City of Centennial Fiber Master Plan

Centennial

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Version 1.0

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- The City Centennial and its Associated Departments
- The Fiber Steering Committee; appointed by Centennial City Council
- Centennial City Council
- Arapahoe County
- Arapahoe County Sheriff's Office
- Arapahoe Library District
- Cherry Creek School District
- Cunningham Fire Protection District
- Littleton Public Schools
- South Metro Fire Rescue Authority
- SPS Innovations, Inc
- Other Centennial Local Businesses

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1.1 Introduction

Forward thinking cities are relying upon municipal fiber-optic (fiber) networks to adapt to the changing digital landscape in their communities. As more municipal functions are carried out online or require interconnectivity, these networks help local governments meet the growing demands of their constituents and the other local public organizations serving them. Municipal fiber networks have also become assets through which municipalities can foster the development of leading edge broadband services in their communities.

The City of Centennial currently owns an existing fiber network that provides connections between traffic signals and City facilities. The network consists of 40 miles of underground fiber-optic cables and conduit that traverse the main corridors of Centennial. Although the network provides a valuable resource to the City today, the opportunities to use this network for other municipal and community purposes are limited by its capacity and reach into much of the area. To pursue any future opportunities, a comprehensive plan to expand Centennial's foundational fiber network is required.

The City of Centennial has embarked on a multi-year fiber initiative to examine the City's fiber network to support additional municipal and community needs. Phase 1 of the fiber initiative evaluated the assets and capabilities of the current network and explored potential opportunities for the City to consider using it for a number of additional purposes. Phase 2 (this report) built on the initial work completed in Phase 1 by determining the organizations in Centennial that would utilize the fiber network and creating the network design, cost estimates, financial plan, and roadmap for deployment. The end result of Phase 2's planning activities is the Fiber Master Plan that the City can consider using to guide expansion of its fiber network using a year-by-year approach.

1.2 Overview of Municipal Fiber Networks

Fiber is the gold standard for municipal communications, broadband services, and Internet access. Fiber is used to transmit large amounts of data securely over long distances with high reliability. It is flexible to support a wide range of applications and scalable to support nearly unlimited capacity and speed. It is considered a capital infrastructure asset similar to water, road, and electric infrastructure and has a lifespan of up to 50 years.

Over 1,000 cities in the US own some form of municipal fiber networks and have used them for decades to support their operations. These networks are becoming increasingly important to cope with the rapid growth in connected devices, from utility assets, to street lights, to traffic signals, to surveillance cameras. Cities that maintain these networks are able to accommodate these "smart city" technologies that make them more efficient, reduce costs, increase the value they deliver to their constituents, and control their own destinies around these key issues.

Within the past 15 years, some cities have expanded the use of these networks to enhance local broadband services in their communities, to support the needs of residents, businesses, and community organizations. As broadband has become a key aspect to support economic development, education, healthcare, and

other community functions, cities have leveraged their networks to foster fiber-based broadband services, either directly or more often, through partnerships with their local broadband providers.

1.3 Opportunity Statement

Centennial's fiber network can become a long-term asset that supports and enhances the communications and technology needs of the City and its community. Centennial already leads the nation with one of the highest rates of Internet adoption and connection, demonstrating the high level of relevance of the Internet to its citizens. Developing a municipal fiber network will foster the opportunity to make Centennial one of the most connected communities in the country; a city where cutting edge technology and communications services are tested and deployed by leading providers. It will also support the goal to ensure Centennial's citizens and businesses are able to take advantage of all opportunities that the Internet has to offer. The fiber network will become a key resource that the City, in partnership with the private sector, will leverage to drive value across a range of municipal and community functions, from economic development, to education, healthcare, and general quality of life.

1.4 Benefits of a Municipal Fiber Network for Centennial

Municipal & Smart City Services

The network will support the City's current operations and be used as an asset to continue to drive efficiencies, reduce cost, and expand capabilities. The network as proposed is robust, redundant, and reliable. It can become a multi-purpose asset of the City that can be used between departments for multiple applications. Most importantly, it will help the City enhance currently provided community services. With an eye towards the future, many applications and services that are collectively referred to as "Smart City" efforts are not possible without a well-designed fiber backbone. This backbone serves as a means of robust data collection and support infrastructure for identifying problems through data analysis.

The City's Innovation Team (i-team) and the City's Public Works provider, CH2M, have undertaken efforts to optimize the City's Intelligent Transportation System (ITS). This optimization initiative focuses on mitigating the effects the I-25 corridor has on operations of Arapahoe Road and improving the systems integration and fiber interconnects necessary to optimize the transportation network. Examples may include "pushing" information out to motorists through Dynamic Messaging Signs (DMS), communicating with vehicles' on-board computers through infrastructure-to-vehicle systems, and improving first responder performance measurements through ITS. Ultimately, the i-team program and the City's potential Smart City efforts are dependent on the establishment and success of Centennial's municipal fiber backbone.

Economic Development

Economic development will become a key beneficiary of the fiber network. The City's asset can be used as a tool to reduce the cost of doing business in the City while enabling high-speed Internet connectivity to attract and retain business. The dark fiber network will be interconnected to at least two key data centers within the City, which provides a gateway to numerous broadband, cloud, and application providers, increasing the choices local businesses have for their communications and technology needs. The City will be able to actively market areas of Centennial as "fiber ready" and provide prospective businesses with a range of available providers. The City will also be able to develop strategic partnerships with current and future broadband providers to market the benefits of Centennial's network and services to businesses.

Education (School Districts and Arapahoe Library District)

The network will provide a platform of advanced connectivity to support educational needs. Educational institutions around the country have become one of the greatest beneficiaries of municipal fiber networks, and Centennial has an opportunity to take a leadership role locally. As schools increase the amount of online learning programs and tools, they need high-speed, reliable connectivity for their students, teachers, and administrators. Littleton Public Schools has already expressed interest in participating in Centennial's municipal fiber network to enhance connectivity to their schools in and around Centennial. The dark fiber network would also provide a platform for future growth, providing long-term cost certainty and easily allowing for future increases in speed at marginal increases in cost. Cherry Creek School District, although unlikely to immediately participate in the network deployment, could easily connect to the network if new needs arise. Many of Cherry Creek's schools (like Littleton Public Schools) will be in close proximity to the City's fiber network and extending it to their facilities in the future would be an option for the City and the school district.

The network will also pass in close proximity to the Arapahoe Library District's facilities within or near Centennial, including the Smoky Hill, Castlewood, Koelbel, and the Southglenn Libraries, as well as the Administration Building, to support their future connectivity needs.

Public Safety (Fire Districts and Arapahoe County Sheriff's Office)

Public safety agencies in Centennial will benefit from additional connectivity to interconnect agencies with one another and provide added redundancy for mission critical applications. South Metro Fire, Cunningham Fire, and Littleton Fire can benefit from the enhanced speeds and reliability that will come from the network and may utilize its capacity to interconnect their organizations to one another. The network will supplement current connectivity in some areas and replace it in other areas, providing significantly higher speeds at similar costs. The connectivity improvements that could be seen from interconnecting the multiple public safety agencies on a single, robust dark fiber backbone include enhanced dispatch abilities, improved communication in the event of an emergency, and preserving opportunities for future enhancement.

Healthcare

Healthcare organizations are carrying out more of their business operations online. With the transition to electronic healthcare, these organizations and the residents they serve require access to high quality, reliable broadband services. As more virtual healthcare and telehealth services are deployed into residents' homes, these organizations will rely on their connectivity to ensure the health of their patients, which requires high quality broadband for healthcare organizations themselves and within patients' homes. The City's network will have future capabilities and capacity to support Centennial's healthcare organizations, enabling them with fiber connectivity to interconnect hospitals, doctor's offices, clinics, and imaging centers, supporting their implementation of digital healthcare programs for Centennial's citizens.

Leading Edge Broadband (Business and Residential)

A municipal backbone network can become a catalyst to accelerate deployment of leading edge broadband services in Centennial. According to a 2014 Governing magazine article[1], Centennial has some of the highest Internet adoption rates in the country, demonstrating that the Internet has a high level of relevance for its citizens. Development of this network presents an opportunity for the City and private providers to work together to bring the latest fiber-to-the-premise technologies to residents and businesses. By lowering cost barriers to deploy fiber-to-the-premise networks, the City can take an active role by developing public-private partnerships with competitive broadband providers. If successful, these partnerships will yield positive economic and social benefits to the Centennial community.

1.5 Fiber Master Plan Roadmap

Today, Centennial's existing fiber network provides connections to traffic signals and City facilities, enabling communications that support the City's IT and public works departments. Expanding the existing network will allow the City to continue these efforts as well as support more of its municipal functions. The Fiber Master Plan proposes extending the network to additional community organizations and businesses that need fiber connectivity in and around Centennial.

During this phase of the fiber-optic initiative, Magellan Advisors and the City conducted significant stakeholder outreach with these stakeholder organizations and found that many of them had needs for fiber connectivity that could be fulfilled through a municipal fiber network. These organizations supplied detailed information that helped the planning team design the network and project its potential costs, including:

- Individual locations for fiber connectivity;
- Technical and operational requirements;
- Timeframe when connectivity was needed; and
- Potential budget for services*

**In many cases, these organizations indicated that they had budgets to support some of the operational or capital costs that Centennial would bear in building and operating the network.*

Through the opportunity assessment, the following organizations were identified as likely near-term users of the proposed network:

- City of Centennial
- Arapahoe County and Arapahoe County Sheriff's Office
- Arapahoe Library District
- Littleton Public Schools
- South Metro Fire & MetCom
- Cunningham Fire District

In addition, City Council participated in a discussion on the design of the proposed network, providing guidance and feedback that directed the Steering Committee in its work on the Fiber Master Plan and

[1] http://www.governing.com/topics/transportation-infrastructure/gov-most-connected-cities-2013-internet-adoption-report.html

network design. As a result of this discussion, the Steering Committee developed Resolution 2015-R-72, recommending City goals for the fiber-optic initiative.

On November 9, 2015 City Council unanimously adopted these goals. Broadly, the goal of the fiber-optic initiative is to "develop fiber infrastructure throughout the City that facilitates access to innovative broadband services for Centennial's residents, businesses, and community institutions." These goals also include:

- Ensuring long-term viability of any infrastructure;
- Enabling the private sector to deliver services; and
- Examining innovative approaches and participation by Centennial.

The core backbone network design and the Fiber Master Plan fulfill these goals while preserving future opportunities. The backbone was designed with three principles in mind:

1. Identify backbone routes that could support connections to community anchor institutions;
2. Identify backbone routes that could support connections for businesses; and
3. Identify backbone routes that could support connections for residences.

Based on the conversations with stakeholders and Council's direction, a conceptual design was developed for the fiber backbone. The backbone, otherwise known as the "core network," provides high capacity fiber-optic cables throughout the major corridors of the City. It incorporates the 40 miles of existing City owned conduit and fiber with additional new construction to result in approximately 60 miles of a robust, redundant, and reliable City-wide backbone fiber network. The backbone will be provisioned with high-count fiber-optic cables that supply ample capacity to support current and future needs.

Additional public agencies or private companies may be interested in participating in the development and deployment of a backbone network, although these opportunities were not fully explored. The City should actively pursue and remain open to any additional partners that may wish to participate in the construction, deployment, and use of the proposed backbone network.

The backbone connects to each organization, supplying direct fiber connectivity between their facilities. It has been designed with provisions for high redundancy, ensuring that these organizations maintain reliable connectivity to support their critical business applications. It also provides numerous "access points" that support the attachment of future devices, facilities, and applications that the City and other organizations may utilize in the future. As new smart city technologies are developed in transportation, utilities management, energy management, safety, surveillance, and community development, Centennial's fiber network will be an asset to support these connected applications and drive innovation for the City.

In addition to the municipal and community functions supported by the network, it may become a platform to expand access to leading edge broadband services for Centennial's businesses and residents. The network has been designed to pass major business and residential districts with available capacity to support future deployments of fiber-to-the-home (and business) services. Although the City does not intend to directly provide any retail broadband or telecommunications services, the City will seek input from broadband providers, telecom companies, and other parties interested in using the network to deliver services to businesses and residents. A Request for Interest (RFI) was released to solicit potential interest from these entities on how they would utilize the network in partnership with the City. The results of this RFI and additional ongoing outreach may influence future City direction.

Ultimately, the Fiber Master Plan represents the next step for the Fiber-Optic Initiative. The network design and master plan fulfill City goals by developing a viable operational model, bringing fiber-optic infrastructure closer to neighborhoods and business corridors, and potentially lowering the costs and other barriers of deployment for private services. Although there is no guarantee that fiber-to-the-home services will ultimately be deployed in Centennial, the City should work with broadband providers to explore all possibilities to do so.

1.6 Financial Summary and Funding

Figure 1 provides an overview of the capital and operational costs incurred in the next 30 months of the project and a recommended request for funding. Capital construction of the backbone network is projected at approximately $4.7 million. This includes all outside plant materials, anticipated labor, and a contingency to account for certain variables in the labor and commodity markets. Construction has been broken down by the network segments that are utilized by each organization identified through the stakeholder outreach as a user of the network. As these segments are built, they will contribute to the overall Citywide backbone network that will be used for the range of purposes described in the previous section.

In addition to the capital construction of the network, project management, software, operations, and staffing costs will be required to manage the network as it is built and placed into operation. Project management, software, operations, and operational support staffing costs total roughly $1.0 million until the end of 2018. These costs are included in the recommended request for funding. After construction is complete, the City may consider assessing future funding and governance structures in light of additional interest. The operational model proposed in this document is sustainable for the foreseeable future, but additional opportunities may present themselves.

Overall, the recommended request for funding for the core network is $5.7 million in 2016. This money is anticipated to cover capital expenditures and operations and maintenance during a construction period that should be completed at the end of 2018. Specific construction phasing has not been identified and funding will not be utilized at one time or in one specific year. This will be an ongoing capital infrastructure project of the City.

Figure 2 illustrates the current projected Operating Income and Net Proceeds for the proposed network, showing total revenue versus total expense. Network revenues will be generated by leasing access to community organizations identified in the Fiber Master Plan. Revenues were estimated by analyzing each organization's budget for connectivity and using this information to establish reasonable, market-sensitive, leasing rates for the City's fiber. Timing of revenues was also taken into account based on these organizations' existing contracts for service.

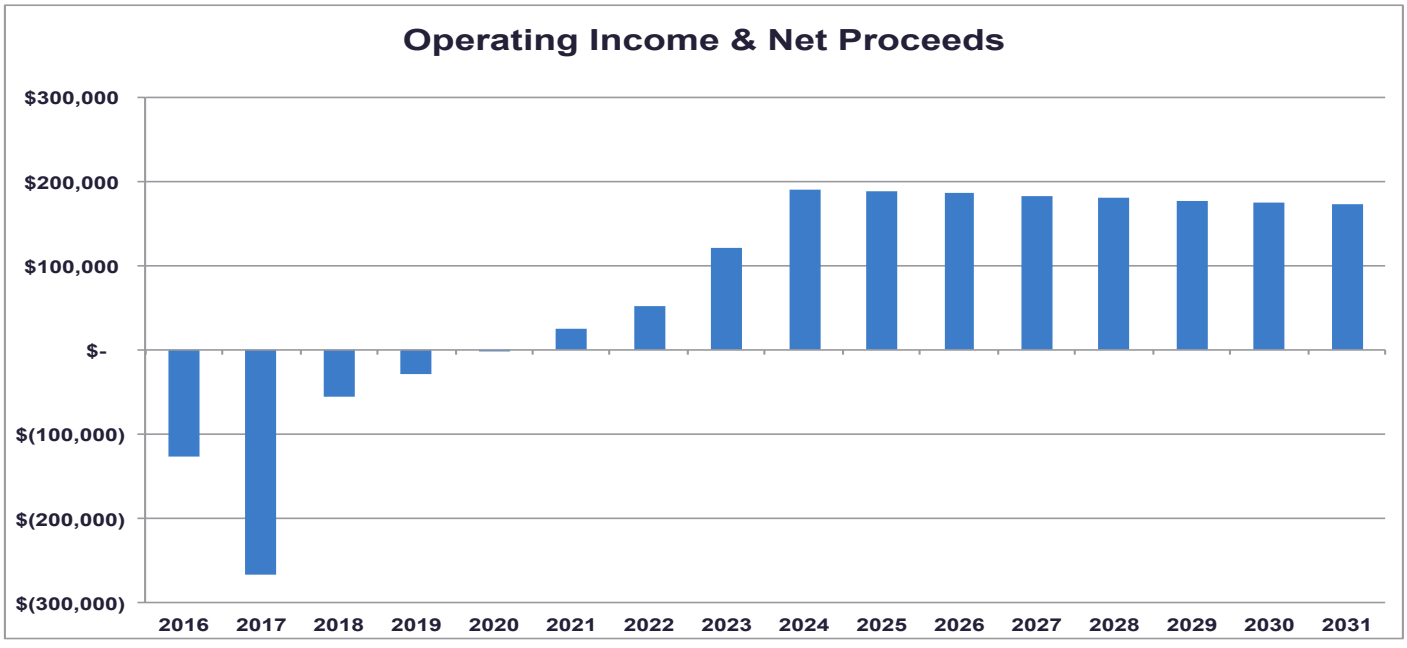
Revenues also include conservative estimates for dark fiber leasing by private broadband providers and other entities that may utilize the City's network. Since the City has not yet determined how broadband providers may partner with the City, this provision allows for some revenue recognition based on the City leasing 20% of the remaining capacity to them over a period of 15 years. These figures are subject to change based on the City's actual negotiation and business model undertaken with broadband providers. Based on the projected revenues, the network is expected to cover its operating costs beginning in year 5 and subsequently thereafter. Based on current analysis, it is unlikely that reduced costs for Centennial and community anchor revenues will solely cover all operating expenses for the network; therefore, subsequent revenues from broadband partnerships or dark fiber leasing are key to achieve positive operating results.

Ultimately, the recommended neutral, open-access, municipal fiber-optic backbone can support additional opportunities, including public-private partnerships, improved service levels and new service models. Without the foundational step of a City-owned backbone, the City cannot begin to consider future possibilities.

Figure 1: Funding Requirements

	2016	2017	2018
Capital Construction Costs[2]			
West Centennial (west of S. Holly Street)	$1,389,115		
Central Centennial (S. Holly Street to S. Parker Road)	$2,150,153		
East Centennial (east of S. Parker Road)	$1,166,633		
Subtotal: Capital Construction Costs	**$4,705,902**		
Operations and Maintenance Costs	**$300,725**	**$367,500**	**$286,209**
Subtotal: Operations and Maintenance Costs	**$340,389**	**$367,500**	**$286,209**
Total Funding Required (2016 – 2018)	**$5,006,627**	**$367,500**	**$286,209**
Recommended Funding Request	***$5,700,000***		

Figure 2: Operating Income and Net Proceeds



[2] As with any capital project, construction may not necessarily occur in the year funding is appropriated. The City should treat the construction of the backbone network as it would any other capital infrastructure project, including the phasing of construction, assessment of alternative options, and constant project management.

1.7 Council Action and Next Steps

Staff is seeking council action to formally accept and adopt the Fiber Master Plan and set aside the funding required for construction and operations of the network. Based on adoption of the plan and availability of funding, Staff will:

1. Seek commitments from community anchor organizations to lease the network from the City;
2. Adjust the network design based on these commitments as necessary;
3. Refine the timeline for construction of the network;
4. Contract for a Fiber General Manager Position; and,
5. Begin procurement for fiber engineering design for the network.

2.0 Background

About the City

The City of Centennial ("City") became a statutory city on February 7, 2001, after a successful incorporation election in the fall of 2000 with an overwhelming 77% of the vote in favor. The establishment of the City of Centennial was the largest single incorporation in US history with a population of more than 100,000. Centennial is the tenth largest municipality in the State of Colorado and the seventh largest city in the Denver Metro area, encompassing approximately 29 square miles. In June 2008, the voters approved a Home Rule Charter, making the City a Home Rule municipality.

The City of Centennial is a high-performing, entrepreneurial-focused municipal corporation. The organizational structure has evolved since the City's incorporation in 2001 to a mix of in-house professionals and contracted service providers that provide the services offered to Centennial's customers. City services that are provided by contractors, which function independently from internal City departments, include: law enforcement, public works, legal services, building services, contractor licensing, animal control, code compliance, sales and use tax administration, and information technology services. Special districts include a library district, three parks and recreation districts, two school districts, a transportation district, eleven water districts, and a fire district.

Centennial operates as a Council-Manager form of government. The City Council consists of eight Council members, two elected from each of four districts, and an at-large Mayor. The size of the City staff remains extremely small in comparison to other municipalities of similar population. In 2015, the City's workforce includes 56.25 full-time equivalent positions, with the majority of City employees being highly-trained professionals that conduct business with little administrative support.

Existing City Fiber-Optic Infrastructure Assets

The City's existing fiber-optic network and facilities, including over 40 miles of underground fiber-optic lines and conduit (collectively, the "Fiber-Optic Infrastructure"), serve as the link between the City's traffic signal system and the City's Traffic Operations Center ("TOC") and as a network connection between City facilities.

The current Intelligent Transportation System (ITS) includes City of Centennial operated traffic signals, closed circuit television ("CCTV") cameras, and traffic signal detection sensors. The City has also installed dedicated fiber connectivity between two existing facilities: the Centennial Civic Center and the Eagle Street Public Works and multi-purpose facility, which houses the TOC as part of the traffic signal system project. This fiber connectivity does not serve as the primary phone or Internet connection for either facility. Its original purpose was to provide connectivity for ITS applications and as such, its capabilities to be used for other applications are limited.

Development of the Fiber-Optic Infrastructure

The development of the existing Fiber-Optic Infrastructure began in 2008 as a Public Works effort to improve connectivity between City assets, including traffic signals, a TOC, weather stations, an Electronic Messaging Center ("EMC") sign, and other public facilities. Additionally, the development of the existing Fiber-Optic Infrastructure was part of an effort to improve traffic flow and reduce traffic congestion within City limits and throughout the major arterials that service neighboring communities.

The City's Public Works Right-of-Way Policy (2015-PW-01) aids in the build-out process of the Fiber-Optic Infrastructure by allowing the City to save time, lower costs, and build partnerships with contractors through the leveraging of colocation opportunities that allow the City to complete missing areas in the fiber-optic network. Under this policy, the City's permitting office is authorized to request the collocation of underground facilities upon the filing of major right-of-way permit requests by outside organizations.

Legal Standing and the 2013 Election

On November 5, 2013, Centennial voters passed Ballot Question 2G with over 76% of the vote. This vote repealed the restrictions placed on the City by Colorado Senate Bill 05-152 ("SB 152") and allowed the City to begin exploring opportunities associated with indirect, competitive, and non-exclusive service provision models that support the transmission of high-speed Internet, advanced telecommunications, and other services to residents and businesses by private companies.

Phase 1 – Opportunity Analysis and Inventory

A committee comprised of City Council Members, City Staff, and representatives from the City Attorney's Office and members of the Centennial Budget Committee ("Steering Committee") selected a consulting firm to perform an Opportunity Analysis and Inventory of Existing Assets. Collectively, the analysis and inventory is referred to as "Phase 1." The results of Phase 1 identified several opportunities for the City, including the conversion of the existing ITS network into a citywide backbone, revisions to regulations, and potential future use cases. As a result of the Phase 1 report, City Council directed the Steering Committee to further investigate potential future uses and complete a backbone design.

Phase 2 – Backbone Design and Fiber Master Plan

With the information gathered in Phase 1, the City contracted the services of Magellan Advisors, a municipal broadband planning firm that works with many local governments, to develop a preliminary high-level backbone design. The Steering Committee tasked Magellan Advisors with designing a carrier-grade backbone that makes use of the City's existing fiber-optic assets and new fiber routes through key corridors of the City. The goals of this backbone are to enhance municipal operations, provide new community anchor connectivity, and create a platform for innovative broadband service deployments, in partnership with private sector broadband providers. Based on the findings and acceptance of the Fiber Master Plan, the Steering Committee will prepare and submit a budget request to City Council for funding the backbone network.

Phase 3 – Construction

Pending direction from City Council, the next steps of the fiber-optic initiative will include the engineering and construction of the carrier-grade fiber backbone network. The schedule and timeline for construction will be dependent on direction from City Council, funding appropriations, and a phasing plan that optimizes the construction based on the needs of the organizations that will use the network. The intent of this backbone is to serve as the City's primary communication network for internal services and to provide partnership opportunities for the delivery of improved service to the City's residents, businesses, and community anchor institutions.

3.0 Fiber Backbone Vision and Design Principles

3.1 Fiber is Investment in Centennial's Future

Cities across the country are investing in municipal fiber networks to support their growing demands for technology and community needs. Instead of leasing expensive connections from providers, they are building their own networks to reduce costs and maintain ownership in a long-term asset that can be used for a variety of other purposes. Thousands of cities across the US already own significant fiber networks that they utilize to support their internal operations, connectivity to anchor organizations, and enhanced broadband services in their communities.

For the City, building a fiber backbone is an investment in Centennial's future. The City will own an asset that can accommodate smart and connected technologies as more municipal and community functions are carried out online. Smart City Technologies and the Internet of Things are two growing trends that will change the way that cities carry out their missions as e-government expands across many municipal functions. More devices, sensors, and people will be connected than ever before. By building a fiber backbone, Centennial will be prepared to accommodate these emerging trends. The network will keep Centennial at the leading edge of innovation and support a range of municipal, community, and broadband applications. Without it, the City cannot consider the vast majority of them.

3.2 Fiber Is Critical Infrastructure

Fiber is critical infrastructure that enables high-speed digital communications across Centennial, connecting City offices and traffic signals today. Expansion of the City's current fiber assets will enable schools, public safety facilities, libraries, and other community resources to be connected as well. This will facilitate a true community-owned asset that benefits multiple stakeholders.

The City should treat fiber similar to other infrastructure resources, a long-term asset that supports the municipal operations and community needs. Fiber maintains an economic life of 20 – 30 years; however, some municipal fiber networks have been in operation for more than 40 years. The City should view fiber as an infrastructure asset that will continue to drive value, cost reductions, and new capabilities in Centennial.

3.3 Fiber Development is a Long-Term Program

The Fiber Master Plan is a strategic plan for the development of the City's fiber backbone. The City should expect this backbone to grow over time to connect more locations and support more applications. The Fiber Master Plan will become a living plan that documents the evolving needs and opportunities for Centennial's fiber backbone and proposes new fiber infrastructure to build on the City's existing network. Centennial should approach fiber infrastructure as a program rather than an individual project. Just as roads are extended and widened periodically to support more traffic, the fiber network will be expanded to support more users in and around Centennial. The City will develop processes and procedures to plan, manage, and expand the network to ensure that the network continues to meet the needs of the City and its community.

3.4 Fiber Backbone Design Principles

The backbone network has been designed to support the City's growing broadband needs across a range of functions and public initiatives. Designing the network in this manner maximizes the City's opportunities to use the network for the purposes defined in the framework below. This framework was developed with participation from the Fiber Steering Committee to ensure the project team accurately designed the network to meet the requirements of the City and Centennial's stakeholders. City Council also provided valuable input into the process to ensure that the City's goals were well aligned throughout development in the backbone.

Municipal & Smart City Services

The network will support the City's current operations and be used as an asset to continue to drive efficiencies, reduce cost, and expand capabilities. The network as proposed is robust, redundant, and reliable. It can become a multi-purpose asset of the City that can be used between departments for multiple applications. Most importantly, it will help the City enhance currently provided community services. With an eye towards the future, many applications and services that are collectively referred to as "Smart City" efforts are not possible without a well-designed fiber backbone. This backbone serves as a means of robust data collection and support infrastructure for identifying problems through data analysis.

The City's Innovation Team (i-team) and the City's Public Works provider, CH2M, have undertaken efforts to optimize the City's Intelligent Transportation System (ITS). This optimization initiative focuses on mitigating the effects the I-25 corridor has on operations of Arapahoe Road and improving the systems integration and fiber interconnects necessary to optimize the transportation network. Examples may include "pushing" information out to motorists through Dynamic Messaging Signs (DMS), communicating with vehicles' on-board computers through infrastructure-to-vehicle systems, and improving first responder performance measurements through ITS. Ultimately, the i-team program and the City's potential Smart City efforts are dependent on the establishment and success of Centennial's municipal fiber backbone.

Network Design Principles Supporting Municipal & Smart City Services

1) **Support Water/Sewer Utility District Needs**
    a. Collaborate with water/sewer utility districts to determine technology needs for fiber and wireless connectivity;
    b. Document utility district asset locations for potential connectivity;
    c. Design the network to provide fiber access points to these locations;
    d. Enable sufficient capacity in the network to support SCADA security and resiliency requirements.

2) **Support Local and State Park District Needs**
    a. Identify Park District facilities;
    b. Identify regional connectivity to these facilities;
    c. Design the network to provide fiber access points to these locations and interconnection with regional networks.

3) **Support Future Smart City Technologies**
    a. Design the network with sufficient strand capacity to support future applications that utilize fiber and wireless connectivity;

b. Maximize fiber access points across the network to accommodate interconnection of future applications;
c. Create splice points at all key intersections;
d. Plan fiber access points and termination for multiple applications;
e. Size fiber vaults, handholes, and splice cases appropriate to facilitate future growth in a multi-application environment.

Economic Development

The City of Centennial is a fiscally responsible, business-friendly City that balances business, residential, and cultural community interests. Known throughout the region as a vibrant business community, the City attracts and retains a strong business base, generates healthy revenue, and encourages ongoing revitalization through thoughtful and responsible development. During the outreach, the project team met with several businesses that expressed the importance of high-quality, reliable broadband services. The project team met with SSP Innovations' leadership, who cited broadband as a key aspect of their decision to move into the City. Their new location happens to be well served by an existing broadband provider; however, they expressed interest in participating in the City's fiber initiative if the City chose to deploy fiber to local businesses.

The network will become a platform that the City can use to support economic development programs that attract new businesses and retain existing ones. There are a variety of business models that the City will consider employing that allow businesses to access the City fiber. Many of these are executed through partnerships with broadband providers. The City's network will connect to the Viawest and Equinix data centers in Centennial, which enables businesses to have access to a number of retail service providers to support their communications needs. This also will allow the City to support new recruitment efforts by marketing affordable fiber services and the choice of providers to prospective businesses.

Network Design Principles Supporting Economic Development

1) Attract New Business

a. Identify commercial growth areas;
b. Design the fiber backbone network to commercial growth areas within the City;
c. Use fiber connectivity as part of the City's "competitive advantage" to complement other incentive packages;
d. Develop a strategy for last-mile infrastructure to connect new businesses to the Centennial backbone.

2) Expand Local Industries

a. Identify the locations and types of high demand broadband users;
b. Design the fiber backbone network to reach areas with the highest concentrations of these users and growth areas for these users;
c. Develop a plan to make affordable, high performance fiber connectivity available to these users.

3) Retain and Expand Existing Businesses

a. Identify areas of greatest revenues for the City;
b. Identify areas of greatest employment for the City;
c. Support redevelopment areas in neighborhood shopping centers;

d. Design the fiber backbone network to provide access into these areas;
e. Develop a plan to make affordable fiber connectivity services available to promote retention and growth of current businesses.
f. Work with Economic Development to aggregate demand for last-mile connectivity to Centennial's backbone network.

4) Support Teleworking & Home-Based Businesses

a. Use business data to identify concentrations of home-based businesses across the City;
b. Identify concentrations of home-based businesses in Centennial, commuting patterns, and teleworking trends;
c. Design the fiber backbone network along key residential thoroughfares that may provide future potential to connect neighborhoods in partnership with broadband providers.
d. Work with neighborhood organizations to aggregate demand for last-mile connectivity to Centennial's backbone network.

5) Promote the City as a Connected Community

a. Work with broadband providers to solicit interest in using Centennial's broadband infrastructure;
b. Develop a plan to interconnect the Centennial network to local data centers;
c. Identify immediate opportunities to use existing assets and small incremental investments that will show immediate progress and demonstrate City's capabilities to execute;
d. Identify potential users within close proximity to existing network;
e. Identify pilot projects and business cases;
f. Market the network as a resource of the City that contributes to Centennial's status as a highly connected community for business.

Public Safety

Public safety agencies in Centennial will benefit from additional connectivity to interconnect agencies with one another and provide added redundancy for mission critical applications. South Metro Fire, Cunningham Fire, and Littleton Fire can benefit from the enhanced speeds and reliability that will come from the network and may utilize its capacity to interconnect their organizations to one another. The network will supplement current connectivity in some areas and replace it in other areas, providing significantly higher speeds at similar costs. The connectivity improvements that could be seen from interconnecting the multiple public safety agencies on a single, robust dark fiber backbone include enhanced dispatch abilities, improved communication in the event of an emergency, and preserving opportunities for future enhancement.

Network Design Principles Supporting Public Safety

1) Support More Access to Video Applications

a. Set aside capacity to support fiber connectivity at intersections for video cameras, in conjunction with intelligent traffic systems.

2) Support High Security, High Resiliency Communications

a. Design fiber network to maintain compliance with law enforcement security standards;
b. Design high levels of redundancy into the network to support mission critical applications;

c. Emergency operations in Centennial's outsourced public safety environment; and,
d. Facilitate communications and technology sharing between public safety organizations.

Healthcare

Healthcare organizations are carrying out more of their business operations online. With the transition to electronic healthcare, these organizations and the residents they serve require access to high quality, reliable broadband services. As more virtual healthcare and telehealth services are deployed into residents' homes, these organizations will rely on their connectivity to ensure the health of their patients, which requires high quality broadband for healthcare organizations themselves and within patients' homes. The City's network will have future capabilities and capacity to support Centennial's healthcare organizations, enabling them with fiber connectivity to interconnect hospitals, doctor's offices, clinics, and imaging centers, supporting their implementation of digital healthcare programs for Centennial's citizens.

Network Design Principles Supporting Healthcare

1) **Enable high-quality, resilient access to healthcare organizations**
   a. Identify hospitals, clinics, doctor's offices, and other healthcare organizations across Centennial;
   b. Design the network to pass as many of these organizations as is economically feasible;
   c. Design the network to provide fiber access points to these locations;
   d. Consider designs that create redundant ring connectivity to support redundancy to support mission critical healthcare needs;
   e. Consider impact to neighborhoods to support telehealth applications.

Education

The City of Centennial is a fiscally responsible, business-friendly City that balances business, residential and cultural community interests. Known throughout the region as a vibrant business community, the City attracts and retains a strong business base, generates healthy revenue, and encourages ongoing revitalization through thoughtful and responsible development.

Network Design Principles Supporting Education

1) **Support high-quality, resilient Internet access at school facilities**
   a. Identify school facilities across the City;
   b. Design the network to pass as many of these organizations as is economically feasible;
   c. Design the network to provide fiber access points to these locations;
   d. Design the network for potential regional interconnection with research and education networks, such as Internet2, Front Range Gigapop, etc.

2) **Support increased access and adoption of Internet services for students**
   a. Identify locations where public Internet access may be improved, including libraries, community centers, and WiFi hotspots;
   b. Design the network to provide fiber access points to these locations;
   c. Allocate sufficient capacity and splice points to support WiFi in public places, schools, and libraries that may facilitate more public access to the Internet;
   d. In conjunction with the residential Network Design Criteria, design the network to pass neighborhoods to facilitate potential upgrades by broadband providers.

Leading Edge Broadband (Business & Residential)

A municipal backbone network can become a catalyst to accelerate deployment of leading edge broadband services in Centennial. According to a 2014 Governing magazine article[3], Centennial has some of the highest Internet adoption rates in the country, demonstrating that the Internet has a high level of relevance for its citizens. Development of this network presents an opportunity for the City and private providers to work together to bring the latest fiber-to-the-premise technologies to residents and businesses. By lowering cost barriers to deploy fiber-to-the-premise networks, the City can take an active role by developing public-private partnerships with competitive broadband providers. If successful, these partnerships will yield positive economic and social benefits to the Centennial community.

Network Design Principles Supporting Leading Edge Broadband

1) **Accelerate the deployment of fiber broadband technologies**
    a. Identify locations where current broadband providers maintain facilities, huts, distribution points, dark fiber, and other assets;
    b. Design the network to pass existing provider assets and plan interconnection points that may facilitate the use of Centennial's fiber;
    c. Design the network to provide fiber access points to these locations.

2) **Support non-discriminatory access to Centennial's network to facilitate a multi-provider environment**
    a. Design the network to support sufficient capacity that enables multiple providers to utilize Centennial's fiber;
    b. Develop policies and procedures to support open-access interconnection policies.

[3] http://www.governing.com/topics/transportation-infrastructure/gov-most-connected-cities-2013-internet-adoption-report.html

4.0 Fiber Backbone Deployment Roadmap

4.1 A Staged Approach to Fiber Development

Municipalities that have enjoyed the successes that come with deploying fiber networks often utilize a staged approach that builds capacity and competency over time. An excellent example of this approach is found in the City of Santa Monica, where the CityNet Network was deployed in a long-term plan to first reduce cost and connect community organizations, then expand access to businesses, and finally create a platform to deploy a range of public WiFi and other community services. (A case study on Santa Monica is provided in Appendix A). A second example is found in the City of Palm Coast, where the City employed a multi-year plan to build out its fiber backbone throughout the City. Its initial goals included reducing ongoing connectivity costs and improving the City's communications resiliency. Following the initial deployment, the City connected 17 local schools with Gigabit and 10 Gigabit fiber connectivity. Finally, the City deployed an open-access network that today is being used by multiple service providers to deliver leading Internet services to about 100 local businesses to support the City's economic development goals. (A case study on Palm Coast is provided in Appendix A).

Municipal fiber backbones grow and evolve over time and each stage may differ from what is anticipated in this Plan. The stages described below provide more of a guidebook of common activities that municipalities participate in as their networks are deployed. The City should be open to entertaining a range of options as it deploys the network.

At each stage, the City will have the opportunity to evaluate the deployment of the network based on its original goals to ensure that the network is serving the community as anticipated. This should be a methodological approach that assesses the realized value of the network to the City and its community. Some key questions will include:

- What have we learned through our deployment?
- Did we plan for needs and opportunities correctly?
- Has the network accomplished its objectives?
- What could we have done better?
- How will we improve future deployments based on what we've learned?

Initial Deployment Stage

Centennial can be successful following a similar approach that first builds backbone infrastructure to support City needs and connects key community anchors. The initial network designed in this Plan is Centennial's fiber foundation from which other uses of the network will be based. In this phase, the City will also solicit information from private sector firms who may be interested in utilizing the City's network. Timing is important for this aspect to ensure that the initial network incorporates any design criteria into it that may lead to potential partnerships or other arrangements with private broadband providers. In December of 2015, the City released a preliminary RFI to gauge interest in the project. A number of responses were received and the City will consider how these third parties may utilize the City's network based on the objectives of the City.

Growth Stage

The City should anticipate that future investments beyond the initial deployment stage are likely. Completion of the backbone will drive new opportunities to utilize the network beyond those targeted in this Plan, some of which may require additional investment. During the growth phase, the City should evaluate the additional opportunities that the network may bring to the City, community organizations, businesses, and residents. The City should be prepared to evaluate the costs, benefits, and risks associated with these opportunities. The growth stage may incorporate significant opportunities for public-private partnerships with broadband providers to address opportunities among businesses and residents. Or, the City may find opportunities to address these needs through wholesale business models that provide only fiber connectivity to these users, while retail broadband providers deliver Internet, voice, television, and other end user services.

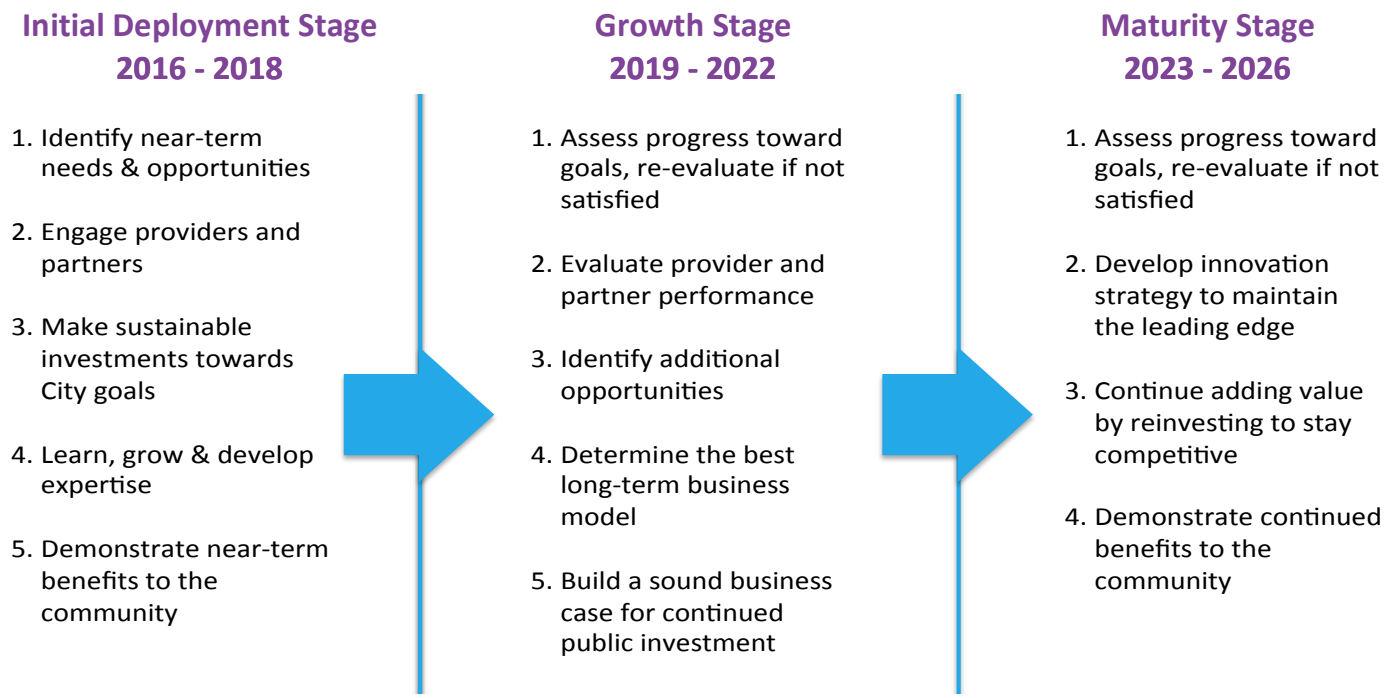
It's also important for the City to assess the performance of the network and determine if it has met the City's essential objectives to date. If not, the City should examine what aspects of the network have not met the objectives of the fiber initiative and revise its strategy accordingly.

Maturity Stage

Generally, municipalities that reach the maturity stage implemented their networks for longer periods and over that time, they have been able to expand their networks to cover significant portions of local business and residential districts. The networks actively become platforms for innovation and many municipal networks have deployed advanced technologies across these networks on a widespread basis to support utility operations, surveillance, weather and temperature monitoring, active traffic management, and other smart city applications.

To support leading edge broadband services, some have decided to implement broadband utilities that provide retail services directly, while others have selected to pursue open-access options or public-private partnerships, depending on their risk/reward profiles. The City should build capacity and expertise on this range of options as its network develops to select the right model or models that will best fit Centennial's needs. The City's fiber backbone has been designed to accommodate any of these opportunities in the future, enabling the City to maintain flexibility in its network to support a range of business models.

Figure 3: Fiber Backbone Deployment Roadmap



4.2 Organizational & Operational Structure

The City will require an organizational and policy framework to manage the construction and operation of the network. The City should consider the network an ongoing "program" rather than a one-time project. The network is likely to expand beyond its initial design over time to serve more community organizations and broadband applications. This will require the City to allocate human and system resources toward the construction of the initial network and manage its ongoing operations.

The City's fiber program should be managed by a dedicated resource with experience in the broadband, telecom and/or outside plant construction industries. The ideal candidate will have worked for a local government in a management role to plan, build, and/or operate a municipal fiber system. This resource should be on boarded by Centennial at the onset of the construction project to ensure a foundational knowledge of the City's goals, strategies, and plans for fiber deployment is well understood.

Policies and procedures will govern how the City manages the fiber backbone, including access to fiber, customer allocation, reserve capacity, expansion capacity, and management of records. Policies will also be required for any commercial transactions for public and private entities to utilize the network. Inter-governmental agreements are anticipated as a streamlined contracting vehicle that can be used between the City and other public organizations for use of the network. Standard contracts will be required for transactions with private entities, which may include broadband providers, data center operators, and individual businesses.[4] In addition, the City will need to design its policies and procedures around common telecommunications industry standards. This includes development of service level agreements ("SLA"), acceptable use policies ("AUP"), and other policies governing use of the network.

[4] The Fiber Master Plan anticipates some businesses leasing dark fiber from the City directly. It does not anticipate the City providing any retail Internet, voice or video services.

4.3 Conceptual Network Design

Through the opportunity assessment, the following organizations were identified as likely near-term users of the proposed fiber backbone:

- City of Centennial
- Arapahoe County and Arapahoe County Sheriff's Office
- Arapahoe Library District
- Littleton Public Schools
- South Metro Fire & MetCom
- Cunningham Fire District

Based on the conversations with stakeholders and Council's direction, a conceptual design was developed for the fiber backbone. The backbone, otherwise known as the "core network," provides high capacity fiber-optic cables throughout the major corridors of the City. It incorporates the 40 miles of existing City owned conduit and fiber with additional new construction to result in approximately 60 miles of a robust, redundant, and reliable citywide backbone fiber network. Access points are strategically placed throughout the fiber routes to allow easy interconnection with facilities, City assets, business districts, and neighborhoods.

Additionally, the network design was optimized to run in close proximity to the majority of Centennial's businesses. Commercial parcels in Centennial were used to generate a heatmap, which identified concentrations of businesses throughout the City. From this heatmap, network routes were optimized so that about 80% of Centennial's businesses were within 1,000 feet of the fiber network. This will facilitate easier connectivity to businesses that may desire access in the future, while keeping costs low for "last mile" connectivity to reach them.

The fiber backbone will generally consist of 432-count fiber-optic cable on major routes. This cable size will enable the City to allocate capacity among multiple applications, including:

- City municipal functions
- Future smart city applications
- Community anchor connections
- Broadband applications
- Spare capacity

Secondary or lateral fiber will consist of 24 to 96-strand cable connecting individual community organizations and other end user locations. The network will use an in-and-out splicing design that allows community anchors to interconnect their locations in a "ring" topology that supports high redundancy for their communications. A range of specialized connections will be made to accommodate additional traffic signal, smart technology, and broadband applications that should be individually engineered based on the application.

General specifications of the backbone are found below. Actual specifications may change based on the forthcoming engineering design; however, it is important that the City maintain compliance with these key specifications for Centennial to achieve its goals.

Fiber Specifications

- Backbone cable size – 432-count fiber
- Lateral cable size – 24-count to 96-count fiber
- Singlemode, loose-tube non-armored cable
- Jacketed central member
- Outer polyethylene jacket
- Sequential markings in meters
- All dielectric
- Gel-free/dry buffer tubes
- 12 fibers per buffer tube
- Color coded buffer tubes based on ANSI/TIA/EIA-598-B Standard Colors

Conduit Specifications

- 36” minimum acceptable depth
- 2” or 3” HDPE smooth wall reel-mounted pipe
- Maxcell innerduct where required

Handhole Specifications

Each route (Backbone / Lateral) will require a unique design and exact box placement will depend on a variety of factors to be determined in the final engineering analysis. Boxes along the backbone are generally placed every 500’ to allow for pulling in the fiber and splicing to adjacent buildings and infrastructure. Conduit sweeps into handholes shall enter in flush with the cut out mouse holes aligned parallel to the bottom of the box, and come in perpendicular to the wall of the box. Conduits shall not enter at any angle other than near parallel. Sweeps from the mainline to the conduit shall be accomplished using radii recommended by the manufacturer. Handholes will be sized based on the size of cable(s) transiting the structures, the total number of cables, and the specific applications required by the City.

Figure 4: East Centennial Backbone - East of Parker Rd.

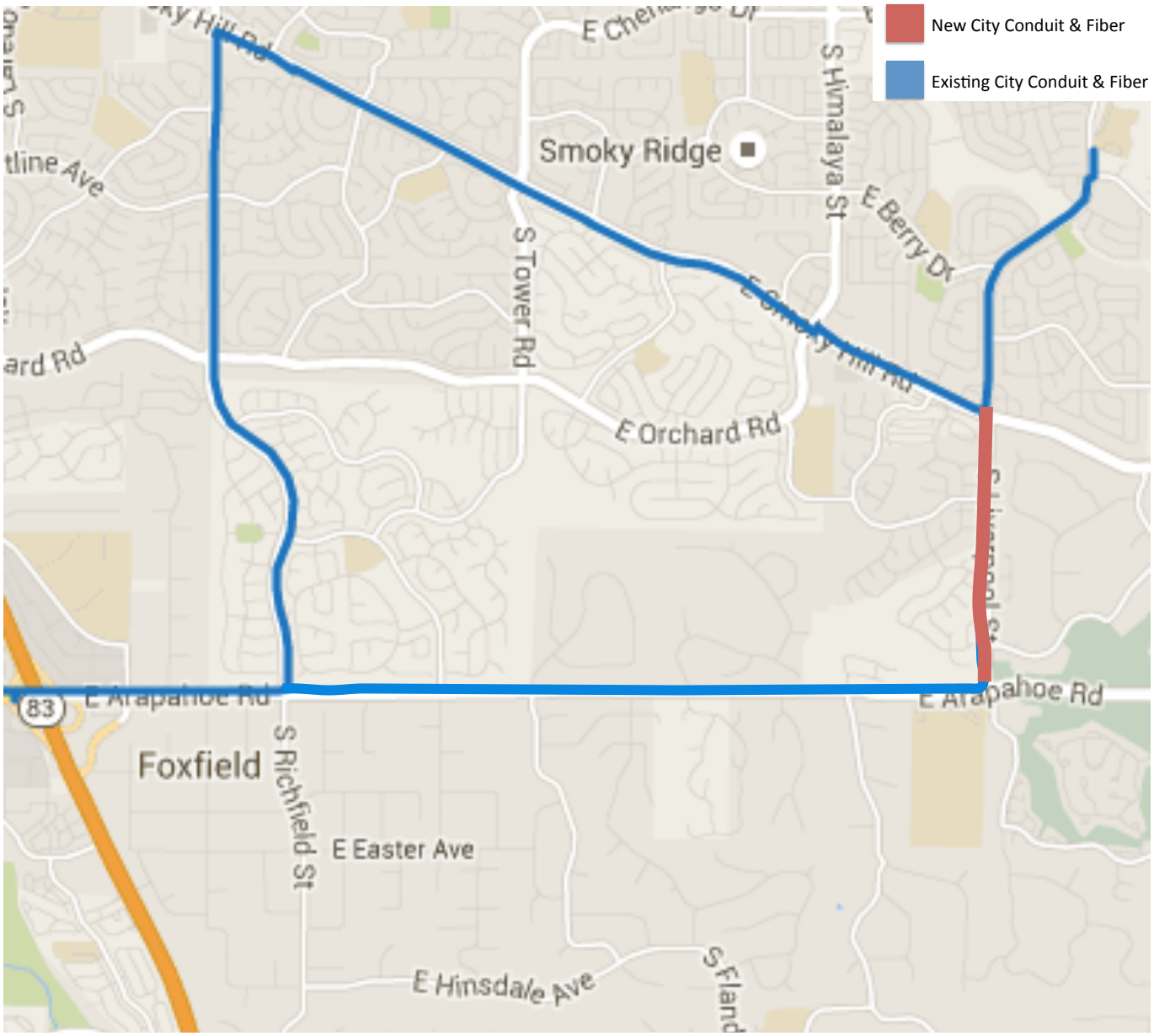


Figure 5: Central Centennial Backbone -S. Holly St. to Parker Rd.

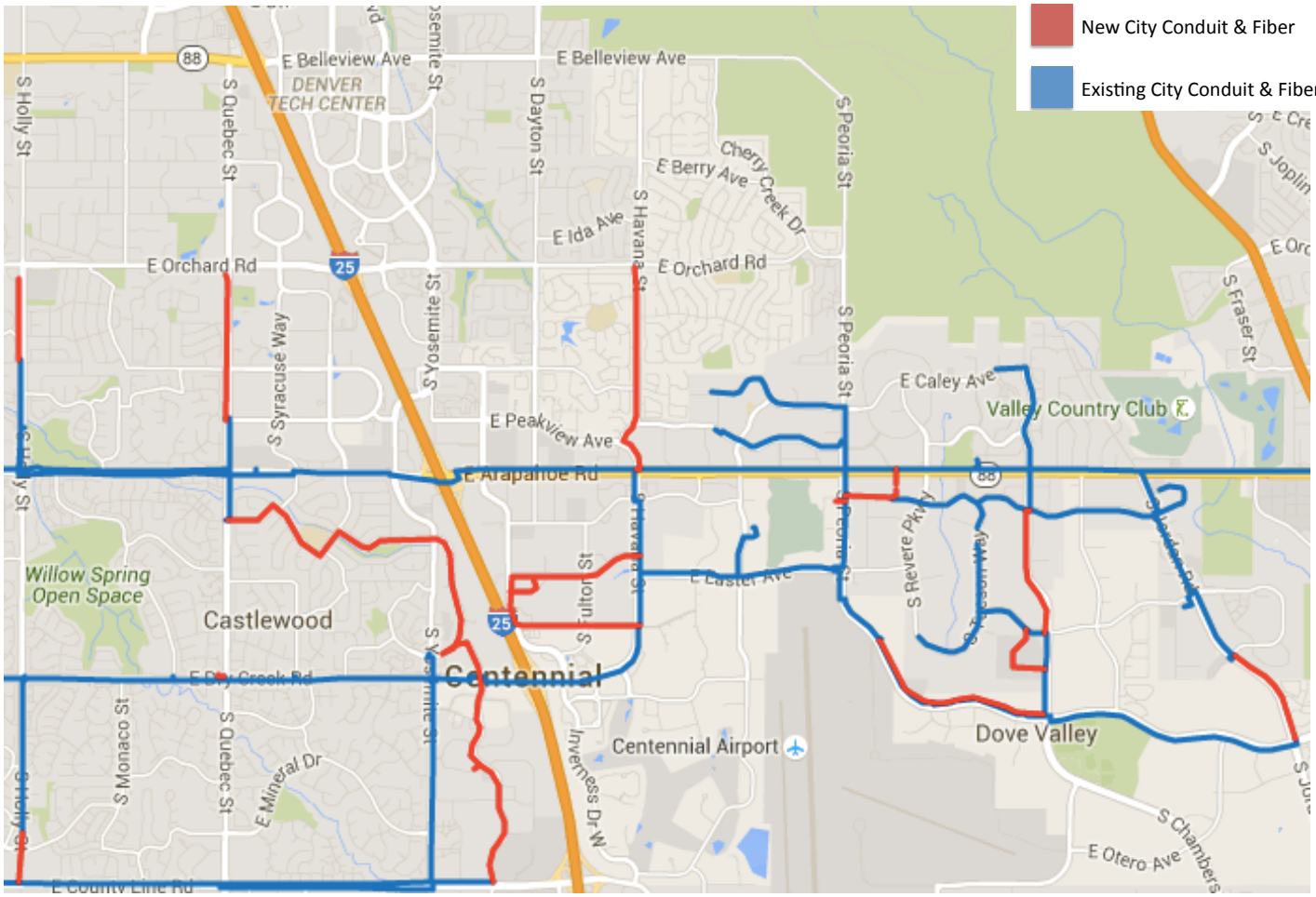
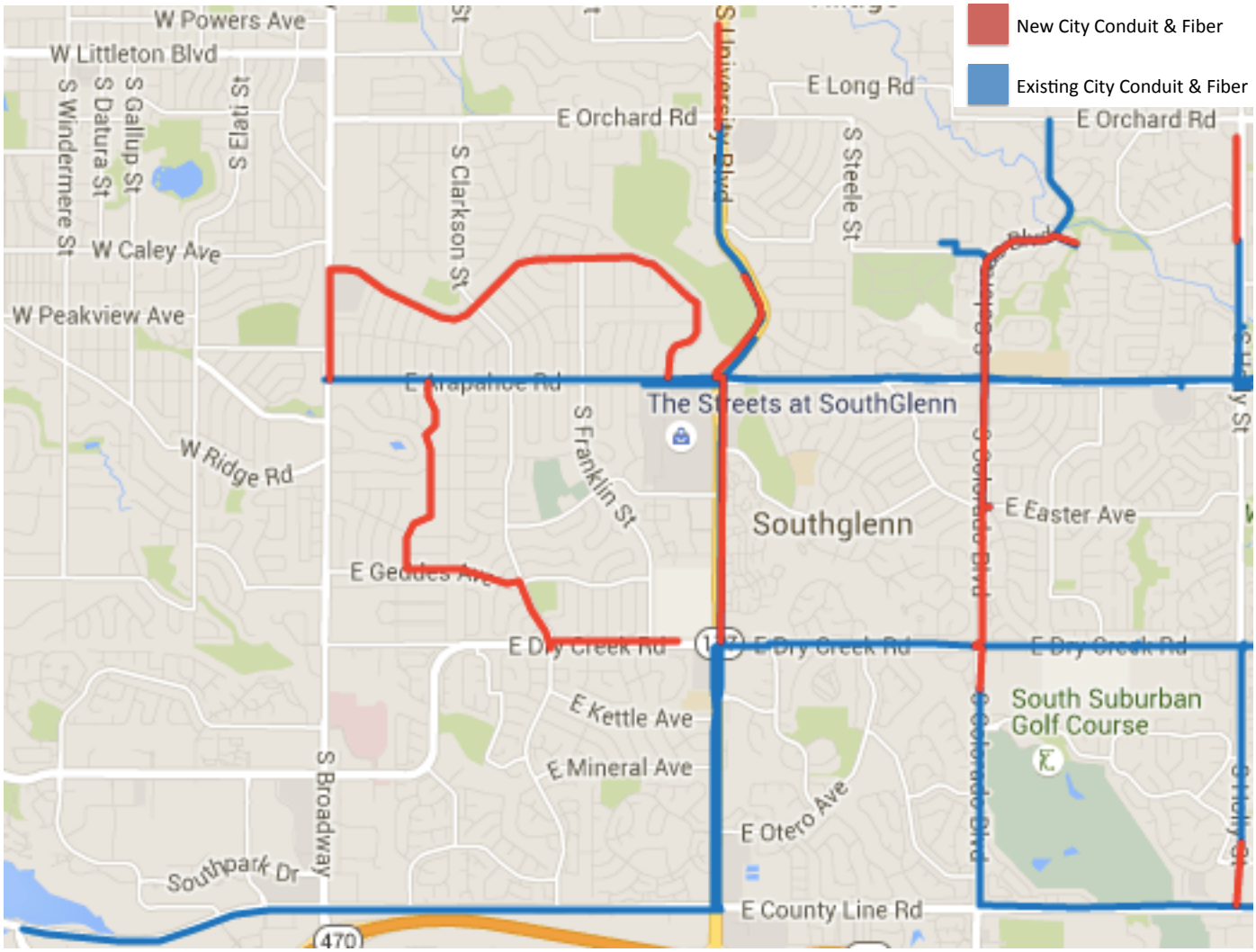


Figure 6: West Centennial Backbone - West of S. Holly St.



4.4 Backbone Financial Summary

Fiber Backbone Capital Costs

Overall, the recommended request for funding for the core network is $5.7 million in 2016. This funding is anticipated to cover capital expenditures and operations and maintenance during a construction period that should be completed at the end of 2018. Specific construction phasing has not been identified and funding will not be utilized at one time or in one specific year. This will be an ongoing capital infrastructure project of the City.

The fiber backbone is segmented into three sections, East, Central, and West. Total costs for the network engineering design, materials, and construction is $4.7M. The project will consist of three types of construction:

1. New Backbone Fiber & Conduit
    a. New underground construction of conduit and installation of backbone fiber
2. New Backbone Fiber in Existing Conduit
    a. New backbone fiber installation in existing City conduit
3. New Secondary Fiber & Conduit
    a. New underground construction of secondary conduit and installation of backbone fiber

In many cases, the network will utilize existing City conduit, which significantly reduces the cost of building the network. In these cases, new fiber will be installed in existing City duct and connected to new conduit that creates continuity on the backbone.

System and Project Management Costs

Other capital costs include system and project management costs that the City will bear in development of the fiber backbone. Project management costs include an independent “Owner’s Rep” function that will ensure that the construction and implementation of the network is carried out according to the specifications set forth in the design-build project. Inspections and quality assurance are included in these costs. Additionally, the Owner’s rep will also assist with integration of the fiber backbone with organizations that will take service from the City. Total costs are $200,000 over 2016 – 2017.

System costs include fiber management software and hardware needed to manage the City’s fiber backbone. These costs include the initial procurement of a fiber management system and professional services required to install the software and configure the system. Total costs are $75,000 in 2016.

Operations & Staffing Costs

Operations and staffing costs consist of key personnel that will manage the fiber program. These include partial FTEs to manage engineering, GIS, and record keeping for the network, as well as a fiber general manager resource to manage its day-to-day operations. The Plan estimates a run rate of $300,000 in annual operations and staffing costs for the ongoing management of the fiber backbone.

Revenues

Revenues were estimated by interviewing each community organization that identified an opportunity to use the City’s network. Two types of revenues could be expected by these organizations; (1) ongoing monthly charges to utilize the network, and (2) one-time capital contributions to use the network.

The project team asked specifically what budget was available from each organization to compensate the City for the use of its network. In some cases, the City's network would replace existing connectivity for these organizations and the existing spend would transfer to the City. In other cases where the City's network would be used as a secondary or redundant connection, these organizations mentioned that supplementary budgets would be required. Finally, some organizations would consider making an upfront capital contribution to the City instead of incurring an ongoing monthly expense.

Revenues also include conservative estimates for dark fiber leasing by private broadband providers and other entities that may utilize the City's network. Generally, cities have found varying degrees of success and revenue generation leasing their dark fiber networks to the private sector. To maintain conservatism in the financial plan, a small portion of the City's fiber backbone was allocated for dark fiber leasing. Since the City has not yet determined how broadband providers may partner with the City, this provision allows for some revenue recognition based on the City leasing 20% of the remaining capacity to them over a period of 15 years, at an average lease rate of $100 per month per pair of fiber. $100 per month per pair is a common industry benchmark that other municipalities have realized by leasing their dark fiber networks.

These figures are subject to change based on the City's actual negotiation and business model undertaken with broadband providers. Based on the projected revenues, the network is expected to cover its operating costs beginning in year 5 and subsequently thereafter. Based on current analysis, it is unlikely that reduced costs for Centennial and community anchor revenues will solely cover all operating expenses for the network; therefore, subsequent revenues from broadband partnerships or dark fiber leasing are key to achieve positive operating results.

Ultimately, the recommended neutral, open-access, municipal fiber-optic backbone can support additional opportunities, including public-private partnerships, improved service levels, and new service models. Without the foundational step of a City-owned backbone, the City cannot begin to consider future possibilities.

Figure 7: Project Funding Request Details

	2016	2017	2018
Capital Construction Costs (Materials & Labor)			
West Centennial Backbone			
New Backbone Fiber & Conduit	$349,577		
New Backbone Fiber in Existing Conduit	$328,956		
New Secondary Fiber & Conduit	$710,583		
Subtotal	**$1,389,115**		
Central Centennial Backbone			
New Backbone Fiber & Conduit	$608,349		
New Backbone Fiber in Existing Conduit	$687,717		
New Secondary Fiber & Conduit	$854,087		
Subtotal	**$2,150,153**		
East Centennial Backbone			
New Backbone Fiber & Conduit	$584,044		
New Backbone Fiber in Existing Conduit	$449,781		
New Secondary Fiber & Conduit	$132,809		
Subtotal	**$1,166,633**		
Total Capital Construction Costs	**$4,705,902**		
Systems & Project Management Costs			
Fiber Management Software & Installation Services	$75,000		
Project Management/QA/QC	$100,000	$100,000	
Total Systems & Project Management Costs	**$175,000**	**$100,000**	
Operations & Staffing Costs			
Fiber General Manager	$92,500	$185,000	$189,625
GIS Resource	$12,500	$25,000	$25,625
Fiber Engineer	$12,500	$25,000	$25,625
Software Maintenance		$15,000	$15,375
General Overhead	$8,225	$17,500	$29,959
Total Operations & Maintenance Costs	**$125,725**	**$267,500**	**$286,209**
Total Funding Required	**$5,006,627**	**$367,500**	**$286,209**
Recommended Funding Request		***$5,700,000***	

Figure 8: Gross Revenue Projections

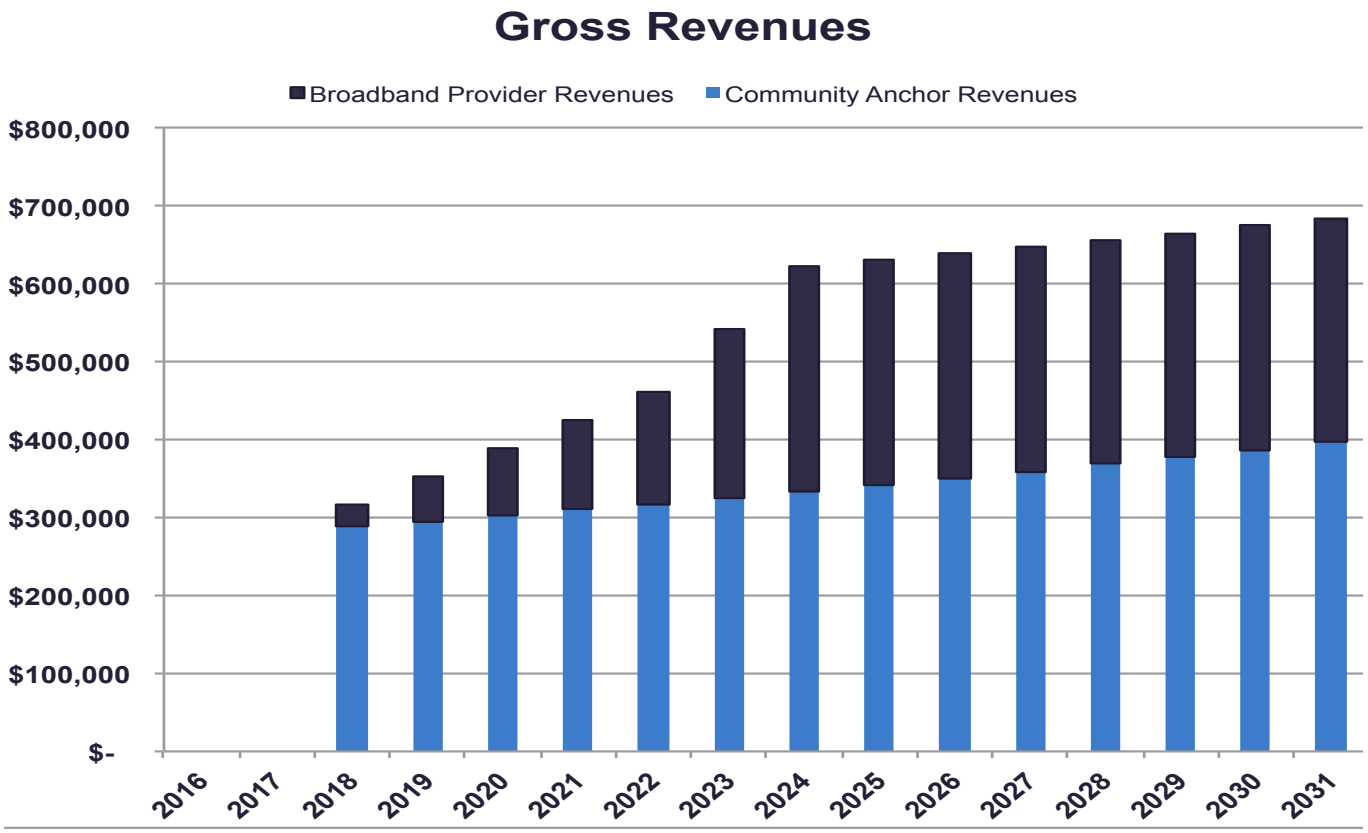
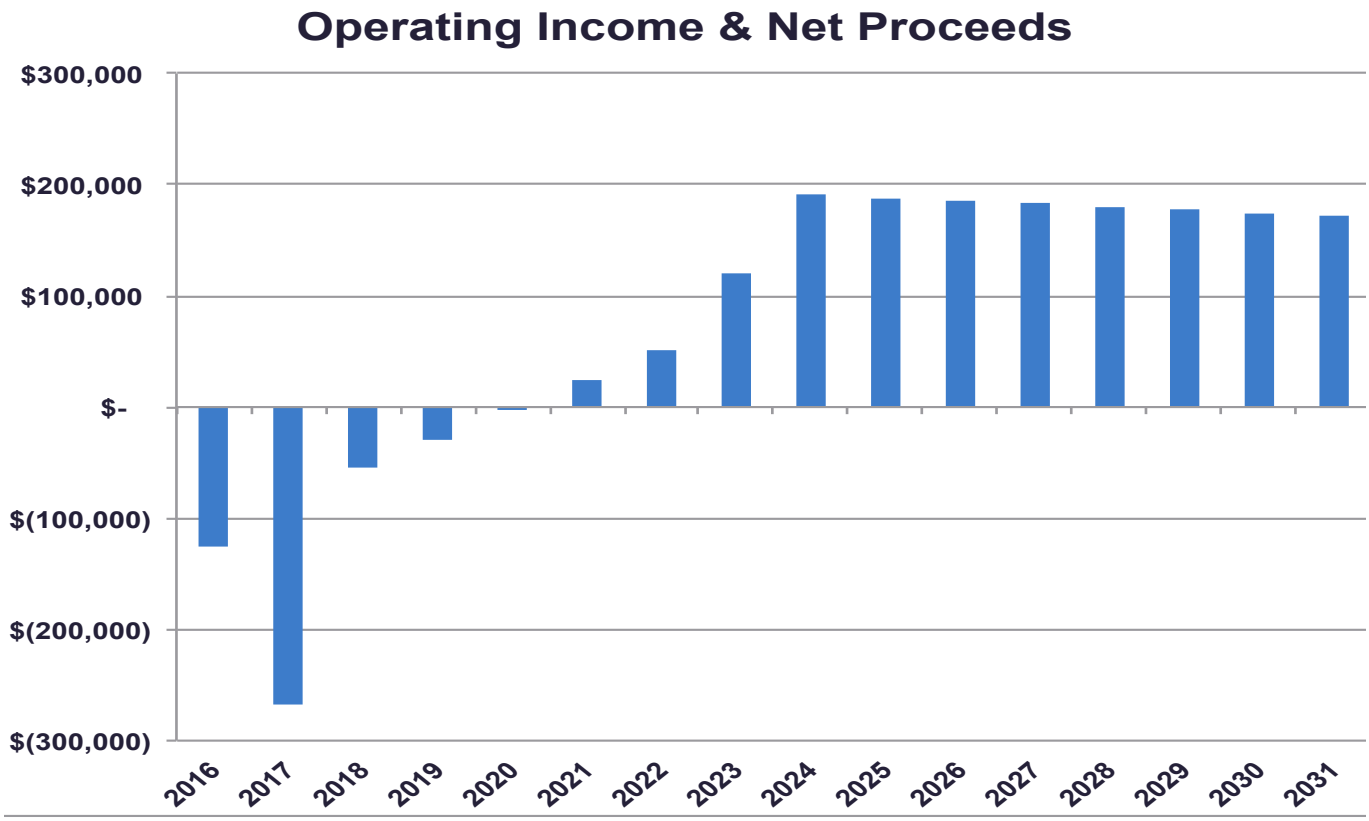


Figure 9: Operating Income & Net Proceeds Projections



Appendix A: Municipal Fiber Case Studies

1.0 Santa Monica CityNet

Community Overview

The City of Santa Monica is a beachfront city in Los Angeles County, California. Santa Monica is home to approximately 91,812 people across 8.3 square miles, giving it a population density of 10,662 people per square mile. The city has approximately 50,192 households with a median household income of $71,400. With a mild and agreeable climate, Santa Monica has long been a resort town and home to many people involved with the Hollywood entertainment industry. The City has experienced a boom since the 1990s with the revitalization of its downtown core, along with significant job growth and increased tourism.

The City of Santa Monica has grown its fiber business steadily over the past five years and in conjunction with technology programs that reduce costs for the government itself. Connecting community anchors provided Santa Monica valuable anchor tenants that helped build the business case for its fiber expansions. The City accommodated future investment in its network by setting a policy that reinvested any excess revenues and savings that the network generated back into expanding the network. The City successfully markets its fiber services in Santa Monica and provides a list of "lit buildings" where fiber connections are available.

Development of the Initial Network

In 2002, when the City renewed its franchise with the local cable provider, it also included as a provision to the agreement a lease of fiber-optic network capacity to connect 43 city sites and a variety of school and community college sites. The City paid upfront construction costs of $530,000 and shared the ongoing costs of the network with the schools and community college. These organizations saved a combined $400,000 in annual telecommunications costs which grew to $500,000 over several years.

The savings were used as seed capital for the development of the City's own fiber-optic network. The City invested in fiber connectivity and 10 Gigabit networking equipment to power the network. The City expanded its own fiber to connect traffic signals, surveillance cameras, smart signs, and other municipal applications to the network. As the network grew, the City built fiber into local data centers for its own Internet connectivity needs, but this quickly became a resource that created demand for business connectivity using Santa Monica's fiber.

Development of Broadband Services

The City began leasing its fiber network to local businesses in 2006. Larger businesses became the first users of Santa Monica's fiber to establish connectivity between their locations within the City. In most cases, these businesses paid the upfront costs for fiber extensions from the City's current network to reach their facilities. The City connected about 15 customers to its network initially between 2006 and 2008. The

City started a marketing campaign to determine the demand for City fiber from the small and medium business community. The campaign focused on businesses in close proximity to the City's current network, surveying about 3,000 businesses within 200 feet of the current network. The results indicated that there was demand for the City's fiber; however, businesses were looking for a complete solution for their Internet services, rather than just dark or lit fiber.

The City realized the demand for these services warranted the investment in building an Internet infrastructure capable of providing commercial Internet services to businesses. The City leased a wholesale Internet circuit connected to the One Wilshire colocation facility in downtown Los Angeles and purchased equipment necessary to provide Internet services. It chose to enable both direct Internet services and open access services as part of its offering, which allowed other providers to utilize its network to deliver Internet access to businesses in the City. The City now offers a combination of dark fiber, transport, and Internet access services to organizations in Santa Monica.

Today, 126 businesses are currently connected to CityNet and approximately five additional ones are added on a monthly basis. CityNet has also been successful with its MDU strategy. Facing high vacancy rates, the City encouraged property owners to install fiber cabling into their buildings as a way to entice tenants to occupy commercial properties. CityNet heavily discounted the cost of installing, operating, and maintaining fiber infrastructure into buildings if the owners passed that savings directly to potential tenants and aggressively marketed the gigabit broadband service. The City reported increases in tax revenues and commercial property values for parcels that were equipped with fiber. The network covers approximately eight square miles of Santa Monica and soon will be delivering up to 100Gbps per second of symmetrical broadband access. Prices for services are negotiated for each business customer individually.

Impact to the Community

Santa Monica's CityNet fiber network was able to achieve the following goals for the community:

- Lower costs of Internet access for the City and schools
- Centralize or integrate municipal services through core data systems
- Establish free WiFi in 35 public hot zones as well as distribute 375 computers in kiosks and libraries in town for free access
- Nurture existing businesses, attract new businesses, support startups, VCs, and incubators
- Create an environment for other incumbents to invest in City infrastructure. The City has no plans to provide residential service to its 90,000 people

Challenges

Santa Monica faced challenges in providing only dark fiber services to local businesses. As demand for high-speed Internet services grew over the past five years, small and medium businesses desired an affordable Internet solution that was enabled by a single provider. This differed from Santa Monica's model of providing simply dark fiber or bandwidth services to local businesses. While larger organizations had IT staff capable of managing dark fiber and bandwidth, small and medium businesses looked for a solution that was handled directly by the provider, as many of them lacked the sufficient resources to manage dark fiber alone. The struggle Santa Monica faced was maintaining lean operations and a "hands off" approach while

still serving a range of business customers. Retail was a new business model that Santa Monica had not encountered yet. This required Santa Monica to "change its thinking" and to have true impact in the small and medium business market, it made the decision to offer direct Internet services as part of its portfolio of services.

2.0 Palm Coast FiberNET

Community Overview

Palm Coast is a city of 75,000 residents in northeast Florida about an hour south of Jacksonville. The City provides a wide range of services including development services, fire services, street construction and maintenance, parks and recreational activities. Palm Coast contracts with the Flagler County Sheriff's Office for law enforcement services. The municipality's number one goal is to "Provide quality services, maintaining the City's financial soundness." From this goal emerged several initiatives designed to provide a greater level of service and an expansion of capabilities while reducing the government's costs. Information Technology has been a key driver for innovation and increased efficiencies across various departments.

Development of the Initial Network

In 2006, the Palm Coast City Council approved a 5-Year fiber-optic deployment project funded at $500,000 annually for a total investment of $3.2 million. The network was developed to support growing municipal technology needs across all public organizations in the area, including city, county, public safety, and education. It was also planned to support key initiatives such as emergency operations, traffic signalization, collaboration, and video monitoring.

Palm Coast utilized a phased approach to build its network using cost-reducing opportunities to invest in new fiber-optic infrastructure. As each phase was constructed, the City connected its own facilities and coordinated with other public organizations to connect them, incrementally reducing costs for all organizations connected to the network. Showing a reasonable payback from each stage of investment allowed the City to continue to fund future expansion of the network. About $500,000 in annual funding was appropriated from the general fund each year to build various components of the backbone network. The City achieved offsetting cost reductions by disconnecting its current connections with telecom providers in the area.

Through deployment of this network over the 5-year period, the city realized a savings of nearly $1 million since 2007 and projects further annual operating savings of $350,000 annually. In addition to these savings, the network provides valuable new capabilities that enhance its mission of serving the residents and businesses of the community.

Development of Broadband Services

Palm Coast experienced staggering population growth between 2000 and 2010, which nearly doubled its size; however, the housing downturn in the late 1990s hit the City particularly hard. Palm Coast's economy suffered from this retraction and the City began a program in 2006 to stimulate economic development.

Palm Coast determined that its network could provide enhanced benefits to economic development and launched a program to take its network commercial. The City evaluated the opportunities to use its network to expand broadband services, particularly focused on retaining local businesses. The City developed a business plan to expand its network in cooperation with local service providers and executed this plan to deploy the network in 2007.

The City employed an open-access business model whereby the City provided the physical fiber-optic network and electronics to connect broadband providers with individual businesses in key serving areas of the community. Broadband providers were charged monthly access fees based on the speed (bandwidth) of the service required by the business. The City builds new connections from its current fiber network to individual businesses, deploys premise equipment to businesses, and interconnects broadband providers to them. Broadband providers are responsible to market, sell and manage all retail services on the network and pay the City access fees to utilize the system, on a per customer basis.

As FiberNET was deployed, the City realized that its network could become a significant resource for other public organizations in Flagler County. In 2009, the City bid and won a competitive E-Rate contract with the Flagler County School Board to provide Gigabit and 10 Gigabit fiber services to 16 county schools. The City incurred a $250,000 upfront cost to extend the network to these schools and generates about $300,000 in annual revenue from this contract. In addition, the City has connected Flagler County offices and various other public organizations that make use of the competitively priced fiber services. In 2010, the local hospital contracted with the City to provide Gigabit connectivity to its main campus in Palm Coast and upgraded fiber connectivity to eight of its affiliated doctor's offices throughout the community. This provided significant upgrades for each local doctor's office and reduced each office's costs from approximately $750 to $300 per month.

The City manages FiberNET through its internal Information Technology Department. FiberNET is managed by shared staff resources within IT, providing technical expertise, engineering, customer management, provider management and related services for FiberNET; approximately two full time employees manage FiberNET today. The City outsources operations and management of the physical fiber-optic network to a local fiber contractor who provides design, construction, repair and maintenance.

Impact to the Community

In a market where local fiber was scarce and unaffordable for all but the largest businesses, Palm Coast FiberNET now provides cost-effective fiber access for as little as $50 per month for a 10Mbps connection. Service providers utilize the network to deliver Internet and business communications services for significantly lower costs than were previously available. FiberNET has reduced the costs of business Internet services across the city by 30%. The City has enabled new competition and introduced a competitively priced fiber product into the wholesale market within Palm Coast. Doing so has enabled competition among local providers using the network and the local incumbents.

Most recently, the Allier Fiber Backbone, a long-haul fiber network that interconnects Miami to Atlanta has been integrated into Palm Coast FiberNET, and providers connected to Allied Fiber have now entered the Palm Coast market. This further diversifies the competitive landscape in Palm Coast and enables local businesses more choices for their broadband needs. FiberNET has four providers operating on its network to date, two of which are new to the Palm Coast market. Key benefits include:

- Multi-use network connecting city, county, school, healthcare, and support organizations
- Reduced overall government spend by nearly $1 million per year
- Lowered business Internet costs by 30% across the city
- Reduced education spending by $300,000 annually
- Upgraded education services to 1 and 10 Gbps speeds
- Secured future bandwidth needs for the community, 100 Gigabit and beyond
- Financially sustainable, cash flow positive within 6 years
- Expanded competition, choice and availability of broadband services for local businesses
- Increased reliability, performance and availability of fiber broadband across the City
- Introduced two new service providers to the Palm Coast market
- Reinvested system revenues into expand the network to cover more of the City's geography
- Future-proofed local business needs with speeds up to 10 Gigabit
- Secured future bandwidth needs for the community, 100 Gigabit and beyond

Challenges

Palm Coast has struggled with developing the business case for new fiber connections in circumstances where local businesses are not in close proximity to the network. FiberNET attempts to set rates for fiber services consistently across the City so that broadband providers pay the same wholesale rates across the entire service area of the network. This ensures that Palm Coast businesses pay consistent costs for their broadband services, regardless of location.

The municipality has experienced some issues with its broadband providers in building new fiber connections that may not present a strong business case. In these cases, the costs for fiber connections exceed the City's payback threshold; however, the broadband provider has customers ready to subscribe for service. Fox example, a new 2,500 foot fiber connection to a business costs the City $20,000 in construction costs with a revenue opportunity of only $1,200 per year, which results in a payback of 16.6 years.

Palm Coast must make the decision whether to build out to this customer in line with City's overall goals of supporting local economic development. In some cases, where the payback has been beyond the City's threshold, it has opted to not build the connections; however, in most cases the City has proceeded with these connections. In some cases, the City has declined to build where these connections are infeasible and the revenues generated do not achieve a reasonable payback on the investment. In most cases, the City has been successful at building out these connections; however, this has been a recurring issue facing FiberNET and several other municipally owned networks. General connection costs range from $2,500 to $10,000 per business and the City is looking at ways of reducing these costs through alternative construction methods.

Appendix B: Glossary

3G – Third Generation	The third generation of mobile broadband technology, used by smart phones, tablets, and other mobile devices to access the web.
4G – Fourth Generation	The fourth generation of mobile broadband technology, used by smart phones, tablets, and other mobile devices to access the web.
ADSL – Asymmetric Digital Subscriber Line	DSL service with a larger portion of the capacity devoted to downstream communications, less to upstream. Typically thought of as a residential service.
ADSS – All-Dieletric Self-Supporting	A type of optical fiber cable that contains no conductive metal elements.
AMR/AMI – Automatic Meter Reading/Advanced Metering Infrastructure	Electrical meters that measure more than simple consumption and an associated communication network to report the measurements.
ATM – Asynchronous Transfer Mode	A data service offering that can be used for interconnection of customer's LAN. ATM provides service from 1 Mbps to 145 Mbps utilizing Cell Relay Packets.
Bandwidth	The amount of data transmitted in a given amount of time; usually measured in bits per second, kilobits per second (kbps), and Megabits per second (Mbps).
Bit	A single unit of data, either a one or a zero. In the world of broadband, bits are used to refer to the amount of transmitted data. A kilobit (Kb) is approximately 1,000 bits. A Megabit (Mb) is approximately 1,000,000 bits. There are 8 bits in a byte (which is the unit used to measure storage space), therefore a 1 Mbps connection takes about 8 seconds to transfer 1 megabyte of data (about the size of a typical digital camera photo).
BPL – Broadband over Powerline	A technology that provides broadband service over existing electrical power lines.
BPON – Broadband Passive Optical Network	BPON is a point-to-multipoint fiber-lean architecture network system which uses passive splitters to deliver signals to multiple users. Instead of running a separate strand of fiber from the CO to every customer, BPON uses a single strand of fiber to serve up to 32 subscribers.
Broadband	A descriptive term for evolving digital technologies that provide consumers with integrated access to voice, high-speed data service, video-demand services, and interactive delivery services (e.g. DSL, Cable Internet).
CAD – Computer Aided Design	The use of computer systems to assist in the creation, modification, analysis, or optimization of a design.
CAI – Community Anchor Institutions	The National Telecommunications and Information Administration defined CAIs in its SBDD program as "Schools, libraries, medical and healthcare providers, public safety entities, community colleges and other institutions of higher education, and other community support organizations and entities". Universities, colleges,

	community colleges, K-12 schools, libraries, health care facilities, social service providers, public safety entities, government and municipal offices are all community anchor institutions.
CAP – Competitive Access Provider	(or “Bypass Carrier”) A Company that provides network links between the customer and the Inter-Exchange Carrier or even directly to the Internet Service Provider. CAPs operate private networks independent of Local Exchange Carriers.
Cellular	A mobile communications system that uses a combination of radio transmission and conventional telephone switching to permit telephone communications to and from mobile users within a specified area.
CLEC – Competitive Local Exchange Carrier	Wireline service provider that is authorized under state and Federal rules to compete with ILECs to provide local telephone service. CLECs provide telephone services in one of three ways or a combination thereof: 1) by building or rebuilding telecommunications facilities of their own, 2) by leasing capacity from another local telephone company (typically an ILEC) and reselling it, and 3) by leasing discrete parts of the ILEC network referred to as UNEs.
CO – Central Office	A circuit switch where the phone lines in a geographical area come together, usually housed in a small building.
Coaxial Cable	A type of cable that can carry large amounts of bandwidth over long distances. Cable TV and cable modem service both utilize this technology.
CPE – Customer Premise Equipment	Any terminal and associated equipment located at a subscriber's premises and connected with a carrier's telecommunication channel at the demarcation point ("demarc").
CWDM – Coarse Wavelength Division Multiplexing	A technology similar to DWDM only utilizing less wavelengths in a more customer-facing application whereby less bandwidth is required per fiber.
Demarcation Point (“demarc”)	The point at which the public switched telephone network ends and connects with the customer's on-premises wiring.
Dial-Up	A technology that provides customers with access to the Internet over an existing telephone line.
DLEC – Data Local Exchange Carrier	DLECs deliver high-speed access to the Internet, not voice. Examples of DLECs include Covad, Northpoint and Rhythms.
Downstream	Data flowing from the Internet to a computer (Surfing the net, getting E-mail, downloading a file).
DSL – Digital Subscriber Line	The use of a copper telephone line to deliver “always on” broadband Internet service.
DSLAM – Digital Subscriber Line Access Multiplier	A piece of technology installed at a telephone company’s Central Office (CO) and connects the carrier to the subscriber loop (and ultimately the customer’s PC).

DWDM – Dense Wavelength Division Multiplexing	An optical technology used to increase bandwidth over existing fiber-optic networks. DWDM works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fiber. In effect, one fiber is transformed into multiple virtual fibers.
E-Rate	A Federal program that provides subsidy for voice and data circuits as well as internal network connections to qualified schools and libraries. The subsidy is based on a percentage designated by the FCC.
EON – Ethernet Optical Network	The use of Ethernet LAN packets running over a fiber network.
EvDO – Evolution Data Only	EvDO is a wireless technology that provides data connections that are 10 times as fast as a traditional modem. This has been overtaken by 4G LTE.
FCC – Federal Communications Commission	A Federal regulatory agency that is responsible for regulating interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Rock Falls, and U.S. territories.
FDH – Fiber Distribution Hub	A connection and distribution point for optical fiber cables.
FTTN – Fiber to the Neighborhood	A hybrid network architecture involving optical fiber from the carrier network, terminating in a neighborhood cabinet with converts the signal from optical to electrical.
FTTP – Fiber to the premise (or FTTB – Fiber to the building)	A fiber-optic system that connects directly from the carrier network to the user premises.
GIS – Geographic Information Systems	A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.
GPON- Gigabit-Capable Passive Optical Network	Similar to BPON, GPON allows for greater bandwidth through the use of a faster approach (up to 2.5 Gbps in current products) than BPON.
GPS – Global Positioning System	a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
GSM – Global System for Mobile Communications	This is the current radio/telephone standard developed in Europe and implemented globally except in Japan and South Korea.
HD – High Definition (Video)	Video of substantially higher resolution than standard definition.
HFC – Hybrid Fiber Coaxial	An outside plant distribution cabling concept employing both fiber-optic and coaxial cable.
ICT – Information and Communications Technology	Often used as an extended synonym for information technology (IT), but it is more specific term that stresses the role of unified communications and the integration of telecommunications, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.

IEEE – Institute of Electrical Engineers	A professional association headquartered in New York City that is dedicated to advancing technological innovation and excellence.
ILEC – Incumbent Local Exchange Carrier	The traditional wireline telephone service providers within defined geographic areas. Prior to 1996, ILECs operated as monopolies having exclusive right and responsibility for providing local and local toll telephone service within LATAs.
IP-VPN – Internet Protocol-Virtual Private Network	A software-defined network offering the appearance, functionality, and usefulness of a dedicated private network.
ISDN – Integrated Services Digital Network	An alternative method to simultaneously carry voice, data, and other traffic, using the switched telephone network.
ISP – Internet Service Provider	A company providing Internet access to consumers and businesses, acting as a bridge between customer (end-user) and infrastructure owners for dial-up, cable modem and DSL services.
ITS – Intelligent Traffic System	Advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.
Kbps – Kilobits per second	1,000 bits per second. A measure of how fast data can be transmitted.
LAN – Local Area Network	A geographically localized network consisting of both hardware and software. The network can link workstations within a building or multiple computers with a single wireless Internet connection.
LATA – Local Access and Transport Areas	A geographic area within a divested Regional Bell Operating Company is permitted to offer exchange telecommunications and exchange access service. Calls between LATAs are often thought of as long distance service. Calls within a LATA (IntraLATA) typically include local and local toll services.
Local Loop	A generic term for the connection between the customer's premises (home, office, etc.) and the provider's serving central office. Historically, this has been a copper wire connection; but in many areas it has transitioned to fiber optic. Also, wireless options are increasingly available for local loop capacity.
MAN – Metropolitan Area Network	A high-speed intra-city network that links multiple locations with a campus, city or LATA. A MAN typically extends as far as 30 miles.
Mbps – Megabits per second	1,000,000 bits per second. A measure of how fast data can be transmitted.
MPLS – Multiprotocol Label Switching	A mechanism in high-performance telecommunications networks that directs data from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table.
ONT – Optical Network Terminal	Used to terminate the fiber-optic line, demultiplex the signal into its component parts (voice telephone, television, and Internet), and provide power to customer telephones.
Overbuilding	The practice of building excess capacity. In this context, it involves investment in additional infrastructure projects to provide

	competition.
OVS – Open Video Systems	OVS is a new option for those looking to offer cable television service outside the current framework of traditional regulation. It would allow more flexibility in providing service by reducing the build out requirements of new carriers.
PON – Passive Optical Network	A Passive Optical Network consists of an optical line terminator located at the Central Office and a set of associated optical network terminals located at the customer's premise. Between them lies the optical distribution network comprised of fibers and passive splitters or couplers. In a PON network, a single piece of fiber can be run from the serving exchange out to a subdivision or office park, and then individual fiber strands to each building or serving equipment can be split from the main fiber using passive splitters / couplers. This allows for an expensive piece of fiber cable from the exchange to the customer to be shared amongst many customers, thereby dramatically lowering the overall costs of deployment for fiber to the business (FTTB) or fiber to the home (FTTH) applications.
PPP – Public-Private Partnership	A Public–Private Partnership (PPP) is a government service or private business venture that is funded and operated through a collaborative partnership between a government and one or more private sector organizations. In addition to being referred to as a PPP, they are sometimes called a P3, or P^3.
QOS – Quality of Service	QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results, which are reflected in Service Level Agreements or SLAs. Elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and error rate. QoS involves prioritization of network traffic.
RF – Radio Frequency	a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals.
Right-of-Way	A legal right of passage over land owned by another. Carriers and service providers must obtain right-of-way to dig trenches or plant poles for cable systems, and to place wireless antennae.
RMS – Resource Management System	A system used to track telecommunications assets.
RPR – Resilient Packet Ring	Also known as IEEE 802.17, is a protocol standard designed for the optimized transport of data traffic over optical fiber ring networks.
RUS – Rural Utility Service	A division of the United States Department of Agriculture, it promotes universal service in unserved and underserved areas of the country with grants, loans, and financing. Formerly known as "REA" or the Rural Electrification Administration.
SCADA – Supervisory Control and Data Acquisition	A type of industrial control system (ICS). Industrial control systems are computer controlled systems that monitor and control

	industrial processes that exist in the physical world.
SNMP – Simple Network Management Protocol	An Internet-standard protocol for managing devices on IP networks.
SONET – Synchronous Optical Network	A family of fiber-optic transmission rates.
Steaming	Streamed data is any information/data that is delivered from a server to a host where the data represents information that must be delivered in real time. This could be video, audio, graphics, slide shows, web tours, combinations of these, or any other real time application.
Subscribership	Subscribership is how many customers have subscribed for a particular telecommunications service.
Switched Network	A domestic telecommunications network usually accessed by telephone, key telephone systems, private branch exchange trunks, and data arrangements.
T-1 – Trunk Level 1	A digital transmission link with a total signaling speed of 1.544 Mbps. It is a standard for digital transmission in North America.
T-3 – Trunk Level 3	28 T1 lines or 44.736 Mbps.
UNE – Unbundled Network Element	Leased portions of a carrier's (typically an ILEC's) network used by another carrier to provide service to customers. Over time, the obligation to provide UNEs has been greatly narrowed, such that the most common UNE now is the UNE-Loop.
Universal Service	The idea of providing every home in the United States with basic telephone service.
Upstream	Data flowing from your computer to the Internet (sending E-mail, uploading a file).
UPS – Uninterruptable Power Supply	An electrical apparatus that provides emergency power to a load when the input power source, typically main power, fails.
USAC – Universal Service Administrative Company	An independent American nonprofit corporation designated as the administrator of the Federal Universal Service Fund (USF) by the Federal Communications Commission.
VDSL – Very High Data Rate Digital Subscriber Line	A developing digital subscriber line (DSL) technology providing data transmission faster than ADSL over a single flat untwisted or twisted pair of copper wires (up to 52 Mbit/s downstream and 16 Mbit/s upstream), and on coaxial cable (up to 85 Mbit/s down and upstream); using the frequency band from 25 kHz to 12 MHz.
Video on Demand	A service that allows users to remotely choose a movie from a digital library whenever they like and be able to pause, fast-forward, and rewind their selection.
VLAN – Virtual Local Area Network	In computer networking, a single layer-2 network may be partitioned to create multiple distinct broadcast domains, which are mutually isolated so that packets can only pass between them via one or more routers; such a domain is referred to as a Virtual Local Area Network, Virtual LAN or VLAN.
VoIP – Voice over Internet Protocol	An application that employs a data network (using a broadband connection) to transmit voice conversations using Internet

	Protocol.
VPN – Virtual Private Network	A virtual private network (VPN) extends a private network across a public network, such as the Internet. It enables a computer to send and receive data across shared or public networks as if it were directly connected to the private network, while benefitting from the functionality, security and management policies of the private network. This is done by establishing a virtual point-to-point connection through the use of dedicated connections, encryption, or a combination of the two.
WAN – Wide Area Network	A network that covers a broad area (i.e., any telecommunications network that links across metropolitan, regional, or national boundaries) using private or public network transports.
WiFi	WiFi is a popular technology that allows an electronic device to exchange data or connect to the Internet wirelessly using radio waves. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards".
WiMax	WiMax is a wireless technology that provides high-throughput broadband connections over long distances. WiMax can be used for a number of applications, including “last mile” broadband connections, hotspot and cellular backhaul, and high speed enterprise connectivity for businesses.
Wireless	Telephone service transmitted via cellular, PCS, satellite, or other technologies that do not require the telephone to be connected to a land-based line.
Wireless Internet	1) Internet applications and access using mobile devices such as cell phones and palm devices. 2) Broadband Internet service provided via wireless connection, such as satellite or tower transmitters.
Wireline	Service based on infrastructure on or near the ground, such as copper telephone wires or coaxial cable underground or on telephone poles.