding them to the concrete feet.
2. Move Y-carriages to 0 (zero) i.e., all the way to the front of the machine.
3. Center the X-carriage on the X-axis to center the point of balance – this will ensure easier and safer lifting of the axis.

With these steps done you can turn power to the printer off and start undoing the electrical plugs. At this point, consider how you are going to store or ship the printer. Leaving the static cables and e-chains on top off and inside the axes will save you a lot of time at the following installation. It is safest to store the plugs of the cables inside of the trusses while transporting or storing. Furthermore, make sure to protect any wires that are not inside of a truss.

With the cabling situation figured out and dealt with it is time for the mechanical disassembly:

1. Using lifting straps secure the X-axis to the crane or telehandler.
2. Remove the Mechanical End Stops and slide off the X-axis while holding it with a crane or telehandler. Place the axis on stackers.
3. Remove the hooks securing the Y-axes.
4. Using lifting straps, lift the Y-axes off one at a time and place on stackers. While the X-axis must be placed on stackers to protect the tooth rack underneath it, the Y-axes can be placed directly on pallets or similar, if needed.
5. With lifting straps hook up the first Z-axis and undo the nuts holding it to the concrete foot.

Always support the Z-axis from the top while undoing the nuts!
6. Lift the Z-axis off the studs, lay it down and put it on stackers.
7. Repeat for the remainder of the Z-axes.

9. TROUBLESHOOTING

Always refer to the error handling guidelines when experiencing issues on the job site. Identify the symptom of the error and proceed to follow the steps in the order they are presented in the “solution” field.

If an error occurs while printing with materials in the system, the materials operator should keep a timer on the materials. This is done to keep track of the time it is standing still in the system to avoid it hardening anywhere in the system. The timeframe should be provided by the Materials Operator. If the troubleshooting at any point extends the given timeframe and there is a risk of material clogging, stop the troubleshooting and clean the entire Materials system (hoses, print head, pump, mixer) before continuing. It is possible to extend the time available and keep the concrete alive by continuously purge material from the print head into a waste container.

Attention: The first thing to check is the troubleshooter in the Soft-NA on the IPC (screen) which will give a clear indication on the issue. Together with the “node number” the user can quickly assess where the issue is and can tell that to a technician to optimize the troubleshooting. Furthermore, the troubleshooter will give a list of possible steps to resolve this as well, which can be helpful to the user and the technician.

9.1.1 ERROR HANDLING

The steps to solve are ordered so that the most likely solution will be the first one presented. When solving an error all steps might not be needed.

Attention: NEVER WORK ON ELECTRICAL COMPONENTS WITH THE POWER ON AS THIS CAN RESULT IN ELECTRICAL SHORTS OR SHOCKS, WHICH CAN HARM THE EQUIPMENT OR PERSONNEL.



9.1.2 REBOOT SEQUENCES

Soft reboot: During a troubleshooting session a soft reboot might be necessary to remove an error, by removing the main power supply to the drivers and main 24V system. How to perform a soft reboot:

1. Turn the main power switch to off and wait for a pop-up in the HMI (Screen).
2. Click pause on the pop-up, this pauses the countdown for the whole shutdown procedure.
3. Turn the main power switch to on and Wait for the pop-up to go away.
4. Go to the troubleshooter and clear all errors.
5. If an issue persists, a hard reboot might be necessary.

Hard reboot: A full shutdown of the printer.

1. Turn the main power switch to off and wait for a pop-up in the HMI (Screen)
2. Let the timer run out and check that all lights inside go off.
3. Turn the main power switch to on and boot up.

9.1.3 NODE NUMBERS

Most error messages will be assigned a node, showing where the issue is.

Nodes:

Node 1 – Z1-main-ebox

Node 2 – Z1-main-ebox EtherCAT coupler

Node 10 – Z1 IO-module

Node 11 – Z1 Motor Driver

Node 12 – Z3 IO-module

Node 13 – Z3 Motor Driver

Node 14 – Z5 IO-module

Node 15 – Z5 Motor Driver

Node 16 – Z7 IO-module

Node 17 – Z7 Motor Driver

Node 4 – Y1 EtherCAT coupler

Node 30 – Y1 IO-module

Node 31 – Y1 Motor Driver

Node 32 – Y2 IO-module

Node 33 – Y2 Motor Driver

Node 34 – Z2 IO-module

Node 35 – Z2 Motor Driver

Node 36 – Z4 IO-module

Node 37 – Z4 Motor Driver

Node 38 – Z6 IO-module

Node 39 – Z6 Motor Driver

Node 40 – Z8 IO-module

Node 41 – Z8 Motor Driver

Node 50 – X1 IO-module (Printhead)

Node 51 – X1 U-Axis Motor Driver

Node 52 – X1 X-Axis Motor Driver

Node 53 – X1 E-Axis Motor Driver

9.2 COMMON ERRORS

9.2.1 THE SIGNAL LAMP IS NOT ON	
Issue:	Printer signal lamp light is not on.
Description:	The printer has not been initiated.
Steps to resolve:	
1:	Plug in the operator module and turn on the printer.
2:	Insert and turn the key on the operator module.

9.2.2 TROUBLESHOOTER: DISCREPANCY ERROR	
Issue:	Printer signal lamp lights red. The printer does not respond to movement commands.
Description:	The system is either in an error state or not activated/turned on properly.
Steps to resolve:	
1:	Check E-stops – Go to the Main E-box and observe the screen for any E-stops triggered. Remember to check the E-stop on the Operator Panel. A triggered E-stop will show with this symbol:  Release any triggered E-stops. All E-stops have two cables that carry the same signal. Discrepancy error happens when the signal switch state not at the same time, and sometimes when an E-stop is triggered slowly. First remedy should be to quickly trigger and then un-trigger the E-stop in question.

9.2.3 TROUBLESHOOTER: SLAVE NODE ADDRESSES DUPLICATED	
Issue:	Printer signal lamp does not light up. The printer does not respond to movement commands. The printer initiation key does not activate the system.
Description:	Some nodes in the printer are duplicated.
Steps to resolve:	
1:	Contact COBOD/Distributor tech support to ensure that the node numbering is correct.

9.2.4 SIGNAL LAMP RED – TROUBLESHOOTER: FSOE SLAVE ADDRESS ERROR	
Issue :	Signal lamp red – troubleshooter: FSoE Slave address error
Description:	The safety system is not validated and needs to be validated.
Steps to resolve:	
1:	Contact COBOD/Distributor tech support to validate the safety system.

9.2.5 TROUBLESHOOTER: SLAVE APPLICATION ERROR

Issue:	Printer signal lamp does not light up. The printer does not respond to movement commands. The printer initiation key does not activate the system.
Description:	The PLC system does not recognize the setup of the printer or the “slave nodes” are not configured correctly.
Steps to resolve:	
1:	Make sure that the installation of the printer is correct and make sure that the wiring of the printer is correct and that all plugs have been inserted firmly. (The U-axis is an exception).
2:	Make sure that no ethernet cables are damaged, (Green cables in the echains or loose cables).
3:	Contact COBOD/Distributer tech support to ensure that the node numbering is correct.

9.2.6 MATERIAL HOPPER RUNNING OUT OF MATERIAL

Issue :	Material hopper running out of material, but the signal lamp is solid green, and the pump is not pumping material.
Description:	Printer is not outputting pump signal.
Steps to resolve:	
1:	Go to the “Materials” tab on the HMI and check if your level setting is set too low. Readjust level settings.
2:	Go to the “Materials” tab on the HMI and if it indicates that the hopper is full then safely clean the level sensor on the printhead.
3:	If needed, home E again.

9.2.7 TROUBLESHOOTER: ENCODER COMMUNICATIONS DISCONNECTION ERROR

Issue :	The light is green, but the troubleshooter is stating a “Encoder Communications Disconnection Error”
Description:	A motor with an encoder has been disconnected. This is very common if the printhead is not attached and the system can move around (except the U-axis).
Steps to resolve:	
1:	Move the printer up and attach the printhead mechanically.
2:	Turn the main power switch to off and connect the U-axis motor.
3:	Reset all errors in the troubleshooter.

9.2.8 TROUBLESHOOTER: MOTION CONTROL - AXIS 18	
Issue:	The printer is unable to turn the U-axis.
Description:	The U-axis cable is not connected.
Steps to resolve:	
1:	Move the printer up and attach the printhead mechanically.
2:	Turn the main power switch to off and connect the U-axis motor.
3:	Reset all errors in the troubleshooter.

9.3 LESS COMMON ERRORS

9.3.1 PRINTER STOPS AND DROPS 5-10MM	
Issue:	Printer stops and drops 5-10mm.
Description:	An emergency stop has been triggered while the printer is doing a Z-movement.
Steps to resolve:	
1:	Identify the reason that an emergency stop was triggered. Fix and restart the printer.
2:	As positioning will be wrong use the "Realign Z" and "Realign Y" on the HMI to restore accurate positioning.

9.3.2 EMERGENCY/COLLISION DETECTION DOES NOT WORK	
Issue:	The safety system does not engage.
Description:	The safety override has been activated.
Steps to resolve:	
1:	Insert and turn the safety-override key to the left position.
2:	Pull out the safety-override key.

9.3.3 THE U-AXIS STOPS TURNING	
Issue:	The U-axis stops working suddenly. Troubleshooter stating motor overload
Description:	The U-axis motor has either stalled or got disconnected.
Steps to resolve:	
1:	Check the troubleshooter to see if the motor has stalled.

2:	Check if it is possible to move the U-axis by hand.
3:	If the U-axis is tight when rotating or the troubleshooter is indicating a motor stall. Check the mechanical assembly for concrete and rusted parts.
4:	If the U-axis moves freely, reset the error, and move the U-axis through the PLC.
5:	If the issue persists, do a “soft reboot” and reset errors in the troubleshooter.
6:	Contact COBOD/Distributor tech support for further assistance.

9.3.4 TROUBLESHOOTER: OVERLOAD ERROR

Issue:	The motor has stalled, and the signal lamp turns red.
Description:	The motor has overloaded due to too much resistance.
Steps to resolve:	
1:	Set the printer to “PLC mode” in SoftNA.
2:	Reset all errors in the troubleshooter.

9.4 RARE ERRORS

9.4.1 SIGNAL LAMP RED – TROUBLESHOOTER: ETHERCAT FRAME NOT RECEIVED

Issue:	Printer signal lamp lights red. The printer does not turn on high power.
Description:	There is a fault on the EtherCAT and/or a EtherCAT cable has been damaged.
Steps to resolve:	
1:	Isolate the damaged cable or plug
2:	Repair the damaged plug or cable according to specifications of a technician.

9.4.2 PUMP IS TURNING ON, THEN REVERSING

Issue:	The pump is turning on and then suddenly reversing.
Description:	There is a bad connection in your pump remote.
Steps to resolve:	
1:	Disconnect the pump remote and check the inside.
2:	If there has been some water sneaking in, dry it out, and reseal it.

9.4.3 TROUBLESHOOTER: MOTOR REPLACEMENT DETECTED

Issue:	The troubleshooter is stating "Motor Replacement Detected".
Description:	A motor has been replaced and needs to be verified in the PLC system.
Steps to resolve:	
1:	Contact COBOD/Distributor tech support to reset the motor errors.

9.4.4 TROUBLESHOOTER: BRAKE INTERLOCK ERROR

Issue:	The printer moves up/down on the Z-axis and when stopping, the printer goes into error mode and the signal lamp turns red. Related to this error message: "Power Module error"
Description:	The printer has a bad connection to one of the braking resistors on for the motor a Z-carriage. Sudden stop of Z carriages motor due to failing braking system.
Steps to resolve:	
1:	If possible, move the printer up, until there is room to work inside the Z-carriages.
2:	Open the Z-carriage that has the issue. (Check the Node number). If in doubt, go through all of them.
3:	Turn the main power switch to off and check the wires going from the braking resistor to the driver. If in doubt, contact COBOD/Distributor tech support for further assistance.

10. ADDITIONAL FEATURES

Additional features contain information regarding features which are not vital for the installation or operation of the BOD2 3D printer. However, they are features that can be implemented in certain situations to ease and expand the overall 3D concrete printing experience.

10.1 HEIGHT MAPPING

Height mapping is used to compensate for an uneven surface and level the printed structure. The height mapping is a function originating from plastic 3D printing and utilized for 3D construction printing. The surface leveling will happen over 500mm-1000mm according to settings and layer height. A rule of thumb for this is the bigger the layer height is, the smaller the surface compensation you will need. Example: 40mm layers, with a 20mm height deviation, a compensation height could be 560mm so according to the layer height, the printed structure is level after 14 layers. The function is most applicable if the surface has a slope or if the surface is very bumpy.

Attention! This function works best when you have a square area and define only the area that is needed for the print as probing a big area takes time and the process cannot be interrupted.

This function would not be needed if the height deviation is less than 10mm with a 40mm layer height or 5mm with a 20mm layer height as the height compensation can be adjusted to the highest point on the surface.

How it works:

The surface-compensation works by probing the surface with the “Z-probe” which is located next to the printhead. The probing of the surface will be executed in a grid with a distance 500mm-1000mm between the probe points. After the probing has been finalized a height map will be saved according to the way you have chosen to save it and can be pulled up before doing a print.

Attention! If the printer is moved or the whole area is not mapped the height map will need to be performed again. It is advised to print on a level surface.

How to perform height-mapping:

- Test and calibrate Z-probe to ensure that the probe will measure correctly.
- Use the Z-probe to calibrate the printer’s Z-height precisely to the ground.
- Read and understand the entire process before attempting to calibrate the Z-probe.

Setup of Z-probe:

Attention! BEFORE ATTEMPTING TO USE THE Z-PROBE, MANUALLY MOVE THE PRINthead TOWARDS THE GROUND IN SMALL STEPS AND MAKE SURE THE ZPROBE VALUE IN THE WEB INTERFACE CHANGES TO 1000 BEFORE THE NOZZLE TOUCHES THE GROUND. PREFERABLY THERE IS STILL A 10CM BUFFER BETWEEN THE TIP OF THE NOZZLE AND THE GROUND WHEN THE VALUE SWITCHES

A) Calibrating the Z trigger height

1. Find a relatively levelled surface that spans from the most frontal part of the nozzle to behind the end of the Printhead. Make sure it is even with the rest of the printing area. Use a spirit level to ensure the surface evenness.
2. Disable the axis limits by sending "M564 S0".
THIS WILL ALLOW THE PRINTER TO MOVE OUTSIDE THE DEFINED PRINTER VOLUME. DO NOT MOVE IN LARGE STEPS. USE WITH CAUTION.
3. Move the nozzle towards the ground in small steps until the nozzle is about 1mm from the ground. Manually set this position as Z0 by sending "G92 Z0".
4. Enable the axis limits by sending "M564 S1".
5. Move the Printhead manually upwards until the Z probe value in the COBOD (DUET) Web interface reads "1000".
Note: If this is not displayed on the web interface, please contact COBOD Tech-support.
6. Move 100mm further up.
7. Start a Z-probing move by sending "G30 S-1". This will move the printhead towards the ground and stop moving when the Z-probe is triggered. Write down the reported Z height.
8. Repeat from step 6 two or three times and calculate the average reported Z height.
9. Save the measured Z trigger height to the G31 command in the "config.g" file:
Example > G31 X0 Y200 ZNNN

B) Using the Z Probe

- Z-probe at the current position
G30
- Z-probe at a specific location
G30 X NN Y NN

C) Setup of the complete bed compensation

1. Find the minimum and maximum X and Y coordinates of the area to be measured and subtract 200mm from the maximum Y coordinate.
2. Decide the probing interval. We recommend values between 500mm and 1000mm
3. Set the calibration are with M557 X MIN : MAX Y MIN : MAX S INTERVALL

4. Alternative set the calibration with M557 X MIN : MAX Y MIN : MAX PXX:YY (where XX:YY represents the total number of reference points in each axis)
5. The M376 H NN command is used to taper off bed compensation over a specified height. We recommend an H value of 500.

D) Use the complete bed compensation

Attention! The printer must be homed in all axes before using the bed compensation.

Example:

- **Probe** the bed in the area defined by M557, save height map to "heightmap.csv" (default) and enable mesh bed compensation.
G29 S0
 - **Save** the current height map file (visible in the "system files" tab, giving the file a name)
G29 S3 P"FILENAME.csv"
 - **Disable** mesh bed compensation (Disable height map).
G29 S2
 - **Load** height map file "FILENAME.csv" and enable mesh bed compensation
G29 S1 P"usual.csv" ;
-
- S0 Probe the bed, save the height map in a file on the SD card, and activate mesh bed compensation. The height map is stored in file is /sys/heightmap.csv.
 - S1 Load the height map from file and activate mesh bed compensation. The default filename is as for S0 but a different filename can be specified using the P parameter.
 - S2 Disable mesh bed compensation
 - S3 Save height map (supported in RepRapFirmware 2.04 and later)
 - P"file.csv" Optional file name for height map file to save with S3 or load with S1.

If G29 is commanded with no S parameter, then file sys/mesh.g is run if it exists, and in RRF 3.3 and later any parameters present are passed to mesh.g. If sys/mesh.g is not present then the command behaves like G29 S0.

11. RELATED DOCUMENTS

In addition to this SOP, the following documents should be consulted:

- Checklists
- Datasheet: concrete feet specifications
- Calculator sheet (Excel)
- Site Acceptance Test overview

Kit overview to use for reference if sourcing locally:

- Setup and Maintenance Kit (can be purchased from COBOD)
- Printing Kit (can be purchased from COBOD)

Other Standard Operational Procedure documents in the COBOD SOP family:

- SOP: Modelling and Slicing
- SOP: Batch Plant
- SOP: Mtec
- SOP: Concrete Pumping System
- SOP: COBOD's guide to D.fab