eProsima Fast DDS

The middleware powering the ESO ELT.

RTC4AO workshop - 6 November 2023

Jaime Martin Losa - CEO
JaimeMartin@eProsima.com
+34 607 91 37 45

www.eProsima.com
twitter.com/eProsima

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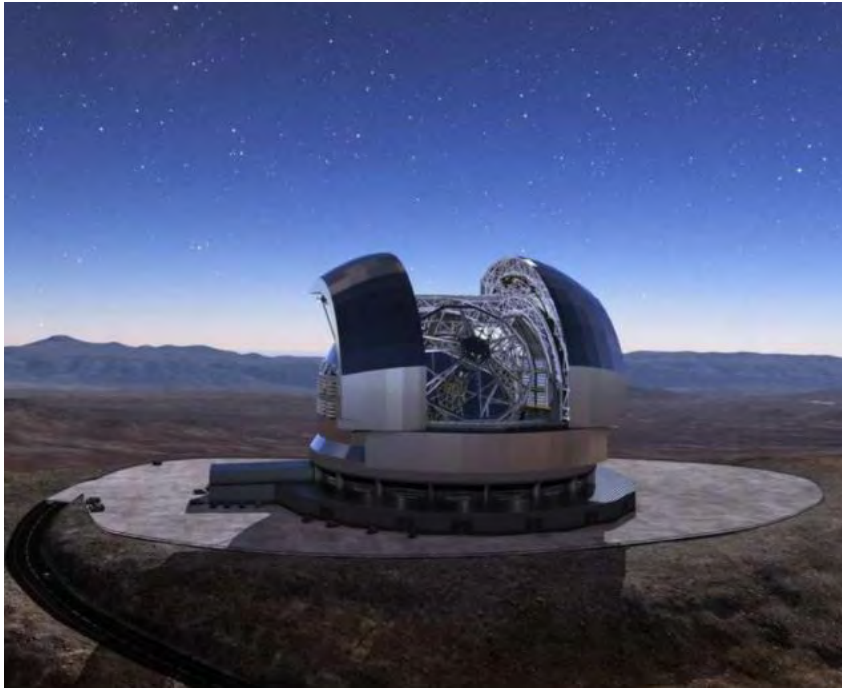
- eProsima Fast DDS and ESO ELT
- What is DDS?
- About eprosima: The company Behind Fast DDS
- Why Fast DDS?
- eProsima services
- Some Success Cases

ESO ELT - DDS Success Case



1. Largest optical telescope in the world (39m diameter)
2. 25.000+ sensors
   15.000+ actuators
3. Reliable and decentralized communication layer:

eProsima Fast DDS

DDS is the underlying middleware for:

- Core Integration Infrastructure Middleware Abstraction Layer (CII MAL)
- RTC Toolkit for propagating Telemetry data.

ESO ELT - Where Fast DDS is used?

1. Core Integration Infrastructure Middleware Abstraction Layer (CII MAL)

2. RTC Toolkit for propagating Telemetry data.

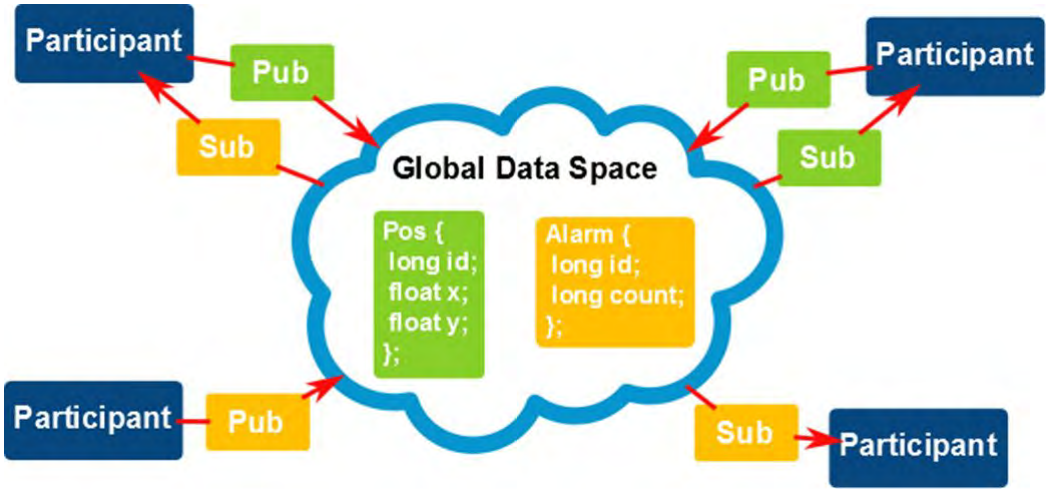
What is DDS?

- **DDS** (Data Distribution Service for Real-Time Systems) is a OMG specification for a pub/sub data centric model (DCPS, Data Centric **Publish/Subscribe**) for **Real-Time** data comms in **distributed systems**.

- **DDS is a networking middleware that:**
  - Simplifies and Standardizes data flows in distributed real-time systems.
  - Provides robust comms (**no single point of failure**) and efficient (**minimum latency**)
  - Provides **all kind of QoS** to shape the data flows and deliver predictable results.

DDS: Architecture

DDS uses the concept of **Global Data Space**. In this Space we define **topics** of data, and the **publishers** publish samples of these topics. DDS distributes these samples to all the **subscribers** of those topics. Any node can be a publisher or a subscriber.



Why DDS?: Decoupled model

- **Space (location)**
  - Automatic Discovery ensures network topology independence
- **Redundancy:**
  - It is possible to configure redundant publishers and subscribers, primary/secundary and takeover schemas supported
- **Time:**
  - The reception of data does not need to be synchronous with the writing. A subscriber may, if so configured, receive data that was written even before the subscriber joined the network.
- **Platform:**
  - Applications do not have to worry about data representation, processor architecture, Operating System, or even programming language on the other side
- **Implementation:**
  - DDS Protocol is also an standard. Different implementations interoperate.

Complete set of QoS settings

	QoS Policy
Volatility	DURABILITY
	HISTORY
	READER DATA LIFECYCLE
	WRITER DATA LIFECYCLE
Infrastructure	LIFESPAN
	ENTITY FACTORY
	RESOURCE LIMITS
Delivery	RELIABILITY
	TIME_BASED_FILTER
	DEADLINE
	CONTENT FILTERS

	QoS Policy
User Qos	USER DATA
	TOPIC DATA
	GROUP DATA
Presentation	PARTITION
	PRESENTATION
	DESTINATION ORDER
Redundancy	OWNERSHIP
	OWNERSHIP STRENGTH
	LIVELINESS
Transport	LATENCY BUDGET
	TRANSPORT PRIORITY

About eProsima

eProsima: about

Middleware experts | **Open source model** | **Standard based**

- OMG Members - **Leading DDS standard contributor**
  - **eProsima Fast DDS** is the most used DDS implementation
  - **>50.000 Clones per month!**
  - Creator of many DDS tools.
- ROS TSC Members - **ROS 2 major contributor**
  - eProsima ROS 2 distribution: **Vulcanexus**.
  - Largest tool set for ROS 2.

eProsima: Core products

Fast DDS	Publish-Subscribe DDS middleware for real-time distributed systems
XRCE DDS	Wire protocol for eXtremely **R**esource **C**onstrained **E**nvironments (micro-controllers)
Safe DDS	ISO-certifiable DDS implementation (Commercial)

eProsima: Graphical Tools

Graphical desktop application to monitor DDS environments and its network performance

Plot your DDS data

Learn about DDS and do quick examples

eProsima: More Tools

Enables communication of geographically spaced DDS networks using WAN over TCP

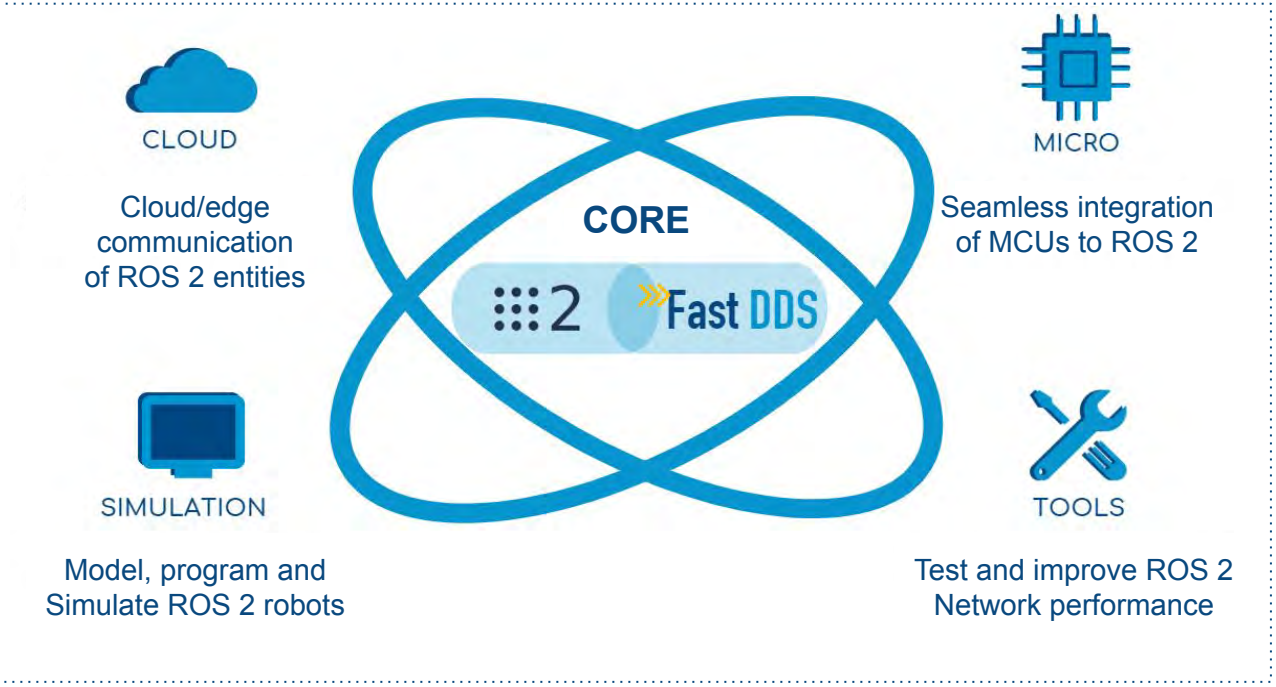
Record and replay your DDS Data

introspection tool for DDS networks

Intercommunication of an arbitrary number of protocols that speak different languages

eProsima: vulcanexus

Vulcanexus, the all-in-one ROS 2 tool set, is an open-source software stack for easy and personalized development of robotic applications.



Key benefits:

- Free and open-source
- ROS 2 compatibility and features
- Exclusive components
- Always up to date

Why Fast DDS?

Fast DDS vs Open-source Alternatives (I)

- Most adopted DDS implementation by far
  - **50.000 clones per month**
  - Highest number of stars and forks in Github Repo
  - Adopted by many open source projects:
    - ROS2, Dronecode, Baidu…
- Highest DDS compliance:
  - Core DDS Spec, RTPS, DDS Security, X-TYPES, XRCE-DDS, RPC over DDS
- The best documentation

Fast DDS vs Open-source Alternatives (II)

- Many important commercial references:
  - Facebook, Intel, amazon, sony, open robotics…
- Affordable support and services
  - eProsima, a company focused on DDS.

- Tools!: The other Open-source alternatives do not include almost any tool.

Fast DDS vs Open-source Alternatives (II)

Tool/implementation	**Fast DDS**	Open DDS	Cyclone DDS(*3)
Shapes Demo	✔	✔	✔
Fast DDS Monitor - Statistics	✔	✘	✘
Fast DDS Visualizer	✔	✘	✘
Record and Replay	✔	✘	✘
DDS Spy	✔	✔ (*1)	✘
DDS Router	✔	✘	✔ (*2)
Microcontrollers: XRCE-DDS	✔	✘	✘
Integration Service	✔	✘	✔ (*2)
RPC over DDS	✔	✘	✘
Simulink DDS Blockset	✔	✘	✘

(*1) OpenDDS Monitor (equivalent tool to Fast DDS visualizer, but it does not support the features of Fast DDS Monitor)
(*2) Through a different protocol: Zenoh
(*3) OpenSplice DDS is no longer maintained in favor of Cyclone DDS

Fast DDS vs Open-source Alternatives (IV)

Performance:

- Multiple studies show eProsima Fast DDS is the **fastest implementation available in the market**. eProsima has published several benchmarking studies and comparisons with other DDS implementations. These studies include code to reproduce the results.

- Independent studies, such as Open Robotics study, led to select Fast DDS as the default middleware for the Robot Operating System, version 2 (ROS 2). Other publicly available comparisons reach the same results.

Fast DDS vs Commercial Alternatives (I)
No Licensing Costs

Forget about

- Commercial license per developer
- Getting charged for runtime licenses!

Be more cost-effective

- Flexibility to scale the project with no additional costs
- Allocate resources in other areas of development

With Fast DDS you can leverage robust DDS capabilities while staying within your budget

Fast DDS vs Commercial Alternatives (II)
No Vendor Lock-in

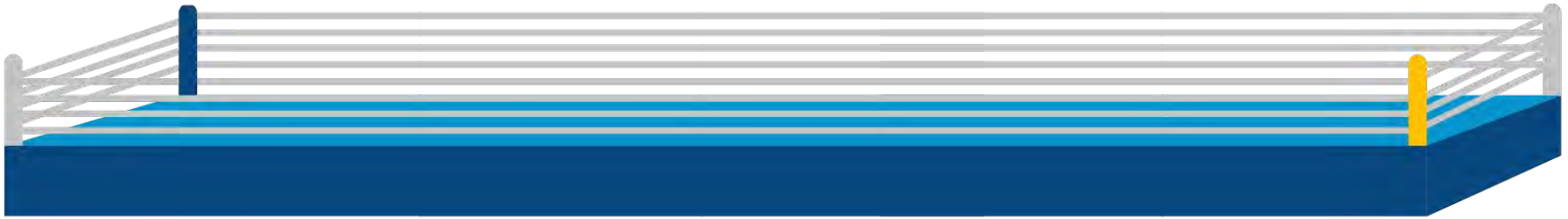
Commercial DDS

Commercial implementations include many non-standard features.

- Making the cost of switching to another implementation higher
- User becomes dependent on vendor product and services

Fast DDS

- Fast DDS is and always will be **open-source** and **free**
- Fast DDS provides **high DDS compliance** (Core DDS Spec, RTPS, DDS Security, X-TYPES, XRCE-DDS, RPC over DDS, etc)

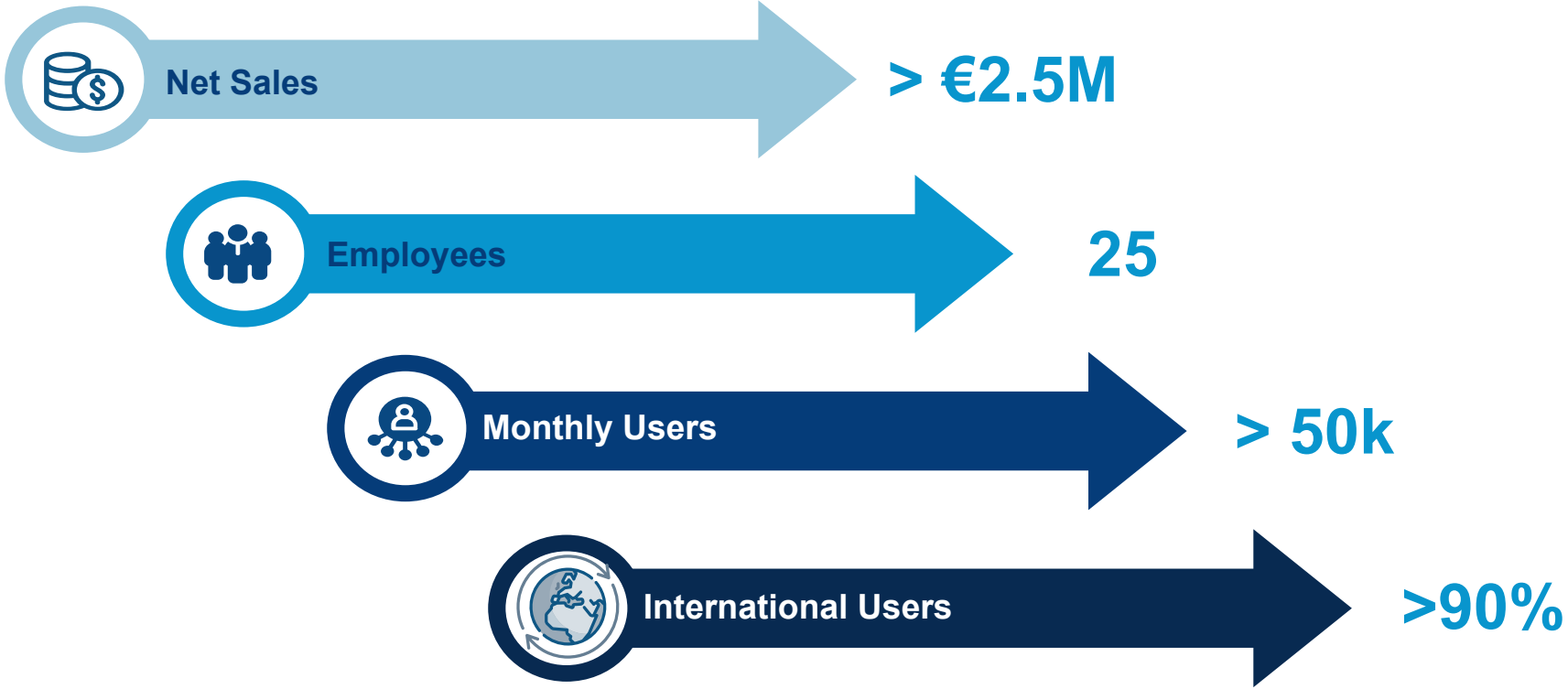


eProsima Services

eProsima Services

- **Architecture Studies & Technical Support:**
  - We help you to develop your distributed system, designing your architecture and providing technical support.
- **Comm layers:**
  - We can go a step further and develop the comm layer of your distributed system.
- **Feature accelerations:**
  - Our products are funded by our customers.
- **Safe DDS:**
  - Safe DDS Licenses, services, and safety consulting.

eProsima in numbers



Some of our **Customers and Partners**

Robotics & Automotive

SONY
open robotics
SIEMENS
Apex.AI
Dronecode
CLEARPATH
amazon
auterion
3D Robotics
MAKINO
Rapyuta Robotics
DB
ASE Technology Holding Co., Ltd.
INTELLIGENT ROBOTS
MathWorks
TTTech
HEXAGON
FZI
ESO

Critical Applications & IoT

THALES
indra
AIRBUS
BOEING
gmv
CATEC
Isdefe
GENERAL DYNAMICS
gtd SYSTEM & SOFTWARE ENGINEERING
ikerlan
tecnobit
Navantia
deimos elecnor group

Partners

BlackBerry QNX
BOSCH
FIWARE
SONY
ROSin
ROS
WIND
LYNX
CISPA
DFKI
zh aw
PIAP
ALGEBRAIC AI
uc3m
Champalimaud Foundation
Inria
TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
VTT
THE AUTOWARE FOUNDATION
NXP
amazon

Open Source Users

Robot
ROBOTIS
RENESAS
NORTHROP GRUMMAN
LG
Baidu apollo
CANONICAL
Intelligent Robotics Lab
Continental
dyson
Google
HUAWEI
intel
KUKA
Microsoft
PHILIPS
pilz
SAMSUNG
TOSHIBA
TOYOTA
Trimble
XIAOMI

eProsima

The Middleware Experts

www.eProsima.com

Jaime Martin Losa - CEO
JaimeMartin@eProsima.com
+34 607 91 37 45

Linkedin.com/company/eProsima

Twitter.com/EProsima

eProsima Success Cases

Updated November 2023

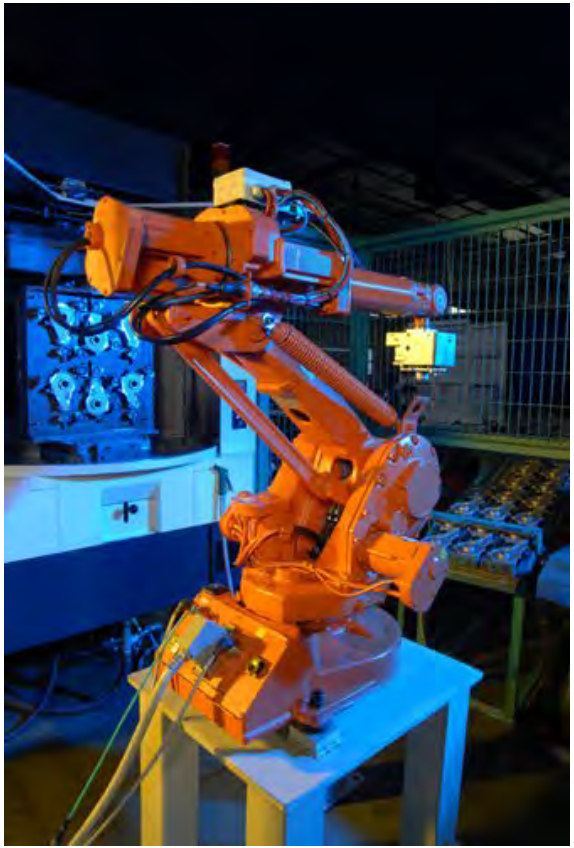
Video Intro

Complete List

[eProsima Customers, Open Source Users & Partners]

Robotics

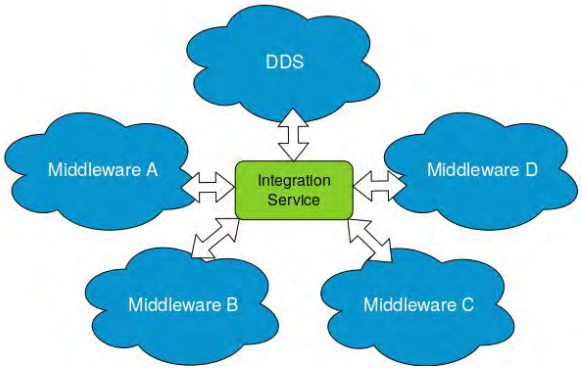
Robot Operating System



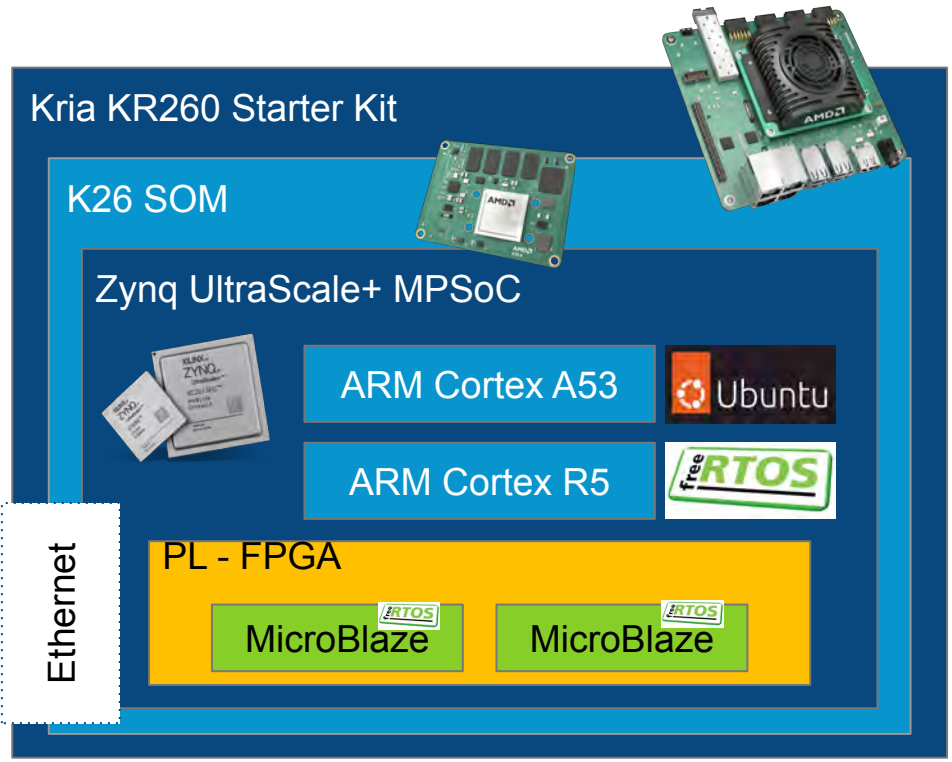
- eProsima Fast DDS is the **middleware of ROS 2**
- eProsima is a member of the **ROS 2 TSC**
- **Thousands of users!**
  - More than 50.000 clones per month of Fast DDS.

Robot Middleware Framework

- Open Robotics Project for **Singapore Hospitals**
- eProsima Fast DDS & eProsima Integration Service
- **Hundreds of nodes**



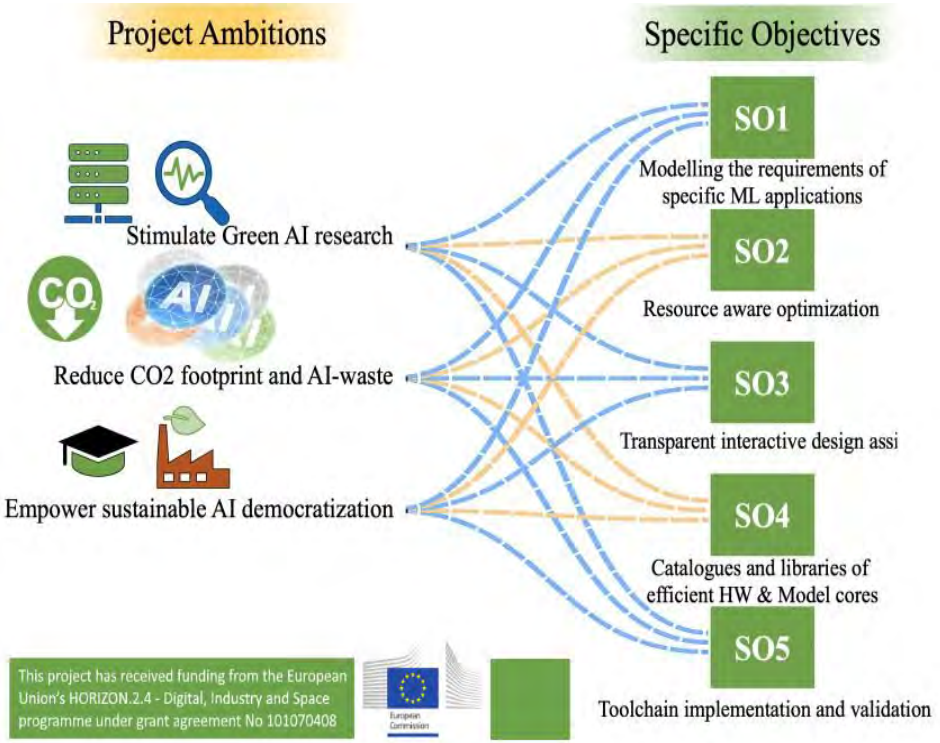
Safe DDS - AMD Kria KR260



Safe DDS

- Safe DDS: Solution for Embedded and Functional Safety
- Fully portable to all kind of hardware
- **AMD Kria KR260** run **Safe DDS**
  - Cortex A53 - Ubuntu
  - Cortex R5 - FreeRTOS
  - Microblaze (FPGA) - FreeRTOS

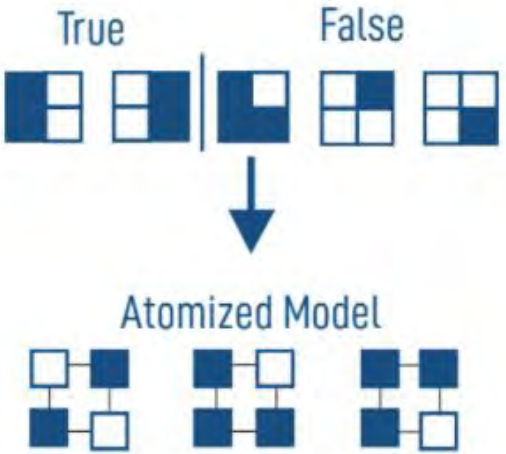
SustAInML



This project has received funding from the European Union's HORIZON.2.4 - Digital, Industry and Space programme under grant agreement No 101070408

- Minimize CO2 emissions and decrease AI-related waste.
- Foster the growth of Green AI Research initiatives.
- Enable the democratization of sustainable AI practices.

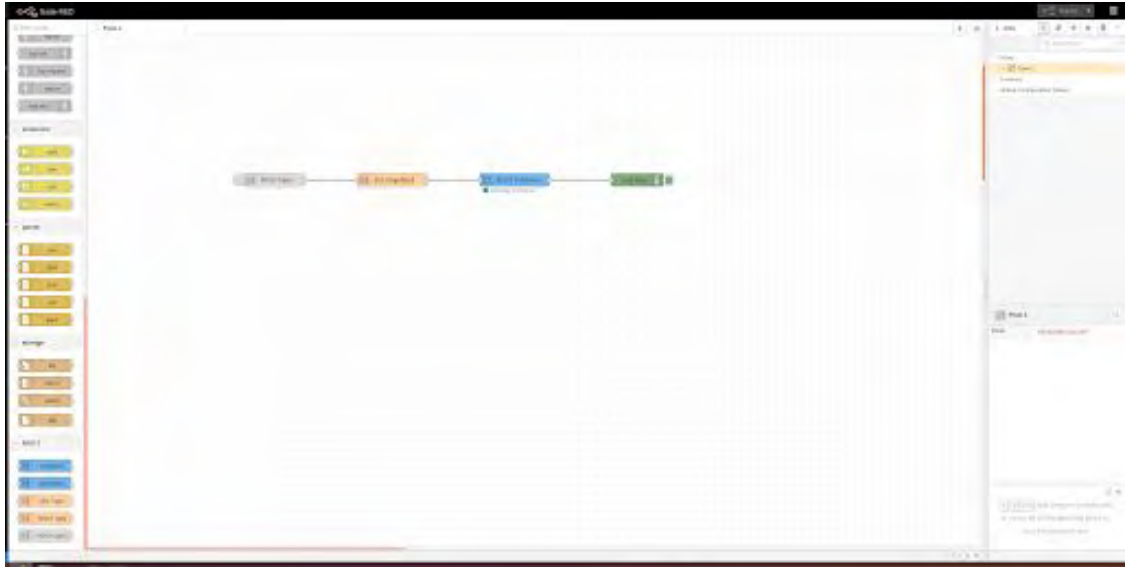
Algebraic Machine Learning



New Learning Paradigm

- Interactive, human-centric machine learning system
- Algebraic representation of data
- Symbolic AI
- Semantic embeddings of data
- No statistical properties
- Parameter-free

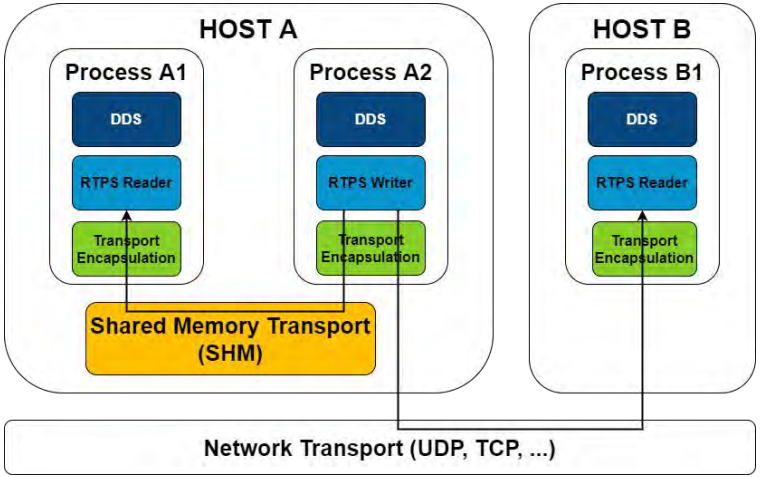
DIH2: visual-ROS



Bridges the gap between factory automation and robotics.

- ROS 2 applications without coding
- Fast DDS and Integration Service

SONY Long-term relationship



- eProsima, Sony & ROS-Industrial
- Increases performance
  - Shared Memory Transport / Zero Copy
  - Content Filtered Topic

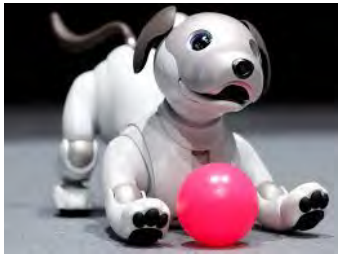
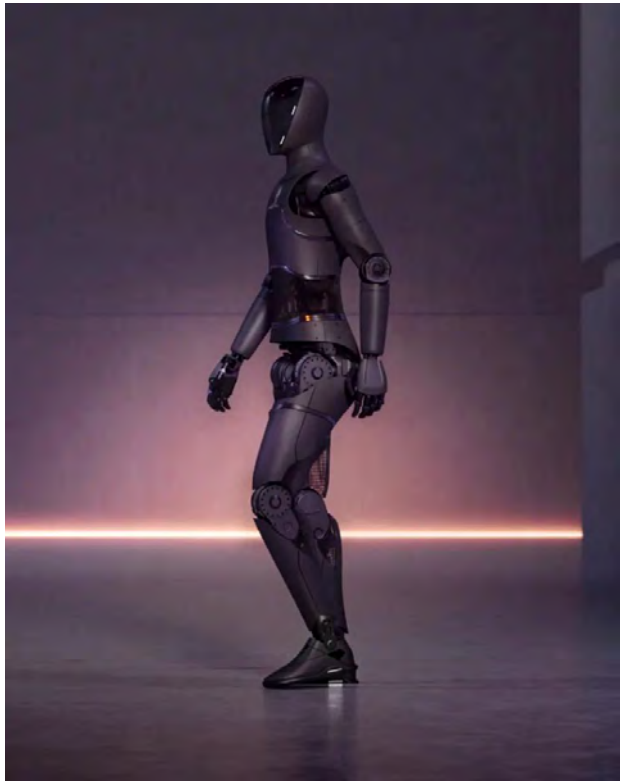


Figure AI: AI-powered Humanoid Robot



- Figure AI is using Fast DDS in their Robotics Framework.
- Collaboration to develop several Fast DDS tools:

DDS Record & Replay

Efficiently Save and Replay DDS Data

Fast DDS Spy

Introspection tool for DDS networks

Fleet Management

- Fleet manager communicates with a large number of vehicles
- Scaling to up to 500 vehicles

RRAI 360° Autonomous Vehicle Solutions

- RRAI is using Fast DDS intheir C2 system to manage their line of autonomous vehicles.
- eProsima helped them develop a high-performance distributed architecture.
- Development of a tool for adaptive video streaming with DDS

Husarion

- ROSbot 2R is an open-source robotic platform using ROS 2, micro-ROS and Fast DDS
- ROSbot 2R implements DDS Router in order to communicate from the Cloud the robot with a controller deployed on an independent network

Arrival

- Using Fast DDS in their production-intent systems for their custom-built AMR's in their Microfactory.
- Developed a high-performance distributed architecture integrating Fast DDS

PKCS#11 support for SROS2

- Feature development of PKCS#11 support for ROS 2 Security
- Support the PKCS#11 basic functionality using SoftHSM library as a reference implementation of a generic PKCS#11 Hardware Security Module (HSM)

Cloud deployment

- Rapyuta.io and ROS 2
- Device-to-cloud communication
- ROS 1 and ROS 2 interoperability
- eProsima Fast DDS and DDS Router

Universidad Rey Juan Carlos

Intelligent Robotics Lab

Robotics Lab: Nav2

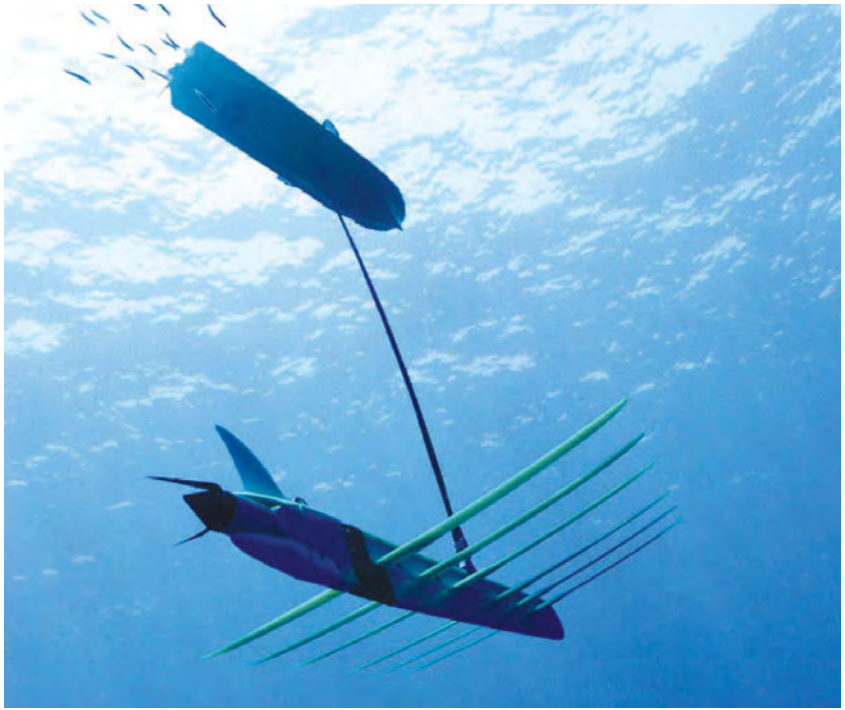
- Testing ROS 2 Navigation 2 with two professional robots
- Fast DDS as the selected dds middleware implementation

New Robotic Architecture

- Redesign of their robotic architecture and the update of their communication system
- Support to boost the concept phase of this project with Fast DDS

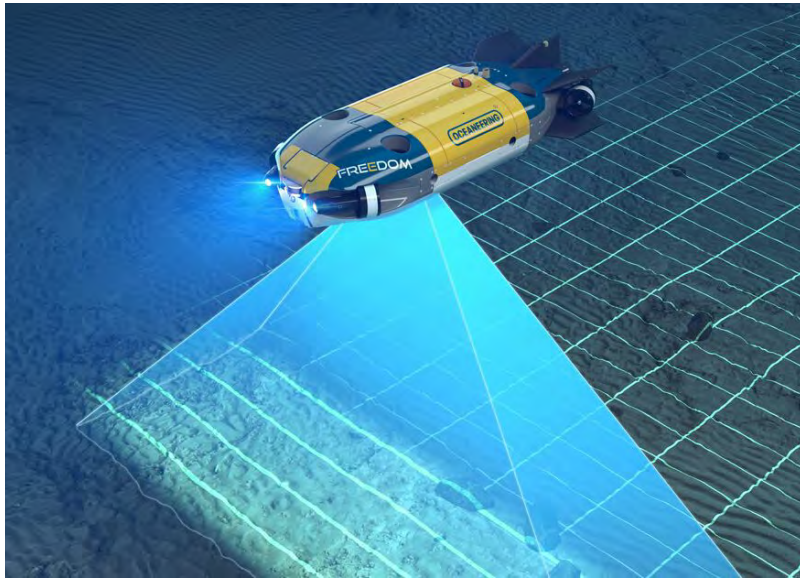
LIQUID ROBOTICS
A Boeing Company

Liquid Robotics



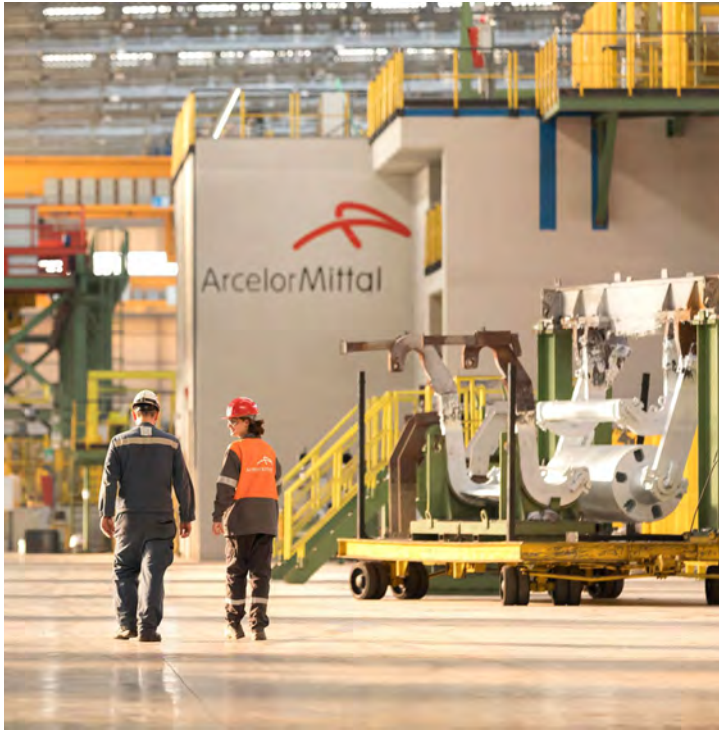
- The Wave Glider, a wave and solar powered unmanned surface vehicle, is using Fast DDS, including ROS 2
- Define and design their architecture and giving support

Oceaneering



- Oceaneering is using Fast DDS for their autonomous vehicle Freedom, an underwater autonomous vehicle
- Support to harden the code base and to tackle these issues

New Robotic Architecture

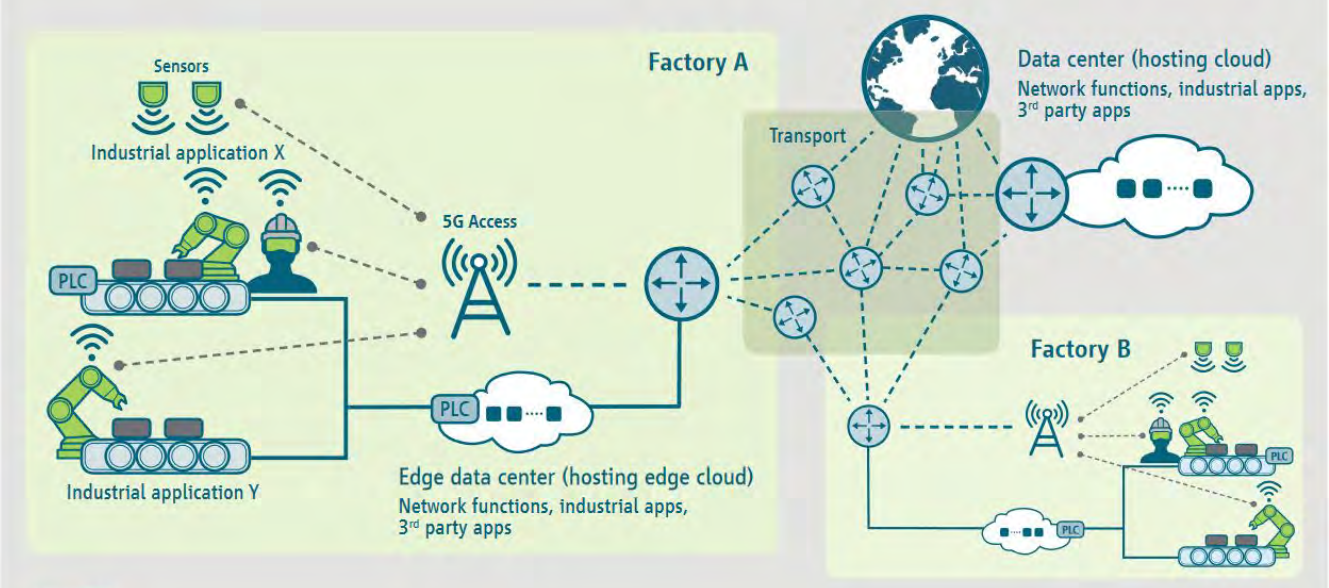


- Fast DDS is the base middleware in their new industrial IoT platform for the whole company ecosystem
- Support in the design of the system architecture of the platform

Dynamic Network Interfaces Discovery

- Tomahawk Robotics uses Fast DDS for its Kinesis project. eProsima added the capability for Fast DDS to re-evaluate the available network interfaces when triggered via a method/API call.
- Tomahawk Robotics also contributed to the effort of bringing official support for Android in Fast DDS

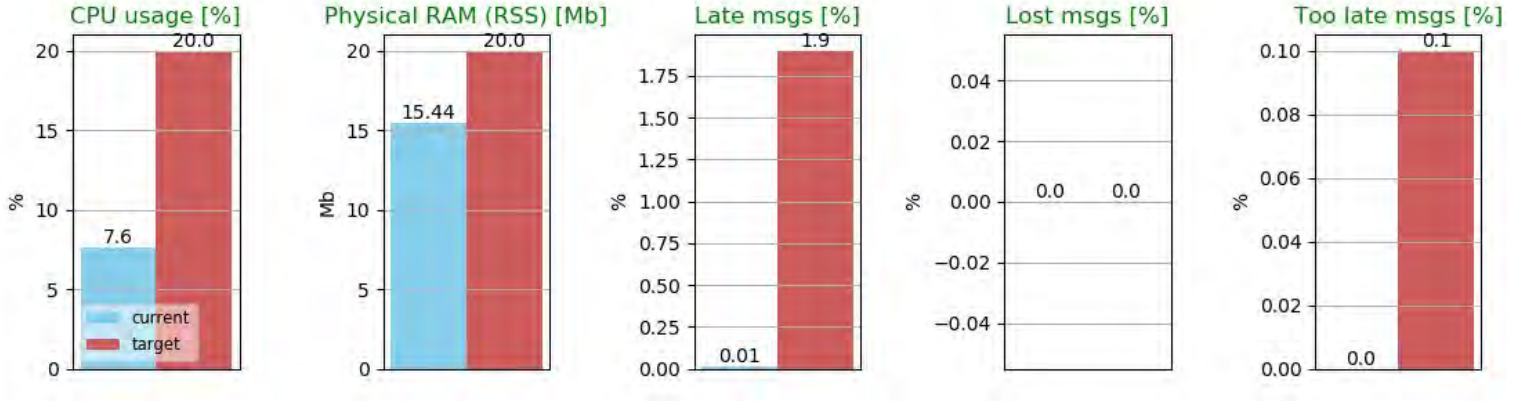
5G support



- Unique network flow: ensure Fast DDS QoS for different channels for low latency

ROS 2 and Fast DDS powering Roomba: Performance optimizations

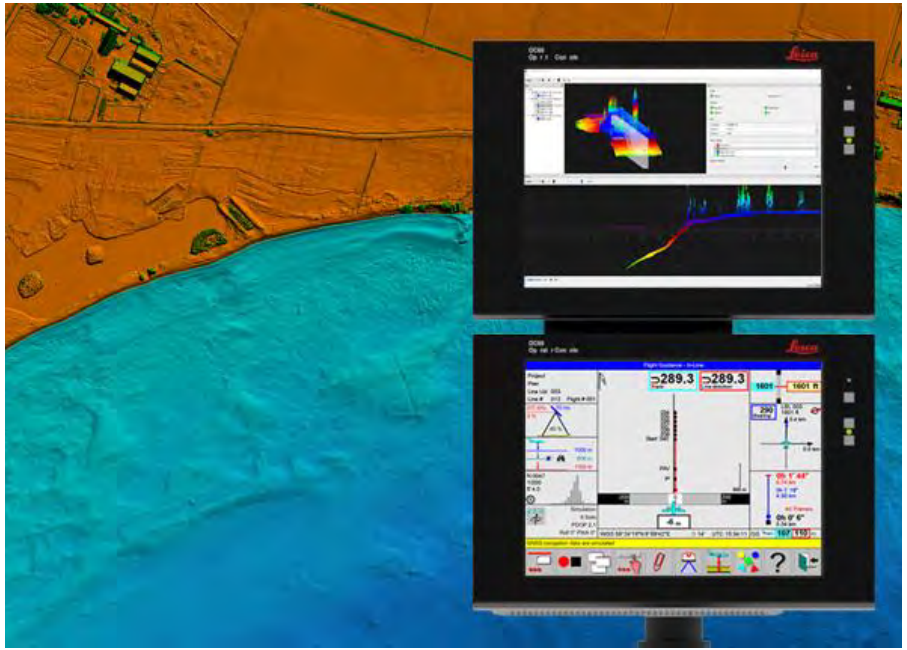
- Fast DDS: faster than ever
- Less memory usage
- Lower latency
- Intra-process mechanism



Hololens with Fast DDS

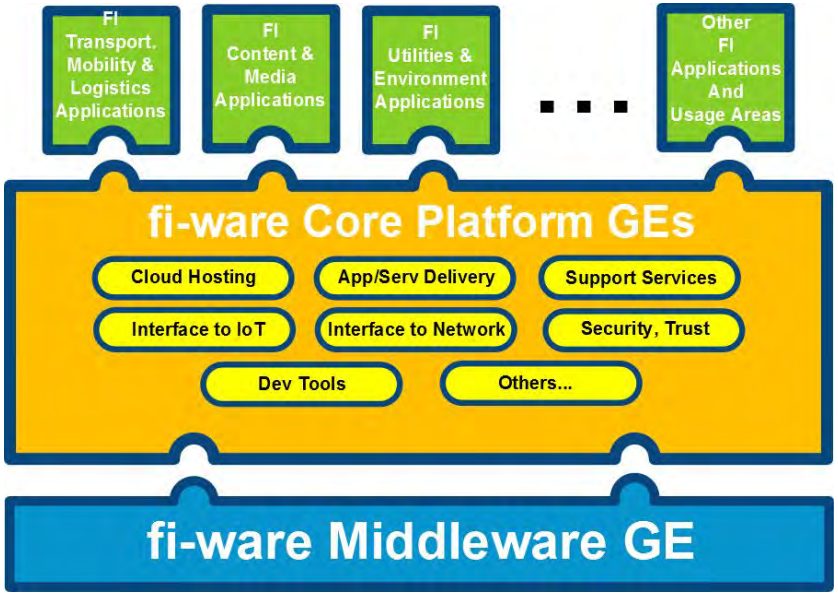
- Holographic Robotic Interfaces project, developing a Mixed Reality Toolkit for ROS 2
- Fast DDS is the chosen DDS middleware by Microsoft inside ROS 2

HEXAGON Geosystems



- Fast DDS middleware assures the reliability of the real-time data transport of an underwater surveillance system on Airbus airplane
- Fast DDS' persistence service enhanced to support data samples larger than 65 kB within this project's scope.

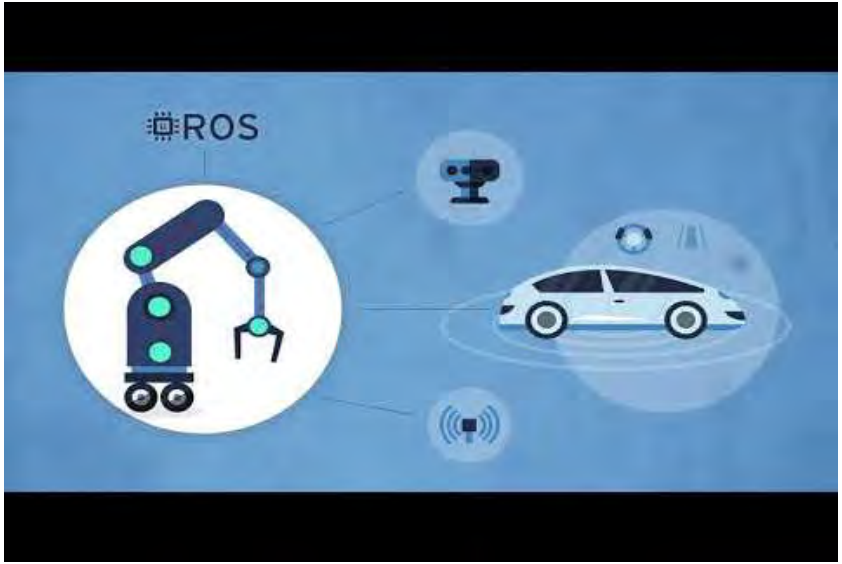
EU Open Source Components



- FIWARE is a EU initiative
- eProsima was selected to develop **Future Internet Middleware** in the FIWARE programme
- **DDS** is the core technology
- **eProsima Fast DDS and Micro XRCE-DDS are FIWARE components**

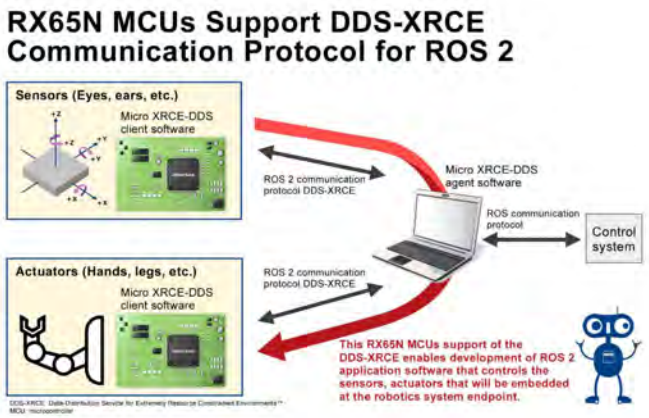
Embedded

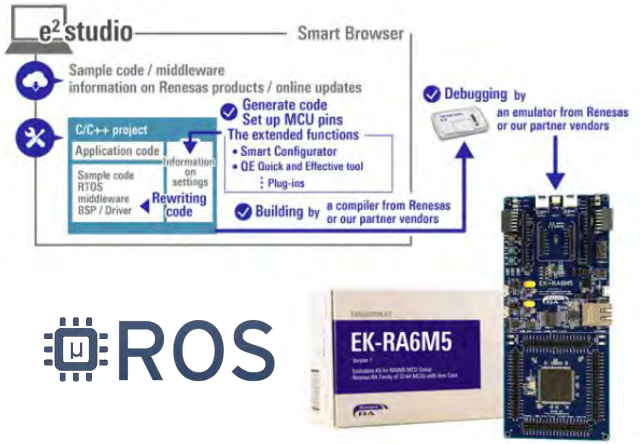
Micro-ROS: ROS 2 for MCUs



- https://micro-ros.github.io/
- OS: NuttX, FreeRTOS, Zephyr, Arduino...
- Users: Open Robotics, Amazon, Dronecode, FIWARE, Renesas, Robotis...
- eProsima Micro XRCE-DDS as default middleware

DDS for microcontrollers





- Communication between microcontrollers and ROS 2
- Micro XRCE-DDS uses <2KB RAM
- RX65N support
- micro-ROS for RA6M5 & e2studio

Dronecode Auterion px4 autopilot

- Communication between MCUs and ROS 2: eProsima Micro XRCE-DDS & Micro-ROS
- Over 10.000 px4 users.

CAPRA ROBOTICS ROS 2/micro-ROS framework

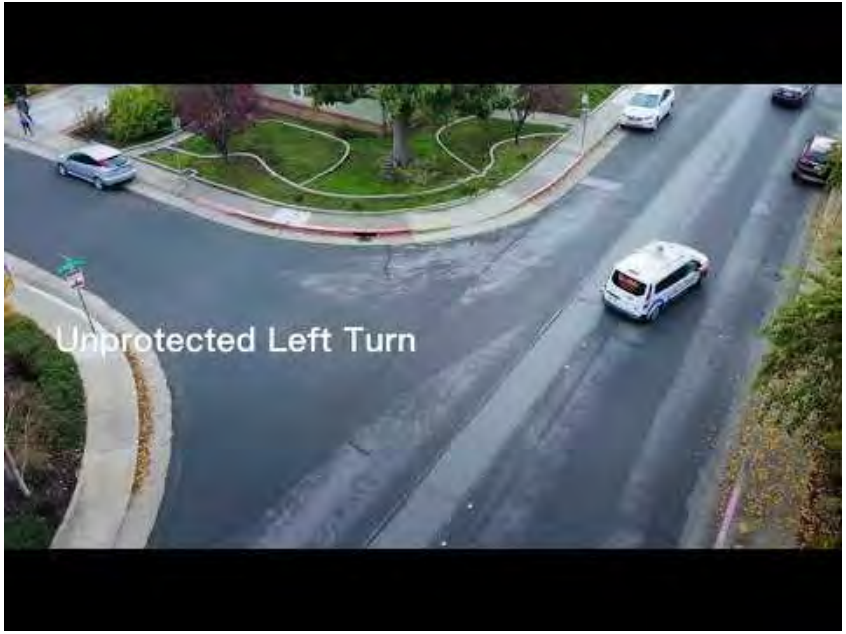
- Mobile robot platform based on ROS 2 with micro-ROS based MCUs
- Fast DDS as middleware for ROS 2
- Micro XRCE-DDS as middleware for micro-ROS

XEL Network

- Communication between XEL Network and ROS 2
- Standardized modular embedded open source hardware for robotos
- **eProsima Micro XRCE-DDS** uses **<2KB RAM**

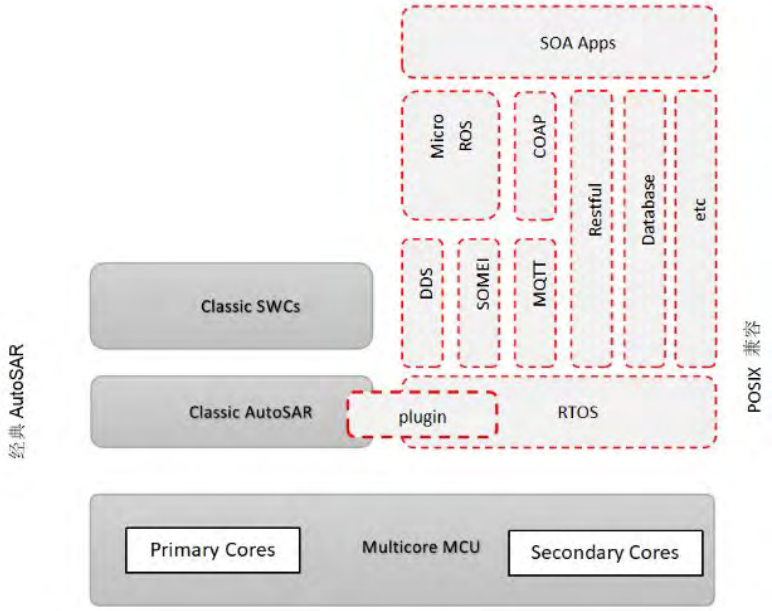
Automotive

Apollo.Auto



- **Open Source Autonomous Driving Solution**
- Fast DDS as safe, secure and reliable DDS implementation with low memory consumption

Landmark

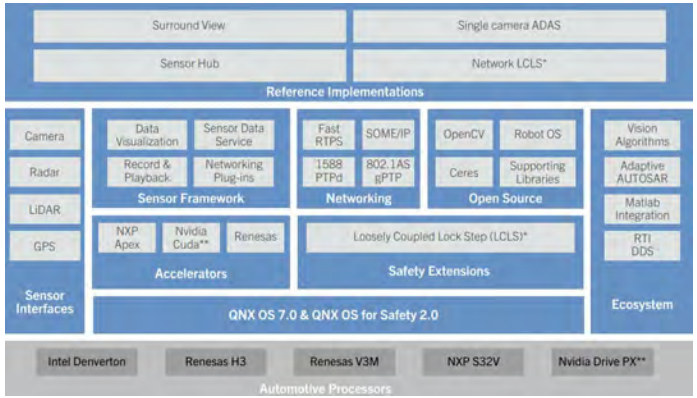


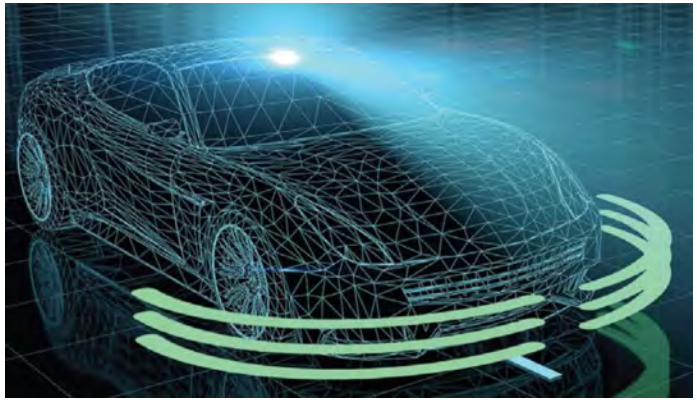
- Landmark is using micro-ROS in the Gemini-OS platform for Automotive.
- eProsima helped Landmark to create a new Ethernet-based middleware solution, porting micro-ROS to RT-Thread

Apex.AI Autonomous Driving

- Safe, secure, robust and certified version of ROS 2
- Fast DDS as one of two backbone middlewares
  - Real- time
  - DDS security
  - Static allocation

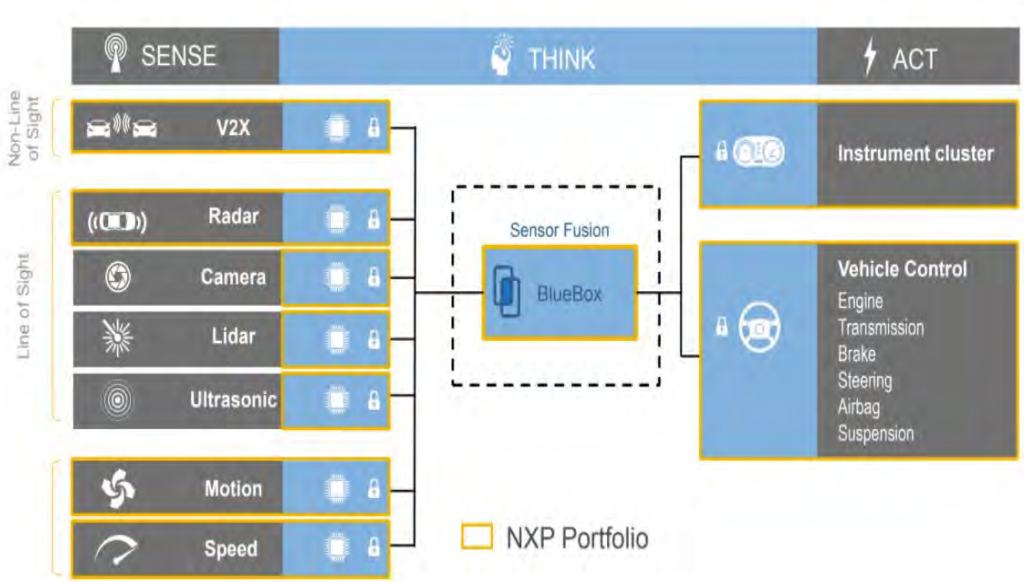
ADAS 2.0

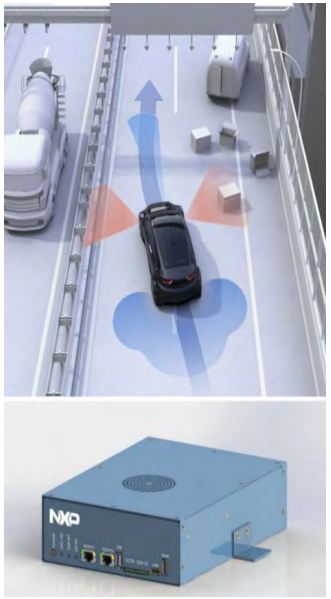




- Fast DDS chosen as middleware for the QNX platform for ADAS
- Built upon the QNX OS, it processes a flood of data from sensors such as cameras, LiDAR and radar in real time

BlueBox



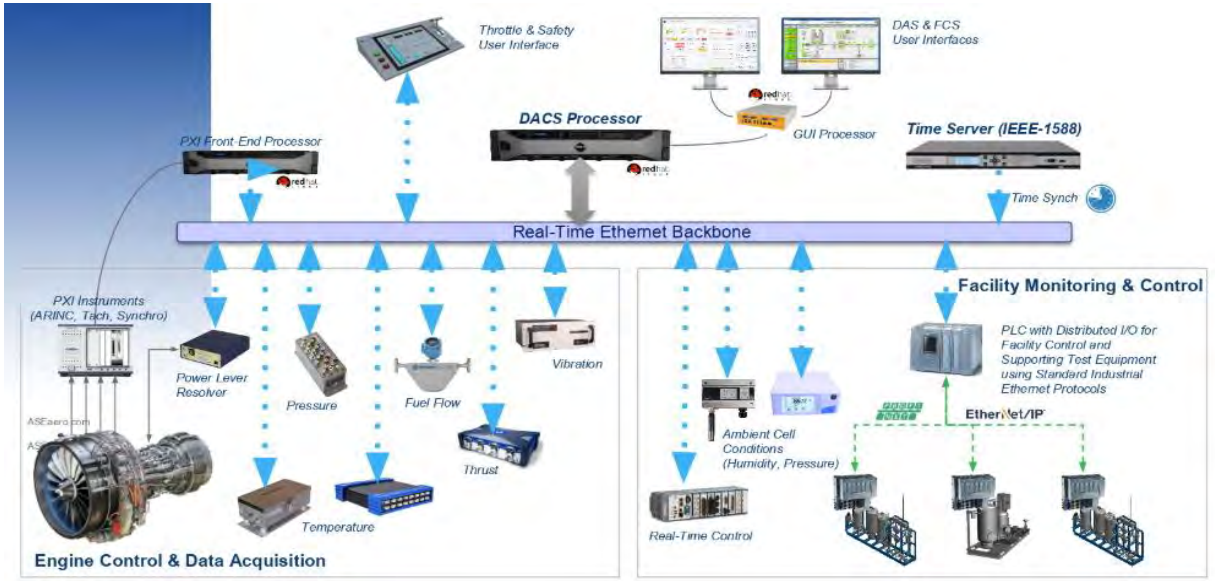


- Development platform for Automated Drive and Central Computing applications
- AI acceleration

Critical Applications

ASE Technology Holding Co., Ltd.

Rolls Royce Jet Engine Testing

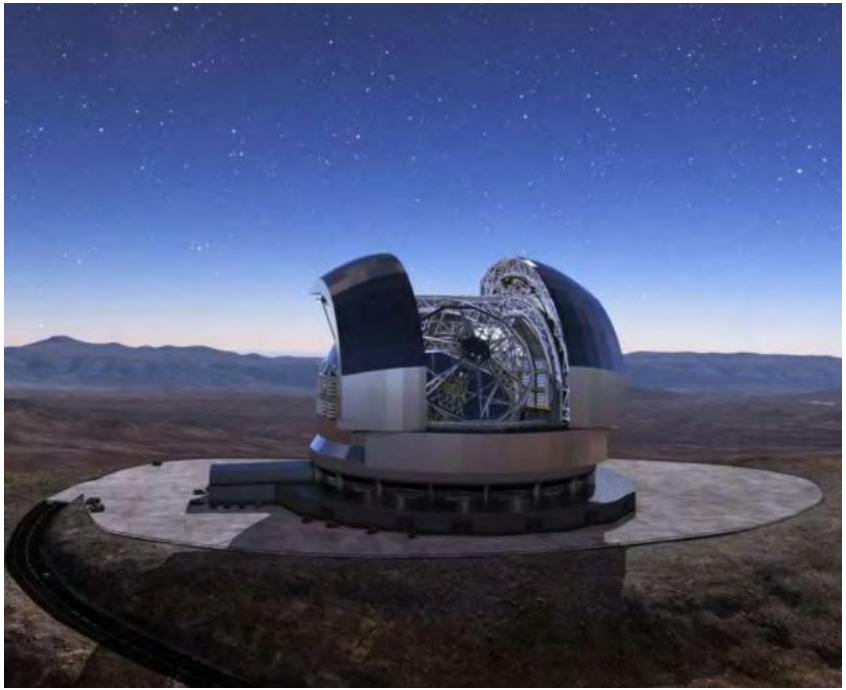


- Fast DDS as core communication layer
- Communication between 800 sensors
- 20.000 measurements per second

Feasibility Study

- Implementation of Fast DDS in their robotic calibration framework for medical instruments
- Data model/architecture proposition of the provided use case
- Developed a prototype of workflow orchestration

European Southern Observatory



- Largest optical telescope in the world (39m diameter)
- Complex system with
  - 15.000 actuators
  - 25.000 sensors
- Fast DDS offers safe, deterministic and fast data transport

Deutsche Bahn - Autonomous Trains

Complex heterogeneous network of redundant perception systems:

- LIDAR, RADAR, INFRARED Cameras
- Checking over 28.000 points
- eProsima Fast DDS, its Discovery Server & Fast DDS Monitor

Financed feature development of Fast DDS Statistics Backend

Train control

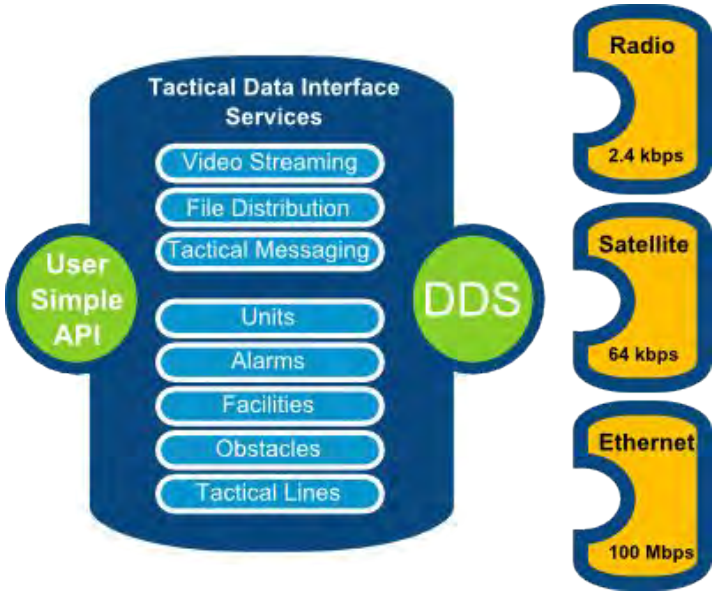
- MRX Technologies is a Siemens Business primarily active in the railway sector
- Communication framework
  - Monitoring of rolling stock, rail infrastructure & inspection systems

Defense & Aerospace

eProsima DDS Low Bandwidth plugins

- eProsima developed the plugins for the Spanish Army Tactical Radios (PR4G)
- Allow the use of DDS in very low bandwidth links, such as **Tactical Radios** and **Satellite**
  - Tested from 2400 bps
- **Basis of the Spanish Tactical Data Interface**

Spanish Army: Tactical Data Interface



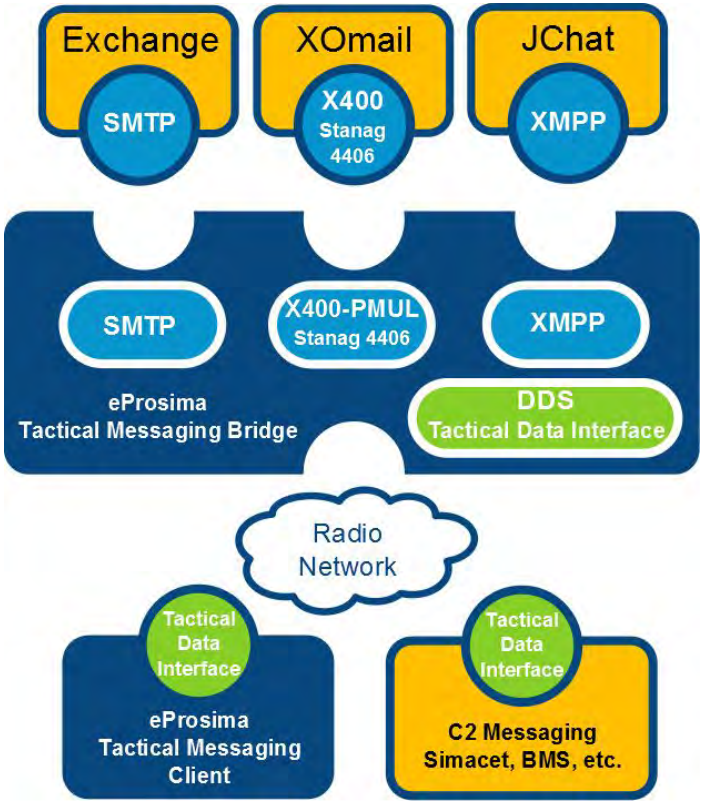
- C2 Interoperability Comm layer:
  - Tactical Radios
    - From 2400bps
  - Satellite
- Mandated for all the Spanish Army C2 systems.
  - Already implemented in the their main C2 systems

eProsima developed the army C2 comm layer using DDS optimized for low bandwidth environments. The project included the design of the Data Model and QoS requisites for the Army.

INDRA, Thales & GMV: C2 Systems

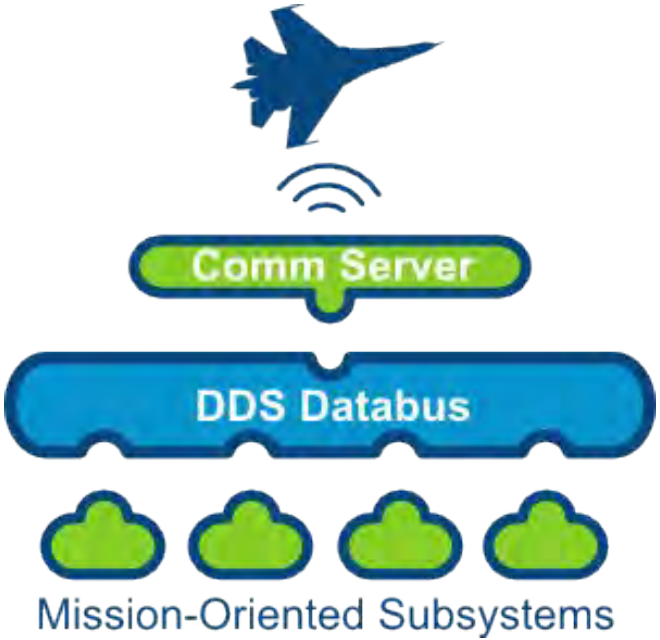
- eProsima provides a DDS based comm layer for **Spanish C2 Systems**.
- eProsima implemented the mandated Spanish Army Tactical Data Interface for Simacet (Main Spanish Army C2 System, Thales) and BMS (Tanks C2 System, INDRA & Thales), AMPS (Air Mission Support, INDRA) also used by Talos (Fire Support coordination,GMV)

Tactical Messaging Bridge



- Unified mail and chat: **Internet**, **NATO** and **Tactical** for the Spanish Army
- Enable **Complete Messaging on the tactical radio network**

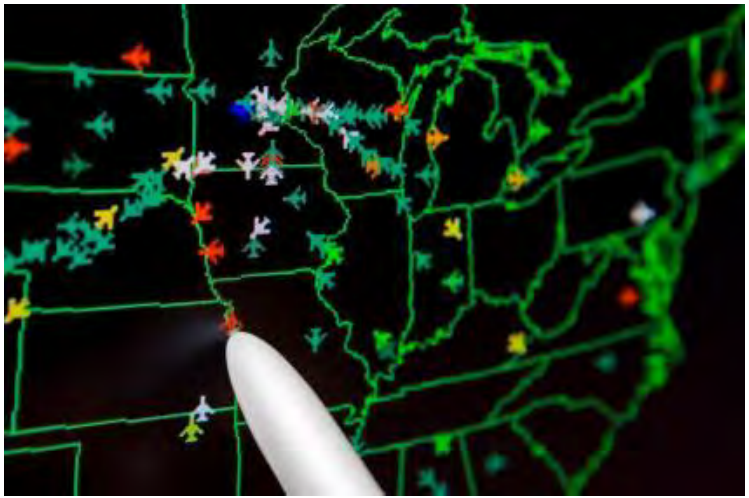
Airbus: nEURon and Atlante GS



- eProsima provides the comm layer for the ground station comm server.

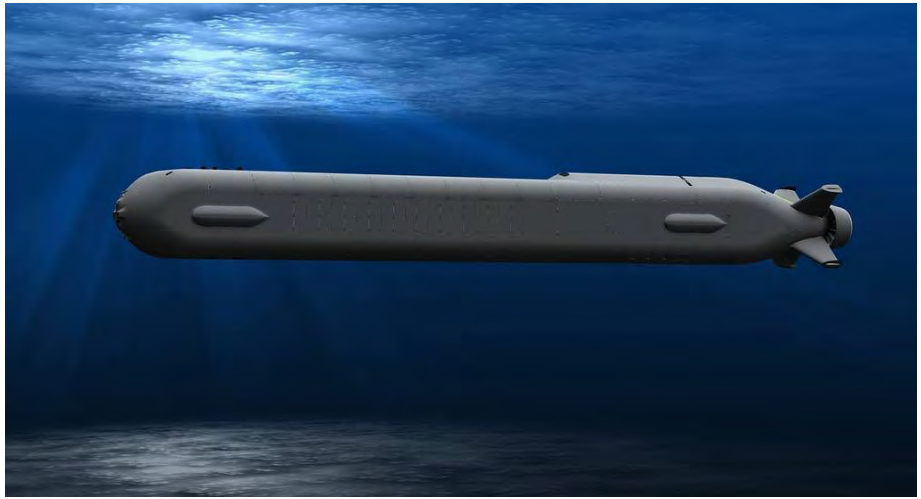
eProsima Non-Intrusive Recorder is used to record the communications for later analysis.

INDRA ATC: SESAR



- eProsima provides middleware research and prototyping for ATC Interoperability.
- Among the different middleware technologies studied, DDS and WS are the SESAR proposed technologies for ATC interoperability.

Fast DDS for Unmanned Underwater vehicles



- The US Navy uses Fast DDS for the communications of their Unmanned Underwater vehicles
- This project is involved in the effort of the Unmanned Maritime Autonomy Architecture (UMAA) project
- eProsima provided support to help scaling to a higher number of vehicles

Northrop Grumman & DARPA OFFSET swarms

- Swarms of autonomous air and ground robots
- planned > 250 robots
- Fast RTPS with real-time behaviour and low memory usage

eProsima

The Middleware Experts

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