# FIBER OPTIC CABLE DIG-UPS - CAUSES AND CURES

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## 1. Executive Summary

### 1.1 Overview and key messages.

As sub-committee member on NOREST, the Fiber Cable Focus Group collected and analyzed industry data concerning service interruptions resulting from cable failures caused by dig-ups. The Group also reviewed the practices of other utility companies and outside groups such as "one-call" associations. Through these activities and a statistical analysis of industry data, the Group has determined that several primary activities can mitigate or certainly reduce cable dig-ups.

Fiber optic cables, whose size is often less than one inch in diameter, routinely carry tens of thousands of telephone calls over glass strands slightly more thick than a human hair. Damage to fiber optic cables can shut down vital communications links to airports, emergency services, and nuclear power facilities. With advances in SONET transmissions and ATM switching technologies comes higher and higher concentrations of traffic placed on fiber cables. Therefore, protecting these vital "information highways" takes on ever increasing significance. To improve the reliability of these critical high capacity links, the Network Reliability Council's Fiber Cable Focus Group collected and analyzed fiber cable failure data, surveyed existing utility damage prevention legislation and held discussions with key representatives of the damage prevention industry.

Based on these findings and discussions, the Group recommends: 1) a strengthening of utility damage prevention legislation - call-before-you-dig enhancement, 2) broad and uniform implementation of "Best Practices" to minimize cable damage - standardized practices and procedures, and 3) endorsement of a benchmarking study - to identify innovative approaches to fiber cable damage prevention and/or assess the need to revise existing practices.

Damage Prevention Legislation

Dig-ups are the largest cause of fiber cable failures and account for nearly 60% of the failures reported by the industry. Examining the root causes of fiber cable dig-ups reveals that 33% of reported dig-ups resulted from the excavators' failure to notify the facility owner before digging started. Although over 40 states have damage prevention laws requiring such prior notification, the laws are generally weak, not adequately enforced, and provide little provision for punitive damages in the event of excavator negligence. Therefore, the Group recommends enforcement, enactment, and/or revision of federal, state, and local damage prevention laws. Paragraph 9.1 of this paper details the intent of this legislation.

Best Practices

Strong damage prevention legislation is essential for reducing the number of cable dig-ups. However, 40% of the reported dig-ups occurred in spite of prior notification by the excavator, accurate cable location, and proper temporary marking of the sub-surface cable route. Therefore, in addition to recommending strengthened damage prevention legislation, the Group has identified a compilation of best practices as procedures which, if uniformly complied with and broadly implemented, can be effective in minimizing occurrences of fiber cable



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dig-ups. These practices are grouped into four general areas:

1) engineering and construction,

2) call-before-you-dig,

3) effective cable location, and

4) additional preventive measures.

Although many of these procedures are currently specified in industry standards, they were generally not practiced in the failure events reported by the industry.

The Group found that although dig-ups were responsible for 70% of sub-surface cable failures, several other failure causes were consistently reported. While having the same probability of failure as sub-surface cable, aerial fiber optic cable was particularly susceptible to damage by a wider variety of causes. To prevent cable damage from causes other than dig-ups, the Group identified a broad range of practices which can be employed. These practices include additional personnel training to reduce accidental damage during cable maintenance or mining activities, installation techniques to minimize potential rodent damage, and other procedural and engineering practices.

Benchmarking Innovations

As the security of fiber optic cable becomes more critical to assuring telecommunications networks reliability, the Group recognizes the necessity of continuing to search for innovative approaches to damage prevention. To help accomplish this, the practices of other industries, in addition to those in telecommunications, must be continuously evaluated for their applicability to current preventive measures. Therefore, the Group recommends an industry-wide benchmarking activity to identify the most successful of these approaches and to highlight effective implementations of established and effective practices. The study would identify the most successful policies, strategies, and implementations for installing, maintaining, and protecting fiber cable from all major causes of damage.

The Group recommends that the benchmarking project be managed through the TIBC. These findings would be shared throughout the industry by the ECSA.

## 2. Background

2.1 The Fiber Cable Focus Group - motivation, goals and objectives.

Protecting fiber cable from physical damage is critical to ensuring the dependability and reliability of the public telecommunications network. During 1992, fiber cable failures were the single largest cause of network outages affecting more than 50,000 customers for more than 30 minutes and accounted for roughly as many outages as tandem and local switch equipment failures combined. As networks place ever increasing amounts of traffic over single fiber cables, the need to protect these vital facilities becomes ever more clear and crucial to the industry's goal of raising systems reliability.

2.1.1 Focus Group motivation.

The NOREST mission statement: "Look at the causes of fiber cable outages and the potential opportunities to minimize these incidents."

Notwithstanding the NOREST mission statement's critical objectives, recurring dig-up problems - validated by industry data - provide vigorous justification for and motivation to sustain Focus Group efforts in reducing cable dig-ups.

Utility company records, industry surveys, and FCC data consistently reveal that cable dig-ups account for more than 50% of all cable failures and are caused largely by construction site excavation activities. Therefore, in an effort to raise systems reliability through reduction of cable dig-ups, this paper will focus on renewed approaches to complete prevention, or certainly minimizing, the occurrences



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of this persistent industry-wide problem. Appendix 4 provides the NRC's Issue Statement concerning areas of study and preventive measures to improve the security and reliability of fiber optic cable.

2.1.2 Focus Group goals and objectives.

With ever increasing awareness of the necessity to protect fiber optic cable, NOREST established the Fiber Cable Focus Group to apply its expertise and ingenuity to define, develop, and implement preventive measures aimed at greatly reducing or ultimately eliminating cable dig-ups.

As envisioned, such measures and/or methodologies - whether new or improvements to existing ones - are the best, perhaps the only, means to increase systems reliability through the significant reduction of cable dig-ups. Preventive measures developed by the Focus Group were presented to NOREST as recommendations and incorporated a balance of legislative, technical, and procedural (e.g., call-before-you-dig) elements.

Focus Group sanctioned preventive measures will have the promise of reducing physical risks to fiber cable and can indirectly have other beneficial effects as well.

2.2 Organization of this presentation.

The basis upon which this paper is developed is the statistical study and methodology used to collect and analyze the Focus Group's request for industry data concerning service interruptions due to fiber cable failures. Study-based conclusions are presented for industry assessment as possible candidates for legislative and standards acceptance. The paper is organized as follows:

Section 1, **Executive Summary** - The Focus Group's connection to NOREST, study objectives and activities performed to develop this paper and its conclusions, and suggested actions to achieve increased network reliability are presented.

Section 2, **Background** - Explains the impetus for the Focus Group and its work, NOREST as the catalyst, and Group goals and objectives.

Section 3, **Team Membership** - Presents personnel and member organizations comprising the Fiber Cable Focus Group sub-committee to NOREST.

Section 4, **Data Collection and Analysis Methodology** - Introduces and describes the study's statistical methodology applied to identify and isolate factors/causes which consistently show they contribute to or directly result in cable dig-ups.

Section 5, **Causes of Fiber Optic Cable Damage** - The definitions of cable failure types and causes as used in this paper and definitions of root causes are presented, the definitions also mark the study's boundaries since they are the basis and the scope of cable failures covered by the Focus Group's efforts.

Section 6, **Key Lessons Learned and Recommended Best Practices** - Statistically-based conclusions, reached after industry data was collected and closely analyzed, are presented. Best practices are proposed along with other options ready for additional assessment by industry, standards, and legislative processes.

Section 7, **Metrics** - Explains that specific metrics will be offered as a result of a benchmarking effort.

Section 8, **Path Forward** - Demonstrates the case for continued monitoring by the ECSA, work still required to develop effective industry policies and procedures to achieve reductions in cable dig-ups is presented.

Section 9, **Conclusions** - Describes the need for assessment of current laws and procedures and suggests an industry-wide strategy aimed at reducing cable dig-ups as well as better serving utility industries at large.

Section 10 - **Acknowledgements**

Section 11 - **Reference**



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Section 12 - **Figures and Exhibits**

Section 13 - **Appendices**

Glossary of Terms - **Abbreviations and Acronyms**

## 3. Team Membership

The Fiber Cable Focus Group team representatives include:

- Dan Crawford, MCI (Chairman)
- Frank Ianna, NOREST Champion
- Ron Binz, NASUCA
- Bob Crawford, Bell Atlantic
- Paul Devaney, Applied Concepts Inc. (formerly with Bellcore)
- Sam Lisle, Fujitsu (formerly with Bellcore)
- Mike Michalczyk, Southwestern Bell
- Peter Shelus, AT&T

## 4. Data Collection and Analysis Methodology

4.1 Data collection emphasis and goals.

The questionnaire employed by the Focus Group for collecting fiber cable damage data parallels the format and content of one developed by Bellcore. This questionnaire is shown in Appendix 1. It is utilized to collect data about service disruptions meeting certain criteria and definition requirements of a failure occurrence, that is: an event that caused the system to fail to perform to specifications and requirements or, an event which necessitates repair action or component replacement in the immediate or near future.

The Group's data gathering effort is patterned after an ongoing data collection and analysis program conducted by Bellcore and its LEC clients. Since 1986 this study, known as the Fiber Optic Cable System Field Failure Analysis (or Field Tracking Study), has been collecting field data on fiber optic cable damage. Detailed data on individual field failures is submitted to Bellcore (using its questionnaire) by outside plant personnel of the participating companies. Results of the Field Tracking Study summarizing the causes and type of fiber optic cable damage, cable repair information, and observed field failure rates have been published.

The study results, which provided direction for the Group's subsequent data request, indicated that the most frequent cause of fiber optic cable damage was damage by dig-up and that a substantial fraction of dig-ups occurred in spite of prior notification to the cable owner by the digging contractor.

Based on this data, the Group aimed its efforts at obtaining detailed root cause data on dig-ups, while continuing to collect data on all causes of cable failure. Companies that had not been participating in the Field Tracking Study received this questionnaire while regular study participants also received a questionnaire combining questions of historical relevance with questions of specific interest to the Focus Group.

A single questionnaire was to be completed for each fiber optic cable failure whether or not the damage affected customer service. For the Group's study, a failure is defined as any event which either 1) causes a fiber optic system to cease to operate to specifications, or 2) which requires timely maintenance activity.

In addition to receiving information specific to field failures, the Group requested data on the deployed population of fiber optic cable. Each company was asked to provide recent totals of their deployed fiber, sheath, and route mileage of fiber optic cable in their networks. For example, a one mile trench containing two 12-fiber cables is equivalent to one route mile, two sheath miles and 24 fiber miles. Mileage totals were classified according to



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installation (see para. 5.2.4, "Failure causes by installation," for definitions), estimates on cable mileage, and amount of fiber cable possessing certain attributes such as metallic armoring. This data was augmented by a recent FCC report on deployed fiber optic cable mileage.

This population data was used to make comparisons of failure susceptibility among various installations and to measure the effectiveness of certain damage prevention practices such as visible markers placed along cable routes. The questionnaire used for population data is shown in Appendix 2.

4.2 Data collection period.

The Focus Group requested data on FCC reportable field failures which occurred between April 1, 1992 and August 31, 1992, and data on all fiber cable failures (whether affecting service or not) occurring between September 1, 1992 and February 12, 1993. Some companies elected to submit failure reports on non-FCC reportable outages occurring prior to September 1, 1992. As of February 12, 1993, 160 failure reports were received in response to the Group's data request. These failures occurred between March 1, 1992 and February 4, 1993.

It should be noted that two major hurricanes, Andrew and Iniki, occurred during the data collection period. As evident in reports filed with the FCC concerning these storms, significant damage was incurred by aerial fiber optic cable in the affected areas. Individual reports describing cable damage caused by these hurricanes was not provided to the Group and consequently not included in the analysis. Therefore, summaries of failure data presented in Section 5 are not influenced by these unusual events.

4.3 Data collection procedure.

As mentioned, the Field Tracking Study is an ongoing data collection effort within Bellcore and its LEC clients, all of whom responded to the Focus Group's data request. Companies that had not been participating completed questionnaires and returned them to Bellcore's point of contact for NRC data collection. Many participating companies continued to submit failure reports directly to the Field Tracking Study director at Bellcore.

Procedures used to complete individual reports varied among companies. In some instances, failure reports were completed by field personnel who performed actual repair work. They then forwarded a report to Bellcore's central coordinator for data submission. In other instances, failure reports were completed by the company coordinator and based on field generated data. Each failure report included a contact person and telephone number to facilitate any necessary follow-up. The Field Tracking Study director is responsible for verifying data accuracy and completeness of all reports and if needed, for contacting reporting companies to clarify data.

4.4 Analytical methods.

Various analytical methods were used to arrive at the Focus Group's conclusions. Pareto analysis identified the most significant failure causes while statistical hypothesis testing was conducted to compare variations in failure cause, relative failure probability, and failure severity among different cable installations. To compare these variations, failure reports from companies which exhibited high levels of reporting were counted and compared with deployed mileage totals from those companies. The hypothesis testing was performed using a 95% confidence level (or 5% significance level).

4.5 Results of fiber optic cable data analysis.

The data analysis was conducted on 160 field failures reported to the Group as of February 12, 1993. In some instances, the analysis is augmented with recent data from the Filed Tracking Study. This section presents a summary of significant findings, information on failure causes, variations in relative probability among cable installations, and repair time statistics.

4.5.1 Summary of findings.



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Following is a summary of the significant findings of the data analysis:

o Dig-ups were the single largest cause of reported fiber cable damage accounting for 58% of the reported failures.

o Failure of the excavator to provide prior notification was responsible for 33% of the reported dig-up failures.

o Of the reported dig-ups, 40% occurred in spite of prior notification by the excavator, accurate cable locates, and proper temporary marking of the sub-surface cable routes.

o Only one reported dig-up failure can be directly attributed to improper burial depth, however the correlation between burial depth and failure probability has not been determined.

o Aerial cable was damaged by a wide variety of causes.

o The causes of cable damage leading to large outages were not substantially different from causes of damage leading to outages of lesser impact.

o There was no significant difference in the relative failure probability between sub-surface and aerial fiber cables.

o There was no significant difference in the relative failure probability due to all failure causes between direct buried cables and cables installed in underground ducts.

o Differences were observed in the relative probability of failure due to dig-ups between direct buried and underground cable. These differences are probably influenced by differences in geography and may not solely be due to the presence of the duct structure.

o The mean time required to restore service after a cable failure is considerably less than the mean time required to completely repair a damaged cable.

## 5. Causes of Fiber Optic Cable Damage

This paper centers on fiber cable failures caused by "dig-ups" and the factors which contribute to and can best account for such incidents. Cable dig-ups typically occur during excavation work at construction sites such as business office complexes, housing developments, public works (e.g., roads, highways, malls, facilities such as sports arenas, airports and others). Cable dig-ups can also occur on private property (e.g., farms) or can result from excavating activities undocumented by federal, state, or county licensing authorities.

### 5.1 Detailed failure causes, definitions and root causes.

Through February 12, 1993, 160 failure reports were received in response to the Focus Group's data request. Nearly 100% of these failures resulted from a broken fiber or cable. This finding is consistent with results of Bellcore's Field Tracking Study which indicates that over 93% of cable failures reported between 1990 and 1992 resulted from a broken fiber or cable. Other types of failures which occur in the field include high loss induced by pressure on optical fibers (known as microbending), sheath damage, and procedural errors not resulting in facility damage.

There is a wide variety of external events reported to have caused fiber and other cables to fail and frequently a chain of events can lead up to cable failure. For example, a dig-up can occur because the digging contractor failed to provide prior notification. Therefore, in the data analysis presented here, failure causes have been categorized according to immediate causes and root causes. An immediate cause is the final event, such as a dig-up, which directly causes the failure. The root cause is the critical event, e.g., lack of proper notification, which eventually leads to a failure.

Table 1 lists the immediate causes of fiber optic cable failures reported to the Group. Every cause responsible for more than one reported failure is



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# Immediate Failure Causes

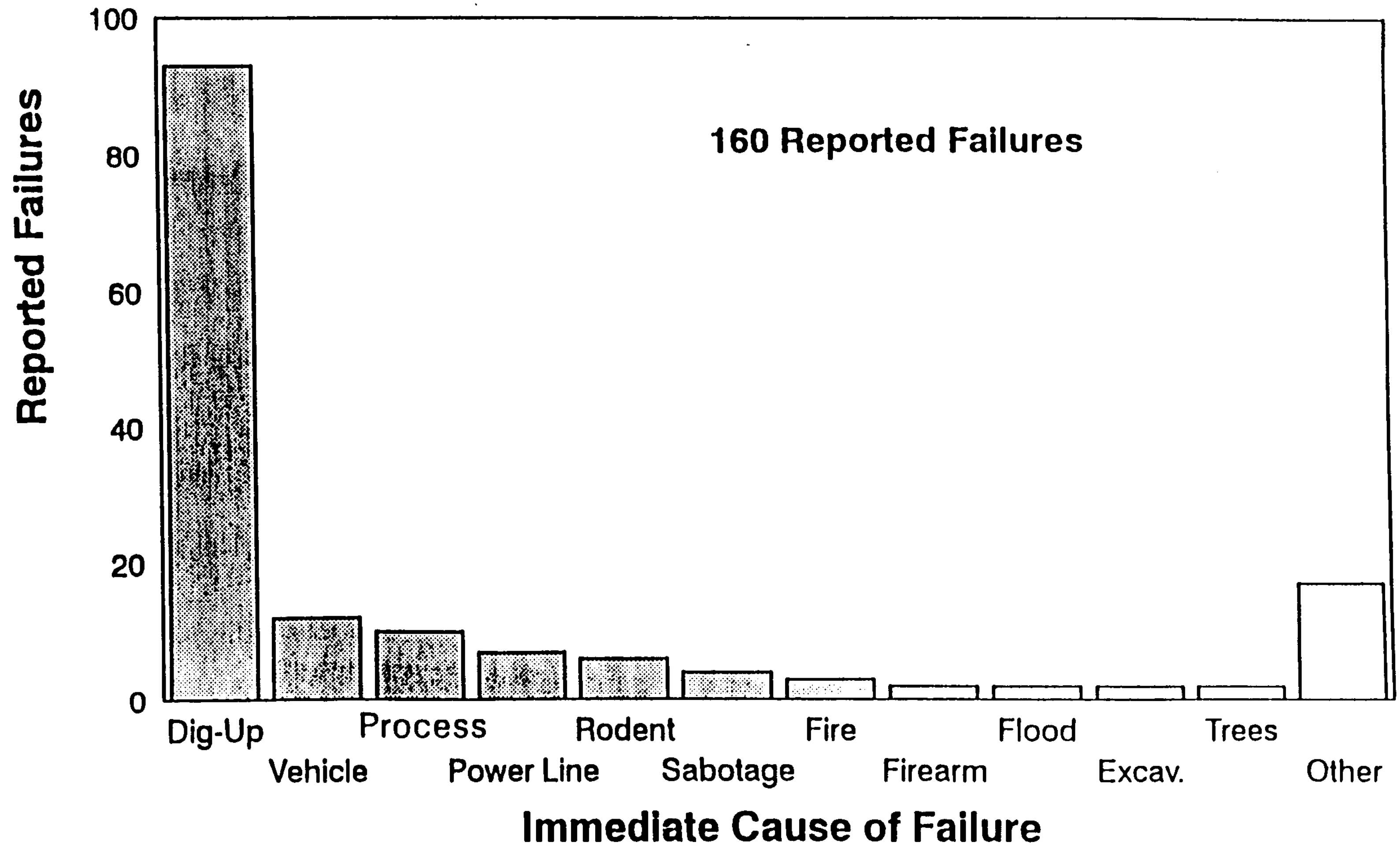


Figure 1



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listed. Figure 1 provides comparisons of the numbers of these reported immediate failure causes.

**Table 1. Immediate Causes of Fiber Optic Cable Failure**

| Cause | # of Reports | % of Total |
|---|---|---|
| Dig-ups | 93 | 58.1 |
| Vehicle | 12 | 7.5 |
| Process Error | 11 | 6.9 |
| Power Line | 7 | 4.4 |
| Rodent | 6 | 3.8 |
| Sabotage | 4 | 2.5 |
| Fire | 3 | 1.9 |
| Firearm | 2 | 1.3 |
| Flood | 2 | 1.3 |
| Excavation (non dig-up) | 2 | 1.3 |
| Fallen Trees | 2 | 1.3 |
| Other | 16 | 10.0 |
| Totals | 160 | 100.0 |

As shown in Table 1, dig-ups are the single largest cause of fiber optic cable damage accounting for more than 58% of the reported failures. Following dig-ups, vehicle induced damage is responsible for 7.5% of the reported failures and process error comprises 7.0% of the reports. The relative magnitudes of these three failure causes, along with most of the remaining failure causes, correlates well with data previously presented in Bellcore's Field Tracking Study.

The following paragraphs define and/or describe each immediate cause and provide some general discussion about the reported failures.

## Dig-ups

A dig-up is defined as damage to fiber optic cable during an activity to penetrate the ground. Dig-ups occur during sign placement, road grading, trenching, and sub-surface facility installation or repair. Occasionally dig-ups involve a procedural error such as failure to properly locate the sub-surface cable. For the purposes of this analysis, dig-ups resulting from procedural errors are classified as dig-ups. Historically, dig-ups have consistently been responsible for 55% to 60% of cable failures reported to the Field Tracking Study.

Of the 93 dig-up reports submitted to the Focus Group, 83 reports specify the excavator involved in the dig-up. In some instances the excavator's affiliation (e.g., telco contractor, highway dept. contractor) was not determined. However, 69 reports indicated whether or not the excavator was employed by the telephone company whose cable was damaged. In 87% of these cases, the excavator involved in the dig-up was not working on behalf of the facility owner while 13% of the reports indicate the dig-up was caused by the telephone company or telephone company contractor.

Other excavators involved in significant numbers of cable dig-ups include: electric, gas, and water company contractors, and highway department contractors. Private landowners account for only four of the 83 reports.

## Vehicle Damage

Typically, this type of cable damage results from vehicle collisions with utility poles which support aerial cable. In three reports a passing vehicle caught a sagging aerial cable. One report involved a vehicle colliding with a highway overpass which housed fiber optic cable. Only one reported sub-surface cable failure was caused by a vehicle.

## Process Error

Process error damage includes failures caused by telco personnel performing maintenance or installation work, but does not include procedural errors leading to dig-ups. Damage due to process error has consistently been responsible for about 7% to 8% of failures reported to the Field Tracking Study. The 11 process errors reported to the Group occurred under a wide variety of circumstances. Three failures were caused when an in-service fiber optic cable was accidentally severed during removal



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of an obsolete cable. Three failures occurred during the repair of a nearby damaged cable.

### Power Line Contact

Damage caused by power lines occurs when an electric power cable makes contact with an aerial fiber optic cable or its metallic messenger strand. When electric current begins to flow in the messenger strand the resulting heat burns through the fiber cable. This type of cable failure was not widely reported to Bellcore's Field Tracking Study prior to 1992.

### Rodent Damage

Damage caused by rodents affects aerial, sub-surface, and intra-building fiber cable and includes failures caused by gnawing animals such as mice, rats, gophers, and beavers.

Frequently, rodent induced damage results in only a partial failure of a cable. Only one of the six rodent induced failures reported severed every fiber in the cable. By contrast, over 80% of reported failures caused by dig-ups severed every fiber in the cable. Considering all rodent induced failures reported to the Field Tracking Study, 50% have resulted in the failure of every fiber in the cable.

### Sabotage

Failures due to sabotage are caused by deliberate human activity whose sole purpose is to damage cables. Two of the four sabotage failures reported to the Focus Group were caused when a handhole (a buried concrete box containing a splicing point) was broken into.

### Fire

Fire damage is defined as cable failure resulting from fire(s) to nearby structures and typically affects aerial and intra-building cable. In three reports submitted to the Focus Group, fires to nearby buildings and a building containing the damaged cable were described. These failures excluded cables which were set on fire upon contact with power lines.

### Firearm

Firearm induced damage occurs when aerial cables are struck by a bullet or shotgun blast. Failures caused by firearms frequently do not sever the cable and can therefore be difficult to locate. These failures are not considered sabotage.

### Floods

Floods cause damage when large quantities of water sever a fiber optic cable. Hydrogen permeation failures resulting in high loss and fiber fractures caused by the corrosive effects of small amounts of water have, in rare instances, been observed in the field but did not account for any failures reported to the Focus Group.

### Excavation Damage

Excavation damage included two failures caused by human activity near an excavation site, but were not directly caused by any digging activity. One failure was caused by a large rock accidently dropped on an exposed concrete duct thereby breaking the duct and severing the cable. The second failure was caused when excavation machinery was used to exert a significant amount of downward pressure on the soil. This downward pressure was sufficient to sever a direct buried cable located beneath the machinery.

### Falling Trees

In two reports, falling trees were considered the immediate cause of cable failure. These failures occurred when an aerial cable was severed by a falling tree limb. Falling tree limbs and sagging branches occasionally led to failures caused by power line contact or damage caused by vehicles.

### Other Causes

Other causes of reported cable failure were mostly



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extrinsic damage caused by human activity. These included failures caused by tree trimming, deliberate cable severing in emergency situations, and other unusual situations. This category also includes 10 failures where the causes were either not reported or not documented.

5.2 Fiber optic cable dig-ups.

A major emphasis of the Focus Group's data request was to gather detailed information on cable dig-ups. This involved determining the root causes of dig-ups and studying the effects of cable installation and damage prevention practices on reducing the probability of dig-ups.

5.2.1 Root causes of dig-ups.

Of the 93 cable dig-ups reported, 61 reports contained sufficient information to assign a probable root cause. Root causes are listed in Table 2 and presented graphically in Figure 2. It should be remembered that these failure reports were submitted by the facility owner, not the excavator. In at least one instance the circumstances surrounding the dig-up (as reported by the telephone company) have been disputed by the excavator.

**Table 2. Root Causes of Fiber Optic Cable Dig-ups**

| Root Cause | # of Reports | % of Total |
|---|---|---|
| Digging Error | 24 | 39.3 |
| No Notification | 20 | 32.8 |
| Cable Unlocated | 7 | 11.5 |
| Inaccurate Locate | 6 | 9.8 |
| Incorrect Notification | 3 | 4.9 |
| Shallow Cable | 1 | 1.6 |
| Totals | 61 | 100.0 |

As shown in Table 2, the leading root cause of reported cable dig-ups is excavator error(s) made during digging. These failures occurred after the facility owner was notified and the route properly located and marked. The second largest root cause is excavator failure to provide notification prior to digging. The following defines each root cause and discusses various details of the reported failures.

Digging Error

This root cause of cable damage is considered a digging error if: the contractor provided accurate prior notification, the route was accurately located and marked, and the cable was buried at a proper depth with sufficient clearance from other sub-surface structures. One failure where the contractor provided notification but did not wait for the cable to be located was also considered a digging error.

ANSI standard EIA/TIA-590, Standard for Physical Location and Protection of Below-Ground Fiber Optic Cable Plant, contains procedural recommendations for excavators to follow when digging near sub-surface cable. In particular, these procedures specify digging with hand tools within a "tolerance zone," specified at 18 in. from the edge of the facility (unless otherwise specified by local state or county laws).

Of the 24 dig-ups whose root cause was a digging error, only one report indicated that digging was performed with hand tools within the tolerance zone while 13 reports indicated that hand digging had not been performed at all.

Some companies require that a representative remain on-site to monitor an excavation. Of the 24 reported dig-ups where root cause was a digging error, three reports indicated that a representative of the telephone company was on-site while digging was performed while 14 reports indicated that a representative was not on-site.

No Notification

Ensuring that excavators provide consistent, accurate, and prior notification of excavation activities to the facility owner, or other responsible organization such as a "one-call" agency, is one of the principal lines of defense for preventing cable dig-ups.



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## Root Causes of Fiber Optic Cable Dig-Ups

### 61 Dig-Up Reports

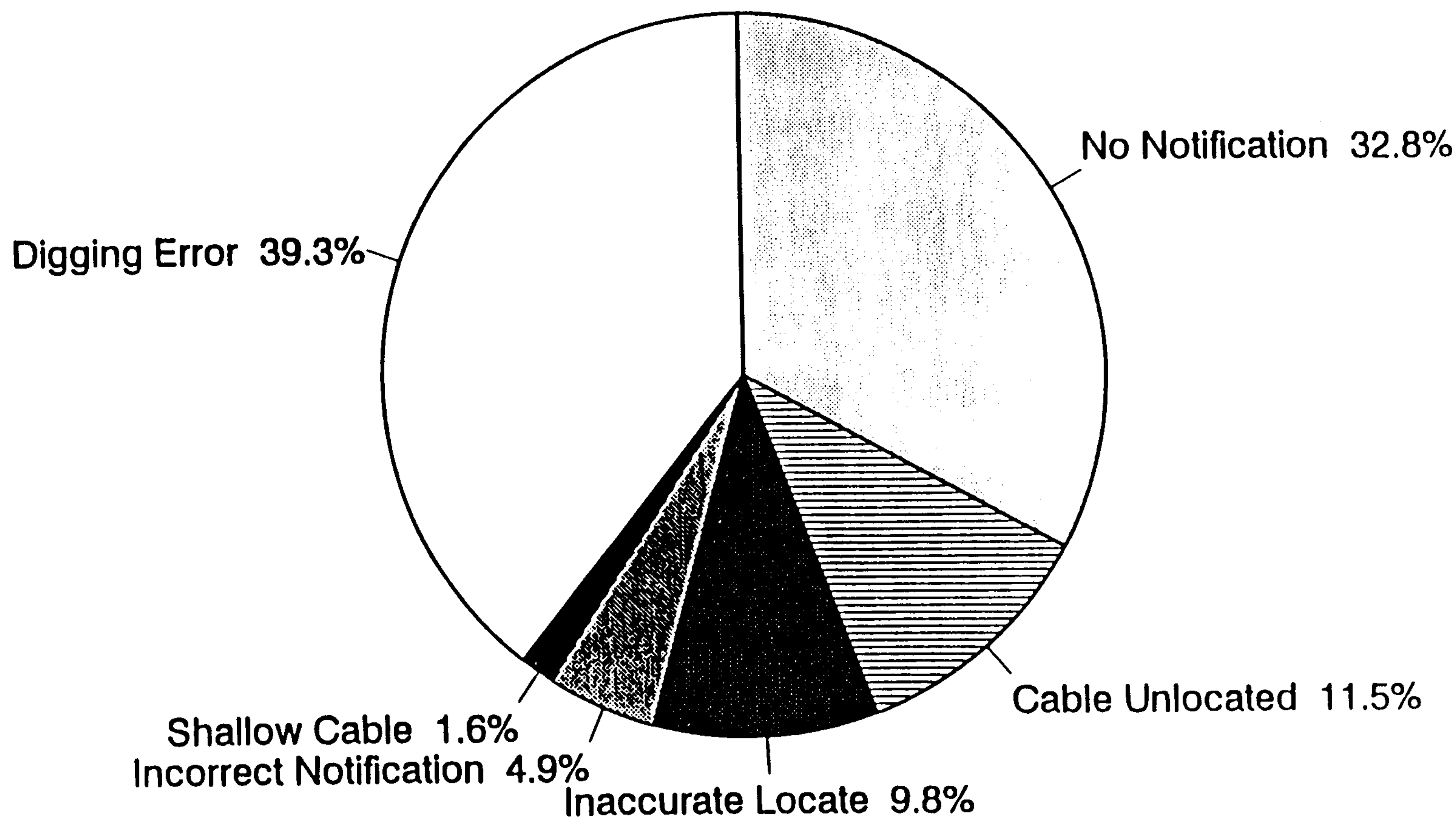


Figure 2

In 33% of the dig-ups having root causes, the excavator failed to provide any notification prior to digging. This finding is consistent with data in Bellcore's Field Tracking Study which indicates that the fraction of dig-ups occurring without prior notification has remained relatively constant over the past few years averaging 37% from 1989 through 1992.

Although a substantial fraction of the reported dig-ups occurred after notification was provided, prior notification appears largely to be acted on effectively by fiber optic cable owners. Two IXCs recorded an annualized total of over 3.5 million locate requests (prior notifications). These requests resulted in roughly 560,000 dispatches to locate sub-surface cable. Of these, only three fiber cable dig-ups occurred after the cable was located. Similar data comparing the number of dig-ups with the number of prior notifications was shared by one major LEC. This information indicates that excavators providing accurate, prior notification has been highly effective in reducing cable damage due to dig-ups.

Because of the success in avoiding dig-ups by acting upon prior notification, the lack of notification is considered to be the root cause of every dig-up in which prior notification was not provided.

### Cable Unlocated

In these seven failures, prior notification was provided by the excavator but the facility owner or locating company failed to establish the presence of a cable which was then eventually damaged. In six of seven reported cases, locating personnel were dispatched in an attempt to locate a cable. In three of these six reports, the locating personnel properly located other nearby sub-surface cables. Of the six reports in which locating personnel were despatched, five locates were performed by a locating company while one locate was performed by the telephone company itself. In two of the failures it was reported that the damaged cable was not shown on locating company maps.

### Inaccurate Locate

The root cause of these damage reports was considered an inaccurate locate because the cables' presence was determined but their locations were not accurately identified. For three of these six incidents, the cables were directly buried in soil while two incidents involved cables deployed in underground ducts. One report indicated a cable took an unexpected right-angle bend. The telephone company performed three of the locate attempts while two were performed by a locating company.

### Incorrect Notification

In these cases, the contractor provided prior notification but did not accurately describe the location of the digging work to be performed. Therefore, the actual cable which was near the proposed excavation was never located.

### Shallow Cable

The root cause of one failure was due to shallow cable burial depth. In this case, the route was properly located and marked and excavation was conducted with hand tools, but the cable was buried to a depth of only four inches. The cable was installed at this depth because the underground right-of-way was highly congested. This depth is substantially more shallow than industry standards recommend, e.g., EIA/TIA-590 specifies 30 in. as the minimum cover for interoffice cables and underground duct, 24 in. for feeder cables, and 18 in. for customer drop lines.

There were 63 dig-up reports received indicating the depth of a below-ground cable. Although four of these reports indicated cable depth at the point of failure was less than specified by the EIA standard, two failures occurred because no prior notification was given and one report did not provide sufficient detail to indicate a probable root cause.

5.2.2 Effect of cable depth on dig-up probability.



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As discussed in the previous section, shallow burial depth was identified as the root cause for only one reported dig-up. To fully quantify the relationship between burial depth and relative dig-up probability, comparisons must be made between the numbers of reported dig-ups at given depth and the quantities of sheath mileage deployed at those depths.

Figure 3, a histogram of burial depth for 63 of the reported dig-up failures, shows that most dug-up cables are buried at a depth of between three and five feet. However, since many companies specify a burial depth of three to four feet for fiber optic cable installation, this result is to be expected. Unfortunately, most companies do not maintain detailed information on the quantity of sheath mileage deployed at various depths. Thus, variations in reliability for different burial depths cannot currently be quantified. Bellcore is continuing to investigate the effect of burial depth on dig-up probability.

5.2.3 Effect of permanent marking on dig-up probability.

EIA/TIA-590 recommends use of permanent above ground markers and/or underground warning tape to identify the general location of a sub-surface cable. Permanent above ground marking is considered effective in reminding excavators to provide proper notification prior to digging. Most companies responding to the Focus Group's data request indicate their standard practice is to place visible permanent markers along sub-surface cable routes.

One way to quantify the impact of above ground markers on reducing the likelihood of dig-ups, is to compare dig-ups occurring (per sheath mile) in marked installations to those occurring in unmarked installations. However, this analysis is complicated by several factors including those shown below.

o Some companies mark nearly 100% of their sub-surface routes and, as expected, reported no failures along unmarked routes.

o Some companies do not keep precise mileage totals of marked and unmarked routes.

o Some companies indicated that although it is standard practice to mark 100% of their sub-surface routes, strict adherence to this practice is difficult in certain metropolitan areas.

o Metropolitan areas can have inherently better records for prior notification than rural areas.

o Although markers may have been placed during installation, the marker(s) nearest a proposed excavation may have been knocked down, broken, or become obscured by brush.

In attempting this analysis, data was considered from one company which exhibited good reporting while having a mixed population of marked and unmarked cable routes. This data was supplemented with data from the same company submitted to Bellcore's Field Tracking Study between 1991 and 1992. Table 3 summarizes these data.

**Table 3. Reported Dig-ups per Sheath Mile - Marked and Unmarked Routes**

| | Marked Routes | Unmarked Routes |
|---|---|---|
| % of Reported Dig-ups | 66.7% | 33.3% |
| % of Sheath Mileage | 63.6% | 36.4% |

Table 3 indicates that, for this company, there is virtually no difference in the reported dig-ups per sheath mile between marked and unmarked routes. When interpreting this result it should be remembered that:

1) much of the unmarked sub-surface cable is probably located in metropolitan areas, these areas can have inherently better notification records and therefore experience fewer dig-ups per deployed sheath mile than in rural areas,



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# Burial Depth of Reported Dig-Up Failures

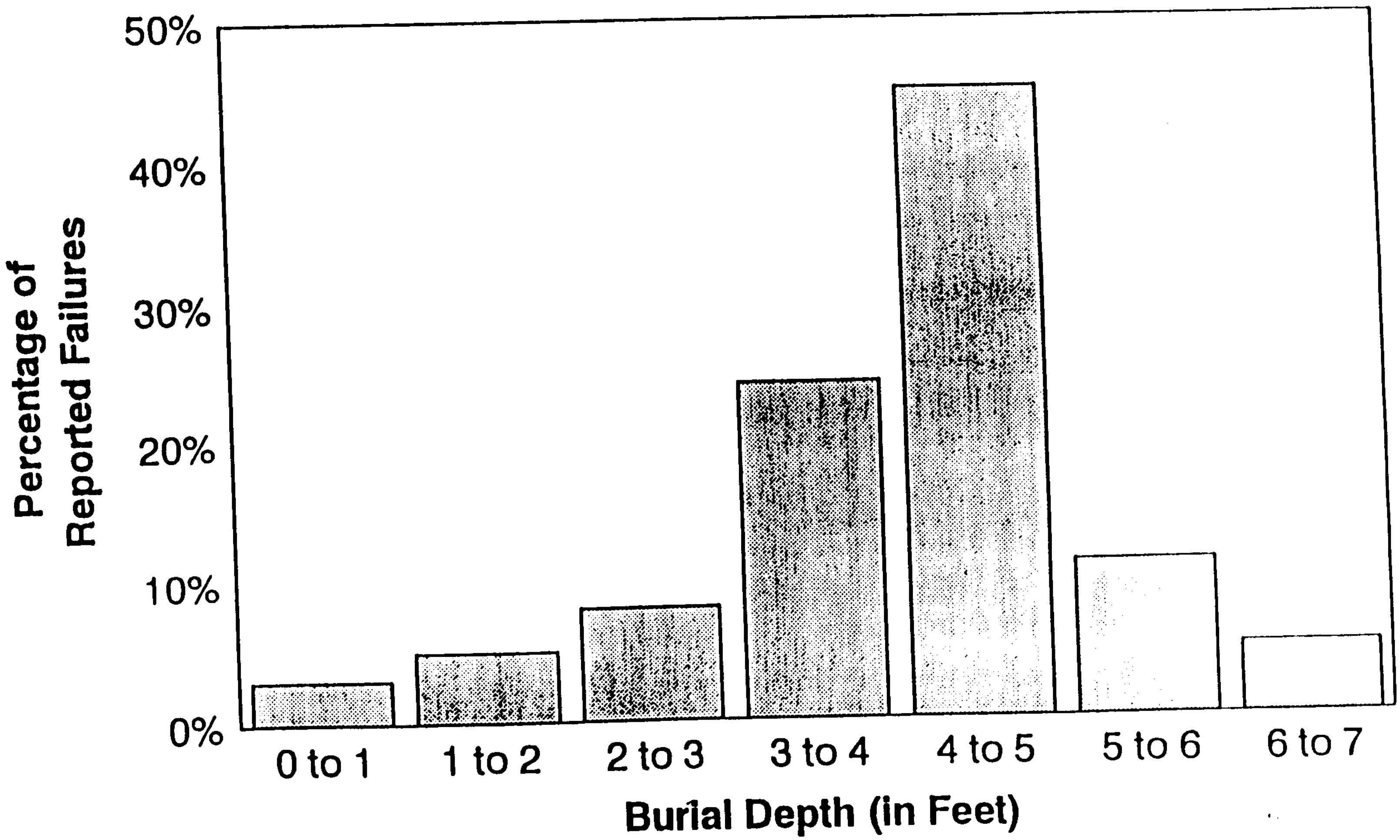


Figure 3



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2) this data was compiled from failure reports which were only submitted as a result of cable damage, therefore, this analysis cannot account for potential dig-ups which were actually averted through the use of above ground markers, and

3) it is possible that the amount of digging activity occurring near areas of marked cable is substantially higher than the amount of activity occurring near unmarked areas.

Bellcore is continuing to investigate the effect of permanent marking on reducing dig-up probability.

5.2.4 Failure causes by installation.

In the United States fiber optic cable is principally deployed in three installations: underground, direct buried, and aerial. Cable installed in a rigid duct structure, typically found under city streets, is referred to as underground cable. Cable directly placed in the soil is referred to as buried cable. Buried cable is frequently installed inside a soft innerduct (also known as ductliner), which in turn can be installed in PVC pipe. Direct buried cable is usually located in rural areas. Aerial fiber optic cable is typically deployed on the lowest portion of joint use utility poles. Of the companies responding to the Focus Group's data request, 99% of all the deployed sheath mileage in the U.S. is found in one of these three installations. The remaining mileage is deployed in indoor or submarine installations.

The immediate causes of cable failure shown in Table 1 and Figure 1 differ according to installation. Table 4 lists the immediate failure causes of sub-surface cable including both buried and underground installations. Sub-surface cable comprises roughly 75% of the sheath mileage of companies responding to the Focus Group's data request.

**Table 4. Immediate Causes of Sub-Surface Cable Failures**

| Cause | # of Reports | % of Total |
|---|---|---|
| Dig-ups | 93 | 71% |
| Process Error | 11 | 8% |
| Rodent | 5 | 4% |
| Sabotage | 4 | 3% |
| Flood | 2 | 2% |
| Excavation (non dig-up) | 2 | 2% |
| Vehicle | 2 | 2% |
| Other | 12 | 9% |
| Totals | 131 | 100.0% |

As shown in Table 4, dig-ups are responsible for more than 70% of reported failures and are the single largest cause of sub-surface cable damage.

In contrast, damage to aerial cable is caused by a wider variety of influences. Table 5 and Figure 4 detail the immediate causes of aerial cable failures as reported to the Focus Group.

**Table 5. Immediate Causes of Aerial Cable Failure**

| Cause | # of Reports | % of Total |
|---|---|---|
| Vehicle | 10 | 34% |
| Power Line | 7 | 24% |
| Fire | 2 | 7% |
| Firearm | 2 | 7% |
| Falling Tree | 2 | 7% |
| Other | 6 | 21% |
| Totals | 29 | 100.0% |

Table 5 indicates the major cause of aerial cable damage is from vehicle collisions with utility polls (see para. 5.1, "Detailed failure causes, definitions and root causes"), responsible for 34% of reported failures. The results also show power line damage is a significant cause of aerial cable failure



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# Immediate Causes of Aerial Fiber Optic Cable Damage

## 29 Aerial Cable Reports

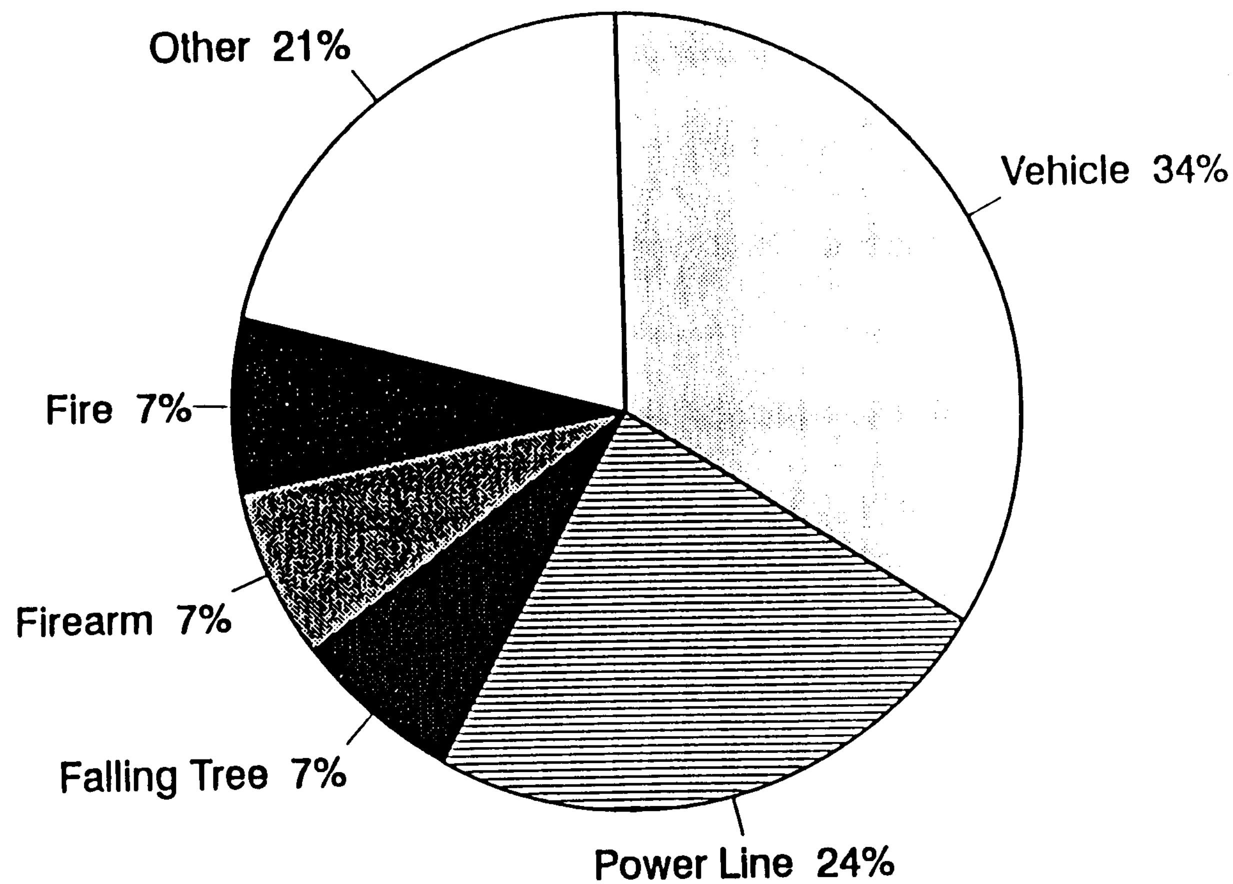


Figure 4

accounting for 24% of the reported failures.

It is important to recognize that aerial cable is frequently damaged by a series of events. For example, one report described a storm that caused a tree limb to fall on and break a power line. The power line then made contact with the aerial cable's messenger thus creating a fire which burned the cable. The immediate cause in this instance is power line contact, however the failure would not have occurred without the storm.

To reflect the complexity of aerial cable damage, Table 6 lists influences known to have contributed to such damage. The sum of these influences exceeds the number of reports since many failures are influenced by more than one event.

**Table 6. Influences on Aerial Cable Damage**

| Cause | # of Reports | % of Total |
|---|---|---|
| Vehicle | 10 | 34% |
| Power Line | 8 | 24% |
| Weather | 7 | 24% |
| Trees | 7 | 24% |
| Fires | 3 | 10% |

Table 6 clearly demonstrates that unlike sub-surface cable whose failures are caused primarily by dig-ups, aerial cable can be damaged by a wide variety of external factors.

5.2.5 Causes of large outages.

The causes of large outages did not significantly differ from the causes of other outages. The Focus Group received 33 reports of cable failure occurring during 1992 which involved outages that were reported to the FCC as affecting at least 30,000 customers, special offices, and for a duration of more than 30 minutes. Table 7 lists the causes of these large outages.

**Table 7. Causes of Large Outages**

| Cause | # of Reports | % of Total |
|---|---|---|
| Dig-ups | 21 | 64% |
| Vehicle | 3 | 9% |
| Process Error | 3 | 9% |
| Sabotage | 3 | 9% |
| Power Line | 2 | 6% |
| Other | 1 | 3% |
| Totals | 33 | 100.0 |

As was the case for all reported failures, dig-ups were the single largest cause of large outages. Statistical analysis indicates that the proportion of failures caused by dig-ups was not significantly different between large and other outages. Table 8 lists the root causes for 19 of the 21 dig-ups which resulted in large outages.

**Table 8. Root Causes of Large Outages**

| Root Cause | # of Reports | % of Total |
|---|---|---|
| Digging Error | 9 | 47% |
| No Notification | 6 | 32% |
| Others | 4 | 21% |
| Totals | 19 | 100.0 |

As was the case for all reported failures, digging error was the single largest root cause of dig-up failures with no notification being the second largest root cause. Statistical analysis reveals that the proportion of dig-ups whose root causes are digging error and lack of notification was not significantly different between large and other outages.

5.3 Comparisons of relative failure probability among installations.

To determine the relative failure susceptibility among installations, failure reports from the companies exhibiting consistent reporting were counted by installation and then compared with



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sheath mileage totals by installation from those companies (small variations in reporting periods across companies were ignored). Hypothesis tests were then conducted by comparing the reported failures per sheath mile for each installation. The comparisons were made at a 5% significance level.

5.3.1 Comparing aerial with sub-surface cable.

Although the failure causes for sub-surface cable are vastly different from those of aerial cable, the reported failure probability (measured in failures per sheath mile per year) is nearly identical for the two installations.

Six companies exhibited good reporting over this variable and provided deployed mileage totals for the two installations. Table 9 lists the percentage of reports received along with the percentage of sheath mileage deployed by these companies for each installation.

**Table 9. Aerial and Sub-surface Cable - Relative Failure Probability**

| | Aerial | Sub-surface |
|---|---|---|
| % of Reported Failures | 24% | 76% |
| % of Sheath Mileage | 25% | 75% |

As shown in Table 9, there was virtually no difference in the reported failure probability between aerial and sub-surface cables.

To further evaluate any possible differences between installations, similar data from Bellcore's Field Tracking Study was analyzed. Failures reported from four companies exhibiting consistent reporting between 1989 and 1991 were compared with sheath mileage totals from those companies. Using the same statistical test, this data again reveals that the observed failures per sheath mile per unit time are nearly identical for the two installations.

5.3.2 Comparing direct buried with underground cable.

When examining the difference in relative failure probability between buried and underground cable, it was necessary to combine data collected in response to the Focus Group's data request with data collected by Bellcore's Field Tracking Study in the first half of 1992.

Bellcore data was included in this analysis because some of the companies who reported consistently did not indicate whether damaged sub-surface cable was deployed in buried or underground installations. Further, no differentiation between buried and underground cable was made in some of the deployed mileage information.

When comparing the failure probabilities of buried and underground installations, it should be noted that buried and underground cables are deployed in geographically diverse regions. Therefore, any observed difference in relative failure probability is strongly influenced by regional geographic features and probably not due solely to the presence of the duct structure itself.

Upon analyzing the data, it was found that when considering all failure causes, there was no statistically significant difference in the reported failure probability between buried and underground installations. However, it is likely that some difference in failure probability exists, but more data is needed to verify whether this is the case. Further, when considering only failures due to dig-ups, a statistically significant difference was observed.

Six companies exhibited good reporting over this variable throughout 1992. For each installation, Table 10 lists the percentage of failure reports received along with the percentage of sheath mileage deployed by these companies.



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**Table 10. Buried and Underground Cable - Relative Failure Probability**

| | Buried | Underground |
|---|---|---|
| % of Reported Sub-surface Failures | 67% | 33% |
| % of Sub-surface Sheath Mileage | 54% | 46% |

Statistical analysis of this data reveals that there was no significant difference in the reported failure probability between direct buried and underground cables.

A somewhat different result is obtained by only considering failures caused by dig-ups. Table 11 lists the percentage of failure reports received along with the percentage of sheath mileage deployed by these companies in each installation.

**Table 11. Relative Failure Probability Due to Dig-ups**

| | Buried | Underground |
|---|---|---|
| % of Reported Failures | 71% | 29% |
| % of Sheath Mileage | 54% | 46% |

Statistical analysis of this data reveals that there is a significant difference in the reported failure probability between the two types of installations.

It is suspected that geographic influences play a significant role in accounting for this difference. In general, most companies stated that underground cable is deployed in urban areas while direct buried cable is prominent in rural areas. Sheath mileage data on the installation of deployed cable by urban and rural environments was not available in sufficient detail to be included in the analysis.

However, between 1986 and 1991 Bellcore's Field Tracking Study collected data on whether fiber optic cable failures occurred in urban or rural areas as a function of the failed cable's installation type. This information can then be used to assess the link between geography and failed cable plant. Table 12 lists, by geography, the number of failure reports received for buried and underground installations.

**Table 12. Geography and Installation of Damaged Sub-surface Cables 1989 - 1990**

| Geography | Buried | Underground |
|---|---|---|
| Urban | 15 | 23 |
| Rural | 40 | 6 |

Statistical analysis indicates a strong association between geography and the installation of failed cables. This provides evidence to suggest that the difference in failure probability due to dig-ups between buried and underground cable may be strongly influenced by geographic considerations.

To help determine the effect of duct structure in preventing cable damage, it is interesting to examine the severity of the damage caused by dig-ups to buried and underground fiber optic cable. One measure of damage severity to consider is the number of fibers broken as a fraction of the total number of fibers in the cable or the fraction of reports indicating a complete fiber break. Table 13 lists the average percentage of fibers broken during dig-ups for buried and underground installations and the percentage of reports indicating a complete cable break. This data combines data submitted to the Focus Group with data collected by Bellcore since 1989.



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**Table 13. Severity of Dig-ups Damage by Installation**

| | Buried | Underground |
|---|---|---|
| Average % Broken Fibers | 95% | 87% |
| % Complete Breaks | 90.5% | 83.0% |

This data indicates that for dig-ups which do occur, the difference in the severity of damage incurred between buried and underground cables is not substantial. It should also be remembered that these events are not reported if there is no damage to the cable. Therefore, if the presence of a duct structure was instrumental in averting a possible dig-up, this would not be reflected in the data.

5.3.3 Comparing public with private right-of-way.

Data submitted to the Group contained information on the right-of-way of the damaged cable. Some companies provided deployed cable mileage totals in public and private rights-of-way. Public right-of-way includes highway right-of-way and other government property while examples of private right-of-way include property owned by railroads, power companies, and private landowners.

Of the IXCs responding to the Focus Group's data request, 75% of their fiber optic cable is deployed in private right-of-way. Of the LECs who provided this population data, approximately 20% of their fiber mileage is deployed in private right-of-way.

The immediate causes of reported cable failure did not vary substantially between cable deployed in public and private rights-of-way. The two most significant causes reported for these two installations were nearly identical. Table 14 highlights these causes.

**Table 14. Failure Causes by Right-of-Way**

| Causes | Private | Public |
|---|---|---|
| Dig-ups | 64% | 71% |
| Vehicles | 11% | 7% |
| Others | 25% | 22% |

The data also indicated that for failures caused by dig-ups, the fractions of dig-ups which occurred without prior notification were identical for cable deployed in each right-of-way.

To compare the relative failure probabilities due to all failure causes of cable deployed in public and private rights-of-way, reports from four companies exhibiting good reporting and who provided sheath mileage totals were counted. These companies include both LEC and IXC representatives. Table 15 lists the percentage of failure reports received along with the percentage of sheath mileage deployed by these companies in each installation.

**Table 15. Public and Private Right of Way - Relative Failure Probability**

| Causes | Private | Public |
|---|---|---|
| % of Reported Failures | 55% | 45% |
| % of Sheath Mileage | 67% | 33% |

Statistical analysis reveals that there was no significant difference in the reported failures per sheath mile between cable deployed in public and private rights-of-way.

5.4 Repair data.

Although the Focus Group did not investigate service restoration or cable repair strategies, data was collected on the time required to restore service after a service affecting cable failure, and the time required to permanently repair the damaged cable. Restoring service can be accomplished by rerouting



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traffic, temporarily repairing the cable, or by switching to a protection fiber. Complete cable repair includes: finding the failure location, splicing the failed cables or splicing in a new section of cable (or possibly replacing the entire cable run), and protecting the respliced area. Due to unusual conditions, long delays are occasionally experienced in complete cable repair. For this reason customer service is usually restored well before a cable is fully repaired.

Table 16 summarizes the mean, median, maximum, and minimum reported service restoration times and complete facility repair times. Histograms of service restoration time and cable repair time are provided in Figures 5 and 6 respectively. For convenience, repair times greater than 25 hours have not been included in Figure 6. However, these reports were included when computing repair time statistics.

**Table 16. Summary of Repair Time Statistics**

| Statistic | Service Restoration Time (hours) | Complete Cable Repair Time (hours) |
|---|---|---|
| Mean | 5.2 | 14.2 |
| Median | 4.6 | 10.0 |
| Maximum | 21.43 | 97.5 |
| Minimum | .1 | .48 |
| # of Reports | 132 | 66 |

As shown in Table 16, the mean time to completely repair a failed cable is slightly over 14 hours while the mean time to restore service is slightly over five hours. The complete repair time data does include five damage reports describing failures which were not service-affecting. However, the mean time to repair these failures was less than 15 hours and therefore has only a small affect on the statistics.

It is evident from Table 16 that the time required to restore service after a fiber optic cable failure is in general substantially less than the time required to completely repair the damage. It is also evident that the complete cable repair time distribution is skewed by the occasional long repair times. This skewness results in the four hour difference between the mean (average value) and the median (50th percentile) of the distribution.

## 6. Key Lessons Learned and Recommended Best Practices

The "best practices" definition as used in network reliability focus area technical papers, and here as well, is: best practices are those countermeasures (but not the only countermeasures) which go furthest in eliminating the root cause(s) of outages. None of the practices are construed to be mandatory; however, a very small number of countermeasures that are deemed by the Focus Team, and concurred by NOREST, to be especially effective countermeasures will be designated as "recommended." Service providers and suppliers are strongly encouraged to study and assess the applicability of all countermeasures for implementation in their companies and products, respectively. It is understood that all countermeasures, including those designated as "recommended," may not be applied universally.

6.1 Key lessons learned, best practices, new approaches.

Dig-ups are the single largest immediate cause of fiber optic cable failures (see para. 5.1, "Detailed failure causes, definitions and root causes"). In the prevention of such failures, industry-wide adherence to established processes and practices is required. However, universal adoption of these practices is complicated by the evolution of fiber optics and its associated implementation requirements. However, effective preventive practices exist and are implemented in the industry. These practices were identified through the examination of the damage prevention measures used, or absent, in the circumstances surrounding failures reported to the Focus Group's data request (see Fig. 2, "Root Causes of Fiber Optic Cable Dig-ups").

The Focus Group identified existing practices that if complied with by telecommunications companies



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# Distribution of Service Restoration Times

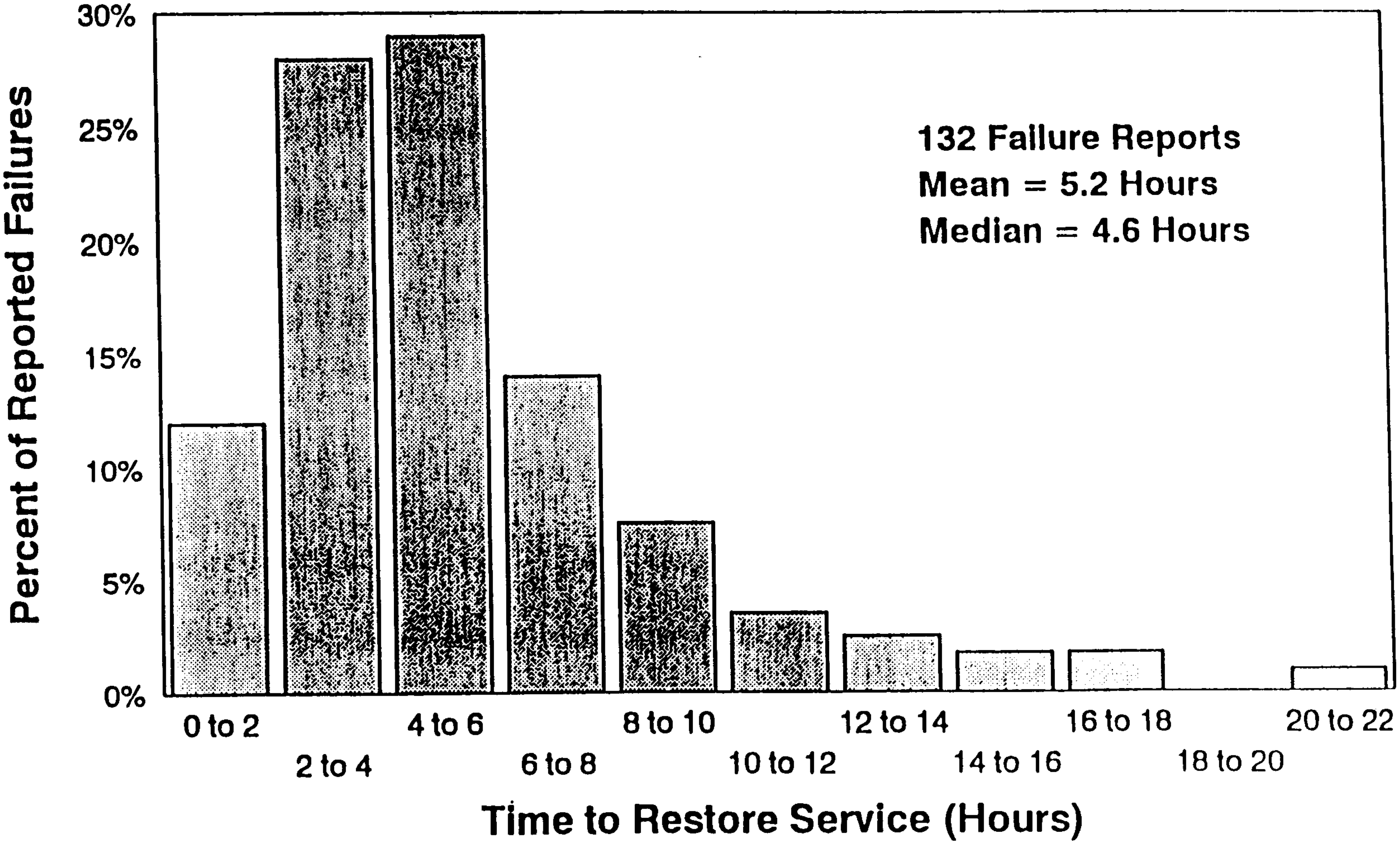


Figure 5

# Fiber Optic Cable
# Complete Repair Time Distribution

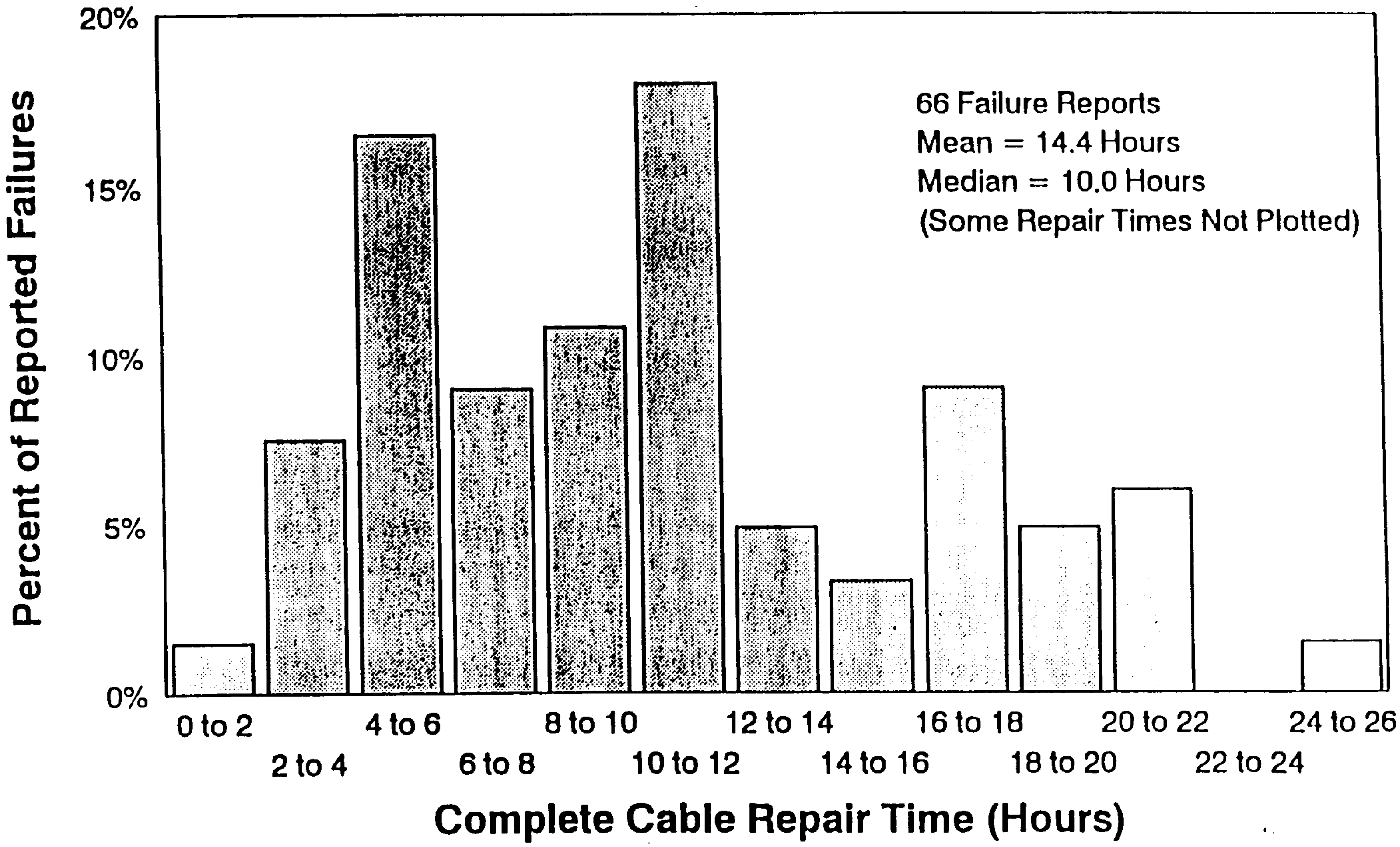


Figure 6



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and excavators, will eliminate, mitigate, or at least minimize cable failures. Many of these practices and procedures relate to cable burial depths and cable mining operations, they are somewhat new and evolving while being implemented. In addition to identifying existing strategies that minimize fiber cable damage, jointly published ANSI, EIA, and TIA documents provide a good starting point for assessment of standards and procedures applicable to reducing the probability of fiber cable dig-ups.

The Group is also confident that reduced cable failures and outages will result if preventive procedures and practices are emphasized in personnel training as well as through elevating public awareness of the significance of cable damage and cable failure.

6.1.1 Best practices to prevent fiber cable damage caused by digging.

The analysis of cable failure information provided to the Focus Group's data request led the Group to align preventive practices, guidelines and procedures (by causes of fiber cable failures), damage caused by digging, and damage caused other than by digging.

The best practices to prevent fiber cable failures are further grouped by installation, maintenance and preventive sub-processes, they are:

o Engineering and construction

Compliance with industry and established company practices based on ANSI, EIA, and TIA minimum standards, e.g., burying cable at standard depths and distances from adjoining structures and marking cable routes with permanent markings and/or warning tapes.

o Call-before-you-dig

Notification to facility owners for cable location marking, enactment and enforcement of federal and state "call-before-you-dig" legislation and underground facility damage prevention laws.

o Locate the cable

It is the facility owner's responsibility to respond to cable locate requests and to promptly and accurately establish and mark cable route locations.

o Use additional appropriate prevention measures

Special care, consideration, and training to ensure fiber optic cable security, e.g., hand digging around safety zones, cooperation and communication between excavators and facility owners, technical training, general awareness elevation, and procedural training.

Complying with best practices and standards in combination with the above processes is essential to improving fiber cable security and thus reliability. It should be noted however, that elements of some practices are necessarily fixed and may conflict. Therefore, it is imperative that environmental, application, and economic considerations be incorporated in the design, implementation, and maintenance of fiber optic cable facilities.

6.1.2 Best practices to prevent fiber cable damage caused by other than digging.

The immediate causes of fiber optic cable damage examined in this paper, as reflected in the data request (see para. 5.1, "Detailed failure causes, definitions and root causes"), and other than by hand digging, are shown in Table 1 and Figure 1.

Associated with immediate causes are root causes (see para. 5.2.1, "Root causes of dig-ups") which, it is believed, could be dramatically reduced or even eliminated through consistent industry-wide observance of best practices.

Appendix 3, "Existing Practices," provides details of several current standards and procedures, not written by EC or IXC companies, aimed at preventing fiber cable damage. Included are ANSI, EIA, TIA, and NCS regulations.



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6.1.3 Details - key lessons learned and best practices.

The Group identified the following baseline of best practices/counter measures as a representative means to bring about reductions in fiber cable failures including dig-ups. Many companies have adopted these practices and others should consider them where applicable. The best practices/counter measures encompass the following:

**Adherence to Procedures** - comply with, utilize, and benefit from existing standards and procedures.

**Warning Tape** - place tape 12 in. above the cable, do not deviate more than 18 in. from the outside edge of the facility.

**Visible Cable Marking** - place permanent markers at line-of-sight intervals to clearly indicate the placement and direction of cables.

**Call-Before-You-Dig Legislation** - enforce, enact, and/or revise state and federal underground facility damage prevention laws.

**Respond To Locate Requests** - execute prompt responses to contractor calls for cable locates.

**Accurate Locates** - expand locate personnel training and skill levels, quality control all work.

**Enhanced Locating Equipment** -utilize current, and/or emerging technologies with long range locating equipment, add a cable-unique sense tone carrier on each cable.

**Use Of Plant Route Maps** - secondary checking of plant drawings relative to marking.

**Hand Dig In Safety Zone** - perform hand digging exclusively within a two foot safety zone around the cable, and pot hole every 50 ft. for construction that is parallel to the cable route.

**Technician Supervision** - assign technical personnel to observe activities at work sites where digging is underway.

**On-Line Technical Support** - centralized support for technicians performing locates, timely answers to technical questions, facility drawing acquisition.

**Cooperation With Contractors** - easy access, open communications and flexible scheduling between facility owners and contractors.

**Training** - continuous refresher training and adherence to standards and procedures, train personnel to recognize conditions potentially hazardous to fiber optic cable.

**Contractor Awareness** - offer public service seminars, publish literature, and announcements by facility owners to educate contractors, right-of-way owners, and private property owners.

**Contact With Land Owners** - proactively educate and communicate with right-of-way owners to stress the importance of cable protection and security.

**Patrol Cable Routes** - regularly patrol fiber optic cable routes.

**Audits/Surveys of Plant** - periodically check and validate outside plant records and data.

**Barriers** - place barriers around poles and above ground structures.

**Buried Cable** - bury fiber cable in accordance with standards, mark and accurately document locations.

**Buried Facilities** - bury structures out of sight and to depths which are standards compliant.

**Shielding** - properly shield/insulate fiber cables.

**Protective Devices** - use rodent devices on poles and cable sheaths in rodent infested areas.

**Stronger Conduit** - use reinforced PVC pipe in rodent infested areas.



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**Separate Pole Lines** - avoid joint use utility poles with fiber optic cable if justified by cost/benefit considerations.

**No Visible Markings** - avoid use of visible markings in areas prone to vandalism.

**Secured Manholes** - utilize lockable manhole covers in areas prone to vandalism.

**Ventilate Manholes** - install automatic purging devices in contaminated manholes.

6.1.4 Effective Countermeasures.

To varying degrees, some Focus Group member organizations have seen that adoption of the following practices has demonstrated positive results. These organizations find improved cable dig-up prevention results when expanding certain practices. Each of these, presented below, indicates what the practice is or should be in order to optimally address industry-wide concerns and issues focused on reducing cable dig-ups. The remaining practices, in addition to those detailed here, should be considered as candidates for close study and evaluation as part of a benchmarking effort.

**Warning Tape** - Warning tape should be used with buried installation but should not be relied upon as a primary means of locating cables. It should be characterized by its compliance with existing or emerging standards. The tape should be marked in recognizable and standardized format to convey its primary message. Warning tape alerts should be simple yet convey a high degree of message impact. "WARNING -- Optical Cable," or "STOP," printed on the tape will likely be very effective in protecting cable or other sub-surface facility assets.

The tape should be made of a non-metallic material to eliminate possible interference with electronic locating devices.

**Technical Supervision/Plant Protection** - It may at times be necessary to have qualified observer personnel on-site to provide cable plant protection. This protection is dependent on the size of the transmission cable, the nature of traffic on the cable, and other environmental factors. Activities having the potential to damage a cable should be determined well in advance and observer coverage should then be required and scheduled. Open excavations exposing cable/splices must also be guarded and protected during certain work activities. Stakes, flags, or other devices designed to capture the attention of construction contractors should be placed directly over a cable to show its direction, changes in direction, curves, and variations in depth (if any). Examples of cable plant protection and safety practices include:

1) accurately locating a cable,

2) digging a test pit to visually confirm a cable's location,

3) permanently marking a cable's location and its hand-dig-only-zone, and

4) guarding the cable plant when/if appropriate.

Effective cable plant safety procedures must be promoted by facility owners and observed, enforced and practiced at all times.

**Hand-Dig-Only-Zone** - A hand-dig-only-zone should be marked with lines or orange paint on each side of the cable. The zone is measured from the actual cable location which is best determined visually and whenever possible.

Size of the Hand-Dig-Only-Zone - The following conditions affect the width of a hand-dig-only-zone:

1) local legislation (some states have laws governing one-call systems and also specify the features of a hand-dig-only-zone, e.g., width and depth),

2) changes in cable direction,

3) buried cable slack loops,

4) cable branching stubs and offsets, and



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5) other utilities crossing or paralleling a cable.

Test Pit Location - Whenever possible, network personnel should obtain an accurate cable location and determine depth by hand digging a test pit and visually confirming an electronic facility location. Test pits should be dug at intervals determined by the nature of the work activities being performed.

**Training** - Training programs, regularly upgraded in response to technology evolution, will sustain the various personnel skills required for fiber optic cable maintenance and operational restoration. All management and technical personnel must obtain the necessary knowledge and skills to satisfy organizational quality goals and customer service dependability expectations. The range of basic skills maintenance personnel should have include the ability to:

- describe and demonstrate proper procedures to purge and ventilate a manhole
- describe, demonstrate, and perform proper cable protection procedures
- use proper excavation methods in the area of a cable
- apply and use cable location techniques

Cable Locating Equipment - Low frequency locators operate in the 1 kHz, or lower, range and can only apply the signal by conduction for use in cable locating. The 60 Hz magnetic field of any cable with power on it interferes with the trace tone generated field. Each locator has its own unique electronic characteristics and practice is needed to learn how each device reacts to various situations. Electronic depth measurement is helpful, but it should not be used to direct powered excavation activities without first verifying location and depth by using hand dug test pits. Shown below are some of the factors that can influence the accuracy of electronic locator devices.

- spurious electrical fields
- other underground utilities
- operator or test set error
- improper ground connection
- soil acidity/soil moisture
- shield wires/cables
- variations in conductor depth
- transmitter proximity to receiver
- cable bonding
- cable deeper than other conductors
- cable not insulated
- cable diameter
- ground faults

**Right-of-Way Maintenance** - Proper right-of-way maintenance by facility owners communicates a strong message to others that underground plant is present in the right-of-way and that its safety and protection are guarded by the owners' enforced and practiced company procedures. Proper maintenance also allows for expeditious access to a fault location in the event of cable damage or failure.

**Cable Patrol** - To reduce the potential for damage to cable facilities, consideration may be given to implementing different levels of surveillance. New conditions arise between contact visits, construction plans and schedules change, and unforeseen activities by foreign parties can occur. The frequency of patrols may be established for each section of cable compliant with local conditions. As the levels of anticipated or planned activity increase, this may require differing frequencies of patrols needed to ensure adequate cable plant security.

**Contractor Awareness/Prevention** - Cable dig-ups by contractors are, historically, the number one cause of cable failures resulting in service outages. In a large number of these occurrences advance notification of the contractor's planned digging was not provided to the facility owner(s). However, given the opportunity to respond to contractor notification, owners can carry out an action plan to protect or guard their cable plant assets until hazards are removed. If facility owners are unaware of excavating activities in proximity to a cable right-of-way, or fail to learn of such activity, the results can be catastrophic. It is therefore imperative that facility owners strive to educate excavators, contractors, and the public at large



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about call-before-you-dig (one-call) procedures and legislation and shift the emphasis from damage repair to damage prevention. In support of this approach, some facility owners have designated personnel to cover a geographic region to actively promote call-before-you-dig damage prevention programs. These efforts should focus on and will be most informative to the following groups:

- small and large contractors

- private contractors

- utility owners

- federal, state, and local governments

- municipalities

- farmers and ranchers

For these programs to achieve optimum beneficial results, cable plant protection concepts and procedures should be presented to audiences with representatives from all or some of these groups. Additionally, an attempt should be made to develop joint efforts with other utilities and the one-call centers and their memberships to promote these programs and concepts. Some of the activities which will be integral to this program will include, but not be limited to, the following activities.

- contractor awareness nights

- contractor safety meetings

- proactive participation/board memberships in local one-call organizations

- damage prevention awareness booths at events such as:

    - utility/heavy equipment expositions
    - state farm bureaus
    - agricultural fairs
    - APWA equipment shows
    - county fairs
    - homebuilders associations

and, memberships in and/or program participation with trade groups such as:

- Associated General Contractors
- National Utility Contractors Association
- ULCC
- APWA

Facility owners may want to set priorities and concentrate their program efforts in areas where cable assets are at the greatest risk. These include areas of high capacity, heavy construction activity, shared rights-of-way, multiple underground facility crossings, areas having a high incidence of cable outages, or near misses. Cable routes defined as critical to facility owners should receive special attention.

**Contact With Land/Property Owners** - Communicating with land and property owners is another measure which can help bring about improved security for cable plant assets. These contacts should be scheduled to correspond with anticipated, planned or scheduled construction activities at or near cable or other sub-surface facilities on property owned by the persons contacted. Contact sessions with property owners could include inquiries concerning a variety of issues ranging from physical attributes and conditions of the property to changes in property ownership.

**Warning Sign/Markers** - Placing markers and signs will maximize plant protection by clearly delineating the presence and path of sub-surface cable routes while also reminding the public that advance notice must be given prior to excavating in the vicinity of marked cable routes. Markers should be placed at line-of-sight intervals to ensure route direction is clearly visible. Adjacent markers should be visible each way from an adjoining marker but should be no more than, e.g., 1000 ft. distant if land features permit such spacing. However, consideration must be given to areas prone to vandalism. Placement of warning signs



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and markers in these areas may not be desirable.

## 7. Metrics

7.1 Metrics to measure the effectiveness of solution recommendations.

Benchmarking conducted for the TBIC will define metrics for dissemination through the ECSA.

## 8. Path Forward

8.1 Benchmarking.

Best practices provide a certain level of assurance in cable damage prevention (see para. 6.1.3, "Details - key lessons learned and best practices"), yet cable damage continues to occur. To define additional practices, a benchmarking study will help identify strategies with the greatest potential for minimizing fiber cable failures. The scope of the study should include "world class" companies, within and external to the telecommunications industry, having excellent records of preventing service outages similar to and including fiber cable failures. The study should include a screening-out process to identify the most effective policies, strategies, and methodologies to implement for maintaining and protecting fiber cable assets. Specific areas a benchmarking study should cover include:

o PREVENTIVE/PROTECTIVE

- Call-before-you-dig
- One-call centers
- Contractor/customer education
- Alarming methods
- Marking and paroling

o INSTALLATION

- Cable design
- Construction methods
- Permanent marking techniques
- Documentation, record keeping

o MAINTENANCE

- Dispatch procedures
- Markers/marking techniques
- Mark and walk procedures
- Service restoration strategies

The Focus Group recommends a formal benchmarking study and solicits the TIBC to perform this task. It is very likely that the findings of an independent benchmarking effort will stimulate process and procedural improvements to increase fiber cable reliability.

MCI will manage the benchmarking study project through the TIBC and upon its completion submit study findings to the ECSA for distribution to all interested parties. The Fiber Cable Focus Group member companies have agreed to fund their portion of the study. Other NRC members have also agreed to join in the TIBC funding of efforts.

The process to perform the study is for the TIBC to support an independent third party consultant to "Identify 'Best In Class' business processes which when implemented, will lead member companies to exceptional performance as perceived by customers." This mission goal fully supports and complements the Group's goal, i.e., improving fiber cable reliability through improving its safety and security. The benchmarking process can access and evaluate performance data from non-industry companies thus providing an alternate, more universal perspective of best practices selectively applicable to minimizing fiber cable failures caused by dig-ups. The issues below would comprise a strong baseline from which a benchmarking effort could be launched, they include:

- which states have one-call systems in place
- what is the geographical coverage of each
- hours of coverage
- legislative details
- notification and response requirements
- excavation guidelines
- participants, members
- penalties for noncompliance



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- exemptions

From a "Path Forward" perspective, Appendix 5, "Network Reliability Industry Initiatives," presents the activities of several focus areas.

## 9. Conclusions

After study data was analyzed and interpreted, several factors contributing to the cable failure problem became very clear but the dominant factor remains dig-ups (see para. 6.1, "Key lessons learned, best practices, new approaches," and Fig. 1, "Immediate Failure Causes"). The Focus Group then recognized that to meet near term needs a triad of actions will collectively, and adequately, address the persistence of this industry-wide problem. However, within the triad is a benchmarking recommendation. This activity will be required to assess the effectiveness of current problem solutions and, perhaps more important, the merit of new, yet to be defined long term solutions. The Group therefore recommends that this triad of activities be broadly implemented as an overall strategy for the industry to adopt until benchmarking yields new and/or revised problem resolution approaches and recommendations. The Group is confident that by implementing this triad, the industry will experience a dramatic reduction in current levels of fiber cable failures and their resultant service outages. The triad's primary components are presented below.

### 9.1 Call-before-you-dig as SOP (Standard Operating Procedure).

The Focus Group found that a very high percentage of reported fiber cable failures were caused by dig-ups (see Fig. 1, "Immediate Failure Causes") and that root causes such as no notification and digging error accounted for a large fraction of these dig-ups (see Fig. 2, "Root Causes of Fiber Optic Cable Dig-Ups").

An assessment of call-before-you-dig legislation revealed that the laws are inconsistent across the country and seem to lack the depth of enforcement and penalties required to deter excavators from digging without providing notification. Similarly, inconsistencies were identified in penalties imposed for digging errors after cables were properly marked. The Group therefore recommends more enforcement, expanded enactment, and/or revision of federal and state underground facility damage prevention laws to achieve enhanced uniformity of use. The legislative process must emphasize and include two key points, they are:

1) that any person or entity, e.g., municipalities and departments of transportation, excavating on utility rights-of-way must notify all underground utility owners at least two days prior to the time excavating work commences, and

2) that any person or entity, e.g., municipalities and departments of transportation, failing to provide notification within the prescribed time and causing damage to underground facilities, or causing damage to properly marked facilities, is financially liable. Such liability includes full compensation to the affected utiity(s) for all costs of emergency restoration and repair work needed to return the facility to its operational condition prior to excavation. This is to include fines and penalties commensurate with state and federal regulations.

Several states have existing legislation that reflects these two points. For example, Pennsylvania requires a contractor to notify the underground facility owner "not less than three nor more than ten working days prior" to excavation. Virginia and Missouri have similar wording in their laws, except that minimum time is two full working days. These states also address the critically important issue of liability which contributes significantly to the credibility and validity of this legislation.

In Pennsylvania, the contractor is deemed liable for damage even if notification was provided but damage was caused by a failure to employ prudent methods (which can include hand-dug test holes). The legislation also calls for split liability if there was non-compliance by the contractor in addition to mismarking by the utility owner. Missouri has similar wording which states that compliance with



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the legislation's provisions does not excuse the contractor from "excavating in a careful and prudent manner." If cable damage occurs and the contractor had not complied with Missouri's legislation, the failure "shall be a rebuttable presumption of negligence."

Appendix 6, "Call-Before-You-Dig - Statute Analysis by State," presents a summary of state-by-state statutes (with effectiveness rankings). In order to make such call-before-you-dig legislation more effective, Appendix 7, "Model Legislation," provides an example of "model wording" for legislation which, if enacted, could produce the desired effects.

9.2 Best practices

The study suggests that if best practices (see para. 6.1.3, "Details - key lessons learned and best practices") are more uniformly implemented and enforced, then a measurable reduction in fiber optic cable damage will quickly result. Consequently, while the facility owners/operators interests are served well by existing best practices, industry failure to adopt and enforce these best practices can keep cable failures due to dig-ups a persistent industry-wide problem.

9.3 Benchmarking.

Benchmarking will help to isolate practices and procedures that are not realizing their full potential to protect facilities and also determine why they are failing to achieve expected results. Benchmarking will also bring about innovative approaches to facility security.

Once a benchmarking study is delivered to ECSA, industry members will have the opportunity to review and adopt its inherent recommendations as additions to present operating practices.


## 10. Acknowledgements

1. Mr. Samuel V. Lisle, Bellcore

Mr. Richard M. Fagerstrom, Bellcore

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2. Mr. Mike Michalczyk, Southwestern Bell Telephone Company

3. Mr. Paul E. Devaney, Applied Concepts, Inc.


## 11. References

None

## 12. Figures and Exhibits

### Figures

Figure 1. Immediate Failure Causes



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**Exhibits**



**13. Appendices**





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