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(54) **SURVEILLANCE SYSTEM WITH DIGITAL TAPE CASSETTE**

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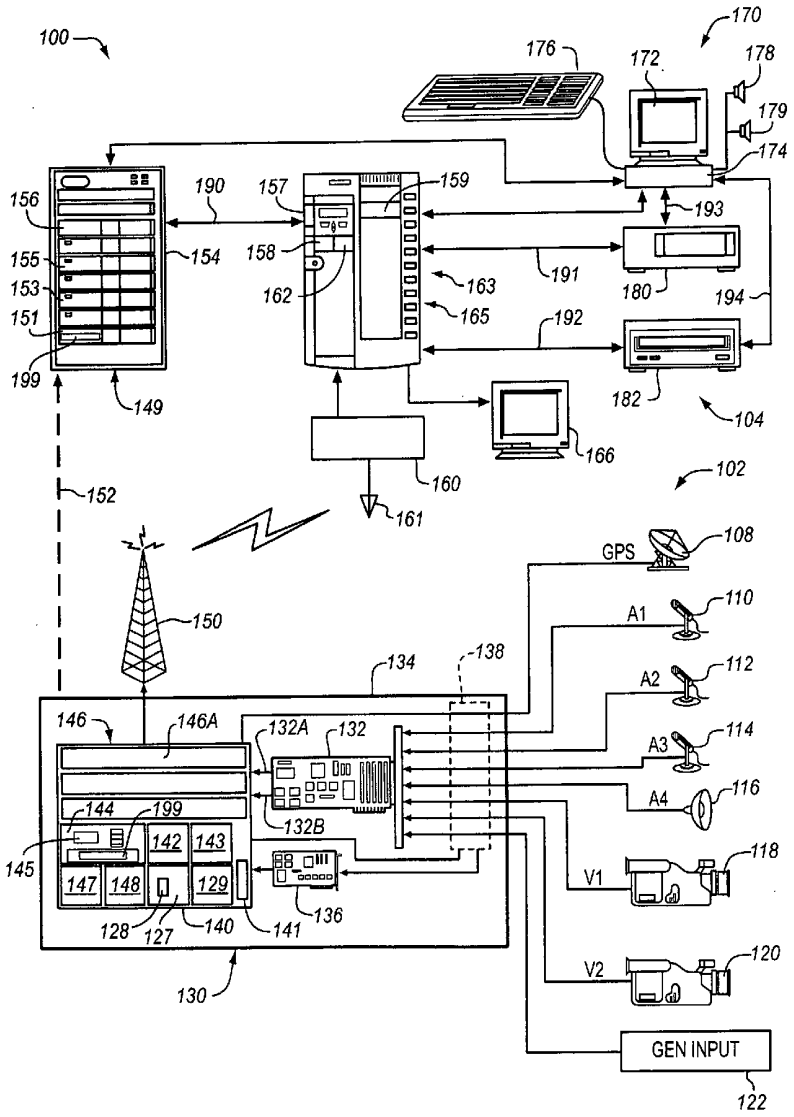
H04N 11/04 (2006.01)
H04N 7/18 (2006.01)

(52) **U.S. Cl.** **375/240.01**; 348/143

(57) **ABSTRACT**

A video surveillance system in which the compressed video is written to a digital tape cassette. The tape cassette includes an EEPROM, which holds directory information relating to the location of particular video on the tape, the identity of the tape, the identity of the video, and other key information relating to the video. The directory on the EEPROM permits rapid access to the video and redundancy of key data. In case of tape error, the tape automatically restores itself when inserted into the tape deck.



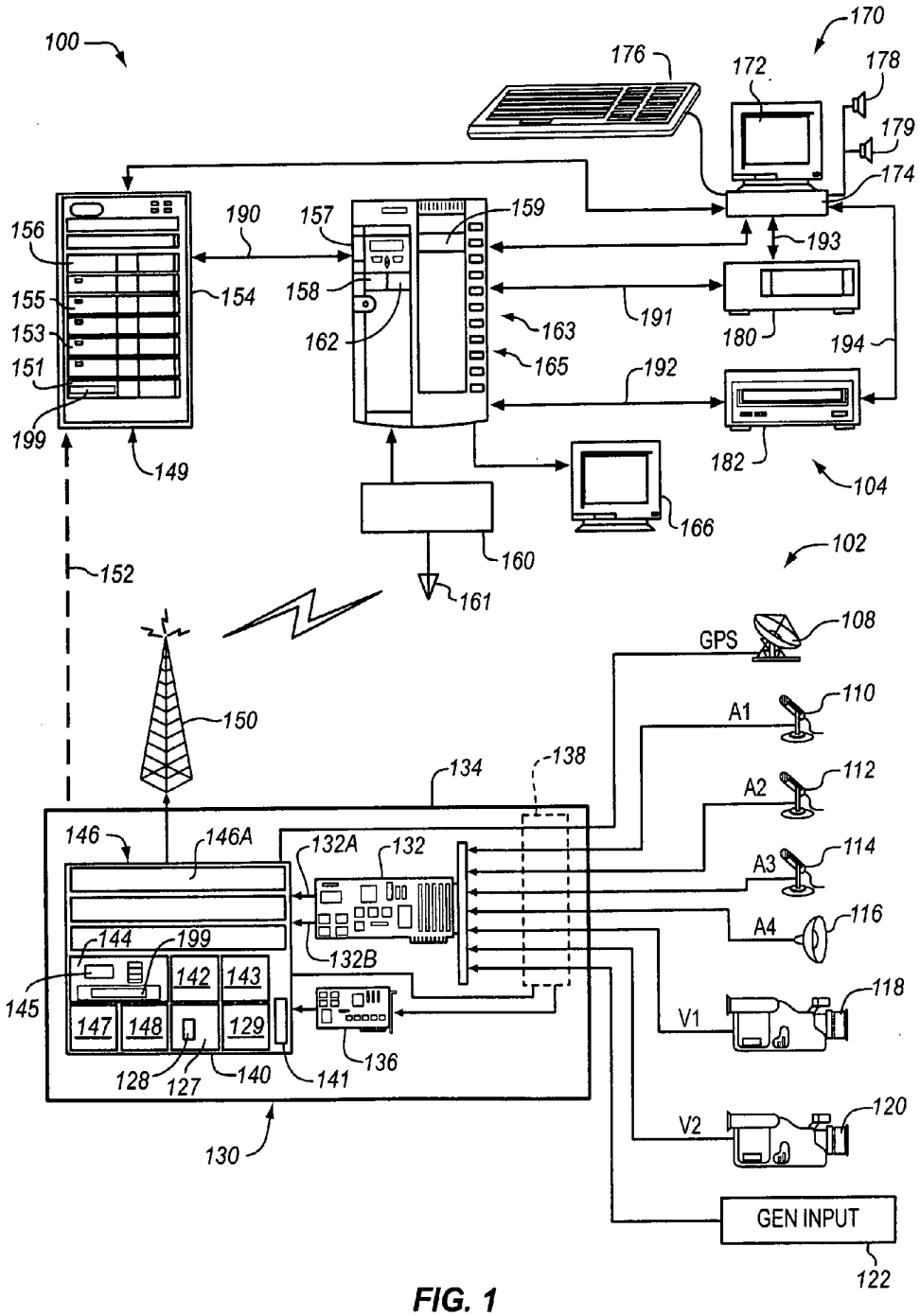

100
170
176
172
178
179
174
156
190
157
159
193
155
154
158
191
153
162
163
180
194
151
165
192
199
149
182
104
166
160
102
152
161
GPS
108
150
A1
110
134
138
A2
112
146
146A
132A
132
A3
114
144
199
132B
A4
116
145
142
143
118
147
148
129
V1
128
127
140
141
136
V2
120
130
GEN INPUT
122

FIG. 1

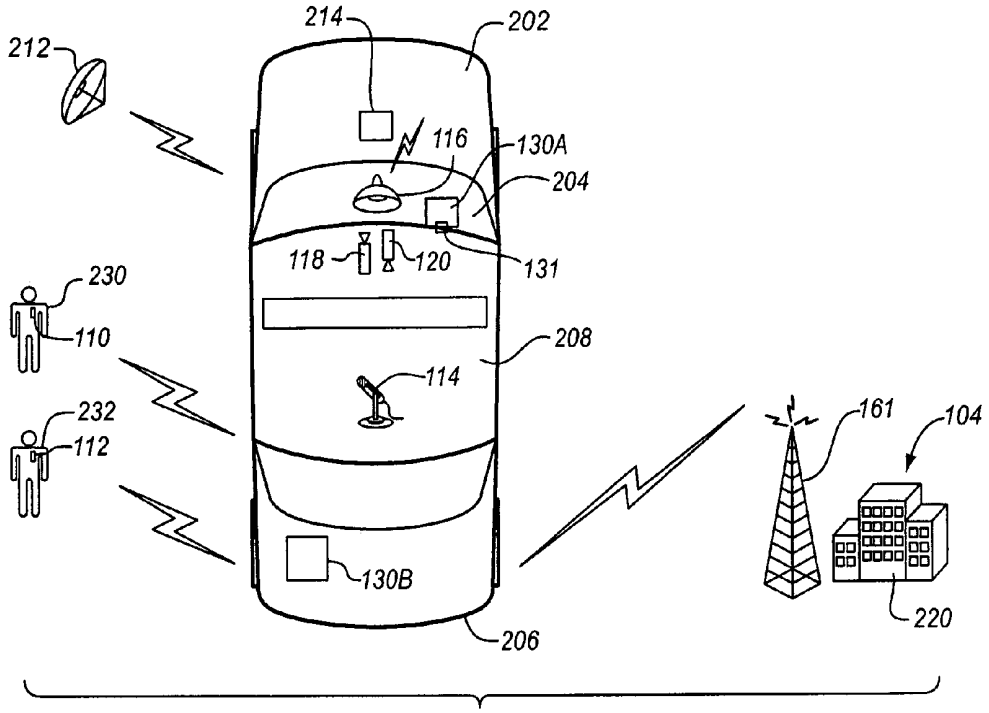

214
202
212
116
130A
204
118
120
131
230
110
208
114
232
112
161
104
130B
220
206

FIG. 2

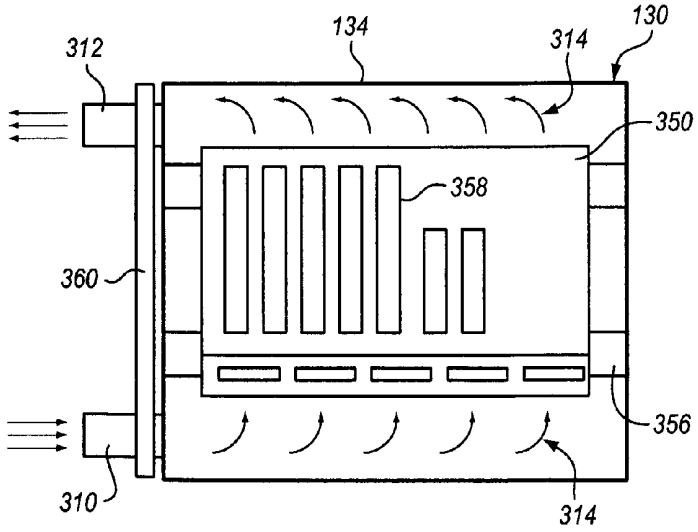

134
130
312
314
350
358
360
356
310
314

FIG. 3

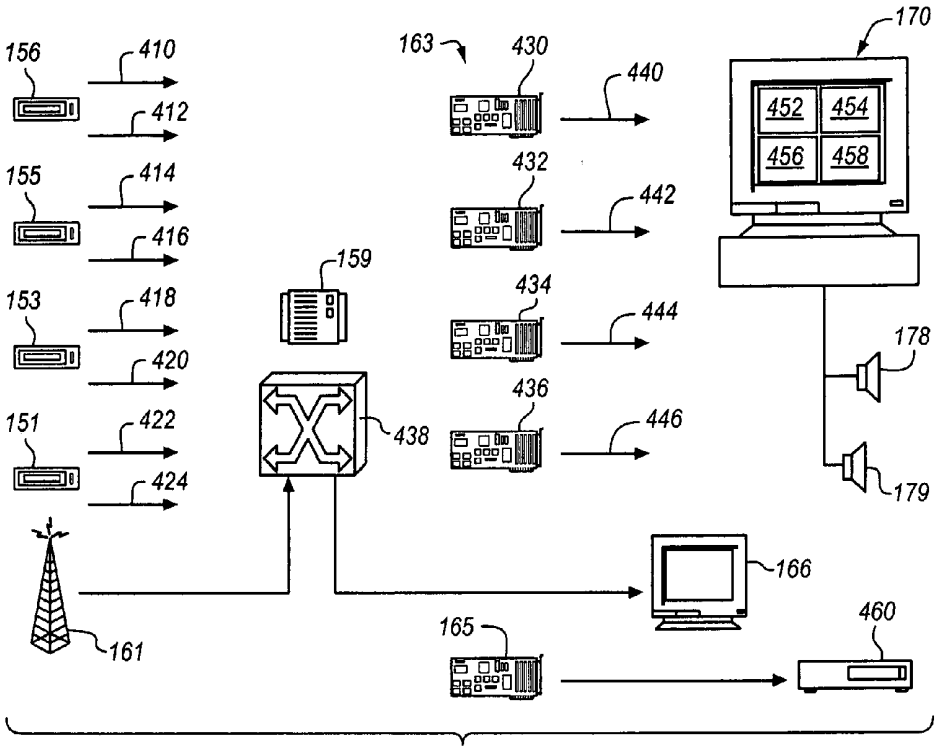

156
410
412
155
414
416
153
418
420
151
422
424
161
159
438
163
430
440
432
442
434
444
436
446
170
452
454
456
458
178
179
166
165
460

FIG. 4

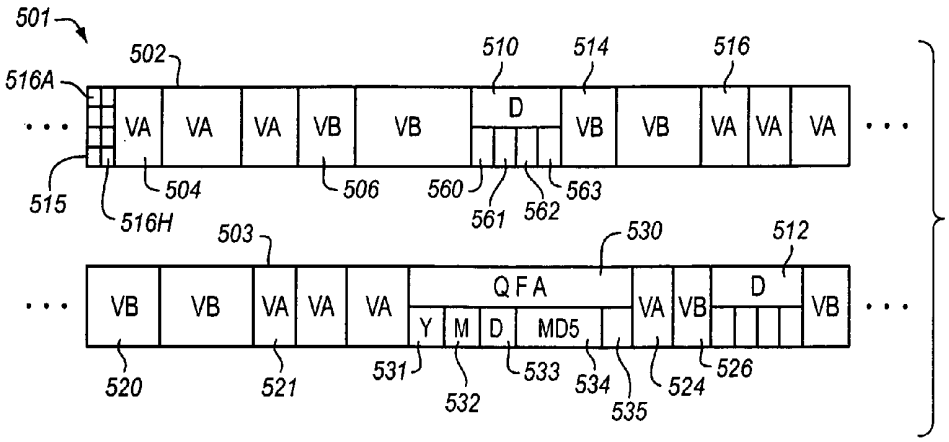

501
502
516A
510
514
516
VA
VB
D
504
506
560
561
562
563
515
516H
503
530
512
QFA
Y
M
D
MD5
520
521
531
532
533
534
535
524
526

FIG. 5

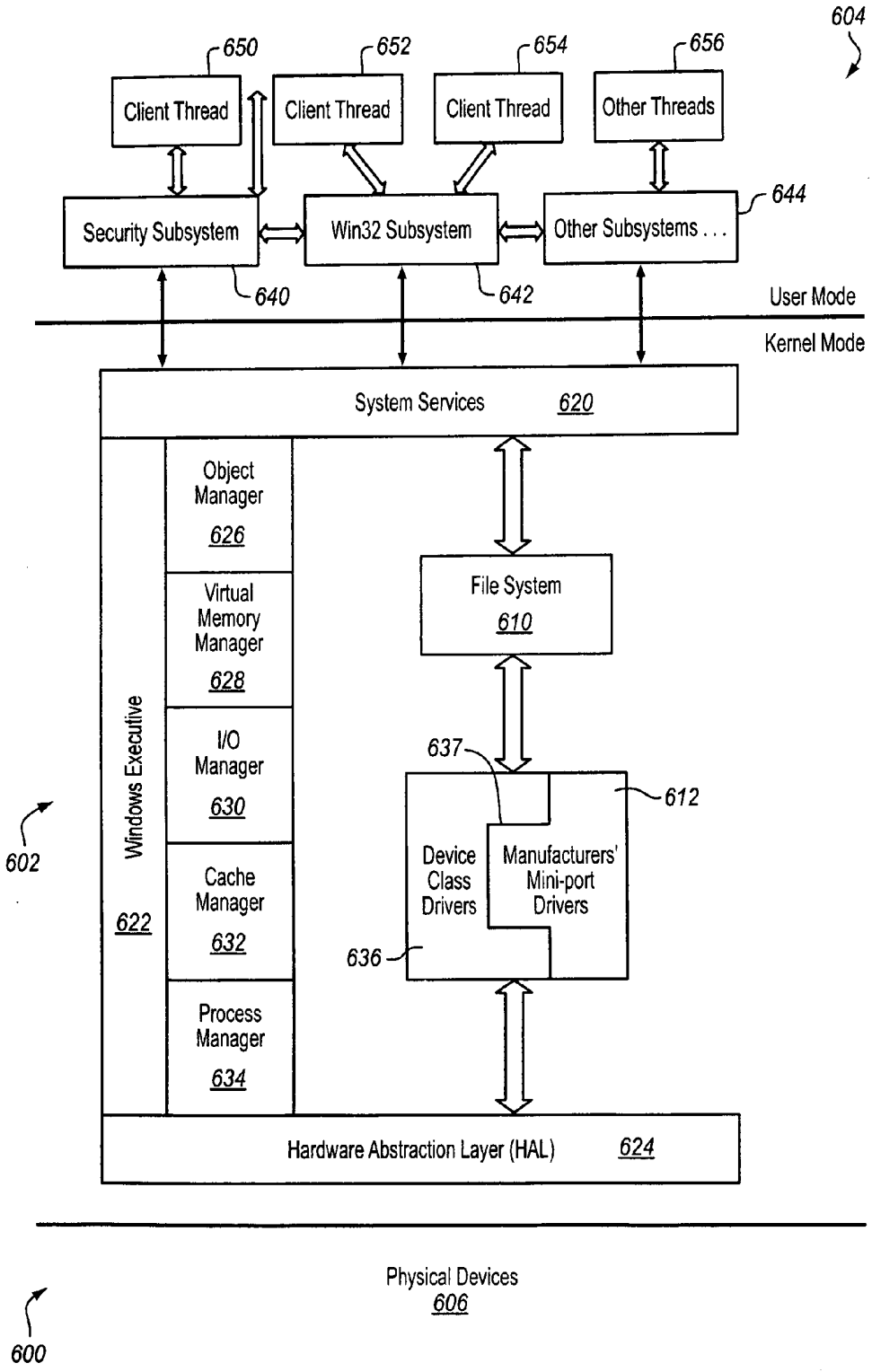

604
650
652
654
656
Client Thread
Client Thread
Client Thread
Other Threads
644
Security Subsystem
Win32 Subsystem
Other Subsystems . . .
640
642
User Mode
Kernel Mode
System Services 620
Object Manager 626
Virtual Memory Manager 628
I/O Manager 630
Cache Manager 632
Process Manager 634
Windows Executive 622
File System 610
637
612
Device Class Drivers
Manufacturers' Mini-port Drivers
636
602
Hardware Abstraction Layer (HAL) 624
Physical Devices 606
600

FIG. 6

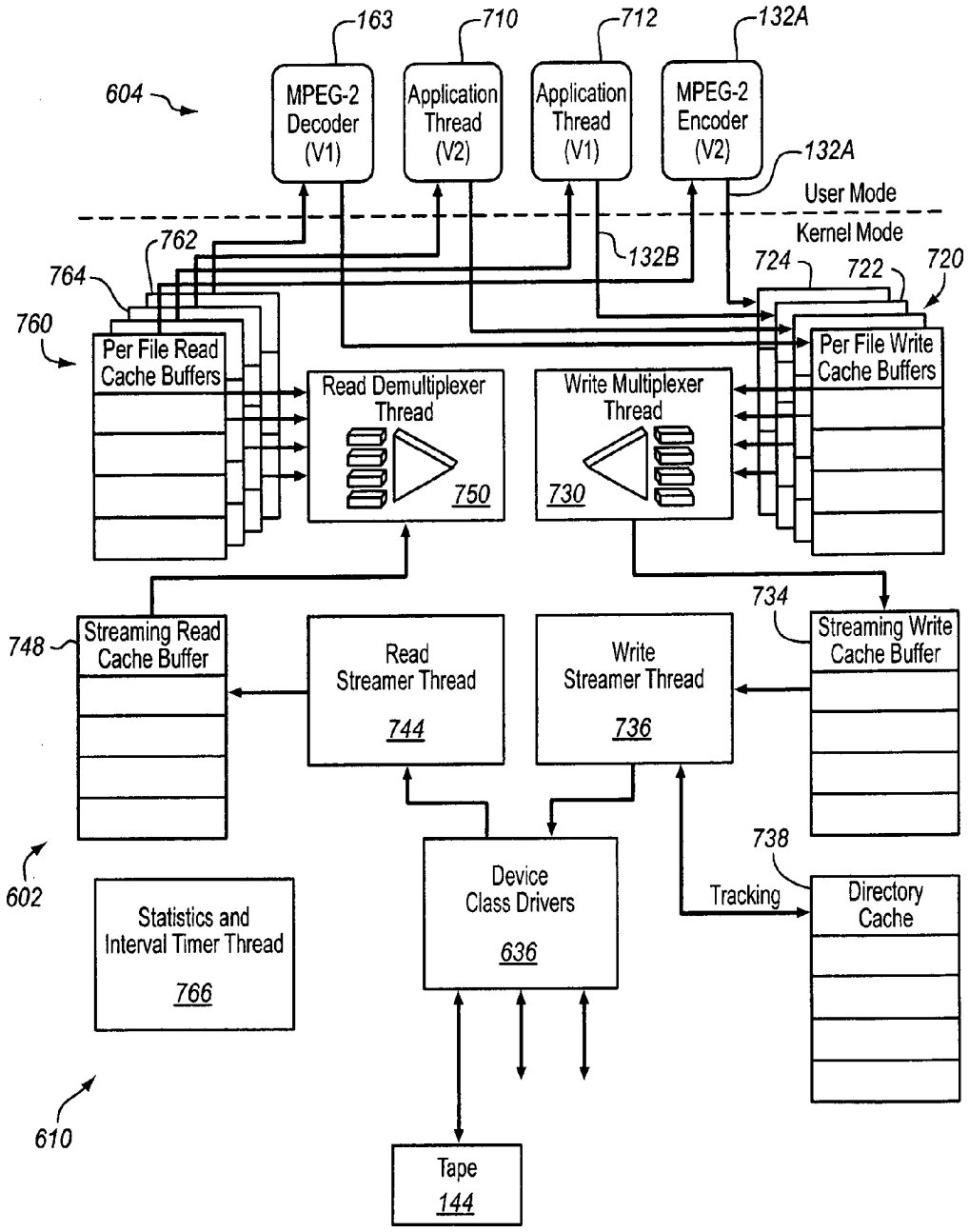

604
163
MPEG-2 Decoder (V1)
710
Application Thread (V2)
712
Application Thread (V1)
132A
MPEG-2 Encoder (V2)
132A
User Mode
Kernel Mode
132B
762
764
760
724
722
720
Per File Read Cache Buffers
Read Demultiplexer Thread
750
Write Multiplexer Thread
730
Per File Write Cache Buffers
734
748
Streaming Read Cache Buffer
Read Streamer Thread
744
Write Streamer Thread
736
Streaming Write Cache Buffer
738
602
Statistics and Interval Timer Thread
766
Device Class Drivers
636
Tracking
Directory Cache
610
Tape
144

FIG. 7

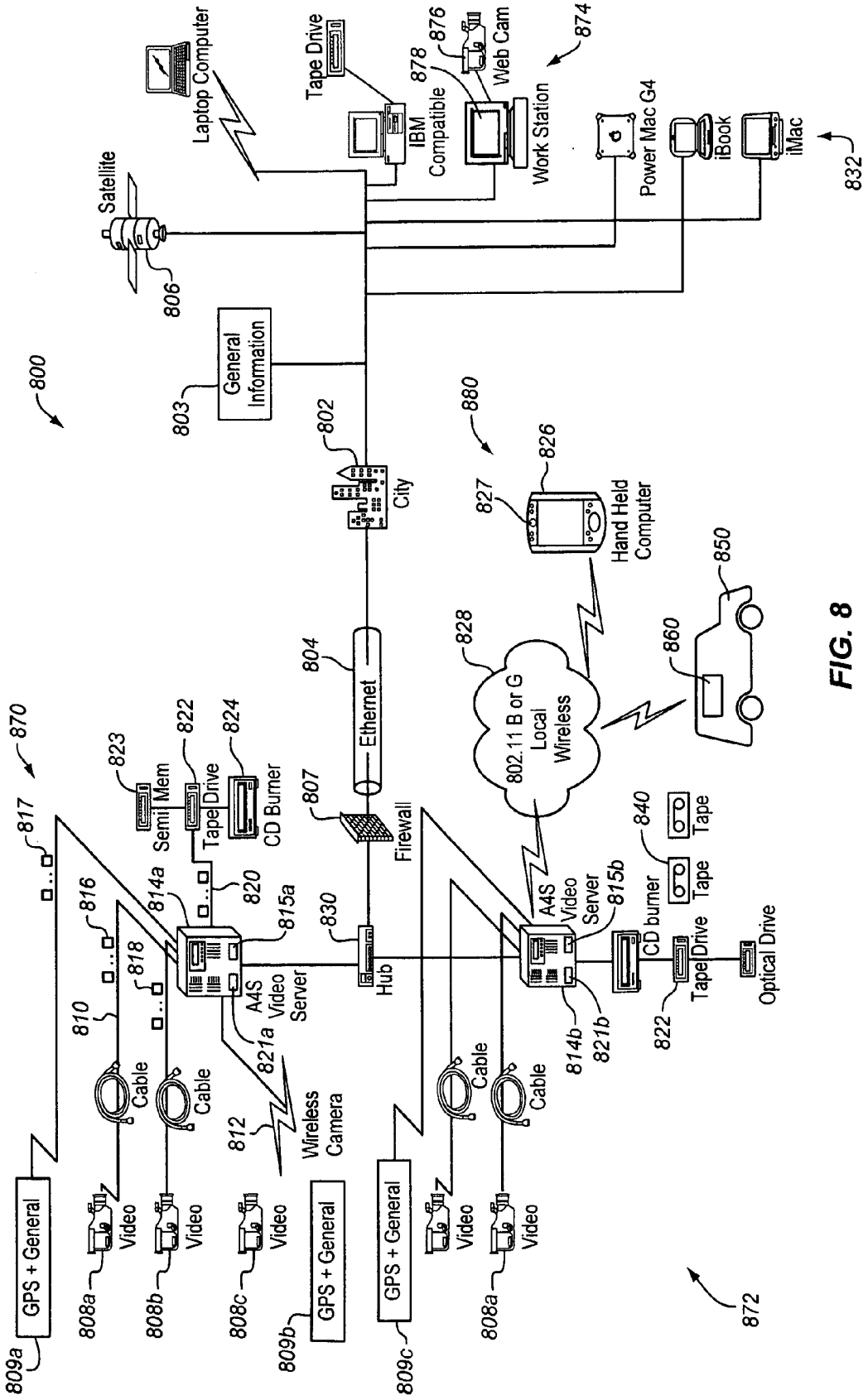

800
Satellite
806
Laptop Computer
Tape Drive
IBM Compatible
878
876
Web Cam
Work Station
874
Power Mac G4
iBook
iMac
832
General Information
803
802
City
880
826
827
Hand Held Computer
850
828
802.11 B or G Local Wireless
860
804
Ethernet
807
Firewall
870
817
823
Semi Mem
822
Tape Drive
824
CD Burner
820
816
814a
815a
A4S Video Server
830
Hub
818
810
Cable
Cable
821a
812
Wireless Camera
Video
Video
Video
808a
808b
808c
809a
GPS + General
809b
GPS + General
809c
Cable
Cable
Video
Video
808a
814b
821b
A4S Video Server
815b
840
CD burner
Tape
Tape
Tape Drive
Optical Drive
822
872

FIG. 8

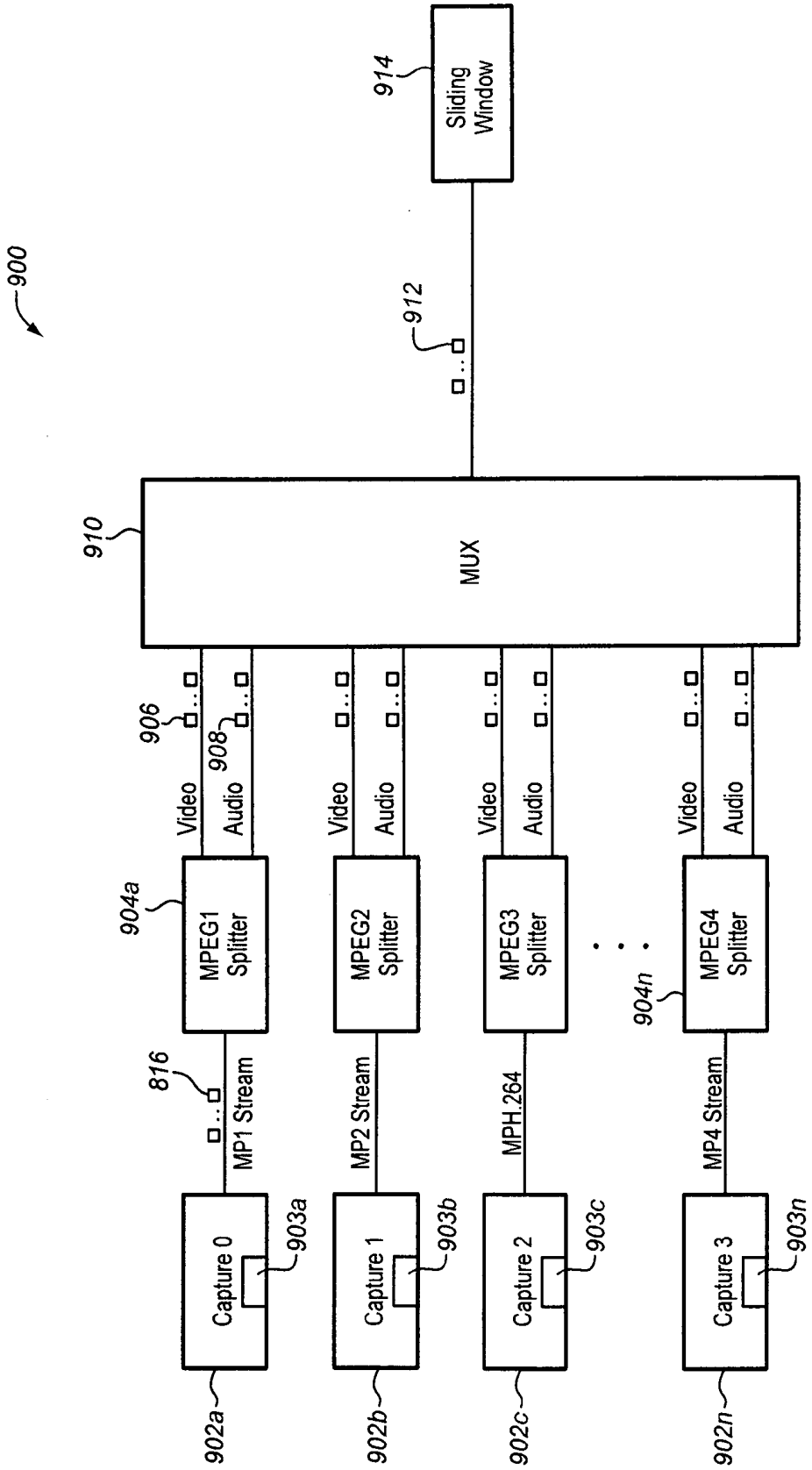

900
914
Sliding Window
912
910
MUX
906
908
Video
Audio
904a
MPEG1 Splitter
MPEG2 Splitter
MPEG3 Splitter
MPEG4 Splitter
904n
816
MP1 Stream
MP2 Stream
MPH.264
MP4 Stream
Capture 0
Capture 1
Capture 2
Capture 3
903a
903b
903c
903n
902a
902b
902c
902n

FIG. 9

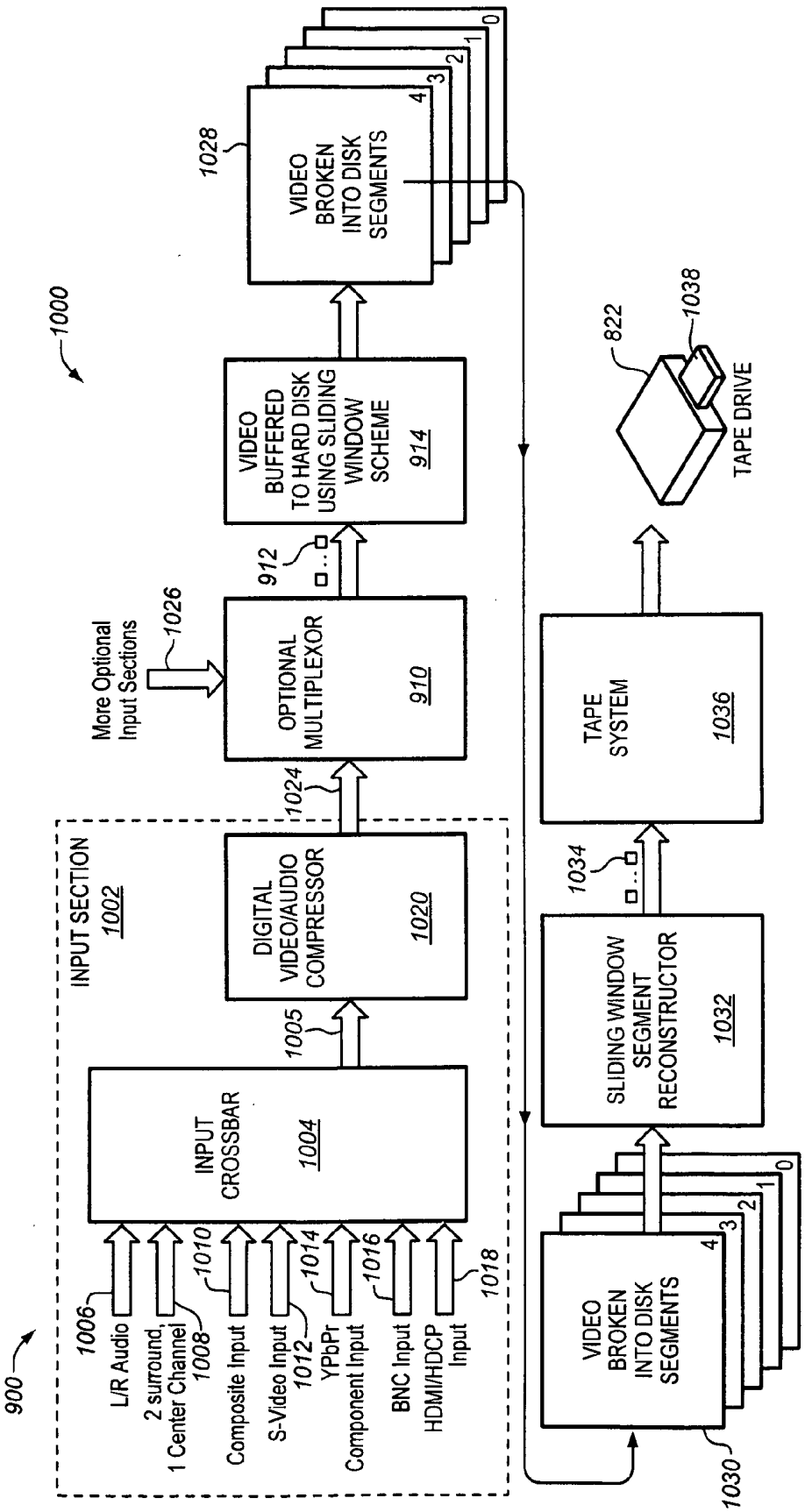

900
1000
INPUT SECTION
1002
L/R Audio
2 surround, 1 Center Channel
Composite Input
S-Video Input
YPbPr Component Input
BNC Input
HDMI/HDCP Input
1006
1008
1010
1012
1014
1016
1018
INPUT CROSSBAR
1004
1005
DIGITAL VIDEO/AUDIO COMPRESSOR
1020
1024
More Optional Input Sections
1026
OPTIONAL MULTIPLEXOR
910
912
VIDEO BUFFERED TO HARD DISK USING SLIDING WINDOW SCHEME
914
1028
VIDEO BROKEN INTO DISK SEGMENTS
0
1
2
3
4
822
1038
TAPE DRIVE
TAPE SYSTEM
1036
1034
SLIDING WINDOW SEGMENT RECONSTRUCTOR
1032
VIDEO BROKEN INTO DISK SEGMENTS
1030

FIG. 10

FIG. 11A

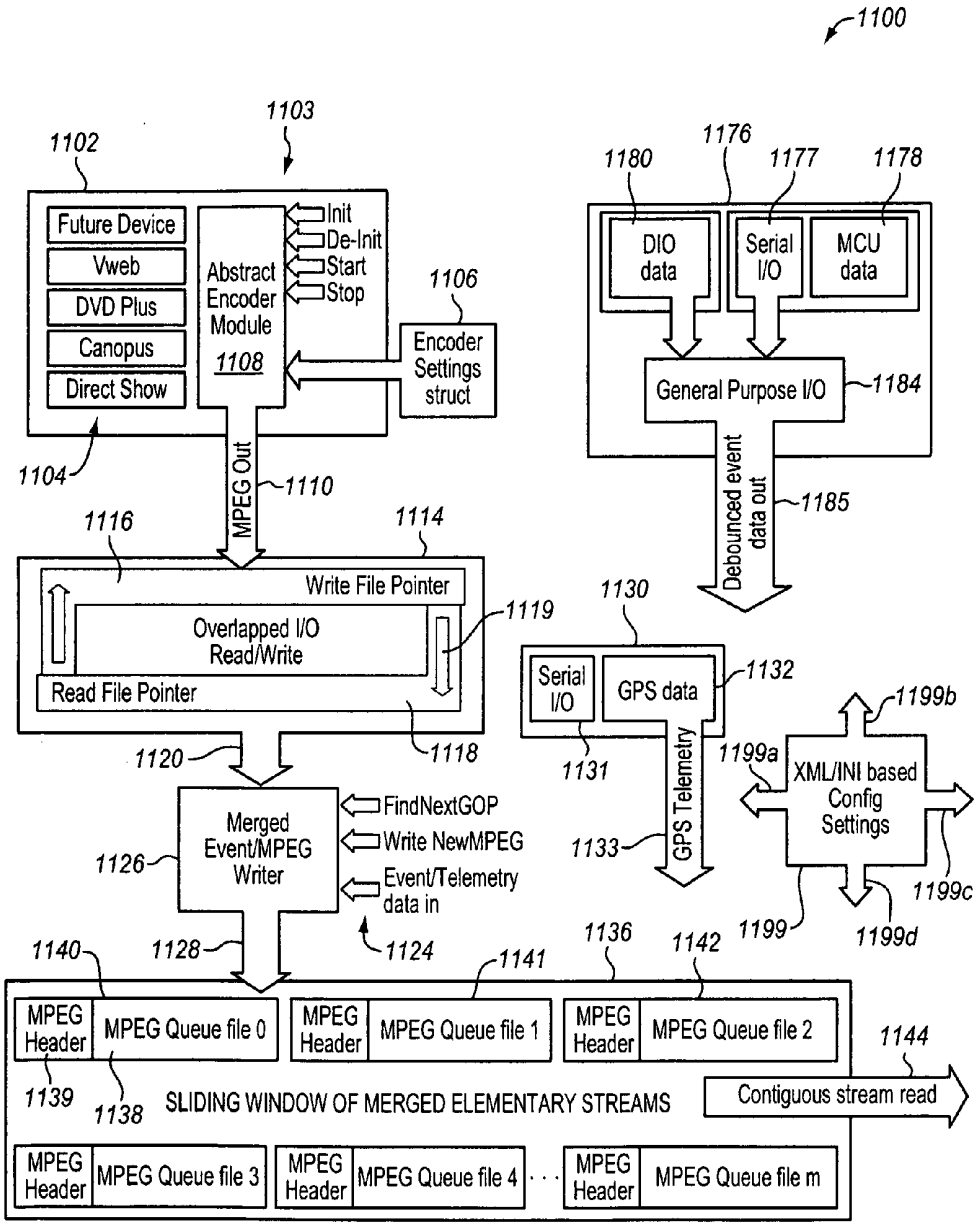
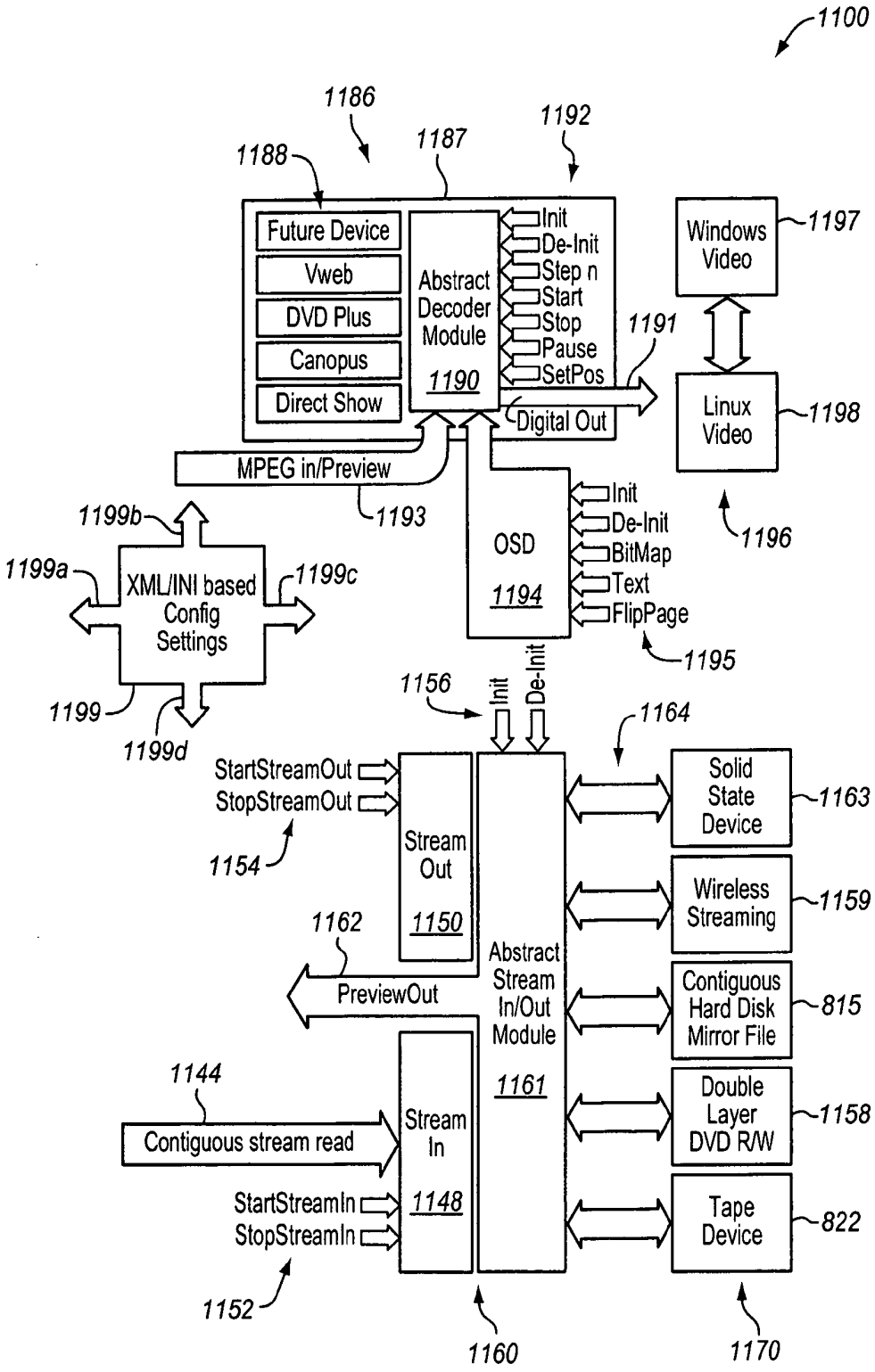

1100
1102
1103
Future Device
Vweb
DVD Plus
Canopus
Direct Show
Abstract Encoder Module
1108
Init
De-Init
Start
Stop
1106
Encoder Settings struct
1104
MPEG Out
1110
1176
1180
1177
1178
DIO data
Serial I/O
MCU data
General Purpose I/O
1184
Debounced event data out
1185
1116
1114
Write File Pointer
Overlapped I/O Read/Write
Read File Pointer
1119
1118
1130
Serial I/O
GPS data
1132
1131
GPS Telemetry
1133
1199a
1199b
XML/INI based Config Settings
1199c
1199
1199d
1120
Merged Event/MPEG Writer
1126
FindNextGOP
Write NewMPEG
Event/Telemetry data in
1124
1140
1128
1141
1136
1142
MPEG Header
MPEG Queue file 0
MPEG Queue file 1
MPEG Queue file 2
1139
1138
SLIDING WINDOW OF MERGED ELEMENTARY STREAMS
1144
Contiguous stream read
MPEG Queue file 3
MPEG Queue file 4
MPEG Queue file m

FIG. 11B


1100
1186
1187
1192
1188
Future Device
Vweb
DVD Plus
Canopus
Direct Show
Abstract Decoder Module
1190
Init
De-Init
Step n
Start
Stop
Pause
SetPos
Digital Out
1191
Windows Video
1197
Linux Video
1198
1196
MPEG in/Preview
1193
1199b
1199a
XML/INI based Config Settings
1199c
1199
1199d
OSD
1194
Init
De-Init
BitMap
Text
FlipPage
1195
1156
Init
De-Init
1164
StartStreamOut
StopStreamOut
1154
Stream Out
1150
1162
PreviewOut
Abstract Stream In/Out Module
1161
Solid State Device
1163
Wireless Streaming
1159
Contiguous Hard Disk Mirror File
815
Double Layer DVD R/W
1158
Tape Device
822
1144
Contiguous stream read
Stream In
1148
StartStreamIn
StopStreamIn
1152
1160
1170

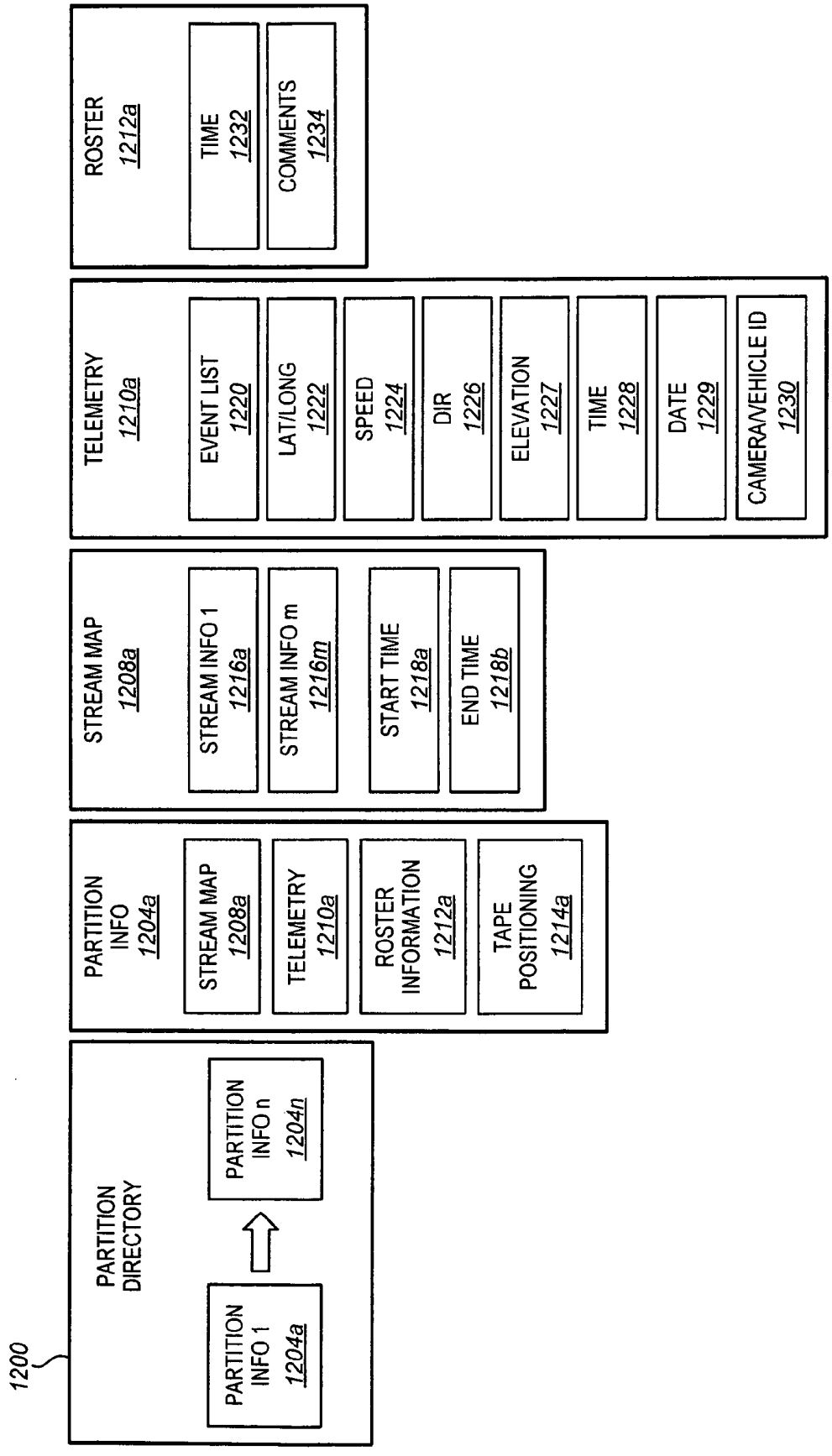

1200
PARTITION DIRECTORY
PARTITION INFO 1 1204a
PARTITION INFO n 1204n
PARTITION INFO 1204a
STREAM MAP 1208a
TELEMETRY 1210a
ROSTER INFORMATION 1212a
TAPE POSITIONING 1214a
STREAM MAP 1208a
STREAM INFO 1 1216a
STREAM INFO m 1216m
START TIME 1218a
END TIME 1218b
TELEMETRY 1210a
EVENT LIST 1220
LAT/LONG 1222
SPEED 1224
DIR 1226
ELEVATION 1227
TIME 1228
DATE 1229
CAMERA/VEHICLE ID 1230
ROSTER 1212a
TIME 1232
COMMENTS 1234

FIG. 12

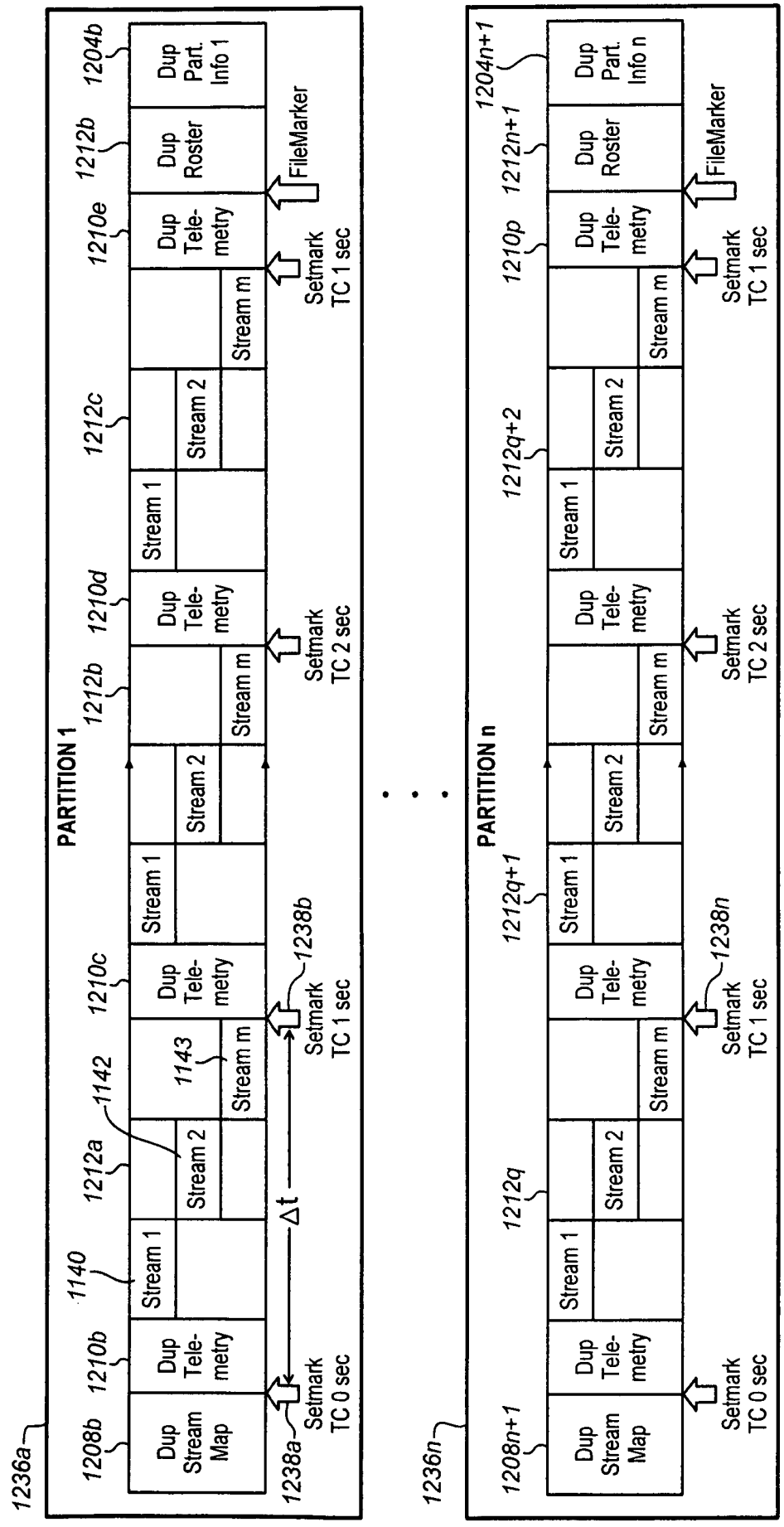

1236a
PARTITION 1
1208b
Dup Stream Map
1210b
Dup Tele-metry
1140
Stream 1
1212a
Stream 2
1142
1143
Stream m
1210c
Dup Tele-metry
Stream 1
1212b
Stream 2
Stream m
1210d
Dup Tele-metry
Stream 1
1212c
Stream 2
Stream m
1210e
Dup Tele-metry
1212b
Dup Roster
1204b
Dup Part. Info 1
FileMarker
Setmark TC 0 sec
1238a
Δt
1238b
Setmark TC 1 sec
Setmark TC 2 sec
Setmark TC 1 sec
1236n
PARTITION n
1208n+1
Dup Stream Map
Dup Tele-metry
1212q
Stream 1
Stream 2
Stream m
1212q+1
Dup Tele-metry
Stream 1
Stream 2
Stream m
1212q+2
Dup Tele-metry
Stream 1
Stream 2
Stream m
1210p
Dup Tele-metry
1212n+1
Dup Roster
1204n+1
Dup Part. Info n
FileMarker
1238n
Setmark TC 0 sec
Setmark TC 1 sec
Setmark TC 2 sec
Setmark TC 1 sec

FIG. 13

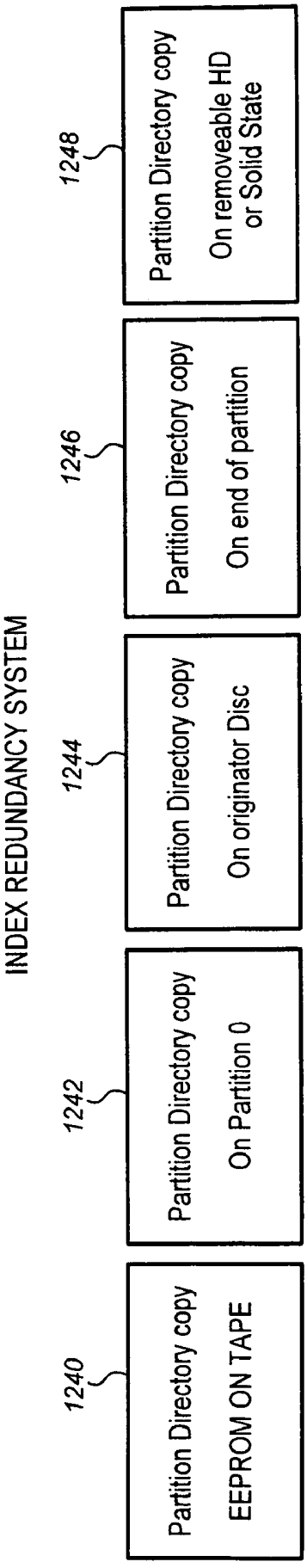

INDEX REDUNDANCY SYSTEM
1240
Partition Directory copy
EEPROM ON TAPE
1242
Partition Directory copy
On Partition 0
1244
Partition Directory copy
On originator Disc
1246
Partition Directory copy
On end of partition
1248
Partition Directory copy
On removeable HD
or Solid State

FIG. 14

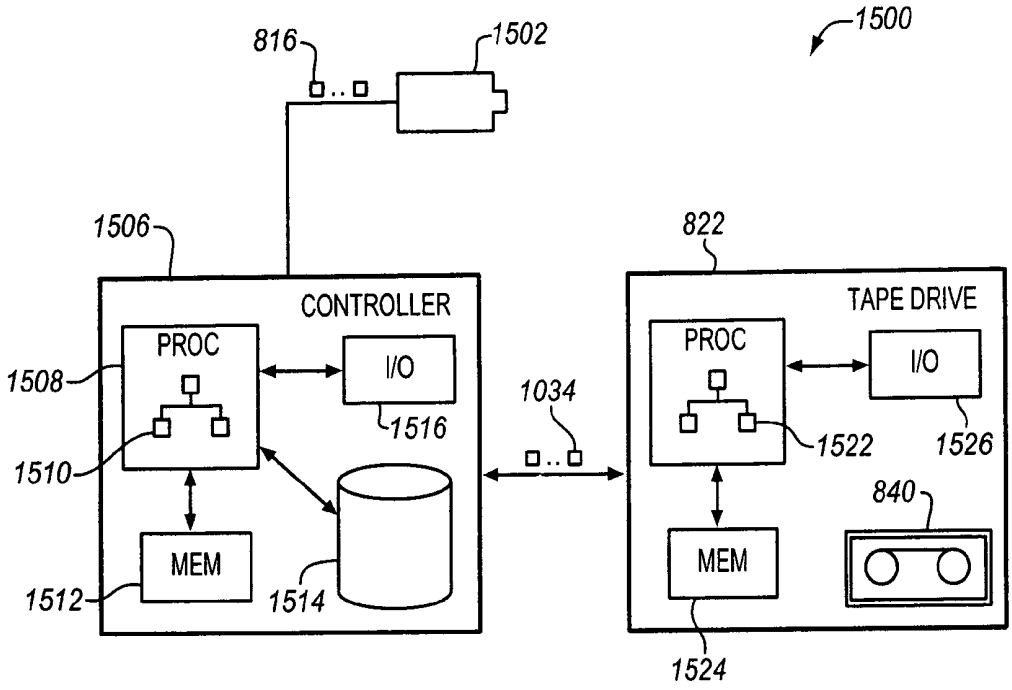

1500
816
1502
1506
822
CONTROLLER
TAPE DRIVE
PROC
I/O
1508
1516
1034
PROC
I/O
1510
1522
1526
840
MEM
MEM
1512
1514
1524

FIG. 15

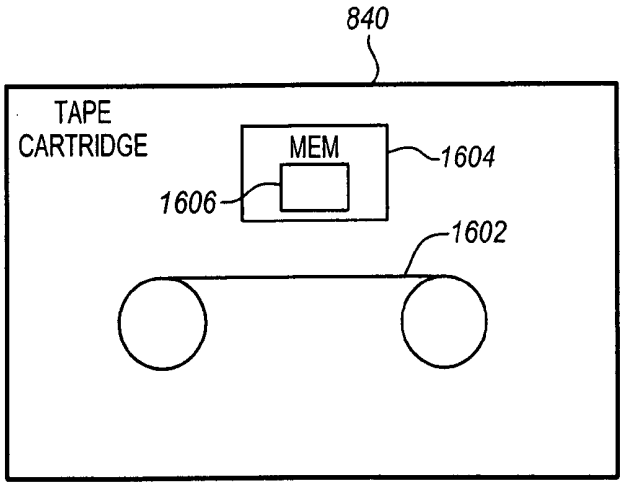

840
TAPE
CARTRIDGE
MEM
1604
1606
1602

FIG. 16

FIG. 17

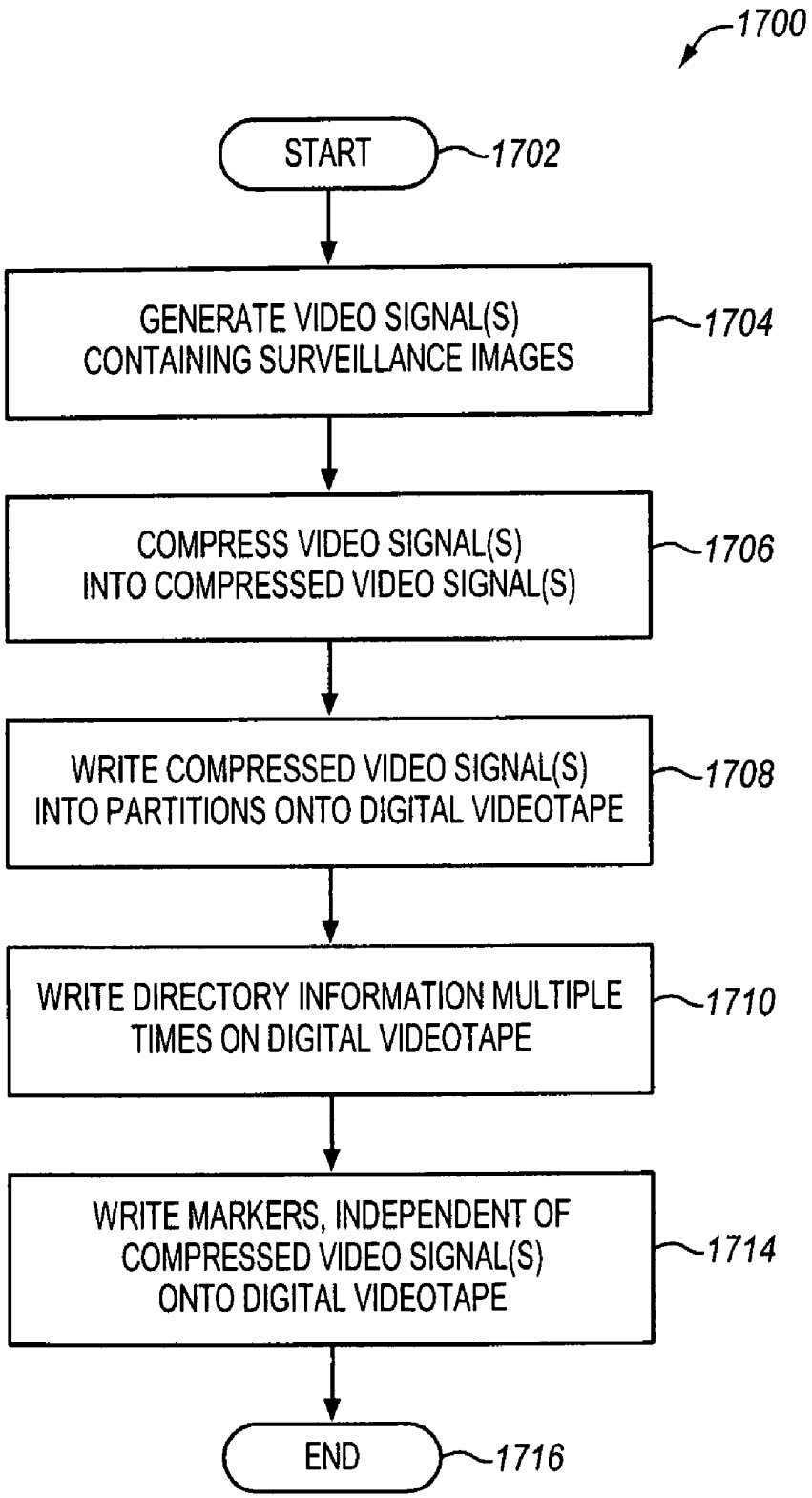

1700
START
1702
GENERATE VIDEO SIGNAL(S) CONTAINING SURVEILLANCE IMAGES
1704
COMPRESS VIDEO SIGNAL(S) INTO COMPRESSED VIDEO SIGNAL(S)
1706
WRITE COMPRESSED VIDEO SIGNAL(S) INTO PARTITIONS ONTO DIGITAL VIDEOTAPE
1708
WRITE DIRECTORY INFORMATION MULTIPLE TIMES ON DIGITAL VIDEOTAPE
1710
WRITE MARKERS, INDEPENDENT OF COMPRESSED VIDEO SIGNAL(S) ONTO DIGITAL VIDEOTAPE
1714
END
1716

FIG. 18

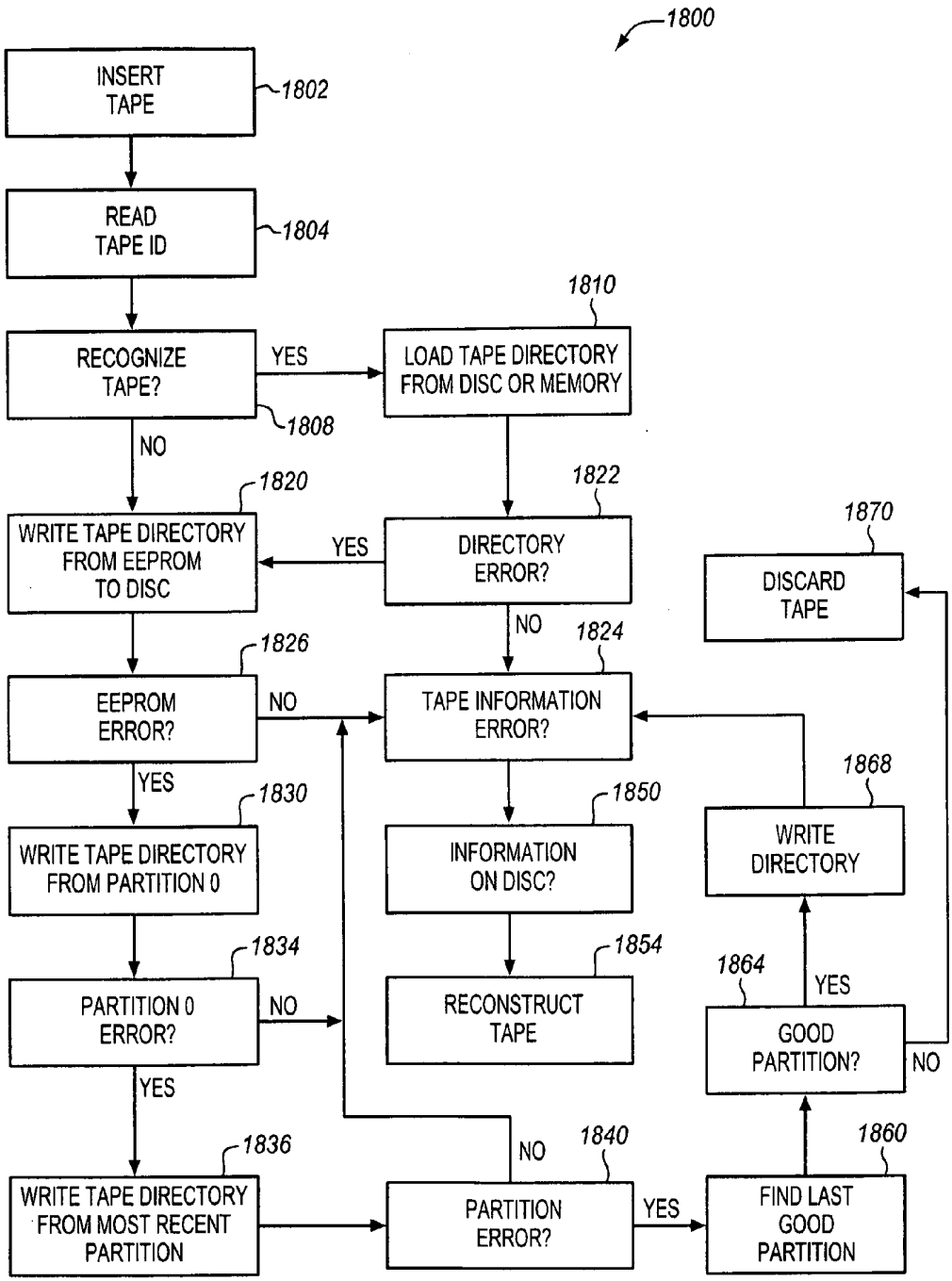

1800
INSERT TAPE
1802
READ TAPE ID
1804
RECOGNIZE TAPE?
YES
1808
NO
1810
LOAD TAPE DIRECTORY FROM DISC OR MEMORY
1820
WRITE TAPE DIRECTORY FROM EEPROM TO DISC
YES
1822
DIRECTORY ERROR?
NO
1824
1826
EEPROM ERROR?
NO
TAPE INFORMATION ERROR?
YES
1830
WRITE TAPE DIRECTORY FROM PARTITION 0
1850
INFORMATION ON DISC?
1834
PARTITION 0 ERROR?
NO
1854
RECONSTRUCT TAPE
YES
1836
WRITE TAPE DIRECTORY FROM MOST RECENT PARTITION
NO
1840
PARTITION ERROR?
YES
1860
FIND LAST GOOD PARTITION
1864
GOOD PARTITION?
YES
NO
1868
WRITE DIRECTORY
1870
DISCARD TAPE

FIG. 19

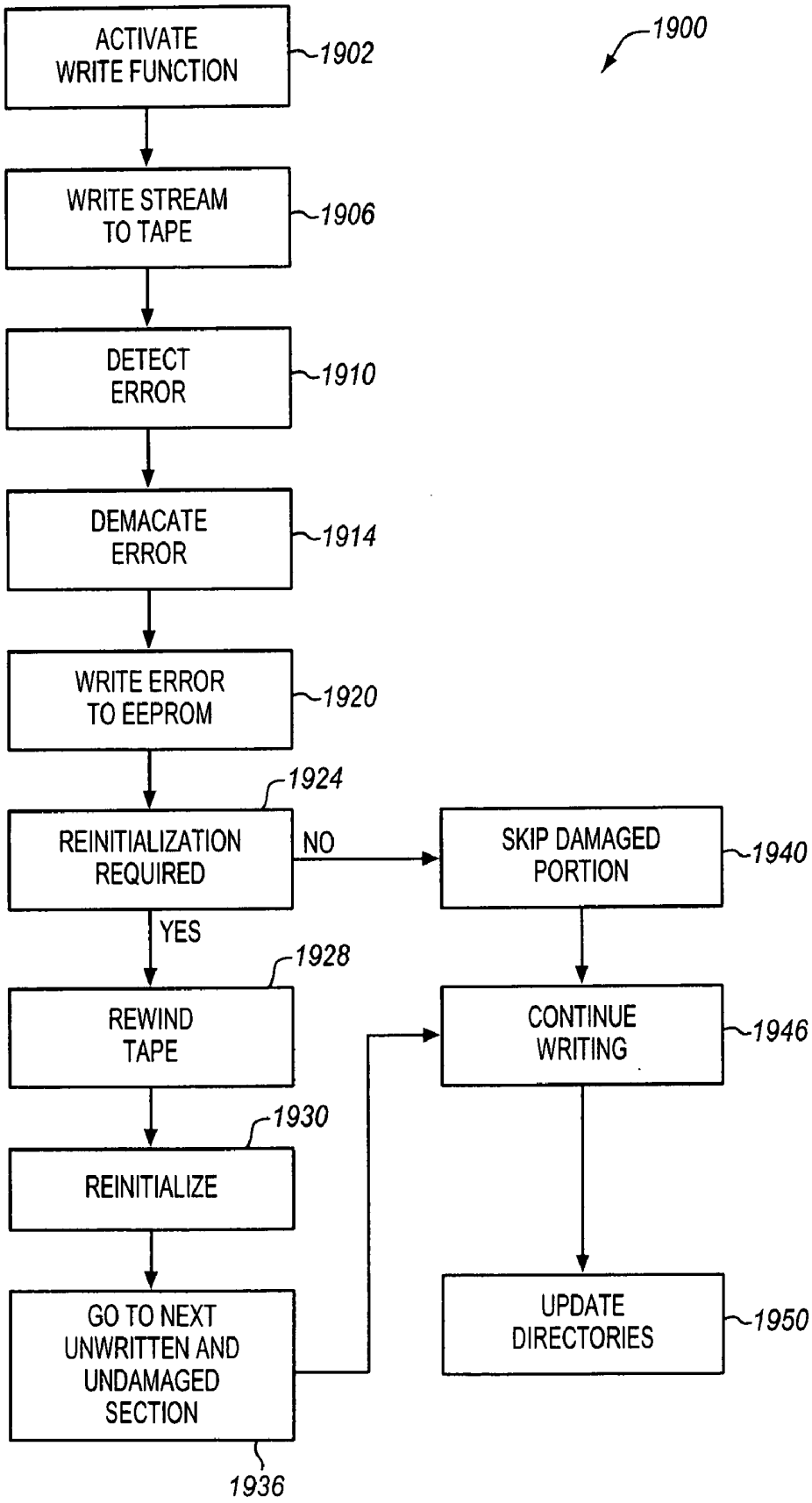
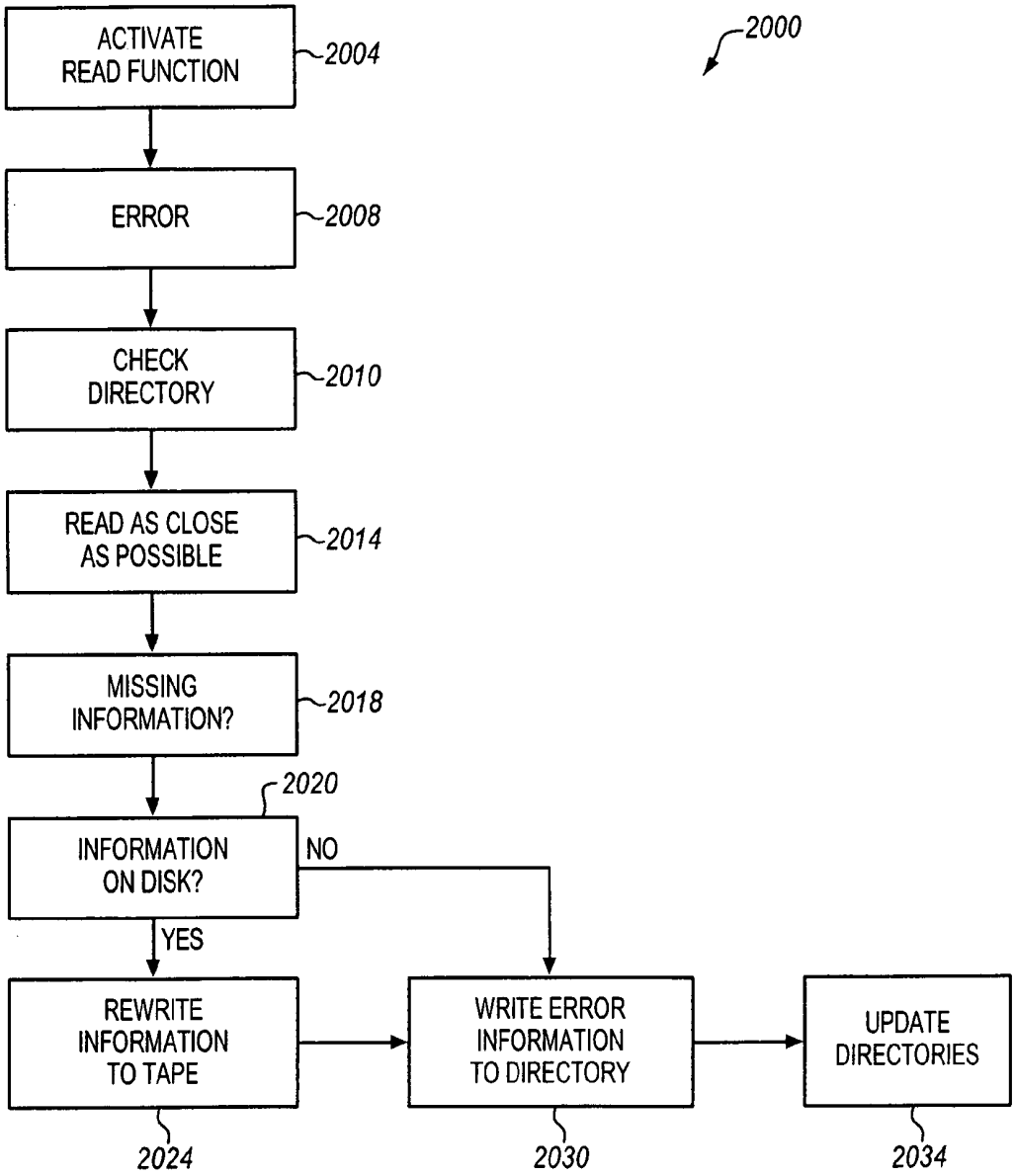

1900
ACTIVATE WRITE FUNCTION
1902
WRITE STREAM TO TAPE
1906
DETECT ERROR
1910
DEMACATE ERROR
1914
WRITE ERROR TO EEPROM
1920
1924
REINITIALIZATION REQUIRED
NO
SKIP DAMAGED PORTION
1940
YES
1928
REWIND TAPE
CONTINUE WRITING
1946
1930
REINITIALIZE
GO TO NEXT UNWRITTEN AND UNDAMAGED SECTION
UPDATE DIRECTORIES
1950
1936

FIG. 20


2000
ACTIVATE READ FUNCTION
2004
ERROR
2008
CHECK DIRECTORY
2010
READ AS CLOSE AS POSSIBLE
2014
MISSING INFORMATION?
2018
2020
INFORMATION ON DISK?
NO
YES
REWRITE INFORMATION TO TAPE
2024
WRITE ERROR INFORMATION TO DIRECTORY
2030
UPDATE DIRECTORIES
2034

SURVEILLANCE SYSTEM WITH DIGITAL TAPE CASSETTE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims the benefit of U.S. Provisional Patent Application No. 60/776,804 filed on Feb. 24, 2006 and U.S. Provisional Patent Application No. 60/719,052 filed on Sep. 20, 2005. All of the referenced applications are incorporated by reference to the same extent as though fully disclosed herein.

FIELD OF THE INVENTION

[0002] The invention relates to the field of remote audio/visual surveillance, and more particularly, but not by way of limitation, to such a system that utilizes digital tape as the recording medium.

BACKGROUND OF THE INVENTION

[0003] Audio/visual surveillance systems that are sufficiently compact to be carried in a vehicle, such as a police or patrol car, are well known. These systems generally involve recording audio and visual information on a local recording system in the vehicle, transmitting the audio and visual information to a central command facility for review and/or recording, or combinations of the foregoing. See U.S. Pat. No. 6,037,977 issued May 14, 2000 to Roger Peterson. These systems also often include the acquiring and storing of location information, e.g., the geographical position of the patrol car. See U.S. Pat. No. 4,152,693 issued May 1, 1979 to Ashworth, Jr. These systems have been developed in response to the need for rapidly informing central command facilities, such as police headquarters, of emergency situations and the audio and visual details thereof, and the need for obtaining and preserving audio and visual evidence of crimes, emergencies, and other events that involve police action or participation. For example, to successfully prosecute an individual accused of a crime, the law of the United States of America requires that due process be shown. Audio and visual records can be of critical assistance in proving probable cause for stopping or arrest, and other due process elements.

[0004] Audio/video surveillance inherently involves a problem of data transmission and storage, because video data files are generally very large and surveillance must occur for significant periods of time, often days or weeks. Generally, this is addressed in surveillance systems by either saving only a few video frames per second, by storing frames for only a short time and then recycling the storage medium by recording over the previously stored data, or by storing or transmitting only portions of the surveillance data. See, for example, U.S. Pat. No. RE37,508 issued Jan. 15, 2002 to Taylor et al.; U.S. Pat. No. 6,211,907 issued Apr. 3, 2001 to Scaman et al.; and U.S. Pat. No. 6,456,321 issued Sep. 24, 2002 to Ito et al. A common solution to the capacity problem is to put the control of the recording devices at the fingertips of the police officers and/or headquarters and have them record only when it is required. See U.S. Pat. No. 6,037,977 referenced above. Surveillance systems also inherently require a system for rapid retrieval of data; and for this reason, most state-of-the-art systems data is stored on hard drives or other systems permitting random access. See, for example, U.S. Pat. No. 5,689,442 issued Nov. 18, 1997 to Swanson et al. However, hard drives are fragile if handled improperly, and downloading them without removing them takes so much time that it is unlikely to be done.

[0005] Audio/visual surveillance systems are employed in tens of thousands of patrol cars today. In mission critical environments, such as those contemplated by mobile surveillance systems, tape is not a first choice, since, for all practical real-time purposes, the tape has been incapable of writing in a random access manner, unlike a hard disk that is a completely random access process. Typically, conventional streaming devices are problematic because losing any information for any reason at any point renders the remaining information beyond that point useless. For example, conventional analog or digital tape has stored thereon a directory or index of content stored on the tape, including start and stop information of content stored on the tape (e.g., streaming video). In the event that the directory or index information is corrupted or some portion of the content is destroyed, all content on the tape is lost. In the event that some portion of the content is destroyed, all content after the destroyed portion of the content is lost. In either situation, the lost content is generally unrecoverable. For these and other apparent reasons as understood in the art, tape systems have generally been avoided for use in mission critical environments, especially those utilized in harsh environments, such as mobile surveillance systems.

[0006] Conventional storage systems utilize storage mediums that are problematic for practical surveillance applications due to capacity limitations. As shown in Table A below, standard random access devices have limited capacity and/or have other serious limitations for practical surveillance applications used in harsh environments. In this table, the capacity of the media is given in bytes. DVD and CD-ROM have limitations in that recording is a once-only operation, and is not capable of start-stop recording. A hard disk can handle moderate shocks, but will be destroyed in a removable application if dropped. Although analog tape will continue recording during a shock many undesirable artifacts are produced for several seconds after the initial shock

TABLE A

Technology	Capacity	Recordable	Shock Resistant	Serious Error Recovery	Removable Media
DVD	8 Gigs	Yes, with limitations	No	No	Yes
Blue-Ray	17 Gigs	No	No	No	Yes
HD-DVD	35 Gigs	No	No	No	Yes
CD-ROM	800 Megs Max	Yes, with limitations	No	No	Yes
Hard Disk	100's Of Gigs	Yes	To a degree	Yes	No
Analog tape	Equivalent To 4 Gigs	Yes	No	Yes	Yes

[0007] To the extent that analog or even digital tape has been used for surveillance applications, conventional techniques for writing to these tapes are problematic for those interested in searching or seeking for content on the tapes. For example, it is generally understood that compression techniques may increase storage capacity of a storage media. In the event of using tape and writing recording time information in the compressed video content, a search of the tape for a particular time of the recorded video requires a system to uncompress the video, read the time stamp information, and determine whether the time stamp matches the time desired for the search. While such a search may operate up to four times normal playback time, in the case of having several hours of content stored on a tape, the search using the technique may take an excessive amount of time. Further, because compressed video using compression techniques such as MPEG-2 (Motion Picture Expert Group-2) is non-linear, searching using techniques other than conventional read search techniques results in an imprecise and timely manual search effort.

[0008] A file directory is typically located at the front of a tape. However, if the tape directory at the front of the digital tape is lost, the content of the tape is effectively lost because all context of what is on the tape is lost, and therefore fatal to further tape usage.

[0009] Accordingly, there is a need for a recording system that provides high resolution in a compact, rugged, and reliable system that stores a high volume of data in a high fault-tolerant manner that is capable of being searched at high rates of speed.

BRIEF SUMMARY OF THE INVENTION

[0010] In overcoming the shortcomings of conventional storage systems for surveillance systems, the principles of the present invention provide for a reliable system that stores data in a high fault-tolerant manner that is capable of being searched at high rates of speed. The invention overcomes the capacity problem by providing a surveillance system that stores data to a high capacity digital tape. In the preferred embodiment, the tape has a capacity of up to 500 Gigabytes. The cassette tape has a semiconductor memory incorporated in it. The semiconductor memory provides a fault-tolerant means of storing directory information. The information stored in the semiconductor memory can be immediately accessed upon insertion of the tape to speed up tape read functions. Many other uses and advantages of the semiconductor memory that greatly enhance the surveillance system will be discussed below.

[0011] The invention provides a surveillance system, comprising: a source of a video signal; a video signal compression system electrically connected to the source and providing a compressed video signal; a directory generator for generating directory information; a digital tape cassette having semiconductor memory incorporated into it; and a digital video recorder electrically connected to the compression system and to the directory generator for recording the compressed video to the digital tape in the cassette and recording the directory information to the semiconductor memory. Preferably, the semiconductor memory is a non-volatile memory. Preferably, the semiconductor memory is selected from a Flash memory and a ferroelectric RAM memory. Preferably, the video compression is selected from the group consisting of: MPEG-1, MPEG-2, MPEG-4, and H-264. Preferably, the video signal is a high density (HD) video signal. Preferably, the directory information identifies the cassette or identifies the video signal. Preferably, the directory information identifies the location of particular portions of the video signal on the tape. Preferably, the directory information includes information for authenticating the tape. Preferably, the surveillance system is a mobile surveillance system contained in a vehicle, and the directory information includes information regarding the vehicle.

[0012] The invention also provides a method of mobile video surveillance, the method comprising: providing on a mobile vehicle a video source producing a video signal; compressing the video signal at the mobile vehicle to form a stream of compressed video data; generating directory data associated with the compressed video; recording at the mobile vehicle the stream of compressed video data to a cassette tape having a built-in solid state memory; and recording the directory information to the solid state memory. Preferably, the directory information comprises information about the vehicle. Preferably, the directory information comprises time information. Preferably, the method further comprises authenticating the video using the directory information. Preferably, the method further comprises identifying the cassette tape using the directory information.

[0013] The above and other advantages of the present invention maybe better understood from a reading of the following description of the preferred exemplary embodiments of the invention taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a block diagram of a preferred embodiment of the invention;

[0015] FIG. **2** is a schematic view showing the location of the audio, visual, and satellite sources and wireless transmissions associated with the invention;

[0016] FIG. **3** is a schematic diagram showing the electronics enclosure of FIG. **1** and the airflow through the enclosure;

[0017] FIG. **4** is a diagram illustrating the synchronization of MPEG audio/video according to the invention;

[0018] FIG. **5** is a schematic diagram of a data packet according to one preferred embodiment of the invention;

[0019] FIG. **6** is a schematic diagram showing the relationships between the software and hardware components of the embodiment of FIG. **1**;

[0020] FIG. **7** is a schematic diagram showing the details of the file system and caching scheme of the embodiment of FIG. **1**;

[0021] FIG. **8** is a diagram of a surveillance network in accordance with the principles of the present invention is utilized;

[0022] FIG. **9** is a schematic illustration of how the system of FIG. **8** captures a variety of video/audio streams and multiplexes them into a sliding window storage system;

[0023] FIG. **10** is a high-level schematic diagram showing a more detailed internal structure of the video/audio capture system according to the invention

[0024] FIGS. **11**A and **11**B together show a diagram illustrating the flow of video/audio data, surveillance data, and control data in an exemplary system according to the invention;

[0025] FIG. **12** is a diagram illustrating an exemplary partition directory and the information stored in the directory,

[0026] FIG. **13** is a block diagram illustrating the partition of the data as it is recorded on digital tape or other media in another preferred embodiment of the invention;

[0027] FIG. **14** is a block diagram illustrating the index redundancy feature of an exemplary surveillance system according to the invention;

[0028] FIG. **15** is a diagram of an exemplary system for capturing and writing data onto digital tape;

[0029] FIG. **16** is a diagram of an exemplary digital tape optionally utilized in accordance with the principles of the present invention to store content in a fault-tolerant manner and for fast retrieval of directory information;

[0030] FIG. **17** is a flow chart describing an exemplary process for capturing and writing surveillance data onto a digital tape in a fault-tolerant manner;

[0031] FIG. **18** illustrates one embodiment of how the system checks itself for errors and corrects them upon insertion of the tape cassette into the tape deck;

[0032] FIG. **19** illustrates one embodiment of how the tape self-corrects during the write function; and

[0033] FIG. **20** illustrates one embodiment of how the tape self-corrects during a read function.

DETAILED DESCRIPTION OF THE INVENTION

[0034] FIG. **1** is a block diagram view of a preferred embodiment of a surveillance system **100** according to the invention. Surveillance system **100** includes a patrol unit **102** and a command center unit **104**. In one aspect of the invention, high resolution video data for an entire patrol car shift is recorded on a tape **199** in recorder **144**, and, at the end of the shift, the tape **199** is removed by the patrol officer and transferred, as indicated by arrow **152**, to a master sled bay **154** in the command unit **104**. In this specification we shall at times refer to video/audio, audio/visual, or simple video for short, all of which mean the same thing unless otherwise clear from the context. That is, "video" is intended to include both visual and audio data. Once in the sled bay **154**, the data may be smoothly retrieved by buffering it temporarily in hard drives **158**, monitored on monitor **172**, stored on a tape via recorder **180**, or archived on a DVD or CD via a DVDR or CDR recorder **182**. In another aspect of the invention, lower resolution audio/visual data is transmitted via transmitter **147** and antenna **150** to command center antenna **161** and receiver **160** where it is buffered on hard drives **159** and monitored on monitor **166**. It also maybe stored via tape drive **180** or DVDR/CDR **182**. In addition, other information is input into system **100**, such as geographical positioning information from geographical positioning system (GPS) **108**, and general information from a generalized input **122**, which general information can be information related to an event, such as shotgun removed from cradle, chase, robbery in progress, accident, explosion, and other information, such as vehicle speed, vehicle direction, vehicle elevation, vehicle or camera identification or any other information useful for surveillance, law enforcement, emergency response or associated with the video/audio being recorded. It should be understood that patrol unit **102** represents an exemplary application of the invention. The invention can be advantageously applied in any mobile vehicle, such as a bus, a car, a truck a train, an airplane, a boat or a ship. As will be seen below, the invention can also be applied in a stationary environment, such as a retail store, a warehouse, a public building, a hospital, an operating room, a classroom, or any other environment where high-resolution fail-safe surveillance would be of advantage.

[0035] Turning now to the details of the invention, patrol unit **102** includes a satellite signal receiver **108**, a first audio source **110**, a second audio source **112**, a third audio source **114**, a fourth audio source **116**, a first video source **118**, a second video source **120**, a general input source **122**, and an electronics box **130**. Electronics box **130** includes a housing **134**, a switch **138**, which is optional and therefore is shown by dashed lines, an MPEG-encoder **132**, an MPEG encoder **136**, and a computer **140**. MPEG encoders **132** and **136** maybe Mpeg-1, MPEG-2, MPEG-4, or H.264, and may have conventional resolution or high density (HD) resolution. High density resolution means any of the formats used or proposed for a resolution greater than the conventional NTSC resolution of 525 lines scanned at 29.97 frames per second with a horizontal resolution of 427 pixels. Computer **140** includes a solid state recorder/reader **127**, solid state media **128**, CD or DVD burner **129**, parallel and serial ports **141**, processor **142**, RAM **143**, a tape drive **144**, a timing marker generator **145**, a plurality of hard drives **146**, a transmitter **147**, and a receiver **148**. Patrol unit **102** also includes antenna **150**. Solid state recorder/reader is preferably a Flash or FeRAM recorder/reader, and solid state media **128** is preferably a Flash or FeRAM memory, though they maybe any other suitable solid state system. Preferably, at least one of the media on which the video is recorded is removable; this maybe the tape **199**, at least one of the hard drives **146**A, or the solid state media **128**. In some embodiments, there maybe more than one removable medium.

[0036] Command center unit **104** includes master sled bay **154**, command center server **157**, receiver **160**, antenna **161**, MPEG-1 monitor **166**, computer **170**, tape recorder **180**, and DVDR recorder **182**. As known in the art, master sled bay **154** is essentially a plurality of removable media drives, such as **151**, **153**, **155**, and **156**, along with control electronics. These drives may be tape drives, hard drives, solid state media drives, or any other drive for reading/recording on a removable media. Command server **157** includes processor **158**, hard drives **159**, RAM memory **162**, MPEG decoders **163**, and MPEG-1 decoder **165**. Preferably, the hard drives **159** are organized into a RAID (Redundant Array of Inexpensive Disks) type storage system. Computer **170** includes monitor **172**, electronics **174**, including a processor and input and output cards as known in the art, and input device **176**, which preferably is a keyboard. The various components of command unit **104** are connected by appropriate interfaces **190-194** as known in the art. Preferably, interfaces **190**, **191**, and **192** are SCSI interfaces.

[0037] In FIG. **1**, only the components of the surveillance system **100** essential for understanding the invention are specifically shown. As known in the art, the system **100** will include many other electronic parts such as clocks, ports, busses, motherboards, etc., necessary for the functions described.

[0038] The invention operates as follows. The satellite antenna **108** receives a GPS (Geographic Positioning Signal) and time signal T from satellites in orbit. How such signals are produced and received is well known in the electronics art. The GPS and time signals are fed to a serial port **141**.

The time signal is used to periodically set the clock of computer **140**. Periodically, the GPS signal is processed, as known in the art, to produce geographic positioning information, which is buffered and recorded as will be described in detail below (FIG. **6**). In the preferred embodiment, the patrol car position is determined every five seconds. The audio sources **110**-**116** provide audio signals A**1** through A**4**, and the video sources **118** and **120** provide video signals V**1** and V**2**. Preferably, audio sources **110**, **112**, and **114** are microphones, and audio source **116** is an audio input that tracks the audio exchange with the police dispatcher via the patrol car radio. Video sources **118** and **120** are high-resolution video cameras. Signals A**1** through A**4** and V**1** and V**2** are directed to MPEG encoder card **132**. Optionally, a switch **138** can direct a selected video signal and a selected pair of audio signals to MPEG encoder card **136**. Switch **138** may be activated from within the patrol car, or it may be activated from the command center via receiver **148**. Alternatively, a predetermined pair of signals A**1** through A**4** and a selected one of signals V**1** and V**2** maybe directed to MPEG encoder **136**, which preferably is an MPEG-1 encoder. Encoder card **132** is a dual decoder in that it decodes two channels **132**A and **132**B of MPEG signals. The encoded MPEG signals, which are preferably MPEG-2, from encoder **132** are buffered in hard drives **146** and written to a tape, preferably a cartridge tape, via recorder **144** as will be described in detail below. The encoded MPEG-1 signal from encoder **136** is buffered in RAM **143** and transmitted via transmitter **147** and antenna **150**.

[0039] The encoded MPEG-1 signal is received via antenna **161** by receiver **160**, processed by processor **158** as directed by software as described in more detail below, buffered in hard drives **159**, decoded by MPEG-1 decoder **165**, and displayed on MPEG-1 monitor **166**. This process, as well as the activation of switch **138** in patrol unit **102**, is controlled via computer **170**. The MPEG-1 signal may also be stored via tape recorder **180** or DVDR/CDR recorder **182**, or, as shown in FIG. **4**, stored via a VHS recorder **460**.

[0040] The removable media on which the MPEG signal is recorded is transferred to sled bay **154** by inserting it into one of removable drives **149** at the end of a patrol car shift or as required by operational policy. The data on the media is then processed by server **157**. As discussed in more detail below, via a software program stored in memory **162**, the instructions of which are processed by processor **158**, the data is buffered in hard drives **159**, depacketized, and decoded by MPEG decoders **163** into audio and video signals. The video signals are applied to monitor **172** to view the video while the audio signals are applied to speakers **178** and **179**. Often, the decoded signals are also stored in some form. For example, utilizing computer **170**, a user may select a certain portion of the recorded tape as being particularly relevant in a particular court matter. This portion may be depacketized and the MPEG data may be burned into a DVD disk via DVDR recorder **182**. This disk may then be taken to court as evidence, without the need to have the entire command center **104** in court. The depacketized and decoded audio and video signals maybe stored by recording on tape via VHS recorder **180**. However, since the VHS tape would not include authentication information (see below), such VHS tapes would generally be used for training purposes only.

[0041] FIG. **2** is a schematic diagram showing the preferred locations of the audio and sound sources and the electronics box **130**A or **130**B with respect to patrol car **202** and officers **230** and **232**. Electronics box **130**A is preferably located in the police car dash, and includes a removable tape, hard drive, or solid state memory **131** that is accessible on the dash. It also is may located in the trunk **206** of patrol car **202**, such as at **130**B, or may be located under a seat or elsewhere. First video source **118** is preferably a high-resolution miniature video camera located just above the rear view mirror, and its lens is directed forward through the windshield **204** of the patrol car **202**. Second video source **120** is preferably a high-resolution miniature video camera located next to the first video source, but is directed rearward and includes a wide angle lens to capture everything that occurs inside the passenger compartment **208**. First audio source **110** preferably is a microphone, preferably located on a first officer **230**. Second audio source **112** preferably is a microphone, preferably located on a second officer **232**. Third audio source **114** is preferably a directional microphone located in a hidden position near the rear of the passenger compartment **208**. The directional characteristics are selected to capture audio anywhere in the passenger compartment **208**. Fourth audio source **116** is preferably a microphone associated with the two-way radio in the patrol car so as to capture the communications with the dispatcher. As known in the art, GPS satellite **212** is preferably located in stationary orbit of the earth. The headquarters **220** may be located anywhere that has access to a wireless signal via antenna **161**.

[0042] FIG. **3** shows the interior of electronics box **130**, which maybe **130**A or **130**B. The electronic components **132**, **136**, **138**, **141**, **142**, **143**, **144**, **146**, **147**, **148** (FIG. **1**) are mounted on one or more circuit boards **350** that are suspended on flexible shock absorber supports **356** attached to housing **134**. Note that the components are only shown generally on board **350**; thus, the various elements, such as **358**, are not meant to illustrate specific components in specific places. The box **130** maybe vented via a fan with cooling air entering at entrance port **310** and exiting at exit port **312**, or may be a non-fan system using heat dissipation fins only. Ports **310** and **312** are preferably coupled to the outside air. Ports **310** and **312** are coupled to enclosure **134** via a flexible strain relief **360** to reduce jarring of the electronics by forces exerted on the ports. The cooling air follows a path shown by arrows **314**. Enclosure **134** preferably has a volume of less than 0.15 meters cubed, more preferably 0.1 cubic meters or less, and most preferably 0.03 cubic meters or less.

[0043] In one embodiment, the tape drives **144**, **151**, **153**, etc., are Sony AIT tapes, which are described in detail below, or maybe an ADR™ tape drive manufactured by OnStream Data B.V., based in the U.S. and the Netherlands. These tapes utilize a completely enclosed cartridge. Several features of the preferred tape drive relevant to the invention are that the tape moves in a serpentine manner, the index is essentially in the middle of the tape, and the tape speed varies with the rate at which data is arriving. The index in the middle of the tape increases the speed at which the index can be written to and read. The variable tape speed allows the density of data on the tape to be maximized. For example, when the video is essentially static and little data is being generated, the tape slows down so that this little data is not spread over an unnecessarily large length of tape. This tape drive has rapid seek speeds, exceptional transfer rates, data reliability, and maximized media life. A single tape can store

60 gigabytes in the preferred mode, and up to 120 gigabytes if necessary. The ADR™ tape system has a 10^{19} bit error rate.

[0044] Turning to FIG. **4**, a graphical representation of the synchronization capabilities of the surveillance system **100** according to the invention is shown. In this illustration, four MPEG channels are synchronized and monitored simultaneously on monitor **170**. The essential elements illustrated are digital removable drives **151**, **153**, **155**, and **156**, the hard drive buffers **159**, MPEG-1 channel selector **538**, MPEG decoders **430**, **432**, **434**, and **436**, monitor **170**, speakers **178** and **179**, antenna **161**, MPEG-1 monitor **166**, MPEG-1 decoder **165**, and VHS recorder **460**. A digital removable media recorded according to the invention is inserted into each of the four drives **151**, **153**, **155**, and **156**. In the preferred embodiment discussed above, from four tapes or other media, eight MPEG channels are available as follows: channel **410** carries the exterior video and the audio from the two officers in a first patrol car, channel **412** carries the interior video, the interior audio, and the dispatch audio from the first patrol car, channel **414** carries the exterior video and the audio from the two officers in a second patrol car, channel **416** carries the interior video, the interior audio, and the dispatch audio from the second patrol car, channel **418** carries the exterior video and the audio from the two officers in a third patrol car, channel **420** carries the interior video, the interior audio, and the dispatch audio from the third patrol car; channel **422** carries the exterior video and the audio from the two officers in a fourth patrol car; and channel **424** carries the interior video, the interior audio, and the dispatch audio from the fourth patrol car. Any four of these eight MPEG channels maybe fed to anyone of MPEG decoders **430**, **432**, **434**, and **436**. The video from the selected channels is synchronized so that frames shot at the same time are simultaneously viewed on monitor **170**. Another feature of the software is that the time and location of an event can be entered and the system will search for this time and location and display it. The time and location maybe displayed with the event. Further, the video can be advanced and monitored frame-by-frame. Thus, if each of four patrol cars were at an event, synchronized videos **452**, **454**, **456**, and **458** of the event shot from four different perspectives maybe viewed simultaneously either in actual motion, slow motion, or frame-by-frame. From such simultaneous monitoring, dynamic analysis of the event, such as echo ranging, audio forensics, and weapon determination, can be quickly and accurately performed. Similarly, selected pairs of the eight audio tracks available maybe simultaneously played on speakers **178** and **179**. Similarly, if a plurality of cars is at an event, one of the plurality of MPEG-1 videos available maybe selected via selector **438** and monitored on MPEG-1 monitor **166**. Alternatively, a selected MPEG-1 channel maybe decoded and recorded on VHS recorder **460**. For example, this MPEG-1 channel could be a real-time video of the same location at which the scenes **452**, **454**, **456**, and **458** were shot. The foregoing is not intended to be exhaustive of the possible uses of the system according to the invention; and, in fact, a myriad of different applications are possible. Rather, the above scenarios have been presented as examples of the use of the system **100** to better illustrate its operation.

[0045] As discussed above, the MPEG encoding and coding used in the invention are standard processes known in the art, and thus they will not be described in detail herein. A detailed description of the MPEG systems and processes is contained in "An introduction to MPEG video compression", by John Wiseman; "Coding of Moving Pictures and Associated Audio for Digital Storage Media at up to about 1.5 Mbit/s", ISO/IEC 11172-2: Video (November 1991); and "Generic Coding of Moving Pictures and Associated Audio Information: Video", ISO/IEC 13818-2 Draft International Standard (November 1994), all of which are hereby incorporated by reference to the same extent as though fully disclosed herein. However, the packetizing of the encoded MPEG data and the arrangement of the packets in the data stream provided by the invention are novel. An illustration of an audio/visual data stream **501** as it can appear on a tape **199** according to the invention is shown in FIG. **5**. FIG. **5** shows two portions **502** and **503** of a single data stream **501**. Portion **503** is a continuation of portion **502**, though there is a substantial portion between the two portions **502** and **503** that is not shown, as indicated by the dots. The two portions are shown on separate lines because of the width limitations of the USPTO drawing page. As discussed above, two MPEG channels, preferably MPEG-2, are encoded from a single patrol car. The data from the first MPEG-2 channel is carried in packets, which in FIG. **5** are designated as VA, while the data from the second MPEG-2 channel is carried in packets designated as VB. Each MPEG-2 channel includes a video channel and two audio channels. In the preferred embodiment, the exterior video photographed through the windshield of the patrol car is combined with the audio from the two officers for one channel, and the video of the interior of the car is combined with the audio from the interior of the car and the dispatcher. This is the preferred arrangement because in many events the police officers are outside the car, and, of course, the dispatcher and internal car audio are more likely to correlate with the interior video of the car. However, other combinations are also possible. In addition to the MPEG-2 channels, the data stream **501** also includes data packets which contain digital data that generally is neither audio nor visual, which packets are designated with a "D". The packets D preferably contain specific types of information at specific locations; for example, geographic information maybe located at a first location **560**, information relating to if and when the officer removes the patrol shotgun from its cradle and when it is returned at a location **561**, radar information, such as recorded speeds, at a location **562**, and any other information of interest to the user at location **563**. More or less data locations may be in the packet D. In the preferred embodiment of the invention, a packet D is generated every five seconds, though other periods may be used, or other criterion for when a data packet D is generated may be used. Finally, the tape includes tracking information that is recorded at a QFA (Quick Find and Access) location **530**. Preferably, the QFA location is at or near the center of the tape. This data includes year data **531**, month data **532**, day data **533**, an MD5 hash value **534**, as well as other data **535**. As will be discussed in more detail below, to enable a quick find function, the tracking information is preferably stored in a buffer and is recorded on the tape just before it is removed. In addition, all the information in the D packet and the QFA is recorded in a header associated with each packet. One such header **515** having data locations **516**A through **516**H is shown for the VA packet **504**. Every VA and VB packet has a similar header. Alternatively, this data is stored in a GOP (Group of Pictures) header extension user data field. The fact that the data

is also stored in the headers permits the D data and the QFA directory data to be reconstructed in case of a sudden power failure or other failure of the system that corrupts the D or QFA information. The system **100** according to the invention provides a utility that performs this reconstruction process.

[0046] The audio/visual packets VA and VB preferably are of variable length, depending on the complexity of the information being captured. For example, if the scene being photographed is rapidly changing, the packets will be longer, and if the scene being photographed is static, the packets will be short. In the preferred embodiment of the invention, the longest packets are 32 kb-20 bytes and the shortest packets are 21 bytes. The packets are created and placed in the stream by a protocol that depends on the amount of data in a buffer and other efficiency factors. Those skilled in the art of communication buffers will be able to create appropriate packets; thus, the details of this protocol shall not be discussed herein. Many different such protocols maybe used. In the portions of the data stream shown in FIG. **5**, the data stream includes three VA packets beginning with packet **504**, four VB packets beginning with packet **506**, three VA packets beginning with packet **516**, two VB packets beginning with packet **520**, four VA packets beginning with packet **521**, and two VB packets beginning with packet **526**. There are also two D packets **510** and **512**, one being inserted just before packet **514** and the other after packet **526**. Packet **524** was not placed sequentially after the other VB packets in the **521** series because the tape is partitioned to reserve the location **530** for the QFA data.

[0047] FIG. **6** is a schematic diagram **600** showing the primary software components of the preferred embodiment of the invention and the relationships between the software and hardware components in the preferred embodiment. In the preferred embodiment, the software of the invention is made to run on a Windows™ operating system. As known in the art, the state-of-the-art Windows™ operating systems include a kernal mode **602** and a user mode **604**. Physical devices **606**, such as tape drives, are connected into the Windows™ system via a hardware abstraction layer (HAL) **624**. In addition to the HAL **624**, the kernal mode includes a system services layer **620**. Between the system services layer and the HAL layer, a Windows™ Executive system **602** operates. Windows™ Executive System **602** includes an object manager **626**, a virtual memory manager **628**, an I/O manager **630**, a cache manager **630**, and a process manager **634**. The system services layer communicates with the HAL layer via device class drivers **636**, which are part of the Windows™ system and specific mini-port drivers **612** provided by the manufacturers of the physical devices, which integrate into the device class drivers as indicated by the notch **637**. The system services layer **620** and the user mode applications above it communicate with the device drivers via unique file system software **610** which forms an important part of the invention and will be described below. As known in the art, the user mode **604** includes a Windows™ security system **640**, a Win32 subsystem **642**, as well as other subsystems **644**. Client threads, also known as applications, such as **650**, **652**, **654**, and **656**, communicate with the kernal mode through one of the subsystems, depending on the functions they implement. As will be seen below, the encoder and decoder systems are specific client threads.

[0048] The inventive file system **610** and how it operates the hardware described above is illustrated in FIG. **7**. The right side of FIG. **7** describes the file system as it operates in the electronics box **130** of the patrol car, while the left side describes the file system as it operates in the command center **104**. As suggested above, the file system **610** accepts data from the application threads **159**, **710**, **712**, and **132**, which are specific instances of the client threads of FIG. **6**, processes the data, and delivers it to the device class drivers **636**, which deliver it to the physical devices. The physical device of most interest herein is the tape drive **144** within the patrol car **202**. The specific application threads of interest are the MPEG-2 encoder **132** channels **132**A and **132**B and the MPEG decoder channels such as **410** and **412** (FIG. **4**). As discussed above, in the preferred embodiment of the invention, there are two MPEG channels **132**A and **132**B from encoder card **132**. In FIG. **7**, one of the threads is labeled **132**. However, the other thread is labeled generally as an application thread **712**. The threads are also labeled V**1** and V**2** to indicate which video source is involved, though it should be understood that audio sources are also included. Likewise, there are two MPEG decoder channels in the preferred embodiment of the invention, but one is labeled generally as an application thread. This has been done to emphasize the fact that the file system **610** according to the invention has many applications other than serving to organize and direct MPEG data. That is, the patrol car application discussed herein is only one example of the use of the file system **610**. In the discussion of the operation of the file system **610** to follow, the functions of the various software elements of FIG. **6** will not be discussed in detail since these are well known in the art. However, it will be understood by those knowledgeable about the Windows™ operating system that many of these elements assist in the operations described.

[0049] In the file system **610** according to the invention, the data generated by application threads **712** and **132**, which in the application herein are encoded MPEG audio/video channels, is directed to per file write cache buffers **720**. Each application thread, that is, each MPEG channel, is directed to a different buffer. The V**1** channel is directed to buffer **724** and the V**2** channel is directed to buffer **726**. In the embodiment shown, there can be up to four application threads, as four buffers are shown; however, more than four application threads and more than four per file write cache buffers may be used. The data in the buffers **720** is organized into VA, VB, and D packets and interleaved into a data stream **501** by write multiplexer thread **730**. The data stream is directed to streaming write cache buffer **734**. The purpose of streaming write cache buffer **734** is to eliminate any differences between the flow of the data stream and the operation of tape **144**, which differences can arise in the mechanical operations of the tape drive. For example, the tape must pause in accepting data when it reaches the end of the tape and reverses. During this time, the streaming write cache buffer will collect and hold the streaming data. The write streamer thread **736** forms the final streamer thread and directs it to driver **636**, which delivers it to tape **144**. The data stream is parsed continually in write streamer thread and tracking data, such as the location of GOP (Group of Pictures) headers, and year/month/day information is stored in directory cache **738**.

[0050] In another embodiment of the invention, the MPEG GOP headers are modified to add the geographic and year/month/day information. Other digital information also may be added to the GOP headers. In this embodiment, the decode system software is modified to read this information.

In another embodiment, this data is periodically added to the MPEG-1 stream with a marker to permit it to be easily found. This information is preferably displayed directly on the screen on the monitor with the video, although this feature can be turned off.

[0051] Content verification of the video, audio, and GPS data is done via computation of an MD5 (Message Digits 5) hash on the data streams as they are output from the hardware encoding devices. To insure that encoded data is not modified and re-hashed, an administratively designated non-retrievable pass-code is assigned to each Mobile Unit before it enters the field. The resultant hash codes, a combination of data and pass-code, is stored with the directory data and can be used to tell if any of the data streams have been modified. MD5 hash codes (128-bits) are computed over video GOP (Group of Pictures) intervals; i.e., they are constructed from all video, audio, and PS encapsulation data between GOP headers. This process is not an encryption or watermarking scheme. The message digest function is also sometimes referred to as a one-way hash function.

[0052] The MD5 hash function is a one-way algorithmic operation that transforms a string of data of any length into a shorter fixed-length value, usually 128 bits or 16 bytes long. The algorithm is coded in such a way that there is a negligible probability that any two strings of data will produce the same hash value. If just a single piece of data is changed, a different hash value results. At anytime, data integrity can be checked by running a utility verification program supplying the original pass-code, which program is generally referred to as a checksum procedure. That is, the data integrity can be verified by running a hash operation on the data and the private pass-code, i.e., the one assigned to the patrol car when it enters the field. The resultant hash value is compared to the hash value stored in the data. If the two values match, that data has not been altered, tampered with, or modified in anyway, and the integrity of the data can be trusted. This comports with the "best evidence rule" and authentication requirements used by courts. The MD5 algorithm is a well-known standardized algorithm. Thus, it will not be further discussed herein. It is generally believed that it is computationally infeasible to duplicate an MD5 message, or to produce any pre-specified MD5 message.

[0053] Just before the tape is removed, the information from directory cache **738** is written to the QFA portion of tape **199**.

[0054] The operation of file system **610** in command center unit **104** is the reverse of its operation in the patrol car. The data stream is read out of the tape drive via the device class drivers **636** and delivered to the read streamer thread **744**. The read streamer thread **744** directs it to streaming read cache buffer **748**, which smoothes out any discrepancies between the flow of data and the mechanical operation of the tape drive **144**. The data stream is demultiplexed by read demultiplexer thread **750**, and the data associated with each application thread is cached in the appropriate one of per file read cache buffers **760**. Namely, the data from the V1 MPEG channel is cached in buffer **762** and the data from the V2 channel is cached in buffer **764**. The buffers then stream the data to the corresponding application thread, which in the exemplary embodiment is the corresponding decoder **163** or **710**. Those skilled in the art will recognize that the hard disks **146**, together with the microprocessors **142**, under software control, act as the buffers and multiplexers of the patrol car side, while the hard disks **159** and microprocessor **158**, under software control, serve as the buffers and demultiplexer of the command center side. These buffering and multiplexing functions are well understood in the computer art and, therefore, will not be described in detail herein. The file system **610** also includes statistics and interval time thread **766**. Thread **766** provides a set of private I/O Control (IOCTL) codes that allow an application program to set options and gather statistics on file system performance. The statistics gathered can be used to tune cache buffer sizes and optimize aspects of the read/write streaming algorithms.

[0055] The streaming write capabilities of sequential access devices dictate that write operations always be performed at the current End-of-Data location. This knowledge forms the basis of the above-described two-stage write cache architecture. Write caching is done on a per-file basis to decouple slow sequential device access times from the application thread requesting the synchronous write operation. For synchronous writes, the application thread is blocked only until write data has been queued to the write cache buffers. The write queue is serviced by an internal worker thread that is directed by a multiplexing algorithm, which places its results into the device's multiplexed-write queue. The multiplexed-write queue is serviced by an internal worker thread that is directed by a streaming algorithm optimized for device write streaming. To mitigate paging area contention, internal cache areas are backed by temporary files on disk-based file systems, preferably on non-paging NTFS drives. Data from multiple file write sessions is multiplexed at the media block level such that the average data rate for a given file is maintained over time.

[0056] The streaming read capabilities of sequential access devices permit random read access. Because of this capability, and the need to permit multiple simultaneous reads, the read cache process is not an exact mirror of the write cache process. Read data is read-ahead streamed off the device and placed into the multiplexed-read queue. When a specific file is opened, its data is broken out from the multiplexed-read queue into its own read cache buffers. The read cache buffers and the multiplexed-read queue are filled by a special algorithm optimized to give increased read performance priority to files that were opened first.

[0057] The system **100** uses a TCP mediated distributed architecture providing flexible scalability through the addition of modular components. This network-based approach uses TCP/IP point-to-point connections for commands that don't require synchronization (i.e., configuration and monitoring). For synchronized activities, a UDP connectionless protocol is used to broadcast commands providing more accurately synchronized record/play/stop/pause functionality across the distributed architecture.

[0058] A feature of the invention is that sequential write performance is equivalent to that of writing to a physical disk drive. Read performance is based on a number of factors. If the files being read were written at the same time, i.e., their blocks were multiplexed close together, then read performance is equivalent to that of reading from a physical disk drive if the average aggregate read data rate is not greater that that of the underlying sequential access device. If aggressive head movement or volume exchange is required to obtain their data blocks, then read threads are delayed until such data can be located.

[0059] Other details of the system **100** are as follows. Since the geographic information is available via the

MPEG-1 stream as discussed above, this information can be used to locate the patrol car in an emergency. It is also evident that the invention can be used to construct all-points news bulletins, notification to other departments, and has many applications for training purposes. The system **100** includes electronic circuitry, software, and processes to provide remote power-on/boot and power-off from the patrol car dashboard, full cycle boot at power up without user intervention, vehicle ignition-controlled start and shutdown, programmable shutdown, battery) fed continuous operation after ignition shut down, vehicle speed, direction, and location integration via the GPS information, out-of area and failure notification, and status of storage available indication. System status lights and failure lights are dashboard mounted. The central command center features include: on-demand wireless communications with mobile units for audio and video "real-time" viewing, post-event playback and review capabilities, multiple unit synchronization, full VTR controls with added search capabilities, and post-production capabilities. Existing MDT, CDMA, or cellular technologies can be incorporated for the wireless transport of the MPEG-1 signal, geographic and time data, patrol unit and shift, and other significant information. Built-in diagnostics monitor video encoder status, battery condition, power supply output, system operating temperature, and many more system conditions. The command server **157** has been designed using a single board computer (SBC) with the Coppermine™ 700 MHz Pentium III Processor, and up to 512 MB of Random Access Memory (RAM). The SBC is designed to be a functioning "mini" computer built onto a PG card. In the event of a failure of the board, CPU, or RAM the card is simply replaced without dismantling the entire system As indicated above, the command server can be equipped with CD-ROM recorders, DVD recorders, or digital tape recorders for long-term archival depending on client needs. The Raid system **159** is preferably a RAID 01 system with mirrored hard drives. The cameras are high-resolution color for normal light IR with monochrome imaging for low or no light situations. They both have wide-angle camera lenses and include a composite video splitter, i.e., two inputs to one composite output. The front facing color camera **118** features a ½-inch CCD capable of capturing an NTSC image with 480 lines of horizontal resolution. The minimum illumination is 1.0 Lux through an auto iris F/1.2 lens. The rear facing wide-angle color camera 120 features a ¼-inch CCD capable of capturing an NTSC image with 350 lines of horizontal resolution. The minimum illumination is 2.0 Lux through an F/2.0 lens. The interior microphone **114** is sensitive to 1V/Pa@1 kHz (−2.5 dBV±4 dBV) and has an output impedance of less than 150 Ohms. The voice input distance ranges from 7 cm to 1.5 m to accurately capture all audio within the seating area of the patrol car.

[0060] The system includes automatic file naming with unit number, date, time, and shift, which is included in the QFA section.

[0061] A feature of the invention is that the streaming tape recorder capable of a data rate equal to or greater than the aggregate recording rate permits VCR-like functionality in a digital tape recorder of much higher resolution.

[0062] Current mobile surveillance systems record to analog VHS tapes or camcorders. The problem with analog VHS tapes is that the video quality is poor and most tapes record for only a couple of hours. Some manufacturers claim much longer recording times of up to eight hours, but those are typically at very slow frame rates of recording, making for jerky movements and poor image quality. A feature of the invention is that DVD-quality video results. Additionally, digital tapes can be reused for 30,000 cycles and the shelf life for digital tapes with no degradation in quality approaches thirty years as compared to 30 cycles and one to five years for analog tapes.

[0063] It is a feature of the invention that the data is streamed to digital tape in real time. Except in cases where the tape is changing direction or some similar event, the data is processed immediately and passed to the tape, rather than being stored for a significant time, for example, for a time greater than normal computer processing time, and then processed later. Real time also means that, from the perspective of a human being, the transfer to tape usually would appear to be instantaneous. A related feature is that, in the system of the invention, the digital recorder and digital tape comprise the primary storage system rather than a backup storage system

[0064] It is another feature of the invention that the system **100** captures full-motion video. Full-motion video is any video that captures at least 24 frames per second and more preferably at least 29 frames per second. As known in the art, the full-motion video NTSC standard is 29.97 frames per second. A related feature of the invention is that the system **100** at the same time captures full-frame video, which means any resolution of at least 720×480 pixels. A further related feature of the invention is that the system **100** can capture at least eight hours of full-motion, full-frame video on a single digital tape. A further related feature of the invention is that the system **100** can capture at least eight hours of two full-motion, full-frame videos on a single digital tape.

[0065] A further feature of the invention is that each data packet, such as **504**, is independent. By "independent", it is meant that at least a portion of the audio and at least a portion of a video frame can be reconstructed from a single packet. In the prior art, if a system were downloading a video file and the process was interrupted before it was completed, the result would be unintelligible. However, in the system **100** according to the invention, the packetization system and process results in a single packet being intelligible. Of course, the more packets that are received, the more of the sound and video can be constructed. Thus, if only a portion of a tape is available, say due to a fire or other catastrophe, useful information can still be obtained from the tape.

[0066] Another feature of the invention is that the mobile system **102** is designed for use in a dynamically changing environment. The basic unit operates in temperatures in excess of −25° C. to 81.1° C. with an optional electric temperature controlled environment. Depending on configuration, operating temperatures required for the power supply are −25° C. to 81.1° C. or −40° C. to 80° C.

[0067] The above describes a novel vehicular surveillance system that permits a full shift of two MPEG channels of full-frame, full-motion audio/video to be captured on a single cartridge tape. The system for the first time permits 24/7 patrol car surveillance at high resolution. Now that the system has been created and disclosed for use in patrol cars, it is evident it will have applications in many situations in which a compact, high-resolution surveillance system is desirable. For example, it will have applications in airplanes, trains, ships, and other vehicles. Thus, wherever the terms "patrol car" or "police car" have been used above, any other

vehicle may be substituted. It also will find use in many security applications. It is believed that the invention will make digital tape cartridges a preferred primary storage device. Examples of such applications are as follows. The system of the invention could be used in a manufacturing facility, such as an automotive assembly line or an integrated circuit manufacturing facility for quality control purposes. In such manufacturing processes, defects often occur that are difficult to find the reason for. Since it usually is known when the particular vehicle or part was manufactured, a library of 24/7/365 tapes would be useful in tracing and correcting defective processes or systems. Another example is any test operation, such as the test of a jet fighter or the destructive test of a system. Since it is often not known when the object being tested will deviate from specification, a 24/7/365 surveillance system would be useful. The system can also be useful in an operating room to record an operation from many different angles for instruction or legal purposes. It may also be used in stores, government and public buildings, and anywhere else that surveillance systems are in use today.

[0068] The surveillance system **100** according to the invention was developed to provide an improved patrol car surveillance system. To achieve this goal many novel components had to be developed. Now that the system has been built, it is evident that many of these elements will have important uses in other applications. For example, the file system **610** according to the invention that streams data to digital tape will be useful in many instances in which rapid streaming of sequential time and/or geographic synchronized data is desired. For example, it is useful in database logging, ISP logging, transaction logging, firewall logging, backups, general audio/video encoding, and data acquisition.

[0069] A feature of the file system **610** is its ability to multiplex data from several streams into one bundled stream that is then stored on and retrievable from the tape drive. Another feature of the file systems **610** is the ability to access the tape drive from a PC as a local drive letter or as a Universal Naming Convention (UNC) mapping across a network In addition, the relative cost of tape drives and their media is less, on a per gigabyte basis, than the cost of hard drives. These features move the tape drive from its traditional position as a data backup product to that of a primary storage medium for many applications. The types of applications that are particularly targeted are: (i) those in which the data does not need to be accessed often; (ii) those in which data does not need to be written onto the tape and accessed at the same time; and (iii) any of the foregoing applications that would benefit from a removable medium.

[0070] The principles of the present invention represent a paradigm shift with respect to patrol car surveillance systems. The prior art patrol car surveillance systems were seen as tools to be subjectively used by police officers. The principles of the present invention view surveillance systems as being objective tools of administrators, prosecutors, and courts.

[0071] In addition, the principles of the present invention advance the art by overcoming conventional surveillance system problems by recognizing that the way to avoid having evidentiary gaps in the audio/visual record is to have high resolution audio/visual recording operating at all times that a police car is on patrol 24 hours a day, 7 days a week 365 days a year. With the prior art video systems, this would immediately lead to data overload. However, as described herein, the above requirement does not mean that the audio/visual system has to be able to store scores of hours or days of data in the vehicle, because patrol officers always work in shifts that generally are of from 8 to 12 hours in length. If changing the data medium is made simple enough, it can become a routine part of the shift change, and operate repeatedly and reliably.

[0072] While the replaceable hard drives that have become part of most surveillance systems today are advertised as being simple to use, in fact, few people can routinely and repeatedly perform the change and/or perform a downloading operation without incident. Further, the fragility of hard drives and the hazards of police work make the use of such drives problematic in the patrol car environment. Changing a tape cartridge is something that most people today can do repeatedly and reliably. Further, tape cartridges are rugged and tape data is rarely inadvertently destroyed. In accordance with the principles of the present invention, an audio/visual surveillance system records data and/or content to a tape cartridge within the vehicle. In one embodiment, the tape is digital tape. This provides an essentially fail-safe system in which data is reliably and routinely transferred to a central storage system at the end of each shift. The system includes a cartridge tape storage sled bay at the police headquarters or other facility to which officers return at the end of a shift. At the beginning of the shift, each officer is provided a tape cartridge, which they insert in the recorder in their patrol car. At the end of each shift, the officer simply removes the tape cartridge from the patrol car and inserts it in the tape storage sled. The rest is automatic.

[0073] The MPEG-2 video/audio compression standard is well known in the movie and video art, though it is usually associated with DVD systems. The MPEG-2 standard provides the high-resolution, dense storage associated with home DVD systems. The system and process permits the direct recording of MPEG-2 audio/visual data to a cartridge tape in a patrol car. Further, with the development of MPEG-4, this and other compression techniques may alternatively be utilized for surveillance systems in accordance with the principles of the present invention. In this disclosure, any reference to MPEG-4 includes H.264, MPEG-4/H.264, MPEG-4 Part 10, H.264/AVC or any other designation that is associated with this standard, as well as any other part of MPEG-4.

[0074] The system also provides for wireless transmission of audio/video directly from the patrol car to the central command center or headquarters. Since wireless transmission does not presently have a broad enough bandwidth to support real time streaming of MPEG-2 audio/visual, the system also provides for MPEG-1 encoding of an audio/visual signal, which MPEG-1 encoded signal is buffered, preferably in a RAM or hard drive, and then maybe transmitted on command. Preferably, the MPEG-1 encoding and wireless transmission can be initiated from either the patrol car or from the central command center via a wireless link

[0075] The system also provides an arrangement of audio and video sources that is designed to capture most, if not all, events of interest. There maybe two or more video sources, one of which captures events outside the patrol car and the other of which captures events inside the patrol car. There maybe three or more audio sources, one of which captures audio inside the patrol car, another which is on one officer's person, and a third that captures the radio exchange with the

dispatcher. If two officers are present, a fourth audio source may be on the second officer's person. One video signal and two of the audio signals are encoded in a first MPEG-2 channel, and the second video signal and the third and fourth audio signals are encoded on a second MPEG2 channel.

[0076] The two MPEG-2 signals are buffered, formed into data packets, and multiplexed into a single data stream. The multiplexed data stream is preferably buffered to remove asynchronies between the tape movement and the incoming stream, and then is recorded on the tape.

[0077] MPEG-4, MPEG-2, and MPEG-1 contain time synchronization data. As known in the MPEG art, each frame contains synchronization information. Further, the synchronization data is keyed to a GOP (Group of Pictures) header that occurs regularly, for example every 15^{th} frame, in the MPEG data, or approximately every one-half second. This synchronization data time correlates the individual MPEG frames. Geographic location data and, preferably, absolute time data may be acquired via a satellite link or otherwise. Hour/minute/second data are automatically incorporated into the MPEG data as known in the MPEG art. The tape maybe parsed and the location of each GOP header is found. This GOP header location information and year/month/day data are cached in a buffer and recorded in a tracking location on the tape. Using the year/month/day data and the MPEG synchronization data, each frame can be accurately time referenced. The absolute time signal is used to periodically update the clock of the system computer. In this manner, each frame can be time referenced within a fraction of a second. The geographic data maybe recorded in a special digital frame that is recorded regularly on the tape, preferably every five seconds. This digital frame may also include information such as if and when the patrol car shotgun is removed from its rack radar data, and any other special data that a user may desire. All of this data may also be recorded in a header to each data packet so that, in case of system failure, all the geographic and time data can be reconstructed.

[0078] Once the tape cartridge is inserted into the sled bay in the central command center or other location, the system, software, and method of the invention permit the audio/visual data to be easily retrieved, monitored, synchronized with other data, stored, and archived. This is facilitated by the fact that it is encoded via the MPEG-4 or MPEG-2 standard. The data on the tape maybe transferred to a hard drive of a command server with a form of RAID data storage. If the data is to be monitored, multiple videos can be synchronized and viewed at the same time. In one embodiment, up to four videos can be viewed at the same time. For example, if four police units were at an event and recorded the event, the event can be viewed from four different angles. The data can also be decoded and transferred to any desired medium, for example, an analog tape or a DVD disk.

[0079] The system permits the tape hard drive cache system to be accessed as a universal naming convention (UNC) drive, which is most commonly implemented as a letter. That is, using conventional software programs, such as Windows™, the invention permits the tape hard drive cache system to be designated as the "D" drive, for example.

[0080] The MPEG-1 low-resolution data stream is also buffered in the central location on a hard drive of a server. It may be decoded and monitored directly, or it may be decoded and stored on any suitable medium, such as a VHS recorder. Via the tracking data, it may be synchronized with MPEG-1 data from other units, or at a later time, with MPEG-2 data in storage.

[0081] An authentication process that ensures that the recorded audio/visual evidence will be acceptable to the courts may also be utilized. In one embodiment, a private pass-code is assigned to each patrol car as it goes in the field. This pass-code is used to generate a verification code that is stored on the tape. This verification code can be used to authenticate the data at any time by running a verification procedure, preferably a checksum procedure.

[0082] Essentially, all audio/visual information associated with a patrol car maybe reliably captured, monitored, correlated, stored, retrieved, and authenticated in accordance with the principles of the present invention. For example, a common occurrence today is that a suspect or criminal will claim officer brutality and point to bruises as evidence of the charge. Often, however, the bruises are self-inflicted after the person has been confined within the back seat of the patrol car. Each such charge, even if false, usually costs the jurisdiction a significant amount of money, on the order of $25,000.00, in investigating the charge and prosecuting it, if necessary. The invention will go a long way toward reducing and/or eliminating such expenses.

[0083] FIG. **8** is a diagram of an exemplary network **800** in which one or more surveillance systems in accordance with the principles of the present invention is utilized. The network **800** maybe configured within a city **802** and be composed of one or more communication networks. The communication network **800** may include an Ethernet network **804**, satellite network **806**, a general information network **803** and/or any other wired, wireless, optical, or the like, network. In these networks, a firewall **807** maybe utilized to ensure that content communicated and stored on the network is uncompromised by any undesirable persons or machines. In FIG. **8**, five different surveillance systems **860**, **870**, **872**, **874** and **880** are integrated into network **800**. Each of the surveillance systems **860**, **870**, **872**, **874** and **880** maybe independent or operate cooperatively with other portions of the network.

[0084] One or more video recorders **808***a*-**808***n* (collectively **808**), embodiments of the video sources **118** and **120**, operate as surveillance devices. The video recorders **808** and GPS and general information devices **809***a*, **809***b*, and **809***c* (collectively, **909**) maybe wired and connected via a physical cable, such as **810**, or wireless and communicated across a wireless link **812**. A video server **814***a* may receive video signals **816** and **818**, for example, from video cameras **808***a* and **808***b*, respectively, and other signals **817** representative of general data, such as event information, as well as GPS data, to be compressed into a compressed video signal **820** (e.g., MPEG-4 video signal and stored on a digital removable media, such as a tape chive **822**, a semiconductor memory drive **823**, or a removable hard drive, in accordance with the principles of the present invention. In addition, the compressed video signal **820** is preferably stored on a hard drive **815***a* in server **814***a* or other medium to either as a backup or as a primary storage device. A timing marker generator **821***a*, **821***b* is also included in servers **814***a* and **814***b*. The video recorders **808** may output the video signals as digital signals in a digital stream, packet format, or otherwise, or as an analog signal to be converted into a digital signal at the video server **814***a* or other controller (e.g., electronic box **130** of FIG. **1**). A CD burner **824** may

additionally be configured with the video server **814***a* or storage of the compressed video signal **820**. As shown, in addition to video recorders **808** being in communication with video server **814***b*, a handheld computer **826** and/or other wireless devices having an integral camera **827** may communicate with the video server **814***b* over a wireless network **828**, such as an 802.11*b* local area network (LAN). Similarly, a mobile surveillance system **860**, which maybe a system **102** as described in connection with FIG. **1**, located in a vehicle **850** can communicate with network **800** via wireless or by physical transfer of tapes **840**, as described more completely in connection with FIGS. **1-4**. It should be understood that while using compression may be preferred for storage of the video content, uncompressed video alternatively maybe utilized in accordance with the principles of the present invention.

[0085] A hub **830** maybe integrated into the network **800** and be configured to enable users on the network to access content stored and maintained by the video servers **814***a* and **814***b* (collectively **814**) accessible to the hub **830**. As shown, there maybe a number of remotely located computers **832** configured to engage the network **800**. In one embodiment, the network **800** is the Internet. The computers **832** may access anyone of the video servers **814** configured on the network as understood in the art. Accordingly, people operating the computers **832** may access content (e.g., surveillance content) that is stored on digital tapes or other media for review thereof in accordance with the principles of the present invention. Alternatively, a camera **876** and other surveillance devices may be connected to a computer or workstation **878** to provide a surveillance subsystem **874**.

[0086] FIG. **9** is a schematic illustration of a portion **900** of a surveillance system, such as **860**, **870**, **872**, **874** or **880** of FIG. **8**, showing how the system captures a variety of video/audio streams and multiplexes them into a sliding window storage system. As shown, a plurality of video capture systems **902***a*-**902***n* (collectively **902**) maybe utilized to generate, or receive and communicate, a digital video signal **816**. In one embodiment, the digital video signal **816** is an MPEG video stream that includes video and audio signals. The capture systems **902** maybe video the video cameras **808***a*, **808***b* etc. of FIG. **8**, video recorders, or other similar devices configured to output the digital video signal **816**, computer hardware, such as a processor, configured to receive a video signal and convert it to a particular format (e.g., MPEG-1, MPEG-2, MPEG-4, MPEGH.264 etc.), a buffer configured to receive and output the digital video signal **816**, or other device as understood in the art. Each capture system **902***a*, **902***b*, **902***c* through **902***n* has a separate control system **903***a*, **903***b*, **903***c* through **903***n*, respectively. Splitters **904***a*-**904***n* (collectively **904**) are utilized to split the video and audio content from the digital video signals **816** into a video signal **906** and audio signal **908**. As shown, the splitters **904** maybe MPEG splitters, but any other compression system splitter may be used. In addition, each of the systems my have a different pixel density or resolution, such as conventional definition 0f 210,000 pixel resolution or high definition of about 2,000, 000 pixel resolution. As shown, each splitter is configured to communicate solely with a respective capture device. The separate capture, control and splitter devices, which are also reflected in the separate encoders **1104** and decoders **1188** of FIGS. **11**A and **11**B, permit each video stream to have its own compression scheme, its own resolution or definition, its own transmission rate, as well as any other special parameter. The transmission rate can be controlled with controls **903***a*-**903***n*, thus, for each channel (stream) the transmission rate is variable. It should be understood, however, that a single splitter maybe configured to handle one or more digital video signals **816** being generated from multiple video capture devices with the use of a switch, multiplexer, or other device to channel the digital video signals **816** from the particular capture device.

[0087] A multiplexer **910** is configured to receive the video signal **906** and audio signal **908** from each of the splitters **904** and form a multi-channel content stream **912** that includes the video signal **906** and audio signal **908**. The multi-channel content stream **912** is input into a sliding window **914** for use in writing onto a medium, such as digital tape, a removable hard drive, or other media. The sliding window **914** maybe a processor executing software configured to operate as a sliding window as understood in the art.

[0088] FIG. **10** is a high-level block diagram of the video flow in the preferred embodiment of the surveillance systems of FIG. **8**. An input section **1002** may include an input crossbar **1004** that, in one embodiment, is configured to select and convert one of an analog or digital input into a pure digital frame, such as a YUV2 frame, as understood in the art, and receive one or more audio inputs. There maybe a number of different inputs into the input crossbar **1004**, including a left/right (L/R) audio input **1006**, two surround—1 center channel input **1008**, composite input **1010**, S-video input **1012**, Yapp component input **1014**, BNC input **1016**, and HDM/HDCP input **1018**, which are well understood in the art.

[0089] The input crossbar **1004** outputs a digital signal **1005** including YUV2 frames and audio signal to a digital video/audio compressor **1020**. The digital video/audio compressor **1020** receives the digital frame and applies a compression scheme to reduce the data to a manageable size. The compression scheme maybe any compression scheme utilized to compress digital video signals as understood in the art. The compressed video signal is output from the digital video/audio compressor to an optional multiplexer **910**. The multiplexer **910** is configured to receive multiple video streams and combine them into a synchronized or multi-channel content stream **912**. The multi-channel content stream **912** is buffered to a hard disk using a sliding window **914**, where video segments are added to the back of previously stored video segments. The multi-channel content stream **912** is separated into disk segments at **1028**. At **1030**, the video stored onto the hard disk is read from the front. A sliding window segment reconstructor **1032** reconstructs the video and generates a video stream **1034**, which is communicated to a tape system **1036**. The tape system **1036** writes the incoming video stream **1034** to digital tape cassette **840** on the tape drive **822** (FIG. **8**). This large buffering scheme allows for real-time video to continue without loss, even if the tape drive **822** slows while performing lengthy seek operations.

[0090] FIGS. **11**A and **11**B together show a diagram illustrating the data flow in an exemplary system **1100** according to the invention, which maybe a portion of any of the surveillance systems **860**, **870**, **872**, **874** and **880** of FIG. **8**, or may include portions of several of these surveillance systems under network control. System **1100** includes a video/audio module **1102**, a general data module **1176**, a

GPS data module **1130**, a video/audio buffer **1114**, a merged event/MPEG writer **1126**, a merged video/audio/GPS/general data buffer **1136**, an input/output module **1160**, recording media **1170**, output system **1186**, video display module **1196**, and control module **1199**.

[0091] Video/audio module **1102** includes encoders **1104**, control electronics **1106**, and abstract encoder module **1108**. Abstract encoder module **1108** is designed to be compatible with all or nearly all off-the-shelve video encoders. Thus, many different video encoders, such as a direct show encoder, a canopus encoder, a DVD plus encoder, a Vweb encoder, a solid state encoder, or anyone of future encoders that become available maybe used with the system **1100**. The customer can specify which encoder is preferred, and one or more of the encoders shown may be incorporated into a specific system. Control module **1106** permits the compression type, such as MPEG 1 through 4, to be set, either variable or constant bit rate to be set, and the specific bit rate, such as 750K per second through 25 MEGS per second, to be set. Other video encoder parameters may also be set as known in the art. Input module **1102** also includes user activated inputs **1103**, such as initialize, de-initialize, start and stop. The encoded signal is output to buffer **1114** at output **1110**. Data input into buffer **1114** circulates in the buffer, is queued, and is output at **1120** as required to create the organized partitions described below.

[0092] At the same time as the video is being compressed and organized, the GPS and general data is being collected and organized in general data module **1176** and GPS data module **1130**, respectively. General data module **1176** includes a digital input/output module **1180**, a mission critical unit (MCU) **1178**, and a serial input/output module **1177**. Digital input/output module **1180** provides vehicle speed, vehicle direction, vehicle elevation, vehicle or camera identification, and other information as specified by the customer. MCU **1178** is also customer specific. It includes a one of more of a variety of relays and switches which develop a specified voltage in response to a specific triggering event, such as shotgun removed from cradle, acceleration of a vehicle that is indicative of a chase, movement of a vehicle as may be indicative of an explosion or an accident, and manual switches such as to indicate a traffic stop, a robbery in progress, or other mission specific data desired by the customer. Data from DIO module **1180** and the combination of serial input/output module and MCU module can include any other information useful for surveillance, law enforcement, emergency response, other application-specific information and other information associated with the video/audio being recorded. GPS data module **1130** includes a serial input/output unit **1131** and GPS data unit **1132**. GPS latitude and longitude telemetry information is output at **1133**.

[0093] Merged event/MPEG writer **1126** receives input from outputs **1185** and **1133**, merges it with video data output at **1120**, and feeds it to merged video/audio/GPS/general data buffer **1136** under control of inputs **1124** which include Find Next Group of Pictures (GOP), Write New MPEG file, and Event/Telemetry Data In, the latter which is a signal indicating that non-video data, such as GPS data, event data or other general data associated with the particular GOP and MPEG file is available to place in buffer **1136**. Buffer **1136** is preferably a hard disk or semiconductor storage, but it also may be any other suitable media. In buffer **1136**, separate streams **1140**, **1141** through **1142** are set up, with each stream corresponding to a particular camera **808***a* etc. or other video input device. Each stream includes an MPEG header, such as **1139**, and MPEG queue files, such as **1138**, are shown in FIGS. **11**A and **11**B. The MPEG headers include the MPEG information as known in the art as well as telemetry, roster and tape positioning information as discussed below. The buffer media **1136** will generally have less storage than a tape, and thus, will run out of storage space before the tape. When this happens, the system begins writing over the oldest data, thus, the buffer is in effect a sliding window. Data is read out from the buffer **1136** in a contiguous stream to streaming in/out module **1160**, which streams data in and out of storage media **1170** via input/outputs **1164**. Stream in/out module **1160** includes a stream-in unit **1148**, which streams data in from buffer output **1144** and stream-out unit **1150**, which streams data out to preview output **1162** and decoder **1186**. Stream-in unit **1148** and stream-out unit **1150** are specific to the particular media and customer. Module **1160** also includes an abstract stream-in steam out module **1161**, which is capable of interfacing with any of media **1170** and any stream-in and stream-out unit. Stream-in unit **1148**, stream-out electronic unit **1150**, and abstract stream-in stream-out module **1161** each are controlled through control signals **1152**, **1154**, and **1156**, respectively. Storage media **1170** preferably includes a tape drive **822** and hard disk **815**, but may also be a double layer DVD read/write system, a wireless streaming system **1159**, or a solid state streaming device **1163**. The data is read into and out of the storage media in a plurality of partitions, which will be described in detail below. In the preferred embodiment there are preferably ten or more partitions on a tape or other media. As will be seen below, the partition structure is designed to permit maximum restorability of the tape or other media in case of error or disaster. It is a feature of the invention that the digital medium on which the video signal is recorded is partitioned into a plurality of independent volumes called partitions, and a portion of the signal is recorded to each partition. Here, "partition" has its common meaning in the digital recording field; that is, as a verb, it means to divide the medium into independent volumes. As a noun, a partition is an independent volume of a digital medium. For example, if a hard disk is partitioned, disk space is allocated to a plurality of different volumes, and each volume behaves as a physically distinct hard disk and similarly for a tape or a solid state memory.

[0094] The signals from storage media **1170** is fed through output **1162** to MPEG In/Preview input **1193** to output system **1186**. Output system **1186** includes a decoder module **1187** including video/audio decoders **1188**, on-screen display control electronics **1194**, and abstract decoder module **1190**. Abstract decoder module **1190** is designed to be compatible with all or nearly all off-the-shelve video decoders. Thus, many different video decoders, such as a direct show decoder, a canopus decoder, a DVD plus decoder, a Vweb decoder, a solid state decoder or any one of future decoders that become available maybe used with the system **1186**. The customer can specify which decoder is preferred, and one or more of the decoders shown may be incorporated into a specific system. On-screen display control **1194** includes the inputs **1195** to control the on-screen display, which inputs include initialize, de-initialize, bit map display, text display, and flip page. Input module **1102** also includes user activated inputs **1192**, such as initialize, de-initialize, step n, start and stop, pause, and set position. Other video

encoder parameters may also be set as known in the art. The encoded signal is output at output **1191** to video display module **1196**, which generally is a computer, and thus the video maybe either a Windows™ display **1197** of a Linux video display **1198**.

[0095] Control module **1199** controls the digital settings for the system, preferably in XML or INI, and feeds control signals to the rest of the system via outputs **1199***a*, **1199***b*, **1199***c* and **1199***d*.

[0096] FIG. **12** is a diagram illustrating a partition directory **1200**. As will be seen below, for redundancy, this directory is written into at least four separate places in the surveillance system. Directory **1200**, includes a partition information **1204** for each of n partitions, where n is preferably ten or more. That is, as digital video is written onto the digital tape in partitions, each partition will include a partition information at the end of the partition. In addition, the partition information **1204***a*-**1204***n* (collectively **1204**) is also written to a separate partition directory **1200**.

[0097] Partition information **1204***a* preferably includes a stream map **1208***a*, telemetry **1210***a*, roster information **1212***a*, and tape position information **1214***a*. It should be understood that the partition information **1204***a* may include different and/or additional information associated with the digital video stored in a particular partition. Each or the n partitions will include this information.

[0098] Stream map **1208***a* preferably includes video stream information **1216***a*-**1216***m* (collectively **1216**) that includes information associated with the digital video stream. The stream **1208***a* preferably further includes start time **1218***a* and end time **1218***b* of the video segment. Different and/or additional information associated with the digital video stream may be included in the stream map **1208***a*.

[0099] The telemetry **1210***a* preferably includes data indicative of physical or other parameters during the recording of the surveillance video. In one embodiment, the telemetry **1210***a* includes an event list **1220** (e.g., shotgun removed from cradle, chase, robbery in progress, accident), GPS location in latitude/longitude **1222**, speed **1224**, direction **1226**, elevation **1227**, time **1228**, date **1229**, and camera or other video input or vehicle ID **1230**. Other parameters may also be recorded, including temperature, lighting conditions, vehicle number, or any other parameter useful to providing information associated with the surveillance video at a later time.

[0100] Roster **1212***a* preferably includes time parameter **1232** and comments **1234**. Comments **1234** may include comments entered by an operator on a computer associated with a video source, for example. Time parameter **1232** is preferably the time the comments were made, or other time associated with the comments. Different and/or additional information maybe included in the roster **1212**. The record is searchable by any information in the partition directory, including, but not limited to, any information in the stream map, the telemetry, and roster.

[0101] A feature of the invention is self-authentication. By self-authentication is meant that the recording can be authenticated, that is, shown to have not been tampered with or forged, with only the record itself and the playback system That is, only the recorded tape, hard drive, solid state memory, or other medium on which the video is recorded and the playback system with authentication software are required to authenticate the record. For example, U.S. Patent Publication No. 2002/0131768 published Sep. 19, 2002, discloses an authentication method that uses encryption and requires a court or other authenticator to have an encryption key to authenticate the record. Thus, that system is not self-authenticated since it requires something outside the record itself and the playback system for authentication. One example of a self-authentication method is the hash value **534** discussed in connection with FIG. **5** above. We have discovered that the multiple time values included in the record, including stream start times **1218***a*, end times **1218***b*, telemetry time **1228**, and roster time **1232**, and the facts that these times are take from a reliable, traceable source, which preferably is the official GPS time, and included to at least a tenth of a second, and preferably to a hundredth or thousandth of a second, and the many times the telemetry is duplicated in the record, provide highly reliable self-authentication. If any frame is changed, these times will not be internally consistent and tampering will be evident. In other embodiments, the time could be taken from an atomic clock.

[0102] FIG. **13** is an illustration that illustrates one embodiment of a partition structure of a tape or other storage media **1170**. Each tape or other media preferably includes a zeroth partition that includes the partition information as shown in FIG. **12**. Each tape or other media also includes partitions **1236***a* through **1236***n* (collectively **1236**) which include the video/audio and other data as illustrated in FIG. **13**. Partitions are generally set up when the tape is formatted. Each partition **1236***a* through **1236***n* includes a variety of information that provides for the redundant, fault-tolerant nature of the system and provides for fast seeking capabilities. Partition**1236***a* includes duplicate stream map **1208***b*, duplicate telemetries **1210***b*-**1210***e*, duplicate roster information **1212***b*, and duplicate partition information **1204***a*. Digital video stream or content segment **1212***a* includes portions **140**, **142**, **143** of multiple video streams, video streams **1**-*m*, that are multiplexed from the multiplexer **910**. In the preferred embodiment, the video stream segments are synchronized in time, that is, the portions **140**, **142**, **143** are all recorded in the same time frame. The video stream portions **140**, **142***m* **143** need not have the same format or utilize the same bandwidth. Similarly, partition**1236***n* includes duplicate stream map **1212***q*, **1212***q*+1 and **12***q*+2, duplicate telemetries, duplicate partition information **1204***n* and digital video stream or content segment **1212***a* includes portions of multiple video streams, video streams **1**-*m*, that are multiplexed from the multiplexer **910**. For simplicity, each partition is shown with three segments of video stream, though preferably each partition will often include many more segments. Generally, a segment ends when taping is interrupted, such as when the user stops recording. A segment will also end at the end of each partition and a new segment begins the next partition. Because duplicate stream maps **1208***b*-**1208***n*+1, duplicate telemetries **1210***a*-**1210***p*, and duplicate roster information **1212***b*-**1212***n*+1, are written into each partition **1236***a*-**1236***n*, a loss of data in an earlier partition is not fatal to reading the remainder of the digital tape. Also, the duplicate partition information **1204***b*-**1204***n*+1 written into each partition provides further redundancy to ensure that the content stored on the digital tape is recoverable.

[0103] To enable fast seeking of video without having to read and uncompress the compressed video and stream map **1208***a* to read the video segment time **1218***a*-**1218***b*, one embodiment includes markers **1238***a*-**1238***r* (collectively

1238). In the embodiment shown, the markers are sound or optical markers placed onto the digital tape with a regular period. A one second period is shown, but other periods maybe used, such as every half-second or every 1.5 seconds. In this embodiment, these markers **1238** are real-time markers indicative of the relative time after recording of the surveillance video starts and are independent of the digital video signals. In other embodiments, the markers may be markers that are generated by an algorithm, or markers pointing to the location of the directory information and stored in memory **1604** (FIG. **16**). If the markers are generated in an algorithm, the algorithm will preferably be stored in memory **1604**. The key point of the markers is that the markers provide a system that points to the location of the directory information, such as stream maps and telemetry, which system is independent of the compression scheme. That is, markers **1238** do not go through the compression process. The markers are special signals recorded by the tape system, which allow the tape to find these markers at full seek speed without actually reading the data on the tape. The full seek speed is preferably 400 times faster or more than normal playback speed. These tape markers as shown in FIG. **13** are used to mark the beginning of a "new stream" and enable the system to quickly reconstruct an index directory if the need should arise. It also frees the system from counting bytes and forcing it to read the data from the tape constantly, which fails if a bad tape spot occurs. As shown, preferably the duplicate telemetry **1210***b*-**1210***p* is written after each marker. A special case of a marker is a file marker **1239** which is written just before the duplicate partition information, such as **1204***b*. A file marker may be a sound or optical signal, or a marker stored in memory **1604**, that contain 64 bytes of alphanumeric information that points to specific information in the data.

[0104] The system, in accordance to the principles of the present invention, incorporates another level of fault tolerance, which is accomplished with logically breaking a tape into multiple independent partitions. Typically, the tape is segmented into ten or more independent tape partitions. By segmenting the tape, the tape system can withstand even a massive failure on tape (such as a wrinkled tape). A conventional tape system cannot continue with such a failure. However, with a multi-partitioned tape, the system deems this partition as unusable and simply skips to the next partition. During recording, there is no loss, as it automatically skips. During playback the maximum possible loss with such an error would be a partition worth of blank video. In most cases, data written up to the error situation is intact. Since the tape system skips immediately upon trouble, the data resumes on the next partition.

Playback and Display

[0105] The system according to the invention can track a single incident from multiple camera angles and, preferably, with multiple audio tracks, with the time and location synchronized. The record is searchable by time, date, vehicle ID, GPS location, and event. Any of these elements, such as GPS location, can be displayed for each stream, i.e., each camera. Zoom and pan can be controlled individually for each stream during playback. The system also permits frame by frame search, generally using time as a locator. Brightness, contrast and saturation can also be controlled individually for each stream. Likewise, each audio channel can be individually controlled. Segments of a recording can be easily clipped and copied to a disk or other medium.

Interruptible Video Stream

[0106] As many users have experienced, it is also usually fatal to have any kind of data corruption in digital data. Any corruption to the data stream itself normally would prove to end a fate similar to any program that has a few bytes in the wrong place. Since the present system is intended for streaming video, advantage is taken of the streaming MPG standards, which periodically insert start codes into the video stream These are markers into the video data indicating the re-sync point. These start codes find and re-synchronize the video stream should a portion of the data be corrupt. The longest video length that could be lost after a corruption is a maximum ½ second, as the system automatically picks up where it left off once the corruption area has been passed.

[0107] With the redundant nature of the tape index and the ability for the stream to re-synchronize again even after a major tape corruption, the present system is extremely fault tolerant and suitable for any mission critical application.

Full Index Reconstruction

[0108] Should the need arise to reconstruct a new index, the tape system goes into full fast forward mode looking only for tape markers. Once a tape marker is found, the tape automatically slows down and starts reading the first block after this tape marker. This block is the redundant demarcation block which contains all the information needed to retrieve the stream's name and information. Should this first block be corrupt, the tape simply continues to read until it reaches another demarcation block which is normally just a few seconds ahead, until it reaches a good block The index in this system does not record the relative byte offset to the stream, but counts the tape markers to reach it. Since the tape can seek at its highest speed, and because it does not need actually to read the tape to search for tape markers, it does not get hung up on the first tape read error. Also, the tape directory cannot be corrupt, bad, or missing due to the fact that there are streams on the tape, which are enough to fully re-construct an index; the demarcation blocks hold a directory entry for the stream.

[0109] This process is done until the end of tape is reached (indicated by a special tape marker). At this point, the index reconstructed in memory is compressed and written to the EEPROM on the tape once again.

Tape Marker Seeking

[0110] Once an entire tape index is created, it is known how many tape markers to count either forwards or backwards from any point on the tape to quickly seek to the stream being sought, which is the same as performing a byte count as understood in the art. There is some optimization information also stored with the index, gleaned from the next and previous demarcation blocks. This allows for predetermining a particular stream and to seek within that stream.

[0111] Even without a tape index ever being created, striping a tape to hard disk can happen instantly if starting from the beginning. A tape can also have large tape errors on it, as long as they are contained within a stream. A seek to the next tape marker can be performed and other streams can be read.

[0112] As discussed above, the invention provides a redundant system that records simultaneously to both a hard disk **146**, **815***a*, **815***b* and to a tape**199**, **840** in tape drive **144**, **822**. The hard disks may be removable, for further redundancy. Further redundancy is provided by semiconductor memory **823** and CD burner **824**. FIG. **14** illustrates the preferred embodiment of a index redundancy system such that loss or corruption of one index is not fatal to recovery of the content on the digital tape. As shown, there are five copies of the partition directory that are written, including one copy on a memory (e.g., EEPROM) on the digital tape at **1240** (see also FIG. **16**), one copy on partition **0** of the digital tape at **1242**, which was discussed above, one copy on an originator disk at **1244**, one copy **1245** at the end of each partition, which also was discussed above, and one copy **1248** on a removable hard drive or solid state memory. Not all of these redundant directories may be used, but preferably at least three are used. This level of redundancy makes it virtually impossible to be unable to recover the partition directory, thereby ensuring robustness of the digital tape or other recordable media **1170**.

[0113] Another factor in the architecture of the present system is also to incorporate a built-in automatic data recovery system such that no extraordinary measures are needed to recover data should there be a massive failure to the system. The first phase of the data recovery system is to store the tape index information redundantly using different technology for each instance as shown in FIG. **14**. Most unrecoverable errors are typically due to loss of critical information, such as a directory. In prior art systems, perfectly good data is worthless if the directory is corrupted. In the system of the invention, the chance of a simultaneous failure in all systems is highly unlikely. Any one or two failures on any system will cause the system to automatically repair the failed system from the remaining working system.

[0114] As mentioned in connection with FIG. **14**, an embedded flash-prom **1404** is built into every cassette tape **1330***b* (FIG. **16**), and a partition directory **1240** is written to the flash-prom. This is a primary system allowing not only near-instant access to content directory, but also a "tapeless" method to hold the index. Incidents that may cause errors in the tape generally do not affect the flash-prom, and vice-versa, thus, the combination is essentially error-free.

[0115] There is a dedicated tape partition **1242** for the index. This index mirrors the primary system and is used only in the case of errors in the primary system. Normally, this is only accessed in case of trouble, as it does introduce a delay and tape re-positioning not present in the primary system.

[0116] There is also a partition directory copy **1246** at the end of data for each partition. Once a video segment is created, and before the tape is re-positioned, the tape directory is duplicated at the back end on the current partition. This directory is only valid for all data previous to this position. However, it affords another level of redundancy available if any of the previous systems have a problem.

[0117] A disk index **1244** is also created on originating system, such as **814***a*, that streams the data to tape. This index is preferably stored on the originating system hard disk, such as **815***b*. This index is a last resort if a tape should have a triple failure. Inserting the tape cassette, such as **840**, into its originating video source, such as **822**, will cause the system to automatically repair the tape.

[0118] FIG. **15** is a simplified diagram of an exemplary surveillance system **1500** for capturing and writing data onto digital tape which is helpful in understanding the fail-safe redundant storage of the preferred embodiment of the invention. The surveillance system **1500** may be utilized on a vehicle or stationary environment and may be any of the surveillance systems **102** (FIG. **1**), **860**, **870**, **872**, **874**, and **880** (FIG. **8**). The system includes at least one video camera **1502** configured to capture video and produce a video signal **816** (see also FIG. **8**). A controller **1506**, which is a generalized depiction of the electronics box **130** in FIG. **1**, **860** of FIG. **8**, and any of the servers or computers of FIG. **8**, may receive the video signal **816** for processing. The controller **1506** may include one or more processors **1508** executing software **1510** for performing one or more functions to process the video signal **1504**. A memory **1512**, storage unit **1514**, and input/output device **1516** all are in communication with the processor **1508**. In one embodiment, the processor(s) **1508** executing the software **1510** performs the functions of compressing the video signal **1504** to generate a compressed video signal, splitting the video signal into a video and audio signal, and multiplexing the video and audio signals to generate a multi-channel content stream **912** (see FIG. **9**). In addition, the processor(s) **1508** maybe configured to operate a sliding window **914** for writing the video signal **1504** to the storage unit **1514** (e.g., hard drive) prior to communicating the video signal **1304** to a tape drive **822**. In one embodiment, the tape drive **822** is a Sony Advanced Intelligent Tape™ (AIT) tape recorder.

[0119] The tape drive **822** includes a processor **1520** that executes software **1522**. Memory **1524**, input/output device **1526**, and tape drive **822** are in communication with the processor **1320**. The tape drive **1328** is configured to write the video signal **1304** onto a digital tape **1330***a*. In the preferred embodiment, the tape deck **822** is configured to write set marks **1238** (FIG. **13**) on the digital tape **1602** (FIG. **16**) in substantially periodic intervals (e.g., every second). The tape drive **822** maybe preprogrammed to write the set marks **1238** on the digital tape **1602** without external commands to write the set marks **1238** from the controller **1506**, for example, or configured to receive a command to write the set marks **1238**.

[0120] FIG. **16** is a diagram of an exemplary digital cassette **1038** optionally utilized in accordance with the principles of the present invention to store content in a fault-tolerant manner and for fast retrieval of directory information. In one embodiment, the digital cassette **1038** is a Sony AIT-3 digital cassette, which has a memory in cassette (MIC) capability. The digital cassette **1038** includes digital tape **1602** and an electronic memory **1604**. The electronic memory **1604** may be an EEPROM memory device or other electronically read/write memory device capable of storing information associated with content being written onto the digital cassette **1038**. In the preferred embodiment, it is a 4K EEPROM The information preferably includes directory information **1606** to provide quadruple redundancy of the directory information **1606** as described in FIG. **14**. The use of electronic memory **1604** integrates well into the principles of the present invention. The use of the electronic memory **1604** to store directory information provides a substantially instantaneous look-up of the directory, as the tape need not be accessed to read the electronic memory **1604**.

[0121] The EEPROM preferably hold a compressed directory and preferably uses set mark or tape marker counts instead of byte counts to indicate correspondence of individual portions of the directory to the tape. Should a catastrophic EEPROM failure or corruption happen, the index can be reconstructed by searching for tape markers at full tape seek speed.

[0122] FIG. **17** is a flow chart describing an exemplary process **1700** for capturing and writing surveillance data onto digital tape in a fault-tolerant manner. The process **1700** starts at **1702** in which one or more video signals containing surveillance images are generated. The video signal(s) are compressed into compressed video signal(s) at **1706**. At **1708**, the compressed video signal(s) are preferably written into partitions onto a digital tape and directory information is written multiple times on the digital tape at step **1708**. In one embodiment, the directory information is written into each partition, as discussed above. In the preferred embodiment, items such as markers, independent of the compressed video signal(s), are written onto the digital tape at **1714**. The process **1700** ends at step **1714**.

[0123] The system architecture revolves around the design goal of minimizing the loss of video. Under any realistic circumstances, the content is recoverable. While the data is being written, is the most sensitive time. Thus, during this time the data is stored on disk tape, and/or a solid state memory. Once the data is written, it can be duplicated to a library and preserved as needed. In addition, the data is a recoverable by a number of user-serviceable processes, meaning no special recovery software is needed. In the prior art, what the tape has physically recorded and what the system thinks it recorded could be out of sync due to video still in the tape drive cache or pending memory buffers waiting to be transferred, but not physically written. The prior art systems relied on a directory structure that had to be in sync with the data on tape and hard disk. Due to the nature of the surveillance business, it is often the case that the tape video system (TVS) would be put in unstable situations; e.g., when power is suddenly turned off before the directory could be written, when the tape recovery operation is interrupted , etc. For example, anything from a brief power outage to an explosion could put the video data in jeopardy, as everything on tape would be considered lost if the directory was corrupt. The system, in accordance with the principles of the present invention, may perform its resume operation by relying on the total data written to tape, which is easily determined via the partition information, and performing a calculation to determine where the data was interrupted from the disk mirror. This process provides reliability, the blocks written to tape as well as a starting time are known for certain.

[0124] In keeping with the absolute reliability goal, the surveillance system according to the invention is designed to automatically correct tape errors and automatically take action to prevent tape defects from corrupting data. In the worst case scenario where data is corrupted on a tape, the tape will automatically reconstruct the data if possible. FIGS. **18**, **19** and **20** illustrate the preferred embodiment of how this is done. FIG. **18** illustrates one embodiment **1800** of how the system checks itself for errors and corrects them upon insertion **1802** of the tape cassette **199**, **840** into the tape deck **144**, **822**. Each tape has a tape identification recorded on it, which ID is read at **1804** upon insertion of the tape cassette. If the system recognizes the tape at **1808**, the tape directory already in memory, which can be the hard disk **146**, **815** or a semiconductor memory **127**, **823**, is loaded. If this directory is found to have an error at **1822**, the system then goes at **1820** to the solid state memory **1606** for its directory. For example, if a cassette is merely removed for some reason and then re-inserted, the system recognizes this as well as all prior operations performed on the tape, and is immediately ready to continue recording or reading upon insertion. However, if a tape cassette is swapped out for a new cassette, the new cassette will not be recognized and the system proceeds at **1820** to write to disk the tape directory from the tape electronic memory **1606**. If an error is recognized at **1826** during this read, the system will go to one of the partition directories, which preferably is the partition zero. At **1830** the partition director will be written to disk but if an error is also found there at **1834**, then the system proceeds to the duplicate directory in the most recently written partition on the tape and writes this directory to hard disk at **1836**. If this is also corrupt, the system will find the last good partition at **1860** and when it finds it at **1869**, it will write its directory to hard disk at **1868**. If this partition is also bad, the tape will be rejected at **1870**. If during the insertion process a tape error is found at **1824**, which error reflects a loss of information, the system will automatically look to see if the information is available on the hard disk or elsewhere, and reconstruct the tape information at **1854**.

[0125] FIG. **19** illustrates one embodiment **1900** of how the tape self-corrects during the write function. At **1902** the write function is activated and writing proceeds at **1906**. If during the write process an error is detected at **1910**, the type and position of the error will be demarcated at **1914** and this information will be written to the partition director in the electronic memory **1606** on the cassette. If the error is such that re-initialization is required, this is determined at **1924** and the tape is rewound at **1928** and re-initialized at **1930**. Once resynced, the tape will find the next unwritten and undamaged section of the tape at **1936** and continue writing at **1946**. If re-initialization is not required, the tape will skip the damages section at **1940** and the continue writing at **1946**. All directories are updated at **1950** once the tape settles back down.

[0126] FIG. **20** illustrates one embodiment **2000** of how the tape self-corrects during a read function. The read function is activated at **2004** and if an error is found at **2008**, the directory, most preferably on the hard disk and preferably, the tape memory **1606**. Using the information from the directory, the tape will read as close as possible to the error to maximize the amount of date recovered. If data is still found missing at **2018**, the system will look to the disk for the data and rewrite the data to the tape at **2024**, then record the corrected information to the directory at **2030**. If the data is not available, the system will proceed to write this information to the directory at **2030**. Then, all the duplicate directories are updated at **2034**.

[0127] The system of the invention provides zero down-time recording. As discussed above, the recording can be reviewed and recorded simultaneously. The writing to disk the buffers, and the partition information allow the tape to be swapped while the system is being used. The system also includes a software function that permits pre and post event recording for from ten seconds to two hours before and after an event.

[0128] The system is capable of producing native MPG format directly, which increases the recovery ability by the user at multiple levels. Should anything happen to the tape, a backup version is available to the user, either an entire tape can be re-created from scratch, or the video can be off-loaded from the tape video system via many methods either via a network or locally.

[0129] The system incorporates true embedded multi-channel recordings. Instead of using one MPG per channel, all channels maybe merged into a single MPG file. This enables synchronization between channels, ease of editing/clipping, and ease of maintaining archives of video, since each channel maybe integrated into a single file.

[0130] Via the abstract encoder and decoder systems, the system provides native support For MPEG4 Part 10 (H.264) and MPEG4. The system is designed to handle newer compression schemes without change to the recording pipeline or format of the tape. As a result, the system is capable of recording any MPG standard compression scheme.

[0131] In addition to handling a variety of compression schemes, it is not necessary for all channels to have the same bit rate, or, for that matter, even use the same compression scheme. In one embodiment, one channel may be configured for a MPEG2 hi-bit rate and another channel for H.264 low bit rate. This allows for flexibility to choose how to allocate total bandwidth instead of dividing evenly between video signals. Thus, a primary camera can be given a bit rate that has the highest quality, and the back-up cameras can share a lower bit rate, without sacrificing the video quality of the primary camera.

[0132] The design of the system has no upper limit imposed on the number of true independent channels it can handle. There is a practical limit based on recording time and capacity of storage, but other than that, there is no limit. For example, eight or more channels are easily achievable.

[0133] The system includes built-in full SSL security Web server technology. The system preferably includes the ability to web-enable any capture box, to allow for web access of the video and/or control. Users can remotely monitor their tape video system from anywhere in the world. In addition, no unauthorized access is possible. In one embodiment, the same security features that PayPal™ uses to secure money transactions to millions of people is utilized to secure content stored in the tape video system. Additional and/or alternative security features may be utilized to maintain unauthorized access to the tape video system. The tape video system includes wireless access, thereby allowing mobile systems to be monitored by either pulling up to a designated monitoring bay or even using a simple Pocket PC to monitor it.

[0134] A user interface ("Command Center") maybe completely web-based, thereby giving the user flexibility in accessing content stored on the tape video system via web-based playback and monitoring. Because the system maybe web-based, users do not need a copy of the application resident on a local computer to access and utilize the system. A user may simply logon to the system's TVS box with Internet Explorer or other web application and the web page presented is the Command Center. No sacrifice has been made to the functionality for this. The web-based technology will pass through firewalls; in fact, it acts just like a normal web page. It allows users to run on or off site. If a user prefers, the user can visit a system website and run the user interface from there. The web-based user interface accesses only the customer's local files for tape and disk playback. Because the Command Center is completely web-based, a custom functionality and look can be done quite easily.

[0135] The tape video system makes a great core component for many other video-based applications. To leverage this even further, a tape video system can be fully controlled and video manipulated via a built-in PHP server-side script engine as understood in the art. Any type of application that can be envisioned can be scripted directly on a tape video system without changing the application. The system provides fully database-driven video playback and multiple tape video system servers networked together. Because of the industry standardized PHP engine, many existing PHP applications can be run directly on the tape video system. In combination with the built-in web-based server, the system's networking ability, and its built-in telemetry clock, it is possible to create huge synchronized capture arrays for such things as stadiums, football fields, casinos, or street traffic. There is no upper performance limit in this case, and a 100-camera system, all monitored by a single administrator either on or off site anywhere in the world, is possible.

[0136] The tape video system incorporates a built-in telemetry system. Not only does the system record the video/audio, but it also embeds telemetry into the stream, the location of the system, the elevation, and even the speed of travel of the capture system, among other parameters. This is valuable for indisputable court evidence.

[0137] The tape video system provides the highest quality video possible with today's technology. It can handle the highest amount of full D1 resolution cameras, the highest quality, the highest recording capacity, and the highest specifications for mission critical applications in the industry. The system, according to the principles of the present invention, embodies several innovations for the implementation of ultra-large real-time recording and playback of video to cartridge tape as a completely digital process. These innovations permit streaming media to/from tape in a manner analogous to a recordable DVD. The advantages of streaming media to/from digital tape over other digital methods (such as DVD, CD-ROM or even a hard disk) include higher capacity and resolution, increased durability, and additional fault-tolerant capability.

[0138] Table B below compares the present system of streaming tape utilizing the principles of the present invention with other conventional recording media. In this table, the capacity of the media is given in bytes. "Shock Resistant" means that the system can record/play without trouble during a slight shock such as is common in mobile environments. Serious Error Recovery means that the system can recover from a serious permanent error, during recording or playback. Removable Media includes that the recording medium is removable, economical, and replaceable. DVD and CD-ROM are recordable but limited in that recording is a once-only operation, and is not capable of start-stop recording. While a hard disk can handle moderate shocks, but will be destroyed in a removable application if dropped. Although analog tape will continue to record during a shock it will produce many undesirable artifacts for several seconds after the initial shock.

TABLE B

Technology	Max Capacity	Recordable	Shock Resistant	Serious Error Recovery	Removable Media
Present System Of Streaming Tape	Up To 500 Gigs	Yes	Yes	Yes	Yes
DVD	8 Gigs Max	Yes, with limitations	No	No	Yes
Blue-Ray	17 Gigs	No	No	No	Yes
HD-DVD	35 Gigs	No	No	No	Yes
CD-ROM	800 Megs Max	Yes, with limitations	No	No	Yes
Hard Disk	100's Of Gigs	Yes	To a degree	Yes	No
Analog tape	Equivalent To 4 Gigs	Yes	No	Yes	Yes

[0139] The only other media having competing capacity to the system of the invention is a high-capacity hard drive. However, such a large hard drive is not practical for removable media applications from a cost standpoint. The other possible removable media types, such as CD-ROM, DVD, HD-DVD, and Blue-Ray, lack any real capacity comparable to the present streaming tape system. In addition, they are totally unusable for recording in a mobile environment, since the slightest shock can render the entire recording unusable. None of these removable media types can withstand bumps and shocks while recording and playing back with no artifacts present. In addition, these removable media types are not typically recordable; and, if they are, they possess the ability to record once, as in the case of DVD or higher.

[0140] Other features by using digital tape for the removable media in a surveillance system include: the system can record multi-channel synchronized video (multiple camera recordings at once); the system can record to inexpensive, convenient, rugged cartridge tape, with many more hours of recording than all the existing and future planned streaming devices; excellence in recording and playback of HDTV resolution video; cartridge tape is more rugged and shock resistant than all other forms of storage; and ability to integrate additional digital information other than video, such as telemetry, roster information, subtitling, on-screen display information, synchronization information, etc. while still maintaining high quality.

[0141] The system can record up to broadcast-quality video from up to 16 cameras attached to a single recording device. In addition to traditional video, the system also records audio and GPS information to authenticate the exact time, date, and location of events, providing the ultimate solution for surveillance applications. Video is recorded to standards-based video formats that can be played back on any standard PC, which provides flexibility and interoperability when managing or reconstructing incidents.

[0142] While virtually all solutions currently available in the mobile digital video surveillance market are disk-based, the present system uses both hard disk and removable digital tape storage to provide critical backup support and an economic advantage. The system also provides a method of archiving large video files to removable digital tape that are consistent with broadcast quality MPEG-2 DVD.

[0143] The system according to the invention provides ease of use and flexibility, minimal downtime, and multi-partitioning. It is also an economical solution with a low cost-per-gigabyte, while delivering superior performance, density, and reliability.

[0144] The system is configured to provide small form factor, high capacity, and reliability needed for demanding security applications at a reasonable cost. The system may further be configured to provide a full-motion, high-resolution video surveillance system with a highly reliable, removable storage solution to manage mission-critical needs.

[0145] The tape drives of the system may include helical-scan recording, highly durable advanced metal evaporated (AME) media formulation, and a performance enhancing memory-in-cassette chip. One embodiment of the system features a range of capacities and performance solutions up to 200 GB native storage capacity and sustained native transfer rates of up to 24 MB/second.

[0146] The system is operable to provide zero downtime recording using broadcast-quality video with four and a half times the resolution of other digital systems, making it superior to other digital or analog security systems on the market today.

[0147] The system may also be configured to provide a true 24/7 recording of over 240 hours of continuous broadcast-quality video on Sony AIT-3 digital tape with no manual intervention. The Sony Advanced Intelligent Tape™ (AIT) platform was selected as the removable digital tape storage technology because it provides high-capacity storage for data security and archiving, high-speed file location and file access, backward read and write compatibility, and write once, read many (WORM) functionality.

[0148] Although the system described herein is directed to surveillance systems, it should be understood that the principles of the present invention could be applied to non-surveillance systems. For example, because the system is configured to handle video streaming, it should be understood that the system could be used with movies or other video recordings. Further, the same principles could be applied to audio signals or other continuous streamed digital information that would benefit from the use of large storage media with high-speed searching capabilities, including telemetry and other recording systems.

[0149] It should be understood that the particular embodiments shown in the drawings and described within this

specification are for purposes of example and should not be construed to limit the invention, which will be described in the claims below. For example, although the system is particularly useful if MPEG-2 compression is used, any MPEG compression scheme, known now or in the future, maybe substituted. In fact, since this is the first disclosure of any direct streaming of compressed audio/visual signal to digital tape, it is inventive to use any present or future digital compression scheme, for example, MJPEG sometimes referred to as motion JPEG (Joint Photographic Experts Group), and it is contemplated that the future versions of the invention will include hardware and software to utilize many other digital compression apparatuses and processes. Further, it is evident that those skilled in the art may now make numerous uses and modifications of the specific embodiments described without departing from the inventive concepts. It is also evident that the methods recited may in many instances be performed in a different order, or equivalent structures and processes maybe substituted for the various structures and processes described. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in and/or possessed by the invention herein described.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A surveillance system, comprising:
- a source of a video signal;
- a video signal compression system electrically connected to said source and providing a compressed video signal;
- a directory generator for generating directory information;
- a digital tape cassette having semiconductor memory incorporated into it; and
- a digital video recorder electrically connected to said compression system and to said directory generator for recording said compressed video to said digital tape in said cassette and recording said directory information to said semiconductor memory.

2. A surveillance system as in claim **1** wherein said semiconductor memory is a non-volatile memory.

3. A surveillance system as in claim **2** wherein said semiconductor memory is selected from a Flash memory and a ferroelectric RAM memory.

4. A surveillance system as in claim **1** wherein said video compression is selected from the group consisting of: MPEG-1, MPEG-2, MPEG-4, and H-264.

5. A surveillance system as in claim **1** wherein said video signal is a high density (HD) video signal.

6. A surveillance system as in claim **1** wherein said directory information identifies said cassette.

7. A surveillance system as in claim **1** wherein said directory information identifies said video signal.

8. A surveillance system as in claim **1** wherein said directory information identifies the location of particular portions of said video signal on said tape.

9. A surveillance system as in claim **1** wherein said directory information includes information for authenticating said tape.

10. A surveillance system as in claim **1** wherein said surveillance system is a mobile surveillance system contained in a vehicle, and said directory information includes information regarding said vehicle.

11. A method of mobile video surveillance, said method comprising:
- providing on a mobile vehicle a video source producing a video signal;
- compressing said video signal at said mobile vehicle to form a stream of compressed video data;
- generating directory data associated with said compressed video;
- recording at said mobile vehicle said stream of compressed video data to a cassette tape having a built-in solid state memory, and
- recording said directory information to said solid state memory.

12. A method as in claim **11** wherein said directory information comprises information about said vehicle.

13. A method as in claim **11** wherein said directory information comprises time information.

14. A method as in claim **11** and further comprising authenticating said video using said directory information.

15. A method as in claim **11** and further comprising identifying said cassette tape using said directory information.

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