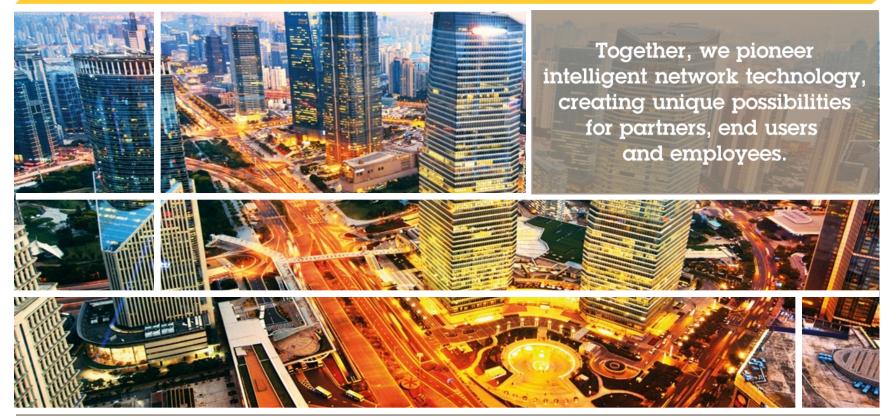# The invention of the network camera

and the VLSI technology behind

Stefan.Lundberg@axis.com

Sep 2016

Axis Mission

Together, we pioneer intelligent network technology, creating unique possibilities for partners, end users and employees.

Axis

> Founded in 1984 at IDEON in Lund

> IT company focused on Network Video Solutions

> 2493 employees (Q2, 2016)

> Sales 2015, 6600 MSEK

> Listed on NASDAQ OMX under acquisition by Canon

> Head office in Lund, close to LTH

> Own presence in more than 50 countries

> 80000 partners in 179 countries

AXIS®
COMMUNICATIONS

Original products

The market's broadest portfolio

Fixed cameras

Thermal cameras

Encoders/ decoders

Fixed dome cameras

Onboard cameras

Software & recording

PTZ cameras

Accessories

Physical access control

AXIS
COMMUNICATIONS

AXIS Q3709-PVE Network Camera

**Multi-sensor, multi-megapixel - 180° overview.
One camera.**

> 180° panoramic **overview**

> Smooth video of movements at up to **30 fps in 3 x 4K**

> Efficient one-camera **installation**

AXIS V59 PTZ Network Camera Series

For high-quality streaming and webcasting

> Easy to integrate with other systems and share information

> Perfect for auditoriums, classrooms, as well as
  peer-to-peer communication in video conferencing

> Up to 1080p HDTV resolution with smooth pan/tilt/zoom and high quality audio

AXIS ®
COMMUNICATIONS

Small business – AXIS Camera Companion

Video surveillance made simple

> Optimized solution for 1-4 camera systems, with support for up to 16 cameras

> Recording on SD cards, removes the need for central recording

> Mobile app for freedom of use

– Axis Secure Remote Access for a secure and easy-to-install way to access the system remotely

– Axis Mobile Streaming for efficient bandwidth usage

> VMS and mobile viewing app **free** for download
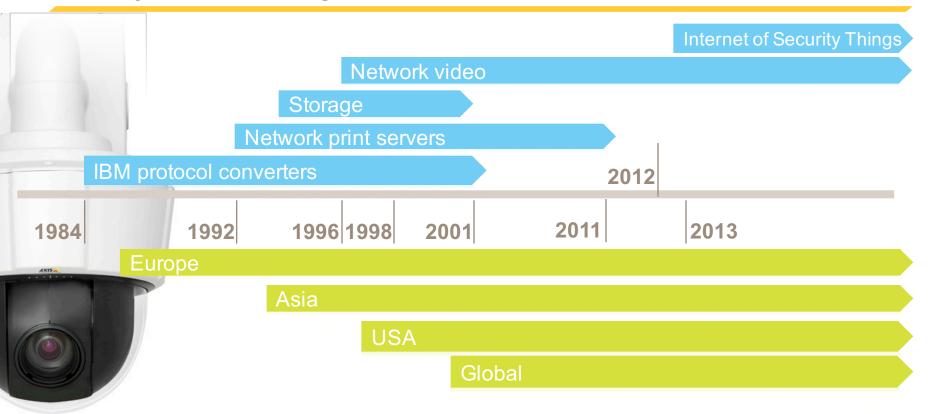
AXIS A8004-VE Network Door Controller

Reliable audio visual identification and entry control

> A perfect complement to any surveillance installation to effectively control entry:

- Identify and talk to visitors

- Record what happens at the entrances

> Suitable for small- and mid-size installations as well as advanced enterprise systems

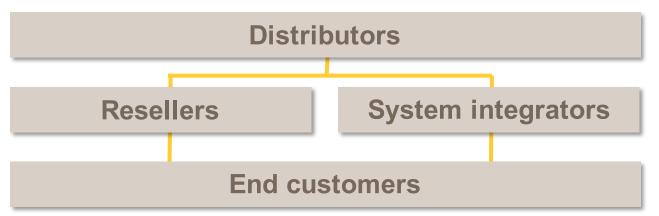# 30+ years of intelligent networks

Internet of Security Things

Network video

Storage

Network print servers

IBM protocol converters

2012

1984 1992 1996 1998 2001 2011 2013

Europe

Asia
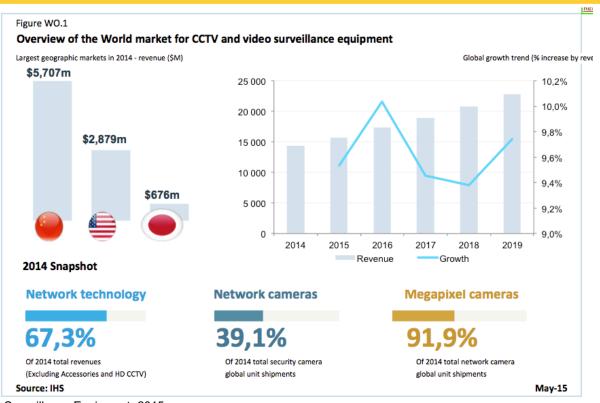
USA

Global

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Our business model

Why is the sales model so important ?

> Everyone can trust Axis

> Integrators never compete with their main partner
  – But they do compete with each other
  – Axis never "steals from the channel"

> Distributors always make money
  – Axis often has no set-up to bypass

> Rebate system to ensure correct pricing
  – Deal pricing, partner pricing, etc.

> Make sure this model fits
  – Analytics, use partners
  – ACS – use for low end, not large systems

Global overview

Figure WO.1

Overview of the World market for CCTV and video surveillance equipment

Largest geographic markets in 2014 - revenue ($M)

Global growth trend (% increase by reve

$5,707m

$2,879m

$676m

2014 Snapshot

Network technology	Network cameras	Megapixel cameras
67,3%	**39,1%**	**91,9%**
Of 2014 total revenues (Excluding Accessories and HD CCTV)	Of 2014 total security camera global unit shipments	Of 2014 total network camera global unit shipments

Source: IHS

May-15

IHS CCTV and Video Surveillance Equipment, 2015

Regional development Q2, 2016

Americas
56%
of sales

> Total sales of SEK 984 M (860)
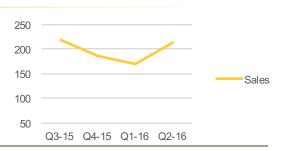> Growth of 14%
> Local growth of 18%

EMEA
32%
of sales

> Total sales of SEK 565 M (554)
> Growth of 2%
> Local growth of 4%

Asia
12%
of sales

> Total sales of SEK 213 M (202)
> Growth of 6%
> Local growth of 13%

Network cameras, security cameras and video encoders (Asia)

Market leadership

Rank	Network cameras	Security cameras	Video encoders
1	Hikvision	Hikvision	Hikvision
2	Dahua	Dahua	Uniview
3	Panasonic Systems Communications	Panasonic Systems Communications	Kedacom
4	Uniview	Samsung Techwin	**Axis Communications** Tiandy
5	Samsung techwin	Uniview	Mitsubishi Electric
6	**Axis Communications**	**Axis Communications**	Dahua

IHS CCTV and Video Surveillance Equipment, 2015

Network cameras, security cameras and video encoders (Americas)

Market leadership

| Rank	Network cameras	Security cameras	Video encoders
1	**Axis Communications**	**Axis Communications**	**Axis Communications**
2	Panasonic System Communications	Pelco (by Schneider Electric)	NICE Systems
3	Sony Corporation	Panasonic System Communications	Verint Systems
4	Bosch Security Systems	Bosch Security Systems	Bosch Security Systems
5	Avigilon	Samsung Techwin	Avigilon

IHS CCTV and Video Surveillance Equipment, 2015

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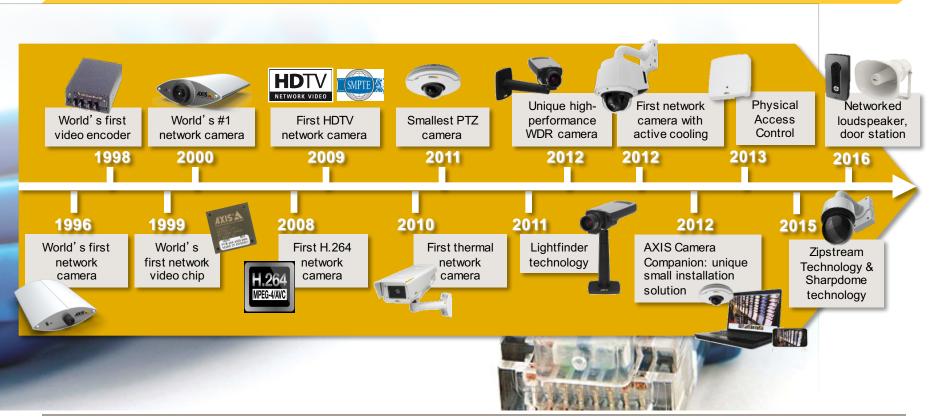
Worldwide presence – close to the customers

Headquarters
Regional headquarters
Sales offices
Configuration & Logistics Centers

HQ Sweden
Nordics
Russia
Czech Republic, Germany, Poland, Switzerland
UK/Ireland
Netherlands
Belgium/Luxemburg
France
Canada
USA
Spain
Italy
Turkey
China
S. Korea
Japan
Qatar
UAE
India
Thailand
Taiwan
Hong Kong
Vietnam
Mexico
Colombia
Malaysia
Singapore
Kenya
Indonesia
Brazil
Chile
Australia
Argentina
South Africa

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Taking long-term responsibility by thinking big

Sustainability highlights

> Continued to enhance and reduce product packaging

> Optimized logistics

> Energy-efficient, more environmentally friendly products

> Anti-Corruption policy

Since 1996, Axis has been driving Network Video evolution

Upper timeline (images and labels):

- World's first video encoder — **1998**
- World's #1 network camera — **2000**
- First HDTV network camera — **2009**
- Smallest PTZ camera — **2011**
- Unique high-performance WDR camera — **2012**
- First network camera with active cooling — **2012**
- Physical Access Control — **2013**
- Networked loudspeaker, door station — **2016**

Lower timeline (images and labels):

- World's first network camera — **1996**
- World's first network video chip — **1999**
- First H.264 network camera — **2008**
- First thermal network camera — **2010**
- Lightfinder technology — **2011**
- AXIS Camera Companion: unique small installation solution — **2012**
- Zipstream Technology & Sharpdome technology — **2015**

HDTV NETWORK VIDEO SMPTE

H.264 MPEG-4/AVC

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Axis – continuously driving innovation in network video

1999
ARTPEC-1
Worlds first
Network camera
ASIC

2004
ARTPEC-2
Dualstream
MPEG-4/MJPEG

2008
ARTPEC-3
HDTV/H.264

2011
ARTPEC-4
Lightfinder
technology

2014
ARTPEC-5
Forensic capture
Zipstream

1996

Off the shelf
Components
(VITEC)

2003

ARTPEC-A

2009

ARTPEC-B

2012

Amabrella
(ARTPEC-C)

20 years of network cameras 1996-2016

Axis invented the world's first network camera

Technology leader with many industry firsts

Continuing to drive innovation for a smarter, safer world

1996 - AXIS NetEye 200

> The world's first network camera

> Launched at Interop Atlanta, September 18th, 1996

> Performance
  - 1 image/second in 352*288 pixe
  - 3 frames/minute in 0.4 Mpixel

More than 10,000 sold!

One of our first camera customers…

> Steve Wozniak, co-founder of Apple

> Was in a car accident during a tech support call

> No injuries and problem was solved

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World's first video encoder in 1998

> AXIS 240 – the world's first video encoder

> Andy Rubin, CTO & founder of Android at Google, in 1997 when he was testing AXIS 240 prototypes

Lightfinder technology, Wall Street Journal Technology Innovation Award

AXIS 221

AXIS Q1602

Perimeter surveillance with no street illumination during night time and approximately 0.1 lux.

In-house R&D – where the coming successes are made

15%
of total sales
2015 R&D

> Substantial R&D investment
>> – 15% of revenue

> Strong network camera patent portfolio

> Canon is very strong on patents

> 3 corner stones
>> – Innovation
>> – Openness
>> – Quality

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More than 800 engineers work in Lund

Mechanics   Software   Electronics   ASIC´s
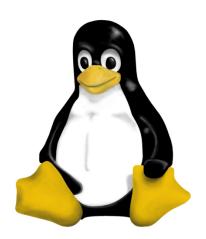
"ASIC" stands for "Application Specific Integrated Circuit".

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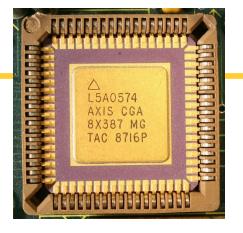
ASIC development at AXIS
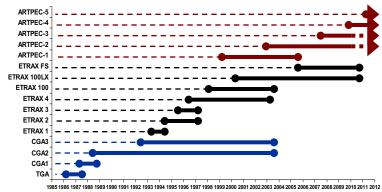
AXIS ASIC history

> AXIS has developed SoC ASICs since late 80ths

> 80s ASICs

  – where used for network protocol converting

> 90s ASICs

  – In-house developed RISC CPU (ARM-style) where added and the proprietary Canon printer protocol Page 21 where added forming the ETRAX chip family.

  – A separate image processing ASIC ARTPEC was developed for the camera business.

> During 2000 to 2010 the ASICs became large unified SoC where more and more external IPs where.

> Today AXIS is focusing on development of differentiating functions such as image processing, analytics, scaling, overlay and the overall specification of the SoC.

AXIS ASIC history

> From start all functionality was developed in-house by a few designers

> There where no market for general building blocks (IP blocks) such as CPUs, Memory Ctrl, Interfaces etc but this has changed over the years,

> Today we need about 60 man years and still half of the functionality is developed by external parties.

> Number of transistors has multiplied by 2500 since then.

>> Moores Law: Number of transistors doubles every 18th months

>> AXIS has historically been one or two step behind latest technology

>> But are now closing in to be able to fulfill requirements

Typical Axis SoC content

> Embedded CPU running Linux

> Image processing pipeline

> Image scaler with dewarping

> Image compression subsystem

> Crypto accelerator

> Ethernet controller

> I/O controller

> Interfaces etc

An ASIC often combines the different functions needed for a complete system on one single chip. This is called "System on a Chip" or "SoC".

ARTPEC 1 - 5

> Five generations of dedicated network camera ASIC's

ARTPEC-1
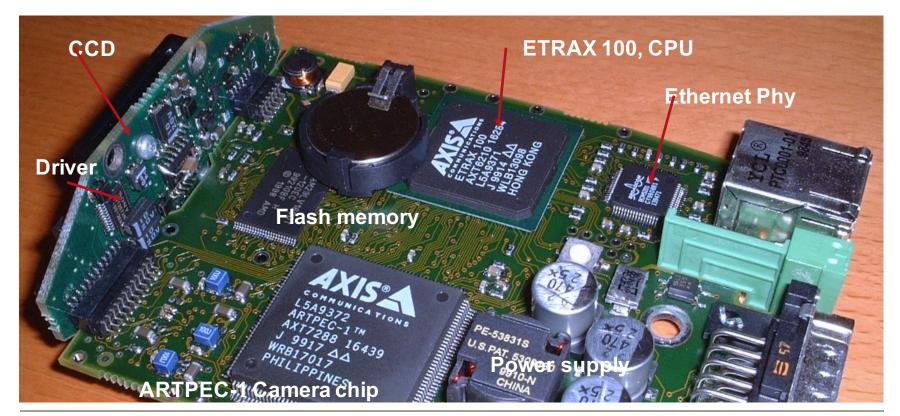
> Worlds first network camera ASIC

> uCLinux on ETRAX CPU

> CCD/CMOS IPP, MJPEG
  compression

> 160 pin PQFP

ARTPEC-1 product

ARTPEC-2

> Worlds first dualstream MPEG-4/MJPEG network camera ASIC

> CCD/CMOS IPP

> 208 pin PQFP

ARTPEC-3

> Worlds first HDTV/H.264 network camera SoC

> HDTV 1080p30

> LFBGA400 17x17mm

ARTPEC-4

> Lowlight/WDR network camera SoC

> HDTV 1080p30

> MIPS CPU

> 400 ball TFBGA
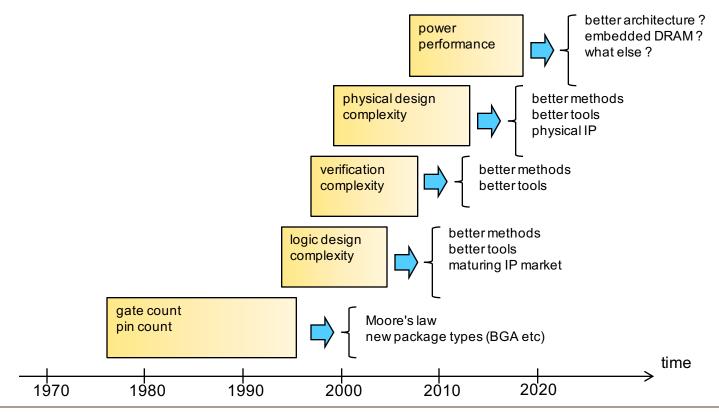
ARTPEC-5

> Faster general purpose CPU

    – Dual core

        – Independent execution units

        – Dual hw threads per core

        – Parallel computing architecture

> Higher memory throughput

> Faster Video Analytics

> New camera features

    – Improved image quality

    – WDR

> Zipstream

AXIS COMMUNICATIONS
ARTPEC-5
39972
ECRS535593A-1N
N6H794.051
1232
Taiwan
(e1)

AXIS COMMUNICATIONS

Electronic design obstacles, history and future

Why ASIC development?

> Benefits:
>
>   – Product performance
>
>   – Product size and power (Size 70 to 100 times less than FPGA in same technology)
>
>   – Unique features (hard to copy by competitors)
>
>   – Secured access to technology (still there are not many external "Platforms" for video market)
>
>   – Unit cost reduction
>
> Challenges:
>
>   – Time to market
>
>   – Development costs
>
>   – Complexity
>
>   – Project risk (Size/Time/Spec)
>
>   – Technology risk

Description of AXIS ASIC development

> We use partners/ASIC vendors for the back-end design and manufacturing of our ARTPEC chips. We have used both partners that has their own fab and fabless companies.

> Design and verification (VCS) using SystemVerilog, main reason to SystemVerilog is verification but we are also using advanced structures that makes design work more effective.

> We have done VMM based random verification since 2005 and are now moving to UVM. Modelling is TLM2.0 and C based

> We do Verilog netlist handoff with timing constraints to our partner. We do both synthesis (DC) and floorplan (DC Graphical) to ensure quality and decrease number of iterations

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Chip development

> The written code will be translated by running a synthesis tool to a specific cell of the selected library of a specific process (e.g 28nm Low power library)

> When all functionality is described in System Verilog and synthesized we call it a Netlist.

> We can simulate functionality, performance (speed), power (dynamic and static) and do an approximate placement and routing (connection).

```
module ff (q, d, clk)
output q; input d, clk;
reg q;
always @(posedge clk) q = d;
endmodule
```

EDA tools

> Tool supplier
>> – We have been using Synopsys tools for a long time.
>> – The license model is Time Based License with pool of tools
>> – Mix changed based on project flow

> Design & Implementation - SystemVerilog

> Synthesis – Design Compiler

> Verification - VCS

> Floor planning – DC Graphical

> STA – Primetime

> DFT – we do not do DFT but we prepare our design for DFT

> Using other point tools for specific design purposes
>> – Power - Power Compiler
>> – High-level modulation - QUEMU, TLM2.0

> Continually evaluation tools and vendors

How to handle risk and development cost?

> Luckily specification of mobile devices is more similar to Surveillance Camera than old Mobile phone i.e. always "On", which gives us benefit from using same IP

> Increased design complexity must be managed
  – Improved design tools and design methods
  – Modularization and reuse
  – Make use of External competence for Top Level integration and General System implementation
  – Make use of external chips for parts of our product portfolio that has specific needs

> NRE (external design and manufacturing cost) cost increase dramatically with newer technologies
  – Carefully specify new designs to reach enough volumes

> Make use of external chips in some products to ensure second source

Two teams

> **Chip Platforms**

  – Manager Lars Branzen

  – Product Manager

  – Project Manager

> Competence Groups

  – Backend group

  – System Architecture group

  – FPGA

> **Chip Platforms IP**

  – Manager

  – Architect

  – Project Manager

> Competence Groups

  – Front End Design Group

  – Verification Group

Responsibilities

> ASIC and FPGA methodology for System-On-Chip

> Models for early SW development (TLM/System-C)

> Suggest chip platform technology solutions

> Chip platform roadmap

> Chip product ownership
  - User documentation
  - HW support during lifetime

> ASIC and IP purchasing

> FPGA development for early SW development, algorithm validation and product functionality extensions

Team support

> Core Technologies – Imaging System - CTIS

- – Optics, sensors, image processing algorithm

> Core Product Platforms - CPP

- – Chip drivers, firmware development, chip bring-up

> Core Technologies – Media and Graphics - CTMG

- – Image Coding, Audio functions and algorithms, GPU

> Core Technologies – Analytics and Systems – CTAS

- – Analytics firmware and algorithms

> Consultants

- – Additional help with verification and in some cases design

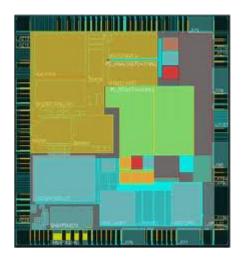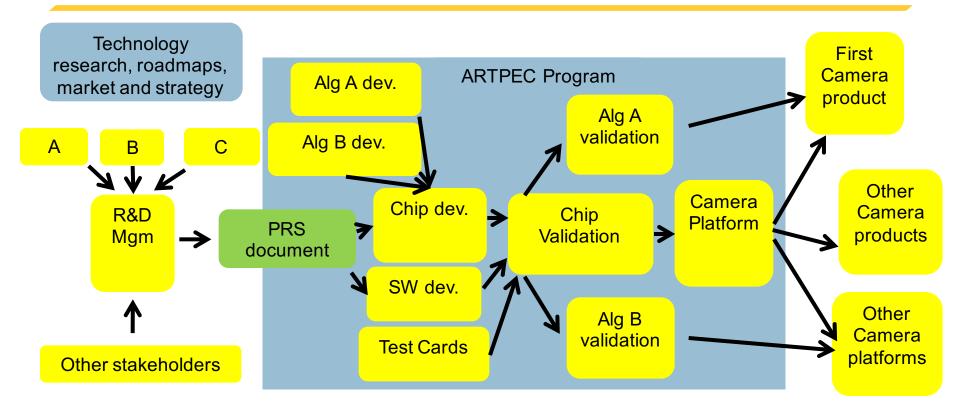**Axis Confidential**

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Chip Project

Chip development

> Axis develop critical functionality

> ASIC Vendor integrate CPU subsystem

> The netlist is then assembled by the ASIC Vendor who will add functionality for test and manufacturing followed by exact placement and routing.

> After iterations between Axis and Vendor (changing floorplan, RTL, specification etc.) the final version of the circuit will be written out in GDSII format which will be used for producing production Masks.

> Prototype production

> Engineering Samples sent to to Axis

Chip development as a Program

Chip IP project

A parallel project develop new specific functions (IP)

> Driven by CP-IP team
  – ~15 ASIC design engineers + 5-10 consultants

> Assisted by
  – Core Technologies Imaging Systems (CTIS)
    – Algorithms and technologies
  – Core Technologies Analytics&System (CTAS)
    – Algorithms and technologies
  – Core Product Platforms team (CPP)
    – HW/SW interface reviews
    – Linux driver development
    – Prototype/sample validation
  – Core Technologies – Media and Graphics (CTMG)
    – Image Coding, Audio functions and algorithms, GPU, Scaling and Overlay requirements

Chip project

Vendor selection and integration

> Driven by our Chip Platforms team
  – ~7 ASIC design engineers

> Assisted by:
  – Tech-Ref and PCB-CAD
    – Electronics
      – Package (ball-out)
      – PCB layout (incl. X-talk and SI-analysis)
    – Mechanics
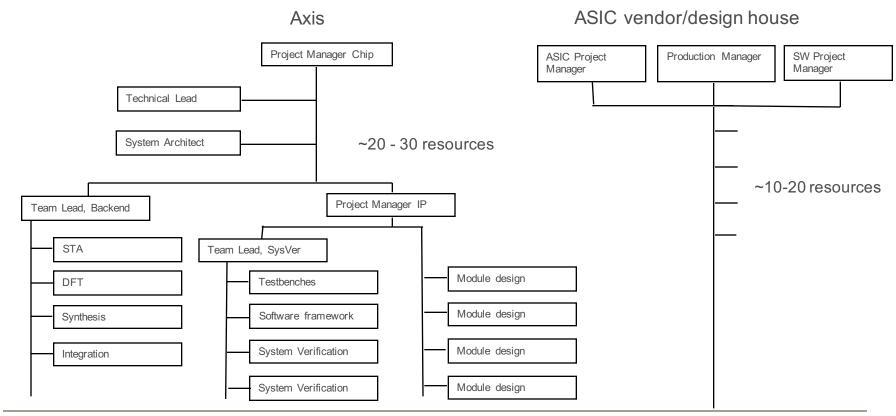   – Thermal design and analysis

Chip project

> Modular design flow

    – Design implemented in the RTL (Register Transfer Level) language System Verilog

        – Parallel processes

        – Synchronous design style

    – Fully verified sub-designs, comprehensive random testing (UVM/VMM)

    – Synthesis, STA and DFT clean sub-designs

    – Design guidelines and checklists

    – Documentation and reviews

    – Predictable integration in ASIC project

Chip Project - Typical ASIC project organization

Axis

Project Manager Chip

Technical Lead

System Architect

~20 - 30 resources

Team Lead, Backend

STA

DFT

Synthesis

Integration

Project Manager IP

Team Lead, SysVer

Testbenches

Software framework

System Verification

System Verification

Module design

Module design

Module design

Module design

ASIC vendor/design house

ASIC Project Manager

Production Manager

SW Project Manager

~10-20 resources

Chip project - Cooperation with ASIC vendor/design house

> Generally 3 main phases in project
  - 0.5 – initial netlist
  - 0.9 – trial netlist
  - 1.0 – final netlist

> Traditional ASIC design flow for ARTPEC
  - Verilog netlist and SDC (Static timing Design Constraints) handover

> Joint work on
  - Package / pinout
  - Power simulations
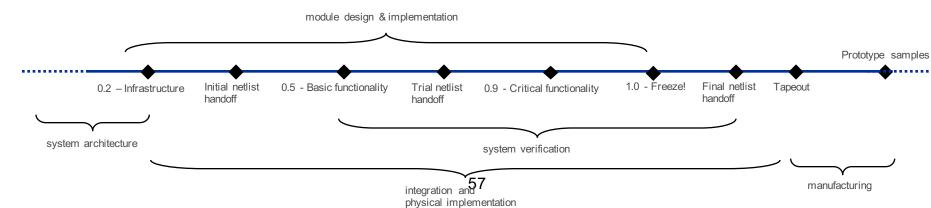 - IP integration
  - DFT
  - Floorplanning
  - Timing closure

18-month ASIC design cycle

Project A ending phase

Tapeout Prototype samples Prototype approval Qualification Handover / Closure

Project B main phase

module design & implementation

Prototype samples

0.2 – Infrastructure Initial netlist handoff 0.5 - Basic functionality Trial netlist handoff 0.9 - Critical functionality 1.0 - Freeze! Final netlist handoff Tapeout

system architecture

system verification

57

integration and physical implementation

manufacturing

Project C starting phase

Start Requirements ASIC design house & IP provider

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Security electronics

Example of security electronics

> Alarm systems
  – Property protection
  – Loss prevention

> Fire
  – Detection

> Gates
  – Automatic gates
  – Toll systems

> Communications equipment
  – Sound
  – Radio
  – Datacom

> Law enforcement

> Lighting
  – Visible
  – IR

> Camera systems
  – CCTV
  – IP Cameras

> Access control
  – ID's, badges and readers
  – Door ctrl

> Vehicles
  – Equipment
  – Protection

> Locks
  – Doors
  – Safe

> IT security
  – Computer security
  – Network security

> Home automation
  – IoT

> Personal emergency

> Public safety

> Special equipment
  – Gas detectors
  – Radar

> Services

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Trade shows

> IFSEC London
  – http://www.ifsec.events/international/

> ISCWest LasVegas
  – http://www.iscwest.com

> Security Essen Germany
  – http://www.security-essen.de/

> Conference/Seminars
  – Education
  – Certifications

> Exhibit
  – Meet the vendors
  – See the equipment

Alarm systems

> Technology

> Equipment
>> – Detectors
>> – Panels
>> – Keypads
>> – Wireless modules
>> – GSM/3G callers
>> – Lights/Sirens
>> – Smoke generators
>> – etc

> Vendors
>> – 1000+ far east
>> – Large western
>>> – Like www.dsc.com

New requirements

> Wireless

> App controlled

> email, whatsapp notifications

> Facebook/Google login

> alarm.com compatible

> ifttt.com/recipes (If this, then that)

Developing electronics

Development challenges

> Distance to production

> China

> Open source

> Free information

> Crowd founding (Kickstarter etc)

> Time to market

> Quality

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Mandatory certifications

> UL
  - Certification for professional US market
  - The "Underwriters laboratories"
  - American safety and certification company

> CE-marking
  - Mandatory conformity marking for the European economic area
  - *Conformité Européenne*, meaning **European Conformity**

> FCC compliance statement
  - Mandatory marking for all electronics
  - Federal communications Commission

Other certifications

> Consumer technology
>> – HDMI, USB
>> – WiFi
>> – SD-Card

> 2G/3G/4G
>> – Carrier certification

> Vendor specific requirements
>> – Apple Lightning
>> – Apple App Review
>> – Windows hardware certification

> Non mandatory testing
>> – Technischer Überwachungsverein – TÜV
>> – Technical Research Institute of Sweden - SP

> Technology license
>> – Dolby
>> – H.265

> Known difficult areas:
>> – Onboard equipment for train and aircrafts
>> – Vehicles

Trends

Consumer Electronics Trends

> **Staying Connected**
  - Consumers want to stay connected, at home and while traveling.
  - Portable equipment with the latest features (More important than ever)
  - Pokémon Go – Who is the real winner?

> **Media and Data Convergence**
  - Media-centric TV and the data-centric computer will merge.
  - New gadgets has to handle both types of tasks and be synchronized

> **In-Home Entertainment**
  - 1080p will be replaced by 4K
  - Video/Movies/Music on demand
  - User interface centric equipment

> **Smart home**
  - Embedded devices for everything
  - Smart/Cost-efficient device integration

More trends

> **IT**
>
> – Cheaper and better tablets and computers
> – Moving to App-oriented business models
> – Corporate cloud solutions
> – Wider use of P2P/streaming media

> **Mobile communications**
>
> – Phone will be user-interface for everything
> – Mobile payments (ApplePay/SamsungPay/Swish)
> – IPv6
> – Wearable devices (Google Glass failure, Apple Watch…)
> – Real time automatic voice translation

> **Other**
>
> – 3D printing going mature
> – Autonomous flying robots (Drones)
> – Screen technology (Large, Unbreakable, Bendable)

Industry Trends in Consumer Electronics

> Difficult to earn money on software

- App-centric world

- Customer lock-in
  - Force customer to the cloud

> Business critical technology development

- Vertically oriented business trend
  - Apple, Microsoft…

- Outsourced development is now moved home

> IPR

- Patents

Ultra high definition

- Aggressive 4K rollout

- Old pixel technology (TFT, TN, IPS, etc)

- OLED is slowly arriving, yield issues

- Quantum dots are enhancing LCD technology

- Every major manufacturer has now 4K in production

- 50" and bigger

- 50% higher panel cost

- 4K World market estimates 15% 2016

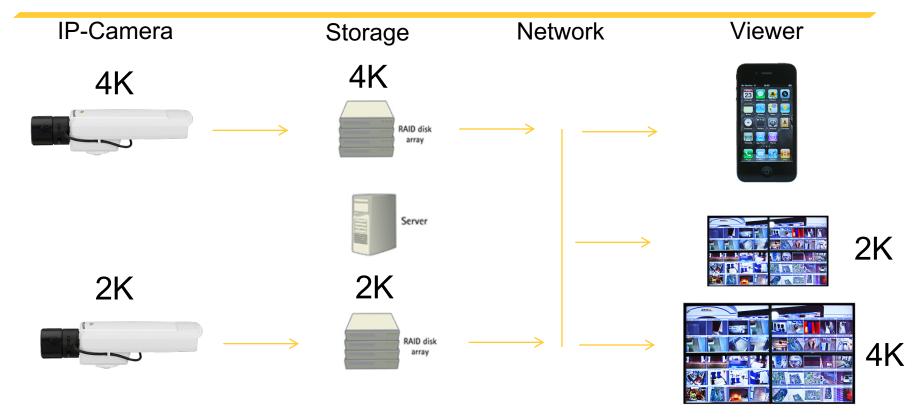- Apple is leading the hires conversion

Ultra high definition / 4K

- Easy in store demo:
  - Visible difference 0.5-2m from the screen
- Lack of content has never stopped set makers before
- Up scaling looks great
- Blu-ray benefit from 4K up scaling
- Ultra Blu-ray player launched at IFA 2015
- PC and consoles will soon be 4K
- Consumers want to be future proof
- Still images on 4K display is perfect
- 4K production is much more easy than 3D
- 4K display with proper content gives 3D feeling

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Axis view on 4K / Ultra-HD

IP-Camera   Storage   Network   Viewer

Innovative
product portfolio

Axis' Zipstream technology – More video, less storage

> Reduce storage and bandwidth by an average 50% or more

- Optimized for video surveillance

- Fully compatible with H.264

- New unique method
  - Acts on motion, details and noise

- Radically lowering bandwidth and storag
  - Keep the essence

50%

How much do I gain?

City surveillance:
Street level recording with small movements most of the time

Zipstream strength:	Dynamic GOP:	
High	**On**	**60%**

Outdoor VMD triggered recording:
Night time, average reduction for 12h surveillance.

Zipstream strength:	Dynamic GOP:	
High	**On**	**75%**

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How much do I gain?

Transportation:
Onboard a train, continuously recording during daytime.

Zipstream strength:	Dynamic GOP:	
High	**On**	**35%**

Transportation:
Airport at night, continuous recoding when preparing a plane for takeoff.

Zipstream strength:	Dynamic GOP:	
High	**On**	**80%**

AXIS COMMUNICATIONS

Huge saving in average file size (still images)

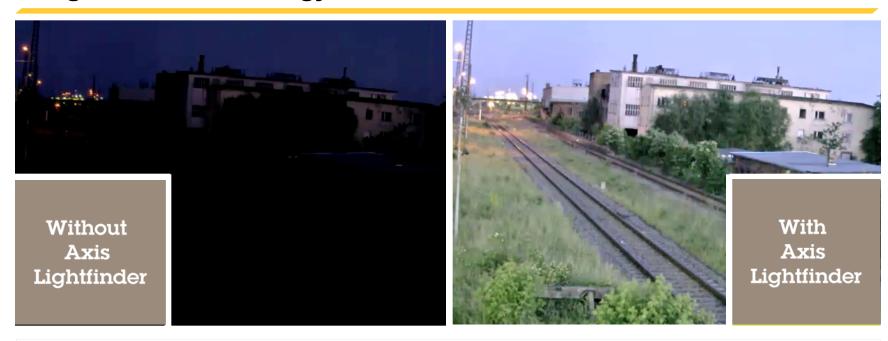> Zipstream disabled: 2881 kbit/s

> Zipstream enabled: 1433 kbit/s

Zipstream SIA award @ ISC-West Las Vegas

Best new product for Video Surveillance Advanced Imaging Technologies 2015
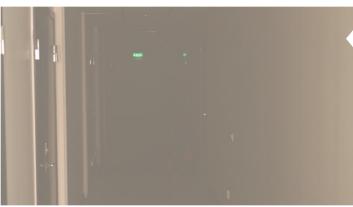
Lightfinder technology – an Axis innovation

Without Axis Lightfinder

With Axis Lightfinder

Extreme light sensitivity

Thermal network cameras – an Axis innovation

**24/7 detection
in tough conditions**

> Bright lights

> Deep shadows

> Rain, snow and fog

> Smoke

Thermal
camera OFF

Thermal
camera ON

www.axis.com