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Toy OBDH system

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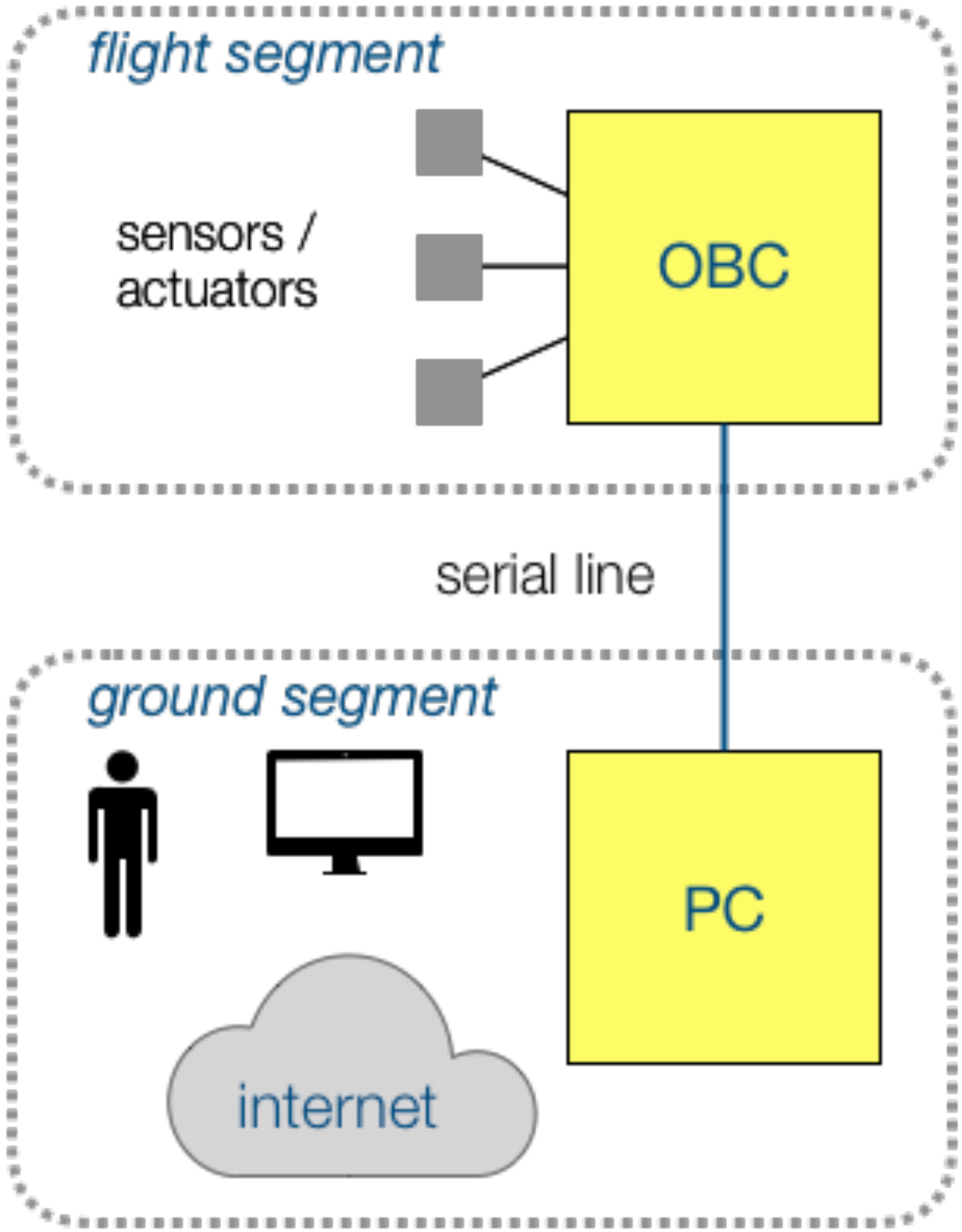
Overview

- The aim of this project is to build a simple mockup of a satellite OBDH system performing basic housekeeping telemetry
  - periodic sensor sampling
  - periodic basic telemetry
  - on-request housekeeping telemetry with recent data

- The target platform is an STM32F407 discovery board
- The host platform is a PC workstation
  - WIndows, MacOS, GNU Linux

Fight and ground segments



Functional requirements

- A set of sensors are periodically sampled with period T_S
- A basic TM message is sent periodically with period T_B. The message contains the last measured values from all sensors
- The system can receive a TC messages from the ground station, and replies with an appropriate TM message
- TM messages are stamped with the mission time when the message is sent
- Sensor measurements are stamped with mission time at which the measurements have been taken
- Time stamp values are given in seconds from the system start time, with a resolution of at least 1 ms

Temporal requirements

- Sensors must be sampled every T_S = 1 s
  - reading to be completed before D_S = 0.1 s
- Basic telemetry must be sent every T_B = 10 s
  - message must be sent before D_B = 0.5 s
- Telecommands are separated by at least T_C = 2 s
  - processing must be completed before D_C = 0.05 s
- Housekeeping telemetry messages are sent after reception of a TC
  - message must be sent before D_H = 0.2 s

Operating modes

- Idle
  - The ground station has no visibility of the satellite
  - Only basic TM is transmitted
  - Only *open link* TC is accepted
- Coverage
  - The ground station has visibility of the satellite
  - Started upon reception of an *open link* TC from ground
  - TC can be sent to the satellite replied by TM
  - Switch back to idle mode upon reception of a *close link* TC
    - or automatically after a maximum visibility window time

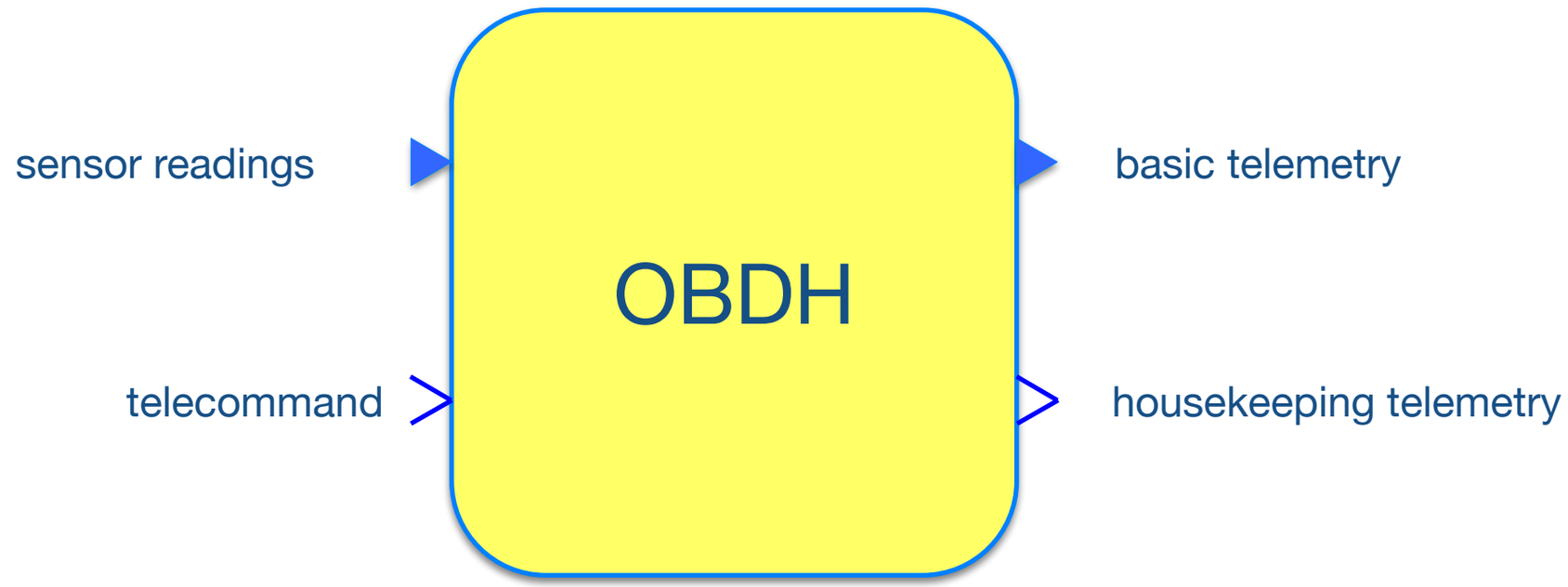
Telecommands

- OPEN : Open link
  - start coverage mode
- REQUEST
  - request housekeeping log
  - only in coverage mode
- CLOSE : Close link
  - end coverage mode

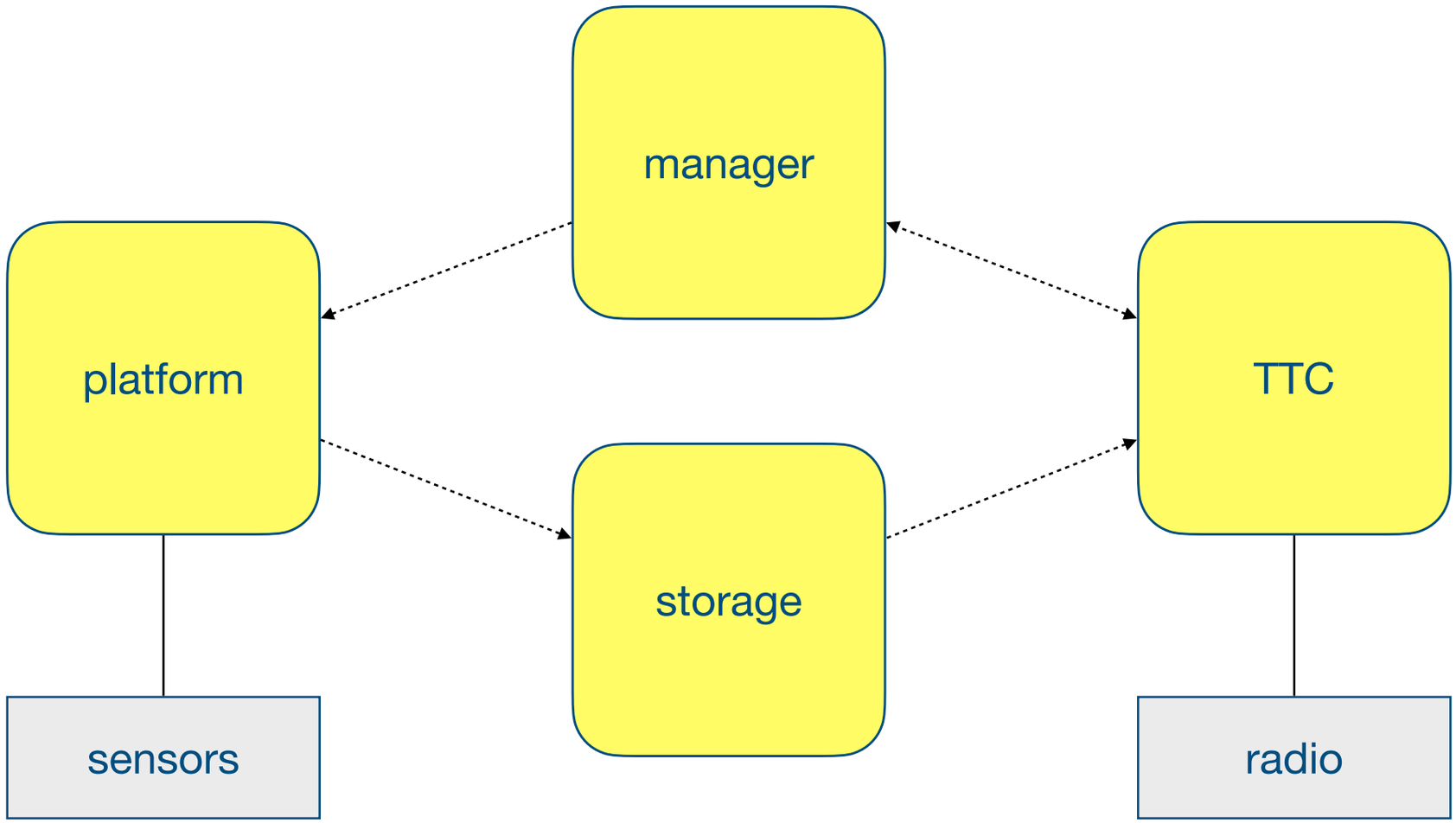
Telemetry messages

- HELLO : basic telemetry
  - last measured values from all the sensors.
  - periodically transmitted in idle mode
- HK : housekeeping
  - record with the last N measurements
  - transmitted in response to a telecommand in coverage mode
- MODE
  - current operating mode of the system
  - transmitted after a mode change in idle or coverage mode
- ERROR
  - abnormal conditions or erroneous TC received

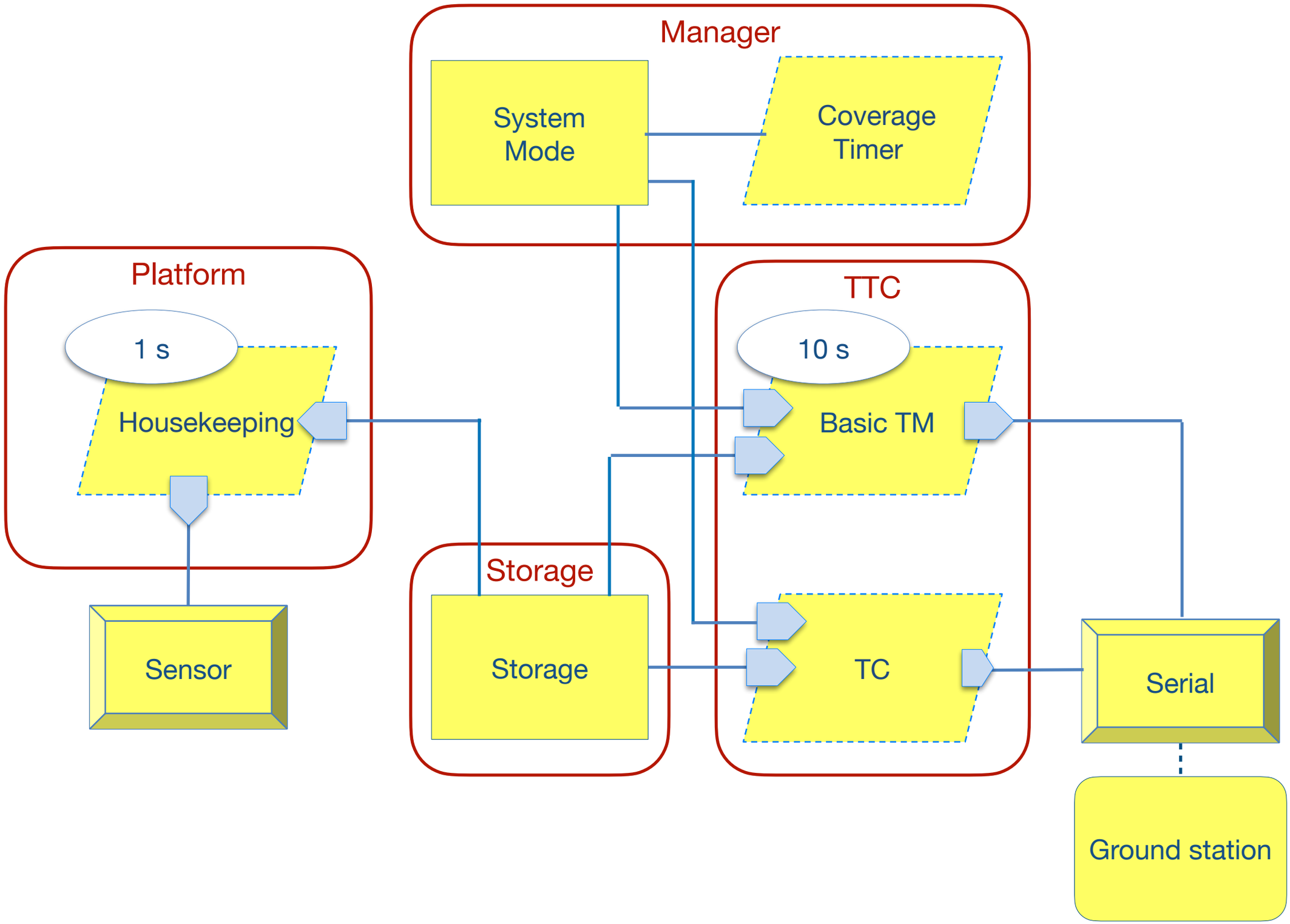
Context diagram



System architecture

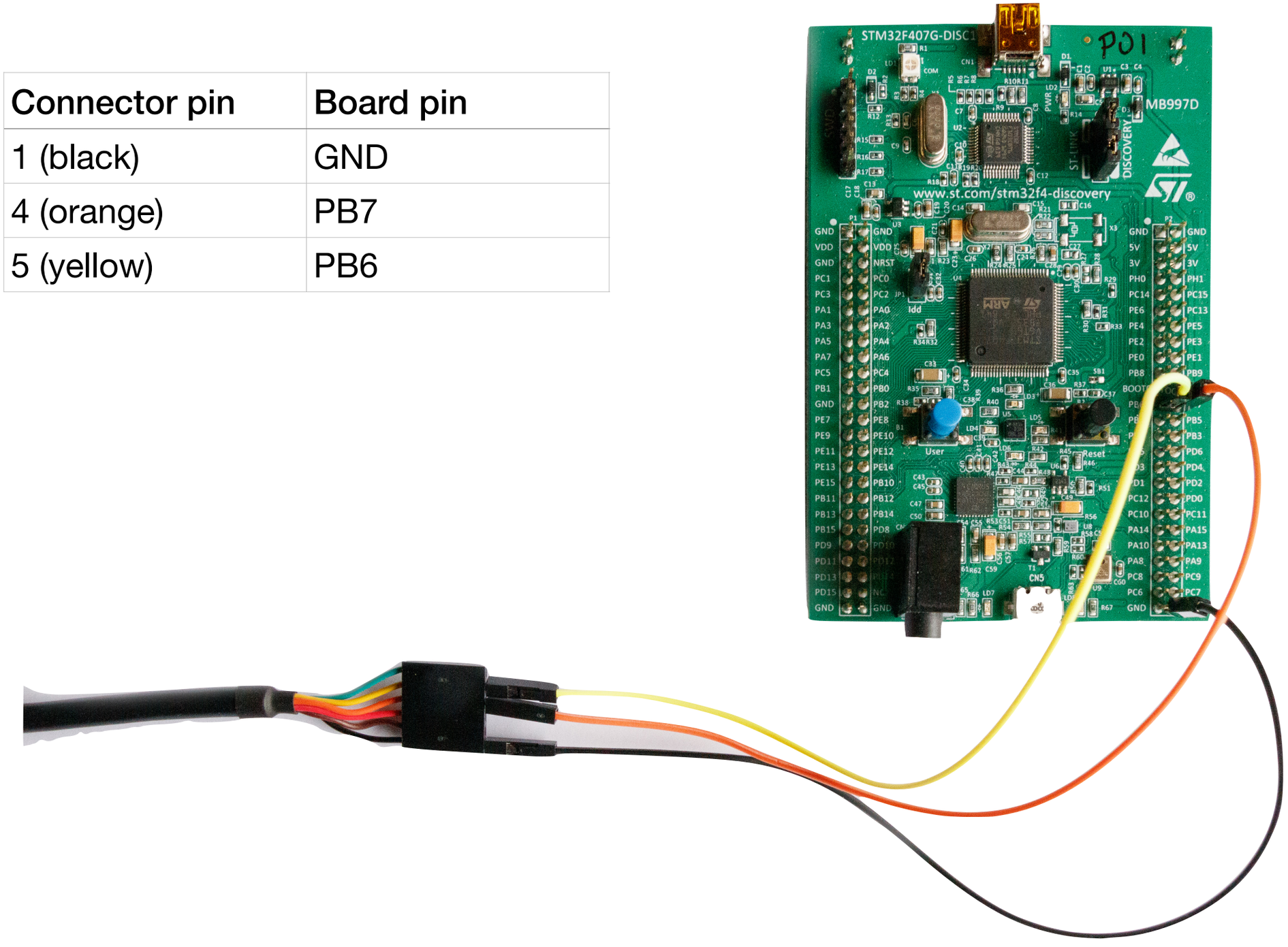


Architectural design (AADL)

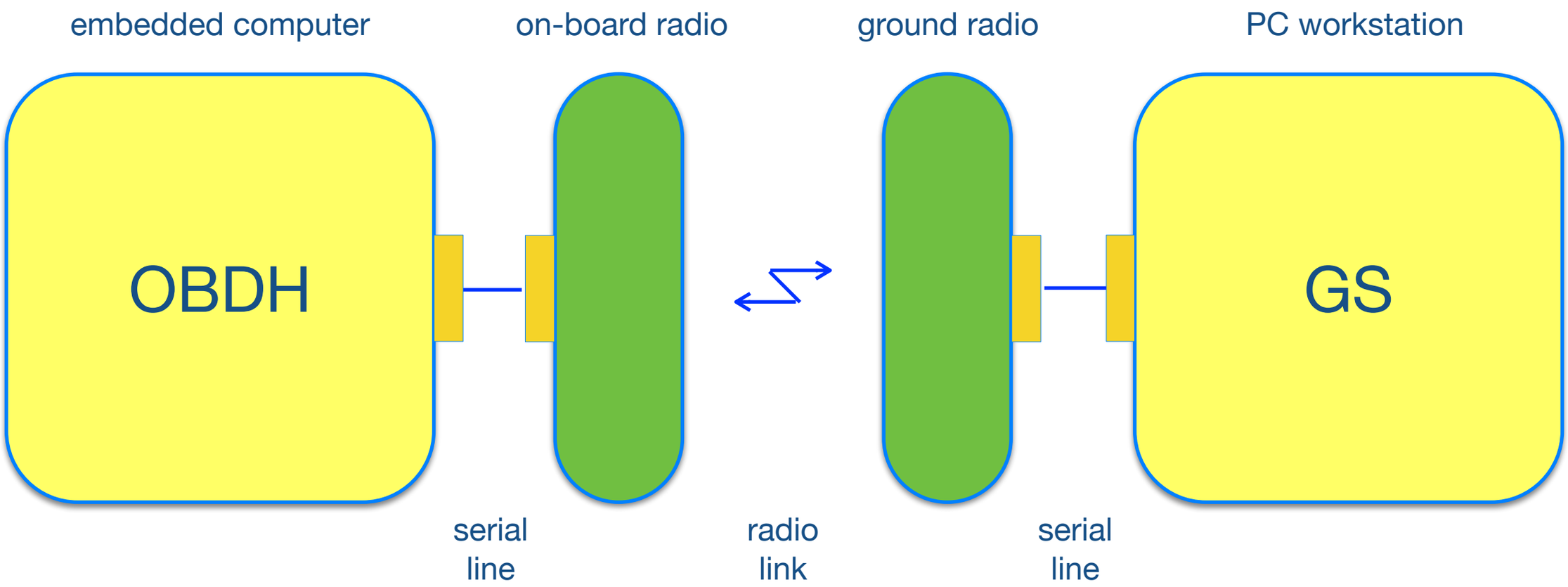


Hardware connections

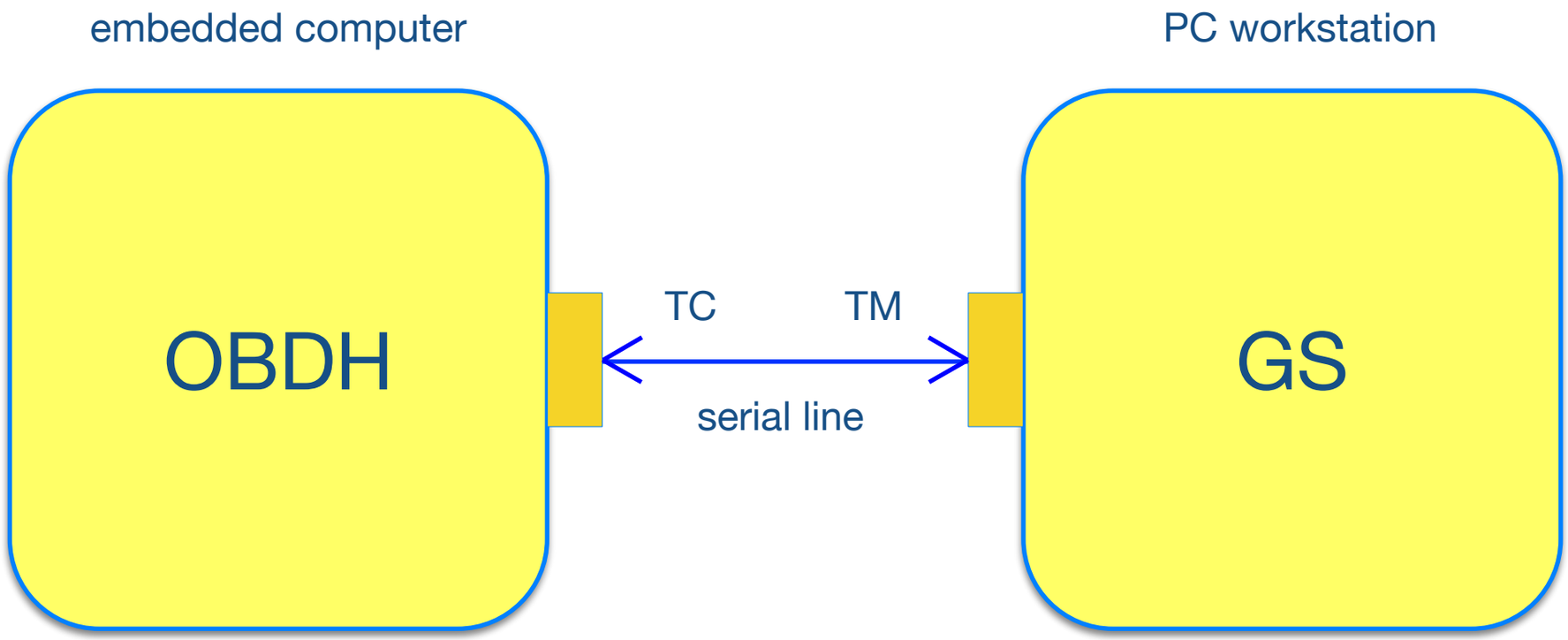
Connector pin	Board pin
1 (black)	GND
4 (orange)	PB7
5 (yellow)	PB6



Ground station



Ground station test arrangement



Ground station output

jpuente — screen /dev/cu.usbserial-FTA5I24G 115200 — screen — screen /dev...

```
0000000026 | HELLO 0000000026:1063:2073
0000000036 | HELLO 0000000036:1063:2078
0000000039 | MODE  COVERAGE
0000000045 | HK LOG
                   0000000040:1064:2080
                   0000000041:1066:2080
                   0000000042:1070:2077
                   0000000043:1063:2080
0000000049 | MODE  IDLE
0000000056 | HELLO 0000000056:1068:2080
0000000066 | HELLO 0000000066:1066:2079
```

Implementation

- `obdh`: compile on development platform
  - download code from the STR-UPM OBDH_LABS GitHub repository
  - compile and build with the arm-elf compiler
  - upload to the board through usb connection

- `gs`: run on linux/Mac/Windows workstation
  - requires python3

RT Analysis

i	Task		P	T	C	B	R	D
1	HK	P	4	1,0	$13 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$17 \cdot 10^{-6}$	0,100
2	Timer	S	3	60,0	$5 \cdot 10^{-6}$	$2 \cdot 10^{-6}$	$20 \cdot 10^{-6}$	0,200
3	Basic_TM	P	2	10,0	$26 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$48 \cdot 10^{-6}$	0,500
4	TC	S	1	2,0	$20 \cdot 10^{-6}$	—	$64 \cdot 10^{-6}$	1,0
	PO							
	Storage		4		$4 \cdot 10^{-6}$			
	Mode		3		$2 \cdot 10^{-6}$			

Cálculo del tiempo de respuesta

- La ecuación del tiempo de respuesta es

$$R_i = C_i + B_i + \sum_{j \in \mathrm{hp}(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j$$

- La ecuación no es continua ni lineal
- No se puede resolver analíticamente

Iteración lineal

- La ecuación del tiempo de respuesta se puede resolver mediante la relación de recurrencia

$$w_i^{n+1} = C_i + B_i \sum_{j \in hp(i)} \left\lceil \frac{w_i^n}{T_j} \right\rceil \cdot C_k$$

  - la sucesión $w_i^0,\ w_i^1,\ w_i^2,\ \ldots$ es monótona no decreciente
  - un valor inicial aceptable es $w_i^0 = C_i + B_i$
  - se termina cuando
    - a) $w_i^{n+1} = w_i^n$ (y entonces $R_i = w_i^n$), o bien
    - b) $w_i^{n+1} > T_i$ (no se cumple el plazo)

Ejemplo

En el ejemplo anterior

$$R_1 = C_1 + B_1 = 17 \cdot 10^{-6}$$ = 13e-6 + 4e-6 = 17e-6

$$w_2^0 = C_2 + B_2 = 7 \cdot 10^{-6}$$ = 5e-6 + 2e-6 = 7e-6

$$w_2^1 = C_2 + B_2 + \left\lceil \frac{w_2^0}{T_1} \right\rceil \cdot C_1 = 20 \cdot 10^{-6}$$ = 5e-6 + 2e-6 + (7e-6/1) * 13e-6 =

$$w_2^2 = C_2 + B_2 + \left\lceil \frac{w_2^1}{T_1} \right\rceil \cdot C_1 = 20 \cdot 10^{-6}$$ = 5e-6 + 2e-6 + (20e-6/1) * 13e-6 =

$$R_2 = 20 \cdot 10^{-6}$$

etc.

- R_i is an upper bound of the response time of τ_i
- C_i is the worst-case execution time of τ_i
- B_i is the worst-case blocking time of τ_i
- T_i is the period (or minimal separation) of τ_i
- hp(i) is the set of all tasks having a higher priority than τ_i