National Aeronautics and Space Administration

Technology Opportunity

Technology Transfer & Partnership Office

TOP3–00231

Portable Unit for Metabolic Analysis (PUMA)

Technology

The National Aeronautics and Space Administration Glenn Research Center (NASA GRC) has developed an innovative device that measures the six key quantities (oxygen, carbon dioxide, flow, temperature, pressure, and heart rate) needed to evaluate human metabolic function. The Portable Unit for Metabolic Analysis (PUMA) is a rugged, self-contained, device capable of measuring metabolic function at rest, during exercise, in clinical settings, or in the field.

Benefits

- Battery powered, and self contained, with an electronics box that fits into a small wearable pack
- PUMA offers several significant advantages over currently available portable and commercial units, including
  - Highly timed-resolved measurements of all relevant quantities, eliminating timing issues present in other devices
  - Integration of gas concentration profiles to obtain breath-by-breath analysis, providing more accurate information than the single concentration per breath measurement obtained by other units
  - Superior technology allowing for measurements of both volume-averaged and end-tidal gas
  - Placement of essential sensors closer to the mouth than other units, eliminating common timing problems and allowing for the sampling of a larger portion of both the inhale and exhale stream

Commercial Applications

PUMA's targeted applications include a variety of situations where basic physiological measurements are required, including

- Determining the caloric requirements of daily living activities for development of dietary/nutrition/weight-loss programs
- Field testing, training, and coaching of athletes to optimize performance and design training programs
- Obtaining occupational fitness evaluations (e.g., Department of Defense and firefighters) to develop training programs and determine metabolic cost of varied activities
- Performing nutritional studies to determine the effect of certain foods on metabolic rate in a clinical environment
- Assessing the nutritional requirements of critical care patients to develop appropriate diets
- Performing periodic evaluations of fitness center clientele
- Performing in-office measurements of obese patients to develop and optimize diet and exercise programs

The PUMA oxygen and carbon dioxide sensors can also be used in any application requiring accurate, portable, and time-resolved measurements of these gases.

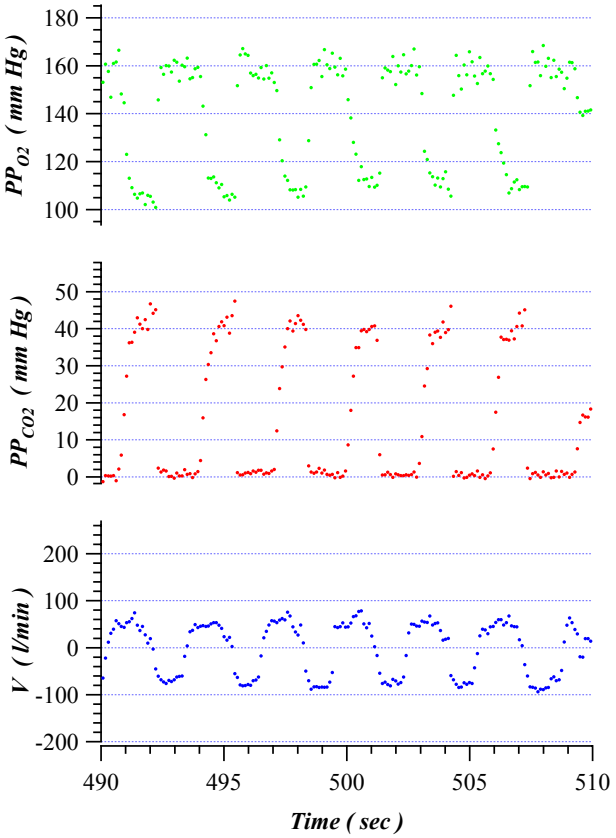
A picture of the prototype PUMA unit. The headgear contains oxygen and carbon dioxide sensors on the left side and the flow sensor on the right side. The sensors are optically and electrically tethered to the electronics box (to the left of the headgear). The electronics box fits into a small wearable pack and is powered by a commercial camcorder battery.

Technology Description

The Portable Unit for Metabolic Analysis is a portable unit that measures six quantities necessary to evaluate metabolic function (particularly during exercise), oxygen and carbon dioxide partial pressure, volume flow rate, heart rate, and gas pressure and temperature. From these fundamental measurements, PUMA can compute the oxygen uptake (rate of oxygen consumption), carbon dioxide output (rate of carbon dioxide production), and minute ventilation (expiratory gas flow rate). The unit is completely portable, battery powered, and connects wirelessly to a laptop computer.

PUMA utilizes individual sensors to measure oxygen, carbon dioxide, flow, pressure, temperature, and heart rate. The oxygen subsystem uses the fluorescence quenching properties of a ruthenium-based dye. The carbon dioxide subsystem uses the strong and unique infrared absorption properties of carbon dioxide. The flow measurement subsystem utilizes a modified commercial ultrasonic sensor. Commercial sensors are used for pressure, temperature, and heart rate.

PUMA provides most of the functionality of a commercial metabolic cart in a unit that is rugged, wearable, and easy to operate. A small embedded computer controls all the subsystems and samples each sensor at 10 Hz. This computer performs rudimentary calculations and relays the data wirelessly and in real time to a remote computer via bluetooth. The remote computer stores and displays the relevant metabolic quantities in real time.



Sample data stream from PUMA during human subject testing. The graph shows the volumetric flow rate (bottom), and carbon dioxide (middle) and oxygen (top) partial pressures as a function of time. PUMA integrates the flow and concentration data with time over a single breath to obtain breath-by-breath data.

PUMA minimizes and often eliminates the timing and sample dilution problems of existing commercial portable and fixed units by (1) sampling the inhale/exhale stream at an accelerated rate (10 Hz), making intra breath measurements and (2) sampling the gas stream very close to the mouth. Commercial devices sample a fraction of the exhale/inhale gas stream and typically make a single gas concentration measurement, which is time-delayed from the breath. PUMA makes multiple gas measurements per breath, and close to the mouth. PUMA also integrates the flow, oxygen, and carbon dioxide concentration measurements over a breath in real time, eliminating the limitations of other units. PUMA uses superior oxygen sensor technology with faster response, negligible drift, and no sensitivity to carbon dioxide (compared to currently available portable units).

Options for Commercialization

NASA has applied for a patent for PUMA. Current uses for PUMA include measuring the metabolic costs of different activities in the development of the new extra-vehicular activity (EVA) suit, measuring oxygen uptake during exercise in the Enhanced Zero-g Locomotion Simulator (eZLS), measuring maximal oxygen uptake during a bed rest study at the Cleveland Clinic and measuring resting metabolic rate during the NASA Extreme Environment Mission Operations (NEEMO) mission.

NASA is seeking an industrial partner to develop a commercial version of PUMA. Assistance for technology development is available from the NASA technical and commercialization staff.

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References

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Key Words

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