

PHM Challenges for a Fleet of Marking Devices Embedded in Human Systems

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Outline

Xerox introduction

Marking device → fleet → system

Context for PHM

History of PHM at Xerox

Challenge: “fuzzy” failures

Challenge: scalability

Summary

Who we are



With sales of \$17.6 billion, we are the world's largest technology and services company specializing in document management.

- 2008 revenue: \$17.6B
- Fortune 500 ranking: No. 144
- NYSE: XRX
- Employees: 57,100 worldwide
- History: Founded in 1906 as The Haloid Company
- Headquarters: Norwalk, CT

What we do

For more than a half a century, Xerox has been in the business of making it easier to get work done.

Our job has never been more important than it is today as the world gets even more lost in information.

Xerox has kept pace with innovations that help your business **clear the path between paper and digital content...cut through the clutter and...make information relevant again.**



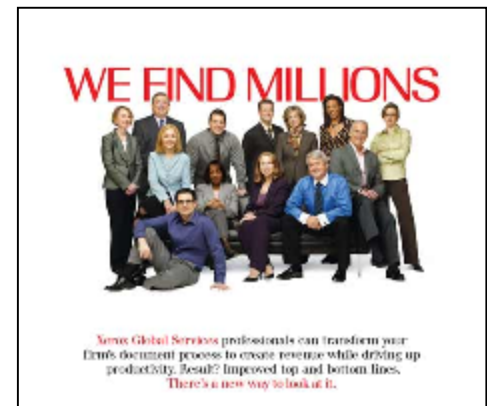
On & Off-Ramps to the digital world



Mass Customization



Document Services



Xerox: A Heritage and Future of Innovation

Our 60 year heritage of sustained & disruptive innovation continues

- Invented and established xerography
- Created laser printing, multi-function and digital publishing



- Shaped modern office computing
- Created the foundation for our “Digital Connected” world

2005 National Medal of Technology



IEEE Corporate Innovation Award



Who Am I?

Xerox Innovation Group: Leveraging world-wide talent to deliver innovative technologies in partnership with product engineering



*Xerox Research Centre of Canada
Mississauga, Canada*



*Xerox Research Centre Europe
Grenoble, France*



*Palo Alto Research Center
California, USA*



*Xerox Research Center Webster
New York, USA*



*Xerox Innovation Hub India
Chennai, India*



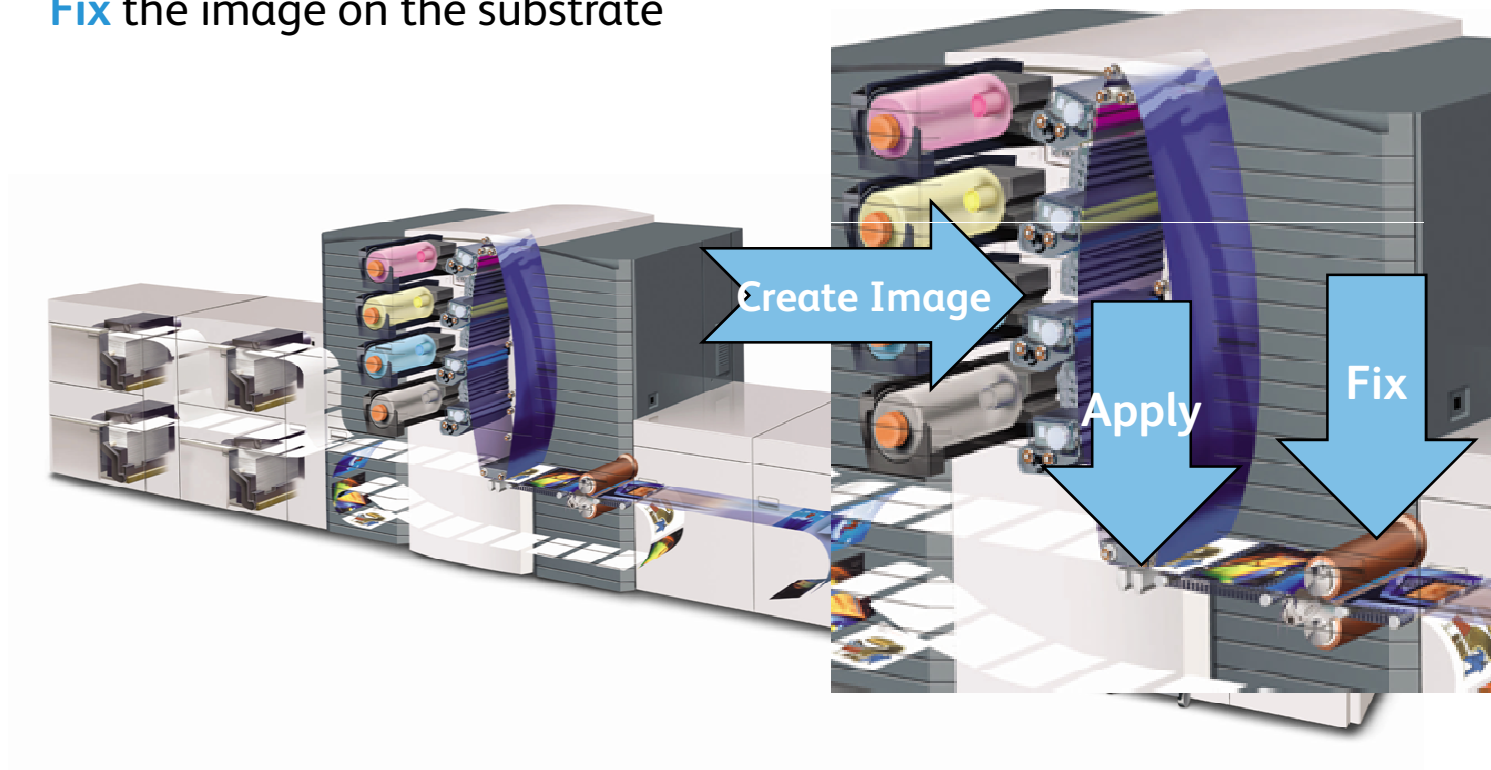
A printing primer

Common elements of all analog and digital print systems

Create the “inked” image

Apply it to the substrate (paper)

Fix the image on the substrate



Marking devices are “green button simple,” right?

- There are over **1 billion** pieces of toner on an 8x10 inch printed color image that have to get to the right place at the right time.
 - The human eye is one of the worlds best sensors and can detect consistent errors (e.g. long white space gaps) of about 5 microns or 1/20th the width of a human hair.
- Laser beams scan the photoreceptor surface at ~80,000 in/sec. This is about 4500 MPH or **~3.5X the speed of the F-35 Lightning II.**
 - We scan a total distance equivalent to the distance to the moon in a days work.
 - Our mirrors in our laser’s have rotational speeds ~3-5X > then those in the best disk drives.
- 100 ppm full color variable data printing requires complex processing of image data at combined rates of 3 Gbits/sec or over **2 times HDTV rates.**
- We accelerate paper from cardboard to tissue at **rates up to 3 G’s.**
 - This is equivalent to a car accelerating from 0-60 mph in < 1 sec. (Ferrari’s do it in 4 sec.) And is equivalent to accelerations achieved in top fuel dragsters and the Space Shuttle at take-off.

Our product fleet and the importance of post sale

Fleet characteristics

- ~1,000,000 devices in the field
- 80 new products launched in the past 3 years
- 160 countries served
- 13,000 service personnel



WorkCentre (office multifunction)



Nuvera (production monochrome)



ColorQube (office solid ink)

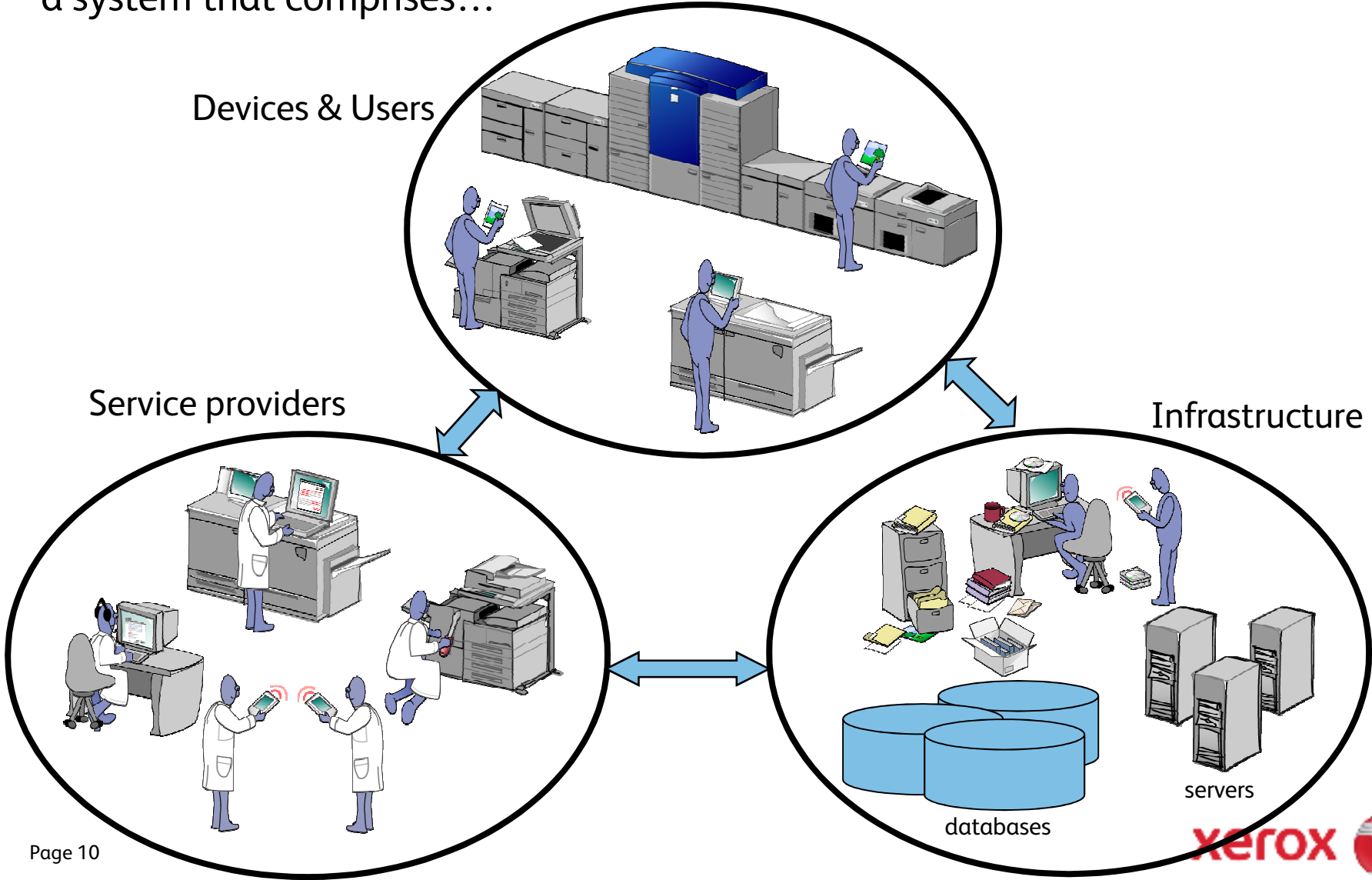


iGen4 (production color)

“**Post sale**” refers to annuity-based revenue from maintenance, services, supplies, and financing. Annually, this is a **\$12.9B** revenue stream (~70 % of our revenue).

System scope of the post sale challenge

Post sale challenge: Deliver superior post sale value at benchmark cost for a system that comprises...



We hear voices...

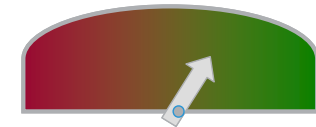
Voice of the customer: Customers want increased self-service

Self-Service

A service offering that incorporates elements of self-service where you or your operators can complete a subset of maintenance and repair tasks for your own devices.

Expected benefits: More uptime; less waiting for service; increased knowledge of machines.

Concerns: Added responsibility and risk; takes time away from machine operation.



High. Majority of customers are willing to put in some work to increase uptime.

Voice of the business: Xerox wants to move more calls to the left



How does PHM fit in?

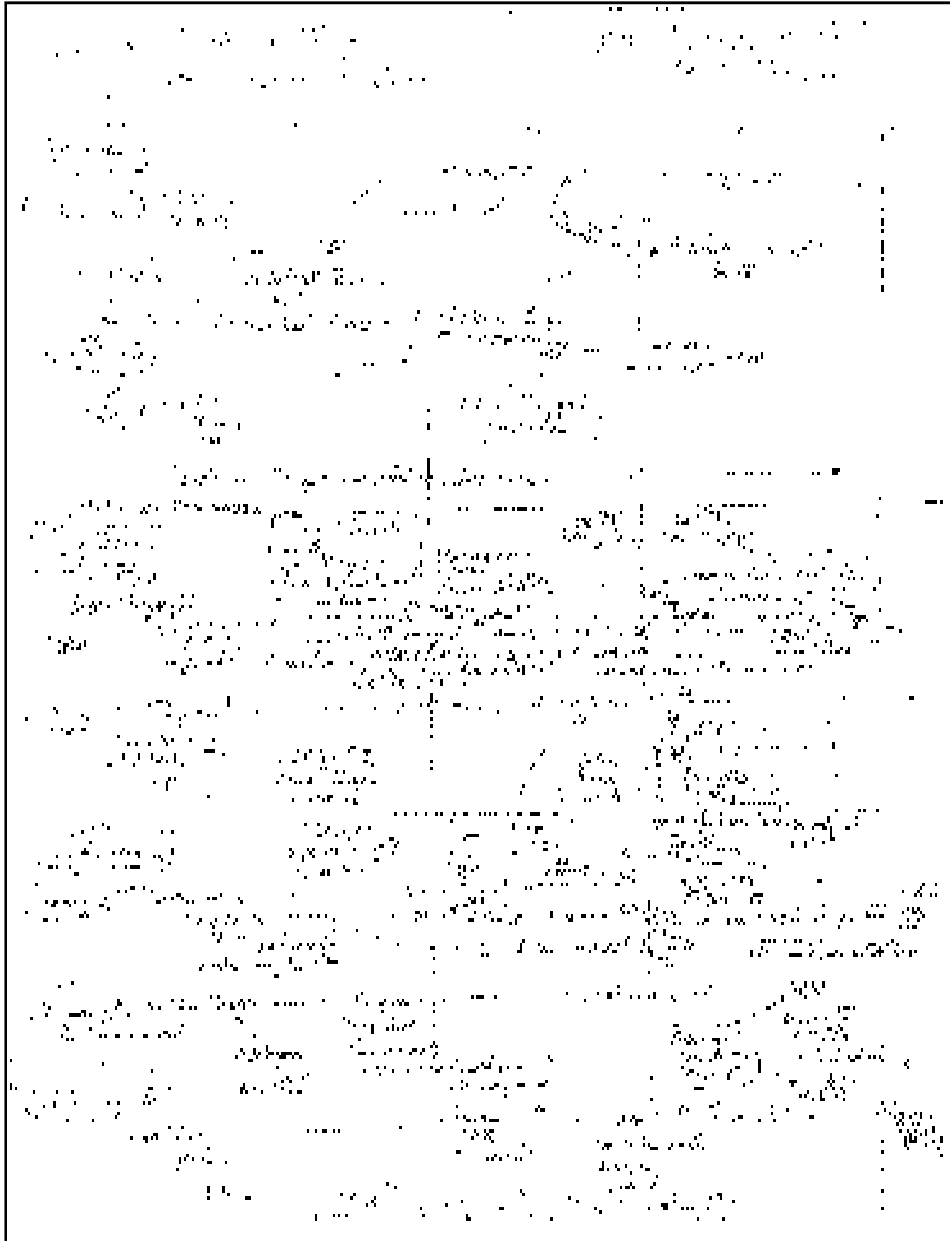
Goal: Delight our customers while meeting the post sale challenge.

Constraints

- Our products are complex electromechanical devices.
- Our product fleet is large, broad, geographically dispersed and ever changing.
- Our product fleet is embedded in human systems of device users and service providers.
- The trend is towards customized service offerings including self-service.

Approach: Embedded and remote PHM are key to our path forward

A brief history of PHM at Xerox



Key Messages

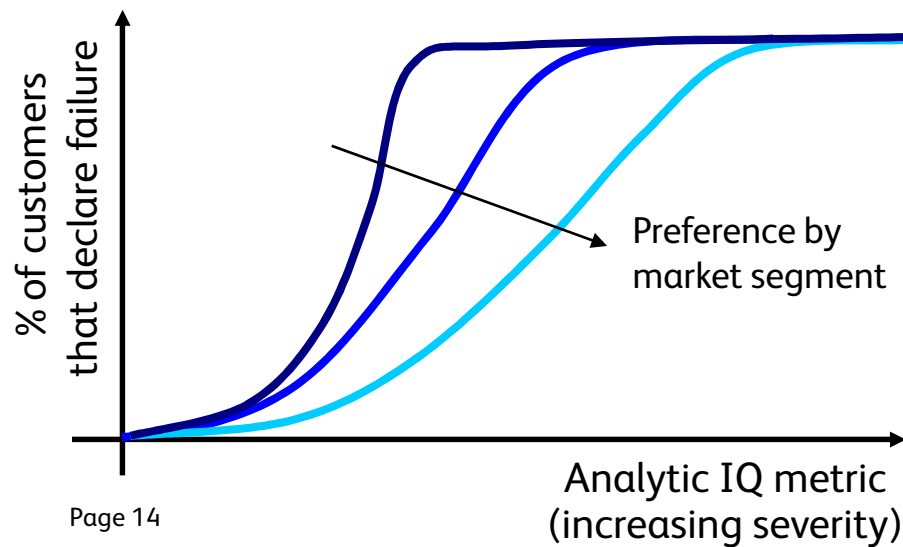
- We have experience with the human-in-the-loop, technological, and system aspects of PHM.
- Two key challenges are in the areas of “fuzzy” failures and scalability.

Challenge: “Fuzzy” Failures

Has a failure occurred?



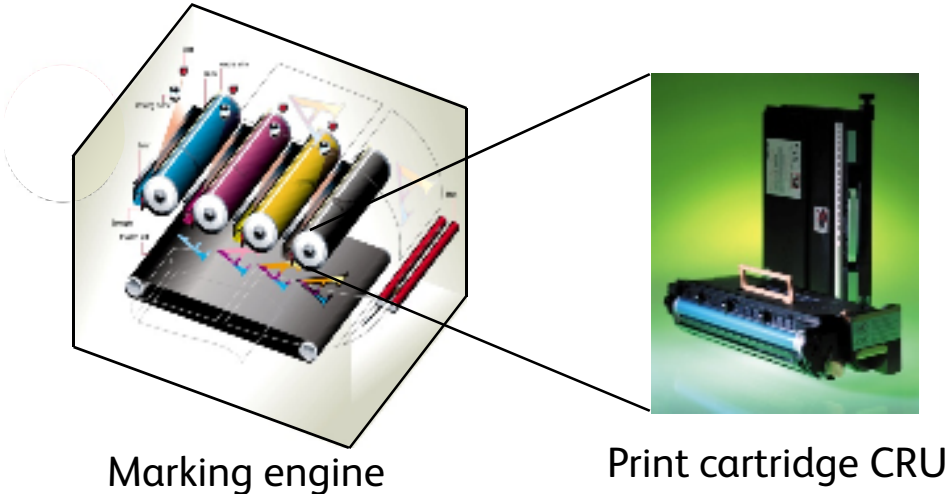
Are they the same?



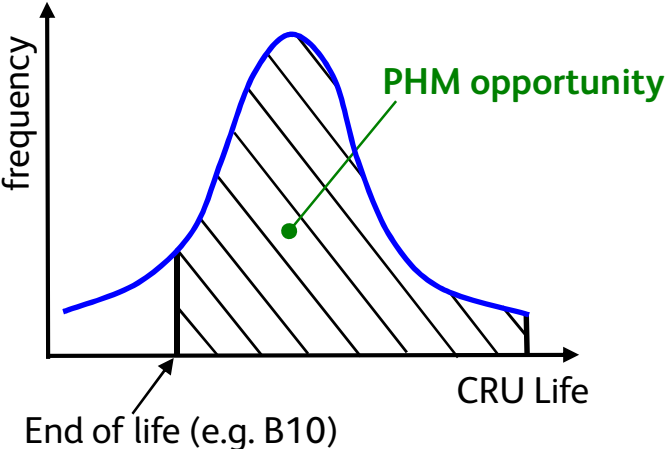
How do we treat fuzzy failures?

1. Give customer control
 - Call for service → lowers perceived reliability
 - Customer replaceable units (CRUs) → enhances perceived reliability
2. Use preventative maintenance

Customer replaceable units (CRUs)



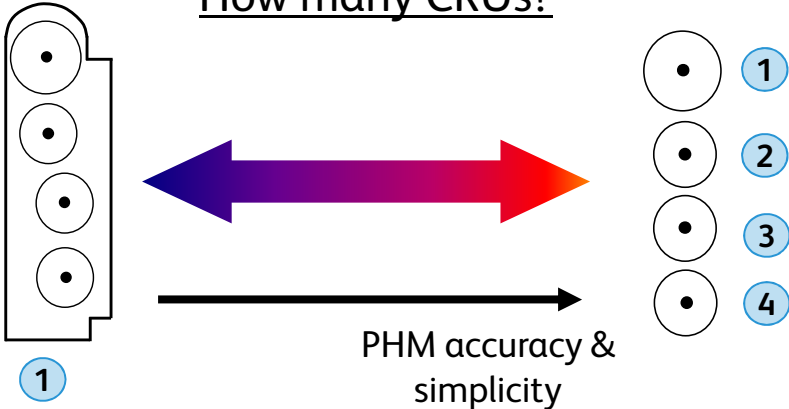
What is the design life?



Key Messages

- Current end-of-life is fixed based on a population statistic (e.g. B10 life) → opportunity for condition based maintenance (CBM).
- A significant portion of CRUs do not meet end-of-life expectations. Design and misdiagnosis are factors.
- Accurate, easy to use, directive PHM along with CRU design are keys for reducing run cost and increasing uptime.

How many CRUs?



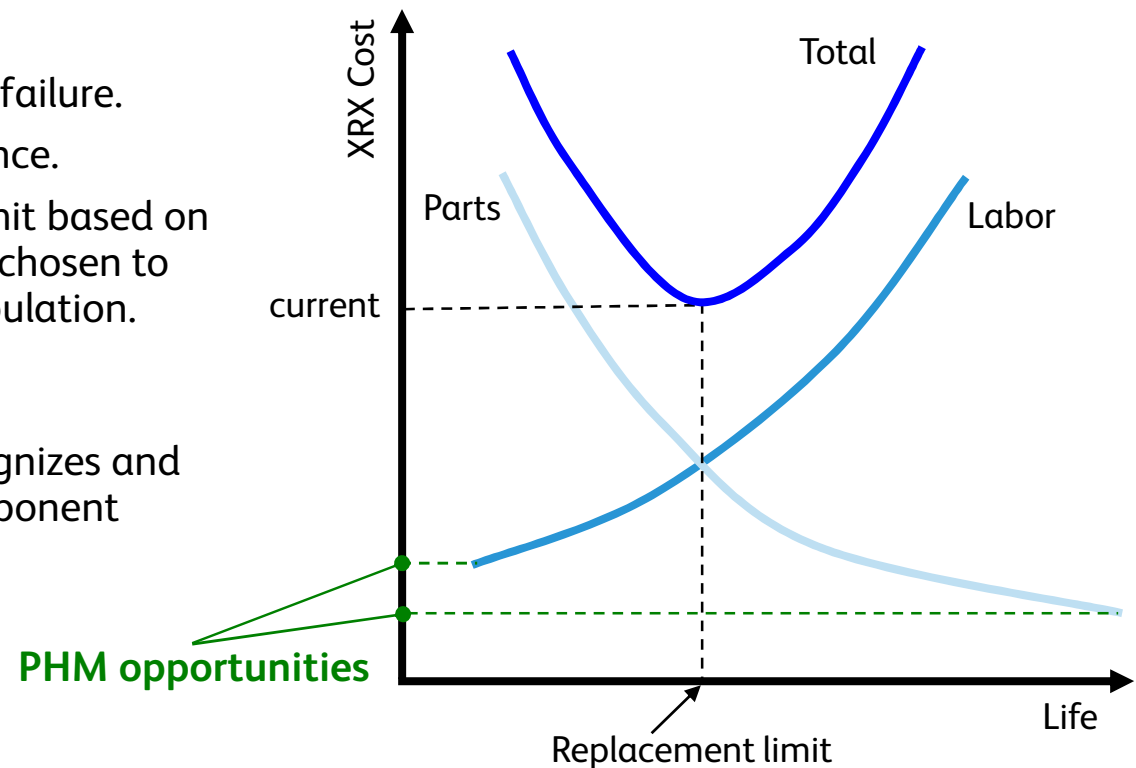
Preventative maintenance to customer self-service

Preventative maintenance (PM)

- Component maintenance prior to failure.
- Xerox service performs maintenance.
- Fixed component replacement limit based on intrinsic failure distribution and is chosen to minimize service cost over the population.

Customer self-service (CSS)

- “Move to the left”: customer recognizes and replaces some percentage of component failures.



Key Messages

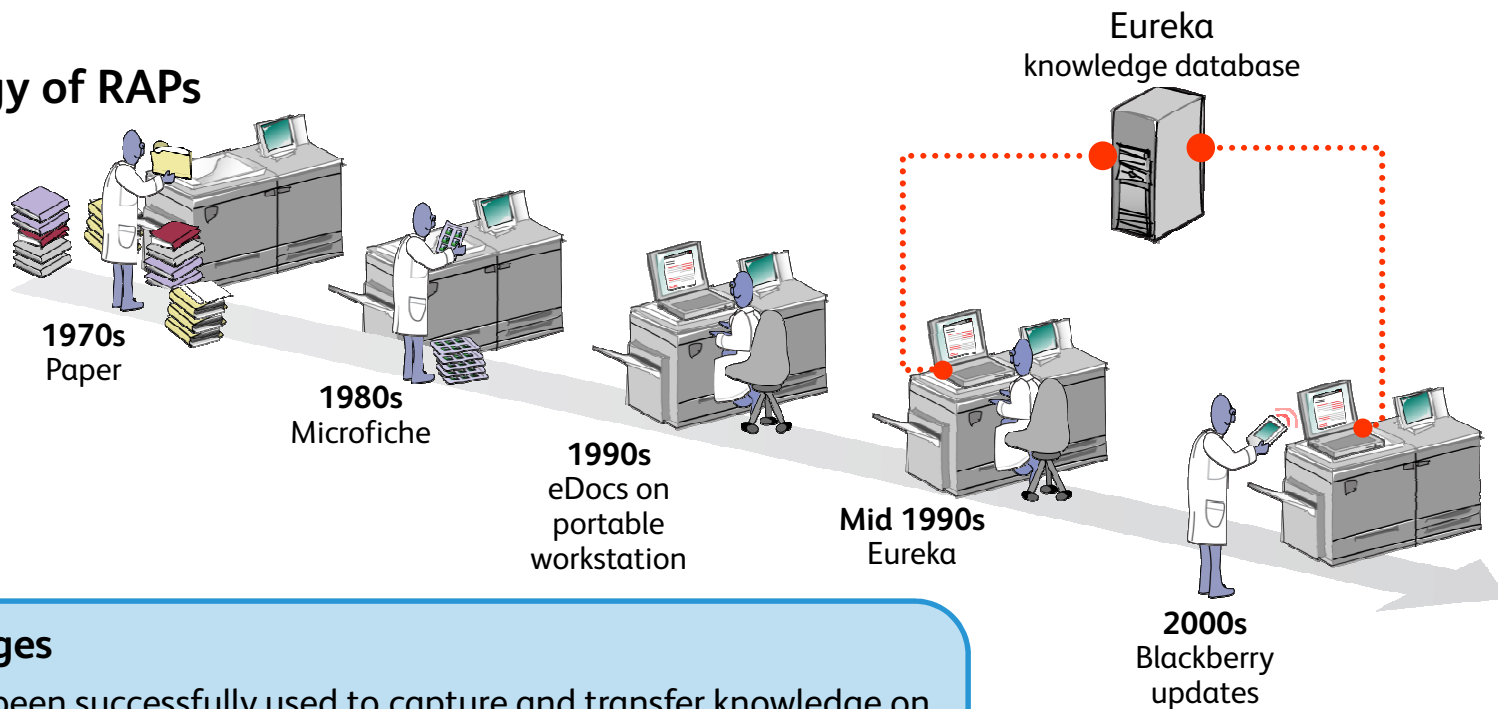
- Current replacement interval is fixed (e.g. B10 life) → opportunity for CBM.
- Transitioning from PM to CSS offers opportunity to reduce labor cost BUT, customer is more prone to mistakes. Need accurate, easy to use, directive PHM to enable.

Challenge: scalability

How do you deploy maintenance actions to service providers and device users across a large, diverse fleet?

- Repair Action Procedures (RAPs)
- Remote connectivity

Technology of RAPs

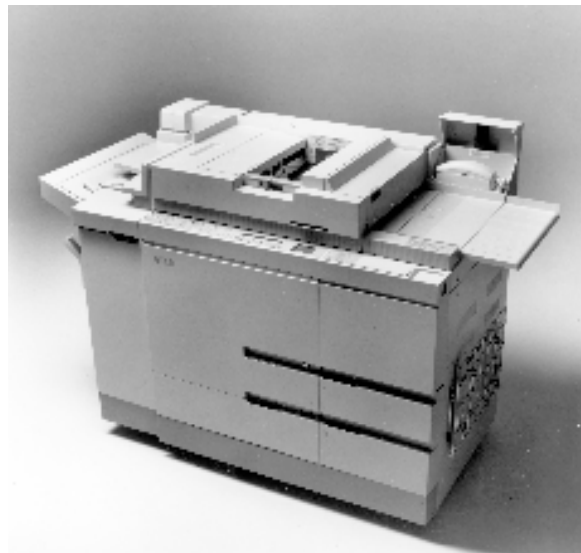


Key Messages

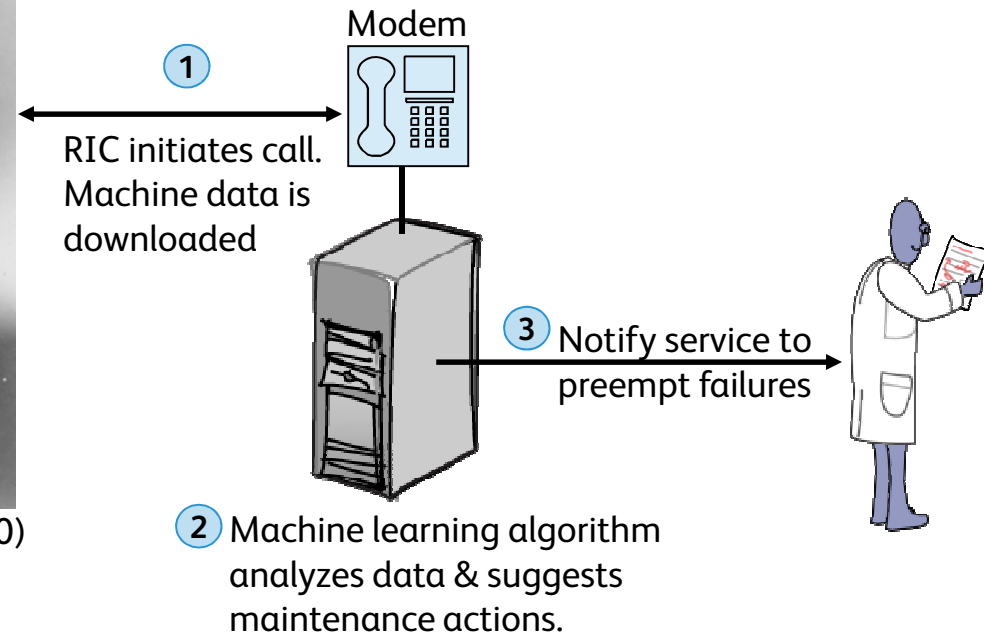
- RAPs have been successfully used to capture and transfer knowledge on maintenance actions. Disseminating RAPs has followed technology trends.
- Automatically generating customized RAPs to match the skill level of the operator (casual user to field engineer) is an important research area.

Addressing scalability via remote connectivity

Remote Interactive Communication (RIC) → an early attempt at remote prognostics



1st copier with RIC: Xerox 5065 (1990)



Key Messages

- **Accuracy:** PHM actions must be spot-on, otherwise actions will be ignored.
- **Service workforce:** Engage service early in the design phase and integrate PHM into the workflow, otherwise PHM actions will be ignored e.g. “I don’t have time to listen to a computer. I have customer calls to address!”
- **Customer:** Show the customer the value of PHM.

Summary

Our system includes...

- **Complex electromechanical devices** that are part of...
- A **fleet** that is large, broad, geographically dispersed, ever changing and embedded in...
- **Human systems** of device users and service providers.

PHM value proposition: Delight customers (→ product differentiation → grow revenue). Deliver post sale value at benchmark cost.

PHM Challenge: “Fuzzy” failures

- Addressed via service policy (CRU and preventative maintenance)
- Lesson: opportunity for diagnostics & CBM
- Going forward → accurate, easy to use, directive PHM

PHM Challenge: Scalability

- Addressed via RAPs delivered through various technologies.
- Addressed through remote connectivity.
- Lessons: include customer & service workflows upfront, accuracy is really important.
- Going forward → accurate, easy to use, directive PHM (notice a trend?)

