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The following approaches were investigated, to various degrees, with the aim of identifying methods for the etection of low-energy neutrinos that are promising enough to deserve an experimental verification: (1) Cryogenic sensor of neutrinos' radiation proessure; (2) Magnetic interaction sensor; (3) Superheated Superconducting Colloid (SSC) Calorimeter; (4) ensor of the neutrino interaction with superconducting electrons; and (5) Bolometric sensor with silicon interaction target. Aprroaches 1, 2, and 3 were found deserving of experimental verification, but project funding limited continuing effort to approaches 1 and 2. Furthermore, DARPA added another task to the project, and this action further limited funding for the remaining approaches 1 and 2. The added task consisted of Ratheon verification of Prof. Weber's claim that he has detected ion-energy neutrinos with room-temperature instrumentation.

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15 SEPTEMBER 1987

ANALYTICAL/EXPERIMENTAL INVESTIGATION OF CORPUSCULAR RADIATION DETECTORS

SUBMITTED TO

DEFENSE ADVANCED RESEARCH PROJECT AGENCY (DARPA)

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CONTRACT #F49620-85-C-0030

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(AFOSR)

DARPA PROGRAM DIRECTOR: U.S. ARMY LT. COLONEL G. P. LASCHE', Ph.D

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Program Manager, Raytheon Co.

RAYTHEON COMPANY
SUBMARINE SIGNAL DIVISION
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ACKNOWLEDGEMENTS

This final report has been prepared by Mario D. Grossi, Principal Investigator and Technical Director, Contract F49620-85-C-0030. The report is a concise summary of project activity, as reported extensively in eight Quarterly Reports. The latter reports give credit to the members of the project team who made specific contributions.

EXECUTIVE SUMMARY

This is the Final Report on Contract #F49620-85-C-0030. The report summarizes the project activity that took place in the 28-month time span from 1 May 1985 to 31 August 1987.

The following approaches were investigated, to various degrees, with the aim of identifying methods for the detection of low-energy neutrinos that are promising enough to deserve an experimental verfication:

1. Cryogenic sensor of neutrinos' radiation pressure
2. Magnetic interaction sensor
3. Superheated Superconducting Colloid (SSC) calorimeter
4. Sensor of the neutrino interaction with superconducting electrons
5. Bolometric sensor with silicon interaction target

Approaches 1, 2 and 3 above (1 and 3 were the subject of the initial Raytheon proposal of October 1983 and 2 was the subject of the proposal addendum of May 1984) were investigated in substantial detail, while only a minor effort was devoted to approach 4 and 5.

All three approaches 1, 2, and 3 were found deserving of experimental verification, but project funding limited continuing effort to approaches 1 and 2. Furthermore, DARPA added another task to the project, and this action further limited funding for the remaining approaches 1 and 2. The added task consisted of Raytheon verification of Prof. Weber's claim that he has detected low-energy neutrinos with room-temperature instrumentation. This includes the procurement from University of Maryland of a replica of Weber's torsion balance, it's accurate calibration, and the conduct of feasibility tests (using a tritium

EXECUTIVE SUMMARY
(cont'd)

source of neutrinos). Testing would be conducted using the torsion balance, a replica of Weber's tuning fork (procured directly by DARPA and delivered to Raytheon as GFE), and the Raytheon cryogenic force sensor. This last sensor is characterized by a threshold sensitivity that is better (by an order of magnitude or two) than Weber's claimed sensitivity. The consequences of the project re-orientation are as follows:

(a) The cryogenic force sensor will operate at 4°K (for the independent reproduction of Weber's results, there is no longer the need of cooling it down to a dilution refrigeration temperature of a few millidegree K, as was advocated in Raytheon's proposal of October 1983);

(b) The magnetic interaction sensor. The budget reduction for this item made it necessary to scale down the effort to an initial laboratory program using an interaction target with a mass of only 25 Kg (instead of the full-scale target with a 250 Kg mass), housed in a small-size 4°K cryostat (procured off-the-shelf instead of a custom-made, large cryostat). The reduction in scope of this effort is not, however, without benefit. Considering JASON's advice (following their release of Report JSR-85-105 dated June 1987), a more cautious course of action would in fact substantially reduce the risk involved in this development, a risk that JASON considers to be high. Proceeding with caution is advisable, however, only if the

EXECUTIVE SUMMARY
(cont'd)

Sponsor is determined to invest additional funds later, on the full-size target, should the preliminary laboratory tests confirm the promise.

As a result of the research and development activity illustrated in this final report, Raytheon is now ready to undertake feasibility tests on the detectability of low-energy neutrinos, with the following sensors:

1. Raytheon cryogenic force sensor (at 4°K)
2. Weber's torsion balance (at room temperature)
3. Weber's tuning fork (at room temperature)

Once the three sensors have been built, the tests will be conducted by using a 100 Kilocurie tritium source, packaged by Lawrence Livermore Laboratory (LLL) in a 3.5" sphere, mounted on the rim of a 1-meter diameter rotating table, and having a distance, at closest approach, of about 15 cm from each of the sensors 1 and 2 above. Testing the tuning fork would not require the rotating table, because this sensor is equipped with a rotating shutter. The tests are expected to be conducted at a Raytheon laboratory in Sudbury, Massachusetts, that is licensed to handle radioactive material.

The sensitivity of the Raytheon cryogenic force sensor is about 10^{-8} dynes in 10^4 seconds integration time. This would be sufficient to detect the force resulting from the transfer to the proof-mass (sapphire crystal) of the <u>total</u> momentum (as predicted by Prof. Weber's theory) of the neutrinos. This is based on a distance of 15 cm from the 100 Kilocurie tritium source and a flux of 1.2 x $10^{12} \bar{\nu}\ cm^{-2}\ sec^{-1}$. Considering the average neutrino energy from the tritium source as 10 KeV, and the sapphire crystal's collecting area as about 50 cm^2, we would in fact have the total momentum transfer producing a force of 3.2 10^{-5} dynes. With an instrument sensitivity of 10^{-8} dynes in 10^4 seconds integration time, we would be able to verify the existance of this force. This would allow Raytheon to check in the most probative and reliable way whether Weber's claimed total momentum transfer effect does exist. Should the momentum transfer be less than total (as other theory predicts), the resulting force would go undetected by the two replicas of Weber's instruments and by the Raytheon cryogenic force sensor. Actually, the force may be as weak as about 10^{-18} dynes, and detection attempts would require a major development/testing effort, along the lines that were outlined in the initial Raytheon proposal of October 1983: (1) operate at dilution refrigeration temperatures (4 mill °K); (2) adopt a 10^6 seconds integration time; (3) improve the Q of the mechanical resonator to 10^8; (4) increase the mass of the cryogenic force sensor to 100 Kg, or larger; etc.

At the time of this final report, Raytheon has already been awarded by DARPA/AFOSR a follow-on contract #F49620-87-C-0050. After the JASON review on 10 July 1987, it was decided by DARPA/AFOSR that the new contract will support the construction of two sensors (Raytheon cryogenic force sensor and Weber's torsion balance) and the testing of these sensors, as well as Weber's tuning fork, with a LLL tritium source. Furthermore, the follow-on contract above will support the conduct of initial laboratory tests on a scaled-down magnetic sensor. Work on the full-scale version of the instrument will be carried out, in later efforts, separately funded by DARPA/AFOSR, only if the initial laboratory tests confirm the promise.

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.1 Cryogenic Force Sensor

Several design alternatives were examined (as reported in our Quarterly Reports), among which a zero baseline differential force sensor that would have reduced the effect of newtonian gravity gradients (gradients produced by the mass of the tritium source) to zero. We gave preference to a configuration that offers the advantage of having already been tested at IFSI-CNR, at room temperature. Our cryogenic force sensor will be therefore a 4°K version of the spaceborne gravity gradiometer under study at SAO and IFSI-CNR, and under development by the latter institution. The IFSI-CNR gravity gradiometer is characterized by the following performance specifications:

o Mass	200 grams
o Temperature	Room temperature (about 300°K)
o Resonance Frequency	about 22 Hz (without negative spring)
	about 15 Hz (with negative spring)
o Q Factor	1,500
o Weakest Force actually detected in lab tests	4 10^{-7} dynes (w/o vibration abatement; with 10^{-4} common-mode rejection)

The cryogenic force sensor that we will construct for DARPA/AFOSR will be characterized by the following performance specifications:

o Mass	250 grams
o Temperature	4°K (liquid-helium cryostat)

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.1 Cryogenic Force Sensor (cont'd)

o Resonance Frequency	100 Hz
o Q Factor	10^4
o Required Integration Time	10^4 seconds
o Minimum Detectable Force	10^{-8} dynes
o Oscillation Decay Time	32 seconds
o Required Abatement of vibration noise	150 dB

We have designed a method for abating mechanical vibrations and seismic oscillations, that consists of a 2-stage vertical suspension. Each stage (a spring) resonates at 1 Hz and provides an attenuation of 80 dB at 100 Hz (signal frequency). Total attenuation provided by the system is 160 dB. With the contribution from common-mode rejection (80 dB), we expect to achieve an overall attenuation of 240 dB, therefore, 90 dB better that the minimum required attenuation of 150 dB.

The sensing of the signal-induced acceleration in each proof-mass of the cryogenic force sensor (one of the two masses will contain sapphire crystals embedded in its aluminum body, the other will be made entirely of aluminum) will be performed with a condenser-probe in a parametric amplifier arrangement. The change in capacitance of the condenser, due to the signal-induced motion of the proof-mass (motion frequency 100 Hz) unbalances a bridge that is fed in one diagonal by a 10 KHz pump. The amplitude-modulated 10 KHz carrier (the sidebands are caused by the signal) appears at the output of the bridge, on the other diagonal, and is amplified by a low-noise FET preamplifier, followed by a coherent phase detector

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.1 Cryogenic Force Sensor (cont'd)

(the demodulator) and a low-pass filter. This output signal is also fed back to another bridge condenser that brings the proof mass to equilibrium (by electrostatic forces). It had been put in sinusoidal motion by the 100 Hz signal ("null-servo" arrangement). The same 100 Hz conditioned output is fed to an A/D converter and then to a channel of the tape recorder. For sensitivity calibration, an external signal can be injected into the condenser probe.

1.2 Rotating Source Assembly

We have designed a rotating circular table, with a diameter of 1 meter, and a vertical axis of rotation. The table is rotated by a DC torque motor capable of providing angular rotation from less than 1 RPM to 6000 RPM. The rotating wheel assembly has a circumferential rim made of a material that has the same density as the 3.5" sphere (cave and made of aluminum) that contains the 100 Kilocurie tritium source. Other identically looking spheres ("dummies") will be used in a variety of verification tests and will be characterized by the same density. This way, we will minimize the variable gravity gradients produced by the rotation of the wheel, at sensor stations (the two sensors most affected by these gradients are Raytheon's cryogenic force sensor and Weber's torsion balance). By installing more than one source in the rim, it will be possible to conduct the experiment with a signal frequency that is a multiple of the wheel's rotational speed. We have to expect, in fact, that the rotating wheel will produce vibrations that will be picked-up as noise by the force sensors, in spite of the fact that we will be isolating the wheel and its motor from the floor, and encasing the wheel

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.2 Rotating Source Assembly (cont'd)

in a vacuum-container to prevent acoustic transmission of vibrations, through the air, to the sensors. The wheel-produced mechanical vibrations are expected to have harmonics less intense than the fundamental, hence the advantage in using a signal frequency that is a multiple of the rotational speed.

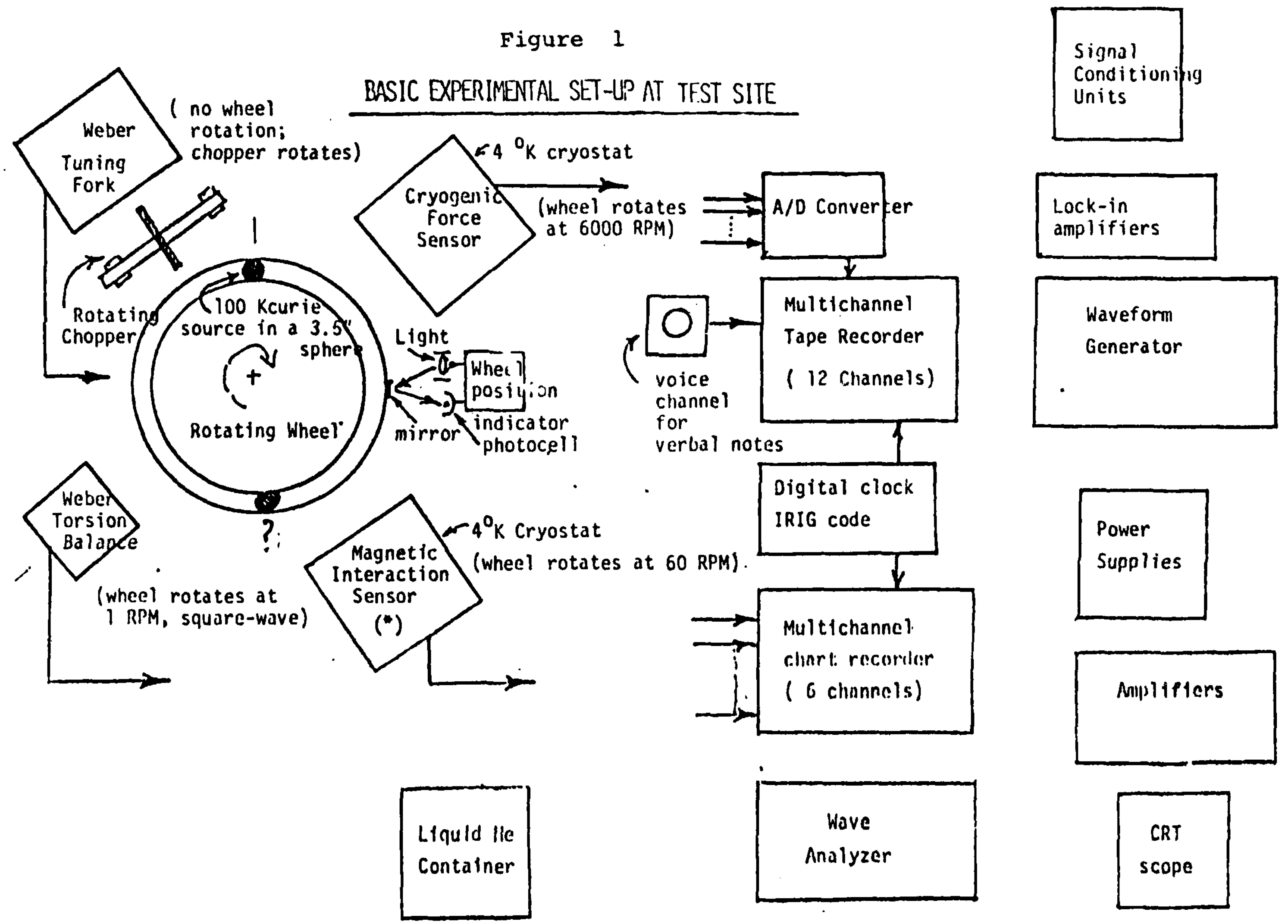
The rotating wheel will have black/white markings (and a reference position mark) on the rim, that will be illuminated by a light source, with the reflections picked-up by a photomultiplier. This signal will provide information on both the frequency (rotational speed) and the phase (angular position) of the rotating wheel, and will be used to feed (through a digital counter and a "Difference" circuit that is also fed by a reference sinusoid) the DC motor-drive of the torque motor that rotates the wheel. Preliminary selection of rotational speeds is as follows: (a) 6000 RPM when experimenting with Raytheon cryogenic force sensor; (b) 1 RPM when experimenting with Weber torsion balance; (c) 60 RPM, in follow-on phases of the project, to experiment with the magnetic interaction sensor.

The design of the rotating source assembly that we will implement has been based on previous SAO experience in developing inertia wheels for balloon flights and scientific satellites, inclusive of related servomechanisms.

The rotating wheel assembly will be the hub of the experimental set-up. As seen in Figure 1, all the sensors are located around it, at its perifery, while the remaining instrumentation (complete with data storage) will be mounted nearby.

Figure 1

BASIC EXPERIMENTAL SET-UP AT TEST SITE



(*) NOT PART OF WEBER VERIFICATION EFFORT

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.2 Rotating Source Assembly (cont'd)

Concerning the location of the test site, Raytheon is making plans for the conduct of the tests at its Sudbury, Massachusetts Nuclear Materials Facility, licensed by the NRC (Nuclear Regulatory Commission) to handle radioactive sources.

1.3 Magnetic Interaction Sensor

We have designed a magnetic interaction sensor based on the theoretical expectation that a flux of low-energy neutrinos will induce a magnetization in a high-permeability, large-mass, interaction target. The intensity of the induction B_ν is expected to be:

$$B_\nu = \sqrt{2}\, G_F \frac{\mu_r}{\mu_e} \cdot \rho \quad \text{(Dyson, 1984)}$$

where:

$G_F = 1.453\ 10^{-49}$ ergs cm^3

μ_r = relative permeability of material

μ_e = electron magnetic moment (= $0.93\ 10^{-20}$ ergs/gauss)

ρ = neutrino density = $\frac{1}{c} J$, with J = neutrino flux, $\nu\ cm^{-2}\ sec^{-1}$ and, c = velocity of light in vacuo = 3.10^{10} cm sec^{-1}

1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.3 Magnetic Interaction Sensor (cont'd)

For the magnetic flux ϕ we have:

$$\phi = B_\phi \cdot A, \text{ where } A = \text{target cross-sectional area, cm}^2$$

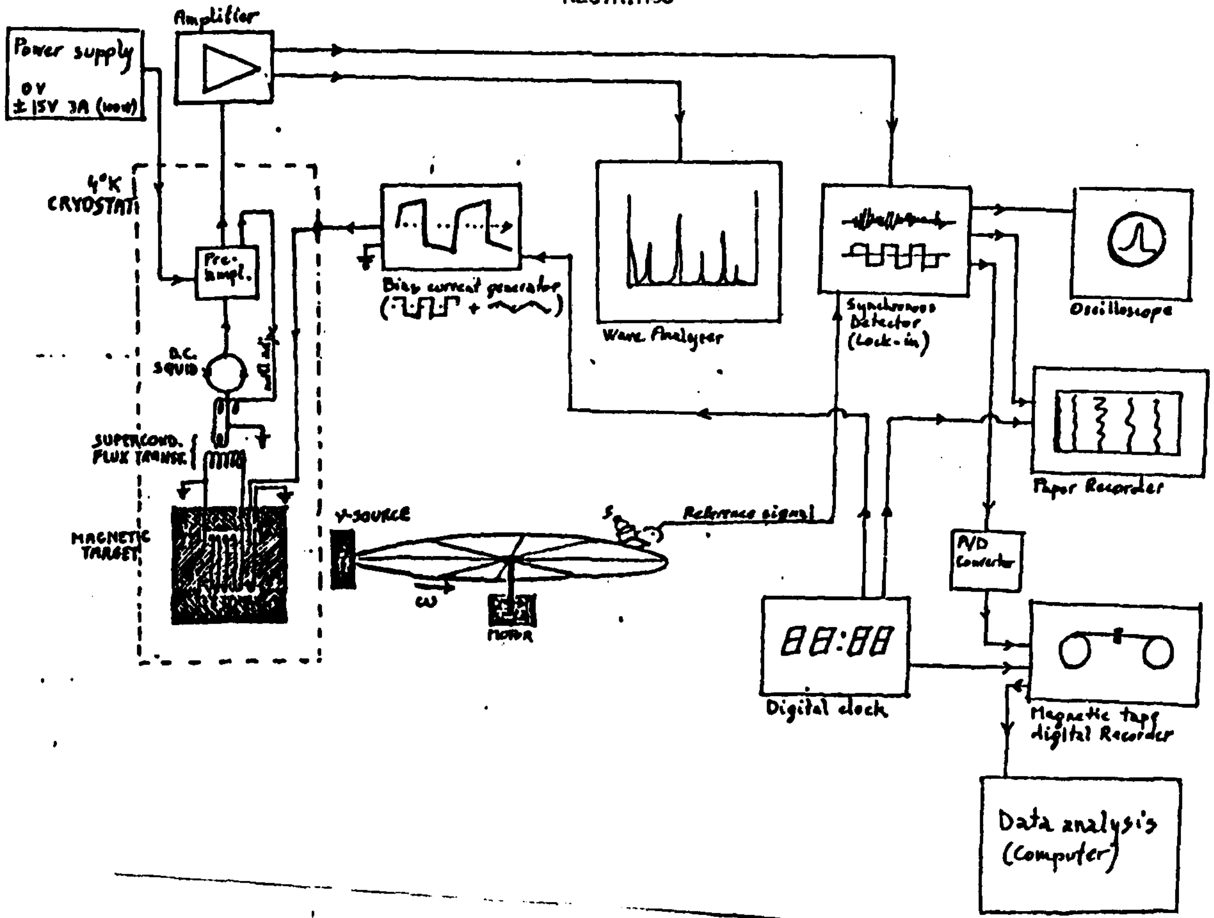
and, in unit of ϕ_0 (ϕ_0 = 2.07 10^{-7} gauss cm^2), we have

$$\frac{\phi}{\phi_0} = \sqrt{2}\, G_F \frac{\mu_r}{\mu_e} \frac{A}{2.07\ 10^{-7}}$$

Based on this formulation, JASON (see their report JSR-85-105, dated June 1987) concluded that the detection of low-energy neutrinos by the magnetic interaction method is hopeless: it would require an integration time of 10^{24} seconds. JASON arrived at this estimate by adopting these values: $\mu_r = 10^3$, $A = 1\ cm^2$, SQUID noise density $10^{-4}\ \phi_0/\sqrt{Hz}$. Raytheon has objected to the values adopted by JASON for the intervening parameters and has submitted instead that it will be feasible to achieve $\mu_r = 10^8$ (by the Bozorth treatment of the magnetic material), $A = 10^3\ cm^2$ (by the adoption of a loss-less superconducting transformer) and a SQUID noise density of $10^{-6}\ \phi_0/\sqrt{Hz}$ (by adopting the approach worked out by Carelli et al, 1985). With Raytheon's proposed values for the three parameters above, the required integration time is reduced to 10^4 seconds, a decrease of 20 orders of magnitude compared to the value computed by JASON. On the basis of these more optimistic evaluations, Raytheon performed a preliminary design of the magnetic interaction sensor, that is characterized by a target mass of 250 Kg, kept at 4°K inside a custom-made large cryostat. Figure 2 illustrates the proposed experimental set-up.

Figure 2

BLOCK-DIAGRAM OF MAGNETIC DETECTOR OF LOW-ENERGY NEUTRINOS



1. HIGHLIGHTS OF ACCOMPLISHMENTS

1.3 Magnetic Interaction Sensor (cont'd)

At the JASON review of the project on 7/10/87, Prof. F. Dyson reconfirmed his position on the magnetic interaction sensor (as spelled-out in JASON report already cited), consisting essentially in the recommendation that Raytheon refrain from embarking at this time in any costly developmental work on the magnetic approach. However, he does not object to the continuation of Raytheon R&D activity on critical issues concerning this sensor. He agreed that we should carry-out laboratory tests and verify experimentally the validity of our hypotheses about achievable μ_r (10^8 instead 10^3), achievable A (10^3 cm^2 instead of 1), and achievable SQUID noise density ($10^{-6}\,\phi_0/\sqrt{Hz}$ instead of $10^{-4}\,\phi_0/\sqrt{Hz}$, when the SQUID is loaded with the interaction target). After the JASON review, Raytheon has planned, with DARPA concurrence, reduced-scope laboratory tests, to be conducted with a 25 Kg interaction target (in lieu of the full-scale 250 Kg version) coupled with a superconducting transformer to the pick-up coil of the SQUID, and housed, together with the SQUID, in a small-size, off-the-shelf, 4°K cryostat. This laboratory work on the magnetic interaction sensor does not actually represent a totally new approach for Raytheon. In the first year of project activity (as reported in our Quarterly Reports) Raytheon had subcontracted to FERMILAB the conduct of laboratory tests on the most important of these critical issues: does the noise density of the SQUID increase when its pick-up loop is loaded by high permeability material, and how much? FERMILAB had started performing lab measurements with a 1 Kg supermalloy, but they could not continue and complete the measurements, because of intervening higher priorities (the starting of their developmental work on the superconducting supercollider, that got approved in the meantime by DOE). Now we will have the opportunity of completing these tests, and

1.3 Magnetic Interaction Sensor (cont'd)

extending them to include the other two points of contention: maximum achievable permeability and maximum achievable collecting area; these two points were not a part of the FERMILAB assignment.

Should these laboratory tests (that we plan to carry out as a part of the follow-on contract just awarded to Raytheon by DARPA/AFOSR) confirm the promise, Raytheon will apply for extra funds to construct the full-scale version of the magnetic sensor.

1.4 Superheated Superconducting Colloid (SSC) Calorimeter

Because of lack of funding (and not because of lack of long-term promise) work on this approach was suspended on September 30, 1986 (as we reported in our Quarterly Reports). Until the cut-off date above, the related laboratory activity, performed under subcontract by the University of British Columbia (UBC), Vancouver, BC, Canada, had been successful. The most notable of the accomplishments was the successful conduct of tests using the experimental arrangement of Figure 3, that measured the response of a colloidal dispersion of 10^4 tin grains (of 5 μm radius) to the gamma-rays (93 KeV photons) radiated by a Ga^{67} source. The tests were carried out at 2.2°K, with a superimposed magnetic field of 310 Gauss. The temperature was about 50 milli °K below the superheating value. A copper block was used to filter the source: when placed over it, it absorbed the majority of the 93 KeV photons. Photon absorption and individual grain flips were expected to lead to abrupt changes in the SQUID output, and we could indeed clearly demonstrate such flipping when the grains were illuminated by the 93 KeV

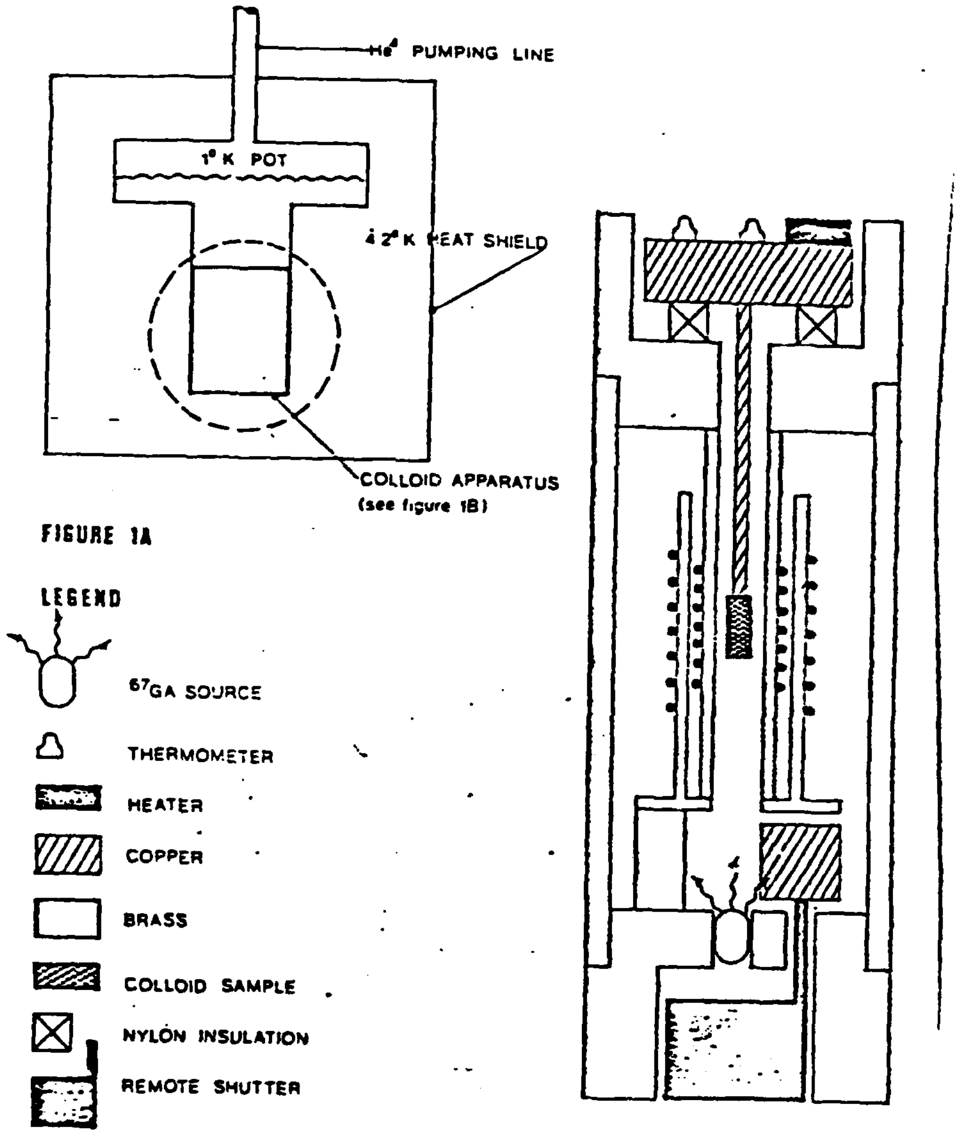


Figure 3

Experiment set-up used in testing the response of a colloidal dispersion of 10,000 tin grains to the gamma-rays radiated by a Ga^{67} source

1.4 Superheated Superconducting Colloid (SSC) Calorimeter (cont'd)

photons. When the copper filter was in place, a strongly reduced flip rate was observed (the residual flip rate was due to leakage of high-energy gamma rays through the copper block). The Quantum Detection Efficiency (QDE) of the sensor was estimated to be as high as 80 to 90 %.

The above results did show that the principle of a SQUID read-out SSC calorimeter is experimentally realizable within the current limits of technology. The high QDE for relatively large gains (R = 5μm) at T = 2.2°K suggest that slightly smaller grains, say R = 3μm, at T = 0.05°K (dilution refrigeration) may be sensitive to energy deposition of a few hundreds electronvolts. Thus our *preliminary experiments confirm* that SSC may detect neutrinos scattering off of the nuclei. With improved (DC-SQUID) electronics we see the possibility of a multi-SQUID read-out of a few-hundred grams SSC detector of neutrinos emitted by a nuclear reactor.

However, to undertake such a test will require several substantial improvements on the experimental set-up:

1) It will be necessary to improve the signal-to-noise properties of the electronic read-out to enable the read-out of bigger samples consisting of slightly smaller grains. Considerable advance in this regard will be achieved through the use of a DC-SQUID, instead of the RF-SQUID which was used at UBC.

1.4 Superheated Superconducting Colloid (SSC) Calorimeter (cont'd)

2) It will be necessary to improve the quality of the granulated detection medium in the SSC. Slightly smaller grains with high uniformity of grain size and spacing are required to improve QDE and to minimize the field-dependent temperature.

3) Further calibration of the detector is necessary, especially the study of QDE for different size grains. The irradiation tests at lower temperature (dilution refrigerator) are crucial.

It was judged by the project that it would take at least two years of hard work on the SSC calorimeter, for this sensor to be ready to perform a neutrino detection attempt. Because of the funding and schedule limitations of our project, and owing to the new emphasis on the verification of Prof. Weber's claim that he detected the radiation pressure of low-energy neutrinos, there was no other choice but discontinue (at least temporarily) the work on the SSC calorimeter. In follow-on efforts, we will again look at the possibility of resuming, at least in a modest funding approach, our work on the SSC.

1.5 Other Approaches that were Briefly Investigated by Raytheon

1.5.1 The Neutrino/Superelectron Interaction

At the beginning of our work, in Summer 1985, we briefly investigated neutrino/superelectron interactions, based on the suggestion by Stodolsky (1975) that a flux of neutrinos exerts a torque on the spins of electrons, which is linear with the weak interaction constant,

1.5 Other Approaches that were Briefly Investigated by Raytheon

1.5.1 The Neutrino/Superelectron Interaction (cont'd)

and is additive over the particles, so that in a bulk material, a global effect should be present and could be detectable. Our principal motivation in studying the Stodolsky effect on superconductors stemmed from the very low energy value of the superconducting gaps (about 1 milli eV). Reasoning in a qualitative way, the torque on the spins of superconducting electrons could possibly flip their orientation, leading to the destruction of Cooper pairs, which are formed by electrons having opposite momenta and spins. A preliminary analysis showed that the breaking parameter goes as h^2, where h is the potential energy acquired by an electron in a flux J of neutrinos ($h = \pm\sqrt{2}\,\frac{G_F}{c}\,J$, with c = velocity of light). With achievable values of J, we found that less than 1 pair/cm^3 is broken in a superconductor. This finding was rather discouraging, and we decided to discontinue the feasibility analysis for this approach.

1.5.2 The Silicon Bolometer

This approach was proposed by Cabrera, Krauss and Wilczek in 1984-1985. It consists of measuring the temperature changes in a slab of crystalline silicon, due to the elastic scattering of neutrinos, off the electrons in the slab. By keeping the slab at dilution refrigeration temperatures (in the range 1 to 10 milli °K) measurable temperature changes are expected to occur in macroscopic amounts of material,

1.5.2 The Silicon Bolometer (cont'd)

even for low-energy neutrinos ($\leq$0.41 MeV). According to the proposers, this new detector is also suitable for low-energy neutrino interactions that involve coherent nuclear elastic scattering. In a later paper, these authors (1986) identified a mechanism potentially more advantageous than strict bolometric detection: the detection of ballistic phonons that would give useful signals from neutrino scattering and could be detected with SIS tunnel junctions or other superconducting devices.

Through the consultantship to our project of Prof. Krauss and Prof. Wilczek, we kept abreast of the bolometer developments. However, while our activity was progressing, we felt the urge to limit the number of alternatives under investigation, and to investigate more thoroughly the fewer alternatives left rather than covering a broad field of possibilities. Then, we received from DARPA/AFOSR the additional task of performing the experimental verification of Prof. Weber's claim. When this happened, it was impossible to maintain even a minor effort on the silicon bolometer.

2. CONCLUSIONS AND RECOMMENDATIONS

While the ultimate objective of the program remains the detection of low-energy neutrinos, several developments have occurred during the 28-month program performance, that have required readjustments of both tactics and strategy on how best to achieve this ultimate objective. Raytheon has published, in the course of the project, eight Quarterly Reports (the first dated 15 September 1985, and the last 15 June 1987), and these reports provide a detailed record of the rationale and the specific circumstances that have characterized these readjustments.

The consequence of all this has been a down-grading of the short-term ambitions and goals of the project: we no longer aim at detecting neutrinos with instruments characterized by the best sensitivity that present-day technology can provide (for instance working at 4 milli °K). We now aim only at verifying, with more modest instrumentation operating at 4°K, whether or not Prof. Joe Weber detected neutrinos with his simple, room-temperature instruments, designed on the basis of his theoretical expectation that an enormously large momentum transfer (a total momentum transfer) takes place from low-energy neutrinos to a sapphire crystal target.

Was the above decision a wise one? Should we see these developments as favorable to the project's interests and the ultimate objective of our activity? Raytheon's answer is a qualified yes. If our current tasking is just an initial step toward the final aim, and if graduality toward this aim is the underlying philosophy, we could not agree more. The Sponsor must recognize, however, that having reduced the initial sensitivity goals of the instrumentation has reduced the chances of success, and should be ready to continue its sponsorship, even if these initial

2. CONCLUSIONS AND RECOMMENDATIONS (cont'd)

tests do not detect neutrinos. This is the reason for qualifying our answer above. We see these initial tests as an opportunity to "flex our muscles", and show that we are able of achieving the theoretical limit that characterizes the specific instrument we are working with. We fully agree that no attempt should be made toward the 10^{-18} dynes goal at 4 milli °K, until we show that we know how to achieve the goal of 10^{-8} dynes at 4°K.

Our recommendation, to conclude, is that the Sponsor express concurrence with Raytheon's position above and make plans for program phases beyond the one reported here, and beyond its immediate follow-on that has been already awarded to Raytheon.

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