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DUMAND - Deep Underwater Muon and Neutrino Detector

REMOTE INSPECTION, MAINTENANCE AND REPAIR OF THE DUMAND ARRAY.

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Remote Inspection, Maintenance and Repair of the DUMAND Array.

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1. Introduction:

It is put forward that the DUMAND detector array could be serviced by a remotely operated vehicle, R.O.V.. This is not a new proposal (ref. Gundersen 1978) but the state of the art of tetherless vehicles has advanced to a stage where such a system becomes feasible (ref. Dunbar, 1983). This possibility has been discussed informally with Dr. J. Craven, Prof. V.Z. Peterson, and Mr. M. Talkington of N.O.S.C. since December 1982 and a more detailed study of the concept was the main reason for the writer's visit to Hawaii during January 1985.

2. Present Status of Undersea ROVs.

Characteristics of some typical underwater vehicles are illustrated in fig. 1, on the basis of installed H.P. versus mass. The diameter of the "point" indicates attainable forward speed. Relatively large manned vehicles, e.g., 15, 16, 17, 19, 20, 22 are much less responsive than unmanned ROVs, e.g., 10, 11, 12, and semi-tetherless eg. 21 or tetherless vehicles e.g., 28, have the highest speed capabilities (or lowest forward power requirements) since they do not have to contend with the hydrodynamic drag of an umbilical cable.

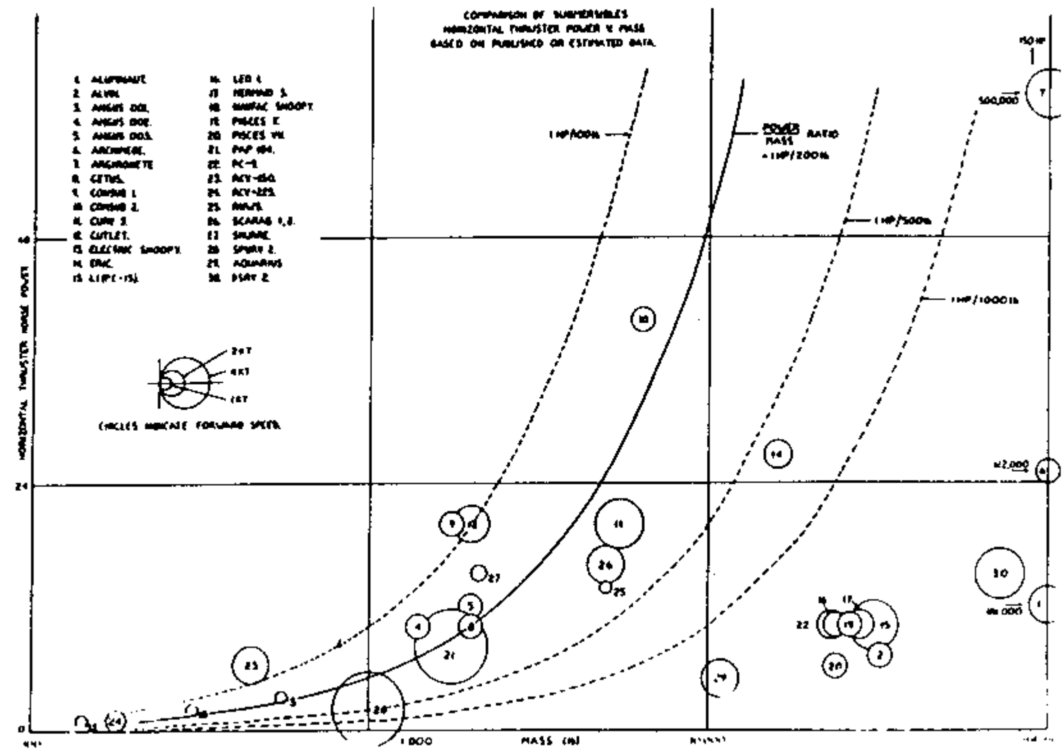
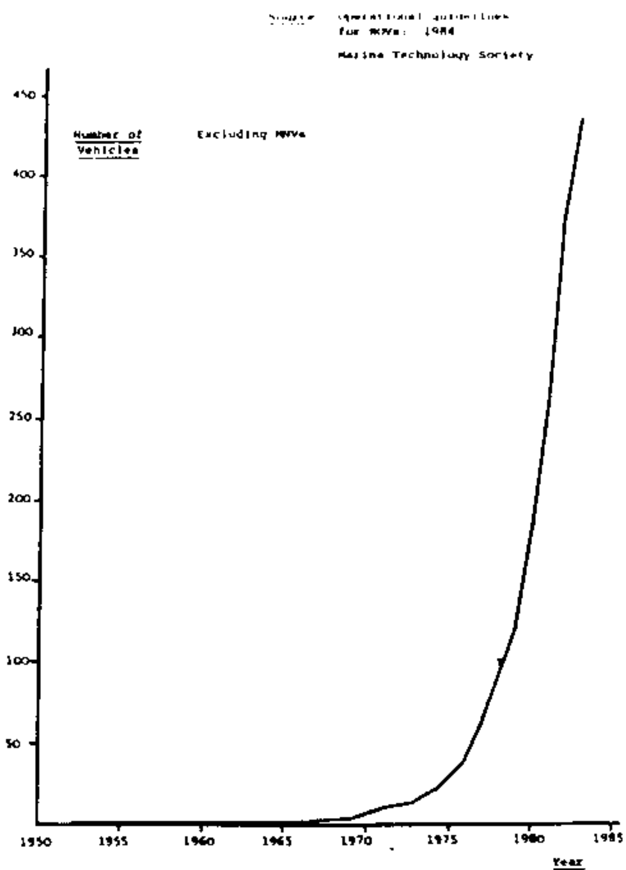


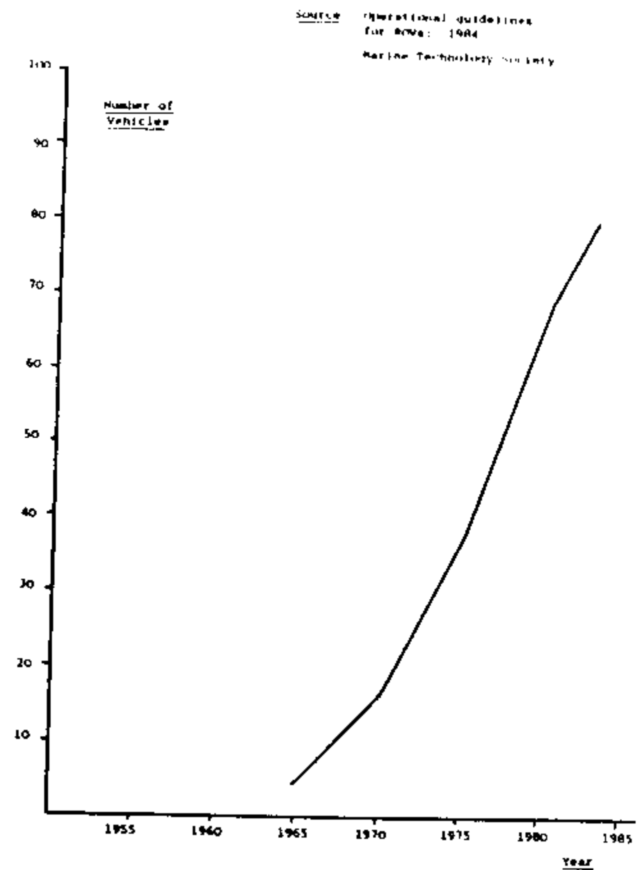
Fig. 1

The rate of increase of numbers of ROVs is illustrated in fig. 2, 3, and 4. Fig. 4 shows that the numbers of ROVs carrying manipulators continues to increase, illustrating the trend towards undersea robotics, essential for the proposed DUMAND application.



Tethered Free Swimming ROV Growth Rate - Cumulative Over 1950 to 1983

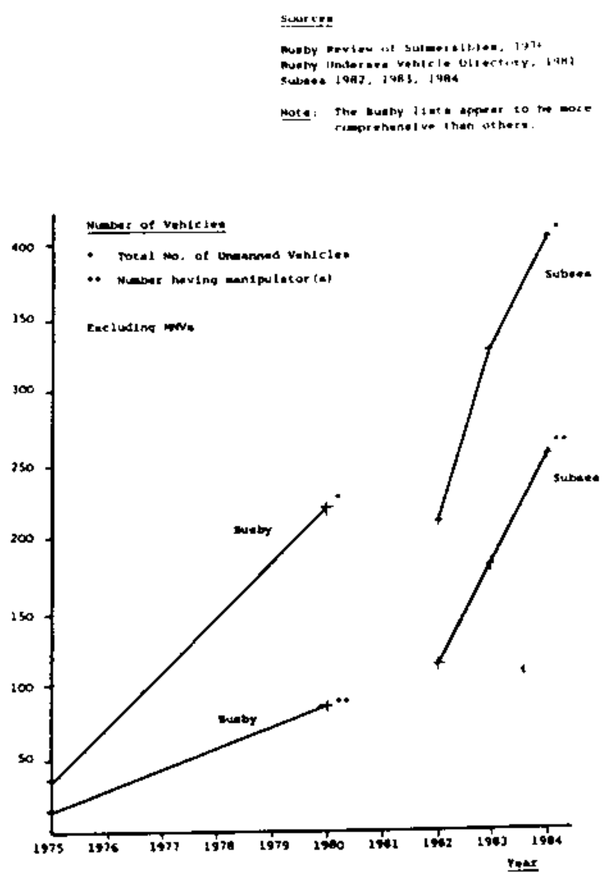
Fig. 2



Bottom Reliant and Towed Vehicle Growth Rate - 1965 to 1983

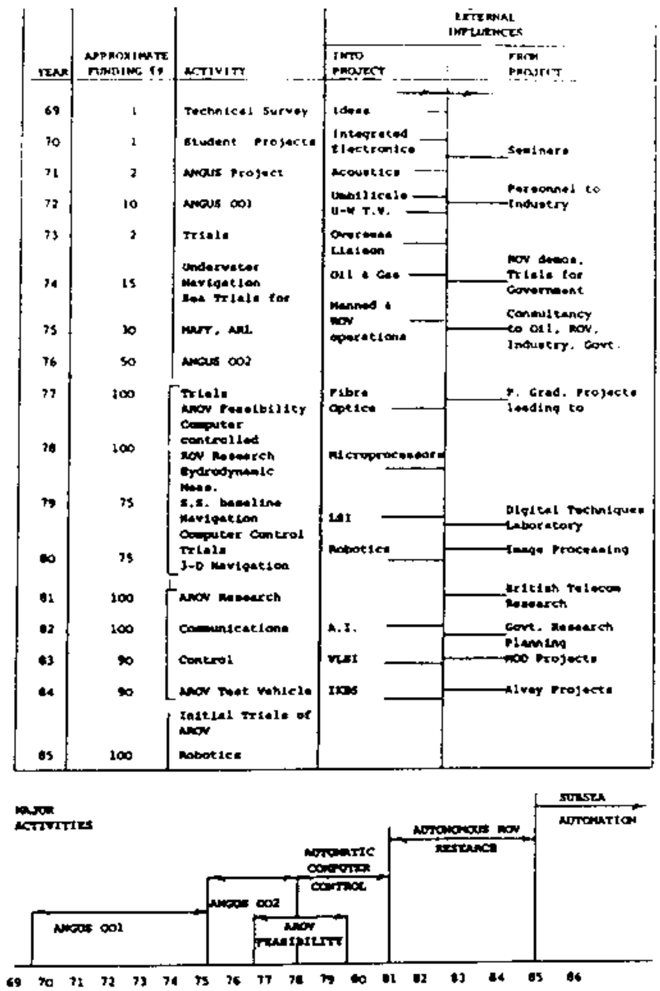
Fig. 3

ROV research at Heriot-Watt University over 1969-1985 is summarized by fig. 5. Experience has been gained in fully automatic computer control of ROVs and current research is centered on the problems of autonomous vehicle operation, both necessary factors in the design of a vehicle for DUMAND.



Total Numbers of Unmanned Submersibles over 1975 to 1984; Number having Manipulator Capacity

Fig. 4



Heriot-Watt University Submersibles Project

Fig. 5

The numbers of the tetherless ROVs world-wide is much smaller than that for tethered vehicles, because of greater technical difficulties, and defence applications are satisfied at present by tethered ROVs. A representative list of mine neutralization vehicles, MNV, is given in fig. 8.

List of Tetherless Unmanned Submersibles

Vehicle	Built By	Application
ARCS	ISE, B.C., Canada	Under ice, mapping
AUSS	NOSC, San Diego, USA	Search, identification
B-1	NUSC, Rhode Is., USA	Laminar flow studies
CMU ROVER	Carnegie-Mellon, Univ. Pittsburgh, USA	Feasibility studies
DMT	EMI, UK	Submarine target simulation
DOLPHIN	ISE, B.C., Canada	Experimental hydrographic surveying: diesel engine
EAVE-EAST	Univ. New Hampshire, Durham, USA	Structure, pipeline inspection: feasibility
EAVE-WEST	NOSC, San Diego, USA	Structure, pipeline inspection: feasibility
ELIT	CNEXO/COMEX, France	Observation & measurement
EPAULARD	CNEXO, France	Seabed photography & topography
OSR-V	MITSUI, Tokyo, Japan	Oceanographic research
ROBOT II	MIT, Cambridge, Mass., U.S.A.	Experimental vehicle
ROVER	H.W. Univ, UK	Research vehicle
SKAT	Inst. Oceanology, Moscow, USSR	Ocean research
SPURV I	APL, Seattle, USA	Oceanographic measurement
SPURV II	APL, Seattle, USA	Mid-water research
UARS	APL, Seattle, USA	Under-ice survey
UFSS	NRL, Washington DC, USA	Long range search
VERA	CEA & France, Dunkerque Shipyard, France	Deep ocean module collection

Fig. 6

Characteristics of Tetherless ROV's

Vehicle	Length m	Beam m	Height m	Mass kg	Payload kg	Max. Depth m	Power Storage	Propulsion H.P	Speed (Kn.) Duration (hrs.)
ARCS	6.8	0.54	0.54	1.5 t	N/A	300	10/20 kWh	N/A	5/10
AUSS	N/A	N/A	N/A	N/A	N/A	6100	N/A	N/A	N/A
B-1	N/A	N/A	N/A	N/A	N/A	90	N/A	N/A	N/A
CMU ROVER	N/A	N/A	N/A	N/A	N/A	Surface	N/A	N/A	N/A
DRT	3.28	0.32	0.324	236	N/A	366	35 Ah	10	2.1/1.6
DOLPHIN	6.5	1.0	1.0	2.4 t	N/A	3/30	Diesel	100	12/20
EAVE-EAST	1.52	1.52	1.04	369	45	50	7.5 kWh	0.5	0.4/N/A
EAVE-WEST	2.74	0.53	0.53	182	~20	600	12 V/ 630 Ah	~0.5	1.2/1.0
ELIT	N/A	N/A	N/A	N/A	N/A	1000	N/A	N/A	N/A
EPAULARD	4.0	1.1	2.0	2900	40	6000	48 V/ 15 kWh	N/A	0.5/6.0
OSA-V	4.8	2.15	1.75	2976	0	250	100 V/ 256 Ah	10	1/N/A
ROBOT-II	2.33	0.37	0.37	110	11.4	61	12 V/ ~30 Ah	~0.25	0.6/6.1
ROVER	2.0	0.7	0.5	100	10	100	40 Ah	2 x 5	3/4
SKAT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SPURV II	3.05	0.61	0.61	454	45	1829	[illegible]	2	1/6
UARS	[illegible]	0.48	0.40	[illegible]	23	457	24 V/ [illegible] Ah	0.25	0.8/12
[illegible]	6.1	1.22	1.22	N/A	N/A	457	N/A	0.33	[illegible]
VEKA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Fig. 7

Comparison of Mine Neutralisation Vehicles

CHARACTERISTIC	VEHICLE					
	PAP-104(IV)	MIN	PINGUIN(B3)	MNS	PLUTO	MINNOW
Dimensions L x W x H (m)	2.7x1.2x1.3	3.6x0.94x1.6	3.5x0.7x1.4	3.8x0.9x0.9	1.6x0.6x0.6	1.5x1.0x1.0 (approx.)
Vehicle Mass (kg)	700	1300	1350	1135	130	150 (approx.)
Disposable Charge (kg)	127	120	2x120	MK57	40	N/A
Horizontal Range (m)	500	250	N/A	N/A	N/A	N/A
Operational Depth (m)	120	150	100	300+	300	N/A
Speed (Kn.)	5.5	5	6-8	6	4	N/A
Mission Profile Endurance	5x20 min	(20 min turn-around)	150 min	unlimited	3-6 hr	unlimited
Umbilical	1000 m disposable	1000 m disposable	600 m recovered	1000 m recovered	500 m recovered	N/A recovered
Comparative Cost	medium	high	high	high	low	low

Fig. 8

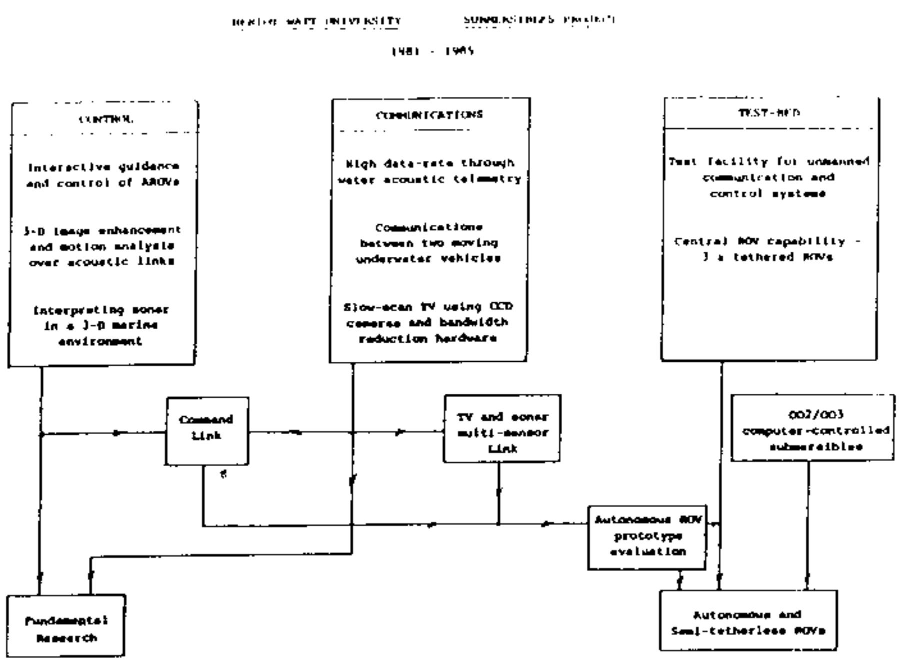
3. Trends in Undersea ROV Design.

a) Towards special purpose generally large, vehicles of modular construction, for offshore platform cleaning, inspection, and non destructive testing

b) Towards smaller cheaper systems for inspection and light manipulative duties.

c) Towards tetherless autonomous AROV systems and advanced intelligent robotics.

The Heriot-Watt University approach to heading (c) is illustrated in fig. 9.



4. AROV Concepts applied to DUMAND

4.1 Inspection

A free swimming or string reliant AROV could visually examine the PMT's and transmit the video in real time by a low level modulated LED beam to a nearby PMT. Illumination is required for the T.V so a compromise is needed between level of illumination, with a cooled low light level CCD T.V., and a de-sensitised PMT: using out-of-phase pulsed illumination and video frame readout would probably aid the compromise. This is illustrated in fig. 10.

An alternative is low-scan acoustic video transmission to a seabed hydrophone, or direct to the surface. Even with bandwidth reduction techniques and high data rate acoustics, real-time T.V. transmission would not be possible, particularly for a seabed to surface link. However, this is generally the case for AROV operation and it is only the unique optical features of DUMAND that offer possibilities of tetherless operation with real time viewing for piloting and robotics.

4.2 <u>String Retrieval and Re-deployment</u>

4.2.1 <u>Retrieval</u>

An automatic release mechanism, electrically, acoustically or ROV commanded, could allow the string to return by free ascent to the surface (Ref. DUMAND Proposed, Nov. 10, 1982; 3.4, 2,3, p. 107). It is recommended that the string bottom electronics module should be included in the releasable package, to aid re-connection only 1 optical fibre connection would be required, compared with 24 string connections. A detachable electrical connection could also be required.

4.2.2 Re-deployment

Re-deployment is much more difficult. It is probably wiser to consider the re-positioning of a string cannister than to attempt to thread a string into position.

The cannister could be dropped near to, but outside the array. A custom-designed AROV could search out the cannister (homing devices, acoustic navigation, automatic computer control), latch on, release pair of the drop weight to make the module just-buoyant, transport to the correct location, mechanically latch to bottom weight, make electrical and optical connections, and retreat.

This operation would require an intelligent (smart) guidance and control system, with multi-sensor input. The operation would be greatly simplified with visual feedback, possible in real-time via an optical-PMT link, or in slow-scan via an acoustic link to the surface with a 6 second overall delay, or to a seabed hydrophone, with a shorter delay.

4.2.3 Other Details

The AROV design should be kept as simple as possible. Murphy's Law: if it can go wrong it will; O'Toole's Law: Murphy was an optimist. Henry Ford: "if you don't fit it, it can't go wrong". Unfortunately, the design of the AROV cannot avoid the implementation of advanced technology, particularly for deep ocean applications. However, ruggedness and reliability should dominate design considerations.

The AROV could be based long-term on the seabed, trickle-charged via the cable from the shore.

During cannister maneuvering, the AROV could maintain altitude using a dragged (streamlined) chain for simple unpowered negative feedback, if bottom disturbance of sediment (DUMAND Proposed, Nov. 10, 1982; 3.1. p. 80. 81).

Inductive couplers are possible for A. C. power transmission, for the string, and also for AROV battery charging, as fig. 11 has example. Wipe-clean optical plug and sockets should be capable of development, even for mono-mode fibre.

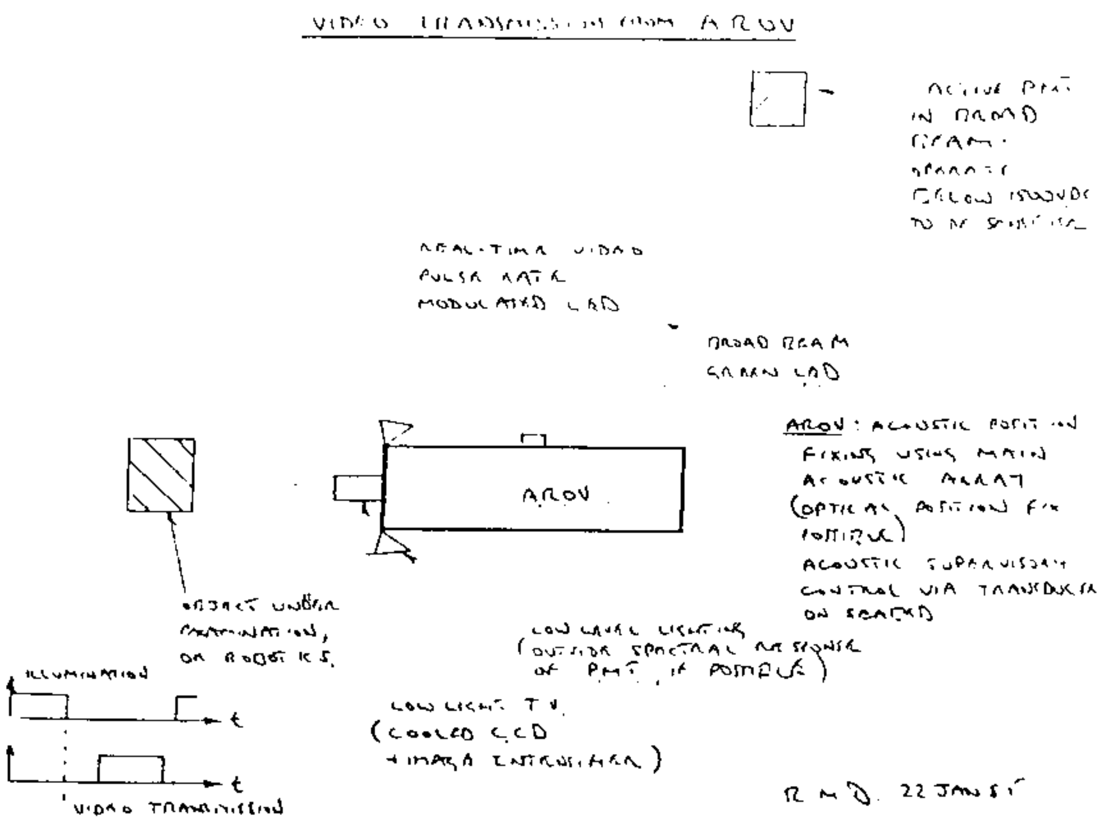


Fig. 10

5 References

5.1 Gundersen, C.R., "Maintenance of the DUMAND Array", 1978 DUMAND Ocean Engineering Workshop, pp. 161-169.

5.2 Dunbar, R.M., "The Role of Tetherless ROVs in Inspection", International Underwater Systems Design, Vol. 5, No. 1, 1983, pp. 9-15.

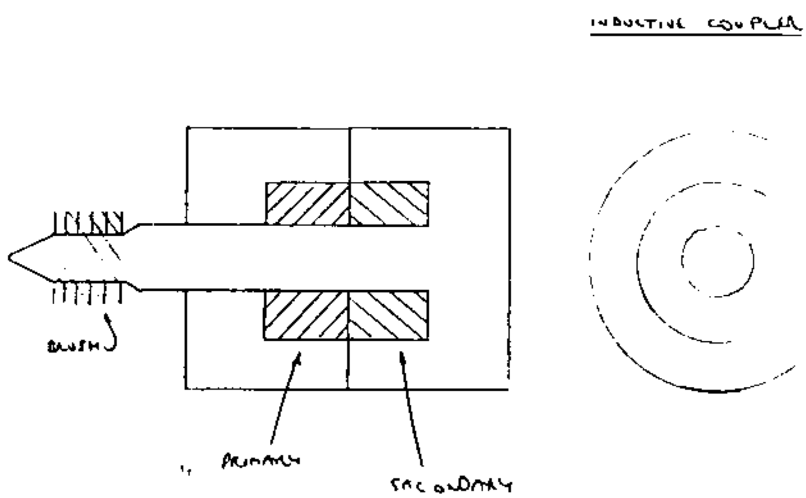


Fig. 11