Software Architecture and Design Practices for Industrial IoT

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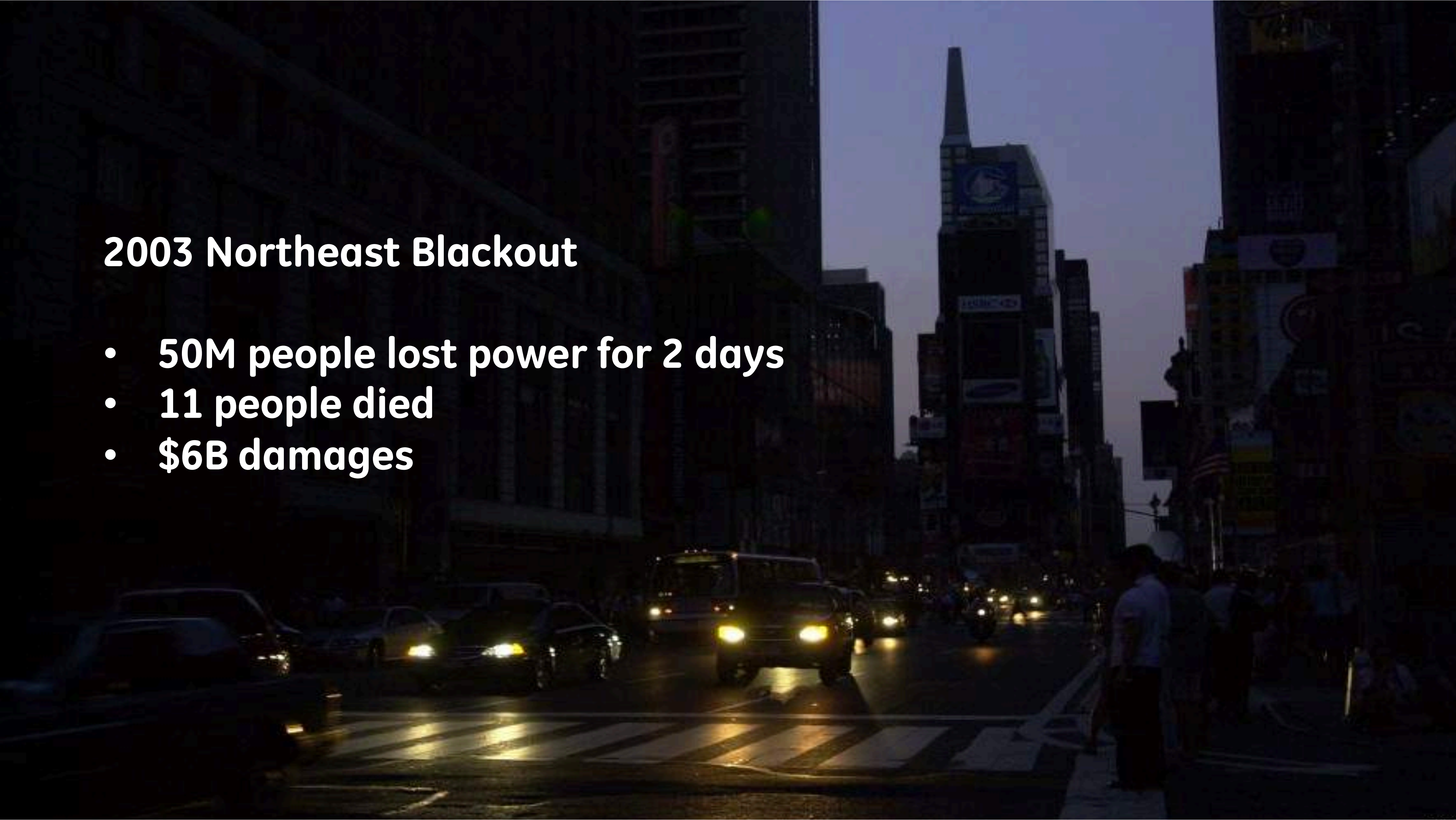
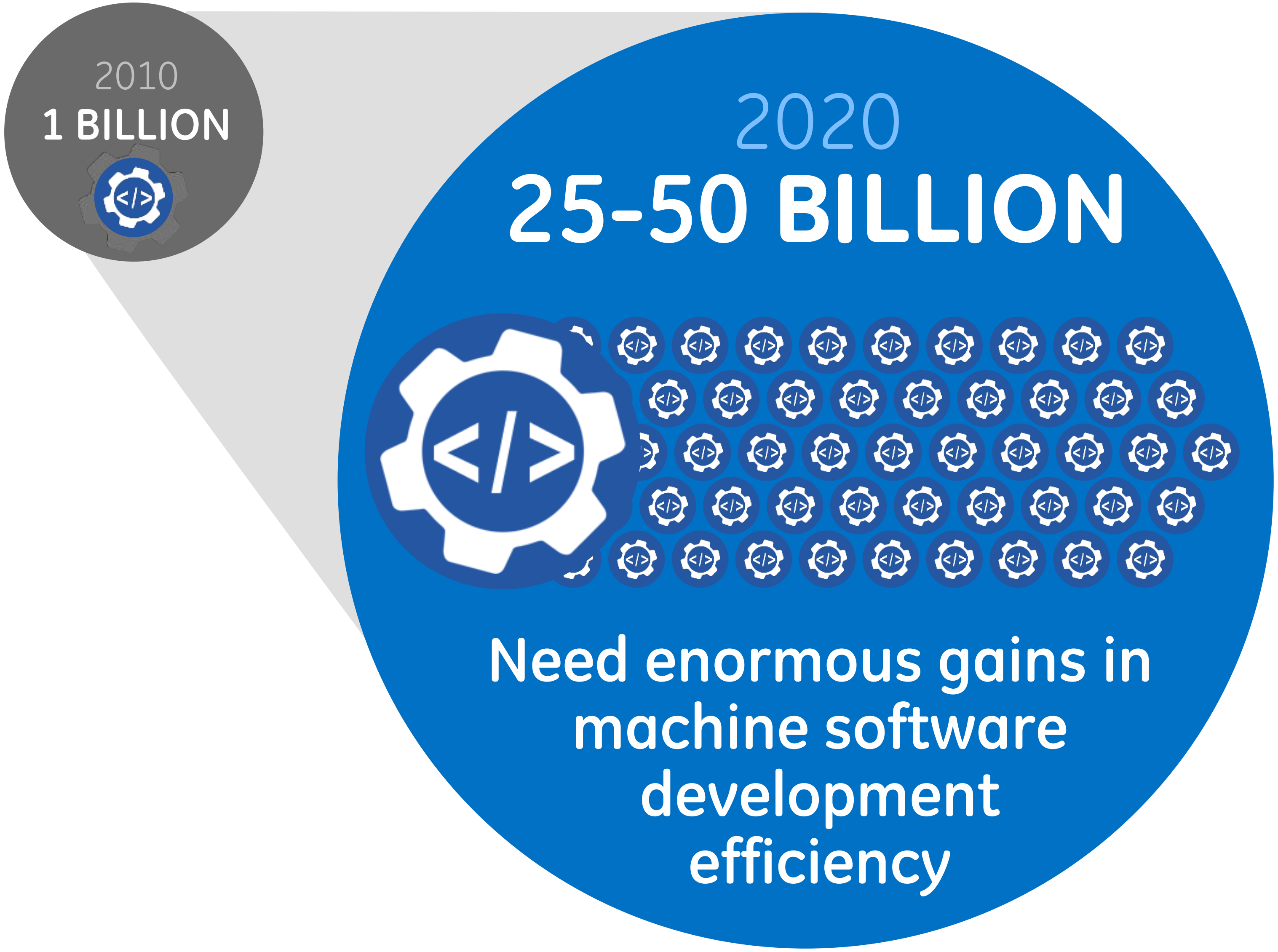


2003 Northeast Blackout

- 50M people lost power for 2 days
- 11 people died
- $6B damages

Connected Devices



2010

1 BILLION

2020

25-50 BILLION

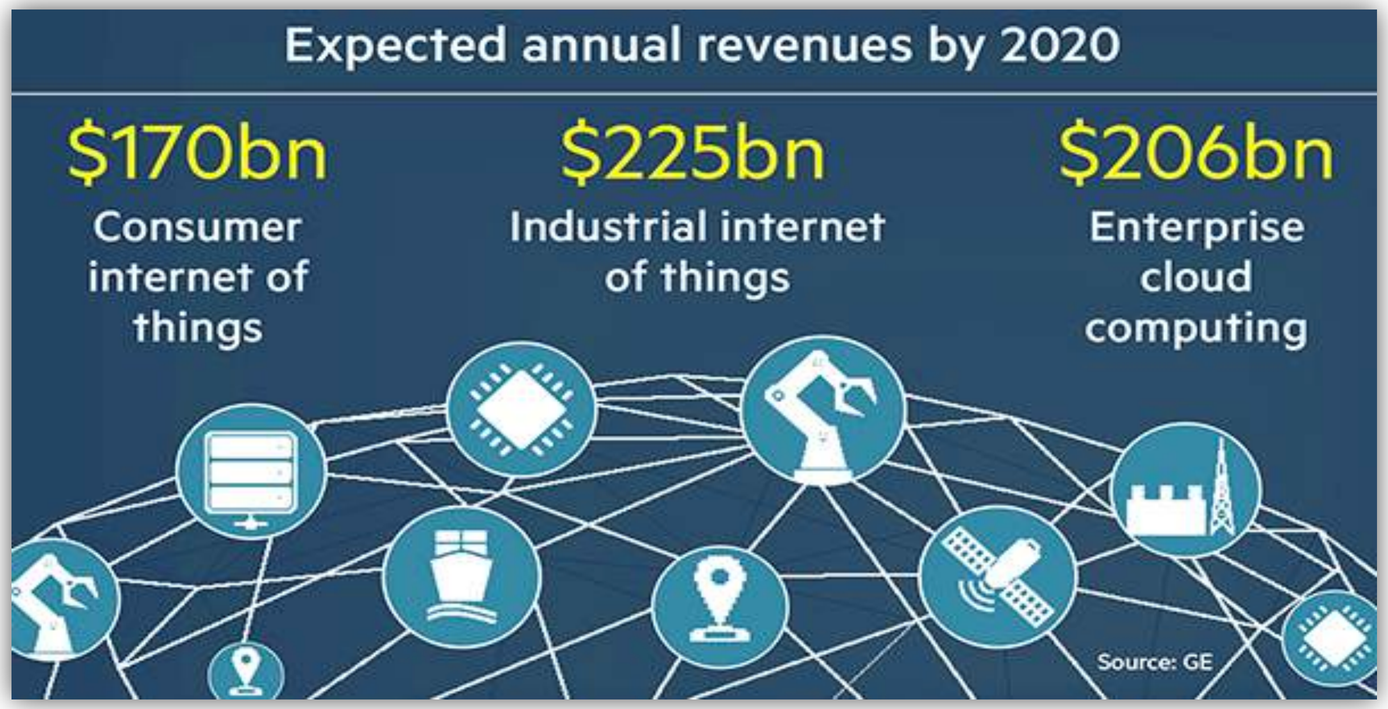
Need enormous gains in machine software development efficiency

Sources: Cisco, Harbor Research, http://www.futuristspeaker.com

What is Industrial IoT?

Wind Turbines

Gas Compressors



Expected annual revenues by 2020

$170bn Consumer internet of things

$225bn Industrial internet of things

$206bn Enterprise cloud computing

Source: GE

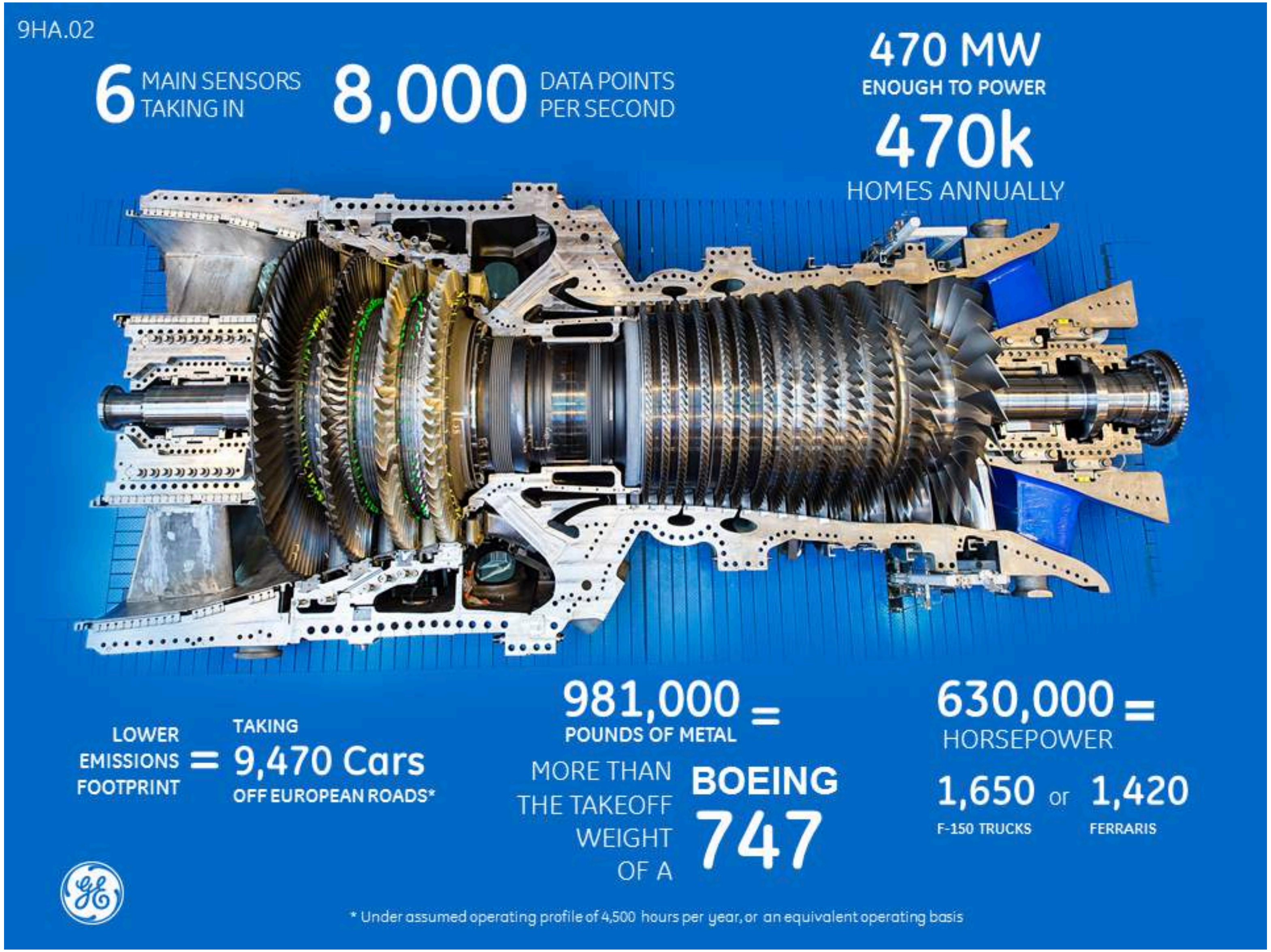
Gas Turbines

MRI Machines

Jet Engines

Locomotives

GE Gas Turbine Example



9HA.02

6 MAIN SENSORS TAKING IN 8,000 DATA POINTS PER SECOND

470 MW ENOUGH TO POWER 470k HOMES ANNUALLY

LOWER EMISSIONS FOOTPRINT = TAKING 9,470 Cars OFF EUROPEAN ROADS*

981,000 = POUNDS OF METAL MORE THAN THE TAKEOFF WEIGHT OF A BOEING 747

630,000 = HORSEPOWER 1,650 or 1,420 F-150 TRUCKS FERRARIS

* Under assumed operating profile of 4,500 hours per year, or an equivalent operating basis

Critical Problems to Solve by IIoT

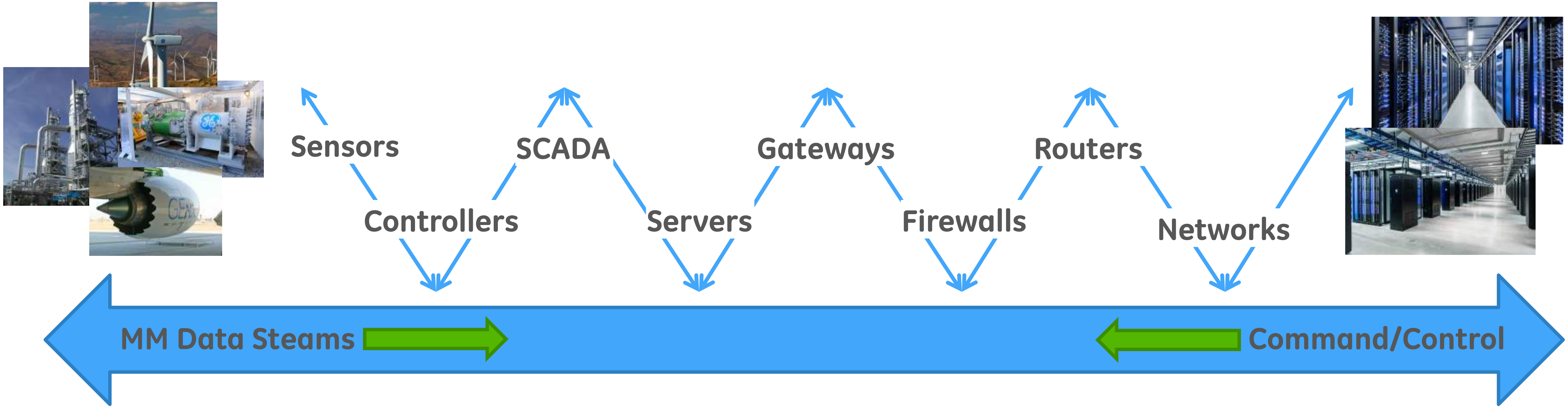
- Unplanned Downtime ↓
- Safety and Reliability ↑
- Maintenance Optimization ↑
- Production Efficiency ↑

Key capabilities: **asset connectivity, visibility, management, analytics, alerting**

Architecture and Design Goals

Industrial Assets
Infinite streams
of real-time data

Industrial Cloud
Infinite data storage
and compute



Sensors
Controllers
SCADA
Servers
Gateways
Firewalls
Routers
Networks

MM Data Steams
Command/Control

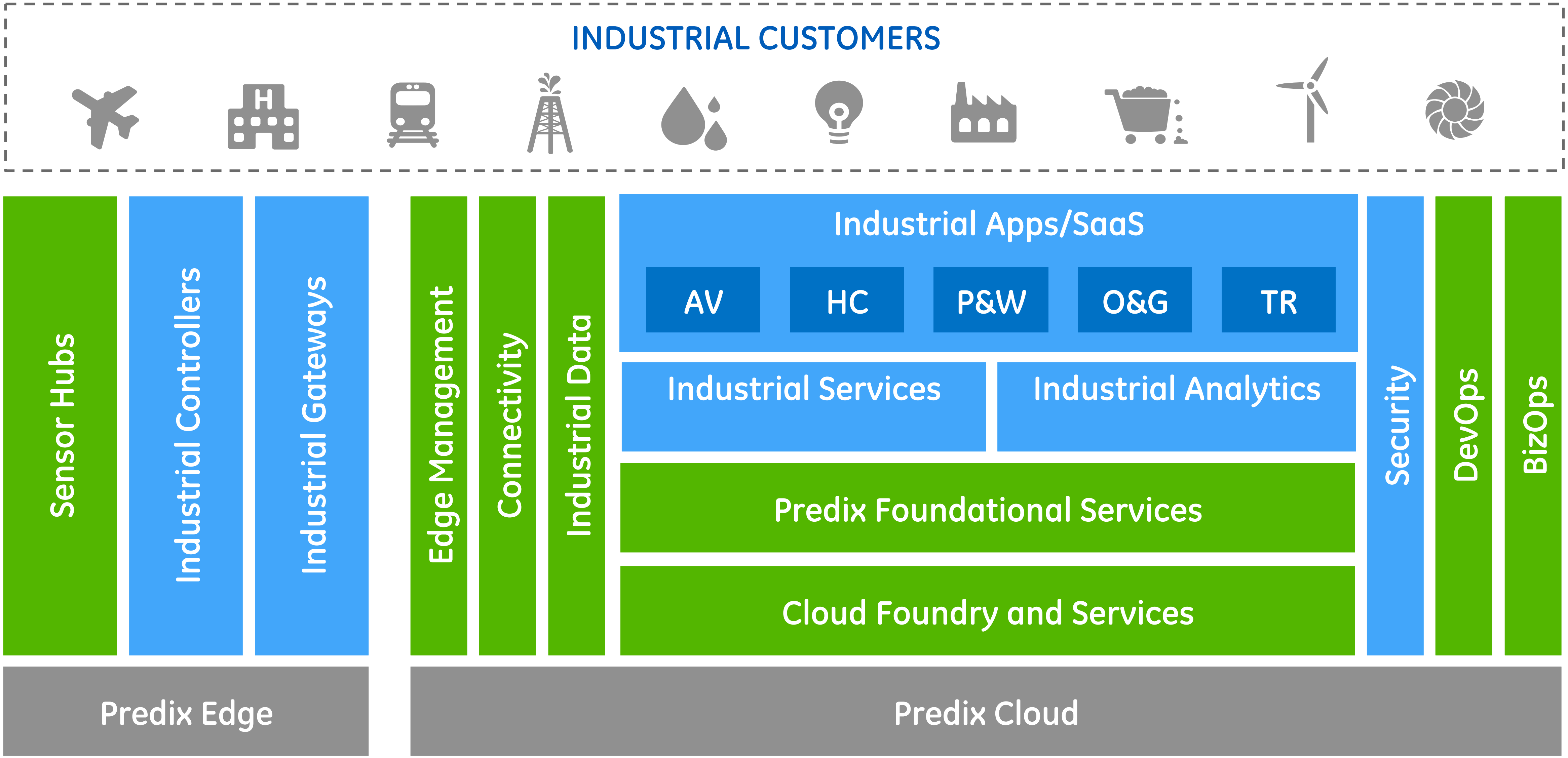
Responsive **Interoperable** **Scalable** **Easy to use**

Fail-safe **Remotely manageable** **Available** **Secure**

Architecture Approach

- On the Cloud:
  - Infrastructure – elastic, secure, available, VMs, containers
  - Microservices – separation of concerns, catalog, management
  - User Experience – domain specialized flows and patterns
  - User Interface – responsive, scalable, consistent
  - DevOps – development, testing, deployment automation
  - Security – infrastructure, apps/services, regulatory compliance
  - Legacy – support for existing legacy apps and services
- On the Edge:
  - Interoperability – industrial protocols
  - Security – holistic approach
  - Data collection – store/forward, transformation
  - Analytics – local processing

Reference Architecture



INDUSTRIAL CUSTOMERS

Sensor Hubs

Industrial Controllers

Industrial Gateways

Edge Management

Connectivity

Industrial Data

Industrial Apps/SaaS

AV

HC

P&W

O&G

TR

Industrial Services

Industrial Analytics

Predix Foundational Services

Cloud Foundry and Services

Security

DevOps

BizOps

Predix Edge

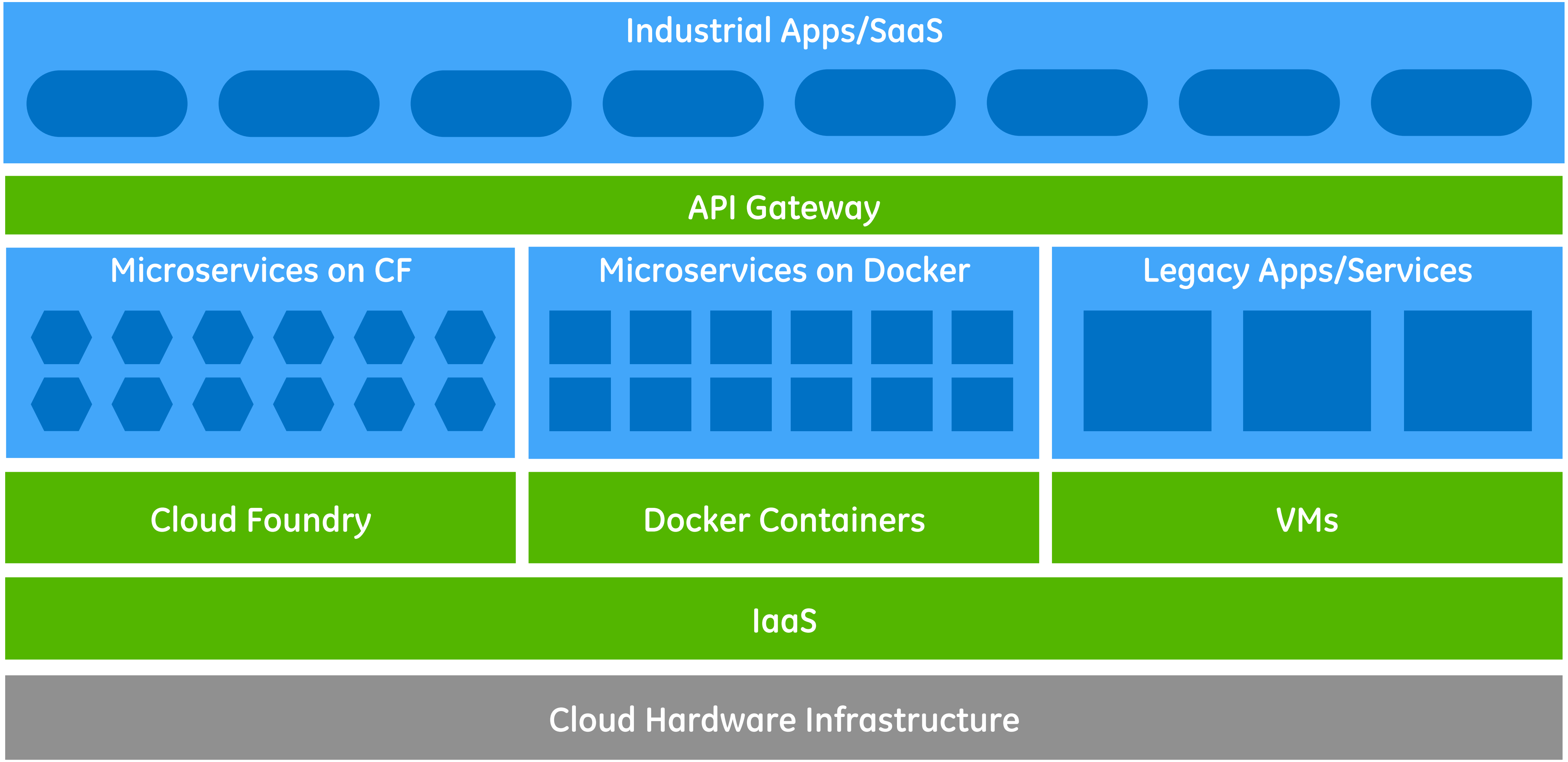
Predix Cloud

■ Hardware Infrastructure

🟩 General-purpose Services

🟦 Industrial Domain Services

Hybrid Infrastructure in the Cloud



Industrial Apps/SaaS

API Gateway

Microservices on CF

Microservices on Docker

Legacy Apps/Services

Cloud Foundry

Docker Containers

VMs

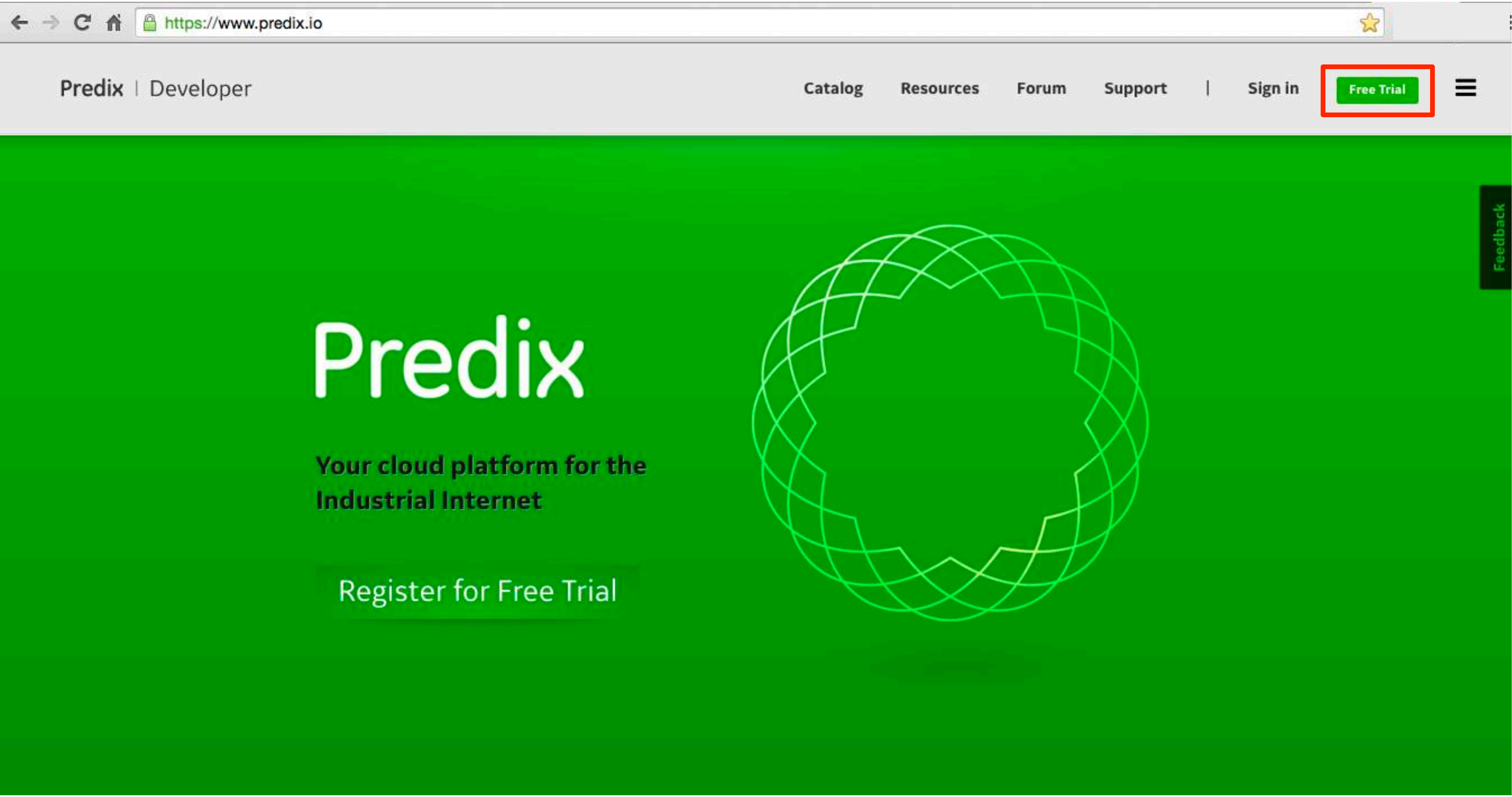
IaaS

Cloud Hardware Infrastructure

⬛ Hardware Infrastructure 🟩 Run-time Services and Discovery 🟦 Industrial Domain Services and Apps

Challenges and Learning

- Architecture:
  - SDK based legacy stack -> Cloud hosted microservices
  - Design patterns, APIs, standards, governance
- Development:
  - Scrum+Waterfall -> Pair programming, “pure” Scrum
  - OSGi+Java -> CF+Java, Go, Node.js, etc.
  - Best practices – 12factor app, configuration, performance
- DevOps:
  - CI/CD – testing, staging, deployment automation
  - Support – 24/7, online forum, phone, email, etc.



https://www.predix.io

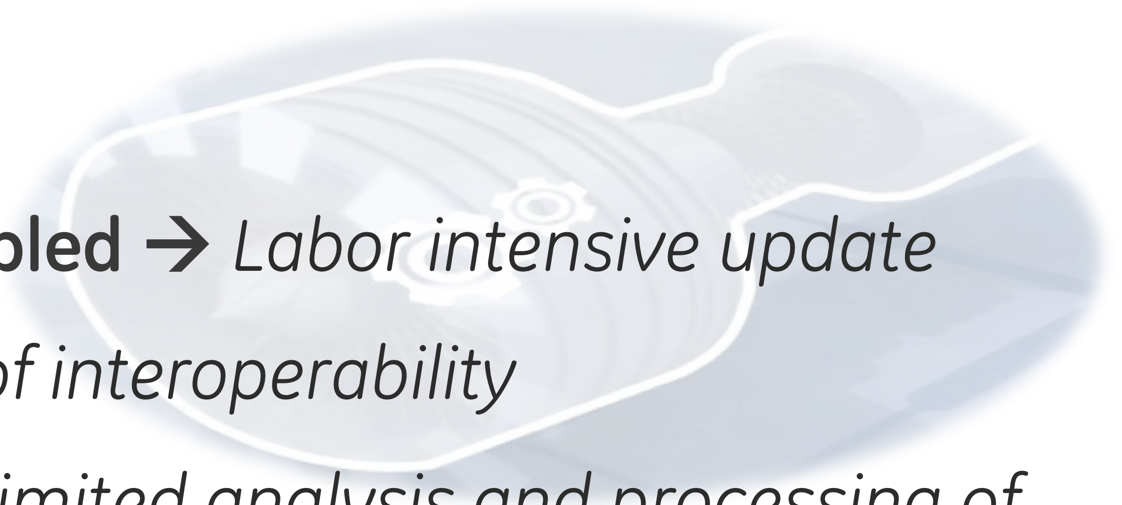
Predix

Your cloud platform for the Industrial Internet

Challenges: Building The Edge Platform

The existing landscape:

1. **Hardware + Software Tightly Coupled** → *Labor intensive update*
2. **Non Standard Interfaces** → *Lack of interoperability*
3. **Lack of Scalable Architecture** → *Limited analysis and processing of data*
4. **High number of Proprietary Software stacks** → *Limited maintainability*

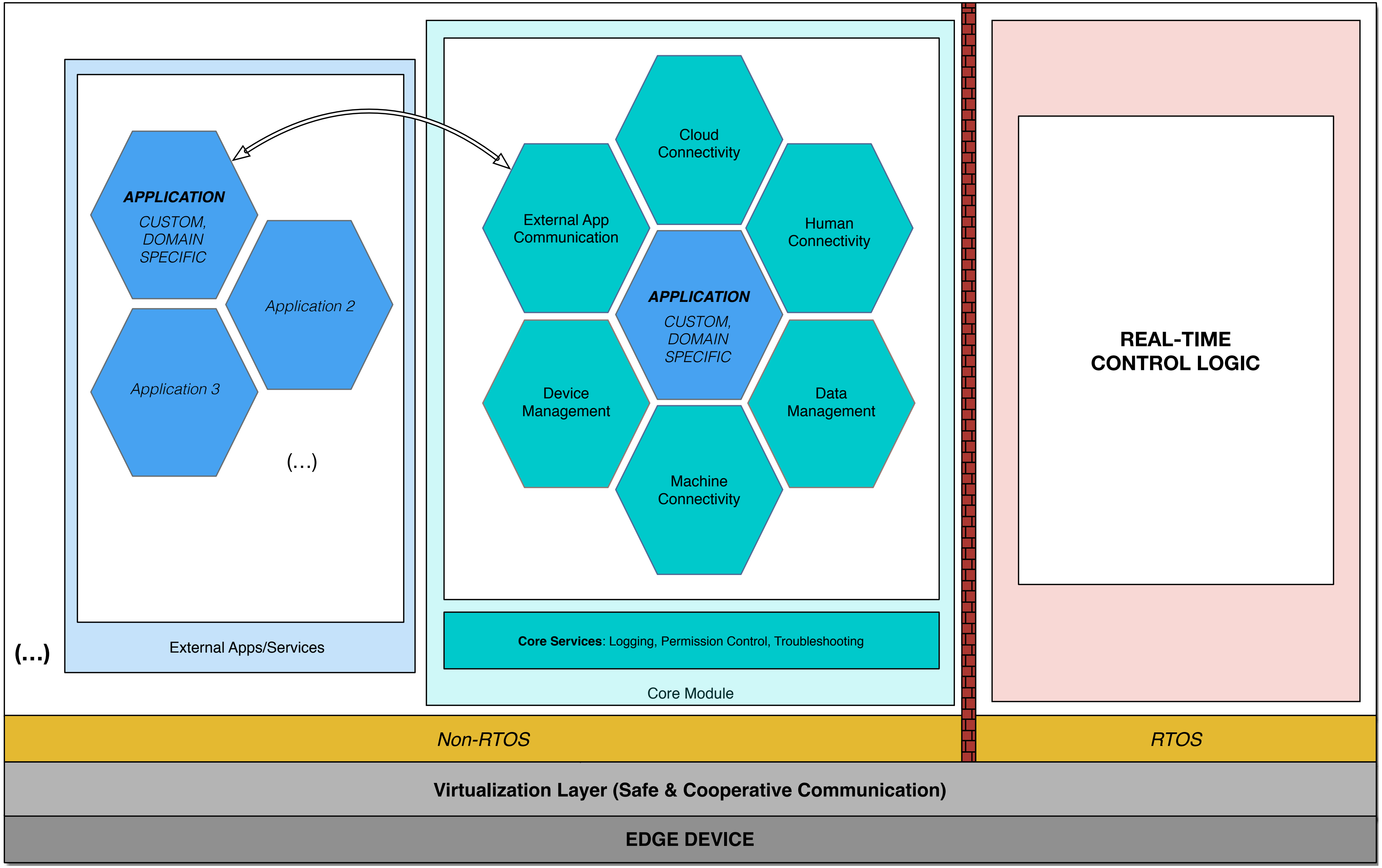


Lessons Learned...

- Platform *must* be:
  - As HW/OS-Agnostic as possible → *Java, migrating to next-gen containers*
  - Scalable → *Footprint down to ~10MB*
  - Pluggable → *Service oriented architecture*
  - Customizable → *SDK*

- Separation of concerns must be achieved between Real-Time (critical) components and non-Real-Time → *Real Time Java ultimately dismissed*

Functional Reference Architecture*



** = Example of a possible deployment*

Challenges: Building The Security Infrastructure

- Different security paradigms from edge to cloud → Isolated vs. Shared services
- Control on full stack (HW+SW) is not always an option
- Aging, unsecure protocols still used in the field

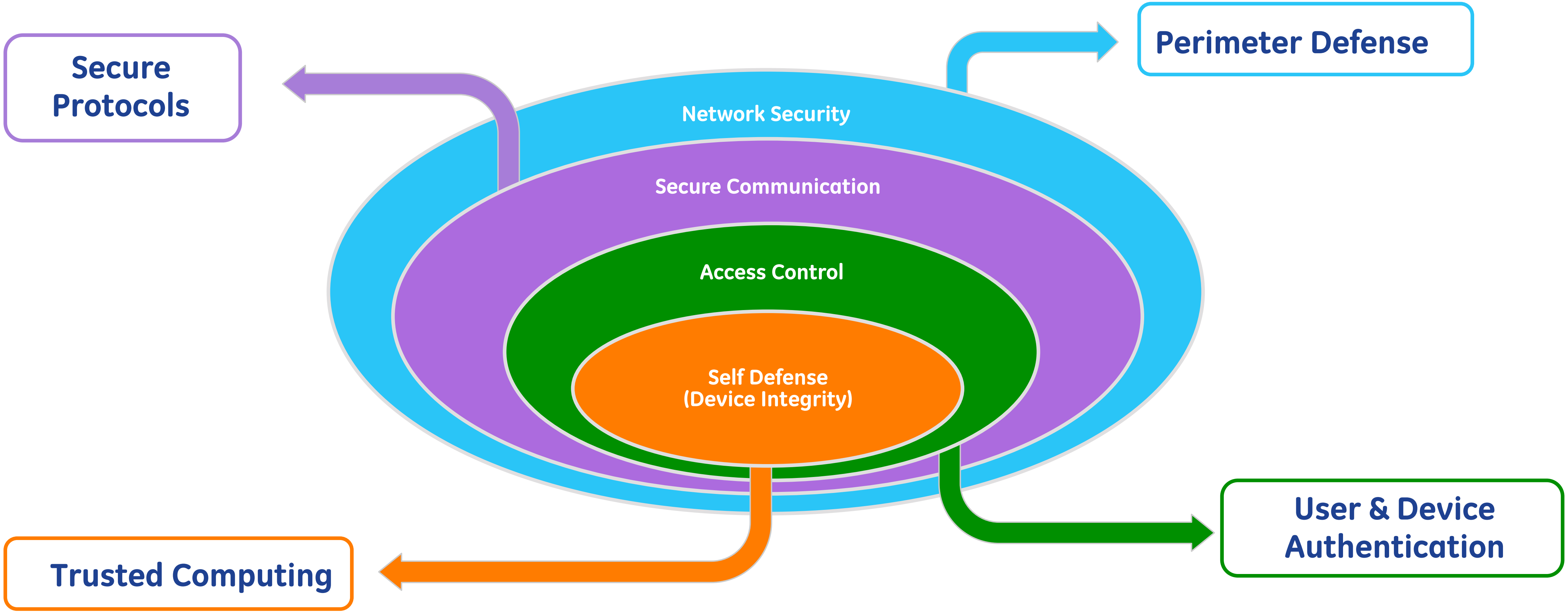
Lessons Learned…

- Security is an integrated story: designs, processes and practices must coordinate → *Device-initiated communication*

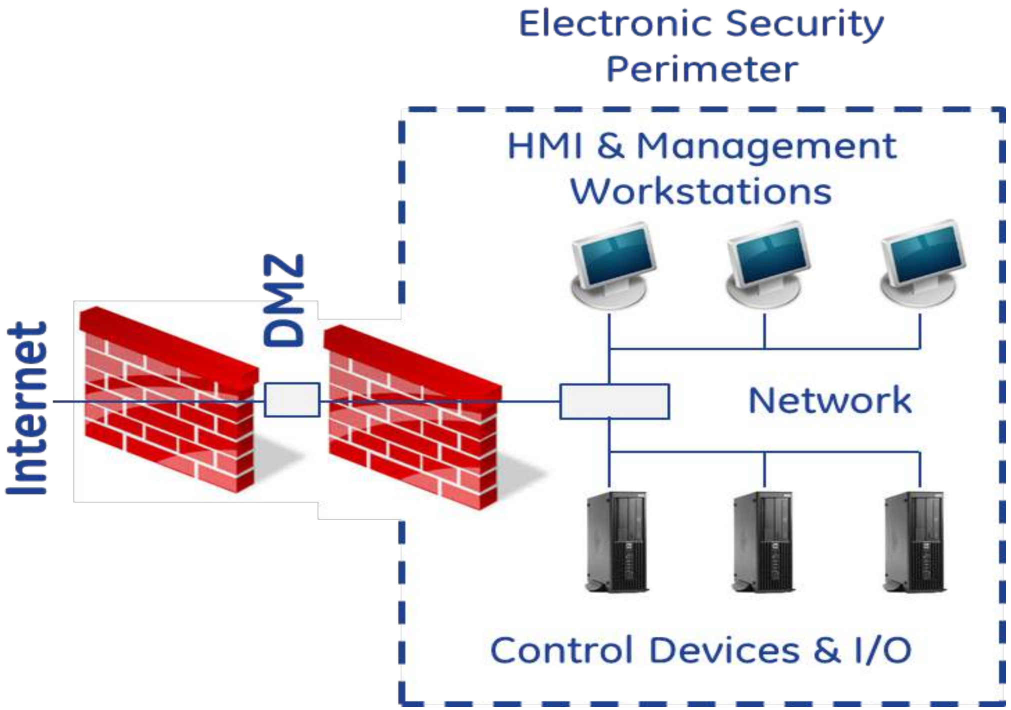
- Certificate-based infrastructure should be preferred to user-based authentication → *Availability of a signing authority*

- Airtight isolation is an illusion…→ *Advocating federated solutions*

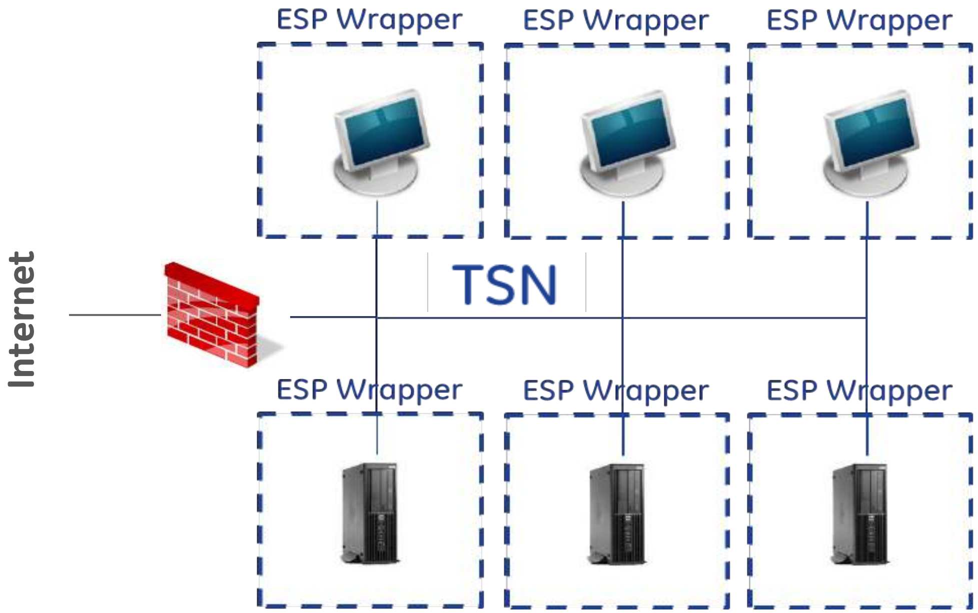
Edge Security Integrated Architecture



Security Perimeter → Security *Fabric*



- Risks due to operational needs leave attack surfaces open to exploitation
- Compromise of any network participant threatens the system
- Network itself is vulnerable



- Leverages Virtualization approach
- Risks due to operational needs can be accommodated minimizing attack surface
- Compromise of any network participant is much harder
- Compromised devices less of a threat to the system
- Network is more secure

Takeaways

- Building a solution for Industrial IoT requires a platform that can stretch from sensors and embedded devices to elastic cloud infrastructure
- Use of microservices architecture and design patterns, 12factor app principles, security patterns, and devops automation are fundamental to our success
- Security has to be designed into hardware and software using holistic approach