DGIWG – 308

DGIWG JPEG 2000 (JP2K) Scoping Study Report

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Abstract:	This is a study of the compression and encoding of geospatial imagery using JPEG2000, and resulting recommendations for ensuring interoperability.

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Executive summary

In 2008, France and other DGIWG nations decided to perform a JPEG 2000 (JP2K) scoping study in order to assess member nation interest in the use of the JP2K compression method and file format within the international defence community.

The French MoD proposed the submission of a technical report based on:

- an initial study on JP2K and other compression options (e.g. PNG, JPEG-LS, ECW, MrSID, JPEG XR) for geospatial imagery (during 1st semester 2008)
- specification of a compressed profile for rapid display basemap products (denominated FAR - ("Fonds d'Affichage Rapide")
- specification of an orthoimagery product (Geobase ORTHO3).

This French study recommended the use of JP2K compression and JP2 formatting in order to optimize interoperability and efficiency for data access and display. It indicated levels of performance based on evaluation of Defence geospatial products and identified JP2K relevant standards, specifications, and profiles. It also identified JP2K-capable open source and commercial software, other related studies, and on-going specification works.

The main recommendations of this technical report for an interoperable JP2K encoding for imagery, gridded and coverage data are:
- JP2K encoding: 15444-1 according to profile 1 constraints
- Georeference: GeoJP2™ + GMLJP2 (warning: the use of GeoJP2 may be sunsetted in the future).
- Additional metadata based on 19115 and 19115-2 standards.
- JP2K formats: use of JP2 format. BIIF (NITF) encapsulation is another option used in US specifications and ECRG product.

For information, the key characteristics / issues of the FAR product are:
- data type: raster or rasterized maps, spacemaps (vector superimposed on orthoimagery)
- local or network data access
- JP2K 15444-1 profile 1,
- JP2 format
- Compression parameters: near-lossless, use of W9X7 wavelet filter,
- codeblock 64x64
- Compression ratio: between 1:10 and 1:30 depending on input data
- Tiling scheme: no tiling, or 1024x1024 tiling (for compression performance / speed)
- Recommended code-stream progression order : RPCL, LRCP, RLCP
- Associated metadata: georeference metadata + other metadata (e.g. 19115 / 19115-2 conformant) and encoding of optional detailed quality information (e.g. local standard deviations and correlation matrix), conformant with DNG metadata specifications[1].

Acknowledgement

The information provided is issued from works on geospatial products (base maps and orthoimagery) funded by the French Ministry of Defence.

[1] Metadata specification for French Defence geographic products

i. Preface

This document is based on a technical report submitted by French MoD to DGIWG and reviewed by nations in January 2010.

ii. Submitting organizations

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iv. Revision history

Date	Release	Editor	Primary clauses modified	Description
2009-10-07	0.1	E. Devys		Initial version
2009-10-15	1.0	E. Devys	All	Integration of comments from DGA and reviewers
2010-03-5	1.1	E. Devys	All	Update in order to solve comments after DGIWG review (refer to document Resolution_Comments_Grid_JP2K scoping_study1.0 on DGIWG portal)

v. Future work

Future work may address a JP2K Best Practice document consolidating the recommendations of DGIWG nations for implementing JP2K in geospatial imagery products and systems.

1. Introduction

1.1. Scope

This document is a technical report for the "JP2K scoping study" performed by the DGIWG Imagery and Gridded Data Coordination Group, which addresses the compression and encoding of geospatial imagery and other gridded coverage data. IGN, on behalf of the French MoD, is the editor of this report.

The report is based on the following information and implementations of French MoD:

- MoD project: JP2K encoding and compression profile for base map products ("Fonds d'Affichage Rapide" - FAR – French for Rapid display basemap product)
- MoD product Specification: GeoBase Defence ORTHO3 product;

Planned implementations of JP2K include the CNES PLEIADES High resolution products (PHR), which will employ both the JP2K compression (Lossless / Reversible or lossy / nominal compression algorithms) and the JP2 format. In the case of lossy compression, the compression ratio must ensure a negligible effect on image quality. The compression ratio is a configuration parameter (default value: 3 bits/pixel/band).

The goals of this technical report are the following:

- identify key issues and options of JP2K compression and encoding
- illustrate level of performance achievable with JP2K compression
- propose recommendations for the implementation of JP2K, in terms of compression and format. These recommendations address DGIWG standards and member nations Defence systems regarding geospatial imagery and raster products.

1.2. Document structure

The document presents the results of the initial study on compression and encoding of geospatial imagery, and the key characteristics of the Rapid Compressed basemap product (FAR) and the orthoimagery product specifications (GeoBase Defense ORTHO3).

In the Conclusions section, key issues for JP2K encoding for geospatial imagery are identified and recommendations made for ensuring interoperability of geospatial imagery encoding based on JP2K.

In the annexes, a comparison of the main JP2K options of the specified implementation profiles is provided.

1.3. Intended audience

This report is intended for system architects and engineers within DGIWG nations that are defining and designing geospatial imagery data products and infrastructures for mapping or C3I systems or other defence purposes.

2. Normative References

- ISO/IEC 15444-1:2004 JTC1 SC29 Portable JPEG 2000 image coding system - Core coding system
- ISO/IEC 15444-2:2004 JTC1 SC29 Portable JPEG 2000 image coding system - Extensions
- ISO/IEC 15444-3:2007 JTC1 SC29 Portable JPEG 2000 image coding system – Motion JPEG 2000
- ISO/IEC 15444-6:2003 JTC1 SC29 Portable JPEG 2000 image coding system – Compound image file format
- ISO/IEC 15444-9:2005 JTC1 SC29 Information technology -- JPEG 2000 image coding system: Interactivity tools, APIs and protocols (JPIP)
- OGC GML JPEG 2000 for Geographic Imagery (GMLJP2) (ref. OGC 05-047r3, available on http://www.opengeospatial.org/standards/gmljp2)

3. Abbreviations

Frequently used abbreviated terms:

ASRP/USRP	ARC /UTM Standardized raster product (DGIWG raster products specifications)
BIIF	Basic Image Interchange Format
BPJ2K	BIIF Profile for JPEG 2000 (in fact BIIF profiles: NPJE, EPJE, APJE, SPJE, LPJE)
CNES	Centre National d'Etudes Spatiales
ECRG	Enhanced Compressed Raster Graphic
FAR	Fonds d'Affichage Rapide
GML	Geography Markup Language
JPEG	Joint Photographic Experts Group
MoD	Ministry of Defence
PLEIADES	New high resolution (0.70 m) optical multi-national satellite system initiated by CNES for civil and defence purposes
PNG	Portable Network Graphics

4. MoD Project: Rapid compressed profile for base map products

4.1. Introduction

The project “Compressed profile for basemap products” (“Fonds d’Affichage Rapide - FAR”) was initiated in 2008 by the French MoD with the aim of addressing raster interoperability issues and storage and transfer limitations through the use of a standardized compression and coding system. The one-year project time-frame included an initial study and requirements analysis and specification (6 months), and development of a FAR product specification and prototypes (6 months).

4.2. Initial study

4.2.1. Presentation

The aims of the initial study were a synthetic, state of the art scoping study of standardized compressions and formats, and an evaluation of imagery compression standards (civil and industrial) on a benchmark set of defence geospatial data.

The standardized or COTS compression systems included in the study were:

- PNG (ISO/IEC 15948 or Portable Network Graphics) is designed for transferring images on the Internet, based on “deflate” algorithm, which combines the LZ77 algorithm and the Huffman Code,
- JPEG-LS (ISO/IEC 14495-1) is based on LOCO-I algorithm (LOw COmplexity LOssless COmpression for Images),
- JP2K (ISO/IEC 15444 – Part 1), the primary object of this study report, is based on a wavelet transform, including lossless and lossy modes
- ECW™ (Enhanced Compression Wavelet) is a proprietary wavelet lossy compression image format optimized for aerial and satellite imagery, developed by Earth Resource Mapping,
- MrSID™ (Multiresolution Seamless Image Database) is a multi-resolution image format based on a wavelet transformation designed and patended by LizardTech, Inc.
- JPEG-XR2 (formerly Microsoft Windows Media Photo and HD Photo) supports both lossy and lossless compressions, and is based on a dedicated transform called Forward Core Transform. The compression scheme is “relatively closer” to original JPEG (ISO/IEC 10918) than JP2K, but the algorithms have been tuned with state of the art technology in order to achieve levels of performance in lossless and lossy modes that may be compared with JP2K.
- GeoPDF™ is a proprietary geospatial extension of Adobe PDF File format developed by TerraGo Technologies (USA). A document presenting this geospatial extension has been published as OGC Best Practise OGC 08-139r1: GeoPDF 2.2 Candidate Best Practice (rev1). GeoPDF defines a container allowing georeference, metadata, annotations and image pixels; it is not associated with any compression algorithm (which may be chosen by user application). GeoPDF may be read directly by any conventional PDF reader and offers several mapping capabilities (e.g coordinates, distance...) with a free plugin GeoPDF Toolbar. It is used by U.S. Army Corps of Engineers Topographic Engineering Center to produce raster versions of National Geospatial-Intelligence Agency (NGA) topographic maps.

The benchmark data includes defense raster maps, rasterized vector maps, and also orthoimagery and elevation data (DTED1 and 2).

Following this initial study, a requirements specification for the FAR product was submitted and reviewed by FR MoD.

[2] JPEG-XR has now been adopted by ISO/IEC/JTC1/SC29 as ISO/IEC 29199-2 dated 14/08/2009.

4.2.2. Methodology: multi-criteria analysis grid

A multi-criteria analysis-grid provided a synthetic comparison of the identified standardized or COTS candidate compression/coding system. The comparison was based on several factors:

- Capabilities
  - Tiling and tiling scheme (tessellation, from ISO 19123): "Partitioning of a space into a set of conterminous subspaces having the same dimension as the space being partition." Usually non overlapping rectangles called tiles. These tiles are compressed separately which reduces memory requirements during compression.
  - Data versatility: this is the choice offered to the user for the codestream or bitstream progression order. In other words, some candidates allow access to the compressed data according to different priorities or orders depending on the image priority use case (faster access to region of interest, faster moves within image at a given resolution …). This option has no impact on the final display of the image.
  - multi-resolution (pyramidal mode): this capability of direct accesses to image sub-sampling with no computation (ratio of 2 between levels). This avoids full decompression and computation when the image is not displayed at full resolution. These pyramids do not increase the size of the image file, as it only relies on the insertion of markers in the codestream and the structure of the wavelet decomposition.
  - Progressive display: capability to decode and display the image progressively. This relies both on the structure of the format and its decoding / decompression. The progression order may be by:
    - resolution (level); the image is first displayed in low resolution and then resolution is increased progressively.
    - quality; spectral quality of the image improves as the decompression process is running.
    - component; the components (e.g R, G, B) are decoded and displayed sequentially.
    - precinct; the image is decoded and displayed by progressive decoding within spatial frequency domain (precincts).
  - Transparency: two main methods for transparency management for imagery :
    - Transparency is dedicated to a specific color (generally Black or White or min / max values).
    - Addition of a dedicated component for transparency, with each pixel associated with transparency value.
  - ROI (region of interest): capability to compress / encode a region of interest by an improved quality.
  - Selective ROI display ROI: capability to decode the only required ROI within the image.
  - Resistance to errors: some formats allow data error detection / correction. This capability may be useful for the image transmission on bad data transmission channels.
- Performance of the system with regard to compression quality, speed of compression and especially decompression for FAR products.
- Limitations
  - client / server limitations (based on existing software and tools)
  - georeferencing and metadata limitations of the candidate
  - annotation limitations, on a compressed image
- Interoperability: evaluation of the usability and limitations of profiles of candidates formats

4.2.3. Main results

4.2.3.1. Introduction

JP2K appears to be the best candidate in terms of capabilities and interoperability (under the condition of using the profiles 0 or 1 defined by ISO/IEC 15444-1). It provides both lossless and lossy compression, though the performance of PNG is in most cases better than JP2K lossless compression, especially in case of large flat colours areas.

The extensive capabilities and versatility of JP2K are the result of a relatively complex set of standard and tools, and in some cases there is additional overhead in JP2K compressed files. For example, the use of JP2K tiling results in additional size due to tile indexing.

For the defense data and expected access and usage of the data by French MoD, profile 1 specified by JP2K (ISO/IEC 15444-1) appears to be an adequate option.

The NSIF Preferred JPEG 2000 Encoding (NPJE) and the Exploitation Preferred JPEG 2000 Encoding (EPJE) choices of JP2K parameters specified in BPJ2K[3] provide satisfactory JP2K encoding parameters for these data with 1024 x 1024 tiling; NPJE with LRCP (Layer-Resolution-Component-Position) progression order, EPJE with RLCP (Resolution Precinct Component Layer) progression and tile-part management optimized for fast extraction at a given resolution.

The ECRG product (Enhanced Compressed Raster Graphic US MIL-PRF-32283) also provides an example of JP2K encoding parameters for a visual near-lossless mode with a compression ratio of 1:20 or 0.4 bit-per-pixel-per band. It is based on an external tiling mechanism (2304 by 2304 pixels tiling, probably for backward-compatibility with the previous CADRG product) and RPCL progression order.

4.2.3.2. Speed and compression ratio levels of performance

The additional complexity of JP2K (compared to ECW or MrSID) has no significant impact on image decompression level of performance, with display time lower than 1 second for “big” images / raster files (about 50 Mb with a 1:20 compression ratio) on single-core CPUs if efficient tools are used (e.g. Kakadu or Lizartech tools / viewers / plug-ins).

JP2K decompression / decoding is significantly faster than compression / encoding. Kakadu software claims a decompression speed of about 120 Mb/sec, and compression speed of 70 Mb/sec on a Core 2 Duo™ 2.4GHz machine.

Note: benchmark and evaluation internet links are provided in section 7.2.

On the French Defence data sets, the achieved compression ratios were the following:

- 1:2.5 in lossless mode for raster maps
- 1:4 in lossless mode for orthoimages
- 1:25 lossy, with satisfactory visual quality preserved.

[3] Other profiles in BPJ2K1.0 [3] (APJE, SPJE and LPJE) are more dedicated to un-georeferenced sensor imagery. NPJE and EPJE are the BIIF profiles relevant for georeferenced still imagery.

4.2.3.3. Georeference

Georeferencing of raster / image data is supported within JP2 format via two methods:

- GeoJP2™, the equivalent to GeoTIFF tags are incorporated in the UUID box mechanism proposed by JP2. This proprietary specification is widely implemented.
- GMLJP2, with georeference information encoded in XML boxes of JP2K – Part 2. This OGC specification GMLJP2 1.0 is currently based on GML 3.1/3.1.1, which is not aligned with ISO 19136 (GML 3.2.1). The next revision is expected to include this alignment. GMLJP2 1.0 is also implemented in many available software tools, though there are notable exceptions (e.g GlobalMapper). The next revision to GML (v.1.1) will align with ISO 19136 and is expected to facilitate a wider implementation of the format.

4.2.3.4. Interoperability

JP2 format is now widely recognised by common COTS and GOTS software, including web browsers via additional free plug-ins. ISO 15444-1 Profile 1 allows maximum interoperability. It should be noted that implementation of 15444-1 does not require license fees or royalties and this is not guaranteed by the other 15444 set of standards.

For compression, free tools are available from Kakadu and ERmapper (with limitations particularly on the size of input files). Otherwise, commercial software is required.

4.2.3.5. Client / server protocol – Net enabled capabilities

JPIP (15444-9) is useful for client / server implementations in that it provides additional versatility in data access. For this purpose, JPIP may even be useful in standalone mode on a single machine.

4.2.4. Main recommendations of the study report

JP2K (15444-1 profile 1), based on wavelet transforms, is the recommended standard in terms of capabilities, performance (more particularly in terms of decompression / decoding speed) and interoperability. JP2K benefits include:

- in most cases, visual near-lossless compression with a compression ratio of 1:20 provides satisfactory solutions
- in some cases, where loss of information is unacceptable, use of lossless compression with ratios between 1:2.5 (in worst cases) up to 1:8 will still provide all of the benefits of JP2K standard encoding and capabilities, particularly the use of JPIP for data access in net-enabled architectures.
- georeferencing information may be encoded according to GeoJP2 and GMLJP2. For maximum interoperability, encoding in both is recommended, despite the overhead / redundancy).
- JPIP use is recommended to facilitate versatility of data access to the JP2K codestream. JPIP allows the re-ordering of pixels in compressed data according to the end user's requirements and preferences. and generally facilitates the transfer of compressed data over the Internet and within client-server networks.
- Optimized tools are available for the production of JP2K compressed data (either freely for small products or commercial tools for heavy production).

- For clients, freely available APIs and open-source software exist. Unfortunately, most freely available tools now have significantly lower performance than commercial software. However commercial companies provide free viewers (e.g. Kakadu viewer and Lizartech Plugin).

Remark: The achievements of the GMLJP2 1.1 SWG works and their alignment with ISO 19136 is a key issue. It should be recommended that Defence communities follow closely these works and participate in the developments.

NB: It should also be noted that numerous hardware JP2K codecs are now available, with a gain in speed compression / decompression of more than 10 compared to software codecs. The currently available codecs are mostly dedicated to motion imagery.

4.3. Rapid compressed basemap product specification (FAR)

4.3.1. Scope

FAR products are base maps of following types:

- raster / rasterized maps, e.g. ASRP/USRP data with a minimum resolution of 254 dpi
- spacemaps (vector data superimposed on orthoimagery).

The products are RGB data that may also include an alpha channel in order to manage transparency for padding areas. They allow fast display in both local and network environments..JP2K compression allows smaller files and faster transmission time, which is especially significant in low bandwidth environments.

4.3.2. JP2K profile

FAR products are based on following JP2K (15444-1) specifications:

- profile 1 of JP2K and JP2 format
- near-lossless compression and the use of W9X7 wavelet filter,
- compression ratio: between 1:10 and 1:30 depending on input data (average ratio of 1:20)
- optional use of ICT transform in order to reduce file size without quality loss (use of YCbCr colour space instead of RGB)
- tiling scheme: no tiling or 1024x1024 tiling (improving compression performance / speed)
- recommended code-stream progression orders : RPCL, LRCP, RLCP

4.3.3. Datum and georeference

FAR products are georeferenced to WGS84 and georeferencing information is encoded in both GMLJP2 and GeoJP2.

FAR georeferencing is based on the coordinates of the center of upper-left / NW grid cell. Coordinates of other pixels are then calculated with pixel ground distance values.

FAR products are projected to either the ARC system or a UTM/UPS projection.

4.3.4. Geospatial metadata

Other metadata must be ISO19115 / 19115-2 conformant and the encoding of optional detailed quality information (e.g. local standard deviations and correlation matrix) must conform with DNG metadata specifications (not provided or referenced in this report).

4.3.5. Conformance

Two compliance classes are specified for FAR products:

- FAR baseline class, including 3 sub-packages:
    - Baseline – JP2K codestream
    - Baseline – georeferencing, including sub-packages for GeoJP2 & GMLJP2
    - Baseline – additional external metadata.
- JP2K ICT Transform (optional)

5. MoD orthoimage product specification: GeoBase Defense ORTHO3

5.1. Scope

ORTHO3 products, including a SPOT HRG orthoimage, with THX colour fusion, in ARC system.

5.2. JP2K profile

ORTHO3 products are based on lossless reversible compression. A JP2K parameter specification is not yet finalized.

5.3. Georeferencing

ORTHO3 products are georeferenced to WGS84 and georeferencing information is encoded in both GeoJP2™ and GMLJP2.

GMLJP2 georeferencing must be conformant with OGC 05-047r3, Version 1.0.0 - 20/01/2006 and georeferencing information encoded in GML must include:

- description information
- dimensions (in pixels)
- axis names
- origin (lat/lon)
- size of pixel (offset along 2 axis, in decimal degrees)
- reference to data (URI)

The bounding box, which is optional in the standard, is not provided.

The syntax of GML tags is conformant with chapter 7.5 (Minimal instance) of OGC 05-047r3.

The encapsulation of GML data in the JP2K file is conformant with the packaging mechanism defined in JP2K part I (XML BOX) and II (label BOX and association BOX).

GML use will be indicated in the 'Reader Requirement box' by flag 67 'Contains GML data based on the OpenGIS standard'.

The compliance with JP2 format must be indicated in the 'File Type box' by the string 'jp2' in the compatibility list (refer to document ISO/IEC 15444-1, annexe I)

5.4. Geospatial metadata

ORTHO3 products include an associated metadata file in XML DIMAP (SPOTImage specification for products metadata, based on ISO 19115).

6. Conclusion: key issues and recommendations for JP2K encoding for geospatial imagery

6.1. Introduction

The following paragraphs identify key issues and options for an interoperable use of JP2K wavelet compression and encoding of geospatial imagery. Some recommendations are proposed, where appropriate.

It should be noted that JP2K, as described in ISO/IEC 15444-1, is designed for continuous-tone still images. It may also be used for motion imagery as specified in 15444-3, but that is outside of the scope of this report. JP2K was evaluated on non-continuous-tone images (e.g. raster maps) and proved to be effective, as explained below.

6.2. Compression and level of performance

JP2K (15444-1) allows two classes of image compression:

- **Lossless**

Common compression ratios achieved on French Defence data were 1:2.5 for raster maps and 1:4 for orthoimages.

The performance of PNG for discrete (non continuous-tone) and synthetic images (e.g. raster maps) is in most cases better than JP2K lossless compression, especially in case of large flat colours areas. The performance of JP2K is better on continuous–tone or photographic images (e.g. orthoimages).

- **Lossy**

Lossy is the more efficient class of JP2K compression. It may be near-lossless (no visual degradation) or with visual degradation of image if very strong compression ratios are required (up to 1:40). Lossy compression applies similarly to both on continuous–tone or photographic or non continuous-tone images or rasters

Common compression ratios achieved on French Defence data are 1:20 to 1:25, with satisfactory visual quality preserved for raster maps and orthoimages.

The key issues for an efficient implementation of JP2K compression with geospatial products are:

1. compression mode: lossless (compression ratio depends on input data) or lossy
2. compression ratio (specified to JP2K codec) and quality of compressed data (near lossless with compression ratio 1:20 – 1:25, or with limited visual degradation 1:40 or more).

NB: JP2K is optimised for minimum visual degradation of pixel information.

3. adequate use of JP2K internal tiling mechanisms: internal tiling (in image space) and precinct (tiling within wavelet domain / subbands) allows fast access to the tiles required by the user within (very) large JP2K files. As a result, better performance is achieved with adequate organisation of data based on very large files and use of JP2K tiling mechanisms as compared to external tiling with a large number of files.
4. JP2K datastream parameters, such as the number of resolution levels, quality layers and tile size, have a strong impact on access and performance. A sufficient number of decomposition layers facilitates access to data at less than full resolution. Profile 1 (presented hereafter) specifies constraints on a minimum

number of decomposition layers so that the lowest resolution element in the image is ≤ 128 pixels

5. adequate choice of codestream progression order (5 possible progression orders between Layer, Resolution level, Component, Position / precinct).

Annex 7.3 shows the parameter options specified in NPJE and EPJE profiles (presented hereafter) and other product specifications.

6.3. JP2K profiles

ISO/IEC 15444-1 allows 3 profiles:

- Profile 0

Profile 0 implementation of JP2K core coding (Part 1) constrains the use of variables in the specification ("restricts the codestream") in order to serve low-complexity applications, e.g., cell phones and PDAs (Personal Digital Assistants). One key restriction limits image tiles to 128 pixels in each dimension; another limit (shared with profile 1) requires that the low resolution element in the image (LLD) also be 128 pixels in each dimension, facilitating the rapid construction of a thumbnail by most de-compressors. Code-block (the base matrix for the transform) size is 32 x 32 or 64 x 64.

- Profile 1

Profile 1 implementation of JP2K Core Coding (Part 1) constrains the use of variables in the specification ("restricts the codestream") in order to serve most commercial applications. One restriction limits image tiles to 1,024 pixels in each dimension; another limit (shared with profile 0) requires that the low resolution element in the image (LL*D*) also be 128 pixels in each dimension, facilitating the rapid construction of a thumbnail by most decompressors. Code-block size may be 16x16, 32 x 32 or 64 x 64.

- **Profile 2**: full 15444-1 (out of Profile 1, e.g. tile size over 1024)

- Other profiles

BPJ2K1.1 [4] proposes several profiles compliant with profile 1, NPJE and EPJE being relevant profiles for georeferenced still-imagery. APJE and SPJE profiles (dedicated to airborne sensors) are also conformant with profile 1. LPJE (for large volume streaming data) is the only profile that is not restrictive to profile 1.

NB: Annex 7.3 provides an overview of compared options and parameters of JP2K profiles.

Recommendation: For maximum interoperability of JP2K implementations, it is recommended to remain within 15444-1 Profile 1 (64 x 64 is the recommended code-block size for maximum performance). It should be noted that implementation of 15444-1 does not require license fees or royalties. This is not guaranteed by the other 15444 set of standards. Profile 2 is not supported by all available JP2K software.

Information: The NPJE and EPJE choices of JP2K parameters specified in BPJ2K[4] provide satisfactory JP2K encoding parameters for these data, with 1024 x 1024 tiling: NPJE with LRCP progression order (Layer-Resolution-Component-Position), EPJE with RLCP progression and tile-part management optimized for fast extraction at a given resolution. US ECRG raster specification does not implement internal tiling. ECRG employs an RPCL progression order in the encoding of the codestream.

[4] These were the only profiles in BPJ2K1.0 [**3**]; the other profiles (APJE, SPJE and LPJE) are relevant only to non-georeferenced sensor imagery. Thus NPJE and EPJE are the BIIF profiles relevant for georeferenced still imagery.

6.4. JP2K formats

Still image compressed JP2K data (codestream) may be encoded according to the following formats:

- Jc2

The extension .jpc (or .j2k) is used for files containing raw JP2K codestream. JP2K codestream data should not be used for file storage due to the absence of a metadata capability.

- Jp2

JP2 (basic) file format is defined in ISO 15444-1, Annex I. The extension for these files is .jp2 (preferred) or .jpg2 (also declared in RFC 3745). MIME subtype name is jp2. JP2 allows metadata such as colour space information (which is essential for accurate rendering) to be included with a JP2K codestream. JP2 uses an extensible architecture shared with the other file formats in the JP2K family defined in the later parts of the standard.

- Jpx

JPX file format is defined in ISO 15444-2, Annex M. The extension for these files is .jpf (recommended) or .jpx. MIME subtype name is jpx (refer to RFC 3745).

- Jpm

JPM file format is defined in ISO 15444-6. The extension for these files is .jpm (recommended) or .jpgm. MIME subtype name is jpm (refer to RFC 3745).

- **BIIF (NITF) encapsulation**

BIIF (ISO/IEC 12087-5) encapsulation of JP2K codestream is specified in [**BPJ2K1.1**]. It is used in ECRG product.

This encapsulation requires 2 capabilities for the decoder / data access: BIIF decoding, and JP2K decoding.

Recommendation: For maximum interoperability of JP2K files for still-imagery, **JP2** format is recommended. JPX, JPM or BIIF formats or encapsulation should be chosen only when specific requirements are not provided by JP2 capabilities (Extended JP2K file format, compound-images file, or image file associated with other data (textual or graphics), or imagery that may not fit into JP2K limitations (e.g. 38 bits per pixel). It should be noticed that the choice of these formats does not favour interoperability, as these are less implemented than JP2.

6.5. JP2 georeferencing metadata

(for georeferenced / georectified data)

Georeferencing of raster / georectified image data is supported by the JP2 format through both GeoJP2 or GMLJP2:

- GeoJP2™

This is equivalent to GeoTIFF tags incorporated in the UUID box mechanism proposed by JP2. This proprietary specification is widely implemented.

- GMLJP2

This OGC standard encodes the georeference information in XML boxes of JP2K – Part 2. This standard is not yet stable, as there is work in progress aimed at aligning the GML application schemas used by GMLJP2 with ISO 19136 (GML 3.2.1).

Recommendation: Until GMLJP2 is aligned with ISO 19136 and implemented worldwide, encoding of georeference metadata in both GeoJP2 and GMLJP2 is recommended (though this creates some overhead / redundancy).

6.6. Sensor model metadata

(for non-georeferenced data – or "raw" sensor data)

Sensor model metadata is required for these data in order to georeference / register the image and its pixels. These data are out of the scope of this scoping study, and only mentioned for information. The envisioned standardized solutions are the following:

- Use of ISO 19130 models

The sensor model information conformant with ISO 19130, Imagery Sensor Models for Geopositioning, may be encoded in XML, and may be provided either as an external associated file, or embedded in JP2/JPX file, by use of the box mechanism.

- Use of SensorML

The sensor model information may be encoded in SensorML, and may be provided either as an external associated file, or embedded in JP2/JPX file, by use of the box mechanism. A recommended practise is associate it with a *lbl* box that marks it as SensorML data in order to make it possible to have more xml boxes with different information without losing the ability to distinguish them from one another.

6.7. Other geospatial metadata (based on ISO 19115)

Other geospatial metadata is associated to images (pixels), giving common metadata information specified by ISO TC211 in ISO 19115 for identification and analysis of general associated information, location, source, quality and distribution of product.

This metadata is usually conformant with ISO 19115 and encoded in XML in conformance with ISO 19139.

It may be provided either as an external associated file, or embedded in JP2/JPX file, by use of the box mechanism. A recommended practise is associate it with a *lbl* box that marks it as Metadata data in order to make it possible to have more xml boxes with different information without losing the ability to distinguish them from one another.

6.8. JP2K data access protocol (JPIP)

JPIP (15444-9) is useful for client / server implementations or in order to provide additional versatility to data access (even on standalone machines).

JPIP use is recommended to facilitate versatility of data access to the JP2K codestream (e.g. it allows re-ordering of pixel between data compressed by the producer according to user's requirements / preferences) and allow for net-enabled and client-server data access.

JPIP allows progressive display of data on the basis of arrival to the client side with transmission of only regions and quality levels required by the client (versus full dataset transmission).

NB: Kakadu JPIP documentation (JPIP Implementation in Kakadu) recommends the use of RPCL codestream progression order for large images.

6.9. Recommendations of supplemental actions

- The achievement of GMLJP2 1.1 SWG works (and alignment with ISO GML version) is a key issue. It is recommended that DGIWG communities follow closely these works and cooperate to this achievement.

- As the options for georeferencing and other metadata are numerous, it is recommended that DGIWG take an action to develop a best practises (or a profile – depending on the requirements level) in order to ensure common use by nations, and if not possible, mapping between national profiles. This action may be undertaken when GMLJP2 revision work is completed.

7. Annexes

7.1. Bibliography

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7.2. Internet references

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http://jj2000.epfl.ch
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7.3. Comparison of options of JP2K profiles / specifications

The aim of the following table is to inform JP2K technical experts and provide a comparative overview of JP2K parameters and options of registered profiles NPJE and EPJE specified in [BPJ2K1.0], and two product specifications, one US ECRG (MIL-PRF-32283) and one French prototype specification.

Notations (please refer to ISO 15444-1 or [4] for information on concepts / notations)

bpppb	bit-per-pixel-per band
R0 – Rn	resolution level 0 – n (for viewing, R0 being full resolution)
LRCP	Layer-Resolution-Component-Position progression order (of the codestream)
W9X7 or 9-7I	Irreversible wavelet Transformation
W5X3 or 5-3R	Irreversible wavelet Transformation
NITF	US MIL-STD-2500
ICT	Irreversible Component Transform
RCT	Irreversible Component Transform

Profile	NPJE	EPJE	ECRG product	FAR products
Use cases	« Preferred options » for inclusion of JP2K codestream in NITF (original image providers)	Exploitation preferred (for « large / very large data »	Raster graphics (external tiling / frames)	Basemap rapid display
15444-1 Profile (codestream profile)	1	1	1	1
Compression ratio	from 0.03125 to 3,5 bpppb + optional lossless	from 0.03125 to 3,5 bpppb + optional lossless	20 (0.4 bpppb)	10-30
Wavelet transform filter	W9X7 for lossy W5X3 for lossless	W9X7 for lossy W5X3 for lossless	W9X7	W9X7
Component Transform	ICT/RCT optional	ICT/RCT optional	ICT	ICT optional
Tiling	1024x1024	1024x1024	no (internal) tiling (1 single tile in JP2K codestream)	no tiling or 1024x1024 tiling
Precincts (tiling within wavelet domain)	X	X	256x256	256x256, 128x128… (to be tuned depending on input data)
code-block size	64x64	64x64	64x64	64x64
decomposition layers (n => n+1 viewing resolution levels R0 - Rn from the codestream)	5	5	5	Minimum constrained by profile 1 rules => minimum 3 for 1024-tiling => also depends on size of image
quality layers	Maximum 20 (20 - 1 lossless layer + 19 layers for visual lossless) (Number of layers depending on production requirements)	Maximum 20 (Number of layers depending on production requirements)	5 (0.03125, 0.0625, 0.125, 0.25, 0.4 bpppb)	5-15 (Number of layers depending on production requirements)
Codestream progression order	LRCP	RLCP	RPCL	RPCL, LRCP ou RLCP
Markers	TLM /PLT (recommended)	TLM/PLT (recommended)	PLT	TLM/PLT (recommended)
Format	JPC/J2C encapsulated in NITF / STANAG 4545	JPC/J2C encapsulated in NITF / STANAG 4545	JPC/J2C encapsulated in NITF / STANAG 4545	JP2 (+ 2 JPX boxes)
Georeference information	STANAG 4545 (DIGEST extension)	STANAG 4545 (DIGEST extension)	STANAG 4545 (DIGEST extension)	GeoJP2 (optional) GMLJP2 (optional)