THE AEROSPACE CORPORATION

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SUBJECT: Investigation of Colony, TX video of Columbia

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A review of a video of Columbia taken from Colony, TX was performed in support of personnel at the NASA Johnson Space Center Earth Science and Image Analysis Laboratory. An amateur video was provided that was taken with a JVC GR-DVL815 digital video camera. The video shows the Columbia at a number of different zoom settings with the most magnified setting being a digital rather than optical zoom. D. Warren's analysis described in this memo is based on JVC data available on the web. Attempts to contact JVC directly were not successful, but the basic optical analysis would not change with the added information that was requested. In summary, the digital zoomed image does not contain resolved Orbiter structure, but instead a magnified, out-of-focus diffraction pattern of the triangular iris in the video camera.

ASSUMPTIONS:

RANGE

VERTICAL	200,000 ft (38 miles)
HORIZONTAL	316,800 ft (60 miles)
SLANT	374,649 ft (71 miles)
ELEVATION ANGLE	32°

LENS

FOCAL LENGTH	36mm (max optical zoom)
f/#	1.8
APERTURE	20mm (maximum)

FOCAL PLANE
1/4" CCD (per camera spec sheet)
The 1/4" CCD format is nominally 3.2(H) x 2.4(V)mm
This gives a 5.08° horizontal field of view at 36mm lens focal length, consistent with measurements of a similar camera by J. Dragg
PIXELS (H x V): 640 x 480 (equivalent – the camera specifications cite 680,000 pixels, but these are believed to be color filtered (e.g. RGB) sub-pixels which are aggregated to create color video output pixels)
EQUIVALENT PIXEL SIZE: 5µm (this is a lower limit)

DERIVED QUANTITIES:

PIXEL IFOV (Instantaneous Field of View - optical)
PIXEL SIZE/FOCAL LENGTH = 5µm/36mm = 138.9urad
AT RANGE: 138.9urad x 374,649 ft = 52.0 ft

DIFFRACTION LIMIT
WAVELENGTH: 0.6µm
APERTURE: 20mm circular
2.44xWavelength/Aperture = 73.2urad
73.2urad x 374,649 ft = 27.4ft

DISCUSSION

With the camera at maximum optical zoom, one pixel would subtend approximately 52 feet at the Orbiter's estimated range. Therefore, an image of the intact Orbiter body would occupy a maximum of 3x4 pixels on the CCD.

The diffraction limit predicts that the camera's lens could barely resolve two point objects separated by 14 feet at the same range. This assumes perfect optics, a circular aperture, and no degradation by the intervening 70+ miles of atmosphere. However, the pixel IFOV is about 4 times larger than this separation, so the pixel IFOV is limiting the spatial resolution to the larger value. A triangular aperture (see below) would have a more structured diffraction pattern, but would not change dominance of the pixel IFOV in setting resolution.

When the camera goes into digital zoom mode, the optical resolution of the pixels is not improved. Rather, a reduced number of existing pixels (e.g the 3x4 covering the Orbiter) are resampled to create new synthetic pixels to fill the format. Any defocus or diffraction effects are magnified, and resampling can produce edge effects, such as ringing and contrast reversals.

The enlarged image in digital zoom mode therefore does not contain any resolved structure on the Orbiter body. The apparent structure is caused by a combination of defocus, diffraction from the lens aperture, possible ghost images of the intensely bright source, and electronic resampling and filtering. The companion object that separates from the main Orbiter body image and appears intermittently as a triangular image is an unresolved, probably tumbling, object.

It should be possible to duplicate the observed artifacts by recording a bright point source with the camera.

Fig 3.3[1] picture (c) shows the diffraction pattern of a triangular aperture. For cost reasons, the aperture of most consumer cameras is a polygon of few sides. A triangle (3-bladed) aperture is not uncommon, and is postulated here. The diffraction pattern would appear in a magnified image of a very intense source. See, for example, the video frame with TM1 (upper right) of 00:00.08.04 and TC (lower left) of 17:00.

The frame with TM1 00:00.01.11 (TC 00:10:07) is taken when the camera appears to be in maximum digital zoom mode. The upper part of the main image appears to be completely saturated, and resampling is producing the dark artifacts at the edges. Compare the image of the companion object with Figure 9.8[1] (a), the near-field diffraction pattern of a triangular aperture. A tumbling, bright point source is most likely producing an out-of-focus, diffracted image of the lens aperture. The bottom part of the main image could be produced by a combination of a ghost reflection of the bright main image plus diffraction.

[1] The attached jpeg scans of Figures 3.3 and 9.8 are taken from the *New Physical Optics Notebook*, by G. O. Reynolds *et al* (SPIE Press, 1989).

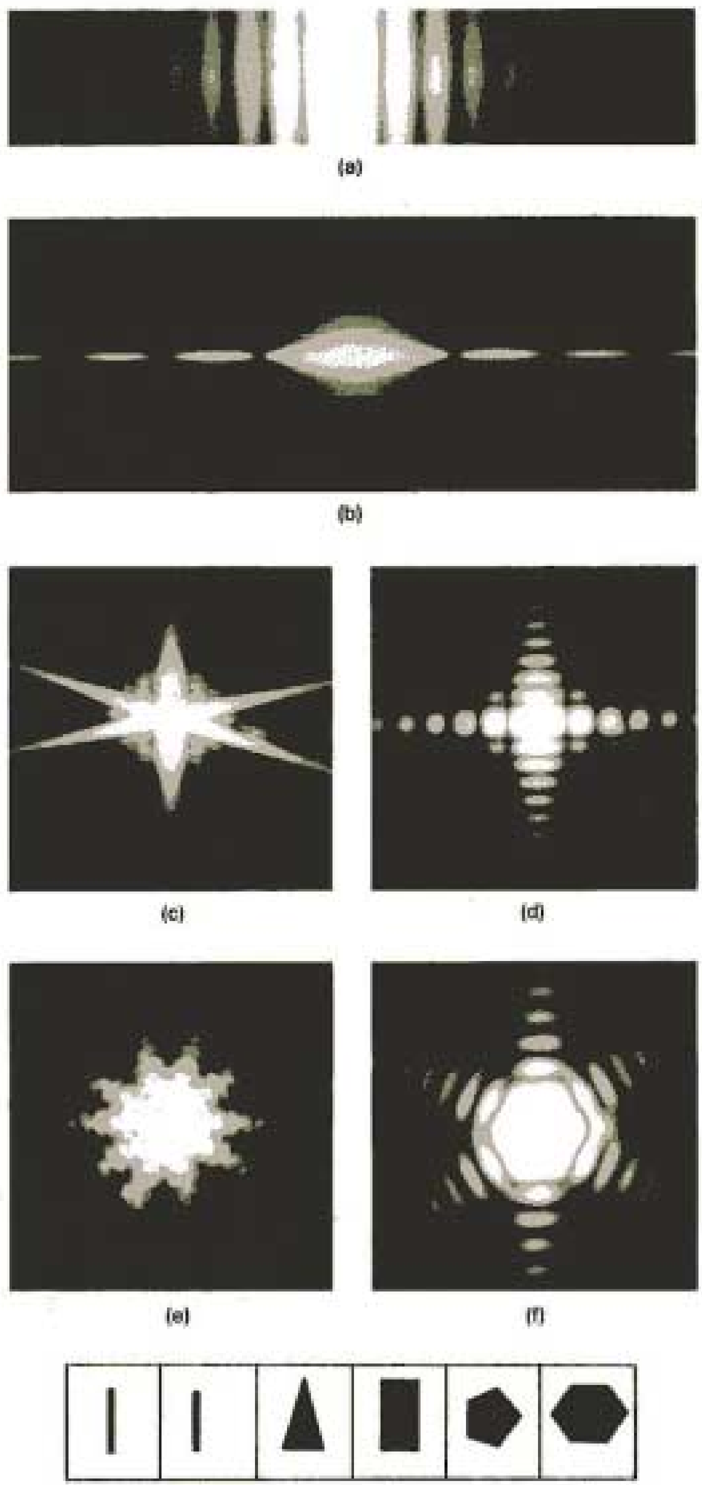

Fig. 3.3 Photographs of the Fraunhofer diffraction patterns (Fourier transforms) of various apertures: (a) slit aperture with a slit source, (b) slit aperture with point source, (c) triangular aperture, (d) rectangular aperture, (e) pentagonal aperture, and (f) hexagonal aperture.


TM1 00:00.08.04
00:17:00

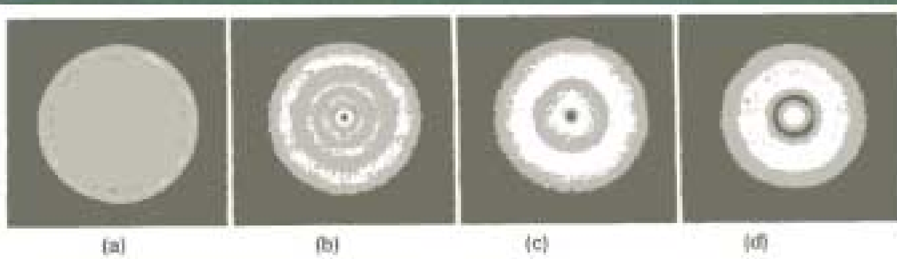

Fig. 9.7 Typical Fresnel diffraction patterns of a circular aperture: (a) is closest to the aperture and (b), (c), and (d) were taken at increasing distances from the aperture.

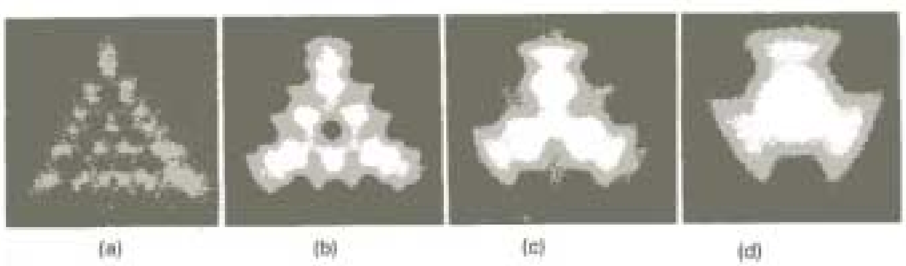

Fig. 9.8 Typical Fresnel diffraction patterns of a triangular aperture; (a) is closest to the aperture and (b), (c), and (d) were taken at increasing distances from the aperture.