# Space Radiation Monitoring System

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AS THE Aeromedical Field Laboratory, Holloman Air Force Base, New Mexico continued investigation of cosmic radiation levels above most of the earth's atmosphere, it became evident that a system to measure levels of all biological significant damaging ionizing radiation would soon be necessary for planned animal and human space flight. Nuclear physicists were concerned with measuring levels of all ionizing radiation in space, but they were not concerned with the energy range of radiation that was only damaging to living tissue. The measurements that the radiobiologist required had to be more precise.

Until a tissue equivalent instrument that accurately assessed biologically damaging radiation was developed, identification of individual particles and their energy was imperative. Extremely energetic particles lose very little energy as they pass through living tissue.

The development of a device capable of accomplishing this task appeared to be formidable, therefore an exhibit was prepared for the procurement of a feasibility study contract and was awarded to Lockheed Missile and Space Division in 1959. The energy regions were selected by determining mathematically the penetrability of the various particles into living tissue. The formula used were extracted from Nuclear Radiation Physics Text, Lapp and Andrews [1] and applied to the density of living tissue. After the final report of this study [2] was reviewed, plans for the procurement of instrumentation were formulated, a technical exhibit [3] was prepared, proposals [4] were submitted and evaluated, and a contract was awarded to the Western Development Laboratory, Philco Corporation, Palo Alto, California.

The contract specified that the instrumentation will provide for categorization of particle intensities into the following groups:

a. Electrons: 0.3-20 MEV, 20 MEV
b. Neutrons: Thermal-5 MEV
c. Gammas: 0.02-0.25, 0.25-1.0, 1.0 MEV
d. Protons: 8-16, 16-36, 36-90, 90-240, 240 MEV
e. Alphas: 32-64, 64-150, 150-360, 360-960, 960 MEV
f. Heavy nuclei: Two groups, with ranges in CsI either below or above 20 gm/cm$^2$.

In addition, accurate dose information within the following limits will be accommodated:

a. Dose rate, from slow low-Z particles: up to 4 x $10^4$ rem/hr
b. Dose rate, from fast low-Z particles: 10 mrem/hr to $10^3$ rem/hr
c. Dose rate, from neutrons: 20 mrem/hr to 2 x $10^3$ rem/hr
d. Dose rate, from gammas: 10 mrem/hr to $10^3$ rem/hr
e. Time integrated dose: 3 x $10^{-6}$ to 3200 rem.

The time resolution of the dose measurements has been chosen as one second.

The choice of RBE factors is arbitrary, and changes in RBE assignments require simple circuit adjustments. A change in the time resolution of the dose measurement or a change in the degree of refinement in energy resolution of the different particle types can be achieved by a deletion or addition of units of circuit types present in the system, resulting in a minor change in system weight, power, and reliability.

A breakdown of weights, volumes and average power requirements for the elements of the system are shown in Table I:

TABLE I. SYSTEM SPECIFICATIONS

| | Weight (Pounds) Ave | Power (Watts) | Volume (Cubic Inches) |
|---|---|---|---|
| Telescope | 11 | 1 | 125 |
| Neutron Detector | 6 | 1 | 160 |
| Logic Circuitry | 5 | 1 | 250 |
| Binary Storage and Commutator | 20 | 7 | 1000 |
| High Voltage P.S., Battery Regulator | 5 | 0.6 | 55 |
| Recorder | 4 | 0.8 | 115 |
| Transmitter | 1 | 0.5 | 520 |
| Batteries | 10 | — | — |
| Total | 62 | 11.9 | 2500 |

Other features that were required for this system are:

Semiconductor Design—Electronic circuitry has been designed around silicon semiconductor elements rather than vacuum tubes or germanium semiconductor elements because of the significant advantages to be gained in reliability over a long lifetime. A similar motivation has led to reducing the number of detectors to a minimum. Two have been found adequate to fulfill the system requirements.

Digital Techniques—Digital data storage, telemetering, and processing techniques have been chosen rather than analogue technique because of the significant reduction in on-board power consumption which can be realized with no associated reduction in the accuracy of the data received on the ground.

Data Recording—Since a vehicle in an earth orbit of a 600 mile altitude is accessible to the ground station for only 5-10 per cent of the orbit period, an on-board tape recorder has been included in the monitoring sys-

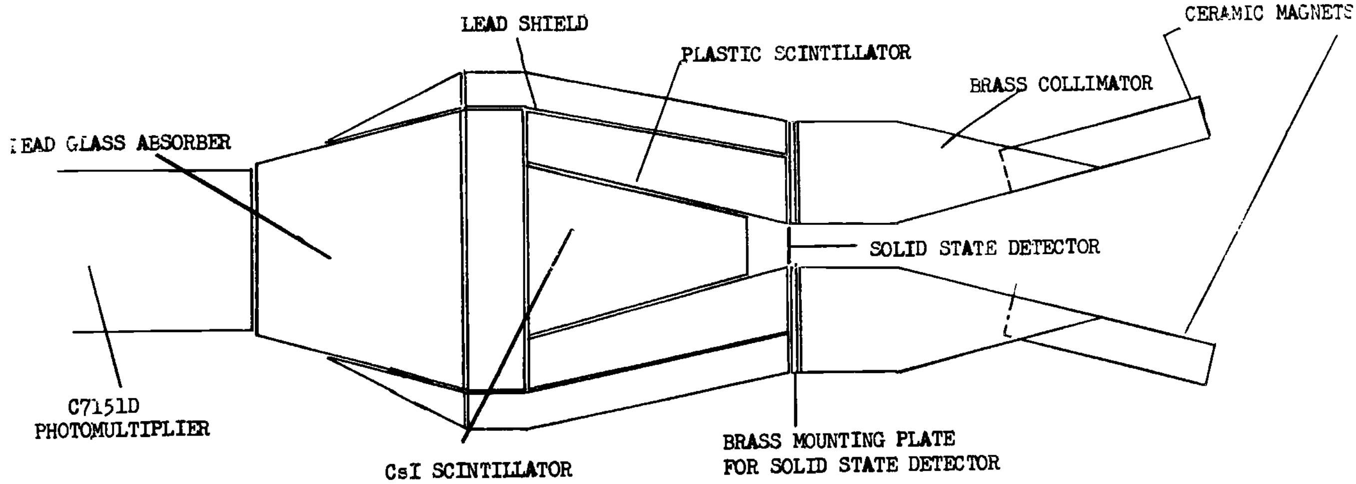


Fig. 1. Charged particle and gamma detector.

tem. A record-to-play-back speed ratio of 1:18 and an expected life of 6 months have been chosen as appropriate recorder characteristics for a 600 mile orbit.

Detectors—The proposed detector for charged particles and gamma rays is shown in Figure 1. A p-n junction detector and CsI crystal form a charged particle coincidence telescope having an aperture defined by the brass collimator. The brass collimator, lead shielding, and lead glass light pipe protect the inner materials against excessively high counting rates to be expected during solar flare occurrences. The plastic scintillator material to the right of the base of the CsI crystal becomes part of the telescope for particles sufficiently energetic to penetrate the CsI crystal. The magnets attached to the brass collimator prevent very soft electrons from reaching the p-n junction and causing errors in the analysis of higher energy particles.

As a gamma ray detector, the p-n junction and the plastic scintillator completely enclose the CsI scintillator and provide similar discrimination against all charged particles. A pulse made in the CsI scintillator, not in coincidence with a pulse in either the junction detector or the plastic scintillator, is interpreted as being produced by a gamma ray. The brass collimator, lead shield, and lead glass light pipe reduce the geometric factor of the instrument to low energy auroral gamma rays and reduce the gamma counting rate to a level within the capabilities of the circuitry.

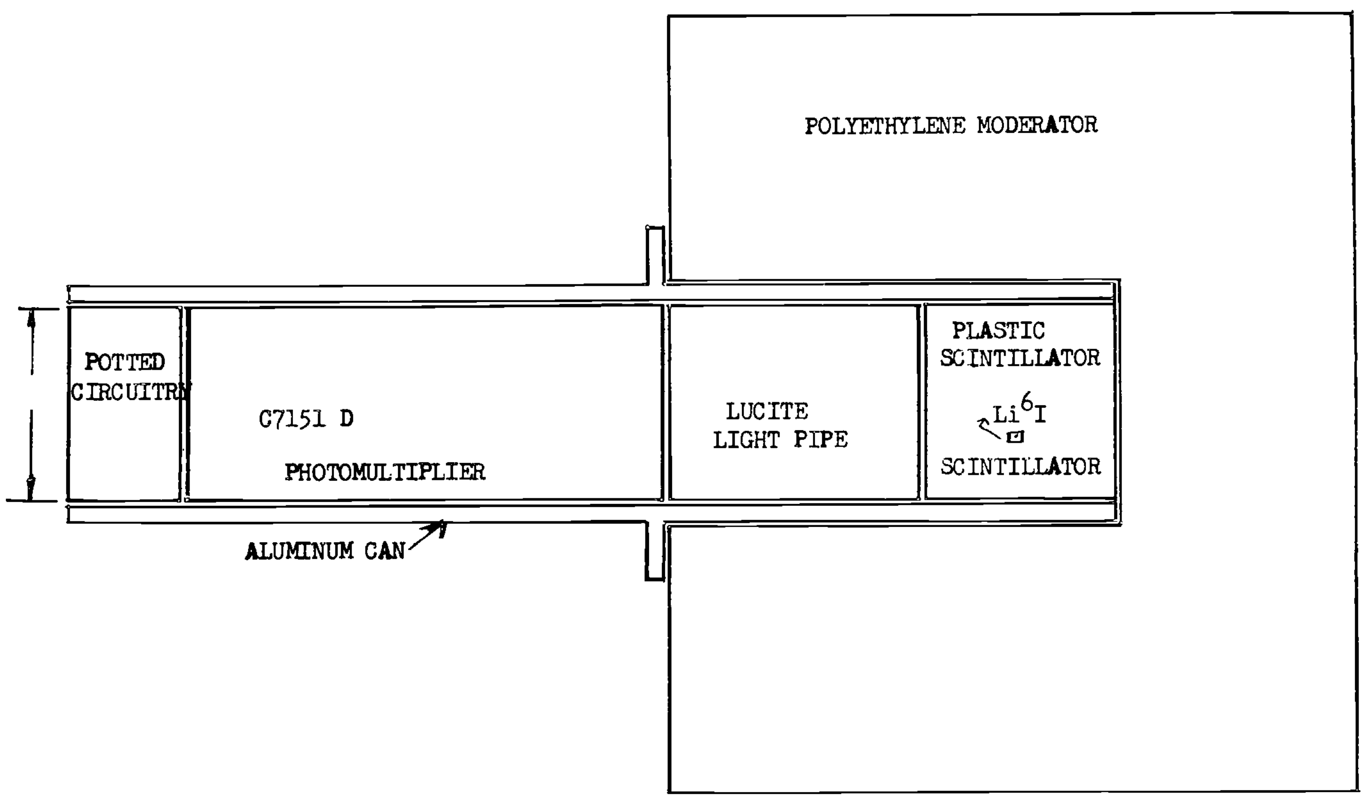


Fig. 2. Neutron detector.

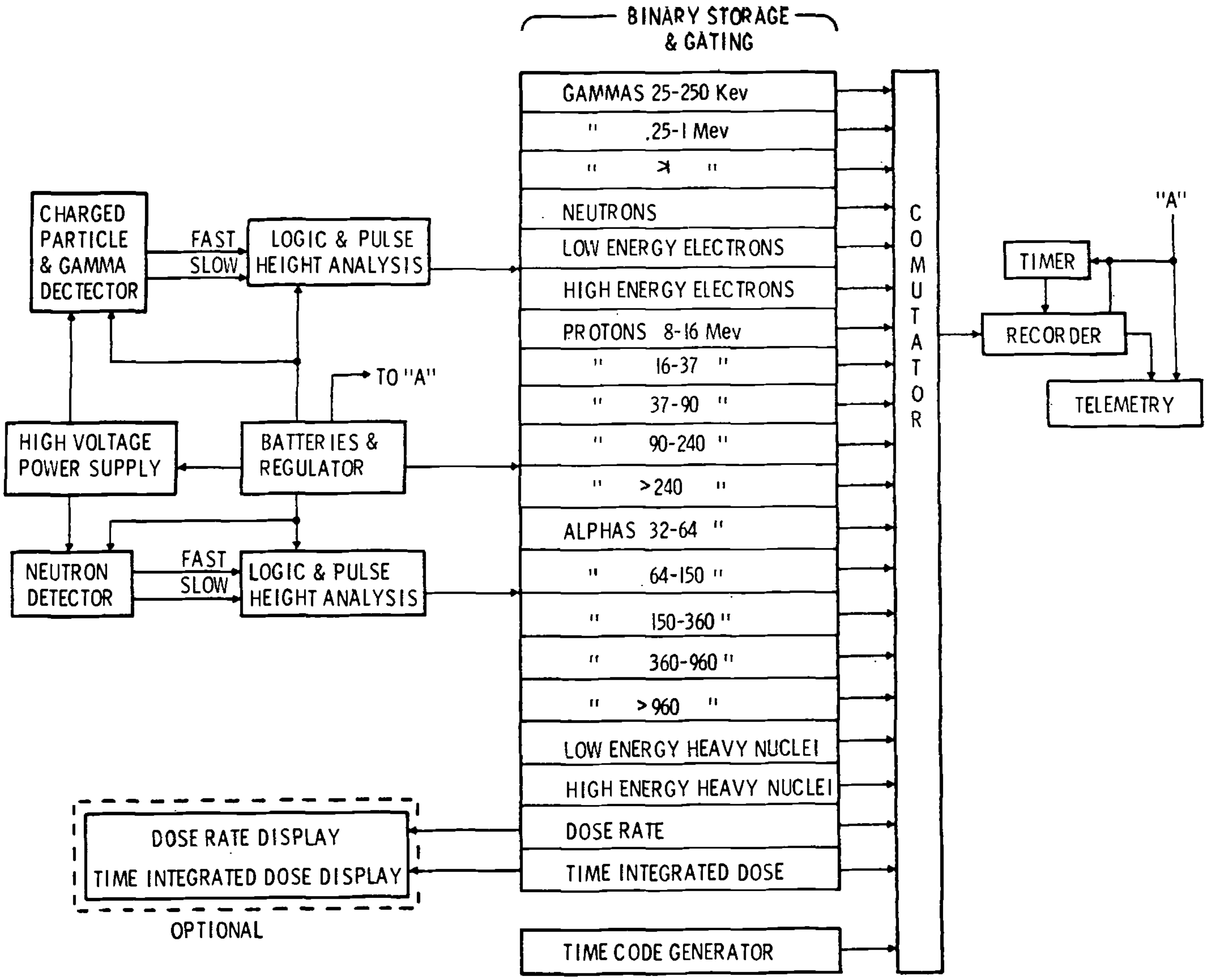


Fig. 3. Space radiation monitoring system functional block diagram.

Neutron Detector—The neutron detector is shown in Figure 2. The plastic covering and lucite light pipe moderate incident neutrons up to 5 MEV with a fairly uniform efficiency. The li I scintillation crystal responds to a neutron flux through the $(n, \alpha)$ reaction. The plastic scintillator surrounding the iodide scintillator provides discrimination against all charged particles. A pulse from the iodide scintillator, not in coincidence with a plastic scintillator pulse, is interpreted as being caused by a neutron if its pulse height is appropriate to that of the $(n, \alpha)$ reaction. The iodide crystal size has been chosen sufficiently small that an incident gamma ray interacting in the iodide crystal cannot make a pulse which could be confused with that made by a neutron.

The block diagram of the entire system is shown in Figure 3 and the actual unit flown on balloon flights is shown in Figure 4.

It can be concluded from the foregoing that the space radiation problem was not as insurmountable as once assumed; however, it became immediately apparent that the answer to space radiation monitoring probably was in the development of a totally solid state radiation detection system which would be more efficient, lighter, less bulky and more rugged. Such a system is now being developed and will be delivered in calendar year 1963 under an Air Force contract that originated at the Aeromedical Field Laboratory, Holloman Air Force Base, New Mexico by the author and Captain Rudolf H. Hoffman, now assigned to the Biophysics Division AFSWC, Kirtland Air Force Base, New Mexico.

## REFERENCES


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2. Lapp, and Andrews: Nuclear Radiation Physics (Text). Second Edition, 1956.
3. MDW-61-R & D-23—Space Radiation Monitoring System Purchase Request. AFMDC Holloman Air Force Base, New Mexico, December 1960.
4. WDL—TP 455, Proposed Space Radiation Monitoring System, January 16, 1961.

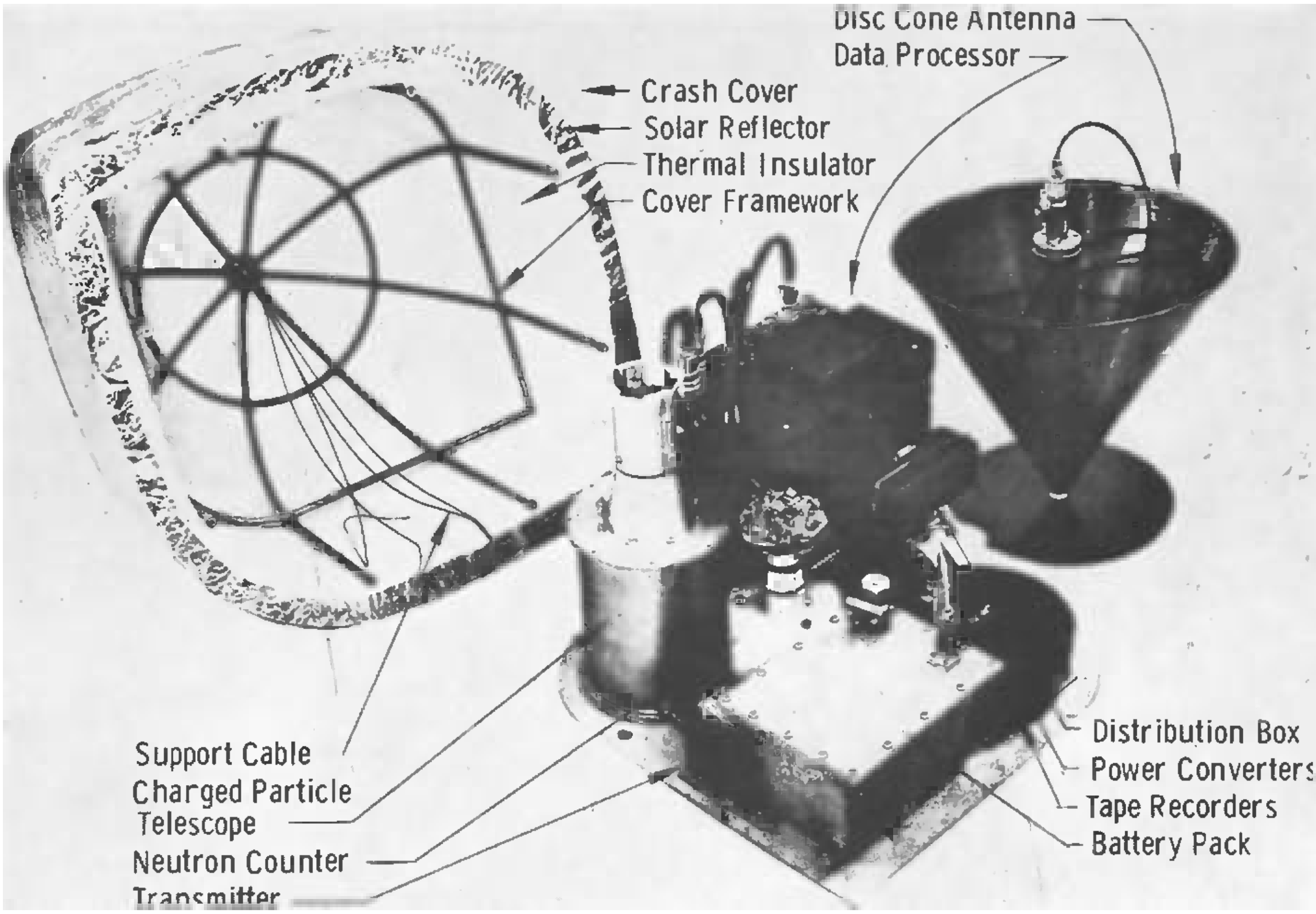


Fig. 4. Space radiation monitoring system, equipment.