Actidyn
Active Dynamics

NATIONAL SURVEY FOR SEISMIC PROTECTION

Centrifuge center proposal

Yerevan November 20th, 2006

ARMENIAN Centrifuge center proposal

Company experience

- First civil engineering centrifuge built in 1980
- 20 centrifuges in operation worldwide
- Designed and built first and only 100 g's robot in operation
- Designed and built dynamically balanced quake simulators
- 10 years of centrifuge equipments manufacturing in operation worldwide
- Vacuumed clay mixer, sand rainer, containers, consolidation system, available from shelves

Key features in centrifuges

- Optimized aerodynamic drag, low power consumption.
- Model optimized accessibility
- Integral counterweights fully automatic balancing.
- Large safety factor to yield limit 1 to 2.7
- Ultra light platform made of high strength steel honeycomb structure
- Monolithic arm no welds in tension in the entire centrifuge
- Low cost foundation and single floor building requirement

ARMENIAN Centrifuge center proposal

- Companion large centrifuges worldwide

Takenaka Komuten (Japan)

US Army Corps of Engineers (USA)

ARMENIAN Centrifuge center proposal

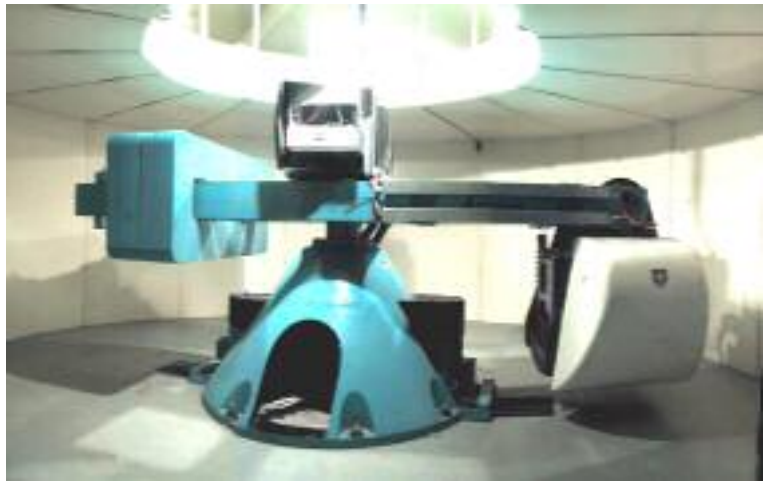
- Companion large centrifuges worldwide

C'CORE Newfoundland Canada

L.C.P.C. Nantes, France with quake simulator

ARMENIAN Centrifuge center proposal

- Companion large centrifuges worldwide



Dundee University, Scotland

INEEL, Idaho Falls

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Model C72-2

5 meters platform radius

1.2 x 1.2 m experimental platform

2400 kg at 100 g (240.000 g*kg)

1400 kg at 130 g

Full automatic balancing **NEW**

Dual cabinet for experiments controllers

Fiber optic rotary joint

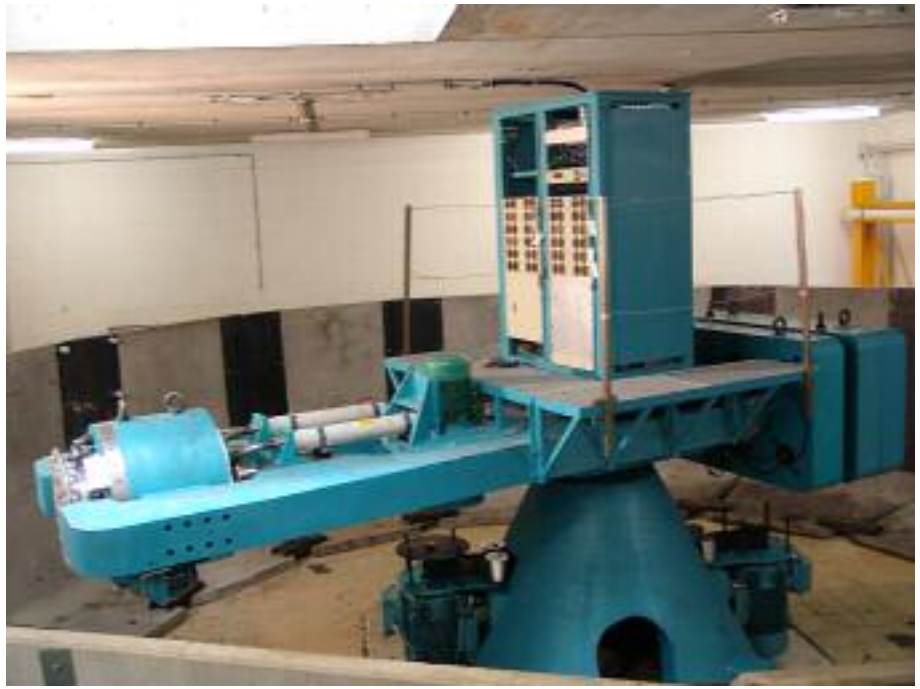
On board 16 ports Ethernet switch

Electrical power rings 200A - 400 V

Hydraulic rotary joints up to 30 MPa

Extremely low power consumption

New base concept for simplified installation



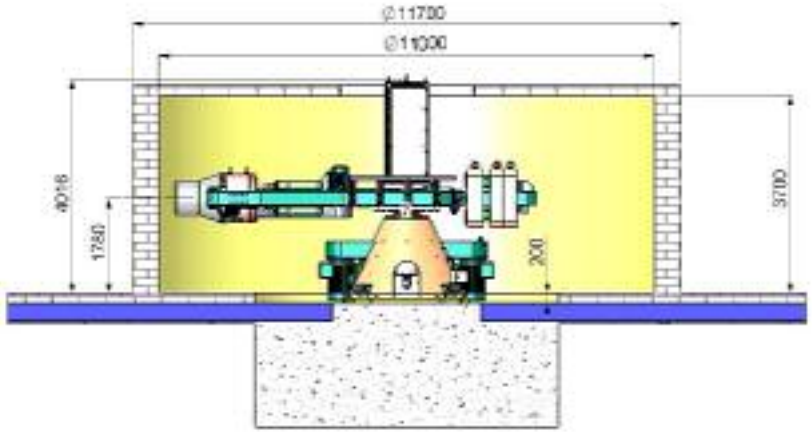
V72-4H Vibrafuge

- **seen in operation at our plant**
- **Share the same base**

ARMENIAN Centrifuge center proposal

- ## Installation building
  - **Centrifuge is delivered fully assembled and rolled on the chamber's floor.**
  - **All parts are assembled at factory and the system is tested at reduced acceleration.**
  - **The centrifuge chamber can be either built in advance or built around the centrifuge during installation.**
  - **Anchoring and leveling are easy to make while centering the centrifuge in the chamber**
  - **Entire installation made on flat floor**
  - **Prefabricated cables are set in place, all connections are tested prior to shipment**
  - **Ultra simple centrifuge foundation consist of the flat reinforced concrete floor of the centrifuge chamber that includes ventilation channels and service conduits.**
  - **Hardware installation time 1 week, system operation and commissioning 4 weeks**

- Building layout principle



- Anchors include balancing strain gage

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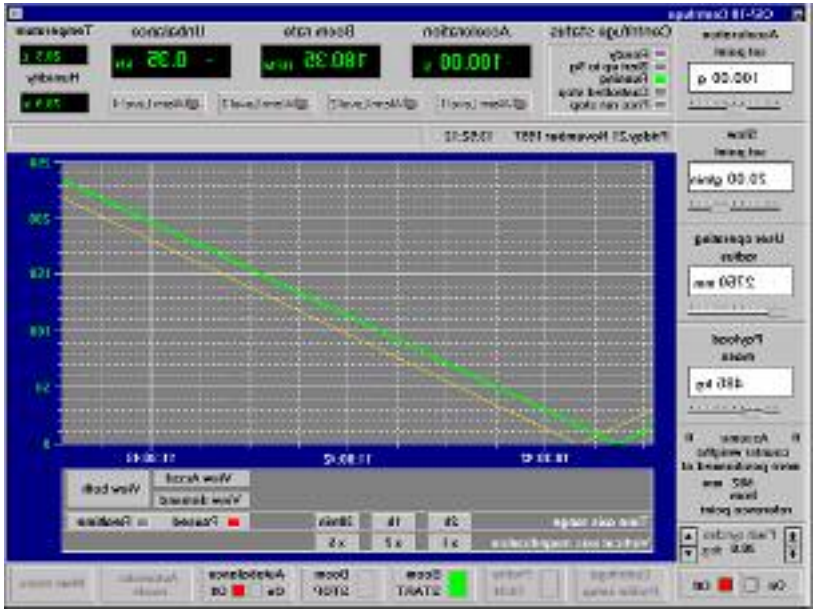
- ## Centrifuge control system
  - **Programmable industrial controller**
  - **Actidyn control software**
  - **Display and operator PC in control room**
  - **Operator safety manual control box**

- **Control room**

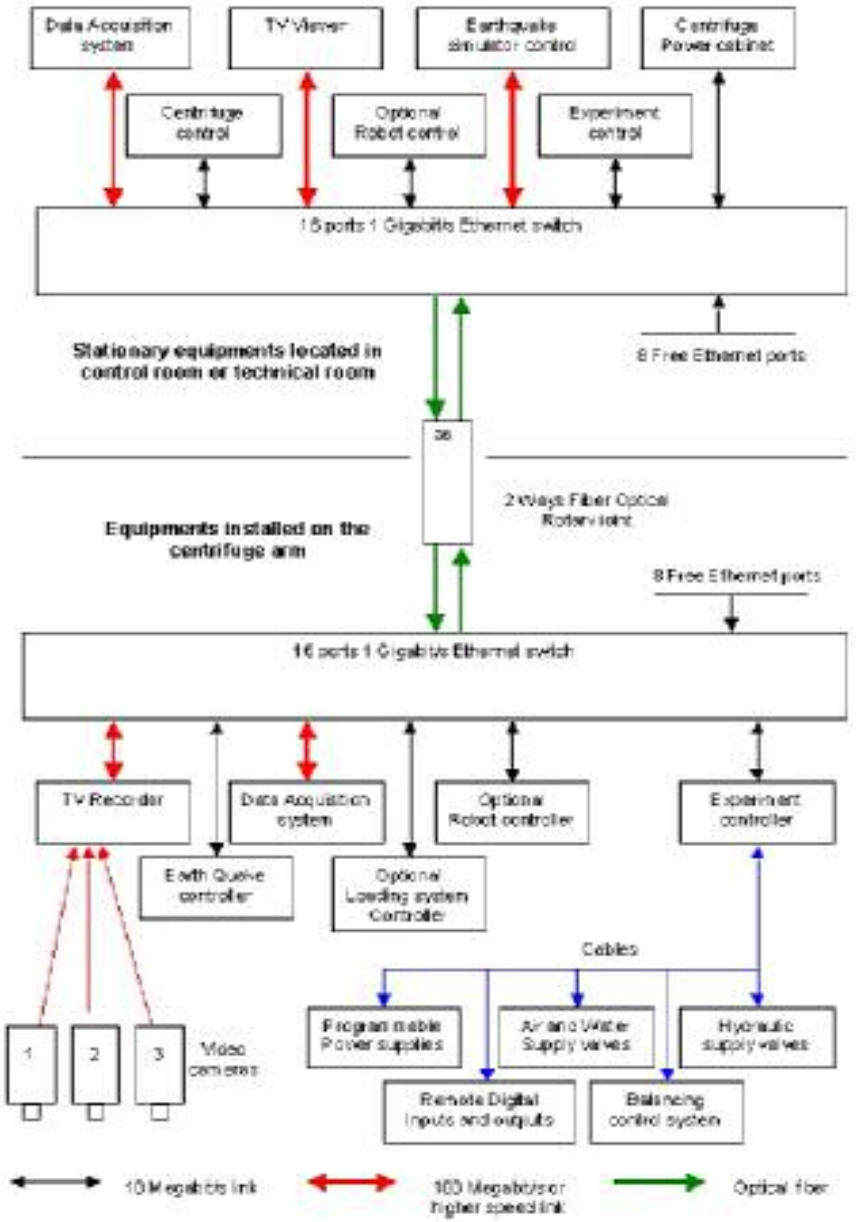
- **Operator PC display panel**



ARMENIAN Centrifuge center proposal

- Data transmission system

  - **Optical rotary joint**
  - **Two 1 Gigabits/s Ethernet switches 16 ports**
  - **Direct connection of any equipment Ethernet compatible**
  - **Extreme flexibility**
  - **Extreme connectivity**



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100 g centrifuge

5 kN vertical force

5 Nm vertical axis torque

1 x 0.6 x 0.5 m displacement (X, Y, Z)

1 mm positioning accuracy at 100 g's

50 mm/s transverse speed

Three tools magazine

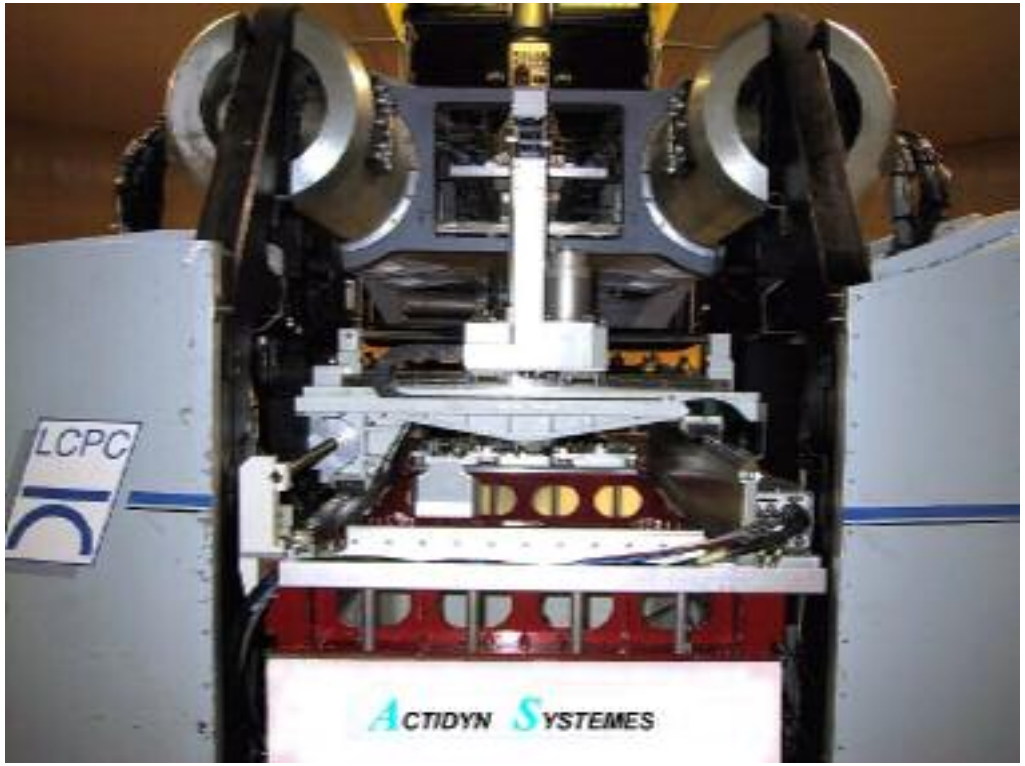
Cone penetrometer tool

Pincer tool

Injection tool

Tools interchangeable with RPI and LCPC

Model R72-2 four axis robot



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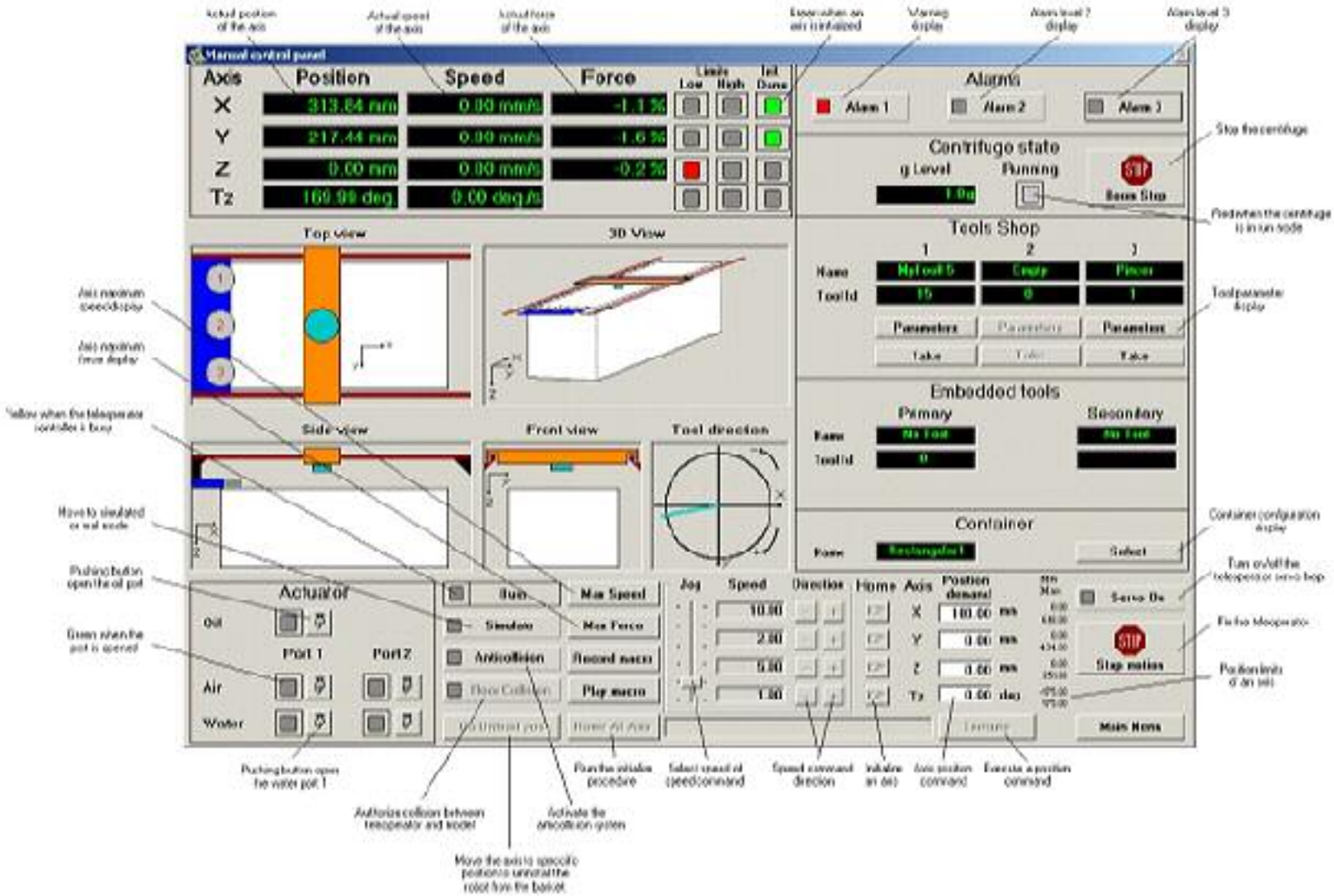
- Robot control panel



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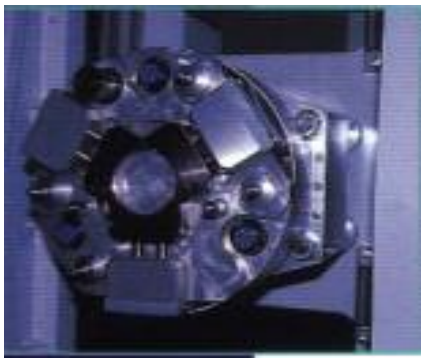
- Robot details

▪ Axis drive controllers

▪ Tools and tools magazine



▪ Tool universal interface

▪ RPI robot on centrifuge

▪ Pincer tool

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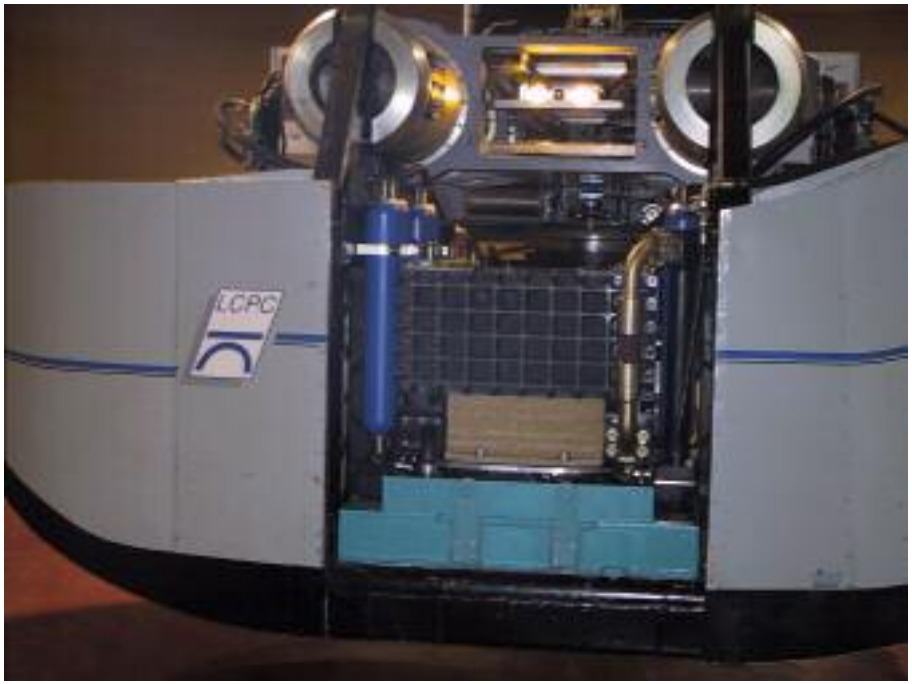
Model Q72-2 Quake simulator

- 100 g centrifuge
- 700 kg moving mass
- 60 g's no load sine
- 20 g's sine at full load
- 40 to 350 Hz operating frequency
- 5 mm displacement peak
- 1.1 m/s peak velocity
- Centrifuge acceleration range 10 to 100 g
- 190 kN actuator force
- Dual axis Matrix controller
- Dynamically balanced



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- Quake simulator system

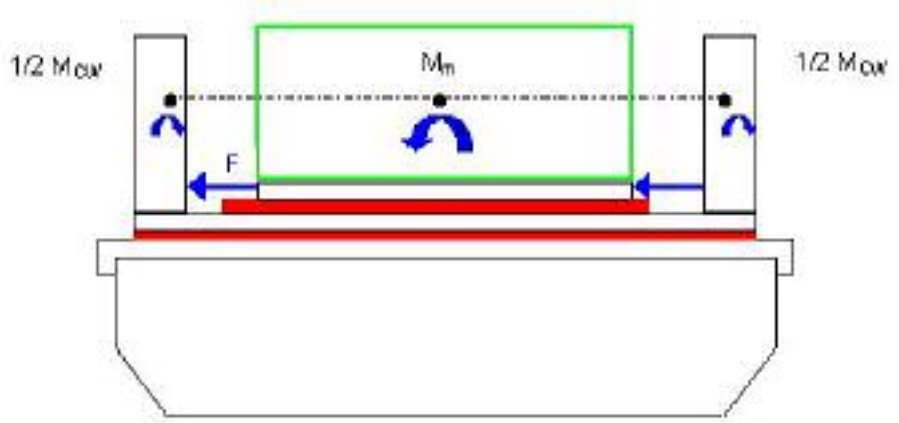
Dynamic balancing principle:

- Two masses in opposite motion in order to eliminate overturning moment
- Two symmetrical actuators to actuate and control two in phase linear motion

Dynamic balancing advantages:

- Eliminates vertical and transverse undesired motion
- True control of the input motion
- Controlled linear guidance better than mechanical guidance at high frequencies
- Safer operation protects the centrifuge structure

- **Kynematics principle**



- **Control principle**

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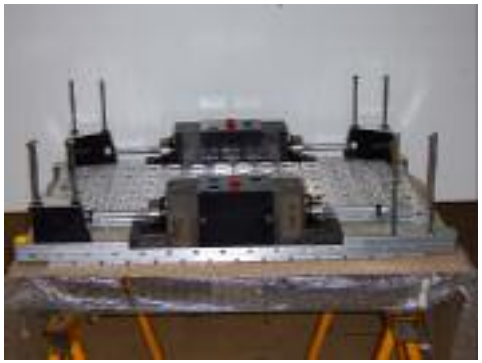
- Quake simulator system
  - Stationary hydraulic power supply
  - On arm hydraulic supply controller booster and scavenging pump
  - Logic control system
  - On arm dual axis Matrix controller
  - On arm servo-valves controller
  - Quake simulator basket & base
  - Counterweights moving platform
  - Model container supporting platform
  - Hydraulic accumulators for energy storage

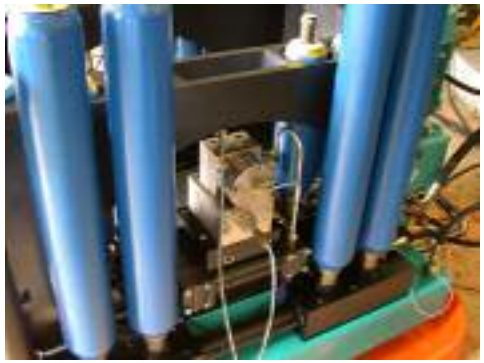
- **Overall view**

- **Container moving slip table**

- **Actuators & bearing**



- **Servo-valve & accumulators**



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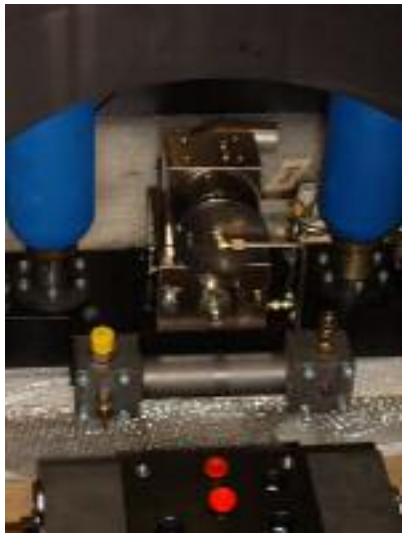
Quake simulator system

- **Base and accumulators**
- **Actuators parts**

- **The QS and its master Michel BART**

- **Base dual hydraulic bearing Actuators and servo-valves**



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Quake simulator system

Controller features:

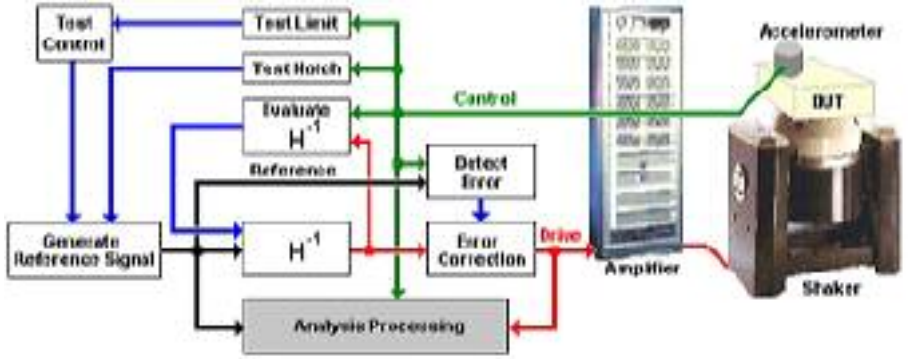
- 120 dB dynamic range
- New abacus digital engine hardware
- 20 years development behind the Matrix controller widely used in aerospace
- Sinusoidal control mode
- Transient replicate control mode
- Built-in real time FFT analysis

System operation:

- Controller on board of centrifuge
- Operator PC in control room
- Multiple attendees can readout data on several PC installed elsewhere
- Noise free data transmission through Fiber Optic Rotary Joint

- **Abacus hardware typical**

- **Controller principle**



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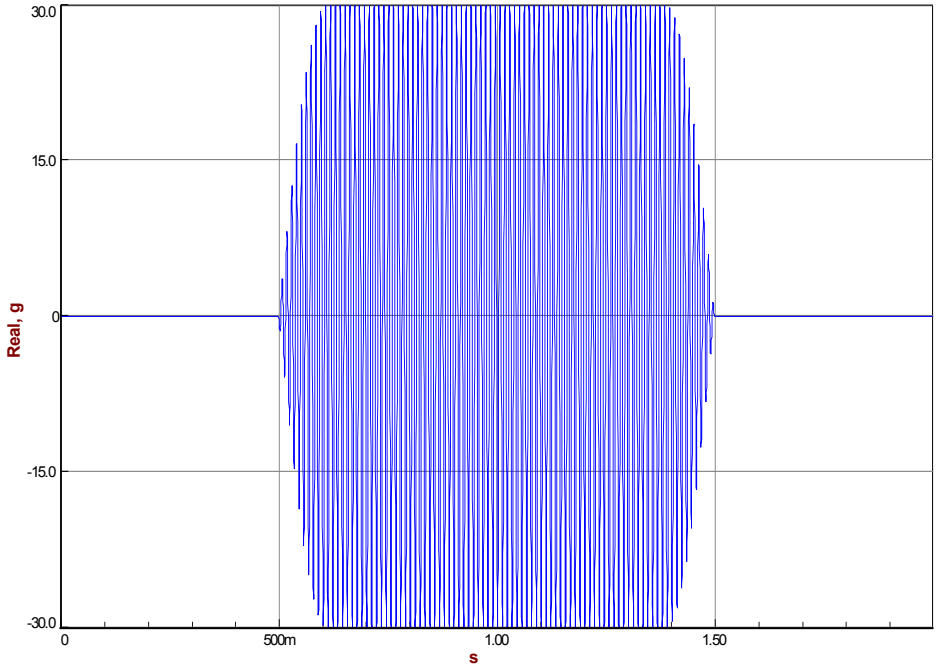
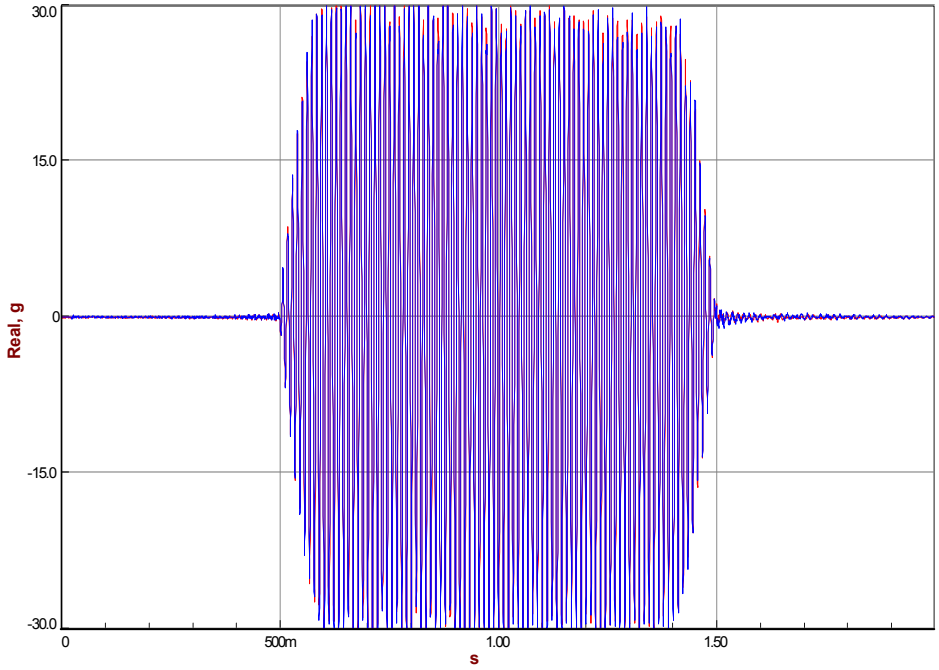
Quake simulator system Sine burst test

- 30 g sine burst with 400 Kg payload at 80 g centrifugal acceleration
- Burst of 1 sec



Reference



Display of the 2 actuators response

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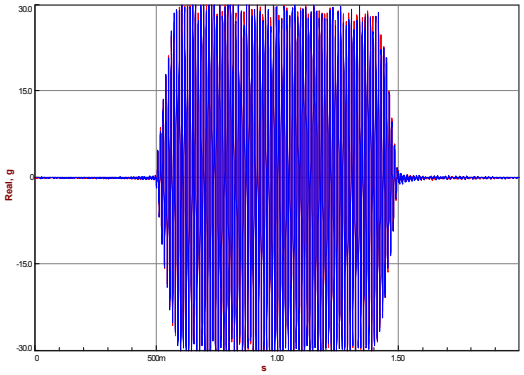
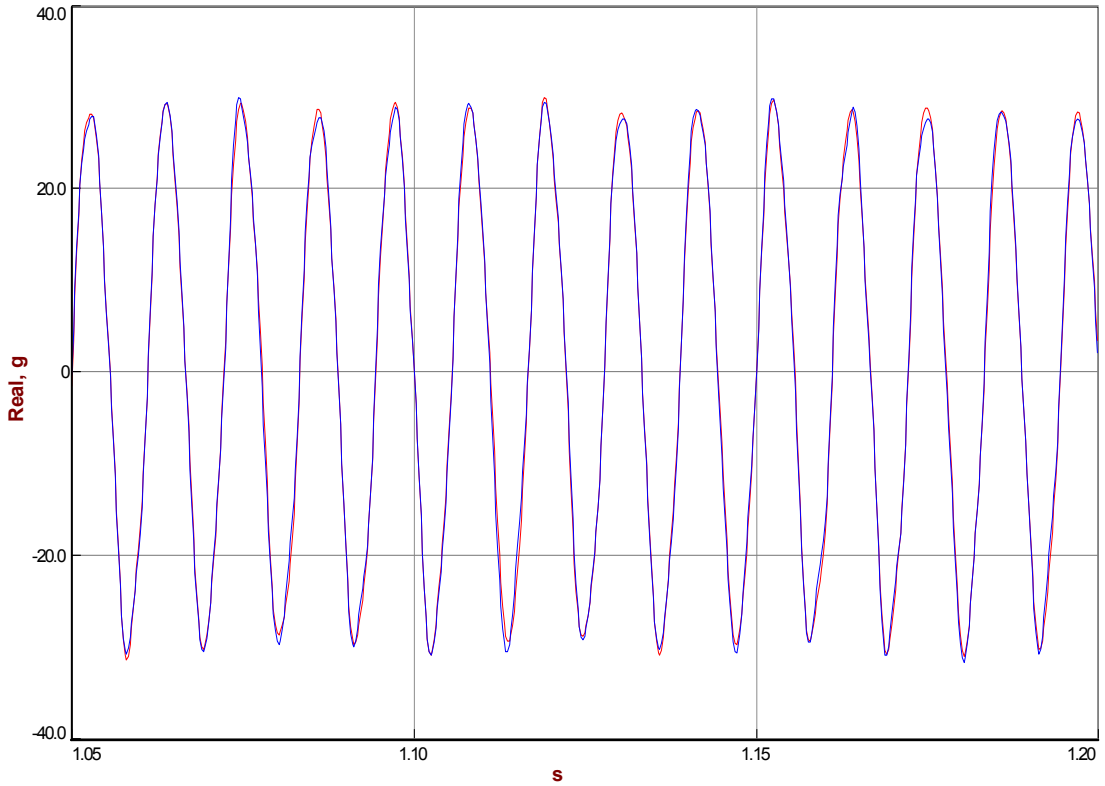
Quake simulator system Sine burst test

- Both actuators are in phase with a perfect amplitude match





- Zoom on the 2 actuators' accelerometers

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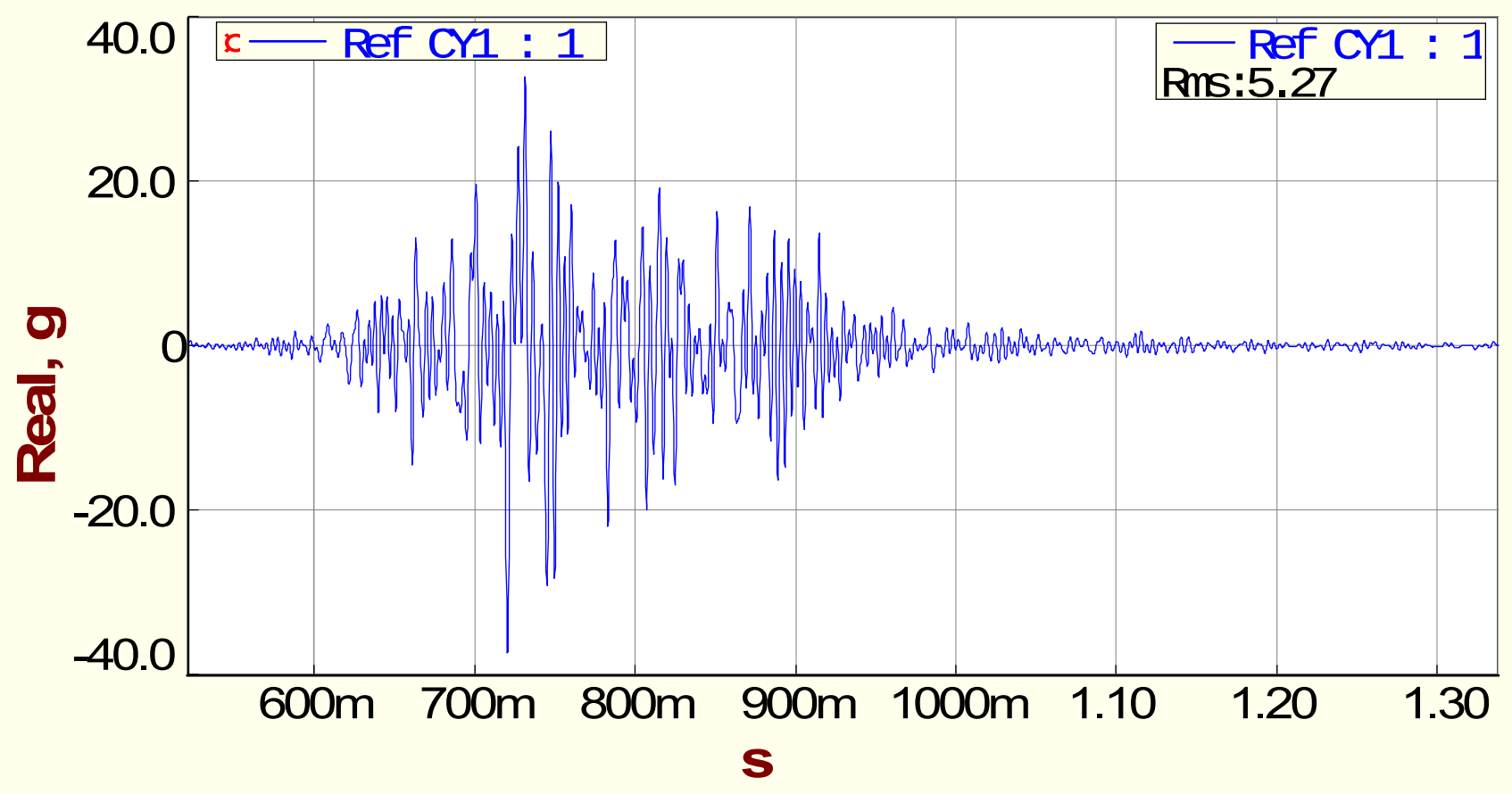
Quake simulator system Earthquake replication

- **The broadband earthquake shown below was performed at 70 g centrifuge with the Actidyn QS80 shaker and the Data Physics Matrix 2 axis vibration controller.**
- **The Lander earthquake was scaled for a 70g centrifuge test with frequency content from 19 Hz up to 300 Hz.**



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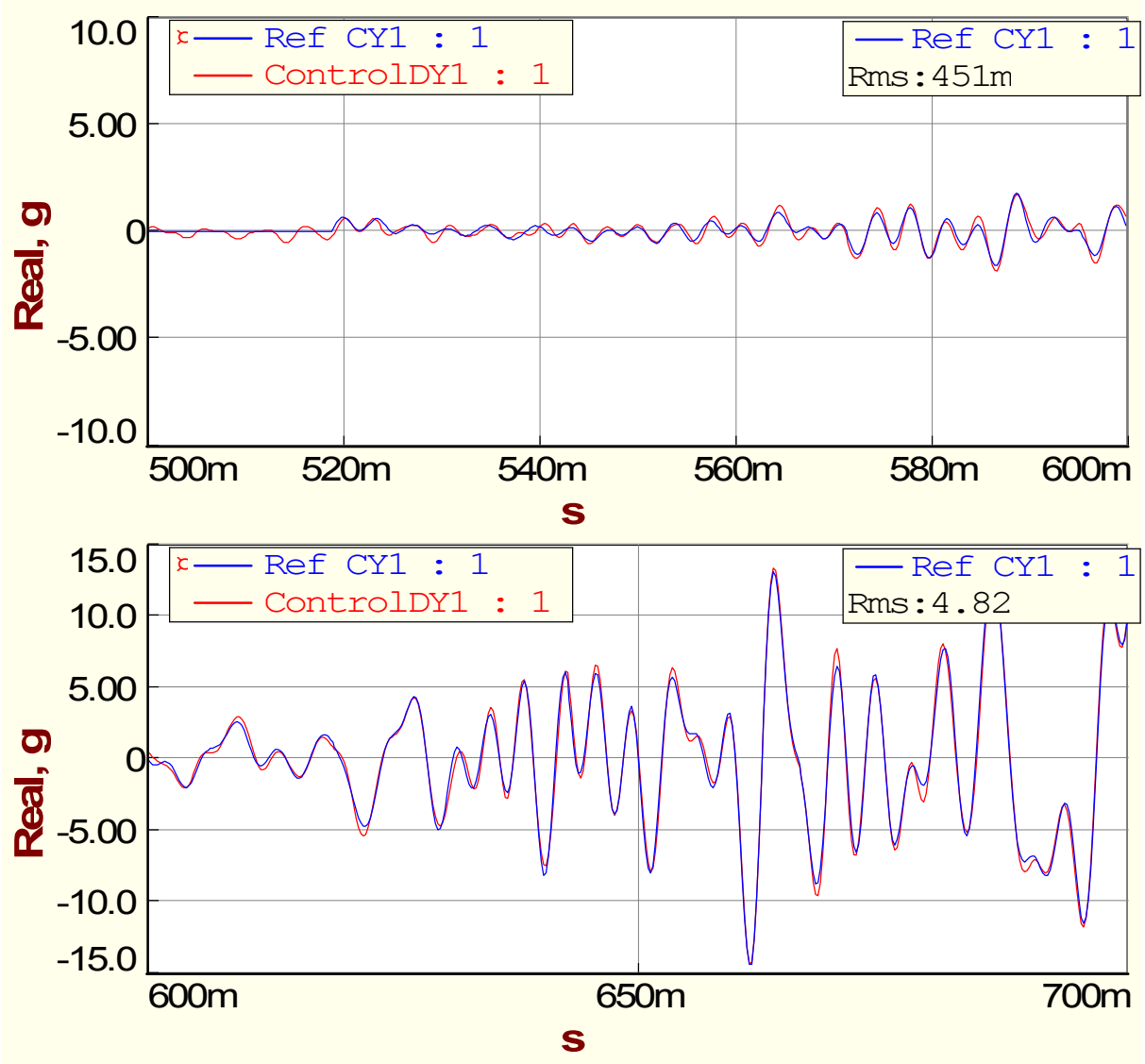
Quake simulator system

Earthquake replication



The plots hereby show the table accelerometers response in blue over plot with the targeted command in red.

Both time signals are zoomed along the time axis.

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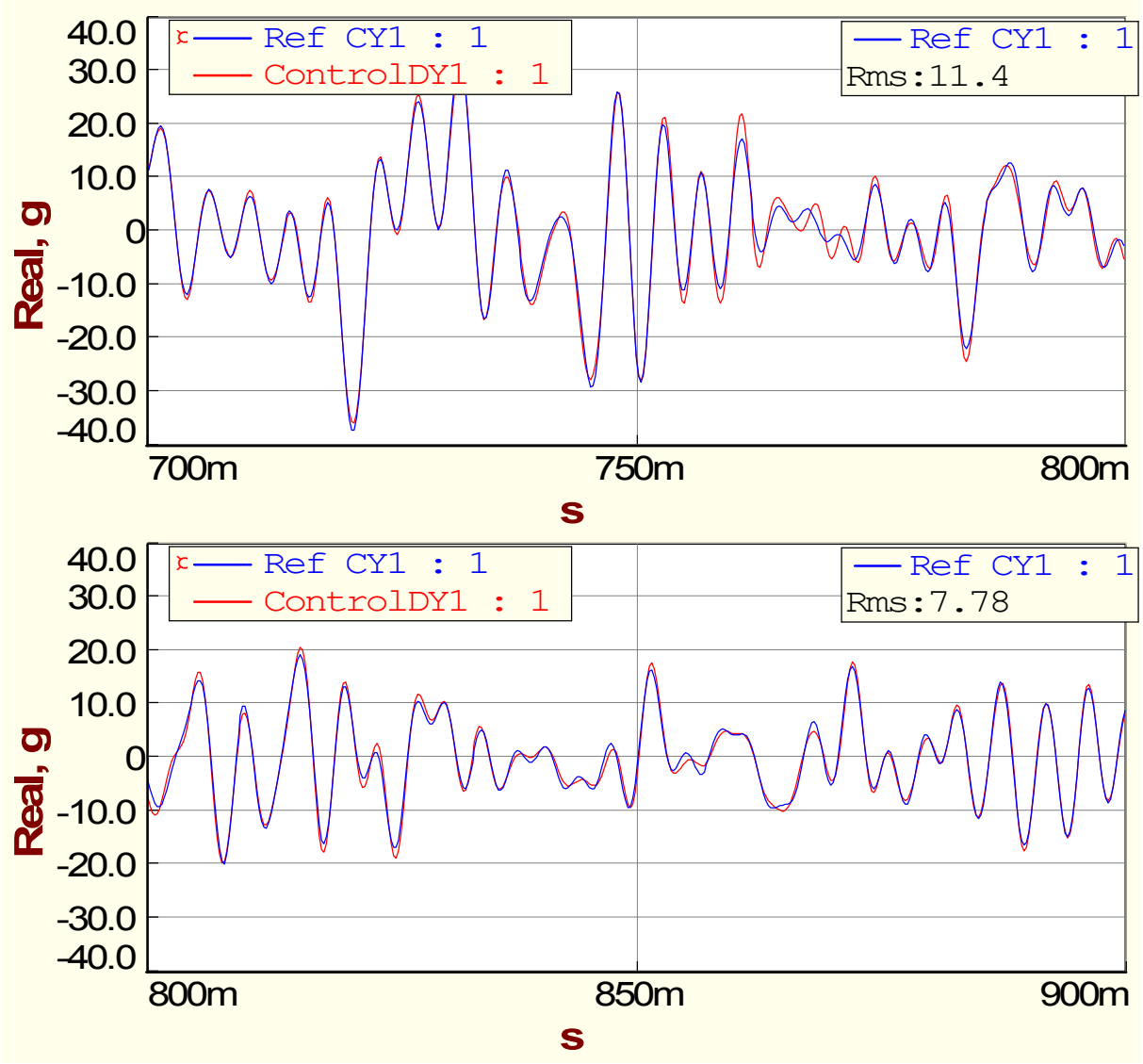
Quake simulator system

Earthquake replication (Continued)



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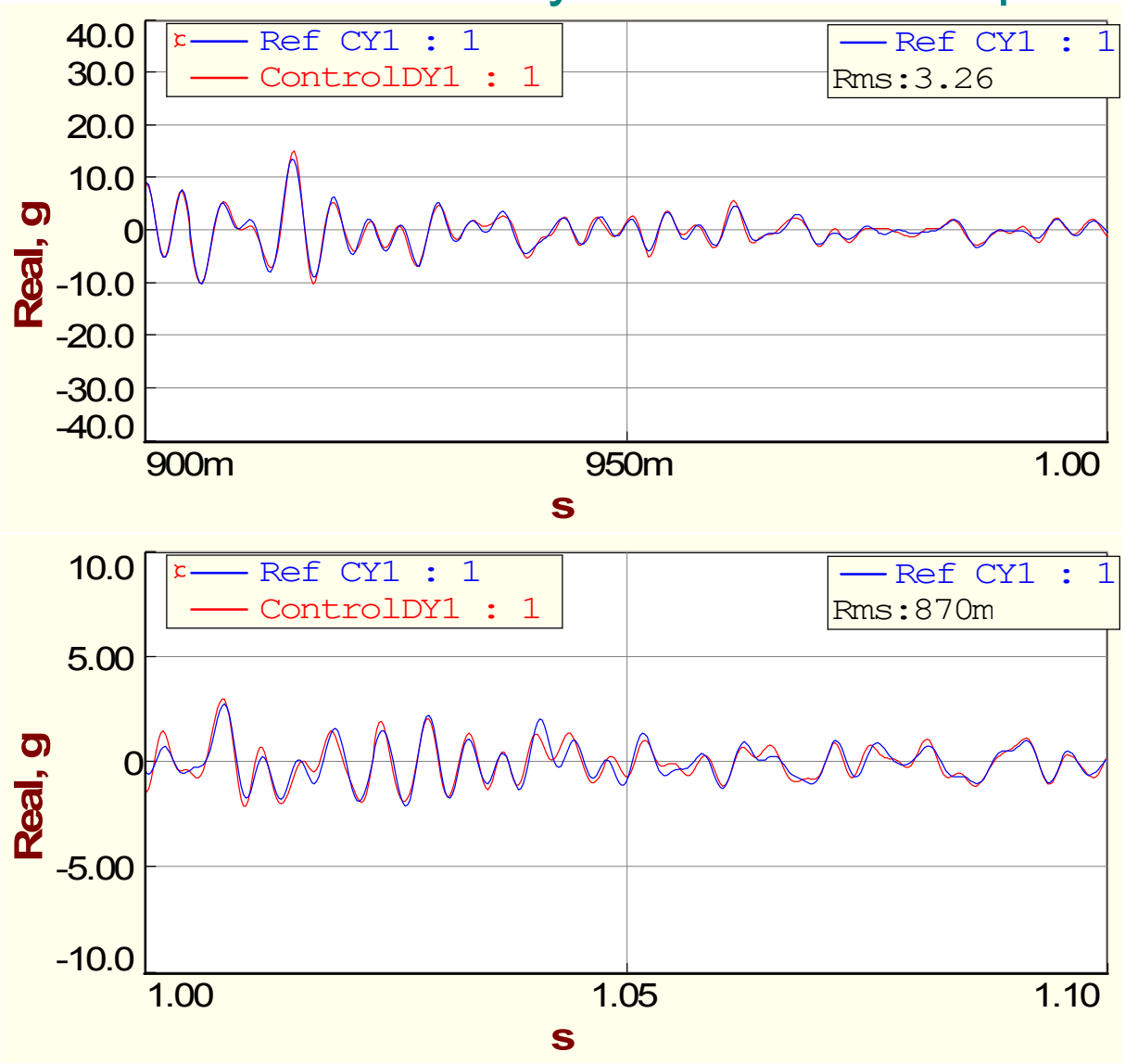
Quake simulator system

Earthquake replication (Continued)



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Both time signals are zoomed along the time axis.

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Model DAS-NI-192
Data acquisition system

- 192 input channels
- Operation on board of the centrifuge arm
- Data storage on disk up to 200 g
- Noise free data transmission through F.O.R.J.
- Expandable to 1024 inputs and more
- Labview 8.0 application software
- Strengthen hardware for centrifuge operation
- Operator PC in control room

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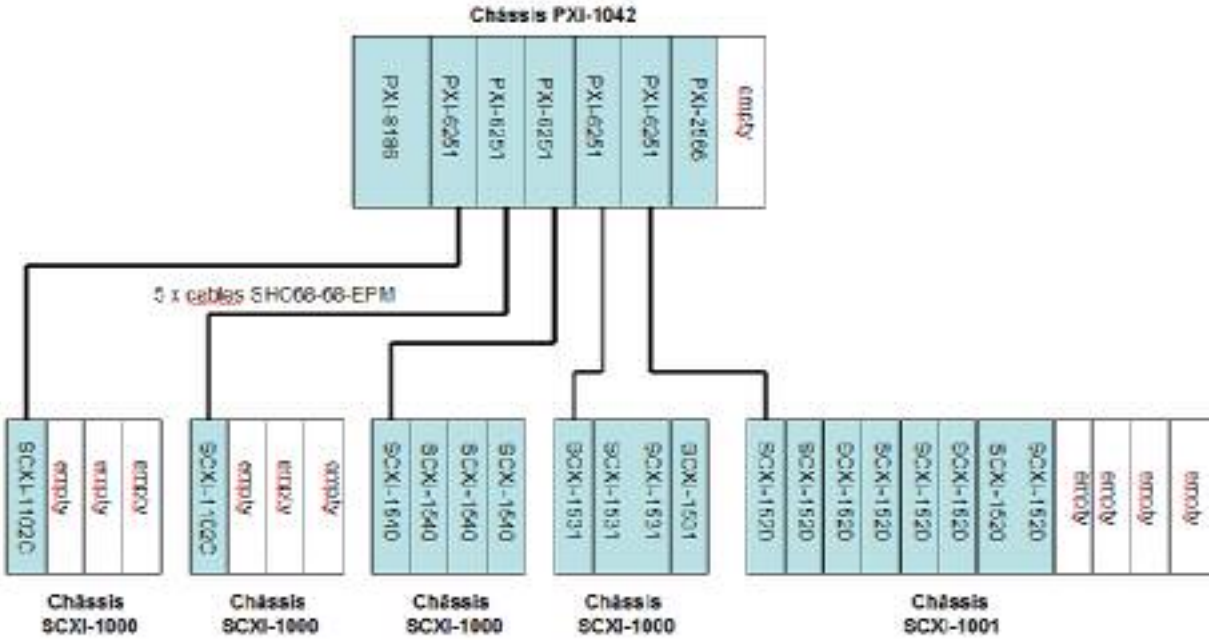
The Data Acquisition System consists of a NI PXI-SCXI hardware and a Labview 8.0 application software.



- **64 strain gage type input channels (NI 1520)**
- **32 LVDT input channels (NI 1540)**
- **64 Voltage type input channels (NI 1102)**
- **32 accelerometers input (NI 1531)**
- **5 high speed A/D boards (NI 6251)**
- **1 general purpose switches and relay driver (16 channels)**

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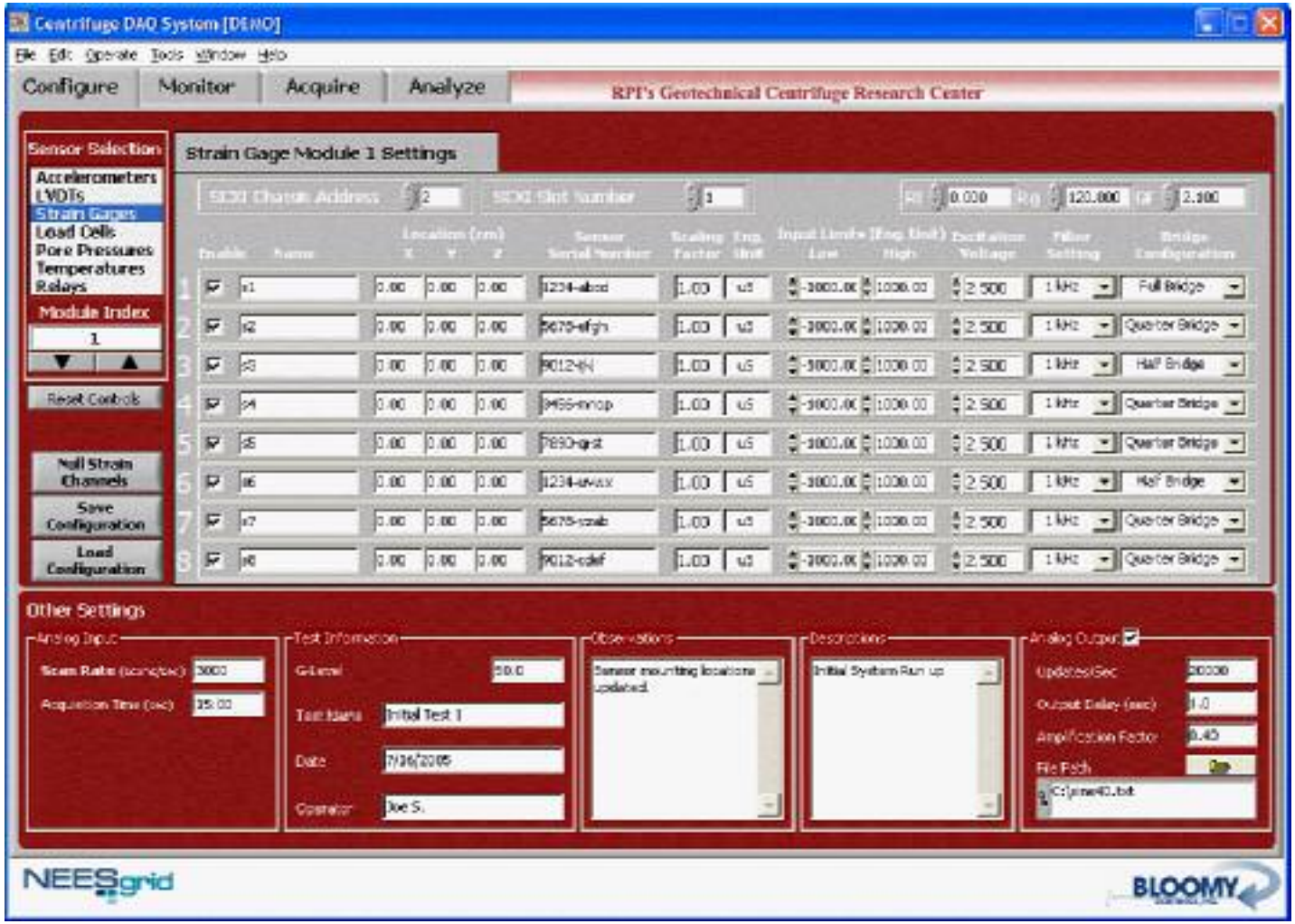
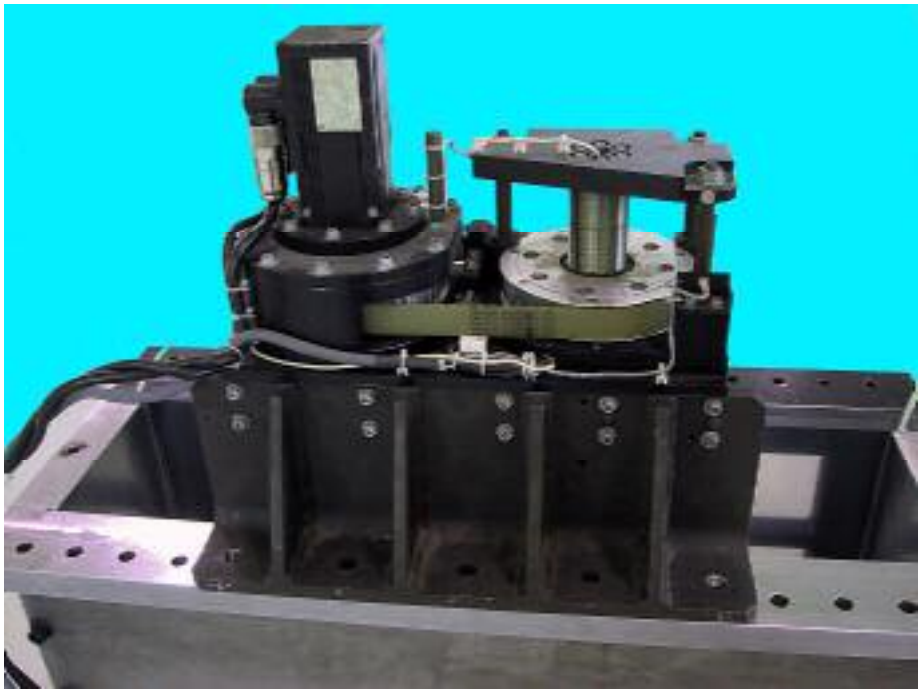
- **Labview 8.0 DAQ software license (Designed for NEES program).**
- **Up to date version.**



ARMENIAN Centrifuge center proposal

Model P72-2 Penetrometer

- 100 g centrifuge
- 100 kN down loading force
- 40 kN up loading force
- Force command resolution 0.01 %
- Force control and readout accuracy 1%
- 400 mm total displacement
- Electrical actuation
- Remote control imbedded in centrifuge controller
- Dual usage as loading system and cone penetrometer
- Adjustable force range and resolution (Interchangeable force transducer)



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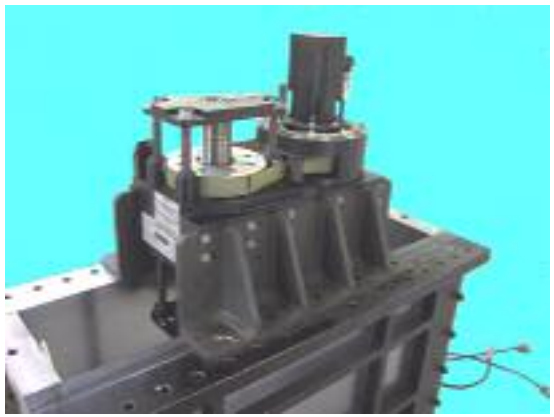
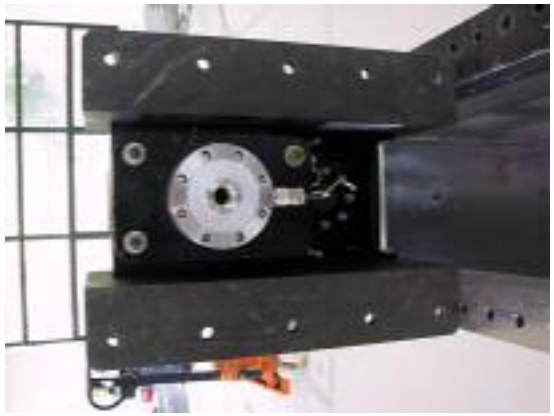
- Loading and Penetrometer system

  - **Penetrometer on container**
  - **Actuator head with force transducer**





- **Control panel**

  - **Penetrometer at Daewoo laboratory**
  - **Transverse view**

ARMENIAN Centrifuge center proposal

• Clay mixer

The purpose of this equipment is the preparation of saturated clay.

The classical methodology used for the construction of clay soils consists of two successive operations :

- Preparation of a slurry by mixing clay and water
- Consolidation of the mix under pressure.

This methodology permits the construction of a soil material with a precisely defined geotechnical profile.

The total duration of the total consolidation is about 4 weeks for a 0.5 meter thick soil model.

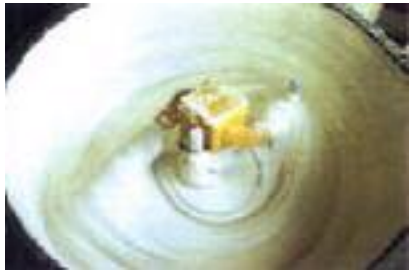
The LCPC method consists of mixing the clay with water under a vacuum in order to create a fully-saturated homogeneous slurry.

This apparatus is equipped with two adjustable height mixing blades and a scraping blade.

As a must compared to classical clay mixer, this system uses a vacuum pump in order to create a light depression in the tank.

The purpose of this depression is to minimize the air concentration in the preparation to obtain a fully saturated slurry.

▪ Model preparation at LCPC



▪ Clay mixer

ARMENIAN Centrifuge center proposal

- ## Consolidation system

The laboratory soil consolidation system permits fine grained soil consolidation in rectangular or cylindrical centrifuge container prior to centrifuge experiment.

The system consists of:
- 1 mainframe
- 1 hydraulic actuator
- 1 rectangular or cylindrical piston
- 1 hydraulic power supply
- 1 control system

Two consolidation methods can be used:

- Uniform consolidation, with a maximum pressure of 0.2 MPa
- Depth variable consolidation (rectangular containers only)

based on the hydraulic gradient method that permits to impose up to 1.5 MPa fluid pressure differential between the top and the bottom surfaces of the soil model.

The control system is made of individual programmable industrial grade controllers.
All parameters such as pressure, flow, temperature, else are independently controlled and monitored.
The control system also includes safety circuitry that are essential to the safe operation of the system.
A personal computer is used as the operator interface but is not an active part of the control and safety circuitry.
The consolidation system is designed to be operated as a fully automatic system that does not require human surveillance.

ARMENIAN Centrifuge center proposal

• Sand rainer

The sand raining technique has been used for the construction of laboratory test-tubes used for shear tests and also for the creation of larger soil samples (calibration room, centrifuge models, test tanks).
The mechanical behavior of sands is controlled by the state of the constraints (reproduced thanks to centrifugation) and by the vacuums index (or relative density).
It was thus advisable to develop a method guaranteeing the density rigorous control.
The sand raining consists in making sand fall in fine rain at constant drop height.
The density of the solid mass is controlled by two parameters: drop height and sand flow (Küs, 1992).

The sand rainer is installed in a special room, put in light depression to limit the air pollution in the adjacent rooms.
Fully automatic operation is programmable this contributes to a good repeatability (fig.4) it avoids exposing operators to a harmful atmosphere.

▪ **Sand rainer during integration**