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Towards Zero Unplanned Downtime of Medical Imaging Systems using Big Data

Mauro Barbieri
Philips Research
31 March 2020

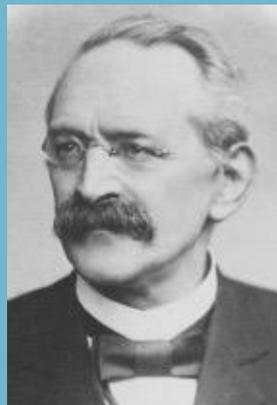
innovation  you



Philips, a born innovator

For over 125 years,
we have been
improving people's
lives with a steady
flow of ground-
breaking innovations

The founding fathers of Philips



Frederik



Gerard



Anton



Economic realities are driving the need for new approaches in healthcare

Volume

Value

Response

Prevention

Episodic

Continuous

Limited

Accessible





We are on a journey to transform Philips into a **health technology leader**

Technology

Health technology

Product

Solution

Transaction

Relationship





Our solutions –
driving quality
of care and
productivity for
our customers



Royal Philips in 2019



EUR 19.5
billion sales

4%

comparable
sales growth

EUR
1.9 billion
invested in R&D

~80,000

employees in over 100 countries

64,500
patent rights
39,000
trademarks

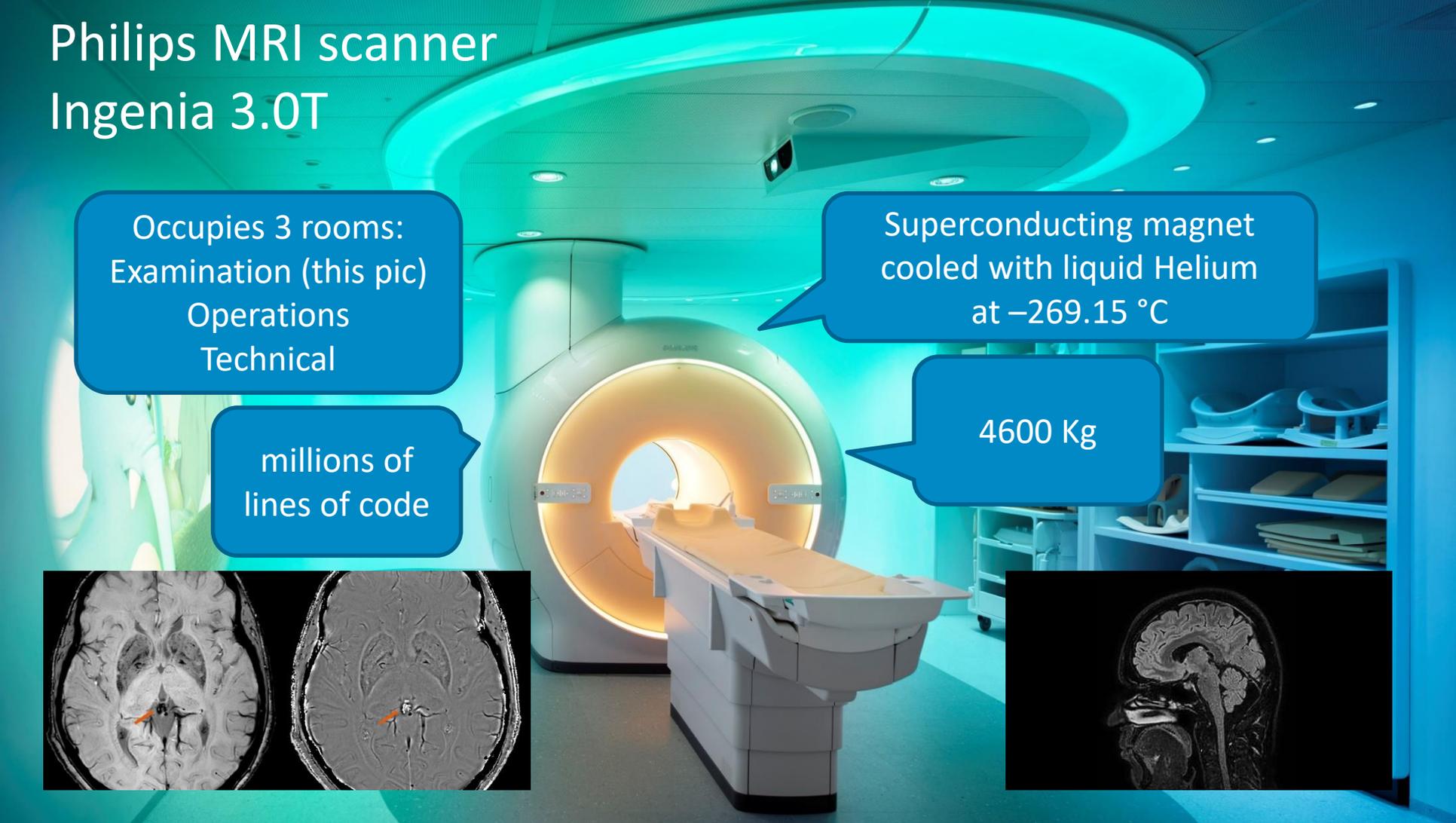
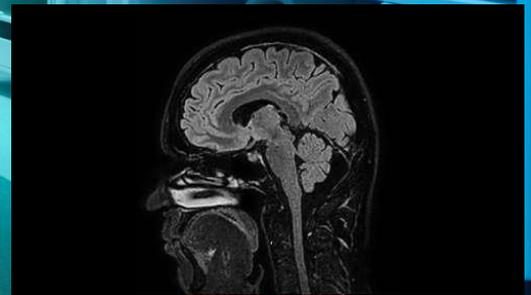
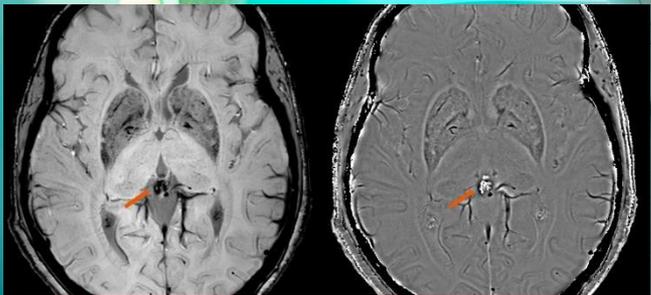
Philips MRI scanner Ingenuia 3.0T

Occupies 3 rooms:
Examination (this pic)
Operations
Technical

millions of
lines of code

Superconducting magnet
cooled with liquid Helium
at $-269.15\text{ }^{\circ}\text{C}$

4600 Kg



Philips IGT Azurion



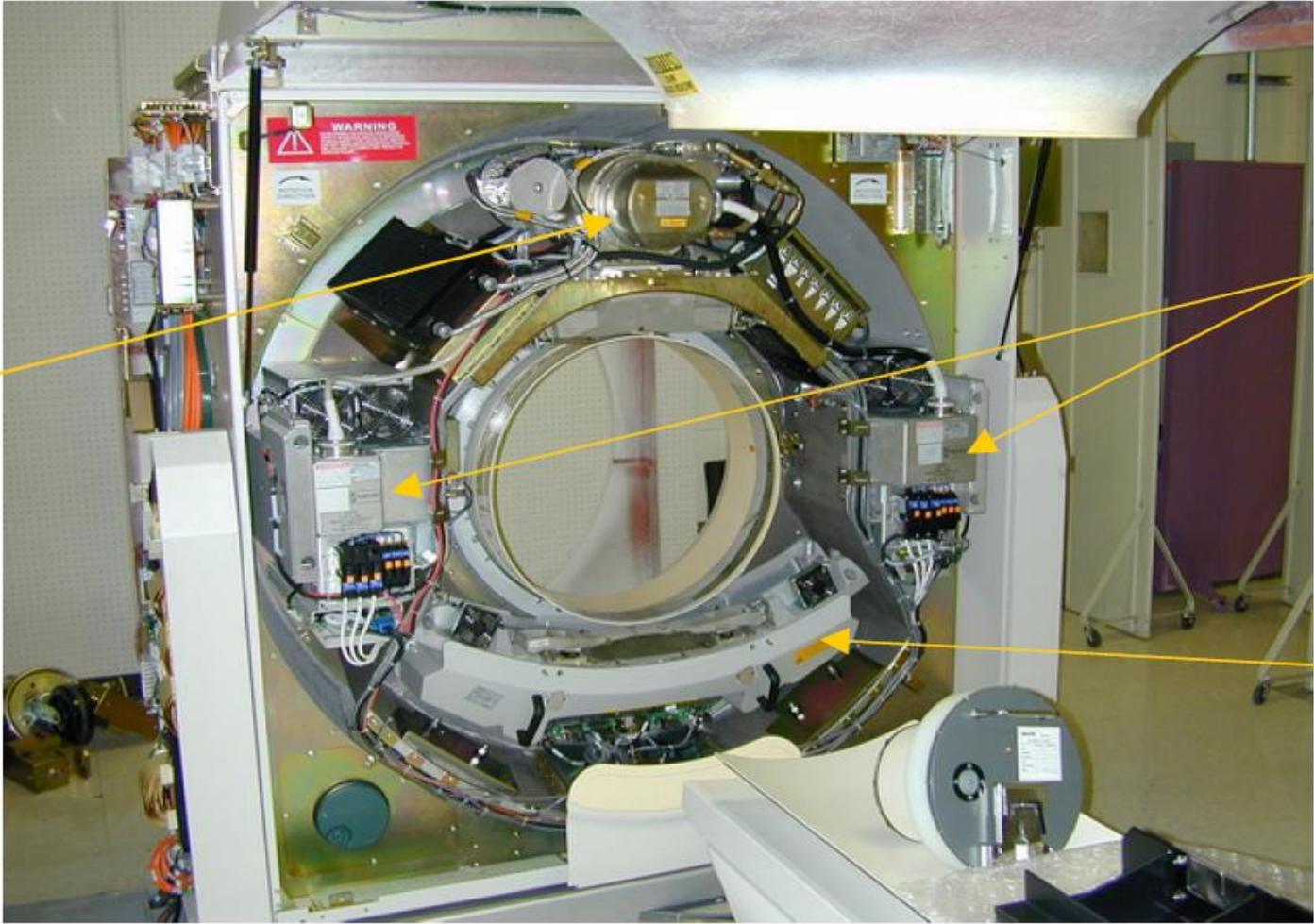
Occupies 2 rooms:
Examination (this pic)
and Technical

6+1 degrees
of freedom





Philips Spectral CT IQon



Tube

Generator

Detectors





From reactive to proactive service



Enablers



Strategic intent

Zero unplanned system downtime



Aiming for zero



Healthcare

At Philips we understand that providing care today means more than just providing technology. It is about making every investment worthwhile and every usable moment count. That's why we are dedicated to working with you to reduce unplanned downtime.

Three ways of increasing your uptime:

1. Reactive customer call handling and maintenance service.
Customer informs Philips of a problem associated with the product. Philips will diagnose the problem remotely and if possible analyze the issue remotely. On-site service engineers will be dispatched with guidance and replacement parts for a single visit repair.

2. Alert response
Alerts that are generated by the device itself or equipment installed at the hospital facility, indicating that critical system and/or environmental parameters and conditions are out of specification.

3. Proactive monitoring
By means of data analytics algorithms, machine learning and service data, continuous analysis is used to identify patterns and trends. These analytics are predicted to estimate existing or future issues before they impact workflow.

Predictive maintenance is on the rise. We envision that, by 2018, one in every five system service events will be triggered by careful analysis of system data - and will therefore take place before any major issues arise. This maintenance can also be planned so there is no disruption to your workflow.

dedicated monitoring engineers are constantly on the lookout for issues that may impact your uptime

>12,000 Philips imaging systems are monitored daily to identify patterns that could indicate preventive action is required

10,000+ cases are proactively handled every year by our centralized monitoring team to reduce unnecessary downtime

central monitoring locations in major time zones help resolve your problems quickly and effectively

Learn more at www.philips.com/aimingforzero

A man wearing glasses and a blue polo shirt with the Philips logo is focused on operating a piece of medical equipment. The background is a clinical setting with a wall-mounted light switch.

PHILIPS

Healthcare

Remote Services

Big data: big benefits for healthcare providers

The September 30, 2013 issue of Time magazine carried an article with the intriguing headline: 'Can Google solve death?' Of course the idea initially seems crazy. Yet the story explained that healthcare "is well on its way to becoming an information science," with doctors and researchers able to harvest massive quantities of data from patients. And that Google is, "very, very good with large datasets."

“ Remote services, driven by the analysis of big data that allows equipment issues to be addressed before impacting workflow or availability, **could ultimately eliminate unplanned downtime completely.**”

Francis Willems, Senior Marketing Communications Manager
at Philips Customer Services.

Using big data analytics for predictive maintenance



- Our medical devices collect lots of data about their functioning:
 - Event and error logs
 - Sensor data
- E.g. every day one MRI scanner logs:
 - 1 million events
 - 200,000 sensor readings
 - Tens of thousands of other data elements
- Unfortunately, in many cases, logging was not designed for predictive maintenance
- Key challenges: **integration of data sources** and **creation of predictive models**



Research challenges

- How to integrate very diverse data sources and automate the costly process of data provisioning and cleaning?
- How to create models that can help predicting failures and degradation of performance of individual devices?
- How to automatically recommend the best service actions from probabilistic information on possible failures?
- How to use these insights to:
 - Plan maintenance (taking into account the overall costs and multiple devices)?
 - Optimally manage spare parts supplies?



Our approach



Large collection of historical data available in ONE database

- Event Logs, parameter values, system configuration, etc.
- Failure records / maintenance records / service work orders

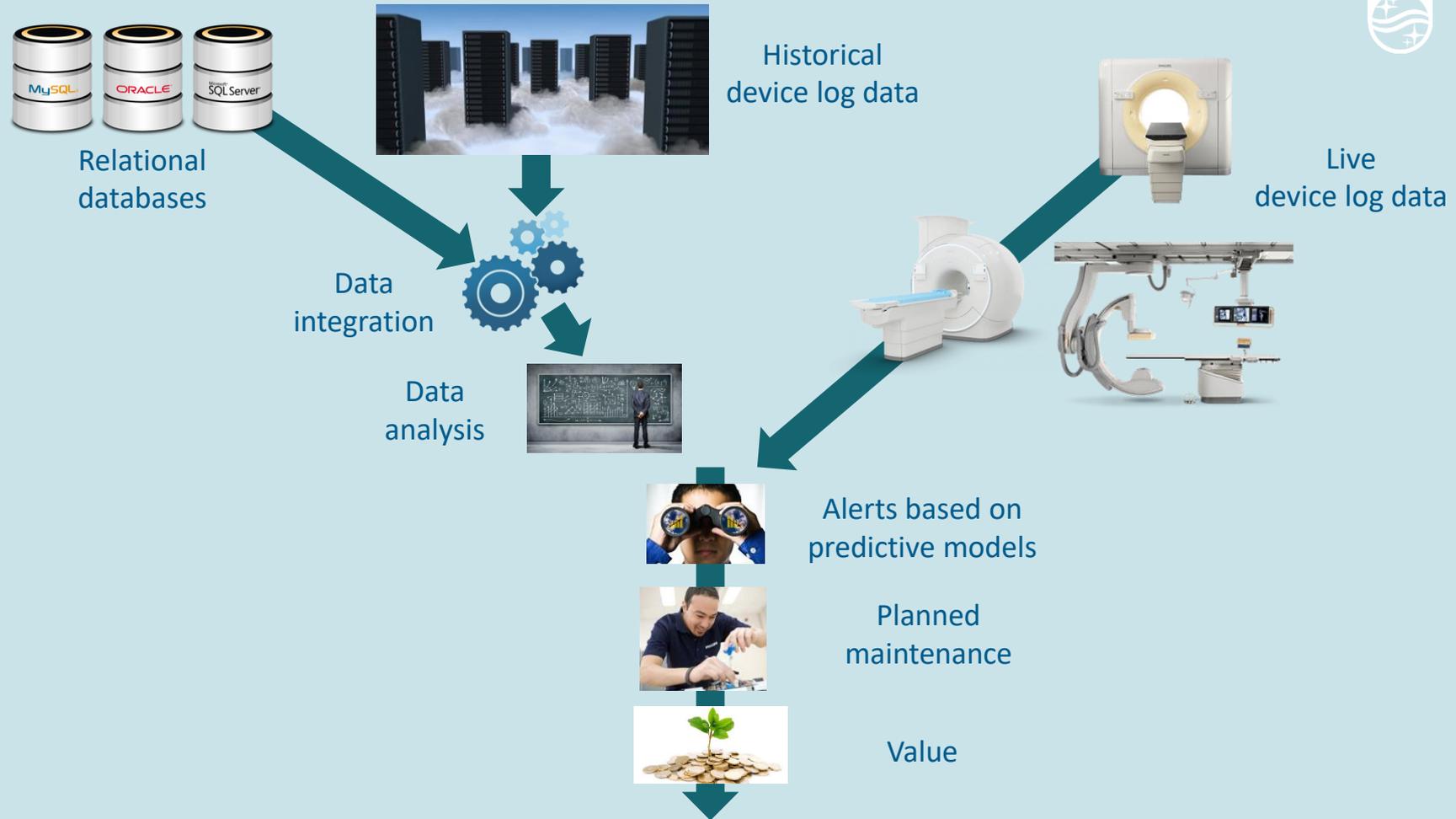
For each use case (e.g. failure mode) one integrated team

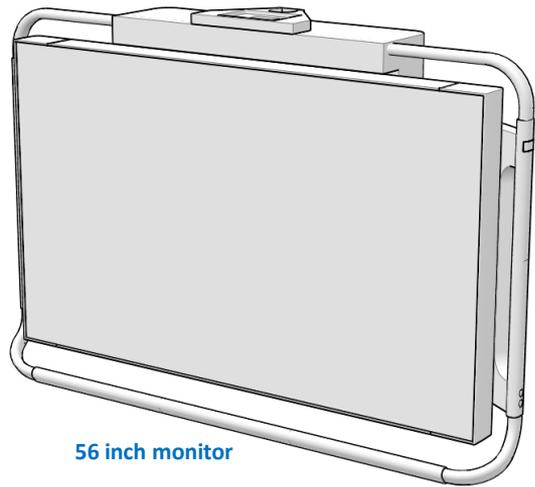
- Business owner from the Service organization
- Data scientists
- Subject matter experts

The team develops

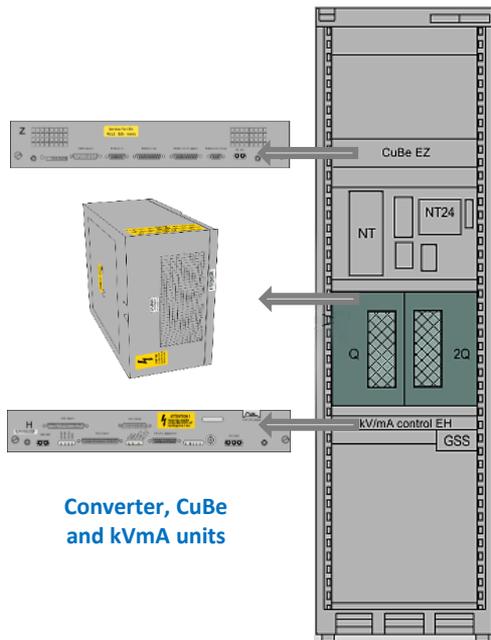
- Insights on the failure mode
- Predictive model with associated alert and service actions
- Additional output: input for R&D to improve the product



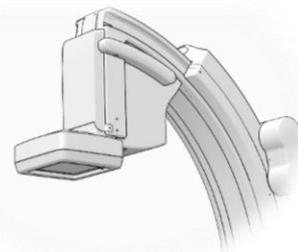




56 inch monitor



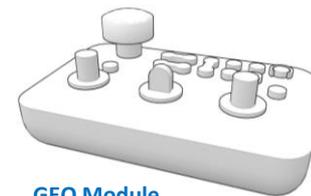
Converter, CuBe and kVmA units



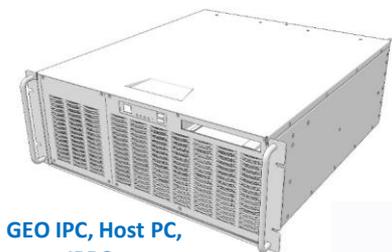
Flat detector, FDC board/ FD controller, flashlite unit, fiber optics and other related interconnections



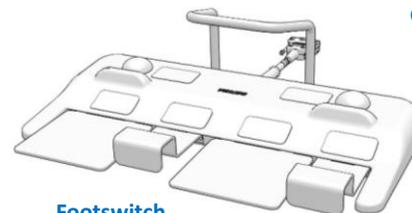
HDDs



GEO Module



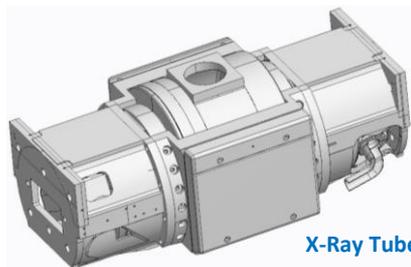
GEO IPC, Host PC, IPPCs



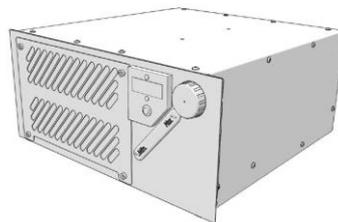
Footswitch



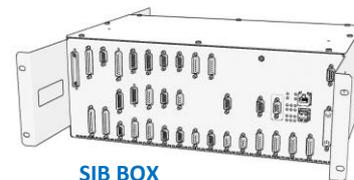
Touch Screen Module



X-Ray Tube



Temperature Control Unit



SIB BOX



TFINT board



dS Shoulder 8ch coil



dS Head 32ch coil



dS Anterior coil



dS Base



dS Head



dS Head-Neck



TR-Knee coil



Temperature humidity sensor



AM3



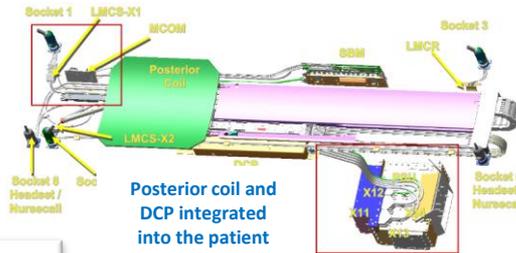
Water-cooled RF-amplifier AN8137



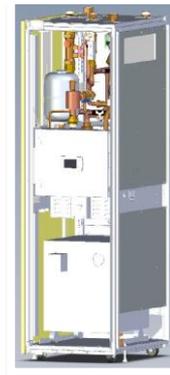
Analog Coil Interface



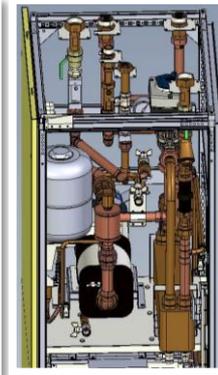
dS Breast 16ch adaptive coil



Posterior coil and DCP integrated into the patient support



LCC4



Secondary circuit



RF-amplifier S30



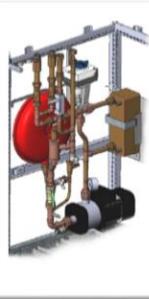
LCC2



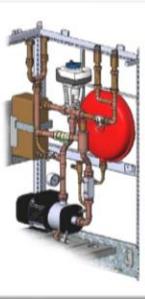
LCC2A



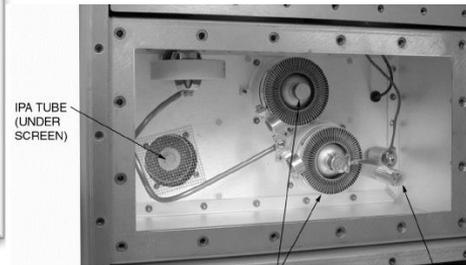
LCC2B



GC circuit



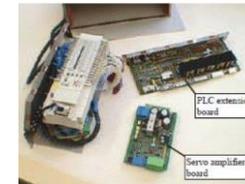
GA circuit



RF-amplifier S23 IPA and PA tube arrangement



RF-amplifier S35



Patient Support Servo Amplifier



Gradient Amplifier Copley 271 & 281+



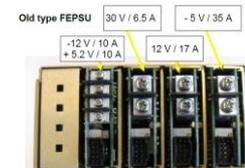
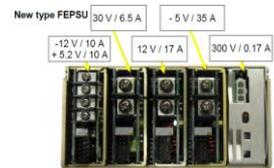
C781



C787



AIBO



Remote monitoring dashboard



Monitoring dashboard

Global Stats

1620 systems processed 48%
Total systems in RDW 1840

21 critical systems 14%
Total systems processed 1840

45 systems analysed 10%
Total critical systems 1840

Location

Find location or a system 🔍

All regions (5478)

APAC (1923)

ASEAN (222)

Australasia (534)

Greater China (1893)

India (222)

Japan (534)

EMEA (222)

LATAM (534)

<input type="checkbox"/>	Country	Site Name	Category	Device type	System ID	Aggregate title	Priority	Last Alert date
<input type="checkbox"/>	Japan	[REDACTED]	<input type="checkbox"/> Predictive	8R5	68942	▶ Highest severity alert description shown	CN 3	20-May-2017
	Japan	[REDACTED]	<input type="checkbox"/> CAT matches	8R5	78456	Alert description shown here	CN	21-May-2017
<input type="checkbox"/>	Japan	[REDACTED]	<input checked="" type="checkbox"/> All	8R5	100200	▶ Highest severity alert description shown	CN 8	22-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> Predictive	1.5T 8R5	35758	▶ Highest severity alert description shown	CN 888	24-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> Predictive	1.5T 8R5	57941	Alert description shown here	IP 4	24-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> CAT matches	1.5T 8R5	57941	▶ Highest severity alert description shown	IP 4	24-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> CAT matches	1.5T 8R5	45887	Alert description shown here	SR	22-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> Predictive	1.5T 8R5	78456	▶ Highest severity alert description shown	SR 24	21-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> Predictive	1.5T 8R5	78456	Alert description shown here	SA 3	21-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> CAT matches	1.5T 8R5	45887	Alert description shown here	SA	22-May-2017
	Japan	[REDACTED]	<input checked="" type="checkbox"/> Predictive	1.5T 8R5	57941	Alert description shown here	SD 210	24-May-2017

Display alert legend

Remote monitoring dashboard



PHILIPS RADAR 2.0
Help User Name ▾

Monitoring Dashboard 100200

100200 Critical need

Site ID 1620420 Type Achieva Model Name FDI0/10 Model Number xx007 Version 8.2.16.4

Overview

Notes +

Open Alerts

<input type="checkbox"/>	Category	AlertID	Occurrence	Alert Name	Priority	Date and time
<input type="checkbox"/>	Category 3	458798	4	+ Cold Plate Over Temperature Error predicted in 10 days	CR	21-May-2017 11:48:14
<input type="checkbox"/>	Category 1	524136	3	+ Description Two	IP	21-May-2017 12:48:15
<input type="checkbox"/>	Category 2	987865	3	+ Description Three	SA	21-May-2017 13:48:15
<input type="checkbox"/>	Category 1	817328	7	+ Description Four	SR	21-May-2017 14:48:15
<input type="checkbox"/>	Category 2	987865	1	+ Description Five	SA	21-May-2017 15:48:15
<input type="checkbox"/>	Category 1	817328	2	+ Description Six	SR	21-May-2017 16:48:15
<input type="checkbox"/>	Category 2	987865	2	+ Description Seven	SA	21-May-2017 17:48:15
<input type="checkbox"/>	Category 1	817328	1	+ Description Eight	SR	21-May-2017 18:48:15

Create new case ▾ No action required View Log

System Usage

Time	Activity	Time	Activity
07:31:17	Starting System	07:32:14	System Started
07:36:17	Case 1 Started	07:36:17	Case 1 Stopped
08:31:17	Case 2 Started	08:31:17	Case 2 Stopped
08:45:17	Case 3 Started	09:20:14	Case 3 Stopped
10:15:17	Case 4 Started	10:20:14	Case 4 Stopped
11:45:17	Case 5 Started	12:20:14	Case 5 Stopped
13:37:17	Case 6 Started	14:10:14	Case 6 Stopped
16:20:00	System Shutdown		

ⓘ Abnormal shutdown
↺ Planned normal restart
⚠ Alert
ⓧ Log file not downloaded

ⓧ Data loss
ⓧ No Data loss
ⓧ System offline
ⓧ LOG file downloaded

Action history

Action	CaseID	AlertID	Alert title	Priority	Action start	User
Case created	6584741, 6584958	AlertID1, AlertID2	Action title	CR	20-May-2017	User1
Comment added		AlertID3	Action title	SR	21-May-2017	User1
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec quis urna vulputate, tempus orci nec, vehicula odio. Aliquam trincidunt, felis vestibulum locinno locinno, quam diam venenatis velit, a iaculis velit velit eu sapien. In gravida porta felis, vitae porta ante congue sed. Etiam dictum ante ac odio semper tristique. Suspendisse ultrices orci vel sapien suscipit, non lobortis nibh.						
SNAR		AlertID5	Action title	IP	20-May-2017	User1

Global Stats and Location

Remote monitoring dashboard



PHILIPS RADAR 2.0 Help User Name ▾

Monitoring Dashboard **100200**

100200 Critical need **3**

Site ID	Type	Model Name	Model Number	Version
1620420	Achieva	FD10/10	xx007	8.2.16.4

Overview

Notes +

Open Alerts

Category	AlertID	Description	Priority	Date and time
<input type="checkbox"/> Category 3	458798	Description One	Critical need	11:48:14 20-May-2017
<input type="checkbox"/> Category 1	987865	Description Three	System restricted	12:48:15 21-May-2017

Enter comment

Priority Ignore these alerts till or till case is closed

Selecting Priority 1 or 2 has safety/security implication!

High-level architecture



Data integrated



- 500 TB in >300 tables
- 30 trillion data points
- >80 different data sources integrated for the complete connected installed base including CRM system, SAP, one factory, one repair shop
- 3-7 years of historical data
- 24/7 live data feeds

Key aspects



- Simplicity of design: from scratch to production in 8 months
- Highly stable due to exhaustive error handling (millions of log files per week)
- Live-data pipeline and processing of large historical datasets
- All components have built-in monitoring capabilities
 - Transparency builds trust
- Documentation of data sources and provenance of each data point:
 - Data issues can be identified and fixed quickly
 - Data can be trusted

Analytics Solution Platforms



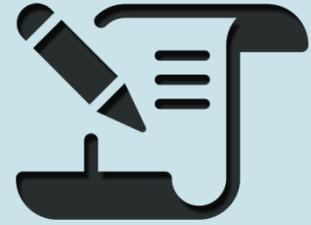
- Data science environment (Philips Private Cloud and Public Clouds)
 - Years of historical data
 - Interactive data exploration, human queries: highly variable load
 - Training of machine learning algorithm
 - Designed and optimized for rapid prototyping and the largest data volume
- Production environment (Philips Private, Public and Customers' sites):
 - Months of data
 - Only optimized queries from applications: stable load
 - Designed and optimized for low latency, throughput and reliability
- Development and staging environment (Philips Private, Public and Customers' sites):
 - Similar to production
 - Importance of elasticity

Data-driven service innovation



- Data is used in every step of the process
- Business case creation: quantitative analysis of current situation and quantitative estimates of value creation
- Maintenance optimization: prioritization of use cases based on measured or estimated business impact (Pareto analysis)
- Failure mode analysis (visualizations, Pareto) and reliability analysis
- Feature engineering
- Model training and validation with historical data
- Analysis and monitoring of the performance of diagnostic and predictive models
- Analysis of impact and value creation

Data integration documentation



- **Data model document:** specifies how data is extracted and how it is stored in the data warehouse. It includes a definition of duplicate records and the query to check for duplicates.
- **Data dictionary:** explains each column in the data model from an SME perspective (definition and meaning, units of measure, range, expected values, raw value or calculated, etc.).
- **ETL design document:** explains how the ETL works, including the failure handling strategy (e.g. import all records or nothing vs. import valid records only) and duplicate avoidance strategy.
- All documents are reviewed and approved by subject-matter experts, data stakeholders, data scientists and a **data architect**.
- All documents are available to end-users of the data (links to the documents in a data warehouse table).



Philips offers the best service performance enabling you to treat more patients

Philips remotely connected systems provide 135 more hours of operational availability per year enabling you to **treat more patients.**

82%

First Time Right fix rate

135 hours

more operational availability per year

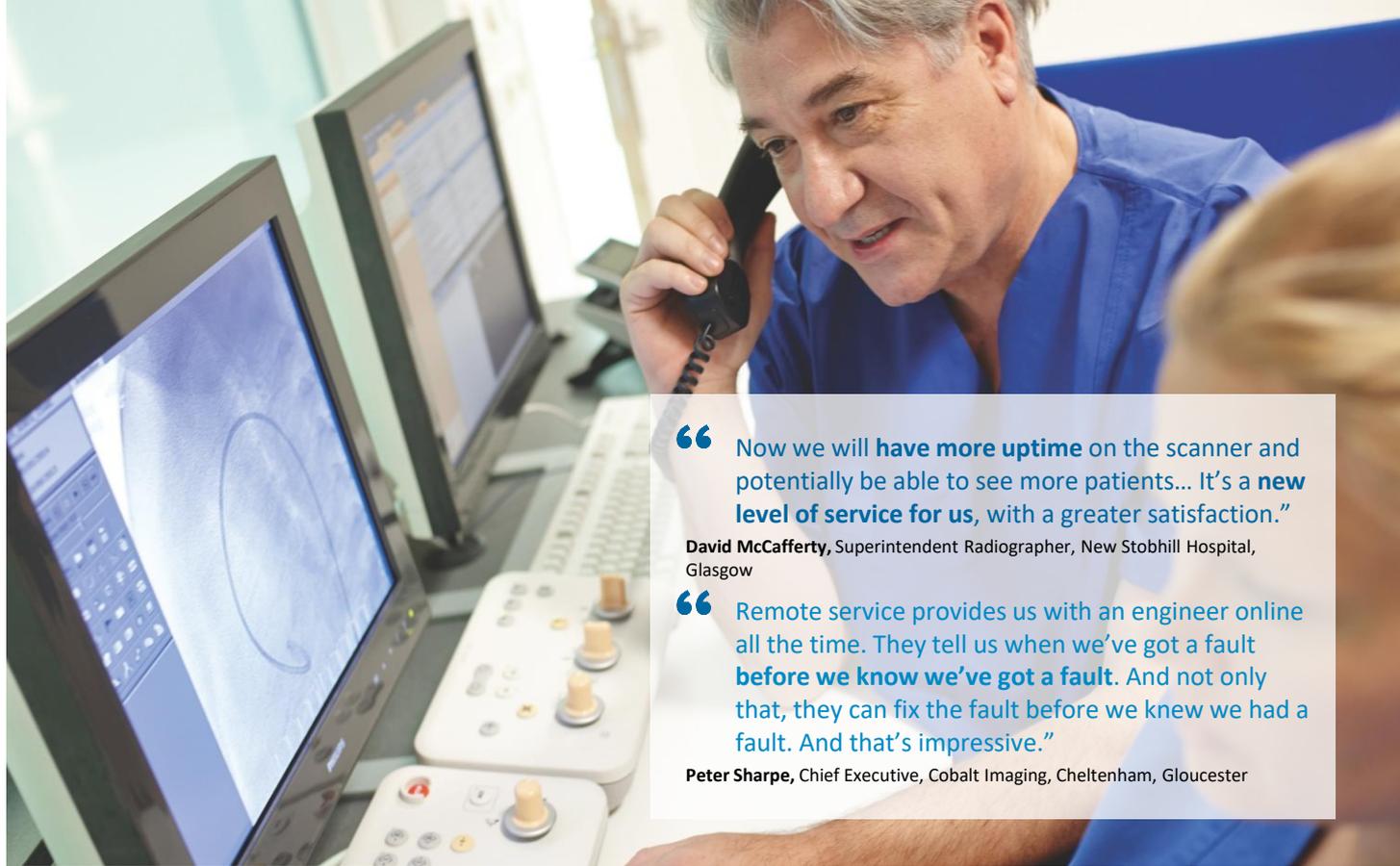
>35%

Remotely resolved cases

14%

Less downtime

The ability to treat more patients



“ Now we will **have more uptime** on the scanner and potentially be able to see more patients... It's a **new level of service for us**, with a greater satisfaction.”

David McCafferty, Superintendent Radiographer, New Stobhill Hospital, Glasgow

“ Remote service provides us with an engineer online all the time. They tell us when we've got a fault **before we know we've got a fault**. And not only that, they can fix the fault before we knew we had a fault. And that's impressive.”

Peter Sharpe, Chief Executive, Cobalt Imaging, Cheltenham, Gloucester

Customer Testimonials

