INL/CON-12-25995

Resilience in Control Room Modernization: Ten Resilient Control Room Principles

Ronald L. Boring, PhD

Vivek Agarwal, PhD

www.inl.gov

Idaho National Laboratory

LWRS
Light Water Reactor Sustainability

control room modernization

the problem space

DOE Light Water Reactor Sustainability Charter

- Assist utilities with safely extending the life of currently operating plants

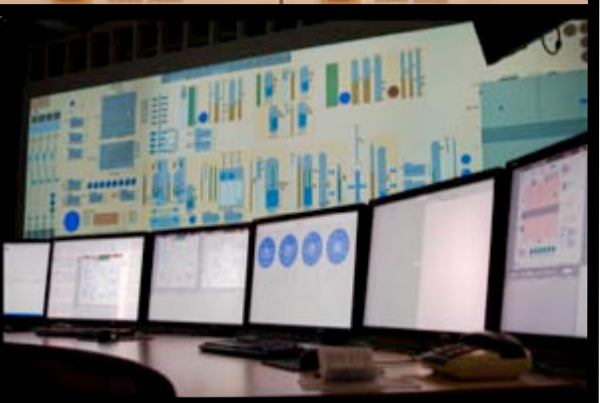
Our Framework

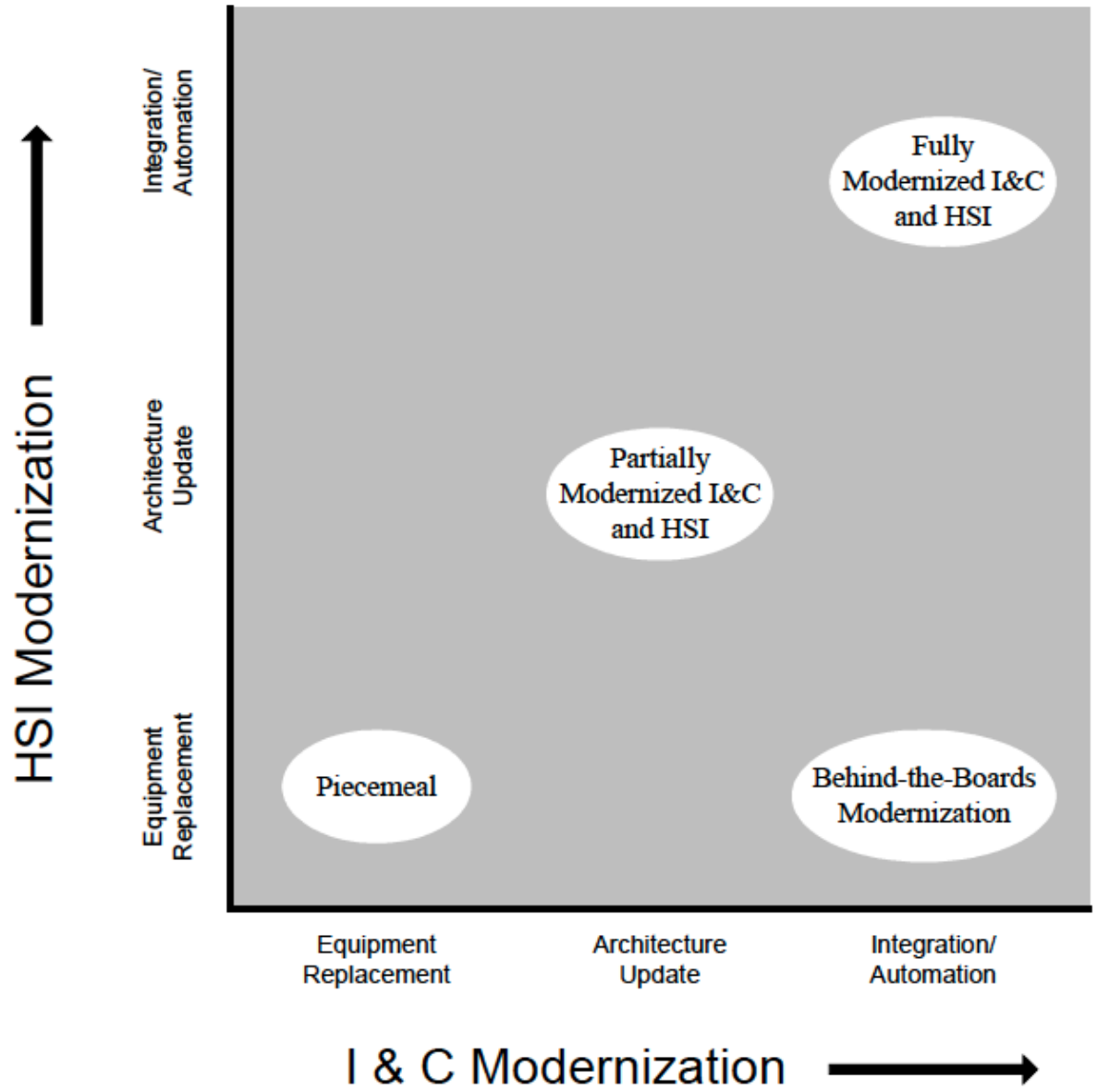
- Work with utilities to help them upgrade main control rooms

The State of Control Room Upgrades at Plants

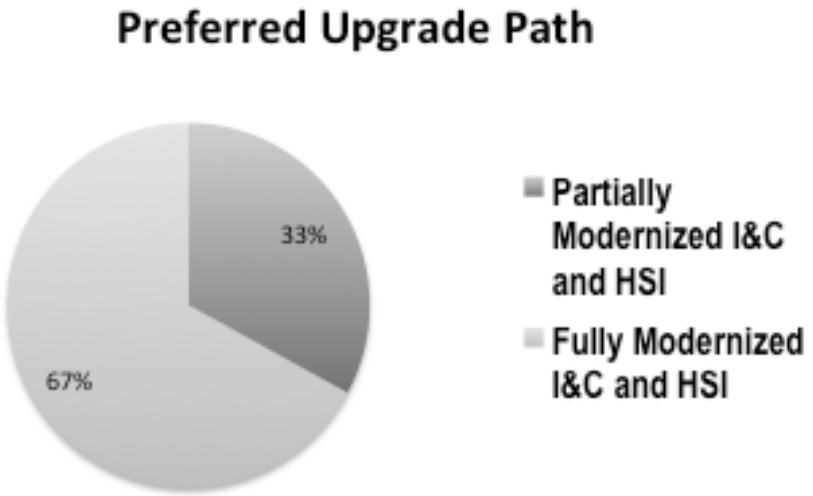
- None of 104 current reactors in US has upgraded main control room yet
- Obsolete analog-only technology with some digital islands
- Regulations make upgrades challenging
- Vendors providing mainly like-for-like replacements
- Piecemeal replacements instead of systematic upgrades
- Limited current human factors experience to leverage for upgrade process

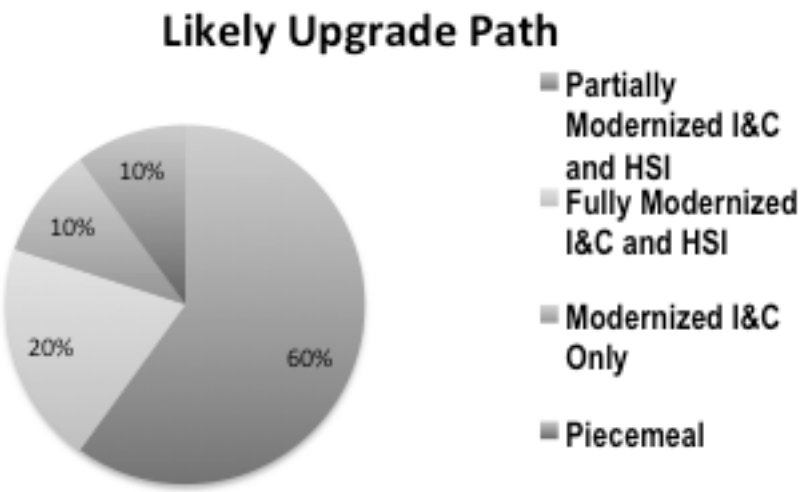
modernization ≠ new control room

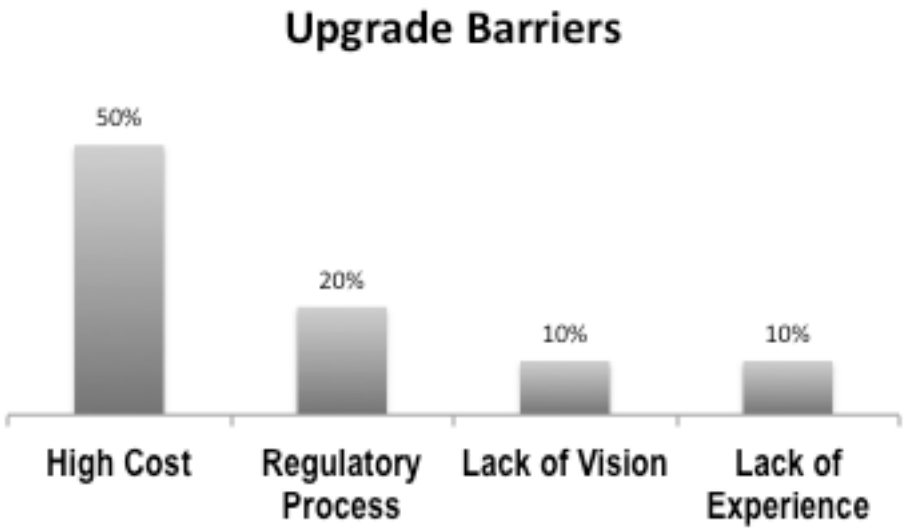




different control room upgrade paths







INL conducted a survey or 11 US utilities and 10 nuclear institutions in March 2012

our mission

Help Utilities Develop End-State Vision

- Vision should realistically address constraints but also move forward
- Bridge utilities, researchers, regulator, and vendors

Pilot Project on Main Control Room Upgrades

- Focus on human-system interface (HSI)
- Provide stepping stones to achieve vision
  - Human factors engineering program plan
  - Digital style guide
  - Operator-in-the-loop testing of candidate digital HSIs
- Champion research where needed
  - Provide proof-of-concept prototypes for eventual implementation by utilities and vendors
- Disseminate results to industry and regulator

Modernization brings new technology that must be integrated into existing systems

Challenge of resilience

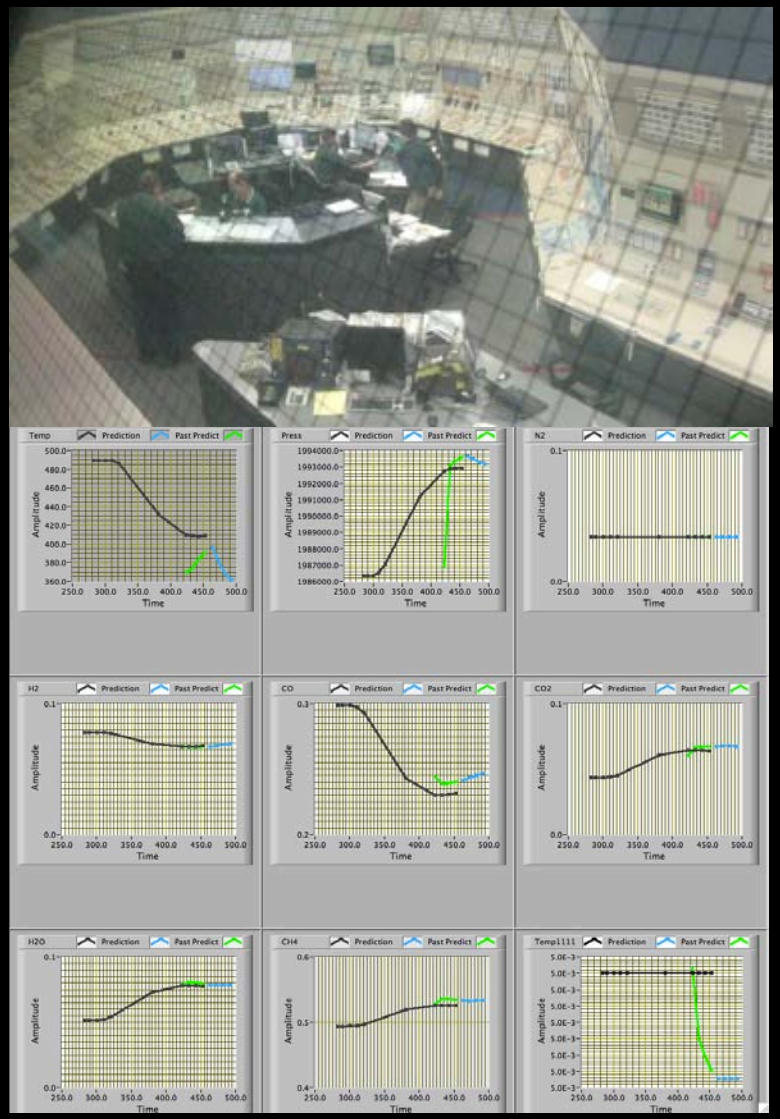
- Manage between analog and digital systems
- Opportunity to improve operator and system performance
  - Solution must include remedy and recovery from upsets

How do we get there?

ten principles for control room resilience

don’t drive backwards

resilient control room principle 1



DON’T DRIVE BACKWARDS

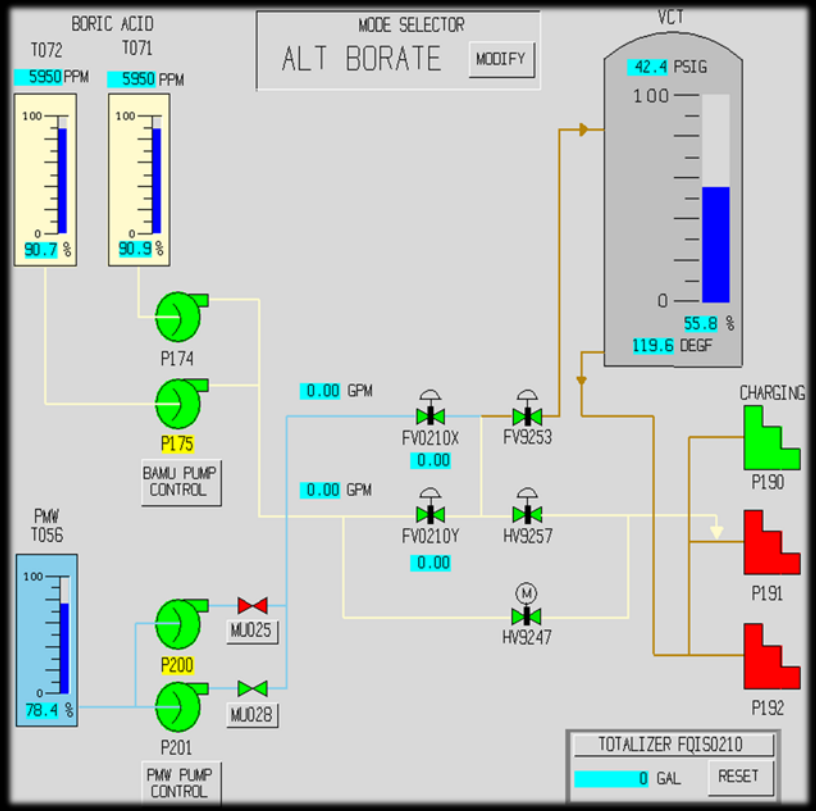
- Indicators in the control room tell what is happening now or trend what has happened
- One of principles of situation awareness is the ability to plan or anticipate
- To increase operator situation awareness, need interfaces that show operators not just where they’ve been but where they’re headed
    - Predictive displays

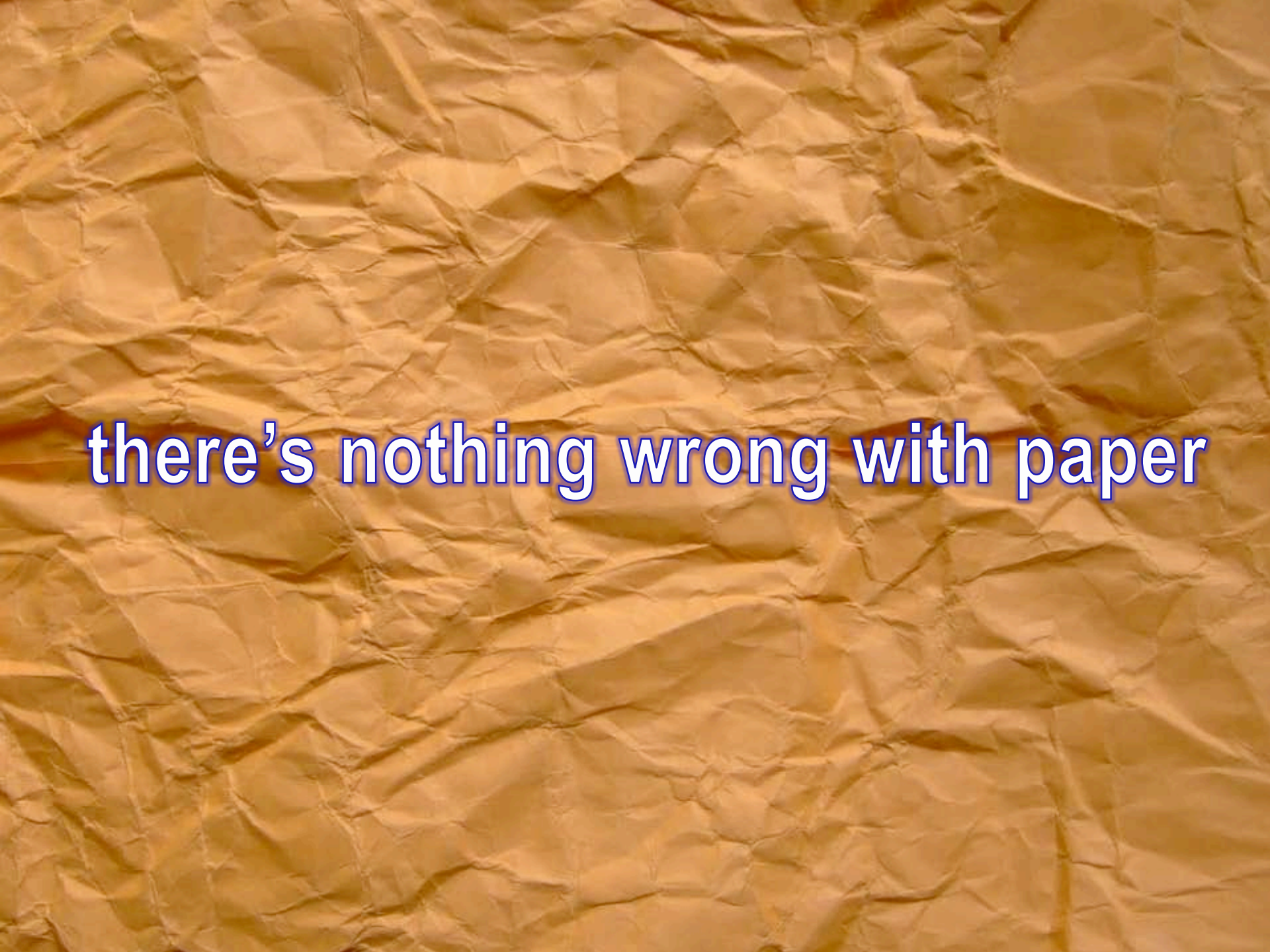
all that glimmers is not gold

resilient control room principle 2

ALL THAT GLITTERS IS NOT GOLD

- Many digital control systems are applying colors liberally
  - One design from an actual plant used color red in six different, contradictory ways on the same display
- Colors should not compete for operator's attention
- Colors should not require a legend
- Colors should have clear meaning
  - Stand out in an otherwise "dullscreen" environment to alert operator

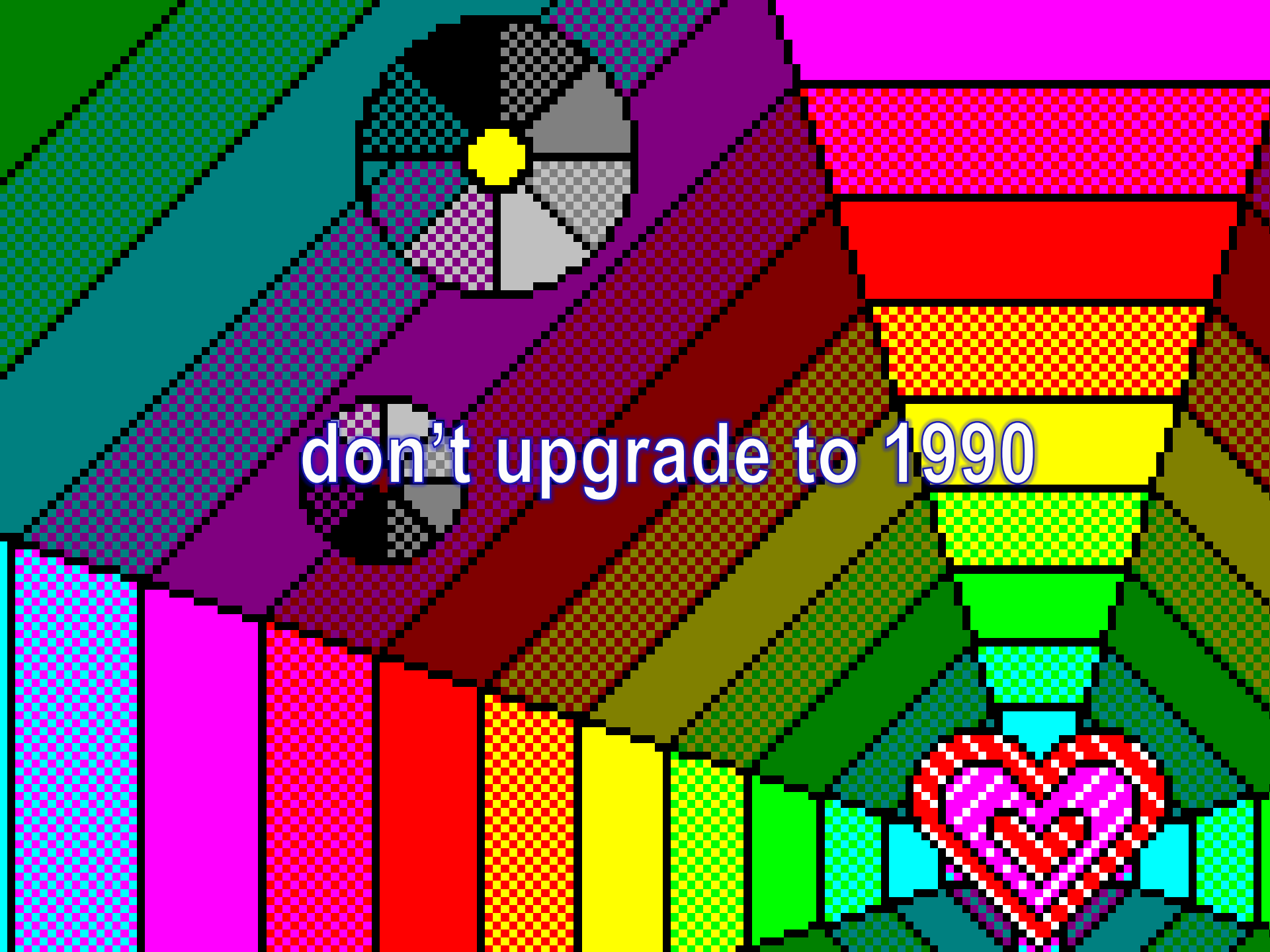



there’s nothing wrong with paper

resilient control room principle 3

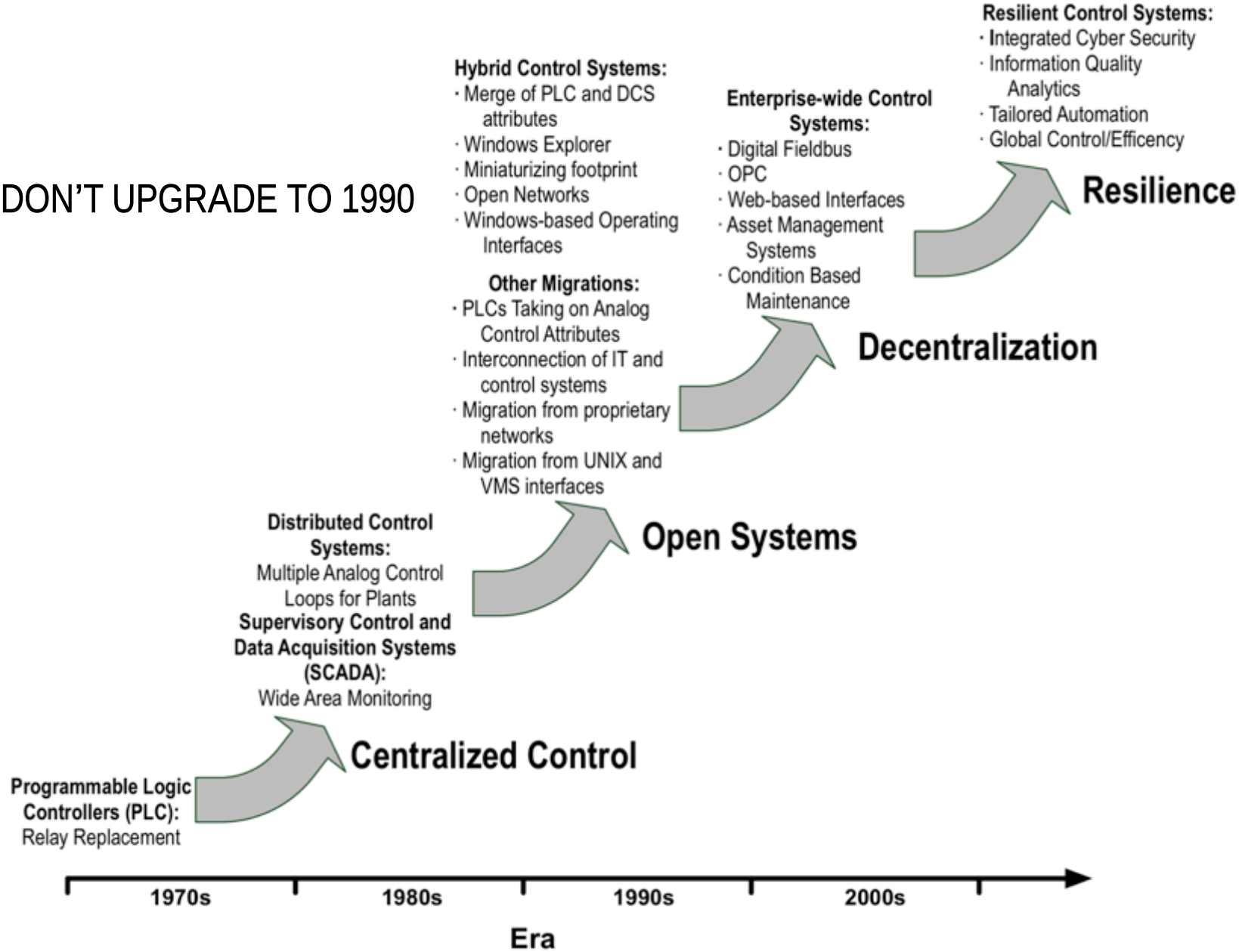
THERE'S NOTHING WRONG WITH PAPER

- Paper based procedures are current standard in plants, but move to replace with computerized procedures
- Experience at French N4 reactors suggests computerized procedures are:
  - Harder to maintain
  - Less reliable (paper doesn't need to be rebooted)
  - Less flexible
- Technology should not be main driver for new procedures


don’t upgrade to 1990

resilient control room principle 4

DON'T UPGRADE TO 1990

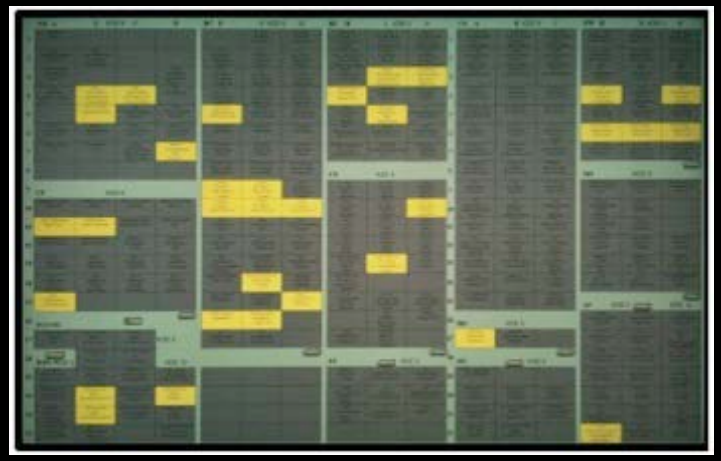


analog is beautiful

resilient control room principle 5

ANALOG IS BEAUTIFUL

- Advantages of analog
  - Graceful degradation
  - Simpler design
  - Operator familiarity
  - Affordance of controls
- Analog controls and indicators have been refined over decades
  - Assumption that digital is better is analogous to saying DOS is better than typewriter
  - Understand unique advantages of digital
  - Propagate what worked in analog



beware of
keyholes

resilient control room principle 6

BEWARE OF KEYHOLES

- Keyhole Effect has been demonstrated in control rooms
  - Operators focus narrowly on workstation
  - Breaks down traditional threeway communication
  - Breaks down shared workspace
- Important to ensure that digital replacement systems allow both individual and collaborative work

find digital islands

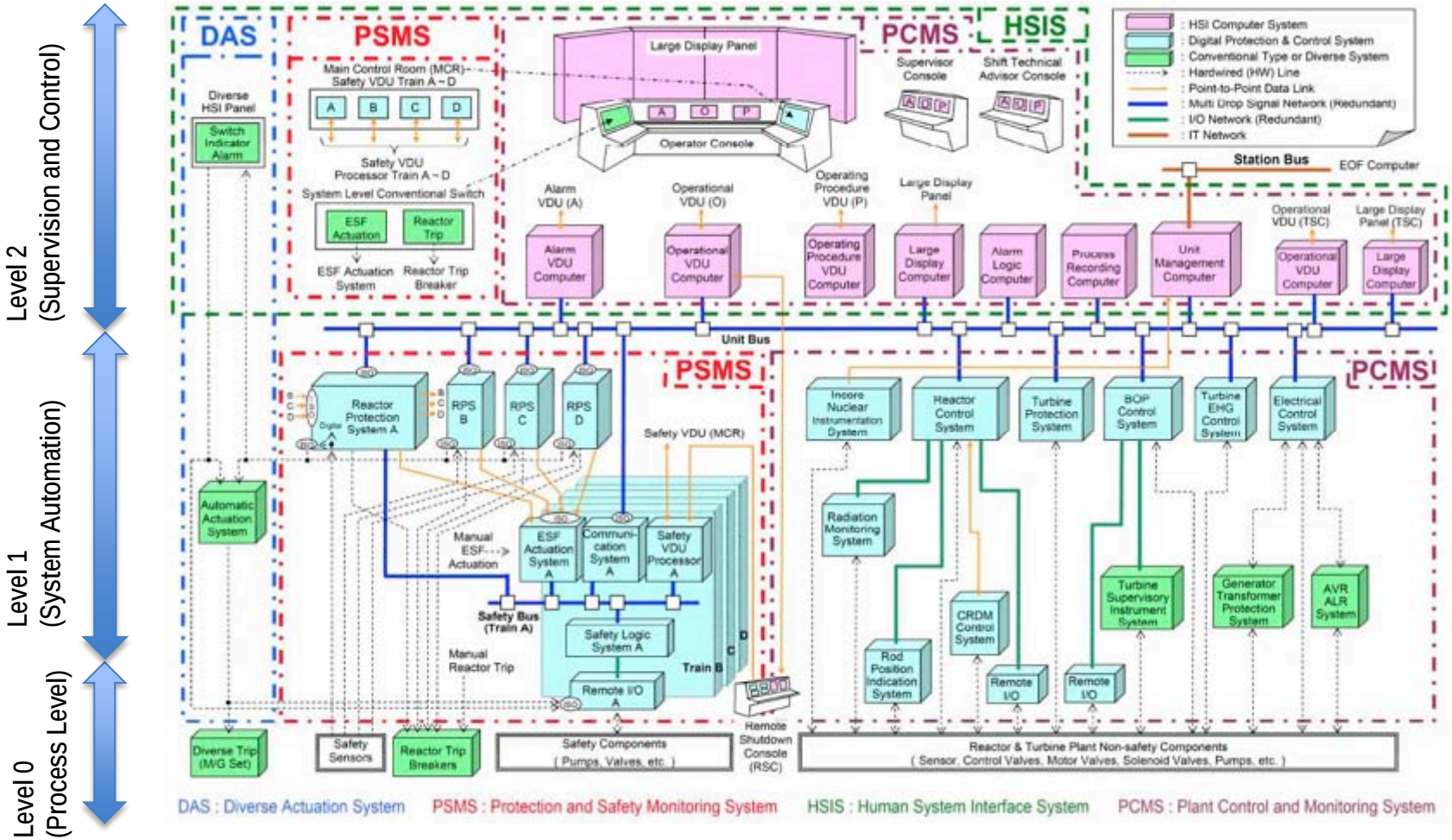
resilient control room principle

FIND DIGITAL ISLANDS

- The 100% solution may not be optimal for costs or operators
- Introducing selective digital systems that help operators make monitor, make decisions, and operate plant can increase overall resilience

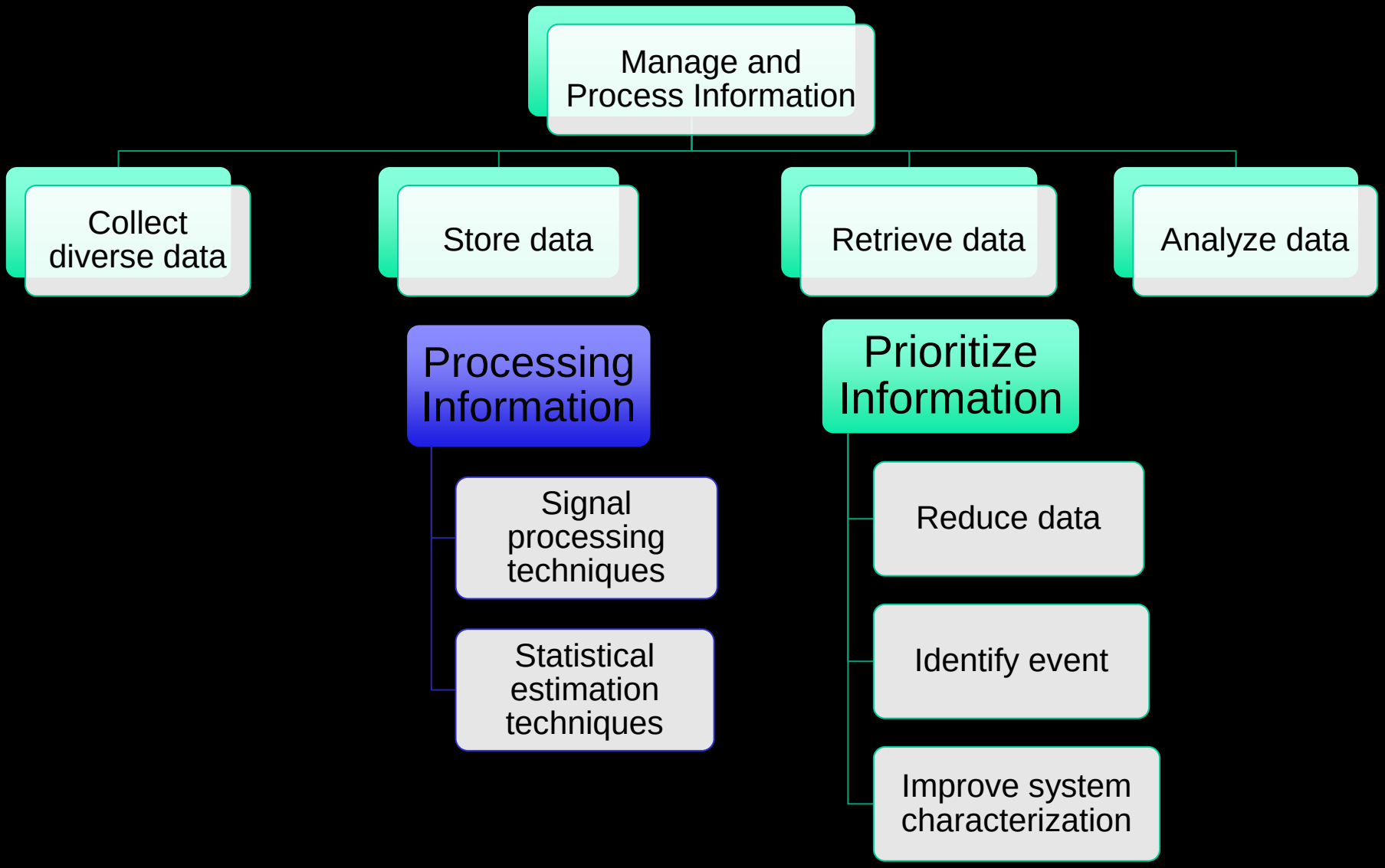
manage
information

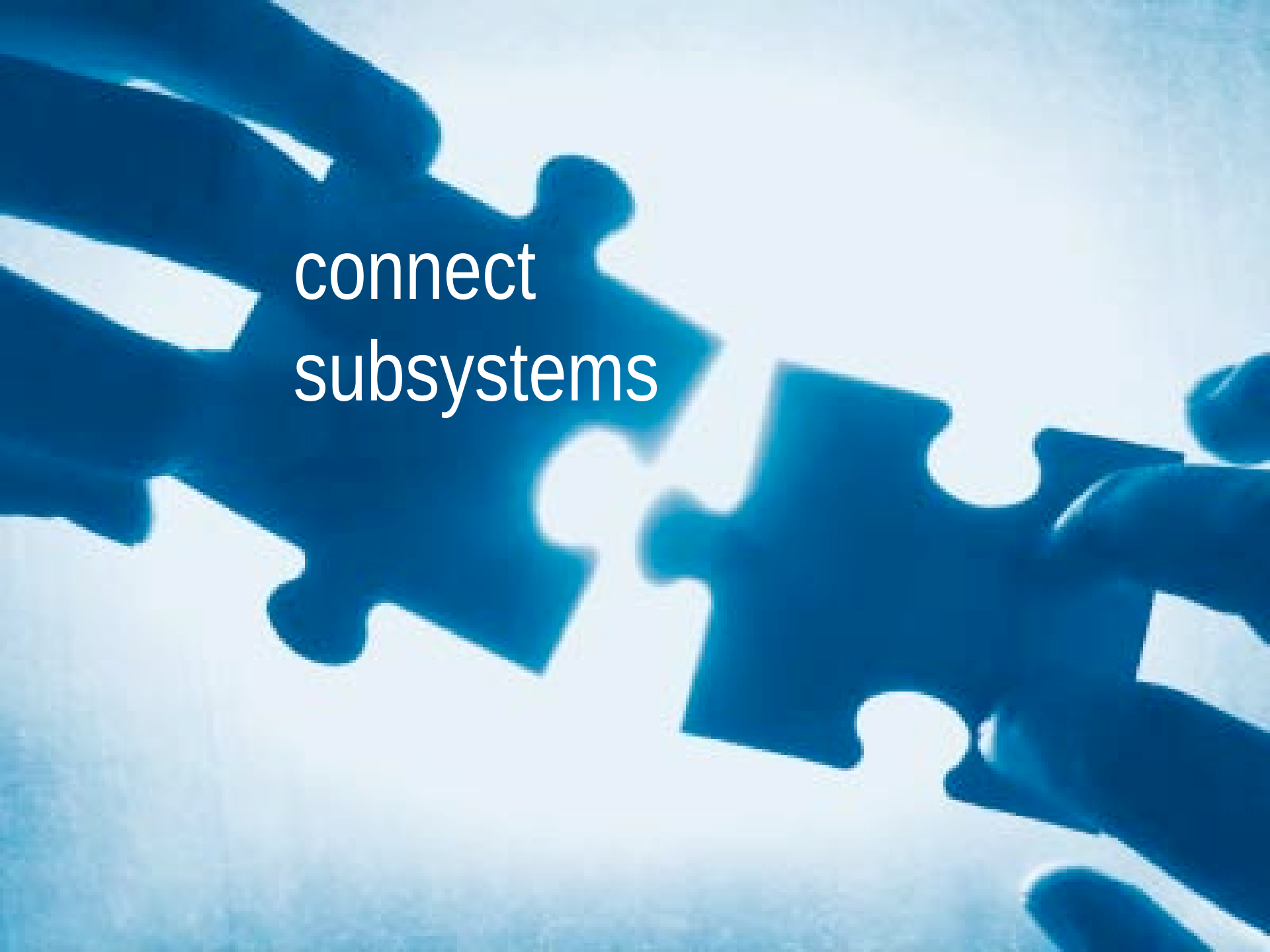
Instrumentation and Control Architecture*



* NUREG/CR-6992: Instrumentation and Controls in Nuclear Power Plant: An Emerging Technology

resilient control room principle 8




connect
subsystems

resilient control room principle 9

CONNECT SUBSYSTEMS

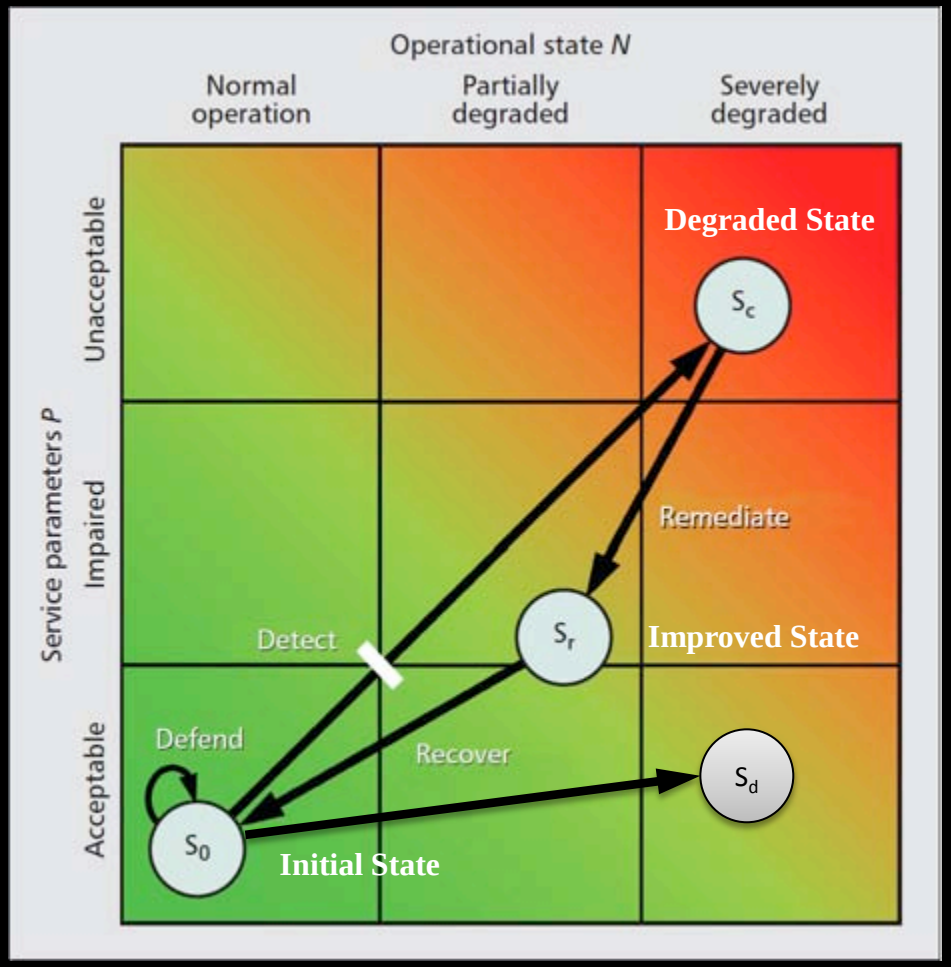
- Maintain knowledge about the communication environment
- Identify and remove challenges
- Minimize delay
- Maintain connectivity
- Distinguish between legitimate disruption versus malicious attack
- Be reconfigurable

measure
Resilience

resilient control room principle 10

MEASURE RESILIENCE

- How to measure and quantify resilience?
- A single value in the interval [0, 1] is preferred to represent the resilience of a network (ideally)
- Due to hierarchical structure, there are many parameters that contribute to the measure of resilience
- Granularity defines the number of states that can be attained



recap

ten resilient control room principles

1. don’t drive backwards
2. all that glitters is not gold
3. there’s nothing wrong with paper
4. don’t upgrade to 1990
5. analog is beautiful
6. beware of keyholes
7. find digital islands
8. manage information
9. connect subsystems
10. measure resilience

ultimately control room modernization

- should enhance operator’s situation awareness
  - improve monitoring, decision making, planning, and control
- should balance novel technology with what backend and interface elements worked already
- should consider opportunities for increasing system alongside operator resilience

questions ?

RONALD.BORING@INL.GOV
VIVEK.AGARWAL@INL.GOV