Discussion Paper on Issues Associated with Large Scale Implementation of Video Monitoring

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Introduction

Video, either alone or in conjunction with other data gathering equipment (electronic monitoring, or EM), is becoming an increasingly viable technology for monitoring some types of fishing activity or enhancing the ability of observers to gather fisheries data. The technologies associated with EM are in a state of rapid development. The combination of increasingly effective data compression algorithms, increased computer processing power, and the rapidly decreasing cost of data storage have reached a point where, on a technology level, electronic monitoring is ready for large scale implementation for some fisheries monitoring applications. However, while many of the technical issues associated with the collection of EM data have been addressed, neither NMFS nor the fishing industry have fully addressed many of the infrastructural and cost related issues associated with larger scale EM program implementation. Finally, EM technologies are complex and rapidly changing while our ability to implement regulations is comparatively ponderous. In other applications, this has created situations where older technologies are effectively enshrined in regulations and, as we seek to develop effective EM programs a regulatory framework that allows us to keep pace with technological change will be necessary.

This paper attempts to summarize the state of current technology, and to discuss issues associated with larger scale implementation of EM as part of any fisheries monitoring program.

Current Technology—What EM systems can and cannot do well

Based on studies conducted to date, it appears that EM technology is able to:

- Function sufficiently reliably in the marine environment.
- Identify fishing events (e.g. net deployment, line retrieval) and the location where those events took place.
- Determine when and if discard events take place on trawl catcher vessels.
- Verify compliance with seabird avoidance measures on longliners.
- Assist an observer in monitoring activities in otherwise unobservable areas of catcher/processors.

On the other hand, EM systems are only moderately able to:

- Quantify the amount of discards on trawl vessels.
- Detect and identify seabird bycatch to species on longliners.
- Estimate the species composition and number of fish in longline catch.

The at-sea portion of the technology, while the focus of most research to date, is only one component of an effective EM system. For an EM system to function properly, the data collected at-sea must undergo some degree of methodical review. In the studies conducted to date, this review has been fairly meticulous, with the assumption being that most missed events have been due to technology and data collection issues rather than data review issues. While such an approach is necessary when testing the applicability of a given technology, it does serve to possibly over inflate the total cost of an effective EM program. Further, at least a portion of EM data must be curated for further review and/or use in the prosecution of violations. Such curation may require a large investment in data storage infrastructure.

Infrastructural issues—roadblocks to large scale implementation

EM can't replace a human observer. In quota based fisheries, such as the rockfish pilot program, it appears that EM could be used to ensure that quota species are not discarded at-sea. However, the rockfish pilot program was designed around 100 percent observer coverage for two reasons. One was to ensure that allocated species were not discarded; the second was to ensure that halibut prohibited species catch quota, which must be discarded at sea, was accurately accounted for. While EM has shown some promise at quantifying catch, it has not been tested against observer data for this application. Unfortunately, scenarios of this type are more the rule than the exception. In most applications where video could possibly be used for routine monitoring of some fishing activities, it would only be possible to reduce observer coverage levels to the extent that the higher observer coverage is for the sole purpose of routine monitoring. In most cases, however, the observer also performs an important role in the collection of data necessary for accurate catch accounting. stock assessment, and the collection of other biological data.

The level of technology may become "fossilized" at the time when large scale implementation takes place. EM technology is, as has been discussed, in a state of rapid evolution and each year has brought significant and meaningful improvements in the availability and cost of EM products. Unfortunately, at the point where a given technology is adopted and large scale implementation takes place, it becomes more difficult to incorporate new technological developments. This can occur for two reasons. First, the Federal regulatory process is not designed to respond rapidly to technological evolutions and developments. More importantly, there are significant costs associated with adopting any given technology. Once those costs have been paid, a newer technology must demonstrate a significant advantage before it is likely to be adopted. As an example, the gaming industry in Las Vegas was probably the first industry to implement large scale video monitoring. Because this implementation took place prior to the availability of digital video, the vast majority of casinos are still reliant of analog video systems where a single camera records directly to a single VCR. Since the average casino has 3,000 individual cameras recording 24 hours a day and the tapes are generally maintained for at least seven days, the number of VCR tapes recorded by even a small casino is prodigious. Clearly it would be an advantage to the gaming industry to use digitally based systems. However, because of the significant investment in analog equipment, this transition is only now starting to occur.

Costs, at this time, may be similar to or even greater than, the use of observers. An analysis of the costs associated with implementation of EM in the rockfish pilot program is attached as Appendix 2. Based on this project, use of EM may not result in any large scale cost savings for the fleet, primarily because of the costs associated with the analysis of the EM data. However, new software tools designed to assist in data review are being developed that may significantly reduce the time for routine data review. Further, it may be possible to reduce these costs through less meticulous analysis of the EM data in certain circumstances. Clearly, however, a reduction in analysis time will reduce the frequency with which various events are identified. Determining the extent to which this is the case has not been researched.

Another problematic aspect of EM costs is determining how these costs should be apportioned between the fishing industry and NMFS. Depending on that allocation, the nature of the regulatory program implementing EM could vary dramatically. For example, in a program where NMFS paid the cost associated with data analysis, the regulatory structure could be comparatively simple since vessels would only be expected to submit EM data to NMFS in a timely fashion. Aspects of the EM program “downstream” from the actual collection and submission of EM data would be handled outside of regulations. However, the cost burden imposed on NMFS by such an approach would be significant and funding mechanisms would have to be identified if a credible program is to be created.

Each application for EM is different, and could require different standards and equipment. System specifications such as the frame rate, amount and type of allowable data compression, individual image size, number of required cameras, and the extent to which EM data must be retained or submitted for analysis could vary widely depending on the application. Clearly, a frame rate and image size that is adequate for determining whether a vessel has deployed seabird avoidance gear would be inadequate for determining whether or not crew discarded a single fish.

For example, in the hake fishery off Oregon and Washington, an EM system is being used under an EFP to ensure that there is no discard by catcher vessels. Such a presence/absence application is simpler than what would be required under the rockfish pilot program where the discard of some species will be required, while the discard of other species will be prohibited. In order to make such a system work, vessels would be required to ensure that all discard took place in specified locations so that it was clear exactly what is being discarded. Thus, application of an EM program in the hake fishery could conceivably take place without requiring changes in crew behavior or vessel layout, whereas application in the rockfish pilot program would probably require both.

As each application for EM is developed, there will be many individual decisions to make that will affect the viability and cost of the resultant program. Because each application is different, this may be a time consuming process. As an example, for a recent NMFS roundtable discussion concerning implementation of EM, a series of decision points in a generic EM program were developed (see Figures 1 and 2). While these decision trees are clearly not exhaustive, they do serve to give a sense of the complexities associated with the process.

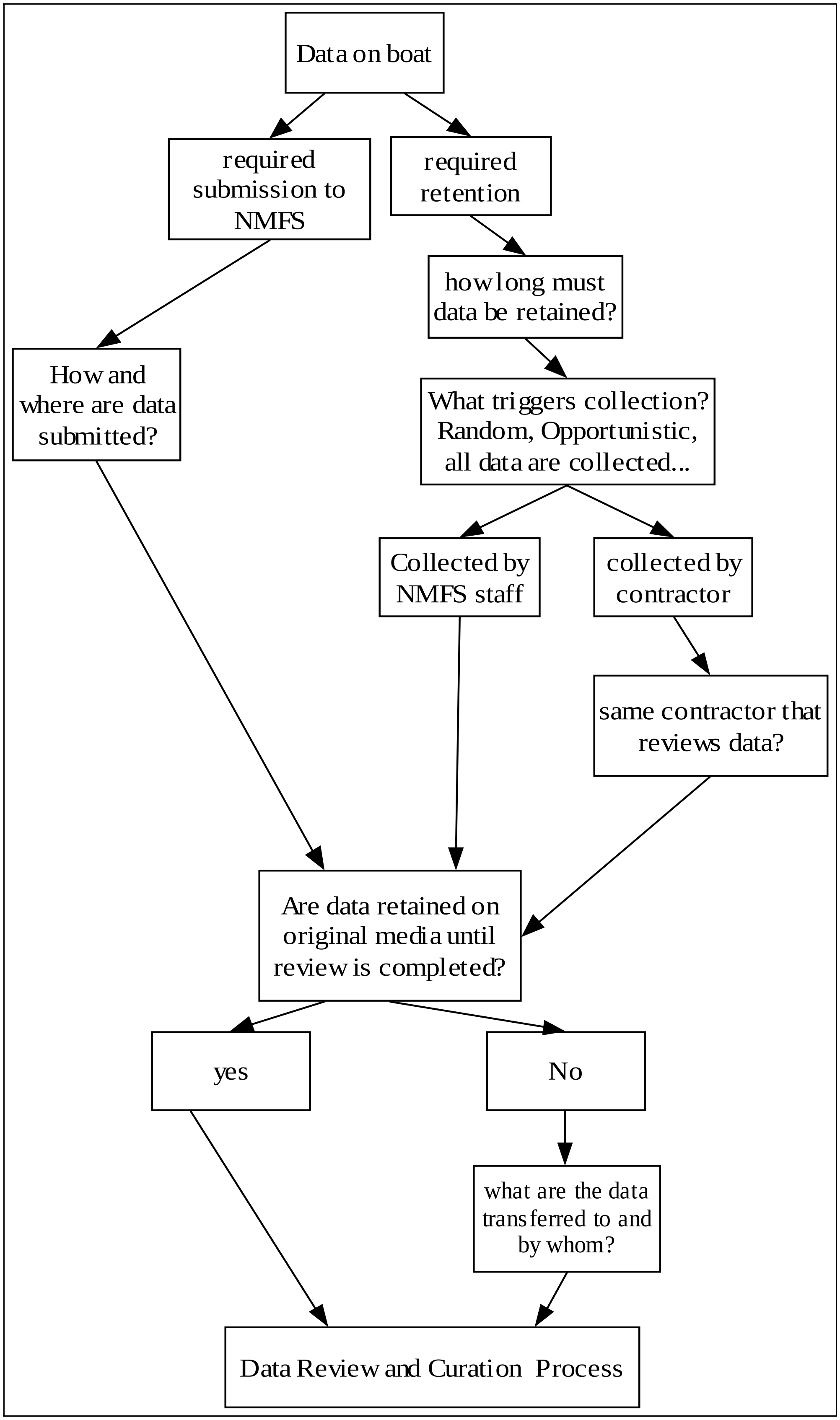

Figure 1. Some of the decision points associated with the data collection process. This does not include decision points related to the actual EM system data recording, nor to those associated with the review and curation of the data.

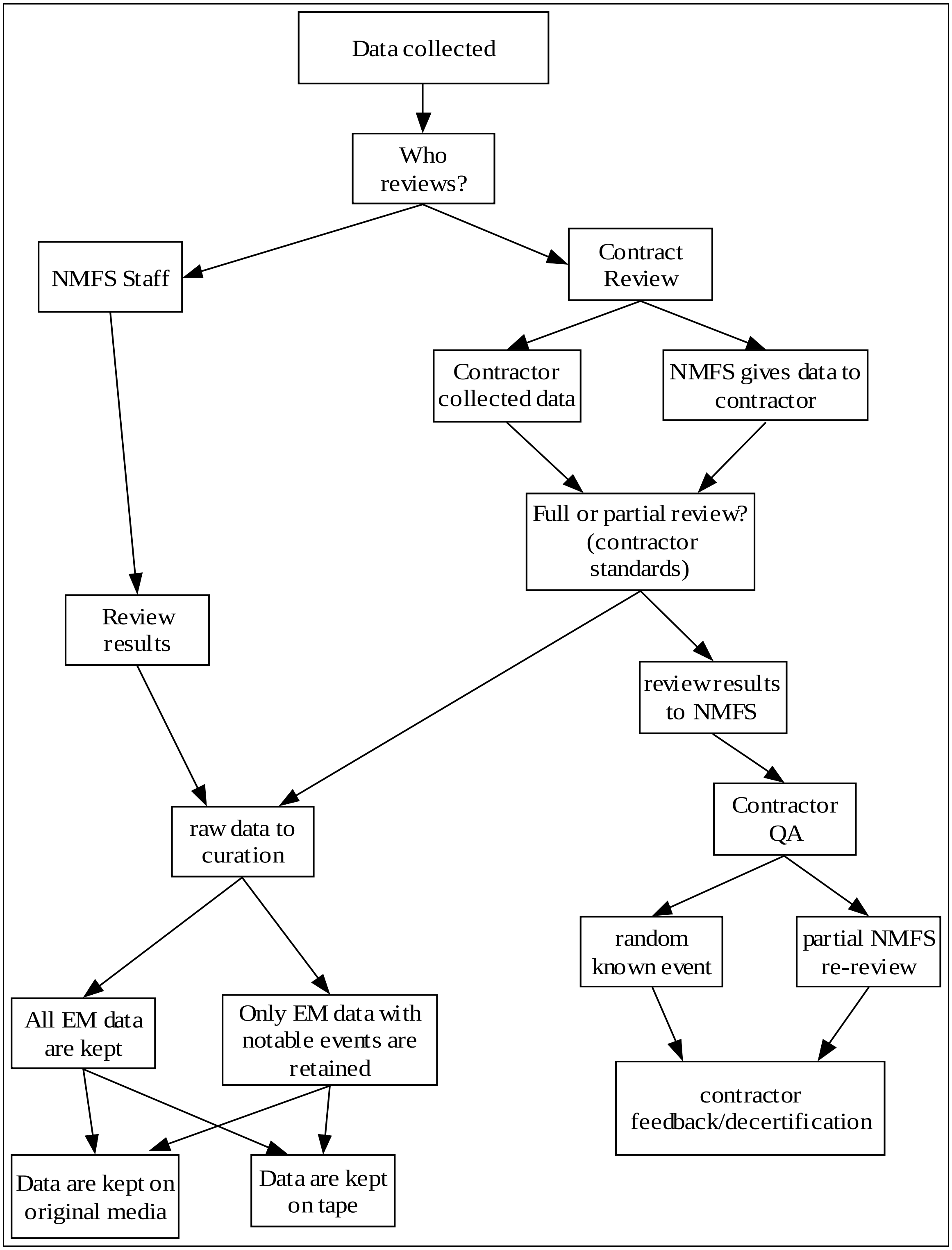

Figure 2. Some of the decision points associated with the data review and curation process. This does not include decision points related to the actual EM system data recording or collection processes.

Regulatory Pathways

As has been discussed above, EM is complex and implementation of an effective program will involve numerous challenges for NMFS as well as the fishing industry. Clearly an effective program must be flexible enough to change as new technologies are introduced and our knowledge of those technologies increases. Finally, the total costs for any large scale program will be high whether borne by NMFS or the fishing industry. Thus, an effective program will have to balance issues of cost, program oversight, flexibility, and enforceability. However, fundamentally, the nature of an EM program is based on the extent to which NMFS exerts direct control over the technology and data flow. In general, as agency control increases, the ability to ensure quality data and respond to changes in technology would be expected to increase, but so would costs and other demands upon NMFS.

In order to framework the problem, we have described four regulatory scenarios ranging from intensive NMFS management of an EM program to minimal NMFS involvement. For each scenario, we have attempted to describe the impact on program costs and anticipated outcomes based on a set of six benchmarks described below. While this crosswalk of benchmarks and scenarios was developed using the implementation of an EM program for monitoring discard in the rockfish pilot program, it is broadly applicable to any EM program. Ultimately, of course, any set of regulations will combine multiple aspects of these approaches.

Benchmarks

<u>Cost to NMFS</u>. Even the lowest cost implementation of EM would involve a significant commitment of NMFS resources. As an example, a projection of the costs associated with large scale implementation of EM in the rockfish pilot program can be found in Appendix 2. For the purpose of this crosswalk, the options have been ranked from highest to lowest cost for NMFS.

<u>Cost to Industry.</u> To a great extent, the regulatory framework determines who takes on the cost burden. As costs increase for NMFS, costs to industry would decrease.

<u>Review Control.</u> How well can we ensure that EM data is properly and reliably analyzed? This benchmark covers the data review process.

<u>Technology Oversight.</u> How well can we ensure that the systems are reliable and that they are appropriate for collecting the "right" data? This includes issues related to camera type, image quality, compression, frame rate, security, system storage capacity, and at-sea system reliability. In effect, this benchmark covers the technical aspects of the system from trip start to the point that the data leaves the boat.

<u>Installation Oversight.</u> How well can we ensure that the system is recording the "right" things at the right times in the right way? One of the lessons learned from the 2005 summer trawl project is that camera location and overall system design is an iterative process. Vessels are uniquely configured and issues on one boat may not be issues on

another. This benchmark covers issues related to system installation and appropriateness such as camera placement, lens selection, and number of cameras.

Enforceability. To what extent does the approach facilitate or hamper enforcement?

Flexibility. As conditions change, how well can the system adapt.–either because of the introduction of new technology, changes in the expectations for an EM system, or changes in available budget. In the case of EM, this is a critical component because of the rapid development of the technology.

Regulatory Scenarios

Full NMFS Ownership. Under this scenario, NMFS would purchase, own, and install all EM equipment. We would also be responsible for collecting and analyzing all EM data. Such an approach would give the agency the greatest flexibility to respond to the development of new technologies and would also give us the greatest oversight over all aspects of the EM process. However, the costs would, unless a fee collection program could be implemented, be borne totally by NMFS.

Approved Contractors. Under this scenario, NMFS would approve EM system contractors based on regulatory specifications. This process would be similar to the existing observer program. The approved contractors would be responsible for installing and maintaining EM systems that met certain criteria and would also be responsible for collecting and analyzing the EM data. NMFS' role would be one of data quality control and auditing. The primary advantages of this approach are that it would allow us to tap into existing expertise and place the majority of the costs onto the industry. However, developing regulations that, on one hand, provided sufficient flexibility for approved contractors to exploit new or different technologies, while at the same time giving NMFS sufficient control, could be problematic. Further, because all raw EM data would pass through the hands of contractors, issues related to chain of custody and data control could be more difficult to resolve. Costs under this model could be born totally by the industry, or the analytical costs could be paid by NMFS. For the purposes of this crosswalk, we assume that all costs are paid by industry.

Type Approval. This is the model currently used for NMFS approved VMS systems and scales. It has three major shortcomings. First, it would be slow to respond to changes in technology; second, it would be very difficult to address issues related to installation oversight; and third, it would be very difficult to write approval standards for the wide variety of possible installation scenarios. To give one example, a wide angle lens combined with a detailed image may be the best choice for a camera that is used to give an overview of the entire deck, whereas a narrower field of view and a smaller, less detailed image might be more appropriate for a discard chute.

Performance Standards. Under this scenario, regulations would specify what the system had to do, not how it had to be done. This approach would allow more rapid adoption of new technology and would more effectively cover issues related to installation. However, enforcement of performance standards can be problematic if not carefully crafted to avoid ambiguity. Further, given the wide variety of available equipment and file types, the data stream could be complex and hamper the analysis process. Finally, a performance standards based approach would be expected to be more labor intensive for NMFS to administer, resulting in higher costs than a comparatively simple type approval process. This is the approach currently under development to allow the use of EM for monitoring personnel in fish bins on catcher/processors in the rockfish pilot program and for Amendment 80.

Table 1. Benchmark and scenario crosswalk. This table qualitatively summarizes the relative advantages and disadvantages of the four scenarios relative to benchmarks. Rankings are numeric (four being relative worst and one being relative best from the perspective of NMFS).

approach	**Benchmark**						
	Cost to NMFS	Cost to Industry	Review Control	Technology Oversight	Installation Oversight	Enforceability	Flexibility
Full NMFS ownership	Highest(4)	Lowest(1)	Highest(1)	Highest(1)	Highest(1)	Highest(1)	Highest(1)
Approved contractor	Lowest (1)	Highest(4)	Lowest(4)	Medium Low(4)	Lowest(3)	Lowest(4)	Medium(2)
Type approval	Medium(2)	Medium(2-3)	High(2-3)	High (2)	Low(4)	Medium(2)	Lowest(4)
Performance Standards	Medium(3)	Medium(2-3)	High(2-3)	Medium(3)	High(2)	Medium(3)	Medium(3)

Conclusion

EM technologies have clearly developed to the point where they can be used to enhance or even replace human observers for certain routine monitoring functions; but because each potential application for EM seeks to answer different questions, different approaches to implementation will be necessary for each application and many infrastructural, cost, and regulatory issues remain to be resolved. We anticipate that the first large scale implementations of EM will be for comparatively simple applications where EM supplements, rather than replaces, human observers. For example, we are in the process of developing an EM based option for catcher/processors participating in rockfish pilot and Amendment 80 fisheries. This option would be one of several bin-access choices that catcher/processor owners could make and would allow crew access to fish bins while at the same time giving the observer an additional tool for ensuring that crew are not presorting catch while in the bins. On the other hand, regulatory complexity and the fact that 100% observer coverage is necessary for accurate halibut PSC quota accounting, precludes the development of an EM option for catcher vessels participating in the rockfish pilot program at this time. Other Regions have successfully “implemented” larger scale programs through the use of EFPs, and this may be a mechanism for continued development of these more complex programs.

NMFS is encouraged by the rapid development of EM technologies and believes that they will play an important future role in the routine monitoring of fishing and fish processing activities. We have established a working group within NMFS that will focus on: developing priorities for future research; developing “best practices” for the analysis and handling of EM data; investigating new technologies: and resolving infrastructural and regulatory issues associated with large scale program implementation.

Appendix. 1. Overview of the 2005 Kodiak electronic monitoring project

Project Summary. During the summer of 2005, video based electronic monitoring (EM) systems designed by two companies (Archipelago Marine Ltd and Digital Observer Inc) were deployed on a total of 10 catcher vessels. The group of vessels covered represented a good cross section of more than a third of the rockfish fleet and included the largest as well as the smallest observed vessels that regularly fish for Gulf rockfish. The goal of the project was: 1) to determine whether an EM system could be used to determine if at-sea discard occurred and 2) whether that discard consisted of quota species that would be required to be retained under the rockfish pilot program, or halibut, which would continue to be a required discard. Over the course of the project, 1,463 hours of fishing activity (towing and catch handling) representing 433 sets were recorded and reviewed. For 194 of those sets, we were able to compare EM records of discard with vessel observer records of discard.

Key Findings.

- The Archipelago systems were highly reliable. 99.99 percent of the sensor data and 99.4% of the video data that could have been collected was. The Digital Observer systems were less reliable. Only 76% of the sensor data and 70.6% of the video data that could have been collected was. With the exception of a bad batch of cameras, failures were due to installation and operations errors rather than unreliable equipment.

- Industry cooperation throughout the project was good. While reservations about the invasive nature of the technology were almost universally expressed by skippers, boat owners, and crew, most appeared ready to adopt the technology if it resulted in clear savings.

- Over 80% of reviewed hauls had discard detected. The discard occurred in three primary ways: large quantity discard of unsorted catch (net bleeding); large quantity discard of sorted or partially sorted catch (shoveling); and small quantity discard of sorted catch.

- Net bleeding was rare. However, EM failed to detect this behavior on the one occasion where it was noted by the observer. Camera placement (lack of a good view over the gantry) appeared to be the problem.

- Approximately 10% of sets had shoveling type discard events. Because fish were discarded in multiple locations and in high volume, identification of individual fish or quantification of the amount of discard was not possible.

- For small quantity discard events, it was generally possible to tell by morphological category (i.e. flatfish vs. roundfish) what the discard consisted of.

- Observer data and EM data agreed 86% of the time on the presence/absence of discard events.

	EM Sets with Discard			
Observer sets with discard		Yes	No	Total
	Yes	146	22	168
	No	6	20	26
TOTAL		152	42	194

- For the 22 events where the observer noted discard and EM did not, reanalysis of the video noted discard on 9 of the hauls indicating reviewer error. Other missed events may have been due to the observer sampling out of sight of the camera or bad camera placement.

- Observer data and EM agreed 78% of the time on the presence/absence of halibut discard events. Re-review of those 28 hauls where the observer noted discard and EM did not were similar, with reviewer error accounting for 13 of those hauls.

- Overall, both systems appear adequate for detecting and categorizing smaller scale discard events. Determination of species group would be dramatically improved if all discard was required to be made through one or two discard chutes.

- Time analysis data presented in the final report allows us to project the actual costs associated with implementing a similar program (see cost data below). The review costs represent the largest share of the expenses. If industry is required to bear these costs, savings realized over using observers may be minimal.

Appendix 2. Implementation cost projection for full implementation of EM in the rockfish pilot program

Assumptions. Cost projections for rockfish pilot program EM are based on the following assumptions:

- The current fleet of approximately 25 boats will consolidate to 18 actively participating boats;
- participating boats will fish an average of 7 trips each; and
- trip length will average 3 days, of which there will be 24 hours of activity that will need to be reviewed.

Hardware and installation costs. These costs are comparatively simple to estimate and would not be as dependent on the exact program contemplated. The Archipelago and Digital Observer systems both appear to be of adequate quality to capture the majority of discard events and serve as a good base point for cost estimation. Archipelago publishes the cost for a complete system and that cost is used in this estimation. However, assembling a system from off the shelf components would reduce these costs considerably. In addition to the actual cost of hardware, system installation and maintenance costs must be considered. For the Archipelago systems, seven vessels required 264 hours for installation and 100 hours for maintenance. Installation times ranged from as little as 10 hours (for vessels already equipped for video in the hake fishery) to as many as 65 hours per vessel. Unfortunately, system installation times for the Digital Observer Systems were not reported.

Out of the box digital video recording systems exist that may be less costly and offer similar reliability rates. However, most use proprietary data compression and very few are equipped with a USB external hard drive. Because of these shortcomings, they were not considered here. Equipment related costs are summarized below.

	min	max
Equipment costs		
Cameras	1500	--
DVR computer system	2000	--
hard drives for at-sea data storage	250	125
Miscellaneous	500	--
package system	--	8000
Labor *		
installation	650	4225
maintenance	975	975
TOTAL EQUIPMENT COSTS	**5875**	**13325**

* labor costs are only for system installation and maintenance, data collection and analysis costs are not included. Costs are based on a labor rate of $65/hr.

Data collection and at-sea storage. Once again, the Archipelago and Digital Observer systems appear to capture data of an adequate quality. Both systems use compression algorithms to reduce the size of the video files. These algorithms are most effective when there is little or no motion in the camera view and least effectively when there is a great deal of motion. Therefore, it isn't possible to give an exact data capture rate per camera. However, over the course of the project, both systems captured data at a rate of approximately 0.7 Gb/hr. For this project, data were collected from the time vessels left the dock until they returned to port. Given that most trips are three days or less, a system must be capable of storing at least 50 Gb per trip. Assuming all data should be backed up, and a vessel would not wish to be trip limited based on the capacity of their video system, it is reasonable to assume a system of two 100 GB hard drives would be sufficient for the actual collection of data.

Data Maintenance and storage. These costs would vary enormously depending on the program requirements. At one extreme, vessels could be required to submit all of the raw data to NMFS. Probably the most practical way to do this would be to require that data be recorded onto a USB compatible external hard disk submitted to NMFS. Assuming vessels choose to use 100 GB hard drives for recording the data, this would impose a per trip cost of approximately $100/trip, for a total fleet-wide annual cost of approximately $12,500. At the other extreme, vessels could be required to make the data available to NMFS during the offload and they would not be required to store or maintain the data after each trip. This would allow the vessel to reuse hard drives and data storage costs for the vessels would be minimal. Vessels could also be required to maintain the EM data for a period of one year (for example) and make those data available to NMFS upon request. Assuming an average of 21 fishing days per vessel/year, this would require one 400 GB hard drive per vessel, at a cost of approximately $400, or approximately $7,200 fleet-wide. Costs in subsequent years would be limited to maintenance/replacement of those hard drives.

Assuming NMFS chooses to collect all of the EM data, approximately 20 terabytes of data per year would need to be stored. Estimating these costs is difficult and would depend on the data management system developed. However, to give a sense of the magnitude of the problem, the Alaska Region currently has a disk array capable of being expanded to 4.5 terabytes and a tape changer that will hold 12 terabytes. Clearly, any regulatory program that envisions the long term storage of most or all of the EM data would require a significant increase in data storage infrastructure. While tape storage is currently the most appropriate medium for storing digital video data in terms of cost/accessibility/stability, the transferring of raw video data to another medium could raise chain of custody issues. These issues have been discussed in other forums by other agencies, but raise the point that a long term storage solution must be carefully designed.

Data review. These costs could vary enormously depending on how much data are reviewed and by whom. The most practical way to look at review costs is the ratio of activity time to review time. In this case, activity time was considered the period when fish were on the deck and sorting/stowing of catch was taking place. In other words, a trip with 24 hours worth of activity that required 2.4 hours to review would have a review ratio of 0.1. For the Kodiak project, review ratios for Archipelago systems ranged from a low of 0.03 to a high of 0.74. Digital observer review times were not reported on a trip by trip level, but had an average review ratio of 0.55.

We hope to use an upcoming project to better estimate the extent to which faster review results in missed discard events. At this time it isn't possible to say to what degree review times can be reduced while still maintaining an accurate record of discard. Assuming review would require an average review ratio of 0.4, review would require approximately 3600 man hours per season. These costs could be reduced by:

- less meticulous review
- review of a randomly selected subset of trips or hauls
- the use of image recognition software to pre-screen sections of data that need human review (i.e. an image recognition program could be "taught" to identify the periods when fish are actually on deck)
- not routinely reviewing observed trips

Additional man hours would be required for tabulating and reporting discard events. Assuming data review costs are approximately $40/hr, full review for the rockfish pilot program would cost approximately $50,000/yr.