# The Latest High-Speed Imaging Technologies and Applications

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# What is the High-Speed Imaging?

- Involves use of video cameras that record at high frame rates and play back at slower rates

- Also called "slow motion imaging"

- Focus of this presentation is on 2-D array cameras that directly create videos(not line scanning , not multi-frame cameras)

- Generally in the 30fps – 100, 000fps

# The Two Competing Reasons of High-Speed Imaging

- Generation of high-quality images

    - Qualitative review of a process

    - Stop-action slow motion repaly

    - Find artifacts

    - Entertainment

Collection of images for extraction and calculation of motion(i.e. "motion analysis")

    - Enables video cameras to become non-contact test devices, analogous to oscilloscopes
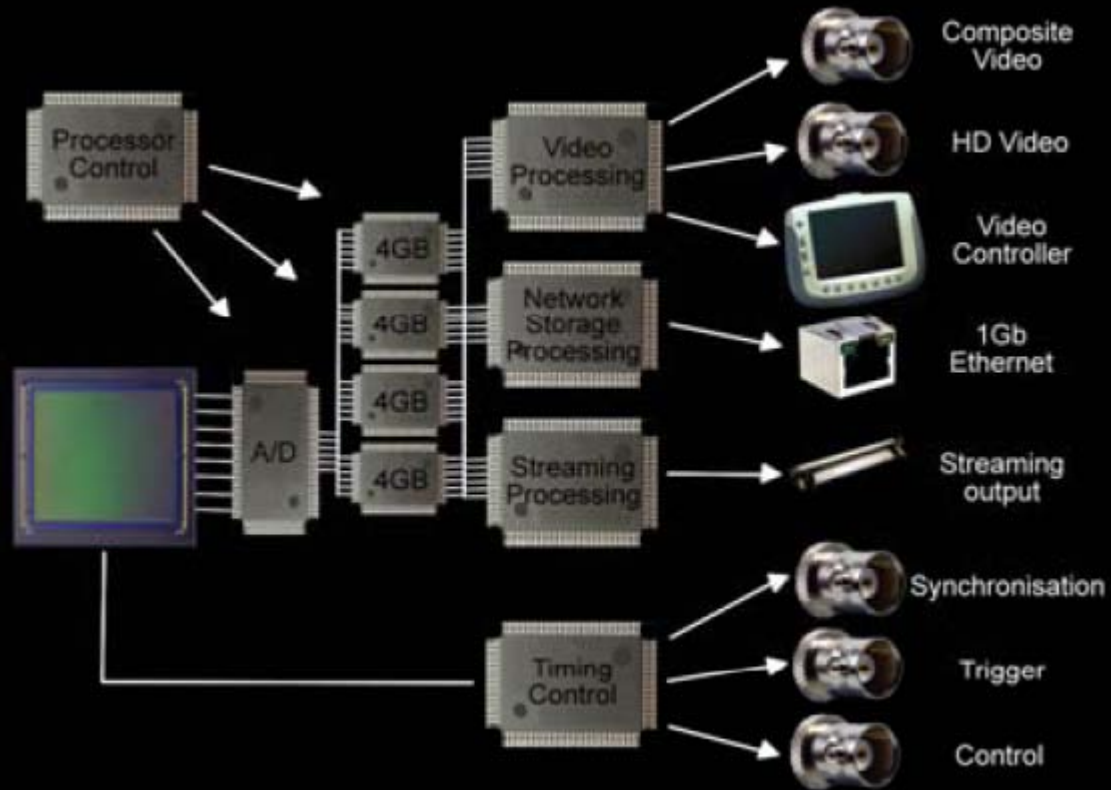
# Example Videos

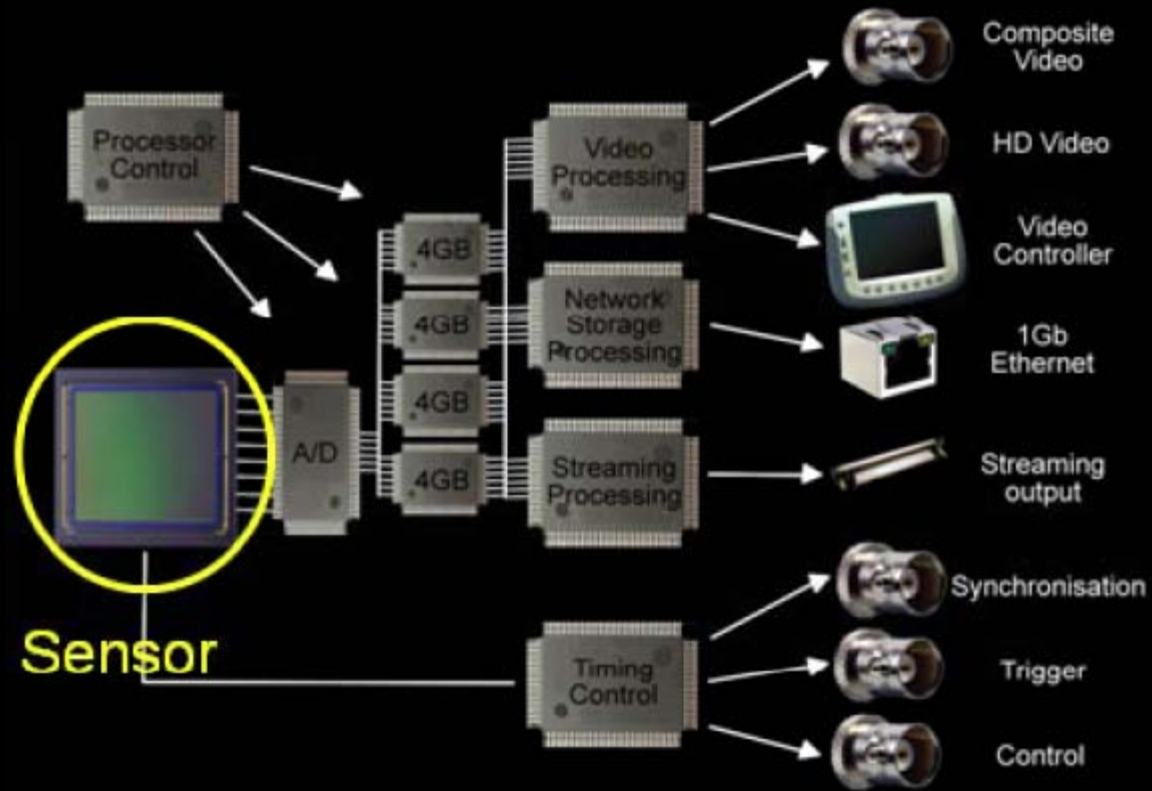# Key differences between high-speed cameras and other cameras

- Very fast throughput rates
- Intermediate memory for fast storage of images
- Lots of data(e. g. pixels, bits) to manage
- Adjustable exposure times
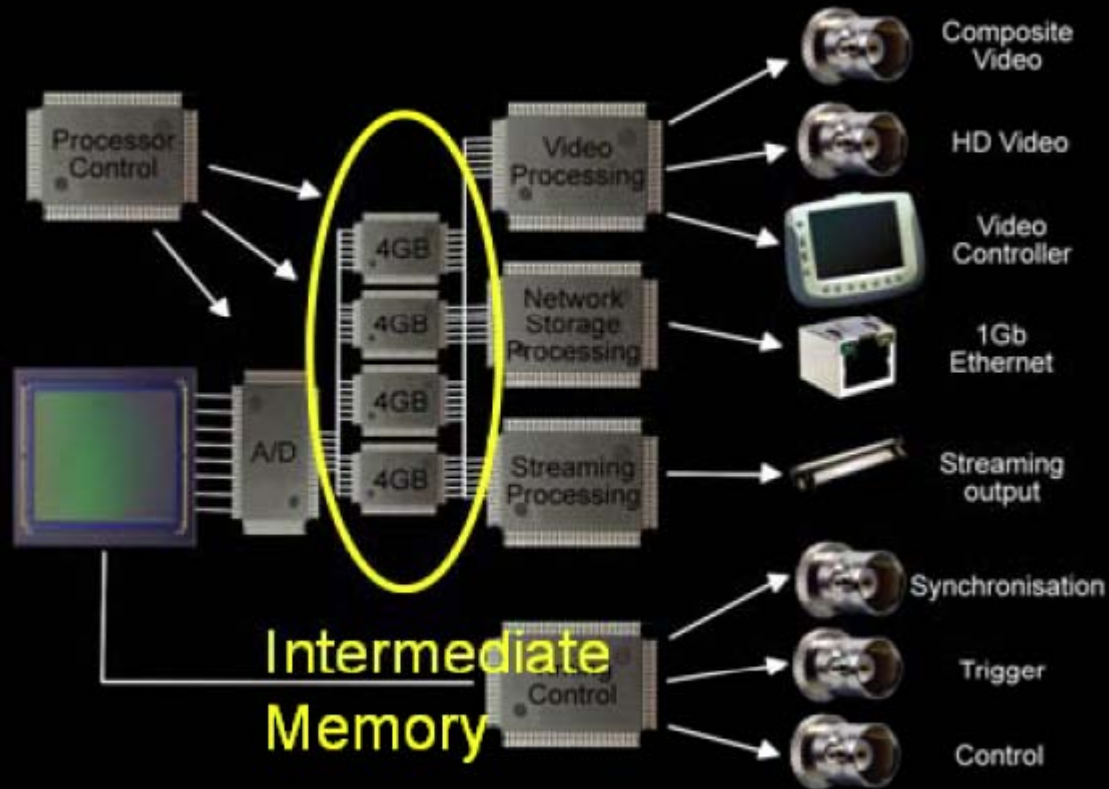- Relationship between frame rate and resolution

# Anatomy of a High-Speed Camera

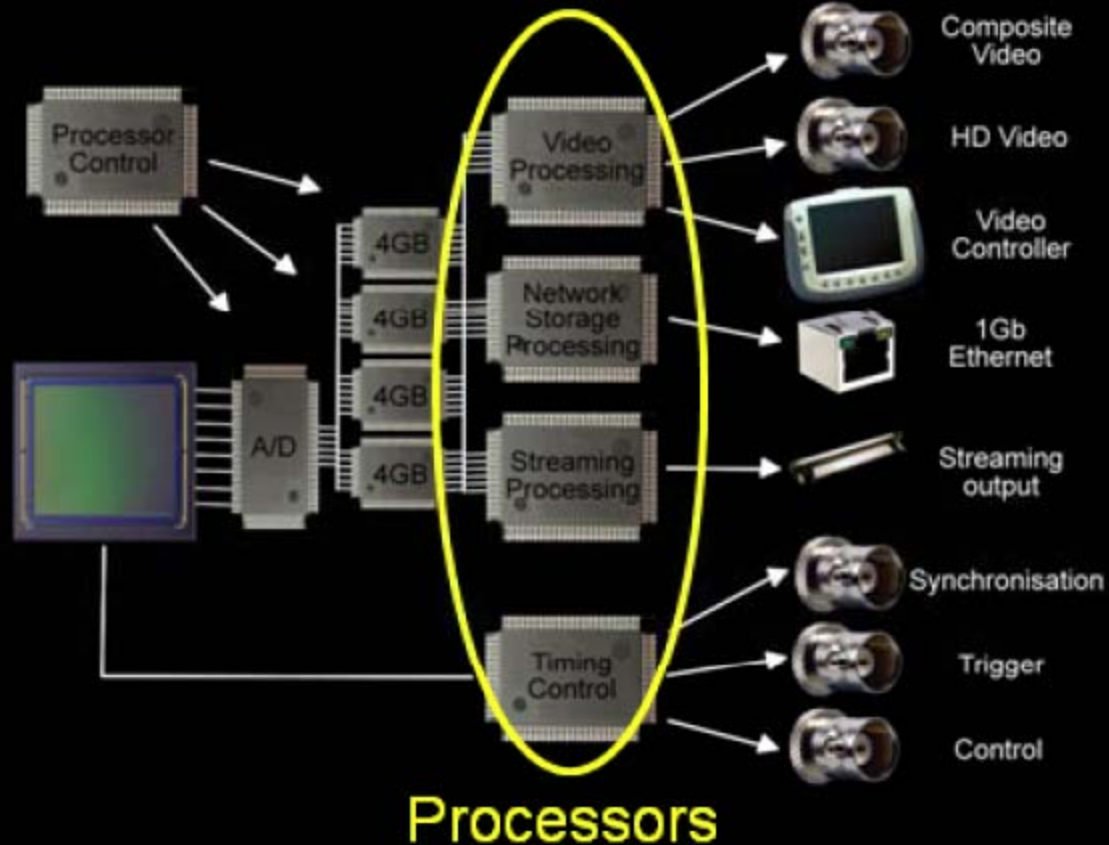# Anatomy of a High-Speed Camera
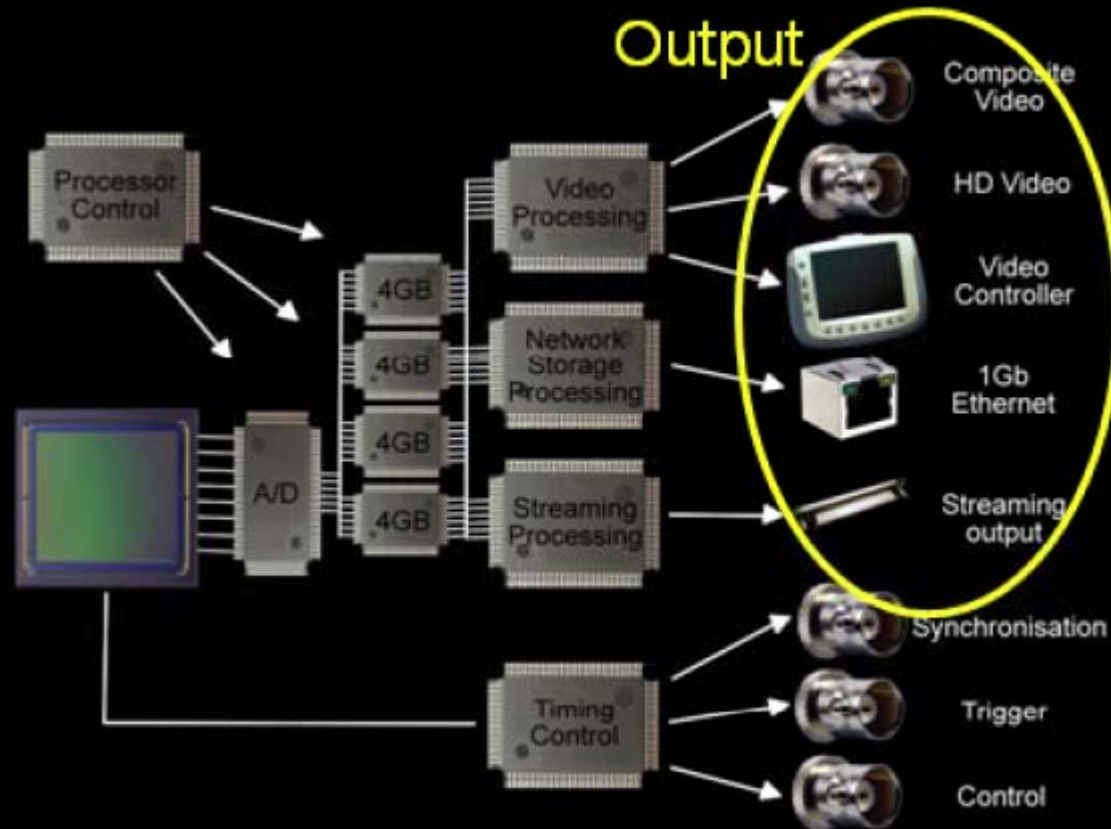
# Anatomy of a High-Speed Camera

# Anatomy of a High-Speed Camera

# Anatomy of a High-Speed Camera

# The Heart of a Camera: The Sensor
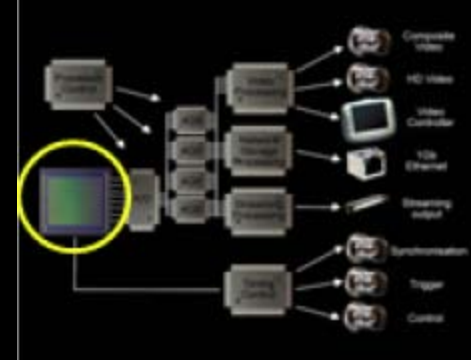
· High – speed cameras use specialized, high-performance image sensors

· Four technical considerations for sensors

1. Resolution(number of pixels)
2. Speed(frame rate)
3. Light sensitivity(converting photons to electrons)
4. Bit Depth and Dynamic Range

# Resolution vs. Speed

- Throughput = speed * resolution = ~ constant for each camera
- Because of bandwidth limitations, each camera can only transfer a fixed amount of data to memory
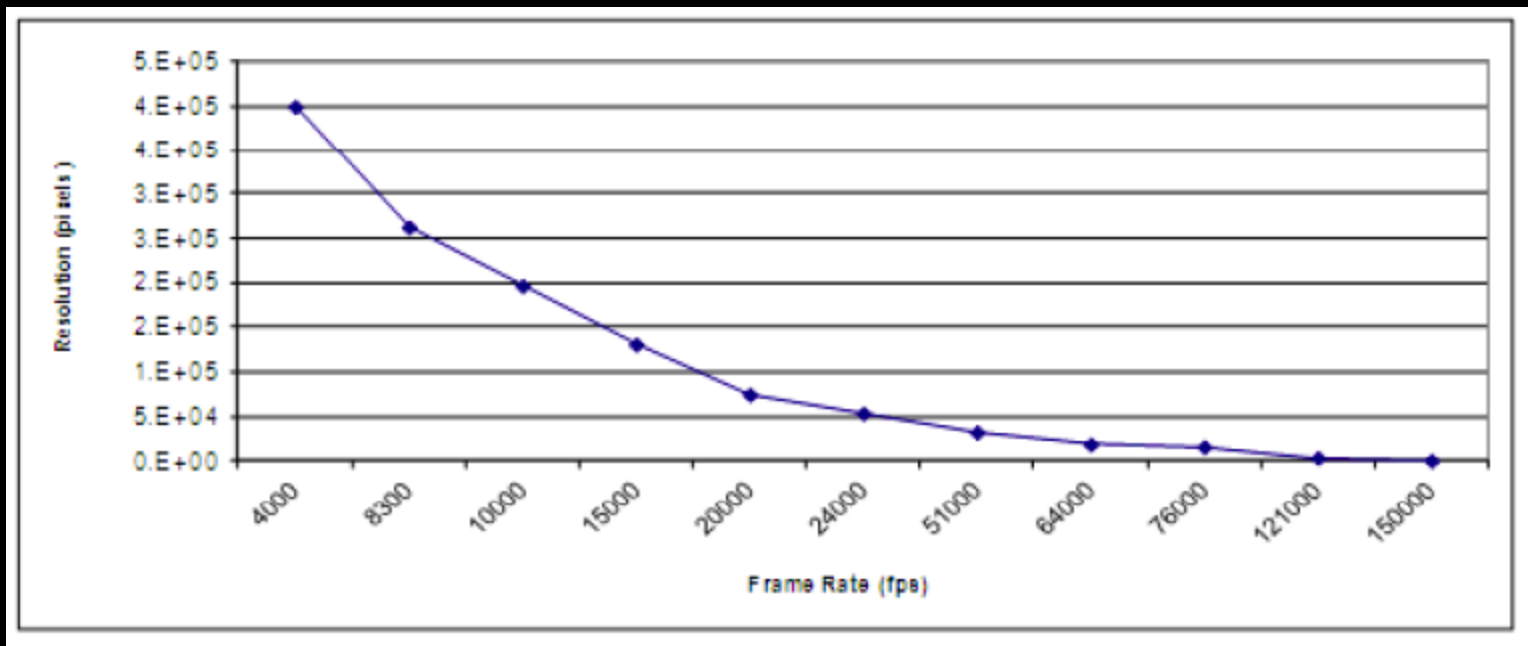
# The Explosion of throughput(Gpx/sec)
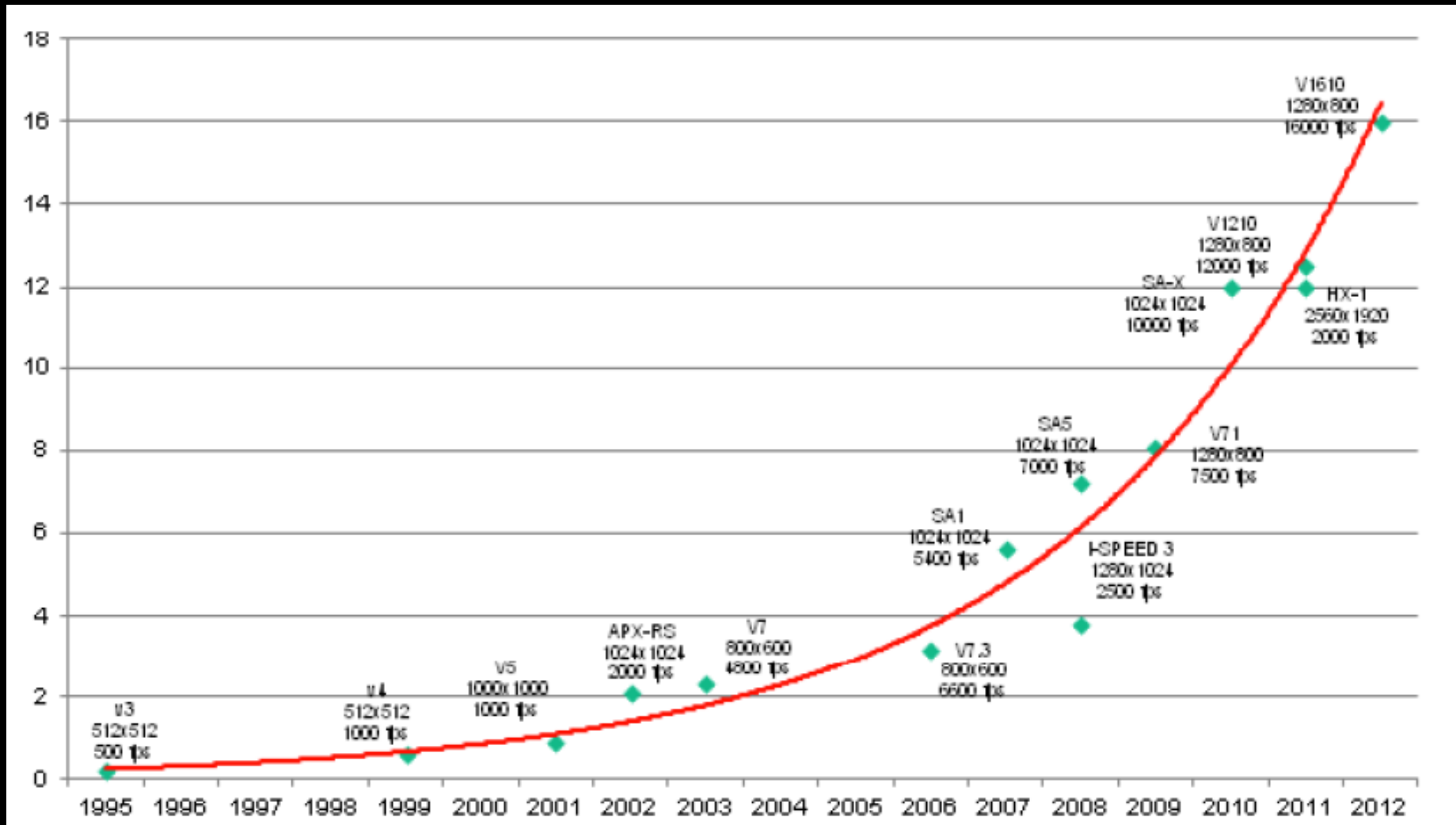
## The Relationship Between Frame Rate and Exposure:
## Frame Rate

- "Frame Rate" describes the time between snapshots in a video

- Motion discretization: defines the distance an object moves between analysis intervals

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# The Relationship Between Frame Rate and Exposure:
# Exposure Time

- Also called "Shutter speed"

- "Exposure time" = 1 /  Shutter speed

- Amount of time that each frame is "open" to the world to collect photons

# Light Sensitivity

- Four contributors to light sensitivity of a sensor
- 1. Quantum efficiency of sensor substrate
- 2. Pixel size (size of each pixel, typically measured in microns)
- 3. Fill factor (the portion of each pixel that is sensitive to light)
- 4. Lensing and filtering

# The Importance of Bit Depth

- Current cameras 8-12 bit mono, 24-48 bit color(3x RGB mono)

- Because we can only save 10-bit and display 8-bit, cameras now have "bit selectors" or "bit sliders"

# Dynamic Range

- The problem: flashes, reflections, saturated images
- The goal: see into bright, saturated areas, without dimming out dark areas
- The solutions

 - Extending the dynamic range so that the conversion of light (e.g. lux) to electrical signals(e.g. volts) is not linear, but instead logarithmic.

  - Dual slope integration – high gain and low gain

# Two Forms of Image Storage
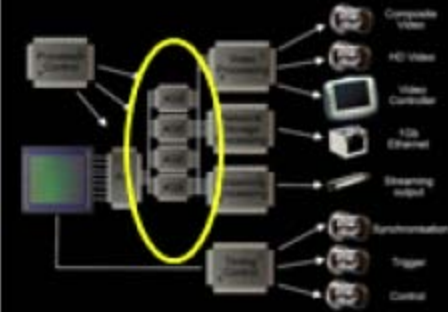
- Intermediate (short term) storage
- Permanent storage

# Intermediate Storage of Images

- Either located in the camera head(RAM) or in computer (SSD, HDD)

- Determines how long the camera can record

# Large Processing Power is required in High-Speed Cameras
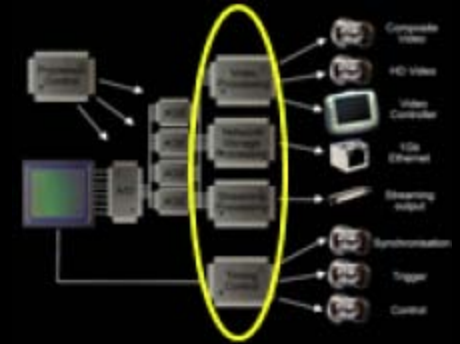
- High-speed cameras typically have 4-5 different processor functions

- Next generation of cameras also have FPGA/DSP on back end for user programming

# What gets Processed?

- Image processing
  - Fixed pattern noise
  - Color reconstruction
  - Image sharpness, contrast, brightness
- Image/Data manipulation
  - Sensor to internal memory
  - Memory to CPU or other devices
  - Dynamic range, exposure
- Camera control and set-up
- Timing and external synchronization

# Fixed Pattern Noise Correction

- CMOS has Fixed Pattern Noise (black level of each pixel is different)

- Compensation circuitry in camera is most common though some manufacturers use PC CPU for compensation

## Models
Y3 – 1280x1024 up to 6,000 fps
Y4 – 1024x1024 up to 5,100 fps
Y5 – 2560x1920 @ 730 fps
Y6 – 1920x1080 @ 1,000 fps
Y7 – 1920x1080 up to 9,000 fps

## Configurations
Mono or Color
Internal RAM 8GB (up to 32GB optional)

## Features
Low-noise, high dynamic range
Ready to publish image output
Automatic black balance
USB-2 and GE Ethernet Connectivity
Live 1080p/720p for image preview
/playback
100G shock and vibration proof

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# Y | SERIES™
## EXPLODED VIEW

**FAN MODULE**
Effective cooling with no dust contanination

**IMAGING SENSOR**
Low noise high-dynamic range

**MEMORY**
8 GB standard. Optionlal 16, 24 and 32 GB

**LENS MOUNT**
C-Mount standard · F&PL Adapter optional

**INTERFACING PANEL**
HDMI · GE Ethernet · USB-2 · Power · Control

**FAN MODULE**
Redundant cooling

**BASE PLATE**
Versatile adapter to standard rigs without obstructing the airflow

# The latest camera models

# MotionPro Y3

Classic – Digital Sensor Architecture – 10 bit ADC
    1280x1024 @1,000 fps
    Plus mode (compression) 1280x1024 @2,000 fps
    Supports 11 and 12 XDR

S1 – Digital Sensor Architecture– 10 bit ADC
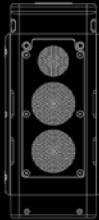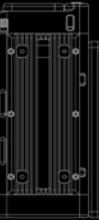    1280x1024 @3,000 fps
    Plus mode NOT supported
    Supports 11 and 12 bit XDR and EDR

S2 – Digital Sensor Architecture– 10 bit ADC
    1280x1024 @6,000 fps
    Plus mode NOT supported
    Supports 11 and 12 bit XDR and EDR

## MotionPro Y4

S1 – Digital Sensor Architecture – 10 bit ADC
    1024x1024 @3,000 fps
      Plus mode (compression) 1024x1024 @6,000 fps
      Supports 11 and 12 bit XDR and EDR
S2 – Digital Sensor Architecture – 10 bit ADC
    1024x1024 @4,500 fps
      Plus mode (compression) 1024x1024 @8,900 fps
      Supports 11 and 12 bit XDR and EDR
S3 – Digital Sensor Architecture – 10 bit ADC
    1024x1024 @5,000 fps
      Plus mode (compression) 1024x1024 @9,900 fps
      Supports 11 and 12 bit EDR and EDR

# MotionPro Y5

Y5 – Digital Sensor Architecture – 10 bit ADC
   2352x1728 @730 fps
   Plus mode (compression) 1024x1024 @6,000 fps
   Supports 11 and 12 bit XDR
Y5HDiablo – Digital Sensor Architecture – 10 bit ADC
   2560x1920 @ 640 fps
   2560x1080 @ 1,000 fps
   1920x1080 @ 1,000 fps
   Plus mode NOT Supported
   Supports 11 and 12 bit XDR

**MotionPro Y6**

Y6 – Analog Sensor Architecture – 12 bit ADC
    1920x1080 @1,000 fps
    Plus mode NOT supported
    Other resolutions at 1,000 fps
    1504x1128 (HG100K compatible)
    1600x1200

# MotionPro Y7

S1 – Digital Sensor Architecture – 10 bit ADC
   1920x1080 @5,000 fps
      Plus mode NOT supported
      Supports 11 and 12 bit XDR
S2 – Digital Sensor Architecture – 10 bit ADC
   1920x1080 @7,500 fps
      Plus mode NOT supported
      Supports 11 and 12 bit XDR
S3 – Digital Sensor Architecture – 10 bit ADC
   1920x1080 @9,000 fps
      Plus mode NOT supported
      Supports 11 and 12 bit EDR

# Y | SERIES™
## CAMERA SPECS
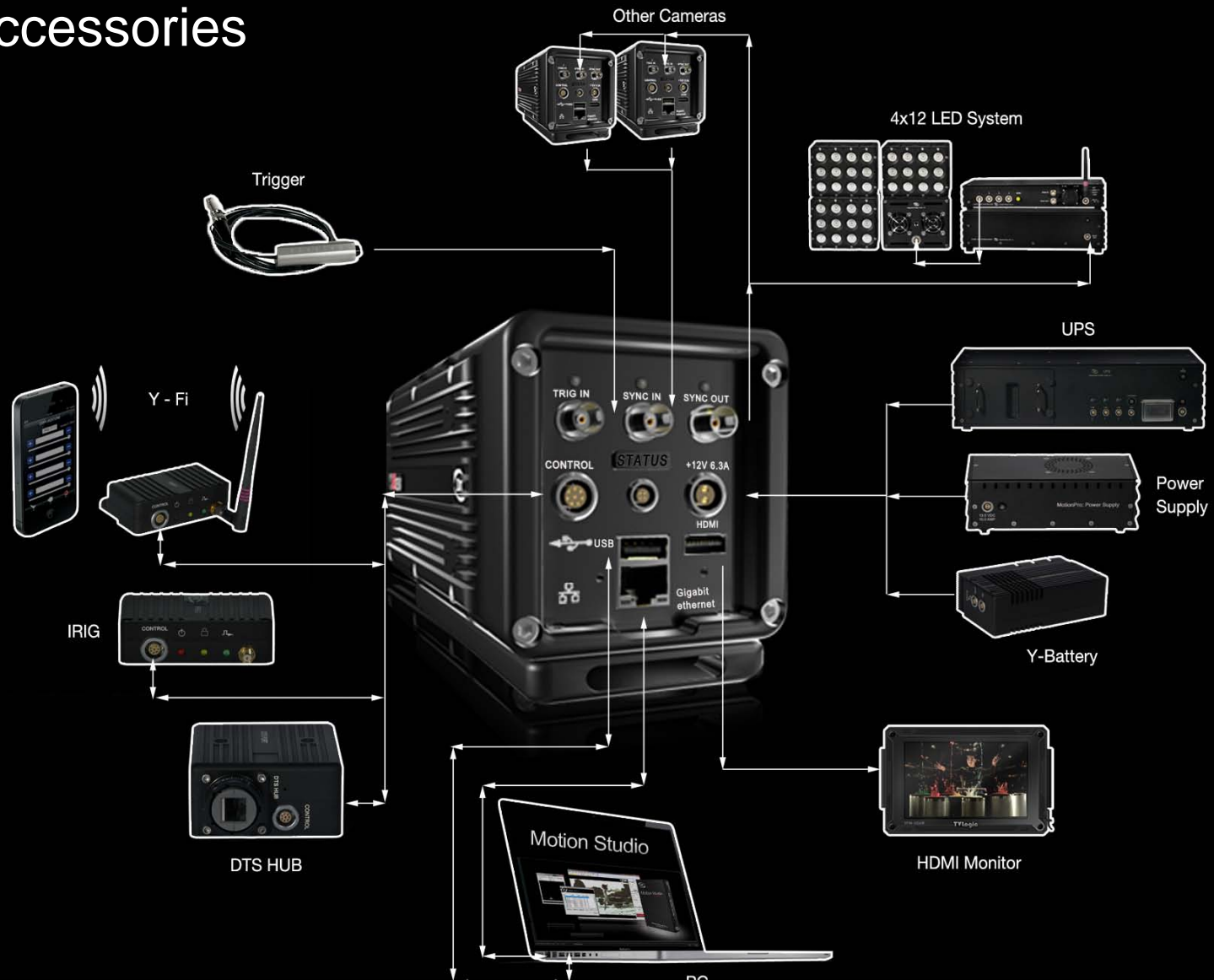
**INPUTS :**

| | |
|---|---|
| SYNC INPUT | Phase-lock TTL |
| IRIG | Optional |
| GPS TIME CODE | Optional |
| YIFI | Optional |

**OUTPUTS :**

| | |
|---|---|
| SYNC OUPUT | Frame sync / Strobe |
| HDMI | 1080p and 720p |
| COMP VIDEO | N / A |

**DIMENSIONS :**

| | |
|---|---|
| APPROX. SIZE | 90.5 x 90.5 x 220 mm or 3.5 x 3.5 x 8.6 inches |
| APPROX. WEIGHT | 3.8 kg or 8.5 lbs |
| SHOCK/VIBRATION RATING | 100G - Al axes Vibration 40G - All axes |

**FEATURES :**

| | |
|---|---|
| BATTERY | Operation and battery back-up up to 2 hours |
| MOUNT | C-Mount standard, F&PL Adapter optional |
| POWER REQ. | Minimum 12V, 6.5A |
| SENSOR FORMAT | 1 inch |

**COMMUNICATION :**

| | |
|---|---|
| CAMERA LINK | N / A |
| ETHERNET | 100/1000 Base T |
| USB 2.0 | Standard |

**SOFTWARE :**

| | |
|---|---|
| MOTION STUDIO | Windows 32/64 Mac to be released |
| PLUG-INS SDK | LabView or Matlab |
| FILE FORMATS | Proprietary RAW (MRF, MCF) |
| ON-FLY CONVERSION | TIFF, BMP, JPG, PNG, AVI, MPEG, QT H.264 |

TRIG IN  SYNC IN  SYNC OUT

CONTROL  STATUS  +12V 6.3A

HDMI

The application of high-speed imaging

# High-Speed Imaging Application