Neutron Chopper controls at ESS

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Mechatronics Engineer

Denim 2018
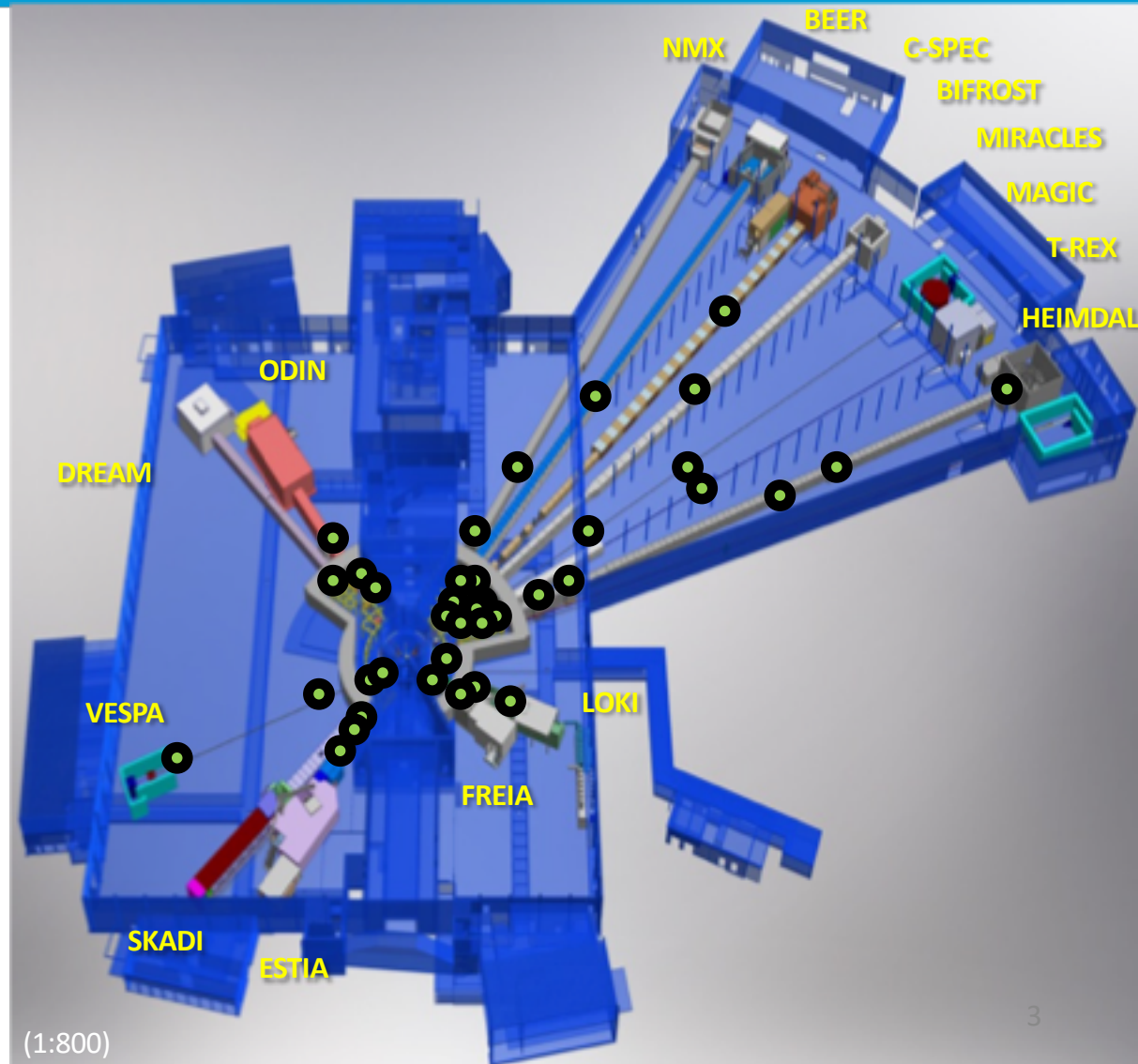
Outline

- Overview of Neutron Choppers at ESS
- Controls architecture
- Hardware
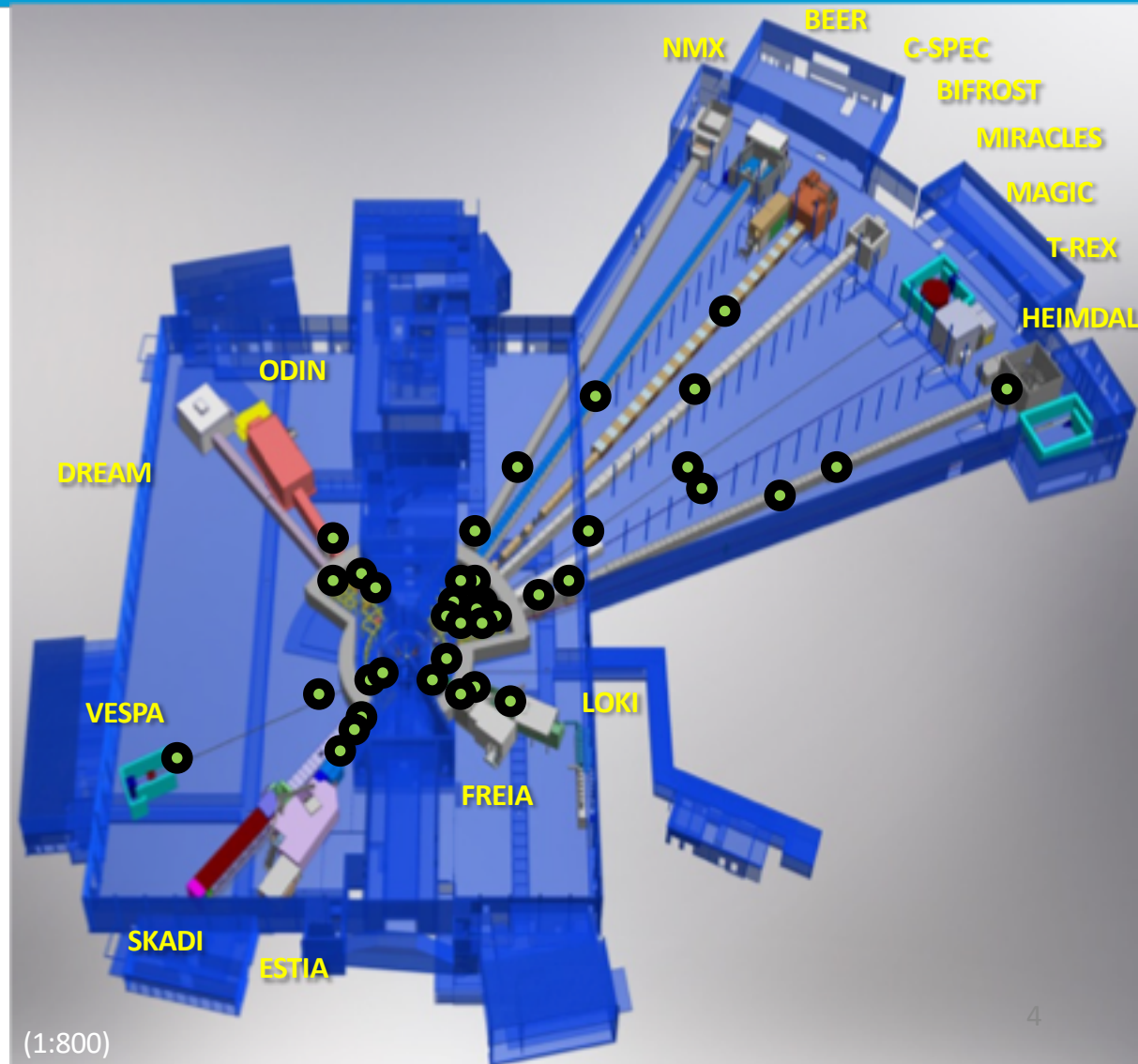- Chopper timing/synchronization
- Q/A

Overview of Neutron Choppers at ESS

- 15 instruments using a total of ~102 choppers in the facility.

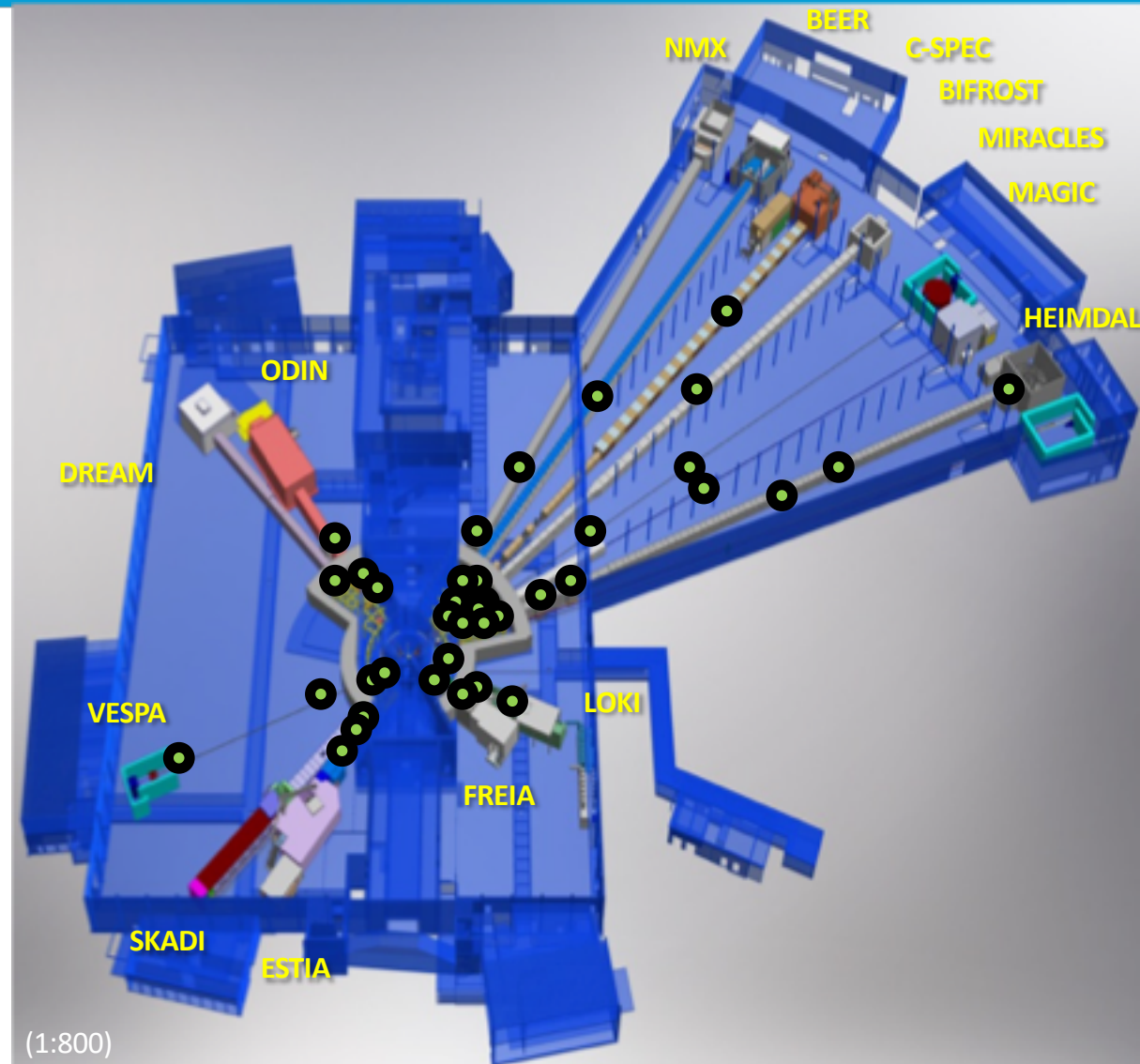- ~50 of those choppers are located inside the bunker.

(1:800)

- Every instrument team is free to build/buy the chopper system that best fits their scientific needs and budget.
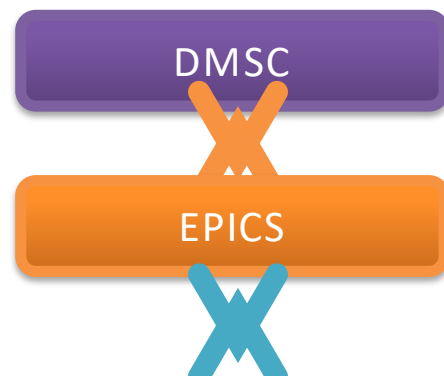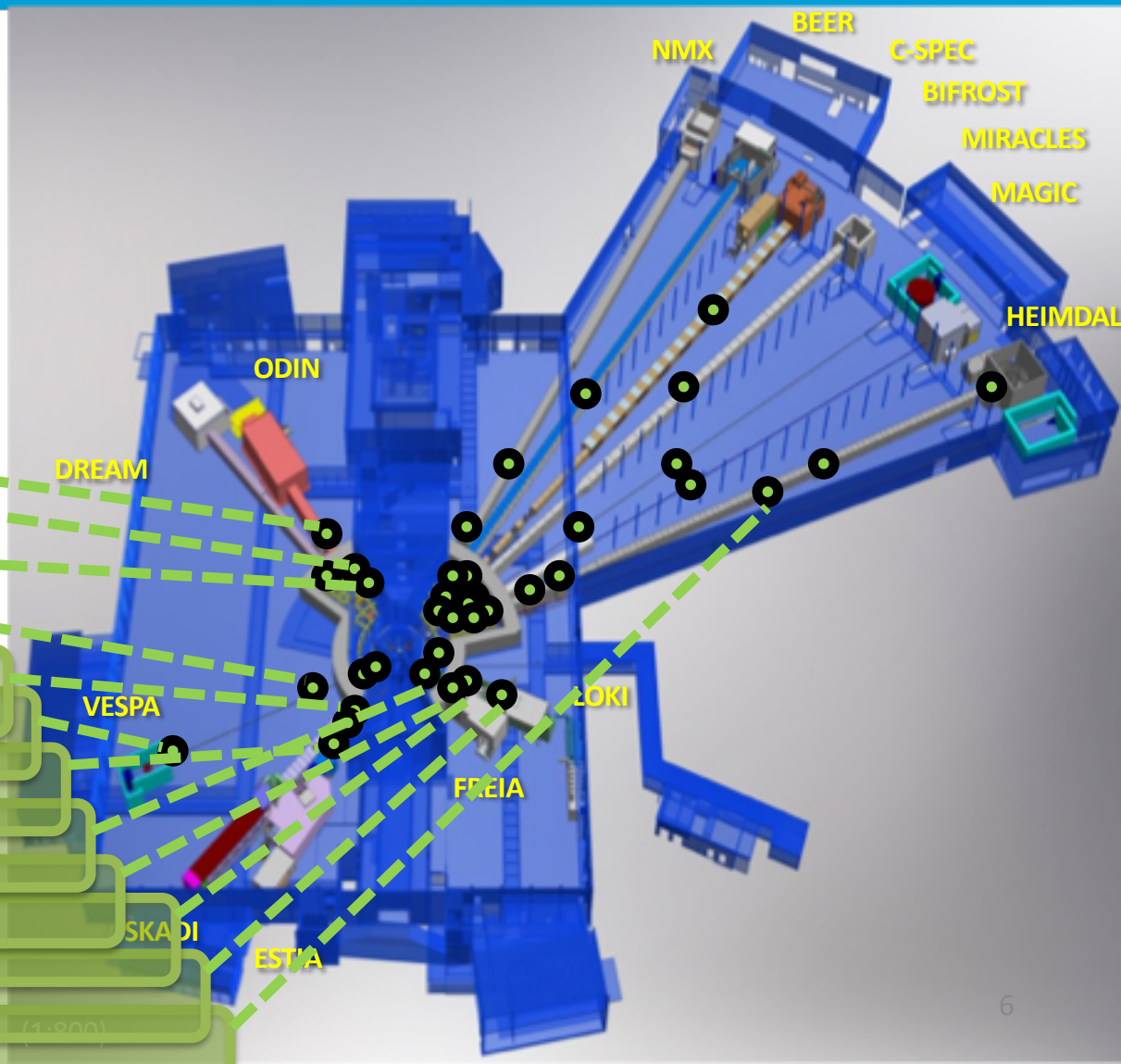
For a large scale facility

Standardise:

- Controls and monitoring
- Integration process
- Software maintenance
- Hardware
- Timing

Controls architecture

Controls architecture

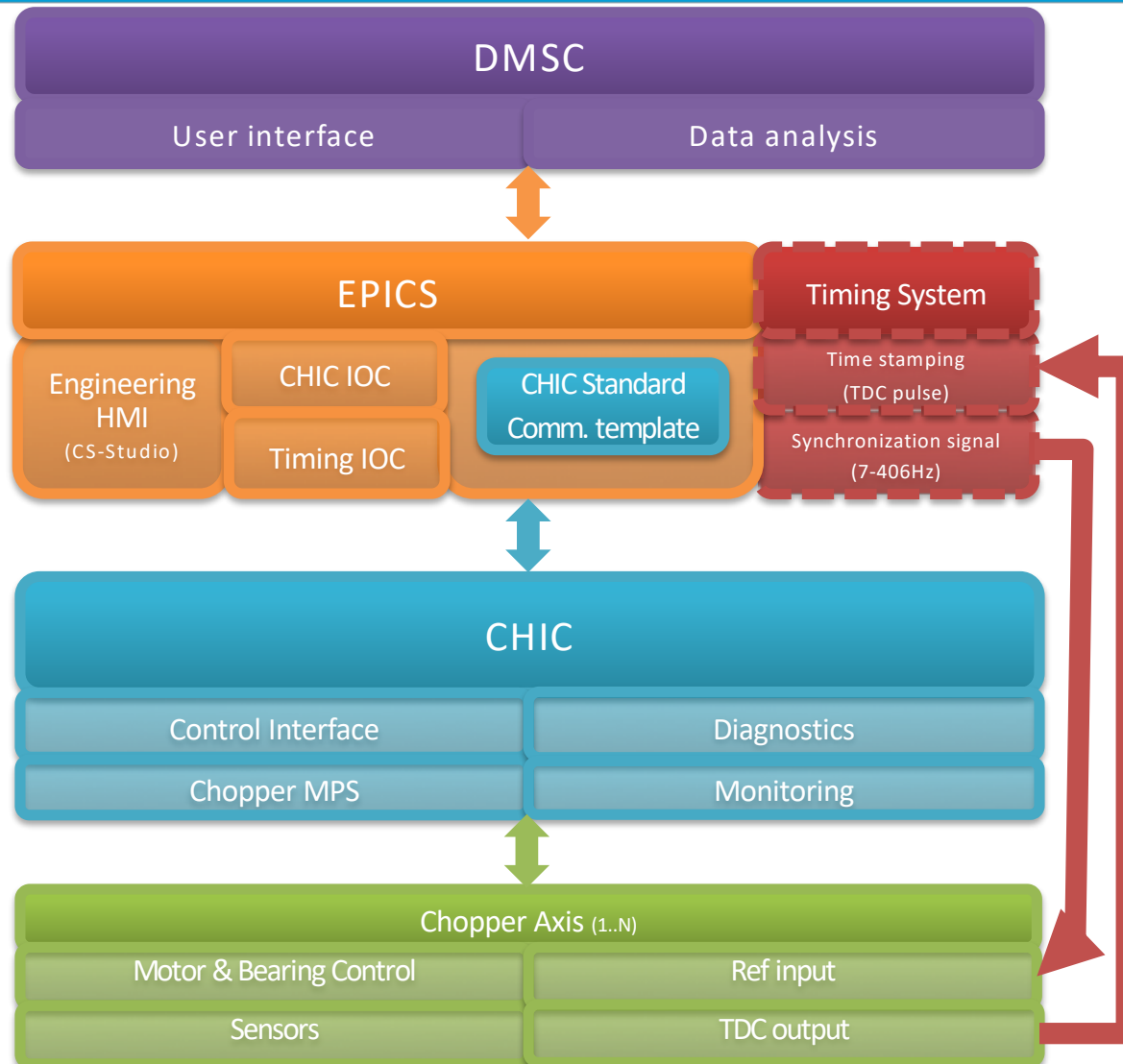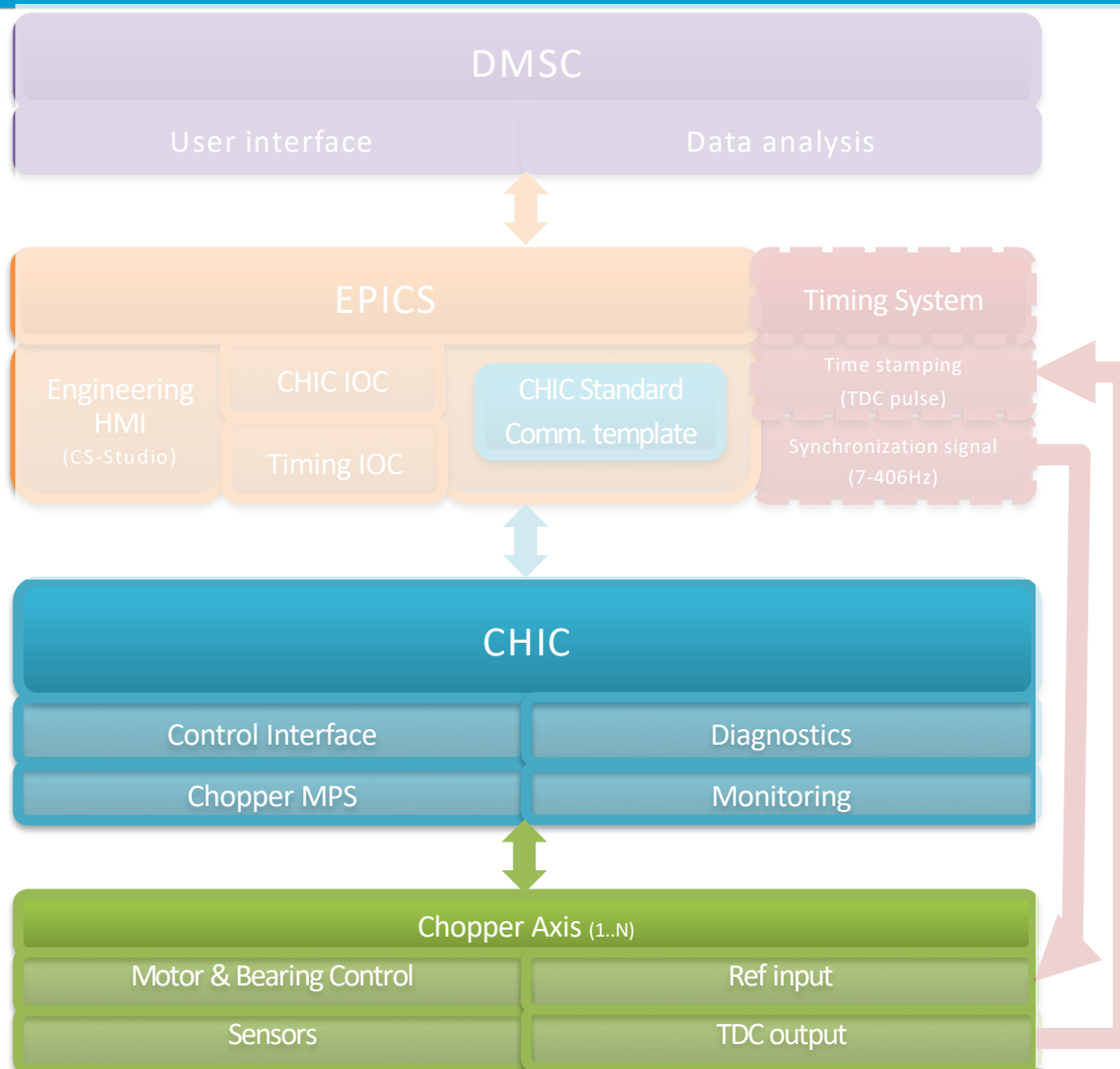# Controls architecture

CHIC- Chopper Integration Controller

- Allows the implementation of all the standarisation needed by acting as a "transducer" between EPICS and the chopper drives.

- It is a monitoring system (predictive maintenance) for external measurements such as vibration, cooling, vacuum and disk temp.

Controls architecture

Controls architecture

DMSC

User interface   Data analysis

EPICS   Timing System

Engineering HMI (CS-Studio) | CHIC IOC | CHIC Standard Comm. template | Time stamping (TDC pulse)
Timing IOC | | Synchronization signal (7-406Hz)

CHIC

Control Interface   Diagnostics
Chopper MPS   Monitoring

Chopper Axis (1..N)

Motor & Bearing Control   Ref input
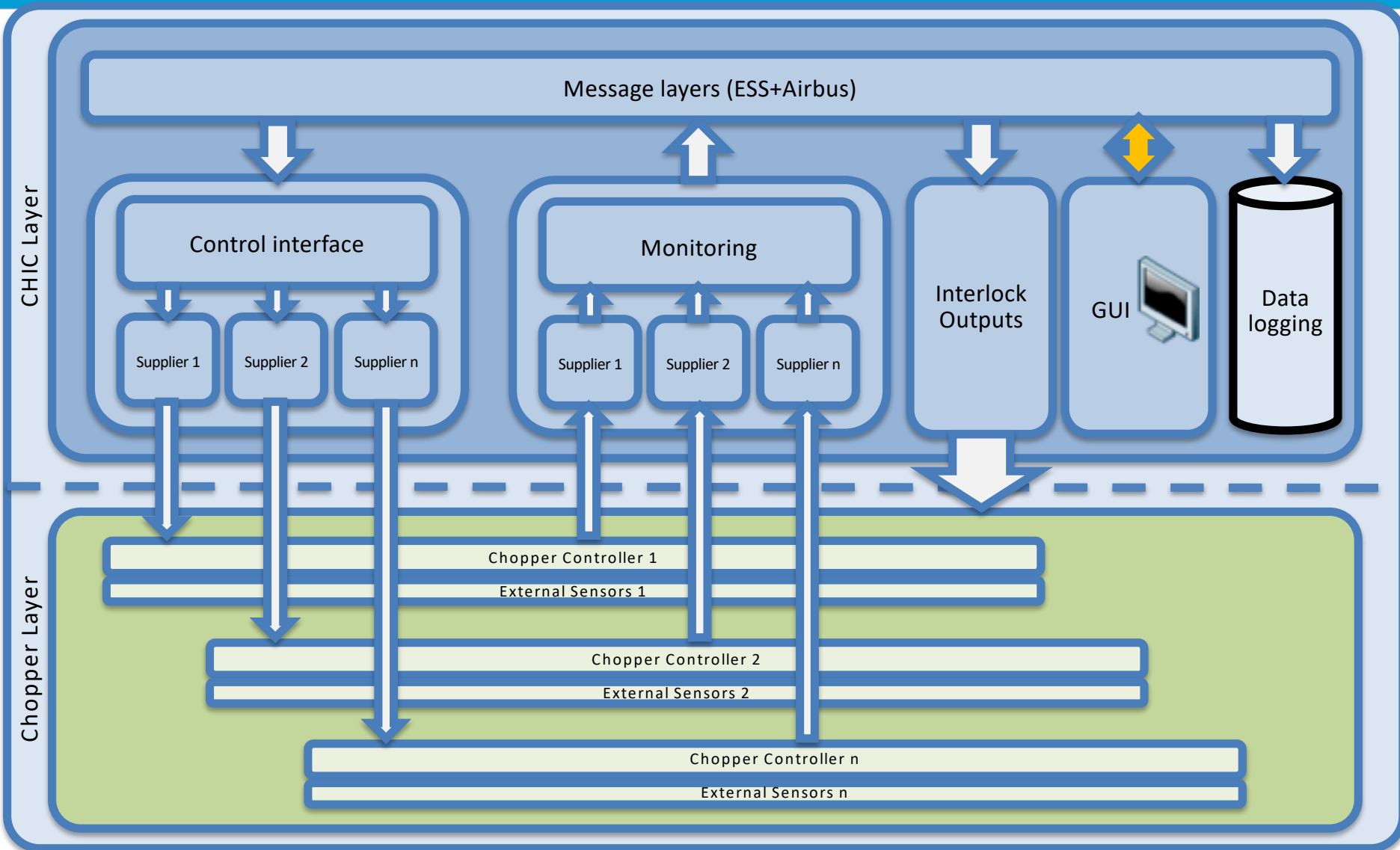Sensors   TDC output
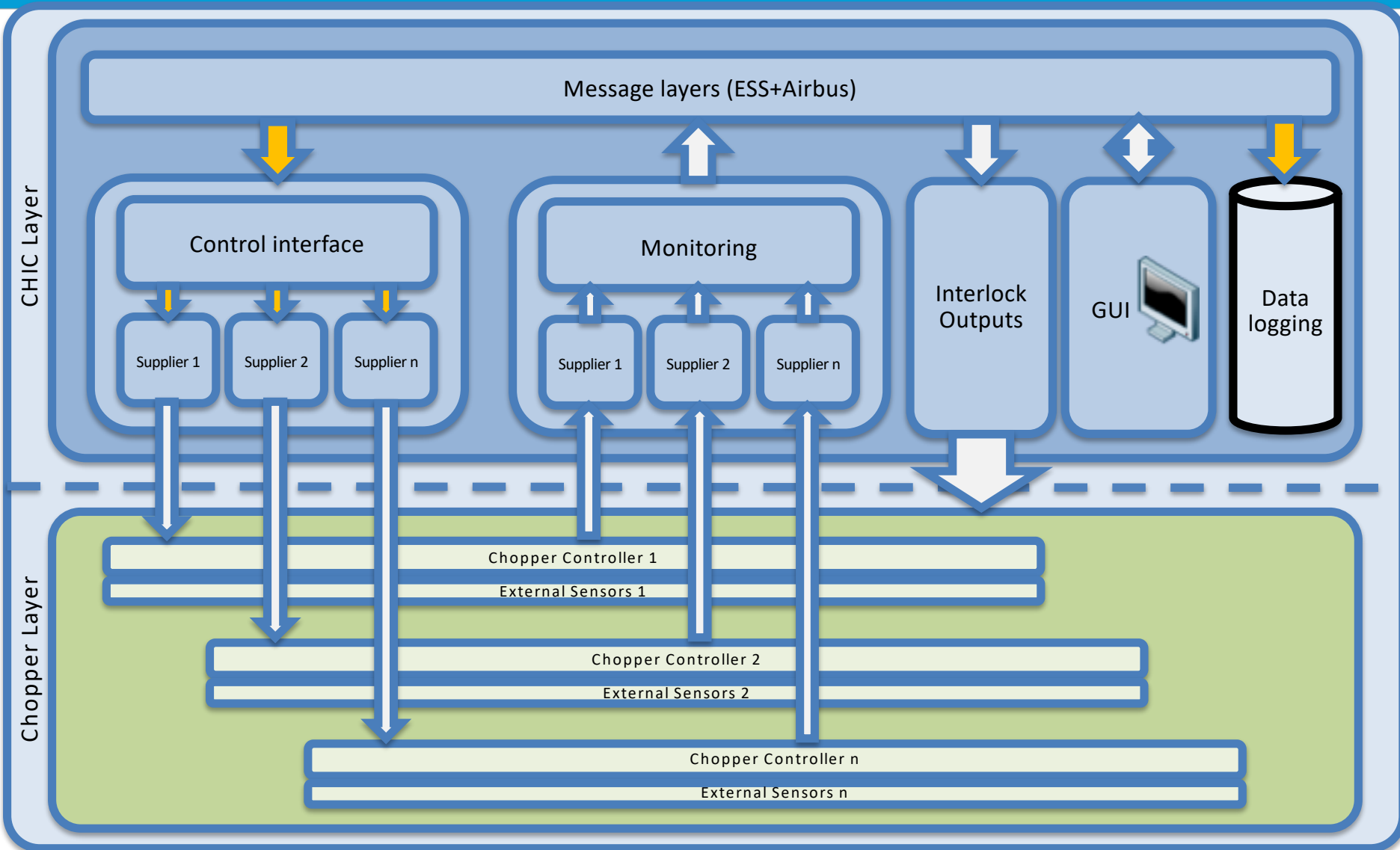
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Standard Control and monitoring

Standard Control and monitoring

Sending a new command

Standard Control and monitoring

Sending a new command

Standard Control and monitoring

Sending a new command

Standard Control and monitoring
Sending a new command

Message layers (ESS+Airbus)

CHIC Layer

Control interface
- Supplier 1
- Supplier 2
- Supplier n

Monitoring
- Supplier 1
- Supplier 2
- Supplier n

Interlock Outputs

GUI

Data logging

Chopper Layer

Chopper Controller 1
External Sensors 1

Chopper Controller 2
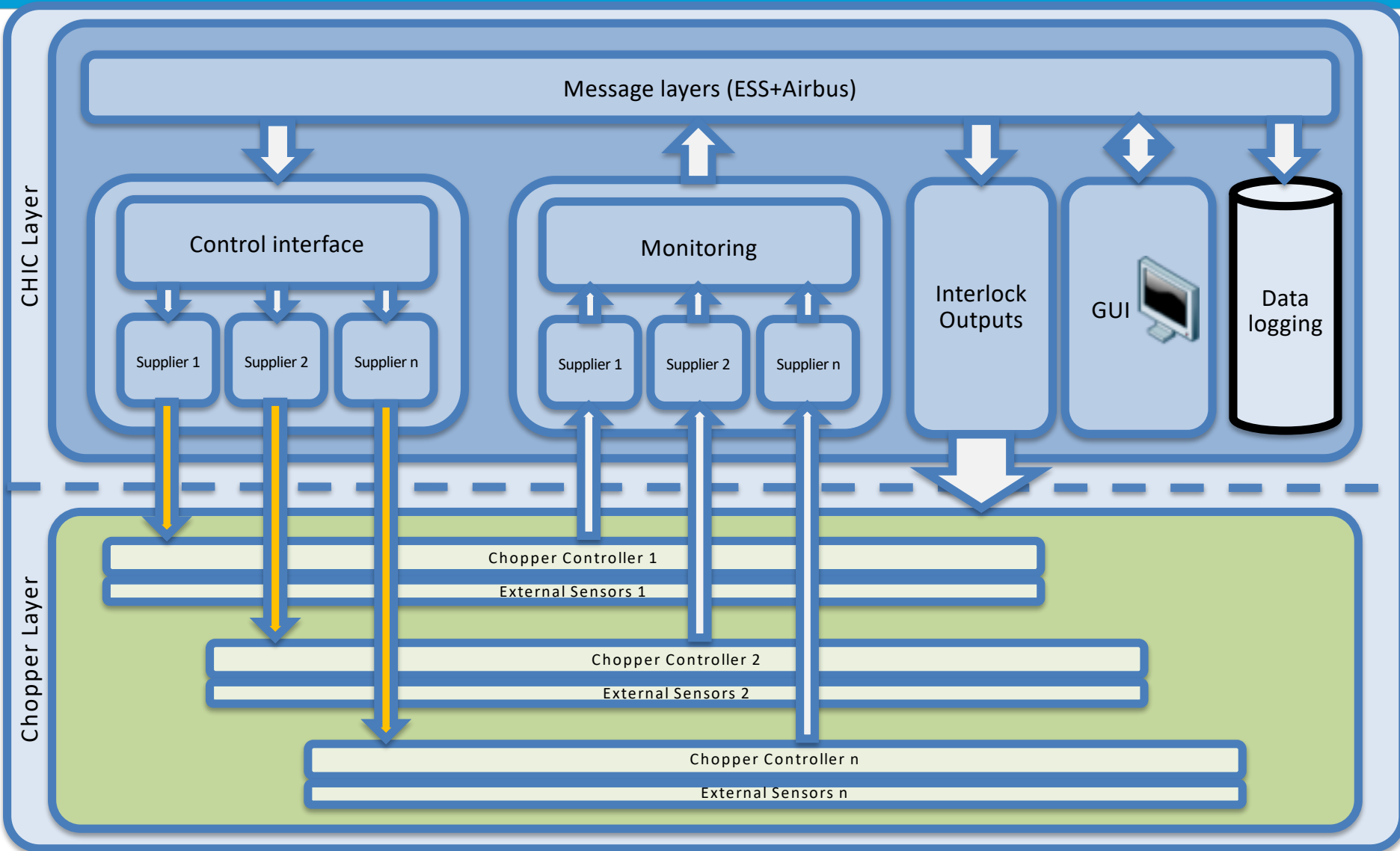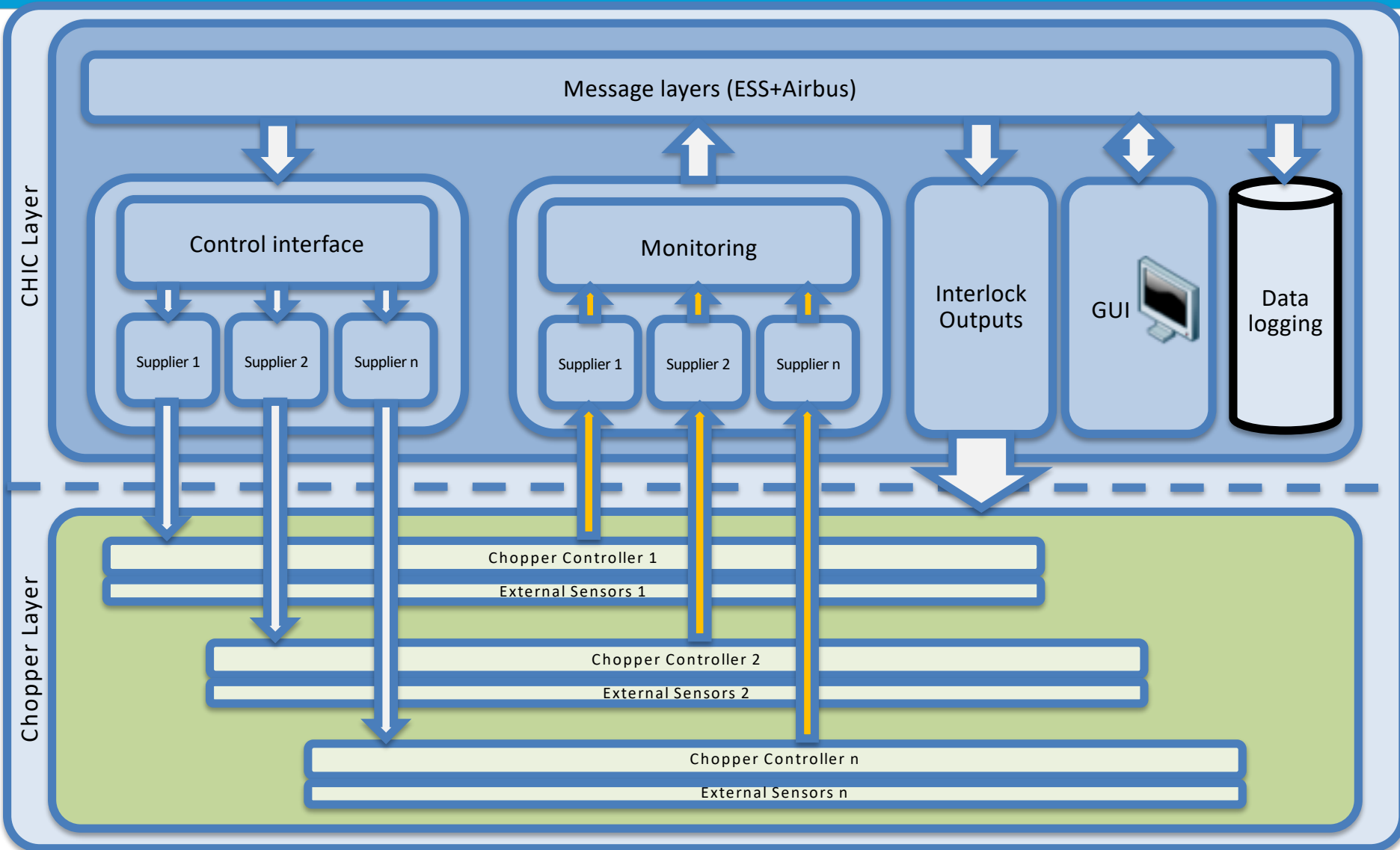External Sensors 2

Chopper Controller n
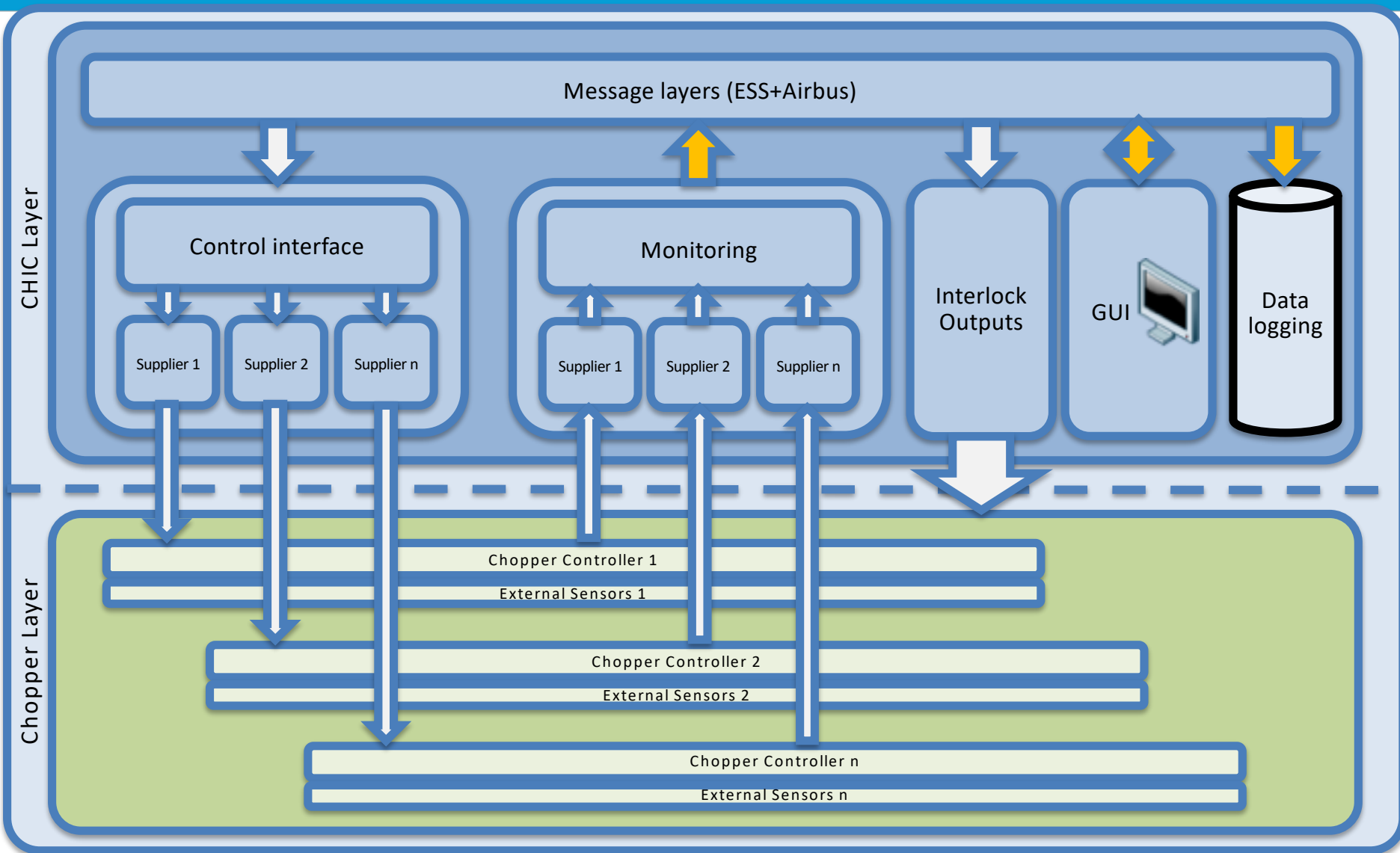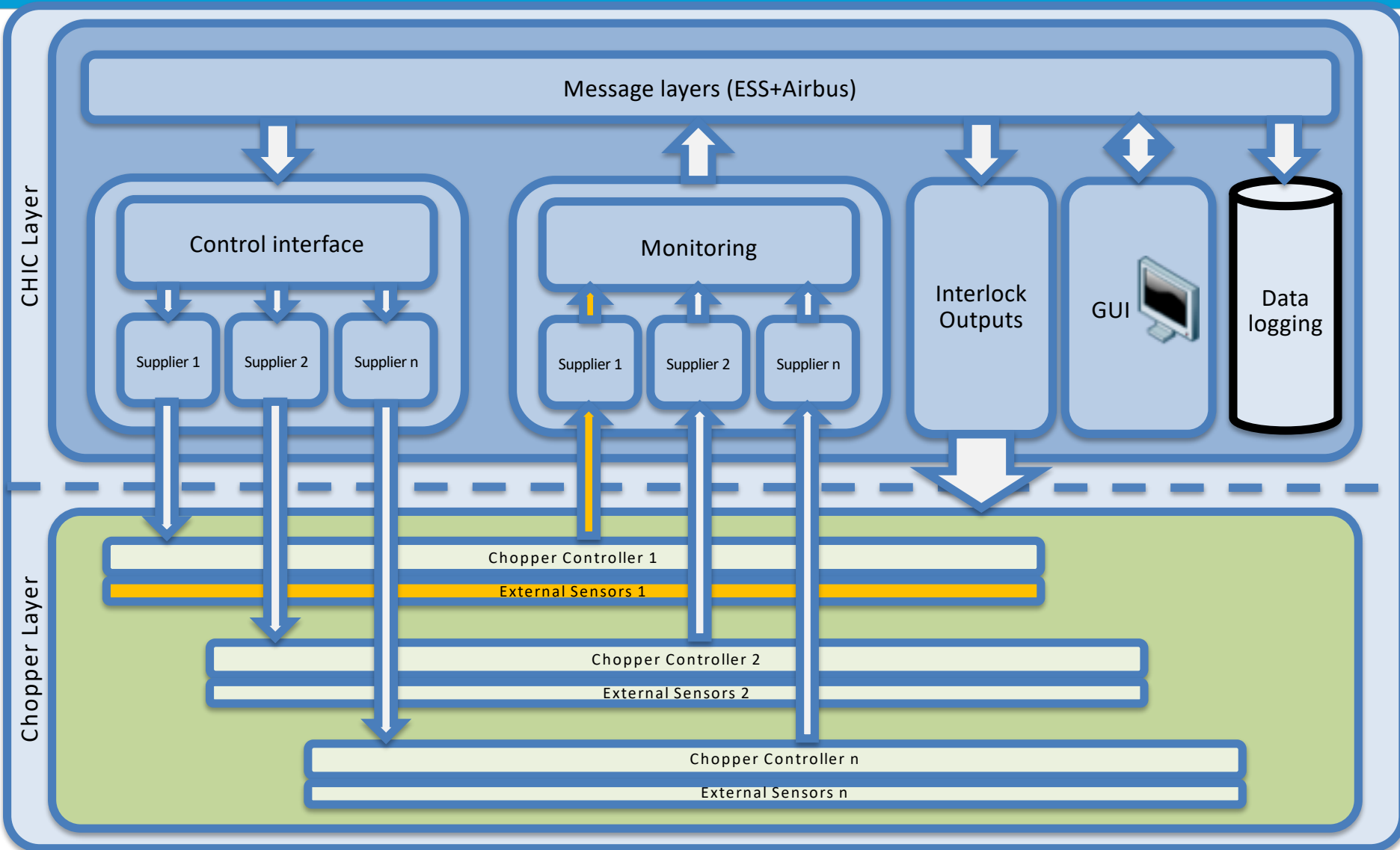External Sensors n

Standard Control and monitoring

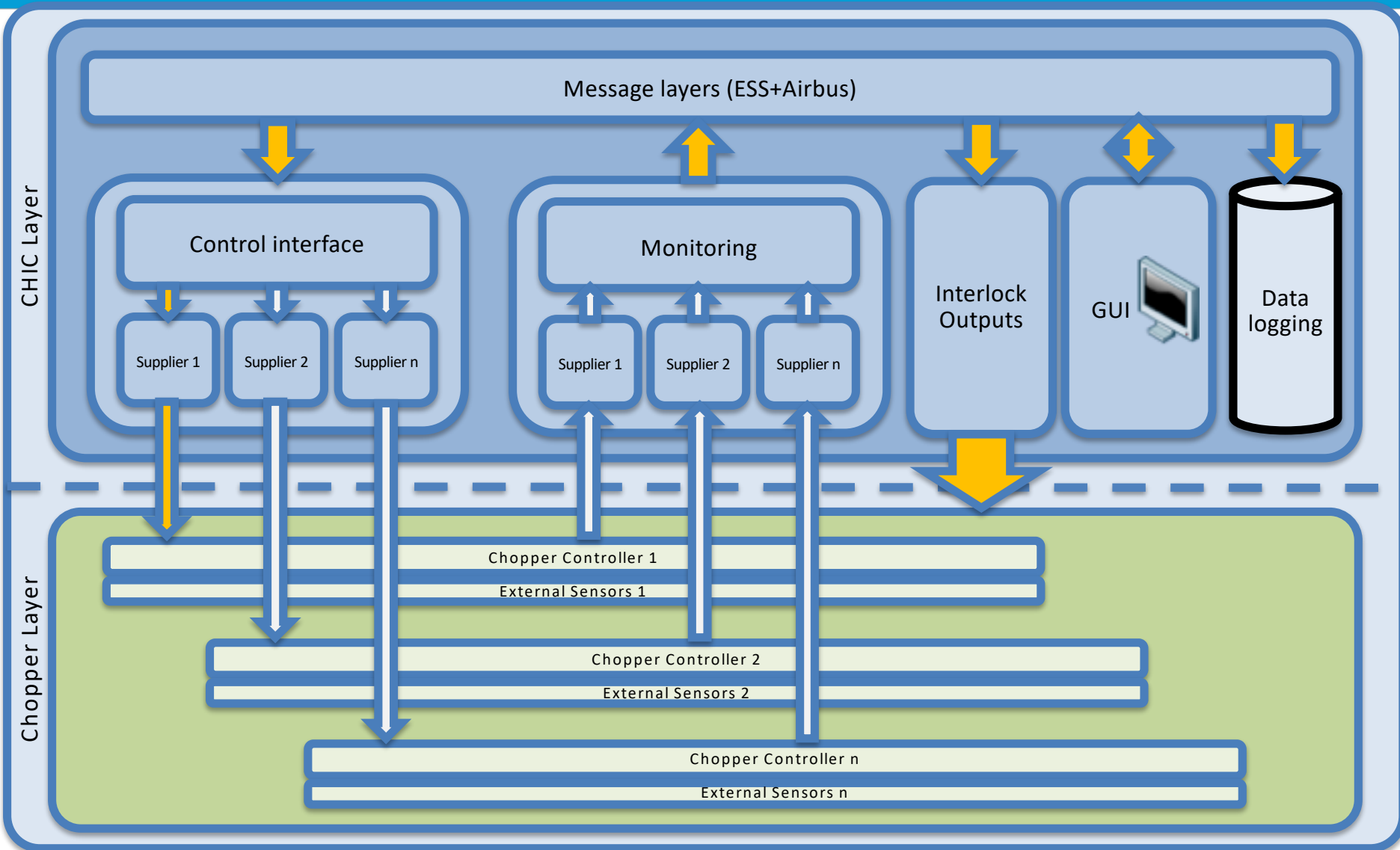Sending a new command

Standard Control and monitoring

Something went wrong

Standard Control and monitoring

Something went wrong

For a large scale facility

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Controls architecture

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| Timing IOC | | Synchronization signal (7-406Hz)

CHIC

Control Interface | Diagnostics
Chopper MPS | Monitoring

Chopper Package (1..N)

Motor & Bearing Control | Ref input
Sensors | TDC output

Controls architecture

EPICS

CHIC IOC (all PVs)

CHIC Standard Comm. template

TCP/IP Client

Modbus Client

TCP/IP Server
1. Close all connections
2. Initialize "Listener"
3. Accept connection
4. Push data to EPICS

Modbus Server
Creates memory locations accessible via Modbus

CHIC

Message layer with all chopper PVs

Controls architecture

EPICS

CHIC IOC
(all PVs)

CHIC Standard
Comm. template

Same code for all EPICS IOCs

TCP/IP Client

Modbus Client

TCP/IP Server

1.Close all connections

2.Initialize "Listener"

3.Accept connection

4.Push data to EPICS

Same code for all PLCs

Modbus Server

Creates memory locations
accessible via Modbus

CHIC

Message layer with all chopper PVs
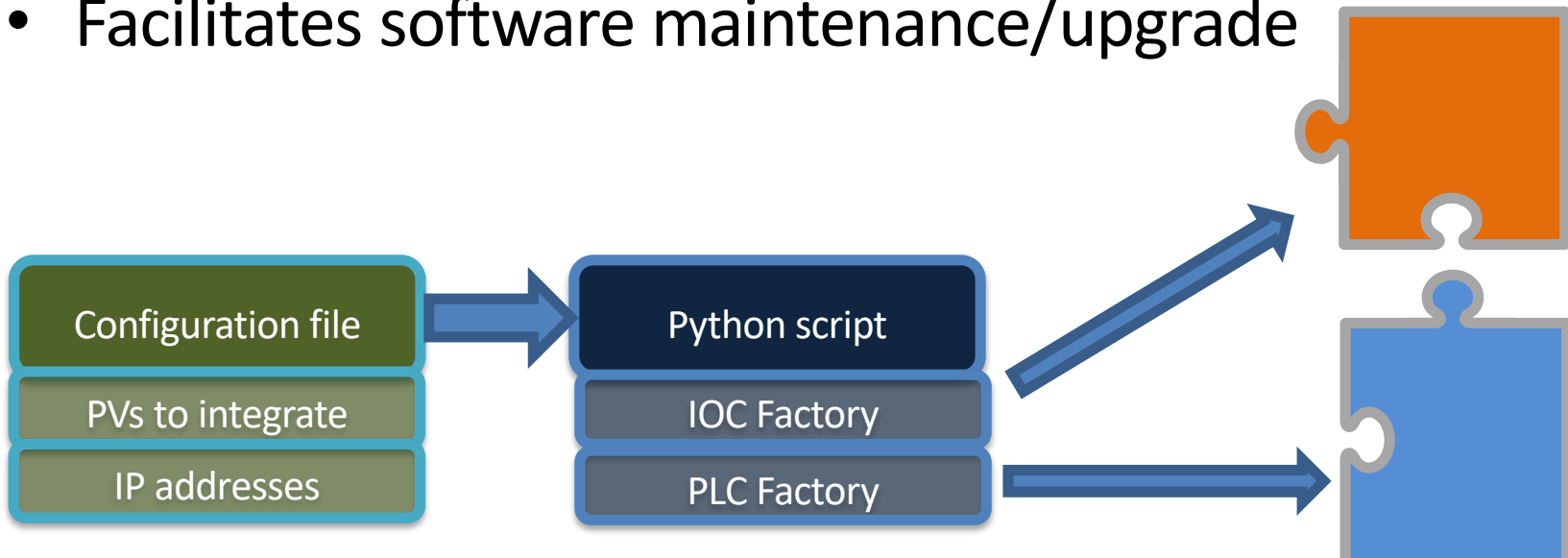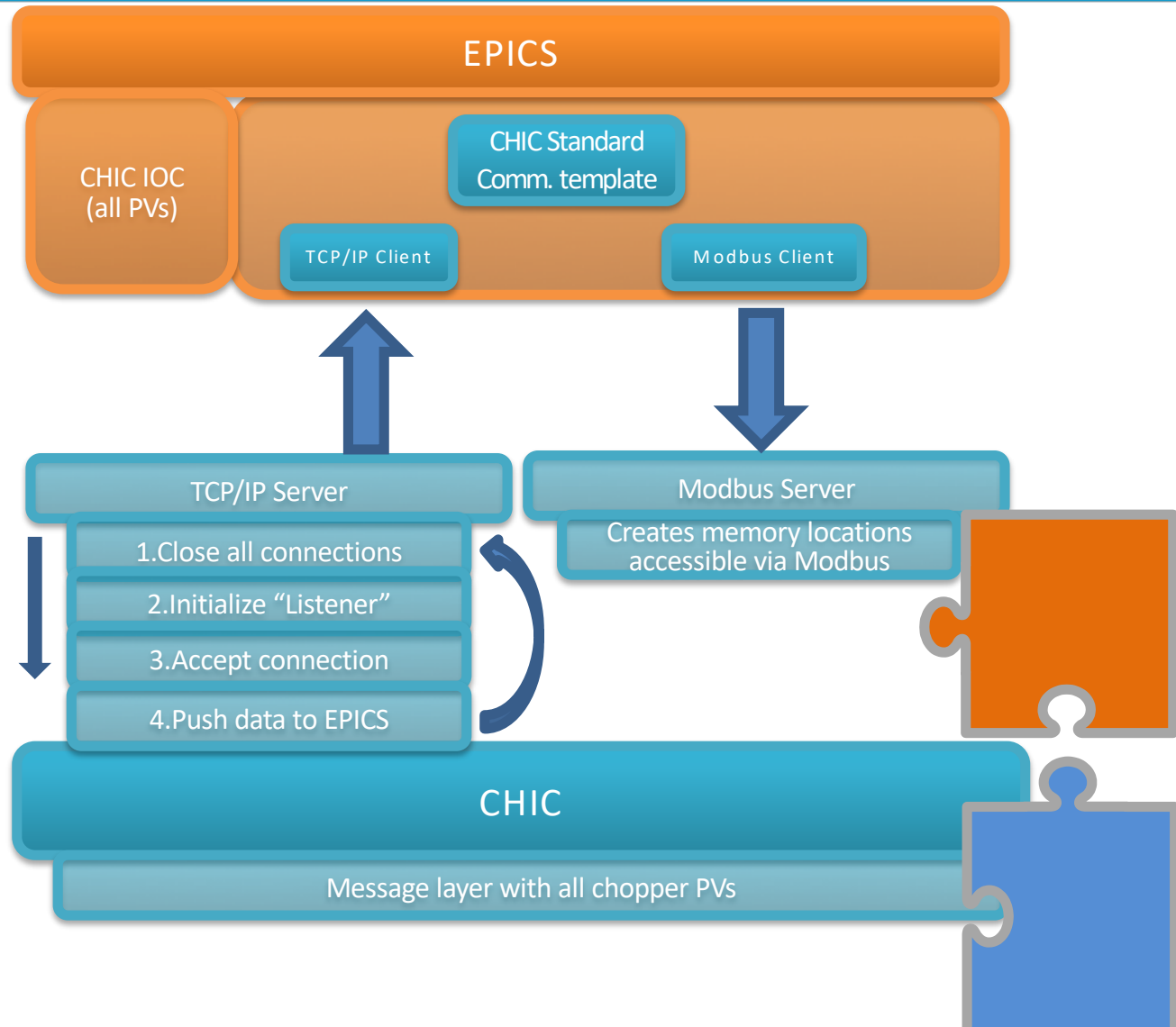
Standard integration process

- Configuration file with process variables for control and monitoring.

- The script creates two equivalent sets of code. PLC and EPICS code.

- Generated codes are with all variables linked.

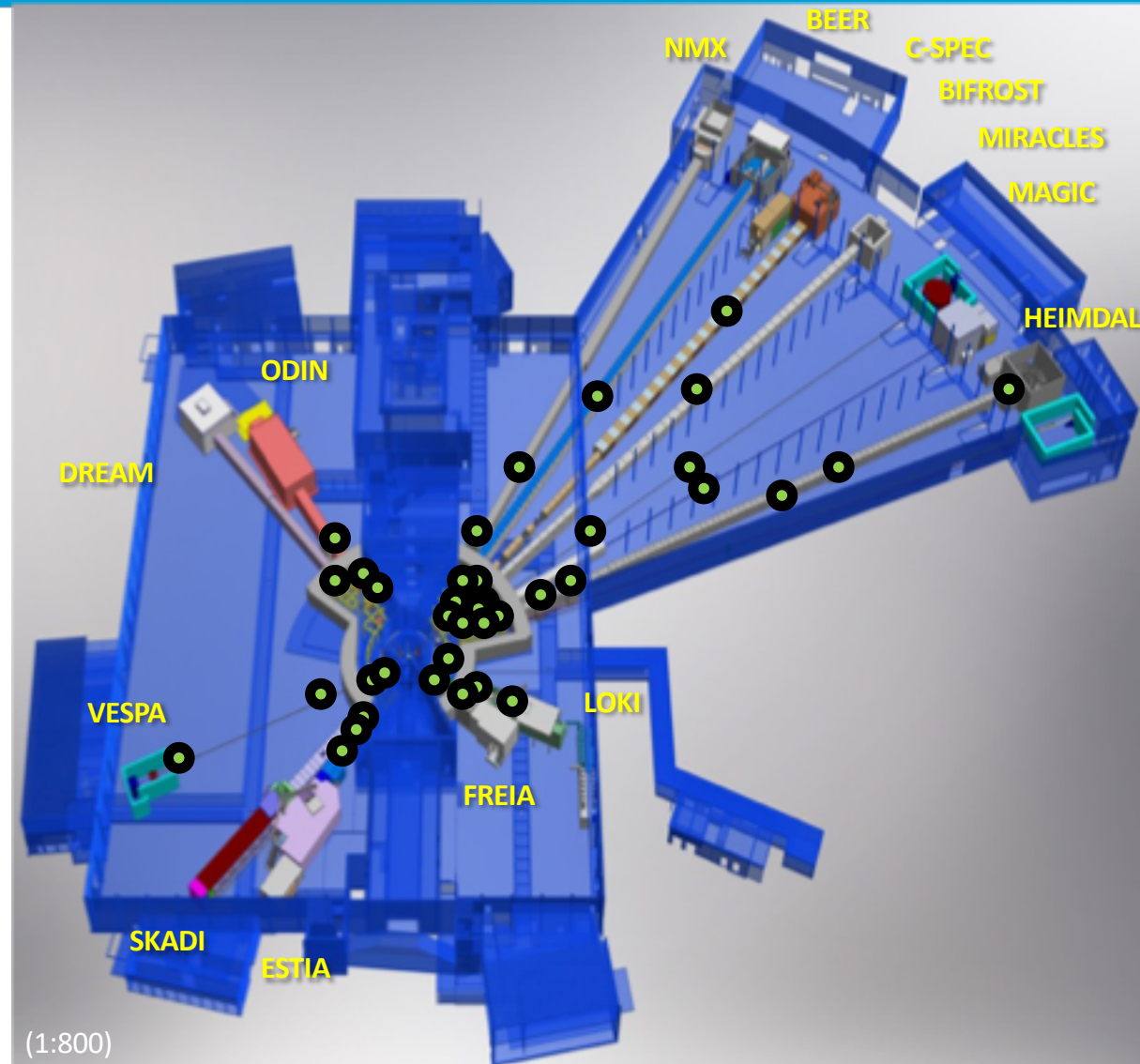- Facilitates software maintenance/upgrade

Configuration file	Python script
PVs to integrate	IOC Factory
IP addresses	PLC Factory

Controls architecture

EPICS

CHIC IOC (all PVs)

CHIC Standard Comm. template

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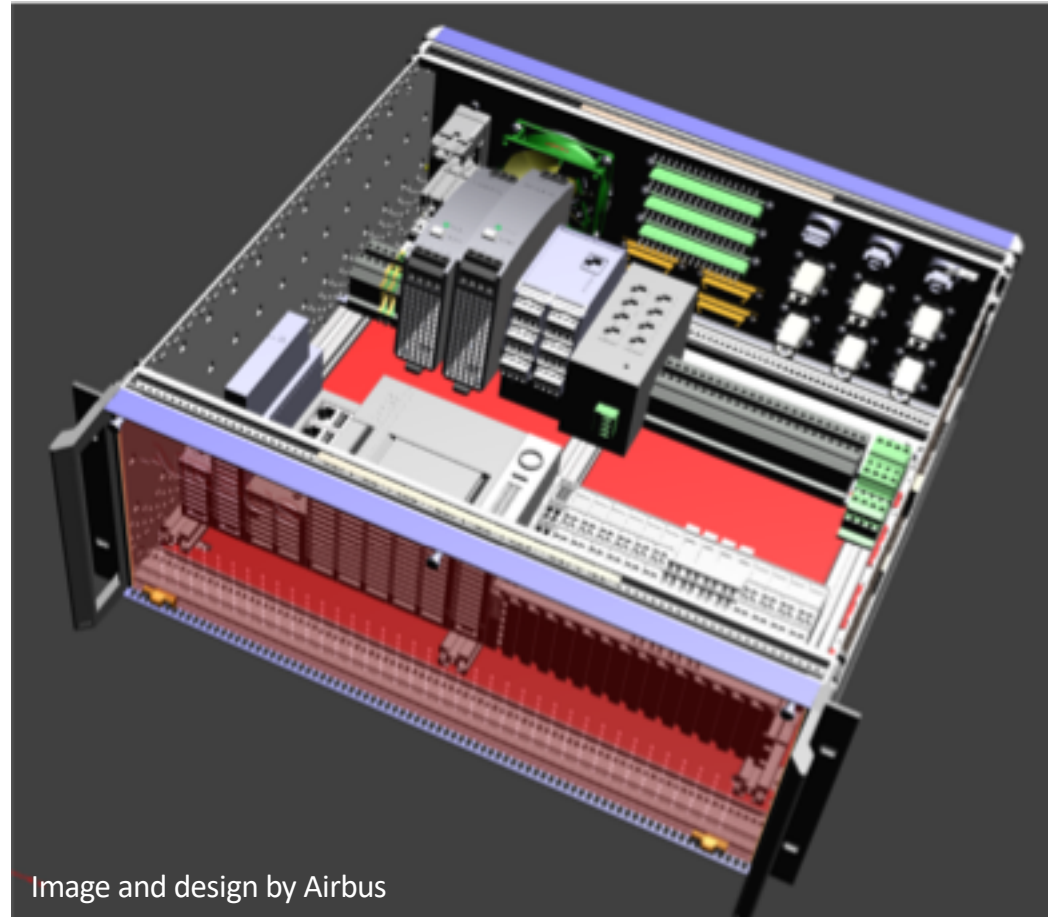
For a large scale facility

Standardise:

- ✓ Controls and monitoring
- ✓ Integration process
- ✓ Software maintenance
- Hardware
- Timing

(1:800)

Hardware

1. Subrack of 4U height
2. PLC (Beckhoff)
3. Vibration Monitoring
4. 2 x Power supply
5. Remote controlled network switch
6. Analog I/Os
7. Digital I/Os
8. Fieldbuses (Ethernet ports)
9. External hard drive

Image and design by Airbus

CHIC crate (In-kind with Jülich)

- First prototype:
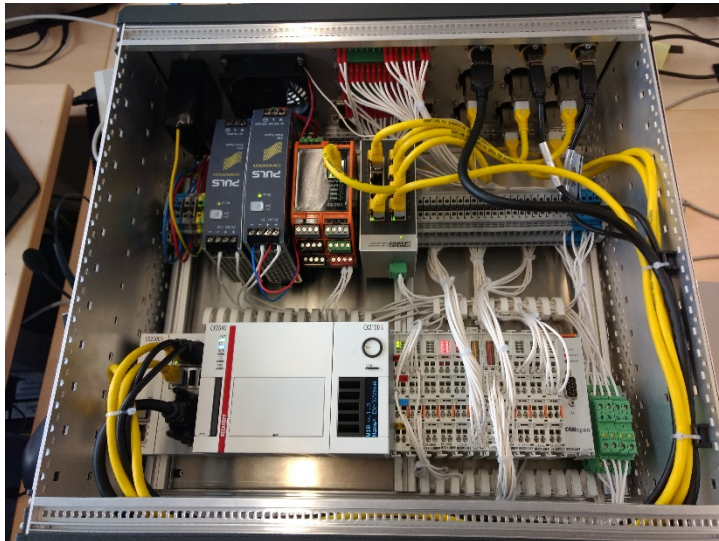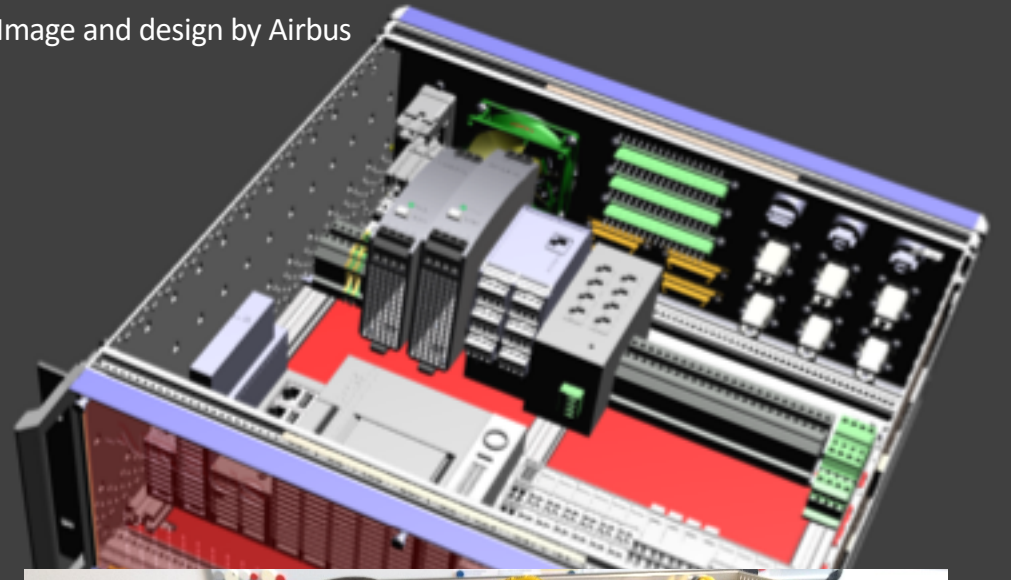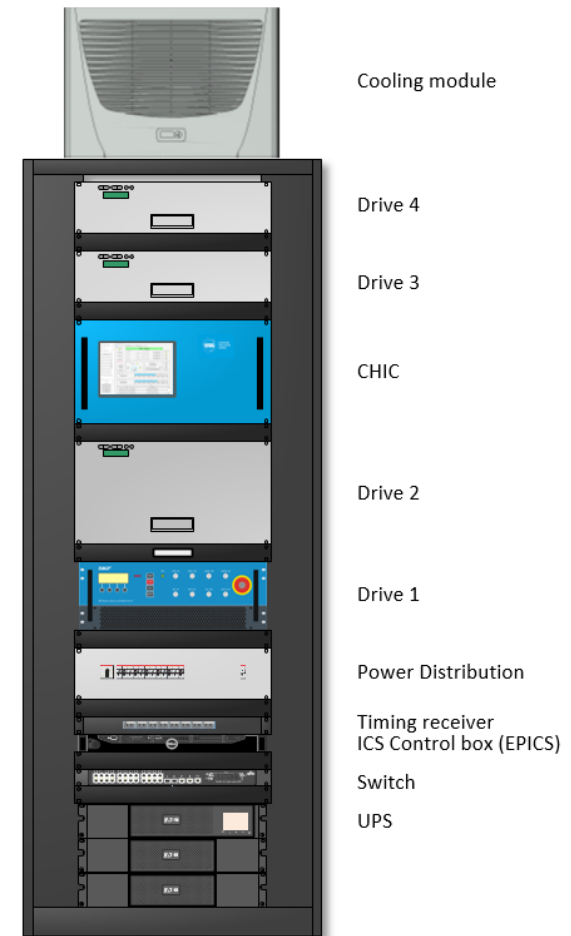 - Controls up to 4 chopper drives (due to rack space limitations)

Image and design by Airbus

Chopper control rack

- Variant of the ESS chopper standard rack
  - Designed according to ESS electrical standards and SE legislation.
- ~40 chopper racks to be installed at ESS
- Part of the control system in-kind with Jülich and Airbus.
- Per rack:
  - 1 CHIC
  - 1 EPICS IPC
  - 1 Timing system
  - Up to 4 chopper drives
  - Power distribution unit
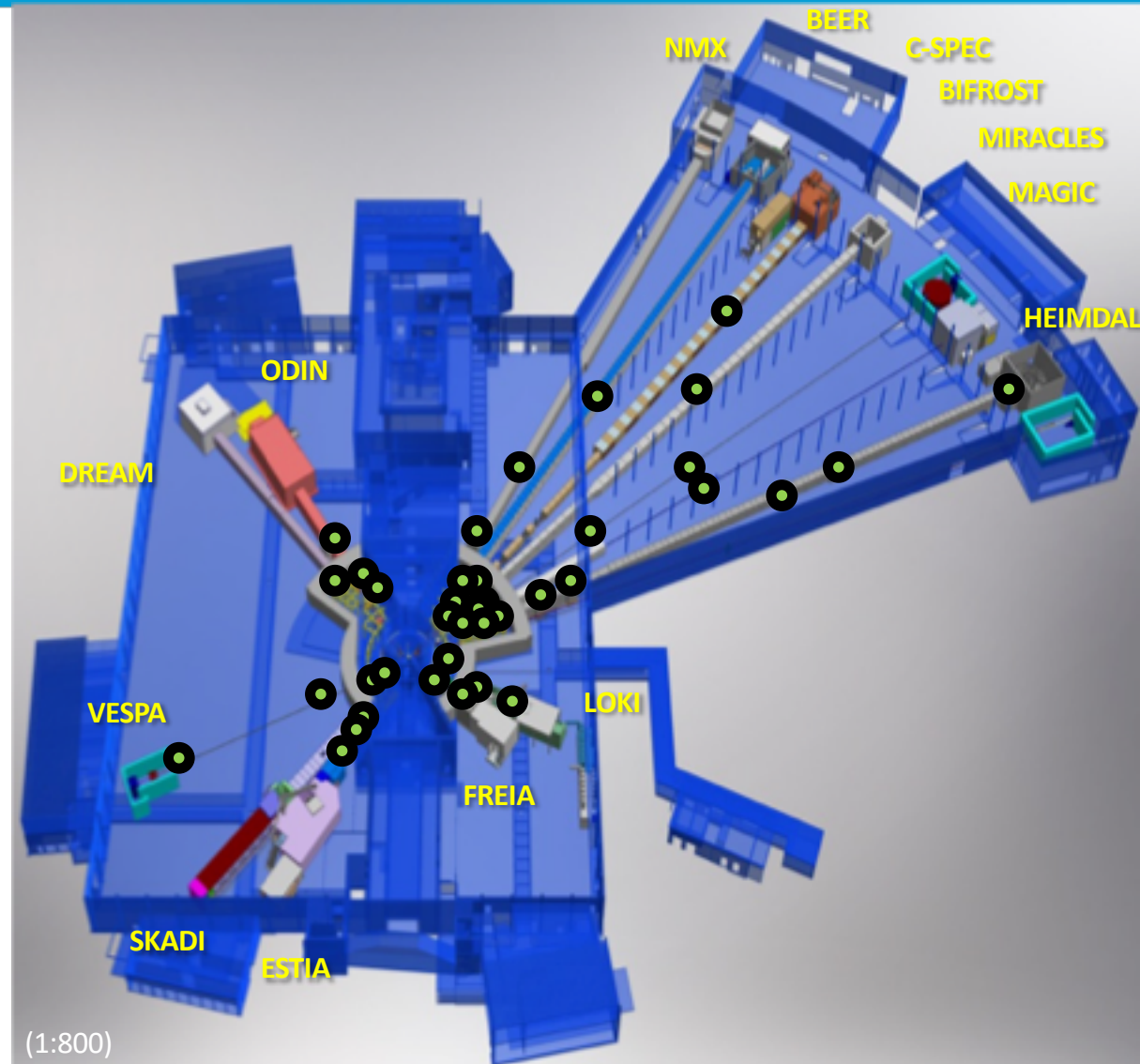 - UPS
  - Cooling unit
  - Network switch

Cooling module

Drive 4

Drive 3

CHIC

Drive 2

Drive 1

Power Distribution

Timing receiver
ICS Control box (EPICS)
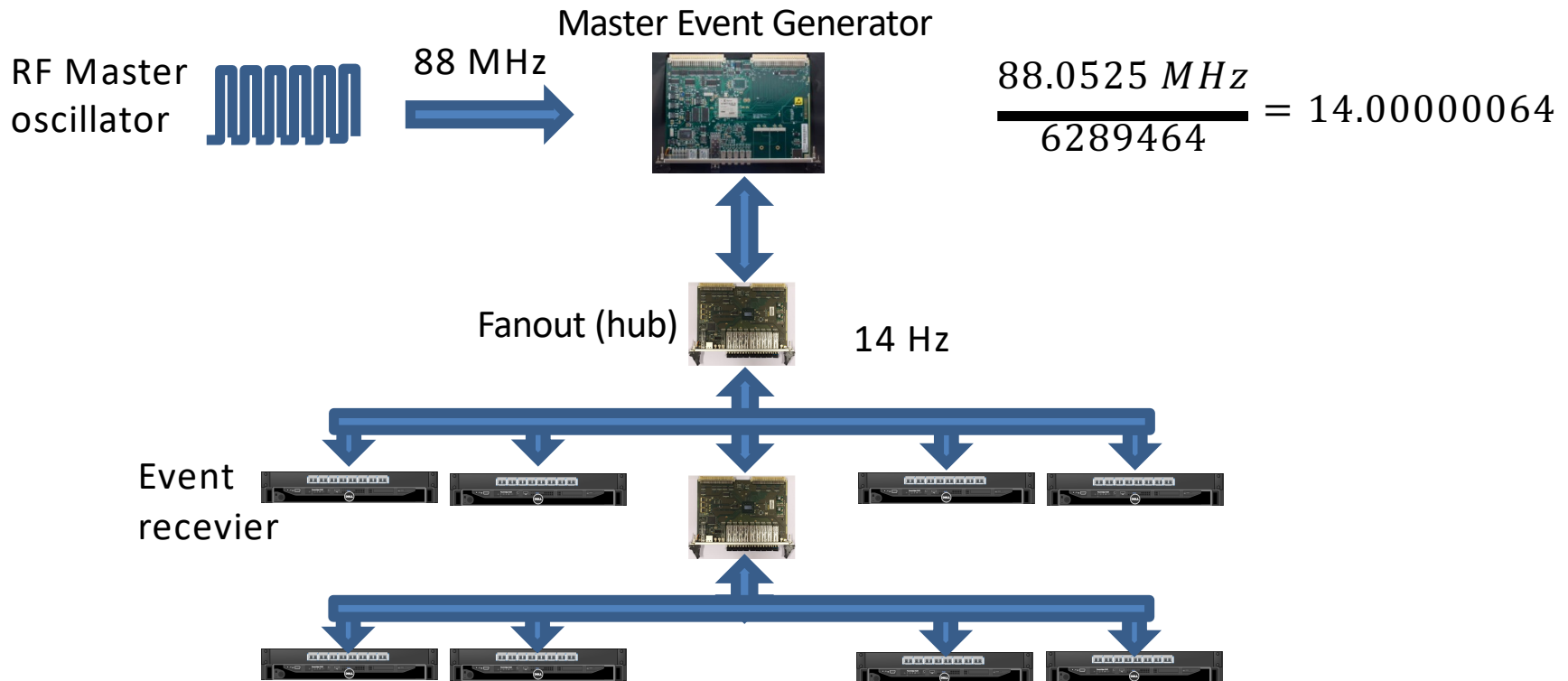
Switch

UPS

Prototype chopper control rack

For a large scale facility

Standardise:

✓ • Controls and monitoring

✓ • Integration process

✓ • Software maintenance

✓ • Hardware

• Timing

(1:800)

ESS Timing

RF Master oscillator → 88 MHz → Master Event Generator → Fanout (hub) → 14 Hz → Event recevier
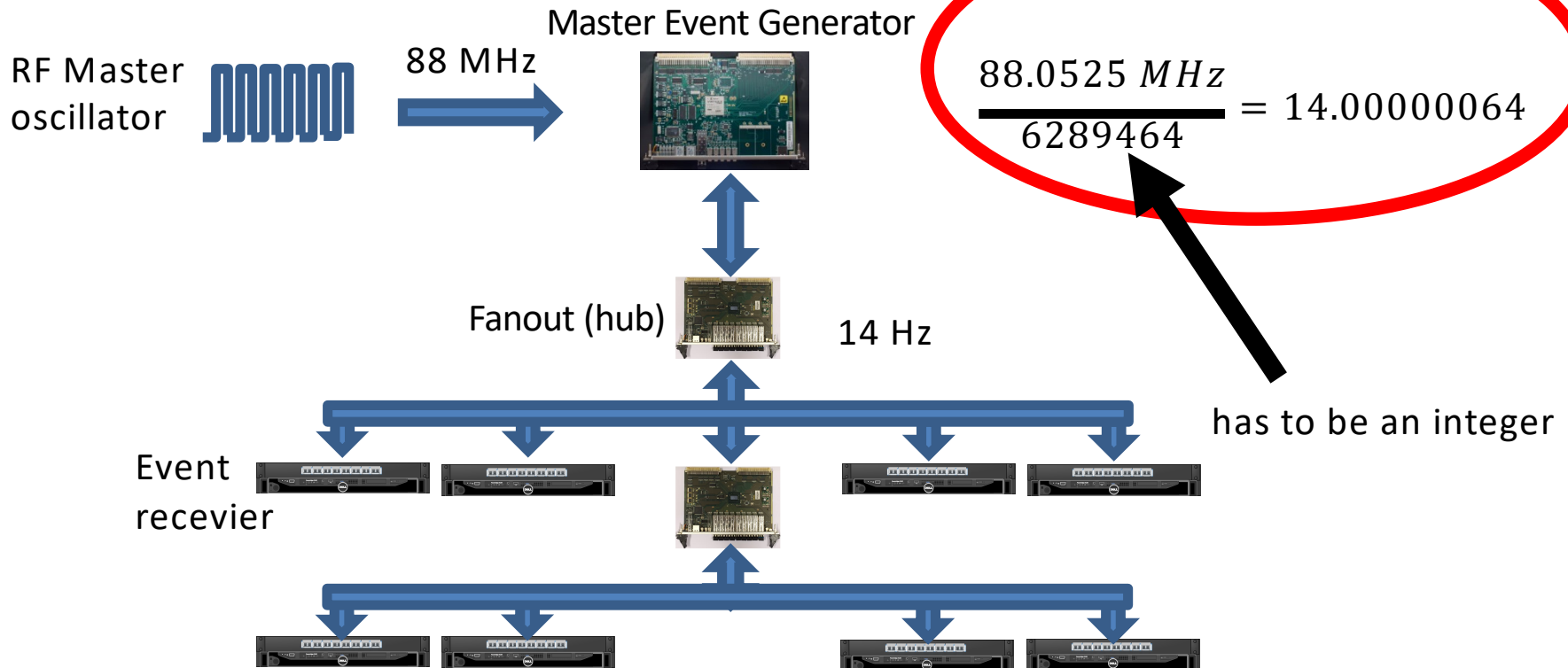
$$\frac{88.0525\ MHz}{6289464} = 14.00000064$$

- The 14 Hz operating frequency will be generated by down conversion from RF in the event generator (divide 88.0525 MHz by 6289464 to get 14.00000064 Hz)
- All timing sequences, events, etc., generated in hardware
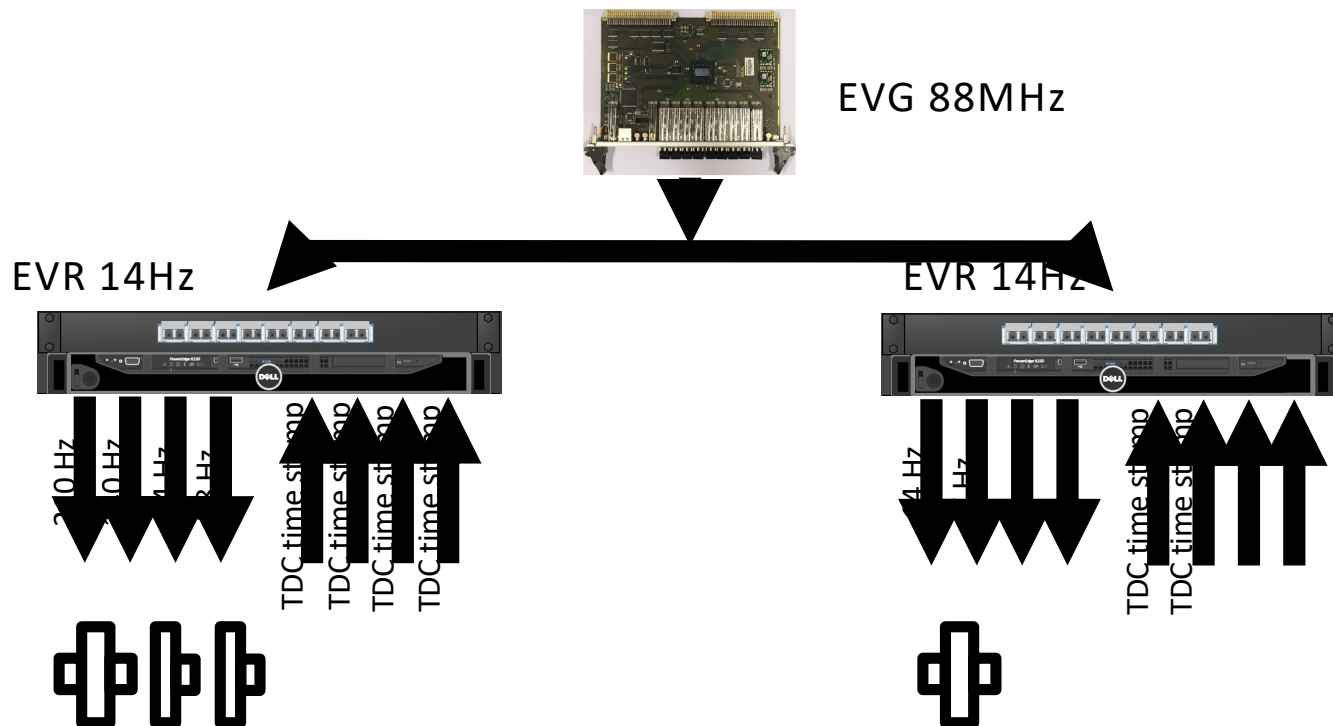- One event generator for ESS

ESS Timing

RF Master oscillator 88 MHz → Master Event Generator

$$\frac{88.0525\ MHz}{6289464} = 14.00000064$$

has to be an integer

Fanout (hub) 14 Hz

Event recevier

- The 14 Hz operating frequency will be generated by down conversion from RF in the event generator (divide 88.0525 MHz by 6289464 to get 14.00000064 Hz)
- All timing sequences, events, etc., generated in hardware
- One event generator for ESS

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ESS Chopper Timing

- Every rack will have an event receiver (EVR) that will provide reference frequencies to the choppers.
- Frequencies from 3.5Hz to at least 336 Hz will be created. (14Hz-350Hz tested)

EVG 88MHz

EVR 14Hz

EVR 14Hz

ESS Chopper Timing

- Normally it would make sense to use a different prescaler (divider) to produce higher frequencies

- Bifrost requires 210,0000095 Hz with the closest integer I will get 209,9998092 Hz
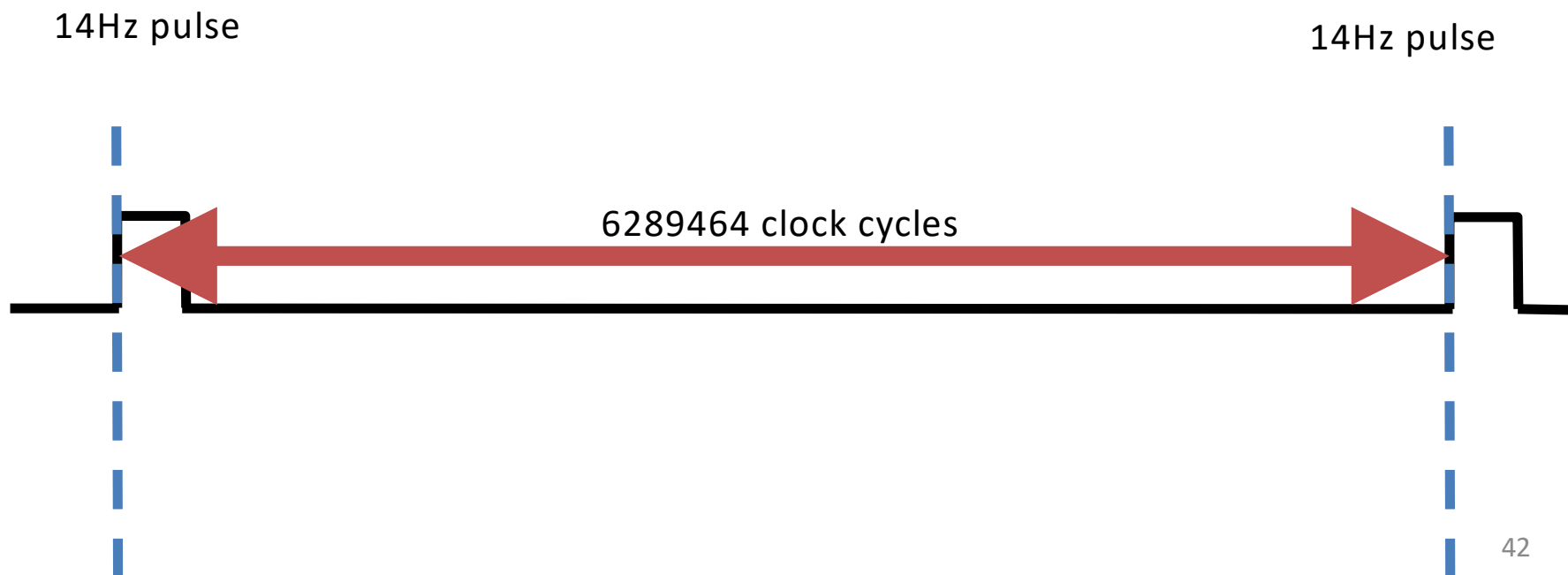
ESS Chopper Timing

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ESS Chopper Timing

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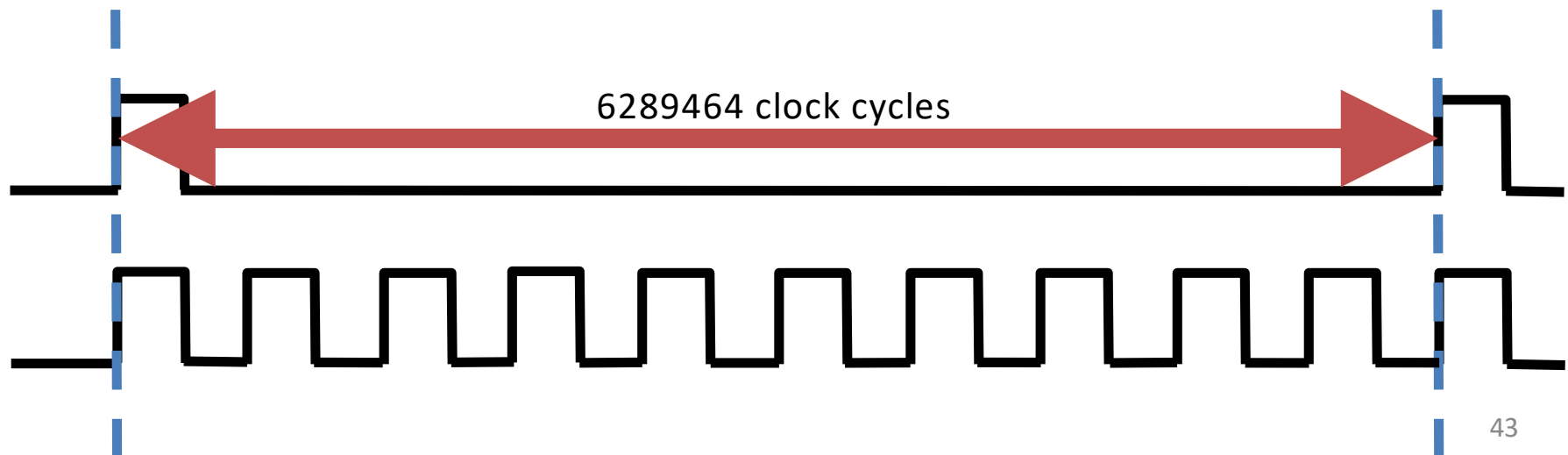
There is a solution

ESS Chopper Timing

14Hz pulse

14Hz pulse

6289464 clock cycles

ESS Chopper Timing

- Pulse train consists of pulses generated at specific clock cycles
- The predefined "pulse train" is triggered by the 14Hz event
- The "pulse train" is regenerated at every 14 Hz pulse
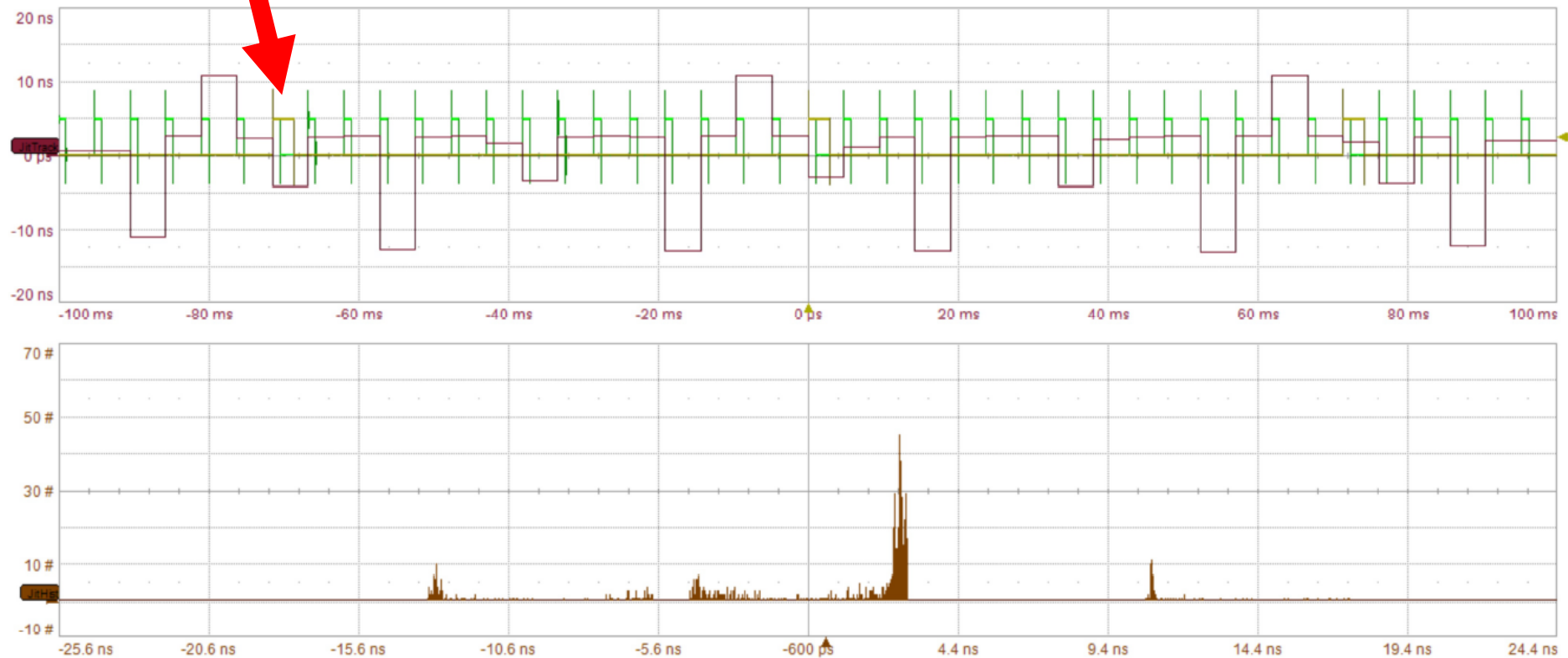- Every pulse in the pulse train can be adjusted back and forth in time with a resolution of 11,3 ns.

14Hz pulse

14Hz pulse

6289464 clock cycles
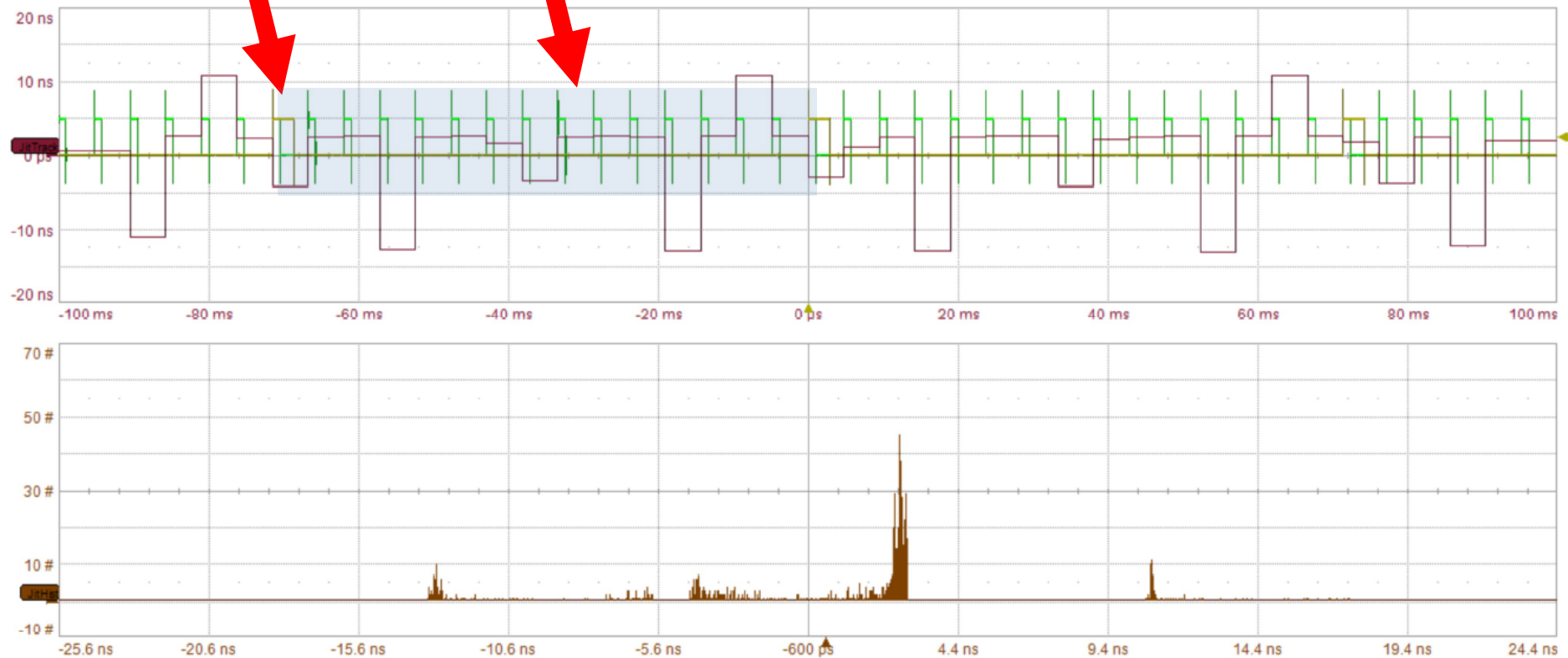
Experiment 210Hz

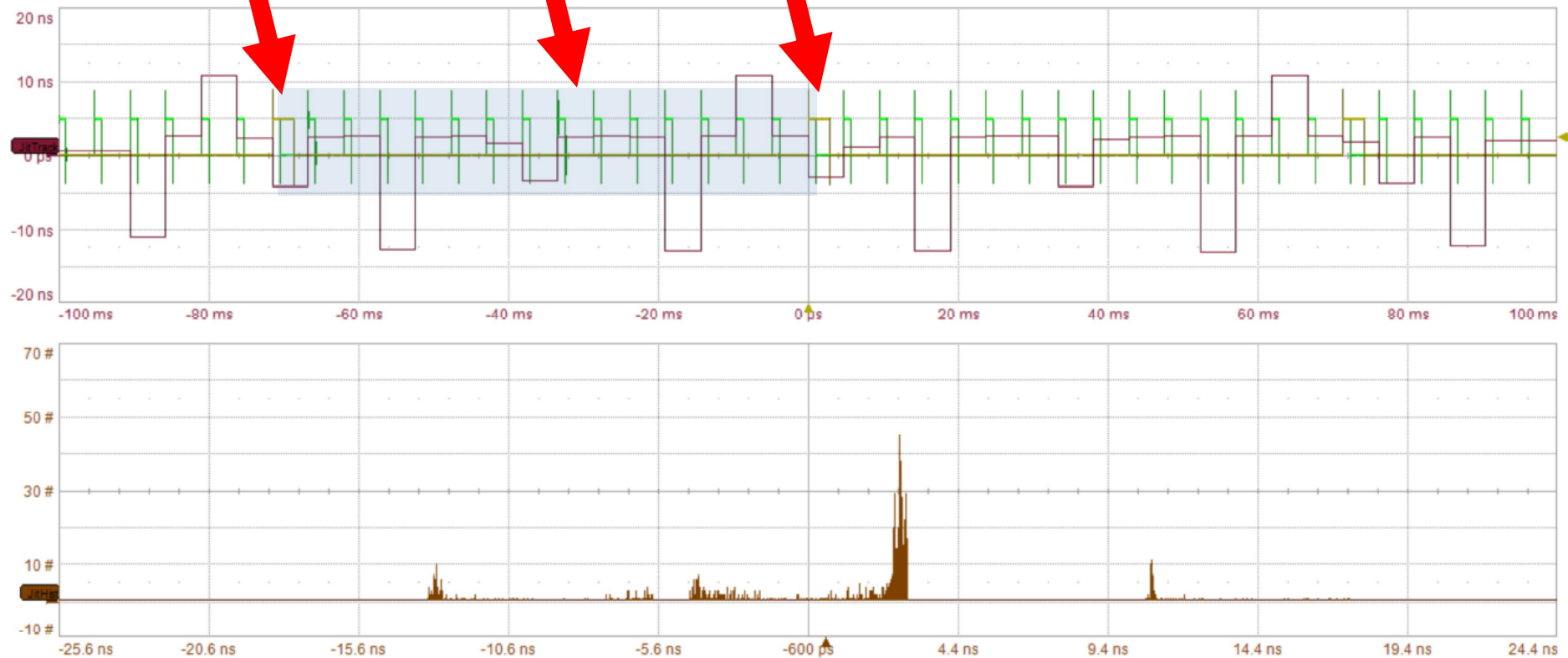14Hz pulse

Experiment 210Hz

14Hz pulse

Pulse train
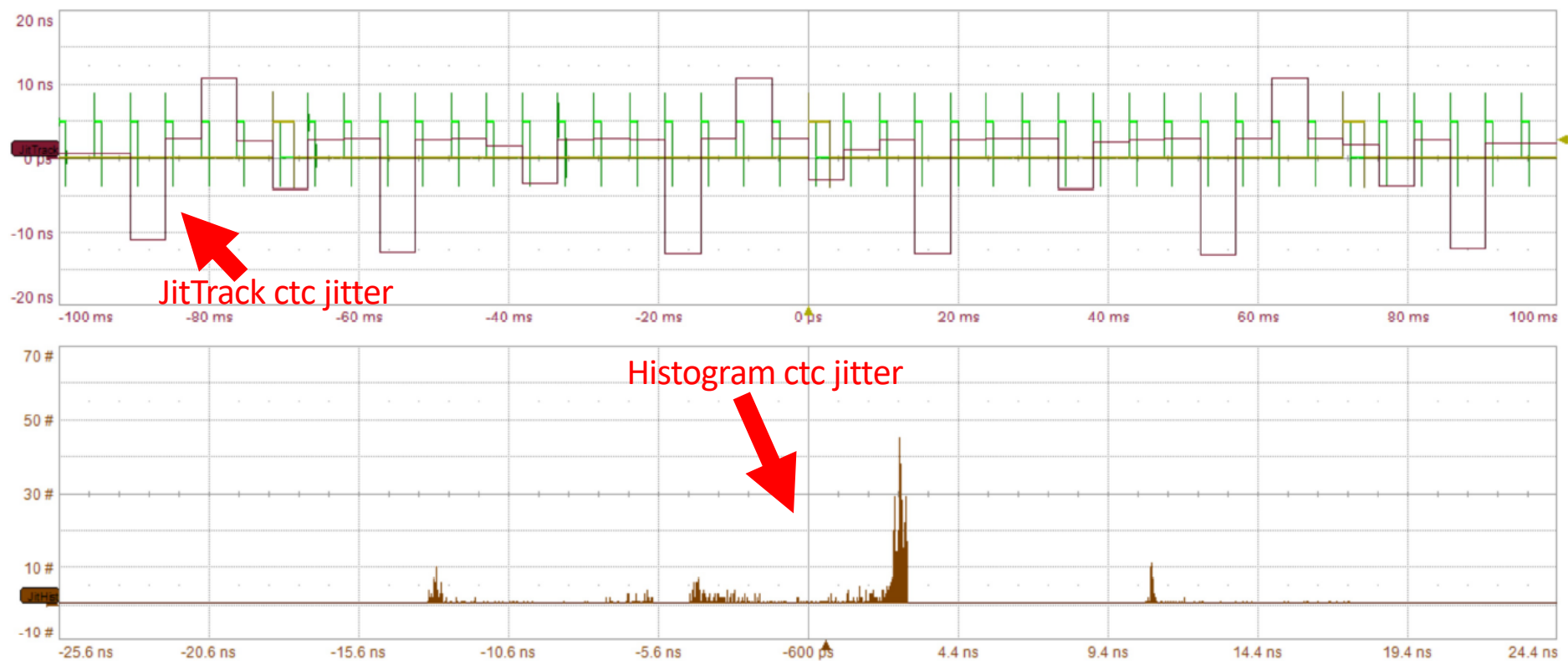
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Experiment 210Hz
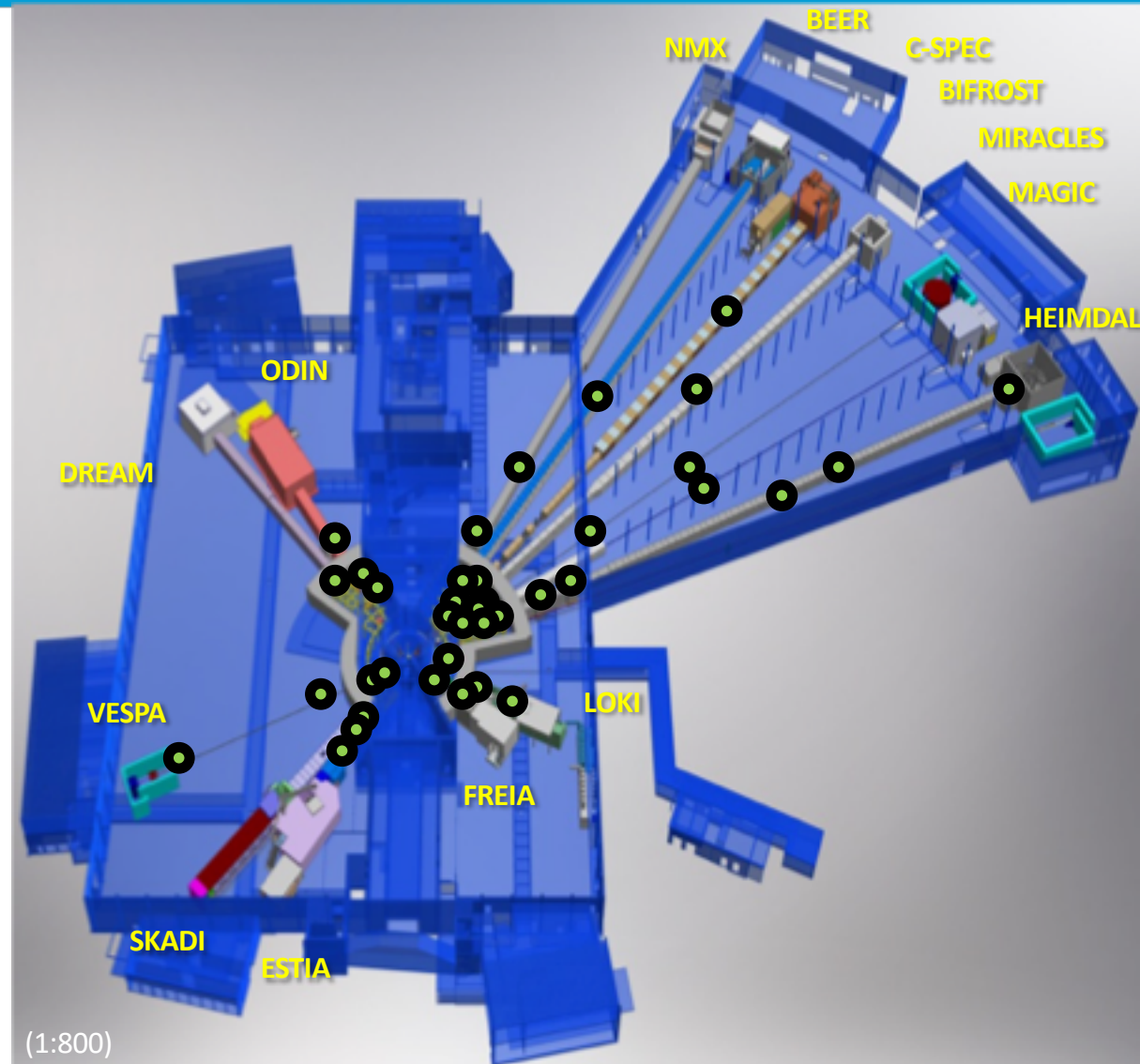

14Hz pulse Pulse train 14Hz pulse

Experiment 210Hz

14Hz pulse

Pulse train

Experiment 210Hz

JitTrack ctc jitter

Histogram ctc jitter

For a large scale facility

Standardise:

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Acknowledgements

- Markus Olsson
- Nikolaos Tsapatsaris
- John Sparger
- Kristian Löki
- Miklos Bóros

- David Brodrick
- Nicklas Holmberg
- Javier García
- Thomas Gahl
- Airbus Space and Defense

We hope to say in the future:

- Any neutron chopper system in the world is compatible with ESS control system.

- ESS does not have drifting choppers.

SKF control from the CHIC