



Boundless Security Systems, Inc.

digital video security systems to deter, intervene and investigate

Boundless Security System™ Satisfies Stringent Reliability and Imaging Needs of Transportation Security



Video security systems that protect large-scale air, land and sea transportation systems must be extremely reliable and meet a wide range of image quality, storage, communications and display requirements. Unfortunately, not only do these imaging requirements compete with one another, but current systems have been designed as components, not as an integrated part of a network, and have not been architected to meet stringent reliability requirements. There is, however, a new solution to all these needs, but first we'll look at the problem in detail.

The problem in detail

Common to all of these requirements is the need for the utmost in system reliability since many lives are at risk. One would never fly in an airplane without redundant controls, or drive a car without an emergency brake. Video security systems must be every bit as reliable. They must be designed assuming things will go wrong and at the worst possible time. Video security systems must be able to instantly and automatically detect and compensate for transient and permanent faults not only in themselves, but also in the network and mass-storage infrastructure on which they rely. Today's systems do not.

Vast storage capacity is required. Large-scale video security systems must be able to digitize, record, manage, search, display, and provide local and remote access to a vast amount of video.

We have developed a simple tool, the "**Rule of Ones™: 1 x 1 x 1 = 1,**" to estimate storage. When **one** video camera is recorded continuously at **one** million bits per second (1 Mbps, only 1/6th the data rate of a motion picture DVD), for **one**-quarter of a year, nearly **one** terabyte of storage is required. Continuously recording 1,000 cameras under these conditions requires a staggering one petabyte (1,000 terabytes or 1 million gigabytes) of disk space for every three months' recording. A system recording 32 cameras continuously at 6 Mbps/camera would fill 1 TB in less than ½ day. Not only is economical, dense, reliable storage with low power dissipation required, but one must be able to instantly access any point in the recorded data and quickly search for suspects who may be planning a future attack or participating in a current one.

The quality of recorded images must be very high so that people, objects and vehicles can be identified. Highest quality is required especially when the subject occupies only a small fraction of the camera field of view because the image must be enlarged to see the subject. Images require not only high numbers of pixels, i.e., the full native resolution of high quality, CCTV cameras, but also high clarity with few compression artifacts. Data rates of several million bits per second (Mbps) are needed for high motion video unless the frame rate is extremely low.

Wide dynamic range is required to capture indoor and outdoor scenes in the same frame, and to see inside vehicles that have tinted glass. The wide exposure latitude of 35 mm film with its several thousand shades of gray, rather than the more common, 256 shades of gray of common video cameras, is desired to clearly capture details in the extremes of light and dark that can occur within a single frame. Yet standard video compression, display and printing technology,

which support only 256 shades of gray, must be used for economy and widespread availability.

Improved capture of the images of moving objects is needed since transportation platforms or subjects, or both, are often moving. Video cameras should have progressive scan, rather than the common interlaced scan of broadcast TV. The problem is that cameras with interlaced scan require two interdigitated snapshots for each full-frame image, one for the even scan lines and one for the odd scan lines. Subjects often move during the time that elapses from the first half of the snapshot to the next, blurring the combined image. The use of progressive scan rather than interlaced scan often gives the increased sharpness equivalent to an exposure period that is reduced by ten-fold for a subject that occupies a fraction of the height of the image.

Unusually capable motion detection is required. The video security system for transportation systems should be able to do a first level of screening in real time of the video captured to reduce the amount of labor required to identify potential threats. The motion detection algorithms used in stationary systems, where the camera is affixed to the wall of a building, are not adequate because the only motion is motion of potential subjects, not motion of the platform, i.e., motion of a train or ship, and thus movement of the camera.

Rapid archival searches are required. The video security system for transportation systems should be able to rapidly search vast amounts of recorded information to locate persons and vehicles that were used in an attack, or that may have been used in planning an attack.

High communication data rates required to view video are a problem. It must be possible to communicate live images in real time from both mobile and fixed platforms to security personnel who are stationed on both mobile and fixed platforms. Requiring the use of only powerful desktop and notebook computers with a high-speed local area network is too restrictive a requirement for viewing live and recorded images from multiple cameras simultaneously.

A single video stream that is suitable for use in investigations can easily require one million bits per second. Yet on the transmit or upload side, the ability of a video security system to send video to the Internet is limited to about 100 kilobits per second with wide area, wireless networks. This low speed applies to users on mobile vehicles although faster, wide area, wireless network speeds are becoming available in limited areas. The transmit speed is limited to a few hundred kilobits per second with inexpensive DSL and cable modem lines, and only 1.5 million bits per second with an expensive, T1 line. Large, fixed installations can use significantly faster and more expensive lines, but most transportation infrastructure, such as for railway right-of-ways, cannot use such high speed due to its high cost and limited availability.

On the receive or download side, first-responders may carry only a PDA that relies on a slow, wide area, wireless network for communications. Even when a fast, wired connection to the Internet is used to receive video, low data rates per video stream are required. This is due to the limited ability of many video security systems to send images, especially multiple video streams, to the Internet when the upload speed of the Internet Service Provider is limited.

The large amount of CPU power that is required in the display device to obtain, decode and display video is a problem. A vast amount of computation power is required to obtain, decode and display multiple high resolution, high frame rate, high sharpness video streams simultaneously. Fast PC's can decode and display movie DVD's because most of the burden is borne by the video card, not the PC's CPU. Part of the problem is that PC video displays use red-green-blue dots, whereas compressed video uses a different way of representing brightness and

color. Cameras and compressed video use a method that is more efficient for representing natural images because it takes into account the human eye's greater sensitivity to brightness than to color. Computationally intensive calculations must be made to convert between the two formats.

Related to the CPU display burden are the **three competing uses for security video**. **Investigations** require video streams with the clearest (lowest quantization) and highest resolution (4CIF) images possible. However, full camera frame rate is not required unless capturing rapid motion is needed. **Monitoring / deterrence** requires images with smooth motion. This requires the full camera frame rate, but full camera resolution and maximum clarity are not needed. Resolution of 1CIF, used by the majority of digital video recorders, is usually adequate so long as it's full rate. Often, an analog CCTV video system with video matrix switches, multiplexers and quad-processors is used alongside digital video recorders to provide this smooth-motion video and to format each TV video display with video from multiple cameras. **Emergency response / intervention**, for viewing on PDA's as well as via the Internet for display on PC video displays when upload speeds from the video security system are limited, requires images with very low data rates. Low resolution (QCIF) and medium frame rate are suitable.

All of these types of streams should be available both live and recorded, and easily accessed. The ability to quickly and easily switch from a live stream to the corresponding recorded stream to investigate an incident in progress, from only seconds ago, is required. Recorded streams can be accessed remotely in slower than real time since the data has already been recorded. Searching lower data rate streams quickly, and then switching to the sharpest streams saves precious time.

Ease of service and upgrade are required. The video security system used for transportation security must operate for many years. Proprietary, soon-to-be obsolete hardware is not desirable.

Finally, since video, access control, biometric and other sensor systems must be integrated together to form a total security solution, the video security system should be designed so that it can easily be integrated into other systems.

A new solution to these diverse and difficult problems

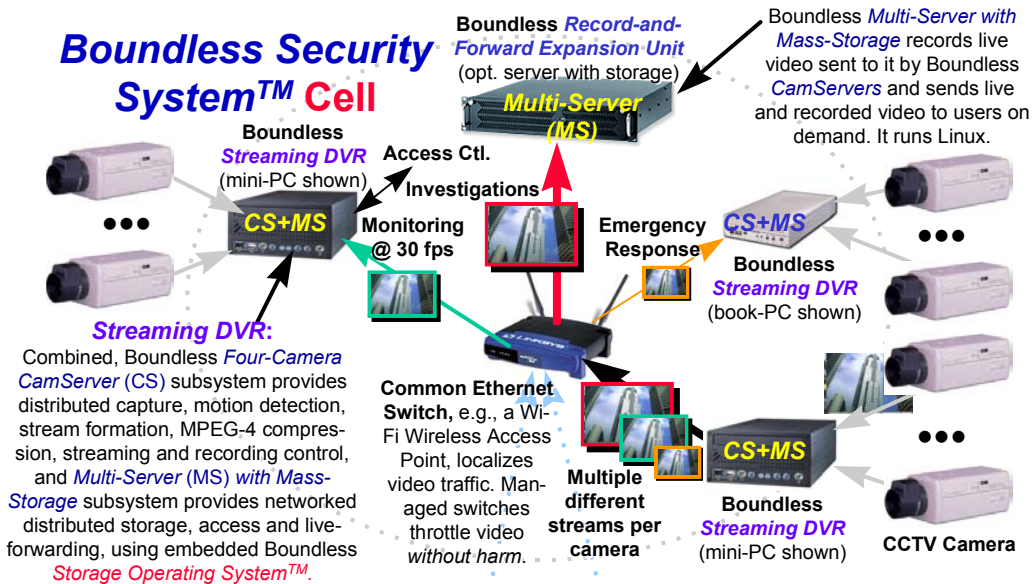
The ***Boundless Security System™*** from Boundless Security Systems, Inc., in Newtown, CT, is a fault-tolerant, redundant, enterprise-class, digital video acquisition, switching, management and display system. It was designed as a part of a network, not as a component connected to a network. It is based on the premise that things go wrong at the worst possible times, and that systems should cope with it. It has been architected to satisfy the difficult needs of large-scale, transportation video security systems. It has been designed to provide the utmost in reliability, storage capacity, and ease of remote access to satisfy the competing needs for image quality, storage, communications and display for investigations, monitoring and emergency response.

Truly a new generation of technology, the ***Boundless Security System™*** is controlled differently than previous generations of digital video security systems. It is a fully distributed, fault-tolerant and redundant system. It is controlled entirely from its "edge" or perimeter using Boundless' ***Storage Operating System™***. The ***Boundless Security System™*** automatically reconfigures itself and resumes operation within seconds if parts of the system are destroyed or disabled. Its software-based storage virtualization provides vast (up to 1 petabyte per network), economical, seamless online storage with high density, low power dissipation, and the ability to repair and expand the system while it operates. It also provides fully integrated access to both live and recorded, audio, video and event data.

The **Boundless Security System™** simultaneously satisfies the competing image quality, storage, communications and display needs of investigations, monitoring / deterrence, and emergency response / first-responders, *without compromise*. It easily retrofits existing video security systems, and economically replaces hybrid, analog/digital, video switching, distribution, monitoring, display-formatting and recording systems in new, large-scale installations.

The **Boundless Security System™** was designed based on experience gained building mission-critical, U.S. Air Force communications spacecraft, and large, central office, telephone switching systems. Designed specifically as a **large-scale system**, the **Boundless Security System™** provides superior performance and reliability in large public and government applications requiring 100's to 1,000's of cameras. It is also cost-effective in much smaller installations. Following the 9-11-01 attacks, it was designed upon completion of a detailed analysis of the limitations and capabilities of the *underlying technologies* behind traditional digital video security systems, including digital video recorders (DVRs) and network video recorders (NVRs).

Operation of the **Boundless Security System™** is shown below. An installation of the **Boundless Security System™** uses one or more **Boundless Security System™ Cells**. Like a guerilla network, the cells work alone and together to quickly recover from temporary and permanent problems. Each cell has one or more Boundless **Streaming DVR's**. The **CamServer** subsystem digitizes, scales, MPEG-4 compresses, motion-detects and streams video from multiple CCTV cameras without multiplexing. **Streaming DVR's** using mini-PC's and book-PC's are shown.



Each Boundless **CamServer (CS)** creates multiple digital video streams per camera simultaneously, with different resolutions, frame rates and compression parameters. These streams satisfy competing needs for image quality, storage, communications and display for archival searches, investigations, monitoring and emergency response. Each Boundless **CamServer** is a master and controls recording by sending its IP-video streams to a co-located and/or one or more external Boundless **Multi-Servers (MS)** (slaves) for recording and live-forwarding, and continually validating proper recording. Non-proprietary hardware is used throughout, avoiding sole-source supply, expansion and maintenance problems, and providing a wide variety of housings for versatility.

Display devices and other **Boundless Security System™ cells** Router / Firewall Internet

Cell for Fault-Tolerant, Redundant, Boundless Security System™

MPEG-4, variable bit rate, also known as *constant quality*, compression is used for the video streams used for investigations. It provides the clearest images regardless of the amount of “motion,” or change between frames, while automatically reducing the data rate when the amount of motion reduces, minimizing storage requirements. Recording is performed continuously, rather than being gated by problem-prone, motion detectors.

Standard CCTV cameras can be used, but advanced, high-resolution CCTV cameras with progressive scan and wide dynamic range are recommended for the best image quality, especially of moving subjects. Each Boundless *Streaming DVR* creates three or more IP-video streams per camera simultaneously, with different resolutions, frame rates and compression parameters. These streams satisfy the diverse image quality, storage, communications and display needs for investigations, monitoring/deterrence, and emergency response/intervention.

After performing many-zone motion detection, Boundless’ *Streaming DVR* encapsulates each compressed video stream in Boundless’ *Storage Operating System™* protocols, encapsulates it in Internet protocols, streams it to a co-located or separate Boundless *Multi-Server*, and continually validates proper recording. Each stream for each camera can have a different storage retention policy, such as maintaining the investigations streams for weeks or months, but the monitoring streams for only minutes or days.

The availability of these multiple types of video streams, with different resolutions, frame rates, quantizations and data rates, has **significant benefit to the display system** by reducing the computation burden of the CPU used in the display device. The reason is that one can display the streams whose resolutions, frame rate and quantizations best fit the need at hand. This is especially important when one wants to view many video streams with high frame rates at once.

Forming a common, two-by-two, TV video display by using the PC’s CPU to decode and scale-down four video streams, each with full resolution, full frame rate, and maximum sharpness, is a task that is well beyond the capability of high performance, desktop and notebook CPU’s. It is much more efficient, much less expensive, and uses less communication bandwidth, to obtain, decode and display four video streams when each stream has only one-quarter the camera resolution, and reduced sharpness compared to the video streams used for investigations. **Boundless reduces the display CPU burden by 80% with this tactic.**

Universal video access is provided. It is provided by Boundless’ combination of not only an enhanced, fully digital, fully interconnected, **virtual video matrix switch**, and also a **virtual video processor** at every display device. This combination provides every user with efficient, independent display of multiple live and live and recorded video streams simultaneously. Every user can freely select and access both live and recorded video using a single, fully integrated system. Every user can simultaneously access and display both live and recorded video from multiple cameras, with multiple resolutions and frame rates, from multiple Boundless *Multi-Servers* on multiple networks. Every user can select and simultaneously place many (up to 64) video streams on his/her screen, independent of all other users.

A fully distributed design, each Boundless *Streaming DVR* completely controls the recording of all of its video streams on one or more Boundless *Multi-Servers*. Protocols are used that ensure reliable recording despite transient network and *Multi-Server* overloads. They also enable the smallest size video streams to be used for investigations since extra data is not needed to compensate for packet loss. If a permanent fault occurs in a network segment or a *Multi-Server*, the *Streaming DVR* detects the fault within seconds, switches to other *Multi-Servers*, and

resends the video that was briefly lost. If the network fault is in the network segment the *Streaming DVR* uses to connect to external *Multi-Servers*, it stores all the video streams in a co-located *Multi-Server* until the network is repaired. No video recording is lost.

Rather than treating the disk storage in each Boundless *Multi-Server* separately, Boundless' *Storage Operating System™* software combines all disk storage in all *Multi-Servers* on a network into a single, seamless pool of storage up to 1 PB (1,000 TB) per LAN. This provides maximum efficiency, storage duration, and ease of access to live and recorded video. It also enables the system to be repaired and expanded while in full operation. Boundless' *Physical Diversity Recording™* stores different digital video streams from a given camera in multiple *Multi-Servers* in different physical locations on a network, significantly improving system reliability and engineering network traffic. It provides fault-tolerance and redundancy that automatically compensate for system faults and catastrophic, destructive events.

The Boundless *Multi-Server* is a store and forward device. It operates both standalone and co-located with a Boundless *CamServer*. The *Multi-Server* records multiple IP-video streams under control of one or more external or co-located *CamServers*. It also forwards live video and provides recorded video to Boundless' *Control Panel* and *Video Player* software. With video capture and recording within each *Boundless Security System™ Cell*, the only network traffic between cells, or between cells and display devices, is **video on demand**, except when storage pooling across cells is performed or when multiple network security zones are desired. As a result, **Wi-Fi** network segments and throttled network segments, which often lose packets, can be used reliably to interconnect cells, and to connect cells to local or remote display devices.

Boundless' *Video Player* software provides a *portal* – a way for third-party software to access – to all live and recorded audio, video and event data, and device controllers in the *Boundless Security System™*. The *Video Player* is multi-threaded so that multiple instances can efficiently run concurrently, each accessing a different stream from local or remote *Multi-Servers*.

Non-proprietary computer hardware is used throughout the *Boundless Security System™* for all functions. Only standard hardware that has been tested extensively, and its performance and reliability verified, is used. This significantly simplifies the final-assembly, integration, installation, maintenance and expansion of large-scale, video security systems. Like a central office telephone switch, it also enables local content to be used for systems installed overseas.

Conclusion

Video security systems that protect large-scale air, land and sea transportation systems must be extremely reliable and meet a wide range of image quality, storage, communications, and display requirements. They must operate for many years, requiring on-going availability and service.

The *Boundless Security System™ with Boundless' Storage Operating System™* from Boundless Security Systems, Inc., in Newtown, CT, uniquely satisfies these diverse and difficult requirements. It is a fault-tolerant, redundant, enterprise-class, digital video acquisition, switching, management and display system. It was designed as a part of a network, not as a component connected to a network. It satisfies the competing imaging needs for investigations, monitoring/deterance, and emergency response/intervention. It provides the utmost in reliability, storage capacity and serviceability. Its non-proprietary hardware avoids sole-source supply, maintenance and expansion problems, and facilitates interoperability and system integration.

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