MBARI's Tiburon II Design Specification

Revision 1.0

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1 Introduction

1.1 General Description

The ROV *Tiburon*, designed and developed by MBARI, is an outstanding science and engineering platform that has completed over 1100 dives since 1997, supporting a wide variety of science and engineering activities. *Tiburon* is now poised for replacement to update obsolete systems, improve reliability, reduce maintenance requirements, and upgrade science capabilities.

During the past 10 to 20 years, the technical and operational requirement to support deep-submergence science activities at MBARI and in the broader sense the ocean science community have become increasingly more complex as new sensors, instruments, and ocean observing systems are developed. *Tiburon* was originally designed to serve primarily as a highly technical ocean observing and exploration tool, with high-quality imaging capabilities in a maneuverable vehicle, incorporating a broad suite of sensors and samplers that could be configured quickly for various science and engineering missions. Since *Tiburon's* development, the priorities for ROV capabilities have evolved from that of a sophisticated exploratory tool well equipped with sensors, to highly capable submersible platform that is easily configurable to support a broad spectrum of activities. Priorities for future MBARI ROV operations include *Ocean Exploration* (Gulf of California, Juan de Fuca Ridge, Hawaii, and eastern Pacific sites), *Ocean Observatory Support* (benthic node connection, subsea fiber-optic cable installation, instrument & sensor installation & recovery, ROV support for AUV docking stations), *Ocean Experimentation & Sampling* (instrument deployment, sample collection in mid-water and benthic habitats), and *Ocean Education & Outreac*h (high quality imagery for collaboration with MBA, BBC, NOVA, etc.). The need for sophisticated imaging & sensing remains, but new requirements for heavy payload capabilities, seamless sensor & instrument integration and data management, and complex manipulations, sample collection, instrument servicing, and seafloor cable-laying have become high priorities for ROV operations, and will likely dominate MBARI's future ROV requirements. The obsolescence of some of Tiburon's systems, coupled with the growing technical demands of MBARI's expeditionary ROV science and the forthcoming requirements to support MOOS and MARS ocean observing systems, has created a juncture for review of *Tiburon's* operational capabilities.

1.2 Purpose of Document

This document represents MBARI's requirements for it's new science class ROV and will be used in conjunction with SMDH's system specification/quote as the "Scope of Work/Technical Specification" for SECTION B of the contract.

2 Equipment Specification

2.1 Mechanical

2.1.1 System of Units

System of units shall be metric

2.1.2 Factor of Safety Method of Design

All pressure vessels shall be hydrostatically tested to 1.25 times the operating pressure. An applicable test procedure shall include cycles, hold times, and temperatures as applicable. An appropriate pressure test procedure shall be mutually agreed on between MBARI and SMDH.

Factors of safety for specific items will be identified at the internal kick off design review. Internal design procedures which form part of the ISO 9001-2000 quality system shall be followed.

2.1.2.1 Dynamic Loading

The vehicle shall be designed to accommodate a launch and recovery in sea state five (5). Design for accelerations shall meet or exceed the *ABS RULES FOR BUILDING AND CLASSING Underwater Vehicles* section 9.3 or other equivalent standard.

2.1.3 Materials

All materials shall provide adequate corrosion prevention for the intended service.

2.1.3.1 Bolts, Screws, other Fasteners

Fasteners shall be of a grade which is appropriate for the application.

2.1.4 Operating Depth

All systems and sub-systems shall be rated to an operational depth of 4000 MSW.

2.1.5 Dimensions & Weights

The vehicle outfitted with the MBARI specified core equipment including a tool sled (<500 kg in air) and the vehicle trimmed to be approximately 23-35 kg positive in salt water will not exceed 5,040 kg in air. Vehicle dimensions shall not exceed 3.5 meters long x 2 m wide x 2 m high. Small changes are acceptable and final weights and dimensions shall be agreed upon during the preliminary design.

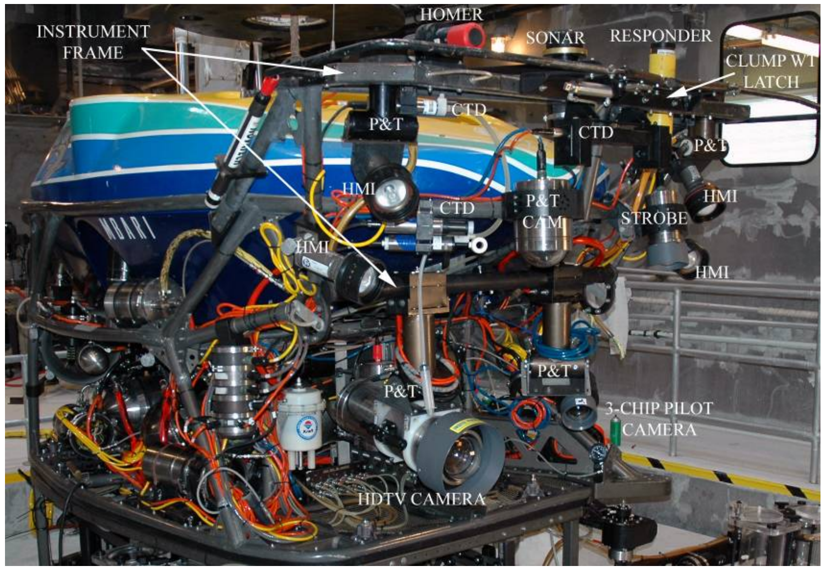
2.1.6 Frame

The vehicle frame shall be manufactured from 6082 T6 aluminum, non-anodized and anode protected and utilize a bolted construction in the load path to avoid the requirement for post fabrication heat treatment. Welding codes to be used will be agreed upon by

MBARI and SMDH during the first design review. The frame will have a through frame lift capacity of 1 ton.

2.1.6.1 Instrument Sub Frame

MBARI shall be responsible for the design and layout of the instrument frame and brackets for the core science gear as listed below. MBARI will work in conjunction with SMDH to design a sub-frame that will bolt on to the vehicles main frame. SMDH shall provide sufficient mounts on the core frame to support the instrument frame and provide an interface drawing for approval by MBARI. This sub-frame shall include the mounts for the majority of MBARI's core instrumentation such as pan & tilts, cameras, sonar, lights, CTD, etc. The Instrument frame shall be designed and fabricated by MBARI and integrated to the vehicle upon delivery to MBARI in 2008. A date for MBARI to complete the frame design and make drawings or 3D models available to SMDH shall be agreed upon during the first kick off meeting.



2.1.7 Buoyancy

2.1.7.1 Syntactic Foam Module

The syntactic foam pack is to be rated for 4000 meter operation and comply with the specification provided by Trelleborg (CRP) "*Typical Properties - TG-28A*" in Appendix A. A Design of the buoyancy module should allow for the placement of a science payload over 91 kg on the front of the ROV with less than 10 degrees induced pitch. The pack shall provide recesses for the VB spheres and umbilical. In addition, the majority of MBARI provided instrumentation will be located forward on the Instrument sub frame. The foam pack should have a protective coating such as a sprayed polyurethane finish and color to be determined.

2.1.7.2 Variable Buoyancy System:

MBARI designed and developed a Variable Buoyancy (VB) control system for assisting in the operational control of Tiburon. The VB system is used primarily to keep the vehicle neutrally buoyant with a secondary function of assisting in the dynamically changing payload to assist in the deployment and recovery of science equipment during a dive without compromising ROV operations. The VB system is not intended to be used for vertical positioning. The VB system uses seawater as the medium for adjusting buoyancy. This is accomplished by opening a valve to flood the buoyancy spheres and lose buoyancy. Gaining buoyancy is accomplished by pumping the entrained seawater out of the spheres. The MBARI provided VB system will be incorporated into the design of the new vehicle. Voids in the syntactic foam module will be provided to accommodate the VB spheres (4) so as not to clutter the open frame of the vehicle. General specifications are listed below in Table 1:

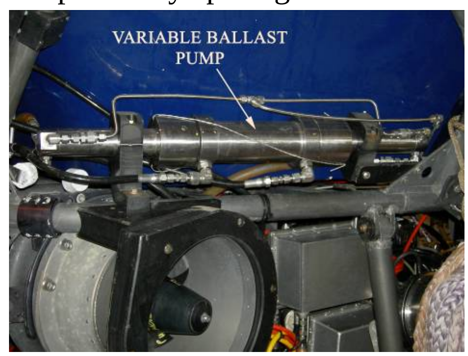


Table 1

VB SYSTEM WEIGHTS (kg)					
Device	*Qty.*	*In air wt*	*Air total*	*In H20 wt.*	*H20 total*
Pump	1	13.18	13.18	9.17	9.17
Sphere (dry)	4	17.39	69.56	-3.68	-14.72
Directional control valve	1	1.36	1.36	1.36	1.36
Flood valve	1	1.5	1.5	1.5	1.5
Plumbing	1	6.82	6.82	5.97	5.97
Total:			***92.42***		***3.28***

The Flood Valve is a specially designed solenoid valve that operates on 24 VDC @ 1A. The VB system can be removed from Tiburon in the first quarter of 2007 and shipped to SMDH's facility for integration.

2.1.7.3 Payload

The vehicle outfitted with the core instrumentation as listed below and a MBARI tool sled (500 kg in-air/236 kg in-water) shall support an additional 273 kg science payload and maintain the ability to be neutral in salt water. 68 of the 273 kg can be variable ballast. Supply and distribution of lead will be by MBARI and lead will be mounted in the tool sled to minimize pitch and roll offset. Sled weight distribution and variation in C of G to be considered as part of complete ROV C of G and stability analysis. Sled drawings and data will be provided by MBARI for calculations of balance during ROV equipment layout design with timescale agreed at first kick off meeting.

2.1.8 Hydraulics

Hydraulics will be used for propulsion of the vehicle, compensation and the operation of hydraulic tools such as manipulators, vibercoring, dredge pump, cable laying tool sled, collection tools, etc. Refer to Appendix A - Hydraulic block diagram.

2.1.8.1 Vehicle Power

The vehicle shall be a 75 SHP, 3kV, 60Hz system. No umbilical cooling system shall be required.

2.1.8.2 Hydraulic System & Components

The hydraulic system will provide a flow up to 136 lpm at a nominal pressure of 210 bar. The system will include the following:

- Curvetech Hydraulic Power Unit (HPU) –75 shp, 3000vac, 4 pole motor with a 100cc/rev on demand pump. Temperature sensors for monitoring motor winding temperature.
- Curvevetech Thruster Control Unit (iTCU) for operation of the thrusters and a spare valve to provide a high flow tooling port. Integral pump load valve, PRV, pressure, temperature, and moisture monitoring.
- Curvetech Intelligent 12 function valve pack (iHCU) for operation of MBARI core and mission specific equipment. The valve pack will be outfitted with (4) 8 lpm proportional valves which permit the remote control of flow for each valve and (8) 15 lpm solenoid valves. Equipped with moisture sensor.
- (4) Curvetech Hydraulic Pressure Compensators – 2.75L rolling diaphragm construction with analog linear level sensors for real time feedback.
- Curvetech Compensator Reservoirs – 10 L with integral 6.3 L compensator with level alarm and oil temperature sensor.
- (7) Curvetech HTE380BA-32 Thruster
- (1) Quark dual tool manifold for operation of the variable ballast system (up to ~30 lpm) and spare tooling port.
- Tool sled supply (up to ~30 lpm) with quick disconnects (type to be determined).
- Schilling T2 supply.
- High and Low pressure filters

SAE ports are preferred over BSPP where ever possible.

2.1.8.3 Thruster Placement & Capabilities

2.1.8.3.1 Thruster Placement

3 vertical thrusters will be positioned one port and one starboard about 25% back from the front of the vehicle and the third thruster mounted aft central. The MBARI tool sleds when mounted on the vehicle, will not provide an unobstructed path for the vertical down

thrust, therefore, the verticals must be angled out sufficiently to provide a clear path for thrust. The horizontal thrusters will be in a conventional vectored configuration, but when performing scientific observations a special thrust control algorithm (Observation Mode) will be selected to minimize the disturbance of the viewing area from thruster wash. When in the Observation Mode, only the rear thrusters will perform fore/aft propulsion and only one set of fore aft thrusters will be used to move the ROV laterally. Details of the algorithm shall be agreed upon by SMDH and MBARI.

2.1.8.3.2 Thrust Capabilities

Power sharing algorithms will be developed to provide a mode of operation that gives priority to vertical or horizontal thrust depending upon the operation at hand. The horizontal thrusters will provide a minimum of 600kg of thrust in both fore/aft and lateral directions. The vertical thrusters will provide a minimum of 500 kg of vertical thrust. Maximum horizontal thrust assumes no vertical thrust and the maximum vertical thrust assumes no horizontal thrust.

2.2 Electrical / Optical

Refer to Appendix A – Electrical / Optical block diagram.

2.2.1 Electrical Assemblies

In addition to SMDH's ground fault detection for the three and single phase AC systems, MBARI will require a ground fault detection scheme to detect and isolate faults on individual DC buses. The system must be able to detect current leakage to sea-water down to approximately 10 micro amps. GFM alarms will be able to be displayed on the GUI and thresholds will be field configurable. MBARI has designed and implemented a ground fault monitoring board to work with the WAGO 750-477 differential analog input module. The circuit is used to scan the high and low outputs of Vicor DC/DC converters that supply the various regulated DC voltages on the vehicle and detects leakage to sea-water. MBARI will provide it's GFM board as describe above for the DC ground fault detection system.

MBARI is performing pressure tests on the MBARI GFM board, VICOR modules and WAGO 750-477 to see if they are suitable for operation in oil to a pressure of 6000 psi. Results of these tests will be provided to SMDH as soon as possible and prior to the preliminary design review. If any of the items fail testing, it will be SMDH's responsibility to come up with an alternate method to meet the design requirement. SMDH will be responsible for the overall design of the DC power system.

2.2.2 Sub-Sea Control Pod

The Sub-Sea Control Pod will be a one atmosphere pressure vessel containing the MBARI provided FOCAL multiplexer, various DC supplies and110vac protection and switching. The Sub-Sea Control Pod will provide independent power switching, GFM and isolation for all connected instruments. In addition, mechanical isolation relays will be provided for all serial data lines to assist with fault detection. The Sub-Sea Control Pod will have environmental sensors for temperature, humidity and water intrusion feedback. 10 to 15% of the total internal volume of the control pod will be uncommitted space for future additions.

2.2.2.1 Connectors & Cables

Seacon MINI-CON series connectors will be used for all camera, data and fiber optic ports coming from the Sub-Sea Control Pod. MBARI will provide the cables for all of the MBARI associated equipment and the 4 pass fiber optic connector . SMDH will be responsible for all other connectors on the Sub-Sea Control Pod and any cables that provide connection to other SMDH equipment. Connector material shall be stainless steel type 316 equivalent or better.

2.2.2.2 FOCAL 903 Video/Data Multiplexer

MBARI will provide a FOCAL 903 for the core vehicle with the specifications listed below in Table 3. This system can be provided to SMDH at any time.

Table 2

FOCAL 903 Remote Configuration					
Item		*RS-23*	*RS-48*	*VIDEO*	*100BT*
VIB-TX, REMOTE VIDEO CARD				4	
VIB-TX-8, REMOTE VIDEO CARD (8X4)				8	
FMB (1310/1550)					
EIB-10/100-1470 (1470/1490)					1
8 CH 485, 907-485			8		
DIB-485			5		
DIB-232-16		16			
CBP-241-HR-24V (CHASSIS)					
Totals:		***16***	***13***	***12***	***1***

2.2.3 Main Junction Box

The Main Junction box will be an oiled filled, pressure compensated enclosure which permits switching, control, isolation and ground fault monitoring of the core vehicle and MBARI provided instrumentation. In lieu of connectors for each device controlled from the main j-box, MBARI requests that cable compression gland fittings be used to reduce the number of possible connector failure points. MBARI has designed a fitting that has been in use on both of our vehicles for several years with success and can provide these to SMDH. 10-15% of the internal volume shall be uncommitted for future expansion.

2.2.3.1 Ground Fault Monitoring

If the required DC power for the instrumentation originates from the Main Junction Box, then ground fault monitoring (GFM) will be performed on both the high and low sides of the main DC power buses (24vdc and 12vdc) and the 110vac input.

2.2.4 Auxiliary Interface Junction Box

The Auxiliary (Science) Interface Junction box will be an oil filled, pressure compensated enclosure that provides a flexible interface for mission specific instrumentation. This junction box must provide a wide range of power buses and data protocols to meet the present and future needs of the science and engineering research and development activities. The control of the Auxiliary J-box will be handled through the core vehicle control software and MBARI must be able to easily configure the GUI to accommodate future analog and digital I/O requirements. The junction box will have a water intrusion detection circuit. Refer to Appendix A – Auxiliary (Science) Junction Box block diagram for more details.

2.2.4.1 Auxiliary Power Requirements

The total auxiliary power requirement for the vehicle is 3000 watts. The J-box will have inputs providing 110vac limited at 1000 watts and 240vdc limited at 2000 watts. These main inputs will have some sort of remote or thermal reset current limit device to provide overload protection. The 240vdc will provide power to Vicor DC/DC converters that provide regulated 48vdc @ 150watts, 24vdc @250w and 12vdc @ 150w. 10-15% of the internal volume shall be uncommitted for future expansion. The individual bus voltages will have switched (high and low isolated) outputs and power ratings as listed below in Table 4.

Table 3

Bus Voltage Outputs and Power Ratings		
Bus	*Number of Outputs*	*Switch Rating (watts)*
110vac	2	1000
240vdc	2	1000
48vdc	1	600
24vdc	8	12
12vdc	4	6

2.2.4.2 Auxiliary Data Requirements

MBARI will provide a Prizm Mini Mux II fiber optic video and data multiplexer to meet the Auxiliary J-box data requirements. A minimum of (2) RS-232 channels will have relays to allow for remote mechanical isolation of the data and ground lines from the multiplexer port. The MiniMux II is pressure tolerant to 4000 meters and has data I/O as listed below in Table 5. This unit can be supplied to SMDH at any time.

Table 4

PRIZM MINI MUX II Configuration					
Item		*RS-232*	*RS-485*	*VIDEO*	*10BT*
Mother board		2	1	2	
Ethernet daughter board		4			1
Total:		***6***	***1***	***2***	***1***

2.2.4.3 Connectors & Ports

The J-box will have a minimum of (12) ports for instrumentation, (1) RS-485 data port for control of the J-Box I/O, (1) fiber port for the MINI MUX and (1 to 2) ports for the incoming power buses. MBARI can provide in-house designed and fabricated gland fittings for the power and data ports.

2.2.4.4 Ground Fault Monitoring

Ground fault monitoring (GFM) will be performed on both the high and low sides of the Auxiliary J-box's four main DC power buses (240vdc, 48vdc, 24vdc and 12vdc) and the 110vac input. Two spare GFM channels are required for future expansion.

2.2.5 Lighting Junction Box

The lighting junction box will be an oiled filled, pressure compensated enclosure that supports the operation of (6) DeepSea Power & Light, 400 watt SeaArc 2 HMI/MSR lamps and (4) 250 watt incandescent lights provided by MBARI. Three dual ballasts which are housed in 1 atm housing will be provided for the operation of the SeaArc HMI lights. The junction box will provide on/off control of all the light circuits and dimming capability for the incandescent lights. In addition, the Lighting Junction box will provide ground fault monitoring for each light circuit and the capability to isolate the fault. The junction box will have a water intrusion detection circuit.

MBARI can provide compression gland fittings for the Junction box and all the cables required for the operation of the lights.

2.2.6 Umbilical Termination / Transformer Junction Box

The Umbilical Termination / Transformer Junction box will be an oiled filled, pressure compensated enclosure. The 10.5 kVA instrument power transformers will be housed in the Umbilical Termination J-Box. The j-box shall provide an easy method to disconnect the umbilical from the ROV (details to be agreed between both parties during the preliminary design review). Burton HV connectors will be used to distribute the HPU and ROV instrument power. A Seacon MINP-4FO-FCRL-RL-TI, 4 pass single mode fiber connector and MINP-4FO-CCPL-TI cable will be provided by MBARI for connection of the fibers to the sub-sea control pod. In addition, MBARI will also provide a Seacon MINF-1FOSM-BCRL-TI connector and associated cable for direct connection of the HDTV camera. The junction box will have a water intrusion detection circuit.

2.2.7 Core Instruments (MBARI Provided)

Tiburon II core instrumentation and associated cables as listed below will be provided by MBARI. Since the equipment is being transferred from the original Tiburon to Tiburon II and Tiburon will remain operational until May of 2008, it won't be possible to provide all of this equipment for test and integration at SMDH's facility.

2.2.7.1 Navigation

Table 5

NAVIGATION SYSTEMS													
Device	*232*	*485*	*422*	*TTL*	*10BT*	*100BT*	*Video*	*110vac*	*240v*	*48v*	*24v*	*12v*	*5v*
usbl				1							1		
gyro	1										1		
sonar	1										1		
homer	1										1		
dvl	1									1			
depth sensor	1										1		
altimeter	1										1		
Total:	***6***	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***0***	***1***	***6***	***0***	***0***

Table 6

NAVIGATION WEIGHTS (kg)					
Device	*Qty.*	*In air wt*	*Air total*	*In H20 wt.*	*H20 total*
DVL	1	18	18	12.1	12.1
Octans	1	18	18	9	9
Altimeter	1	5	5	2.7	2.7
Depth sensor	1	1.33	1.33	1.33	1.33
Homer	1	2.1	2.1	1.3	1.3
Responder	1	4.5	4.5	2.5	2.5
VHF radio beacon	1	1.6	1.6	0.95	0.95
Xenon strobe	1	1.7	1.7	1	1
Sonar	1	6.4	6.4	3.3	3.3
Total:			***58.63***		***34.18***

2.2.7.2 Cameras & Viewing

Table 7

CAMERA & VIEWING													
Device	*232*	*485*	*422*	*TTL*	*10BT*	*100BT*	*Video*	*110vac*	*240v*	*48v*	*24v*	*12v*	*5v*
HDTV											1		
pilots camera	1						3					1	
digital still		1					1					1	
digital strobe													1
down camera	1						1					1	
umbilical camera							1				1		
aux cameras							4				4		
pan & tilts		1									4		
Total:	***2***	***2***	***0***	***0***	***0***	***0***	***10***	***0***	***0***	***0***	***10***	***3***	***1***

Table 8

CAMERA AND VIEWING WEIGHTS (kg)					
Device	*Qty.*	*In air wt*	*Air total*	*In H20 wt.*	*H20 total*
HDTV	1	36.7	36.7	16.8	16.8
Pilot camera	1	5.67	5.67	2.95	2.95
Still camera	1	5.67	5.67	2.95	2.95
Strobe	1	5.67	5.67	2.95	2.95
Internal P&T camera	1	11.8	11.8	6.4	6.4
Aux camera	4	0.4	1.6	0.28	1.12
PT-10	2	4.4	8.8	4.2	8.4
PT-25	2	9.8	19.6	5.7	11.4
HMI Ballast	3	15.56	46.68	9.29	27.87
HMI Light	6	3.67	22.02	1.8	10.8
Incandescent Light	4	1.25	5	0.57	2.28
Total:			***169.21***		***93.92***

2.2.7.3 Science Tools

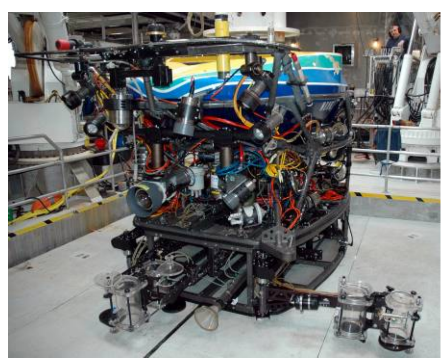
Table 9

TOOL SYSTEMS														
Device	*232*	*485*	*422*	*TTL*	*10BT*	*100BT*	*Video*	*110vac*	*240v*	*48v*	*24v*	*12v*	*5v*	*Watts*
ctd	1										1			5
toolsled interface	1						2		1	1				1200
vb valve											1			50
acoustic modem	1										1			30
schilling	1									1				72
Total:	***4***	***0***	***0***	***0***	***0***	***0***	***2***	***0***	***1***	***2***	***3***	***0***	***0***	***1357***

Table 10

TOOL WEIGHTS (kg)					
Device	*Qty.*	*In air wt*	*Air total*	*In H20 wt.*	*H20 total*
Schilling	1	90.9	90.9		0
CTD	1	13.7	13.7	8.6	8.6
Clump weight latch	1	6.81	6.81	5.75	5.75
Acoustic modem	1	2.75	2.75	2.1	2.1
Emergency cutter	1	2.27	2.27	1.81	1.81
Tool Sled	1	613.81	613.81	235.172	235.172
Total:			***730.24***		***253.432***

2.2.7.3.1 Tool Sleds



In addition to the core vehicle, MBARI has individual tool sled packages designed for specific science missions that are always coupled to the vehicle. MBARI will design and build the tool sleds to bolt on to the bottom of the core vehicle. MBARI will provide the tool sled hardware (guide cones) required for the attachment of the sleds. The weight of each Tool sled will not exceed 500 kg. in air and 236 kg. in water. The 273 kg payload requirement is in addition to the weight of the tool sled. The Kraft manipulator is part of the tool sled and therefore the weight is included in the tool sled total weight. Interconnect requirements are as follows:

- RS-232 data channel for operation of the tool sled controller.
- RS-422 data channel for operation of the Kraft manipulator.
- 48 vdc @ 5 amps (unregulated) for tool sled controller power
- 240 vdc @ 4 amps (unregulated) for tool sled tools.
- Two video channels for tool sled cameras.
- Hydraulics requirement, >= 8 gpm @ 3000 psi. (quick disconnects TBD)

2.3 Surface Control Equipment and Power Distribution

Refer to Appendix A – Surface Block Diagram for MBARI's interpretation of the configuration of the top side hardware.

2.3.1 Control Room

The panoramic view of Tiburon's control room is shown below. Starting at the far left is the Co-pilots station. The co-pilot is responsible for manipulator, sonar and other instrument operations, umbilical haul in / pay out and alarm & data monitoring. The pilots station is next and the then the chief scientist and co-scientist. MBARI will utilize as much of the control room equipment as possible. MBARI shall provide a drawing showing available rack / panel space for SMDH hardware.

2.3.2 Control System

The Control system must provide interfaces that are designed to be flexible and configurable to allow easy integration of third party systems into the control system.

2.3.2.1 Software

2.3.2.1.1 Redundant Device Selection

The system shall provide a method for selection of primary and secondary instruments for redundant devices to provide input for control or display of information. An example would be the option to select the Altimeter or DVL for input into the Auto-Altitude function or display onto the GUI. Other redundant devices would include heading sensors.

2.3.2.1.2 Graphical User Interface (GUI)

The system must provide at a minimum, 3 work stations with Graphical User Interfaces (GUI) for control and monitoring of vehicle systems. The individual GUI screen layouts must be able to be expanded or modified by MBARI when required. The GUI's must support touch screens. An example of MBARI required graphical, in addition to numeric displays are as follows:

- Graphic display of vehicle thrusters and level of thrust commands
- Pitch & Roll (some type of artificial horizon)
- Pan & Tilt feedback (x, y graph type display)
- Turns counter history with set point (compass rose showing set point and vehicle heading history).

Numeric displays are required for the following MBARI items:

- HDTV camera lens feedback (focus, zoom and Iris)
- Umbilical out (Delta)

A list of standard GUI items will be finalized during the preliminary design review.

2.3.2.1.3 Joy Stick Integration

Tiburon's existing joysticks shall be incorporated into the new vehicle system. MBARI can provide Tiburon's spare joysticks to SMDH for integration and testing when required.

Some operational tasks require the ROV to track very delicate animals in the mid-water column. MBARI has utilized the capability to reduce the thruster output by scaling the joystick command output to allow for finer control of the vehicle during these maneuvers. MBARI will require this capability to be incorporated into the new vehicle.

During sample collection activities, the pilot is sometimes required to precisely position the vehicle to place a specimen in a sampler and then quickly close the door to that sampler to capture the animal. The pilot can't afford to let go of the joystick to activate the hydraulic valve through the GUI, so we currently provide the capability to map a particular valve in advance to a button on the joystick. This allows the pilot to never have to take his eyes off the screen nor hands off the joystick. A summary of the integration of control system items with the joy sticks are as follows:

- Button on main joystick for enable/disable of MBARI observation mode. When the observation mode is enabled by the joy stick, the joy stick command is scaled to the percentage that is selected on the GUI. When the observation mode is disabled, the joy stick command is set back to 100%

- (2) Buttons on vertical joystick for enable/disable of vertical and main joy stick lock. The vertical or main joy stick command value is locked, when the joystick lock button is activated. After the joystick value is set and the input from the joystick is returned to zero, if a new joystick value of 50% or greater is detected, the joystick lock is disabled. The joystick lock is also disabled when the button is pressed again after lock condition is set.
- Switch on main joystick for operation of mapped valve from GUI.
- Trigger on main joystick for enable/disable of AutoROV Heading function.

The specifications for the joy sticks are as follows:

- *Vertical axis:* (Measurement Systems, Inc. P/N = 523U).
- *Horizontal axis:* (Measurement Systems, Inc. P/N = 547 – 3 axis)

2.3.2.1.4 Focal Video Switcher

The MBARI provided Focal 903 multiplexer has one 8x4 video card (8 switched to 4) which can take 8 input channels of video and via the FOCAL console, select 4 channels for output. The control of the video switcher is performed through the FOCAL console mux by providing +5vdc to 4 channels to select Video input A or B. The control of the FOCAL video switcher shall be incorporated in to the control system and the switcher operated through the GUI.

2.3.2.1.5 Advance Navigation Controls (MBARI R&D)

Tiburon currently supports an interface that allows an external controller to receive real-time ROV telemetry. The interface also executes ROV thrust commands sent by the external controller. The ROV telemetry data and thrust commands are sent and received by the Tiburon control system over a serial port. The Tiburon control system sums the received thrust commands with the pilot joystick commands to allow the pilot to assist or disturb the external controller. The Tiburon control system also monitors a digital input, the closure of which disables the external controller interface. An emergency cutoff button is attached to this digital input to allow the pilot to immediately disable external control.

Tiburon II shall support a similar advanced controls interface to allow for the control of the ROV by an external controller. The data in table 12 shall be sent to the advanced controls interface from the Main Control Computer via a serial connection. The data is required to have a latency of no more than (TBD) ms. The data string shall be sufficiently flexible as to allow for the addition of future data items with minimal configuration changes. The format of the data string as well as the serial port configuration shall be agreed upon by MBARI and SMDH.

The Main Control Computer shall also receive thrust commands as shown in table 13 from the advanced controls interface and sum those commands with the pilot commands in real-time. The format of the command string shall be agreed upon by MBARI and SMD.

Table 11

SMD control system data to be sent to Advanced Controls Interface		
data	*type*	*units*
Heading	float	degrees
Pitch	float	degrees
Roll	float	degrees
Depth	float	meters
Altitude	float	meters
AutoHead state	boolean	N/A
Emergency Cutoff state	boolean	N/A
Observation Mode state	boolean	N/A
Bypass Mode state	boolean	N/A
Heading Thrust	float	TBD
Lateral Thrust	float	TBD
Axial Thrust	float	TBD
Vertical Thrust	float	TBD

Table 12

Advanced Controls Interface commands sent to SMD control system		
data	*type*	*units*
Heading Thrust	float	TBD
Lateral Thrust	float	TBD
Axial Thrust	float	TBD
Vertical Thurst	float	TBD

2.3.2.1.6 Navigation Processor

The MBARI Navigation Processor or NavProc is a computer that interfaces various ship and ROV navigations systems together. NavProc can send and receive data over serial ports or via a proprietary publish/subscribe data distribution system know as Datamanager. Once data has been published to Datamanager any other Datamanager node on the network can subscribe to that piece of data.

The data in Table 14 shall be sent to the NavProc computer from the Main Control Computer via a serial connection. The data is required to have a latency of no more than (TBD) ms. The data string shall be sufficiently flexible as to allow for the addition of future data items with minimal configuration changes. The format of the data string as well as the serial port configuration shall be agreed upon by MBARI and SMD.

The Main Control Computer shall also receive MBARI system variables as shown in table 15 to be displayed on the GUI. The format of the data string shall be agreed upon by MBARI and SMD.

Table 13

SMD control system data to be sent to NavProc		
data	*type*	*units*
Vehicle in water	boolean	N/A
Heading	float	degrees
Pitch	float	degrees
Roll	float	degrees
Altitude	float	meters
Depth	float	meters

Table 14

NavProc System Data sent to SMD control system		
data	*type*	*units*
Umbilical payout	float	meters
Umbilical delta	float	meters
HDTV humidity	float	percentage
HDTV leak detect	boolean	N/A
HDTV zoom position	float	TBD
HDTV focus position	float	TBD
HDTV iris position	float	TBD

2.3.2.1.7 Video Overlay

Tiburon II will use the Options VIGRA video overlay to display vehicle information on the pilots video display. The VIGRA overlay system can receive this data via a serial or TCP connection.

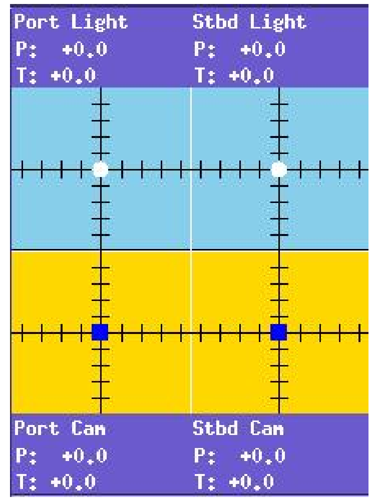
The data in table 16 shall be sent to the VIGRA overlay unit from the Main Control Computer via a serial or TCP connection. The data is required to have a latency of no more than (TBD)ms. The data string shall be sufficiently flexible as to allow for the addition of future data items with minimal configuration changes. The format of the data string as well as the serial port configuration shall be agreed upon by MBARI and SMD.

Table 15

SMD control system data to be sent to VIGRA overlay Unit		
data	*type*	*units*
Heading	float	degrees
Hydraulic Pressure	float	PSI
Depth	float	meters
AutoHead state	boolean	N/A
Altitude	float	meters
Divenumber	integer	N/A
Date	string	date string

2.3.2.1.8 Integrated Viewing System

Tiburon currently uses an integrated viewing system or IView to control the camera and light pan and tilts. This system allows the control of the cameras to be shared between the pilots and scientists. The IView system also supports special viewing modes that have proven useful in different observation scenarios.



Though the pan and tilts will be controlled via the IView controller it is necessary to have the pan and tilt positions displayed both graphically and numerically on the pilot GUI for diagnostic purposes. In order to display the pan and tilt positions on the pilot GUI the Main Control Computer shall receive pan and tilt data as shown in table 17 via a serial string. The format of the serial string shall be agreed upon by MBARI and SMD. The data shall be displayed on the pilot GUI both graphically and numerically in a similar fashion as shown in figure to the right. The layout of the pan and tilt portion of the GUI shall be agreed upon by MBARI and SMD.

Table 16

IView pan and tilt data sent to SMD control system		
data	*type*	*units*
Port light pan	float	degrees
Port light tilt	float	degrees
Starboard light pan	float	degrees
Starboard light tilt	float	degrees
Port camera pan	float	degrees
Port camera tilt	float	degrees
Starboard camera pan	float	degrees
Starboard camera tilt	float	degrees

2.3.2.2 Control System Hardware

2.3.2.2.1 Top Side Hardware

All SMDH control system hardware such as PC's, monitors, etc. must run on 110VAC/60Hz.

2.3.2.2.2 Sub Sea Hardware

SMDH will provide a Tritech IGC gyro compass and IFG fiber optic gyro as backup for MBARI's Octans 6000 FOG.

2.3.2.2.3 Video Equipment

MBARI will provide all the associated equipment such as monitors, recording decks, video overlay, control room video switcher, video distribution and conversion equipment.

2.3.2.2.4 MBARI Core Instrumentation

MBARI will provide all the associated equipment required to support MBARI core instrumentation such as PC's, cabling and deck boxes.

2.3.3 ROV Auto Functions

The vehicle will have the following suite of automatic control routines:

- Auto Depth. ROV automatically remains at a constant water depth (+/- .02% at 4000m). This function will incorporate a nudge feature to modify the current set point. MBARI will provide a Digiquartz depth sensor with .01% resolution as the vehicle's depth sensor.
- Auto Altitude. ROV automatically remains at constant distance from the seabed (+/- .2 meters?). Feedback will be provided from an altimeter or DVL. This function will incorporate a nudge feature to modify the current set point. A provision shall be provided to enter an offset value for altimeter data to compensate for the location of the altimeter or DVL on the vehicle. MBARI will provide a Simrad model 1007 altimeter and a RDI 1.2 mHz "Workhorse Navigator" DVL as the altimeter sensors.
- Auto Heading. ROV automatically maintains a constant heading (+/- 2 deg.?). Feedback will be provided by the vehicle's FOG. This function will incorporate a nudge feature to modify the current set point. MBARI will provide an Octans 6000 FOG as the primary heading sensor.
- Auto Hold. ROV maintains current position in X and Y (+/- x cm). Feedback will be provided by the DVL when bottom lock is available and by the Sonardyne fusion system when bottom lock is not available. This function will incorporate a nudge feature to modify the current set point.
- Auto Step. ROV moves a user input distance in X and/or Y direction (+/- x cm). Feedback will be provided by the DVL. This function will incorporate a nudge feature to modify the current set point.
- Auto Home. ROV automatically returns to a preset "home" position (+/- x cm). Feedback will be provided by the DVL.
- Auto Track. ROV automatically follows pipe / cable using TSS or equivalent tracking device. SMDH will provide description of input protocol for Auto Track.
- Auto Route. ROV automatically follows a pre-programmed route of waypoints.
- Thruster Plane Priority. Vertical or horizontal thrusters are selected to take priority.
- Control Reversal. Joystick commands are reversed for moon pool launch & recovery operations.
- Lost Thruster Compensation. If a thruster fails, it can be isolated and the control system will modify control algorithms to compensate.

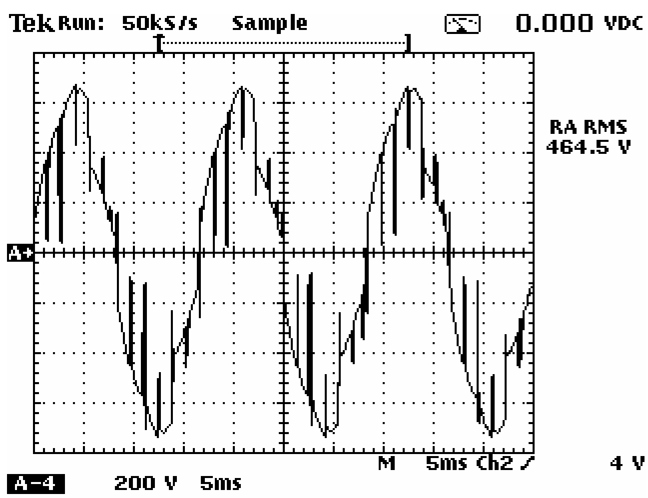
- Pitch, Roll, Horizontal and Vertical Trims.

The tolerances specified above for the auto functions are for a controlled environment such as a test tank. Procedures for verification and testing will be agreed upon by MBARI and SMDH during the initial kick off meeting.

2.3.4 Power Distribution

2.3.4.1 Western Flyer Power

The Western Flyer is a diesel electric propelled vessel with SCR controllers and therefore ships power is considered noisy. The figure below is a screen capture from a scope which show the effects of the SCR drives on the main power during typical operations while in DP. The ROV's 3 phase HPU motor and it's step up transformer will be capable of running directly off the Flyer main 480 VAC power bus.



The Western Flyer power specification for the ROV supply circuit is 480 vac 3 phase (delta) – 60 Hz / 400 amps. The existing ROV power conditioning equipment on the Western Flyer for the single phase (60Hz) instrument power will be used to provide a clean and stable ROV instrument supply.

2.3.4.2 High Voltage Systems & GFD and Interruption

The GFD and interruption system shall continually monitored the insulation of the umbilical conductors. If insulation falls below a preset level an alarm will sound and if it falls below a lower preset level the high voltage power to the ROV is shut off. The PDU and high voltage transformers systems shall be manufactured to IMCA (AODC) guidelines.

2.4 Deployment System

2.4.1 Umbilical Handling System (UHS)

The UHS is designed to deploy, tend, recover and store 5000 meters of 0.68 inch diameter armored umbilical. The ROV & UHS consists of a traction winch, storage drum, motion-compensated crane and ROV launch & recovery crane. The system was designed and built by Dynacon Inc.

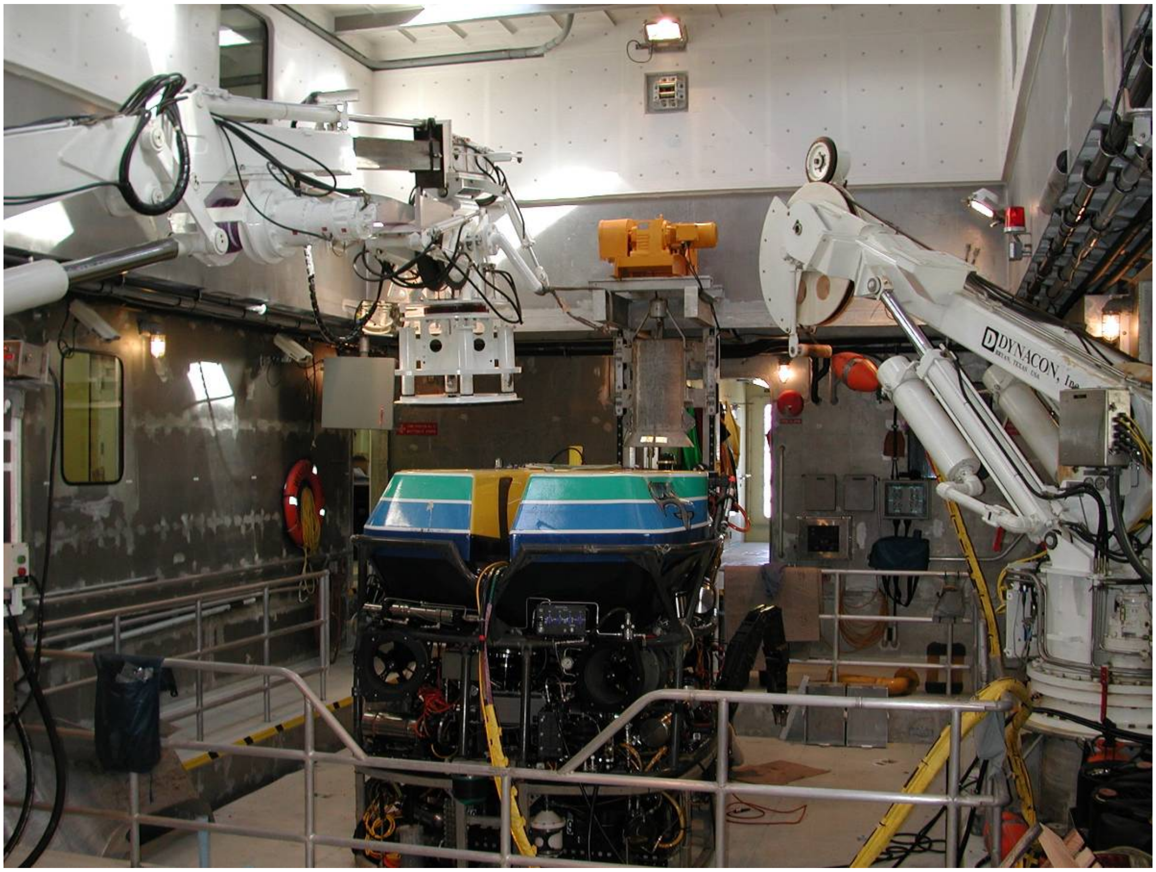
2.4.1.1 Slip ring

MBARI shall provide a PRIZM Model CK7206 which provides 7 single mode fiber passes with < 4db attenuation for any pass and 20 power rings (5 sets of 4 rings) rated at 5000 volts @ 20 amps maximum.

2.4.2 Launch & Recovery System (LARS)

The R/V Western Flyer is a dynamically positioned SWATH vessel with a dedicated moon pool for launch & recovery of the ROV. The launch process starts with the ROV picked up using an articulated crane outfitted with a motion-damped docking head. The umbilical and its mechanical termination pivots aft at the latch and is laid down flat in a recess in the foam pack to allow the docking head to make positive contact with the foam pack. The vehicle is attached to the crane through a spectra braid lift line. The moon pool doors are opened, the crane is tipped down and the winch is operated to lower the vehicle in water. The vehicle is outfitted with a motorized latch for release of the spectra braid line once the ROV is in the water. The umbilical is deployed through the Dynacon motion-compensated crane. Before deployment, floats and a second spectra lift line are attached to the first 30 meters of umbilical from the ROV for recovery.

The recovery process starts by deploying a clump weight / guide wire in the moon pool area to a depth of approximately 50 meters. The vehicle is equipped with a guide wire latch on the bow that allows it to couple on to the wire. The vehicle locates the guide wire on sonar at a depth of about 40 meters, flies in on the wire and attaches to it. The ROV then ascends to a depth of 25 meters where the previously attached second spectra line is attached to the recovery crane. The vehicle continues its ascent up the guide wire until it reaches the surface and is then winched in to the docking head of the crane, lifted through the moon pool, and placed on deck.



Western Flyer LARS / Moon Pool Area.

2.4.2.1 Remote Belly Pack

A belly pack is required for control of the vehicle during launch and recovery of the vehicle as it transits through the moon pool interface. SMDH shall provide a new belly pack with joysticks for thruster control, a display for depth and the capability to enable/disable auto heading. The Belly Pack shall be splash proof. Figure 3 shows the Tiburon Belly Pack located in the Moon Pool area.

2.4.2.2 Vehicle Latch

After reviewing the existing Tiburon launch & recovery latch. It has been determined that it is not capable of supporting the increased weight of the new vehicle. Therefore, SMDH shall provide a vehicle latch which provides a means to release the “Spectra” deployment line, an attachment point for the “Spectra” recovery line and an emergency lift bail for recovery of the vehicle in the event that the “Spectra” recovery line is damaged. One of the 12 hydraulic valves can be used to release a pin if desired.

2.4.3 Umbilical Cable

2.4.3.1 Cable Specifications

The provided umbilical must be compatible with MBARI's UHS on board the RV Western Flyer and suitable for deep water (4000 meters) ROV operations. The umbilical shall support its own weight and the dynamic loads produced by the ship (estimated at 1.52 G's). The umbilical is not required to support the load of the ROV in air. The ROV will be deployed and recovered by a separate line. The umbilical shall be designed to provide an expected 5 years of service in a dynamic ocean environment. It shall be SMDH's responsibility to insure that ROV and all sub systems work as expected through the provided umbilical at full operational depth (4000 meters). The general specifications for the umbilical are as follows:

- Length - The delivered umbilical shall not be less than 5000 meters.
- Finished Diameter – The umbilical diameter shall be 17.3 +/- .5mm
- Fibers – There shall be 5 single mode fibers. Attenuation in each fiber under the working load and pressure will not exceed .6 db per kilometer at 1310 and .7 db per kilometer at 1550 nm. wavelengths.
- Induced Rotation – Free end rotation shall not exceed .5 deg/m at loads up to 60kN
- Weight – 1110 kg/km in air, 870kg/km in water.
- Minimum Bend Radius – 210mm (static), 230mm (dynamic)
- Minimum Breaking Load – 180kN
- Working Load – 60kN

2.4.3.2 Testing

The purpose of the testing is to demonstrate the suitability of the umbilical for the normal service conditions encountered by the ROV. The umbilical shall be tested to show that it meets the specification to which it was manufactured. This test procedure is to be agreed between SMDH and MBARI with the following used as a guide line:

- Production Testing – Performed by the umbilical manufacture during production.
    - Dimensional – Size of components, insulation thickness, lay lengths, copper polyester tape overlap, sheath thickness and diameter.
    - Electrical – High voltage and insulation resistance test at 5kVdc, conductor resistance, capacitance, screen resistance, Impedance and attenuation on the quad.
    - Optical – OTDR traces on all fibers both prior to lay-up and on completed umbilical (measured at 1300 and 1550 nano meters.
    - Strength – A sample will be tested to destruction in a tensile test machine. The minimum value to be attained is 180kN.
- Functional
    - Load & Elongation – Elongation against load, overall diameter against load, optical attenuation, electrical continuity

  - Rotation – Rotation of umbilical under working load.
  - Bend Cycling Under Load – Assess the effects on the electrical and optical properties resulting from bend cycling under load.
- Hydrostatic Pressure – (6000 psi)
  - Electrical – conductor resistance and core insulation resistance.
  - Optical – OTDR traces on all fibers measured at 1300 and 1550 nano meters.
- Material Tests – Ensure that all materials are compatible with the type of oil (Shell Tellus or equivalent) to be used with the umbilical termination j-box
- Thermal Behavior – Thermal behavior of the cable will work with MBARI's UHS drum with nominal amount of current load.

2.4.3.3 Terminations

A suitable means for a mechanical termination and strain relief of the umbilical to the vehicle shall be provided. The strain relief and termination must be able to pivot aft to a horizontal position and be recessed to allow for the mating of the LARS docking head.

SMDH shall provide a suitable means for termination (Junction boxes) of the umbilical to the top-side slip ring and the slip ring to the SMDH provided deck cable. In addition, SMDH will provide a PDU/Transformer to deck cable j-box if required. The existing j-boxes do not have the capacity for the additional power conductors or fiber passes. MBARI will provide access dimensions at the first kick off meeting.

2.4.3.4 Deck Cable

SMDH will provide a 30 m deck cable suitable for the required power and fiber runs from the slip ring to the PDU/Transformer.

3 Documentation

A complete documentation set for the operation and maintenance of the ROV system will be provided, comprising of the following:

- Equipment specifications and description
- Equipment operating procedures
- Maintenance procedures
- Relevant assembly drawings
- Electrical and hydraulic circuit diagrams
- Parts lists
- Software description and user interface instructions
- Proprietary equipment manuals
- Equipment interface documents

Three paper copies of the above documentation will be provided along with three electronic copies stored in Adobe Acrobat format on CD. Electrical and hydraulic circuit diagrams will be provided as a separate document in electronic DXF or DWG format to allow MBARI to update the documents as hardware is changed or upgraded.

4 Spares

A final list of spares shall be agreed between both parties after the completion of CDR.

5 Design Review and Acceptance Testing

As part of the design process, MBARI will participate in a minimum of a preliminary and critical design review at the offices of SMDH. MBARI will witness the FAT and will sign off against each of the agreed tests during the FAT. FAT test will be agreed upon by SMDH and MBARI during the PDR.

6 MBARI Project Team Contact Information

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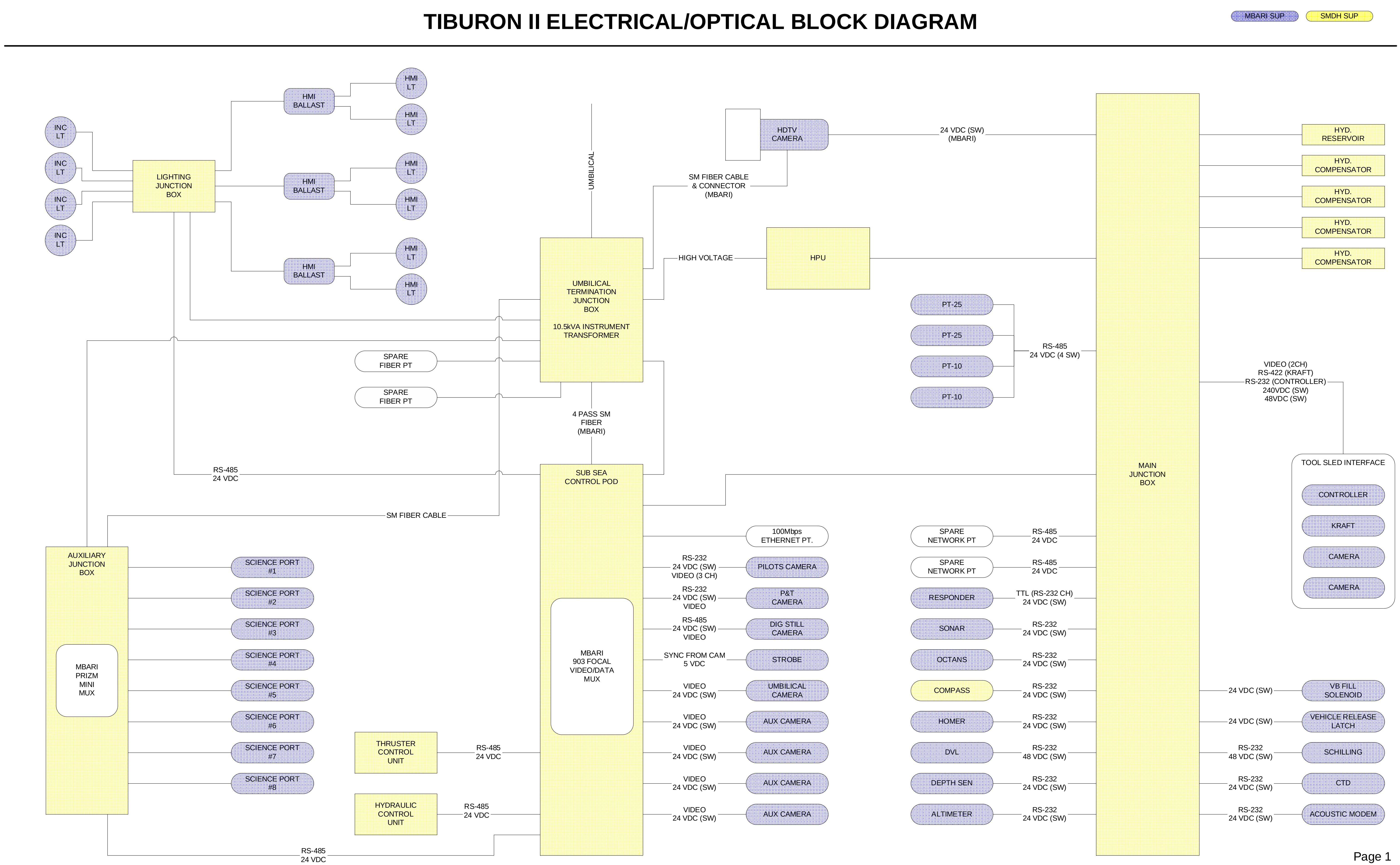
Appendix A

Block Diagrams

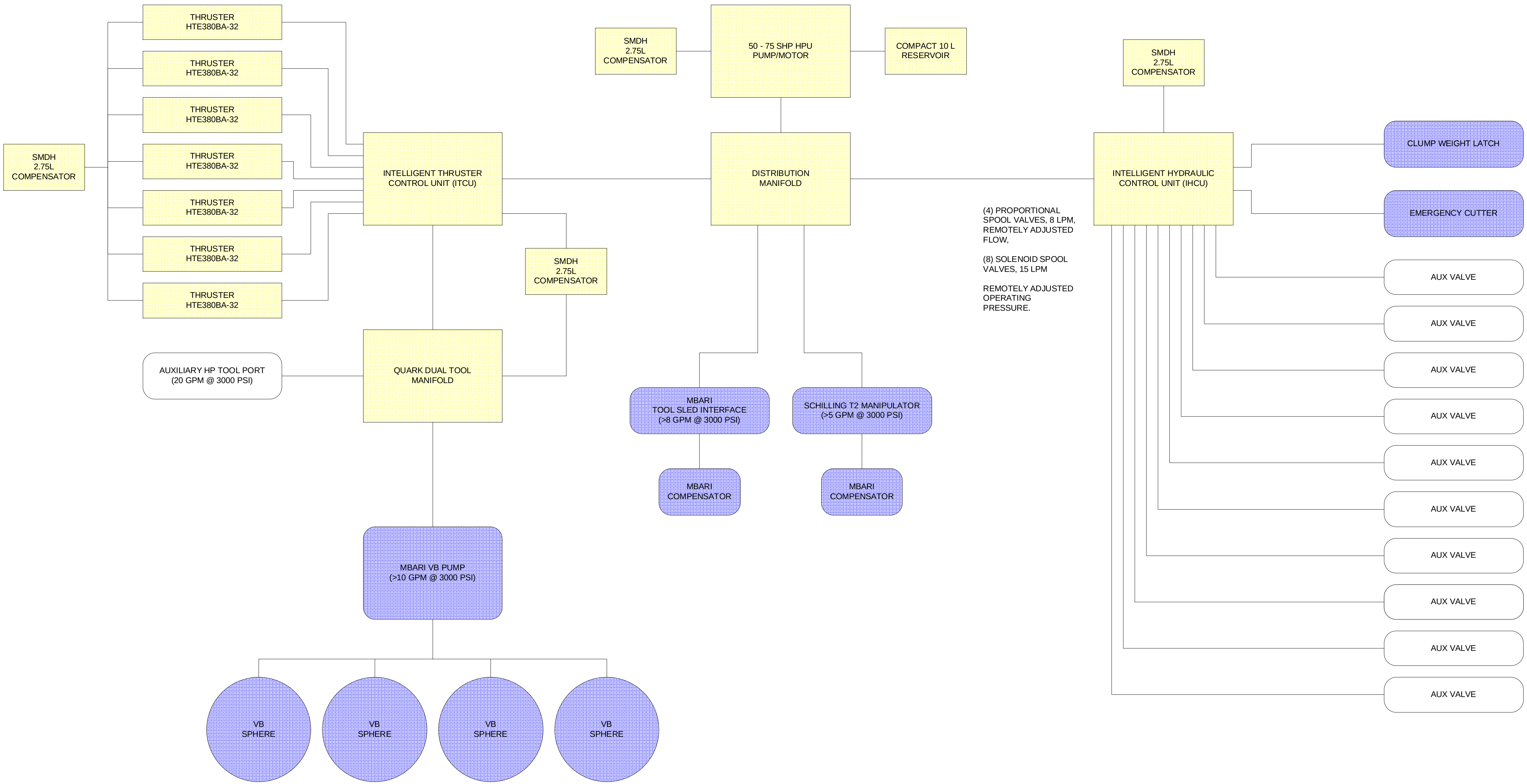
Electrical / Optical Block Diagram
Surface Block Diagram
Hydraulic Block Diagram
Auxiliary (Science) Interface J-Box Block Diagram
ROV Power Distribution Block Diagram
TRELLEBORG TG-28A Syntactic Foam

TIBURON II ELECTRICAL/OPTICAL BLOCK DIAGRAM



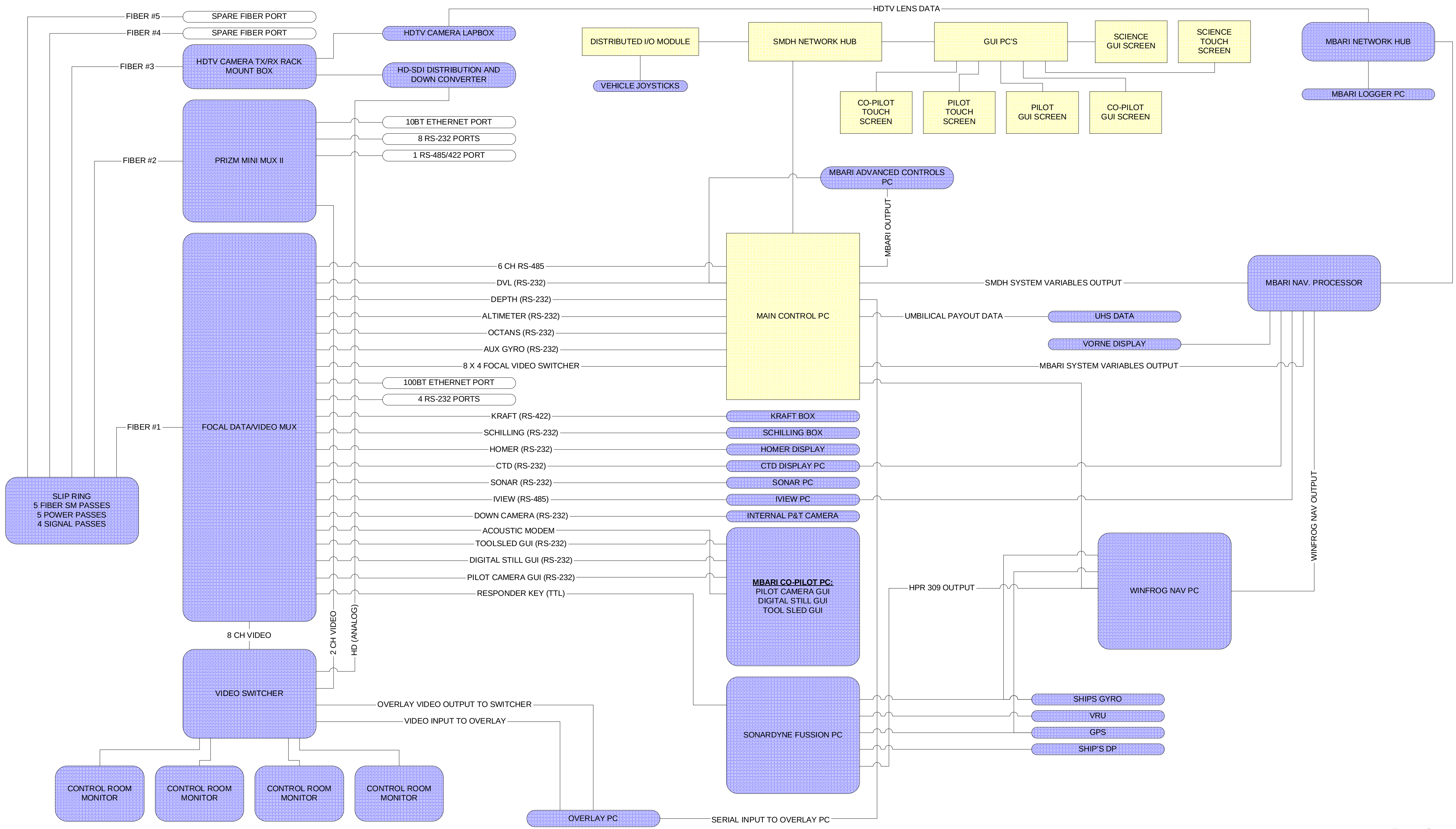
TIBURON II HYDRAULIC BLOCK DIAGRAM

Thursday, January 25, 2007



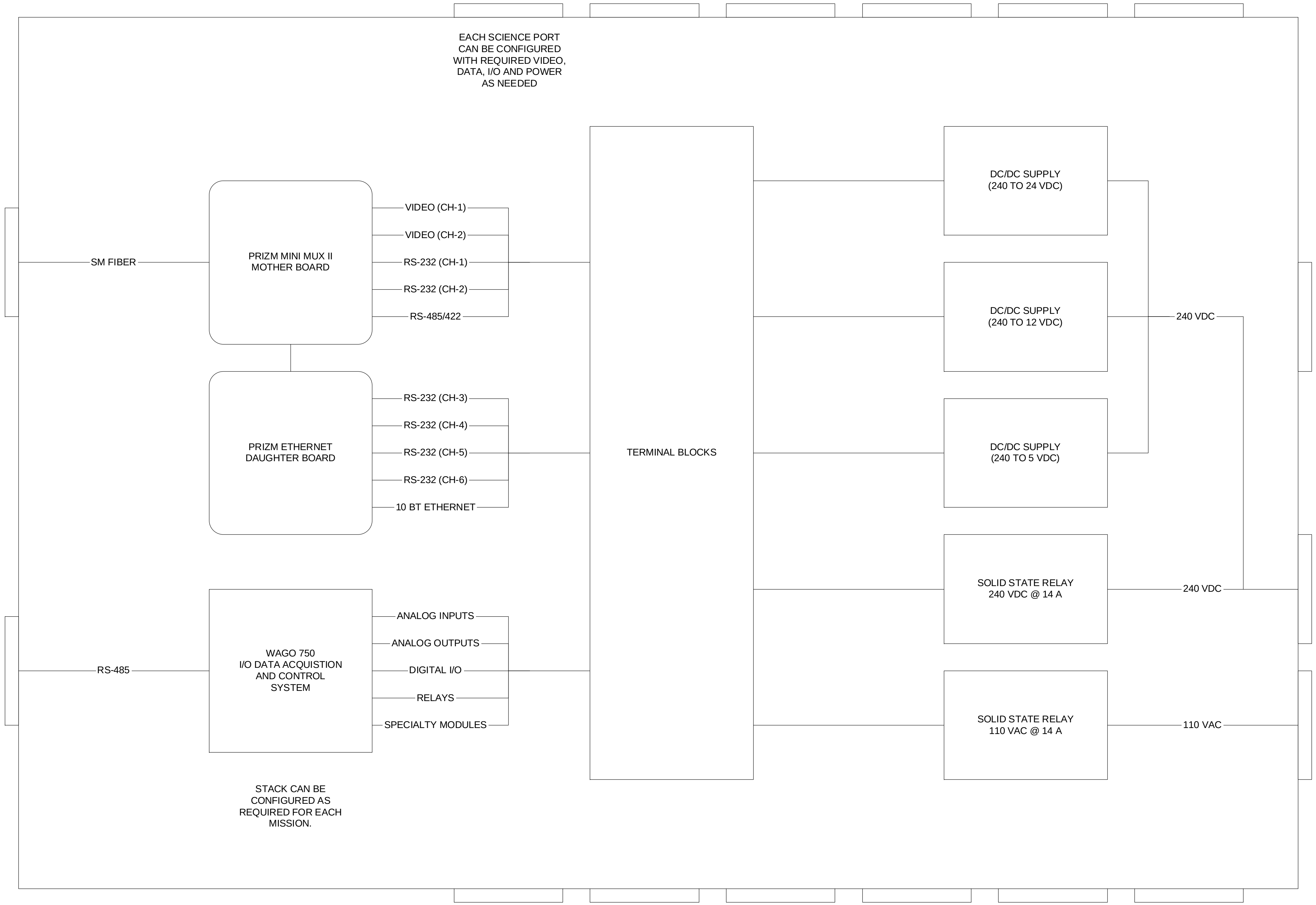
SURFACE BLOCK DIAGRAM

Thursday, January 25, 2007



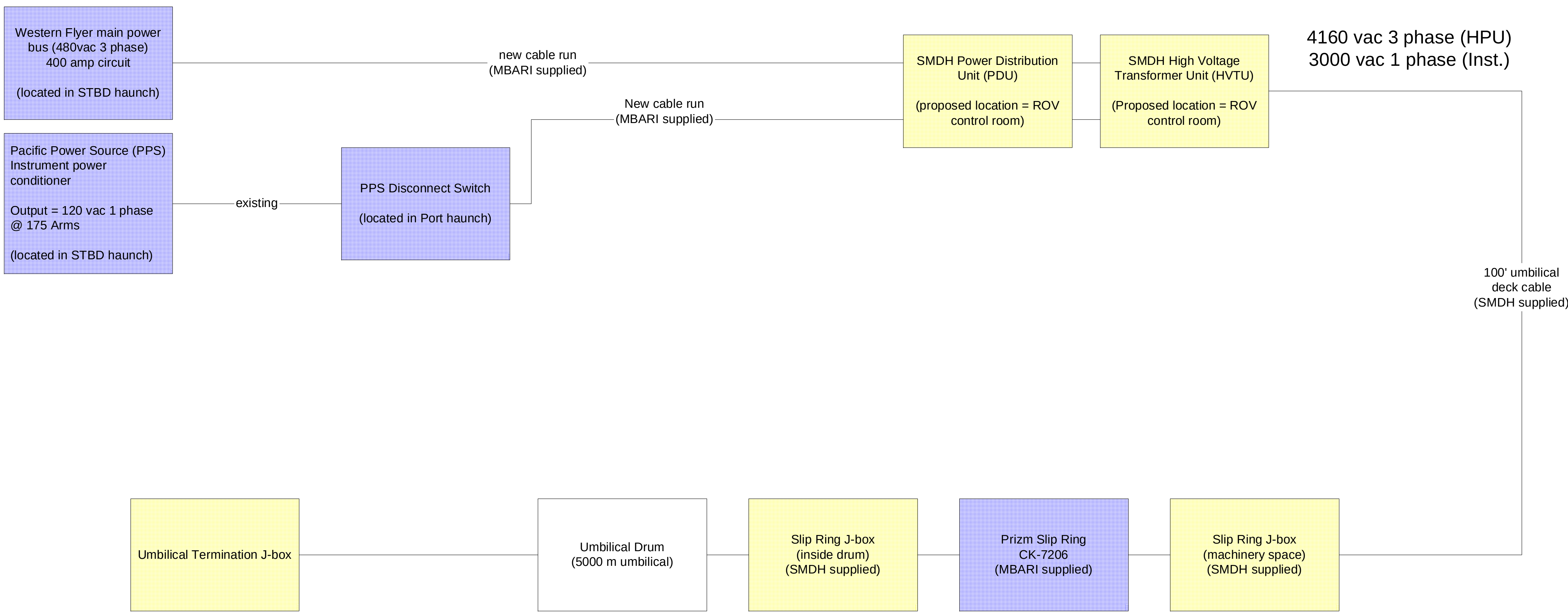
AUXILIARY (SCIENCE) INTERFACE J-BOX

Thursday, January 25, 2007



ROV Power Distribution Block Diagram

Thursday, January 25, 2007



TRELLEBORG
ENGINEERED SYSTEMS

Typical Properties

TG-28A

4000MSW rated low density syntactic foam for buoyancy applications

	Property	Test Method	Value	SI Units	Value	Imp Units
	Colour	-	Violet	-	-	-
	Density	ASTM D1622	448	kg/m^3	28	lb/ft^3
	Depth Rating at 10°C		4,000	MSW	13,120	FSW
	Uniaxial Compressive Strength	ASTM D695	32.4	MPa	4,700	lbf/in^2
	Uniaxial Compressive Modulus	ASTM D695	1,448	MPa	210,000	lbf/in^2
	Hydrostatic Crush Pressure	ASTM D2736	670	bar	9,700	lbf/in^2
	Bulk Modulus	ASTM D2926	1,870	MPa	271,200	lbf/in^2

Author	Zoe Murphy	Issue No	2
Approved By	David Hamnett	Date of Approval/Issue	14 Nov 2006

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