ResilientGrid

Smart and Resilient Human-Systems Interactions for Installations of the Future

Mike Legatt, Ph.D.

Installations of the Future
19 June 2018

Overview

- Introduction
- Brain overview: amygdala vs. prefrontal cortex
- Reliability, Resiliency, and Robustness
- Overview of today's problems (electric power as an example)
- Human behavior, energy demands, and emerging grid technologies
- Managing cognitive load in control rooms and the field
- Habits and reducing activation energy
- Organizational culture in resilient installations
- Visual system design
- Fatigue and reliable operations

Core Philosophy:

"All organizations are perfectly aligned to get the results they get."

Arthur W. Jones

Interconnecting Organizations

In many ways, human beings are like components on the grid. They each have their tolerances and optimal ranges of function. With advanced training, you can finely tune can calibrate many of these ranges, but only within limits.

If you interconnect them well, you can build a strong, reliable and self-healing system. Conversely, you can create sub-synchronous resonances by incorrectly interconnecting them: in this you create inefficient circuits that waste energy and time, and create heat, risk and cost.

Managing people is no more and no less than being an organizational reliability coordinator.

Interconnecting Organizations

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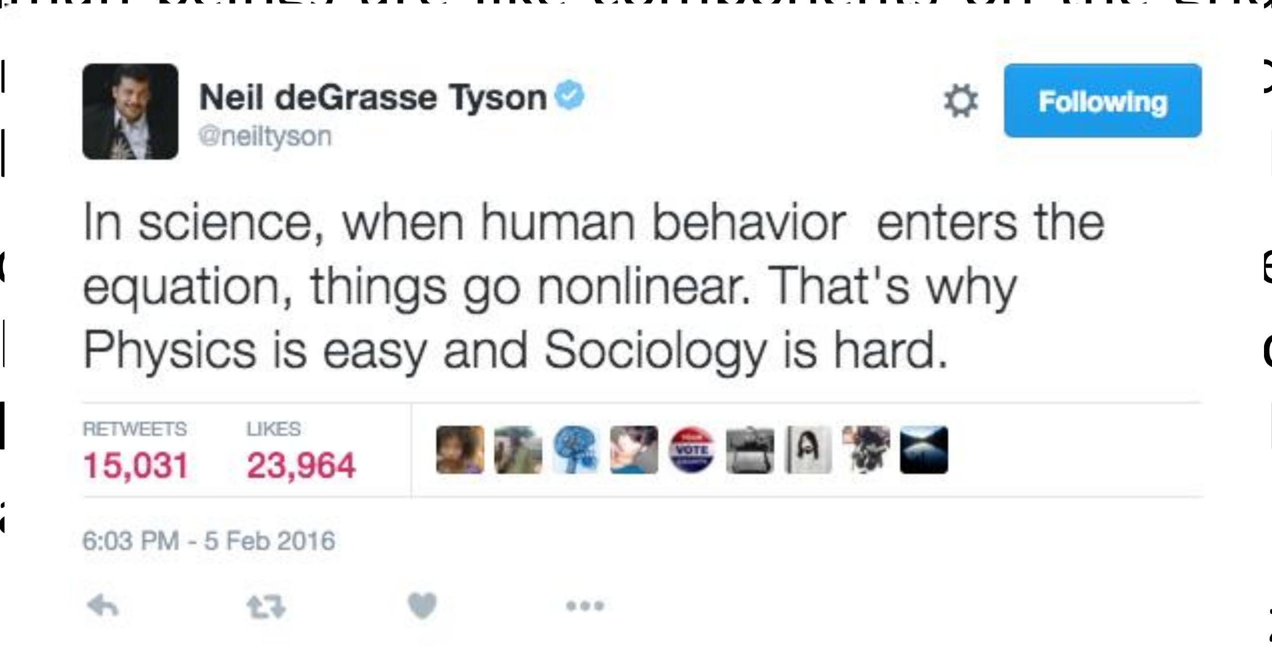
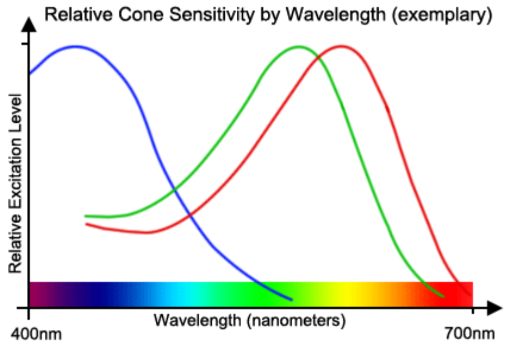
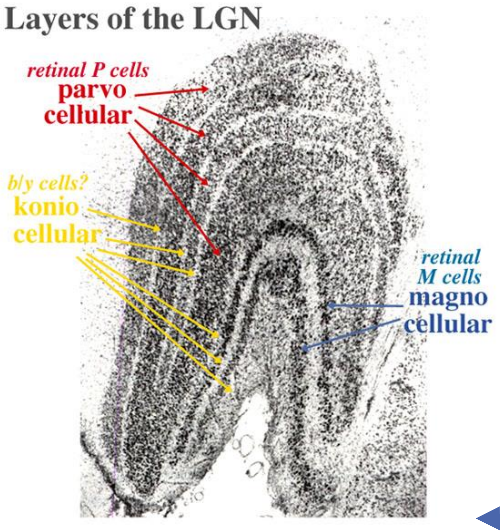
Managing people … …zational reliability coordinator.

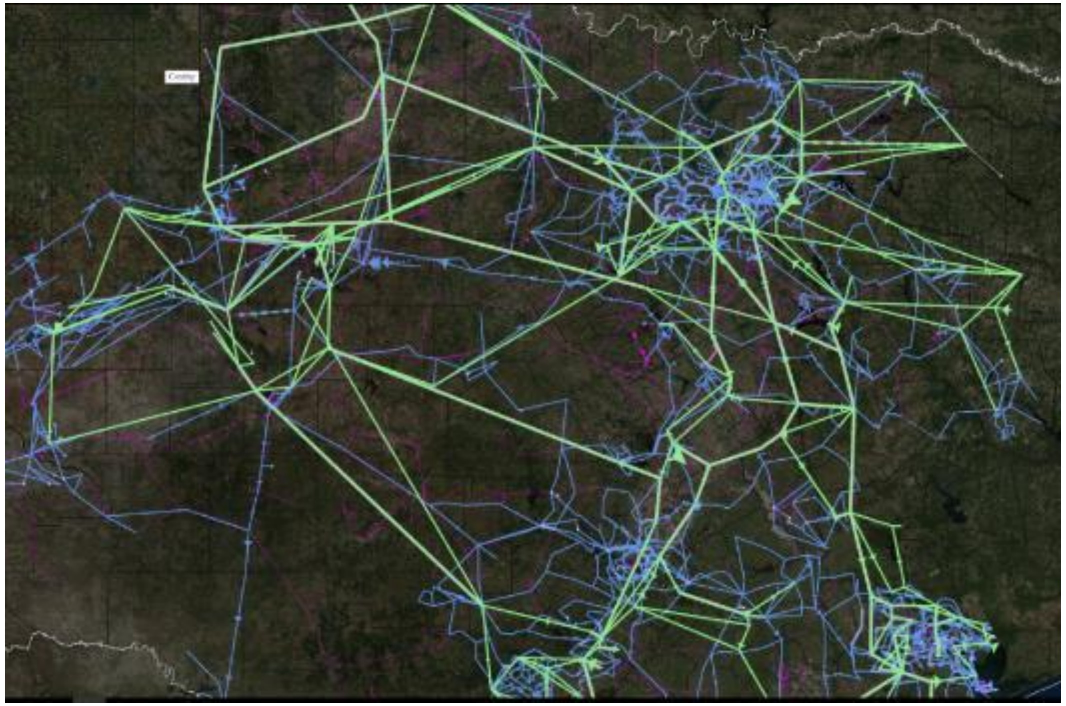


Who Am I?

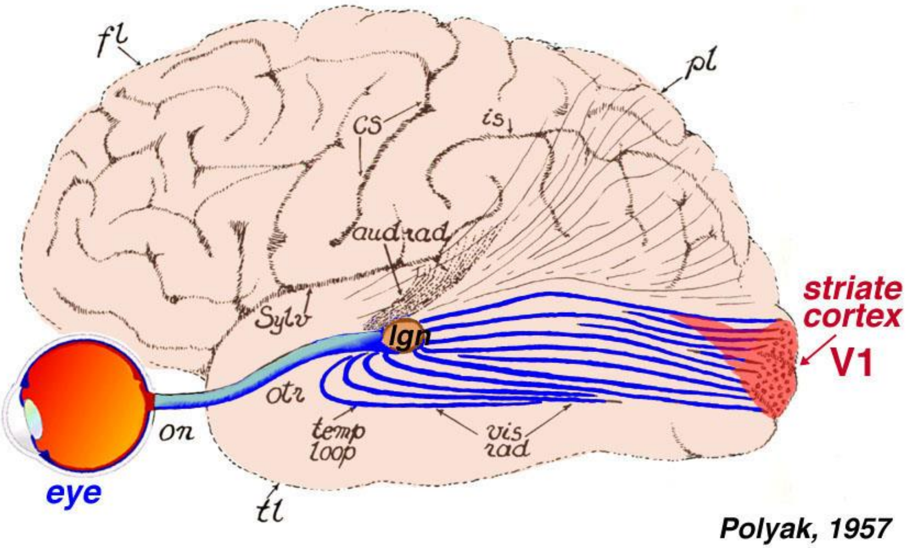
What do I do?



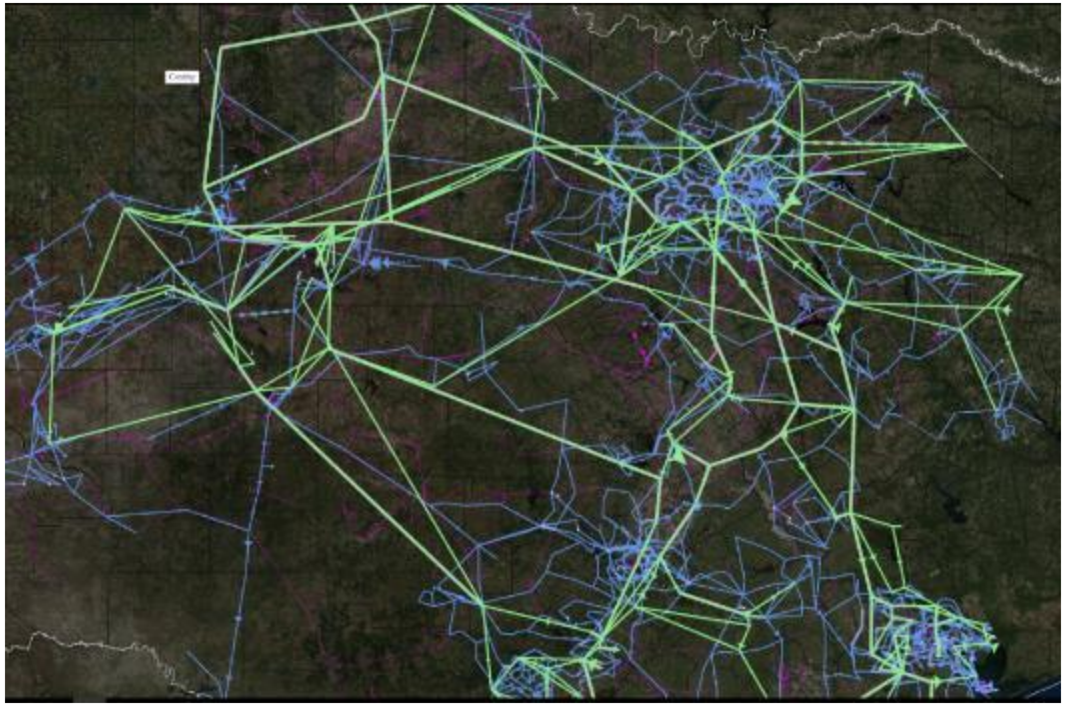




Nonlinear
Contrast
Gain
Control



What do I do?



Normal Ops ⟷ Emergency Ops

Socio- ⟷ Technical

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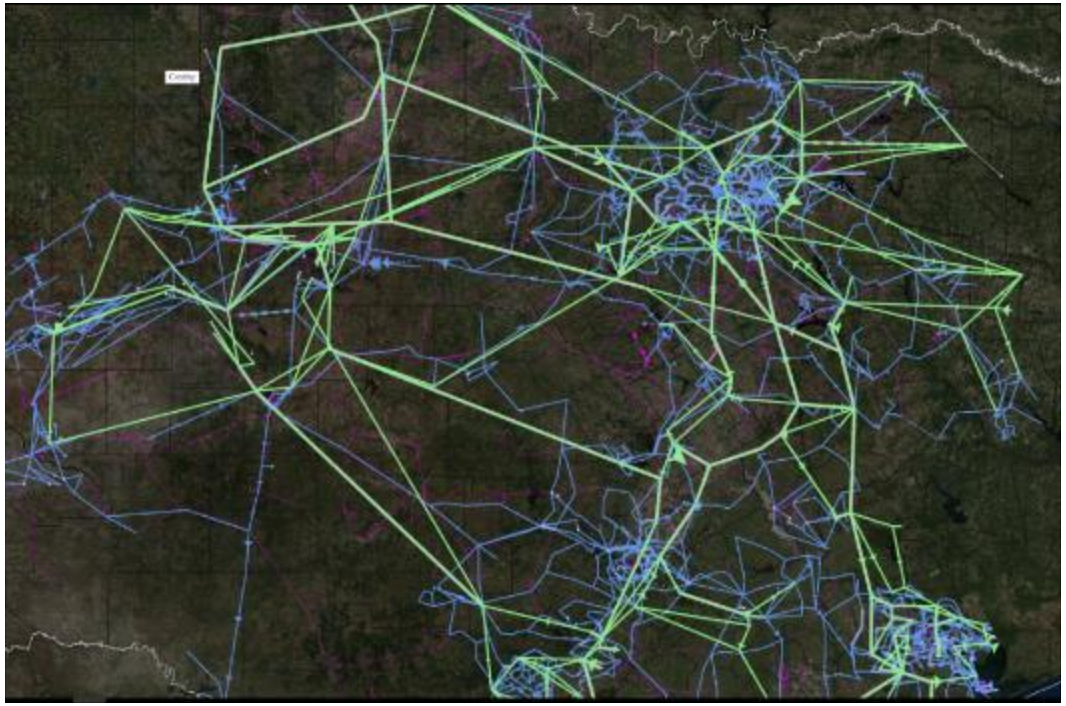
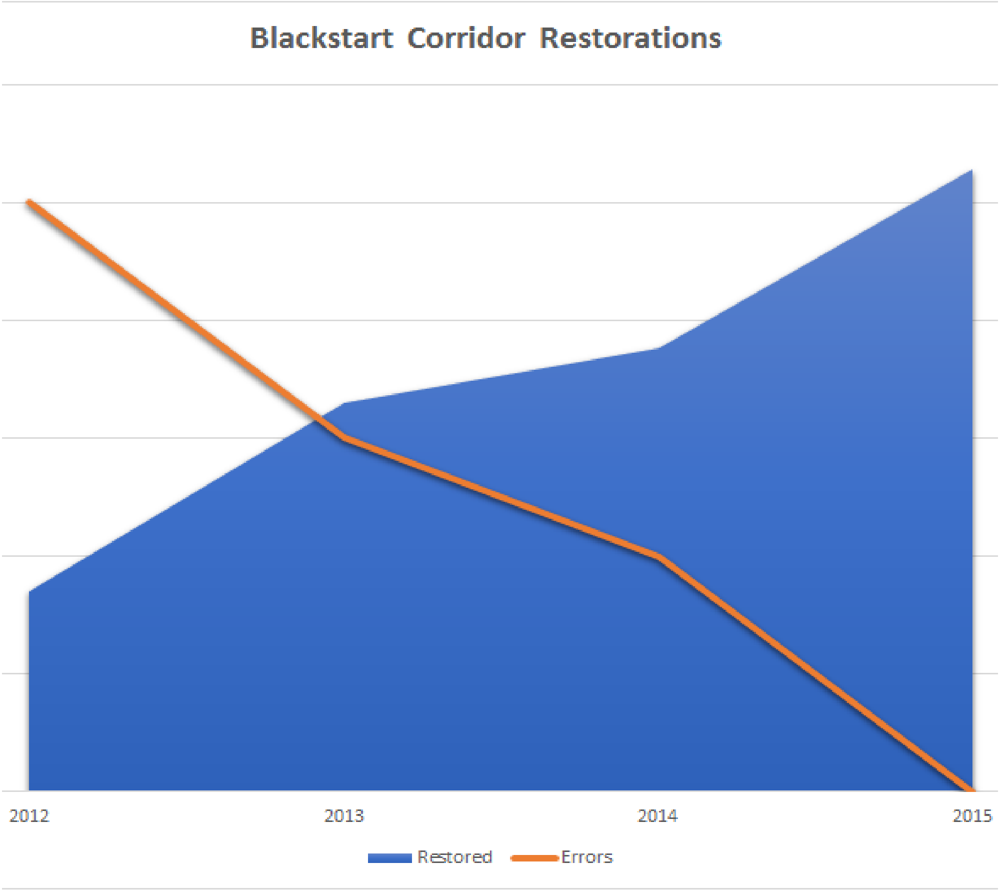
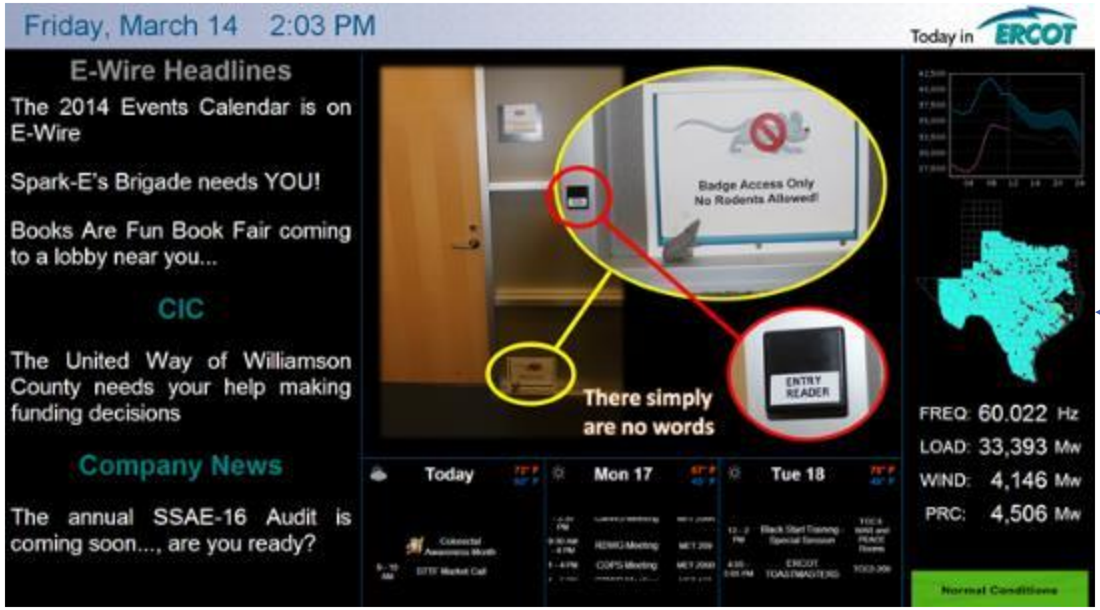
Does It Work?




Blackstart Corridor Restorations
2012
2013
2014
2015
Restored
Errors

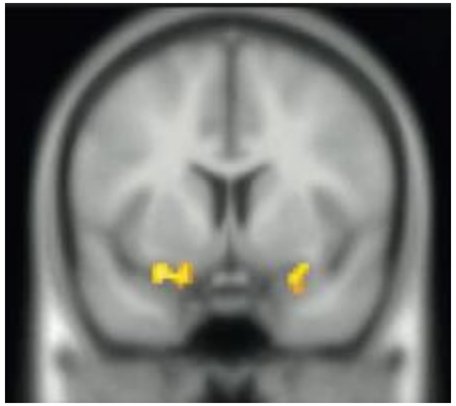
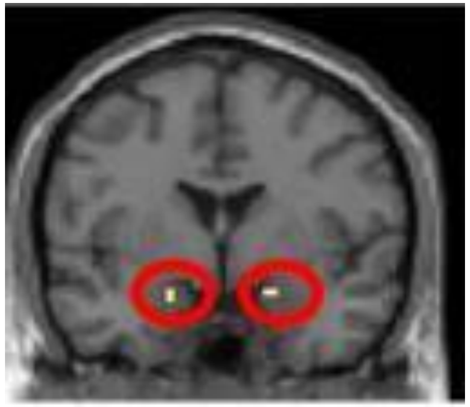
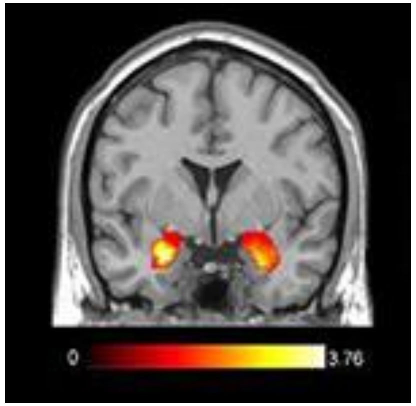
What do I do?

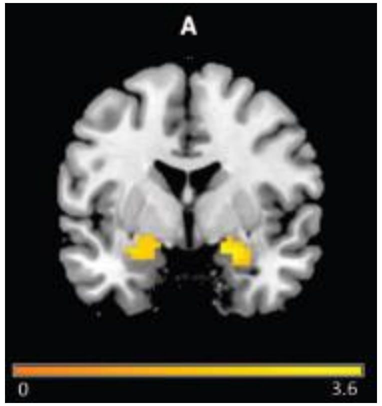
What do I do?


Friday, March 14 2:03 PM
Today in ERCOT
E-Wire Headlines
The 2014 Events Calendar is on E-Wire
Spark-E's Brigade needs YOU!
Books Are Fun Book Fair coming to a lobby near you...
CIC
The United Way of Williamson County needs your help making funding decisions
Company News
The annual SSAE-16 Audit is coming soon..., are you ready?
Badge Access Only
No Rodents Allowed!
ENTRY READER
There simply are no words
Today
Mon 17
Tue 18
FREQ: 60.022 Hz
LOAD: 33,393 Mw
WIND: 4,146 Mw
PRC: 4,506 Mw


WELCOME
2015
BEST PLACES
AUSTIN BUSINESS

Studying the Brain



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Reliability, Resiliency, and Robustness

– Reliability: "Is it working now?"
  - Evaluating the consistency of service in real-time, often measured by interruptions (Clark-Ginsberg, 2016)

– Resiliency: "How well/quickly can it bounce back/transform from an adverse event?"
  - Evaluating the ability of the system to reduce the magnitude and/or duration of disruptive events…depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event" (NIAC, 2009)

– Robustness: "How much can it absorb/withstand disturbances and crises before they become adverse events"?

Reliability, Resiliency, and Robustness

- Critical infrastructure resiliency: both physical infrastructure, and the human components
- Resiliency Engineering: Humans are the primary source of resiliency for an infrastructure
- Therefore, to strengthen an organization’s resiliency, you need:
  - Strong ways of measuring resiliency
  - Creating the optimal environment for human resiliency
    - High Reliability Organizational Culture
    - Just Culture
    - “Team of Teams” approaches
  - Building habits of resiliency, rather than unprepared emergency response

What is the Problem?

© Independent Electricity System Operator, CA

What is the Problem?

- Technological
  - Cyber and blended physical/cyber threats
  - Physical threats such as EMP/GIC, sabotage
  - Big data: sensors, telemetry, wearables
  - Intermittent renewable generation
  - Electric vehicle loads
  - Growth in machine learning and AI
  - Social media and connectivity
  - Drive to more advanced SIGINT, less focus on HUMINT

What is the Problem?

- Organizational
  - Constantly evolving security requirements, procedures and system changes
  - Cost savings being looked for everywhere
  - Faster moving markets (e.g., energy)
  - Workforce changes
  - Organizational culture
  - “Halo effect” – hoping expertise transfers from SME to leader
  - Growing needs for collaboration and information sharing

What is the Problem?

- Human
  - Growth in human error
  - Loss of situational awareness
  - Systems not built around human information processing capabilities
  - “Out of the loop syndrome” with automation
  - Avoiding “small signals” and missed learning opportunities
  - Training for facts, not habits
  - Fatigue on shift
  - Culture of self-assessment and improvement

ResilientGrid

What is the Problem?

- Human
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  - Cult ovement

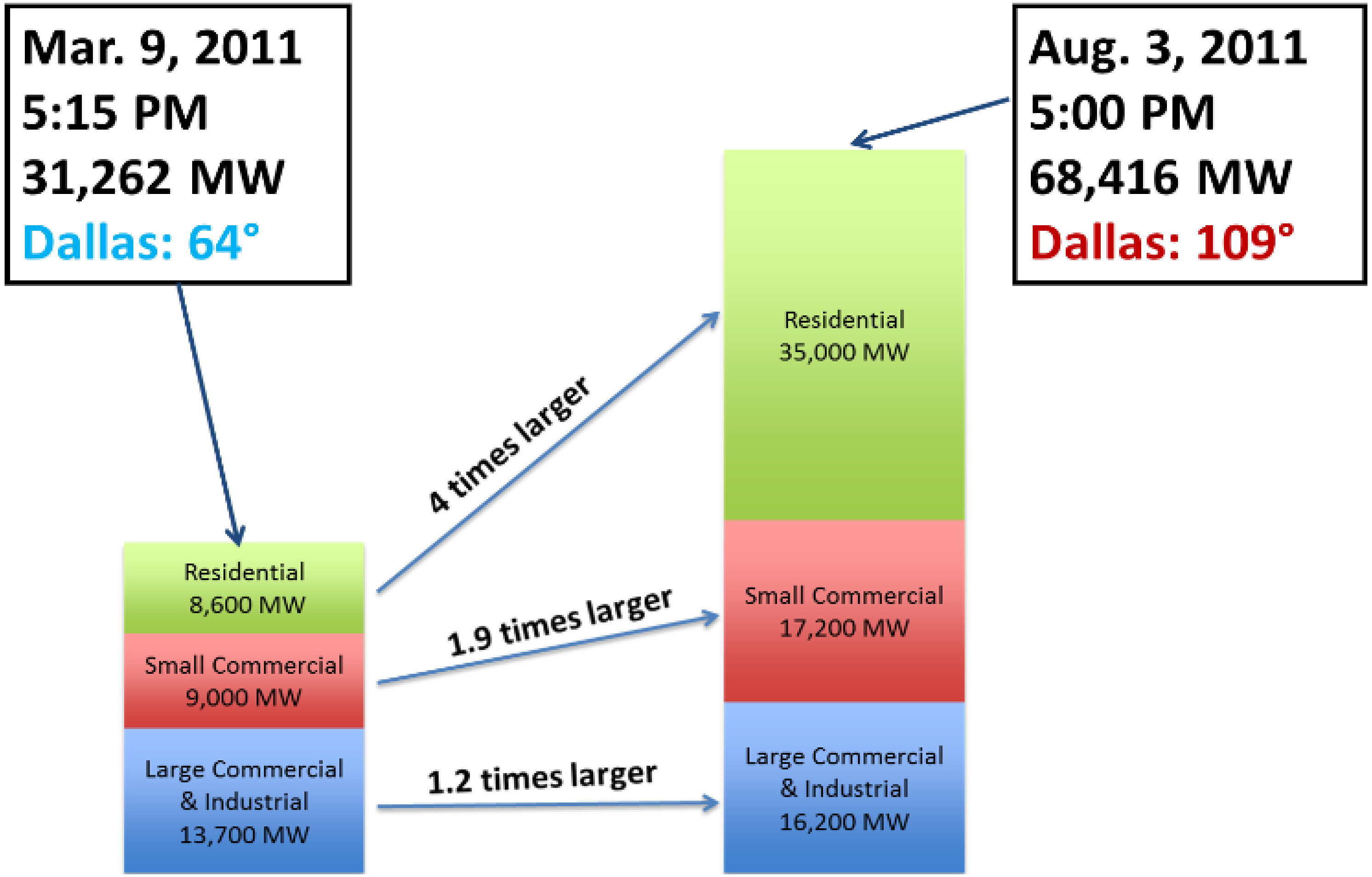
Installations and Energy

– Electrical system has many constraints:
  - 60 Hertz frequency (load + losses matching demand).
  - Voltages balanced (reactive power)
  - All equipment operating within thermal limits
  - Balancing intermittent renewables and at-times unpredictable load.
  - Most load is uncontrolled, and offers no load shedding
  - Avoiding real-time and contingency issues
  - Relays set to operate when people don't – frequency, voltage, phase angle

– Also, many constraints for other sources: communications, water, natural gas, etc.

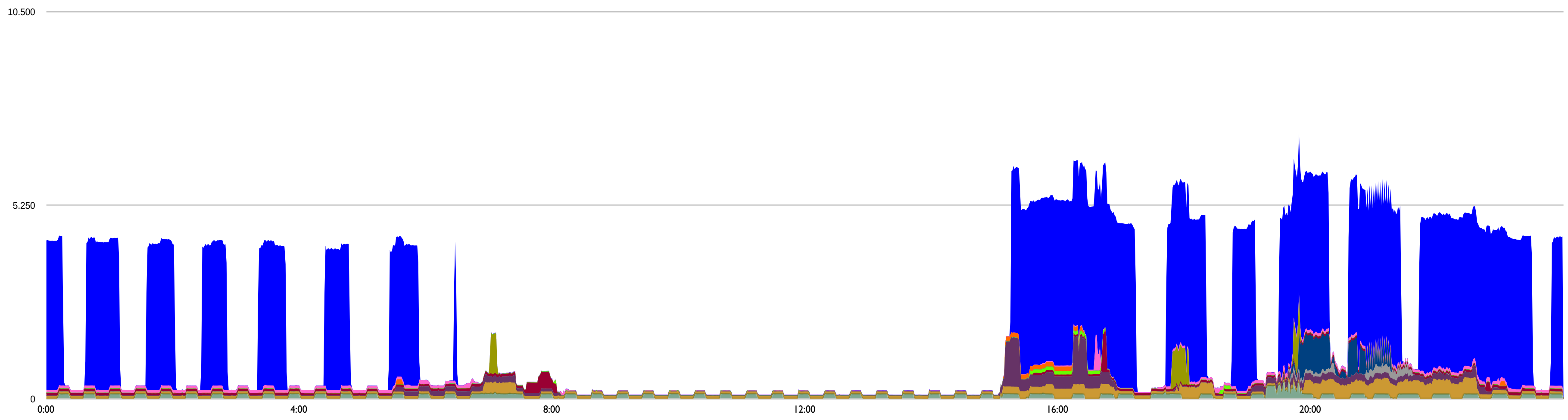
– Most of these are interconnected with each other and thus harder to optimize

ERCOT Load Case Study



Source: ERCOT

ERCOT Load Case Study



Refrigerator

Microwave / toaster oven

Bathroom 1

Living room / TV

Washer / dryer

Bedroom 2

Kitchen lights

Dishwasher

Bathroom 2

Garage

Master bedroom

HVAC

Source: Pecan Street Project

Emerging Technologies at the Grid Level

– Several new types of devices are not only transiting in electric power, but also data

– Some examples:

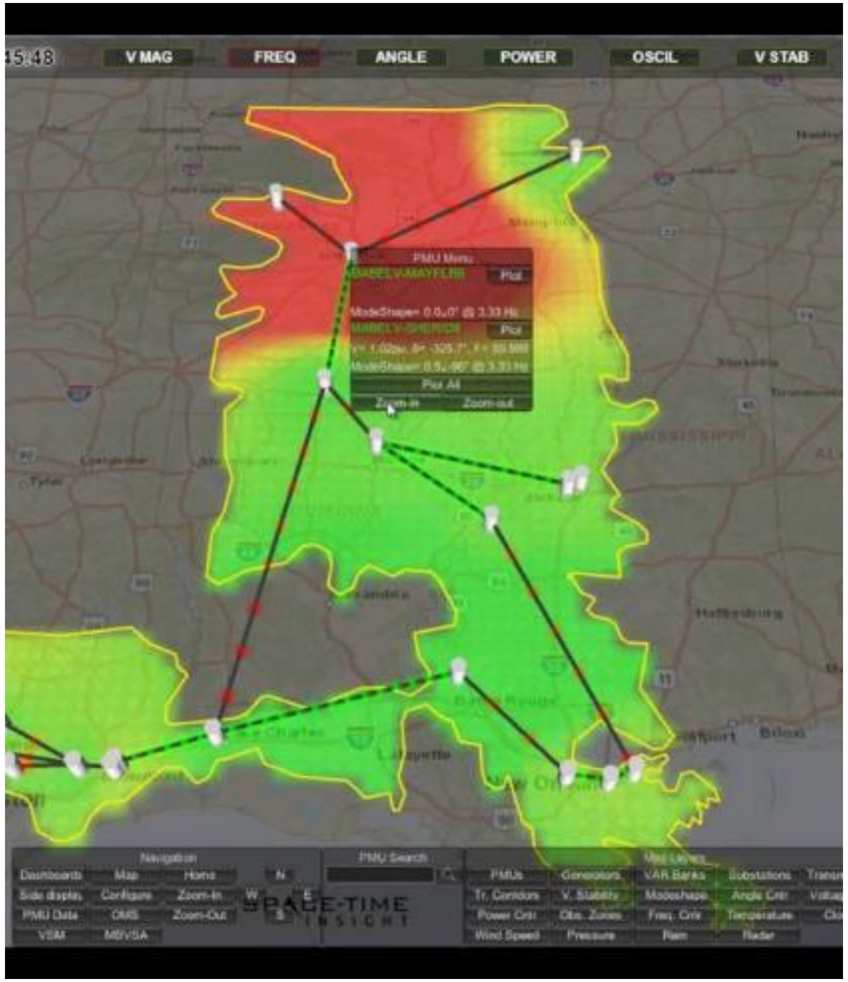
- Synchrophasors
- Electric vehicles (and their charging stations)
- Controllable thermostats
- Photovoltaics and “Smart” inverters
- “Smart” lighting and sprinkler systems
- Battery storage systems

Emerging Technologies: Synchrophasors

– Most telemetry for critical infrastructure traditionally comes over SCADA, at 1 – 5 second increments

– An emerging technology in the electric power space, a synchrophasor, samples up to 300x/second, and provides its samples linked against a GPS time reference

– This allows an operator to stitch together an instantaneous view across a large area, and see new issues not previously seen



Source: Space-Time Insight

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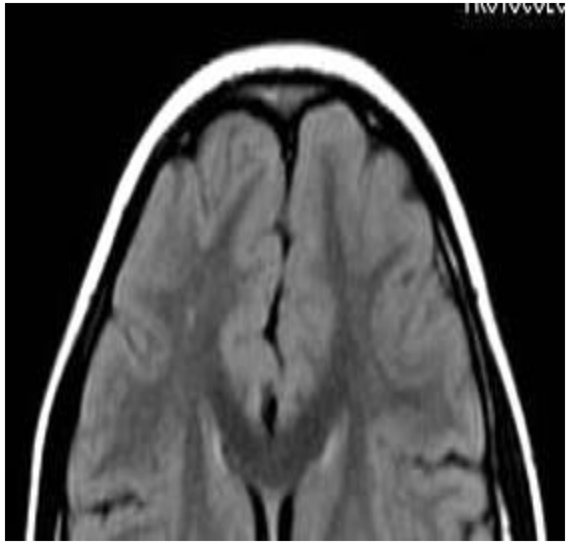
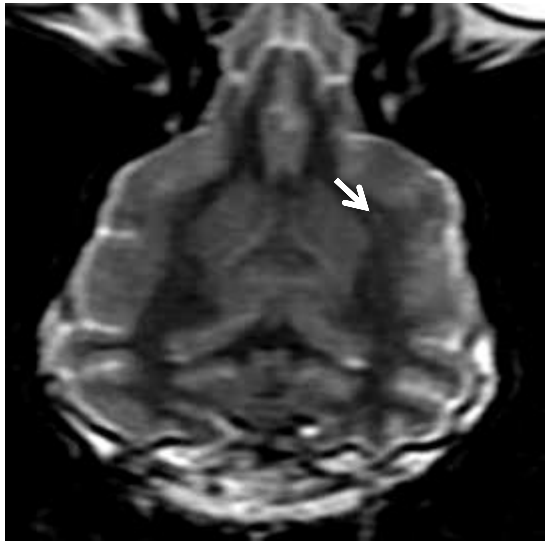
Emerging Technologies: Electric Vehicles

– Implications of transportation electrification
  - Per-mile emissions reductions for all except SO_2
  - Strategies (e.g., aligning against distributed PV, SOFC microgrid generation) reduce per-mile emissions further, including the SO_2 reductions.
  - Harmful UFPM (largely unaffected by wind) moved away from major population centers

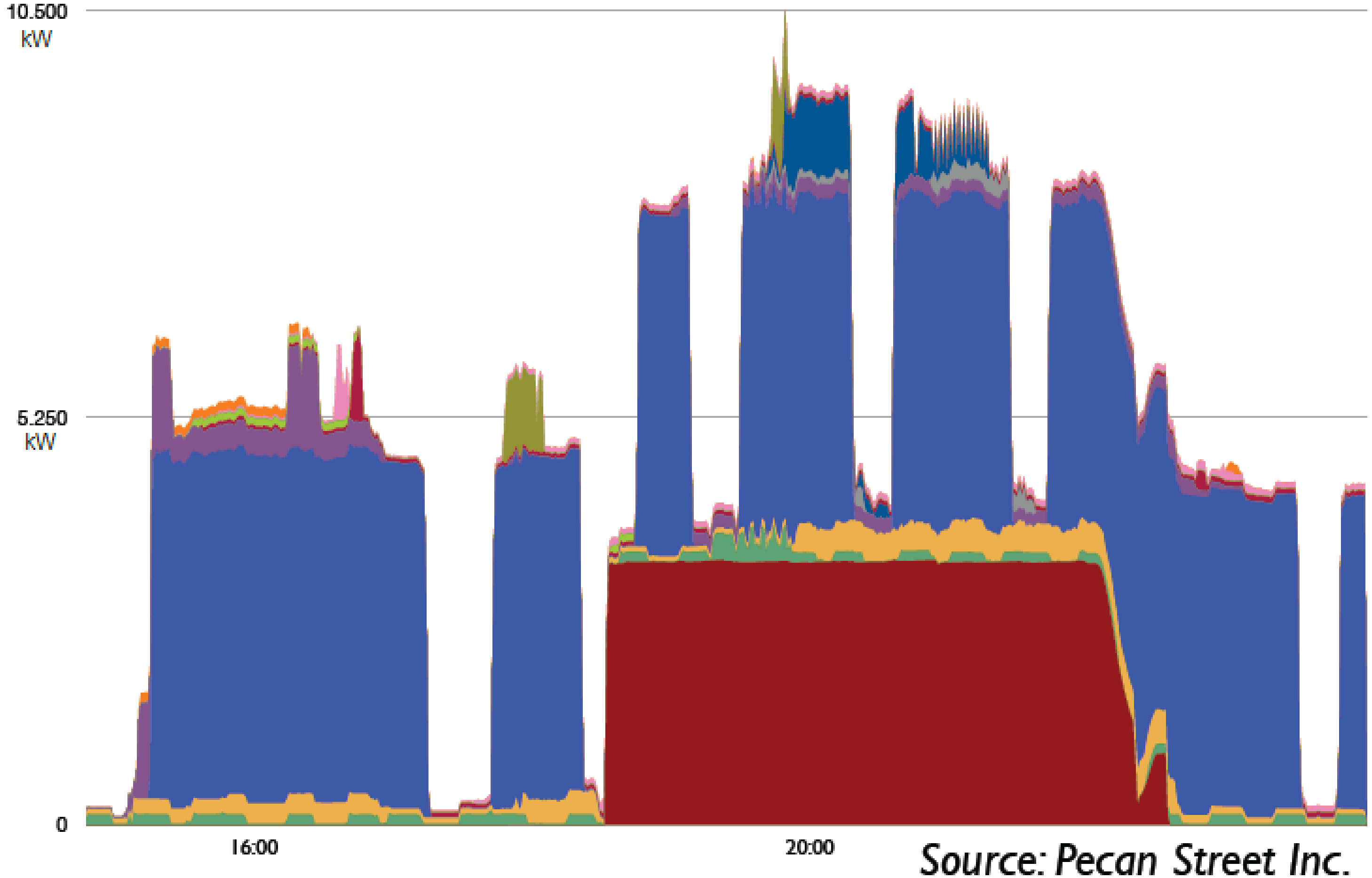
Source: jf1772 Flickr





Source: Calderon-Garcuidenas, 2008

Emerging Technologies: Electric Vehicles



Source: Pecan Street Inc.

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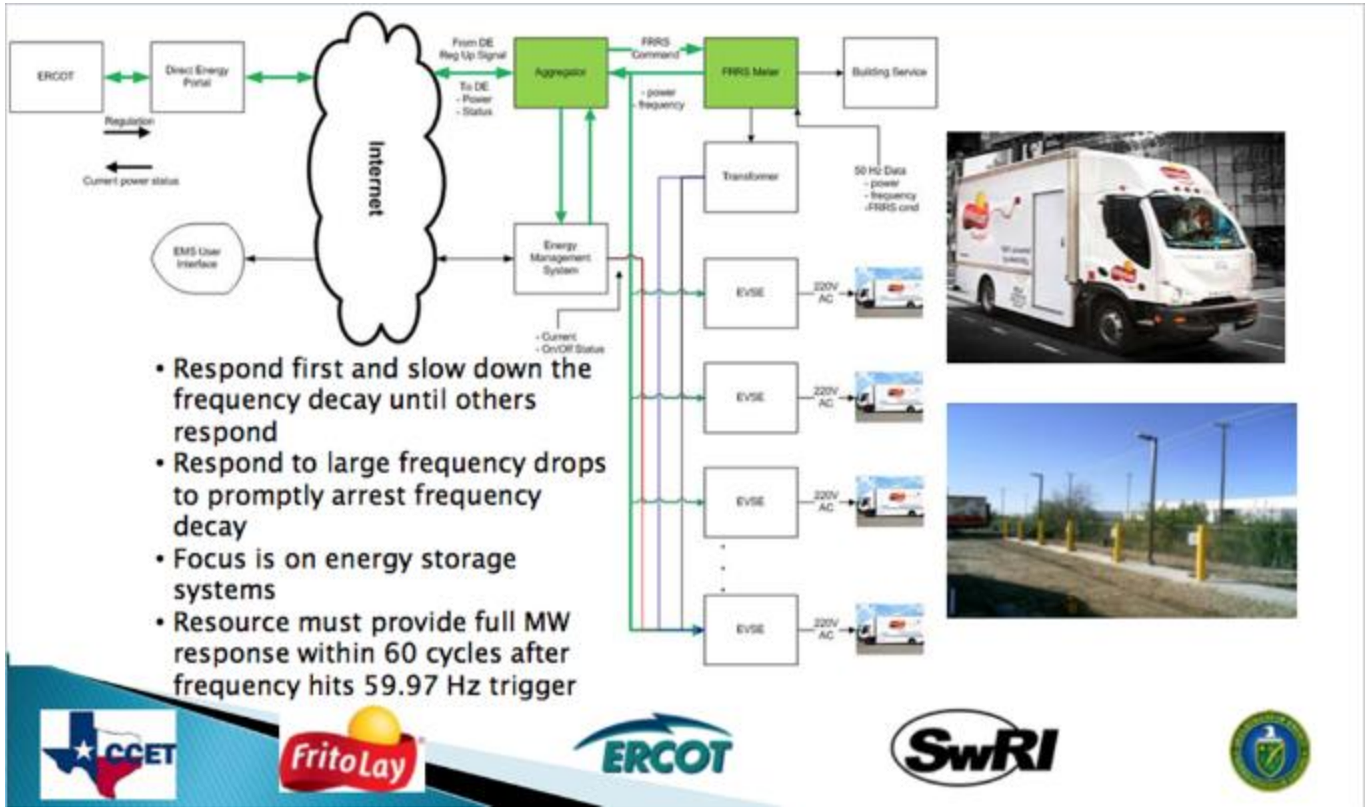
Emerging Technologies: Electric Vehicles

- As a flexible load, these devices can have a profound impact on the grid: either negative (uncontrolled) or positive (controlled).



Source: ERCOT

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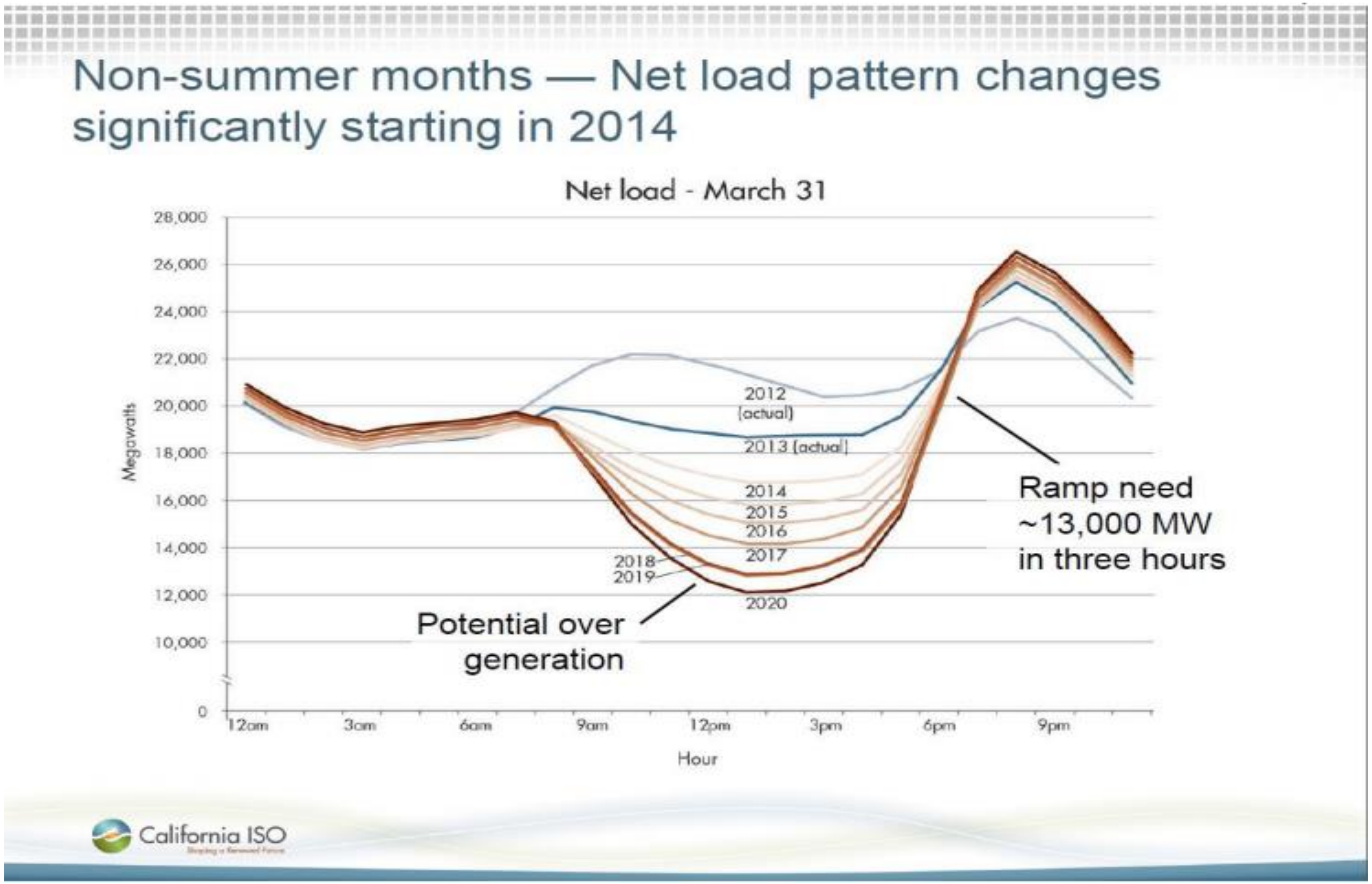
Emerging Technologies: Photovoltatics



Source: CaISO

Emerging Technologies: Smart Inverters

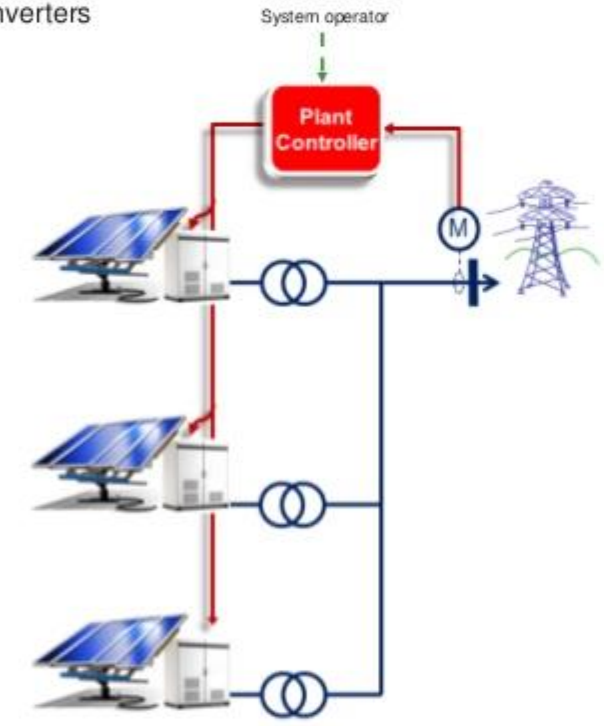
Source: NERC

Emerging Technologies: Smart Inverters

Implementation of advanced inverter functionalities

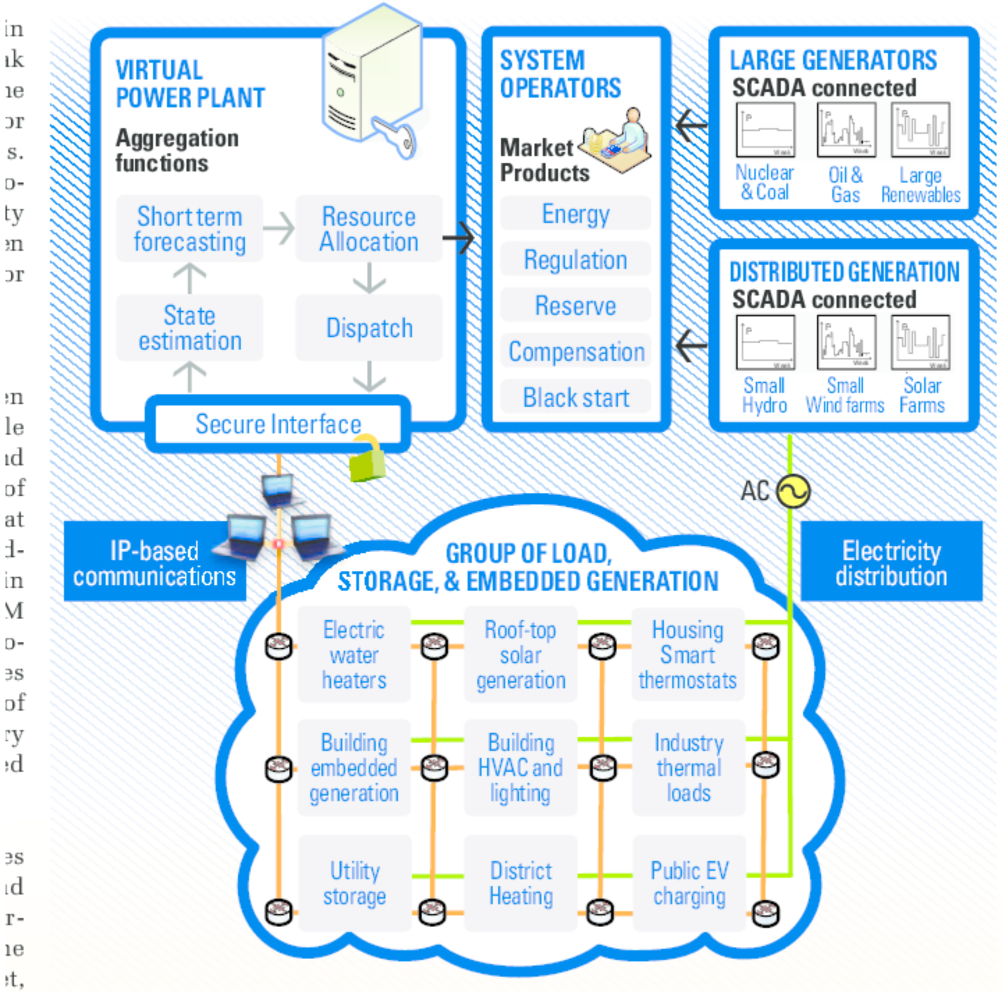
Advanced functions can be implemented at the inverters or at the point of interconnection (POI):

- Point of interconnection:
  - Active power limit
  - Power factor
  - Volt-var
  - Voltage regulation
  - Constant reactive power
  - Under/over frequency ride through (relay)
  - Under/over voltage ride through (relay)
- Smart inverter:
  - Volt-var
  - Frequency-watt
  - Soft start
  - Under/over frequency ride through (inverters)
  - Under/over voltage ride through (inverters)



Source: Sandia Nat'l Labs

Emerging Technologies: Controllable Thermostats

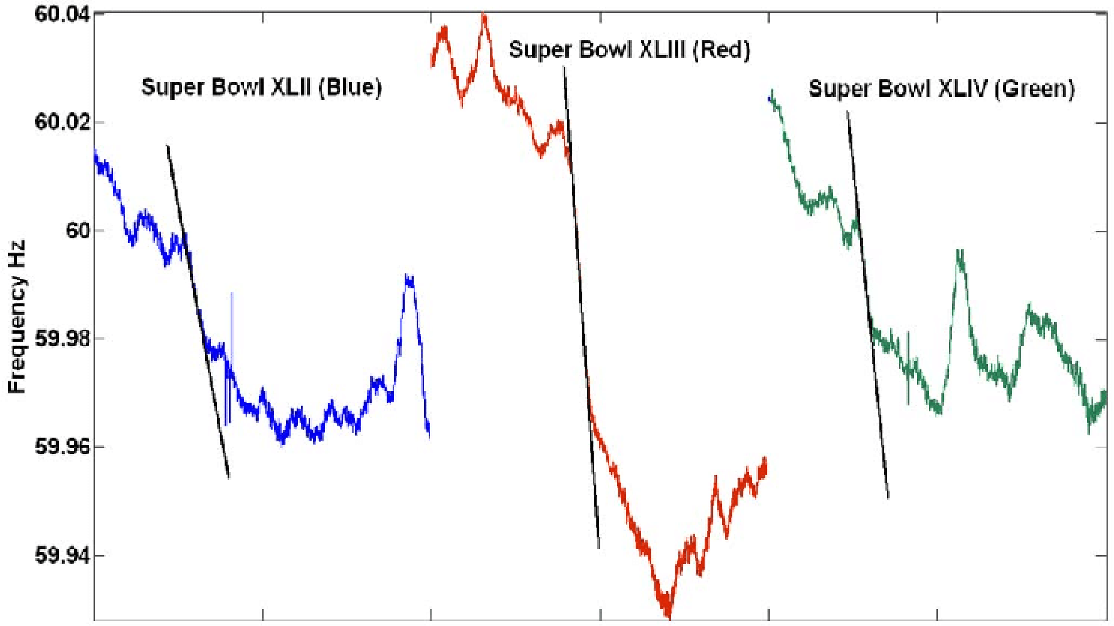


Source: Beauvis et al, 2015

- In Texas, cooling (HVAC) is a significant load, and as such, being able to control or shift the demand can significantly help reliability
- Because HVAC compressors and motors consume reactive power also, they can be used to help support voltage
- Many thermostats (e.g., Nest) also have occupancy sensors that help save energy, and may provide other useful analytics

Emerging Technologies: Smart lighting and sprinklers

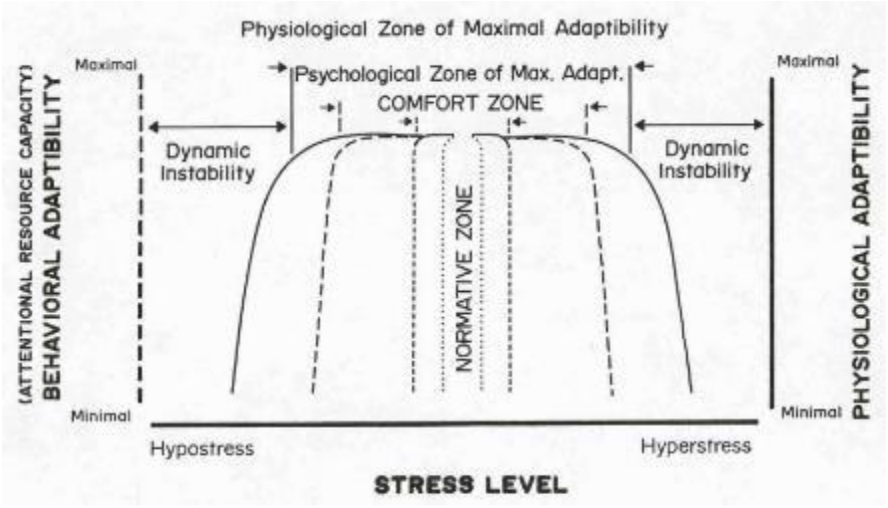
- Controllable lights and sprinklers also can provide additional resources to the grid
- Water and natural gas activities can also affect power (e.g., super bowl halftime)



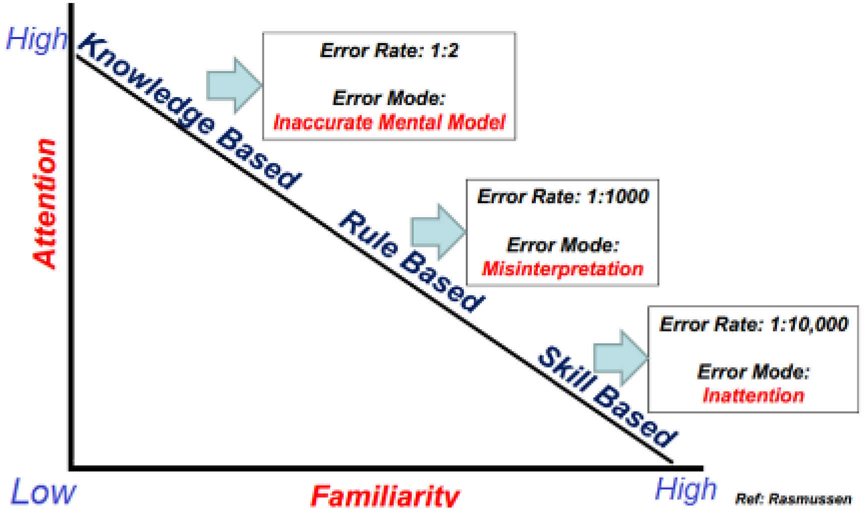
Source: Chen et al, 2011

Manage Cognitive Load

- Workflow analysis, specific and holistic
- Analysis of short-term memory loading (7 ± 2 chunks; Miller, 1956)
- Recognition that humans make 3-7 mistakes per hour, 11-15 under stress (Muschara, 2014)
- Recognition of lower cognitive resource availability in emergencies
- Analysis against predictable failure modalities in emergencies



A Dynamic Model of Stress and Attention, from Hancock & Warm (1989)

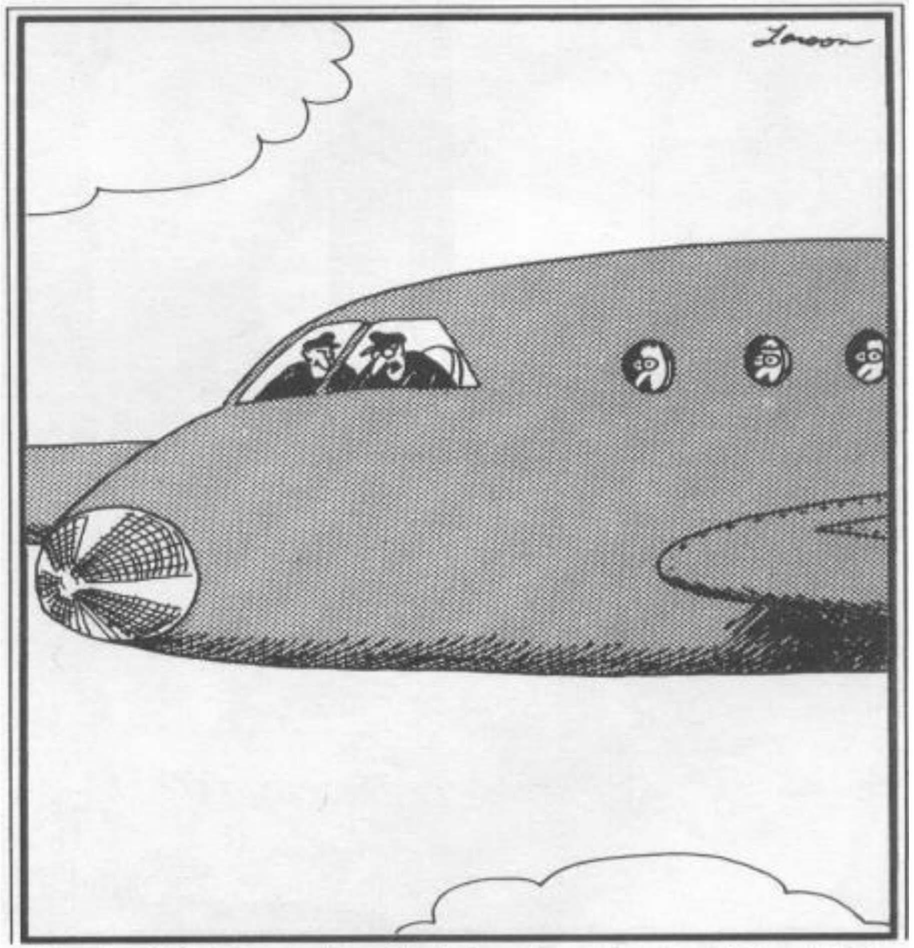


Situational Awareness

Three levels of situational awareness:

- Level 1: Perception
  - What is going on?
- Level 2: Comprehension
  - What does it mean?
- Level 3: Projection
  - Where is it going? What am I going to do about it?

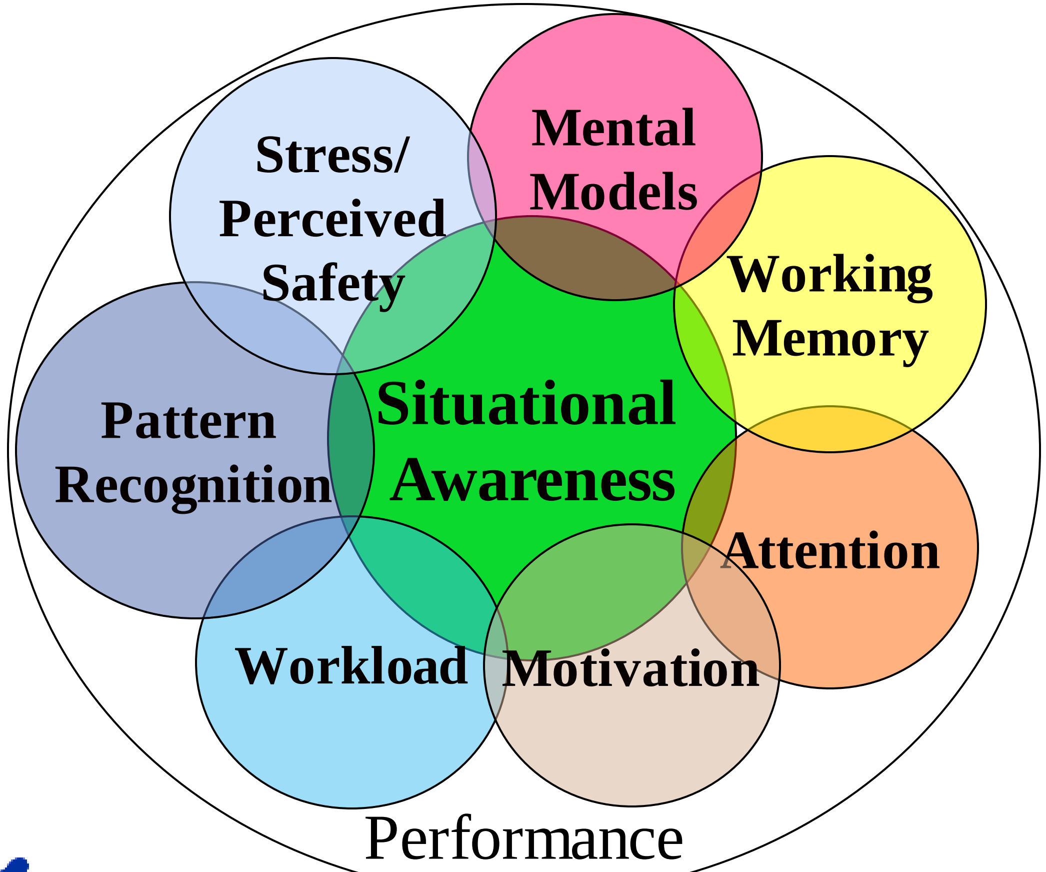
Situational awareness is necessary both in individuals and within teams.

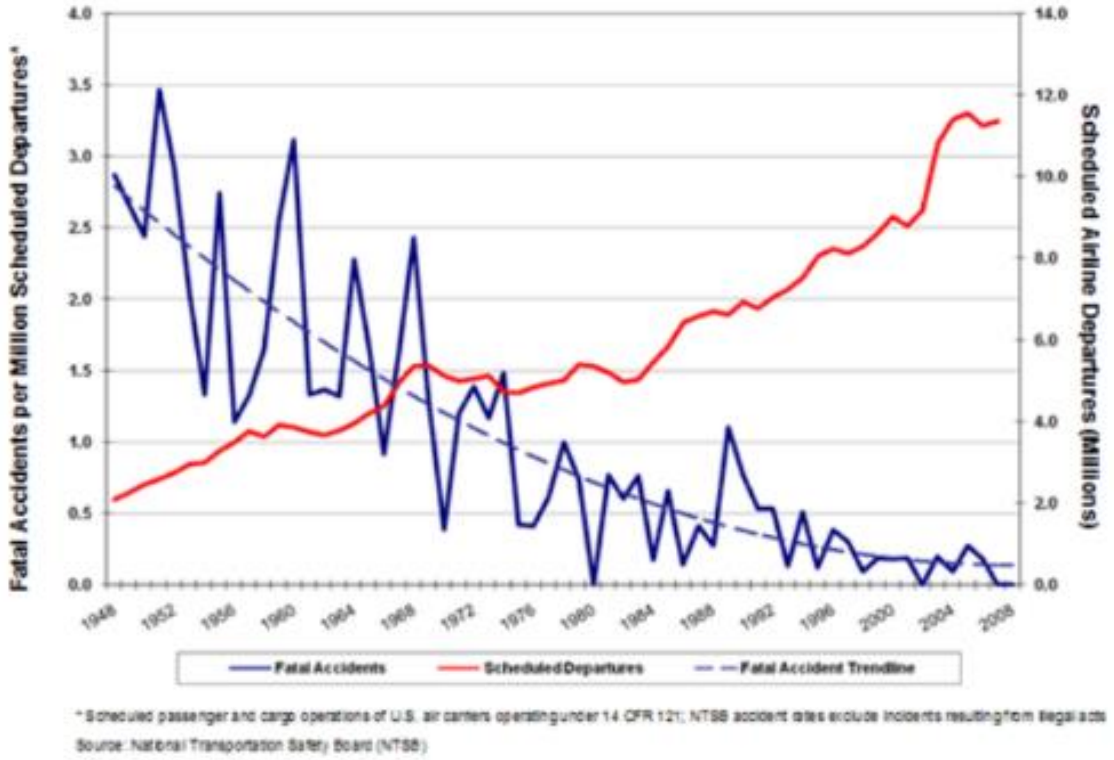


"The fuel light's on, Frank! We're all going to die! ... We're all going to die! ... Wait, wait. ... Oh, my mistake—that's the intercom light."

Design for Situational Awareness

– Building strong mental models, complex pattern recognition and situational awareness requires time, space, and adaptive capacity/slack, as well as the right environment and training





Based On: Kass, S. Military Psychology

Situational Awareness – Common Pitfalls

Source: NERC

Situational Awareness – Common Pitfalls

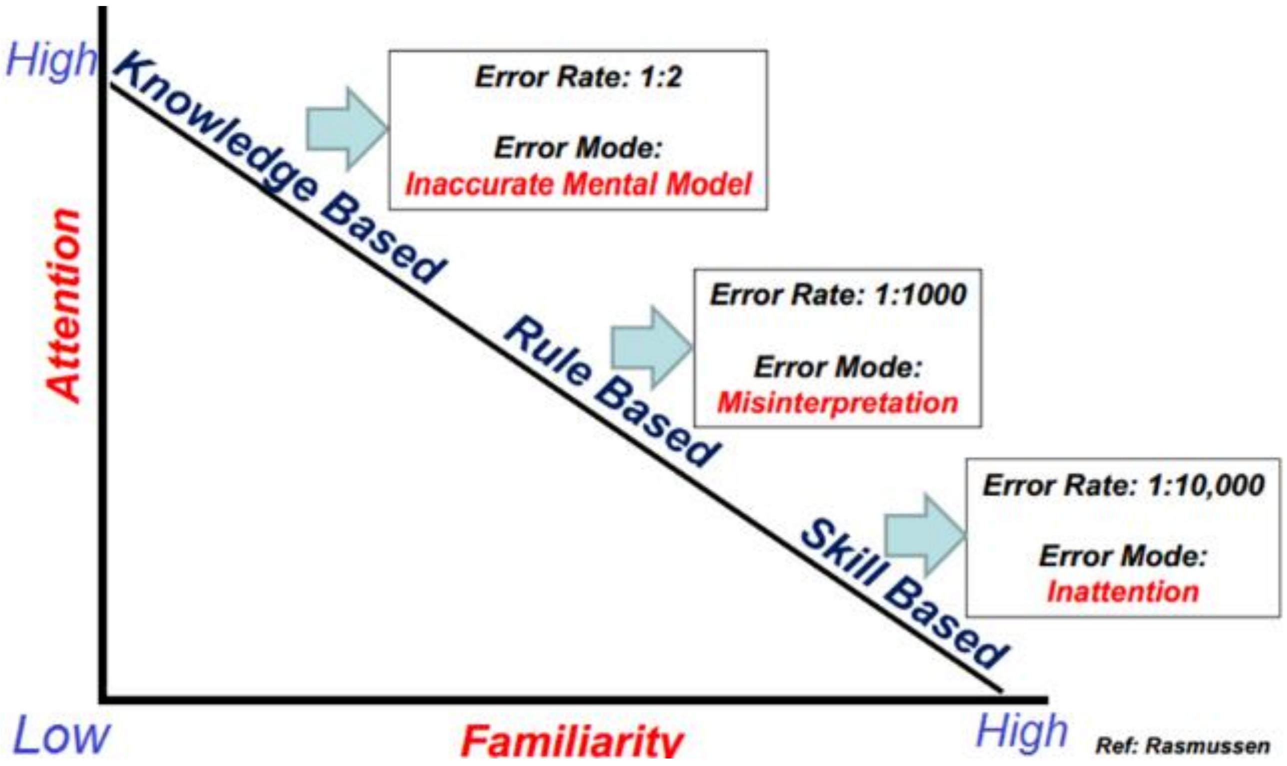
Source: NERC

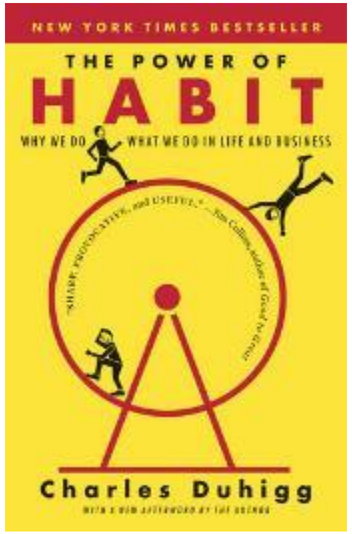
Habits of Human Performance

Cue -> Routine -> Reward -> Cue…

– Patterns unfold automatically – brain spends resources on other tasks

– Much (> 40%) of what we do each day not a decision, rather a habit.





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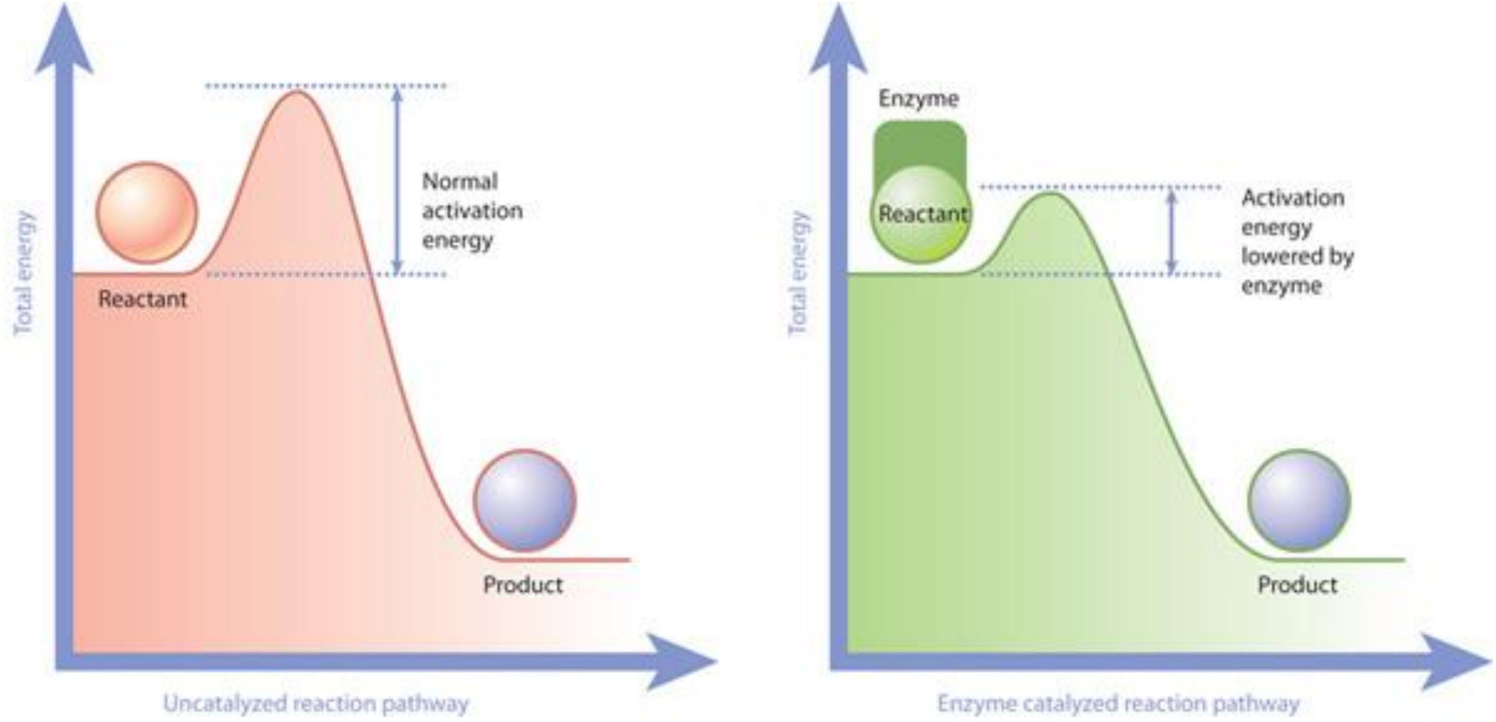
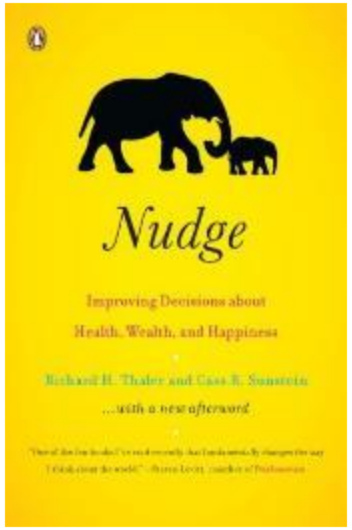
Interactions with Emerging Technologies

In Chemistry, **activation energy** is what's needed to make a reaction happen; without it, the reaction won't occur.

In Psychology, it's the motivation needed to start a task.





From http://www.nature.com/scitable/content/enzymes-and-activation-energy-14711476

"Multitasking" or switchtasking

"Multitasking" is the attempt to carry on two or more tasks or activities at the same time.

But, really what is happening is both

- – Habit / automation – learned behaviors being repeated with little thought
- – Frequent "mental set shifting" / "context switching" which is computationally intensive and risky.
- – Should something (e.g., driving a car) need a jump in attention, there may be insufficient resources available to help.

Responding To Human Error

Outcome Bias

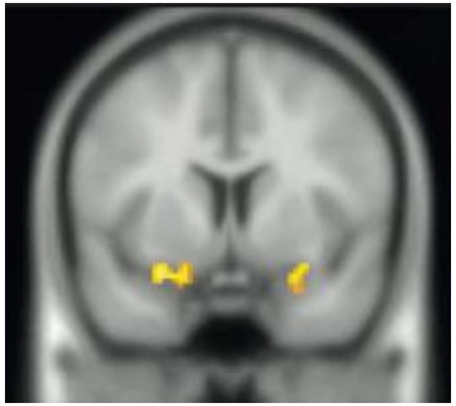
Over-Reaction	Under-Reaction
• Discipline of discrete error	• Turn a blind eye to risky choices
• Discipline person who didn’t see risk	• Allow reckless people to go unchecked
• Over-reaction to singular events	• Pass over severe system design flaws

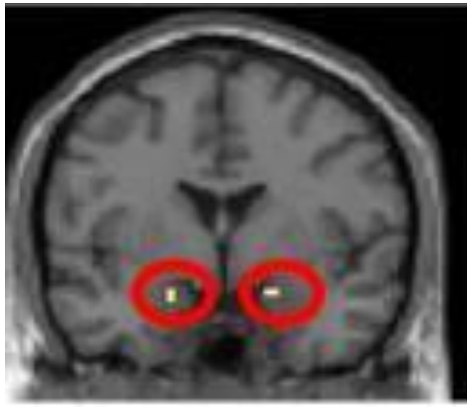
“The single greatest impediment to error prevention…
is that we punish people for making mistakes.”

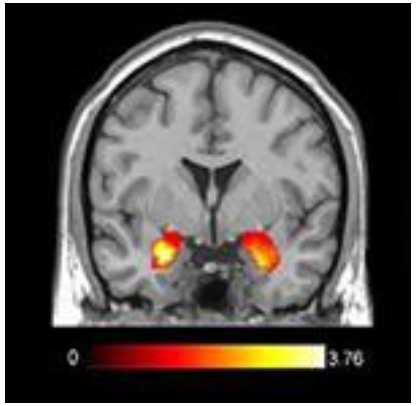
– Dr. Lucian Leape, Professor, Harvard School of Public Health,
1999 Testimony before Congress on Health Care Quality Improvement

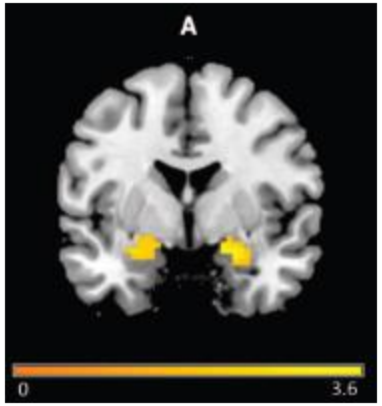
Continuously Improve Organizational Culture

- Capture and act upon “small signals”, such as near misses
- Recognize that success in an emergency requires adaptive capacity
- Ensure *Deference to Expertise*
- Avoid *Outcome Bias* and other cognitive biases
- Ensure fast-moving automation incorporates operators “In the loop” and recognizes human information processing capabilities





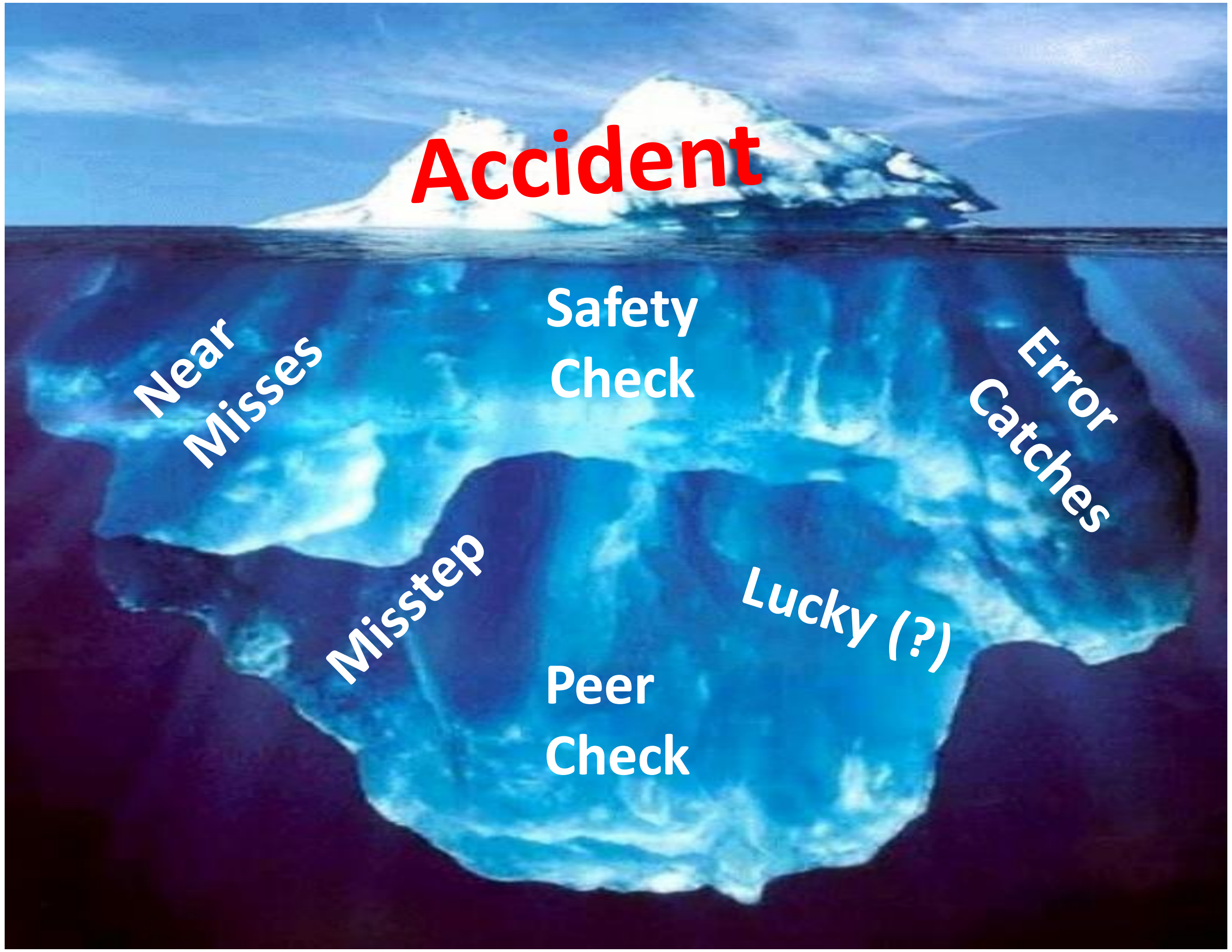




Near-Miss Reporting

An organization focused on being proactive, not reactive

An organization with the ability to not only capture, but also track and trend near misses (organizational situational awareness)



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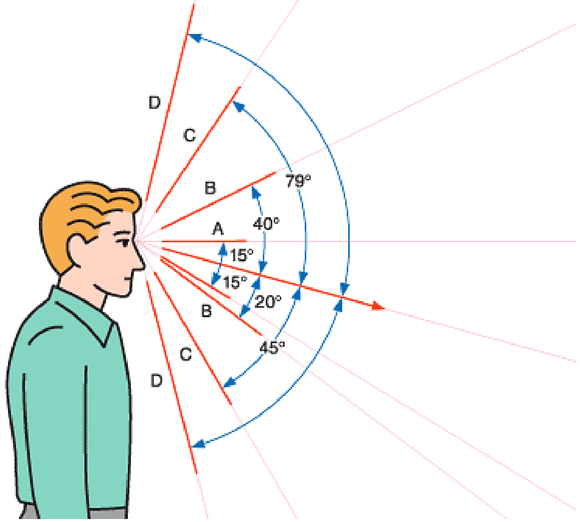
Human Factors Engineering

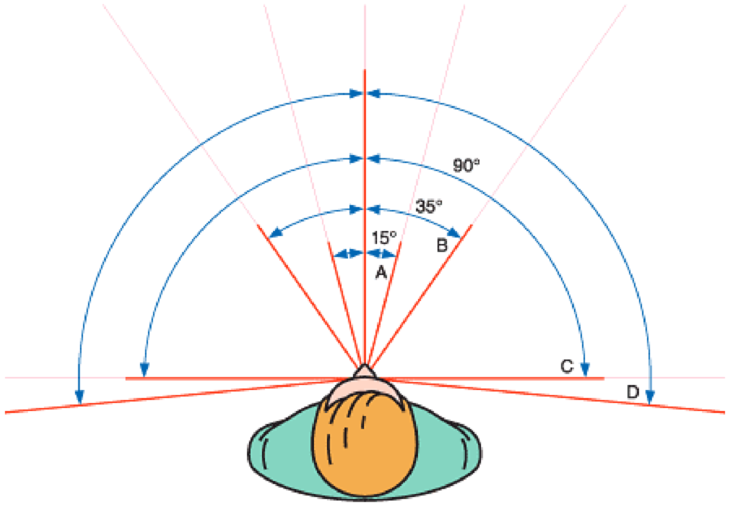
- A great many human factors influence the overall reliability of the system, for example:

Exercise	Visual system function
Sleep	Cognitive biases
Corporate culture	Mood
Genetic factors	Training
Self-monitoring	Abstract reasoning, empathy
Diet	Self-actualization
Stress & fear	Positive thinking
Perceived safety	Key performance indicators / HR metrics

Field of Vision

- Resolution on retina highest at center, lower towards periphery.
  - Farther out, you can only detect motion & vague shapes.
  - Motion in the periphery can be distracting

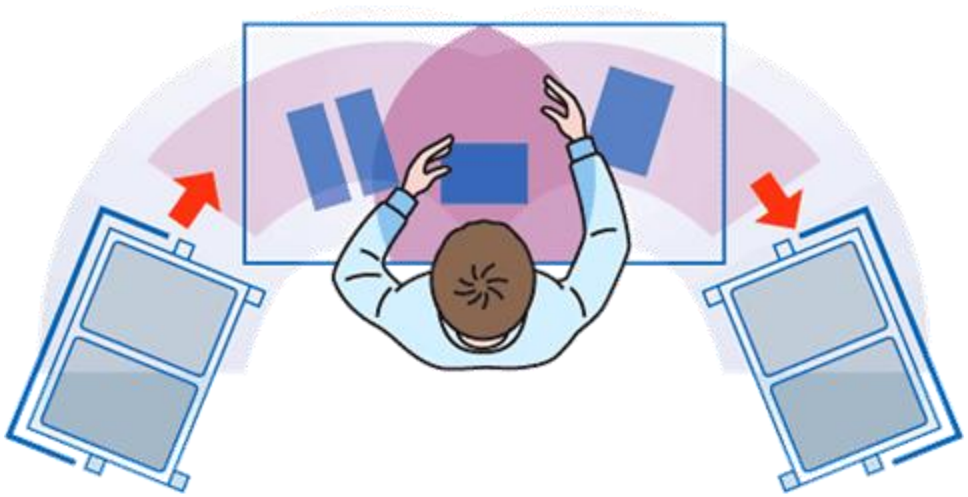




Source: Lean Valley

Area of Reach

- Lay out your workspace, and user interfaces so the most commonly-used interfaces and materials are in front of you, and less frequently used materials/interfaces are on the periphery.



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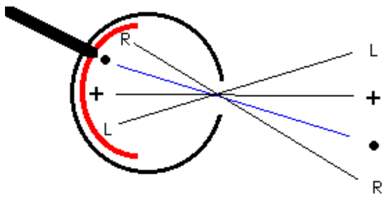
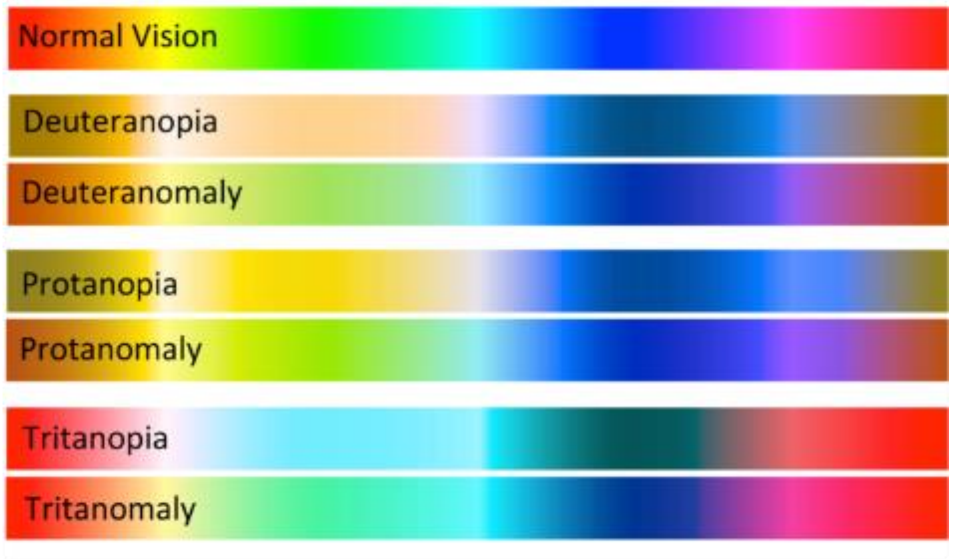


Blind Spot

- Close one eye and stare at the cross (if right eye open) or dot (if left eye open). Move your head back or forward

Issues with color

- Color discriminability decreases both with age and nicotine use
- Color deficiency / blindness



Source: Chroma: A wearable augmented reality…

Shift Work Disorder

- Social Rhythm Disruption is also something to consider:
  - Loss of social cues predicts a bipolar event more than general psychological stress
  - Social support may be lacking
  - Spending time with loved ones and friends may be harder on night shift rotations, etc.
  - Even outside shiftwork, social media doesn't make people feel as connected as in-person interactions

Source: Schartz, H. (2013)

Systems Design of the Future

- Design systems based on knowledge of the visual system (e.g., color choice, contrast, reduce misplaced salience risks)
- Look holistically at the system (e.g., contrast differentials between system and background)
- As improved methods for human-systems interfaces grow (e.g., AI, ML, neural interfaces), ensure design based around operations in high-stress fast-paced environments

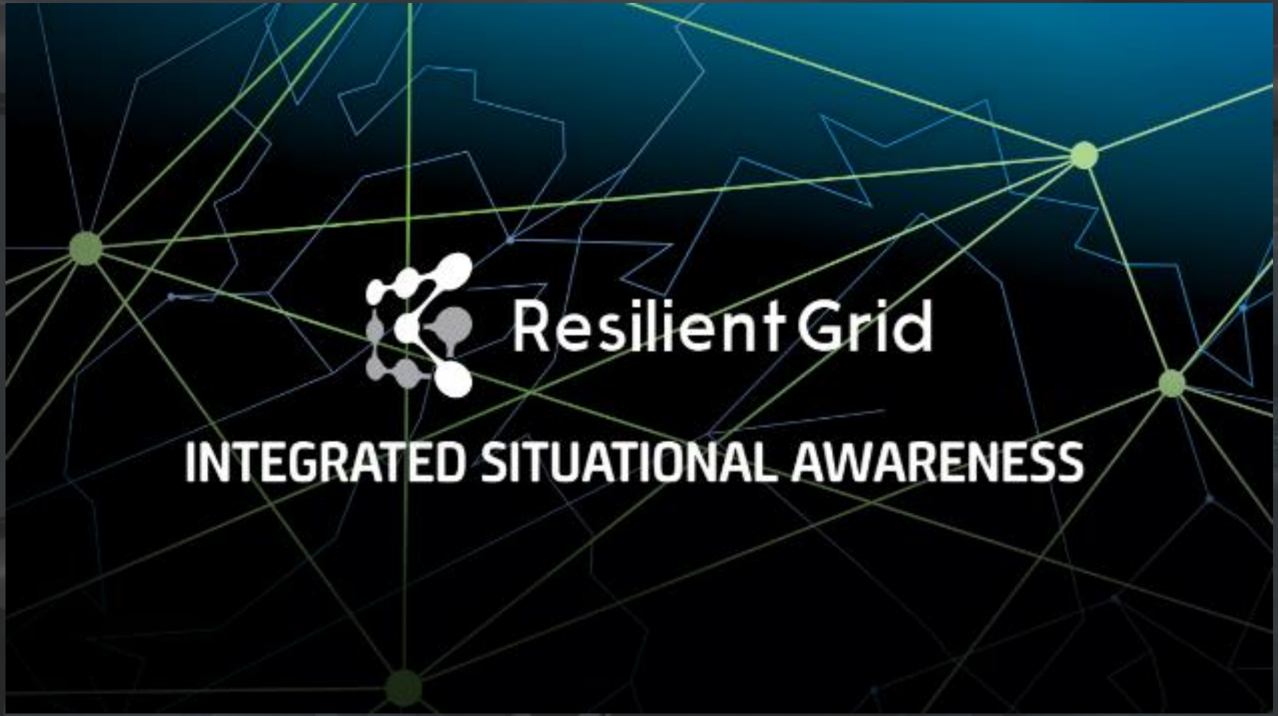
Unintended Consequences

The Cobra Effect

Focus on what's important

Source: J. Merlo

Focus on What's Important



Thank you

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