the first two missions combined. Before returning to earth, the space shuttle had completed 129 orbits and had flown 5.3 million kilometres, 230 kilometres above earth. It was necessary to remain in space for an extra day than originally planned, owing to inclement weather at the landing site.

Columbia's *remote manipulator system extends outward from the earth in this view made from a TV monitor. The Canadian-built arm grips an instrument package lifted from the cargo bay. At bottom left is the tail assembly of the shuttle. In background is the earth, with slightly curving horizon diagonally across the photo.*

Tests started immediately

Throughout the flight the Canadian-built manipulator arm, which mimics the way the human brain controls arms and fingers, was put through a battery of tests.

The first tests were a series of high level twists, originally planned for the second mission that was curtailed after two days when *Columbia* developed fuel cell trouble. Once these tests were successfully completed, the Canadarm was tested for the cargo-lifting job it was designed to perform.

Operating from a station in the cockpit, Colonel Fullerton tested the device. The arm was first tried out for its manoeuvrability, hinged in the cargo bay, five times.

In the next four tests, the arm lifted a 160-kilogram plasma diagnostic unit designed to look at shock waves that ripple down the orbiter as it is bombarded by the highly-charged particles streaming towards earth on the solar wind. On two occasions the unit was only grabbed, picked up and then secured back in position. On the other two occasions, Fullerton manoeuvred the arm over a package of scientific instruments in the cargo bay, lowered it onto a grappling fixture and locked on with the crane's wire-snare hand. Flexing the spindly arm's metallic muscles he then lifted the payload from its berth, moved it around the cavernous bay and brought it high out of the cargo bay.

The tests were almost cancelled, owing to the malfunction of the wrist camera of the Canadarm which was to have aided Fullerton in guiding the arm's wire-mesh fingers to the plasma diagnostic package. Fullerton was able to complete the task using the camera mounted on the elbow of the arm, a pair of binoculars and a simulator in Houston. The efficiency of the elbow camera was of some surprise even to NRC scientists.

"At first we didn't realize just how much that elbow camera could pan and tilt," said Dr. Edwin Gantz, an NRC research scientist. "It can go almost full circle and a full-range of experiments were carried out."

Canadian engineers were especially pleased when their predictions, that it would only take the arm six minutes for rebirthing in these tests proved correct, despite the failure of the camera.

The test, in which Canadarm was to lift the 360-kilogram induced environmental contamination monitor, was cancelled owing to the failure of the cargo-bay and wrist cameras which were critical to the replacement and securing of this electronic sniffer.

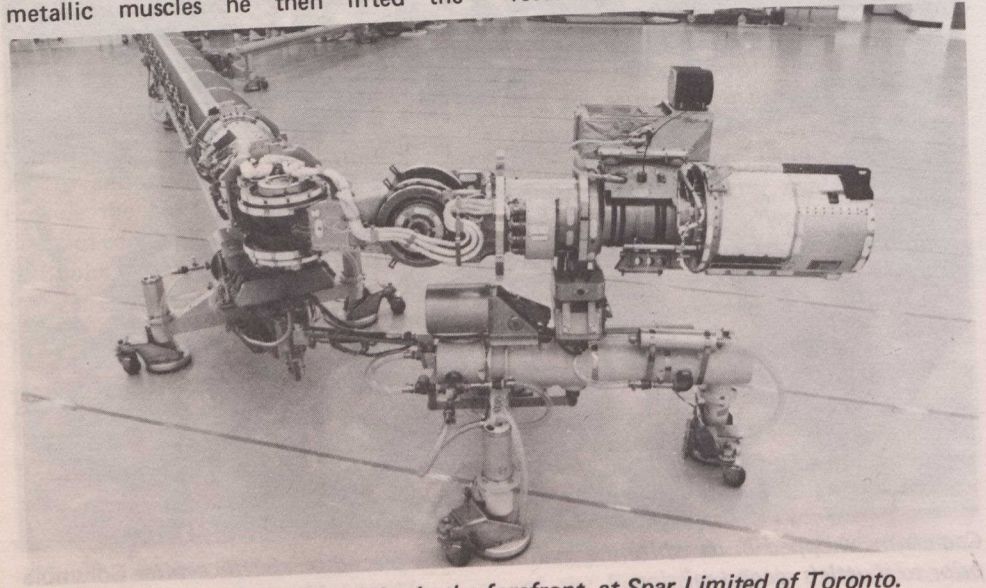
The sniffer was to measure the environmental contaminants released by *Columbia's* jets and protective heat-resistant tiles. Among the more potent compounds the sniffer was to look for was hydrogen peroxide — normal hair bleach — and monomethyl hydrazine, which is highly toxic when it reacts with water.

Canadian scientists, such as a team led by the National Research Council's, Dr. Ian McDiarmid, eventually hope to put the shuttle to work studying the sub-atomic particles in the earth's outer atmosphere. They need to know the extent of contamination from the orbiter that might interfere with the experiments.

For NASA the information is critical, as the pollutants might cloud optical lenses on satellites that the shuttle will be carrying into space during the next ten years.

During the mission *Columbia* and the Canadarm were put through three tail-to-

(Continued on P. 8)



View of Canadarm, with wrist joint in the forefront, at Spar Limited of Toronto.