Availability: A New Specification for Hyper-channel Seismic Recording Systems

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Summary
A new generation of seismic recording systems with more than 10,000-channels capability will require new specifications. This paper will introduce the concept of "Availability", widely used in telecommunications, to the seismic industry. We will show that improvements to availability can improve the profitability of current crews. Further, we will show that availability will become a specification for this new generation of recording systems.

Introduction
Seismic recording systems are in the early stages of a new revolution in size and complexity. Over the last few years, the average number of channels recorded on a crew has crept up from a few hundred to few thousand. Now design engineers are working with systems with upwards of thirty thousand channels. These systems will cover areas of 300 sq. km. with a single spread. These systems will be expected to begin collecting data early in the day and in many cases late into the night. Studies show that current recording systems using less than two thousand channels are able to record data only about half of the time. The other half of the time the crew is replacing or repairing equipment in the field. The studies further show that the vast majority of these failures are related to problems with the telemetry cables used to send the data from remote boxes to the central recording system. Even if the cables are replaced by radios, the need for all the data to return to the central recorder limits the ability of the crew to record data. In the majority of cases these cable failures are not caused by the crew but are the result of outside factors. A moderate size seismic crew can be expected to create revenue (or data) at the rate of about three thousand dollars per hour. The addition of even two hours per day of recording time could be expected to increase the crew revenue by over a million dollars per year.

Modern system analysis developed for the aerospace and communication industry address the issues of system "availability". That is the percentage of the time that the system can meet the requirements of its "mission". This analysis method goes further than the analysis of simple failure rate to include factors of system design and corrective actions. It is the purpose of this paper to apply this technique of analysis to seismic recording systems, their design and operation. In the first portion of the paper, we will explain the theory and mathematics behind the method of availability analysis. Then we will examine the mission profiles of current seismic operations to calibrate the terms of the availability equation. The calibrated availability equations will be applied to a currently available recording system with different system architecture to calculate the availability. The availability method will also be applied to new operating methods for other equipment to quantify the benefit of new capabilities. The focus of the paper is to project this current experience forward to hyper-channel recording systems. If the same rates of failure and system architecture are scaled to a 10,000-channel system, the crew effectively never records data. The telemetry cables are failing faster than the crew can repair them. The availability method of analysis will show that the new generation of recording systems must use advanced network architecture. The system must have redundant paths and automatic rerouting to provide productive recording systems that provide value to the seismic contractor and their energy producer client.

Theory
Product reliability is often described in terms of its availability. Availability is the percentage of time a system is ready for use and/or operating satisfactorily with repairs being allowed when it fails. The availability of a seismic system represents the amount of time the system is able to acquire and record an acceptable amount of seismic data over a specified time interval. System availability depends not only on the reliability of the equipment in the system but also on the configuration of that equipment, fault isolation, ease of repair, and number of spares. The system availability may be determined by looking at the availability of each component or subsystem.

Component availability depends heavily on the rate of failure, or Mean Time Between Failure (MTBF) and the rate of repair, or Mean Corrective Time (MCT). The seismic subsystems were modeled using exponential distributions for both failure and repair rates. The exponential distribution is commonly used in reliability engineering to represent life distributions of complex, nonredundant systems having a constant failure rate [1].

For constant failure and repair rates, the reliability R(t) and availability, A(t), of individual components can be calculated based on the following equations:

$$R(t) = e^{-\lambda t}$$

$$A(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t}$$

where λ = failure rate = $\frac{1}{MTBF}$

$$\mu = \text{repair rate} = \frac{1}{MCT}$$

The availability for the system may be calculated using the network reduction approach [2]. This approach pays particular attention to the configuration of the system. Systems may be comprised of any number of components in series, as shown in Figure 1.

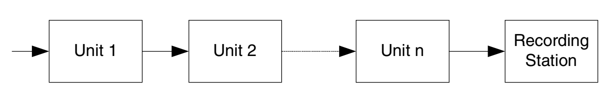

Figure 1 Series system with n components

For items in series, the availabilities multiply to give the series network availability, $A_s(t)$:

$$A_s(t) = \prod_{i=1}^{n} A_i \quad \text{for n units in series}$$

Components may also be configured with any number of components in parallel, as shown in Figure 2.

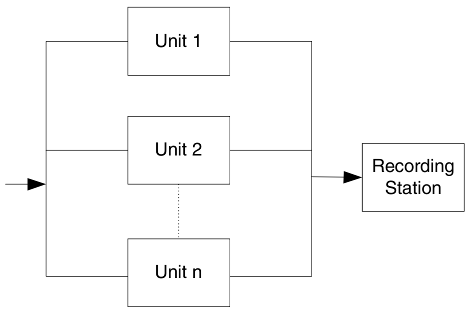

Figure 2 Parallel system with n components

For a parallel redundant network, r units out of n units must work normally for system success. All the units in the system are active. The availability for r out of n network, $A_{r/n}(t)$, is given by:

$$A_{r/n} = \sum_{i=r}^{n} \left(\frac{n!}{i!(n-i)!} \right) A^i (1-A)^{n-i}$$

The failure rate, h(t), for the system may be calculated based on the system reliability as shown in the following expression:

$$h(t) = -\frac{\frac{dR(t)}{dt}}{R(t)}$$

Crew experience

In seismic operations terms, the mission profile would be the operating environment, the number of channels and the configuration. Calibration with current operations is needed to establish failure rates that are being observed in current operations.

To provide some points of calibration we asked several crews about their operating environment and the availability they were observing. We also added detailed information from a crew that we have worked with to improve their availability. We have not indicated the crew, company or geographic location to protect the information that crews shared with us. We have made three broad classification of terrain to simplify the analysis and to provide some statistics. The first class we have called "Desert". This would be wide-open terrain with few animals or people. This would not necessarily be limited to classic desert, but would include the Arctic and remote areas of South America. "High Population" areas are the bulk of normal operations. There are people in the area. There is an abundance of farm and wild animals. There are roads to help time to correct, but there are also fences and other obstacles. The third area is "swamp". This would also include heavily forested areas and mountains. The basic data is shown in Figure 3.

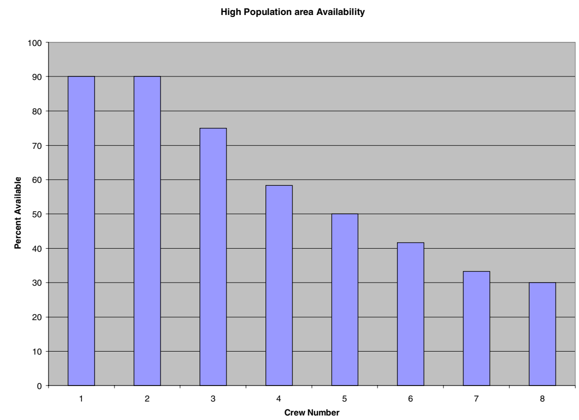

Figure 3 Availability of crew for recording

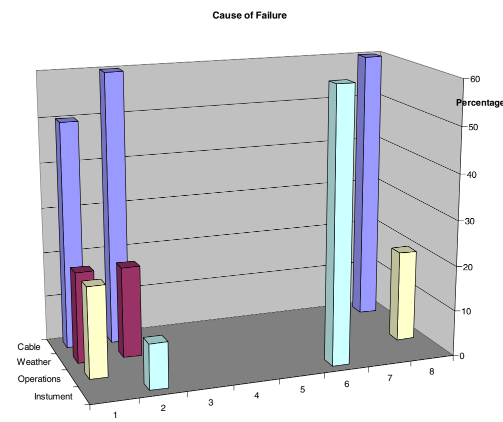

Figure 4 Major causes of down time

In addition to the mission profile information of terrain and number of channels, we also need information about the cause of the down time. The causes are listed in the importance that the crew indicated. The percentages are the approximate allocation of the down time. For example, the first crew reports that they are not available 10% of the time. Fifty percent of that that time is caused by cable failures. It is not surprising to anyone that has spent time on a crew that essentially all crews report that cables are the major source of downtime. Some of the downtime could be eliminated with aggressive maintenance programs. Most of the causes are outside of the control of the crew, but effect the overall performance of the crew. This is a new challenge for the designers of hyper-channel recording equipment. Not only must the equipment be intrinsically reliable, it must continue to operate with failures introduced by outside forces.

Current Systems

Clearly there is a range of results with variations from situation to situation. In the following chart, we form a general average of these values for the remainder of the study.

Availability for 1000 channel Crew

Environment	Equipment	Availability
Desert	Cable	84%
	Radio	80%
	Stored Data	88%
High Pop.	Cable	45%
	Radio	40%
	Stored Data	70%
Swamp	Cable	40%
	Radio	N/A
	Stored Data	60%

We can check this table against our intuition to see if the basic order is reasonable. The desert environment shows the highest availability for cable crews. The radio crew does less well in this area. A check of the original note finds that the leading cause of failure is the instrument electronics on what the crew describes as a very old system. We would expect all systems to perform about the same in this environment. The availability of the cable system falls dramatically in the high population environment. The stored data mode losses some availability, but not as much as the cable systems. Radio systems continue to show poorly. The further decline in the swamp environment reflects the longer time to correct problems because of speed of transport and access. Thus, the data does seem to make sense. Our intention here is not to be accurate to a percent, but to show the general class of availability.

What improvements could be made to current operations to improve the availability of the crew and thus the crew economics? The stored data system is a parallel architecture that sends control information and start commands over a narrow band radio to all boxes. The data is stored locally in each box. This is therefore a parallel architecture. This system does not have a single point of failure, so the system can continue with the normal 4-5% of channels failures allowed by most operators. This explains the very high availability experienced by these crews. This also explains why the availability does not drop off as strongly as the environment becomes more hostile to cables or radio waves.

A recent addition to some cable systems is the ability to redefine the routing of the data. This has been used to allow the crew to break a line and return data from the far portion of the line via an adjacent line. This allows safer and faster operations in some circumstances. This capability can also be used to improve the availability of a crew. Our studies show that on a typical crew it takes about one hour to replace a failed cable. With even manual rerouting of the data, the time to "correct" a failed cable is on the order of 10-15 minutes. In the high population case, this could be expected to improve availability from 45% to 70%. This would add three-and-a-half hours per day to the recording time of a typical crew. The financial implications of this to the crew and the client are very significant. This also shows the importance to the crew of keeping track of the "mean time to correct" and to strive to improve that time.

Future Systems

The purpose of this study was to define specification and capabilities of the next generation of hyper-channel recording systems. The geophysical interest in longer offsets, denser sampling and multi-component recording is forcing recording system design to higher and higher channel count. Many crews currently record between 1500 and 2500 channels. This is well below the technical capabilities of the instruments and may represent the informal balance between the number of channels and availability that crews have found. For this study, we used the availability mathematics and current crew experience to project the availability of 10,000 active channel operations. These projections show that using current methods a crew working in a high population area will observe 105 failures in a normal day. The resulting availability is only 1%. It is possible to apply limited automatic rerouting of data to system designs. This could be considered as redundant path communication for the "inline" direction. This improves the system availability to 67%. The crew would still need to correct the 105 failed cables to maintain long term production, but it would not stop recording. The replacement of cables could be on a routine basis, instead of the priority method used in today's operations. The system design must allow the cables to be replaced without interruption of operations. Further, the telemetry system must learn that replaced sections are available and continue to use the simplest communication path. As the power requirements of the electronics have decreased, many system designs are delivering power to many units on the same cable as the data. This practice greatly reduces the issues associated with the maintenance and charging of the batteries. However, it places the power in the same category as the data in availability calculations and forces the system designer to consider alternate power distribution.

The availability of 67% is well above the 42% that current crews report, but does not approach the 90% that would be desirable for high production operations. The final step in this study was to consider the impact of cross-line redundancy to operations. The availability increases to a very good 94%. These results are shown graphically in Figure 5.

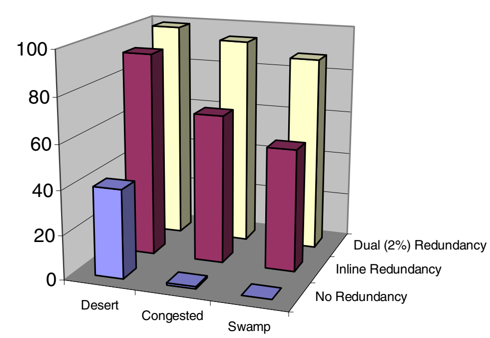

Figure 5 Projected availability with different redundancy

Conclusions

Availability is an analysis system widely used in the telecommunication industry. This method of analysis was applied to seismic recording systems. It was shown that crew economics could be dramatically improved if operational procedures and equipment are chosen based on availability analysis. These analysis methods were applied to the design of new systems capable of recording 10,000 channels, and it was found that availability using current practices would be nearly zero. Different levels of redundant communication were studied to improve system availability. In most cases, two levels of redundancy will be required on future recording systems. The paper has shown that availability is an important new specification for seismic recording systems and the economics of crew operations.

References

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