DSP Solutions For High Quality Video Systems

Todd Hiers
Texas Instruments

TI Video Expertise Enables
Faster And Easier Product Innovation

**TI has a long history covering
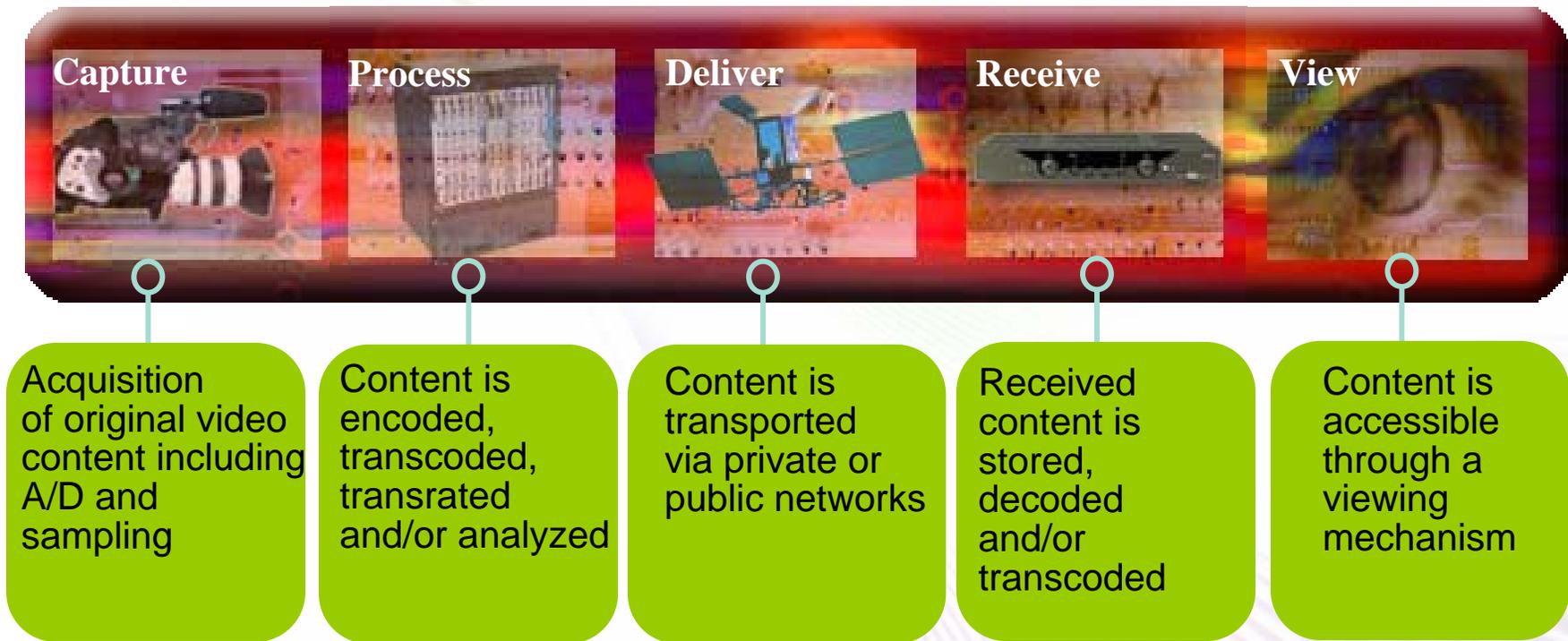the video market from end to end**

R&D began on image processing in the early 80s

**TI leverages video systems expertise and R&D across
internal design teams to drive innovation
and business development**

**Customers can leverage TI's expertise in end-to-end
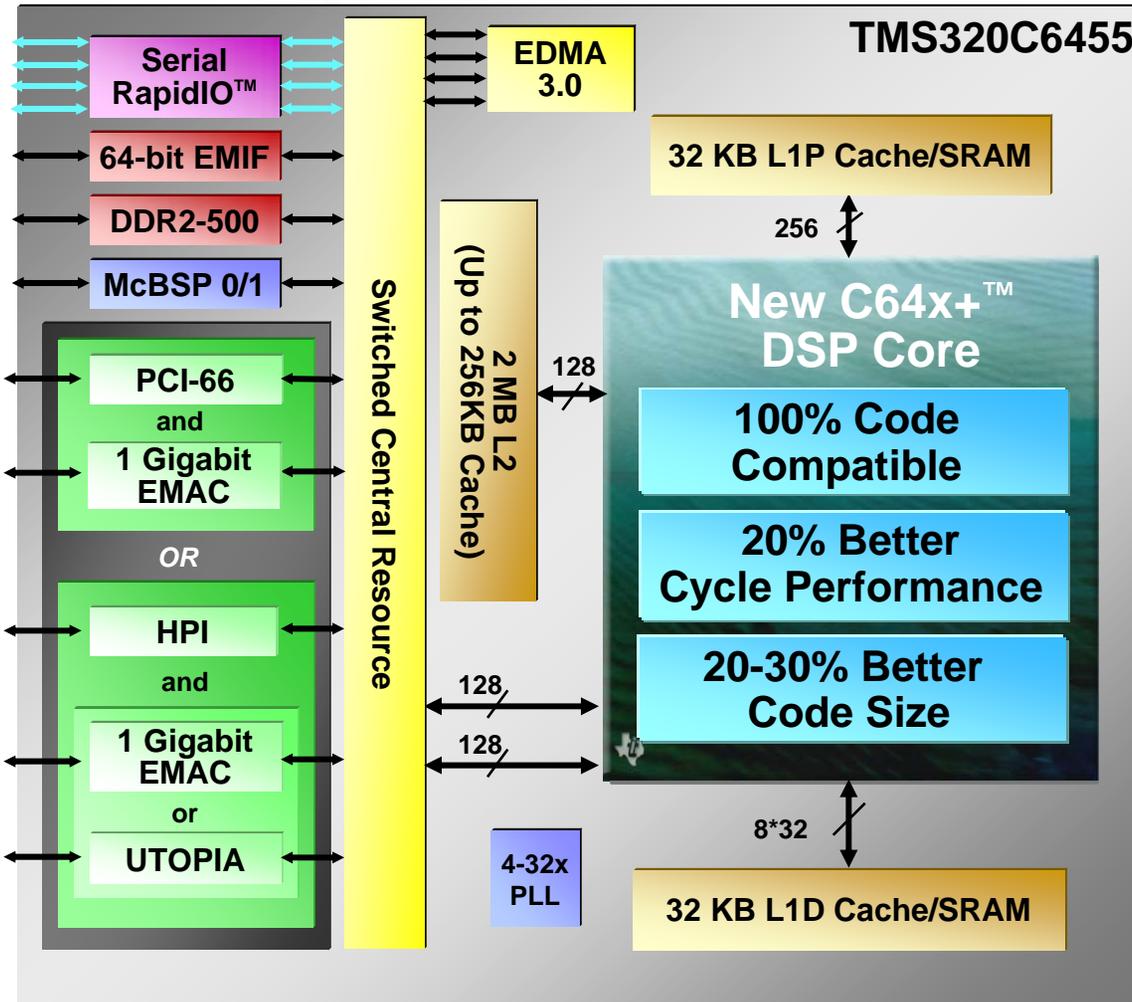video to quickly launch into multiple video markets**

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TEXAS INSTRUMENTS

Defining the Video Chain

Capture — Acquisition of original video content including A/D and sampling

Process — Content is encoded, transcoded, transrated and/or analyzed

Deliver — Content is transported via private or public networks

Receive — Received content is stored, decoded and/or transcoded

View — Content is accessible through a viewing mechanism

Platforms & Uses

Platform \ Likely Uses	Encode	Transcode	Transrate	Decode
Multi 6455	✔	✔		
645x + FPGA	✔	✔		
Multi DM643x	✔			✔
DM643x + FPGA				✔
Multi Cat LC			✔	
C6424 + FPGA			✔	
DM644x (DaVinci)	✔			✔

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C6455 Quick Introduction

TMS320C6455

Serial RapidIO™

EDMA 3.0

64-bit EMIF

DDR2-500

McBSP 0/1

PCI-66 and 1 Gigabit EMAC

OR

HPI and 1 Gigabit EMAC or UTOPIA

Switched Central Resource

2 MB L2 (Up to 256KB Cache)

4-32x PLL

32 KB L1P Cache/SRAM

256

128

New C64x+™ DSP Core

100% Code Compatible

20% Better Cycle Performance

20-30% Better Code Size

128

128

8*32

32 KB L1D Cache/SRAM

Package: 697 BGA, 24 mm, 0.8 mm Pitch, Lead-Free Balls

Serial RapidIO™

- ◆ Up to 10 Gb/s Bi-di communication
- ◆ Connect to any RapidIO device

New C64x+ Core – Up to 1 GHz

- ◆ ISA enhancements for better performance and code size
  - C6455 - 720 MHz: $179
  - C6455 - 850 MHz: $219
  - C6455 - 1 GHz: $259

  (TMS Production prices 2006 / 07 - 10Ku)

Memory Architecture

- ◆ 2 MB L2
  - ❖ 256K Cache/SRAM; Remainder is SRAM only
- ◆ 32 KB L1D Cache/SRAM
- ◆ 32 KB L1P Cache/SRAM

Two EMIFs

- ◆ 32-bit DDR2 (DDR2-500 SDRAM)
- ◆ 64-bit EMIF

GEMAC / UTOPIA / PCI-66 / HPI

- ◆ Multiple connectivity options

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C642x Quick Introduction

Features

- ### New C64x+™ Core
  - 400 MHz, 500 MHz, 600 MHz
  - Up to 4800 MMACs performance

- ### Memory – C6421
  - 16-KB L1D and 16-KB L1P cache/SRAM
  - 64-KB L2 cache/SRAM

- ### Memory – C6424
  - **80-KB L1D** and **32-KB L1P** cache/SRAM
  - **128-KB L2** cache/SRAM

- ### Peripherals – C6421
  - Two EMIFs – 16-bit DDR2 333MHz; 8-bit EMIF
  - VLYNQ™/ EMAC (RMII/MII) or HPI / RMII
  - McBSP or McASP – Audio and telecom interfacing
  - UART (2), I²C, GPIO, PWM (3), 64-bit timers (2)

- ### Peripherals – C6424 enhancements:
  - **32-bit DDR2 333MHz**; **16-bit EMIF**
  - **PCI33** or VLYNQ™ / **EMAC** (RMII) or HPI / RMII
  - **McBSP (2)** or McASP

- Package: 361 pin 16×16-mm BGA, 0.8-mm Pitch, 376 pin 23 x 23 mm BGA, Lead-Free Balls
- Samples: 4Q06; Production: 4Q07
- **Price C6421/C6424: $8.95/$15.95** at 400 MHz / 10 KU – 2007/08

Benefits

- **C6421:** Lowest cost DSP with C64x+ performance and Ethernet
- Smallest package C64x DSP
- C6421/24 pin Compatible

C6424

OSC	PLL	JTAG
	DDR PLL	Timer WDT

DDR2 32

EDMA 3.0

EMIF 16

PCI 33
or
VLYNQ™
RMII
or
HPI
RMII

I²C

DSP Subsystem

L1D 80 KB
C64x+™ Core
L1P 32 KB

L2 128 KB Cache/SRAM

GPIO

McBSP
McBSP
or
McASP

Timer x2

PWM x3

UART x2
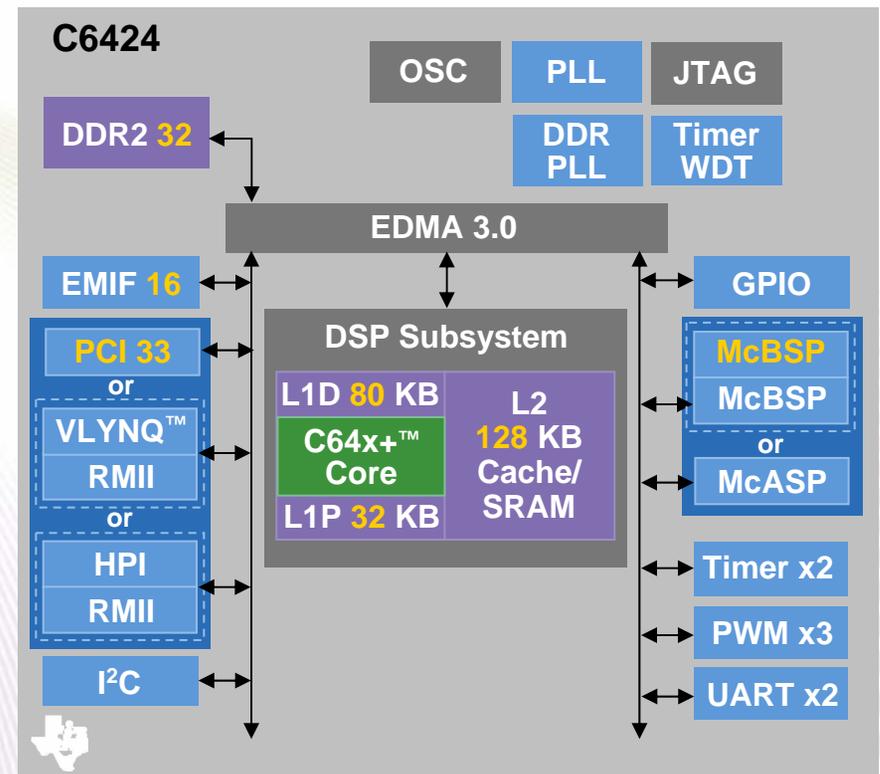
DM643x Quick Introduction
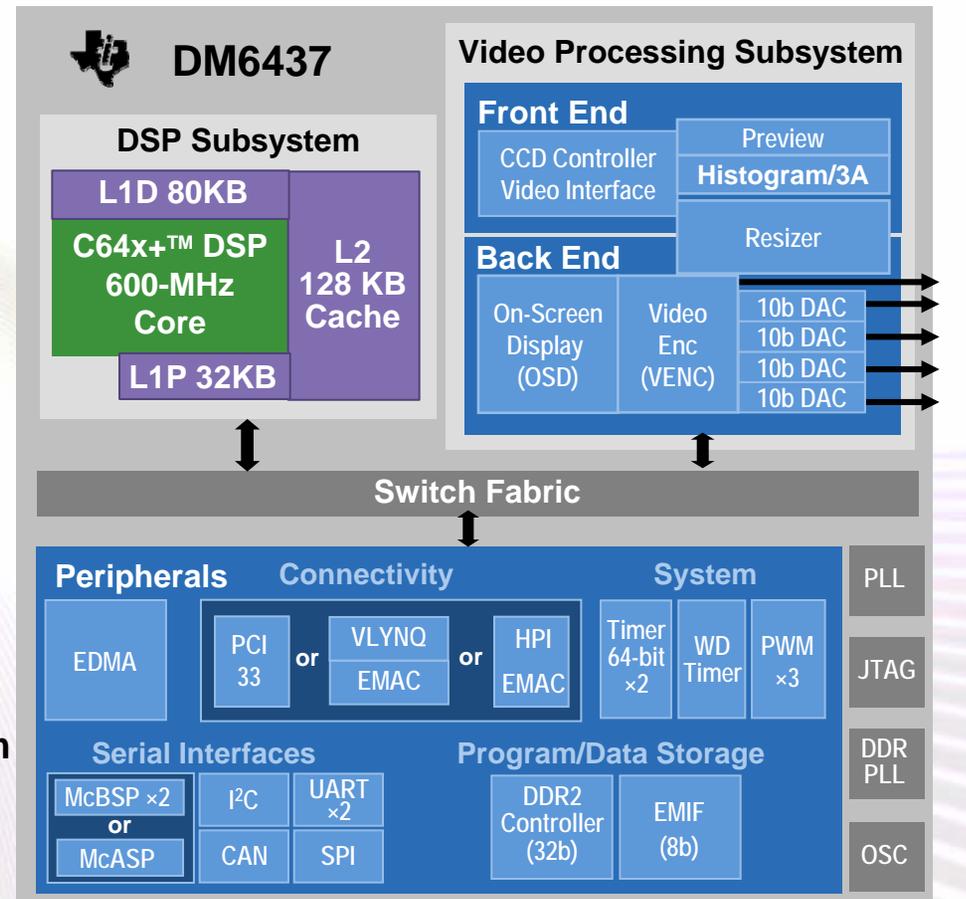
Features

- **New C64x+™ Core**
  - C64x+™ Core @ Up to 600 MHz
- **Memory**
  - 80 KB L1D, 32 KB L1P Cache/SRAM
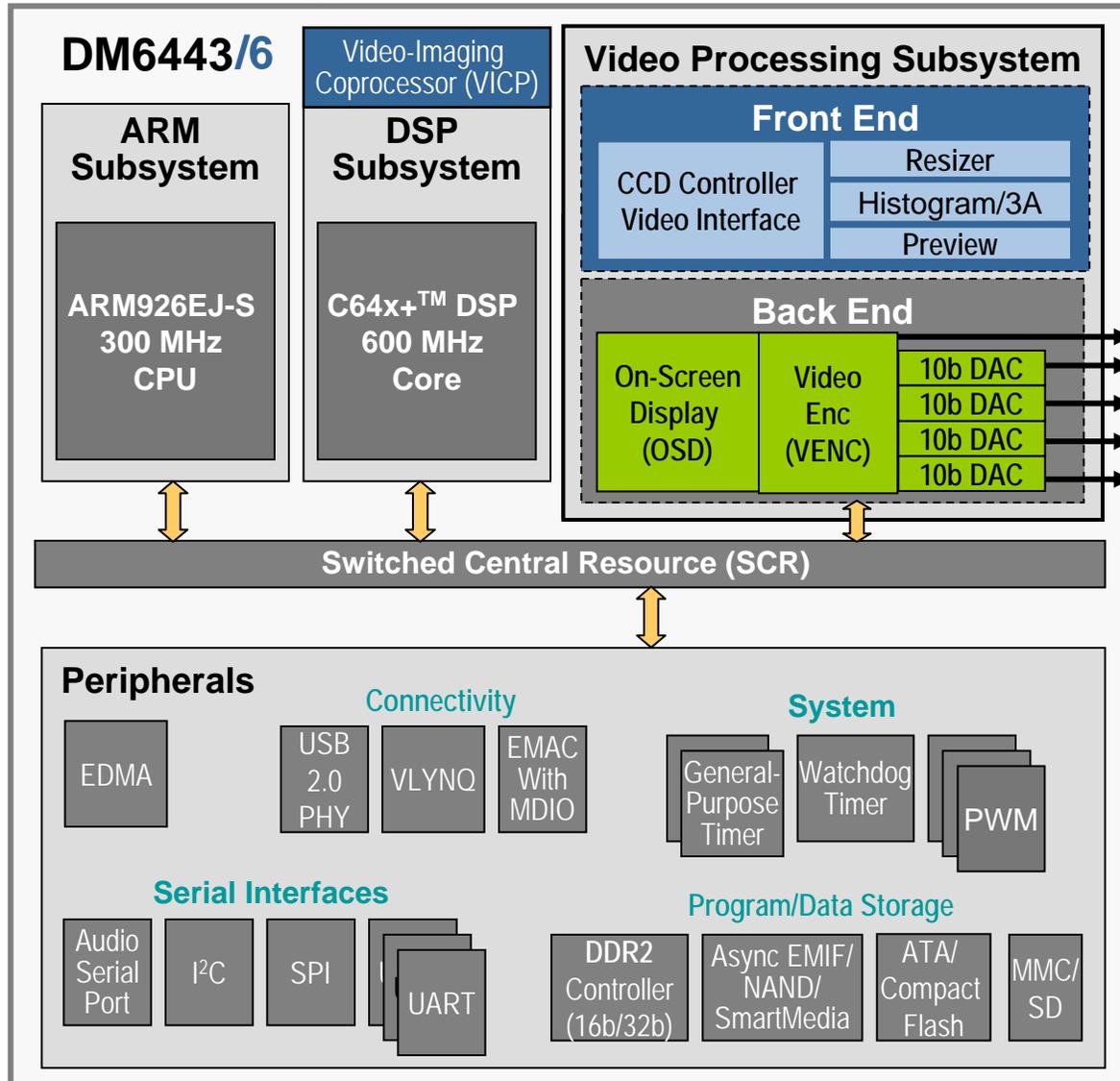 - 128 KB L2 Cache/SRAM
- **Peripherals**
  - Video Port Sub-System (VPSS): Input (CCDC), Output (w/DACs), Resizer, OSD, and Camera Control
  - Two EMIFs: DDR2-266: 32 bits, 133 MHz; EMIF 2.1
  - 10/100 Ethernet MAC (MII); PCI 33 MHz; HPI; McASP
  - VLYNQ™ – Serial Interface to FPGAs
  - UART (2), I²C, SPI, GPIO, PWM (3), CAN (HECC), 64-bit Timers (2)

- **Package: 16×16mm or 23×23mm, 361 Pin, 0.8mm or 376 Pin 1.0mm Pb-Free Balls**
- **Pin Compatible with DM6435/3/1**
- **Samples 4Q06; Production 2Q07**
- **Price: $22.95 @ 600 MHz, 10 KU – 2007/08**

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DM644x Quick Introduction

DM6443/6

Video-Imaging Coprocessor (VICP)

ARM Subsystem

ARM926EJ-S 300 MHz CPU

DSP Subsystem

C64x+™ DSP 600 MHz Core

Video Processing Subsystem

Front End

CCD Controller Video Interface | Resizer | Histogram/3A | Preview

Back End

On-Screen Display (OSD) | Video Enc (VENC) | 10b DAC | 10b DAC | 10b DAC | 10b DAC

Switched Central Resource (SCR)

Peripherals

Connectivity
EDMA | USB 2.0 PHY | VLYNQ | EMAC With MDIO

System
General-Purpose Timer | Watchdog Timer | PWM

Serial Interfaces
Audio Serial Port | I²C | SPI | UART

Program/Data Storage
DDR2 Controller (16b/32b) | Async EMIF/ NAND/ SmartMedia | ATA/ Compact Flash | MMC/ SD

Video-Optimized TMS320C64x+™ DSP @ 600MHz

- H.264 MP@L3, 30fps SD Decoding
- VC1/WMV9 Full D1 SD Decoding
- MPEG-2 MP@ML SD Decoding
- MPEG-4 ASP Full D1 SD Decoding

- H.264 BP D1 Encoding
- Simultaneous H.264 BP CIF Coding

Dedicated video processing sub-system

- Back end - Integrated OSD, four video DACs, 24-bit digital RGB output
- Front end – Resizer, Image processing engine, 16-bit digital input

2006 10KU Price:
TMS320DM6443 $29.95
TMS320DM6446 $34.95

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SRIO Quick Introduction

Serial RapidIO is a high-performance, packet-switched, interconnect technology that addresses the embedded industry's need for:
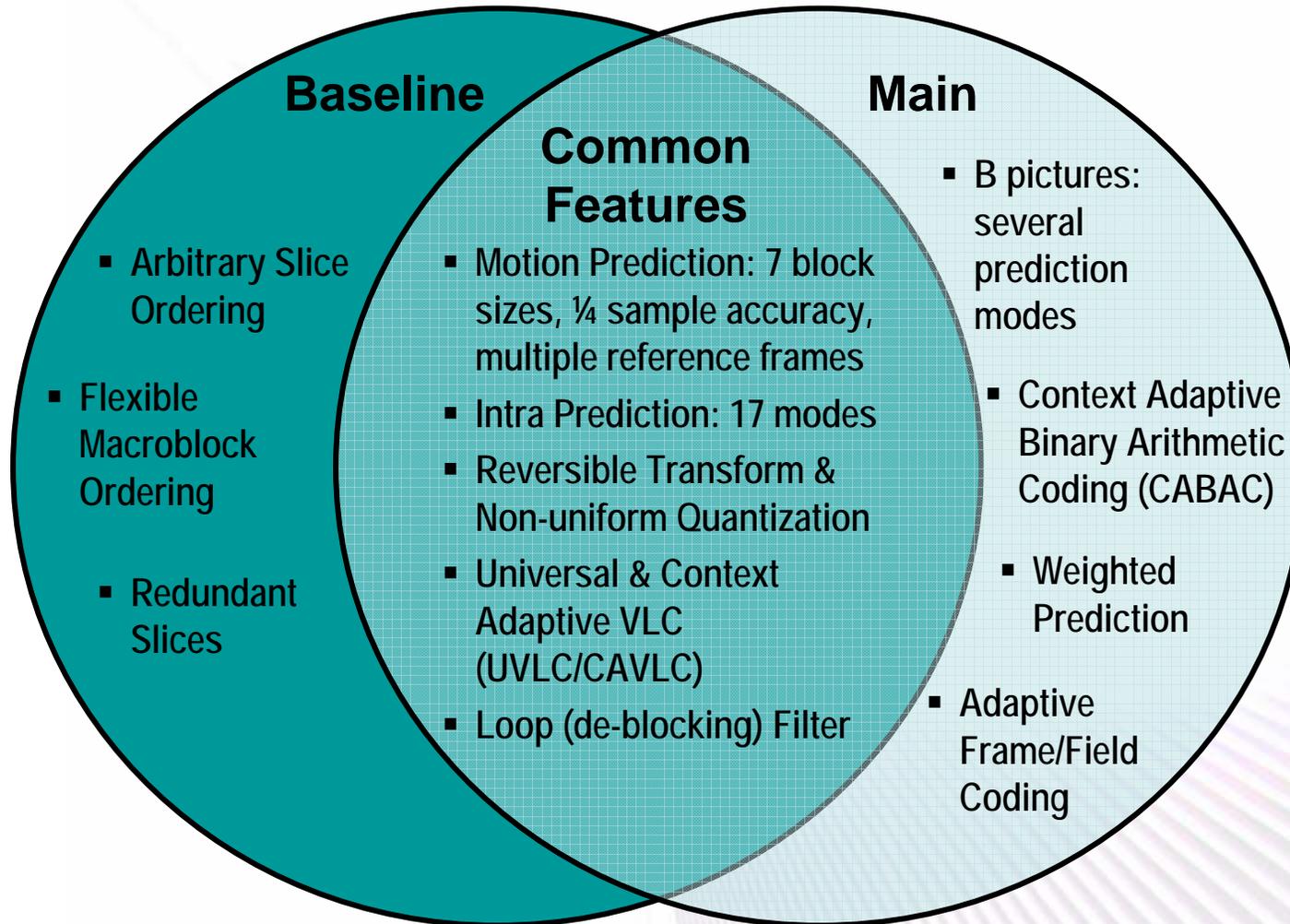
Reliability   **Increased Bandwidth**   **Increased Scalability**

Serial RapidIO allows chip-to-chip and board-to-board communications at performance levels scaling to ten Gigabits per second and beyond

RapidIO™

- C6455 Serial RapidIO Support – IEEE 1149.6 Compliant
  - 1, 2, or 2.5 GBit/sec per link
    - Up to four 1x links (each 1x link is bidirectional) *--OR--*
    - One 4x link (bi-directional pipe), which provides up to 10 GBit/sec
  - Supports connecting to any other Serial RapidIO device
  - Supports wide variety of network topologies: Rings, Meshes, Stars, & Others

- Benefits
  - 1x Link is fast enough to send HD 1080i raw video between devices
  - 4x Link is easily fast enough to send HD 1080p raw video between devices
  - Reduction in chip count, board area and system cost

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H.264 Quick Introduction

Baseline   **Main**

Common Features

- Arbitrary Slice Ordering

- Flexible Macroblock Ordering

- Redundant Slices

- Motion Prediction: 7 block sizes, ¼ sample accuracy, multiple reference frames
- Intra Prediction: 17 modes
- Reversible Transform & Non-uniform Quantization
- Universal & Context Adaptive VLC (UVLC/CAVLC)
- Loop (de-blocking) Filter

- B pictures: several prediction modes

- Context Adaptive Binary Arithmetic Coding (CABAC)

- Weighted Prediction

- Adaptive Frame/Field Coding

H.264: Baseline & Main Profiles   **Minds in Motion**

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H.264 Quick Introduction
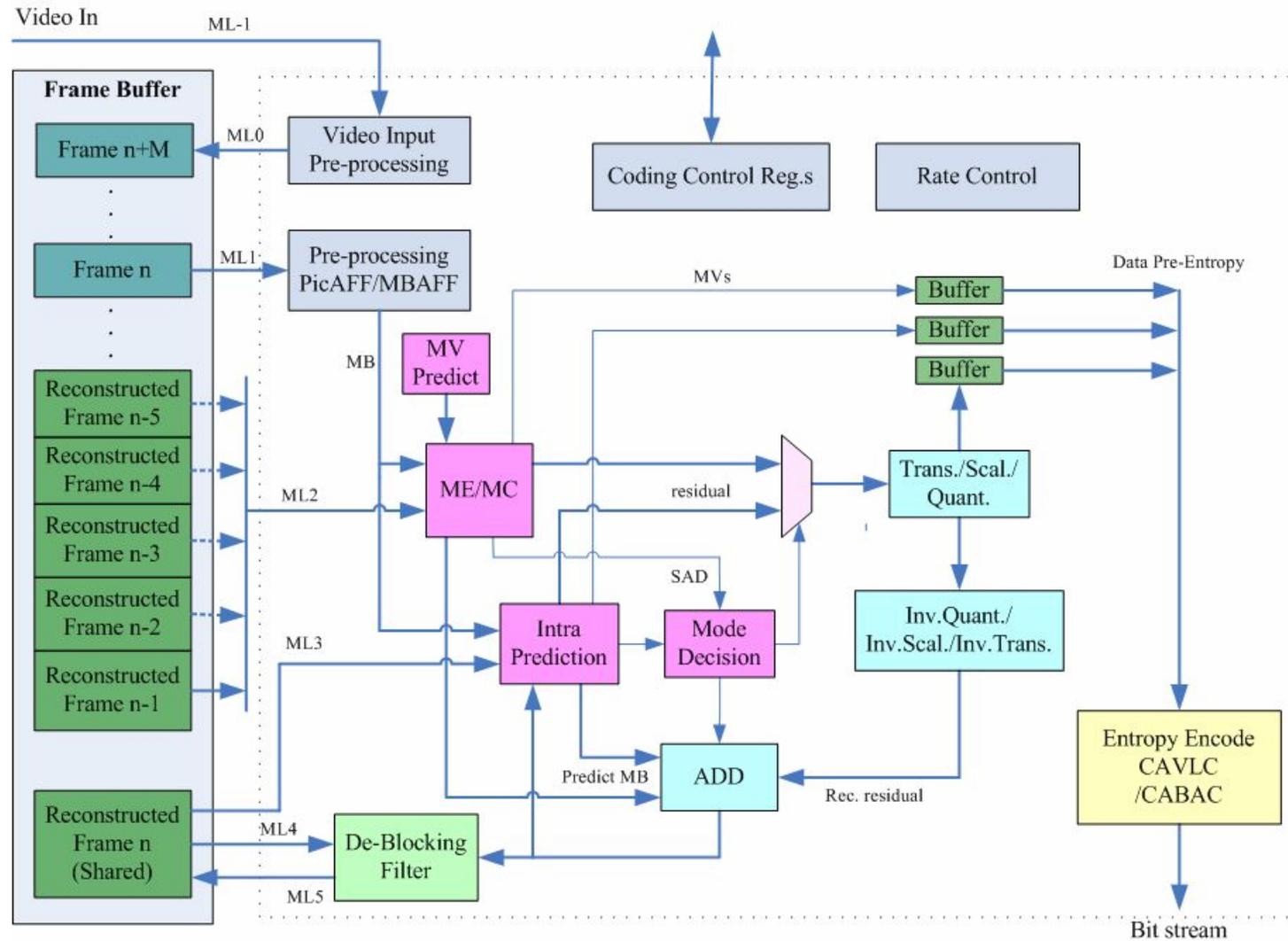
Lots of Knobs to Turn

- Resolution
- Frame rate
- Output bitrate
- Encoder Profile (Base, Main, High)
- Encoder Features
  - Search Range
  - Search Algorithm
  - Search Partitions
  - Refinement
  - Number of Reference Frames

All can affect processing load, video quality

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Multi 6455

- Homogenous processing on "General Purpose" DSP
- Highest Performance
- Most Flexible
- Most Scalable
- Most Software Differentiable
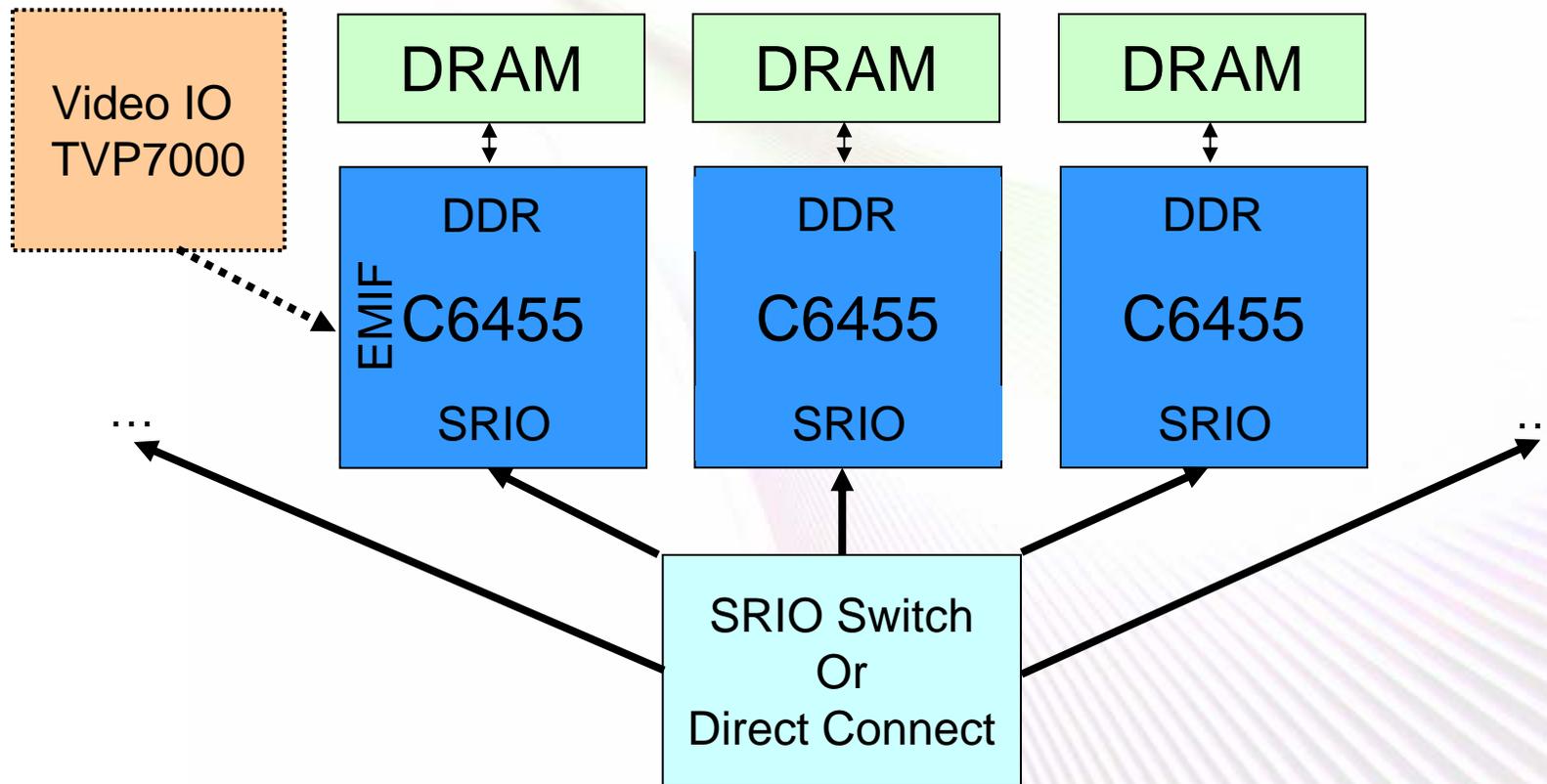
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Multi 6455 – Encode Partitioning
(Functional Partition)
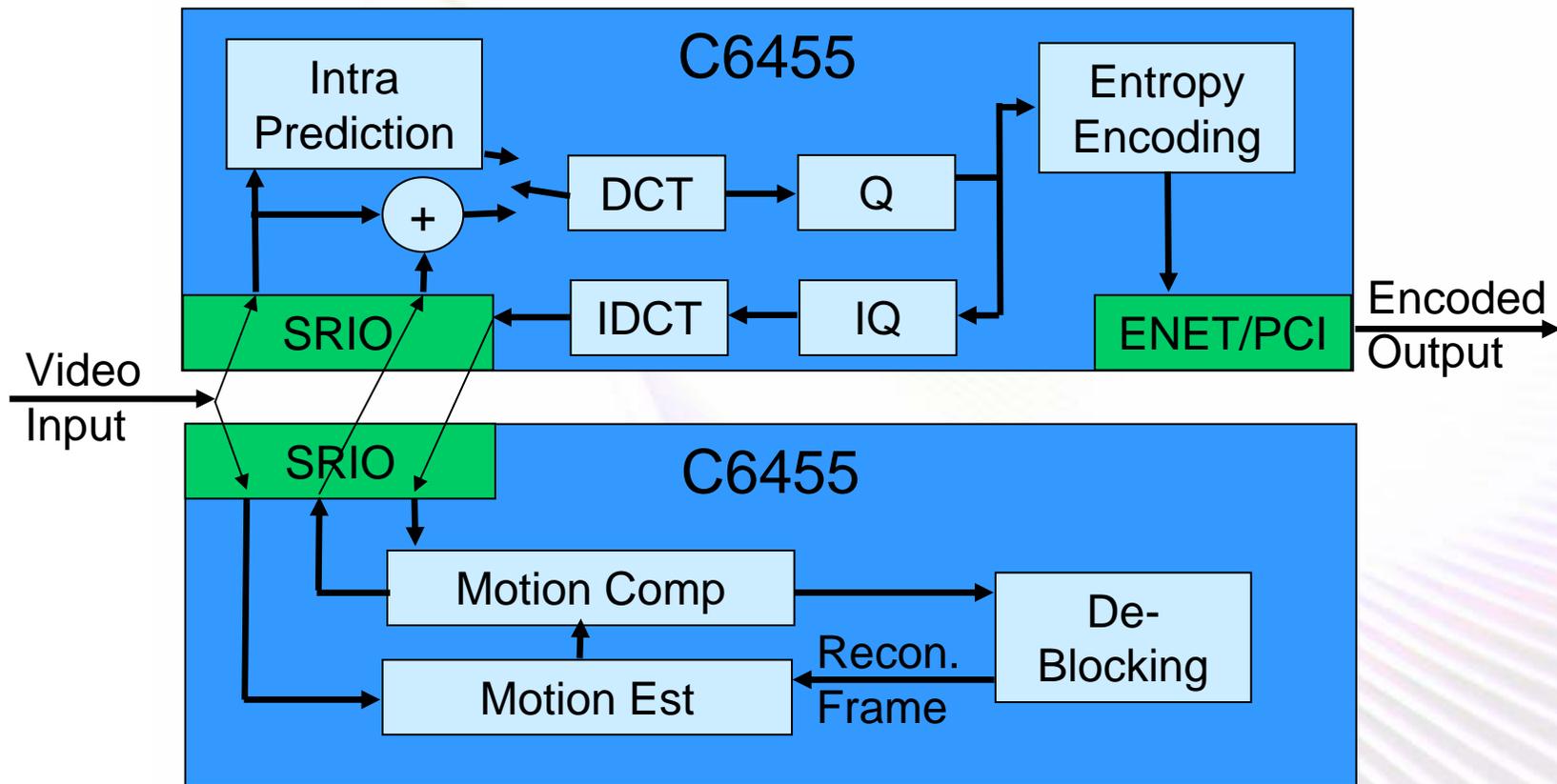
Multi 6455 - Encode Performance
(Functional Partition)

Est. Utilization / Resource	720p30 BP (2 DSPs)	720p30 MP (2 DSPs)
CPU	800 MHz	1200 MHz
SRIO	165 MB/s	165 MB/s
DDR	900 MB/s	1575 MB/s
ENET/PCI	5 Mb/s	5 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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Multi 6455 – Encode Partitioning
(Sliced Partition)

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TEXAS INSTRUMENTS
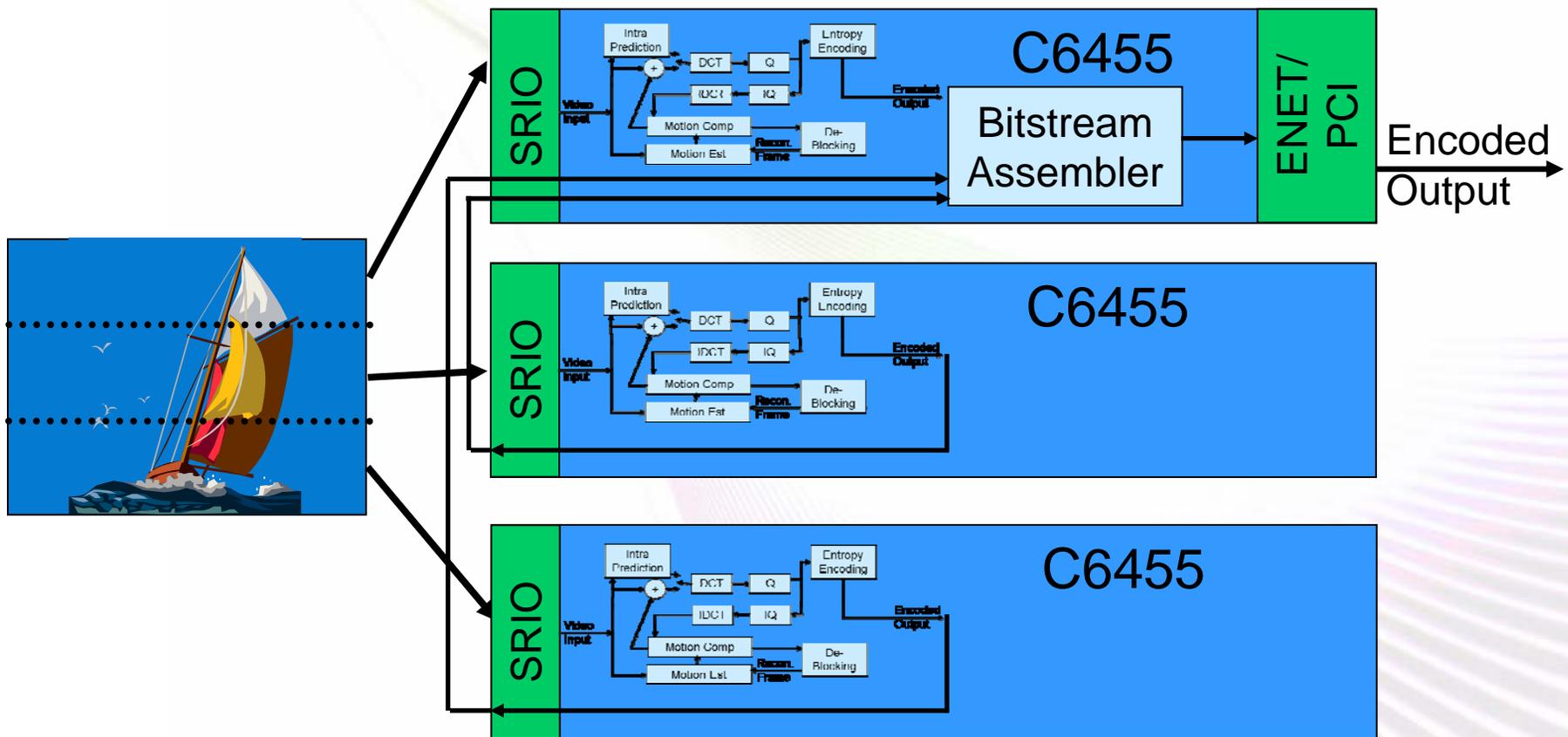
Multi 6455 - Encode Performance
(Sliced Partition)

Est. Utilization / Resource	720p60 BP (3 DSPs)	720p60 MP (4 DSPs)	1080i60 BP (4 DSPs)	1080i60 MP (6 DSPs)
CPU	880 MHz	1000 MHz	750 MHz	750 MHz
SRIO	210 MB/s	210 MB/s	240 MB/s	240 MB/s
DDR	600 MB/s	790 MB/s	510 MB/s	590 MB/s
ENET/PCI	10 Mb/s	10 Mb/s	10 Mb/s	10 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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Multi 6455 – Encode Partitioning (Combination Partition)
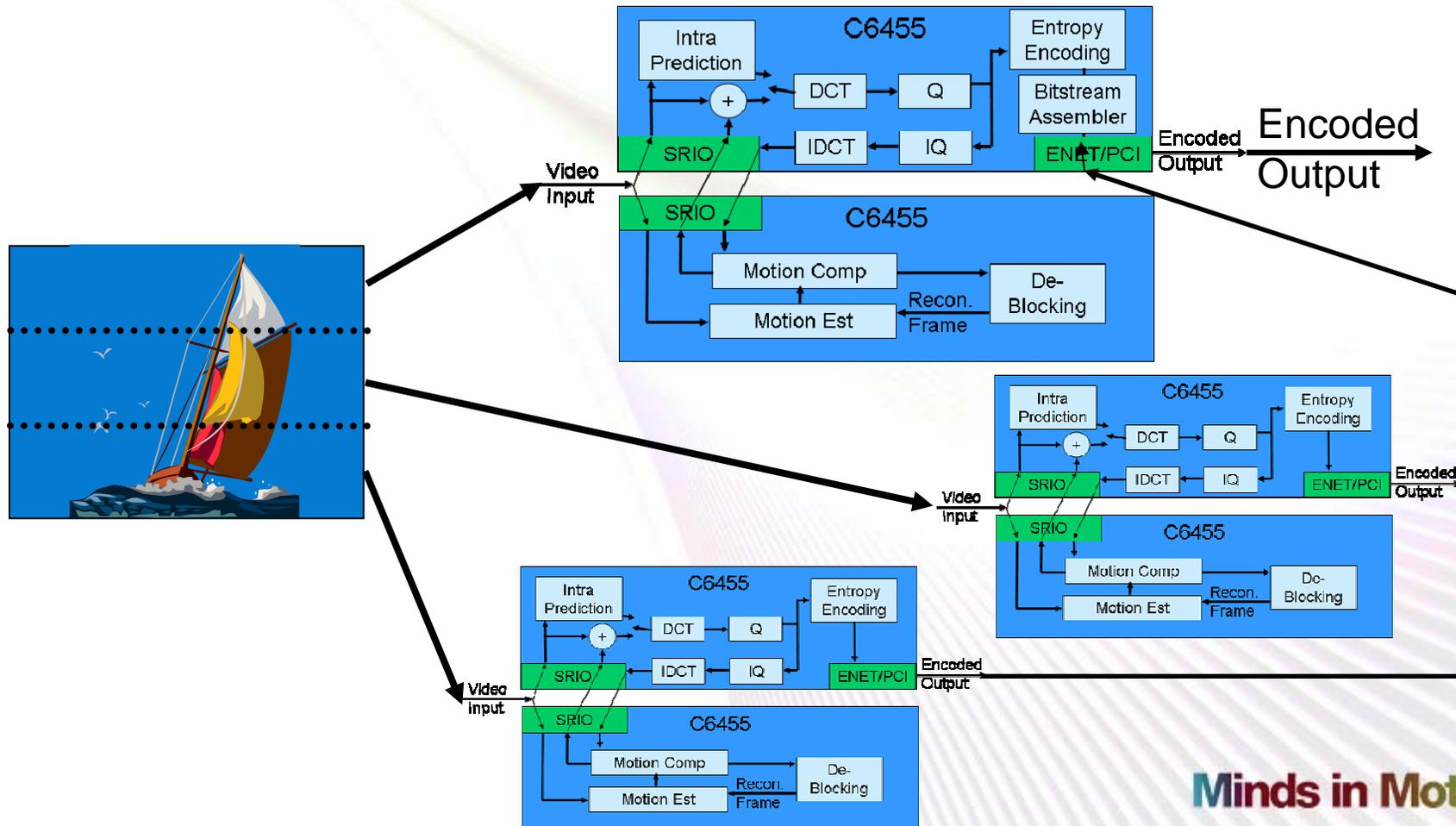
Multi 6455 - Encode Performance
(Combination Partition)

Est. Utilization / Resource	720p60 BP (4 DSPs)	720p60 MP (4 DSPs)	1080i60 BP (4 DSPs)	1080i60 MP (6 DSPs)
CPU	740 MHz	1100 MHz	830 MHz	820 MHz
SRIO	525 MB/s	525 MB/s	600 MB/s	600 MB/s
DDR	600 MB/s	790 MB/s	510 MB/s	590 MB/s
ENET/PCI	20 Mb/s	20 Mb/s	30 Mb/s	30 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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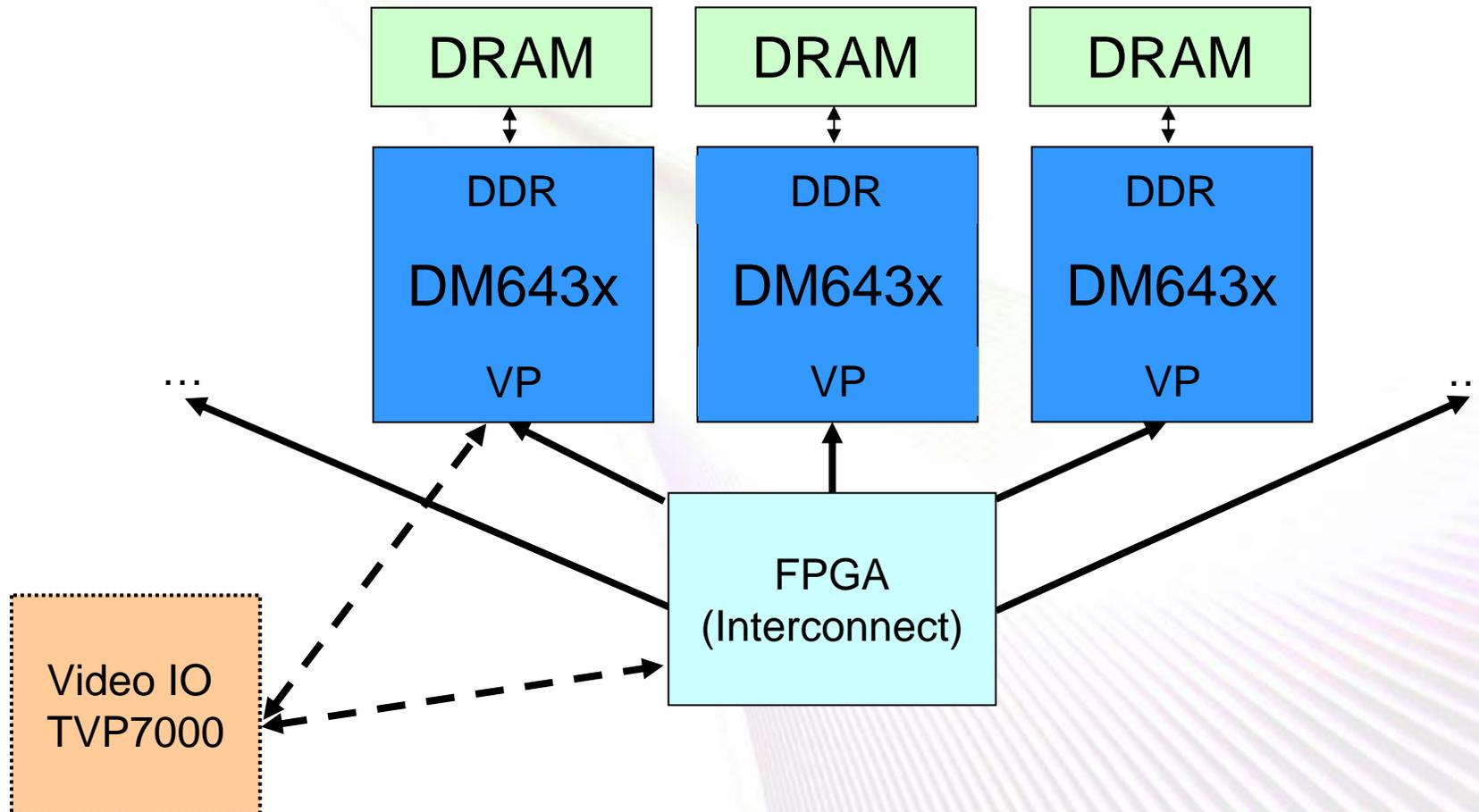
Technology for Innovators™   TEXAS INSTRUMENTS

Multi 6455 – Transcode Partitioning
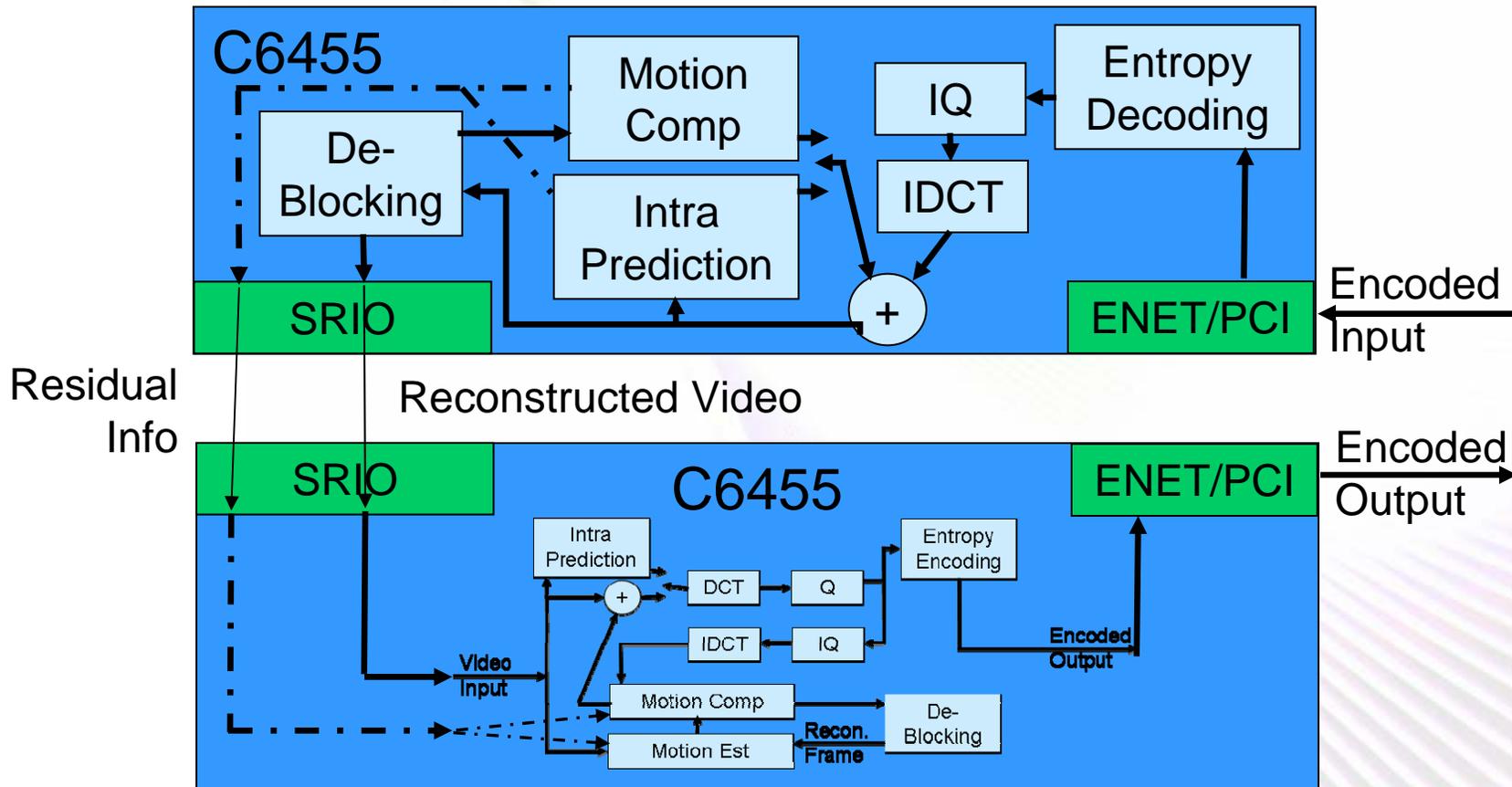
Multi 6455 - Transcode Performance

Est. Utilization / Resource	720p60 BP (3 DSPs)	720p60 MP (4 DSPs)	1080i60 BP (4 DSPs)	1080i60 MP (2 DSPs)
CPU	750 MHz	850 MHz	640 MHz	960 MHz
SRIO	110 MB/s	110 MB/s	120 MB/s	120 MB/s
DDR	120 MB/s	120 MB/s	135 MB/s	135 MB/s
ENET/PCI	20 Mb/s	20 Mb/s	20 Mb/s	20 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, Refinement only

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645x + FPGA

- "General Purpose" DSP
- Customizable Acceleration
- Highest Performance
- Flexible
- Scalable
- DSP is ideal for sequential processing steps
- FPGA is ideal for highly parallel processing steps

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645x + FPGA - Architecture

With SRIO

DRAM	DDR	C6455

SRIO

SRIO — FPGA

Video IO
TVP7000

Without SRIO

DRAM	DDR	C6454

EMIF

EMIF — FPGA

Video IO
TVP7000
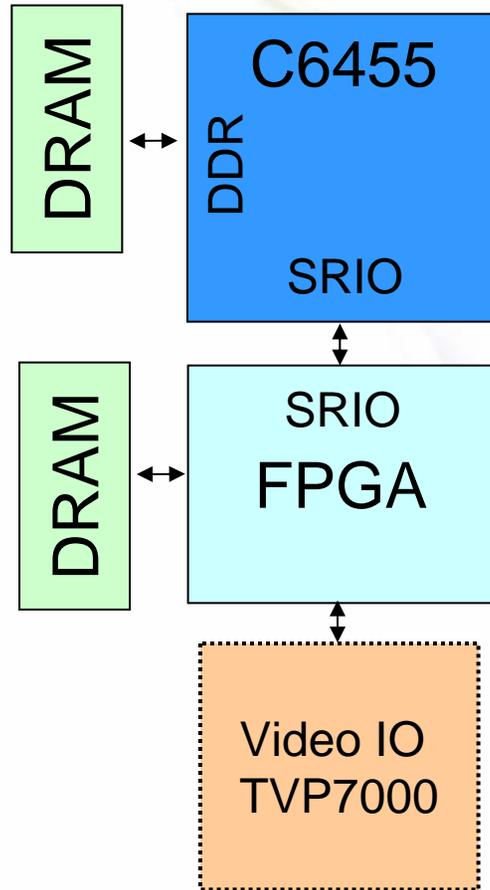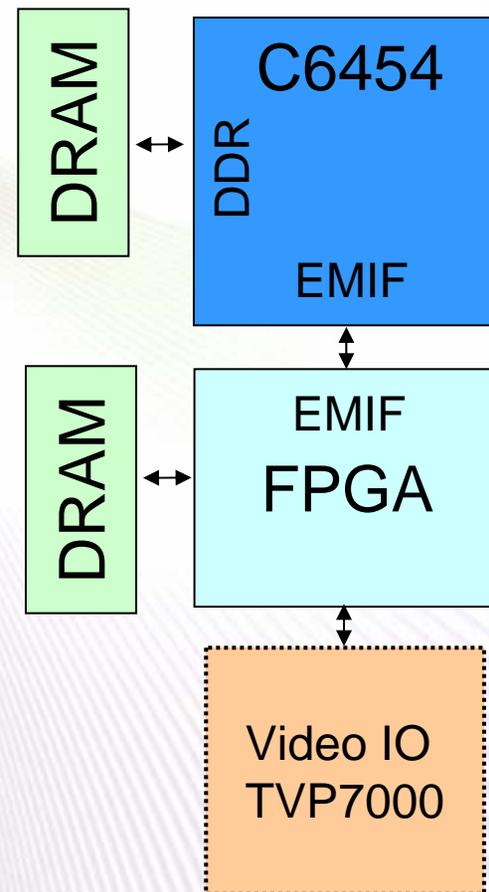
Minds in Motion

645x + FPGA – Encode Partitioning

645x + FPGA - Encode Performance

Est. Utilization Resource	720p30 BP (1 DSP)	720p30 MP (1 DSP)
CPU	570 MHz	850 MHz
SRIO/EMIF	165 MB/s	165 MB/s
DDR	150 MB/s	165 MB/s
ENET/PCI	5 Mb/s	5 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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Technology for Innovators™   **TEXAS INSTRUMENTS**

645x + FPGA – Transcode Partitioning

645x + FPGA - Transcode Performance

Est. Utilization / Resource	720p30 BP (1 DSP)	720p30 MP (2 DSP)
CPU	1170 MHz	850 MHz
SRIO/EMIF	110 MB/s	110 MB/s
DDR	385 MB/s	235 MB/s
ENET/PCI	15 Mb/s	10 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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Technology for Innovators™   TEXAS INSTRUMENTS

Multi DM643x

- Homogenous processing on DSP with Specialized Video IO
- Lower cost
- Flexible
- Scalable
- Software Differentiable

Multi DM643x - Architecture
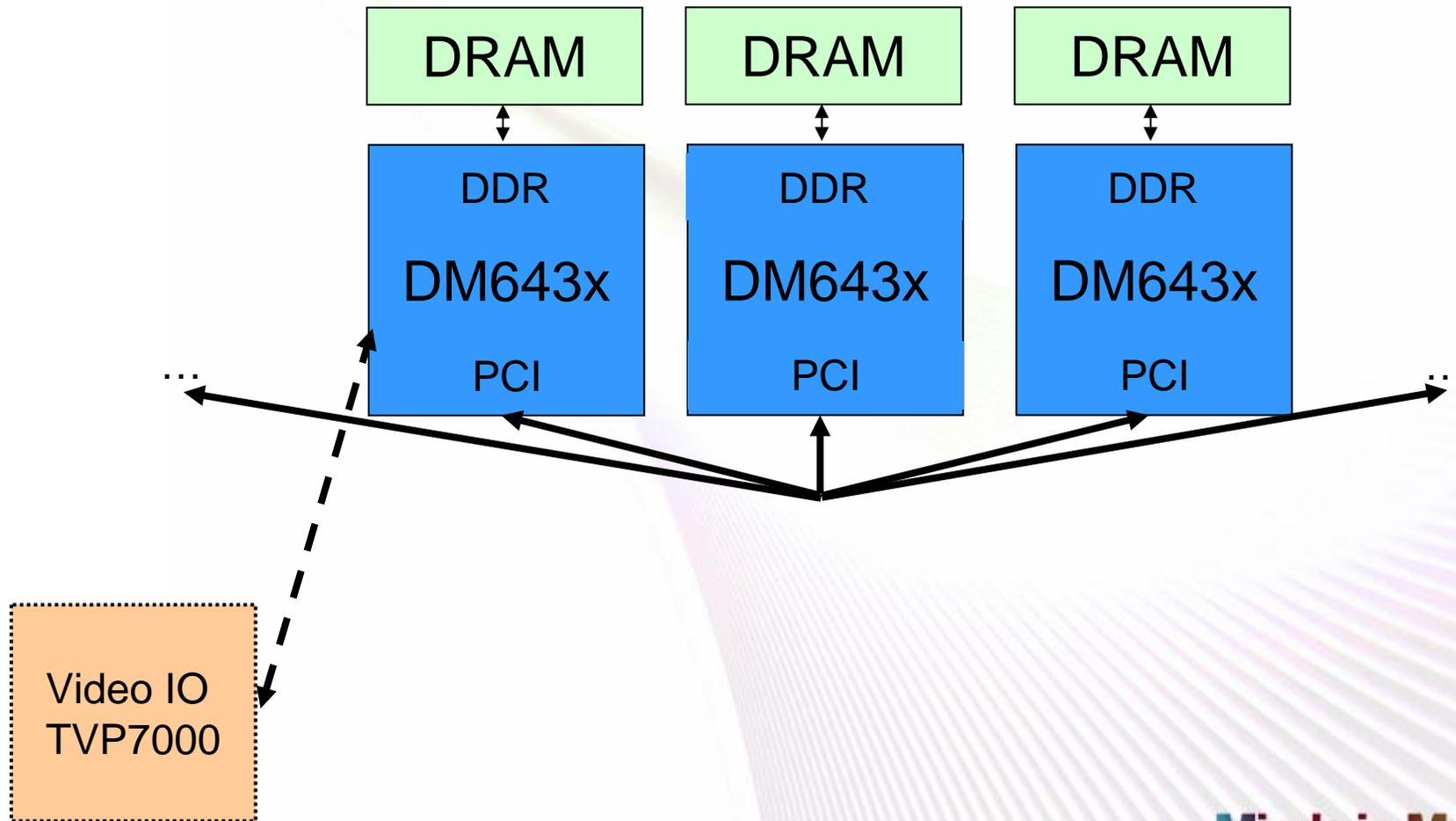
Multi DM643x – Encode Partitioning
(Sliced Partition)

DM643x
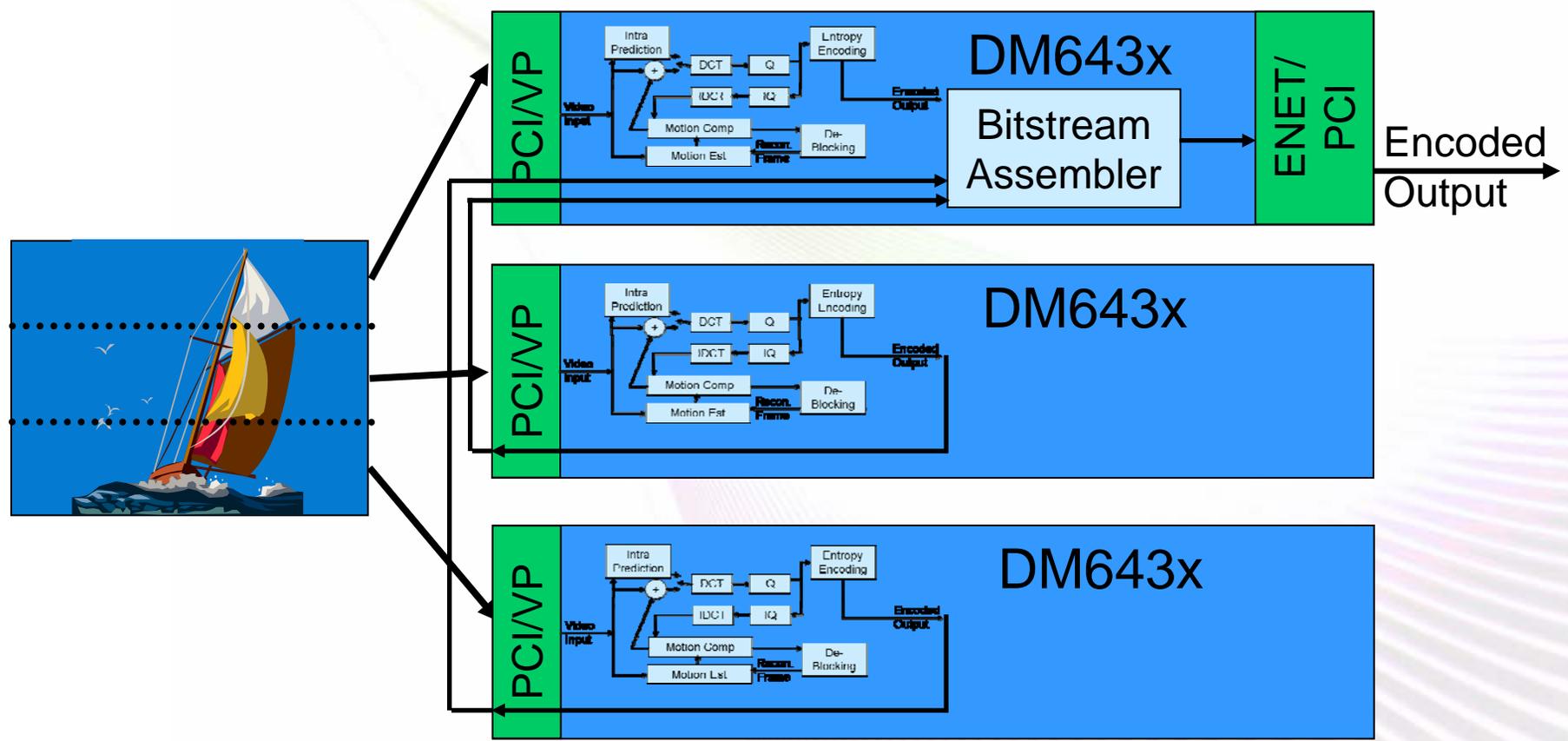
DM643x

DM643x

Encoded
Output

Multi DM643x - Encode Performance
(Sliced Partition)

Est. Utilization / Resource	480p30 MP (2 DSPs)	720p30 BP (4 DSPs)	720p30 MP (4 DSPs)	1080i60 BP (6 DSPs)
CPU	375 MHz	335 MHz	500 MHz	500 MHz
VP	10 MB/s	15 MB/s	15 MB/s	20 MB/s
DDR	300 MB/s	300 MB/s	520 MB/s	340 MB/s
ENET/PCI	10 Mb/s	20 Mb/s	20 Mb/s	20 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 64 Search range

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Multi DM643x – Decode Partitioning

Multi DM643x - Decode Performance

Est. Utilization Resource	720p30 MP (2 DSPs)	720p60 BP (2 DSPs)	1080i60 BP (2 DSPs)
CPU	330 MHz	440 MHz	500 MHz
VP	110 MB/s	220 MB/s	240 MB/s
DDR	415 MB/s	470 MB/s	530 MB/s
ENET/PCI	10 Mb/s	20 Mb/s	20 Mb/s

Resource Utilization is worst case of the DSPs in the system

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DM643x + FPGA

- DSP with Specialized Video IO
- Customizable Acceleration
- Lower Cost
- Flexible
- DSP is ideal for sequential processing steps
- FPGA is ideal for highly parallel processing steps

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Technology for Innovators™   ♦ TEXAS INSTRUMENTS

643x + FPGA - Architecture

DM643x + FPGA – Decode Partitioning

DM643x + FPGA - Decode Performance

Est. Utilization Resource	720p30 MP (1 DSP)	720p60 BP (1 DSP)	1080i60 BP (1 DSP)
CPU	330 MHz	440 MHz	500 MHz
VP	60 MB/s	110 MB/s	120 MB/s
DDR	150 MB/s	150 MB/s	150 MB/s
ENET/PCI	10 Mb/s	20 Mb/s	20 Mb/s

Resource Utilization is worst case of the DSPs in the system

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Multi C642x

- Homogenous processing on "General Purpose" DSP
- Lowest Cost
- Flexible
- Some Scalability
- Software Differentiable

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Multi C642x - Architecture
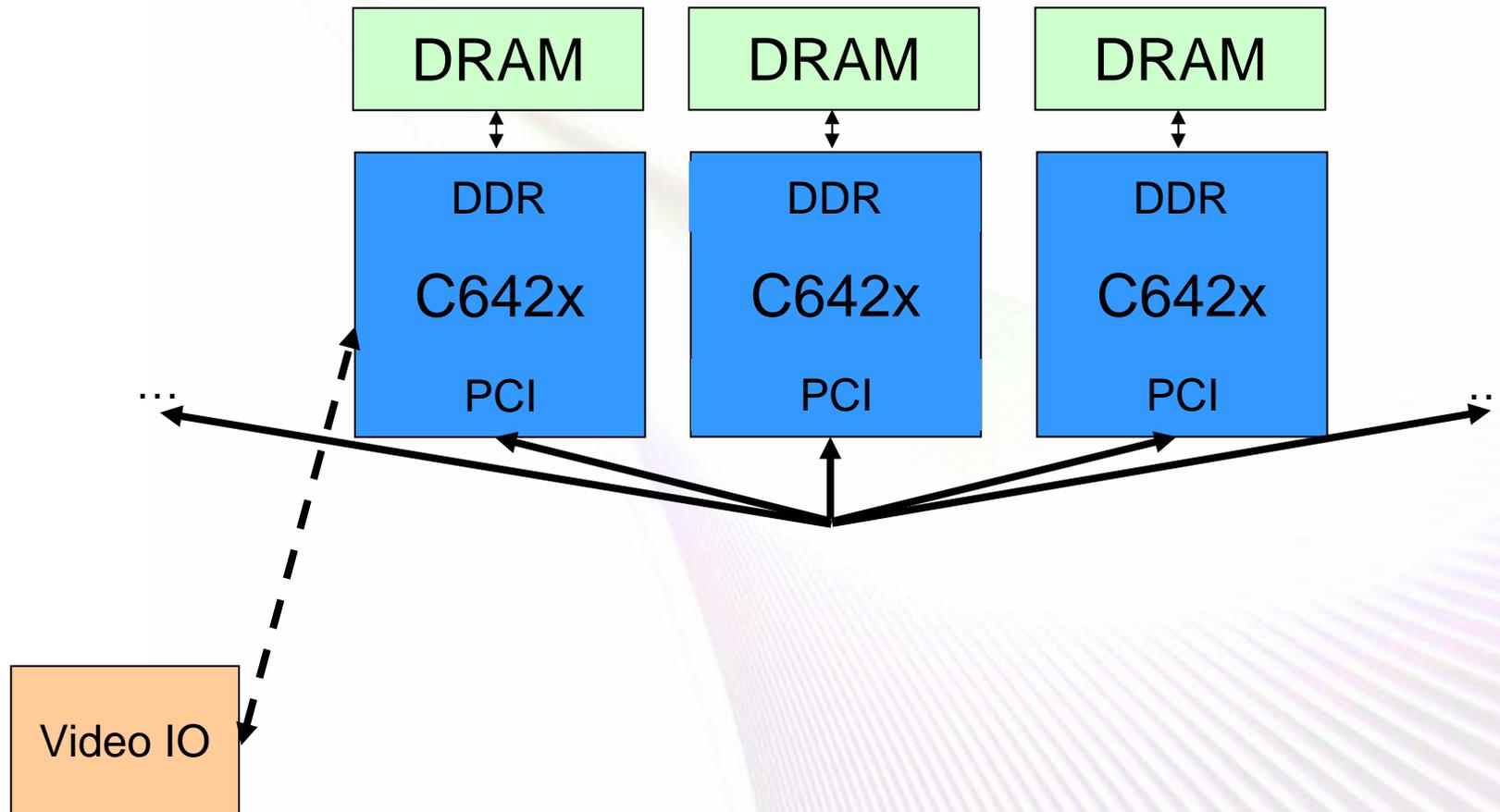
Multi C642x – Transrate Partitioning

Multi C642x - Transrate Performance

Est. Utilization / Resource	480p30 MP (2 DSPs)	720p30 BP (2 DSPs)
CPU	320 MHz	570 MHz
PCI	40 MB/s	105 MB/s
DDR	155 MB/s	235 MB/s
ENET/PCI	15 Mb/s	30 Mb/s

Resource Utilization is worst case of the DSPs in the system
No Motion Estimation

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Technology for Innovators™   **TEXAS INSTRUMENTS**

C642x + FPGA

- "General Purpose" DSP
- Customizable Acceleration
- Lowest Cost

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TEXAS INSTRUMENTS
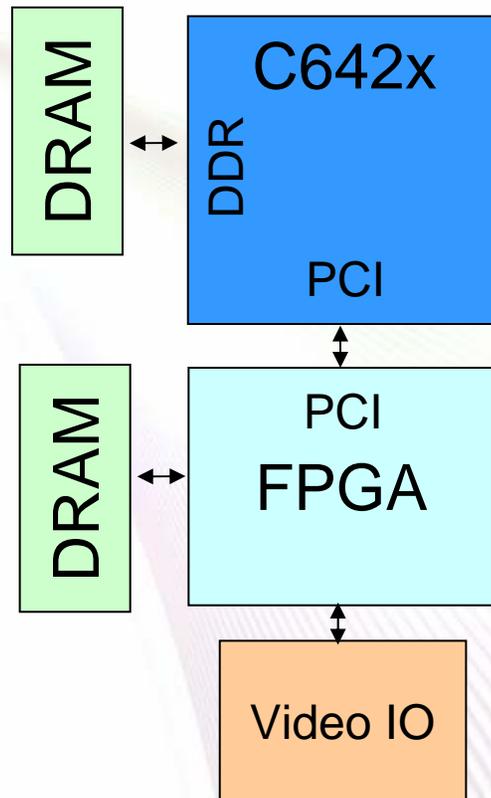
C642x + FPGA – Transrate Partitioning
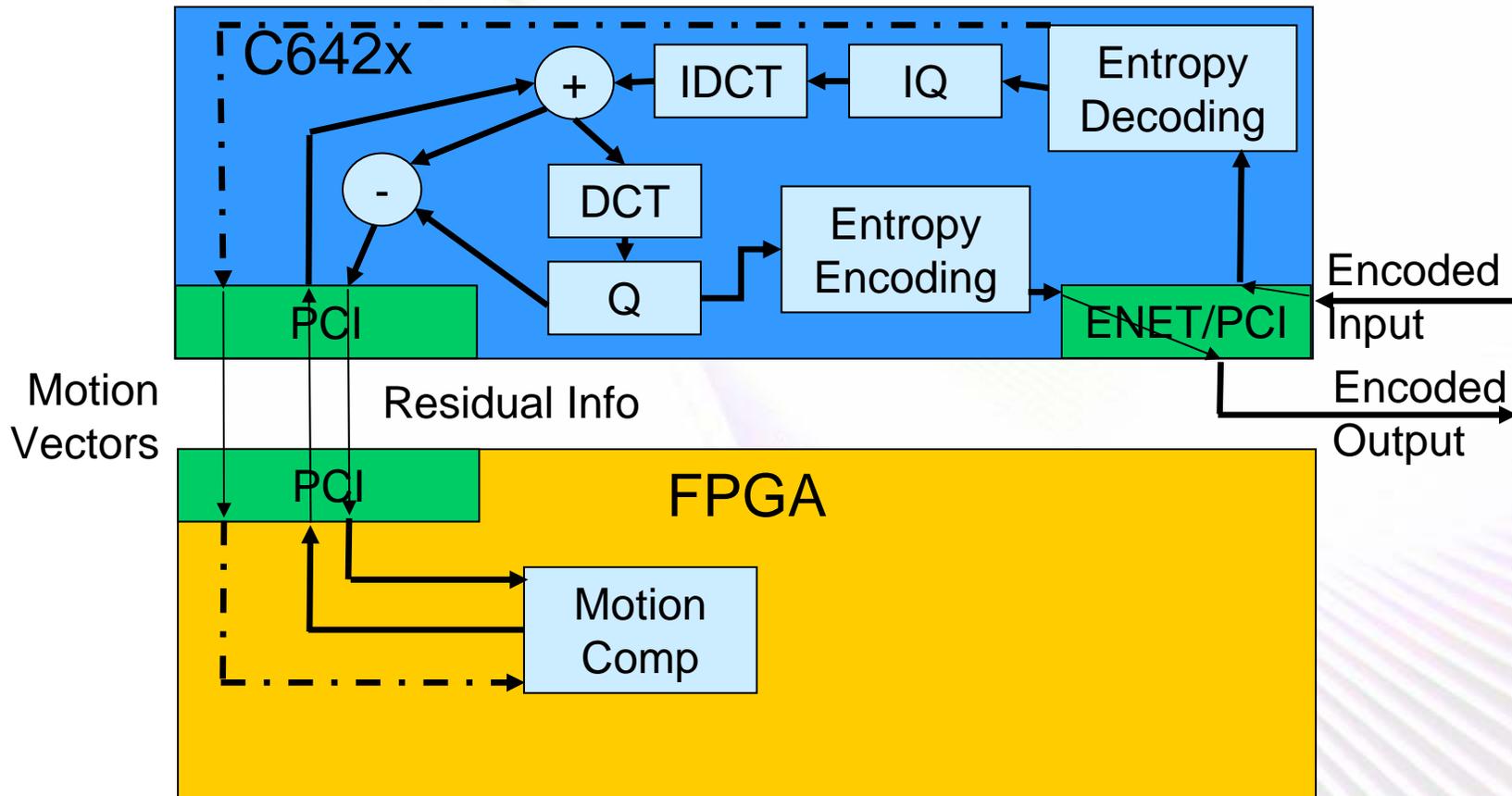
C642x + FPGA - Transrate Performance

Est. Utilization / Resource	480p30 MP (2 DSPs)	720p30 BP (2 DSPs)
CPU	320 MHz	570 MHz
PCI	40 MB/s	105 MB/s
DDR	155 MB/s	235 MB/s
ENET/PCI	15 Mb/s	30 Mb/s

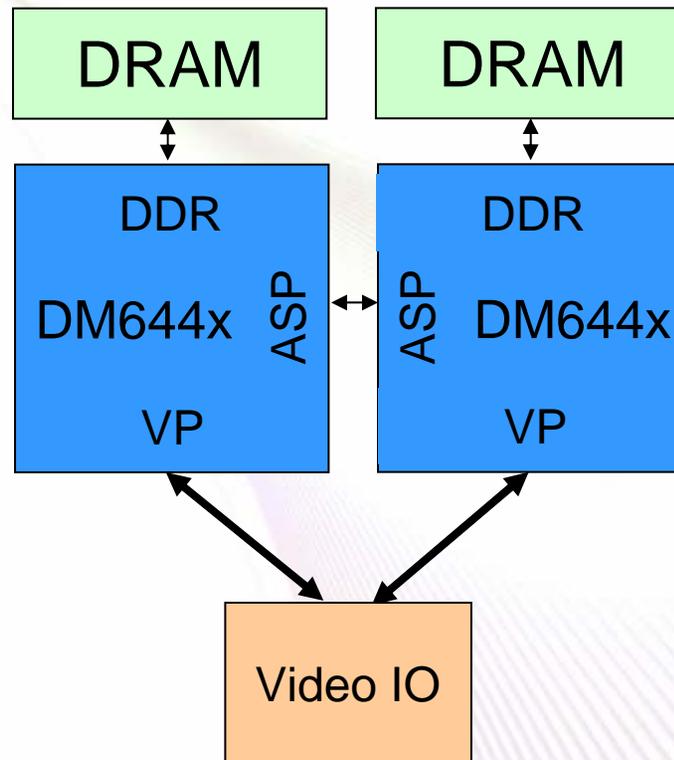Resource Utilization is worst case of the DSPs in the system
No Motion Estimation

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Multi DM644x (DaVinci™)

- Homogenous Multiprocessing on Specialized Video DSP
  - On-board accelerators
  - Video IO
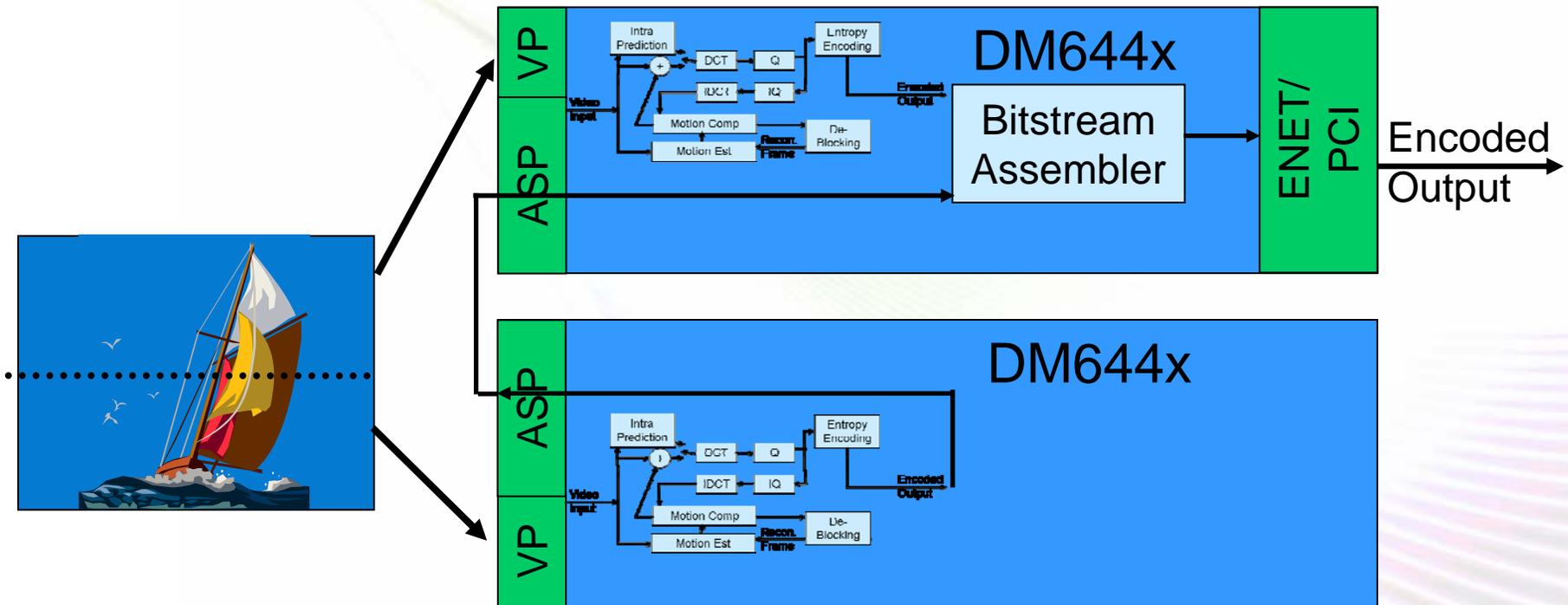- Wide 3rd Party & Video Library Support
- Lower cost

Multi DaVinci – Encode Partitioning (Sliced Partition)

Multi DaVinci™ - Encode Performance

Est. Utilization Resource	480p30 MP (2 DSPs)	720p30 BP (2 DSPs)
CPU	310 MHz	550 MHz
VP	10 MB/s	30 MB/s
DDR	150 MB/s	225 MB/s
ENET/PCI	5 Mb/s	10 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 32 Search range

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Multi DaVinci™ - Decode Performance

Est. Utilization \ Resource	480p30 MP (2 DSPs)	720p30 BP (2 DSPs)
CPU	250 MHz	440 MHz
VP	40 MB/s	110 MB/s
DDR	145 MB/s	220 MB/s
ENET/PCI	5 Mb/s	10 Mb/s

Resource Utilization is worst case of the DSPs in the system
1 Reference Frame, +/- 32 Search range

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Conclusions

- Elegant solutions exist for video systems that won't fit in one DSP
- Many different solutions for different
  - Resolutions
  - Quality needs
  - Price points
- Mixing and combing examples shown creates an even wider spectrum of solutions