MARTe Framework

Middleware for RT Control Development

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Framework important functions

- Provides development and execution environment for control systems
- Defines a way of designing/developing
  - Limits what you can do to what is needed!
  - Reduces mistakes
- Provides standard interfaces to outside world
- Facilitates test & commissioning
- Ensures and monitors real-time

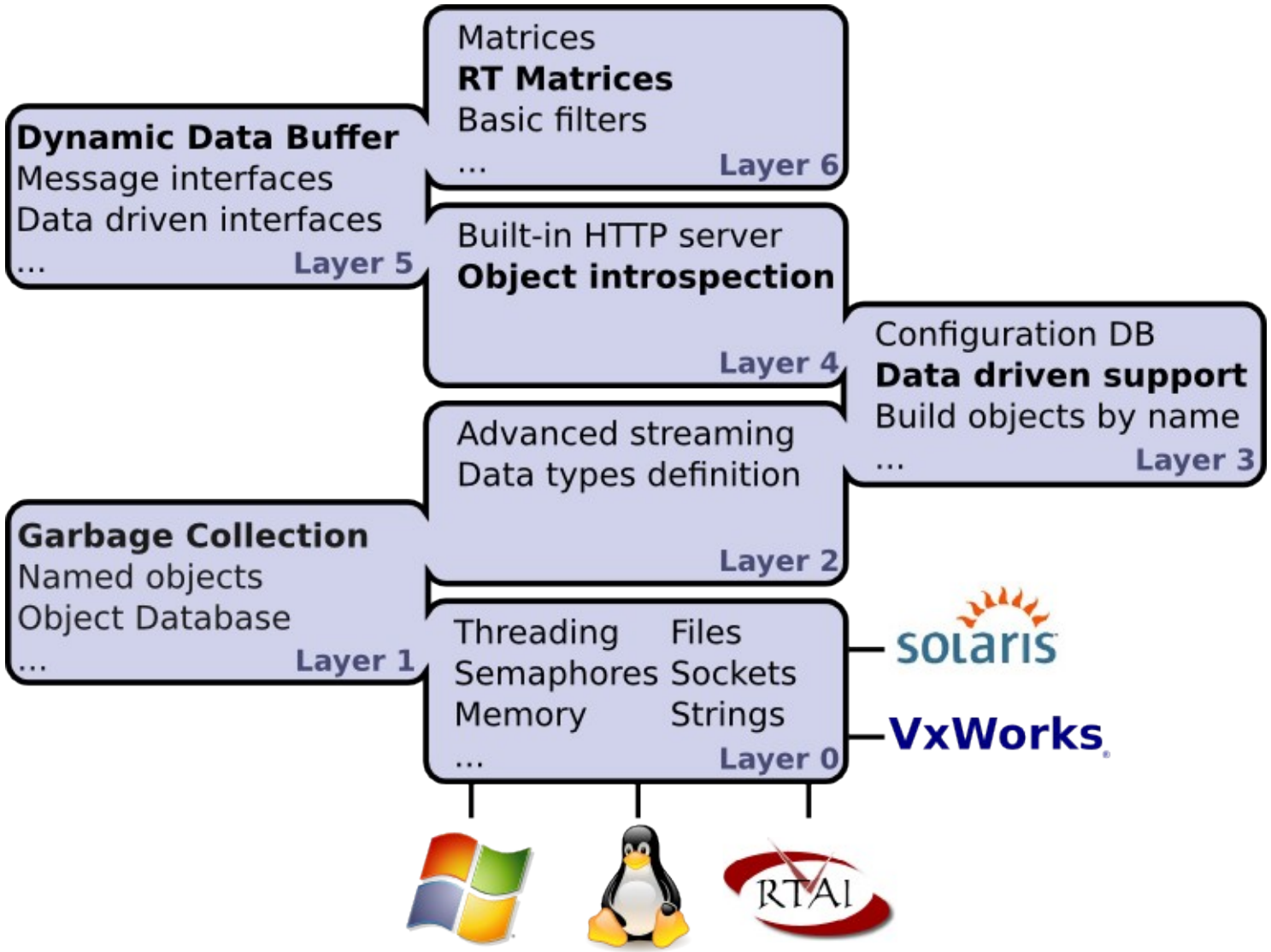
Main ideas

- Multi-platform C++ middleware
  - Simulink-like way of describing the problem
- Modular
  - Clear boundary between algorithms, hardware interaction and system configuration
  - Reusability and maintainability
  - Simulation
- Minimize constraints with the operational environments (portability)
- Data driven
- Provide live introspection tools
  - Without sacrificing RT

Multi-platform?

- Why?
  - Debug and develop in non RT targets
  - Eases the debugging process
  - Usually better developing environment
    - Debugger
    - IDE
- How?
  - Provide an abstraction layer/library which solves all the specificities of a given OS
    - Optimize code here
- Possible?
  - Yes, runs in Linux, Linux+RTAI, VxWorks, Solaris and MS Windows

BaseLib2 – support library



Data driven components

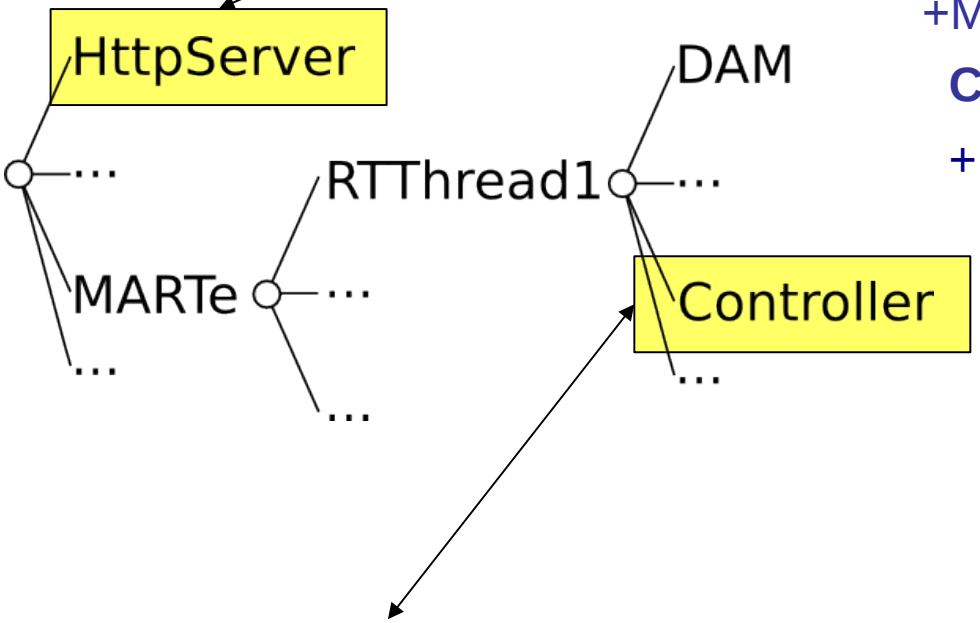
- Define common language
  - As simple as possible
    - But complete
    - Human understandable configuration
  - Should provide built-in validation
  - Should provide a clear way of expressing the problem
- Components are expected to be parsed only once per configuration request
  - Avoid unpleasant surprises

Object Configuration

- Structured syntax
- Similar to XML
- Classes are automatically created
- Configuration is validated by the created object
- Asserting and parsing functions available

```
+HttpServer = {
  Class = HttpService
  Port = 8084
}
...
+Control = {
  Class = ControlGAM
    Controller = {
      NoPlasmaVelocityGain = 0.0
      NoPlasmaCurrentGain = 40.0
      IPWaveform = {
        Times      = {0 120}
        Amplitudes = {0.5 0.5}
        Rounding   = 50
      }
...
```

Configuration DB

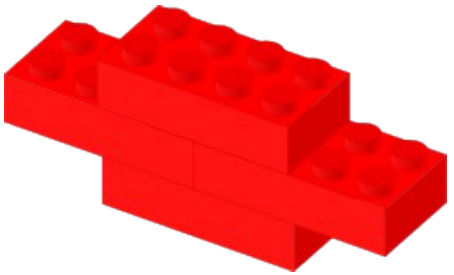


MARTe.RTThread1.Controller

```
+HttpServer = {
  Class = HttpService
  Port = 8084
}
+MARTe = {
  Class = MARTeContainer
  +RTThread1 = {
    Class = RealTimeThread
    +Controller = {
      NoPlasmaCurrentGain = 40.0
      IPWaveform = {
      Times       = {0 120}
      Amplitudes = {0.5 0.5}
    }
...
```

Modularity (GAMs)

- Define boundaries
  - Algorithms and hardware don't mix!
  - Modules do only what they advertise
  - No interdependence or *a priori* knowledge
- Generic by design
  - Same goals, same module
  - Reusability and maintainability



- Simulation
  - Replace actuators and plants with models
    - Keep all the other modules untouched

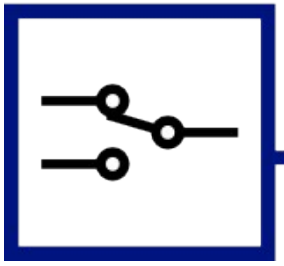
Common GAMs


Hardware I/O


Persistence

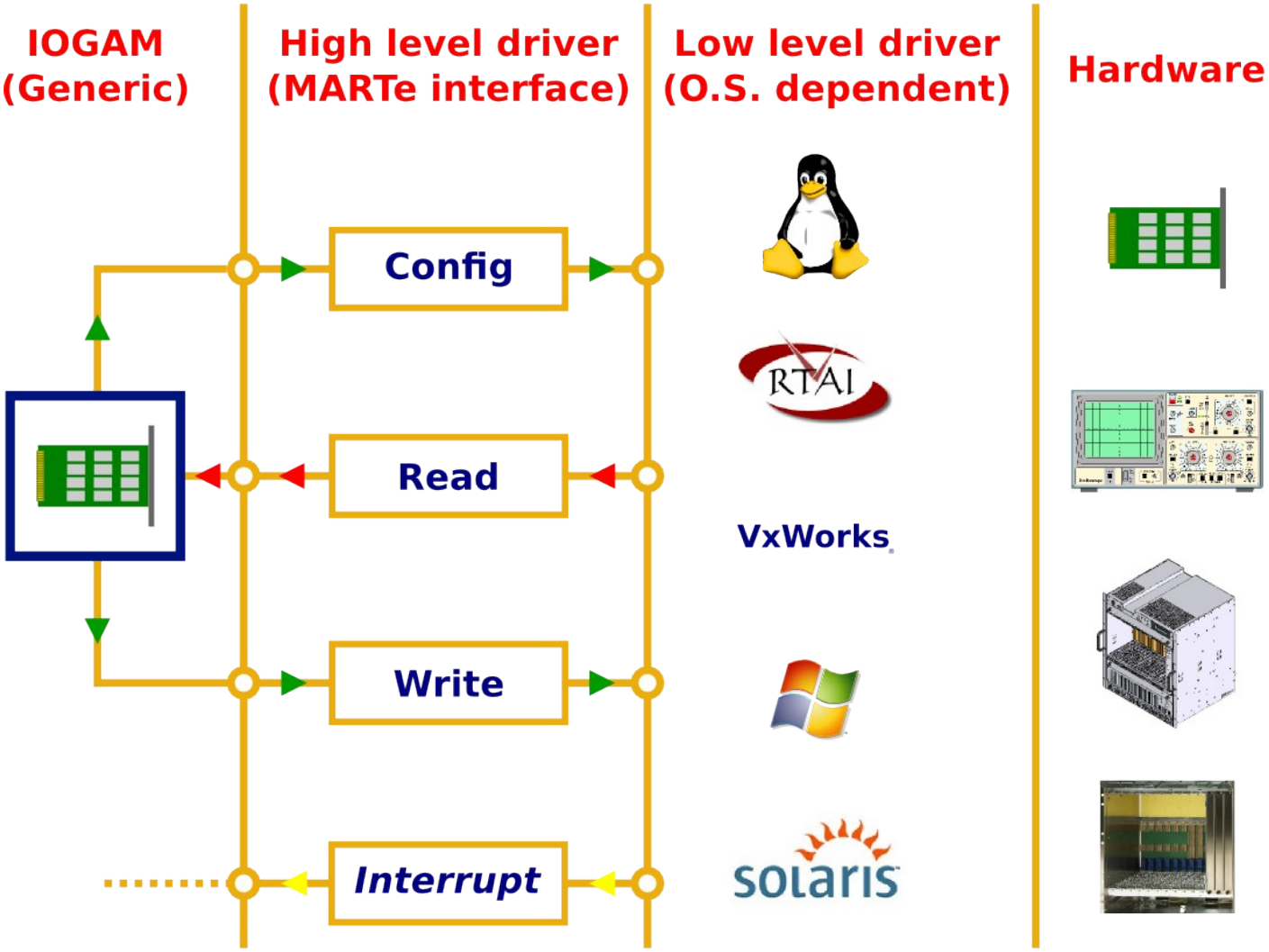

Algorithms


Debug


Decision taking

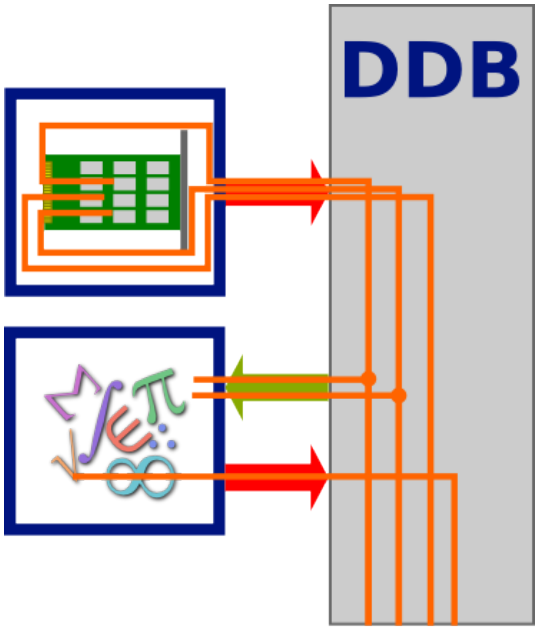

Information

IOGAM


IOGAM
(Generic)
High level driver
(MARTe interface)
Low level driver
(O.S. dependent)
Hardware
Config
Read
Write
Interrupt
RTAI
VxWorks
solaris

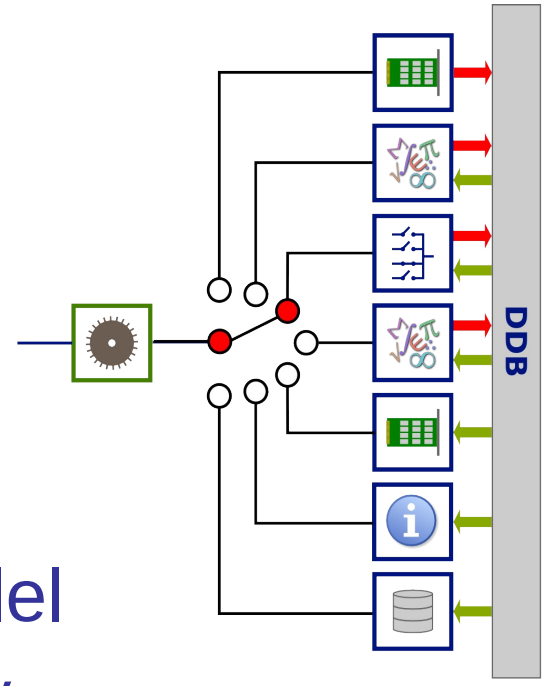
Dynamic Data Buffer

- GAMs shared data through a memory bus
- MARTe guarantees coherency between requested and produced signals
- Set of GAMs allow to stream data to different MARTe systems



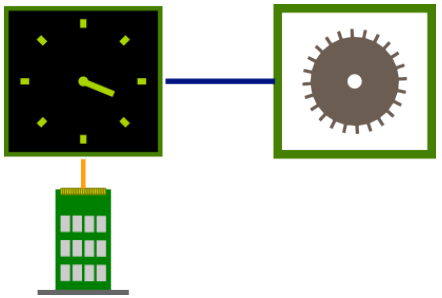
RT-Thread

- Sequentially executes GAMs
  - Works as micro-scheduler
  - Can be allocated to specific CPUs
- Keeps accurate information about execution times
- Requires an external time and triggering mechanism
- Multiple RTThreads can run in parallel
  - synchronously or asynchronously



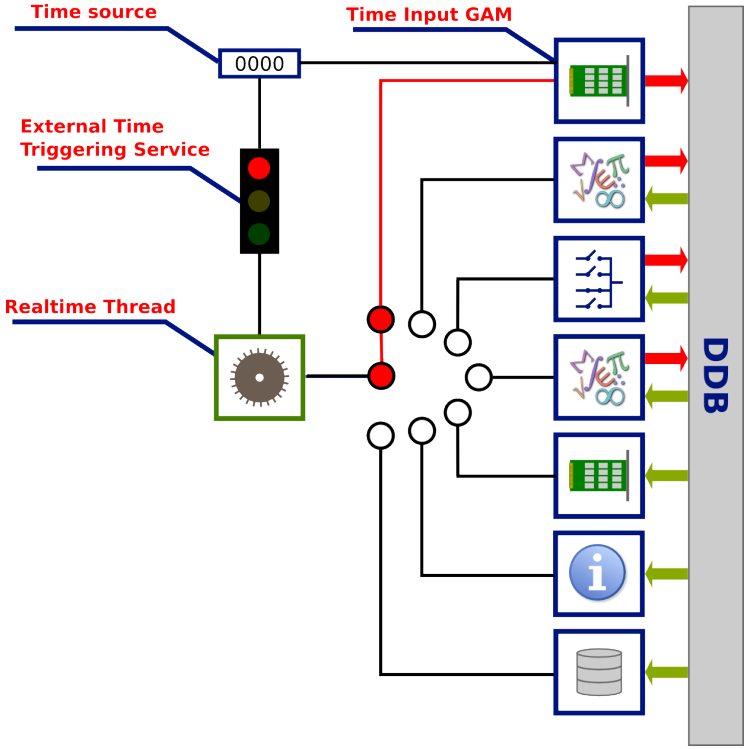
Synchronisation

- Asynchronous
  - Get latest available value
  - Verify acceptable latency (sample too late?)
- Synchronous
- Routinely used both schemes
- ADC, time input, ...
- Network
- From other control loop



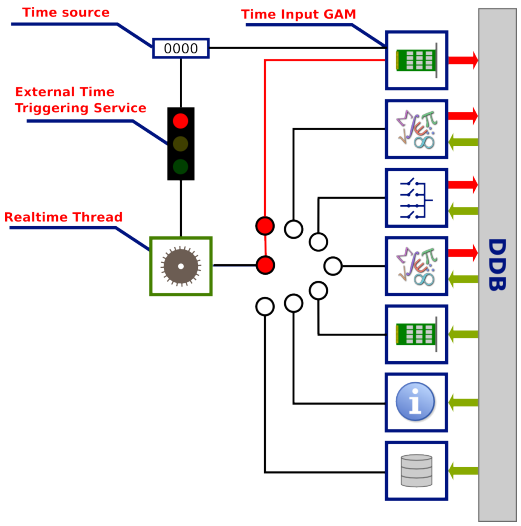
Synchronisation demo (1)

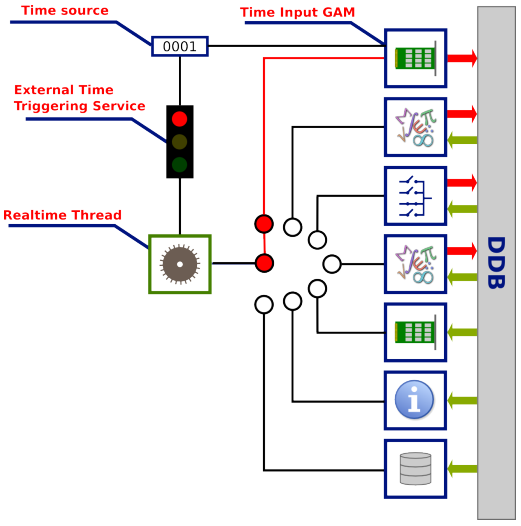
- ETTS waits for trigger from time source
- Current time multiple of cycle time?
- If so, unlock realtime thread and execute GAMs
- ETTS can be configured to exit after timeout
  - Trigger an error

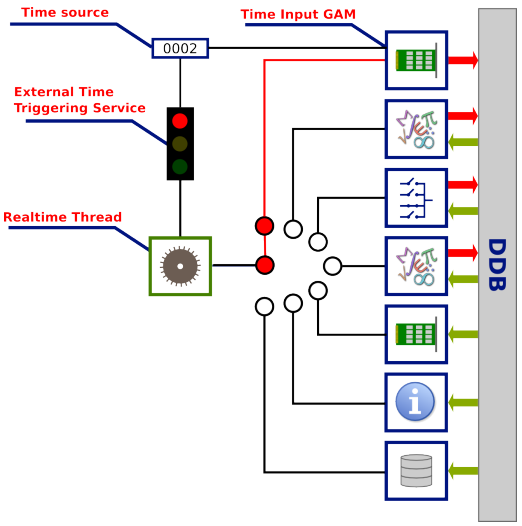


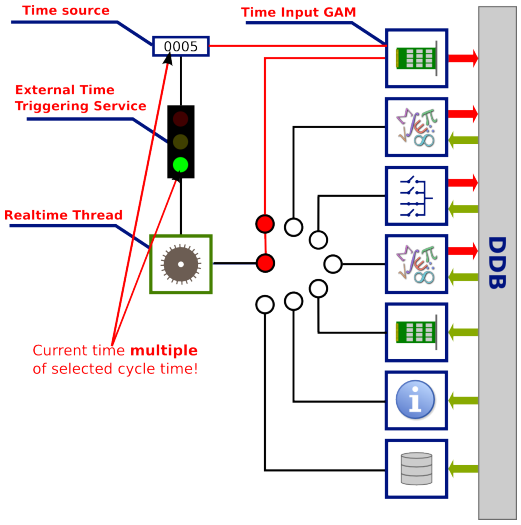
http://baco.ipfn.ist.utl.pt/efda/rtframenet/etts.gif

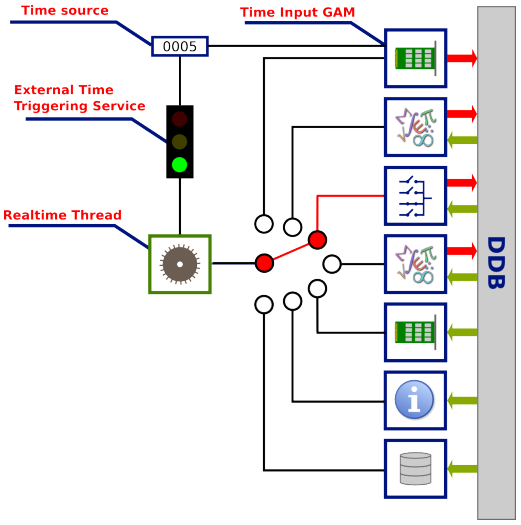
Synchronisation demo (2)

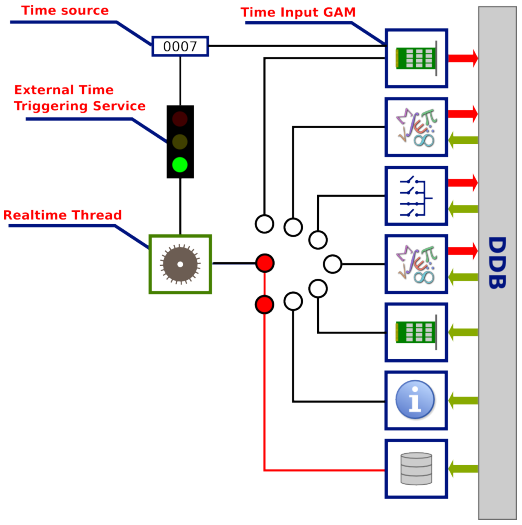












Interfacing with MARTe (1)

- Why?
  - Send configurations
  - Retrieve acquired data
  - Query status
- How?
  - Message server accepts orders from outside
- MARTe is interface agnostic
  - No predefined GUI
  - No predefined high level protocols

Interfacing with MARTe (2)

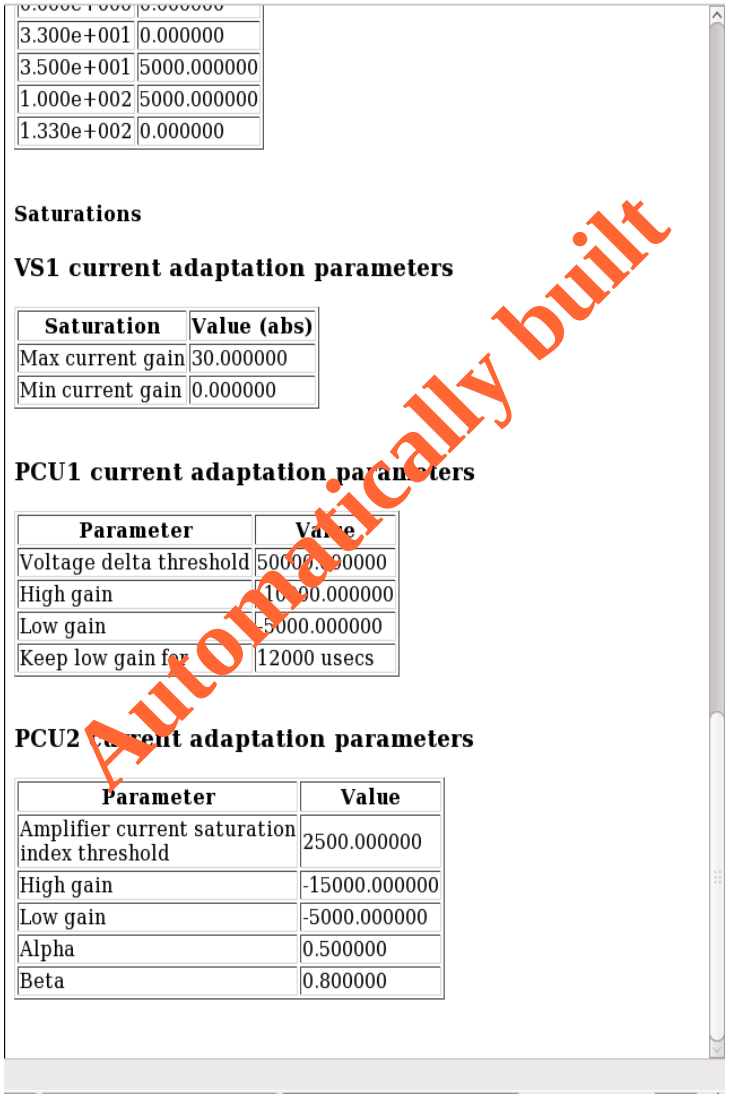
- Price?
  - Requires the development of a module which translates your language to MARTe's language
  - MARTe forwards the messages internally
  - A message server is provided
- HTTP interaction is widely used for retrieving information
  - Can also be used to change values
    - GAMs configuration
    - State machine
    - ...

MARTe Internal State Machine

- MARTe has its internal state machine
- It can be triggered by
  - External events
    - Has its own message interface
  - Internal events
    - e.g. errors while executing
- Capable of sending messages upon state changing

Introspection

- Probe the system
- Without sacrificing RT
- Crucial for an expedite debugging
- Does this still makes sense?
  - New data streaming concepts, leverage concept?
    - Stream your probes?



3.300e+001	0.000000
3.500e+001	5000.000000
1.000e+002	5000.000000
1.330e+002	0.000000

Saturations

VS1 current adaptation parameters

Saturation	Value (abs)
Max current gain	30.000000
Min current gain	0.000000

PCU1 current adaptation parameters

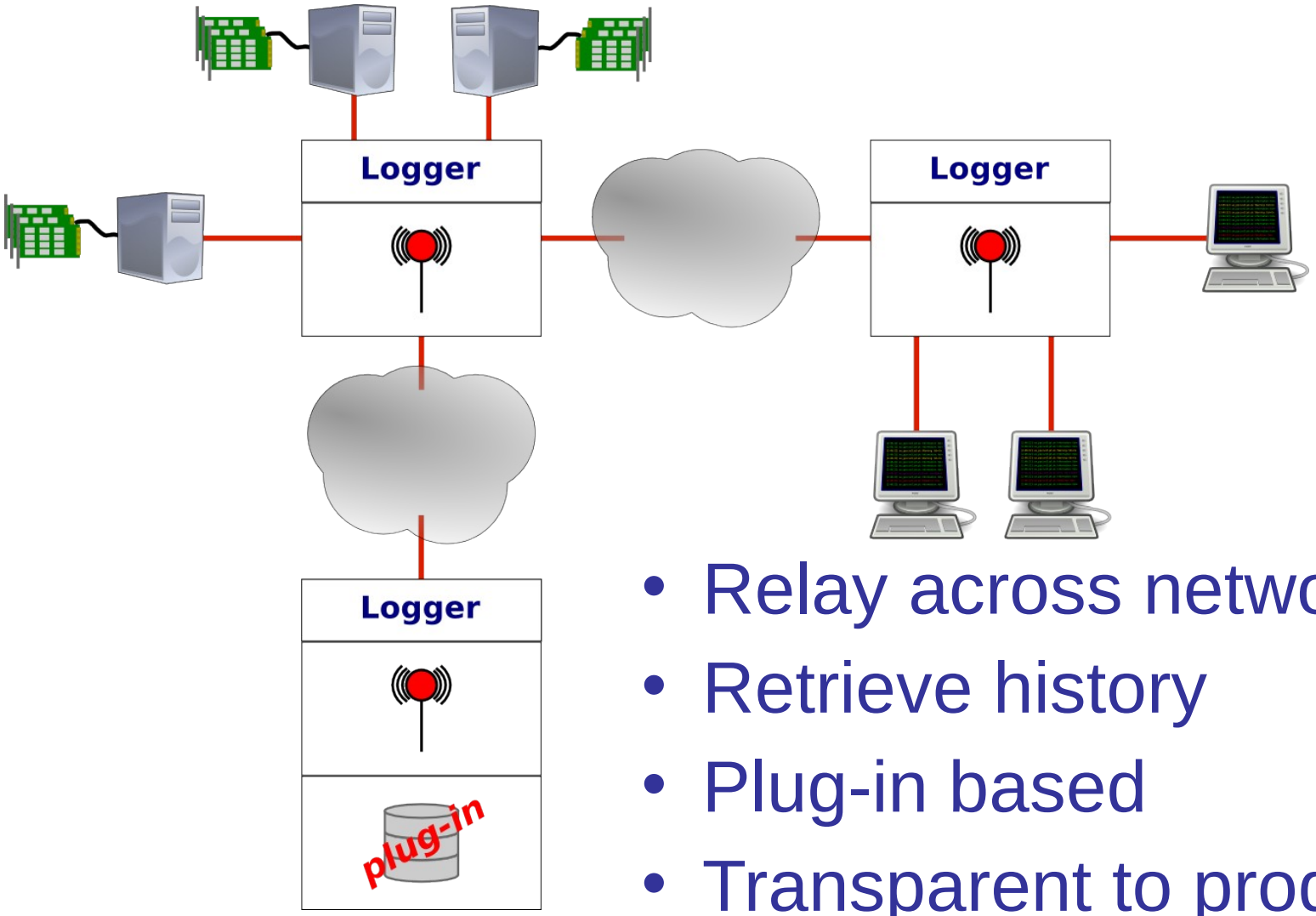
Parameter	Value
Voltage delta threshold	50000.000000
High gain	10000.000000
Low gain	5000.000000
Keep low gain for	12000 usecs

PCU2 current adaptation parameters

Parameter	Value
Amplifier current saturation index threshold	2500.000000
High gain	-15000.000000
Low gain	-5000.000000
Alpha	0.500000
Beta	0.800000

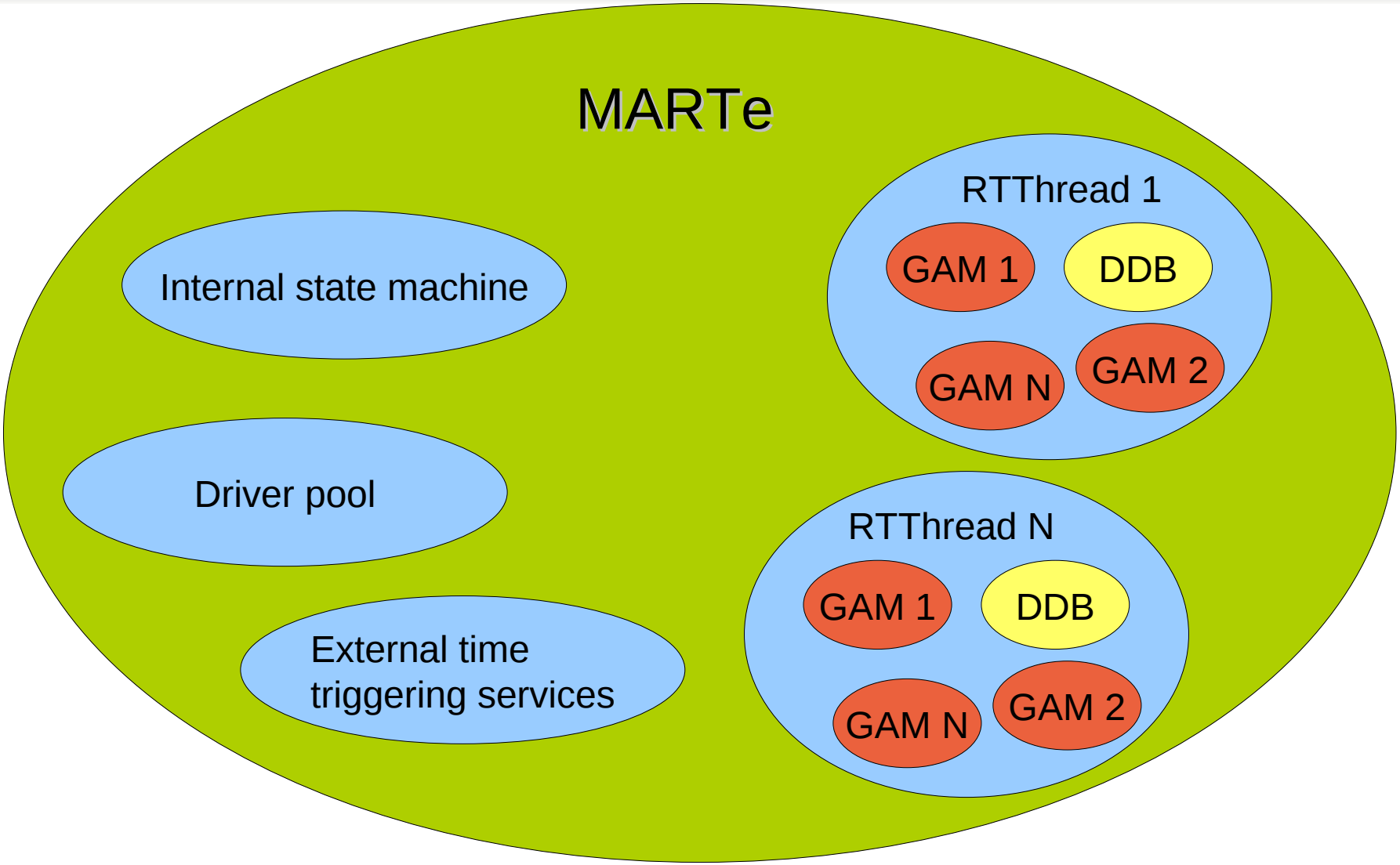
Automatically built

MARTe - logger

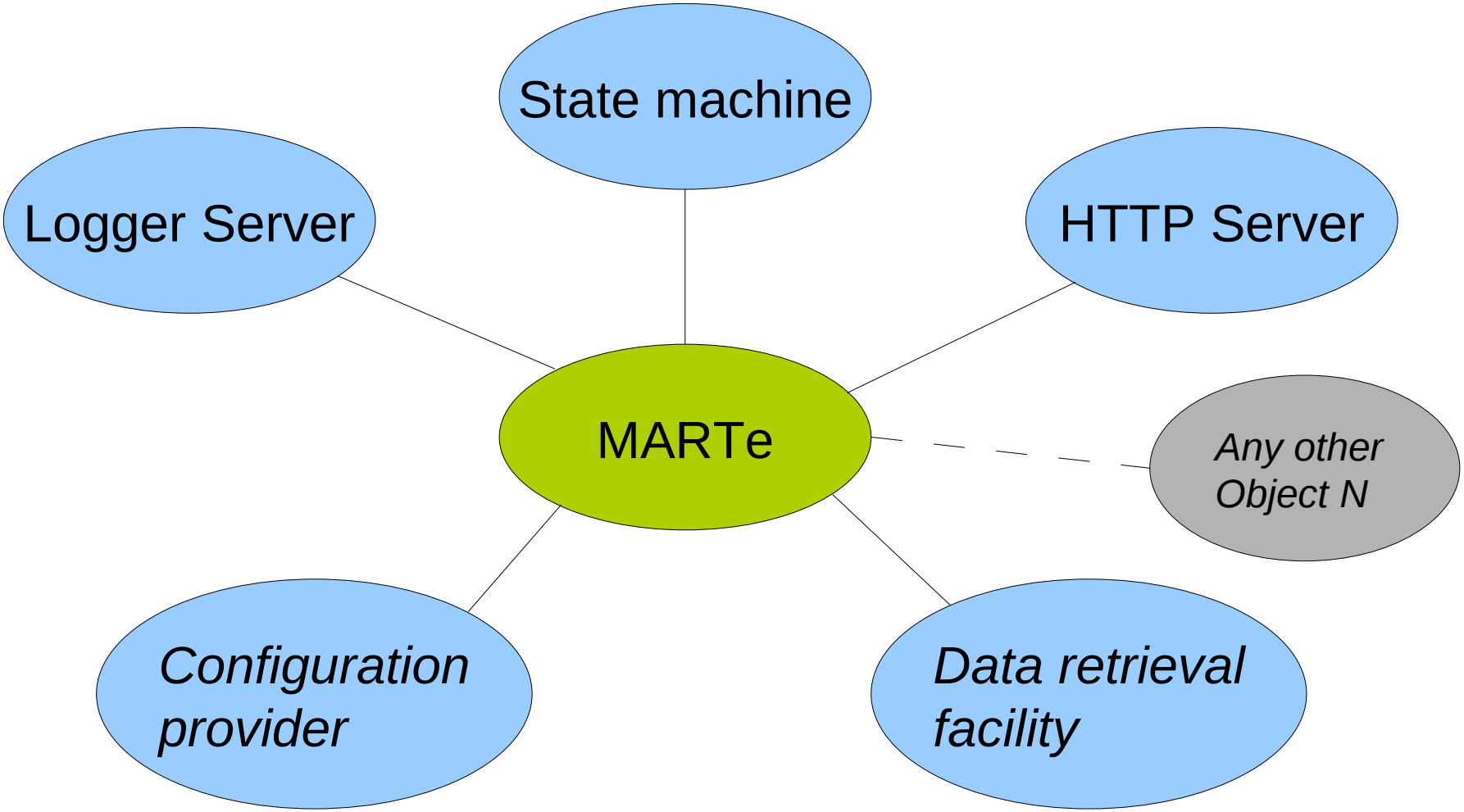


- Relay across networks
- Retrieve history
- Plug-in based
- Transparent to producers

MARTe World


MARTe
Internal state machine
Driver pool
External time
triggering services
RTThread 1
GAM 1
DDB
GAM N
GAM 2
RTThread N
GAM 1
DDB
GAM N
GAM 2

MARTe Universe

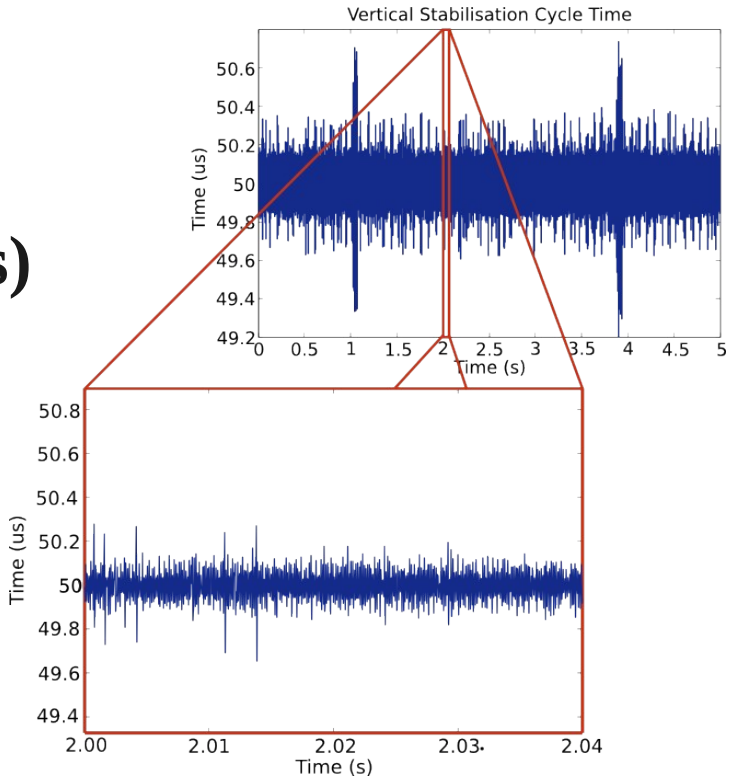


Does it work?

It is possible!

- Modular
- Data driven
- Introspection
- Reliable
- Performance
- Low jitter

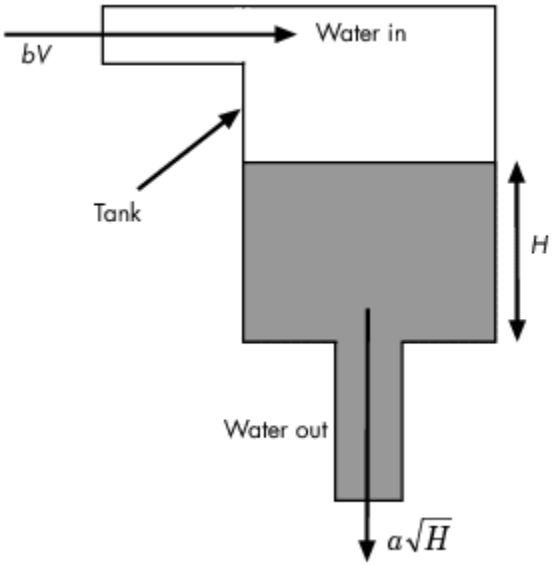
VS Achieved:
50 ± 0.10 µs
(max jitter of 0.80 µs)



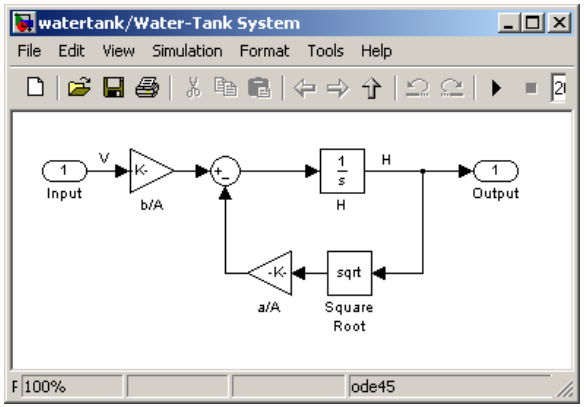
Working systems

JET VS	Linux-RTAI	50 µs
JET EFCC	VxWorks	200 µs
COMPASS SC	Linux*	500 µs
COMPASS VS	Linux*	50 µs
ISTTOK Tomography	Linux-RTAI	100 µs

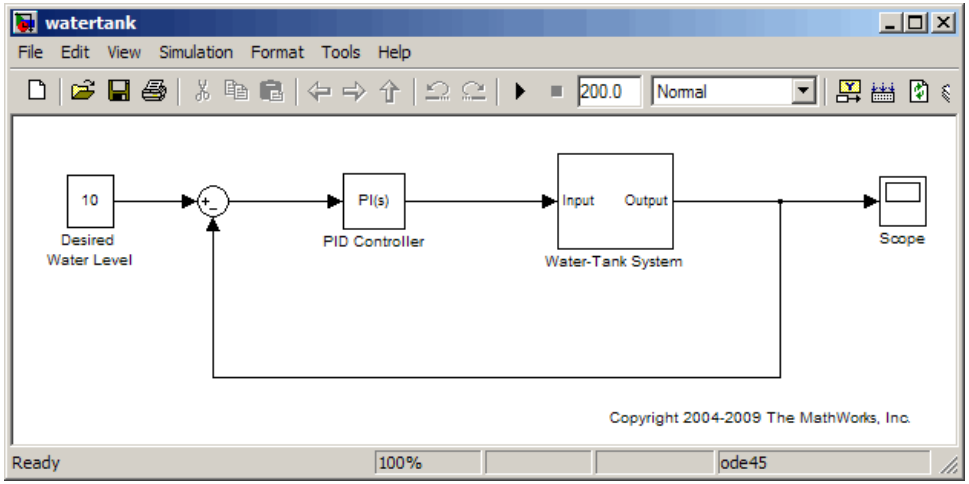
The water tank



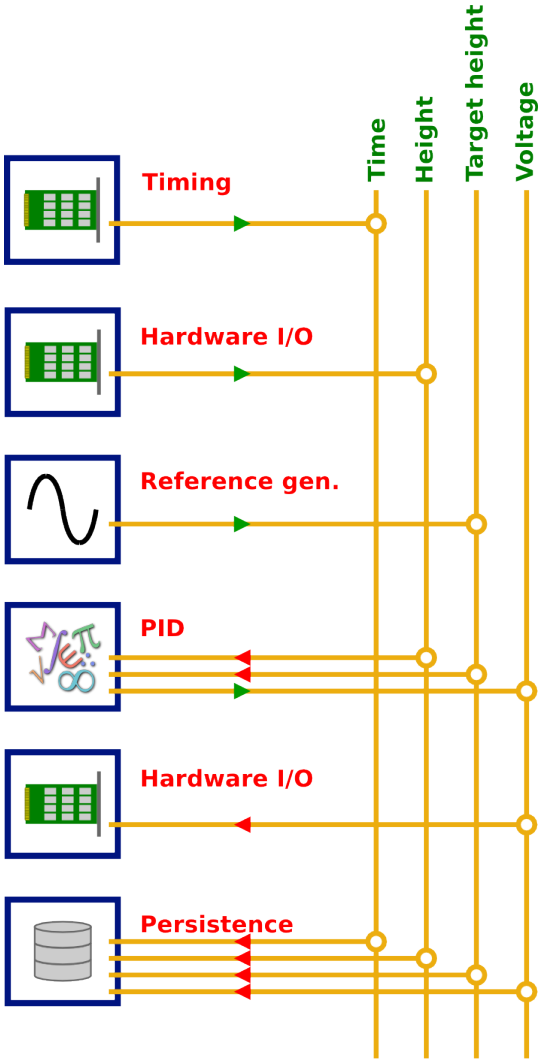
$$\frac{d}{dt}Vol = A\frac{dH}{dt} = bV - a\sqrt{H}$$

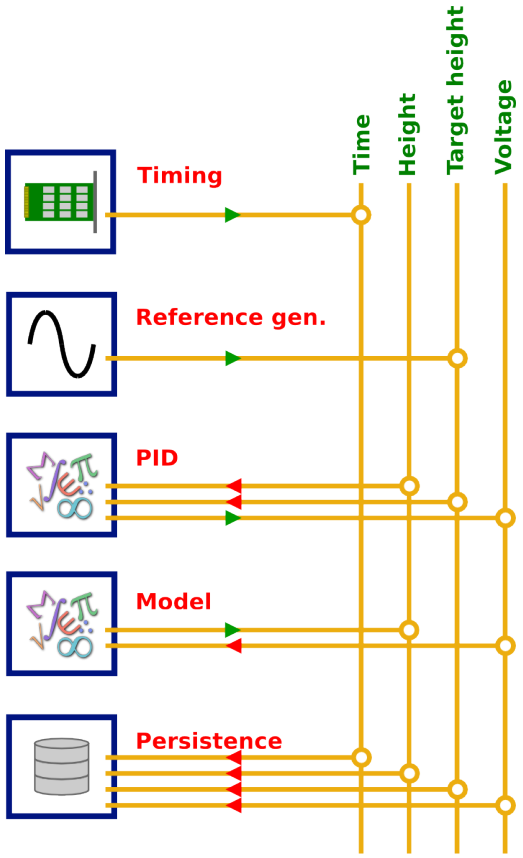


- Vol – volume of water in tank
- A – cross-sectional area of water in tank
- b – constant related to flow rate into the tank
- a – constant related to flow rate out of the tank
- H – height of water



What GAMs for the water tank?





GAMs for the water tank

- Apart from the water tank model all GAMs are generic and can be easily reused
- For this presentation we only add to write the code for this GAM
- More on development and deployment on this afternoon's talk

Future work

- MARTe is interface agnostic...
  - Would be good to have standard tools which help on the development and deployment of new systems
    - Simulink, Ptolemy
    - EPICS
- MARTe has its own language
  - Would be good to have a meta-language with builtin validation features
    - XML
- More and better documentation
  - We have quite a lot (thanks to Antonio) focused on the core system logic and the library classes (> 280pp)
  - Practically none targeted at the end user
    - Deployment and installation manual, GAM development manual
    - Configuration file writer manual, Real world examples
    - Tutorials

Backup slides