ACIC Photo-Visual System for Lunar Charting

Robert O'Connell and Anthony Cook

In this web-based supplement to 'Revisiting The 1963 Aristarchus Events'[1], we present a brief overview of each component comprising the USAF lunar mapping photo-visual system on the 24-inch Clark refractor in place during both transient lunar phenomena (TLP) episodes of 'The 1963 Aristarchus Events'.[2] This supplement available for download at www.the1963aristarchusevents.com

Introduction

The Lowell Observatory lunar mapping program for NASA's *Project Apollo* was established in 1961 and ended in 1972. To produce the vitally needed charts in time for the looming deadline of a manned lunar landing by the end of that decade, the USAF *Aeronautical Chart and Information Center* (ACIC) in St. Louis, MO developed a photo-visual system for cartographer-observers mounted to the tailpiece of the Lowell Observatory 24-inch Clark refractor.

Lowell Observatory 24-inch Alvan Clark Refractor

The 24-inch f/16 equatorially mounted Clark refractor was erected in 1896 by wealthy Boston businessman Percival Lowell (1855-1916) who used it as his primary instrument for his study of the planet Mars. The objective lens was produced by the Alvan Clark & Sons firm and is an air-spaced doublet with its crown and flint glass components each 1.5 inches thick set four inches apart in a cast iron cell.[3]

In 1905 the lenses were refigured by Carl Lundin giving its current color correction in the visual region of the spectrum between 5000Å and 6200Å.[4] The objective lens is considered excellent and Hartmann tests have found that it had the least aberrations of 13 refractors tested.[5] During moments of best seeing ACIC lunar cartographers were able to observer (albeit not resolve) small craters on the order of 600 feet.[6] It was through this telescope that observers witnessed both transient TLP episodes of *The 1963 Aristarchus Events*.[7]

Photo-Visual System

The ACIC photo-visual system was designed for use by lunar cartographers spending long hours at the Clark charting the Moon's surface. The system allowed for quick changeover from a zoom eyepiece for visual observing to a camera for recording supplemental reference images during observing runs. Modification of the Clark tailpiece and fabrication of the initial system was overseen by Lowell Observatory director John S. Hall working in close collaboration with the ACIC's first Lowell site manager, William D. Cannell.[8] The system gradually evolved from its initial 1961 configuration of a monocular zoom eyepiece and 16 mm motion picture camera to its final configuration several years later which included a binocular viewer and 70 mm sequence camera.[9] This system was used until 1967 when high resolution imagery from NASA's *Lunar Orbiter* missions made continued visual and photographic telescopic observations virtually unnecessary.

Figure 1. The Lowell Observatory 24-inch Clark refractor used to map the Moon for *Project Apollo*. Note 6-inch finder and 12-inch guide scopes. *Lowell Photo Archive*.

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Figure 2 is a diagram of the system as it existed in late 1963 during both episodes of *The 1963 Aristarchus Events*.

Cannell described the system in March 1962: "*The eyepiece and camera are arranged as one unit with reflex prisms diverting the optical beam to the eyepiece. The observer changes from visual to photographic observing by pulling a plunger to retract the first prism allowing the beam to fall unreflected on the film placed in the focal-plane of the objective lens. The second reflection to the eyepiece is introduced to erect the image which was inverted by the first. Also, this allows the second prism to be rotated about the optical axis so that the observer may assume a comfortable observing posture. There is no noticeable loss of visual resolution caused by the second reflection.*"[10]

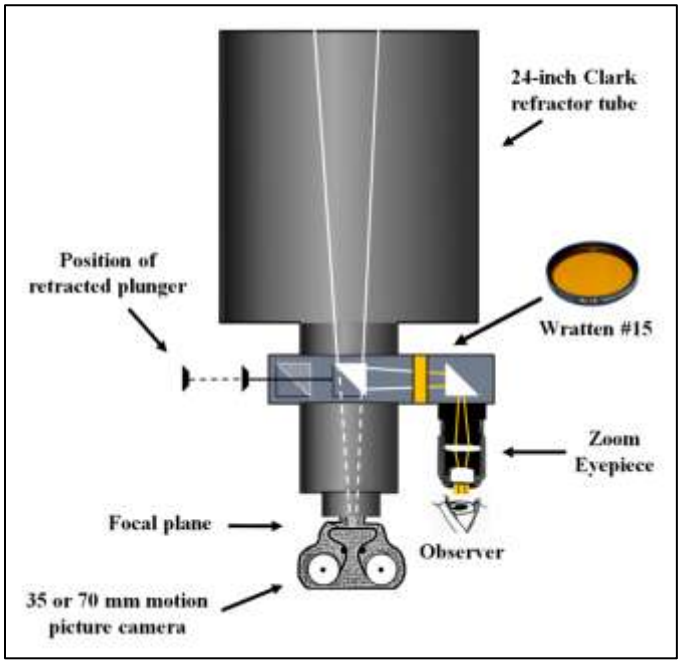

Figure 2. ACIC photo-visual system. The placement of a Wratten 15 filter in the optical path was standard procedure for visual observations to eliminate blue spurious colors from the Clark's achromatic objective lens and improve contrast. The zoom eyepiece provided magnifications from ~ 430 to 1050x. It is unknown if a filter or correcting lens was placed in the optical path to the camera. Image © 2013 R. O'Connell & A. Cook based on Figure 7.7 in Kopal & Carder, 'Mapping the Moon Past and Present' (1974), p. 154.[4]

Visual Observations

In 1963 Cannell briefly summarized the visual mapping process in a newspaper interview: *"The observer works at the telescope with the rectified photos sent from St. Louis overlaid with tracing paper. As he observes new features and intricate details, he carefully traces them on the overlay".*[11] (See Figure 3).

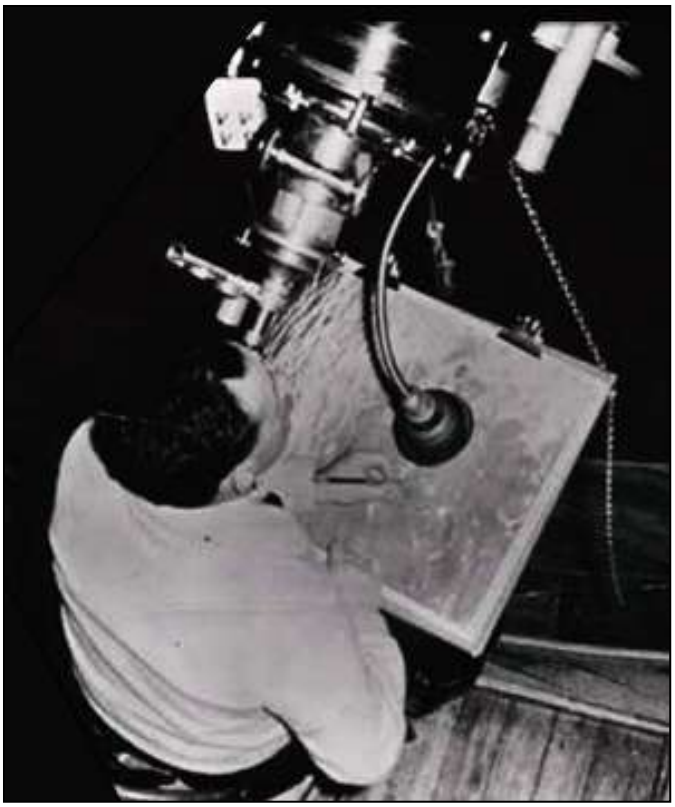

Figure 3. William Cannell adding details to a base photograph at the monocular eyepiece of the 24-inch Clark refractor. Image: ACIC.

Many years later, Greenacre elaborated more fully on the charting routine: *"And ... so we would take the best photographic* [images] *we had and make a mosaic or a map of the scale, one-to-one-million ... and take it up to the telescope and sit there... there was such and such crater and you just start working. All of a sudden, wham! There were ten little craters that showed up, see. You do the best you could to place them. And then in the meantime, you're shooting photography. And you could verify placement by . . . re-scaling your photograph to the scale one to one million scale. It was very surprising, usually you're only off a pencil or two, just from . . . You know, you had such good stuff to work with. You know, here's a crater and here's one and there's one right... You could see right square in between so you put it there and that was just about right."*[12]

In 1963 Greenacre would develop the film negatives and produce prints the next day in the modest darkroom he arranged in an office closet at Lowell. All visual and photographic observational data from a night's observing run was then turned over to scientific illustrators who used this material to produce final airbrushed lunar charts. The original *Lunar Aeronautical Chart Series* (LAC) is available in high-resolution digital form on the web.[13]

In 1962 Cannell had noted the desirability to chart under low solar illumination conditions close to the lunar terminator where "*. . . the shadows are optimum for detail interpretation . . . Along the terminator, the very low and gentle relief features such as Maria Ridges and valleys, will show up prominently. Craters, small prominences, and rilles can easily be interpreted from 5 to 15 degrees in front of the terminator*." Greenacre on October 30th and Barr on November 28th had both been charting under this familiar low illumination along the northern terminator of a waxing gibbous Moon in the Aristarchus region when the TLP appeared through the eyepiece.

Zoom Eyepiece

During both episodes of The 1963 Aristarchus Events observers at the Clark were using a zoom eyepiece. According to Cannell: "*We use the zoom eyepiece which has a range of focal-lengths from 21 to 8 millimeters. On the 24-inch refractor, this amounts to a magnifying power range from about 428 to 1,050. We normally use a magnifying power of 500, and only on rare occasions has use been made of powers in excess of 800. The zoom eyepiece is very convenient in that the optimum magnifying powers can be found by merely turning a knurled ring*."[14] (See Figure 4).

Figure 4. James C. Greenacre viewing through the zoom eyepiece on the 24-inch Clark refractor.

The zoom eyepiece appears to have been a variant of the commercially available coated orthoscopic eyepiece advertised in the 1960s by Criterion in *Sky and Telescope Magazine*. (See (Figure 5). Greenacre was using ~500X magnification when the first October 30th (UT) TLP appeared. At this magnification the eyepiece's variable apparent field-of-view (FOV) would have been ~40º giving Greenacre an actual

Figure 5. It is believed the ACIC used some variant of the commercially available Criterion eyepiece advertised in S&T in the 1960s. Image: *Sky and Telescope Magazine*.

Figure 6. Aristarchus Plateau under repeat illumination conditions for TLP observation at 01:30 October 30, 1963 UT simulating approximate FOV seen by James Greenacre through the 24-inch Clark refractor. Image: Bob O'Connell, 2011-03-17, 8-inch Mak-Cass, Keystone Heights, Florida.

FOV through the Clark resembling like that in Figure 6, although image brightness, resolution and libration would have been different.

Wratten 15 Filter

During visual observations through the Clark it was standard procedure to employ a yellow-orange Wratten 15 filter to minimize chromatic aberration effects in the two-element achromatic refractor. (See Figure 7). The Clark is notorious for producing blue fringes close to bright objects and as this filter blocks off wavelengths below 520 nm, it allowed observers to compensate for this deleterious optical effect by largely removing blue chromatic aberration. (See Figure 8).

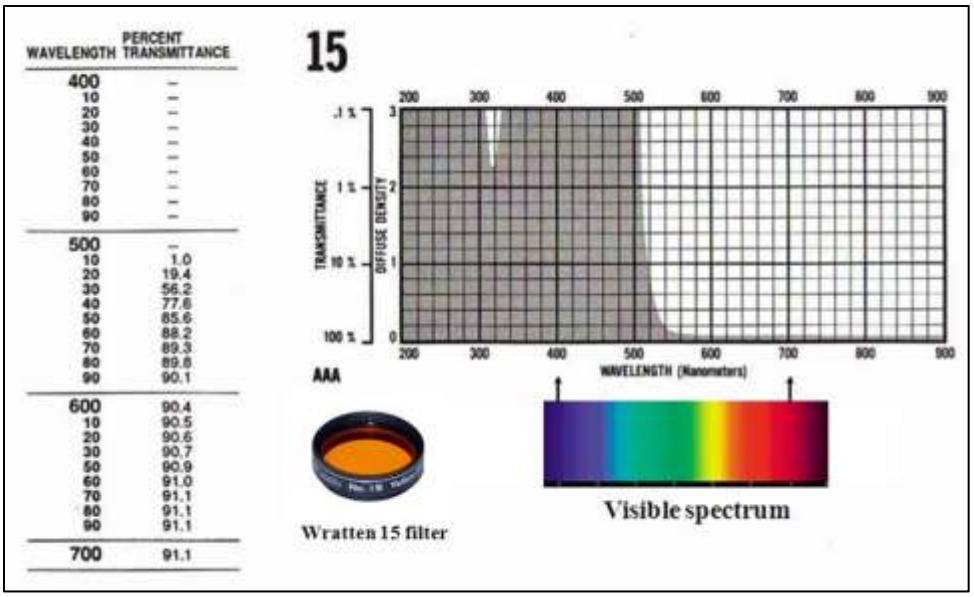

Figure 7. Wratten 15 filter transmittence by wavelength from *Handbook of Kodak Photographic Filters*, Eastman Kodak Company, Rochester, New York (1990). Images of filter and visible spectrum added by the authors for reference.

On October 30th, Greenacre repeatedly switched between filtered and unfiltered views to determine whether or not the TLP were due to spurious colors and concluded they were not.

Figure 8. Image of Aristarchus Plateau through a Wratten 15 filter under repeat illumination conditions for the Oct. 30th TLP episode. Note: image brightness, resolution and libration would have been different for Greenacre. Image Bob O'Connell, imaging details same as in Figure 6.

Iris Diaphragm

Percival Lowell originally had a diaphragm installed on the Clark which allowed stopping down the aperture to 18, 12, 9 and 6 inches based on seeing conditions. Sometime later ". . . *Stanley Sykes devised the more efficient continuous diaphragm*" allowing observers to vary the scopes' aperture and focal ratio between full 24-inch and f/16 down to 6-inches and f/64 by turning a knob proximal to the eyepiece. This diaphragm was in place in 1963. (See Figure 9). Cannell explained the use of this iris diaphragm based on the prevailing seeing conditions: "*There are times when the effect of atmospheric turbulence can be minimized by using a smaller aperture. Mediocre seeing conditions become worse with a larger aperture telescope. If the air cells caused by turbulence, which act as lens themselves, are smaller than the telescope aperture, their effect is longer lasting as they move in front of the objective. By using an aperture that is smaller or no larger than the air cells, the seeing is affected by only one cell at a time. The 24-inch refractor is fitted with an iris diaphragm in front of the objective lens which permits aperture stops from 24 inches down to 6 inches. Normally, we find that mediocre seeing conditions can he optimized between 12 and 18 inch aperture. There are many times, however, that*

even a 6 inch aperture may not help, and the only thing that can be hoped for is that seeing conditions will improve during the night."[15]

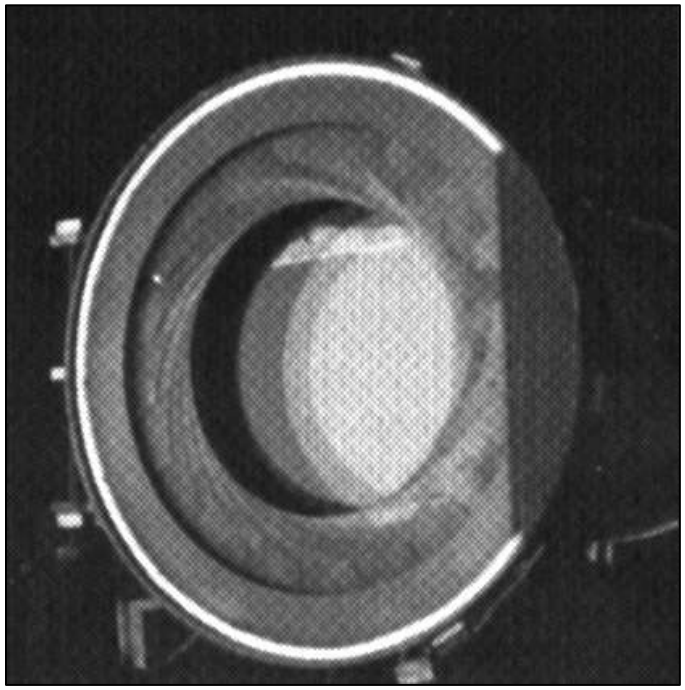

Figure 9. Iris diaphragm over the 24-inch Clark objective. Image: Lowell Observatory archives as published in '100 Years of Good Seeing: The History of the 24-Inch Clark Telescope', K. Schindler, 1998.[3]

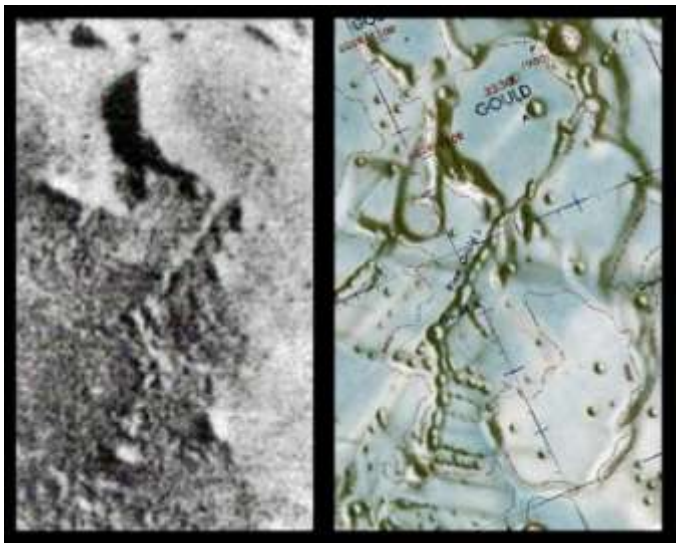

Figure 10. *(left)* Limited level of detail captured in an image of the crater *Gould* (19.2S, 17.2W - IAU) in *Mare Nubium* taken with the 70 mm Hulcher camera on the Clark. *(right)* Portion of final *Lunar Aeronautical Chart* of same area produced by incorporating visual observations.

It is not known if Greenacre employed the iris diaphragm during the TLP observations on either night but may have to determine his estimation that a 20 inch refractor or a 16 inch reflector would be required to see the phenomena.

Photographic Observations

As noted above, observers could quickly switch from visual to photographic observations by simply pulling a plunger to retract a prism in the optical path to the camera. (See Figure 2). Taking images of the Moon during observing runs was standard protocol and all visual and photographic material from an observing session was passed onto scientific illustrators who would combine this information to produce airbrushed Lunar Aeronautical Charts (LAC). (See Figure 10).

During both episodes of The 1963 Aristarchus Events a Hulcher 70 mm sequence motion picture camera was attached to the Clark.[16] It was only during the second TLP episode that this camera was pressed into service in a failed attempt to capture the phenomena on Kodak B&W SO-136 Panatomic X film.[17] Figure 11 shows Dr. Howard L. Cohen, Associate Professor Emeritus from the University of Florida, in 1964 at the controls of the ACIC Clark with attached ACIC photo-visual system.

Figure 11. Howard Cohen at the Clark with attached 70 mm Hulcher camera. Image: © 2011 H.L. Cohen

Cohen, although not associated with the ACIC program, was a Lowell staff member in 1964. The Hulcher camera seen in this figure is that used by Greenacre in his failed attempt to capture photographic evidence of the reddish colored TLP seen on November 28, 1963. Cohn recalls visiting the dome at night and "*. . . seeing the observers mapping the Moon*." (Personal communication 2011).

Conclusion

The ACIC photo-visual system on the 24-inch Clark refractor served the USAF lunar cartographers well during the program's visual lunar mapping phase. In 1983 Greenacre recalled that while the program's smaller 20-inch Morgan refractor "*wasn't a very good telescope . . . the old Clark refractor they had, boy that was something . . . when the scene was good you could see things down to 100 meters. You could only see them for a fraction of a second but you could see them*."[18] With regard to the Clark configuration and the October 31, 1963 UT Greenacre-Barr TLP observations, Lowell Observatory Director John S. Hall noted: "*As for the equipment used, and the possibility that some unusual change may have influenced the observations, I think that it would be difficult to imagine a more stable telescopic setup. No changes in the observational technique had been introduced during the entire period that this area has been under study*."[19] Finally, after witnessing his own color TLP episode through the Clark on November 28th, it is interesting to note Hall wrote in December 1963 personal correspondence: *"Contention made here is that this coloration is not produced in the optics of the telescope or by the earth's atmosphere".*[20]

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Addresses: **RO**: P.O. Box 1963, Keystone Heights, FL 32656. [admin "at" the1963aristarchusevents.com]. **AC:** Institute of Mathematical and Physical Sciences University of Wales Aberystwyth, Penglais, Aberystwyth, Ceredigion, SY23 3BZ, WALES, UNITED KINGDOM. [atc "at" aber.ac.uk] Website: www.the1963aristarchusevents.com

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3 Schindler K., '100 Years of Good Seeing: The History of the 24-Inch Clark Telescope', Lowell Observatory, p. 11, (1998)

4 Kopal Z. & Carder R. W., *'Mapping of the Moon: Past & Present'*, (Dordrecht−Holland/Boston: D. Reidel Publishing Co., 1974), p. 147.

5 Bell L., 'The Telescope', (New York: McGraw-Hill Book Co., 1922) Fig.187, p. 268.

6 Kopal 1974, *op. cit*., ref. 4, p. 147.

7 The 20-inch "Morgan" (Tinsley) apochromatic refractor was added to the program in 1964 but never performed as well as the Clark. For more information on this telescope see: Schindler, K., 'Rising to the Heavens: The 20-inch Telescope Dome', *The Lowell Observer*, (61), p. 8 (2004); Schindler, K. S. & Sheehan, W. P., 'Mapping the Moon', *Lowell Observer*, (93), p. 3, (Winter 2012).

8 Various correspondence between Hall and Cannell in Lowell Observatory archives.

9 *"Binocular eyepieces have been fabricated and installed on both the 20-inch and 24-inch Lowell refractors, which have increased observer efficiency by a factor of 2. The binocular affords better eye-relief and, therefore, less fatigue. Plans are being made to provide both refractors and their guide telescopes with common adapters so that the same observational equipment can be used on either telescope."* Anonymous, 1965, 'ACIC Lunar Charting Program Quarterly Progress Report', *Aeronautical Chart and Information Center, St. Louis, MO*, (3), p. 3., (1965) [progress report for 1 January 1965 - 31 March 1965]

10 Cannell, W. D. 1962, 'Photogrammetric and Visual Compilation of Lunar Charts', 28th Annual Meeting of the Society of Photogrammetric Engineering, Society of Photogrammetric Engineering, pp. 579-583.

11 Hoyt W., 'Moon Mapping Intricate Job', *The Arizona Daily Sun*, Flagstaff, Arizona, p. 4. (1963 January 31).

12 Baker T., 'Oral History with Focus on Sandia Cave: 1983 taped interview with James and Doris Greenacre', Transcribed by Baker T. (2005), serial line entry 1660 at http://www.ele.net/sandia_cave/greenacre1501_2000.htm (Accessed 2013 Jul 28)

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14 Cannell 1962, *op. cit* ref. 10, p. 582

15 *Ibid*., p. 580

16 For more information on this camera, see paper supplement: *Hulcher 70 mm Sequence Camera* at: www.the1963aristarchusevents.com

17 For more information on the SO-136 film used on night 2, see paper supplement: *Failure to Photographically Record Nov. 28 TLP* at: www.the1963aristarchusevents.com

18 Baker 2005, *op. cit.* ref. 12, serial line entry 1660 at http://www.ele.net/sandia_cave/greenacre1501_2000.htm (Accessed 2013 Jul 28)

19 From Hall's original *unedited* passage in his "*Supplementary Report*" sent to *Sky and Telescope* (1963 November 4) in Hall J. S. papers, Lowell Observatory Archives. His report appeared with James Greenacre's article 'A Recent Observation of Lunar Color Phenomena", *Sky and Telescope Magazine*, **26**(6), p. 316-317, (1963 December)

20 J. S. Hall letter to Phil Bury, 1963 December 5, in J. S. Hall papers, Lowell Observatory Archives.