Middleware for Mission-Critical Systems

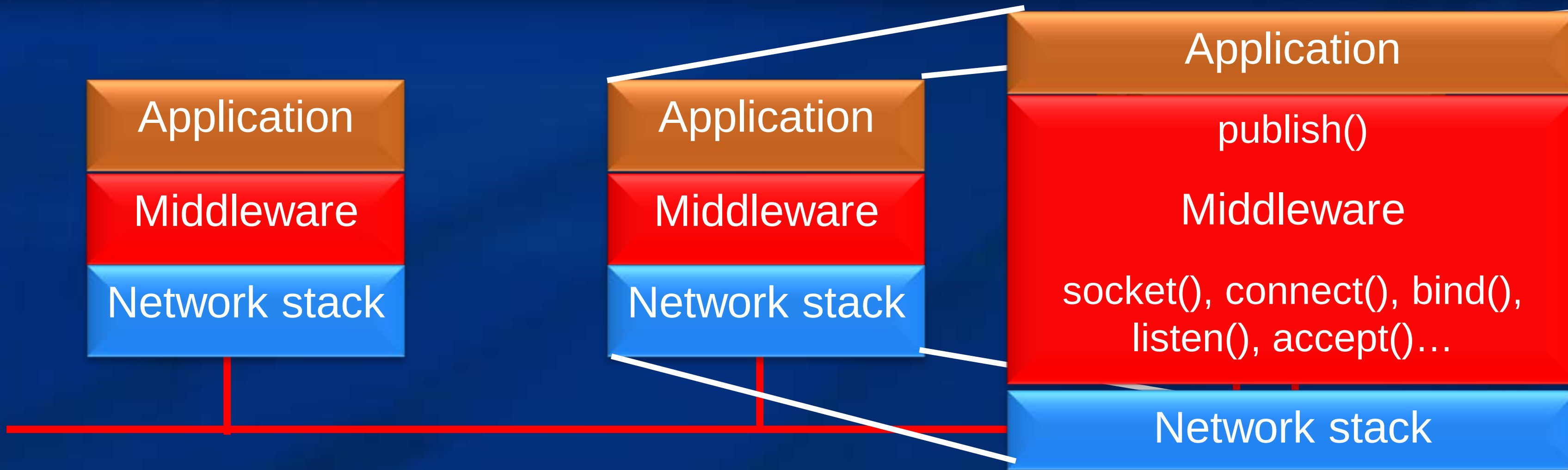
The Real-Time Middleware Experts

Stan Schneider, PhD CEO

Topics

- What and why is middleware?
- Who uses real-time middleware?
- What does middleware do?
- How does middleware work?
- Is there a place for middleware in NASPI?

What & Why is Middleware?



- What?
  - Middleware is a layer between application and network stack
  - It presents a more powerful API to the application
  - It handles connections, failures, changes
- Why?
  - Simpler conceptual model
  - Easier programming
  - Seamless interoperability
  - Control communications “Quality of Service” (QoS)

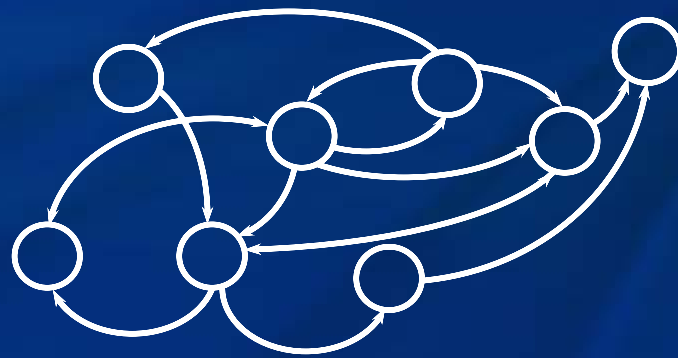
Why Not Use TCP?

- Rigid reliability protocol
- No multicast
- No OOB data
- Only global timeouts
- Can’t do real time, can’t filter
- Does not scale
- No prioritization
- Can’t handle varying delivery QoS needs

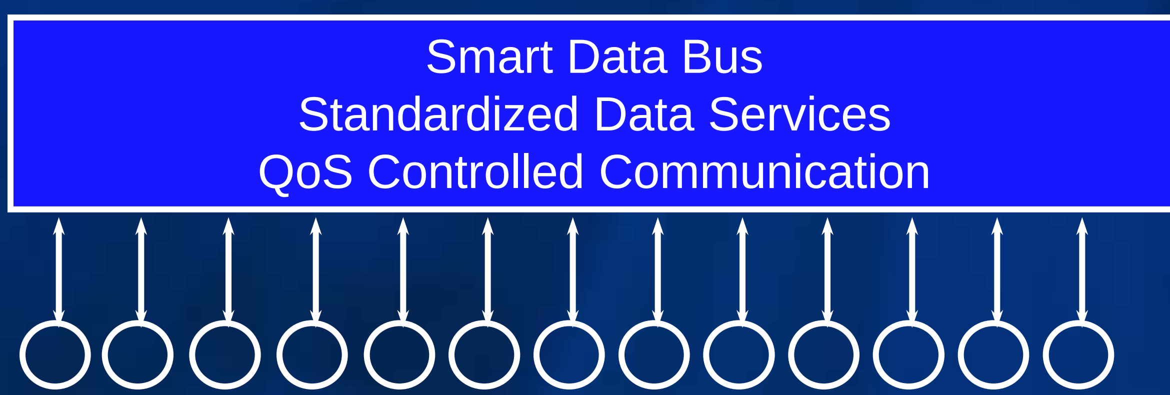
Not intended for mission-critical real time

Data-Centric Smart Bus

Connection Oriented
- Multi-hop
- Hard-wired
- Brittle
- Hard to evolve



Data Oriented
- Peer-to-peer
- Loosely coupled
- Scalable
- Evolvable



Source: [modified] Raytheon Keynote Presentation September 2006 at DDS Information Day, Anaheim , CA

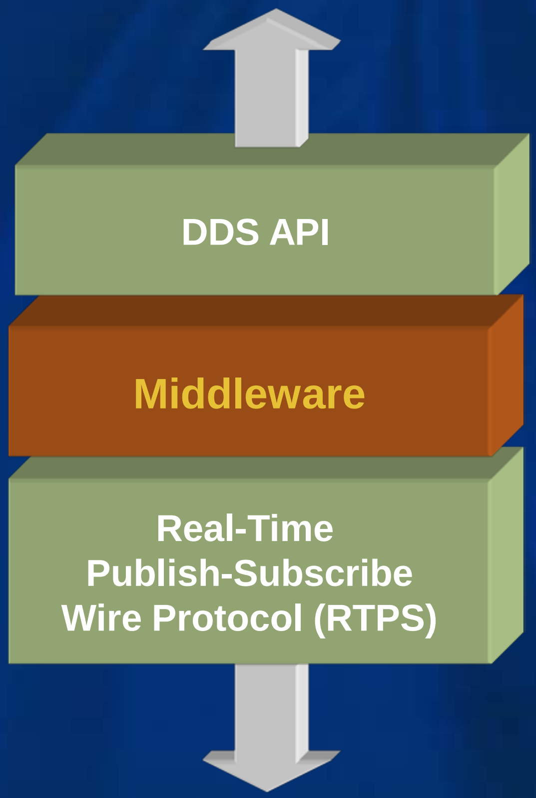
Who Uses Real-Time Middleware?

- 25 years of best practice
  - Thousands of designs
  - $Ts of mission-critical systems
- Successful deployment in:
  - Defense
  - Finance
  - Unmanned vehicles
  - Simulation
  - Industrial automation
  - Medical
  - Transportation

The DDS Standard

- OMG Data Distribution Service for Real-Time Systems
  - Data-centric pub-sub
  - Per-channel QoS
    - Right data to the right place at the right time
  - Content and time aware
- No vendor lock-in
  - API for source portability
  - Message encoding for interoperability
- Transparent connectivity
  - C, C++, Java, .NET (C#, C++/CLI)
  - Windows, Linux, Unix, embedded, real-time

Cross-vendor portability



Cross-vendor interoperability

RTPS also standardized as IEC 61148

DDS Adoption

- Multiple vendors
  - 9 implementations!
- Dominant in military
  - DISA: DISR mandated
  - Navy: Open Architecture, FORCEnet
  - Air Force, Navy and DISA: NESI
  - Army: FCS / SoSCOE
  - NATO, South Korea, many more
- Many other applications
  - Air traffic control, industrial automation, transportation, medical
- Hundreds of active programs

What Does Middleware Do?

LPD-17

- LPD-17 Ship-Wide Area Network (SWAN)
- Runs everything: Machinery, damage control, steering, magnetic signature, mission control, navigation, communication
- 200+ nodes
- Redundant nodes, networks, data, sensors
- Middleware provides non-stop reliability

Ship Self-Defense System

- The Ship Self Defense System is the “last line of defense”
- SSDS coordinates high-speed radars, targets defensive missiles, and directs 1000+ rounds/sec at incoming cruise missiles
- SSDS is in sea trial now

Middleware *reliably delivers messages in real time*

DDG 1000 Ship Communication

Raytheon Total Shipboard Computing Environment Infrastructure (TSCEI) for US Navy DDG 1000 destroyer

Coordinates and manages complex, diverse onboard hardware and software systems

RTI connects *200+ computers, 8000 applications, 79k readers/writers, 11m PS pairs*

Middleware extends scalability in real time

Flight Simulation

"In the past we probably would have developed an expensive, proprietary system for data communications. By using RTI, we were able to deliver a proven, reliable and cost effective solution to our customers."

--Peter Jarvis, Chief Designer

CAE, one of the world's leading providers of simulation and training, uses RTI over high-bandwidth IEEE-1394 on its Sim XXI product line.

Middleware provides transport portability and architecture interoperability

Air Traffic Management

Air traffic control flow traffic through busy metropolitan air spaces

Reliability is critical – hardware or software failures mean flight delays and substantial costs

Without disrupting the data flow, middleware permits fast addition, updating and removal of system nodes

AWACS Radar Upgrade

- Airborne control system for surveillance, command & control and battle management
- Upgrading system to be open, supportable, less expensive to maintain and extend
- Open and extensible middleware reduces integration risk

Predator Ground Control Station

General Atomics Aeronautical Systems developed advanced cockpit ground control stations (GCSs) for unmanned aircraft systems such as Predator®

Required real-time data distribution for acquisition, analysis, and response of remote controlled aircraft

RTI selected for proven software & services.

This application was delivered in under 14 months, significantly faster than with alternative software or building their own.

Middleware speeds development

Insitu (Boeing) Unmanned Air Vehicle

"…we have seen a 30% increase in productivity based on not having to handle data communication issues." Gary Viviani, VP of Engineering

- Insitu is a recognized leader in the exploding UAV space
- The next generation of UAV's including the Scan Eagle and newer platforms
- RTI allows seamless switch control between multiple ground stations while connecting reliably over unreliable links.
- Middleware enables orchestrated, flexible information flow

Next-Generation Intelligence

TCP-based

Broker-based

Peer-to-peer

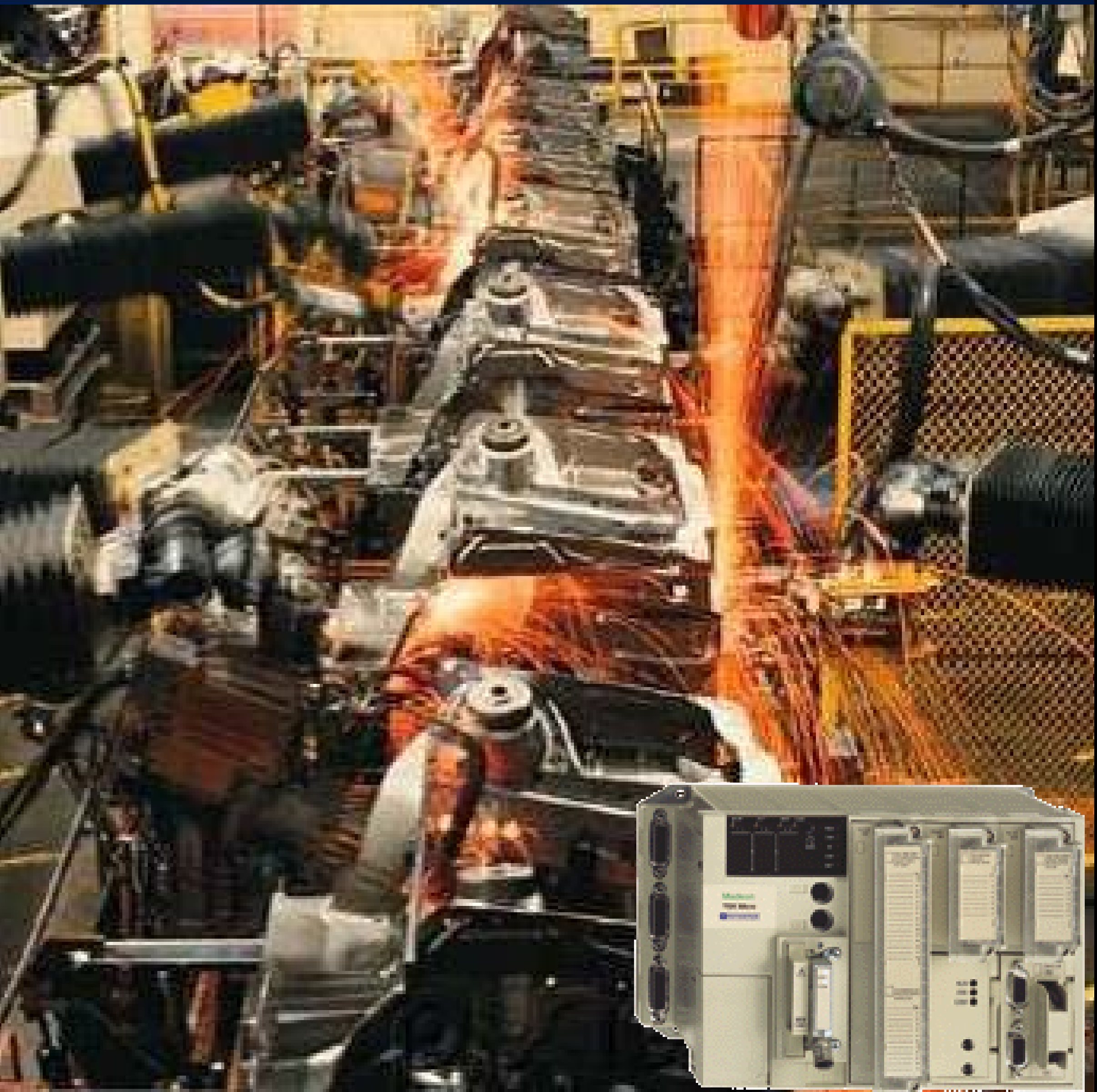
- Intelligence applications push performance/scalability limits
- Data centric model eases complex application design and integration
- RTI's fully decentralized, peer-to-peer, "no bottlenecks" architecture brings performance
- RTI Router brings global scalability

Middleware builds a *globally-scalable, high performance, reliable infrastructure*

Traffic Monitoring in Tokyo

- Real-time information to commuters and officials
- Hundreds of traffic monitors and information kiosks along the highway
- Variety of server & client platforms, via links varying in bandwidth & location
- Middleware supports wide-area deployment

Schneider PLCs



- Global discrete manufacturer of factory automation equipment
- Modern factories require up-to-the-minute data, even with limited memory and processing power
- Standardized protocol IEC 61148

- Middleware controls large SCADA systems

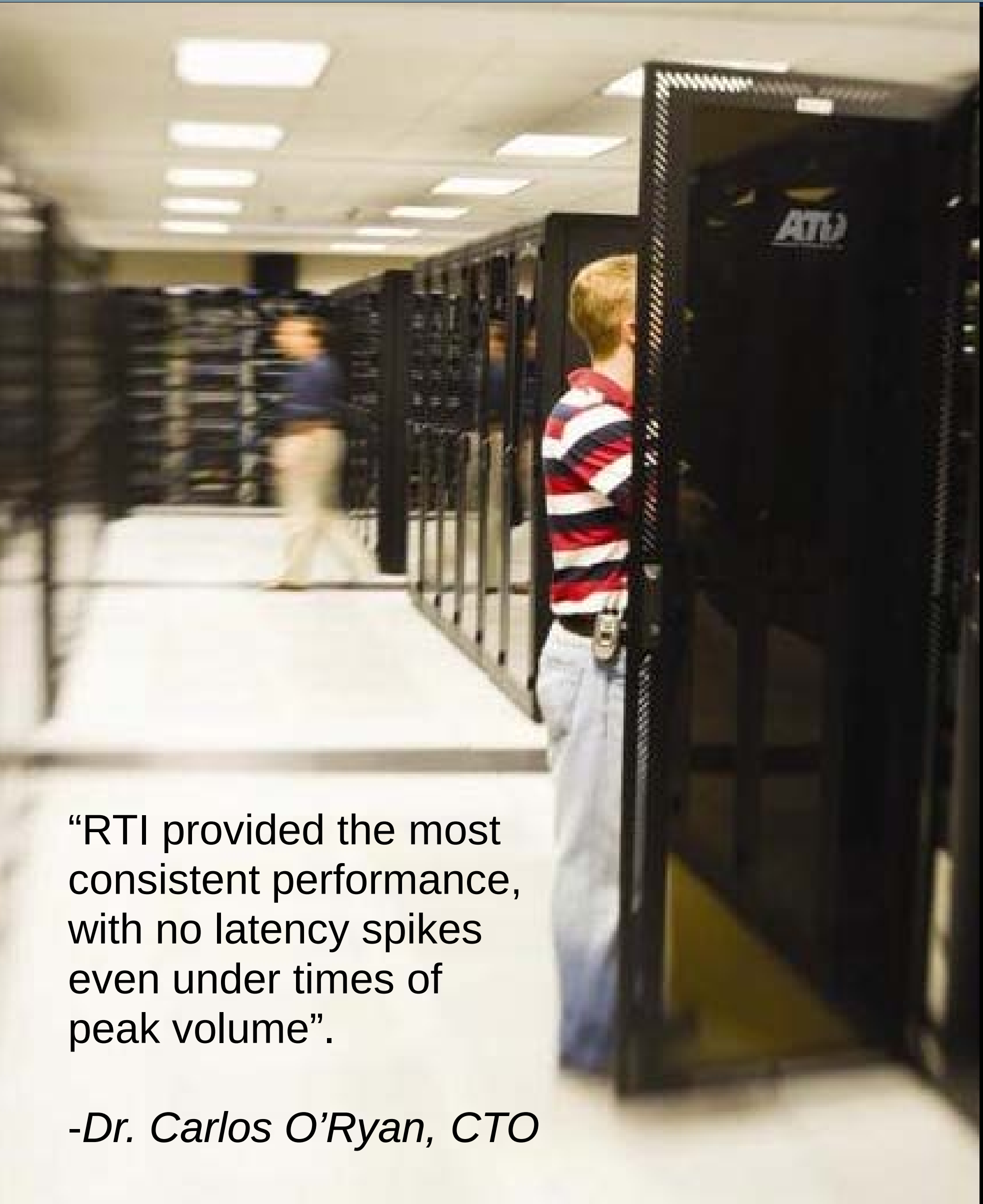
Medical Imaging

"RTI delivered great functionality at a low cost. Using RTI middleware saved us a lot of money, time, and effort compared to our previous in-house developed solution."

- RTI powers Varian's entire NMR and MRI product lines
- A single MRI receiver can saturate a 1Gbit network. An instrument may have 16…
- RTI's flexible and powerful QoS optimizes network use

- RTI middleware *handles megabytes of data*

High-Speed Trading



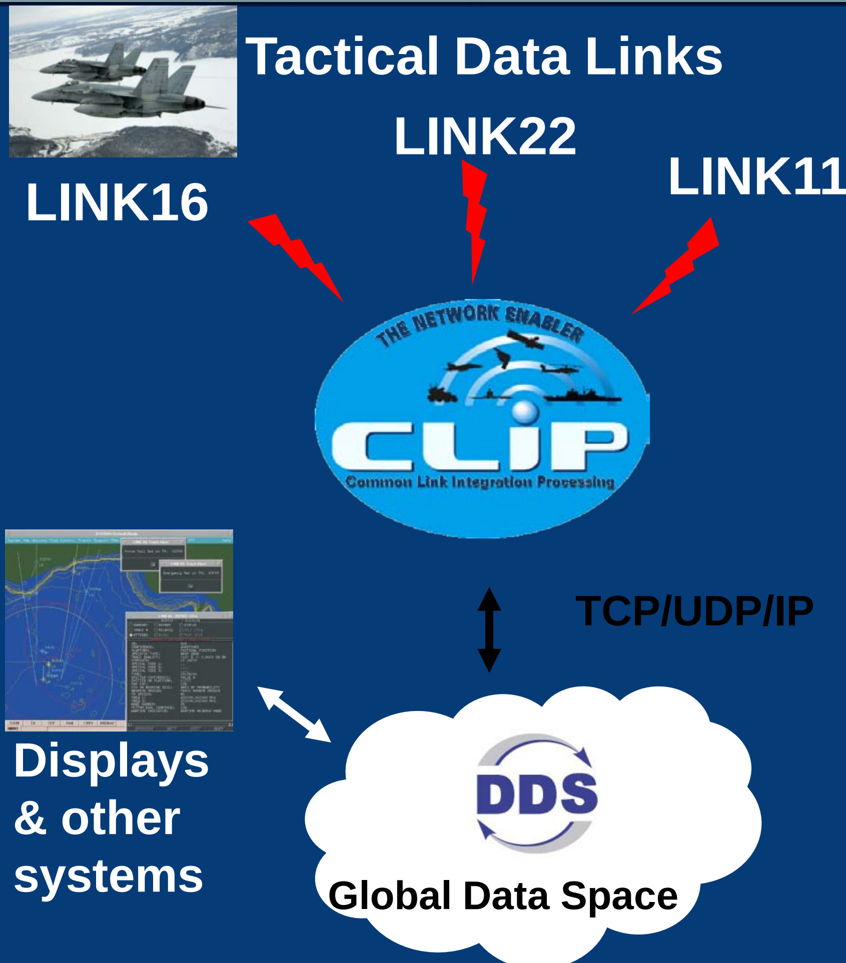
“RTI provided the most consistent performance, with no latency spikes even under times of peak volume”.

-Dr. Carlos O’Ryan, CTO

- Citi’s ATD division is using RTI as the foundation of a new market-data distribution infrastructure
- RTI feeds price-prediction engines and automated trading applications
- Competitive win against 29West and Tibco
- Priced by power & hdw saving!

RTI middleware provides competitive advantage because it *delivers low latency under load.*

CLIP Mediator Bridge



"Working with RTI has been both effective and productive."

– Jim Miller, CLIP Program Manager

Common Link Integration Processing (CLIP): a key U.S. Air Force and Navy joint project to build Tactical Data Link (TDL) aggregator

RTI Services helped architect, design, develop, and test software that 'mediated' between platform systems and CLIP

RTI middleware *bridges legacy networks*

Automotive Safety

The VW Driver Assistance & Integrated Safety system provides steering assistance when swerving to avoid obstacles, detects when the lane narrows or passing wide loads, and helps drivers to safely negotiate bends.

RTI middleware *bridges high speed networking to the CAN bus*

Advanced Telescopes

- ESO's Very Large Telescope array has four 8.2m diameter telescopes.
- Each can see objects four billion times fainter than can be seen with the unaided eye
- RTI coordinates hundreds of servo mirrors and scientific instruments.
- Middleware *coordinates control and measurement*

NASA KSC Launch Control

The Constellation program will be the next generation of American manned spacecraft.

RTI delivered 300k instances, at 400k msgs/sec with 5x the required throughput, at 1/5 the needed latency

NASA used RTI’s Architecture Study to lower risk.

Middleware *connects thousands of sensors and actuators*

Grand Coulee Dam, Columbia River, WA

Largest single electricity producer in the US:

- 6.8 Giga Watts output
- 3.5x more than Hoover Dam

Pilot program for 12 other US hydro retrofits

Middleware implements an extremely available system

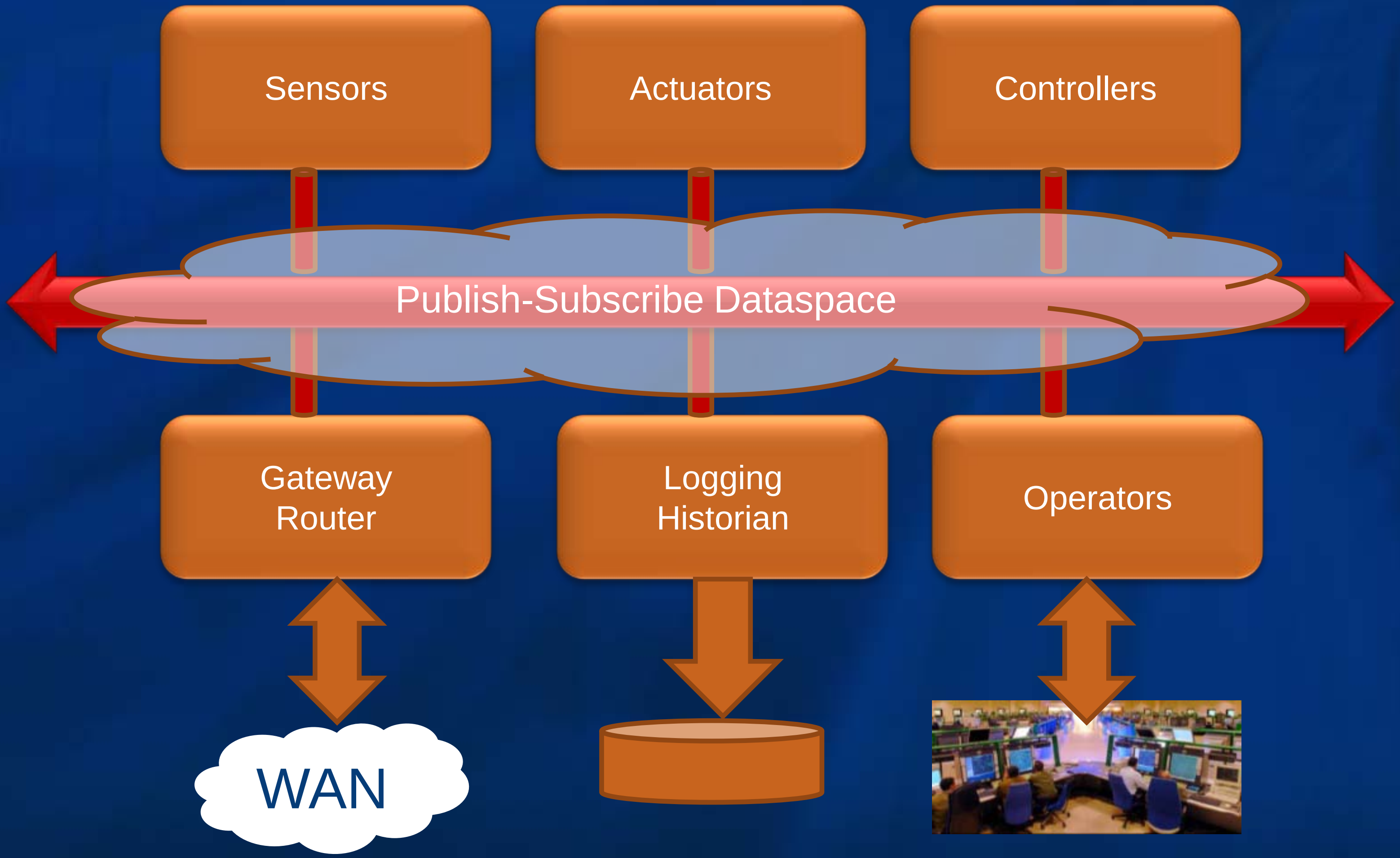
- No single points of failure
- N-way redundant software

Data centric architecture allows

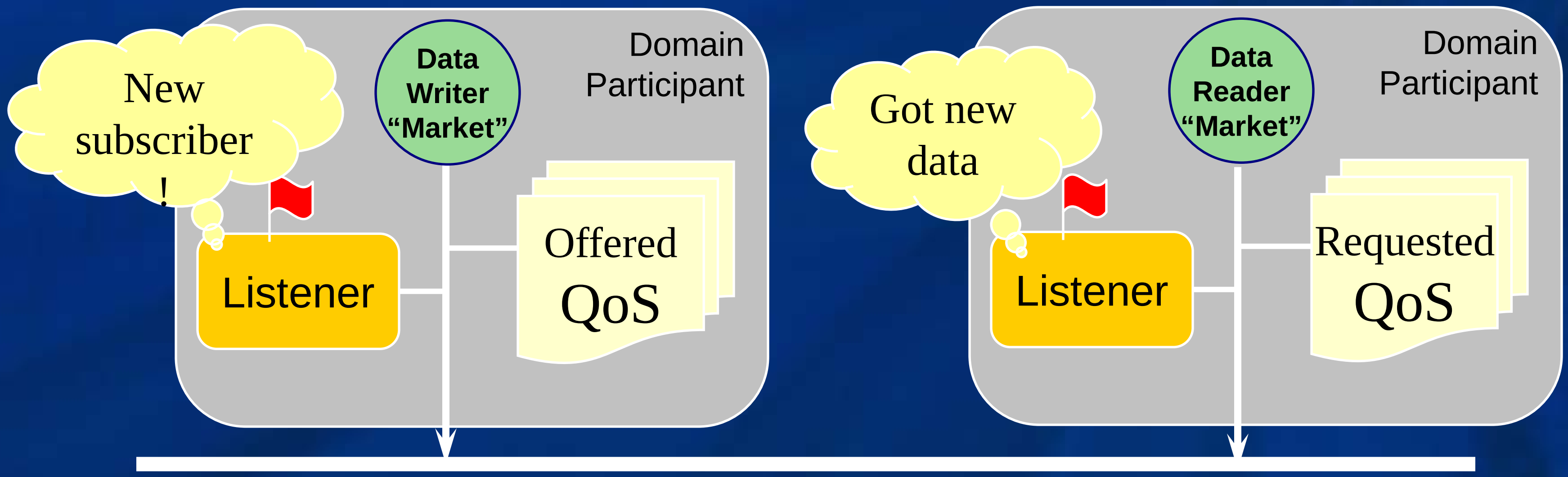
- Easy bring up/ bring down
- Fast reaction to change

How Does Middleware Work?

Real-Time Integration Infrastructure

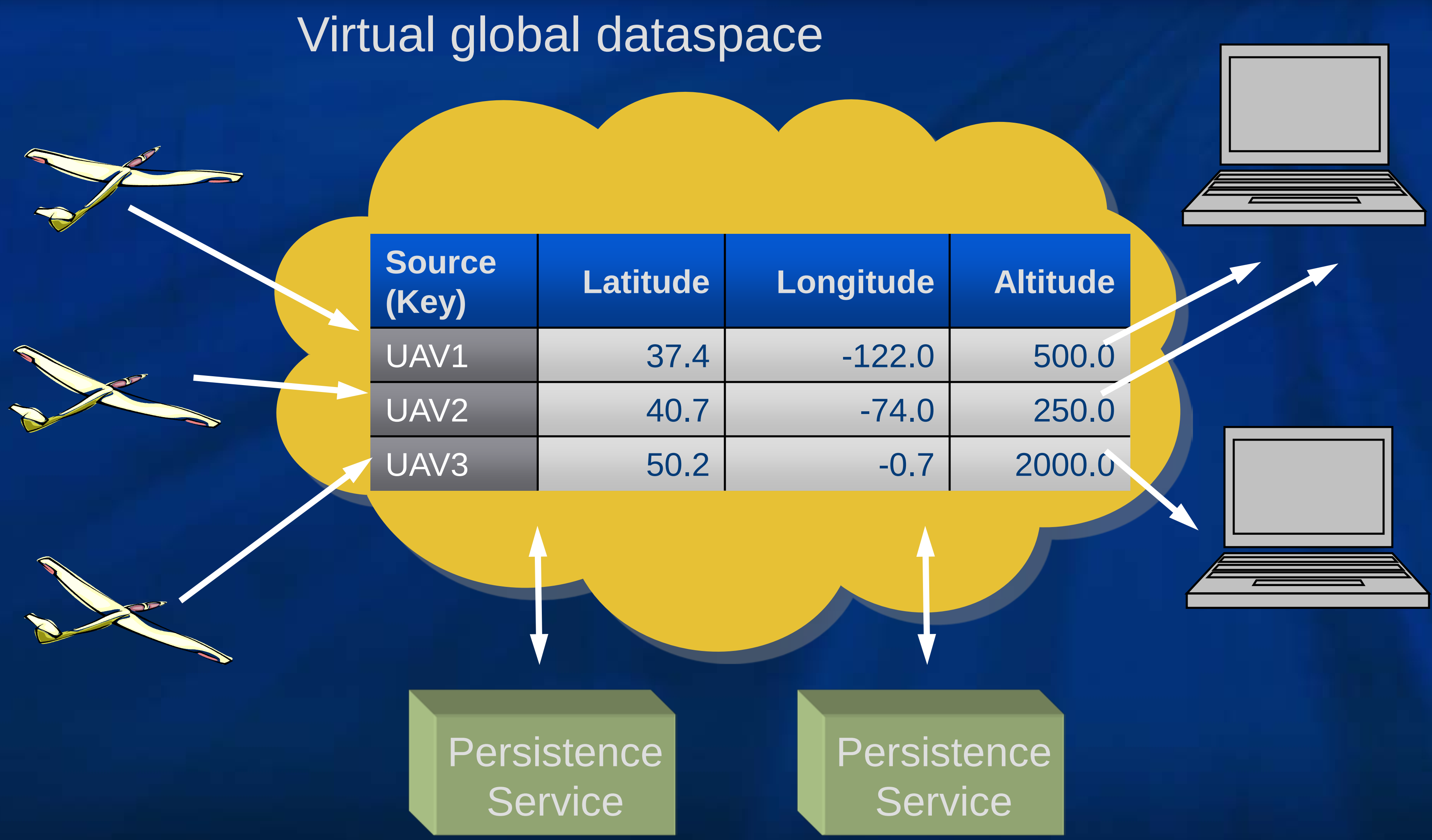


DDS communications model



- Topic-Based subscriptions
- QoS Contracts control information flow
  - Reliability, filtering, liveliness, resources
- Real-time listeners provide immediate event notification

DDS "Global Data Space" Simplicity

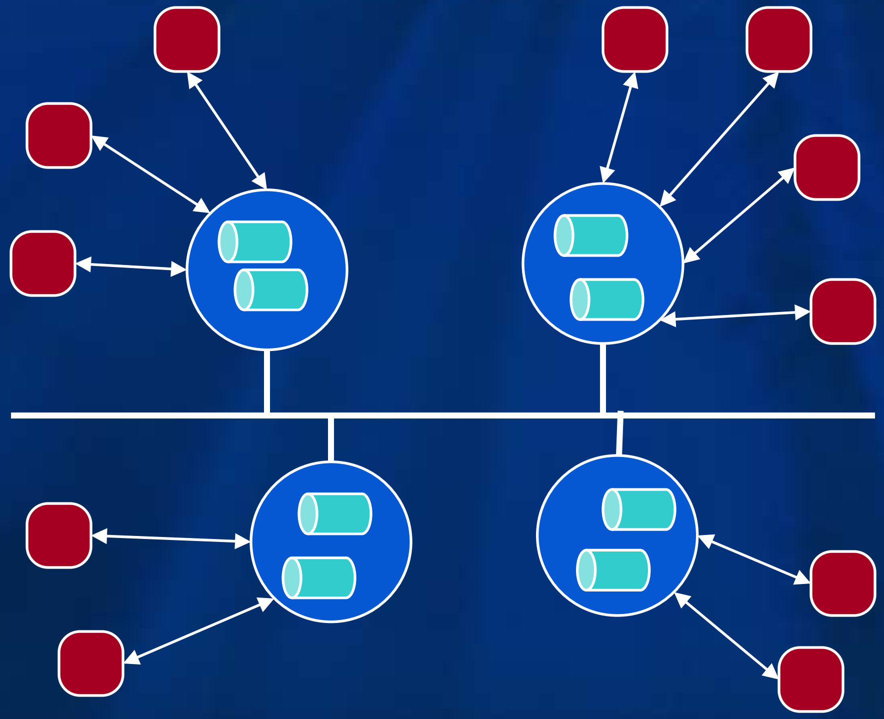


Source (Key)	Latitude	Longitude	Altitude
UAV1	37.4	-122.0	500.0
UAV2	40.7	-74.0	250.0
UAV3	50.2	-0.7	2000.0

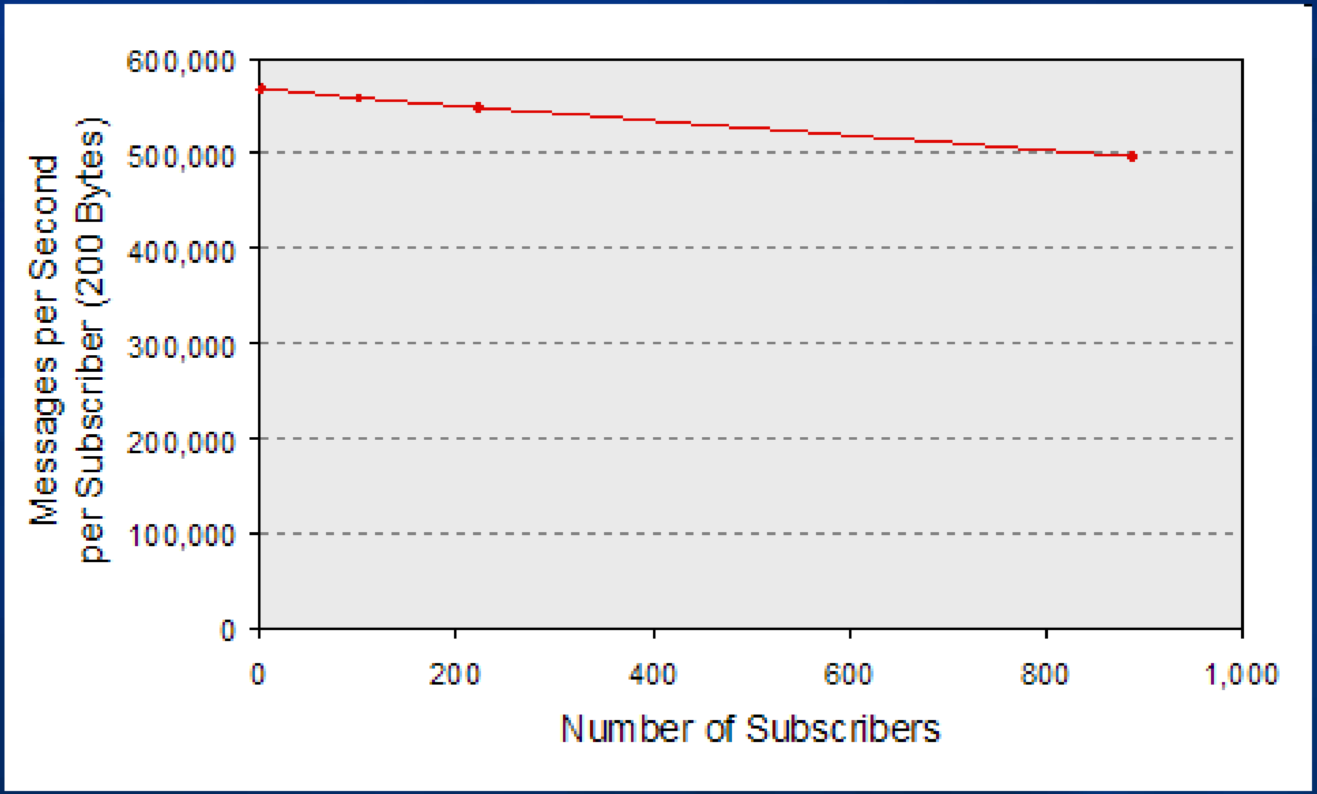
Peer-to-Peer Efficiency

Peer-to-Peer

Broker-based



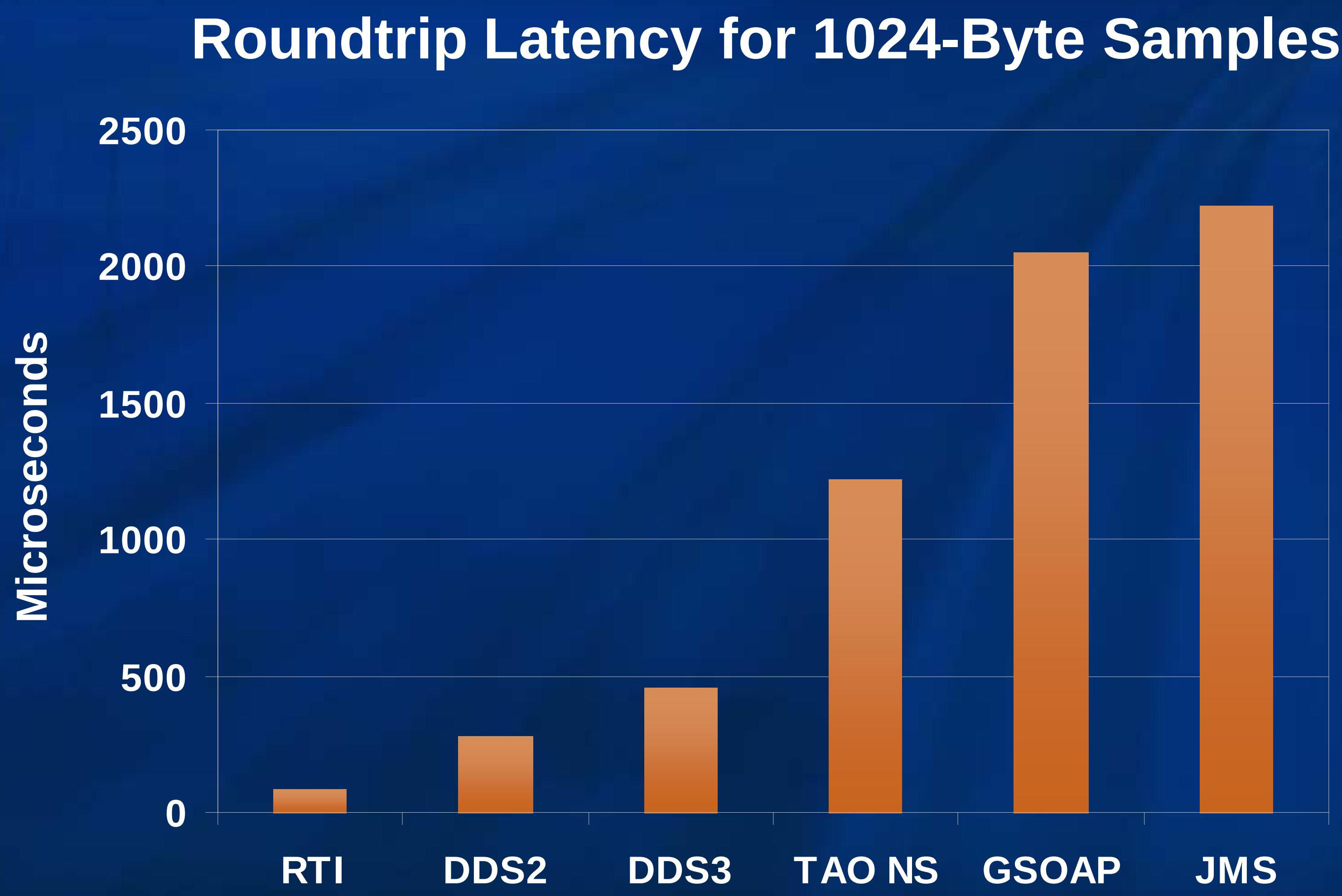
Highly Scalable



- 500k+ 200 byte messages/sec
- Scale from 1 to 1000 subscribers with 10% impact
- Reliable multicast expands to many nodes with almost no slowdown

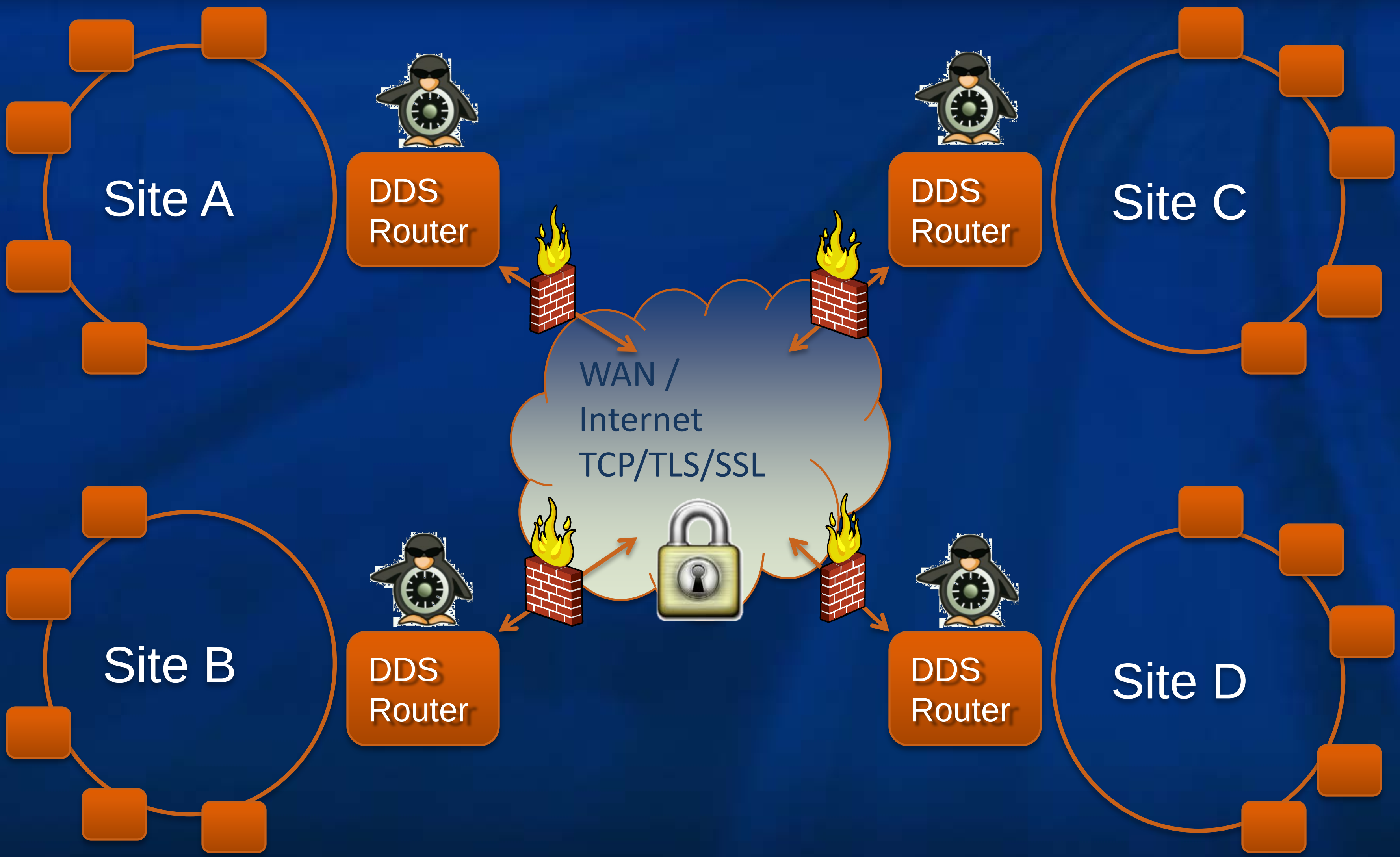
http://www.rti.com/products/dds/benchmarks-cpp-linux.html

Real-Time Latency



http://www.dre.vanderbilt.edu/DDS/

Global Scalability: LAN to WAN…
…without sacrificing Performance and Security



Is there a place for middleware in NASPI?

NASPInet Architecture

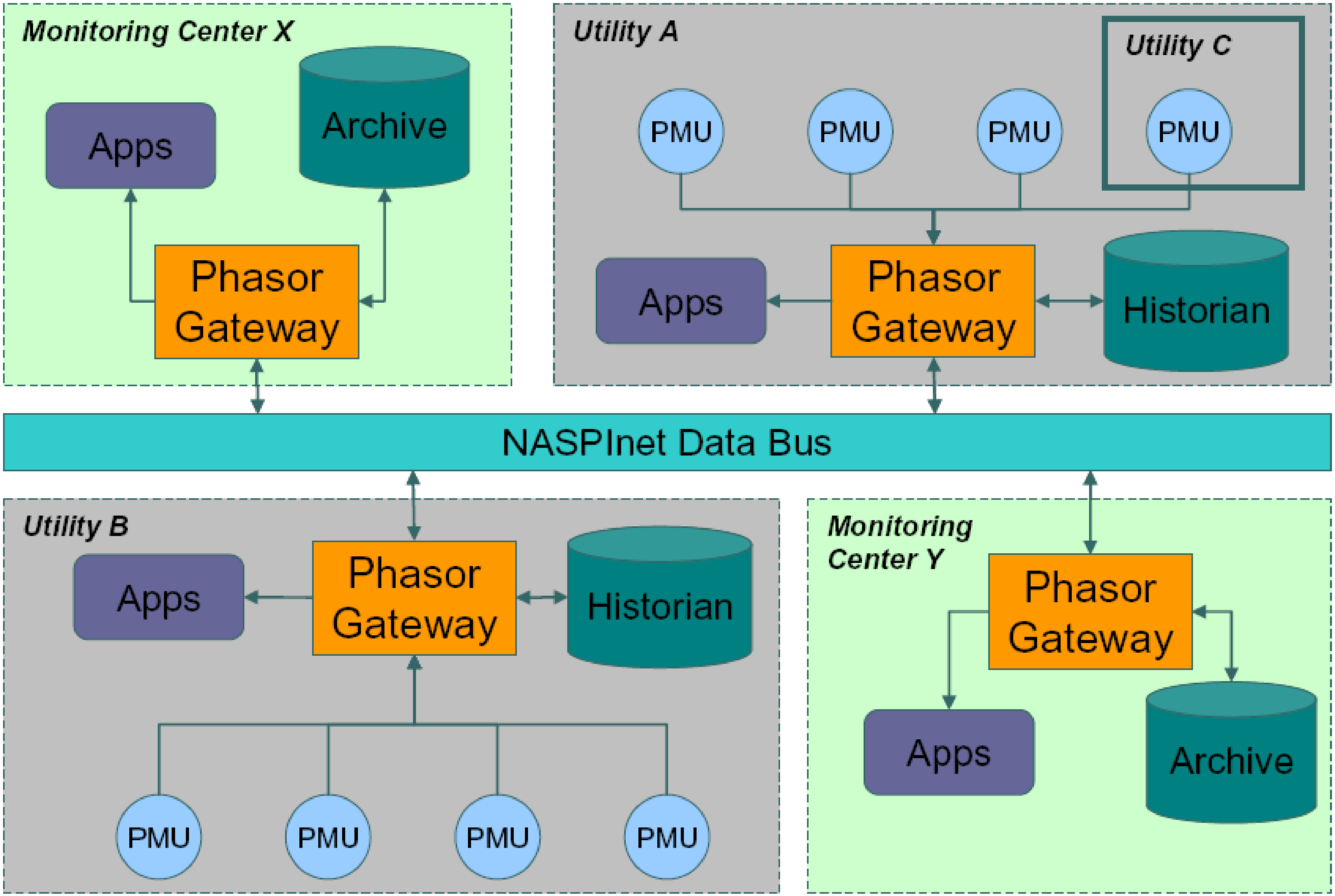
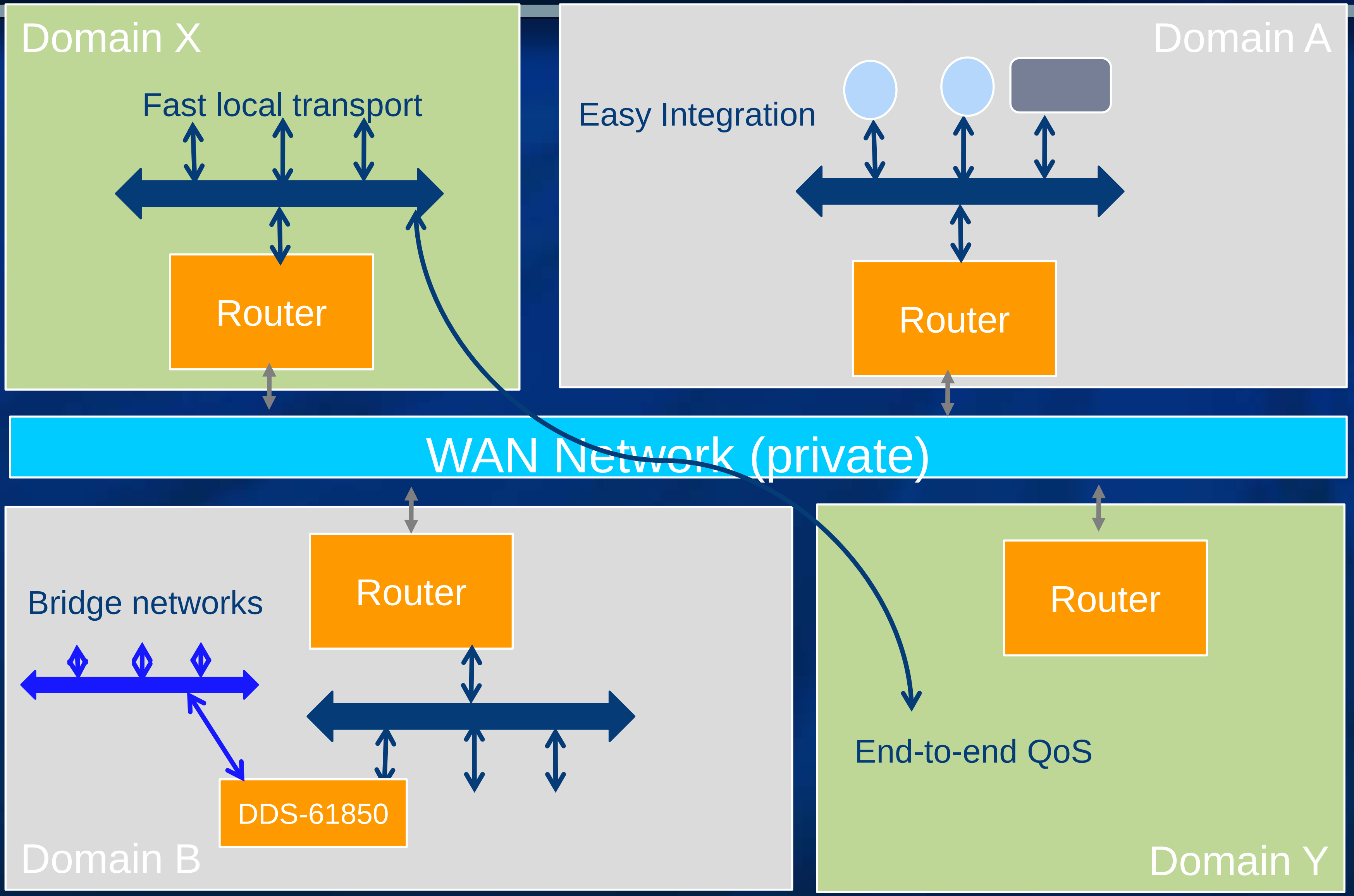
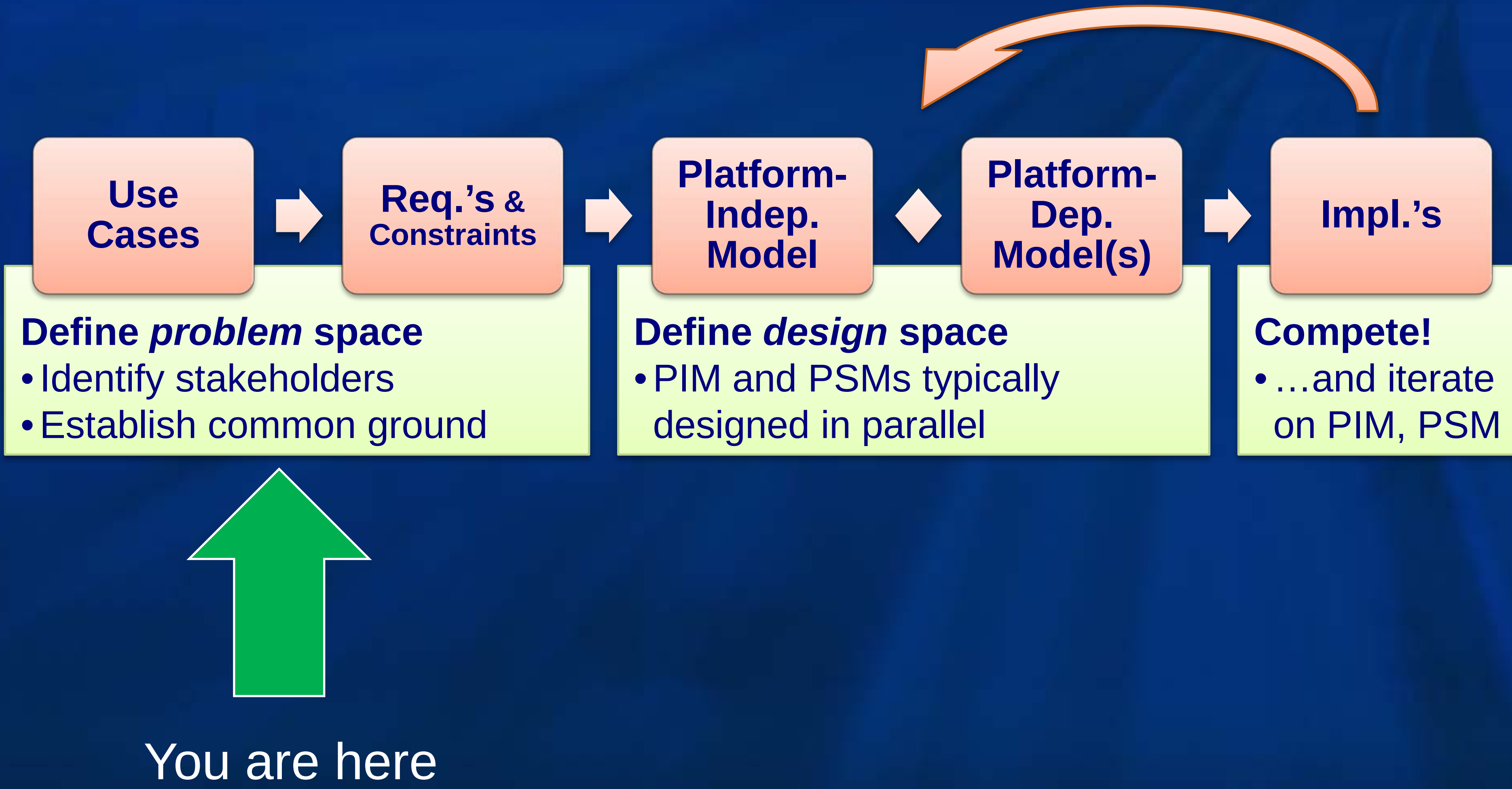


Figure 1 Basic NASPInet Architecture

NASPInet Middleware Vision



Modern Software Process

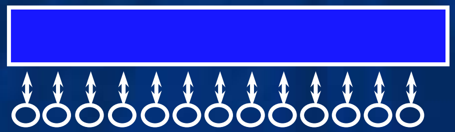


One Boat


PASSAGES
what it's really like

Summary

- Why middleware?
  - Easier to program and change
  - Fast & scalable
  - Interoperable
    - Across operating systems, languages, network transports, chip architectures, vendors
  - Future proof
    - No vendor lock-in
    - Allows updating to new technologies
- Can NASPInet leverage middleware?
  - Maps cleanly to architecture and requirements
  - Integrates other networks, protocols
  - Builds on field-proven technology



The Real-Time Middleware Experts

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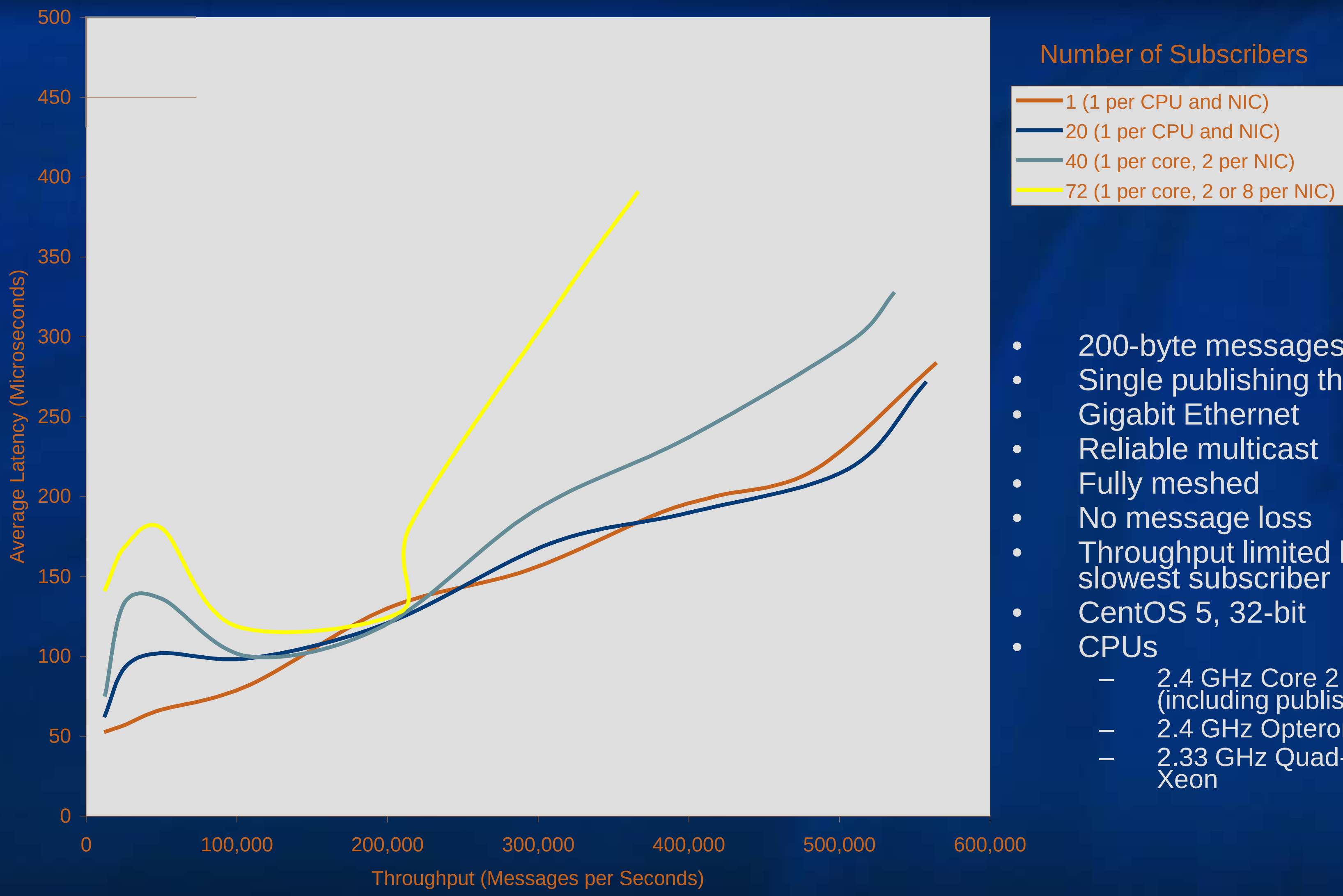
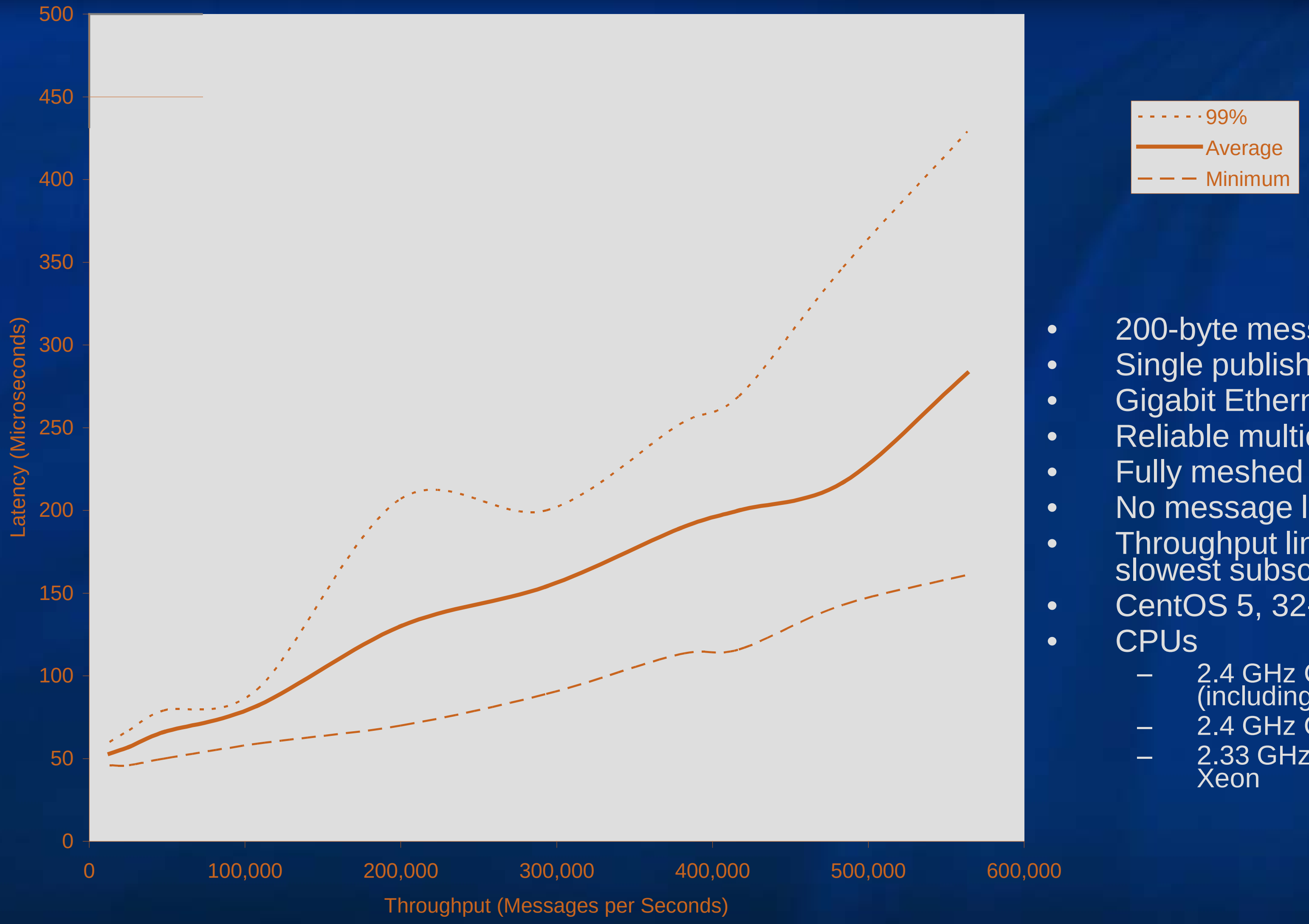
Backup & cutouts

Latency under load



- 200-byte messages
- Single publishing thread
- Gigabit Ethernet
- Reliable multicast
- Fully meshed
- No message loss
- Throughput limited by slowest subscriber
- CentOS 5, 32-bit
- CPUs
  - 2.4 GHz Core 2 Duo (including publisher)
  - 2.4 GHz Opteron
  - 2.33 GHz Quad-Core Xeon

Jitter



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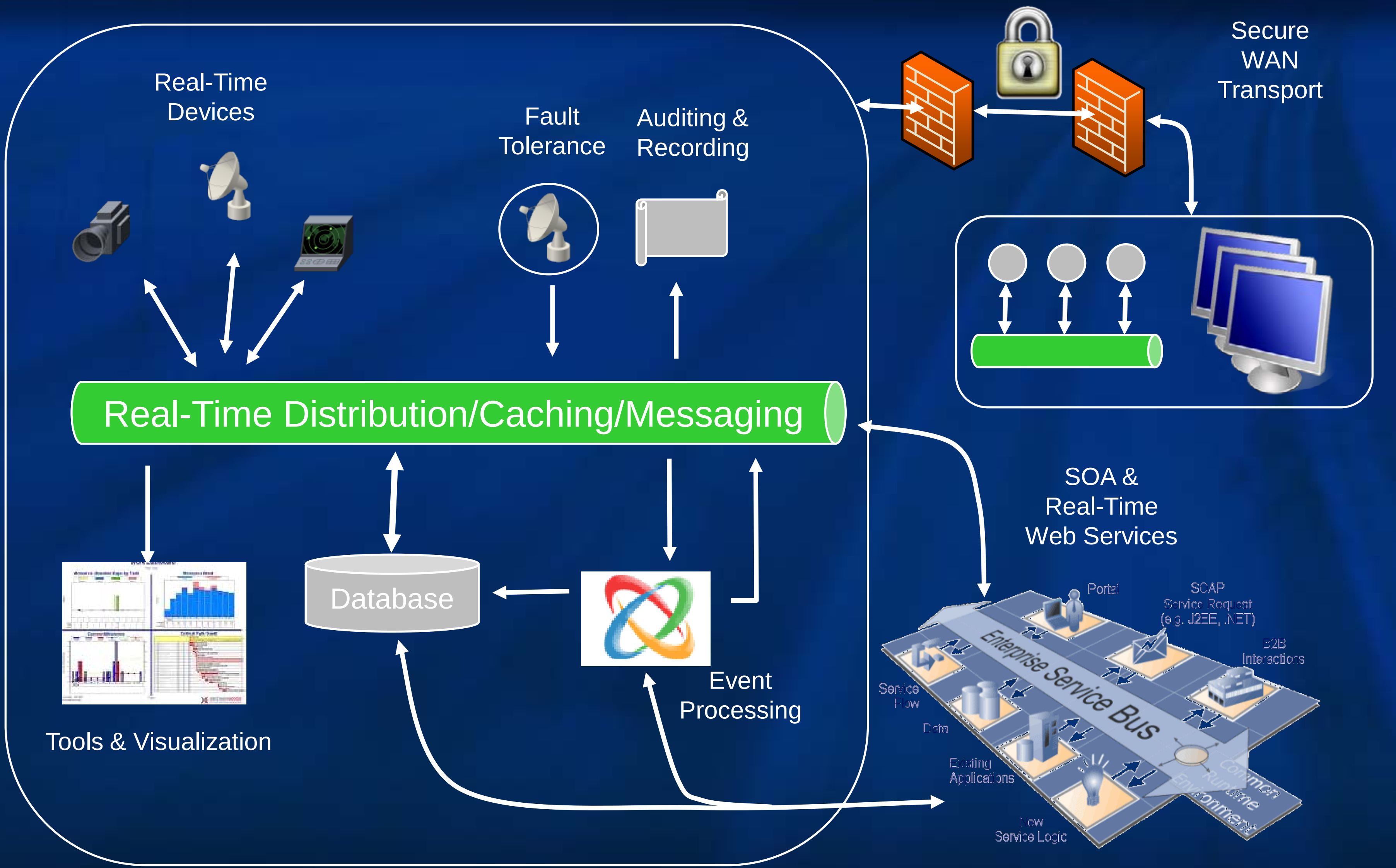
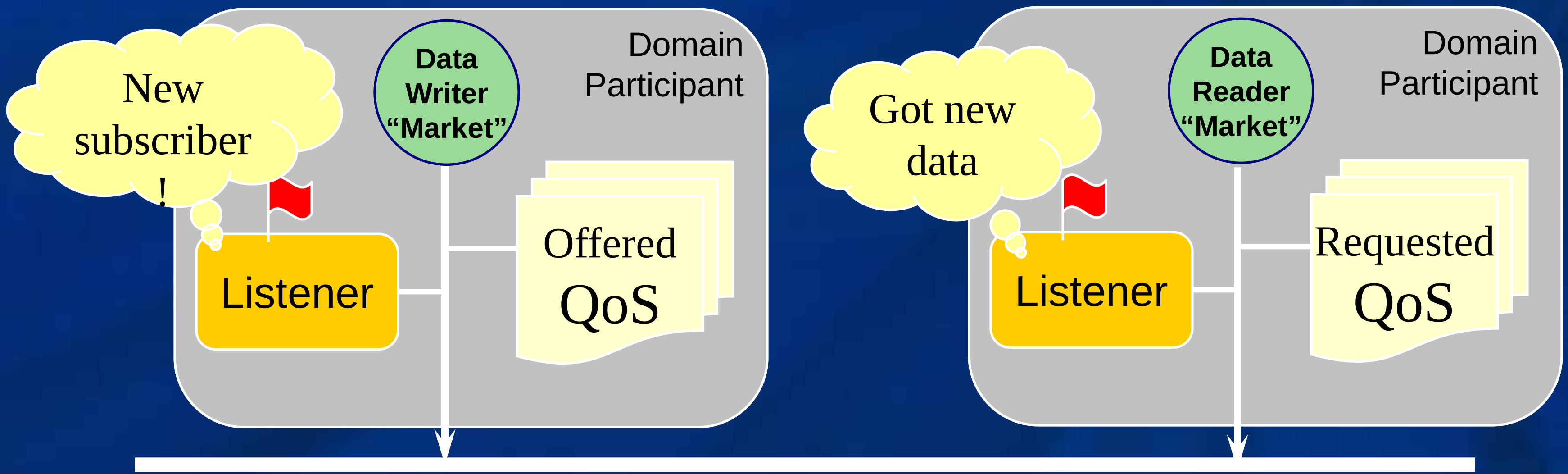
Integrated Infrastructure



5 Pending Patents

DDS communications model



- **Topics** define the data-objects (collections of subjects)
- **Writers** publish data on Topics
- **Readers** subscribe to data on Topics

- **QoS Contracts** control information flow
- **Listeners** immediately notify the application of events

Quality of Service Control

QoS Policy	QoS Policy
DURABILITY	USER DATA
HISTORY (per subject)	TOPIC DATA
READER DATA LIFECYCLE	GROUP DATA
WRITER DATA LIFECYCLE	PARTITION
LIFESPAN	PRESENTATION
ENTITY FACTORY	DESTINATION ORDER
RESOURCE LIMITS	OWNERSHIP
RELIABILITY	OWNERSHIP STRENGTH
TIME BASED FILTER	LIVELINESS
DEADLINE	LATENCY BUDGET
CONTENT FILTERS	TRANSPORT PRIORITY

RTI Leadership

- Market Leader
  - Over 70% DDS market share[1]
  - Largest embedded middleware vendor of all types[2]
- Standards Leader
  - OMG Board of Directors
  - Co-chair DDS SIG
  - Chair DDS committee
- Maturity Leader
  - Founded by Stanford control researchers in 1991
  - Years of commercial availability
  - Diverse industries: defense, finance, medical, industrial control, power generation, communications
  - 300+ commercial customers, 100+ research projects
  - 100,000+ licensed copies
  - U.S. DoD Technology Readiness Level (TRL) 8/9

[1]Embedded Market Forecasters
[2]VDC Analyst Report