2025年11月10日(月)～11日(火)
京都産業大学 神山天文台

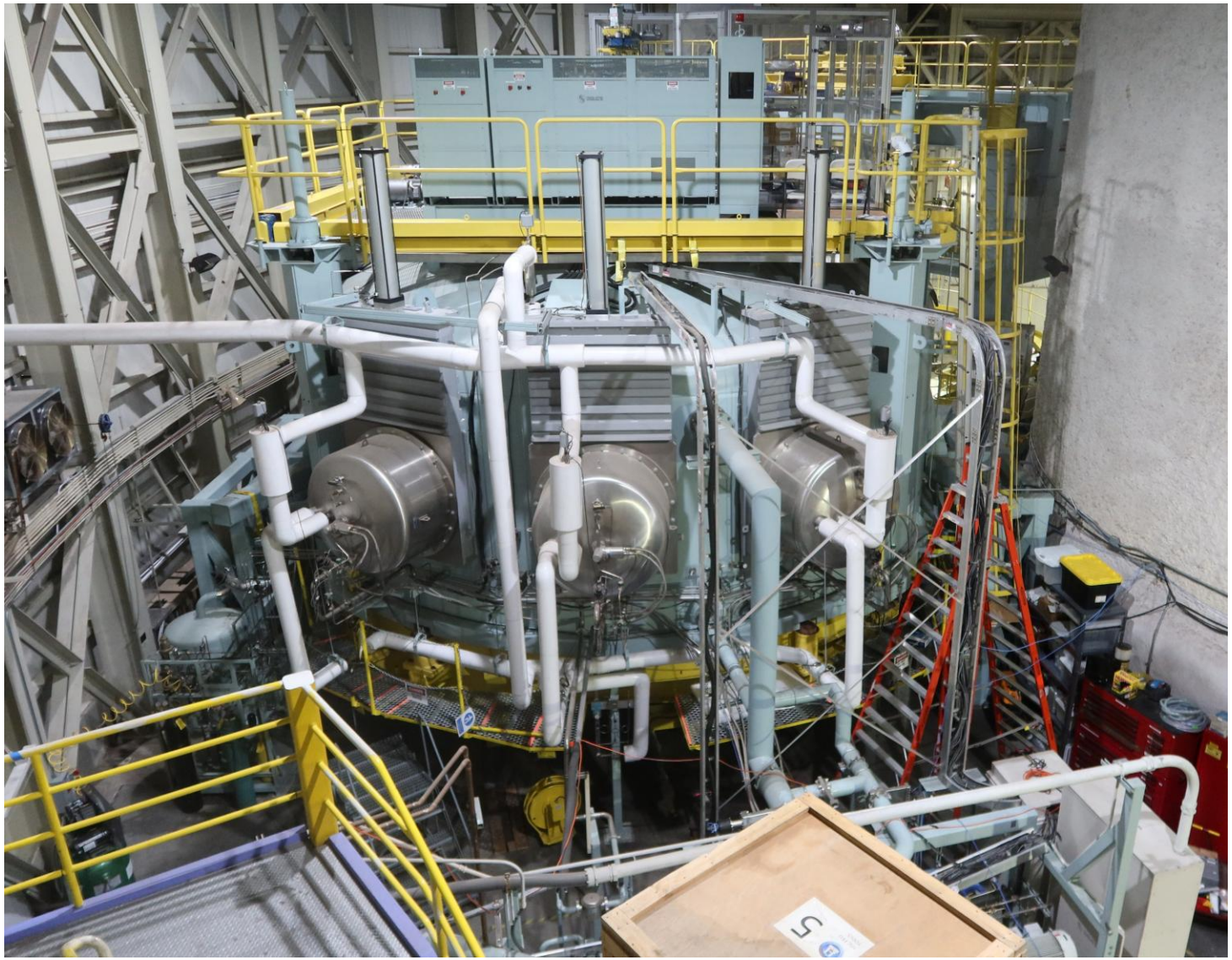
PLCを用いた すばる望遠鏡蒸着装置の改修

Large Vacuum Chamber Renovation using a Programmable Logic Controller for the Subaru Telescope

国立天文台ハワイ観測所（三鷹）

沖田博文

1. Large Vacuum Chamber 大型真空蒸着装置



Specification

- Installation: 1997
- Manufacturer: PSI (no longer available)
- Size: 9-meter in diameter
- Vacuum: 2.0E-6 Torr (3.0E-4 Pa)
- Rough Vacuum : scroll pump & 2x booster pumps
- High Vacuum: 3x cryo pumps & Meisner coil, LN2 110L/hour
- Glow discharge: Argon gas, 20 min
- N of filaments: 288
  - 3x 96 filaments each,
- Electricity: AC16V、6000A (~100kW)

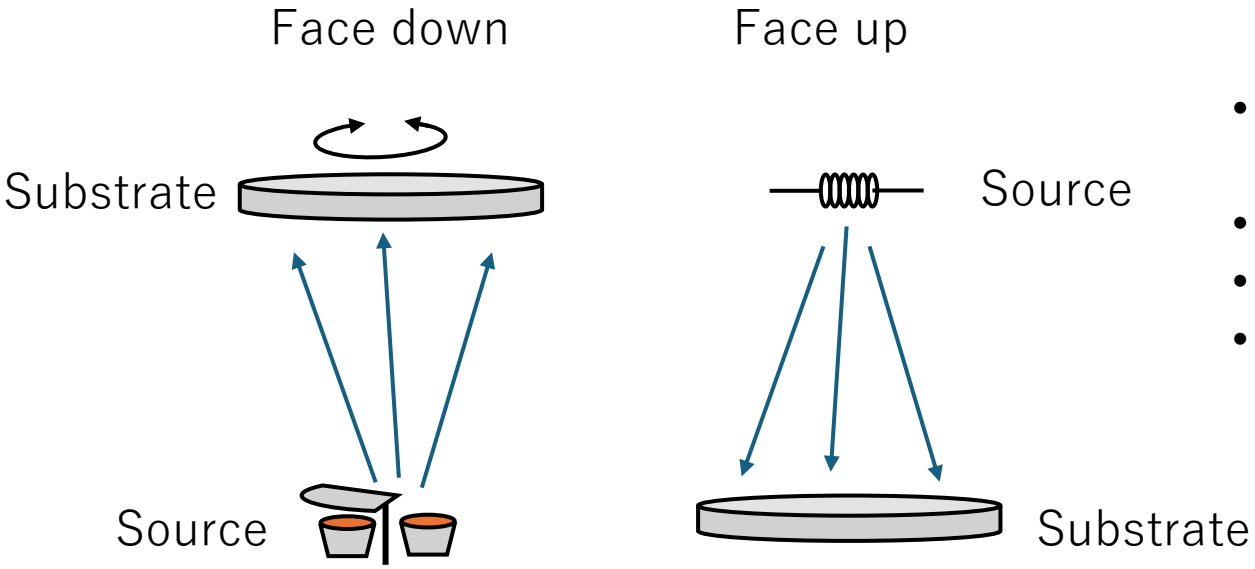
Coating for all Subaru mirrors: i.e.,
M1, IR-M2, Opt-M3, and IR-M3

2. Coating Process 成膜プロセス

Pre-wet filament (made with Tungsten)

Due to large optical components…

- Difficulty of transportation → in-house coating
- Difficulty of handling
  → Face up coating
  → Pre-wet filament
  → Very simple, thermal deposition
  → No under coat, No over coat
  → Bare Aluminum, Bare Silver



Main Controller

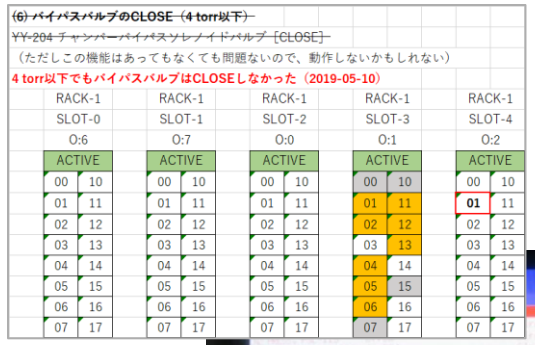
- Allen Bradley
- Programable Logic Controller (PLC)
- Graphic Operation Terminal (GOT)
- Control vacuum pumps
- Control power supply
- (logging)

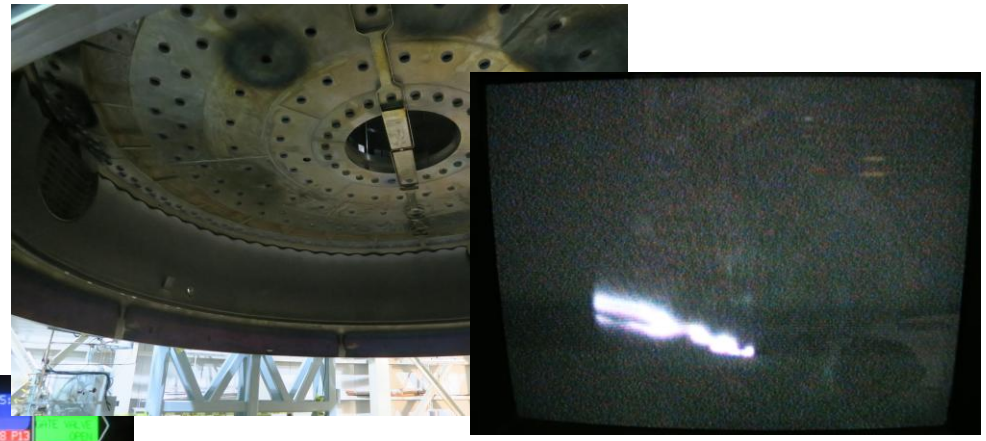
3. Many Troubles 度重なる不具合

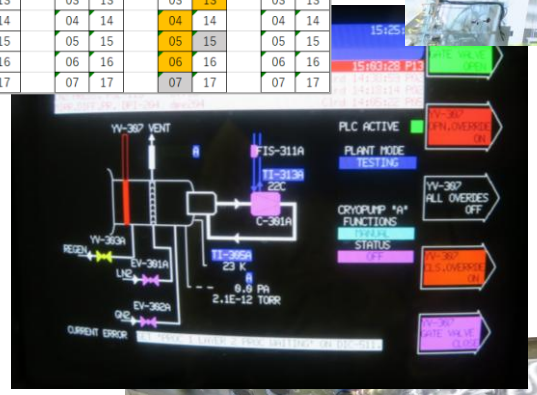
- Battery run-out
- Unexpected mode transfer
- Temperature transmitter breaking
- Short circuit
- Unexpected vacuum level
- Error beep from the vacuum controller
- Nonsensical logic in the ladder program
- No backup files
- Gate valve not operational
- Glow arm malfunction
- Fuse burn out
- Trouble in high vacuum (leakage)
- Glow arm runaway
- …

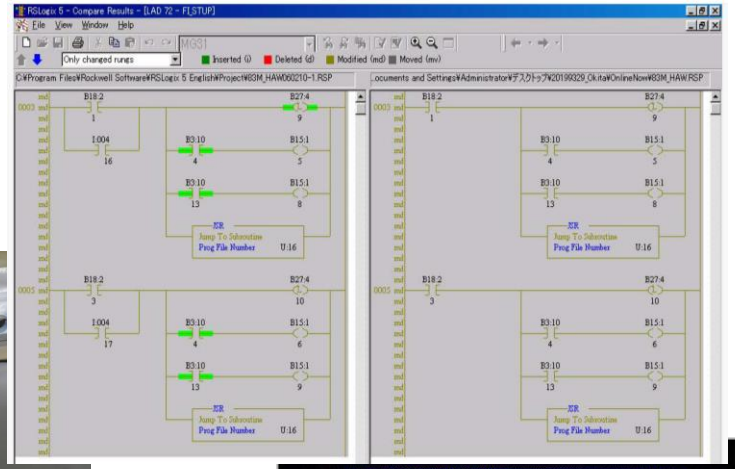
→ **Renovation was planned**

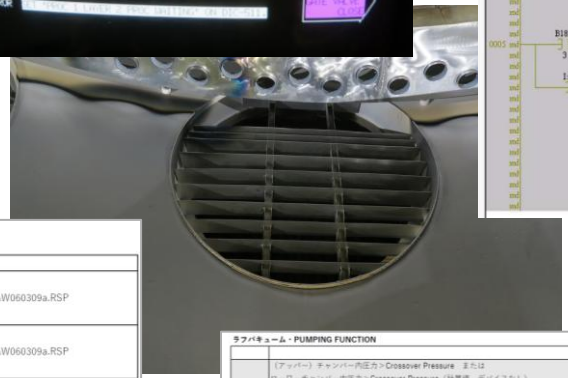
- 2021 On-site Study 調査
- 2022 Design 設計
- 2024 Manufacturing 製造
- 2025 Installation 設置

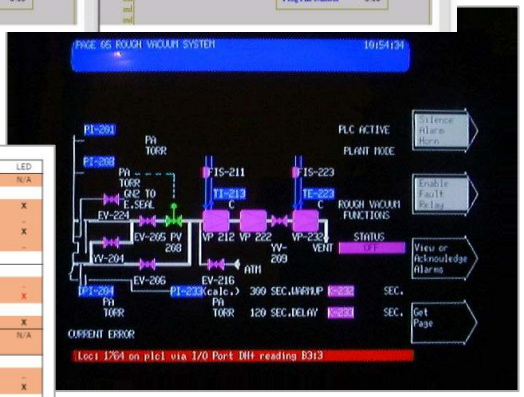




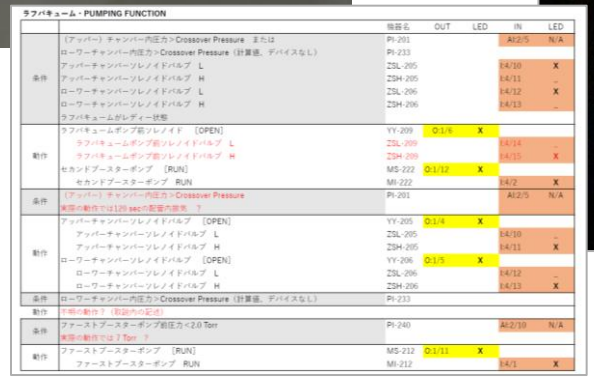








	RAM	ROM
2010年の不具合の発生前	83M_020200.RSP または 83M_HAW060309.RSP または バックアップの存在しないデータ	83M_HAW060309a.RSP
2010年の不具合が判明し、電池を外した後	83M_HAW060309a.RSP	83M_HAW060309a.RSP
トラブルシュート中に使用した仮のデータ	83M_HAW060210-1_BAK000.RSP	83M_HAW060309a.RSP
トラブルシュート完了時	83M_HAW060210-1.RSP	83M_HAW060309a.RSP
2017年の主機廃棄時	83M_HAW060210-1.RSP	83M_HAW060309a.RSP
2019年3月の状態	83M_HAW060309a.RSP	83M_HAW060309a.RSP
2019年9月13日	83M_HAW091319_new.RSP	83M_HAW060309a.RSP
2019年10月4日	83M_HAW100419.RSP	83M_HAW100419.RSP



4. Renovation 機能更新

- The main controller contains PLC, so PLC itself should be **highly reliability**, as long as the hardware is functioning properly.

- The design concept and logic of the program was NOT fully understandable (and no clear documents), which led to **poor maintainability**.
  - It was difficult to identify the route cause of the problem
  - It was also difficult to find alternative hardware/solution

- Unused programs and unused devices made reverse-engineering much more difficulty.
  - We were always afraid a “hidden reason” …
  - It is a kind of “devil’s proof” …

→ We finally decided to discard the existing ladder programs and write new ladder programs from scratch.

Old

New

5. Interlock and Logic

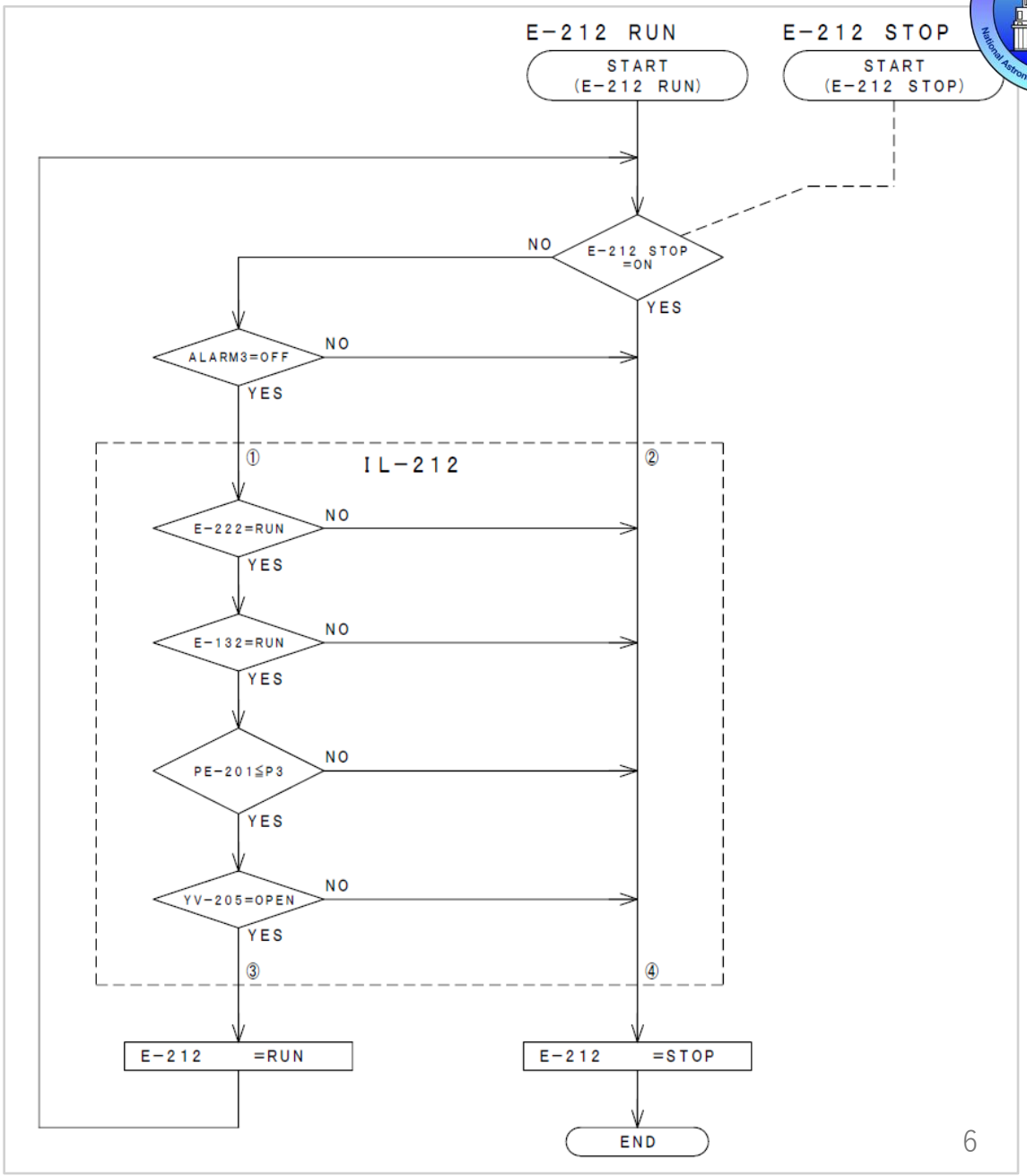
- Logic for operation
- Flow chart
- Interlock for each device
- Bottom-up development
  - Individual devices are safe
  - Entire system becomes safe

INTERLOCK

ID	機器名称	内容
IL-232	E-232 ROUGH PUMP	「E-132: COOLANT PUMP」がRUNの時のみ、RUN可 「TE-136: COOLANT TEMP」≦K8の時のみ、RUN可
IL-209	YV-209 ROUGH PUMP VALVE	「timer1: ROUGH PUMP WARM UP TIME」 =0、または≧T1の時のみ、OPEN可
IL-216	EV-216 ROUGH PUMP VENT VALVE	「E-232: ROUGH PUMP」がSTOPの時のみ、OPEN可 「E-222: SECOND BOOSTER PUMP」がSTOPの時のみ、OPEN可
IL-222	E-222 SECOND BOOSTER PUMP	「E-232: ROUGH PUMP」がT1以上RUNの時のみ、RUN可 「YV-209: ROUGH PUMP VALVE」がOPENの時のみ、RUN可 「EV-216: ROUGH PUMP VENT VALVE」がCLOSEの時のみ、RUN可
IL-212	E-212 FIRST BOOSTER PUMP	「E-222: SECOND BOOSTER PUMP」がRUNの時のみ、RUN可 「E-132: COOLANT PUMP」のRUNの時のみ、RUN可 「PE-201: CHAMBER PRESSURE」≦P3の時のみ、RUN可 「YV-205: UPPER ROUGH VALVE」がOPENの時のみ、RUN可

Interlock table for rough vacuum pump

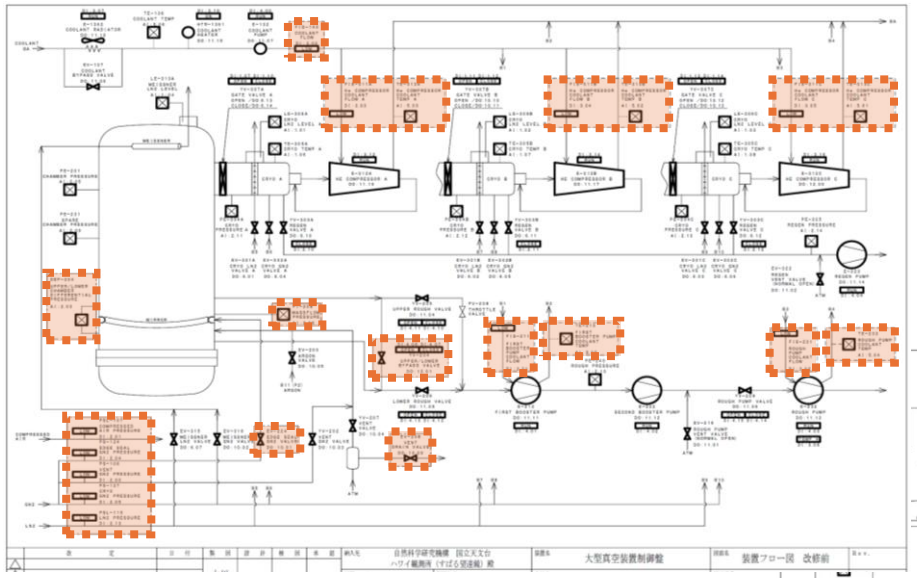
Flow chart for E-212 first booster pump



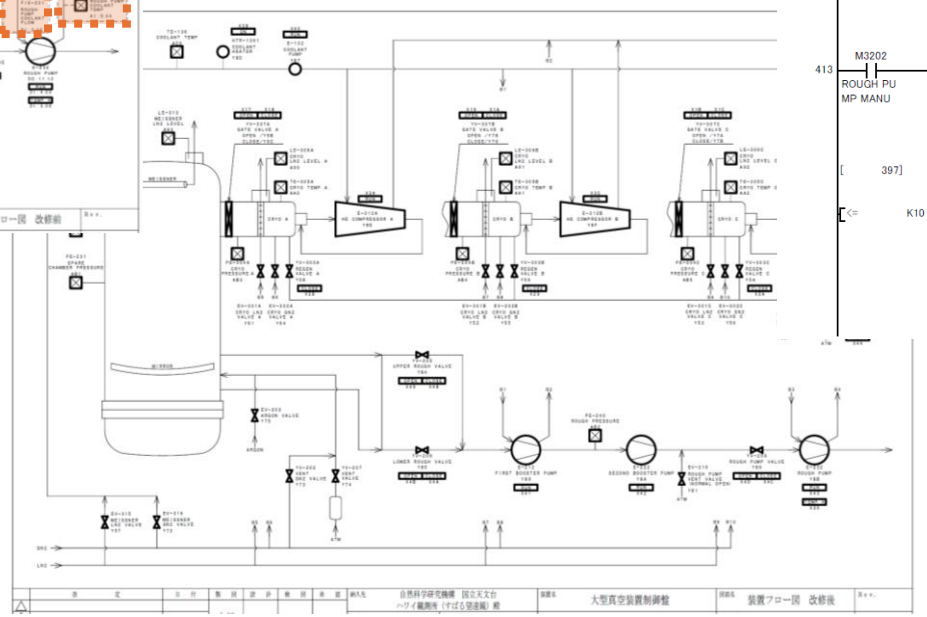
6. Minimum Configuration 最小構成

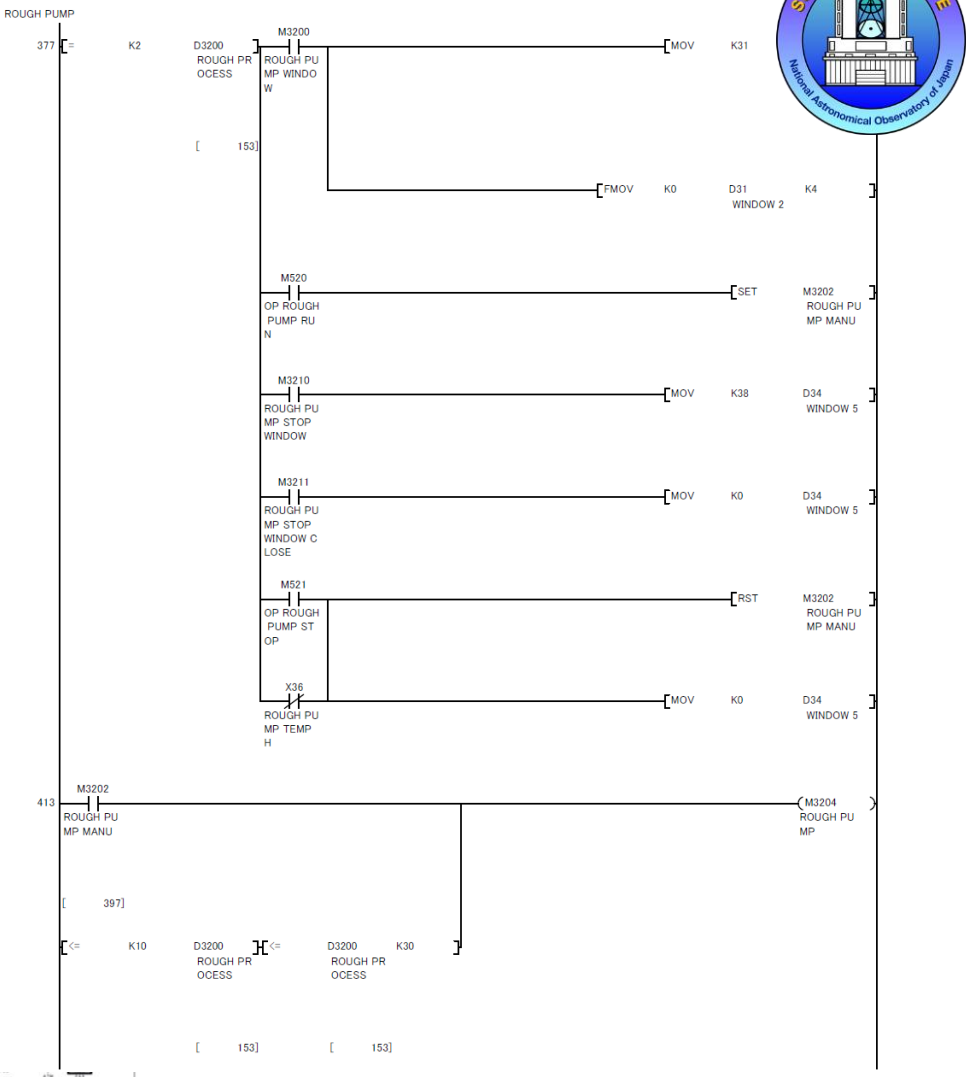
- Identify unused hardware
- Discard unused hardware and to make simple
- Readable source code w/comments

Old



New





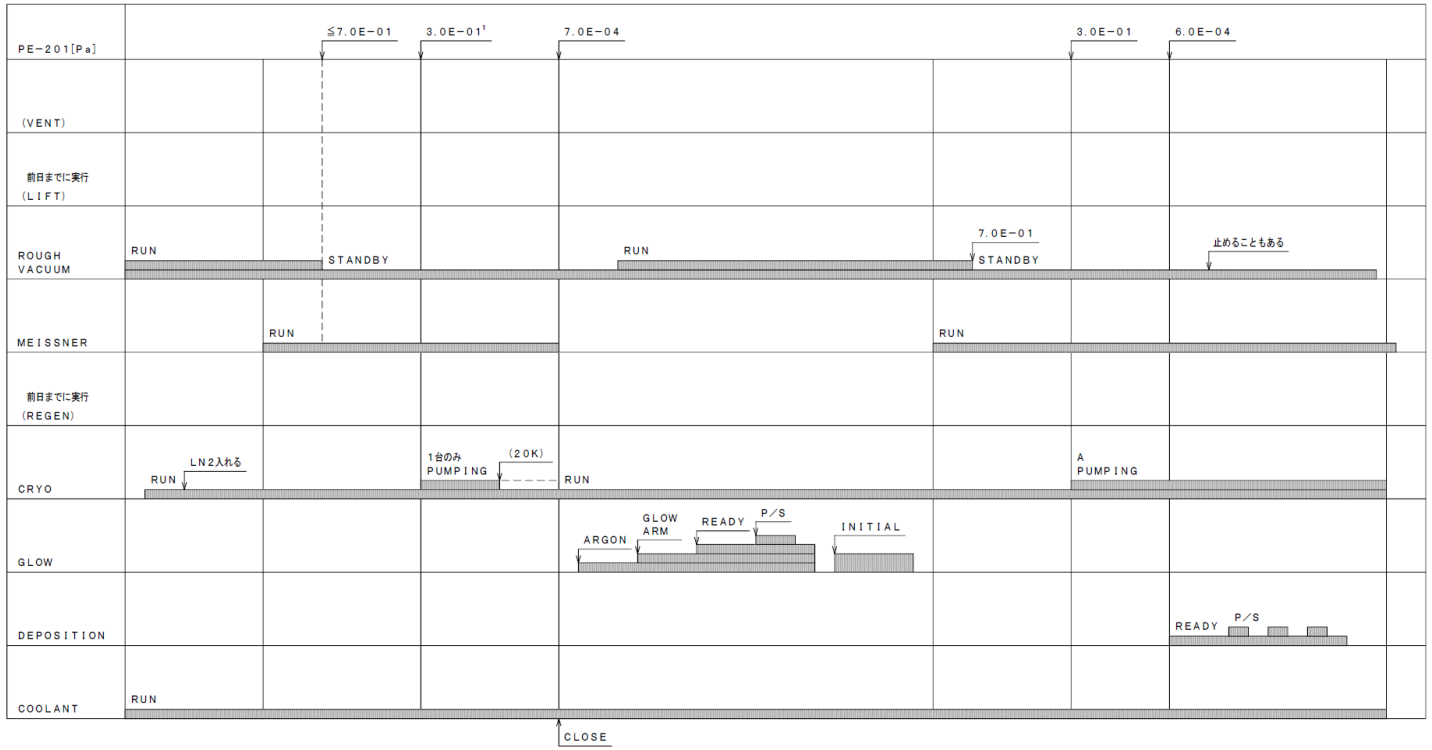
Ladder Program
13,059 lines

7. Maintainability 保守性

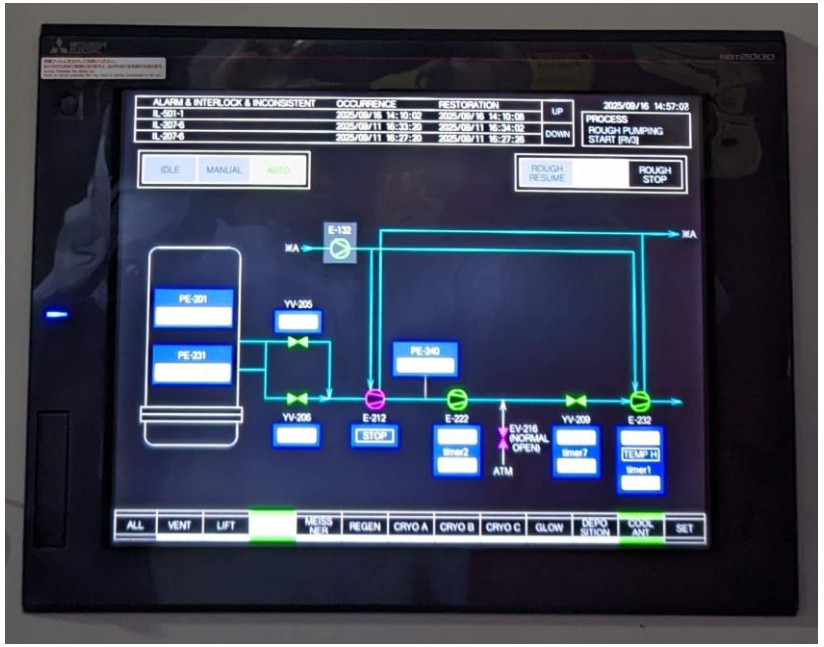
1. PLC itself is **high reliability**.
2. However, **maintainability is not from PLC itself**.

3. Really high reliable system, i.e., highly maintainable system must be developed with fully deeply understand of the design concepts and logics of the object by the client themselves.

~~• top-down development~~
~~• multiple interlock~~



Time chart



GOT interface

8. Summary

1. We Replaced/renovated the Large Vacuum Chamber of the Subaru Telescope
2. We developed a new ladder program from scratch
3. NO black-box is in the system.

4. **PLC itself is high reliability**, as long as the hardware is functioning properly.
5. However, **maintainability is not from PLC itself**.

6. Really high reliable system, i.e., highly maintainable system must be developed with **fully deeply understand of the design concepts and logics of the object** by the client themselves.