

Tools and Techniques for the Exploitation of Motion Video

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1. Introduction

As today's military, public safety, and intelligence organizations fight terrorism and combat weapons of mass destruction and their proliferation, it is increasingly important that they expand their data collection and analytical capabilities into new and innovative methods. To this end, there is increased interest in incorporating full motion video data sources, such as those from unmanned aerial vehicles (UAV) and other unmanned aircraft systems (UAS) into strategic and tactical analysis workflows. UAV/UAS have already been instrumental in providing real-time surveillance and operational support to military and intelligence organizations, and are now being looked at more closely as a viable source for public safety organizations, with closer attention paid to post-collection analysis and integration with other forms of intelligence.

Recent advances in the development of lightweight, yet durable materials; advanced communication and navigation systems; computer hardware and software; smaller, yet more sophisticated sensors; and improved fuel efficiency contribute to the rapid growth of UAV/UAS technologies. This increased usage makes it more critical than ever to establish a reliable and robust infrastructure ground-side that can effectively collect and manage video and other data, then make it seamlessly available to a wide variety of consumers for integration, analysis, and visualization. This responsible focus on the back-end system ground-side will substantially increase the value and applicability of these systems well into the future.

Intergraph® has increasingly focused on expanding its rich set of geospatial exploitation solutions with applications that provide improved analysis of full motion video, integration with other forms of intelligence and geospatial information, and robust management and dissemination of imagery and video data collections. These new applications exploit the power of georeferenced video sources to create profound improvements in analytical and decision-making ability, and can be directly applied to the emerging disciplines of wide-area persistent surveillance (WAPS) and motion imagery (MI) intelligence.

2. Not Just for the Military Anymore

The Global Positioning Satellites (GPS) and the Internet are two important examples of technologies initially developed for military applications, but that then transcended to the civilian space. These two technology sets have dramatically transformed government, business, and personal lives. The UAV technology set is also expected to have a substantial impact in non-military sectors and will experience rapid growth in the coming years. According to a July 2010 press release by the EDA-EC Conference on Unmanned Aircraft Systems (UAS), "Military and civil UAS markets are highly interdependent, with technology developments inevitably driving both.". This includes widespread applications for law enforcement, firefighting, and numerous environmental and scientific purposes. The Federal Aviation Administration (FAA) is currently working to establish airspace safety regulations that would allow the systems to achieve wider-spread usage. Some examples of civilian applications include:

- Natural disasters and other catastrophes (forest fires, hurricane flood damage assessment, earthquakes, etc.)
- Search and rescue (land and sea)
- Monitoring natural resources
- Delivery of relief supplies and other payloads
- Harbor, coastline, and border security
- Monitoring and inspecting long expanses of pipelines and other forms of critical infrastructure
- Establishing ad hoc communication relay networks

3. High-level Workflow

A typical high-level workflow consists of four key areas that must function in harmony to properly support the end-to-end requirements of the mission. Technology must be deployed prudently in each of these four areas to support the rapid transfer of data and analytical results to other areas. These areas are the following, as shown in Figure 1:

- Automated and manual capture of geospatial information, including imagery, video, and other sensor data
- Management of enterprise geospatial content, including traditional vector data sets (layers, features), imagery, video, and terrain models
- Integration and analysis of multiple overlapping sets of geospatial and non-geospatial information
- Visualization and dissemination through a variety of interfaces

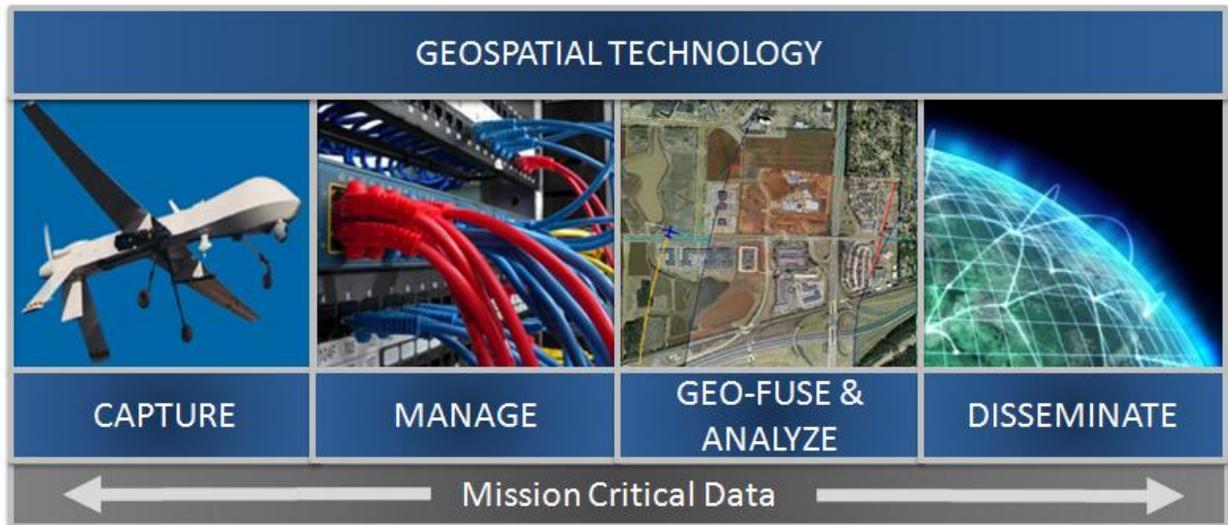


Figure 1: These four key areas must function in harmony to properly support the end-to-end requirements of a mission.

It is important to note that standard formats for imagery, full motion video, and other data types are essential for the smooth transfer of information from one workflow segment to the other. This gives system designers' improved flexibility as to what type of technology they choose to deploy at each stage. Proprietary formats limit the choices of technologies and force the selection of compatible technology elements at other points along the workflow. To that end, Intergraph does not store data in a proprietary format, but rather embraces open standards for data storage as well as for open dissemination of geospatial information, such as through Open Geospatial Consortium (OGC[®]) Web services. This methodology encourages innovation throughout the workflow by allowing a seamless upgrade and integration of technologies.

4. The Power of Geospatial Fusion

Video-based data sources provide the most recent view of a situation and can augment other forms of geospatial intelligence – such as satellite imagery and aerial photos – to provide a richer, more detailed view of the area of interest. To effectively use video as a source of intelligence, however, the analyst needs to seamlessly fuse the video with these other types of intelligence, such as map features and annotations, as shown in Figure 2. This is highly beneficial, as these other sources can help orient the analyst’s point-of-view and improve understanding of the activities occurring within the video by eliminating the “tunnel vision” effect of viewing the video in a dedicated video window. Intergraph is developing a solution that supports this direct fusion and provides a rich decision-support environment.



Figure 2: Fusion of video information, including telemetry, with imagery and other geospatial content can greatly improve analysis and decision-making.

This analysis and integration can greatly assist in properly orienting the analyst and provide insight into actions and objects occurring within the video, as shown in Figure 3. In many cases, the UAV-based video represents the most recent information pertaining to the battlefield and so, when effectively integrated into an existing intelligence analysis workflow, it can yield a powerful analytical advantage and serve to make future planning activities more effective. It is important to understand the advantages and disadvantages of UAV video sources and to then effectively incorporate those sources into existing architectures.

The geospatial layer then serves as a backdrop for integration of the video sources with additional forms of intelligence, such as human intelligence (HUMINT), signals intelligence (SIGINT), and measurement and signature intelligence (MASINT). The need exists to geo-fuse and correlate these disparate intelligence sources to analyze, understand, and visualize information and then derive intelligence value in innovative and exciting ways.

The blending of georeferenced video with other forms of geospatial information can then allow the video source to be a source of geospatial data collection. It may be used as a source of updated information as to the location or portable assets, or characteristics of existing features, such as the length of a runway. Analysts may use the source to update attributes of existing features, such as the operational status of an industrial plant, or bomb damage assessment on a target of interest.



Figure 3: Geospatial features, such as road networks and text annotations, orient the analyst to better understand the environment covered by the video.

5. Geospatial Content Management

Another important factor in using video for analytical purposes is the ability to easily query vast archives of video for specific clips that meet an analyst's search criteria, and to rapidly deliver the results to the analyst's exploitation environment. Some of these criteria may include sensor type, date and time of collection, geospatial extents of the video coverage, and keywords that directly describe objects or activities occurring within the video. The key to providing this type of robust query ability is establishing an enterprise content management system that handles the variety of video formats, along with other complex file formats, such as satellite imagery and elevation models. The end result is a scenario where an analyst can quickly zoom to a part of the world – possibly even down to a street corner resolution – and instantly queue up segments from collected video from the last 10 days that pertains to that street intersection. The analyst can then fuse those results with satellite images and signals intelligence, and effectively plan out an activity, such as the routing of a convoy.

Although the growing volume of imagery, motion video, and other location-based sensor data provide greater coverage and information, they also create data-handling challenges. Traditionally, analysts maintain data in a file-based format through CDs, tapes, and other electronic media. The data-management challenges that arise from this practice can easily overwhelm the analyst and impose limitations on data sharing. In some cases, the analysts can spend more time using Microsoft® Windows® Internet Explorer® searching through the file/folder hierarchy than they actually do analyzing the image. To further describe the problem, image data often is copied directly to the analysts' hard drive without important metadata that describes the life-cycle of the image (when it was acquired, when it was modified and by whom, and when it should be retired and archived), as well as duplicating storage and cluttering up the disk space, requiring the analyst to spend precious time "cleaning house."

Digital file management is a growing influence even outside of the military and intelligence communities. In the digital music consumer market, Apple® provides a digital music file management system, iTunes®, which accompanies every iPod digital music player sold by the company. iTunes provides a user-friendly and powerful interface for managing tens of thousands of digital music files, photos, and videos – completely removing the burden from users to navigate folders and files using Windows Explorer to find those files. This provides the advantage of making the music easily discoverable and provides direct interfaces with the digital music players themselves.

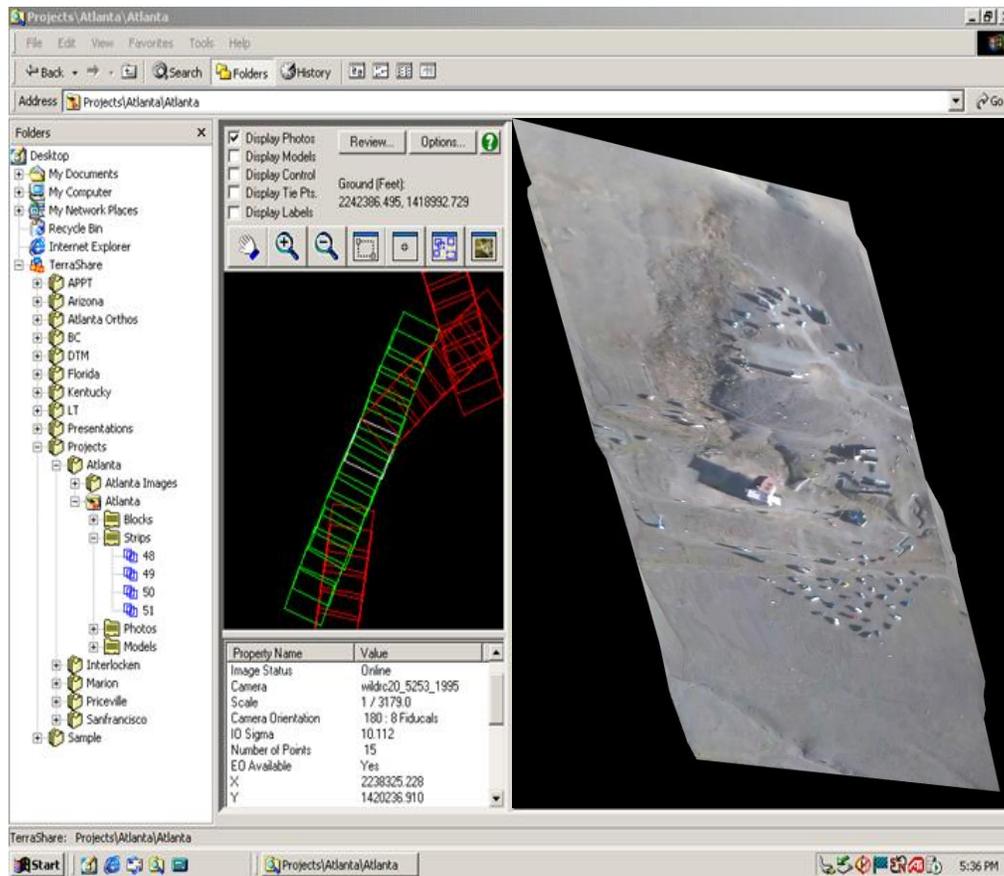


Figure 4. Intergraph's TerraShare provides intuitive access to vast amounts of online data, such as imagery, video, and terrain models.

Likewise, Intergraph provides technology to automate the management of very large amounts of satellite imagery, motion video, aerial photos, elevation data, and other digital files that are essential to the geospatial intelligence exploitation workflow. Intergraph's commercial off-the-shelf (COTS) solution for enterprise image and elevation management, TerraShare® (shown in Figure 4) can provide multiple users with transparent access to large amounts of common imagery. This can greatly reduce the time from collection to exploitation while improving efficiency, collaboration, and quality. This allows for the imagery to be indexed and cataloged, making that imagery discoverable to end users performing manual searches for imagery, and to image exploitation applications that need the most recent set of images covering an area of interest.

As an open system, Intergraph's TerraShare does not require the image, full motion video, LiDAR, or elevation information to be converted into different formats, enabling an efficient IT footprint. In addition, TerraShare can interface with non-Intergraph end-user applications, such as Google Earth, ESRI, and others, to allow users working with those applications to realize the benefits of TerraShare data management.

Just as imagery ingest and management are the keys to more effective use of imagery in a time-sensitive environment, the same holds true for collected video. In order for the video to gain increased usage and value after real-time collection and surveillance, it must be tagged in a way that it can be easily retrievable in the future. In order for this to integrate seamlessly, it will need to be tagged by date/time, as well as geographic context. In some cases, depending on the size of the video clips, some of this tagging may need to happen on individual frames rather than the entire video clip.

6. Automated Geospatial Content Ingest

Although image management systems such as TerraShare provide a robust solution for the storage and distribution of data, many organizations still need methods and technologies that ease the administrative burden of finding, preparing, and uploading the data into these archives. These processes can consume a significant amount of the operators' and analysts' time. As larger volumes of high-resolution data are being collected, and as the turnaround time for results is being compressed, it is essential that the image ingest part of the overall workflow be automated to the greatest extent possible. Today's fast-paced, dynamic environment also demands around-the-clock monitoring and processing of new data. It is clear the only way to ease this burden and realize the full value of these extremely expensive and complex collection assets is to implement a mechanism for automating the ingest, organization, and preprocessing of new imagery as it becomes available. Intergraph's TerraShare Automatic Data Ingest technology provides these capabilities.

TerraShare Automatic Data Ingest completely relieves analysts of the many tedious tasks required to effectively process, organize, and exploit image and full motion video data. TerraShare Automatic Data Ingest automatically generates reduced resolution datasets, histograms, thumbnails, footprints, and necessary image metadata for images as they are ingested into TerraShare. As an additional upstream process, TerraShare Automatic Data Ingest can be configured to process full motion video. The result is that everyone in the organization has direct access to imagery and video that is "ready to exploit" upon arrival, minimizing the time required to search for and process imagery and maximizing the effectiveness and productivity of the entire organization. The confidence level in the analysis results and exploitation tasks dramatically increases as individuals know beyond any doubt they are working with the most recent and relevant data possible. This confidence results in significant time savings and more trusted analyses.

TerraShare Automatic Data Ingest provides executable "services" that continually monitor the system to maintain the customer workflow at the peak of efficiency. The ingest service allows the user to identify specific folders that are "watched" for incoming data. As data is received in these folders around the clock, it is automatically processed without human intervention and placed in a user-specified location with notification to the analyst that new data is available. Note that the actual data file is stored one time only and multiple references to the image are handled via pointers to the original image. This enables the maximum exploitation of time-critical imagery through automatic processing, relieving operators from tedious tasks and optimizing storage space. TerraShare Automatic Data Ingest provides tools that allow the user to define the metadata configuration and auto-populate metadata from imagery headers and user-specific sources. This provides the maximum exploitation of current and historical imagery and video by capturing user-specific metadata that may be used as search criteria. See Figure 5 for an illustration of the TerraShare Automatic Data Ingest workflow.

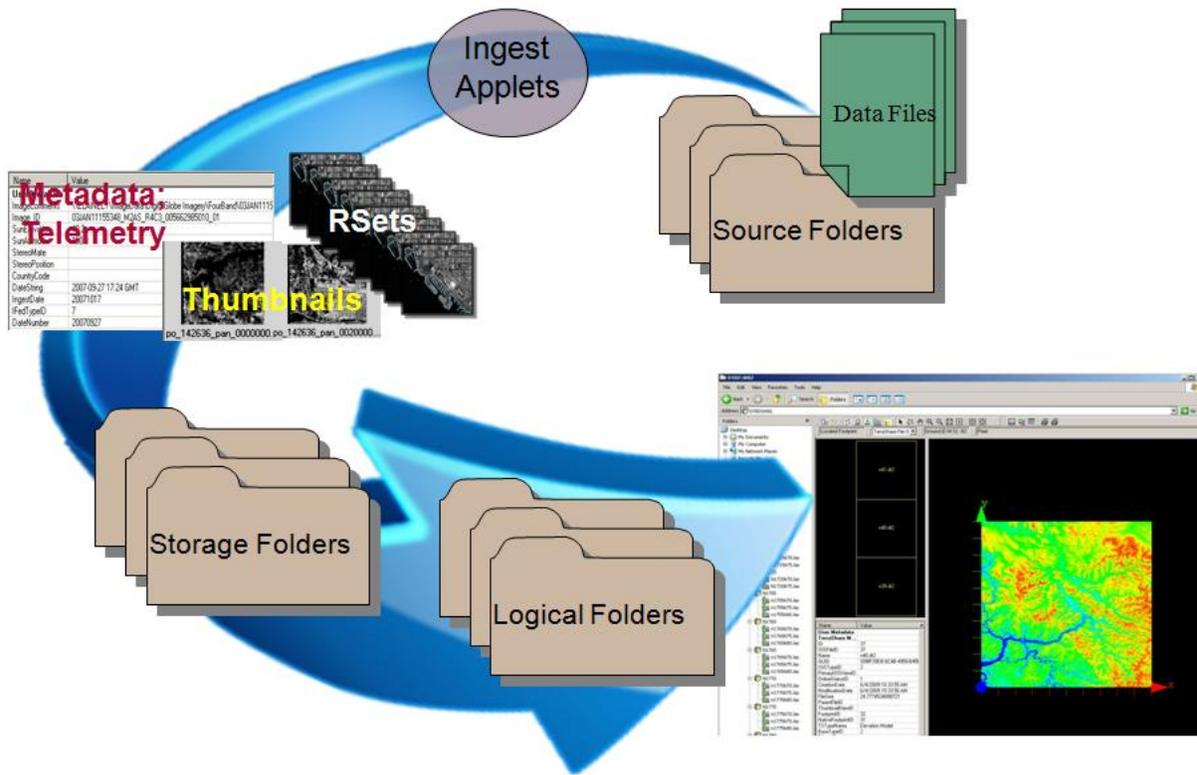


Figure 5: Intergraph's TerraShare Automatic Data Ingest supports customizable, rule-based processing that allows Intergraph and third-party capabilities to be executed on the server side. Output from the upstream processes is managed within TerraShare.

7. Forensic Video Analysis and Real-time Quality Enhancement

In some cases, even with proper content management tools and powerful data integration and visualization tools, poor-quality video can hamper the analytical process. In some cases, the original captured video is of poor quality or is unusable due to flight path, altitude, tilting and buffeting of aircraft, and other factors. Therefore, it is important to provide technology that can work in a modular fashion to perform real-time enhancements and corrections on the video, such as removing atmospheric distortion, correcting for shadows that affect brightness and contrast, and stabilizing jittery video. Intergraph provides state-of-the-art technology for performing these types of enhancements, increasing the usefulness of UAV video in a real-time and forensic capacity. By providing the operator with the ability to set thresholds, tolerances, and other parameters, this video enhancement can be done in batch or interactively, providing multiple opportunities for handling the ever-increasing volume of video that needs to be processed for analysis.

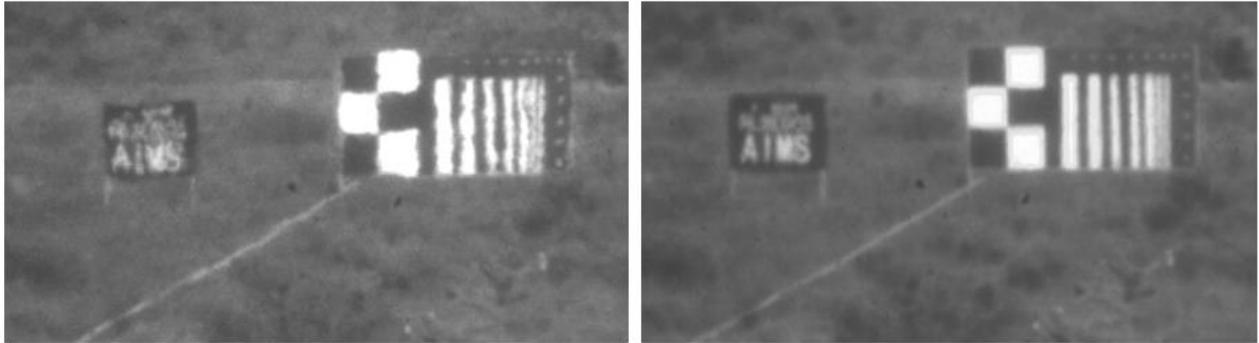
Forensic video analysis can provide much-needed detail into the content within captured video. In some cases where the original captured video is poor quality – possibly due to poor lighting conditions or movement of a vehicle-mounted camera, post-processing is essential for gaining appropriate intelligence. Change detection between video frames can quickly direct an analyst to a specific point of interest within the video.

Intergraph has a strong history of deployment of its forensic video technology in the public safety and law enforcement sectors through its Video Analyst product. It has traditionally been used to enhance and analyze video from closed circuit video systems and dashboard cameras in police and other emergency vehicles. Intergraph is currently enhancing this post-collection-based technology to function in real-time mode to bring these capabilities to operational environments.

Figure 6 shows “before and after” images using Video Analyst out-of-the-box functionality, which includes:

- Image stabilization
- Brighten
- Deinterlace
- Magnify
- Rotate
- Reposition
- Frame average
- Field to frame
- Color tracker
- Audio noise filter
- Absolute difference video transition filters
- Demultiplex
 - Individual and unlimited cameras at one time
 - Individual cameras at a field or frame level simultaneously (user-selected control)

- Select areas of interest
- No lost or dropped frames (patented functionality)
- Additional standard enhancement tool



Original Video stream

Enhanced video stream

Figure 6: Video Analyst can perform real-time quality enhancements, such as removing atmospheric distortion caused by heat haze.

8. Generation of Georeferenced Imagery from Video

A key step towards achieving the fusion of a video data source with other forms of intelligence is generating a georeferenced image as the result of stitching together or “mosaicking” hundreds or thousands of individual video frames. Intergraph is developing an application that automatically generates this georeferenced image, which can then be seamlessly integrated with other forms of static data, such as aerial photos, satellite imagery, or geospatial layers and features. This process can dramatically improve the clarity and accuracy of the video, improving the ability to perform analysis on the video. This video mosaic capability can provide a mechanism to glean additional details from the entire collection sequence that otherwise could not be obtained from individual frames. In cases where satellite imagery or aerial photos are not recent enough, this process will provide a more current representation of an area, which can then be compared to previous images to form a foundation for change detection from video sources. This also reduces the workload for analysts, since they can view the finished product more quickly and completely than by viewing the video in sequence. Since the resulting image is made up of multiple frames that overlap to some degree, the mosaic can provide a clearer representation of the area of coverage, which is essential for exploitation. Figure 7 illustrates the process of generating a georeferenced image from UAV video.

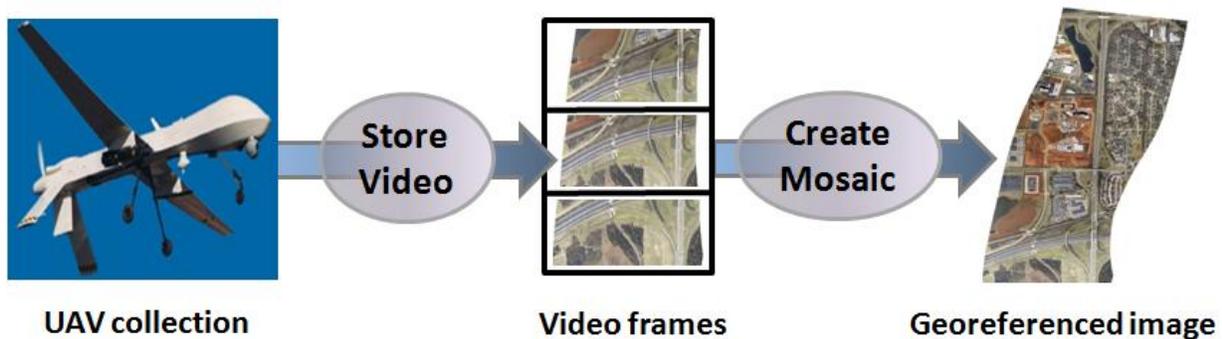


Figure 7: Hundreds or thousands of individual video frames can be quickly processed into one continuous, georeferenced image.

It is important to also retain the original raw video for additional analysis and integration, but this by-product can better orient the analyst and make the video source a viable candidate for geospatial analysis. The resultant video mosaic can serve as the basis for updating geospatial features, such as airfields, roads, bridges, and other types of critical infrastructure.

9. Conclusion

As defense and intelligence organizations work to expand the use of motion video sources for wider-spread purposes, it is important to appreciate that many civilian organizations are also incorporating video data sources into their existing processes and systems. Many civilian organizations of the federal government, as well as state and local governments, are establishing offices and programs to address unmanned aerial systems. As these systems become more reliable and economical, and as policies are implemented, a vast new array of new and innovative applications will emerge. To make the most effective use of aerial video collection in a civilian and military context, it will be extremely important for these organizations to implement the types of technologies that provide reliable enterprise data management, fusion with other forms of geospatial information, cleanup of distorted or jittery video, and superior analytical abilities. The combination of these components is the key to providing the right information at the right time to solve his problem, achieving improved analytical quality, performance, and superior decision making. Intergraph looks forward to working with our partners and customers to provide these types of essential capabilities.

Military and intelligence agencies are faced with the need to adapt to wider-reaching demands and quicker response times than they have in the past. Furthermore, they are assimilating and analyzing more available data than ever before, such as high-resolution imagery, real-time video, and GPS-tracked objects. Never before has there been a greater focus worldwide on security and emergency preparedness. Today's military and intelligence agencies must also meet the expectations of people and organizations who are dealing with natural disasters, an unsettled economy, and devastating global events. Therefore, they need to quickly and effectively collect and analyze relevant information that helps make sense of current situations and reduce conflict around the world. With the continued evolution in technology, such as service-oriented architectures, advanced geospatial applications, mobile technology, and speed and method of transmission, now is the time to provide powerful and intuitive geospatial intelligence solutions that can help military and intelligence agencies be more effective and cost-efficient.

Intergraph has met the challenges of military and intelligence agencies with proven solutions – including products, processes, and experienced professionals – since 1969. Intergraph continues its role as a worldwide geospatial solutions provider with its innovative technology and products focused specifically on the workflows of geospatial intelligence agencies. Integrating geospatial data and workflows with scalable enterprise technology, our solutions help military and intelligence professionals meet their operational goals and enable data sharing across the enterprise. Defense and intelligence agencies around the world consistently rely on Intergraph to provide advanced geospatial solutions for every facet of their operations.

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