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Advances in Detectors for DUMAND Arrays.

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The spacing of optical detectors in a DUMAND array depends critically upon their sensitivity; and the total number of sensors for a given detector volume will of course vary inversely as the cube of their spacing. Consequently it has been a long-term objective of DUMAND to increase the sensitivity of available detectors, until a critical value is reached at which increasing sensor-related costs - the sensor itself, its packaging, associated equipment, and deployment - outstrip the savings consequent upon decreasing the total number of sensors.

Following a suggestion of R. Winston, we have extensively explored a geometry of wavelength-shifting sensors (WLSS) that we have called Sea Urchin, which remains the best of all WLSS tested to date. In this design, (see Fig. 1) a hemispherical-cathode photomultiplier tube is optically coupled to a large number of radial "spines", each a transparent tube filled with a wavelength-shifting solution. Extensive laboratory tests on fluors, solvents, spine materials, etc., and extensive Monte Carlo studies of spine optics, self-shadowing by the array of spines, and related matters, have led to a final design of Sea Urchin which we now consider the best achievable at this time. The properties of the final design are shown in Table 1. The optical properties have all been measured in the laboratory, and the design is based upon achievable values (1-4). We therefore believe we can build a sensor of sensitivity 6 stengers*, using a single 13" EMI PMT tube, whose sensitivity if used directly is 1.0-1.5 stenger. The achievable gain is thus 6, which could be stretched perhaps to 10, but at the expense of increased size and weight.

A study of the problems of packaging and deployment of DUMAND strings using a variety of different sensors has recently been made at a DUMAND Workshop on Deployment, held in December 1980 at LaJolla. It turned out (5-6) that the large volume of the Sea Urchin package, and its considerable weight in air, result in high costs of packaging and deployment (See Table I.) It appears that not only Sea Urchin, but the large direct-view tube proposed by Wright (7), and in fact, any very large sensor will suffer from this difficulty. It has thus become a matter of great importance to discover whether the requirement for minimum overall cost can best be satisfied by lower sensitivity detectors. For the case of arrays designed for muon detection, that subject has been investigated, and it has been found (8) that asymmetric-spaced arrays with low-sensitivity sensors are entirely satisfactory for this purpose. The possible use of Sea Urchin thus de-

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*A sensor has a sensitivity of S stengers if an incident flux of 100 photons/m^2 produces S photoelectrons at the first dynode.

pends upon whether there exists another array usage that demands high-sensitivity sensors and can accept the high cost of deployment. No such usage has been suggested to date.

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Table I.
Design of Sea Urchin Module.

Pressure Vessel	26" glass sphere
PMT	13" EMI hemispherical photocathode.
Spines	1" Diam., 8 ft long.
No. of Spines	900
Filling	Toluene with 10-20 mg/1 Hostasol Yellow 8G
Total estimated Wt.,air	1400 kg.
Total estimated wt.,water	-50 kg.
Sensitivity	6 stengers.
Volume when packed for deployment:	1m diam., 4m long.

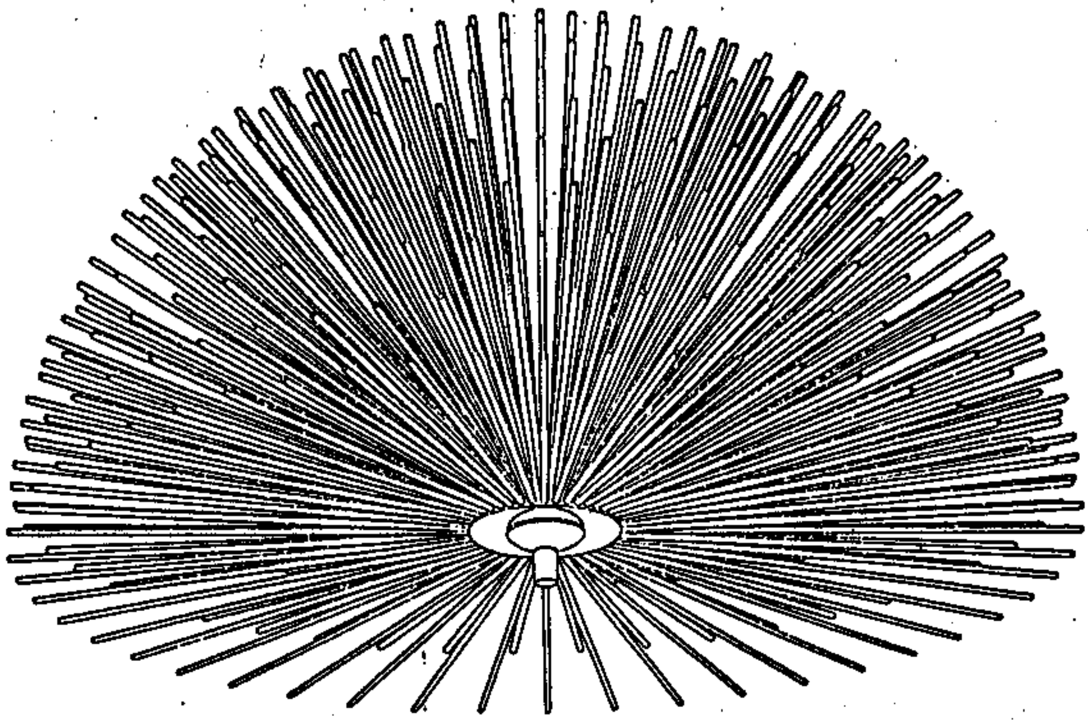

Fig. 1. Sea Urchin detector in operating configuration. The most favorable design to date has 900 1"-diameter glass spines, filled with a solution in toluene of Hostasol Yellow 8G, a proprietary fluor of high efficiency in shifting Cerenkov light centered at 450 nm to green light at ca. 510 nm. The PMT that gives best calculated results is a 13" hemispherical-photocathode tube. The spines are affixed radially to a 26"-diameter glass sphere, inside which the 13" PMT is concentrically located. The light from each spine is therefore collected on the photocathode, as shown in refs. 1-4. Calculations of the efficiency of Sea Urchin include light losses in the spines, shadowing of spines by each other, fluorescent efficiency, internal reflection losses, etc., and are verified by laboratory measurements.