



中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

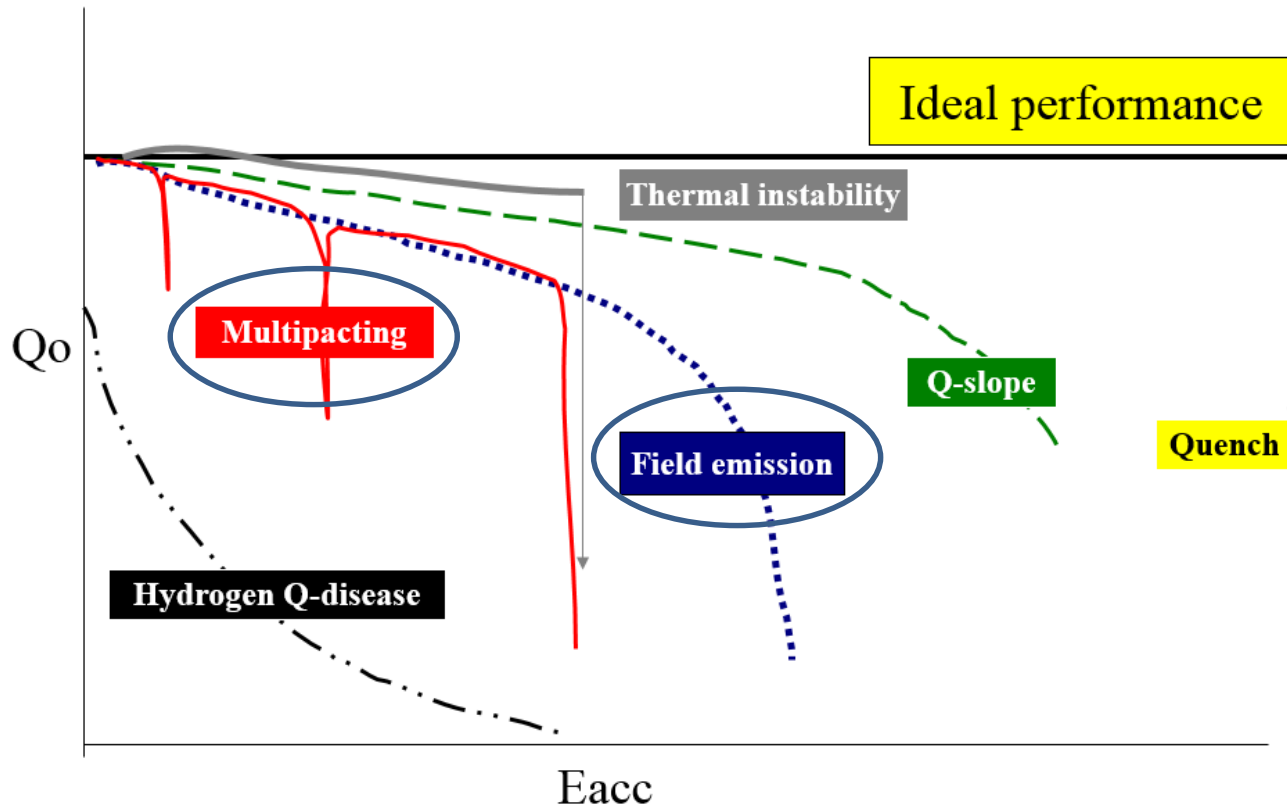
Robotization of Clean Room Processing and Assembly at IMP

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On behalf of ADS SRF Team, Institute of Modern Physics, CAS



Possible cavity improvement by cleanroom-processing



Lecture note in Tokyo University on May 2011 (Courtesy of Kenji Saito)



Outline

- 1. Robot assisting activities in IMP cleanroom
- 2. Full automated HPR system and AGV cleanroom application
- 3. Cleanroom robotization plan for CiADS and HIAF



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Project requirements

Project	Cavity	Quantity of cavities	Weight of cavities (kg)	Port numbers
CiADS	HWR010	9	~50	8
	HWR019	24	~180	8
	DSR042	40	~180	8
	Ellip062	40	~140	4
	Ellip082	24	~140	4
HIAF	QWR007	30	~160	7
	HWR015	66	~120	8

Except HWR010 cavities, all other types of cavities are over the maximum permissible weight to be carried by one adult.

In 1967, the 'International Labor Conference' gave a suggestion of maximum permissible weight to be carried by one worker. The weight is 50kg.

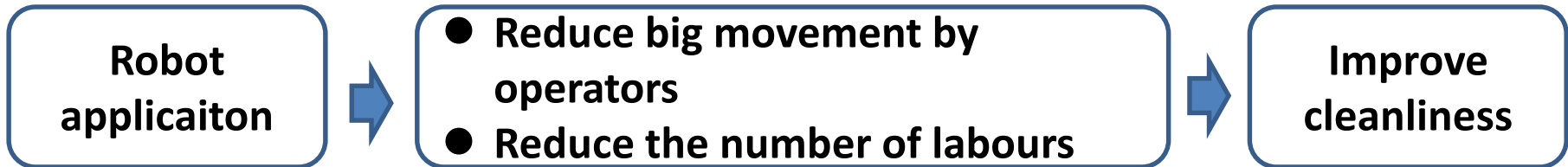


Robot application VS. cleanliness

Human activities are the most serious source of particle emission in a cleanroom. Meanwhile, different movement type means different emission rate, as shown in Table.

Results are summarized in Table. Emission rate (Average (and standard deviation) at particle size $\geq 0.5 \mu\text{m}$).

Test	Arm	Knee	Walk	Stay
A+c/1WD	638 (477)	2922 (1074)	709 (320)	456 (312)
A+c/ 75WD	1200 (248)	3122 (1082)	828 (516)	488 (136)
A+p/ 1WDS	1402 (306)	2326 (519)	849 (236)	478 (142)
B+p/ 60WDS	330 (115)	446 (235)	174 (72)	184 (88)
C+c/ 60WDS	1106 (537)	5036 (2198)	510 (217)	595 (302)
D+p/SU	120 (46)	168 (58)	72 (23)	47 (15)
E+p/SU	504 (264)	386 (252)	127 (76)	156 (87)



The cleanliness improvement is the biggest advantage of the robot application.

(Francesco Romano, et al. Airborne particle and microbiological human emission rate investigation for cleanroom clothing combinations, building and environment, 2020.)



Robot in cleanroom

In 2017, the first robot had been introduced in IMP cleanroom.

Parameters of Robot chosen in IMP

Brand of robot	KUKA
Cleanliness	ISO4 & ISO5
Rated payload	210 kg
Pose repeatability	$\pm 0.06\text{mm}$
Number of axes	6

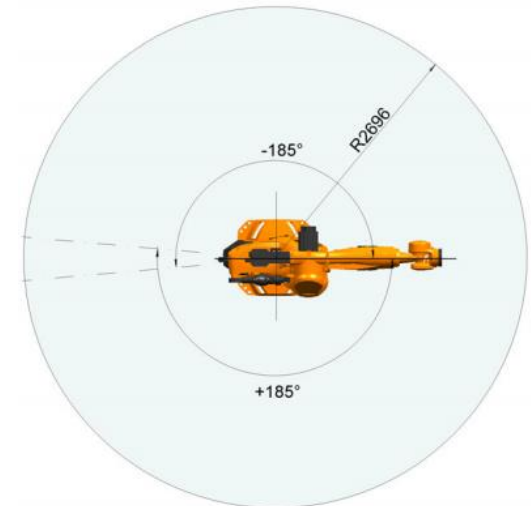
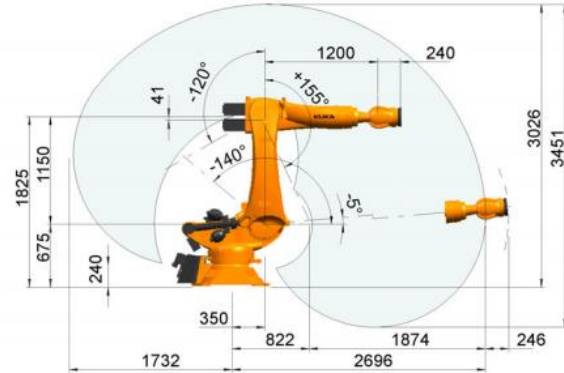
Characteristics

High load

High
precision

Multi-degree
of freedom

Labour saving

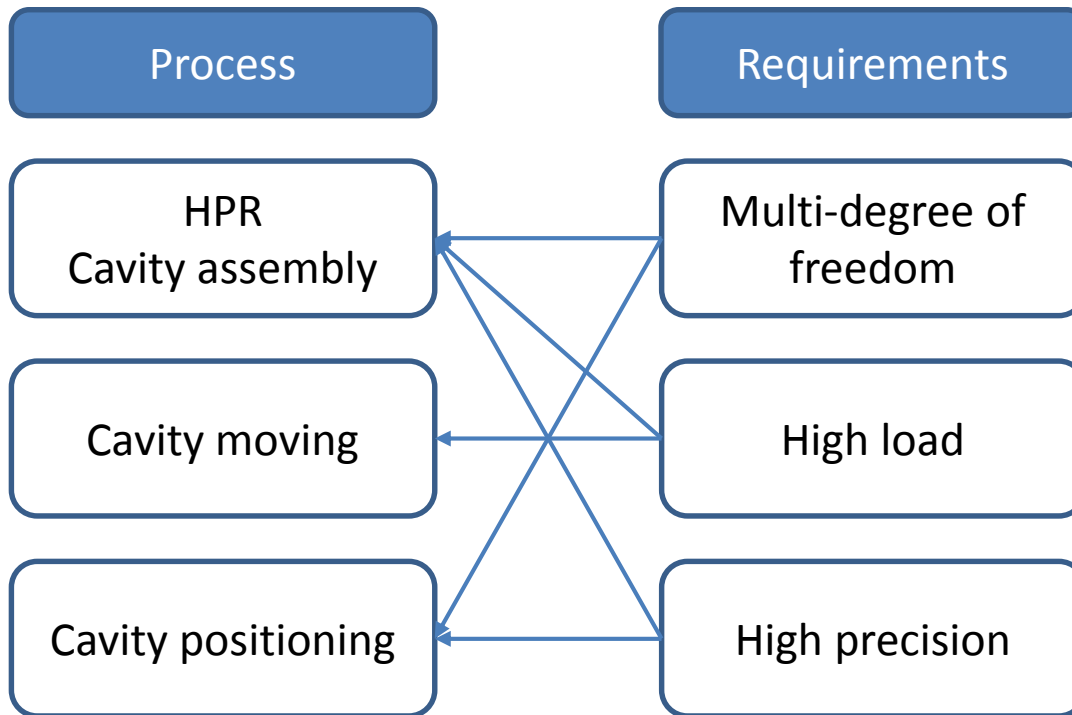


The shape and size of the working envelope for robot (mm)



Robot in cleanroom

There are three requirements on post process for SRF cavities which could be satisfied by robot.





Robot assisting – HWR010 cavities

Parameter of HWR010 cavities

β	0.1
Weight	~50kg
Ports number	8

Robot assisting on cavity moving and assembly

◆ Labour saving (for one cavity)

Process	Operators (normal)	Operators (with robot)	Man-hours saving
Cavity moving	2	1	8
Cavity assembly	2	2	0
The whole cleanroom process (include strings assembly)			16





Robot assisting – HWR015 cavities

Parameter of HWR015 cavities

β	0.15
Weight	~120kg
Ports number	8

◆ Labour saving (for one cavity)

Process	Operators (normal)	Operators (with robot)	Man-hours saving
HPR	3	1	16
Cavity moving	3 (with special fixture)	1	16
Cavity assembly	2	2	0
The whole cleanroom process (include strings assembly)			64

Robot assisting on HPR, cavity moving and assembly



Robot assisting on HPR process



Robot assisting on cavity assembly

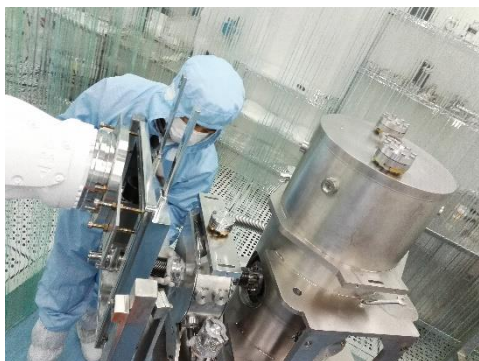


Robot assisting - strings assembly

End flange



HPR process



Positioning and assembly

Solenoid & BPM



HPR process



Positioning and assembly

Cavity

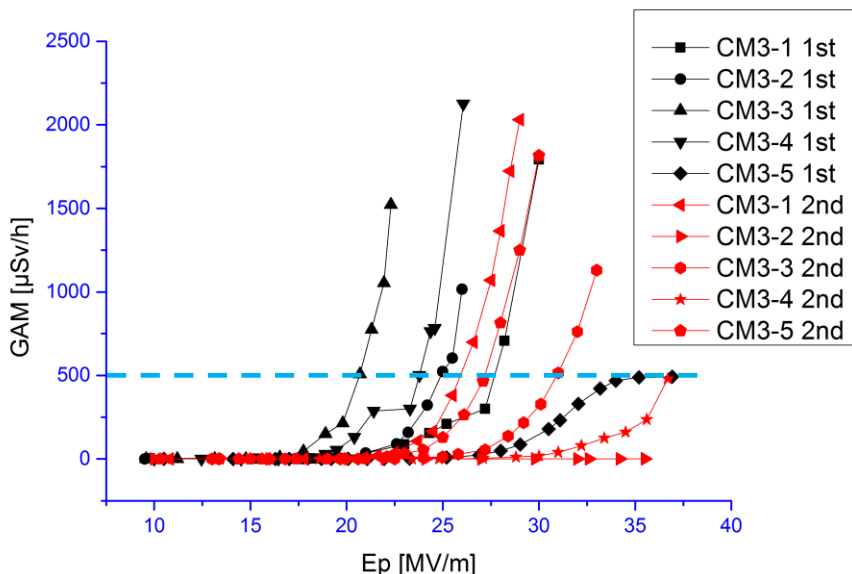


Cavity moving and positioning



Robot assisting in cleanroom

Cavity online RF result compared between CM3 1st and CM3 2nd
 All cavities in CM3 1st and CM3 2nd have similar FE onset in vertical test.



Cavity number	FE Onset (1st)	GAM<500 µSv/h(1st)	FE Onset (2nd)	GAM<500 µSv/h(2nd)
CM3-1	23MV/m	28MV/m	21MV/m	26MV/m
CM3-2	19MV/m	25MV/m		36MV/m
CM3-3	16MV/m	20MV/m	25MV/m	31MV/m
CM3-4	18MV/m	24MV/m	29MV/m	36MV/m
CM3-5	26MV/m	36MV/m	22MV/m	27MV/m
Average	20.4MV/m	26.6MV/m	24.2MV/m (4 cavities)	31.2MV/m

CM3 1st

- Hard alignment between flange to flange
- Assembled 5 times due to vacuum leak
- 3 operators needed on assembly and disassembly for HPR process

contaminated

CM3 2nd

- Easy alignment between flange to flange with robot assisting
- Assembled only one time
- 1 operators needed on assembly and disassembly for HPR process

improvement



Improved by robot assisting



Expected man-hours saving

Project	Cavity	Quantity of cavities	Weight of cavities	Expected man-hours saving	Total man-hours saving
CiADS	HWR010	9	~50kg	144	14480 hours would be saved by robot assisting.
	HWR019	24	~180kg	1536	
	DSR042	40	~180kg	2560	
	Ellip062	40	~140kg	2560	
	Ellip082	24	~140kg	1536	
HIAF	QWR007	30	~160kg	1920	
	HWR015	66	~120kg	4224	

Expected man-hours saving on strings component assembly (without cavities): at least 2000 hours

Robot assisting would save nearly 17000 skilled man-hours (about 102 months · person) and reduce over 1×10^{11} particles over $0.5 \mu\text{m}$ in cleanroom.

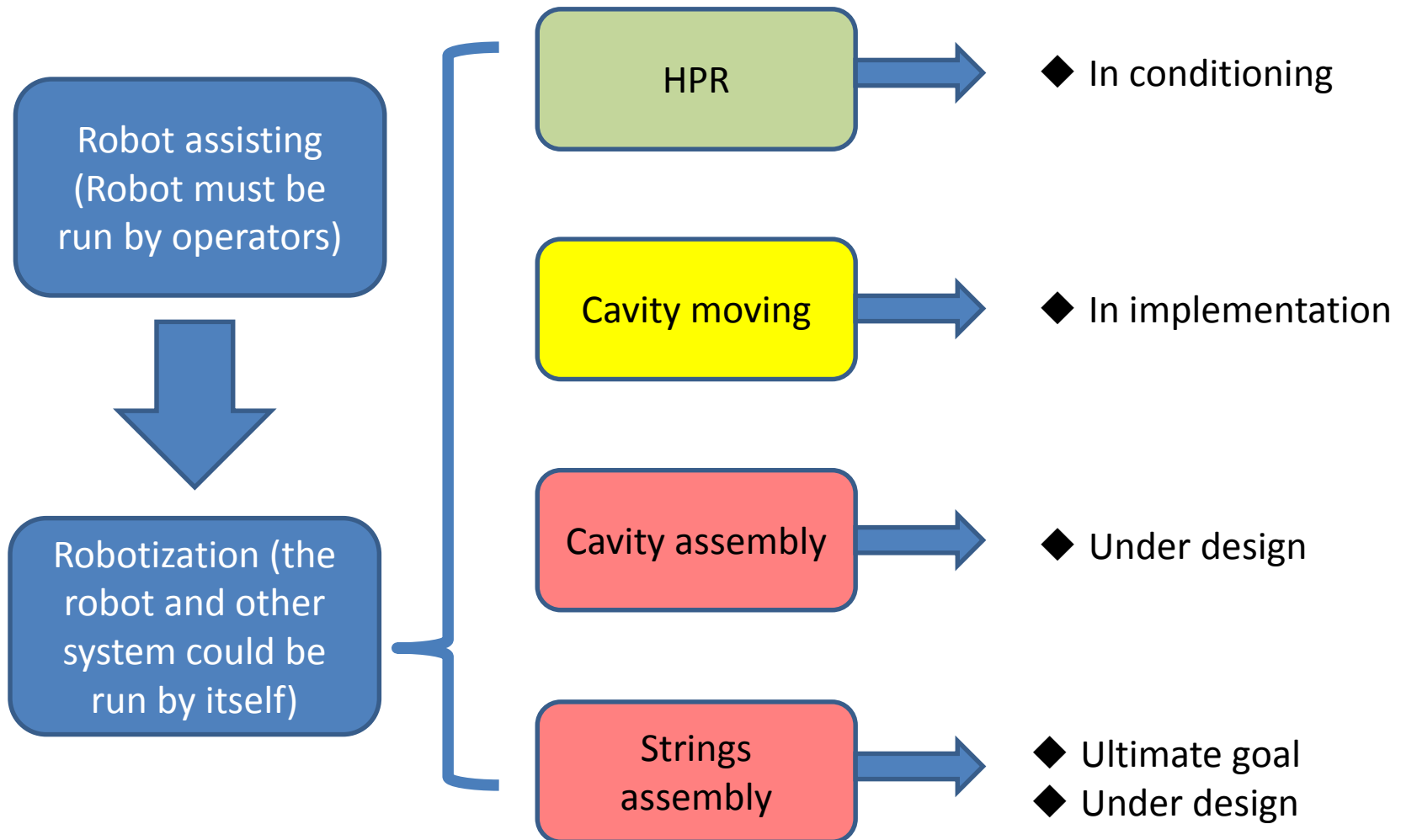


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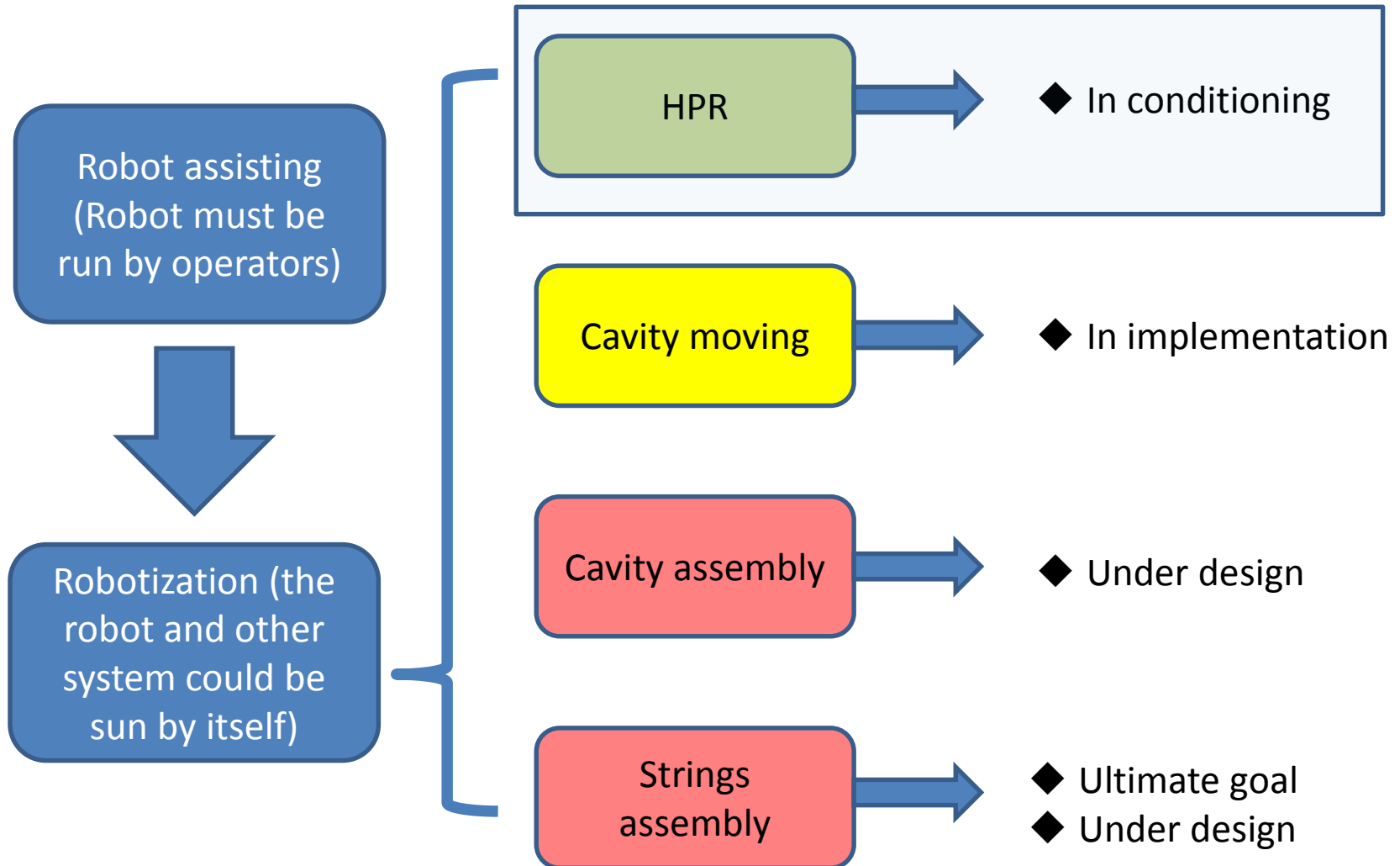


Robotization roadmap





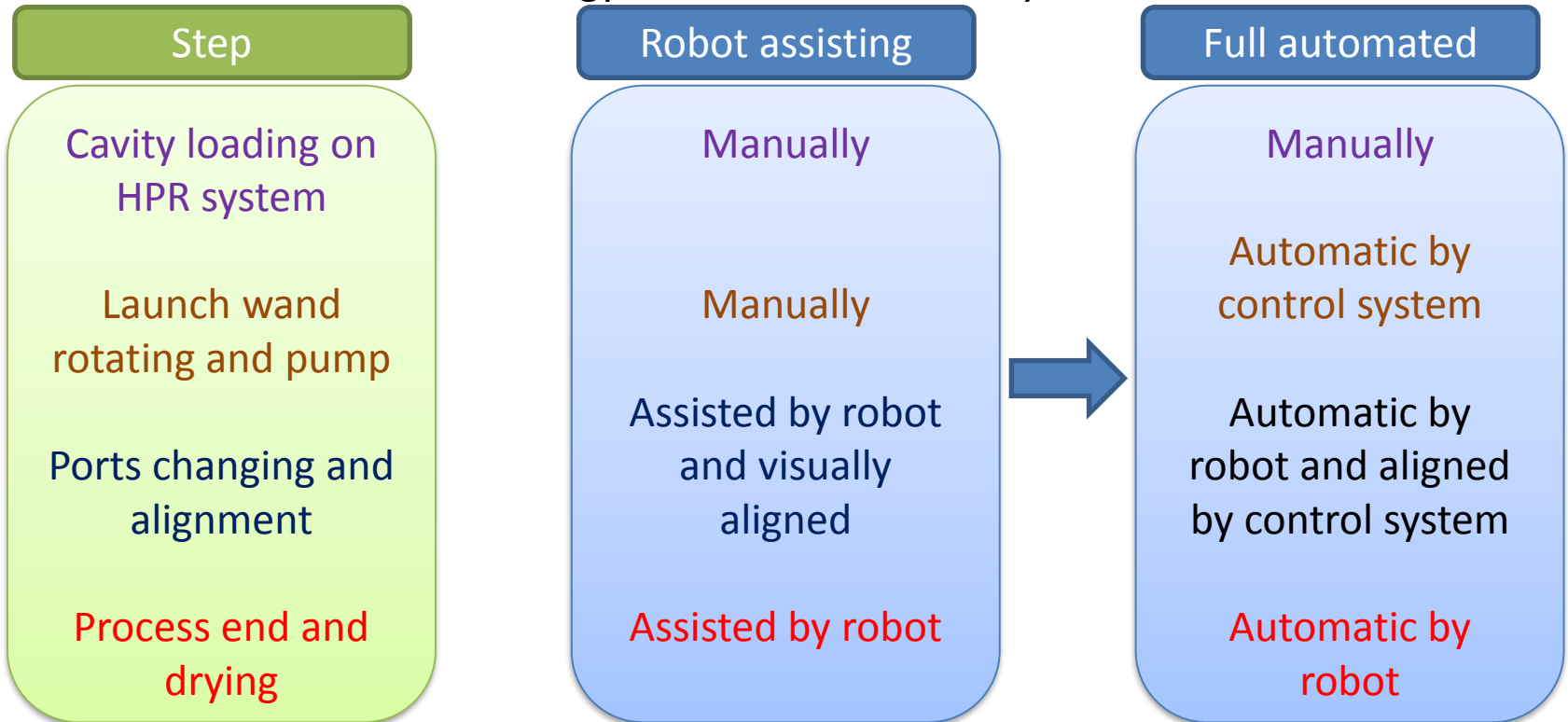
Robotization roadmap





Full automated HPR system

Based on robot technology, full automated HPR system is feasible.



Process	Operators (robot assisting)	Hours (robot assisting)	Operators (full automated)	Hours (full automated)	Hours saved
HPR	1	8	1	1	7
Cavity moving and drying	1	1	0	0	1



Full automated HPR system

2019

The first version design



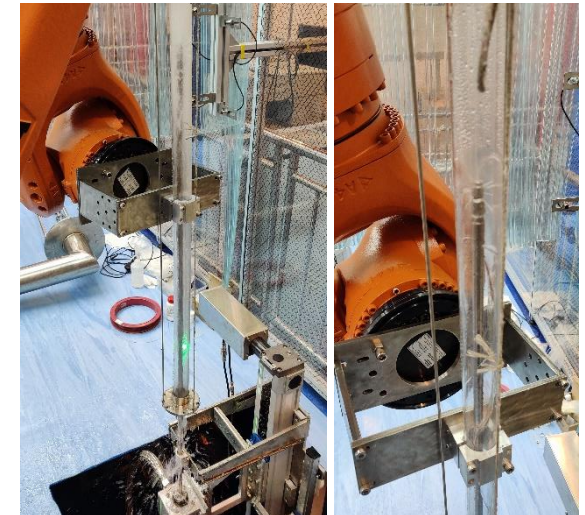
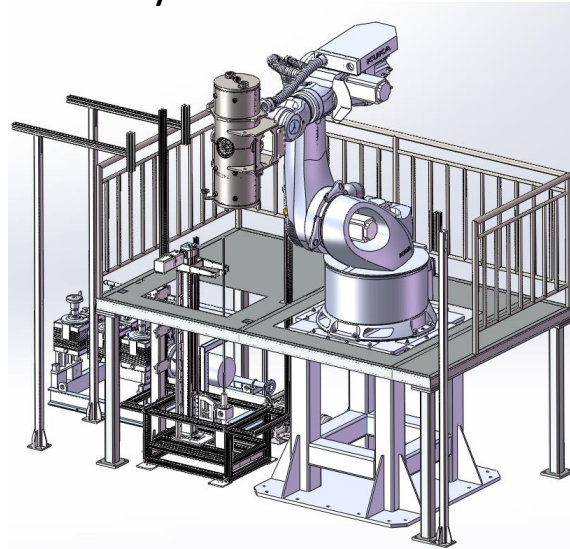
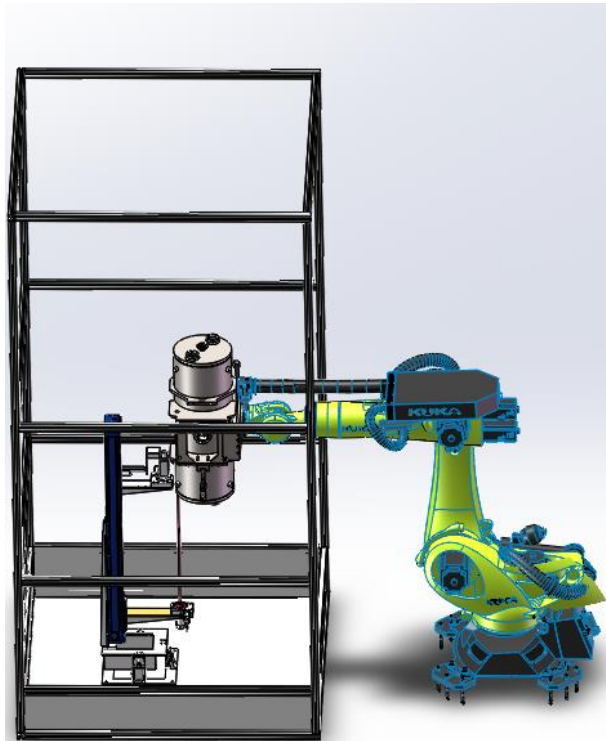
2020

The detail design &
System installation



2021

System conditioning

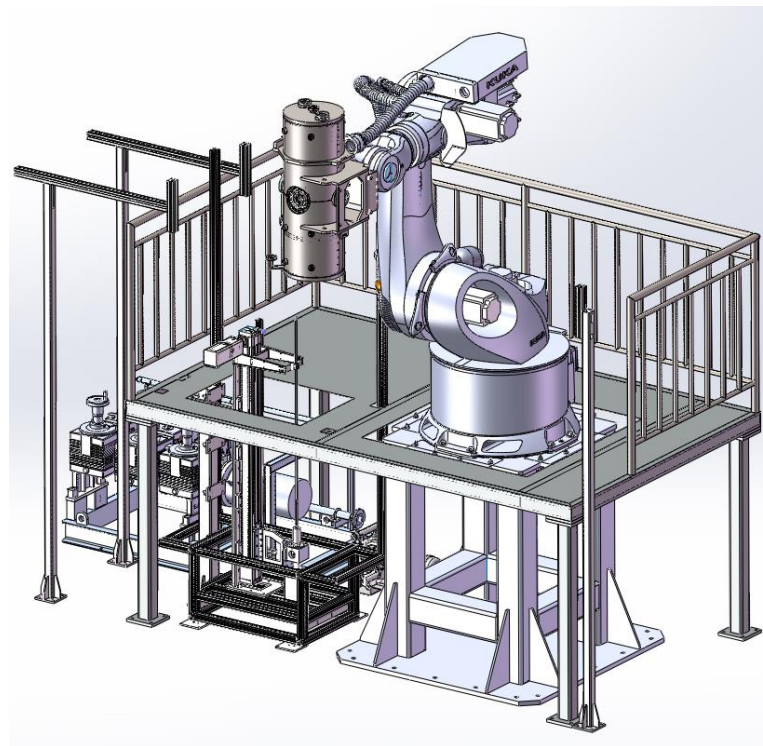




Full automated HPR system

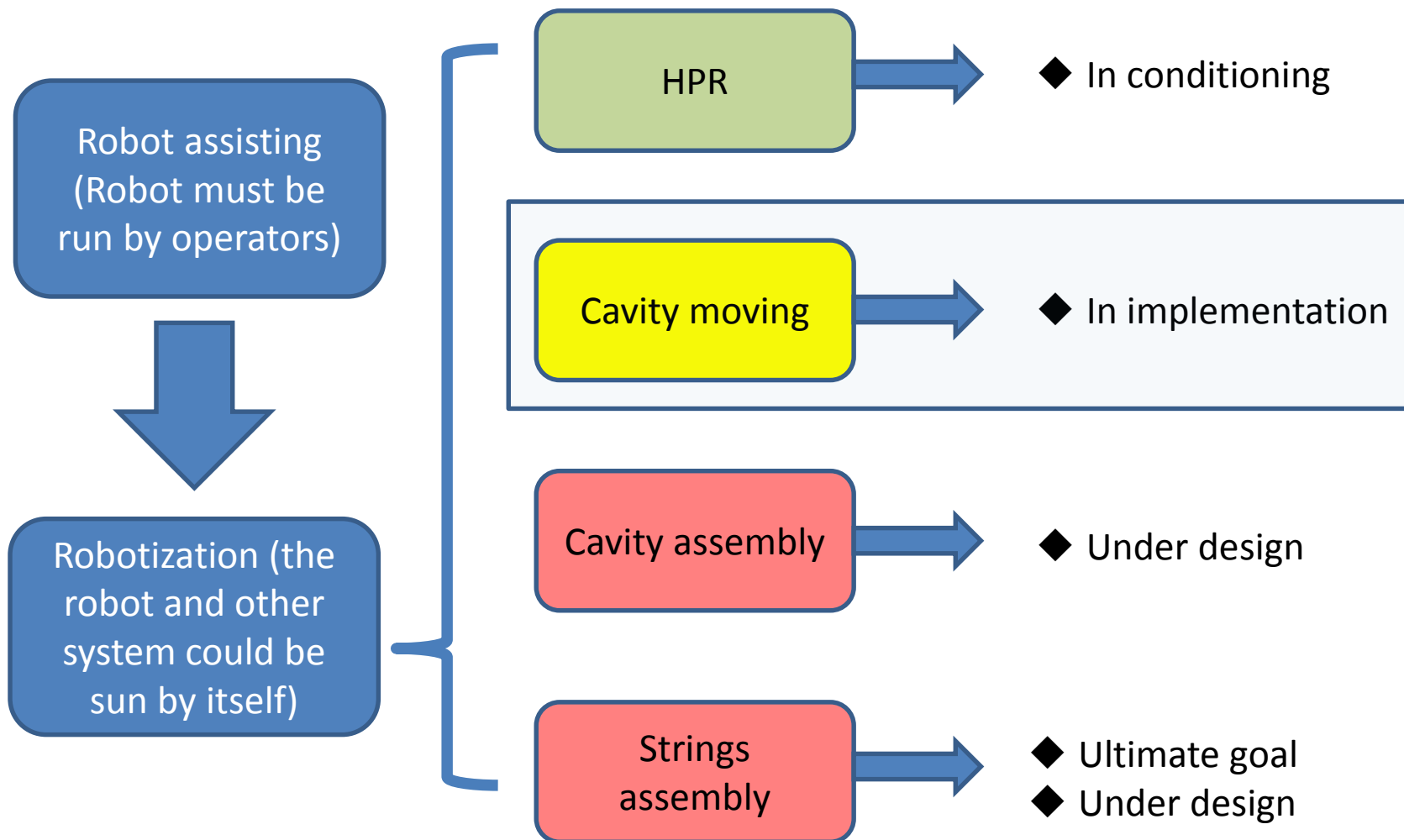
Some of main design goals for the automated HPR system:

- Rated payload: >200 kg
- Ingress protection: IP67
- Cleanliness: ISO class 5
- Stroke of wand: 1300 mm
- Length of wand: 1400 mm
- Minimum diameter of wand: 15 mm
- ***Cavity type: Suit for all cavity types (include Tesla cavities)***





Robotization roadmap





Cavity and component moving

AGV (Automatic Guided Vehicle)



AGV applied on aircraft manufacturing industry (Airbus A380)
(www.kuka.com)

AGV applied in cleanroom
(<http://www.siasun.com>)





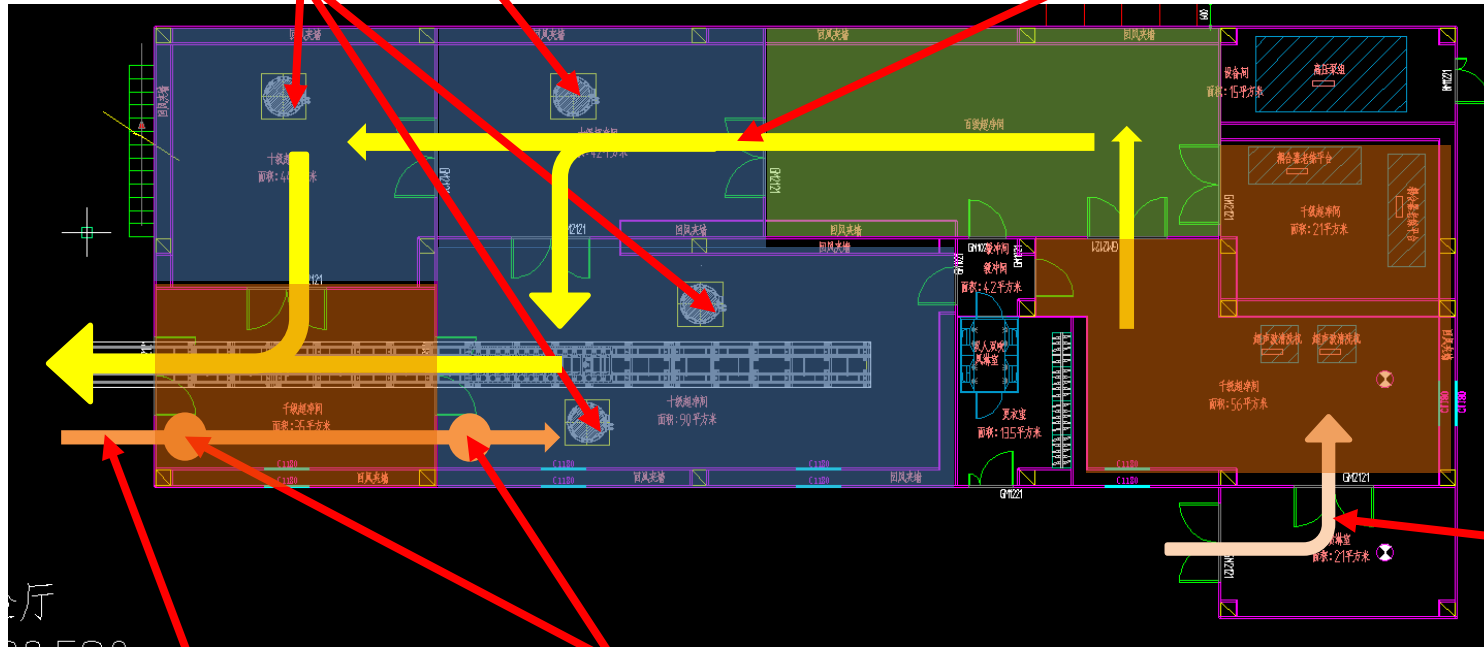
AGV route in cleanroom



Robot

Route for clean AGV

Cavities and components out of the cleanroom



ISO 4

ISO 5

ISO 6

Route for dirty AGV

Cavities and components enter into cleanroom

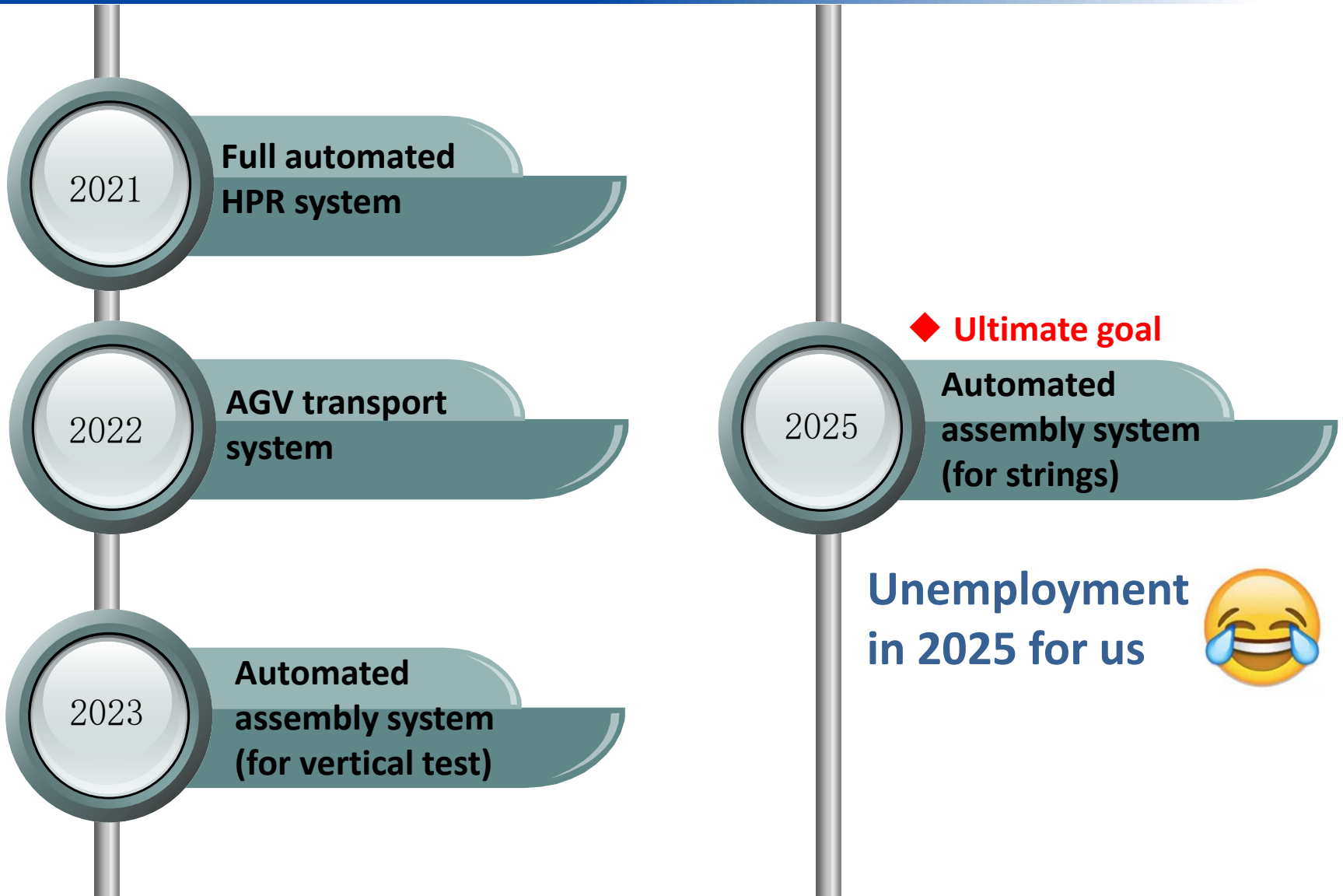
Route for clean AGV
AGV back cleanroom

AGV clean ports

The new cleanroom designed for CiADS and HIAF project



Robotization plan





Thank you!