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EXPENDABLE AUTONOMOUS PROFILER (XAP)

FINAL REPORT

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11/30/92 **FINAL REPORT**

PROJECT TITLE: Expendable Autonomous Profiler (XAP)

CONTRACT NUMBER: N0014-92-C-0038

PRINCIPAL INVESTIGATOR: Jeffrey Callahan, PRB Associates, Inc.

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RESULTS: The initial focus of the work performed in this study was to determine the feasibility and utility of different approaches to the buoyancy control system (elevator) required for an expendable autonomous profiler (XAP) which would be an air-deployable, A-size sonobuoy-like device. Two approaches were analyzed in detail, one using a hydraulic elevator and the other using a compressed gas elevator. Some conclusions were reached regarding the recommended technical approach for building XAP prototypes. The certification process for sonobuoys was investigated as well as the certification requirements for using lithium-based batteries. Finally, a functional description and initial cost estimates for a potential XAP prototype were developed.

Statement A per David Evans
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NWW 12/9/92

1. INTRODUCTION

The purpose of this study was to determine the feasibility of an air-deployable, A-size sonobuoy-like device known as the eXpendable Autonomous Profiler (XAP), which would be able to make profiling dives to a maximum depth of 1,000 meters (3,281 feet) and return to the surface, where it would relay data, via a satellite, to a processing center. The A-size form-factor and survivability of aircraft launch and water entry are the two major design considerations. The number of dives, duration of dives, payload capabilities and overall life expectancy of XAP are characteristics which were to be established.

Depth is controlled by an a self-contained elevator system. Two candidate elevator methods were investigated, hydraulic and gas. The hydraulic version is based on the existing design of the Autonomous Lagrangian Circulation Explorer (ALACE)[1.] produced by Webb Research Corporation for ocean current research. Like ALACE, XAP would cycle between the ocean surface and a programmed depth, collecting data at specific depths (pressures) during its vertical transits and relaying the data and surface position data via satellite while on the surface. A gas driven version was also investigated because of the potential for longer life expectancy, lighter weight and increased resistance to damage inflicted during aircraft launch and water entry.

2. EMPLOYMENT CONCEPTS

A major limitation in efforts to improve our knowledge of the ocean for either naval tactical purposes or non-defense applications is the difficulty and high cost of obtaining data sets of adequate quality and coverage. The operational effectiveness of naval units and systems is strongly dependent upon environmental conditions, which are constantly changing. While our ability to understand and predict these changes has greatly improved in recent years, it is still limited, in part by deficiencies in available data. Collecting environmental, acoustic, or other data sets of adequate quality and coverage for either operational or research purposes is costly and resource intensive.

Modern technology has significantly increased our capability to gather data from the ocean. Spacecraft, for example, are able to monitor large expanses of the ocean surface, and a variety of expendable devices deployed from ships and aircraft provide subsurface profiles that complement the surface picture available from satellites. Still other devices, known as neutrally buoyant vehicles, are able to gather data as they drift at predetermined depths within the ocean.

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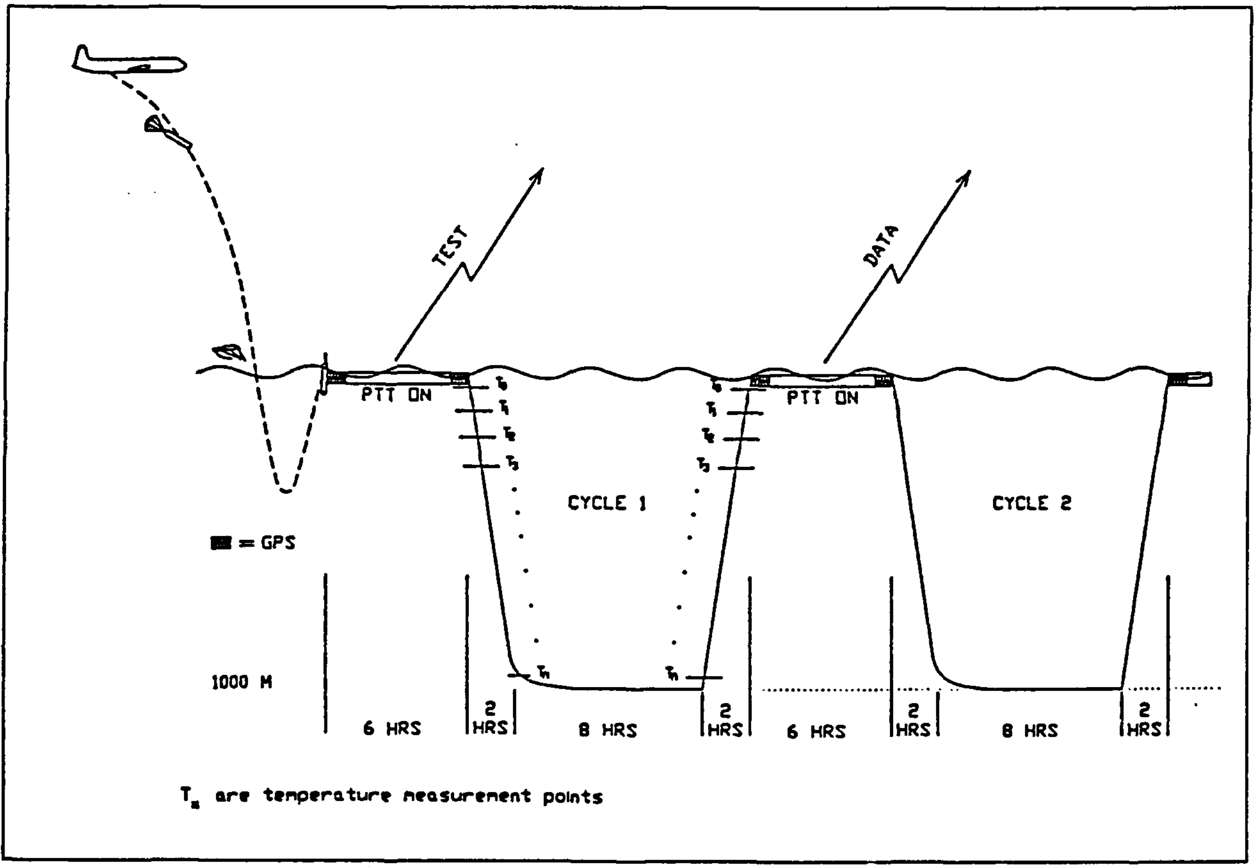
1. Davis, R.E., Webb, D.C., Regier, L.A., and Dufour, J.; "The Autonomous Lagrangian Circulation Explorer (ALACE)". Journal of Atmospheric & Oceanic Technology, Vol. 9, No. 3, 1992.

2.1. FUNCTIONAL OVERVIEW

This research investigates the combination of some of the features of spaced-based, expendable, and neutrally buoyant observation technologies to provide a cost-effective method of making long term, large area measurements of key oceanographic parameters. The proposed device is a free drifting, air-deployable unit that can be launched like an A-size sonobuoy. After water entry, it performs repeated cycles between the ocean surface and a maximum depth of 1,000 meters. During each transition from the surface to maximum depth (and from maximum depth back to the surface) it will sample temperature at selected depths (pressures). At the end of each cycle it relays data back to processing centers via a satellite link. A typical mission profile is depicted in figure 1.



T_x are temperature measurement points

Figure 1. XAP Mission Profile

After launch, XAP deploys a small parachute (decelerator) that stabilizes the device and slows its descent. Upon entering the water the parachute and its associated components are released, the stowed antenna deploys, and the device begins to sink. At the same time, the internal electronics are powered and the internal electric pump starts transferring oil from the oil reservoir to the external bladder. After pumping for approximately 30 minutes, the unit becomes positively buoyant and returns to the surface where it remains for the normal surface period (for example, 6 hours) and performs standard functions of taking global positioning system (GPS) fixes and transmitting to the ARGOS satellite. The purpose of the on-surface period is to verify that the unit survived the launch, it is operating and to initialize the GPS.

After completing its initial period on the ocean surface, XAP begins its first complete cycle. The valve is opened to deflate the external bladder and it begins to dive to its maximum depth (nominally 1,000 m). It samples sea water temperature and other parameters at prescribed depths (pressures), which are at every 10 m near the surface increasing to 200 m at depth and stores the data. After it settles at its maximum depth, it goes into a "sleep mode" for a prescribed period (for example, 8 hours) before transferring oil again and rising to the surface. On the way to the surface, it samples at the same depths as it did on the way down and stores the data. The GPS is powered when the device reaches the surface and makes another positional fix, then is powered off. The ARGOS platform transmitter terminal (PTT) is then powered on and it relays the data acquired during the cycle just completed, using a format similar to that shown in figure 2. PTT transmissions are periodic, approximately every 90 seconds, and alternate between data collected during the dive phase and data collected during the ascent phase of the cycle.

At the end of its prescribed PTT transmission period, XAP *again* takes a GPS fix before diving and beginning the next cycle. It is estimated that XAP will be capable of performing approximately 60 cycles to 1,000 m depth. Thus, if it were programmed for one cycle every 24 hours, it would operate for two months. XAP cycle periods are determined by the amount of time the unit remains at depth; on-surface time and dive/rise times do not vary. At the end of its lifetime, having insufficient battery energy to drive the pump, it "scuttles" by remaining at maximum depth.

XAP could be configured in future vehicles to measure and record such variables as seawater temperature and salinity. Other payloads could be incorporated provided they satisfy the weight, volume and energy constraints of the vehicle.

The device is programmable with respect to depth, stationing, and data collection type and frequency and capable of being used tactically to monitor environmental-acoustic parameters in naval operating areas for periods of up to several months. Its long life compared to other expendable devices and its use of existing satellite data links make XAP cost effective, because it requires significantly fewer resources to deploy and monitor a field of conventional instruments. XAP's programmability could be used in several ways to enhance its tactical utility. For example, it could be set to activate a specified number of days after launch or

Cycle	**Dive/Rise**	**Dive/Rise Start (Day)**	**Dive/Rise Start (Hour)**
Dive/Rise Start (Min)	Last GPS Latitude (Degrees)	Last GPS Latitude (Minutes)	Last GPS Longitude (Degrees)
Last GPS Longitude (Minutes)	GPS Time (Day)	GPS Time (Hour)	GPS Time (Minute)
Start Voltage Dive/Rise	Temperature @ 0 m	Temperature @ 10 m	Temperature @ 20 m
Temperature @ 30 m	Temperature @ 40 m	Temperature @ 50 m	Temperature @ 60 m
Temperature @ 80 m	Temperature @ 100 m	Temperature @ 150 m	Temperature @ 200 m
Temperature @ 300 m	Temperature @ 400 m	Temperature @ 600 m	Temperature @ 800 m
Temperature @ 1,000 m	Pressure at end of dive or start of rise	Time at end of dive or start of rise (Hour)	Time at end of dive or start of rise (Minute)

Figure 2. Example: XAP Data Format for Service ARGOS

at a specified position, allowing it to drift into a tactically important but difficult-to-reach area, such as the coastal zone within an enemy's air defense envelope.

2.2. DEPLOYMENT STRATEGIES

The design objective for XAP is to provide a device which can be launched as a sonobuoy, so it could be air dropped or launched from a surface ship or submarine. One of its primary attractions is its ability to be deployed from the P-3 aircraft, which is in service with many countries throughout the world. The range, dependability and commonality of the P-3 make it a good candidate for deploying XAP on a routine basis over a large part of the world ocean. Figure 3 illustrates the fact that most of the North Atlantic Ocean could be covered by P-3 flights staged from just five airports, four of which are U.S. Navy bases.

In ocean areas that are not accessible to aircraft (notably under the Arctic ice cap) XAP could also be launched from submerged submarines through the Trash Disposal Unit (TDU). TDUs are

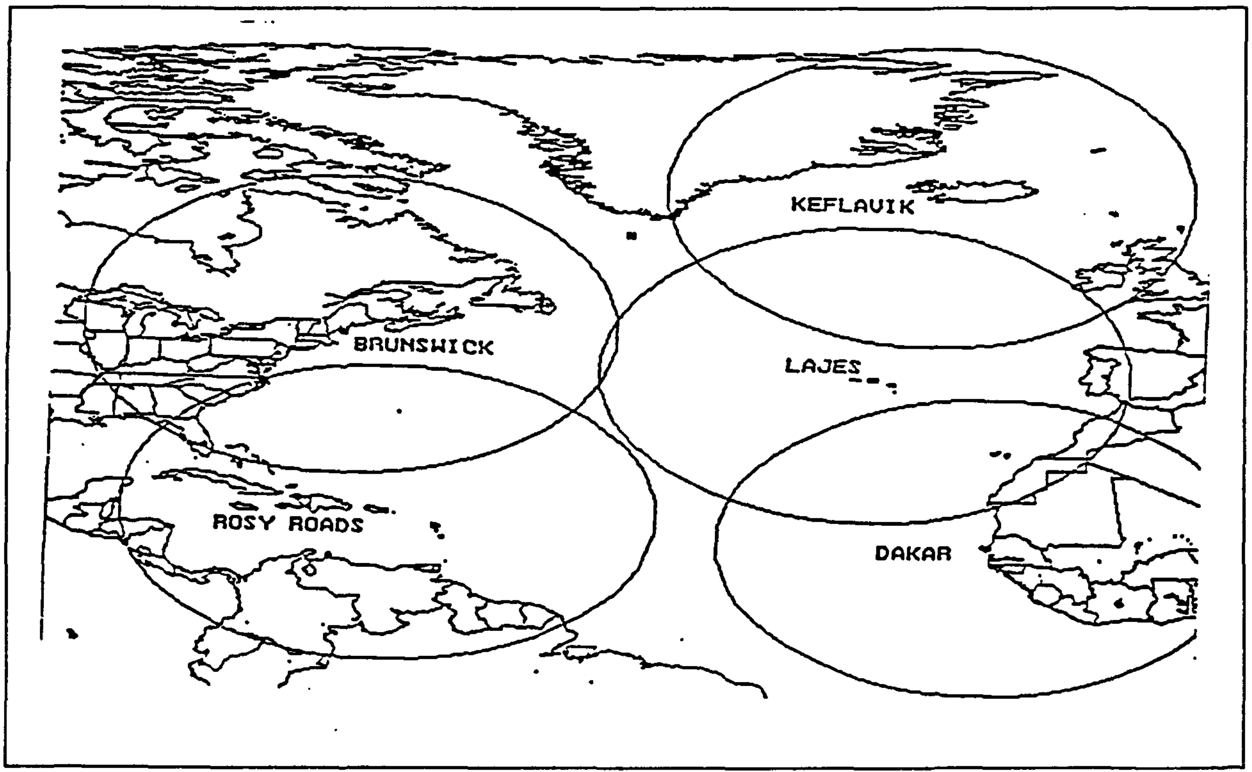


Figure 3. Potential XAP Coverage of the North Atlantic

vertically oriented tubes approximately 40 cm in diameter and 5 m in length. There is a large ball valve at the seawater end and a door on the inboard end. Objects to be ejected from the TDU are lowered into it while it is dry. The tube is then flooded with seawater, the ball valve is opened and the object (for example, XAP) drops out the bottom. The submarine-launched version of XAP would require a different antenna release mechanism than the air-dropped version. Given the dimensions of the TDU it would be possible to design a much larger and more capable version of XAP specifically for launch by submarines.

The environmental parameters imposed on XAP which affect design are launch/water entry shock and water pressure. The air launch capability would require survivability to higher shock loads than surface ship or submarine launches.

Although the use of a commercial satellite link, ARGOS, is considered in this study, alternate communications networks could be used. ARGOS has a small data transfer capability (32 bytes) which limits the amount of data which can realistically be transferred from the device during any one transmission period. However, for proving the overall concept the ARGOS system provides sufficient data transfer capability.

3. DESIGN CONCEPTS

The physical constraints for XAP are those of the A-size sonobuoy for size, weight and center of gravity which are necessary to satisfy the design requirements for air launch. The fixed size of the device dictates its weight (in air) because it must be neutrally buoyant at a depth of 1,000 m. Other design parameters are closely coupled because of the neutral buoyancy requirement.

3.1 Constraints

The primary design constraint of this project is that the XAP package conform to the A-size sonobuoy form factor. According to the Military Specification for the *AN/SSQ-53D sonobuoy (MIL-S-81487E)*, the overall length of an A-size device can not exceed 915 mm and the diameter can not exceed 124 mm. Unlike ALACE, which is 170 mm diameter by 1070 mm long and weighs 23 kg, XAP will be packaged in the standard A-size sonobuoy configuration and will weigh approximately 10.8 kg for an equilibrium depth of 1,000 m.

This goal imposes several technical challenges, driven by the fact that an A-size sonobuoy is approximately half the volume of an ALACE float. Since the volume of a neutrally buoyant device determines its displacement and mass, this constraint has a strong impact on the weight and energy budgets of XAP because it limits the size and weight of batteries used. The preliminary weight and center of gravity budgets using candidate devices are shown in figure 4.

3.2 Hull

The outer hull will be designed to house the total system and withstand aircraft deployment, water entry, and depths of 1,000 meters in sea water. It will have the form factor of an A-size sonobuoy and will be capable of being launched from a maritime patrol aircraft (MPA). If the hull is designed to a crush depth of 2,000 m and is made of aluminum, it will need to be approximately 5 mm thick. It will have a mass of approximately 5 kg. End caps are required to complete the hull and provide water integrity. O-rings, or other components, will be required to seal the end caps with the hull.

3.3 Elevator

The elevator is the subsystem which provides the ability for XAP to dive to a preset depth and return to the surface. Theoretically, there are several methods for making a device move in vertically in the water column. We chose to examine two: (1) the "hydraulic" approach used by ALACE, in which the vehicle's buoyancy (volume) is altered by transferring oil between an internal reservoir and an external, inflatable bladder; and (2) using high pressure gas to inflate the external bladder. Both concepts were evaluated to

ITEM	DESCRIPTION	SIZE or NUMBER	WEIGHT (KG)	DISTANCE FROM BASE (CM)	PRODUCT
Hull Cylinder	Aluminum	t=5 mm	4.33	45.75	198.10
Top End Cap	AL, flat	t=18 mm	0.60	84.60	50.76
Lower End Cap	Al, hemisphere		0.77	5.00	3.85
Pump			0.30	10.00	3.00
Motor			0.28	21.00	5.88
Oil		v=400 cc	0.36	0.00	0.00
Solenoid Valve	New Design		0.08	10.00	0.80
Coupler			0.12	18.00	2.16
Misc Plumbing	Bladder, Retainer,		0.50	40.00	20.00
Batteries	D-Cells, Lithium	5	0.43	30.00	12.75
	wt=85 gm ea	5	0.43	38.00	16.15
	two layers of 5				
Controller	TT-5F		0.10	60.00	6.00
Chassis & Wiring			0.20	60.00	12.00
Global Positioning System (GPS)	Garmin, GPS10		0.15	60.00	9.00
Platform Transmitter Terminal (PTT)	Telonics ST-6		0.03	70.00	1.75
Antenna	Extended		0.20	130.00	26.00
Press. Xducer	Transmetrics P21-L		0.20	80.00	16.00
Thermistor	YSI44006		0.01	83.00	0.83
		Totals:	9.08		385.03
CG (Product/Budget Wt.):				36.50	
Budget:			10.55	40.00	
Ballast (negative means over budget):			1.48		
CG Difference (budget-predicted):				-3.50	
XAP length (less chute):		85.50			
Bladder volume (cc):		400.00			
Freeboard (cm):		0.56			
Center of buoyancy (CB) at surface:		42.19			
CB-CG (cm; unstable if neg):		5.69			

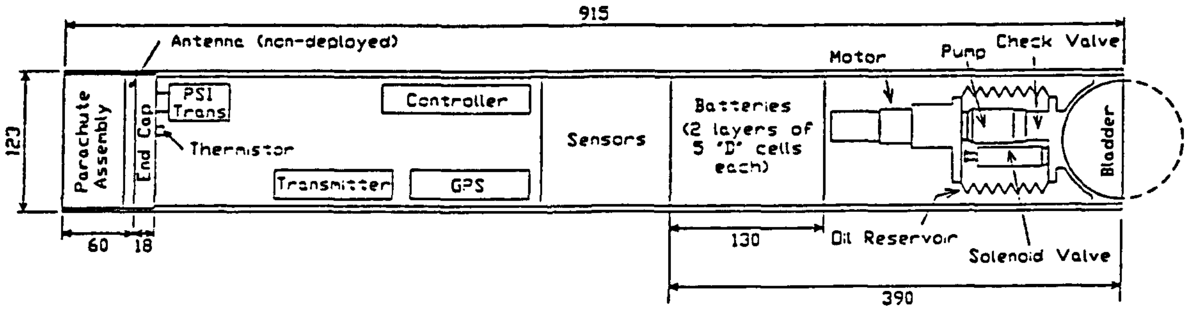
Figure 4. Preliminary XAP Weight & Center of Gravity Budget

determine which is more suitable for a XAP device.

3.3.2 Hydraulic Elevator

The hydraulic elevator has been proven in the ALACE project and in the Buoyant Undersea Search System (BUSS) project sponsored by the U.S. Navy. However, it is a relatively heavy system: 3.3 kg using current components and scaling the oil capacity to XAP. This does not include the weight of the batteries required to power the pump. Some weight and energy could be saved by using a smaller pump and less powerful motor, thereby reducing the weight of the elevator system to approximately 2.3 kg.

The major components of the hydraulic elevator consist of a pump, valve, manifold assembly, bladder, lower end cap and oil (see figure 5). Unlike the elevator used in ALACE, the pump and valve could be contained within the internal oil bladder to conserve space. A valve must be developed which will minimize weight, size and energy consumption. A less complicated valve is possible since it must open only at the surface (low pressure) and close at depth (also at low pressure).



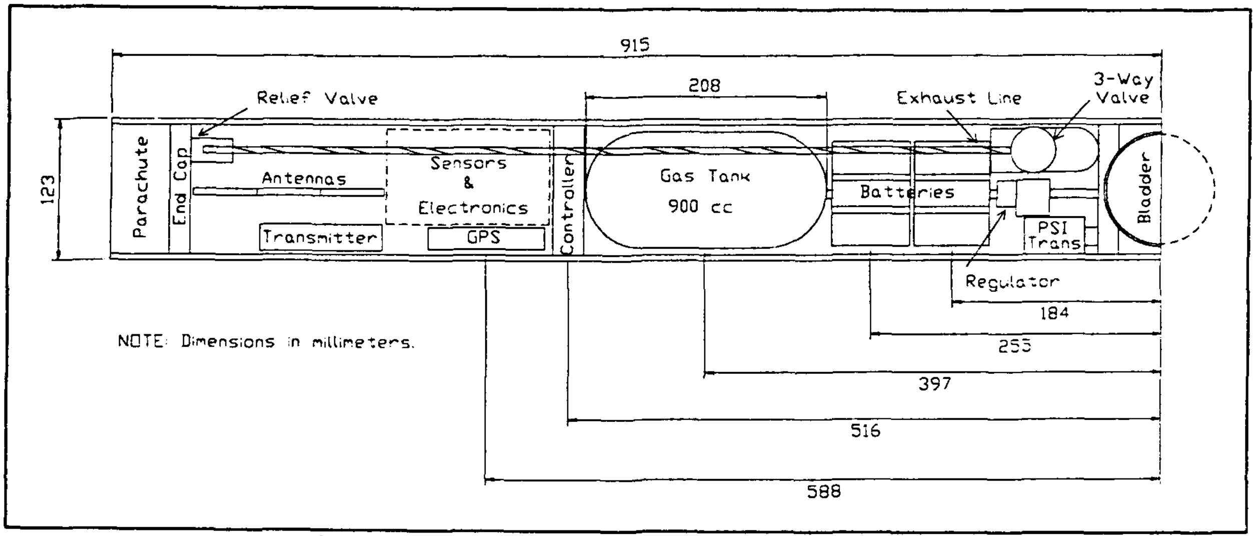
NOTE: Dimensions in millimeters
Motor and pump from ALACE

Figure 5. Hydraulic Elevator Powered XAP

3.3.1 Gas-Powered Elevator

The primary advantage of the gas system is that it provides a higher energy density and lighter system than the hydraulic version which uses a battery-powered pump to transfer the oil. An example of a gas-powered elevator vehicle is shown in figure 6. Gas allows more of the on-board energy stored in the batteries to be used for electronics. The major drawback of the gas is that some gas must be discharged before every trip from the surface to depth, thereby significantly changing its ballasting. (One gram of mass loss reduces XAP's equilibrium depth by approximately 15 meters.) To compensate for this effect and to allow the device to return to the same depth on each cycle requires adding an auto-ballast subsystem. The hydraulic version is a closed system and its basic displacement, therefore, is constant. The major components of the gas-powered elevator are the gas tank, valve, regulator and external bladder.

Gas Tank - Candidate designs were solicited from vendors to



NOTE: Dimensions in millimeters.

Figure 6. Gas Powered Elevator XAP

determine what volume of gas could be contained in a tank of minimum weight and size and still provide the elevator function equal to that of the hydraulic elevator. The most favorable tank was proposed by Structural Composites Industries, Pomona, CA which consisted of a 900 cc composite tank which could operate at 20.7 kPa (3,000 psi) and would weigh 0.8 Kg. Using this tank, it is estimated that approximately 120 cycles could be attained. However, the high gas pressure stored in the tank must be regulated as it is transferred into the external bladder. Also, the amount of gas transferred must also be accurately regulated.

Gas Valve - A valve is required which regulates the quantity of gas released and regulates the pressure so that it does not rupture he external bladder. The pressure must be reduced from 20.7 kPa to 10.1 kPa as it enters the bladder. Analysis indicates that it takes 15 cc of gas (at depth, 10.1 kPa) to provide the buoyancy necessary to reach the surface. Discussions with valve vendors indicate that accurate regulation for this volume would be extremely difficult using standard valve/regulator orifices. A means of venting the gas at he surface must also be provided to allow XAP to dive again.

3.4 Electronics

In addition to the elevator system there are electronic components contained within the hull. The major electronic components consist of a controller, PTT, GPS, antenna and sensors.

3.4.1 Controller

The controller is used to provide power control, data collection, data storage and data transfer via the PTT. Numerous low-powered complimentary metal oxide semiconductor (CMOS) devices are available which have characteristics necessary for the XAP application. Onset Computers, Falmouth, MA produces controllers which have been used successfully in similar applications. Characteristics which are needed in the controller are as follows:

Digital control channels - for power control of other devices.

Digital data channels- for receiving GPS data and sending PTT data.

Analog channels - for sampling pressure, temperature, and other sensor data.

Memory - for storing and executing the program, storing mission parameters and storing data.

Clock - for measuring elapsed time and maintaining current calendar.

Processor - for performing all functions in a timely manner.

Low-Power Mode - for energy conservation.

Program - for executing all control, data input and output. An example of the software flow is shown in figure 7.

The candidate controller is electrically compatible with the GPS, PTT and other sensors (temperature, pressure, etc.) is small, light weight and very energy efficient.

3.4.2 Platform Transmitter Terminal (PTT)

There are a variety of ARGOS-approved PTTs which are small, light weight and energy efficient. Telonics, Mesa, Arizona manufactures a variety of PTTs which are suitable for the XAP application. These devices provide small amounts of data (32 bytes) to be transmitted. The System ARGOS provides position information of the received data. Since a GPS is to be used which has higher positional accuracy, the ARGOS position data capability is not needed. A candidate PTT, Model ST-6 provides the necessary transmitter functions, is physically small, light weight and energy efficient.

3.4.3 Global Positioning System (GPS)

GPS technology has advanced and now makes available small board sets which can be embedded into other systems. A candidate GPS built by Garmin, Lenexa, KA, is capable of providing positional indications by tracking up to eight satellites. The device uses 5 vdc, but consumes very little energy.

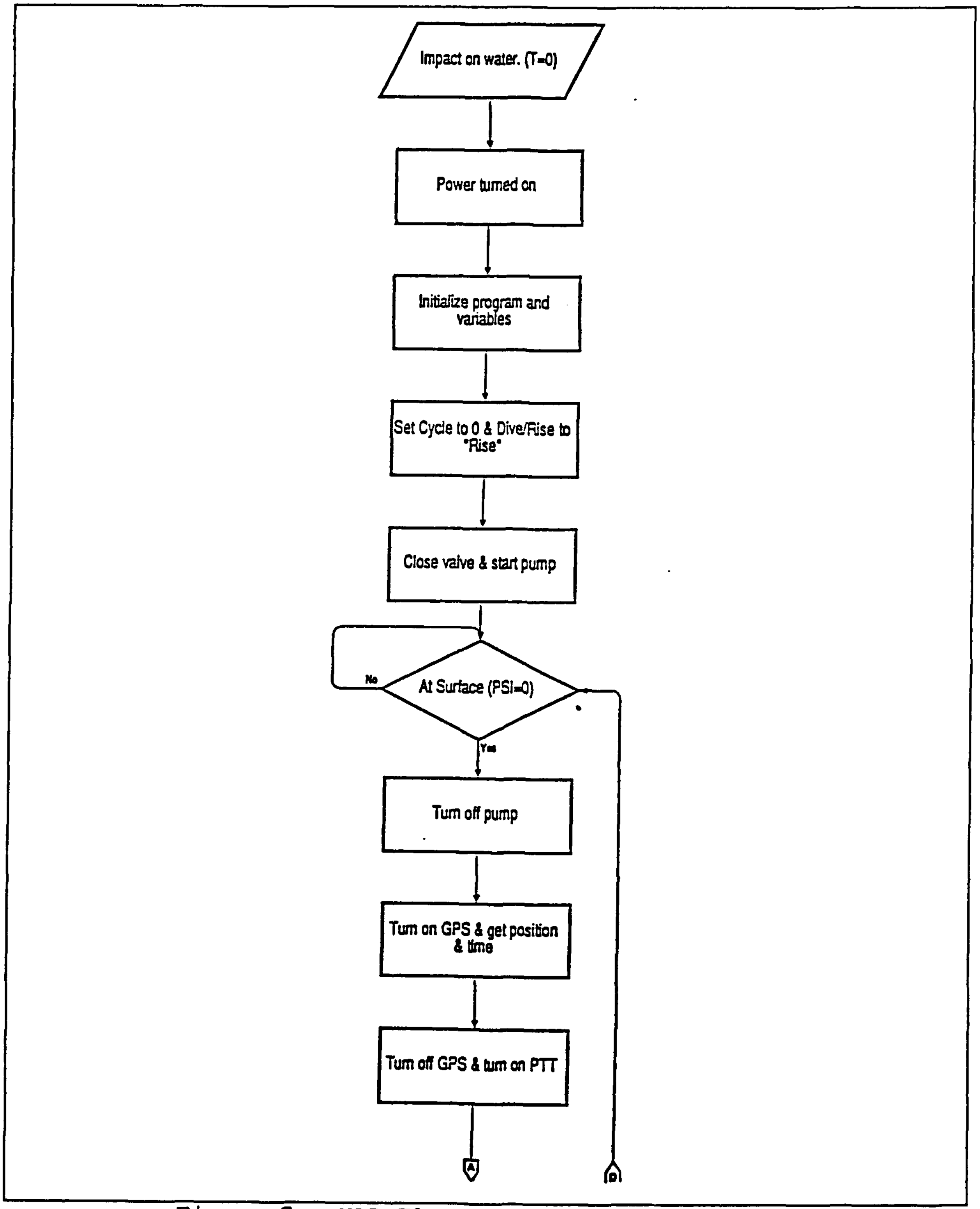


Figure 7. XAP Flow Control (Sheet 1 of 4)

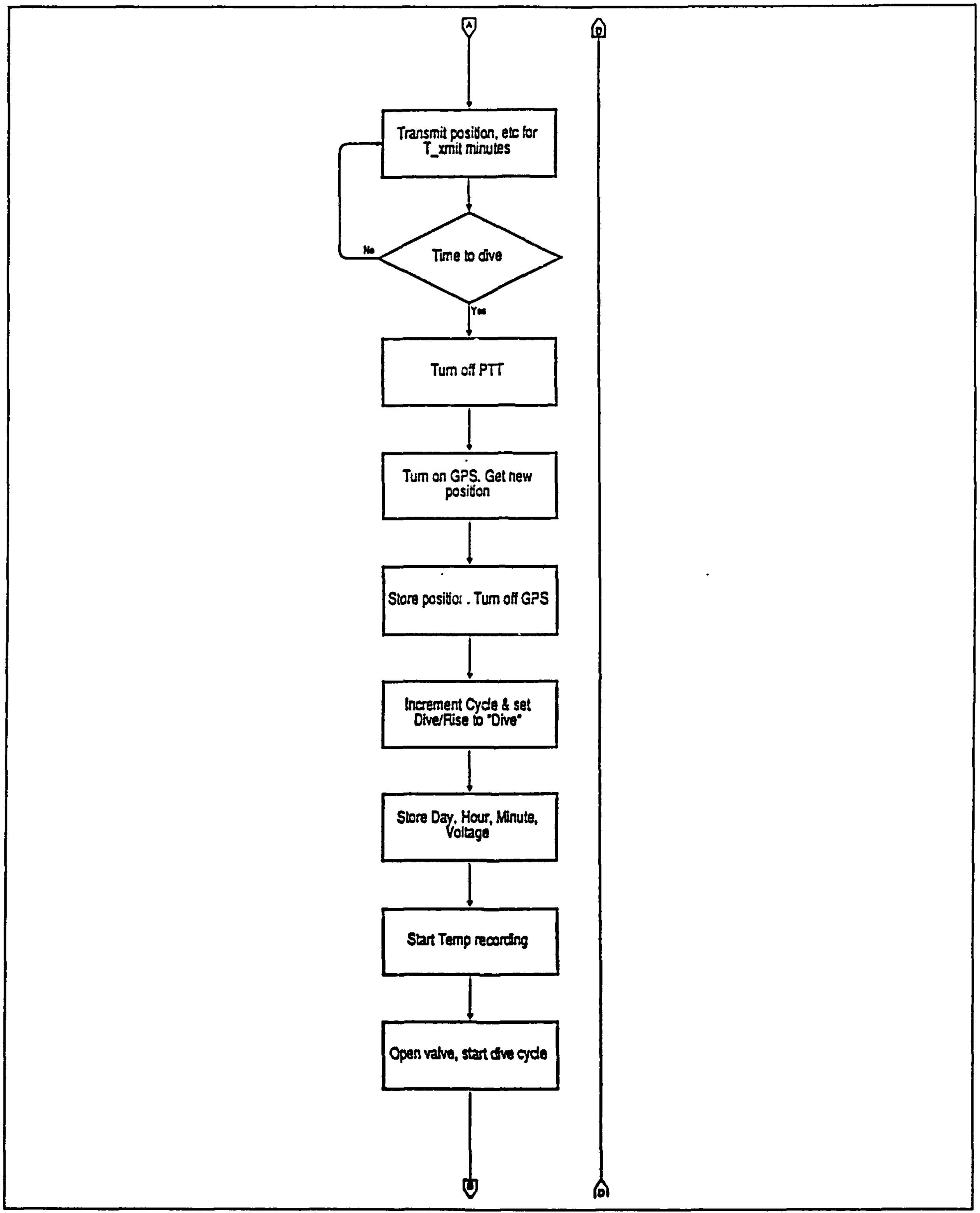


Figure 7. XAP Flow Control (Sheet 2 of 4)

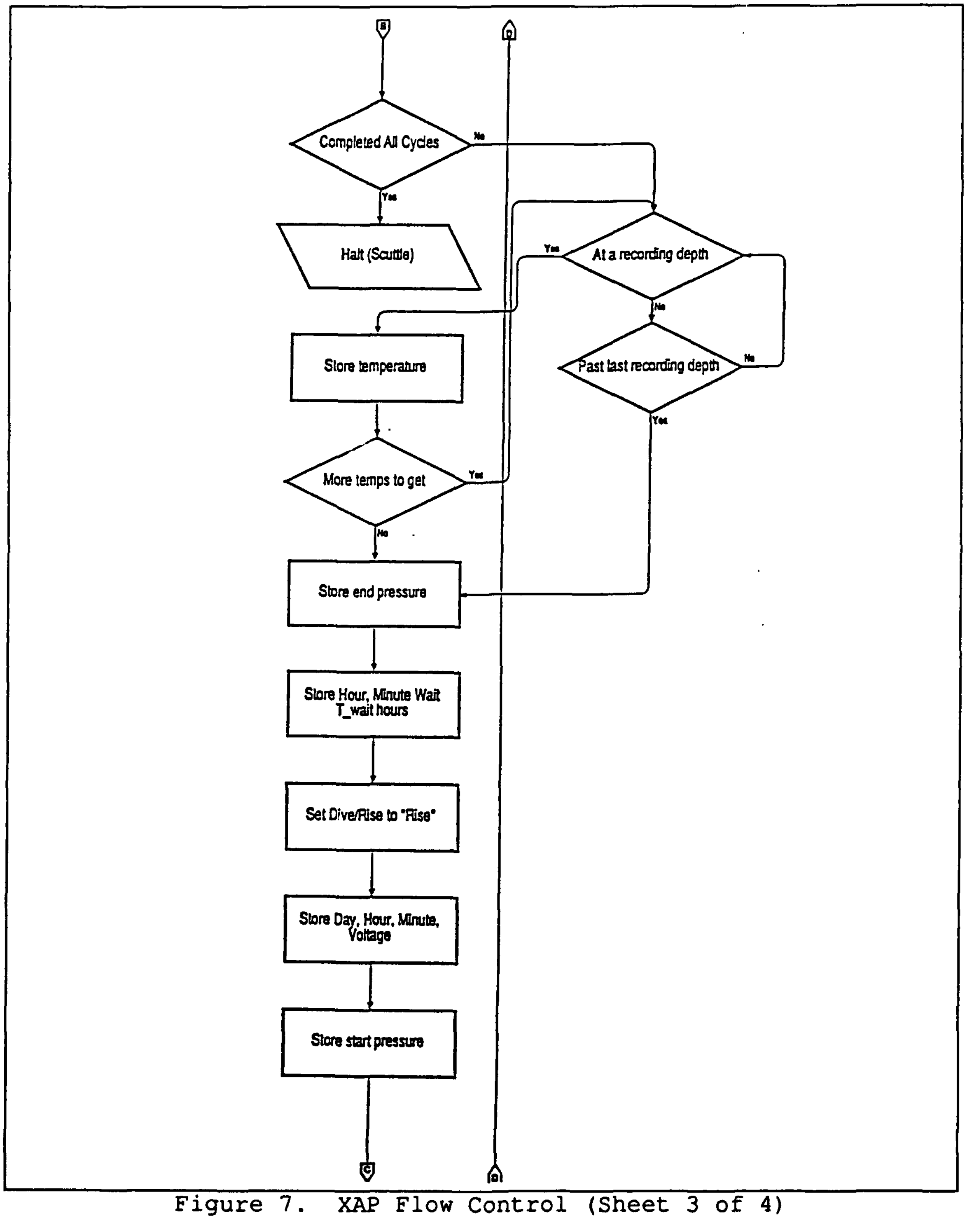


Figure 7. XAP Flow Control (Sheet 3 of 4)

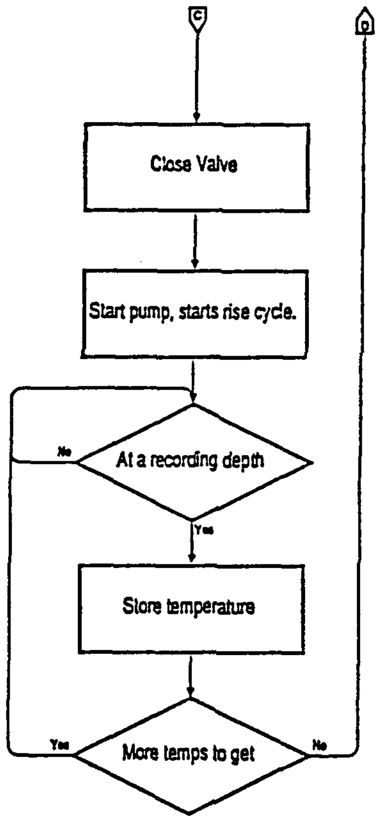


Figure 7. XAP Flow Control (Sheet 4 of 4)

3.4.4 Antenna

A suitable antenna is required which can be used by both the GPS receiver and the PTT transmitter. The antenna must also be stowed prior to launch and released after the vehicle has been launched and deployed in the water. A single antenna was investigated to minimize the number of penetrations required into the hull as well as to minimize weight and simplify deployment. The additional challenge is to make the total device small and low weight. It must fit inside a 124 mm diameter container, which is the maximum outside diameter of the device.

The wavelength of the ARGOS transmitter is approximately four-times that of the GPS. Since the GPS is a receive-only device, it appears that it should function correctly with a longer antenna (quarter-wavelength for the ARGOS transmitter).

3.4.5 Sensors

A thermistor, such as the Model YSI 44006, YSI Inc.,Yellow Springs, OH, attached to the housing would suffice as a temperature sensor. A high accuracy pressure transducer, such as the Model P21-L, Transmetrics Inc., Solon, OH, would be suitable for the pressure measurements.

3.5 Energy

Various battery technologies were investigated to determine which were suitable for XAP. Alkaline batteries were used in ALACE, but lithium-based batteries would provide a better energy density. In the past, the Navy has been reluctant to use lithium-based battery systems because of safety considerations. Recently the Navy's attitude has changed. There is now an established program, administered by NAVSEA, for certifying lithium-based batteries in systems that are carried on operational ships and aircraft. (See NAVSEA Technical Manual S9310-AQ-SAF-010.) The program generally requires completion of a series of tests on a sample of the devices being certified. The tests involve subjecting the devices to extreme temperatures and other potentially destructive conditions in order to verify that the battery components do not pose an unacceptable hazard. The tests are conducted at NSWC Crane and NSWC White Oak.

A candidate lithium sulphur dioxide battery has been identified which has been approved by the Navy, Model LO26SX produced by Saft America, Valdese, NC. Assuming a battery pack of two clusters of five cells each would provide 7.5 ampere hours (Ah) at a nominal 14.0 volts. Assuming the use of candidate devices, the energy budget supports a 50 cycle mission for a prototype, as shown in figure 8. It is realistic to assume that increased mission cycles could be obtained in production versions.

If XAP enters a phase II status, it would be an experimental prototype rather than an operational system. We have been advised by NAVAIR that we could probably defer submitting to a full certification process until after phase II is completed. However, it would be wise to conduct a partial certification during phase II to uncover any major safety issues early in the development and reduce the risk of finding a flaw which could prove fatal in the final design. A candidate battery has been found in NAVSEA's lithium-based battery data base that appears to satisfy the initial design criteria for XAP. If this battery proves useable, we may be able to expedite (but not entirely avoid) the certification process.

Device	Current (ma)	At Surface (GPS On & PTT Off) On-Time (Minutes) 22	At Surface (GPS Off & PTT On) On-Time (Minutes) 338	Dive On-Time (Minutes) 120	At Depth On-Time (Minutes) 480	Ascent On-Time (Minutes) 120	Total mAh for Device/ Cycle
PTT	225.00		0.06				0.23
GPS	200.00	22.00					73.33
Controller (On)	18.00	0.17	0.06	12.00		12.00	7.27
Controller (Sleep)	2.50	21.83	337.94	108.00	480.00	108.00	43.99
Valve (Latch)	1400.00					0.00	0.00
Valve (Release)	750.00			0.00		0.00	0.01
Pump	400.00					14.24	94.91
Temp Thermistor	0.60	0.17		120.00		120.00	2.40
* MAX625 (2)	0.28	22.00	338.00	120.00	480.00	120.00	5.04
Pressure Trans.	1.50	0.17		120.00		120.00	6.00
	Total mAhr:	74.40	15.91	12.86	22.24	107.78	233.19

Ahr/Cycle: 0.23
Battery Ahr: 15.00
Total Cycles: 51 (Assuming 20% Energy Reserve)

ASSUMPTIONS:

1. GPS takes 15 min to get fix when first turned on & 7 minutes each time after first.
2. Pump is on approx. 14 minutes, based on energy est. of 4,100 Joules.
3. PTT has 90 sec. cycle.
4. Controller is "sleeping" except during pumping, xmitting and data collection.
5. * MAX625 chips each have 0.140 ma "off" leakage current (0.07 ma typical). They are part of the controller interface.
6. Total cycle time = 18.0 hours.

Figure 8. Estimated XAP Energy Budget

3.6 Packaging

Sonobuoy certification, handling/initialization and shelf life requirements were analyzed to determine if XAP could conform.

Certification - The XAP vehicle must satisfy the certification process for sonobuoy launch from a Navy aircraft. In the interest of anticipating issues that may arise should a phase II SBIR prototyping effort result from this project, meetings were held with NAWC-AD Warminster personnel to discuss the sonobuoy certification process. From these discussions it appears that obtaining clearance for flight testing of prototype devices may involve several Navy agencies. NAVAIR is the final authority for obtaining flight clearance, but several other agencies appear to have advisory roles in the process. As a practical matter, we were advised that obtaining permission to conduct aircraft drop tests would be facilitated if the prototype device resembled an existing sonobuoy in terms of weight, center of gravity, decelerator (parachute), etc. NAWC-AC Warminster, Code 5044 offered to assist in working through the certification process, initially by providing as government furnished equipment (GFE) two excess AN/SSQ-53B sonobuoys to use as models.

The AN/SSQ-53B sonobuoys use an electrically-operated parachute jettison technique which would be favorable for XAP. The space and weight allocation for the parachute and other associated deployment components were used in estimating comparable parts for XAP.

Handling/Initialization - It is envisioned that a production XAP would contain an external manual setting feature similar to existing sonobuoys which would allow setting cycle parameters such as "sleep" period or number of cycles. Handling would be identical as for a standard sonobuoy.

Shelf life - A nominal 5-year shelf life is desired for sonobuoys and other similar expendables. This was considered during the analysis of XAP requirements. Lithium-based batteries provide an acceptable shelf life and would not require charging, or replacement. The use of a gas elevator, however, would require that the tank and valve satisfy leakage and other requirements for compressed gas. Leakage and catastrophic failure requirements, appear to be obtainable for tanks and valves investigated for the XAP application.

IV. COST ANALYSIS

The cost of developing a prototype XAP is based on using available off-the-shelf devices for the PTT, GPS, controller, batteries and sensors (pressure and temperature). The elevator, hull, end caps, antenna and deployment devices would be developed using existing devices as models. A phase II SBIR effort should be capable of producing prototype vehicles which could be used in verifying the ability to construct such a device and performing initial tests. It is estimated that six vehicles could be constructed, integrated and subjected to system-level and water integrity tests for $500,000. This cost would not include aircraft launch tests. The cost of fabricating an additional six XAP vehicles and providing test support for aircraft launch testing would be approximately $200,000. Production costs for XAP would depend upon the sensors selected, but the basic vehicle would cost approximately $8,000 in production quantities.

Operational costs would be minimal because it would be handled as a sonobuoy. Receiving data from ARGOS, or other satellite system, requires minimal support which should not impact current operations. If different sensors are incorporated, however, a support system may be required to alter the mission parameters within the vehicle.

V. CONCLUSIONS & RECOMMENDATIONS

Design of an A-size XAP vehicle capable of being launched from aircraft, surface ships or submarines appears feasible. Technical analysis indicates that an elevator can be constructed of a size necessary for the available vehicle form factor. The hull and associated end caps can be designed using previous projects as models. Deployment mechanisms can be adapted from existing designs of approved, existing sonobuoys.

After weighing the advantages and disadvantages of each elevator concept, we conclude that the better choice for this application is the well-tested hydraulic system. Given that the elevator will use a pump powered by batteries, XAP is designed to perform multiple cycles and is only by available battery energy.

A phase II SBIR effort is recommended to produce prototype XAP vehicles to be used for system tests, water integrity tests and other tests leading to aircraft launch testing.