BEFORE THE WASHINGTON

UTILITIES & TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

Complainant,

v.

CENTURYLINK COMMUNICATIONS, LLC

Respondent.

DOCKET UT-181051

DIRECT TESTIMONY OF BRIAN ROSEN ON BEHALF OF WASHINGTON STATE OFFICE OF THE ATTORNEY GENRAL PUBLIC COUNSEL UNIT

Exhibit BR-1CT

December 15, 2021

Shaded Information is Designated Confidential per Protective Order in Docket UT-181051

DIRECT TESTIMONY OF BRIAN ROSEN
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I. INTRODUCTION / QUALIFICATIONS

Q. Please state your name and business address.

A. My name is Brian Rosen and my business address is 470 Conrad Drive, Mars, Pennsylvania 16046.

Q. By whom are you employed and in what capacity?

A. I am the principal consultant for Brian Rosen Technologies LLC, where I provide guidance to states and local governments on deployment of Next Generation 9-1-1 ("NG9-1-1").

Q. On whose behalf are you testifying?

A. I am testifying on behalf of the Public Counsel Unit of the Washington Attorney General's Office ("Public Counsel").

Q. Please describe your professional qualifications.

A. I have worked in the telecommunications industry for 30 years. I am an expert in NG9-1-1.[1] I am the co-chair of the National Emergency Number Association (NENA) i3 Architecture working group, which produces the NG9-1-1 base technical specification. I am also co-chair of the Session Initiation Protocol Core ("sipcore") working group in the Internet Engineering Task Force (IETF). Session Initiation Protocol (SIP) is the signaling protocol[2] for Voice over Internet Protocol (VoIP), mobile phones and NG9-1-1. I have experience in creating and

[1] Internet Protocol (IP)-based 9-1-1 systems.

[2] Protocols are a set of rules that computers use to transmit data, or communicate, between one another. Signaling protocols exist to determine the connection between the sending device and the receiving device.

maintaining highly reliable telecom systems and root cause analysis of failures.

Please see Brian Rosen, Exhibit BR-2 for my full resume.

Q. What exhibits are you sponsoring in this proceeding?

A. I am sponsoring the following exhibits:

Exhibit BR-2	Resume of Brian Rosen
Exhibit BR-3C	WMD Response to Public Counsel Data Request No. 2, Confidential Attachment 2, Transition Plan Presentation
Exhibit BR-4C	WMD Response to Public Counsel Data Request No. 3, Attachment Washington State Military Department Contract E09-196 and Confidential Attachment Washington State Military Department Contract E09-106 Amendment M
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Q. What is the purpose of your testimony?

A. In this testimony, I review CenturyLink Communications' ("CenturyLink" or "Company")[3] role in the 9-1-1 outage that began on December 27, 2018. I will describe the nationwide outage event and its impact on Washington 9-1-1 service. I will outline CenturyLink's role in providing 9-1-1 services to the state and explain how the 9-1-1 service was being transferred to TeleCommunication Systems, Inc. ("Comtech") at the time of the outage. I will discuss CenturyLink's failure to provide adequate notice of the outage and its insistence on using an unnecessarily complex system design. I will also refute CenturyLink's claims with which it attempts to evade responsibility for the outage and outline CenturyLink's actions, which exacerbated the impact of the nationwide outage on the state's 9-1-1 system.

Q. Please summarize your conclusions.

A. CenturyLink unreasonably claims that it bears no responsibility for the impacts of the nationwide outage on the state's 9-1-1 service. CenturyLink made a series of design and implementation decisions during the transition of the 9-1-1 system to Comtech that exacerbated the impact of the nationwide outage on Washington's 9-1-1 service. CenturyLink required the use of outdated technology to

[3] CenturyLink is now known as Lumen but was called CenturyLink at the time of the outage. For clarity and consistency, we will refer to the company throughout this testimony as CenturyLink.

interconnect the two companies during the transition, which subjected the connection to the known failures of the older technology. CenturyLink also refused to connect directly to Comtech, requiring the insertion of a third party in the middle of the interconnection, thereby increasing the complexity and decreasing the reliability of the system. CenturyLink also failed to ensure redundancy in its system design, which may have prevented the outage or mitigated its impacts. Finally, when the system failed, CenturyLink failed its duty to notify Public Safety Answering Points (PSAP) of the outage.

CenturyLink's claims are also disputed by the Washington Military Department ("WMD"), the agency responsible for overseeing the statewide 9-1-1 system. WMD disagrees with CenturyLink's assertion regarding the location in the interconnection between the two companies at which point CenturyLink was relieved of its obligation to ensure a call completed. WMD believes CenturyLink retained a role, and thus an obligation, under its contract with the state during the transfer of services to Comtech. WMD also believes strongly that the citizens of Washington expect that any entity involved in the process of completing a 9-1-1 call has an obligation to ensure that call successfully reaches help.

Testimony from Public Counsel's witness, Stephanie Chase, discusses how CenturyLink's actions and culpability in the outage combine with a number of other factors to warrant the maximum penalty proposed by UTC Staff ("Staff").[4]

[4] Direct Testimony of Stephanie K. Chase, Exh. SKC-1T.

II. DESCRIPTION OF THE 9-1-1 OUTAGE AND CENTURYLINK'S ROLE

Q. Please briefly describe the events surrounding the 2018 9-1-1 outage at issue in this proceeding.

A. On December 27, 2018, Washingtonians experienced an outage lasting 49 hours and 32 minutes, which impacted a variety of telecommunications services, including the 9-1-1 system, causing a disruption to emergency and public safety communications across the state.[5] During the outage, 9-1-1 calls placed by Washington residents could not reach PSAPs because of a failure on CenturyLink's nationwide fiber optic network. According to the Federal Communications Commission (FCC), equipment on CenturyLink's nationwide optical network generated malformed packets[6] that were continuously transmitted in a never-ending feedback loop,[7] or packet flooding.[8] This packet flooding prevented equipment from appropriately routing and transmitting data,[9] causing multiple voice, IP, and transport outages across the Company's nationwide network.[10] The failure of CenturyLink's national optical network disrupted the routing of Washington 9-1-1 calls from CenturyLink's 9-1-1 vendor, Intrado,[11] to

[5] Investigation Report, CenturyLink Communications, LLC, UT-181051, Staff Investigation, Consumer Protection and Regulatory Services at 3 (filed Dec. 2020) [henceforth "Staff Investigation Report"].

[6] Packets are units of data routed between an origin and a destination on a network. The packets in this instance included instructions on how to route the information contained in the packet. Because those instructions were flawed, it caused the packets to be sent repeatedly, overwhelming the system.

[7] Pub. Safety and Homeland Sec. Bureau, DECEMBER 27, 2018 CENTURYLINK NETWORK OUTAGE REPORT, 6–8 (Fed. Commc'n Comm'n, Aug. 19 2019) [henceforth "FCC Report"], https://docs.fcc.gov/public/attachments/DOC-359134A1.pdf.

[8] Staff Investigation Report at 4.

[9] *Id.*

[10] FCC Report at 8–14.

[11] Formerly West Telecom Services, Inc.

the state's new 9-1-1 provider, Comtech. I will describe the impact of CenturyLink's nationwide outage on Washington's 9-1-1 network in greater detail in the next sections.

Q. What service was CenturyLink providing with respect to the Washington 9-1-1 system at the time of the outage event?

A. CenturyLink and Qwest Corporation, a subsidiary of CenturyLink, had provided 9-1-1 services under contract to the state since 2004.[12] In 2016, WMD awarded the state's 9-1-1 contract to Comtech.[13] At the time of the outage, the full transition from CenturyLink to Comtech had not yet occurred, so CenturyLink remained directly responsible for 15 of the state's 62 PSAPs.[14] CenturyLink also remained responsible for [redacted][15] [redacted] [redacted] [redacted][16] [redacted].[17] [redacted] at the time of the outage.[18]

[12] Staff Investigation Report at 6.

[13] Staff Investigation Report at 8.

[14] Staff Investigation Report at 9.

[15] Originating service providers are the carriers and other telecommunications companies that provide telephone service and deliver 9-1-1 calls to the 9-1-1 service provider in the state.

[16] Automatic Location Identification (ALI) is a feature of 911 systems that identifies and forwards the originating caller address and related information to a designated PSAP.

[17] Staff Investigation Report at 8; Brian Rosen, Exh. BR-3C (WMD Response to Public Counsel Data Request No. 2, Confidential Attachment 2, Transition Plan Presentation).

[18] *See* Rosen, Exh. BR-4C (WMD Response to Public Counsel Data Request No. 3, Attachment Washington State Military Department Contract E09-196 and Confidential Attachment Washington State Military Department Contract E09-106 Amendment M).

Q. What service was Comtech providing with respect to the Washington 9-1-1 system at the time of the outage event?

A. CenturyLink was in the process of transitioning 9-1-1 services from itself to Comtech, and at the time of the outage, 47 of the PSAPs had transitioned to Comtech's Emergency Services IP Network (ESInet).[19] However, because none of the originating service providers had been provisioned,[20] CenturyLink determined which calls were destined for PSAPs served by Comtech. CenturyLink passed those calls through the interface between CenturyLink and Comtech. Comtech then routed the calls to the proper PSAP.

Q. Please explain the interface between CenturyLink and Comtech and how the networks were connected at the time of the outage.

A. To describe the network configuration at the time of the outage, I will refer to Exhibit BR-5, which includes two network diagrams provided by CenturyLink. Attachment PC-7a is a simplified version of the network diagram and Attachment PC-7b contains additional information.[21] Importantly, Public Counsel does not endorse CenturyLink's assertions in the diagram regarding the location of the point of demarcation between CenturyLink and Comtech, an issue that will be discussed later in this testimony. I refer to these diagrams solely to help describe the network.

During the transfer of 9-1-1 services from CenturyLink to Comtech, the

[19] Staff Investigation Report at 9.
[20] Staff Investigation Report at 8.
[21] Attachment PC-7b includes references to CLC and Qwest Corporation. CLC stands for CenturyLink Communications, LLC, and Quest is a subsidiary of CenturyLink.

ESINets of both companies were connected using older technology called Signaling System 7 (SS7). SS7 has two parts: a signaling connection and a voice trunk connection. The signaling connection alerts the other side that a call is to be completed. The signaling messages include the called party (in this case, 9-1-1), the calling party's telephone number, and the voice trunk the originating service has selected for the call. Signaling messages pass from an originating device to a terminating device.

CenturyLink's ESINet was handled by its contractor, Intrado. With respect to the interface between CenturyLink and Comtech, the originating device was the Intrado gateway between CenturyLink/Intrado's ESInet and the SS7 system.[22] The terminating device was the Comtech gateway between the SS7 system and Comtech's ESInet.[23] The signaling passes through one or more Signaling Transfer Points (STPs), which are switches that route the SS7 signaling messages from the originating device to the terminating device. In this case, the STPs were supplied by Transaction Network Services, Inc. ("TNS").[24]

When a caller placed a 9-1-1 call, regardless of which PSAP the call was intended for, it traversed CenturyLink/Intrado's ESInet to the Intrado gateway. Calls intended for PSAPs that had transitioned to Comtech's ESInet were then routed to the interface between CenturyLink/Intrado's ESInet and Comtech's ESInet, which consisted of the aforementioned two gateways connected by the

[22] Rosen, Exh. BR-5 at 4 (Attachment PC-7a, Intrado RCL, Item 7).
[23] Rosen, Exh. BR-5 at 4 (Attachment PC-7a, Comtech RCL, Item 8).
[24] *See* box labeled TNS SS7 Network on Rosen, Exh. BR-5, Attachment PC-7a.

SS7-based network.

A call setup message would then originate from the Intrado gateway (originating device) to be sent to one of TNS's STPs. The setup message would then travel through TNS's network of STPs to Comtech's STP and then to the Comtech gateway (terminating device). An acknowledgement of the setup was sent back through the SS7 to the Intrado gateway and the call was accepted.

The Intrado and Comtech gateways both consisted of two physical gateways as shown in items 7 and 8 on Exhibit BR-5, Attachment PC-7b. Each of these gateways had two, redundant signaling links that connected to the STPs. The STPs were arranged in pairs, and each had two links to each of the devices it served, as well as redundant links to other STPs. In total, there were four SS7 signaling links at each end. If at least one of these signaling links was working, calls could traverse the interconnect between Intrado and Comtech. If none of the four links were working, no calls could complete.

Q. What does CenturyLink assert caused the Washington 9-1-1 outage?

A. CenturyLink concludes that all four links carrying the SS7 signaling between the TNS network and the Comtech network were affected by the outage, and that this was the reason calls were unable to be completed to Comtech.[25] CenturyLink supplied all four links.[26]

[25] *See* Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachments PC-7a and PC-7b).
[26] *Id.*

Q. What does Comtech assert to be the cause of the Washington 9-1-1 outage?

A. Comtech agrees that the four links cited by CenturyLink failed.[27] Comtech also asserts that, although [redacted],[28] there were periods when none of the four links were available,[29] [redacted], and 9-1-1 calls could not complete.[30]

Q. Was CenturyLink aware of the outage?

A. CenturyLink was aware that it was experiencing a major network incident but was not immediately sure about what had caused the problem.[31] CenturyLink was notified that there were failures to complete 9-1-1 calls in Washington, though they may not have initially understood why the issue was occurring.[32] After WMD created an open conference call line[33] and [redacted].[34]

[27] *See* Rosen, Exh. BR-6 (Comtech Response to Public Counsel Data Request No. 25).

[28] *See* Rosen, Exh. BR-7C (Comtech Confidential Response to Public Counsel Data Request No. 2).

[29] *See* Rosen, Exh. BR-8C (Comtech Confidential Response to Public Counsel Data Request No. 30).

[30] Rosen, Exh. BR-9C (Comtech Final PUC Report at 5 - Comtech Root Cause Analysis CenturyLink Network Outage and Related E-911 Call Routing Impairment, MOR Due Date 01-11-2019, Unredacted Version).

[31] FCC Report at 8.

[32] *See* Rosen, Exh. BR-11C (Comtech Confidential Response to Public Counsel Data Request No. 8).

[33] Staff Investigation Report at 20.

[34] Staff Investigation Report at 21; *see also* Rosen, Exh. BR-10 (WMD Response to CenturyLink Data Request No. 4, Attachment 'RE CenturyLink outage 122718 (58)').

Q. Did CenturyLink notify the affected PSAPs?

A. No, it did not notify the affected PSAPs.[35]

Q. Did CenturyLink notify Comtech?

A. No, it did not notify Comtech. Instead, Comtech notified CenturyLink of failures it saw, which CenturyLink acknowledged. Comtech, however, states that it did not receive updates from CenturyLink with the standard levels of detail or regularity, and also asserts that it was unable to reach CenturyLink personnel to obtain information on the status of the outage.[36]

Q. Did Comtech notify the affected PSAPs?

A. Yes, records indicate Comtech communicated with the PSAPs during the outage and [redacted].[37]

Q. Were other entities affected by the outage?

A. Yes, I believe some of the originating service providers that sent 9-1-1 calls were affected by the outage. The FCC report specifies some impacted providers, including Comcast.[38] Some providers used IP connections that were affected by the outage, which likely resulted in calls not being able to be completed. It is also likely that other providers relied on CenturyLink services were affected.

Q. How would these problems appear to consumers and to originating service providers?

A. For services that were IP based, they would most likely result in intermittent

[35] Staff Investigation Report at 21.
[36] Rosen, Exh. BR-11C (Comtech Confidential Response to Public Counsel Data Request No. 8).
[37] *See* Staff Investigation Report at 19–20.
[38] FCC Report at 12.

ability to connect a call, and possibly some impairment in audio quality. The former would not necessarily be noticed by the PSAP or the originating service provider, and a subsequent call attempt might succeed. The latter might be noticed by the caller or the call taker in the PSAP, or not noticed at all.

For services that were SS7 based, some calls might succeed using backup facilities. Others might fail completely where the failure took down both the primary and backup connections. A call failure would be visible to the originating service provider.

Q. How would we determine if 9-1-1 calls to the PSAPs that were not transitioned were dropped during the outage?

A. 9-1-1 service providers are supposed to log all events in their systems. A Next Generation 9-1-1 system, such as the one CenturyLink claimed it provided to the state,[39] has explicit requirements for logging in specific data formats that would clearly show us what happened to any call attempt that reached the edge of the ESInet during the outage.

Q. Have you been able to see such detailed log records?

A. No. CenturyLink informed us that they did not have an NG9-1-1 standard logging service, despite the standards requiring it.[40] They also claimed an inability to supply Call Detail Records[41] for the systems for which we requested logs, including details of the Selective Router to which all originating service providers

[39] *See* Rosen, Exh. BR-4C at 15 (WMD Response to Public Counsel Data Request No. 3, Attachment Washington State Military Department Contract E09-196).
[40] Rosen, Exh. BR-22 (CenturyLink Response to Public Counsel Data Request No. 10).
[41] Rosen, Exh. BR-23 (CenturyLink Response to Public Counsel Data Request No. 1).

were connected, the Intrado ESInet, and the interconnect between the Intrado and Comtech ESInets.

Q. Were you able to obtain any data from CenturyLink?

A. Yes. Once CenturyLink indicated that it would not provide Call Detail Records, we requested simple call tallies—numbers of calls during the 90 days before, during, and after the outage, and for the same periods for several years before and after. CenturyLink's tallies show the volume of calls placed through originating service providers. To find out how many calls were getting through to Comtech, we also requested and received data from Comtech for the same periods. Importantly, Comtech does not know how many calls were not delivered to it. Rather, Comtech only has records of calls it actually received. CenturyLink was unable to provide data from different parts of the network for all the years we requested.[42] By contrast, Comtech was able to provide all the data requested.[43] Nevertheless, we received sufficient data to analyze the call tallies.

Q. What did you learn from analyzing these tallies?

A. We examined call counts from both Comtech and CenturyLink and analyzed the data for the same days of week, which significantly affects call patterns, across several years.

During periods when at least one SS7 link was operating and calls were being completed to Comtech, CenturyLink data shows counts of calls placed increased dramatically during the incident compared to what would be expected

[42] Rosen, Exh. BR-24 (CenturyLink Supplemental Response to Public Counsel Data Request No. 35).
[43] Rosen, Exh. BR-25 (Comtech Response to Public Counsel Data Request No. 17).

on average. While there is no way to know for sure why their call counts were elevated during the outage, I believe it is because call failures were occurring and callers tried again, often multiple times.

Comtech data shows it received many fewer calls than would have been expected compared to average counts of calls received. Based on the Comtech call tallies, call volume during the outage, compared to historical averages, suggest at least 10,752 fewer 9-1-1 calls were received than expected, a drop of 34 percent.[44]

III. 9-1-1 SYSTEM OPERATORS' NOTICE RESPONSIBILITIES

Q. In the event of an outage, are 9-1-1 system service providers required to notify WMD and impacted PSAPs?

A. Yes. 9-1-1 service providers have notice obligations under FCC rules, Washington WAC,[45] and more specifically, CenturyLink agreed to a Communication Plan with WMD and the UTC that included notice requirements.

Q. Why is it important that 9-1-1 system service providers provide notice of service disruptions?

A. During a 9-1-1 outage, the public will need to use alternate methods to reach PSAPs, mainly by using 10-digit telephone numbers that are answered by the same systems that handle normal 9-1-1 calls. Whenever the 9-1-1 system encounters failures, PSAPs can advise callers to use these alternate telephone

[44] *See* Workpapers of Brian Rosen.
[45] *See* WAC 480-120-412.

numbers to get help through public service announcements, media, social media, and other methods. Without notice, PSAPs do not know to make such announcements to the public.

Q. What is a "Covered 9-1-1 Service Provider"?

A. "Covered 9-1-1 Service Provider" is a legal term in the FCC regulations that defines responsibilities for service providers of 9-1-1 services.[46] Among other things, the FCC requires Covered 9-1-1 Service Providers to meet certain notification obligations.

Q. Was CenturyLink the Covered 9-1-1 Service Provider?

A. For the PSAPs that had not transitioned to Comtech, yes. For the PSAPs that had transitioned, the WMD contract specified that Comtech was the Covered 9-1-1 Service Provider.[47]

Q. Does that mean Comtech was responsible for notice during the outage?

A. From FCC's point of view as to the transitioned PSAPs, perhaps. However, from Washington State's point of view, CenturyLink was still providing half of all 9-1-1 service to those transitioned PSAPs (access from the originating service providers[48] [redacted][49]).

During the outage, the companies appear to have been unclear for some

[46] FCC Regulation, 47 CFR § 9.19(a)(4).
[47] Rosen, Exh. BR-4C (WMD Response to Public Counsel Data Request No. 3, Confidential Attachment Washington State Military Department Contract E09-106 Amendment M).
[48] Originating service providers are the carriers and other telecommunications companies that provide telephone service and deliver 9-1-1 calls to the 9-1-1 service provider in the state.
[49] Rosen, Exh. BR-3C (WMD Response to Public Counsel Data Request No. 2, Confidential Attachment 2, Transition Plan Presentation).

time about which portions of the system were impacted or whether that impact was isolated. CenturyLink came to know early during the outage that there were significant problems affecting the 9-1-1 system.[50] Additionally, all PSAPs were [redacted].[51] This reality is not diminished simply because Comtech may also have been responsible for notifying the PSAPs it served at that time.

Therefore, in my expert opinion, CenturyLink should have notified all PSAPs, not just the ones for which it would explicitly have been the "Covered 9-1-1 Service Provider." CenturyLink should have also notified every originating service provider that their calls might not go through during the incident.

Q. Did Comtech fulfill its responsibilities as the Covered 9-1-1 Service Provider?

A. Yes, it appears to me that they did.

Q. In your expert opinion, are there best practices applied by providers at the outset of an apparent 9-1-1 outage that CenturyLink should have employed during this event, but did not?

A. Yes, in the initial phase of any outage, it is industry practice that emergency officials and providers take an "all hands on deck" approach, bringing their best people to hunt the problem wherever it may be without regard to blame. However, CenturyLink's data responses identify a single person – a Senior Operations

[50] Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachments PC-7a and PC-7b); Exh. BR-12C (Comtech Confidential Response to Public Counsel Data Request No. 18).
[51] Staff Investigation at 8.

Service Manager—mobilized to attend the WMD conference call line.[52]

While a service manager is typically capable of deploying assets and is certainly a valuable part of any 9-1-1 outage response, CenturyLink does not indicate it mobilized its 9-1-1 Network and Center Operations team. Had it done so, using the "all hands on deck" approach necessary during a statewide 9-1-1 outage, members of that team should have realized CenturyLink had a more broad notification responsibility. They should have realized that communications were urgently needed by all PSAPs, and by extension, all Washington 9-1-1 customers. Moreover, had CenturyLink applied additional resources, it is possible that they could have restored 9-1-1 services sooner than 49 hours and 32 minutes.

Further, CenturyLink stipulated to a communications plan in Docket UT-132234, requiring the Company to maintain a 9-1-1 Network and Center Operations within CenturyLink's Public Safety Services organization. That communications plan also holds CenturyLink's 9-1-1 Network and Center Operations responsible for, among other things, telephone service outage notifications to WMD and to "Public Service [*sic*] Access Points (PSAPS) in all states where CenturyLink provides telephone service."[53]

IV. 9-1-1 SYSTEM DESIGN COMPLICATIONS

Q. Please discuss how total system failures typically occur in 9-1-1 systems.

A. Software failures cause most large system failures in telecom systems, including

[52] Rosen, Exh. BR-13 (CenturyLink Response to Public Counsel Data Request No. 8).
[53] Rosen, Exh. BR-14 (CenturyLink Response to Public Counsel Data Request No. 5, Attachment A, Second Revised Washington State Outage Communications Plan of CenturyLink).

failures that involved CenturyLink. Regarding the December 2018 outage specifically, CenturyLink ultimately restored service through a software change that stopped transmitting the malformed packets.[54]

Q. In your experience and expertise, how should a 9-1-1 system be designed to be reliable?

A. Generally, we make reliable systems by replicating instances of a function, so that if one fails, another is available to take its place. CenturyLink's system in this case consisted of multiple optical network switches supplied by Infinera Corporation.[55] Theoretically, the optical network was redundant, such that a failure of one of the optical network switches would not take down the entire system.

In this case, the entire optical network failed due to software defects. Software failures often affect all instances of a redundant system. As a result, a single software error (a "bug") can take down an entire system, as it did here.

Q. How are software failures mitigated in highly reliable systems?

A. The remedy for software failures is never to rely on a single piece of software. The easiest way to accomplish that would be to use two vendors' equipment, each with different software.

Until recently, it was common telecom practice to "qualify" two vendors for any major deployment. In the past several years, however, it has become common to deploy only one of these qualified vendors, primarily so the provider

[54] FCC Report at 8.
[55] FCC Report at 5.

can gain cost savings. The better practice remains to deploy two vendors, particularly in a system as important as 9-1-1.

Q. Did CenturyLink design its optical network to mitigate software failures in this manner?

A. No, in this case, CenturyLink built its optical network using multiple optical network switches supplied by one vendor, Infinera Corporation.[56] Had CenturyLink deployed two vendors, the nationwide failure that impacted Washington's 9-1-1 system either would not have happened, or the scope and duration of the failure would have been reduced dramatically.

Q. Was the design of the interface between CenturyLink and Comtech sufficiently redundant?

A. Yes and no. The general advice for highly reliable systems like 9-1-1 is to provision at least two physical locations, with at least two of everything at each of those sites. In this case, the failure happened in the SS7 signaling links between the Comtech STP and the Comtech RCL,[57] where there were indeed two sites and two links from each site.[58] It would appear, therefore, that a lack of redundancy at the apparent failure point was not the source of the failure.

I believe the failure occurred because all four links used the same optical network.[59] In building 9-1-1 systems, I generally advise that supplier diversity be

[56] *Id.*
[57] *See* Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request 7, Attachment PC-7a).
[58] *Id.*
[59] *Id.*

used to guard against the kind of failure that occurred here. In this case, there was no supplier diversity. CenturyLink supplied [redacted].[60]

Q. Was Comtech aware of the link supplier diversity issue?

A. [redacted].[61] [redacted].[62] Had they been able to complete this process before the outage, I believe the system would have remained functional.

Q. Please discuss the problems you have identified with CenturyLink's design of the 9-1-1 system in this case.

A. When CenturyLink provided 9-1-1 service to Washington, it used Intrado as its third-party vendor.[63] When WMD later awarded Comtech the 9-1-1 contract, CenturyLink/Intrado's system had to interconnect with Comtech's system to effectuate the transition between the two companies.[64] Both CenturyLink/Intrado's ESInet and Comtech's ESInet are based on Internet Protocol (IP). The way CenturyLink designed the interconnection between the

[60] Rosen, Exh. BR-15C (Comtech Confidential Response to Public Counsel Data Request No. 1); *see also* Rosen, Exh. BR-5 at 5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachment PC-7b).
[61] Rosen, BR-16C (Comtech Confidential Response to Public Counsel Data Request No. 3).
[62] *Id.*
[63] Staff Investigation Report at 6.
[64] *Id.* at 8.

CenturyLink/Intrado system and the Comtech system was unnecessarily complex and contributed to the December 2018 system failure.

Comtech asserts that CenturyLink refused to use an IP interconnection or connect directly.[65] Comtech states that they requested to connect directly to CenturyLink but were told by CenturyLink to use SS7 instead. This decision required Comtech to utilize a third party, TNS,[66] for the SS7 interconnection.[67] TNS is not a 9-1-1 service provider.

Adding another entity to the path increases the probability of failure. In fact, since both Intrado and Comtech were using gateways between their respective ESInets and the SS7 connections that CenturyLink required, adding the third party greatly increased the complexity of the interconnect. Simpler arrangements should have been made, which would have significantly reduced the risk of failure.

Q. How were these two IP based systems connected?

A. As explained, above, the Intrado system received all Washington 9-1-1 calls in CenturyLink/Intrado's ESInet. It then decided which calls needed to be sent to Comtech. For calls sent to Comtech's ESInet, the Intrado system routed those calls to the interconnect between CenturyLink/Intrado's ESInet and the

[65] *See* Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4 with Confidential Attachment B.1(b)); Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26).

[66] *See* FCC Report at 10.

[67] *See* Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4 with Confidential Attachment B.1(b)); Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26).

Comtech's ESInet.[68]

Despite both ESInets being IP-based, documents show CenturyLink insisted that this interconnect be SS7-based.[69] This design required a conversion between IP on the Intrado IP network to SS7, and then required another transition between SS7 and IP on the Comtech IP network for all calls traveling over the interconnect from the CenturyLink/Intrado ESInet to the Comtech ESInet.[70] In other words, once call information came to the interconnect in one format, CenturyLink's choice of SS7 required that it be translated into another format, put through the interconnect, and then translated back to the original format on the other side.

Moreover, CenturyLink's system design introduced an added level of complexity even before calls reached the interconnect. The Intrado gateway, which received all 9-1-1 calls from the originating service providers, used SS7 exclusively. This meant that all 9-1-1 calls at the time of the December 2018 failure had to be converted from SS7 to IP to go through CenturyLink/Intrado's ESInet. This resulted in calls converting between SS7 and IP at least three times through the system.[71]

[68] *See* Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7 with Attachments PC-7a and PC-7b).

[69] Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26); Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4 with Confidential Attachment B.1(b)).

[70] *See* Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7 with Attachments PC-7a and PC-7b).

[71] *Id.*

Q. What other complications arose because of different types of technologies CenturyLink used in its system?

A. At the time of the outage, many PSAPs still connected via "CAMA" trunks, which are not SS7, but use similarly older technology. This means a call from an IP based VoIP or mobile carrier would undergo several conversions before it could complete. Based on CenturyLink's system design, the call would be:

- converted to SS7 to get through the Intrado gateway;
- converted to IP to get through CenturyLink/Intrado's ESInet;
- converted to SS7 to get through the CenturyLink/Comtech interconnect;
- converted to IP to get through Comtech's ESInet; and
- in most cases, converted to CAMA to get to the older PSAP equipment.

This example call would traverse five conversions. The complexity CenturyLink added to this by insisting on the SS7 interface between it and Comtech increased the risk of, and likely contributed to, the 2018 failure in this 9-1-1 system. Had this interconnection been IP based as Comtech requested, it would have used few, if any, of the circuits that failed in 2018. Even if that outage had managed to impair the IP network, it still could have delivered most calls to the transitioned PSAPs. Indeed, connections between CenturyLink and Comtech that are largely IP based, such as ALI, continued to function throughout the incident.[72]

The December 2018 9-1-1 system failure occurred because CenturyLink insisted on using an SS7-based system to interconnect with Comtech and because

[72] *See* Rosen, Exh. BR-19 (CenturyLink Response to Public Counsel Data Request No. 23); *see also* Exh. BR-20 (Comtech Response to Public Counsel Data Request No. 9).

all four signaling links in the interconnect used the Infinera network.

Q. Would there have been advantages if the system had been IP based?

A. Yes. Generally, IP technology performs better in degraded conditions, such as those experienced during this outage. Even if the failure had been able to take out several IP "paths," enough paths should have remained to get some calls through.

V. CENTURYLINK'S CLAIMS REGARDING THE OUTAGE

Q. What does CenturyLink claim regarding the 9-1-1 call failures in Washington?

A. CenturyLink claims that the failures occurred on circuits it provided to Comtech that were beyond the point of demarcation between it and Comtech.[73] CenturyLink asserts that the links that failed were Comtech's contractual and regulatory obligation to design, construct, and maintain, and therefore, CenturyLink is not responsible for the 9-1-1 failures.[74]

Q. Why is the position of the point of demarcation important?

A. In general, responsibility shifts from one party to another at the agreed point of demarcation. If the agreed point of demarcation was in the middle of the TNS network, then Comtech was responsible for the connections that failed. If the point was at the Comtech gateway,[75] then CenturyLink is responsible for the

[73] *See* Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachment PC-7b).

[74] Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7).

[75] Rosen, Exh. BR-5 at 4 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachment 7a, Item 8, Comtech RCL).

connections that failed.

Q. Are CenturyLink's assertions reasonable?

A. No. The only reason Comtech and CenturyLink were connected using an SS7 was because CenturyLink refused to use an IP-based connection.[76] The design of the connection between the two companies was not Comtech's preferred solution and was driven by CenturyLink.[77] CenturyLink makes its claims even though it acknowledges that it provided all four of the links between the Comtech STP and the Comtech RCL that were impacted by the outage.[78] [redacted].[79] The other two links between the Comtech STP and Comtech RCL were contained in two circuits ordered by TNS, a subcontractor for both Intrado and Comtech, and provided by CenturyLink.[80]

CenturyLink's ESInet contractor, Intrado, chose to use TNS,[81] which is not a 9-1-1 service provider, to provide SS7 signaling services. Comtech also used TNS, which, given Intrado's choice, made the most sense. A consequence of that

[76] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4); Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26).
[77] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4); Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26).
[78] Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachment PC-7b); *see also* Exh. BR-26 (CenturyLink Response to Staff Data Request No. 9).
[79] Rosen, BR-15C (Comtech Confidential Response to Public Counsel Data Request No. 1).
[80] Rosen, Exh. BR-26 (CenturyLink Response to Staff Data Request No. 9); *see also* Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachment PC-7b, Washington Network Design diagram). These links were contained in two DS-3s.
[81] Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7); *see also* Exh. BR-21C (CenturyLink Response to WMD No. 1, Confidential Attachments CLC-002938, CLC-003101, and CLC-003102).

choice is, however, that the circuits carrying the SS7 signaling throughout the TNS network are normal commercial services, which do not have the required service level agreements 9-1-1 services need. Moreover, TNS does not enforce supplier diversity in its network, a problem I discussed, above. CenturyLink claims it did not know that these specific circuits were part of the 9-1-1 service,[82] but CenturyLink was aware, or should have been aware, that TNS was providing SS7 services to Comtech during the transition between companies.[83]

Q. Are there additional reasons CenturyLink's assertions are not reasonable?

A. Yes, the amended contract with WMD clearly anticipates that eventually, CenturyLink would cease having any responsibilities as a 9-1-1 service provider because it would no longer be the contract holder,[84] but at the time of the incident, the transition to Comtech was only partly completed. CenturyLink was not relieved of its obligations.

The amended contract specifies that Comtech is responsible for routing calls to PSAPs that have been transitioned onto Comtech's system and that Comtech becomes the "Covered 9-1-1 Service Provider" for those PSAPs once calls reach the demarcation point between CenturyLink and Comtech.[85] However, under the contract CenturyLink had more obligations than just being the "Covered

[82] Rosen, Exh. BR-26 (CenturyLink Response to Staff Data Request No. 9).

[83] *See* Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4 with Confidential Attachment B.1(b)); *see also* Rosen, Exh. BR-4C at 34 (WMD Response to Public Counsel Data Request No. 3, Confidential Attachment, Washington State Military Department Contract E09-196 Amendment M at 16, items 0-5 and 0-6).

[84] *See* Rosen, Exh. BR-4C at 19 (WMD Response to Public Counsel Data Request No. 3, Confidential Attachment, Washington State Military Department Contract E09-196 Amendment M at 1).

[85] Rosen, Exh. BR-4C at 19 (WMD Response to Public Counsel Data Request No. 3, Confidential Attachment, Washington State Military Department Contract E09-196 Amendment M at 1).

Service Provider." Even if CenturyLink was relieved of its responsibility to route calls and act as the Covered 9-1-1 Service Provider at the demarcation point, the contract did not relieve CenturyLink its additional responsibilities.

The original contract with WMD required CenturyLink to provide an IP-enabled 9-1-1 system, "including network, transport, PSAP interfaces, 911 trunk support, selective routing and ALI interfaces," and required this system to be "scalable, affordable, reliable, redundant, and capable of resolving the limitations of the current legacy system."[86]

WMD assessed CenturyLink's obligations as follows:

> WMD believes CenturyLink retained a role, and thus an obligation, under the Washington Military Department (WMD) and CenturyLink, Contract No. E09-196, until there were no parts of the originating network nor the terminating network connected to the CenturyLink/Intrado ESInet. Generally speaking, WMD believes that the citizens of Washington expect that any entity involved in the process of completing a 911 call, from a "call-maker" (the citizen) to a "call-taker" (the PSAP), has an obligation to ensure the call is successfully completed.[87]

It appears to me that the call failures remain CenturyLink's responsibility. That being said, Comtech also had responsibilities under the contract for calls that successfully reached the point of demarcation.

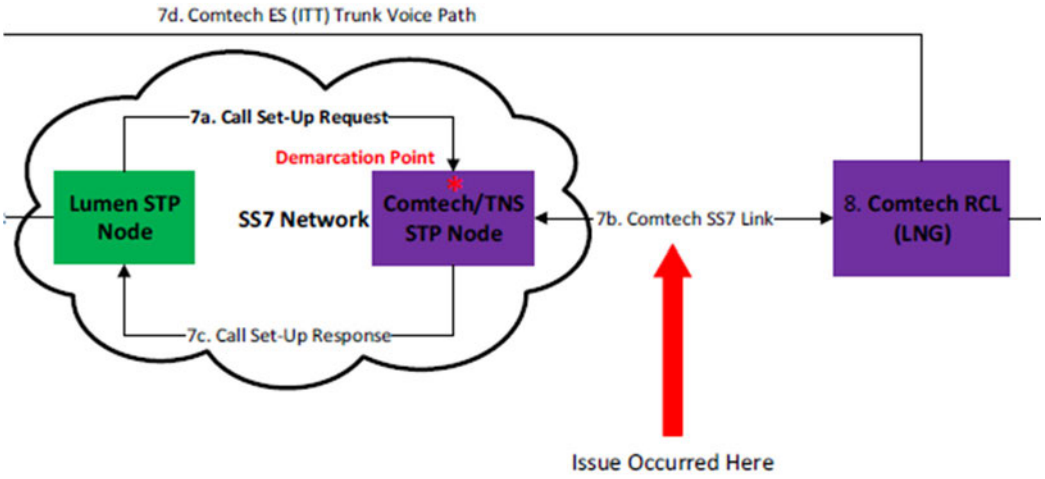
[86] Rosen, Exh. BR-4C at 15 (WMD Response to Public Counsel Data Request No. 3, Attachment Washington State Military Department Contract E09-196 at 14).

[87] Rosen, Exh. BR-27 (WMD Supplemental Response to Public Counsel Data Request No. 7).

Q. Are CenturyLink's assertions regarding the point of demarcation also unreasonable?

A. Yes, CenturyLink mistakenly asserts that the point of demarcation sat in the middle of the TNS network, since both Intrado and Comtech contracted with TNS to provide SS7 signaling services.[88] CenturyLink provided a network design schematic, excerpted below, showing a red arrow where they claim the failure point occurred, between the Comtech STP node and the Comtech RCL.

Figure 1 Excerpt from Exh. BR-5, Attachment PC-7a to CenturyLink Supplemental Response to Public Counsel Data Request No. 7



WMD, however, confirms that the contract documents do not identify any specific demarcation point, and that WMD understood the demarcation point to be the Comtech RCL (labeled as item 8 in the figure above).[89] This puts the point of demarcation after the point at which the outage affected the connection between

[88] Rosen, Exh. BR-5 (CenturyLink Supplemental Response to Public Counsel Data Request No. 7, Attachments PC-7a and PC-7b).
[89] Rosen, Exh. BR-28 (WMD Supplemental Response to Public Counsel Data Request, No. 6).

CenturyLink and Comtech. Therefore, CenturyLink was not yet relieved of its obligation as a Covered Service Provider at the point where the problem occurred. As a result, CenturyLink remains responsible for the call failures.

VI. CONCLUSIONS

Q. Please summarize your conclusions regarding how CenturyLink's network design and implementation decisions during the transition to Comtech exacerbated the impact of the outage.

A. CenturyLink's nationwide outage caused by malformed packets on its optical network disrupted Washington's 9-1-1 system. I focused my review in this case on CenturyLink's actions that specifically impacted Washington 9-1-1 service. I believe that well before the outage event, CenturyLink made a series of decisions and deliberately carried out a sequence of actions it should not have. These decisions and actions resulted in the network failure impacting Washington's 9-1-1 system much more severely than it could have.

Requiring SS7. The most serious mistake CenturyLink made was to insist that it connect its system to Comtech's system using old SS7 technology.[90] The original contract between CenturyLink and WMD memorialized the need to avoid using outdated technology:

> To accommodate Next Generation 911 and provide the citizens of Washington State with a modern internet protocol system that will allow the 911 system to accept information from a wide variety of communication devices from consumers in emergencies, it is first necessary to update the network used to transfer voice/data

[90] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4); Rosen, Exh. BR-17 (Comtech Response and Supplemental Response to Public Counsel Data Request No. 26).

> information from the consumer to the Public Safety Answering Point (PSAP). To accomplish this, there must be a switch from the antiquated legacy analog telephone system to a system as used in cellular and computer voice over internet (VOiP) protocols by telephone and communication providers.[91]

WMD and CenturyLink clearly recognized the superiority of IP networks for modern 9-1-1 systems, and that the entire nation was—and still is—switching from SS7 to IP. By nonetheless insisting that its system interconnect be SS7 despite Comtech's objections,[92] CenturyLink subjected the 9-1-1 interconnect to all of SS7's well-known failures.

The contrast could not have been sharper during the outage between the failure of the call signaling and the success of the ALI system between Comtech and CenturyLink,[93] which is based on IP technology. The ALI system worked, and the call signaling did not.[94] As an expert in 9-1-1 system design, it is my opinion this was a serious technical error on CenturyLink's part. It should never have insisted on SS7 technology. Transfer of calls between ESInets was well understood, and CenturyLink's contractor Intrado could have been instructed to make the interconnect work with IP. Had the system used IP for its interconnect as it did with ALI, few calls would have been lost during the outage.

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[91] Rosen, Exh. BR-4C at 15 (WMD Response to Public Counsel Data Request No. 3, Attachment Washington State Military Department Contract E09-196, p. 14).

[92] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4); Rosen, Exh. BR-17 (Comtech Response and Supplemental to Public Counsel Data Request No. 26).

[93] *See* Rosen, Exh. BR-19 (CenturyLink Response to Public Counsel Data Request No. 23); *see also* Exh. BR-29C (Comtech Confidential Response to Public Counsel Data Request No. 9).

[94] *See* Rosen, Exh. BR-19 (CenturyLink Response to Public Counsel Data Request No. 23); *see also* Exh. BR-29C (Comtech Confidential Response to Public Counsel Data Request No. 9).

Inserting a third-party company into the SS7. Comtech requested to interconnect directly to CenturyLink, but CenturyLink refused to do so.[95] Direct connection would have minimized SS7's loss of reliability. CenturyLink's refusal required Comtech to utilize a third party, TNS, for the SS7 connection.[96] Any extra element in the path between points decreases reliability, and incorporating another company increased the probability that Washington's 9-1-1 system would wind up as it did—having to use the same optical network for all four connections between TNS and Comtech.

Lack of Redundancy/Vendor Diversity. A failure can affect all call elements from a single vendor in a network. If the network has only one vendor, the failure can impact the whole network. Failures in a network that lacks vendor diversity is one of the most common sources of widespread outages. I believe the only defense against these kinds of failures is never to rely on a single vendor, with a single software stack, in any network that supports 9-1-1.

Telecom companies like CenturyLink routinely qualify at least two vendors for such equipment as the Infinera systems that failed here. Had CenturyLink deployed two vendors, failure of all the Infinera devices could likely not have caused failure of the 9-1-1 system.

Similarly, CenturyLink failed to ensure vendor diversity in the interconnect with Comtech. The CenturyLink experts who worked on the design

[95] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4); Rosen, Exh. BR-17 (Comtech Response and Supplemental to Public Counsel Data Request No. 26).
[96] Rosen, Exh. BR-18C (Comtech Response to Public Counsel Data Request No. 4).

of Washington's network certainly should have reviewed the entire network design between Intrado and Comtech. Any such detailed review would have shown them that all four links were provisioned in the same network, which I believe would not have been acceptable to any expert, no matter whether physical redundancy was achieved. Based on the design used, I believe CenturyLink's experts either did not conduct the needed review, or did so but lacked the ability to spot this issue.

Q. Please summarize your conclusions regarding CenturyLink's responsibilities and obligations at the time of the outage.

A. The contract between WMD and CenturyLink made CenturyLink responsible not just for routing and delivery of calls, but for network and transport as well. As the transition from CenturyLink to Comtech occurred, subsequent contract amendments relieved CenturyLink of responsibility for routing and delivery to PSAPs that transitioned to Comtech, but did not relive the Company of its network and transport responsibility. In fact, CenturyLink provided network and transport for both signaling and voice all the way from Intrado to Comtech. Accordingly, CenturyLink bears responsibility for the failure of that network and transport.

Additionally, WMD, the agency responsible for overseeing the statewide 9-1-1 system, believes CenturyLink retained a role, and thus an obligation, under its contract that would not end until no parts of the originating or terminating networks were connected to CenturyLink. WMD also believes strongly that the citizens of Washington expect that any entity involved in the process of

completing a 9-1-1 call has an obligation to ensure that call successfully reaches the PSAP.

Finally, WMD understood the demarcation point to be the Comtech RCL, beyond the location at which the outage affected the connection between CenturyLink and Comtech (see Figure 1 above). Under WMD's configuration, CenturyLink was not yet relieved of its obligation as a Covered Service Provider at the point where the outage impacted the network and is therefore responsible for the call failures.

Q. Does this conclude your direct testimony?

A. Yes.