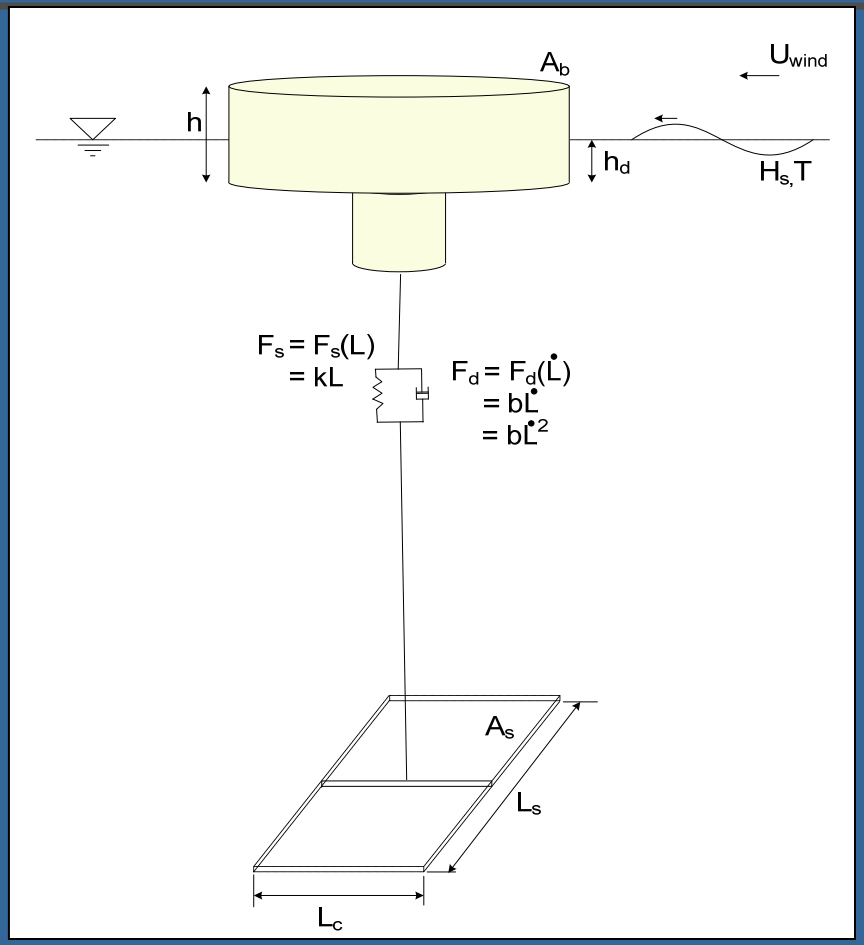
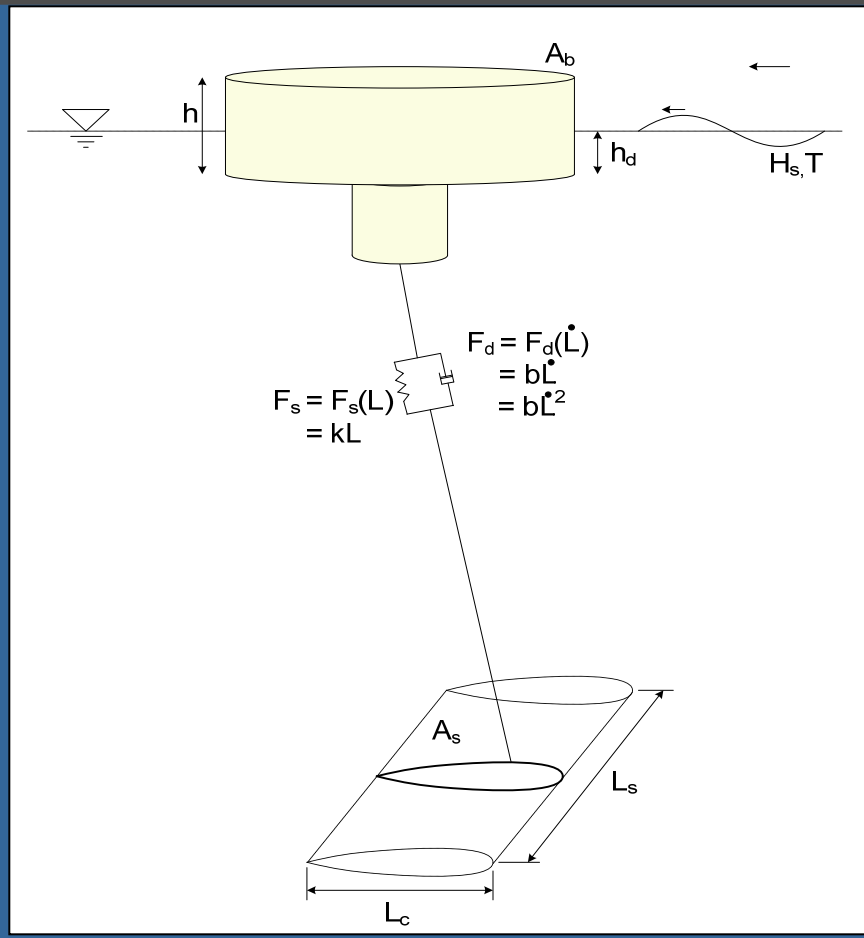
Submerged Plate and Foil
Parametric Study

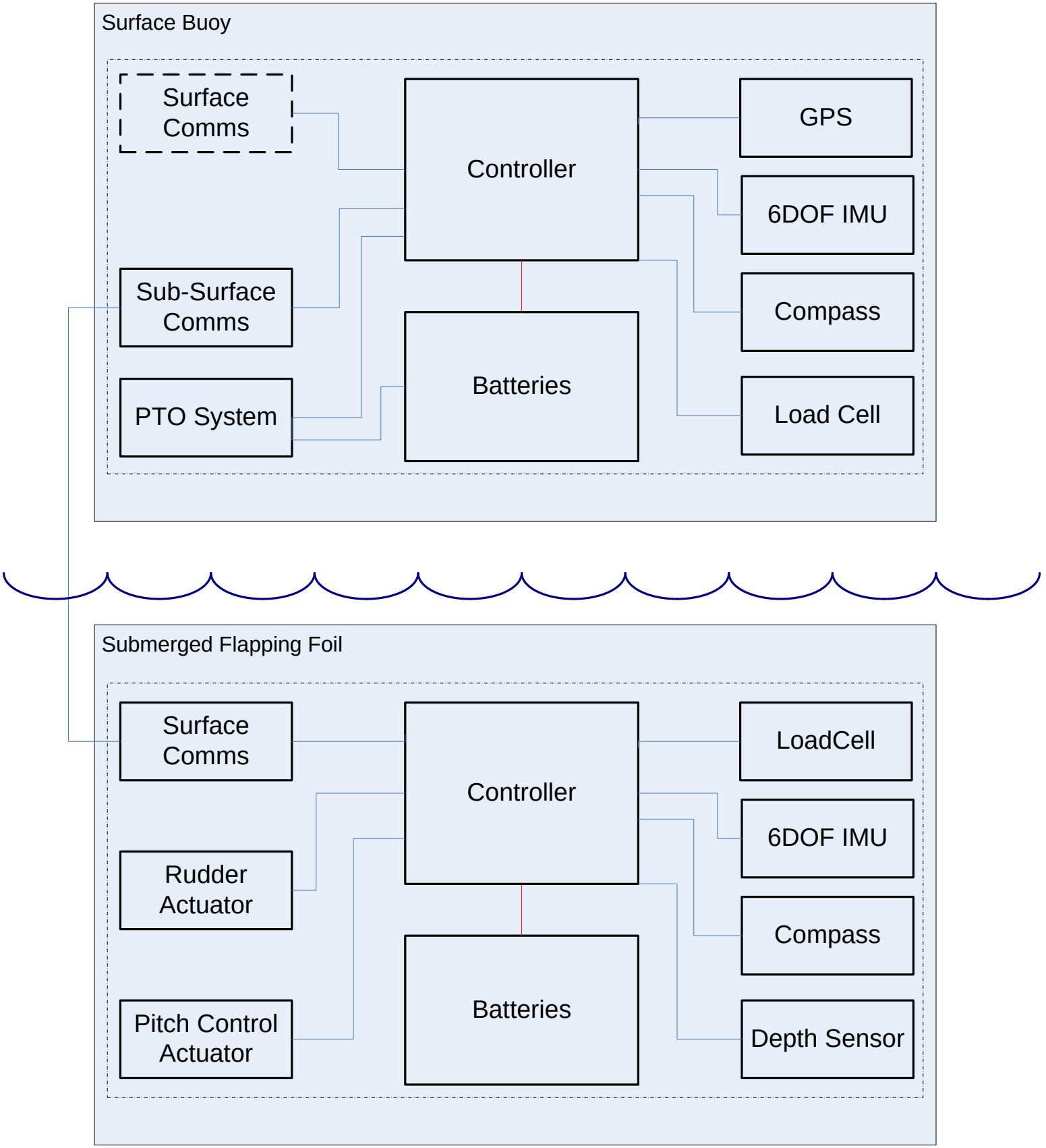




Parameters: H_S = [1 3 5] m (PM Spectrum)
Ab = [2 10 20] m^2
Af = [.25 .5 1 2 4 6 8] X Ab (Foil to Buoy Area Ratio)
b = [0 1000 2000 3000 … 12000] N/m/s

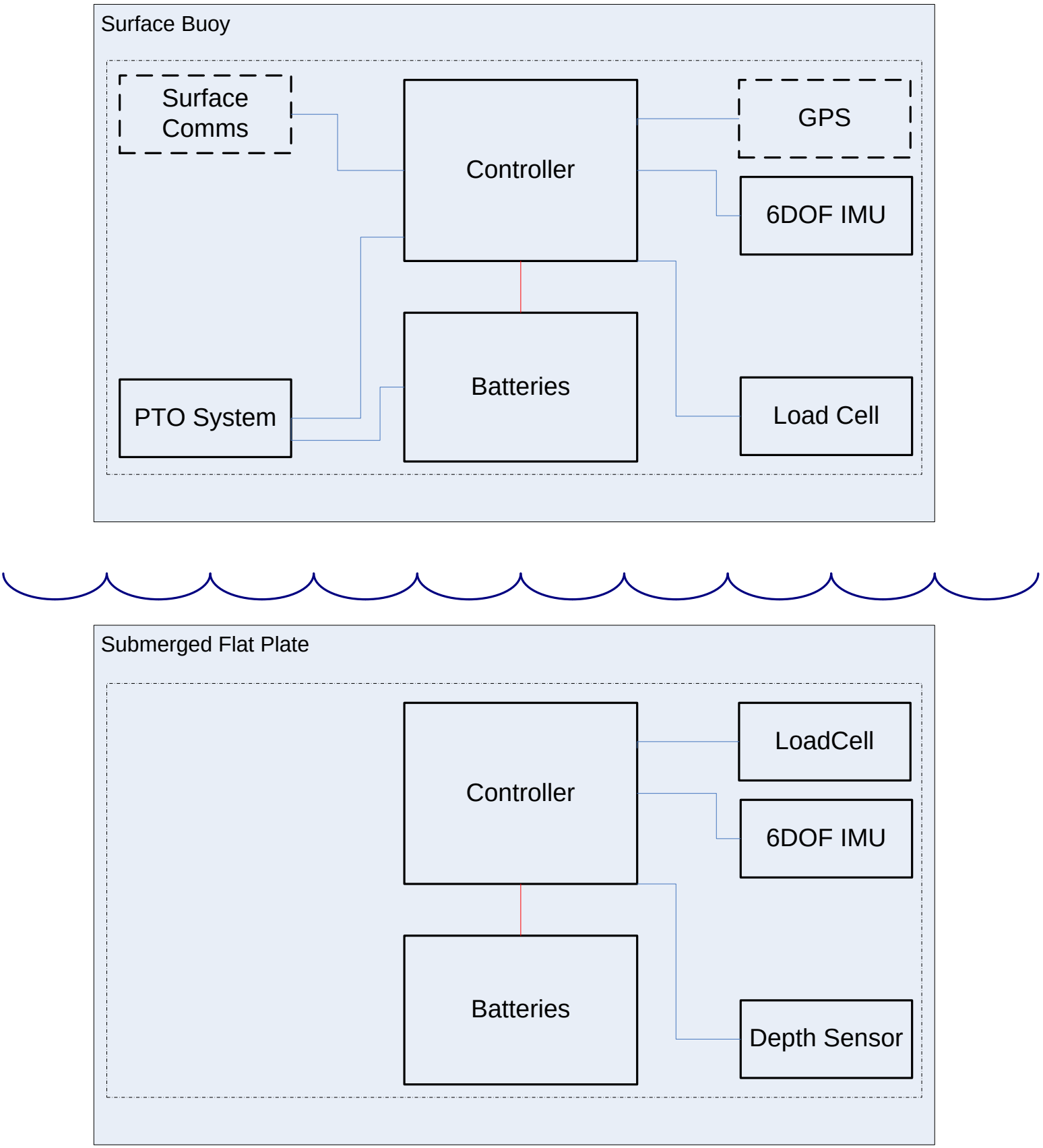
1638 Combinations!

Configuration 1 – Instrumented Submerged Flapping Foil System Block Diagram

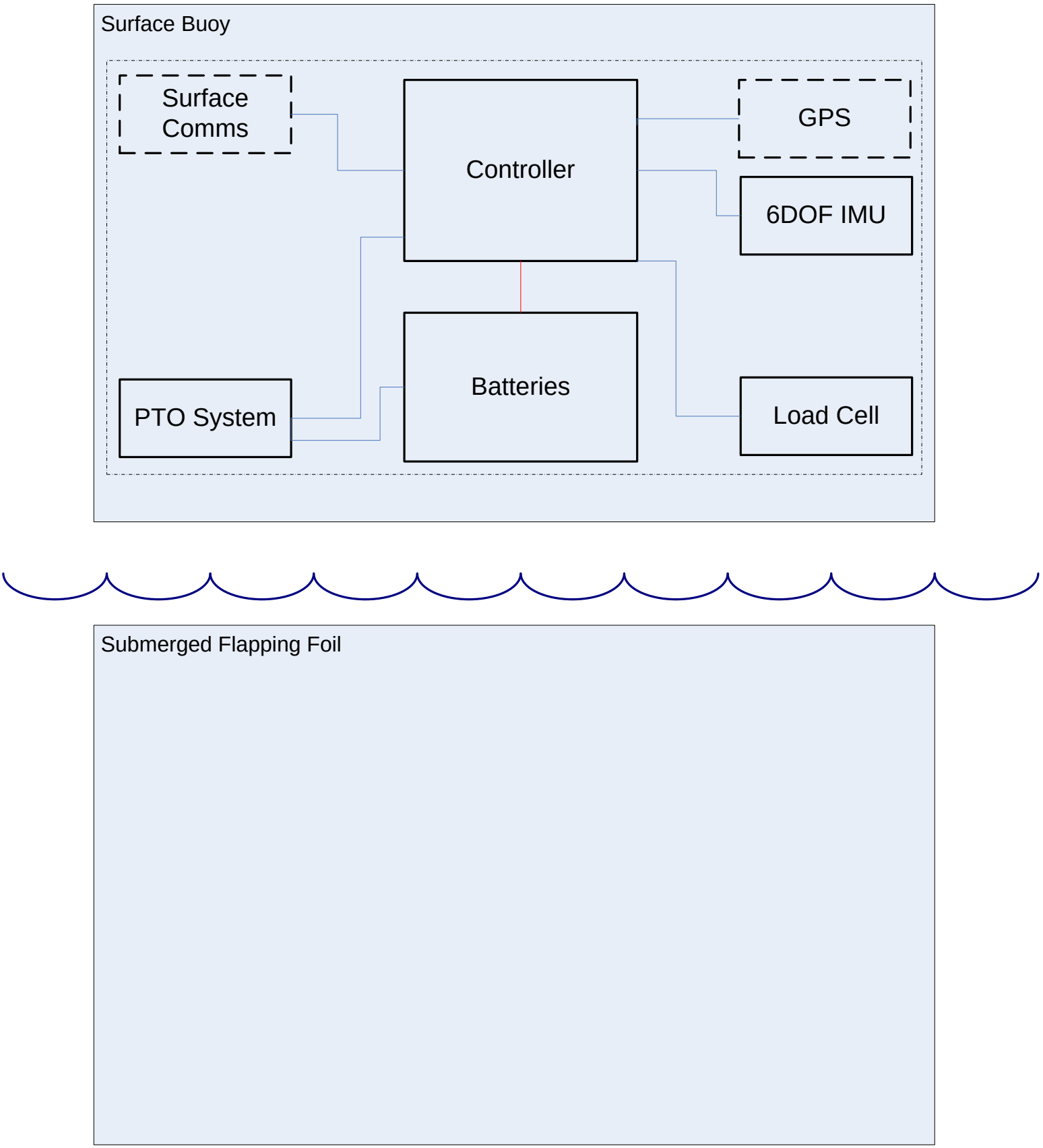


---------- Optional Item

Configuration 2 – Instrumented Submerged Flat Plate System Block Diagram



Configuration 3 – Un-Instrumented Submerged Flat Plate System Block Diagram



PowerBuoy Proof-of-Concept Prototype Functional Requirements

Ver 0.1 1/5/2010 - JAH

General

The prototypes described by these functional requirements are intended for proof-of-concept and shall be designed for multiple short term (1-2) day deployments. For this reason the following general functional requirements apply to all aspects of the design and construction.

1. The device shall be engineered to operate for a maximum of 48 hours.
2. The device does not need to be self-powering; for example, it is completely acceptable that there are auxiliary batteries designed into the system to power any needed equipment.
3. The device does not need to be engineered for corrosion resistance or extreme conditions sea conditions.
4. The device does not need to be engineered for subsequent transition to another group (such as operations or support engineering), it is fine if the engineers who design the various systems are the only ones who can operate them.
5. Wherever possible COTS hardware shall be used.

Configuration 1 – Full Featured Flapping Foil

This configuration represents the most complete system envisioned for an instrumented proof-of-concept device and includes an instrumented surface expression with power take-off system and an instrumented submerged flapping foil for propulsion.

Surface Element (Instrumented Buoy with Power Take-Off device)

1. The surface expression shall have a circular water plane area of 10 square meters (diameter = 3.6 meters).
2. The surface expression shall have a displacement of 5.3 m^3 when supporting the static weight of the submerged foil (8400N/1880lbs).
3. The surface expression shall have a reserve buoyancy of 5.0 m^3.
4. The structure shall be sufficient to float in water without significant deformation and support at least a 25000N force downward at the submerged foil attachment point.
5. The surface expression shall support the power take-off device described in the PTO functional requirements section.
6. The surface expression shall be designed to support up to 1500kg of lead-acid batteries. For testing these batteries may not be present but ballast with a similar density will be installed in place of the batteries.
7. The surface expression shall have a minimum of structure above the still waterline.
8. The exterior shape of the surface expression shall be axi-symmetric around a vertical axis.
9. The surface expression shall include a controller that is capable of hosting the following instrumentation and performing the associated tasks: (see the sensor requirements section below for more details).
    a. GPS: Log and timestamp GPS measurements no slower than a rate of 0.5Hz.
    b. 6 DOF Inertial Measurement Unit: Log and timestamp IMU measurements at the rate the sensor produces measurements (TBD).
    c. Compass: Log and timestamp compass measurements no slower than a rate of 5Hz. Accurate to 1 degree, suitable for use in magnetic environment dictated by the surface expression structure construction (which may be steel)
    d. Load Cell: Log and timestamp load cell measurements no slower than a rate of 5Hz. (0-10000lb, accurate to +/- 5lbs (0.05% FS)).
    e. All timestamp measurements shall be accurate relative to 10% of sample rate. The absolute timestamp accuracy shall be xxx s.
    f. Computing infrastructure shall be sufficient to create a target direction based upon current and desired location.
    g. Surface / Sub-Surface communications sufficient to allow the surface electronics to specify a target direction to the sub-surface element and the sub-surface element to report back current status. (Specifics TBD).
    h. Power Take-Off device: Computing infrastructure shall be sufficient to manage data logging and control algorithms required by the power-take off system (if any).

i. Surface communications: Sufficient for transmitting system status to shore or support vessel via line-of-site radio or satellite system. Controller system shall also be able to accept target location instructions over the same radio link.

Sub-Surface Element (Instrumented Flapping Foil)

1. The sub-surface structure shall support 20 m^2 of foil area.
2. The sub-surface element shall weigh 8400 N (1880lbs) in seawater.
3. The structure and attachment points shall be strong enough to allow at minimum a 25000 N (5600 lbs) force to be applied vertically upwards.
4. The structure shall hang in a stable horizontal orientation from a single attachment point (with the use of a bridle if required).
5. The sub-surface device and electronics shall be suitable for use up to 50m water depth in seawater.
6. The sub-surface element shall include a controller that is capable of hosting the following instrumentation and performing the associated tasks: (see the sensor requirements section below for more details).
    a. Pressure Sensor (0-50m, accurate to +/- 0.05m (0.1% FS)). Log and timestamp pressure measurements no slower than a rate of 5Hz.
    b. 6 DOF Inertial Measurement Unit: Log and timestamp IMU measurements at the rate the sensor produces measurements (TBD).
    c. Compass: Log and timestamp compass measurements no slower than a rate of 5Hz. Accurate to 1 degree, suitable for use in magnetic environment dictated by the sub-surface structure construction (which may be steel)
    d. Load Cell: Log and timestamp load cell measurements no slower than a rate of 5Hz. (0-10000lb, accurate to +/- 5lbs (0.05% FS)).
    e. Rudder actuator and control: Suitable actuator and control capability to perform needed rudder motions (TBD).
    f. Foil Pitch actuator and control: Suitable actuator and control capability to perform needed foil pitch motions (TBD).
    g. All timestamp measurements shall be accurate relative to 10% of sample rate. The absolute timestamp accuracy shall be xxx s.
    h. Surface / Sub-Surface communications sufficient to allow the surface electronics to specify a target direction to the sub-surface element and the sub-surface element to report back current status. (Specifics TBD).

Configuration 2 – Instrumented Flat-Plate Configuration

This configuration represents a reduced system that an instrumented surface expression with power take-off system and an instrumented submerged flat plate that does not include any actuators for direction control..

Surface Element (Instrumented Buoy with Power Take-Off device)

1. The surface expression shall have a circular water plane area of 10 square meters (diameter = 3.6 meters).
2. The surface expression shall have a displacement of 5.3 m^3 when supporting the static weight of the submerged foil (8400N/1880lbs).
3. The surface expression shall have a reserve buoyancy of 5.0 m^3.
4. The structure shall be sufficient to float in water without significant deformation and support at least a 25000N force downward at the submerged plate attachment point.
5. The surface expression shall support the power take-off device described in the PTO functional requirements section.
6. The surface expression shall be designed to support up to 1500kg of lead-acid batteries. For testing these batteries may not be present but ballast with a similar density will be installed in place of the batteries.
7. The surface expression shall have a minimum of structure above the still waterline.
8. The exterior shape of the surface expression shall be axi-symmetric around a vertical axis.
9. The surface expression shall include a controller that is capable of hosting the following instrumentation and performing the associated tasks: (see the sensor requirements section below for more details).
    a. GPS: Log and timestamp GPS measurements no slower than a rate of 0.5Hz.
    b. 6 DOF Inertial Measurement Unit: Log and timestamp IMU measurements at the rate the sensor produces measurements (TBD).
    c. Compass: Log and timestamp compass measurements no slower than a rate of 5Hz.
    d. Load Cell: Log and timestamp load cell measurements no slower than a rate of 5Hz. (0-10000lb, accurate to +/- 5lbs (0.05% FS)).
    e. All timestamp measurements shall be accurate relative to 10% of sample rate. The absolute timestamp accuracy shall be xxx s.
    f. Computing infrastructure shall be sufficient to create a target direction based upon current and desired location.
    g. Power Take-Off device: Computing infrastructure shall be sufficient to manage data logging and control algorithms required by the power-take off system (if any).
    h. Surface communications: Sufficient for transmitting system status to shore or support vessel via line-of-site radio or satellite system.

Sub-Surface Element (Instrumented Flat Plate)

1. The sub-surface structure shall have an area of 20 m^2 projected vertically and a minimum of area projected horizontally.
2. The sub-surface element shall weigh 8400 N (1880lbs) in seawater.
3. The structure and attachment points shall be strong enough to allow at minimum a 25000 N (5600 lbs) force to be applied vertically upwards.
4. The structure shall hang in a stable horizontal orientation from a single attachment point (with the use of a bridle if required).
5. The sub-surface device and electronics shall be suitable for use up to 50m depth in seawater.
6. The sub-surface element shall include a controller that is capable of hosting the following instrumentation and performing the associated tasks: (see the sensor requirements section below for more details).
    a. Pressure Sensor (0-50m, accurate to +/- 0.05m (0.1% FS)). Log and timestamp pressure measurements no slower than a rate of 5Hz.
    b. 6 DOF Inertial Measurement Unit: Log and timestamp IMU measurements at the rate the sensor produces measurements (TBD).
    c. Load Cell: Log and timestamp load cell measurements no slower than a rate of 5Hz. (0-10000lb, accurate to +/- 5lbs (0.05% FS)).
    d. All timestamp measurements shall be accurate relative to 10% of sample rate. The absolute timestamp accuracy shall be xxx s.

Configuration 3 – Un-instrumented Flat-Plate Configuration

This configuration represents the most reduced system envisioned and includes an instrumented surface expression with power take-off system and an un-instrumented submerged flat plate.

Surface Element (Instrumented Buoy with Power Take-Off device)

1. The surface expression shall have a circular water plane area of 10 square meters (diameter = 3.6 meters).
2. The surface expression shall have a displacement of 5.3 m^3 when supporting the static weight of the submerged foil (8400N/1880lbs).
3. The surface expression shall have a reserve buoyancy of 5.0 m^3.
4. The structure shall be sufficient to float in water without significant deformation and support at least a 25000N force downward at the submerged plate attachment point.
5. The surface expression shall support the power take-off device described in the PTO functional requirements section.
6. The surface expression shall be designed to support up to 1500kg of lead-acid batteries. For testing these batteries may not be present but ballast with a similar density will be installed in place of the batteries.
7. The surface expression shall have a minimum of structure above the still waterline.
8. The exterior shape of the surface expression shall be axi-symmetric around a vertical axis.
9. The surface expression shall include a controller that is capable of hosting the following instrumentation and performing the associated tasks: (see the sensor requirements section below for more details).
    a. GPS: Log and timestamp GPS position measurements no slower than a rate of 0.5Hz.
    b. 6 DOF Inertial Measurement Unit: Log and timestamp IMU measurements at the rate the sensor produces measurements (TBD).
    c. Compass: Log and timestamp compass measurements no slower than a rate of 5Hz.
    d. Load Cell: Log and timestamp load cell measurements no slower than a rate of 5Hz. (0-10000lb, accurate to +/- 5lbs (0.05% FS)).
    e. All timestamp measurements shall be accurate relative to 10% of sample rate. The absolute timestamp accuracy shall be xxx s.
    f. Computing infrastructure shall be sufficient to create a target direction based upon current and desired location.
    g. Power Take-Off device: Computing infrastructure shall be sufficient to manage data logging and control algorithms required by the power-take off system (if any).
    h. Surface communications: Sufficient for transmitting system status to shore or support vessel via line-of-site radio or satellite system.

Sub-Surface Element (Un-Instrumented Flat Plate)

1. The sub-surface structure shall have an area of 20 m^2 projected vertically and a minimum of area projected horizontally.
2. The sub-surface element shall weigh 8400 N (1880lbs) in seawater.
3. The structure and attachment points shall be strong enough to allow at minimum a 25000 N (5600 lbs) force to be applied vertically upwards.
4. The structure shall hang in a stable horizontal orientation from a single attachment point (with the use of a bridle if required).
5. The sub-surface device shall be suitable for use up to 50m depth in seawater.

Power Take-Off System Functional Requirements

The power takeoff system described by these functional requirements shall be used in all configurations of the system described above.

1. The power take-off system shall convert reciprocating linear motion to electricity in the most efficient and reliable manner possible.
2. The power take-off system shall constitute the connection between the surface expression and submerged element.
3. The linear elements of the power take-off system shall include a spring element that exerts a force of 8400N for every meter of extension from the fully retracted position.
4. The power take-off system shall be capable of withstanding forces up to 25000N at any stage of elongation.
5. The power take-off system shall approximate a linear damping element with a damping coefficient not less than 8000 N/(m/s) and not to exceed 15000 N/(m/s). The actual value shall be chosen to optimize efficiency within this range.
6. The power take-off system shall include all required electronics to control the system and condition the resulting power and efficiently charge batteries at a bus voltage not to exceed 48V.
7. The power take-off system shall provide internal performance data logging and/or continuous performance data output suitable for logging by the main system controller.