THE GSFC COSMIC RADIATION EXPERIMENT FOR THE PIONEER F/G JUPITER MISSION

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This experimental hardware is probably the Center's best example of an extremely light-weight, low-power design for severe environmental conditions. In fact, comparing other experiments of our own and others on IMP-I and H, we have succeeded in more than a factor of three reduction in weight and power. Flight performance is excellent, and costs were not really affected.

The first figure shows an external view of the experiment. The red-tag items and carry-handles are still on in this photograph. As discussed in an earlier paper, this experiment has three sensor telescopes for the detection of nuclear particles. The lowest energy sensor is contained within the Pb-Al shield, obvious in the center of the figure. A higher energy sensor is shown protruding through the side wall. The highest energy sensor system can't be seen; it is mounted internal to the package at 45° across the front corner at the top. The individual elements within a sensor are silicon discs (actually reverse-biased, totally depleted diodes) with areas from 50 mm^2 to 10 cm^2 and thicknesses from 50 microns to 2.5 mm. Our lowest energy thresholds are at 50 keV and range to 5 MeV for electrons, 800 MeV for protons, 600 MeV/nuc for helium and to 200 MeV/nuc for ions through neon. We are able to identify particles and often distinguish isotopes. We monitor a great many logical count rates with respect to time and sector of spacecraft spin.

Weight was the major problem. With just over one kilogram in the lowest energy system with the Pb shield and a total weight of approximately 3.2 kilograms, that leaves just over two kilograms for all else. All else includes more than 8000 discrete electronic components per system; more than 50,000 transistors – largely in medium and large scale integrated circuits; the other sensors; low and high voltage power supplies; the data system; and the mechanical system. This was all to be subjected to a hard ride, since our qualification vibration was to 40 g's.

We were able to accomplish this successfully using less than 10 percent of the total weight for the mechanical system. Both the baseplate and the top plate you see are aluminum honeycomb with 0.3 mm (0.012 in) skins. The top is only 3.2 mm (1/8 in) thick. The side panels are magnesium trusswork with 5-mil aluminized mylar bonded as the skin. The circuitry inside was stacked like a sandwich, cross-tied to the side trusses and to each other. Each electronics layer was interleaved with a sheet of flexible, compressible polyester-urethane foam for vibration damping.

Figure 2 shows a top view of one of the circuit boards for the linear electronics systems. Note the technique used here – daughter boards (15 mm by 30 mm) mounted on-edge on

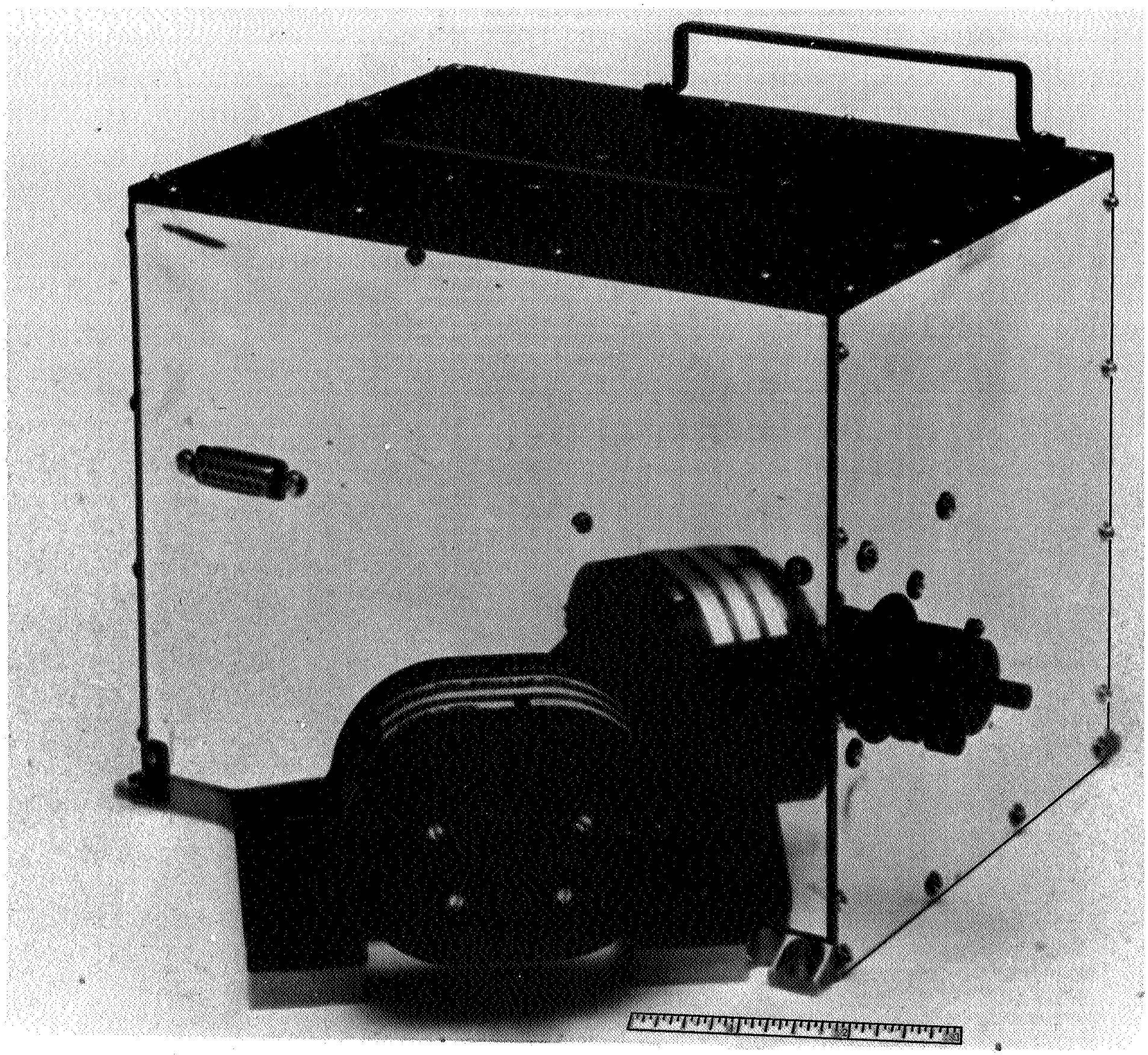

Figure 1. GSFC cosmic radiation experiment for the Pioneer F/G Jupiter mission.

the mother board or interconnect board. Again the polyester-urethane foam for damping is visible. There would also be a large sheet above and below this board in the stack-up.

You can see another lightweight technique at work here also. Many of the daughter boards are hybrid, thick-film circuits on ceramic substrates. Note the chip capacitors, discrete diodes in the glass dot packages with ribbon leads, and dual transistors in ceramic pacs (TO-80). You can't see special tantalum capacitors in rectangular plastic packages with alloy 180 leads. The overall construction also leads to a very low magnetic signature as required for the Pioneer mission – in our case approximately 1γ at 45 cm and is mostly due to integrated circuit packages.

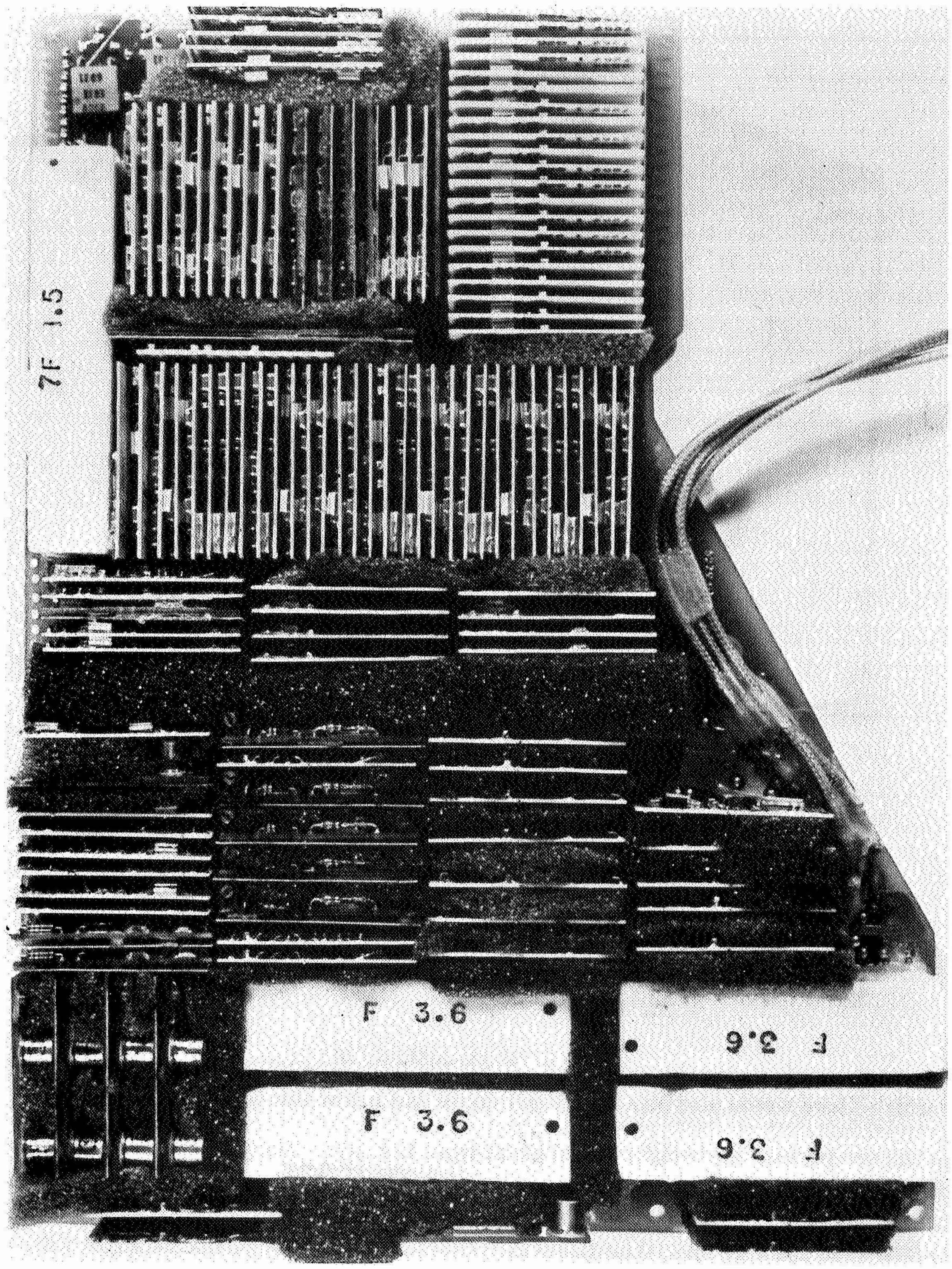

Figure 2. Circuit board for a linear electronic system.

The third figure shows front and back views of a daughter board from the P-channel MOSFET data system. These are the GSFC family of custom MOSFET bugs made by American Micro Systems Incorporated and used in Imp, Pioneer, and Helios to date. The welded interconnect uses gold-plated alloy 180 ribbon wire and nail-head terminals of the same materials. The relative simplicity of the interconnect is obvious. It's really great when you can have a powerful data system of greater than 50,000 transistors, which weighs less than one-half kilogram and uses less than 0.75 watt.

The total power for the experiment is 2.3 watts and this is very low considering all the electronics. At the beginning I mentioned that we were at a factor of more than three below previous competitive designs. This was accomplished by using low power design techniques everywhere: 100 microamp collector currents in bipolar transistors, for instance, and power strobing those circuits was not needed 100 percent of the time.

Time doesn't allow, but further severe constraints were imposed by the temperature range and the radiation environment including the spacecraft RTGs and the Jovian radiation belts. The experiment is functioning well and the date of closest approach at Jupiter will be December 4, 1973.

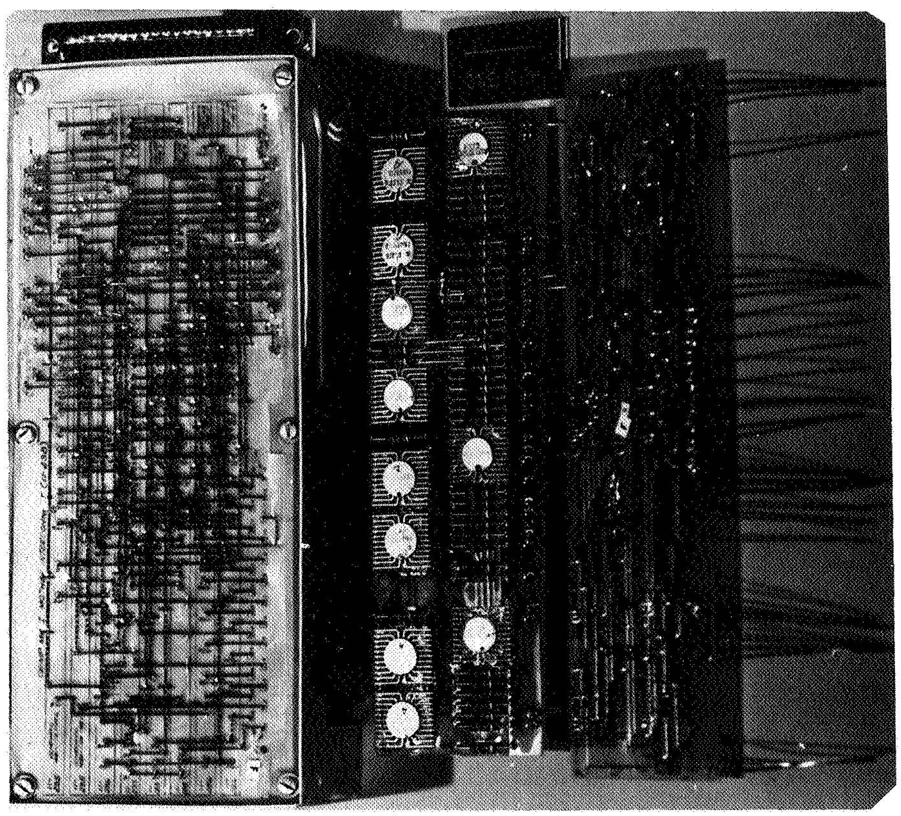

Figure 3. Front and back views of a daughter board from the P-channel MOSFET data system.