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Project
# OBDH system

Juan A. de la Puente

<jpuente@dit.upm.es>

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
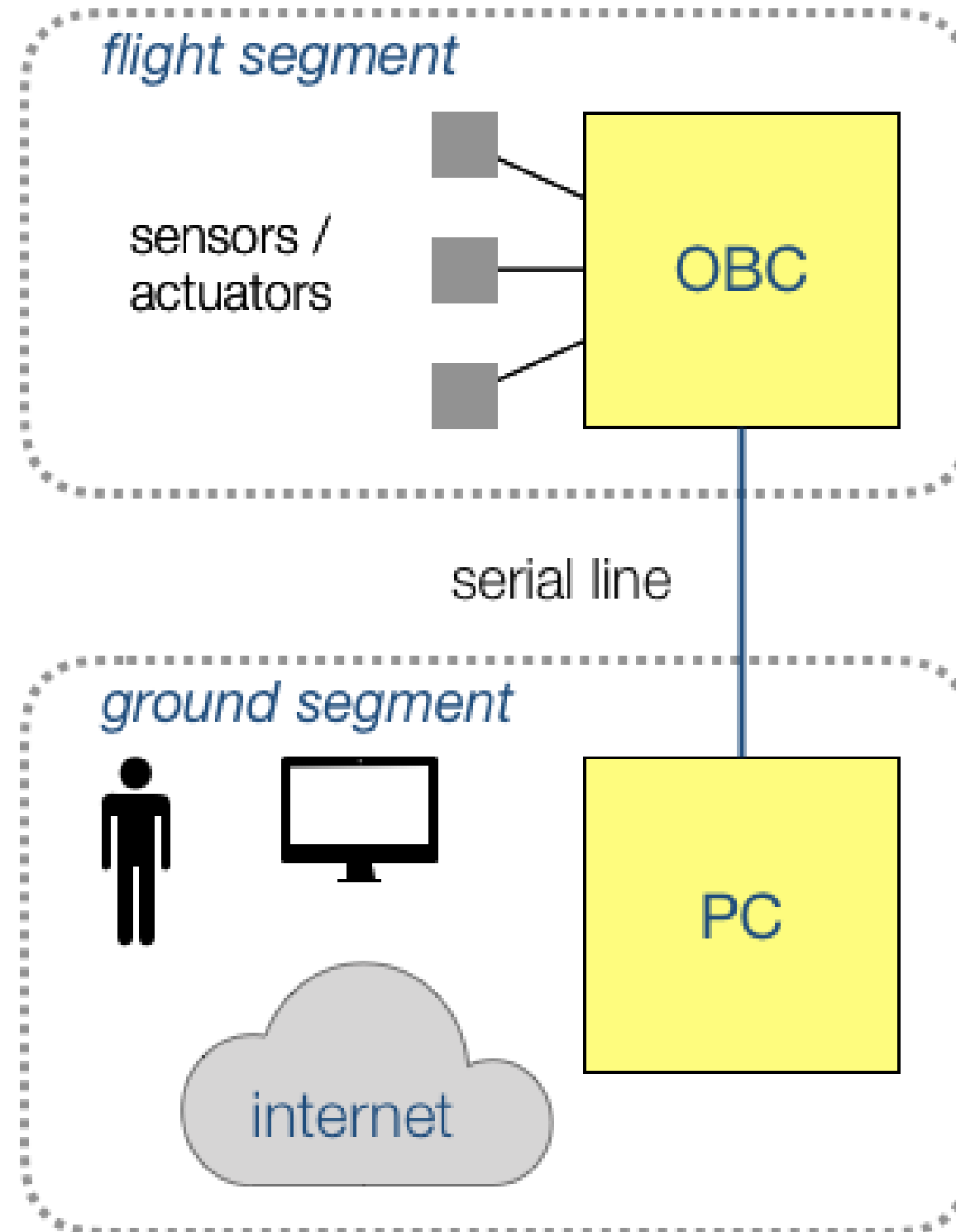
Functional requirements

- 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
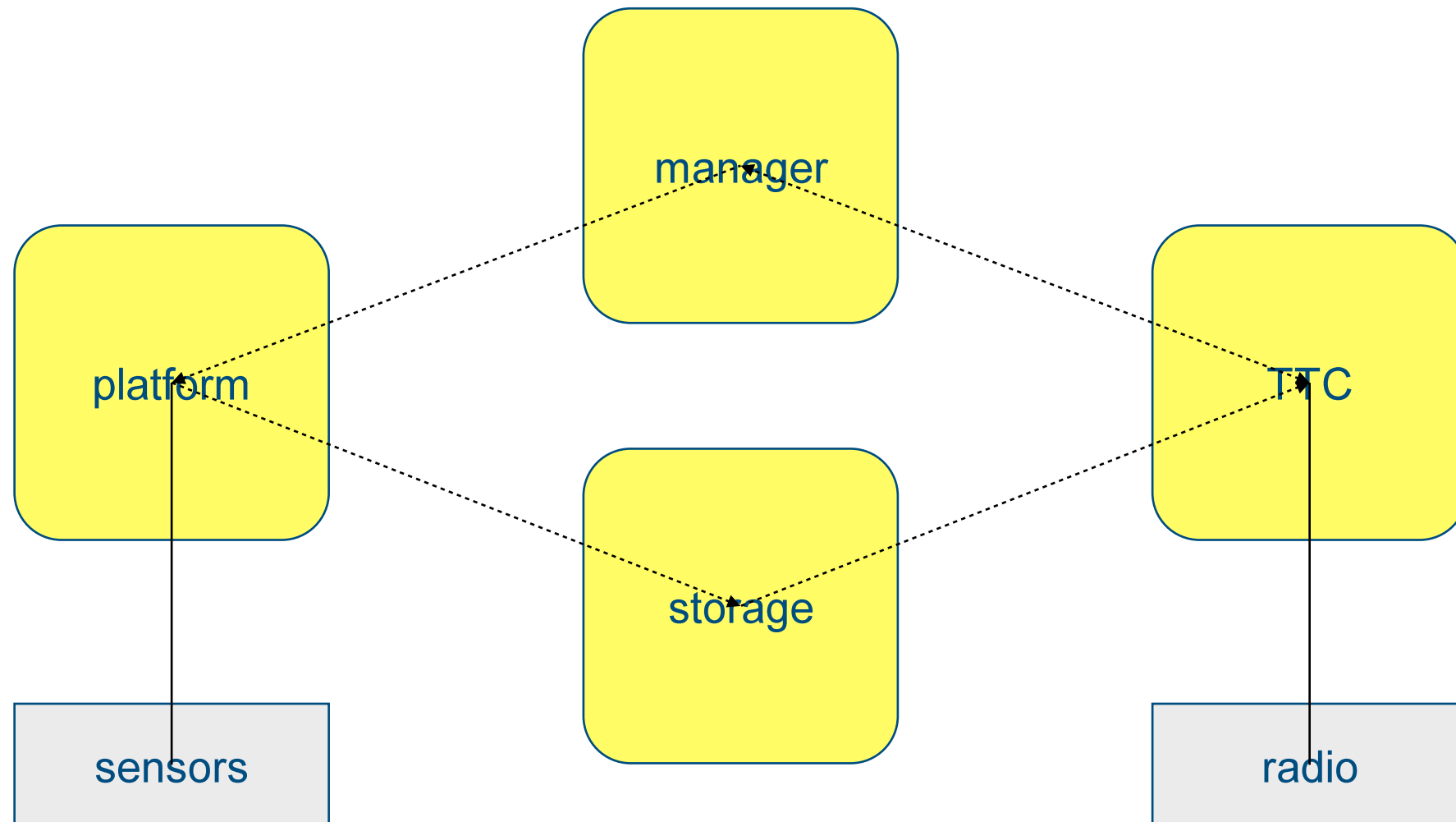 - ‣ abnormal conditions or erroneous TC received
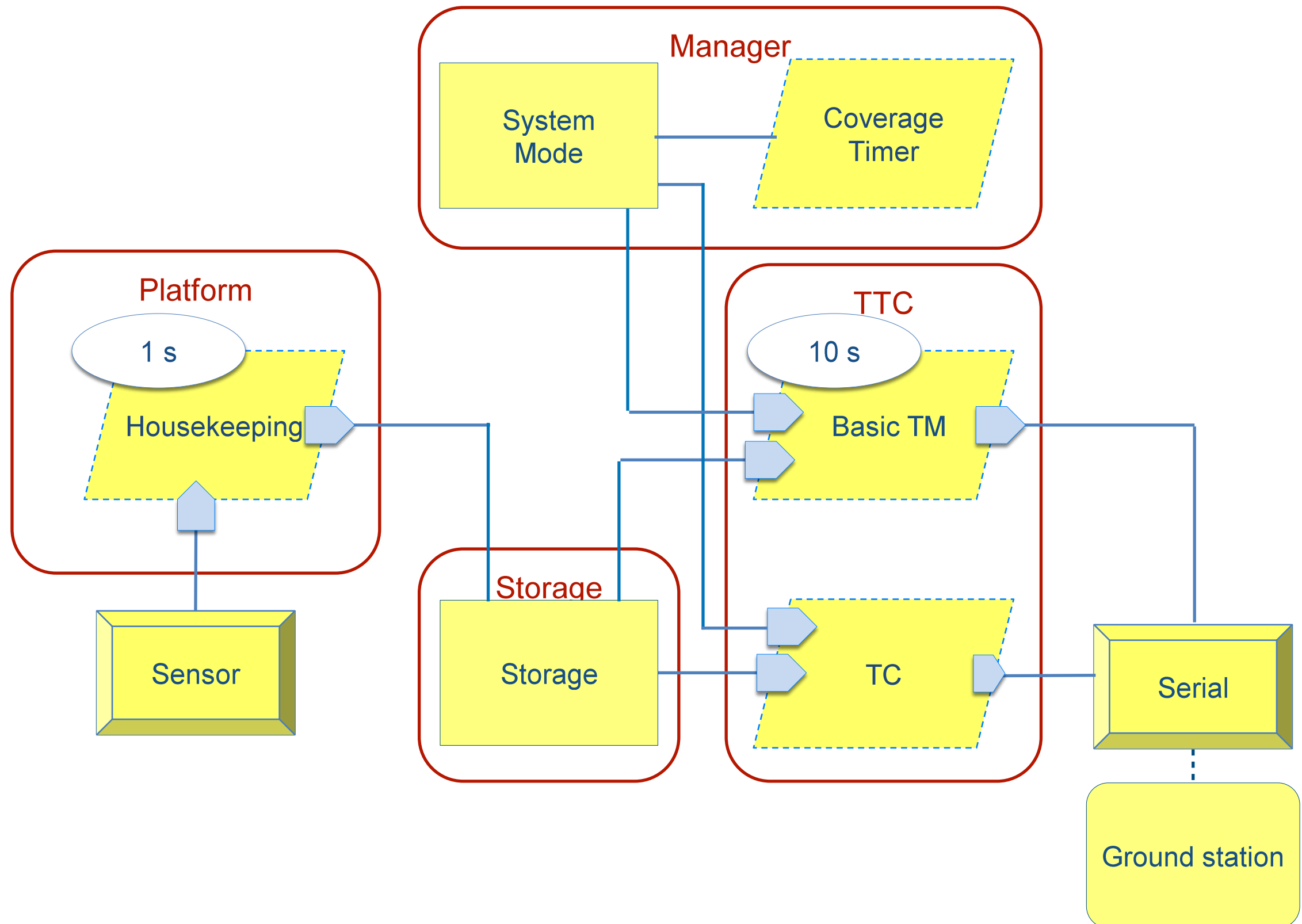
Context diagram
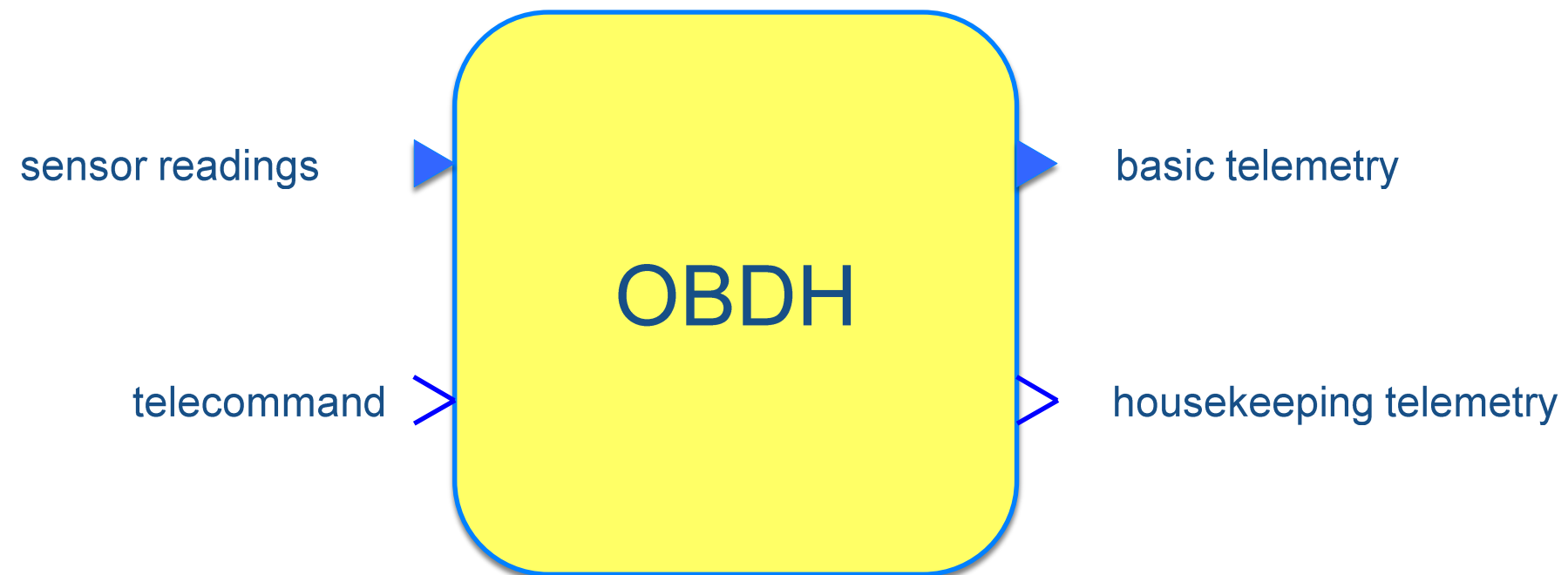
System architecture

Architectural design (AADL)

Hardware connections

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

Ground station

embedded computer   on-board radio   ground radio   PC workstation

OBDH   **GS**

serial
line

radio
link
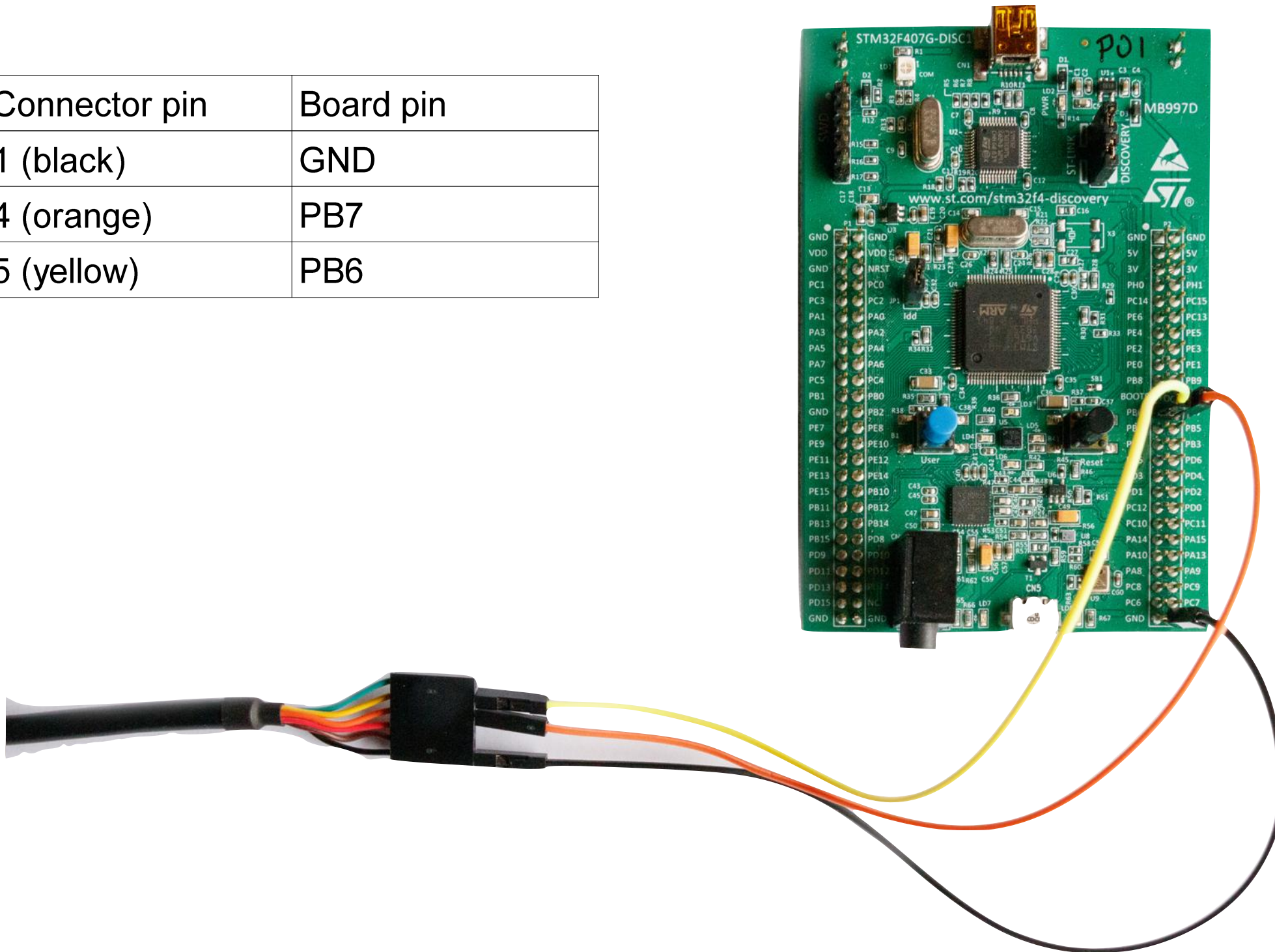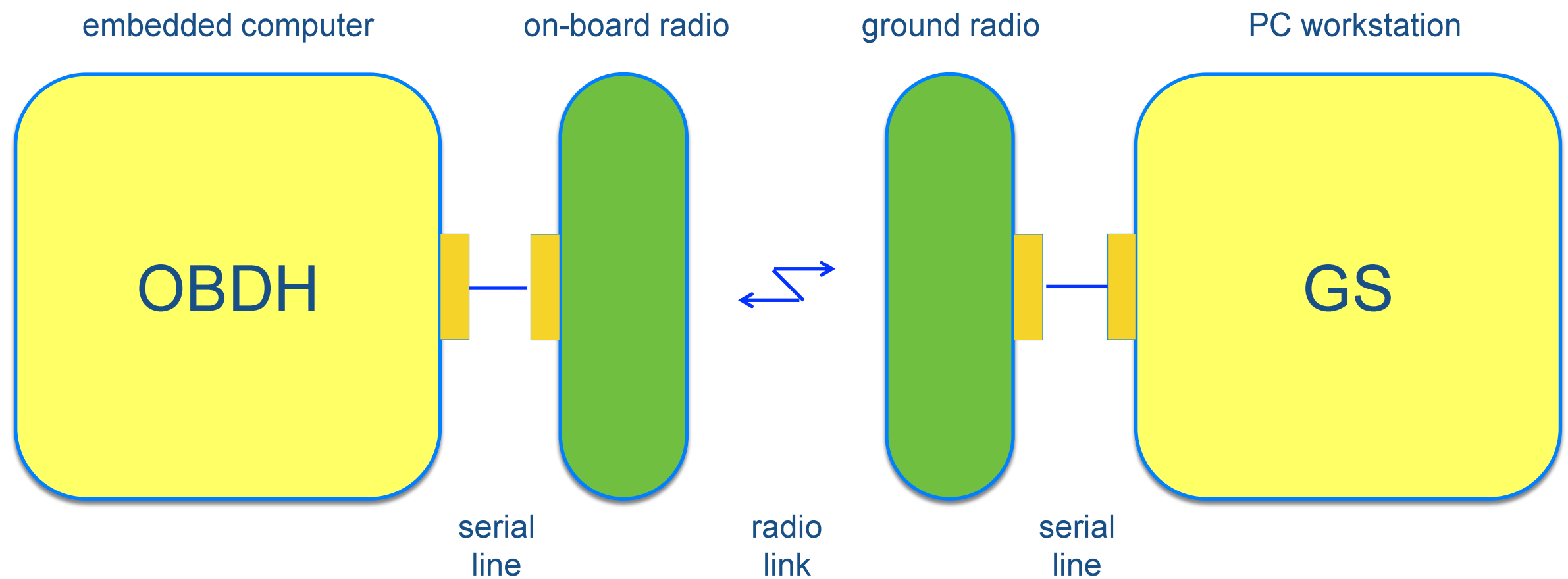
serial
line

Ground station test arrangement

embedded computer

PC workstation

OBDH

TC TM

serial line

GS
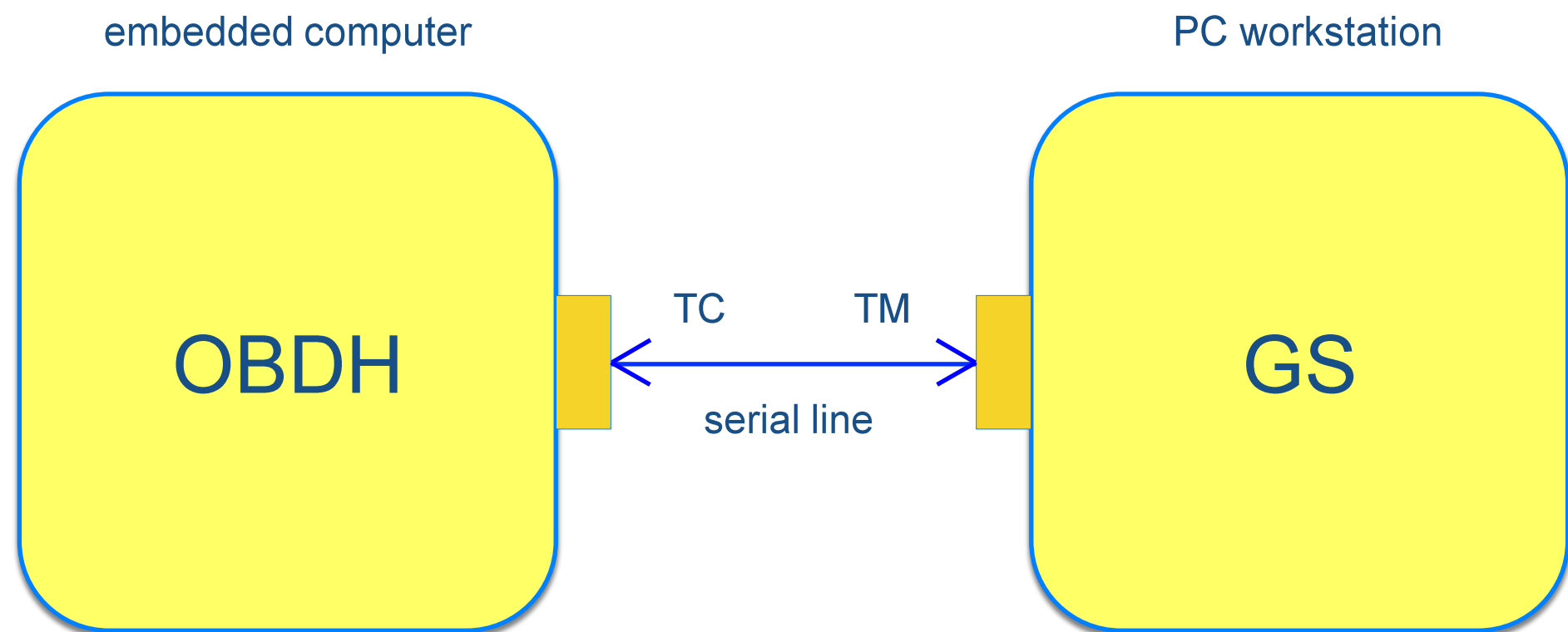
Ground station output


```
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 <u>STR-UPM OBDH_LABS</u> 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 and pyserial.py

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		$2 \cdot 10^{-6}$			

Response time analysis

- **The response time equation is**

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

  ‣ not continuous nor linear
  ‣ cannot be solved analytically

Linear iteration

- The response time equation can be solved by the following recurrence relationship:

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

‣ the succession $w_i^0, w_i^1, w_i^2, ...$ es non-decreasing monotonic

‣ an acceptable initial value is $w_i^0 = C_i + B_i$

‣ the iteration ends when

- a) $w_i^{n+1} = w_i^n$ (and then $R_i = w_i^n$), or
- b) $w_i^{n+1} > T_i$ (deadline missed)

Example

In the previous example

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

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

$$w_2^1 = C_2 + B_2 + \left\lceil \frac{w_2^0}{T_1} \right\rceil \cdot C_1 = 20 \cdot 10^{-6}$$

$$w_2^2 = C_2 + B_2 + \left\lceil \frac{w_2^1}{T_1} \right\rceil \cdot C_1 = 20 \cdot 10^{-6}$$

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

etc.