The factory of the future is here:
Boosting productivity. Reimagining the way we design, manufacture and service products.
Introducing the ‘Brilliant Factory’

Scott Parent
Sr. GM Technology & Operations - Distributed Power, GE Power
Leading the next manufacturing revolution

**THE 2nd INDUSTRIAL REVOLUTION**
[PAVING THE WAY]

- **1900**
  - FORD ASSEMBLY LINE
  - ELECTRICITY + MASS PRODUCTION

- **1918**
  - TOYOTA PRODUCTION SYSTEM
  - THE AGE OF DIGITAL ELECTRONICS

- **1985**
  - GE BRILLIANT FACTORY
  - THE INTERNET OF THINGS + ARTIFICIAL INTELLIGENCE

- **2025+**

**GE BRILLIANT FACTORY**
Driving **digital maturity**, built on **lean foundation**, with **continuous improvement**
Our evolution ... becoming ‘Digital Industrial’

Applying over 120-years' experience in building powerful machines. Merging the physical and digital worlds, connecting them with software to drive better results for YOU!

Every day at GE, we analyze 50m data elements from 10m sensors on $1tn of managed assets.

INDUSTRIAL INTERNET
The integration of physical machinery with networked sensors + software. Gathering and analyzing data in real-time to detect flaws and reduce unplanned downtime.

PREDIX™
An operating system, built by GE, for the Industrial Internet. Provides the technical foundation needed to run industrial apps.

DIGITAL TWIN
A digital copy of a physical asset or process that lives and evolves over its lifetime, spanning GE’s portfolio.

TALK THE TALK

BRILLIANT FACTORY
Factories where lean manufacturing and optimal productivity are combined with advanced software analytics for better outcomes, improving speed and efficiency.

DIGITAL THREAD
Connecting the inner workings of GE through our most common thread ... data. From the start of a customer engagement through to the servicing of our products.

ASSET PERFORMANCE MANAGEMENT (APM)
A suite of software + service solutions leveraging data and analytics to reduce unplanned downtime, improve reliability + availability, and reduce operational risk.
A NEW ERA

of manufacturing, merging hardware and software, and reimagining how products are designed, made and serviced

GE IS LEADING THE CHARGE

in the Digital Industrial space, leveraging sensor-enablement and advanced software analytics to help enhance productivity in our factories

THE RESULTS WILL BE SIGNIFICANT

Consider the power of just a 1% increase in productivity. This has the potential to equal massive gains
Lean Manufacturing

Lorenzo Romagnoli
Global Supply Chain Leader – Subsea Production Systems, GE Oil & Gas
Our Oil & Gas ‘Showcase’ sites

- Florence, Italy – 2016 ‘Showcase’
- Minden, Nevada – 2017 ‘Showcase’
- Brent Avenue, UK
- Dammam, Saudi Arabia
- Le Creusot, France
- HTC, Houston
- Jacksonville, Florida
- Massa, Italy
- Monterrey, Mexico
- Nailsea, UK
- Newcastle, UK
- NHR, Houston
- Talamona, Italy
NOT JUST THINKING. DOING.

500+
GE factories globally: Deep manufacturing expertise

>400
3D printing machines in use across GE today

30%
Increase in first pass yield for subsea equipment pressure testing

45mins
Lead time for Bentley Nevada probe manufacturing line. Reduced by >5 days, due to ‘single piece flow’ Lean process improvement

~80%
Reduction in engineering defects through use of virtual validation (subsea XT 3D model)

37%
Lead time reduction for GE’s small BCL centrifugal compressor line in Florence – targeting 50% through ‘17

92%
OTD improvement through factory + supply chain optimization at our Digital Solutions facility in Minden, US

20-44
Capacity increase from units per month, using robotic cladding technology for subsea XT tubing hangers and flexible pipe end-fittings

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The key [to the Toyota Way and what makes Toyota stand out] is not any of the individual elements ... But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner, not in spurts.

- Taiichi Ohno
Living Lean: On the shop floor

**LEAN FACTORY MATURITY FRAMEWORK**

**Lean getting started**
- Vision + structure established

**BASIC**
- Engaged & Committed (L2)
- Customer Focus (L1)

**BRILLIANT**
- Improvements starting to have an impact
- Inventing New Levels of Success (L4)

**Lean Fundamentals**
- S5
- Standard Work
- Value Stream Mapping (VSM)
- Total Productive Maintenance (TPM)
- SMED (Single Minute Exchange of Die)
- Lean Product and Process Design

**Continuous improvement a way of life**

**Mature in all regards – on road to world class performance**

**Seeking Perfection (L5)**

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The GE Store in action. Derived from GE Aviation’s Production System framework. Designed to drive a common language, site-to-site.

Primary Outcomes: ↑ OTD ↓ Cycle ↓ COQ

3 FUNDAMENTALS
Standard metrics, consistent operating rhythms and shared, full team accountability
Digital Maturity

Donatella Banchi
TMS CIO for GSC & Quality, GE Oil & Gas

Nicola Campo
Senior Director, TMS-Enterprise Application Engineering, GE Oil & Gas
The digital revolution

**WHY**

- **VIRTUAL MANUFACTURING**
  - Bridge information gap between engineering & manufacturing via digital tools
  - **Cycle**
  - **Cost**

- **WHAT**
  - Bill of Process & Part Program in PLM/MES
  - Electronic Work Instruction
  - Virtual Validation

- **SENSOR ENABLED**
  - Enable higher uptime & quality at each individual manufacturing machine tool
  - **VCP**
  - **Downtime**

- **FACTORY + SUPPLY CHAIN OPTIMIZATION**
  - Increase throughput & inventory turns by enhancing data visibility at factory level
  - **OTD**
  - **Cycle**

- Connect shop machines
- KPI Metrics & Analytics
- Condition Based Maintenance
- Smart Facility Solutions

- Quality management: Statistical Process Control & Digital Gauges
- Scheduling
- Manufacturing Execution System
Digital Thread & Model Based Enterprise
Digitizing within and connecting data across all systems and functions

Create a **Digital Thread** to improve efficiency, productivity and quality ... remove **hidden waste** in data manipulation across functions.

**HOW?**

- **Unique** BoM... Engineering & Manufacturing
- Annotated **3D Models** as the Master of Product Definition ... database for downstream re-use
- Item **classification**

... foundation for the creation of a new Industrial Environment: **Digital Twin** of assets to predict, measure & optimize performance
MBE Digital Thread for TMS Brilliant Factory

What is in place in Florence?

From Digital Product Definition ...

... to the Brilliant Factory

SINGLE SOURCE OF INFORMATION ...

Searchable + CAM

Re-usable + CMM

Aligned to 3D + Inspection Plan

Virtual Validation for Machining and Assembly + Multimedia Content

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MBE Digital Thread for TMS Brilliant Factory

What is in place in Fòt?

From Engineering Digital Design ...

... to the Brilliant Factory

Remote FAT

MFG & Internal Test

Factory Acceptance Test

Design for MFG: CNC Machines interface

Simplified HW Test w/Remote connectivity

DB Driven Loop Checks Automatic Test Report

Remote Functional Test from SW Lab

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Embracing sensor enablement in Subsea

- Predix™-based, custom solution designed for capture and analysis of pressure test data, with built-in flexibility for future upgrades
- In future, tests could be defined as bar codes for operators to scan, to validate and initiate the required test
- Today, we are working with our customers to enable them to access their test data remotely – a real step-change for our industry

24 DATA ACQUISITION SYSTEMS
Feeding data from hydrostatic test cells and gas pits into the cloud

INCREASED FIRST PASS YIELD FROM 55-85 PER CENT
Condition Based Maintenance

Scope:
- Machine deviation from standard performance
- Reduce number of failures
- Proactively identify hidden failure before it happens

Strategy:
- Transform from preventive maintenance to condition based maintenance
- Rules designed to cover 12 5-axis machines

Activities performed in CBM tool

1. Tool view of alerts and actions to achieve production savings (hrs)

2. Example of rule highlighted by CBM Tool

COLLABORATION WITH GE DIGITAL, GLOBAL RESEARCH CENTER & ACROSS ‘SHOWCASE’ SITES
Optimizing solutions

Improving performance with GE’s Predix™ platform

QUALITY MANAGEMENT
A Predix™ based solution to capture quality data and run analytics (SPC)

MAINTENANCE MANAGEMENT
From preventive maintenance to condition based maintenance

PERFORMANCE MONITORING + ANALYSIS
Smart Facility Solutions: A Predix™ based system to supervise systems remotely

DATA COLLECTION + ACQUISITION
Dashboard & Analytics to optimize machining and productivity

DISPATCHING + SCHEDULING
Deliver smarter production plan, improving productivity and decision-making

改善性能的途径

GE的Predix™平台

质量管理
基于Predix™的解决方案，用于捕获质量数据并运行分析（SPC）

维护管理
从预防性维护到基于条件的维护

性能监控 + 分析
智能设施解决方案：基于Predix™的系统，用于远程监督系统

数据采集 + 收集
仪表板和分析，优化机床和生产率

调度 + 安排
提供更智能的生产计划，提高生产率和决策

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Image credit: GE Reports/Chris New
Advanced Manufacturing

Francesco Saverio Chiari
Senior Engineering Manufacturing Technology Manager, GE Oil & Gas
Advanced Manufacturing:

A family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities. This involves new ways to manufacture existing products and the manufacture of new products emerging from new advanced technologies.
Advanced labs ... investing in tech innovation

Welding/NDE  Metrology  Metal Working  Virtual Reality

HT Mats + Powder Metal (HIP)  Metallurgical Lab  Corrosion Lab  Additive Mfg

ROBOTICS IN 2017
Meet the NovaLT GT family’s combustion chamber (CC) line

9
MAIN
TECHNOLOGIES
A very complex item

TEAMWORK
Engineering,
Manufacturing and
Sourcing

1ST CC MADE
... DELIVERED ON
SEPTEMBER 7, 2016

2017
Complete CC internal
line this year

Combustion chamber line simulation by Virtual Reality
Meet the NovaLT GT family’s combustion chamber (CC) line

TEAMWORK
Engineering, Manufacturing and Sourcing

Complete CC internal line this year

Combustion chamber line simulation by Virtual Reality

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Introducing automation to Subsea

Manufacturing capacity increase from 20 to 44 units per month

3x increase in manufacturing capacity

ROBOTIC CMT (COLD METAL TRANSFER) CLADDING

Lower Iron Dilution

3 x higher deposition rate

Ultra High Precision

Easy control of Heat Input

Great Flexibility

Full process automation

FRONIUS SPEEDCLAD™ TWIN (DUAL CATHODE GAS TUNGSTEN ARC WELDING)

COLLABORATIVE ROBOTICS

Meet Sawyer ... one of our subsea ‘co-bots’
Manufacturing process simulation

2012
Machining FEM Analysis
Cutting forces and temperature, tool wear

2013
Welding FEM Analysis
Distortion and stresses calculation ...
Validation of numerical results

2014
Machining optimization
Cutting forces analysis and load levelling

2015
NDE simulation
Probability of detection, critical defect assessment, technique validation

2016
Virtual Reality
Assembly simulation

2017
Additive Technology
Process parameters & residual stresses

Increase domain knowledge ... Faster technology introduction
“We keep moving forward, opening new doors, and doing new things, because we're curious and curiosity keeps leading us down new paths. We're always exploring and experimenting.”

- Meet the Robinsons, Walt Disney
Additive Manufacturing

Giulio Canegallo
Additive Manufacturing Product Manager-TMS, GE Oil & Gas

Iacopo Giovannetti
Additive Manufacturing Engineering Manager-TMS, GE Oil & Gas
Additive manufacturing

SPEED

PERFORMANCE

PRODUCTIVITY
Our panel of experts look forward to your questions...

SCOTT PARENT
Sr. GM Technology & Operations - Distributed Power, GE Power

LORENZO ROMAGNOLI
Global Supply Chain Leader – SPS, GE Oil & Gas

DONATELLA BANCHI
TMS CIO for GSC & Quality, GE Oil & Gas

GIULIO CANEGALLO
Additive Manufacturing Product Manager-TMS, GE Oil & Gas

ICACOPO GIOVANNETTI
Additive Manufacturing Engineering Manager-TMS, GE Oil & Gas

FRANCESCO SAVERIO CHIARI
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