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Visualizing High Definition Full Motion Video for Unmanned Vehicle Systems

Content

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ABSTRACT

This paper presents available solutions for real-time, interactive, and collaborative viewing of multiple high definition (HD) sensor feeds for networked visualization systems. In support of the unmanned vehicle industry transition to HD sensors, technologies from commercial arenas can be packaged for rugged environments and deployed today to enhance mission effectiveness. The information discussed can be used by system designers to help evaluate appropriate types of equipment for different user environments and applications. User benefits of high definition video for increased image understanding are summarized. Challenges for handling the increased load on networks, servers, workstations, and displays are characterized in terms of new demands for bandwidth, processing power, and screen resolution. Enabling technologies for ground system visualization positions including ground control stations, analyst workstations, and collaborative command centers are discussed. Networked visualization client capabilities for decoding, processing, and displaying multiple HD channels are presented.

INTRODUCTION

Motion imagery represents a core capability for Unmanned Vehicle Systems (UVS). During critical surveillance and situation awareness operations, the capture of high quality motion imagery maximizes the benefits of deployed mission resources and enables advanced downstream processing, exploitation, and dissemination (PED). Observing moving objects using clear and detailed image sequences improves perception of the operational environment. This enables increased understanding of past and current activities as well as improved projection of behavior in the near future. Accurate real-time interpretation of sensor imagery can be a critical factor in distinguishing training camps from wedding parties, hostages from pirates, or approaching friends from foes.

Full Motion Video (FMV) is a common form of motion imagery that leverages rapidly advancing commercial technologies. Driven by broadcast and streaming video applications, these technologies provide several options for implementing high quality distributed video capabilities for UVS. Built upon decades of experience with analog standard definition (SD) systems, high definition (HD) capabilities are now commonplace for several commercial industries. Mature standards, components, and products are in use today, delivering HD video content via widely distributed systems. However, the transition to HD for UVS lags far behind the commercial applications.

Driving the HD Transition

To address this issue, the Motion Imagery Standards Board (MISB - US DoD) and NATO Standardization Agency (STANAG - NATO) standards bodies have defined end-state objectives for migration from legacy analog motion imagery systems to higher resolution digital systems “as technology enables”. These standards and related recommended practices (RP), engineering guidelines (EG), and implementation conventions (IC) provide the roadmap for deploying higher performance interoperable FMV systems.

In this arena, these agencies do not necessarily define new standards, but specify profiles of common standards to promote interoperability across multiple components and systems. Common requirements for motion imagery, metadata, transport/file formats, and timing references are addressed. Motion Imagery Standard Profiles (MISP) define sets of requirements for various capability levels ranging from minimal imagery intended for wireless handheld devices up to and beyond today’s commercial high-end HD video. The general requirements of these profiles are summarized in a Motion Imagery Standard Matrix (MISM) for each level.

One primary focus of these standardization efforts is to drive the transition from MISM Level 3 (Standard Definition) to MISM Level 9 (High Definition) – see Figure 1. In general, this migration is calling for all new systems and system upgrades to evolve from legacy analog and SD streaming video to 720p/60 and 1080p/30 HD video formats and beyond.

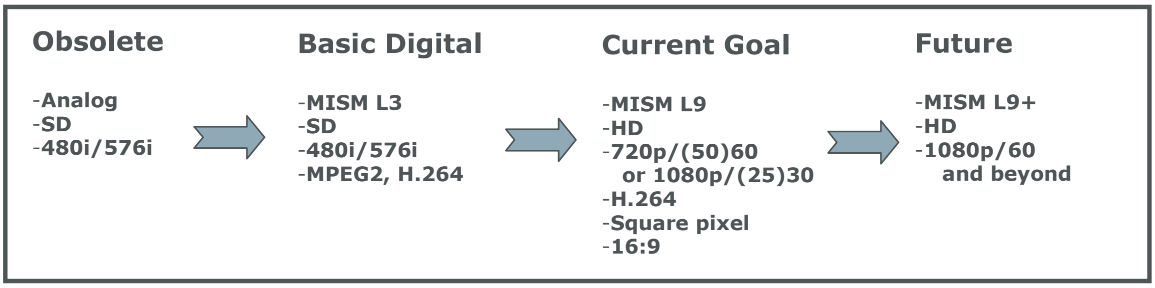


Figure 1 – Full Motion Video Migration Objectives

<u>Impact on PED Systems</u>
While this evolution is largely paced by rugged sensor and secure communications technologies, deploying high quality HD video also places new demands on ground system equipment. Increased capabilities for network bandwidth, processing power, storage space, and display surfaces are needed to make effective use of the increased information available.

The evolution to HD impacts all manned positions that need access to motion imagery content. These include ground control stations, dismounted remote terminals, tactical operation and other command centers, as well as analyst positions. The following paragraphs discuss benefits, challenges, and enabling technologies for deploying networked visualization client equipment at these manned positions. Solutions are available today to support the HD objectives defined by current MISB and STANAG efforts.

TRANSITION TO HIGH DEFINITION

Benefits

The visual benefits of HD versus SD include increased resolution, clarity, and information density. Higher resolution provides a greater number of pixels representing the same field of view. Having more pixels to represent a given scene provides the following benefits:

- Increased clarity of small objects and details resulting in improved perception for identification and tracking
- Increased ability to resolve the position of small objects resulting in improved accuracy for geo-location and targeting
- Increased density of information supporting zooming in on regions of interest without sacrificing image quality
- Increased density of information supporting larger display sizes for multiple viewer collaboration without sacrificing image quality

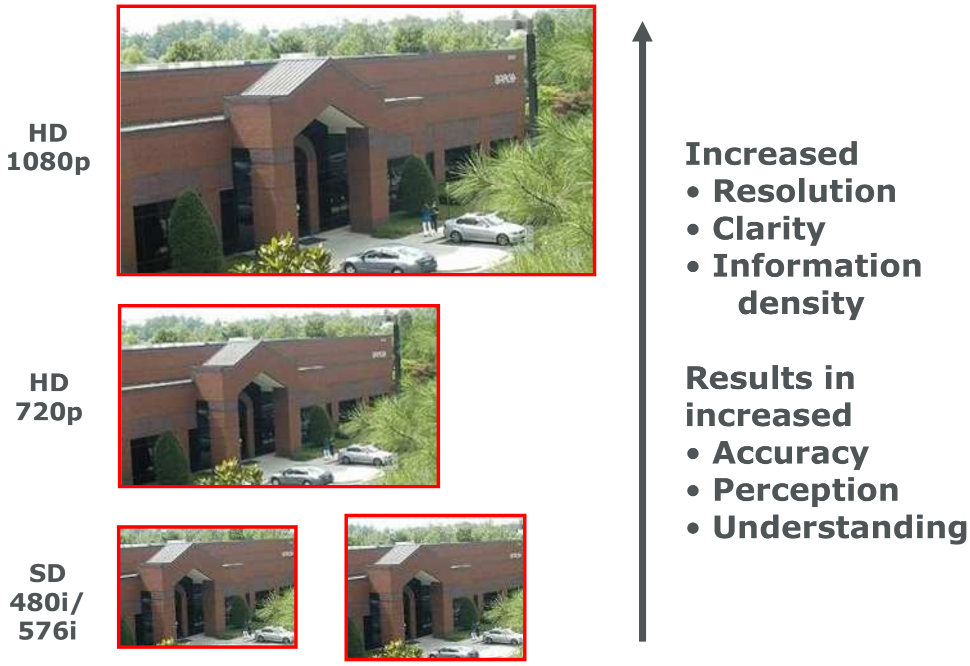


Figure 2 – Relative image sizes with constant pixel size

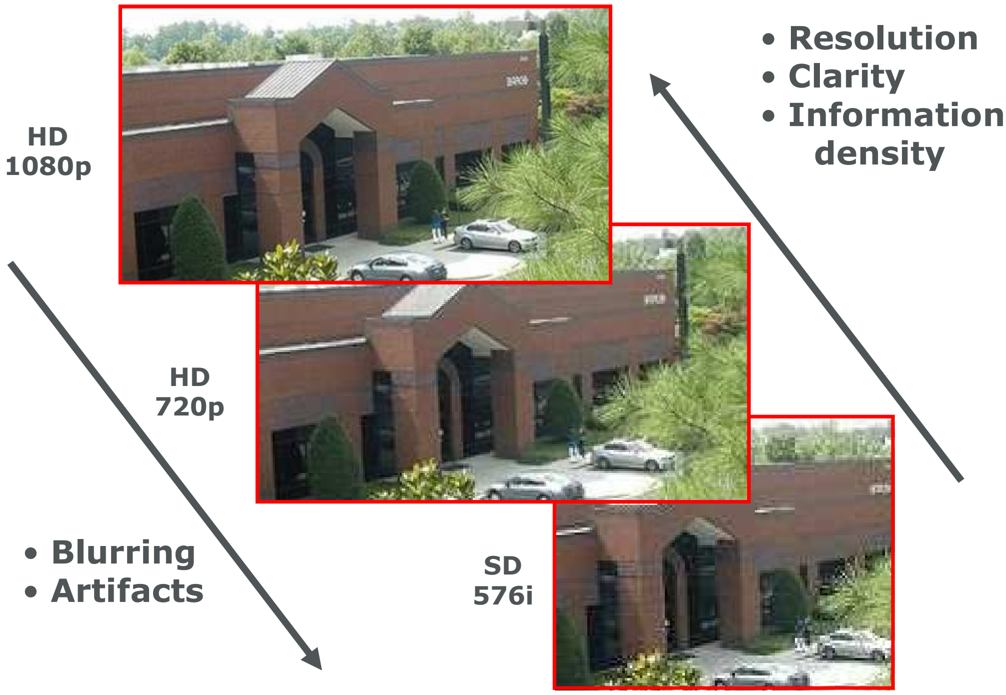


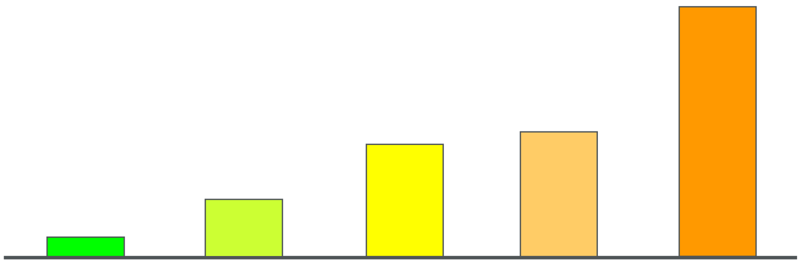
Figure 3 – Relative image quality with constant image size

While the subjective benefit of higher definition is obvious to most, the benefits for specific use-cases can also be quantified. For example, higher resolution provides more "pixels-on-target" for a given object at a given distance. More pixels-on-target means recognition of objects at a farther distance from the sensor. This can be critical when trying to identify small, rapidly approaching objects. For such a case, the range at which a defined target can be identified can be measured and the benefits of increased resolution can be stated in terms of the useful range of the sensor and visualization chain.

<u>Challenges</u>
Of course, using more pixels comes at a cost. PED systems involving multiple channels of HD video require:

- Increased network bandwidth
- Increased processing power
- Increased storage space
- Higher resolution and/or larger display surfaces for full resolution viewing

For each channel, common HD formats represent more than a 6:1 increase in the volume of data over SD. For systems that are already stressed by an overwhelming amount of visual information, this increased volume of data places new demands on communications, processing, and visualization subsystems. The role of compression systems becomes increasingly important in order to push megabits per second per channel in near real-time to where it can be used effectively. Computational demands for video analysis grow with the increased number of pixels to process. Archive sizes and retrieval times for recorded imagery also increase proportionally. At the user endpoints, larger and smarter higher resolution displays are needed to visualize multiple channels at full resolution.



	SD 480i/30 and 576i/30	HD 720p/30 HD 720i/60	HD 720p/60	HD 1080p/30 HD 1080i/60	HD 1080p/60
Pixels/Frame	.307M .415M	.922M	.922M	2.07M	2.07M
Raw Bits/Second (16-bits/pixel)	147M 199M	442M	884M	994M	1987M
Compressed Bits/Second (50:1)	3M 4M	9M	18M	20M	40M

Figure 4 – HD impact on computing and visualization system loading

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NETWORKED VISUALIZATION CLIENTS FOR UVS

The primary function for a distributed video system is to deliver important motion imagery information to people. Therefore, effective presentation capabilities at all manned positions play a critical role in mission success. Visualization clients implement the functions necessary for requesting, receiving, formatting, viewing, and analyzing video sources. These sources may include live, recent, and/or historical video content.

Typical environments that utilize visualization clients for Unmanned Vehicle Systems include:

- *Mobile Shelters* – vehicle mounted Ground Control Stations involving multiple manned working positions for flight and payload control with full system-level communication. For visualization, relatively powerful semi-rugged servers, workstations, and thin-clients are used, often with multiple large high-resolution displays (e.g. 30” with 2560x1600 pixels).
- *Dismounted Terminals* – portable Ground Control Stations with flight and payload control, but with limited communications capability. Processing and display equipment must provide useful visualization capabilities within size, weight, and power (SWaP) constraints. Fully rugged equipment is required to withstand exposure to the elements and rough handling.
- *Transportable Operations Centers* – truck and tent-based command posts used to guide tactical operations during a mission. Semi-rugged transportable computers and displays are used, often in conjunction with larger screen collaborative viewing sub-systems.
- *Command Centers* – permanent facilities providing centralized decision making. Commercial compute servers, workstations, and displays are used with significant communications connectivity. Large screen displays and walls are used for center-wide collaborative viewing.
- *Analyst Workstations* – office environment working positions for detailed exploitation analysis of near-real-time or recorded video. Professional-grade computing and display systems are deployed with ultra-high resolution capability for maximum viewing fidelity.

Each environment and use-case involves varying needs for visualization processing and display. However, compatible video feeds and recordings may need to be viewed and shared between any of these client positions. In addition to viewing raw or processed video sources, each position can add tags or other annotation information that is communicated along with the video via metadata. This is an important capability for communicating critical information in near-real-time or enabling later searching for recorded segments of interest.

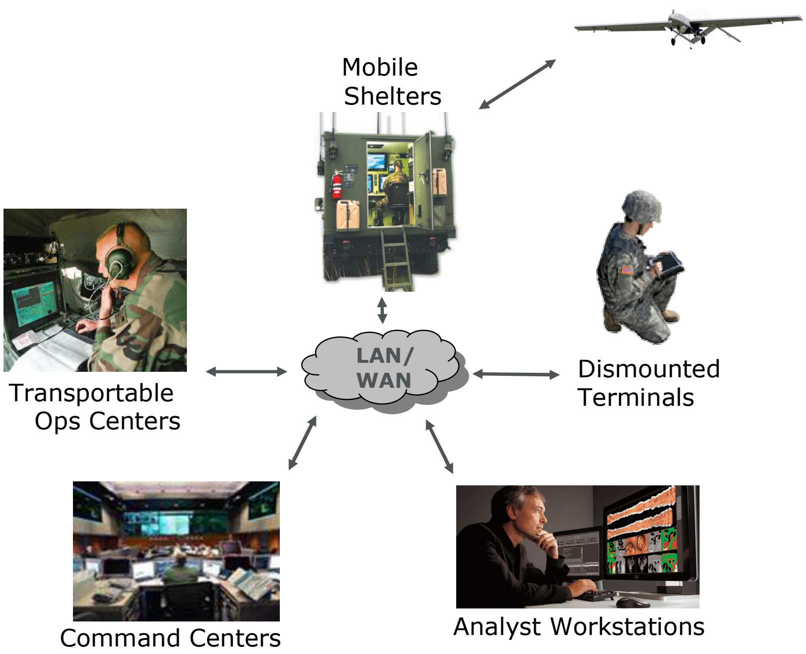

Figure 5 – Networked Visualization Positions in a Generalized UVS Environment

ENABLING TECHNOLOGIES

Several enabling technologies exist today that can be used to support high performance visualization capabilities for HD video feeds.

Displays

High Resolution

High-resolution displays are needed to view HD video streams at full resolution. For example, displaying a single 1080p HD channel at full resolution requires a screen size of at least 1920x1080. With some exceptions, higher resolution displays are normally implemented with larger screen sizes. The number of FMV channels that can be displayed at (or near) full resolution on common screen resolutions is summarized in the following table. Optimum combinations making the most use of screen space are highlighted.

Table 1 – Maximum number of HD channels mapped onto common screen sizes at full resolution

Common Screen Resolutions	Typical Screen Size	# of 480/576-line SD channels (720x480/576)	# of 720-line HD channels (1280x720)	# of 1080-line HD channels (1920x1080)
1024x768 (XGA)	10"/15"	1	~1	<1
1280x768 (WXGA)	15"	1	1	<1
1280x1024 (SXGA)	17"	~4	1	<1
1600x1200 (UXGA)	20"	4	1	~1
1920x1080 (FHD)	23"	~6	~2	1
1920x1200 (WUXGA)	15"/24"	~6	~2	1
2560x1440 (QHD)	27"	~9	4	1
2560x1600 (4MP)	30"	~9	4	1
3280x2048 (6MP)	30"	~16	~6	~2 landscape 3 portrait

The benefit of higher resolution is also influenced by viewing distance. This is because more, smaller pixels can be perceived when viewing closer to the screen. Therefore, small high-resolution screens may be valuable for applications with short viewing distances such as ground vehicles with limited space. Larger, but lower resolution screens may be adequate for applications with larger viewing distances such as Command Centers.

4 x 720p at native resolution
4MP resolution – 2560x1600

3 x 1080p at native resolution
6MP resolution – 3280x2048

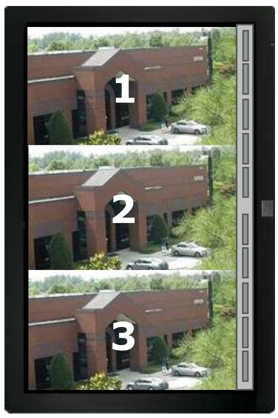

Figure 6 – Mapping multiple HD video channels to high-resolution display surfaces at full resolution

Networked and Smart Displays
Networked displays support the presentation of streaming video and remote desktop sources over a network connection, commonly using 1Gbit ethernet. Adding this capability into the display removes the need for additional equipment to receive and display video and graphics. These types of displays provide remote access to centralized servers where application output is rendered and transmitted. Any media source on the network can be received and mixed with remote graphics content.

Additionally, computing capabilities can be integrated in or near the display to create a smart display terminal. Rugged display processing modules are available that provide powerful computing elements such as Intel processors and Nvidia graphics modules. This client configuration localizes visual computing and presentation operations at the display where the output is used. For many system configurations, this architecture provides the highest visualization performance, ensuring that critical real-time performance and interactivity are maintained. Smart clients can also offload other computing and network resources for local visual computing operations.

Figure 7 – Networked and smart display equipment

<u>Video Streaming</u>
A variety of compression standards are available for distributing video and each technique has its purpose and benefits. A few common standards are summarized in the following figure. In general, there is a tradeoff between image quality and required transmission bandwidth. MISB and STANAG profiles for HD video focus primarily on H.264 to optimize the use of communication link bandwidth and provide good video quality. For ultra-high-resolution imaging systems where image quality is paramount, JPEG2000 offers some advantages.

Best use of wireless link bandwidth

Optimized for motion video

Optimized for ultra-high res

	Image Quality	Network Bandwidth /File Size	Use Case
MPEG2	Improving Quality (↓)	Lower Utilization (↑)	Wide distribution Software decode
H.264			Wide distribution Long term recording
MotionJPEG			Software encode/decode
JPEG2000			High fidelity imaging Low latency
Uncompressed Networked (ex. GigEVision)			High fidelity imaging Low latency
Uncompressed Direct (ex. HD-SDI, DVI)			Very low latency

Figure 8 – Generalized compression comparison

For networked visualization clients, there are several implementation options to decode these standard streams. Highly tuned software solutions can provide full frame rate performance at the expense of consuming a portion of the client's computing resources. Today's CPUs and GPUs include integrated hardware for decoding a limited number of channels with little or no CPU/GPU usage. For applications requiring large numbers of channels, low latency, or hard real-time performance, dedicated hardware accelerators can be installed in the client.

High performance H.264 decoding is supported by standard graphics boards

		H.264	JPEG2000
Software (2.5GHz Core2Duo)		1080p at 30fps (full CPU utilization)	480i at 30fps 1080p at 10fps (full CPU utilization)
Integrated Hardware	**CPU**	Ex. Intel ClearVideoHD 1080p at 24fps (little CPU utilization)	NA
	GPU	Ex. NVIDIA PureVideo Four 720p at 30fps Two 1080p at 30fps (little CPU utilization)	GPGPU 480i at 30fps 1080p at 10fps (some CPU utilization)
Dedicated Hardware (DSP, FPGA, ASIC)		Multi-channel 1080p (little/no CPU util)	Multi-channel 1080p (little/no CPU util)

More dedicated Hardware:

- Less use of computing resources
- Improved hard real-time behavior

High performance JPEG2000 requires hardware acceleration

Figure 9 – Options for implementing video client decoding

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Video Processing and Visualization

Today's smart display processors are capable of providing advanced video processing capabilities at the display. Dedicated hardware accelerators and/or GPU-accelerated software can process multiple video streams received from the network in real-time. Advanced mixing and formatting operations executed locally on a visualization client can serve to present the complex visual information from the system in the most useful way to the operator. These types of processing operations include:

- *Image enhancement* – Imaging operations such as noise reduction, contrast enhancement, and stabilization can be applied to improve video quality or highlight aspects of interest.
- *Integration of multiple sensors* – Different types of sensors observing the same view can be overlaid and fused to combine the content into one image. Also, streams from multiple similar sensors observing adjacent views can be stitched together to form more natural panoramic presentations.
- *Automated analytics* – Real-time video analysis capabilities can also be embedded in the display to provide intelligent motion detection, target tracking, and target identification.
- *Integration with metadata* – Associated metadata can be rendered and overlaid or blended with video content.
- *Integration with 3D graphics* – Video streams can be mapped onto 3D terrain or integrated with synthetic vision to increase understanding of the spatial orientation of the sensor's field-of-regard.
- *Dynamic screen sharing* – Screen content from any position on the network can be captured and transmitted for collaboration at other positions. When combined with graphics overlay capabilities, interactive annotation can be supported for highlighting aspects of interest between shared positions.
- *Screen recording and playback* – Screen content from any or all positions can be captured and transmitted to networked storage devices for mission recording.

EVALUATION CRITERIA

When evaluating visualization client equipment or software, several characteristics should be considered including the following:

- *Functionality* – General equipment capabilities need to match the system configuration requirements and operating goals. These include hardware and software footprint, system impact, operating system support, operating modes, information assurance and security, ruggedization level, and ease-of-use.
- *Performance* – Performance capabilities need to match the system operating goals in terms of supported resolutions, real-time behavior, latency, jitter, and computing resource utilization. Tools are available, including standardized test sequences, for analyzing and quantifying streaming video performance.
- *Image Quality* – Both subjective and objective evaluation methods are used for quantifying overall picture quality as well as artifacts created by compression. Standardized approaches are defined for subjective scrutiny of images to characterize how good an image looks to a human. Automated test equipment tries to mimic this human analysis by applying various computational techniques.
- *Interoperability* – Adherence to common standards and profiles is a critical factor for using equipment in a real system involving multiple elements from multiple vendors. However, standards compliance does not guarantee plug-and-play integration and interoperability. Compatibility validation is normally required early in the system integration process and formal certification via agencies such as JITC (Joint Interoperability Test Command) may be required.

CONCLUSION

The Unmanned Vehicle Systems industry transition from standard definition to high definition full motion video has been directed by guiding defense standards agencies. A variety of enabling technologies and components are available today that provide the core capabilities needed to implement this visualization chain from sensor to display. The benefits of bringing this technology to secure rugged environments for mission critical applications like UVS significantly outweigh the challenges.

Today's high-resolution displays with embedded intelligent computing and high performance video, graphics, and imaging enable the integration of advanced HD capabilities. For ground systems, these visualization clients form an end-point for ground control stations, dismounted remote terminals, collaborative command centers, and analyst positions. Advanced Full Motion Video capabilities are a common and critical requirement for all of these manned positions to reap the benefits of the transition to HD.

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ABOUT THE AUTHOR

As Technical Director, Jeff Malacarne focuses on defining the strategic roadmap for visualization system products for the Barco Defense organization. Jeff also directs the engineering team in Duluth, Georgia for the execution of visualization system projects supporting US programs. Since joining Barco in 1992, Jeff has led the development of graphics and video processing products for air traffic control, naval, airborne, and ground vehicle systems. Prior to joining Barco, he worked at Hughes Aircraft Co. developing computer graphics technology for mission critical systems and holds 8 related patents. Jeff received a BSEE from SUNY at Buffalo and an MS in Computer Engineering from the University of Southern California.

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