



Atacama Large Millimeter/submillimeter Array  
In search of our Cosmic Origins



# Exploring Alternatives and Designing the Next Generation of Real-time Control System for ALMA Observatory

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2021-10-22

ICALEPCS 2021





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# ALMA Observatory

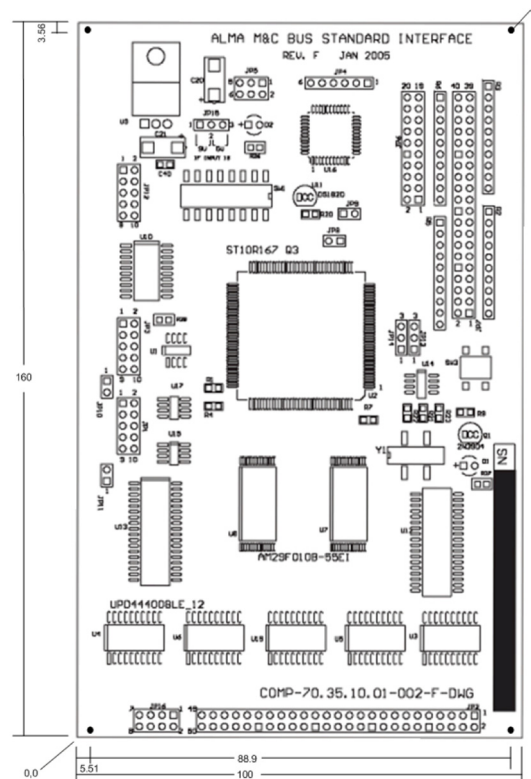
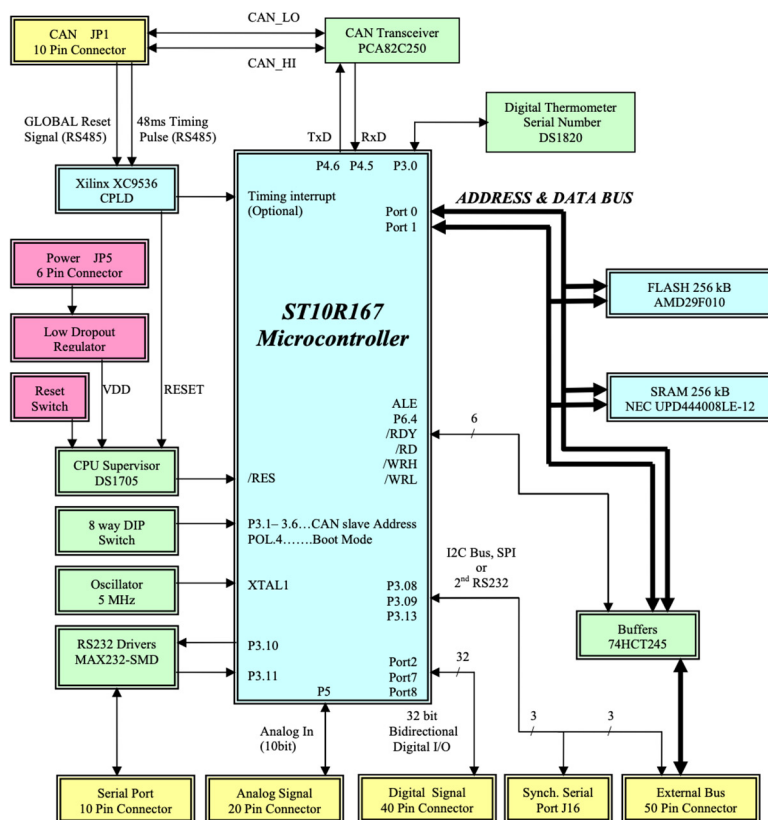


*Credit: Clem & Adri Bacri-Normier (wingsforscience.com)/ESO*

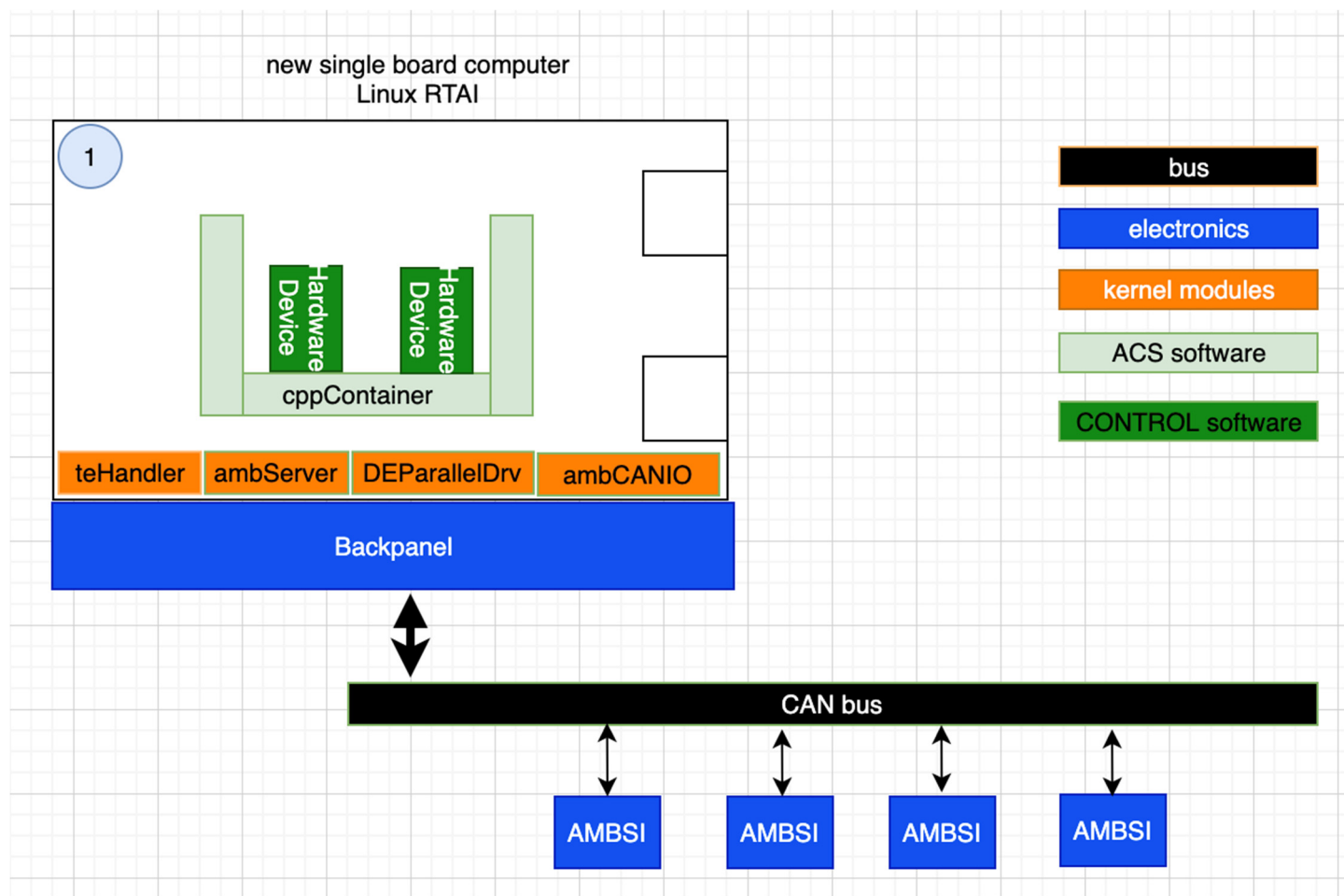


| Servers in the production STE |                                       |                  |          |
|-------------------------------|---------------------------------------|------------------|----------|
| Item                          | Description                           | Type             | Quantity |
| 1                             | Antenna Bus Master                    | abm              | 66       |
| 2                             | Central LO Realtime Computers and DMC | lo-x,dmc         | 9        |
| 3                             | Base Line Correlator CDPMaster, CCC   | cob-cdpm, cob-cc | 2        |
| 4                             | Base Line Correlator CDP Nodes        | cob-cdpm         | 16       |
| 5                             | ACA Correlator CDPMaster, CCC         | coj-cdpm, coj-cc | 2        |
| 6                             | ACA Correlator CDP Nodes              | coj-cdpm         | 32       |
| 7                             | General network services servers      | gns              | 2        |
| 8                             | General application servers           | gas              | 6        |
|                               |                                       | Total            | 135      |

# ALMA Monitor & Control Bus Standard Interface



# Current Architecture



# Quimal Project Status

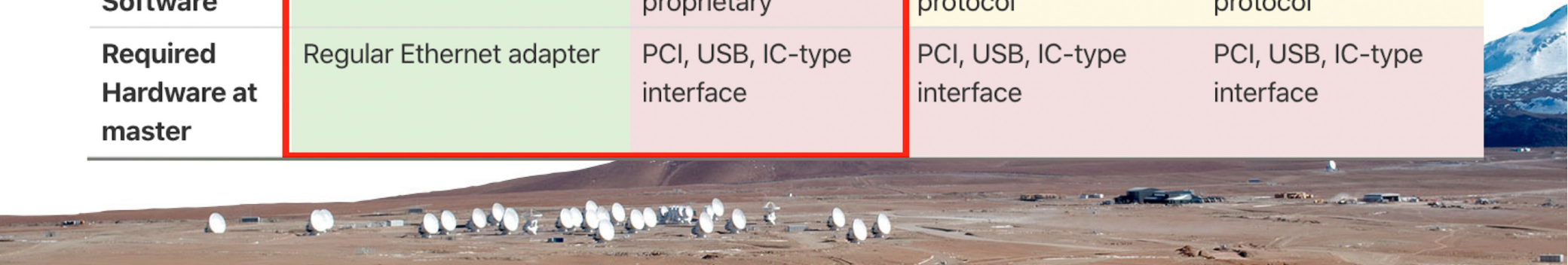
| Folio        | Nombre IR           | Nombre proyecto                                                                                    | Duración Proyecto | Institución Patrocinante   | Tipo de postulación | Monto adjudicado | Monto adjudicado | Monto adjudicado año 3 | Total Adjudicado | Pr |
|--------------|---------------------|----------------------------------------------------------------------------------------------------|-------------------|----------------------------|---------------------|------------------|------------------|------------------------|------------------|----|
| QUIMAL190009 | Patricio Galeas     | Explore alternatives and design the next generation real-time control system for the observatories | 2                 | Universidad de la Frontera | Institucional       | \$157.358.940    | \$42.640.000     | \$0                    | \$199.998.940    |    |
| QUIMAL190004 | Marcos Diaz Quezada | cubesat space telescope designed to protect our dark night skies                                   | 3                 |                            |                     | \$136.000.000    | \$63.200.000     | \$500.000              | \$199.700.000    |    |
| TOTAL        |                     |                                                                                                    |                   |                            |                     | \$293.358.940    | \$105.840.000    | \$500.000              | \$399.698.940    |    |

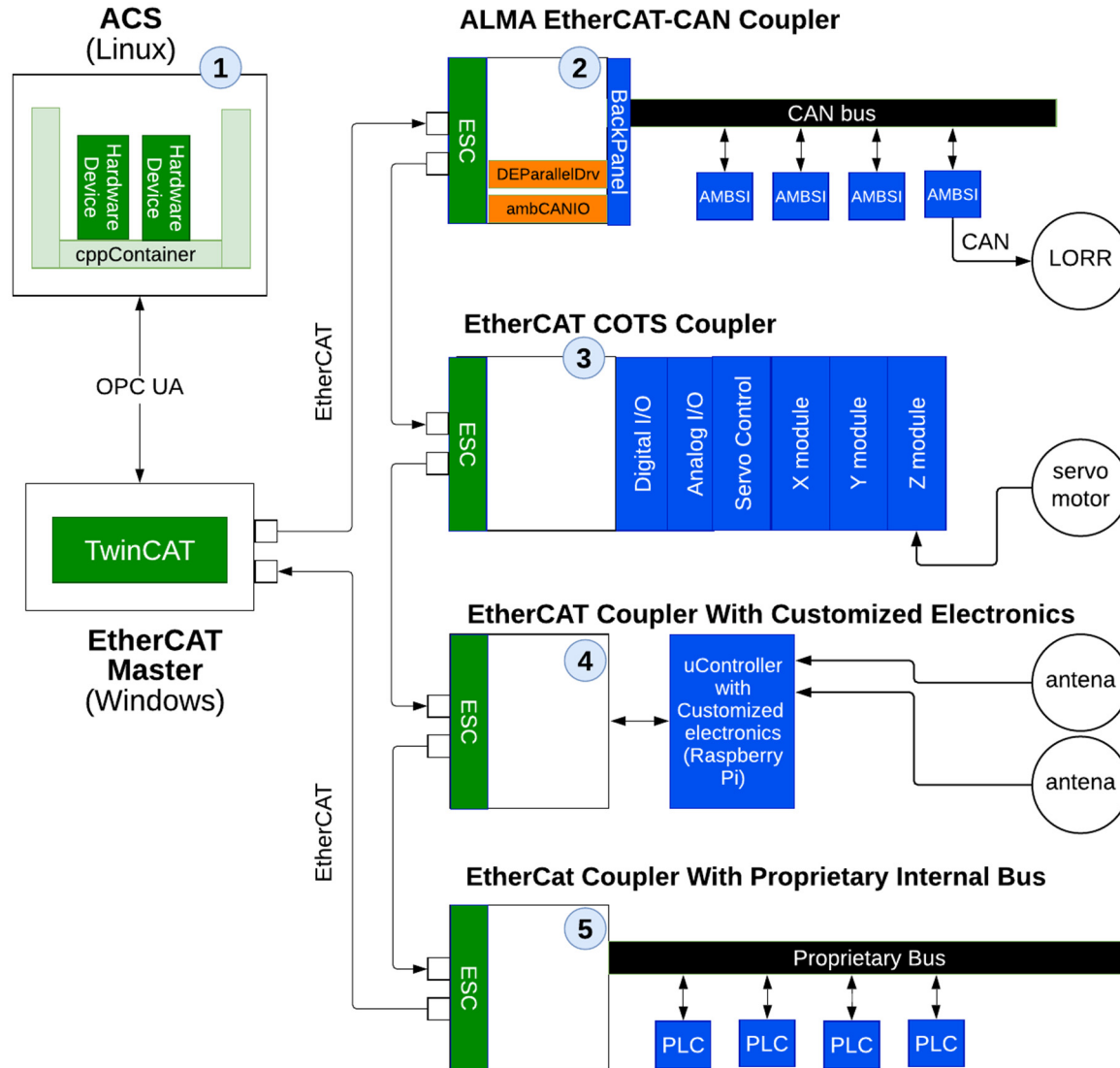


# Control Buses Comparison

## Comparison Table

|                             | EtherCAT                                              | CAN-Bus                                    | RS232                                                 | RS485                                       |
|-----------------------------|-------------------------------------------------------|--------------------------------------------|-------------------------------------------------------|---------------------------------------------|
| Speed/Cable Length          | 100 Mbps at 100 m between two nodes for full speed    | 1 Mbps at 40 m from the start to end nodes | <u>19,200 bps at 15 m from the start to end nodes</u> | 1 Mbps at 120 m from the start to end nodes |
| Cable Topology              | Daisy Chain, Point-to-Point, Combination of the above | Daisy Chain                                | Point-to-Point                                        | Daisy Chain, Point-to-Point                 |
| Max Number of Nodes         | 65535                                                 | 128                                        | 1                                                     | 32                                          |
| Open Source Software        | Yes                                                   | Most of CANOpen is proprietary             | No predetermined protocol                             | No predetermined protocol                   |
| Required Hardware at master | Regular Ethernet adapter                              | PCI, USB, IC-type interface                | PCI, USB, IC-type interface                           | PCI, USB, IC-type interface                 |





## New Architecture

Use Cases to be implemented:

**use case 1)** ALMA OPCUA Hardware Device driver and EtherCAT master (ex ABM)

**use case 2)** EtherCAT Coupler for ALMA current CAN bus device

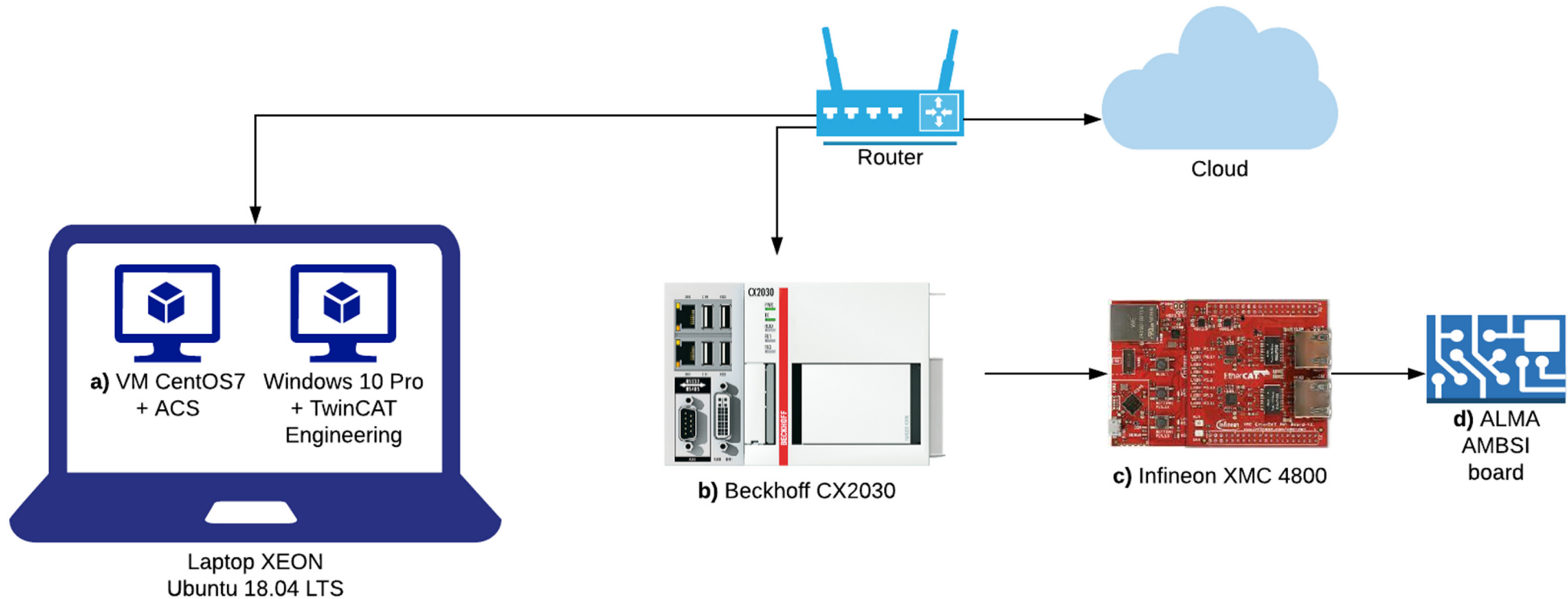
**use case 3)** COTS EtherCAT Coupler with digital, analog I/O.

**use case 4)** EtherCAT Coupler with customized electronic of new hardware related to the ALMA-2030 initiative.

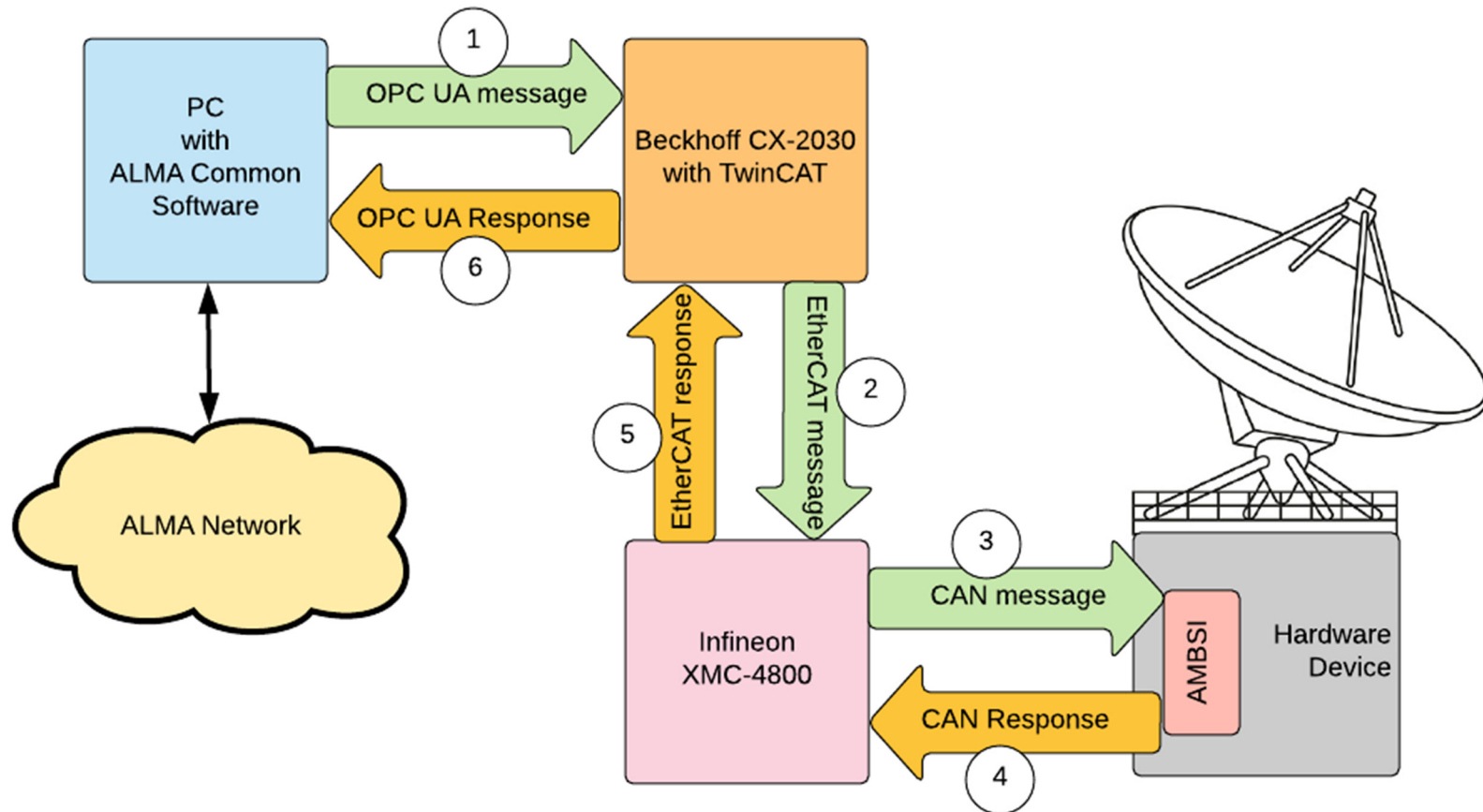
**use case 5)** EtherCAT coupler to interface proprietary bus



# Physical Setup

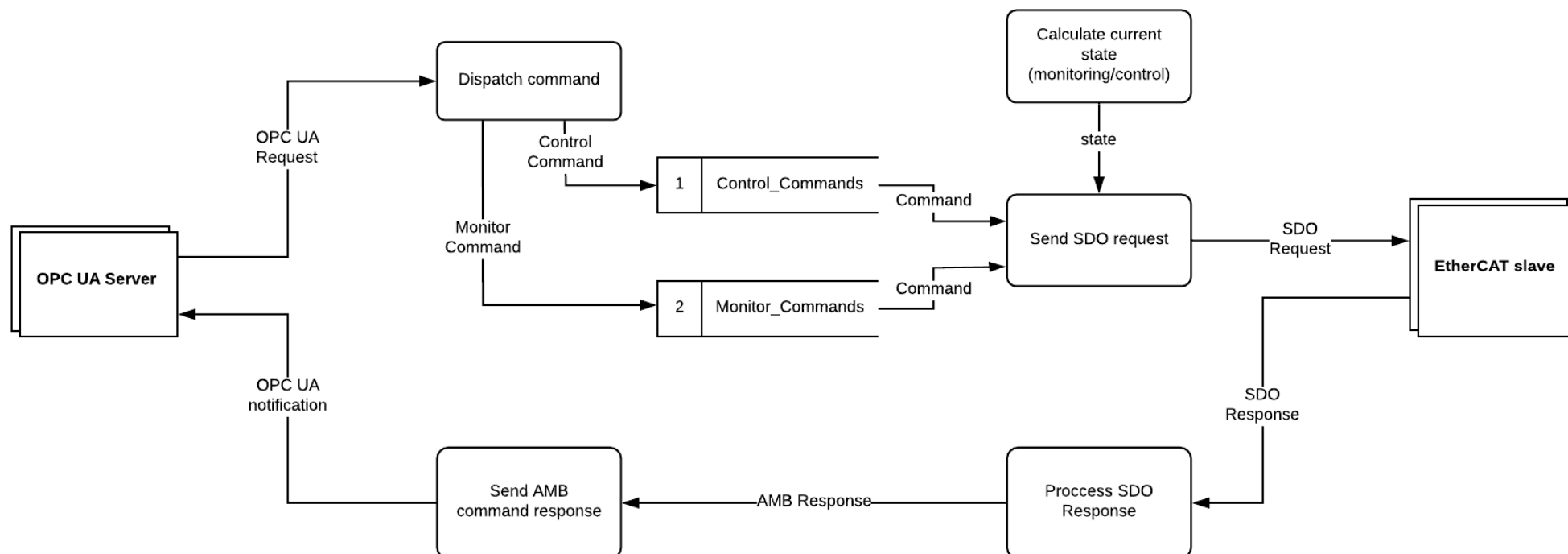


# M&C Message Flow

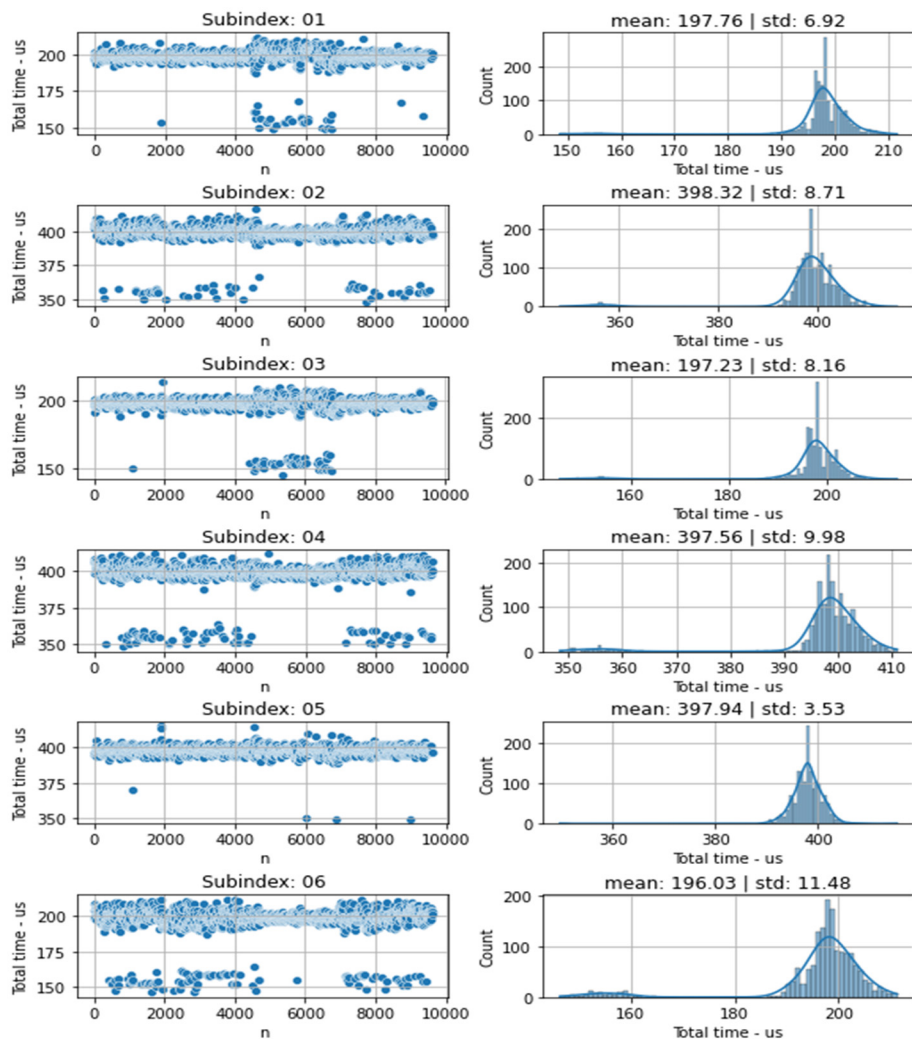


# M&C Message Flow

|         |                     |                            |
|---------|---------------------|----------------------------|
| 5001:0  | ALMA_CAN_Device1    | > 6 <                      |
| 5001:01 | AMBSI_SERIAL_NUMBER | RO 0xe70008027e4fe110      |
| 5001:02 | AMBIENT_TEMPERATURE | RO 0x100F0046 (269418566)  |
| 5001:03 | PROTOCOL_REV_LEVEL  | RO 0x00000000 (0)          |
| 5001:04 | CAN_ERROR           | RO 0x00000000 (0)          |
| 5001:05 | TRANS_NUM           | RO 0x64000000 (1677721600) |
| 5001:06 | SW_REV_LEVEL        | RO 0x00000002 (2)          |



# Results



|         |                     |                            |
|---------|---------------------|----------------------------|
| 5001:0  | ALMA_CAN_Device1    | > 6 <                      |
| 5001:01 | AMBSI_SERIAL_NUMBER | RO 0xe70008027e4fe110      |
| 5001:02 | AMBIENT_TEMPERATURE | RO 0x100F0046 (269418566)  |
| 5001:03 | PROTOCOL_REV_LEVEL  | RO 0x00000000 (0)          |
| 5001:04 | CAN_ERROR           | RO 0x00000000 (0)          |
| 5001:05 | TRANS_NUM           | RO 0x64000000 (1677721600) |
| 5001:06 | SW_REV_LEVEL        | RO 0x00000002 (2)          |

- Test: send 10000 messages defined in the OD of a hardware device
- Time of fly were extracted analyzing TCP packages by using Wireshark.
- Sub-index 1,3 : 200  $\mu$ S
- Sub-index 2,4 : 400  $\mu$ S

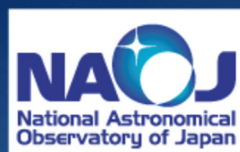




# Conclusion & Future Works

- A tentative alternative based on COTS hardware is presented to solve the obsolescence problem of the existing Realtime Computer.
- Demonstrated that EtherCAT is a suitable protocol to replace the existing fieldbus based on a customized version of CAN protocol.
  - SDO structure suits to the purpose of monitoring and control, but PDO could allow more performance (under investigation).
- This architecture also fulfills the possible scenarios of new systems that may come with ALMA2030 initiatives.
- XMC-4800 is a very versatile micro-controller (120MHz), and the feature of MultiCAN suits perfectly to replace the existing ABM with 5 independent CAN buses. We also want to test other brand of ESC: TI Sitara AM335x, Microchip 9254, etc.

# Questions?



## Acknowledgements

ACS presentations were originally developed by the ALMA Common Software development team and has been used in many instances of training courses since 2004. Main contributors are (listed in alphabetical order): Jorge Avarias, Alessandro Caproni, Gianluca Chiozzi, Jorge Ibsen, Thomas Jürgens, Matias Mora, Joseph Schwarz, Heiko Sommer.

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO) which is managed by Associated Universities, Inc. (AUI) and on