

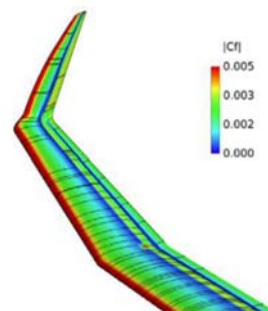


XXXIII OSTIV CONGRESS

8 - 13 January 2017

Benalla, Victoria, Australia

Congress Program and Proceedings



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Rolf Radespiel (Ed.)

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Welcome to the OSTIV Congress 2017 in Australia. Every two years the Congress offers new information and latest research results in soaring and sailplane technology to scientists and engineers from all over the world. The meeting presents unique opportunities for scientific exchange and coordination of future activities.

This year the Congress is hosted by the Gliding Federation of Australia, along with the 34th FAI World Gliding Championships, in Benalla, Victoria. We are thankful that the OSTIV Congress can take place in the Benalla Performing Arts Centre (BPACC) near the club house at Benalla Airfield.

We thank our industrial sponsors, Alexander Schleicher Segelflugzeugbau, GP Gliders, Jonker Sailplanes, and Schempp-Hirth Flugzeugbau, who made it possible for us to offer free access to the Congress and give special support to participating students.

The Call for Abstracts issued by OSTIV generated response by engineers and scientists from 11 countries worldwide. The received extended abstracts were reviewed, and they are published in this proceeding booklet. We believe that a varied program has been generated this way. For their efforts in recruiting high-quality contributions we acknowledge the members of the Program Committee:

Zafer Aslan, Turkey	Götz Bramesfeld, Canada	Helmut Fendt, Germany
Mark Maughmer, USA	Judah Milgram, USA	Ian Oldaker, Canada
Lukáš Popelka, Czech Republic	Rolf Radespiel, Germany	Gerard Robertson, New Zealand

Preparing the Congress took endless hours of work by the Organizing Team, consisting of Murray Stimson, Australia, Stu Smith, Australia, Rolf Radespiel, Germany and Britta Schlenker, Germany. We are very thankful for their efforts. Our thanks also go to Alexander Barklage and Tim Landa of Technische Universität Braunschweig for booklet editing.

The OSTIV Congress is the perfect setting to bestow the OSTIV Prize 2017 and the OSTIV Best Student Paper Awards. We look forward to the Opening Ceremony and the Congress Closing Dinner for presenting the Award Winners.

We wish all Congress participants an exciting and rewarding week in Benalla.

Prof. Rolf Radespiel	Prof. Mark Maughmer
OSTIV President	OSTIV Vice President

OSTIV acknowledges support provided by



Welcome to Benalla for the XXXIII OSTIV Congress

Benalla is a town of around 10,000 people situated 200km NE of Melbourne on the main Melbourne-Sydney train line and freeway (the “Hume”). It has been a significant regional town since European settlement the 1840s. The original inhabitants are the Taungurong people, who must have had abundant resources with the rivers, swamps, plains and hills in this rich area. Today Benalla’s resources for eating, entertainment and accommodation are greater than a town of its size due to it having a major Motor Racing circuit at Winton used most weekends except mid-summer, and Australia’s premier gliding club, GCV, to keep it busy over the summer. Benalla also boasts a major regional Art Gallery, many fine parks, a “must-see’ local museum, 2 Golf Clubs, a wide range of shops, cafés, restaurants and hotels.

The Great OSTIV BUS TOUR of North East Victoria

Wednesday 11th Jan. 2017

OSTIV delegates are invited to join in on this fun tour. Doug Hamilton of Precision Airmotive at Wangaratta has generously offered to allow us a special viewing of his Warbird Restoration business. Current aircraft include P-40 Kittyhawk, PT-22 Ryan, Lockheed 12, Harvard and many others in and around his business. P-40 construction is in progress. Doug expects to soon offer P-40 rides too!



From “Wang” the tour continues east to Milawa for a morning tea stop at this village bakery (user pays, not included in price). Passing through Myrtleford (quickstop) we head up to the Alpine plateau of Mt Buffalo for cool air and a scenic spot for lunch. You’ll get a good view of the alpine soaring conditions in the WGC contest area. We then descend and head to the Warby Ranges for wine tasting of our best Reds, Muscat, Tokay and Port, at a personal favourite, Baileys of Glenrowan, est. 1870. After a leisurely tipple, the tour picks up again and heads for the Winton Wetlands, a natural depression with much Australian birdlife. From there we’ll have you back at the airfield in time to see the finishing gliders.

Cost: \$30 per person includes lunch and wine tasting.

Departs: Benalla Airfield near BPACC. Meet 8.45am for a strict 9:00am departure

Please pay at registration time. OSTIV wishes to thank our Tour Partners:

Precision Airmotive & Classic Air Adventures – Doug Hamilton
 Absolutely Delicious – lunch cuisine from Sue & Kelly

Baileys of Glenrowan
 Benalla Bus & Coach Lines

OSTIV Congress Dinner @ North Eastern Hotel

Friday 13th January 2017

After the fascination of a solid week of technical presentations, all OSTIV Speakers, Delegates, family and friends of OSTIV are invited to enjoy a relaxed and friendly dinner together at the North Eastern Hotel in Benalla. (1Nunn St, near the Benalla Railway Station) from about 7:00 for 7:30 pm. This is really a lovely restaurant, disguised as a classic old Aussie country hotel. You’ll find excellent quality cuisine and a great range of wines. Drinks from the bar, pay as you go, and order meals off the menu, so you can eat light, or have couple of courses, or have 3 or more. No set fee, you pay for what you order. We’ll almost take over the whole place, so it could go late! It is centrally located and therefore walking distance to most accommodation. You can spend \$20 eating very light or \$100, but allowing \$50-60 each would be roughly two courses with a couple of drinks.

Please advise attendance and numbers at Registration desk when you register.

Stu Smith and Murray Stimson

	Sunday, 8 January 2017	
	Rotunda in the Rose Garden, Botanical Gardens, Bridge St, Benalla VIC 3672	
15:45 - 16:30	Opening Ceremony and Presentation of OSTIV-Prize 2017	
	Monday, 9 January 2017	
	Benalla Performing Arts Centre (BPACC), 57 Samaria Rd, Benalla VIC 3672	
08:00 - 10:00	registration	BPACC Room 3
	Aging Sailplane Structures Chair: Helmut Fendt	BPACC Room 1+2
09:00 - 09:30	PIK-20D GLIDER FATIGUE REVIEW. E. Soenne, Helsinki, Finland.	
09:30 - 10:00	RISK OF FLUTTER IN AGING SAILPLANES. U. Kopp, J. Gross, Braunschweig, Germany.	
10:00 - 10:30	A CASE STUDY IN GELCOAT CRACK PROPAGATION BELOW PU PAINT. R. Hanbury, Broadmeadows, Australia.	
10:30 - 11:00	coffee break	
	Sailplane Safety Chair: Helmut Fendt	BPACC Room 1+2
11:00 - 11:30	IS IT NECESSARY TO UPDATE SPIRAL DIVE REQUIREMENTS? G. Waibel, Bad Hindelang, Germany.	
11:30 - 12:00	PERCEPTUAL ERRORS IN THE TURN FROM BASE TO FINAL. D. Johnson, Menomonie, Wisconsin, USA.	
12:00 - 12:30	COMPARATIVE STATISTICAL ANALYSIS OF FATAL SPIN ACCIDENTS FOR TRAINING GLIDERS. S. Smith, M. G. Stimson, Melbourne, Australia.	
12:30 - 14:00	lunch break / registration	
	Electric Propulsion Chair: Helmut Fendt	BPACC Room 1+2
14:00 - 14:30	ELECTRIC PROPULSION FOR GLIDING - STATE OF THE ART AND FUTURE. A. Lange, Zweibrücken, Germany.	
14:30 - 15:00	SIDE-BY-SIDE FLYING WITH E-POWER: INDEPENDENT AND SAFE. L. Muth, Wildau, Germany.	
15:00 - 15:30	coffee break	
	Medical Factors Chair: Stu Smith	BPACC Room 1+2
15:30 - 16:00	FIELD PHYSIOLOGY: INFLIGHT MEASUREMENTS TO MONITOR OXYGEN SATURATIONS OF PILOTS DURING HIGH-ALTITUDE GLIDER FLIGHTS OF THE MOUNTAIN WAVE PROJECT IN THE HIMALAYAN REGION AND THE FRENCH ALPS. C. Ledderhos, R. Heise, Ch. Gamel, A. Gens, Fürstenfeldbruck, Germany.	
16:00 - 16:30	LOW-ALTITUDE HYPOXIA. D. Johnson, Menomonie, Wisconsin, USA.	
	Evening Session Chair: Stu Smith	BPACC Auditorium
20:00 - 20:30	FES TECHNOLOGY DEVELOPMENT MILESTONES. L. Žnidaršič, Logatec, Slovenia.	
20:30 - 21:30	INITIATIVE PROSEGELFLIEGER - A PACKAGE OF MEASURES FOR THE EFFECTIVE ENHANCEMENT OF PASSIVE SAFETY OF SAILPLANES. M. Volck, Wiener Neustadt, Austria.	

	Tuesday, 10 January 2017	
	Benalla Performing Arts Centre (BPACC)	
08:00 - 09:00	registration	BPACC Room 3
	Boundary Layers Chair: Mark Maughmer	BPACC Room 1+2
09:00 - 09:30	INFLUENCE OF ZIGZAG-TAPE ON PROFILE DRAG AT LOW REYNOLDS NUMBERS. T. Hofmacher, P. Scholz, Braunschweig, Germany.	
09:30 - 10:00	LAMINAR-TURBULENT TRANSITION ON WINGS WITH 3D FLOW EFFECTS. F. Muñoz, R. Radespiel, Braunschweig, Germany.	
10:00 - 10:30	VALIDATION OF NUMERICAL MODELS FOR TRANSITIONAL FLOWS ON AIRFOILS. J. Příhoda, P. Straka, J. Fürst, L. Popelka, D. Šimurda, Praha, Czech Republic.	
10:30 - 11:00	EFFECTS OF STRUCTURAL MOTION ON SEPARATION AND SEPARATION CONTROL: AN INTEGRATED INVESTIGATION USING NUMERICAL SIMULATIONS, THEORY, WIND-TUNNEL AND FREE-FLIGHT EXPERIMENTS. H. Fasel, S. Hosseinverdi, J. Little, A. Gross, Tucson, USA.	
11:00 - 11:30	coffee break	
	Sailplane Performance Chair: Murray Stimson	BPACC Room 1+2
11:30 - 11:50	SPEED-TO-FLY THEORY #1: INSIGHTS ON THE IMPLICATIONS OF FLYING INCORRECT SPEEDS WITH QUADRATIC AND NON-QUADRATIC POLARS. M. Steckner, Beachwood, USA.	
11:50 - 12:10	SPEED-TO-FLY THEORY #2: IMPLICATIONS OF FLIGHT TEST DATA VARIABILITY. M. Steckner, Beachwood, USA.	
12:10 - 12:30	SPEED-TO-FLY THEORY #3: POTENTIAL ISSUES WITH MODERN SAILPLANES WITH NON-QUADRATIC POLARS. M. Steckner, Beachwood, USA.	
12:30 - 14:00	lunch break	
	Atmospheric Waves Chair: Zafer Aslan	BPACC Room 1+2
14:00 - 14:30	USING DATA FROM HIGH-ALTITUDE SAILPLANE FLIGHTS TO STUDY ATMOSPHERIC MOUNTAIN WAVES. R. Millane, N. Zhang, E. Enevoldson, J. Murray, Christchurch, New Zealand and Edwards, USA.	
14:30 - 15:00	THE HARZ-FOEHN-PROJECT - EMPIRICAL RESEARCH ON MOUNTAIN WAVES IN AN NORTHERN GERMAN LOW MOUNTAIN RANGE. K.-H. Dannhauer, Leipzig, Germany.	
15:00 - 15:30	coffee break	
	Atmospheric Convection Chair: Rick Millane	BPACC Room 1+2
15:30 - 16:00	HEAT TRANSFER BY CONVECTION FROM THE GROUND TO A TYPICAL AUSTRALIAN THERMAL. D. M. Wilson , Glen Iris, Australia.	
16:00 - 16:30	INVESTIGATION OF THE VEGETATION EFFECTS ON CONVECTION BY USING COSMO-CLM. N. Akataş, S. Yeşilköy, Z. Aslan , Istanbul, Turkey.	

	Wednesday, 11 January 2017	
08:00 - 09:00	registration	BPACC Room 3
	Departing Benalla Air Field, Carpark BPACC	
09:30 - 17:00	Excursion to North East Victoria region	
	Wangaratta Warbirds, Mt Buffalo / Victorian Alps, Baileys Winery, Winton Wetlands	
	Benalla Performing Arts Centre (BPACC)	
	Evening Session	BPACC Auditorium
	Chair: Rolf Radespiel	
20:00 - 21:30	FUTURE OF THE OPEN CLASS. Panel Discussion: Loek Boermans, Tilo Holighaus, Atti Jonker, Axel Lange, Gerhard Waibel.	

	Thursday, 12 January 2017	
	Benalla Performing Arts Centre (BPACC)	
	Configuration Aerodynamics	BPACC Room 1+2
	Chair: Rolf Radespiel	
09:00 - 09:30	SAILPLANE WINGLETS: HOW MANY TIPS ARE TOO MANY TIPS? T. Krebs, G. Bramesfeld, Toronto, Canada.	
09:30 - 10:00	INVESTIGATING DESIGNS OF AUTONOMOUS GLIDER EXPLORATION OF OUTER SOLAR SYSTEM ATMOSPHERES. C. Colletti, R. P. LeBeau, G. Bramesfeld, Saint Louis, USA.	
10:00 - 10:30	THE USE OF COMPUTATIONAL FLUID DYNAMICS ANALYSIS IN WING-WINGLET DESIGN. M. D. Maughmer, J. G. Coder, University Park, PE, USA.	
10:30 - 11:00	coffee break	
	Sailplane Loads	BPACC Room 1+2
	Chair: Götz Bramesfeld	
11:00 - 11:30	ON THE GUST LOAD OF SAILPLANES. L. M. M. Boermans, Delft, Netherlands.	
11:30 - 12:00	LIFETIME CONSIDERATIONS ON SAILPLANES. C. Kensche, J. Wassenaar, Bruchsal, Germany.	
12:00 - 13:30	lunch break	

	Soaring in Atmosphere Chair: Zafer Aslan	BPACC Room 1+2
13:30 - 14:00	DO NOT GET CAUGHT-ON-TOP! E. Hindman, Wurtsboro, USA.	
14:00 - 14:30	GRAVITY WAVE OVER FLAT TERRAIN. D. Johnson, Menomonie, Wisconsin, USA.	
	Meteorology Poster Session Chair: Edward Hindman	BPACC Room 1+2
14:30 - 14:40	COMPARISON OF FIELD MEASUREMENTS AND MODIS ALBEDO DATA AND ITS EFFECT ON LATENT HEAT FLUX. S. Yeşilköy, N. Akataş, L. Şaylan, F. Bakanoğulları, Z. Aslan, Istanbul, Turkey.	
14:40 - 14:50	ATMOSPHERIC CONVECTION AND SEA SURFACE TEMPERATURE. İ. Osanmaz, Istanbul, Turkey.	
14:50 - 15:00	CLIMATE CHANGE, AVIATION AND GLIDING. A. Tokgözlü, K. Temurçin, K. Yasdıman Uysal, İnönü-Eskişehir, Turkey.	
15:00 - 15:10	HIGH EVAPOTRANSPIRATION AND HUMIDITY ON THE AVIATION AND SOARING. F. Dökmen, Z. Aslan, Kocaeli, Turkey.	
15:10 - 15:30	Poster Discussions	
15:30 – 16:00	coffee break	
	OSTIV Meteorology Panel Meeting Chair: Zafer Aslan	
16:00 - 18:00	Contributions by Edward Hindman; Loek M. M. Boerman; René Heise, Thorsten Reinhardt, Peter Frei, Ralph Paul; Bruno Neining, David Braig, René Heise and Frank Janser; Rick Millane and Morgan Sandercock; Fred Kucharski, Zafer Aslan, Uğur Şener; Ramazan Çağlar, Serhat Şeker, Jelena Dikun, T. Çetin Akıncı, Emel Önal, Emine Ayaz.	
	New developments in weather forecasting models for soaring flights, new trends in mountain wave analyses, short - term forecasting of soaring parameters, wind speed, wind shear, turbulence, high altitude sailplane flights, ABL.	
	Evening Session Chair: Murray Stimson	BPACC Auditorium
20:00 - 21:30	THE FIRST YEAR IN ARGENTINA WITH THE PERLAN 2 GLIDER. M. Sandercock, Bend, USA.	

	Friday, 13 January 2017
	Benalla Performing Arts Centre (BPACC)
	Sailplane Propulsion BPACC Room 1+2 Chair: Götz Bramesfeld
09:00 - 09:30	ELECTRIC PROPULSION IN GLIDERS IS MORE THAN AN ALTERNATIVE TO TRADITIONAL COMBUSTION ENGINES. R. Klein, Mosbach, Germany.
09:30 - 10:00	INVESTIGATIONS INTO THE DESIGN OF A TWO-SEAT SELF-LAUNCHING MOTOR GLIDER. R. Taouk, K.C. Wong, Sydney, Australia.
10:00 - 10:30	SOARING MEETS CRUISING – OPTIMAL STRATEGIES IN POWERED FLIGHT. T. Mörssel, P. Scheffel, Strausberg, Germany.
10:30 - 11:00	MEASUREMENT AND SIMULATION OF POTENTIAL ELECTROMAGNETIC INTERFERENCE SOURCES IN SMALL AIRCRAFT. M. Fröhner, R. Geise, B. Neubauer, Braunschweig, Germany.
11:00 - 11:30	coffee break
	Simulation BPACC Room 1+2 Chair: Bernald Smith
11:30 - 12:00	THE USE OF SIMULATION IN GLIDING: CURRENT STATE AND FUTURE DIRECTIONS. G. Robertson, New Zealand.
12:00 - 13:30	lunch break
	Performance and FAI Class BPACC Room 1+2 Chair: Mark Maughmer
13:30 - 14:00	FLIGHT PERFORMANCE MEASUREMENT OF GLIDERS WITH GNSS-SYSTEM. K. Rohde-Brandenburger, Braunschweig, Germany.
14:00 - 14:30	REINFORCEMENT LEARNING ALGORITHMS FOR SOARING FLIGHT IN TURBULENT ENVIRONMENTS G. Reddy, J. Wong-Ng, A. Celani, T. Sejnowski, M. Vergassola, La Jolla, California, USA.
14:30 - 15:00	ASPECTS OF FAI 13.5M CLASS. H. Fendt, Braunschweig, Germany.
	North Eastern Hotel, 1 Nunn Street, Benalla
19:00	Congress Closing Dinner

Field Physiology: Inflight Measurements to Monitor Oxygen Saturations of Pilots During High-Altitude Glider Flights of the Mountain Wave Project in the Himalayan Region and the French Alps

Carla Ledderhos¹, Rene Heise², Christine Gammel¹, André Gens¹

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Abstract: Recent F-22 fleet incidents show that unnoticed oxygen deprivation is still an issue during high-altitude flights. Currently, aircrews are trained in altitude simulation set-ups to recognize their individual symptoms, hoping that they would recognize them in a real-life scenario. Oxygen deficiency sensors are not commonly used.

Earlier work of our group showed that various pulse oximeters are accurate enough to be used as warning systems for oxygen deprivation in pilots and that the sensors' signal quality degrades only negligibly in tests on vibration platforms and in flight.

The objective of this study was to evaluate the failure rate of these systems at different measuring points (forehead, sternum, shin) in high-altitude flights with heavy turbulences and wide-ranging ambient temperatures and to optimize the crew's oxygen management.

Keywords: oxygen saturation, detection of hypoxia inflight, high altitude physiology, non-invasive physiological monitoring, risk management

Introduction

After two expeditions to the Andes, the OSTIV-Mountain Wave Project (MWP) Team carried out a research campaign to the Himalayas in 2013/2014. Based on a motor glider-bound (STEMME S10VT) multidisciplinary approach, the team amongst others realized scientific measurements of the distribution and transport of atmospheric pollutants in Nepal as well as new digital aerial imageries of exceptional resolution and highest accuracy to create a 3D terrain model of glaciers close to the Mount Everest and Aconcagua.

Within the project, members of the MWP worked together with scientists of the German Aerospace Center (DLR, Institute of Optical Sensor Systems), the Aerospace Technology Faculty of the University of Applied Sciences Aachen and the research team of the German Air Force Center of Aerospace Medicine.

Firstly, participating pilots wanted to explore the Himalayas and the Mt. Everest region, feared for their bad weather conditions in pioneer flights. There was only one former Himalayan soaring expedition in 1985 by Alvaro de Orleans Borbon, but never before a pilot succeeded to fly up to the height of the Mt. Everest with a motor-glider.

Secondly, the project served to enhance the knowledge in turbulence research and improvement of weather forecast models.

Thirdly aerosol measurements were conducted in order to record the vertical distribution of particulate matter and their optical properties for source apportionment in Nepal.

Fourthly, digital aerial imagery with a resolution, as high as never used before, should be taken in this region to enhance the geographical knowledge about this region, draw conclusions regarding global warming, predict flood impacts and produce documentations of natural or cultural heritage.

And last but not least, concomitant aeromedical aspects of human performance and limitations with a special focus on an early detection of hypoxic hypoxia in pilots under these uniquely extreme environmental conditions (high altitude, low temperature, turbulences) were of particular interest.

Historically oxygen deprivation was one of the first environmental challenges Aerospace medicine had to deal with. As recent F-22 fleet incidents have demonstrated impressively, it is still an issue this field of medicine is engaged in. Worldwide, aircrews are trained in altitude simulation set-ups to become familiar with their individual symptoms, hoping that they would recognize them in a real-flight scenario. Till now, sensors to detect oxygen deficiencies in flight are not in common use.

With the introduction of pulse oximetry (SpO₂), an easy-to-use method to quantify oxygen deprivation of individuals was established in clinical routine. However, and this is surprising, not much effort regarding this technology in the field of Aerospace Medicine was made so far. Earlier work of our group of the GAF CAM could demonstrate that several of those pulse oximetry systems, used in clinical routine, are accurate enough to be also considered as warning systems for pilots. Trials on vibration platforms as well as in-flight tests with different types of aircraft have confirmed that the signal quality of the devices tested is degraded only negligibly. Therefore, with the due degree of prudence, these sensors can be considered to suit the intended purpose of an early warning system in flight.

With this in mind a reflectance pulse oximetry system was tested in the environment of high-altitude glider flying with its expected heavy turbulences and wide-ranging ambient temperatures. In addition, the intended measurements were tailored to optimize the crew's oxygen management during those high-altitude flights.

Methodology

In preparation of the Himalaya campaign pilots completed a comprehensive theoretical and practical training in the hypobaric chamber of the GAF CAM in Koenigsbrueck. Among other things, the curriculum was meant to familiarize the pilots with the handling of oxygen equipment and the advantages and limitations of the technique of pulse oximetry. During the campaign the signal failure rate of pulse oximetry sensors was determined in 28 high-altitude glider flights (up to FL 290) in the Himalaya including the Mt. Everest region and (to enhance the number of flights) in the French Alps. All 7 individuals were equipped with three Nonin, bicolor reflectance sensors and the associated WristOx 3100 system. The sensors were fitted at three different measuring points (forehead, sternum and shin). In addition to oxygen saturation, the heart rate and altitude values were also recorded during the flights.

Results

In total, 19 complete data sets with readings from all sensor locations used could be gathered. SpO₂ values recorded at different measuring points showed distinct differences: the highest values were observed at the forehead ($95.39 \pm 2.11\%$) (Mean \pm standard deviation), the values detected at the sternum were the lowest ($84.38 \pm 6.74\%$). Furthermore, the failure rate was highest at the sternum ($26.51 \pm 18.56\%$ of the measuring time). At the shin, the mean SpO₂ was $93.93 \pm 4.24\%$ with a failure rate of $11.67 \pm 19.74\%$ of the measuring time. Measurements at the forehead were most robust, showing a failure rate of $3.28 \pm 6.29\%$ of the measuring time. The mean duration of failures was $12,8 \pm 4,7$ s at the forehead, $15,5 \pm 12,8$ s at the sternum and $13,7 \pm 11,0$ s at the shin.

Conclusions

Without any question, the use of pulse oximetry added to enhance flight safety in this campaign to the Himalayas. However, the results also clearly reveal the difficulties of obtaining robust signals that reliably reflect inflight blood oxygen saturation that have to be overcome. This is particularly true for the shortfalls anyway inherent to the method itself. Nevertheless, in this day and age, the objective continuous detection of a pilot's oxygen deprivation is inevitable with respect to flight safety. Among the application points for the sensors tested, the forehead appears to be most suitable.

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Figure 1: High altitude measurement flights with the motor glider Stemme S10VTX with the crew Keimer/Heise over the Kali Gandaki Gorge and Annapurna region on the 27th of January 2014

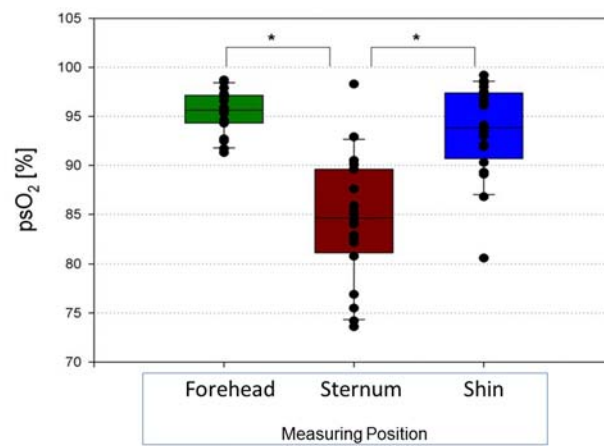


Figure 2: Comparison of the oxygen saturations measured at the forehead, sternum and shin

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