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July 9, 2019

BY ECFS

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Notice of *Ex Parte* Presentation of ACA Connects, GN Docket No. 18-122

Dear Ms. Dortch:

On July 8, 2019, Ross J. Lieberman, Senior Vice President, Government Affairs, ACA Connects – America's Communications Association ("ACA Connects"), Nikos Andrikogiannopoulos, Cartesian, Inc., Tunde Ibiyemi, Cartesian, Inc. (attendance by telephone), and the undersigned met with representatives from the Wireless Telecommunications Bureau, International Bureau, Office of Engineering and Technology, and Office of Economics and Analytics copied below.

In the meeting, ACA Connects presented the enclosed study it commissioned, which was referenced in the Joint Proposal filed by ACA Connects, Competitive Carriers Association, and Charter Communications, Inc. last week.[1] The study illustrates that at least 370 MHz of C-band spectrum can be cleared in an expedited timeframe for use by next generation wireless services while making whole and incentivizing stakeholders and benefiting the public. The study further illustrates the process and cost of clearing that spectrum, including transitioning video programmers and multichannel video programming distributor earth station users from C-band delivery to terrestrial fiber video delivery while ensuring that the remaining narrowband earth station end users can continue to utilize the C-band for an appropriate period with minimal disruption.

[1] *See* Letter from Ross Lieberman, ACA Connects – America's Communications Association, Alexi Maltas, Competitive Carriers Association, and Elizabeth Andrion, Charter Communications, Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122, at 5 (July 2, 2019) ("Joint Proposal").

Respectfully submitted,

/s/________________________
Pantelis Michalopoulos
Georgios Leris
Counsel for ACA Connects – America's Communications Association

Enclosure

CC: Donald Stockdale
Julius Knapp
Blaise Scinto
Max Staloff
Kerry Murray
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Anna Gentry
Kenneth Baker
Margaret Wiener
Lauren Earley
Michael Ha
Becky Schwartz
Thomas Derenge
Ira Keltz
Matt Pearl
Evan Kwerel*
Paul Powell*
Brian Wondrack*

*indicates attendance by telephone

C-band Spectrum Clearing Plan

Prepared for: ACA — America's Communications Association #ACAConnects

July 8, 2019

www.cartesian.com

Executive Summary

Our plan aims to support the clearing of at least 370 MHz of C-band spectrum in a timely manner over the United States

Our Spectrum Clearing Plan		
1. Amount of Spectrum	› **At least 370 MHz**	• At least 370 MHz throughout the United States, nearly twice the amount of the CBA proposal
2. Process	› **FCC-led Auction** › **Reimbursements** › **Incentives**	• An FCC-led auction, which may include an incentive auction • Programmers and MVPDs will switch from C-band to fiber delivery; satellite operators will continue to serve non-MVPD customers on the remaining C-band spectrum
3. Timing	Y1 Y2 Y3 Y4 Y5 › **Urban: 18 Months** › **Majority: 3 Years** › **Hard-to-reach Areas: Up to 5 Years**	• At least 370 MHz of spectrum in all urban markets (i.e. areas where 5G is expected to be first deployed) could be cleared in 18 months • Other markets to be cleared in 3 years, except in a few areas where fiber deployment is harder and clearance could take up to 5 years
4. Benefits	› **Up to $29 Billion** › **Rural Fiber Deployment** › **200K+ Jobs**	• Benefits to U.S. Treasury from auction's proceeds, direct/indirect new jobs creation, and socioeconomic benefits from increased fiber availability/capacity

Source: Cartesian, ACA Connects

Our Plan vs. CBA Plan

We propose a transparent process that delivers almost twice as much spectrum as the CBA proposal in a faster timeframe. Our plan also provides fiber connectivity in rural areas and proceeds to the U.S. Treasury

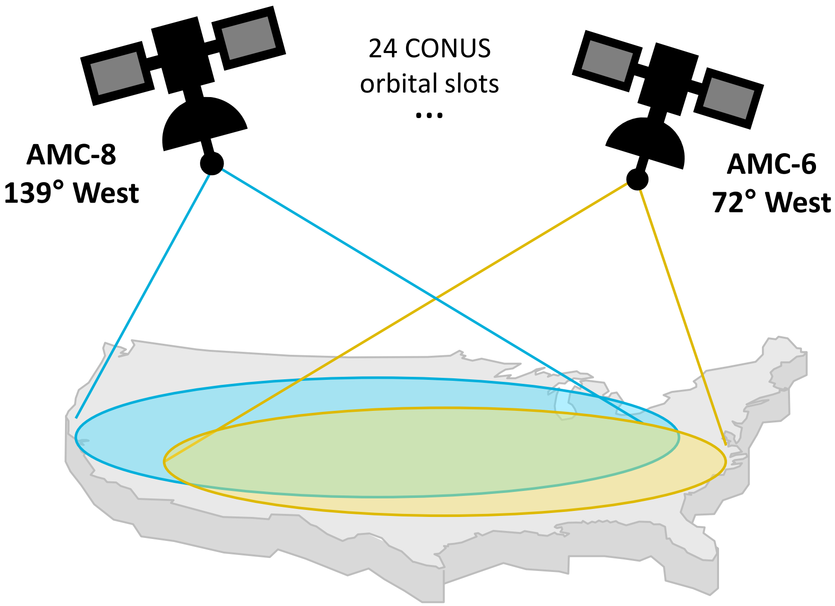
Our Plan	CBA Plan
Spectrum: At least 370 MHz	**Spectrum:** At most 200 MHz
Timing: 18 months in urban markets, within 3 years in most of country, and 5 years in hard-to-reach areas.	**Timing**: Within 3 years
Process: FCC-led auction	**Process:** Private sale
U.S. Treasury Proceeds: Up to $29B	**U.S. Treasury Proceeds:** $0
Satellite Launches: None needed within first 3 years	**Satellite Launches**: Needed within 3 years
Fiber Deployment: ~420K route miles of fiber	**Fiber Deployment:** 0 miles

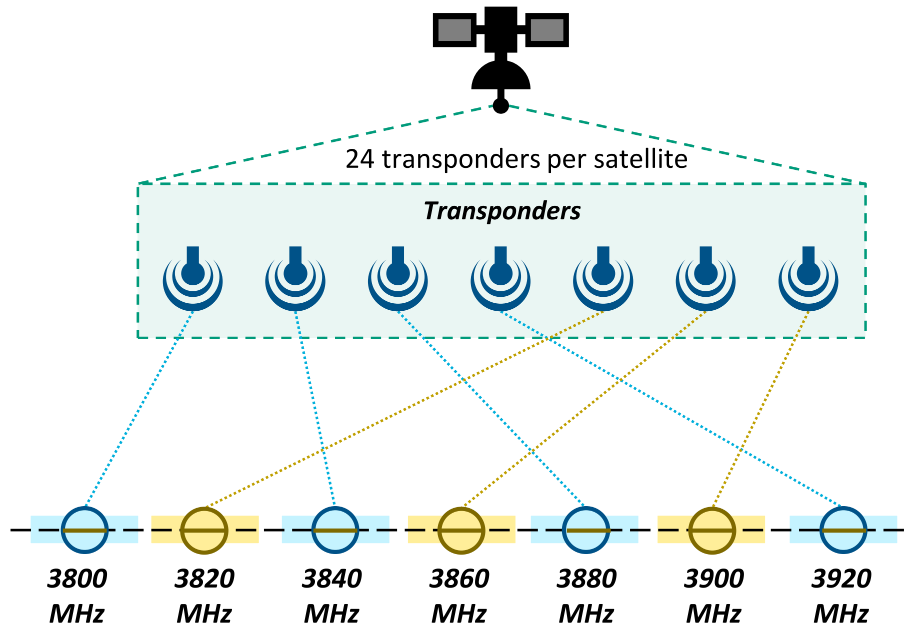
Source: Cartesian, ACA Connects

C-band Satellite Capacity

Each C-band satellite uses the entire 500 MHz through 24 transponders

C-band Transponders, Satellites & Orbital Slots





- *There are 24 orbital slots with CONUS coverage*
- *Each satellite utilizes the entire C-band, i.e. 500 MHz*
- *There are currently 23 in-orbit satellites plus spares*

- *Each satellite has 24 transponders, spaced 20 MHz apart from one another*
- *A satellite customer may need only a small fraction of a transponder*

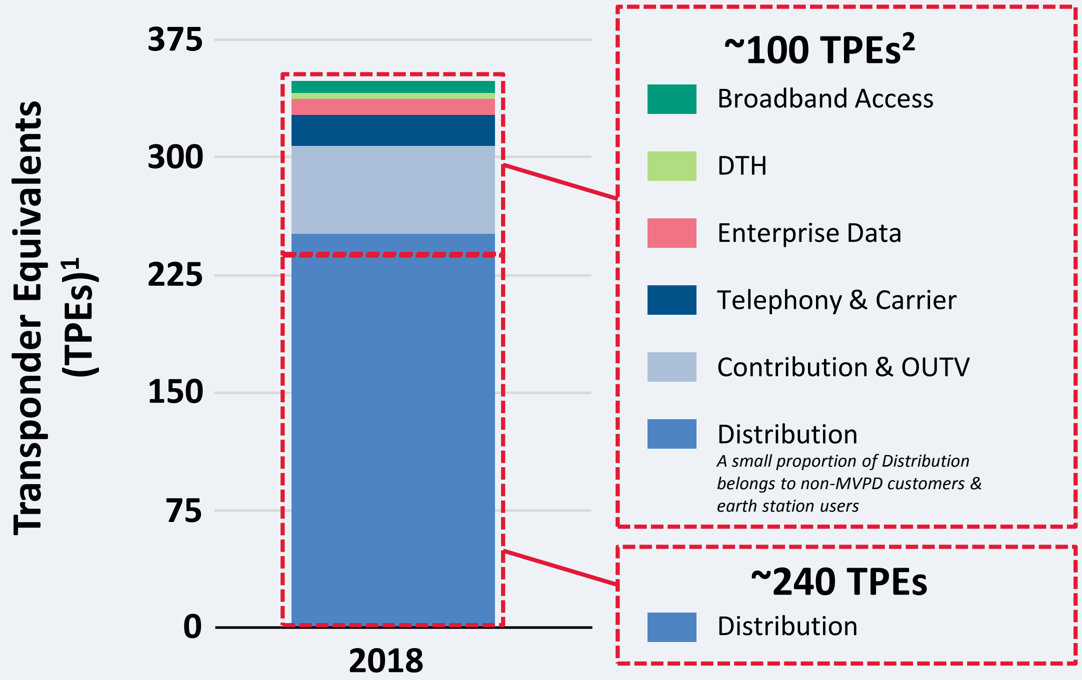
Shutting down one transponder on each satellite clears 20 MHz nationwide

Source: Cartesian, Intelsat, Northern Sky Research

How is the C-band Being Used?

MVPD Programming occupies ~70% of the C-band in use; providing MVPDs an alternative delivery platform provides a viable path to freeing up a large portion of spectrum

C-band Demand by Application



Up to ~70% of transponders' bandwidth is being utilized by Distribution, i.e. MVPDs

	MVPD	Non-MVPD
Estimated Number of TPEs	**~240**	**~100**
Estimated Number of Earth Stations	**~2.6K**	**~14K**

[1] Refers to number of transponders given bandwidth of 36 MHz per transponder
[2] We conservatively picked the higher of the two estimates (100 TPEs, 94 TPEs), see slide 35
Source: Ericsson/NSR, IBFS

130 MHz is more than enough to satisfy non-MVPD C-band demand

We estimate no more than 130 MHz is needed to support non-MVPD use, leaving at least 370 MHz free to be reallocated for 5G wireless services

Percentage Used *(%)* **X** **500 MHz** *of total available spectrum* **=**

Estimated Transponder Availability (TPEs)		Estimated Transponder Distribution (%)	Estimated Spectrum Required (MHz)
~138[2]	Non-MVPD	~25%	< 130 MHz
~240	MVPD	~43%	~ 220 MHz
~174	Unused	32%	> 150 MHz
552[1] (2018 Estimate)			

Available Transponder Equivalents (TPEs)

[1] Based on 23 in-service satellites times 24 transponders per satellite

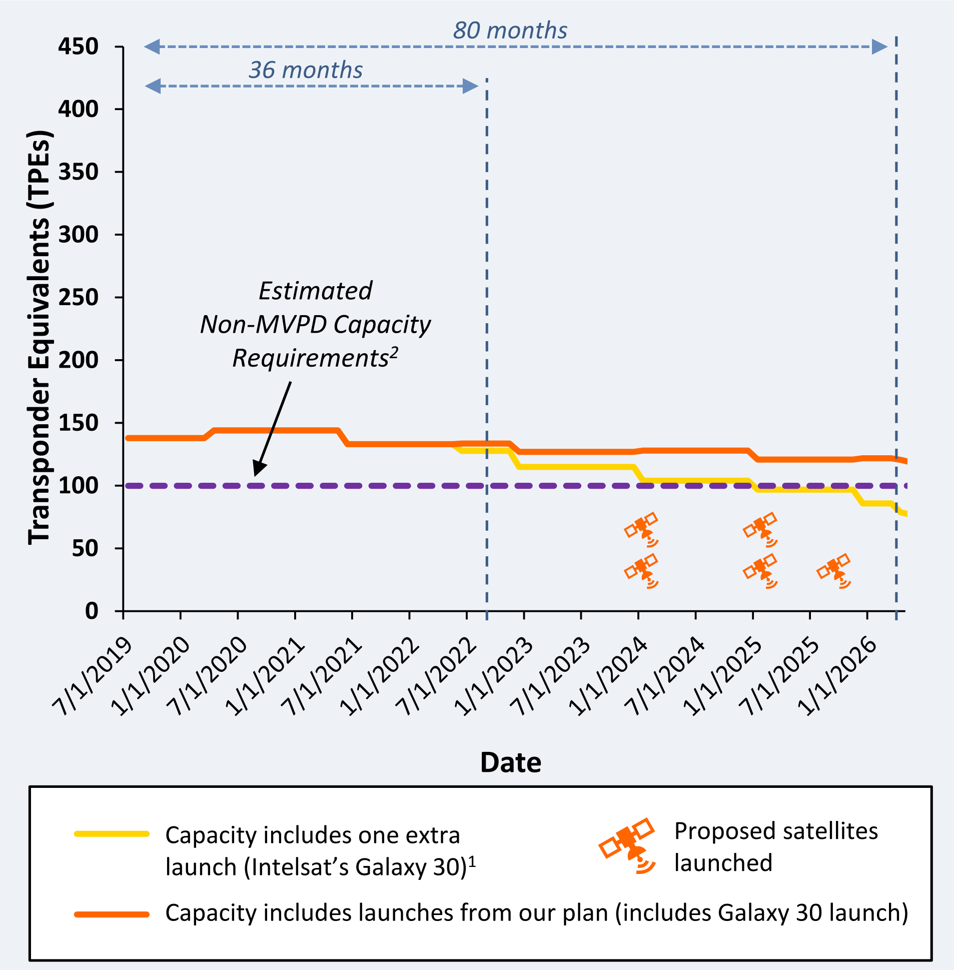
[2] Conservative estimate of supply based on 138 TPEs (6 transponders x 23 satellites) more than capable of addressing demand of 100 TPEs over the next few years

Source: Cartesian, LyngSat, Northern Sky Research, C-Band Alliance

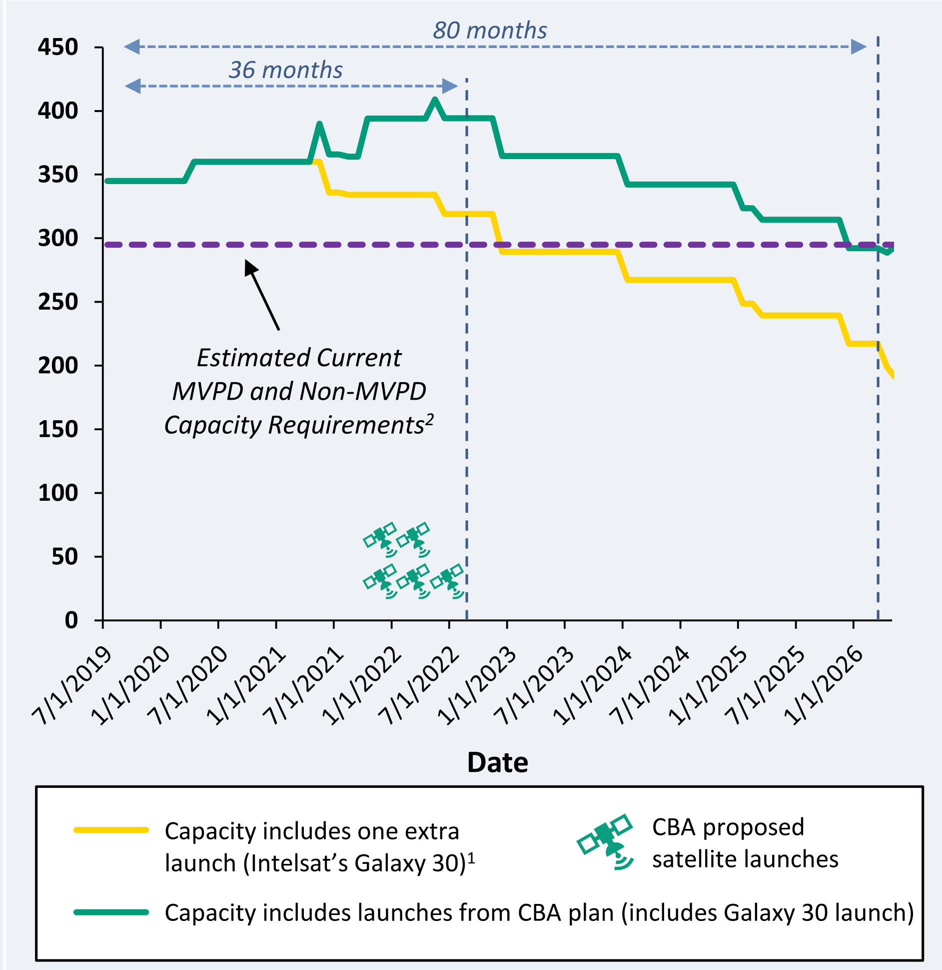
Ensuring C-band Supply Exceeds Demand (Our Plan vs. CBA Plan)

With the same number of satellite launches as the CBA plan, our plan can clear spectrum and meet customer demand without needing a satellite launch within the first 3 years

Our Plan



CBA Plan



[1] Based on average transponder payload of 24 per satellite launch and assumed 6 TPEs available in upper 130 MHz band

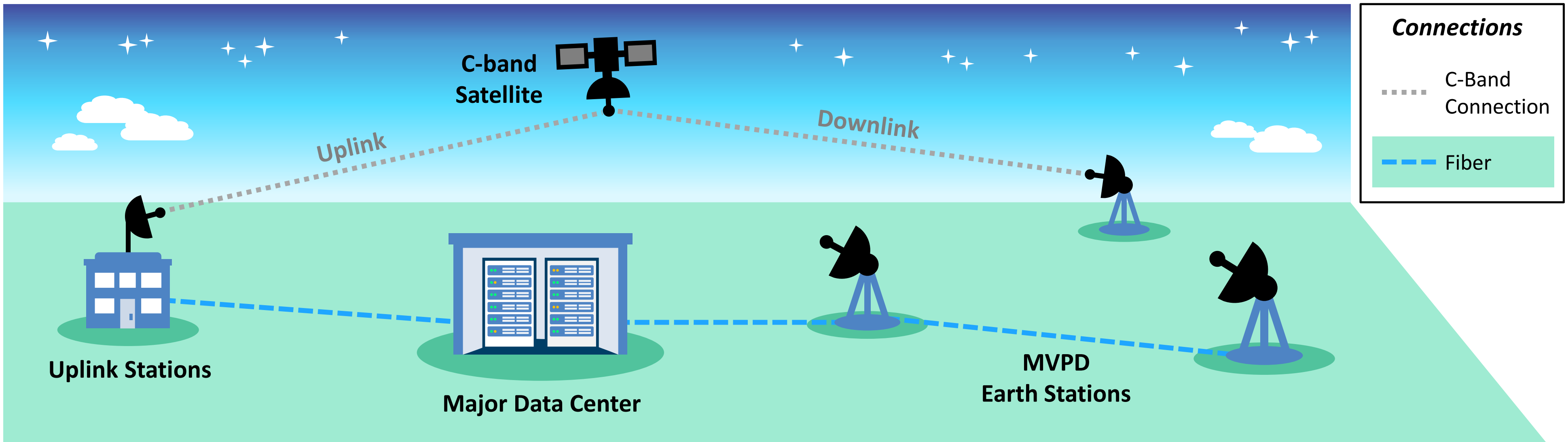
[2] We are conservatively using 100 TPEs for non-MVPD demand under our plan and the more recent lower estimate for the total demand under the CBA plan, i.e. 295 TPEs = 100 TPEs (non-MVPD) + 195 TPEs (MVPDs)

Source: Cartesian, LyngSat, Northern Sky Research, C-Band Alliance

Part 1: Transitioning the MVPD Industry from C-band to Fiber Video Delivery

Similar to how programmers and MVPDs transport programming via fiber today, they will deploy fiber to interconnect their headends and to peer in major data centers nationwide[1]

Terrestrial Fiber Video Delivery Model



Key Metrics:	$6.2 - 7.0B[2] NPV	2.6K+[3] MVPD Earth Stations	300K[4]+120K[5] Fiber Route Miles	10 Gbps Bandwidth

Programmers

Programmers, who already utilize fiber today to deliver their programming to uplink earth stations, will expand their use of fiber by purchasing IRUs and obtaining and installing equipment necessary to deliver (over redundant paths) their programming to 40 to 50 data centers across the country. Some programmers will also provide two C-band feeds for a limited time during the transition.

MVPD Earth Station Users

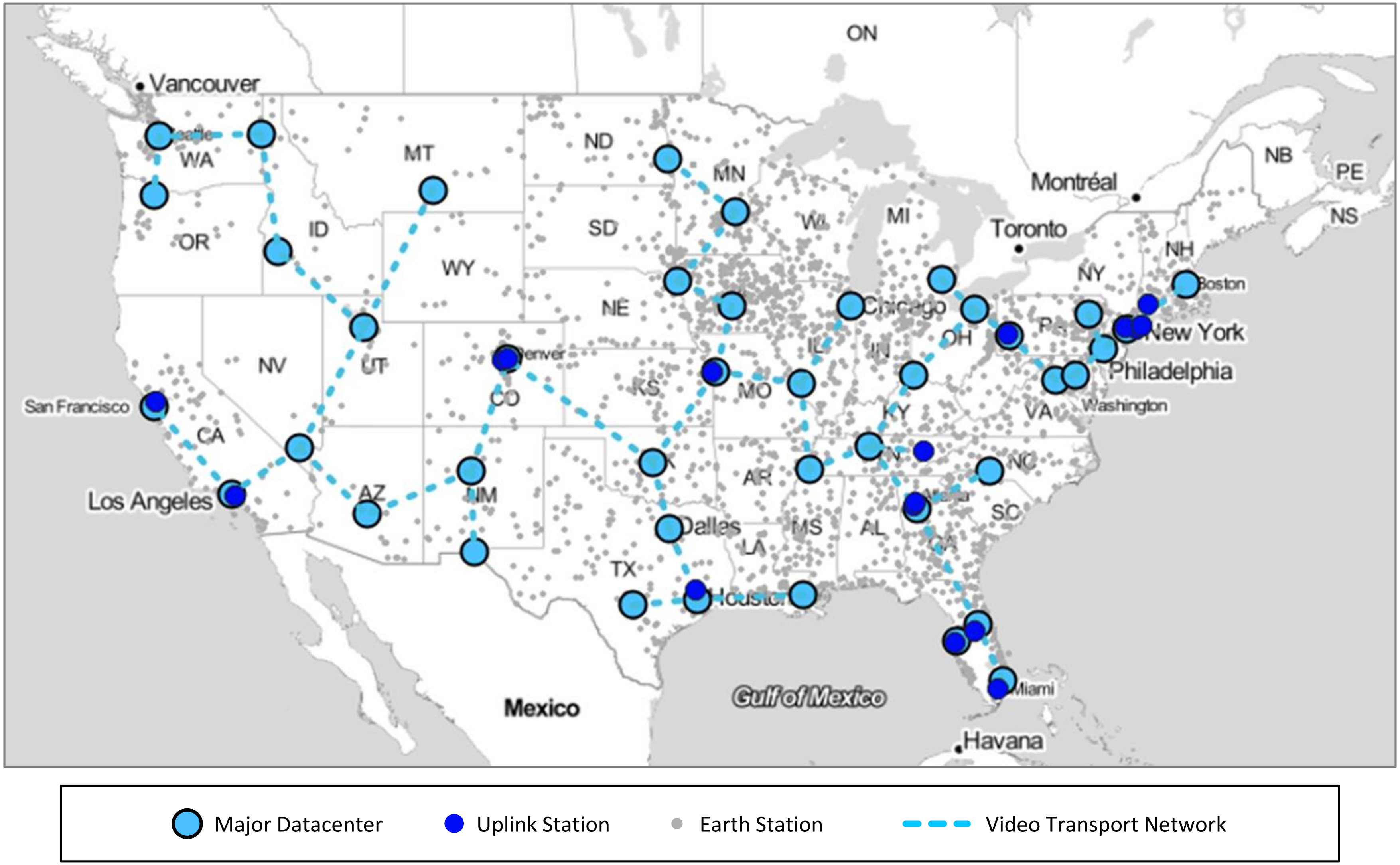
MVPD earth station users will purchase IRUs and deploy fiber (over redundant paths) to interconnect their headends and connect to data centers, and obtain and install equipment (e.g. multicast routers, transcoders, DRM) needed to deliver the transported programming to their headends. Some MVPD earth station users will need to repoint antennas while they establish fiber connectivity.

1. The plan provides for alternative delivery solutions in remote areas of Alaska where fiber deployment is not possible 2. Uses 8% cost of capital, 3. Model uses extrapolation to cover all MVPD subscribers, 4. Fiber obtained through IRU purchases, 5. Newly built fiber

Source: Cartesian, ACA Connects

Modeling Methodology: Video Transport Network

We used 42 existing data centers across the country to transport video content from uplink earth stations to endpoints closer to the earth stations

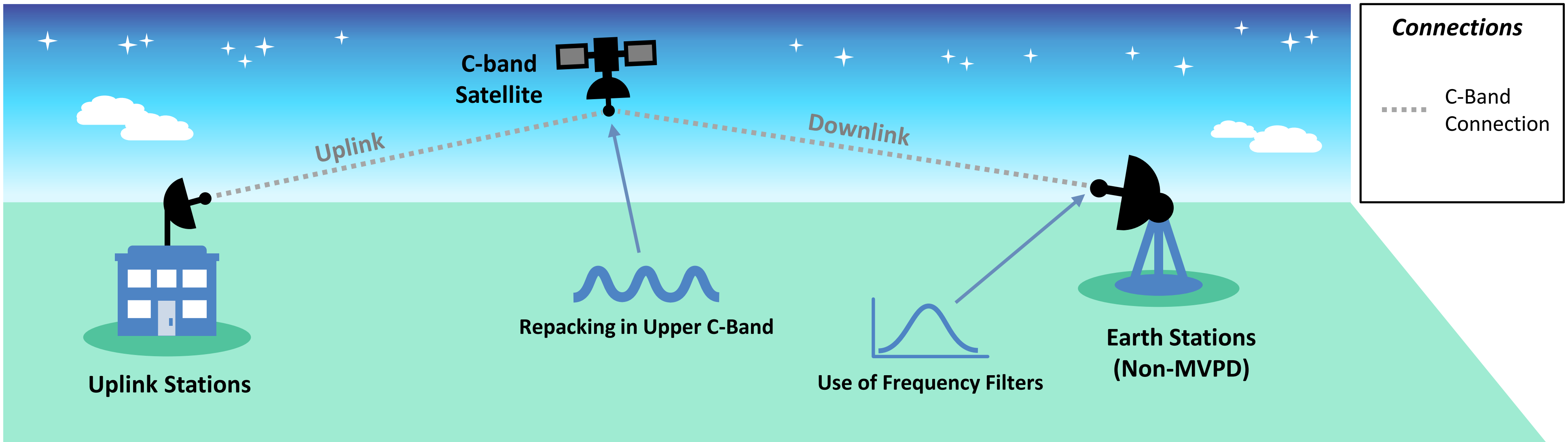


Source: Cartesian, IBFS Earth Stations Registrations, ACA Connects

Part 2: Taking care of Non-MVPD Customers & Earth Station Users

Non-MVPD C-band users will continue to use the C-band, after a transition comparable to the CBA plan, including repacking, antenna repointings and filter installations

Non-MVPD Satellite Services Delivery



Key Metrics:	$3 - 4B[1] Repacking + Satellite Launch Costs	~14K Non-MVPD Earth Stations	≤ 130 MHz C-band Spectrum

Satellite Operators

Similar to the CBA plan, non-MVPD satellite customers in the lower portion of the C-band will be repacked to the upper portion. No greater number of satellite launches needed compared to the CBA plan.

Non-MVPD Customers & Earth Station Users

Similar to the CBA plan, non-MVPD earth station users will repoint antennas, if needed, and receive filters to prevent interference form 5G users.

[1] Based on JP Morgan Spectrum & 5G Overview - March 2019. Includes provision for operational costs

Source: Cartesian, ACA Connects, Kerrisdale Analysis

Part 3: Timeline for Clearing Spectrum

Urban markets can be cleared within 18 months, most other markets within 3 years, and certain hard-to-build areas within 5 years

	Urban Markets	Majority of Remaining Markets	Hard–to-Build Areas
	Urban and other fiber-rich markets	*Suburban and other easy-to-build markets*	*Rural, remote and other hard-to-build markets*
Transitioning MVPDs to Fiber Delivery	*Programmers set up to peer in data centers, some migrate to lower portion of C-band. Urban MVPDs acquire fiber to interconnect. Non-urban MVPDs repoint antennas to migrated programmers in lower C-band.*	*Non-urban, MVPDs acquire and/or build fiber to interconnect.*	*Remaining MVPDs acquire and/or build fiber to interconnect. Programmers cease utilizing C-band at the end of this stage.*
Taking Care of Non-MVPD C-band Users	*Non-MVPD customers migrate to upper portion of C-band; Urban, Non-MVPD earth station users repoint antennas (as needed) and obtain filters.*	*Non-urban, non-MVPD earth station users repoint antennas (as needed) and obtain filters.*	*Remaining non-MVPD earth station users repoint antennas (as needed) and obtain filters.*
Replacement Satellite Launch			5 satellites to be launched in 7 years; no satellite launches needed until year 3, unlike CBA plan.

Year: 1 — 2 — 3 — 4 — 5

Programmers | MVPDs | Non-MVPDs | Satellite Operators

Source: Cartesian, ACA Connects

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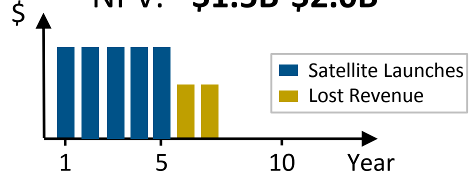
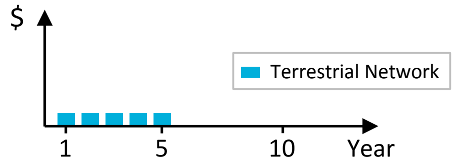
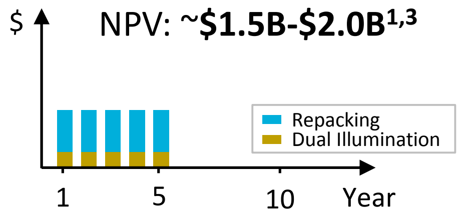
Costs to Be Reimbursed

Satellite operators and non-MVPD C-band users to be reimbursed for costs similar to those recognized under the CBA plan. Programmers and MVPDs to be reimbursed for costs to purchase or build fiber and switch to terrestrial fiber-based network

Stakeholder	Costs	Comments
Satellite Operators	NPV: ~**$1.5B-$2.0B**[1,2] (chart 1)	• Reimbursement of approximately $1.1 billion for new satellite launches to replace satellites reaching end of life. • Reimbursement of about $240M/year for two years of lost revenue from the programmers after the MVPD industry completes its transition to fiber in year five.
Programmers	NPV: **$200M+**[1,4] (chart 2)	• Reimbursement of an average $40M per year for the purchase of IRUs to deliver programming via fiber across 40-50 data centers for 5 years. ***Note**: Upon completion of the MVPD transition from satellite to fiber delivery in year five, the programming industry's annual video delivery cost will drop from the current $240M to only $40M.*
Non-MVPD C-band Users	NPV: ~**$1.5B-$2.0B**[1,3] (chart 3)	• Reimbursement of about $300-400M per year for the migration to the upper portion of the C-band, and to repoint antennas if needed, and install filters.
MVPD Earth Station Users	NPV: ~**$6.0B-$6.8B**[1]	• Reimbursement for fiber IRUs and new fiber deployment to allow delivery of programming between data centers and MVPD headends, among other costs.







Estimated Total Costs Needed from Auction Proceeds to Clear Spectrum: $9.2 – 11.0B[1]

[1] Totals are based on a 10-Year Net Present Value (NPV) using 8% cost of capital for fiber and 7-Year NPV for other items
[2] C-band revenues are estimated in the range of $340M-$400M annually; assuming 60-70% can be attributed to programmers, this is approx. $240M per year
[3] Estimate based on p.39 of Kerrisdale analysis
[4] In addition, programmers will be reimbursed for the use of two feeds during transition period
Source: Cartesian, ACA Connects, Ericsson, Kerrisdale Analysis, NSR

Incentive Payments & Commitments

Our plan balances incentives with commitments to ensure smooth operational transition for all involved C-band stakeholders

Stakeholder	Incentives	Commitments
Satellite Operators	• Satellite industry to receive all incentive payments (over and above 'make whole' payments) appropriate for the clearing of 200 MHz • Satellite industry to receive a portion of the incentive payments appropriate for clearing the C-band spectrum above 200 MHz	• Continue serving non-MVPD earth station operators over the remaining spectrum without price increases for extended period of time
MVPD Earth Station Users	• MVPD Earth Station Users to receive a portion of the incentive payments (over and above 'make whole' payments) appropriate for clearing the C-band spectrum above 200 MHz	• Forego the use of investments in C-band earth stations and equipment[1]

[1] See Coleman Bazelon, The Brattle Group, Maximizing the Value of the C-band, at 22 (attached as Appendix A to Joint Comments of Intel Corp., Intelsat License LLC, and SES Americom, Inc., GN Docket No. 18-122 (Oct. 29, 2018))

Note: The estimated cost of re-farming and transitioning the C-band could serve as the equivalent of a reserve price—i.e., no spectrum is cleared unless the proceeds from the 5G auction suffice to cover all estimated costs

Source: ACA Connects, JP Morgan Spectrum & 5G Overview - March 2019, T-Mobile's Refined C-band Incentive Auction Proposal

Plan Benefits – U.S. Treasury

The U.S. Treasury will significantly benefit up to $29B through the auction of C-band spectrum

	Value ($)	Comments
C-band Auction Proceeds	$30B - $37B	• Conservatively assumes $0.25 - $0.30 / MHz / PoP • 370 MHz of spectrum cleared and 325M population
Total Reimbursements	$9 – 11B	• See slide 12
Incentive Payments	TBD	• See slide 13
	Up to $29B in Benefits to U.S. Treasury	

Source: Cartesian, JPMorgan, ACA Connects

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Plan Benefits – Socioeconomic

Increased fiber connectivity in rural areas has several direct and indirect socioeconomic benefits arising from faster internet connectivity and dark fiber availability

Benefits of Increased Rural Fiber Connectivity

5G Backhauling

Accelerated Deployment of 5G Small Cells

Mobile operators place small cells in proximity to existing fiber networks

Internet Reliability

Increased Internet Reliability

Constructing multiple fiber routes increases redundancy level of internet backhauling links, offering protection from fiber cuts and service disruptions

Fiber Capacity

Increased Fiber Capacity

Putting more fiber into the ground allows for higher dark- and lit-fiber capacity in rural areas

Smart Grids

Enablement of Smart Grid & Smart Metering Applications

Power utilities have been increasingly upgrading their infrastructure, using dark fiber to connect their smart

Ultra-Fast Broadband

Ultra-Fast Broadband Benefits

Past Cartesian study estimated the socioeconomic benefit per household, which was grouped into six categories: e-work, e-health, e-learning, e-commerce, consumer video use, and cloud computing

Underserved Households

Increased Broadband Access to some Underserved Locations

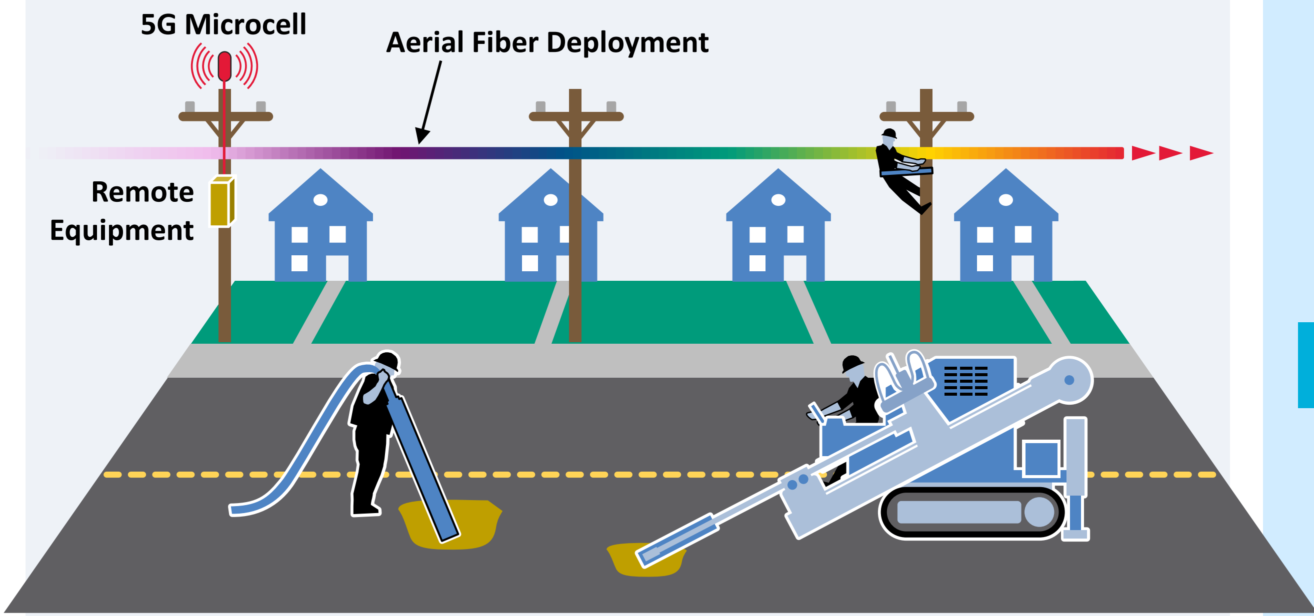
~100 MVPD earth stations are in areas where there is no broadband service within a 3 mile radius, affecting ~100K households

Source: Cartesian, Referenced Cartesian 2014 Ultra-fast Broadband Study for Corning

Plan Benefits – Job Market

On top of the socioeconomic benefits, there are significant direct and spillover effects of fiber investment in increased number of jobs over and above the CBA plan

Fiber Deployment Labor Effects



Expert Economists' Studied Effect of Broadband Investment

$6-7B investment in fiber broadband

x

16-20K jobs per $ billion of broadband investment[1]

=

96-140K direct jobs

x

~1x spillover effect in downstream jobs[2]

=

192-280K total direct + indirect jobs

+

Incremental 5G jobs from more players deploying 5G given more spectrum availability

[1] p.253, Digitized Labor: The Impact of the Internet on Employment
[2] p.3 FCC Comments of Corning Inc.

Appendix

- Additional Considerations
- Terrestrial Fiber Video Delivery Costs
- C-band Capacity Requirements
- Spectrum Clearing Timelines

Additional Considerations

The following elements, which are mentioned in our July 2 letter, are considered beneficial

- Protection for out-of-band emissions (“OOBE”) from 5G users towards C-band earth station users that will continue to utilize the band
- Fully-functional 5G (downlink and uplink) spectrum that will have 100% geographical availability after reallocation, allowing 5G user equipment (“UE”) to rely upon international standards
- Spectrum aggregation limits and licensing rules to encourage auction participation and interoperability

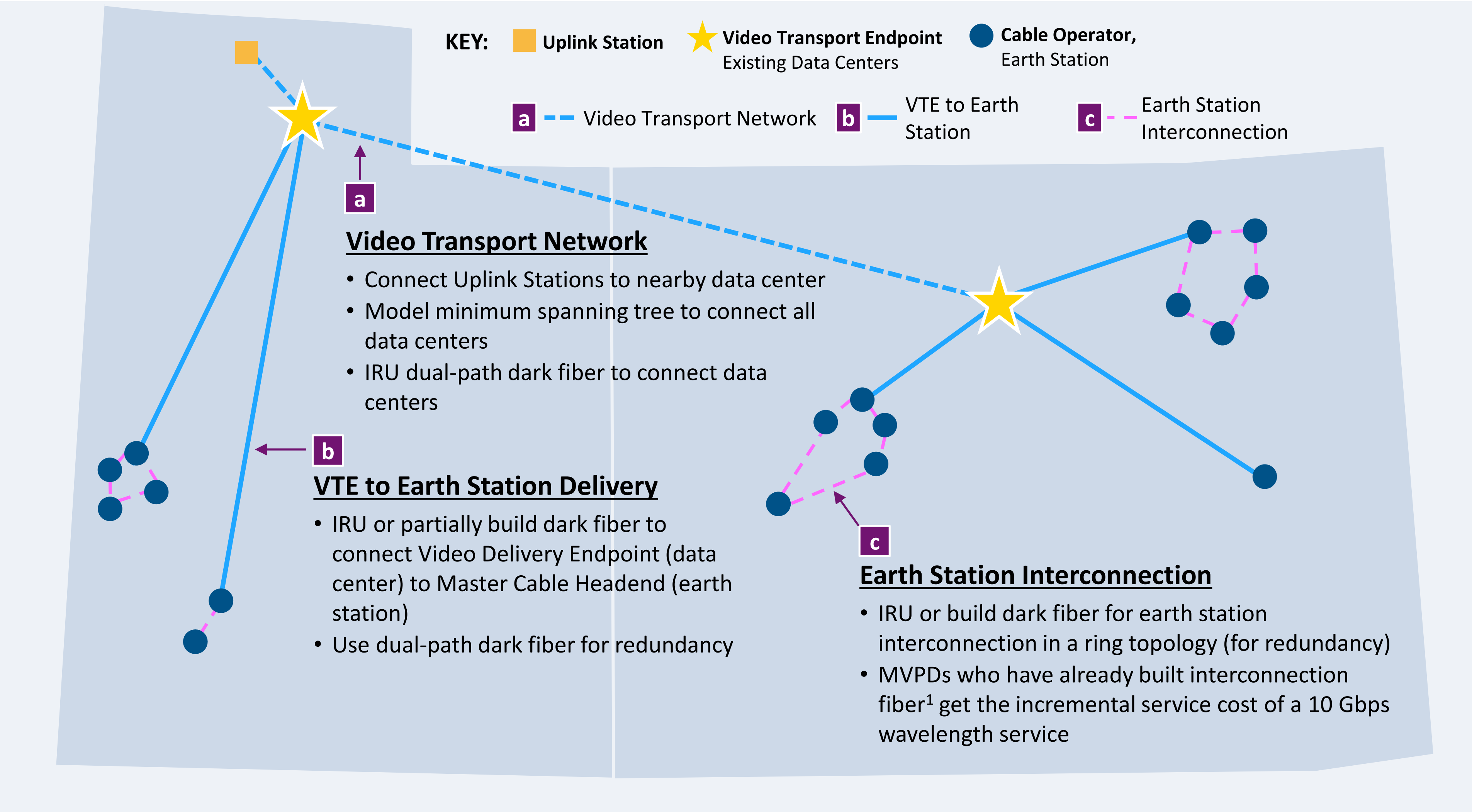
Source: ACA Connects

Appendix

- Additional Considerations
- Terrestrial Fiber Video Delivery Costs
- C-band Capacity Requirements
- Spectrum Clearing Timelines

Modeling Methodology – An Example

We modeled a terrestrial video transport mechanism with 3 components: (a) Video Transport Network, (b) Video Transport Endpoint ("VTE") to Earth Station Delivery, and (c) Earth Station Interconnection



Video Transport Network

- Connect Uplink Stations to nearby data center
- Model minimum spanning tree to connect all data centers
- IRU dual-path dark fiber to connect data centers

VTE to Earth Station Delivery

- IRU or partially build dark fiber to connect Video Delivery Endpoint (data center) to Master Cable Headend (earth station)
- Use dual-path dark fiber for redundancy

Earth Station Interconnection

- IRU or build dark fiber for earth station interconnection in a ring topology (for redundancy)
- MVPDs who have already built interconnection fiber[1] get the incremental service cost of a 10 Gbps wavelength service

[1] Per ACA Connects member interviews, we've assumed large, sophisticated MVPDs with more than 30K subscribers have already built interconnection fiber

Source: Cartesian

Modeling Cost Breakdown

Costs are primarily driven by fiber between video transport endpoints and earth stations with second largest cost item being interconnecting multiple earth stations with fiber

Item	Cost Estimate	Est. Fiber Route Miles	Comments
Video Transport Network	$0.2B	30K	**IRU:** Redundant dark fiber paths support a ~30K-mile video transport network across 42 data centers
Switching & Transcoding Equipment	$0.6B	-	**Downcoding and Optical Equipment:** Equipment must be purchased to downcode 4K and MPEG-4 content to MPEG-2, as well as optical equipment to transmit over fiber
Data Center Maintenance Fees	$0.1B	-	**Rackspace and Cross-Connect Fees:** Carriers must pay for space for equipment within datacenters and cross-connection with the VTN
Endpoint to Earth Station Connection	$2.8B-$3.3B	110K	**Build vs. IRU:** An assumed mix of 70% IRU'd fiber and 30% built fiber in markets with limited dark fiber supply
Earth Station Interconnection	$1.4B-$1.9B	200K	**Interconnection:** 70% IRU'd fiber; larger MVPDs (> 30K) have access to wavelength services whereas smaller ones use a similar mix (70-30) of IRU'd and newly constructed fiber
Non-CONUS Provider Costs	$0.03B	-	**Video Delivery over Subsea Leases:** The few non-CONUS cable providers can still connect to the VTN over lit services on subsea fiber to the non-CONUS territories.[1]
Extrapolated Unmodeled Costs	$0.9B	80K *(implied miles)*	**Subscribers of MVPDs not in Model[1]:** Extrapolating more extreme costs per subs to the remaining % of subs to address unmodeled, hardest-to-reach MVPD subscribers
Total Cost	**$6-7B**	**420K**	**10-Year NPV Cost**

Largest Cost Items

[1] In Alaska, other means of connectivity are available.

Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects

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Bandwidth Requirement Estimations

We estimated required bandwidth currently and in the future based on # channels, definition, compression and increased 4K adoption; 10 Gbps capacity seems to satisfy video needs

Bandwidth Estimates

Current Estimate

Channel Type	Channels	Bandwidth/Channel	Bandwidth
UHD Channels	10	15 Mbps	150 Mbps
HD Channels	400	6 Mbps	2.4 Gbps
SD Channels	400	2 Mbps	800 Mbps
Blackout Channels	10	6 Mbps	60 Mbps
VOD Channels	10	6 Mbps	60 Mbps

Total Bandwidth: **3.5 Gbps**

Current MVPD: Represents the bandwidth requirements for operators with a well developed linear TV product

Blackout & VOD: Additional streams required for regional sports and video-on-demand content (HD streams in current estimate, UHD in future estimate)

Future Estimate

Channel Type	Channels	Bandwidth/Channel	Bandwidth
UHD Channels	200	10-15 Mbps	2-3 Gbps
HD Channels	400	6 Mbps	2.4 Gbps
SD Channels	0	2 Mbps	0 Mbps
Blackout Channels	10	10-15 Mbps	100-150 Mbps
VOD Channels	10	10-15 Mbps	100-150 Mbps

Total Bandwidth: **4.6-5.7 Gbps**

Future-Proofed MVPD Service: Represents the bandwidth requirements of a scenario where a larger proportion of linear TV is delivered as both 4K UHD and HD considering any improvements in 4K video compression

Source: Cartesian, MVPD Operator Interviews, Netflix, Amazon

Estimated Fiber Transport Availability

We estimated at least 20% of fiber miles need to be constructed in areas with low dark fiber supply

	# of Fiber-Based Service Providers				
	0	1	2	3	4+
% of MVPDs	**3.4%**	**7.7%**	**15.9%**	**16.6%**	**56.3%**
% of Total Fiber Miles	**2.1%**	**5.4%**	**12.5%**	**15.1%**	**64.8%**
Population Density (Pop/Sq Mile)	**112**	**97**	**186**	**136**	**425**
Avg. Size (Subscribers)	**1.9K**	**2K**	**3K**	**4K**	**120K**

>20% of fiber route miles in low fiber supply markets

Comments

Small, Rural Providers: Small, rural providers are present in less competitive areas – MVPD size and population density increases when there is more fiber competition (4+ Fiber-Based Service Providers)

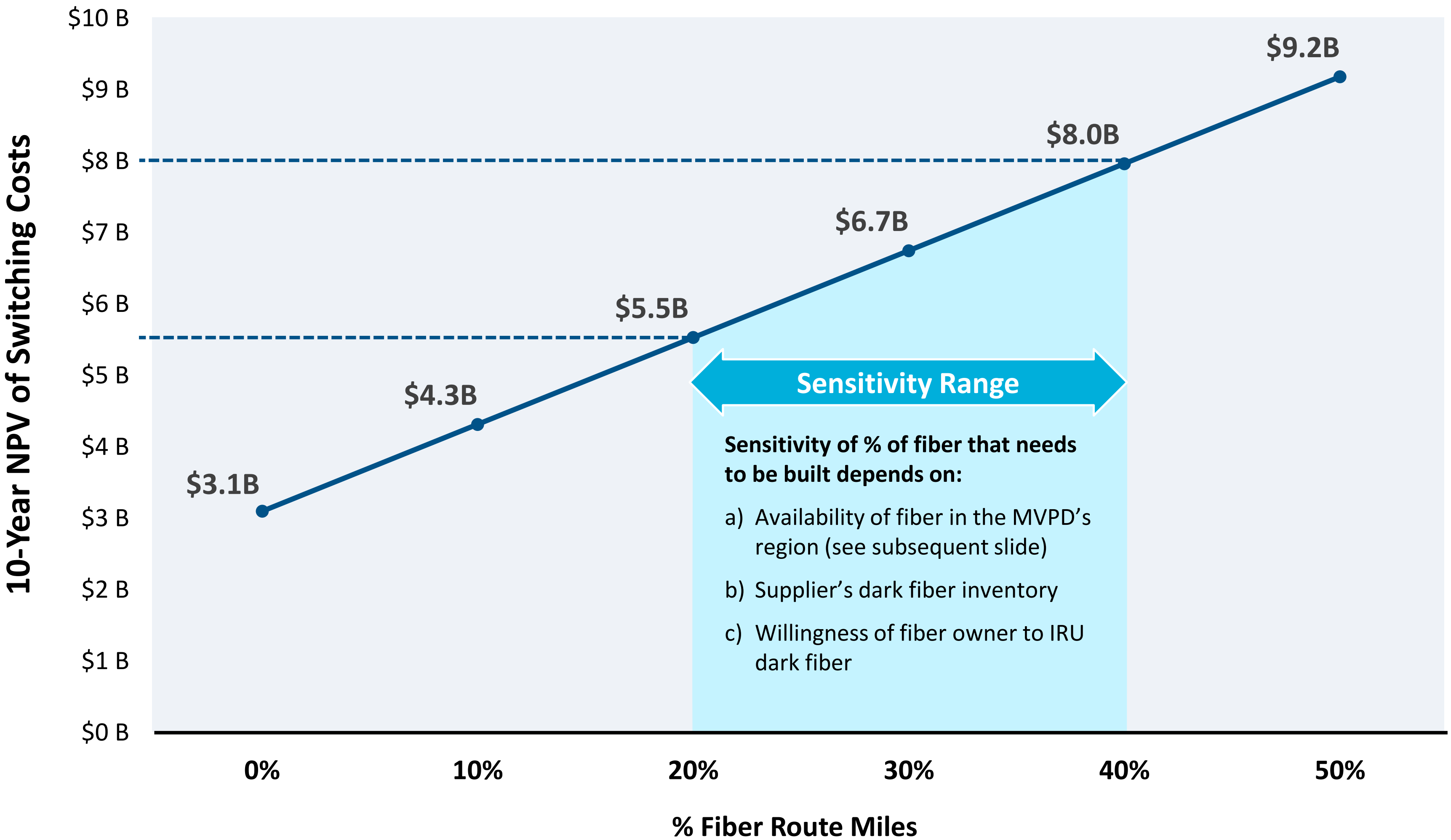
VTN Endpoints: Per the following slide, we selected endpoints to minimize transport distance, which reduced the amount of miles operators in rural areas have to traverse to connect to video transport endpoints

Cost: Our conservative estimate of 30% of built fiber miles reflects the low-levels of fiber transport options for small, rural MVPDs

Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects

Sensitivity to % Built vs % IRU

Base case in our modeling uses a 70%-30% split between IRU'd and built fiber resulting in $6.7B of fiber deployment costs



Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects

Video Transport Network Assumptions

Modeled video transport network uses IRU'd fiber between existing data center locations in Tier 1, 2 and a select few other markets

Cost Driver	Assumption	Rationale	Source
Interconnections	42 Major Markets, 17 Uplink Stations	**Major Markets:** Tier 1/2 markets selected to minimize video transport endpoint connection costs for MVPDs **Uplink Stations:** Earth Stations registered to major content providers (e.g., NBCU) operating in the 5.925-6.425 GHZ frequency	Data Center Map IBFS C-band Uplink Earth Station Registrations
Equipment	$100K Optical MUX or Layer 2/3 Routers	**Location:** Optical MUX or Layer 2/3 Routers required at all interconnection points to support broadcast of linear video content	Cartesian
Architecture	Redundant Minimum Spanning Tree	**Common Routes:** Takes advantage of high-traffic routes where fiber leases are available **Backup Feed**: Redundant feed required to support broadcast in case of a fiber cut or other network outage	ACA Connects Member interviews
Lease Type	100% IRU	**Existing Fiber:** Major fiber providers (e.g., Zayo, Level 3/CenturyLink, Windstream, etc.) have already built fiber between large markets **Optimal Spectrum Alternative:** Dark fiber obtained through an IRU provides an optimal secure channel with enough bandwidth to transmit bandwidth	Fiber provider reported network maps ACA Connects Member interviews
Compression	100% MPEG-4 Transport	**Current Standard:** Most channels currently transported terrestrially via fiber use MPEG-4 compression **Efficient Transport:** MPEG-4 compression reduces the bandwidth requirements of video transport	NBC Sports ACA Connects Member interviews

Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects, Data Center Map

Video Delivery Fiber Network Assumptions

Fiber availability over routes derive from Form 477 analysis; construction costs are based on rural fiber deployment benchmarks (mostly aerial, rural) and verified over ACA Connects interviews

Cost Driver	Assumption	Rationale	Source
Equipment	$70K Layer 2/3 Switches $10K Long Range SFPs $30 Ethernet Patch Cords	**Location and Quantity:** 2 SFPs and 1 patch cord/router for every interconnect point an operator has **Ethernet Protocol:** SFPs enable ethernet over dark fiber or built fiber – an alternative is to lease ethernet services	Cartesian
Colocation Space	$1.5K per data center connection/month	**Rack space:** Space must be rented at each of the data centers a carrier obtains the IPTV for necessary switching/conversion equipment **Cross connect:** Data centers charge a fee to connect to the VTN signal	Cartesian
Proportion of Existing Route Fiber	20% Build, 80% IRU,	**Form 477:** For each carrier, we analyzed the presence of access fiber as a proxy for transport fiber availability **IRU Lease Decision:** We assume a higher portion leased as an IRU due to strategic benefits	Form 477
Aerial vs. Underground	70% Aerial, 30% Underground	**Utility Poles:** Depending on the existence of utility poles and the terrain along a proposed route, some miles of built fiber must be built underground	Cartesian
Aerial Build Costs	$30K/ mile	**Cost Estimation**: Vast majority of interviewed members use aerial fiber deployment with varying costs around the country based on level of make-ready work required; average cost used in our calculations which includes utility pole attachment fees	Cartesian Columbia Telecommunications Corp.
Underground Build Costs	$80K/ mile	**Regulatory Fees:** Laying underground fiber incurs a more stringent regulatory and permitting process **Cost of Labor:** Includes labor costs for digging and boring	Cartesian Columbia Telecommunications Corp.
Built Fiber Maintenance Opex	5% of yearly construction costs	**Repairs:** Once fiber has been built, occasional fiber breaks must be repaired **Rental fees:** Space on utility poles and right of way permitting must be maintained on a yearly basis	Cartesian CTC FCC
IRU	$3K/mile Down payment, $20/mile/month Maintenance	**Down payment Range:** Down payments range from $2K in rural areas to $4K in urban areas – we used the midpoint as our assumption **Maintenance:** Multiple operators indicated a range for maintenance cost that encompassed $20/mile/month	ACA Connects interviews CTC Net
Wavelength	$5K/ route	**Average Global Price:** Based on Zayo's average price **Higher QoS:** Wavelengths provide greater QoS for operators that seek higher quality service	Zayo ACA Connects interviews
Price Decline	-10% CAGR	**Commoditized Service:** Transport services are becoming increasingly commoditized, creating pricing pressure **Zayo Price Trends:** We analyzed Zayo prices trends to estimate the decline of wavelength and ethernet prices	Zayo
Redundancy	Dual-Path Fiber	**Critical Traffic:** Operators would need a redundant path to ensure service availability in the event of a network outage	ACA Connects Interviews

Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects, Data Center Map

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Earth Station Interconnect Assumptions

Our fiber build assumptions have the greatest impact on the earth station interconnect costs

Cost Driver	Assumption	Rationale	Source
Equipment Costs	20 Transcoders, $10K/Transcoding	**Transcoder Capacity:** $10K of transcoders can handle 50 channels **Channels Offered:** Most interviewed operators offer 200-300 channels **Transcoder Requirement:** 20 sets of transcoders, handling 50 channels can support 1000 channels, which covers most MVPDs' needs for current and future encoding needs	ACA Connects Member interviews
	$70K Layer 2/3 Switch $4K Mid Range SFPs	**Location and Quantity:** 2 SFPs and 1 switch for each earth station **Ethernet Protocol:** SFPs enable ethernet over dark fiber or built fiber – an alternative is to lease ethernet services	Cartesian
Compression	MPEG-2	**Legacy Set-Top-Boxes:** Many operators have set-top-boxes that require MPEG-2 compression **Transcoding:** We assume operators will need to transcode MPEG-4 broadcast into MPEG-2 to deliver to subscribers	ACA Connects Member interviews Zayo Telegeography
Current Interconnection Status	MVPDs with 30K+ Subscribers Already Interconnected	**Headend Consolidation:** The smallest MVPD we spoke to (~30K) subscribers had already consolidated headends and built out interconnection fiber, so we assumed all MVPDs with 30K+ subscribers have done the same	ACA Connects Member interviews and Survey
	33% of MVPDs with Unknown Earth Stations Assumed to Use OTT Services	**Cost Estimation:** For MVPDs with unknown earth stations, we estimated the switching cost and then removed 33% of the cost to account for MVPDs that are currently using OTT services (e.g., Vubiquity) to deliver video content – use of OTT services estimated from ACA Connects Member Survey	
Aerial Build Costs	$30K/ mile	**Cost Estimation**: Vast majority of interviewed members use aerial fiber deployment with varying costs around the country based on level of make-ready work required; average cost used in our calculations which includes utility pole attachment fees	Cartesian Columbia Telecommunications Corp.
Underground Build Costs	$80K/ mile	**Regulatory Fees:** Laying underground fiber incurs a more stringent regulatory and permitting process **Cost of Labor:** The cost of labor for digging and boring is greater than laying fiber along utility poles	Cartesian Columbia Telecommunications Corp.
Built Fiber Maintenance Opex	5% of yearly construction costs	**Repairs:** Once fiber has been built, occasional fiber breaks must be repaired **Rental fees:** Space on utility poles and right of way permitting must be maintained on a yearly basis	Cartesian CTC FCC
Redundancy	Ring Architecture, Dual-Path Fiber	**Broadcast Requirements:** QoS is extremely important for broadcasting linear content and purchasing dual-path fiber to transport fiber between earth stations guarantees service will remain up in the event of a circuit failure	ACA Connects Member interviews

Source: Cartesian, Form 477, IBFS Earth Stations Registration, ACA Connects

Other Assumptions

Other model build assumptions related to the use of "straight-as-the-crow-flies" distances converted to road distances and a discount rate used in the 10-year NPV cost calculations

Cost Driver	Assumption	Rationale	Source
Road Distance Conversion	1.4X Straight-Line Distance	**"Detour Index":** 1.417 is the slope of the regression model a researcher at the NIH ran to compare straight-line and road distances	National Institute of Health
Discount Rate	8%	**Commonly Used Discount Rate:** A number of MVPDs use 8% as a discount rate for long-term business planning	Cable MVPD Operator Public Reports

Source: Cartesian, National Institute of Health, Public Reports

T-Mobile vs. Our Plan's Fiber Investment Cost Comparison

The difference between the T-Mobile and our plan's estimates of fiber investment cost is mainly driven by considering earth station proximity to data centers rather than census blocks, and accounting for fiber path redundancy

Category	T-Mobile	Our Plan	Comments
Number of Earth Stations	**13.4K**	**2.6K**	• T-Mobile's estimate is based on providing fiber to all earth stations, and seems to leave out thousands of earth stations in use today. • Our estimate is based on providing fiber to ~2.6k MVPD earth stations.
Total Fiber Route Miles (miles)	**21K miles**	**420K miles**	• T-Mobile's estimate measures the distance from earth stations to the closest fiber-connected census block. It wrongly assumes interconnection would be available at these points, and even if so, that such locations could provide connectivity with SLAs that's necessary for most c-band services. • Our estimate measures the distance from MVPD earth stations to Tier 1 data centers. It also accounts for dual-path fiber and fiber rings for redundancy.
Average Cost per Fiber Mile ($/mile)	**$65K**	**$11K**	• The lower cost per mile in our plan is largely driven by the inclusion of ~70% IRU, consistent with the view that fiber connectivity is already available in most locations under consideration
Total Investment ($)	**$1.4B**	**$4.6B**	• T-Mobile's estimate of fiber investment cost is about one-third less than our estimate, and doesn't include other costs necessary for earth stations to transition from c-band to fiber delivery.

CBA Comments on Terrestrial Fiber Delivery

Our plan addresses all the points that CBA's letter[1] highlights, i.e. complexity, timing, reliability and deployment costs of fiber networks

Category	CBA Comment	Our Comments
Complexity	• *"Complexity of **a massive fiber infrastructure design …**"* • *"Terrestrial solutions are much more complex than satellite … **Expertise** that are not typically found at many earth stations"* • *"**Thousands of earth stations** will be required to connect to hundreds of content sources …"* • *"The **aggregation points will be extremely complex**. They will **need to accommodate a multitude of services** with differing service quality requirements …"*	• Our plan transitions to fiber only MVPDs (less than 15% of earth station users) that occupy the majority of the spectrum; MVPDs already operate on- or near-net fiber networks • Urban MVPDs already today get part of the linear video programming delivered via fiber • Fiber redundancy and SLAs are standard industry practices today widely used by enterprise, government, wireless towers, wholesale, etc.
Timing	• *".. the timeline to implement and bring into service a fiber-based architecture to replace the current C-band satellite infrastructure **is well-beyond the 18-36 months**"*	• Only 15% of earth station users (MVPDs) need to connect via fiber: – Urban MVPDs are already connected with fiber to major data centers and already receive a portion of programming terrestrially – Majority of MVPDs have access to fiber (from ILECs, pure-play fiber providers, etc.) and can procure fiber IRUs
Acceptance / Reliability	• *"… availability is approximately **six-sigma (99.999%)** " … "Fiber network reliability can be improved with the installation of redundant, geographically separated fiber lines, but the improvements still will **likely not achieve** the six-sigma reliability offered by satellite."*	• Five nines level of reliability is industry standard across enterprise, government and wholesale connectivity, covered under fiber SLA terms • As CBA mentioned, fiber path redundancy, equipment redundancy as well as processes in place to guarantee mean time to repair(MTTR) guarantee smooth operation of today's enterprise, government and wireless tower networks
Total Lifecycle Costs	• *"Considering both non-recurring and recurring costs, the total estimated 30-year incremental (above current ecosystem costs) rate-adjusted lifecycle cost could be in the range of **$20 billion to $30 billion or more**."*	• Our plan proposed only MVPD earth stations to get connected via fiber, leveraging existing fiber that exists on-/near- net MVPD footprint • This approach significantly reduces the total fiber deployment cost while avoiding non-MVPD rural earth stations driving exponentially high fiber costs in the outmost rural areas

1. CBA Letter (July 2, 2019)

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Appendix

- Additional Considerations
- Terrestrial Fiber Video Delivery Costs
- C-band Capacity Requirements
- Spectrum Clearing Timelines

Current US C-band Satellites

There are currently 23 satellites providing C-band coverage to the United States

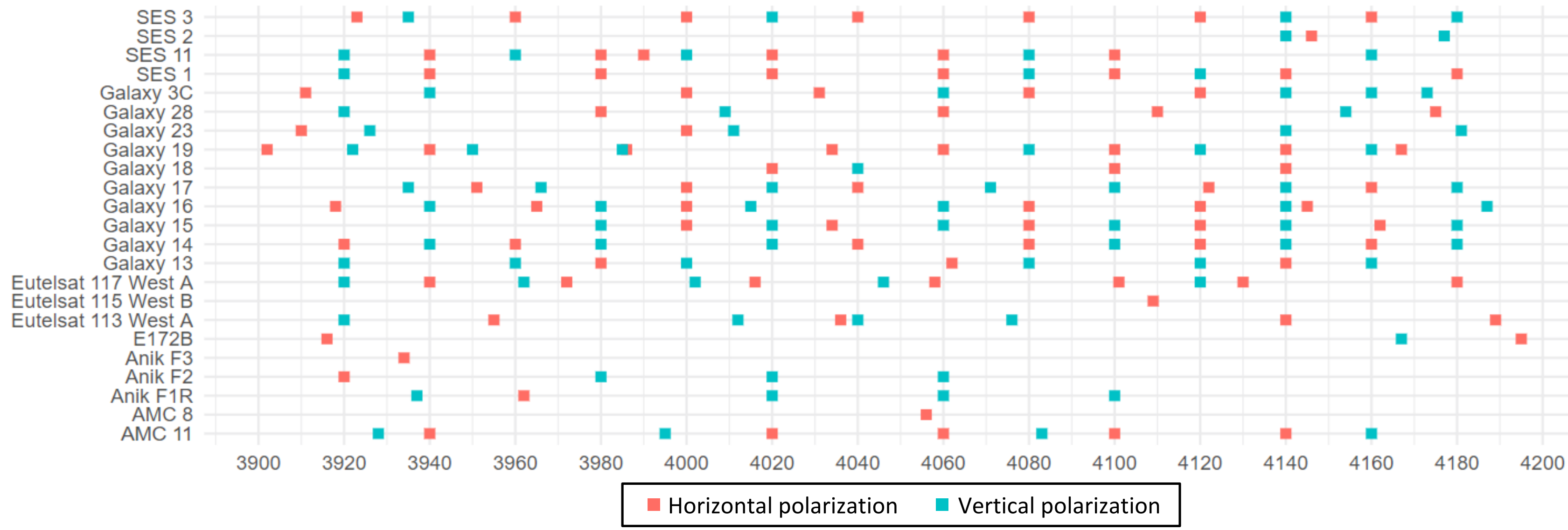
#	Satellite[1]	Owner	Position	Launch Year	Age	Estimated Useful Life (in Years)[2]	TPs[3]	TPs in Use	Status
1	Eutelsat 113 West A	Eutelsat	113 °W	2013	12	21	24	18	Active
2	Eutelsat 115 West B[4]		115 °W	2015	15	21	24	1	Active
3	Eutelsat 117 West A		117 °W	2013	14	21	24	21	Active
4	E172B[4]	Intelsat	172 °E	2017	18	21	24	3	Inclined Orbit[5]
5	Galaxy 28		89 °W	2005	15	21	24	11	Active
6	Galaxy 17		91 °W	2007	2	21	24	21	Active
7	Galaxy 3C		95 °W	2002	8	21	24	17	Active
8	Galaxy 19		97 °W	2008	9	21	24	22	Active
9	Galaxy 16		99 °W	2006	8	21	24	16	Active
10	Galaxy 23		121 °W	2003	14	20	24	9	Active
11	Galaxy 18		123 °W	2008	16	23	24	4	Active
12	Galaxy 14		125 °W	2005	14	16	24	22	Active
13	Galaxy 13		127 °W	2003	11	23	24	15	Active
14	Galaxy 15		133 °W	2005	16	19	24	18	Active
15	SES 2	SES	87 °W	2011	13	21	24	7	Active
16	SES 1		101 °W	2010	11	23	24	19	Active
17	SES 3		103 °W	2011	17	21	24	19	Active
18	SES 11		105 °W	2017	12 .0	17	24	19	Active
19	AMC 11		131 °W	2004	14	17	24	15	Active
20	AMC 8		139 °W	2000	2	21	24	1	Active
21	Anik F1R	Telesat	107 °W	2005	6	21	24	8	Active
22	Anik F2		111 °W	2004	4	21	24	7	Active
23	Anik F3		119 °W	2007	6	21	24	1	Active
					Average Age: ~11 years	Total:	552	294	

[1] Satellite list collated from grooming plans provided by satellite owner in ex parte filings
[2] Based on Intelsat estimates of C-band fleet at end of FY2018; average of Intelsat launch-to-life-end time used for non-Intelsat satellites
[3] Assumes 24 transponders per satellite (per industry grooming plans in ex parte filings)
[4] Does not cover the entire US
[5] Satellites in inclined orbit are typically not used for DTH
Source: Cartesian, Intelsat, LyngSat, Intelsat, SES, Telesat, Eutelsat

Upper-Band Transponder Utilization

We have estimated transponder availability in the upper band based on current usage

Satellite	Transponder Frequency Midpoint (MHz)[1] – Upper band (Above 3.9 GHz)



Spectrum Reallocated (MHz)[2]	200	220	240	260	280	300	320	340	360	370	380	400	420	440	460	480
Spectrum Remaining (MHz)	300	280	260	240	220	200	180	160	140	130	120	100	80	60	40	20
Current Transponders in Use in Remaining Spectrum[3]	186	171	155	144	135	123	109	95	87	76	74	64	52	41	24	10
Transponder Supply - Maximum Available in Remaining Spectrum[4]	345	322	299	276	253	230	207	184	161	138	138	115	92	69	46	23

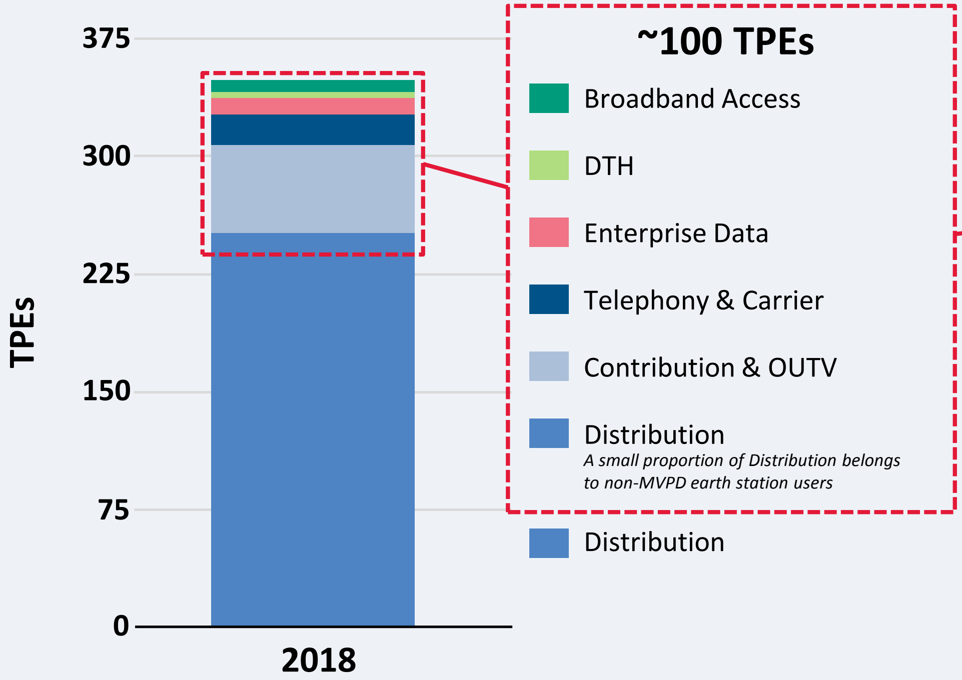
***Estimated Capacity**: 138 TPEs*
***Estimated Current Usage**: ~100 TPEs*
***Assumed Usage**: ~120 TPEs (Mid-point of estimated capacity and current usage)*

[1] Corresponding to the middle of an estimated 36-MHz range for each transponder. Overlaps across satellites indicate geographic or time-based segmentation
[2] Includes a 20 MHz guard band
[3] Assumes customers on TPs currently in guard band are relocated to other locations
[4] Based on 23 satellites and 20 MHz per Transponder
Source: Cartesian, Lyngsat, Northern Sky Research

Demand: Non-MVPD Required Transponders

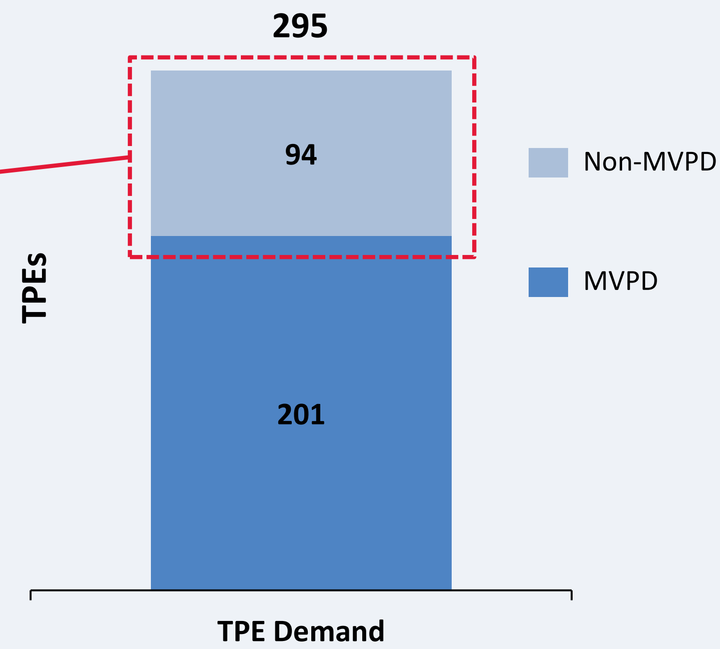
Bottom-up estimation of non-MVPD TPE demand corroborates with top-down estimate of ~100TPEs

Top-down Non-MVPD Demand (TPEs)



Non-MVPD demand is mostly driven by Contribution & OUTV (e.g. moving news, broadcasts) with the remaining being more intermittent type of spectrum utilization

*Bottom-up Non-MVPD Demand (TPEs)**



~32% of current satellite capacity supports non-MVPD use cases

* Where a transponder appeared to have both MVPD and non-MVPD content, capacity was apportioned in proportion to number of channels

Source: Cartesian, Ericsson/NSR, IBFS, Lyngsat

Spectrum Reallocation Sensitivity Analysis

Clearing at least 370 MHz is feasible and does not impact clearing timelines as there is sufficient time to launch new satellites before upper band non-MVPD TP capacity is exhausted

	Spectrum Reallocated (MHz)[2]	Transponders Remaining Available[3]	Total Replacement Satellites Launched: 36 / 80[4] Months	First Satellite Launch (Months)	Timeline Impact (Months)[5]	Estimated Auction Proceeds[6]	Total Satellite Launch Costs[7] ($)
CBA Proposal[1]	200	345	5 / 5	0	+25	$20B	$1.1B
Additional Scenarios / Sensitivities	300	230	0 / 0	84	None	$27B	-
	310	207	0 / 0	83	None	$28B	-
	320	207	0 / 1	79	None	$29B	$0.5B
	330	184	0 / 1	79	None	$30B	$0.5B
	340	184	0 / 2	70	None	$31B	$0.7B
	350	161	0 / 3	68	None	$32B	$0.8B
	360	161	0 / 4	56	None	$33B	$1.0B
	370	138	0 / 5	43	None	$34B	$1.1B
	380	138	0 / 6	37	None	$35B	$1.3B
	390	115	2 / 8	0	+25	$36B	$1.6B
	400	115	3 / 9	0	+25	$37B	$1.9B
	410	92	6[8] / 12	0	+25	$38B	$2.2B

370 MHz of spectrum can be cleared with the same number of satellites launched as the CBA plan.
To clear spectrum and meet ongoing demand, the first replacement satellite need not be launched for at least 3 years

1 The CBA plan keeps all existing distribution customers (need ~295 TPEs), while our plan only requires ~100 TPEs)
2 Includes a 20 MHz guard band
3 Across 23 satellites over remaining spectrum
4 Under the CBA, 5 satellites will be launched within 25 - 36 months and the next launch would be needed at ~80 months; assumes start date of July 2019
5 According to the CBA plan at least 25 months (up to 36 months) is needed to launch a satellite
6 Based on $0.3 per MHz-pop, 325 million population
7 Total satellite launch costs: Assumes $100m per build, $100 m per launch (2 satellites per launch), $100m per ground spare. Includes 2 ground and 1 in-orbit spare
8 Number of replacement satellites necessary exceeds available CONUS orbital slots

Source: Cartesian, LyngSat, Northern Sky Research, C-Band Alliance

Appendix

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Stakeholder Groups

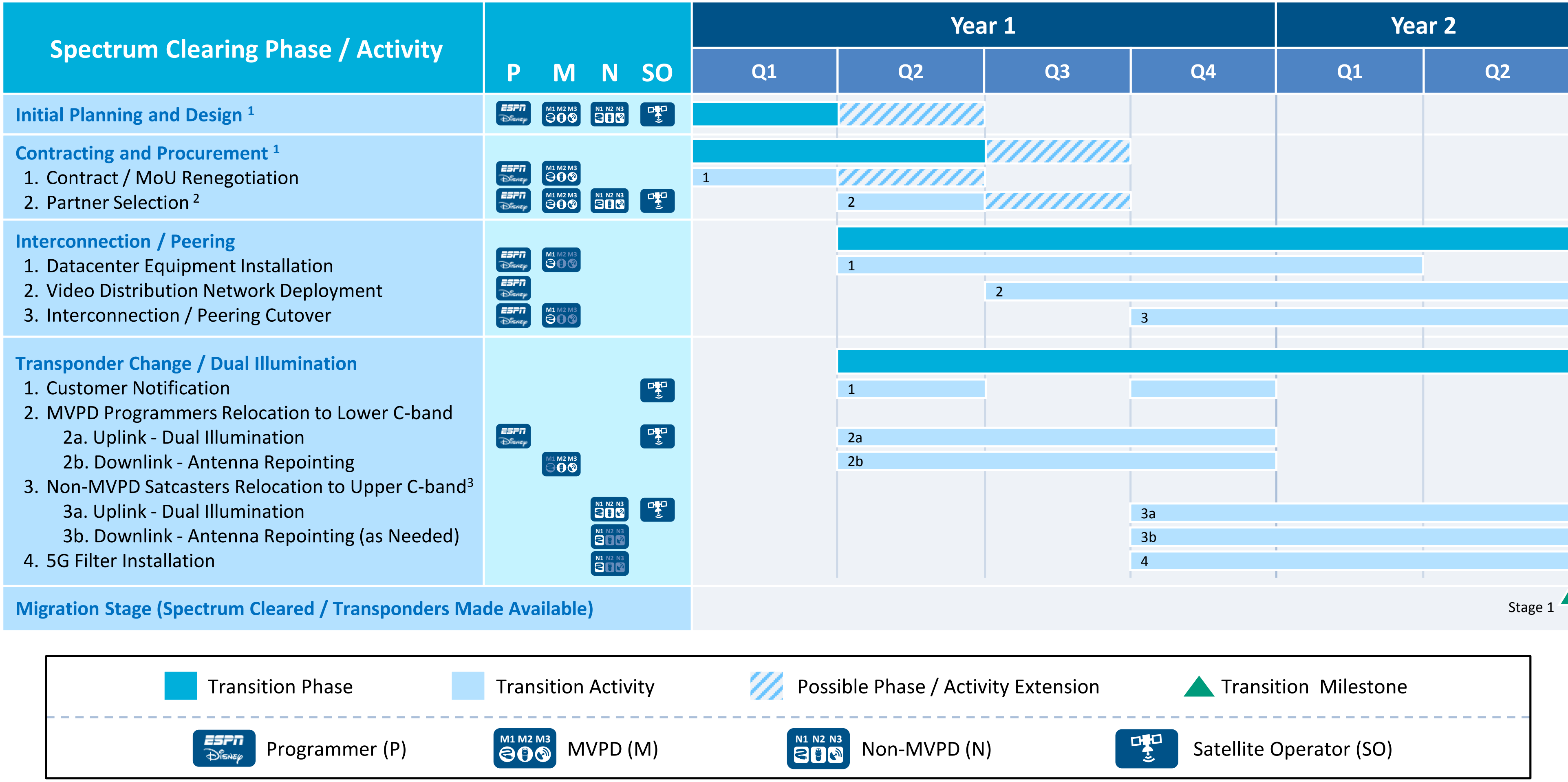
Our plan requires coordination between four groups: programmers, MVPDs, satellite operators and non-MVPD users

Stakeholder Groups		Description
Programmers	P	All major content providers supplying content to MVPDs
MVPD Earth Station Users	M1	MVPD earth stations users - comprising mostly of the main MVPDs - located primarily in fiber-rich urban areas
	M2	Earth station users, possibly including major cable providers and smaller regional providers in locations that are not currently fiber-rich, but are easier to build
	M3	Earth station users located in hard to build, rural or remote locations
Satellite Operators	SO	The 4 major satellite owners (Intelsat, Telesat, Eutelsat and SES) with transitions plans in the CBA plan
Non-MVPD Customers and Earth Station Users*	N1	Non-MVPD customers and earth stations users located primarily in fiber-rich urban areas
	N2	Non-MVPD customers and earth stations users located primarily in fairly easy to build areas, primarily located in suburban areas
	N3	Non-MVPD customers and earth stations users located in hard to build, rural or remote locations

Note: Programmers are expected to engage a third party video distribution vendor or form a coalition to allow for a consolidated set of peering points. Similarly, third parties will also be need to be engaged for filter installation in all markets
* This refers to both Non-MVPD customers and earth station users (i.e. used for downlink and for uplink services)
Source: Cartesian

Clearing Timeline: Urban Markets (M1)

Spectrum in urban markets can be re-farmed within 18 months, once programmers have established data center presence and non-MVPDs are migrated to the upper C-band



Note: It is assumed that all M1 MVPDs (in urban markets) already have access to fiber and would not need to acquire new connectivity

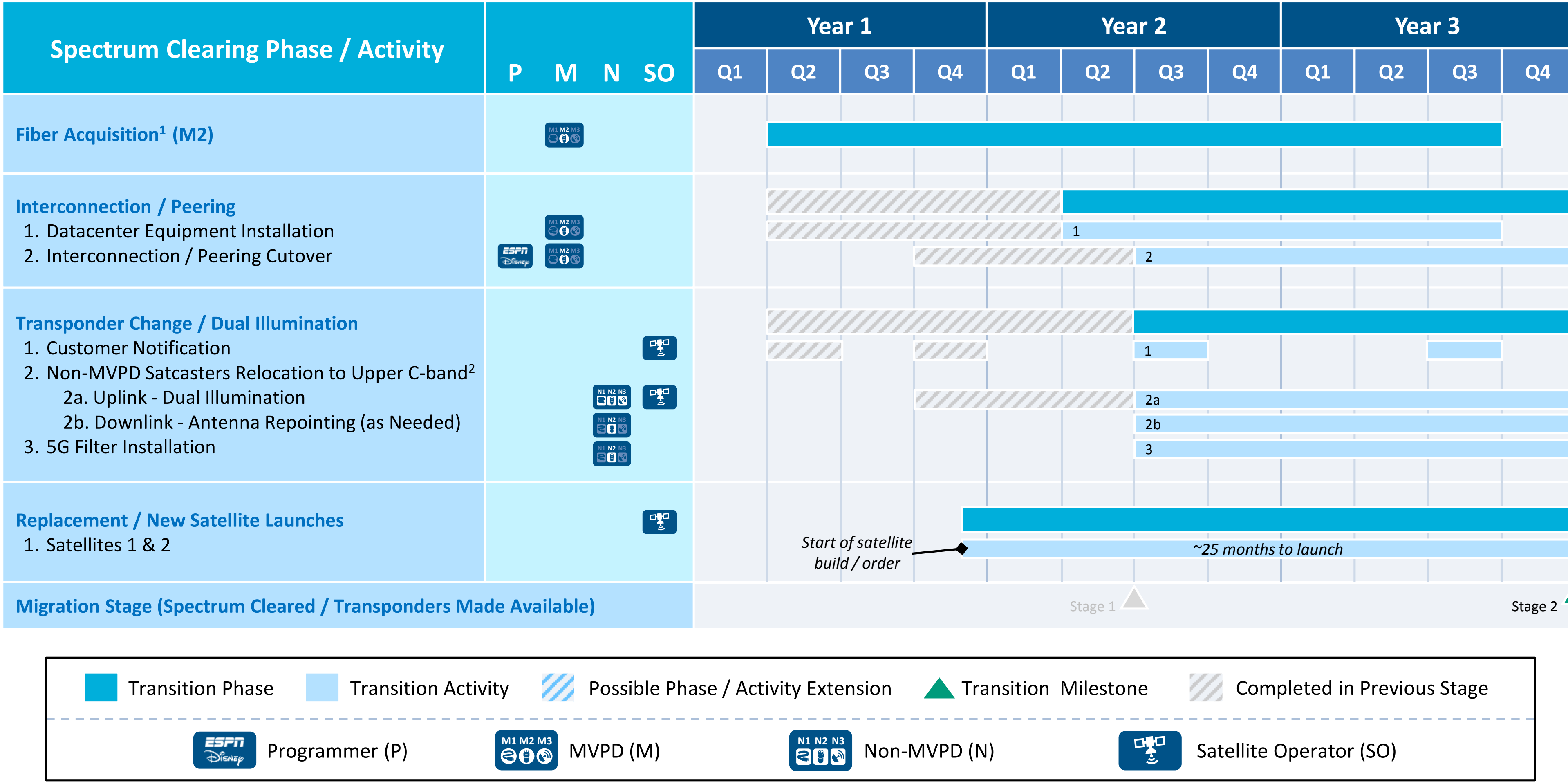
[1] Assumes initial planning, contracting and partner selection commences prior to Day 1. Day 1 is the point at which the FCC issues a Final Order

[2] Vendor and supplier selection to provide equipment, infrastructure, services and/or expedite any spectrum clearing activities

[3] Some Non-MVPDs will be impacted by changes to both uplink and downlink channels

Clearing Timeline: Suburban Markets (M2)

In the majority of the urban and suburban markets, and areas where IRUs are available, re-farming of spectrum used by MVPD users can be completed within the first 3 years



Notes:

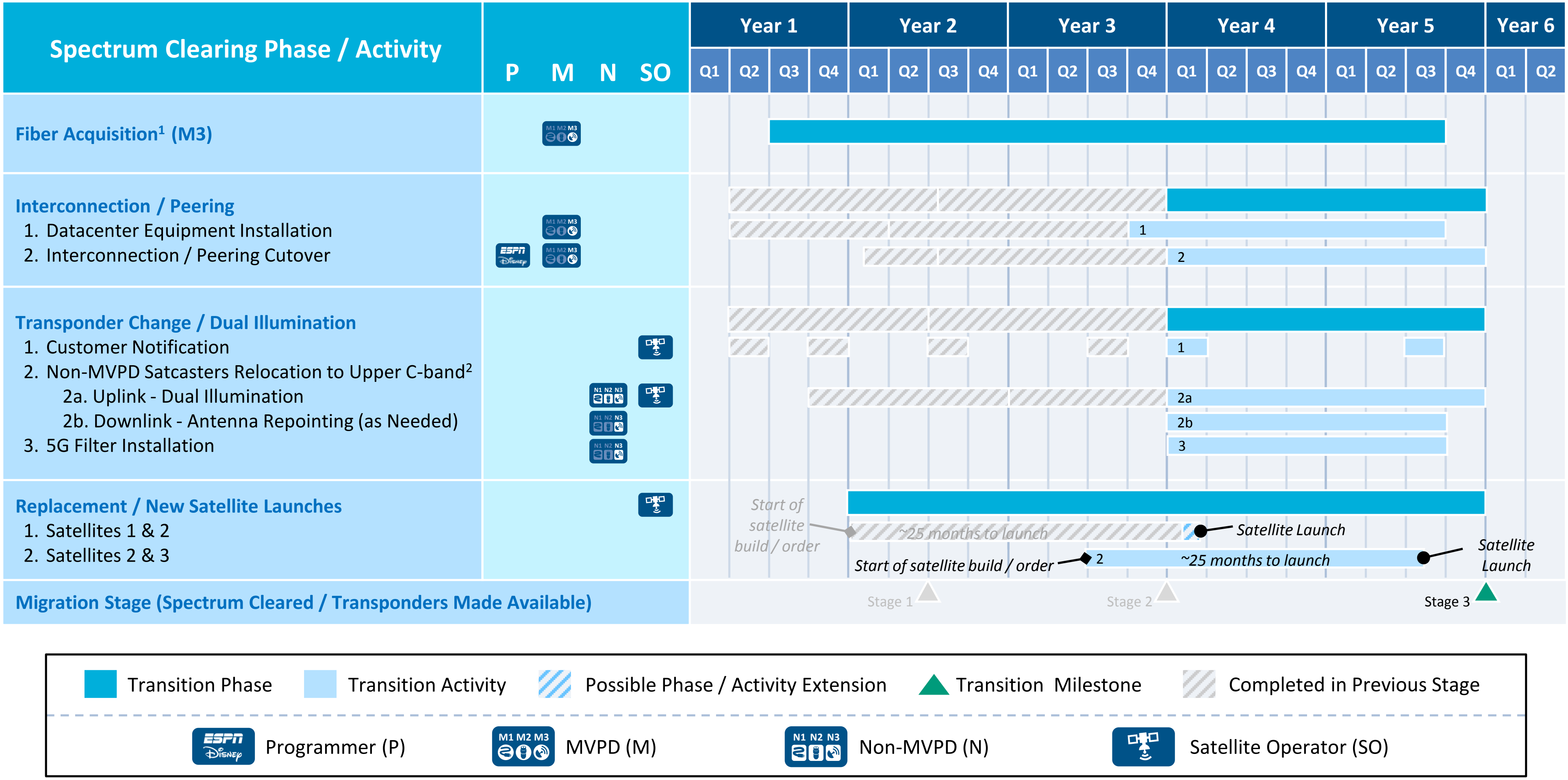
- Spectrum is re-farmed market by market as soon as possible, once fiber has been acquired
- Second round of notifications sent towards the end of stage 2 to ensure all stakeholders complete preparation before dual illumination ends

[1] 70k miles of fiber IRU purchased (@1.1k miles per month and 330k miles of fiber built (@5.5k miles per month)

[2] Some Non-MVPDs will be impacted by changes to both uplink and downlink channels

Clearing Timeline: Rural Markets (M3)

The remaining markets in rural and remote locations, where fiber is hard to build, re-farming of spectrum can take up to 5 years



Notes:

- Spectrum is re-farmed market by market as soon as possible, once fiber has been acquired.
- Second round of notifications sent towards the end of stage 3 to ensure all stakeholders complete preparation before dual illumination ends

[1] 70k miles of fiber IRU purchased (@1.1k miles per month and 330k miles of fiber built (@5.5k miles per month)

[2] Some Non-MVPDs will be impacted by changes to both uplink and downlink channels

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