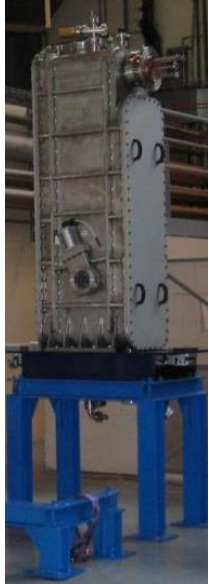


Comparison on assembly and alignment procedures & standards for the different designs CEA made in the last years

N. Bazin

TTC Meeting – December 6th 2023, Fermilab

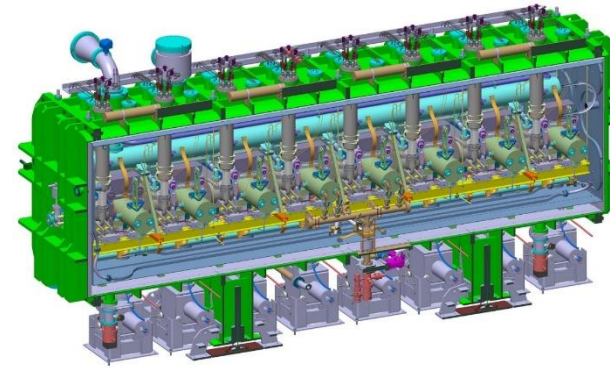
Introduction



SPIRAL2: design and assembly of 12 cryomodes



XFEL: assembly of 103 cryomodes (1 CM/wk)



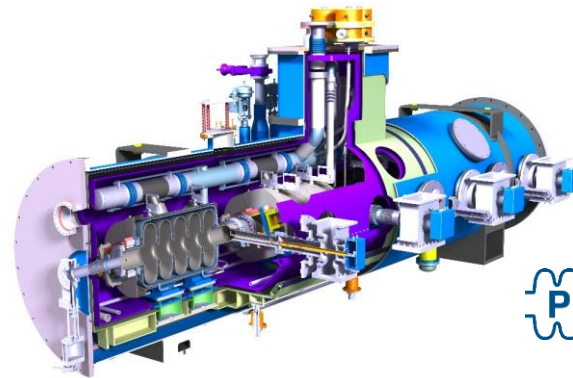
IFMIF EVEDA: 1 cryomodule



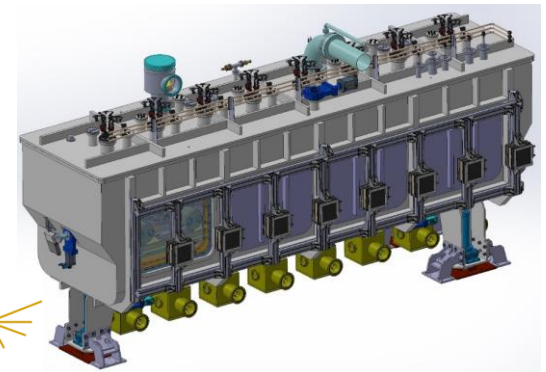
ESS: cavity and coupler design, integration of 30 cryomodes



SARAF Phase2: 4 cryomodes



PIP-II: 9+1 cryomodes

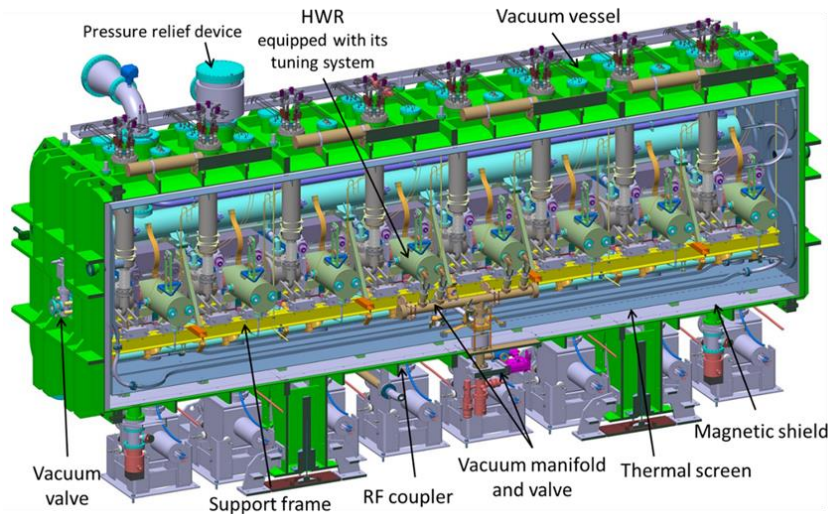


IFMIF DONES: 5 cryomodes

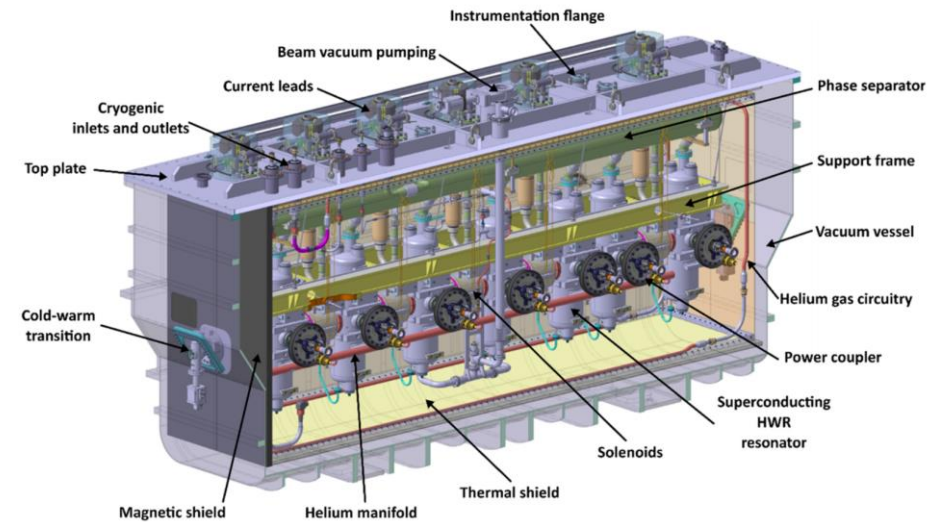
IFMIF/EVEDA & SARAF

- IFMIF/EVEDA & SARAF cryomodules: design very similar
 - Half-wave resonators (similar frequencies & beta) and 6-T superconducting solenoids to accelerate and focus the beam
 - Titanium frame to support the cavity string
 - Cold mass suspended to the top lid of the vacuum vessel using 10 vertical tie rods made of titanium alloy (TA6V).
 - Four horizontal antagonist tie rods to position the cold mass in the horizontal plane of the vacuum vessel.

IFMIF/EVEDA



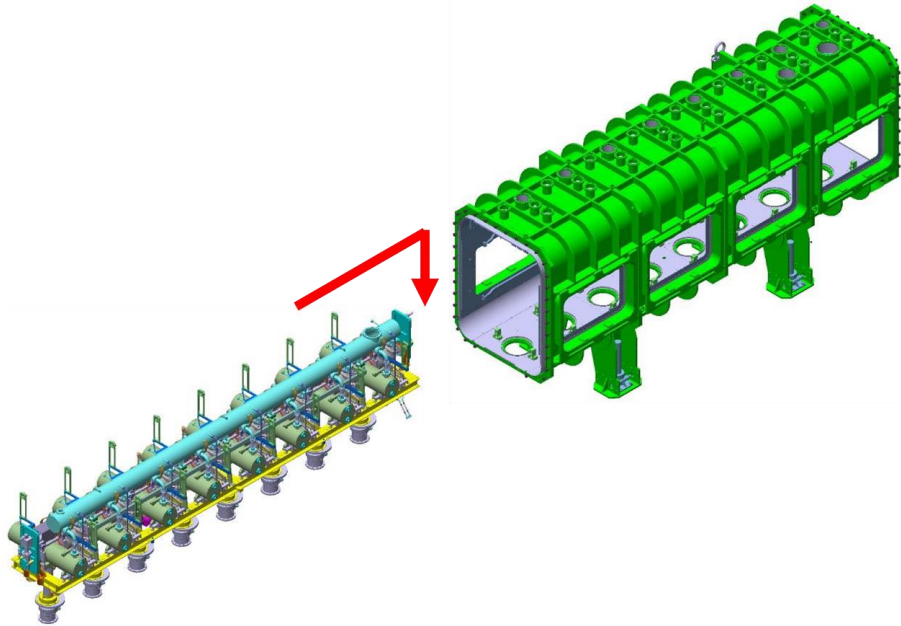
SARAF



IFMIF/EVEDA & SARAF

- **First major difference:** Insertion of the cold mass inside the vacuum vessel

IFMIF/EVEDA: side-loaded



SARAF: top-loaded



Due to the couplers, the frame must be inserted in two steps:

- Horizontal sliding of the frame which is higher than its final position. The frame should be set up so that the couplers are facing the flanges of the vacuum tank.
- Vertical motion of the frame until the coupler flanges touch the vacuum tank flanges.

IFMIF/EVEDA & SARAF

- **Second major difference:** use of the frame as a support

IFMIF/EVEDA

The frame is used as a support for the string assembly in clean room



SARAF

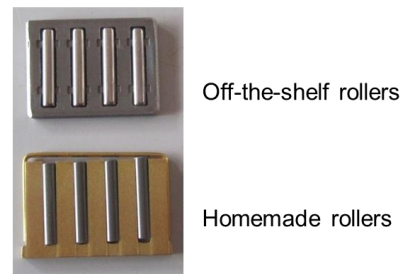
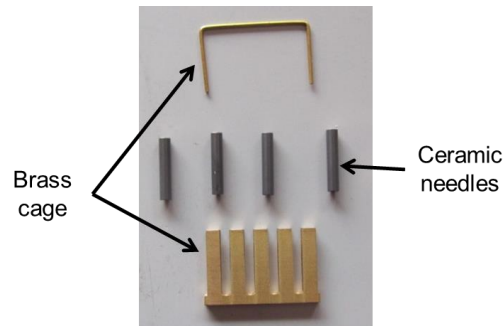
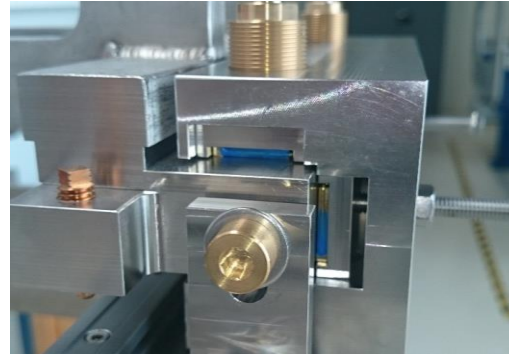
- Trolley with posts for the string assembly in clean room
- Outside clean room: the cavity string is attached to the support frame



Implementation of Lessons Learnt: Example of the C-Clamps

IFMIF/EVEDA

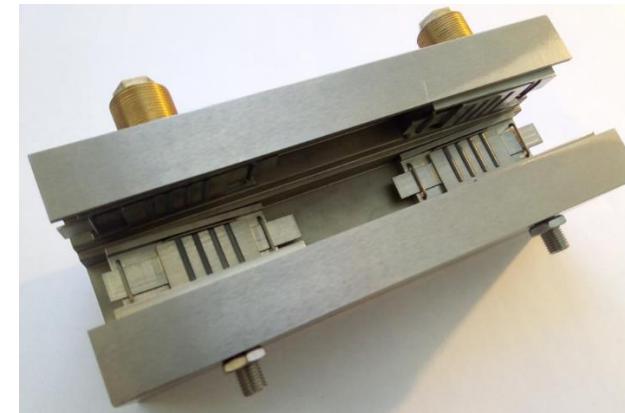
- C-Clamp design similar to the XFEL one
- Magnetic hygiene plan:
 - Needles made of ceramic
 - Some parts made of titanium instead of stainless steel



- Drawback: assembly of the needle rollers is not easy, with the risk to drop them

SARAF

- Improved magnetic hygiene plan: maximum use of non-ferromagnetic materials (titanium and brass), only the screws are made of stainless steel
- The C-clamp is fully pre-assembled on workbench before its installation on the cavity string.



- CEA design will be used on the PIP-II 650 MHz cryomodules

Clean Room Assembly Procedures

No major changes in the clean room assembly procedures but continuous improvements over the years

- Slow and venting pumping systems: improvement of the robustness
- Temporary closure of flanges
 - XFEL string assembly: flange-to-flange (metal-to-metal) contact
 - ESS string assembly: use of plain Gore-Tex gasket (lessons learnt from Jlab)
 - risk reduction of creating particles
- Archiving the data from the particles counter:
 - Before: manual transfer of the data from the particle counter to the archiver using USB drive, no direct link between the data file and the assembly traveler
 - Near future: Wifi transfer of the data from the particle counter to the archiver, automatic creation of a cleanliness file in the documentation set.
- 3D printing for quick tooling prototyping and also supports → time saving in the development of small tooling
- Cobot:
 - More details in C. Madec presentation: “*Robotization development for ESS and PIP-II projects*”

Clean Room Assembly: Mock-Ups

- Dummy components are useful
 - To test the tooling and the procedures
 - To develop new assembly process (example: cobot) without the risk of damaging or degrading a component
- For ESS, IFMIF/EVEDA and PIP-II, CEA developed dummy cavities and couplers having the same characteristics than the real devices:
 - Same interfaces with other components (possibility to install a tuning system on the cavity)
 - Same weight

Clean Room Assembly: Mock-Ups

IFMIF/EVEDA

- One dummy cavity, one dummy coupler, one dummy solenoid
- Assembly test bench to validate the clean room assembly tools and procedure
- Tool for the cavity – coupler validated using the dummies
- Used in Europe for training the operators before the assembly in Japan



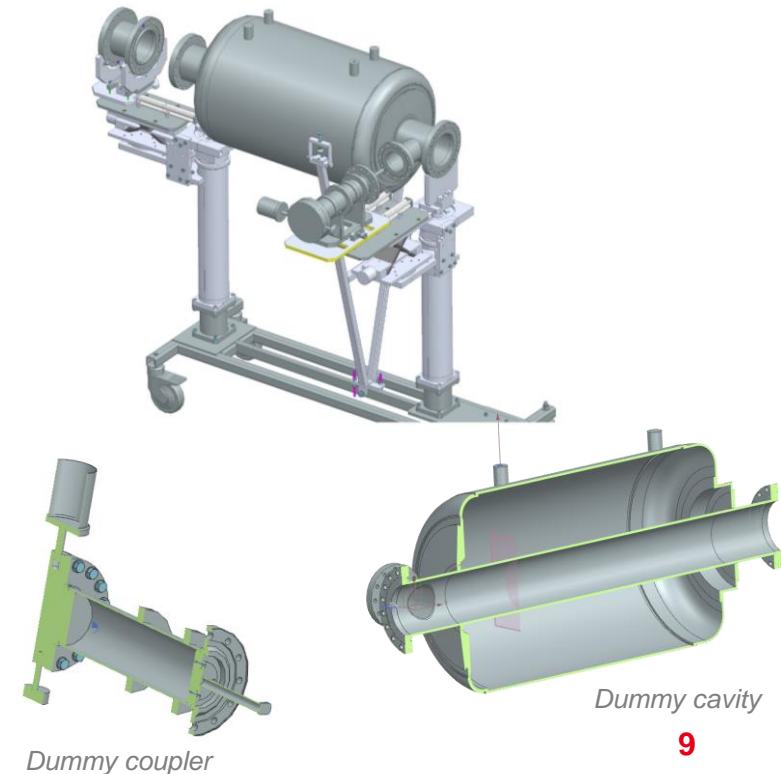
ESS prototype cryomodule

- One dummy cavity and one dummy coupler
- Three other cavities replaced by a tube
- First validation of assembly tooling and assembly procedures
- Integration until the vacuum vessel



PIP-II LB650

- One dummy cavity and one dummy coupler
- Test bench for trial assembly of a power coupler and a bellows on a cavity
- Trial assembly with and without a cobot



Cryomodule Assembly: Internal or External Ressources?

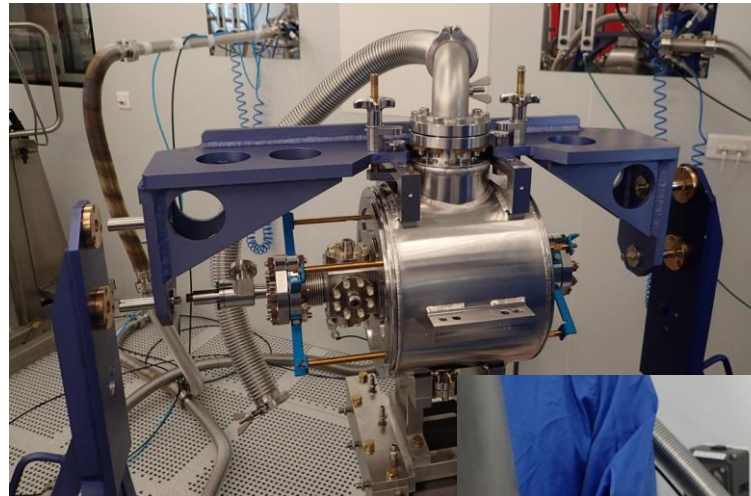
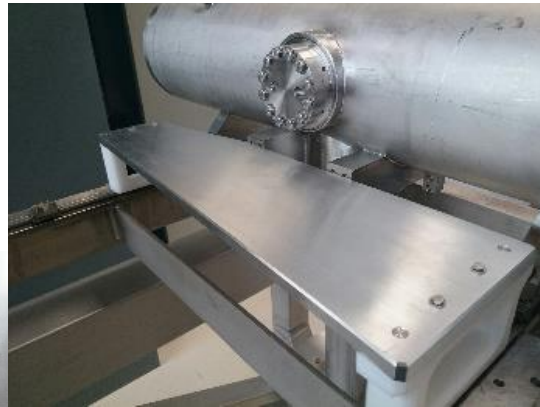
- The assembly of cryomodules at CEA can be done according to two principles:
 - Using CEA human resources:
 - Spiral 2: 12 cryomodules
 - SARAF Phase 2: 4 cryomodules (on-going at CEA)
 - As project owner, with a contractor in charge of the assembly using CEA infrastructures
 - E-XFEL: 103 cryomodules (throughput of 1 cryomodule per week)
 - ESS: 30 cryomodules (on-going at CEA)
- Lessons learnt from the assembly of the XFEL and ESS cryomodules by external companies:
 - Long learning curve for the contractor operators
 - Turnover of operators
 - Required a well-staffed CEA team to follow-up the contractor
- No ideal solution, the choice to perform the cryomodule assembly on internal or external resources depends on many parameters: the number of cryomodules, the throughput, the availability of the resources ...

Alignment Procedures

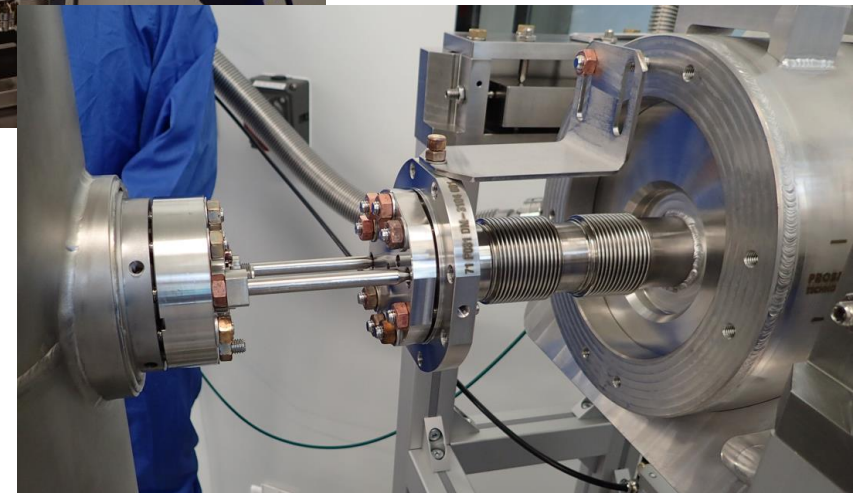
No major changes in the alignment procedures but continuous improvements over the years

- Pre-positioning of the components during the cavity string assembly using jigs
 - SARAF: accuracy = +/- 0.5 mm

IFMIF/EVEDA



SARAF



Calibrated gauges are used to with the C-template when positioning

Alignment Procedures

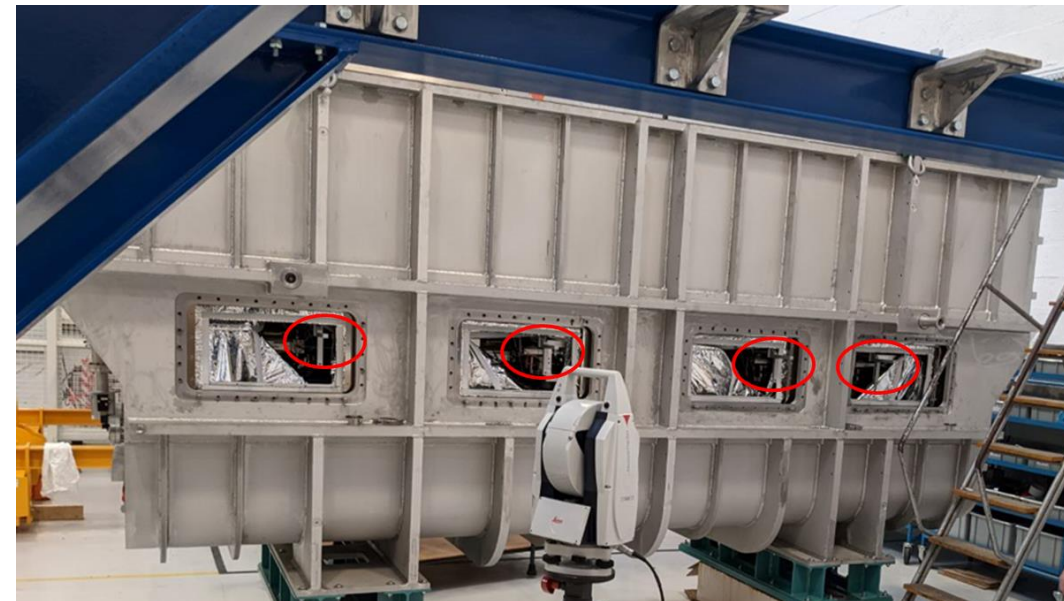
- Alignment of the cavity string outside the clean room using laser tracker
- When the cold mass is inside the vacuum vessel: control of the alignment using dedicated tooling



ESS



SARAF

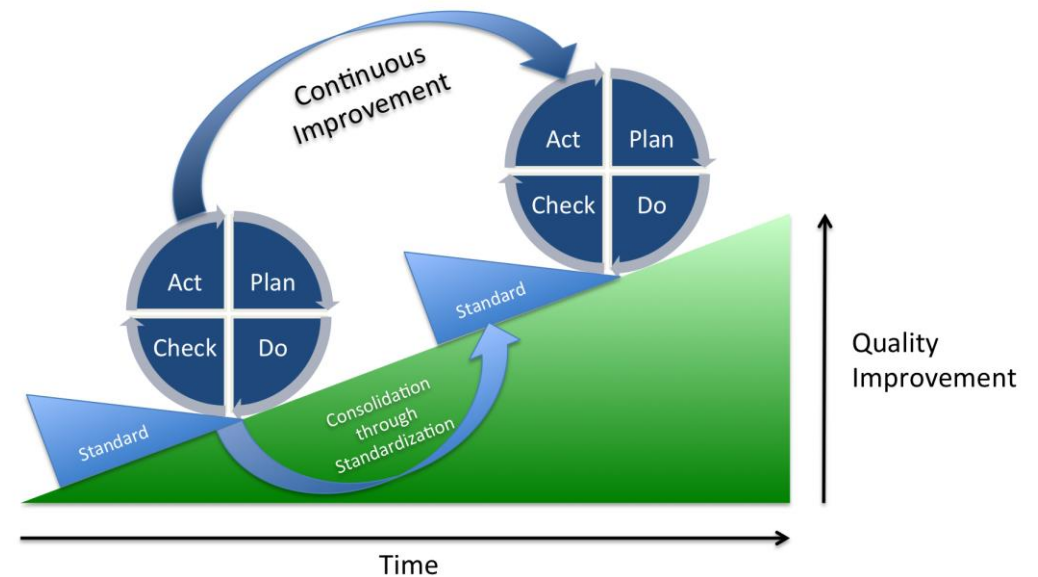


Quality Assurance & Quality Control

- QA & QC are ones of the keys to obtain particle-free cryomodules.
- Quality must be an integral part of all aspects and phases of a project, from the design to the installation on the beam line.
- When starting a new project at CEA, a Quality Management Plan is implemented. This one is based on QMP written for previous CEA projects, and benefits from the lessons learned and continuous improvement (mainly based on the PDCA principle).

PDCA principle:

- **Plan** : Identify an opportunity for change
- **Do**: Implement the change on a small scale.
- **Check**: Use data to analyze the results of the change and determine whether it made a difference.
- **Act**: If the change was successful, implement it on a wider scale and continuously assess your results. If the change did not work, begin the cycle again.





Thanks for your attention

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