

# INSPIRE - 100



***An Emergency Ventilator Device***



*Unmatched Affordability*

*Unmatched Remote Monitoring via WiFi*

*Unmatched Ease-of-use*

*No need for compressed Air Pipeline*

*Connect to Oxygen Cylinder or Concentrator*

*Full range of Mainstream Respiration Parameters*

*Breath Synchronization for Patient Comfort*

*Field Upgradeable*

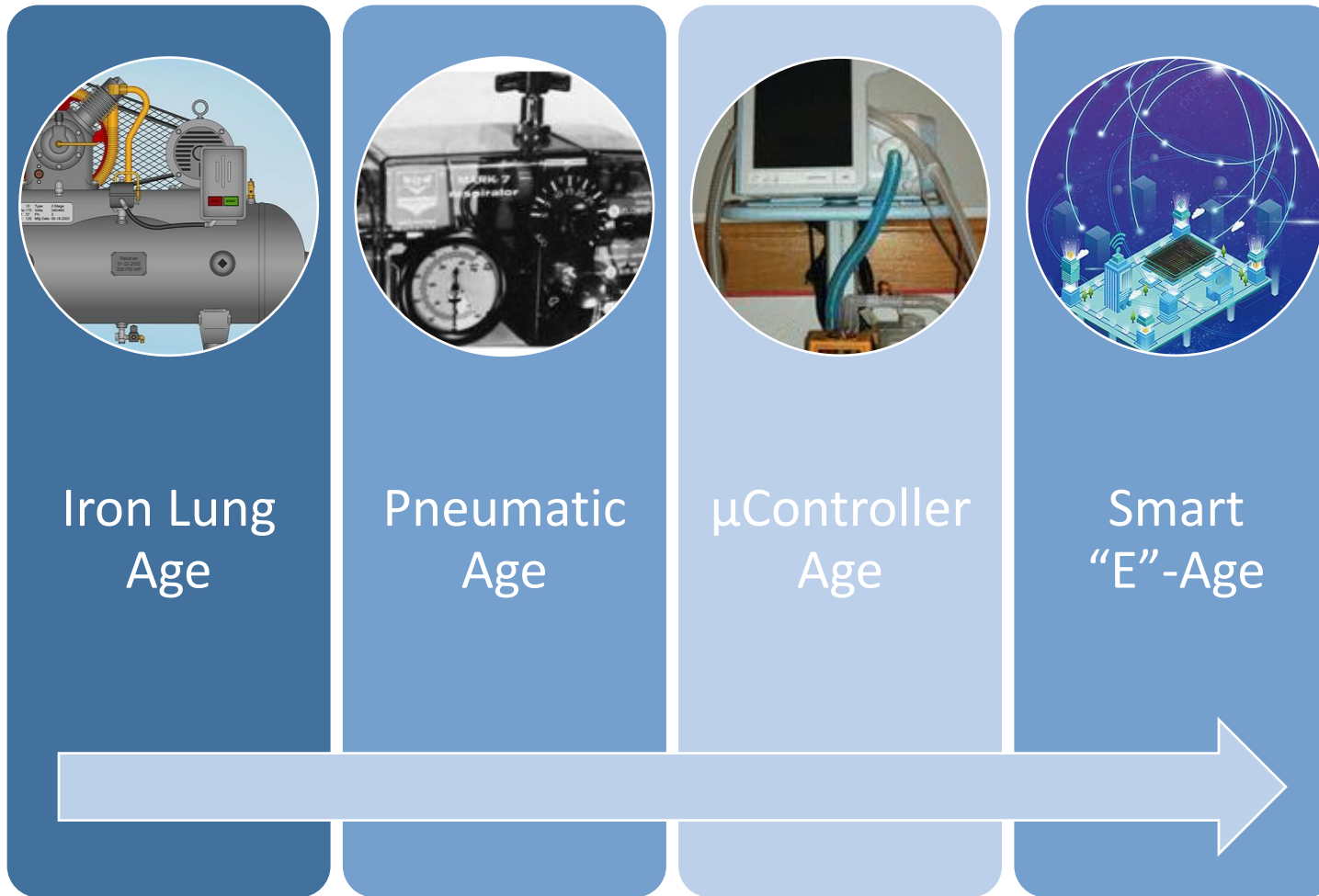
*Rugged and Robust*

# *Setting the Context*

The Problem Statement

The Motivation

# Evolution of Ventilators



## Most-used Ventilation Modes have not changed

- Volume and Pressure Control
- Control BPM, I/E, VT and PS
- Monitor pressures and flow
- Safety Alarm systems

## Diminishing Returns from what has evolved ...

- Exotic Ventilation modes
- Multitude of Sensors
- Touch-screen Displays

# The Problem Scarcity & Affordability



## India has amongst the lowest per capita ICU beds in the World\*

- 1.46 beds / 1000 people\*
- 3.65 ICU beds / Lakh people\*
- Only half of ICU beds are equipped with Ventilators
- A meagre 1.8 Ventilators for one lakh people\*

ICU ventilators are expensive equipment

- Unaffordable in remote clinics

Ventilator Ambulances are

- Non-existent except in few urban centers,

*\* As per April 2020 Study by Center for Disease Dynamics, Economics & Policy at Princeton University, USA*



# Respiration Assist Devices

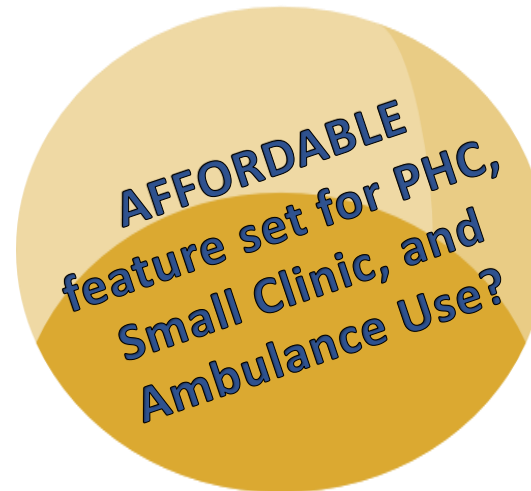
## Categories – Usage and Pricing



CPAP



BiPAP

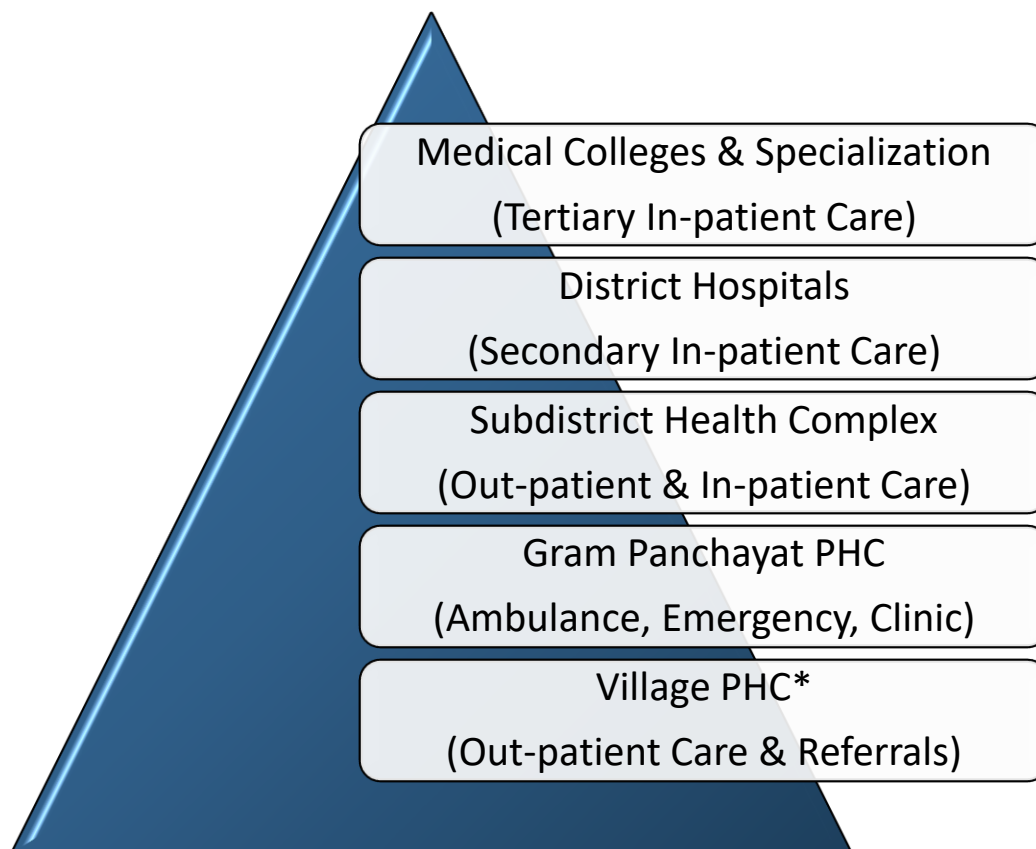


Big Hole



ICU Ventilator

# The Motivation



*\*As of 2021, there were **1,56,231 Primary Health Centers (PHCs)** in India with minimal infrastructure*



Provide a robust, portable ventilator system for facilities that lack sophisticated hospital infrastructure



A system that requires minimum training and provides ventilation support from initiation to weaning with full range of mainstream parameters



A system that can supplement the scarce, expensive ICU Ventilators, sparing them for more complex cases



A system within the budget of the bottom of the pyramid at a fraction of the cost of an ICU Ventilator



A system to bridge the gap between nothing and an expensive ICU ventilator



A system that works in harsh uncontrolled environments and as a travel ventilator

# *INSPIRE-100 Details*

System Components

Technical Details

# Elegance in Simplicity



*Simple, Easy-to-read Front Control Panel*

*Prominent, Always-on Parameters Display*

*Menu-driven HMI*

*Prominent, Tactile Control Buttons*

*LCD Screen for Menu and Message Display*

*Colored LEDs show System state at-a-glance*

*Brightness and Buzzer Volume Controls*

*Backed by Comprehensive Remote Displays*



# Product Overview

## Salient Features

Exceptionally  
Budget Friendly

Comprehensive  
Remote  
Monitoring

Easy-to-use  
Easy-to-train  
Rugged & Robust

Works without  
Compressed air or  
Piped O<sub>2</sub>

Complete Set of  
Mainstream  
Respiration  
Parameters

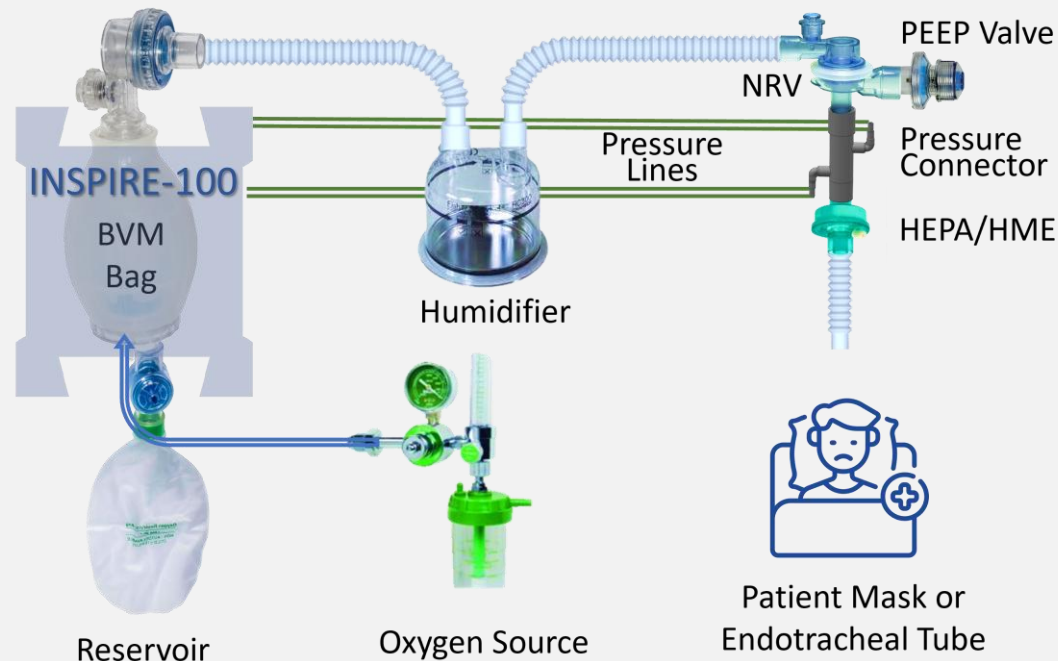
Power  
Consumption  
100W

## Patient Comfort

Mandatory Breaths  
synchronized with  
Patient-initiated  
Breaths

No breath stacking

## Breathing Circuit



$$Q \propto \sqrt{\frac{(P_{G1} - P_{G2})}{(P_{G1} + P_{G2}) + 2 \cdot P_{atmosphere}}}$$

An important and necessary simplification is that  $P_{G1}$  and  $P_{G2}$  encountered in our system are of the order of tens of cmH<sub>2</sub>O while  $P_{atmosphere}$  is of the order of a thousand cmH<sub>2</sub>O of pressure. At sea level,  $P_{atmosphere}$  is approximately 1000 cmH<sub>2</sub>O. Even at an altitude of 15,000 feet,  $P_{atmosphere}$  is approximately 600 cmH<sub>2</sub>O. On the other hand, the  $P_{G1}$  and  $P_{G2}$  in the system range from 1 cmH<sub>2</sub>O to 60 cmH<sub>2</sub>O.

Thus the  $(P_{G1} + P_{G2})$  term is negligible compared to  $(2 \cdot P_{atmosphere})$ , even at sea level since it is preceded by a square root. The equation can be simplified to the one below.

$$Q \propto \sqrt{\frac{P_{G1} - P_{G2}}{2 \cdot P_{atmosphere}}}$$

Recalling Equation 2 from the theory section, the equation can be recast as below given that the orifice characteristics and pressure characteristics are the same for every system.

$$Q = C \cdot \sqrt{\frac{P_{G1} - P_{G2}}{P_{atmosphere}}} \quad \text{where } C = f(Re) \text{ Reynold's number}$$

At a given geographical location,  $P_{atmosphere}$  is also a constant. So, the above equation further reduces to the one below.

$$Q = \left( \frac{C}{\sqrt{P_{atmosphere}}} \right) \cdot \sqrt{(P_{G1} - P_{G2})}$$

The equation needs further simplification to ease the computation burden of the square root computation for an inexpensive micro-controller. The constraints are as below.

## Commonly used Ventilation Modes

<b>CMV</b>	Continuous Mandatory Ventilation
<b>ACV</b>	Synchronized Assist Control Ventilation
<b>SIMV</b>	Synchronized Intermittent Mandatory Ventilation
<b>PSV</b>	Pressure Support Ventilation (BiPAP equivalent)

## Full Set of Alarm Alerts

Max Pressure	Pressure Leak	Pressure Loss
Airway Blockage	Coughing Hiccupping	Inconsistent Parameters
Extreme Parameters	System Temperature	And many more ...

## Volume Controlled Breaths

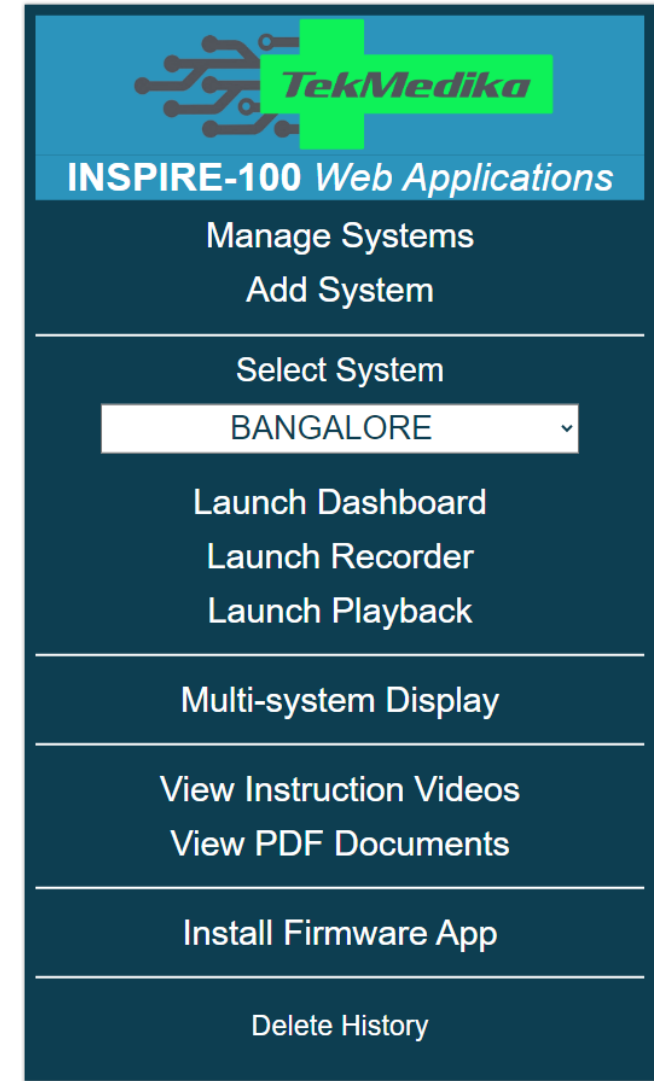
<b>Tidal Volume</b> 200 - 600 ml	<b>Respiratory Rate</b> 10 - 30 bpm	<b>I:E Ratio</b> 1:1   1:2   1:3
<b>PEEP</b> 4 - 15 cmH <sub>2</sub> O	<b>Max Pressure</b> 15 - 60 cmH <sub>2</sub> O	<b>FiO<sub>2</sub> Support</b> System Managed Externally Controlled

## Pressure Supported Breaths

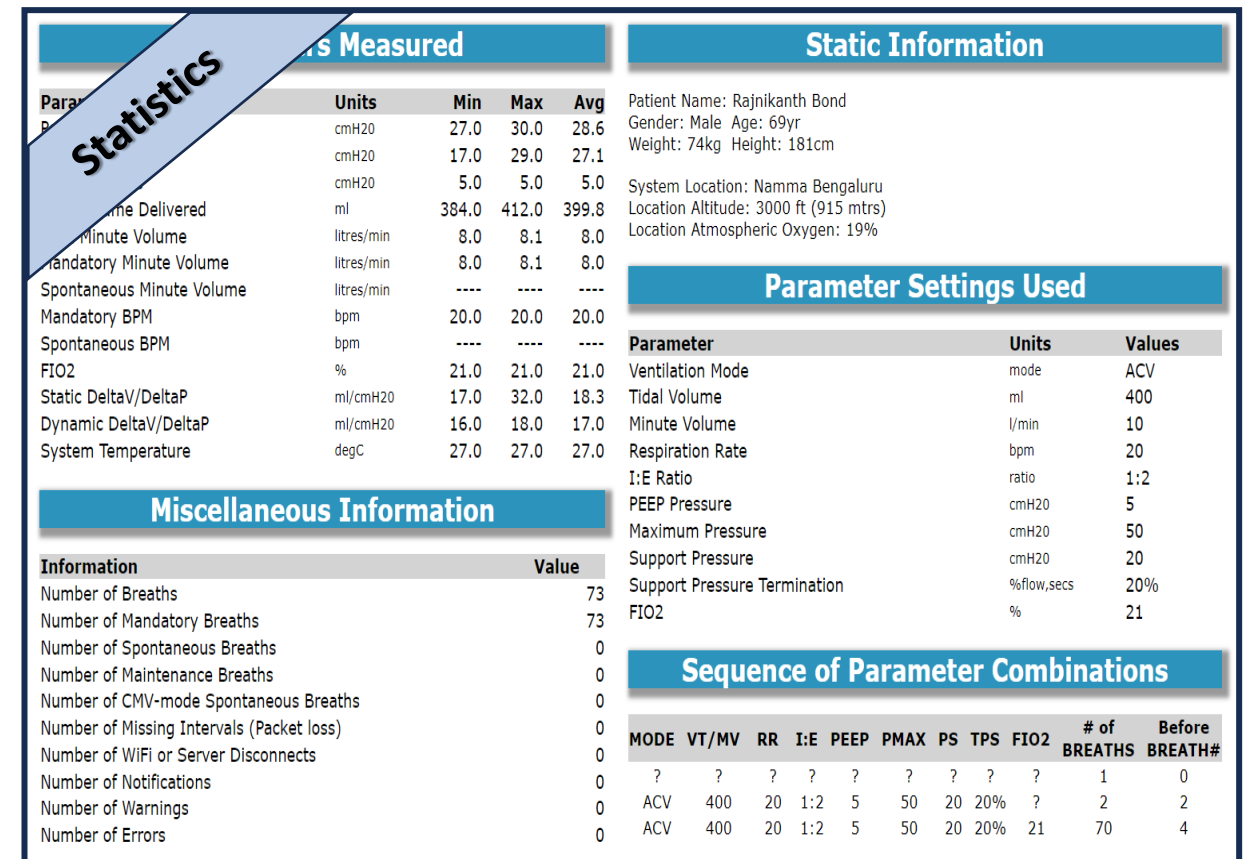
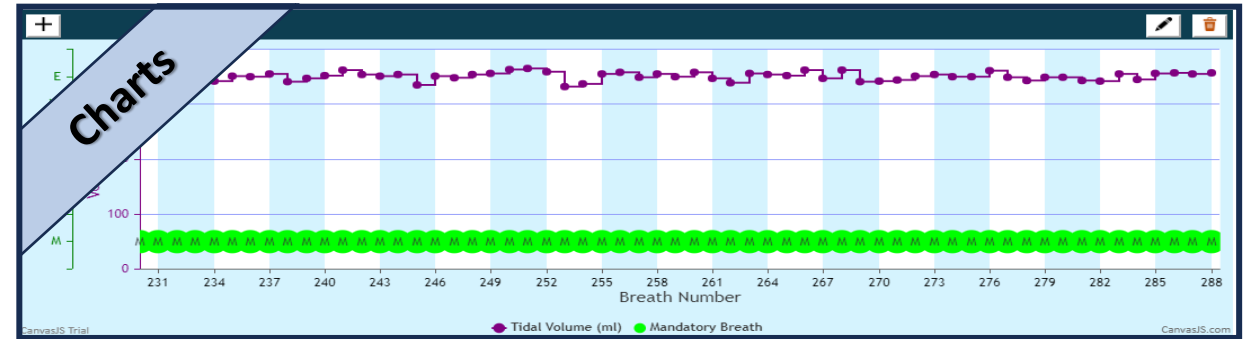
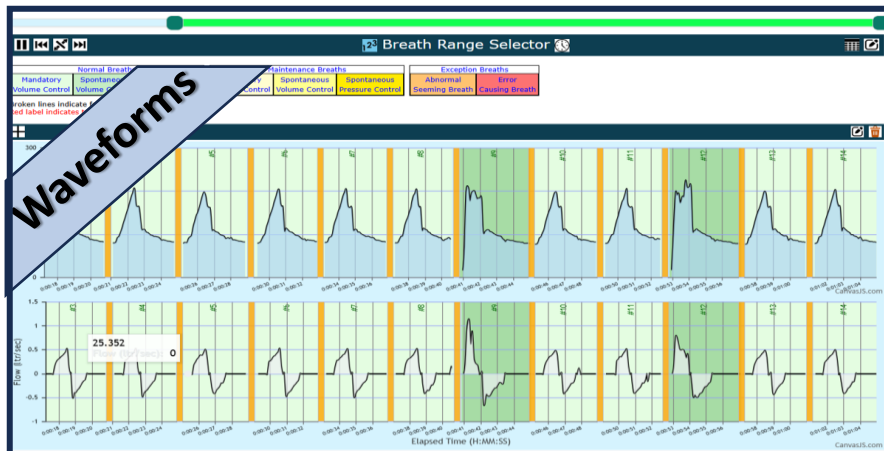
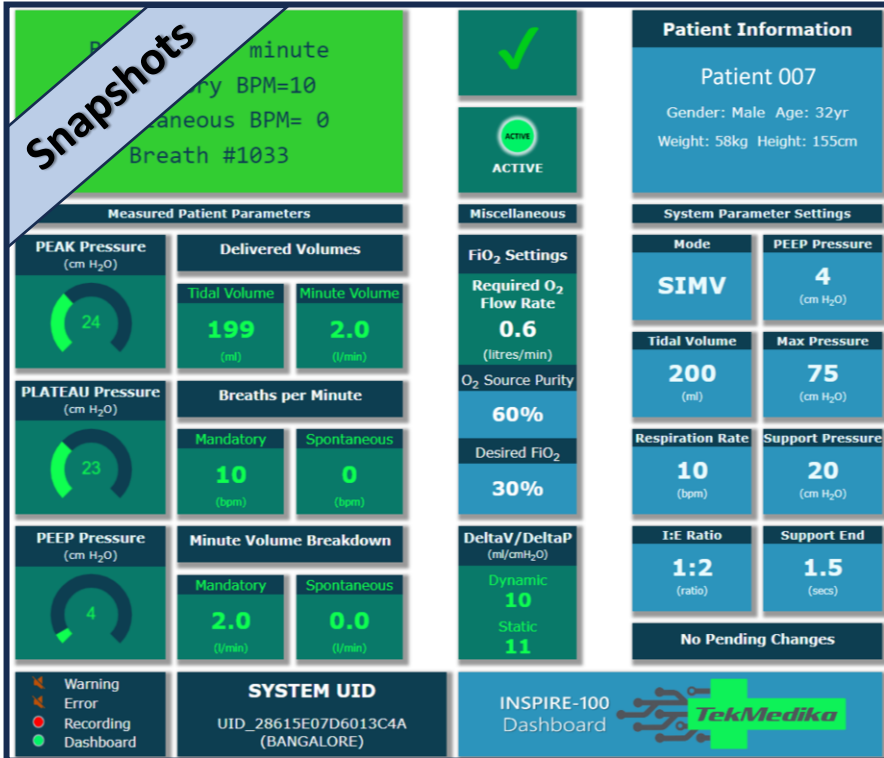
<b>Support Pressure</b>	5 - 35 cmH <sub>2</sub> O
<b>Support Pressure Termination</b>	Flow Triggered Time Triggered

# Elaborate Remote Monitoring

- ✓ Live Dashboard
- ✓ Detailed Breath Waveforms
- ✓ Charts for all Parameters
- ✓ Detailed Statistics
- ✓ System Alerts and Alarms
- ✓ Recording and Playback
- ✓ Multi-system Display



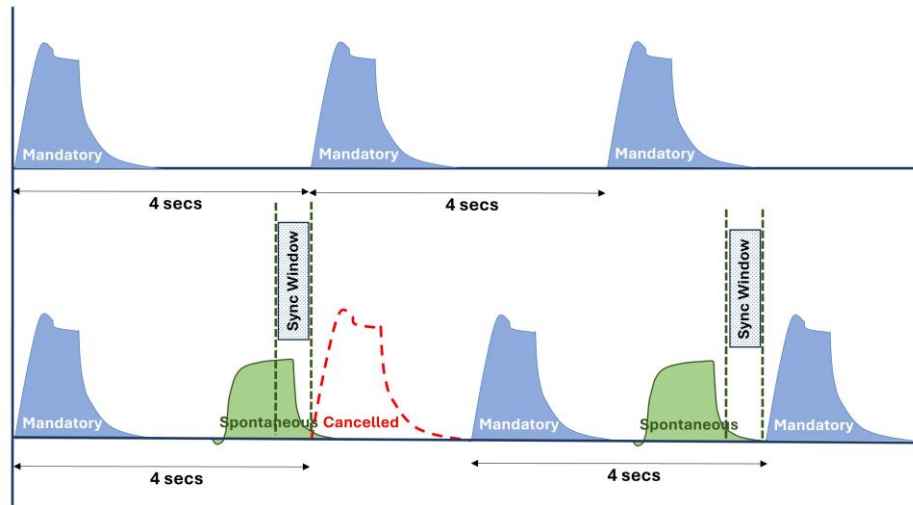
# Remote Monitor Screenshots



## Synchronize Mandatory breaths with Spontaneous breaths Prevent breath stacking

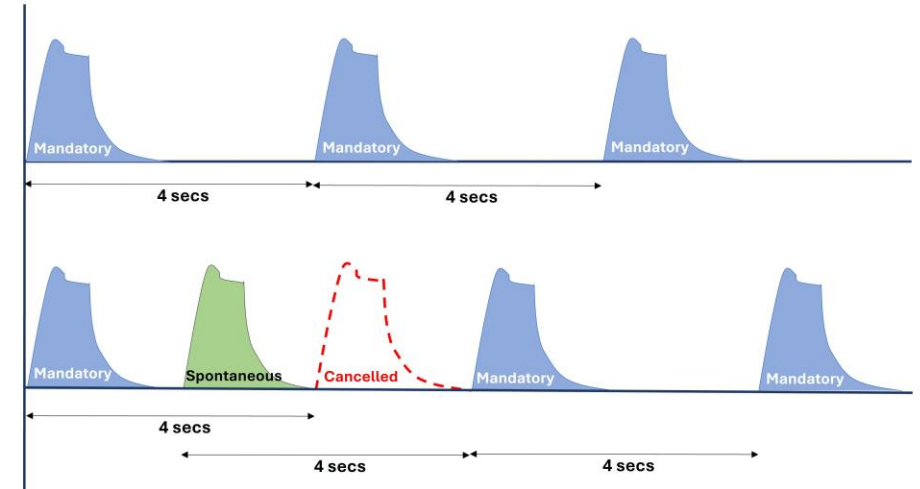
### Breath Synchronization in SIMV Mode

e.g. RR=15 bpm (4 secs per breath)



### Breath Synchronization in ACV Mode

e.g. RR=15 bpm (4 secs per breath)





# FiO<sub>2</sub> Settings

Without the Reservoir bag, FiO<sub>2</sub> delivered is the Atmospheric O<sub>2</sub> content at site

FiO<sub>2</sub> delivery with the Reservoir bag is mathematically modelled, calibrated and verified in the Lab to provide +/- 10% accuracy

Front-panel guides the user in setting the appropriate input O<sub>2</sub> flow rate from the O<sub>2</sub> source for a given FiO<sub>2</sub>

The mathematical model provides for an O<sub>2</sub> concentrator as an O<sub>2</sub> source (purity < 100%)

To Patient

Tubing to  
Oxygen  
Source



## INSPIRE-100 FiO<sub>2</sub> Calculator



Required Incoming O<sub>2</sub> Flow

0.0 (litres/min)

Altitude: 0 feet

Desired VT (ml)



Desired RR (bpm)



O<sub>2</sub> Purity (%)



Desired FiO<sub>2</sub> (%)



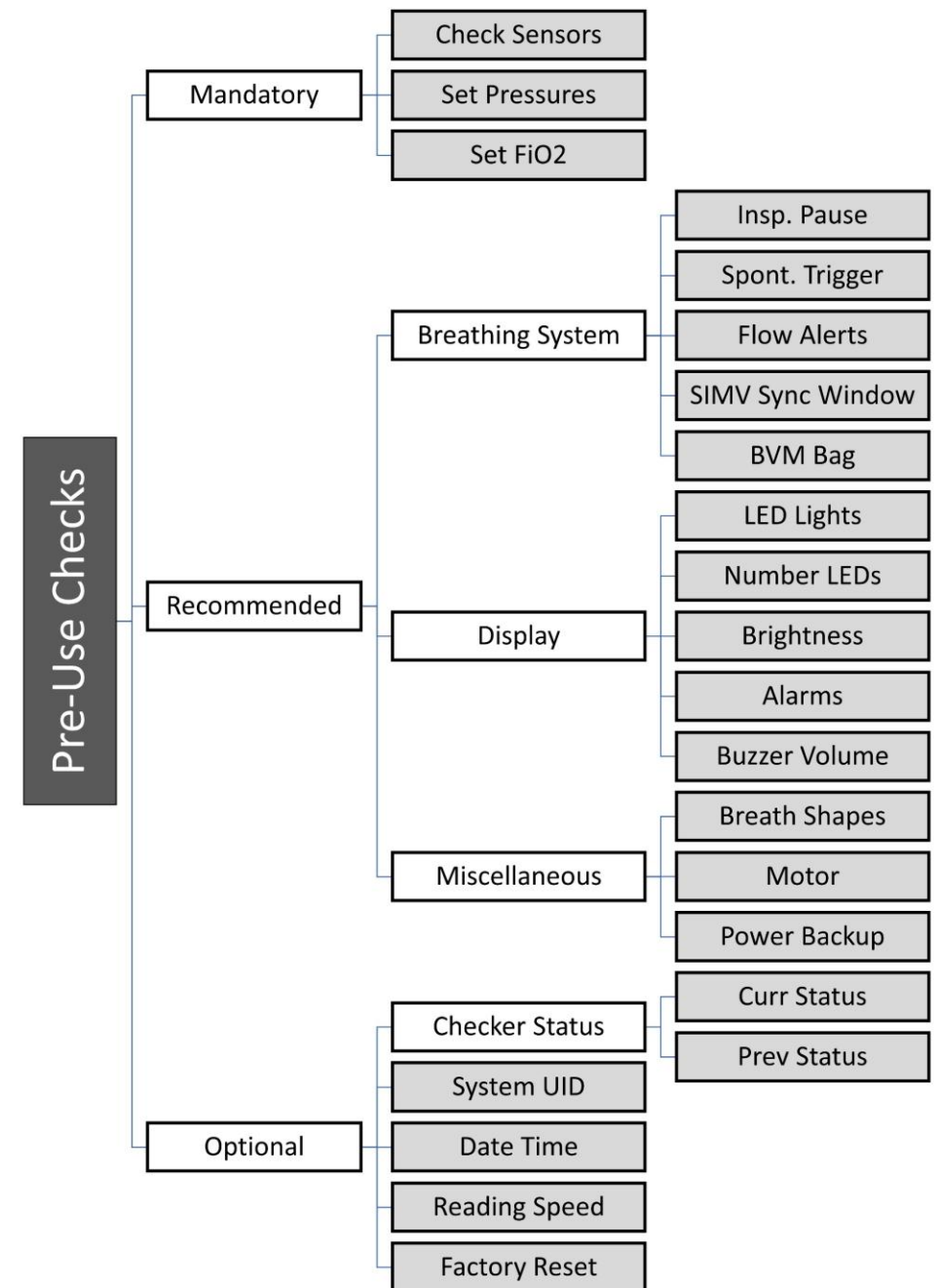
# Alarms & Safety Features

## Enforcement of Pre-use checks

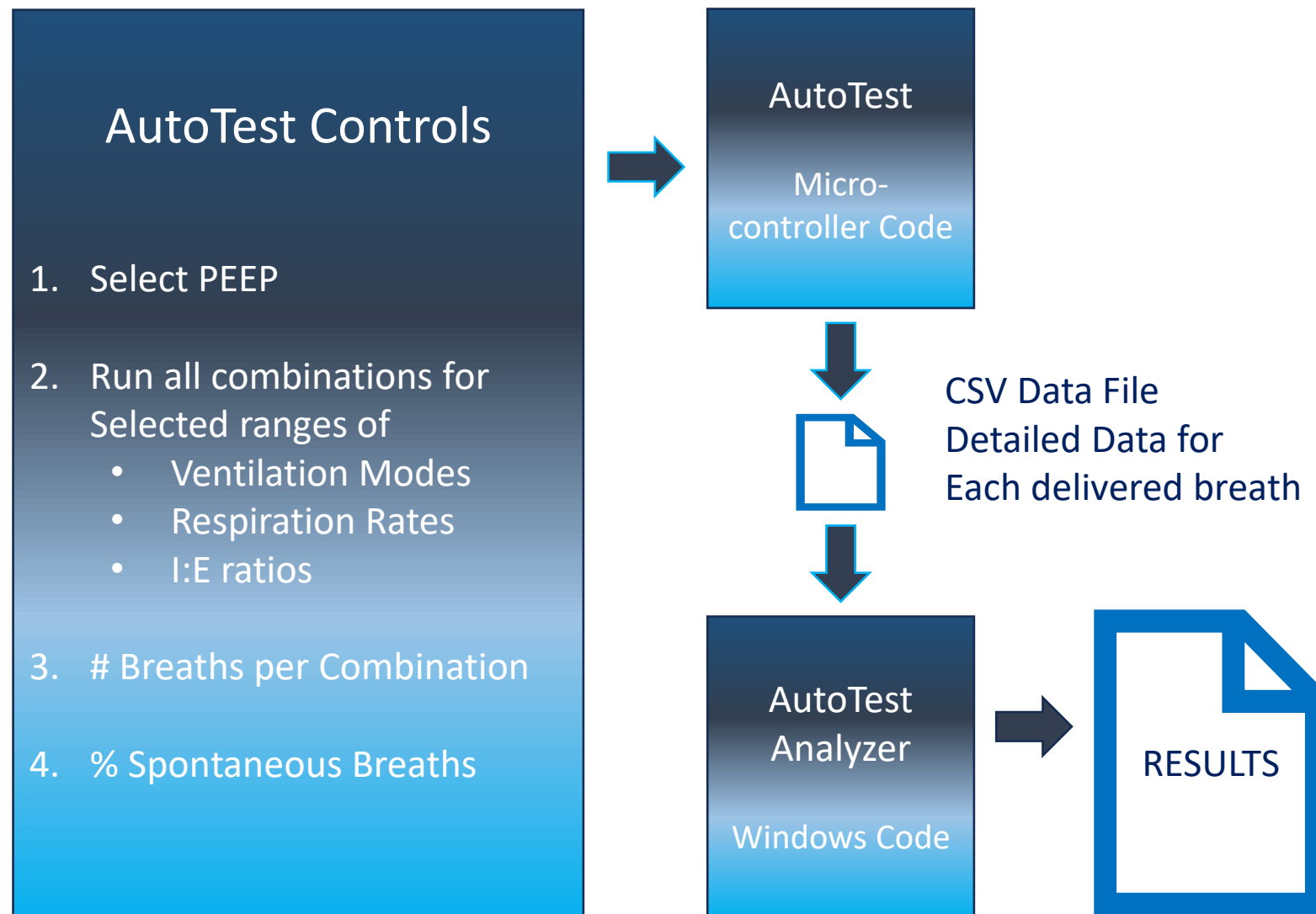
## Maintenance Breaths till Alarm situation rectified

## Alarms, Warnings and Notifications

- Max Pressure Alarm
- Pressure Leak Alarm
- Pressure Loss Alarm
- Airway Blockage Alarm
- System Temperature Alarm
- Sensor Failure Alarm
- Breathing Circuit Failure Alarm
- Detect coughing/hiccupping fits
- Inconsistent input parameters
- Extreme parameter combination warnings
- And many more ...



# Extensive Automated Testing



*BACKUP*

# CPAP v/s BiPAP v/s INSPIRE-100 v/s ICU-VENTILATOR

CPAP	BiPAP	Respimatic 100	ICU Ventilator
Continuous Positive Airway Pressure	Continuous Bi-Level Airway Positive Pressure	Mechanical Ventilation with 4 most-used ventilation modes and controls	Mechanical Ventilation with very sophisticated modes and controls
Non-invasive	Non-invasive	Non-invasive + Invasive	Non-invasive + Invasive
High Flow + PEEP	Inspiratory Pressure + PEEP	Tidal Volume + Support Pressure + PEEP	Tidal Volume + Support Pressure + PEEP
Useful for Type 1 respiratory Failure (Hypoxemic)	Useful for Type 2 respiratory Failure (Hypercapnic)	Useful for Hypoxemic and Hypercapnic respiratory failure	Useful for Hypoxemic and Hypercapnic respiratory failure
Continuous flow of air at a constant pressure. Increases mean airway pressure to recruit collapsed alveoli	Continuous flow of air at different constant pressures during inspiration and expiration breathing phase	Independent control over the volume, the respiration rate and pressure	Independent control over the volume, the respiration rate and pressure
Useful only when patient can breathe on his own	Useful only when patient can breathe on his own	Useful when patient can or CANNOT breathe on his own	Useful when patient can or CANNOT breathe on his own
Only Spontaneous breaths that are patient triggered.	Only Spontaneous breaths that are patient triggered.	Spontaneous breaths + Mandatory breaths controlled by RR and I:E	Spontaneous breaths + Mandatory breaths controlled by RR and I:E
External FiO2 control	External FiO2 control	System assisted FiO2 control	Direct FiO2 control
Breath Synchronization N/A	Breath Synchronization N/A	Full Breath Synchronization	Full Breath Synchronization
No Tidal Volume control	Indirect Tidal Volume control (IPAP-EPAP)	Direct Tidal Volume control	Direct Tidal Volume control
No Respiration Rate control	No Respiration Rate control	Direct Respiration Rate control	Direct Respiration Rate control
No Inspiration:Expiration ratio control	No Inspiration:Expiration ratio control	Direct Inspiration:Expiration control	Direct Inspiration:Expiration control
External Humidity control	External Humidity control	External Humidity control	Direct Humidity control
No display of Peak, Plateau or PEEP	No display of Peak, Plateau or PEEP	Full display of Peak, Plateau and PEEP	Full display of Peak, Plateau and PEEP
Minimal alarm signals	Minimal alarm signals	Full set of Alarm signals	Full set of Alarm signals
No remote monitoring	No remote monitoring	Sophisticated Remote WEB Dashboard	Minimal Remote monitoring (if any)



*Thank You*