

MBARI 4K ROV Camera System Requirements

Doc. # 100221373

rev. C. 20SEP19 Mark Chaffey. Initial release.

Discussion and summary. The purpose of this document is to provide the requirements for a “4K” or Ultra-high definition camera system for MBARI Remotely Operated Vehicles (ROV’s).

The ROV application places demanding requirements on camera systems. Aside from the environmental conditions, the platform and/or target are often moving in relation to each other requiring constant adjustment of the lens focal distance. While the artistic goals of traditional cinematography often favors a limited Depth of Field (DOF), ROV video demands the widest DOF possible. Complicating matters, the ROV application is often light limited requiring wide lens apertures which works against a wide DOF. Maintaining manual focus under these conditions requires a fast position control servo on the lens focus element. An example of the focusing challenges can be seen in this video clip at about 53 seconds in: <https://www.youtube.com/watch?v=X8oWnbclI40>

The overall requirement is to provide a professional level 4K camera system suitable for ROV use that has an optical dome and adapter optics that maintain a 4K resolution and a high MTF¹ across the image plane. In addition, the lens and camera controls must be of a professional standard equivalent to current “broadcast level” camera systems.

MBARI 4K Camera Requirements

1. Camera module, lens and relay optics specifications.

- 1.1. **Imager format:** The camera shall have an imager size nominally referred to as 2/3” with a 4096 x 2160 or 3840 x 2160 progressive scanning format capable of 59.94 or 60 frames per second.
- 1.2. **The camera lens mount** shall be B4 format.
- 1.3. **The camera.** The camera module shall be the Sony HDC-50 with the 4K/UHD unlimited software license.
- 1.4. **Camera settings control.** Camera parameters such as iris, gain, color balance, etc. shall be settable from the ROV control room. The use of the camera module manufactures control panel is preferred. *See appendix 1, example of a camera control panel.*
- 1.5. **The camera lens** shall be 2/3” B4 mount professional quality designed for full “4K” resolution and a minimum focal range between 4 and 5.2 mm. The lens shall have a minimum of 10X zoom. Examples of suitable lenses are the Fujinon UA13x4.5 BERD lens, UA14X4.5BERD lens or the Canon CJ12ex4.3B lens.

¹ Modulation Transfer Function or contrast ratio.

- 1.6. **The dome/relay optics** (dome port and relay lenses for dome field curvature correction) should be of high enough quality to not significantly degrade the image the camera module is capable of. This is an area where design trade-offs need to be made between the camera viewing angle, optical resolution, optical distortion and dome port diameter (housing size and weight). To preserve the maximum quality in a 4K image the following optical parameters are highly desirable:
- 1.6.1. The polychromatic spot diameter less than 2.5 microns across all zoom positions in the middle zone and have minimal roll-off through the outer zone to the picture edge (high field angles) (see figure 1).

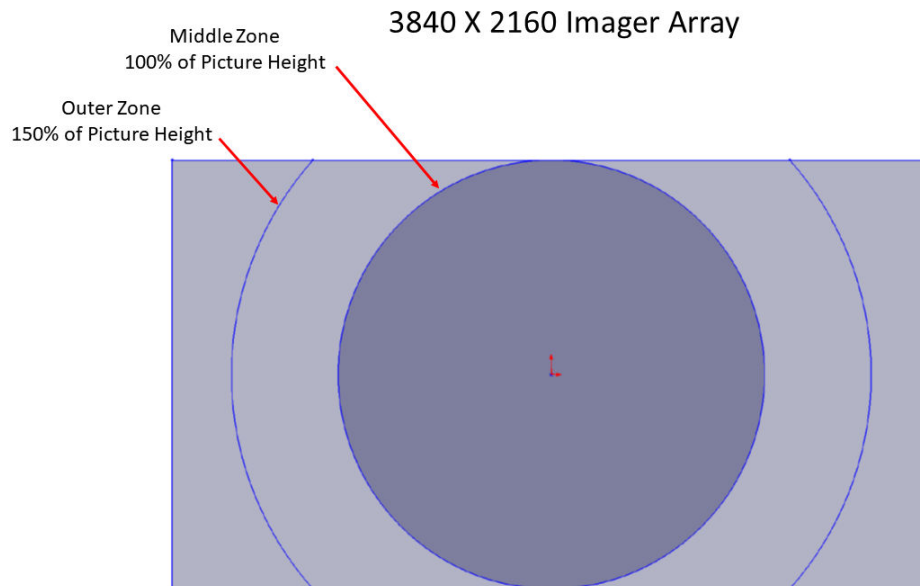


Figure 1. Zones for evaluating spot diameter and MTF.

- 1.6.2. Polychromatic MTF (modulation transfer function). This specifies the lenses ability to transmit sufficient light and maintain resolution and contrast across the visible spectrum for the range of zoom positions. The MTF should be around 50% at 100 line-pairs per millimeter. Full 4K resolution is around 200 lp/mm. The ultra HD camera lenses listed above have a center MTF >70% at 100 lp mm at all zoom settings.
- 1.6.3. Field curvature/distortion. This is the optical systems ability to faithfully reproduce the image across the visual field, i.e. do straight lines appear straight in the image. Some distortion, up to about 10%, is tolerable in our application, especially at the edges of a wide-angle image. For our application high MTF at the corners is more important than low distortion.

- 1.6.4. The image should be free of “flare” and “ghosting” resulting from stray light paths and exhibit minimal vignetting or loss of brightness at the edges of the visible image.
 - 1.6.5. The relay optics shall use coated lenses to minimize internal reflections and transmission loss.
 - 1.6.6. The camera, lens and optical port system must have the ability to focus from 30cm to 15 meters in seawater from the front of the optical dome port when the zoom and iris are at maximum (longest focal length and widest iris). Focus shall be retained as the zoom control is changed to from maximum to minimum zoom (wide angle) at any viewing distance.
 - 1.6.7. The camera, lens and optical port system must have a horizontal field of view width greater than 80 degrees and less than 95 degrees in seawater.
 - 1.6.8. It is not necessary that that the optical system meet any of these requirements in air.
- 1.7. **Lens control.** MBARI takes pride in the quality of the control servos that are used on our camera systems. We support full position control for the lens focus and variable rate control for the zoom position. This increases the quality of our in-house recordings by providing for the best possible focus control as the image moves in relation to the camera – as ROV imaging subjects often do. It also allows professional videographers to get the most out of the system. Many alternative lens control strategies use simple on-off toggles for moving the lens elements which is not acceptable.
- 1.7.1. The lens follow focus control shall have variable position servo control, i.e. the focus must smoothly and quickly ramp to a commanded focus position without detectable lag, drift, overshoot or “hunting”.
 - 1.7.2. The lens zoom control shall have a variable rate servo control for zoom position without detectable lag, drift, or overshoot.
 - 1.7.3. The lens focus and zoom positions shall be digitally encoded and available on a EIA 232 or Ethernet standard interface in the ROV control room for logging lens position for quantitative video applications. *Note: still reviewing the position reporting requirement, it may not be required.*
- 1.8. **Camera system status monitoring and alarms.** It is required that the camera housing include sensors for water intrusion, housing internal pressure, humidity and temperature and that there be a system for alerting the operators if any of these values exceed safe operational limits. In addition, the camera module shall be automatically powered down if the internal housing temperature exceeds the camera manufactures maximum environmental operating temperature specification.

2. Video uplink/Control link.

- 2.1. The video uplink shall transmit the full baseband video signal to the ROV control room using an industry standard format such as Quad 3G-SDI (SMPTE 424M), 12G-SDI (SMPTE ST-2082) or HDMI 2.0. Note: Quad 3G-SDI or 12G-SDI/SMPTE ST-2082 is preferred.
- 2.2. The video uplink shall operate over 5000 meters of single mode optical fiber and provide a minimum link optical budget of -20dB. Note that to assure reliable operation the fiber optical properties of material and chromatic dispersion at the operating wavelengths need to be taken into account to assure reliable system operation at the transmitted bit rate.
- 2.3. The optical system transceivers shall use SFP modules and transmit the system signals on the following Coarse Wave Division Multiplexing (CWDM) channels conforming to ITU-T Recommendation G.694.2:
 - 2.3.1. Video uplink signal on wavelength TBD.
 - 2.3.2. Communications uplink on wavelength TBD.
 - 2.3.3. Communications downlink on wavelength TBD.

3. Camera housing requirements.

- 3.1. **Housing material.** 6AL4V Titanium (Glass, Delrin and other corrosion resistant materials may be used for the optical dome, retaining rings, etc).
- 3.2. **Depth Rating.** The working depth is 4000 meters of sea water (5800psi). The design safety factor for the housing and optical dome shall be a minimum of at least 1.25 times working depth before failure or yield (7250psi).
- 3.3. **Housing optical port.** Suitable for the lens specified and meeting the optical requirements.
- 3.4. **Working life.** Housing and dome shall be designed for a minimum working life of 5 years with a mechanical reliability of 99.5%, assuming an average of 130 pressure cycles per year from 0 to 4000 meters ocean depth.
- 3.5. **Pressure rate-of-change.** The maximum rate of change for pressure cycling in operation and testing shall be less than or equal to 200 p.s.i per minute.
- 3.6. **Size.** Housing and dome combination should be anticipated to be designed for a maximum preliminary size camera module of 20 inches internal length from the front optical element and 7.0 inches internal diameter. The exact housing size will be determined when the camera chassis and lens element spacing designs are complete.
- 3.7. **Weight.** Housing and dome combination should be custom designed for the required depth rating to allow for minimum possible weight.
- 3.8. **Temperature.** The housing must maintain water integrity at specified depths across a temperature range of -8 to +27 degrees Centigrade.
- 3.9. **Interface connectors.** The housing interface shall include one Titanium Brantner/SeaCon "MiniCon" MINK19#22FCR bulkhead connector and one Titanium Brantner/SeaCon "MiniCon" MINF-1-FOSM-FCRL bulkhead connector. Alternate connectors may be substituted with MBARI written agreement.

4. Appendix 1, example of shipboard camera control panel.

