Digital Transformation

GE Perspectives

GE's Digital Industrial Transformation Strategy

Our Play

GE for GE
"Productivity"

GE for Customers
"Apps"

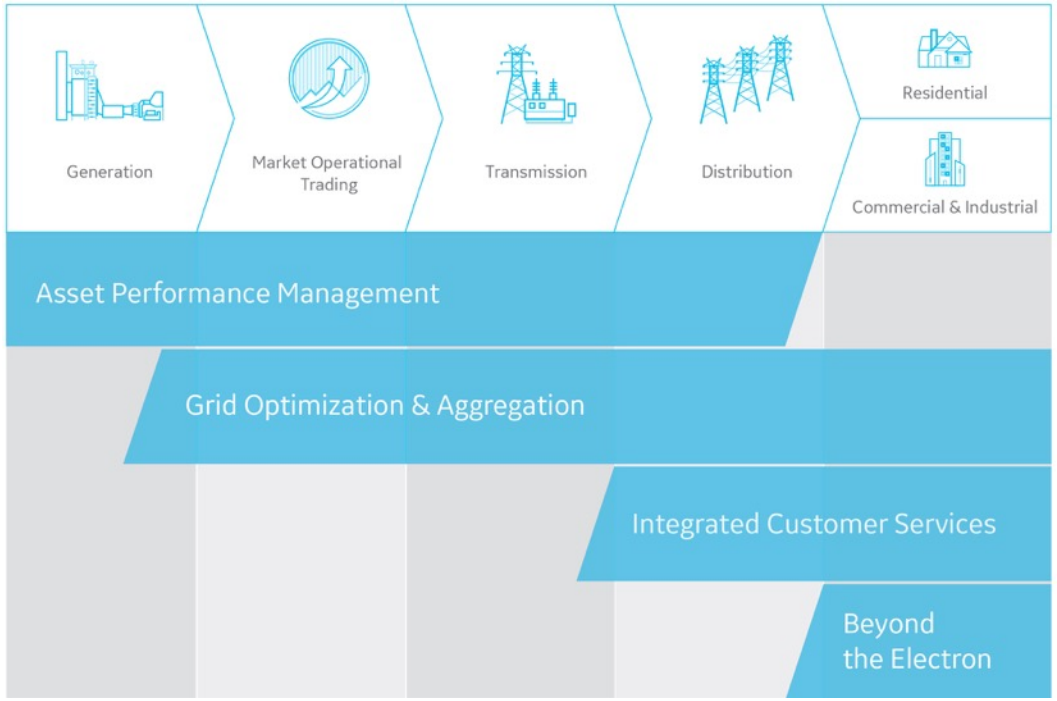
GE for the World
"Platform"

How we Win

1. Capabilities & Operating Model — *Change the Game*
2. Data and Connected Infrastructure — *Harness the Platform*
3. Partner Ecosystem — *Go Together, Go Far*
4. Digital Talent and Culture — *Building Digital DNA*
5. Business Model Innovation — *All About Outcomes*

Very different capability set than consumer internet; GE is building capabilities that are necessary to win

Digital Transformation of Electricity Through 2025



$1.3T

Industry Value from:

Service platforms

Smart devices

The 'cloud'

Advanced analytics

$387B

Asset Performance Management Value from:

Lower repair & maintenance costs

Lower downtime of assets

Fewer critical breakdowns

$2+T

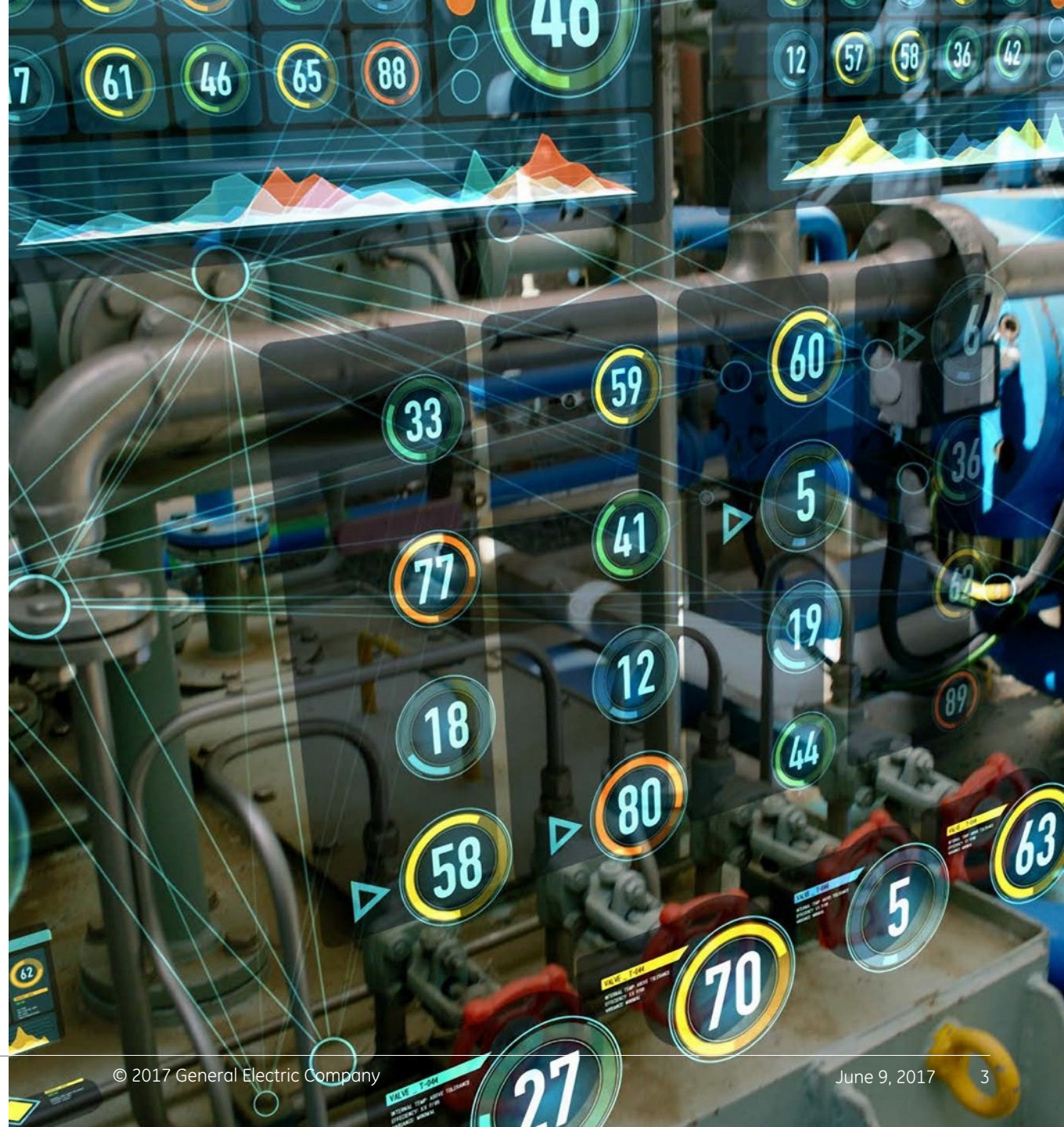
Societal Benefits from:

Reduction in carbon emissions

Net new job creation

Value creation for consumers

Source: World Economic Forum White Paper Digital Transformation of Industries: Electricity Industry, January 2016



Digitalization Yields Benefits Across the EVN

CROSS EVN BENEFITS

Asset Performance Management: Up to **5%** reduction in unplanned downtime; **15%** increased asset utilization (T&D grid)

Cyber: From avoidance of **$1MM** per NERC infraction to millions per day in lost production from catastrophic cyber event

Predix: Up to **15%** IT cost reduction; up to **30%** application acceleration; millions in benefits from cross-EVN data sharing

Digital Worker: Up to **8%** reduction in service costs

REAL CUSTOMER RESULTS*

FOSSIL

3% increased fuel efficiency

10% increase in output capacity

3%–4% emissions reduction

NUCLEAR

Up to **$2K/MW** annual O&M reduction

RENEWABLE ENERGY

10% reduction in O&M cost

8% increase in production

TRANSMISSION & DISTRIBUTION

33% reduction in system interruption

20%+ increased carrying capacity of networks

COMMERCIAL AND INDUSTRIAL CUSTOMERS

Up to **10%–20%** reduction overall energy consumption

Up to **70%** reduction in lighting costs

*Representative customer outcomes are not guarantees of results.

GE Solutions

GE Power Digital Solution Map – **Nuclear Specific Focus**

Operations Optimization

Nuclear Focus Area	Analytic / Data Science Basis	Targeted Impact	
Outage Optimization • Staffing Planning • Scheduling Analytics • In-Processing	➢ GEH Nuclear Staffing Database ➢ GE's Global Research Center ➢ GE Digital Data Science	• 5% - 10% Labor Reduction • 1 Day of Outage Duration • 5% Dose Reduction	**~$5-6MM Per Outage**
Thermal Performance • System/Plant Modeling • Decision Support tools	➢ GEH Nuclear Systems Engineering ➢ New Plant Design Models ➢ Industry Standards	• 1% - 3% Increase • Simplified Monitoring	**~$300-500K Per Year**
Operational Risk Management • Human Factors Models • Proactive - Plant Risk Management	➢ GE Digital Advanced Data Science ➢ GEH Advanced Data Science	• Forced Loss Reduction • SCRAM Reduction • Reactivity Event Reduction	**~$1-2MM Per Year**

Asset Performance Management

Nuclear Focus Area	Analytic / Data Science Basis	Targeted Impact	
Analytics Orchestration • Advanced Pattern Recognition • Machine Learning • Neural Nets • Advanced Data Science	**Nuclear Specific Asset Analytics** ➢ GEH Nuclear Systems Engineering ➢ New Plant Design Models ➢ Industry Standards ➢ Other Customer Models ➢ 3rd Party Partners	• 10 Day Advanced Alert • >50% Coverage on Failure Modes that Impact Generation	**~$1300 to $2000 Per MW**

APM Components/Failure Modes - Examples

Turbine & Generator

1. Rotor shafts
2. Main stop valves
3. Control valves
4. Intercept valves
5. Other turbine valves
6. Lube oil pumps
7. Lube oil coolers
8. Lube oil system valves and piping
9. Lube oil pump drive
10. Hydraulic system pumps
11. Hydraulic system coolers
12. Hydraulic system filters
13. Hydraulic system pipes and valves
14. Automatic turbine control systems
15. Shaft coupling mechanism
16. Exciter drive - motor
17. Exciter drive - shaft
18. Hydrogen cooling system piping and valves
19. Hydrogen coolers
20. Generator voltage control

Balance of Plant

1. Condenser tube leaks
2. Condenser tube fouling shell side
3. Condenser tube fouling tube side
4. Expansion joint
5. Hot well
6. Tube sheet fouling
7. Air ejectors, piping & valves
8. Hot well level controls
9. Circulating water pumps & motors
10. Circulating water piping fouling
11. Circulating water valves
12. Traveling screens & fouling
13. Condensate booster pump
14. Condensate booster pump motor
15. Condensate piping & valves
16. Feedwater pump drive controls
17. Feedwater pump
18. Feedwater pump drive
19. Feedwater pump coupling and drive shaft
20. Feedwater piping and supports
21. Feedwater regulating (boiler level control) valve
22. Other feedwater valves
23. Heater drain pumps

Reactor Components

1. Control rod scram mechanisms
2. Control rod instrumentation
3. Control rod drive controls
4. Jet pumps
5. Reactor coolant/recirc pumps
6. Reactor coolant/recirc pump motors
7. Reactor coolant/recirc pump MG sets
8. Reactor coolant system piping
9. Power operated relief & safety valves
10. Non-power operated safety valves
11. Pressurizer spray valves
12. Recirculation loop flow control valves
13. Pressurizer level instruments & controls
14. Pressurizer instruments and controls
15. BWR feedwater controls
16. BWR pressure controls
17. Main steam isolation valves
18. Atmospheric or condenser dump valves
19. Steam generator controls
20. Nuclear closed cooling water pumps
21. Nuclear closed cooling water piping
22. Nuclear closed cooling water valves
23. Nuclear closed cooling heat exchanger
24. Nuclear service water pumps
25. Nuclear service water piping
26. Nuclear service water valves
27. Nuclear service water heat exchangers

** Component names from NERC GADS database*

Digital Twin: Four Pillars of Data Analytics

Analytics	Operational Insight
Algorithms	Data Science
Data Mgmt	Data Model
Data	Data Quality

Digital Twin: The Core Innovation Behind GE's Digital Solutions

>550,000
GE Digital Twins created

WHAT IS A DIGITAL TWIN?

A Digital Twin is a digital replica of any industrial asset — like a gas or wind turbine that is used to monitor, analyze and improve its performance.

HOW THEY WORK

A Digital Twin continuously collects sensor data on the asset and applies advanced analytics and self-learning AI to gain unique insights about its performance and operation.

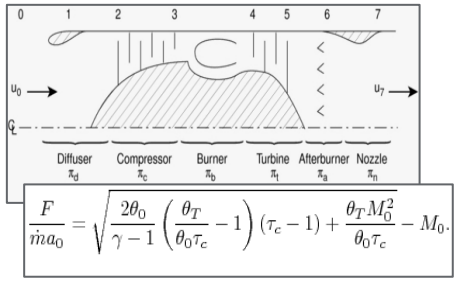
DIGITAL TWIN RESULTS

Digital Twins predict and respond to any customer problem and improve the operational and financial performance of an asset, plant or fleet.

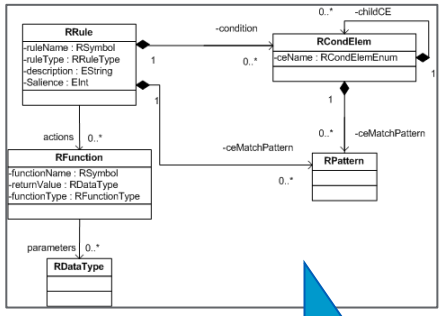
WATCH VIDEO:
Minds + Machines: Meet the Digital Twin
www.ge.com/digital/power-digital-twin

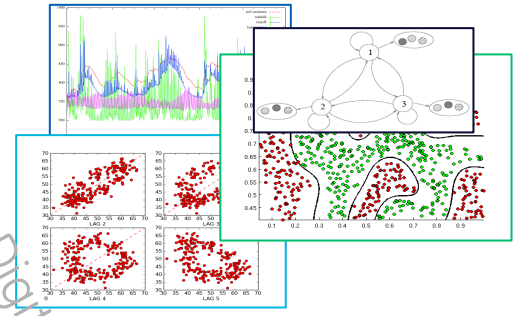
Key Differentiator: Digital Twin using Data Science:

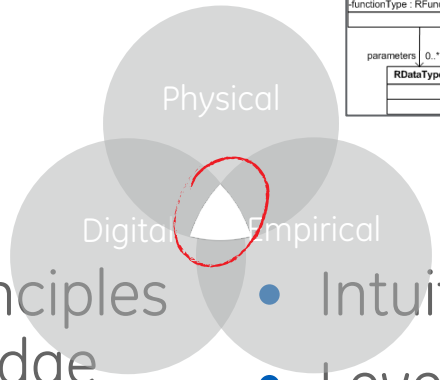
We work in the intersection of Physical, Empirical, and Digital

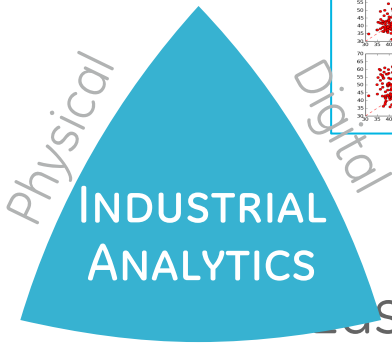


$$\frac{F}{\dot{m}a_0} = \sqrt{\frac{2\theta_0}{\gamma - 1}\left(\frac{\theta_T}{\theta_0 \tau_c} - 1\right)(\tau_c - 1) + \frac{\theta_T M_0^2}{\theta_0 \tau_c}} - M_0.$$









Physical

- Based on First Principles & Domain Knowledge
- Little Data Needed
- Loses Impact Over Time

Empirical

- Intuitive
- Leverages Accumulated Expert Knowledge
- Updates Along with Domain Experts

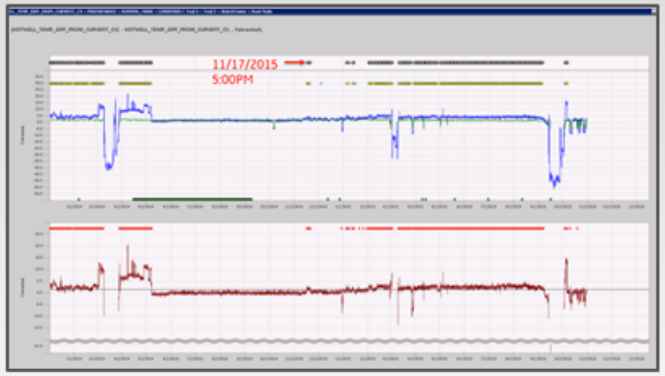
Digital

- Easy to Maintain & Scale
- Limited Data from Industrial Domain
- Bias: Predictively Limited to Past Events

APM increases event lead time detection – Earlier Prediction

1

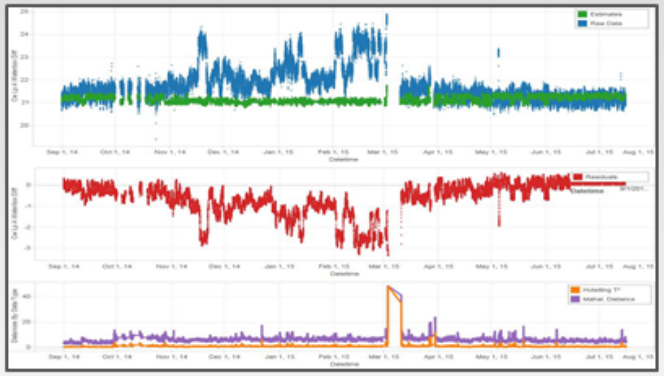
Legacy Analytics - **Good**



Condenser Issue Detected:
11/17/2015

2

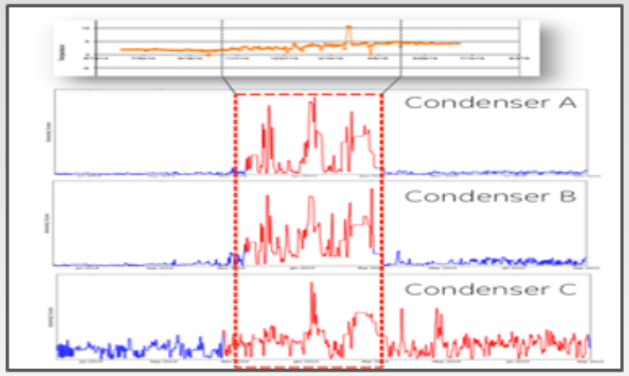
APM Analytics 2016- **Better**



Condenser Issue Detected:
11/16/2015

3

APM Analytics 2017 – **Next Generation**



Condenser Issue Detected:
11/07/2015 … 10 days earlier

Informing Customers Earlier on issues converts unplanned outages to planned outages. Reduces O&M Costs

The journey for formulating a Digital Transformation Strategy

Start with digital ambitions

Declare your ambition

Know where you Stand

Turn toward capability and value

Design the Future

Valuate & Prioritize Initiatives

Create the Roadmap

Execute to Achieve your North Star

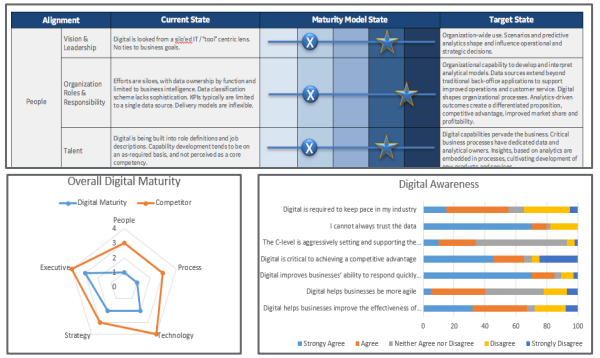
What is Digital Transformation Services?

GE's Digital Transformation Services *engages* and *emotes* senior business leaders in the changing world of industrial technology to define and accelerates their digital agenda.

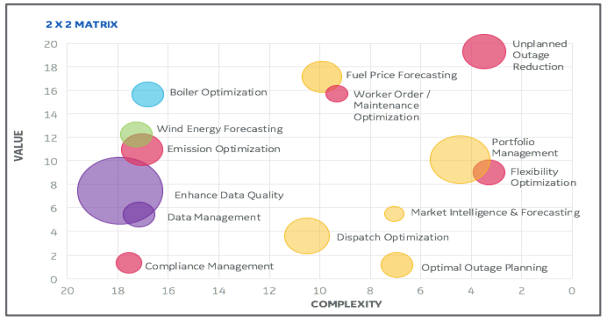
GE's Digital Transformation Services include...

Digital Visioning	Digital Effectiveness Diagnostic/ Assessment	Business Value Engineering	Digital on the Inside (People & Org)	Digital Transformation Mapping
What must I know?	*How are we doing?*	*What business value can we achieve?*	*How should we work?*	*How do we change?*

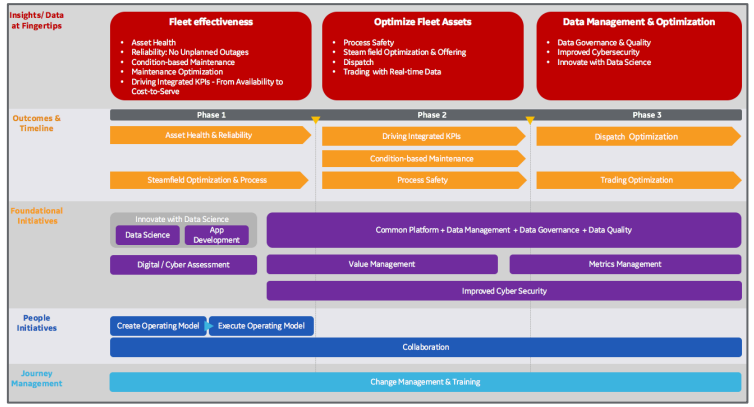
Pursuing digital transformation across the energy value chain is the **most effective** and **cost-efficient** way to address business challenges and achieve sustainable growth.



Capability & Maturity Assessment



Value Complexity Matrix



Digital Transformation Roadmap

Personal Experiences/Learning's …

1. **Action oriented approach has never been more important**
   Market / Environment evolving so fast, need to be comfortable moving without typical depth of analysis

2. **You must have a data strategy**
   Data is the new currency in our world. The wisdom behind step change improvements in operations and efficiency is embedded in readily available data. You must have a plan to effectively harness the data to leverage

3. **Need a mix of pragmatists and dreamers around you**
   Disruption is coming, and it will be significant. Need people who will challenge old beliefs and the status quo. Don't be afraid to disrupt yourself.

4. **Experimentation is not only OK, it's necessary**
   Digital allows for validation/invalidation of hypothesis relatively quickly/inexpensively. Not every hypothesis will be right… learn quickly and move to next.

5. **Be selective about who you partner with**
   Same optimism and enthusiasm toward the future paradigm shifts in our world, bias toward action vs. talk, significant investments / visions in the Digital space

Incredible Change / Disruption to Status Quo