THE ONBOARD PROCESSOR ON OAO-3

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Figure 1 is a picture of the onboard processor, or OBP, which was developed here at Goddard by the Spacecraft Data Management Branch. This computer was developed specifically for flight applications, and I would like to address myself to the first application of this computer on OAO-3, or Copernicus, which was launched on August 21 of this year.

Before talking about the boxes, I would like to mention that the computer was turned on the day after launch, and has been executing instructions at the rate of 2½ billion a day. We have executed 2×10^{11} instructions since launch. This is an 18-bit, parallel, medium-scale computer. The four boxes on the right are four memory units. Each memory unit is 4096 words. There is a central processor unit, an IO unit, and off to the left is the power converter for the computer. It is a 40-watt machine. Its capability lies somewhere between that of an XDS-920 and 930, to compare it with the capability of a ground computer. It has a ten-microsecond add time and a hardware multiply/divide capability.

In interfacing the computer on the OAO spacecraft, we could only connect to signals which were on connectors, but we were still able to gain access to the spacecraft telemetry, and

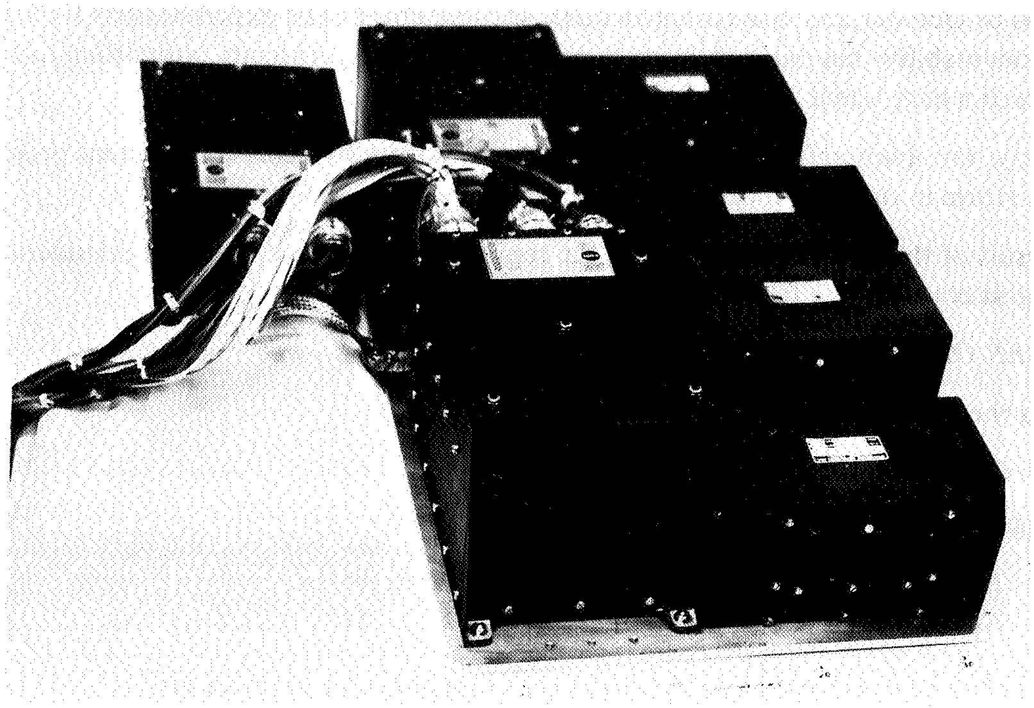

Figure 1. The OAO-3 onboard processor (OBP).

so have access to all spacecraft status data. There are four analog signals out of the computer, three of which control the fine wheels and one controls the power regulator unit on the spacecraft. The computer can also issue commands, and therefore, the computer has powerful interface with access to all spacecraft telemetry and the ability to send any OAO command.

Next, I will discuss the applications of the computer, but I wanted to say in passing that the design of this computer was tailored for space applications and it is a very worthy design. Such features as hardware memory protect, the ability to load and dump the memory without program execution, and the very powerful interrupt structure have proved useful and made it easy to program. These features have increased its utility as well as its security.

There are three main application areas: commanding, data processing, and as in Figure 2, worker programs, or subsystem programs. In the commanding area, the hard-wired command handler on OAO stores 256 commands. One day's operation requires the execution of about 1000 commands. The computer provides an additional 1024 command storage capacity, so that the spacecraft can be loaded with commands once a day, sending 256 to the wired command handler, an additional 1024 to the computer, and then in the back orbit the computer transfers commands in blocks of 128 to the hard-wired command handler. This has reduced the need for ground station coverage for OAO. Commands are loaded at only Rosman. There is no need to load commands at remote sites and ground station requirements have been reduced by 40 percent with this feature.

COMMANDING

- AUXILIARY COMMAND STORAGE
- SCRATCH-PAD COMMAND STORAGE

DATA PROCESSING–STATUS BUFFER

- DUMPED ONCE/ORBIT
  - OBP COMMAND ACTIVITY
  - S & C MODE CHANGES
  - ATTITUDE-FIX DATA FOR GROUND
  - POWER SNAPSHOTS AT D/L/D
  - PERIODIC SNAPSHOTS
  - ALARMS
- VALUABLE FOR TRENDS AND ALARM

Figure 2. OBP applications.

There is also what is called a scratch-pad command storage. This essentially augments the command execution of the command handler on the spacecraft. Commands may be sent to the computer rather than being sent to the command handler. The computer imitates the command handler, in that it compares the execute time of the command with the spacecraft time. When a time equality exists, the computer formats the command as though it were coming from the ground and sends it to the command handler for immediate execution. This affords the interleaving of commands from preprogrammed command memory with the computer. It is a very important feature which has been used successfully many times in orbit.

The scratch command feature is used for engineering tests in which the engineering test commands are loaded in the computer and it performs the engineering test and does not interfere in any way with normal experiment operations. Also, it is a good emergency feature so that should a problem be detected during a ground station contact, corrective commands which must be issued in the back orbit can be sent to the computer and it will execute them in the back orbit without interfering with the normal command memory load.

In the data processing area, there is a 320-word block of memory, which is continually stored into during the back orbit of the OAO. In there, the computer records its command activity, and stabilization and control mode changes, some attitude data for the ground to assist in attitude determination of the spacecraft, and snapshots of the power system at dark-light and light-dark transitions.

The 320-word block of memory has a very good synopsis of the condition of the spacecraft, and also a list of the significant events of the spacecraft in the back orbit. This data is dumped once an orbit, and a realtime printout is given to the ground controllers. It has virtually eliminated the need for tape recorder playback and analysis which has a two- to three-week turnaround time.

In the subsystem area we were fortunate in having access to all telemetry data in the computer, because this contains data from all the subsystems on the spacecraft, coupled with the ability of the computer to send any spacecraft command. With that interface, the computer is able to perform a broad range of functions in the various subsystem areas (Figures 2 and 3).

For example, in the case of the Princeton Experiment Package spectrometer temperature control, the computer can provide a thermostatic function better than a thermostat, because even though it is a trivial function, the threshold is adjustable and the hysteresis can be diminished as much as thermodynamics allows.

Heat pipe control is a program which turns heaters on and off to maintain a constant power to the bay in which there are heat pipes on the spacecraft. It is a complicated algorithm. The computer duty cycles the heaters to maintain a constant power, and all that's needed is a program to do this function. The interface allows it and it would require considerable hardware to do the function on the spacecraft.

WORKERS (COMMANDING)

- THERMAL
  - PEP SPECTROMETER TEMP CONTROL
  - HEAT PIPE CONTROL
- POWER
  - MAX POWER
- S & C
  - HOLD WHEEL SPEED
- WORK-AROUND PROGRAMS
  - BST STAR SEARCH
  - FINE GUIDANCE BACKUP
  - RELIEF VALVE (GAS LINE)
  - UNDER VOLTAGE DETECT
  - SUN AVOIDANCE
  - I-STAR INSTABILITY

Figure 3. OBP applications (continued).

In the power area there is a max-power algorithm in which the computer controls the voltage regulator. The computer essentially sets the operating point of the array to maintain the maximum power from the array.

There are several workaround programs which will be called into use should that need arise. One of them, the undervoltage detect, is going to be committed to operations this week, because the level is adjustable if the function is done from a computer. It has turned out on OAO that the undervoltage level does not permit the optimum charging of the batteries, so the project is going to commit to computer operation of this point.

So we feel that the computer on OAO has enhanced ground operations, and has made them simpler. We feel that the computer has improved the performance of the spacecraft. And we feel that we have proved that a central computer on a spacecraft can do subsystem jobs in a cost and performance effective way.

MEMBER OF THE AUDIENCE:

Have you used the arithmetic unit portion of the computer?

MR. TAYLOR:

Yes. The heat pipe control program has been our main use. That is a complicated algorithm. We are multiplying, dividing – in fact, we do the logic in double-precision arithmetic.