

White Paper

**SelectFocusVIDEO™ Ultra-Low-Bit-Rate
Video Compression and Transmission Software****EXECUTIVE SUMMARY**

General Dynamics C4 Systems is pleased to provide this white paper that outlines the operation and capabilities of our SelectFocusVIDEO™ video compression software. SelectFocusVIDEO is a video compression tool that combines a state-of-the-art compression core together with on-the-fly parameter adjustability to provide video compression and transmission over IP-based, ultra-low-bandwidth links. Its efficient, software-only implementation allows SelectFocusVIDEO to operate effortlessly on any Unix®/Linux/Windows®-based platform.

SelectFocusVIDEO OVERVIEW

SelectFocusVIDEO (SFV) is designed to provide true real-time video compression and transmission over IP-based links. It can operate over ultra-low-bandwidth links, such as a 2.4 kbps Iridium® link, or over higher bandwidth links, such as dial-up connections or multi-megabit local area networks (LANs). SelectFocusVIDEO allows on-the-fly adjustment of coding parameters such as bit rate, frame rate, temporal correlation, and single/multiple channel operation, which allow it to be tailored to a wide variety of applications. SelectFocusVIDEO also incorporates a sophisticated bandwidth throttling mechanism that allows it to automatically find the maximum sustainable bandwidth available on a particular link. This white paper outlines the features and capabilities of SelectFocusVIDEO, and highlights each of its main components.

Features	Benefits
SelectFocusVIDEO is a COTS software product that performs real-time, ultra-low-bit-rate video compression and transmission	Facilitates video sharing between networked users over disadvantaged links
Accepts video in a variety of standard formats (Motion JPEG, MPEG 1, 2, 4, H.261, H.263, H.264) or directly from a webcam or capture card	Interfaces seamlessly with a wide variety of hardware devices and software applications
Full multicast capability	Multiple users can view the same real-time video stream
Web server and applet capability	Allows users to post video to the server and view video files via applets
Automatic client discovery and instant messaging	Instant identification of and communication with other users on the network

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Compression Performance

The real-time transmission of video over limited-bandwidth, wireless communication channels poses a host of technical challenges. In many applications, because of the extremely limited bandwidth available, conventional compression standards such as MPEG 2/MPEG 4 are insufficient to adequately code the video at the desired fidelity. Moreover, these standards typically require hardware-based computing platforms as well as additional processing and bandwidth to cope with the transmission errors introduced by the wireless link.

To address the aforementioned low-bit-rate, error-prone scenario, we have developed a state-of-the-art, wavelet-based video coder/decoder (codec) that is designed for ultra-low-bit-rate operation. The codec is a source-optimized design, which optimally codes the video at the encoder, and emphasizes error recovery at the decoder to compensate for lost packets. The video codec builds upon our vast expertise in error-resilient source coding and ultra-low-bit-rate video coding. To illustrate the core technology that is employed, Fig. 1 shows examples of our ultra-low-bit-rate video coding technology. In the figure, Frame 32 of the QCIF (176 pixel X 144 pixel) “Coastguard” video sequence (monochrome only) was encoded at 13 kilobits per second (kbps) and 10 kbps, each at 5 frames per second (fps), using our ultra-low-bit-rate video coder. Note the excellent quality obtained at each specified bit rate. Also, because of our efficient, software-only implementation, the video codec runs in real time on any contemporary, general-purpose computing platform. Finally, because of our source-optimized design, no error-correcting codes whatsoever are employed to cope with transmission errors.



Figure 1. Frame 32 of QCIF “Coastguard” video sequence. Left: Original frame; Middle: SelectFocusVIDEO at 13 kilobits/second and 3 frames/second; Right: SelectFocusVIDEO at 10 kilobits/second and 3 frames/second.

Graphical User Interface and Control Settings

SelectFocusVIDEO is a single application that can function as either a transmitter or a receiver depending upon the user’s selection from a centralized graphical user interface (GUI). Fig. 2 shows a typical SFV configuration over a satellite network whereby the input is a video stream from a capture device or a video file in a variety of standard formats.

The two SFV modes are accessed identically from the main interface window and require only a different series of button clicks to differentiate between them. The entire program

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operates in a single panel, with the exception of optional settings panels that can be displayed at the user's request. Fig. 3 shows the main control and viewing panel of SelectFocusVIDEO.

SelectFocusVIDEO is designed to operate over a vast range of compression settings. Fig. 4 shows the "Codec Settings" panel that allows the user to adjust a variety of parameters such as bit rate and frame rate. SFV supports bit rates from 0.5 kbps to 20 Mbps, and frame rates from 0.1 fps (one frame every 10 seconds) to 30 fps. Moreover, these parameters can be adjusted "on-the-fly" by either the encoder or decoder while SFV is transmitting video.

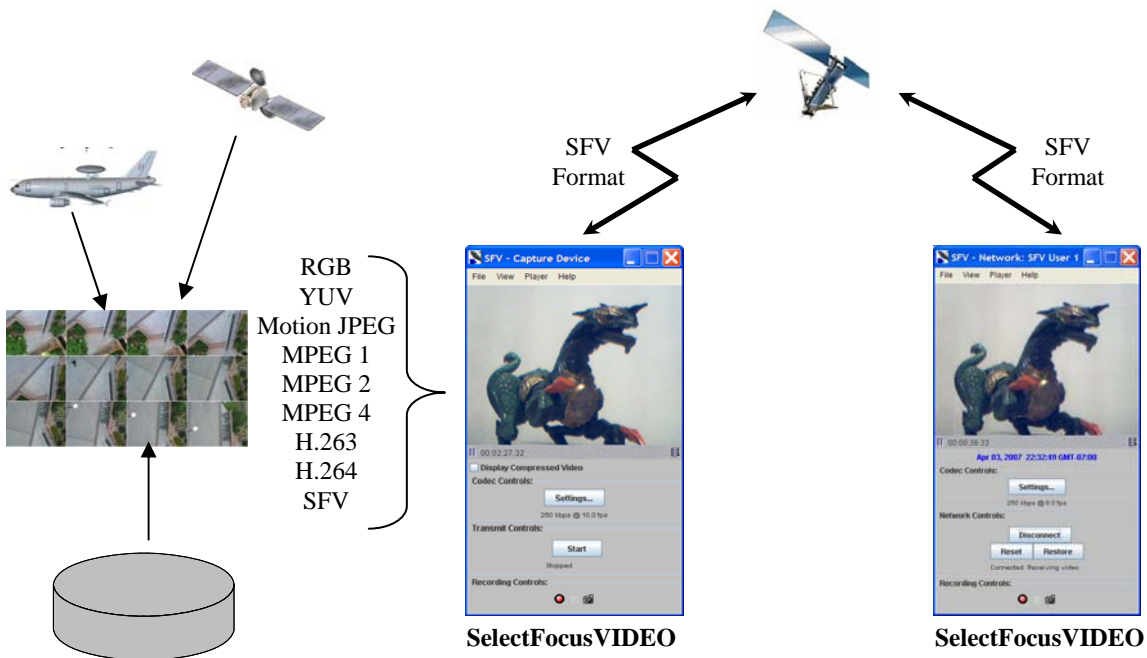


Figure 2. Typical SelectFocusVIDEO configuration.

SelectFocusVIDEO supports a variety of video sizes, including 160X120, 176X144, 320X240, 352X288, and 640X480 pixels. The size can also be adjusted while the coding process is in progress.

SFV provides the flexibility to code a video sequence in a variety of ways. Since adjacent video frames tend to be very similar, rather than code each frame individually as an individual image, SFV forms a prediction of the next frame in the sequence, subtracts this prediction from the actual frame, and codes the difference. This methodology is called *interframe* coding, and it substantially reduces the number of bits required to code the difference frames.

On the other hand, for some applications, it is desirable to code each video frame as an individual image. This coding methodology is called *intraframe* coding, and generally requires more bits than the aforementioned interframe coding.

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Typically, however, it is desirable to break up a video sequence into shorter subsequences called *Groups of Pictures* (GOP), as shown in Fig. 5. For each GOP, the first frame is intraframe coded, while the remainder of the frames are interframe coded. Generally speaking, a longer GOP provides greater coding efficiency, while a shorter GOP provides more error resilience.

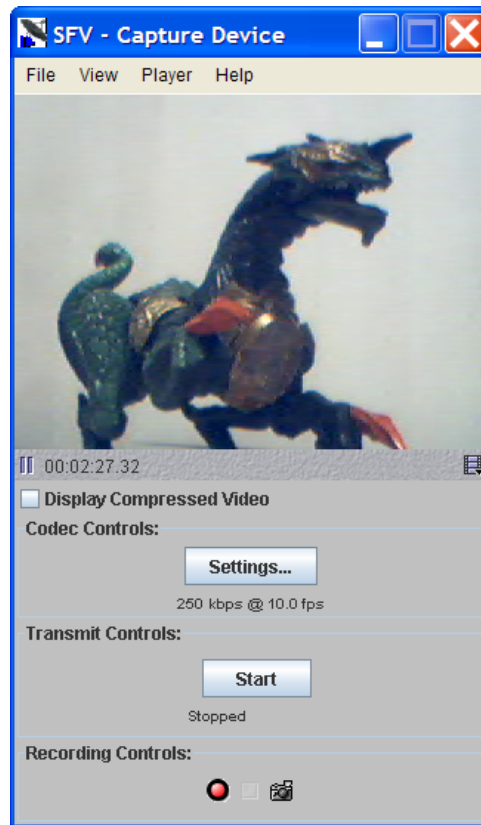


Figure 3. SelectFocusVIDEO main control and viewing panel.

SFV allows all parameters related to the GOP to be specified. Referring to Fig. 5, the intraframe-coded image is also called the key frame. The GOP size is specified by inputting a value into the “Key frame every [x]” box on the SFV Codec Settings panel in Fig. 4. The size of the GOP can range from 1 – 50, where 1 corresponds to intraframe-only coding (i.e., every frame is coded as an individual image). For GOP sizes greater than 1, the “Correlation %” specifies how similar adjacent frames are, and ranges from 0 – 100. If the frames in a video sequence are very similar, then a high value such as 95 would be entered. This would be the case for most surveillance applications where the background would be substantially the same from frame to frame. If the frames in a video sequence are substantially dissimilar, then a lower value would be indicated.

SFV also allows the user to optionally select the motion compensation mode. In this mode, blocks of pixels of the previous frame are “mapped” to the current frame. This mapping corresponds to the “motion” of the blocks within the frame. Motion

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compensation tends to increase the quality of the coded video for many video sequences. SFV offers the choice of full motion search or hexagonal motion search algorithms. Full search provides greater performance as compared to hexagonal search, at the expense of greater computational complexity.

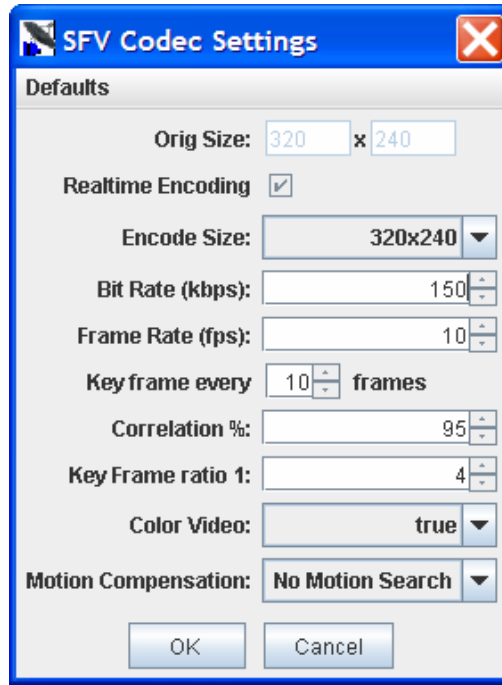


Figure 4. SFV Codec Settings panel.

Finally, SFV allows the user to specify the number of bits used to code the intraframes relative to the interframes. This is specified using the “Key Frame Ratio.” For example, a value of 4 would allocate four-times the number of bits for each intraframe as compared to each interframe.

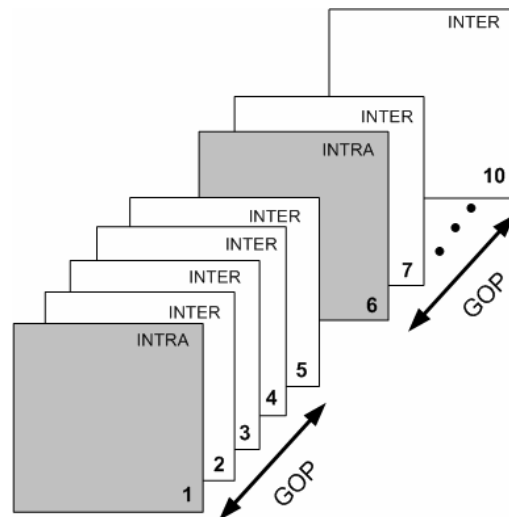


Figure 5. Group of Pictures.

Automatic Bandwidth Throttling

SelectFocusVIDEO incorporates a sophisticated bandwidth throttling mechanism that enables it to find the maximum sustainable bandwidth available on a given IP-based link. To accomplish this, SFV creates two virtual connections using a single physical link. The first connection is UDP/IP (guaranteed throughput), which does not utilize packet retransmission, and guarantees that the compressed video is not unduly delayed in the transmission process. The second connection is TCP/IP (guaranteed delivery), which incorporates packet retransmission, and is used to establish a “control channel,” whereby the transmitter and receiver are in constant contact. Thus, if the video transmission bit rate exceeds the channel’s ability to pass the data, the receiver instructs the transmitter to decrease the transmission bit rate until a sustainable rate has been obtained. This allows SelectFocusVIDEO to adapt to most channels quickly and automatically.

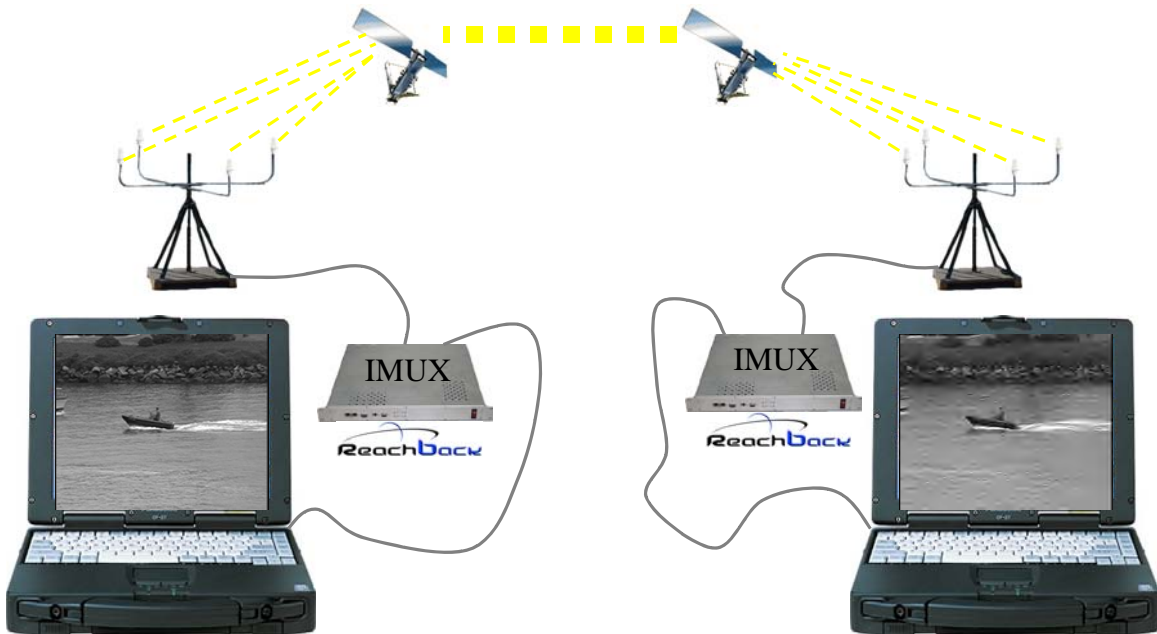


Figure 6. SelectFocusVIDEO over inverse-multiplexed channels.

Multichannel Operation

Transmission of video over low-bit-rate, wireless links is extremely problematic due to limited channel bandwidth and inherent channel errors. In particular, for wireless links with very low bandwidths, such as a single Iridium channel, real-time transmission of video is infeasible using standard compression methods. If several low-rate channels are available, however, these channels can be combined to form an effective higher-rate channel, where the total bandwidth is directly proportional to the number of channels

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combined. This function is called *inverse multiplexing*, and the device that enables this functionality is called an *inverse multiplexer (IMUX)*.

SelectFocusVIDEO is capable of compressing and transmitting video over inverse-multiplexed channels when used in conjunction with an inverse multiplexing device, such as the General Dynamics Reachback™ Iridium Inverse Multiplexer. Accordingly, special coding techniques have been employed to facilitate operation over the multiplicity of channels provided by the IMUX, even in the event of channel failure. Fig. 6 shows SFV configured to operate over multiple, inverse-multiplexed Iridium channels using the Reachback IMUX.

Video Transmission Modes

SelectFocusVIDEO provides multiple video transmission modes to suite a wide variety of applications. Table 1 illustrates the various transmission modes supported, and Table 2 provides a description of each mode.

Table 1. SelectFocusVIDEO transmission modes.

	Single Channel		Multiple Channels (4)
Multicast – UDP/IP (One-to-Many)	No Back Channel	Back Channel	Back Channel
Unicast – UDP/IP (One-to-One)	No Back Channel	Back Channel	Back Channel
Unicast – TCP/IP (One-to-One)	Back Channel		N/A

Table 2. Description of SelectFocusVIDEO transmission modes.

Multicast Single channel No Back Channel	This configuration supports a single transmitter sending video data to multiple receivers. The data is sent as UDP packets without the network overhead of guaranteed delivery of the video packets. This setup is a pure one-way UDP transmission and is useful when the video data is being transmitted over an ultra-low-bandwidth network or a network that does not support TCP/IP traffic (e.g., various radio networks).
Multicast Single Channel With Back Channel	This configuration supports a single transmitter sending video data to multiple receivers. The data is sent as UDP packets without the network overhead of guaranteed delivery. This setup is one-way UDP transmission of the video packets from the transmitter to the receiver, but a TCP/IP back channel connection from the receiver to the transmitter. This configuration allows the receivers to communicate back to the transmitter and change the encoding parameters (i.e., bandwidth, fps, etc.).
Multicast Multiple Channels With Back Channel	This configuration supports a single transmitter sending video data to multiple receivers. The data is sent as UDP packets without the network overhead of guaranteed delivery. This setup is one-way UDP transmission of the video packets from the transmitter to the receiver, and uses a TCP/IP back channel connection from the receiver to the transmitter. This configuration supports using multiple channels to create a higher-bit-rate virtual channel and

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	allows the receivers to communicate back to the transmitter and change the encoding parameters (i.e., bandwidth, fps, etc.).
Unicast Single Channel No Back Channel	This configuration supports a single transmitter sending video data to a single receiver. The data is sent as UDP packets without the network overhead of guaranteed delivery. This setup is useful when the video data is being transmitted over an ultra-low-bandwidth network where multicast routing is not supported.
Unicast Single Channel With Back Channel	This configuration supports a single transmitter sending video data to a single receiver. The data is sent as UDP packets without the network overhead of guaranteed delivery. This setup provides a TCP/IP back channel connection from the receiver to the transmitter. This configuration allows the receiver to communicate back to the transmitter and change the encoding parameters (i.e., bandwidth, fps, etc.).
Unicast Multiple Channels With Back Channel	This configuration supports a single transmitter sending video data to a single receiver. The data is sent as UDP packets without the network overhead of guaranteed delivery. This setup provides a TCP/IP back channel connection from the receiver to the transmitter. This configuration supports using multiple channels to create a higher-bit-rate connection and allows the receiver to communicate back to the transmitter and change the encoding parameters (i.e., bandwidth, fps, etc.).
Unicast Single Channel With Back Channel Guaranteed Delivery	This configuration supports a single transmitter sending video data to a single receiver. The data is sent as TCP/IP packets to guarantee delivery. This setup is a bi-directional TCP/IP connection from the transmitter to the receiver, and provides another TCP/IP back channel connection from the receiver to the transmitter. The video stream is typically not real time when guaranteed delivery is used on a network that has frequent packet loss. This configuration is useful when transmitting a video file that does not need to be received in real time and when degradation of the transmitted video cannot be tolerated.

Video Transcoding

SelectFocusVIDEO provides full transcoding capability whereby any Motion JPEG, MPEG 1, MPEG 2, MPEG 4, H.261, H.263, or H.264 video sequence can be automatically decoded and re-encoded in SFV format with dramatic reductions in bit rate, frame rate, and frame size for dissemination to users operating over ultra-low-bandwidth links. For example, a 640 X 480 MPEG 2 video sequence originally encoded at 2 Mbps and 30 fps can be decoded and re-encoded in SFV format at 320 X 240, 20 kbps, and 5 fps, and transmitted to a disadvantaged user, all in real time, without any dedicated hardware. This extraordinary capability provides almost unlimited flexibility and allows very large video files to be viewed by disadvantaged users for the first time.

Automatic Client Discovery

SelectFocusVIDEO provides full automatic client discovery capability. Automatic client discovery enables a SelectFocus user to “discover” all other SelectFocus users on the same network. This capability allows an SFV client to receive a video transmission from another user by simply clicking on that user in the auto discovery dialog panel, as shown

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in Fig. 7. The auto discovery information contains all of the connection parameter information needed by an SFV receiver to establish a video stream connection. The auto discovery mechanism is operable over both multicast and unicast configurations.

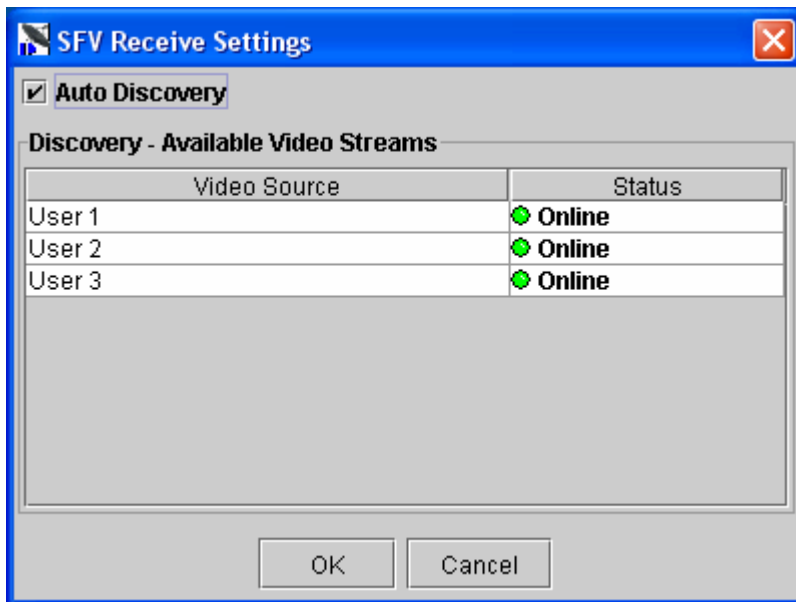


Figure 7. Automatic client discovery panel.

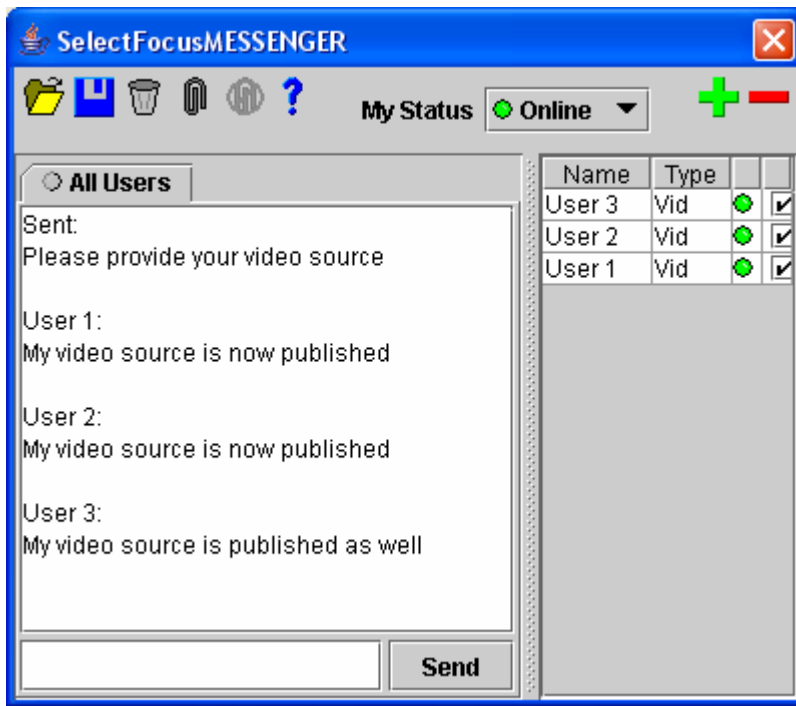


Figure 8. SelectFocusMESSENGER instant messaging utility.

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Instant Messaging

SelectFocusVIDEO includes the SelectFocusMESSENGER instant messaging utility shown in Fig. 8. This enables any SelectFocus user to send/receive real-time text messages and files to/from any other SelectFocus user on the network without having to resort to third-party instant messaging software, which typically does not operate over all three SelectFocus-supported operating systems. SelectFocusMESSENGER allows users to conduct multiple simultaneous conversations with their choice of recipients.

Web Server/Applet Capability

In the “site license” configuration, a SelectFocus web server downloads applets to give multiple users full SelectFocusVIDEO functionality without having SFV preinstalled on their machines. It also allows SelectFocusVIDEO Applet users to upload and download SFV files to/from the web server, thus providing maximum video transfer flexibility.

Specifications

SelectFocusVIDEO incorporates a C++ compression core and a JAVA-based GUI, which gives the system maximum execution speed as well as maximum versatility. It is also compatible with Unix/Linux/Windows-based computing platforms. As mentioned previously, SelectFocusVIDEO accepts a video bit stream from a capture device or from stored video files in a variety of formats, and compresses/transmits the video stream in real time over an IP-based network to another instance of SelectFocusVIDEO. SelectFocusVIDEO also incorporates fully adjustable control settings that allow a tradeoff between computational complexity, video fidelity, and available network bandwidth. Table 3 provides a listing of the main features of SelectFocusVIDEO.

Table 3. SelectFocusVIDEO specifications.

Software-only implementation	X
Unix/Linux/Windows compatible	X
Real-time compression and transmission	X
Operates over IP-based networks	X
Fully adjustable bit rate: 0.5 kbps – 20 Mbps	X
Fully adjustable frame rate: 0.1 fps – 30 fps	X
Fully adjustable frame size: 160X120, 176X144, 320X240, 352X288, 640X480, etc.	X
Multichannel operation	X
Multicast capability	X
Automatic bandwidth throttling	X
Full Record/Playback modes	X
Interfaces with a wide variety of capture devices	X
Transcoding capability (Ability to decode Motion JPEG, MPEG 1, MPEG 2, MPEG 4, H.261, H.263, H.264 formats and re-encode into SFV)	X

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format at reduced resolution, bit rate, and frame rate)	
Seven network transmission modes accommodate a wide variety of communication scenarios	X
Automatic client discovery provides automatic identification of and one-click transmission to other SelectFocusVIDEO users	X
Instant messaging provides real-time, text-based communications and arbitrary file/directory transfer between SelectFocus users across disparate platforms	X
Web server and applet capability allows users to download SFV applets and upload/download video files to/from web server	X

CONCLUSION

As a major provider of services, solutions, and support to U.S. and international governments, General Dynamics C4 Systems has developed SelectFocusVIDEO ultra-low-bit-rate video compression software for commercial and government users. General Dynamics' SelectFocusVIDEO compression software enables the transmission of tactically useful video over ultra-low-bandwidth communication links, such as a single 2.4-kbps Iridium channel. Our efficient, software-only implementation enables real-time video encoding/decoding on any Windows/Unix/Linux-based platform. SelectFocusVIDEO allows on-the-fly adjustment of coding parameters such as bit rate, frame rate, temporal correlation, and single/multiple channel operation, which enables it to adapt to a wide variety of IP-based network configurations.

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