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TO CATCH A COMET II

Technical Update on CAN DO

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Abstract

Since the presentation of "To Catch A Comet" was given at the last G.A.S. Symposium, many events have impacted the CAN-DO Comet Halley program. This paper summarizes the changes to the payload and its mission, including improvements in camera control and CAN-DO's participation in the "Halley Armada".

The System

The Astro-1 / CAN-DO payload is configured for widefield astrophotography in the visible and ultraviolet spectrum, under active astronaut control. Sealed with one atmosphere of dry nitrogen in a five cubic foot canister, four Nikon F-3 35 mm cameras with 250 exposure film backs photograph through a fused silica window protected by a motorized door assembly. Four lenses were chosen for the study of Comet Halley on STS-61E in support of the Astro-1 mission, a 200 mm / F2 ED, a 105 mm / F2.5, a 105 mm / F4.5 Ultraviolet Nikkor with a Schott UG-11 3000-3300 Å Ultraviolet filter, and a 58 mm / F1.2 . Kodak EES P800/1600 color film was selected based on extensive film tests for visible light coverage and Tri-X Pan 400 for its UV sensitivity.

Operation

All cameras would be fired simultaneously under GCD relay control (Fig-1). At about 30 hours M.E.T., GCD-B energizes the environmental systems, the camera control systems, and opens the enabled MDA. At the beginning of each window, when an object of interest is aligned with the shuttle's Z-axis, toggling GCD-C starts a five photograph series of varying exposure lengths. Each camera is controlled by its own

C-3

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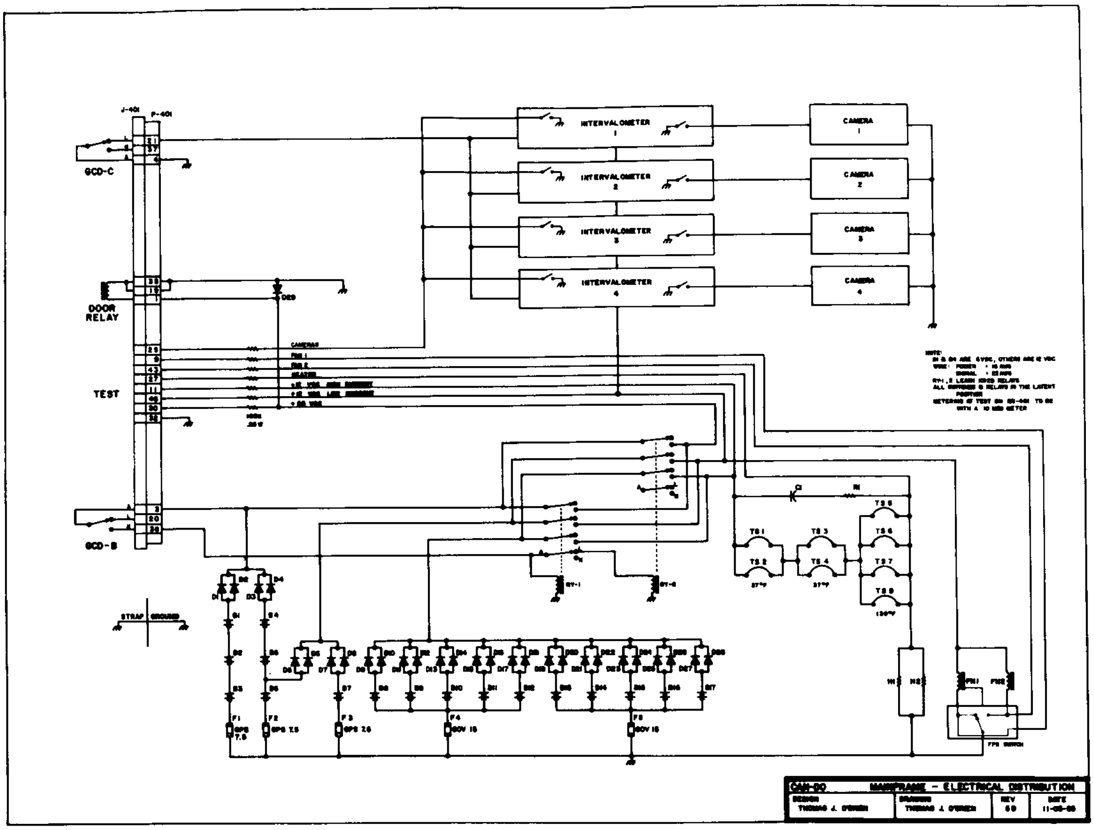

Fig-1

intervalometer which can be programmed for up to eight exposures selecting from ten exposure lengths before it resets to await the next "fire" command.

In an effort to extend CAN-DO's operational life to more fully support Astro-1, further testing was performed in cooperation with the Langley Research Center and the Goddard Space Flight Center. A full mission profile was "flown" in a thermal chamber to identify heat loss paths and improve on insulation since heat loss was the prime mission limiting factor. Additional G-10 thermal barriers were added to conductive heat paths and a conformal jacket of Rubatex EVA closed-cell foam insulated the payload interior. Testing now indicated CAN-DO's mission life should exceed 150 hours. While new thermal, EMI, shake and vibration tests were being conducted, a new window was being manufactured by Muffoletto Optical Co. in Baltimore, Md. under the supervision of Goddard with the support of the Astro-1 project. This new optically clear 0.92 inch fused silica window would allow a full one atmosphere Nitrogen seal while allowing both visible and ultraviolet photography. Delivery was scheduled for January 2nd which allowed time for flight certification testing to meet CAN-DO's mid-January integration at the Goddard Space Flight Center. After further testing and integration, CAN-DO was shipped to the Cape for its January 26th date in the OPF with Columbia.

With news of the Challenger disaster and the hold placed on further operations, consideration was given to operating the payload cameras piggy-backed on a tracking telescope similar to the ones used for the film tests. During this time, it was learned that the N.A.S.A. / Ames Research Center Medium Altitude Division would deploy their two airborne observatory aircraft to the Southern Hemisphere in March and April to study Comet Halley, several IRAS objects, and others unavailable for study further north. After technical proposals, numerous drawings, and many test results were exchanged with the Ames staff, Astro-1 / CAN-DO joined the Kuiper on its Southern Deployment to Christchurch, New Zealand.

The Kuiper

The Ames Research Center - Gerard P. Kuiper Airborne Observatory is a modified Lockheed L-300 Starlifter (Air Force C-141A) with a 36 inch infared telescope mounted in a cavity forward of the wings. This telescope and cavity (Fig-2) is open to the outside world for unobstructed infared astronomical observations.

The telescope itself floats on an 18 micron film of air around a 16 inch Invar air bearing mounted on four pneumatic vibration isolators. Rotating on its air bearing, the telescope can be mechanically elevated from 35° to 75° above horizontal. During an observation leg which is plotted to set the telescope azimuth, the autopilot maintains a pointing window within the ±2° cone-of-correction of the ADAMS tracking computer, even in moderate turbulence. Under normal conditions, pitch and yaw can be maintained within a few tenths of a degree. Pointing is referenced to azimuth, elevation, and line-of-sight gas bearing gyroscopes.

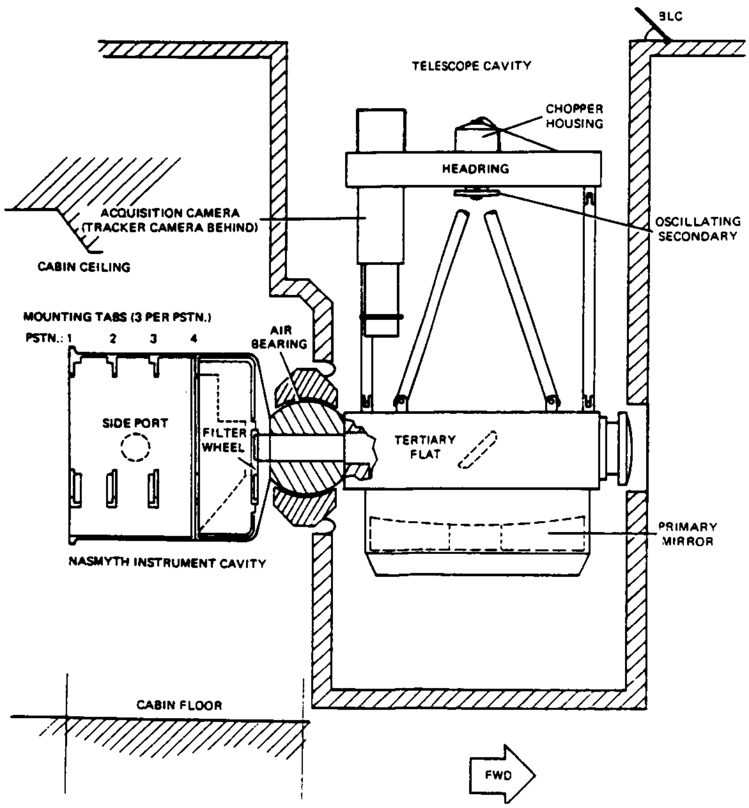

Fig-2

To begin an observation, the desired star field is located on the widefield acquisition television camera. After the star field is identified and centered, the narrowfield tracking television camera is locked on a reference target which provides tracking information to the computer controlled tracking servo system.

The System

Since the KAO would be studying Comet Halley on several flights during its stay in New Zealand, it provided the ideal tracking platform, well above most atmospheric water vapor and possibly with enough ultraviolet light for photography for the Astro-1 / CAN-DO camera system. The drawings supplied by Ames showed just enough room to mount two Nikon F-3's without the 250 exposure film backs, on the headring of the telescope (Fig-3). This location, however, introduced several problems. Instead of an internal canister ambient temperature of 0°C at one atmosphere, the cameras would be exposed to a 6 to 8 hour pre-flight pre-cool cycle at -50°C and a mission operating temperature of between -40 and -55°C at only 0.15 atmosphere. In addition, mounting the cameras on the face of the headring would expose them to some turbulence.

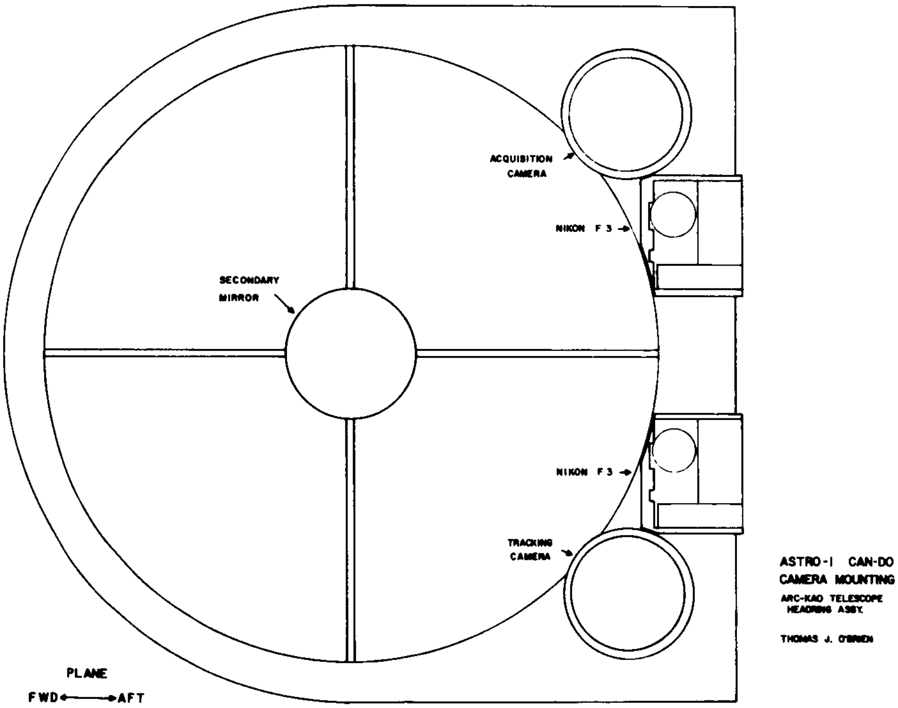

Fig-3

This is where testing can really pay off. The extensive thermal, EMI, shock and vibration test history compiled on the payload and its components as part of the design process indicated the cameras could well be expected to tolerate these conditions. Film stock and power sources were another matter. Although testing had shown the film did not get brittle, even at -70°C, below -20°C it became susceptable to catastrophic tearing from the slightest nick or snag. Further, below 0°C, battery efficiency fell off rapidly and at -50°C it was terrible.

Powering the cameras remotely from inside the KAO solved the power problem but but film handling looked insurmountable. The threat of interference with the sensitive infared detectors in the telescope ruled out strip heaters and the tight space constraint on the camera mounting assemblies didn't allow for insulation. After considering the alternatives, it was decided that a "soft" start for film advance would do the trick. To seperately "ramp-up" each film advance motor would add four additional wires to the four shutter control and four camera power wires. In spite of the quiet performance of the F-3 on the EMI tests, 125 feet of a 12 conductor cable seemed to be tempting fate.

Now the Nikon F-3 shutter interlock allows a unique solution to this problem. During one of the many tests on the F-3, it was found that when the shutter is permanently enabled, if the power is removed and reapplied, the shutter will open and remain open until the power is removed, closing it. When power is reapplied, the film will advance and reset the shutter to await the next off/on cycle. By monitoring the supply current, the operating mode, film condition, and electronic performance can be followed.

In the control system (Fig-4) S-102/S-104 can control each camera individually, while S-103 or S-105 control both cameras simultaneously. The control signal from a switch or external source determines the exposure length by either start/stop pulses of less than 1.5 seconds each or a single pulse the length of the desired exposure.

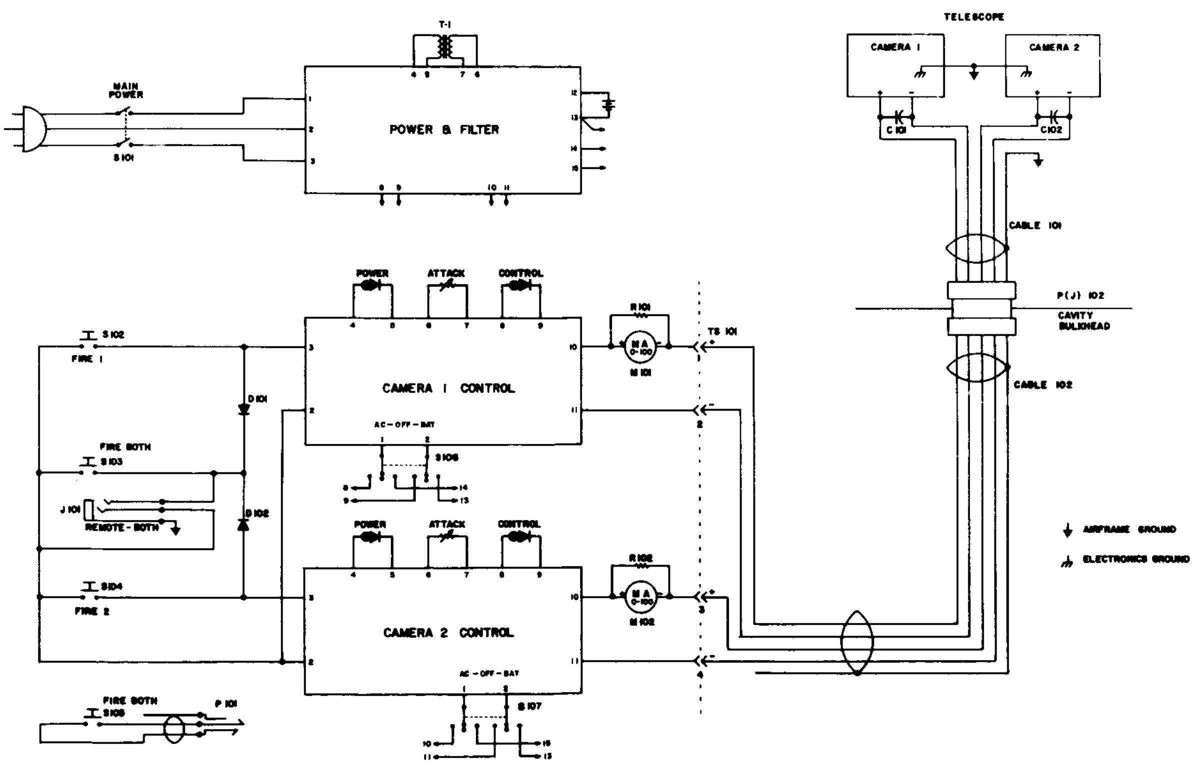

Fig-4

The monostable multivibrator U2A/B (Fig-5) delivers a 1.5 second pulse for every positive or negative transition of the control input (U2 1-10). If the transitions are seperated by more that 1.5 seconds, the first initiates the next camera function (ie: shutter open) and the second starts the following function (close shutter, advance film). If, however, the second transition occurs before the end of the multivibrator 1.5 second output, it will be ignored and a third

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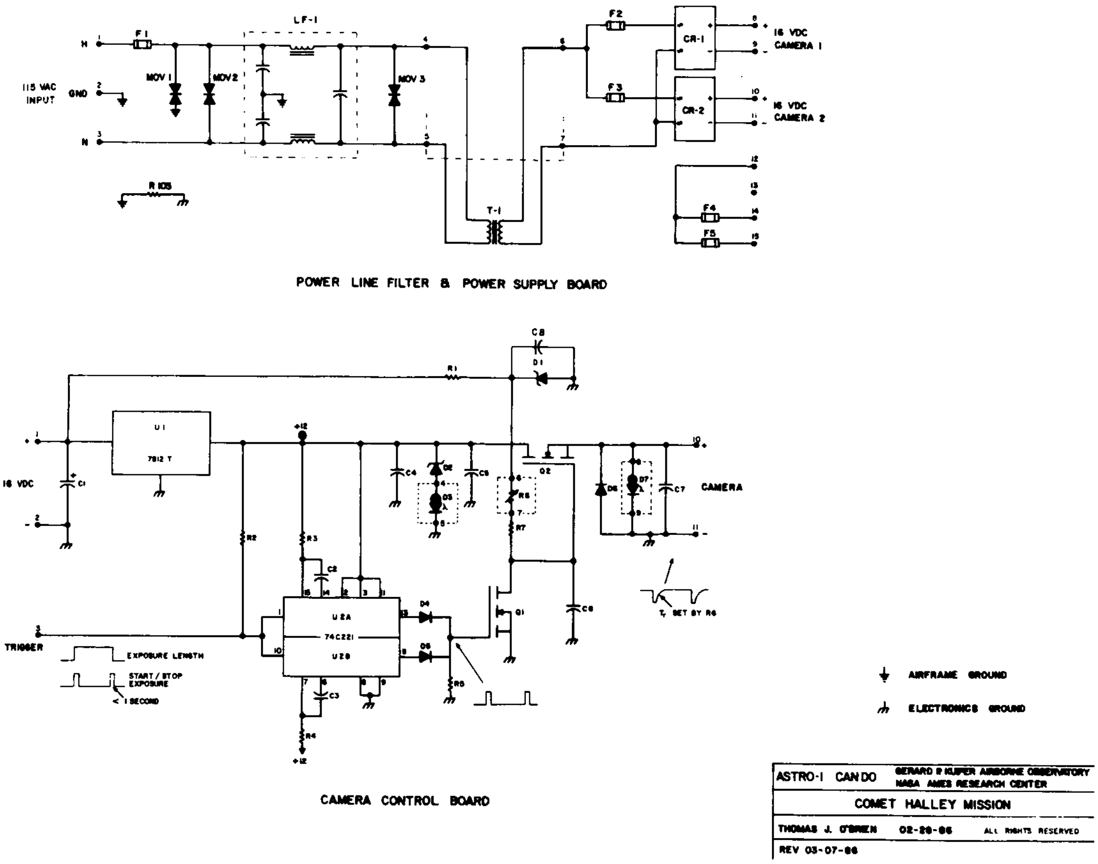

Fig-5

transition will be needed to initiate the next function. The multivibrator outputs are applied to the gate of FET Q1 via D4/D5. On command of U2, Q1 saturates and discharges C6. After 1.5 seconds, C6 is released by Q1 and begins to charge through the R/C time constant formed with R6/R7. This "soft" exponential rise in voltage controls the conduction of Q2, the series pass control FET for the cameras operating voltage.

Although primary power was intended to be drawn from the KAO's 115 VAC/60 Hz supply, the possibility of a ground loop, noise on the line, or availability in our location in the plane had to be considered. As an emergency backup, an internal 18 VDC Duracell Alkaline battery stack from the shuttle payload was included for independent "floating" operation.

Mounting the Cameras

An extensive test history with a three point mounting system on the F-3 led to a design for mounting the cameras that gave easy access to the film and lenses between flights. These brackets (Fig-6) were mounted on the face of the telescope headring (Fig-3) by an aluminum "Y" that was bolted to the bracket through existing three inch holes inboard of the tracking and acquisition cameras.

Flights

The first flight on April 6th yielded spectacular results and the cameras performed flawlessly. To verify the film tests, it was decided that on this flight,

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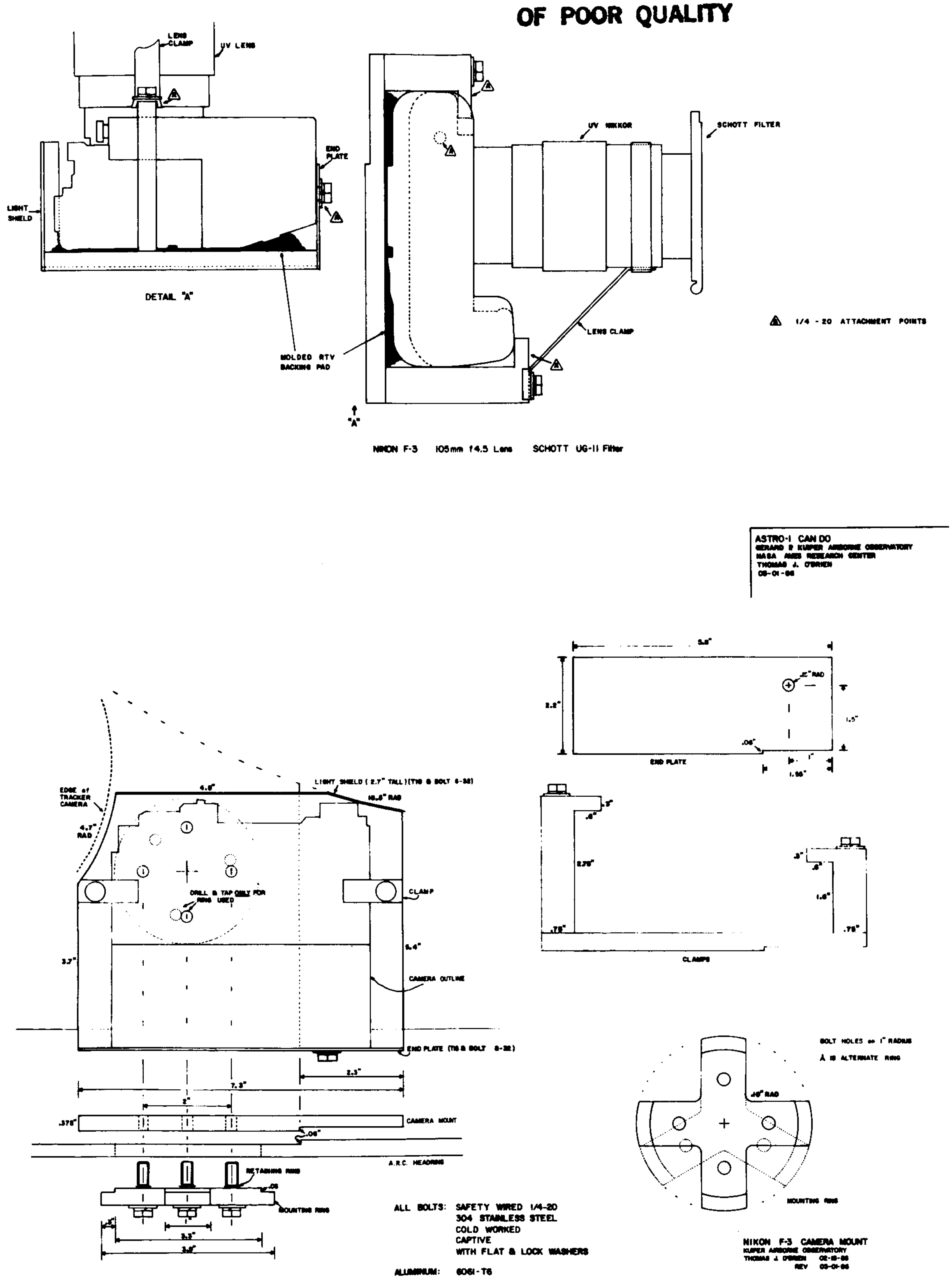

Fig-6

both Kodak EES P800/1600 and Fiji P1600D film would be flown with the 58 mm / F1.2 lenses. The Kodak EES outperformed the Fuji as it had in the earlier tests.

It was now time to go for the ultraviolet with the 105 mm / F4.5 UV Nikkor filtered with the Schott UG-11 filter using Kodak Tri-X Pan 400 film and a 105 mm / F2.5 lens and Kodak EES covering a matching visible light field. The next flight on April 8th spent an hour and ten minutes on Halley. When the film was developed, there was Halley's UV emission, from the coma, from the ion tail, with a tail disconnection as a bonus. Unfortunately, because of the thin dry air and its greater UV sensitivity, the Tri-X also picked up a static discharge stripe (Fig-7). Examination of the film path found the source, the felt light shield on the film cartridge. On the next flight, all parts in the film path were bonded to ground, even the film cartridge. The results were slightly better, but in the end, removing the film from the cartridge and loose loading it proved the only reliable field fix. With the all-metal 250 exposure film back on the shuttle, this shouldn't be a problem but it's one more thing that must be tested.

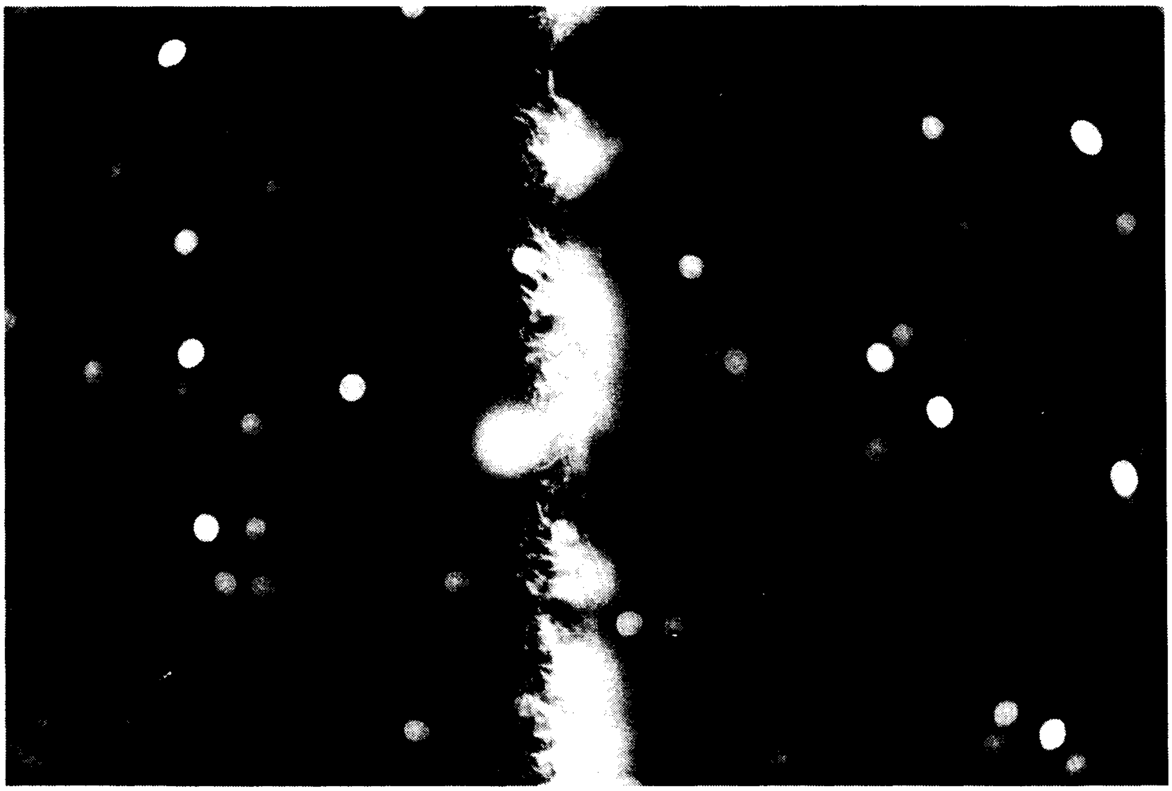

Fig-7

Postscript

Altogether, 89 objects were photographed on the KAO flights from April 5th to the end of the deployment on May 12th. The photographic results were very favorably received by the Principal Investigators and the Ames Research Center staff. Widefield photographic coverage, which was previously unavailable from the KAO, will continue now using the Astro-1 / CAN-DO control system and camera mounts. The photographs and flight logs are being compiled by NASA and the Charleston County School District into teaching packets for student use. These programs and further information on the CAN-DO project is covered in another paper presented at this Symposium.