

# Express Server: Standards-Based Image Delivery for the Geospatial Industry

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*Advancements in the collection of geospatial imagery in recent years have resulted in the increasing availability of greater quantities of higher quality imagery, and that availability has been matched by increasing demand as business and nonbusiness users have grown to expect high-quality geospatial imagery in more applications on more devices. What has not changed is that the bandwidth available for transferring this imagery is limited, which means that, in general, delivery is the bottleneck in any workflow involving image repositories and end users. This paper describes a software solution that takes advantage of the architecture of the wavelet-based MrSID and JPEG 2000 image formats to deliver high resolution imagery to more users, faster, over any connection.*

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## Introduction

In recent years, the volume and variety of geospatial imagery has skyrocketed. Not only has the accuracy of satellite imagery increased, but so has the complexity. It is now common for new satellites to capture multispectral imagery with dozens of bands. Moreover, these improvements have been matched by the rise of microsattellites and unmanned aerial vehicles, both of which promise cheaper and more frequent image collection.

All of this innovation however comes at the cost of increased image sizes, which for modern organizations presents new problems in the form of rapidly rising file storage costs and increased complexity when hosting and distributing the newly acquired imagery. Indeed, the need for reliable and storage efficient image-delivery has never been more pressing.

In this white paper, LizardTech presents one solution to this problem using LizardTech's Express Server software, which delivers compressed MrSID and JPEG 2000 imagery to reduce storage costs and decrease image loading times.

## Express Server Overview

LizardTech Express Server is a software application for rapidly distributing high-resolution satellite imagery, aerial photographs, and other large raster datasets. Imagery hosted on Express Server is stored in the MrSID or JPEG 2000 image formats, which are compressed image formats that reduce storage costs and minimize required network bandwidth.

MrSID is a patented compression technology perfected by LizardTech over twenty years, and JPEG 2000 is an ISO-standard file format though it was not created specifically for geospatial applications. Both file formats rely on similar advanced compression technologies, including the wavelet transform and arithmetic encoding.

## Comparison with Traditional Image Servers

Express Server reads and serves imagery directly from compressed source images to reduce storage costs. This is in contrast to traditional image servers, also called tile servers, which generate and cache tiled images from the source images hosted on the server. By creating these tiled images, the tile server avoids reading an entire source image every time that a small portion of the image is requested. Although this increases the efficiency of the server, it requires duplicating the source image data at multiple resolutions, such that the cached tiles are often several times the size of the source image.

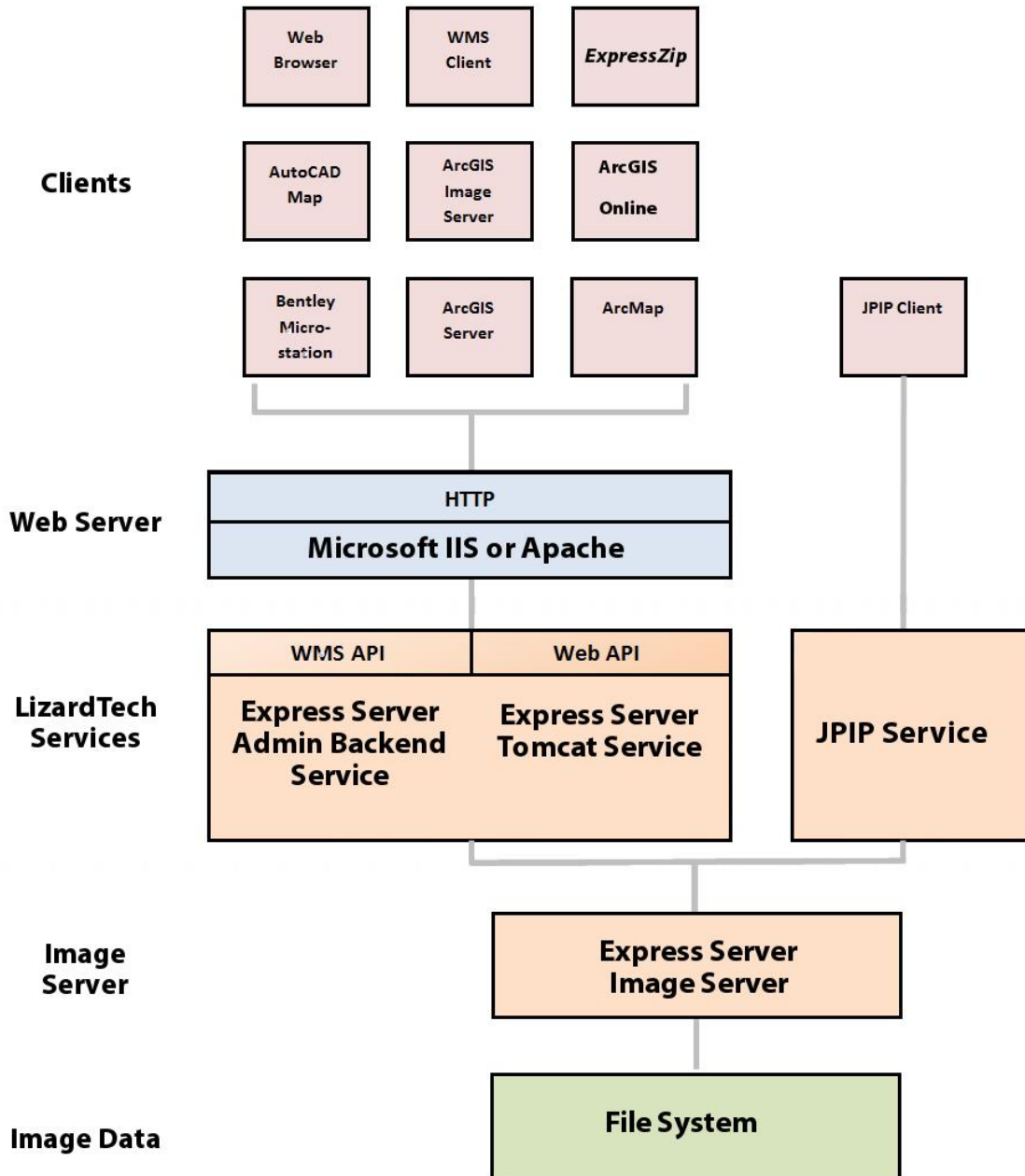
The exceptional characteristic of Express Server is that it can read directly from compressed images without sacrificing responsiveness and efficiency. This special quality is due to the wavelet-based nature of the MrSID and JPEG 2000 formats which can be decompressed selectively and can incorporate multiple image resolutions without duplicating image data.

With MrSID and JPEG 2000 encoding, images are compressed such that multiple resolution levels of an image, from an overview all the way up to the full resolution, are the natural result of compressing the image. Additionally, because of the way the actual bits representing the image are stored, any portion of an image can be decompressed at any resolution level without the necessity of decoding the entire image. Express Server is built specifically to take advantage of this selective decompression feature of MrSID and JPEG 2000, extracting the requested scene quickly and converting it to an image scene in one of several output formats.

## Express Server Architecture

Express Server runs on top of an existing web server and provides access to compressed imagery stored on the server's file system or on the network. Clients can then connect to the web server using multiple protocols, including the OGC Web Map Service (WMS) standard, the streaming JPEG 2000 Interactive Protocol (JPIP), and an Express Server-specific web API.

Figure 1: Express Server Architecture



## Clients

Express Server imagery can be accessed from any WMS client. WMS is a widely-supported standard that users can access to view imagery from web browsers, from desktop GIS applications, from the ExpressZip web application included with Express Server, and more.

If the optional Express Server JPIP component is installed, then users can also access imagery from JPIP clients.

## Web Server

Express Server works in conjunction with an existing web server installation to distribute imagery. Express Server is compatible with both the Microsoft IIS web server on Windows and the Apache web server on Linux.

## LizardTech Services

LizardTech services provide an interface between the web server and the image server. The following list describes the LizardTech services created during the installation of Express Server:

- **Express Server Admin Backend Service.** The Admin Backend service, or the Express Server Agent, processes requests from the Express Server Manager to start or stop the web server and perform licensing tasks.
- **Express Server Tomcat Service.** The Tomcat service runs the Express Server web applications, including Express Server Manager for managing Express Server and ExpressZip for image-export.
- **JPIP Service.** The JPIP service is an optional service added during the Express Server installation. The JPIP service processes requests from JPIP clients.

## Image Server

The image server is the core of the Express Server installation and processes all image requests. When users connect to Express Server, the image server receives the image request and renders the image.

By default Express Server delivers extracted scenes as JPEG images. Other options for final delivery format are PNG (.png), GIF (.gif), TIFF (.tif and .tiff) and Bitmap (.bmp).

## Image Data

The source image data distributed by Express Server is stored on a local or network file system. Express Server supports MrSID, JPEG 2000 and NITF imagery.

## Supported Image Formats

MrSID and JPEG 2000 are both wavelet-based formats that facilitate the efficiencies of raster data storage and distribution. Because their wavelet-based algorithms naturally and automatically result in multiple resolutions of an image within the compressed image file itself – from the full resolution image down to a

low-resolution thumbnail – both formats provide the high image quality required by geospatial professionals yet obviate costly and time-consuming image pyramiding.

MrSID images are identified by generation and may be MrSID Generation 2 (MG2™), MrSID Generation 3 (MG3™) or MrSID Generation 4 (MG4™). There are important differences among them. MG2, the oldest version, has a 2-gigabyte file-size limit and does not support lossless compression. MG3 introduced support for lossless compression and a number of other features including reprojection, color balancing, despeckling and encoding areas of interest, and removed the 2-GB size limit.

MG4 is the most recent evolution of the MrSID format. In addition to mosaicking datasets together, color balancing raster imagery, and manipulating data in other ways as do MG2 and MG3, MG4 enables geospatial professionals to losslessly compress 3-banded and multispectral (including hyperspectral) geospatial data so that they can make full use of the most up-to-date imagery. MG4 also introduced support for alpha bands, which remove the problem of speckling in the transparency areas of mosaics.

The following table illustrates the differences between versions of the MrSID format and JPEG 2000.

**Table 1: Support for Common Requirements in LizardTech File Formats**

Situation/Requirement	Supported by Output File Format			
	MG2	MG3	MG4	JPEG 2000
Lossy output with maximum 3 bands, cropping but no advanced encoding, output less than 2 GB*	♦	♦	♦	♦
Advanced encoding (reprojection, color balancing, despeckling, area of interest encoding, etc.)		♦	♦	♦
Output file size greater than 2 GB		♦	♦	♦
Lossless output		♦	♦	♦
Mosaic that has MrSID tiles as input		♦	♦	♦
Multispectral input			♦	♦
Optimization		♦	♦	
Alpha band			♦	♦
Signed datatypes (e.g. s8, s16)			♦	♦
Arbitrary band mapping			♦	
Per-band compression			♦	

NITF (National Imagery Transmission Format) is a suite of standards for the exchange, storage, and transmission of digital-imagery products and image-related products within the U.S. Department of Defense and the Federal Intelligence Community. NITF supports compression to JPEG 2000 format.

## Visualizing Image Requests

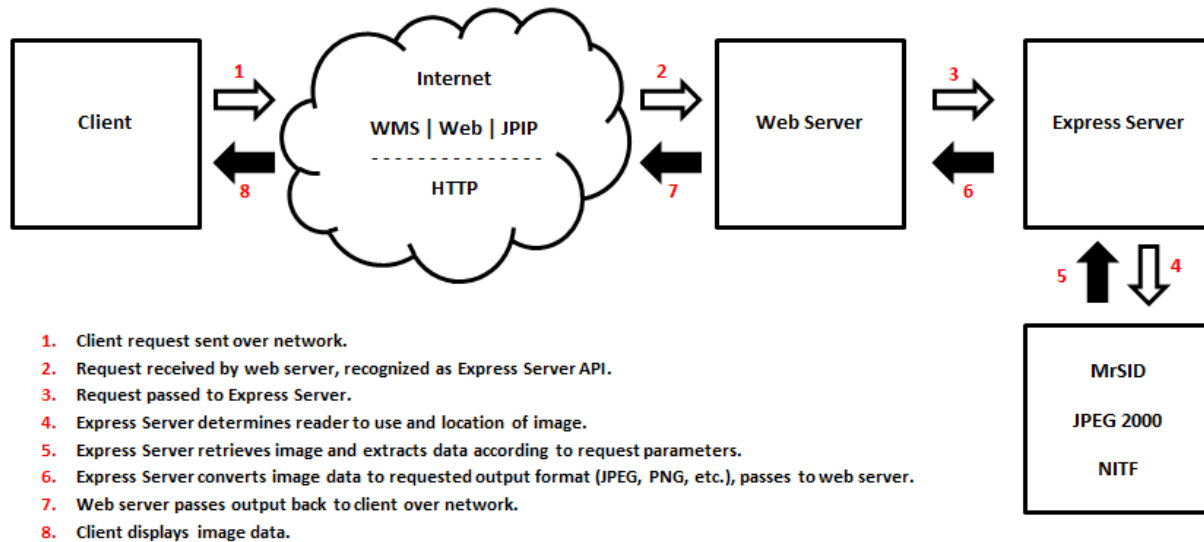
The diagram below illustrates the roundtrip of an image request to Express Server and back. Once a client image request is received by the web server, the request is recognized as belonging to one of the protocols supported by Express Server. The Express Server engine then:

- determines what reader to use
- locates and opens the image after consulting the various caches



- extracts the requested scene based on requested parameters such as level (resolution), width and height, and geospatial coordinates
- engages an image writer based on the specified output format
- delivers the image

Figure 2: Visualizing Image Requests



## Hosting Imagery

Express Server hosts imagery directly from a local or network file system. This file-system based approach simplifies image management and requires minimal server administration. Administrators can use a simple web-based administration tool called the Express Server Manager to point Express Server to the location of imagery on the file system and configure Express Server settings.

Images on the file system correspond to image catalogs in Express Server. Catalogs are simply image directories that administrators make accessible on the server.

## Image Catalogs

Express Server treats every image as part of a catalog. The catalog is the basic edifice used by Express Server to organize images and house information about them and instructions about how to treat them. For the purposes of WMS, a catalog is the same thing as a layer.

Additionally, catalogs can be organized into catalog groups so that users can view multiple related image catalogs through a single virtual catalog.

Catalogs include several configuration options which change how the image appears to users. For example, administrators can configure the following properties for each catalog:

- the name of the catalog

- the directory of the images that make up the catalog
- whether the catalog should have an overview image
- the coordinate reference system to use for the catalog
- the image bands to display if the image is a multispectral image

## Viewing Imagery

Express Server's architecture is standards-based, which enables image delivery quickly to virtually any client viewer, regardless of the device or the amount of bandwidth. Express Server responds to a request formulated according to one of three protocols: WMS, JPIP, or the Express Server web API. Each request is in the form of a URL.

### Protocols

The Web Map Service standard (WMS) provides a simple HTTP interface for requesting georeferenced map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more georeferenced map images (returned as JPEG, PNG, etc.) that can be displayed in a WMS-enabled GIS application. The WMS protocol is an Open Geospatial Consortium standard, and is nearly universal among GIS applications and GIS viewers.

The JPIP client/server communication protocol is defined in Part 9 of the JPEG 2000 suite of standards, (ISO/IEC 15444-9). JPIP progressively streams the wavelet coefficients for a requested part of a picture, which saves bandwidth, computer processing on the server, and time. It allows for speedy viewing of a large image in low resolution or a higher-resolution part of that same image. Using JPIP, it is possible to stream large images (for example 1 gigapixel) to relatively lightweight hardware such as mobile tablet devices.

### Comparing Requests from WMS and the Express Server Web API

Though the syntax of the requests is different, the WMS API is functionally equivalent to the web API. Express Server's web API enables web browsers to make requests for images or scenes from images according to various specified parameters. The URL request can be formed either through the clicking of graphic elements or by manual entry in the URL field. The WMS API essentially does the same thing, but WMS was created as a standard means of importing data in diverse locations into a GIS. The WMS API enables geospatial applications to pull in Express Server catalogs as layers.

A catalog is WMS-enabled (available for WMS requests) when it is *spatially indexed*. This means that Express Server understands how to fit all the images in a catalog into a mosaic and has assigned the catalog a coordinate reference system (CRS) in the form of an EPSG code. Instead of having to open each image in the catalog to find out where it belongs in the world and in the mosaic, Express Server consults a single index file that contains this information for all the images in the catalog.

The following two requests both return a summary of available catalogs on an Express Server installation hosted at "demo.lizardtech.com". The first is a WMS API request, the second a web API request. Express

Server supports version 1.1.1 of the OGC WMS specification via the `GetCapabilities` and `GetMap` calls.

<http://demo.lizardtech.com/lizardtech/iserv/ows?SERVICE=WMS&REQUEST=GetCapabilities>  
<http://demo.lizardtech.com/lizardtech/iserv/browse?style=none>

The reply sent back by Express Server is an XML document (which in the web API gets turned into an html page displaying thumbnails of the available catalogs). The above URLs are live and will each return XML output. A user will not normally see the XML, but a look at some XML excerpts will show some interesting items.

Below is the return from a WMS “`GetCapabilities`” request showing one catalog. Note that it is referred to as a “`layer`”, and that the extents are described in terms of a “`bounding box`”.

```
<Layer opaque="1">
<Name>Florida</Name>
<Title>Florida</Title>
<SRS>EPSG:26917</SRS>
  <LatLonBoundingBox maxx="-81.248255" maxy="29.572644" minx="-82.908008" miny="26.740052" />
  <BoundingBox SRS="EPSG:26917" maxx="475315.500000" maxy="3271459.500000" minx="315151.500000"
miny="2958993.500000" resx="1.00000000" resy="-1.00000000" />
<ScaleHint max="92681.900024" min="1.414214" />
</Layer>
```

***Note:** For more information about how the various XML elements are used in WMS requests and what their values signify see the [Further Reading](#) section at the end of this document.*

Below is the same catalog listed in the return from a web API “`browse`” request.

```
<Item georgn="315151.500000,3271459.500000,475315.500000,2958993.500000" name="Florida"
srs="EPSG:26917" />
```

Following is a WMS request to open the catalog which it identifies as the layer called “`Florida`”. We’ve broken up the URL into rows so it can be viewed more easily.

<http://demo.lizardtech.com/lizardtech/iserv/ows?SERVICE=WMS>  
[&VERSION=1.1.1](#)  
[&REQUEST=GetMap](#)  
[&LAYERS=Florida](#)  
[&SRS=EPSG:26917](#)  
[&BBOX=207753.9,2958993.5,582713.1,3271459.5](#)  
[&WIDTH=600](#)  
[&HEIGHT=500](#)  
[&FORMAT=image/jpeg](#)  
[&TRANSPARENT=FALSE](#)

In the web API, the same catalog is requested using the “`getImage`” command, as follows:

<http://demo.lizardtech.com/lizardtech/iserv/getimage?>  
[cat=Florida&item=iserv-catalog-index](#)  
[&rgn=207753.9,3271459.5,582713.1,2958993.5&geo=true](#)  
[&wid=600&hei=500&method=scale](#)  
[&oif=jpeg](#)

The above examples demonstrate the basic methods by which clients retrieve imagery and information from Express Server. They are live examples that both open the same Florida mosaic.

## JPIP Requests

Express Server’s JPIP API is an optional component that works with any JPIP viewing client.

In a JPIP transaction, the viewing client sends a request for a connection along with some information about how large of a “chunk” of image data it wants to receive at a time and a summary of what it knows about the imagery it hopes to view. The server sends back a channel ID number and opens a transfer session. The channel ID number identifies the session and is used by the client in each subsequent request for more data.

Because Express Server’s JPIP server component streams wavelet coefficients instead of sending images there is always something to render in a JPIP viewer. Image detail is filled in as it arrives. This can be taken advantage of in several ways depending on the capabilities of the viewing client. For example, the image data might be requested in such a way that priority is placed on rendering the entire image at low- quality before more detail is rendered in any given portion of the image, or the opposite might be requested: an area of interest can be specified that receives priority as the data is being delivered, and where the maximum image detail is filled in first. In practice, a user might open the image as a layer in a GIS application and, before the image renders at full quality, draw a rectangle specifying an area of interest. At that point, Express Server stops filling in the entire image and focuses on supplying image data for just that area of interest.

For example, compare the following two requests from a JPIP viewer:

```
http://localhost:9013/jpip?fsiz=482,813,closest&roff=0,0&rsiz=482,813&stream=0&context=jpxl<0>&len=2000&cid=JPH_FFFC70D8428336C1:
```

```
http://localhost:9013/jpip?fsiz=4849,6497,closest&roff=3228,2480&rsiz=267,169&stream=0&context=jpxl<0>&len=2000&cid=JPH_FFFC70D8428336C1
```

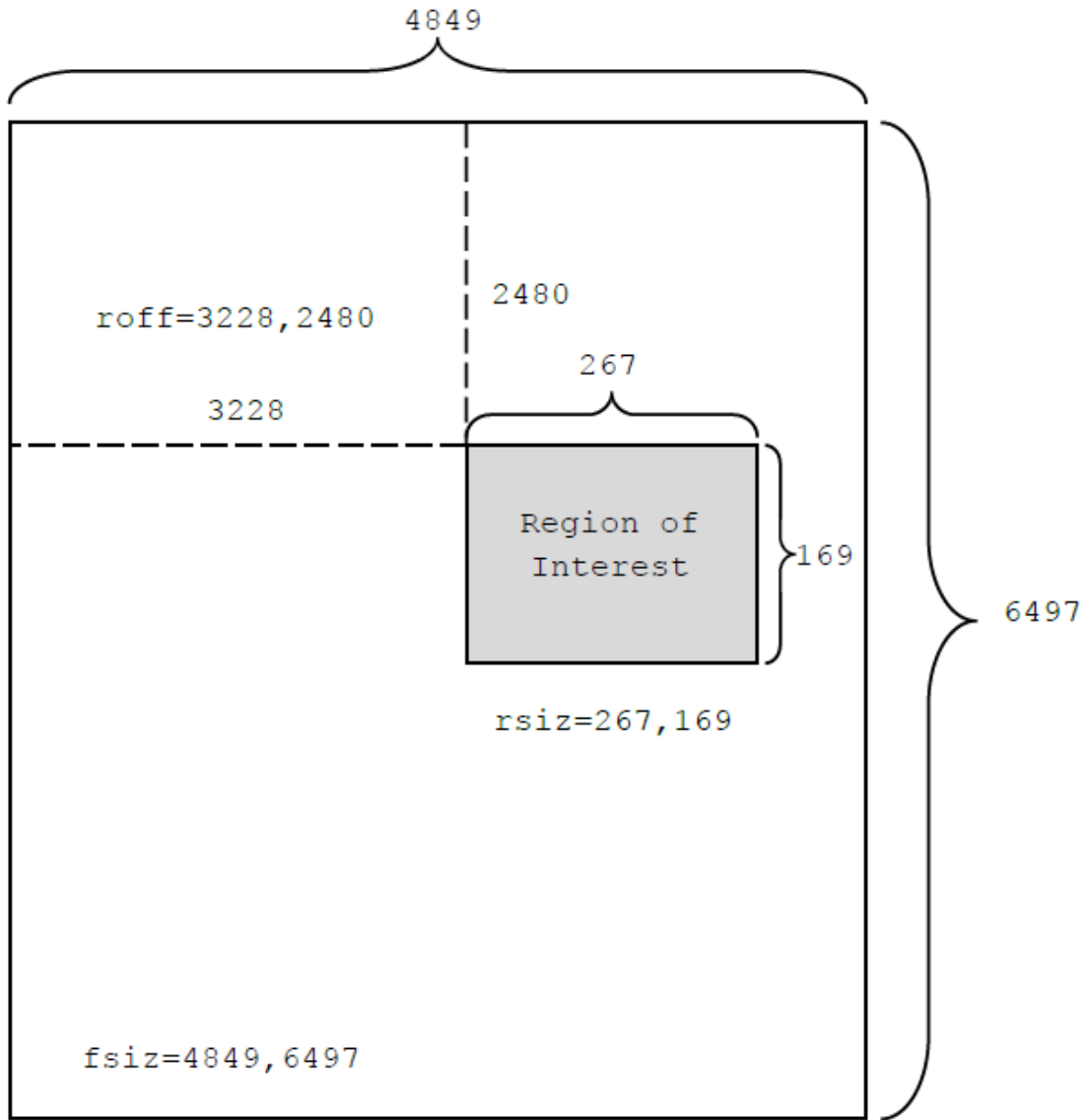
*Note: For more information about how the various XML elements are used in JPIP requests and what their values signify see the Further Reading section at the end of this document.*

Important words have been highlighted for emphasis. In both URLs you can see the channel ID number (`cid`) at the end. Also, the desired chunk size or “length” of the stream (`len`) is 2000 bytes in both. You’ll notice that in the first URL, `fsiz` (the size of the entire image) and `rsiz` (the size of the region of interest) are the same – 482 pixels on the *x* axis and 813 on the *y* axis – and that the `roff` (region offset) has a value of zero, which means that there is no particular region of interest being specified. The region starts in the upper left corner of the image (0, 0) and is the same size as the image. In this case the detail for the entire image will be filled in at an even rate.

But in the second URL (see Figure 3 below) there is an offset of 3228 pixels on the *x* axis and 2480 on the *y* axis and the size of the area of interest is only a small part of the image – 267 pixels by 169 pixels. In this case Express Server will send the detail for that smaller region first.

This is just one application of the capabilities of the JPIP protocol in Express Server software.

Figure 3: A JPIP Region of Interest



## Conclusion

Express Server is a technologically advanced and efficient method of serving raster imagery that has been compressed to MrSID and JPEG 2000 format. Because it is designed to take advantage of the multiresolution nature of these formats and their support for selective decoding, Express Server used with other GIS image servers delivers imagery faster than those image servers can do alone, especially as the number of concurrent requests and size of imagery increase.

As geospatial image data increases both in quality and in quantity, so does user demand for that imagery, especially now that applications with geospatial components are in the hands of millions of everyday mobile users. Express Server is the fastest and most efficient method for ensuring that the imagery will be there whenever and wherever users need it.

## Further Reading

For more information about LizardTech Express Server see the following:

- The Express Server product page at <http://www.lizardtech.com/products/exp/>.
- Express Server's online documentation at <http://demo.lizardtech.com/lizardtech/iserv/docs/manual/>.
- Case Study: [Air Force Special Operations Command](#)
- Case Study: [State of New Jersey Office of Geographic Information Systems](#)
- Case Study: [Quebec Ministry of Sustainable Development, Environment and Parks](#)

For more information about Web Map Service (WMS) see the following:

The WMS specification, available for download on the Open Geospatial Consortium (OGC) website:  
<http://www.opengeospatial.org/standards/wms>.

For information about JPIP see the following:

- JPEG 2000 Interactive Protocol (Part 9 – JPIP) at <http://www.jpeg.org/jpeg2000/j2kpart9.html>.
- The JPIP specification, available for download at the International Telecommunication Union (ITU) website:  
<http://www.itu.int/rec/T-REC-T.808/en>.

# Glossary

Following is a list and definitions of several words, phrases and acronyms appearing in the foregoing text.

**alpha band** – also called *alpha channel*. An additional band used to contain masking or transparency information about other bands in an image. See also *transparency*.

**API** – A language and message format used by an application program to communicate with the operating system, communications protocol or some other control program.

**band** – a set of samples corresponding to one spectral component of an image, e.g. the “red” band of an RGB image.

**Bitmap** – a raster graphics image file format used to store bitmap digital images, independently of the display device (such as a graphics adapter), especially on Microsoft Windows and OS/2 operating systems. Also known as *BMP*. The BMP file format is capable of storing 2D digital images of arbitrary width, height, and resolution, both monochrome and color, in various color depths, and optionally with data compression, alpha channels, and color profiles.

**cache** – generally, a component that transparently stores data so that future requests for that data can be served faster. Express Server employs several cache strategies in concert for optimal performance.

**catalog** – an array of folders with images in them, located on one or more file systems to which Express Server has access. A catalog can also be a single indexed image.

**client** – the viewing computer or application. More broadly, the requesting end of the spectrum in a request/supply relationship between programs.

**composite mosaic** – a compressed MrSID mosaic in which all the input tiles remain individual images wrapped by a single file structure. Unlike in a *flat mosaic*, which becomes a single image upon encoding, any image in a composite mosaic can be updated in place. See also *flat mosaic* and *mosaic*.

**compression** – an operation that creates a new image file from an original image file such that the file size of the new image is smaller. The reduction in file size may be at the expense of some image quality. (Note that the file size is what is reduced, not the dimensions of the image itself.) See also *lossless* and *lossy*.

**coordinate reference system** – (also referred to as *CRS*, *projection*, *spatial reference system*, *SRS*), a coordinate-based local, regional or global system used to locate geographical entities. A coordinate reference system defines a specific map projection, as well as transformations between different coordinate reference systems. Coordinate reference systems are defined by the OGC's Simple feature access using well-known text, and support has been implemented by several standards-based geographic information systems. Coordinate reference systems can be referred to using a SRID integer, including EPSG codes defined by the International Association of Oil and Gas Producers.

**CRS** – See *coordinate reference system*.

**despeckling** – a process by which pixel values that have been slightly changed in compression are returned to the specified transparency value to eliminate artifacts, usually a speckling in collar or "no- data" areas.

**element** – a discrete section of an XML document. An element can contain other elements, which can then be thought of as subelements. See also *XML*.

**EPSG code** – a series of numbers representing a coordinate reference system recognized as one in a set compiled by the European Petroleum Survey Group (EPSG). EPSG was a scientific organization consisting of specialists working in applied geodesy, surveying, and cartography related to oil exploration. EPSG compiled and disseminated the EPSG Geodetic Parameter Set, a widely used database of Earth ellipsoids, geodetic datums, geographic and projected coordinate reference systems, units of measurement, etc. An example of an EPSG code is 4326, which identifies the coordinate reference system WGS 84.

**flat mosaic** – a mosaic of tiled images that has been encoded as a new, single image, as opposed to a *composite mosaic*, which is an indexed image file wrapping many separate image tiles. Any tile in a composite mosaic can be replaced in an update operation. In a flat mosaic the original tiles that comprise it do not retain separate identities. See also *composite mosaic* and *mosaic*.

**georeferenced** – defined in physical space. The location of a georeferenced image is established in terms of map projections or coordinate reference systems.

**GIF (Graphics Interchange Format)** – a bitmapped graphics file format developed by CompuServe and widely used on the Internet.

**grayscale** – having a single sample for a value, rather than three (RGB) or more (multispectral). A grayscale pixel carries only intensity information. Grayscale images, also known as black-and-white, are composed exclusively of shades of gray, varying from black at the weakest intensity to white at the strongest.

**HTTP (HyperText Transfer Protocol)** – the communications protocol used to connect to web servers on the Internet or on a local network (intranet). Its primary function is to establish a connection with the server and send HTML pages back to the user's browser. It is also used to download files from the server either to the browser or to any other requesting application that uses HTTP.

**hyperspectral** – see *multispectral*.

**image pyramid** – a digital image storage construct in which multiple versions of the same image are created at different resolutions for responding to image queries at various zoom levels. For comparison see *multiresolution*.

**JPEG 2000** – an image compression standard and coding system created by the Joint Photographic Experts Group committee in 2000. Their purpose was to supersede their original discrete cosine transform-based JPEG standard (created in 1992) with a newly designed, wavelet-based method.

**JPIP (JPEG 2000 Interactive Protocol)** – a compression streamlining protocol that works with JPEG 2000 to produce an image using the least possible bandwidth. JPIP has the capacity to download only the requested part of a picture, saving bandwidth, computer processing on both ends, and time. It allows for the relatively quick viewing of a large image in low resolution or a particular region of the same image at a higher resolution.

**layer** – with regard to Express Server, an image or catalog of images spatially indexed for viewing in a GIS via WMS.



**lossless** – encoded with no loss of data. A *losslessly* encoded image contains a representation of all of the original pixel values. When decoded, a lossless image is mathematically identical to the original. See also *lossy*.

**lossy** – encoded in such a way that some image data is permanently discarded. A lossy image contains an approximation of all of the original pixel values. When decoded, depending on the quality of the compression, a lossy image may appear to be a poor representation of the original, visually indistinguishable from the original, or anywhere in between. The perceived image quality is affected by changes in the sharpness of edges, color balance, reduced resolution, and so forth. See also *lossless*.

**MG2** – see *MrSID*. **MG3** – see *MrSID*. **MG4** – see *MrSID*.

**mosaic** – a composition of two or more images to form a new, larger image. Positioning of the images is generally based on geospatial coordinates. See also *composite mosaic* and *flat mosaic*.

**MrSID** – MrSID is a wavelet-based image format designed for large, high-quality geospatial imagery. There are three versions of MrSID, known as MrSID Generation 2 (MG2), MrSID Generation 3 (MG3) and MrSID Generation 4 (MG4). MG2, the first released version of the format, is limited to lossy encoding and does not support optimization. MG3, the second version, supports lossless encoding, image optimization, and composite images. MG4, the most recent version, supports alpha bands, multispectral imagery, and improved composite mosaicking.

**multiresolution** – containing all the image data for multiple representations of an image at different resolutions. MrSID images are multiresolution images, in that a single MrSID file contains compressed data that viewers decode at any desired resolution or “zoom level”. For comparison see *image pyramid*.

**multispectral** – having more than three bands. A multispectral image contains image data at a range of frequencies across the electromagnetic spectrum. An example of a multispectral image is RGB-IR, which contains bands housing data from the red, green and blue wavelengths plus an infrared band.

Multispectral imagery includes hyperspectral imagery, which contains potentially hundreds of bands that correspond to extremely narrow divisions of the spectrum.

**NITF/NITFS (National Imagery Transmission Format Standard)** – a suite of standards developed and used by the U.S. Department of Defense and Federal Intelligence Community for the exchange, storage, and transmission of digital-imagery products and image-related products.

**no-data** – See *transparency*.

**OGC (Open Geospatial Consortium)** – an international voluntary consensus standards organization that originated in 1994. In the OGC, more than 400 commercial, governmental, nonprofit and research organizations worldwide collaborate in a consensus process encouraging development and implementation of open standards for geospatial content and services, GIS data processing and data sharing.

**optimization** – the process of creating an MG3 image from a source MG3 image, such that the new image is better suited for some purpose or workflow. The most common optimization is compression; other optimization operations include cropping and removal of resolution levels.

**PDA (Personal Digital Assistant)** – A handheld computer for using personal productivity applications such

as those for managing contacts, appointments and tasks..

**PNG (Portable Network Graphics)** – A bitmapped graphics file format endorsed by the World Wide Web Consortium.

**port** – an application-specific or process-specific software construct serving as a communications endpoint in a computer's host operating system. A port is associated with an IP address of the host, as well as the type of protocol used for communication.

**projection** – See *coordinate reference system*.

**raster image** – a dot matrix data structure representing a generally rectangular grid of pixels, or points of color, viewable via a monitor, paper, or other display medium. Raster images are stored in image files with varying formats.

**reprojection** – the process of changing the coordinate reference system or “projection” that an image is displayed in. See also *coordinate reference system*.

**resolution** – the scale at which an image is represented, as expressed in pixel dimensions. Resolution can also refer to ground units per pixel as used for georeferencing (a value stored in the metadata of an image). See also *zoom level*.

**RGB** – an additive color model in which red, green, and blue light is added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue. The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers.

**scene** – the area of an image requested by the client for viewing, anything from a zoomed-in portion of the image to the entire image. In the rendering of a requested scene all portions of the image that constitute any part of that scene at the quality specified are decoded and delivered.

**selective decompression** – decoding of a portion of an image or mosaic so that some image data can be viewed immediately, as opposed to decoding the entire image before showing any desired portion.

**spatial index** – an index used to optimize spatial queries or, in this case, requests for imagery. A spatial index describes the spatial relationship of each image in a catalog to every other image in that catalog, enabling Express Server to mosaic the images together so that each image is in the right place and is correct according to a given projection system.

**speckling** – artifacts in collar or "no-data" areas of a mosaicked image caused by drifting pixel values during compression. See also *despeckling*.

**streaming** – in Express Server's JPIP implementation, transmitting wavelet coefficients from a compressed image file instead of transmitting an image. See *wavelet coefficients*.

**TIFF (Tagged Image File Format)** – A bitmapped graphics file format developed by Aldus Corporation that handles monochrome, gray scale, 8-and 24-bit color.

**transparency** – also called *no-data*. A feature of some image file formats, including MrSID and JPEG 2000, whereby pixel data in specified areas are ignored in favor of imagery underneath. In an image mosaic source tiles often overlap, and valid image data in one tile is sometimes covered by non-image (collar) data

from another. A transparency color value can be assigned so that any pixel whose values match the transparency value is discarded in favor of the pixel below it.

**wavelet coefficients** – arrays of numbers arrived at via a wavelet-based mathematical algorithm. Wavelet coefficients represent a given set of image data's spatial position within an image, scale (or "resolution"), and quality contribution.

**wavelet** – a mathematical representation of a pixel value that varies by frequency and duration; in wavelet space, the importance of a pixel depends on the values of its neighboring pixels. Wavelet-based image formats are able to present images at multiple levels of resolution without the overhead of pyramidal formats. See also *multiresolution* and *image pyramid*.

**WMS (Web Map Service)** – a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. The specification was developed and first published by the Open Geospatial Consortium in 1999.

**XML (Extensible Markup Language)** – a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is defined in the XML 1.0 Specification produced by the World Wide Web Consortium (W3C).

**zoom level** – the resolution of an image expressed as a scale or magnification number. See also *resolution*.