ICRR
Institute for Cosmic Ray Research
University of Tokyo

# 計算機を利用した~~LCGT~~の制御(II)
# KAGRA

2012/3/24(土) 日本物理学会2012年年次大会
於　関西学院大学　西宮上ヶ原キャンパス

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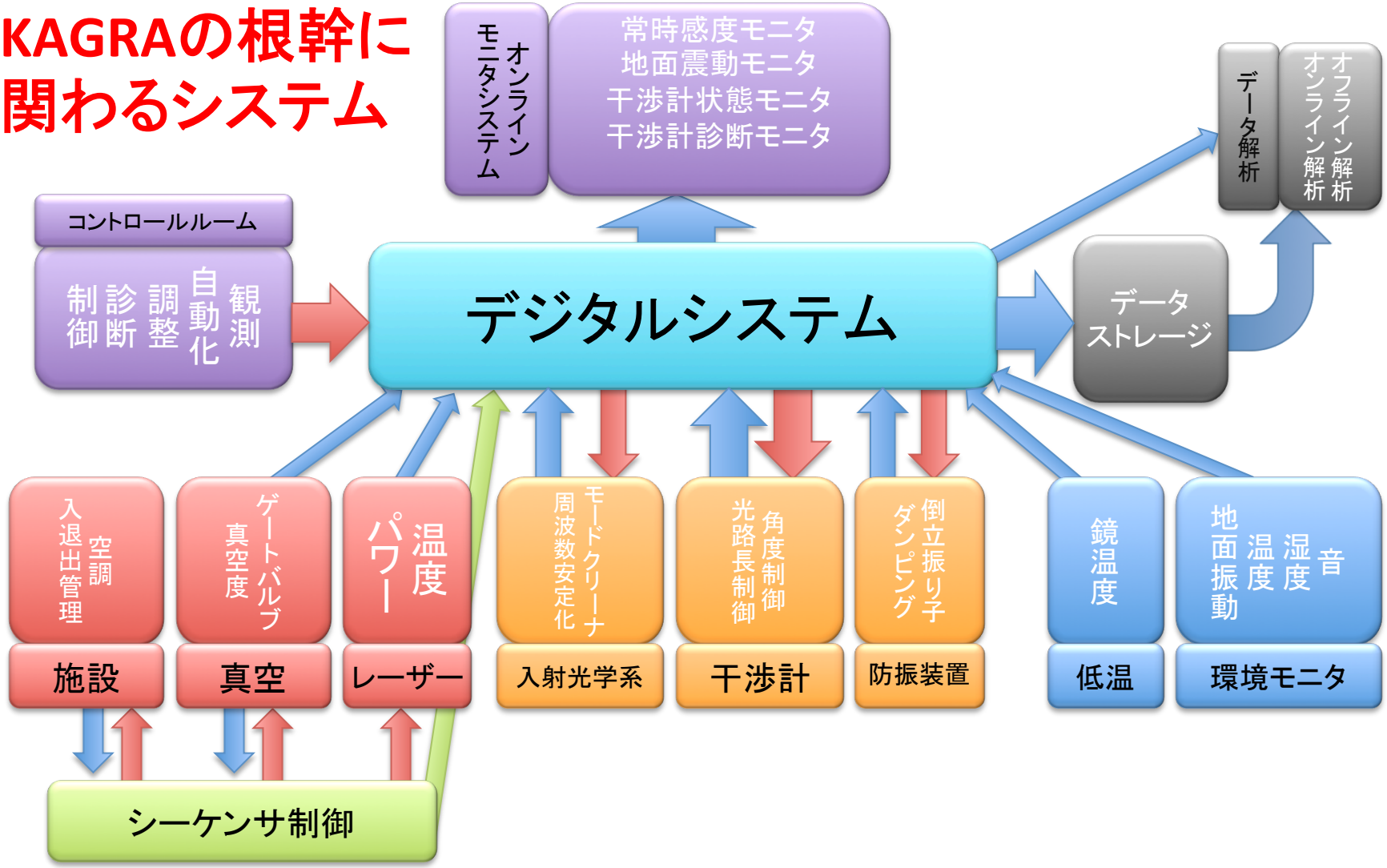
LCGT collaboration

# KAGRAに必要な計算機による制御

1. リアルタイム制御としての役割
   - 複雑な多自由度制御への対応
2. 重力波データ取得システムとしての役割
   - 制御信号＝重力波データ
3. 干渉計調整システムとしての役割
   - 感度向上までの時間短縮
4. 干渉計自動運転としての役割
   - 安定した観測体制
5. 各種情報収集システムとしての役割
   - 多チャンネル信号の自動割り振り

# 各種サブシステムとの関連

**KAGRAの根幹に関わるシステム**



# Schedule for KAGRA RT control

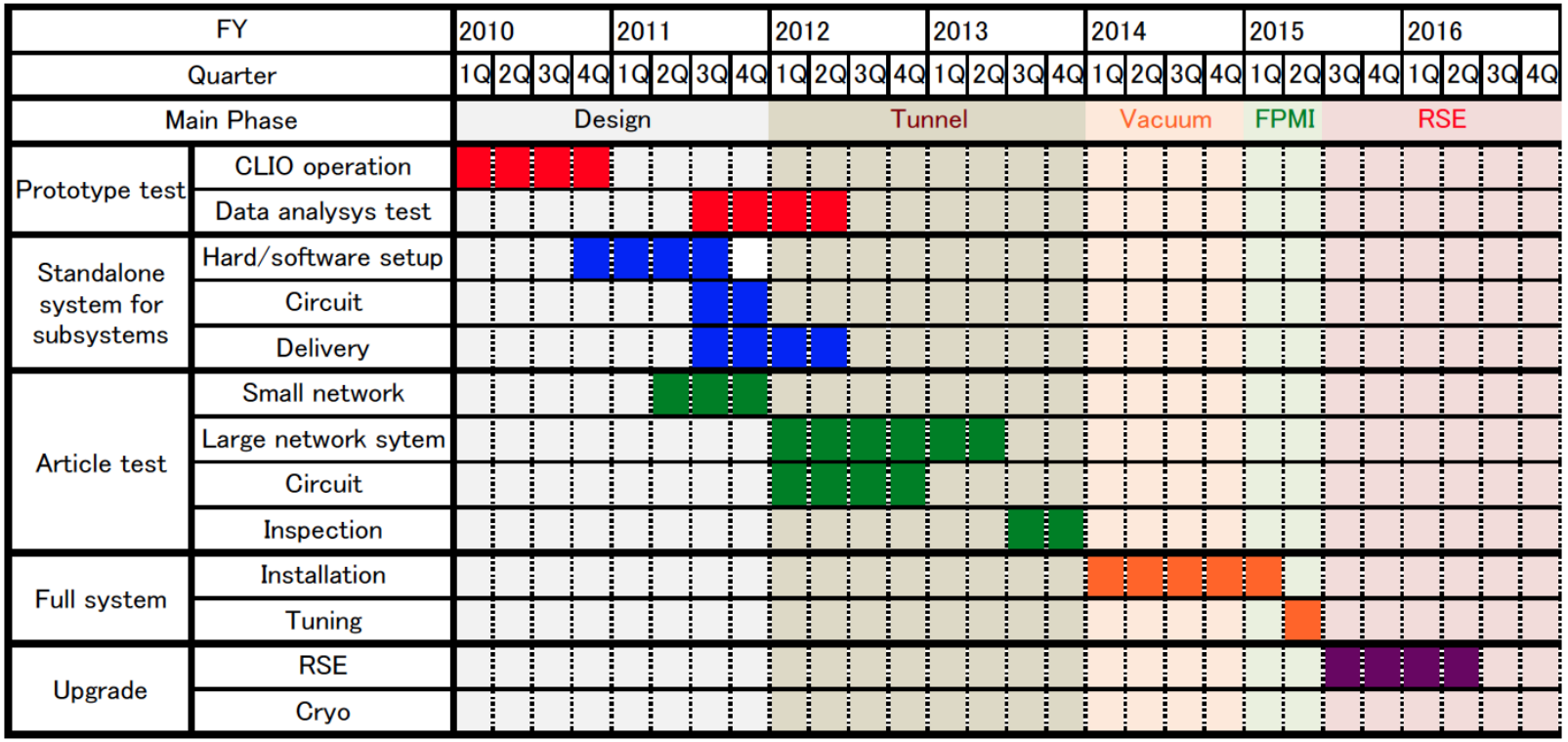
A. 2009-2010 prototype test @ CLIO
   - Basic IFO operation and noise performance

B. 2011~ standalone system for subsystem
   - Data analysis, VIS, (IOO, CRY…)

C. 2011 Small network test with 1 master and 2 RT PCs
   - GE RFM, Dolphin RFM, DAQ, timing network

D. 2012-2013 Full test@ Kamioka new facility
   - Constructing many RT rack modules

→ Installation into mine



# Standalone system for subsystems

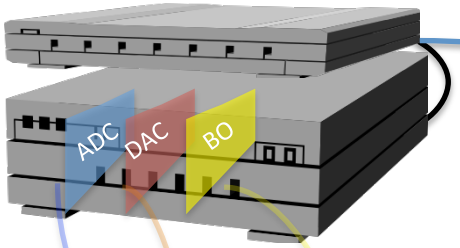
5sets of stand alone digital system are constructed at Kamioka building and will be delivered to subgroups in FY2011/FY2012

1. Real time control computer as front-end
2. Client workstation PC with software setup
3. PCIe I/O chassis for ADC/DAC/BO modules
4. ADC, DAC, Binary Output
5. Anti Alias/Anti imaging filters
6. 10A DC power supply x2
7. 19'' rack etc.

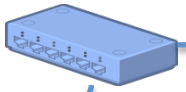
- good chance for subgroups to be accustomed with a digital system before the commissioning of KAGRA

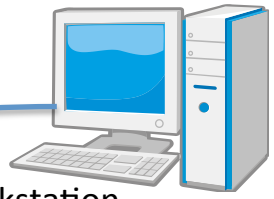
# Connection with subsystems

Front-end PC + IO chassis
- Real time core




Network router



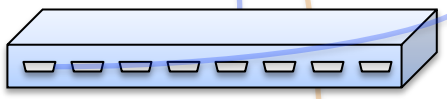


Workstation
- Dataviewer(oscilloscope)
- DTT(FFT)
- Foton(digital filter setting)

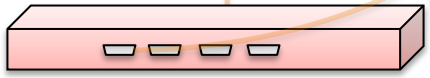
Prepared by each subgroup

Interface/driver box
- Variable gain stage
- Whitening
- dewhitening filter
- Switch by BO

Anti Alias Chassis

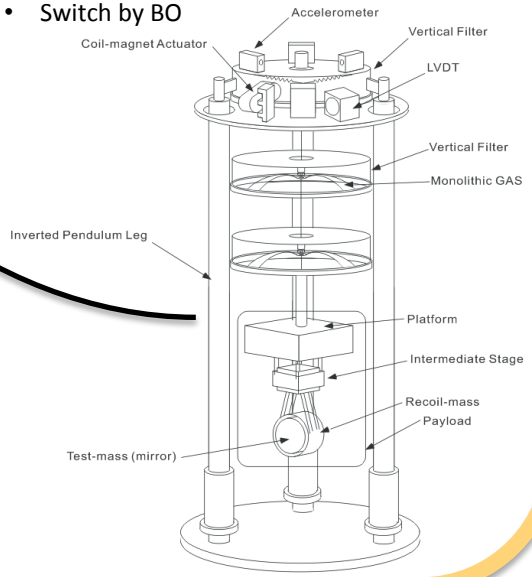


Anti Image Chassis



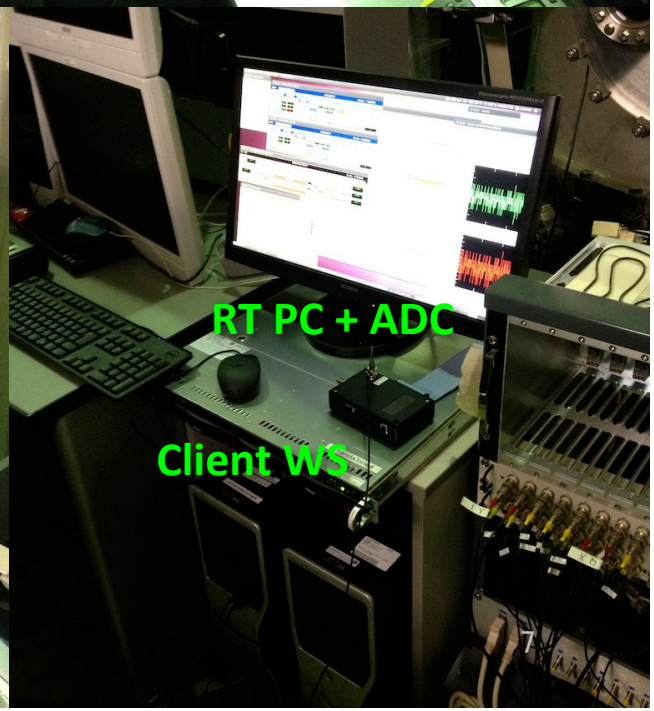
Binary Output interface box

:D-sub connector

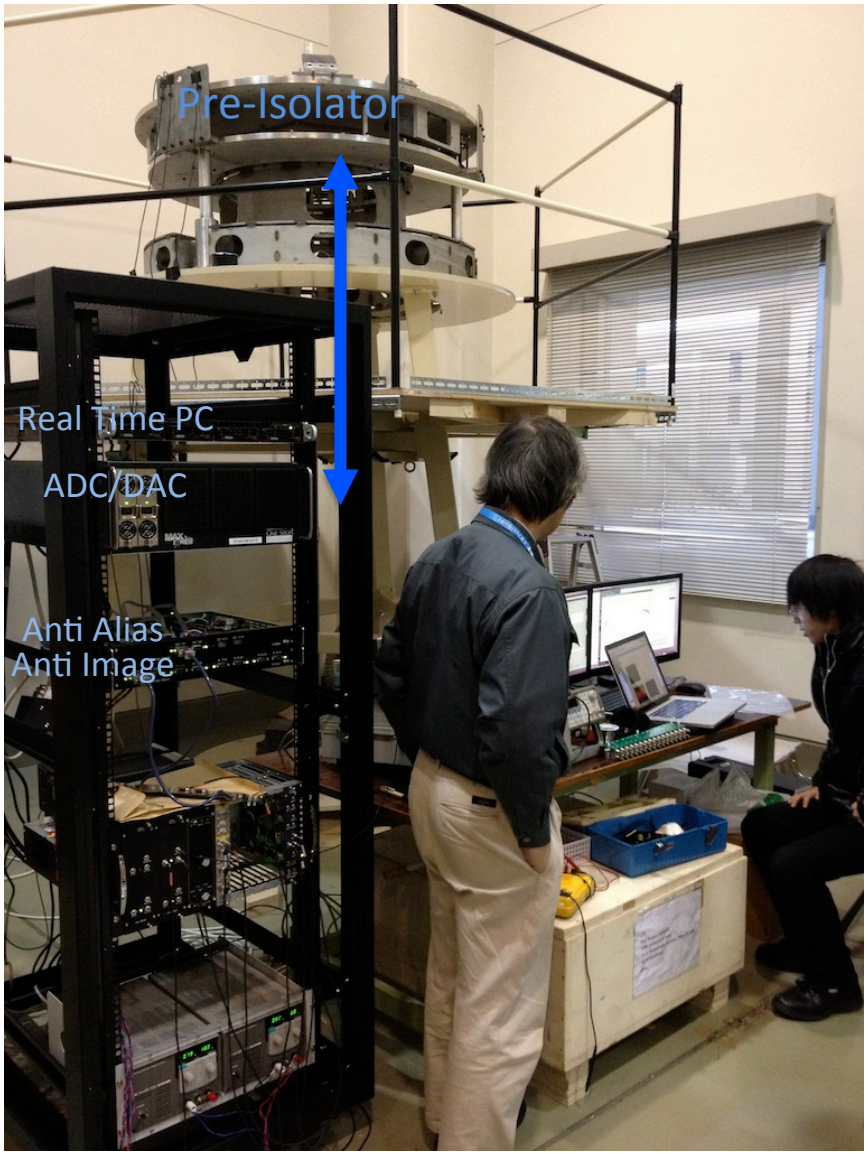


# Delivering standalone digital system to NAO for online data analysis

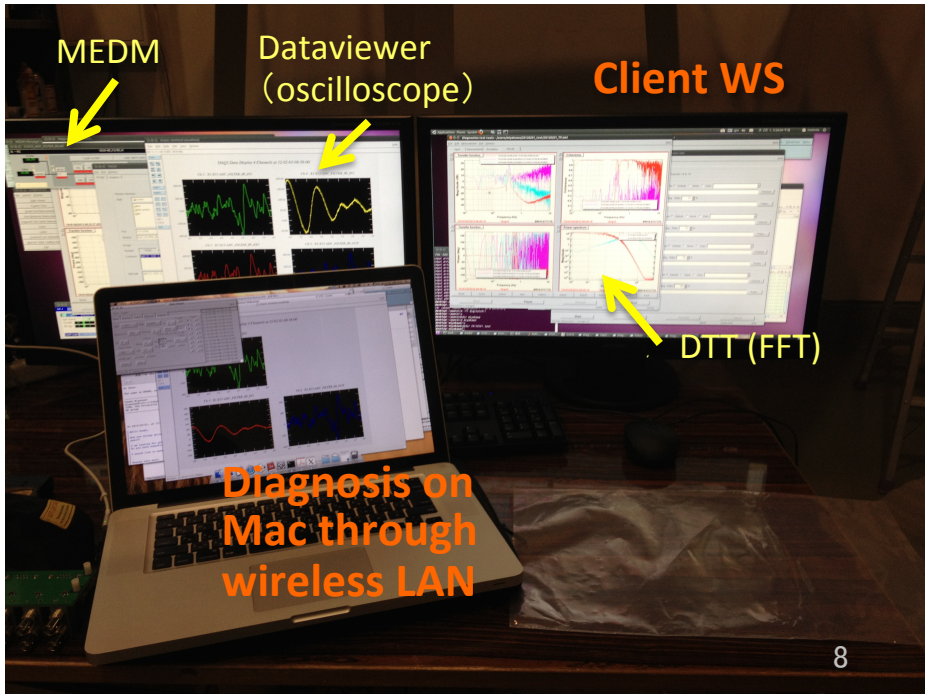
- Simple standalone system (RT PC + ADC, Client WS, router) has been delivered to NAOJ on 12/6/2011.
- 3days work for installation, lecture and training
- Online analysis software will be developed by DAS group.

# Delivering standalone digital system to VIS group at ICRR, Kashiwa




- Simple standalone system (RT PC + ADC/DAC, AA/AI, Client WS, router) has been delivered to VIS group at Kashiwa on 1/30/2012.
- 3days work for installation, lecture, training and measurement/control



# Preparation for mass production of electronics for digital system

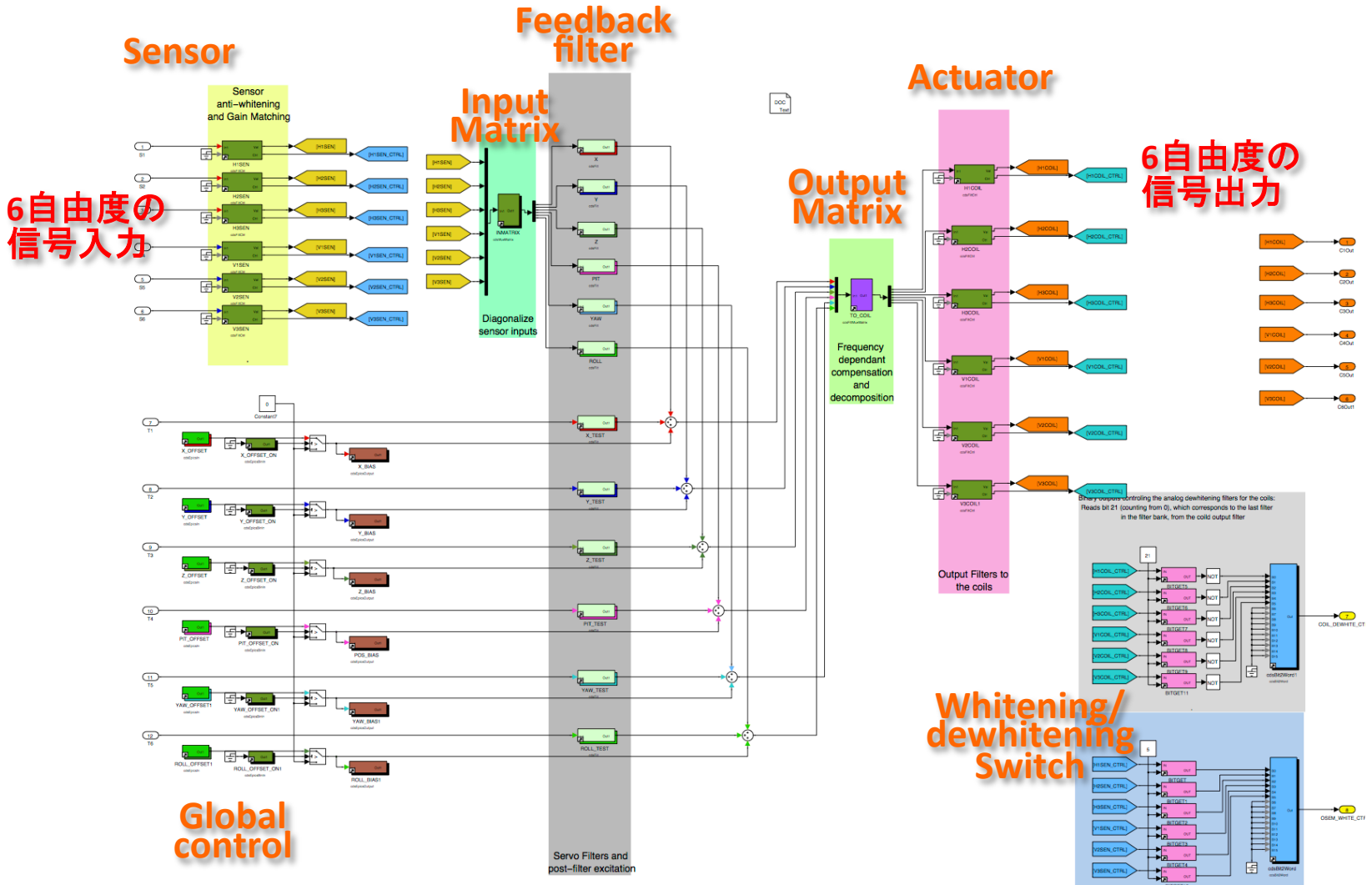

- 6 layers circuit board
- 0.2A/board

- Same boards for AA/AI by reversing
- 8 D-SUB 9pin connectors as 32/16ch signals input at front panel for ADC/DAC

- SCSI 68pin connector as input/output at rear panel
- D-SUB 3pin connector as DC power supply input

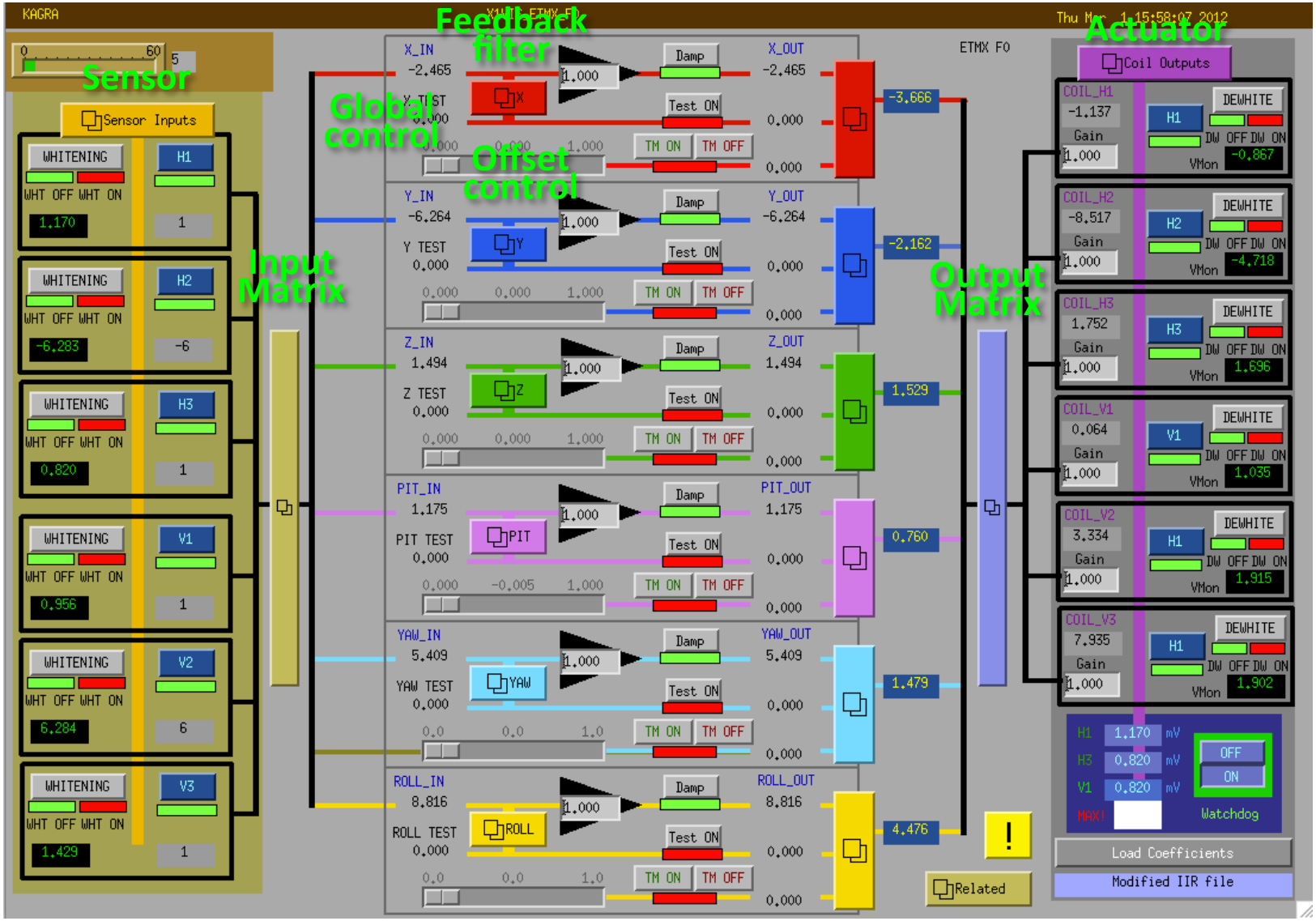
大量の回路
KAGRA全体で合計500枚
組み立て（電源、箱）
全チャンネルのチェック

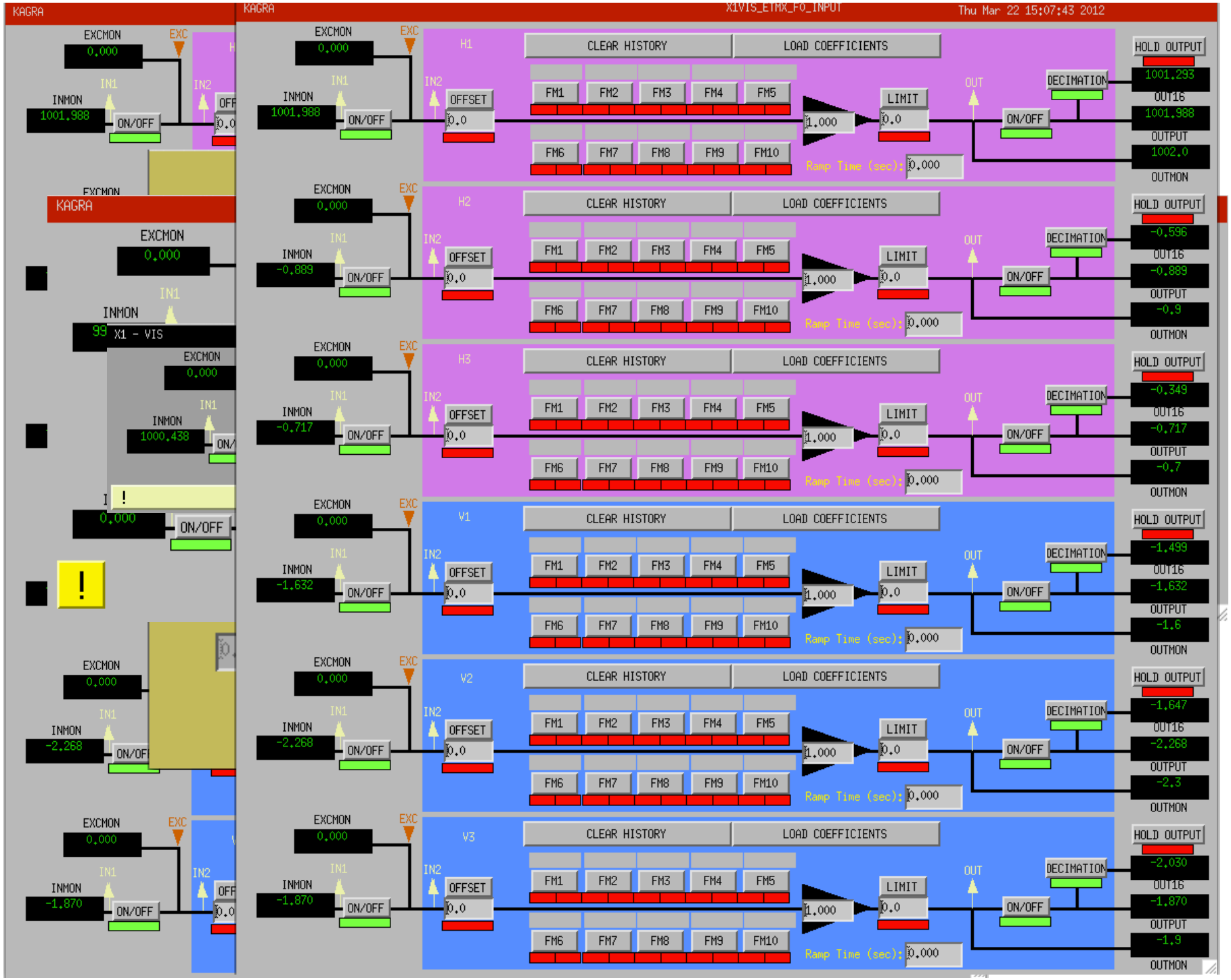
# Real time model for Pre-Isolator



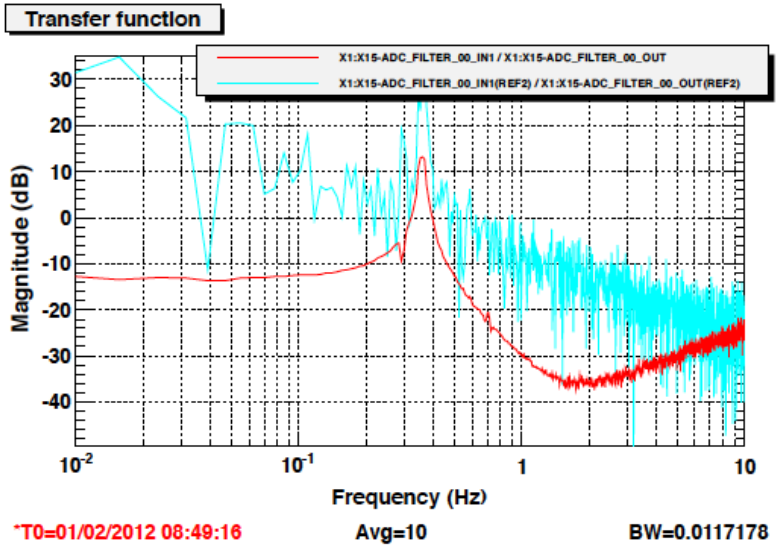

- このGUIのデザインをもとにCのコードが生成され、ビルドされる。
- RT coreはカーネルのモジュールとして動作する

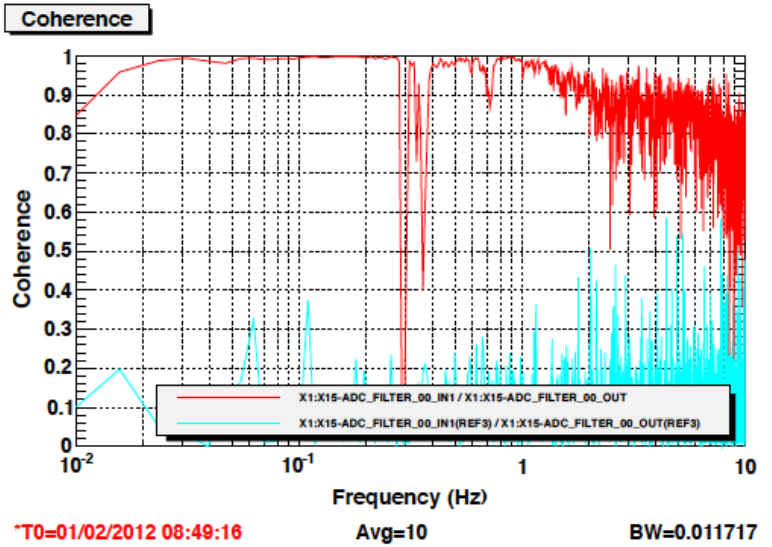
# MEMD screen -- GUI for EPICS --

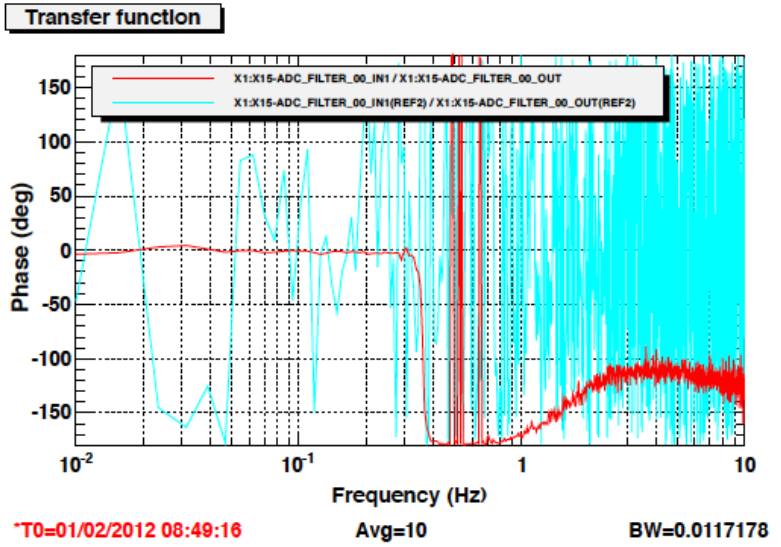


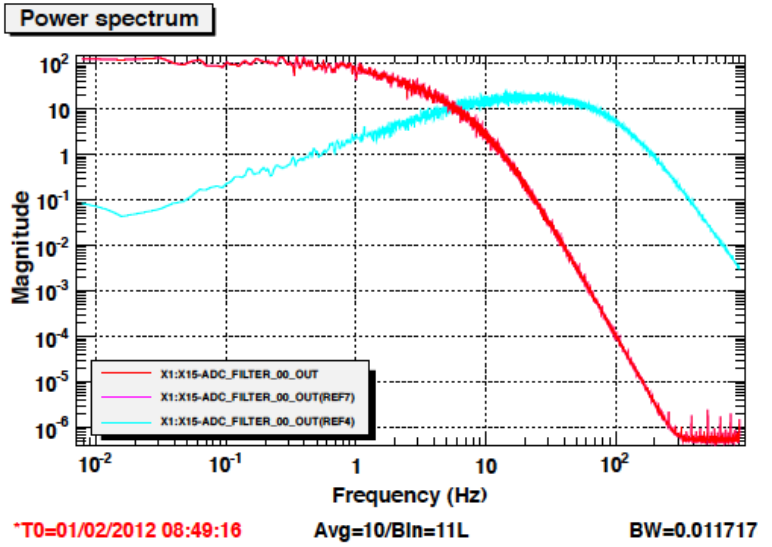

KAGRA
X1VIS_ETMX_FO_INPUT
Thu Mar 22 15:07:43 2012
H1
H2
H3
V1
V2
V3
EXCMON
INMON
IN1
IN2
EXC
OFFSET
ON/OFF
CLEAR HISTORY
LOAD COEFFICIENTS
FM1
FM2
FM3
FM4
FM5
FM6
FM7
FM8
FM9
FM10
LIMIT
OUT
DECIMATION
Ramp Time (sec):
HOLD OUTPUT
OUT16
OUTPUT
OUTMON
1001.988
1001.293
1002.0
-0.889
-0.596
-0.9
-0.717
-0.349
-0.7
-1.632
-1.499
-1.6
-2.268
-1.647
-2.3
-1.870
-2.030
-1.9
99 X1 - VIS
1000.438

# Response of Pre-Isolator vertical motion measured by digital system

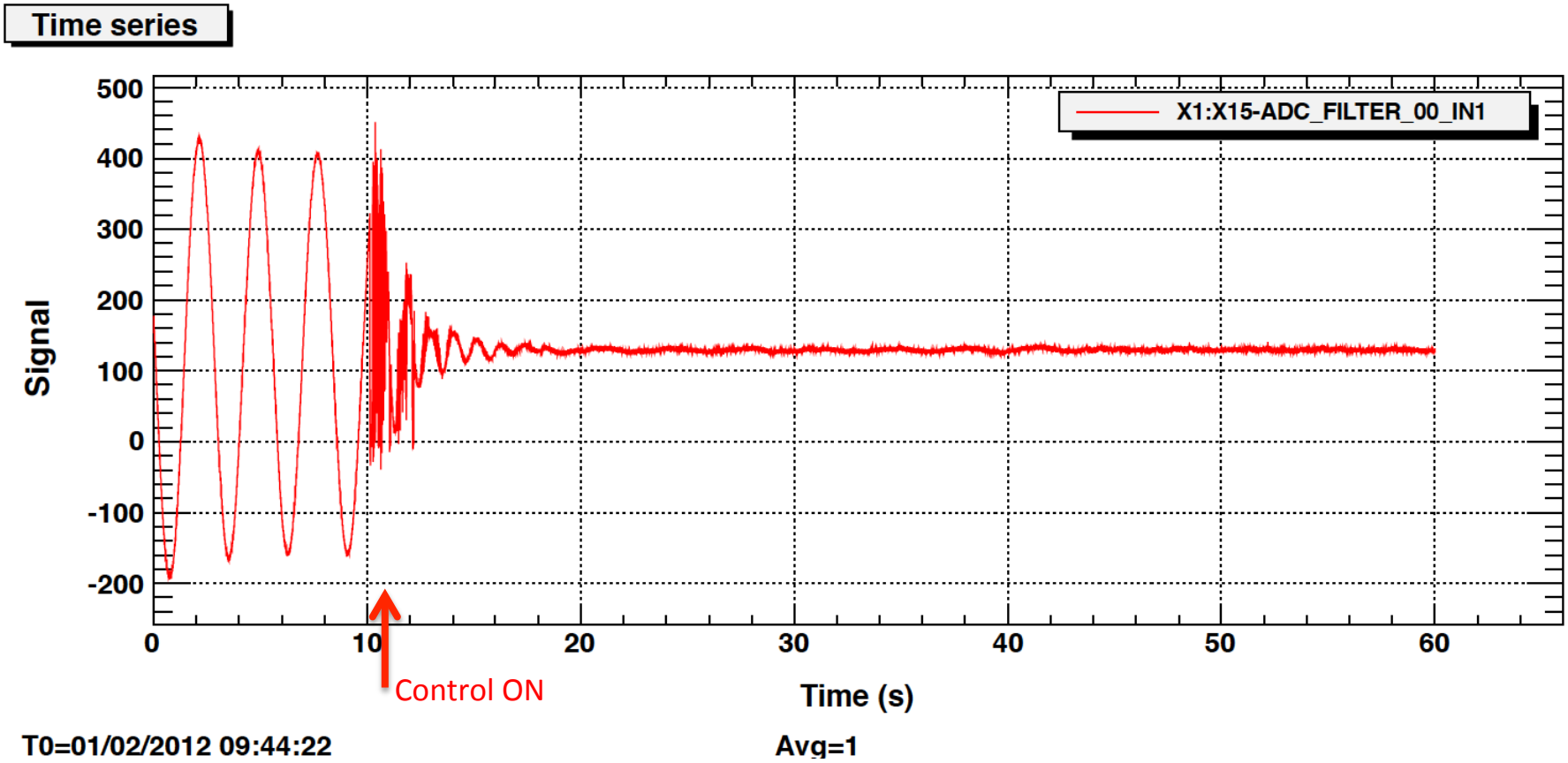


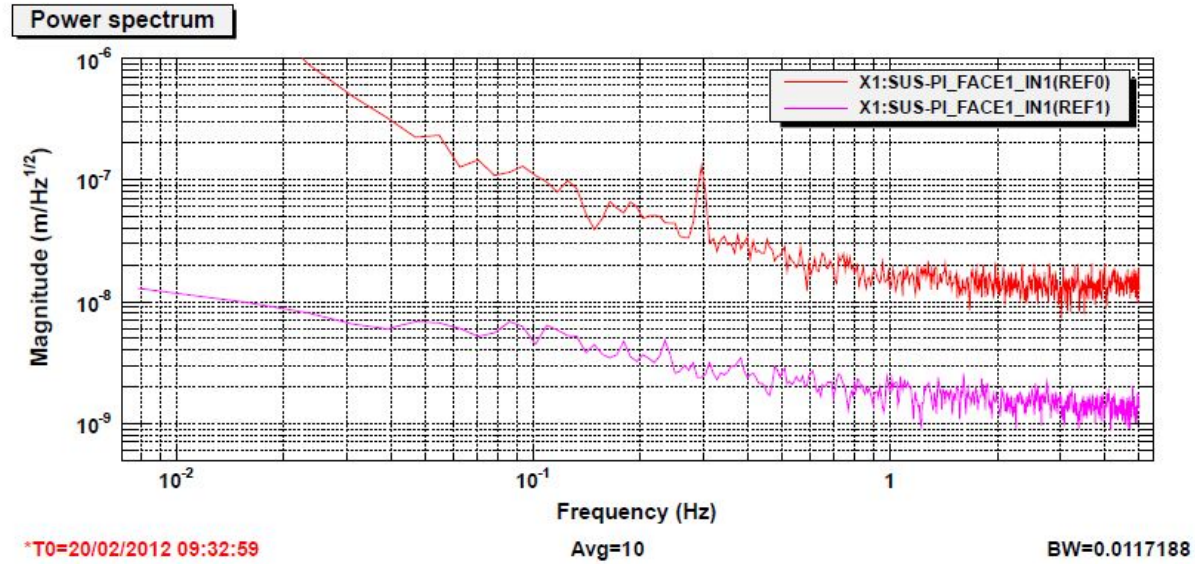



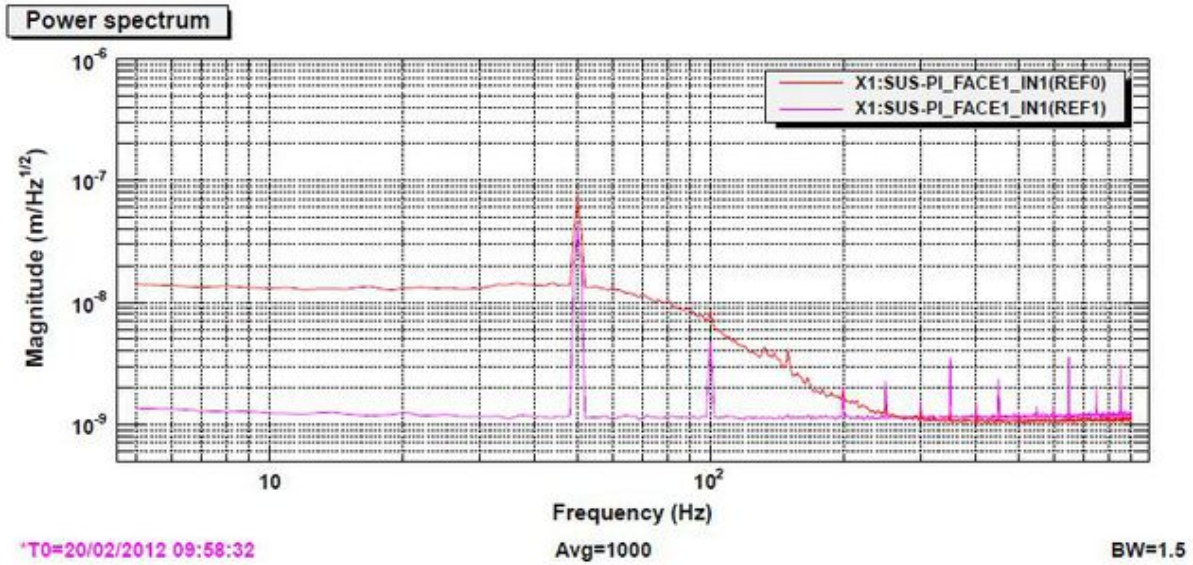
# First control for Pre-Isolator vertical motion using digital system



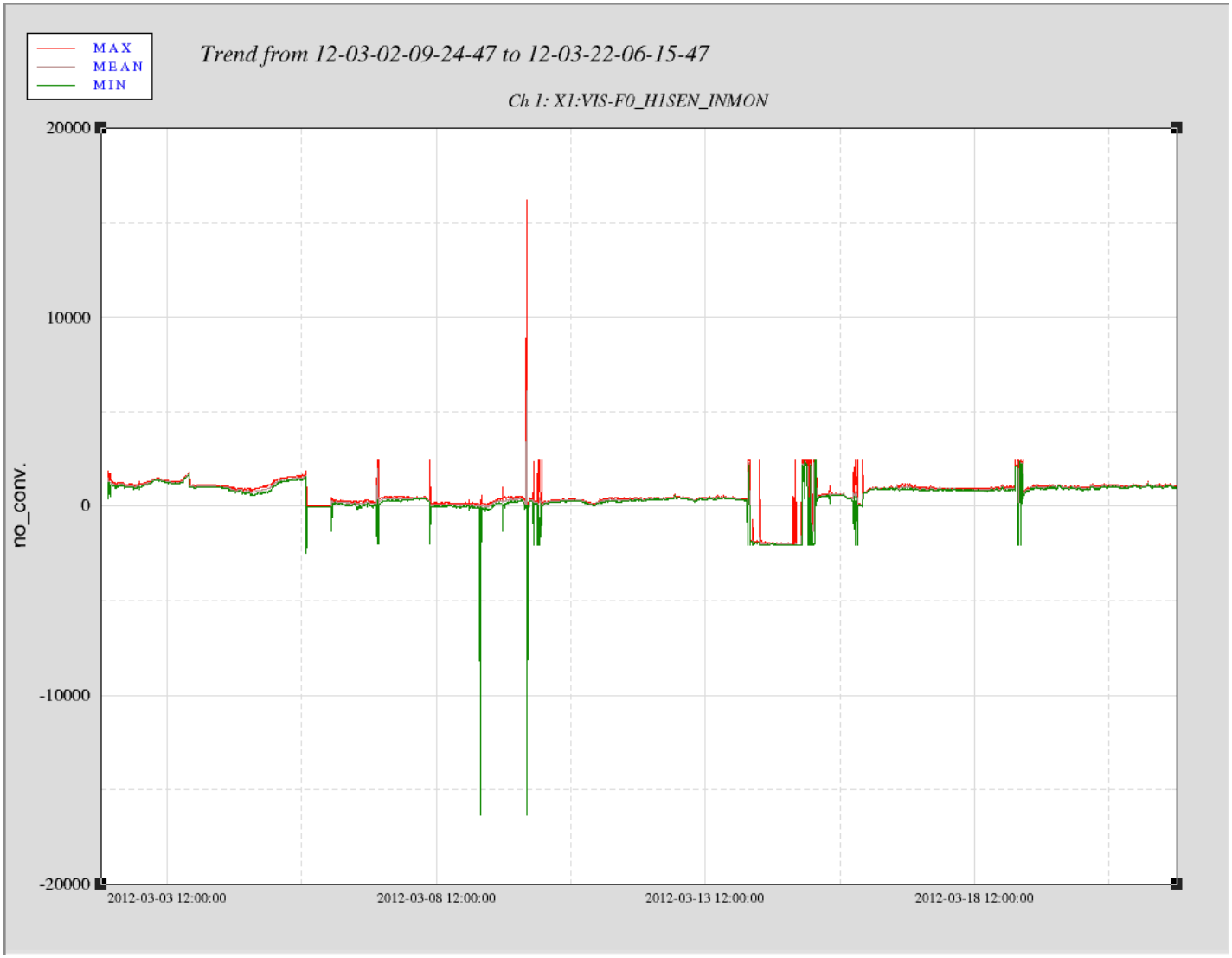

- Sensor: LVDT, Actuator: coil and magnet
  - Connected to digital system through 2-pin LEMO to 9-pin D-SUB adapter card
- Control and damping with a simple digital filter by Zero:0Hz, Pole:1Hz^2

# ADC noise


Power spectrum
X1:SUS-PI_FACE1_IN1(REF0)
X1:SUS-PI_FACE1_IN1(REF1)
Magnitude (m/Hz^1/2)
10^-6
10^-7
10^-8
10^-9
10^-2
10^-1
1
Frequency (Hz)
*T0=20/02/2012 09:32:59
Avg=10
BW=0.0117188


Power spectrum
X1:SUS-PI_FACE1_IN1(REF0)
X1:SUS-PI_FACE1_IN1(REF1)
Magnitude (m/Hz^1/2)
10^-6
10^-7
10^-8
10^-9
10
10^2
Frequency (Hz)
*T0=20/02/2012 09:58:32
Avg=1000
BW=1.5

# Long term data




- 一例として20日分のデータを表示
- 長期データは

16Hzで数百ch
1024Hzで8ch

分保存されている

# Full system

All below items are being discussed and will be ordered as a full LCGT control system

- ADC ~100, DAC ~50, BO ~100
- AA 100 case, AI 50 case, BO 100 case
- Remote IO chassis ~30
- RT PC ~30
- Servers ~10
- Control WS ~10
- Security, redundancy
- Data storage (~500TB)
- Network switches
- Timing
- Full channel test
- 3km test

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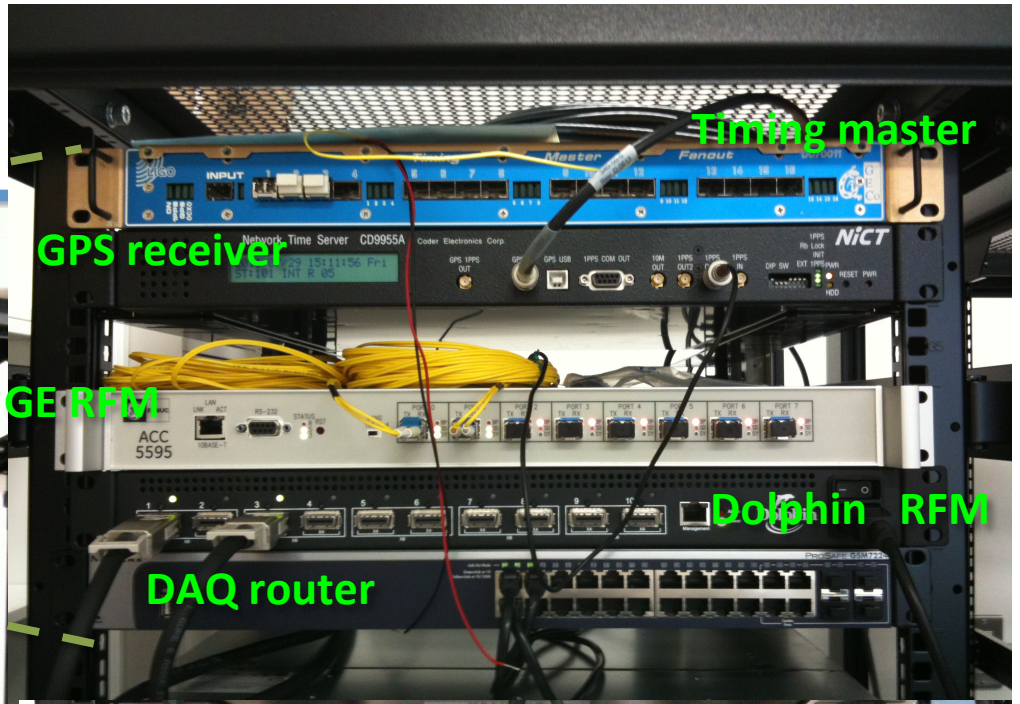
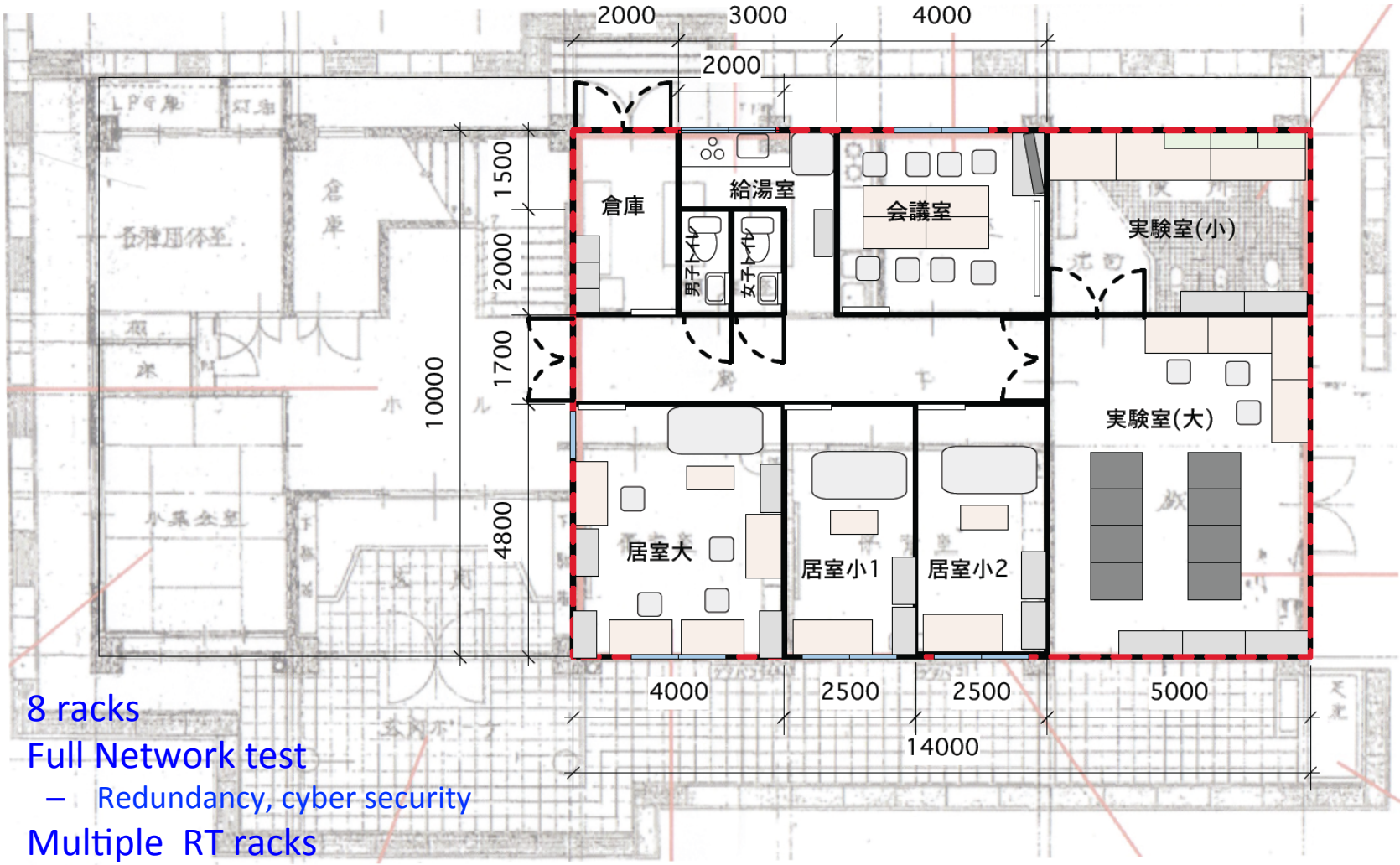
# Network test


# Full test at Kamioka new building




- 8 racks
- Full Network test
  - Redundancy, cyber security
- Multiple RT racks

# Summary

- 複雑で多数の自由度を持つKAGRAでは計算機を用いた柔軟な制御システムが必須である
- 複数台の計算機を用いてのリアルタイム制御は、非常に困難であるが、基本的なネットワークを組み、これを大型化することでKAGRAに導入していく
- 防振系、解析パイプライン形成のためのテストベンチを構築した
- 特に防振系への導入は短時間で制御まで成功する等、デジタルシステムならではのパフォーマンスを示し始めている。
- デジタル上で開発した技術はコピーが非常に容易であるため、ここで開発した技術はそのままKAGRAへと適用できる

- 今後の予定
  - LVDTの変調復調プロセスをデジタルで出来ないか
  - 安定性及び冗長性の検証
  - 大型システムへの拡張とKAGRAへのインストール