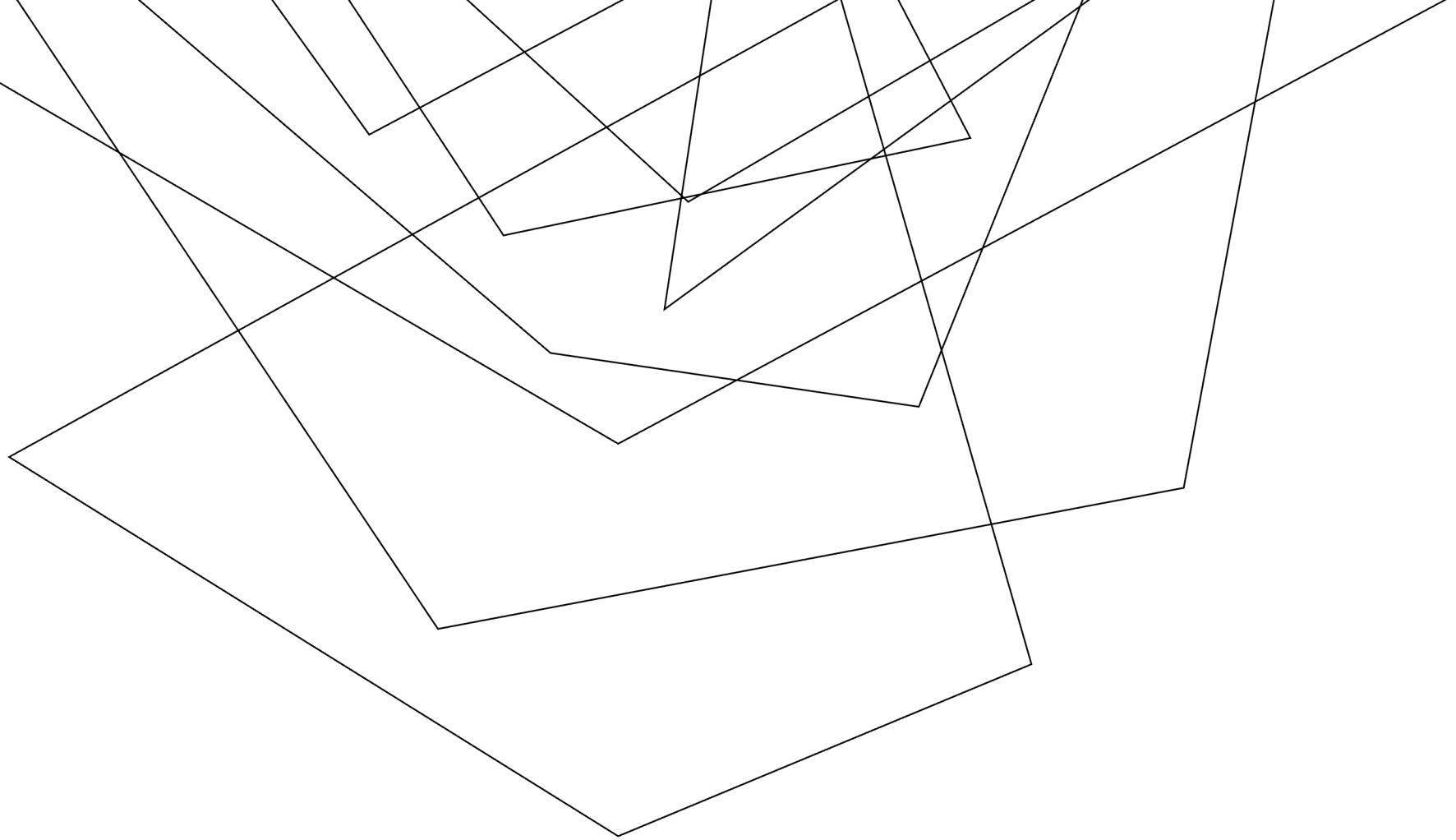


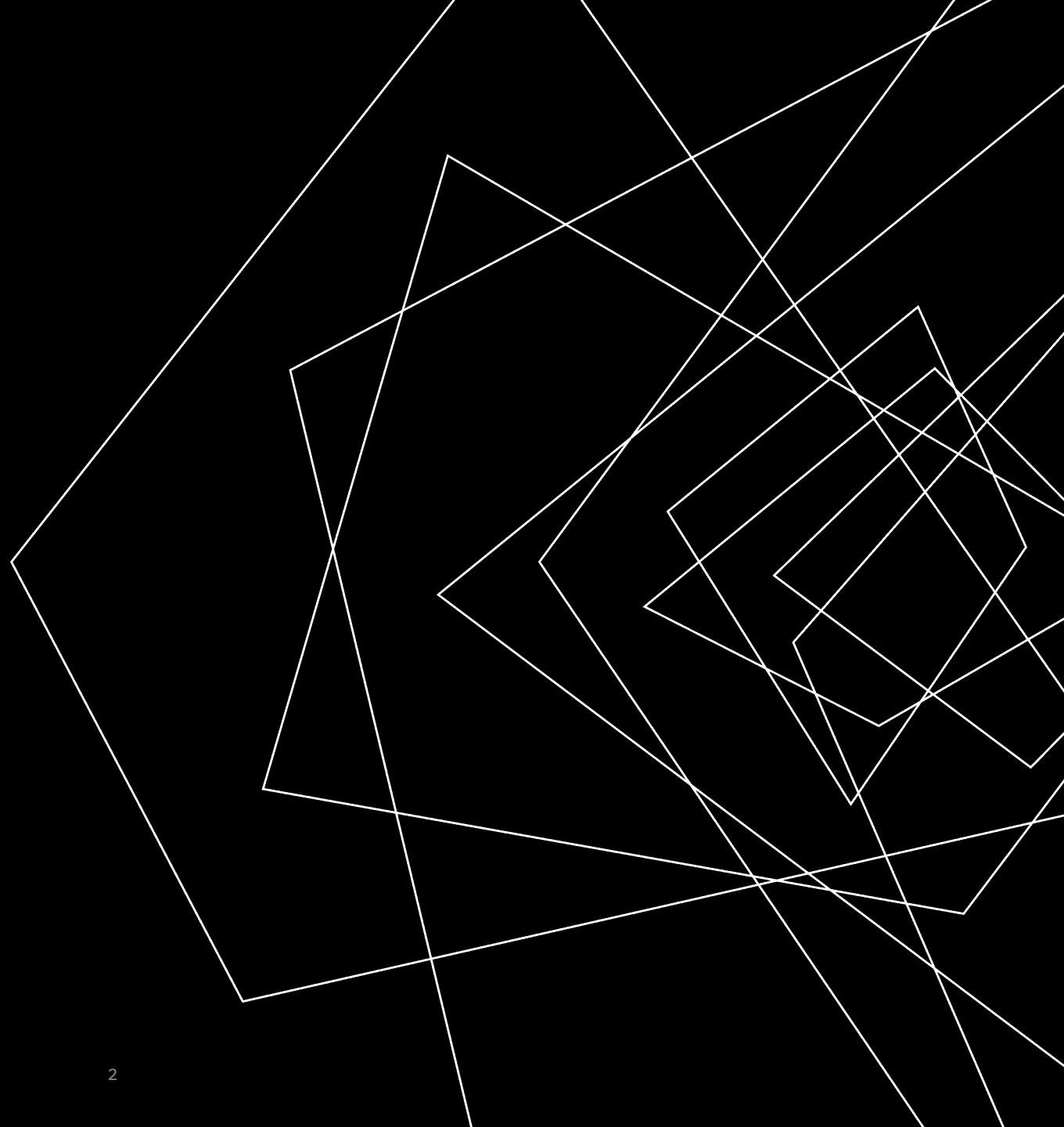
BATHTUB KINGS

MSE 980 Project

ABOUT US

Who are we?

A team of engineers with the ultimate goal of completely automating the bathtub manufacturing industry



WORKFLOW — Possibility of workflow interruption if an employee is unable to work

LEVEL OF AUTOMATION — Current manufacturing systems in the bathtub manufacturing industry aren’t 100% automated

COSTS — Human labor is costly

SPEED — Slow workflow due to the involvement of human labor

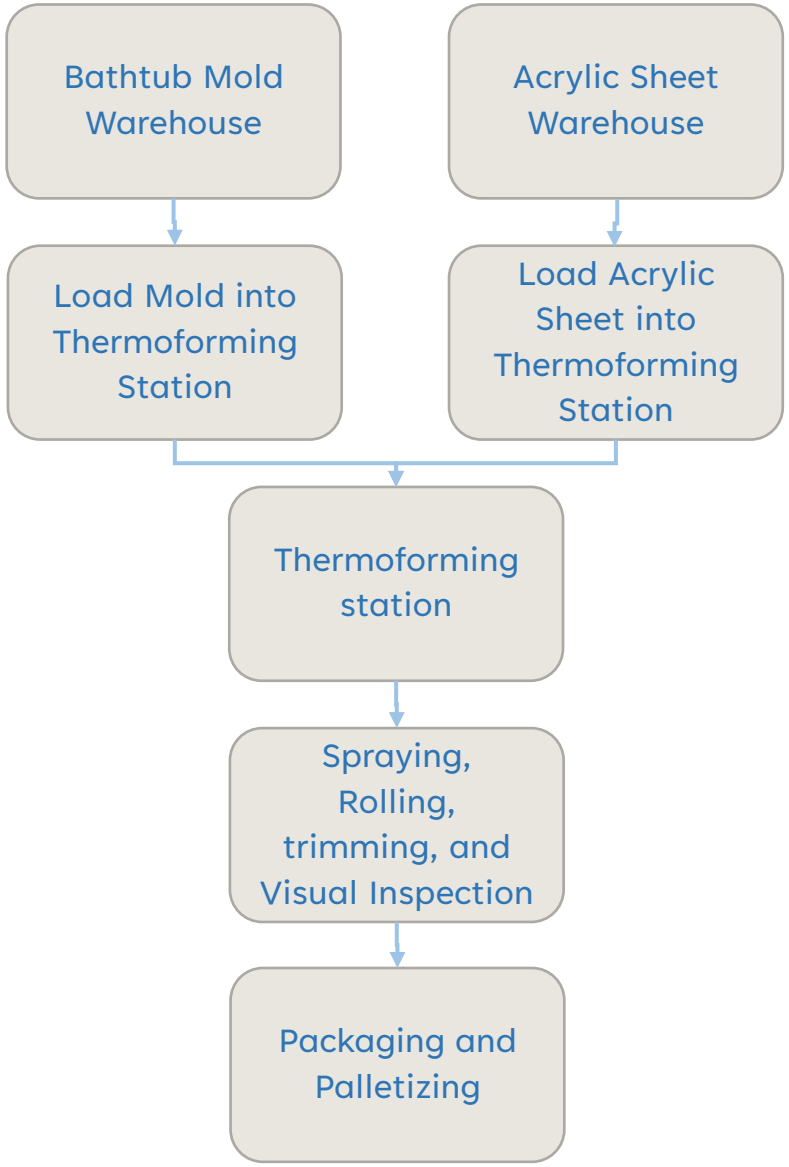
PROBLEM

SOLUTION?

100% Automation

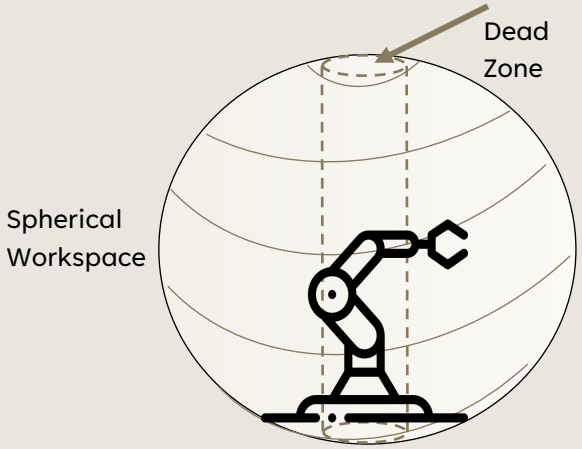
A full automation will not only reduce costs, but will also increase speed and efficiency as well as reduce downtime

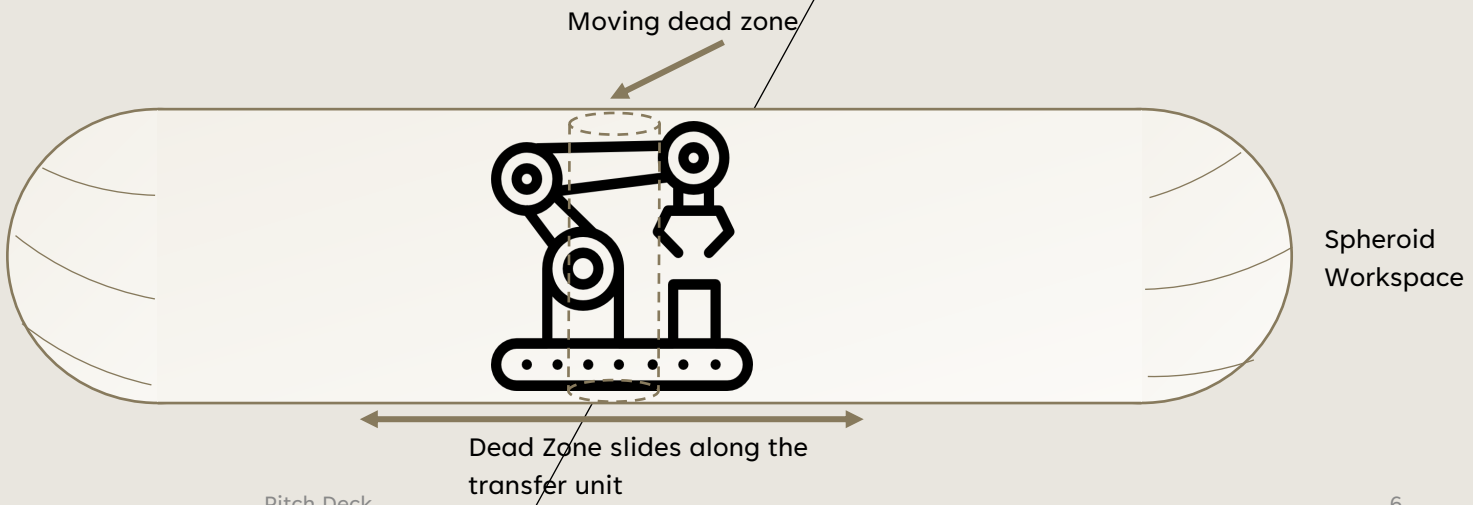
SYSTEM OVERVIEW



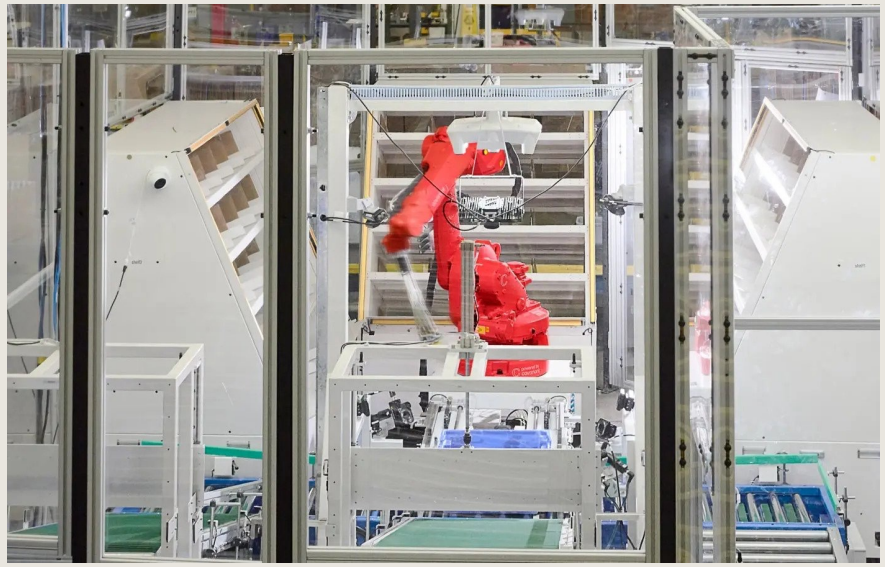
BATHTUB MOLD WAREHOUSE

- First step of the bathtub manufacturing process
- Robot must retrieve molds from the warehouse and place it on the mold transfer system
- Bathtub molds are heavy, can weigh up to 700lbs
- Most important requierments for choosing a robot for this step is payload limit, speed, and reach limit
- Warehouse layout depends on the floor plan shape which also affects the robot choice
- Two possible layouts
  - Circular Warehouse, around a static articulated robot
  - Rectangualr rows of shelves spanning both sides of an artuiculated robot on a transfer unit (7th axis), eliminating the deadzone





BATHTUB MOLD WAREHOUSE



Static articulated robot in a radial warehouse

Articulated robot on a transfer unit in a rectangular warehouse

BATHTUB MOLD WAREHOUSE ROBOT CHOICE

Name	DOF	Workspace (20%)	Payload (kg) (10%)	Speed (°/s) (5%)	Interfacing (10%)	Programming Complexity (15%)	Ruggedness (5%)	Repeatability (25%)	$ (5%)	Support (5%)
M-900iB/330L (FANUC)	6	Sphere (max 3203 mm)	330	100-165	4 (R-30+B Plus controller)	Medium	IP67	± 0.1	$95,000	3
IRB 7600 (ABB)	6	Sphere (max 2250 mm)	400	60-160	4 (IRC5 controller)	Medium-High	IP67	± 0.1	$94,000	4 (> 40 service locations in NA)
KR 340 R3330 (KUKA)	6	Sphere (max 3326 mm)	340	75-130	4 (KRC5 controller)	Medium-Low (teach pendant + virtual sim)	IP65-IP67	± 0.08	$101,000	2
MX350-L (KAWASAKI)	6	Sphere (max 3018mm)	350	70-120	3 (F04 controller)	Medium	IP67	± 0.1	$92,000	1

BATHTUB MOLD WAREHOUSE ROBOT CHOICE

From the previous decision matrix we can see that the **KUKA 340 R3330** is the best option for this application as it scored the highest from between all 4 options at 65% matching the important requirements for this application

This model is compatible with a wide variety of end effectors, most importantly grippers and vacuum pads.

For the purpose of this application, the most important features are Workspace, Payload, the I/Os available, programming type, and repeatability

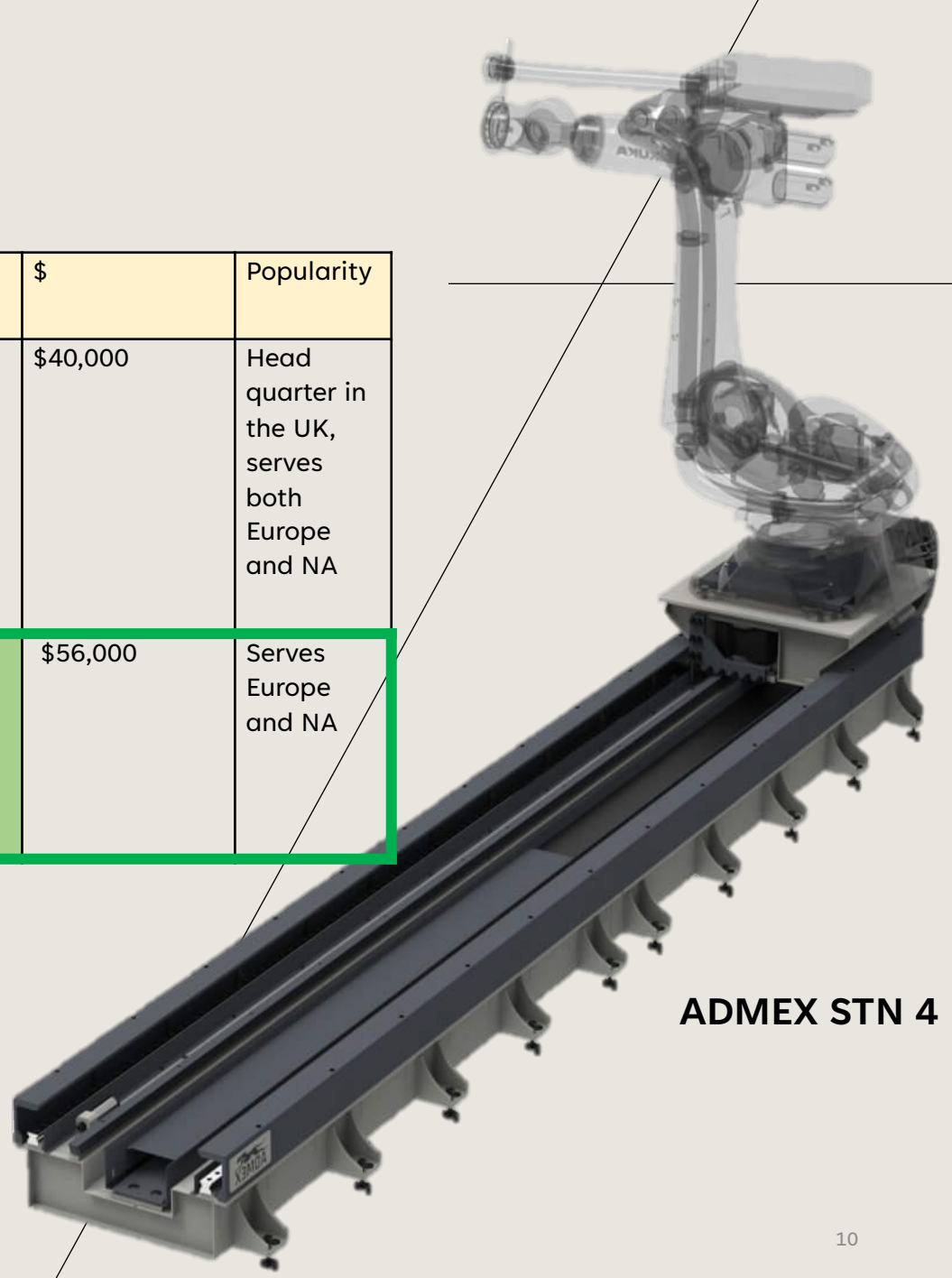
Workspace and Payload affects our ability to store and retrieve the bathtub molds, while I/Os, programming type and repeatability affects our ability to operate the robot efficiently

KUKA 340 R3330

BATHTUB MOLD WAREHOUSE TRANSFER UNIT CHOICE

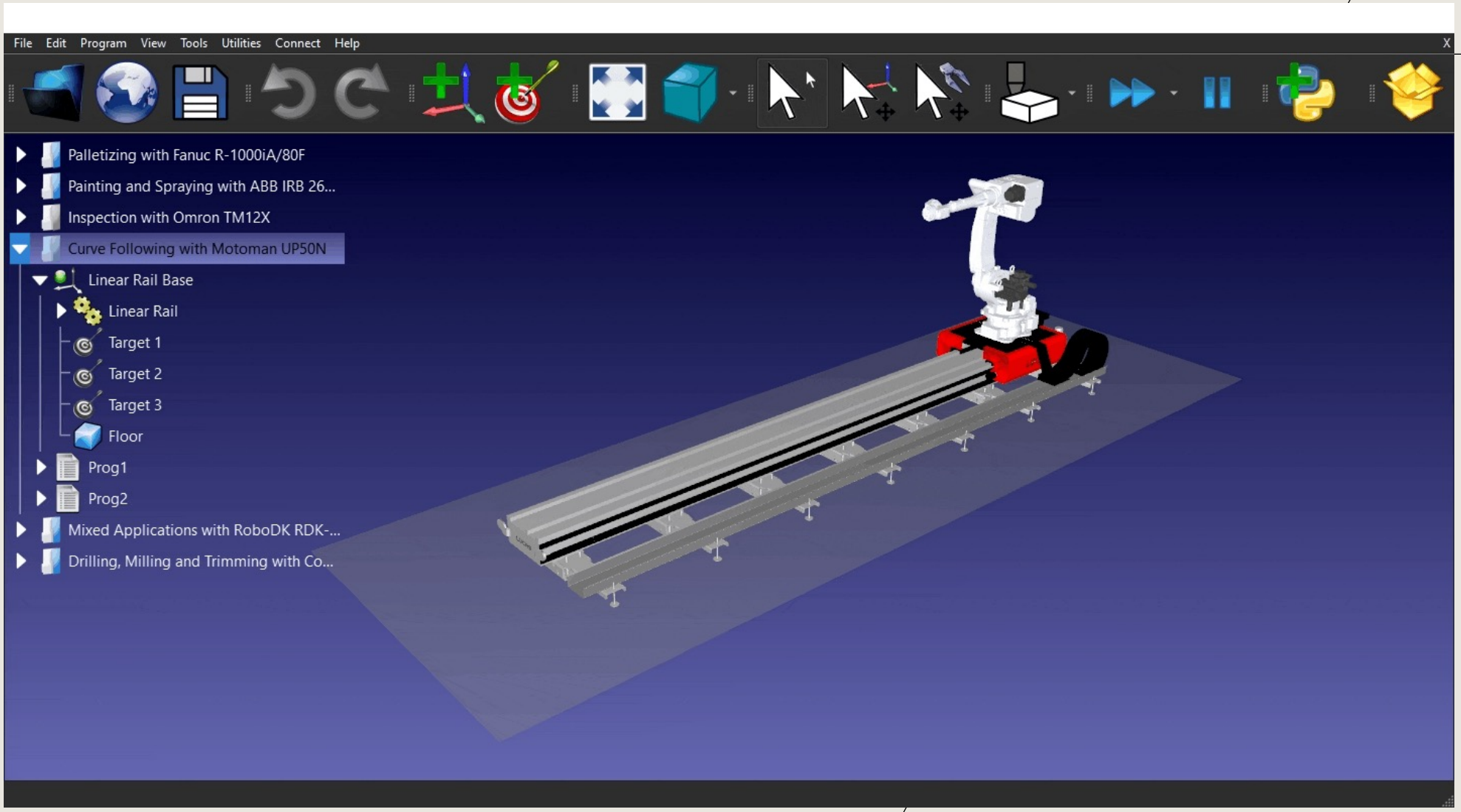
Name	DOF	Workspace	Payload	Speed	IOs	Prog	Harsh Env	Repeat	$	Popularity
HiGlyde Max	1	Spheroid, with length of stroke+2* max reach of used robot	4000kg (robot + robot payload)	1.5 m/s	Can use the same controller used by the robot of choice	N/A	severe dust and liquid protection, IP67	± 0.1	$40,000	Head quarter in the UK, serves both Europe and NA
STN 4	1	Spheroid, length of stroke+2* max reach robot	4000kg (robot + robot payload)	2 m/s	Can use the same controller used by the robot of choice	N/A	severe dust and liquid protection, IP67	± 0.01	$56,000	Serves Europe and NA

we can see that the **ADMEX STN 4** has a slight edge over the HiGlyde Max in the speed and repeatability criteria making it the preferred option



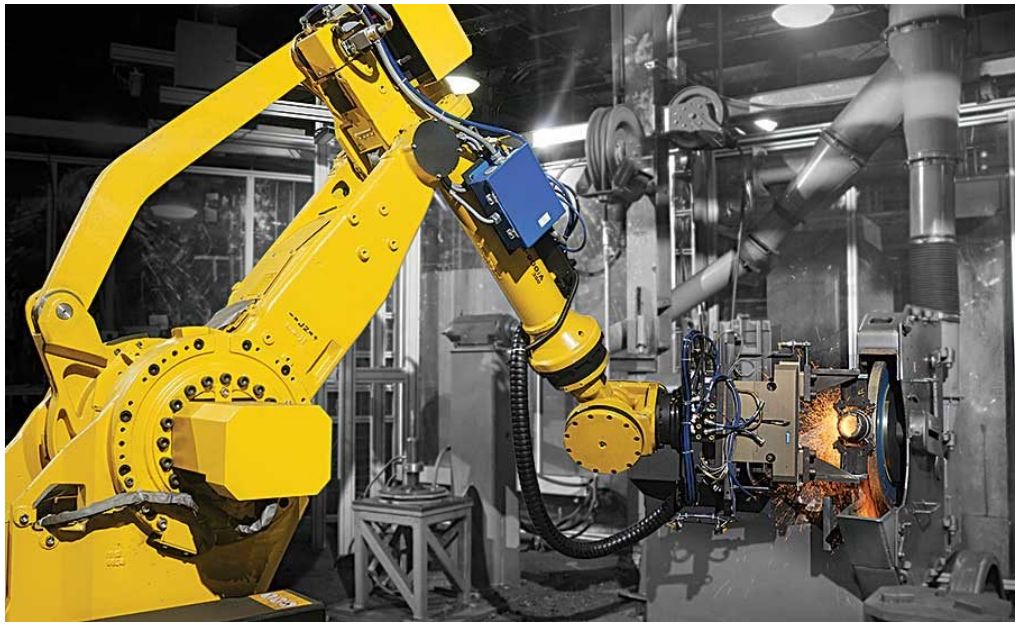
ADMEX STN 4

BATHTUB MOLD WAREHOUSE TRANSFER UNIT SIMULATION



LOADING MOLD INTO THERMOFORMING STATION

- Here the robot must pick the mold from the transfer system and place it into the thermoforming station
- Most important requierments for choosing a robot for this step is payload limit and speed
- There is no need for a transfer unit for this step as space utilization isn’t important, we only need to load/unload the mold into/from the thermoforming station



LOADING MOLD INTO THERMOFORMING STATION ROBOT CHOICE

Name	DOF	Workspace (20%)	Payload (kg) (10%)	Speed (°/s) (5%)	Interfacing (10%)	Interfacing (10%)	Ruggedness (5%)	Repeat (25%)	$ (5%)	Support (5%)
M-900iB/330L (FANUC)	6	Sphere (max 3203 mm)	330	85-165	4 (R-30+B Plus controller)	4 (R-30+B Plus controller)	IP67	± 0.1	$95,000	3
IRB 6700 (ABB)	6	Sphere (max 2701m)	300	88-180	4 (IRC5 controller)	4 (IRC5 controller)	IP67	± 0.1	$104,000	4 (> 40 service locations in NA)
KR 300 R2700-2 (KUKA)	6	Sphere (max 2701 mm)	300	101-180	4 (KRC5 controller)	4 (KRC5 controller)	IP65-IP67	± 0.05	$107,000	2
MX350-L (KAWASAKI)	6	Sphere (max 3018mm)	350	70-120	3 (F04 controller)	3 (F04 controller)	IP67	± 0.1	$92,000	1

LOADING MOLD INTO THERMOFORMING STATION ROBOT CHOICE

We can see that the **KUKA KR 300 R2700-2** is the best option for this application as it scored the highest from between all 4 options at 50% matching the important requirements for this application

For the purpose of this application, the feature required would be the Workspace, Payload, the I/Os available, programming type, and repeatability.

Workspace and Payload affects our ability to place and retrieve the bathtub molds into/from the thermoforming station, while I/Os, programming type and repeatability affects our ability to operate the robot efficiently

KUKA KR 300 R2700-2

END EFFECTOR CHOICE

Since the payload being lifted for this application is a heavy steel mold (up too 700lbs) the only available grippers are electrical magnet grippers. We couldn't find claw grippers that can handle the application payload, and vaccum grippers require large flat surfaces which isn't possible for a bathtub mold.

End effector	Magnet area (cm^2)	Holding force (N)	Recommended payload (kg)
EMH-RP 084-B (Shunk)	41.25	5370	547.4
HMS-PLAY70x2 MDC-70MM (Goudsmit)	174.44	3150	321.1

We can see that the Shunk end effector can carry heavier payloads, but it has far smaller magnet area, which can be a concern for lifting mold with large dimesions while maintaining stability, thus we chose the Goudsmit magnet gripper

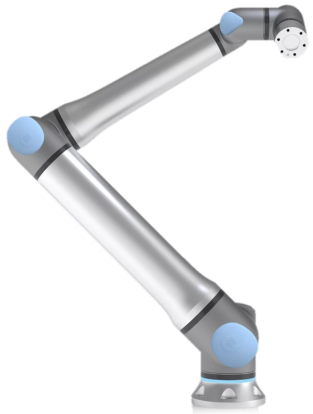
HMS-PLAY70x2 MDC-70MM

SPRAYING/ROLLING STATION ROBOT CHOICE

Name	DoFs	Workspace (20%)	Speed (5%)	Repeatability (mm) (10%)	Ruggedness (20%)	Price (USD) (15%)	Interfacing (5%)	Programming Complexity (10%)	Support (15%)
Yaskawa EPX1250/MotoSight 2D/Robo (x2)	6	Sphere (max 1852 mm)	185 - 500 (°/s)	± 0.15	IP54, 0-40 °C	~$82,000	4 (NX100-FM controller)	High	4
Fanuc P-40iA/IRVision 3D/Robo (x2)	6	Sphere (max 1300 mm)	1500 mm/s	± 0.03	IP67	~$52,000	4 (R-30+B Plus controller)	High	3
Kuka KR 10 R1100 EX/Robochop X-Gun/*	6	Sphere (max 1101 mm)	140 cycles/min	± 0.03	IP65, IP67	~$56,000	3 (KCR5 controller)	Medium	4
ABB IRB 5510/Robochop X-Gun/*	6	Sphere (max 2560 mm)	100 - 535 (°/s)	± 0.15	IP54, IP66, 0-40 °C	~$24,000	4 (IRC5 controller)	Medium	4

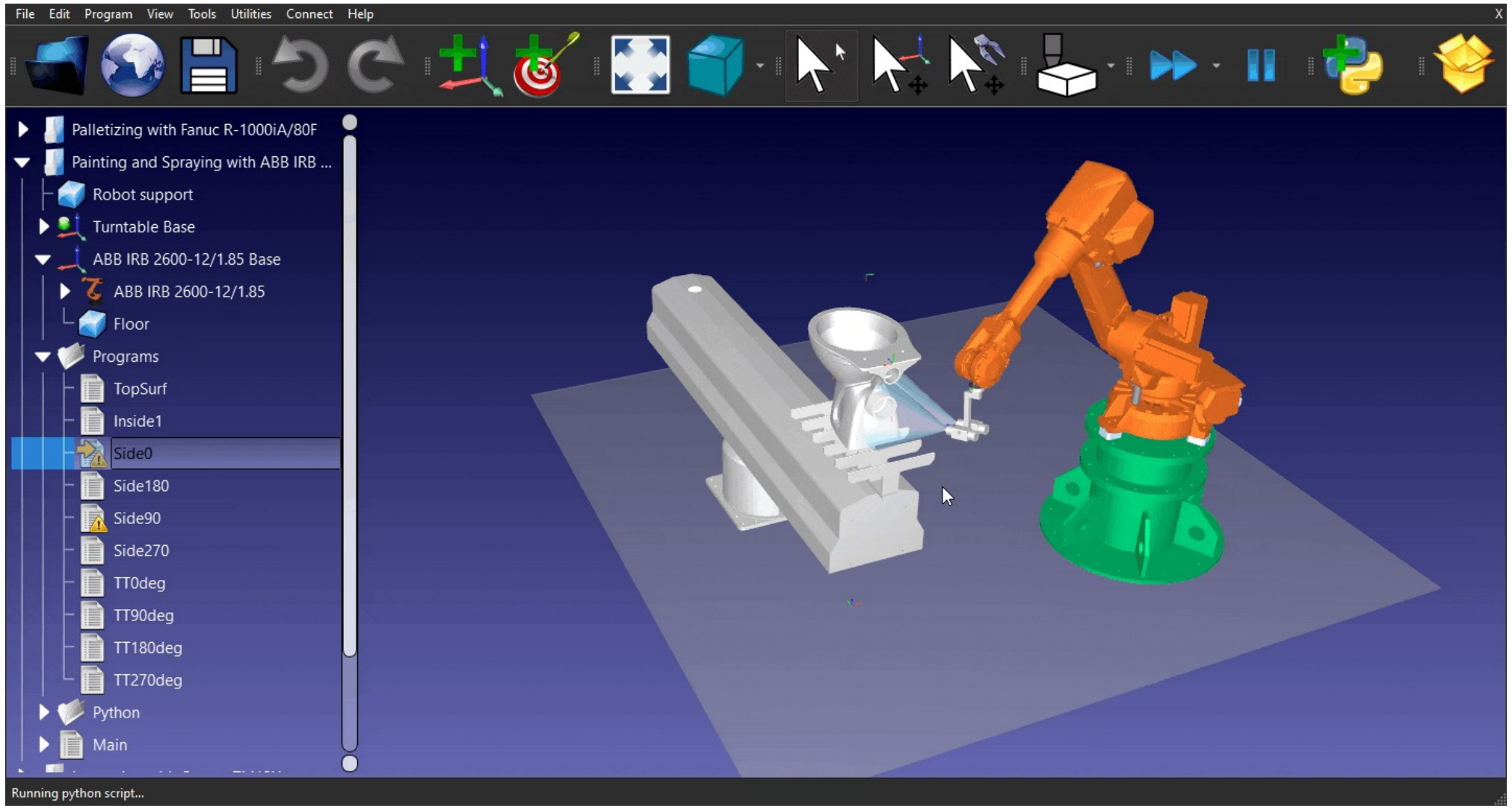
*Includes two-headed end-of-arm tool (McMaster Carr Two-Headed mount - 4900N11 (x1))

PLACING BOARD ON THE BATHTUB

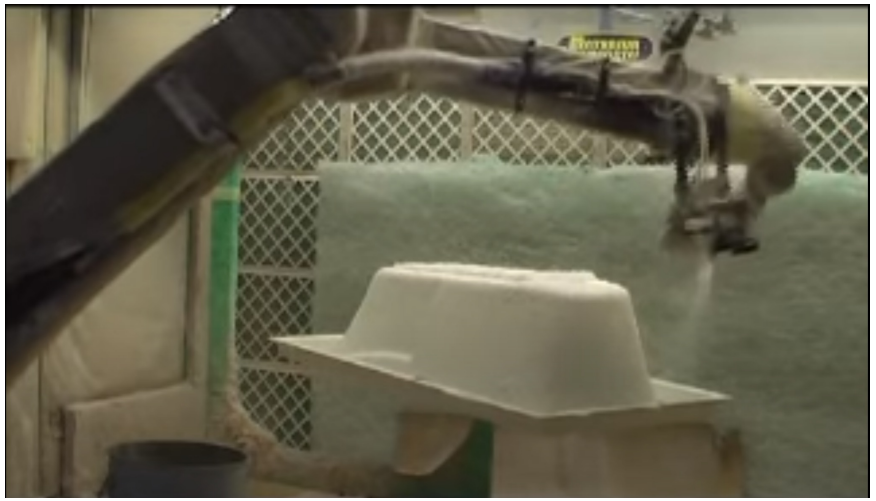


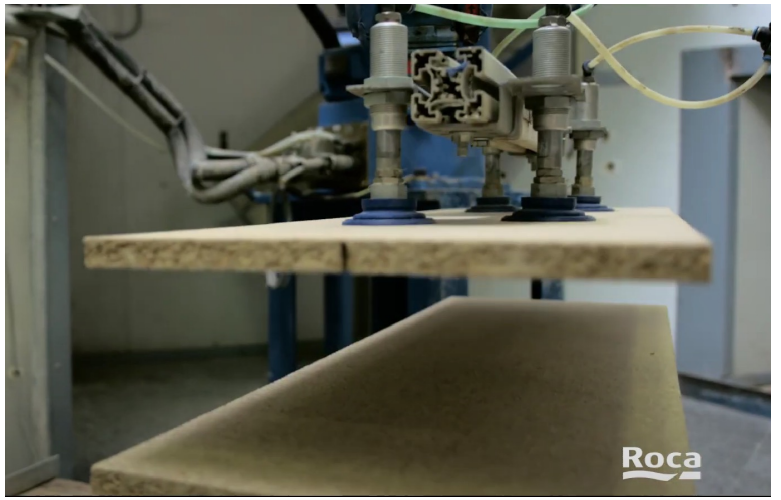
Name	DoFs	Workspace (15%)	Payload (kg) (15%)	Repeatability (mm) (10%)	Ruggedness (20%)	Price (USD) (15%)	Vacuum Gripper Suction Cup #s	Vacuum Gripper Sizing Area (mm x mm x mm) (10%)	Support (15%)
Fanuc CRX-10iA/Schmalz FQE Xc 220x80	6	Sphere (max 1249 mm)	10	± 0.04	IP67	~$53,000	22	220 x 80 x 85	3
Fanuc CR-15iA/Schmalz FQE Xc 220x80	6	Sphere (max 1441 mm)	14	± 0.02	IP54/67	~$48,000	22	220 x 80 x 85	3
Kuka KR 16 R1610-2/McMaster Carr Robot-Ready Vacuum Lifter	6	Sphere (max 1612 mm)	16	± 0.04	IP65	~$39,000	N/A	162 x 110 x 110	4
UR-20/OnRobot VGP20 Gripper	6	Sphere (max 1750 mm)	20	± 0.01	IP40/IP67	~$63,000	24	264 x 184 x 92	2

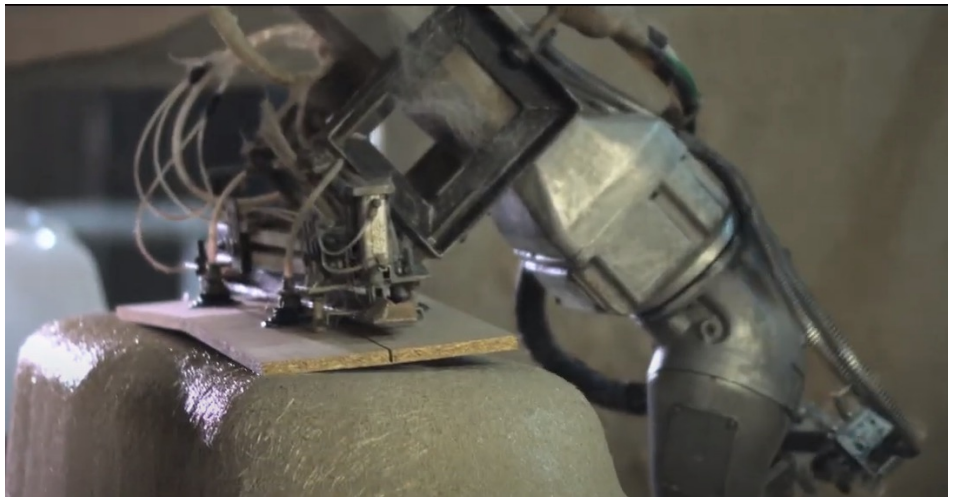
SPRAYING ROBOT SIMULATION



SPRAYING/BOARDING INFLUENCES



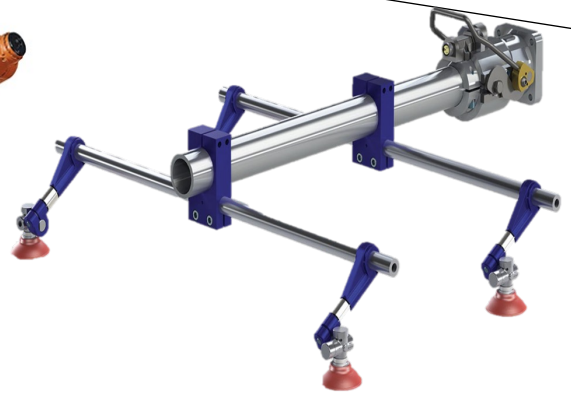




VISUAL INSPECTION

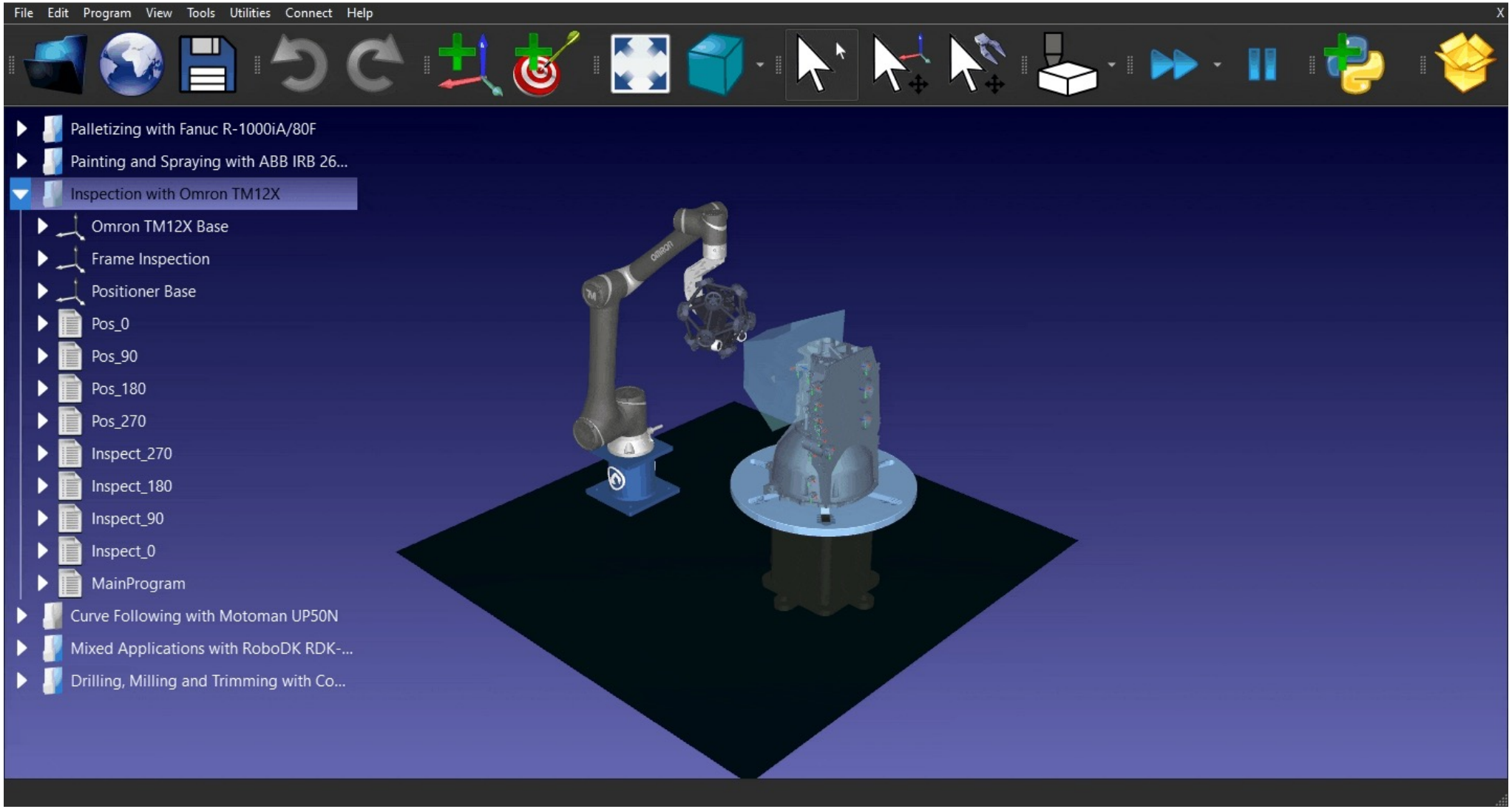
Name	DoFs	Workspace (15%)	Speed (10%)	Repeatability (mm) (15%)	Ruggedness (10%)	Price (USD) (10%)	Interfacing (10%)	Programming Complexity (15%)	Support (15%)
UR-20 with DoAll Camera	6	Sphere (max 1750 mm)	2 m/s, 120-210 degrees/s	± 0.1	IP65, 0-50 °C	~$60,000	2 (UR controlbox)	Low	2
Fanuc CRX-25iA with IRVision 2D	6	Sphere (max 1756 mm)	2 m/s	± 0.05	IP67	~$65,000	4 (R-30+B Plus controller)	Medium	3
Kuka KR 6 R1840-2 with Keyence CV-X VS	6	Sphere (max 1840 mm)	220 - 472 degrees/s	± 0.04	IP65/IP67, 0-55 °C	~$35,000	4 (KCR5 controller)	Medium	4
ABB SWIFTI CRB 1300	6	Sphere (max 1400 mm)	6 m/s	± 0.01	IP40/IP67	$56,500	4	Medium	4

LIFTING/FLIPPING

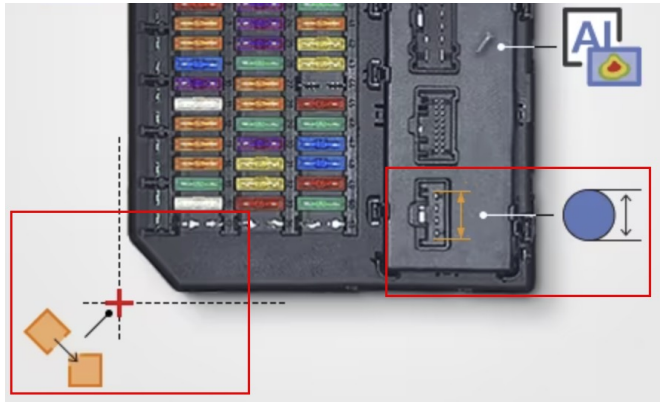


Name	DoFs	Workspace (25%)	Speed (°/s) (5%)	Payload (kg) (15%)	Ruggedness (15%)	Price (USD) (10%)	Vacuum Gripper Suction Cup #s	Vacuum Gripper Sizing Area (mm x mm x mm) (10%)	Support (20%)
Fanuc M-710iC/50/FQE XC 300X130 (x2)	6	Sphere (max 2050 mm)	175-355	50	IP54/67	~$52,000	59	300 x 130 x 88	3
Kawasaki RS050N (x2)/Destaco Vac Tooling/McMaster Carr Cup 5427A735	6	Sphere (max 2100 mm)	180-360	50	IP67, 0 - 45 °C	~$45,000	8 (~15 lbs per)	Lifting: 500 x 300 x 500 Flipping: 350 x 300 x 500	2.5
Yaskawa Motoman (x2)/Destaco Vac Tooling/McMaster Carr Cup 5427A735	6	Sphere (max 4715 mm)	180-350	70	IP67	~$47,000	8 (~15 lbs per)	Lifting: 500 x 300 x 500 Flipping: 350 x 300 x 500	4
Kuka KR50 R2100 (x2) /Destaco Vac Tooling/McMaster Carr Cup 5427A735	6	Sphere (max 2101 mm)	180-360	50	IP65/67, 0 - 50 °C	~$51,000	8 (~15 lbs per)	Lifting: 500 x 300 x 500 Flipping: 350 x 300 x 500	4

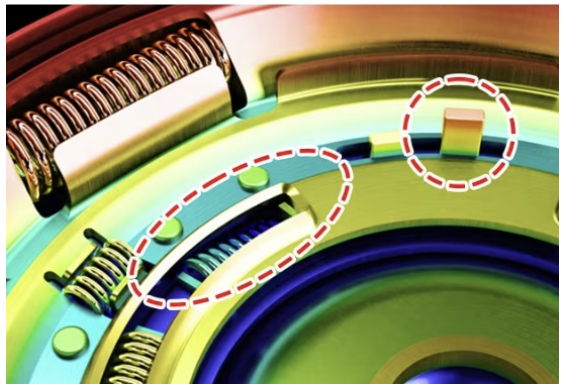
VISUAL INSPECTION SIMULATION



VISION/LIFTING/FLIPPING INFLUENCES



3D image (height image)



LOADING OF ACRYLIC SHEETS INTO VACUUM THERMOFORMING MACHINE

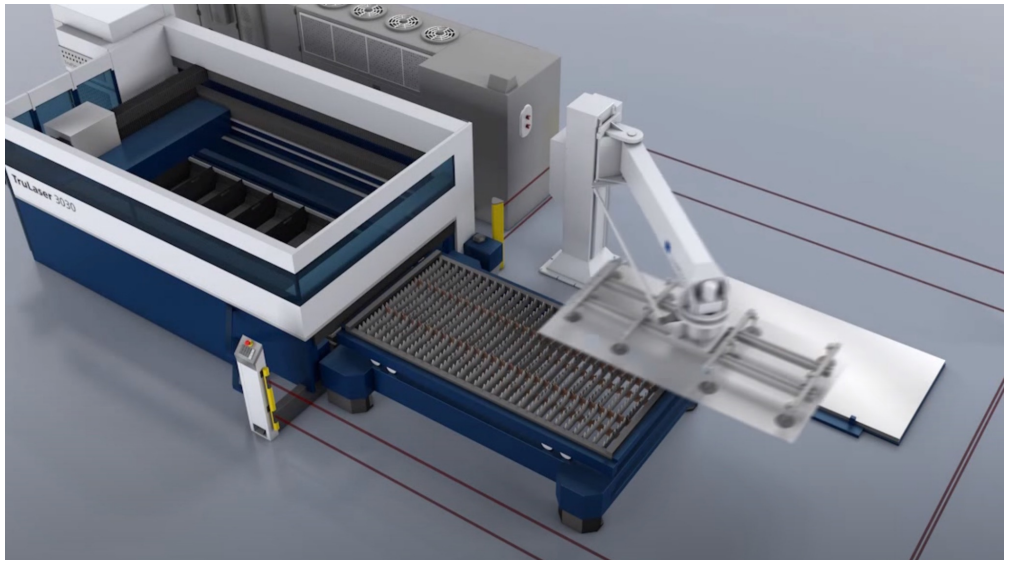
- Load Acrylic Sheet from Sheet Warehouse to Vacuum thermoforming station
- End-effector: Vacuum Gripper

Regular Apron (SB-6106)
Price inquiry (see details)

CAD drawing download | Download PDF drawings | JPG drawing download

1550/1630/1730 x 530

origin Korea
manufacturing company SATURN BATH
weight 5kg



DECISION PROCESS

- Acrylic Sheet Weight: 5kg, Dimension: 1730 * 530mm
- Vacuum Thermoforming Machine Dimension: 5300 * 4800 * 3500 mm (L*W*H)
- Workload: 10kg
- Enough to fit?

Regular Apron (SB-6106)

Price inquiry (see details)

CAD drawing download | Download PDF drawings | JPG drawing download

1550/1630/1730 x 530

origin Korea
manufacturing company SATURN BATH
weight 5kg

SELECTION: COBOT

Advantages

- Safety: Safe to work with people
- More Space: No cage or safety guarding required
- More Flexibility: Can easy to change to different locations for similar/different tasks, Flexible Mounting
- Customizable Speed; Light Weighted: Easy to move

DECISION PROCESS FOR SHEET LOADING COBOTS

Name	DoFs	Workspace (25%)	Payload (kg) (5%)	Speed (°/s) (15%)	Repeatability (mm) (5%)	Ruggedness (5%)	Price (USD) (10%)	Interfacing (5%)	Programming Complexity (10%)	Support (20%)
FANUC CR-15iA/L/ SCHMALZ FQE-M-120x60 Suction cups	6	Sphere (max 1441 mm)	15	800	± 0.02	IP54 Body Standard IP67 Wrist & Arm	$51,600	4 (R-30iB Controller)	Low	3
ABB SWIFTI CRB 1300-10/ ABB FlexGripper - Vacuum	6	Sphere (max 1150 mm)	10	228-720	± 0.04	IP40 IP67 (Optional)	$58,000	3 (C30 or C90XT)	Low	4
KUKA iiwa 14 R820/SCHMALZ ROB-SET FXCB KUKA SPB2	6	Sphere (max 800 mm)	14	85-135	± 0.15	IP54	$35,000	3 (KUKA Sunrise Cabinet,)	Low	4
YASKAWA HC10DTP/SCHMALZ ROB-SET FXCB YASKAWA SPB2	6	Sphere (max 1379 mm)	10	130-250	± 0.05	IP67	~$56,960	5 (YC1000 or YC1000 Micro)	Low	3
UNIVERSAL ROBOTS UR10e/ROB-SET FXCB UR SPB2	6	Sphere (max 1300 mm)	12.5	120-180	± 0.05	IP54	$47,600	5 (OEM Control Box)	Low	2

DECISION PROCESS FOR SHEET LOADING ROBOTS

Name	DoFs	Workspace (25%)	Payload (kg) (5%)	Speed (°/s) (15%)	Repeatability (mm) (5%)	Ruggedness (5%)	Price (USD) (10%)	Interfacing (5%)	Programming Complexity (10%)	Support (20%)
FANUC LR Mate 200iD/14L/SCHMALZ FQE-M-120x60 Suction cups	6	Sphere (max 911 mm)	14	58-400	± 0.01	IP67/IP69K (Optional)	~$35,000	5 (Controller: R-30iB Plus)	Medium	3
FANUC LR-10iA/10/SCHMALZ FQE-M-120x60 Suction cups	6	Sphere (max 1101)	13	230-800	± 0.02	IP67	~$35,000	5 (R-30iB Plus)	Medium	3
KUKA KR10 R1100/SCHMALZ ROB-SET FXCB KUKA SPB2	6	Sphere (max 1101 mm)	10	225-492	± 0.03	IP67	$39,833	4 (KR C4)	Low	4
ABB IRB 1300-10/ABB FlexGripper - Vacuum	6	Sphere (max 1150 mm)	10	228-720	± 0.04	IP40/IP67 (Optional)	$45, 500	3 (OmniCore V250XT)	Low	4
YASKAWA GP12/SCHMALZ ROB-SET FXCB YASKAWA SPB2	6	Sphere (max 1440 mm)	12	130-700	± 0.02	IP67 wrist, IP54 body	$24,331	5 (YC1000)	Medium	3

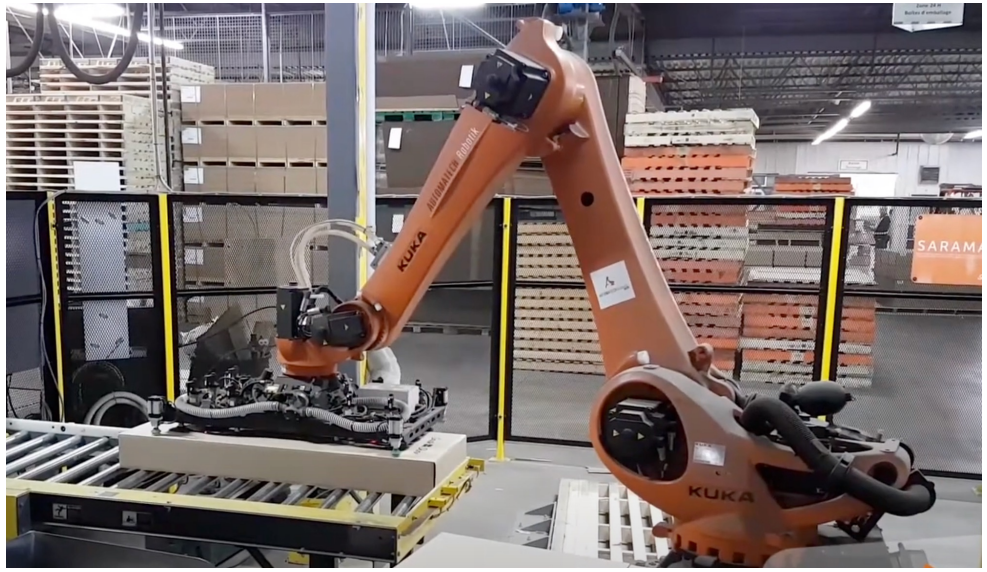
END-EFFECTOR SELECTION FOR SHEET LOADING

[Onrobot]

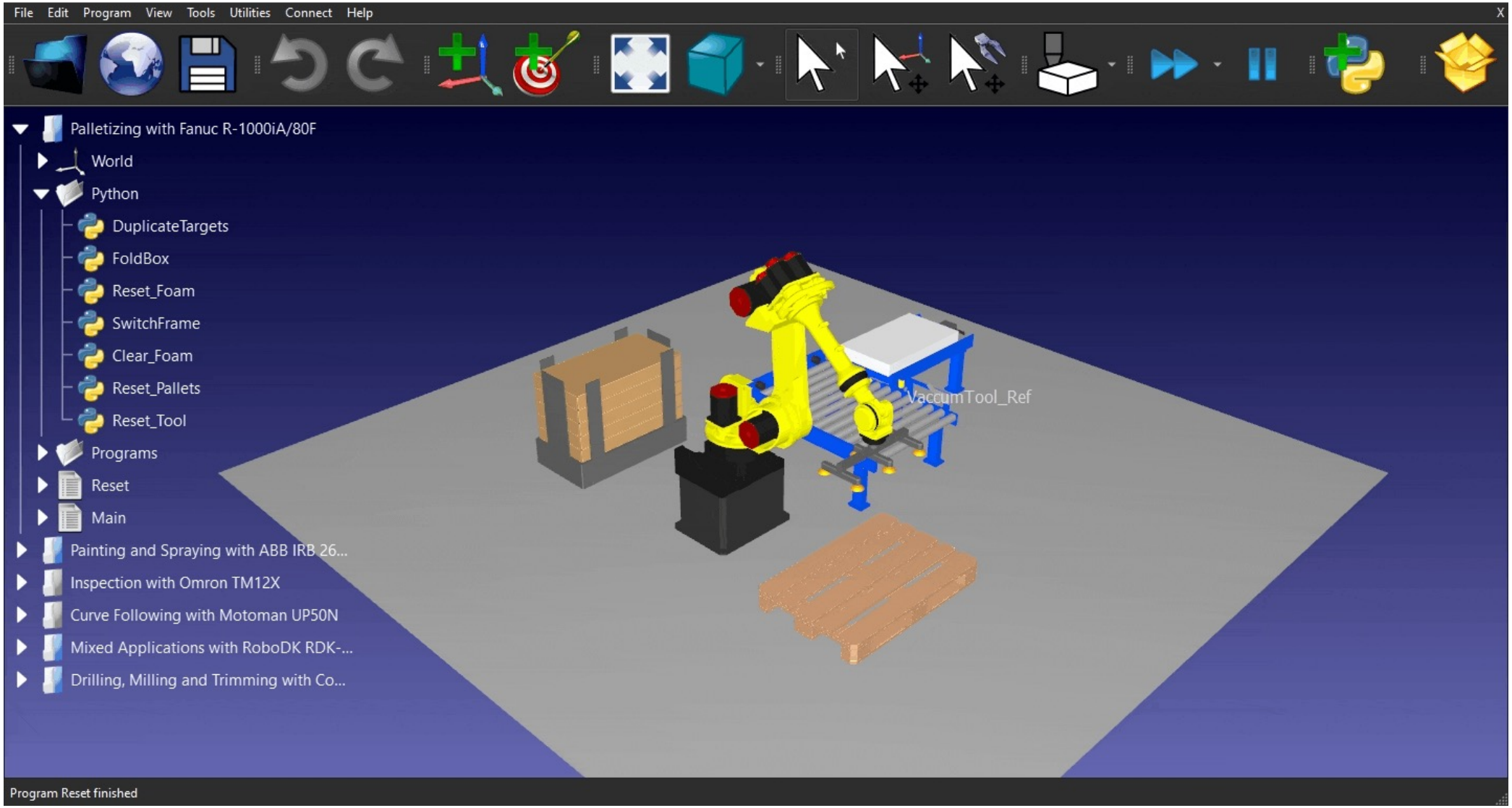
[SCHMALZ]

AUTOMATIC PALLETIZING OF THE BOXES

- “connect” to roller conveyor
- palletizing boxes on a pallet
- end of the production line
- ready to ship



PALLETIZING ROBOT SIMULATION



BOXES SIZE?

Good Seller Brand and Model	Packaged Weight (LBS)	Packaged Length(Inch)	Packaged Height (Inch)	Packaged Width (Inch)
Ove Decors Kaylee 63-inch Freestanding Acrylic Tub	83.8	35.43	23.23	64.96
Vanity Art Freestanding Acrylic Bathtub 6815	106	26	32	61
ANZZI Sofi 67.37 inch Acrylic Freestanding Bathtub	241	77	31	44
Vanity Art Freestanding Claw Foot Acrylic Bathtub 6310-L	200	32	32	71
Jade Bath 5 ft. Manchester White Acrylic Bathtub	154	64	29.5	34
MAAX Delsia 60L x 32W x 26.5H Freestanding Bathtub	105	67	28	37
Streamline 60-inch N-240-60FSWH-FM Soaking Tub	111	36.63	5.25	63.75
SATURN BATH DARWIN (SBA-1270DA) (Company from description Youtube Video)	100	23	31.5	60
SATURN BATH IRON (SB-1107)	55	15.75	29.53	63

Weight: maximum 241 lbs ~ 110 kg, Mostly: below 200 lbs ~ 90kg

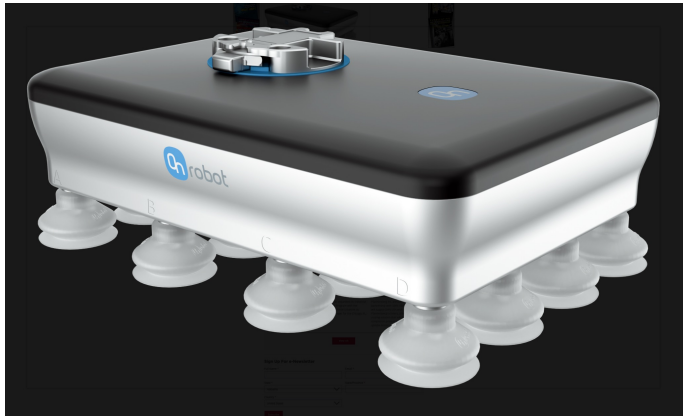
Length: around 80 inch ~2m, Height: 32 inch ~1m, Width: 65 inch ~ 1.65m

DECISION TABLE FOR PALLETIZING OF THE BOXES

Name	DoFs	Reach(mm) (20%)	Payload (kg) (20%)	Speed (°/s) (10%)	Repeatability (mm) (5%)	Ruggedness (5%)	Price (USD) (5%)	Interfacing (5%)	Programming Complexity (10%)	Support (20%)
FANUC M-410iB/140H/SCHMALZ Layer Gripping Systems SPX-M	5	2850mm	140kg	115-420	± 0.05	IP54	$29,500	6 (R-30iB Plus Controller)	Medium-Low	3
KUKA KR 140 R3200-2 PA/SCHMALZ Layer Gripping Systems SPX-M	5	3195mm	140kg	111-321	± 0.07	IP65	$32,000	5 (KR C5)	Medium-Low	4
ABB IRB 660/SCHMALZ Layer Gripping Systems SPX-M	4	3150mm	180kg	130- 300	± 0.05	IP67	$30,000	4 (ABB C90XT)	Medium-Low	4
YASKAWA GP180/SCHMALZ Layer Gripping Systems SPX-M	6	2702mm	180kg	115-265	± 0.05	IP67	$29,500	5 (YRC1000)	Medium	3

END-EFFECTOR SELECTION FOR PALLETIZING — GRIPPERS

Vacuum Cups

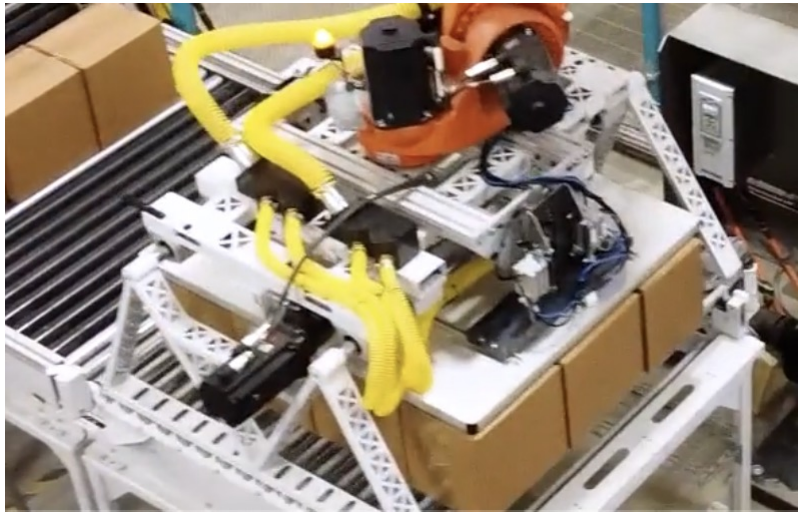


[JOULIN]

[ANVER]

Box Gripper

[SCHMALZ Layer Gripping Systems SPX-M]



[NuMove]

ROBOTS AND COBOTS EFFECTS ON THE BATHTUB MANUFACTURING PROCESS

- Robots ensure precision and consistency for quality products.

- Cobots quickly handle tasks at high speeds, boosting production.

- Robotics speeds up physically demanding tasks, reducing injuries.

- Robots operate 24/7 for sustained productivity.

- Cobots enhance safety by handling hazardous tasks.

ROBOTS AND COBOTS EFFECTS ON THE BATHTUB MANUFACTURING PROCESS

- Robotics enables real-time data collection for optimization.

- Programmable robots adapt seamlessly, minimizing downtime.

- Advanced sensors in robots quickly identify manufacturing defects.

- Increase in cost savings.

DRIVING FORCES BEHIND INTRODUCING ROBOTS IN BATHTUB MANUFACTURING

There are many driving forces that helped thrust robots and cobots into bathtub manufacturing and manufacturing in general

- Skilled Labor Shortages
- Safety and Risk Mitigation
- Technological advancements making robots more accessable
- Cost reduction and increased ROI
- Increased efficiency and productivity

CALCULATING RETURN ON INVESTMENT (ROI)

Calculating the Return on Investment (ROI) for deploying Robots or Cobots in manufacturing lines involves considering both the costs and benefits over a specific period.

$$ROI = \frac{\text{Net Benefit} - \text{Costs}}{\text{Cost}} \times 100$$

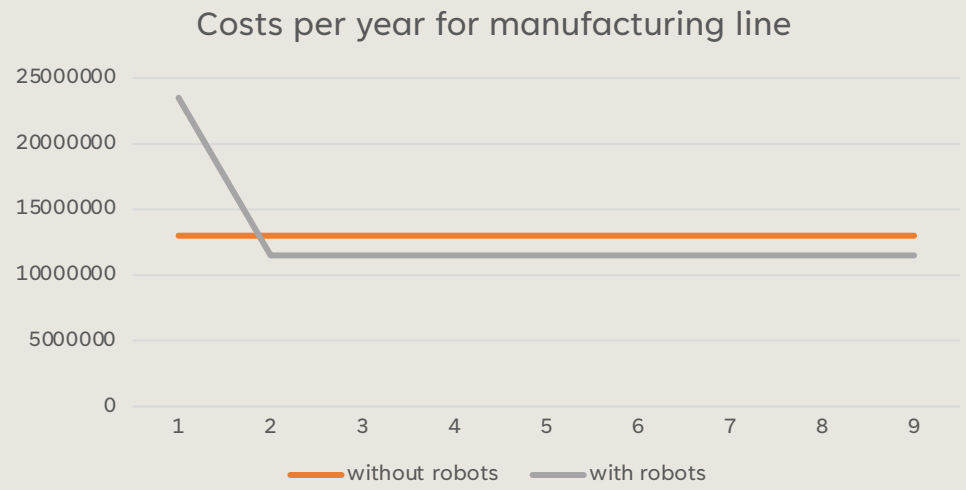
The most important aspect of ROI for manufacturing lines is the savings they incur while also increasing throughput

CALCULATING RETURN ON INVESTMENT (ROI)

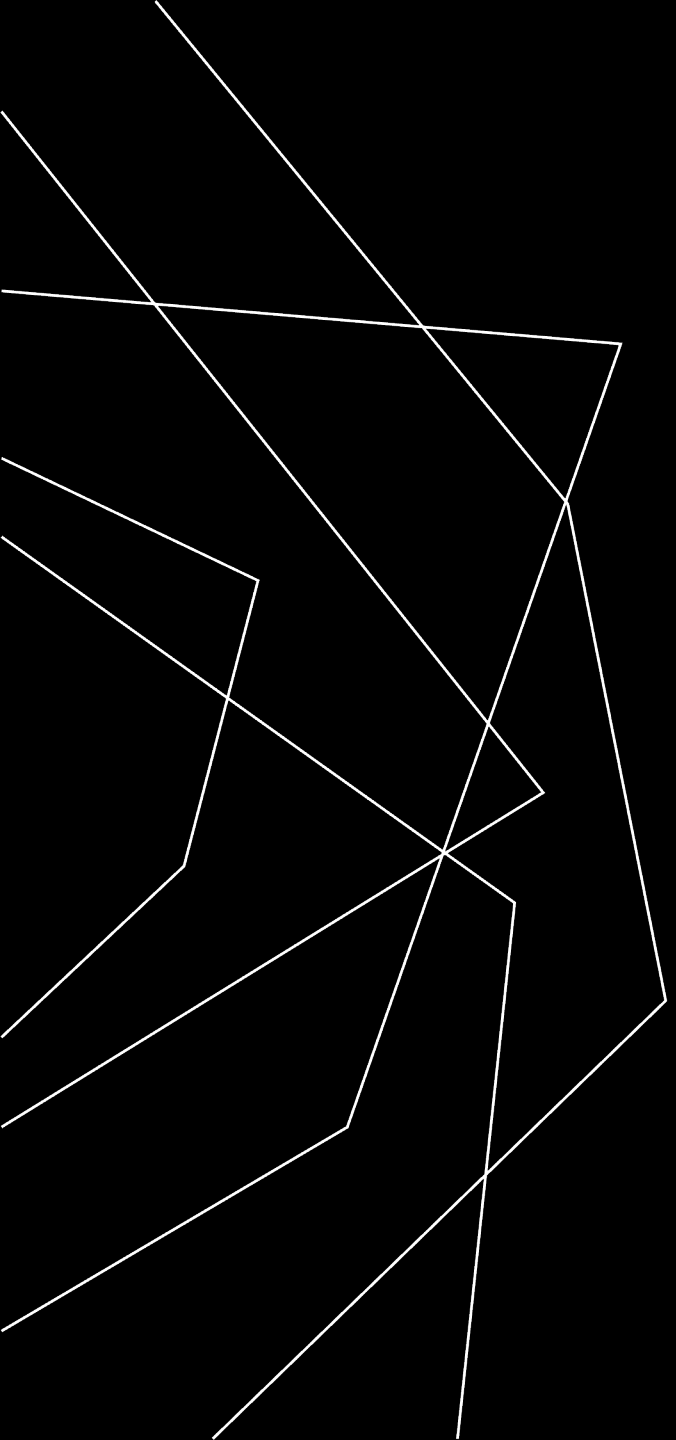
without robots	$
# of workers	100
salary per worker	100000
training costs per worker	20000
benefits and other stuff	10000
total	13000000

year	1	2	3	4	5	6	7	8	9
	13000000	13000000	13000000	13000000	13000000	13000000	13000000	13000000	13000000
	23500000	11500000	11500000	11500000	11500000	11500000	11500000	11500000	11500000
difference	-10500000	1500000	1500000	1500000	1500000	1500000	1500000	1500000	1500000
break even	10500000 at year 8								

with robots	$
initial investment	12000000
# of workers	50
salary per worker	100000
training costs per worker	20000
benefits and other stuff	10000
robot maintainance	100000
total year 1	23500000
total subsequent years	11500000



From this simple calculation we can see that using robots and cutting the workforce in half will result in savings of $1.5M per year after breaking even. This doesn't take into account the increased throuput which increases sales



THANK YOU

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