The HEV* Project

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*High Energy community Ventilator

EP Experimental Physics Department

HEV Driving Principles

- **HEV is designed in response to the Covid-19 crisis**
  using guidelines from various bodies (MHRA, FDA, WHO, ISO)

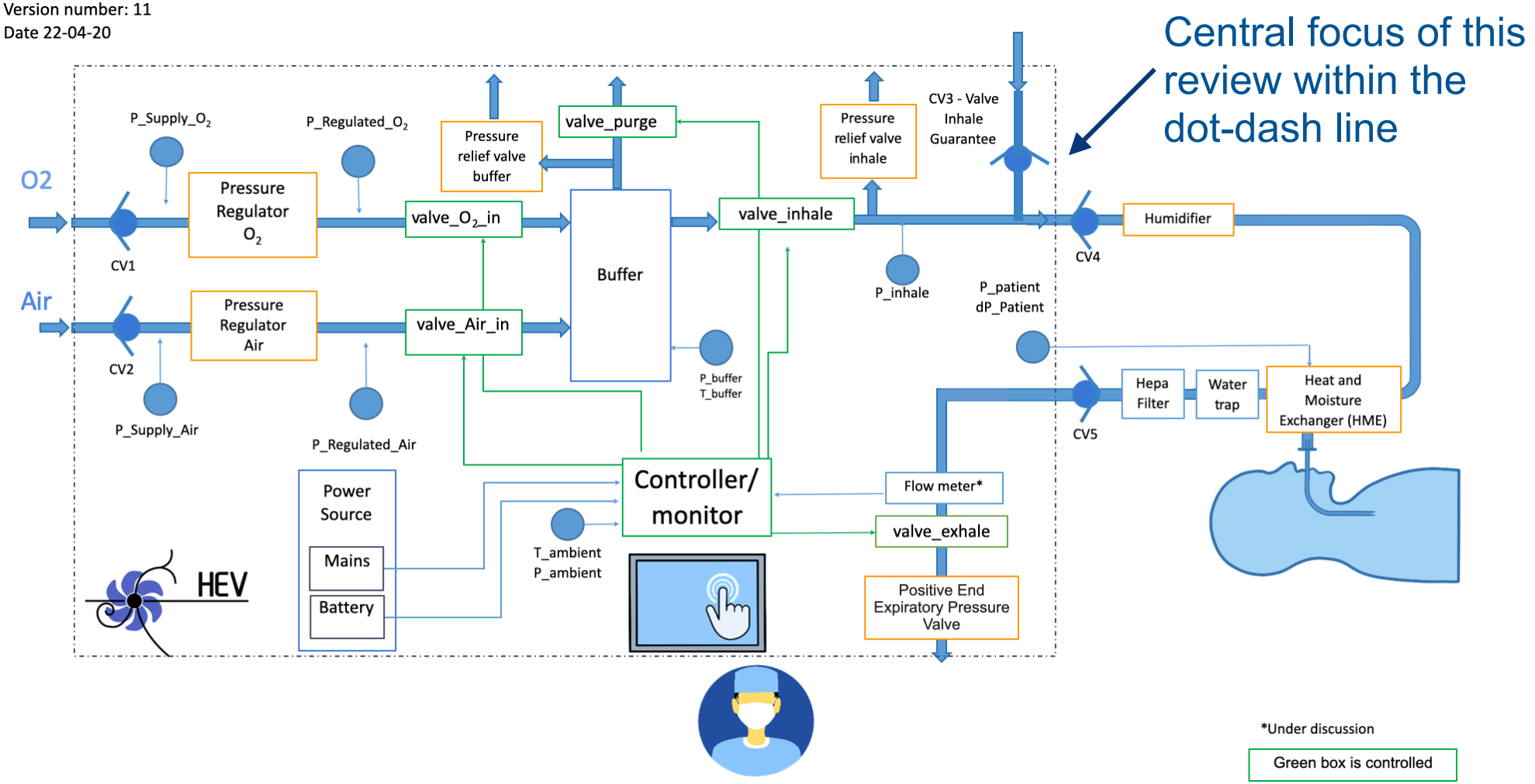
- HEV aims to cover the the vast majority of requirements for a **high quality ventilator**, and can be deployed to **multiple environments**

- HEV is based on **inexpensive** and **readily available** components.
  Designed to be rapid and simple to construct

- ***Patient Comfort and, obviously, Patient safety are primary concerns***

Design Outline

Version number: 11
Date 22-04-20

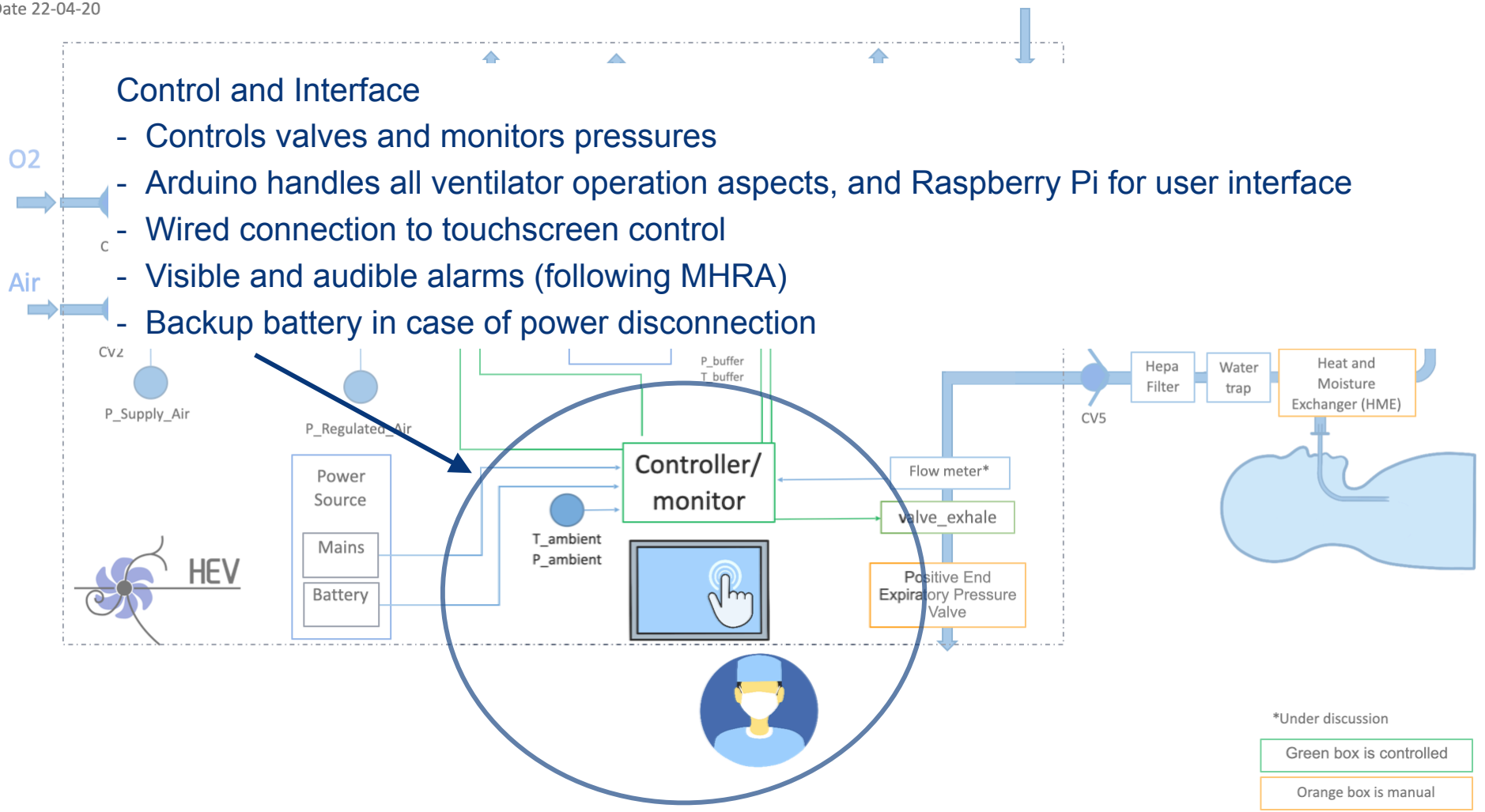


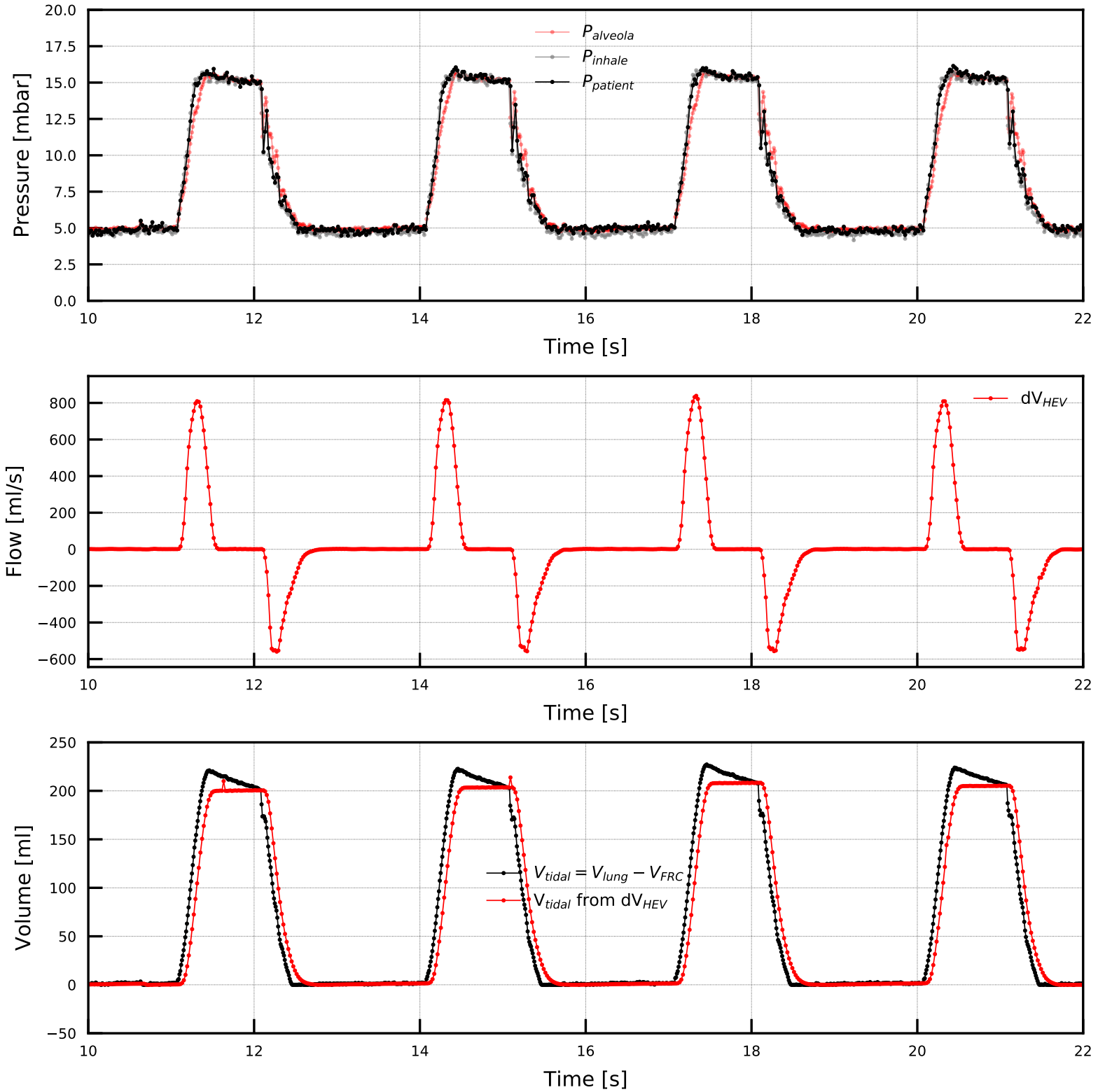
Design Outline - embedded controls

Version number: 11
Date 22-04-20

Control and Interface

- Controls valves and monitors pressures
- Arduino handles all ventilator operation aspects, and Raspberry Pi for user interface
- Wired connection to touchscreen control
- Visible and audible alarms (following MHRA)
- Backup battery in case of power disconnection




Pressure [mbar]
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
$P_{alveola}$
P_{inhale}
$P_{patient}$
10
12
14
16
18
20
22
Time [s]
Flow [ml/s]
800
600
400
200
0
−200
−400
−600
dV_{HEV}
10
12
14
16
18
20
22
Time [s]
Volume [ml]
250
200
150
100
50
0
−50
$V_{tidal} = V_{lung} - V_{FRC}$
V_{tidal} from dV_{HEV}
10
12
14
16
18
20
22
Time [s]

Who is HEV

Three core development teams: Pneumatic/Mechanical, Electronics, Controls

Small core groups (~ 6 people) mainly drawn from LHCb Members, consisting of CERN and external institutes.

Extremely significant workload over the last four weeks.

Technical support and resources from “CERN against COVID-19” group, webpage here

Special technical and practical support from:

CERN EP-DT (Detector Technologies) group, in particular for mechanical design, choice and control of pneumatic components

CERN EP-ESE (Electronics Systems) group, in particular for electronics design and integration

CERN HSE (Safety at CERN) unit, in particular for medical contacts, working practices at CERN during Covid-19 era, working relationship with HUG, conformity with applicable legislation and health and safety requirements

CERN BE-CO, BE-ICS, webpage, open source consultation, functional safety analysis of control systems

CERN DG-LS, IPT-KT, ongoing consultation on deployment, knowledge transfer and legal aspects

University of Liverpool, EPFL (Lausanne) for financial support for the purchase of TestChestLight (only significant investment, device will be relocated appropriately after this phase of the HEV project is finished)

EPFL (Lausanne) for the development of a relationship with the CHUV clinical team

Arxiv author list reflects participation

https://arxiv.org/pdf/2004.00534.pdf

University of Liverpool (Liverpool), EPFL (Lausanne), UFRJ (Rio de Janiero), IGFAE/USC (Santiago de Compostela), Nikhef (Amsterdam), University of Manchester (Manchester), University of Nis (Serbia), CUT (Cracow), University of Applied Sciences (Offenberg)

Who is HEV

HEV has profited greatly from the advice drawn from the support groups of clinicians (respiratory therapists, anesthetiologists, medical engineers etc…)

Lise Piquilloud, Patrick Schoettker, CHUV, Lausanne
Philipp Rostalski and Georg Mannel, Luebeck University
Laurence Vignaux; Hôpital de La Tour, Geneve
Josef Brunner: Neosim, and ventilator design
Gordon Flynn and David Reiner; Canberra Hospital, Canberra
Hamish Woonton: Dandenong Hospital, Dandenong
Bruce Dowd, Prince of Wales Hospital, NSW
Carl Roosens, University Hospital Ghent
M. de Carvalho, N. Dousse, M. Saucet, HUG Geneve

Design constantly improved following precious feedback from these experts

Special thanks to the HUG who have loaned equipment, via the special collaborative agreement between CERN and HUG, and to the Pneumology and Cardio-Respiratory services and NIC centre of Hôpital de La Tour

HEV Prototype (#3 of 3)