University of New Orleans
ScholarWorks@UNO

Ocean Waves Workshop

Dec 7th, 8:30 AM - 9:00 AM

Wavemaker Improvements at the University of New Orleans Towing Tank

Ryan D. Thiel
University of New Orleans

Follow this and additional works at: https://scholarworks.uno.edu/oceanwaves

Part of the Oceanography Commons

Thiel, Ryan D., "Wavemaker Improvements at the University of New Orleans Towing Tank" (2017). *Ocean Waves Workshop*. 1.
https://scholarworks.uno.edu/oceanwaves/2017/Introduction/1

This Event is brought to you for free and open access by ScholarWorks@UNO. It has been accepted for inclusion in Ocean Waves Workshop by an authorized administrator of ScholarWorks@UNO. For more information, please contact scholarworks@uno.edu.

December 07, 2017

Wavemaker Improvements
at the University of New Orleans Towing Tank

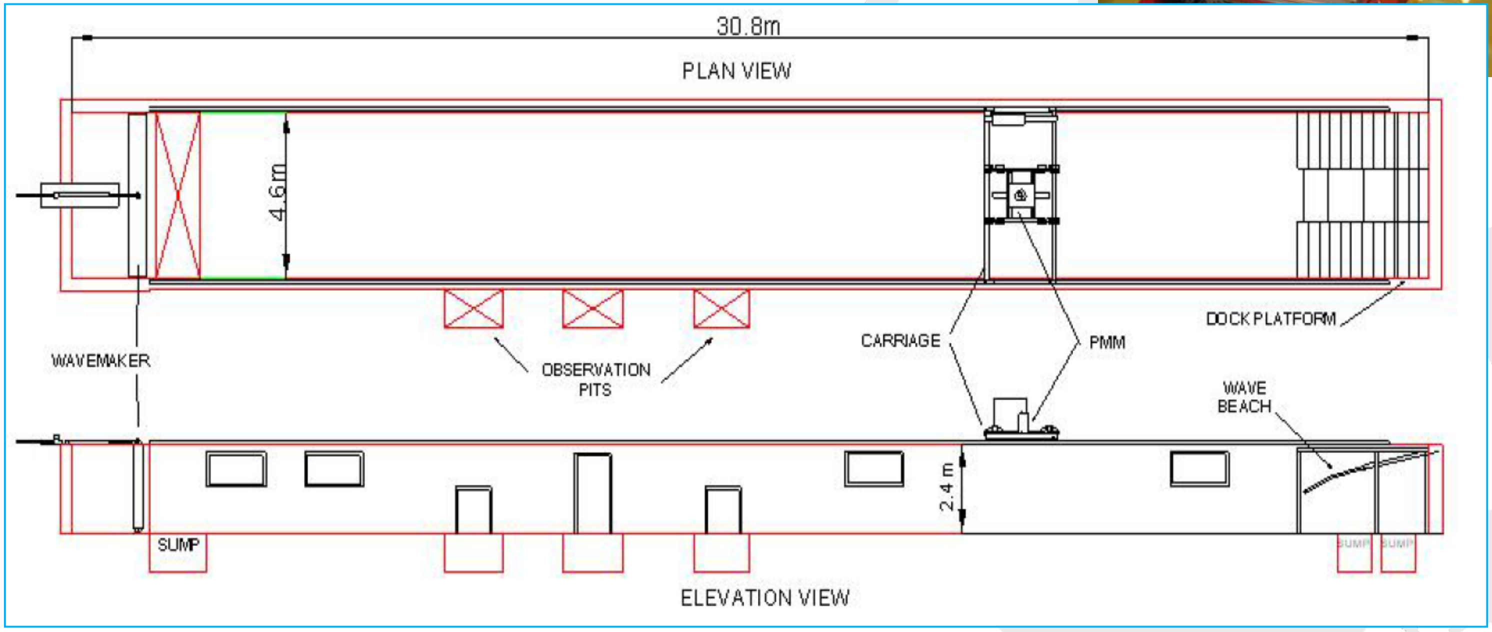
Ryan D. Thiel

School of Naval Architecture and Marine Engineering

College of Engineering - University of New Orleans

UNO Towing Tank

- 30.8m long x 4.6m wide x 2.4m deep
- Carriage with a tow speed of 3.1 m/s
- Wave maker



UNO Wavemaker

Education/Research

- NA&ME Class Labs
- Graduate Theses

Commercial

- Offshore Platforms
- Energy Conversion Device

Other

- Movie Monster!

UNO Wavemaker

Originally Designed and Built by Arctec Offshore Corporation circa 1990

- Hinged Single Flap
- Flooded Back
- Hydraulically Actuated
- Computer Controlled

Included

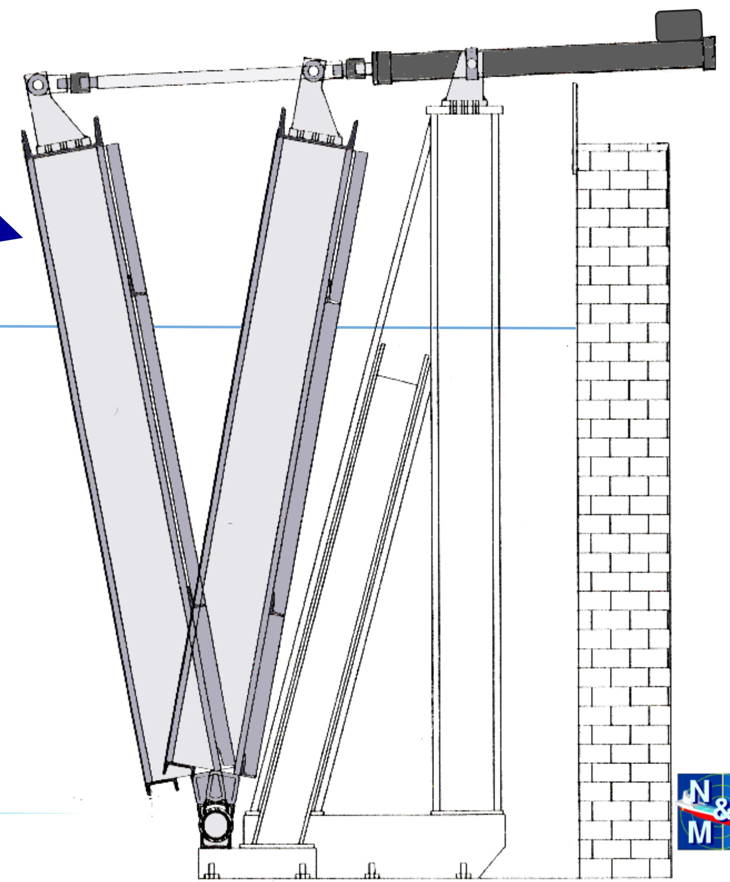
- Data Acquisition
- Wave Probes

UNO Wavemaker

Original 1990 Configuration

Single Wave Board

- Bottom Hinged
- Flooded Back
- A36 Steel
- Zinc Primer
- Epoxy Top Coat

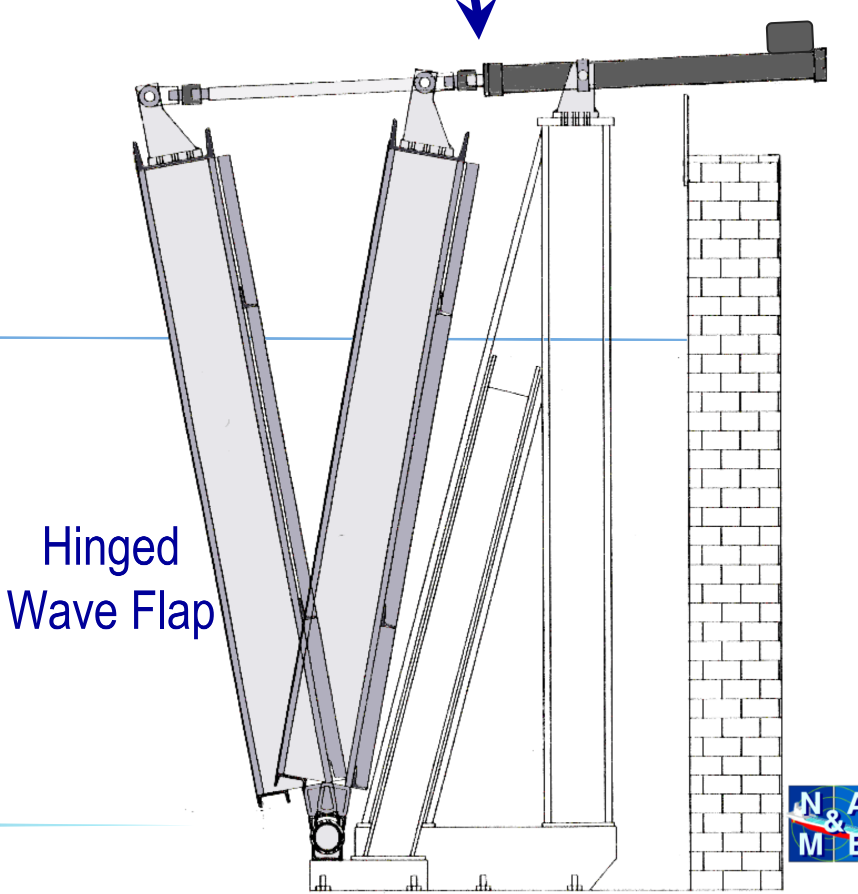


UNO Wavemaker

Original 1990 Configuration

Linear Hydraulic Actuator

- 2” Bore
- 30 inch stroke
- 3000 psi
- LDT Feedback Sensor

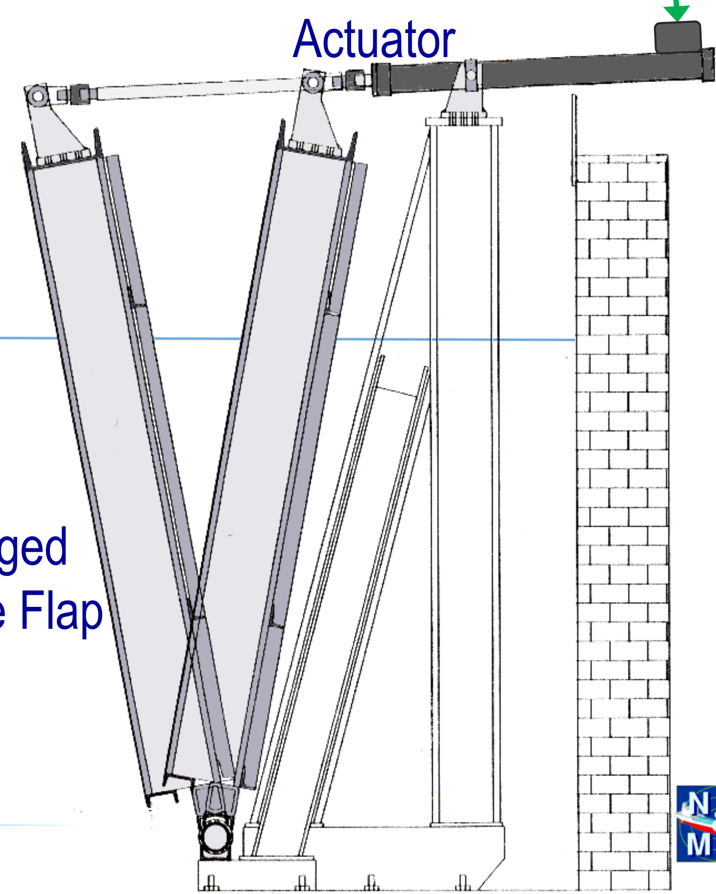


UNO Wavemaker

Original 1990 Configuration

Hydraulic Power Unit

- 480 Volt
- 40 Horsepower
- 3000 PSI
- Replaced in 2006

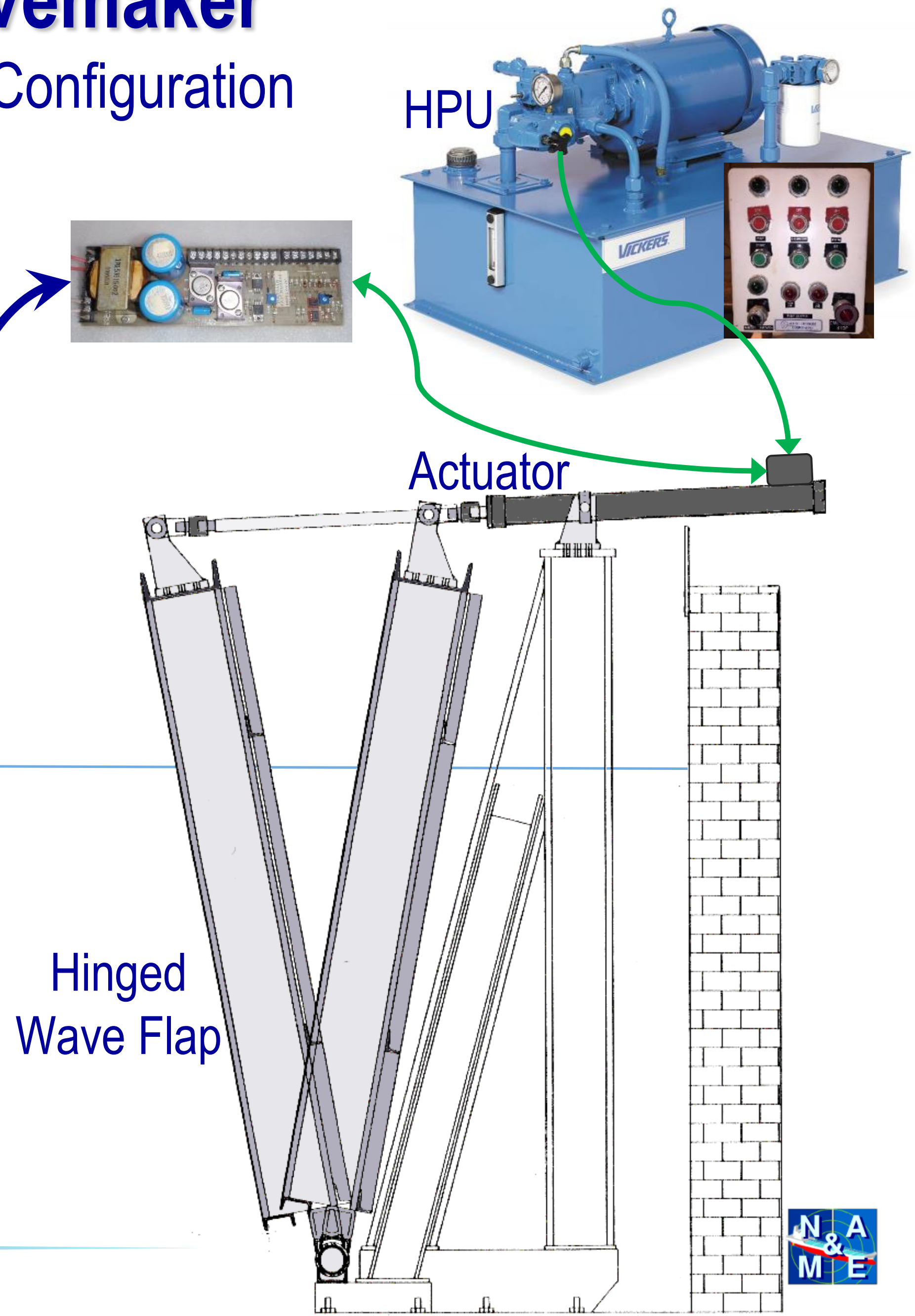


UNO Wavemaker

Original 1990 Configuration

Moog Servocontroller

- Proportional Control of Actuator Position
- Accepts Voltage Input Signal Proportional to Actuator Position



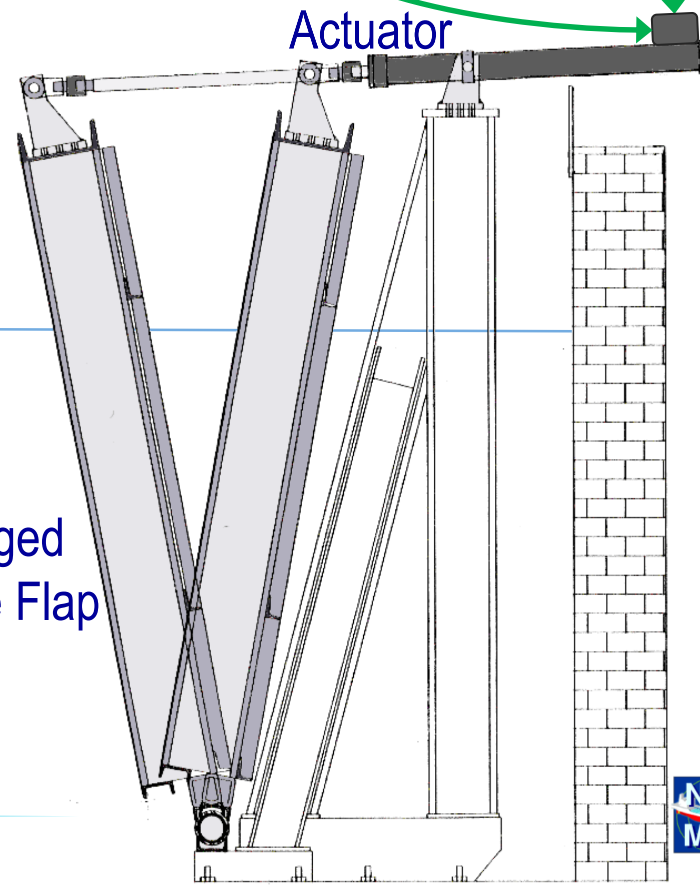
UNO Wavemaker

Original 1990 Configuration

Servocontroller

HPU

Actuator



Hinged Wave Flap

Computer Interface Enclosure

- Signal conditioning
  - Wave output signal
  - Wave probes
- Interfaces with PC

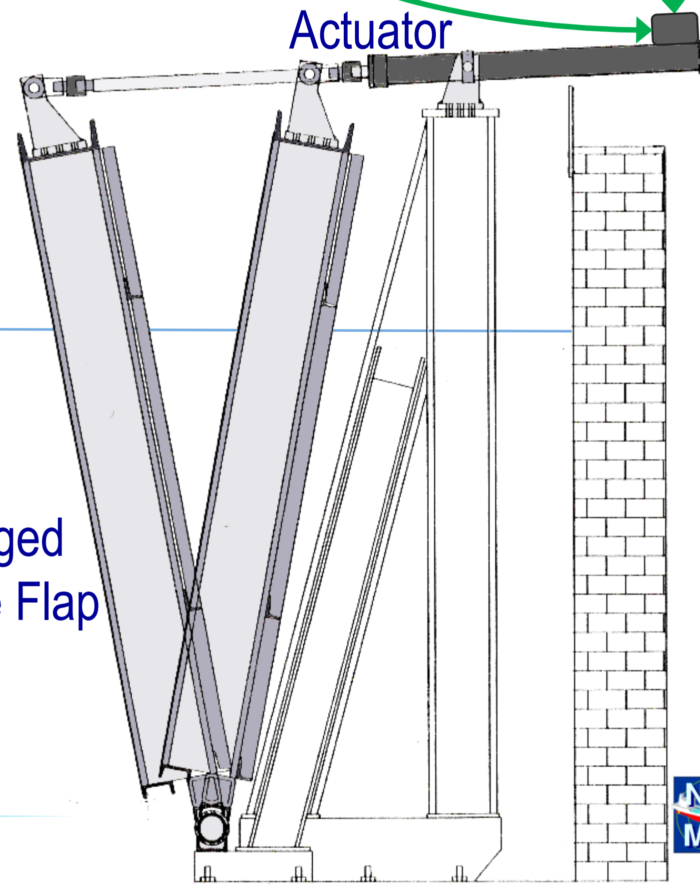
UNO Wavemaker

Original 1990 Configuration

Computer Interface Enclosure

Servocontroller

HPU



Actuator

Hinged Wave Flap

IBM 80386Sx

- 16 MHz Processor
- 1MB RAM
- 65 MB HDD
- Hercules Graphics Monochrome Monitor
- Dot-Matrix Printer

UNO Wavemaker

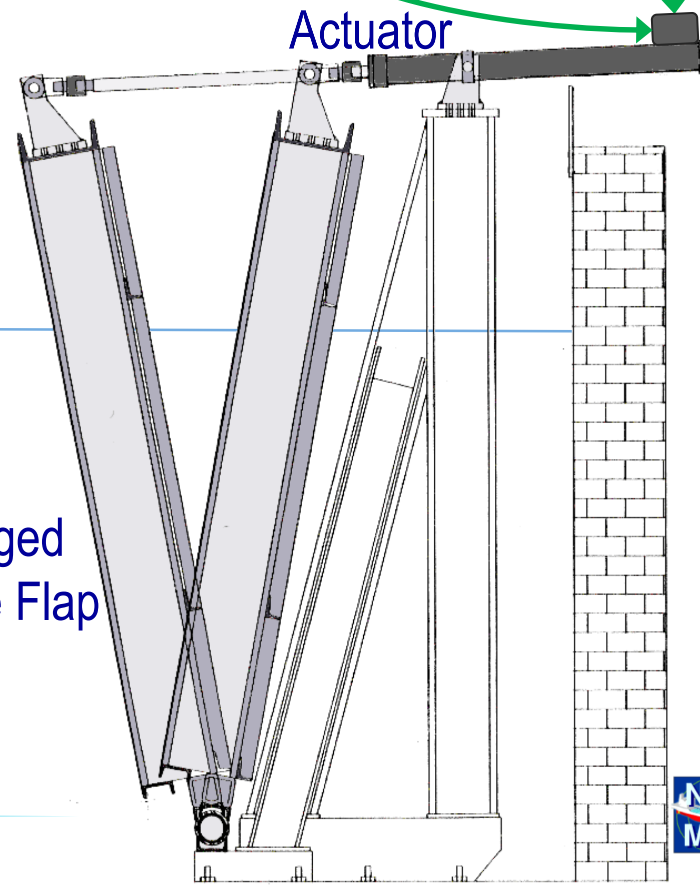
Original 1990 Configuration

Computer Interface Enclosure

Servocontroller

HPU

Actuator



Hinged Wave Flap

Software:

MKWAVES

- Create regular and irregular waves

ACQSYS

- Run experiments and record data

UNO Wavemaker

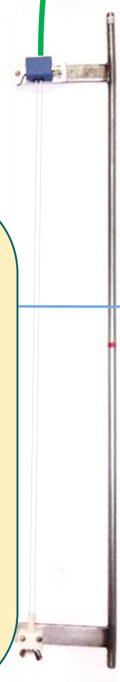
Original 1990 Configuration

IBM 386SX PC
MKWAVES
ACQSYS

Computer Interface Enclosure

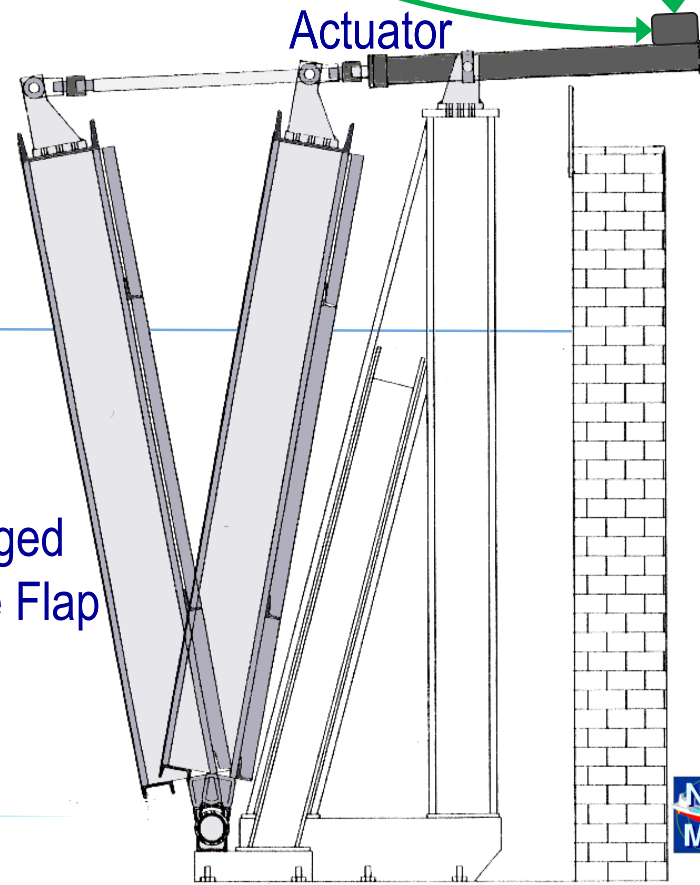
Servocontroller

HPU



Capacitance Wave Probe

- Measures wave elevation

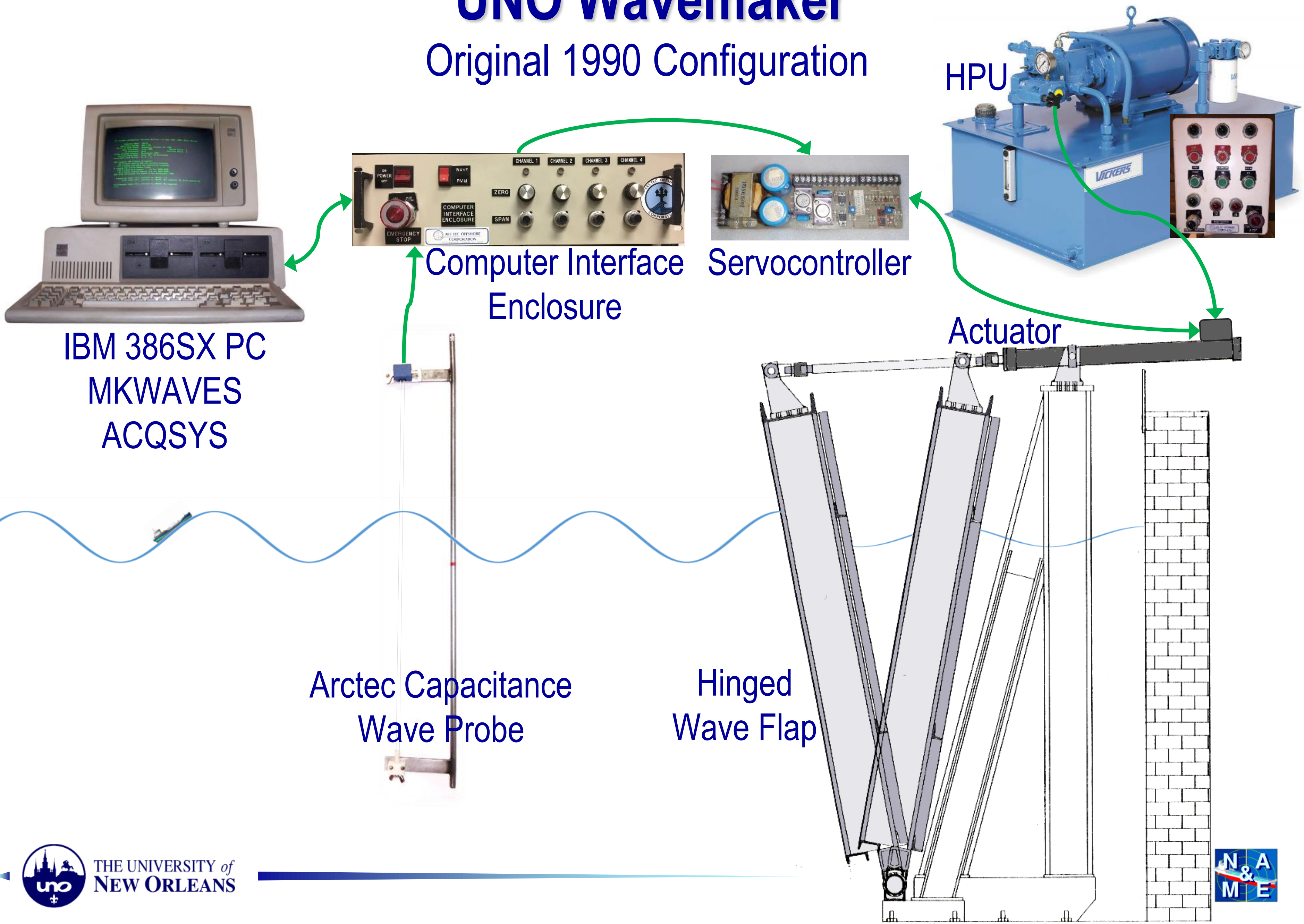


Actuator

Hinged Wave Flap

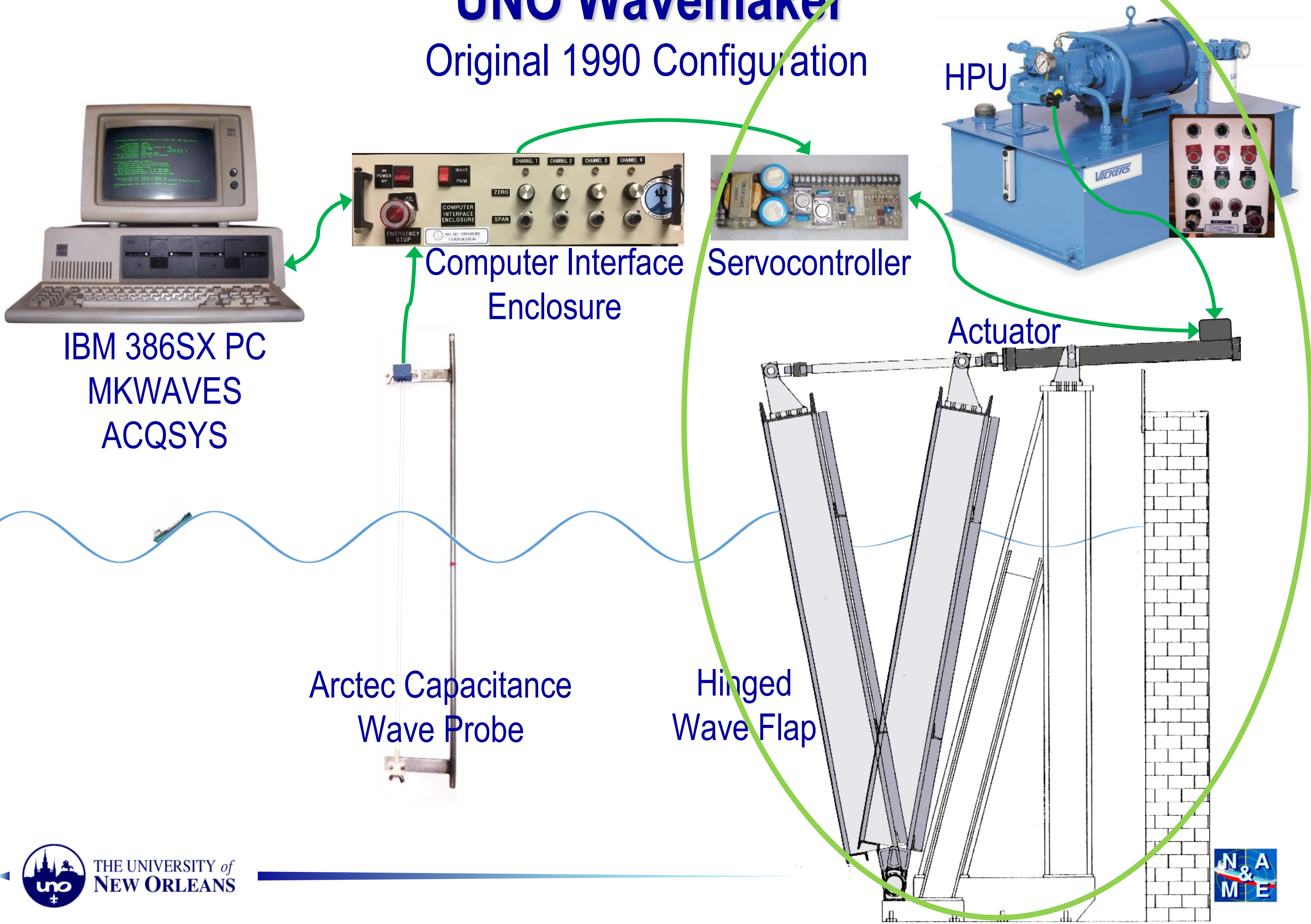
UNO Wavemaker

Original 1990 Configuration



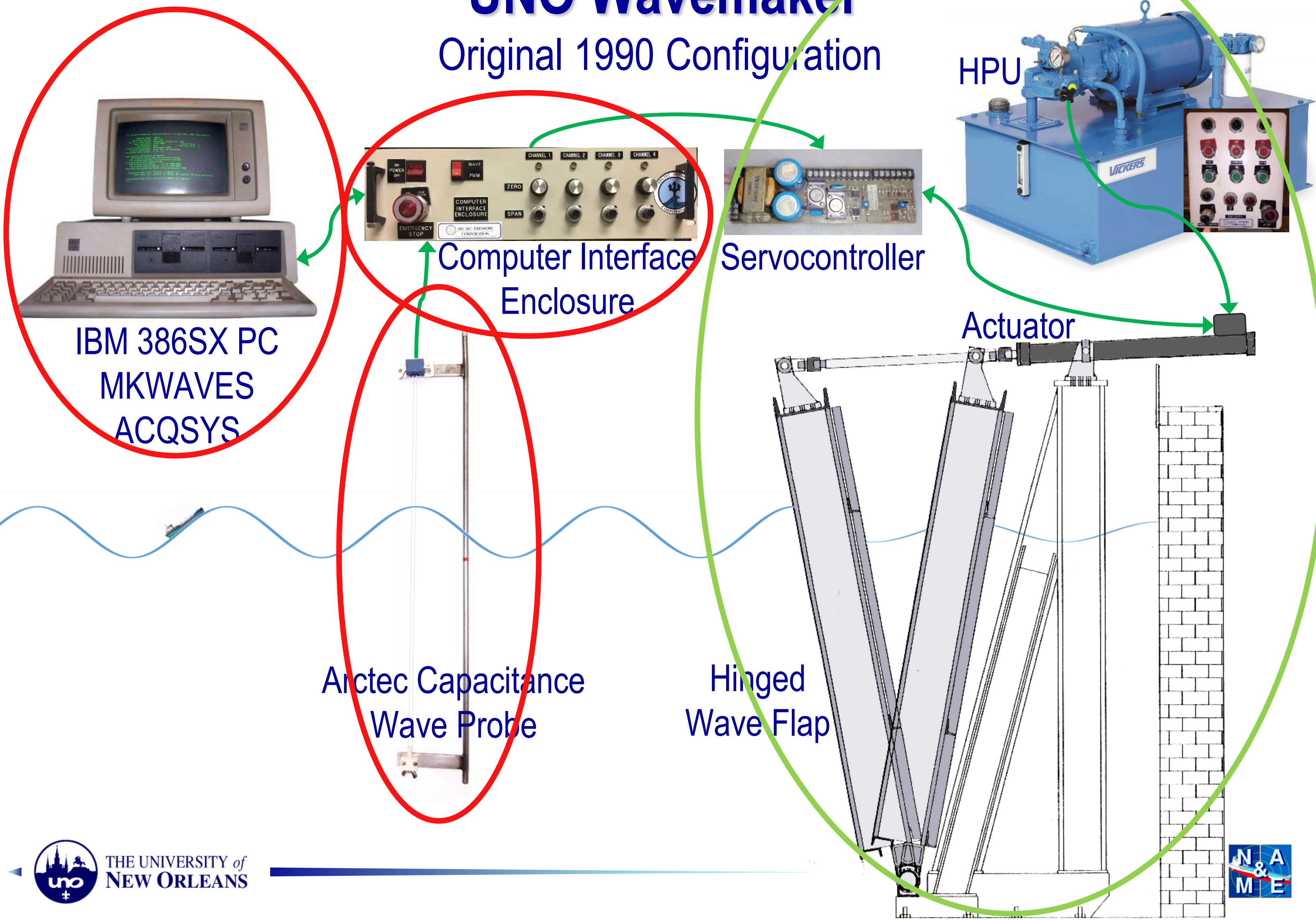
UNO Wavemaker

Original 1990 Configuration



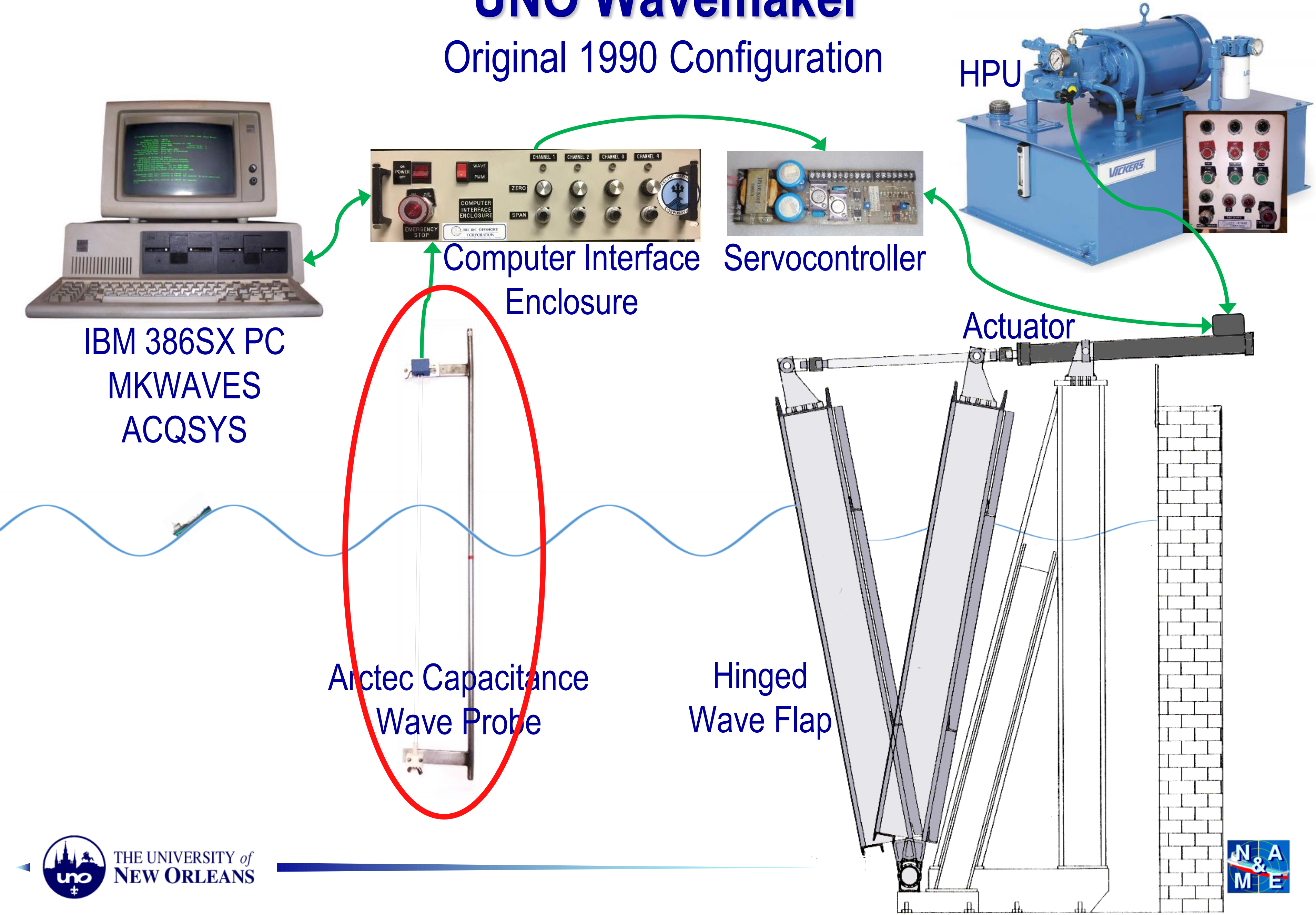
UNO Wavemaker

Original 1990 Configuration



UNO Wavemaker

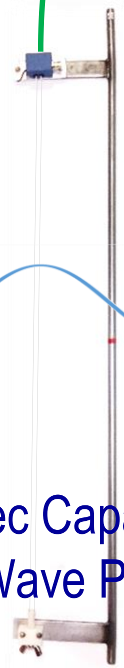
Original 1990 Configuration



UNO Wave Probes

Original 1990 Configuration

Computer Interface Enclosure



Arctec Capacitance Wave Probe

Arctec Wave Probes

- Capacitance Type Wave Probe
- Signal conditioning is part of Computer Interface Enclosure

Disadvantages

- Difficult to use with other measurement systems
- Long immersion time causes drift.

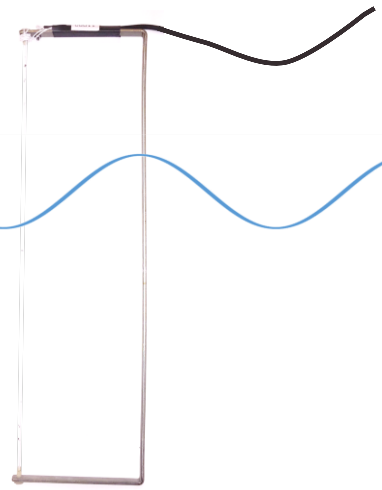
UNO Wave Probes

RBR WG-50

RBR WG-50 wave probes were purchased to replace the Arctec Probes, circa 2003

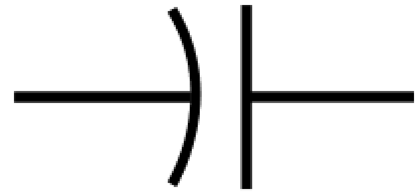
RBR WG-50

- Voltage Output
- PTFE insulated
- Capacitance Type



UNO Wave Probes

Capacitance Wave Probes

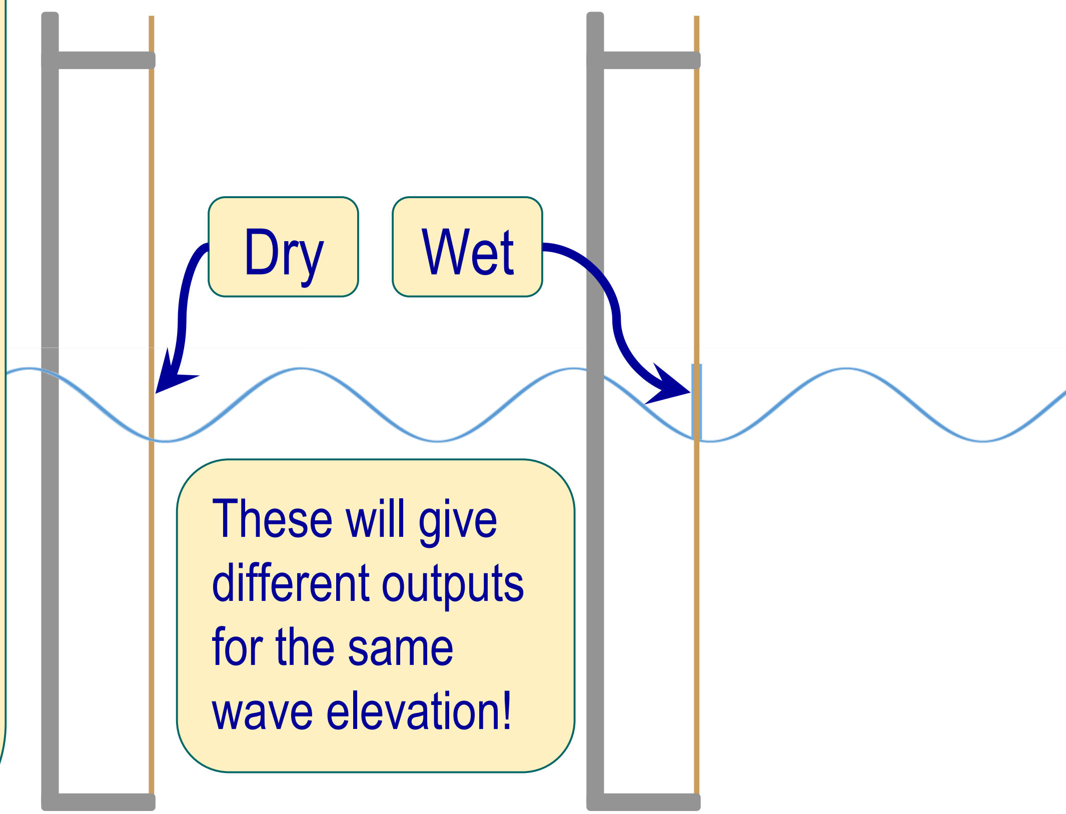


The Problem:

When the un-immersed part of the probe gets wet, it temporarily stays wet.

The capacitance is changed until the probe dries, usually a few minutes.

This gives an error of up to ¼ inch which slowly decreases.



These will give different outputs for the same wave elevation!

UNO Wave Probes

Senix Ultra-S

Senix Ultra-S

- Ultrasonic
- Non-contact
- Voltage, Current, or Serial Output

Problem:

Poor performance when measuring short wavelength waves.

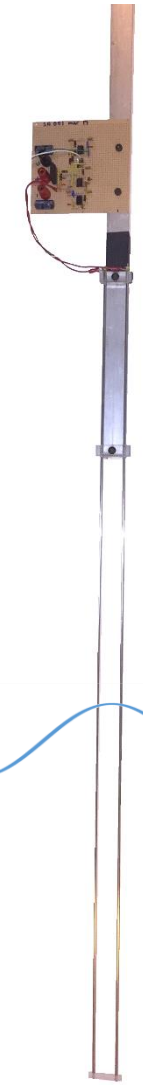
UNO Wave Probes

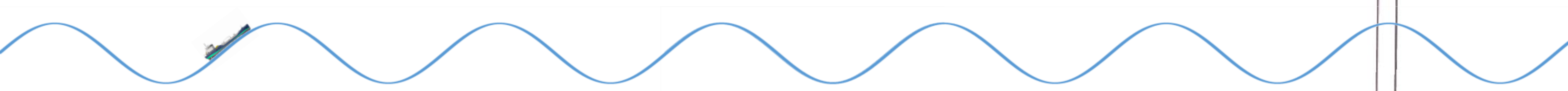
Conductance Wave Probes

aka Resistance Wave Probes

UNO Conductance Probe Prototype

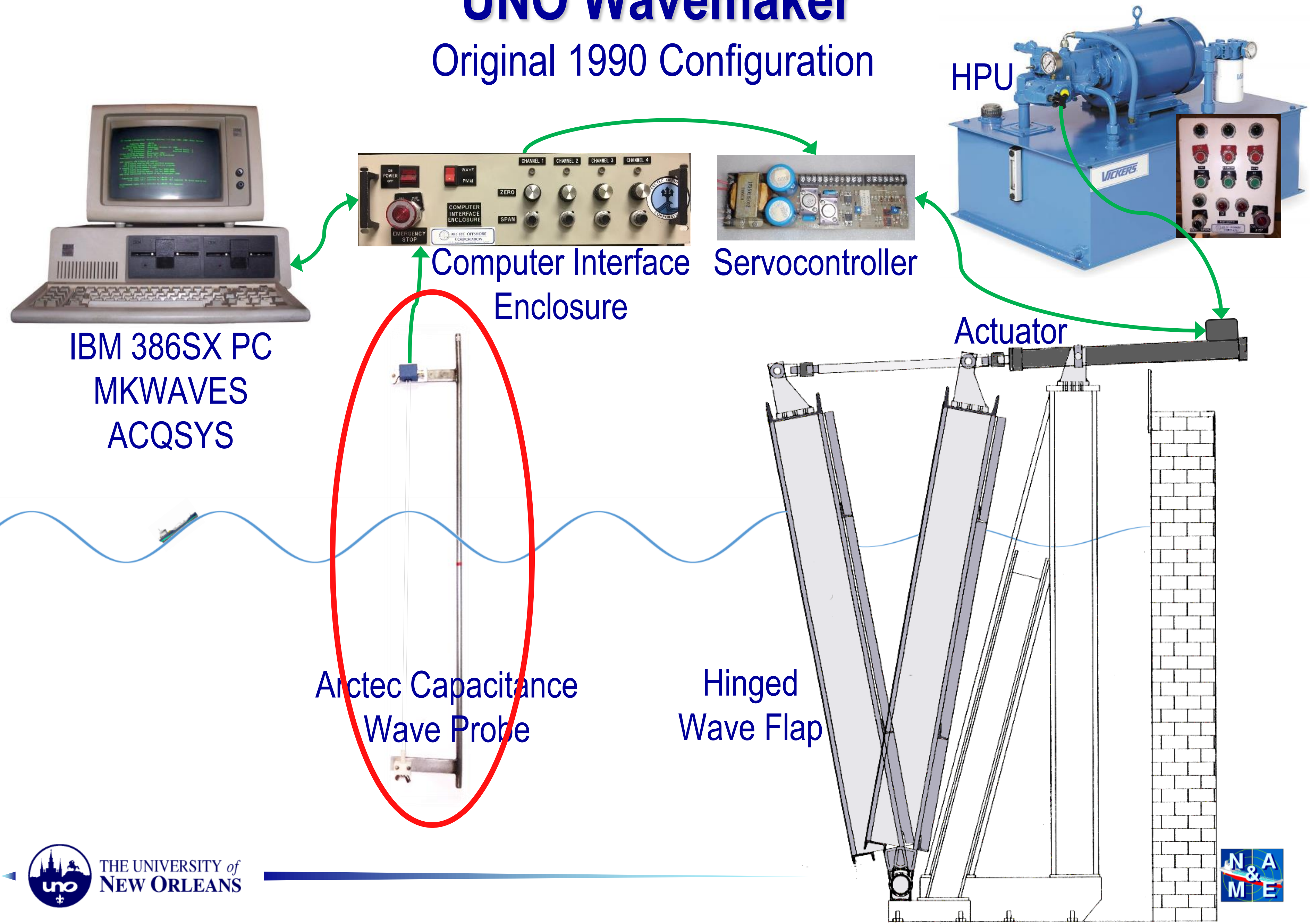
- Designed in-house
- 3 units constructed
- Currently in use





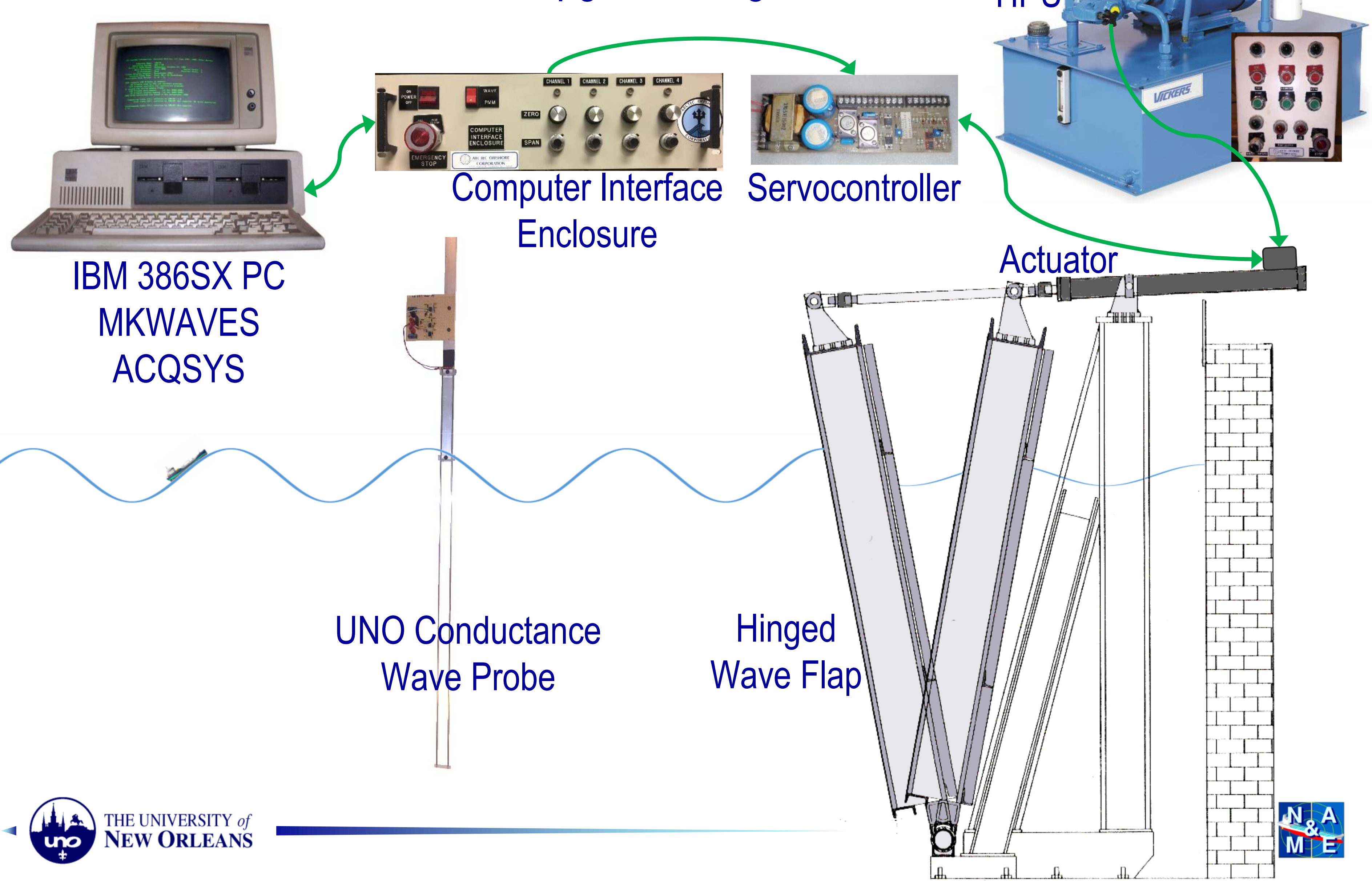
UNO Wavemaker

Original 1990 Configuration



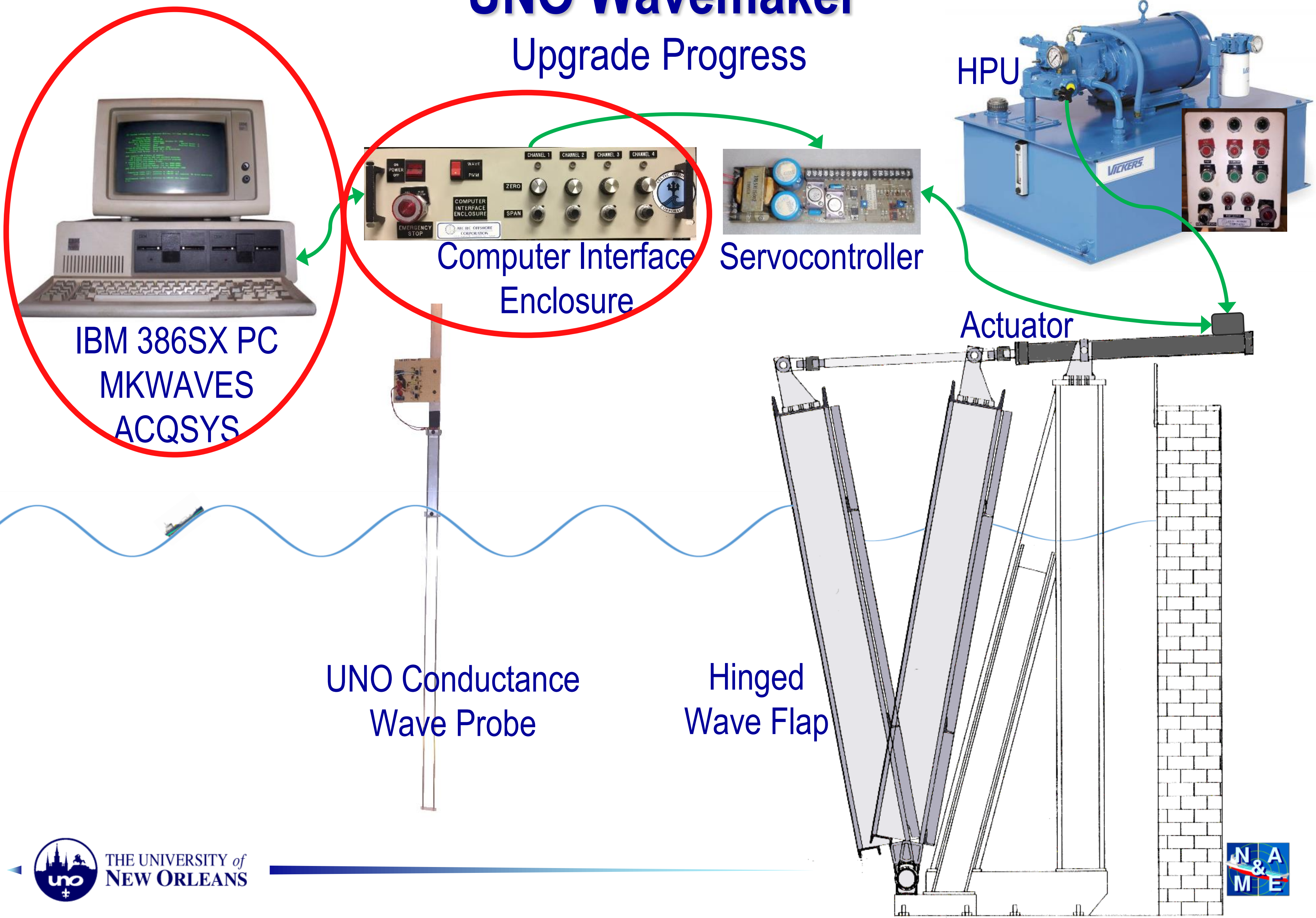
UNO Wavemaker

Upgrade Progress



UNO Wavemaker

Upgrade Progress



UNO Wavemaker

Original Software

IBM 386SX PC
MKWAVES
ACQSYS

MKWAVES and ACQSYS Software

- DOS based software.
- Required native DOS system
- Would not run in DOS Emulator
- Primary outputs are to the printer

UNO Wavemaker

Original Computer Hardware

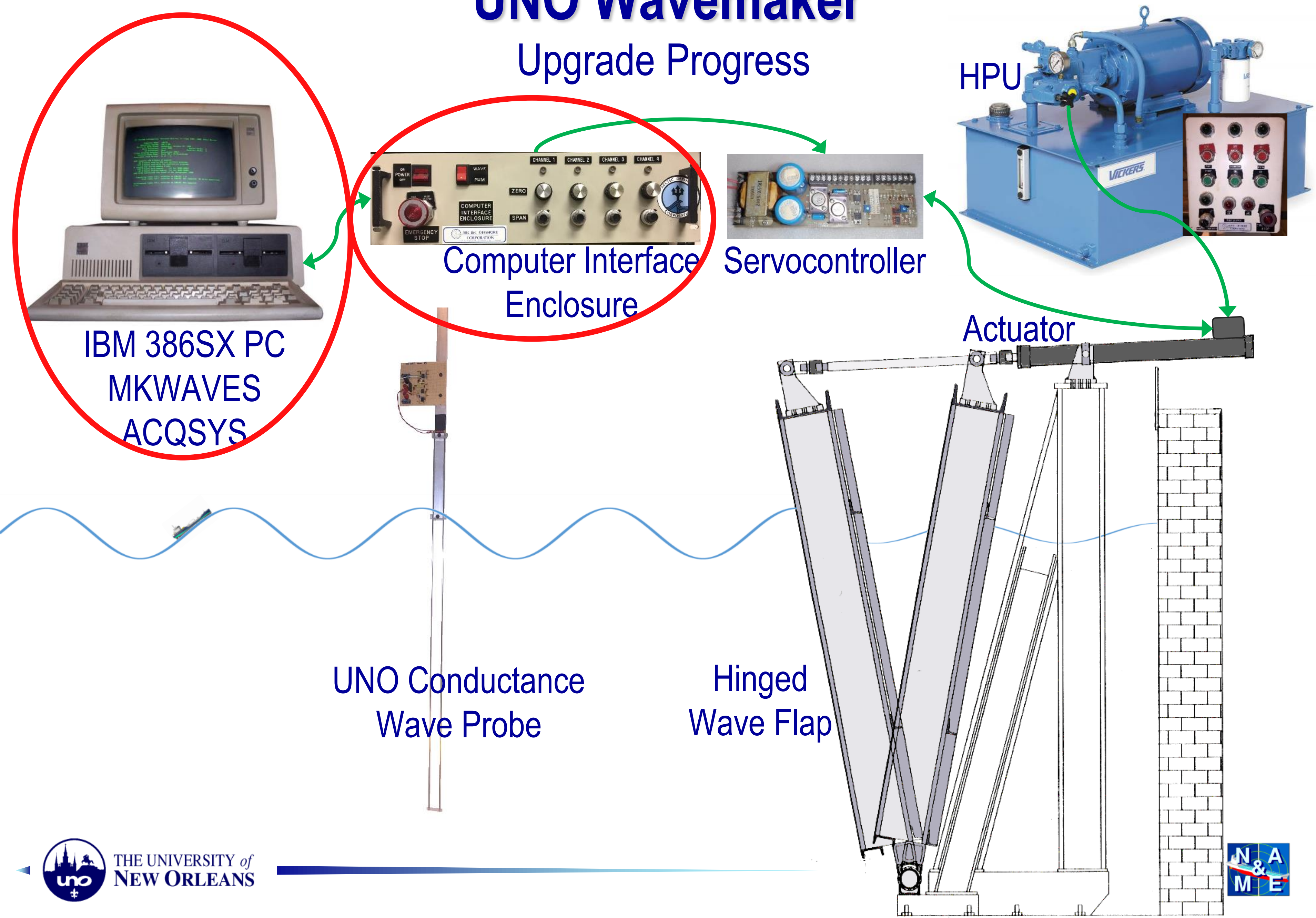
IBM 386SX PC
MKWAVES
ACQSYS

IBM 386SX

- Hardware was upgraded as far as it could go.
- The data card required an ISA bus.
- Eventually became unusable.

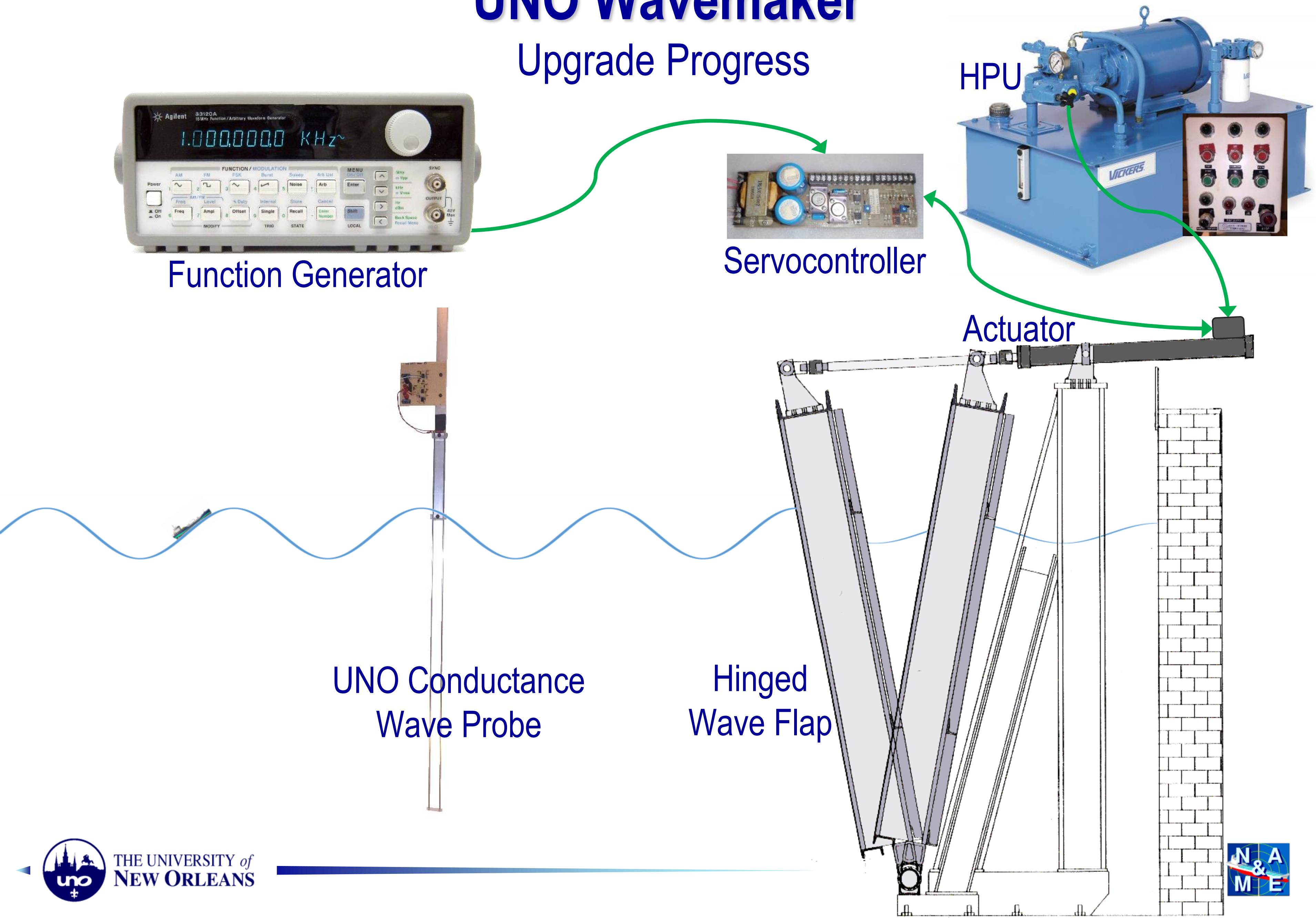
UNO Wavemaker

Upgrade Progress



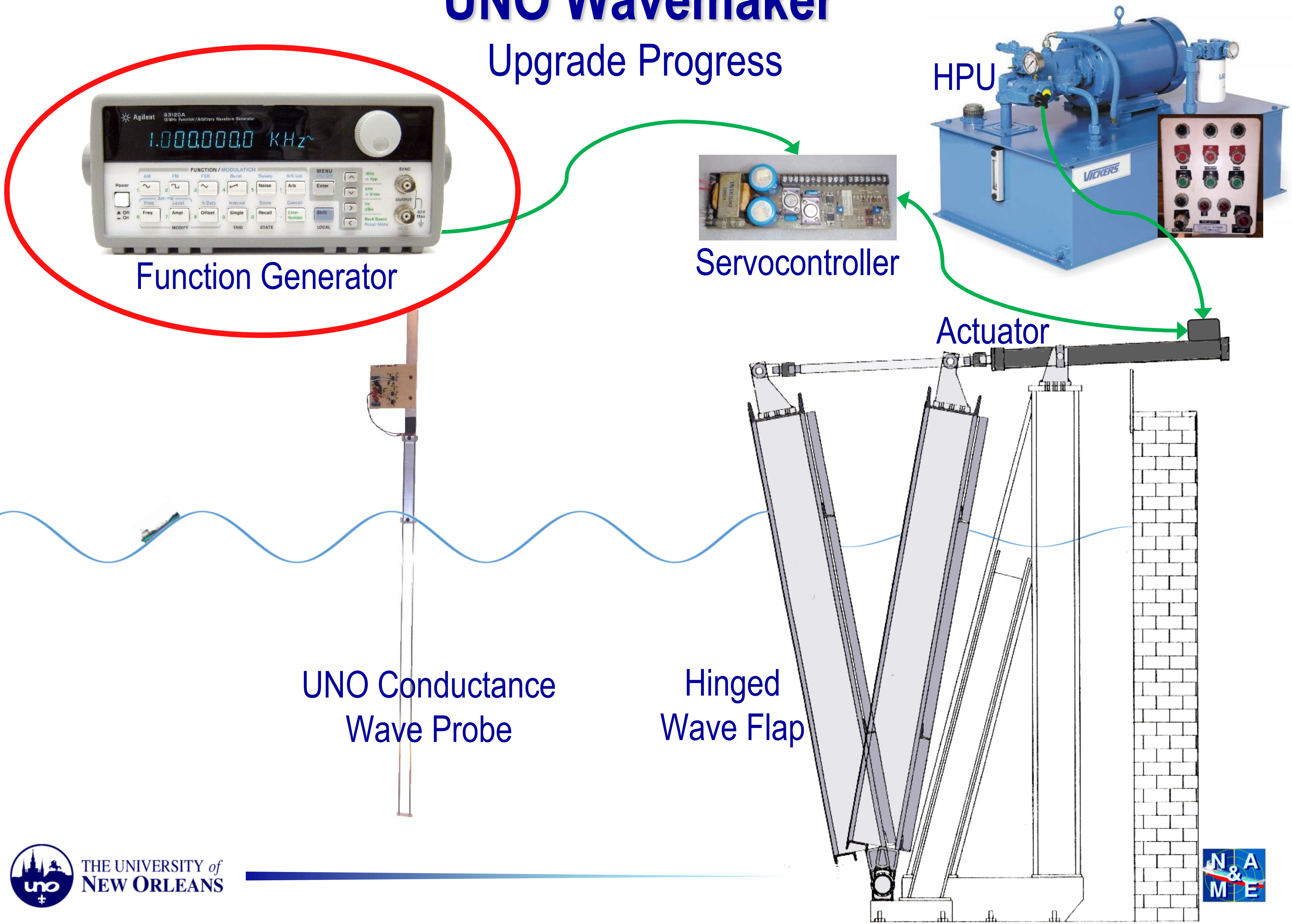
UNO Wavemaker

Upgrade Progress



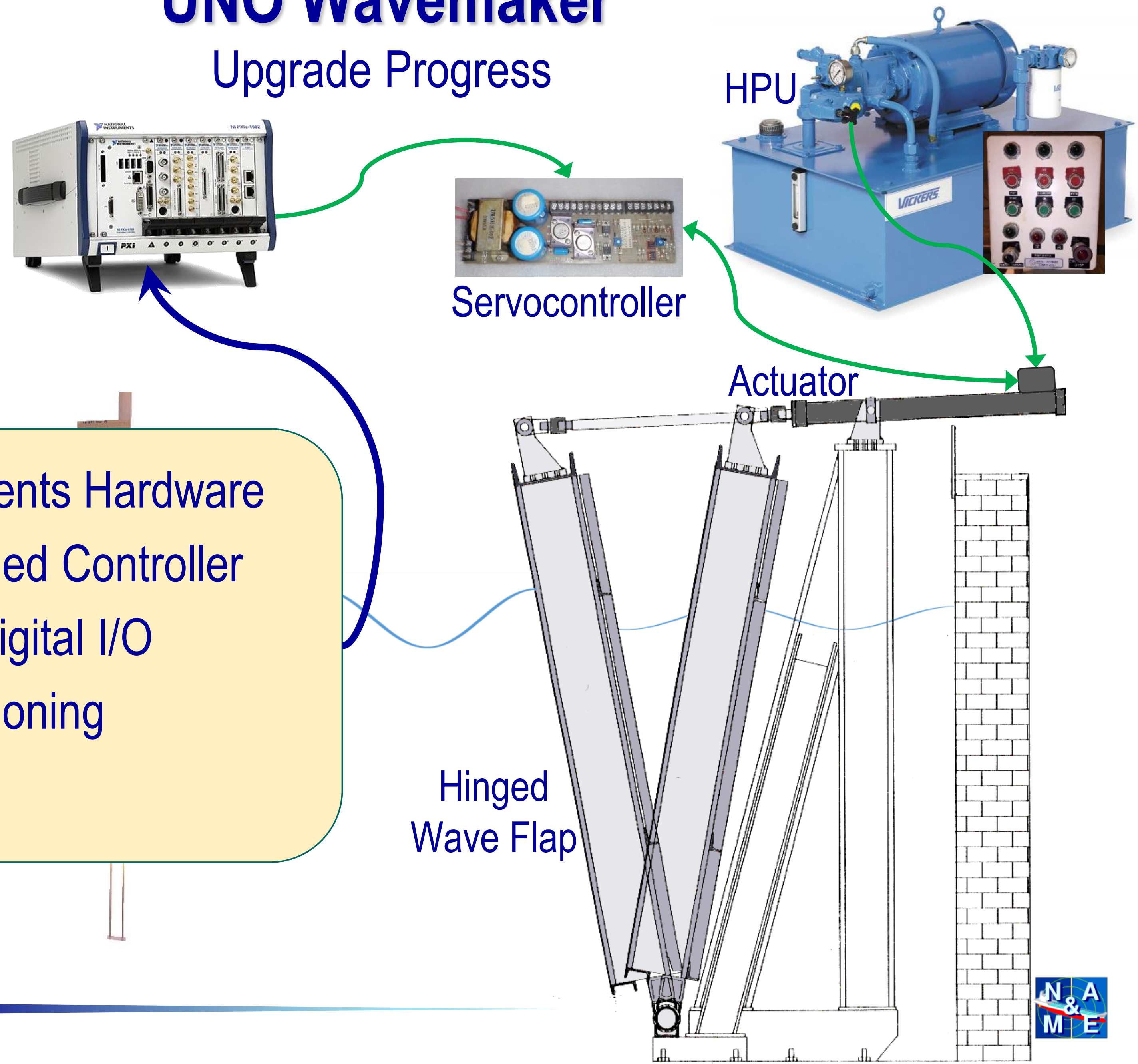
UNO Wavemaker

Upgrade Progress



UNO Wavemaker

Upgrade Progress

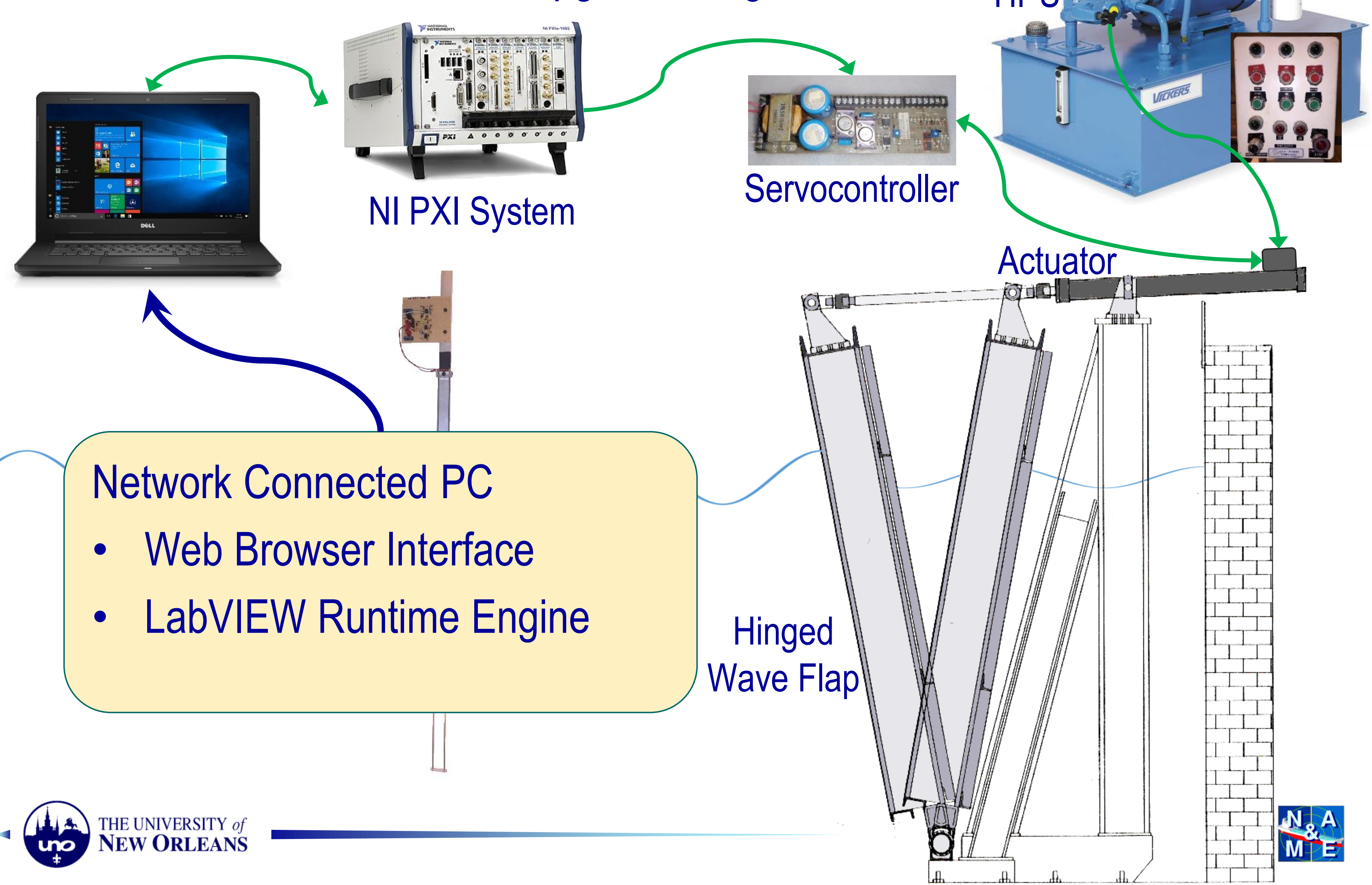


National Instruments Hardware

- PXIe Embedded Controller
- Analog and Digital I/O
- Signal Conditioning

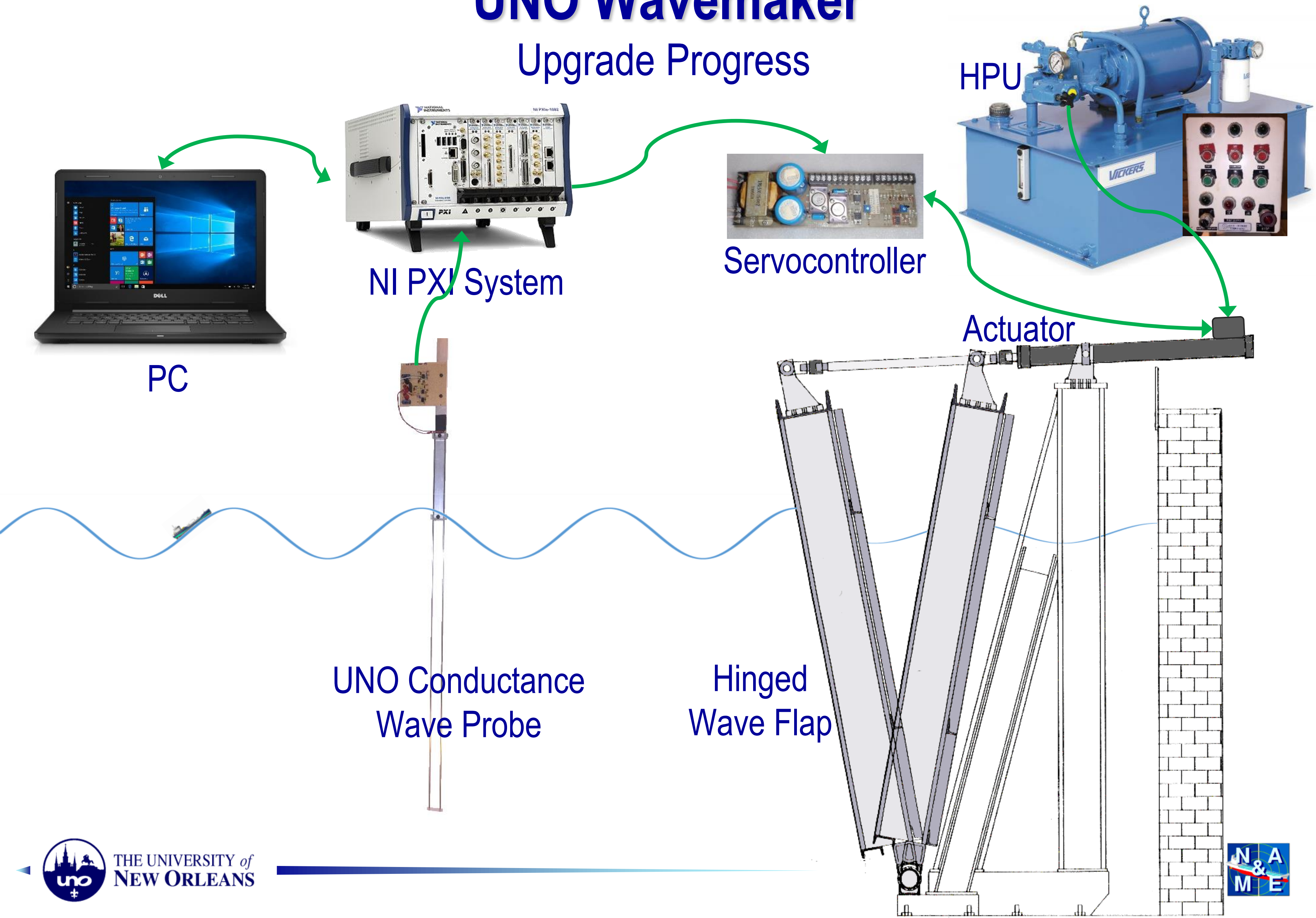
UNO Wavemaker

Upgrade Progress



UNO Wavemaker

Upgrade Progress



UNO Wavemaker

Software

NI PXI System

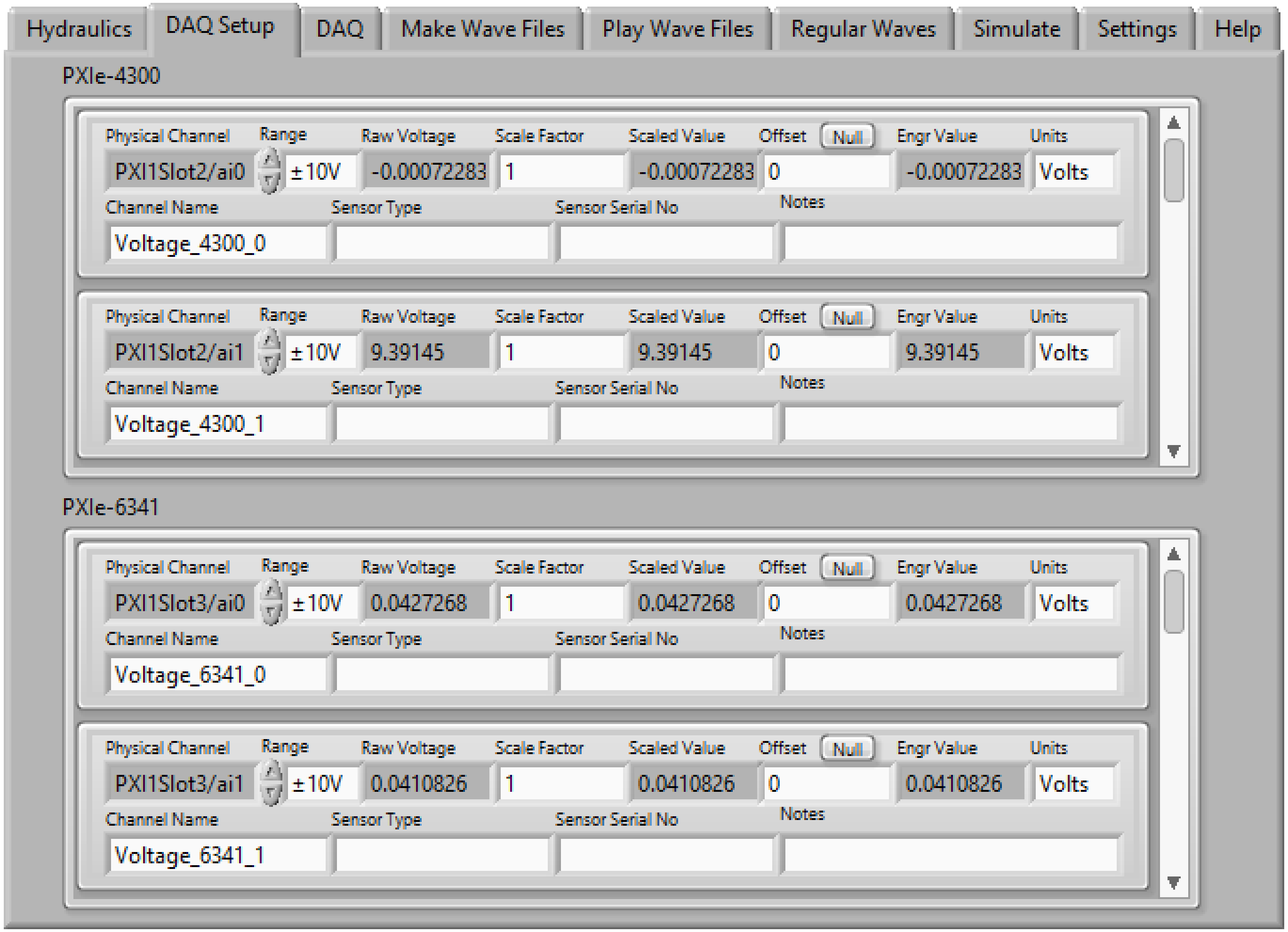
PC

Software

- Written in-house
- Runs on real-time embedded OS
- Written in LabVIEW
- Hosts webpage for user interface

UNO Wavemaker

User Interface



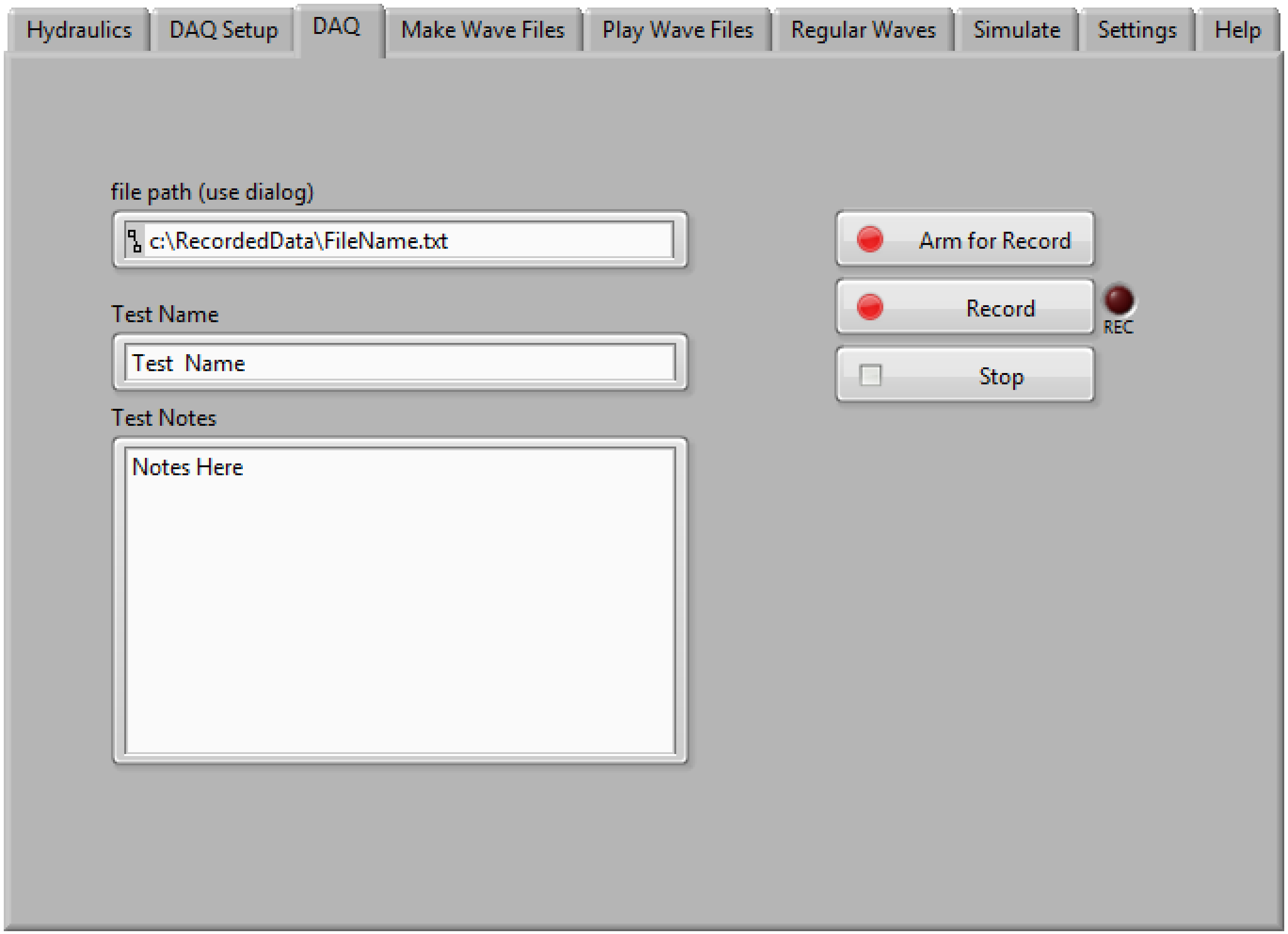
DAQ Setup

Configure DAQ Channels

Scale & Offset Measurements

UNO Wavemaker

User Interface



DAQ

Name File

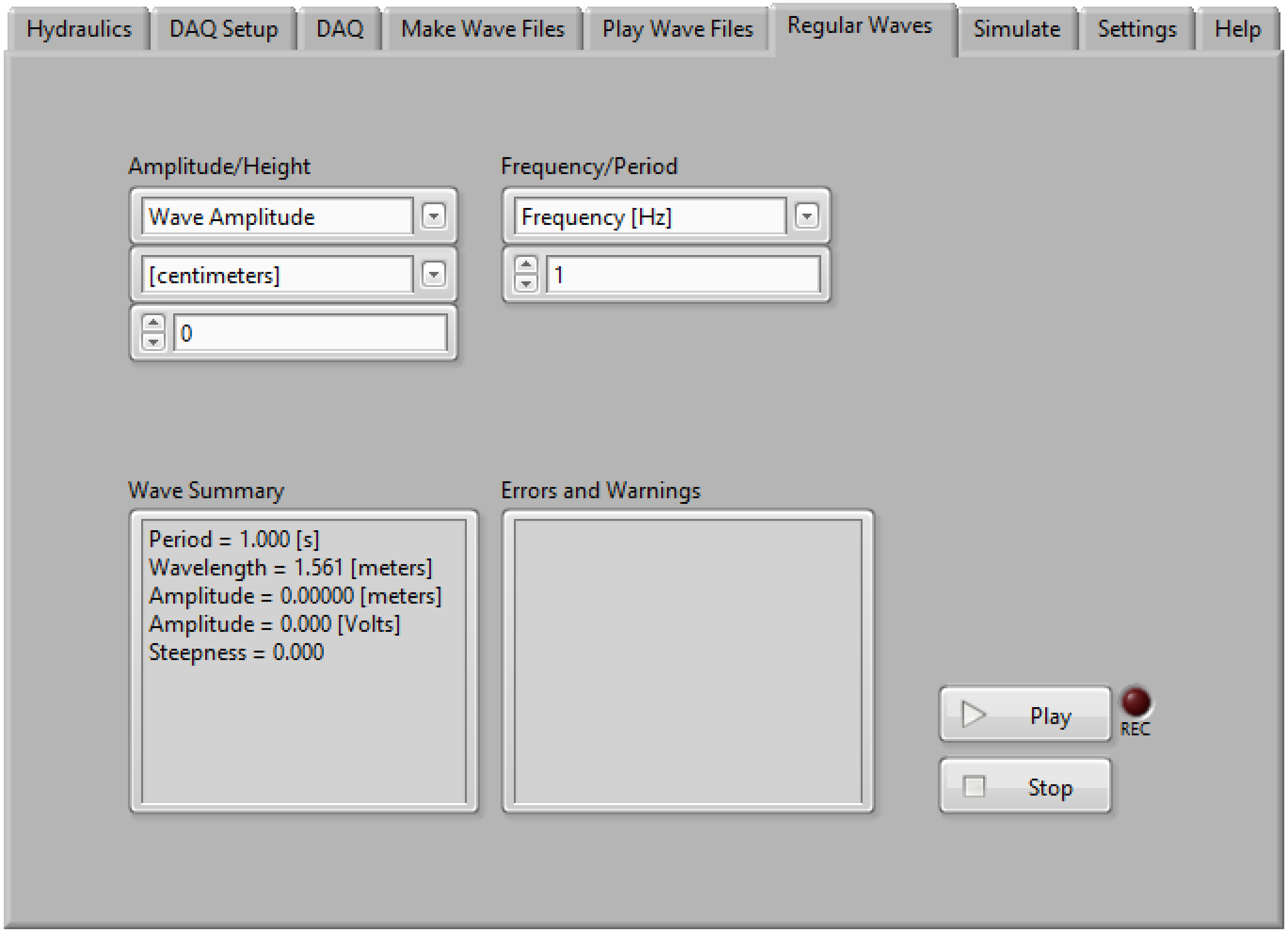
Name Test

Write Notes

Start, Stop, and Arm Recording

UNO Wavemaker

User Interface



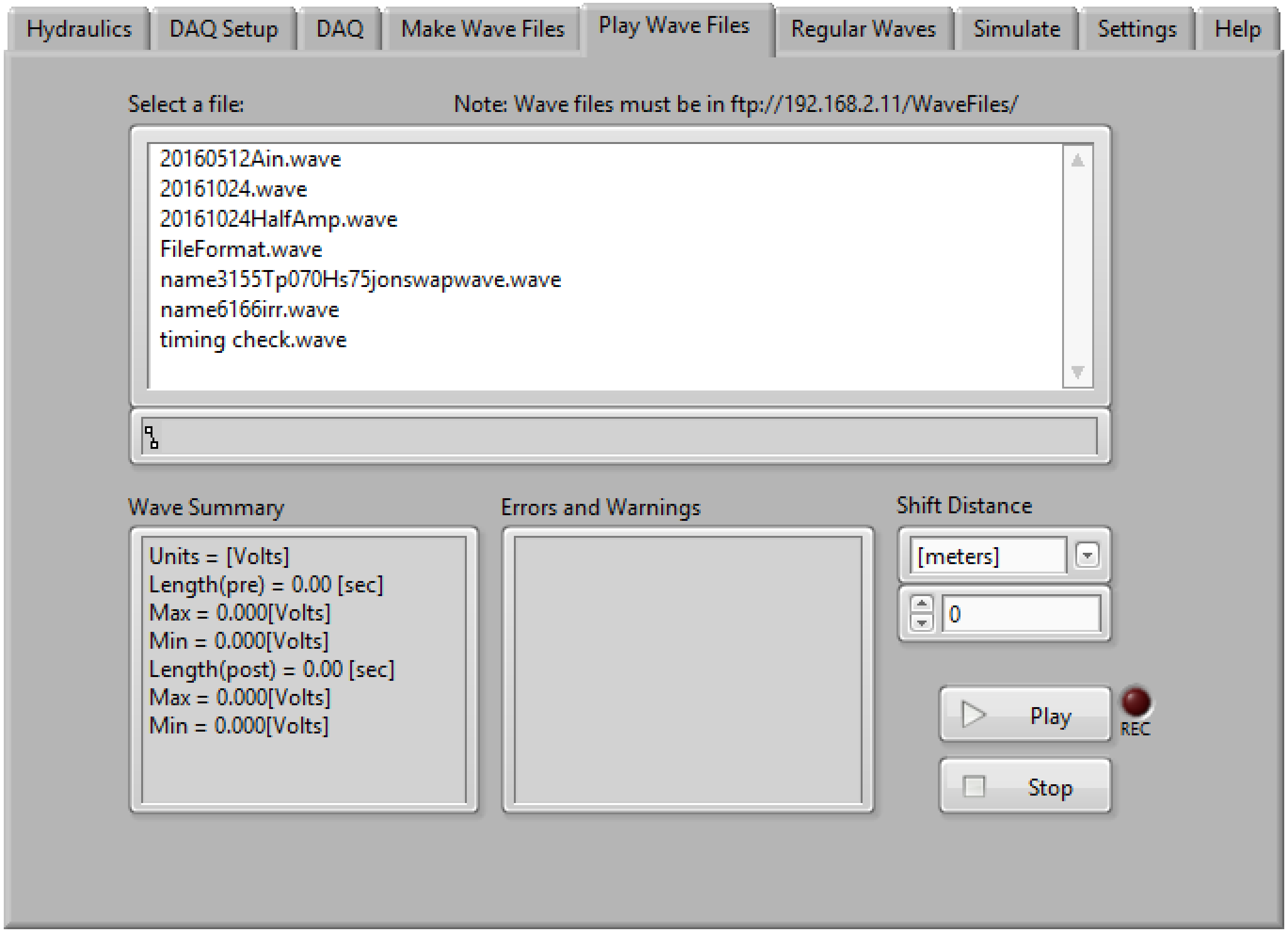
Regular Waves

Specify wave height

Specify wave period, frequency, or wavelength

UNO Wavemaker

User Interface



Play Wave Files

Run premade wave files

Choose location along tank of time series

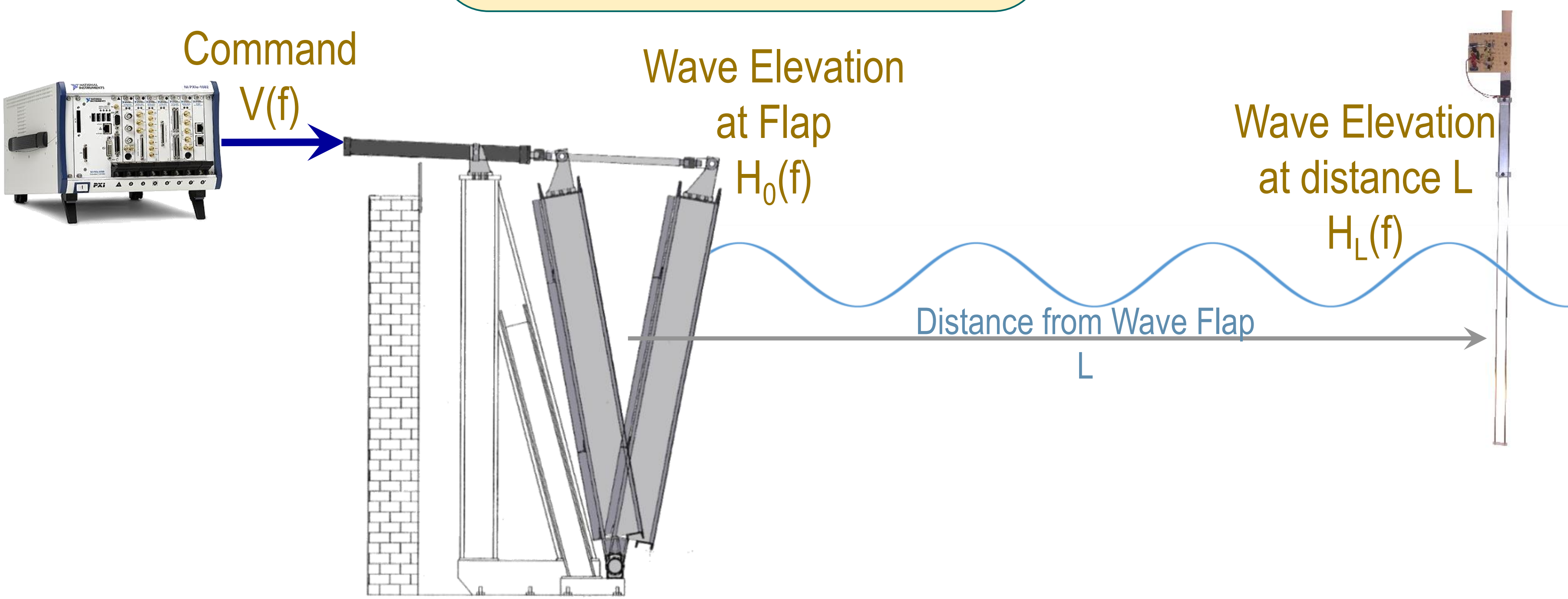
Filetype *.wave

UNO Wavemaker

Wavemaker Theory

Wavemaker Signals

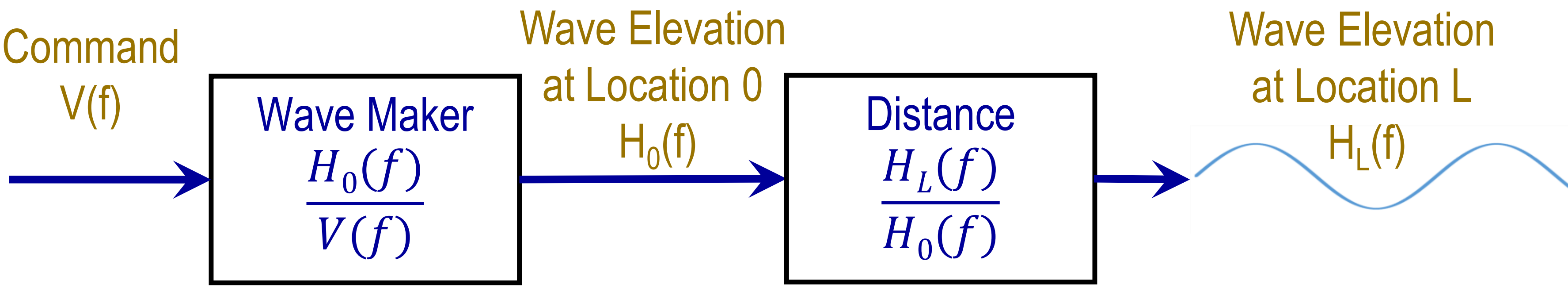
- Command Voltage
- Wave Elevations



UNO Wavemaker

Wavemaker Theory

The parts of the wavemaker can be modeled as transfer functions if linear system behavior is assumed.



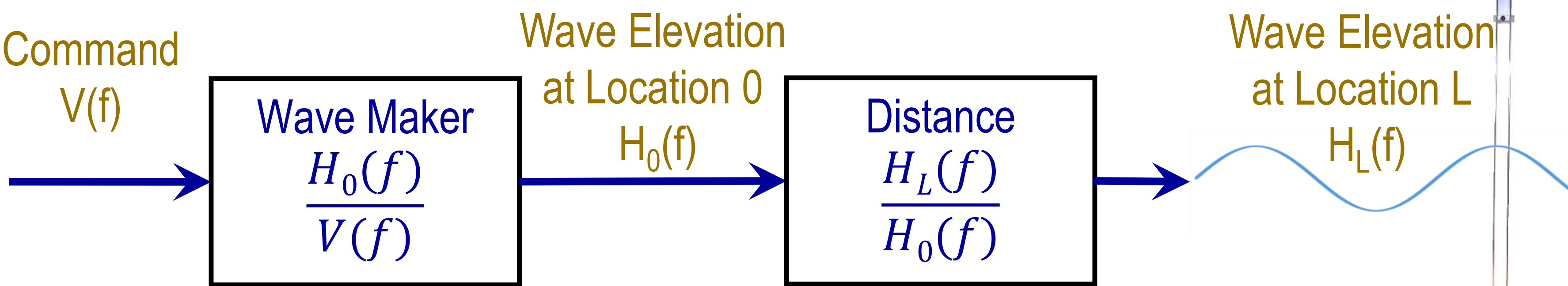
Can be measured.

Can be determined from wave celerity equation.

UNO Wavemaker

System Identification

To measure the system response, the wave elevation, h(t), was measured at a distance L from the wave flap for a given input, v(t).



The input signal was designed to include the frequency bandwidth of interest without wave-breaking and to have the entire wave pass the wave probe before reflections returned from the end of the tank.

UNO Wavemaker

System Identification

The response of the wavemaker was measured with a conductance wave probe and recorded.

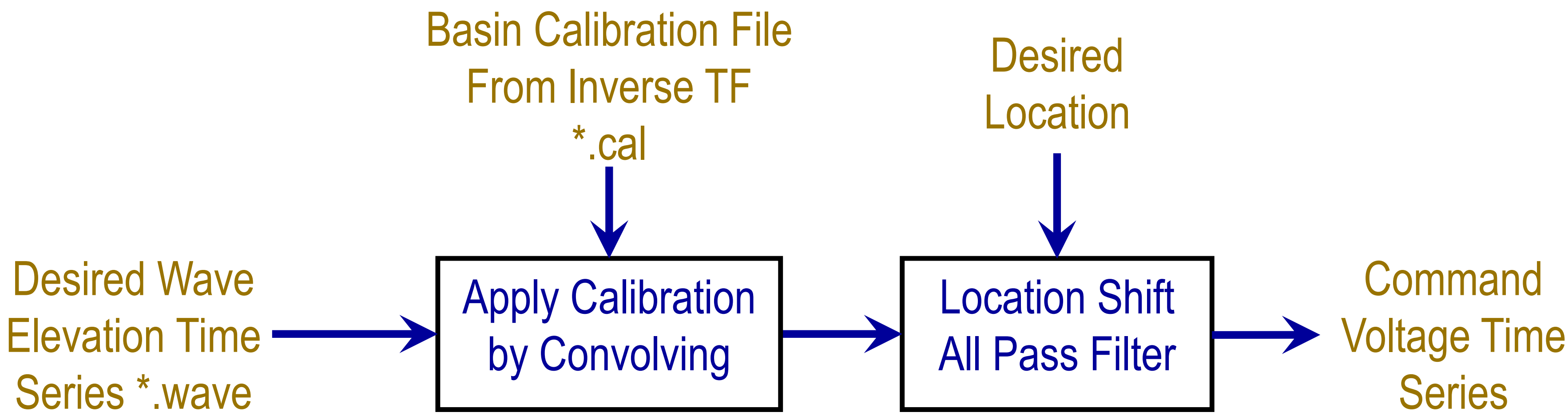
Wiener deconvolution was used to determine the forward and inverse transfer functions from the input and output data.

The inverse transfer function can now be used to determine the appropriate input signal for a desired wave elevation. It is described by its impulse response in a basin calibration file.

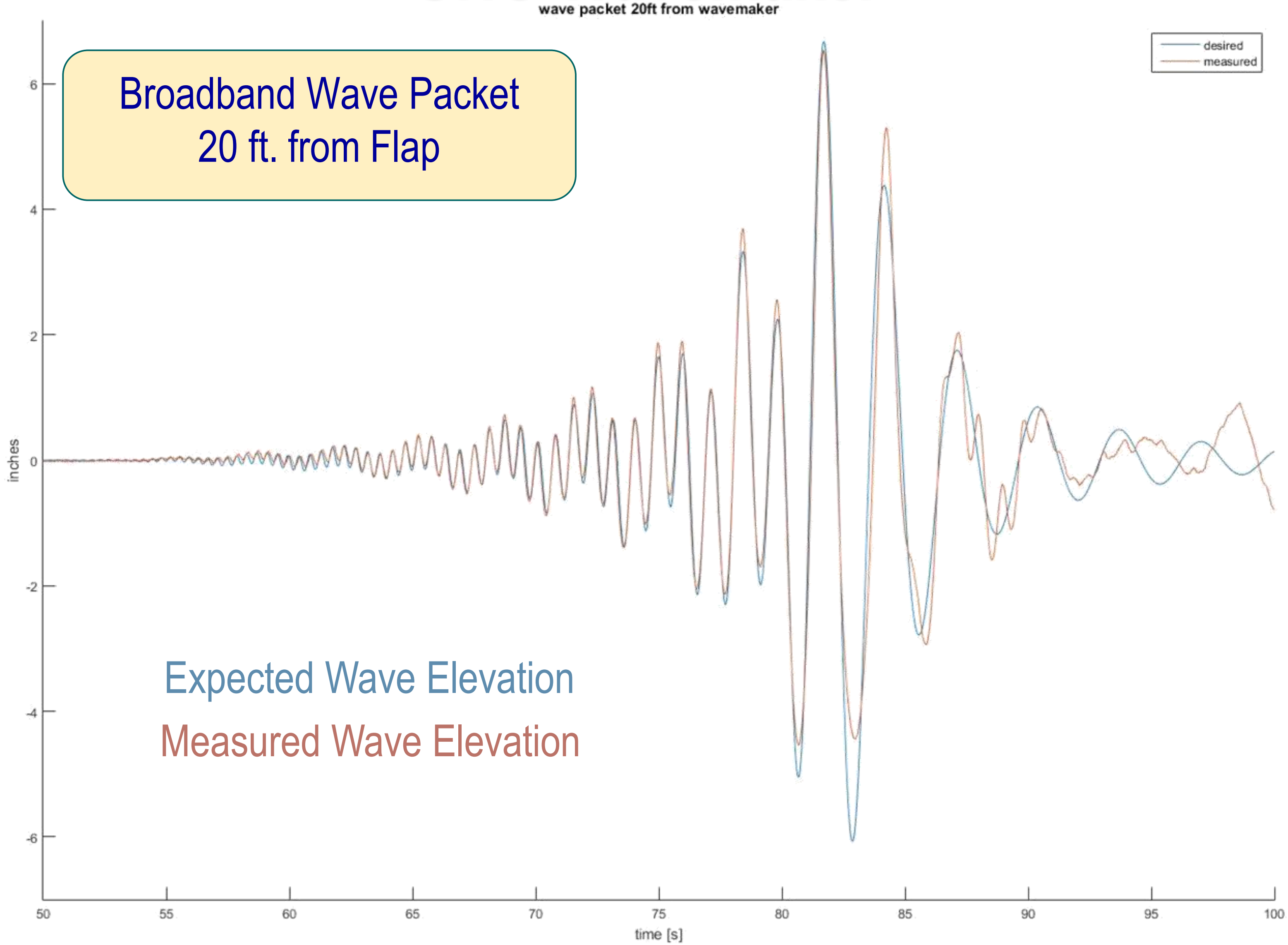
UNO Wavemaker

Wavemaker Software

Software Functional Diagram
for Playing Wave Files

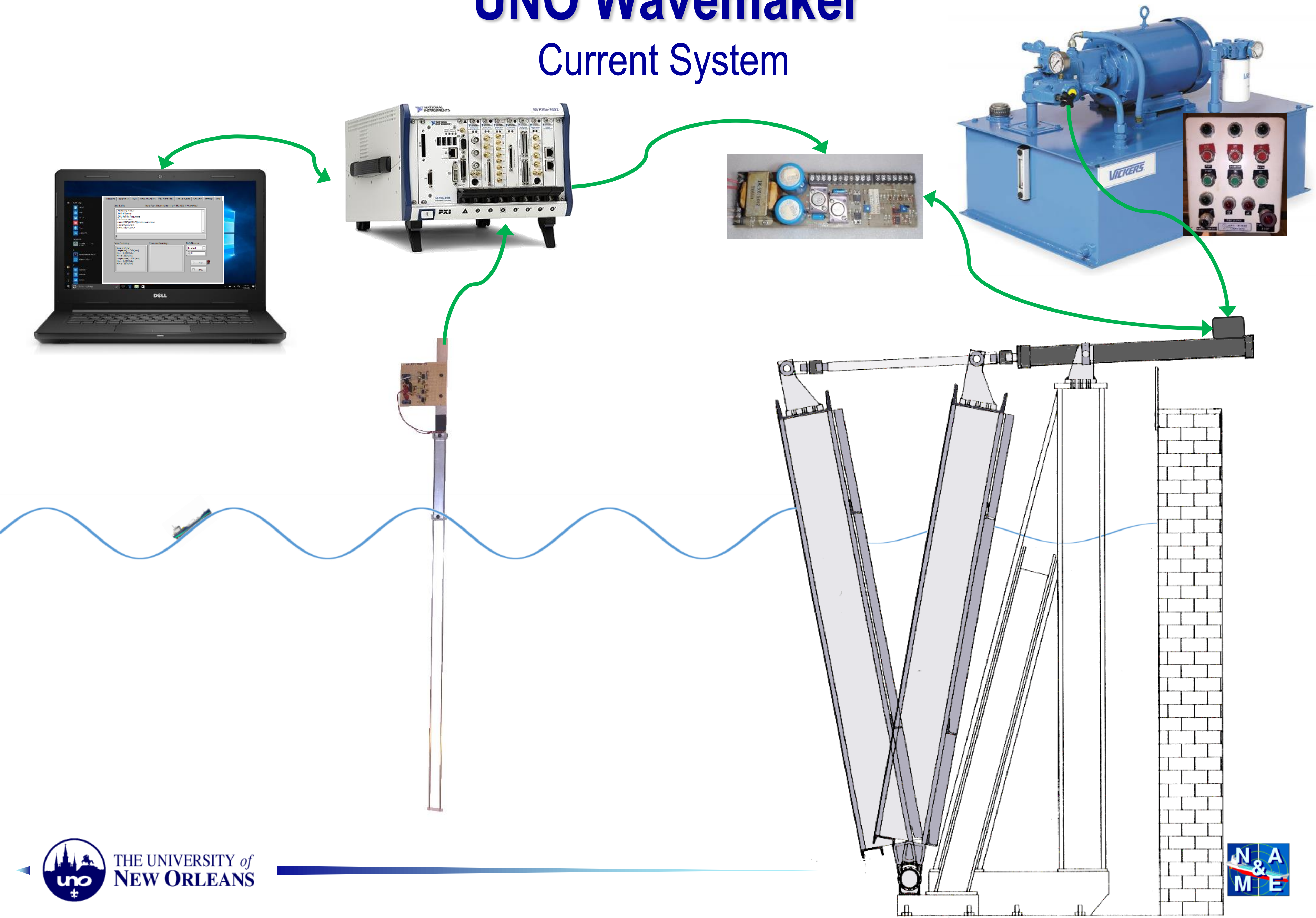


UNO Wavemaker

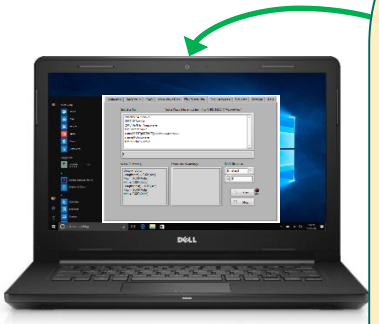


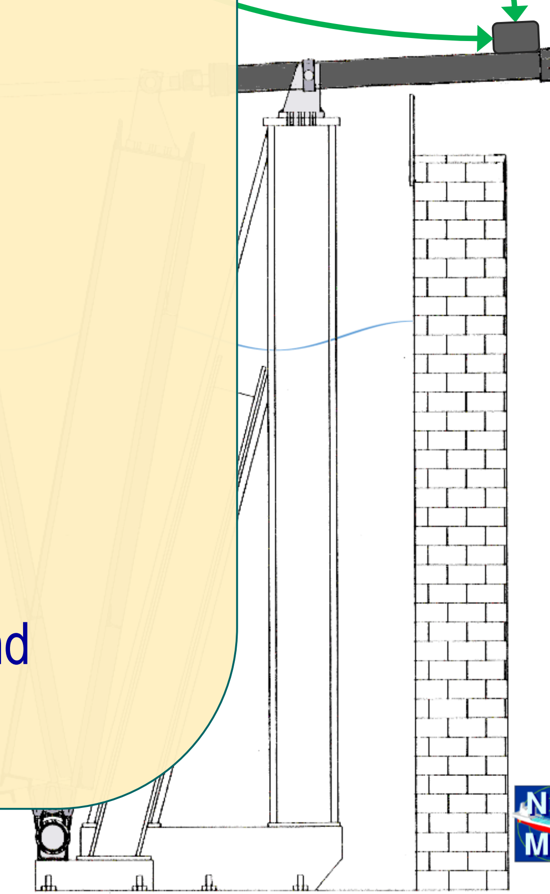
UNO Wavemaker

Current System



UNO Wavemaker





Future Work

Theory

- Quantify limitations of LTI approach

Software

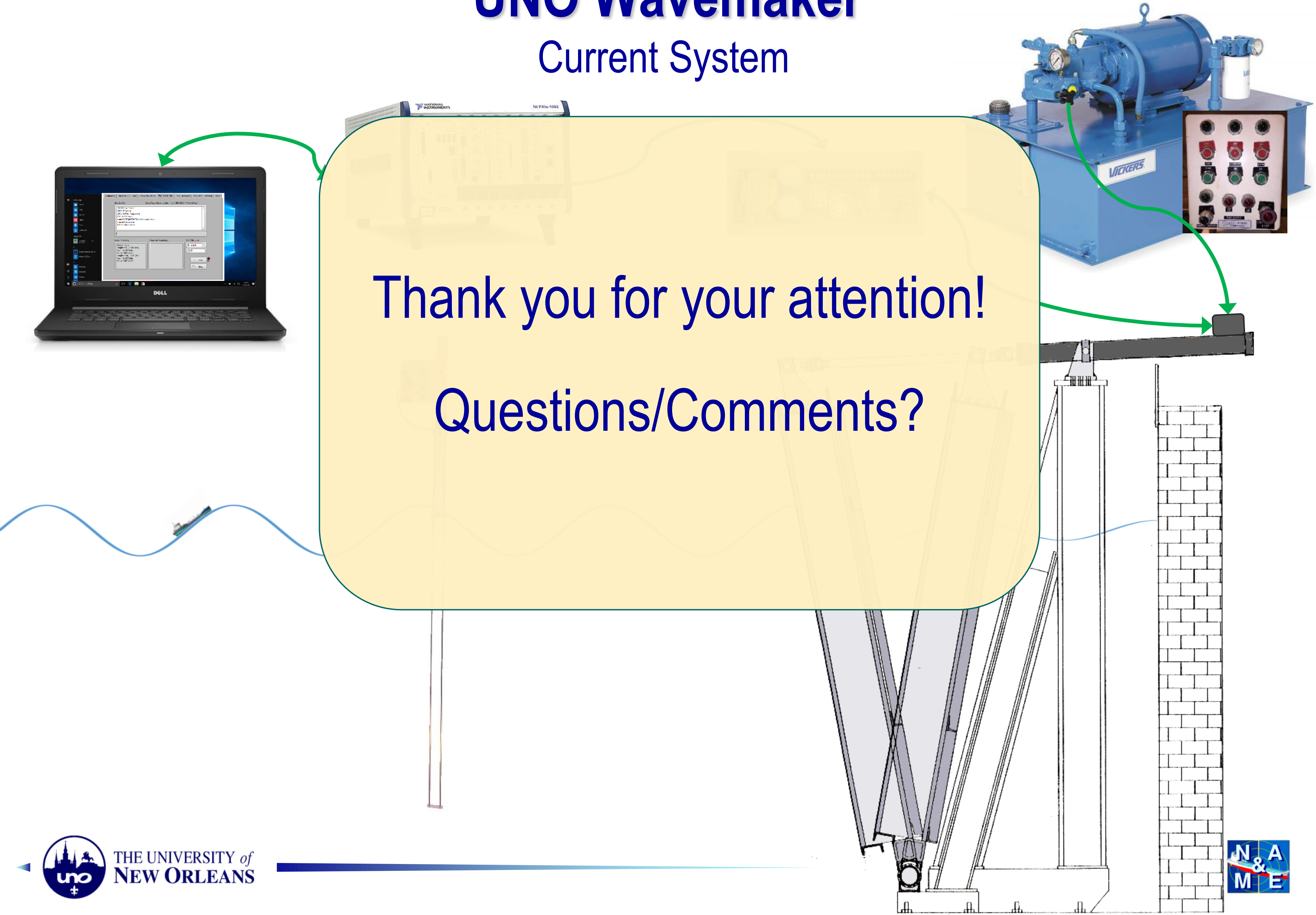
- Control HPU
- Create wave files in application
- Automate series of tests
- Simulate waves from wave files

Hardware

- Reduce Noise of HPU
- Create PCBs for wave probes
- Improve wave probe mounting and calibration hardware

UNO Wavemaker

Current System



Thank you for your attention!

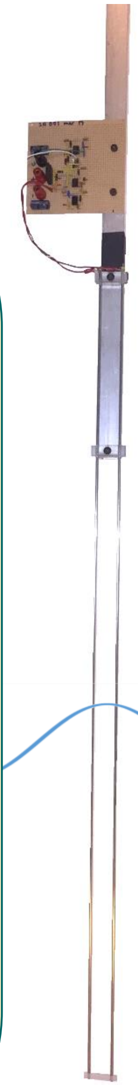
Questions/Comments?

Backup Slides

Text box

UNO Wave Probes

Conductance Wave Probes



Theory:

Conductance, G, between submerged conductive probes is

$$G = z\frac{\pi d K}{D}$$

z = immersion depth

D = separation distance

d = wire diameter

K = conductivity of fluid

$$G \propto z$$

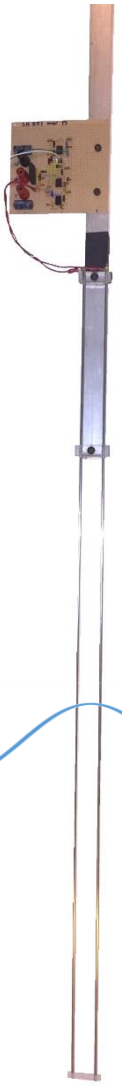
Conductance is proportional to immersion depth

UNO Wave Probes

Conductance Wave Probes

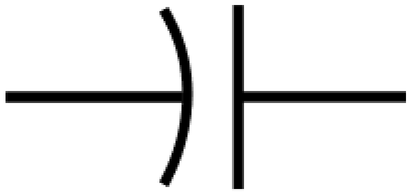
Functional Description

- Two stainless steel rods 1” apart are partially immersed.
- An AC voltage is placed across the probes.
- The current through the circuit is measured, rectified, and filtered.
- The resulting signal $\propto$ wave elevation.



UNO Wave Probes

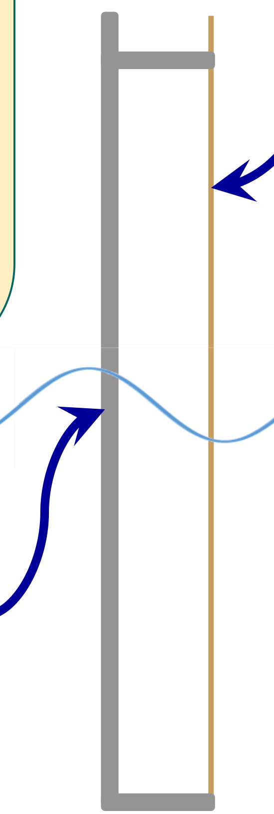
Capacitance Wave Probes



Capacitance Wave Probes

- Capacitance varies linearly with immersion
- Signal conditioning converts capacitance to voltage

Insulated Conductor



Conductive Frame

The water and insulated conductor act as two "plates" of a capacitor.

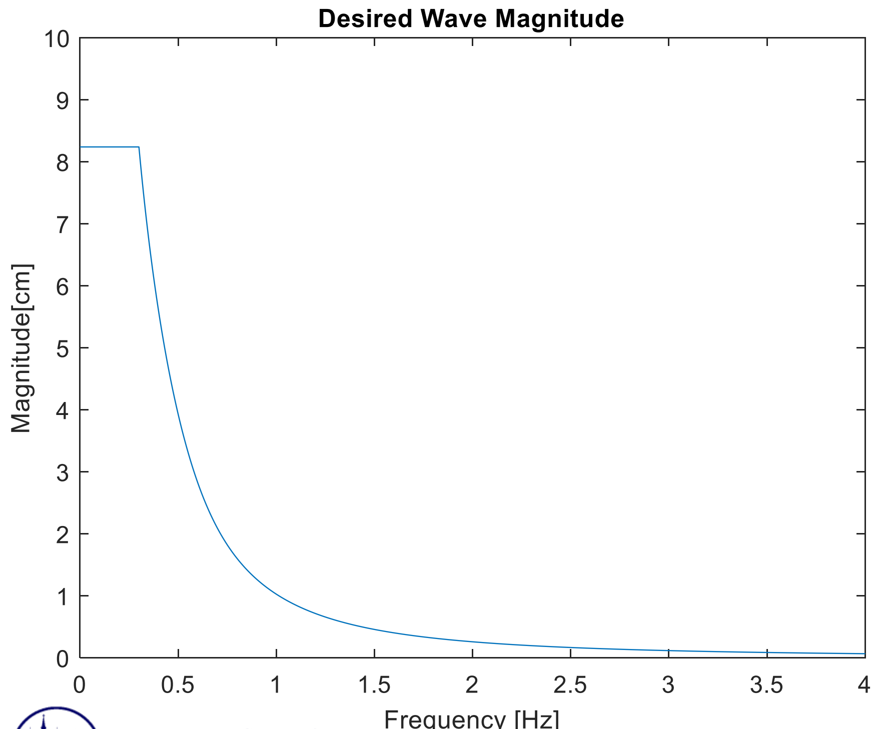
As immersion changes, the area between the two plates changes, changing the capacitance.

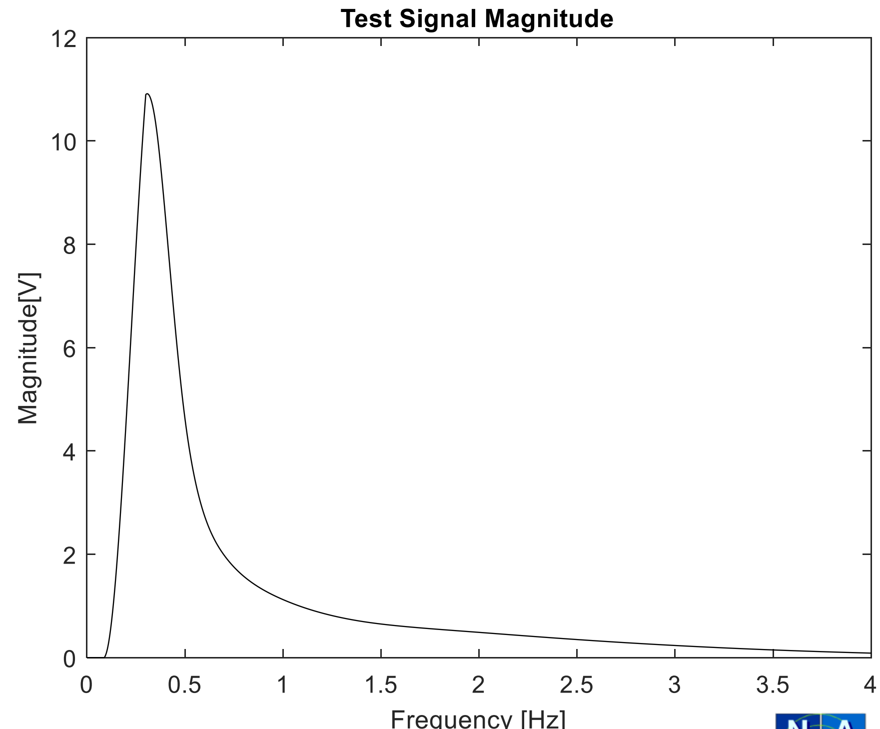
UNO Wavemaker

System Identification

Defined a desired wave elevation magnitude, $H(f) = \frac{Wavelength}{Constant}$ for a constant wave steepness.

Determined a command signal based on a transfer function estimate.

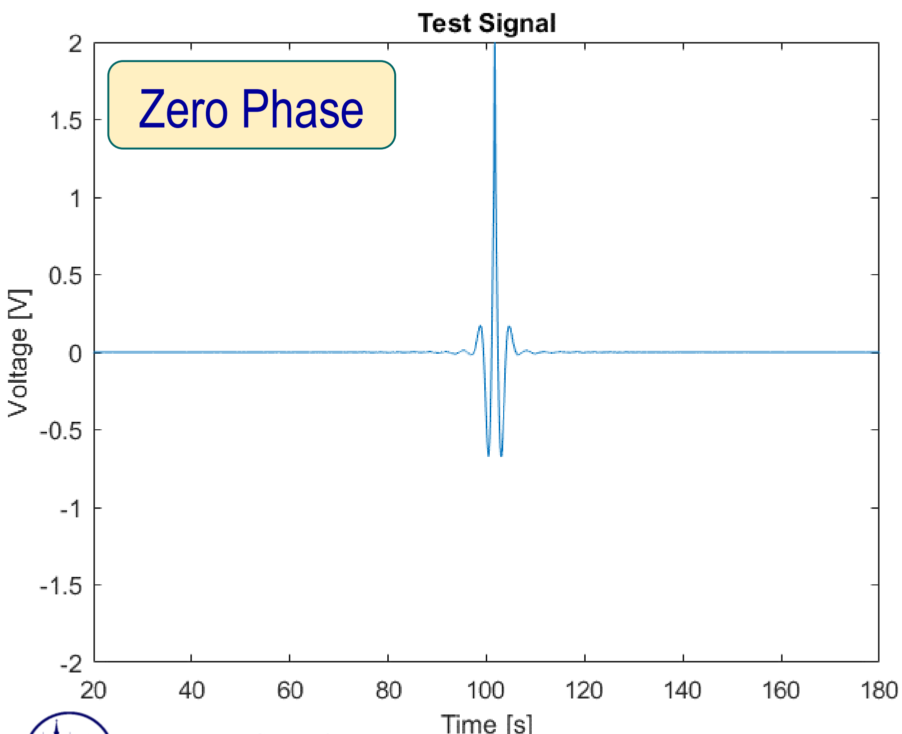


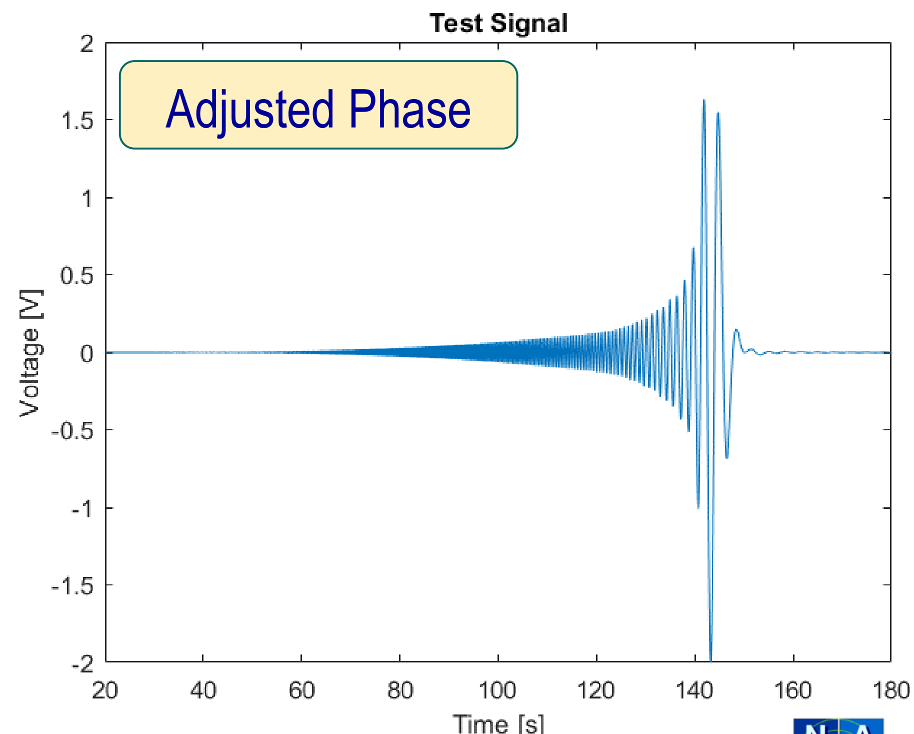


UNO Wavemaker

System Identification

The phase of the test signal was chosen such that the entire wave would pass the wave probe before reflections from the end of the tank returned. This is based on the wave celerity equations.



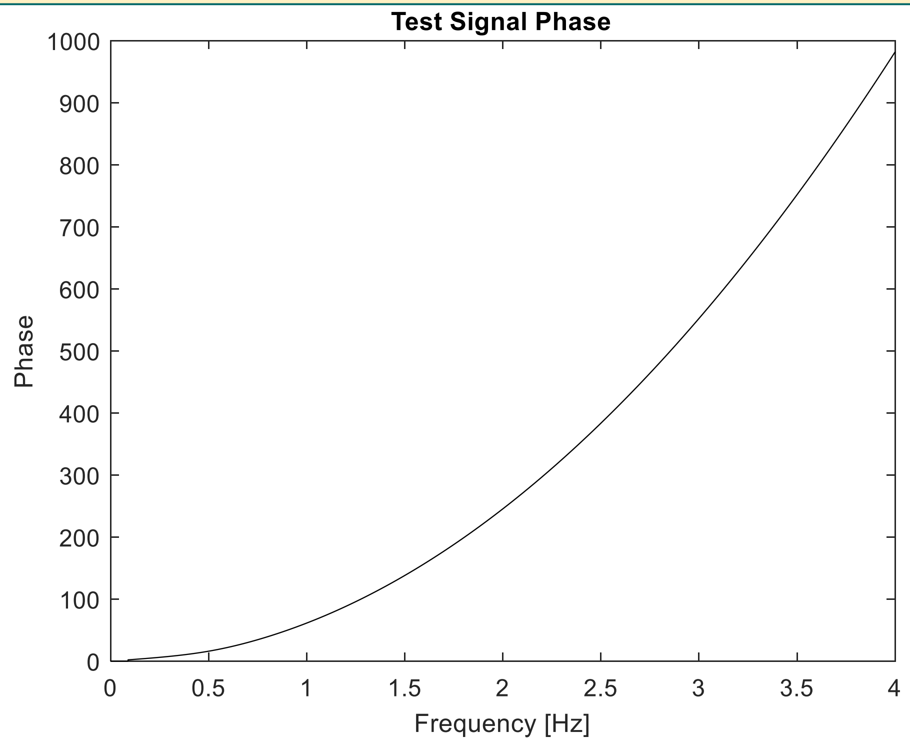


UNO Wavemaker

Wavemaker Theory

Designing the test signal v(t)

Based on wave celerity and wave probe position, the phase of the signal was chosen to locate the concentration point past the probe.

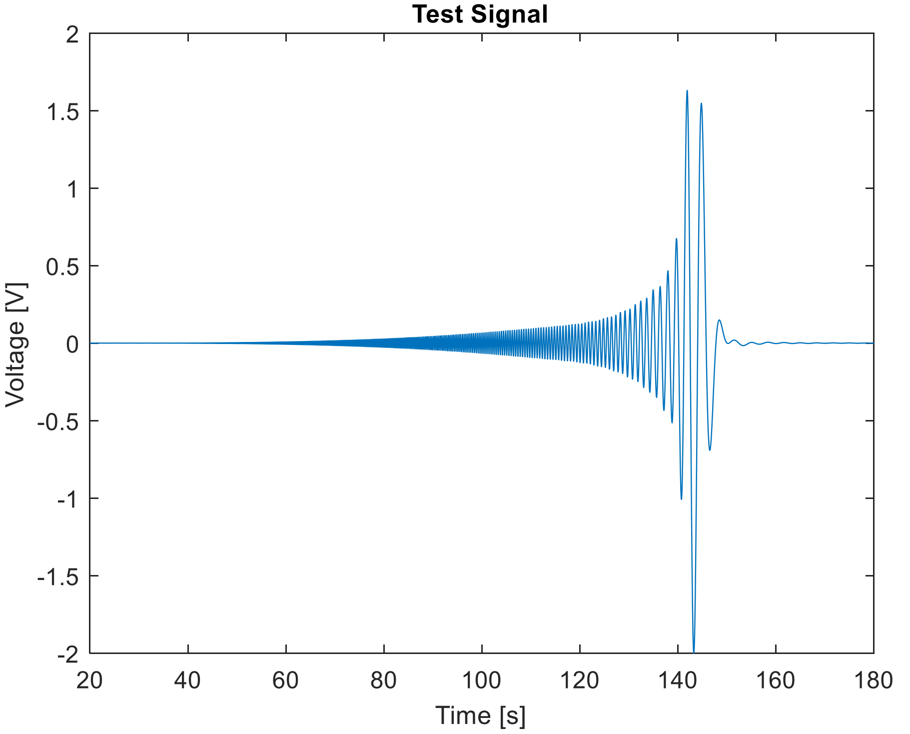


UNO Wavemaker

Wavemaker Theory

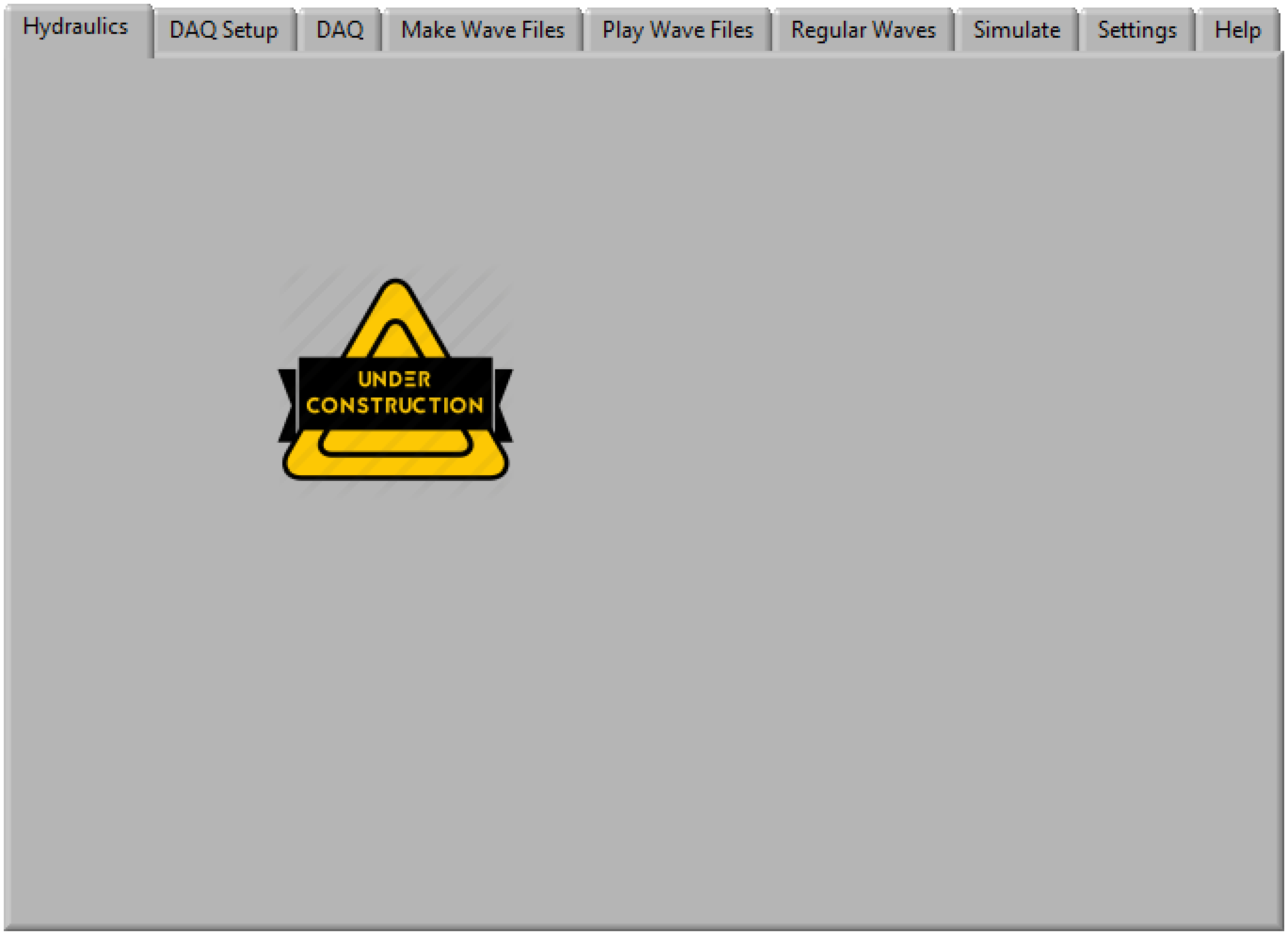
Designing the test signal v(t)

Combing the magnitude and phase, then taking the inverse Fourier transform yields the time domain test signal.



UNO Wavemaker

User Interface



To Come:

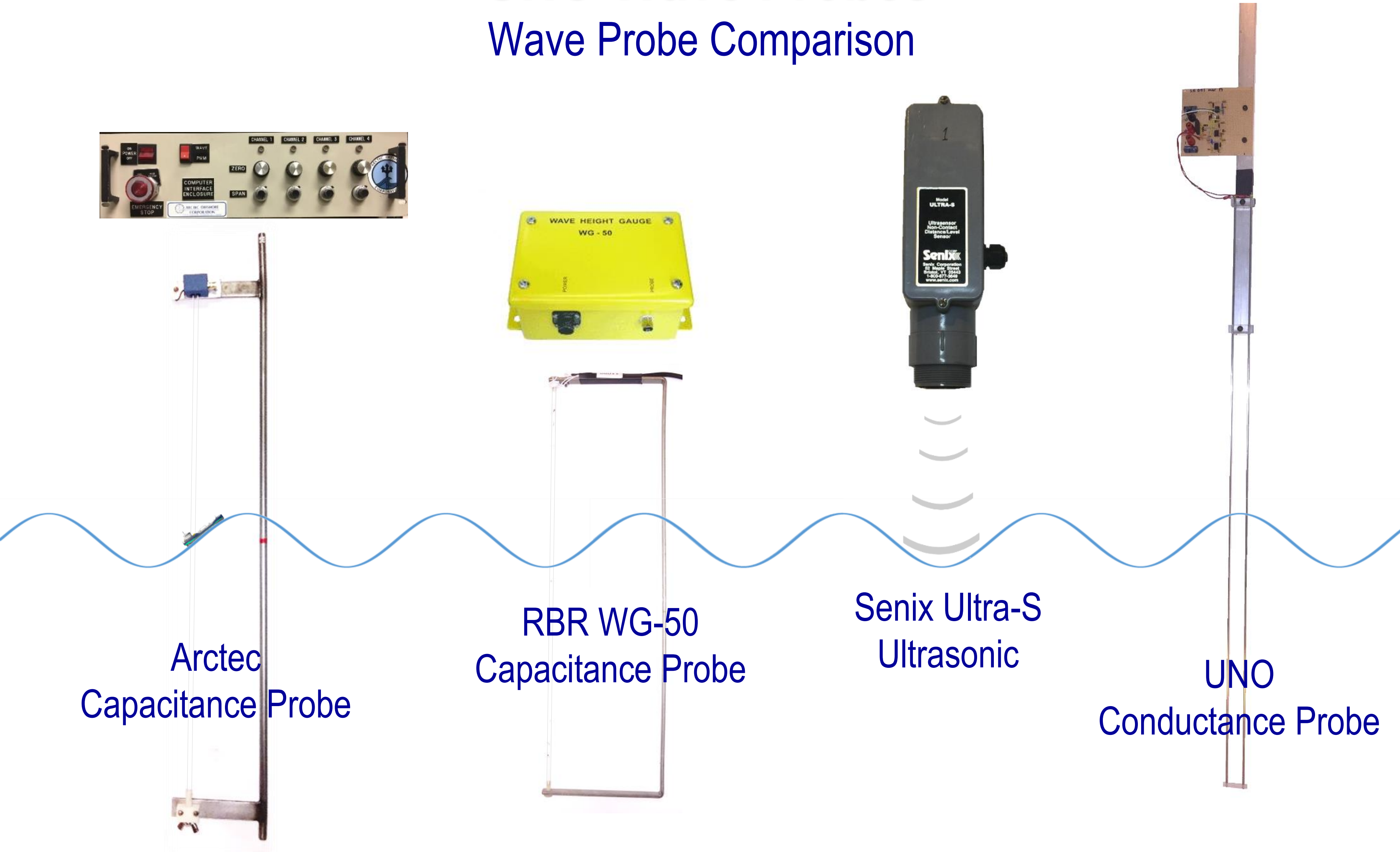
Hydraulic Interface

Make Wave Files

Simulate Waves

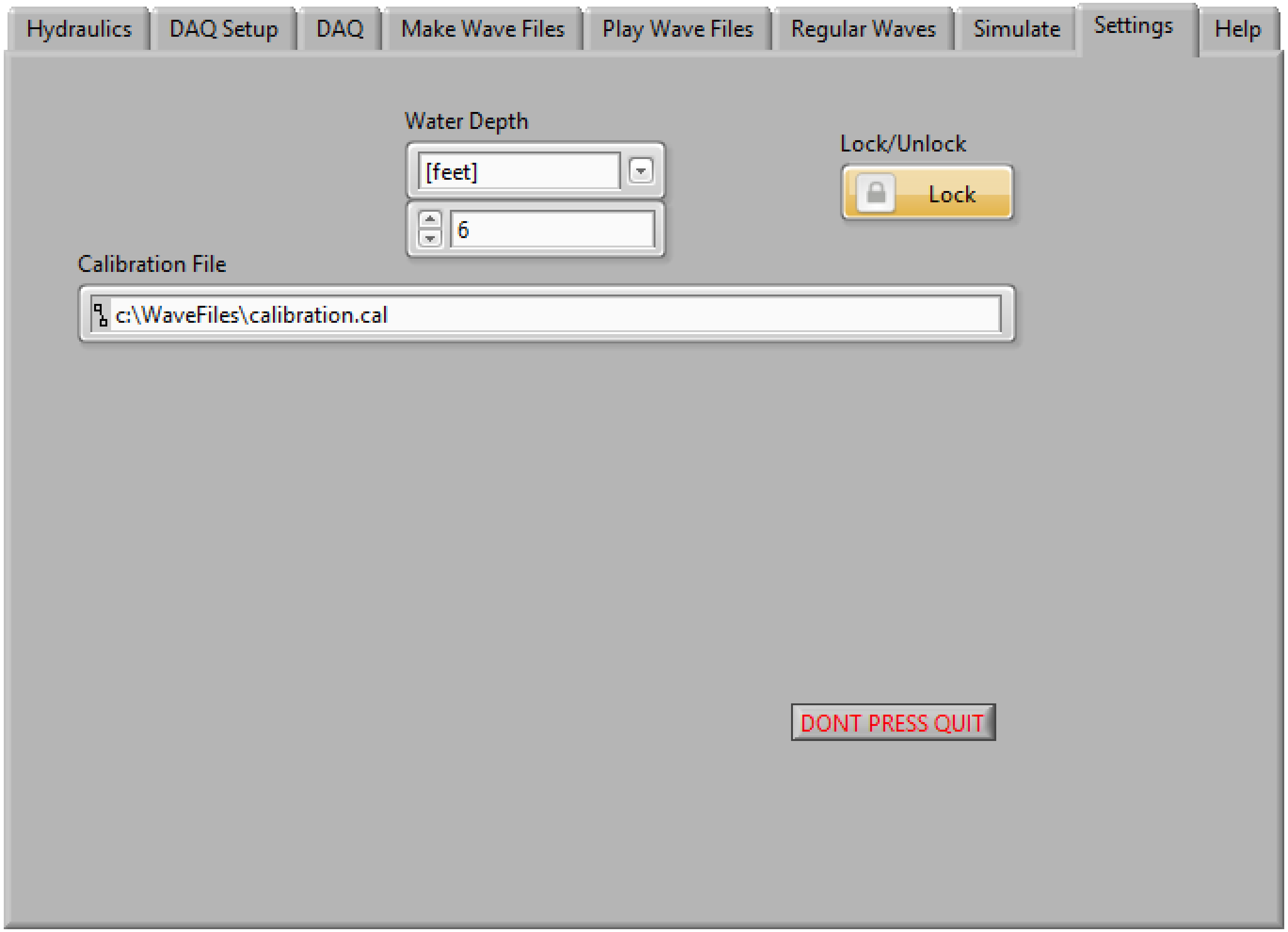
UNO Wave Probes

Wave Probe Comparison



UNO Wavemaker

User Interface



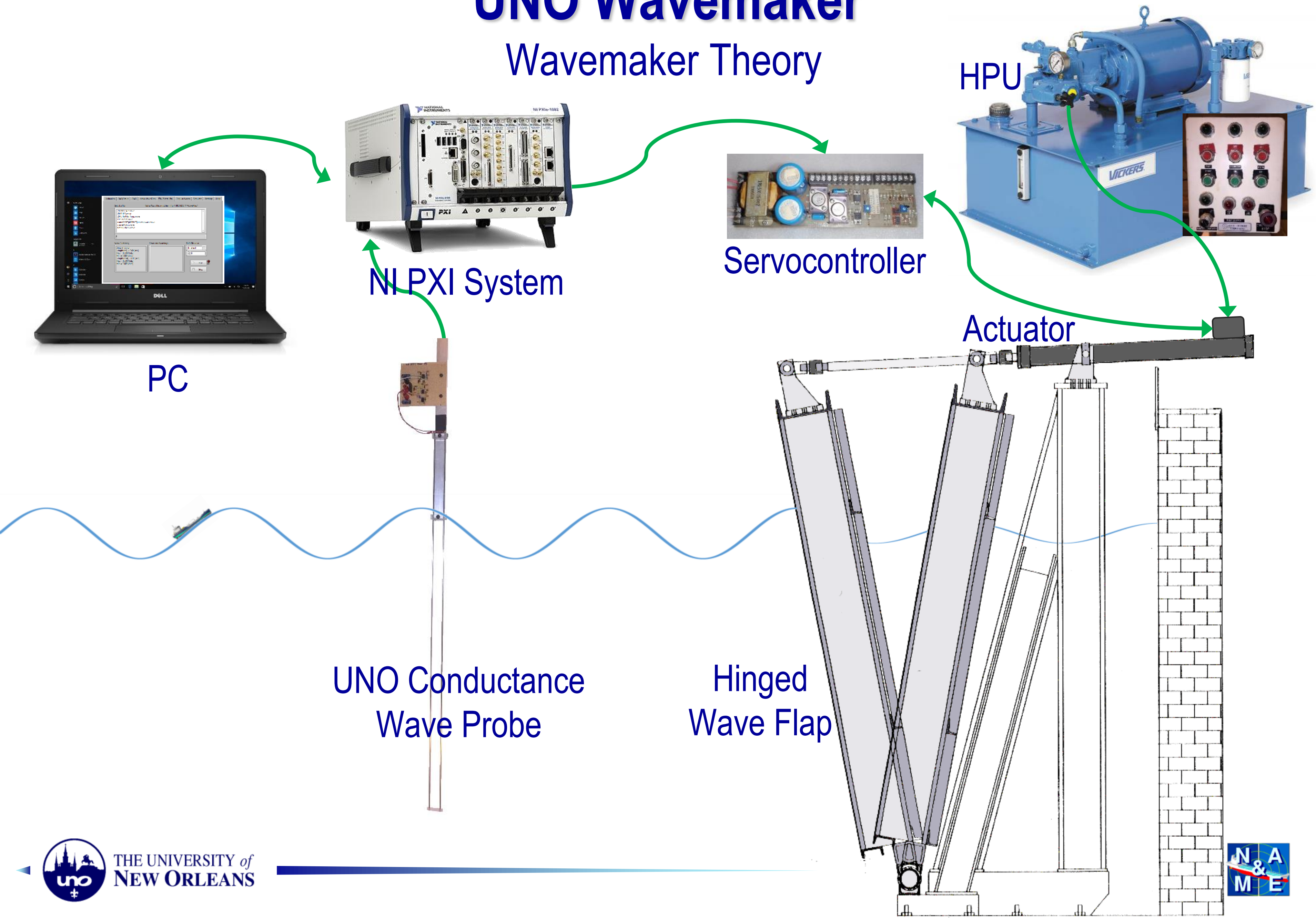
Settings

Water Depth

Calibration File

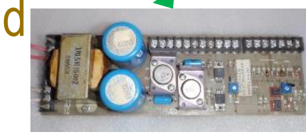
UNO Wavemaker

Wavemaker Theory



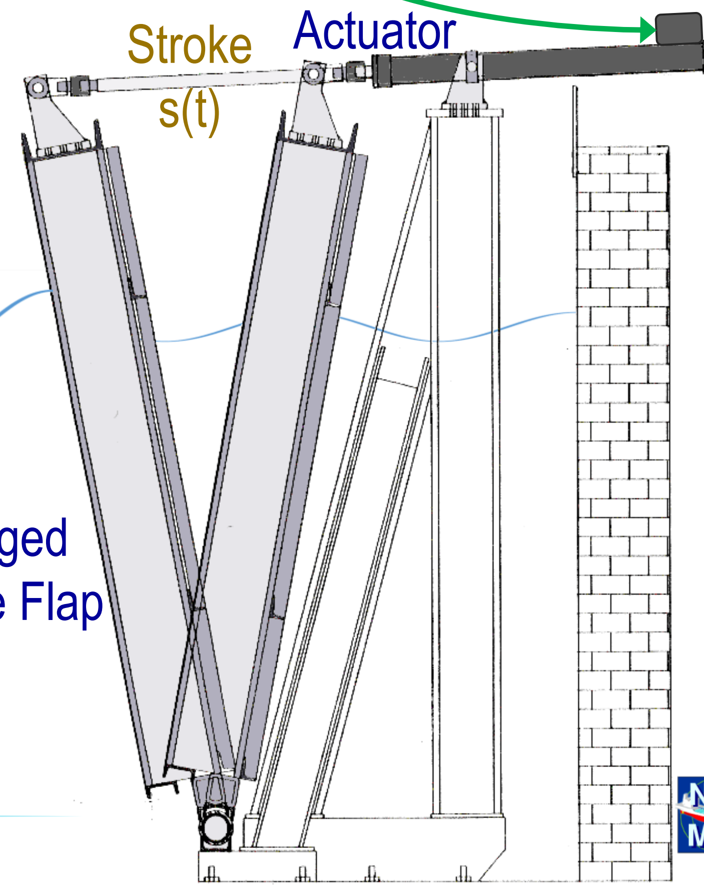
UNO Wavemaker

Wavemaker Theory



One objective of the software is to provide the appropriate Command signal v(t) to produce a desired Wave Elevation h(t).

The desired wave time series h(t) is described by the user in a *.wave file.

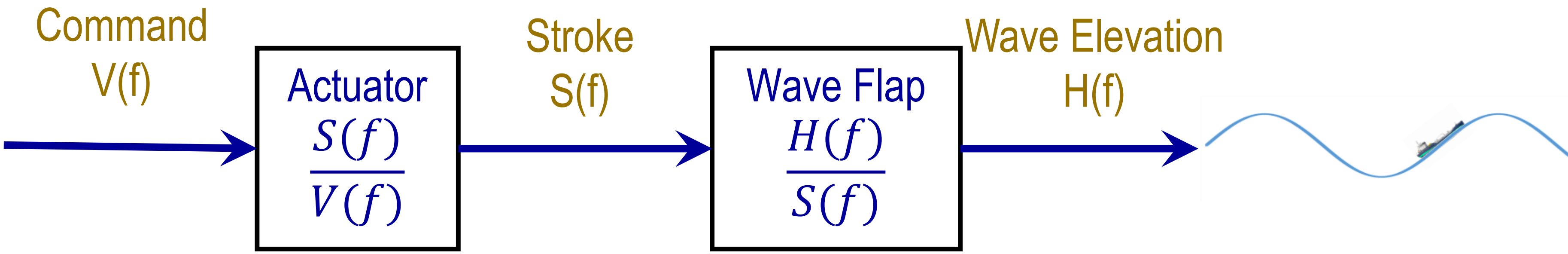


UNO Wavemaker

Wavemaker Theory

The Wavemaker can be modeled as a linear system.

Transfer Function Block Diagram of System

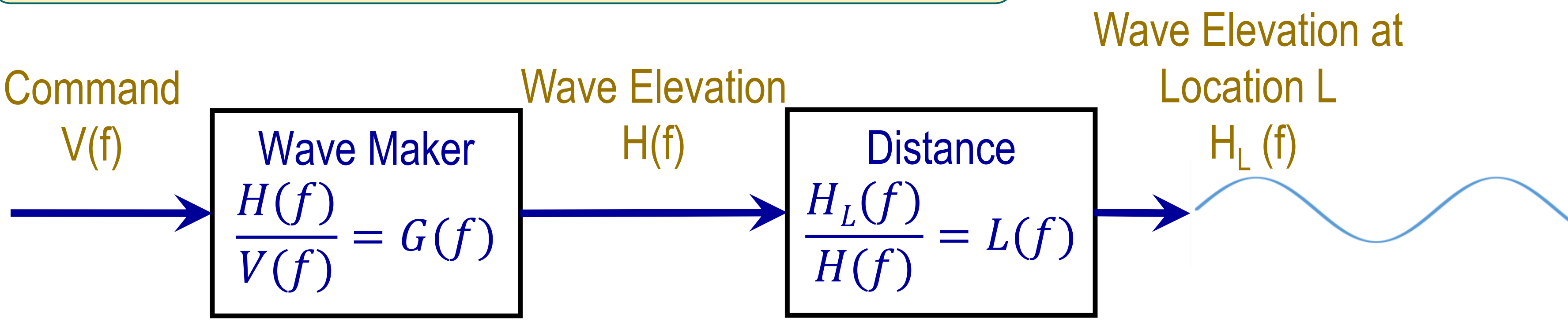


Biesel and Suquet 1954 describe the magnitude of this TF

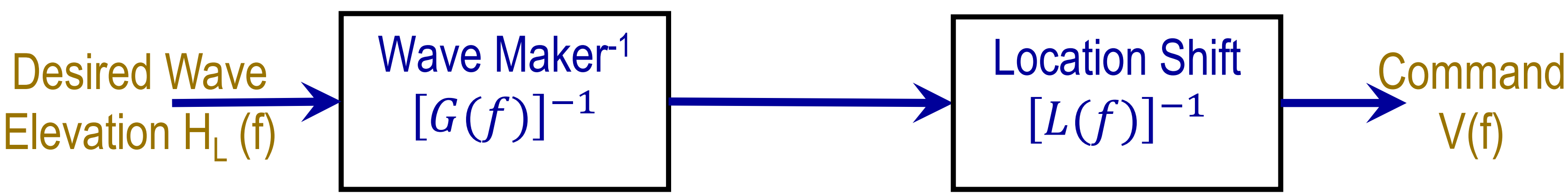
UNO Wavemaker

Wavemaker Theory

Wavemaker Transfer Function Block Diagram



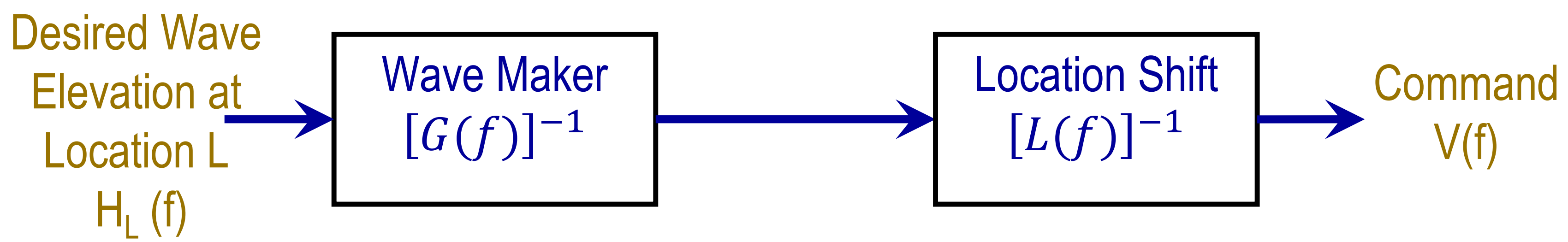
To Calculate the Command Signal from the desired wave the Inverse Transfer Function was determined.



UNO Wavemaker

Wavemaker Theory

Inverse Transfer Function Block Diagram

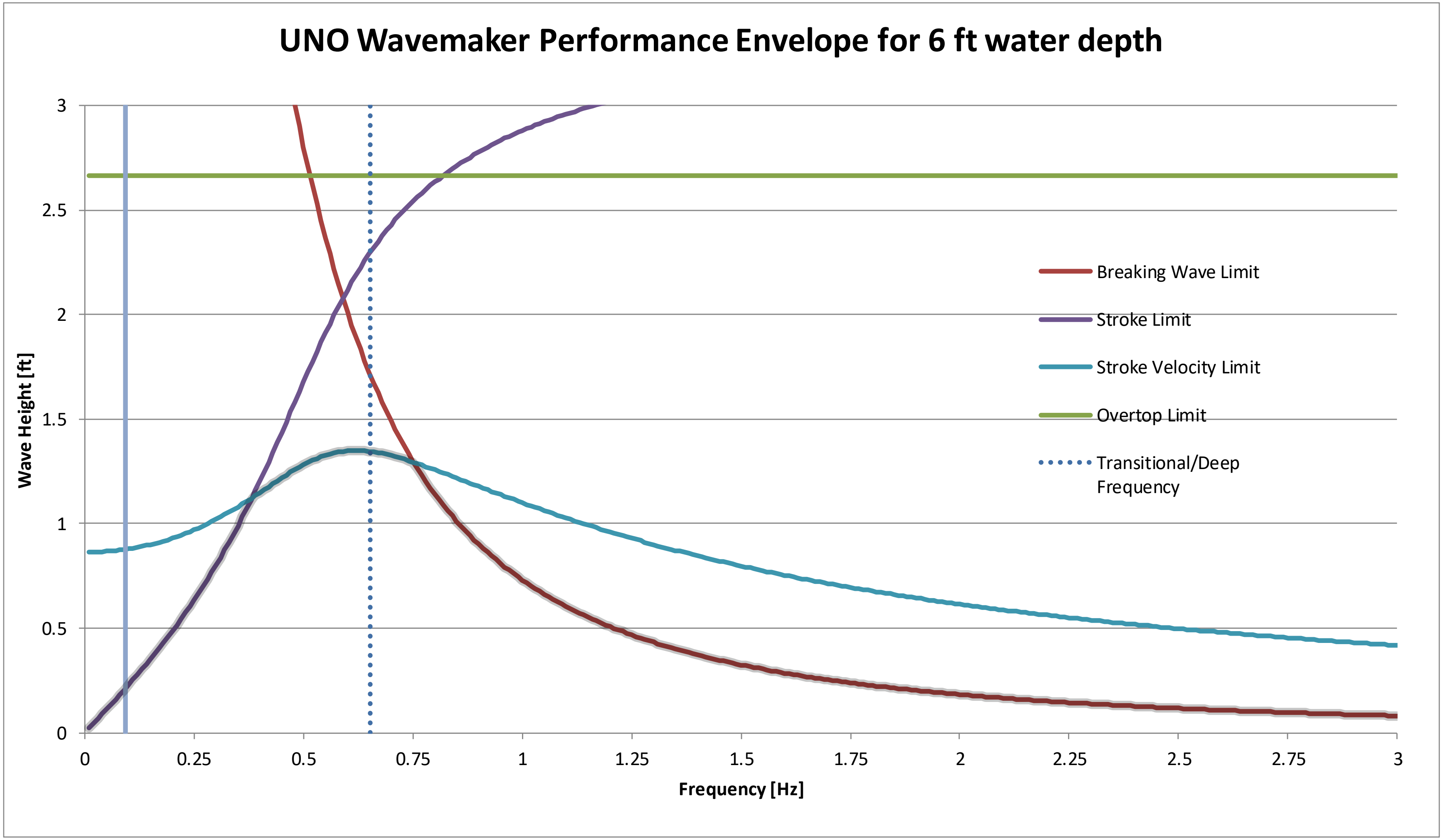


The time domain representation of the $[G(f)]^{-1}$ is used to create the Basin Calibration File, *.cal.

The location shift is calculated based on the given distance an wave celerity. It is implemented as an all-pass filter.

UNO Wavemaker

Wavemaker Envelope



UNO Wavemaker

Wavemaker Envelope