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# The Virtual Control Buoy - A New Application For Solar-Powered AUVs

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## Abstract

The Virtual Control Buoy (VCB) concept uses Autonomous Underwater Vehicles (AUVs) to provide control functions to remote subsea wellheads for the production of natural gas. The concept eliminates the need for expensive long distance umbilicals, or control buoys, which are inexpensive but can have operational limitations.

The types of AUV which are presently under consideration are the seaglider and the solar-powered AUV (SAUV). Seagliders are constrained by their power consumption and the energy available from their batteries, which may limit the mission duration. This paper describes the SAUV, and the benefits it presents for this application.

This concept combines a number of existing proven technologies in a new way which could provide technical and economic benefits for many of the large gas developments off the North West Shelf of Australia.

## Keywords:

Subsea, Control Buoy, Umbilical, Stranded Gas, Remote, Seaglider, Solar-Powered AUV.

## Introduction

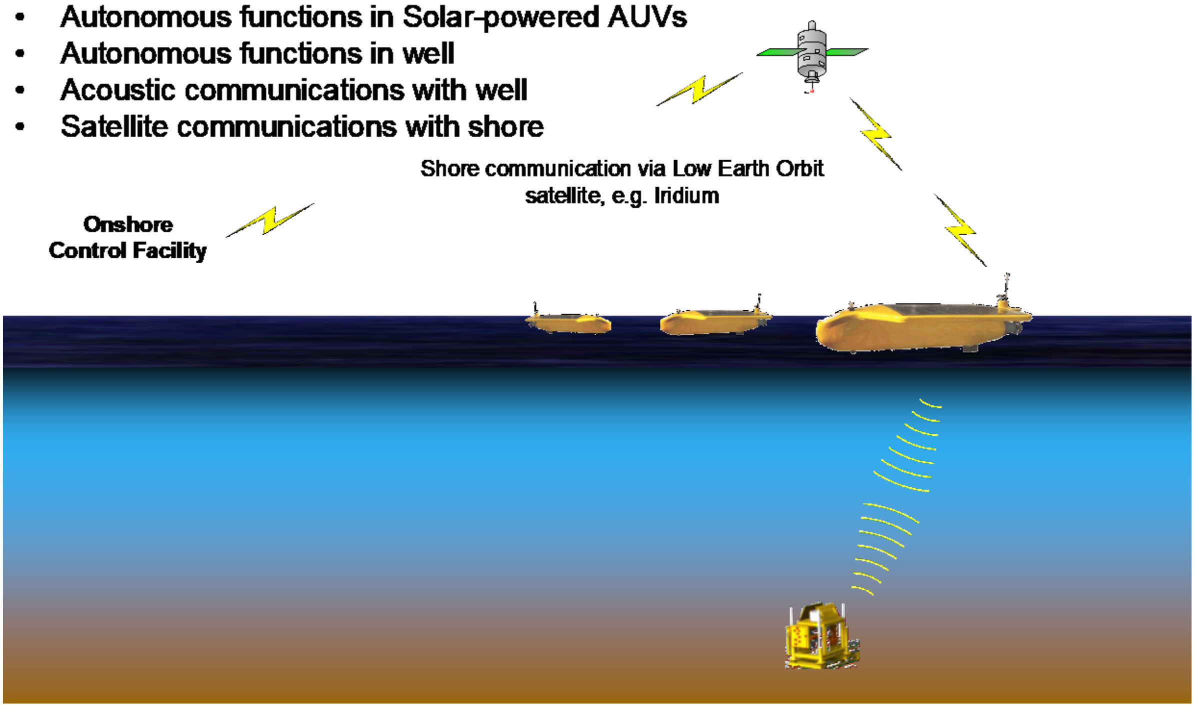
While Australia is fortunate to have very large gas reserves, 80% are located in deep water in regions remote from existing infrastructure, major markets and large population centers [Ref. 1]. Control of these remote deepwater gas fields requires either long distance umbilicals, or control buoys, or platforms or floating facilities, each of which bring economic or operational penalties.

The Virtual Control Buoy concept is an alternative method of controlling these remote wells. The VCB is robust and fault tolerant, and works at any step-out. It is cheaper than control buoys, without the difficulties associated with the operation and maintenance of remote facilities or umbilical systems.

The VCB concept uses Autonomous Underwater Vehicles to provide a means of communicating from the onshore control facility to the subsea wells [Figure 1]. Two different types lend themselves to this application, the seaglider[1] [Ref. 2] and the Solar-powered AUV (SAUV).

[1] The seaglider solution is described in detail in a previous paper [Ref. 2] and will not be discussed in depth here.

**Figure 1 The Virtual Control Buoy Concept**




A fleet of two or three SAUVs drift above each subsea wellhead, communicating with the subsea wellhead by acoustics, and with the onshore control facility by Low Earth Orbit (LEO) satellite. Each SAUV uses GPS to track its position, and if it drifts outside its watch circle, it autonomously guides itself back on location.

As the umbilical is eliminated, the wellheads would be self-powered, using one of numerous technologies proposed and trialled over the years.

The aim of the concept is to achieve mission durations for the SAUVs of 12 months. The SAUVs can be launched and retrieved from shallow water close to the onshore base. They make their own way out to the field, and return at the end of mission for maintenance.

Power for the SAUVs is generated during daylight hours when the SAUVs are on the surface.

The concept uses a number of existing technologies:

- Solar-powered AUVs;
- Virtual moorings;
- LEO satellite communications;
- Subsea acoustic communications; and
- Self–powered autonomous wellheads.

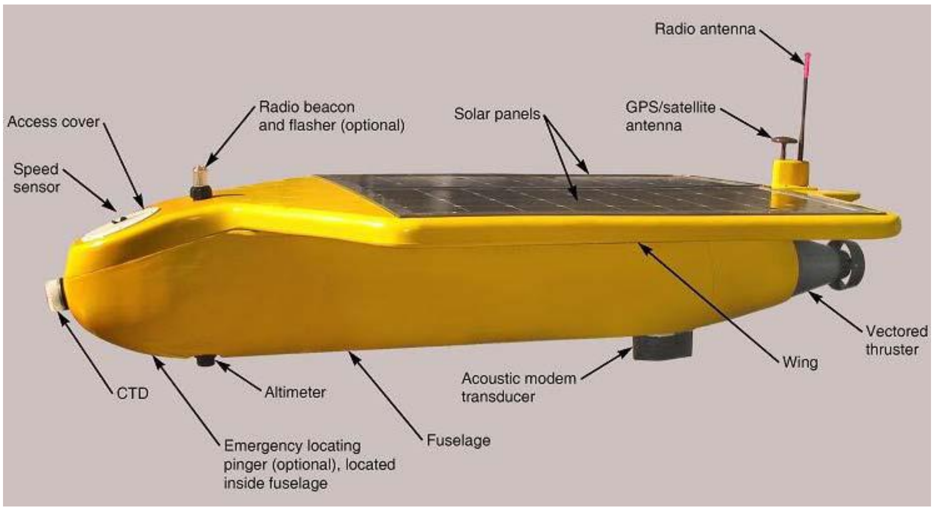
All the technologies proposed are proven and the only novel aspect is using them together for this application.

**Solar-powered AUVs**

Concerning the maturity of AUV technology, there are two opposing views. The U.S. Commission on Ocean Policy said in 2004 that AUV technology had evolved over the past 10 years to a point where the technology was relatively stable and had been accepted as a viable method for many underwater applications [Ref. 3]. Conversely, there is a saying among folk who work with AUVs: many of them will start any interview by saying, "Damn, damn, damn!" Other may postpone interviews altogether so they can spend time troubleshooting their hardware [Ref. 15]. Despite that, it is a fact that solar-powered AUVs are not longer just a research curiosity, but are being put to use by academic and military customers.

The first generation of SAUVs was designed and developed under a cooperative research program which began in 1998, between the Autonomous Undersea Systems Institute (AUSI) and the Institute for Marine Technology Problems, Russian Academy of Sciences. Successful testing of the prototype design led to the development of the second-generation SAUV II [Figure 2].

**Figure 2 SAUV II**




SAUV II is capable of around-the-clock operations. It uses solar energy to recharge its high capacity lithium ion batteries during the daylight hours and carries out its assigned mission during day and night. This strategy manages energy consumption and allows the vehicle to remain on station for several months. This concept offers a paradigm shift for the control of subsea gas wells by providing a communications medium that is both autonomous and mobile with virtually unlimited endurance [Ref. 4].

SAUV II is 2.3 m long, 1.1 m wide, and 0.5 m high; its topside solar panel is 1 $m^2$; and its overall weight in air is 200 kg. Because of it relatively small size, the SAUV II is easy to deploy and operate. It can be launched from a boat ramp on shore and can autonomously swim to the field, taking GPS fixes on the way to keep on track. SAUV II can be pre-programmed before the mission, or it can have the program changed during the mission via Iridium satellite.

SAUV II is made of a fiberglass composite material capable of operating in depths up 500 metres. A vectored thruster provides directional control at 1 to 3 knots, depending on mission parameters.

Global low-power satellite communication is a key enabling technology for the SAUV, allowing it to operate worldwide with real-time communications.

## Communications and Control

The SAUV will communicate with the subsea wellhead by acoustics, and with the onshore control facility by LEO satellite. Both of these technologies are very well proven with seagliders [Ref. 2], and have been used successfully with SAUVs, so will not be discussed at length here.

Acoustic communication from an SAUV using a Benthos MODEM is good for up to 2 km through the water at about 800 bytes per second [Ref. 5]. The power requirement needed for acoustic transmission will increase if the SAUV drifts off station, resulting in a longer communication path through the water. Establishing a small watch circle for the motions of the SAUV will help, but this may not be the most energy-efficient strategy, so further work is needed to establish an acceptable energy/power/bandwidth balance for the VCB concept.

From land to an offshore SAUV, the ideal means of communication is LEO satellite link (e.g. Iridium and Globalstar networks) [Ref. 6 and 7]. This is well suited to the small amount of data, and the low transfer rates required, for the control of subsea wells. Using a messaging system such as the Iridium Short Burst Data (SBD) service will provide cheap bidirectional transfer of information.

## Autonomous Behaviour

The VCB concept relies on autonomous operation in several areas:

- Autonomous position keeping by the SAUV;
- Cooperative SAUV behaviour;
- Autonomous shutdown of the subsea wellhead on loss of signal; and
- Emergency Shutdowns.

The use of autonomous systems is a challenging concept, because the user has little if any control over the movement of the SAUVs as they perform their task. The use of low bandwidth messaging services in the satellite communication channel will give some delay in the control of the subsea wells, unlike conventional subsea control systems which have near-instantaneous monitoring and control.

Generally, the issues with SAUVs are similar to those with seagliders, which are covered in detail in a previous paper [Ref. 2].

The Virtual Mooring Mode is a well-proven concept with seagliders. As long as currents are not stronger than seaglider speed, a seaglider can be programmed to perform repeated dive profiles while holding its location nearly constant. In this mode of operation, a glider can hold station within a kilometre of a subsea wellhead, as proven by an early demonstration of glider performance in 2000, when a Spray seaglider was virtually moored in an underwater canyon off Monterey [Ref. 7].

SAUVs will have equal or better station-keeping ability than seagliders, due to their greater maneuverability Another advantage of the SAUV is its significantly higher forward speed, of up to 1.54 m/s. This will allow it to maintain station in conditions which would impossible for a slower-moving seaglider.

Because SAUVs do not need to submerge, potentially only one is needed for each wellhead (or drill centre). Nevertheless, at least one spare SAUV will be needed, so there will still be a need for cooperative behaviour between the different SAUVs. Extensive academic research and trials have been carried out on multi-AUV cooperative control of fleets of AUVs [Ref. 8 and 9], and it is expected that this issue can be solved in a satisfactory manner.

Should the communication system via the SAUV fail for any reason, safe operation of the subsea wellhead is essential, and a fail-safe approach should be taken. Safe operation can only be achieved in this situation by autonomous shutdown of the subsea wellhead after a certain period of time without communication from onshore, say 15 minutes.

Other precautions are used in subsea systems to guard against pipeline or jumper rupture. A pressure sensor at the outlet of the wellhead can monitor the line for a sudden drop in pressure, signifying pipeline rupture, and the control system at the wellhead can carry out an Emergency Shutdown, and autonomously stop the flow.

## Power Generation on the Seabed

The use of a self-powered wellhead, with power generation on the seabed, is needed to facilitate the VCB concept. Generation of electrical power is needed to operate the control and communication systems at the wellhead, and also to operate pumps to generate hydraulic power for the operation of valves in the subsea xmas tree and downhole [Ref. 2].

Significant developments were made in this area in the late 80s and early 90s by Kvaerner and ABB, but were not taken up by the oil companies. Agip developed the SWACS autonomous control system, which used a subsea battery for power [Ref. 10], with acoustic communication from a platform to the subsea well [Ref. 11]. The unit was deployed the Ionian Sea (in the Mediterranean) in January 1996 at a depth of 180 m.

At present, the only company working in this area is Weatherford, who are currently developing the technology for Subsea Hydraulic Power Units, for this and other applications [Ref. 12].

## Proving Reliability

The availability of the VCB system is expected to be as high or higher than other technologies such as umbilicals or control buoys. The VCB does not have a single point of failure (such as trawling of the umbilical, or sinking or fire on the physical control buoy). The distributed nature of control, from multiple SAUVs, makes the system inherently robust and immune to single point failure. The ability to reassign SAUVs from one wellhead to another gives an additional layer of protection, and more SAUVs can be launched from shore to make up for any failures.

The reliability of the subsea equipment for the autonomous wellhead should also be considered in assessing system availability.

## Back-Up Systems

A back-up means of control can easily be implemented using an acoustic transponder put over the side of a vessel on the surface, in order to bypass the satellite/SAUV system. It would be similar to the Back-Up Intervention Control System (BUICS) used on Snohvit, but very much simpler, and far easier and quicker to deploy. Dynamic positioning would not be needed, as the vessel could be kept on station by following GPS signals, and the dunking transducer would communicate with the wells below. This means of control could also be used during commissioning and initial start-up of the field, and then run alongside the SAUV fleet until it is evident that the SAUVs are performing as required.

## Marine Fouling

While marine fouling may certainly be an issue, the community of oceanographers appear to be happy with ocean gliders, and have not rejected their use because of potential fouling. Build-up of fouling is very dependent on the area in which seagliders are deployed, and the season.

During a 30 day endurance study of an SAUV [Ref. 13], biofouling was evident on the vehicle shell and solar panels as early as day 11. By the end of the experiment, the vehicle showed a significant amount of biofouling [Figure 3].

**Figure 3 Biofouling of Vehicle Shell after 25 Days**


There are reports that biofouling of solar panels on the SAUV can drop its power output to 50% after 30 days [Ref. 14].

## SAUV Launch and Recovery

Because SAUVs can make their own way out to the remote field, they can be launched and retrieved from a boat ramp at the onshore base. Launch and recovery times can be programmed during periods forecast to be calm. SAUVs can readily be launched from a trolley [Figure 4]. The SAUV sails out to the field, and then returns at the end of the mission for retrieval and maintenance.

The mission duration for SAUVs is potentially 12 months, so the work involved in maintaining the SAUV fleet is not excessive.

**Figure 4 Launching SAUV from a Trailer**

**Legal Issues**

There are legal issues that need to be addressed in case an AUV is involved in a collision with another moving or stationary platform:

- The status of shore-based AUV missions in national and international law is unclear;
- AUVs are been registered or classified as is done for other vessels;
- International Maritime Organization (IMO) assessment procedures are not formulated with AUVs in mind; and
- Shore-launched AUVs have increased risks relative to ship-borne AUVs, particularly in operational integrity, collisions with ships, loss of life and injury, and loss when transiting to the site of operation, and in transiting across maritime zones.

**Limitations of the VCB Concept**

Firstly, it needs to be said that the concept is not put forward as being suitable for all applications. Some situations are unsuitable for the VCB concept using SAUVs, i.e.:

- Potential for damage by passing vessels in heavily travelled areas;
- Negotiating shipping lanes on the way out to, and back from, the offshore field, after launching in a near-shore position;
- Theft in indigenous fishing areas;
- "Salvage" by passing vessels;
- Areas with low solar radiation;
- Ice;
- Areas with constant currents > 3 knot (1.5 metres/second);
- Conservative attitude of oil and gas companies.

The SAUV is capable of diving to 500 metres, which may allow it to travel safely through shipping channels. This property could also be used when the SAUV is on station; it could listen for approaching propellors, and dive if they came too close!

There are some things that the VCB can not do, i.e.:

- Chemical Injection – need chemical injection lines from shore/surface;
- Annulus venting – ideally, inject annulus pressure build-up into production side; and
- Hydrate remediation – other provisions need to be made if this is a requirement.

## Conclusions

Solar-powered AUVs are not longer just a research curiosity, but are being put to use by academic and military customers. They are available on a commercial basis from a scientific instrument manufacturer, Falmouth Scientific, Inc. [Ref. 16].

Solar energy systems allow the endurance of AUVs to be increased dramatically thereby allowing long duration missions, so reducing the burden of recovering and recharging AUVs. The solar-powered AUV is ready for trial as a Virtual Control Buoy, for the control of remote subsea gas wells. The big question is, are the oil and gas companies ready for it?

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