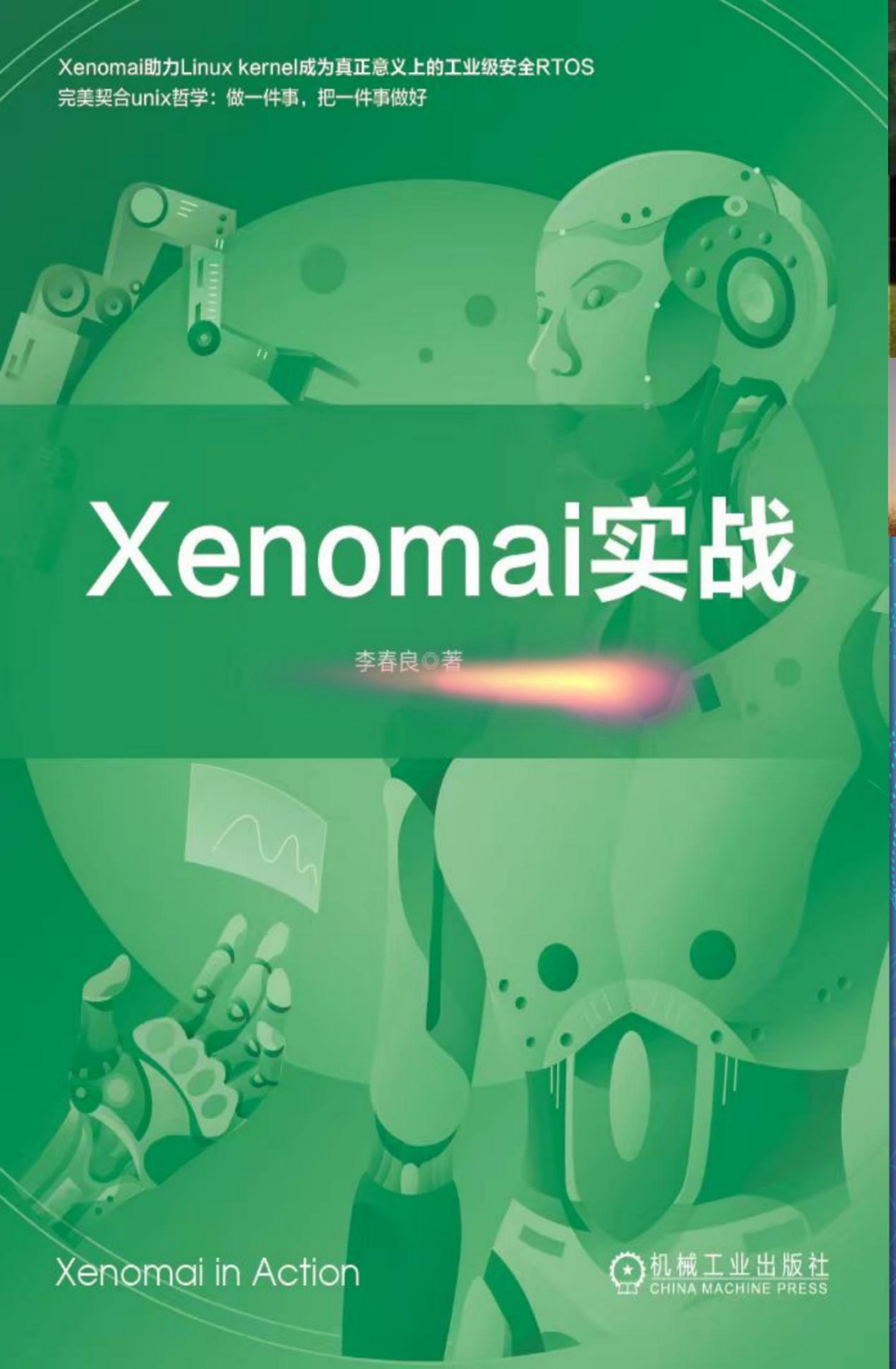


xenomai4 在多模态陆海空天一体化机器人的落地应用The landing application of xenomai4 in multimodal land, sea, air and space integrated robots 李春良

Xenomai
李春良

目 录 DIRECTORY

PART
1

Xenomai在机器人领域应用现状

天上飞的

Aitech and Embedded Flight Systems team up to integrate
NASA's cFS into a space SBC

Xenomai 4
Real-time Linux

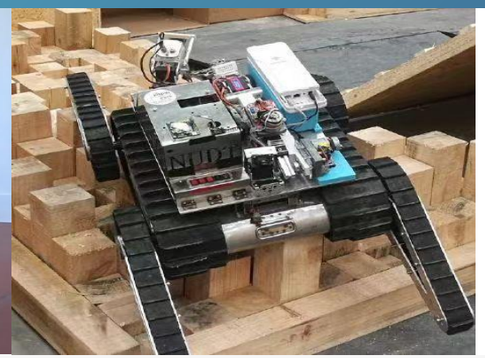
NASA running Linux 4.14 with Xenomai 3.0.6

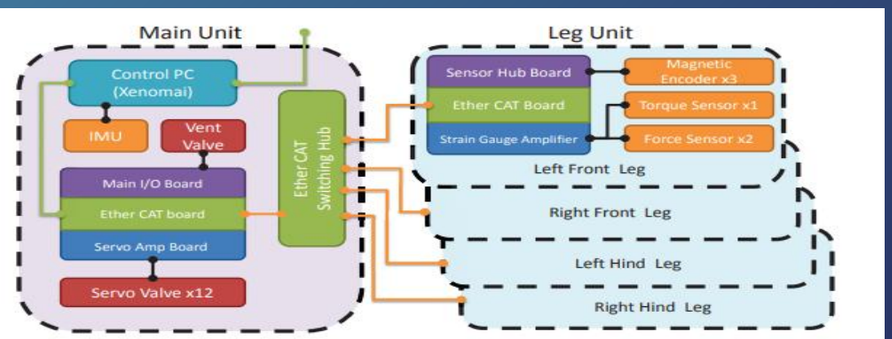
NXP MPC8548E PowerQuicc processor

Aitech's SPo-S space processor

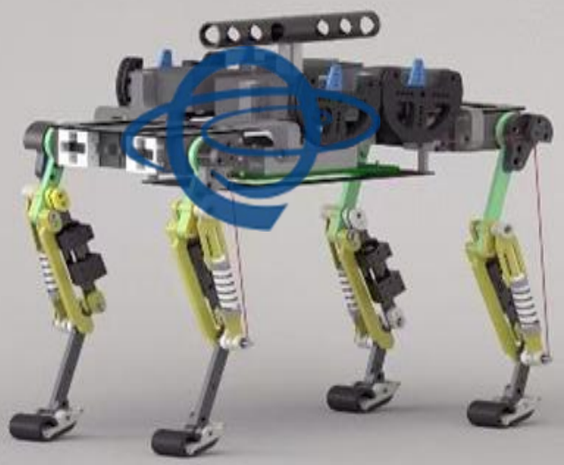
实时响应和确定性
使用 NXP MPC8548E PowerQUICC 处理器提供的经过验证的低功耗和高性能，以及 Xenomai 实时 Linux 的先进 Linux 环境，Aitech 的 SP0-S 空间处理器已向运行 Linux 4.14 和 Xenomai 3.0.6 的 NASA 展示，以提供硬实时、硬截止保证。
Update xeno4

地上跑的

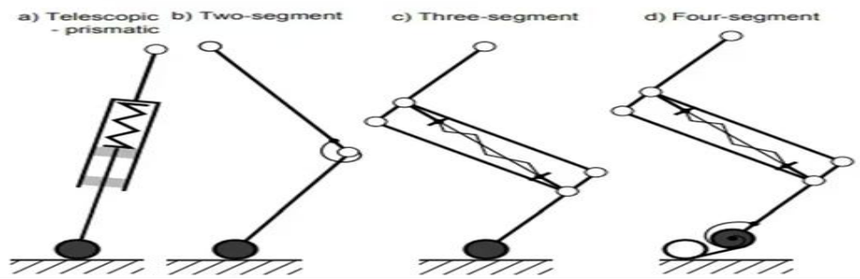




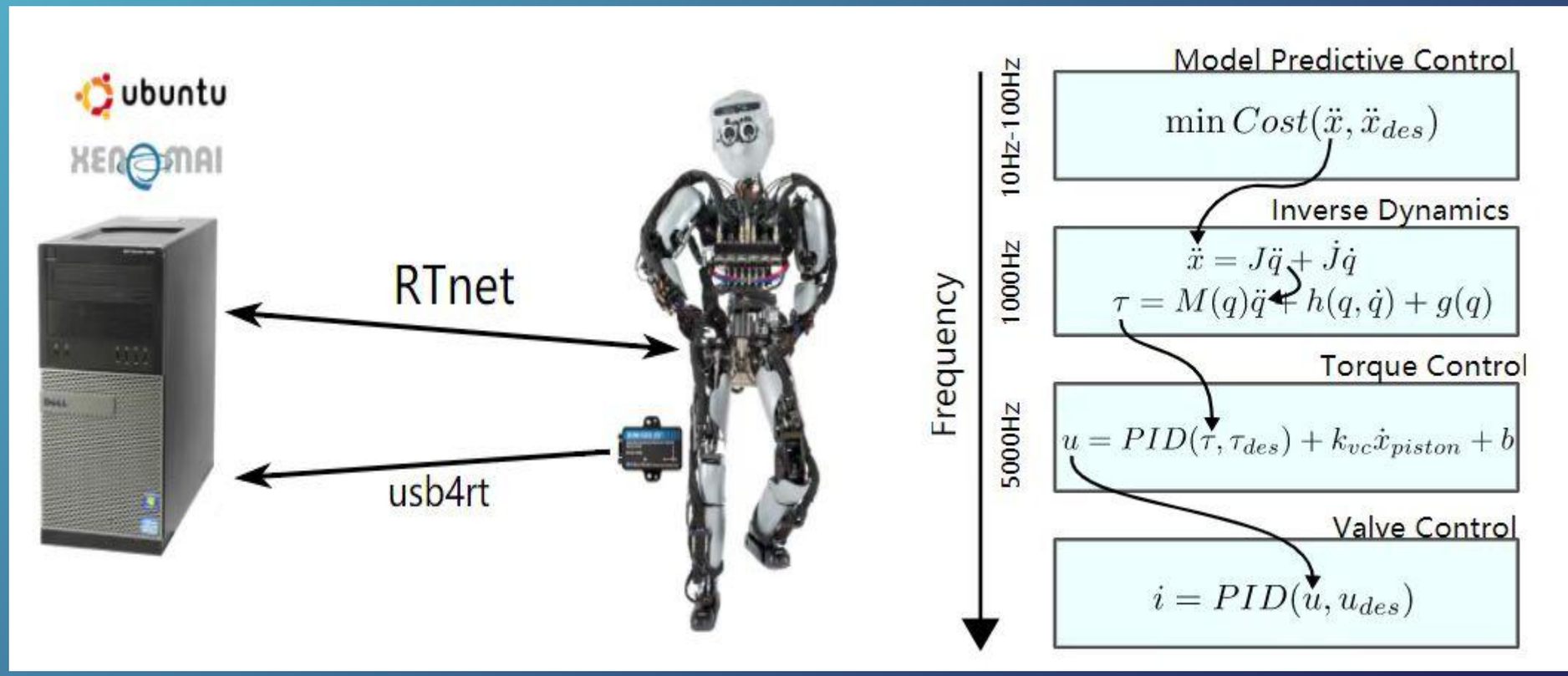

```
[15247.217455] uhci_hcd 0000:05:00.0: remove, state 1
[15247.217462] usb usb1: USB disconnect, device number 1
[15247.217609] uhci_hcd 0000:05:00.0: USB bus 1 deregistered
[15247.217647] ehci-pci 0000:00:1a.0: remove, state 1
[15247.217652] usb usb3: USB disconnect, device number 1
[15247.217653] usb 3-1: USB disconnect, device number 2
[15247.224546] ehci-pci 0000:00:1a.0: USB bus 3 deregistered
[15274.708025] ********** Realtime USB-Core Module 0.0.5 **********
[15274.708028] RT-USBCORE: Max 16 Controller
.
.
.
[15274.708042] RT-USBCORE: Loading Completed (1152 Byte allocated)
[15275.706935] ********* Realtime Driver for Universal Host Controller 0.0.5 **********
[15275.706939] RT-UHC-Driver: Searching for Universal-Host-Controller
[15275.706943] USB Universal Host Controller found : Vendor = 0x1106, Device = 0x3038, IRQ = 16, IO
-Port = 0x00002020 (32 Bytes)
[15275.706944] RT-UHC-Driver: Request IO-Port @ 0x00002020 (32 Byte) for UHC[0] ... [OK]
[15275.706947] RT-UHC-Driver: Request RTDM IRQ 16 ... [OK]
.
.
.
[15276.185863] --- LIST USB-DEVICES -------------------------
[15276.185865]  No HCD VENDOR   PROD  CLS SCLS PROT ->CTRL CTRL-> ->BULK BULK->  ->INT  INT-> ->ISOC
ISOC-> STATE SPEED USED
[15276.185867] 001 000 0x199b 0x3065 0x02 0x00 0x00 0x0001 0x0001 0x0002 0x0008 0x0004 0x0000 0x0000
0x0000 00000 00002    X
[15276.185868] --- END USB-DEVICES -------------------------
[15276.185869] rt_cdc_acm[0]: device found, vendor=0x199b, product=0x3065
```



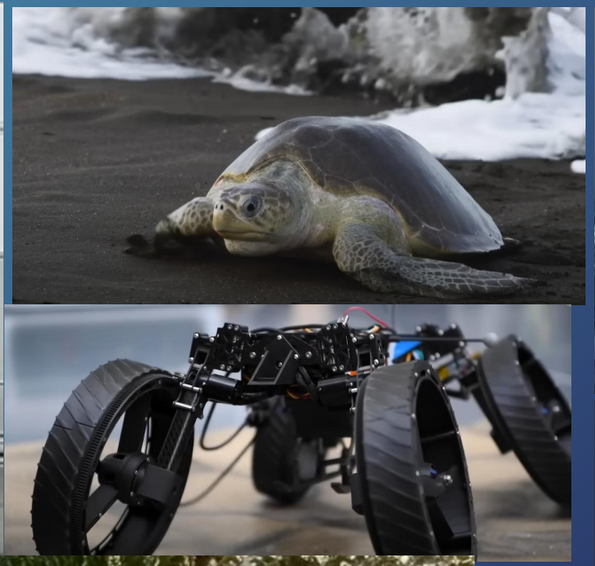
Characteristic	Value
M_{robot}	1100 g
$M_{actuators}$, sum	590 g
M_{l1}, M_{l2}, M_{l3}, M_{foot} (front)	11 g, 24 g, 4 g, 6 g
M_{l1}, M_{l2}, M_{l3}, M_{foot} (hind)	12 g, 24 g, 3 g, 6 g
l_{hip}, standing height	0.158 m
$d_{shoulder-shoulder}$	0.1 m
$d_{hip-shoulder}$	0.205 m
RC servo motor	Kondo KRS2350 ICS (8x)
Control board	RoBoard RB110
Operation system	Linux Xenomai
Communication	Wifi Card Via VT6655
Power supply, tethered	8 V to 14 V
Length foot l_{foot}	14 mm
Stall torque RC servo	2 Nm at 6 V
Speed max RC servo	0.16 s / 60deg at 6 V
$k_{diagonal}$	2300 N/m
$k_{second,front}$	4800 N/m
$k_{second,hind}$	2330 N/m
time step SLP, ASLP	2 ms, 0.2 ms (Webots model)
Coulomb friction ground-feed	1 (Webots model)
Spring damping	150 N/ms (Webots model)

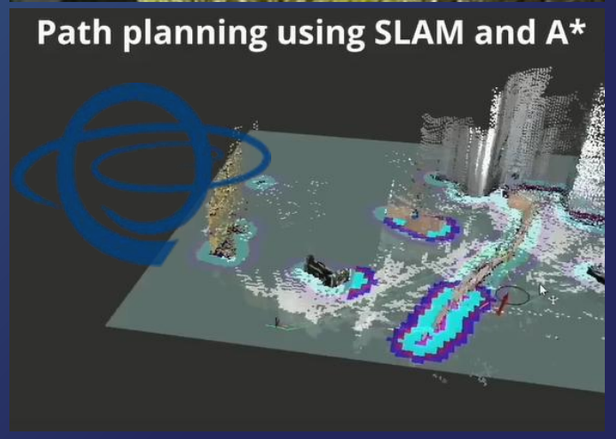


人形机器人应用


ubuntu
RTnet
usb4rt
Frequency
10Hz-100Hz
1000Hz
5000Hz
Model Predictive Control
$\min Cost(\ddot{x}, \ddot{x}_{des})$
Inverse Dynamics
$\ddot{x} = J\ddot{q} + \dot{J}\dot{q}$
$\tau = M(q)\ddot{q} + h(q, \dot{q}) + g(q)$
Torque Control
$u = PID(\tau, \tau_{des}) + k_{vc}\dot{x}_{piston} + b$
Valve Control
$i = PID(u, u_{des})$

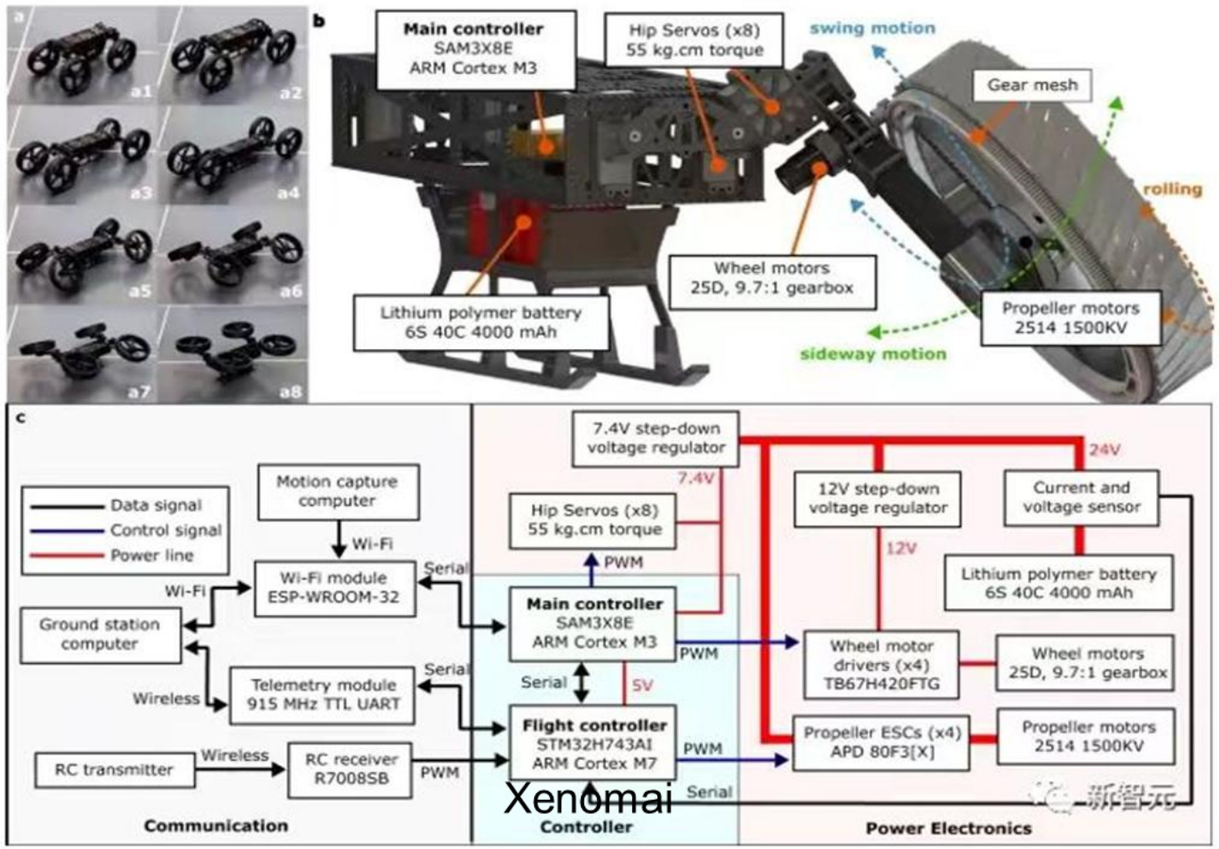
Taibot海陆空多模态具身智能机器人





对标M4国内首创海陆空天一体化具身智能多模态机器人，解决了传统足式机器人灵活性不足和电机关节组网延迟问题，首先发布陆空两用场景机器人

多模态机器人-双模态陆空一体

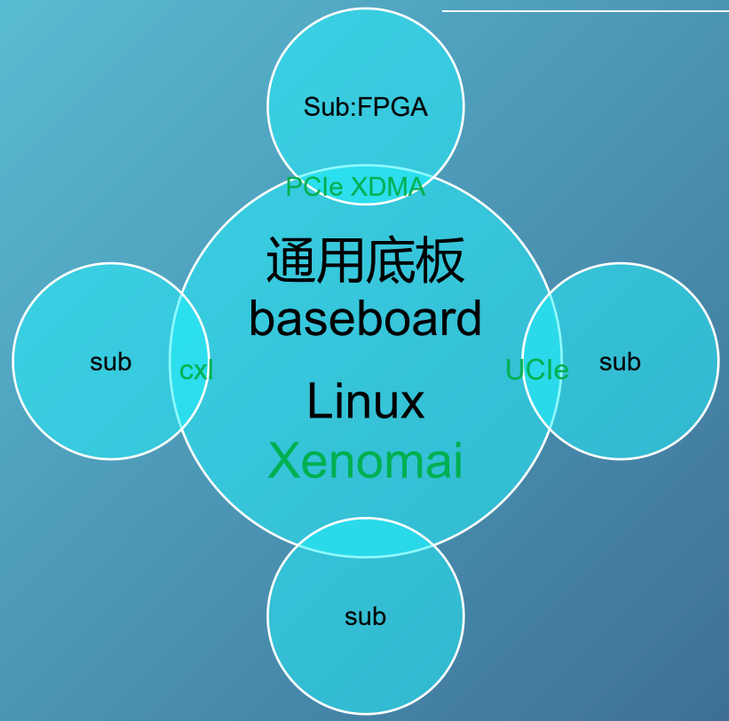


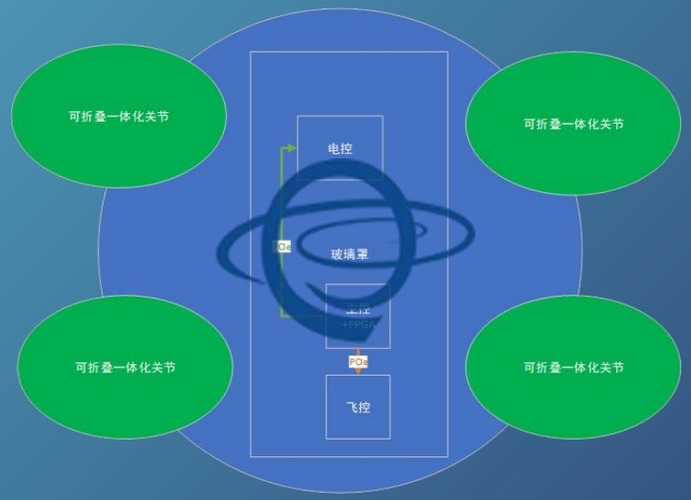
硬件		软件
主控	nuc	Embedded linux; Android; Px4; QGC; Plugin; Xenomai
	SAM3x8e	
飞控 STM32H743 ARM cortex M7		
电控 PWM ESC		
通信 wifi 5G 915MHz 433MHz		
power		
深度相机		
激光雷达		
机械结构外观cover		

单击此处添加备注

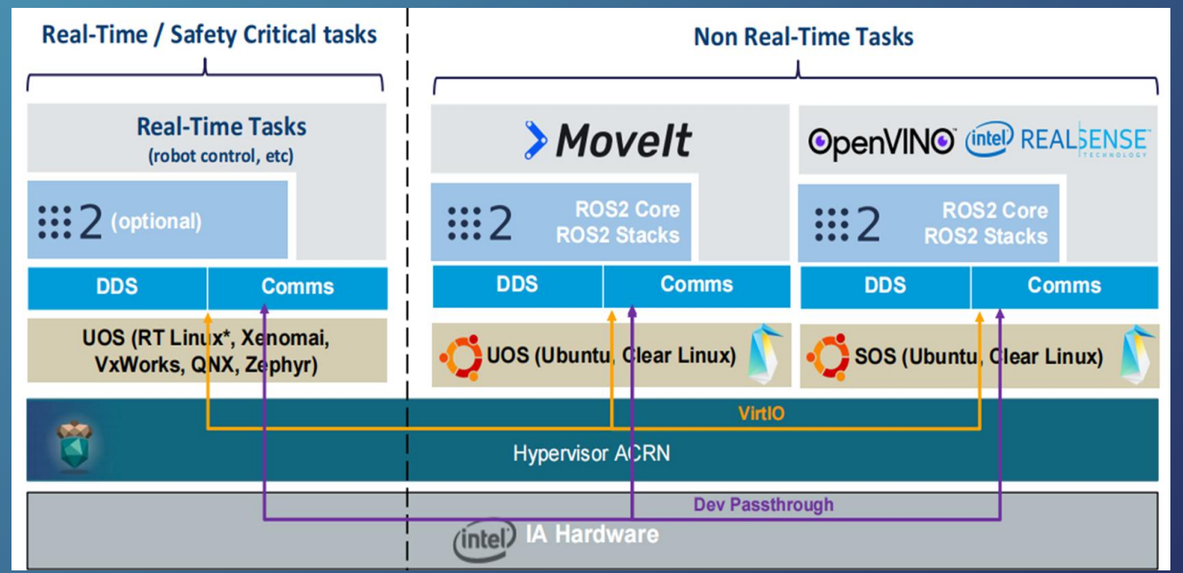
水里游的

```
== Sampling period: 100 us
== Test mode: periodic user-mode task
== All results in microseconds
warming up...
RTT|  00:00:01  (periodic user-mode task, 100 us period, priority 99)
RTH|----lat min|----lat avg|----lat max|-overrun|---msw|---lat best|--lat worst
RTD|      1.615|      1.923|      9.846|       0|     0|      1.615|      9.846
RTD|      1.615|      1.923|      9.692|       0|     0|      1.615|      9.846
RTD|      1.538|      1.923|     10.230|       0|     0|      1.538|     10.230
RTD|      1.615|      1.923|     10.384|       0|     0|      1.538|     10.384
RTD|      1.615|      1.923|     11.230|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.923|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.923|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     11.076|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.538|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     11.076|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.538|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     11.076|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.615|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.076|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.923|       0|     0|      1.538|     11.230
RTD|      1.538|      1.923|     10.538|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.923|       0|     0|      1.538|     11.230
RTD|      1.538|      1.923|     10.153|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.615|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|     10.769|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.153|       0|     0|      1.538|     11.230
RTD|      1.538|      1.923|     10.307|       0|     0|      1.538|     11.230
RTD|      1.615|      1.923|      9.538|       0|     0|      1.538|     11.230
RTT|  00:00:22  (periodic user-mode task, 100 us period, priority 99)
RTH|----lat min|----lat avg|----lat max|-overrun|---msw|---lat best|--lat worst
RTD|      1.615|      1.923|     11.384|       0|     0|      1.538|     11.384
RTD|      1.615|      1.923|     10.076|       0|     0|      1.538|     11.384
RTD|      1.538|      1.923|      9.538|       0|     0|      1.538|     11.384
---|-----------|-----------|-----------|--------|------|-------------------------
RTS|      1.538|      1.923|     11.384|       0|     0|    00:00:25/00:00:25
```





落地实现畅想



Baseboard主要是实现规范定义的各种接口及通用外设，Linux Xenomai RTOS 硬实时任务调度管控；而可插拔的subboard则是实现各种功能的扩展cpu io板卡，例如：电控板，飞控板，i/o接口板，EtherCAT通信接口板，数字仪表盘系统、车载信息娱乐系统、车载机械臂子系统、核心计算板卡负责主控、自动驾驶车辆分流数据采集、backup板卡用于紧急情况的热切换，当某个板卡出现问题故障时系统可以将其工作负载转移到备用办卡

Baseboard硬件：Intel凌动处理器 E3960 ，由于是通用插卡设计，因此方便使用下一代的cpu板卡进行升级替换;

subboard FPGA：

扩展CSI/DSI/IIC 等io;

Camera(GMSL gPTP)、 screen、 sensor、 机械臂AMR、ADAS EtherCAT分流采集等外设

PART
2

Xenomai在陆海空天一体化多模态具身智能机器人落地应用

Cpu与FPGA通信Jitter控制

中央计算核心控制：
X e n o m a i

CPU-FPGA

Intel x86,FPGA PCIe扩展FPGA subboard

01

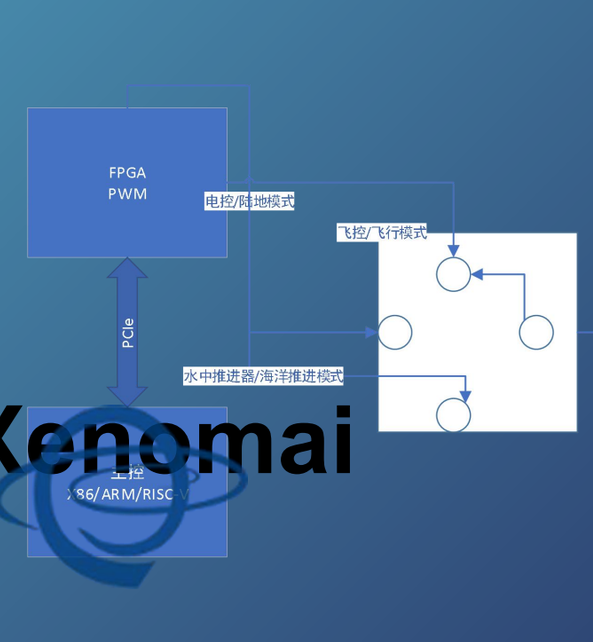
RT Task Xenomai

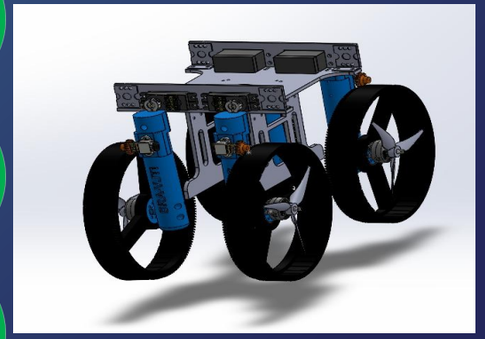
02

Edge Computing

rapyuta

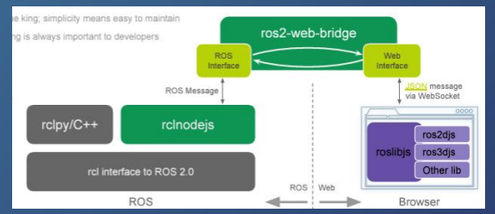
03



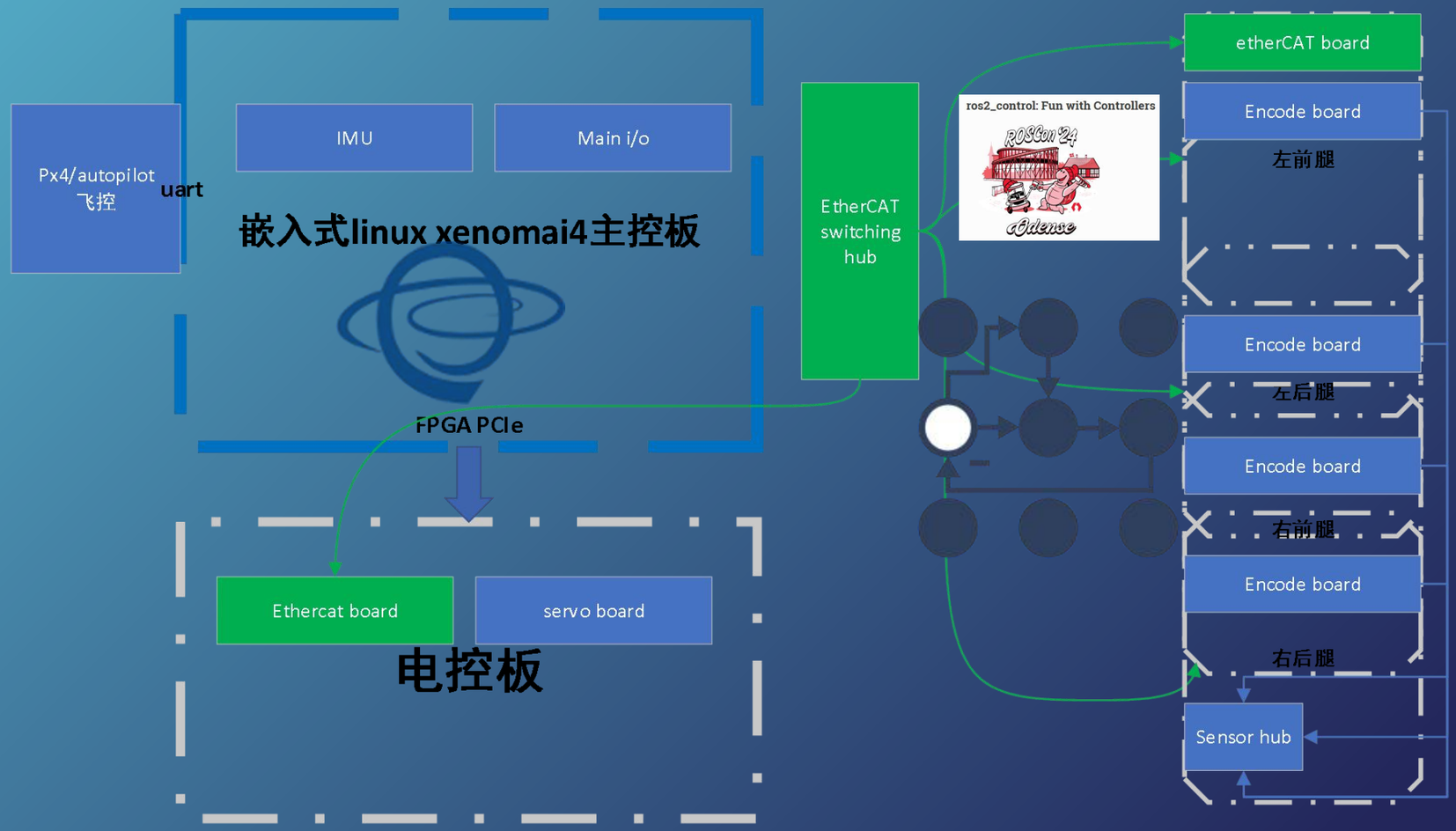


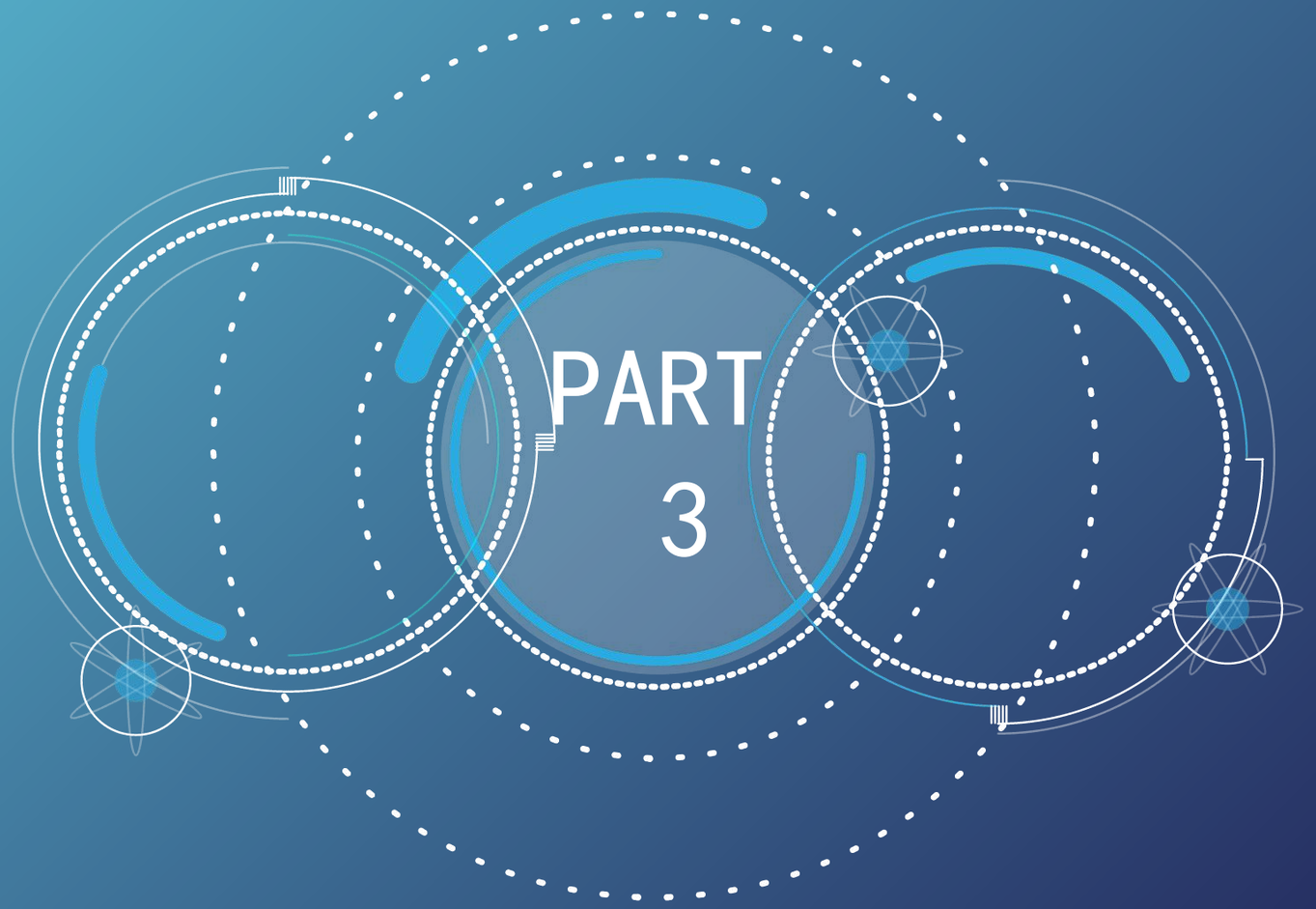
main unit

webrtc_ros



Leg unit

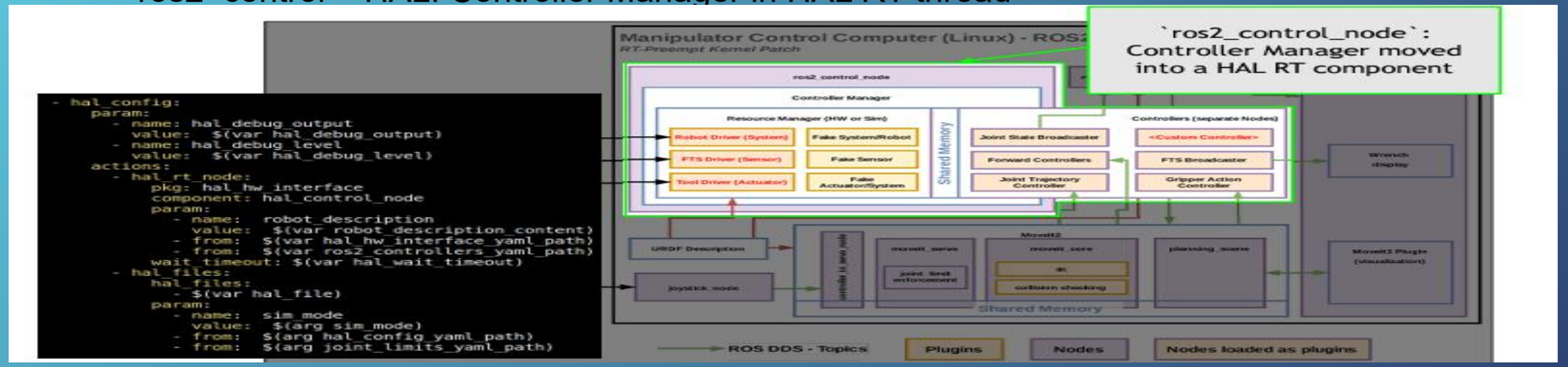




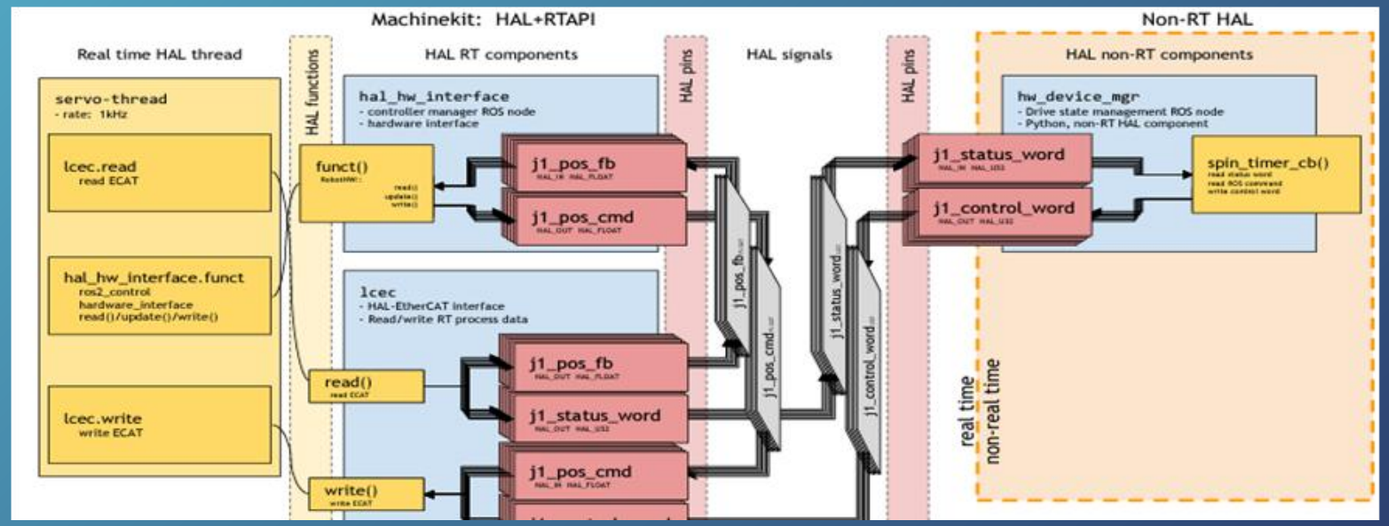
Xenomai realtime ros2_control

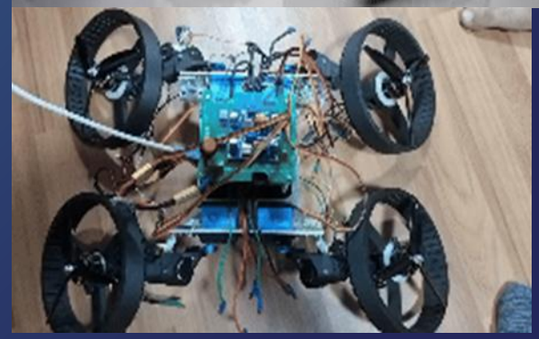
Hard real-time webrtc_ros

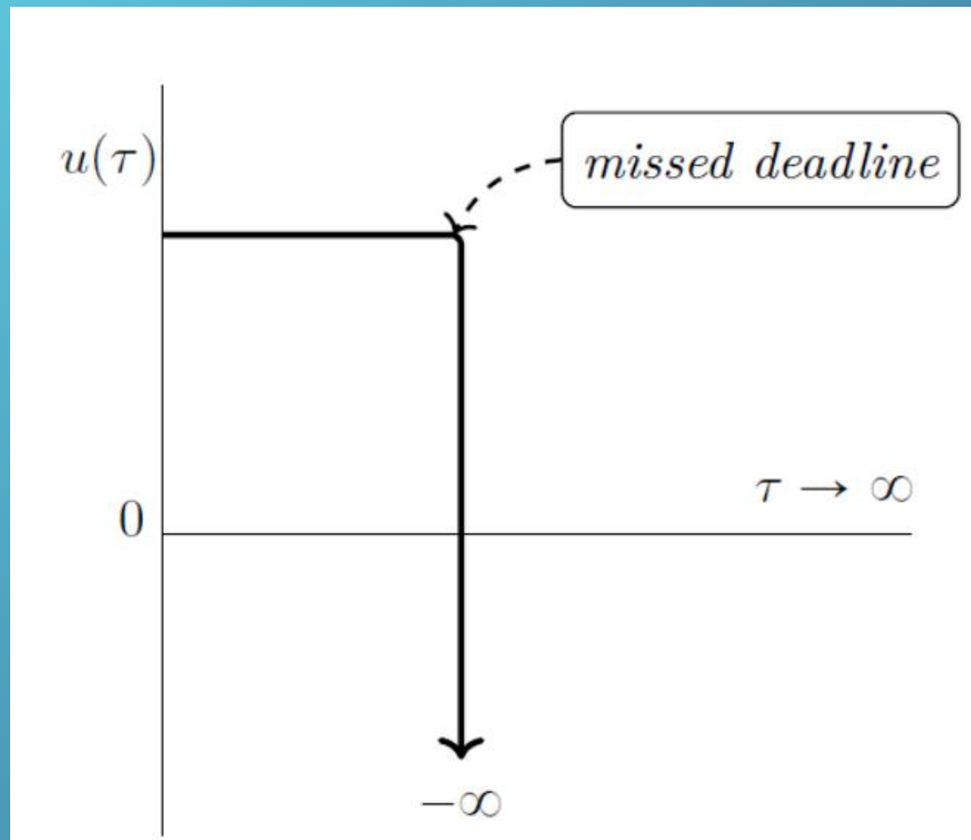
ros2_control + HAL: Controller Manager in HAL RT thread

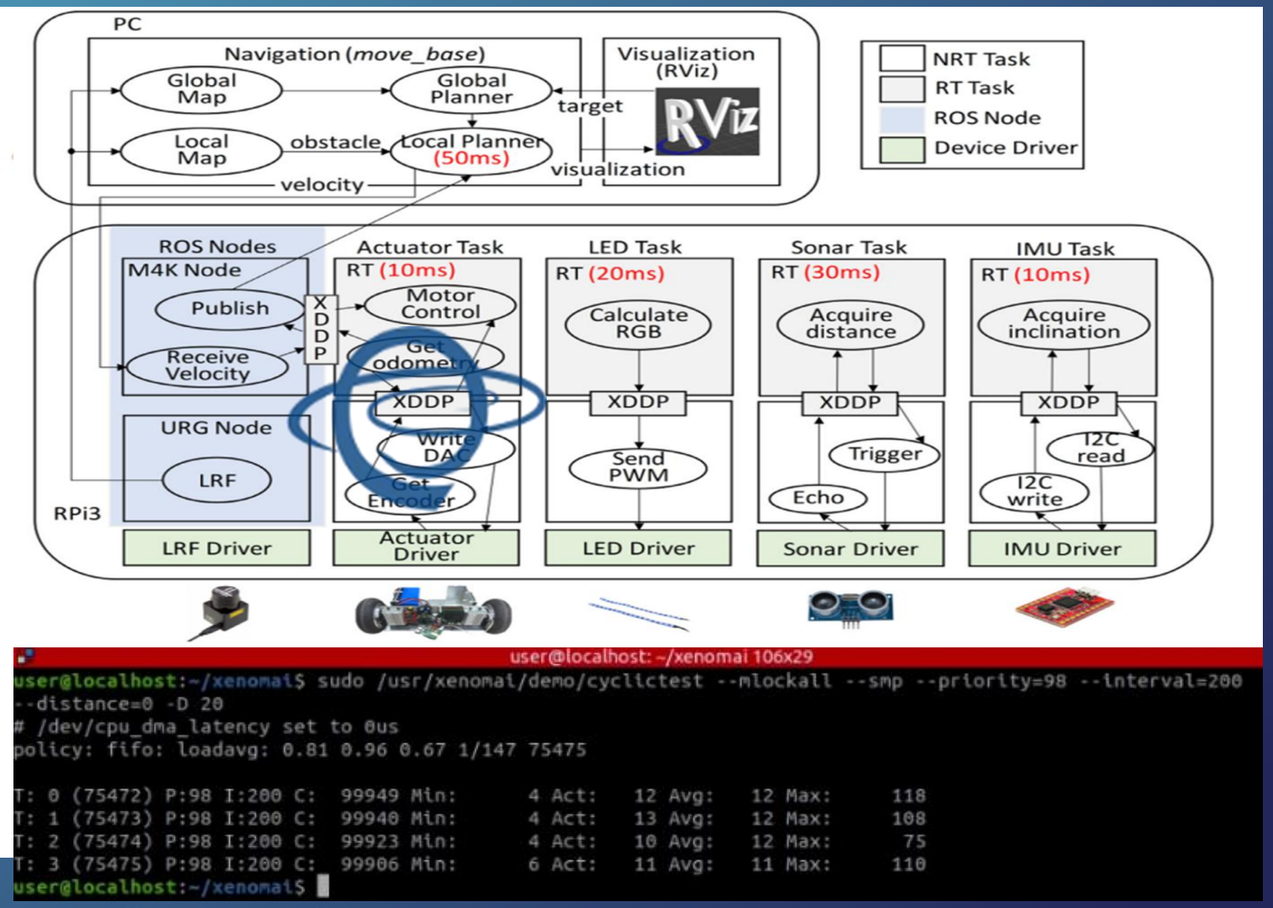


Basic `hal_ros_control` robot hardware configuration





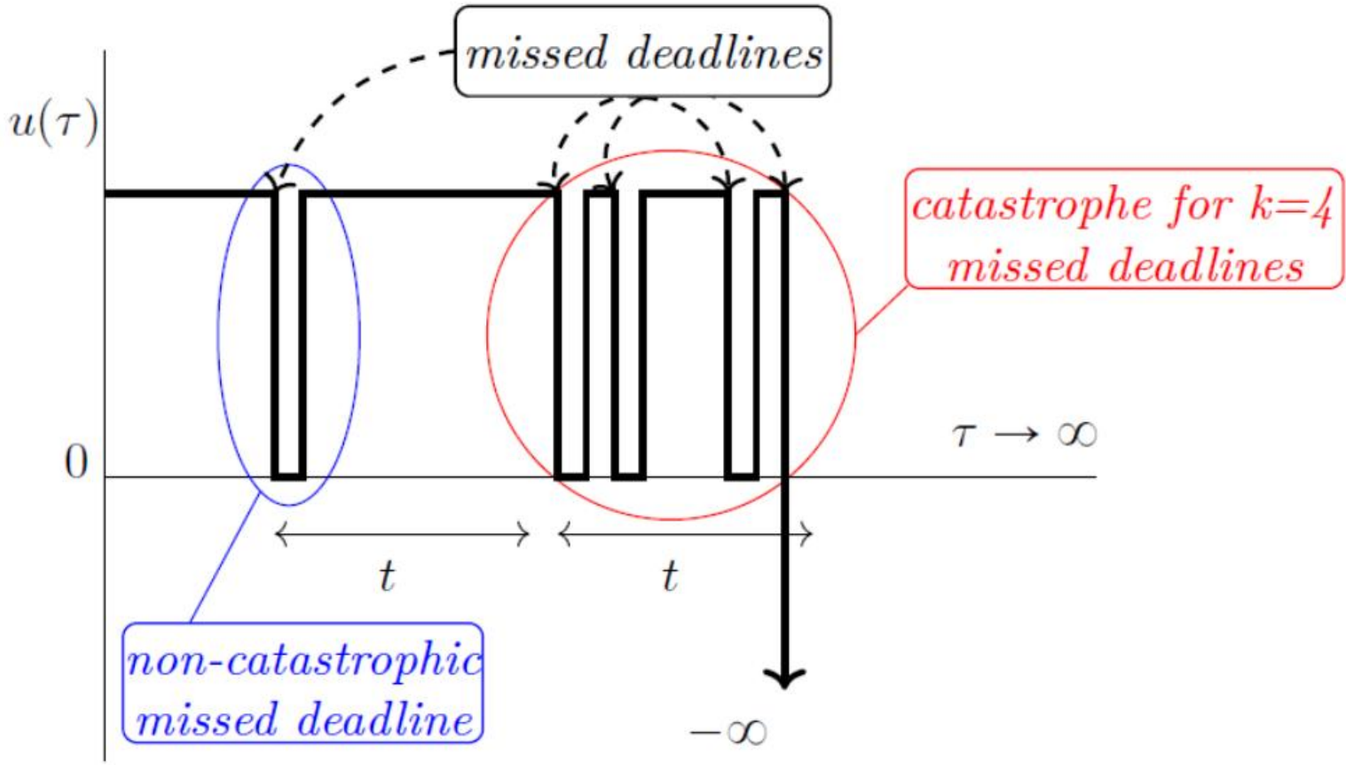


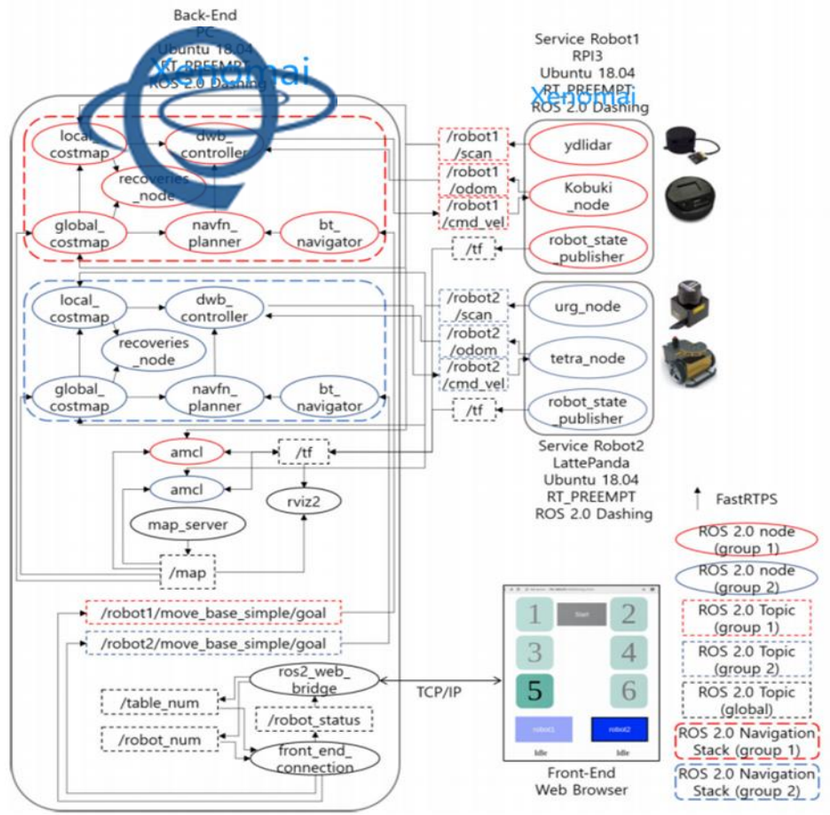


Aviation computers, precise robotics, and power-plant applications all have in common that they must be controlled very precisely. If this is not achieved, the results are cata strophic. Applications such as these require the use of ‘hard’ real time. In the case of hard real-time, there is absolutely no flexibility. A missed deadline could cause a big dis aster, which is why these systems are designed to be deterministic.

Hard real-time task

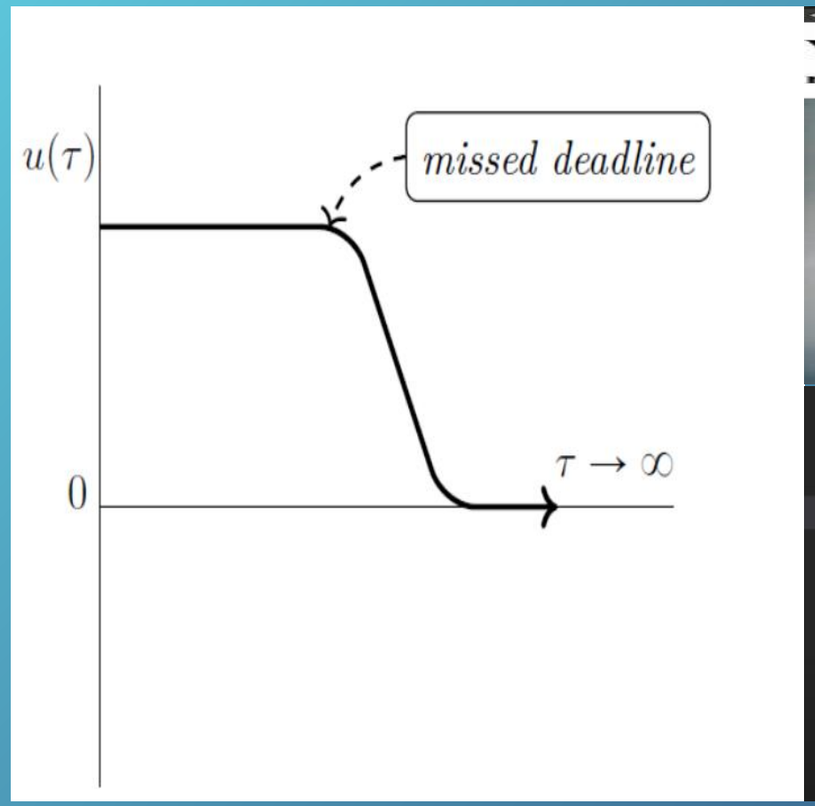
utility drops to minus infinity when a deadline is missed

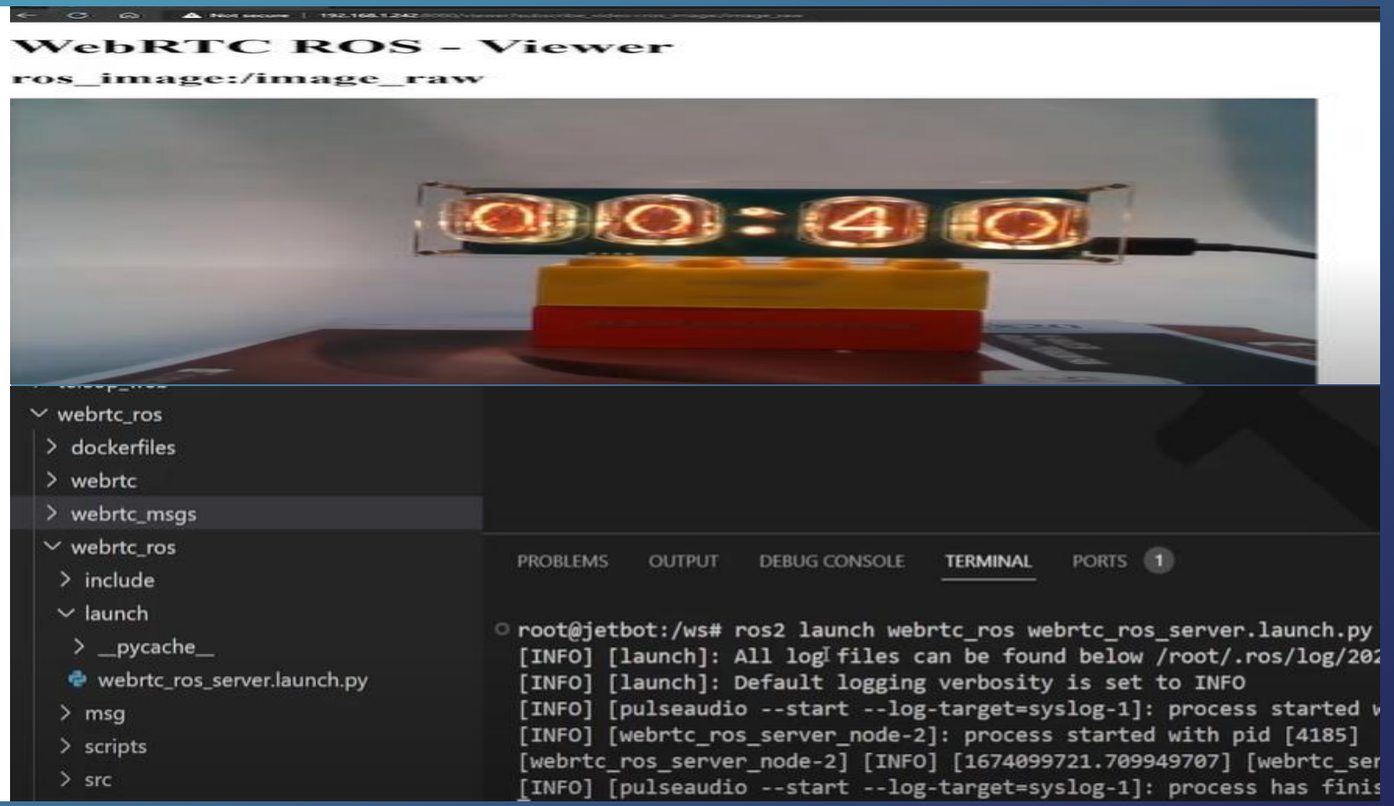




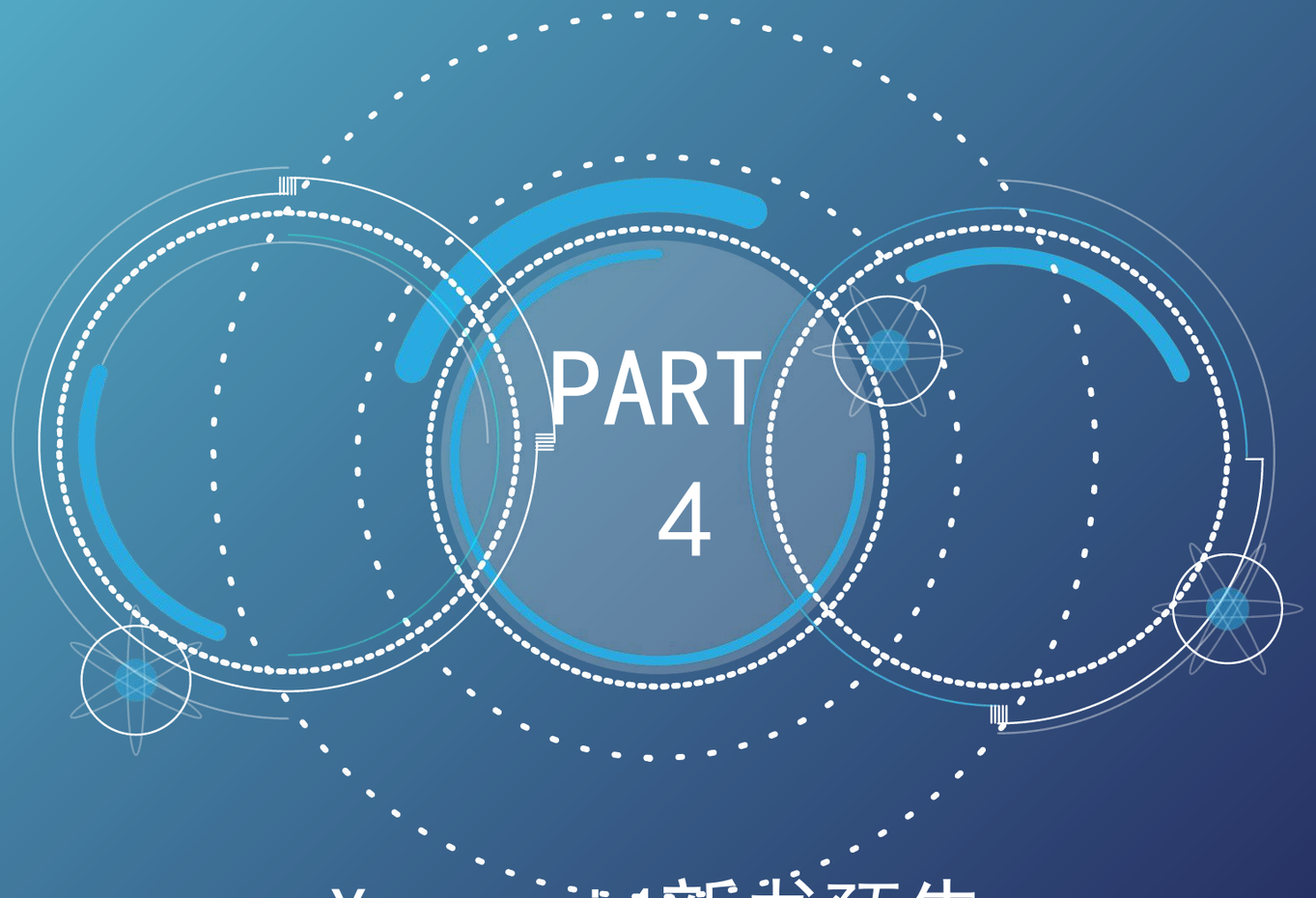
Systems where calculations are done in high frequency and are not a safety hazard often allow a number of deadline misses. Multiple missed deadlines within a certain period of time could increase the likeliness of a critical failure. These tasks are considered firm real-time.

Within a **firm real-time** system, a task may miss *k* deadlines within a period *t* before the utility drops to $-\infty$.





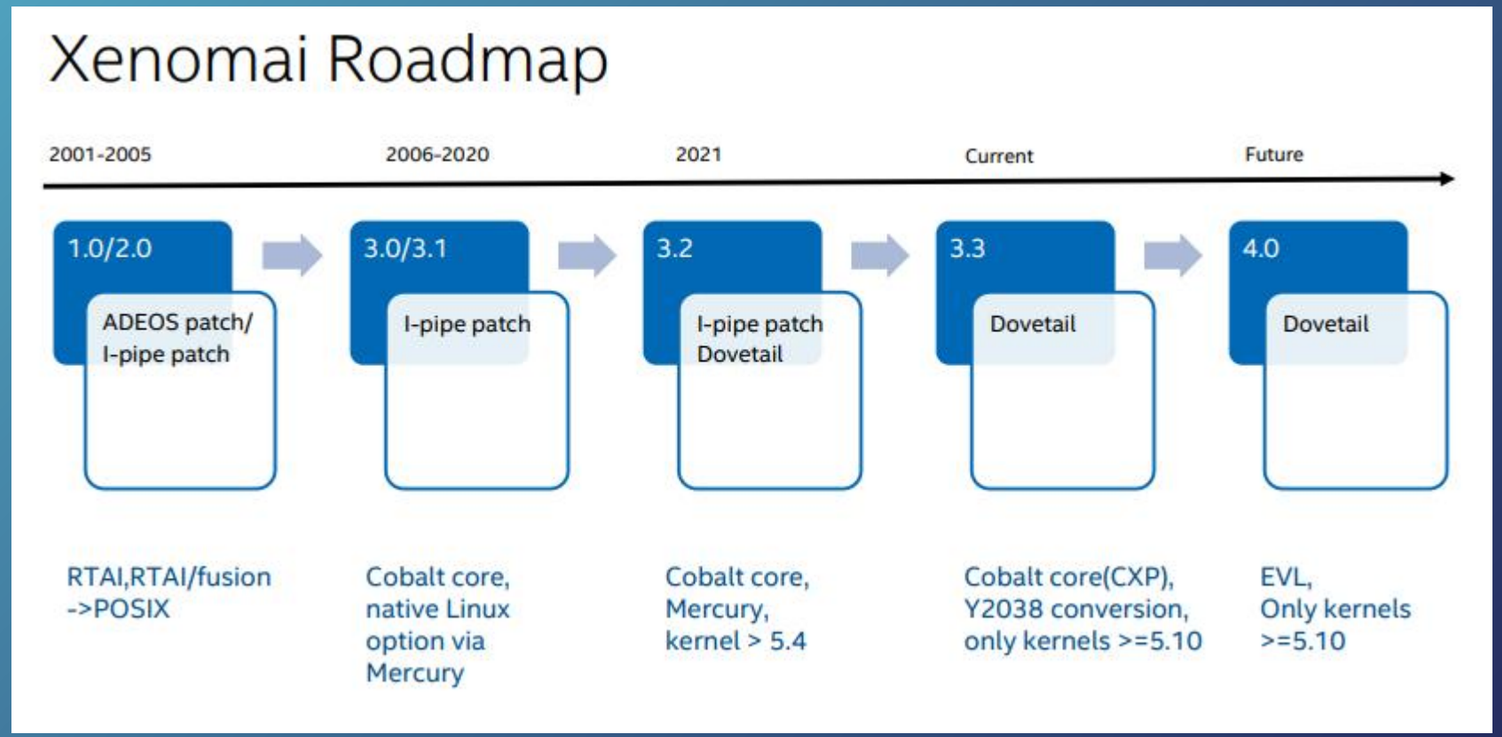
Soft real-time is the most flexible system of all real-time systems, where the result of a missed deadline can still be used. Nevertheless, it can most often only be used up to a certain point in time.
Soft real-time systems are most used in streaming services or internet services.
webRTC ROS



Xenomai4新书预告

https://v4.xenomai.org/

Xenomai roadmap



Xenomai系列图书规划介绍

系列书规划方案

1.《Xenomai实战：入门与进阶》（如何使用）

读者定位：Xenomai的初级读者为主，中级读者为辅。

主要内容：Xenomai的概念、功能、使用、基本原理等。

2.《深度实践Xenomai》（如何用好）

读者定位：Xenomai中级读者为主，初级和高级读者为辅

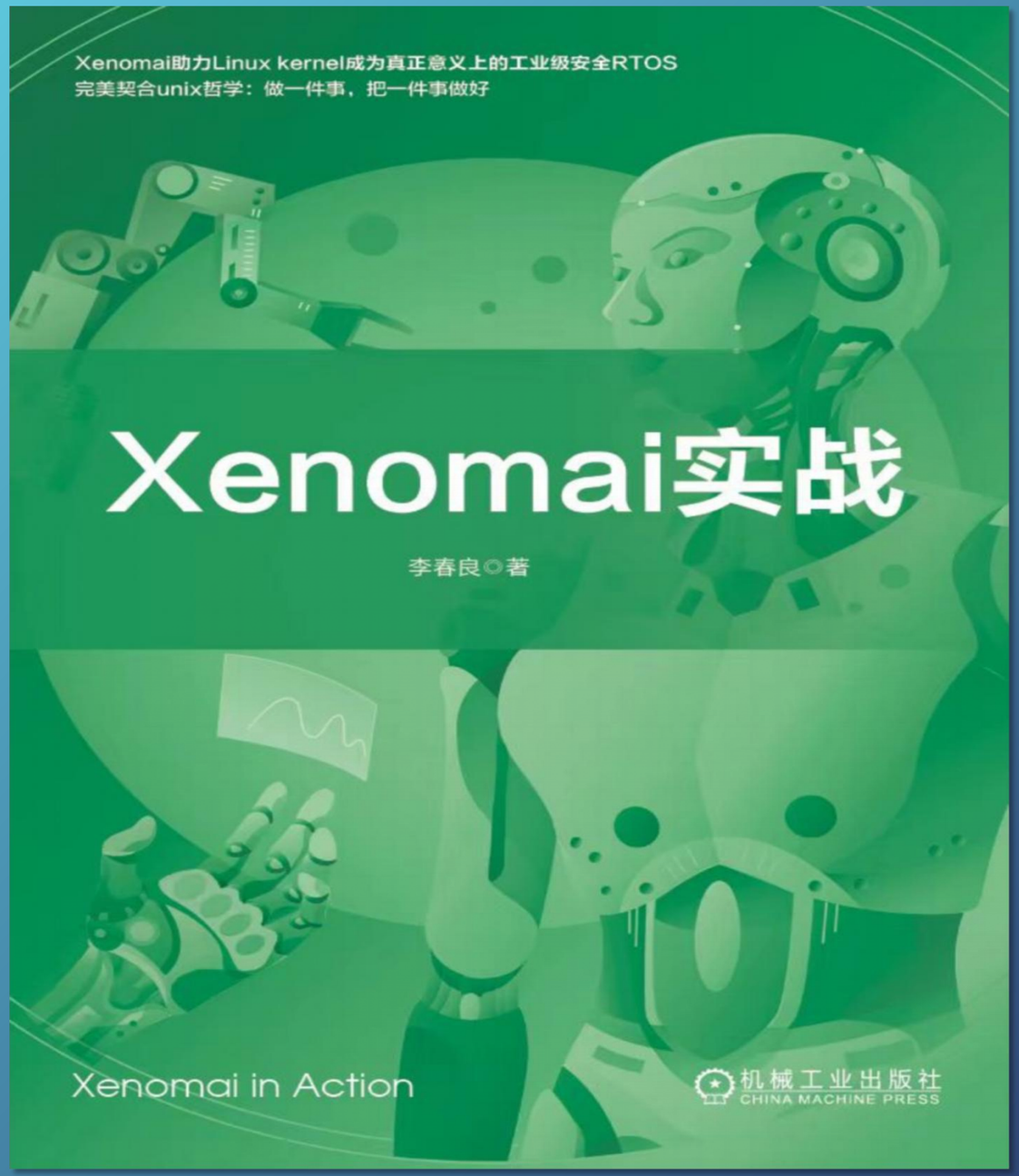
主要内容：Xenomai重要模块的原理、高级特性、最佳实践、二次开发等。

3.《Xenomai技术内幕：架构设计与实现原理》（内核实现）

读者定位：Xenomai高级读者为主，中级读者为辅

主要内容：Xenomai的源代码分析、与底层原理相关的高级应用等。

这3本书依次递进，但是内容上会略有重叠，这个不影响每本书的单独定位。


Xenomai助力Linux kernel成为真正意义上的工业级安全RTOS
完美契合unix哲学：做一件事，把一件事做好
Xenomai实战
李春良◎著
Xenomai in Action
机械工业出版社
CHINA MACHINE PRESS

感谢观看

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李春良