Unified Grid Monitoring, Control, and Protection Platform Concept

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Agenda

- Introduction – goals
- Why do we need a new PAC design - **Unified Grid Control Platform (UGCP)**?
- What utility operating and management functions does UGCP absorb?
- UGCP substation architecture
- UGCP wide-area functional enterprise architecture
- Review of the functions in UGCP functional enterprise architecture
- What PAC technologies support UGCP? What IT and business technologies support UGCP?
- Benefits
- Roadmap
- Experimentation in communications and processing on UGCP platform slice

Introduction - goals

We see variety of presentations on emerging technical approaches to protection, automation, and control (PAC):

- Ethernet LANs and WANs for protection functions.
- IEC 61850 functional modeling via standard Logical Nodes (LNs)
- LNs and functional models as key to automated point-interconnection PAC engineering.
- System model reconciliation for fault and stability studies
- Configuration and asset management
- Wide-area observation & PAC with synchronized measurements/PMUs (WASA and WAMPAC)
- “Centralized” Protection and Control (CPC)
- Digital twins
- Containerized functions on various operating systems for ADMS, DERMS, etc.
- *Sustainable designs and business cases*

What is the common future for all of these, and why are we headed there?

Why do we need a new PAC platform?

- Industry drive for zero-carbon grid
- Massive numbers of DER at T&D levels replace large dispatchable generators
- Unpredictable energy flows; no dispatch capability
- Massive rotating synchronous machines are displaced by IBRs
  - Low or oddly balanced fault current; inverter blocking on disturbances
  - Grid easily disturbed – dynamically brittle – swings require faster action than F relays can give
  - IBR – machine mix varies wildly over hours and days
- Transportation and industrial electrification
- New reliability standards; new regulatory and reporting demands
- Security and cybersecurity protection demands – how to consolidate fragments?
- Customer power quality and reliability demands
- Exploding and mixed utility asset base including PAC functions

Adding to legacy PAC systems will make problems worse and become unmanageable

Why do we need a new PAC platform?

- Deploying more racks of defined-function IEDs is unsustainable – we already are challenged to keep up with the obsolescence treadmill.
- The industrial, business, and communications/IT worlds have moved to new wide-area flexible generic platforms and tools.
- Leading-edge developments we see in PAC give us methods and tools to adapt to the emerging grid.

The new PAC architecture concept that merges these developments is the Unified Grid Control Platform (UGCP)

Unified Grid Control Platform Concept

A **decentralized** *or* **distributed** *array of redundant standardized data sensing, processing, and storage resources interconnected with redundant high-reliability cybersecure data communications.*

UGCP enables utilities to:

- Adapt functional behavior quickly and holistically across the grid.
- Operate a reliable, redundant, resilient, maintainable, and sustainable array of sensing, computing, and communications.
- Leverage emerging OT and IT networking solutions for integration of digital substations across the grid.
- Simplify life cycle maintenance with proven IT-based tools for centralized management of communications and computing environments.
- Continuously adapt cybersecurity capabilities.
- Holistically analyze operating information for grid and asset management.

Systems we use today are building blocks from which we evolve – more later.

Centralized P&C?

- IEEE Standards Committees publishing reports/requirements for *Centralized Protection & Control (CPC)*.

Author's opinions:

- *Language* of 'centralization' discourages experienced PAC engineers:
  - CPC invented by George Rockefeller in 1967 IEEE paper – but made a single line-zone relay in 1971.
  - 1970s-80s *integrated* P&C (EPRI WESPAC) - separate zone/redundant protection units with network interconnection.
  - This evolved to today's communications-based substations with function/zone/redundant separation.
  - 1990s CPC products had problem failure modes and were tough to maintain.

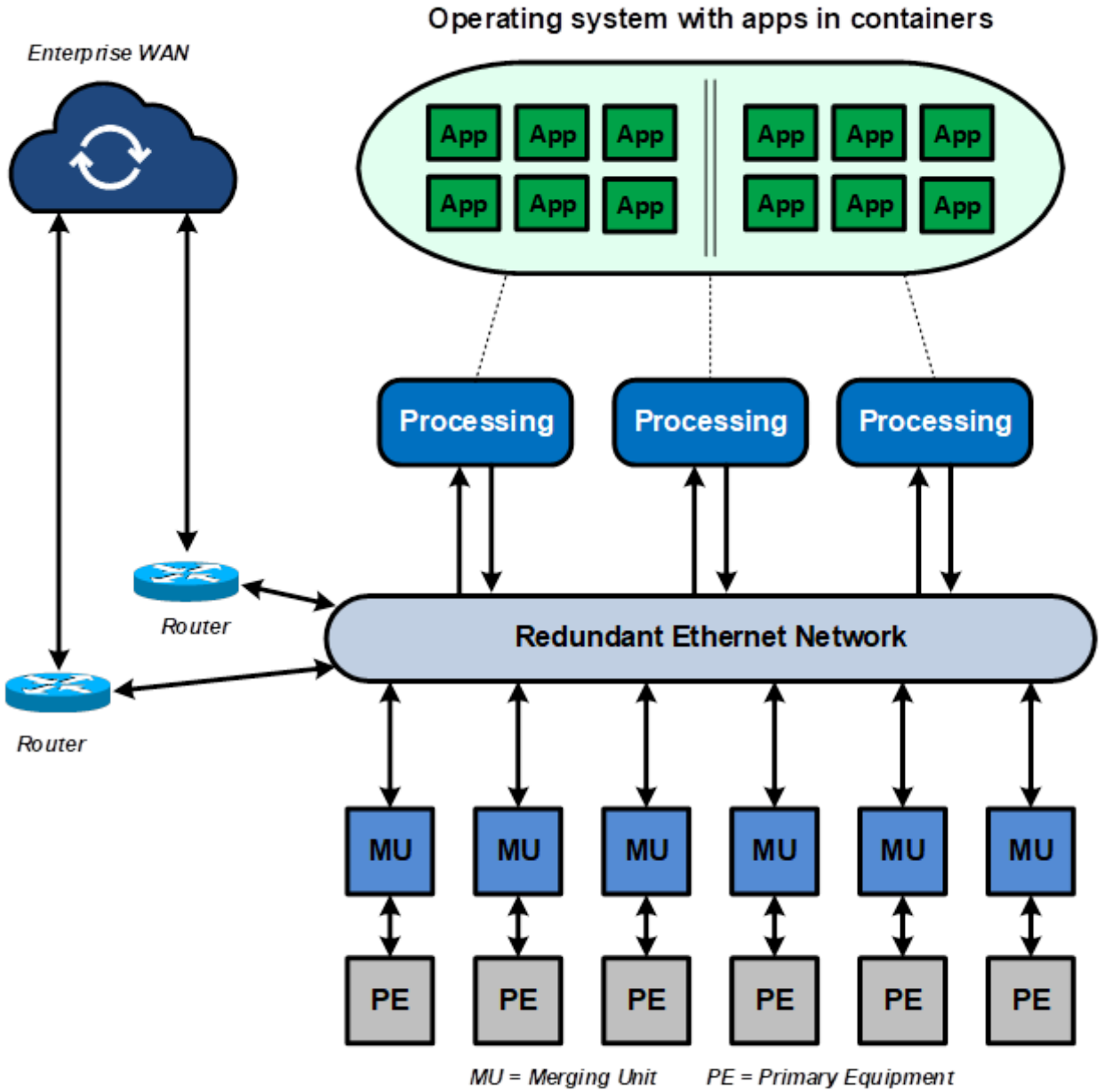
UGCP and industry direction actually ***unifies functionalities*** with modeling, processing compartmentalization, and communications.

- Controllable and acceptable sharing of physical processing components that can fail.
- Wide-area grid PAC and management ***functions*** are centralized on a distributed platform.

The CPC language will continue - but think of *centralized* as unified functionality with separation and redundancy.

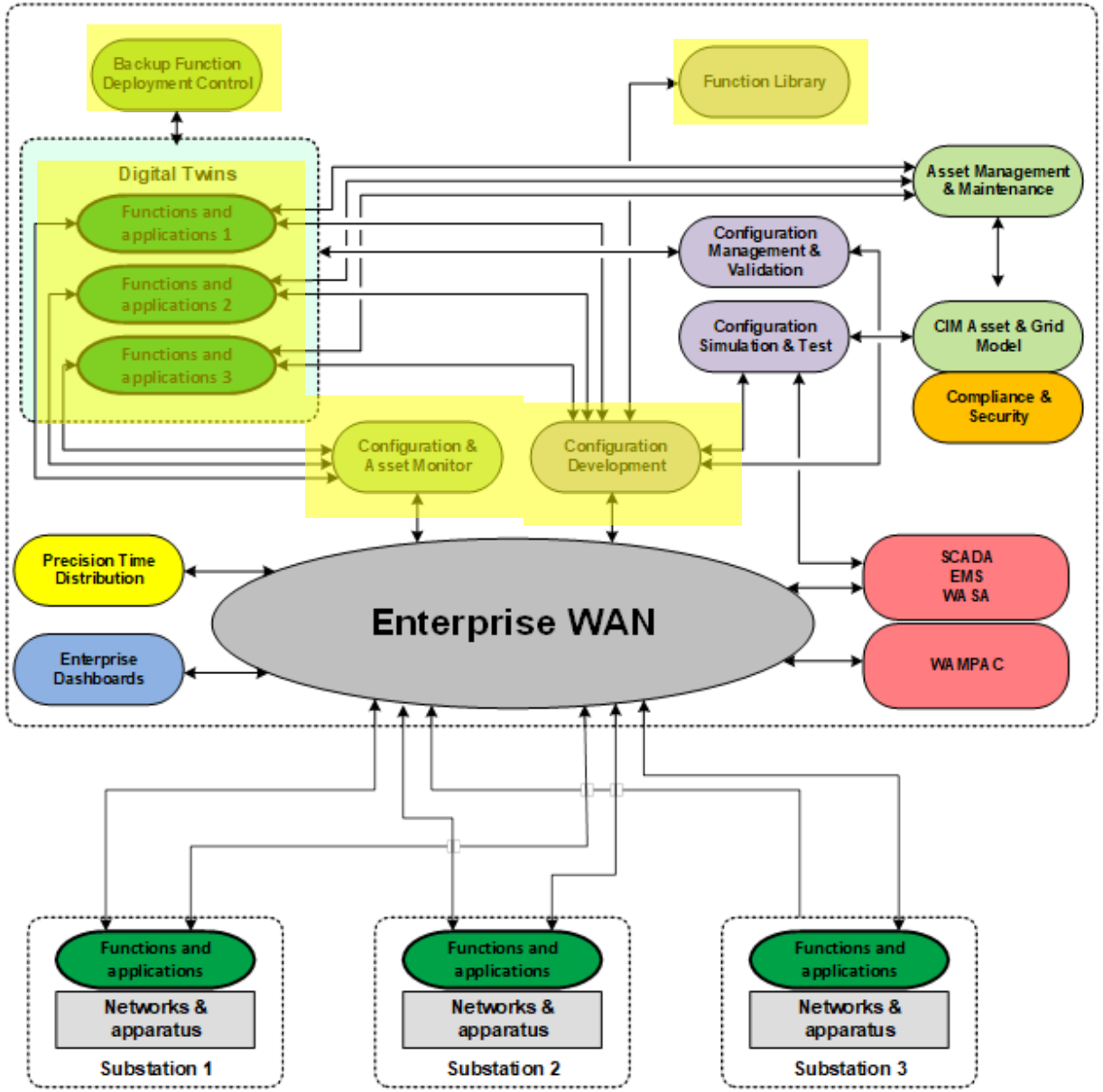
UGCP Substation Architecture

- Inherits IEC 61850 digital substation elements.
- Distributed redundant processing platforms and networks.
- Isolated apps with Logical Node (LN) interfaces.
- Redundant processing and networking to avoid loss of functions for single or multiple points of failure.
- Centrally managed configuration and modeling.



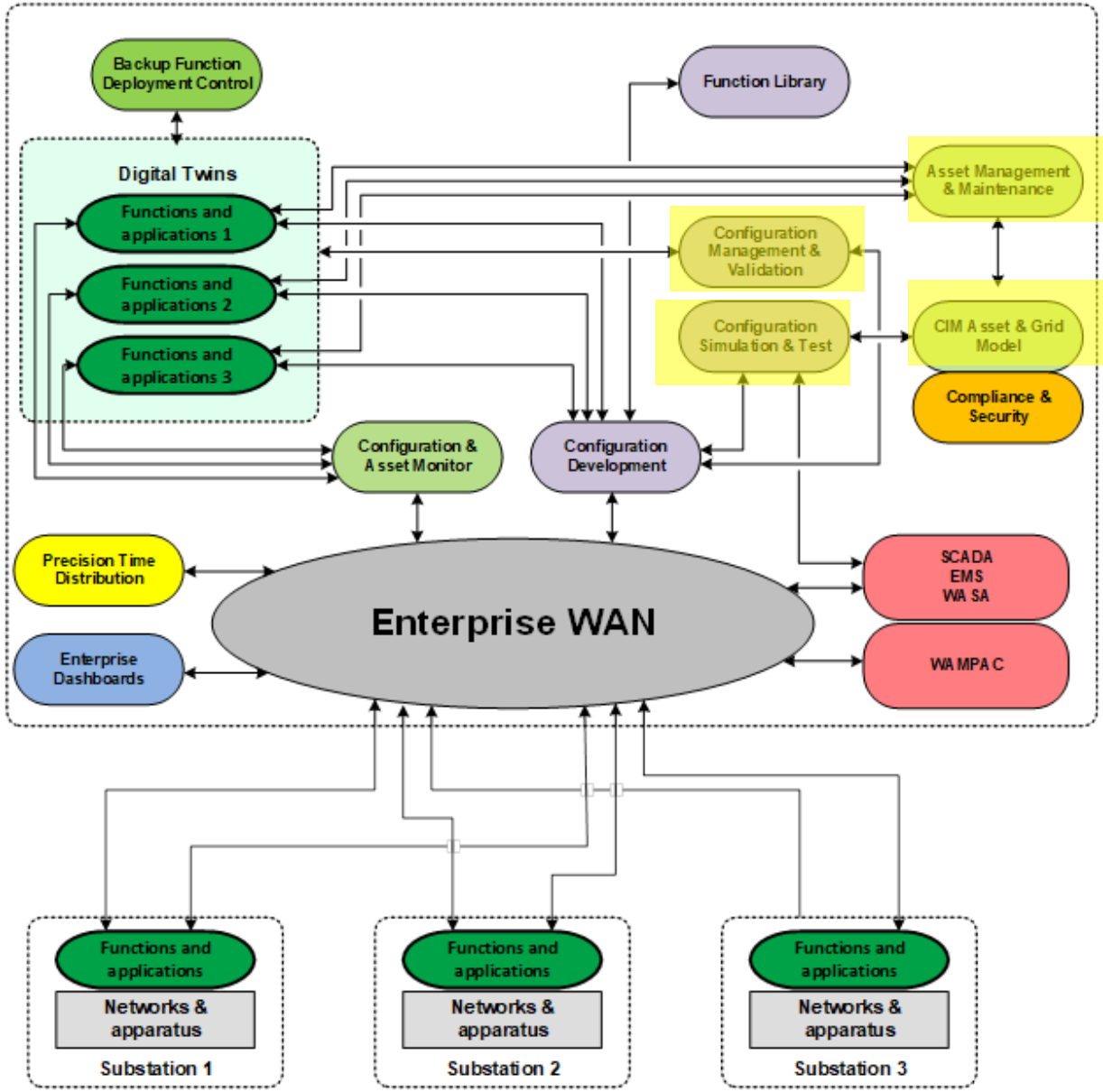
UGCP Wide-Area System Functional Architecture

- ***Config & Asset Monitor*** - live information on status of apps and PAC equipment.
- ***Digital Twins*** - mirror images of PAC, power system equipment, & topology, as configured and managed here.
- ***Backup Function Deployment Control*** - interacts with the digital twin status of each grid node or wide-area PAC function.
- ***Configuration Development*** - assemble new app configurations from a managed library in an operating element or area to update operation without outages.
- ***Function Library*** – version controlled, in-service and newly deployed.



UGCP Wide-Area System Configuration

- ***Configuration Simulation & Test*** - validates changes using the digital twin PAC/grid model in existing or extreme operating states.
- ***Configuration Management & Validation*** -ties the operating configurations to their digital twins, backup adaptations, and updates under development.
- ***Asset Management & Maintenance*** - tracks all power system and UGCP infrastructure through Digital Twins function & dispatches actions.
- ***CIM Asset & Grid Model*** – maintains database for condition, history, topology, ratings, and plans for all grid and UGCP assets.



Development facilities for constantly-evolving functions (1)

Familiar but unsustainable practices for P&C:

- Observe field problems and test equipment in lab
- Depend on supplier to share other bug fixes and new product function updates as firmware updates.
- Test the new firmware in the lab on typical standard design (if there is one in the lab).
- Find all the relays or IEDs that should get this particular new firmware.
- Technicians drive trucks to substations and update subject relays or IEDs.
- Technicians perform commissioning tests on relays.
- Engineering or Asset Management or Maintenance team updates configuration records.

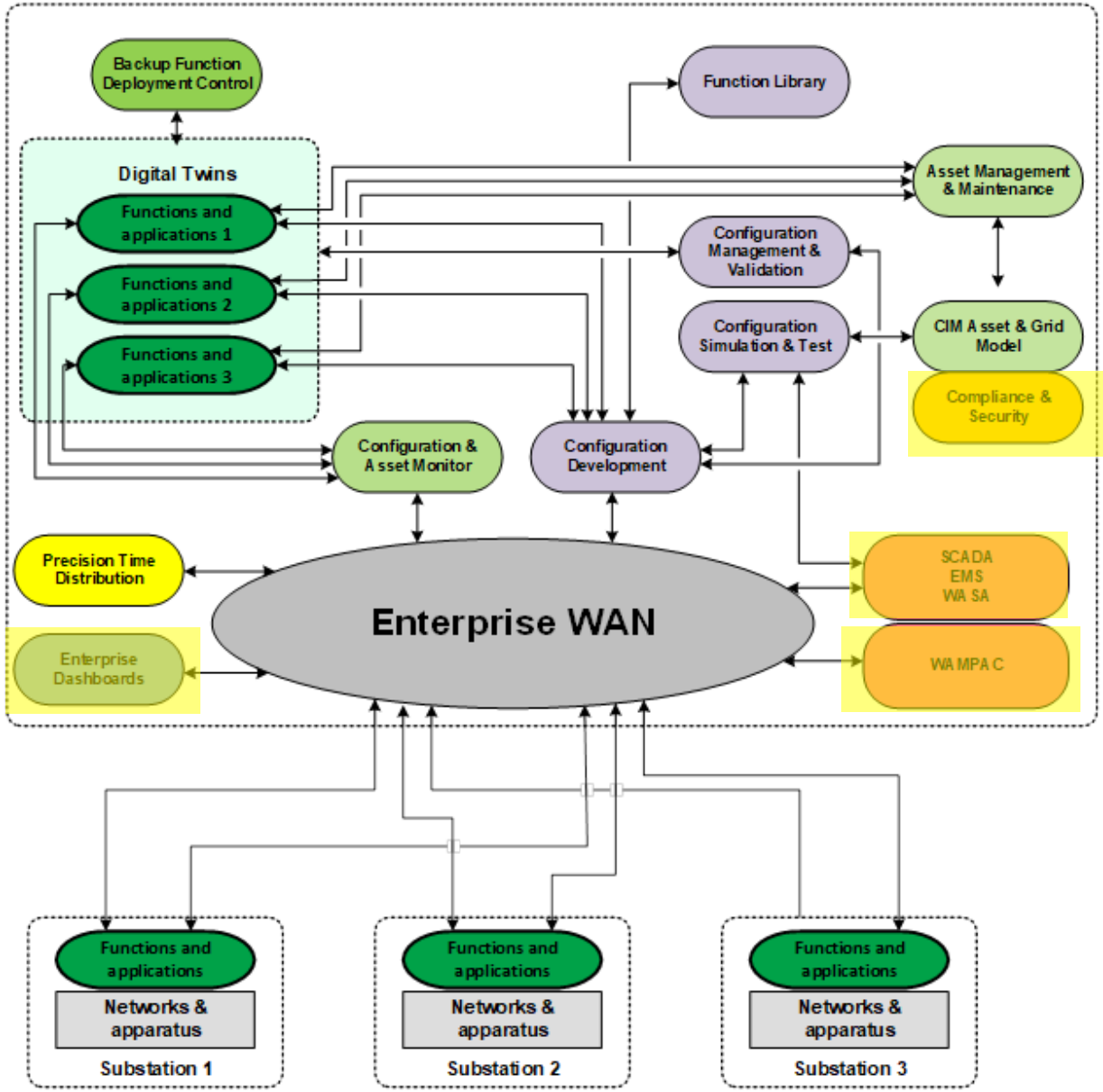
Development facilities for constantly-evolving functions (2)

Facilities in UGCP:

- ***Development environment*** – debug functions or test new functions in a complete replication of the existing or newly-conceived substation or wide-area configuration.
- ***Pre-deployment or Commissioning Test environment*** – test existing or proposed new function configurations in a complete replication of the production substation or wide-area configuration.
- ***Production environment*** – the working function configuration as replicated in the grid-wide platform and the Digital Twin model of grid-wide functions
- ***Digital twins*** – test and integrate functional updates to find out how they really work before downloading into production service.
- ***Cybersecure WAN communications among containerized local environments*** – upload, download, and continuously manage configurations of containerized functions on uniform-looking platforms.
  - Hardware can vary but containers isolate the differences.

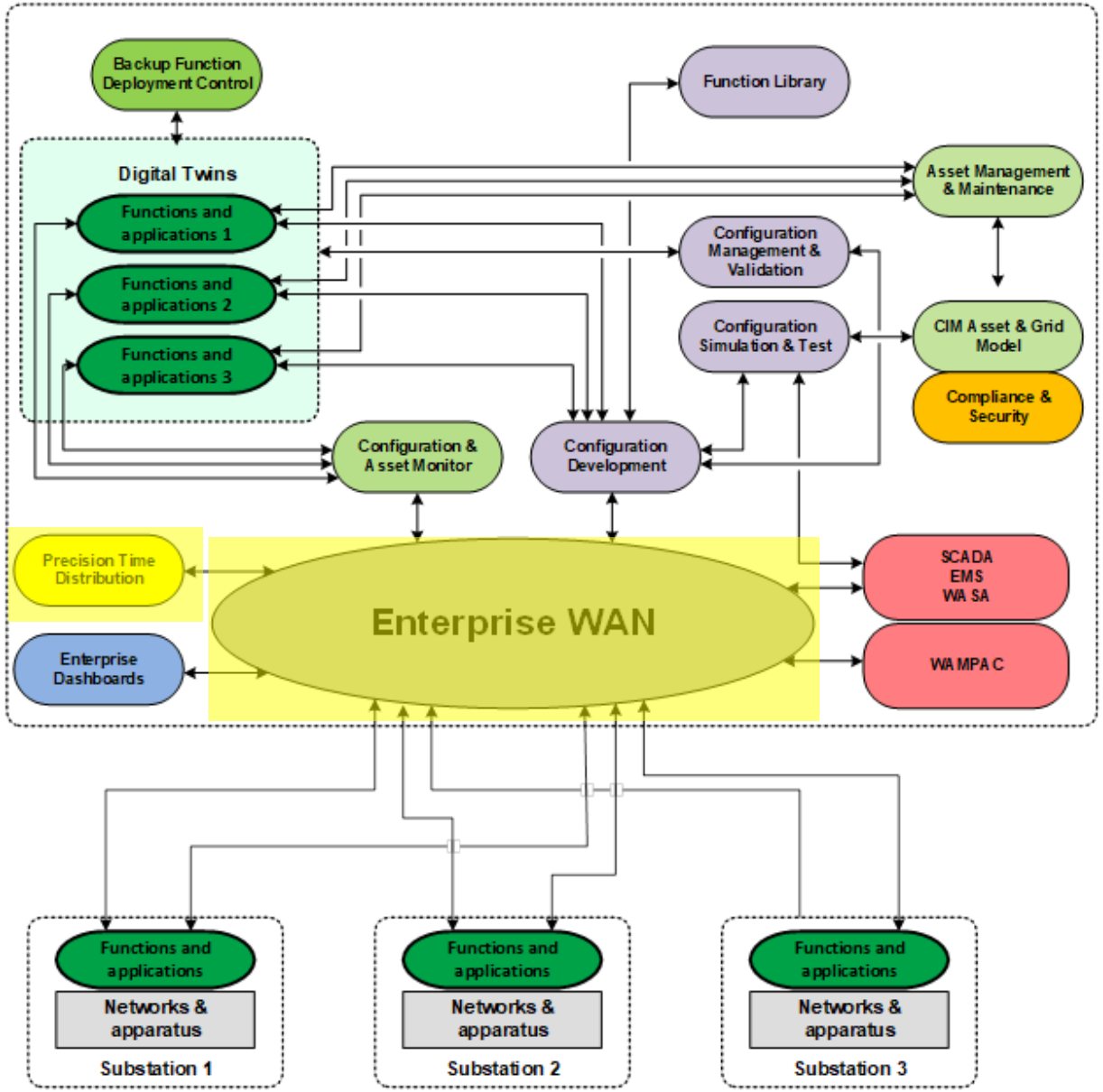
UGCP Wide-Area System Configuration

- ***Compliance & Security*** element – real time holistic monitoring in depth with compliance and contingencies.
- ***SCADA-EMS-WASA*** - grid control center with redundancy and separation plus high-speed synchronized measurement-based displays and analyses
- ***WAMPAC*** - wide-area protection, automation, and control including wide-area protective relaying schemes using synchronized measurements for fault and stability protection.
- ***Enterprise Dashboards*** - business applications and overall utility enterprise management functions for specific organizational stakeholders or leaders.



UGCP Wide-Area System Configuration

- ***Precision Time Distribution*** – with mission-critical redundancy and grid-wide self-sufficiency.
  - Ethernet PTP as it evolves – GPS/GNSS is insecure, costly, tough to sustain
  - For synchronized PMUs and WASA/ WAMPAC, plus event analysis.
  - Core requirement for emerging IT-OT communications infrastructure.
  - Many utility IT teams resist so far.
- ***Enterprise WAN*** – redundant, resilient operational and enterprise private cloud communications infrastructure - operational monitoring, management, and security functions. Integrate or segregate OT versus IT/business communications.



Integrating Utility and IT technologies into UGCP

Utility industry developments bring:

- PAC apps
- IEC 61850 models, engineering, protocols
- IEC 61968 CIM
- Grid behavior models to be harmonized or integrated
- Real-time transient models
- DERMS, ADMS, EMS
- Synchronized (PMU) measurements and apps
- Specialized redundant networking – PRP & HSR

IT-industry business development brings:

- LAN standards, switches, and networking technology
- Wide-area high-speed networking routers, links, infrastructure
- Mission-critical cloud architectures or services
- Containerization and isolation tools
- Arrays of standardized high-powered computing platforms
- Multi-contingency redundancy architectures
- Distributed or remote network security and management tools
- Big-data analytic, management, and AI tools.

Features and Benefits of UGCP Architecture

- Sensor and system data is processed only once for all users at higher levels (with redundancy where needed).
- Hierarchical processing overarches physical locations for holistic sharing.
- Functional deployment is isolated from physical boxes but keeps needed separation.
- Grid equipment and UGCP operation are all modeled in digital twins for configuration management, validation, contingency analysis, and development of new functions on-line.
- No-outage upgrading, repair, and evolution of UGCP.
- Large numbers of DERs and supporting apps are continuously integrated.
- The entire UGCP configuration can continuously monitor and historize its behavior and performance.
- UGCP benefits from economies and advances flowing continuously from the IT world.

Technical Operations Center (TOC) Concept

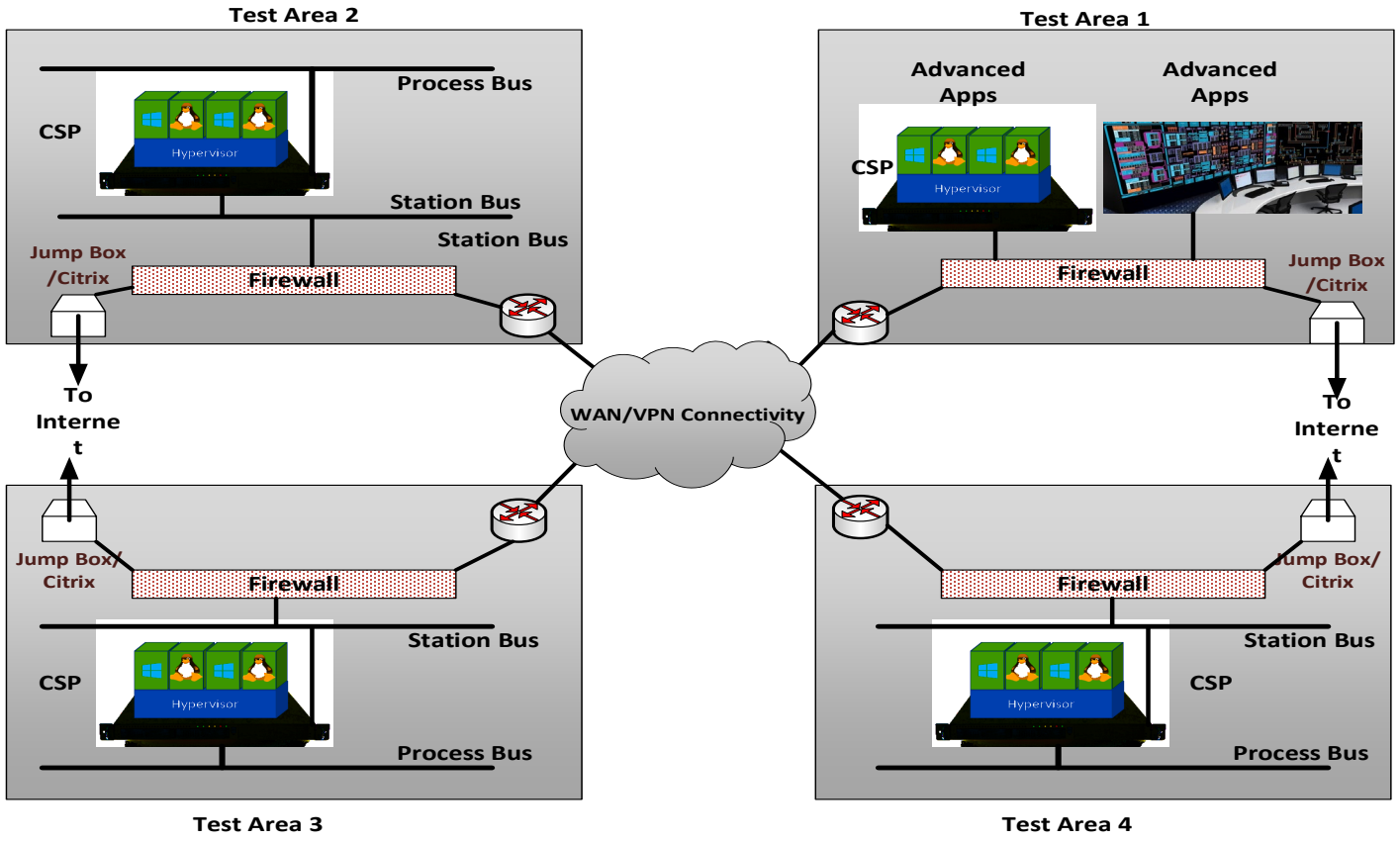
Not a physical center or location – an assembly of enterprise and UGCP management functions.

- Maintenance monitoring, performance and security management, and asset management.
- Field crew dispatch driven by effective diagnosis and assessment of mission with operational support.
- Operational tracking, state validation, and alarming of data issues.
- Event data and situation reporting for operators, engineers, regulators.
- Unified organizational database, all modeling and digital twin management, configuration management, and asset management.
- Remote automated configuration change validation for updating of all UGCP apps and systems.
- Management and operation of IEC 61850-based PAC system configuration based on IEC 61850-6 Substation Configuration Language (SCL).
- Site access and physical security monitoring.
- Real-time management dashboard configuration
- Tools for training of users for all TOC functions.
- TOC management - KPIs & metrics based on SLAs.

Specify data flows to support TOC functions

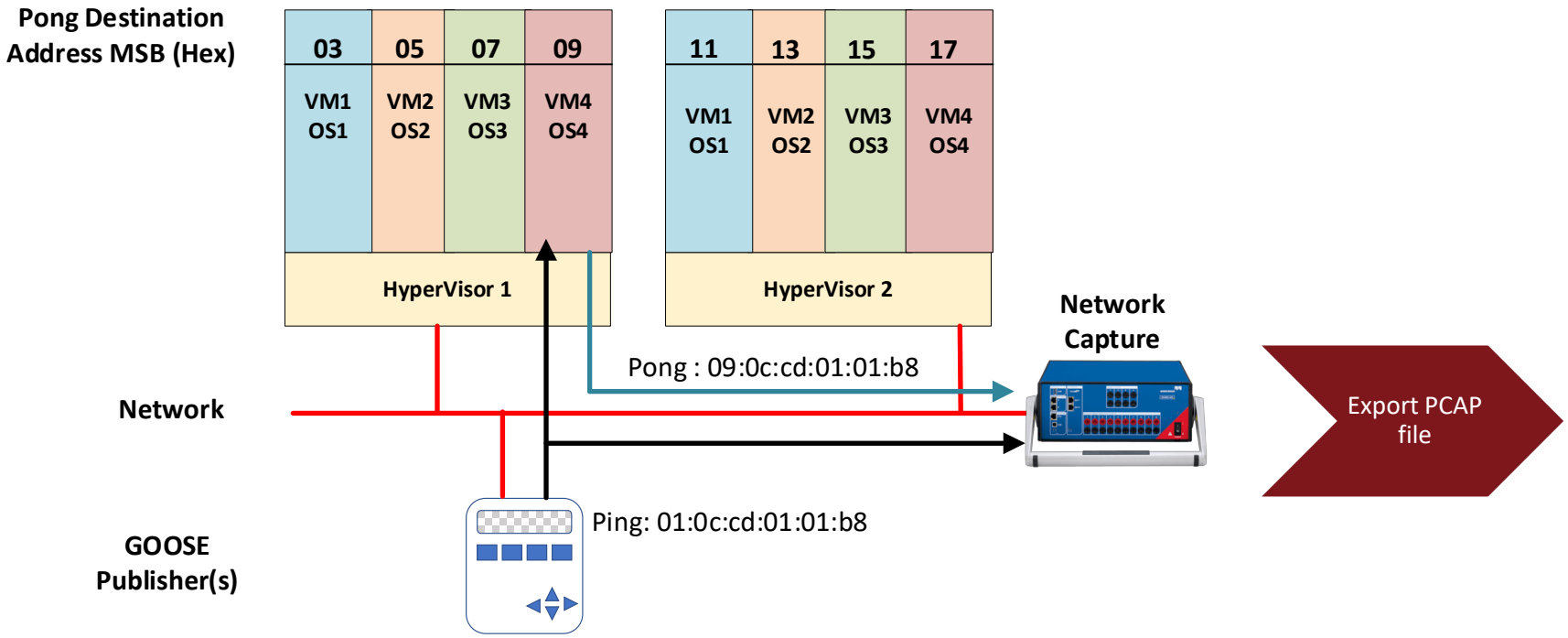
Roadmap for UGCP Advancement

1. Specify components for a demonstration.
2. Design demonstration architecture.
3. Integrate a lab digital substation Test Area.
4. Develop and test substation functions on general-purpose computing platforms, networks.
5. Create additional substation Test Areas with WAN integration.
6. Integrate distributed environments for demonstration enterprise functions.
7. Develop demos of high-speed PAC, data archiving, and Technical Operations Center functions.
8. Revise specs for practical industry UGCP architecture.
9. Plan and support industry adoption and commercial development.
10. Develop industry program for training organizations to adapt.



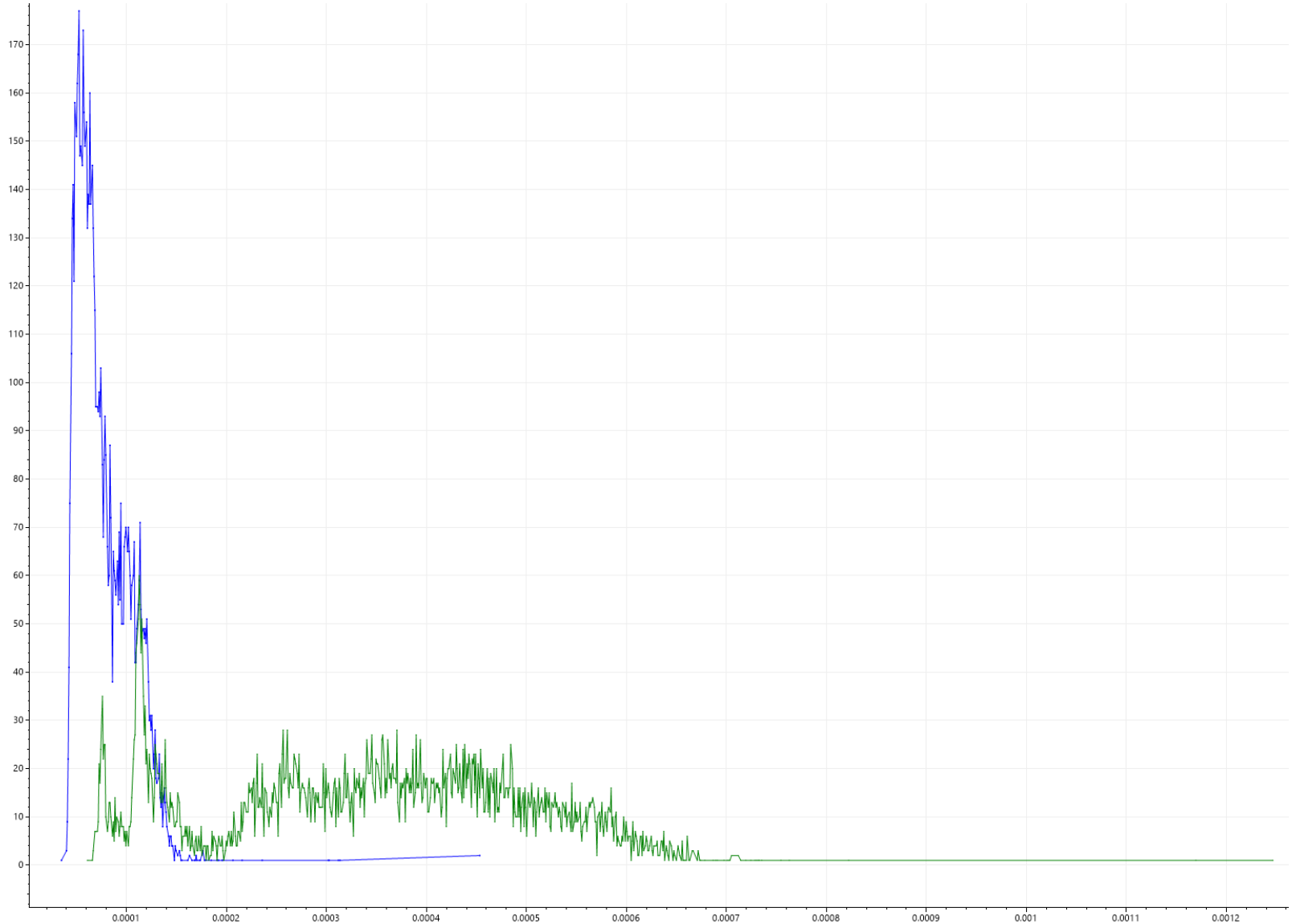
EPRI initial testing of GOOSE communications among platforms and containers

- Separate hardware platforms can be different.
- Hypervisor (Type 1 runs on HW) manages containers with virtual machines.
- Virtual machines are networked and can exchange GOOSE or any other PAC traffic



EPRI initial testing of GOOSE communications among platforms and containers

- Typical 100 ns inter-container GOOSE messaging response time depending on loading.
- Tests on today's practical hardware showed plenty of capacity for full-substation PAC functions exchanging messages continuously.



Conclusions

- Continuing PAC via racks of special-purpose devices is unsustainable as we create the carbon-free grid – that would be riskier than UGCP.
- Key elements of UGCP are already available from our leading-edge P&C technologies and from other mission-critical industries.
- Readily available IT equipment, computing, application, and communications products can support the evolution of a fully functional UGCP.
- Integration of first UGCP designs is practical today – steps and demo here.
- Industry forums and standards committees must coordinate design and deployment to maximize the economic and functional benefits.

Thank you! *Questions?*

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