Your systems.
Working as one.

DDS Applications in the Industrial Internet of Things

Stan Schneider, PhD. RTI CEO, IIC Steering Committee

The Future *is* Intelligent Distributed Machines

DDS Experience in IIoT

- Designed into over $1 T of IIoT
  - Healthcare
  - Transportation
  - Energy
  - Industrial
  - Defense
- 15+ Standards & Consortia Efforts
  - Interoperability
  - Multi-vendor ecosystems

DDS

OMG OBJECT MANAGEMENT GROUP

FACE Future Airborne Capability Environment

EUROCONTROL

SGIP SMART GRID INTEROPERABILITY PANE

ICE Alliance Integrating Clinical Environments

ROS

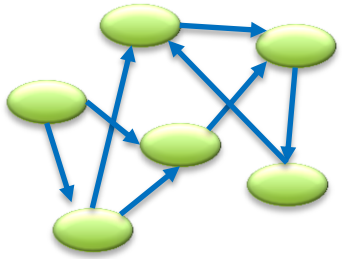
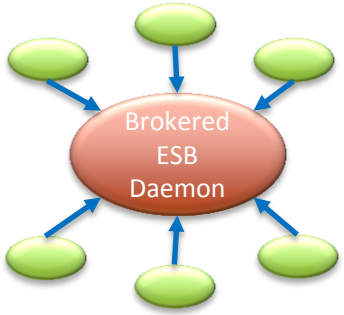
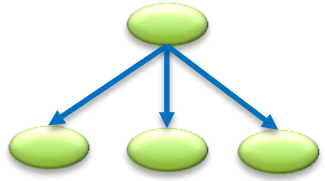
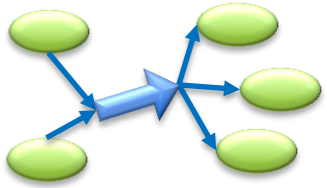
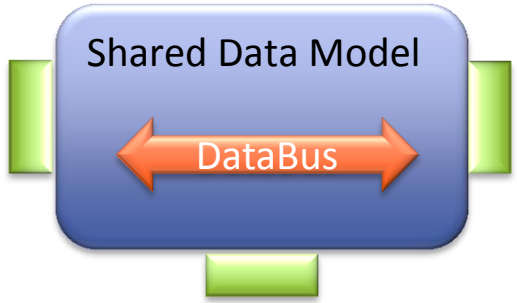
OSA

DUKE ENERGY

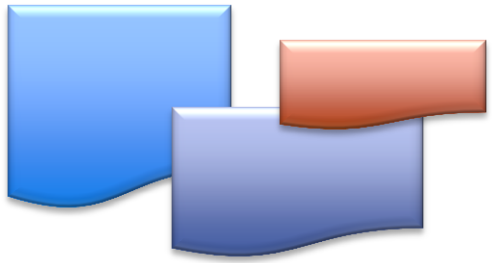
MD PnP Getting connected for patient safety

SAE INTERNATIONAL

DDS is Different!

Point-to-Point	Client/Server	Publish/Subscribe	Queuing	Data-Centric
				
				
TCP Sockets	MQTT REST XMPP OPC	Fieldbus CANbus	AMQP Active MQ	DDS

It's All About the *Data*

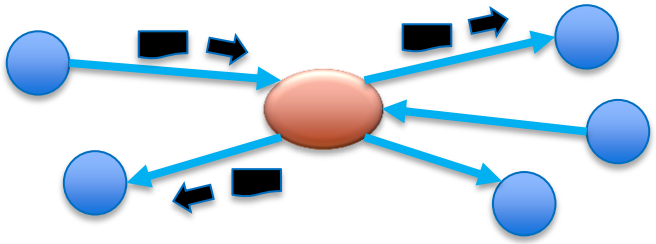


Unstructured files

Data Centricity

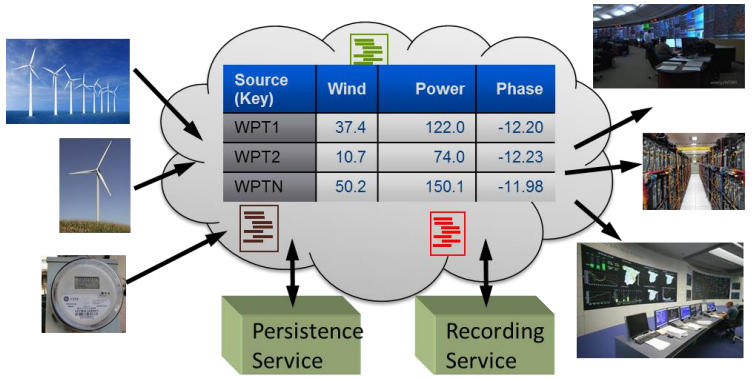
Database

Data at Rest



Messaging middleware

Data Centricity



DataBus

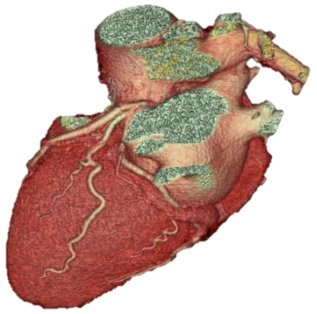
Data in Motion

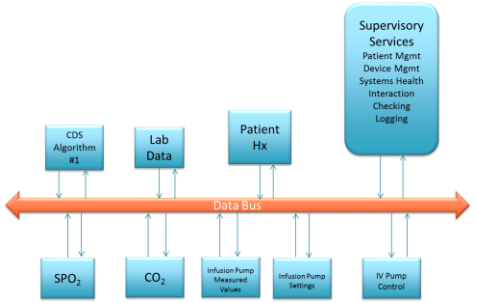
Data centricity enables interoperation, scale, integration

What Does DDS do for the IIoT?

Systems Challenges in Medical

- Imaging & Treatment Systems
  - Compelling problem: high-performance-system integration
- Surgical Systems
  - Compelling problem: feedback, video, patient monitoring
- Connected Medical Devices
  - Compelling problem: Patient safety, multi-device platform, hospital integration

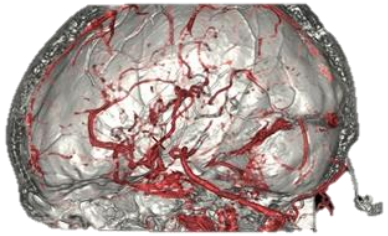




Provide a Common Platform

"GE Healthcare chose the DDS standard because it can handle many classes of intelligent machines. RTI Connext DDS satisfies the demanding requirements of our devices and supports standardization on a single communications platform across product lines."

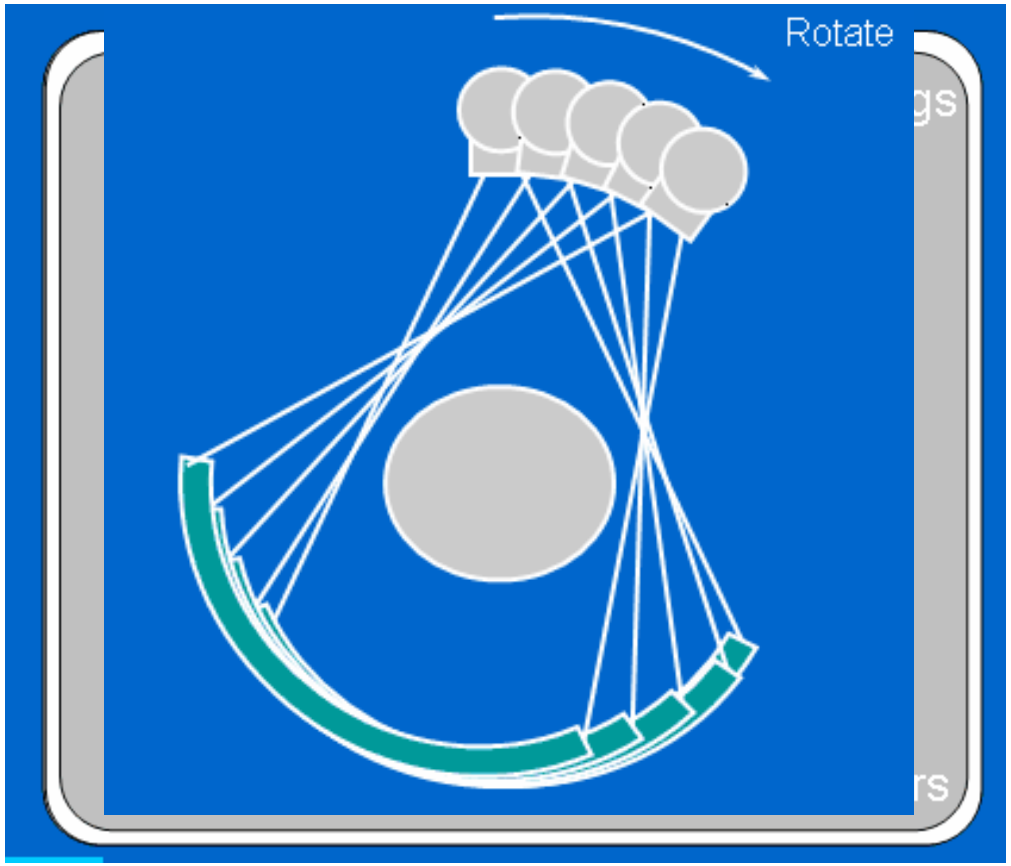
Revolution®



-- J Gustavo Perez, General Manager for MI&CT Engineering

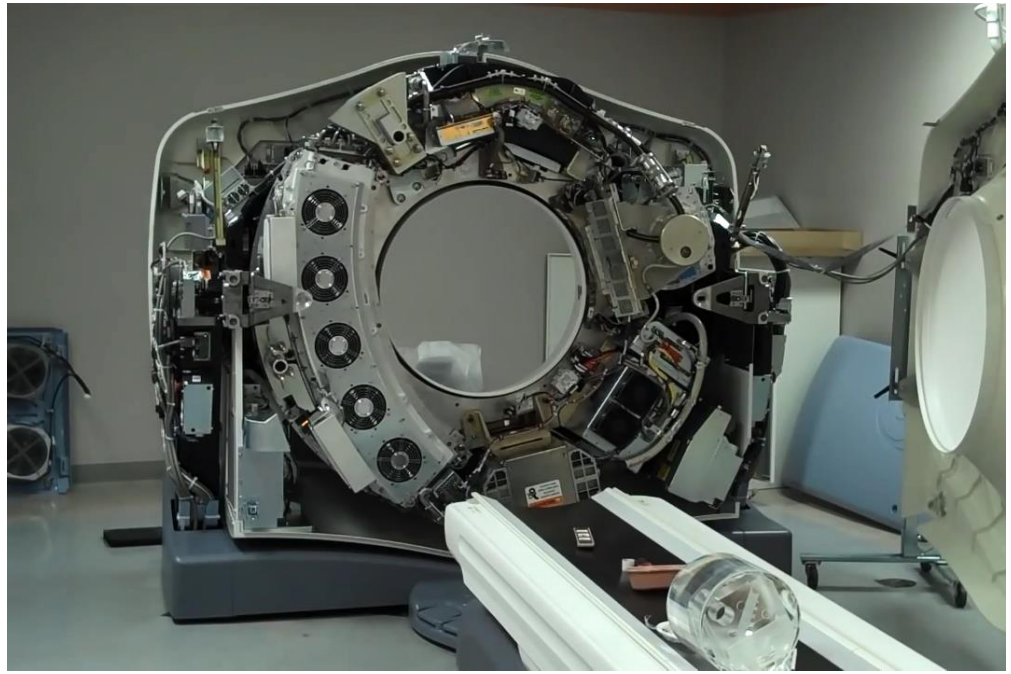
CT Basics

- Spin an xray source around an object
- Time exposure carefully to get the right image or freeze motion
- Collect the projection data during spin
- Do the math

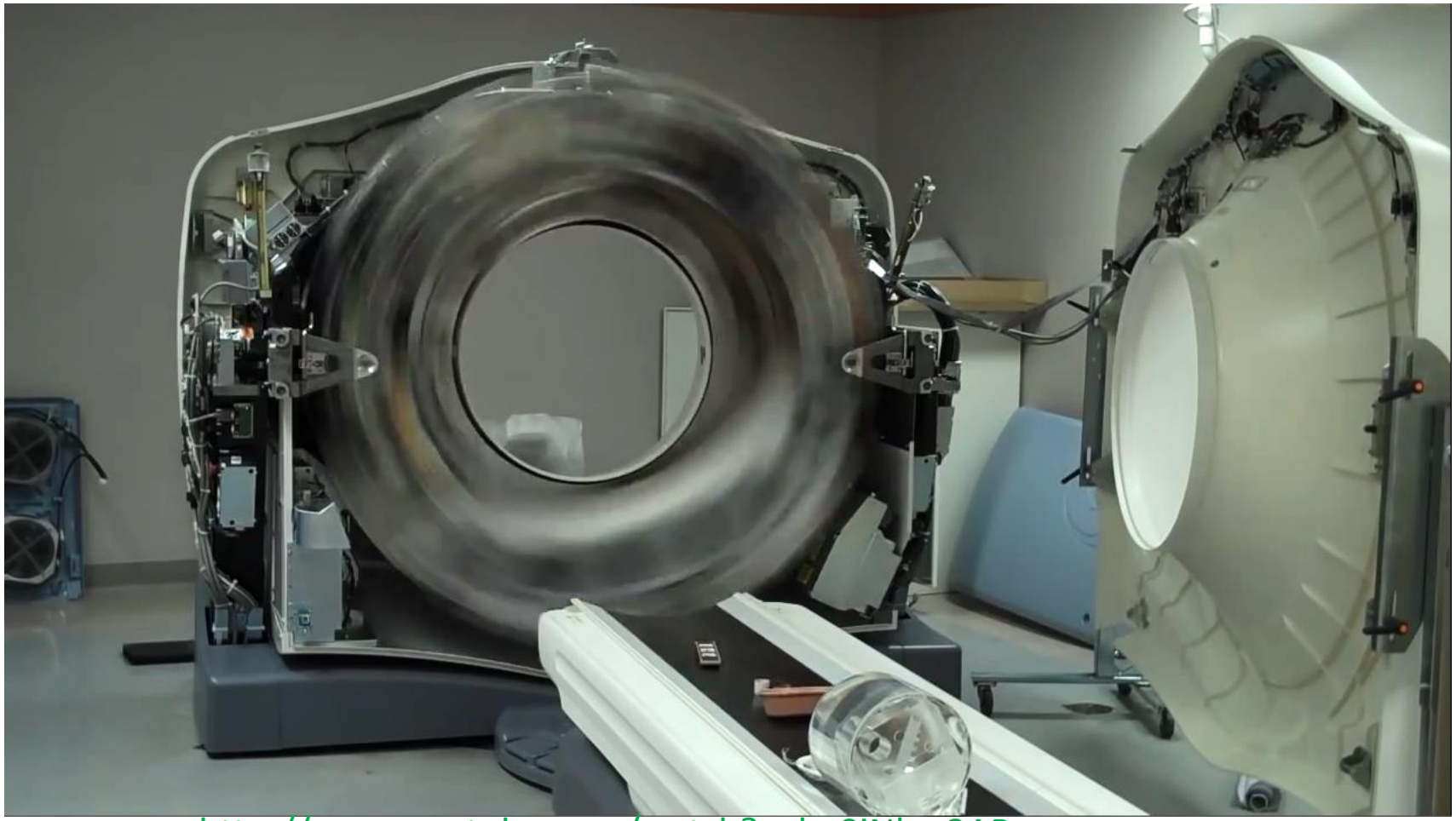


CT Scanner: Coordinated Control

- Coordination
  - Generator
  - Scanner
  - Power
  - Servo
- Burst image data acquisition
- Control & monitoring
  - Systems ready for scan
  - Status during scan
- Operator interface
- Integration
  - Multiple programming languages, OS, data models
  - Data archiving

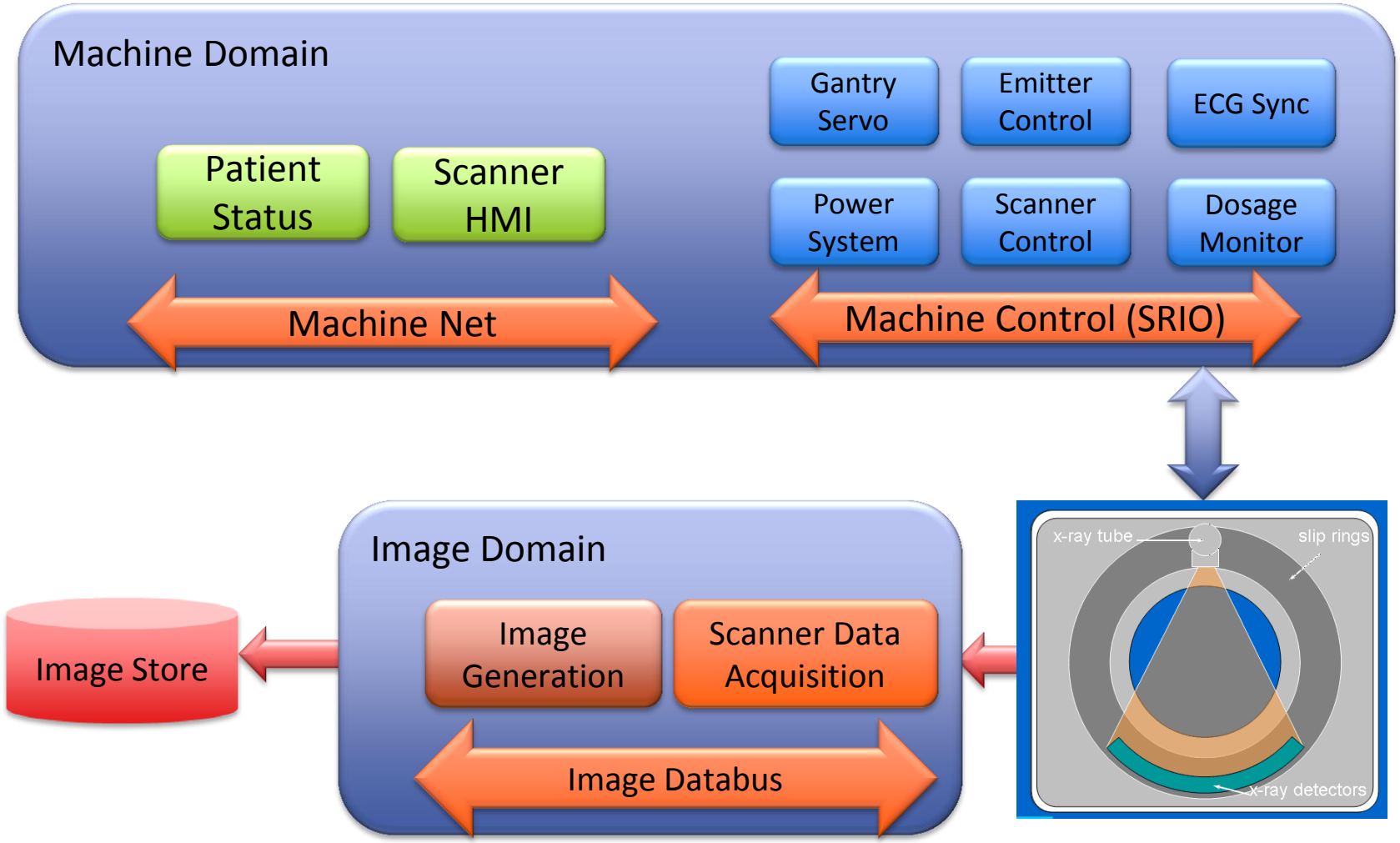


CT Scanner in Operation



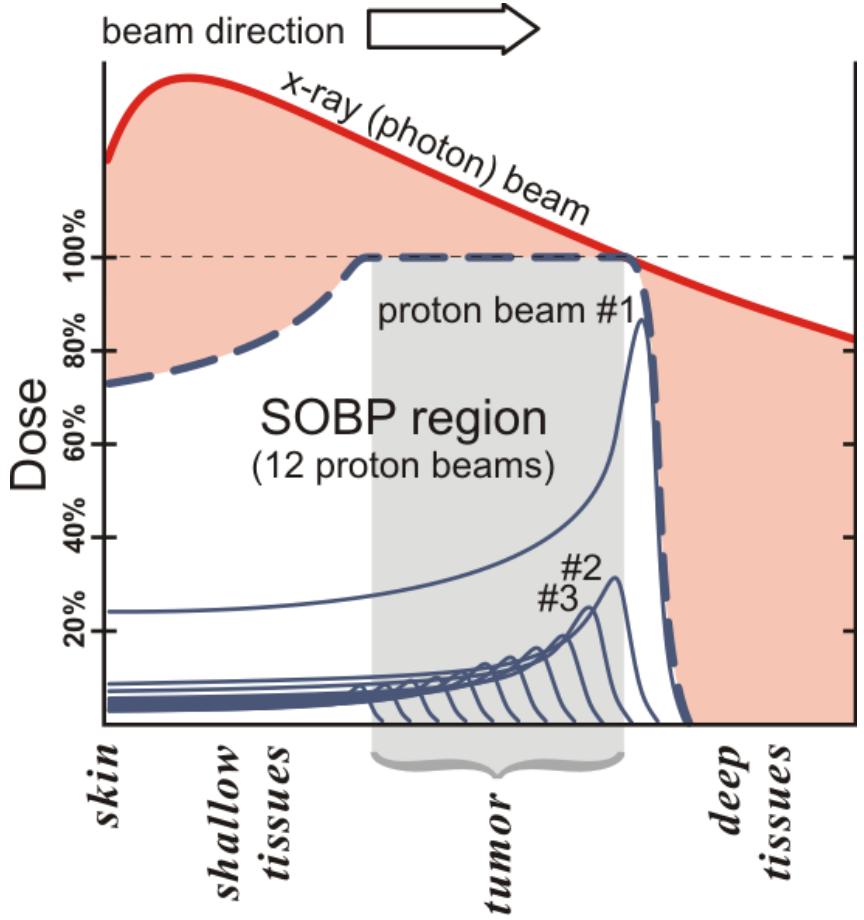
http://www.youtube.com/watch?v=bg0iNhw2ARw

CT Scanner Control

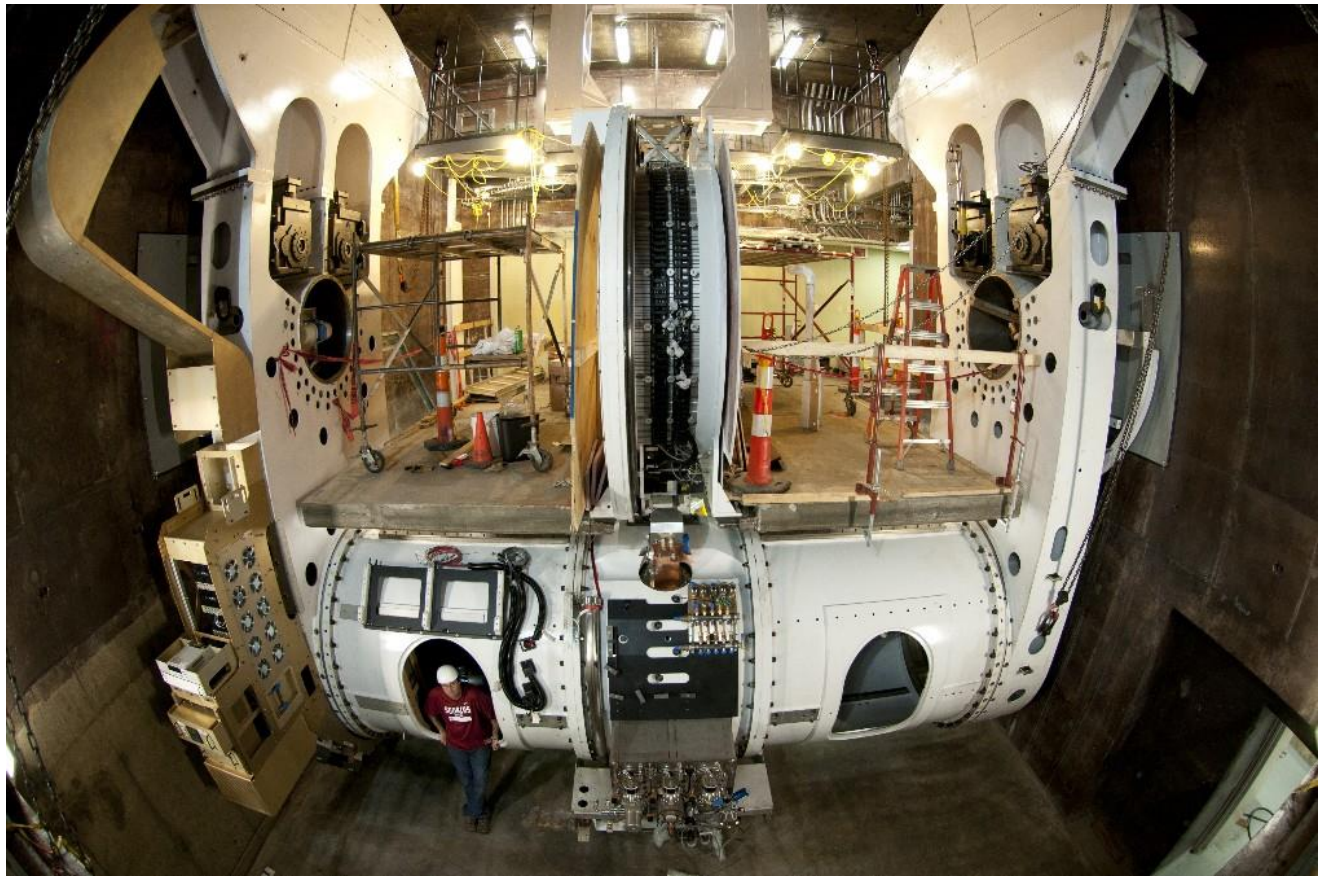


Proton Beam Therapy

- Unlike Xrays, PBRT precisely delivers energy with little tissue exposure
- Controlling exposure requires positioning patient in 3D



Ensure Reliability for Complex Systems



MEVION medical systems

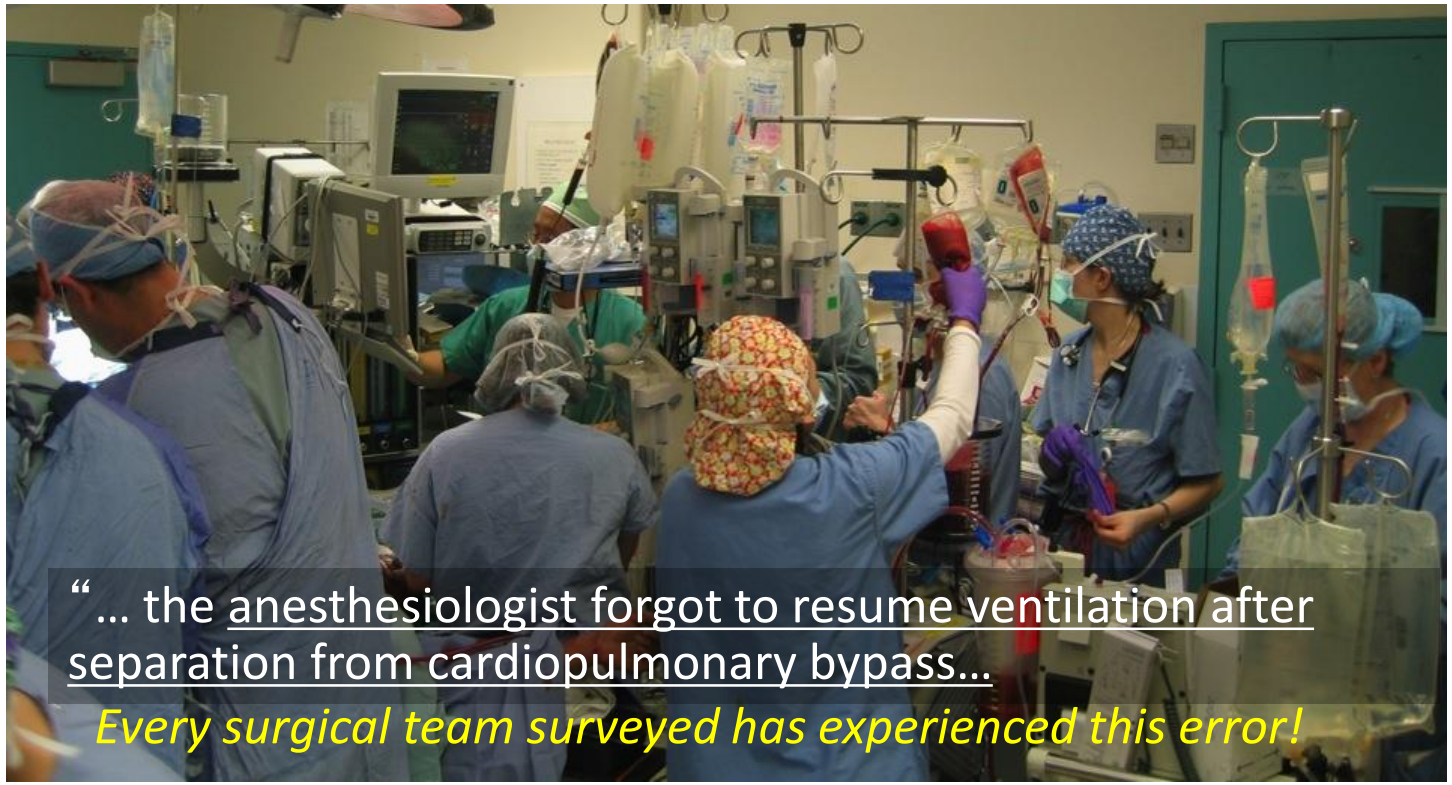
First patient treated Dec 2013,
Siteman Cancer Center, St. Louis

- Mevion's Proton-Beam Radiation Therapy system zaps tumors with accelerated protons
- The treatment must be continuous for 30-40 days; downtime endangers treatment success

- With RTI Connext DDS, Mevion's PBRT delivers dependable treatment at low cost

Improve Safety by Connecting Devices

- Hospital error is the 3rd leading cause of death
- The Integrated Clinical Environment (ICE) standard specifies interoperability for medical devices
- The IIoT ties together instruments in real time



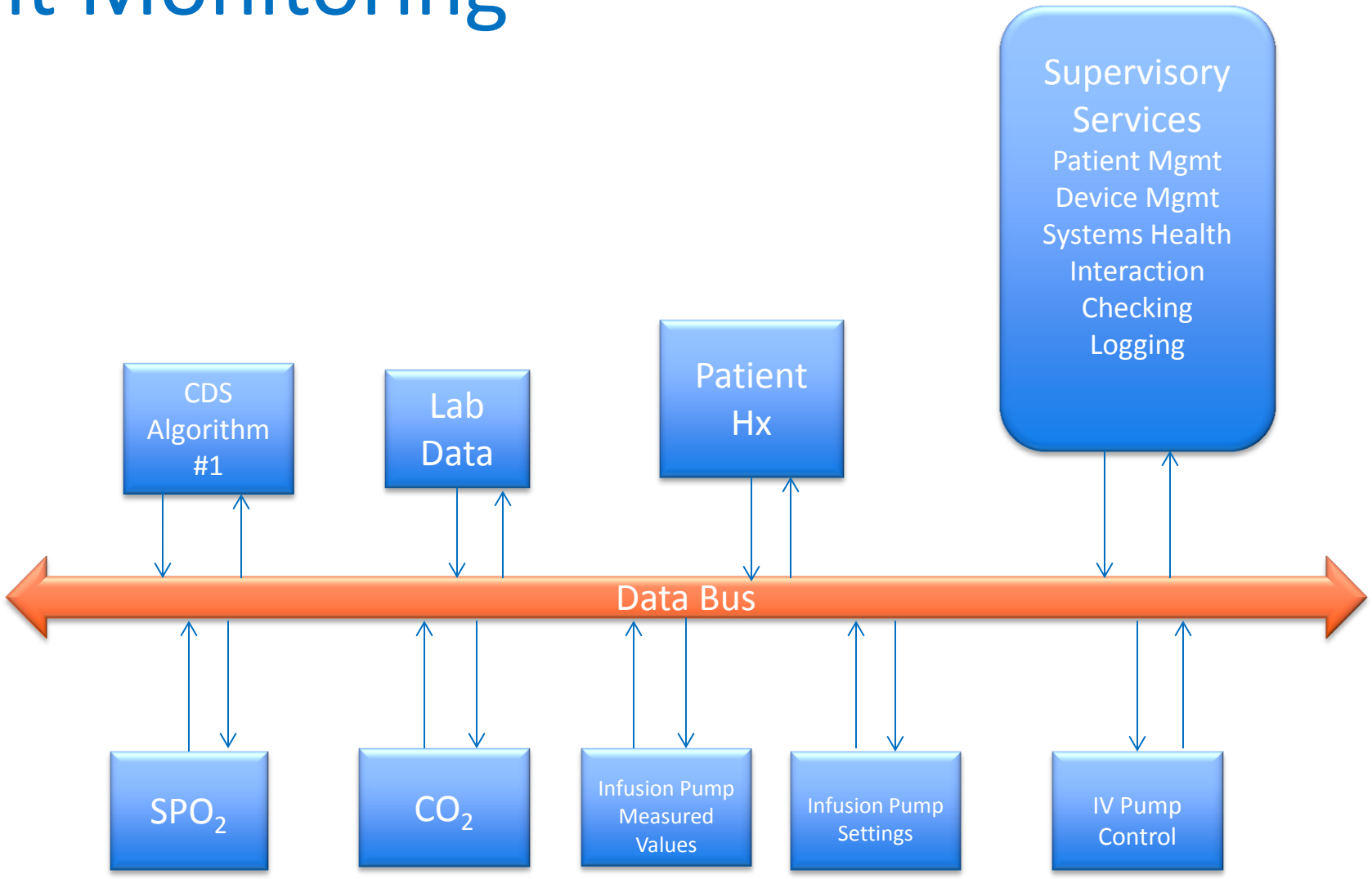
CIMIT®
Center for Integration of Medicine & Innovative Technology

MD PnP™
Getting Connected for Patient Safety™

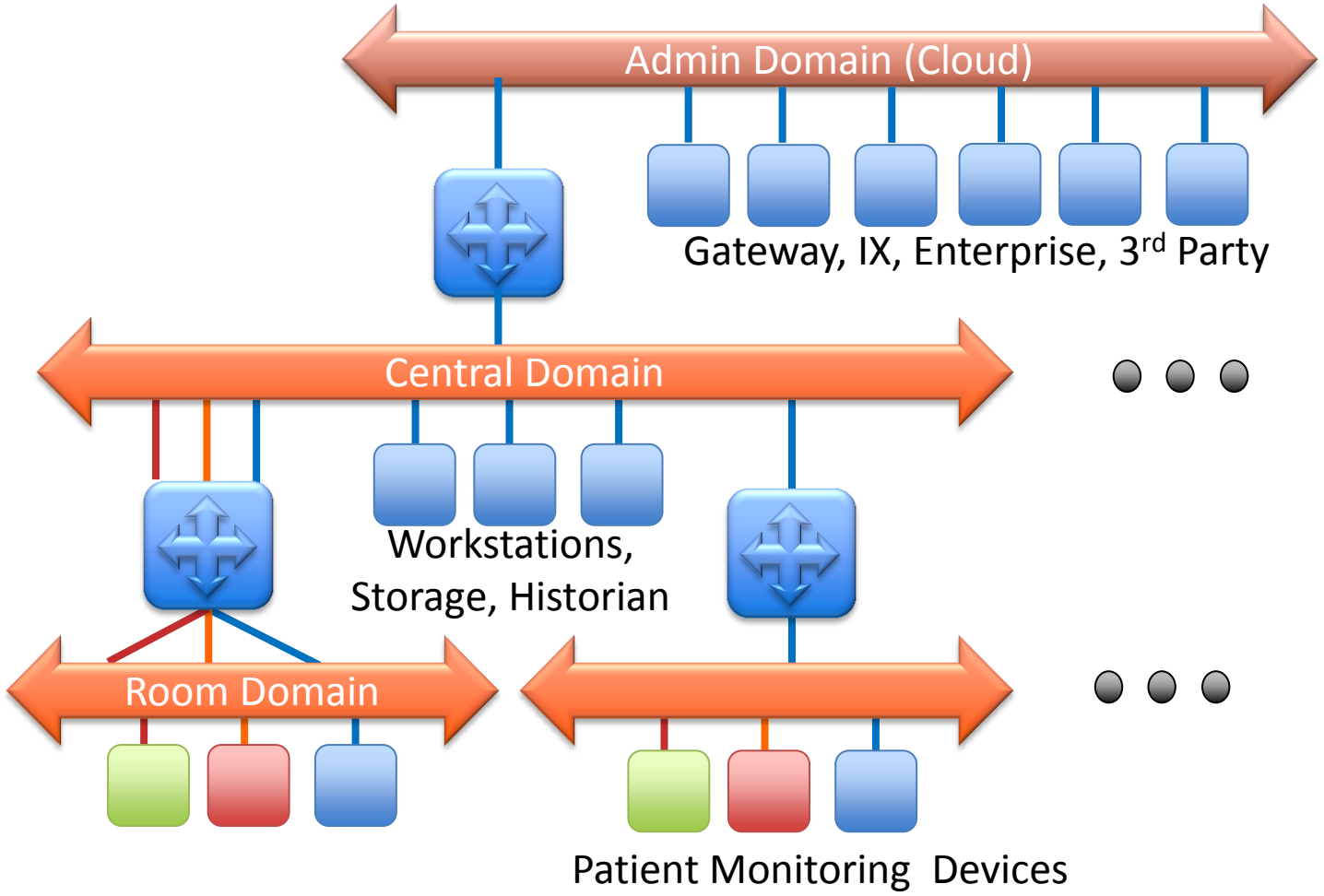
THE HARVARD MEDICAL SCHOOL

DOCBOX

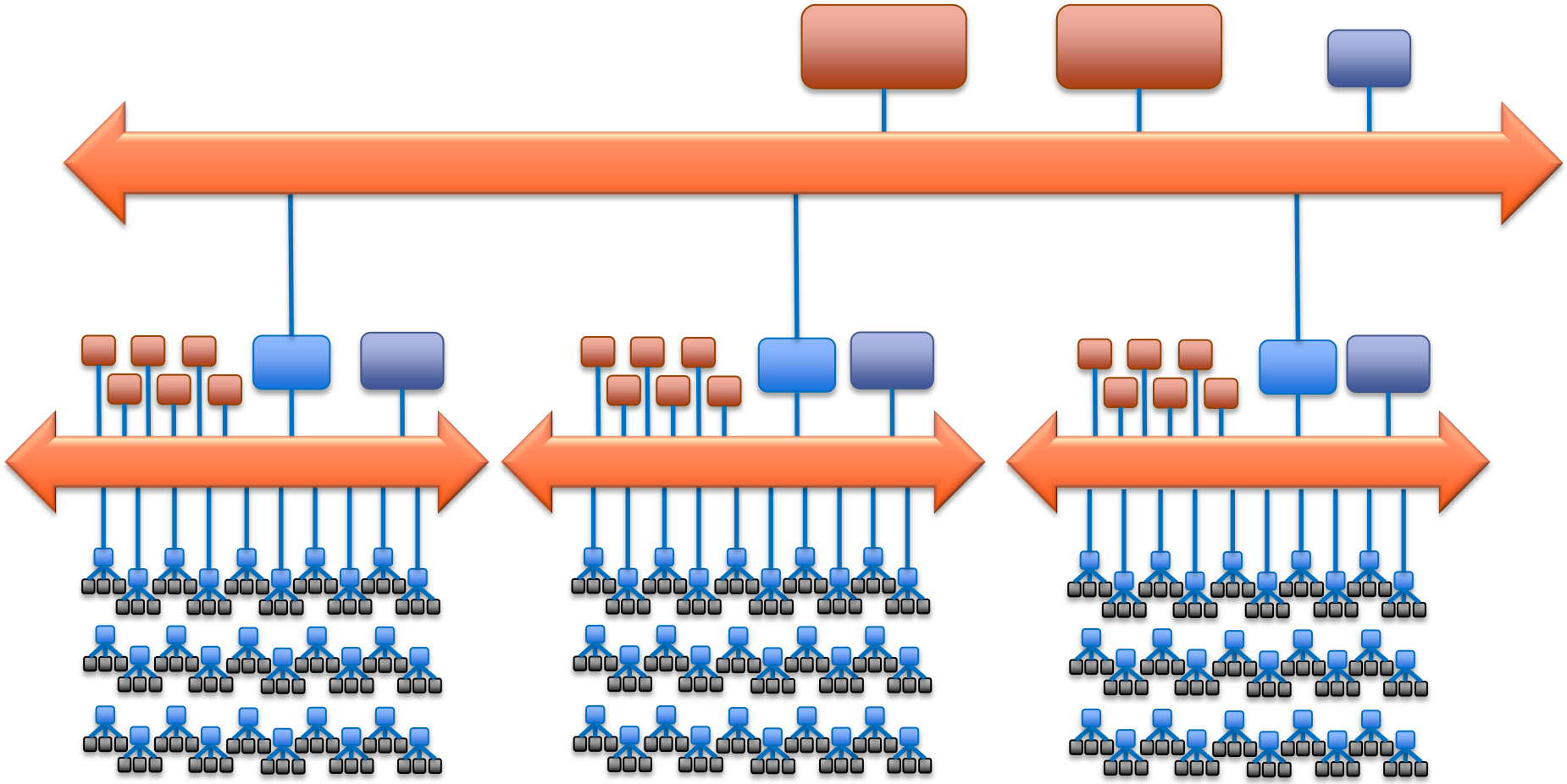
Patient Monitoring



CDS Data Architecture

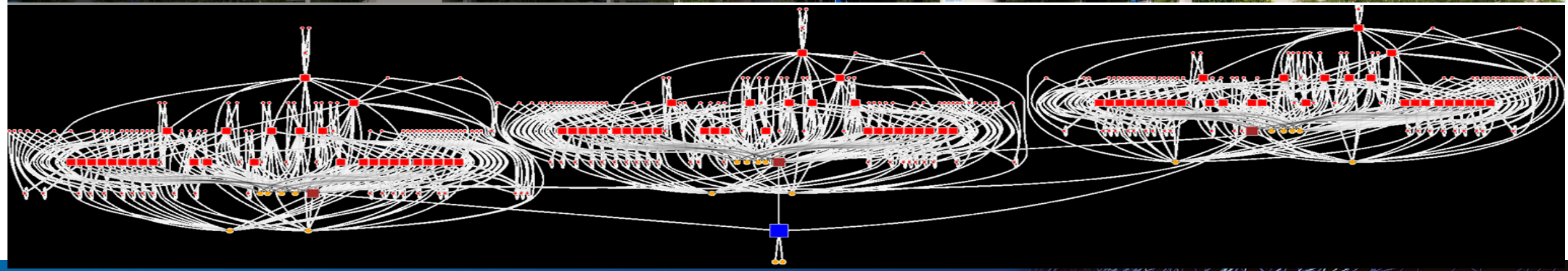


CDS System of Systems



Integrate System of Systems

1000s of patients, >100k devices

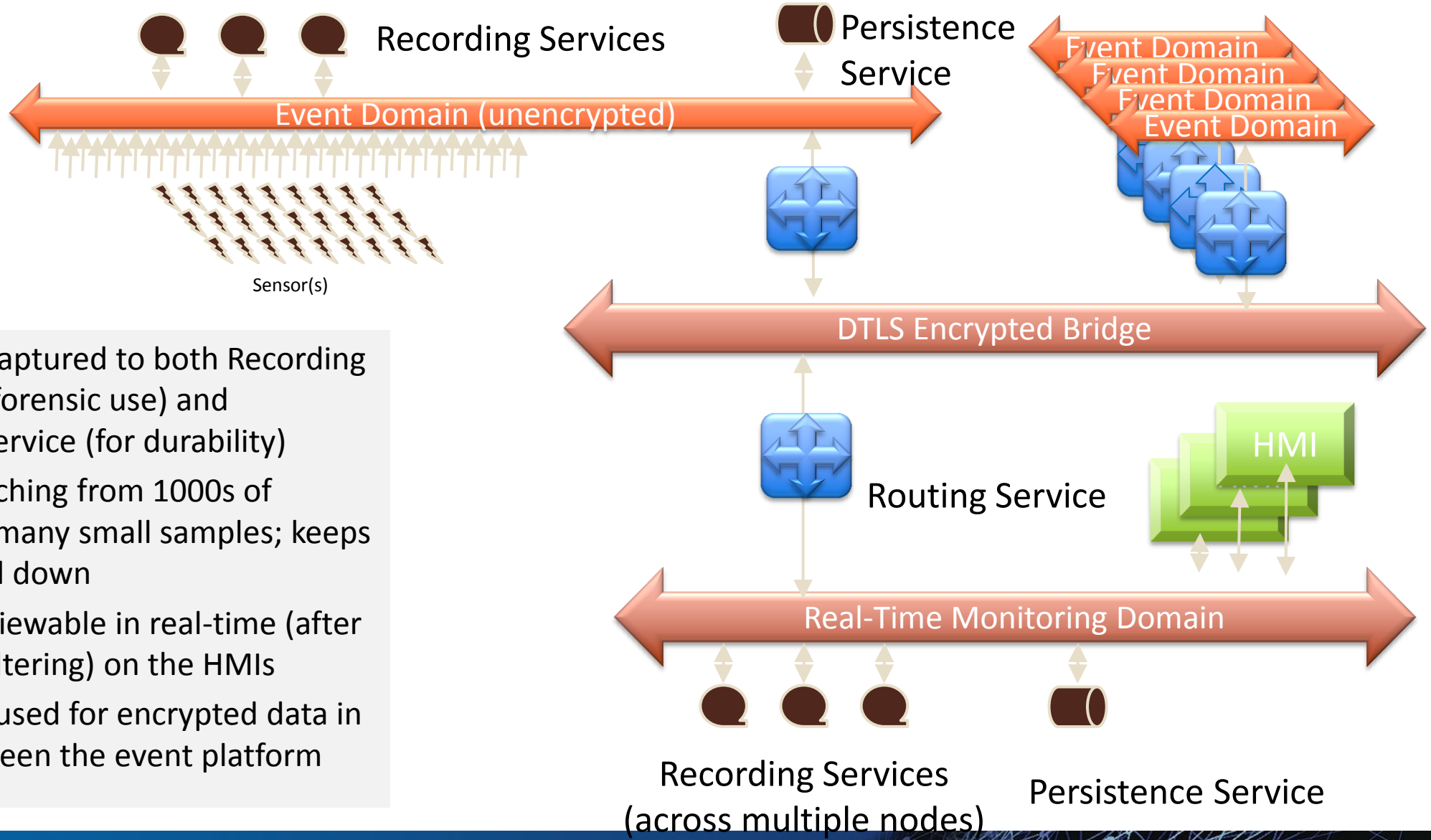


Control Mission-Critical Operations

- NASA KSC uses RTI for the launch control SCADA for Orion
- RTI delivered 300k points, at 400k msgs/sec with 5x the required throughput, at 1/5 the needed latency
- Launch control, in-flight monitoring, UAV tracking ground station, LPD recovery ship…all run RTI DDS

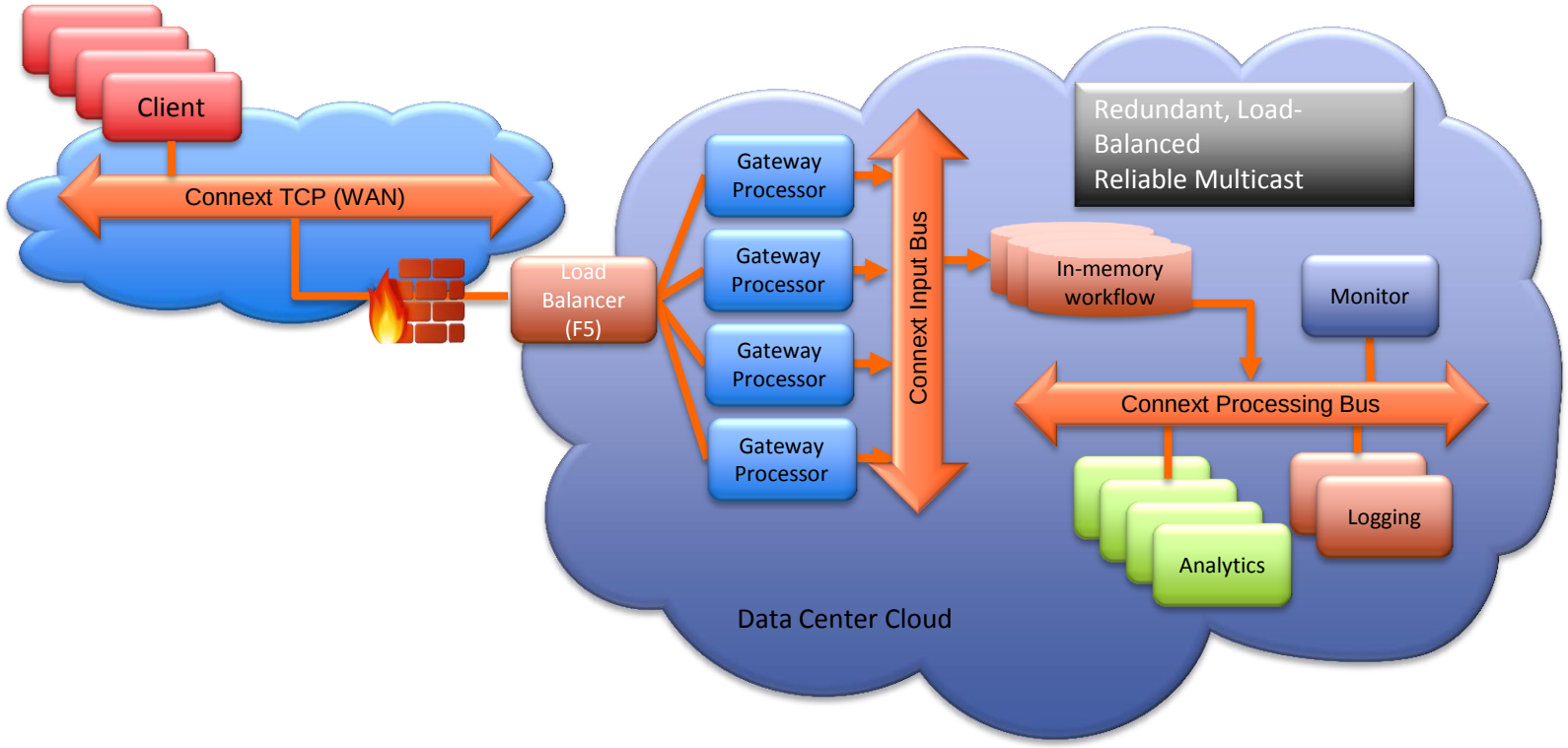
- DDS connects thousands of sensors and actuators

Large-Scale Real-Time Processing



- Sensor data captured to both Recording Services (for forensic use) and Persistence Service (for durability)
- Multicast batching from 1000s of sensors with many small samples; keeps interrupt load down
- Sensor data viewable in real-time (after time-based filtering) on the HMIs
- RS-RS bridge used for encrypted data in motion, between the event platform and control

Connect Cloud and Operations



- Eze Software delivers financial trading software to more than 1,500 buy-side and sell-side institutions in 30 countries
- RTI will be the core middleware for the Eze financial trading platform.

EZE SOFTWARE GROUP

RealTick EMS / Eze OMS / Tradar PMS

Coordinate Operations

In operation at Shanghai PVG ground control since 2015.
Expanding to air operations and between PuDong and Hongqiao.
Future expansion to entire South East China region.

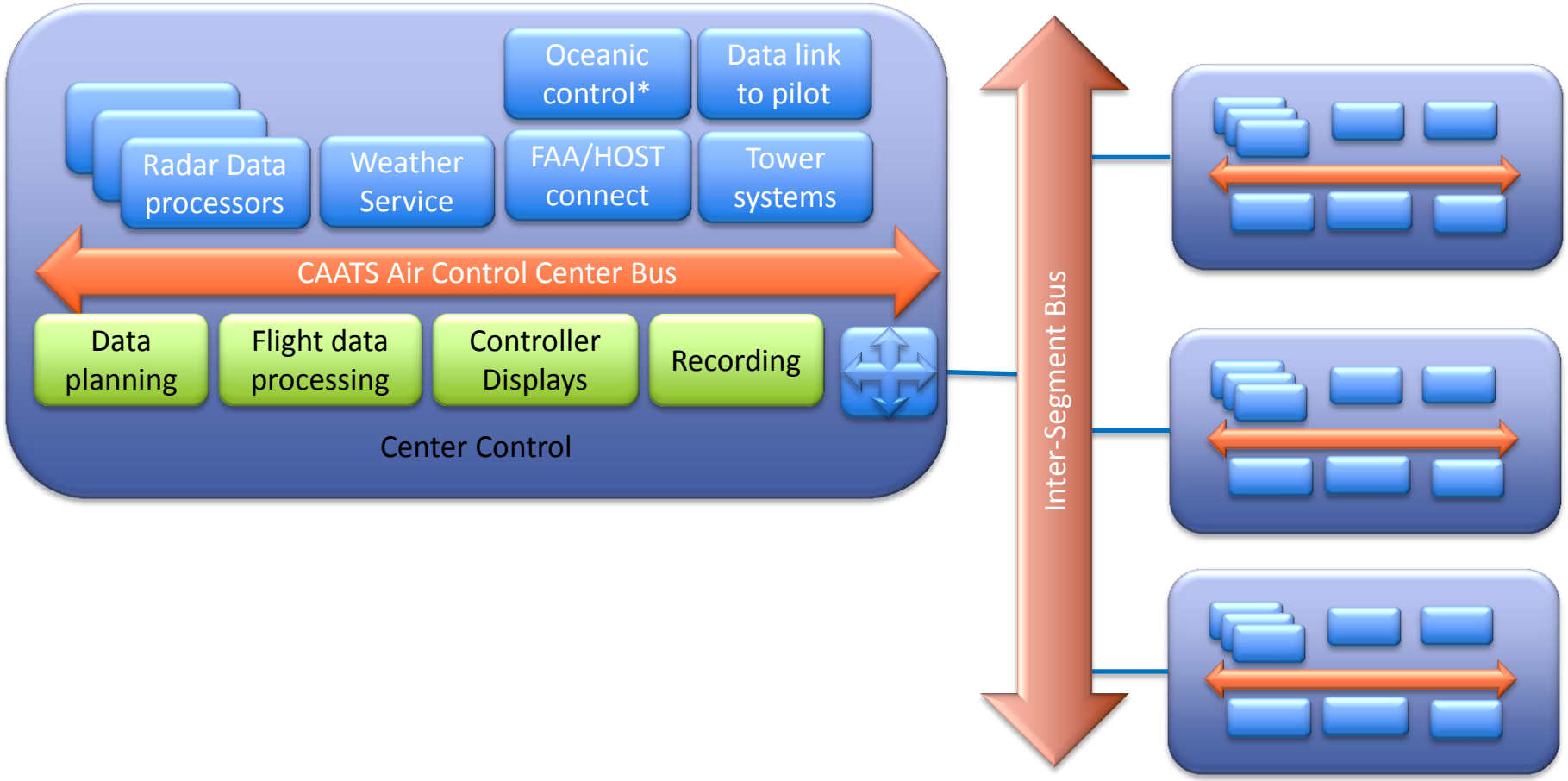
Operate 24x7 Across Continents

We selected Object Management Group (OMG) DDS standard for its high security rating; its wide support of tools and programming languages, and its reputation for performance, scalability, and 24/7 reliability

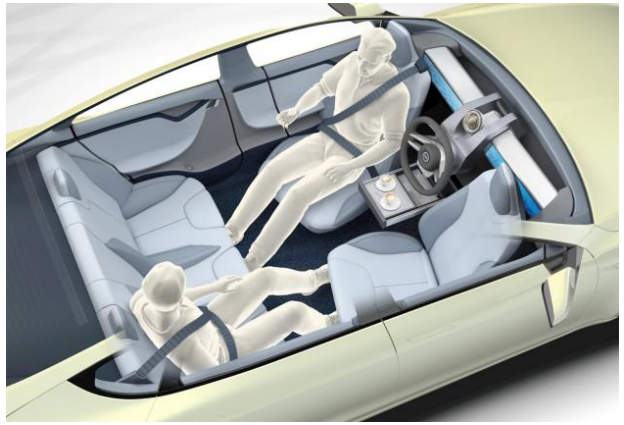
Sid Koslow, Chief Technology Officer,
NAV CANADA

Air Traffic Control for Canada
2nd largest ANSP in the world
7 major centers

Continent-Wide Air Traffic Control



Drive Autonomy



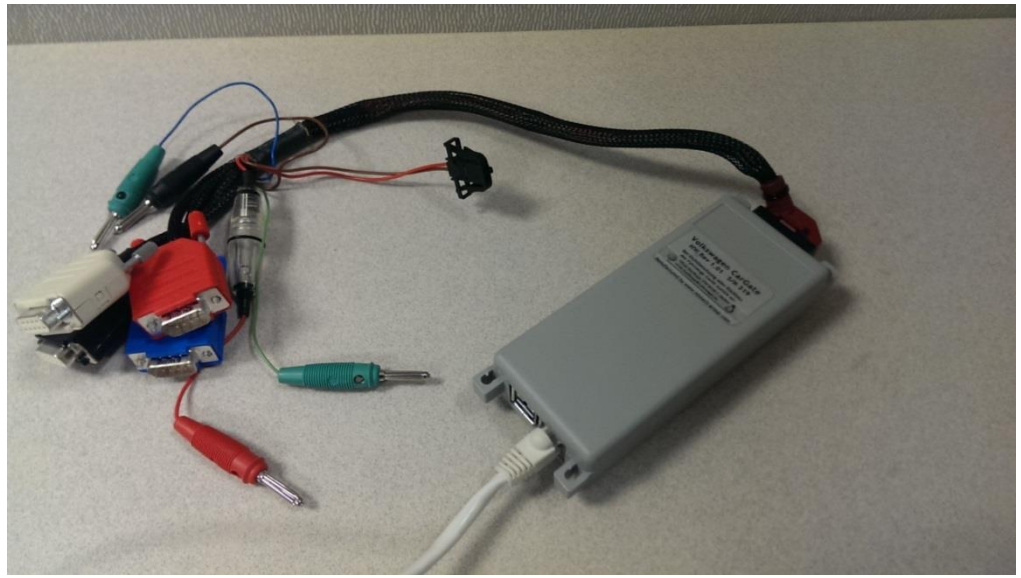
- RTI has long and deep experience in autonomous systems, land, sea, and air
- Several self-driving vehicles use DDS middleware.
- RTI led the US UAS ground station architecture. DDS will underlie the US system to allow drones in the NAS.

- DDS enables advanced reactive systems in transportation

Add Intelligence to Legacy

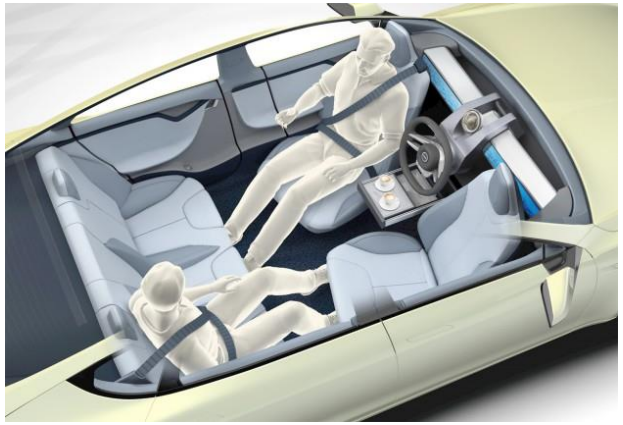
- VW Cargate ECU
- Connect fast Ethernet bus to slower CANbus
- Automated data translation
- Simple pub sub between busses

http://www.youtube.com/watch?v=7xQfKTAtyNU



Ease Safety-Critical Systems

- Connext DDS Micro Cert
  - Stringent SWaP requirements
  - Complete certification evidence
  - Full interoperability with DDS product line
- DO-178C Level A
  - Flight management systems
- ISO 26262
  - Road vehicle functional safety
- IEC 60601 class 3
  - Medical devices



Support Massive Scalability & Evolution

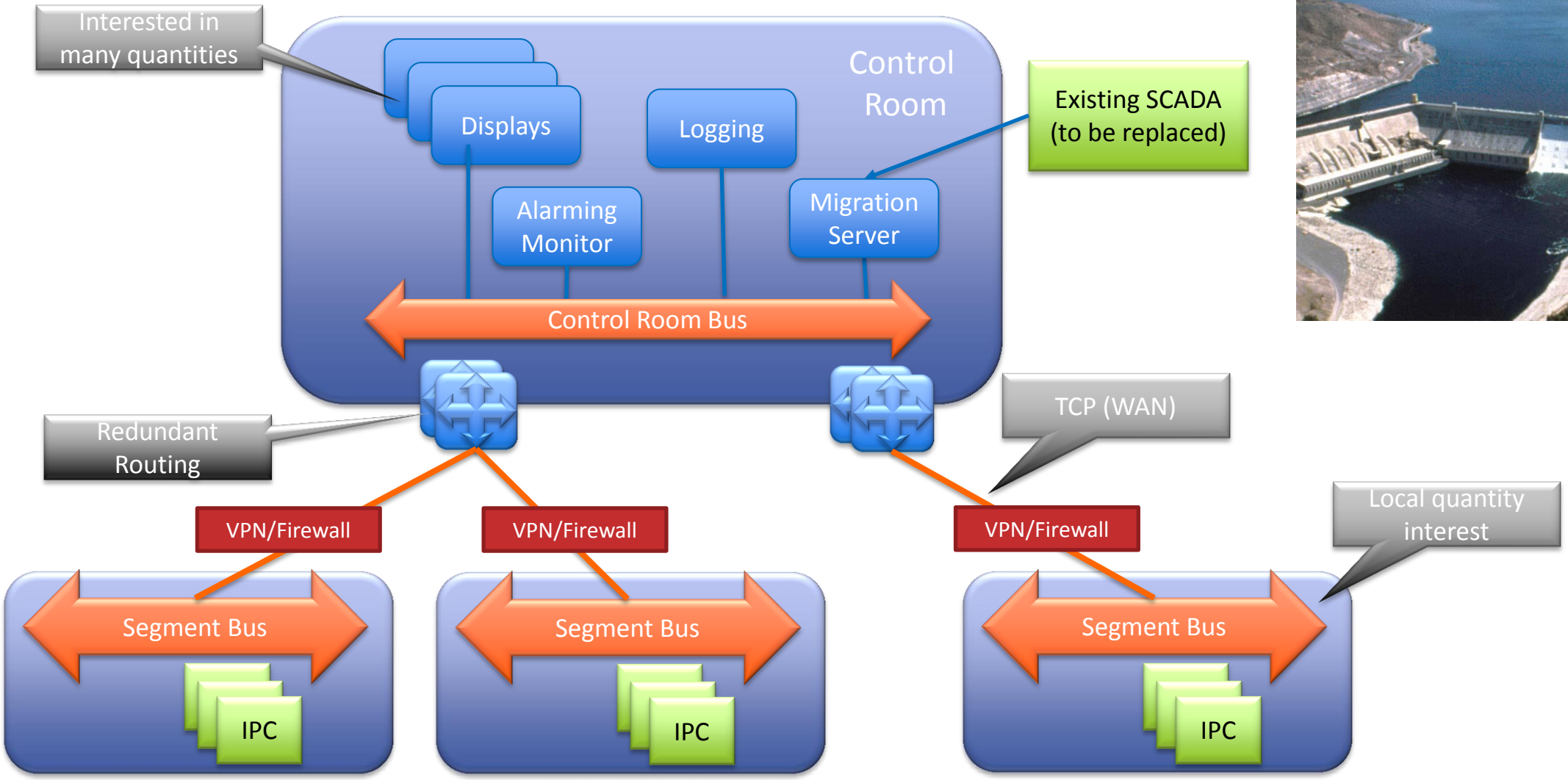
- The new Zumwalt DDG 1000 destroyer coordinates:
  - Hundreds of computers
  - 1500 applications, *teams*
  - *10m* publish-subscribe pairs
- DDS data-centric middleware
  - Controls (and evolves) interfaces between modules
  - Locates data by name and property
  - Extends real-time scalability
  - Supports decades-long lifecycle

Power Critical Infrastructure

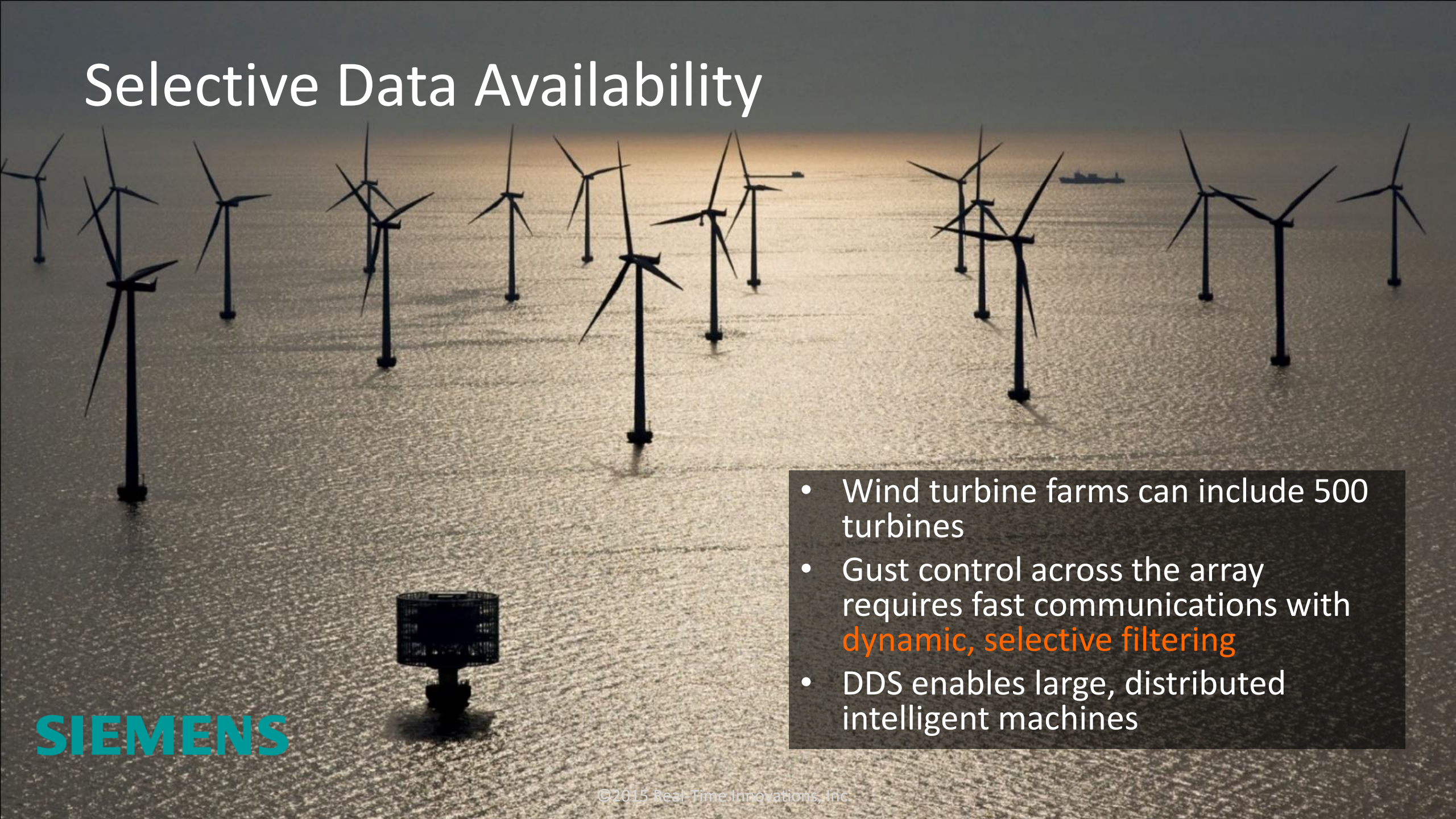
- DDS controls the 6.8 GW GC Dam
  - Largest power plant in North America
  - Fastest-responding major power source on the Western Grid
  - Requires 24x7 operation
- Connext DDS met the challenges
  - Extreme availability
  - Wide area communications
  - Multi-level routing
  - High security
  - 300k data values
- RTI system live since Jan 2014

U.S. Army Corps of Engineers®

Ultra Available Plant Control



Selective Data Availability



- Wind turbine farms can include 500 turbines
- Gust control across the array requires fast communications with dynamic, selective filtering
- DDS enables large, distributed intelligent machines

SIEMENS

IIC Microgrid Testbed

Goals

- Efficiently use solar, wind, & EVs
- Create an open marketplace
- Prove viability DataBus

Leads

- RTI: DDS middleware and system integration
- NI: Engineering software and hardware
- Cisco: Grid communications

Phases

1. Proof of Concept at National Instruments
2. Realistic simulation at Southern Cal Edison
3. Live test at CPS Energy San Antonio Grid of the Future

DUKE ENERGY

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

CPS ENERGY

SGIP SMART GRID INTEROPERABILITY PANEL

rti

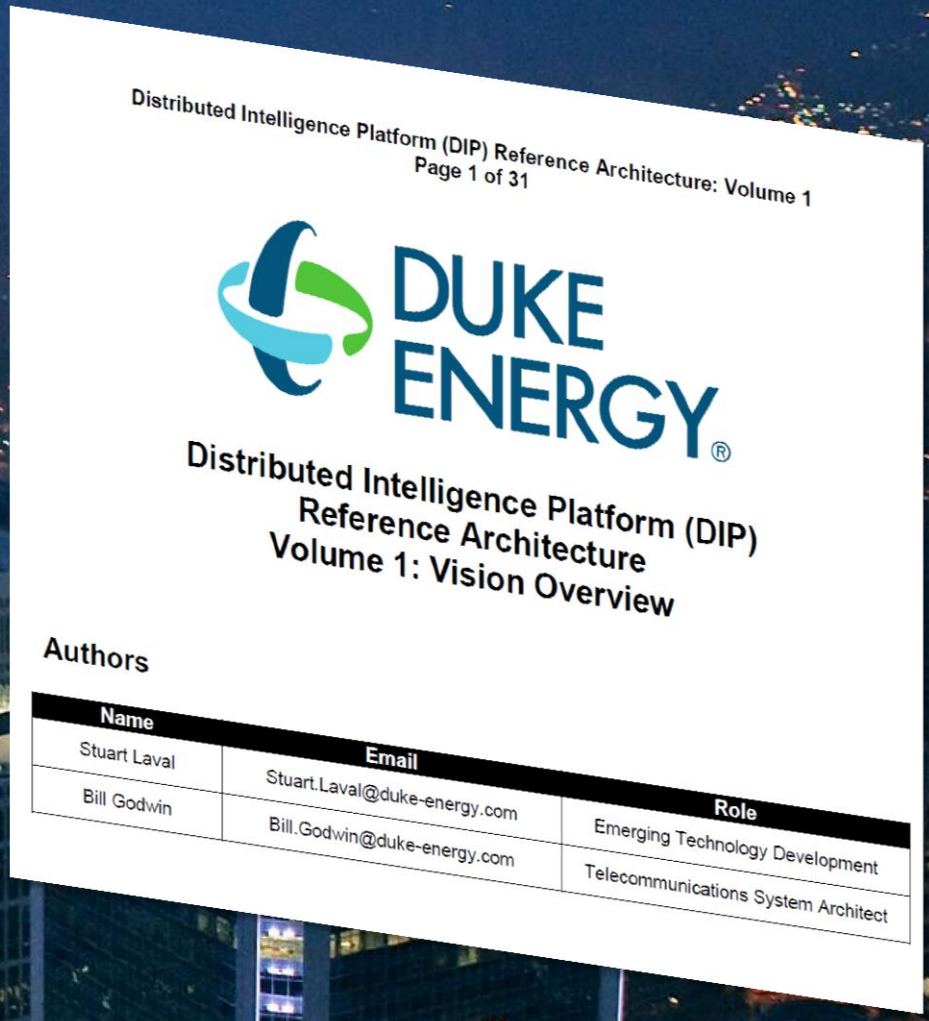
CISCO

NATIONAL INSTRUMENTS

DER Architecture

Duke's Coalition of the Willing II will demonstrate a microgrid with solar & battery on a DDS-based distributed platform with 24 vendors

The SGIP OpenFMB Priority Action Plan recommends data models, QoS, & standards

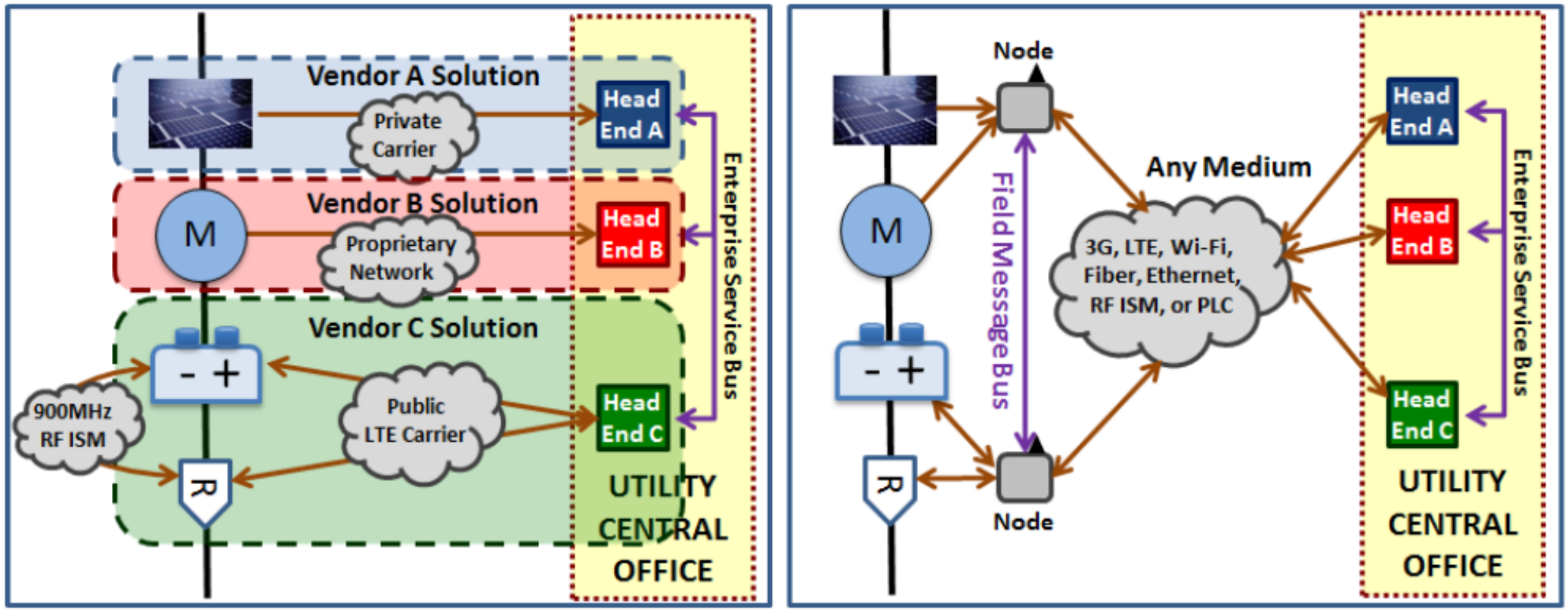


SGIP SMART GRID INTEROPERABILITY PANEL

Open Field Message Bus

DUKE ENERGY®

Field Message Bus Concept



Current State: Message Bus at Data Center

Future State: Message Bus in Field and Data Center

Figure 3-5: Duke Energy Distributed Intelligence Platform: Field Message Bus

5 Tier Architecture

- Specifies functionality from behind-the-meter to central station
- Deployment hardware, OS, middleware recommendations for each

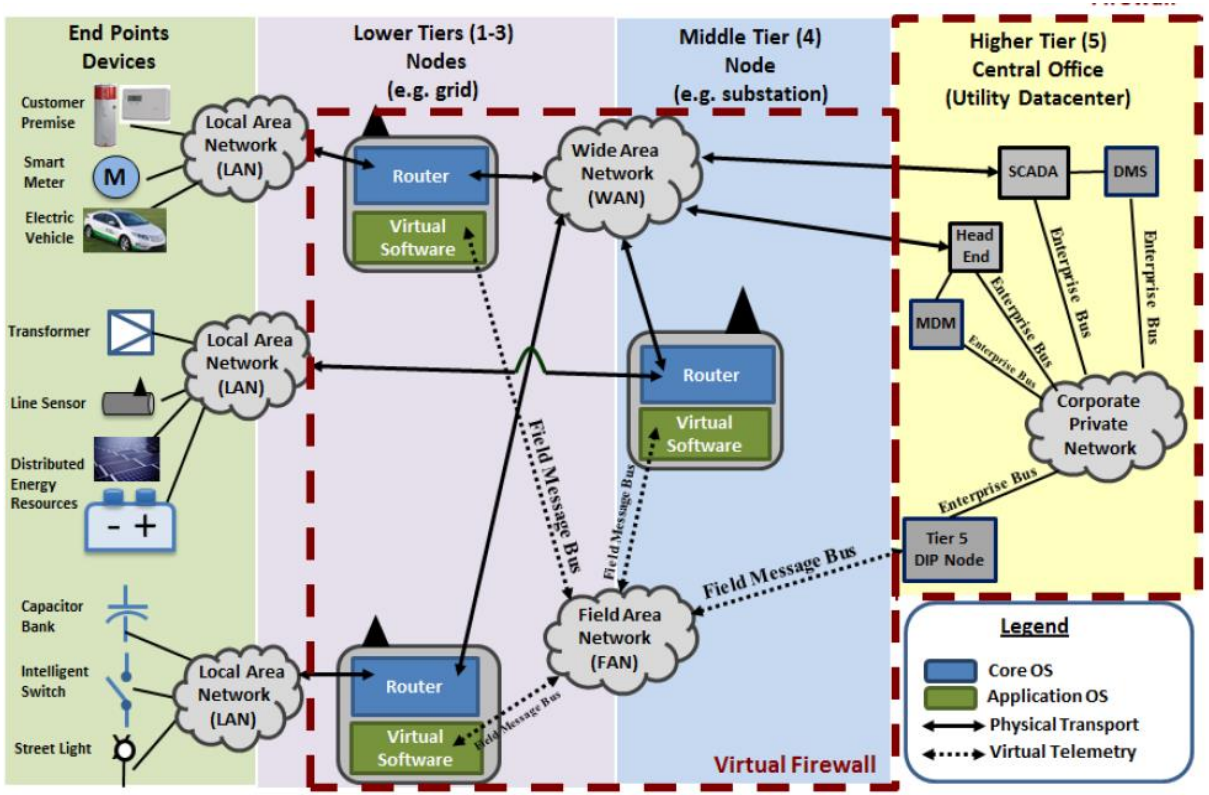


Figure 3-9: Duke Energy Distributed Intelligence Platform Vision: Node Hierarchy

Protocols	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
MQTT	Recommended	Recommended	Optional	Optional	Optional
DDS	Optional	Optional	Yes	Yes	Optional
AMQP	Optional	Optional	Optional	Optional	Optional
CoAP	Optional	Optional	Optional	Optional	Optional

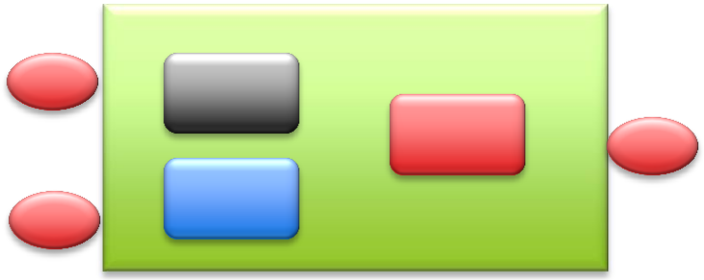
Table 4-9: Message Bus Protocol considerations for the multi-tiered node reference architecture

Why Choose DDS for Core Connectivity?

- Reliability: Severe consequences if offline for 5 minutes?
- Performance/scale:
  - Measure in ms or µs?
  - Or scale > 20+ applications or 10+ teams?
  - Or 10k+ data values?
- Architecture: System lifecycle >3 yrs?

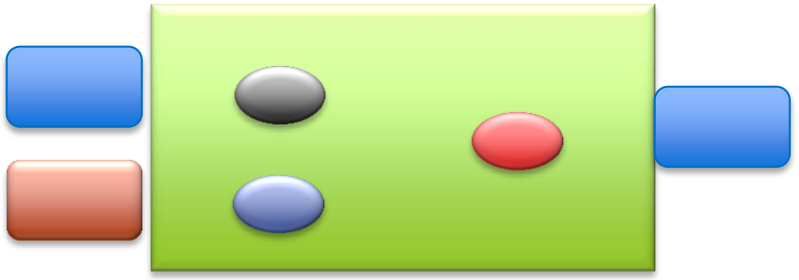
2 or 3 Checks? → DDS

Data Centric is the *Opposite* of OO



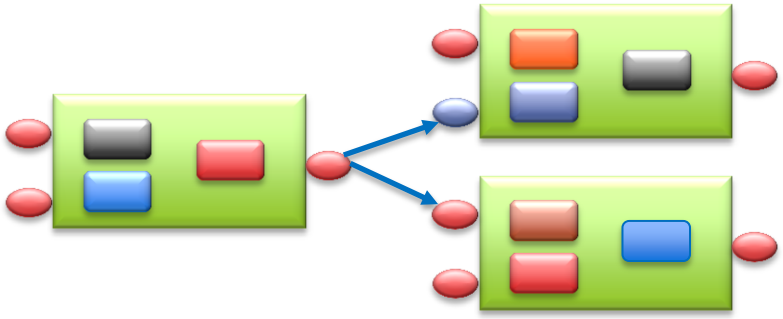
Object Oriented

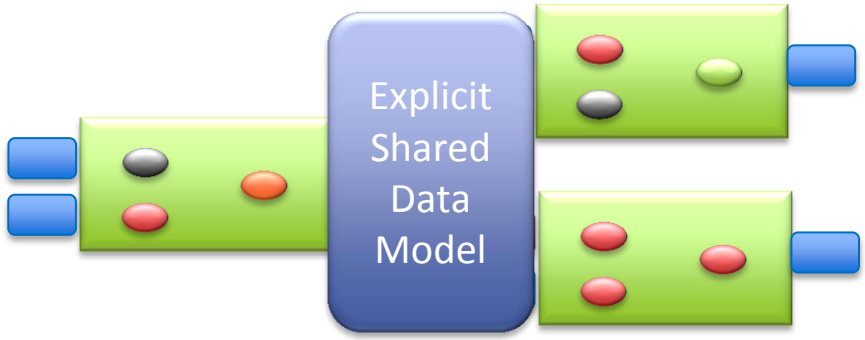
- Encapsulate data
- Expose methods



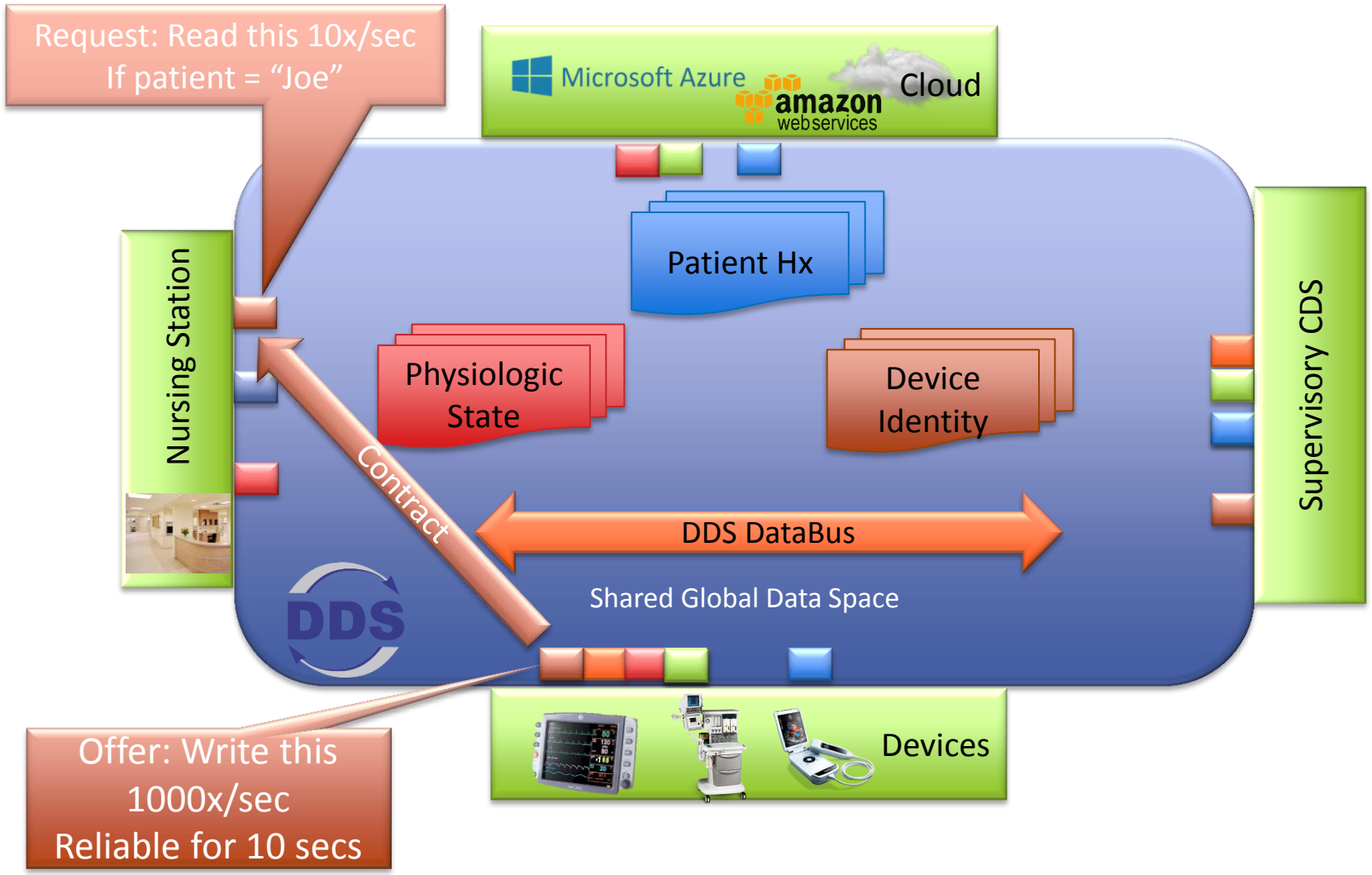
Data Centric

- Encapsulate methods
- Expose *data*





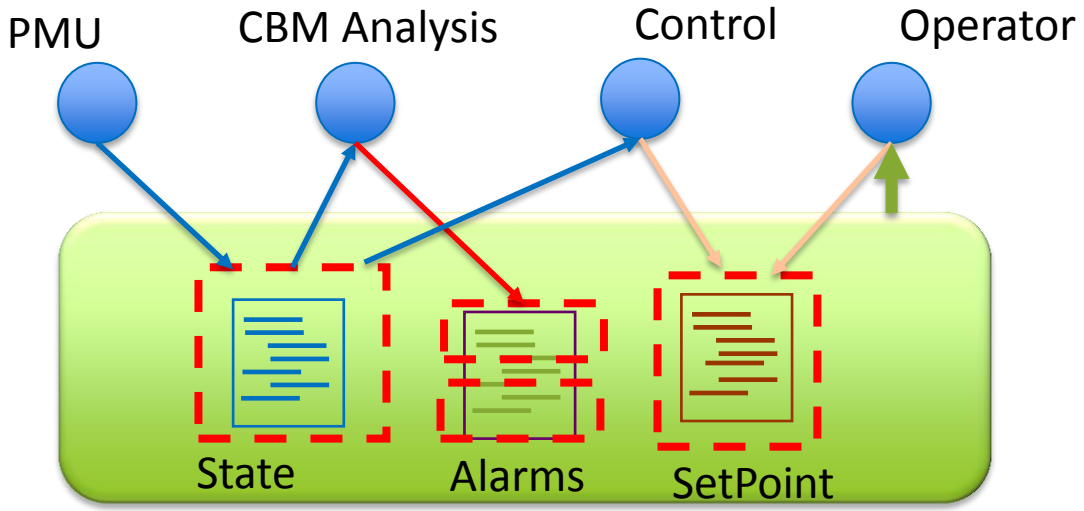
Data-Centricity = Data-Path *Control*



- Global Data Space
  - Automatic discovery
  - Read & write data in any OS, language, transport
  - Redundant sources/sinks/nets
- Type Aware
- QoS control
  - Timing, Reliability, Ownership, Redundancy, Filtering, Security

Practical Fine-Grain Security

- Per-Topic Security
  - Control r,w access for each function
  - Ensures proper dataflow operation
- Complete Protection
  - Discovery authentication
  - Data-centric access control
  - Cryptography
  - Tagging & logging
  - Non-repudiation
  - Secure multicast
  - 100% standards compliant
- No code changes!
- Plugin architecture for advanced uses



Topic Security model:

- PMU: State(w)
- CBM: State(r); Alarms(w)
- Control: State(r), SetPoint(w)
- Operator: *(r), Setpoint(w)

Connect Sensor to Cloud

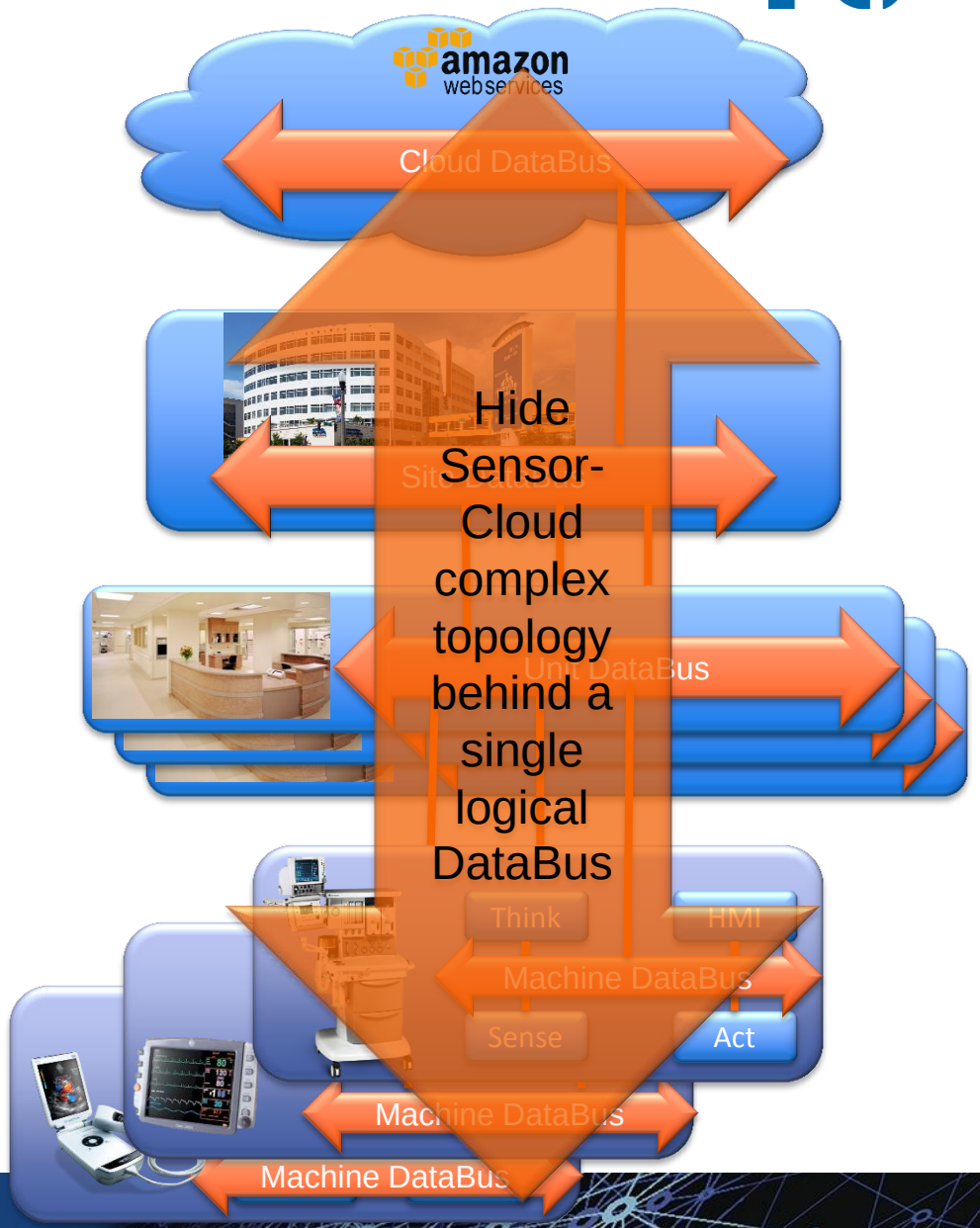
- Connect…
  - Fast
  - Seamless
  - QoS controlled
  - Secure
  - Data centric
- Across 80 Platforms…
- Over 12 Transports

Intelligent Industrial Internet

Intelligent System of Systems

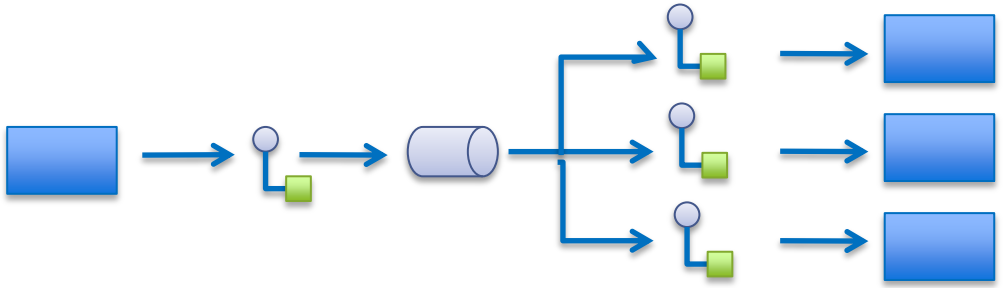
Intelligent Systems

Intelligent Machines



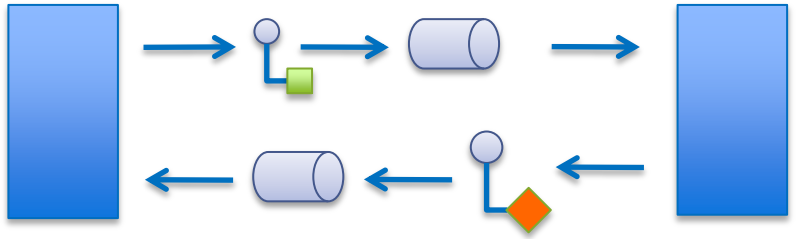
Data Centricity is Orthogonal to Pattern

- Publish-Subscribe



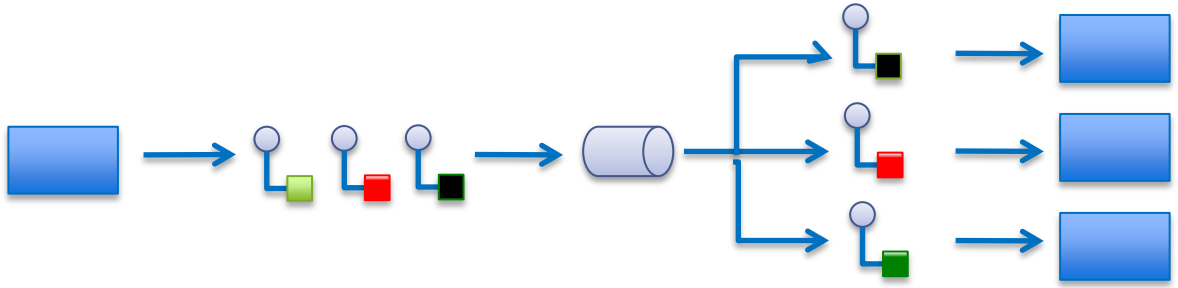
Standard 2004

- Request-Reply



Standard 2013

- Queuing



Vendor support 2015

Interoperation Despite Complex Evolution

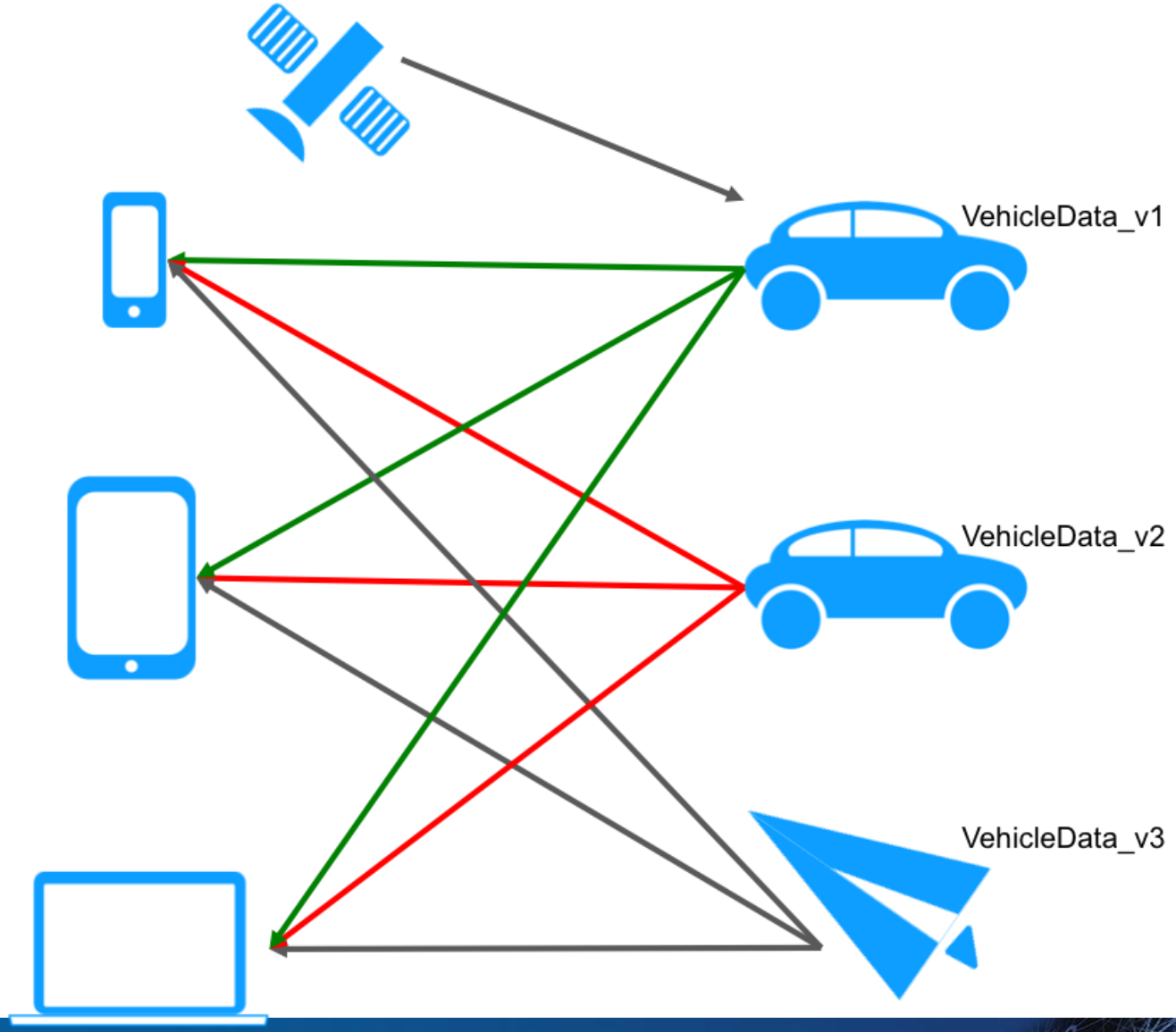
```
struct Position_v1 {
   double latitude;
   double longitude;
};

struct Position_v2 {
   double latitude;
   double longitude;
   double altitude;
} ;

struct VehicleData_v1 {
   long vehicleID; //@key
   Position_v1 position;
}; //@Extensibility
MUTABLE_EXTENSIBILITY

struct VehicleData_v2 {
   long vehicleID; //@key
   Position_v1 position;
   double speed;
}; //@Extensibility
MUTABLE_EXTENSIBILITY

struct VehicleData_v3 {
   long vehicleID; //@key
   Position_v2 position;
   double speed;
}; //@Extensibility
MUTABLE_EXTENSIBILITY
```

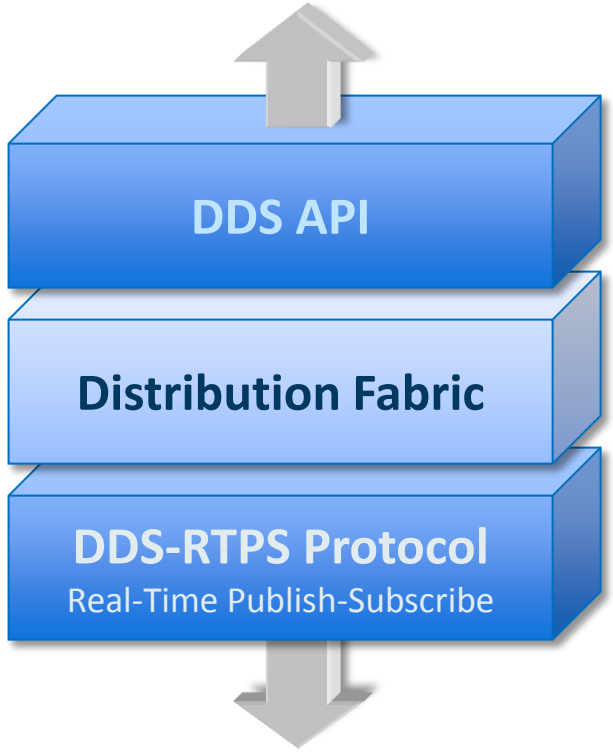


- DDS Xtypes supports
  - Extensions (adding fields)
  - Mutations (changing field order, addition or deletion)
  - Optional members (partial structure matching)

The DDS Standard

- The Data Distribution Service (DDS) is the Proven Data Connectivity Standard for the IoT
- OMG: world's largest systems software standards org
  - UML, DDS, Industrial Internet Consortium
- DDS: open & cross-vendor
  - Open, Free Standard
  - 13+ implementations

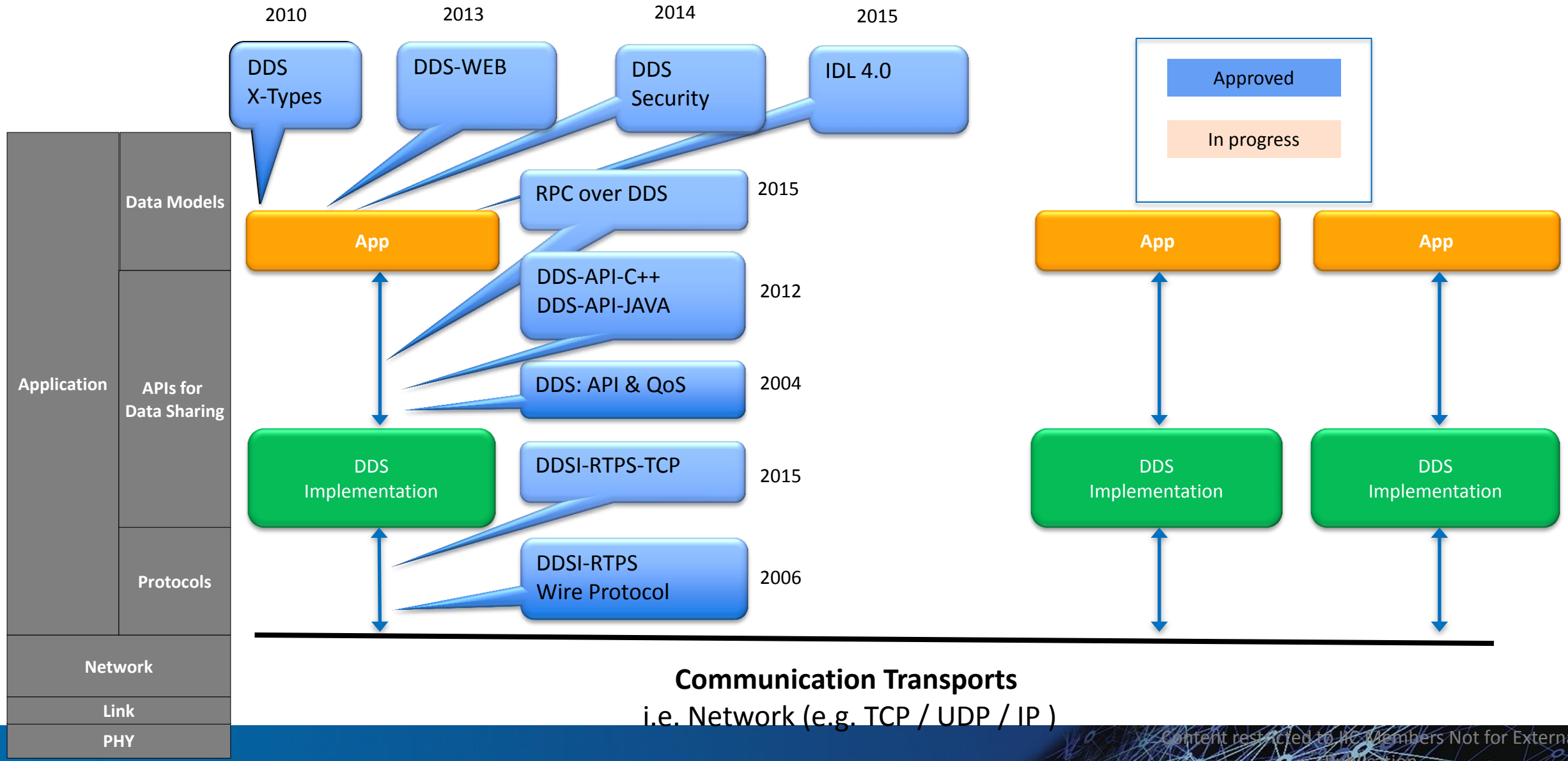
Interoperability between source written for different vendors

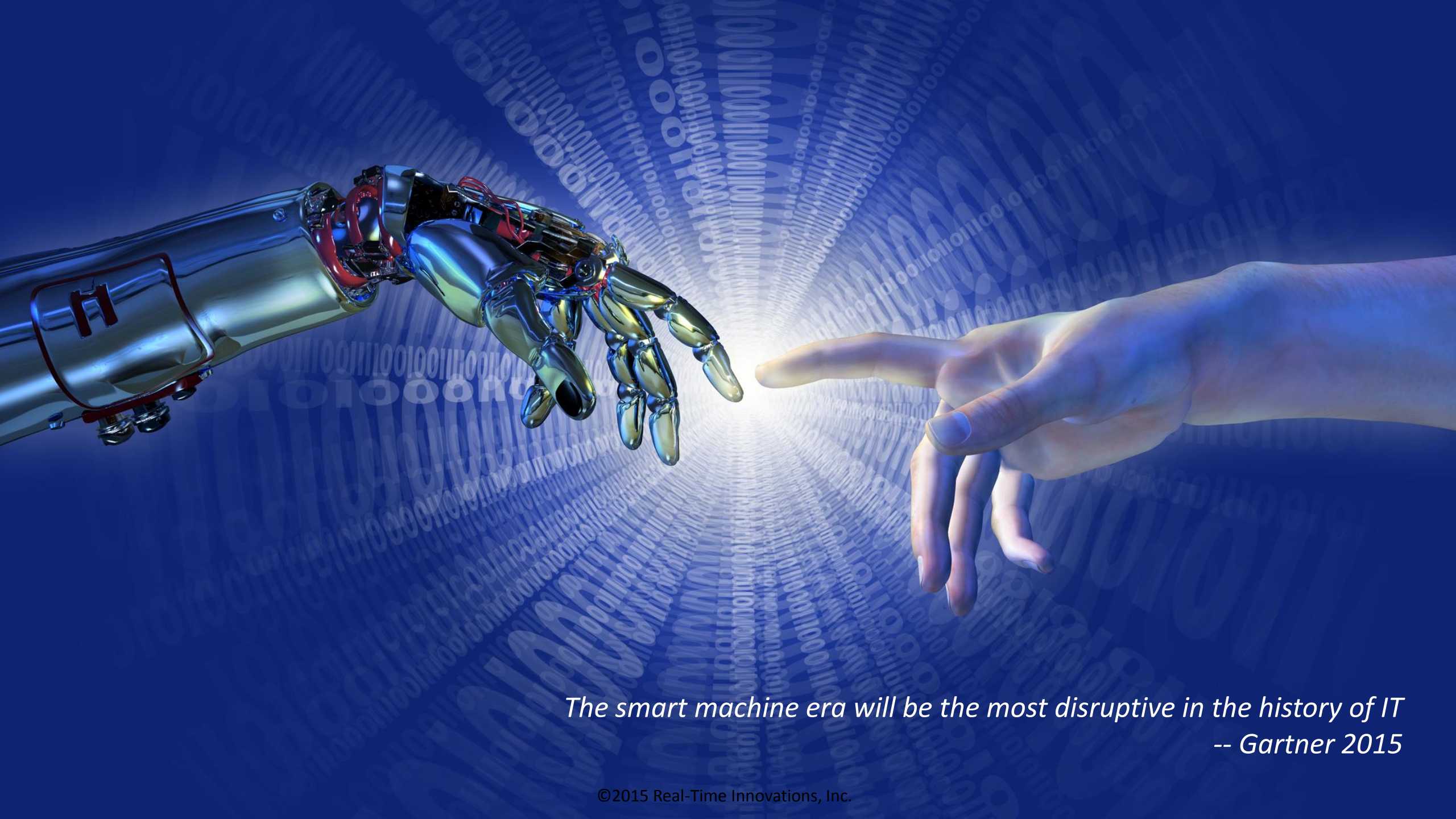


Interoperability between applications running on different implementations

2004 - Now

DDS Family of Specifications





The smart machine era will be the most disruptive in the history of IT
-- Gartner 2015

The IIoT Disruption

Common technology that spans industries brings bold new approaches and enables fast change

The real value is a common architecture that connects sensor to cloud, interoperates between vendors, and spans industries

The Network is the Future