EVENT VIDEO PRODUCTION AND WEBCAST EQUIPMENT

REVISION HISTORY		
-	16 JULY 2015	INITIAL RELEASE

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1 OVERVIEW

For the 2015 *FIRST* Robotics Competition (FRC) season, Mid-Atlantic Robotics (MAR) developed and deployed High Definition (HD) video production equipment to produce in venue video display and live webcasting of events over the internet. This system provides a standardized set up for all events requiring minimal volunteer training and easy setup. Minimizing cost was also a major factor in the design of the system to further reduce recurring event costs and limit capital expenses.

All questions, comments, and manufacturing inquiries should be sent to Kevin Dieterle at kdieterle@midatlanticrobotics.org. Usage of the information in this document is free and unrestricted for *FIRST* related activities, however we would love to hear if you use this exact system or a derivative for your events.

2 FEATURES

- Capable of in venue and live webcast of resolutions up to 1080p 60fps (scaled per venue bandwidth availability).
- 4 High Definition Camera Inputs:
    a. Fixed Full Field View
    b. Red Alliance Camera View
    c. Blue Alliance Camera View
    d. Optional Auxiliary/Roaming Camera View
- Flexibility to be used with multiple camera models using HDMI or HD-SDI inputs.
- Capable of long camera and projector cable runs up to 350ft.
- Supports FRC provided FMS Audience Screen overlay via chroma key functionality on all camera feeds.
- 2 computer inputs via built in Media Server computer for sponsor presentation, awards presentations, and recorded video playback.
- Minimum volunteer requirement of 1 operator. Supplemental volunteers are required if camera views are not static.
- Operator control software provided for standard video production and automated software for FRC specific video production such as opening ceremonies.
- Simple documented set up, operation, and tear down of all equipment.
    a. Only 9 input/output connections are required for a fully functioning system.
        i. 4 Camera Inputs
        ii. 1 Projector Output
        iii. FMS Audience Screen Input
        iv. Internet Connection
        v. Audio Output to DJ (for video playback)
        vi. Audio Input from DJ (Emcee, game announcer, and game sounds are isolated from in venue music at DJ Audio Mixer)
- Protective road cases for all equipment that is consistent with standard FRC road case sizes enabling easier transport.

3 SYSTEM OVERVIEW

3.1 SYSTEM ARCHITECTURE

The diagram below in Figure 1 provides a high level overview of the components of the video system and their interconnection. Further details of the components are provided in the following sections.

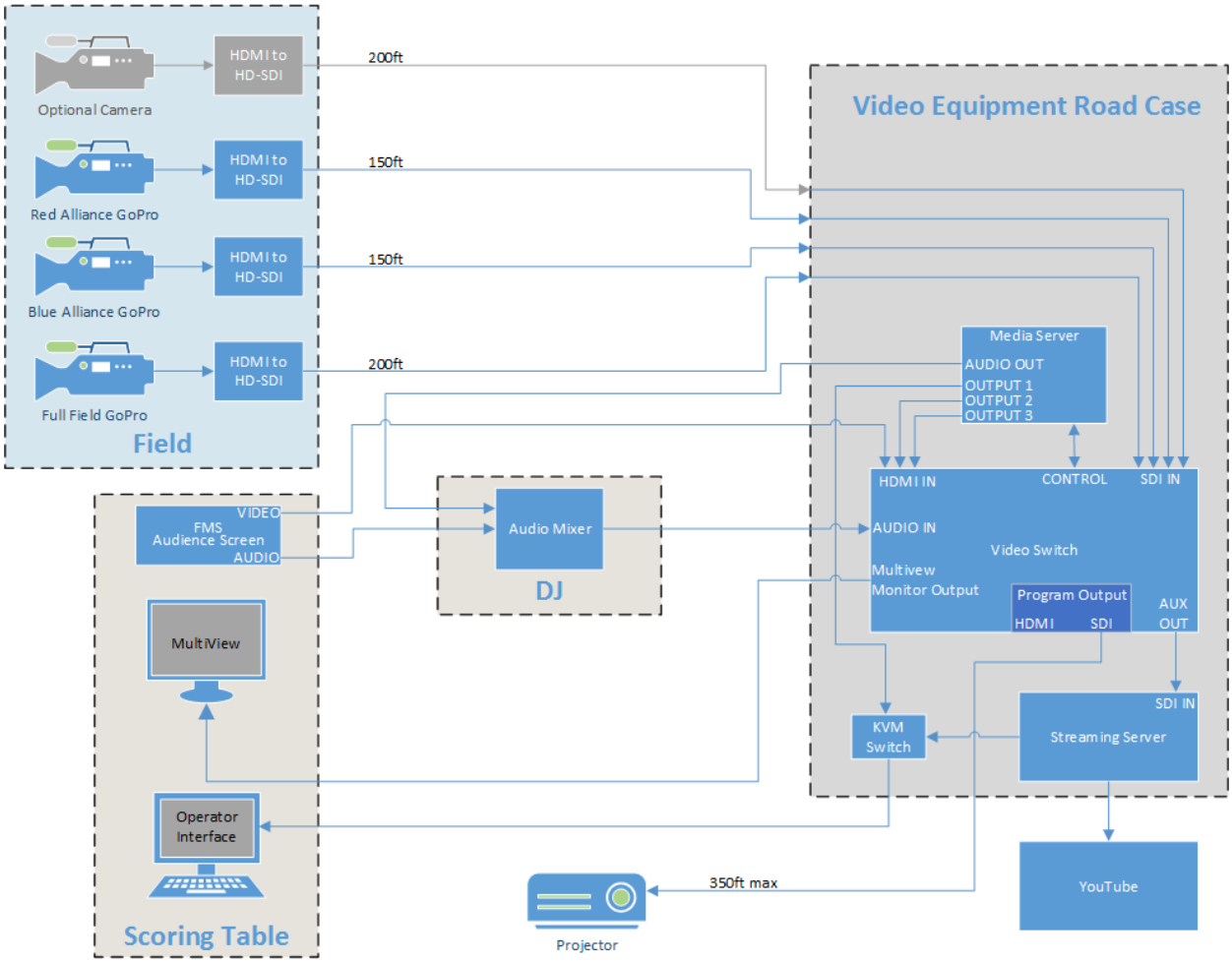

Figure 1 – System Diagram

3.2 EQUIPMENT ROAD CASE

The bulk of the equipment for the video production system is contained within a rack mount road case pictured below in Figure 2 and Figure 3. All external input and output connections are made via the connector feedthrough panel at the bottom front of the road case shown in Figure 4. Other equipment located in this road case is a power strip, cooling fans, the video switch, the media server and the streaming server.

Figure 2 – Video Equipment Road Case

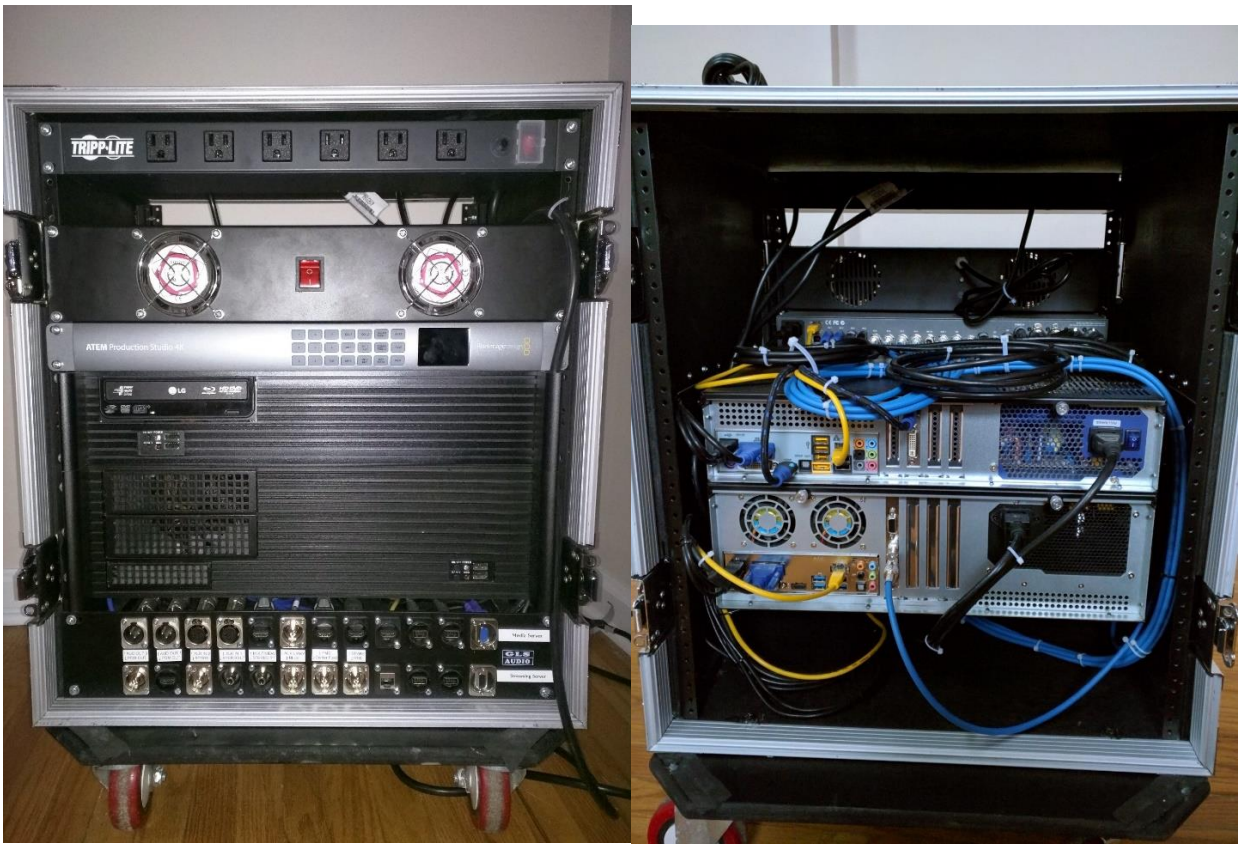

Figure 3 – Front and Rear of equipment road case (covers removed).

Figure 4 – Connector Feedthrough Panel

3.3 CAMERAS

For cameras MAR has opted to use 3 static GoPro cameras for the full field, red, and blue alliance camera angles. The red and blue alliance cameras are placed on tripods close to the field while the full field camera is placed on an approximately 8ft tall tripod around 12ft from the field perimeter. The static view of the cameras, while less interesting for close up shots, allows our limited volunteer resources to be used elsewhere. Additionally, GoPro cameras are the cheapest available high definition cameras offering an acceptable picture quality. There are trade-offs however as the GoPros only offer a wide-angle, fisheye camera view and are somewhat fragile in this usage environment. Despite this, the video production equipment is not limited to GoPro cameras and supports a wide range of high definition cameras if the organizer's budget and use case allows.

High quality coaxial HD-SDI cables provide the connection from the cameras to the video switch in the equipment road case as well as to the in-venue projector. These cables are not cheap and range from $150 to $300 for appropriate lengths to run to the cameras and projector. The theoretical limit in length for HD-SDI cable is approximately 350 feet. MAR used two 150 foot, one 200 foot, and one 350 foot cable for all of the events in the 2015 season. Longer connection lengths are possible through the use of other cable mediums but this requires additional equipment outside the scope of this document.

3.4 VIDEO PLAYBACK AND SPONSOR PRESENTATION

Throughout the course of an FRC event there are multiple times in which video playback is required as a part of the in-venue "show" such as opening ceremonies and the award ceremonies. Additionally, the rolling sponsor presentation needs to be displayed at various times throughout the event. In this video production system, this capability is provided by the Media Server computer located in the equipment road case. The use of the Media Server eliminates the need for extraneous laptops used as inputs to the video system for video and PowerPoint playback.

The Media Server has 3 video outputs: 1 for the computer monitor for the operator of the system and two video inputs to the video switch. The 2 video inputs allow seamless transitioning and playback of videos and PowerPoint presentations. For video playback, the Media Server uses the software program Media Player Classic Home Cinema (MPC-HC). MPC-HC supports playback of almost all common video file formats and had no issues with playback of any videos during the 2015 season whether they were provided by *FIRST* or teams for the Chairman's Award.

3.5 STREAMING/WEBCAST

The live webcast functionality of the video system is provided by the second computer in the equipment road case, the Streaming Server. The Streaming Server is a powerful computer dedicated solely to capturing, encoding, and sending data to the webcast provider over the internet. No other activities are performed on the Streaming Server to prevent any degradation of quality or interruptions to the live webcast.

Wirecast, Open Broadcaster Software (OBS), and Flash Media Live Encoder (FMLE) were used over the course of the 2015 FRC season as the video encoding software package to encode the video to send to the webcast provider. Through trial and error, MAR found that FMLE provided the best video quality, reliability, and ease of use.

Multiple webcast providers such as YouTube, Twitch.tv, UStream, and LiveStream are available, some free and some require a fee. MAR has elected to use YouTube as our webcast provider for a multitude of reasons.

- Free with no required advertisements.
- Live recording for up to 4 hours of the webcast which allows pausing and rewinding enabling the user to watch the webcast on their own terms.
- Easy multiplatform access. iPhones, iPads, Android Devices, and SmartTVs all either come with the YouTube app preinstalled or readily available in addition to standard access via a browser on a computer.
- Familiarity with YouTube. Parents and grandparents are largely already familiar with YouTube and how it works. Other providers such as Twitch.tv are not as well known to the broader general public and cater to a more niche audience.
- Automatic recording of the entire event. The entire event is archived and available uninterrupted for viewing within a couple of hours of the conclusion of the webcast.
- Automatic re-encoding of the webcast to lower resolutions for users with limited internet bandwidth availability.

The main downside to using YouTube is their ContentID system which automatically detects usage of copyright material during the webcast. There are varying consequences of the system including interruption of the webcast until the copyrighted material is no longer being used. MAR has mitigated this by isolating the emcees, game announcer, and game sounds from the music as detailed in the audio section below.

One of the difficulties in providing a live webcast of any event is the available internet bandwidth at the venue. At the maximum resolution of 1080p 60fps approximately 9Mbps (Megabits per second) of upload bandwidth is required. The recommended internet connection bandwidth for a 9Mbps webcast is approximately double that at 18Mbps upload. During the 2015 season all but 2 of the MAR venues (7 high schools and 1 college) had internet upload speeds greater than 100Mbps with the highest at approximately 700Mbps. The other venues had approximately 10Mbps upload and the webcast resolution and bitrate had to be lowered to prevent any issues with the webcast. In those cases, 720p resolution with a bitrate of 3.8-5Mbps worked well.

3.6 OPERATOR INTERFACE

Operation of the entire video system is controlled via one computer monitor, keyboard and mouse. These are connected to both the Media Server and the Streaming Server via a Keyboard Video Mouse (KVM) switch. As required, the operator can switch between controlling the Media Server and the Streaming server at the press of a button.

Controlling the video display output to the projector and the webcast is done via one of two software interfaces. The first is the software control panel provided with the video switch hardware shown in Figure 5. The second is via a custom piece of software created for usage at FRC events shown in Figure 6. This software provides a customized, simplified interface for controlling the video system as well as automated control of transitions and playback of standard videos used during the FRC event such as the opening ceremony.

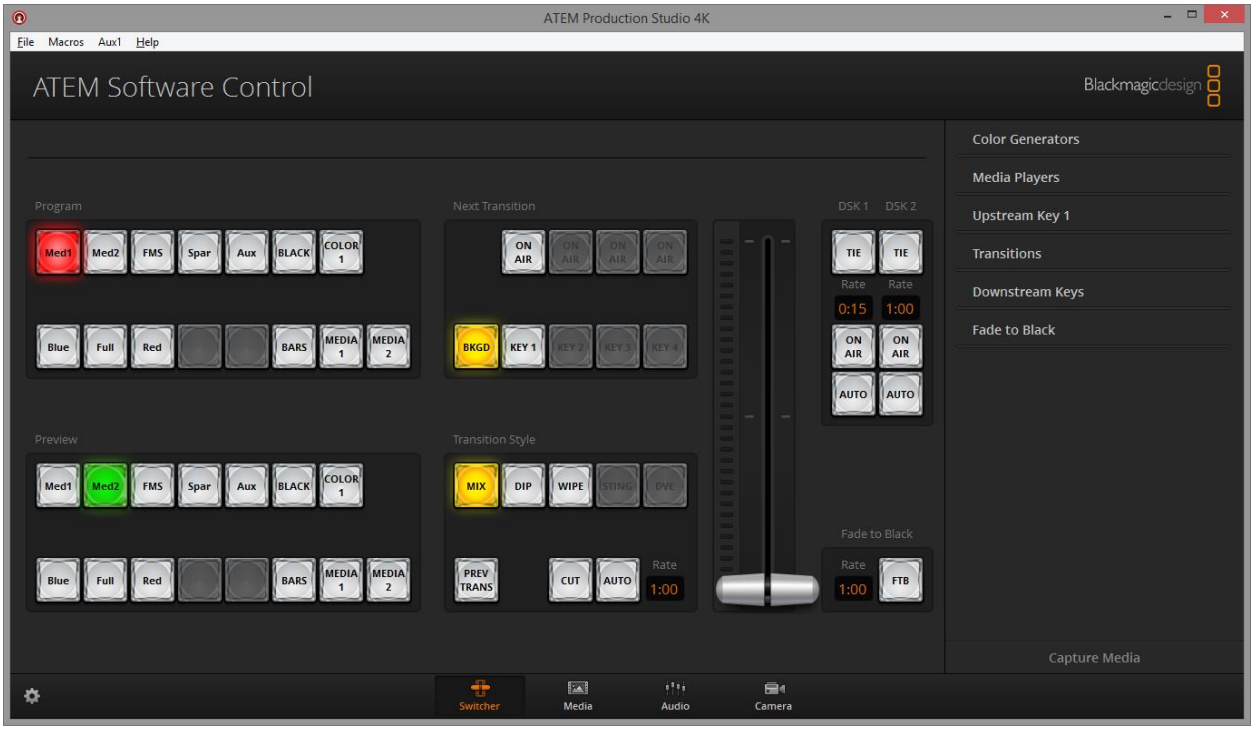

Figure 5 – Video Switch Software Control Panel

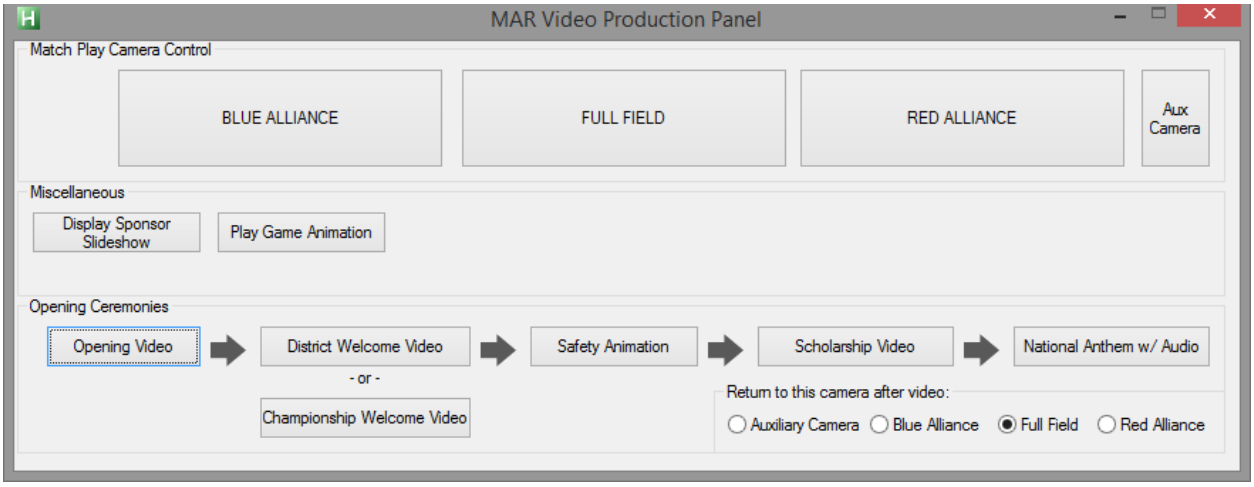

Figure 6 – MAR Video Production Panel

3.7 AUDIO INPUT/OUTPUT

MAR contracts a single DJ company for all of our events which standardizes the audio connections of the video production system and FMS Game sounds. The DJ provides an audio mixer which has inputs for all required microphones for the event and RCA inputs for audio from videos (such as Chairman's award videos) and the FMS game sounds. Through the mixer, the DJ outputs a clean audio feed over standard XLR audio connections to the video system without in-venue music for the video production system to broadcast over the internet. This avoids any copyright issues with copyrighted music playing on the event's live webcast. Unfortunately this creates "dead air" on the webcast when no one is speaking or there are no game sounds.

3.8 FMS AUDIENCE DISPLAY

For district events, the *FIRST* provided FMS does not include a scan converter for the audience screen output. Instead, a computer monitor output is provided via a DVI-I connection which can easily be converted to VGA, HDMI or left as DVI as required. A limitation of the 2015 and earlier versions of the FMS software is that the Audience Screen display is limited to a maximum resolution of 1280x720 (720p). As all camera and video inputs into the video switch hardware must be at the same resolution, the system either needs to run all camera inputs at 720p to match the audience screen resolution or an external scan converter may be used to scale the audience screen to the desired resolution such as 1080p. Both use cases work well and provide an excellent quality display of the audience screen in-venue and over the internet via the webcast.

3.9 LOOSE COMPONENT TRANSPORTATION

For the 2015 FRC season, loose components such as wires, computer monitors, and various converters were transported in two Pelican cases shown below in Figure 7 and Figure 8. This worked well as the whole system was transported individually in a personal vehicle from event to event. For the 2016 season and on, MAR is constructing a road case to store these components within standard road case dimension for transportation in the PODS used for transporting the field and all event equipment. This road case has not been designed at the time of publication of this document.

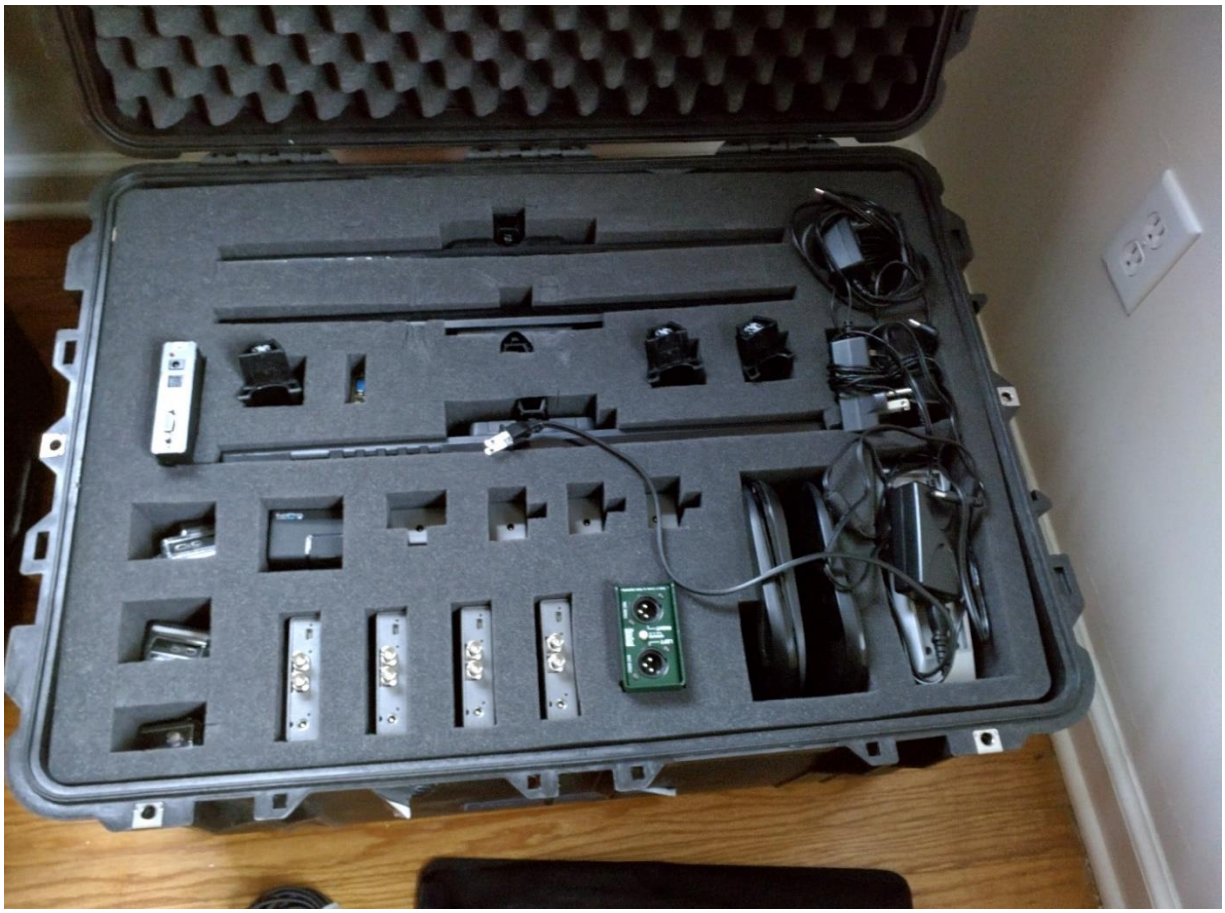

Figure 7 - Pelican 1660 Case used for monitors, converters, GoPros and miscellaneous electronics.

Figure 8 - Pelican 1610 case used for HD-SDI cables and miscellaneous other cables.

4 BILL OF MATERIALS

4.1 OVERALL

Item	Description	Part Number	Price ea	Qty	Total Cost
1	Gator Cases 12U 24" Rackmount Road Case	G-TOUR12UCA-24D	$549.99	1	$549.99
2	Blackmagic Design ATEM Production Studio 4K Live Video Switcher	SWATEMPSW04K	$1,610.25	1	$1,610.25
3	Streaming Server (Computer)	See table below	$1,230.81	1	$1,230.81
4	Media Server (Computer)	See table below	$701.39	1	$701.39
5	GoPro Hero4 Silver Music	CHDBY-401	$399.99	3	$1,199.97
6	90 Degree Micro HDMI to HDMI Female (17cm)	MicroHDMI1	$6.90	3	$20.70
7	Switronix Battery Eliminator USB for GoPro Hero4 (10ft)	DV-GP4-USB	$30.00	3	$90.00
8	9.8 Feet HDMI Cable	ZYYM	$6.49	3	$19.47
9	Blackmagic Design Mini Converter HDMI to SDI 4K	CONVMBHS24K	$280.25	3	$840.75
10	Gefen HDMI EDID Detective Plus	EXT-HS-EDIDPN	$120.49	3	$361.47
11	Atlona PC/Laptop to HDMI Converter	AT-HD500	$279.05	1	$279.05
12	LG Widescreen LED Backlit LCD Monitor	22MP57HQ-P	$129.00	1	$129.00
13	Connector Feedthrough Panel	See table below	$301.42	1	$301.42
14	4 Port USB/VGA KVM Switch	GCS24U	$34.99	1	$34.99
15	1U 12 Outlet Rack Mount Power Strip	RS1215-RA	$46.99	1	$46.99
16	2U Rack Cooling Fans	SARF1	$50.18	1	$50.18
17	DVI-I to HDMI, 15ft (FMS Audience Screen Input)	HDMI-DVI-15FT	$8.49	1	$8.49
18	5 pack, 3ft HDMI Cables	B00ELJM5I	$14.99	1	$14.99
19	6 pack, 3ft XLR Patch Cables	37-288	$33.99	1	$33.99
20	USB B to USB A 3ft cables	105437	$5.25	4	$21.00
21	3ft HD-SDI Coaxial Cable	L4SDI3	$17.00	6	$102.00
22	3ft 3.5mm to RCA Audio Cable (Media Server Audio Output)	109767	$6.43	1	$6.43
23	25ft 3.5mm to RCA Audio Cable (FMS Audio Output)	500002-BLACK-25	$11.99	1	$11.99
24	6in. XLR Female to Dual XLR Male Splitter	37-379	$9.99	1	$9.99
25	25ft XLR Patch Cable	MC25	$14.99	1	$14.99
26	60-Inch Tripod with Bag	WT3540	$23.49	2	$46.98
27	Manfrotto 13ft Tripod Stand	1004BAC	$114.99	1	$114.99
28	350ft HD-SDI Cable, BNC to BNC (Projector Connection)	Blue Jeans Cable	$260.75	1	$260.75
29	150ft HD-SDI Cable, BNC to BNC (Red/Blue Alliance Cameras)	Blue Jeans Cable	$119.75	2	$239.50

Item	Description	Part Number	Price ea	Qty	Total Cost
30	200ft HD-SDI Cable, BNC to BNC (Full Field Camera)	Blue Jeans Cable	$155.00	1	$155.00
31	3ft CAT6 Ethernet Cable	109797	$8.68	4	$34.72
32	50ft CAT6 Ethernet Cable (Connection to venue internet)	105905	$22.99	1	$22.99
33	8-Port Gigabit Ethernet Switch	SE2800	$41.87	1	$41.87
34	Low Profile VGA Cable	P502-003-SM	$6.21	2	$12.42
35	Microsoft Wired Keyboard 200	JWD-00046	$9.95	1	$9.95
36	Microsoft Optical Mouse 200	35H-00006	$7.95	1	$7.95
			Total Cost:		$8,637.42

4.2 STREAMING SERVER

Item	Description	Part Number	Price ea	Qty	Total Cost
1	Intel Core i7-4790K 4.0GHz LGA 1150 Boxed Processor	301275	$279.99	1	$279.99
2	ASRock H97M Pro LGA1150 mATX Intel Motherboard	H97M Pro	$47.99	1	$47.99
3	Crucial Ballistix Sport 16GB DDR3-1600 (PC3-12800) CL9 Dual Channel Desktop Memory Kit	649528757913	$109.99	1	$109.99
4	Corsair Builder Series CX 430W ATX/EPS Power Supply		$59.99	1	$59.99
5	iStarUSA D Value D-313SE-MATX 3U Compact Rackmount Server Chassis	D-313SE-MATX	$87.99	1	$87.99
6	KINGWIN 120X25MM BB CASE FAN BLK	531822	$3.99	1	$3.99
7	KINGWIN 80MM ADV-SRS CASE FAN BLK	531814	$2.99	1	$2.99
8	FANNER 60MM SLEEVE BEARING FAN	607507	$2.99	2	$5.98
9	Samsung 850 EVO 500GB 2.5in SATA 3 Internal SSD	MZ-75E500B/AM	$161.99	1	$161.99
10	Microsoft Windows 8.1		$119.99	1	$119.99
11	Blackmagic Design Decklink SDI 4K Capture & Playback Card	BDLKSDI4K	$280.25	1	$280.25
				Sub-Total:	$1,161.14
				Tax:	$69.67
				Total:	$1,230.81

4.3 MEDIA SERVER

Item	Description	Part Number	Price ea	Qty	Total Cost
1	Intel Core i3-4370 3.8GHz LGA 1150 Boxed Processor	381970	$139.99	1	$139.99
2	ASRock H97M Pro LGA1150 mATX Intel Motherboard	H97M Pro	$39.99	1	$39.99
3	Crucial Ballistix Sport 8GB DDR3-1600 (PC3-12800) CL9 Dual Channel Desktop Memory Kit	649528755988	$54.99	1	$54.99
4	Corsair Builder Series CX 430W ATX/EPS Power Supply		$59.99	1	$59.99
5	iStarUSA D Value D-213-MATX 2U Compact Rackmount Server Chassis	D-213-MATX	$80.38	1	$80.38
6	KINGWIN 80MM ADV-SRS CASE FAN BLK	531814	$2.99	2	$5.98
7	Samsung 850 EVO 250GB 2.5in SATA 3 Internal SSD	MZ-75E250B/AM	$97.99	1	$97.99
8	Microsoft Windows 8.1		$119.99	1	$119.99
9	Sapphire Radeon R7 240 2GB Dual HDMI Low Profile Graphics Card	11216-07-20G	$74.73	1	$74.73
10	TP-LINK 10/100/1000Mbps Low Profile Network Adapter	TG-3468	$12.90	1	$12.90
				Sub-Total:	$686.93
				Tax:	$14.46
				Total:	$701.39

4.4 CONNECTOR FEEDTHROUGH PANEL

Item	Description	Part Number	Price ea	Qty	Total Cost
1	24 Hole Rack Patch Panel	32-131	$25.99	1	$25.99
2	XLR Female to Male Feedthrough (XLR Audio IN)	NA3FDM	$7.67	2	$15.34
3	XLR Male to Female Feedthrough (XLR Audio OUT)	NA3MDF	$7.29	2	$14.58
4	HDMI Feedthrough Connector	EHHDM12	$16.85	4	$67.40
5	75ohm BNC Female to Female Feedthrough (HD-SDI)	EHBNC2	$10.25	6	$61.50
6	HD15 Female to Female Feedthrough (VGA, PC monitor)	EHHD15FF	$15.26	2	$30.52
7	CAT6 Ethernet feedthrough (Internet)	EHRJ45P6S	$15.22	1	$15.22
8	USB A to USB B Feedthrough	NAUSB-W-B	$11.50	4	$46.00
9	RCA Female to Female Feedthrough (RCA Audio)	EHRCA2BX	$11.96	2	$23.92
10	Blank Hole Cover	DBA-BL	$0.95	1	$0.95
				Total:	$301.42