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May 2007

NDSF Underwater Imaging Program

A Review of Present NDSF Imaging and a Preview of Possible Future Directions

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NDSF Underwater Imaging Program

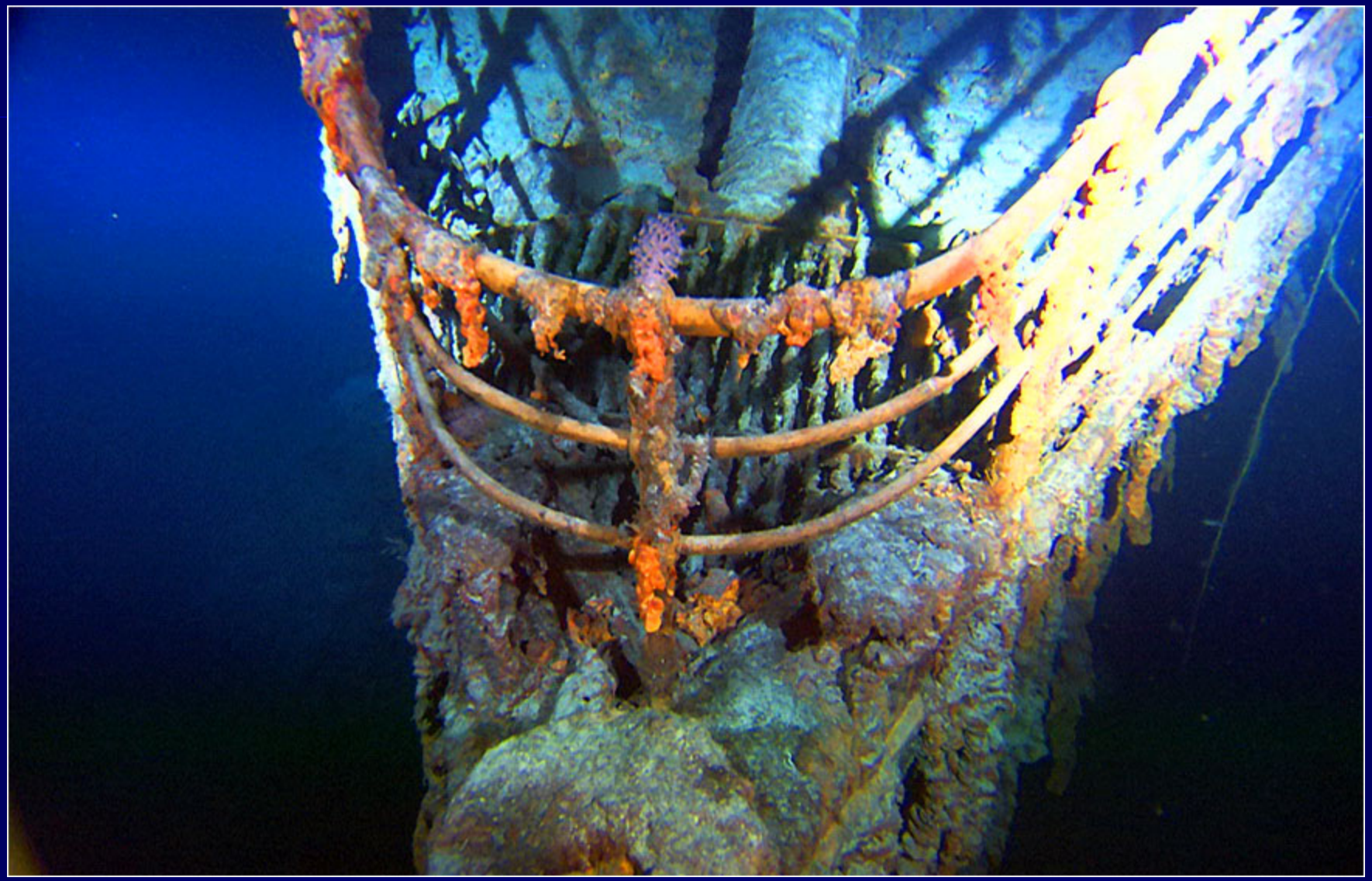
Advanced Imaging and Visualization Laboratory WHOI

- Develop Imaging Systems for scientific and film-making projects.
- Specializing in High Resolution Imaging for Underwater, Aerial, 3D, Spacecraft/Monitoring Applications

- Designed the current color camera systems on *Alvin*

- Since 1995 we have been working with HDTV ITU 709 format imaging
  Jason-Derbyshire
  Alvin, *Mirs*, HBOI, HURL, Navy

- Projects Include:
  Imax Films, Blue Planet, Planet Earth and many TV documentaries
  Stills have been published in Nature, Science, Scientific American, National Geographic and many hard cover publications



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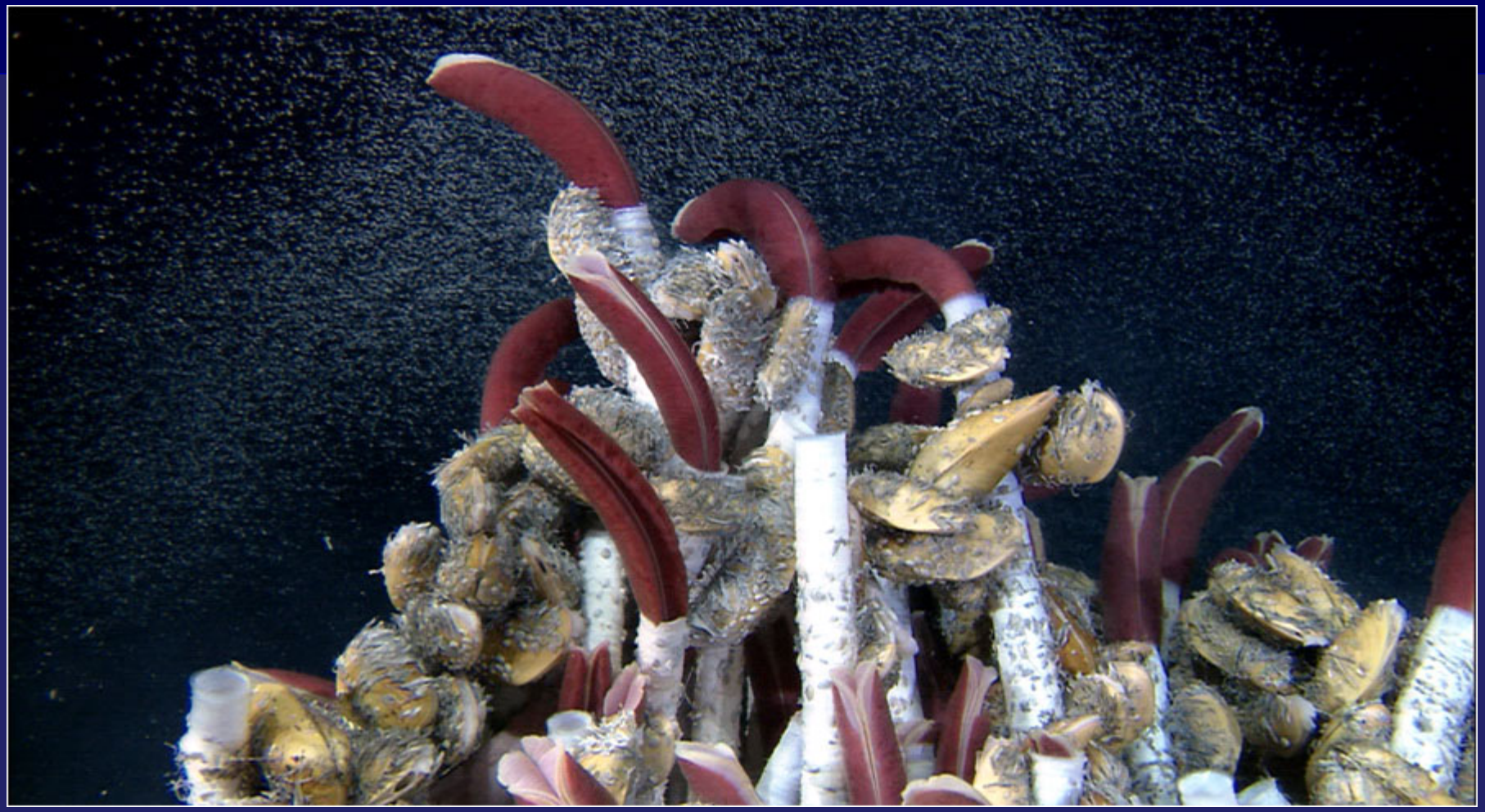

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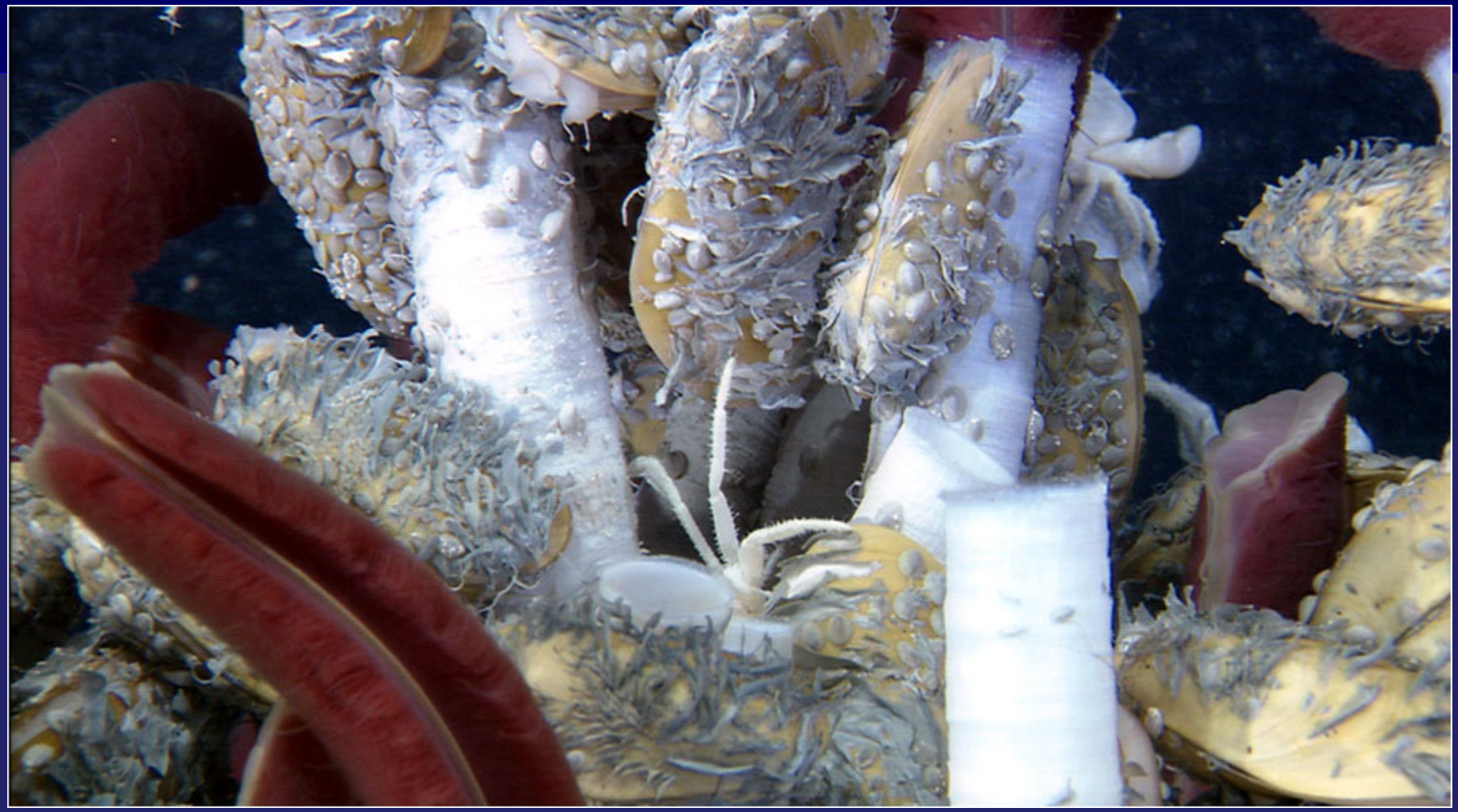

NDSF Underwater Imaging Program

Deep submergence underwater imaging is very complex and differs greatly from other imaging environments

- Lighting intensity is drastically attenuated with distance
- Lighting is spectrum shifted due to longer wavelengths being attenuated first
- Contrast and MTF is drastically attenuated making resolution and contrast range dependant
- Lighting and imager are typically co-aligned
- Lack of global illumination source
- Back and forward scattering of Illumination sources are water quality dependant

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Deep Submergence Imaging Platforms

- There are three main types of vehicles within the facility
- These can be broken down into two main imaging platform categories: AUVs and HOV-ROVs

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AUV Imaging Platforms

- Fixed lighting, camera geometry
- Fixed, under-exposed optics on wide dynamic range sensor
- Defined optimum optical range
- Fixed light-to-object geometry
- Medium camera/light separation
- Subject distance fixed
- Still image-based data collection

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HOV-ROV Imaging Platforms

- Lighting systems are variable:
  intensity, position, number, color temp, beam patterns
- Short camera/light separation
- Cameras can move independent of lights
- Lights move independent of cameras
- Subject distance varies greatly, including smear
- Camera/light operational ranges not documented
- Cameras typically have variable focal length lenses
- Need for workspace and operational lighting systems
- Motion and still-based imaging and recording

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Three Main Categories of Underwater Imagers:

- **Motion Cameras**
- **Still Cameras**
- **Hybrid Cameras, Still and Motion**

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Current State High Resolution Motion Imaging Sensors on *Alvin* and *Jason*:

Vehicle	Sensors	Resolution	Interface	Recording Resolution	Display Resolution
Alvin	3CCD Arm	800TVL	Y/C RGB Comp	DVCAM 25Mbits/Sec	YC, Comp Y,R-Y, B-Y SDI
Jason	3CCD	800TVL	Y/C	DVD 4Mbits/Sec	Composite, YC
Alvin	3CCD 2 each PATS	540 TVL	Y/C Comp	DVCAM 25Mbits/sec	YC, Comp Y,R-Y, B-Y SDI

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Overall Camera Complement, *Alvin* and *Jason*

Alvin	***Jason***
3CCD Arm Camera 800 TVL YC	3CCD Camera 800 TVL YC
3CCD PATS Camera 540 TVL YC	2 @ Insite Single CCD
3CCD PATS Camera 540 TVL YC	2 @ DSPL Single CCD
Down-Looking Sit Camera 400 TVL	
Still Cameras	
Insite Digital Still Camera	Insite Digital Still Camera
	Mosaicking ESC

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High Resolution 3CCD Cameras

- The 3CCD Cameras on *Alvin* and *Jason* are complicated and are designed to be used by operators with some degree of experience with camera operations

- Some basic video guides and further training should be provided to improve the skill levels of both NDSF operators and scientific users on the best use of these tools

- Some controls should be disabled to discourage untrained tweaking

- Understanding that white balance levels change with each vehicle's lighting footprint and pointing direction

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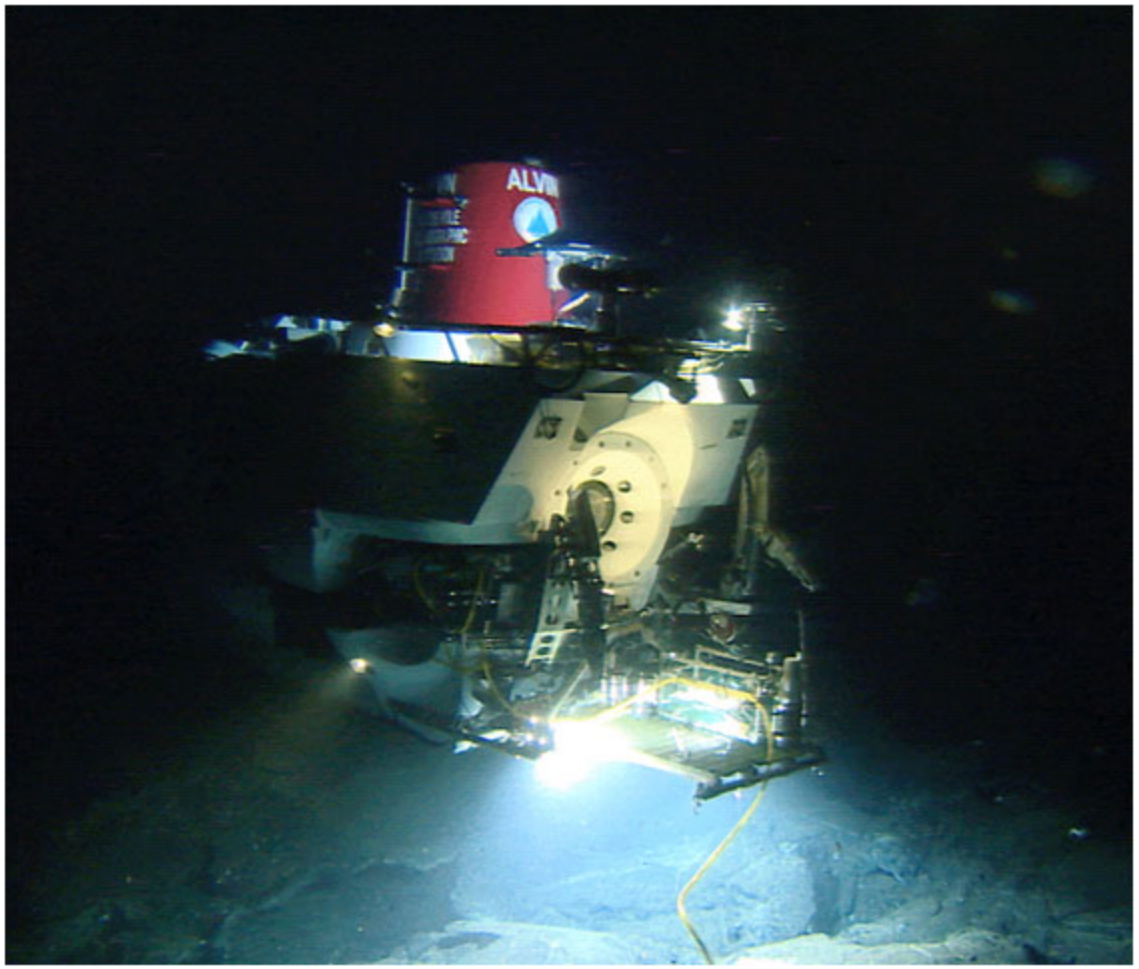

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Recording Format Comparison - *Alvin* and *Jason*

Alvin Y/C
DVCAM 25 mbits/sec

Optional
Digital Betacam 120 mbits/sec

Jason Y/C
DVD 4 mbits/sec

Optional
DVCAM 25 mbits/sec

Y/C upgrade completed on *Jason* in 2006

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Display and Monitoring

- One display in the Jason control van was converted to Y/C in 2007

- This was done to improve the quality of monitoring for the camera operators and the scientific users

- The *Jason* van has video test equipment, and when used with the Y/C monitor with the control knobs defeated should provide proper indication to the user of the true recorded signal

- *Alvin* currently is using composite and Y/C monitors in the sphere and SDI-component monitoring in the science duplication station

- QC viewing on *Alvin* is currently accomplished via the VTR display or in the future via the pilot display

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Lighting

- Both vehicles currently have configurable lighting systems
- Lighting is critical for the success of any imaging operation
- Lighting modes:

✓Down-looking survey
✓Wide-area forward
✓Close-up inspection
✓*Jason-Medea* multi-vehicle lighting
✓Offload lighting

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Lighting

- Recommendation that NDSF develop and distribute lighting configuration information to DESSC, Chief Scientists and operations personnel and through the web user manual

- Included in this information will be impacts on time for refits, payload and dive time/power

- Both vehicles have lighting “booms” which can greatly improve survey style imaging. Users need to be made aware of these options and impact to other operations.

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Lighting Geometries

- In general, greater light to camera separation reduces back-scatter and improves the illumination field for underwater imaging

- Geometries on *Alvin* and *Jason* are optimized for vehicle operations, not necessarily for imaging applications. At times these lighting geometries are in conflict with the needs of operations and science.

- Scientific users can find themselves attempting to conduct imaging operations in areas around the vehicle where insufficient lighting is available

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Lighting Recommendations

In the short term, better communication and exchange between operations groups and the scientific users, perhaps through meetings at Woods Hole with an imaging specialist involved at the pre-cruise planning stage, may contribute to improved and more efficient use of the vehicles and ship-personnel time at sea.

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Still Cameras

- **Digital still cameras have had a major impact on NDSF vehicles since the development of the first electronic still camera at WHOI-DSL in 1987**

- **NDSF vehicles no longer acquire film images, but there are some issues appearing in user comments about still image quality on NSDF platforms**

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Current NDSF Digital Still Cameras

- Mostly modified, re-packaged consumer grade still cameras
- A variety of models and designs have been tested or used
- Common factors affecting image results:
    - o Complicated user menus
    - o Many user options with no application underwater
    - o Localized storage typically not integrated to host data collection systems
    - o Use of consumer devices creates a short life time to model obsolescence
    - o Lag time in image acquisition after command given
    - o Base camera model not designed for these applications

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Digital Still Image Short-Term Recommendations:

- **Improve image/data collection logistical meetings with operators**
- **Camera simulators for pre-dive training**
- **Lighting and user configuration guides for *Alvin* and *Jason***

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The best camera-lighting system in the world will always be limited in its ability to produce high quality images by the experience and talents of the operators and the physics of the environment.

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Digital Still Image Long-Term Recommendations:

- **Incorporation of hybrid still-motion imagers**
- **Using HDTV and hyper definition imaging systems**

Hybrid sensors can acquire motion and still images of sufficient quality suitable for scientific exploitation, publication and documentary/ broadcast distribution

Single sensor package instead of separate motion and still cameras:

- Reduction in payload and number of camera housings
- 30 frames per second to acquire stills:
  - Real-time still acquisition
  - Post collection still acquisition from tape
- High performance viewfinder for stills

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The Pathway to HDTV and Beyond

- **There are currently more than 38 HDTV standards and formats**
- **There are currently more than 7 consumer and HDV standards and formats**

There are many choices!

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HDV is not HDTV

- HDV data rate is equal to DVCam
- HDV does not support progressive imagers
- HDV uses very small sensors which require lighting
- No COTS lenses exist today that can provide full optical resolution to HDV CCDs
- Most HDV imagers are up-converted and are not native HD resolution
- Still image extraction from HDV is low quality due to compression system

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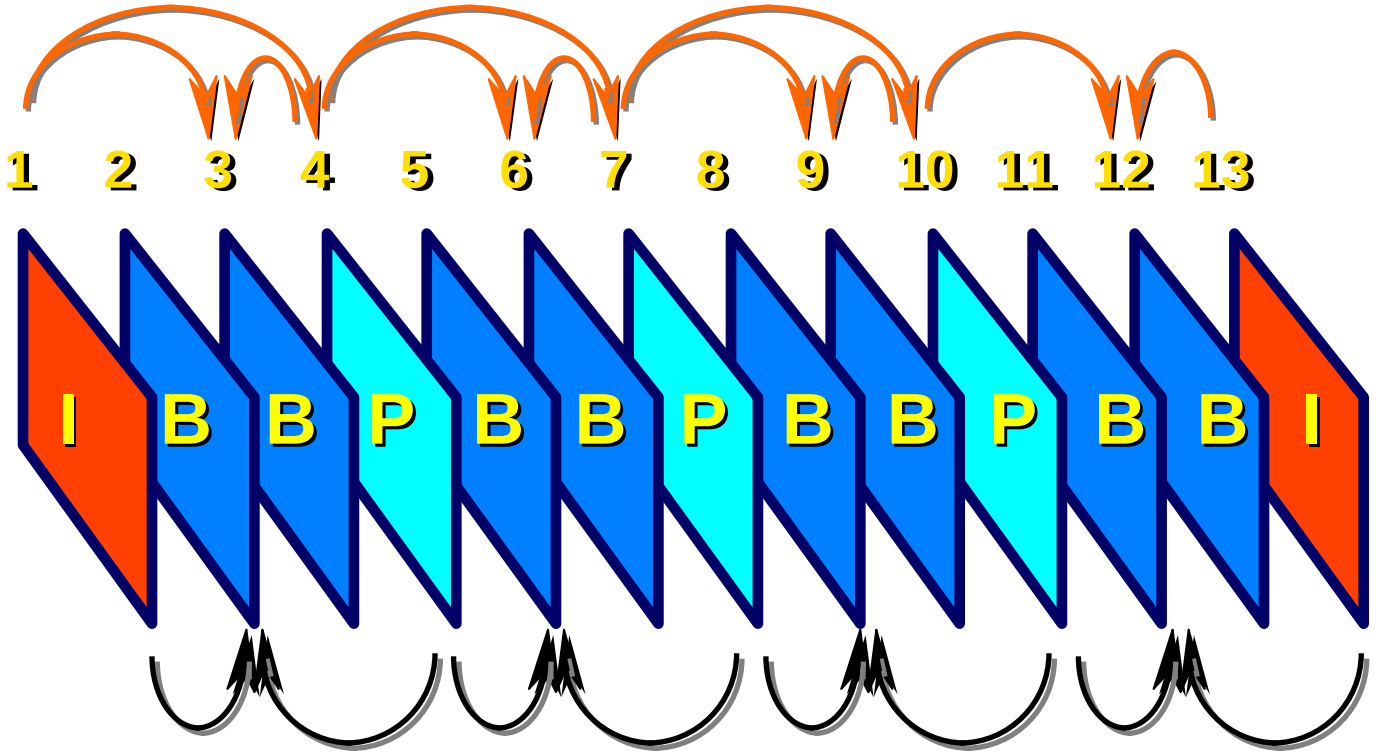
Compression is not friendly to science

- Inter-frame compression (within a set of frames or GOP)
- Intra-frame compression (within a frame)
- DCT
- Wavelet JPEG-2000

- Long GOP (group of pictures)
- HDV uses a Long GOP of 15 pictures
  - 2 real frames per second
  - 28 predicted or interpreted frames per second

Inter-frame Compression System



I = Intra-Coded Frame
P = Predictive-Coded Frame
B = Bidirectional-Coded Frame

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Inter-frame compression limits the quality and accuracy of feature extraction from still images obtained from motion video.

Measurements of size and motion will be qualitative, not quantitative.

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HDTV systems use intra-frame compression at low loss levels. We support ITU-709 HDTV format, 1920 by 1080 pixels and have successfully deployed HDTV camera systems on deep submergence vehicles for over a decade.

We currently have two HDTV camera systems that are *Alvin*-friendly (arm mountable), and numerous other HDTV and hyper definition camera systems for use by the scientific and documentary community, including macro and 3D cameras.

Discussions are underway for further testing and integration of these types of sensors with the *Jason* ROV.

The Lab has a number of hyper definition motion and still cameras currently under development and testing.

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Hybrid Imager Concept

- HDTV or Hyper Definition Camera System
  - With fixed or variable focal length optics
  - Remote aperture control will net approx 2-3 f-stops
  - Remote aperture produces the equivalent of 4 bits dynamic range
  - Hybrid camera will operate at motion rates 15-60 frames per sec (based upon sensor)
- Image data will have a dual path:

  1) Native full resolution data is acquired in a still image mode 12 bits or higher
     - Rep rate TBD or on demand
     - Stored such as *Alvin* framegrabber but at full resolution
  2) Motion data is converted to an industry standard format
     - HD-SDI SMPTE-292
     - HDV/DVCAM Fire-wire/analog video

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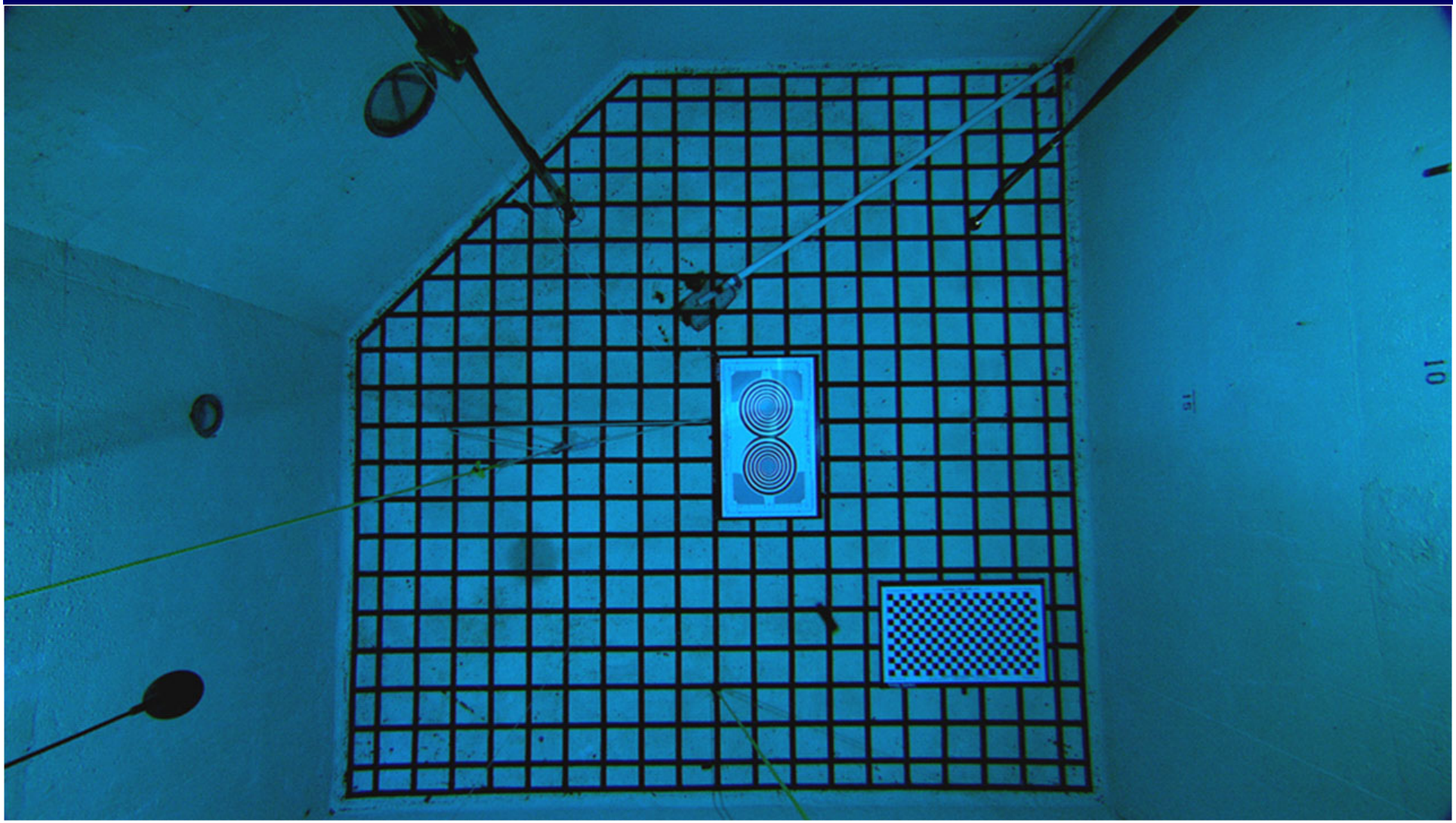
The Hybrid Sensor approach has many benefits:

- Allows for high quality stills to be acquired simultaneously with high quality video
- Improves the resolution of the existing video cameras
- Does not require an immediate change to the motion recording infrastructure
- Allows for wide dynamic still images to be collected and processed post collection
- Provides an upgrade path to HDV or HDTV systems while minimizing the effects of the compression schemes

- ***Alvin* and *Jason* could be converted without immediately changing the motion video infrastructure on both platforms**

- **A majority of this work has already been developed at Advanced Imaging and Visualization Lab for Navy programs**



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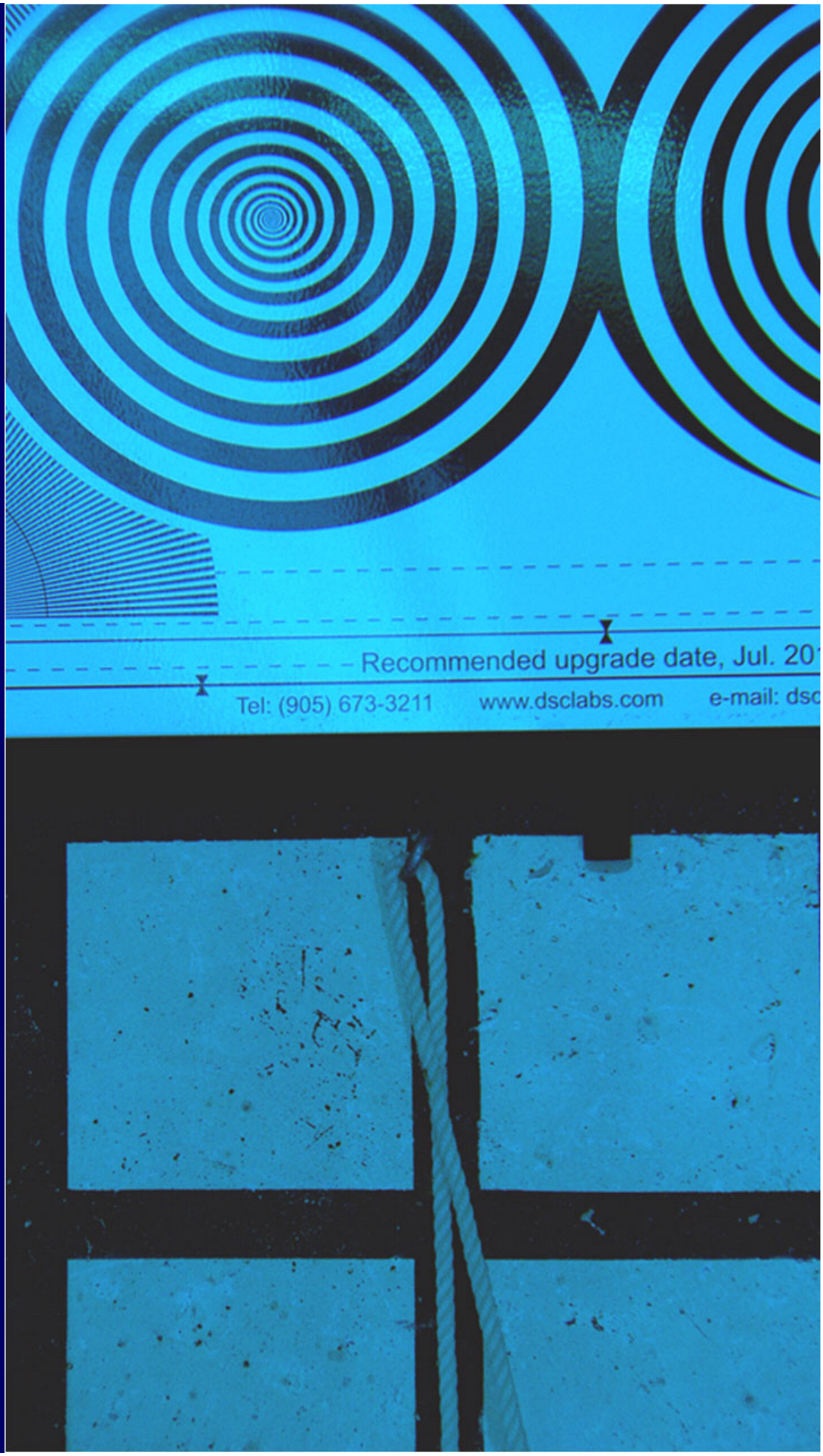

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Long-Term Motion HDTV Recording

- **In the next 1-2 years, optical technology may offer NDSF a cost effective manner to record HDTV signals at costs more in line with DVCam rates**

- **Currently, we are limited to $60/hr or greater tape costs for recording HDTV video**

Tape Media Cost:	**DVCAM**	**$12/hr**
	DVD	**$1/hr**
	HDV	**$12/hr**
	HDTV	**$65/hr**

- **It is expected that in the next few years the optical HDTV rates will be around $25/hr**

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Lab demonstrations will be available at the Blake Trailer, next to Blake Building in the village, Thursday morning

- **Motion Imagery from *Alvin* and *Mirs***
- **HDTV still and motion test data**
- ***Alvin* 3D HDTV camera system**
- **WHOI Mini-Cam HDTV camera heads**