Connected Infrastructure

Innovations in Education, Demonstration, and Applied Research (CIEDAR)

Keynote Presentation for ICDT 2021,
the 16th Int'l Conference on Digital Telecommunications
Porto, Portugal, April 18-22, 2021
(https://www.iaria.org/conferences2021/ICDT21.html)

Stan McClellan & Andres Carvallo
Texas State University, San Marcos TX, USA

Abstract

- Innovations in "Connected Infrastructure" are becoming increasingly important in the advent of "smart" everything .. smart cities, smart grid, smart transportation, smart buildings, et.al.
- Cross-domain issues in communications, technology standardization, federation of data, and interoperability clearly point towards a need for independent, large-scale testbed facilities.
- A similar need for closing gaps in workforce knowledge in-sync with the pace of technical evolution also leads toward facilities which enable just-in-time training and directed project evaluation.
- This presentation discusses an innovative approach to meshing research & development, large-scale demonstration & validation, and multi-disciplinary training in the context of an open consortium of industry, government, academia, and municipal actors.
- Specific projects are highlighted, and a "deep dive" into a novel approach to "DevSecOps" in the context of critical energy management is presented.

Stan McClellan

stan.mcclellan@txstate.edu

Professional Experience

- Co-Director, Connected Infrastructure Initiative (CIEDAR), Texas State University
- Professor, Ingram School of Engineering, Texas State University (2008 – Present)
- Director, Ingram School of Engineering, Texas State University (2013 – 2018)
- CTO & co-Founder, Power Tagging Technologies (2008-2010)
- Chief Architect – Systems & Solutions, ZNYX Networks (2006 – 2008)
- Technical Director & Distinguished Technologist, Hewlett Packard (2000 – 2006)

Publications & Activities

- Smart Cities in Application: Healthcare, Policy, and Innovation. Springer. 2019
- Smart Cities: Applications, Technologies, Standards and Driving Factors. Springer, 2017.
- The Smart Grid as an Application Development Platform. Artech House, 2017.
- “Smart City Applications,” IEEE GreenTech 2018, Apr. 2018.
- “The Smart Grid as an Application Deployment Platform,” IEEE GLOBECOM, 2014.
- “Cyber Security & Threat Management for the Smart Grid,” IEEE ICC, June 2012.
- “Security & Network Management in the Smart Grid,” 4th IEEE Computer & Communication Workshop (CCW), Oct. 2010.

Andres Carvallo

andres.carvallo@txstate.edu

Professional Experience

- Co-Director, Connected Infrastructure Initiative (CIEDAR), Texas State University
- Professor of Innovation and MARC Fellow, Texas State University (2019 – present)
- Executive Vice President of Energy Solutions & Chief Strategy Officer, Proximetry (2011 – 2013)
- Executive Vice President & Chief Strategy Officer, Grid Net (2010 – 2011)
- Chief Information Officer, Austin Energy (2003 – 2010)
- Chief Technology Officer, Pecan Street Project (2003 – 2010)

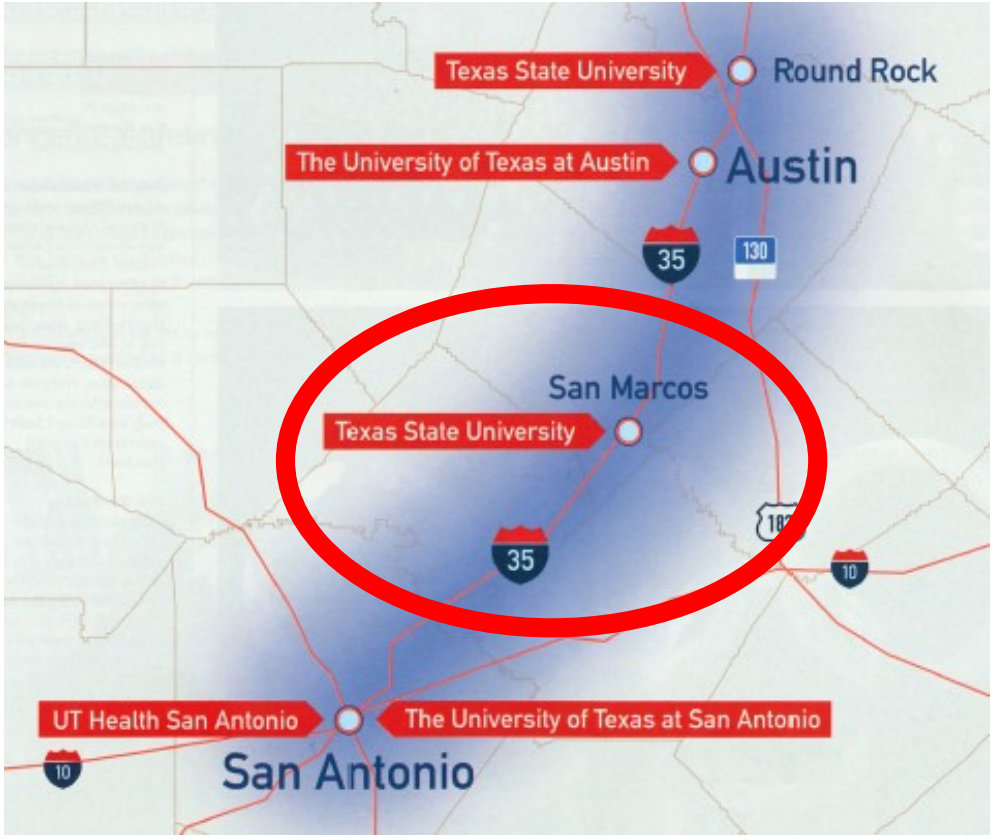
Publications & Activities

- The Advanced Smart Grid: Edge Power Driving Sustainability 1st ed, Artech House, 2015.
- The Advanced Smart Grid: Edge Power Driving Sustainability 2nd ed, Artech House, 2011.
- Smart Electric Power Alliance – Technology Board Advisor (2017 – present)
- Smart Grid Interoperability Panel (SGIP) – Board of Directors (2015 – 2017)
- Utility Telecom Council Smart Network Council – Board of Directors (2011 – 2014)
- Center for Commercialization of Electric Technologies – Board of Directors – 2006 – 2010
- “The Smart Grid Emerges,” UTC Journal, 2013.

CIEDAR … Defined

- Consortium model for collaborative evaluation and prototyping at-scale
- Integrates industry partners, government entities, municipal entities, academic institutions
- A platform for targeted research, development, demonstration, and validation of “smart” tech

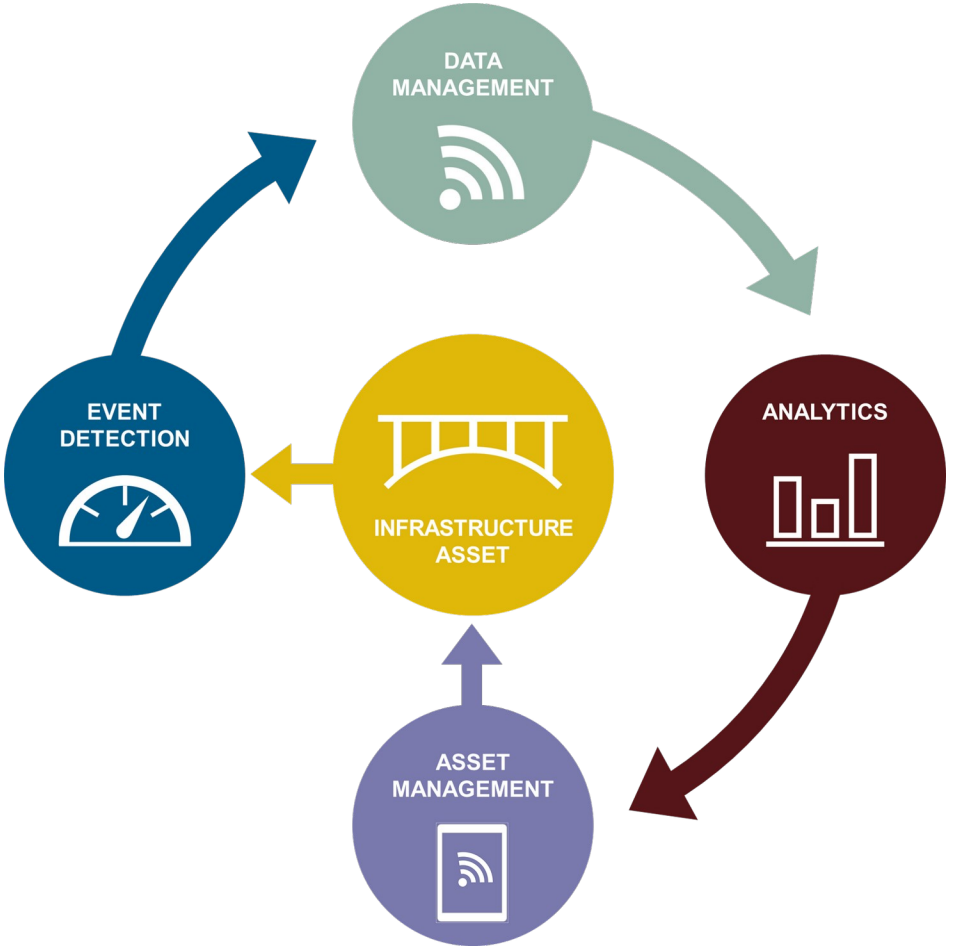
The Heart of the “Texas Innovation Corridor”



CIEDAR Vision

- Connected Infrastructure for Education, Demonstration, and Applied Research (CIEDAR).
- The creation of multiple living labs within a smart neighborhood in partnership with industry to accelerate digitization and digitalization of industry
- Vision: **Technology Enhanced Infrastructure**

Technology Enhanced Infrastructure

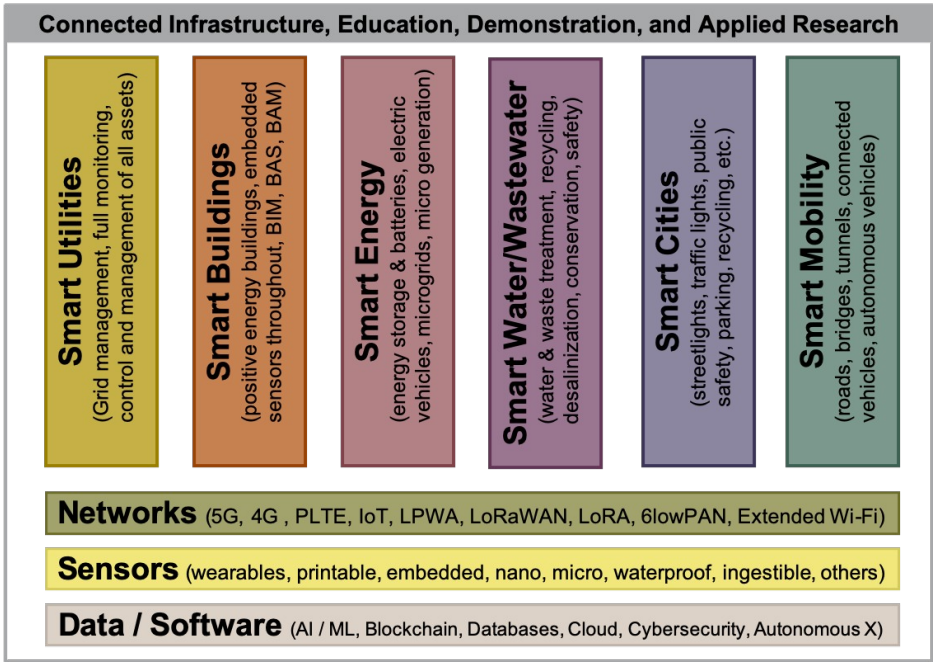


CIEDAR Mission

- The transdisciplinary study of technologies with application to infrastructure and lifecycle monitoring.
  - Activities: Validation, Evaluation, Development
  - Project teams: Civil, Electrical, Industrial, Mechanical engineers, Geographers, Mathematicians, Computer Scientists, Industrial Design and many others.

CIEDAR Overview

- Multi-Disciplinary Industry Research Center with 9 living labs
- Utilities, Cities, Structures & Buildings (IRL), Energy, Water & Wastewater, Mobility, Networks, Sensors, and Data/Software
- 92 faculty, 291 projects, 250 students, 32 laboratories, 7 centers



CIEDAR Locations

Round Rock Campus
100 acres

Freeman Ranch
4,100 acres

Muller Ranch
1600 acres

ALERRT Center
20 acres

San Marcos Campus
500 acres

STAR Park
100 acres

Smart Networks Lab

- LTE, 5Ge, 5G, 6G, LPWA, LoRAWAN, LoRA, NB-IOT, IEC61850, Goose, DNP3, 6LowPAN, Extended Wi-Fi, WiSUN, Wirepass, RF-Mesh
- Power Management, GIS, Location Services, Applied AI/ML
- Sensors (wearables, embedded, nano, micro, water proof, printable, others)
- Data / Software (AI / ML, Blockchain, Databases, Cloud, Cybersecurity, Autonomous X, others)

Smart Buildings & Infrastructure Lab

- Steel, Aluminum, Wood, Composites, Concrete, Cement, Sand, Rocks, and others
- Roads, Sidewalks, Highways, Bridges, Tunnels, Overpasses, Trusses, Beams, Roofs, Columns, Doors, Windows, Escalators, and more
- Smart elevators, stairs, doors, windows, stairs, floors, roofs, ceilings, garage doors, locks, card readers, video cameras, motion detectors, and security alarms.
- Smart lighting, water systems, smoke detectors, vending machines, vehicle charging, ceilings, walls, roofs, and evacuation systems.
- Smart meters, broadband, Internet, energy systems, solar PVs, energy storage, smart appliances, electric vehicles.
- Smart HVACs, gas heating, chillers, boilers, pumps, thermostats, fans, air filters, humidifiers, fire alarms, and CO2 alarms.

Smart Energy Lab

- Smart Meters - Power and Gas (AMI: pre-pay, power factor, TOU pricing), Demand Response (DRMS for sensors)
- Smart Grid (SCADA/EMS, ADMS/DMS, OMS, GIS, VVO, VVC, CVR, FDIR, FLISR, Power Factor, Harmonics, Modulation, Power Electronics)
- Distributed Energy (DERMS for any DG: Solar PV, Fuel Cells, Micro-CHP, Micro-Wind, Energy Storage, Electric Vehicles)
- Power, Heating and Cooling Microgrids (Home, Community, Campus)
- Energy NOC (Video Wall)
- Transmission and Distribution Gear (Transformers, Reclosures, Switches, Feeders, Tap Changers, Bushings, HV Wires, MV Wires, LV Wires, Cap Banks)
- Crews and Vehicle Management (GPS, WMS, AVL)
- Billing and Payments (CIS, MDM)
- Security (video, encryption, tunneling, NERC/CIP)
- Utility Scale Power Plants (CHP, Solar, Geothermal, GMS, SCADA/EMS, GIS, GPS)

Smart Utilities Lab

- OT Systems: SCADA, Energy Management System, Generation Management Systems, Distributed Control Systems, Distribution Management System, Outage Management System, Geospatial Information System, Asset Management Systems, Work Management Systems, Mobile Work Management System, Metering Data Management System, Trading Systems, Load Forecasting Systems.
- IT Systems: Call Center Systems, Billing System, CRM System, Business Intelligence and Data Warehouse Systems, Enterprise Content Management Systems, Enterprise Resource Planning applications, Demand Response Management System, Written Equations, Applied AI/ML, Visualization.

Smart Cities Lab

- Street Lights, Traffic Lights, Traffic Management System, Parking Systems, Recycling Systems, Gunshot Detection, Noise Management Systems, Telemedicine Platforms, Remote Education Platforms, Payment Systems
- Customer Emergency and Citizen Comments (911, 311)
- Flood Control Systems, Emergency Management Systems, Mass Transit Systems, CO2 Control Systems, Methane Control Systems, Aquifer Management Systems
- Police, Fire and EMS Vehicles (WMS, AVL, GPS), Body worn cameras (AVL, GPS), Public Safety NOC (Video Wall)

Smart Mobility Lab

- Roads, Sidewalks, Highways, Bridges, Tunnels, and Overpasses
- Connected Vehicles, Electric Vehicles, Charging Stations, Autonomous Vehicles, Control Software, Safety Systems
- Vehicle Tracking – Taxis, Ride-sharing, Commercial, Private, and Self-driving (GPS), Planes, Drones, Buses and Trains (GPS and Public DB), Car and Bike sharing (GPS), Bridges and Tunnels (GPS), Crews and Vehicle Management (WMS, AVL)
- Wi-Fi Customer Access at all Vehicles, Ticketing and Payments, Security (video, encryption, tunneling), Transportation NOC.
- Robotics, Flying Systems, Driving Systems, Sailing Systems, Boating Systems.
- AI / ML, Blockchain, Databases, Cloud, Cybersecurity, Autonomous X, others.
- Street Signage, Mapping Technologies, Voice Control, GIS, Location Services, Written Equations, Applied AI/ML, Smart Street Lights (AMI), Smart Traffic Lights (AMI), Smart Parking Meters (GPS)

Grid CPU

A “Deep Dive”
on a Specific CIEDAR Project
with Large-Scale Implications

Segments of this material derive from an invited presentation to
the SRC/DoE Workshop on ICT Hardware Enabled Security, August 25-27, 2020,
with collaborators Hongyu Wu – Kansas State Univ. and Erfan Ibrahim – Bit Bazaar, LLC

Stan McClellan will provide more detail …

“Grid” vs. “Smart Grid”

- Today’s “Grid”
  - Embedded computing systems distributed throughout for telemetry and remote control (“SCADA”)
  - These systems are largely disconnected from the Internet via private networks (“air gap”)
- Tomorrow’s “Smart Grid”
  - Enhances these systems, connecting them together (“IIoT”)
  - Trend toward privately managed wireless continues, with interconnects
  - Virtually impossible to maintain “air gap” end-to-end

Technology / Network Context

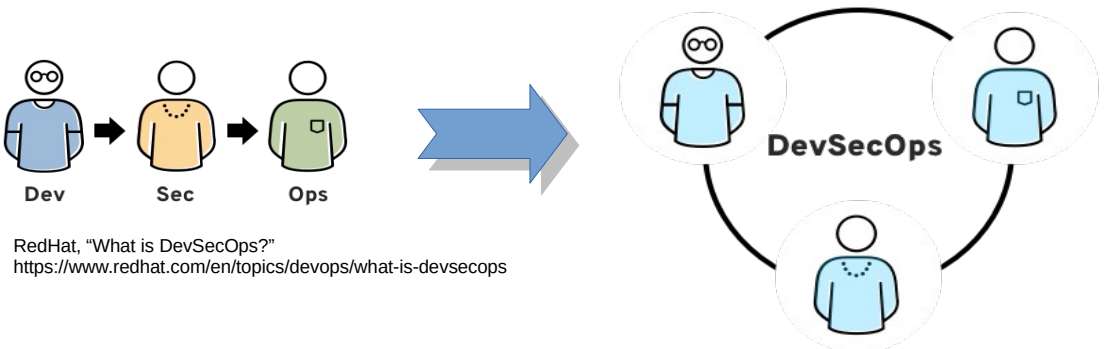
- Abiding Issues
  - Software … fuggeddaboudit
  - Hardware … difficult to fix, broad-based effects (Spectre, IDS/IPS)
- Interesting Concepts
  - Statistically optimized CPU architecture based on workloads
    - Hennessy & Patterson … RISC vs. CISC
  - Lockstep & Redundancy: Parity between CPUs, modules, cores
    - ARM “TrustZone” – NXP “SecureElement” – Synopsys “DesignWare”

Security: Continuous Integration

- Integration
  - To address cyber-security issues in all network-connected devices, measures must be integrated into the technology stack, from top to bottom … not just via software or external devices (IDS/IPS)
  - Security (and *compliance*) must be integrated longitudinally throughout the development & deployment cycle … to mitigate system risk
- Lowest-level devices may benefit from "Analysis By Synthesis"
  - Consider RISC vs. CISC … static Analysis By Synthesis (sort of)
  - Consider adding telemetry … dynamic Analysis By Synthesis

IT Precedent: DevSecOps

- Building security into system development, from end to end
- Continuous and integrated, at every stage of the system life cycle
- Is an approach to "Analysis By Synthesis" for complex, networked systems with substantial software content



RedHat, "What is DevSecOps?"
https://www.redhat.com/en/topics/devops/what-is-devsecops

Proposal: Joint Optimization

- Control systems used in today's "Smart Grid" are vulnerable
  - Large "threat surface" due to underlying, general-purpose CPUs
  - Systems not jointly optimized for cyber-resilience and critical use-cases
- Integrate DevSecOps with Machine Learning
  - We propose an approach which combines Machine Learning with telemetry to jointly and continuously optimize the CPU architecture
  - Includes critical use-case analysis, metrics for evolving / simulated threat vectors, and cost of upgrade vs. liability of compromise

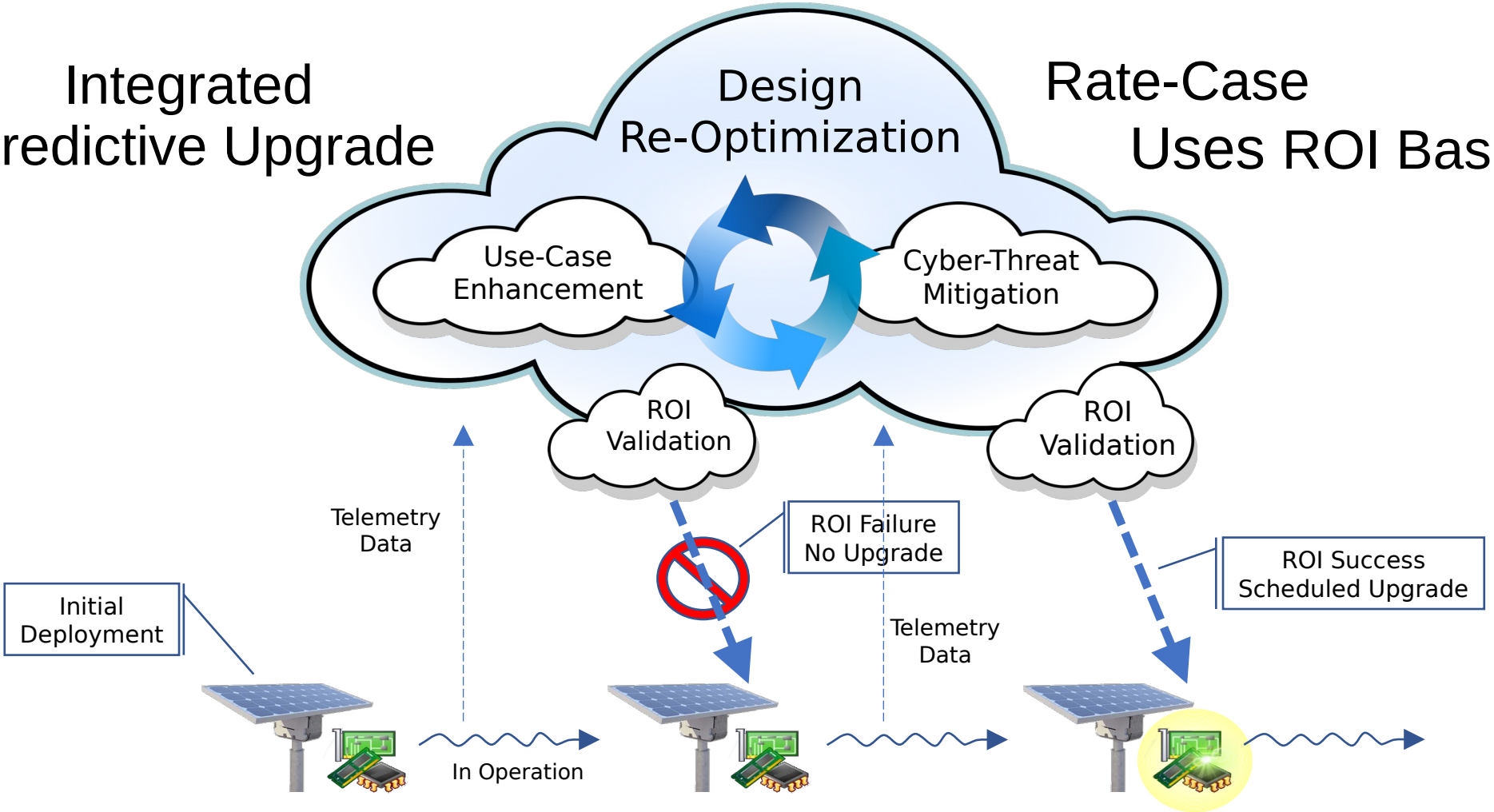
"Dynamic Machine Architecture via Analysis By Synthesis"

Cloud-Based Re-Optimization

- Optimization
  - Analyze sequences of power-system operations (“SCADA”) using ML techniques
  - Optimize the system response including extant and simulated threat vectors
  - Encode operating parameters in self-validating lists of context blocks
  - Cross-validate groups of context blocks with related use-case sequences
- Operation
  - “Meta-fetch” pre-validated context blocks enables application-level authentication
  - Cross-validation of blocks with actual use-case context before execution
  - Execute verified sequences of blocks, guaranteeing fidelity during disruptive events

Integrated Predictive Upgrade

Rate-Case Uses ROI Basis

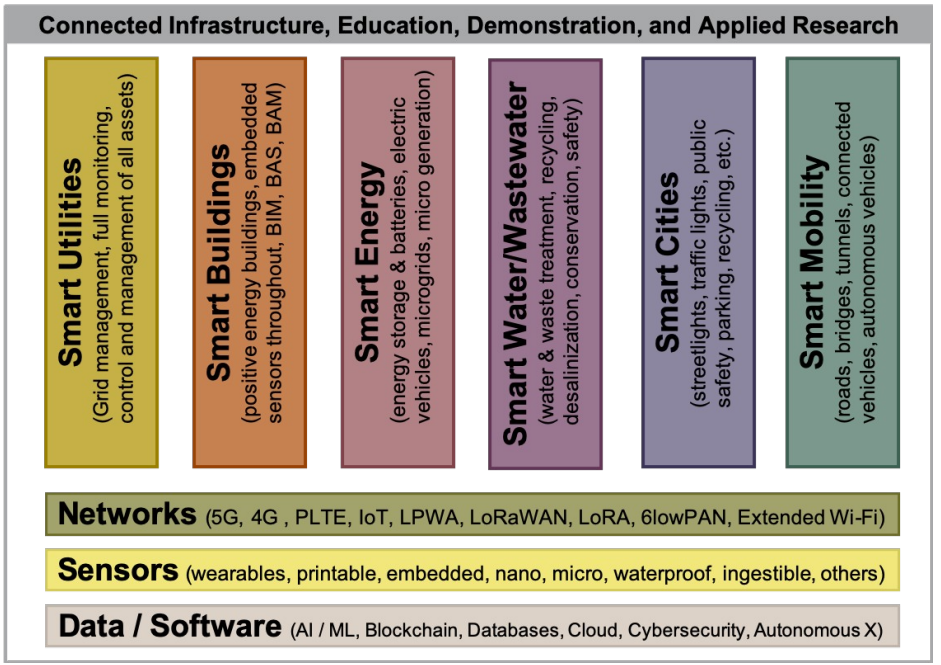


Benefits

- Ongoing, joint optimization with known & simulated threat vectors
  - Design of primitive functional sequences for “fail-safe” operation
  - Addresses emerging / unknown cyber-threats
- Cloud-based design approach
  - Ongoing joint-optimization includes use-cases and evolving threat vectors
  - ML algorithms operate via telemetry from slices of deployed systems
- Mitigates threats for critical systems
  - Clearly-defined cost/benefit metric (“ROI” includes security metric)
  - Enables prioritizing costly upgrades of deployed or at-risk subsystems

Recap: CIEDAR Key Projects

- Facilities
  - Smart Building & Infrastructure Lab
  - Smart Public Safety mass shooting testbed
  - Workforce Housing competition & buildout
- Energy
  - 300-acre Solar PV Farm testbed, competition, & Smart Energy Lab
  - Digital Substation of the Future and Smart Utilities Lab
- Drones & Transportation
  - Power Line and Tower Inspection testbed
  - Package Delivery & People Transport testbed
  - 100-acre Smart Mobility Track and Smart Mobility Lab
- NetworkTestbeds
  - Private LTE/5G 900 MHz licensed
  - Wirepass & Wi-SUN 900 MHz unlicensed
  - LoRA WAN 2.4 GHz unlicensed



Thank You!

More information on CIEDAR:

- https://hillviews.txstate.edu/issues/2020/bobcat-strong/project-ciedar.html
- https://www.marc.txstate.edu/CIEDAR.html
- https://vimeo.com/445306772