ANNUAL REPORT: CHAIRS IN DESIGN ENGINEERING[1]

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Please add your personal information below.

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Please verify the information below and make the necessary corrections.

Chair in Design Engineering Name: "NSERC Chair in Design for Aluminium"
Partner name & contacts:

- Aluminium Association of Canada (AAC), Jacques Internoscia, Director Strategic Programs (new partner for 2016)
- REGAL Aluminium Research Centre, Mario Fafard, Director
- Alcoa Innovation, François Racine, President
- Centre québécois de recherche et de développement de l'aluminium (CQRDA), Maurice Duval, Scientific director
- Ministry of Economy, Science and Innovation (MESI), Gabriel Audet, industrial development counselor, metallurgy and chemistry.

Top 3 contributions for the year.

1.

Setting up a new Chair support infrastructure, in line with the Chair's objectives for its second term:

The Chair objectives for the first term were aligned toward the implementation of a "prototype to product" stream within the undergraduate capstone projects. Conversely, the objectives for the second term seek to widen this vision at the graduate level and toward a more comprehensive "consumer need to market" approach encompassing an upstream phase from "need assessment to idea and prototype" and dowmstream from "product to market".

Putting this philosophy into action entailed a new team with corresponding work split:

- A professional (Jonathan Nadeau, hired in October 2016) whose mandate is to set up a "Load Case Characterization and Prototype Validation Laboratory" (LCCPVL) to meet student needs in terms of measurements and data acquisition, thereby allowing the definition of accurate design targets and the means to assess whether or not these have been met in the end. This facility will be described in more details in an upcoming section.
- A post-doctoral fellow (Jason Mejane, hired in April 2017) providing expertise, guidance and follow up on aluminium related projects, in a bid to support the extension of design related training at the graduate level (mostly at the course based master degree level). From a broader perspective, this initiative also aims at training the next generation of design engineering professors.

2.

Setting up a "Load Case Characterization and Prototype Validation Laboratory":
One of the key deliverable for the second Chair mandate is to set up an original facility so as to extend the reach of design beyond current paradigms centred solely on prototype design and construction. In fact, the new facility (120m^2) features equipment more directly related to product requirement identification, material characterization and product validation; themes which all point to the *"customer need to idea, to prototype, to product and to market"* wholesome philosophy.
More specifically, the new facility addresses upstream issues such as material characterization and load case identification using material testing machines (hardness, strain) and portable data acquisition systems, sensors and measurement devices. These will provide more accurate data for the design phases. Conversely, other, downstream issues pertaining to product reliability will be dealt with, using a servo-hydraulic testing machine for the fatigue validation of prototypes. Other peripheral equipment, such as a scanner to provide numerical models for digital simulation and validation, will also be considered. Workbenches and computers will complete the facility set-up. Finally, the Chair professional, with its mechatronics background will help students and oversee their work so as to ensure that the equipment is used properly and safely.

3.

Supporting the Chair objective toward Design projects and methodology at the graduate level:
As evidenced above, a progressive shift toward design at the graduate level has been initiated as part of the Chair second mandate. Here are some of the actions being laid out toward that goal:

- A project cluster, based on a set of related or connected, design-oriented, research projects sharing common products and/or processes, has been initiated in 2016 and will be described in further details in an upcoming section.
- At the course based master degree level, an initiative is being pushed at the faculty level to introduce a Course based Master degree in Design, with internships. To further help things move along, I have been named Director of the Course based Master degree in Mechanical Engineering.
- At the research based master degree and Ph.D. levels, I am the principal investigator of a 3,07M$ NSERC, Collaborative Research and Development (CRD) grant with BRP, awarded in January 2017, that will involve 14 graduate students and 5 professors. Details are provided in section 1.c.
- Again, at the Ph.D. level, I am newly involved in a faculty led reform of the Ph.D., in an effort to integrate industry relevant productions and learning in the curricula.
- Finally, at the post-doctoral level, Jason Mejane, has taken charge of the coordination and scientific leadership of the project cluster, and the follow up on design projects with industrial partners (more details to come).

Best Practices

Please present one best practice implemented, to share with other CDE Chairholders.

1.

Empowering staff in the conduct of Chair related affairs
With an ambitious program and a small staff, the need for efficiency becomes paramount. Moreover, both of my assistants (professional and post-doctoral fellow) hold PhD's. Hence. It makes much sense to give them enough latitude to take on challenges and take ownership of their specific, individual mandates. This provide several advantages:

- It is in line with the objective of training the next generation of design professors and mentors;
- It allows my assistants to become known in the faculty as Chair legitimate representatives and to act on behalf of it, when needed;
- They provide day to day follow up on ongoing projects and initiatives;
- They contribute to the Chair visibility and reach;
- They nurture the growth of the local design community;
- The time that these two, new assistants spare me, can be used more productively to promote design and aluminium at the highest level.

1. Overview

a. Chair Structure

Please provide an overview of the participation in and contributions to the CDE action plan of each member of the Chair's team (Chairholder(s), professional staff, company experts, collaborators, post-doctoral fellows, students, etc.).

Chair resources		Mandate/interests	Relation to Chair
Partners		***Promotion of aluminium in products and HQP training***	Chair reporting to partners ***** Partners providing aluminium related projects, knowledge & funding
	NSERC	Fulfilling the Chair in Design Engineering mandate and sharing best practices amongst Design Chairs	
	Aluminium Association of Canada (AAC)	General interest in Chair mandate toward aluminium in finished products (new partner for Chair 2nd term)	
	CQRDA	Provincial granting agency supporting the development of aluminium products	
	REGAL Research Centre	Graduate student training and research toward aluminium applications	
	Alcoa Innovation	Production of webinars for knowledge diffusion of aluminium uses	

	Ministry of Economy, Science and Innovation (MESI)	Québec aluminium strategy: Training of professionals fostering the use of aluminium in product design	
Faculty resources		***Supporting and facilitating the execution of the Chair mandate across the Faculty***	Chair reporting to Dean and Interdepartmental committee ***** Program directors and collaborators as contributors to Chair objectives
	Dean	Overseeing Chair accomplishments and granting space for Chair initiatives	
	Program directors	Formal integration of Chair proposals in academic programs (undergraduate and graduate)	
	Chair interdepartmental committee	Providing advices and political support as well as additional connections to the rectorate	
	Chair collaborators	Technical expertise from the many colleagues involved in design projects and research targeting aluminium usage	
Chair internal resources: Aluminium oriented		***Human resources reporting to the Chair for the "aluminium track"***	Chair plan execution by internal team ***** Internal team delivering expected outcome as per Chair program
	Post-doctoral fellow (PDF) #1	Supporting the many aluminium specific Chair initiatives, conduct an original research program on aluminium generic technologies (structural panels & extrusions, assembly methods, etc) and contribute to enhance the Chair visibility	
Chair internal resources: Product design oriented		***Human resources reporting to the Chair for the "design track"***	
	Technical support	Management and operation of the Chair facility equipment (Claude Dugal and Sébastien Harvey, mechanical engineering technicians)	
	Mechatronic professional	Setting up the Load Case Characterization and Prototype Validation Laboratory (LCCPV) and providing students with help and expertise regarding the use of data acquisition and control systems hardware and software	

b. 5 Year Term Objectives Overview

Please provide a brief overview of your Chair, its goals and objectives.

The general mandate of the Chair is to promote the training of competent engineers in the design of aluminium products through project-based learning. This mandate is twofold: 1) to develop and teach knowledge and expertise on the design of products, rather than prototypes, where reliability, manufacturing and assembly constraints are properly taken into account and 2) to encourage the use of aluminium in products from a cost/benefit/performance perspective. The Chair supports undergraduate and graduate programs from the departments of Mechanical, Electrical and Computer Science as well as Civil Engineering.

c. Annual Objectives/Tasks

Please provide a list of the activities that were to be achieved in the past year and your progress toward these objectives.

For 2016, two main objectives were identified and have already been presented as Top contribution #2 and 3 for the year.
The following lines will provide additional details on each one:

1) *Setting up a "Load Case Characterization and Prototype Validation Laboratory" (LCCPVL):*
The main thrust behind this initiative is to provide students with tools and support to address the experimental phases of the design process, both at its beginning (load case identification) and end (prototype validation and performance assessment), therefore closing the product development loop.
Recognizing the relevance and novelty of this initiative, the faculty provided it with prime space (C1-2108; 78 m^2 and C1-2109; 51 m^2), strategically located in front of the Mini-Baya and SAE Formula's own rooms. The current layout of the LCCPVL rooms is presented in appendix.
As previously mentioned, to actually set-up the laboratory, a professional researcher in mechatronic, Jonathan Nadeau, has been hired in October 2016. Taking advantage of his core competencies, he was assigned the task of selecting the most appropriate equipment and proposing a corresponding acquisition timeline, spanning over the five years Chair duration.
The LCCPVL philosophy encompasses the following principles:

a. To provide undergraduate students with equipment, control, sensors and data acquisition devices that are natural extensions of what is being used in courses (i.e. Matlab compatibility);
b. To allow graduate students to experiment with the most state of the art equipment available, and be able to take on any experimental measurement or control challenge;
c. To provide "consumables" for free but have the student pay when they require a sensor with very specific features that do not bear much chance of being reused afterward;
d. To make the laboratory open to all on a need basis, but with places not being assigned to specific student teams;
e. To offer the services of a mechatronics professional to assist students.

From a technical standpoint, the purpose of the laboratory will be to:

- Conceive and create various experimental test benches;
- Implement appropriate sensors, instrumentation and control devices and strategies;
- Perform measurements through data acquisition and processing.

In terms of equipment, workstations and workbenches with electronic and mechanics tools will be made available for the students, along with mechatronic equipment and other specialized systems (embedded systems, control and acquisition systems, power electronic systems,

electronic measurement, etc.). Example of such equipment and associated furniture include:

a. Portable data acquisition and control systems, real-time rapid prototyping systems (compatible with Matlab and/or Labview software);
b. Measurement and debugging systems: Oscilloscopes, power supply, multimeters, etc.;
c. Embedded systems;
d. Electric motor test bench and engine dynamometer;
e. Sensors of all kinds: Accelerometers, torque-meter, thermocouples, encoders, current-meter, pressure sensors, strain gauges, signal conditioners, etc.)
f. Mechanics and electric furniture and tools;
g. Electronic assembly: Welding and soldering tools;
h. Specialized systems: Thermal camera, 3D scanner, 3D printer, etc;
i. Vibration testing systems;
j. Power electronic systems;
k. Spectroscopy-meter,

Currently, equipment that have been acquired include those of category a (partly), b, c, d, e (partly), f and h. A servo-hydraulic fatigue testing machine belonging to Prof. Desrochers will also be moved in the new facility, therefore making it available to undergraduate students in addition to graduate.
Moreover, the newly acquired equipment of Prof. Joao Trovao, holder of the Canada Research Chair in Efficient Electric Vehicles with Hybridized Energy Storage Systems, will be installed in this location as well. This will result in a stimulating and productive collaboration between the Department of Mechanical Engineering and the Department of Electrical Engineering and Computer Science Engineering, both at the undergraduate and graduate student levels, therefore further expanding the reach of design in the engineering curricula at UdeS.
From a time table perspective, as things currently stand, most equipment have been ordered, the electricity outlets and other required connections are being completed and the date for the servo-hydraulic testing machine transfer and calibration has been set to June 12th, 2017. Starting from the last weeks of August 2017 at the latest, undergraduate and graduate students will therefore be able to use the laboratory for their educational activities and projects.

2) *Supporting the Chair objective toward Design projects and methodology at the graduate level:*

As mentioned earlier, this goal is one main thrust for the second term of this Chair. This point having been driven home in previous sections, this report will not drag on to provide too much details on the projects having been undertaken to that end. A few tables will summarize past and ongoing projects:
In 2016, a project cluster on structural aluminium (*Al*) panels was established and involved 7 Master degree students on related subjects, as indicated in the following table:

No	*Name*	*M.Sc. Type*	*Duration (m.)*	*Start*	*Description*
1	C. Laverne	Research	24 (ongoing)	Fall 2015	*Al* bus floor extrusions
2	M. Mbodj	Course	8	Sum. 2016	*Al* structural panel design
3	M. Hedhili	Course	4	Sum. 2016	*Al* panel optimization
4	P-O. Bru	Course	8	Sum. 2016	*Al* panel sintering
5	M. Cazaubon	Course	8	Sum. 2016	*Al* bus roof panel
6	T. Lherm	Course	8	Sum. 2016	*Al* panel production
7	A. Buffard	Course	4	Sum. 2016	*Al* battery pack panel

In 2017, two projects involving three students have been launched; one on the design of a bike shelter and the other on the design of an aluminium suspension and structural panels for a micro-caravan called iGoutte.

No	*Name*	*M.Sc. Type*	*Duration (m.)*	*Start*	*Description*
1	M. Cazaubon	Intern	4	Sum. 2017	*Al* suspension for caravan
2	M. Nocturne	Course	4	Sum. 2017	*Al* panel for small caravan
3	M. Chantre	Course	8	Sum. 2017	*Al* panel optimization

Of utmost importance is a recently awarded NSERC Collaborative Research and Development (CRD) grant titled: "Atlas: Structure lightening program applied to recreational vehicles". As indicated earlier, this 3,07M$ project, for which I am principal investigator, will benefit 14 graduate students and 5 professors. Industrial partners for the project include BRP (Bombardier Recreational Products), Centre de technologies avancées BRP – Université de Sherbrooke (CTA), Rio-Tinto, Shawinigan Aluminium and Verbom.
The Atlas project overall objective is to design and optimize a recreational vehicle aluminum frame so as to reduce its weight, while minimizing cost and part number, and offering an adequate lifespan, vibration isolation and ride.
Although CRD grants typically point to original research contributions, this project really connect to design processes and product development. It features four tasks on: 1) Best practices in alloy selection and joining; 2) Load case identification; 3) Design and optimization of a new aluminium frame for a Spyder tricycle, and 4) Fatigue based, prototype validation. As it quite plainly appears, design is the spine along which the project was structured.
Although officially waiting for one last signature on the Intellectual Property Partner Agreement, two research-master degree students (F. Corriveau and N. Joubert) have already launched their investigation work into the first two tasks.

d. Objectives/Tasks for Upcoming year

Please provide a list of the activities that you are planning for the upcoming year.

2017 will be the second year of the second Chair mandate and as such, should see the continuation of two actions targeted toward graduate programs: a) Fully deploy the course-based master degree in design with internship, at the faculty level; b) Increasing the number of industrial design projects offered in research-based program (master and Ph.D.) as the Atlas program unfolds.
In addition to the graduate program oriented initiatives, support to design projects will be further enhanced with the development of web-based, laboratory training material, the launching of the *Load Case Characterization and Prototype Validation Laboratory" (LCCPVL*) and the continued free supply of aluminium for student projects.
The development of a web platform is also ongoing and will be achieved to increase the Chair visibility, to recruit new students on projects and to offer an internal platform for sharing documents and references efficiently.
For the second part of the year, two graduate projects that have already been started, will be completed: the first features the design and prototyping of the modular and environmentally friendly, aluminium bike shelter, while the second proposes the design of new, lighter, aluminium suspension and body panels for the iGoutte micro-caravan.

e. Impact of Semi-Annual meetings

Please describe the influence last year's semi-annual meetings have had on your Design Chair. Note any impact or changes as a result of the meetings.

In last year's semi-annual meeting, it was interesting to note that some colleagues, and especially those at the helm of newer chairs, were embracing the two-pronged approach toward design in undergraduate/graduate programs or at the capstone/research project levels. It was comforting to see that the vision I had presented in my Chair renewal proposition was somehow gaining traction in our design community.

2. Established Partnerships

Briefly describe the nature and extent of the involvement of the partners. Include details on how the results have been communicated to the partners (e.g. meetings, reports) and how the industrial partners have transferred knowledge and know-how to the university students, staff, and faculty.

In 2016, three regular partners have supported the Design Chair: REGAL, Alcoa Innovation, CQRDA and the Ministry of Economy, Science and Innovation (MESI). The extent of their involvement is still in line with their initial commitment.
Alcoa's contribution is in kind, but is central to the good operation of the Chair. Indeed, it includes the involvement, as industrial co-chair, of Russell Long, Chief Engineer, Ground transportation, at the Alcoa Technical Center (ATC) in Pittsburgh as well as technical resources from Alcoa Innovation in Montreal. Joint webinars are regularly broadcasted from the Université de Sherbrooke and the ATC.
The contribution of the Centre Québécois de Recherche et de Développement de l'Aluminium CQRDA is through grants for projects involving students from the Université de Sherbrooke and Small to Medium size Enterprises (SME). Although unsuccessful this past year in meeting the grant proposal deadlines, two applications have recently been successfully filed by the Chairhoder for the two on-going projects regarding the design of a bike shelter and that of a miro-caravan.
The REGAL Research Centre on Aluminium was instrumental in the creation of the Design Chair as it was part of its strategic plan. REGAL promotes collaboration and support toward aluminium related projects at the graduate level. In 2016, M.Sc. student Françis Corriveau and post-doctoral fellow Jonathan Nadeau, have been partially paid by the REGAL contribution.
The contribution of the Ministry of Economy, Science and Innovation (MESI) allowed an upgrade from a technician to a mechatronic professional (Jonathan Nadeau) to set-up, launch and follow up on the *Load Case Characterization and Prototype Validation Laboratory*.

3. Sources of Financial Support

Please provide information about the cash and in-kind contributions received during the past year, noting the impact on the Chair activities as well as the estimated values for Chair leverage.

As indicated in the yearly financial reports, the in-kind commitments from the industrial partners have been honoured and their cash contributions received. However, as mentioned in the preceding section, although efforts have been devoted into identifying eligible CQRDA projects, it has not been possible to secure CQRDA funds through project grants this past year. Indeed, the contribution from the CQRDA is based on fund leveraging for aluminium related projects

involving at least one industrial partner, depending on the Technological Readiness Level (TRL), which mirrors more or less the engineering uncertainties and associated risks in a project. In the end, identifying eligible projects supported by industrial partners turned out to be a more challenging task than it initially appeared. Nonetheless, two CQRDA grant applications have been submitted in May 2017.
In addition to the "official" Chair partners that have been duly declared in the original Chair renewal proposal, one important additional partner joined ranks in 2016: the Ministry of Economy, Science and Innovation (MESI) of Québec, which pledged for a 33 k$/year commitment to explicitly support the training of design competencies in the use of aluminium in products. More broadly, this contribution is part of the Québec Strategy for the Development of Aluminium, whose objective is to double the transformation of aluminium within ten years to 2025.
Regarding graduate projects related to aluminium, thanks to the Atlas project, 225 k$ in cash and 399 k$ in in-kind contributions are to be received from the partners. Over the four years duration of the project, a total of 14 students will be involved (6 master degrees, 6 Ph.D. degrees and 2 post-doctoral fellows).

4. Progress to Date

Please describe the progress to date made toward the following objectives.

a. Training

Please include all relevant information about courses developed or modified by the Chair focusing on design, the impact of these courses as well as any involvement in competitions etc. Please include the number of students impacted.

I. At the undergraduate level

Since the beginning of 2017, Jonathan Nadeau, Chair professional, has provided support to students for their capstone projects, in the areas of mechatronics and experimental investigations. Therefore, although the *Load Case Characterization and Prototype Validation Laboratory (LCCPVL)*, was not up and running yet, Jonathan nonetheless offered the students his expertise and the equipment the Chair had purchased in the past months. More specifically, the following teams have benefited from the support of Jonathan : team NAVIOS (recreational boat powered by human energy), team ExodUS (exoskeleton), team MoDiH (production and injection of hydrogen in a diesel engine), team Shark (personal watercraft with stability and static buoyancy that allows the user to stand upright when stationary). Examples of support provided include :
- Debugging and developing the computer program code for various kinds of control and acquisition systems;
- Loaning and supporting the use of equipment and sensors for test campaigns: thermocouple, hydraulic systems, motor encoders, embedded systems;
- Proposing strategies and methods for test campaigns related to the usage of mechatronic systems.
Also, two trainee students (Inès Boukherbache and Quentin Wild) have been supervised by Jonathan Nadeau and Prof. Alain Desrochers, from January to mid-March. They have worked on the characterization of a new concept of structural aluminium sandwich panels that can be put into use in public transit applications such as buses.

II. At the graduate level

The project cluster on structural panels and extrusion came to an end, and resulted in several promising prototypes. Seven students were involved and others are to come. The quality of the results and deliverable, and the success in the management and training of the students are a proof of the potential that the project clusters bear in the fulfilment of the Chair objectives.
Also worth mentioning is a recently ended, research and design project (NSERC-CRD) called dSkibel, aiming at reducing the noise of BRP snowmobiles, which saw, in the last few months, three graduate students writing and submitting their results in peer reviewed journals.

b. Design and Development

Describe all relevant information about the design and development of innovative products, processes, systems and technologies.

Several designs of aluminum sandwich panels have been fabricated and characterized as part of the 2016 projects cluster. Completely made of aluminum and making use of structural adhesive, those panels consist in two skins joined by an internal, sheet metal, open web. Overall, the concept brings a definite improvement over more traditional panels featuring honeycomb or rigid foam cores :

- Services (electric cables, pneumatic piping,…) can be routed directly inside the panels without additional machining or resistance losses;
- The panels numerous design parameters facilitate custom design to suit specific applications and standards;
- The two panel skins can be used directly as finished surfaces since there are no brackets or services to be concealed.

Moreover, the panels are just slightly heavier than similar honeycomb panels, but the improvements outlined above make this point negligible.
The panels have been tested experimentally and also numerically to validate that they are able to meet automotive standards. The case for city transit bus roofs was investigated more thoroughly.

c. Collaboration

Describe any collaborations and interaction of the Chair with the department, faculty, university and outside colleagues during the past year in connection with the CDE action plan. Include collaborations with other CDEs, but do not include the Chairs regular workshop meetings.

The *Load Case Characterization and Prototype Validation Laboratory (LCCPVL)* implies multidisciplinary projects within the faculty of engineering, mostly with the Mechanical Engineering department and the Electrical engineering and Computer Science engineering department. Thus, several actors (professors, professional researchers, technicians) from these departments were consulted to get their suggestions and inputs on the development of the LCCPVL, so as to identify and meet the needs which are not currently fulfilled at the faculty level. So far, ten persons have been consulted and other meetings are still to be planned.
Also, the professor Joao Trovao, holder of the Canada Research Chair in Efficient Electric Vehicles with Hybridized Energy Storage Systems, confirmed his collaboration with the LCCVPL by sharing his equipment. In return, the laboratory will provide support and services to his Chair and graduate students.

d. Promotion

Describe any events and activities that were organized to raise the awareness and appreciation in the research and outside communities for all aspects of design engineering.

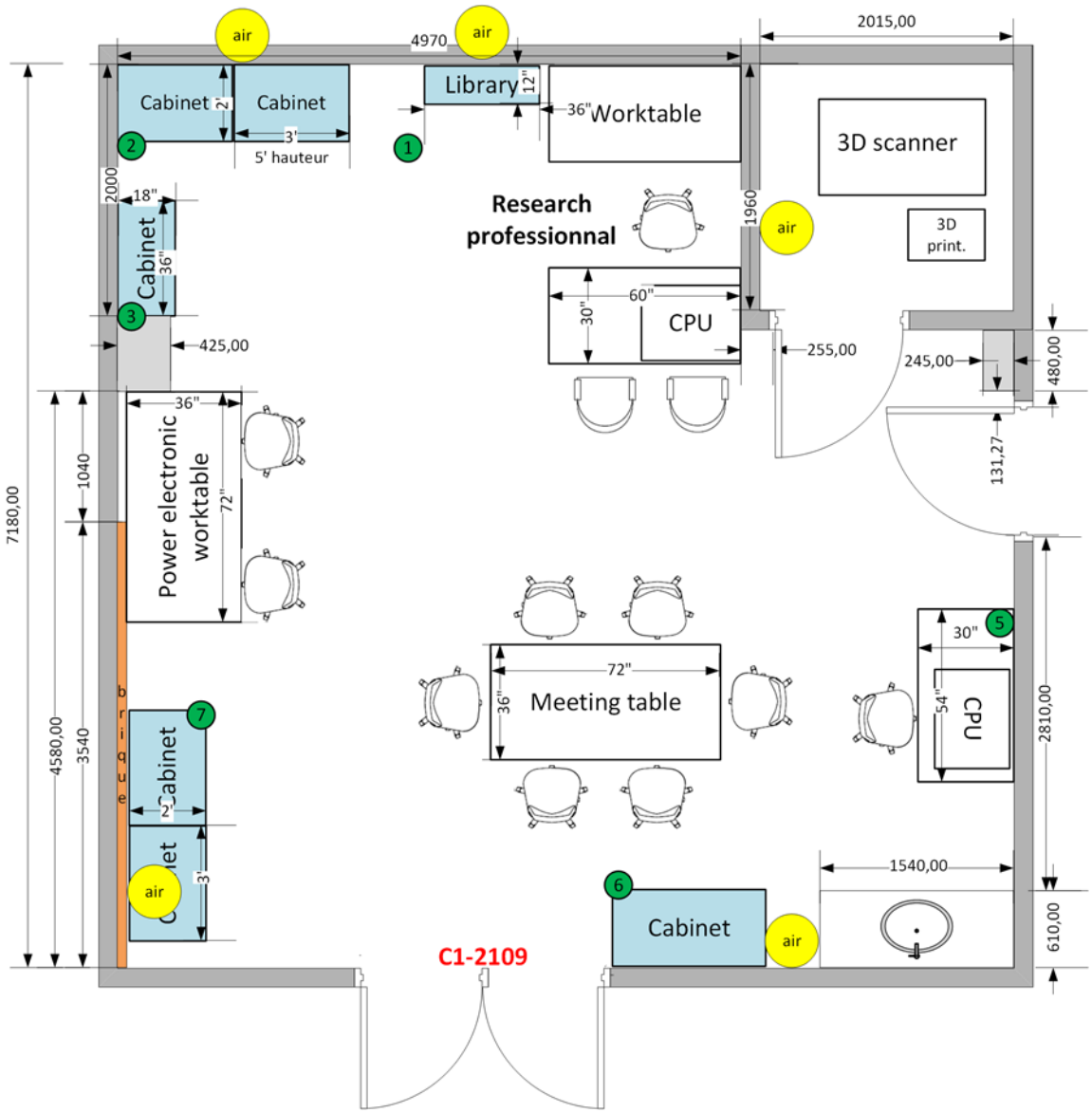
Professor Desrochers has been attending many forums (REGAL students day, AluQuébec strategic planning meeting, Ground transportation pole, AluQuébec extrusion think tank meeting, etc.) pertaining to aluminium transformation and use in finished products. He is very much known in the design and aluminium community and is routinely consulted on various matters (member of the selection panel for Chairs in Design Engineering, member of the selection committee for the next director of the REGAL Research Centre).

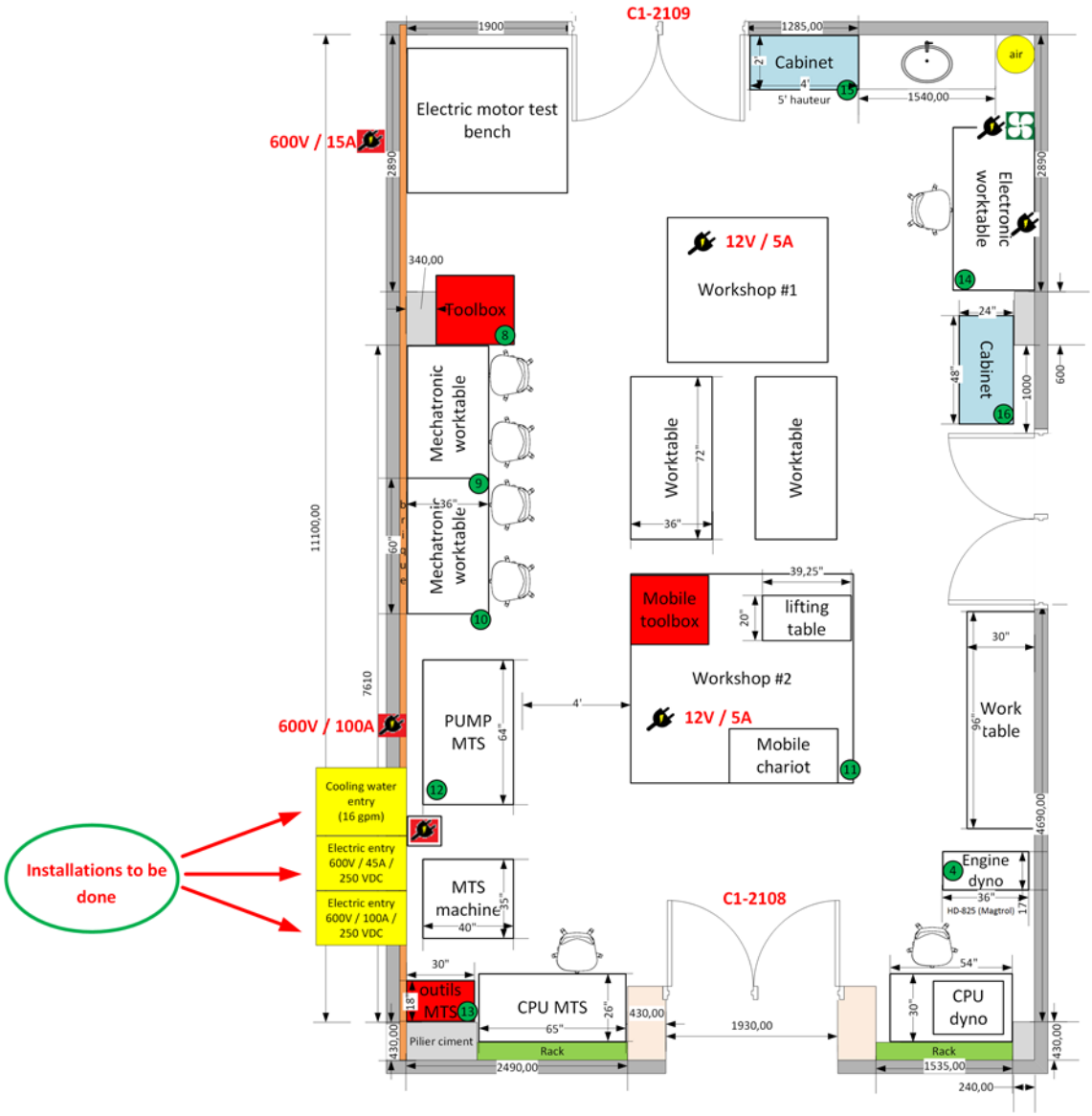
5. Problems Encountered

Identify the main problems encountered during the past year, their impact and the steps taken to resolve each issue.

Several hurdlles arose in the organization and set-up of the *Load Case Characterization and Prototype Validation Laboratory (LCCPVL).* However the momentum gained along the way and the active collaboration of the Engineering Faculty staff and management team, allowed overcoming the problems most effectively.
Otherwise, delays owing to a good willed, but overworked associate dean academics, hampered the progress of the proposal for a course based Master degree in Design, with internships, even though I had been named Director of the Course based Master degree in Mechanical Engineering to provide additional thrust. The second half of 2017 should see this through.

APPENDIX: Layout of the Load Case Characterization and Prototype Validation Laboratory





[1] In this document references to Chairs in Design Engineering (CDE) also should be interpreted