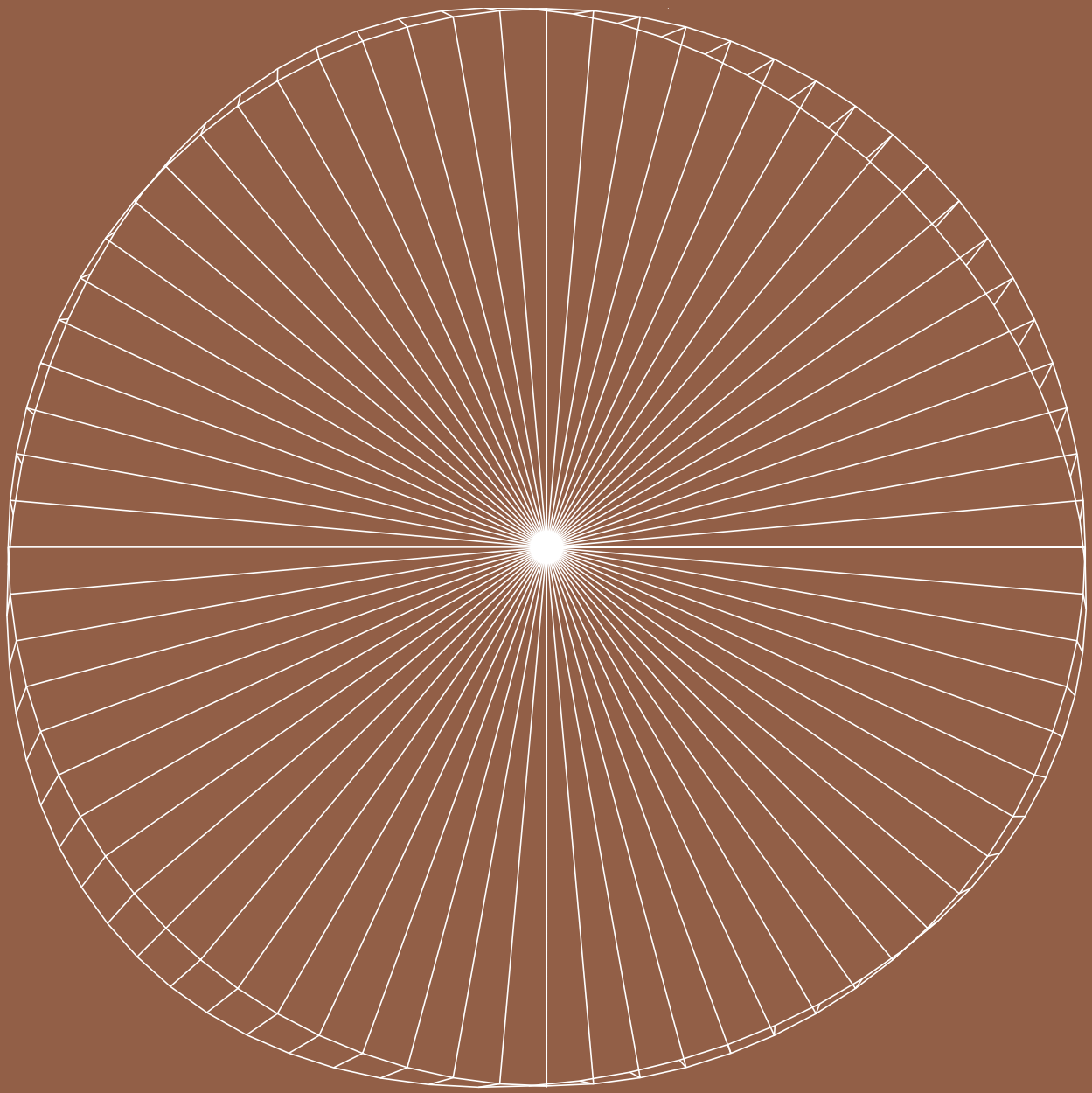
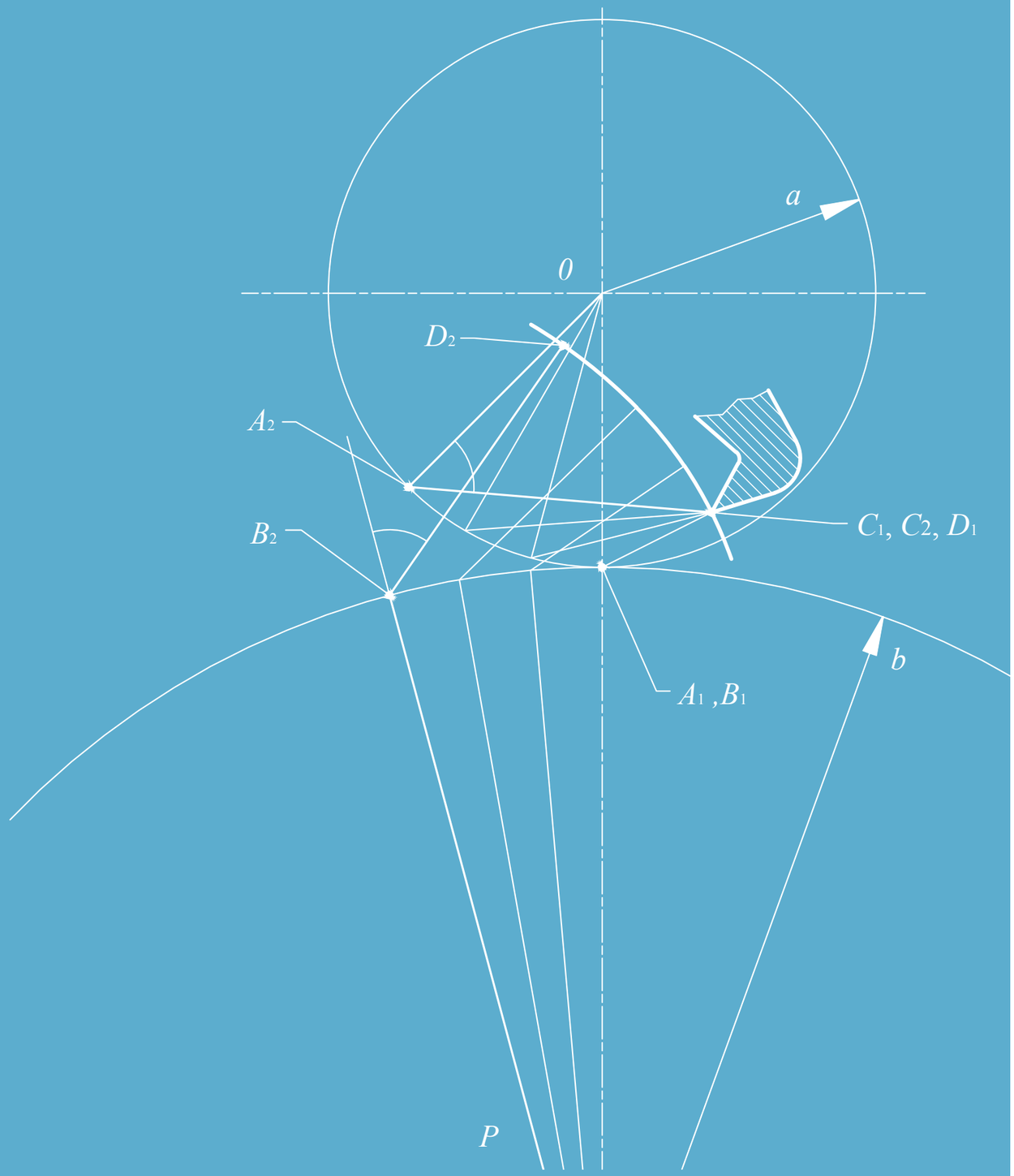
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Patek Philippe Chair

Micromechanical and Horological Design Laboratory
INSTANT-LAB

Annual Report 2013





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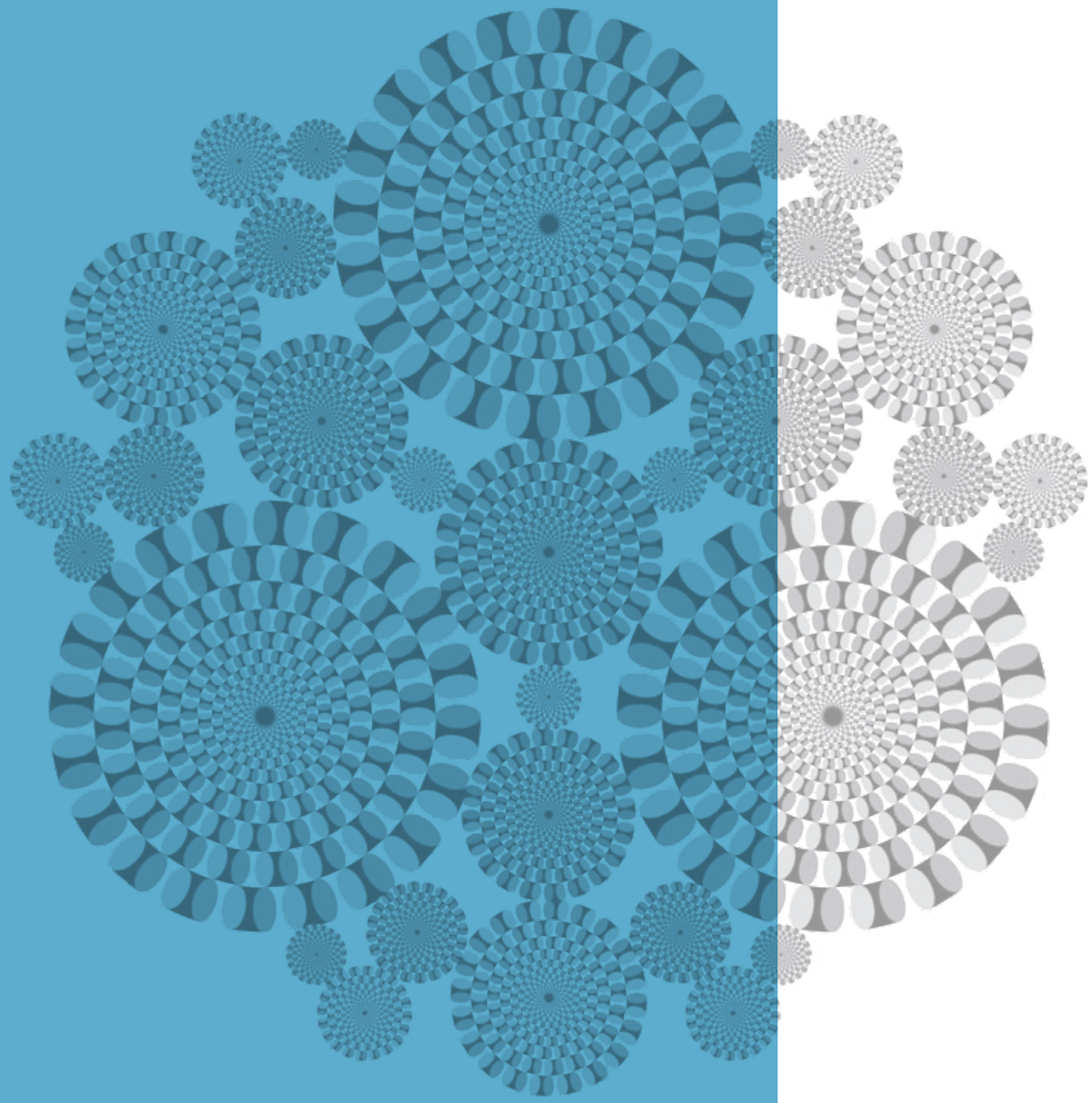

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INTRODUCTION

Following the April 2012 announcement of a partnership between watchmaking manufacture Patek Philippe and the EPFL, the Patek Philippe Chair in Micromechanical and Horological Design was established on November 1, 2012, with the nomination of Professor Simon Henein. Instant-Lab, the name chosen for the new laboratory, is located in Microcity, the EPFL Microtechnology centre in Neuchatel, Switzerland. Instant-Lab currently consists of a dozen senior scientists, postdoctoral scholars and graduate students.

The laboratory's specialty is the creation of new mechanisms featuring kinematic and technological innovation at the centimeter scale. The scientific approach is inspired from mechanical design in fields such as new and classical horology, robotics and aerospace. Current projects apply to mechanical watchmaking and biomedical instrumentation, these fields being quite close, both technologically and in their industrial fabric. Beyond the laboratory's academic mission to pursue excellence in fundamental research and teaching, it is also committed to strengthen ties with the Swiss watchmaking industry and therefore welcomes collaboration with all its industrial partners.

The present report gives an overview of the activities of Instant-Lab since its creation on November 1, 2012 until December 31, 2013.

HUMAN RESOURCES

In addition to Professor Henein, 12 persons were hired to work at Instant-Lab.
As of December 2013, the team is constituted as follows:

Lab head

Professor Simon Henein

Karine Frossard
(administrative assistant)

Senior Scientists

Dr. Charles Baur

Dr. Ilan Vardi

Post-Docs

Dr. Lennart Rubbert

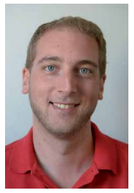
Dr. Roland Bitterli

Scientific Assistants

Nicolas Ferrier

Marine Clogenson

David Lengacher



Tristan Derbanne

Ph.D. Students

Johan Kruis

Olivier Laesser

Sebastian Fifanski

INFRASTRUCTURE AND EQUIPMENT

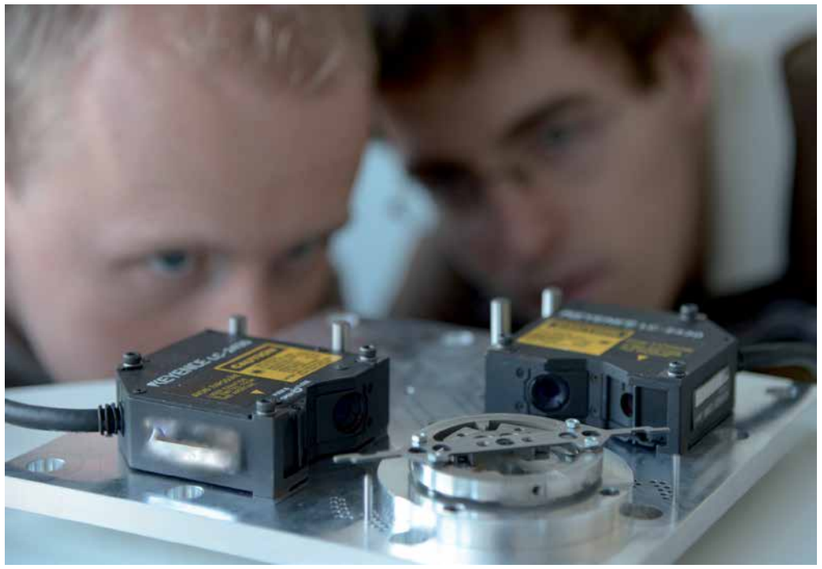
Instant-Lab was first located in the historical building rue Breguet 2, Neuchatel, from November 1, 2012 until October 2013. On October 16, 2013, the laboratory was relocated to the new Microcity building, rue de la Maladière 71b, Neuchatel, with the following surface allocation:

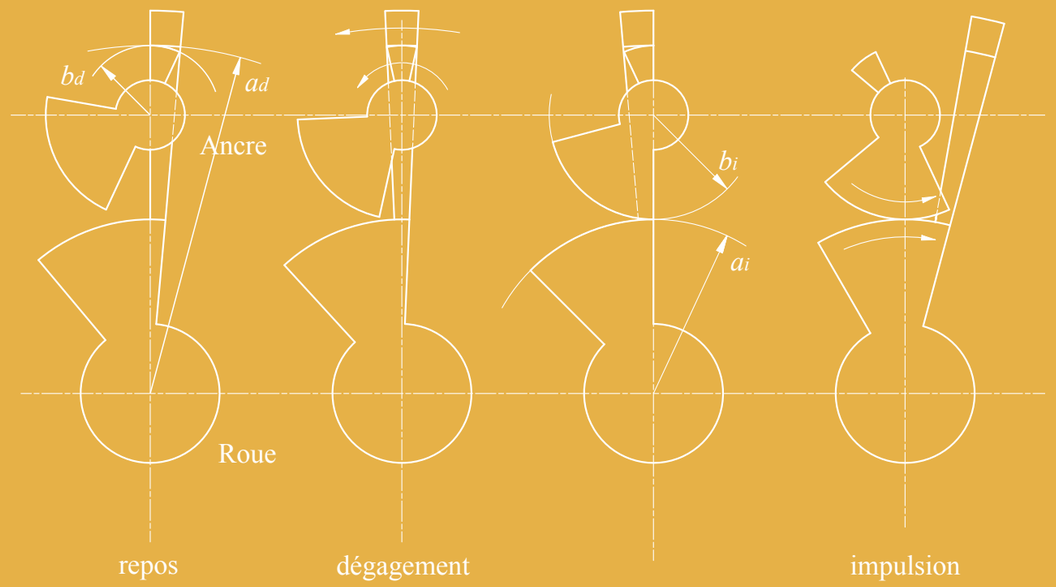
Offices: 125 m²
Laboratories: 170 m²
Grey room: 51 m²

No major equipment was acquired during 2013 since the lab was not yet installed in its final location. The equipment acquisition phase will start in 2014.

SPIN-OFF

The spin-off company GraniteApps SARL (www.graniteapps.ch) was founded in January 2013 by Dr Charles Baur and Tristan Derbanne. It focuses on the development of software applications for smart phones and tablets. The goal is to extend daily activity and/or every day life devices by using smart phone and tablet connectivity as well as data management capabilities.





RESEARCH

Ongoing Ph.D. theses

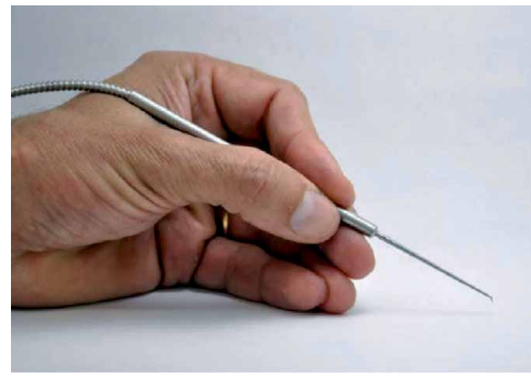
O. Lasser, preliminary thesis title: *Analyse, synthèse et création d'échappements par la théorie des engrenages*.
Expected completion May 2014.

Kinematics of the Swiss lever escapment reproduced based on gear sectors (primitive circles)

J. Kruis, preliminary thesis title: *Novel Design for Assembly Concepts for Centimeter-scale 3D flexure-mechanisms*.
Expected completion January 2016.

Delta robot consisting of three assembled flexure-based silicon slabs (size 20x20x20 mm) (courtesy of CSEM).

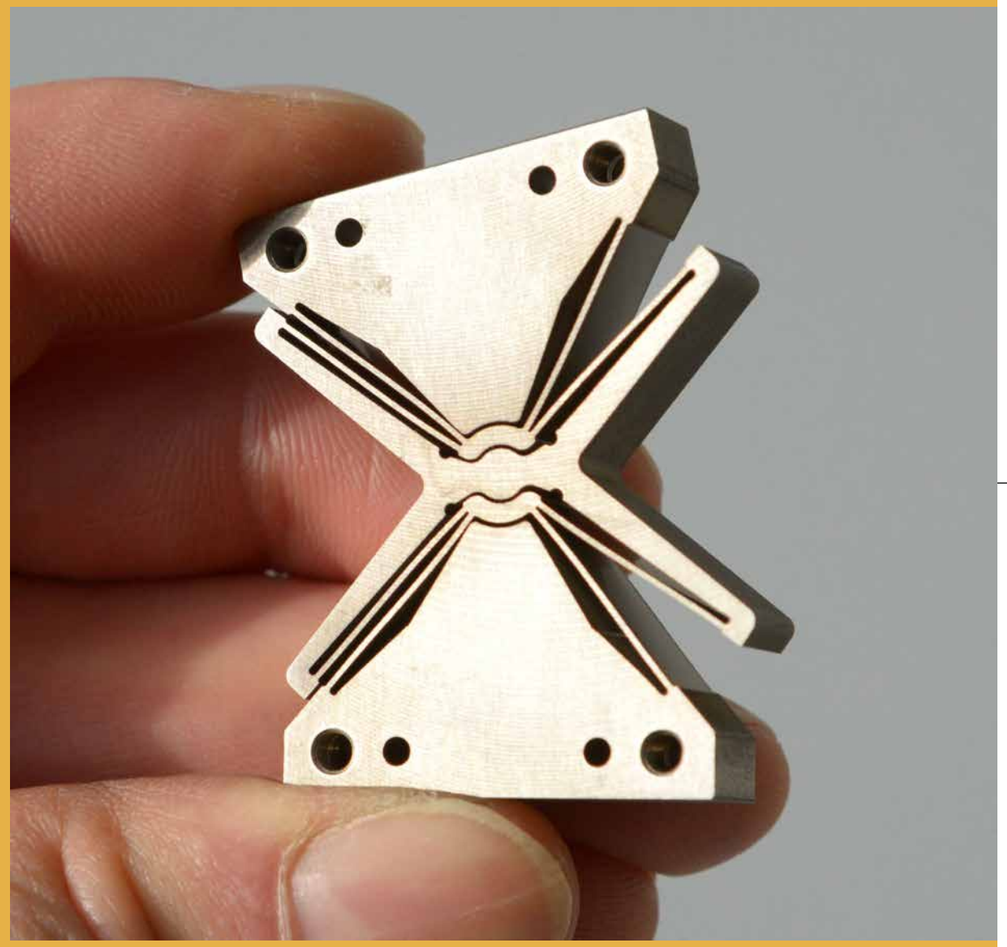
S. Fifanski, preliminary thesis title: *Miniature flexure structures for contact force sensing in pointed tools*.
Expected completion August 2017.



Tri-axial in vivo force sensors for force feedback dedicated for ear surgery

RESEARCH

Main ongoing research projects



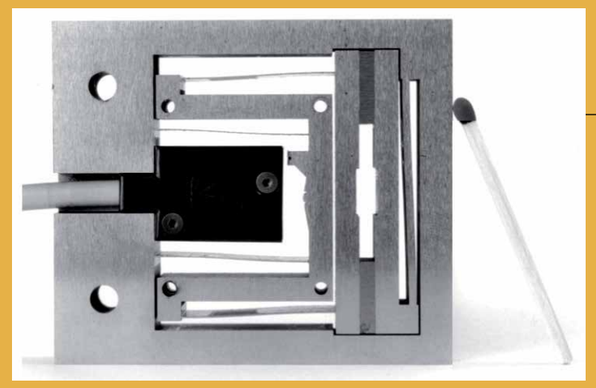
High quality factor oscillators for wrist watche

Current mechanical wrist watches have as time base an oscillator consisting of a balance wheel mounted on jeweled bearings and a hairspring. The use of flexure bearings instead of the traditional journal bearing lead to a high increase in quality factor, i.e., reduced damping and energy loss. As a result the power reserve can be significantly increased and chronometric precision can be improved due to reduced oscillator perturbation. This project aims at exploring fundamental and practical issues in the design of novel flexure-based high quality factor oscillators for watches.
This project is run in collaboration with CSEM SA.

Butterfly flexure pivot for balance wheel suspension leading to increased quality factor (courtesy of CSEM).

Multistable meso-scale springs and their use for watch-making applications

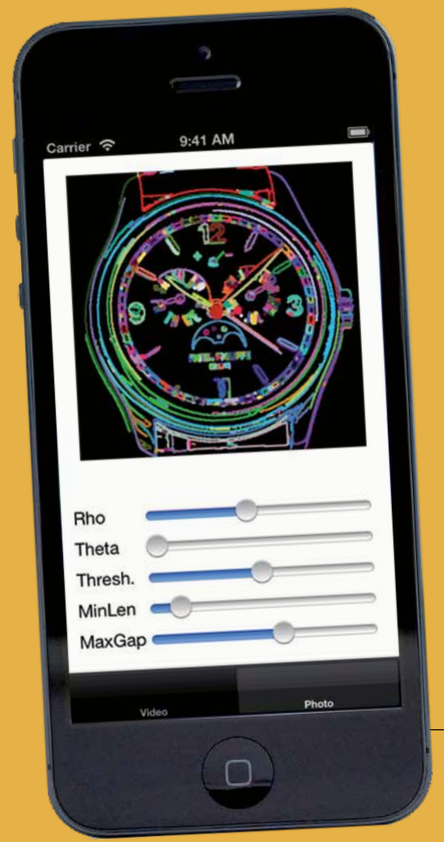
Flexure based mechanisms can be designed in order to produce strongly non-linear spring behavior and judicious arrangement can yield constant force-springs, zero-force springs, bi-stable springs or multi-stable-springs. Combined with the use of advanced materials such as mono-crystalline silicon or other alloys or composites with their respective fabrication technologies, such springs enable completely new functionalities at the centimeter scale, for example, to harvesting devices, mechanical watches or surgical instruments. This project aims at exploring the fundamental principles of elastic energy storage mechanisms, their production methods and their integration into complete functional devices.
This project is being set up with a confidential industrial partner.



Negative stiffness linear guide including position sensor for characterization

RESEARCH

Main ongoing research projects



Watch diagnostic iPhone application

A new algorithm for telling time was invented at Instant-lab then implemented as an iPhone application. It allows a computer to tell time by reading the watch hands only, independently of the display. The advantage of this algorithm is that watch hands are more amenable to pattern recognition algorithms than watch displays. The latter are extremely variable and difficult to recognise systematically using computer image processing algorithms. This application can be used for several purposes: simplified observation of daily rate (marche diurne); internal prototype chronometric testing (chronométrie au porter employés); large scale chronometric testing (chronométrie au porter client); centralized data collection to Manufacture; remote diagnostics; measure of second/minute hand synchronization (user adjustment); verification of minute/hour hand synchronization (manufacture assembly); verification of hand/dial relative positioning; client/watch connection.
This project called *5.5° of separation*, is being developed with Granite Apps, an Instant-Lab spin-off.

iPhone application screen captures showing hand detection and calculation of displayed time using the angle between watch hands as input to the algorithm invented and developed by Instant-Lab

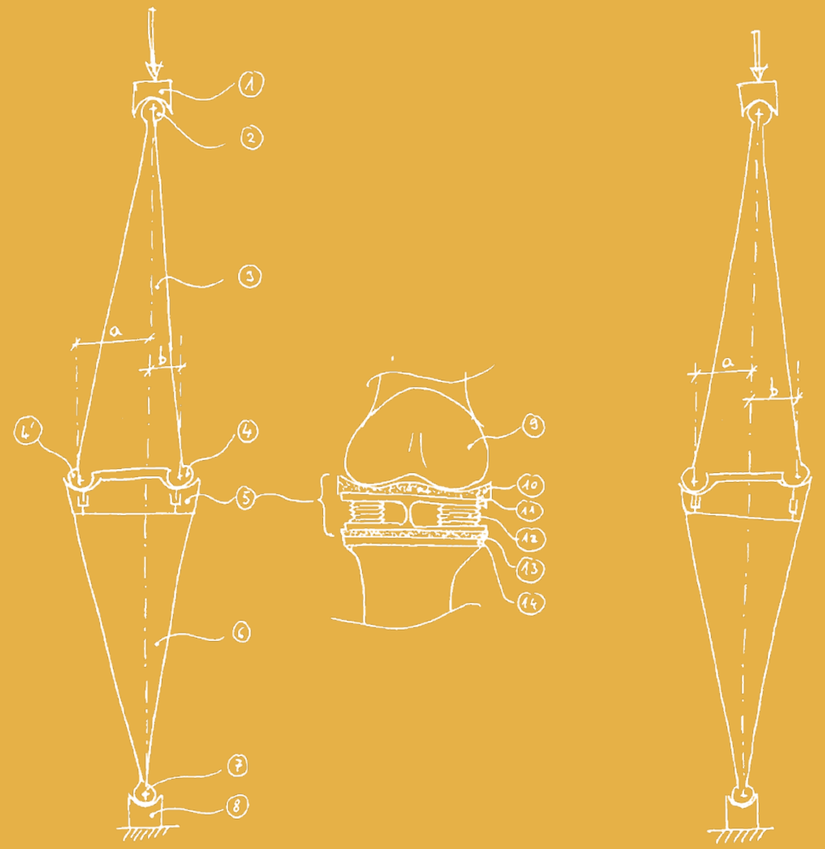
Miniature flexure structures for multi-degree of freedom contact force sensing

The goal of the project is to develop active surgical tools that fit microsurgery requirements (e.g. eye surgery, brain surgery, etc.) in terms of tool size, force range and required reliability. It will combine flexible structure technology provided by Instant-Lab together with in house optical fiber based sensing technology of Sensoptic SA that has been successfully introduced into active tools in heart, ear, nose and throat surgery. Focus will be on flexible and sensing structure topology and design, extreme miniaturization, multiple DOF force and torque measurement as well as industrialization aspects such as sealing or in situ reliability of the sensing parts. To provide surgical instruments with force measurement capabilities at the tool tip will allow performing surgical gesture in precision and reliability that exceed those performed currently by an order of magnitude. Application of such sensors for manual watch-making tools is also foreseen.
This project is being set up in collaboration with Sensoptic SA.

Tri-axial in vivo force sensors for force feedback based on flexure structure and light optical fibre interferometers. Outer-diameter: 2mm.

RESEARCH

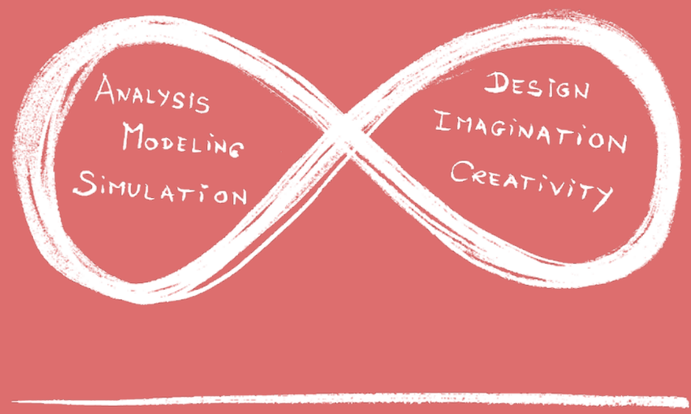
Main ongoing research projects



Programmable-compliance inserts for geometrically tunable prostheses

The present project consists in a geometrically adjustable knee prosthesis based on a mechanism that is integrated into the polyethylene insert placed between the tibial and femoral metallic components. The geometry of this insert can be modified easily pre- per- and post-operatively without any invasive operation on the knee. The adjustment of the prosthesis will be performed time to time during the whole life of the implant to compensate its wear and adapt to the changes in condition of the patient. The expected benefits include longer lifetime of the implant and reduction of the number of invasive revision surgeries required to realign or replace the implant.
This project is being set up in collaboration with other EPFL labs and CHUV

Scale 2:1 prototype of 3 degrees of freedom programmable-compliance insert composed of a flexure structure for the bearing function, flexible bellows filled with incompressible fluid for the position locking function and remote-controlled valves for the compliance command function.



EDUCATION

The laboratory is strongly involved in teaching design to students at all levels. The focus is on training the creative process starting with the act of design and following up with the analytical method necessary to model, simulate and predict machine behavior.

Bachelor students during their “Mechanism Design I” exam, December 17th 2013

Teaching: EPFL

Mechanism Design I & II / Conception de mécanismes I & II (2013-2014)
Lecturer: Prof. S. Henein
Section: Microtechnique (90 students)
Bachelor semesters 2 and 3
3 periods per week

Elements of mechanical design I & II / Construction mécanique I & II (2013-2014)
Lecturers: Course under the responsibility of Prof. S. Henein & Prof. J. Schiffman and taught by two external lecturers.
Sections: Microtechnique / Génie mécanique (500 students)
Bachelor semesters 1 and 2
3 periods per week

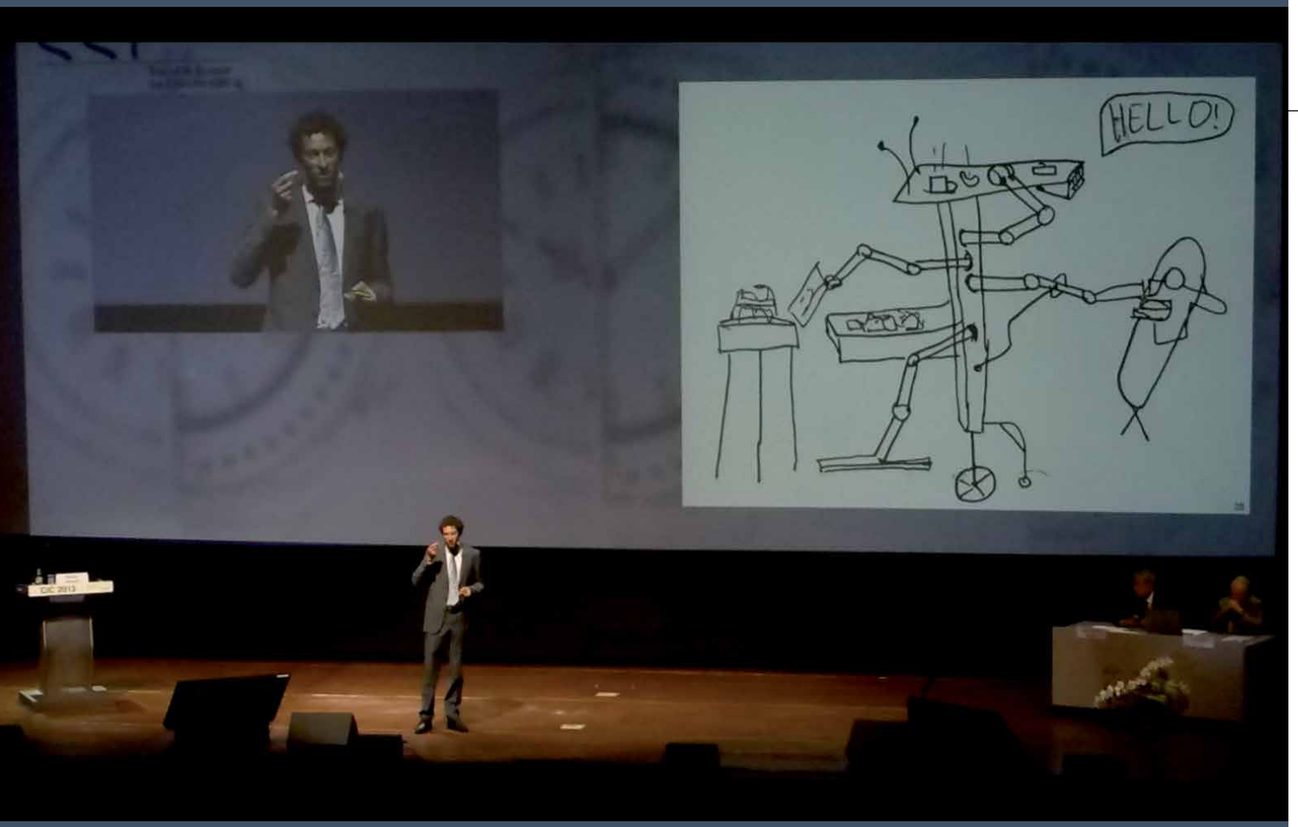
Industrial and applied robotics / Robotique industrielle et appliquée (2013)
Contributions to the course by Prof. S. Henein and Dr Ch. Baur
Flexure mechanisms
Design of mechanisms for vacuum application
Medical robotics
Section: Microtechnique (60 students)
Master semestre 2

Microengineering Components / Composants de la microtechnique (2012-2013)
Lecturer: Prof. S. Henein & Prof. Ch. Moser
Section: Microtechnique (90 students)
Bachelor semesters 2 and 3
3 periods per week

Completed master projects
Development of a 7-DOF force feedback haptic interface for microsurgery, Billy Nussbaumer, in collaboration with Stanford University, completed in April 2013, won the Omega Prize and the Hilty Prize.

Teaching: outside EPFL

FSRM, 1 Day Tutorial, Neuchâtel, S. Henein, 13.2.2013, Conception des guidages flexibles
ESRF, 2 Days Tutorial, Grenoble, S. Henein, 28-29.4.2013, Conception des guidages flexibles
FSRM, 1 Day Tutorial, Neuchâtel, I. Vardi, 13.12.2013, Astronomie de la montre



INVITED TALKS

16ème Congrès International de Chronométrie, Montreux, September 25, 2013, S. Henein, Instant-Lab: *la nouvelle chaire de l'EPFL en conception micromécanique et horlogère*

Assemblée Générale de l'ASRH, Neuchâtel, S. Henein, March 14, 2013, Instant-Lab: *la nouvelle chaire de l'EPFL en conception micromécanique et horlogère*

IMT-DAY, Rolex Learning-Center EPFL, S. Henein, May 8, 2013, Instant-Lab: *la nouvelle chaire de l'EPFL en conception micromécanique et horlogère*

Présentation at Patek-Philippe, Geneva, S. Henein, May 15, 2013, Instant-Lab: *la nouvelle chaire de l'EPFL en conception micromécanique et horlogère*

Fleurier célèbre le changement de l'heure, *A recherche de l'heure perdue*, I.Vardi, Fleurier March 30, 2013

Soirée des régleurs, *Une nouvelle complication horlogère*, I. Vardi, La Chaux-de-Fonds, July 2, 2013

First FSRM public lecture, *L'astronomie de la montre*, I. Vardi, Neuchatel, October 30, 2013

GDR Robotique (GT1: robotique médicale) et le **GDR STIC-Santé** (Thème F: gestes médico chirurgicaux): Gestes médicaux guidés par l'image et interactions avec des organes déformables, Systèmes haptiques et dispositifs médicaux, l'expérience Force Dimension – EPFL, C. Baur, INSA – Lyon, December 2, 2013

Statismo, toolkit for PCA shape model building, M. Clogenson, *University of Basel, Department of Mathematics and Computer Science*, March 4-8, 2013

Summer Slicer Project week 2013 (NAMIC), M. Clogenson, MIT Boston, 17-21 June 2013
1st Statismo model building days, M. Clogenson, *University of Basel, Department of Mathematics and Computer Science*: December 4-6 , 2013

PUBLICATIONS

Book chapters

R. Clavel, S. Henein & M. Richard, Flexible Robotics: Applications to Multiscale Manipulations, Chapter 7: Flexures for High-Precision Manipulation Robots, pages 243–274, Wiley-ISTE, July 2013

R. Clavel, S. Henein & M. Richard, Robotique flexible: manipulation multi-échelle, Chapter 8: Guidage flexible pour les robots manipulateurs à très hautes précision, pages 253–285, Hermes, July 2013

Ilan Vardi, rewrote the chapter *L'équation du temps*, for the 5th edition of the book *Les montres compliquées* by François Lecoultre, Edition Simonin, Neuchatel, September 2013.

Book reprints

S. Henein, Conception des guidages flexibles, Collection Meta, Presses Polytechniques et Universitaires Romandes, Lausanne, Switzerland, 1st printing (2001) 500 copies, 2nd printing (2002) 300 copies, 3rd printing (2013) 100 copies.

Conference proceedings

P. Janphuang, R. Lockhart, S. Henein, D. Briand, and N.F. de Rooij, "On the experimental determination of the efficiency of piezoelectric impact-type energy harvesters using a rotational flywheel," *in Proc.13th Int. Workshop PowerMEMS*, London, UK, December 3-6, 2013.

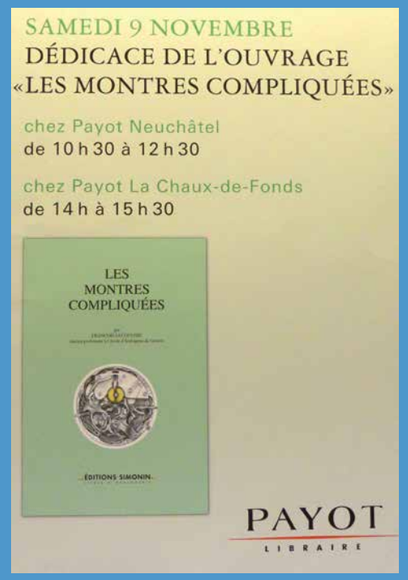
J. Kruis, F. Barrot, L. Giriens, D. Bayat, R. Fournier, S. Henein, S. Jeanneret, "Design and fabrication of a novel centimeter scale three dimensional silicon tip, tilt and piston mirror mechanism," *Proceedings of the 13th euspen International Conference*, Berlin, May 2013

O. Laesser, "Masse oscillante idéale ; CQFD : Théorie semi-empirique de la vitesse de remontage au Cyclotest," *Actes du 16ème Congrès International de Chronométrie de la SSC (2013)*, p. 25-30.

Articles in peer reviewed journals

P. Janphuang, R. Lockhart, D. Isarakorn, S. Henein, D. Briand, and N.F. de Rooij, *Harvesting Energy from a Rotating Gear Using an AFM-like MEMS Piezoelectric Harvester*, Journal of Microelectromechanical Systems, (submitted and under review).

I. Vardi, *L'équation de l'âge de Lune, une nouvelle complication horlogère*, Bulletin de la Société Suisse de Chronométrie 73, septembre 2013, 31-37.



SCIENTIFIC DISSEMINATION

Poster presentations

J. Kruis, Smart systems for a better life, *Mesoscale systems for medical and surgical applications*, Besançon,12th of September

I. Vardi, Festival della Scienza, *L'eleganza del Tempo*, Matematica e meccanica dell'orologeria, Genoa, October 24 – November 3, 2013 (scientific supervision).

Newspaper and magazine articles

NZZ Equity-Magazin, Die Uhr weniger oft aufziehen, E. Stamm, May 2013, p. 21.
http://instantlab.epfl.ch/files/content/sites/instantlab/files/Articles/Bild1.pdf

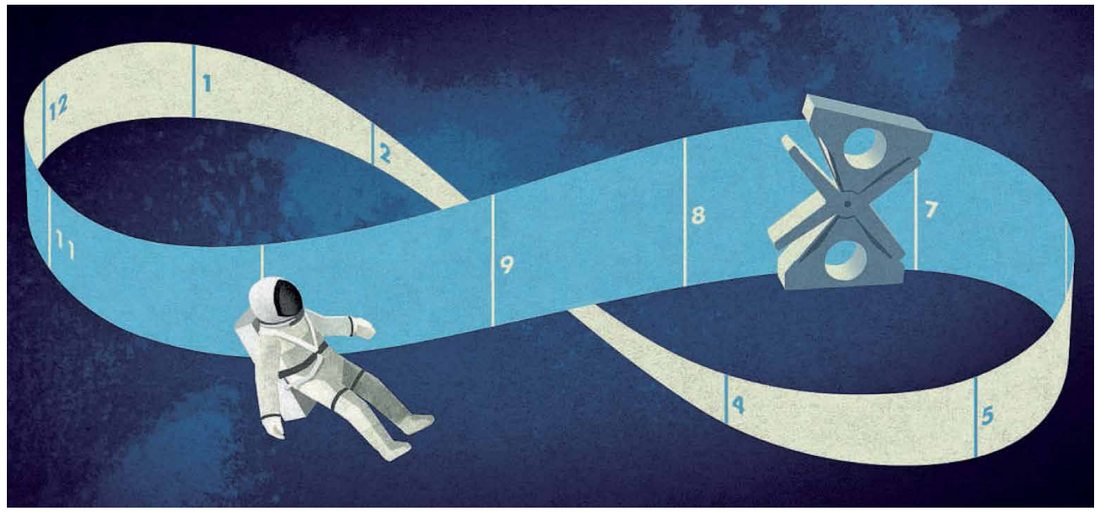
HH Magazine, De l'utilité des fonctions dans l'horlogerie, F. Eschmann, October 22, 2013
Bulletin SSC n°74, De l'utilité des fonctions dans l'horlogerie, F. Eschmann, December 2013

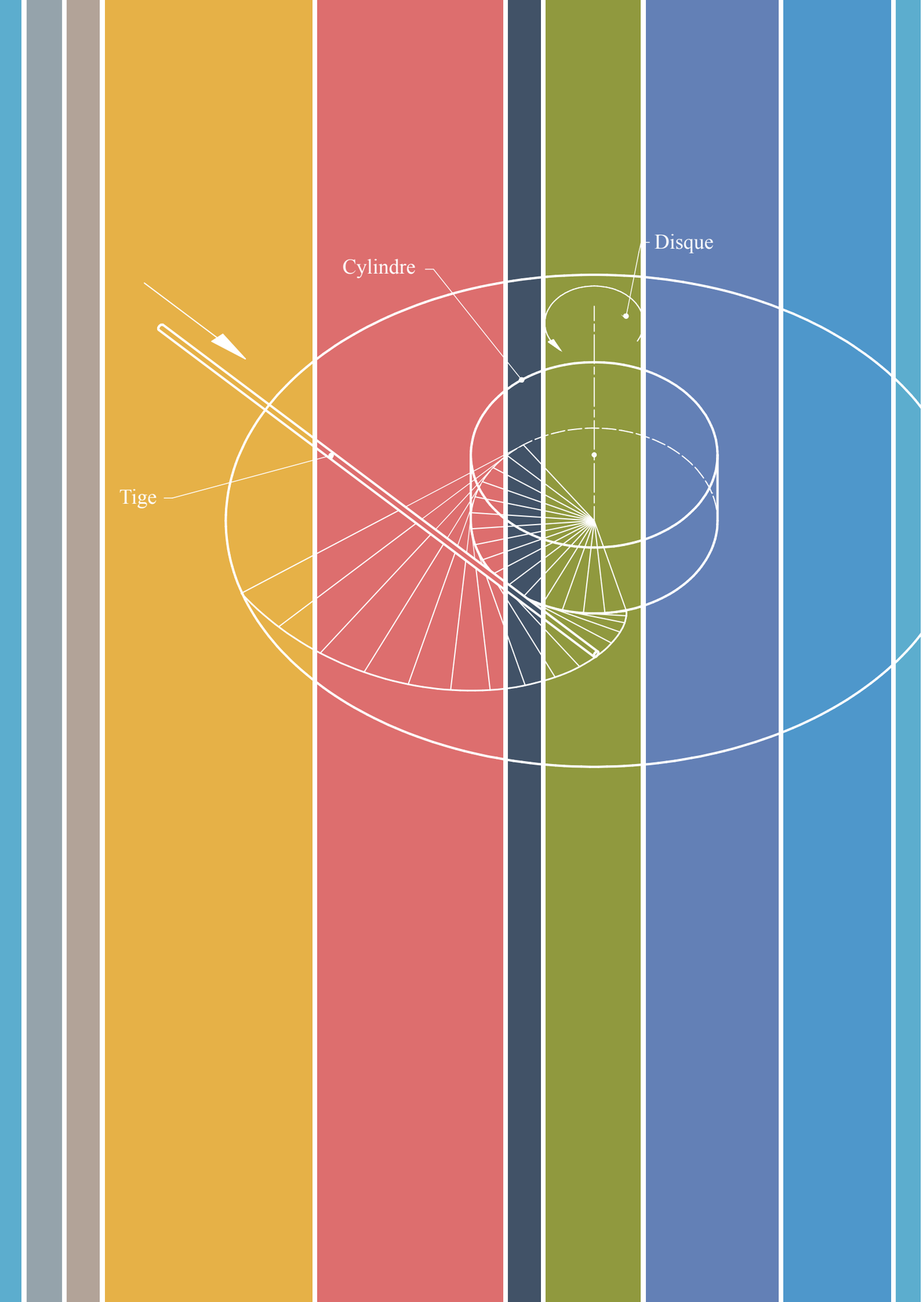
Television programs

RTS, I. Vardi, March 30, 2013, http://www.rts.ch/video/info/journal-19h30/4782371-fleurier-ne-s-est-autoproclamee-capitale-mondiale-du-changement-d-heure.html
Canal Alpha, I. Vardi, March 30, 2013, http://www.canalalpha.ch/actu/fleurier-capitale-du-changement-dheure-2/

Book signing events

I. Vardi, *Les montres compliquées*, Payot Neuchâtel and La Chaux-de-Fonds, November 9, 2013





CONCLUSION AND PERSPECTIVE

Instant-lab's key achievement in its first year of existence was to set up a complete team having the required expertise. Additionally, the research has been launched and the first results have been published through three PhD theses and a number of industrial collaborations. Several patents were filed allowing academic publication of their subject matter. The teaching of mechanical design started directly after the creation of Instant-Lab. Our newly created courses were taken by all first year Bachelor students in Mechanical and Microengineering sections and by all second year Bachelor students in Microengineering.

Perspective for 2014:

In 2014 we will equip the laboratory with the essential physical tools required for research and prototyping; the grey room will be equipped in a subsequent phase. Further development of the laboratory will be sought via funding sources such as the FNS (Swiss National Science Foundation) for fundamental research, and the CTI (Commission for Technology and Innovation) as well as industrial partners for applied research. We will patent then publish results obtained in 2013 and present them at international conferences. Our Ph.D. students will also publish their results in scientific journals and conference proceedings. Finally, several 2013 industrial projects will be completed to the partners' specifications.

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