Biospherical Instruments Inc.

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Adjustable buoyancy modification to SuBOPS and C-OPS backplanes

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Introduction.

Boyle's law states that for any gas at sufficiently low pressure and sufficiently high temperature, the volume occupied by the gas is inversely proportional to the pressure:

$$V=1/P$$

where P is pressure, V is volume. It is a convenient coincidence that for seawater, the volume of air in a flexible bladder will decrease by about 50% for every 10 m of additional depth. By replacing a significant volume of rigid syntactic foam used for buoyancy on SuBOPS with an air-filled flexible bladder, the SuBOPS would be maximally buoyant at the surface of the water but increasingly negatively buoyant as it sank. In theory, at 30 m, the bladder would be $1/2^3$ or 12.5% the original size on the surface. At 60 m, the bladder would be 1/64 (1.5%) the original volume and the SuBOPS would be sinking at a rate equivalent to having no air bladder whatsoever.

Air bladder selection

Initial testing with commercially available parts (rubber model aircraft tires) and hand-made, thermally sealed, inflated polyethylene "pillows" was provocative, but did not lend themselves to integration with the SuBOPS and C-OPS back planes. The problem was solved using inflatable plastic tubes made from heat shrink tubing, thermobonded at the ends after inflating (Figure 1). The tubing is mechanically strong, easily cut to length and sealed, and remains flexible at temperatures below freezing without unsealing.

The approach was initially tested in San Diego bay using a bladder that was cable-tied to the backplane. For final testing, a 1¼" hole was drilled through the large syntactic float on a SuBOPS backplane and the tubing inserted. Long threaded shafts with acorn nuts held the tube in place within the chamber.

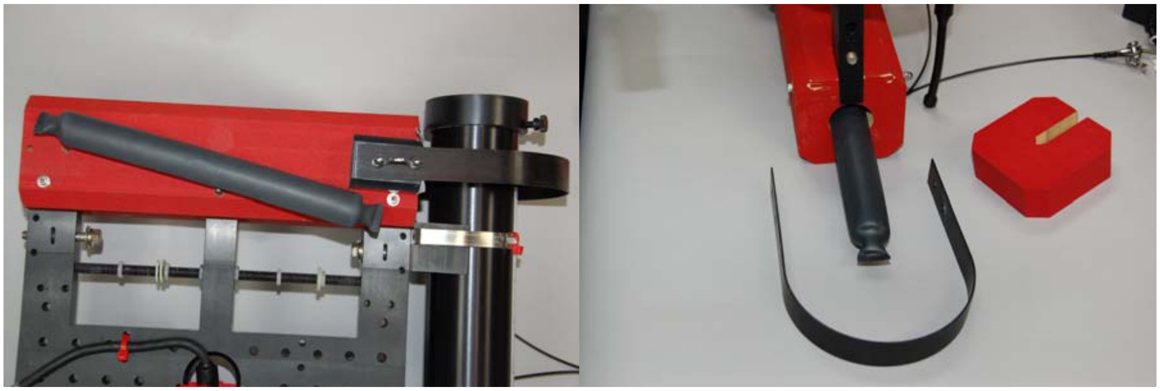

Figure 1. (Left) A 1"x12" inflatable bladder was made from plastic heat-shrink tubing. (Right) The tubing was inserted into a 1¼" hole bored through the main syntactic foam float.

Field Testing

The backplane was reassembled and the instrument was deployed at approximately 1.5 miles off the coast of San Diego from a 20 m runabout in 11 Nov. 2008 (Figure 2).

Figure 2. No new difficulties were encountered with the modified backplane and 12 casts at 2 stations were collected in about 90 minutes before the loss of computer power ended data acquisition.

Deployment conditions were ideal. The day was cloud-free and we arrived at the first station with completely calm conditions albeit a 1-2 ft swell from the NW. Vertical profiles of downward irradiance reflect the sunny conditions with pronounced focusing and defocusing near the surface from the swell (Figure 3). The wind freshened during the morning to 2-8 knots which was ideal for moving the boat away from the profiler.

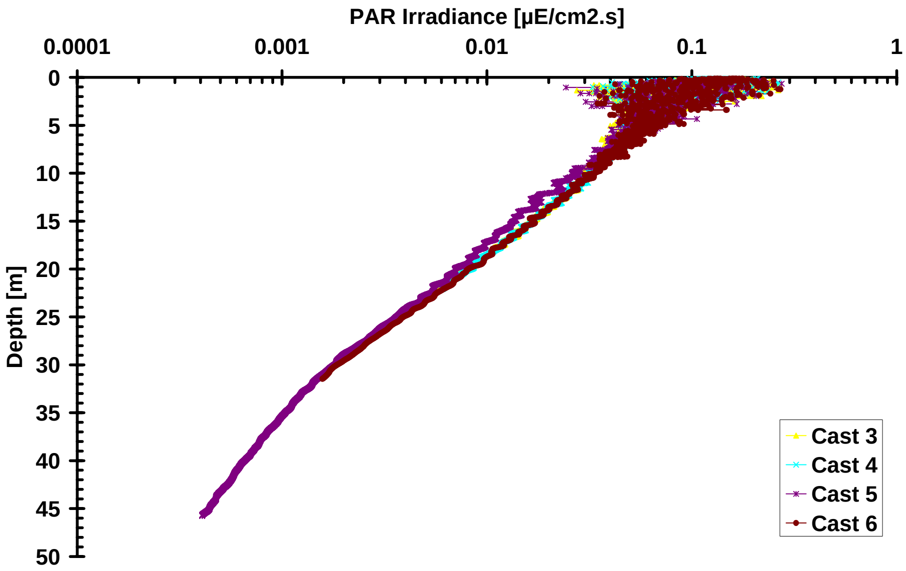

Figure 3. Vertical profiles of PAR downward irradiance.

Results and discussion

The adjustable bladder approach was an unqualified success. To a first approximation, the bladder provides 5.3 oz positive buoyancy in seawater. While on-station, were able to trim the buoyancy of the new system to near-neutral at the surface, affording about 13 seconds of loiter time (200 data frames) in the upper 1 meter, and about 20 seconds in the upper 2 meters as the system accelerated (Figure 4).

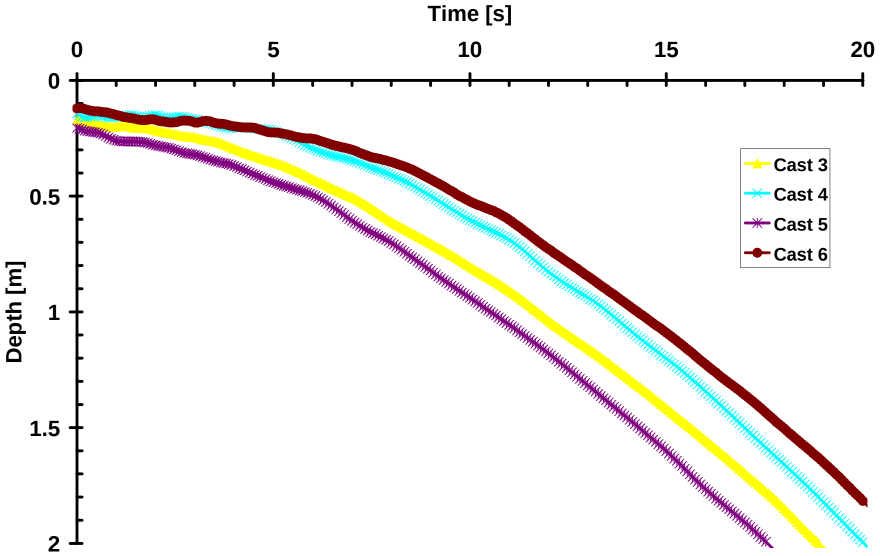

Figure 4. The system starts a profile with the air bladder fully inflated and sinking very slowly. As the system sinks, the fall rate increases and the unit accelerates. The system takes about 13 seconds to fall through the first meter, but only 7 seconds to fall from the 1st through the 2nd meter.

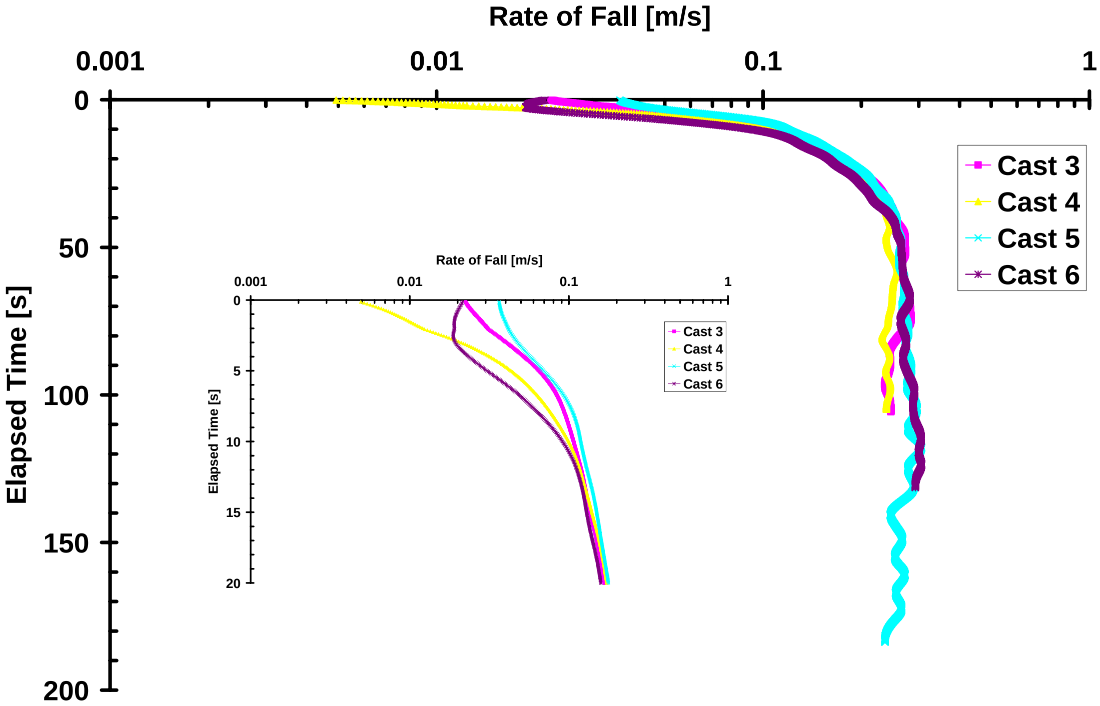

Figure 5. Fall rate (m/s) during 4 casts from station 1. The profiler achieves terminal velocity at about 50 seconds having reached a depth of about 10 m.

There was some small variability in fall rate in the first few cm, possibly due to the prevailing swell (Figure 5). The package achieves terminal velocity (about 25 cm/s) after about 50 seconds. This corresponds to a depth of about 10 m. At this depth, the bladder is 50% of the surface buoyancy.

The profiler does an uncommonly good job of sampling the upper few meters (Figure 6). The slope of a profile of cumulative data acquired is the instantaneous rate of data acquisition at depth. This is an estimate of the number of data frames that would be collected per meter of profile if the system continued to fall constantly at the indicated rate. Above 4 m, this value is typically many hundreds of data frames per meter. Terminal velocity is approached at about 10 m, collecting about 75 data frames per meter (the typical minimum is around 60 data frames per meter).

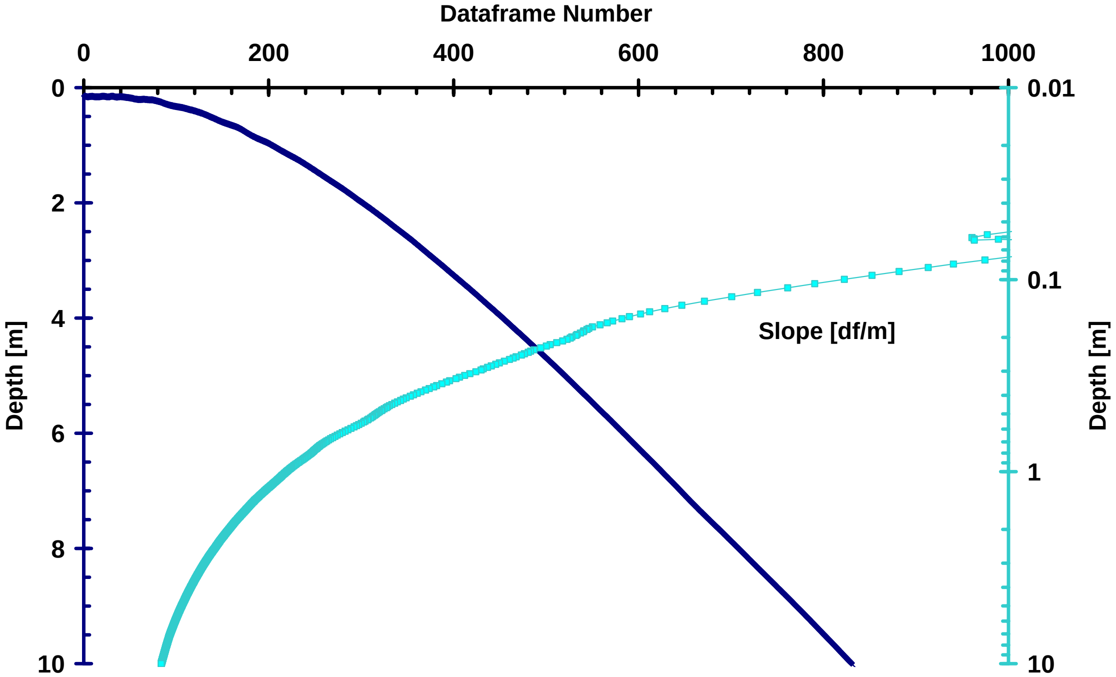

Figure 6. Vertical distribution of the cumulative data acquired at depth contrasted with the slope of the profile (in data frames per m).

Additional Observations.

Clearly there is a relationship between the terminal velocity and the size of the bladder. To achieve higher terminal velocities, use a larger bladder. Or two. And possibly offset the bladder with additional weight. To reduce terminal velocity and loiter in the upper water column longer, use a smaller bladder so that the differential between the surface buoyancy and buoyancy at depth is smaller.

Variable buoyancy

The bladder is effectively housed in the large float, which offers protection from damage and secure positioning (Figure 7). However, in order to change the bladder quickly, we new use a two piece float, sliced horizontally and hollowed out to hold up to three bladders. Drain and fill holes allow trapped air to escape.

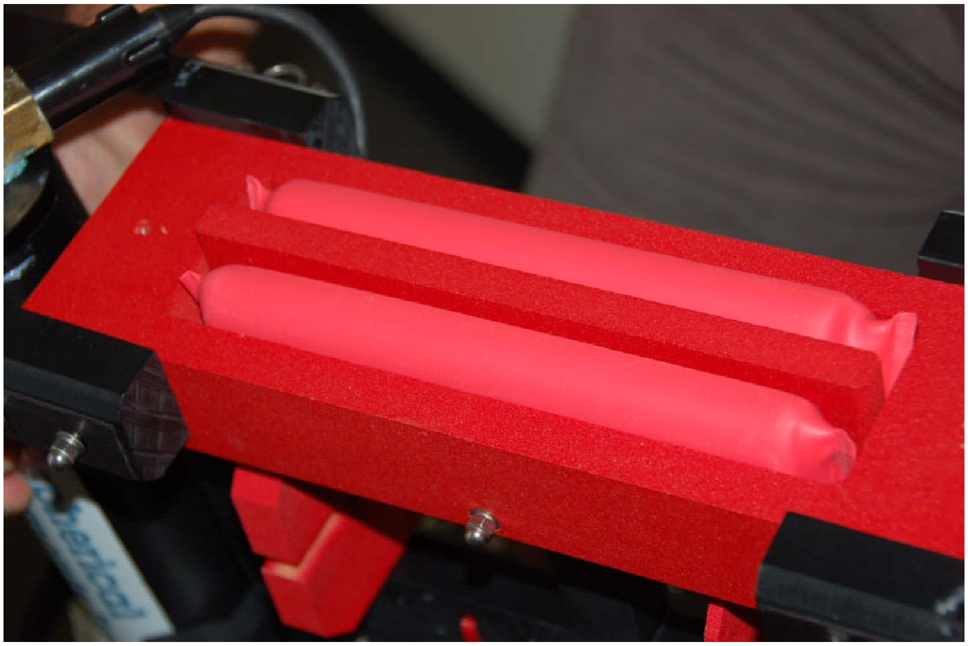

Figure 7. C-OPS near-surface buoyancy is easily adjustable using syntactic floats. As the system descends, increasing water pressure compresses air-filled bladders, reducing buoyancy and increasing descent rate from <3 cm/s at the surface to over 30 cm/s below 10 m.

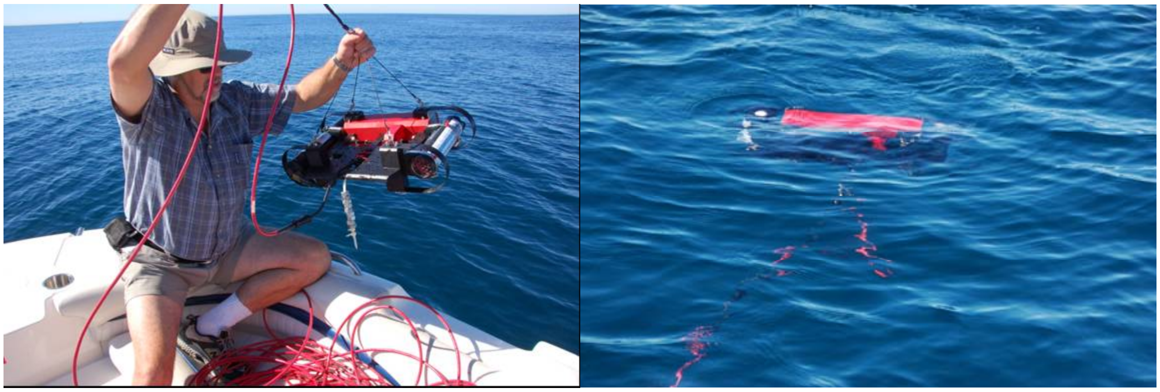

Figure 8. In the final modification, the large red float would be bisected laterally and the air bladder encased in a groove in the float. To change the bladder, the float would be open from the top simply by removing a pair of wing nuts.

Slide in secondary floats

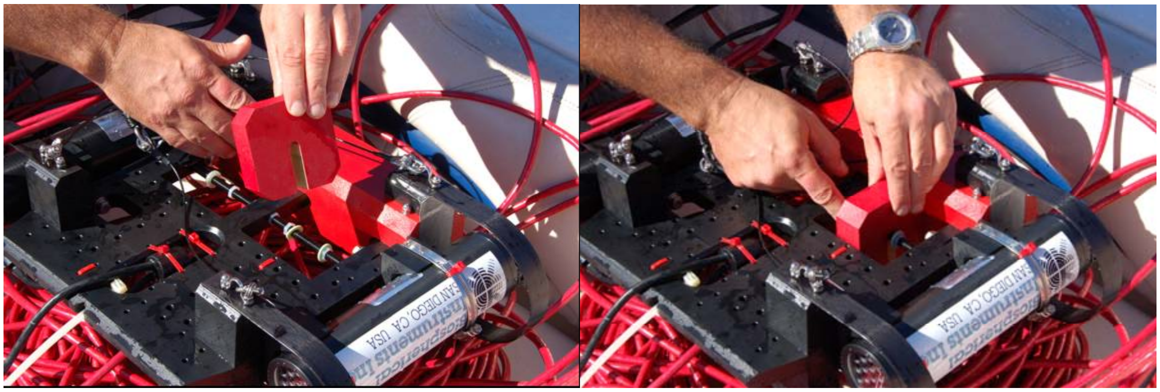

Figure 9. We have found that the secondary floats are essential to “tuning” the backplane, particularly for platform roll. New, thinner “slotted” floats slide into the existing design and do not require disassembly of the system to add or remove. The horizontal position of these floats is maintained on the cross bar by nylon washers and nuts. The thickness of the floats has been standardized at 0.44”, 0.66”, and 0.88” of syntactic foam. This corresponds to approximately 2, 3, and 4 ounces of positive buoyancy in fresh water. It is also convenient that one, ½” stainless steel nut weighs about one ounce (+/- 5%).

Note. The position of the cross bar in the past was maintained by opposing nuts pushing outward on the frames. This has been changed and the cross bar is now kept in position by locking nuts screwed against the center of the frame, where they cannot be accidentally loosened and lost.

Cable-tie “stinger”

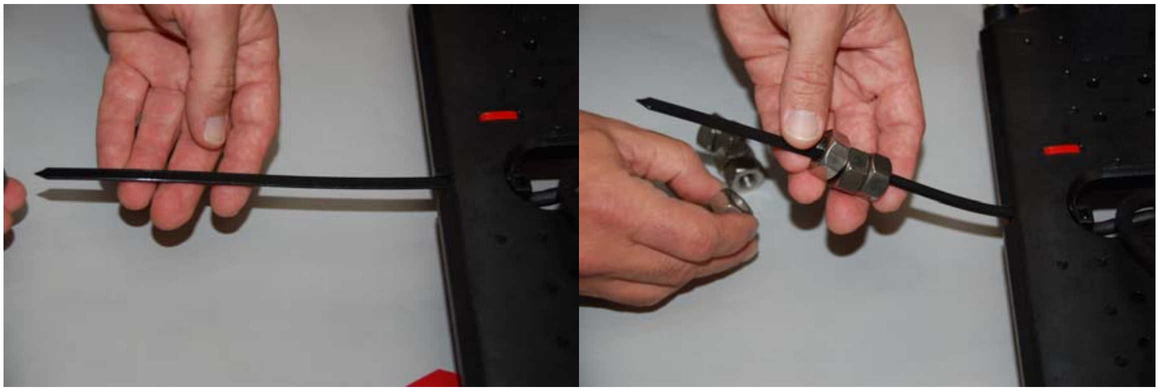

Figure 10. The rigid FRP threaded stinger has been replaced by a flexible stinger made from a UV-resistant plastic cable tie. This idea is probably the hardest for others to accept because it is perceived badly at first. Nevertheless, it is simple, inexpensive, and works very well. If we invented the cable tie for this application, we would be heralded as geniuses. This approach will be most helpful in situations such as when sampling from a bay up into a river, where the buoyancy of the profiler will need to be adjusted as the water looses salinity. A second advantage of the flexible stinger is that it is more effective as a counterpoise.

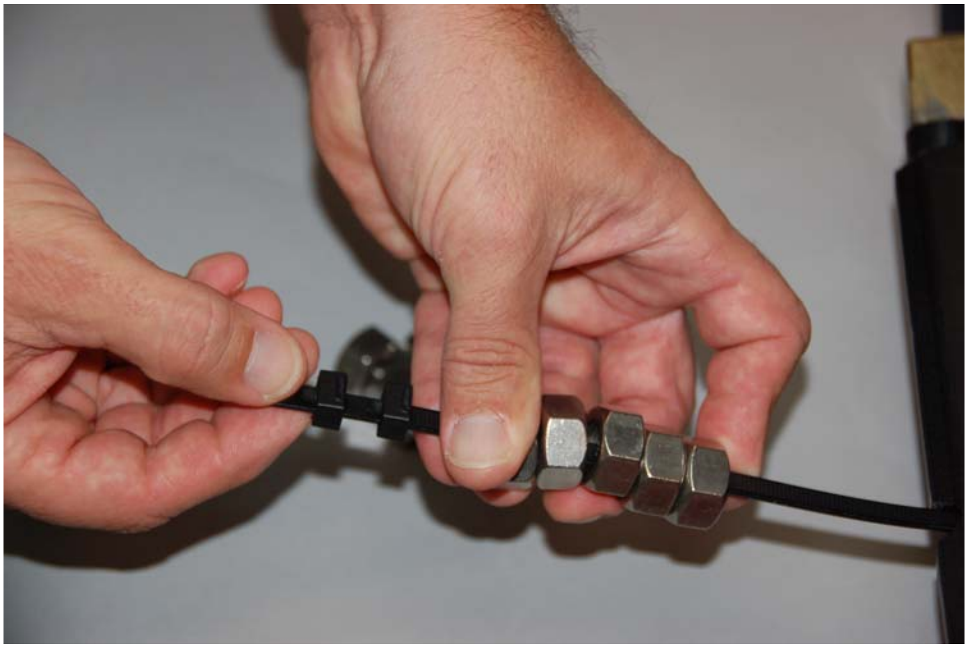

Figure 11. Two removable tie-locks are used for added security.

For a new backplane (rather than a retrofit), the tie would exit a purpose-built slit in the backplane rather than a stinger-type Helicoil. The head of the cable tie would tuck inside a pocket in the backplane where it would still be amenable to replacement, but it wouldn't look like a cable tie stuck into a hole as an afterthought (perception is important, right?).

End