Creating a bridge between Brazil and Sweden

Case: Prof. Dan Henningson

Produced by CISB

Project Team

Alessandra Holmo

Cláudio Mazzola

Vitor Dias

Letícia Morales

Summary

1. Executive Summary 3
2. Objective 4
3. Introduction 4
4. Knowledge Transfer via Swedish Professor Chair at ITA 4
5. About Dan Henningson initiatives 5
6. About activities and results of Swedish Endowed Professors Chair at ITA 7
6.1. Bilateral Research Project 7
6.2. Promote Long-term Cooperation 9
6.3. Joint Education 10
7. Conclusion 12
8. Annex 13
8.1. Joint Publications 13
8.1.1. International Journals 13
8.1.2. International Conferences 13
8.1.3. Workshops Organised 14
8.1.4. Participation in Conferences 14

1. Executive Summary

During past decade Brazil and Sweden have been building a long-term Bilateral Collaboration in Aerospace & Defence (A&D) Sector, especially for Science, Technology and Innovation (ST&I) cooperation, establishing technical networks in prioritized areas and fostering knowledge transfer between the two countries, all in order to create and improve innovation ecosystems.

Among the various forms of knowledge transfer between countries, mobility programmes, such as the Swedish Endowed Professor Chair at ITA in Honor of Peter Wallenberg Sr., are important mechanisms to promote innovation activity and a prosperous environment for collaboration.

In this context, in 2016 Professor Dan Henningson from Royal Institute of Technology (KTH) was selected by the program at ITA to perform research on linear and nonlinear hydrodynamic stability and numerical simulation of transitional and turbulent flow together with Brazilian Researchers lead by prof. André Cavalieri, from ITA (Aeronautics Institute of Technology). For practically 3 (three) years of interaction with his fellows from Brazil and Sweden, several research and development (R&D) activities at low Technology Readiness Level (TRL) were performed, contacts were nurtured and networks created.

From the Bilateral Research Project perspective, the co-development of PreLaFloDes project has generated knowledge transfer between both Swedish and Brazilian groups increasing thus, the TRL level of active flow control techniques through the testing of novel methods. This has been opening opportunities to strengthen the competitiveness of the Swedish and Brazilian aircraft industries.

From Joint Education perspective, the Chair allowed the exchange of knowledge via presentation of one-week courses to students, postdocs, researchers and industries representatives from Sweden and Brazil. Also, the Chair permitted professors Henningson and Cavalieri, to co-supervise three doctorate students from ITA and one from KTH.

From the International Knowledge Exchange perspective during the period of the Chair 9 joint papers between Brazil and Sweden were published. Also, professors Cavalieri, Ardeshir Hanifi, from KTH and Henningson held in Paraty the 13th ERCOFTAC SIG 33 Workshop and participated in the 31st Congress of the International Council of the

Aeronautical Sciences (ICAS) Conference, in Belo Horizonte, where 5 papers were published.

2. Objective

This report aims to describe the impact of Bilateral Collaborations between Brazil and Sweden by evaluating the deliverable of Professor Dan Henningson during his Chair at ITA from 2016 to the first quarter of 2019.

3. Introduction

Since more than a century, Brazil and Sweden have a joint history of trade and industrial activities, primarily within automotive, telecommunications, and energy transformation industries and democratic governance.

More recently, a number of Agreements, Memorandum of Understandings (MoU) and Protocols have been signed between both countries establishing common policies and areas of Bilateral Collaboration in A&D sector, greatly strengthened by the industrial and technological partnership established on the basis of the Saab's Gripen NG Program in 2014.

It has been known the A&D sector can act as a catalyst for joint aeronautical research and development, leading to innovations and more industrial partnerships in several sectors and societal benefits.

Therefore, both countries recognize that building joint aeronautical R&D activities is mutually beneficial to enter a long-term strategy for close Science, Technology and Innovation cooperation, establishing technical networks in prioritized areas and fostering transfer of knowledge between the two countries, all in order to create and improve innovation ecosystems.

4. Knowledge Transfer via Swedish Professor Chair at ITA

Recent findings have shown that collaboration promotes innovation activity. An efficient Bilateral Collaboration environment is desirable to facilitate and foster a culture of innovation and Knowledge Transfer (KT) between countries in several areas. Most of international KT occur as a result of human mobility and the high mobility of R&D activities. One important example of mobility programme is the Swedish Endowed Professor Chair at ITA in Honour of Peter Wallenberg Sr. This program refers to a triple-helix initiative to bring Swedish leading researchers to Brazil, for an initial 3-year period,

to create and strengthen long-term collaboration between both countries in research, education and innovation in aeronautical technology. It is expected from this initiative to become in the near future a key enabler to build a sustainable bilateral innovative research ecosystem in aeronautics and expand it to other areas such as energy, sustainability, defence and security, transport and logistics and urban development.

5. About Dan Henningson initiatives

Dan Henningson[1] is an outstanding professor of Fluid Mechanics at Royal Institute of Technology (KTH). His research area is focused on linear and nonlinear hydrodynamic stability and numerical simulation of transitional and turbulent flow. In 2016 he was one of the three professors granted with the Swedish Endowed Professor Chair at ITA.

However, before receiving the Chair several initiatives were made in order to establish basis for future cooperation. More specifically, to create and strength a long-term collaboration is imperative to nurture contacts and create networks in an efficient way in order to overcome the geographical distance and cultural differences between the two countries.

As an academic, his first professional visit to Brazil backs to March 2014, when as member of Scientific Committee of the International Union for Theoretical and Applied Mechanics (IUTAM)[2] he was invited to organize and participate in the IUTAM Symposium on Laminar-Turbulent transition, held in Rio de Janeiro on September 2014.

This Symposium gave him the opportunity to meet several local organisers, especially, professor Marcelo Medeiros[3] from Aeronautical Engineering dept. of University of São Paulo - USP São Carlos who was studying the influence of roughness on transition to

[1] He was the Chairman at KTH Mechanics for eight years and is now the Director at the Swedish e-Science Research Centre and the Swedish Aeronautical Research Center. Being one of the most respected researchers in his subject he has won one Alexander von Humboldt prize and has already received an ERC Advanced grant of 2 Million Euros and has a couple of projects funded by Vinnova, the Swedish Innovation Agency, Energimyndigheten, the Swedish Energy Agency and Vetenskapsrådet, The Swedish Science Council. In recognition of his outstanding contribution to physics, he is a fellow of the EUROMECH (European Mechanics Society) and the APS (American Physical Society), he was also part of the Scientific Council for Natural and Engineering Sciences for six years and was an Associate Editor of the journals Physics of Fluids and is currently an Associate Editor of the Journal of Fluid Mechanics.

[2] International Union for Theoretical and Applied Mechanics is an affiliation of about 500 mechanicals in about 50 countries, and involving about 20 associated organizations, including the International Council for Science (ICSU).

[3] Professor at Universidade de São Paulo, São Carlos Campus, with degree in Mechanical Engineering from Universidade Federal do Rio de Janeiro (1987), master's in Mechanical Engineering from Universidade Federal do Rio de Janeiro (1990) and ph.d. in Aerospace Engineering from University of Cambridge (1996). Has experience in Aerospace Engineering, focusing on Aerodynamics, acting on the following subjects: hidrodynamic instability, boundary layers, transition, turbulence, aeroacoustics, computational, theoretical and experimental fluid mechanics.

turbulence. This was the first time he established connections with academy (USP and ITA) and industry (Embraer).

In November 2014, Prof. Ardeshir Hanifi, colleague of Prof. Henningson, attended the first Brazilian Swedish Workshop in Aeronautics, in São José dos Campos, during which the first ideas for a collaboration were discussed with Prof. Medeiros and Prof. André Cavalieri [4] (ITA), whose main research areas is on aeroacoustics, hydrodynamic instability and turbulence.

One year later (2015), professor Henningson returned to Brazil with Prof. Hanifi. Both accompanied by professor Medeiros met Prof. Julio Meneghini [5] from Mechanical Engineering dept of USP São Paulo scheduled visits at ITA and Embraer, in order to explore the opportunity to create collaborative projects. During these visits Prof. Henningson was also able to meet Professor André Cavalieri.

Initial conversations were a success and for one more period, on April 2016, professors Henningson, Hanifi and Cavalieri evolved to a more detailed discussions on how they could combine Swedish and Brazilian research capabilities and efforts in aerodynamics especially focusing on Transition to turbulence and Laminar Flow Control (LFC).

Since professors Henningson and Hanifi were already performing research activities in aeronautics with Saab AB via Innovair, a strategic innovation programme funded by Vinnova and Swedish Defence authorities, they considered aligning objectives of their Innovair's funded project (PreLaFloDes) with the objectives of Swedish Endowed Professors Chair at ITA.

The combination of Swedish version of PreLaFloDes project with the Swedish Endowed Professors Chair activities demonstrated strategic and complimentary for both professor's (Henningson and Cavalieri) research lines and teams in LFC.

In the long run, developing the capability for high fidelity analysis of the flow over laminar wing, will be useful in the prediction and control of the transition process either to prevent or enhance turbulence and contribute to improved capabilities needed for design of future low-drag aircraft, resulting in lower fuel consumption and reduced pollution.

[4] Assistant Professor at the Instituto Tecnológico de Aeronáutica (ITA), with a degree on Aeronautical Engineering at ITA (2004), Master degree on Aerospace Engineering at ITA (2006), PhD on Acoustics at the Université de Poitiers (2012). Post-doctoral research on jet noise in the University of Cambridge (2012), awarded by a David Crighton Fellowship.

[5] Full Professor of Applications and Principles in Mechanical Engineering, Escola Politécnica, University of São Paulo, PhD in Aeronautics, Imperial College – University of London (1993). DIC-Diploma of Imperial College in Aeronautical Engineering (1993).

This is one of the reasons why Prof. Henningson was granted with the Swedish Endowed Professors Chair.

6. About activities and results of Swedish Endowed Professors Chair at ITA

The activities of Professors Henningson's and Cavalieri's teams in Brazil under the Chair is divided in three main parts:

6.1. Bilateral Research Project

6.1.1. PreLaFloDes Project

Initiated by Swedish NFFP6 programme, the PreLaFloDes is a preliminary project created under the Chair as part of collaboration between KTH, Saab, Linköping University (LiU), USP, and ITA, aimed to understand the research questions of passive and active Laminar Flow Control (LFC) on wings surfaces before executing a project called LaFloDeS (Laminar Flow Design and Surface quality requirements).

PreLaFloDes is a low Technology Readiness Level (TRL)[6] project which basics principles are observed, technology concept formulated and eventually, technology validated in lab. This is a high risk and uncertain research activity, where interaction and knowledge transfer are essential to achieve success.

Thus, PreLaFloDes activities under the Chair initiated on October 2016 with first mobility visits from Sweden to Brazil of professor Hanifi from KTH and more three PhD students, Pierluigi Morra, Nicoló Fabbiane and Shervin Bagheri. They made visits to USP São Carlos in order to align with professor Medeiros the scope of research activities such as analysis of numerical simulations for three-dimensional flow, as well as to assess the quality of flow of the new, low-turbulence wind tunnel for use in PreLaFloDes experiments. Visits were also made to ITA where professor Cavalieri involved professors Tiago de Araujo and Flávio Silvestre, as well as, PhD students Kenzo Sasaki and Pedro Brito. ITA researches were also involved in PreLaFloDes to provide analysis of preliminary direct numerical simulations performed by KTH researches. Embraer participated as an observer partner in the project.

[6] The TRL scale determines to what extent a technology is suitable for implementation in a real operational environment, ranging from TRL 1 (basic principles observed) to TRL 9 (actual system proven in operational environment), and where anything below TRL 4 is technology that has not been validated yet. A sufficient level of TRL is a prerequisite for the successful transition of research from an idea, to a laboratory experiment and finally to a real operational application. That is, there is a significant inverse relationship between the TRL and the risks of adopting technology: higher levels of TRL indicate lower perceived risks, and the low TRL indicates a higher level of risks.

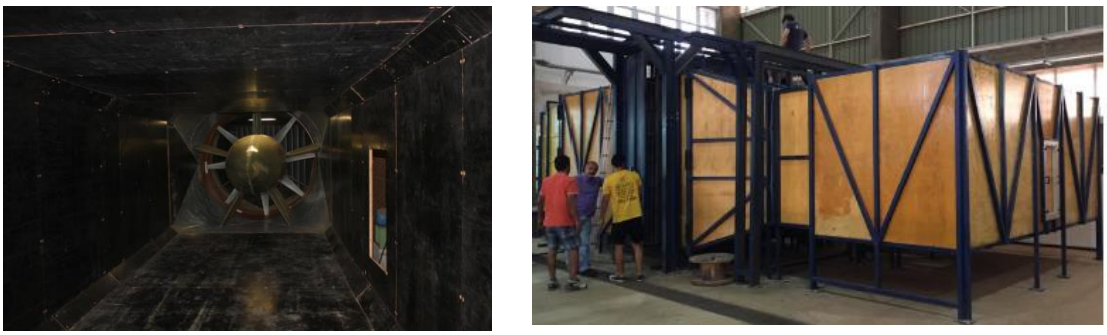

Figure 1 - USP São Carlos Wind Tunnel

Furthermore, the participation of Saab involved the provision of a peripheral equipment (aircraft wing) to test different actuators and sensors for active flow control using plasma. Before testing objects equipped with flow actuators is necessary first design robust control law and algorithms. Thus, this was an activity investigated by researchers at LiU, KTH and ITA. Figure 2 presents schematic of the wing model used in flow control project by plasma an actuator (left) and structures found in the simulations of turbulent flow around a wing section (right).

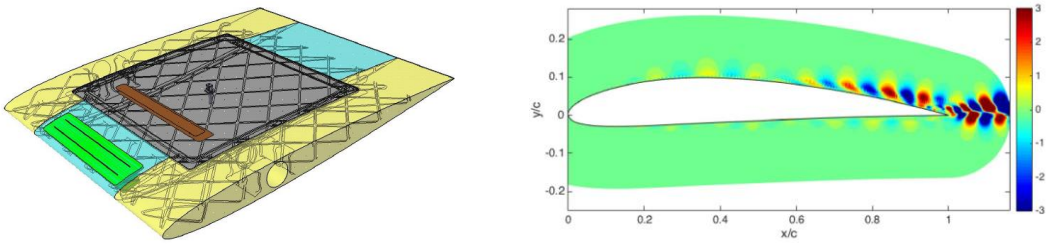

Figure 2 - Projects developed under Professor Chair

PreLaFloDes ran from 2016 to 2018 and first results demonstrated successful providing thus, a deeper understanding of the use of active flow control to improve the laminar flow quality on wings. It is important to point out PreLaFloDes project generated knowledge transfer between both Swedish and Brazilian groups. These results increased the TRL level of active flow control techniques through the testing of novel technics, and opened opportunities to strengthen of the competitiveness of the Swedish and Brazilian aircraft industries.

The sequence of PreLaFloDes project is the development of LaFloDeS project which aims to investigate the quality requirements in terms of step/gaps and roughness for maintaining laminar flow on wings via active flow control, as well as, to understand the transition to turbulence in such flows.

Initial activities have already started by Pedro Brito an Industrial Doctorate (DAI) student supported by CNPq (Brazilian National Council for Scientific and Technological

Development) and Embraer scholarships. He is co-supervised by professors Cavalieri and Tiago Barbosa de Araújo from ITA; and Professor Hanifi. This is an evidence of TRL level increase where project complexity discussions are involving more researches and industrial partners.

6.2. Promote Long-term Cooperation

The Promotion of Long-term Cooperation aims to develop a world class university network between Brazil and Sweden in the aeronautics related areas, with a strong industrial relevance. Building a strong network starts by creating an aligned research agenda that identifies strengths from each side complementary academic competences. This can be seen when Prof. Henningson identified Prof. Cavalieri as a potential complementary partner in view of his expertise in aerodynamics applied in turbulent jets in aircraft engines, involving modelling and controlling turbulence and noise emission. This combination of knowledge allowed them to expand their work to the boundary layer around the wings, where their techniques could be developed in a new context and quickly led to new joint lines of research.

Also, in an academic environment, to promote a sustainable long-term bilateral cooperation it is preferable to develop joint projects at low TRL. Initially, at low TRL, the costs are not large to set up a number of projects. Also, better understanding of lower TRLs projects generates knowledge within the industry regarding which areas are approaching industrialisation. Furthermore, projects at low TRL are very useful for building contacts, learning of any outstanding difficulties in handling either technical, personal (mobility, families), financial (funding) or legal (IP rights and classified information) questions.

Thus, initiating a long-term joint bilateral aeronautical R&D program at low TRL encourages researchers from Brazil and Sweden to agree on priorities, solve involved funding issues, set up joint time schedules, divide the technical responsibilities and etc.

The interaction and collaboration between Swedish and Brazilian researches were so positive that during 2017 several other visits to ITA and USP São Carlos/São Paulo were made by Professor Hanifi and others KTH researchers, Professors Philipp Schlatter and Ricardo Vinuesa to discuss with Professors Cavalieri and Meneghini common projects evaluating coherent structures in turbulence for aeroacoustics.

Visits to ITA and USP continued during 2018, the last year of Professor Chair Program. Professor Henningson accompanied by his students Mattias Brynjell Rahkola and Elektra Kleusberg went to USP Sao Paulo to explore with Professors Meneghini and

Bruno Carmo from Research Centre for Gas Innovation potential collaboration in the area of wind power research.

6.3. Joint Education

Joint Education envisages participating in the daily activities at ITA, as well as other universities and in this way deepening the collaboration. These activities are divided in:

(i) short courses;

(ii) student co-supervising; and

(iii) promoting international knowledge exchange.

6.3.1. Short courses

During the Chair, Professor Henningson, in collaboration with his fellow countryman Prof. Tomas Grönstedt (Chalmers University of Technology) and Prof. Petter Krus (Linköping University), all of them professors honoured by the program Professor Chair at ITA created the Swedish Aeronautical Research Center (SARC), an initiative focused to conduct research and/or education within the aeronautics sector.

Figure 3 - SARC's Academy Summer School

On March 2019 SARC Academy organised in Florianopolis the 5-day Course on Conceptual Aircraft Design. This event brought together 50 postdocs, researchers and industries representatives from Sweden and Brazil to attend the course. It was highly successful and currently, the Brazilian researchers in Aeronautical Engineering are starting a similar national organization as SARC in aeronautics, called BARC (Brazilian Aeronautical Research Centre).

6.3.2. Student co-supervising

The Chair made the following co-supervision possible; Dr. Kenzo Sasaki, finished his doctorate, supervised by Prof. Cavalieri and co-supervised by Prof. Henningson with a one year stay at KTH.

Three doctorate students (Petrônio Nogueira, Leandra Abreu e Pedro Brito) from Prof. Cavalieri group are being co-supervised by Professor Henningson. Pedro Brito, more specifically, as an Industrial Doctorate student co-supervised by Professors Cavalieri and Tiago Barbosa de Araújo from ITA, Professor Hanifi from KTH and funded by CNPq and Embraer.

Pierlugi Morra, doctorate student at KTH was co-supervised by Prof. Cavalieri with several visits in Brazil at ITA.

Thus, due the relevance of professor Chair students are improving their education through mobility exchange programs between Sweden and Brazil. Brazilian students in Sweden are acquiring 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 the country.

6.3.3. Promoting International Knowledge Exchange

The participation in scientific conferences and publications of scientific articles are important means for the creation and dissemination of knowledge. In this way, during the period of the Chair Prof. Henningson was able to participate in at least one important International Conference in Brazil and to publish 9 joint papers with Brazilian and Swedish academic peers.

Furthermore, the Chair provided the opportunity to Prof. Henningson to fund and organize the 13th ERCOFTAC[7] SIG 33[8] Workshop on Progress in Flow Instability, Transition and Control, held in Paraty, Rio de Janeiro State. This event had the objective to provide an open forum of discussions for new ideas and concepts on flow instability and control. During three days, researchers from different nationalities presented 33 abstracts and working papers. For a full list of papers and events, please refer to ANNEX.

[7] European Research Community on Flow, Turbulence and Combustion
[8] Special Interest Group on Transition Mechanisms, Prediction and Control

7. Conclusion

Mobility programmes, such as Swedish Endowed Professor Chair at ITA, have been an important mechanism to promote innovation activity and a collaborative environment through Bilateral Collaborations by establishing technical networks in prioritized areas and fostering knowledge transfer between the two countries, all in order to create and improve innovation ecosystems.

For practically 3 (three) years, Prof. Henningson has been building and strengthening joint aeronautical research network focused on linear and nonlinear hydrodynamic stability and numerical simulation of transitional and turbulent flow.

The combination of Swedish version of PreLaFloDes project with the Swedish Endowed Professors Chair has been demonstrating complimentary for both Professor's Henningson and Cavalieri research lines and teams in Transition to turbulence and Laminar Flow Control (LFC). This combination of knowledge allowed them to expand their work to the boundary layer around the wings, where their techniques could be developed in a new context and quickly led to new joint research topics. Results have already been presented in international conferences and published in high impact journals.

Further, much more than simply setting up joint time schedules, divide the technical responsibilities, the development of a low TRL project under the Chair was a very useful mean for building contacts, learning of any outstanding difficulties in handling either technical, personal (mobility, families), solving involved funding issues or legal questions.

Therefore, the Swedish Endowed Professors Chair at ITA has been generating knowledge transfer between both Swedish and Brazilian academia, and opening opportunities to strengthen the competitiveness of the Swedish and Brazilian aircraft industries.

8. Annex

8.1. Joint Publications

8.1.1. International Journals

- SASAKI, K., VINUESA, R., CAVALIERI, A. V., Schlatter, P., & HENNINGSON, D. S. (2019). Transfer functions for flow predictions in wall-bounded turbulence. Journal of Fluid Mechanics, 864, 708-745.
- SASAKI, K., MORRA, P., FABBIANE, N., Cavalieri, A. V., HANIFI, A., & HENNINGSON, D. S. (2018). On the wave-cancelling nature of boundary layer flow control. Theoretical and Computational Fluid Dynamics, 32(5), 593-616
- MORRA, P., SASAKI, K., HANIFI, A., Cavalieri, A. V., & HENNINGSON, D. S. (2019), A realizable data-driven approach to delay bypass transition with control theory. Journal of Fluid Mechanics (under revision).
- SASAKI, K., MORRA, P., Cavalieri, A. V., HANIFI, A., & HENNINGSON, D. S. (2019), On the role of actuation for the control of streaky structures in boundary layers. Journal of Fluid Mechanics (under revision).

8.1.2. International Conferences

- SASAKI, K.; MORRA, P.; CAVALIERI, A. V. G.; HANIFI, A.; HENNNINGSON, D. S.; SASAKI, K.. On the wave-cancelling nature of boundary layer flow control. In: 31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018, Belo Horizonte. 2018.
- MORRA, P.; SASAKI, K.; CAVALIERI, ANDRÉ V. G.; HANIFI, A.; HENNNINGSON, D. S.. Control of streaky disturbances in the boundary layer over a flat plate. In: 31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018, Belo Horizonte. 2018.
- NOGUEIRA, P.A.S.; CAVALIERI, A.V.G.; HANIFI, A.; HENNINGSON, D.S. Resolvent-based control of streaks in boundary layers. In: 31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018, Belo Horizonte. 2018.
- ABREU, L. I.; CAVALIERI, A. V. G.; VINUESA, R.; SCHLATTER, P.; HENNINGSON, D.; HANIFI, A. Reduced order models to analyse wavepackets

in turbulent flow over an airfoil. In: 13th ERCOFTAC SIG 33 Workshop, Progress in Flow Instability, Transition and Control, March 6-8, 2018, Paraty, Brazil.

- ABREU, L. I.; CAVALIERI, A. V. G.; VINUESA, R.; SCHLATTER, P.; HENNINGSON, D. Wavepackets in turbulent flow over a NACA 4412 airfoil. In: 31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018, Belo Horizonte. 2018.

8.1.3. Workshops Organised

- 13th ERCOFTAC SIG 33 Workshop, Progress in Flow Instability, Transition and Control, March 6-8, 2018, Paraty, Brazil. (https://www.ercoftac-sig33.conf.kth.se)

8.1.4. Participation in Conferences

- 31st Conference of the International Council of the Aeronautical Sciences. September 2018, Belo Horizonte, Brazil.