Interconnection for Public Television: The Way Forward

Key Findings and Recommendations

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Cognizant Technology Solutions

Cognizant

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1 Executive Summary

1.1 Key Recommendations

It is Cognizant's primary recommendation that the system adopt a single interconnection system that is cloud-based, using mainly the public internet and an ecosystem of centralized master control service providers. Specifically, we recommend the selection of the Sony solution underlying the Public Media Management (PMM) proposal as a means to provide for non-real time (NRT) content (>80% of content today) interconnection. This is pending the negotiation of an acceptable commercial arrangement amongst the parties.

This system should be put in place under the leadership, operation, and governance of PBS. Satellite usage will shrink from three transponders to one which will be retained for live and near live transmission and will be consolidated to the NPR Satellite Operations Control center. A private fiber network will be used for stations which currently uplink national content today. All current centralized master control organizations (PMM, DCA, and CentralCast) will remain and provide a competitive market for addressing the very large near term master control refresh capital requirements while providing for operational cost reductions throughout the system.

This system should be fully in place by May of 2018. This approach requires relatively little additional R&D before beginning deployment as it is already deployed at several stations and operational. This provides the best timing to begin and eventually complete the transition to a new system.

The Cognizant recommended approach will provide for benefits with regards to the interconnection needs alone, but also will provide the basis of a solution to separately address the master control needs of public television system wide. The interconnection component of this cost is approximately $20M a year (including steady state operations). With widespread adoption of centralized master control, funded separately from interconnection, this approach should save the system in excess of $300M over 10 years. These savings will vary depending on actual adoption of centralized master control. This solution adopts an operating expenditure (Opex)based model with a steadier funding requirement year over year and should allow CPB and PBS to better plan for funding while still allowing continuing system innovation and refresh without future major capital requirements.

This recommendation will continue to be further refined as Cognizant examines the interconnection needs for public radio.

1.2 Executive Background and Analysis

In June 2015, the Corporation for Public Broadcasting (CPB), responsible for overseeing federal appropriations for public broadcasting, engaged Cognizant Business Consulting to evaluate interconnection plans for public television. The satellite leases of the current v5 interconnection system were set to expire in September 2016. As part of the due diligence, Cognizant conducted an assessment of the financial, operational, technical, and organizational parameters of the current state. In this

assessment, the proposal from the Public Broadcasting Service (PBS) for a new v6 interconnection system was compared to an alternative proposal from Boston-based member station WGBH (PMM), in addition to other commercial industry solutions. The interconnection system was evaluated from the perspective of all stakeholders involved:

- CPB
- Public media entities (PBS, APT, and NPR)
- Public television (PTV) member stations

The public television landscape is made up of 170 licensees that operate 363 television stations in all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, Guam, and American Samoa. Of these 170 PTV licensees, 79 are joint licensees with public radio. The interconnection system is responsible for delivering all broadcast content to stations. For the purposes of this assessment, Cognizant focused primarily on public television. Initial opportunities for interconnection in radio were also explored and Cognizant will be conducting further analysis as to the benefits that can be obtained in the public radio system.

In this context, interconnection can be defined as 'the set of technologies and operations required to send content (and metadata) from content producers/ aggregators to stations." Content delivered to stations is live, near-live, or non-real time (NRT). To conduct its assessment, Cognizant employed a structured approach with three broad phases:

- Discovery
- Evaluation and Analysis
- Summary and Definition

In the discovery phase, all available documentation was reviewed and stakeholders in the interconnection system from CPB, public media entities, and member stations were interviewed. The current v5 system is satellite-based and transmits content via 3 transponders. Regarding the current v5 system, the overwhelming majority of stakeholders agreed that there were challenges with the way NRT content was handled in the solution. Although many stations had found alternative methods of receiving and sharing NRT content (primarily pre-recorded), it was agreed that the new interconnection system must fix the current issues since NRT content constitutes at least 80 - 90% of their programming.

The v6 interconnection system proposed by PBS is a terrestrial fiber-based network with satellite backup that uses mesh connectivity to provide all stations with bi-directional functionality. PBS proposed that the v6 system would reduce long term costs by reducing the number of transponders from 3 to 1 (and uses that remaining transponder as mere contingency). Stakeholder interview responses to the PBS proposition brought into question the necessity of bi-directional functionality as a feature to interconnection, as the majority of stations currently produce little to no content for national or even regional broadcast. PBS has considered additional services that could be offered by themselves or others on top of the v6 system (such as master control), but has not planned to provide these services initially.

WGBH has proposed their Public Media Management (PMM) system (in partnership with Sony) as an alternative to v6 for interconnection. Originally intended as a replacement for master control, PMM is a cloud-based solution that leverages the internet to store and deliver NRT content, which, with the addition of one satellite transponder as the source of live and near live content, could serve as a viable interconnection system. Currently, having implemented the system for its own station as well as two others, WGBH states that the PMM system will reduce costs more significantly than the proposed v6 system, as it would eliminate the need to spend on a fiber infrastructure (while still reducing transponder costs). Furthermore, PMM provides the benefit of adding master control services on the same infrastructure. The ability to centralize master control as an aspect of implementing a new interconnection system creates the potential for increased savings should stations adopt it. In recent years, joint master control (JMC) facilities have been adopted by at least 23 stations with the capability of expanding to many more. These initiatives have been considered successful. Most stakeholders interviewed responded that they were aware of the PMM solution; however, the majority of these stakeholders did not believe that WGBH should supervise the governance of the new interconnection system. PBS was viewed as a neutral party that would maintain the interests of all stations in any deployed solution.

The financial forecasts for the v6 system and PMM were used in conjunction with interview responses from technology vendors, industry experts, and further research. Along with this data, Cognizant used the 2014 Station Activities Benchmarking Survey results to analyze the PTV station landscape and understand the available resources at the station level in order to create a rollout plan for a new system. From all of these inputs, Cognizant created a financial Total Cost of Ownership (TCO) model that recalculated and projects the costs and benefits for the 5 separate interconnection system options while normalizing the financials of the two systems (v6 and PMM) as originally proposed.

Cognizant concluded that addressing master control in addition to interconnection provides the greatest opportunity for member stations to avoid incurring unnecessary costs in daily operations as well as large capital refreshes. It enables an individual station to maintain authority as to which centralized master control provider to use, or whether it would prefer to keep master control in-house. There have already been numerous demonstrated benefits from the most recent JMC initiatives, and with PMM as an option there is the potential of more competitive and economical service offerings for member stations going forward.

Several alternative commercial solutions were evaluated in the context of v6 and PMM. After the discovery phase, they were determined to have significantly higher costs than the other proposed systems. As a result, the four approaches evaluated were:

- v6 (as adjusted and estimated by Cognizant)
- PMM (as adjusted and estimated by Cognizant)
- Cognizant Recommended Approach (Ecosystem of 3 centralized master control providers with competitive potential)
- No change to system (maintain status quo – maintaining v5 technologies and problems)

Following the analysis phase, Cognizant drafted a recommended approach for interconnection for public television. Overall, Cognizant recommends that the public television system adopt the Sony technology as the solution for distribution of NRT content under the governance of PBS. Live and near-live content will continue to transmit via satellite; however, the number of transponders can be reduced from 3 to 1. As the system evolves, the options to distribute live content over terrestrial can be evaluated. Individual member stations can have the option of using master control services through PMM or one of the existing two JMC's. Additionally, the recommendation will be refined as Cognizant enters the next phase of assessment wherein the incorporation of public radio to interconnection will be evaluated. The following key action items are detailed in this document:

- Resolve NRT distribution first and consider live over terrestrial subsequently
- Address master control and NRT interconnection simultaneously by using the Sony cloud-based solution in addition to the existing JMC's
- Bring PBS and WGBH together to work through the details of the right solution
- Keep the existing interconnection governance model
- Convert to a smaller set of common master control technologies throughout the system (CPB offers incentives for stations to adopt new master control or sets cut-off date from old system)
- Move to a service-based model
- Negotiate flexibility with vendors with regards to NRT and master control solutions
- Rapidly select a solution and begin implementation
- Allow vendors to engineer, build, and manage; PBS should oversee
- Move from large scale implementations to continuous incremental upgrades
- Convert from Ku to C-band and consolidate PBS and NPR satellite operations, while considering the use of High Efficiency Video Coding (HEVC) or other advanced compression technologies
- Adopt a more widely used media file standard
- Negotiate operational flexibility with a technology vendor
- Eliminate pre-flattening of content
- Keep the current two JMCs connected to PBS and provide the option for stations to use their master control services
- Perform a cyber-security audit
- Document lessons learned from R&D to date
- Ensure appropriate change management practices are followed

The interconnection system strategy suggested comprehensively addresses the build, deploy, rollout, and operate phases of implementation such that it is achieved at the minimum cost and an accelerated time to benefit. The Cognizant approach takes into account the security, technical reliability, and governance of the system, ensuring the most effective transition to a new interconnection approach for public television. Interconnection costs were compared for all options:

Approach #:	1	2	3
Category	v6 Based Solution	PMM Based Solution	Recommended Approach
Description	Current v6 solution from PBS for interconnection (with additional estimated expenses from Cognizant)	PMM solution from WGBH for interconnection (with additional estimated expenses)	Cognizant's Recommended Approach
Interconnection (Without Additives)	$227.9	$182.9	$178.2
System Refresh/ Enhancement	$17.1	$13.7	$13.4
Contingency	$0.0	$9.1	$8.9
Overhead	$2.5	$2.5	$2.5
Interconnection Total	$247.5	$208.3	$203.0

Figure 1 – Summary of Interconnection Cost Projection and Comparison (USD millions)

Subsequently, the view of widespread master control adoption was compared for all options:

Approach#	1	2
Category	Current State	Cognizant Recommended Approach
Description	A station-operated model/ ecosystem is assumed for Master Control,projected costs as per current numbers (as reported by stations)	An ecosystem of multiple providers is planned for Master Control, Including PMM, JCT and Centralcast
Master Control - Central Facility	$0.0	$176.3
MC Connectivity	$0.0	$0.8
MC Equipment Cost	$88.8	$0.0
MC Operations Cost	$479.8	$119.9
Contingency	$0.0	$14.9
Master Control Total	**$568.6**	**$311.9**

Figure 2 – Summary of Master Control Cost Projection and Comparison (USD millions)

This recommendation also takes into account the larger technological trend of transitioning appropriation and spending on the interconnection system from a capital expenditure (CapEx) to an operating expenditure (OpEx) model. Historically, large-scale system implementations were re-evaluated approximately every 10 years, and new funding was determined. However, given the rapid advancements in distribution technology, increasingly more broadcasters are moving towards an annual, service-based model. By shifting to smaller and recurring annual spending for interconnection,

the public television system as a whole will be better able to take advantage of future technological changes than if it follows the historical “big bang” implementation strategy.

The total cost of providing interconnection and centralized master control using the Cognizant approach is approximately $515M over 10 years. Less than half of this cost is interconnection related, with the majority being master control related. The total potential cost savings is slightly greater than $300M over 10 years when compared to a solution that includes master control operated by stations.

An evolutionary budget has also been incorporated to provide for technology and industry evolution. This budget will be used to continually update the system. Examples of updates would be addressing the transition to 4K content from HD content, High Dynamic Range (HDR) content, or increased Over-the-Top (OTT) capabilities. This evolutionary budget is critical to avoiding the need for major refresh cycles going forward, thus ending the approximately 10-year interconnection special major funding cycle that has been required for previous systems. The program can fully reach a steady state of operations by May 2018 including the transition of Ku band to C-band satellite (subject to a January 2016 commencement).

2 Introduction

In June 2015, CPB engaged Cognizant Business Consulting to evaluate interconnection plans for public television. Cognizant has evaluated the financial, business, operational and technical aspects of all proposed plans and commercial options for future delivery of interconnection services to the public broadcasting system.

2.1 Interconnection Assessment Objectives

The core objectives and activities of this interconnection assessment included:

- Performing a financial and technical evaluation of the interconnection plans to determine their efficacy and efficiency. This evaluation considered the current content distribution infrastructure, projected near-term future technological trends and resource constraints faced by the public broadcasting system.
- Comparing proposed interconnection plans and the current public broadcasting interconnection system to the distribution systems employed by commercial (or other non-commercial) television networks.
- Reviewing the potential for local stations to utilize the bi-directional communication capabilities of the proposed v6 system and exploring the potential for new local station business models and capabilities enabled by such a system.
- Reviewing and taking into consideration previous findings on collaborative possibilities between PBS and NPR in the provisioning of interconnection services to the public broadcasting system, and recommending steps to realize some of those possibilities.
- Providing recommendations regarding viable alternative strategies for public broadcasting interconnection systems with a focus on reducing capital expenditure and increasing both flexibility and efficiency.

2.2 Interconnection Assessment Approach

2.2.1 FOTO Framework

Cognizant applied its Financial, Organizational, Technical, Operational (FOTO) methodology for the evaluation of the proposed solutions:

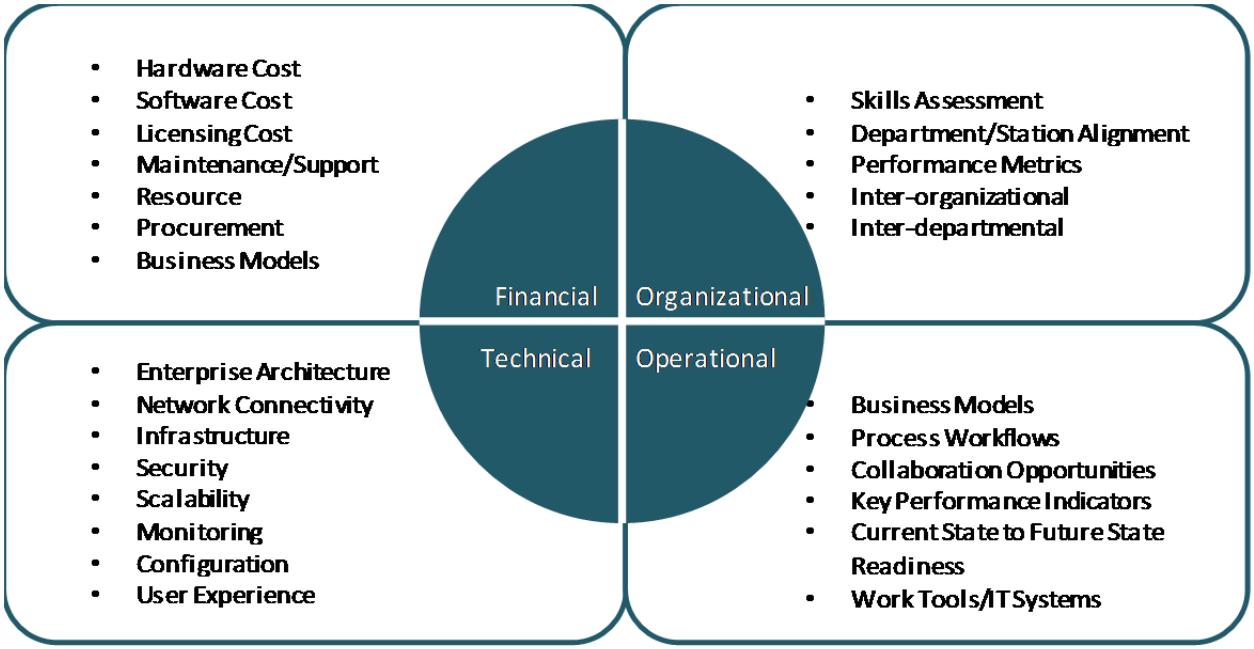


Figure 3 - FOTO Framework

Key Evaluation Parameters

- Cost: Build, Deploy, Rollout, and Operational
- Time-to-market considerations
- Functional adherence to requirements
- Need to universally address all classes of stations
- Security, reliability, and scalability of network
- Risk of implementation and acceptance

- **Financial**
  In the financial considerations for interconnection, the costs of building, deploying, rolling out and operating a new system were evaluated. Starting from the costs provided by PBS and WGBH for their respective solutions, a comprehensive model was constructed by Cognizant to outline the initial hardware and software costs of the varying options for interconnection. Specifically, procurement, licensing, maintenance and support costs were built into the model over a 10-year period, with several different options for rollout plans based on individual public television (PTV) station size, access to bandwidth and geographic location. Furthermore, interconnection stakeholders were interviewed and asked about their opinions on future business models for both PBS and member stations.

- **Organizational**
  In the organizational evaluation of the interconnection system, the governance and PTV station landscape as a whole were examined. Member stations were categorized as small, medium, and large as a means of assessing and comparing individual station resources and aligning them with an implementation plan. Additionally, inter-organizational and inter-departmental dynamics were taken into consideration, specifically with the governance of the current and future interconnection system.

- **Technical**
  In the technical approach to interconnection, Cognizant evaluated a variety of all available technology for content contribution to and among member stations. This analysis comprised of comparing different infrastructure models and projecting the future state of distribution technology. Specifically, the enterprise architecture and network connectivity of fiber, satellite, and public internet and cloud were compared against one another to determine the most technologically effective medium for interconnection. In addition, these technologies were compared on metrics of security as well as scalability to implement among all 170 licensees. Finally, different configurations of and combination of these technologies were used to create potential hybrid models that most effectively leveraged pre-existing distribution systems with larger technological trends.

- **Operational**
  In the operational approach to interconnection, Cognizant researched the current workflows in place at PBS, the NOC (Network Operations Center), MOC (Media Operations Center), member stations, and joint master control facilities. The variance in distribution strategies was analyzed and incorporated in creating an overall recommendation. Similarly, an analysis of workflows was used to examine which stations are most prepared for transitioning to a future state model, and what business models they foresaw on the horizon.

2.2.2 Structured Approach

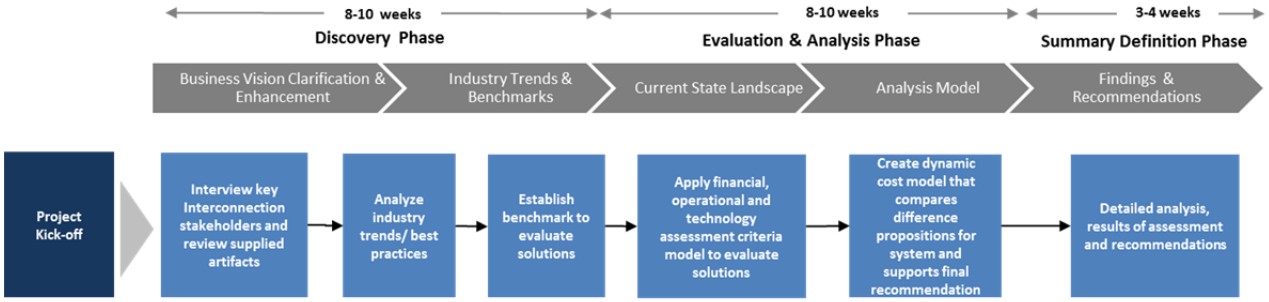


Figure 4 - Structured Approach

To effectively apply the FOTO framework, Cognizant structured its engagement by starting with a comprehensive discovery phase in which all of the documentation relevant to interconnection was reviewed and a large group of interconnection stakeholders were interviewed. Documentation included previous assessments that were used when creating the v5 system, various system requirement guidelines for the new proposed v6 system, PTV station financial survey results, video file specifications, bandwidth analysis, transponder analysis, and alternative system propositions. Documentation was received from CPB, PBS, and individual PTV member stations.

Cognizant conducted over 50 total interviews and meeting sessions with stakeholders in the interconnection system, commercial and non-commercial broadcasters, and third party technology vendors. Throughout the duration of the interview phase, the meeting agendas were evolved to reflect new information and a sharper focus on targeting the key elements of interconnection. First, Cognizant created a definition of what specifically comprised the modern concept of interconnection that was agreed upon among all stakeholders. Following this, interviewees were questioned on their experience with the current v5 system, their current knowledge on the developments of a new system, their knowledge on alternative approaches, and what risks they could project for the near and long term future.

Following this, Cognizant moved into an Analysis phase, wherein all of the documentation, interview results, and numerical data that was received was placed under close review. Interview results from station stakeholders were normalized and quantified to illustrate the station landscape as a whole and understand the needs of the PTV system. Cognizant conducted an analysis of the available bandwidth available (see section 8.3) to 170 licensees that operate 363 television stations in all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Island, Guam and American Samoa. Of these 170 PTV licensees, 79 are joint licensees with public radio.

One member station noted particular concerns with the v6 propositions for bandwidth requirements, and a follow-up interview was conducted to investigate the v6 proposition and evaluate it in the context of the PTV system at an individual member station level. All available financial data for stations was aggregated and analyzed as a means of understanding the size and available resources that currently exist in the PTV system. In the technological evaluation, the entire landscape of products was comprehensively reviewed, from historical satellite usage up to most current releases of technology that were demonstrated at the 2015 International Broadcasting Conference held September 10th through 14th. Based on this analysis, Cognizant has structured a recommendation that is supported by all available data.

CPB provided the initial list of stakeholders for Cognizant to engage with, which was added to throughout the course of the engagement. These stakeholders were divided into the following categories:

- **CPB Core Assessment and Management Team**
  CPB stakeholders were comprised of the Chief Operating Officer, the Chief Financial Officer, the Chief Strategy Officer, vice presidents, and senior vice presidents throughout the functions of Information Technology, Media Strategy, Operations, System Planning, Business Affairs, Government Affairs, Finance, and General Counsel. These stakeholders are directly and indirectly involved with media strategy, funding, and interconnection and were interviewed and regularly engaged throughout the assessment to review findings and establish next steps.
- **Technical Advisory Group**
  The Technical Advisory Group (TAG) is largely made up of CTO's and engineers from member stations that consult with CPB, PBS, and stations on technological initiatives. In addition to the standing interview template, stakeholders from TAG were specifically questioned on their knowledge and opinions of the current and future state of fiber networks, satellites, cloud-based storage, archiving, transcoding, video codecs, and television distribution overall.
- **Public Television (PTV) Representatives**
  PTV representatives were comprised of CEOs, COOs, general managers, and engineers at a sample group of member stations and master control facilities as determined by CPB. Sample stations were selected to encompass a broad range of size, geographic placement, and resources so as to effectively reflect the larger PTV landscape of 170 licensees. In addition to the standing interview template, PTV station stakeholders were questioned on daily operations, the size of the population served, and the implications that the implementation of a new interconnection system would have for their station.

- **Public Media Entities: PBS, NPR, and APT**
  Public media entity interviewees were comprised of stakeholders at the Public Broadcasting Service (PBS), National Public Radio (NPR), and American Public Television (APT) that pertained to distribution strategy for moving content from creators/ aggregators to PTV stations. These stakeholders consisted of roles including, CEO, CTO, and vice presidents and directors of Operations, Engineering, Technology Strategy, and Distribution. As the original architects of the current v5 interconnection system, stakeholders from PBS (both current and former) were regularly engaged throughout the assessment to review the design and planning for the proposed interconnection solution.

3 The Public Television Landscape (and Interconnection)

3.1 The Current Interconnection System (v5)

The current interconnection system is referred to as "v5." v5 was implemented and is managed by PBS to deliver live, near-live, and non-real time (NRT) content to the stations via satellite.

3.1.1 Interconnection Timeline

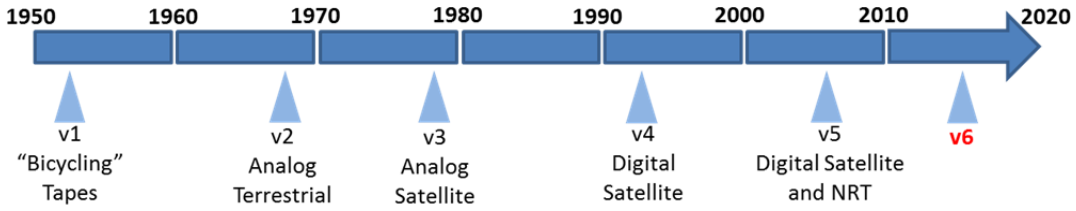


Figure 5 - Interconnection Timeline for Public Television

2016 will see the sixth incarnation of the public television interconnection system, with all predecessors receiving funding through CPB's annual and special appropriations. The original system consisted of "bicycling" audio and video tapes via a delivery service from station to station (v1). Following this, low quality programs began being transferred via AT&T's telephone communication network, while high quality programs remained on tape (v2). In 1978, PBS moved its National Program Service content from the terrestrial system to analog satellite (v3). In the early 1990's this was converted to a digital, linear satellite-based interconnection system (v4).

As the satellite contracts for both television and radio began to reach their termination, CPB worked with PBS and NPR to overhaul the systems. Congress provided a total of $119M for the Next Generation Interconnection System (NGIS) (v5), and $78M for the Public Radio Satellite System (PRSS). With this funding, NPR and PBS each created a separate NRT (file-based) IP over satellite digital distribution system. PBS purchased a NRT file delivery system for 169 stations, developed operations and training software, and provided interconnection services for American Samoa and Guam as well.

3.1.2 Feedback and Perspectives from Stakeholders

3.1.2.1 CPB

CPB petitions Congress for the appropriation of funds and distributes that appropriation to the system in accordance with the relevant statutes. Per the Public Broadcasting Act of 1967, it is the responsibility of CPB to "assist in the establishment and development of one or more interconnection systems to be used for the distribution of public telecommunications services so that all public telecommunications entities may disseminate such services at times chosen by the entities." As such, CPB has an interest in ensuring

that the funds requested for a new interconnection system are of an appropriate amount and that they are distributed in support of an effective solution. While the CPB representatives interviewed do not directly use the v5 system, the majority were aware that stations raised several issues with both the implementation process and end result.

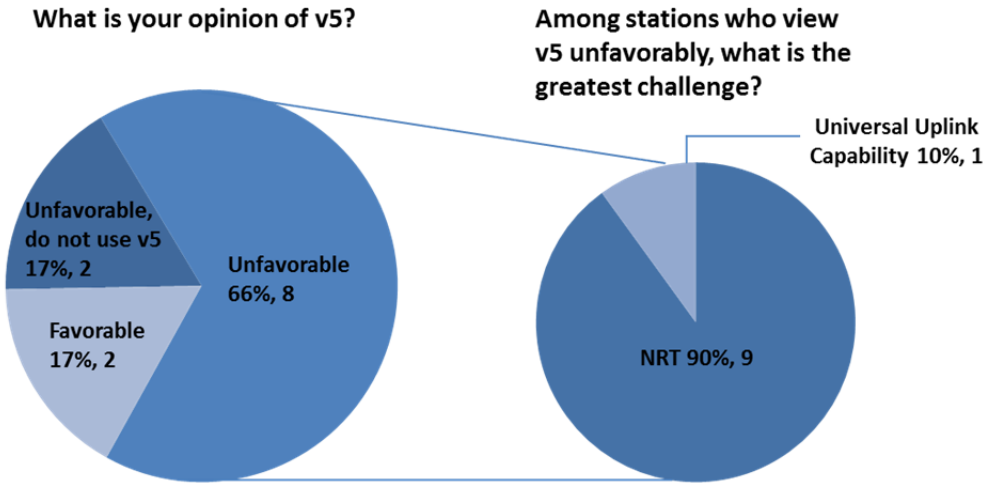
3.1.2.2 Public Television Stations and Technical Advisory Group

Cognizant interviewed a representative group of PTV member stations specified by CPB to understand their perspectives on public television and interconnection. In general, the findings have been consistent with the Engineering Technology Advisory Committee (ETAC) Survey Report released in February 2013.

A majority of station stakeholders (8 of the 12 licensees interviewed) were dissatisfied with the current v5 system. The salient feedback was:

1. As a distribution system, v5 can effectively deliver live content to stations.
2. v5 has been unable to deliver non-real time (NRT) content to stations in a consistent or reliable manner.
3. As a result of the lack of consistent NRT file delivery, many stations have not fully adopted v5.

Several stations have reported that the transcoding engine in v5 was inadequate and subject to occasional failure. In a few cases, v5 has been used solely for live and near-live content with alternatives such as File Transfer Protocol (FTP) (or media movement software such as Aspera and Signiant) being used for NRT content. Inadequate rollout planning of v5 resulted in stations not being prepared to adapt their systems to v5 by the time of deployment. This impacted v5 adoption across stations. A few stations have built their own solutions centered on a joint master control as a hub for content distribution and delivery. Two stations interviewed did not use the v5 system at all.



*Based on a sample size of 12 representative of total population

Figure 6 - PTV Station Perspective on v5

For one station that did not have uplink capability, stakeholders reported that the costs of content distribution prohibited them from being able to share content with other stations. If provided the capability, this station reported that they would like to share local content such as documentaries, news coverage of special events, and investigative reports.

The Technical Advisory Group (TAG) largely consists of CTOs from a subset of the public television stations. This group consults and advises CPB on the various needs of the public television system. In assessing the v5 interconnection solution, the members of TAG provided insight on the drivers behind v5 and their view of whether it has met station needs.

The current mix of live, near-live and NRT content varies based on station requirements related to interconnection. The more a station relies on live content, the more the v5 system worked without issue. However, it should be noted that in all cases, there was relatively little live content. All stations indicated that live content was less than 20% of broadcast content. TAG members speaking on behalf of their own stations noted that they were able to manage with the current v5 NRT approach by either using the v5 solution or a workaround of their own development. However, TAG members also acknowledged that the low adoption of v5 was a significant issue in terms of the investment for interconnection. Stations that maintain significant local archives or are part of a joint master control are not largely impacted by the design of v5 as their NRT content needs are largely addressed by other mechanisms. For most stations relying on NRT content, there were varying degrees of dissatisfaction with v5.

Three primary reasons were cited for the low adoption rate:

1. The design of v5 was not suitable for all stations.
2. The communication of the change to v5 was not adequate.
3. The implementation process was not consistent.

3.1.2.3 Public Media Entities: PBS, APT, NPR

Across the major public media entities, 10 stakeholders were interviewed: 5 from PBS, 2 from APT, and 3 from NPR. There was a shared awareness in this group that the satellite contracts are due to expire in September 2016. Similar to PTV stations and the Technical Advisory Group, PBS and APT stakeholders agreed that delivery of live content has worked smoothly. However, delivery of NRT files has been unreliable, which has resulted in a lower adoption of v5 across stations. Anecdotal feedback from PBS suggests that the issues with NRT content delivery are due to failures in the then new software technology being used, as well as operational challenges with file formatting. While many of these issues have been subsequently resolved, the initial challenges slowed or prevented adoption.

The needs of the distribution system for public radio are different from that of public television. Approximately 80% of NPR content is live and there are many more stations. Therefore, content is most easily delivered by satellite. Transmission costs for NPR are also lower due to smaller bandwidth requirements vis-à-vis PBS.

3.1.3 Content Processing Model

The v5 interconnection system was funded via CPB and operates through PBS. PBS aggregates content that is transmitted to stations via the PBS Network Operations Center (NOC). Processing and interstitials are also handled at PBS prior to pushing content out to stations. PBS devised and oversaw the rollout of v5, and, along with APT, is responsible for most of the national content that is aired by PTV member stations. Depending on the station, some content is archived locally after airing. However, local storage for national content can be lacking depending on a station's individual resources, especially for smaller stations. As such, it is not uncommon for a station to receive the same content from PBS multiple times and then delete the content after each broadcast.

3.2 Perspectives on the Proposed Interconnection System (v6)

3.2.1 CPB

As a part of the appropriations request for a new interconnection system, CPB worked with Cognizant to define what would constitute a minimum threshold for a new interconnection system. This definition needs to adhere to relevant statutes ensuring alignment with the expectations from an appropriation perspective. Per the Public Broadcasting Act of 1967, the federal appropriation "shall be distributed by the Corporation [for Public Broadcasting] to the licensees and permittees of non-commercial educational television broadcast stations providing public telecommunications services or the national entity they designate for satellite interconnection purposes and to those public telecommunications entities participating in the public radio satellite interconnection system or the national entity they designate for satellite interconnection purposes, exclusively for the capital costs of the replacement, refurbishment, or upgrading of their national satellite interconnection systems and associated maintenance of such systems." As such, interconnection expenses have historically been defined largely by satellite costs. However, given the sea change in media distribution technology, it is now possible to cut costs throughout the system in areas that were previously considered separate entities from interconnection, such as archival storage and master control.

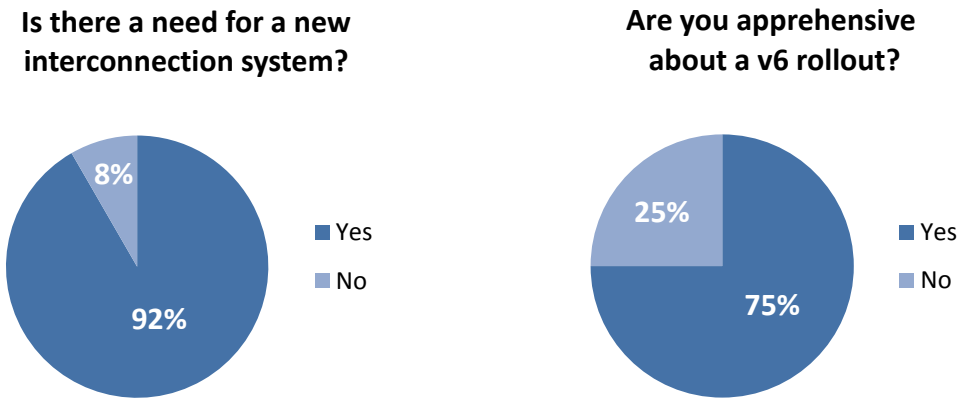
A universally agreed upon definition of interconnection is also necessary to address business needs should CPB receive limited or no funding for a new interconnection system and a minimum operational threshold needs to be provided for public television. In the case of limited or no interconnection funding, a new interconnection must still be implemented due to the expiration of the satellite leases. CPB also recognizes the use of modern technology by commercial broadcasters to address similar issues in a changing media environment with evolving consumption patterns. There is a focus to move away from large capital expenditure to incremental and iterative models of building (or upgrading) technology infrastructure to reduce risk and total operating costs over time.

3.2.2 Public Television Stations and Technical Advisory Group

Based on our interviews with this group, the key elements of a v6 system were:

1. Delivery of NRT content must be more reliable than v5.
2. A terrestrial network should be more cost effective than a satellite network.
3. The new system should facilitate collaboration among stations.

Our interviews indicated a wide range of views on the need for a v6 system, the value it could bring, its typical features, and the risks of implementation. Interest and potential demand for universal bi-directional content delivery is also mixed based on the lack of clarity of the need. However, there is interest in advanced features including transcoding, closed captioning and storage. Current limitations with storage and archive infrastructure resulted in several stations having to receive the same content multiple times, creating an inefficient transmission model and higher operating costs.



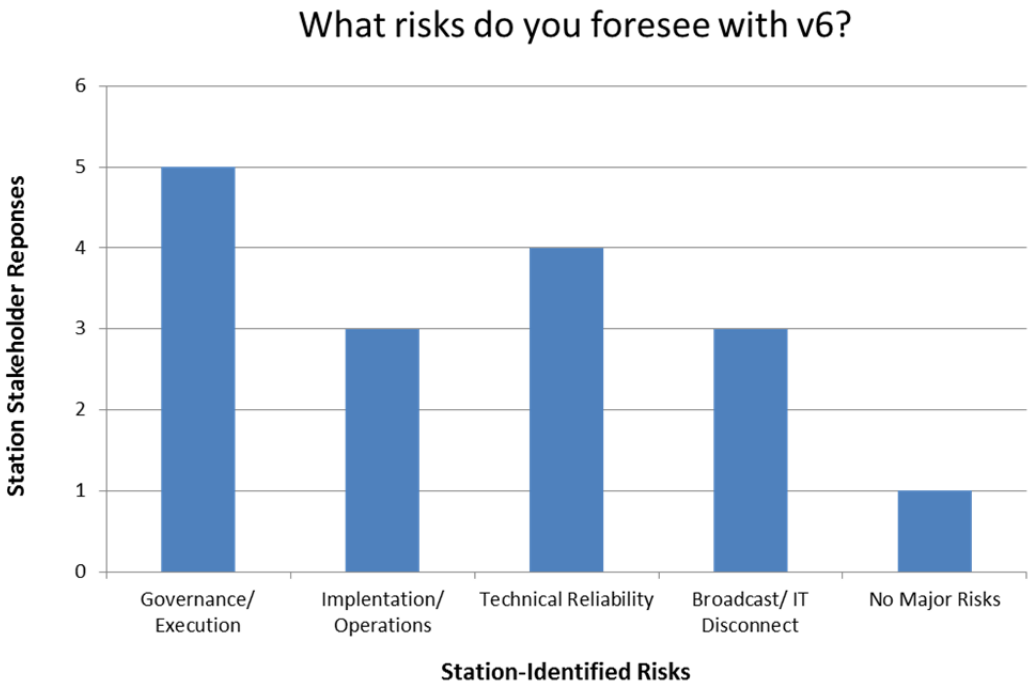
*Based on a sample size of 12 representative of total population

Figure 7 - PTV Station Perspective on v6

TAG and ETAC members are aware of the proposed v6 system and the alternative solution from WGBH which is also being considered for interconnection. Though most stakeholders have limited detailed information, they see a new interconnection system addressing the current challenges with NRT content and providing value-added services such as collaborative content production and enhanced emergency services. However, there are concerns regarding funding and how it may impact the new system in terms of scope and rollout. There are also misgivings about the governance model to be instituted. There is agreement on shorter, incremental implementation cycles in comparison to the traditional implementation models which limit flexibility and adaptability.

PTV and TAG stakeholders see implementation, operation, and governance risks with v6 based on earlier experiences (primarily reliability of v5 NRT content delivery). Variation between the content delivery

workflows at individual stations and staff training is likely to be a potential issue for the implementation and rollout of v6. The cultural differences between IT and broadcast engineers are also an issue with varying perceptions on acceptable quality and SLAs (Service Level Agreements).

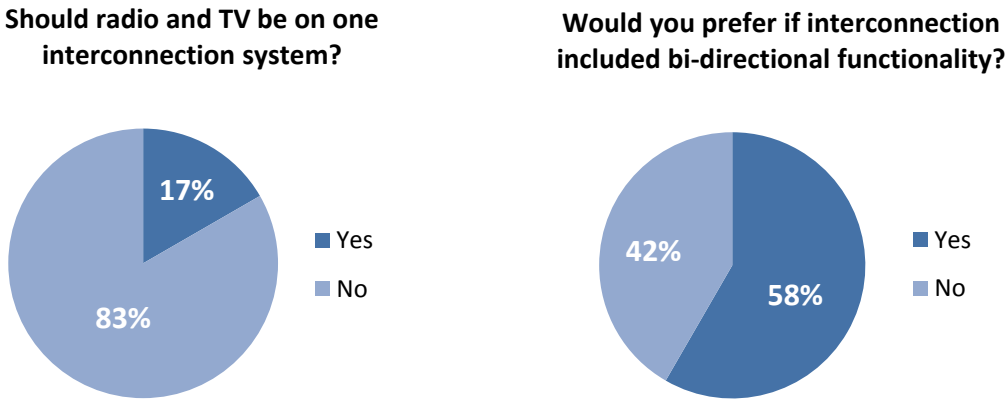


*Based on a sample size of 12 representative of total population (Some stations identified multiple risks)

Figure 8 - PTV Station-Identified Risks

Interview results were quantified as a means to gain subjective insight from a small sample as to the current state of interconnection and predictions for its future.

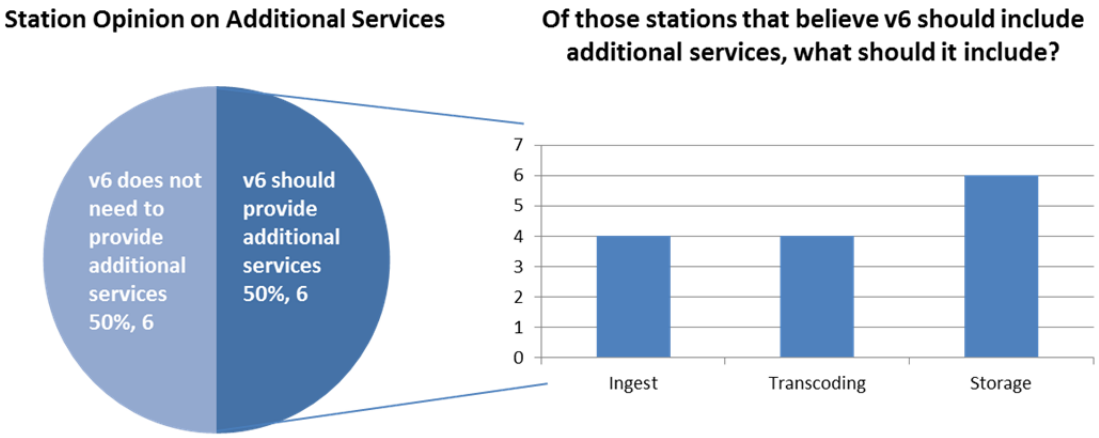
Of the twelve (12) stations interviewed, the majority noted that the current v5 system was not reliable; however, many stations also responded that they were wary of PBS' propositions for v6. Of those that did not report problems with v5, stations either used no NRT content in their workflows or utilized an FTP or cloud-based workaround for some content.



*Based on a sample size of 12 representative of total population

Figure 9 - PTV Station Perspectives on Additional Features of Interconnection

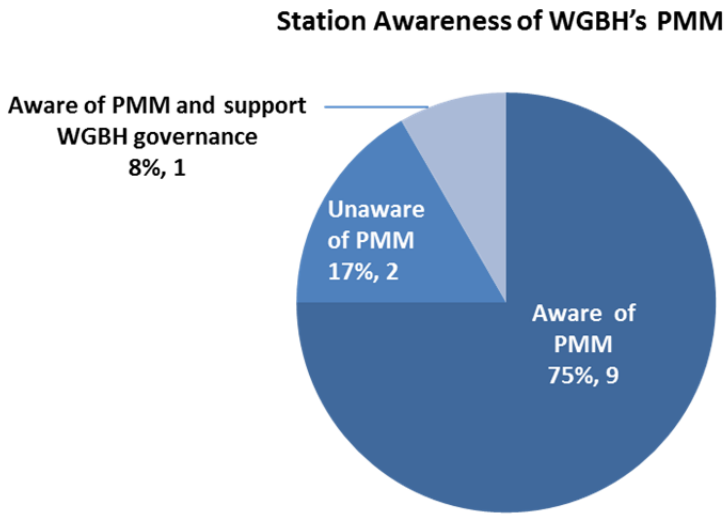
All but one station quoted the need for a new interconnection system; however, most stations felt that it was unnecessary to include radio on the same interconnection system as TV. Reasons cited for this were that radio had very different needs from TV, there were more member stations, and it did not require as much bandwidth.



*Based on a sample size of 12 representative of total population

Figure 10 - PTV Station Perspectives on Additional Services

Seven of the twelve licensees cited that the system needed bi-directional functionality. However, two of these respondents also fell into the category of the top 5 licensees that with the highest number of production hours for national broadcast, which is not representative of the larger PTV landscape. Additionally, it is the opinion of Cognizant that this engineering preference did not match the expressed business needs for bi-directionality in the system as a whole.



*Based on a sample size of 12 representative of total population

Figure 11 - Station Awareness of PMM Solution

The majority of stations had heard of the WGBH PMM solution, and, of those who had heard of it, the majority of stations did not think that PMM alone was a solution for interconnection without a satellite overlay for live. Additionally, stations expressed concern of a single licensee holding governance for the entire interconnection system.

3.2.3 Public Media Entities: PBS, APT, NPR

The public media entities recognize the upcoming expiration of satellite leases. PBS has analyzed the financial impact of upgrading the current v5 system vis-à-vis implementing a new v6 interconnection system. PBS has determined that the cost of implementing a new hybrid satellite-terrestrial system would not be significantly higher than upgrading the current v5 system and is, therefore, a strong supporter of a new v6 system.

There is consensus that v6 must address the issues with NRT content delivery as well as continue to deliver live and near-live content reliably. Universal bi-directional functionality and collaboration services are seen as key features to enable a rich PTV community allowing even smaller stations an opportunity to contribute more widely. PBS' recent 'round-robin' style newscast between Texas, Chicago and New York was mentioned as an example of collaborative content production.

Additionally, PBS is of the opinion that a v6 system provides the opportunity to improve the national emergency communications system and can be extended to provide a communication platform for local police and fire departments. The education sector can benefit from a fiber infrastructure to connect public libraries and schools throughout the nation including the provision of high speed internet access in areas of low or no current penetration.

A new type of interconnection system which includes radio is conceptually desired, though the technical and operational requirements may make a fiber based terrestrial solution for radio unfeasible. NPR envisions that the cost of fiber is significantly greater than satellite transmission costs. Additionally, the rollout would be more complex and expensive given that there are more than 400 public radio stations licensees compared to the 170 PTV licensees.

3.3 Centralized Master Control

3.3.1 Historical Attempts

3.3.1.1 ACE

The ACE system was initially developed by PBS in 2004 to be a centralized master control system serving public television. There were two forms of the ACE system – ACE for member stations and ACE for the PBS NOC. ACE at the station level was labeled as Local ACE and was intended to create savings based on enhanced efficiencies for master control monitoring. Local ACE was designed to be an integrated system that included playout, storage, scheduling traffic, avails management, and channel branding.[1] Additionally, it would bring automation to stations, which would enable them to operate unattended while PBS staff monitored transmission from Virginia. It would also provide stations with the ability to add multicast channels without hiring additional technicians.

However, the rollout of ACE was met with mixed reviews by stations and ultimately did not receive widespread adoption. By September 2006, the ACE system was adopted at only eight stations, while the original plan was to have it installed at 25 to 30 sites.[2] Six stations reported using ACE as a substitute for their master control setups, with only one station reporting problems. During a widespread rollout attempt, some stations began reporting technical challenges during installation. According to Broadcasting & Cable, by October 2006 "stations largely rejected the new automated system, which they said was too expensive and didn't live up to its billing."[3]

[1] Broadcast Operations Systems Assessment. Merrill Weiss Group. June 1, 2005.

[2] Behrens, Steve. "Move to PBS' ACE Master Control Gets Mixed Reviews." *Current*. September 25, 2006.

[3] Dickson, Glen. "PBS' Automation Effort Stalls." *Broadcasting & Cable*. October 7, 2006.

3.3.2 Recent Initiatives

3.3.2.1 Public Media Management (PMM, a Partnership Between WGBH and Sony)

The PMM system was created out of a partnership between Boston-based PBS member station WGBH and Sony Media Cloud Services. Designed for cloud-based centralized master control, a predominant benefit that it advertised to stations was that it provided an economical substitute to acquiring and operating their own master control equipment. The WGBH NOC processes live and NRT files and provides services such as transcoding, QC, and metadata entry. On the station side, the traffic system downloads content from the cloud and assembles streams for playout based on an individual station's local schedule. Additionally, the PMM solution is equipped with offsite disaster recovery.

PMM provides stations with the option of master control services such as closed captioning, local inserts and messaging, content ingest, content stream customization, and QA. Stations can opt out of these additional services and retain local master control if it is better suited to do so at the individual level. Each station connects to the PMM cloud to push or pull content using the station node. PMM also employs one set of metadata and processes that it can use for multi-platform distribution across broadcast, web, mobile, OTT, etc. Member stations can create individualized streams of content to target particular audience segments, which could ultimately lead to greater retention and, potentially, donations. Additionally, PMM addresses data storage by providing archiving in the cloud.

The stations or entities that use or shortly plan to use PMM are listed below, with five additional stations currently in contractual negotiations (at the time of writing this report):

- WGBH (Boston)
- WGBX (Boston)
- Maryland Public Television (Maryland)
- WGBY
- New Hampshire Public Television
- World Channel
- Detroit Public Television
- Alabama Public Television

3.3.2.2 Digital Convergence Alliance

The Digital Convergence Alliance (DCA) originated out of a partnership of eleven PTV stations, with the purpose of serving as a binding governing body through which stations would create and execute initiatives that increase efficiencies and enable new revenue opportunities. The first of these initiatives was the creation and operation of a centralized master control service NOC. Launched in 2012, the DCA contracted WJCT (Jacksonville) to manage the NOC. The DCA became fully operational in August 2015.

Currently, the facility serves 11 stations with a total of 39 streams. The operating budget is $2.3 million a year, with $235,000 in connectivity costs. Level 3 is the network provider. The facility is HD and SD file-based and designed to support up to 50 stations. "Hub-and-spoke" fiber-optic lines send programming

to member stations via a private internet connection, and the NOC services combine master control, traffic operations, and delivery systems. Since its launch, the NOC has been utilized by stations largely for interstitials.

Results from interviews that Cognizant conducted showed that no stations that are connected to the NOC have fully utilized its capabilities at the time of this report. JCT also projects that there will be a transition to 4k resolution, and that stations will not have the capacity to upgrade individually and will thereby rely on joint master control facilities. In terms of projected growth, the facility estimates that it will need to add 1 employee for every 3 stations added. A primary driver of savings for individual stations will be the reduction of staff in these roles. The facility was also included as part of the v6 Proof of Concept.

The stations that currently use the JCT NOC are listed below:

- KERA (Dallas)
- MPTV (Milwaukee)
- WEDU (Tampa)
- WEFS (Cocoa Beach)
- WFSU (Tallahassee)
- WILL (Champaign)
- WJCT (Jacksonville)
- WPBA (Atlanta)
- WPBT (Miami)
- WTTW (Chicago)
- WUCF (Orlando)

3.3.2.3 CentralCast

CentralCast is another joint master control facility in the public television system. Becoming operational in 2012, as of September 2015 it served 13 member stations. It was initially designed to support 35 stations and a total of 200 DTV channels. At the time of its launch, it was projected that the CentralCast facility would result in a savings of over $25 million over the course of its first 10 years in operation by eliminating redundant equipment and decreasing maintenance costs.

Similar to the DCA NOC, CentralCast is a HD and SD file-based facility that uses “hub-and-spoke” fiber optic lines to send content to stations. The facility is designed to support up to 200 streams of content delivery and maintains a 24x7x365 staffed centralized operations control center. The facility was also included as part of the v6 Proof of Concept.

The stations that currently use CentralCast are listed below:

- WCFE (Pittsburgh)
- WCNY (Syracuse)
- WLIW (Long Island)
- WMHT (Albany)
- WNED (Buffalo)
- WNET (New York)
- WNJB (New Brunswick)
- WNJN (Montclair)
- WNJS (Camden)
- WNJT (Trenton)
- WPBS (Watertown)
- WSKG (Birmingham)
- WXXI (Rochester)

4 A New Interconnection System

4.1 Interconnection: Definition, Scope and Benefits

4.1.1 Definition

Per the federal statute, the term "interconnection" refers to the "use of microwave equipment, boosters, translators, repeaters, communication space satellites, or other apparatus or equipment for the transmission and distribution of television or radio programs to public telecommunications entities" and the term "interconnection system" refers to "any system of interconnection facilities used for the distribution of programs to public telecommunications entities."

It is essential to appropriately define interconnection prior to assessing candidate solutions and recommending the most suitable interconnection approach for PTV in the United States. In simple terms, interconnection can be defined as 'the set of technologies and operations required to send content (and metadata) from content producers/ aggregators to stations.'

It is noteworthy that interconnection does not extend to the communication mechanism between content producers and content aggregators or between stations and viewers. Because of this, the needs for a "clear feed" transmission mechanism to individual satellite dish owners was not evaluated in detail. A brief review of the arguments for removal of the clear feed requirement by Cognizant found that we agree with PBS and CPB that this should be eliminated by Congress due to cost per viewer.

4.1.2 Key Services of a New System

Stakeholders across the PTV community differ in their opinion on what constitutes an interconnection system and the services it may provide (which can include a combination of the following):

- Bi-directional capability (ability for a station to both uplink and downlink)
- Universality of services (equal level of service offerings to all 170 PTV stations)
- Connection to a joint master control (JMC)
- Cloud-based editing, transcoding, and closed captioning
- Provision for storage and archival
- Consolidation of public television and public radio on one interconnection platform

The platform provided by an interconnection system can be utilized to provide additional services (e.g. joint master control) although that may not be the core focus of the interconnection system itself. It is noteworthy that additional unrelated benefits can be derived from supplementing the interconnection infrastructure with value-added services.

4.1.3 Primary Business Drivers for a New System

The business drivers for a new interconnection system include:

- **Reduced spend on satellite transmission**
  One of the predominant drivers of the new interconnection system is the ability to downsize the current distribution infrastructure down from 3 transponders to 1 transponder, resulting in a reduction in spend.
- **Addressing the shortcomings of the (current) v5 system including aging equipment and technologies (which may be unsupported in the future)**
  There is universal agreement that the current v5 system cannot effectively process NRT files, and that NRT is and will continue to be the most common form for content in the PTV system. Furthermore, aging equipment throughout stations needs to be addressed so that individual stations with fewer resources can continue to effectively broadcast content.
- **A sustainable long-term solution for content distribution to stations better addressing current and future needs**
  Fast-paced advancements in video codecs and resolutions will necessitate a responsive and adaptive interconnection system should PTV wish to remain relevant in the larger television ecosystem.
- **Allowing investments to be OpEx-based (from the predominantly CapEx-based model currently in place) and thus increasing flexibility**
  Historically, major interconnection system implementations have occurred approximately once every 10 years and have been incurred as capital expenditures. However, given the transforming landscape of technology, implementations are transitioning into service-based models that rely on smaller, recurring OpEx costs rather than large, one-time CapEx costs.
- **Enabling public media to remain competitive for audience in a changing media landscape**
  Given the evolving distribution model for television as a whole is moving from broadcasting a signal to a home television set to distribution via applications over a variety of over-the-top (OTT), console, mobile and tablet platforms, public media stakeholders must remain conscientious of industry trends and adjust their strategy and operations accordingly.

4.1.4 Key Benefits

A base interconnection system needs to only move content (and metadata) to stations. However, the infrastructure can be used for additional services which can include the following:

- **Peer-to-peer collaboration**
  Stations share or receive content using FTP software (e.g. FileZilla) or video tapes and disks via courier service. They can also be part of a regional terrestrial network which allows exchange of content. A new interconnection system can offer a peer-to-peer communication mechanism for all stations across the United States allowing each station to contribute content to any other. This can be extended to offer collaboration services for content production between stations.

- **Content storage**
  Locally-produced content and an unreliable NRT delivery leads to many stations having to store content locally. Local archives can frequently reach capacity and result in content being deleted from the system. As such, this would necessitate a station to put in another request for content from the content aggregator/ provider should it want to re-air it at a later date. A cloud storage model in a new interconnection system could help reduce this and streamline and optimize content storage for stations.

- **Public services**
  The new interconnection system can be used to enhance national emergency communications systems and provide a communication mechanism for local police and fire departments. A national fiber network can connect public libraries and schools and potentially provide internet access to regions not serviced currently.

- **Shared services**
  The new interconnection system can provide an infrastructure for shared services such as transcoding, closed captioning, quality control and joint master control. This could lead to high-quality, consistent and on-demand services being offered to stations at a reduced cost, thus also enabling stations to convert their fixed costs to variable costs.

4.2 Approaches to Implementing a New Interconnection System

4.2.1 PBS v6 Approach

The current v5 interconnection system is a satellite-based distribution system through which PBS distributes real-time and NRT content to the stations. Additionally, approximately 20 stations also have uplink capability to deliver content via satellite. Currently, v5 uses 3 transponders. PBS satellite contracts are set to expire in September 2016 and the equipment and technologies currently in use are aging, thereby creating the need to either refresh the current system or implement a new one.

PBS has proposed a new interconnection system, v6, which is designed over a hybrid satellite-terrestrial fibre-based network. The v6 interconnection system plans to connect 170 licensees via a Multi-Protocol Label Switching (MPLS) mesh network. Stations will have 100 Mbps connectivity to this network although a few may have DS3 (45 Mbps) connectivity where 100 Mbps is not available. The PBS Network Operations Center (NOC) and other entities may be connected with a higher capacity connection (1-10 Gbps).

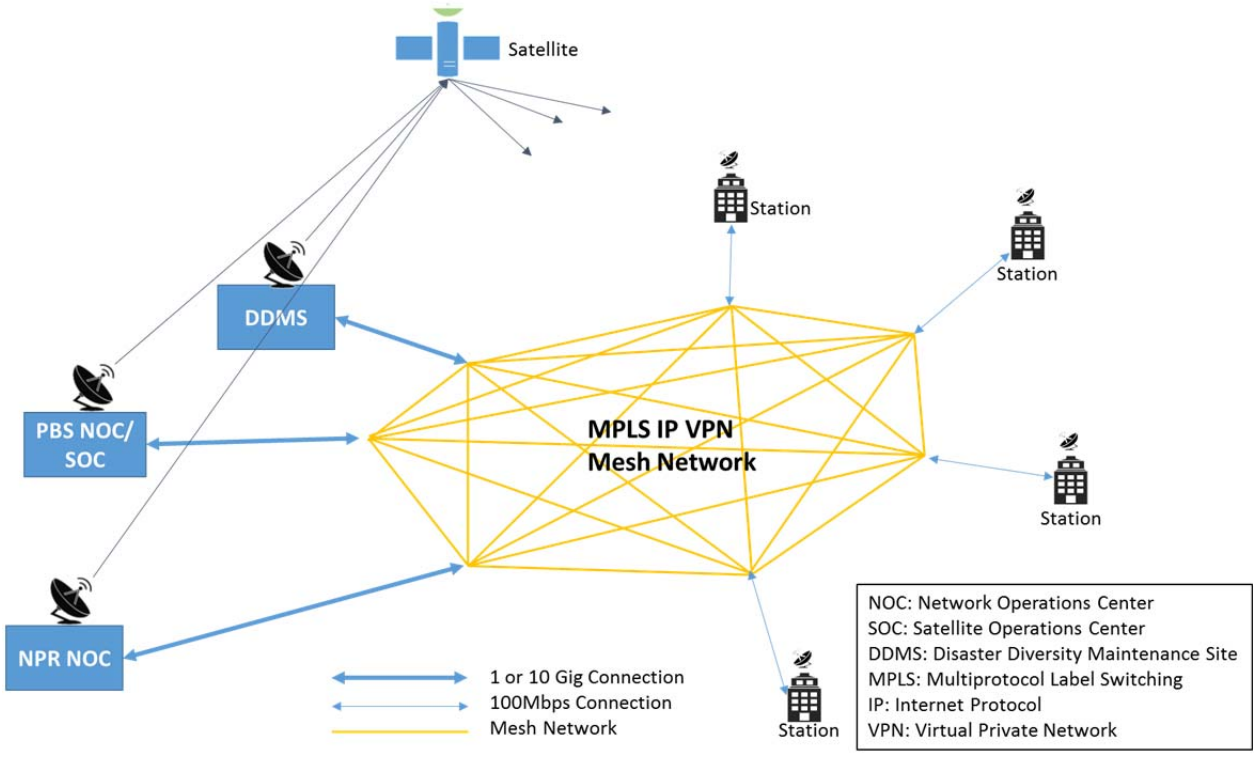


Figure 12 - High Level Overview of the v6 Interconnection system

The v6 system will replace most of the current satellite transmissions with terrestrial feeds and reduce the number of satellite transponders from 3 (current) to 1. Most of the content will be distributed through the terrestrial fiber network with satellites providing contingency for live and near-live content. This is a significant shift from the current model:

- The current v5 linear satellite feeds from PBS to stations will be replaced by terrestrial feeds that will be multicast to the stations from the PBS NOC over the terrestrial network.
- The v5 NRT feed will be replaced by file transfer over the terrestrial network and stations will be able to pull the content when they need it.
- Other linear feeds from contributing stations will also be replaced by NRT file transfer over the terrestrial network. In addition, stations will have the capability to multicast their content.

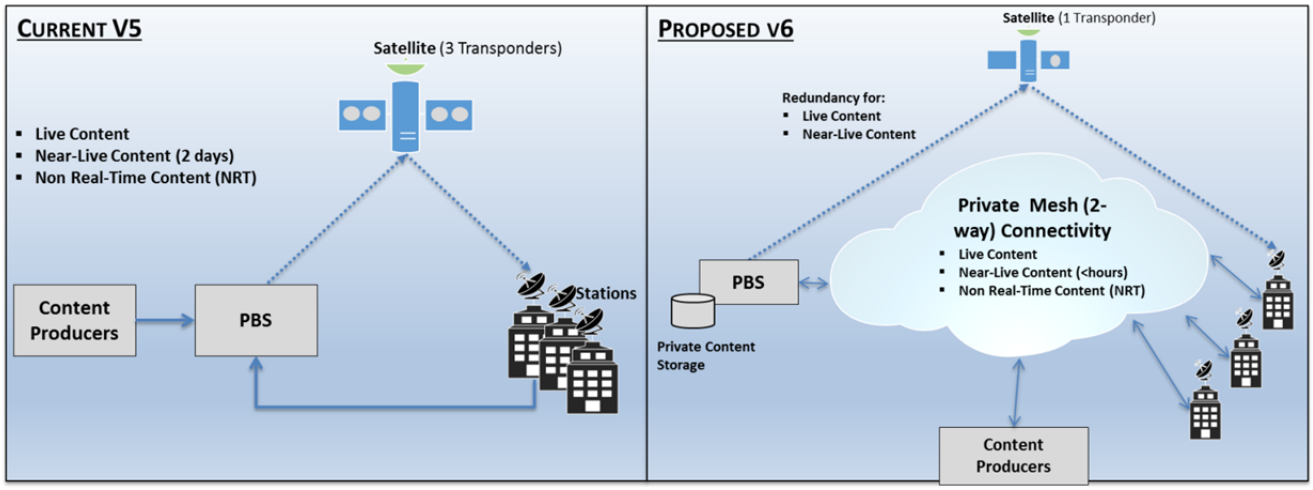


Figure 13 - Interconnection Current and Proposed States (v6 Perspective)

Features of v6:

- PBS' new interconnection system will provide multicast capability to all the PTV stations through the MPLS network (i.e. each station can be the origination point and serve one or many stations in the network). Currently, only approximately 20 stations have the ability to uplink their content.
- The v6 interconnection system will use a standard file format for NRT delivery, whether originating at PBS or member stations or other contributors. The file will not be transcoded to meet the station format requirement unlike the v5 interconnection. The stations will have Advanced File based Integrated Receiver Decoders (A/F IRD) that will be able to play out these files locally as Serial Digital Interface (SDI) output if they are not able to accept the standard file format or transcode it.
- Stations will be on a comprehensive mesh network allowing them to share content directly with each other.

In 2014, PBS conducted a Proof of Concept (PoC) for the v6 system. Participation in the PoC was comprised of the PBS NOC, 15 PTV stations (of which 2 were serviced by joint master control facilities), the two joint master control facilities (CentralCast and JCT), and NPR's Public Radio Satellite Services (PRSS) NOC. Stations were provided with equipment sets and PBS contracted Level 3, CenturyLink, and Internet2 as the service providers for the MPLS IP-VPN infrastructure. PBS noted that although there were some minor adjustments to station workflows that were anticipated, it was not expected that the transition to v6 would result in any major changes. In contrast, PBS would need to significantly alter its internal workflows, and must do so without disrupting operations at either the NOC or member stations.

The interconnection system will rely on the PBS Enterprise Service Bus, a backbone that would enable the network to transition to a "Service Oriented Architecture."[4]

PBS developed a common IP addressing stream and a common Class of Service and Quality of Service (COS/ QOS) model which demonstrates scalability. Per the model, a test site with 100 Mbps bandwidth will have 30 Mbps for the highest COS traffic going into the MPLS network.[5] The COS tagging assigns a priority to traffic and occurs at the v6 kit in ingest to the network. High COS is typically used for IP multicast linear video, and is provided using the v6 mesh network. In instances when the highest COS is used, the remaining 70 Mbps can be used for other traffic; in instances where the highest COS is not used, the full bandwidth is available for lower priority traffic.

4.2.2 WGBH PMM Approach

PBS member station WGBH has built a cloud-based solution, Public Media Management (PMM), to refresh master control and media management technology at the stations. The solution leverages the public internet to connect stations to the cloud, and with the addition of a satellite overlay, could function as a viable interconnection system. The PMM solution provides a managed service model for master control where it provides and maintains the equipment required at the stations to use its services. WGBH has proposed PMM as an alternative to the new v6 interconnection system proposed by PBS.

The PMM solution comprises the WGBH Network Operations Center (NOC), nodes placed at each station and PBS, and the Sony Ci cloud built on Amazon Web Services with 100 Mbps public internet connectivity. Given that it will provide master control functionality in addition to interconnection services, PMM contains a software-based solution for stations to manage master control services such as closed captioning, local inserts and messaging, content ingest, content stream customization, and Quality Assurance (QA). Each station will connect to the PMM cloud to push or pull content using the station node. WGBH will provide equipment at the station to integrate with the local traffic system (ProTrack, from Myers).

[4] v6 System Requirements Definition for the PBS v6 Proof of Concept (v6 PoC '14) Project (February 24, 2015)

[5] Ibid.

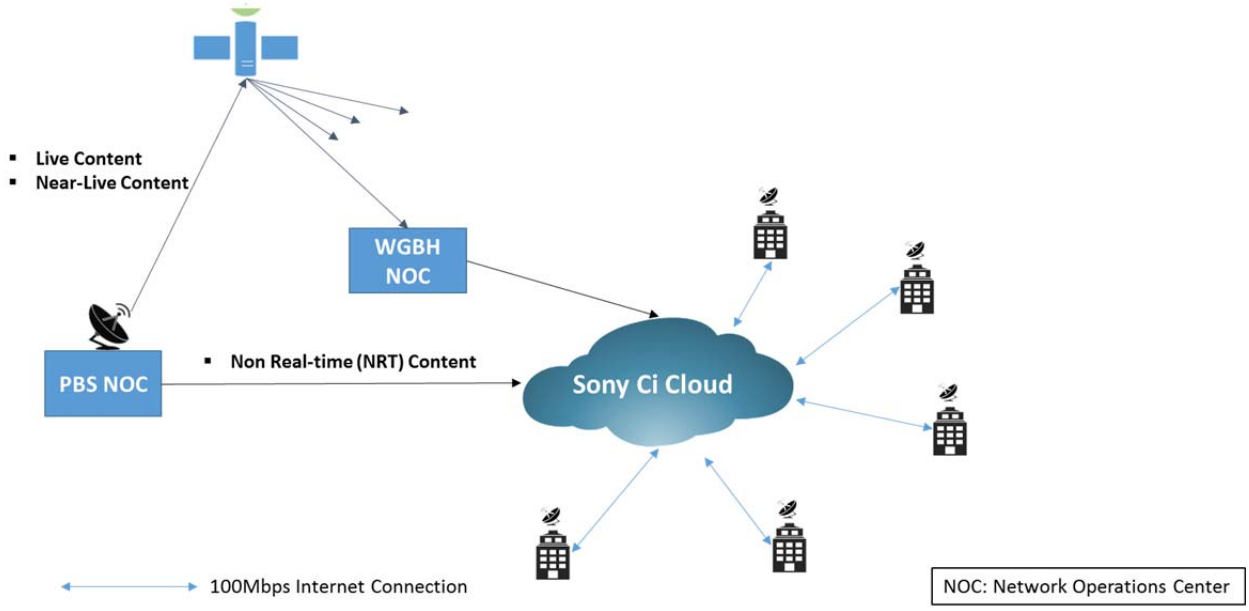


Figure 14 - High Level Overview of the WGBH PMM system

The PMM solution, though initially intended to refresh master control technology and workflows, can act as an interconnection system with the addition of a satellite overlay:

- The PMM NOC will record the live and near live content from PBS satellite feeds, transcode it into a standard format, and perform quality control. The content will then be moved to the Sony Ci cloud where it will available to stations. PMM will leverage the satellite facilities at the PBS NOC for this content. PMM will also download this content to local storage at the station node which will be maintained for 30 days.
- For NRT content, PMM will ingest content from PBS and move it to the Sony Ci Cloud. Ingest technology similar to a node would be installed at PBS.

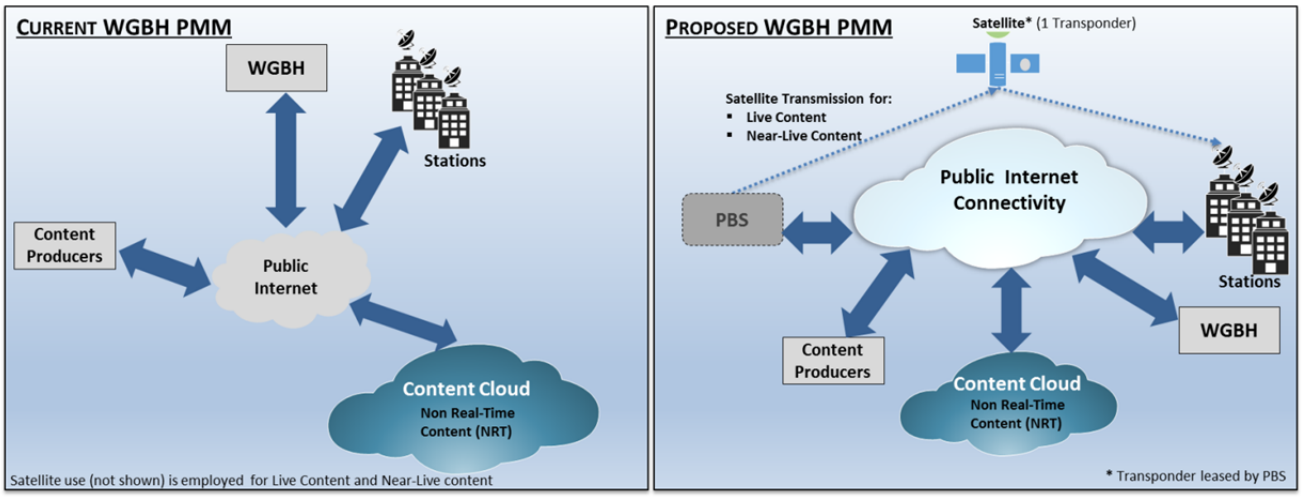


Figure 15 - WGBH PMM Current and Proposed States (PMM Perspective)

Features of the WGBH PMM solution:

- PMM will ingest and process content at a centralized location (the WGBH NOC) and store it in the Sony Ci cloud. PMM will download content from the cloud and assemble streams for playout based on the station's local schedule. The ProTrack system at stations will integrate with the station's PMM node.
- Collaboration among stations is projected to increase as stations will be able to share their content with each other via the cloud.
- WGBH has noted that, due to the resources of Sony as a provider, PMM is a highly scalable solution and could be extended to member stations nationwide with relative ease.

Additionally, PMM employs one set of metadata and processes that it can use for multi-platform distribution across broadcast, web, mobile, OTT, etc. WGBH has also stated that this new system would enable member stations to create individualized streams of content to target particular audience segments, which could ultimately lead to greater retention and potentially donations. PMM also provides a solution for data storage and archiving in the cloud. Stations can elect to opt out of the master control services that are included in PMM should they want to retain master control at a local level.

WGBH maintains that the public cloud is equally, if not more than, secure as private fiber. Specifically, Amazon Web Services, the cloud provider for PMM, guarantees over 99.99% reliability.

5 Findings and Recommendations

5.1 Analysis (Disposition) of Member Stations

Using the CPB Station Activities Benchmarking Study (SABS) from 2014, the landscape of stations was assessed against a variety of parameters, including annual revenue, expenses, population coverage, number of Full Time Equivalents (FTEs), and hours of content produced for national broadcast. This study provided the data used for further analysis of stations in relationship to their interconnection needs. The data is self-reported by licensees and has not been further validated for accuracy.

In order to understand the PTV station landscape as well as determine a rollout strategy, licensees were split by reported FTE count and classified as small, medium, or large. Stations are categorized by licensee type: community, state, local authority, and university. University licensees were extracted from our segmentation analysis group and segmented using different values as determinants of size categorization, as they commonly have unpaid student interns and therefore cannot be directly compared to the number of FTEs at a licensee of a different type. For all licensee types excluding university, licensees were categorized as small if they had 20 FTEs or fewer, medium if they had between 20 and 150 FTEs, and large if they had 150 FTEs or greater. Out of the 170 licensees that participated in the SABS 2014 Survey, 58 stations identified as university licensees. University licensees were categorized as small if they had 15 FTEs or fewer, medium if they had between 15 and 109 FTEs, and large if they had 110 FTEs or greater.

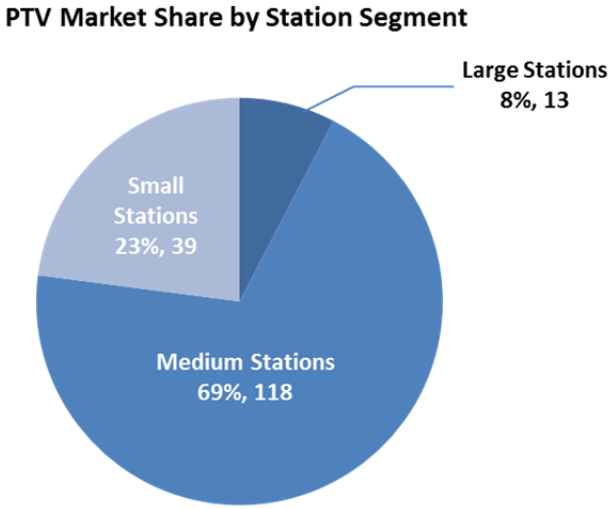


Figure 16 – Number of PTV Stations By Segment

Results from segmentation showed that the mean large station had over 4 times more FTEs than a mean medium station and over 15 times more FTEs than a mean small station (see Figure 16). Furthermore, the two largest licensees, WGBH and WNET, respectively, accounted for 36% of FTEs for all large stations. In 2014 revenue, large stations had a mean of $52.8 million as, compared to $9.2 million and $2.3 million, respectively for medium and small stations. WGBH and WNET accounted for 20% of the total revenue for all 170 stations. In contrast, population coverage showed some correlation with the number of FTE's for an individual licensee, but regression analyses showed no statistical significance.

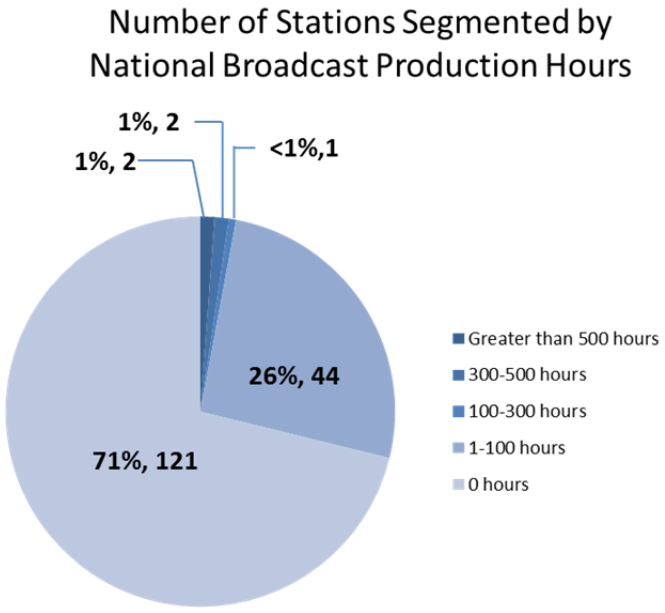


Figure 17 - Stations Segmented by National Broadcast Production Hours

In addition to the segmentation analysis, the station assessment was used to determine whether a universal, bi-directional network would be fully utilized. The analysis showed that the top 4 licensees in national broadcast production accounted for 77% of all national broadcast production, and that 121 licensees had zero hours of national broadcast production. These results call into question the necessity of universal, bi-directional functionality among all stations.

5.2 Interconnection: Current Industry Trends

5.2.1 Commercial Broadcasters in the United States

In recent years, technologies like the Cloud have matured in the quality, reliability and relevance to media of solutions and services being offered. This has led to several of the major commercial broadcasters in the United States to incorporate across their enterprise the use of cloud and other modern distribution technologies. Disney's ABC Television Group (DATG) has collaborated with Imagine Communications to transition its linear broadcast operations – global programming playout, delivery

and network operations – to an IP cloud architecture using Imagine's VersioCloud platform.[6] Turner utilizes Elemental video solutions for multiscreen delivery to deliver any NBA game over broadband to any subscriber on any platform (Android, iOS, PC, Roku, etc.) equivalent to 30 games a night or over 800 live streams.[7]

The use of fiber networks to distribute content to the primary urban areas across the distribution landscape is becoming increasingly common. Broadcasters have embraced the use of the public internet as a primary or backup medium (based on business need and after having drawn a clear distinction between hard-live and soft-live content). Modern solutions provided by specialized vendors in each of these areas (see section 5.2.3.) have increased the adoption of these technologies across the world in recent times. Those who have not moved to take advantage of cloud and fiber/internet-based distribution technologies are considering their use and actively investigating how best to adjust their business processes to benefit from them.

5.2.2 Public Television in the UK

Cognizant has had conversations with the BBC in the UK to get perspectives on interconnection technologies and models which have worked well for them in recent years. Notwithstanding the number of differences between the deployment requirements and scenarios for public television in the UK and the US, there are experiences which can be leveraged in the context of public broadcasting interconnection (in the US).

The BBC primarily uses satellite technology for distribution (though terrestrial networks are used for audio and mobile content and for content contribution). The use of the public internet for media movement brings cost efficiencies to them while a backup is provisioned by the use of terrestrial or satellite connectivity.

One of the considerations for fiber or internet-based interconnection would be the bandwidth available to stations (especially those in remote locations). This becomes especially relevant depending on future plans for the broadcast of 4k content which may challenge the terrestrial connectivity available (see section 5.2.3). Also, given the costs of setting up fiber networks, the use of the public internet may be more beneficial and cost-effective. In such a scenario, satellite could be used as backup for interconnection services. The BBC's experience with fiber transmission has been that when compared to satellite transmission, fiber can scale better in managing increased file sizes at a relatively lower (or no) financial impact.

[6] Imagine Communications and Disney/ABC Television Group Redefine Future of Broadcast Television
http://www.imaginecommunications.com/resources/blog/imagine-communications-and-disneyabc-television-group-redefine-future-broadcast

[7] Elemental Makes IBC 2014 Innovation Awards Shortlist with Content Delivery Finalists BBC and Turner Sports
http://www.elementaltechnologies.com/newsroom/press-releases/elemental-makes-ibc-2014-innovation-awards-shortlist-content-delivery

Another area of inefficiency Cognizant has discovered with the way the current (v5) system manages interstitials has been reinforced by the BBC. Sending programming content and underwriting spots/promos separately to the stations to do the final compiling optimizes content transmission and brings process efficiencies in content delivery. Currently, the pre-compilation or flattening at PBS with the interstitials being stitched together with the content results in excessive duplicate transmission of the same media to stations.

5.2.3 Commercial Solutions and Providers for Interconnection Services

Commercial providers have made significant technological advances in recent times to offer innovative solutions and services for broadcast distribution. Some of these have been briefly discussed earlier (5.2.1). In this section, we discuss some of the specific technologies and solutions available to public television in the area of interconnection:

- **Fiber-based Media Distribution**
  Commercial providers of terrestrial fiber and satellite networks can provide services including media distribution, archival, and disaster recovery for broadcasters, cable networks, and other media companies. Encompass Digital Media and other providers offer solutions in high bandwidth fiber network for broadcasters featuring point-to-point and point-to-multipoint transmission of content to a variety of locations, platforms, and formats. Additionally, most of them offer 24/7/365 fiber switching facilities for broadcasters, television networks, and for IP distribution.

  The Switch provides a service called Inter City On-Demand (ICOD). ICOD is a transport service offering that connects 47 cities and 200 video and data points of presence across the US, Canada, and UK. It enables customers to transmit high-quality video files and streams over a fiber network.

- **Distribution Over the Internet**
  The public internet can potentially serve as a substitute for private MPLS terrestrial networks as a means of transmitting live broadcast-quality video. A few providers including Octoshape (now, an Akamai company) and others offer solutions to facilitate live broadcast distribution. The Octoshape solution, for instance, is unaffected by traditional challenges the internet poses (like congestion and packet loss which lead to issues with reliability and sustainability of video quality over the internet). Its proprietary transport technology based on UDP (User Datagram Protocol)[8] sustains high quality video delivery for traditional devices over the public internet.

  Some major broadcasters and cable networks in the United States utilize these services to transmit live and OTT (Over-the-top) content across the world over the internet. The public

[8] The User Datagram Protocol (UDP) is one of the core members of the Internet protocol suite. The protocol was designed by David P. Reed in 1980 and formally defined in RFC 768. UDP uses a simple connectionless transmission model with a minimum of protocol mechanism.

internet is used for many live events a day (at the time of writing this report) with broadcasters using full-time services running over it as well.

Newer video formats such as VP9 from Google provide higher resolution and deliver high-quality video without the need for higher bandwidth. An open source codec, VP9 is said to reduce bandwidth usage by up to 50% for HD and 4K videos as compared to other codecs. Currently, Google is developing a VP10 codec that is expected to reduce bandwidth by an additional 50%. There are also new codecs being introduced now that claim even better characteristics. Some have claimed bandwidths as low as 2mbps for 4k video. This is an area where a sea change is happening right now that should settle out in the next couple of years.

At the 2015 International Broadcasting Convention, Axon Digital Design announced the launch of TIDE, a multi-codec processing platform for the contribution and distribution of live video. Leveraging Reliable Real-Time Transport Protocol (R2TP), the TIDE platform optimizes bandwidth usage ratio for streaming over the public internet and open networks. Additional features include ultra-low latency encoding and faster than real time file transfer. Axon CEO Jan Eveleen stated that the TIDE platform is a "high-performing, cost-effective platform for streaming from live events, for news contribution, studio interconnection, and the backup of satellite broadcast."[9]

- **Cloud-based Services**

  Vubiquity offers a content-as-a-service model (AnyVu) that provides services in the cloud for media and entertainment players enabling them to ingest, process and deliver content with different formats quickly to multiple locations. Similarly, Grass Valley offers cloud-based SaaS (Software-as-a-Service) services for broadcast playout. They are rapidly moving towards a cloud-based model as it offers a solution to issues with centralization and one-to-many distribution. Commercial broadcasters like ABC have been working with Imagine Communications towards moving their master control operations in the cloud. LTN Global Communications provides a broadcast distribution service called SmartCloud that is available for both full-time and single-use. Through a proprietary global network of private super-nodes, SmartCloud is accessible from anywhere in the world via a standard internet connection.

  Overall, cloud technologies have now matured into relevant solutions for the broadcast industry, and there is a significant increase in them being considered for adoption by several broadcasting organizations worldwide.

- **Managed Services**

  Many of the industry's solution providers offer relevant operational solutions for interconnection. Vubiquity provides a wide spectrum of managed services including for NOC (Network Operations Center) operations and claims to successfully manage millions of files on an annual basis for leading media and entertainment companies around the world. They also provide a 10 Gbps fiber network across the United States which has been instrumental in

[9] "Axon to Launch Tide, Multi-format Processing Platform." Sport Talk Live, IBC 2015. September 8, 2015.

reducing satellite transmission (and lease costs for transponders) for their clients. Similarly, other companies like Encompass offer distribution services on a global basis including in the area of centralized master control.

5.3 Analysis of the Proposed Solutions

5.3.1 Analysis Model

Cognizant has developed a weighted matrix model to analyze the proposed v6 and PMM solutions. The model assesses the solutions in the following four categories:

- Technology
- Organizational
- Operational
- Financial

Each category comprises several evaluation parameters, described in the table below, on which the solution is assessed.

Assessment Category	Evaluation Parameter	Description
Technology	Design & Specifications	Utilizes industry standards and best practices, considers new and emerging technologies in the industry, while considering the "real world" requirements of PTV stations
	Network connectivity	Provides content interconnection to all 170 Public TV licensees
	Infrastructure	Provides robust infrastructure which is reliable, secure and scalable and is based on common industry technologies
	Security	Offers secure delivery and storage of content and prevents intentional and unintentional disruption and malicious damage
	Scalability	Provides an architecture that is designed for expansion or reduction
	Reliability	Provides the ability to quickly resume business with no or minimal disruption to business in the event of a failure or disaster
	Sustainability	The solution is sustainable over a long period of time and will not need to be replaced wholesale in a shorter period
	Interoperability	Allows for media/ metadata exchange with other systems

		without special development/ integration effort
	Manageability	Allows for easy maintenance and control
	Hardware	Utilizes industry standard hardware
	Software	Utilizes industry standard software
	Monitoring	The system supports a supervisory monitoring and control system
	Configuration	The solution can be configured with ease
	User experience & Usability	The solution has a good business user experience and capabilities
Organizational	Skills assessment and Roles/ reporting matrix	Required skills are available or can be easily obtained for implementation and operations
	Department/ station alignment	Alignment with the current organizational structure
	Company culture	Alignment with the business culture of public television
	Performance metrics	Alignment with the operational needs and metrics of public television today
Operational	Collaboration opportunities	Allows stations to collaborate - share content with each other, produce content together
	Business Models	Addresses current and future business models (PTV business model, multi-channel/ platform distribution, new standards)
	National Security	Provides an infrastructure that benefits National Security or public safety
	Current state to future state readiness	The stations are in a state where the solution can easily be deployed and they can start using the new interconnection. A roll-out plan exists for the stations.
	Process workflows	Alignment with existing PBS and station workflows
	Key Performance Indicators	Visibility of appropriate Key Performance Indicators for PBS and station operations
	Work tools/ IT systems	Appropriate tools and technologies for use by public television employees
Financial	Procurement	Initial cost to procure the interconnection system
	Maintenance/ support	On-going maintenance and support costs

5.3.2 v6

5.3.2.1 Qualitative Analysis

A detailed analysis of the v6 interconnection solution is presented in this section.

- **Technical Analysis**
  - **Design & Specifications**
    The v6 design and specification makes good use of industry standard and common technologies such as MPLS, BXF, FIMS and others. Given the business direction that the designers were given, the decisions made were appropriate for the time. This business direction is the most critical factor affecting design decisions. Also note that the technologies surrounding interconnection are rapidly changing and the assessments that were made regarding v6 design could be refreshed.
  - **Network Connectivity**
    v6 will connect the 170 public TV licensees, PBS Network Operations Center, Satellite Operations Center and the Disaster Recovery, Diversity & Maintenance Site with an IP multicast enabled MPLS IP-VPN mesh network with full duplex, symmetrical, mesh, Layer 3 connectivity. The stations will be connected with 100Mbps or 45 Mbps connections. Major nodes like PBS NOS, SOC, DDMS and major operators will likely be connected with 1Gbps or 10Gbps connections. It utilizes MPLS which can be more efficient and reliable than other networking approaches. Mesh topology allows each node to serve as an origination point to all the other nodes. All the stations will have IP-multicast capability, i.e. they will be able to distribute their content to one or many stations over the network.
  - **Infrastructure**
    v6 will provide a robust infrastructure to the public TV system. It will create an extensive terrestrial fiber VPN network that connects 170 public TV licensees and the PBS NOC, SOC and DDMS which will be reliable, fast, deterministic and secure. The PBS NOC node will broadcast the transport streams to the member stations. The NOC will also monitor and control the network traffic. The station nodes will be provided with equipment by PBS through which they will connect to the network, receive and transfer streams and files over the network. The infrastructure will support technologies beyond distribution within the public TV system like OTT delivery, joint master control, transcoding, archiving and cloud services.
  - **Security**
    The v6 network is a MPLS Virtual Private Network and benefits from the security features of a private network. MPLS is often used by companies that require higher levels of privacy and security. It will provide greater security than a public network/ internet in the event of a cyber-attack. It will also provide a secure platform for public safety and emergency alerting systems. While attention has been paid to security needs, in light of recent high profile cyber-security events – including against broadcasters – it

is important to fully vet the security aspects of the design as well as to vet the proper implementation of security technologies and protocols.

- **Scalability**
  PBS plans to connect all its member stations through the MPLS mesh network. MPLS networks are highly flexible and scalable. The stations will be connected with fiber with 100Mbps bandwidth. The connectivity can easily be scaled up to 1Gbps if stations need higher bandwidth. However, it is relatively costly and potentially disruptive to add nodes to the MPLS mesh network.

- **Reliability**
  A MPLS network provides built-in support for Quality of Service (QoS) that assures bandwidth and allows administrators to assign priority to the traffic (Class of Service CoS), i.e. higher priority for linear, lower priority for non-real time.

  v6 interconnection will also provide satellite back-up for its linear feeds. In case there is a failure of the terrestrial network, it will switch to satellite.

- **Sustainability**
  v6 will allow for the addition or subtraction of stations as needed if properly contracted for with terrestrial network vendors. It allows for evolution of the system and also allows for an expansion of content volume. These factors mean that it will be sustainable and useful to the system over a long period of time. However, v6 is a CapEx intensive model that doesn't have the financial sustainability that an OpEx model offers, with cost spread out over the full lifetime.

- **Interoperability**
  The v6 solution supports the current standard PBS AS-03 format as well as any other common media format. It will interface with ProTrack, the primary traffic system used by the stations via Broadcast Exchange Format (BXF) which is a SMPTE standard for data exchange between traffic and automation systems in the broadcasting industry. Some integration effort will be required for the few stations that don't use ProTrack. Alternatively, these stations can migrate to using ProTrack as well.

  The design is built on broadcast industry standards - MXF, FIMS, BFX etc. and offers high levels of interoperability with other current technologies as well as future enhancements.

- **Manageability**
  v6 is a manageable solution. It has interfaces intended for operational and technical management. It is being built by PBS and will be managed by them. For monitoring and control, it uses Simple Network Management Protocol (SNMP) which is a common standard for monitoring and managing devices on IP network. V6 has provided for full visibility into the systems operations and technology.

- **Hardware and Software**

  The v6 solution includes an IP multicast enabled MPLS IP-VPN mesh fiber network to connect all the stations. The PBS NOC will connect to the MPLS network via a Layer 3 switch. The NOC will also have a multicast IP host and file transfer agents to send and receive files over the network.

  It includes a traffic system for scheduling and will interface with the stations system (95% of stations use ProTrack) using BXF.

  The nodes will have VLAN switches to connect to the network. The Advanced File based Integrated Receiver/ Decoder (AF/IRD) that PBS will provide to the stations will provide SDI decoding of linear content and be able to transfer file based content to a station's automation and playout system. They can also playout file based content to SDI if the stations can't process the files. The AF/IRDs will also act as an IP multicast source to provide linear content from one station to other stations over the v6 network. Generally, all hardware selected for v6 is commodity standard IT hardware.

  v6 uses Cinegy for playout and other core functions of the AF/IRD. It also uses tools to monitor and control the hardware, software and network health. The Cinegy technology has a mixed reputation in the broadcast industry with some very difficult, but ultimately successful deployments. This is due in part to the size of the company as well as its "hands-off" approach to implementation.

- **Monitoring**
  The v6 solution will provide monitoring and control of hardware and software that comprise v6 interconnection via SNMP and other network management protocols. All critical elements of the system will have monitoring probes and can be monitored from a central location. The key concern with monitoring will be that PBS will not have lower level visibility into the v6 network. Historically there have been problems experienced on fiber networks when providers make changes for reasons that may be unrelated to the needs of the broadcaster. These will have to be covered carefully in any agreements and PBS will need to watch the provider very carefully to avoid as many as possible of such issues.

- **Configuration**
  The solution provides interfaces for configuration, viewing and scheduling of linear playout, non-linear distribution and bandwidth needs by PBS and stations. All required configuration elements have been considered. The only concern is the configuration of

the MPLS network. As this is in third-party control – which itself must contract with other parties – changes may take time to activate and propagate.

- **User Experience & Usability**
  User experience was obviously a critical factor in the design of v6. PBS considered user interface as key to the adoption of v6, and solicited input from various parties in the system as to interface design. Given that this solution will require a greater number of software components be built custom, there is an opportunity to better optimize the user experience generally.

- **Organizational Analysis**
  - **Skills Assessment and Roles/ Reporting Matrix**
    Generally, the v6 plans involve a number of technologies for which there isn't a great deal of existing background within PBS. There are plans to train the personnel and these are likely to be successful. There is a risk present that there may be some skill gaps that will have to be addressed in deployment.
  - **Department/Station Alignment**
    The interconnection committee represented by stations and other national entities reports to the PBS board. PBS is responsible for providing universal service, i.e. distribution of content to all the stations. It is considered to have the best interest of the member stations at heart. Input of stations has been considered throughout the process; however, there were a number of complaints in our interviews about transparency. These concerns are likely not founded, but PBS should look into further opportunities to provide transparency to stations.
  - **Company Culture**
    The culture of public media is one which is unique and different from that of commercial broadcasters. The v6 plans, which were originated within PBS and are to be built out by PBS, properly reflect that culture.
  - **Performance Metrics**
    The system is designed to accommodate all of the current requirements for performance that exist today. It will meet or exceed all current requirements. This means that all organizations within PBS will be able to successfully accomplish their needed interconnection goals with the system.
- **Operational Analysis**
  - **Collaboration Opportunities**
    The MPLS network provides a peer-to-peer communication mechanism for all stations across the United States allowing each station to contribute content to any other. This can be extended to offer collaboration services for content production between stations. Stations can produce live content in collaboration with other stations which has been tested in the v6 PoC. Stations that share or receive content using FTP software (e.g. FileZilla) or video tapes and disks via courier service can utilize the infrastructure to

share content. Note that the demand for these services is questionable - as seen elsewhere in this report.

- **Business Models**
  The proposed v6 solution brings a lot of potential benefits with it. It is a flexible, scalable, and reliable IP infrastructure which can support the current and future PTV business model(s). It can facilitate OTT, multi-channel/platform distribution. It can also enable other services sought by stations like master control, closed captioning, transcoding, OTT, VOD, joint master control. It can support emergency services, and public or private cloud services. However, these additional services – which are important to the long term health of the public media system – were not seen as a primary driver in the design of v6.

- **National Security**
  The v6 interconnection system can be used to enhance national emergency communications systems and provide an enhanced communication mechanism for local police and fire departments.

  A MPLS VPN network is highly secure and reliable. It is less vulnerable than a public network/ internet if there is a cyber-attack. In case of a national emergency, if the public communication channels like the internet are disrupted, the v6 system can provide a robust infrastructure to communicate through the v6 connected stations located all over the country. Even if the electrical grid is down, the stations and telecommunications providers will generally have back-up power which can keep the network up. Security related potential was considered, but was not a primary driver of design. There is an opportunity in future evolution of the system to include more capabilities that support this area.

- **Current State to Future State Readiness**
  Generally, the readiness of stations to accept a v6 solution is very good. The planners of the solution considered very carefully how to improve adoption given the problems that had been seen during the v5 rollout. A roll out plan exists that seems to be robust.

  The primary concern with v6 is the time to begin deployment. A number of custom software modules need to be created and these could prove to be a significant bottleneck. In other words, the system is not ready today to be deployed and will require some further R&D before beginning deployment.

- **Process Workflows**
  The system is designed to integrate well with station side and PBS side workflows. The designers have specifically produced the needed workflow designs and these are likely to simply work at the majority of stations. However, there will be some stations for which modification of workflows or adaptation of the v6 system to the station needs will be required.

- **Key Performance Indicators**

All necessary Key Performance Indicators (KPIs) for operational purposes should be visible to PBS and locally relevant ones to a station. The use of a Business Process Management (BPM) engine in the v6 design enhances this and provides for additional use beyond the v6 requirements. However, the reliance on a not yet fully ready (at PBS) technology (Enterprise Service Bus (ESB)/BPM) means that there is some risk that some KPI's will take longer than others to be made visible to management/operations.

- **Work Tools/ IT systems**
  The v6 design makes good use of industry standard tools and IT technologies. It uses commodity servers and networking equipment. The software being used is of the type used by other large media organizations. However, the selection of Cinegy as a key software component presents some risks as mentioned elsewhere in this report.

- **Financial Analysis**

  - **Procurement**
    The initial rollout costs of the v6 solution for interconnection purposes are higher than any other solution we examined. This is primarily due to the additional capabilities provided by an MPLS network such as live video, 2-way communications, and deterministic bandwidth. Furthermore, the reliance on a CapEx approach rather than an OpEx approach presents the need for a large amount of funding at the beginning of the project cycle.

  - **Maintenance and Support**
    Ongoing maintenance and support costs are reasonable for v6, however there exists some support risks given the reliance on Cinegy for core technology. Cinegy is a small company that has had support issues in other installations. It is an acceptable technology, but the relatively hands off approach of Cinegy versus other common broadcast manufacturers should be thought through.

Assessment Category	Evaluation Parameter	Assessment Rating for v6
Technical	Design & Specifications	
	Network Connectivity	
	Infrastructure	
	Security	
	Scalability	
	Reliability	
	Sustainability	
	Interoperability	
	Manageability	
	Hardware	
	Software	
	Monitoring	
	Configuration	
	User Experience & Usability	
Organizational	Skills Assessment and Roles/ Reporting Matrix	
	Department/ Station Alignment	
	Company Culture	
	Performance Metrics	
Operational	Collaboration Opportunities	
	Business Models	
	National Security	
	Current State to Future State Readiness	
	Process Workflows	
	Key Performance Indicators	
	Work Tools/ IT Systems	
Financial	Procurement	
	Maintenance/ Support	

● Fully meets criteria ○ Does not meet criteria

Figure 18 - Assessment Rating for v6

5.3.2.2 v6: Key Risks

- **High Implementation Complexity and Time Frame**
  The v5 satellite contract will end by September 2016. This has been extended to September 2017 and PBS is hoping to roll-out v6 to all the 170 public TV licensees by then. Given the complexity of v6 implementation, it will be a challenge to accomplish implementation of the v6 solution across all the PTV stations in the given time frame. It is likely to take a few years to successfully reach all 170 stations. PBS will need to have a contingency plan to continue distributing content over satellite until that time. This does not mean that all transponders will need to remain active for the entire time, but that transponder shut off may occur later than desired due to the complexities involved.

- **Adoption by Stations**
  The v5 interconnection was not fully adopted by many stations. This was due to various reasons including the unreliability of the NRT file delivery and the inadequate communication of change from v4 to v5. At this time, about 30% of the stations still don't utilize the v5 NRT delivery mechanism. Many of those that use it do not use it regularly or as much as they would like due to a variety of factors including the probabilities of content coming in to late and being sent near real-time or live instead. Additionally, a lot of stations have an outdated master control system which may not be compatible with the new v6 interconnection. This was addressed in the planning for the AF/IRD, but these stations may require more hand holding as they adopt a new system. Due to these and other factors, low adoption of v6 by stations is a risk and this has been cited as a major concern by the majority of the stakeholders interviewed.

  This can be mitigated in a number of ways. Chief among them is a robust change management process that focuses on proper communication and training as well as providing a robust initial operations support to hand hold stations until they are comfortable.

- **Management of Multiple Vendor by PBS**
  Multiple vendors are involved in the v6 interconnection solution and each of them will have their own service levels, escalations, reporting structures, warranty arrangements. PBS will need to effectively manage all the vendors and the dependencies between them. Furthermore, the telecommunications provider selected will have subcontracts with other telecom companies for last mile or other services. This produces a complexity that may result in a higher cost to manage and some increased risk.

- **Dependency Management Between Multiple Tracks During Implementation**
  Multiple aspects of the v6 project plan cannot be completed until other aspects are completed. These are called "dependencies" in project management. Effectively managing dependencies will be key to keeping the project on time and within budget. The v6 plans developed by PBS are generally robust and account for the tasks and dependencies appropriately. It is likely, however, that the time frames of some tasks have been underestimated and that – like many projects of this scale – there will be overruns for which PBS will have the burden of covering the costs of.

- **'Big Bang' Implementation**

  Due to the increasingly rapid, changing pace of technology development, the industry as a whole is transitioning away from the traditional 'big bang' implementation and moving towards a model of consistent, iterative upgrades to evolve systems and provide new capabilities. To cite an example, in September 2009, the British Broadcasting Corporation (BBC) brought a large-scale implementation project called the Digital Media Initiative (DMI) in house from a previously contracted agreement. By April 2014, the project was abandoned and universally considered a failure, having cost BBC a total of £98.4M. According to former BBC CTO John Linwood, BBC "objected to the [agile] approach. Small incremental releases would allow the business to get hands-on with the technology so it would not need to wait until the end of the program. The business then said it didn't want to spend time testing, but wait until large incremental pieces [were completed]."[10] He went on to elaborate that users of the system were reporting the need to make changes to each build they received, resulting in delivery delays that ultimately contributed to the project's failure.

  The lesson to be learned for the industry from this effort is that it is best to break up large programs into smaller pieces that each provides business value inherently. This reduces risk. While there is some of this in the approach selected for v6, more consideration should be given to how to further reduce the size of constituent steps while still providing value along the way.

5.3.2.3 Summary of the v6 Candidate Solution

v6 interconnection brings a lot of benefits for the member stations and the public TV system. It solves one of the major challenges with the v5 system - the delivery of non-real time content. It moves away from the expensive satellite-based delivery to a terrestrial IP delivery with a satellite backup. The network also provides the capability to the member stations to collaborate with other member stations to produce content and to share content directly with other stations. It enables all stations to distribute live content, an ability which only a few stations have currently. It provides a secure, reliable and scalable infrastructure that could be utilized to enable a number of new services like transcoding, closed captioning, OTT, VOD, JMC services and cloud. It will create a robust infrastructure which could be of great value to national security in times of national emergency.

However, the proposed implementation plan is complex, and that complexity poses a risk that will need to be mitigated with effective management and careful roll-out planning including proper communication to and training of the stations. Additionally, PBS will need to have a contingency, i.e. satellite contract extension back-up, for any delay in the roll-out.

The v6 solution is a CapEx based model with a funding cycle over a period of 10 years which doesn't provide as much flexibility to adapt to technological changes. This is concern given that there has been a widespread movement towards shorter technology cycles.

[10] Glick, Brian. "The BBC and its former CTO have engaged in tit-for-tat allegations over its failed £100 digital media project. But who was right?" Computer Weekly. February 5, 2014.

When looking at the overall financial picture, the v6 solution has the greatest overall Total Cost of Ownership. This is primarily due to the higher cost of MPLS network technology.

5.3.3 PMM

5.3.3.1 Qualitative Analysis

A detailed analysis of the PMM interconnection solution is presented in this section.

- **Technical Analysis**
  - **Design & Specifications**
    The PMM design and specification makes good use of industry standard and common technologies such as the public internet, BXF, FIMS and others. Given the business direction that the designers were given the decisions made were appropriate. This business direction is the most critical factor affecting design decisions.
  - **Network Connectivity**
    The PMM solution doesn't provide network connectivity directly to the stations. It requires the stations to have a 100Mbps internet connection to connect to the PMM cloud to push/pull non-real time content. It doesn't have multicast capability. Also, it will rely on satellite connectivity for Real-time and near real time content distribution.
  - **Infrastructure**
    PMM's infrastructure is based on the PMM cloud which is built over Amazon web services and the Sony Ci cloud, the PMM NOC node, the PBS NOC node and station nodes and satellite. The nodes will connect to the PMM cloud via a 100Mbps or greater public internet connection that the station will procure. The PMM NOC receives the content from the satellite or other sources and processes it before pushing it to the cloud. The NOC will also monitor the network health and system environmental conditions. The station nodes will use equipment provided by WGBH/Sony which will integrate with ProTrack systems at the stations and receive instructions from PMM.
  - **Security**
    PMM relies on the public internet which is more vulnerable than a private network from security breaches or cyber-attacks. However, it is built on Amazon web services which complies with a wide range of industry security standards and is considered to offer high security. The Sony Ci cloud is ISO/IEC 27001:2005 and ISO/IEC 27001:2013 (July) certified.
  - **Scalability**
    The solution utilizes cloud computing and public internet which can easily be scaled up as needed. The content is stored in Amazon storage and the applications run on Sony's cloud. The stations push/ pull content through public internet connections. To be added to PMM a station needs access to 100Mbps internet connection. The

equipment/software is assembled and deployed by WGBH and Sony, and can be easily integrated with the stations' systems.

- **Reliability**
  PMM is built on Amazon Web Services cloud computing which is considered to be highly reliable. The NOC and nodes have a redundant server for each key function. When the primary server goes down the secondary server comes into play.

  The PMM local node at each station pulls and stores content for up to 30 days from the cloud. In the event of a major internet failure, if the stations can't connect to the NOC, they will be able to use the content at the local node and operate directly.

  The station node can also switch to the satellite in case of internet failure and receive content from satellite.

- **Sustainability**
  PMM will allow for the addition or subtraction of stations as needed with the right contracts. It allows for evolution of technology and services and also allows for the expansion of volume. These factors mean that it is sustainable and useful to the system over a long period of time. It uses an OpEx model and will have better financial sustainability over time as the cost is spread out over years and is more stable from year to year.

- **Interoperability**
  The PMM solution, like v6, supports the standard PBS AS-03 format as well as any other major format. It will interface with ProTrack, the primary traffic system used by the stations via Broadcast Exchange Format (BXF) which is a SMPTE standard for data exchange between traffic and automation in the broadcasting industry. Some integration effort will be required for stations that don’t use ProTrack, or they will need to be converted to ProTrack.

  For monitoring and control it uses Simple Network Management Protocol, a standard for managing devices on IP network. This provides full visibility into the system’s operations and technology.

  It relies on Amazon Web Services which means that new services from third parties can be integrated relatively quickly.

  The design is built on broadcast industry standards - MXF, FIMS, BFX etc. and offers a high degree of interoperability.

- **Manageability**
  PMM is a manageable solution. It has interfaces intended for operational and technical management. Although, PMM is run by a third party, it is possible to design contracts with clear SLA's and flexibility for change.

- **Hardware and Software**
  PMM’s solution includes various standard and modern hardware and software at the WGBH NOC and station nodes that can work in combination over the internet.

PMM uses a Service Oriented Architecture middleware Sony Media Backbone enterprise management system which orchestrates PMM workflows. It manages ingest and processing of content and pushes it to the Sony CI cloud.

The Myers ProTrack traffic system is used to determine availability of content and communicate with the station nodes. 95% of the stations also use ProTrack. Crispin Automation and Harmonic Playout servers are used to manage recording and playout of the content. Amberfin and Digimetrics are used for transcoding, rewrapping of content to AS-03 specifications and Quality Check.

Sony Ci cloud is used for media management and storage. It is runs on top of Amazon Web Services (in an Amazon data center) which is highly reliable and secure.

PMM also utilizes Sony's SystemWatch technology to monitor the health of hardware, software and network.

- **Monitoring**
  The solution leverages Sony's SystemWatch technology to monitor network health and system environmental conditions including NOC and nodes. It also provides 24/7 exception monitoring of stations' streams.

  It uses Simple Network Management Protocol (SNMP), a standard for managing devices on an IP network for monitoring and control and has a full visibility into the system's operations and technology.

- **Configuration**
  The solution provides interfaces for configuration, viewing and scheduling of linear playout and non-linear distribution. All required configuration elements have been considered.

- **User Experience & Usability**
  User experience was obviously a critical factor in the design of PMM. The system is in operation currently and no user complaints were received by Cognizant.

- **Organizational Considerations**

  - **Skills Assessment and Roles/ Reporting Matrix**
    Sony, which provides and operates the PMM solution, has adequate staff with the expertise and skill needed. This staff will need to be expanded as the system is deployed further, but it is not expected that it will be particularly difficult to find new staff that have the proper skills.

  - **Department/Station Alignment**
    WGBH, like other public TV stations, is a member station. It doesn't have a mandate for universal service and stations have expressed concerns with WGBH managing the interconnection. If PMM is deployed as currently proposed, this concern will have to be addressed via the development of a robust governance model on par with the current interconnection governance.

- **Company Culture**
  The culture of public media is one which is unique and different from that of commercial broadcasters. The PMM plans were originated within WGBH to meet the needs of public broadcasters and properly reflect that culture.

- **Performance Metrics**
  The system is designed to accommodate all of the current requirements for performance that exist today. It will meet or exceed all current requirements. This means that all organizations within PBS will be able to successfully accomplish their needed interconnection goals with the system.

- **Operational Considerations**

  - **Collaboration Opportunities**
    The PMM does not provide a live peer-to-peer collaboration capability like v6. It does facilitate sharing of content between stations by allowing them to upload their content to the cloud via files.

  - **National Security**
    PMM relies on public internet which is easier to disrupt with cyber-attacks and may not offer much additional benefit to national security.

  - **Current State to Future State Readiness**
    The readiness of stations to accept a PMM solution is very good. The planners of the solution considered very carefully how to improve adoption given the problems that had been seen during the v5 rollout.

    Time to deployment is a primary advantage of PMM. It is already in operation and will require little development before full implementation.

  - **Process Workflows**
    The system is designed to integrate well with station side workflows. It is likely to simply work at the majority of stations. However, some stations may need to modify workflows or adapt the PMM system to their particular needs.

  - **Key Performance Indicators**
    All necessary KPI's for operational purposes should be visible to the PMM NOC and locally relevant ones to a station. The use of Sony's BPM engine in the PMM design enhances this and provides for additional use beyond the initial requirements.

  - **Work Tools/IT systems**
    The PMM design makes good use of industry standard tools and IT technologies. It uses commodity servers and networking equipment. The software being used is of the type used by other large media organizations.

- **Financial Analysis**
  - **Procurement**
    The initial rollout costs of the PMM solution for interconnection purposes are to be borne by a vendor – Sony. This reliance on an OpEx model for deployment provides a lower and steadier funding requirement.
  - **Maintenance and Support**
    Ongoing maintenance and support costs are included in the PMM fees. This provides steady costs in the same manner as the initial procurement.

Assessment Category	Evaluation Parameter	Assessment Rating for PMM
Technical	Design & Specifications	
	Network Connectivity	
	Infrastructure	
	Security	
	Scalability	
	Reliability	
	Sustainability	
	Interoperability	
	Manageability	
	Hardware	
	Software	
	Monitoring	
	Configuration	
	User Experience & Usability	
Organizational	Skills Assessment and Roles/ Reporting Matrix	
	Department/ Station Alignment	
	Company Culture	
	Performance Metrics	
Operational	Collaboration Opportunities	
	Business Models	
	National Security	
	Current State to Future State Readiness	
	Process Workflows	
	Key Performance Indicators	
	Work Tools/ IT Systems	
Financial	Procurement	
	Maintenance/ Support	

● Fully meets criteria ○ Does not meet criteria

Figure 19 - Assessment Rating for PMM

5.3.3.2 PMM: Key Risks

- **Equipment Refresh**
  The equipment for PMM will be provided by Sony as a service to the stations and will be responsible for refreshing the equipment. Refreshing equipment at such a large scale, 170 licensees across the United States, will need to be planned well in advance. Contracts and SLAs will need to be in place for services and maintenance, including refresh of the system, for it to operate effectively and deliver the benefits of a service based model.

- **Scale of Implementation**
  PMM, if chosen as the interconnection solution, will need to be implemented in 170 stations. WGBH may not have the experience to implement a solution at this scale even though technologically the solution may easily be scalable. This is mitigated by the selection of Sony as a vendor. Also, there is no universal roll-out planning done for PMM yet. Scaling the implementation to connect 170 stations in the given time frame will need to be done with effective planning and management.

- **Quality of Understanding of Public Television Need is Not Adequate**
  The public TV system has stations of different sizes serving diverse communities, operating under different licenses (college, state etc.) with some with large operations producing content and some simply passing through content from PBS. They are diverse in their characteristics and needs and Sony may not have adequate experience in and quality of understanding of the public television space. This is mitigated by the presence of WGBH in the partnership.

5.3.3.3 Summary of the PMM Candidate Solution

PMM offers stations benefits of a centralized master control as well as interconnection. By centralizing master control operations, stations can achieve operational efficiencies and reduce management overhead. They will also avoid large capital expenses required to refresh master control equipment. The stations can free up master control resources and focus on other tasks like content production, etc. PMM will reduce the archival required by the stations at their end and the associated cost by providing centralized cloud storage. The solution includes Amazon Web Services which means new services could be integrated quickly.

The solution is based on an OpEx model where the interconnection and master control solutions are offered as a service. It provides greater flexibility and agility to adopt changes in technology and business needs as long as the right contracts are in place.

Effective management, a robust governance model and planning are needed for implementation roll-out and operation of the PMM in the public TV system. Sony may not have sufficient understanding of the public TV domain and WGBH may not have the experience of handling an implementation and operation of such a scale.

A key advantage of the PMM approach is the use of the OpEx model for financing. This provides for a financial model that is more likely to be initially doable and sustainable for public TV.

5.4 The Argument for Centralized Master Control

Master control operations result in stations incurring expenses on services, technology, equipment, management, workforce and union management and other associated costs. The cost of keeping aging technology and equipment refreshed has also been of significant concern in public television in the United States.

Outsourcing the master control facility can address this issue to a large extent for a station. A suitable broadcast provider can offer master control services as a managed service taking care of technology, equipment and professional services in order to get desired content out to stations in a timely manner. Such a provider would be responsible for managing the technology and equipment to keep up with industry trends based on an appropriate contract. This would save a station the management and operational overhead of managing and evolving their own master control.

Extending such a service to a group of stations would bring in additional cost and process efficiencies. This is the business driver for centralized master control for public television where a group of stations can outsource their master control operations to a suitable provider.

The CentralCast centralized master control initiative is a collaborative formed by the Association of Public Broadcasting Stations of New York which currently serves 13 stations. The Digital Convergence Alliance (DCA), managed by JCT Services LLC, originated out of a partnership of 6 Florida PTV stations and 5 other PTV stations and serves these 11 stations. This can result in significant financial benefits to parts of the system which participate in such a program.

5.4.1 Considerations and Qualitative Analysis

The CentralCast and JCT (and, for that matter, the WGBH-led PMM solution, see section 3.3.2.1) master control services were preceded by an earlier, less successful attempt to transform master control operations across public television in the early to mid-2000s (section 3.3.1). PBS' Advanced Control Environment (ACE) was adopted by a mere handful of stations after its launch in 2003. Stations who embraced it were also reported to have continued with their earlier master control setups even after installing ACE. The ACE program was built on robust technology, according to industry experts, but probably suffered from poor rollout management and adoption, thereby becoming too expensive and eventually failing to meet its objectives (see section 3.3.1).

On the other hand, maturing technology and its increasing, wider acceptance have enabled the recent master control initiatives to show greater success. In many cases, however, these initiatives have exhibited an evolving path to their current status of becoming a comprehensive and stable offering.

5.4.2 Operational Benefits

A centralized master control offers a number of operational benefits to stations:

- **Cost Savings:**
  One of the current challenges the system faces is the significant expenditure in refreshing aging master control technology and equipment. A centralized master control setup can address this challenge for stations and the system overall (subject to adoption and contractual agreements).

  The current model of most stations managing their own master control requires skilled staff to perform these operations. A centralized model takes away the need to maintain skilled staff and frees them up for redistribution or separation bringing cost savings to stations. It also avoids each station needing to perform its own refresh when technology needs to be replaced.

- **Quality and Consistency:**
  A centralized team can provide a more uniform and consistent set of services across the system (the part which is consuming such services). With a small operations team and arrangement providing services for several stations, participating stations will benefit from similar skills and service quality. With consistency in training, capability development and other processes, a high level of consistency and quality can be maintained.

- **Training:**
  Training for a smaller team (or teams) providing centralized master control services will be more cost-effective and better return on investment. Stations will not have to spend individually on training costs and to keep skills of staff refreshed. The provider will take care of associated training costs when technology and equipment change. Training will also be more effective from a quality perspective and a smaller team (or a set of smaller teams) will find it easier to render high-quality, cost-effective master control services for the system.

- **Efficiencies in Transmission:**
  Programming content will be available in the cloud for distribution to stations as per the agreed model. Content will be uploaded to the cloud as per an appropriate timeframe and participating stations will receive it for local storage or for broadcast as per the specified schedule. This will make the distribution process much more efficient for the entire system and likely reduce the volume of content being transmitted from PBS.

- **Management Efficiencies:**
  Stations will be able to reduce the management overheads associated with maintaining local master control operations including in the areas of technology, hardware equipment, software and services, workforce needs and capability development. This will enable stations to focus on core programming decisions and community engagement and allow them to operate more effectively.

- **Competitive Ecosystem:**

Having a few providers of centralized master control services will allow stations the flexibility of choice based on their individual needs and the value of the offering from providers. A competitive environment will motivate the providers to offer greater quality and operational efficiencies.

5.4.3 Risks and Likely Challenges

While centralized master control offers a number of operational benefits to stations, it also entails the following risks/ considerations:

- **Assessment of Quality and Scale:**
  Individual efforts to achieve centralized master control need to be assessed for their quality of services and implementation technology, model and equipment. This has to be done while understanding the objectives of such a service and the number of stations (and the nature of requirements) they aim to cater to. The ability of individual solutions to provide such services to the target group of stations on a consistent, reliable and cost-effective basis will need to be examined.
- **Ecosystem of Multiple Providers:**
  With multiple providers offering centralized master control services, the ecosystem must be designed for appropriate throughput to the system. An optimal number of such services, an appropriate governance and roll-out strategy, and the coverage and adequacy across the system needs to be identified and implemented. If these are not addressed at the outset of larger roll-out across the system, the initiative(s) are likely to suffer from governance and operational challenges and their collective ability to deliver to the strategic objectives of centralized master control.
- **A New Competitive Environment:**
  With multiple providers of centralized master control, a new competitive environment will be further enhanced in the public television system. While this can lead to several benefits and allow stations to derive greater value, it will challenge (and, in some cases, has already been challenged) the traditional environment. Having a new provider-driven ecosystem needs to be governed effectively to derive maximum overall benefits for the system.

5.4.4 Centralized Master Control in Summary

Centralized master control offers a number of benefits to the system. Providers can help stations save costs while enabling reliable, consistent and high-quality master control operations. Process efficiencies in content distribution and access can be achieved while eliminating management overheads for stations – allowing them to focus on business priorities. A competitive environment can offer choice and increased value for individual stations.

The risks which such an ecosystem entails can be managed by ensuring that individual providers provide reliable and high-quality services, and demonstrate their ability to scale to the desired level while adhering to well-defined timeframes. The overall ecosystem needs to have a strategic and robust

governance model to allow such initiatives to deliver to the strategic objectives of centralized master control.

5.5 Cognizant Recommendations

5.5.1 Recommended Approach

Cognizant interviewed a number of stakeholders across stations, PBS, NPR and CPB and reviewed all the documentation available to understand the pain points of the current v5 Next Generation Interconnection System, the drivers for the new interconnection, and the two interconnection solutions – v6 and PMM offered by PBS and WGBH respectively. Cognizant also interviewed commercial and technology vendors to understand what other players are doing in the broadcasting industry and the alternative technologies available for interconnection. Several alternative commercial solutions were evaluated in the context of v6 and PMM and after the discovery phase were determined to have significantly higher costs than the other proposed systems. As a result, Cognizant focused its evaluation on v6 and PMM, and reviewed each for a number of financial, technical, operational and organizational parameters.

It is Cognizant's primary recommendation that the system adopt a single interconnection system that is cloud-based, using mainly the public internet and an ecosystem of centralized master control service providers. Specifically, we recommend the Sony solution underlying the PMM proposal as a means to provide for non-real time content (>80% of content today) interconnection, with a satellite overlay for live and near-live content, to be put in place under the leadership, operation, and governance of PBS. This is pending the negotiation of an acceptable commercial arrangement.

Satellite usage will shrink from three transponders to one, which will be retained for live and near live transmission and will be consolidated to the NPR Satellite Operations Control center. A private fiber network will be used for stations that currently uplink national content today. All current centralized master control organizations (PMM, DCA, and CentralCast) will remain and provide a competitive market for addressing the very large near term master control refresh requirements while providing for cost reductions throughout the system.

A detailed set of recommendations are provided in the subsequent section.

5.5.1.1 Recommended Actions

- **Recommended Action 1: Resolve NRT distribution first and consider live over terrestrial subsequently**

  Background: An overwhelming number of the challenges cited with the current interconnection system are with NRT (non real-time) content distribution (See 3.1.2 –Feedback and Perspectives from Stakeholders). Live content distribution is considered by stations to be working well in the current v5 system. Additionally, there are only a small number of stations (approximately 20) that contribute national content today and thus a universal bi-directionality is not widely

demanded. This is based on interviews conducted with stations in mid-2015 by Cognizant. There is also a desire to reduce costs associated with satellite transmission.

Recommendation: In the context of interconnection, solve all issues related to NRT content distribution first, and continue to use satellite distribution for live. The MPLS/ Mesh could be used initially for a small number of stations (about 20) and producers that contribute content; public internet can be used for the remaining content providers. The universal live over terrestrial network should be addressed in a period of 2 to 5 years. At that point look at the possibility of universal private mesh or simply use of public internet given advances in technologies for compression and stream reliability (See 5.2.3 -Commercial Solutions and Providers for Interconnection Services).

Benefits: Streamlining NRT distribution solves a majority of the current problems faced. Moving NRT distribution from satellite reduces the cost to certain extent by reducing the count of transponders. Solving only NRT now defers universal live over terrestrial to the future with a high potential for lower cost. MPLS has been stable in cost (hasn't seen much of a drop in pricing); however, public internet costs have gone down consistently. It also allows on-the-cusp technologies to mature, and the public internet might meet the live distribution with broadcast quality requirements within 5 years. Deferring live will also allow spreading of the budget over a longer period.

- **Recommended Action 2: Address Master Control and NRT interconnection simultaneously**

Background: A lot of stations across the public TV system have outdated master control technology/ equipment or it is coming to end of live and needs refreshing. This will result in significant expenses. Stations have relied on federal funding received via the Public Telecommunications Facility Program (PTFP) to replace master control equipment every 7 years, but that was eliminated in 2011. As per 2013 CPB content distribution data, there is $75M in depreciation of distribution equipment of which only $157K was funded. A lack of funding for master control replacement is a major near-term problem.

Recommendation: Overall, this is an inflection point in infrastructure for the system. There is a significant overlap in the technologies and equipment needed for interconnection and master control. This brings the opportunity to solve the more pressing problem of master control refresh in the public television system simultaneously with interconnection. It is therefore recommended to address the master control problem at the same time as NRT interconnection. The implementation and operating budgets can be separated appropriately. It is also possible to separate interconnection costs versus master control costs in any selected solution.

Benefits: Since much of the technology needed for interconnection and master control overlap, it provides options to help resolve the near-term master control problem and provide significant additional savings for the system.

- **Recommended Action 3: Bring PBS and WGBH together to work through the details of the right solution**

Background: PBS and WGBH have capable and dedicated staffs that have set out to solve different problems, with PBS' focus on interconnection and WGBH's focus on master control. These solutions overlap (See 4.2 - Approaches to Implementing a New Interconnection System). Both the solutions are designed around standard technologies in the broadcasting space.

Recommendation: It is recommended that the differences in approach between PBS and WGBH should be resolved through joint discussions between PBS, WGBH and other major stakeholders (WNET). These discussions could be facilitated by CPB. The focus of the meeting should be to agree on the right interconnection solution for the public television system. Once this is resolved, it will be easier to resolve any issues around the governance of the system.

Benefits: It will reduce friction between PBS and WGBH and within the public TV system as a whole. It will also gain further acceptance to assist in system-wide change management if there is one voice about what to do with interconnection.

- **Recommended Action 4: Keep the existing interconnection governance model**

Background: The current interconnection system is governed by the Interconnection Committee, which reports to the PBS Board of Directors and includes members from national distributors (PBS, APT and NETA), CPB, APTS and stations, via the Affinity Group Coalition and PBS' Enterprise Technology Advisory Committee. The Interconnection Committee is chaired by PBS. PBS has long been responsible for the day to day management of the interconnection system. Some of the stakeholders have expressed concerns (perhaps unfairly) over a lack of transparency of plans by PBS. However, there is widespread satisfaction within the public TV system over PBS' role in interconnection.

Recommendation: Interconnection should remain under the current system of governance and under day-to-day control of PBS.

Benefits: Keeping stable governance will reduce change management challenges. PBS is viewed as having the whole system's interests at heart.

- **Recommended Action 5: Convert to a smaller set of common master control technologies throughout the system**

Background: There are numerous master control technologies present in the system. A number of stations have outdated master control technology that will not work easily and directly with the Cognizant recommended plan. Also, some stations use technologies that might be easily compatible with the Cognizant recommended plan, but are reaching end of life and need to be refreshed.

Recommendation: CPB should consider a "carrot and stick" approach with stations to incentivize them convert their master control to a centralized system. Stations that have outdated master control system or reaching end of life need to convert their master control systems. Even if the system isn't reaching end of life, CPB should have mechanism in place to facilitate conversion.

Benefits: Greater commonality will reduce the overall support and integration costs and new master control options will provide savings throughout much of the system.

- **Recommended Action 6: Move to a services based model**

  Background: The current public TV interconnection system follows a CapEx model and refreshing technology/ equipment results in substantial costs. A number of stakeholders have expressed a need to move from a capital intensive investment approach to a services based model.

  Recommendation: The solution should be biased heavily to be a service rather than a capital intensive purchase.

  Benefits: Moving costs to a service will allow greater flexibility for change in the future and lower and steadier costs spread over time.

- **Recommended Action 7: Negotiate flexibility with vendors with regards to NRT and MC solutions**

  Background: Some stations have recently engaged in master control replacement or joined a JMC and do not need an immediate master control solution (see 3.3 - Centralized Master Control). Others may find it difficult to change the roles of staff or eliminate positions.

  Recommendation: While selecting vendor(s) PBS should negotiate technology flexibility options with them. There are stations that might be part of a joint master control or might have replaced or upgraded their master control recently. Such stations might only need a solution for NRT access only. The vendor should provide flexibility to the stations to opt for NRT access only and allow master control replacement to be an upgrade; perhaps with additional licensing only.

  Benefits: This will reduce costs of full deployment by not requiring every station to use master control services when they may not be needed.

- **Recommended Action 8: Rapidly select a solution and begin implementation**

  Background: Sony already has a working solution in place for NRT and master control which is being used or soon will be used by approximately 8 public TV stations. There are approximately 6000 titles already on PMM cloud. A similar solution with different vendors will take time to build (see 4.2.2 - WGBH PMM Approach). It will also take time for alternate solutions to build the library of content already available in PMM. However, the current commercial deal with Sony may not be as flexible as required and may need renegotiation. A lot of research has already been done on vendors and solutions for interconnection and master control technology (see 5.2.3 - Commercial Solutions and Providers for Interconnection Services). This should allow for a more rapid final selection process for an alternate vendor if necessary.

  Recommendation: Sony should be considered first as the vendor for NRT interconnection and as an option for centralized master control. If not, engage in a rapid selection that includes existing JMCs and select vendors (Grass Valley, Vubiquity, Encompass, Cinegy, etc.). There should not be a need to go through a long and extensive RFP process.

Benefits: Sony has already finished a system that works for NRT and master control and that is deployed at a number of stations who are happy with the results. If not, choosing from already vetted vendors and solutions will save time and effort. Any system selected should move as quickly as possible into deployment given the potential for savings across the system.

- **Recommended Action 9: Allow vendors to engineer, build, and manage; PBS should oversee**

  Background: PBS has been implementing the v6 interconnection project predominantly with its own resources.

  Recommendation: Most engineering, development, and project management should be in the hands of the vendor and perhaps a system integrator (SI), with as little engineering as possible being done by PBS. PBS should minimize the size of its team involved and should only oversee all efforts.

  Benefits: The most efficient value of resources at PBS is in overseeing the efforts of vendors and system integrators in the solution. PBS Engineering resources can then focus on other related tasks.

- **Recommended Action 10: Move from large scale implementations to continuous incremental upgrades**

  Background: The current model of funding is based on a 10-year cycle. In the last decade there has been a widespread movement towards shorter technology cycles given the rapid advance of options and changing business requirements. All the stakeholder groups interviewed by Cognizant have acknowledged that there is a need to move away from large capital expenditures to incremental and iterative OpEx-style models of building (or upgrading) technology infrastructure (see 3.2 - Perspectives on the Proposed Interconnection System (v6)).

  Recommendation: The funding and governance model should evolve for the future to allow for continual system upgrades and evolution. Interconnection v7 should never exist per se. Instead it will be of the form incremental upgrades v6.1, v6.2, etc.

  Benefits: If this can be done, it will allow for a more agile system that is capable of responding to changes in technology and business needs more quickly. It is almost impossible to predict exactly what is needed 5 years from now and this would give the needed flexibility.

- **Recommended Action 11: Convert from Ku to C-band and consolidate PBS and NPR satellite operations while considering the use of HEVC or other advanced compression technologies**

  Background: PBS currently uses Ku band transponders which are more susceptible to atmospheric interference (rain fade) than C-band technology. NPR uses 2 partial C-band satellite transponders for distribution. The NTC report suggested that if PBS can reduce its satellite transponder usage and convert to C-band, it will provide an opportunity for PBS and NPR to

consolidate and use shared transponders. Currently, PBS currently operates its Satellite Operations Center out of Springfield, VA, while NPR operates out of Washington D.C.

Recommendation: C-band conversion should be done as recommended by multiple parties. There is widespread agreement on the value of doing this. Also, NPR and PBS should combine satellite operations at the NPR SOC which would be possible only if PBS converts from Ku to C-band.

Benefits: PBS C-band can be combined with NPR use and is more reliable. Consolidating the satellite operations will enable PBS and NPR to derive efficiencies and hence reduced costs of operation.

- **Recommended Action 12: Adopt a more widely used Media File standard**

Background: PBS uses a proprietary flavor of the MXF standard – AS-03 (MPEG-2 file) for the NRT system. This is not universally supported and does not support advances in codecs. PBS is currently testing XDCAM 1920x1080 35MB MPEG4 with AAC audio as the file format.

Recommendation: PBS should select a new media file standard that is more compatible with many existing technologies. It is recommended that PBS completes the evaluation underway and uses a more compatible file standard.

Benefits: While all proposed solutions would support the existing AS-03 format, a new selection would be more likely to be directly supported by numerous devices and would support new technologies such as UHDTV. This will provide greater flexibility in the use of files for other or new needs.

- **Recommended Action 13: Negotiate operational flexibility with a technology vendor**

Background: Station operations are very diverse and they may not be able to redeploy or eliminate their staff in favor of a third-party or vendor operated model as some are part of union and others perform multiple roles.

Recommendation: The solution should allow for operational flexibility with master control technology. There should be options for the station to choose between a vendor operated or a third-party operated (an existing JMC, PBS or other commercial provider) model. Additionally, if the stations want to operate master control themselves, they should have the option to do so.

Benefits: Operations will not be amenable to a one size fits all approach. For those stations that cannot easily eliminate operations, this will allow flexibility.

- **Recommended Action 14: Eliminate pre-flattening of content**

Background: PBS currently pre-flattens content for distribution with graphics and interstitials embedded. Many different versions of the same content are created with different interstitials and redistributed. It will be expensive if the same content has to be downloaded from the cloud again and again.

Recommendation: PBS should eliminate the flattening of program blocks and produce elements to be assembled in master control. This is the common practice throughout the broadcast industry. However, some change management will be needed at the stations to adapt to the new process. It should be noted that for stations that adopt a centralized master control, this will not impact them and will be handled at the JMC.

Benefits: It reduces the number of times a piece of content must be transmitted. It facilitates easier media management. It will result in reduced MOC costs for PBS. It will reduce the need to send near-live content out live. It will provide for greater flexibility in sponsorship arrangements at the national and local level.

- **Recommended Action 15: Sustain the current JMCs**

Background: Currently there are 3 joint master control solutions in the public TV system – CentralCast, NY; DCA, Florida and PMM. The 3 joint master controls provide similar services to member stations (see 5.4 - The Argument for Centralized Master Control).

Recommendation: It is recommended that the current joint master control solutions are sustained and CPB continues to support them.

Benefits: With multiple JMCs there will be a competitive environment that can offer choice and increased value for individual stations. The stations will have the flexibility to choose from the providers that best suit their needs. Having multiple JMC's will help keep the primary selected vendor for interconnection aligned in cost and services.

- **Recommended Action 16: Perform a cyber-security audit**

Background: A lot of emphasis is placed on the importance of public internet, which is more susceptible to cyber-attacks, for distribution of content.

Recommendation: It is recommended that a cyber-security audit be performed at each station vis-a-vis public internet access, given the additional importance of the public internet connection. A standard audit could be included as part of an agreement with the vendor selected or done by a third party. System-wide training on cyber security may be needed as the importance of common IT technologies increases.

Benefits: Regular cyber security audits at each station will help in discovering any potential vulnerability to the public television distribution network and help to make it more secure.

- **Recommended Action 17: Document lessons learned from R&D to date**

Background: A great deal of research and thinking has been done on interconnection in the last couple of years. This has included the testing of PoCs and the development of a great number of documents that cover specifications, requirements, and user interfaces.

Recommendation: It is recommended that the lessons learned from v6 connectivity research to date be documented to speed re-evaluation in 2 to 5 years. These documents can also be used in negotiations with a vendor to insure that all requirements are met that are relevant.

Benefits: Using the documentation generated to date will assist in insuring that the details thought through in the last two years are accounted for in the negotiation with a vendor. Documenting them for posterity will allow a future evaluation of terrestrial live television in 2 to 5 years to not start from scratch and save time at that point.

- **Recommended Action 18: Ensure appropriate change management practices are followed**

  Background: Perhaps the most critical failure of the v5 implementation was the lack of proper use of change management techniques and the subsequent resistance to the system. This is a common problem in large technology projects and a number of tools and techniques have been developed to reduce such problems.

  Recommendation: Learn about and ensure that appropriate and modern change management techniques around communication, stakeholder involvement, and training are in place before beginning implementation. It is also recommended that any deployment consider significant station hand-holding after going live for several weeks to ensure that early problems are resolved quickly.

  Benefits: A proper change management approach should assist with reducing resistance to adoption of the system. It should also provide for a smoother transition to the new system with reduced problems.

5.5.1.2 Indicative Timeline

Cognizant has designed an initial program plan for the implementation of interconnection for the system. The interconnection solution is recommended to be executed along with the Ku to C-Band migration as indicated in Figure 20:

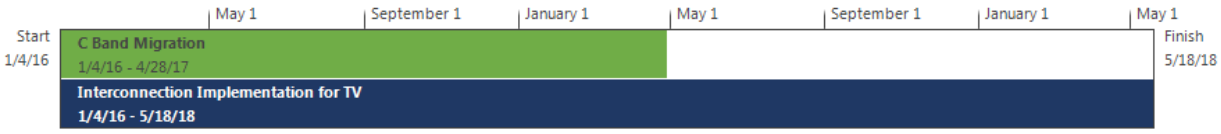


Figure 20 – High-level Overview of Program Plan

A start date of January 4th, 2016 (the first Monday of that month) has been assumed for the program. The C-Band migration is expected to complete for the entire system (as per the "aggressive" scenario discussed in the financial modeling tool, section 0) by April 28th, 2017 and the interconnection rollout by May 18th, 2018.

The detailed plan for Interconnection is shown in Figure 21 and outlines the plan to get agreements on approach (January 4th to February 26th, 2016), plan the execution approach thereafter (till March 25th, 2016) and then build the technical solution (expected completion May 20th, 2016).

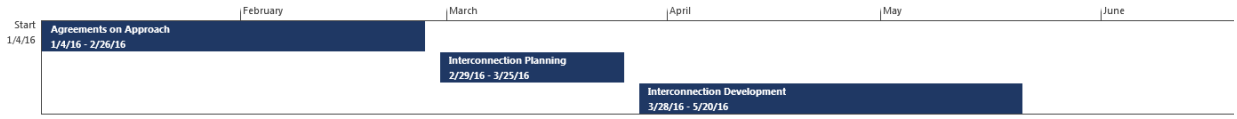


Figure 21 – Interconnection Plan (Pre-Rollout)

The rollout plan for Interconnection is divided over 3 phases as shown in

Figure 22:

- Phase 1 starts on May 23rd, 2016, covers 5 stations and ends on August 19th, 2016.
- Phase 2 starts on August 22nd, 2016, covers 21 stations and ends on November 25th, 2016.
- Phase 3 starts on November 28th, 2016, covers 144 stations and ends on May 18th, 2018.

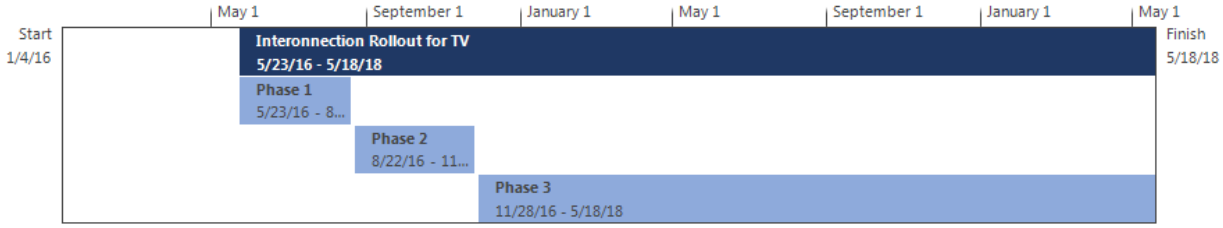


Figure 22 – Interconnection Rollout Plan

The detailed plan for C-band migration is illustrated in Figure 23:

- An initial phase of planning and vendor selection (for 12 weeks starting January 4th, 2016 and expected to complete by March 25th, 2016) will be used for planning, request for proposals, vendor selection and contracting.
- This will be followed by the rollout comprising three phases:
  - Phase 1 starts on March 28th, 2016, covers 3 stations and ends on April 15th, 2016.
  - Phase 2 starts on April 18th, 2016, covers 14 stations and ends on June 3rd, 2016.

- Phase 3 starts on June 6th, 2016, covers 153 stations and ends on April 28th, 2017.

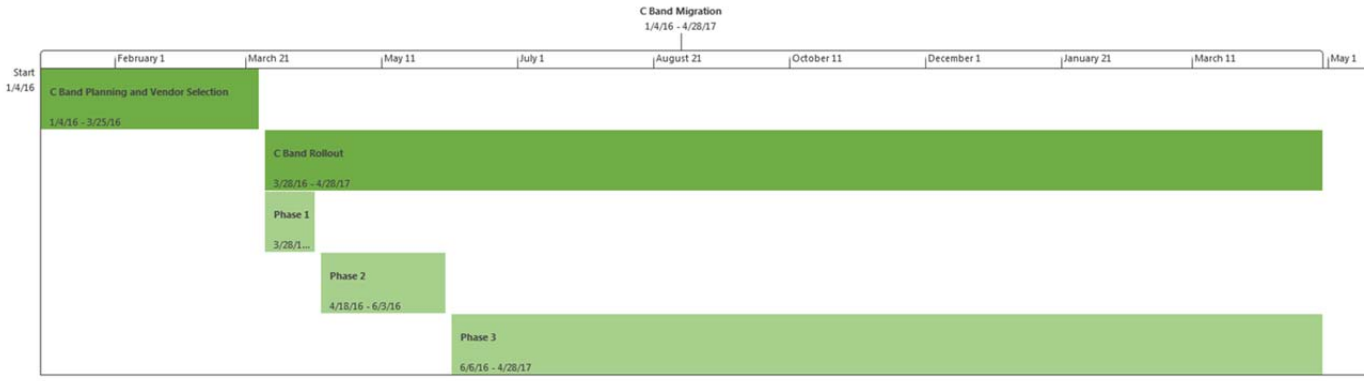


Figure 23 – C Band Migration Plan

The overall mid-level program plan is illustrated in Figure 24 and indicates the key milestones of the C-Band and interconnection rollout being completed and steady state of operations beginning from May 18th, 2018:

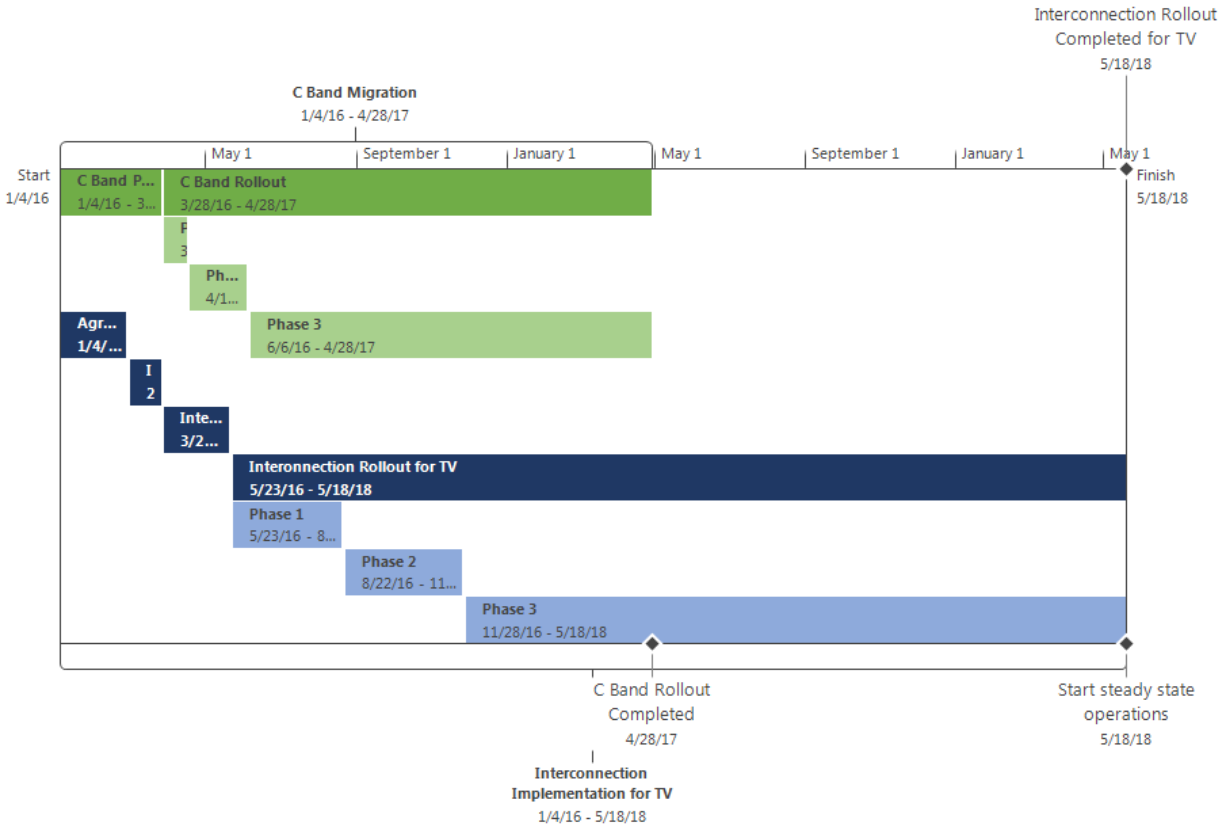


Figure 24 – Overall Program View (Partly Obscured)

5.5.1.3 Governance and Operational Model

Currently, the interconnection is governed by the Interconnection Committee, which reports to the PBS Board of Directors and includes members from national distributors (PBS, APT and NETA), CPB, APTS and member stations, via the Affinity Group Coalition and PBS' Enterprise Technology Advisory Committee. The interconnection committee is chaired by PBS. PBS has managed the public TV interconnection system that connects 170 or more public TV stations, for over 40 years. PBS has long been trusted in its role at the helm of the public TV and it has the obligation to keep the whole system's interest at heart. PBS also has the responsibility to meet the needs of the lowest common denominator. The interconnection should remain under the current system of governance and under day-to-day control of PBS. This will keep stable governance and reduce change management challenges.

5.5.1.4 Financial Analysis and Cost Comparisons

Cognizant has developed a financial modeling tool to capture and estimate the detailed costs for equipment, technology and professional services across the build, deployment and rollout, and operate phases of the interconnection program:

- The tool is dynamically modeled and includes the detailed costing for the two proposed solutions for interconnection from PBS and WGBH (namely, v6 and PMM) over a 10-year timeframe.
- It includes multiple rollout scenarios for the adoption of interconnection services and incorporates the existing centralized master control solutions.
- The tool estimates and compares the costs for an interconnection solution based on v6, PMM, v5 and multiple scenarios for the approach recommended by Cognizant.
- It also provisions for an evolving scenario of additional channels over time which can be flexibly described year-on-year over the 10-year plan.
- The tool incorporates the existing 3 transponders in use (v5) and their separation between live and NRT content.
- Master control costs are fully incorporated and separated by equipment costs, technology costs, and staff compensation, which account for inflation (as per the average Consumer Price Index over 10 years, a number which is configurable in the tool).
- Each element of the costing can be revised to dynamically calculate total cost of ownership for the various scenarios modeled.
- Equipment costs are separated from the service and satellite costs and the annual maintenance is expressed as a configurable percentage.

Using this tool, Cognizant has drafted an initial cost for interconnection for the following scenarios.

1. A v6-based interconnection (Approach #1)
2. A PMM-based interconnection (Approach #2)
3. The approach recommended by Cognizant with all stations using a cloud-based NRT solution for interconnection (Approach #3).

This costing has several assumptions built in, owing to the lack of information which is needed to estimate to a greater degree of accuracy. It is intended to be used for high-level decision-making to support the identification of the most suitable way forward to manage interconnection for public television. It is not intended to be used for budgetary or detailed planning purposes or as a basis to request for Congressional funding.

Approach #:	1	2	3
Category	v6 Based Solution	PMM Based Solution	Recommended Approach
Description	Current v6 solution from PBS for interconnection (with additional estimated expenses from Cognizant)	PMM solution from WGBH for interconnection (with additional estimated expenses)	Cognizant's Recommended Approach
Interconnection (Without Additives)	$227.9	$182.9	$178.2
System Refresh/ Enhancement	$17.1	$13.7	$13.4
Contingency	$0.0	$9.1	$8.9
Overhead	$2.5	$2.5	$2.5
Interconnection Total	$247.5	$208.3	$203.0

Figure 25 – Summary of Initial Costing Model Comparing Various Approaches for Interconnection (USD millions)

This table shows the approaches described above and the respective total costs estimated for each approach.

The following key observations can be made from this comparison:

- The total cost of providing interconnection using v6 is approximately $248M over 10 years.
- The total cost of providing interconnection using PMM is around $208M over 10 years. This is approximately $40M less than the costs using the v6 approach.
- The total cost of providing interconnection using the Cognizant approach is around $203M over 10 years.
- An evolutionary budget has been added to all approaches to cater for changing technology (e.g. 4K, new models of distribution and the like).
- A contingency of 5% has been added to the PMM and Cognizant approaches.
- General overhead expenses of $250K have been added per year for the timeframe of 10 years.

In addition to the costs of interconnection, Cognizant assessed the total costs of centralizing master control functions throughout the system.

Approach#	1	2
Category	Current State	Cognizant Recommended Approach
Description	A station-operated model/ ecosystem is assumed for Master Control,projected costs as per current numbers (as reported by stations)	An ecosystem of multiple providers is planned for Master Control, Including PMM, JCT and Centralcast
Master Control - Central Facility	$0.0	$176.3
MC Connectivity	$0.0	$0.8
MC Equipment Cost	$88.8	$0.0
MC Operations Cost	$479.8	$119.9
Contengency	$0.0	$14.9
Master Control Total	**$568.6**	**$311.9**

Figure 26 – Summary of Initial Costing Model Comparing Various Approaches for Master Control (USD millions)

The following key observations can be made from this comparison:

- The total cost of master control in the current state is under $569M. This is assuming a fully station operated master control for the system (as per self-reported financial data).
- The total cost of providing master control using the Cognizant approach is marginally less than $312M over 10 years. In this scenario, the currently operational centralized master control solutions continue to operate with their existing subscribers. This is the scenario that is most recommended as it provides for internal and external competitive pressures and thus drives down costs somewhat while keeping them better in check in the future.
- A contingency of 5% has been added where applicable.

While centralized master control could be implemented under any of the interconnection solutions outlined above, the Cognizant recommended approach of a cloud-based solution for NRT helps facilitate the implementation of a centralized master control in certain respects, as the equipment and technologies overlap.

5.5.1.5 Comparative Analysis

Assessment Category	Evaluation Parameter	Assessment Rating for v6	Assessment Rating for PMM	Assessment Rating for Cognizant Recommended Solution
Technical	Design & Specifications	●	●	●
	Network Connectivity	●	●	●
	Infrastructure	●	●	●
	Security	●	◑	◑
	Scalability	●	●	●
	Reliability	●	●	●
	Sustainability	●	●	●
	Interoperability	●	●	●
	Manageability	●	●	●
	Hardware	●	●	●
	Software	●	●	●
	Monitoring	●	●	●
	Configuration	●	●	●
	User Experience & Usability	●	●	●
Organizational	Skills Assessment and Roles/ Reporting Matrix	◑	●	●
	Department/ Station Alignment	●	◑	●
	Company Culture	●	●	●
	Performance Metrics	●	●	●
Operational	Collaboration Opportunities	●	◑	●
	Business Models	●	●	●
	National Security	●	◔	◑
	Current State to Future State Readiness	●	●	●
	Process Workflows	●	●	●
	Key Performance Indicators	●	●	●
	Work Tools/ IT Systems	●	●	●
Financial	Procurement	◑	●	●
	Maintenance/ Support	●	●	●

● Fully meets criteria ○ Does not meet criteria

Figure 27- Assessment Ratings for all Solutions

6 Summary Conclusion

The current interconnection system, namely v5, has had mixed reviews. Most stations have reported challenges with using v5 for NRT (non real-time) content which forms at least 80% of public television programming. There are apprehensions stations have of the new interconnection solution (v6), which they fear will suffer from similar technical and rollout challenges.

One of the key aspects of the v6 solution is the use of a MPLS/fiber network throughout the system. This is an expensive proposition with the fiber network alone costing more than $90M over 10 years. The justifications for such an expense include enhanced collaboration between stations (for instance, bi-directional capabilities) and a richer variety of production elements to hard or soft-live programming. However, we have discovered that the system's appetite for bi-directional capabilities is low. Also, given the evolution of the public internet which is increasingly being able to facilitate broadcast quality video, we do not recommend such an expensive investment and a technology approach which is strongly committed and offers more limited flexibility.

Meanwhile, there have been initiatives in centralized master control which seek to bring benefits like increased quality and consistency, significant cost savings in operational costs and efficiencies in process, management, training and content transmission. These initiatives also eliminate the need for periodic replacement of expensive equipment and technology and enable a healthy, competitive environment with multiple providers.

The PMM solution from WGBH, which has seen success as a solution for centralized master control, has been offered as an alternative solution for interconnection. We have assessed this approach in detail and find that the technology underlying this solution offers significant commercial and operational benefits. However, there is apprehension amongst stations about WGBH managing their interconnection environment (with PMM).

Cognizant has recommended an approach that borrows from PMM's NRT solution and suggests retaining their chosen provider (Sony Media Cloud Services), taking into consideration execution and rollout timelines. This approach also seeks to minimize satellite usage after the expiration of the current satellite contract in September 2016 and proposes all stations migrate to a centralized master control, which would save the system slightly greater than $300M for interconnection and master control (over a 10-year timeframe).

An overall indicative timeline which combines the proposed C-Band transition (from the existing Ku Band) and the recommended interconnection solution rollout aims to reach steady state of operations by May 2018 (after rolling out the new solution to all 170 public television licensees, subject to a January 2016 commencement).

7 Bibliography

ACE Due Diligence Executive Overview with Key Findings
Willis Group
December 22, 2004

ACE Status Report Comments: CPB Digital Consultation Panel
Merrill Weiss Group LLC
January 6, 2005

Axon to Launch Tide, Multi-format Processing Platform
Sport Talk Live, IBC 2015
September 8, 2015.

The BBC and its former CTO have engaged in tit-for-tat allegations over its failed £100 digital media project. But who was right?
Glick, Brian
Computer Weekly
February 5, 2014
http://www.computerweekly.com/news/2240213773/The-BBC-DMI-project-what-went-wrong

Broadcast Operations System Assessment Executive Summary: A Report for the Corporation for Public Broadcasting
Merrill Weiss Group LLC
June 1, 2005

Cloud 101
Pecena, Wayne
PBS TechCon 2014

Cloud Services - Request for Information for the Public Television Interconnection System (PTISv6)
Public Broadcasting Service
November 11, 2013

Companies that Responded to v6 Request for Information
Public Broadcasting Service

CPB OMB Justification
Corporation for Public Broadcasting
September 15, 2014

ETAC Survey Report
PBS Enterprise Technology Committee
February 11, 2013

Framework for Improving Critical Infrastructure Cybersecurity Version 1.0
National Institute of Standards and Technology
February 12, 2014

Future System Planning Update: Connecting Through Collaborating
National Public Radio System-wide Webinar
June 11, 2015

Interconnection Satellite Usage Plan
Public Broadcasting Service

IP Multicast, Does it Really Work?
Pecena, Wayne
PBS TechCon 2014

Joint Master Control Test Plan in support of the PBS v6 Proof of Concept Project
Public Broadcasting Service
December 1, 2014

Joint Television and Radio Interconnection Planning: Future Interconnection Services – NPR/PBS
Collaboration
National TeleConsultants
January 27, 2015

Location Acceptance Test Procedure for the Provision of MPLS IP-VPN Connectivity Services in Support of the PBS v6 Proof of Concept Project
Public Broadcasting Service
November 5, 2014

Master-Control Alliance in Florida gets $7 Million from CPB
Sefton, Dru
Current
June 12, 2013
http://current.org/2013/06/master-control-alliance-in-florida-gets-7-million-from-cpb/

Move to PBS' ACE Master Control Gets Mixed Reviews
Behrens, Steve
Current
September 25, 2006
http://current.org/files/archive-site/tech/tech0617ace.shtml

Moving Public Media Forward: The Future of Media Technology
Vecchi, Mario
PBS TechCon 2015

NGIS Non-Real Time Program Delivery: A Station Perspective
Popkin, Alan

NLRB Throws out CNN's Joint Employer Challenge
Communication Workers of America Press Release
March 24, 2015
http://www.cwa-union.org/news/entry/nlrb_throws_out_cnns_joint_employer_challenge#.ViCJl9KrTDd

N.Y. Public Broadcasters Centralize Master Control
Kienzle, Claudia
TV Technology
September 18, 2012
http://www.tvtechnology.com/news/0086/ny-pubcasters-centralize-master-control/215517

PBS' Automation Effort Stalls
Dickson, Glen
Broadcasting & Cable
October 7, 2006
http://www.broadcastingcable.com/news/news-articles/pbs-automation-effort-stalls/81124

POC Connectivity Services – Request for Quotation for the Public Television v6 Interconnection System
Public Broadcasting Service
May 1, 2014

Preliminary Benefits Analysis
Public Broadcasting Service
July 31, 2014

Preliminary Station Survey Results for the v6 Proof of Concept (POC '14) Project
Public Broadcasting Service
November 10, 2014

Proof of Concept Categories and Participating Vendors
Public Broadcasting Service
June 2015

Public Broadcasting Act of 1967

Public Media v6 Interconnection System Annual Meeting Brochure
Public Broadcasting Service

Request for Information Process and System Requirements Overview for the Public Television Interconnection System – version 6 (PTISv6)
Public Broadcasting Service
October 31, 2013

Sony, WGBH Roll Out Cloud-based Alternatives to Master-control Systems
Halonen, Doug
Current
April 16, 2015
http://current.org/2015/04/sony-wgbh-roll-out-cloud-based-alternative-to-master-control-systems/

Strategic Schedule as of 070815
Public Broadcasting Service
July 8, 2015

System Integration and Equipment/Software Suppliers – Request for Information
Public Broadcasting Service
November 11, 2013

System Requirements Definition for the v6 PoC ’14 Project
Public Broadcasting Service
December 15, 2014

TechCon v6 Discussion Panel: Your Future v6 Interconnection System
April 1, 2015

Technical Operating Specification Program Submission 2013 Edition
PBS Technology & Operations

Technical Operating Specification Program Submission 2014 Edition
PBS Technology & Operations

Technical Operating Specification Satellite Uplinks 2013 Edition
PBS Technology & Operations

v6 Budget: Federal Ask Summary
Public Broadcasting Service
2014

v6 Content Storage Service Requirements Definition in Support of the PBS v6 Proof of Concept Project
Public Broadcasting Service
February 24, 2015

v6 Design Requirements and Assumptions
Public Broadcasting Service
June2015

v6 Glossary of Terms
Public Broadcasting Service
June 2015

v6 Interconnection Project Budget: Cash Flow Submitted to OMB
January 2015

v6 Master Scheduling Service Requirements Definition for the PBS v6 Proof of Concept Project
Public Broadcasting Service
February 24, 2015

v6 Project Timeline
Public Broadcasting Service
June 16, 2015

v6 System Monitoring and Control (M&C) Service Requirement Definition in support of the PBS v6 Proof of Concept Project
Public Broadcasting Service
February 24, 2015

v6 System Requirements Definition for the PBS v6 Proof of Concept Project
Public Broadcasting Service
February 24, 2015

v6 System User Interface Requirements Definition for the PBS v6 Proof of Concept Project
Public Broadcasting Service
February 24, 2015

WGBH Educational Foundation's Response to CPB Questions Regarding PMM
WGBH
May 3, 2015

WGBH Partners with Sony for Virtual Master Control Platform
Grotticelli, Michael
The Broadcast Bridge
April 3, 2015
https://www.thebroadcastbridge.com/content/entry/2435/wgbh-partners-with-sony-for-virtual-master-control-platform

8 Appendices

8.1 Glossary

Term	Definition
A/F-IRD	Advanced file based integrated receiver decoder provides IRD functionality, transfers file-based content to station automation and playout systems and plays out file-based content to SDI as needed.
Cloud	Cloud computing relies on sharing a pool of physical and/ or virtual resources, rather than deploying local or personal hardware and software. Clouds can be classified as private, public and hybrid.
Cloud - Hybrid	Utilizes both private and public clouds to perform distinct functions within the same organization.
Cloud – Private	Pooled services and infrastructure stored and maintained on a private network which only a specified client can operate. Enables greater security and control.
Cloud - Public	Services and infrastructure are hosted off-site by a cloud provider, shared across provider's base and accessed by public networks such as the internet. Highly scalable and cost effective, but potentially more vulnerable than a private cloud.
Community Service Grant (CSG)	Community Service Grant is a program managed by CPB to award funding to public media stations that apply for it for providing public service programming to their communities.
Fiber	Network cable designed for long distance and very high bandwidth network communications.
FTP	File Transfer Protocol based software allows for file sharing over a network between parties that have the required authorization and credentials.
Integrated Receiver Decoder (IRD)	A device that receives radio-frequency signals (such as linearother encoded program services) and decodes digital information (selected programs) into industry standards such as Serial Digital Interface (SDI) video.

Joint Master Control	These are entities that provide centralized master control services to PTV stations. These are not CSG grant qualified PTV stations but are funded in part by CPB. JMC facilities exist in Syracuse, New York and Jacksonville, Florida.
Linear	A stream of content intended to be consumed in a continuous manner.
Mesh	A network where each node can relay data for the network– any node on the network can serve as an origination point to one or many nodes on the network.
Metadata	Technical or descriptive data about the media. Descriptive data may contain series and episode name, description of the show, ratings, language, etc. Technical data may contain video format, audio format, frame rate, duration etc. Metadata is used to improve discovery of the media or drive integration between various systems or automate processes.
MPLS	Multi-Protocol Label Switching is a packet switched network that is scalable and protocol independent.
Multicast	The capability to deliver information (video) to multiple receivers from a single source in a network.
Network - Private Network	A network which is not accessible from devices outside the network. Access restrictions, high-security hardware and applications like firewall are in place to promote a secured environment.
Network - Public Network	A network that provides access to anyone. Public network has few or no restrictions, users need to be wary of possible security risks when accessing it.
Network - Virtual Private Network (VPN)	Private network built over a public or shared infrastructure; security mechanisms allow VPN (Virtual Private Network) users to securely access a network from different locations via a public telecommunications network, most frequently the internet.
NGIS	The current v5 interconnection is also known as Next Generation Interconnection System which distributed content over satellite and is operated by PBS.
Non-real time (NRT)	Content that is recorded, stored, and distributed to stations for later airing.

OTT	"Over-the-top" platforms enable a user to view content via the public internet through consoles, set-top boxes, tablets, personal computers and mobile devices.
Satellite Broadcasting	Satellite broadcasting is the distribution of content via a satellite network. The signals (originate from PBS and some stations) and are uplinked to a geo-stationary artificial satellite for redistribution to stations. Satellites enable broadcasting high-quality content over large geographical areas particularly when the content is required to be "live."
Stream	A continuous feed of isochronous video frames and audio. In the context of interconnection, this is the same a broadcast channel.
Transponder	A device on the satellite which receives signals at a specific frequency and transmits that signal for distribution of content. There are multiple transponders associated with a given satellite.

8.2 Interview List

- **CPB & Public Media Entities:**

Organization	Stakeholder Group/Name	Date of Interview(s)
CPB	SVP, Media Strategy	6/16/2015; 6/25/2015
CPB	VP, Information Technology	6/17/2015
CPB	EVP and COO	6/17/2015
CPB	VP, Operations	6/23/2015
CPB	Digital Media Strategy	6/18/2015
CPB	VP, Media Strategy Operations	6/18/2015
CPB	System Planning and Strategic Advisor	6/18/2015
CPB	VP, Government Affairs	6/19/2015
CPB	SVP, General Counsel	6/22/2015
CPB	CFO and Treasurer	6/22/2015
CPB	SVP, Business Affairs	6/23/2015
CPB	Chief Strategy Officer and EVP	6/24/2015
PBS	CTO	6/30/2015
PBS	VP, Operations & Engineering	6/24/2015
PBS	VP, Information Technology	6/24/2015
PBS	VP, Technology Strategy & Management	7/7/2015
PBS	Sr. Director of Engineering	7/14/2015; 8/14/2015; 9/15/2015
PBS	CEO	Scheduled for 10/21/2015
APT	VP, Technology	7/23/2015
NPR	VP, Technology Operations, Distribution, and Broadcast Engineering	7/8/2015
NPR	VP, Distribution	7/9/2015
NPR	Sr. Solutions Architect	7/9/2015
Consultant	Public Broadcasting Consultant	8/31/2015
WJCT (Master Control)	CEO	9/3/2015

- **Technology Vendors:**

Organization	Stakeholder Group/Name	Date of Interview(s)
Encompass	CTO	9/17/2015
Miranda	Global Strategy Account Manager	8/24/2015
The Switch	EVP	8/25/2015
Vubiquity	CEO	9/3/2015
Octoshape	VP, Global Sales	9/3/2015

- **PTV Member Stations:**

Station	Stakeholder	Member of TAG	Date of Interview(s)
WNET New York	CTO	Yes	6/17/2015
WETA Washington DC	VP of Engineering	Yes	6/18/2015
NET Nebraska	CTO	Yes	7/7/2015
KLCS Los Angeles	Director of Engineering	Yes	7/7/2015; 9/11/2015
WHYY Philadelphia	CTO	Yes	7/14/2015
TPT Minneapolis	CTO	Yes	7/14/2015
WGBH Boston	CEO, CTO, COO	Yes	7/10/2015; 7/15/2015; 7/16/2015; 9/8/2015; 10/1/2015
Lakeland PTV Brainerd/Bemidji	CEO	No	7/22/2015
WUSF Tampa	GM	No	7/24/2015
TAMU/KAMU	Electrical Engineering Dept. Head	Yes	7/20/2015
Rocky Mountain PBS Denver	COO	No	7/21/2015
KUSM Bozeman, Montana	GM	No	7/8/2015
Maryland Public Television	CEO, CTO	No	8/28/2015

8.3 Bandwidth Analysis for Public Internet Across the United States

Below is a listing of the maximum bandwidth which may be available for stations based on publicly available data. Stations that did not have publicly available data are listed as "NA".

			Maximum Bandwidth Available				
Grantee Name	**City**	**State**	**10-25Mbps**	**25-50Mbps**	**50-100Mbps**	**100Mbps-1Gbps**	**1Gbps+**
Alabama PTV	Birmingham	AL				X	
Arkansas Educational TV	Conway	AR				X	
Connecticut Network	Hartford	CT				X	
Georgia P.B.	Atlanta	GA					X
Hawaii PTV	Honolulu	HI				X	
Iowa PTV	Johnston	IA				X	
KACV-TV	Amarillo	TX			X		
KAET-TV	Phoenix	AZ					X
KAID-TV	Boise	ID					X
KAKM-TV	Anchorage	AK				X	
KAMU-TV	College Station	TX					
KAWE-TV	Bemidji	MN					X
KBDI-TV	Denver	CO					X
KBTC-TV	Tacoma	WA					X
KBYU-TV	Provo	UT					X
KCET-TV	Burbank	CA					X
KCOS-TV	El Paso	TX					X
KCPT-TV	Kansas City	MO				X	
KCSM-TV	San Mateo	CA				X	
KCTS-TV	Seattle	WA				X	
KCWC-TV	Riverton	WY		X			
KEDT-TV	Corpus Christi	TX				X	
KEET-TV	Eureka	CA			X		
Kentucky Network	Lexington	KY			X		
KENW-TV	Portales	NM				X	
KERA-TV	Dallas	TX					X
KETC-TV	St. Louis	MO					X
KGTF-TV	Barrigada	GU	X				
KIXE-TV	Redding	CA				X	
KLCS-TV	Los Angeles	CA				X	
KLRN-TV	San Antonio	TX					X

KLRU-TV	Austin	TX				X	
KLVX-TV	Las Vegas	NV				X	
KMOS-TV	Warrensburg	MO				X	
KNCT-TV	Killeen	TX				X	
KNME-TV	Albuquerque	NM				X	
KNPB-TV	Reno	NV				X	
KOCE-TV	Los Angeles	CA				X	
KOOD-TV	Bunker Hill	KS				X	
KOZK-TV	Springfield	IL					X
KPBS-TV	San Diego	CA				X	
KPBT-TV	Midland	TX					X
KPTS-TV	Wichita	KS					X
KQED-TV	San Francisco	CA				X	
KRCB-TV	Rohnert Park	CA			X		
KRMA-TV	Denver	CO				X	
KRSU-TV	Claremore	OK				X	
KRWG-TV	Las Cruces	NM				X	
KSMQ-TV	Austin	MN				X	
KSPS-TV	Spokane	WA				X	
KSYS-TV	Medford	OR					X
KTCA-TV	St. Paul	MN				X	
KTOO-TV	Juneau	AK				X	
KTTZ-TV	Lubbock	TX	NA	NA	NA	NA	NA
KTWU-TV	Topeka	KS				X	
KUAC-TV	Fairbanks	AK				X	
KUAT-TV	Tucson	AZ				X	
KUED-TV	Salt Lake City	UT					X
KUEN-TV	Salt Lake City	UT					X
KUHT-TV	Houston	TX				X	
KUON-TV	Lincoln	NE					X
KUSM-TV	Bozeman	MT		X			
KVCR-TV	San Bernardino	CA				X	
KVIE-TV	Sacramento	CA				X	
KVPT-TV	Fresno	CA				X	
KVZK-TV	Pago Pago	AS	NA	NA	NA	NA	NA
KWCM-TV	Appleton	MN				X	
KWSU-TV	Pullman	WA				X	
KYUK-TV	Bethel	AK	X				
Louisiana P.B.N.	Baton Rouge	LA				X	
Maine Network	Lewiston	ME				X	
Maryland Network	Owings Mills	MD				X	

Mississippi P.B.	Jackson	MS					X
Nebraska Network	Lincoln	NE					X
New Hampshire Network	Durham	NH				X	
New Jersey Network	Trenton	NJ				X	
Oklahoma Network	Oklahoma City	OK				X	
Oregon Network	Portland	OR					X
Prairie PTV	Fargo	ND					X
S. Carolina Network	Columbia	SC			X		
South Dakota PTV	Vermillion	SD					X
UNC-TV	Research Triangle	NC					X
Vermont PTV	Colchester	VT					X
WBGU-TV	Bowling Green	KY			X		
WBRA-TV	Roanoke	VA				X	
WCET-TV	Cincinnati	OH			X		
WCFE-TV	Plattsburgh	NY					X
WCMU-TV	Mt. Pleasant	MI				X	
WCNY-TV	Syracuse	NY					X
WCTE-TV	Cookeville	TN				X	
WCVE-TV	Richmond	VA					X
WDCQ-TV	University Center	MI				X	
WDSC-TV	Daytona Beach	FL					X
WDSE-TV	Duluth	MN					X
WEDU-TV	Tampa	FL				X	
WEFS-TV	Cocoa	FL					X
WEIU-TV	Charleston	IL				X	
WETA-TV	Arlington	VA					X
WETP-TV	Knoxville	TN				X	
WFSU-TV	Tallahassee	FL				X	
WFWA-TV	Fort Wayne	IN					X
WFYI-TV	Indianapolis	IN					X
WGBH-TV	Boston	MA					X
WGCU-TV	Fort Myers	FL					X
WGTE-TV	Toledo	OH				X	
WGVU-TV	Grand Rapids	MI				X	
WHA-TV	Madison	WI				X	
WHRO-TV	Norfolk	VA					X
WHUT-TV	Washington	DC				X	
WHYY-TV	Philadelphia	PA					X
WILL-TV	Urbana	IL					X
WIPB-TV	Muncie	IN					X
WIPR-TV	San Juan	PR					X

Wisconsin Network	Madison	WI				X	
WITF-TV	Harrisburg	PA				X	
WJCT-TV	Jacksonville	FL				X	
WKAR-TV	East Lansing	MI	X				
WKNO-TV	Cordova	TN					X
WKYU-TV	Bowling Green	OH			X		
WLAE-TV	Metairie	LA					X
WLJT-TV	Martin	TN				X	
WLRN-TV	Miami	FL				X	
WLVT-TV	Bethlehem	PA					X
WMEC-TV	Springfield	MO					X
WMHT-TV	Troy	NY					X
WMTJ-TV	Rio Piedras	PR				X	
WMVS-TV	Milwaukee	WI			X		
WNED-TV	Buffalo	NY					X
WNEO-TV	Kent	OH			X		
WNET-TV	New York	NY					X
WNIN-TV	Evansville	IN			X		
WNIT-TV	South Bend	IN					X
WNMU-TV	Marquette	MI				X	
WNPT-TV	Nashville	TN				X	
WNYE-TV	New York	NY					X
WOSU-TV	Columbus	OH					X
WOUB-TV	Athens	OH			X		
WPBA-TV	Atlanta	GA					X
WPBS-TV	Watertown	NY					X
WPBT-TV	Miami	FL					X
WPSU-TV	University Park	PA				X	
WPTD-TV	Dayton	OH			X		
WQED-TV	Pittsburgh	PA					X
WQLN-TV	Erie	PA					X
WQPT-TV	Moline	IL					X
WSBE-TV	Providence	RI					X
WSIU-TV	Carbondale	IL				X	
WSKG-TV	VESTAL	NY					X
WSRE-TV	Pensacola	FL				X	
WSWP-TV	Charleston	WV			X		
WTCI-TV	Chattanooga	TN					X
WTIU-TV	Bloomington	IN					X
WTJX-TV	St. Thomas	VI	NA	NA	NA	NA	NA
WTTW-TV	Chicago	IL				X	

WTVI-TV	Charlotte	NC			X		
WTVP-TV	Peoria	IL				X	
WTVS-TV	Wixom	MI					X
WUCF-TV	Orlando	FL				X	
WUFT-TV	Gainesville	FL				X	
WUSF-TV	Tampa	FL				X	
WVIA-TV	Pittston	PA				X	
WVIZ-TV	Cleveland	OH					X
WVPT-TV	Harrisonburg	VA				X	
WVUT-TV	Vincennes	IN					X
WXEL-TV	West Palm Beach	FL					X
WXXI-TV	Rochester	NY					X
WYBE-TV	Philadelphia	PA				X	
WYCC-TV	Chicago	IL				X	
WYES-TV	New Orleans	LA				X	
WYIN-TV	Merrillville	IN					X

Source:

1. www.broadbandmap.gov
2. The website of Time Warner Cable
3. The website of Suddenlink Communications
4. The website of Charter Communications
5. The website of Comcast Cable
6. The website of Century Link
7. The website of Cox Communications