

Creating a bridge between Brazil and Sweden

Case: Prof. Petter Krus

Produced by CISB

Project Team

Alessandra Holmo

Claúdio Mazzola

Eduardo Nascimento

Letícia Morales

Summary

1. Executive Summary	3
2. Objective	5
3. Bilateral Research Collaboration	5
3.1. Building a bilateral collaboration: Prof. Petter Krus trajectory	5
4. The Swedish Professor Chair at ITA in Honour of Peter Wallenberg Sr	7
4.1. Bilateral Research Project:	7
4.1.1. MSDEMO Project	7
4.1.2. MSDEMO Bilateral Work Packages	8
4.1.3. MSDEMO Results	9
4.2. Promote Long Term Cooperation	9
4.2.1. Research Projects	10
4.2.2. Other Initiatives	11
4.3. Joint Education	12
4.3.2. Short courses	12
4.3.3. Students co-supervising	13
4.3.4. Promoting student exchange	13
5. First results achieved by the Bilateral Collaboration	14
5.1. Benefits for Academy	14
5.2. Benefits for Industry	15
5.3. Benefits for the Society	16
6. Key Performance Indicators – KPIs	17
6.1. R&D and Other Projects/Initiatives	18
6.2. Human Resources	19
6.3. Financial Resources	20
6.4. Economical Resources	22
6.5. Joint Publications	23
6.6. Institutional Agreements	24
7. Conclusion	25
8. ANNEX	26

1. Executive Summary

This report aims to describe the results of Bilateral Collaboration between Brazil, and Sweden. Professor Petter Krus from LiU became one of leading pioneers to build and strength joint research and development and industrial collaborations among both countries. His trajectory is described into three phases:

Before 2011- research activities before Prof. Petter mains missions to Brazil.

From 2011 to 2014 - research activities during mains exploratory missions to Brazil, but before being awarded by Endowed Professor Chair.

After 2015 - research activities after Endowed Professor Chair grant to present days.

Before 2011, Prof. Petter was engaged with applications in aircraft systems and aircraft conceptual design and was involved in building a scaled demonstrator of a Generic Future Fighter (GFF) concept in collaboration with SAAB and Swedish Defence Material Administration (FMV).

Motivated by his involvement with Generic Future Fighter (GFF) concept and in view of the Agreement on Innovative High Technological Industrial Cooperation signed in 2009 between Brazil and Sweden, from 2011 to 2014, Prof. Petter made several missions to Brazil and with support of CISB office, he was able to establish, strength and consolidate his academic network with some of major Education and Research Institutions in Brazil like ITA, UFSC, USP and UFABC.

As consequence, one of the main results from these efforts, in 2015, Prof. Petter Krus was awarded with Swedish Endowed Professor Chair in Honour of Petter Wallenberg Sr. at ITA, where he acted as an ambassador motivating the establishment of connections between the two countries to build a sustainable innovative research ecosystem in aeronautics and aiming to expand to other areas such as sustainable energy, environmental technology, defence and security, transport and logistics and urban development. The activities of the Swedish Endowed Professor Chair Program can be divided in 3 categories:

- I. Bilateral Research Project
- II. Promote Long Term Collaboration; and
- III. Joint Education.

Regarding **Bilateral Research Project**, Prof. Petter Krus is engaged with MSDEMO project which is opening and offering possibilities for LiU to collaborate with ITA and USP/EESC and to develop state of the art methods for subscale demonstrator, with investigation of control law development for dynamical scaled demonstrator.

Regarding promotion of **Long Term Collaboration**, the engagement involves several academic peers who are developing a world class university network in Brazil and Sweden in the aeronautics related areas, with a strong industrial relevance.

Regarding **Joint Education**, Prof. Petter Krus is engaged with daily activities at ITA, as well as other universities. These activities are: (i) short courses, (ii) student co-supervising, (iii) mentoring young Professors and (iv) promoting student exchange.

There are numerous benefits that derive from bilateral collaboration relationship, including to Academy, Industry and Society, which are able to produce models replicable and generate learned lessons at national-level to improve higher education, research and innovation policy.

Therefore, in order to quantify and qualify the benefits generated from prof. Petter efforts the report considered to analyse the time evolution of six KPIs categories: R&D and Other Projects, Humans Resources, Financial Resources, Economical Resources, Joint Research Publications and Institutional Agreements.

R&D and Other Projects - up to now, **6** bilateral projects started and are divided into two groups: 3 (three) R&D projects and 3 (three) of other initiatives:

Besides “MSDEMO”, the leading project with LiU-ITA- USP/EESC –Saab, there are the projects: “Digital Hydraulic Actuator for Aeronautics for flight control” with Prof. Victor de Negri from UFSC and “New Methodologies for Conceptual Design of Aircraft - Supersonic Aerodynamics” with Prof. Alvaro Aballa from USP/EESC. Other initiatives involve the creation of one innovative master’s program with Prof. Lucina Pereira from UFABC, establishment of connections that allowed the creation of Santa Catarina Convergence Centre on Aerospace Technologies to attend demands and competences from Academy and Industry of both countries and the Partnership in Digitalization initiative.

Humans Resources – currently there are at least **18** (eighteen) individuals from Brazil and **13** (thirteen) from Sweden, such as Project leaders (Professors and Specialists), Young researchers (Post-docs) and Students (PhD and Masters), performing research directly in the projects.

Financial Resources - available funding for the start and continuation of projects such as missions (air ticket and *per diem*), project funding (specialized people, equipment, etc), scholarships for graduates and/or the Professor Chair program have already reached almost one million American dollars (**USD 931,350**) and it is a key component to build and to consolidate long-term cooperation between Brazil and Sweden.

Economical Resources – this means the commitment of industries and universities to collaborate, in terms of their employees working time for the projects. Currently there are about **15** (fifteen) researchers (Professors and Industry employees) from both countries participating in projects. It should be point out most of industry researchers is from Sweden, while the majority Academy researches is from Brazil.

Joint Publications – the rising of joint publications shows the first results of bilateral collaboration in terms of scientific production and its importance for the internationalization of the science. Up to now at least **8** (eight) scientific production were published. It is important to point out that research takes time as well as publication of results. It is expected an increase of submission and publication of collaborative papers for next years.

Institutional Agreements - the increase of agreements (Memorandum of Understanding, Non-Disclosure Agreement and Cooperation agreement) at the institutional level shows the positive impact of the collaboration between the two countries during last years. Currently, **9** (nine) institutions have signed institutional agreements, being **4** (four) from Sweden and **5** (five) from Brazil. In terms of triple helix classification there are 6 (six) universities, 2 (two) industries and 1 (one) research institute.

Finally, according to graphics all KPI categories raised since 2011 when prof. Krus initiated first missions to Brazil and gained higher level of intensity after awarding the Swedish Professor Chair.

2. Objective

This report aims to describe the benefits of Bilateral Collaboration between Brazil, and Sweden.

3. Bilateral Research Collaboration

For decades Brazil and Sweden have a joint history of trade and industrial activities, primarily within vehicle, telecommunication and energy transformation industries. More recently, a focus on extending cooperation within Technology and Innovation (T&I) has been initiated. In 2009 through the signing of the Agreement on Innovative High Technological Industrial Cooperation between Brazil and Sweden, both countries expressed high expectations of future joint research and development (R&D) and industrial collaborations (IC), leading to innovations and more industrial partnerships in aeronautics and in other strategic industrial sectors.

3.1. Building a bilateral collaboration: Prof. Petter Krus trajectory

Professor and head of the Division of Fluid and Mechatronic System (FluMeS) at the department of Management and Engineering of Linköping University (LiU) in Sweden, Petter Krus became one of leading pioneers to build and strength joint research and development and industrial collaborations among Brazil and Sweden. His trajectory can be described into three phases:

3.1.1. Phase I - Before 2011- this period refers to Prof. Petter research activities before his first mission to Brazil

Petter at LiU was engaged with applications in aircraft systems and aircraft conceptual design, road vehicles and construction machines. The FluMeS division has been rewarded a contract with SAAB and Swedish Defence Material Administration (FMV) to realise and build a scaled demonstrator of a Generic Future Fighter (GFF) concept.

The concept constituted a goal and common study object for the Defence Area long term research and development strategy within aeronautics within the framework of NFFP4, Swedish National Aeronautics Research Programme. Maiden flight took place in November 2009 and according to all stakeholders, it was a success.

3.1.2. Phase II - From 2011 to 2014 - this period refers to Prof. Petter first exploratory missions to Brazil, but before being awarded by Endowed Professor Chair.

From late 2010: On December 2010 and February 2011 Prof. Petter made his two first mission to Brazil where, supported first by Saab for the kickoff of the Swedish-Brazilian Research and Innovation Centre (CISB) and he was introduced to several Brazilian institutions such as Technological Institute of Aeronautics (ITA), Federal University of Santa Catarina (UFSC), Federal University of ABC (UFABC) and University of São Paulo, establishing thus, first academic contacts, with Prof. Agenor Fleury from USP, Prof. Victor de Negri/UFSC, and Prof. Luciana Pereira/UFABC, which later became his main local partners for international collaboration. Also, in 2011, invited by Prof. Agenor Fleury/USP, Prof. Petter participated as guest lecturer at the Dynamic Problems in Mechanical Engineering (DINAME) conference which enabled him to get introduced to other important research groups which dramatically increased his network in Brazil.

In 2012, during another mission to Brazil, Prof. Petter strengthened his relationship with his contacts by:

- introducing SAAB to universities: ITA, UFABC and USP/São Carlos Engineering School (USP/EESC). At USP/EESC he met Prof. Alvaro Aballa, which was his first Guest Researcher in Sweden later in 2012 and also Prof. Luiz Goes at ITA;
- organizing in collaboration with Prof. Victor de Negri, Prof. Lucina Pereira and CISB the first Workshop in Innovative Fluid Power (1st WIEFP) in São Paulo at Brazilian Machinery Builders' Association (ABIMAQ) which showed up a success, bringing at least 50 participants from both academy and industry; and
- lecturing as guest Professor (invited by Prof. Luiz Goes) for short course at ITA.

In 2013, Prof. Petter consolidated his academic network and was invited to present lectures at several important events such as DINAME conference, MDA (Motion, Drive & Automation) industrial fair and COBEM (International Congress of Mechanical Engineering) conference where he also brought one PhD student and one postdoc from LiU to present papers.

By the time he was able to disseminate his research interests in academic workshops and conferences throughout Brazil, new contacts from industry and government were also established, creating thus, a new triple-helix network for collaborations within and outside his R&D projects.

During 2014, Prof. Petter strengthened and increased his network visiting known and new Academic Institutions: UFABC, Federal University of Minas Gerais (UFMG), Engineering Military Institute (IME/RJ) and USP/EESC, Industry (EMBRAER, Belo Horizonte unit) and Government (Brazilian Army Department of Science and Technology, in Brasília). All these efforts resulted in a dynamic network which enabled him to:

- present courses at ITA;
- receive ITA Professors to spend six months at LiU with his research group;
- send the first PhD student for a three month stay at USP/EESC;
- invite Prof. Victor de Negri as a keynote speaker for Swedish fluid power conference in Linköping

As consequence, one of the main results from these efforts, Prof. Petter Krus was awarded with Swedish Endowed Professor Chair in Honour of Petter Wallenberg Sr in 2015.

3.1.3. Phase III - After 2015 - this period refers to Prof. Petter research activities after Endowed Professor Chair grant to present days.

4. The Swedish Professor Chair at ITA in Honour of Peter Wallenberg Sr

The program Swedish Professor Chair at ITA in Honour of Peter Wallenberg Sr. creates a chair at ITA to establish bilateral cooperation in research, education and innovation in aeronautical technology. The Chair includes Swedish Professors who are expected to spend substantial time per year in Brazil, with ITA as their hub, over an initial 3-year period. The program also includes costs for stays in Brazil by Swedish Post Docs as well as PhD and Master Students. Further, the chair aims to benefit from other mechanisms to foster collaboration, such as the CNPq-CISB-Saab scholarships for Brazilian researchers to develop part of their projects in Sweden.

The tasks for the Swedish Professors include three main areas of activity:

- I. Bilateral Research Project;
- II. Promote Long Term Collaboration; and
- III. Joint Education.

It is expected that this initiative will enable to build a sustainable bilateral innovative research ecosystem in aeronautics and expand it to other areas such as sustainable energy, environmental technology, defence and security, transport and logistics and urban development.

4.1. Bilateral Research Project:

4.1.1. MSDEMO Project

Methods for Subscale Flight Test and Demonstration or simply, **MSDEMO**, is a project, created under the Chair, to study methods and tools to produce concepts for future combat aircraft and make demonstration by subscale flight testing. Aircraft Design is a challenging area and involves many tightly-coupled sub disciplines. The challenge during this early design phase is the use of higher-fidelity methods typically applied in later development stages. Due to its tremendous complexity aircraft development is often plagued by delays and budget overruns. Maximising knowledge during early design stages is of critical importance.

Subscale models are physical, downsized reproductions of components or vehicles used to examine characteristics of larger full-scale counterparts. There is a strong correlation between aircraft size and cost, agreeing that the use of subscale demonstrators represents in most cases a satisfactory trade-off between risk, cost, and fidelity of results, especially for evaluation of radical or unconventional designs for which no previous experience exists.

The most critical contributions are to provide confidence, reduce risk and reduce technology gap by introducing a scaled demonstrator as a viable means to mature and validate new aircraft technologies and aircraft configurations to high levels of technology readiness. This would mean that it will be necessary to forecast technology in different areas such as aerodynamics, structure, propulsion, on-board systems and weapon systems.

This project is also an important exercise for the collaboration between Sweden and Brazil. From the Swedish side of the project the main focus is on the use of subscale demonstrator for early flight testing and validation. From the Brazilian side, the focus is to build a subscale prototype in Brazil as well as a providing flight control laws to be implemented in the prototypes. Furthermore, they will work on redesign for input to a continuation of this project.



Figure 1 - Subscale Flight Testing Model

The project has a strong focus on low-cost test techniques using as much off-the-shelf equipment as possible. Components such as miniature gas turbine engines, powerful and precise actuators, robust and redundant data links, telemetry systems, and other advanced equipment are now available at low cost. Furthermore, technologies such as morphing (wing) technologies and alternative means of flight control could be incorporated. The project also involves study of integration of new weapon systems, such as directed energy weapons.

Regarding funding, the project started with independent financing on both sides. The Swedish side of the project is funded by the National Program for Aeronautics Research (NFFP/Innovair) with a budget of approximately 300,000 Euro for two-year duration, with a plan for continuation. The Brazilian side initially didn't present financial funding for the project, but rather economic funding, such as working hours of Professors, access to specialized laboratories and equipment and undergraduate and graduate scholarships.

In 2017 a continuation project was approved in the joint call from the Brazilian Funding Agency FINEP and Swedish Funding Agency Vinnova, with financial funding of BRL 400,000 (aprox. USD 120,000) in the Brazilian side and SEK 1.000.000 (aprox. USD 120,000) in the Swedish side, for the duration of 2 years.

4.1.2.MSDEMO Bilateral Work Packages

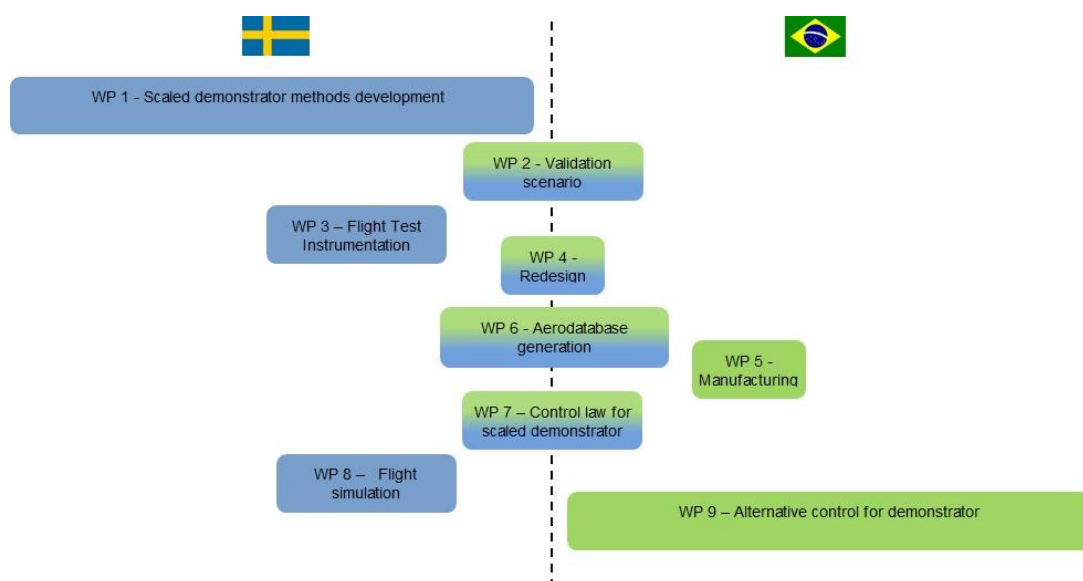


Figure 2-MSDEMO Bilateral Work Packages

Note: Work packages in blue refer to the Swedish part of the project and in green to the Brazilian part. The ones with both colours will be performed in collaboration

4.1.3.MSDEMO Results

Expected tangible results obtained from the collaboration are:

- A scaled demonstrator with flight test instrumentation allowing testing of control laws; and
- A unique aerodynamic data set based on Computational Fluid Dynamics (CFD), wind tunnel data and flight test data that will be made available to the entire aerospace community. This data set provides opportunity to publication with high citations potential and good exposure of a unique collaboration.

The project will also provide an opportunity to present common joint bilateral aeronautical R&D results from Universities located in both countries, Brazil and Sweden, showing the value of collaboration beyond borders. One important evidence of the success of such cooperation is the signature of official agreements between institutions. In 2016 it was signed a Non-Disclosure-Agreement (NDA) between ITA, LiU, SAAB and USP/São Carlos, overcoming the differences of intellectual property at intuitional level and at the level of countries culture and laws. This is an important result of the joint-collaboration that is under development between Brazil and Sweden and can show the path for other agreements to come.

This is an important result of the joint-collaboration that is under development between Brazil and Sweden and can show the path for other agreements to come.

Exemplifying the evolution of the activities, in 2017 the project started a new phase, with the approval of funding from the coordinated call FINEP-Vinnova. The new project subset is called “Methods for Subscale Flight Testing and Analytics (MESTA)” and represents the continuation MSDEMO activities and the achievement of two important milestones of its development:

- the bilateral funding in both countries; and
- the integration one Brazilian company in the project (FT Sistemas).

This new subset also brought the possibility of integration with another project approved by FINEP-Vinnova call, denominated: “Digital Hydraulic Actuator for Aeronautics for flight control”, involving the collaboration established between LiU and UFSC, which will be further discussed latter in this report.

4.2.Promote Long Term Cooperation

The second goal of Endowed Professor Chair, Promotion of Long-term Cooperation aims to assist the development of a world class university network in Brazil and Sweden in the aeronautics related areas, with a strong industrial relevance. In order to build a strong capability in aeronautics related areas, the university network in Brazil with ITA as the focal point, should be consolidated to bring together all expertise at a national level.

Another important instrument for building a strong aeronautics research platform at Brazilian universities is the creation of aligned research agendas both in Brazil and in Sweden. The Swedish agenda was recently updated and there is a great opportunity to initiate work on a Brazilian research agenda in parallel. The work involves identifying strengths from each side and especially complementary competences to build a research platform for development of future aeronautical systems, and a system for sustainable improvement of that platform.

Thus, Prof. Petter, during the past years, was able to establish several Research Projects and catalyse other initiatives, promoting the bilateral Long Term Cooperation, as indicated below:

4.2.1. Research Projects

4.2.1.1. Digital Hydraulic Actuator for Aeronautics for flight control at UFSC

This project is performed in collaboration with Prof. Victor de Negri from UFSC. Both to Sweden and Brazil, mobile systems, such as heavy vehicles and airplanes are important application fields. The increasing need for sustainable solutions means that new technologies are being introduced at an increasing rate, producing great challenges in the technical integration leading to increased complexity.

Actuation systems in aircraft are an area where focus on energy efficiency resulting on weight reduction of components is very important. In construction machines, the design of systems with increased energy efficiency is also a requirement from industry and final users.

A technology called digital hydraulics has being applied in this project which comprises the use of on/off valves to link different supply pressure sources to different cylinder chambers. This strategy can be also combined with analogue control of hydraulic components creating hybrid systems.

System monitoring and analysis under the point of view of safety and reliability are also topics of research. A key tool for development of such systems is modelling and simulation, where functional characteristics of a system and fault detection strategies can be evaluated. A test rig is being used to validate the mathematical models and to analyse the system performance under operational conditions similar to the real use. The project is also about the tools for modelling and simulation, and system optimization, and how they can be used to enable collaboration.

This project was also approved in the Coordinated Call between the FINEP and Vinnova with financial funding of BRL 400,000 (aprox. USD 120,000) by the Brazilian side and SEK 1.000.000 (aprox. USD 120,000) by the Swedish side, for the duration of 2 years project. Besides, it counts with several scholarships of sandwich doctorate and post-doc, approaching and strengthening the collaboration between the research groups of UFSC (LASHIP) and LiU (FluMeS).

Despite the focus in aeronautics, the knowledge generated in this field can be applied to other areas, such as automotive. One example is the involvement of one Masters Student from Prof. Victor de Negri group in a related project with Volvo Construction Equipment. This project led to an exchange of that student in Sweden, funded by Volvo, working on hydraulic hybrid drive systems for wheel loaders, for the period of 4 months as an intern in the company and in the research group of Prof. Petter Krus. Other example of the spillover effect of this project were the research projects "Speed governor based on condition monitoring for early fault detection" and "Hydrostatic Transmission for Rotor-Generator Coupling", which involved the companies Reivax and Parker. They were performed by Prof. Victor de Negri and Prof. Petter Krus in collaboration and also involving Brazilian and Swedish students (Masters and PhD), which were able to spent some time abroad during the project.

4.2.1.2. New Methodologies for Conceptual Design of Aircraft - Supersonic Aerodynamics at USP/EESC

This project is performed in collaboration with Prof. Alvaro Abdalla from USP/EESC. It aims to add a high-fidelity tool that calculates supersonic aerodynamic coefficients, on SANCA program that was developed earlier by Prof. Alvaro Abdalla (USP/EESC) in his Post-Doctoral work at LiU. The tool should establish current and new methodologies that predict aerodynamic coefficients at supersonic conditions. For new methodologies

wind tunnel and CFD data will be referenced to validate the method. The tool is being developed by coordinated activities among LiU, USP/EESC, ITA and SAAB.

4.2.2. Other Initiatives

4.2.2.1 UFABC Master Program: “Engineering and Innovation Management”

This program was created in collaboration with Prof. Luciana Pereira from UFABC. The Masters in Engineering and Management of Innovation aims to enable engineers and managers of innovation to be skilled of acting in the solution of problems related to innovation, either from the point of view of technological development or its management.

These Professionals are expected to act as agents of innovation within the productive sector, the public sector or education and research, so that the knowledge acquired meets the demands necessary for the development of new businesses as well as in the formulation, implementation and evaluation of management models.

The program has relevance to the LiU department of Management and Engineering and its own master programs. This is an opportunity to have students working on relevant projects co-supervised by the Endowed Chair program. Prof. Petter also donated a 3D Printing Equipment to the Master's Program as a stimulation for the innovation environment for the students, as well as a practical tool for their research projects.

4.2.2.2. Santa Catarina Technological Convergence Centre

This initiative can be considered a spillover effect of the collaboration established between Prof. Krus and Prof. Victor de Negri.

The Santa Catarina Convergence Centre on Aerospace Technologies (SC2C.aero) is a virtual centre composed by a network of technical/research groups focused on real technological challenges presented by industry, operating in cycles of continuous improvement under the same informational database. Its objective is to connect Brazilian and Swedish partners, in a similar business model, identifying complementary capabilities and creating bases for collaboration. The points of convergence - between companies and institutions, from Brazil and Sweden, are potential investments in 2 + 2 (industry-academy/Brazil-Sweden) projects or in consortium format.

The creation of SC2C.aero (ongoing) is a consequence of a pre-study financed by Santa Catarina State Funding Agency (FAPESC) aiming at expanding the performance of the state of Santa Catarina in the Brazil-Sweden cooperation. This pre-study, in turn, begins with the cooperation between Prof. Petter Krus and Prof. Victor De Negri, both in the technical field, as well as with strategic actions, such as the organization of workshops and the rapprochement between Brazilian and Swedish stakeholders. That cooperation also expanded to other areas and institutions that have strong capabilities in the two countries, such as the collaboration KTH-UFSC in vibrations and acoustics and MDH-UFSC in biofuels.

The creation of the SC2C.aero has reached the phases of business plan and pilot project, with the identification of 50 (fifty) technological challenges and 10 (ten)

technological groups in the Santa Catarina state. The official inauguration of the centre will be on May, 2018.

4.2.2.3. Initiatives in Digitalization

In March of 2016, Prof. Petter Krus and Prof. Paulo Kurka from State University of Campinas (Unicamp) and identified some synergies between the departments of Mechanical Engineering from Unicamp and LiU, as well other Brazilian universities that Prof. Petter already had partnership, starting important collaboration. Despite being new, this initiative has generated some outcomes already, listed below:

- Connection of Prof. Paulo Kurka with LiU's Professor Rolf Johan Ölvander and the start of the research project "A 3D Augmented Reality Integrated Environment for Turbine Assembly Process" with a CISB-Saab scholarship for a PhD Sandwich;
- Organization of the Workshop "Digitalization of Amazon" by Prof. Petter Krus, Prof. Luiz Goes from ITA, the Rector of University of Nilton Lins Prof. Giselle Lins and Mikael Roman from the Swedish Embassy in Brasilia. The workshop brought together Professors from LiU, Unicamp, ITA and UFABC and included visits in the Federal University of Amazon (UFAM), Amazon State University (UEA) and the Superintendence of the Manaus Free Trade Zone (SUFRAMA).

As an outcome, there is the intention of holding a Summer School in Manaus in 2019 with external funding.

4.3. Joint Education

The third main goal of Endowed Professor Chair, Joint Education, envisages participating in the daily activities at ITA, as well as other universities and in this way deepening the collaboration. These activities can be divided in:

- (i) short courses;
- (ii) student co-supervising;
- (iii) mentoring young Professors; and
- (iv) promoting student exchange.

4.3.2. Short courses

Building and flight testing sub-scaled demonstrators is an important part of the aircraft design education at ITA and it provides aeronautical students with a fundamental holistic view of the entire design cycle of an aircraft and a valuable portion of practical work.

Activities related to this part of the Professor Chair Program include:

- The restructuring courses at ITA in the areas of Aeronautical Systems and Aircraft design;
- Several Lectures from LiU professors under the subjects "Aircraft System Modelling and Simulation" and "Aircraft Design" at ITA, the subjects "Design

Practice” and “Engineering System Design” at UFABC and “Transmission line dynamics” and “System simulation” at UFSC.

4.3.3. Students co-supervising

- A LiU's PhD was granted with two months stay in Brazil at USP in 2016, under the co-supervision of Prof. Fernando Catalano and Prof. Alvaro Abdallah, performing research related to MSDEMO Project.
- Another LiU's PhD was granted with two months stay in Brazil at ITA in 2016 and two weeks in 2017, under the co-supervision of Prof. Roberto Annes Gil, performing research related to MSDEMO Project.
- There have been at 6 (six) ITA postgraduate students involved in the MSDEMO Project. Two of them are from Embraer.
- Prof. Petter Krus is also co-supervisor of an UFABC student from the Master Program in Engineering and Innovation Management in the field of digital transformation of aircraft maintenance.

4.3.4. Promoting student exchange

- Two UFSC's PhD students were granted 1 year stay in Sweden at LiU under the CNPq-CISB-Saab calls, supervised by Prof. Petter Krus.
- One UFSC's PhD student was granted 6 months stay in Sweden at LiU under the CISB-Saab Call, supervised by Prof. Petter Krus.
- One Masters student from ITA has applied for PhD scholarship at LiU, related to subscale flight-testing.
- One Master student from UFSC was granted a period of 4 months in Sweden to work in a collaborative project between UFSC, Volvo Cars and LiU.
- One PhD student from LiU spent 1 month at UFSC in collaborative project between UFSC, LiU and Reivax SA.
- One undergraduate student from UFSC spent 5 months at LiU supervised by Prof. Petter Krus..
- Four undergraduate students from LiU spent 2 months at UFSC supervised by Prof. Victor de Negri.
- Two Masters student from LiU spent 6 months at UFSC supervised by Prof. Victor de Negri.

5. First results achieved by the Bilateral Collaboration

There are numerous benefits that derive from bilateral collaboration, for the Academy, for Industry and for Society in general. These results are a source for the creation of replicable models and generation of lessons at national-level to improve higher education, research and innovation policy.

5.1. Benefits for Academy

Collaborative R&D projects are a great opportunity to create network, increase the research capacity and improve groups overall performance. In bilateral research collaboration, the creation and exploitation of connections between the countries are clear, but it can (and it has proven to do so) also help to increase the connections between partners inside the countries. For instance, Prof. Petter Krus projects allowed the approximation of research leaders from ITA, USP/EESC, UFSC, UFAB, Unicamp, IME, FEI, UEM, UFAM with no previous relations, creating an active network. In Sweden, Prof. Petter Krus reported his approach with leaders from Royal Institute of Technology (KTH) and Chalmers University of Technology (CTH) that he had not collaborated before. It also has creating a stronger network among researchers within LiU where Brazilian collaboration is the common denominator.

From the point of view of LiU, the MSDEMO project is opening and offering possibilities for LiU to collaborate with ITA and USP/EESC and to develop state of the art methods for subscale demonstrator, with investigation of control law development for dynamical scaled demonstrator. The view of LiU is that the project will also position the university with competences within subscale demonstrator development and testing that will be relevant for future EU research project, such as Clean sky 2.

At ITA, Prof. Petter Krus was one the first researchers to establish collaboration and since then he has acted as an ambassador motivating the establishment of connections between the two countries. One clear result of those actions was the increase of CAPES (Brazilian Federal Agency for. Post-graduate Education) evaluation of ITA's post-graduation in Aeronautical and Mechanical Engineering. One of the criteria for this evaluation is the internationalization of the university and ITA claims that the collaboration with Sweden was essential for the improved result in that matter.

From the point of view of UFABC, the integration brings a new culture and enhances the creation of knowledge process. The creation of the Master's Program in Engineering and Innovation Management is a great example, there is no such a program in Brazil and Professor Petter Krus participation was essential in the challenge of its creation and consolidation. Prof. Krus also enable the creation of connections between researchers from UFABC and LiU, expanding the cooperation between these institutions.

5.1.1. Internationalization of Education and Research

The internationalization of universities has been recognized as essential for academic and scientific development in a globalized world. Not only in terms of curriculum development and teaching improvement, but also as a way to share and discuss ideas and experiences, build long-term partnerships, enable student exchange and so on. Brazilian human resources may improve their formation/education through training exchange programs between Sweden and Brazil. Brazilian students in Sweden acquire not only technical competence, but also international experience, which will be valuable for the country once they will contribute to increase competences of Brazilian Institutions when returning to their home country.

5.2. Benefits for Industry

5.2.1. Innovation

Regarding MSDEMO project, the possibilities to use scaled demonstrators for control law development allows developer to implement and test novel methods on a “real” object and thereby introducing relevant additional complexity not always catch in a pure simulation environment. This leads to continuing skill development and competencies enhancement in-between regular product development cycles and provides an opportunity to incorporate novel control laws in a low risk, low cost budget.

Continues miniaturization and improved microelectronics also permit to test new technics in a scaled demonstrator, this can be a precious tool to bridge the Technology Readiness Level (TRL) gaps between lab environment and full-scale demonstrator. This will help reducing the bottleneck of new technologies at the TRL Valley of Death and will therefore be beneficial for involved partners: academia and research institute can work closer to industries, and industries can take advantages of new technologies earlier. Scaled demonstrator will also provide a platform for control law development and evaluation, allowing continuous competences development in a real environment and not only based on simulation models.

One important benefit of the development of MSDEMO is its strong connection with other strategic projects for the Swedish Program for Aeronautics Research, thus maximizing the funding efficiency. For instance, it started with some funding from the “Conceptual Aircraft Design Laboratory – CADLab” project approved in 2014 in the 6th Call of NFFP. In its new phase started in 2016, it is also related to two other projects approved in the 7th Call of NFFP: “S2TEP System-of-systems trade space exploration” and “Effective actuators for aircraft control”

5.2.2. Shared R&D Costs

Costs and risks associated with the investment of time, money and other resources, generating benefits for all parts can be shared, when different institutions interested in the same technology decide to establish an R&D partnership.

Furthermore, when institutions from different countries such as Brazil and Sweden are involved in those arrangements, there are challenges to overcome, but the benefits of such collaboration can also improve, exploiting the differences in the innovation system of each country. For instance, Professor's salaries in Brazil are fully funded by the universities, making the Brazilian part of the project less dependent of external funding. On the other hand, Sweden has “Industrial PhD” programs, where the PhD student doesn't have a scholarship, but is employed by the industry to work in projects according to demands of the company and thus, having a better understating of the challenge from the application perspective. Their salaries are paid with funds from the projects, which means that, in order to have the same amount of people involved in a project, there are about three times as much financial resources needed.

5.2.3. Spillover Effects

Outside of the scope of MSDEMO, the creation of SC2C.aero is another example of how industries can benefit from the established collaboration. Such centre allows the focus of

attention, expanding the base of contacts/relationships and increasing assertiveness in technological proposals. It starts with the identification of the capabilities of the research groups and industry from the Santa Catarina state in order to create a database to integrate business challenges and execution capacity. With the expected sharing of databases with the Swedish partners, a significant improvement of joint proposals and consortia creation is expected, as well as indirect benefits such as training of people, strengthening of technology-based companies and increasing the participation of the aerospace sector in the Santa Catarina state economy.

5.2.4. International Cooperation in R&D

Developing method to reduce risk and development cost in the aerospace industry will strengthen the position of Swedish and Brazilian industry, and help reaching the goals of increased international competitiveness.

Results from scaled demonstrator can be very valuable during development of new programs, where undesirable or even catastrophic behaviour can be identified early. In addition, flight test data and data collected during development of the scaled demonstrator can provide valuable information and guidance to test and evaluate organization for the full-scale testing. The payoff is higher for unconventional or radical configuration with no existing experience.

The project will also be a link between Swedish and Brazilian industries with in Aircraft conceptual design and aircraft development. This will path the way for coming common research and development efforts between both countries academia and industries.

5.3. Benefits for the Society

5.3.1. Knowledge Generation and Exploitation

Sharing the knowledge generated is a crucial part of science and it is essential for the exchange and validation of information and ideas and, thus, for the further development of the object of research. The participation in scientific conferences and publications of scientific articles are important means for the creation and spreading of knowledge. In this way, the missions funded, and the partnerships established, enabled Prof. Petter to participate in at least **4 important International Conferences** and to publish **8 joint papers** between Brazil and Sweden, during the period of the Chair.

It is also important to share the findings of the research with public other than the scientific, such as industries, government and the society in general, so the participation in workshops and other events are opportunities to exchanging knowledge and also building a network of contacts. In this matter, the Chair allowed the **participation of Prof. Petter Krus in 9 events** other than conferences and **organization/co-organization of 7 workshops**.

For a full list of paper and events, please refer to **ANEEX**

5.3.2. Training of High Qualified Manpower

Sweden has a long history of collaboration between academia and industry, experience that is under development in Brazil. By collaborating in R&D with Prof. Petter Krus,

undergraduate and graduate students have the opportunity to collaborate also with industry partners and become better qualified employees in the future, even if they don't choose the academic career. Great examples are the Brazilian exchange students that worked with Saab and Volvo, as mentioned before. The students having a better qualification can have better job opportunities, better salaries and so on. The industry also benefit from having engineers and other graduates with industrial experience, better qualification, new ideas and other perspectives. The Professors also benefit from this experience, learning how to bring academia and industry together.

6. Key Performance Indicators – KPIs

The determination of Key Performance Indicators (KPIs) is a form of measuring the achievement of objectives of certain endeavour. In this case, the objective is to measure the evolution over time of the research collaboration between Prof. Petter Krus and his Brazilian partners. Therefore, considering the three main activities of Swedish Professor Chair (R&D Collaboration, Long Term Cooperation and Joint Education), the KPIs were divided into six categories:

- R&D and Other Projects;
- Humans Resources;
- Financial Resources;
- Economical Resources,
- Joint Research Publications and
- Institutional Agreements.

The table below summarizes the relation between the six chosen KPIs and the three main activities of the collaboration:

Table 1 - Distribution of KPIs per Swedish Professor Chair activities

	R&D and Other Projects	Humans Resources	Financial Resources	Economical Resources	Joint Research Publications	Institutional Agreements
R&D Collaboration	✓	✓	✓	✓	✓	✓
Long Term Cooperation	✓	✓	✓	✓	✓	✓
Joint Education	✓	✓		✓		✓

In the following sections the KPIs are presented in relation of their evolution over time, according to the following scheme:

- **Before 2011**- Prof. Petter research activities before his first mission to Brazil;
- **From 2011 to 2014** - Prof. Petter research activities during his missions to Brazil but before being awarded by Endowed Professor Chair;
- **After 2015** - Prof. Petter research activities after Endowed Professor Chair grant.

6.1. R&D and Other Projects/Initiatives

Starting with short visits and seed funding, Prof. Petter Krus was capable of meeting new groups, creating a network of collaboration and starting new projects.

This KPI describes these collaborative projects and how they evolved over time. The term “R&D Projects” refers to collaborative projects between Academia and Industry for the development of technologies, whereas the term “Other projects/initiatives” refers to spill overs of the relationships built by Prof. Petter Krus.

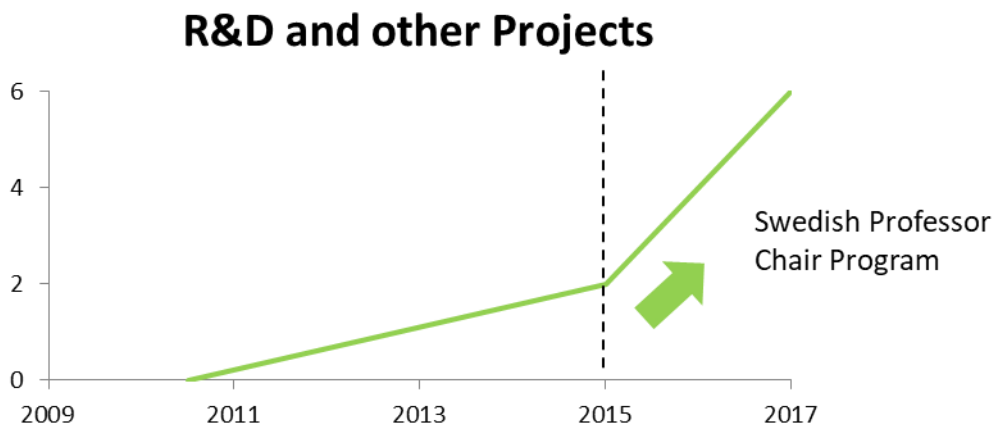








Figure 3 - R&D and other Projects

Table below describes details of R&D and Other initiatives' KPI.

Table 2 - R&D and Other Projects

				Before 2011	2011 - 2014	2015 - 2017
R&D and other Projects/Initiatives				0	2	6
R&D Projects	MSDEMO – Methods for Subscale Flight Test and Demonstration (LiU-ITA- USP/EESC -Saab)			-	-	✓
	Digital Hydraulic Actuator for Aeronautics for flight control (LiU-UFSC-Saab)			-	✓	✓
	Supersonic Aerodynamics for Aircraft Conceptual Design (LiU- USP/EESC)			-	✓	✓
Other initiatives	Master in Engineering and Innovation Management (LiU-UFABC)			-	-	✓
	Santa Catarina Convergence Centre for Aerospace Technologies (LiU-UFSC-CERTI) (LiU-UFSC-CERTI)			-	-	✓
	Initiative in Digitalization (LiU-Unicamp-ITA-UFABC-Swedish Embassy)			-	-	✓

So far, 6 bilateral projects were started, divided in 3 R&D projects and 3 of other initiatives. These initiatives represent important spill overs of Prof. Petter Krus' endeavour in Brazil. The R&D Projects are also showing significant results as discussed before. It can be noticed that the collaboration began to grow in 2011 with seed money, but it gains force in 2015 with the inauguration of the Swedish Professor Chair Program.

Figure 4 below summarizes the evolution of activities executed by Prof. Petter and the first results achieved.

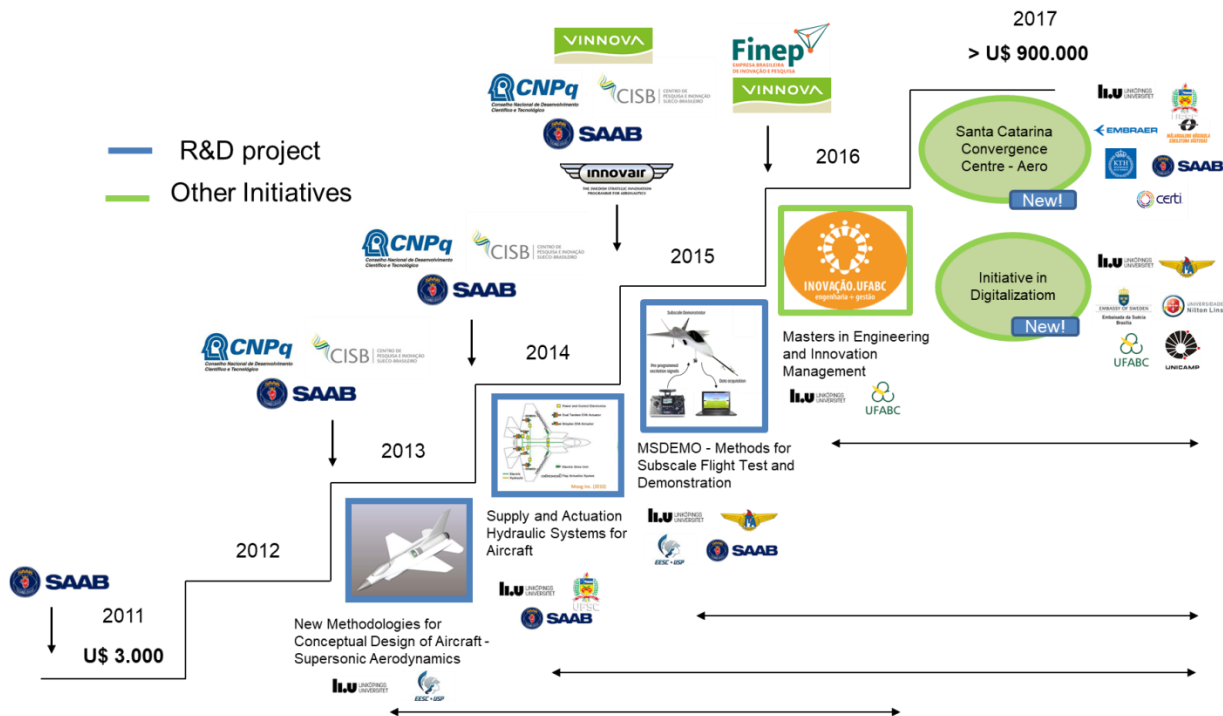


Figure 4 - Bilateral Research Collaboration timeline

6.2. Human Resources

The Human Capital is an important resource, which drives creations and innovations. Measuring the increase of the number of individuals in the projects and initiatives shows the capability of engage new actors, find complementary capabilities and increase the network of collaboration. It is also possible to show the exchange and or interaction of people between different countries, with different cultures and backgrounds.

In this KPI it was measured only the individuals directly engaged in the activities: Project leaders (Post-doc and Specialists), Young researchers (Post-Doc) and Students (PhD and Masters) performing research directly in the projects. It is important to point out that the indirect people in the projects, such as fellow researchers, partners and other actors, were not included at this time, but represent also an important resource.

Human Resources

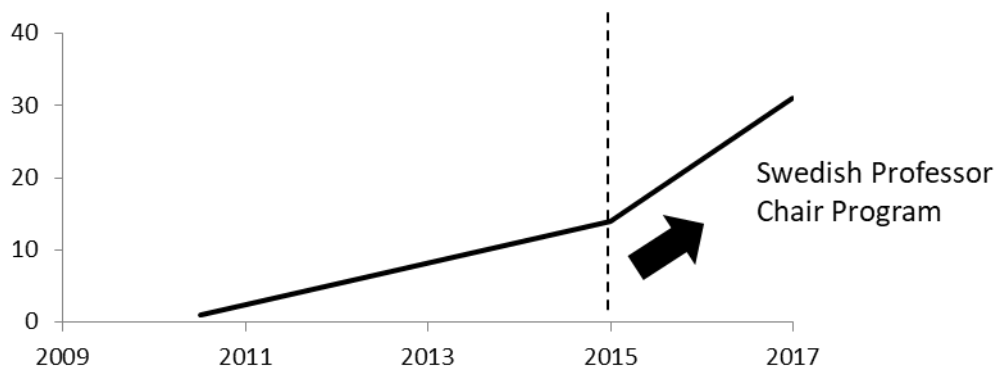




Figure 5 - Human Resources

Table below describes details of Human Resources' KPI.

Table 3 - Human Resources per Periods

	Before 2011	2011 - 2014	2015 - 2017		
Human Resources	1	14	31	18	13
Professors	1	4	10	7	3
Post-Doc	0	0	1	1	0
PhD Student	0	6	9	3	6
Masters Student	0	0	6	6	0
Specialist	0	3	5	1	4

According to his KPI currently there are a least 18 researches from Brazil and 13 researches from Sweden with full or partial dedication to projects. It is possible to see the involvement of individuals from different countries and thus, the exchange of knowledge and culture. Those factors bring benefits not only for the projects, with innovation and creativity, but also for the individuals, which will be better qualified technically, will learn from other cultures and will transform these experiences in benefits for themselves and for the society in general.

6.3. Financial Resources

Financial resources refer to the financial funds available for the initiation and continuation of projects. In the present report, they are divided in: missions (air ticket and *per diem*), project funding (specialized staff, equipment, etc), scholarships for graduates and/or the Professor Chair program, which includes missions and project funding, as described before. All the values presented below are approximated and were converted from their respective currency to US Dollar (according to the respective year's average exchange rate). **It is important to note that the values are cumulative, i.e. the values presented in the previous year are added up on the next year amount.** The objective of doing that was to show, through this KPI, the capacity of funding raising over time.

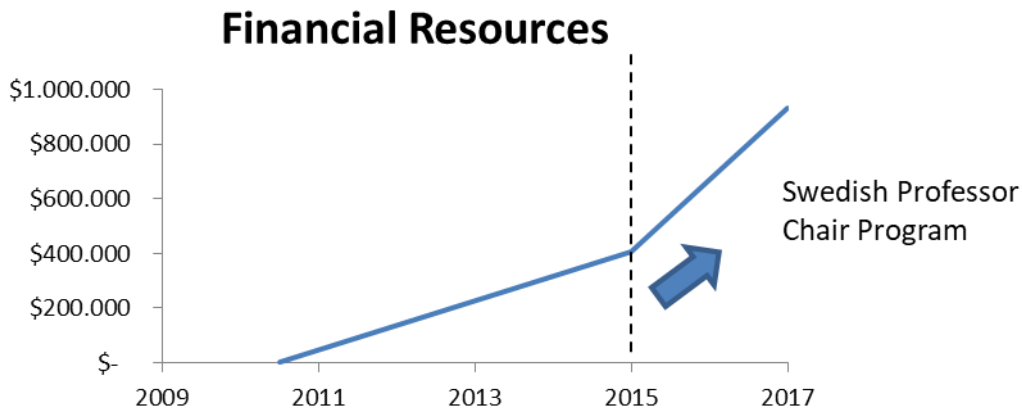















Figure 6 - Financial Resources

Table below describes details of Financial Resources' KPI.

Table 4 - Financial Resources per Periods

	Before 2011	2011 - 2014	2015 - 2017
Financial Resources (in USD)	\$ 3.000	\$ 407.000	\$ 931.350
Short Missions (Saab funding)	\$ 3.000 	\$ 27.000 	\$ 27.000 
Short Missions (Other funding)		\$ 18.000 	\$ 18.000 
Project Funding (NFFP)		\$ 305.000 	\$ 305.000 
Professor Chair Program			\$ 140.000 
International Missions (CISB Grants)			\$ 27.850 
Scholarships (CNPq-CISB-Saab)		\$ 57.000 	\$ 152.000 
Scholarships (CISB-Saab)			\$ 11.500 
Project Funding (FINEP-Vinnova)			\$ 250.000 

This is an interesting KPI that show several important features of building international long-term collaboration:

- the different types of funding;
 - the potentiality of funding raising starting with seed money; and
 - the bilateral effort of Brazil and Sweden to fund collaborative projects.
- The different types of funding (missions, scholarships, equipment, etc) play an important role in the success of the projects, showing the importance of that variety to build long term collaboration.

- In terms of fund raising, the total funding for the projects increased significantly since the initial missions.
- In terms of bilateral funding, almost 50% of the total money raised was funded bilaterally in important partnerships such as CNPq-CISB-Saab and FINEP-Vinnova, showing that the establishment of those partnerships are essential to build and long-term cooperation.

6.4. Economical Resources

Economical resources refer to assets that not necessarily can be measured in terms of value, such as the human labour or the use of specialized equipment and laboratories. In the present report we refer to it as economical resources specifically to the researchers (Professors and Industry employees) as working force, as they cannot be financially compared in terms of salaries due to the differences in the two countries, but they compose an important part of the project value. Other economic resources are also important, such as use of laboratories, and it can be further investigated, but was not the purpose of this initial report.

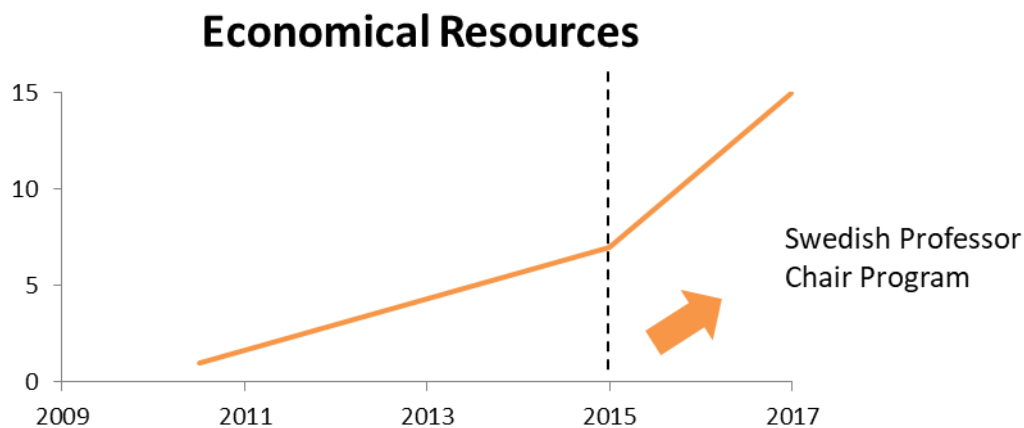




Figure 7 - Economical Resources

Table below describes details of Economical Resources' KPI.

Table 5 - Economical Resources per Period

		Before 2011	2011 - 2014	2015 - 2017
Economical Resources		1	7	15
In kind from Industry		0	3	5
In kind from Academy		1	4	10

This KPI describes the commitment of industries and universities to collaborate, in terms of their employees working time. The interaction between academia and industry is essential for innovation to occur and it is a relatively new concept in Brazil, although is well established in the Swedish Innovation System. For that reason, the majority of in kind from industry is from Sweden, while the majority of the in kind from Academy is from Brazil. But this scenario is changing as a result of the bilateral cooperation that is under construction between the countries.

6.5. Joint Publications

The number of scientific joint publication between partners of different countries is an important indicator of the internationalization of the academic production and also of the success of these collaborations. This KPI considers publications such as papers and scientific journal articles.

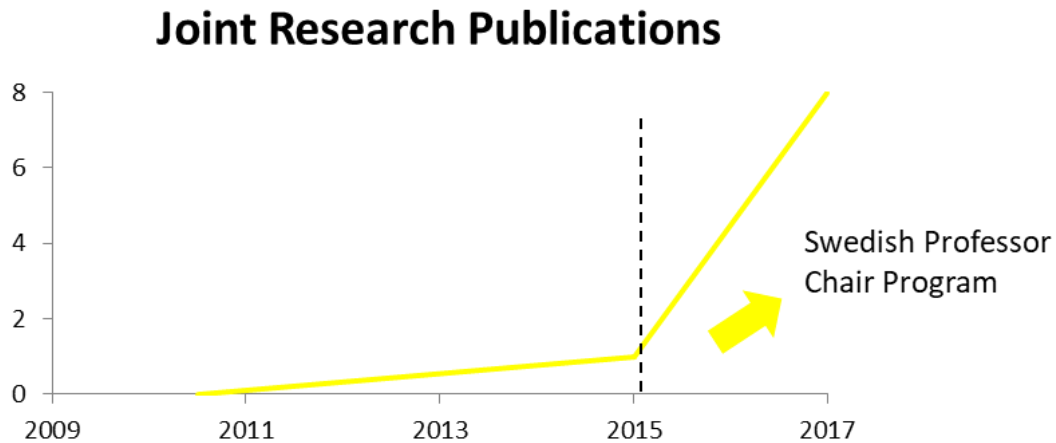


Figure 8 - Joint Research Publications

Table below describes details of Joint Research Publications' KPI.

Table 6 - Joint Research Publications per Periods

	Before 2011	2011 - 2014	2015 - 2017
Joint Research Publications 	0	1	8

The rising of the number of joint publications shows the first results of bilateral collaboration in terms of scientific production and its importance for the internationalization of the science. It is important to point out that research takes time to develop as well as publication of results, so it is expected an increase of submission and publication of collaborative papers for next years.

6.6. Institutional Agreements

Collaborations can start at the individual level, with two people working together, but it can be much more valuable when it reaches the institutional level, establishing the willingness to expand the cooperation between these institutions and demarking objectives, areas, conditions and so on. One way to measure that is the number of institutional agreements signed.

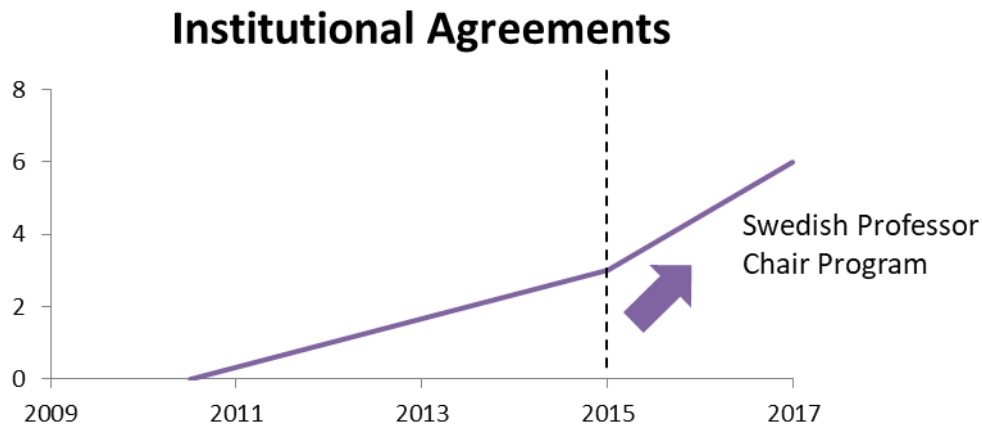








Figure 9 - Institutional Agreements

Table below describes details of Institutional Agreements' KPI.

- A Memorandum of Understanding expresses the intention of two or more parties to take some action plan in collaboration;
- A Non-Disclosure Agreement is a legal document that determines some information that will be shared between the institutions for certain purpose but should not be disclosure for others;
- A cooperation agreement outlines the scope of a project, with responsibilities and rights of which part.

Table 7 - Institutional Agreements per Periods

	Before 2011	2011 - 2014	2015 - 2017
Institutional Agreements	0	3	6
Memorandum of Understanding: LiU-ITA 	0	1	1
Memorandum of Understanding: LiU-UFSC 	0	1	1
Memorandum of Understanding: Saab-LiU-ITA 	0	1	1
Non-Disclosure Agreement: Saab-LiU-ITA-USP/SC 	0	0	1
Cooperation agreement: Saab-LiU-ITA-FT Sistemas 	0	0	1
Cooperation agreement: Saab-LiU-KTH-MDH-UFSC-CERTI 	0	0	1

The increase of agreements at the institutional level shows the positive impact of the collaboration starting in the individual level, meaning that successful partnerships reach high levels starting from low levels. It also important to notice the number of institutions involved: 9 in total, 4 from Sweden and 5 from Brazil, 6 from academy, 2 from industry and 1 research centre.

7. Conclusion

Collaborative R&D projects are a great opportunity to create network, increase the research capacity and improve groups overall performance. Collaborations can start at the individual level, with two people working together, but it can be much more valuable when it reaches the institutional level, establishing the willingness to expand the cooperation between these institutions and demarking objectives, areas, conditions and so on.

Prof. Petter Krus became one of leading pioneers to build and strength joint research and development and industrial collaborations among Brazil and Sweden, following the perspectives established with the Agreement on Innovative High Technological Industrial Cooperation signed in 2009 between the two countries.

His efforts were essential in a first moment to establish fist contacts with main Brazilian peers from academy and industry for international collaboration. Furthermore, receiving Swedish Professor Chair at ITA was key to establish at institutional level Bilateral Collaboration between both countries.

All main objectives of Swedish Professor Chair at ITA are evolving and they are leading to R&D and more industrial partnerships in aeronautics and in other strategic industrial sectors.

8. ANNEX

8.1. Participation in conferences:

- 7th Int. Conf. on Recent Advances in Aerospace Actuation Systems in Toulouse, France – March 2016;
- 30th Congress of International Council of the Aeronautical Sciences (ICAS 2016) in Daejeon, Korea – September 2016
- FT2016 Congress in Stockholm, Sweden – October 2016;
- 9th FPNi International PhD Symposium in Fluid Power in Florianopolis, Brazil – October 2016.
- DINAME 2017 – Dynamic Problems in Mechanical Engineering in São Sebastião, Brazil – March 2017.
- SICFP2017 – Scandinavian International Conference on Fluid Power in Linköping, Sweden – June 2017.

8.2. Joint Publications:

- Sobron R., D. Lundström, P. Krus, C. Jouannet, L. Goes, Flight test design for remotely-piloted aircraft in confined airspace. 6th CEAS Air & Space Conference, At Bucharest, Romania, 2017.
- Lundström, D.A. Sobron, P. Krus, C. Jouannet, R. G. A. da Silva. Subscale Flight Testing of a Generic Future Fighter Aircraft. Aerospace Technology Congress 2016, 2016, Stockholm, Sweden.
- Pereira, L., P. Krus. Design Decisions and Technology Readiness Assessment for Aircraft Electrical Power Systems. Aerospace Technology Congress 2016, 2016, Stockholm, Sweden.
- Pinto, L. P. G.; Belan, Henri Carlo; LOCATELI, C. C.; KRUS, P.; DE NEGRI, V. J.; LANTTO, B. New perspectives on digital hydraulics for aerospace applications. In: Aerospace Technology Congress 2016, 2016, Stockholm, Sweden.
- Krus, P. & Pereira, L., 2016. Systems Engineering: An Interdisciplinary Challenge. In 30th Congress of the International Council of the Aeronautical Sciences, ICAS2016. Daejeon.
- Belan, Henri Carlo; Lantto, Birgitta; Krus, Petter; De Negri, Victor J. (2016). Digital hydraulic actuator (DHA) concept for aircraft actuation systems. In: Conference of Recent Advances in Aerospace Actuation Systems and Components, March 16-18, 2016, Toulouse, France.
- Belan, H. C. , Locateli, C. C. , Lantto, B. , Krus, P. and De Negri, V. J. Digital, (2015) Secondary Control Architecture for Aircraft Application, The Seventh Workshop on Digital Fluid Power, February 26–27, 2015.
- Locateli, C. et al., 2014. Actuator Speed Control Using Digital Hydraulics. doi:10.1115/FPMC2014-7837. In ASME. Fluid Power Systems Technology, ASME/BATH 2014 Symposium on Fluid Power and Motion Control.
- Also one journal paper submitted to Journal of Systems Engineering with LiU/UFABC.

8.3. Workshops organized:

- 3rd Workshop in Systems, Product Development and Innovation at UFABC – November 2015.
- Workshop on Strategic Actions for Engineering Teaching and Research at UFSC – November 2015.
- 1st Workshop in Systems Engineering and Innovation at Linköping University – October 2016.
- 9th FPN/ASME International PhD Symposium in Fluid Power at UFSC – October 2016.
- 3rd Workshop on Innovative Fluid Power WIEFP 2016 at UFSC – October 2016.
- 2nd Workshop in Systems Engineering and Innovation at Linköping University – June 2017.
- Workshop on “Digitalization of the Amazon” in Manaus – October 2017.
-

8.4. Participation in other events:

- Presentation at 2nd BR-SE Workshop in A&D in São José dos Campos – May 2015;
- Participation in the Swedish Academic Collaboration Forum in São Paulo - August 2015.
- Presentation at 3rd BR-SE Workshop in A&D in São José dos Campos – November 2015.
- Participation in the Swedish Academic Collaboration Forum in Brasilia - May 2016.
- Presentation at 4th BR-SE Workshop in A&D in Linköping - October 2016.
- Participation in the 1st Brazilian Army Innovation Workshop - System Defence/Industry/Academia (SISDIA) in Sao Paulo – October 2016.
- Presentation at the 5th BR-SE Workshop in A&D – May 2017.
- Participation in the Army SISDIA technical conference in São Paulo – October 2017
- Participation in the 6th BR-SE Workshop in A&D in Stockholm – October 2017.