A Quantitative Low-Light Imaging Module for MBARI's AUV - Feasability Study

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Introduction:

The MBARI ROV supported midwater transecting time series study has resulted in an incomparable video based data set. It provides a high-resolution assessment of abundance, vertical distribution and seasonal variability of midwater animals that has led to significant new insights into the structure and dynamics of mesopelagic ecology in Monterey Bay and beyond. Bioluminescence transecting to detect and categorize stimulated bioluminescence using a low-light video camera is another method of video survey that has gradually been implemented on MBARI's ROVs. However, issues of tether dynamics, human endurance, and available ship time limit the scope and duration of ROV based surveys of these types.

The purpose of this investigation is to determine the feasibility of developing a payload for a Dorado class AUV that will allow it to expand the scope of these types of scientific missions while maintaining the quality of observations that we currently enjoy using Ventana and Tiburon. In order to completely utilize the increased data load that will result when this system is fielded, we anticipate utilizing the technology developed by the Visual Image Event Detection Technology Exploration project.

Problem Statement:

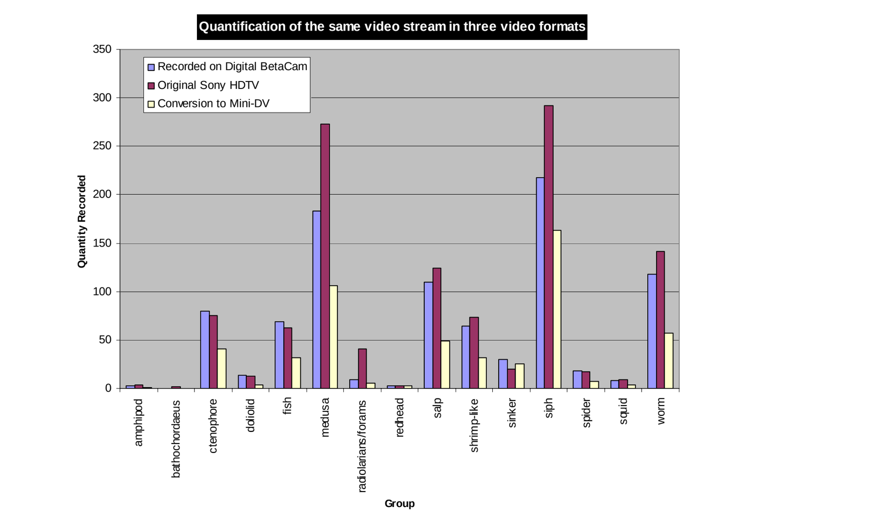
The scientific problem presented to engineering is “can MBARI engineers build a system to quantify the animals encountered in the midwater, minimizing the disturbance to those same animals?” This project addresses the input stage of such a system: the ability to see the animals.

The project must address two distinct, but very similar, needs, non-bioluminescent and bioluminescent creatures. In the first case, the system uses a light source to see what is in the water volume directly in front of an imaging device. As animals pass into the light field, the imaging device records their images for analysis on shore. In the second case, the bioluminescent creatures are the light source, but they only generate light when they are physically disturbed. A stimulation and retention screen disturbs the creature and holds it in front of the camera long enough to record it's images for analysis on shore.

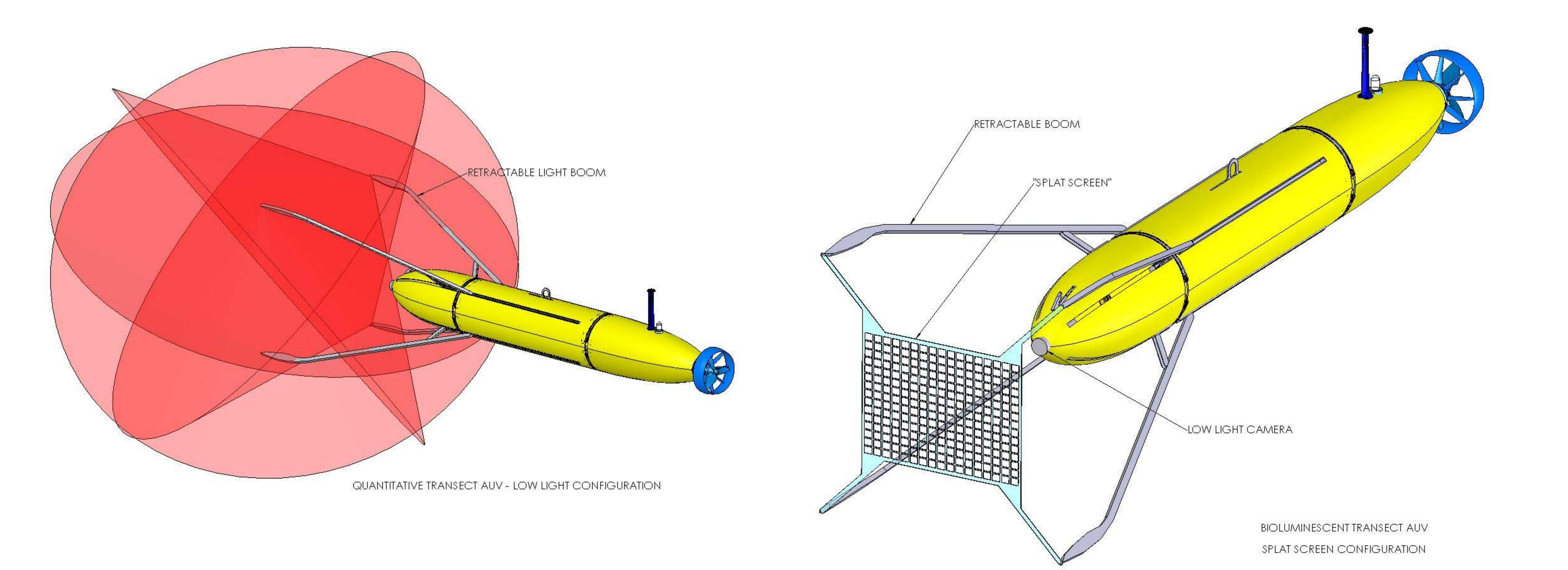
The first 6 months of the 2003 Quantitative Low-Light Imaging Module project (QLLIM) have been devoted to investigating the feasibility of developing a quantitative video imaging module for a Dorado class AUV that will allow this vehicle to take over and expand the long term midwater time-series transecting investigations currently conducted using MBARI's ROV resources, as well as develop a bioluminescence transecting capability.

Topics of investigation include:

- low-light, high resolution imaging cameras
- lighting sources and characteristics
- video compression techniques and data processing and storage
- power consumption requirements
- system architecture
- vehicle configuration

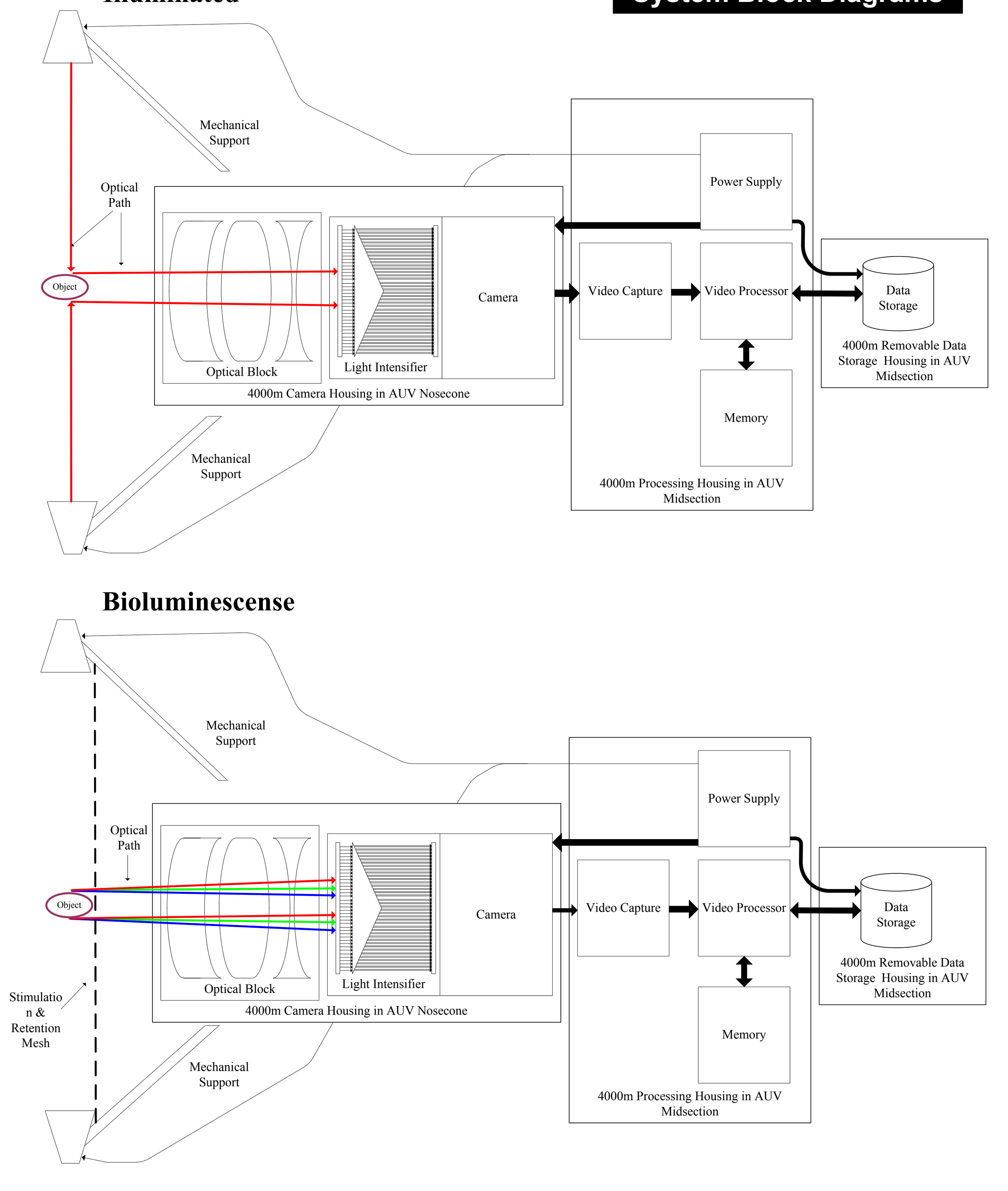


As shown in the chart above, we evaluated an existing transcect video for animal quantification for both video resolution and compression reduction. The original video was recorded in both HDTV and Digital Betacam and we downsampled and converted it to MiniDV, the format used in most digital camcorders, from the original Betacam.



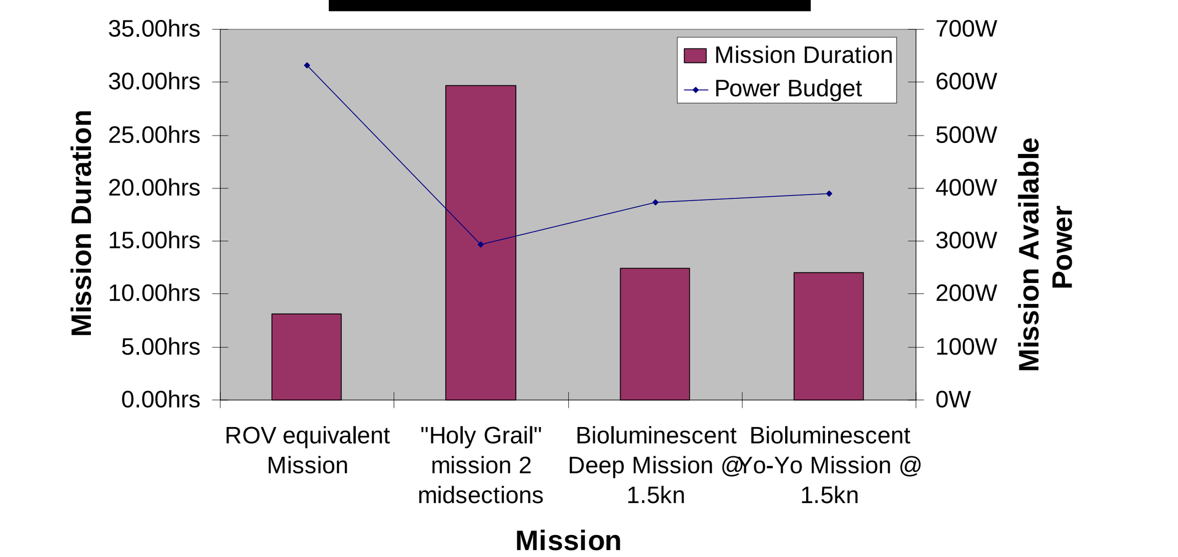
Mechanically, the module must provide a way to illuminate a non-bioluminescent animal and stimulate and retain bioluminescent animals. We envision four light booms, spaced equally radially around the AUV, that will retract and expand for deployment and recovery. Mission requirements dictate that there won't be a combined non-bioluminescent/bioluminescent mission, and that the stimulation/retention screen is expendable. For bioluminescent missions, the booms will keep the splat screen tensioned at 1m from the nose of the vehicle. For non-bioluminescent missions, the booms will provide side illumination of the water volume in front of the vehicle, with an LED at the tip of each boom.

System Block Diagrams



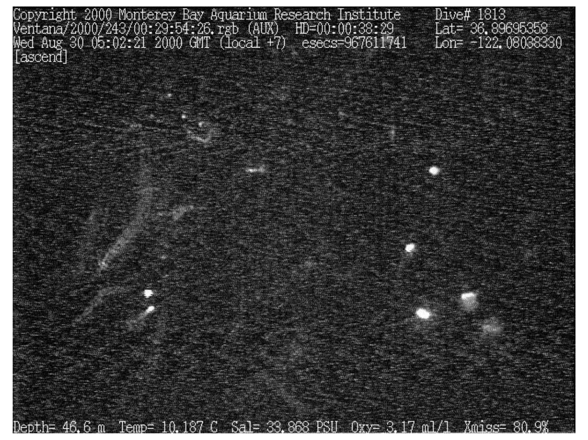
The block diagrams above show the module's primary components as they would be used for the two scientific applications, an illuminated scene and bioluminescense.

Module Power Analysis



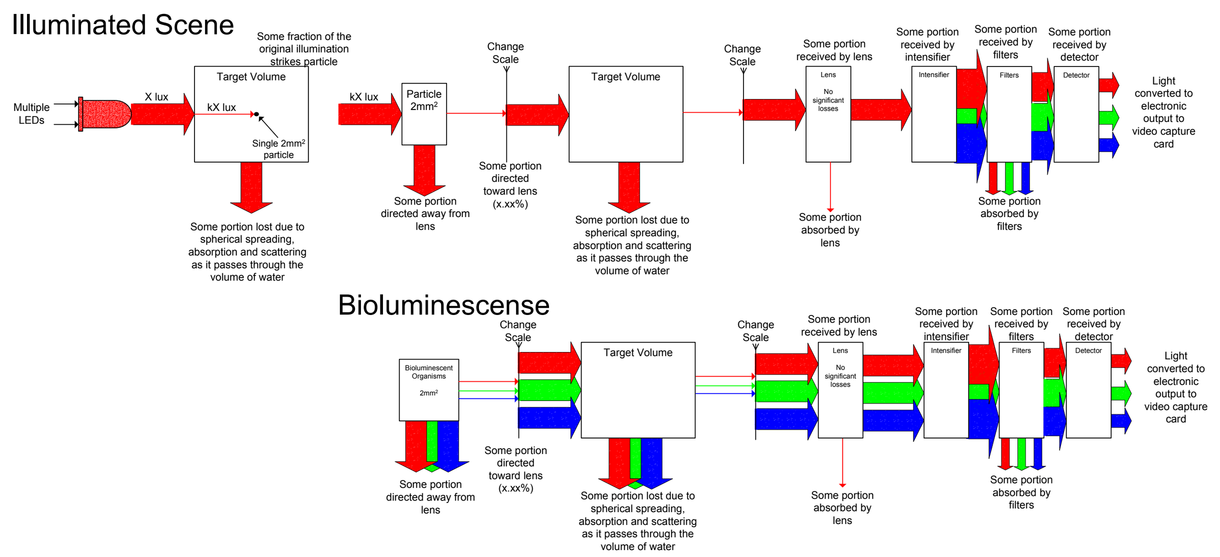
We have identified several concept missions. The mission duration defines the amount of continuous power available for the module. That available power is divided among the submodules, with a healthy reserve in case a submodule actually consumes more than was budgeted.

We expect the video compression process to require significant processing power, especially if we decide to use a color high-definition camera. The light intensification module allows us to drastically reduce the power required for illumination, compared with a typically ROV, without losing detail in the image. Overall, there is plenty of available power for the mission applications.



As an example of the image quality currently used for quantitative analysis of transect data, the image on the left is an illuminated scene from Ventana and the image on the right is from a bioluminescent transect.

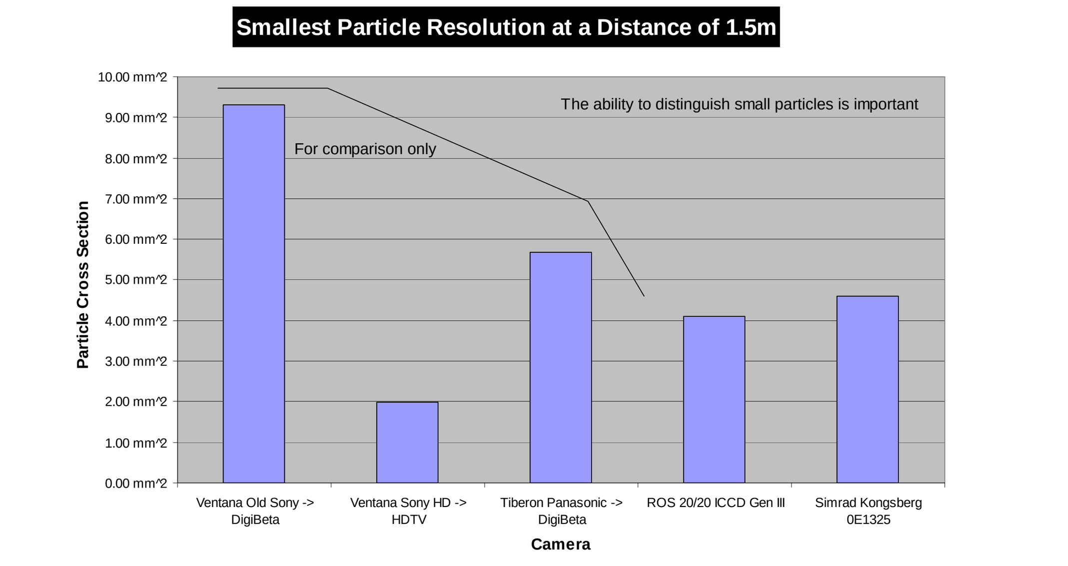
Tracking Illumination Through the Quantitative Low-Light Imaging Module



As light, electromagnetic energy, travels through water, both pure and seawater, it's energy is reflected, absorbed and scattered by the particles and atoms it encounters. The wavelength of the light may be shifted, and different wavelengths of light are absorbed more than others. For example, the red light used for illumination gets absorbed by water far more than the blue & green light generated by the bioluminescent animals.

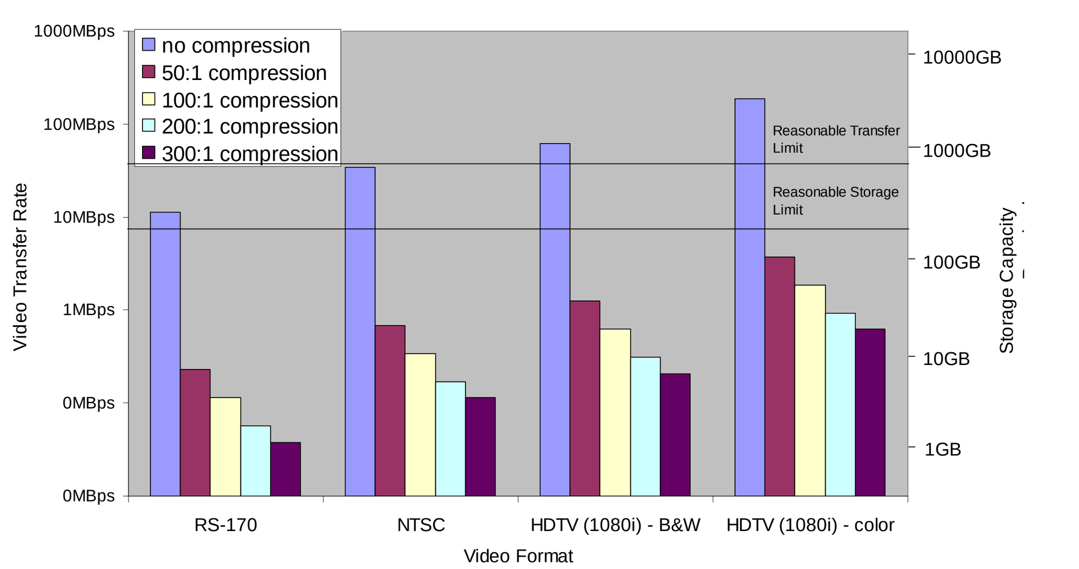
Based on equations describing the physical system, it is possible to create an optical, or photon, budget of the system. As light passes through the system, the budget reveals the amount transferred and lost as it goes through each stage.

Smallest Particle Resolution at a Distance of 1.5m



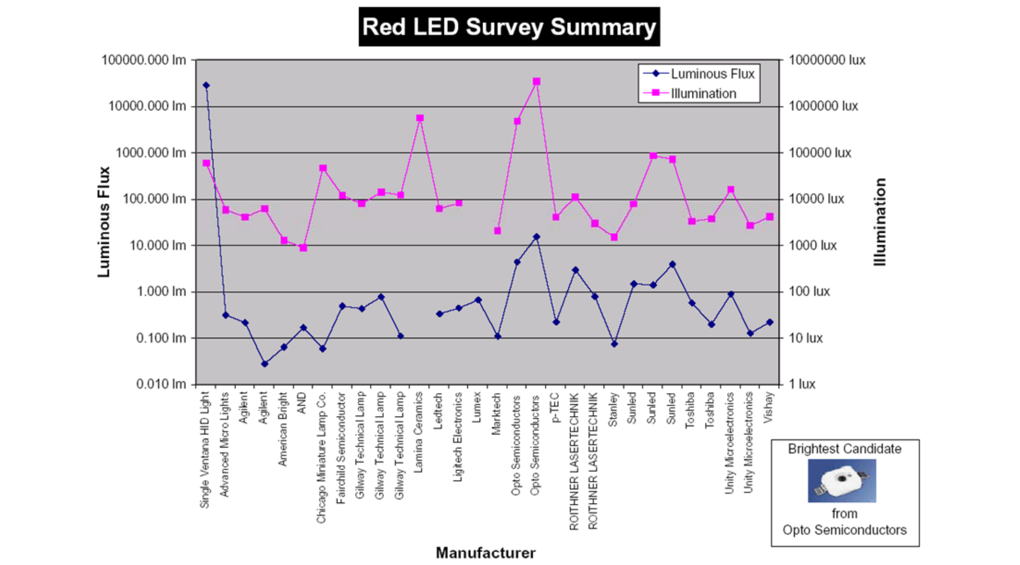
Resolution describes the imaging module's ability to reproduce object detail. It depends on the lens, camera, video capture system, and monitor. The final product of this new module must be comparable to that of the systems currently used on MBARI's transect missions. We are considering many different camera/lens solutions and have identified several that meet the basic requirements. For comparison, the resolution of two of these camera/lens systems are shown to the right of the resolution of cameras we currently use on ROV *Ventana* and ROV *Tiburon* in the graph above.

Video Data Transfer Rates and Storage Requirements for ROV Equivalent Mission



The choice of compression is critical to the quantification aspect of the project. We have identified a form of MPEG as the most likely compression algorithm for the project, although we haven't clearly identified the one of over fifty MPEG sub-specifications we intend to work with.

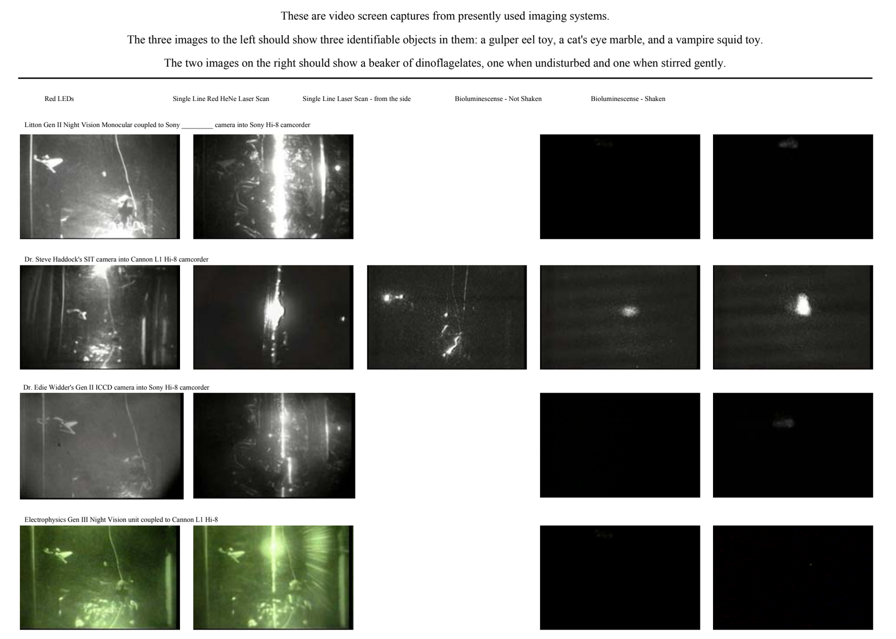
For comparison, the graph above shows how the raw video, from our target formats, needs video compression. A hard-drive with 250GB of storage, that can sustain a transfer rate of 59MB per second is on the cutting edge of the consumer desktop market. For the ROV Equivalent mission, only the NTSC formats can be reasonably transferred directly to hard-drive and none of the formats will fit on a single drive without compression. A 50:1 compression should be easily obtainable and allow the video to be transferred and stored.



Since non-bioluminescent creatures typically can't see red light, we'll shine red light on them so we can see them. Also, although most bioluminescent creatures generate blue/green light, some generate red light too, so we're also evaluating full-color low-light imaging systems.

VIDEO TEST RESULTS

Low Light Imaging Module for the AUV



The test results shown above are from preliminary testing of components and technology we have used at MBARI. We were able to see positive results from all of the systems we tested, and will work to optimize the results in future testing.

Summary:

Although the team has proven that many of the technical challenges facing the project are surmountable, we still have a few steps to take to ensure that the project concept is 100% feasible.

Next Steps:

Camera and Lighting Testing

- Photonic budget will be finalized
- Further camera and lighting testing will take place in the test tank.
- When available, in situ testing of a prototype camera/ lighting will take place using Ventana as the test bed.

Video Compression

- Prototype compression achieved with identified standards on Tiburon and Ventana SDTV and HDTV video streams
- Measure quality of video after video compression (by annotating before and after compression)

Lighting and Splat Screen Configuration Testing

- Mock-ups of the lighting booms will be manufactured and attached to Dorado for stability testing with, and without the splat screen attached.

Concept Review

- A concept review will take place prior to the submittal of the 2004 project proposal.

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For more information, contact either
Kim Reisenbichler (x1720) or Lance McBride (x2046).
You may also refer to the project website (http://mww.mbari.org/llim/)