NIMA
Systems Engineering Services

Current USIGS Compression Capability

Bernie Brower
NSES – Kodak
bernard.brower@kodak.com
+1 585 253 5293

NIMA
Systems Engineering Services

Image Compression History

- Technology, Events, and Standards Timelines
  - 1948 Information Theory Principles (Shannon)
  - 1951 Huffman Codes developed (Huffman)
  - 1951 DPCM technology developed (Shannon)
  - 1974 DCT technology developed (Ahmed)
  - 1976 Arithmetic encoding technology developed (Rissanen)
  - 1980 Group 3 & 4 bi-level compression (fax machines)
  - **1983 IDEX 1-B Develops 5 bpp DPCM for local storage compression**
  - **1984 DDS-1 2.0 bpp Compression (Adaptive Compression)**
  - 1984 The building blocks of wavelet transform technology (Mintzer)
  - 1986 IBM Q Coder
  - 1989 Emmy Award for Image Transmission Receiver
  - **1989 DDS-III Standardizes 1.3 DCT**
  - **1989 NITFS 1.1 Including ARIDPCM**

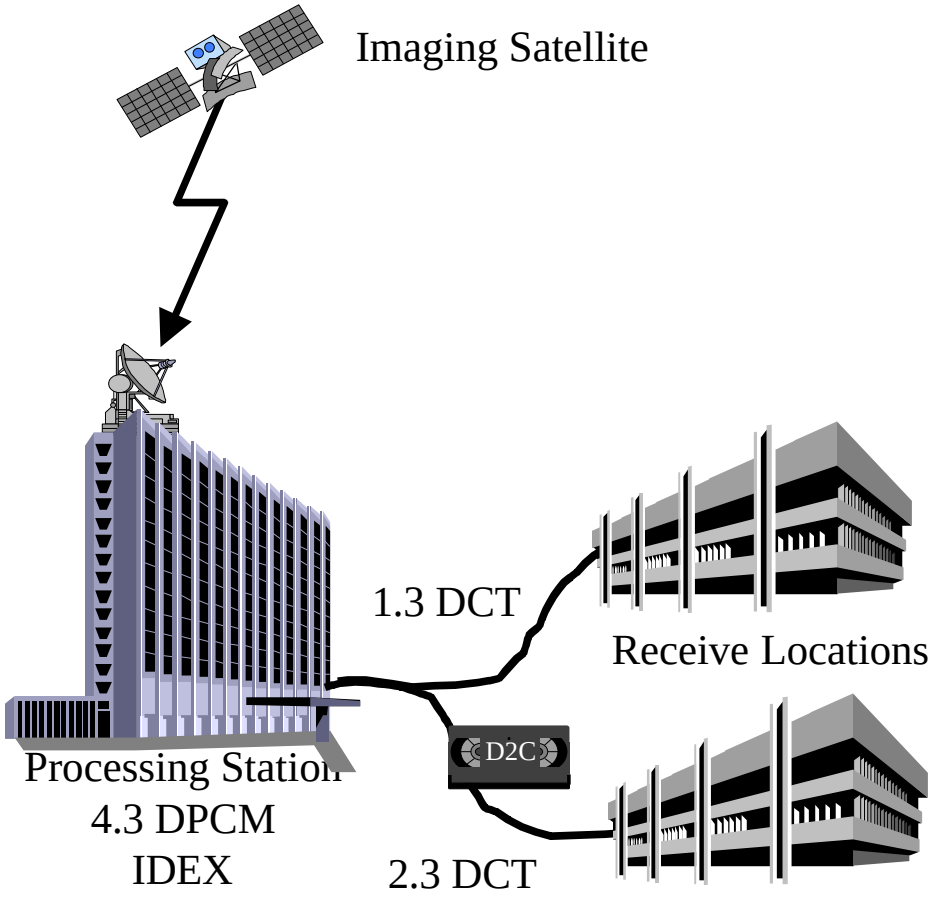
NIMA
Systems Engineering Services

Image Compression History

- Technology, Events, and Standards Timelines (continued)
  - 1990 H.261standard (video conference)
  - **1992 IDEX II Standardizes on 4.3 DPCM**
  - 1992 ISO JPEG becomes a standard (ISO 10918-1)
  - **1993 NITFS JPEG Standard (MIL-STD-188-198A)**
  - **1993 NITFS Bi-Level Compression (MIL-STD-188-196)**
  - **1993 ARIDPCM Military Standard (MIL-STD-188-197A)**
  - 1994 ISO MPEG 1 becomes a standard
  - 1994 ISO JBIG becomes a standard
  - **1994 NITFS VQ Standard (MIL-STD-188-199)**
  - 1995 ISO MPEG 2 becomes standard (DirectTV, DVD)
  - 1996 Emmy for MPEG and JPEG technology
  - 1999 ISO MPEG 4 becomes a standard
  - 2000 ISO JPEG 2000 becomes a standard (ISO 15444-1)
  - 2000 JBIG 2 becomes a standard
  - **2001 JPEG 2000 Profile Draft Developed for NITFS 2.1**

National System for Geospatial Intelligence (NSGI)

National Systems



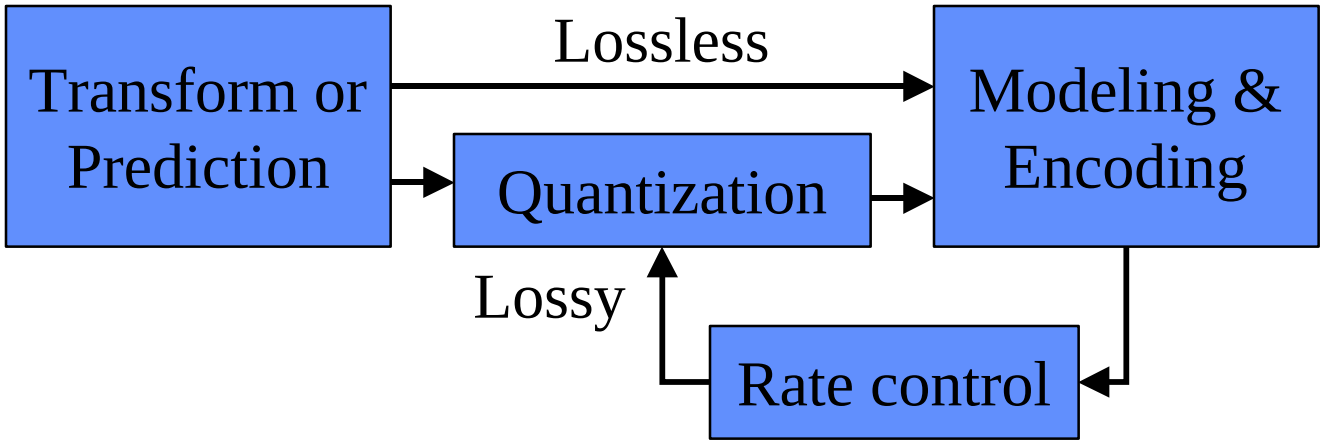
NIMA
Systems Engineering Services

Primary Dissemination of National Data

- Two Basic Algorithms
  - Both algorithms developed before commercial standards existed.
  - Both algorithms were state of the art at the time.
  - 4.3 DPCM
    - Developed for visually lossless, rate-controlled simple compression for storage and transmission (IDEX).
    - Old technology; current technology can significantly outperform
    - 4.3 DCPM Requirements:
      - 0.0 NIIRS loss, 2:1 or better compression, fast decompression
  - 1.3 DCT/2.3 DCT
    - Significant development effort to produce a high quality at low bit rates.
    - Required special hardware to achieve the throughput until recently
    - Old technology, still very competitive but not very flexible
    - 2.3 DCT Requirements
      - 0.1 NIIRS loss, 3:1 or better compression, spatial accuracy
    - 1.3 DCT Requirements
      - 0.2 NIIRS loss or less, 1.3 bpp or less, robust to channel errors

NIMA
Systems Engineering Services

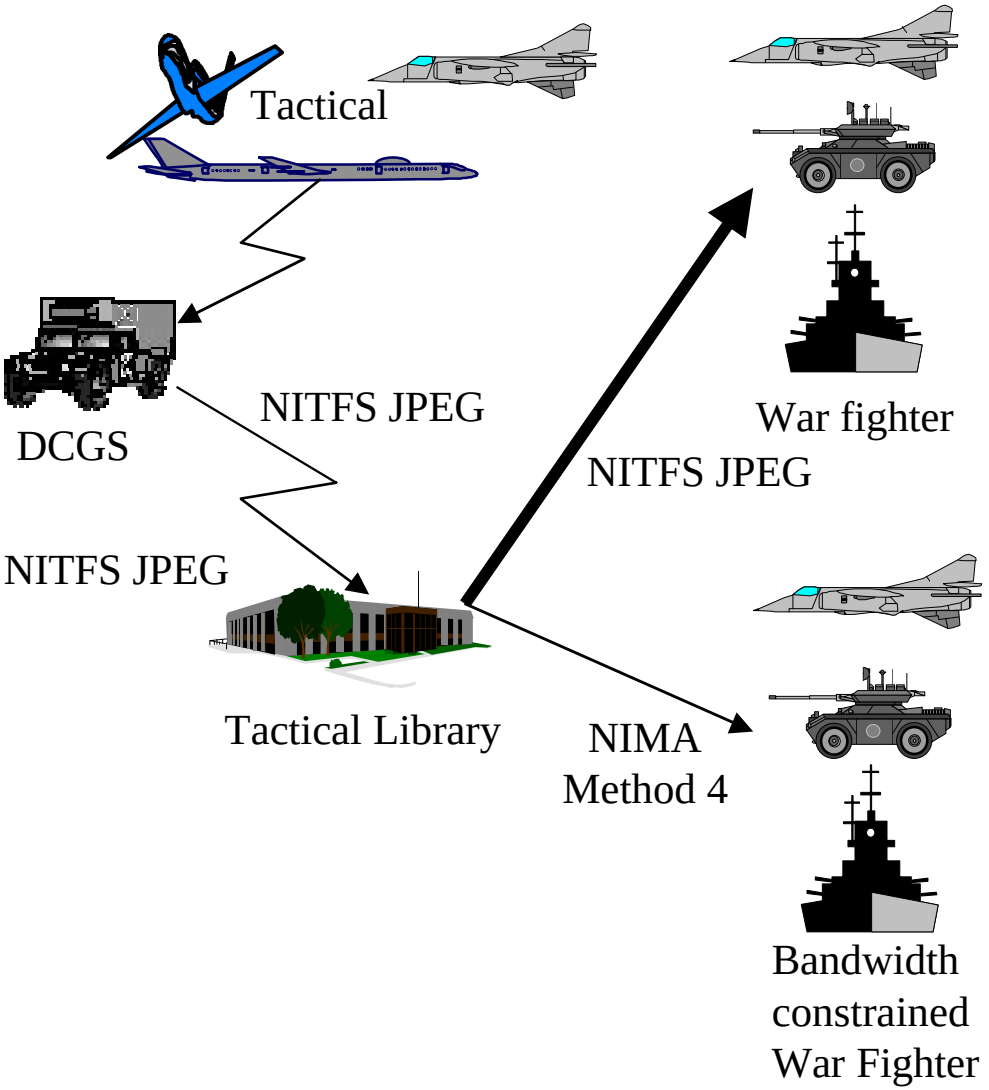
Building Blocks To Compression



- Transform/prediction changes the data into a form that is easier to compress, usually a lossless transform (takes advantage of redundancy of the data)
- Quantization reduces data to make it easier to encode. This is where data loss occurs (takes advantage of irrelevancy of data). This step can be skipped to achieve lossless compression
- Encoding reduces the number of bits it takes to represent a data set (takes advantage of the statistical properties of the resulting data).
- Rate control is used to achieve a given bit rate by changing the quantization.

National System for Geospatial Intelligence (NSGI)

Tactical Systems



NIMA
Systems Engineering Services

Secondary Dissemination (tactical)

- Two Main Algorithms for Tactical Dissemination
- Algorithms selected to support end users with flexibility and COTS availability
- The quality of these algorithms do not meet the compression versus the quality required for the national primary dissemination systems
- JPEG DCT/NITFS JPEG DCT
  - Developed as a commercial standard to run on commercial PCs (386s) and commercially viable hardware.
  - NITFS/DoD adopted because of quality, flexibility and COTS products
  - JPEG DCT Requirements:
    - 0.5 NIIRS loss at 8:1 compression, 2.0 min. decompression time
      Variable compression ratios, robust to channel errors
- NIMA Method 4
  - Developed to achieve dissemination to warfighters with very low bandwidth communication lines with minimal impact on systems and their cost
  - NIMA Method 4 Requirements:
    - High compression ratios with minimal image quality loss, low cost

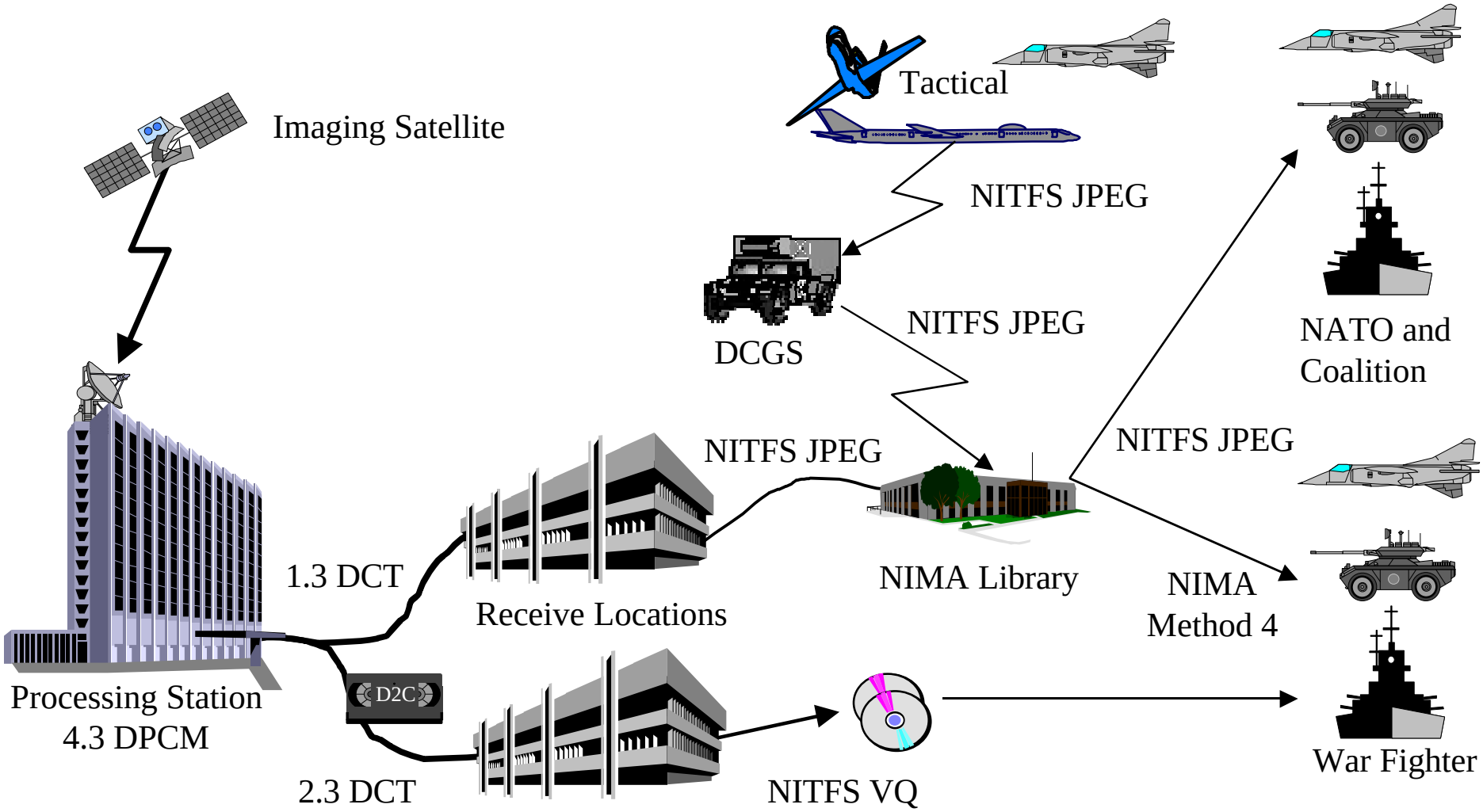
NIMA
Systems Engineering Services

Special Product Compression

- There are three algorithms that are part of NITFS for special products:
  - Lossless JPEG DPCM
    - Commercial standard that produces lossless compression at about 2:1
    - Used for imagery where no loss of image information is acceptable
  - Vector Quantization
    - Used for compression of maps and image-map products
    - VQ Requirements:
      - Fast decompression, variable compression, robust to channel errors
      - 32:1 Compression on maps (11:1 on image-map products)
  - Bi-Level Compression
    - Commercial standard for Fax machines
    - Used for the compression of bi-level imagery and graphics
    - Bi-level Requirements:
      - Interoperability with Fax machines

NIMA
Systems Engineering Services

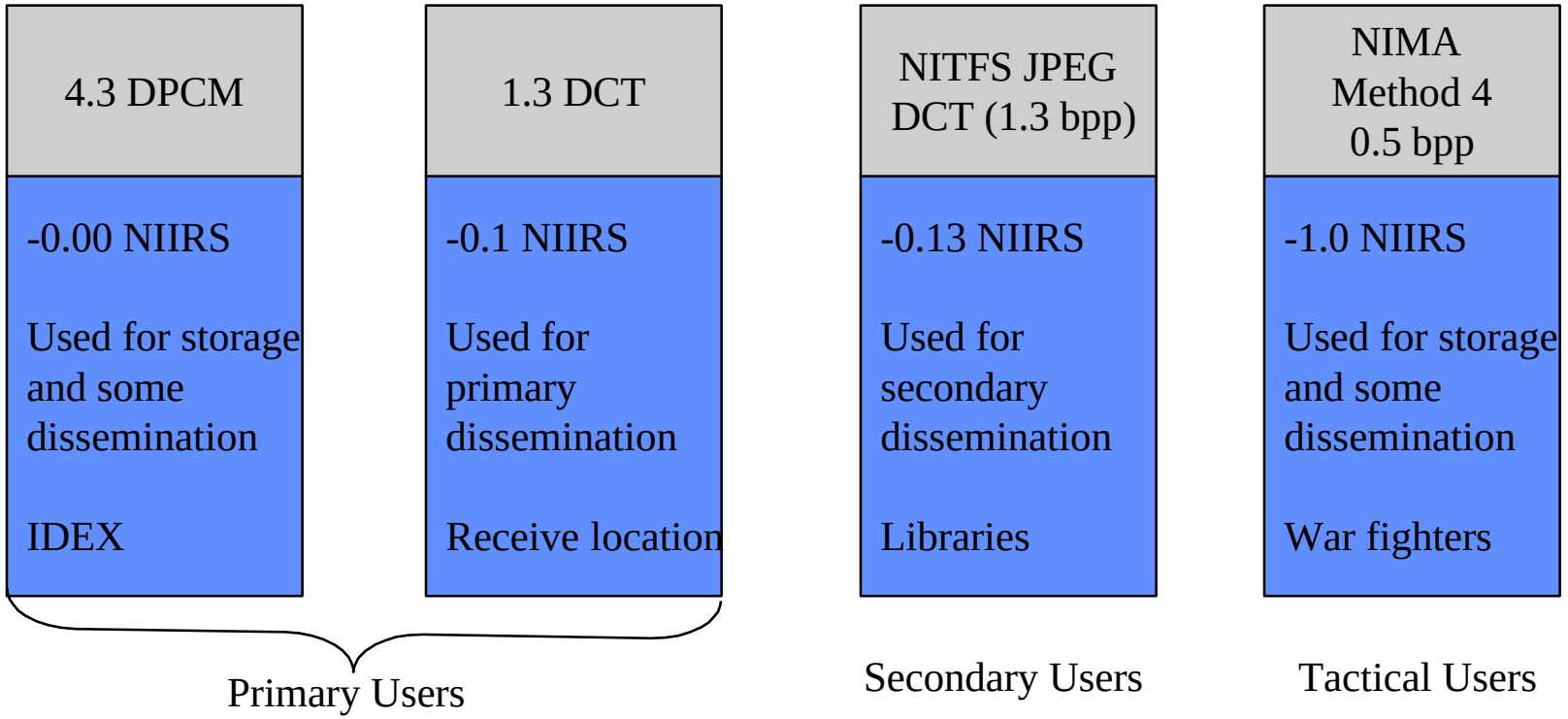
National System for Geospatial Intelligence (NSGI)



NIMA
Systems Engineering Services

Current NSGI Compression of Imagery

- The primary system's compression algorithms were developed for high quality for primary dissemination and exploitation of data.
- The secondary system's compression algorithm was adopted from commercial sources because of flexibility and COTS availability.
- The tactical BWC was derived from JPEG to be backwards compatible and meet the tactical dissemination requirements.



NIMA
Systems Engineering Services

Compression Overview

Compression Algorithm	Transform Technique	Quantization	Encoding	Comments
4.3 DPCM	Linear prediction from neighboring pixels	Table look-up	Variable length Huffman encoding	• Low complexity • High quality • Low compression ratio
NITFS JPEG DCT	8-by-8 block Discrete Cosine Transform (DCT)	Human Visual System (HVS) Response quantization in DCT space	Variable length Huffman encoding	• Can be rate controlled • 8-by-8 transform used for speed
1.3 / 2.3 DCT	32-by-32 block DCT	HVS quantization	Variable length Huffman encoding	• Rate controlled to either 1.3 bpp or 2.3 bpp
Vector Quantization	No transform performed	Vector code book matching	Code book numbers	• Low channel error susceptibility
NIMA Method 4	Down-sampled followed by JPEG DCT	JPEG DCT	JPEG DCT	• Achieves very low bit rate at reasonable quality
JPEG 2000	Wavelet-based sub-band transform	Scalar Quantization with Dead-Zone	Bit-Plane Arithmetic encoder	• Highest quality of any of the algorithms • Most functional

NIMA
Systems Engineering Services

Compression Overview

Algorithm	Advantage	Disadvantage
4.3 DPCM	• Low complexity (low power/size/weight) • Visually lossless quality • Low memory requirements • Government standard • Rate controlled	• Low compression ratios compared to frequency-based transform techniques.
1.3 DCT	• High quality • Military standard • Rate controlled	• High complexity (32-by-32 transform, rate-control) • Blocking artifacts
2.3 DCT	• Near lossless quality • Government standard • Rate controlled	• High complexity (32-by-32 transform, rate-control) • High bit rate (2.3 bpp)
NITFS JPEG DCT	• International/commercial standard • Low cost implementation (COTS) • Low complexity (8-by-8 transform)	• Blocking artifacts • Lower quality than 1.3 DCT and wavelets
NITFS VQ	• Low complexity for decompression • Low susceptibility to channel error • High quality on DMA maps • Military standard	• High complexity for compression • Relatively poor quality on images
NIMA Method 4	• Interoperable with NITFS JPEG • High quality at low bit rates • Military standard	• Does not perform well at higher bit rates • Not flexible
Wavelets	• Better quality to compression ratio than any other compression algorithm • Significantly more functionality • Commercial Standard	• Large memory requirements • Computational Complexity • Significant start-up cost