

12-2005

# Causes of Failure in Web Applications (CMU-PDL-05-109)

Soila Pertet  
*Carnegie Mellon University*

Priya Narasimhan  
*Carnegie Mellon University*

Follow this and additional works at: <http://repository.cmu.edu/pdl>

 Part of the [Computer Sciences Commons](#)

---

This Technical Report is brought to you for free and open access by the Research Centers and Institutes at Research Showcase @ CMU. It has been accepted for inclusion in Parallel Data Laboratory by an authorized administrator of Research Showcase @ CMU. For more information, please contact [research-showcase@andrew.cmu.edu](mailto:research-showcase@andrew.cmu.edu).



## Causes of Failure in Web Applications

Soila Pertet and Priya Narasimhan

CMU-PDL-05-109

December 2005

**Parallel Data Laboratory**  
Carnegie Mellon University  
Pittsburgh, PA 15213-3890

### Abstract

*This report investigates the causes and prevalence of failure in Web applications. Data was collected by surveying case studies of system failures and by examining incidents of website outages listed on technology websites such as CNET.com and eweek.com. These studies suggest that software failures and human error account for about 80% of failures. The report also contains an appendix that serves as a quick reference for common failures observed in Web applications. This appendix lists over 40 incidents of real-world site outages, outlining how these failures were detected, the estimated downtime, and the subsequent recovery action.*

**Acknowledgements:** We thank the members and companies of the PDL Consortium (including EMC, Hewlett-Packard, Hitachi, IBM, Intel, Microsoft, Network Appliance, Oracle, Panasas, Seagate, Sun, and Veritas) for their interest, insights, feedback, and support.

**Keywords:** Web applications, causes of failure, fault chains, unplanned downtime.

## 1 Introduction

The Web serves as an integral part of the day-to-day operation of many organizations. Businesses often rely on the Web to attract clients, communicate with suppliers, and generate revenues. As a result, the cost of failed online transactions can be significant: a single hour of downtime could cost a retailer thousands of dollars in lost sales. For example, during the Thanksgiving holiday weekend in 2001, Amazon.com suffered a series of outages, which cost the retailer an estimated \$25,000 per minute of downtime [1]. The true costs of downtime are much higher: lost or dissatisfied customers, damage to the company's reputation, possible impact on the company's stock price, and lost employee productivity [2].

This report investigates the causes of failure in Web applications, and looks into the prevalence of these failures. Data was collected by surveying case studies of system failures and by examining incidents of website outages listed on technology websites such as CNET.com and eweek.com. The report contains an appendix that serves as a quick reference for common failures observed in Web applications. This appendix lists over 40 incidents of real-world site outages, outlining how these failures were detected, the estimated downtime, and the subsequent recovery action. A summary of the findings in this report is given below:

- Software failures and human error account for about 80% of failures [3].
- The incidents of software failures on the Web suggest that a large number of non-malicious failures occur during routine maintenance, software upgrades and system integration. It is unclear whether these failures are mainly due to system complexity, inadequate testing and/or poor understanding of system dependencies. Site owners tend to be vague about the underlying cause of the failure.
- Other significant causes of software failure are system overload, resource exhaustion and complex fault-recovery routines.
- Site outages ranged from a few minutes to several weeks (see appendix). During this period, the site may be completely unavailable or experiencing intermittent outages. Prolonged downtime often occurs when multiple components are implicated in the failure (i.e. large fault-chains).
- Business research [4] shows that planned downtime accounts for at least 80% of all downtime while the balance of less than 20% is unplanned downtime. Planned downtime contributes to about 15% of unplanned downtime, for instance, when a backup takes longer than planned.

The remainder of this report is organized as follows. Section 2 discusses the causes and manifestation of failures in Internet Services. Section 3 describes incidents where multiple components are implicated in the failure (i.e., large fault-chains). Section 4 examines the prevalence of failures. Section 5 compares planned downtime to unplanned downtime. Section 6 concludes the report. The appendix lists examples of real-world site outages.

## 2 Causes and Manifestations of Failures

Websites experience permanent, intermittent or transient failures, which may affect the entire site or be restricted to parts of the site. Permanent failures persist until the system is repaired, e.g., a disconnected network cable. Transient failures eventually disappear without any apparent intervention. Intermittent failures are transient failures that recur occasionally, e.g., when the system is overloaded. In this section, we explore the common causes of failures in Web applications and the manifestation of these failures.

### 2.1 Causes of Failure

We classified the causes of failures in Web applications into four categories namely: software failures, operator error, hardware and environmental failures, and security violations. We focus on non-malicious failures but list some failures that occur due to security violations for the sake of completeness.

The appendix gives a more detailed description the causes of failure and lists examples of outages. The categories listed in the appendix are not mutually exclusive and some failure modes may overlap several categories. Vijayaraghavan's taxonomy of e-commerce failures [5] is another comprehensive resource that outlines the causes of failure in e-commerce systems. This taxonomy lists test cases for a shopping cart application.

#### 2.1.1 Software Failures

The incidents of software failures on the Web suggest that a large number of non-malicious failures occur during routine maintenance, software upgrades and system integration. It is unclear whether these failures are mainly due to system complexity, inadequate testing and/or poor understanding of system dependencies since site owners tend to be vague about the underlying cause of the failure.

Other significant causes of software failure are system overload, resource exhaustion and complex fault-recovery routines. Table 1 highlights examples of software failures.

| Failure trigger            | Examples  | Real-world Incident   |
|----------------------------|---|---|
| Resource exhaustion        | <ul style="list-style-type: none"> <li>• Memory leaks</li> <li>• Thread pool exhausted leading to slow or unresponsive server</li> <li>• Resource intensive processes cause server requests to timeout</li> <li>• Fast-growing log files consume disk space and cause server to crash</li> </ul>  | <p>Zopewiki.org experiences memory leak in July 2004. Cause is unknown and the workaround is to reboot the server daily.</p> <p><a href="http://zopewiki.org/ZopeWikiNews">http://zopewiki.org/ZopeWikiNews</a></p>   |
| Computational/logic errors | <ul style="list-style-type: none"> <li>• Reference non-existent table in database</li> <li>• Pricing errors</li> <li>• Use of deallocated memory</li> <li>• Corrupt pointers</li> <li>• Synchronization errors, e.g., race conditions, deadlocks, starvation</li> </ul>   | <p>Pricing error on Amazon's UK site lists iPaq H1910 Pocket PC for under \$12 instead of regular retail price of \$449 resulting in abnormally high sales in March 2003</p> <p><a href="http://news.com.com/2100-1017_3-993246.html">http://news.com.com/2100-1017_3-993246.html</a></p>   |
| System Overload            | <ul style="list-style-type: none"> <li>• System overload can lead to resource contention and unanticipated interactions between other software processes running on the same machine, e.g., synchronization errors such as race conditions</li> </ul>   | <p>Comair airlines cancels over 1,000 flights on Christmas Day 2004 when its computer systems for reservations crashed after severe weather caused a surge in crew flight re-assignments that knocked out its computer reservations system</p> <p><a href="http://www.internetnews.com/bus-news/article.php/3451981">http://www.internetnews.com/bus-news/article.php/3451981</a></p> |
| Recovery code              | <ul style="list-style-type: none"> <li>• Fault-recovery routines may be complex and not well tested.</li> </ul>   | <p>A bank in Denmark experiences outage due to errors in database recovery routines following replacement of defective disk in April 2003</p> <p><a href="http://www.eweek.com/article2/0,1759,1008687,00.asp">http://www.eweek.com/article2/0,1759,1008687,00.asp</a></p>  |
| Failed software upgrade    | <ul style="list-style-type: none"> <li>• Failure to back up the web-store before upgrade</li> <li>• Files upgraded successfully but did not go "live" after upgrade (failed deployment).</li> <li>• Upgrades performed without checking inter-compatibility between existing or newer software processes</li> <li>• Software upgrades sometimes sets all options to 'default' automatically after the installation is complete</li> <li>• Integration errors/Third party software failures</li> </ul> | <p>PayPal battled on-and-off service outages for about five days in October 2004 after upgrading site. They blamed glitches in the software update and waived customer fees for a day</p> <p><a href="http://www.eweek.com/article2/0,1759,1684427,00.asp">http://www.eweek.com/article2/0,1759,1684427,00.asp</a></p>  |

Table 1: Examples of software failures

### 2.1.2 Human/Operator Errors

We classified operator errors into three categories: configuration errors, procedural errors and miscellaneous accidents. Configuration errors occur when operators define incorrect settings for system parameters, e.g., specifying an insufficient number threads to service user requests to the web server. Procedural errors occur when the operator either omits an action or executes an incorrect action during system maintenance. Table 2 describes examples of operator errors.

| <b>Failure trigger</b>  | <b>Examples</b>  | <b>Real-world Incident</b>   |
|-------------------------|--|--|
| Configuration errors    | <ul style="list-style-type: none"> <li>• System reset to default configuration by mistake</li> <li>• Accidentally corrupt configuration file</li> <li>• Omit necessary services from startup script</li> </ul>   | Incorrect configuration change in January 2001 to the routers on the edge of Microsoft's DNS network disrupts Microsoft.com, MSN.com, MSNBC.com, Hotmail.com and Encarta.com.<br><a href="http://www.internetnews.com/xSP/article.php/570171">http://www.internetnews.com/xSP/article.php/570171</a> |
| Procedural errors       | <ul style="list-style-type: none"> <li>• Failure to back up database</li> <li>• Restored the wrong backup</li> <li>• Forgot to restart web server</li> <li>• Deleted files by mistake</li> <li>• Incorrect input, typos</li> <li>• Forgot to prune logs (disk fills up)</li> </ul> | University of Michigan's ICPSR web server goes down in July 2002 when web logs grew too large due to a significant increase in traffic.<br><a href="http://www.icpsr.umich.edu/org/policies/webouts-2002.html">http://www.icpsr.umich.edu/org/policies/webouts-2002.html</a>                         |
| Miscellaneous accidents | <ul style="list-style-type: none"> <li>• Equipment trauma caused by drop or fall</li> <li>• Accidentally disconnect power supply</li> </ul>  | Anne Lear [6] reports eBay incident where electrician came in to audit power usage and on his way out accidentally knocked out a plug.   |

Table 2: Examples of operator errors

### 2.1.3 Hardware and Environmental Failures

Hardware failures can occur for several reasons, e.g., wear and tear of mechanical parts, design flaws, loose wiring. Table 3 gives of hardware and environmental failures.

| <b>Failure trigger</b> | <b>Examples</b>   | <b>Real-world Incident</b>  |
|------------------------|---|---|
| Hardware failures      | <ul style="list-style-type: none"> <li>• Device driver failures</li> <li>• I/O errors, e.g., hard disk failures (see database media failures)</li> <li>• Memory parity errors</li> <li>• Network hardware failures</li> </ul> | Hardware failure at the Wall Street Journal website causes 1hr outage in March 2004<br><a href="http://news.com.com/2110-1025_3-5171623.html">http://news.com.com/2110-1025_3-5171623.html</a>  |
| Environmental failures | <ul style="list-style-type: none"> <li>• Power outages</li> <li>• Overheating</li> <li>• High humidity</li> <li>• Natural disasters, e.g., hurricanes, floods</li> </ul>  | Loss of internal power distribution unit at youritdepot.com in August 2004 caused a air conditioning and temperature spikes to more than 113°F. Overheating caused equipment failure and resulted in significant loss of internet traffic.<br><a href="http://www.youritdepot.com/index/nid/147">http://www.youritdepot.com/index/nid/147</a> |

Table 3: Examples of hardware and environmental failures

### 2.1.4 Security Violations

This report focuses on non-malicious failures. However, we included examples of failures due to security violations for the sake of completeness. The list below highlights some of the common security violations that occur in websites:

- Password disclosures
- Denial of Service (DOS) attacks
- Worms and viruses
- Browser vulnerabilities
- Authentication failures
- Theft

## 2.2 Manifestation of Failure

The manifestation of the failure deals with the user-visible effects of a failure. Although the underlying causes of failure in Web applications are varied, the manifestation of the failure typically falls within the following broad categories:

- **Partial or entire site unavailable:** The user's request times out causing the user to receive error notices such as "404 file not found". This may be due to server crashes and hangs, network congestion or denial of service attacks.
- **System exceptions and access violations:** The executing process often terminates abruptly when a system exception is thrown. The error messages that arise vary depending on the error handling within the application that crashed, e.g., the system may display a very detailed access violation message with addresses and numbers, or nothing at all [7].
- **Incorrect results:** The executing process does not terminate but returns erroneous results, e.g., the site serves blank pages, returns wrong pages or wrong items. Since no exceptions are thrown, these failures are usually discovered only after a customer complains.
- **Data loss or corruption:** Data loss occurs when users are unable to access data from a previously functioning computer system, e.g., due to the accidental erasure of data. Corruption is probably the most difficult problem to diagnose. Corruption typically occurs from a boundary overwrite in memory. It is common to end up chasing the effect of memory corruption, rather than the problem that is causing it. The characteristics of corruption generally include random access violations or corrupt data [7].
- **Performance slowdowns:** Slowdowns may occur due to a variety of reasons, e.g., server overload, process hangs, deadlocks, resource exhaustion and network congestion.

## 3 Fault Chains

The fault chain refers to the series of component failures that led up to the user-visible failure. For instance, if a user-visible failure occurs after the failure of both the primary and backup servers, this failure has a fault-chain of length two. Large fault chains complicate recovery (see Table 4).

Fault-chains can be either *uncoupled* or *tightly-coupled*. *Uncoupled fault-chains* occur when independent failure events interact to produce user-visible failure. For instance, the primary server may fail due to resource exhaustion while the backup server fails independently due to hardware failure. On the other hand, *tightly-coupled fault-chains*, e.g., correlated or cascading failure, occur when failure events are tightly connected, for instance, a power outage causes air conditioning to fail resulting in equipment failure due to overheating.

The prevalence of large fault-chains varies from system to system. Gray [8] found that 60% of failures had fault chains of length two. This is because the Tandem system is single-fault tolerant so the second fault usually results in a user-visible failure. He also found that 20% of the failures had lengths of three or more. These failures chains were largely due to relatively high human error rates when invoking recovery procedures and complex recovery software that was not well tested.

Oppenheimer et al [9] found few failures with a failure chain of three or more in their study of failures in Internet services. Amir and Wool [10] showed that correlated hardware failures occur in large-scale Internet systems. They attributed this to the machines' dependence on common resources such as disk servers, naming servers, maintenance activities, and power supply.

| Incident                   | Fault Chain   | Coupling        | Downtime                      |
|----------------------------|---|-----------------|-------------------------------|
| Youritdepot.com outage [9] | <ul style="list-style-type: none"> <li>• Loss of internal power distribution unit causes a failure in air conditioning</li> <li>• Temperature spikes to more than 113°F.</li> <li>• The heat caused equipment failure and resulted in significant loss of internet traffic</li> </ul> | Tightly coupled | Several hours                 |
| MSN Messenger outage [10]  | <ul style="list-style-type: none"> <li>• Disk controller of primary database server fails</li> <li>• Backup for this controller also has an error occur which results in a more lengthy path to full service recovery</li> </ul>  | Uncoupled       | 6 days (Intermittent outages) |

Table 4: Examples of fault-chains

## 4 Prevalence of Failures

Studies suggest that user-visible failures in Web applications are prevalent. A survey done by TeaLeaf in October 2005 indicates that 89% of all online customers have experienced problems when completing transactions online [11]. A separate survey [2] of the forty top-performing Web sites during the 2002 holiday shopping season found that 72.5% of these sites exhibited application failures within the first fifteen minutes of testing. These failures included blank pages, incorrect data shown on Web pages, incorrect items displayed in response to a user request, and the inability to complete a purchase.

Human/operator error and application software failures account for a significant proportion of these failures [3 and 9]; hardware failures account for 10% or less of all failures. The trend represents a shift from the mid-80's when hardware failures were the dominant cause of system failures [8]. The reduction in the proportion of hardware failures is due to a steady increase in hardware reliability coupled with the skill of IT personnel to identify potential faults before they result in user-visible failures.

Although software is a dominant cause of site outages, this does not necessarily imply that software quality has gotten worse over the years. Gray [8] observed that while software complexity had increased dramatically, software fault rates held constant. The increase in software complexity relative to the other components of the system might be the reason why software is a dominant cause of outages.

The other dominant cause of site outages is operator errors. Operator errors typically arise when operators are making changes to the system, e.g., scaling or replacing hardware, or deploying or upgrading software. A study done by Oppenheimer et al [9] suggests that operator error occurred as often as hardware or software problems but was less frequently masked by the redundancy mechanisms in the system, and therefore more likely to result in a user-visible failure. For example, in the content hosting service they studied, less than 24% of hardware and software component failures resulted in user-visible failures whereas half of the operator failures resulted in user-visible failures. Their studies also suggest that operator errors were mostly configuration rather than procedural errors.

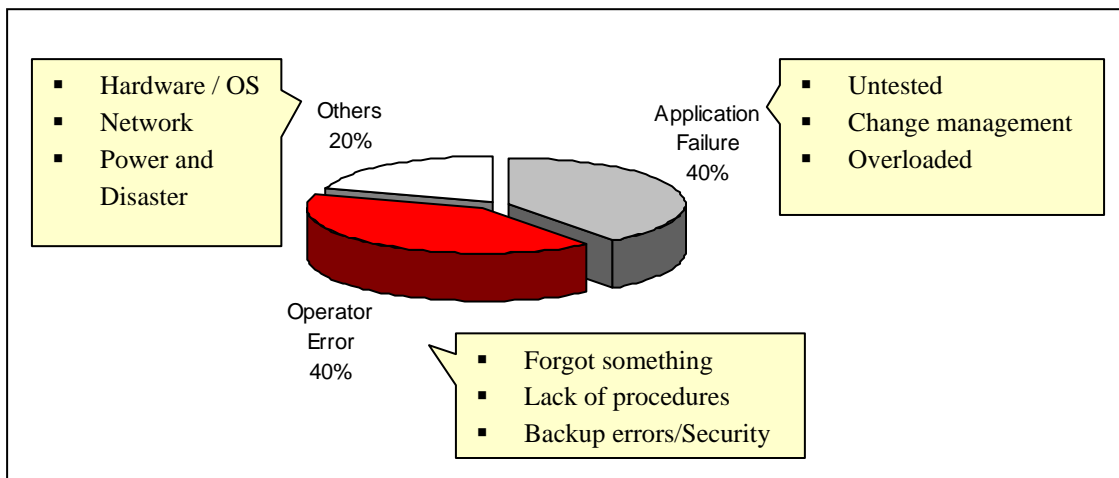


Figure 1: Causes of site failure (Source: Gartner Group- 2001 [3])

## 5 Planned vs. Unplanned Downtime

A recent study [4] looks at the main causes of downtime in business systems. Although their study does not distinguish between e-business and traditional business systems, it does provide insight on the prevalence of planned and unplanned downtime in businesses as a whole. Their study indicates that planned downtime accounts for at least 80% of all downtime in businesses while the balance of less than 20% is unplanned downtime.



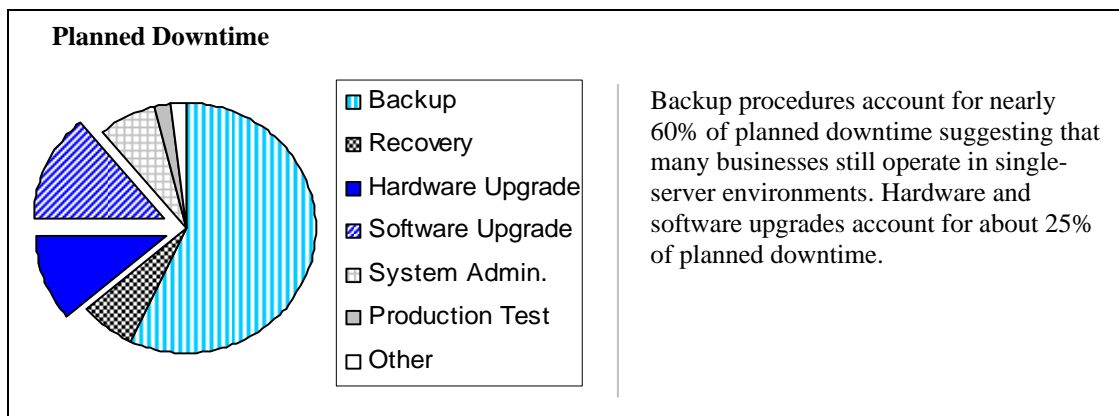


Figure 3: Causes of planned downtime [4]

Planned downtime (Figure 3) consists of: (i) normal IT infrastructure operations like backups; (ii) maintenance activities such as program fixes; (iii) unique periodic events that can be scheduled with substantial lead time like software upgrades and disaster recovery testing. Planned downtime is often a leading contributor to unplanned downtime (operational overruns in Figure 4), for instance, when a backup takes longer than planned.

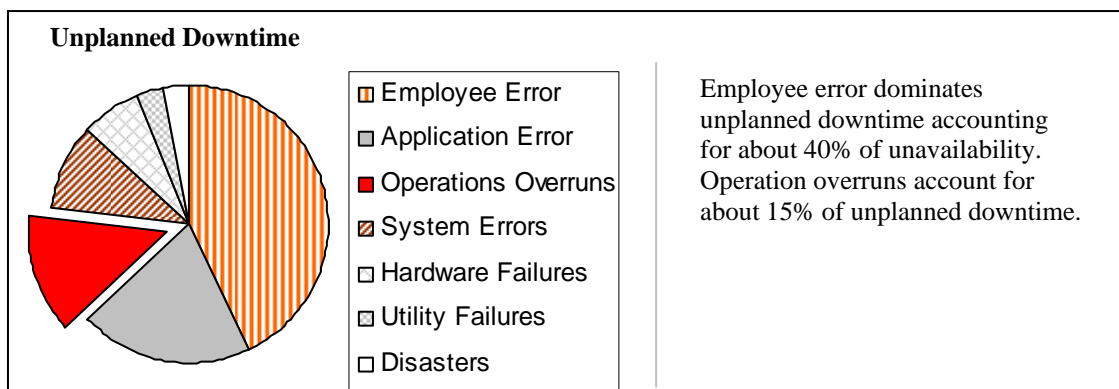


Figure 4: Causes of unplanned downtime [4]

## 6 Conclusion

Software failures and human error account for about 80% of failures [3]. The incidents of software failures on the Web indicate that a large number of non-malicious failures occur during change management. It is unclear whether these failures are mainly due to system complexity, inadequate testing and/or poor understanding of system dependencies. Other significant causes of software failure are system overload, resource exhaustion and complex fault-recovery routines.

Site outages ranged from a few minutes to several weeks (see appendix). During this period, the site may be completely unavailable or experiencing intermittent outages. Prolonged downtime often occurs when multiple system components are implicated in the failure (i.e. large fault-chains). Some sites resort to periodic restarts to fix problems that they cannot diagnose.

This report contains an appendix that serves as a quick reference for common causes of failures in Internet services. The appendix lists over 40 incidents of real-world site outages, outlining how these failures were detected, the estimated downtime, and the subsequent recovery action.

## 7 References

- [1] California power outages suspended--for now, by Rachel Conrad, *CNET news.com*, January 18, 2001  
<http://news.com.com/2100-1017-251167.html>
- [2] Open for Business? Real Availability Is Focused on Users, Not Applications, *A TeaLeaf Technology Inc. white paper*, October 2003
- [3] Business Considerations for Uptime, by Anisha Chauhan , Aamer Ali and Michelle Beaulieu, *Microsoft Enterprise Services White Paper E-Commerce Technical Readiness*, April 2001  
<http://www.microsoft.com/technet/archive/itsolutions/ecommerce/plan/buscons.mspix>
- [4] Understanding Downtime, *A Vision Solutions White Paper*, August 2004  
[http://www.visionsolutions.com/bcss/White-Paper-102\\_final\\_vision\\_site.pdf](http://www.visionsolutions.com/bcss/White-Paper-102_final_vision_site.pdf)
- [5] A Taxonomy of E-Commerce Risks and Failures, by Giridharan Vijayaraghavan, *Master's thesis, Florida Institute of Technology*, July 2003  
<http://www.testingeducation.org/a/tecrf.pdf>
- [6] Managing e-commerce reliability, eBay style, by Anne Lear, *IT Professional, Vol.2, Iss.2*, Mar/Apr 2000  
Pages:80-79
- [7] The Troubleshooting Process, by Reed Robison, *Microsoft E-Commerce White Paper Series*  
<http://www.microsoft.com/technet/archive/itsolutions/ecommerce/support/trblshpr.mspix>
- [8] A Census of Tandem System Availability Between 1985 and 1990, by Jim Gray, *HP Labs Technical Report – TR-90.1*, January 1990  
<http://www.hpl.hp.com/techreports/tandem/TR-90.1.pdf>
- [9] Why do Internet services fail, and what can be done about it?, by David Oppenheimer, Archana Ganapathi, and David A. Patterson, *Usenix Symposium on Internet Technologies and Systems*, March 2003
- [10] Evaluating quorum systems over the Internet, by Yair Amir and Avishai Wool, *International Symposium on Fault-Tolerant Computing*, June 1996
- [11] A Study about Online Transactions, *prepared for TeaLeaf Technology Inc. by Harris Interactive*, October 2005
- [12] Distributed System Management: PlanetLab Incidents and Management Tools, by Robert Adams, *PlanetLab Consortium*, November 2003  
<http://www.planet-lab.org/PDN/PDN-03-015/>

## 8 APPENDIX: Causes of Failures

### 8.1 Software Failures: System Software

| FAILURE   | EXAMPLES   |                              |  |  |
|---|--|------------------------------|--|--|
|   | INCIDENT   | DOWNTIME                     | DETECTED   | RECOVERY   |
| <b>OPERATING SYSTEM</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Memory and resource leaks</li> <li>▪ Memory access violations</li> <li>▪ DLL conflicts</li> <li>▪ Security vulnerabilities</li> <li>▪ Device driver failures</li> <li>▪ Failed OS upgrades</li> </ul>  | Bug in updated module in PlanetLab [12] kernel leads to problems accessing TCP sockets.  | Not specified                | Users reports  | Fixed bug in module.   |
|   | Overload on software update server on PlanetLab [12] causes long delays and cron jobs hang for at least 5hrs.  | 5 hrs                        | Users report long delays   | Nothing -waited for upgrade to complete                        |
|   | Websites hosted on America Online experience intermittent outages over several weeks due to server upgrade.<br><a href="http://news.com.com/2100-1023-827901.html">http://news.com.com/2100-1023-827901.html</a>   | Several weeks (intermittent) | Inability to update websites, loading blank pages o              | Not specified  |
| <b>CACHE SERVER FAILURE</b><br><i>Cache servers are used as intermediaries for web requests and retain previously requested copies of resources</i> <ul style="list-style-type: none"> <li>▪ Loads stale data</li> <li>▪ Shopping carts that use IP address to track state of the cart, may fail because interception proxies at ISP level may alter client's IP</li> </ul> | Symantec issues patch for DNS cache-poisoning and redirection vulnerability that affects multiple gateway security products in March 2005.<br><br>Attackers redirected traffic from popular domains such as google.com, ebay.com and weather.com to rogue sites that attempt to load the ABX toolbar spyware onto the victim's machine.<br><br><a href="http://www.eweek.com/article2/0,1759,1776762,00.asp">http://www.eweek.com/article2/0,1759,1776762,00.asp</a> | Not specified                | <ul style="list-style-type: none"> <li>▪ User reports</li> </ul> | Blocked IP addresses of rogue sites<br><br>Patched DNS servers |

| FAILURE  | EXAMPLES  |                     |                      |                               |
|--|---|---------------------|----------------------|-------------------------------|
|  | INCIDENT  | DOWNTIME            | DETECTED             | RECOVERY                      |
| <b>WEB SERVER AND APPLICATION SERVER FAILURES</b><br><i>A web server is software that serves HTTP pages. An application server sits between the database and the web server and supports business applications.</i> <ul style="list-style-type: none"> <li>▪ Memory leakage</li> <li>▪ Thread pool exhausted leading to slow or unresponsive server (hangs)</li> <li>▪ Configuration errors</li> <li>▪ Web servers buckle under peak load</li> <li>▪ Resource intensive processes may cause server requests to timeout</li> <li>▪ Failed upgrades</li> <li>▪ Fast-growing log files consume disk space and choke the Web server</li> </ul> | Stray file conflicts with startup of Omicron web server at asmallorange.com in January 2005.<br><a href="http://forums.asmallorange.com/index.php?showtopic=2409">http://forums.asmallorange.com/index.php?showtopic=2409</a>   | 15 mins             | Site unavailable     | Removed conflicting file      |
|  | Zopewiki.org (open source WAS) experiences memory leak in July 2004. Cause is unknown and the workaround is to reboot the server daily.<br><a href="http://zopewiki.org/ZopeWikiNews">http://zopewiki.org/ZopeWikiNews</a>  | A few minutes daily | Performance slowdown | Daily reboots. Cause unknown. |
|  | Anti-Unix Web site “wehavethewayout.com” experiences 2-day outage. Speculation is that the problem occurred when switching over from FreeBSD and Apache to Windows and IIS or site overload. No official explanation for failure<br><a href="http://news.com.com/2100-1001_3-875884.html">http://news.com.com/2100-1001_3-875884.html</a> | 2 days              | Site blank           | Not specified                 |
|  | University of Michigan’s ICPSR web server goes down in July 2002 when web logs grew too large due to a significant increase in traffic.<br><a href="http://www.icpsr.umich.edu/org/policies/webouts-2002.html">http://www.icpsr.umich.edu/org/policies/webouts-2002.html</a>  | 1 hr                | Site unavailable     | Pruned web logs               |

## 8.2 Software Failures: Database<sup>1</sup>

| FAILURE  | EXAMPLES  |               |   |  |
|--|---|---------------|---|--|
|  | INCIDENT  | DOWNTIME      | DETECTED  | RECOVERY                                       |
| <b>DATABASE STATEMENT FAILURE</b><br><i>Failure occurs due to logical failure in handling of a statement</i> <ul style="list-style-type: none"> <li>▪ Reference non-existent table</li> <li>▪ Insufficient permissions</li> <li>▪ Flawed query may lead to incorrect computations (application bug)</li> <li>▪ Inadequate table space allocation for the user/operation</li> </ul> | In February 2005, Basecamphq.com database incorrectly flagged table as read-only and resulting in failed updates to table.<br><a href="http://everything.basecamphq.com/archives/000316.php">http://everything.basecamphq.com/archives/000316.php</a>                                     | ½ hr          | Some visitors to site get "Sorry, something went wrong" error | Fixed permissions on table                     |
|  | A bug in the new system's query function at BugRegister causes customers doing look-ups on their accounts to see other customer's domain records in February 2001.<br><a href="http://www.internetnews.com/xSP/article.php/598541">http://www.internetnews.com/xSP/article.php/598541</a> | Not specified | User reports  | Fixed bug and verified correctness of database |
| <b>DATABASE-PROCESS FAILURE</b><br><i>Failure that prevents a database instance from continuing to run</i><br>May result from hardware problem, such as a power outage, or a software problem, such as an operating system crash   | Database glitches at Walmart.com cause 9 hrs of downtime in April 2001.<br><a href="http://www.internetnews.com/ec-news/article.php/4_739221">http://www.internetnews.com/ec-news/article.php/4_739221</a>  | 9 hrs         | Not specified   | Not specified                                  |
|  | Orbitz site experiences downtime in July 2003 due to glitch in database software.<br><a href="http://news.com.com/2100-1017_3-1026450.html">http://news.com.com/2100-1017_3-1026450.html</a>  | 24 hrs        | Not specified   | Not specified                                  |

<sup>1</sup> For a more detailed description, refer to "[Continuous Data Availability with Oracle9i Database](#)", An Oracle white paper, May 2001

| FAILURE   | EXAMPLES   |                          |   |  |
|---|--|--------------------------|---|--|
|   | INCIDENT   | DOWNTIME                 | DETECTED  | RECOVERY                                   |
| <b>DATABASE-PROCESS FAILURE (CONTD)</b> <ul style="list-style-type: none"> <li>▪ Client PC hangs and user state not saved/retrievable</li> <li>▪ Failure to rollback process on detection of user process failure</li> <li>▪ Database hangs increasing response times</li> <li>▪ Number of simultaneous connections allowed is less than the maximum allowed</li> <li>▪ Configuration errors</li> </ul> | US Airways' flight-operation database malfunctioned and grounds American Airlines and US Airways flights in August 2004<br><a href="http://news.com.com/2100-1016_3-5292245.html">http://news.com.com/2100-1016_3-5292245.html</a>   | 3 hrs                    | Not specified   | System taken offline for 3hrs to remediate |
|   | Overwhelming traffic during launch of Sony's "Star Wars Galaxies" game causes intermittent database errors in June 2003<br><a href="http://news.com.com/2100-1043_3-1021900.html">http://news.com.com/2100-1043_3-1021900.html</a>   | 1 day (intermittent)     | User error messages during registration and user reports of data loss | Not specified                              |
| <b>DATABASE-MEDIA FAILURE</b> <ul style="list-style-type: none"> <li>▪ Physical problem reading or writing to files</li> <li>▪ Head media crash</li> <li>▪ Disk controller failure</li> <li>▪ Failed backup</li> <li>▪ Insufficient system memory for database</li> </ul>   | MSN messenger experiences partial outages for a week due to disk controller failure in July 2001. The backup for this controller also had an error complicating recovery.<br><a href="http://news.com.com/2100-1023_3-269529.html">http://news.com.com/2100-1023_3-269529.html</a> | 1 week (partial outages) | Users report missing buddy lists and connection problems.             | Reboots and other unspecified methods      |

### 8.3 Software Failures: Application Failures

| FAILURE   | EXAMPLES  |                                |  |  |
|---|---|--------------------------------|--|--|
|   | INCIDENT  | DOWNTIME                       | DETECTED                                       | RECOVERY   |
| <b>RESOURCE EXHAUSTION</b><br><i>e.g.,</i> <ul style="list-style-type: none"> <li>▪ Exhausting file descriptors</li> <li>▪ Memory leaks</li> <li>▪ Filling up disk space</li> <li>▪ Eating up CPU cycles</li> </ul> | PlanetLab [12] nodes hang due to application bug which exhausted file descriptors   | Not specified                  | Nodes could not be logged into but pingable    | Fixed application bug  |
| <b>COMPUTATIONAL/LOGIC ERRORS</b>   | Users at LiveJournal.com who incorrectly answer a captcha (security code) the first time will subsequently receive an error that their answer is incorrect every time following. (March 2005)<br><a href="http://www.livejournal.com/support/">http://www.livejournal.com/support/</a>  | Not specified                  | User reports                                   | Not specified  |
|   | AOL mistakenly deactivates a number of AIM accounts in December 2004 during its regular cycle of opening unused screen names to new users.<br><a href="http://www.eweek.com/article2/0,1759,1739115,00.asp">http://www.eweek.com/article2/0,1759,1739115,00.asp</a>   | Several days                   | Users unable to access accounts                | Restored user accounts   |
|   | Bug in the ad server at DoubleClick causes 80% drop in ad delivery in August 2000<br><a href="http://www.clickz.com/news/article.php/442661">http://www.clickz.com/news/article.php/442661</a>  | 1½ hrs                         | Users saw error messages instead of banner ads | Rerouted traffic away from faulty servers, applied software patch and rebooted servers |
|   | Pricing error on Amazon's UK site lists iPaq H1910 Pocket PC for under \$12 instead of regular retail price of \$449<br><a href="http://news.com.com/2100-1017_3-993246.html">http://news.com.com/2100-1017_3-993246.html</a>   | 2½ hrs                         | Abnormally high sales volumes                  | Not specified  |
|   | Server glitch at Microsoft Money prevents users from accessing their online personal finance files. Money's servers were unable to recognize usernames and passwords through the Microsoft's Passport authentication and log-in service.<br><a href="http://news.com.com/2100-1012_3-5289896.html">http://news.com.com/2100-1012_3-5289896.html</a> | Nearly 4 days (partial outage) | User reports                                   | Not specified  |

| FAILURE  | EXAMPLES  |   |                                       |   |
|--|---|---|---------------------------------------|---|
|  | INCIDENT  | DOWNTIME                                    | DETECTED                              | RECOVERY  |
| <b>SITE OVERLOAD</b>   | Comair airlines cancels over 1,000 flights on Christmas Day when its computer systems for reservations crashed after severe weather caused a surge in crew flight re-assignments that knocked out its computer reservations system<br><a href="http://www.internetnews.com/bus-news/article.php/3451981">http://www.internetnews.com/bus-news/article.php/3451981</a> | Several days                                | Not specified                         | Not specified   |
| <b>SOFTWARE UPGRADES</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Failure to back up the web-store before upgrade</li> <li>▪ Files upgraded successfully but did not go “live” after upgrade (failed deployment).</li> <li>▪ Upgrades performed without checking inter-compatibility between existing or newer software processes</li> <li>▪ Software upgrades sometimes sets all options to ‘default’ automatically after the installation is complete</li> </ul> | Comcast suffers 24hr email outage due to problems with email distribution service in March 2004 on the same day that the cable giant revamped a Web-based version of the service.<br><a href="http://news.com.com/2100-1032_3-5170281.html">http://news.com.com/2100-1032_3-5170281.html</a>  | Not specified                               | User complaints. Performance slowdown | Not specified   |
|  | Software glitch blocks Yahoo access for 45 minutes in March 2002. No official explanation for outage but Yahoo was in the process of is in the process of merging its Yahoo Groups and Yahoo Clubs<br><a href="http://news.com.com/2100-1023-864186.html">http://news.com.com/2100-1023-864186.html</a>   | 45 mins                                     | Yahoo Groups unavailable              | Not specified   |
|  | PayPal battled on-and-off service outages for about five days in October 2004 after upgrading site. They blamed glitches in the software update and waived customer fees for a day<br><a href="http://www.eweek.com/article2/0,1759,1684427,00.asp">http://www.eweek.com/article2/0,1759,1684427,00.asp</a>   | 5 days (Intermittent outages)               | Intermittent outages to the site      | Not specified   |
| <b>INTEGRATION ERRORS/THIRD PARTY SOFTWARE FAILURES</b>  | eBay's Half.com integration causes feedback ratings to be out of sync for many Half.com sellers in March 2002<br><a href="http://news.com.com/2100-1017-867028.html">http://news.com.com/2100-1017-867028.html</a><br><a href="http://www.auctionbytes.com/cab/abn/y02/m03/i25/s01">http://www.auctionbytes.com/cab/abn/y02/m03/i25/s01</a>                           | Not specified (Possibly several hours)      | User complaints on erroneous fee      | Temporary fix: Users asked to log in with suffix “-half” in account |
|  | Integration of separate HP and Compaq implementations of SAP AG's enterprise software costs Americas division of HP's Enterprise Storage Group about \$400 million in revenue and \$275 million in operating profits.<br><a href="http://www.eweek.com/article2/0,1759,1640523,00.asp">http://www.eweek.com/article2/0,1759,1640523,00.asp</a>                        | 6 weeks (Overran planned 3-week disruption) | Not specified                         | Not specified   |
|  | AOL's attempt to deploy the new client, AOL Anywhere, in April 2002 results in sporadic access to email service<br><a href="http://www.eweek.com/article2/0,1759,125973,00.asp">http://www.eweek.com/article2/0,1759,125973,00.asp</a>  | Over 1 week (Intermittent outages)          | Email service unavailable             | Rolled back upgrade until issues resolved.                          |



### 8.4 Human Errors

| FAILURE   | EXAMPLES   |  |   |   |
|---|--|--|---|---|
|   | INCIDENT   | DOWNTIME                               | DETECTED  | RECOVERY                                    |
| <b>CONFIGURATION ERRORS</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ System reset to default by mistake</li> <li>▪ Software configured incorrectly</li> <li>▪ Corrupted the configuration file by mistake</li> <li>▪ Omit necessary services from startup script</li> </ul>   | Human error during scheduled maintenance causes outage at Orbitz.com in July 2003<br><a href="http://news.com.com/2110-1017_3-5053617.html">http://news.com.com/2110-1017_3-5053617.html</a>   | Several hours                          | Not specified                                       | Not specified                               |
|   | Incorrect configuration change in January 2001 to the routers on the edge of Microsoft's DNS network disrupts Microsoft.com, MSN.com, MSNBC.com, Hotmail.com and Encarta.com.<br><a href="http://www.internetnews.com/xSP/article.php/570171">http://www.internetnews.com/xSP/article.php/570171</a>                             | Ranged from several hours to 1 day     | Sites unavailable                                   | Not specified                               |
|   | MSN mistakenly lists incoming messages from Earthlink and RoadRunner as spam and blocks them. Speculation this was due to operator error.<br><a href="http://news.com.com/2100-1025_3-990653.html">http://news.com.com/2100-1025_3-990653.html</a>   | Not specified                          | Users complain that email to MSN not being received | Earthlink and RoadRunner put on "safe list" |
| <b>PROCEDURAL ERRORS</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Failure to back up database</li> <li>▪ Restoring the wrong backup</li> <li>▪ Forgetting to restart web server</li> <li>▪ Deleting files by mistake</li> <li>▪ Incorrect input, typos etc</li> <li>▪ Forgetting to prune web logs (disk fills up)</li> </ul> | Gforge3 site down due to failure to restart database daemon after applying database patch (December 2003)<br><a href="http://fms.gfdl.noaa.gov/forum/forum.php?forum_id=30">http://fms.gfdl.noaa.gov/forum/forum.php?forum_id=30</a>   | Not specified (possibly several hours) | Site unavailable                                    | Restarted database daemon                   |
|   | University of Michigan's ICPSR web server goes down in July 2002 due to web logs that were too large (about 2GB) due to a significant increase in traffic.<br><a href="http://www.icpsr.umich.edu/org/policies/webouts-2002.html">http://www.icpsr.umich.edu/org/policies/webouts-2002.html</a>                                  | 1 hr                                   | Site unavailable                                    | Pruned web logs                             |
| <b>MISCELLANEOUS ACCIDENTS</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Equipment trauma caused by drop or fall</li> <li>▪ Accidentally disconnect power supply</li> </ul>  | Anne Lear [6] reports eBay incident where electrician came in to audit power usage and on his way out accidentally knocked out a plug. The device he unplugged had a backup battery, so nobody knew anything was wrong until 30 minutes later when the battery ran down and the device went out, taking the system down with it. | Not specified                          | System unavailable                                  | Restored power                              |

## 8.5 Hardware Failures

| FAILURE  | EXAMPLES   |                                       |                           |   |
|--|--|---------------------------------------|---------------------------|---|
|  | INCIDENT   | DOWNTIME                              | DETECTED                  | RECOVERY  |
| <b>EQUIPMENT AND DEVICE DRIVERS FAILURES</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Device driver failures</li> <li>▪ I/O errors, e.g., hard disk failures (see database media failures)</li> <li>▪ Memory parity errors</li> <li>▪ Overheating</li> </ul> | PlanetLab[12] nodes crash due to Ethernet driver that was incompatible with new OS. Failure occurs under heavy system load. Crashes persist for several weeks.   | Several weeks (Intermittent failures) | User notices node crash   | Temporary fix:<br>Reboot nodes<br>Permanent fix:<br>Updated kernel  |
|  | Hardware failure at the Wall Street Journal website causes 1hr outage in March 2004<br><a href="http://news.com.com/2110-1025_3-5171623.html">http://news.com.com/2110-1025_3-5171623.html</a>   | 1 hr                                  | Not specified             | Not specified   |
|  | Customers of Apple Computer's .Mac online services unable to access their information for several hours due to equipment failure in October 2002<br><a href="http://news.com.com/2100-1040_3-961055.html">http://news.com.com/2100-1040_3-961055.html</a>  | Several hours                         | Not specified             | Installed new equipment   |
|  | Yahoo Groups down for several hours due to hardware problems in March 2002<br><a href="http://news.com.com/2100-1023_3-851276.html">http://news.com.com/2100-1023_3-851276.html</a>  | Several hours                         | Yahoo Groups unavailable  | Not specified   |
| <b>POWER OUTAGES</b>   | Power outage on e-bay's web hosting facility cripples site for 3 hrs in August 2003<br><a href="http://news.com.com/2100-1017_3-5066669.html">http://news.com.com/2100-1017_3-5066669.html</a>   | 3hrs                                  | Not specified             | Power restored  |
|  | Power outage knocks LiveJournal blogs offline for about 24 hrs in January 2005<br><a href="http://www.eweek.com/article2/0,1759,1751832,00.asp">http://www.eweek.com/article2/0,1759,1751832,00.asp</a><br><a href="http://www.livejournal.com/powerloss/">http://www.livejournal.com/powerloss/</a>   | 24hrs                                 | Site unavailable          | Restored power.<br>Restored data from backups but some backups were corrupt so service restoration took longer than planned |
|  | Loss of internal power distribution unit at youritdepot.com in August 2004 causes a failure in air conditioning and temperature spikes to more than 113°F. The high heat caused equipment failure and resulted in significant loss of internet traffic.<br><a href="http://www.youritdepot.com/index/nid/147">http://www.youritdepot.com/index/nid/147</a> | Several hours                         | Not specified             | Not specified   |
| <b>HARDWARE UPGRADES</b>   | iWon experiences intermittent outages after installing \$2 million worth of new hardware to handle increased traffic when switching Excite email users to new system in January 2002<br><a href="http://news.com.com/2100-1023_3-803872.html">http://news.com.com/2100-1023_3-803872.html</a>  | Several days (Intermittent failures)  | Email service unavailable | Not specified   |

### 8.6 Network Failures

| FAILURE   | EXAMPLES  |                                     |   |   |
|---|---|-------------------------------------|---|---|
|   | INCIDENT  | DOWNTIME                            | DETECTED  | RECOVERY  |
| <b>EQUIPMENT AND DEVICE DRIVERS FAILURES</b> <i>e.g.</i> , <ul style="list-style-type: none"> <li>▪ Network congestion</li> <li>▪ Performance issues</li> <li>▪ Configuration errors.</li> <li>▪ Node or link inoperative</li> <li>▪ Failures in underlying telecommunication switching systems</li> <li>▪ Router failures</li> <li>▪ Network adapter fails at the server site</li> <li>▪ Network hardware failures/ link failures</li> <li>▪ Copper cables damaged/cut/ corrosion/magnetic interference</li> </ul> | PlanetLab[12] experiment overloads university's Internet connection   | Not specified                       | System administrator observes bandwidth spikes                | Placed a per-node bandwidth cap   |
|   | Network connection problems slowed Bank of America's online banking service experiences several days of sporadic outages and slow service in February 2001<br><a href="http://news.com.com/2100-1017-252715.html">http://news.com.com/2100-1017-252715.html</a> | Several days (Intermittent outages) | Performance slowdown  | Not specified   |
|   | Network interruption causes of BlackBerry outage for 15 hrs in February 2003<br><a href="http://www.eweek.com/article2/0,1759,1661386,00.asp">http://www.eweek.com/article2/0,1759,1661386,00.asp</a>   | 15 hrs                              | Several customers experienced long delays in receiving e-mail | Backup node takes up service operation while Blackberry and Cingular work to restore service. |
|   | ISP in Virginia (MAI Network services) passes bad routing information to Sprint causing network outage<br><a href="http://news.com.com/2100-1033-279235.html">http://news.com.com/2100-1033-279235.html</a>   | 2hrs                                | Abnormal traffic flows  | Reset routing tables  |

### 8.7 Security Violations

| FAILURE   | EXAMPLES  |                                   |   |   |
|---|---|-----------------------------------|---|---|
|   | INCIDENT  | DOWNTIME                          | DETECTED                                  | RECOVERY                                    |
| <b>SECURITY BREACHES</b> <i>e.g.</i> ,<br><ul style="list-style-type: none"> <li>▪ Password disclosures</li> <li>▪ Cross-site scripting</li> <li>▪ Denial of Service (DOS) attacks</li> <li>▪ Worms and viruses</li> <li>▪ Browser vulnerabilities</li> <li>▪ Authentication failures</li> <li>▪ Theft</li> </ul> | DOS attack on Microsoft’s corporate website causes 1 hr outage in August 2003<br><a href="http://computercops.biz/article2609.html">http://computercops.biz/article2609.html</a>  | 1 hr                              | Site unavailable                          | Not specified                               |
|   | DOS attack on Akamai’s DNS servers causes 2hr site outage on Google, Yahoo, Apple and Microsoft in June 2004<br><a href="http://news.com.com/2100-1038_3-5236403.html">http://news.com.com/2100-1038_3-5236403.html</a>   | 2hr                               | Sites unavailable                         | Not specified                               |
|   | MyDoom worm causes outage for several outage on Google, Altavista and Lycos in July 2004<br><a href="http://news.com.com/2100-1023_3-5283750.html">http://news.com.com/2100-1023_3-5283750.html</a>   | Several hours<br>(Partial outage) | Site unavailable/<br>Performance slowdown | Not specified                               |
|   | Theft of network cards from a Verizon central office in New York has caused some customers there to lose their Internet access for a day in May 2004<br><a href="http://www.eweek.com/article2/0,1759,1583346,00.asp">http://www.eweek.com/article2/0,1759,1583346,00.asp</a> | 1 day<br>(Partial outage)         | Not specified                             | Restored service using backup network cards |