LEAN ROBOTICS

ACME inc.

Lean Robotics in Action

ACME Inc.

ACME Corporation is a large contract machining manufacturer.

Get a big contract, weee! (oh, wait…)

Need to increase production: Lights out production with a robot

Manual Map - Overview

Steps	Information to capture
1. Identify Cell Customer	Where do the parts go when the station is done with them?
2. Define Output	What are the qualities of a “good input” for the next station? In other words, how does the customer define value? • Parts and their specifications • Part presentation method • Cadence/cycle time
3. Define Input	What is coming in to this station? • Parts and their specifications • Part presentation method • Pace/cycle time
4. Define Process	How are the parts processed? • Which steps are done manually? • Which steps are value-added? Which are not?

Manual Map - Overview

Steps	Information to capture
5. Document Flow of Information	• What information is used at the station? • Where does it come from? In which form? • What information is produced and transferred from the station? Where to, and in what form?
6. Measure KPIs	• What are the KPIs and their target values? • How will the KPIs be measured? KPI examples include: • Cost of producing parts • Cycle time • Inventory at cell
7. Summarize Map	• Combine all the previous information in a visual representation of the map
Manual cell layout	
Sketch Current Layout	• What is the current spatial arrangement of the station?

Manual Map

1. Identify cell customer

The cell customer is the operator who brings the machined parts to an inspection station.

2. Define valuable output

As the internal customer (the operator), what I need you to give me is…
A tray of 60 parts every 2 hours
Specifically, the part numbers made at this cell are AGS202, AGS204, AGS225, AGS400.

so I can ...
Transport it to the inspection station.

Manual Map - Output

Are the parts singulated? What is the space around them?

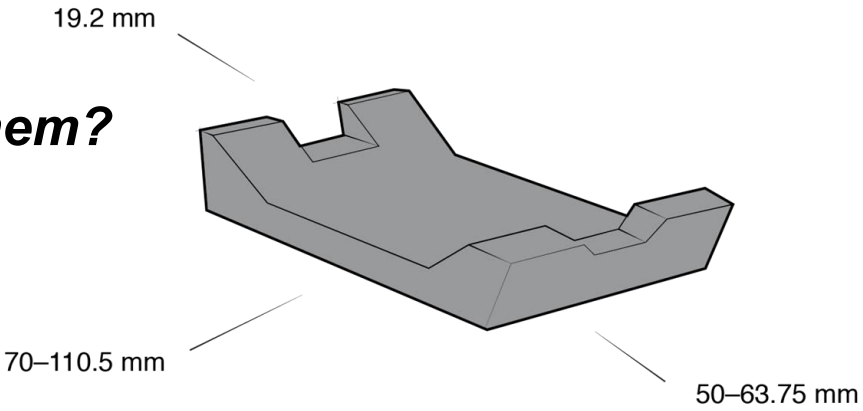
Placed stacked on top of each other

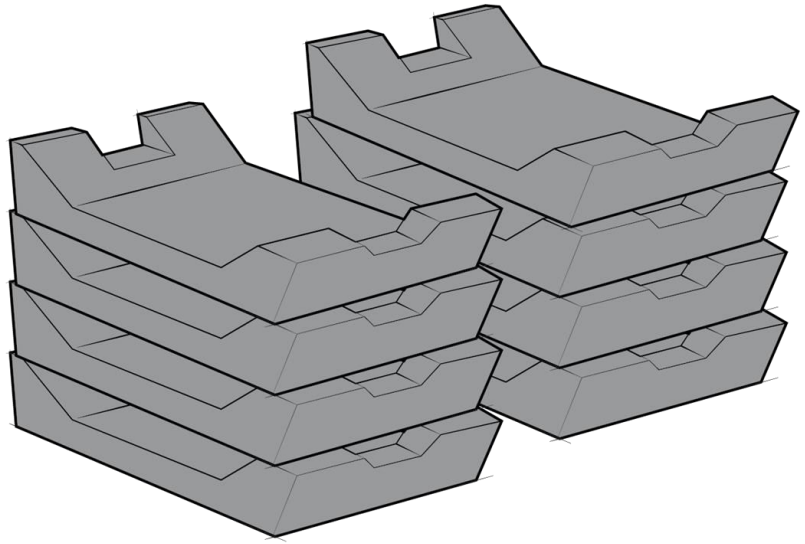
What is the packaging?

On a table

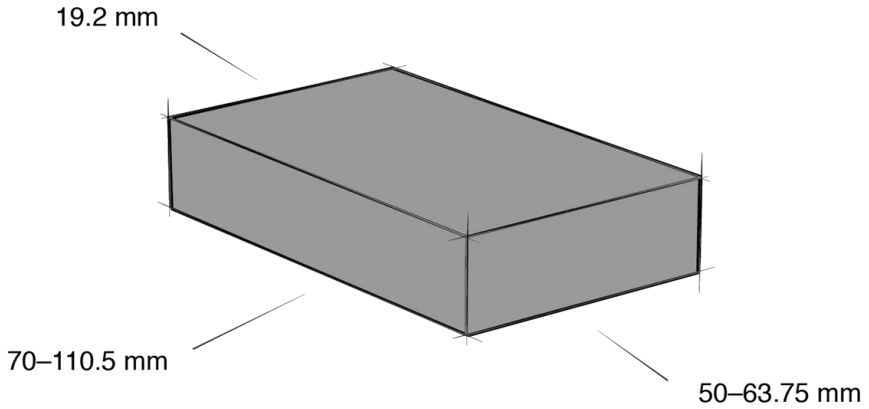
Is the output target moving?

On a stable surface





Manual Map - Input



Number of parts
4 different blanks

Characteristics of the parts
Size:
max: 110.5mm x 63.75 mm x 19.2 mm rectangular blocks
min: 70 mm x 50 mm x 19.2 mm rectangular blocks

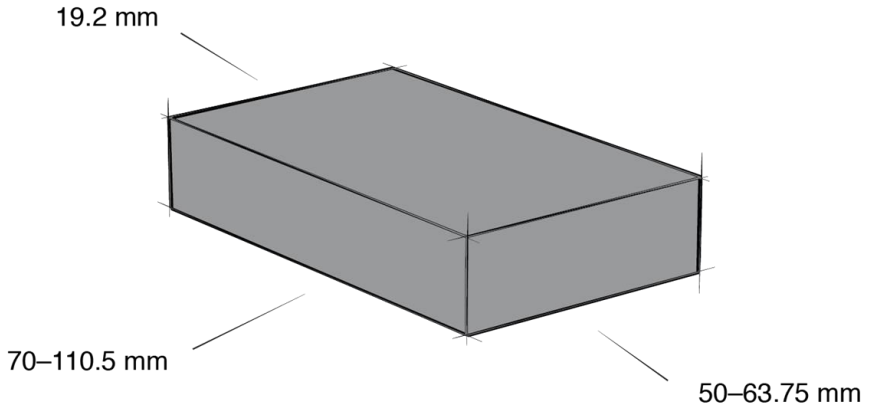
Weight: max: 0.36kg
Material: Solid aluminum

Manual Map - Input

Variation in time

Are there changeovers at this station?

2-3 times a week



Are you planning to introduce new parts in the near future?

Maybe in 9-12 months, similar kind of blank at input, will be within min-max defined above.

Manual Map - Input

Part presentation

Are the parts singulated? What is the space around them?

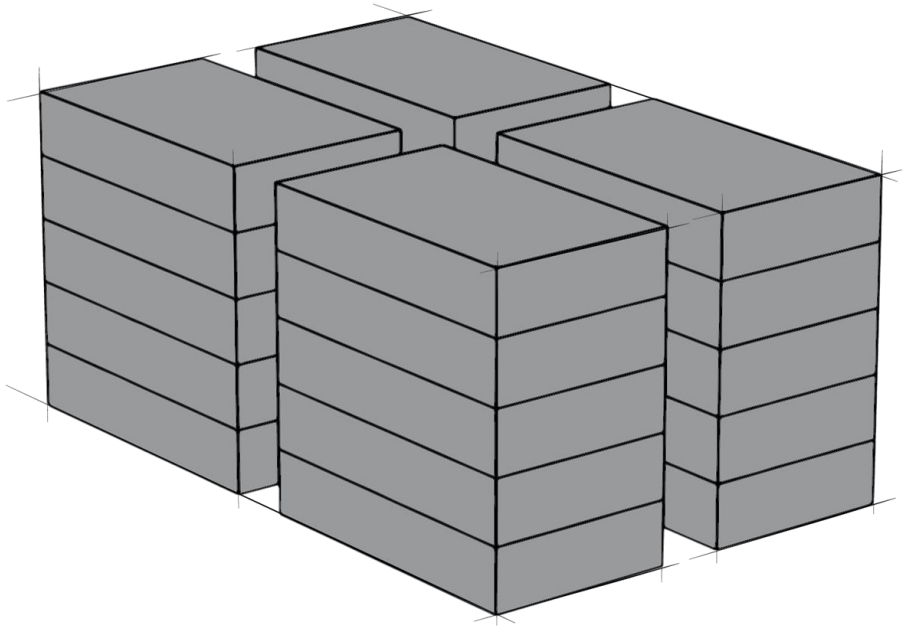
Come stacked on top of each other

What is the packaging?

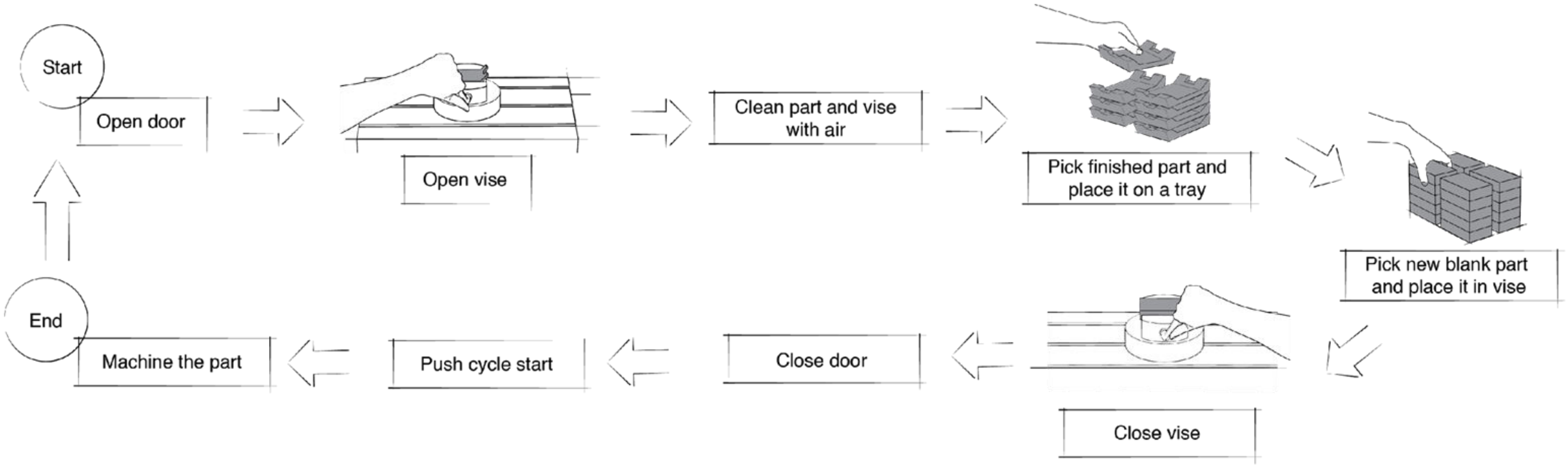
On a table

Are they moving?

Stopped when picked



Manual Process



Manual Map - Process

	Nonvalue-added time (s)	Value added time (s)	
Open door	2		
Open vise	3		
Clean part with air	2		
Pick finished part and place it on tray	2		
Pick new blank part and place it in vise	2		
Close vise	3		
Close door	2		
Push cycle start	2		
Machine the part		75	
Total (s)	18	75	93

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Manual Map - Information Flow

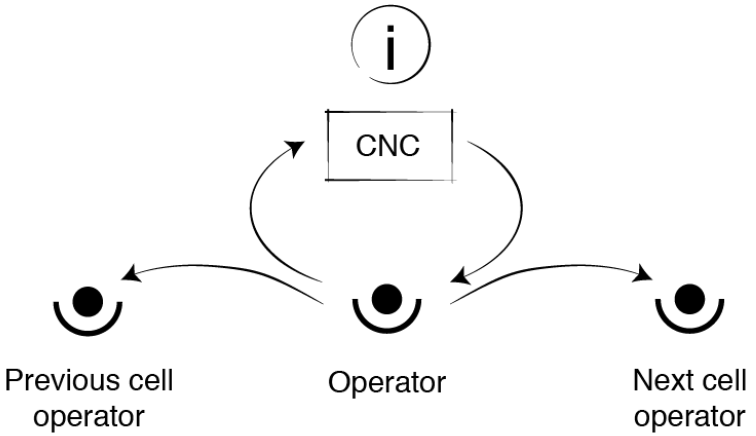
Information	Coming from	Going to	Format	How it's used
Cycle finished	CNC	Cell operator	Light signal	• Operator comes to remove part • Machine allows door opening
No infeed parts	Cell operator	Previous cell operator	Verbal	• Previous cell operator gets more blank parts
Outfeed full	Cell operator	Net cell operator	Verbal	• Next cell operator delivers part to inspection station

Manual Map - KPIs

The most important performance indicators for the cell are:

- Real cell output — 210 parts per day.
- First-pass yield — 97% (3% of the parts are rejected at the next station, which is quality inspection).

Manual Map - Task



KPIs

Cell output: 210 parts / day
First pass yield: 97%

Input

- 4 types of parts
- Aluminium blocks
- Stacked on table

Process

- Open door
- Clean part and vise with air
- Pick finished part, place on tray
- Pick blank part, place in vise
- Close vise
- Close door
- Push cycle start button
- Machine part

Output

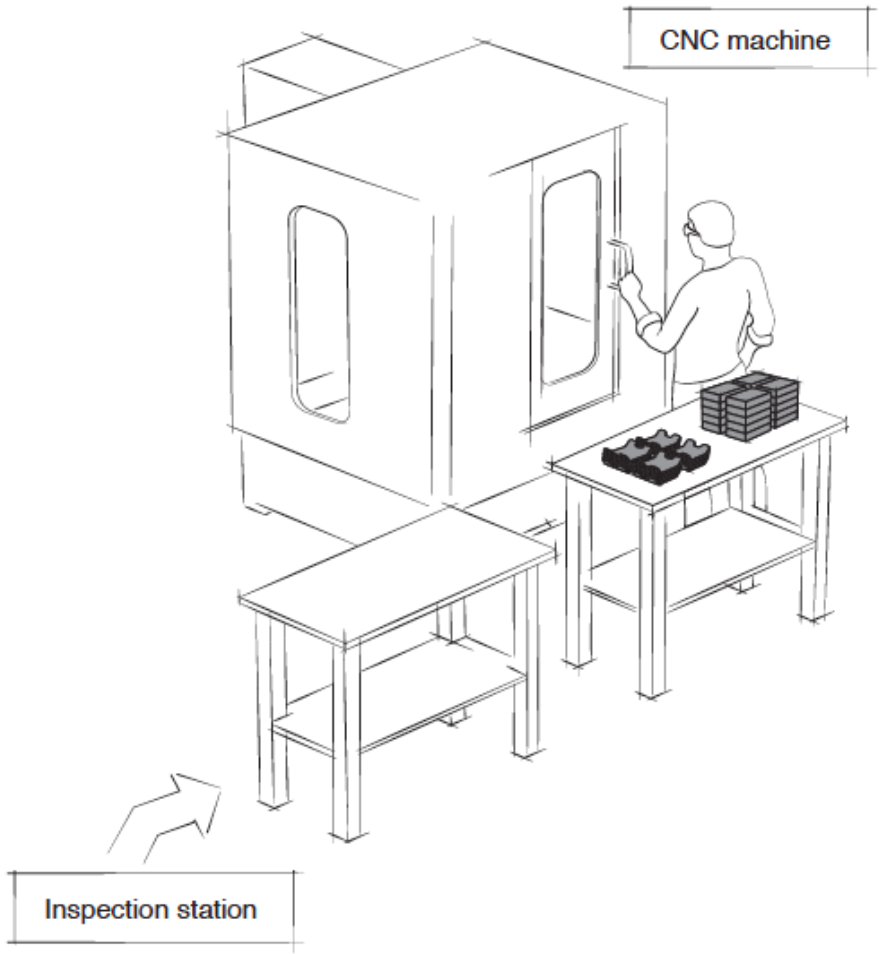
Part family #AGSxxx on a tray

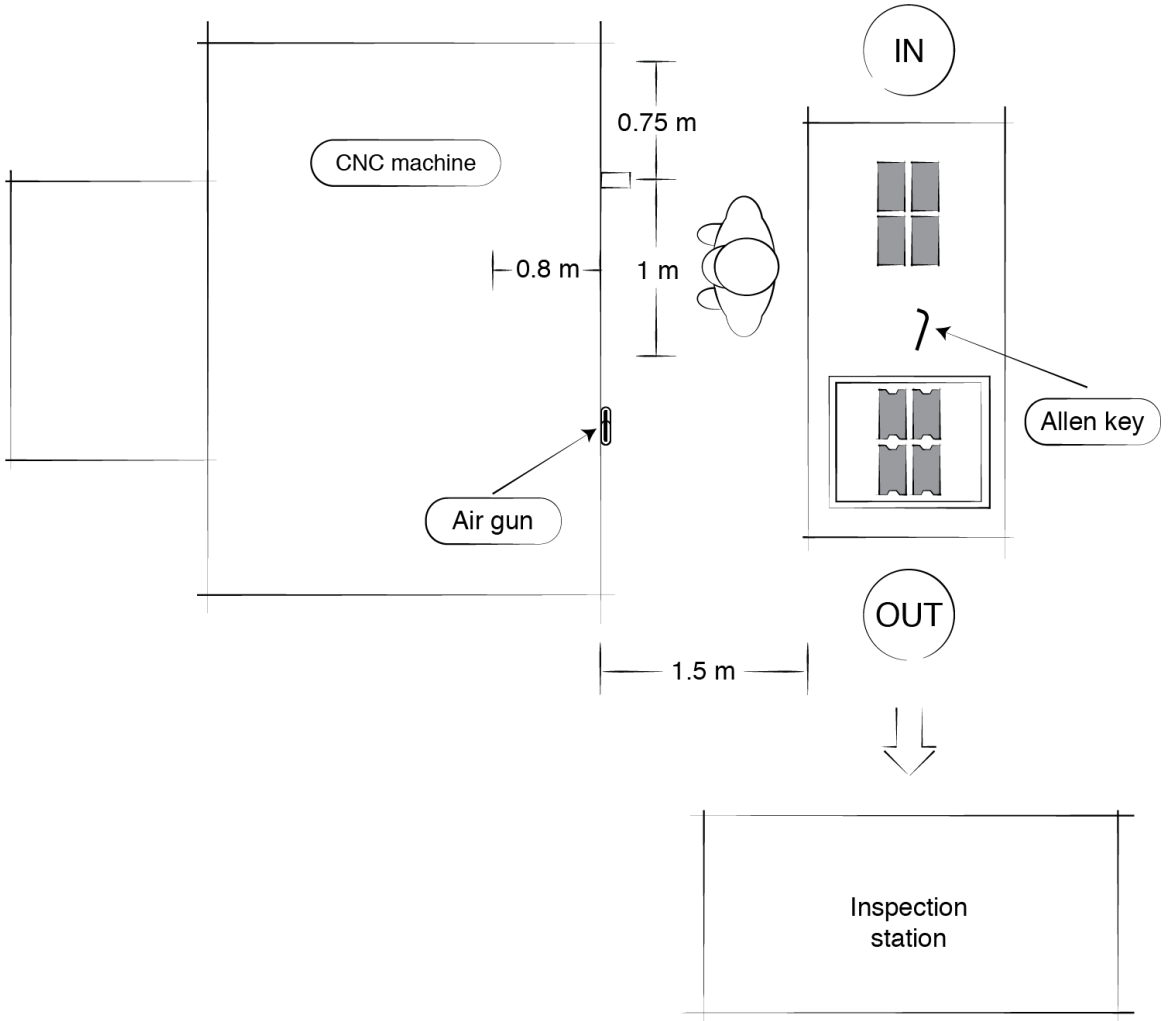
Customer

Operator who can bring tray of 60 parts to inspection station every 2 hours

Value-added time (s)	75
Nonvalue-added time (s)	18
TOTAL (s)	93

Manual Map - Layout





Robotic Map - Overview

Steps	Information to define in the Robotic Task Map
High level robotic cell concept	
Concept	Cell components and concept
Robotic cell layout	
Sketch of robotic cell concept	• What would be the spatial arrangement of the station?
Robotic task map	
1. Identify customer	What's the next step after the robotic cell finishes its task?
2. Define output	How does the customer define value? • Parts specifications • Part presentation • Pace/cycle time

Robotic Map - Overview

Steps	Information to define in the Robotic Task Map
3. Define input	What's coming in at the robotic cell? • Parts (list of parts and specifications) • Part presentation • Pace/cycle time
4. Define process	• How are the parts processed? • What is the sequence of events happening at the station? • Which steps are value-added, and which are not?
5. Document information flow	• What information comes into the robotic cell, in what format, and where from? • What information goes out of the robotic cell, in what format, and where to? • Same thing with the robotic cell.

Robotic Map - Overview

Steps	Information to define in the Robotic Task Map
6. Measure KPIs	• What are the target KPIs? • How will we measure them?
7. Summarize task map	Combine all the previous information into a visual representation of the map.

Robotic Map - Output

1. Identify cell customer

The cell customer is the operator who brings the machined parts to an inspection station.

2. Define valuable output

As the internal customer (the operator), what I need you to give me is…
A tray of 60 parts every 2 hours
Specifically, the part numbers made at this cell are AGS202, AGS204, AGS225, AGS400.

so I can ...
Transport it to the inspection station.

Robotic Map - Output

Are the parts singulated? What is the space around them?

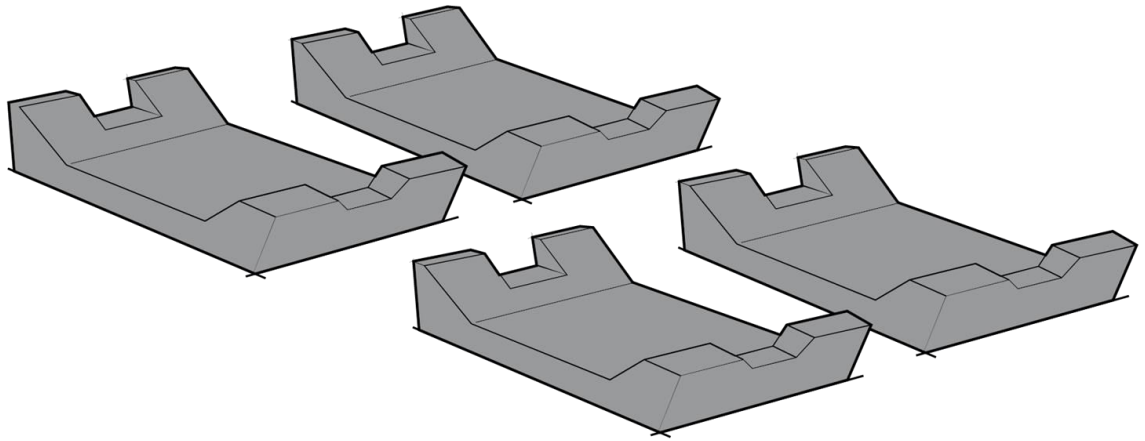
The parts will be laid side-by-side on a table according to a matrix (rows and columns) with enough space in between each one for the gripper's fingers to fit.

What is the packaging?

On a table

Is the output target moving?

On a stable surface



Robotic Map - Input

Number of parts

4 different blanks

Characteristics of the parts

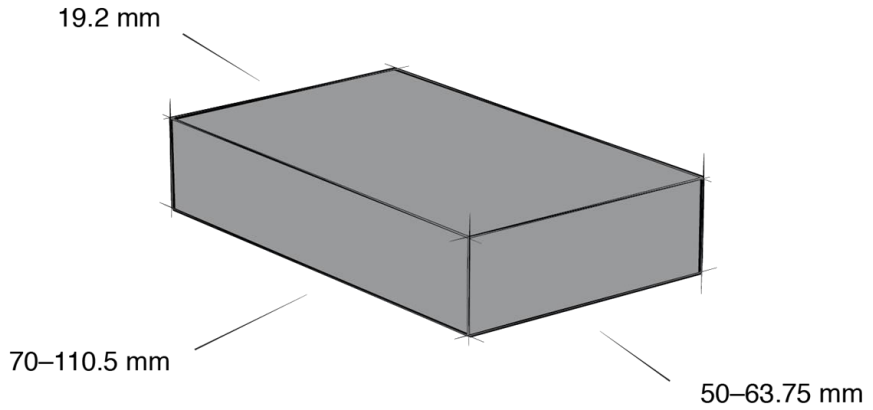
Size:

max: 110.5mm x 63.75 mm x 19.2 mm rectangular blocks

min: 70 mm x 50 mm x 19.2 mm rectangular blocks

Weight: max: 0.36kg

Material: Solid aluminum



Robotic Map - Input

Variation in time

Are there changeovers at this station?

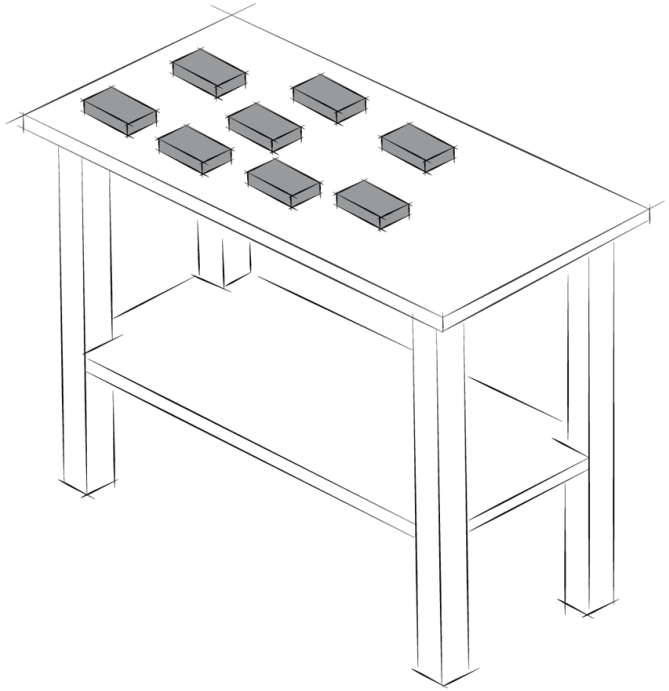
2-3 times a week.

Are you planning to introduce new parts in the near future?

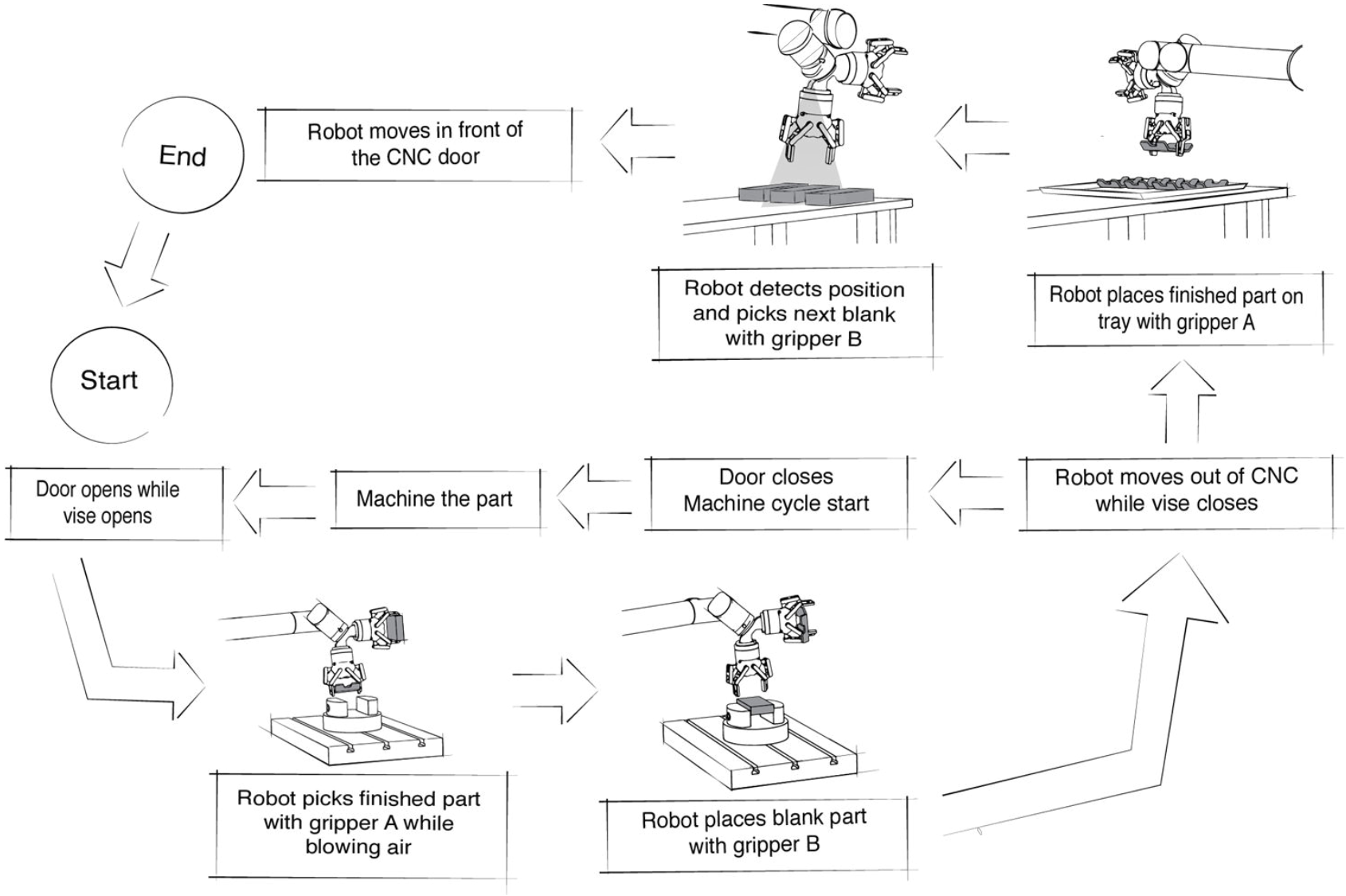
Maybe in 9-12 months, similar kind of blank at input, will be within min-max defined above.

Part presentation

The chosen concept is to position the parts on a table and use a camera to locate them.



Robotic Map - Process



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Robotic Map - Process

	Value-added (seconds)	Nonvalue-added (seconds)	Total (seconds)
Door opens while vise opens		2	
Robot picks finished part with gripper A while blowing air		5	
Robot places blank part with gripper B		2	
Robot moves out of CNC while vise closes		2	
Door closes		2	
CNC machining cycle starts		0	
CNC machining of part while robot detects next blank position	75		
Robot places finished part on tray*		0	
Robot detects next blank position*		0	
Robot picks new blank part*		0	
Robot moves in front of door*		0	
TOTAL	75	13	88

Robotic Map - Information Flow

Information	Going from	Going to	Format	How it's used
Close CNC door	Robot controller	to CNC controller	Digital I/O	When the robot is out of the CNC machine, the door can be closed
Start CNC cycle	Robot controller	to CNC controller	Digital I/O	CNC can start machining cycle
Dimensions of blank	Operator	Robot controller	Manual input in program via teach pendant	Modify gripper opening and camera parameters
Door is opened	CNC controller	Robot controller	Digital I/O	Robot can enter the machine
Vise is opened	CNC controller	Robot controller	Digital I/O	Robot can pick the part if it is inside the machine
Vise is closed	CNC controller	Robot controller	Digital I/O	Robot can open the gripper to release the part
No more parts infeed	Robot controller	Operator	Message on teach pendant	When the robot can't find parts at input, a message is given to the operator

Robotic Map - KPIs

What is the target KPI?

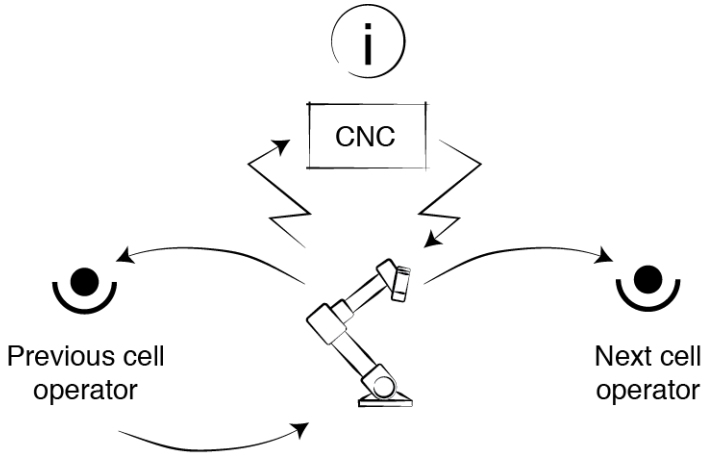
The KPI is the number of parts machined per day. The target number is up to 300 parts per day (running during breaks plus 1 tray unattended during night, plus shorter cycle time)

We're also targeting a first-pass yield (FPY) of 97%.

How will the KPI be measured?

Using a counter in the robot's program.

Robotic Map



KPIs

Cell output: 300 parts / day
First pass yield: 97%

Input

- 4 part types
- Aluminium blocks
- Stacked on table

Process

-Door opens while vise opens
- Robot picks finished part with gripper A while blowing air
- Robot places blank part with gripper B
- Robot moves out of CNC while vise closes
- Door closes
- Machining cycle start
- Machine part
- Place finished part on tray
- Detect next blank position
- Pick new raw part
- Robot moves in front of door

Output

- Part family #AGSxxx on a tray

Customer

Operator who can bring tray of 60 parts to inspection station every 2 hours

Value-added time (s)	75
Nonvalue-added time (s)	13
TOTAL (s)	88

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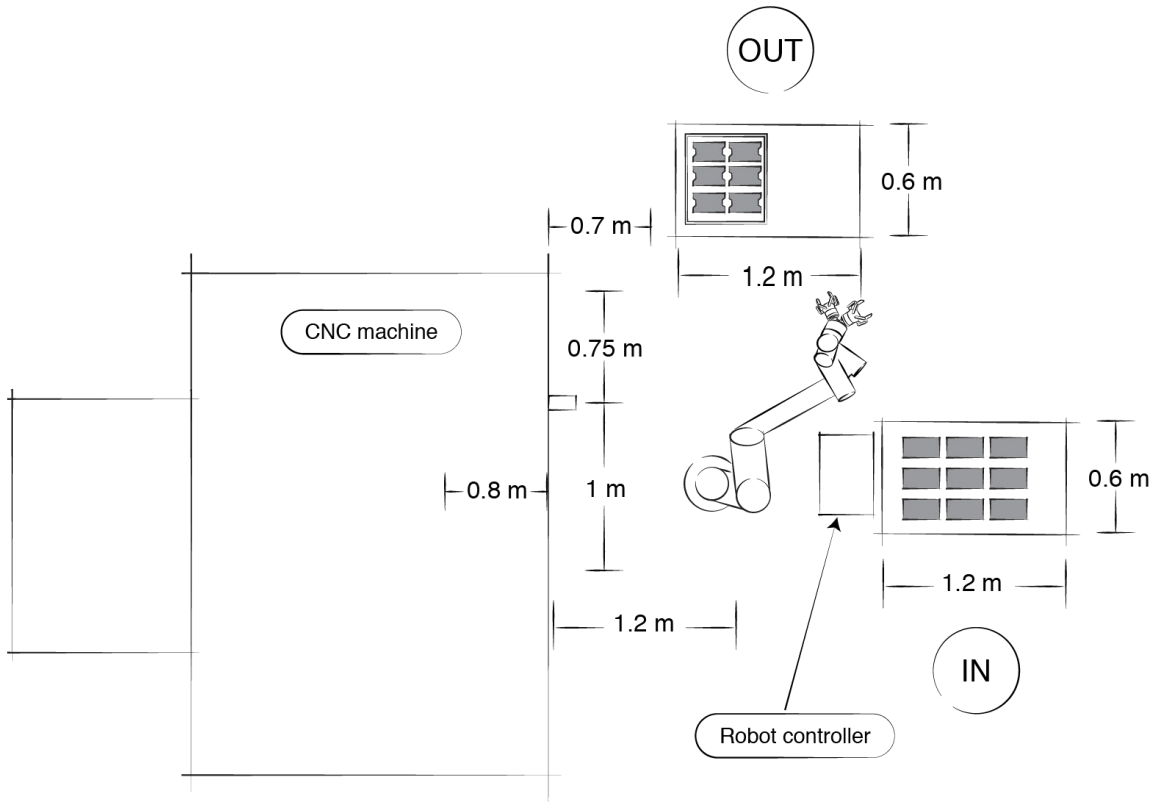
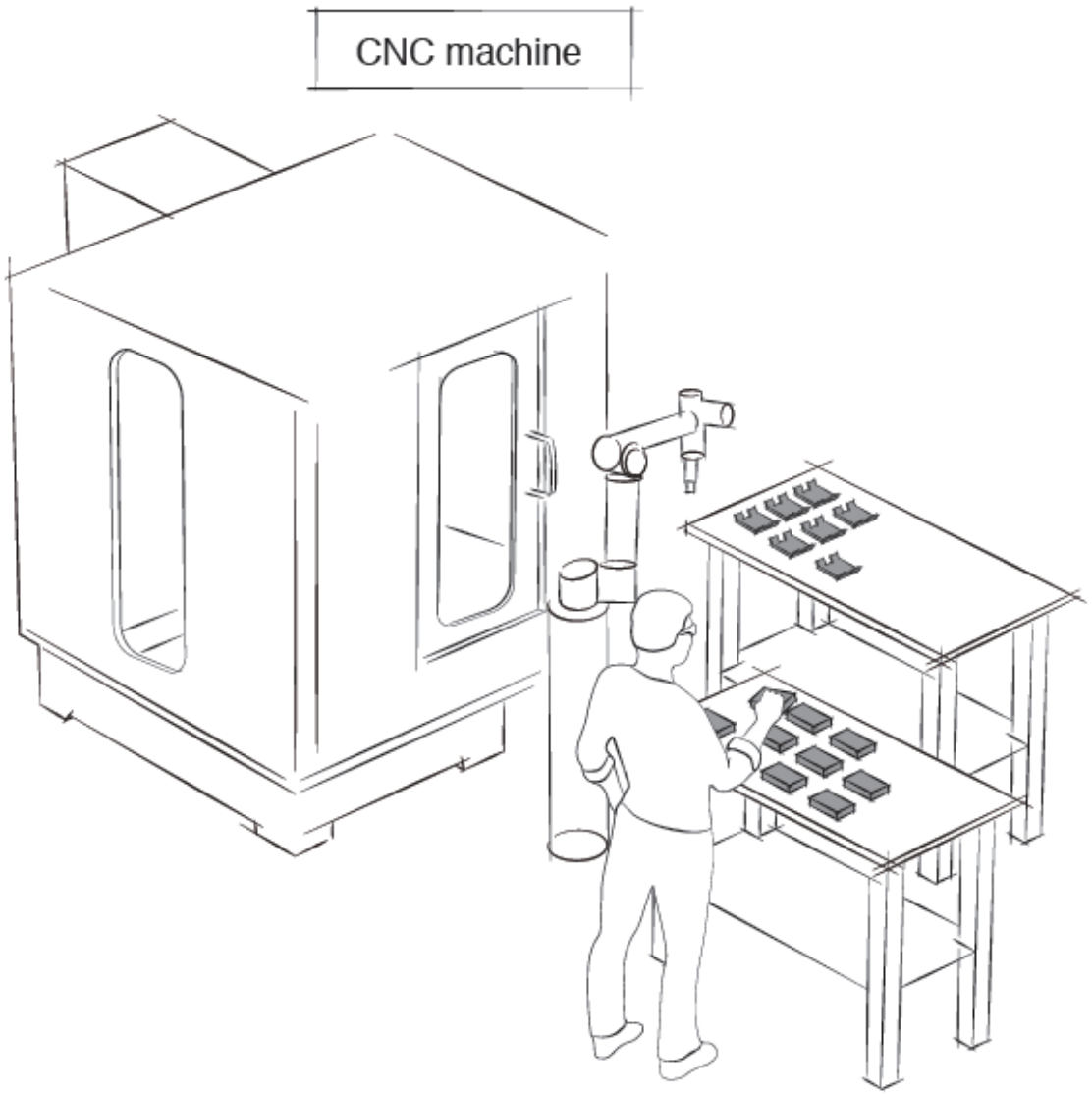
Robotic Layout





Manual/Robotic Comparison - Overview

Tasks map comparison	
1. Identify Customer	Can we provide what our customer originally needed, or should we add an intermediary step?
2. Define Output	Are we raising or lowering the amount of value provided to the customer's cell?
3. Define Input	Do we need to change how the parts are presented?
4. Define Process	Are we improving the process? Reducing the number of nonvalue-added operations?
5. Document Information Flow	Do we need to change the input or output information? Do we generate new information that can be useful elsewhere?
6. Measure KPI	How does the robot cell affect the KPIs themselves? Do the KPIs need to be tracked differently?
Layouts comparison	
	Will you need to add, modify, move equipment in this cell, or neighboring cells?

Manual/Robotic Comparison

	Same	Different
1. Identify Customer	The customer of the robotic is the same as the customer of the manual cell.	
2. Define Output	The parts provided to the robot cell and to the manual cell are the same. All the parts will still be produced.	The robot will not be able to stack the parts on top of each other. The tray will need to be slightly larger in order to receive the 60 parts.

Manual/Robotic Comparison

	Same	Different
3. Define Input	The parts provided at the cell input will be the same. The robotic cell will be able to pick the complete range of input parts	The part presentation will need to be different. Parts will need to be separated and spaced out on a single plane since the robot will not be able to work with stacked parts. The operator will need to come 3x more often to feed parts to the cell.
4. Define Process		The steps taken by the robot will be different than the ones taken by the manual operator. A manual operator will not be needed anymore at the cell. Total cycle time should be shorter and more repeatable with the robotic cell (88 sec. vs. 93 sec.).

Manual/Robotic Comparison

	Same	Different
5. Document Information Flow		Digital communication will need to be set up between the robot and CNC controllers. Operator will need to input the dimensions of the blank in robot controller when there is a changeover. Operator from input station will need to check on the infeed more frequently. Robot has no way to tell him if parts are missing.
6. Measure KPI	FPY should stay constant	Production capacity should go from 210 to 300 parts per day. Counter in robot program will be used to measure.
7.Layout		The CNC machine will stay at the same place. The table currently used by the operator will need to be moved, giving room to the robot. Marks on the ground will be added to identify robot workspace.

Finalizing Robotic Cell Design: Overview

Calculate ROI	Payback period: ((Cost of project)/(Monthly gains from project)) + Time from start of project to production ROI: Monthly gains X (12 months - project time) / project cost Calculate 12 months in, and 24 months in
De-risk the project	Identify and analyze unknowns, plan for validation or plan B
Part list	What will you need for this project?
Freeze your MVRC	You've got a minimum viable cell design ready to move to the integration phase!

Finalizing Robotic Cell Design: ROI

Gross margin per item produced:	$10
Working days per month:	20
Robotic cell cost:	$115,000

	Manual	Robotic	Change
Daily production, after FPY	204	291	+87
Daily gross margin produced	$2,040	$2,910	+$870
Monthly gross margin produced	$40,800	$59,200	+$17,400

Finalizing Cell Design: Payback Period

$$\frac{\text{Cost of robot cell}}{\text{Monthly gains}} + \text{Months spent on design, integration phases}$$

$$\frac{\$115{,}000}{\$17{,}400} + \textbf{3} \text{ months spent on design, integration phases}$$

$$6.6 + 3 = \textbf{9.6 months payback period}$$

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Finalizing Cell Design: ROI over 12 months

$$\frac{\left(\text{Target period} - \text{Months spent on design, integration phases}\right) \times \text{Gains per month}}{\text{Cost of robot cell}}$$

$$\frac{\left(12 - 3 = 9\right) \times \$17{,}400}{\$115{,}000}$$

$$\frac{\$156{,}600}{\$115{,}000} = \textbf{136\% ROI after 1 year}$$

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Finalizing Cell Design: ROI over 24 months

$$\frac{\left(\text{Target period} - \text{Months spent on design, integration phases}\right) \times \text{Gains per month}}{\text{Cost of robot cell}}$$

$$\frac{\left(24 - 3 = 21\right) \times \$17{,}400}{\$115{,}000}$$

$$\frac{\$365{,}400}{\$115{,}000} = \textbf{318\% ROI after 2 years}$$

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Finalizing Robotic Cell Design - De-Risking

Question	Hypo-thesis	Confidence level	Impact on cell	Validation plan	Time and $ to validate it?
Will the camera be able to find the input parts reliably?	Yes	Low	Critical	Test with robot, camera and parts	Supplier can validate in 1 day of work, already have the equipment
Will we be able to communicate between the robot and CNC controllers?	Yes	Medium	Critical	Connect controllers, make simple I/O exchange.	Robot vendor can take 2 days, collaborating with CNC vendor to test communication. Will need to stop production by moment.
Will it be simple enough for the operator to enter the part dimensions when changeover occurs?	Yes	High	Critical	Demo from partner	2 hours demo

Finalizing Robotic Cell Design - De-Risking

Question	Hypothesis	Confidence level	Impact on cell	Validation plan	Time and $ to validate it?
Will the pneumatic vise work well?	Yes	Medium	Critical	Test from vise vendor	1/2 day trial on CNC, need to stop production
Will we reach the target cycle time?	Yes	High	Critical	Proof of concept at partner	2 days work from robot vendor. Will be able to reuse for production cell.

Finalizing Robotic Cell Design - Parts List

- UR10 Collaborative robot
- Stand for UR10
- Robotiq 2-Finger 85 Adaptive Gripper x2
- Dual Gripper coupling for Universal Robots
- Robotiq Wrist Camera
- Pneumatic/Hydraulic Vise for CNC Machine
- Robot Ready Interface for CNC Machine

Freeze Robotic Cell Design!

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